PO-0169 New Orleans Landbridge Shoreline Stabilization and Marsh Creation Project

Coastal Wetland Planning, Protection, and Restoration Act PPL 24

30% Design Report

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TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

ABBREVIATIONS:

ACM	Articulated Concrete Mat
BA	Borrow Area
CMFE	Constructed Marsh Fill Elevation
CPRA	Coastal Protection and Restoration Authority
CPT	Cone Penetration Test
CRMS	Coastwide Reference Monitoring System
CWPPRA	Coastal Wetlands Planning, Protection and Restoration Act
CY	Cubic Yard
DPC	Dredge Pipeline Corridor
EAC	Equipment Access Corridor
ECD	Earthen Containment Dike
EPA	Environmental Protection Agency
ESLR	Eustatic Sea Level Rise
FT	Foot
HME	Healthy Marsh Elevation
LDWF	Louisiana Department of Wildlife and Fisheries
LF	Linear Foot
LS	Lump Sum
MC	Marsh Creation
MCA	Marsh Creation Area
MHW	Mean High Water
MLW	Mean Low Water
MNA	Marsh Nourishment Area
MTL	Mean Tide Level
PPL	Project Priority List
RSLR	Relative Sea Level Rise
SF	Square Foot
SHPO	State Historic Preservation Office
SONRIS	Strategic Online Natural Resources Information System
TME	Target Marsh Elevation
TY	Target Year
USACE	United States Army Corps of Engineers
USFWS	United States Fish & Wildlife Service
WVA	Wetland Value Assessment

1.0 INTRODUCTION

1.1 Authority

The New Orleans Landbridge Shoreline Stabilization and Marsh Creation Project (herein referred to as PO-0169) is located in the Pontchartrain Basin on either side of Hwy. 90 in Lake Pontchartrain and Lake St. Catherine as shown in Figure 1. The Louisiana Coastal Wetlands Planning, Protection and Restoration Task Force designated PO-0169 as part of the 24th Priority Project List. The United States Fish and Wildlife Service was designated as the lead federal sponsor with funding approved through the Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA) of 1990 by the United States Congress and the Wetlands Conservation Trust Fund by the State of Louisiana. The Louisiana Coastal Protection and Restoration Authority (CPRA) is serving as the local sponsor and will also be providing engineering and design services.

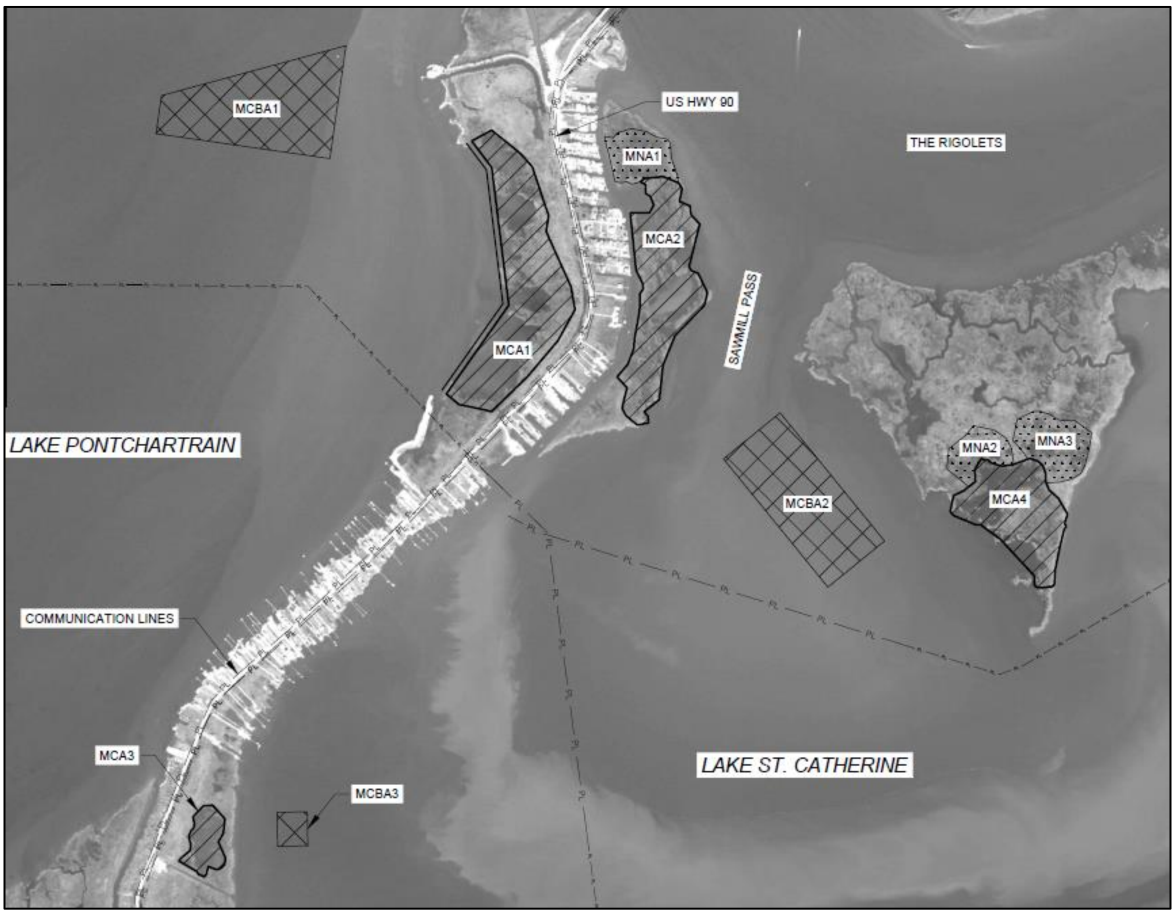


Figure 1: PO-0169 Vicinity Map

1.2 Project Area History

The area more commonly referred to as the New Orleans Land Bridge is an approximately 13 mile stretch of land that separates Lake Pontchartrain and Lake Borgne in southeast Louisiana. Two primary tidal channels, Chef Menteur Pass and The Rigolets connect the two lakes. The PO-0169 project area comprises the most western portion of the New Orleans Land Bridge and spans roughly 6 miles. The area forms an important geomorphic boundary and has been identified as a critical feature in terms of wetlands and storm protection.

The primary influence of marsh loss in the project area has been tropical storm and hurricanes. Since 1956, approximately 110 acres of marsh has been lost along the east shore of Lake Pontchartrain between Hospital Road and the Greens Ditch. This land loss was accelerated by Hurricane Katrina which passed 8 miles to the east of the project footprint. USGS land change analysis determined a loss rate of -0.35% per year for the 1984 -2011 period of analysis (Coast 2050).

1.3 Project Goals

The primary goal of PO-0169 is to create 169 acres and nourish an additional 102 acres of brackish marsh (WVA 2014). Containment dikes will be constructed along four marsh creation areas along the shores of Lake Pontchartrain and Lake St. Catherine. The containment dikes aligned in open water areas fronting the lakes will be enhanced for protection against storm and wind induced wave energy.

The engineering and design, environmental compliance, real estate negotiations, operation/maintenance planning, and cultural resources investigation have been completed to the 30% design level as required by the CWPPRA Standard Operating Procedures Version 22.

2.0 EXISTING CONDITIONS

2.1 Land Ownership

The four marsh creation cells are owned by five different land owner groups. MCA 1 is owned by Park Investments, LTD. MCA 2 is owned by Bryan Burch, et al to the north and Chef Menteur Landco LTD & Bryan Burch, et al to the south. MCA 3 is owned by EIP Chef Menteur LLC. MCA 4 is owned by Chef Menteur Landco LTD. MCA 1, 2 and 4 all contain different lessees. The tax ownership map is shown in Figure 2.

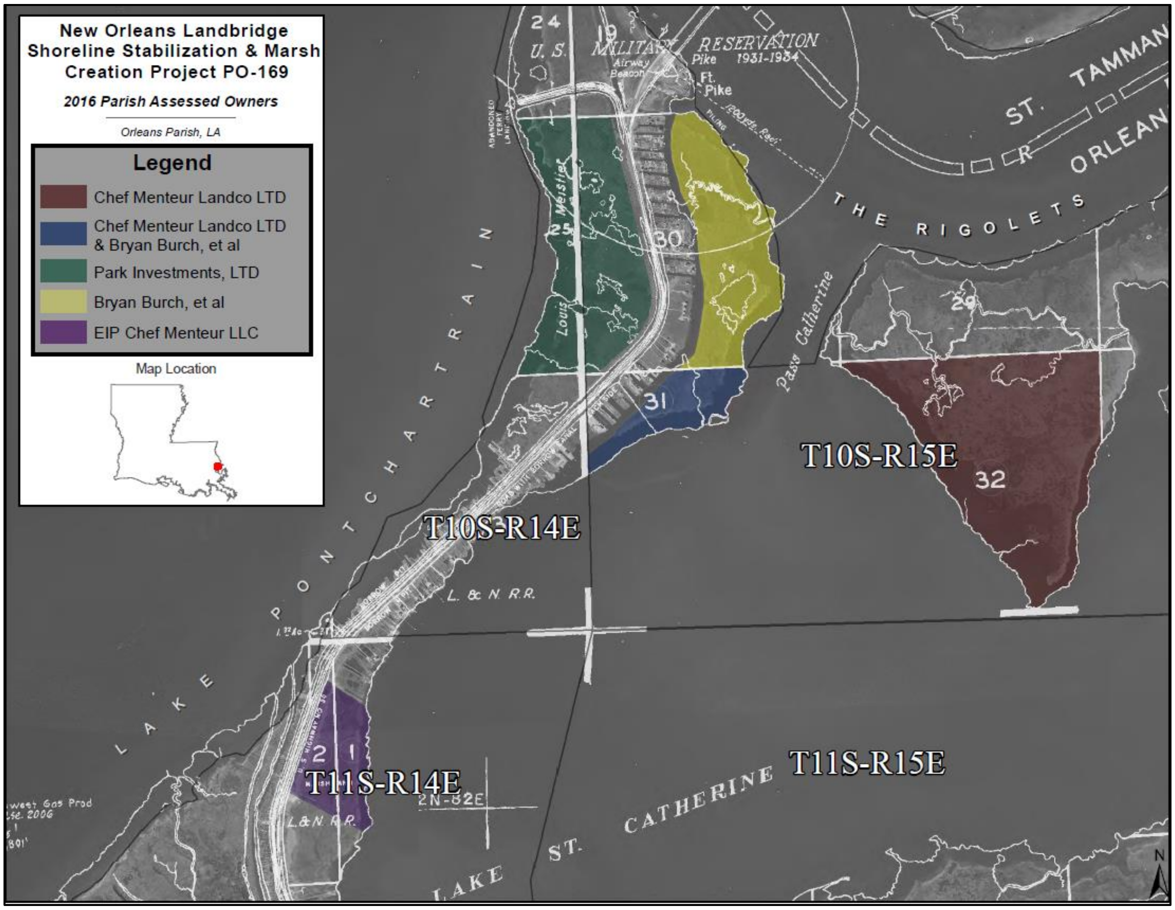


Figure 2: Tax Ownership map.

2.2 Cultural Resources Assessment

Coastal Environments, Inc. (CEI) performed a cultural resources survey on the marsh creation areas. The USFWS contacted the State Historic Preservation Office (SHPO) regarding the PO-0169 project requesting a determination of effect for any Area of Potential Effects that might be recorded within the project areas. After a review of the provided survey, the USWS was issued a letter stating that no known culturally significant sites would be disturbed through the creation of the PO-0169 marsh creation areas. However, it was stated that an investigation should be conducted on any offshore areas where work would be done. Copies of the letters can be found in Appendix A.

As part of the survey of the borrow areas performed by Fugro Geospatial Inc. a Registered Professional Archeologist (RPA), as per LR 20:410 (April 1994), was present for the efforts. The RPA determined that no areas of concern were present (Appendix B). The SHPO will be consulted once borrow areas are finalized.

2.3 Oyster Lease Assessment

No oyster leases have been identified within the marsh fill or borrow areas.

2.4 Sea Level Rise

In order to properly design the PO-0169 project and ensure it is built and performs according to the objectives for the 20-year project life, certain natural processes such as sea level rise (SLR) must be assessed. Relative sea level rise (RSLR) consists of two components: eustatic (or global) sea level rise (ESLR) and subsidence. For the purposes of the 30% level of design, ESLR will be used. The annual incremental ESLR is shown in the Table 1 below (Reed et al 2016).

Table 1: PO-0169 Annual Incremental ESLR (feet NAVD88 Geoid12A)

Year	Annual Incremental Eustatic Sea Level Rise taking into account project start year (ft)
2018	0.000
2019	0.019
2020	0.039
2021	0.059
2022	0.080
2023	0.101
2024	0.122
2025	0.144
2026	0.167
2027	0.189
2028	0.212
2029	0.236
2030	0.259
2031	0.284
2032	0.308
2033	0.333
2034	0.359
2035	0.384
2036	0.411
2037	0.437
2038	0.464
2039	0.491
2040	0.519

2.5 Tidal Datum

The tidal datum is a standard elevation defined by a certain phase of the tide and issued to measure local water levels and establish design criteria. Typically, the primary objective for computing the tidal datum is to establish the target construction marsh fill elevation that maximizes the duration that the restored marsh will be at intertidal elevation throughout the 20 year project life.

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 heights 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.

The Coastwide Reference Monitoring System (CRMS) monitoring station CRMS3784 located at 30°09'23.97"N, 89°39'52.68"W was selected as the control station because of its proximity to the project area (Appendix D). The period of record used was January 8, 2013 to January 8, 2018, a five year period as per CPRA's *Marsh Creation Design Guidelines 1.0 (MCDG 1.0):* Appendix D: *Marsh Inundation Methodology*. The results of the tidal datum determination for the PO-0169 project area are as follows:

- MHW = +0.99 feet, NAVD88
- MLW = +0.05 feet, NAVD88
- MTL = +0.52 feet, NAVD88

Historically, the tidal range has been the accepted range for healthy marsh. However, this method neglects non-tidal water level influences such as precipitation and management regimes. In order to account for tidal and non-tidal influences, an additional water level determination method, the Percent Inundation Method, was used to determine the optimal marsh elevation range.

2.6 Percent Inundation Determination

The vertical positioning of marsh platforms and the frequency with which the marsh floods strongly influences plant communities and marsh health (Visser 2003, Mitsch 1986). Historically, the tidal range between MHW and MLW has been the accepted range for healthy marsh. This approach only takes into account the tidal influences on the water levels, whereas in many areas, non-tidal influences such as meteorological events, river discharges, and management regimes often have a large impact on the water levels found in that region. Percent inundation refers to the percentage of the year a certain elevation of land would be flooded. Therefore, using percent inundation rather than tidal range as a proxy for marsh health can give a more accurate representation of the water levels found in the area.

To determine percent inundation, the percentiles were calculated based on data gathered from the CRMS3784 station for the period from January 8, 2013 to January 8, 2018. Table 2 presents the results for a Target Year 0 (TY0) of 2020.

Using the CRMS3784 station and discussion with the project team the marsh type for PO-0169 was determined to be brackish. Brackish marshes are most productive when flooded between 10% and 65% of the time (Snedden 2012). 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 ESLR (Figure 3).

Table 2: Percent inundation elevations for TY0.

Percent Inundated	Marsh Elevation (ft. NAVD88 Geoid 12A)
10%	**1.38**
20%	1.09
30%	0.90
40%	0.73
50%	0.56
60%	0.40
65%	**0.32**
70%	0.22
80%	0.03
90%	-0.23

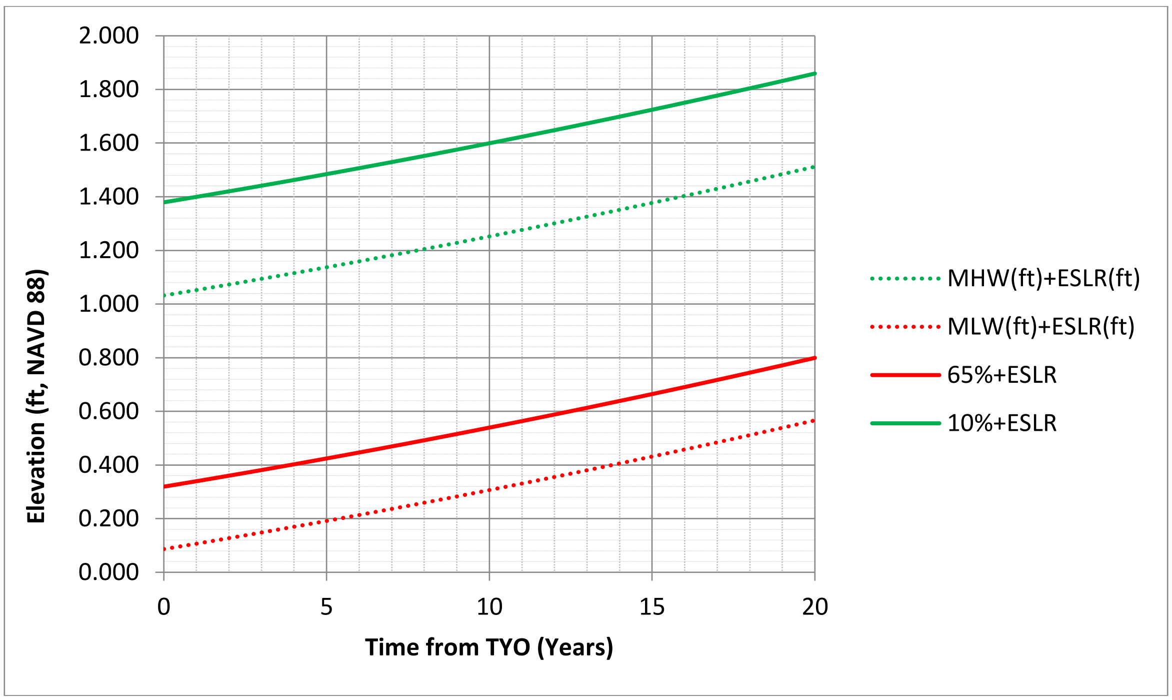


Figure 3: Percent inundation and MHW, MLW comparison.

3.0 SAND SEARCH INVESTIGATION

In 2003, NOAA National Marine Fisheries Service and USFWS jointly declared Lake Pontchartrain and Lake St. Catherine Gulf Sturgeon Protected Habitat. As such, it is required that each federal agency shall, in consultation with the USFWS, insure that any action authorized, funded or carried out by the federal agency is not likely to adversely modify critical habitat. In coordination with USFWS, it was determined that areas with sand concentrations greater than 75 percent should be avoided. This percentage was based upon a report that sturgeon are often located in areas where sand comprised eighty percent or more of the substrate (Fox et al. 2000). This is also consistent with projects recently constructed through CWPPRA.

In order to clear these areas a sand search was performed in the three potential borrow areas. These borrow areas were conservatively sized to allow for delineation. In coordination with the USFWS, sample spacing was determined to be 650 feet on center in borrow areas 1 and 2 and 325 feet on center in borrow area 3. The sampling map is shown in Appendix C. Samples were taken with a split spoon sampler to 1 foot below the mudline. The top 3 inches were trimmed and tested for grain size distribution. Sediments retained in the #10 sieve were considered sands desirable for sturgeon habitat.

Borrow Areas 2 & 3 contained no samples with sand concentrations higher than 75% and were cleared for dredging. Borrow area 1 had sand in the north-central portion and was resized accordingly. These maps can be found in Appendix C.

4.0 SURVEYS

Topographic, bathymetric, magnetometer, and geophysical survey data were collected within the project area, proposed borrow areas and potential dredge pipeline alignments in order to facilitate the design of the marsh creation area and the borrow areas. The design survey effort was performed in May 2016 and July 2016 by Chustz Surveying, LLC (Appendix E). All horizontal coordinates are referenced to Louisiana State Plane Coordinate System, North American Datum of 1983 (NAD83). All elevations are referenced to North American Vertical Datum of 1988 (NAVD88) GEOID12A.

4.1 Horizontal and Vertical Control

One CRMS, National Geodetic Survey (NGS) style monument CRMSPO-SM-25 exists in the vicinity of the project area. CRMSPO-SM-25 is located southeast at the intersection of U.S. Hwy. 90 and La. Hwy. 433 in St. Tammany Parish, Louisiana. The field survey was accomplished utilizing RTK surveying procedures and checked using NGS Online Positioning User Service (OPUS). The data sheet for the survey monument can be found in Appendix D.

4.2 Marsh Creation Area Surveys

Survey transects were taken in a grid approximately every 500 feet in MCA 1, 2 and 4 and 250 feet in MCA 3 as shown in Appendix E. Transects were taken across open water areas, broken marsh, and across pipeline canals. Position, elevation, and water depths were recorded every 25 feet along each transect or where elevation changes were greater than 0.5 feet. Topographic and bathymetric survey methods were used as applicable to obtain all transects and were consistent with CPRA's *Marsh Creation Design Guidelines Version 1.0 (MCDG 1.0):* Appendix A: *A Contractor's Guide to the Standards of Practice*. The topographic portions were merged with the bathymetric portions at the land/water interface and were separated by no more than 50 feet. Side shots were taken as necessary to pick up variations in topographic features (highs and lows) such as trenasses, meandering channels, broken marsh areas, or any other existing infrastructure such as pipelines, well heads, wooden gates, and warning signs which may affect project design implementation. Surveys in MCA 1 extended to Hwy. 90 to capture the elevation of the road. The use of a fixed height aluminum rod (8 feet or 10 feet in length) with a 6 inch diameter metal plate as the base of the rod was used to prevent the rod from sinking when topographic data was collected.

A magnetometer survey was taken along the shorelines of all fill areas and one transect was taken through MCA 4 as shown in Appendix E in order to locate any pipelines or other infrastructure in the fill area. A Geometrics G882 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.

Significant anomalies (> 50 Gammas) were probed. The magnetometer survey did not identify any significant anomalies within the fill area. An abandoned well-head was discovered south of MCA 2 well clear of any potential construction activities.

4.3 Borrow Area Survey

Survey transects of the proposed borrow area were taken every 98 feet. Position, elevation, and water depth were recorded every 50 feet along each transect or where elevation changes were greater than 0.5 feet. Bathymetric survey methods consistent with the CPRA *MCDG 1.0*: Appendix A were used to obtain all transects (*A Contractor's Guide to the Standards of Practice*).

In addition to a bathymetric survey, a magnetometer survey was performed along the same transects as the bathymetric survey. This survey identified any pipelines, well heads, or any other infrastructure within the borrow area. Similar equipment that was used on the marsh fill area magnetometer survey was utilized in the proposed borrow area.

One hundred twenty (120) magnetic anomalies were detected. Significant anomalies (> 50 Gammas) were probed. No structures were discovered within the borrow areas. The only potential pipeline probed was south of MCBA 2 and this borrow area boundary was adjusted accordingly.

4.4 Dredge Pipeline Alignment Surveys

A magnetometer survey was performed along the potential dredge pipeline alignments to check for any anomalies. No anomalies were discovered, however further surveys may be conducted if the dredge pipeline alignments change.

4.5 Healthy Marsh Elevation Survey

Elevations from points that appeared to have healthy marsh were utilized to determine an average elevation of healthy marsh (Appendix E). Table 3 shows the results of the average healthy marsh survey. According to this survey, healthy marsh elevation is approximately +0.81 ft, NAVD88. At this elevation, the marsh surface is estimated to be inundated between 30-40% of the time based on water elevation data from CRMS3784 (Table 2).

Table 3: Average healthy marsh elevation survey results.

Location	Elevation (ft NAVD88)
M-1	0.57
M-2	0.98
M-4	0.89
Average	**0.81**

5.0 GEOTECHNICAL ENGINEERING ANALYSIS

The geotechnical subsurface investigation and geotechnical engineering analysis was conducted by S&ME Inc. CPRA's Project Engineer provided guidance and performed portions of the analysis as described below.

S&ME Inc. was tasked to collect borings in the borrow and fill areas, perform laboratory tests to determine soil characteristics, perform a column settling test to determine the settling characteristics of the slurry, perform low pressure consolidation tests in order to aid in the settlement determination of the slurry, and perform standard consolidation tests in order to aid in the settlement in the marsh creation area and beneath the containment dikes. The CPRA Project Engineer was present during composite sample selection and preparation.

S&ME, with the assistance of the CPRA Project Engineer, performed a detailed slope stability analysis of the proposed earthen containment dikes, articulated concrete block mats, and rock dike. S&ME estimated the total settlement of the proposed earthen containment dikes and marsh creation areas, and determined an adequate cut-to-fill ratio for the dredge and fill operations.

5.1 Preliminary Geotechnical Investigation and Data Gap Analysis

Prior to conducting the field subsurface investigation a search of any historical data on the area was conducted. This included looking at prior subsurface investigations that occurred in the area as well as reviewing historical geological maps.

The review found several borings in the area that were drilled by the USACE. USACE was contacted and the borings logs were requested. Additionally, the geological map (Figure 4, Appendix I) was obtained and analyzed to locate any fault lines and determine any potential historical ridges or low strength areas.

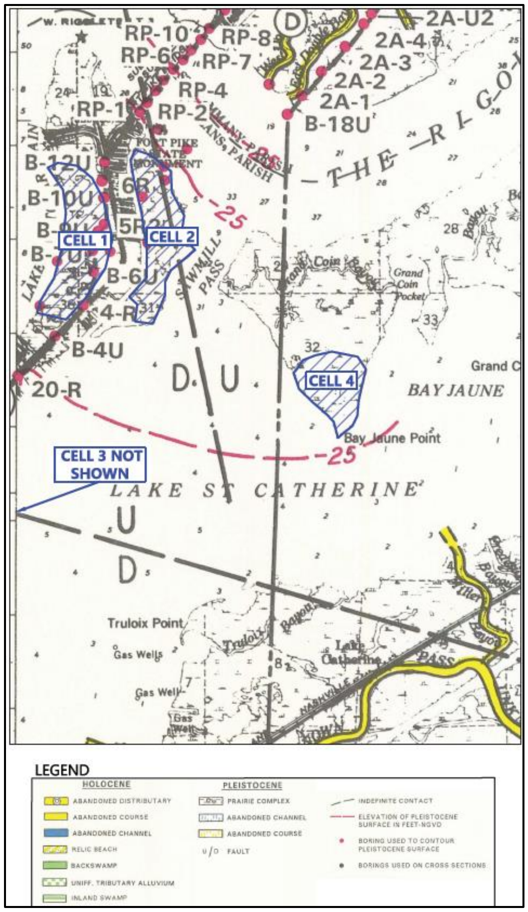


Figure 4: USACE Geological Map.

5.2 Marsh Creation Area Geotechnical Subsurface Investigation

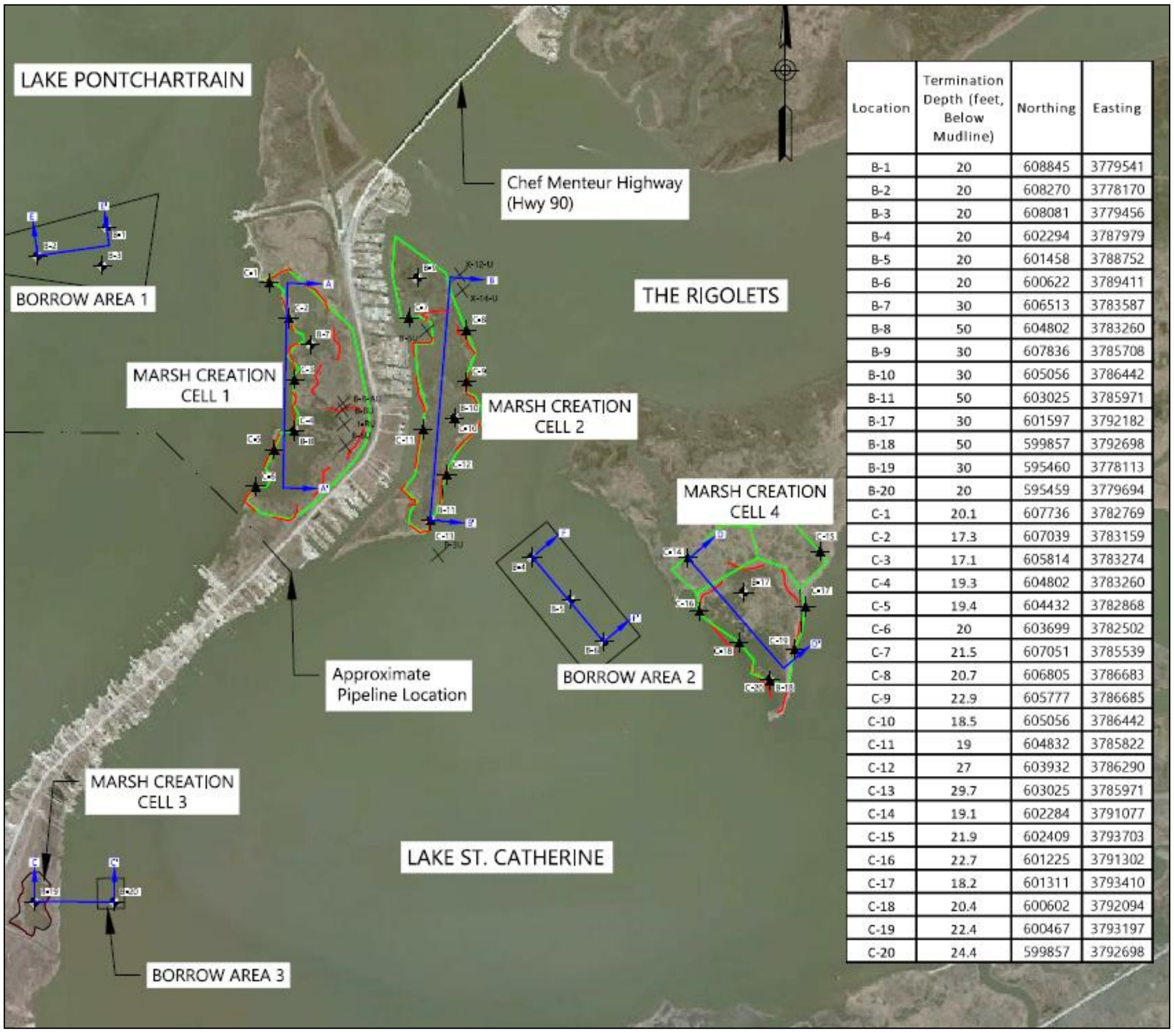
Soil conditions were evaluated in the marsh creation area by performing twenty (20) cone penetration tests (CPTs) at depths ranging from 18 to 30 feet below the existing mudline and advancing eight (8) soil borings to depths ranging from approximately 30 to 50 feet below the existing mudline. Water levels ranged from elevations of -2 feet to +1 feet NAVD 88. The approximate sampling locations are shown in Figure 5.

CPTs were performed first in the marsh fill area using an airboat mounted rig. CPTs were performed prior to the borings to assist in determining any substantial changes in soil stratigraphy. Based upon this effort boring locations could be adjusted. The CPTs were completed in May 2017. Locations and data can be found in Appendix H.

After examination of the CPT data, borings were then drilled using a drill rig mounted on a marsh buggy. Samples were collected with a piston sample in Shelby tubes continuously in the upper 20-feet of the soil and on 5-foot centers thereafter to boring completion depths. Those samples unable to be collected using Shelby tubes were collected using the Standard Penetration Test (SPT) Method with split-barrel sampling spoons. All samples were then classified, stored, and transported to the laboratory. The soil borings were completed in June

2017 using a marsh buggy mounted rotary-drill rig. Locations and data can be found in Appendix H.

Shelby tube samples were tested for miniature vane shear strength and removed from their tubes. Laboratory tests included soil compressive strength, moisture content, organic content, grain size analysis, specific gravity, consolidation with rebound, and Atterberg limits.



Location	Termination Depth (feet, Below Mudline)	Northing	Easting
B-1	20	608845	3779541
B-2	20	608270	3778170
B-3	20	608081	3779456
B-4	20	602294	3787979
B-5	20	601458	3788752
B-6	20	600622	3789411
B-7	30	606513	3783587
B-8	50	604802	3783260
B-9	30	607836	3785708
B-10	30	605056	3786442
B-11	50	603025	3785971
B-17	30	601597	3792182
B-18	50	599857	3792698
B-19	30	595460	3778113
B-20	20	595459	3779694
C-1	20.1	607736	3782769
C-2	17.3	607039	3783159
C-3	17.1	605814	3783274
C-4	19.3	604802	3783260
C-5	19.4	604432	3782868
C-6	20	603699	3782502
C-7	21.5	607051	3785539
C-8	20.7	606805	3786683
C-9	22.9	605777	3786685
C-10	18.5	605056	3786442
C-11	19	604832	3785822
C-12	27	603932	3786290
C-13	29.7	603025	3785971
C-14	19.1	602284	3791077
C-15	21.9	602409	3793703
C-16	22.7	601225	3791302
C-17	18.2	601311	3793410
C-18	20.4	600602	3792094
C-19	22.4	600467	3793197
C-20	24.4	599857	3792698

Figure 5: Soil Boring and CPT Locations

5.3 Borrow Area Subsurface Investigation

Soil conditions were evaluated in the proposed borrow areas by advancing seven (7) Shelby tubes to 20 feet below the existing mudline. The borings were performed in approximately 5 to 16 feet of water using a pontoon mounted drill rig and a piston sampler. Index properties observed during drilling and laboratory test results are located on the boring logs in Appendix H.

Settling column tests and low-pressure consolidation tests were performed on two separate composite samples: one from the borrow area in Lake Pontchartrain using borings B-1, B-

2 and B-3 and one from the borrow area in Lake St. Catherine using borings B-4, B-5 and B-6. Pilot tests were performed on each of the composite samples to determine initial concentrations. For the Lake Pontchartrain composite sample concentrations of 149.2 g/L, 108.5 g/L and 128.6 g/L were used for the pilot tests and the full scale column settling test was conducted at a concentration of 128.6 g/L. For the Lake St. Catherine composite sample a full column settling test was conducted on a concentration of 135.8 g/L.

5.4 Earthen Containment Dike (ECD) and Rock Dike Slope Stability Analysis

Global slope stability analyses were performed on the proposed earthen containment dikes (ECDs) at different elevations and geometries. The slope stability of the ECD has two types of driving forces: (1) the forces induced by the soil weight, and (2) any seepage forces, which tend to cause the soil to slide. In response to these driving forces, the subsurface soils have a resistant force in the form of shear strength, which attempts to keep the slope from sliding. Both the driving forces and the resisting forces are dependent on the geometry of the situation: the "Failure Surface". S&ME and the CPRA Project Engineer performed stability analyses that computes factors of safety against potential failure based on limit equilibrium theory.

For this project, multiple scenarios were run based upon the alternatives analysis (see Section 7.2). Stability runs included evaluating:

1) earthen containment dike with borrow on one side
2) earthen containment dike with fill on one side
3) earthen containment dike with articulated concrete mat with borrow on one side
4) earthen containment dike with articulated concrete mat with fill on one side
5) rock dike with a floatation channel on one side

Each of these runs was conducted with or without geotextile reinforcement placed as necessary and is indicated in the results (Appendix I). A factor of safety of 1.2 was determined by CPRA in consultation with S&ME Inc. to be acceptable for ECD slope stability analyses, based on experience, risk and similar projects.

Table 4: ECD and RD Slope Stability Results

Location	Condition	Estimated Berm Crest El. (ft. NAVD88)	Borrow Excavation Offset (ft)	Berm Side Slope	Geogrid	Factor of Safety
MCA 1	**Rock Dike to Floatation Channel**	+3.5	10	2.5H:1V	Y	1.44
	ECD No Fill	+3.5	10	4H:1V	N	1.5
	ECD Max Fill	+3.5	10	4H:1V	N	1.43

MCA 2	**Rock Dike to Floatation Channel**	+3.0	10	2.5H:1V	Y	0.81*
	ECD with ACM and No Fill	+3.0	10	4H:1V	N	1.35
	ECD with ACM with Fill	+3.0	10	4H:1V	Y	1.22
MCA 4	**Rock Dike to Floatation Channel**	+2.5	10	2.5H:1V	Y	0.89*
	ECD with ACM and No Fill	+3.5	10	4H:1V	N	1.22
	ECD with ACM with Fill	+3.5	10	5H:1V	Y	1.23

*__Bearing capacity failure__

5.5 Earthen Containment Dike and Rock Dike Settlement Analysis

Consolidation settlement of the foundation soils beneath the earthen containment dikes were computed based on the dike geometries determined from the slope stability analyses and the soil properties of the underlying soils. For this project a rock dike was also analyzed. Total settlement factors include regional subsidence and elastic settlement of the in situ soils. Elastic settlement (construction settlement) of the in situ soils will occur quickly and will likely result in an increase in the quantity of fill required to reach the design construction elevation.

This project required multiple settlement analysis runs. The runs determined settlement due to the placement of traditional containment dikes, enhanced earthen berms, and containment dikes with articulated concrete mats placed on top and rock dike as per the alternatives analysis described in Section 7.3.

Elevations of +3.0 and +3.5 feet NAVD 88 were analyzed to provide a 1 foot freeboard to the +2.0 and +2.5 foot fill elevations as is described in section 7.2 . A full table of the settlement results can be found in Section 4.4 of the Geotechnical Engineering Report (GER) and the input and output files in the appendices. The GER is provided in Appendix I.

5.6 Marsh Creation Area Settlement Analysis

A marsh creation area settlement analysis was performed to determine the construction marsh fill elevation of the marsh creation areas and the total volume of fill material. The final elevation of the marsh creation area (at year twenty) 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. Data from column settling tests and low-pressure consolidation tests was used to estimate the magnitude and time-rate of settlement of the slurry and data from traditional consolidation testing was used to determine the settlement of the underlying soils of the marsh creation areas.

A new approach was used for this project based upon previous project experience. Borrow area samples were grouped into two types of materials: Type I and Type II. Type I materials are soils that when pumped in slurry form are less flowable. This includes sand, silty sand, clayey sand and any soft to stiff clay balls. Type II material are soils that when pumped in slurry form are flowable. This includes clay, silty clay, clayey silt and silt. Settlement analysis was conducted independently on Type I and Type II borrow material. Concurrently, traditional settlement analysis was conducted on the subsurface material. These settlements were then combined to achieve the total settlement. The estimated total settlement is shown in Figure 6.

The ideal final marsh platform would settle into the optimal brackish marsh range (10%-65% inundated) shortly after construction and would remain there for the duration of the 20 year project life. This data was utilized to design the marsh creation area as specified in Section 7.1.

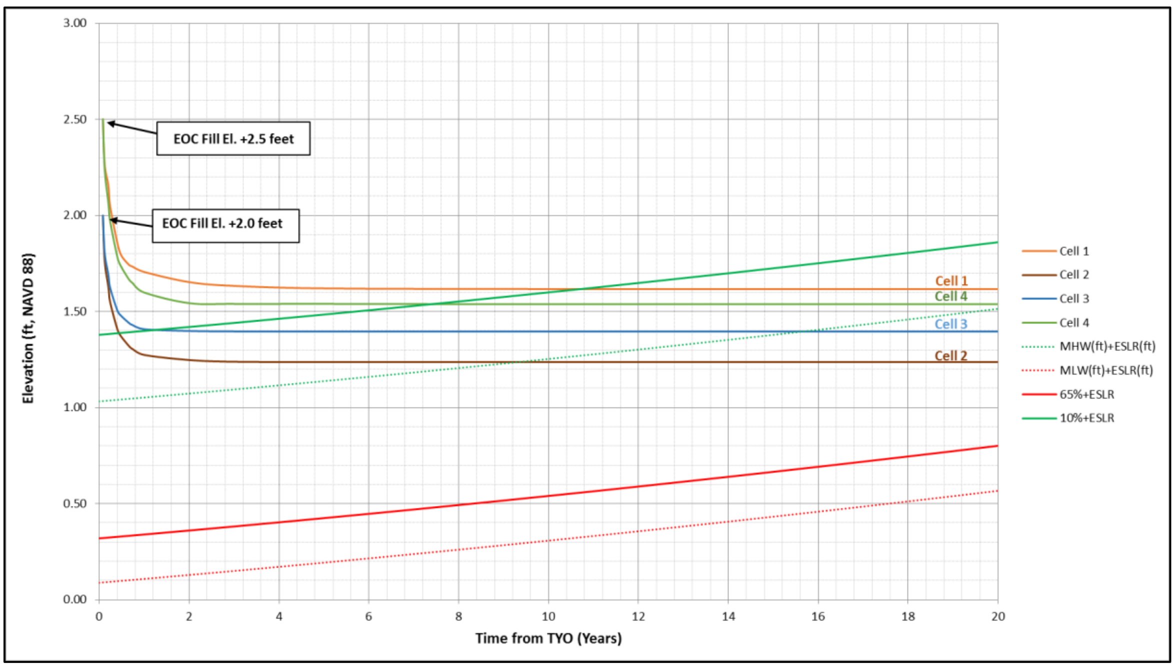


Figure 6: Estimated Total Settlement Curves, 10% & 65% inundated, MHW & MLW lines including ESLR.

5.7 Cut-to-Fill Ratio Recommendations

Cut to fill ratios were determined by S&ME in order to account for losses due to dredging, containment, and dewatering. A cut to fill ratio of 1.0 will be applied for all hydraulically dredged marsh fill sediment. Mechanical dredging of the containment dikes has generally yielded a cut to fill ratio approximately between 1.2 and 1.6. For this project a cut to fill of 1.5 will be used for mechanical dredging of the containment dikes.

6.0 HYDRAULICS

6.1 Model Setup

Mott MacDonald (M. M.) was tasked to analyze the wave environments along the shorelines of Lake Pontchartrain and Lake St. Catherine. Due to the open-water configuration of the dikes there were constructability concerns as well as short-to-long term erosion concerns. Therefore, M. M. analyzed the wave conditions from 1, 2 and 5 year storm events along the proposed containment dikes.

SWAN (Delft University of Technology, 2012) was chosen to run the model scenarios. SWAN is a 2-D, selected spectral (phase-averaged) wave transformation model that can be used to generate wind-waves and transform wave conditions.

M. M. utilized bathymetric/topographic data, water elevations, wave height, wave period and direction, wind speed and direction and sediment characteristics from the proposed project area and borrow areas to calibrate the model. Data was extracted from the data collection efforts for the project as well as the 2017 Coastal Master Plan.

6.2 Model Scenarios

To analyze potential impacts to the proposed containment dike and marsh creation areas, several return periods were selected: 1 year, 2 years and 5 years. These return periods allowed the team to observe wave heights that would occur throughout construction (roughly 1-2 years) as well as through 5 years at which point the marsh platform should be established. Effects were measured by comparing the MHW and MLW levels with the extreme water surface elevations, surge and wave heights.

6.3 Model Inputs

The inputs for the model are shown in Table 5. These inputs includes storm tide water levels and wind speeds. Project Area 1 and Project Areas 2, 3 and 4 had different inputs due to the location of the marsh creation cells. Project Area 1 is located on the eastern shore of Lake Pontchartrain and Project Areas 2, 3 and 4 are located along the shores of Lake St. Catherine. Wind and water gauges were chosen accordingly.

Table 5: Wave model inputs for design conditions

Return Period [years]	Wind Speed [mph]*	Project Area 1 Storm Tide [ft NAVD]	Project Area 2, 3, 4 Storm Tide [ft NAVD]
1	32.4	3.1	2.9
2	36.2	3.6	3.1
5	42.1	4.4	3.8

6.4 Model Results

Results for the three return periods are shown in Table 6 below. Focusing on the 1 year storm, which would take into consideration construction, the results show that MCA 1 will experience waves of 3.5 feet, MCA 2 & 3 will experience waves of 1.8 feet and MCA 4 will experience max waves of 1.7 feet. This equates to top of wave elevations of +6.6 feet, +4.7 feet, +4.7 feet and +4.6 feet for MCAs 1, 2, 3 and 4 respectively.

Table 6: Maximum significant wave height at each Project Area

	Project Area 1 Max Hs [ft]	Project Area 2 Max Hs [ft]	Project Area 3 Max Hs [ft]	Project Area 4 Max Hs [ft]
1yr	3.5	1.8	1.8	1.7
2yr	3.9	2.1	2.1	2.0
5yr	4.4	2.6	2.5	2.5

6.5 Model Summary

Based upon the model results, it can be concluded that some method of shoreline stabilization will be needed along the open water areas where containment dikes will be placed. In particular MCA 1, which experiences significant wave events even in a one year storm. A detailed analysis of different alternatives for shoreline stabilization is discussed in Section 7.2. A copy of the results of the modeling effort can be found in Appendix G.

7.0 MARSH CREATION DESIGN

The project proposes to create marsh by hydraulically dredging material from three different borrow areas into four separate marsh creation areas shown in Figure 7 and the Preliminary Design Drawings located in Appendix J. The marsh creation design was broken up in the following sections: the marsh creation area, the earthen containment dikes, the shoreline stabilization component, the dredge borrow area and the dredge pipeline alignments. The shoreline stabilization component included an alternative analysis for different methods. The design, including the alternatives analysis, is discussed in detail below.

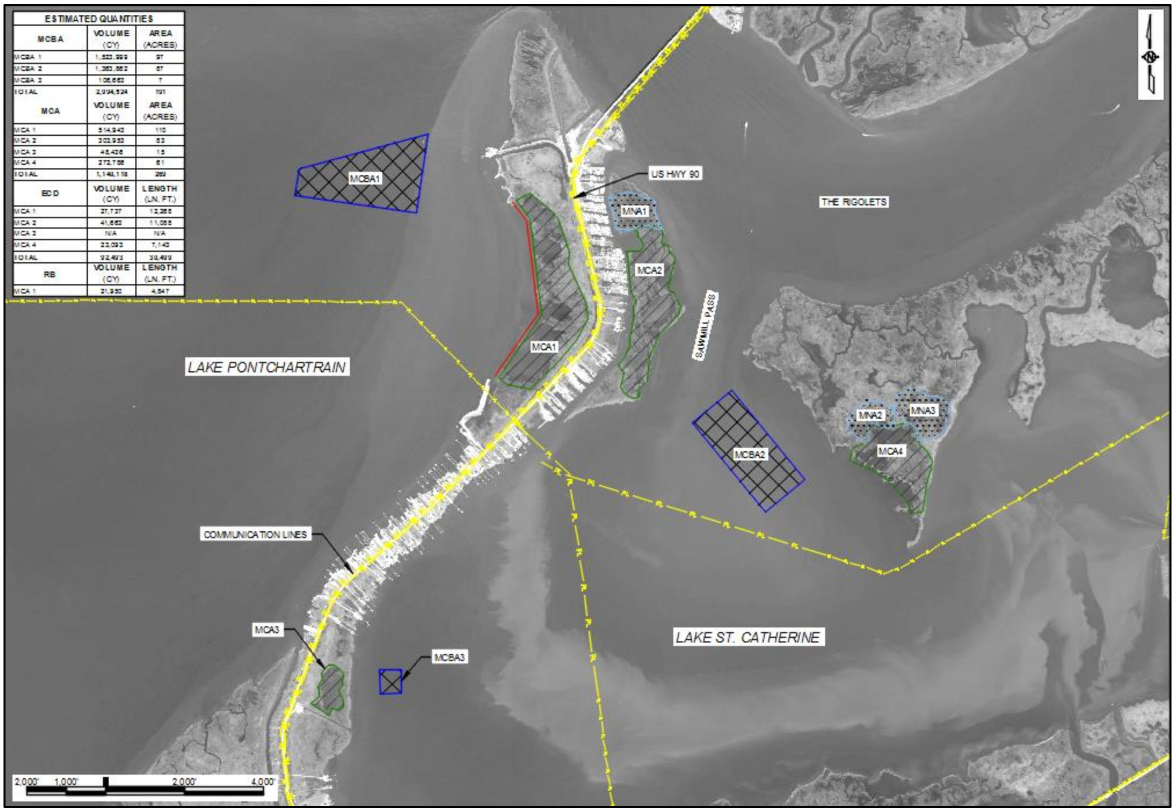


Figure 7: Plan view of the project design features.

7.1 Marsh Creation Area Design

The goal of the marsh creation area feature is to address the land loss in this area to protect the existing shoreline and maintain the structural integrity of the Orleans Landbridge. The alignment of the fill area went through several changes from the original Phase 0 configuration before arriving at the current configuration shown in the 30% Plans. The Phase 0 configuration had four marsh creation areas with containment features traversing multiple open water segments. Based upon the surveys conducted on these areas the alignments were shifted to depth contours that could support containment based upon the geotechnical analysis.

The next step in the marsh creation design involved determining an appropriate constructed marsh fill elevation. This elevation was governed by several factors including the tidal range, percent inundation, the healthy marsh elevation, the physical properties of the borrow material and the bearing capacity of the foundation soils in the marsh creation area. Determination of the constructed marsh fill elevation was based on consideration of the average marsh elevation over the life of the project with respect to intended functioning of the marsh from both a habitat perspective and meeting the project goals and objectives. One element of the design is to maximize the time period that the marsh platform has an elevation within the functional brackish marsh inundation range (10%-65% inundated). Over the 20-year project life, including ESLR as discussed in Section 4.4, the preferred inundation range is expected to rise from 0.32 ft NAVD88 and 1.38 ft NAVD88 (65%-10% inundated) to 0.80 ft NAVD88 and 1.86 ft NAVD88.

To achieve the project goals, the dredged slurry will need to initially be placed to a constructed fill elevation above the functional brackish marsh range and settle into the range over the design life. To satisfy these conditions, the marsh creation area will be pumped to an elevation of +2.5 ft NAVD88 for MCAs 1 and 4 and an elevation of +2.0 ft NAVD88 for MCAs 2 and 3.

After determining the constructed marsh fill elevations, the total volume of the marsh creation area was calculated using AutoCAD Civil software. The software creates a 3-Dimensional surface based on XYZ coordinate data from the survey cross-sections. This surface is known as the Triangulated Irregular Network (TIN). The TIN model represents a surface as a set of contiguous, non-overlapping triangles. Both a TIN surface containing the 2016 survey data from Chustz Surveying, LLC and a flat TIN surface at the creation construction elevation was created by AutoCAD. AutoCAD then uses the XYZ differences of each surface to calculate the volume of the marsh creation area. Since the containment borrow must be refilled, the volume to build the containment dikes plus a cut-to-fill ratio of 1.5 for the dikes is then added to the volume required to fill the marsh creation areas. Finally, the cut-to-fill ratio of 1.0 is applied, resulting in a final estimate of volumes for the marsh creation areas. Table 8 summarizes the fill volumes for the PO-0169 project.

Table 7: Summary of creation acreage and volume

Fill Area	Constructed Fill Elevation (ft NAVD88)	Area (Acres)	Cut to Fill	Volume of Fill (yd^3)	Volume of Cut (yd^3)
1	+2.5	110	1.0	514,943	514,943
2	+2.0	83	1.0	303,953	303,593
3	+2.0	15	1.0	48,436	48,436
4	+2.5	61	1.0	272,786	272,786

Though the final constructed fill elevation of the marsh fill area will be +2.5 ft and +2.0 ft, NAVD88, volume calculations were determined near the final settled constructed marsh fill elevation to allow for primary consolidation settlement of the fill to occur. As shown in the settlement curve in Figure 7, the fill elevation decreases at a much quicker rate within the first few years after construction as compared to the mid to later years due to the draining of excess pore water. Near the completion of primary consolidation settlement, the material has a chance to mostly dewater giving a more accurate estimate of the actual volume of dredged material needed to achieve the target marsh elevation.

7.2 Earthen Containment Dike Design

The primary design parameters associated with the earthen containment dike (ECD) design include crown elevation, crown width and side slopes. A minimum of one foot of freeboard is recommended to contain the dredge slurry within the proposed marsh creation fill area while maintaining an acceptable factor of safety. The ECDs are required to be maintained to the constructed elevations throughout the duration of dredging operations.

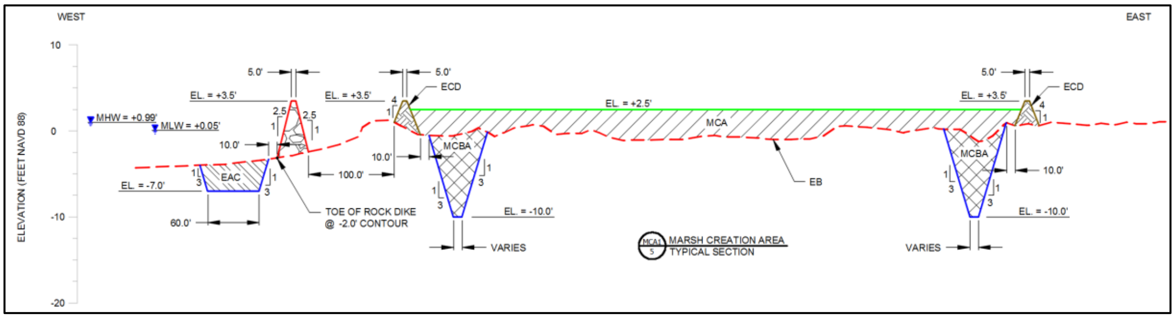


Figure 8: Typical earthen containment dike section for MCA 1.

As discussed in Sections 5.4 and 5.5, settlement of the soils beneath the earthen containment dikes was computed based on the dike geometries. The settlement curves for the final dike geometry and elevation is shown in Figure 8. The results show that a minimum of one (1) foot of freeboard will be present at all times during construction and throughout the 20 year project design life.

Table 8: Summary of earthen containment dike design.

Marsh Creation Area	Length of Containment (ft)	Cut to Fill	Volume of Fill (yd3)	Volume of Cut (yd3)
1	12,268	1.5	27,737	41,606
2	41,663	1.5	41,663	62,495
3	N/A	N/A	N/A	N/A
4	23,093	1.5	23,093	34,640

7.3 Shoreline Stabilization Design & Alternative Analysis

The Phase 0 design of this project featured enhanced earthen berms as the shoreline stabilization method. The potential for poor geotechnical soil conditions and the high wave energy environments of Lake Pontchartrain and Lake St. Catherine led to a more detailed look at this option.

Three alternatives were analyzed: and enhanced earthen berm, articulated concrete mats and foreshore rock dike. All three alternatives were analyzed from the perspective of geotechnical soil conditions and wave conditions. Adjustments to project benefits will be conducted moving forward to 95% design.

7.3.1 Alternative 1-Enhanced Earthen Berm

The first alternative evaluated constructing an enhanced earthen berm as originally planned. These berms would be constructed similar to typical containment dikes with increased slopes and crown widths. Side slopes would be a minimum of 6:1 and the crown width would be 10 feet. Material would be borrowed from the exterior.

Material would be placed with a clamshell bucket with restrictions on drop distances to minimize disturbance of the material to improve soil shear strength. Typical containment dikes constructed with marsh buggies produce almost fully disturbed material causing significant loss in shear strength. Clamshells allow for larger portions of material to be excavated and placed more strategically. This tends to produce dikes that are more tolerant to wave energy and erosion. To avoid access floatation for the clamshell barge, the enhanced earthen berm would be excavated from the outside of the berm.

Geotechnical analyses revealed no major failures with this alternative. However, slope stability concerns would require the use of geotextile material at the base of the dikes along the shorelines of MCAs 2 and MCA 4. Both construction and long term settlements were less than 1 foot. A summary of the geotechnical analysis can be found in Section 5.4 and 5.5 and the full report is available in Appendix I.

Wave analyses of this alternative displayed potential problems. With nearly 1 mile of enhanced earthen berm being constructed in water depths of roughly -2 feet, wave heights would be significant. The wave modeling results (Section 7.4) indicated that waves could reach a height of 3.5 feet for a 1-year storm with storm water elevations of +3.1 NAVD 88, meaning wave elevations would be approximately +6.6 feet NAVD 88. Waves of this size would make even construction of these dikes difficult.

Two recent case studies are available: Bayou Bonfouca Marsh Creation (PO-0104) and Lost Lake Marsh Creation and Hydrologic Restoration (TE-0072). These two projects both attempted constructing earthen berms fronting lake shorelines.

TE-0072 built an enhanced earthen berm along Lost Lake in Terrebonne Parish, LA. Side slopes were 6:1 with a 10 foot crown with exterior borrow. The contractor encountered significant issues during construction. Wave action continuously eroded the base of the berm as it was constructed requiring the base to be overbuilt to counteract the erosion. The wave action caused material to be further disturbed as it was eroded and washed back into the borrow pit. Due to the constant reworking of the material and continued wave action through construction, the finished product was not as desired. As of June 2018, approximately 6 months since the end of construction, nearly half the berm has been eroded.

PO-0104 attempted to build earthen dike along the northern shore of Lake Pontchartrain. Side slopes were 4:1 with an 8 foot crown and interior borrow. However, the contractor encountered constructability issues on this project as well. Constant wave action eroded the dikes faster than it could be constructed. Aquadams were installed in to attempt to block the wave action, but this failed as well. Ultimately, articulated concrete mats (ACMs) were installed upon the dike as it was constructed. ACMs are described in more detail in the following section.

7.3.2 Alternative 2-Articulated Concrete Mats

The second alternative evaluated placing articulated concrete mats (ACMs) on top of the constructed containment dikes. For the alternative analysis it was assumed that 4 inch thick, 65 pcf ACMs would be used. As in Alternative 1, the dike would be constructed using a clamshell with exterior borrow. However, instead of constructing an enhanced earthen berm, a conventional dike would be constructed with 4:1 side slopes and a 5 foot crown. The ACM would then be placed from the toe of the dike, over the crown and down the back of the dike.

Geotechnical analyses for this alternative revealed no major failures. However, slope stability concerns would require the use of geotextile material at the base of the dikes along the shorelines of MCAs 2 and MCA 4. Additionally, geotextile fabric would be needed to be placed prior to the ACMs being installed. This prevents material from leaving the system. Both construction and long term settlements were less than 1 foot. A summary of the geotechnical analysis can be found in Section 5.4 and 5.5 and the full report is available in Appendix I.

There are numerous projects where ACMs have been used throughout coastal Louisiana. That being said, these have always been used in channels. ACMs were designed and created to be used as channel liners to prevent erosion from stream flows. They have not been used in open water areas with significant wave energies. The only project to date in which they have been used in this capacity is PO-0104 as mentioned in Section 7.3.1. This project used them with some success. Significant settlement did occur and continues to occur due to toe scour and material loss through the toe. As of June 2018, several failures have occurred.

7.3.3 Alternative 3-Rock Breakwater

The final alternative evaluated involves placing a foreshore rock breakwater prior to constructing a traditional containment dike on the interior. The rock dike would be constructed to an elevation of +3.0 to +3.5 feet with 2.5:1 side slopes. Floatation would be needed for access to place the rock. A containment dike with side slopes of 4:1 and a 5 foot crown width would then be constructed. Borrow for the dike would come from the interior.

The rock would serve to dissipate the wave energy as it approached the containment dike, thus protecting the dike and ultimately protecting the marsh built behind it. The rock would be offset at a set distance and fish dips provided to allow fisheries access. The rock design is discussed in more detail Section 8.0

Geotechnical analyses for this alternative revealed potential failure of the rock breakwater for two of the MCAs. MCA 1 could be placed to an elevation of +3.5 feet NAVD88, but would need geotextile material placed at the base of the rock in some sections to prevent slope failures. Settlement would be approximately 1.3 feet and would need to be accounted for in quantities. At MCA 2, with geotextile reinforcement material and limiting the rock height to an elevation of +3.0 feet NAVD88, a passing factor of safety could only be achieved in limited areas. MCA 4 displayed similar results. However rock height in this cell was limited to +2.5 NAVD88. A summary of the geotechnical analysis can be found in Section 5.4 and 5.5 and the full report is available in Appendix I.

The wave analyses indicated that rock would need to be placed at an elevation of +4.85 feet to completely block a 1-year storm event. However, the geotechnical analysis limits the height to +3.5 feet. Despite this limitation, placing the rock to +3.5 feet would significantly dissipate waves. This alternative is discussed in detail in Section 8.0.

7.3.4 Preferred Alternative

After evaluating the three alternatives, the project team decided to move forward with a combination of the options. MCA 1 would use rock and MCA 2 and MCA 4 would a combination of traditional earthen containment dike and ACMs.

MCA 1, which lies along the shoreline of Lake Pontchartrain, has significantly higher waves than the other MCAs. This would make placing ACMs risky. Therefore using a foreshore rock breakwater on this cell would provide the best level of protection.

MCA 2 and MCA 4 were unable to support rock in the majority of sections as shown in section 5.4. However, these MCAs have many sections of existing or broken marsh on which a traditional earthen containment dike could be offset from the shore line and constructed. Open water sections, although unable to support rock, allow for the installation of ACMs. The reduced wave energy in Lake St. Catherine versus Lake Pontchartrain make this a much safer option in these MCAs. These factors, combined with cheaper cost and ease of construction make this an acceptable alternative.

At the 30% design level, it is assumed a 4 inch open cell ACM would be used. Geotextile fabric will be sized prior to 95% design. A detailed discussion on the rock breakwater design is provided in Section 8.0.

7.4 Borrow Area Design

The typical controlling factors in the borrow area design are the location, size and available material. It is preferred that the borrow area be located in close proximity to the marsh creation area in order to minimize the pumping distance of the dredged material. The borrow area should be free of any existing oyster leases, critical habitat, culturally significant sites, and oil and gas infrastructure, if possible.

As mentioned previously, the areas are clear of oyster leases and were cleared of cultural resources by investigation. However, all three borrow areas are in Federally-designated critical Gulf Sturgeon habitat. The borrow areas were designed in coordination with the USFWS and NMFS to avoid and minimize impacts to designated critical habitat. Coordination with those agencies will continue. The USFWS will make a determination of project impacts on the Atlantic Sturgeon and designated critical habitat per Section 7 of the Endangered Species Act and request concurrence from the NMFS. The areas were delineated to avoid the critical habitat as described in Section 3.0 Sand Search Investigation.

This project has four separate marsh creation areas spread out across two bodies of water: Lake Pontchartrain and Lake St. Catherine. MCA 1 lies in Lake Pontchartrain and has a borrow area in the lake just to the west for its use. MCA 2 and MCA 4 lie in the northern portion of Lake St. Catherine and has a borrow area centrally located to the two marsh creation areas. MCA 3 lies on the southern shore of Lake St. Catherine. However, it is approximately 2.25 miles southwest of the borrow area for MCAs 2 and 3 and as such has a borrow area due east for its use.

A cut-to-fill ratio should be applied when placing hydraulically dredged material to account for bulking of the dredged sediment as well as any lost material during the dredging and dewatering processes. A cut-to-fill ratio of 0.85 to 0.95 was estimated due to bulking. Taking into account 5% - 15% losses, a cut-to-fill of 1.0 was applied to the total fill quantities to determine the needed cut volume for the borrow area. A summary of in-place fill and cut volumes is found in Table 7.

A cut depth of 10 feet was determined to be sufficient to ensure adequate volume would be available. Borrow areas were designed to tie into the deeper water areas of the Rigolets and Sawmill Pass to allow for deeper dredging and access if needed. The total volume of available borrow material was calculated using AutoCAD Civil software as described in Section 7.1. The available volume of material within each of the three potential borrow areas can be found in Table 9.

Table 9: Proposed borrow area acreages and volumes.

Borrow Area	Area (Acres)	Available Volume (CY)
1	97	1,523,999
2	87	1,363,862
3	7	106,663
Total	**191**	**2,994,524**

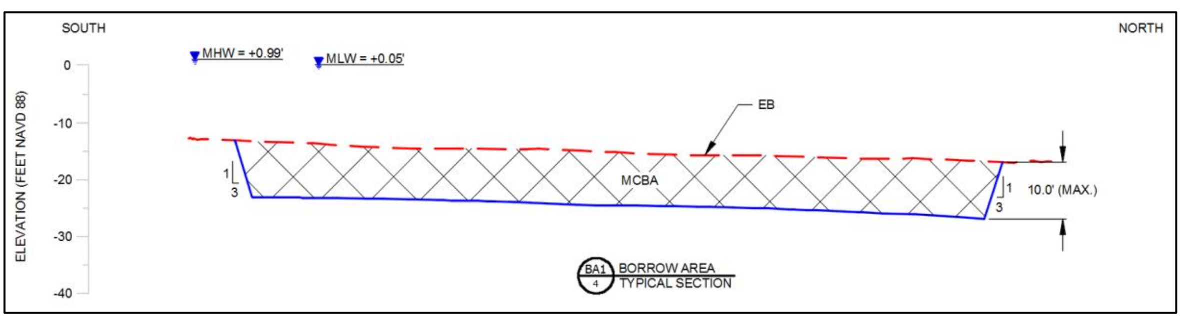


Figure 9: Borrow Area typical section.

7.5 Dredge Pipeline Alignment Design

This project did not have any planned borrow source, therefore no pipeline corridor alignments were predetermined. Presently at the 30% level of design, several transects were surveyed to investigate any potential pipelines or other areas of concern (Appendix F).

These surveys did not encounter anything of significance. However, as the design progresses to 95% and borrow area polygons are finalized a more detailed survey will be conducted.

8.0 ROCK BREAKWATER DESIGN

As a result of the shoreline stabilization alternatives analysis it was determined that a foreshore rock breakwater would be needed along MCA 1. The rock dike was assumed to be constructed at a contour of -2 feet NAVD88. A limiting geometry was determined by the geotechnical analysis.

The next step in the rock dike design was selecting a design storm and based on that design storm's wave heights, to select a rock dike elevation. Furthermore, once the dike height was determined, the spacing from the shoreline, or in this case the ECD which would be the future shoreline, needed to be selected.

Dr. Jim Chen with LSU conducted an extensive research study titled "Optimizing the Design of Shoreline Protection to Reduce Marsh Edge Erosion Based on Integrated Field Observations and Modeling" examining all of the rock projects constructed in Lake Borgne. Based upon his research specific equations were developed for determining this spacing. For a design condition, Dr. Chen recommends selecting the typical cold front storm and using the equation below to select a design rock height.

$$H_{rd} = WSE + \frac{H_w}{2}$$

H_{rd} = Height of Rock Dike
WSE = Extreme Water Surface Elevation
H_w = Height of 1-year Storm Wave

For the spacing from the shoreline Dr. Chen suggests building 1.5 to 2.5 times the wave length away from the shoreline with a maximum spacing of 30 meters. This allows the wave energy to be attenuated and the sediments to settle out without the waves reforming.

$$S_{rd} = (1.5\ to\ 2.5)\ x\ T_p$$

S_{rd} = Spacing of Rock Dike
T_p = Wave Period

Based upon the equations above it was determined the rock dike would need to be placed to an elevation of +4.85 feet and offset from 72 feet to 98 feet from the shoreline. However, based upon the geotechnical analysis, it was determined that the rock dike could only be placed an elevation of +3.5 feet. This height exceeds the target slurry height as well as the target 20-year heathy marsh height.

For the 30% level of design, the rock size is assumed to be LDOTD 250-lb class with an average density of 140 lb/ft^3. In moving towards the 95% design, the rock dike geometry will be analyzed further.

9.0 CONSTRUCTION

9.1 Duration

An approximate construction duration was developed using the CDS Dredge Production and Cost Estimation Software and Microsoft Project. Assuming a 24 inch hydraulic cutter head dredge and incorporating weather days, a total construction time from mobilization to demobilization is approximately 400 days.

9.2 Cost Estimate

A cost estimate of Probable Construction Costs was prepared for this project using the CWPPRA PPL 28 spreadsheet and historic bid data. The estimated construction cost including a 25% contingency is $19,476,493. This cost is more than the Phase 0 cost estimate of $12,644,095.

9.3 Risk

Engineering Design Documents, Plans and Specifications were prepared by or under the direct supervision of a licensed professional engineer and registered in the state of Louisiana following professional engineering standards as per La. R.S. Title 37, and Louisiana Administrative Code Title 46, Part LXI, Professional and Occupational Standards, as governed by the Louisiana Professional Engineering and Land Surveying Board. The engineering analyses effort completed for this preliminary design report provides guidance and insight pertaining to the construction of the proposed project features based on the data acquired to date, and shall not be used for bidding. These documents are not to be used for construction, bidding, recordation, conveyance, sales, or as the basis for the issuance of a permit.

10.0 MODIFICATIONS TO APPROVED PHASE 0 PROJECT

As a result of Phase 1 activities, the features originally approved in Phase 0 have been modified to present a more constructible project for consideration of Phase II funding. Specific modifications include the addition of a foreshore rock breakwater along MCA 1, the addition of articulated concrete mats placed on the ECDs being constructed in open water in MCA 2 and MCA 4 and the shifting of all earthen containment dikes to depth contours which support the geotechnical analyses. Based on the acquisition of data and the engineering analysis, as specified in this preliminary design report, the current project configuration of features provides the best constructible project for this area.

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Appendices A-J See Link Below:

ftp://ftp.coastal.la.gov/PO-0169/30%25%20Design%20Package/Appendices/