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ABBREVIATIONS

ASTM	American Society of Testing and Materials
BOC	Bottom of Cut
CC	Conveyance Corridor
CL	Centerline
CHF	C. H. Fenstermaker & Associates, LLC
CMFE	Constructed Marsh Fill Elevation
CO-OPS	Center for Operational Oceanographic Products and Services
CPRA	Coastal Protection and Restoration Authority of Louisiana
CPT	Cone Penetrometer Test
CRMS	Coastwide Reference Monitoring System
CWPPRA	Coastal Wetlands Planning, Protection, and Restoration Act
DP	Design Profile
ECD	Earthen Containment Dike
EL	Elevation
FS	Factor of Safety
ESLR	Eustatic Sea Level Rise
GEO	GeoEngineers, Inc.
HNC	Houma Navigation Canal
HTRW	Hazardous, Toxic, and Radioactive Waste
LDNR	Louisiana Department of Natural Resources
LDWF	Louisiana Department of Wildlife and Fisheries
LL&E	Louisiana Land and Exploration Company
MCDG	Marsh Creation Design Guidelines
MHW	Mean High Water
MLW	Mean Low Water
MTL	Mean Tide Level
MRDHM	Mississippi River Hydrodynamic and Delta Management
MTR	Mean Tide Range
NAC	Northern Access Corridor
NAD83	North American Datum of 1983
NAVD88	North American Vertical Datum of 1988
NGS	National Geodetic Survey
NOAA	National Oceanic and Atmospheric Administration
NMFS	National Marine Fisheries Service
PAC	Pointe-aux-Chênes
PAC WMA	Pointe-aux-Chênes Wildlife Management Area
PL	Pipeline
PSDDF	Primary Consolidation, Secondary compression, and Desiccation of Dredge Fill
PSF	Pounds per Square Foot
RSLR	Relative Sea Level Rise
SAC	Southern Access Corridor
SOP	Standard Operating Procedure
SOS	Scope of Service
SWAN	Simulating WAves Nearshore

TBS	T. Baker Smith, LLC
TIN	Triangulated Irregular Network
TOP	Top of Pipe
TY	Target Year
ULL	University of Louisiana at Lafayette
USACE	United States Army Corps of Engineers
UU	Unconsolidated Undrained

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.

In response to the devastating effects of Hurricanes Katrina and Rita in 2005, the Louisiana Legislature was directed to respond to this event through Act 8 of the First Extraordinary Session. Act 8 created the Coastal Protection and Restoration Authority (CPRA) of Louisiana, which is mandated to develop, implement, and enforce a comprehensive protection and restoration master plan for coastal Louisiana, as defined by the Louisiana Coastal Zone. As part of CPRA's mandate, the Authority has oversight over all matters relating to the study, planning, engineering, design, construction, extension, improvement, repair and regulation of integrated coastal protection projects and programs including CWPPRA projects. Further information pertaining to the CPRA may be obtained at http://coastal.la.gov.

Louisiana's Comprehensive Master Plan for a Sustainable Coast (hereinafter referred to as Master Plan) identifies projects designed to build and maintain land, reduce flood risk to citizens and communities, and provide habitats to support ecosystems. **Figure 1** depicts the 2017 Master Plan project concepts called for in Terrebonne Parish. As shown, the TE-0117 restoration area (approximate vicinity shown) is consistent with Master Plan polygons TER.01N and 03a.MC.01b.

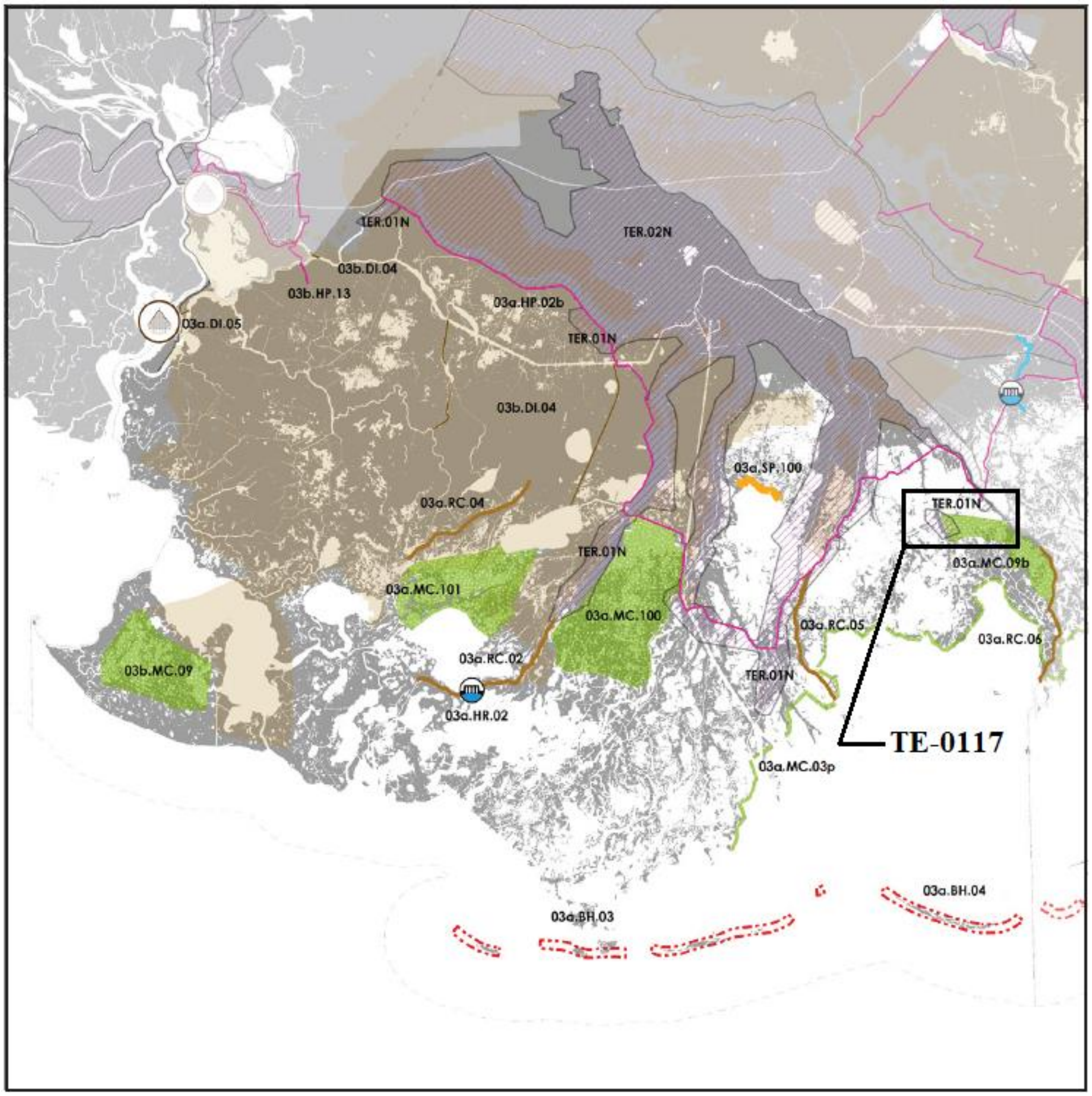


Figure 1: 2017 Master Plan Projects in Terrebonne Parish

1.2 Project Funding, Sponsors, and Team

The Island Road Marsh Creation and Nourishment Project (hereinafter referred to as TE-0117) is a CWPPRA project currently funded for Phase I (engineering and design) under the 23rd Priority Project List (PPL 23). The National Oceanic and Atmospheric Administration's (NOAA's) National Marine Fisheries Service (NMFS) is the Federal Sponsor and is also providing oversight on environmental compliance and cultural resources. CPRA is the Local Sponsor and is also the engineering and design lead. CPRA also entered into contracts with GeoEngineers, Inc. (GEO), T. Baker Smith, LLC (TBS), C. H. Fenstermaker & Associates, LLC (CHF), Tetra Tech, Inc. (Tetra Tech), and associated subcontractors in order to support data collection needs for TE-0117, which are further explained in this report. **Figure 2** shows the CWPPRA Phase 0 authorized project map.

Figure 2: TE-0117 Phase 0 Authorized Project Map

1.3 Project Site Characteristics and Location

TE-0117 is located within the Terrebonne Hydrologic Basin in Terrebonne Parish, with the marsh creation area located approximately 20 miles southeast of Houma, LA. The landscape within the vicinity of TE-0117 is comprised of a network of distributary bayous intermingled with weak and highly organic soils and open water areas that are affected significantly by erosion and subsidence processes. **Figure 3** contains a vicinity map.

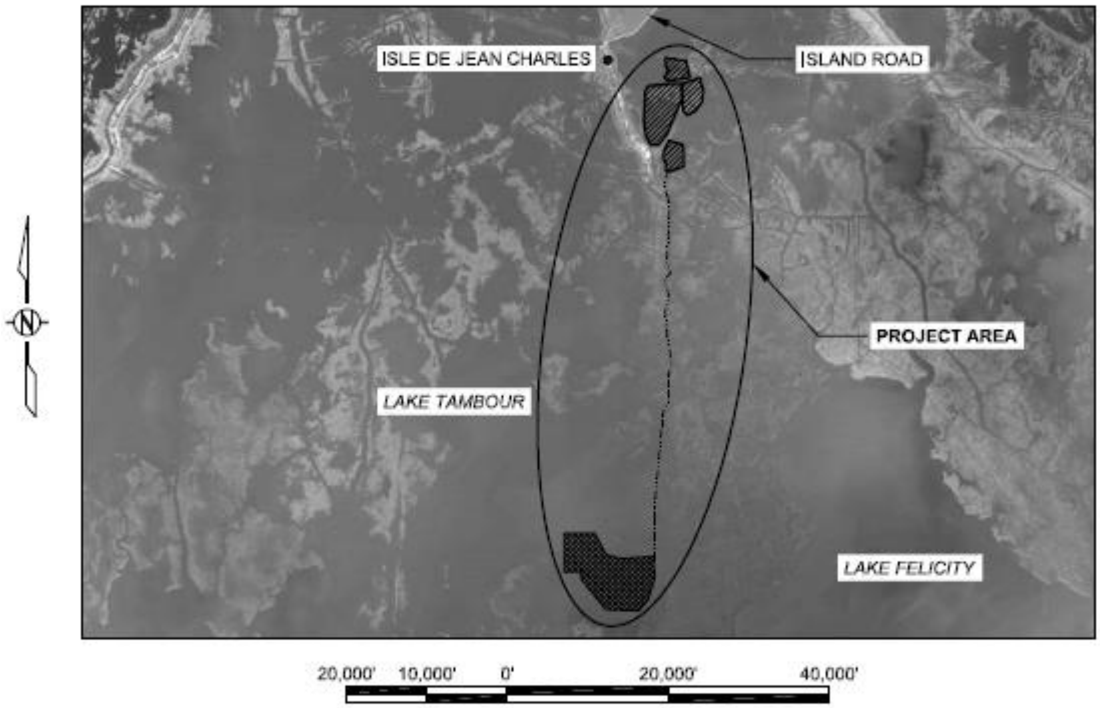


Figure 3: TE-0117 Site Vicinity

To the north of the TE-0117 marsh creation area is the Pointe-aux-Chênes Wildlife Management Area (PAC WMA), which can be accessed via LA 665. To the south is saltwater marsh that leads to the Gulf of Mexico by way of interior lakes and bays. To the east is Cutoff Canal and Bayou Jean LaCroix, which flow generally north-south amidst saltwater marsh that eventually borders Bayou Pointe-aux-Chênes. To the west is the community of Isle de Jean Charles that is situated on the banks of Bayou St. Jean Charles, which flows generally north-south through marsh that borders Madison Bay and eventually Bayou Terrebonne. Montegut, LA is the nearest incorporated town, which can be accessed via LA 55.

The proposed TE-0117 borrow area is located approximately seven (7) miles to the south of the TE-0117 marsh creation area in Lake Tambour. Proposed equipment access routes and dredge pipe corridor will provide marine access to all portions of the project site as well as provide connectivity between the marsh creation area and borrow area.

1.4 Project Goals

As established in Phase 0 and as stated on the CWPPRA PPL 23 Project Fact Sheet, the primary goals of TE-0117 were proposed to create 364 acres and nourish 19 acres of emergent saline marsh by hydraulically dredging material from a borrow source near Lake Felicity. Containment dikes are to be constructed around the marsh creation area cells to retain sediment and will be degraded and/or gapped no later than three (3) years post construction. Half of the newly constructed marsh is to be planted following construction to stabilize the platform and reduce time for full vegetation establishment. See **APPENDIX A** for the CWPPRA PPL 23 Project Fact Sheet and map.

General Phase 0 and Phase 1 Goals

- Develop a constructible design
- Rebuild the structural framework of degraded inland marsh along Twin Pipelines corridor via marsh creation and nourishment
- Decrease vulnerability of coastal communities and infrastructures by addressing rates of land loss in this area (approximately 1.60%/year) through direct landbuilding from hydraulic dredging and disposal

Throughout Phase I, adjustments to project features were made resulting in four (4) total marsh creation cells totaling 291 acres located south of the original Twin Pipelines orientation. A revision to the Phase 0 borrow source has also occurred, with hydraulic dredging to come from a borrow source in Lake Tambour located approximately four (4) miles to the west of the originally proposed borrow source in Lake Chien/Lake Felicity, and with a maximum pumping distance of approximately eight (8) miles.

The steps taken during the early stages of design and during a screening process and alternatives analyses are captured in **Section 3.0**, while design changes are further discussed in **Section 8.0**. The modifications to the anticipated construction costs and benefitted acres are discussed in **Section 9.0** and **Section 10.0,** respectively.

2.0 EXISTING SITE CONDITIONS

2.1 Land Ownership

The entire marsh creation area is located on property owned by Apache Louisiana Minerals, LLC and ConocoPhillips/Louisiana Land & Exploration (LL&E) Company. The entirety of the borrow area is located in Lake Tambour on waterbottoms that are under ownership between the State of Louisiana and Apache Louisiana Minerals, LLC. The access corridors are located on property owned by Apache Louisiana Minerals, LLC, ConocoPhillips/Louisiana Land & Exploration Company, and the State of Louisiana. **Figure 4** contains a land ownership map of the entire project area.

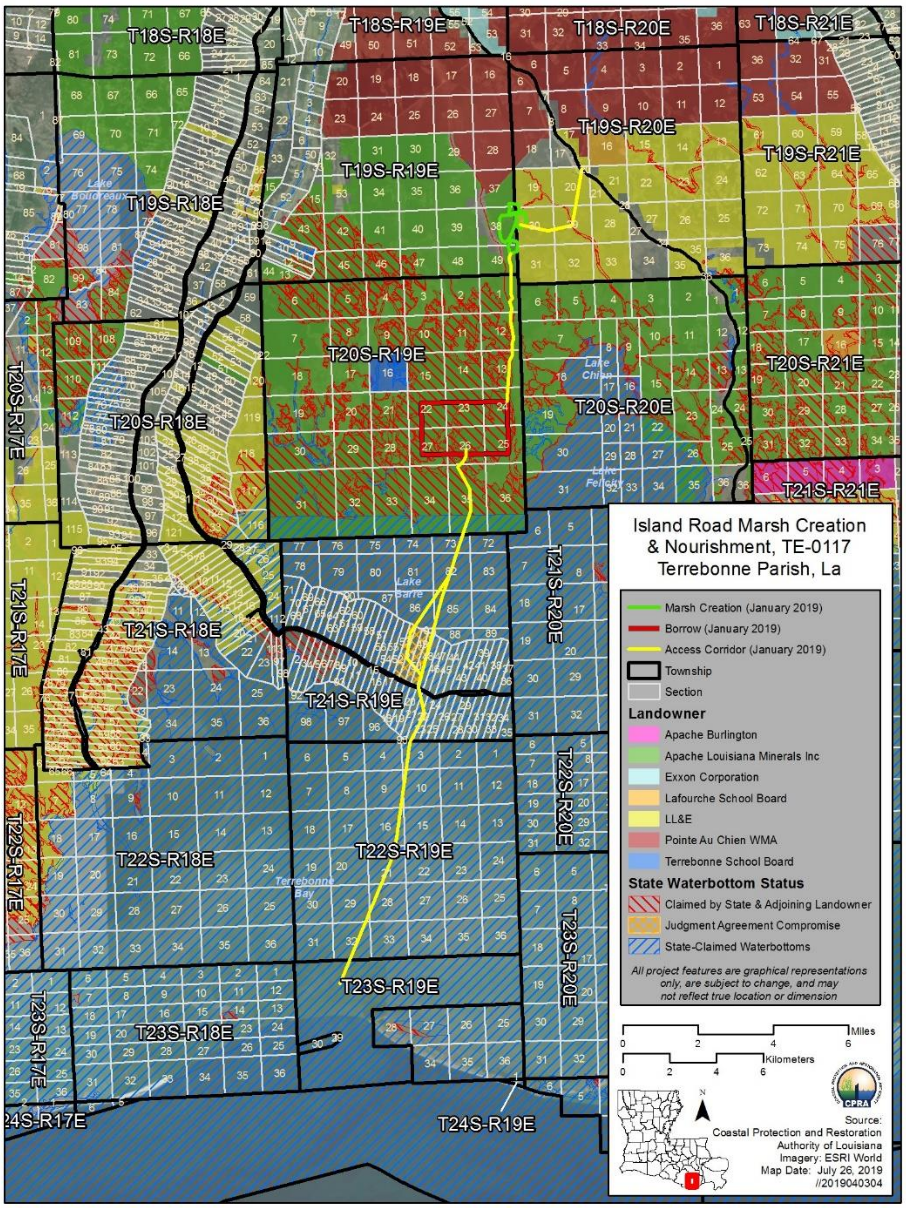


Figure 4: Land Ownership Map

2.2 Infrastructure Inventory

The TE-0117 project team identified all critical infrastructure in the project vicinity to inform the screening process and alternatives analyses. The Louisiana Department of Natural Resources (LDNR) Strategic Online Natural Resources Information System database was utilized to obtain permit documentation for existing infrastructure. Literature reviews were then performed on existing infrastructure, which are categorized in the following types.

- Civil Infrastructure (roads, levees, flood protection systems)
- Hydraulic and Hydrologic Infrastructure
- Waterways and Marine Infrastructure
- Oil and Gas Infrastructure (pipelines, wellheads)
- Environmental Infrastructure (oyster leases, oyster seed grounds)
- Residential/Recreational Infrastructure (houses, camps, overhead utilities)

Due to the proximity of coastal infrastructure to the conceptually proposed marsh creation areas and envisioned equipment access routes, it was necessary to evaluate alternatives by obtaining information for the infrastructure believed to exist in this area. For example, Twin Pipelines oil and gas infrastructure, recreational/residential infrastructure served by overhead utility lines, and drainage from the Isle de Jean Charles pump station were key infrastructure and services to maintain in restoration plan formulation and refinement. **Section 5.4** contains applicable discussion on pipeline information determined for TE-0117. The identification of all known infrastructure is available electronically in the infrastructure inventory contained in **APPENDIX B**.

2.3 Oyster Resources

Oyster resources in the project area, specifically the borrow area and dredge pipe corridor, played a significant role in borrow area selection and development throughout the project life. During Phase 0 of the project a specific borrow area was not defined, but Lake Felicity was identified as a likely candidate, with a conveyance corridor to be developed in Bayou Jean LaCroix. During early design it was discovered that there are two (2) Tier I Louisiana Department of Wildlife and Fisheries (LDWF) oyster seed grounds in the Lake Felicity/Lake Chien area and that Bayou Jean LaCroix contained multiple oyster leases. It was determined by the design team that a borrow area in Lake Felicity that avoided oyster seed grounds was not feasible and a search for a new borrow area began.

Lake Tambour, located to the west of Lake Felicity, was identified as the next suitable candidate for a borrow area. Lake Tambour contains a Tier II LDWF oyster seed ground. Therefore, the boundary of the selected borrow area was positioned to maintain a minimum buffer of 1,500 ft from any area in the seed ground. The conveyance corridor from Lake Tambour, Bayou St. Jean Charles, contains oyster leases that will need to be addressed prior to construction. Lake Tambour contains a combination of private and State of Louisiana issued oyster leases. Considerations were made to avoid leases during borrow area development.

During data collection for geotechnical investigations, a third party observer documented and tracked the boring equipment and vessels observing for any potential oyster resources liabilities. The determination of these reports was that no water bottom impacts were observed during geotechnical investigation activities. Oyster observation reports were included as part of the geotechnical deliverables as further discussed in **Section 6.0**.

2.4 Cultural Resources Assessments

Coordination regarding adverse impacts to cultural and archaeological resources was sent to the State Historic Preservation Office from NOAA-NMFS on August 18, 2014. The letter stated that no cultural resources are likely to be adversely impacted by the proposed action. The State Historic Preservation Office replied on September 23, 2014 that no known historic properties will be affected by this undertaking.

2.5 Neighboring Project Activity

The southeastern Terrebonne area is active for CWPPRA and non-CWPPRA projects alike. Through the Morganza to the Gulf project, several miles of flood protection infrastructure are expected to be operational to the north of TE-0117 in the coming years. Together with this, the Terrebonne Levee & Conservation District, as well as numerous other Federal, State, Parish, and local governmental entities, have become increasingly involved constructing multiple mitigation projects of various types within this vicinity. Also in development are terracing fields currently being designed and constructed by Ducks Unlimited, Inc.

TE-0117 marks the third attempt at utilizing CWPPRA funds for marsh creation project implementation in the southeastern Terrebonne region. The Madison Bay Marsh Creation and Terracing Project (TE-0051) and the Terrebonne Bay Marsh Creation and Nourishment Project (TE-0083) have previously been nominated for Phase I funding through CWPPRA. After multiple years of being explored through engineering and design, authorization of construction funds (Phase II funding) for both projects was unsuccessful, resulting in project inactivation and deauthorization.

3.0 ALTERNATIVES ANALYSIS AND STEPWISE DESIGN APPROACH

3.1 Regional Historical Design Considerations

The landscape in southeast Terrebonne Parish is characterized by thick Holocene deposits that were transported alluvially from a series of historic progradational delta complexes dating back 1,000 years ago or more. During this time, the Mississippi River was in its Lafourche-era delta lobe, when the majority of the river's flowrate discharged to the Gulf of Mexico along present day Bayou Lafourche. The greater Houma metropolitan area was developed along historic bayou ridges whose waterways exist today as relicts of when the delta built this part of Louisiana. Small communities are scattered throughout the area along the numerous bayous, lakes, bays, and marsh. There are also numerous canals and navigation channels comprised in this area and in particular at and around the TE-0117 project site.

Coastal restoration project design entails some significant challenges in this vicinity. Aside from the rapid rates of land loss observed in this area, flooding due to storms and interior drainage issues are frequent occurrences. The communities of Isle de Jean Charles and Pointe-aux-Chênes face these threats of flooding and land loss not only under the possibility of named storms but also against day-to-day wave action and tidal influences. It is well understood that as time increases these coastal communities and their infrastructure systems are left in state of increasing vulnerability to the effects of land loss and relative sea level rise.

The TE-0117 project site contains weak organic and highly compressible soils combined with expanses of deep water depths across the identified restoration areas. Additionally, there are few available open water bays for use as potential borrow sourcing, with the only two inland lakes located outside a five (5)-mile radius from the marsh creation areas. This, combined with inherent challenges in accessing project features among degrading coastal wetlands located far inland at this part of the state, make for challenging conditions in establishing applicable dredge slurry transport corridors. Pipelines and oil and gas infrastructure are also encountered throughout this area and in the TE-0117 project site in particular. As stated in **Section 2.5**, CWPPRA has a thorough and well-established knowledge of past project challenges in this part of Terrebonne Parish.

3.2 Project Development Timeline

Table 1 contains a list of items completed throughout the development of TE-0117 Phase I.

Table 1: Project Development Timeline

Year	Items Completed
2014	• Project authorized for Phase I funding • Project Fact Sheet produced by NOAA-NMFS • Cost Share Agreement authorized • Geotechnical services procured from GEO for exploratory geotechnical investigation
2015	• Exploratory geotechnical investigation deliverables submitted by GEO to CPRA • Marsh creation area screening process and alternatives analysis initiated based on exploratory geotechnical findings • Topographic, bathymetric, and magnetometer surveying services procured from TBS
2016	• Topographic, bathymetric, and magnetometer surveying services deliverables submitted by TBS to CPRA • Geotechnical services procured from GEO for supplementary geotechnical investigation • Borrow area screening process and alternatives analysis initiated based on marsh creation area alternatives analysis, pumping distance, oyster resources, and conveyance corridor availability • Borrow area development services procured from CHF for professional land surveying and geophysical surveying services at borrow rea • Borrow area geotechnical sampling services procured from GEO for borrow area geotechnical investigation • Hazardous, Toxic, and Radioactive Waste (HTRW) fieldwork initiated
2017	• Supplementary geotechnical investigation deliverables submitted by GEO to CPRA • Borrow area development services deliverables submitted by CHF to CPRA • HTRW deliverables submitted by Tetra-Tech, Inc. to CPRA • Stakeholder meetings and engagement with landowners
2018	• Supplementary geotechnical investigation deliverables submitted by GEO to CPRA • Borrow area development services deliverables submitted by CHF to CPRA • 30% design activities underway
2019	• 30% design activities underway

3.3 Stepwise Design Approach

3.3.1 Conceptual Level Project Development

Prior to PPL 23, NOAA-NMFS, other federal, state and local government agencies, and stakeholders advocated that southeast Terrebonne Parish was in need of and high priority for coastal restoration specifically along the areas of the Twin Pipelines canal that cuts across the southern half of Terrebonne Parish into Lafourche Parish from Bayou Barre at Point Barre Road to the Larose to Golden Meadow Levee project just south of Golden Meadow, LA. Marsh creation, as recognized by the Master Plan, was decided as a primary project type to aid in developing a landbridge in the vicinity of the Twin Pipelines, with proposed dredge fill to come from inland lakes, bays or other available open water bodies. TE-0117 was proposed during the PPL 23 cycle as one increment of an overall concept to restore a cross-basin alignment of tidal marsh along this corridor.

During Phase 0, The Island Road vicinity of Twin Pipelines was targeted to help begin restoring the structural framework of marshes and bayou banklines that have deteriorated. Various restoration alignments were considered along Island Road, north and south of Twin Pipelines, east and west of Grand Bayou and Cutoff Canal, and parallel to Isle de Jean Charles. Marsh creation areas were refined during Phase 0 based on water depths, pipelines and utilities, and inlet/outlet needs for a pumping station and a water control structure.

3.3.2 Phase I Authorization

As shown in the Phase I authorized project map in **Figure 2**, CWPPRA PPL 23 ultimately proposed a marsh creation area configuration that called for marsh creation cells along the north side of Twin Pipelines and the west side of Cutoff Canal. The TE-0117 project proceeded to Phase I with the understanding that a borrow source in Lake Chien would be developed in further design with a dredge slurry conveyance corridor to be established in Bayou Jean LaCroix.

3.3.3 Project Feature Development in Conjunction with Data Collection Activities

Following the authorization and initiation of Phase I, the TE-0117 project team identified the need for design-level data collection to support further project design and to assist in further refining project features. Given the challenges of site conditions and the importance of restoration in the project vicinity to local stakeholders for ecological and storm protection synergy, the project team adopted a step-wise data acquisition and design approach to develop a constructible design. It was decided that the marsh creation areas would be developed then refined based on preliminary then advanced geotechnical, topographic, bathymetric, and magnetometer surveying and engineering.

The project team acknowledged that producing a marsh creation design for the TE-0117 project would be constrained with respect to expected geotechnical conditions, water depths, and oil and gas infrastructure. CPRA and NOAA-NMFS recognized these constraints and expressed concerns about limiting the team to the Phase 0 project footprint given the outcomes for TE-0051 and TE-0083. Therefore, the team decided to first pursue an exploratory geotechnical investigation effort across an expanded marsh creation area to facilitate a screening process based primarily on geotechnical site conditions for containment dike constructability as a focal point. In July 2014, GEO was tasked with performing an exploratory geotechnical investigation for the originally authorized marsh creation area polygons as well as an expanded area to the south of Twin Pipelines. **Figure 5** shows the geotechnical sampling locations for the exploratory geotechnical investigation. More discussion on geotechnical investigations is available in **Section 6.0**.

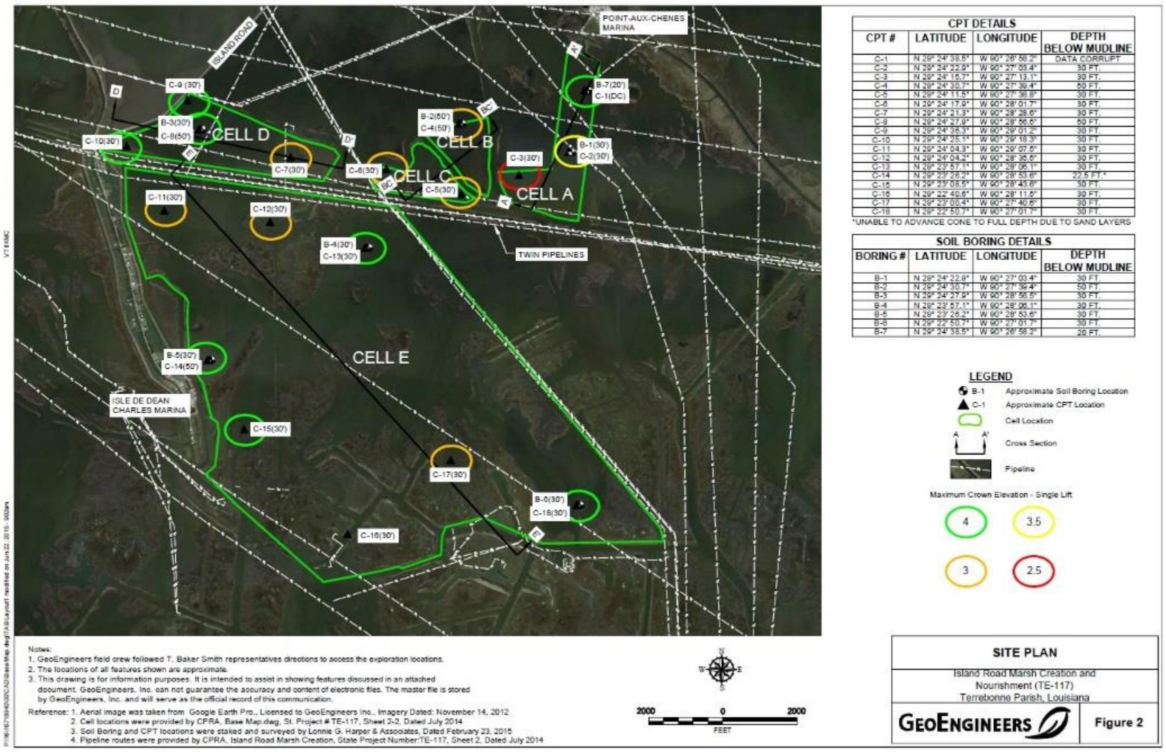


Figure 5: TE-0117 Exploratory Geotechnical Investigation Coverage Area

In 2015, based on a preliminary understanding of soil conditions in the project vicinity from the exploratory geotechnical investigation, the project team decided to pursue topographic, bathymetric, and magnetometer survey data collection in the region denoted by “CELL E” to the south of Twin Pipelines. From a geotechnical perspective, the originally authorized marsh creation cells were determined to be less desirable and more challenging from a constructability perspective than the area located further south. Based on geotechnical site conditions and expected containment dike slope stability concerns, the TE-0117 project team made the decision to abandon the original northern marsh creation area polygons and to collect survey data in the general area to the south of Twin Pipelines. **Figure 6** shows the relative limits of survey data collection coverage for the marsh creation area surveying effort. More discussion on surveys is available in **Section 5.0**.

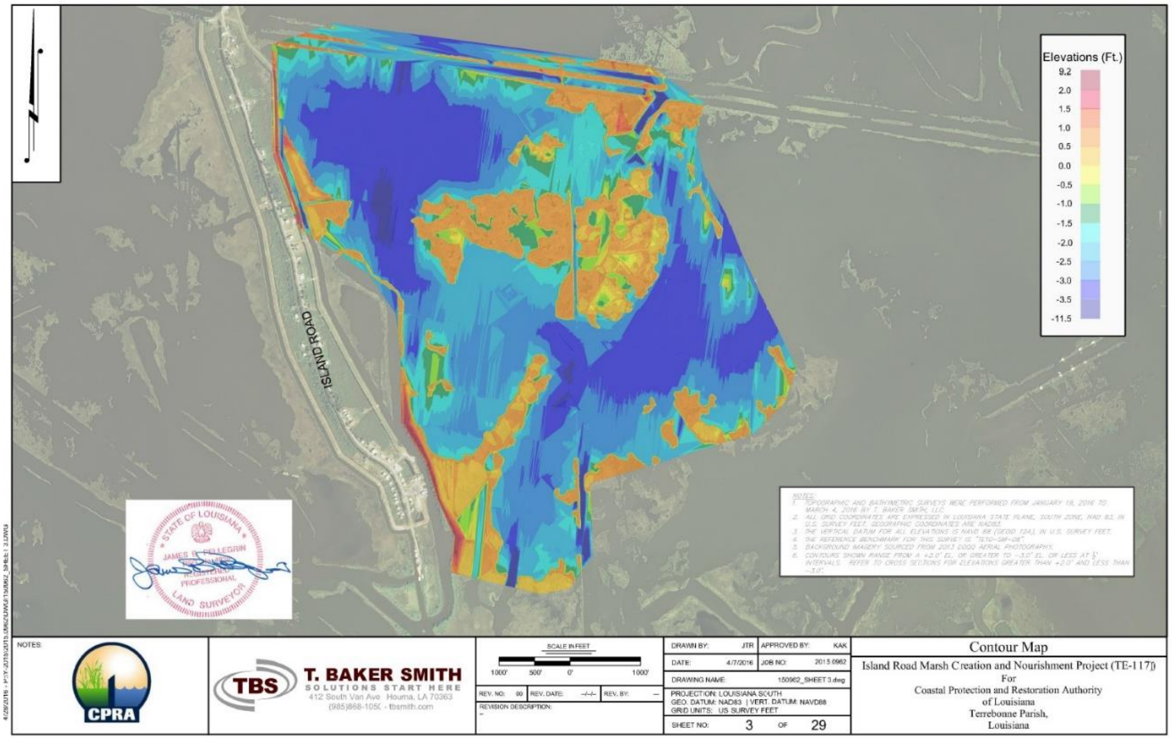


Figure 6: TE-0117 Survey Data Collection Coverage Area

Following the exploratory marsh creation area geotechnical investigation and marsh creation area survey, subsequent data collection efforts were performed not only on the marsh creation area project feature but also on the borrow area, conveyance corridor, and equipment access corridors. More discussion on the details of this data collection is available in **Section 5.0**, **Section 6.0**, and **Section 7.0**.

3.4 Alternatives Analysis and Project Feature Development

3.4.1 General Approach and Goals

Due to site and vicinity conditions, four (4) marsh creation alternatives and six (6) borrow alternatives were evaluated to develop a constructible design with acceptable risk and having synergy with local infrastructure.

The stepwise design approach used for the marsh creation areas resulted in a new configuration of marsh creation area polygons to the south of the originally proposed Phase I configuration. The modification of this project feature, which was linked to the borrow area alternatives analysis further explained in **Section 3.4.3**, resulted in a revision to essentially the entire project concept initially proposed by PPL 23. While the majority of this design report focuses on the as-proposed 30% project design, the following sections are an account of the screening process taken on by the TE-0117 team to arrive at the revised TE-0117 project design currently proposed and further discussed in the later sections of this report.

3.4.2 Marsh Creation Area Project Feature Development and Alternatives Analysis

Based on the progression of marsh creation area alternatives informed through data collection, the team performed an alternatives analysis and screening process of potential marsh creation area cell configurations. Four (4) alternative alignments were evaluated including one north and three south of the Twin Pipelines. The progression of this alternatives analyses is captured in **Figure 7**, **Figure 8**, and **Figure 9**.

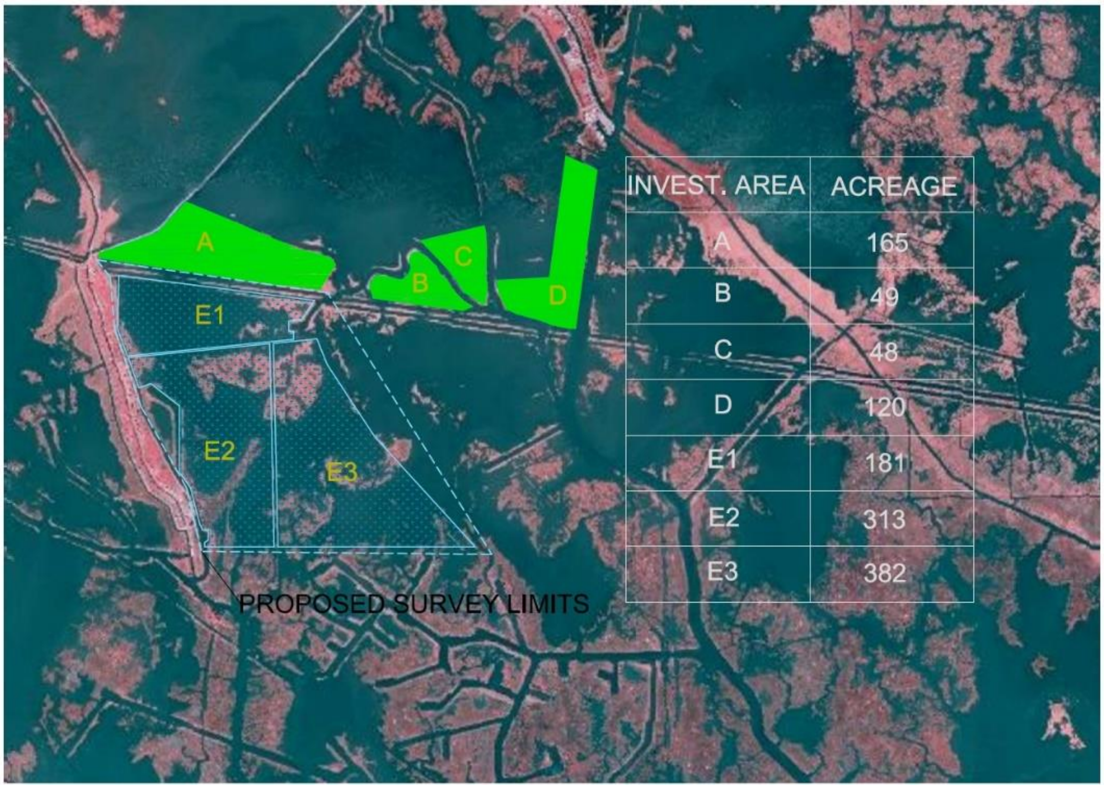


Figure 7: Marsh Creation Area Alternatives (1 of 3)

Figure 8: Marsh Creation Area Alternatives (2 of 3)

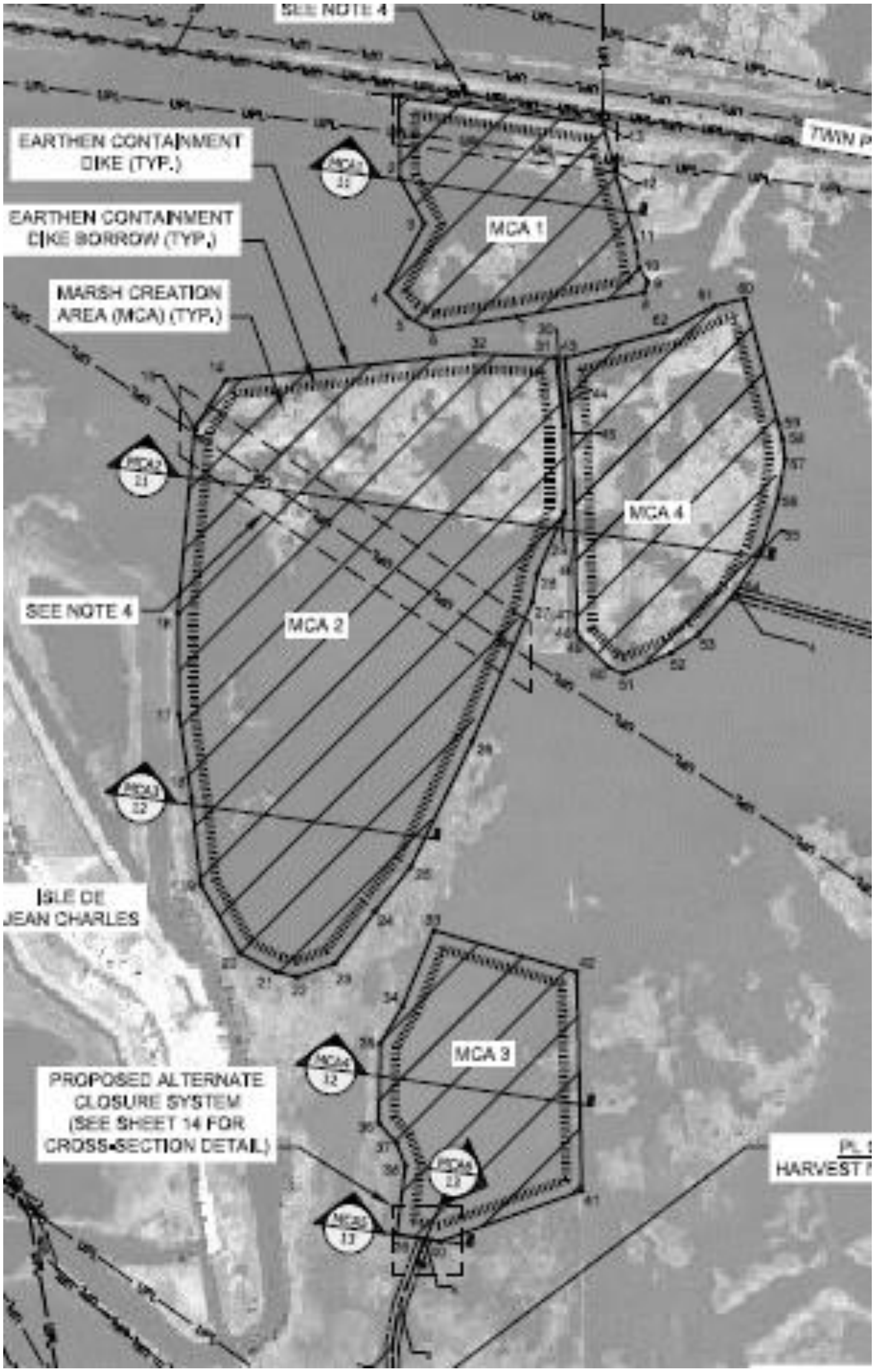


Figure 9: Marsh Creation Area Alternatives, 30% Design Status (3 of 3)

3.4.3 Borrow Area Project Feature Development and Alternatives Analysis

After the initiation of the marsh creation area alternatives analysis, a similar process was initiated for the borrow area. Criteria included minimizing the pump distance, avoiding and minimizing impacts to existing public seed grounds and leases, avoiding impacts to drainage and existing wetlands, and minimizing impacts to privately owned water bottoms. Upon further exploration of the originally proposed Lake Felicity/Lake Chien borrow source, LDWF Tier I oyster seed grounds were discovered in this region. Official LDWF shapefiles were obtained, and a 1,500 ft offset distance was applied to the polygon boundaries of the seed grounds as per consult with the CPRA Landrights Section. The team concluded that producing a borrow source in this region was cost-prohibitive based on a maximum pump distance in excess of 12 miles. As such, the open water area in Lake Tambour was selected as the optimal site to further develop the borrow area, with Bayou St. Jean Charles to be utilized as the conveyance corridor connecting the borrow area and the marsh creation area. **Figure 10**, **Figure 11**, and **Figure 12** depict the progression of borrow area alternatives analyzed.

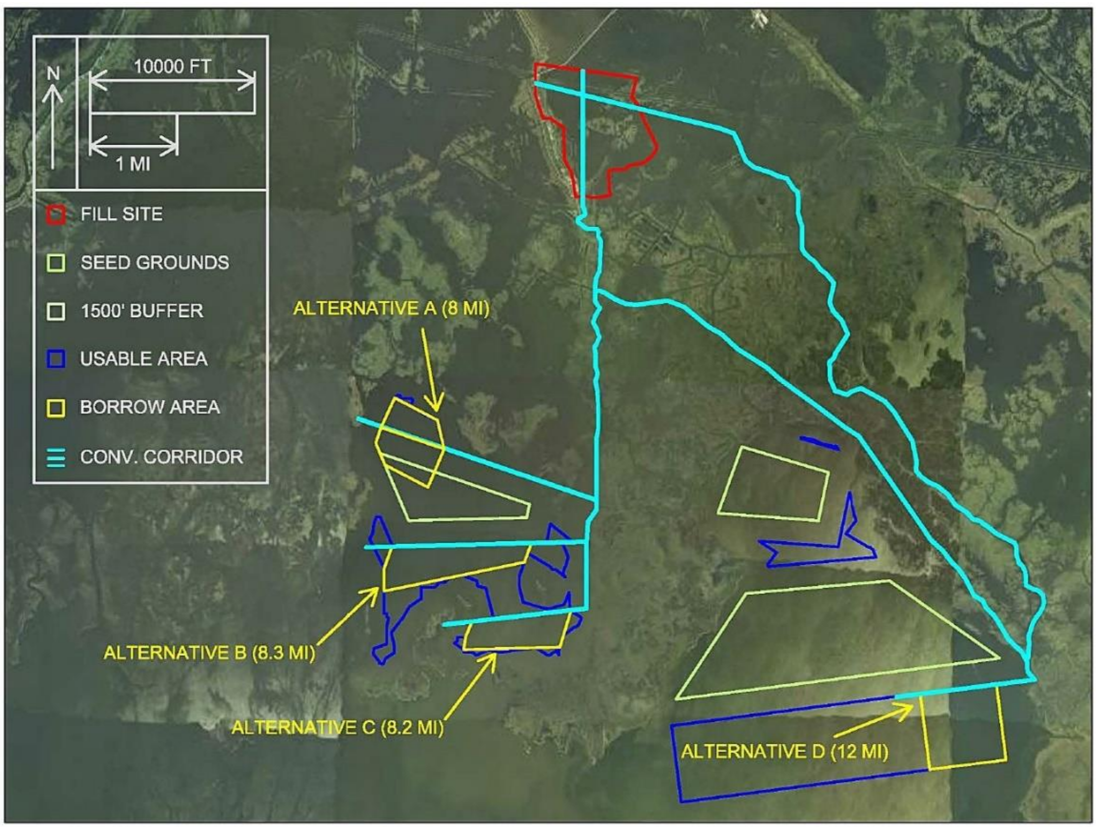


Figure 10: Borrow Area Alternatives (1 of 3)

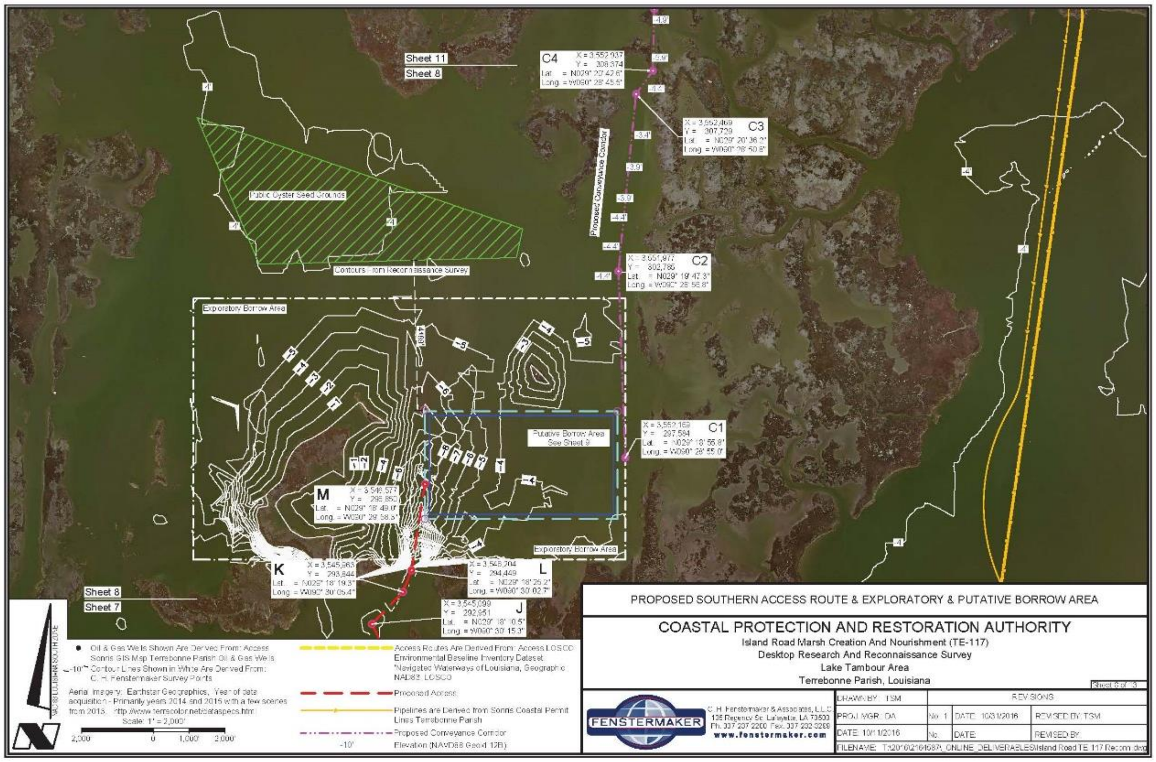


Figure 11: Borrow Area Alternatives (2 of 3)

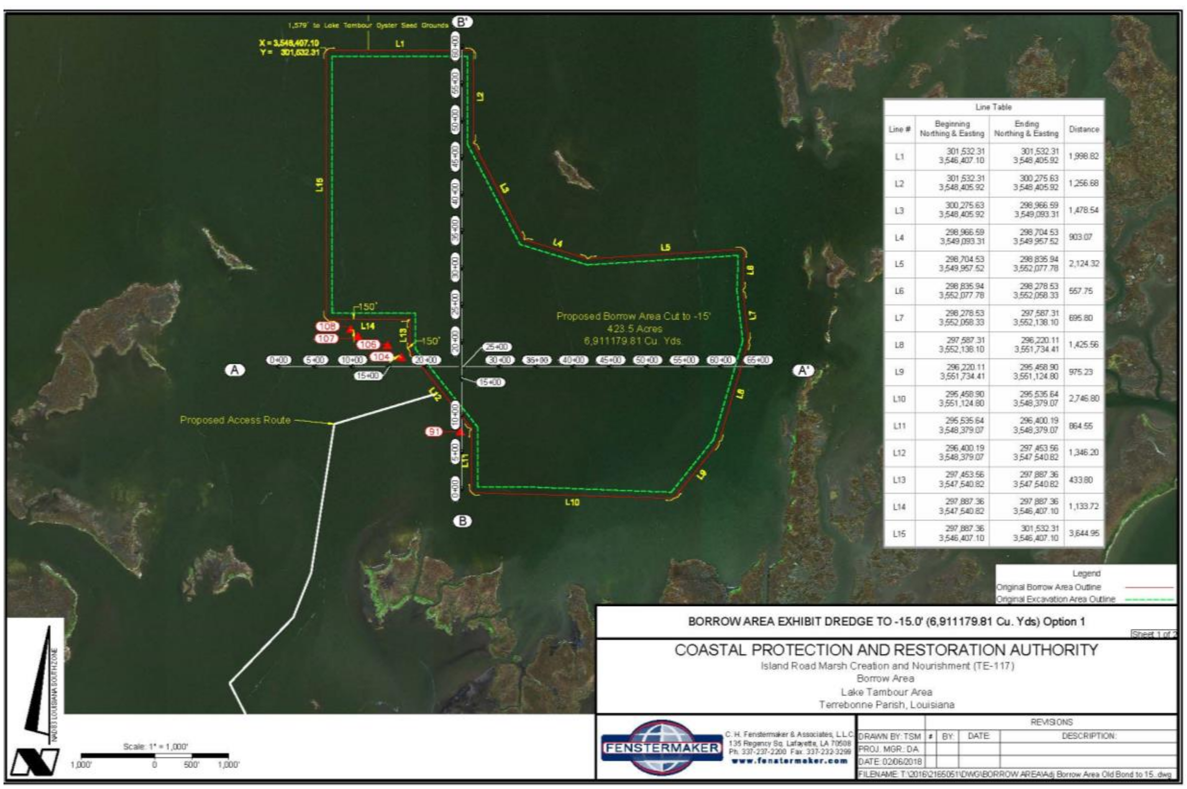


Figure 12: Borrow Area Alternatives (3 of 3)

3.4.4 Summary of Alternatives Analysis Screening Process

Table 2 below contains highlights of the alternatives analysis and feature screening process.

Table 2: Summary of Alternatives Analysis and Screening Process

Feature	Highlights
Marsh Creation Area	• Began with an original configuration of marsh creation cells located north of Twin Pipelines • Geotechnical conditions warranted expansion to the south of Twin Pipelines during data collection along a second configuration of marsh creation cells • Survey and geotechnical conditions south of Twin Pipelines were determined to be more suitable for design • A third configuration of marsh creation alternatives was developed in the area to the south of Twin Pipelines • An analysis of geotechnical conditions and water depths for containment dike constructability resulted in a fourth and final configuration of marsh creation cells in the area to the south of Twin Pipelines

Borrow Area	• Began with a concept to utilize a borrow polygon in Lake Chien/Lake Felicity, with conveyance corridor in Bayou Jean LaCroix
	• Oyster leases were identified in the conveyance corridor, and Tier I seed grounds were identified in the borrow area
	• Relocation in the Lake Felicity/Lake Chien area was cost-prohibitive, with a 12 mile max pump distance being the closest
	• Exploration of the Lake Tambour area yielded three (3) potential borrow alternatives
	• The northernmost alternative was excluded on the basis of overlap with Tier II oyster seed ground overlap (see **Figure 10**)
	• The remaining two were considered potential borrow options and further developed through data collection
	• A putative borrow area was selected for data collection coverage, representing the fifth alternative
	• A sixth and final alternative was developed based on the following, which resulted from data collection activities:
	    ○ Produced available borrow volume meeting volumetric needs
	    ○ Contained soils that were geotechnically sufficient for marsh creation
	    ○ Maintained at least 1,500 ft from seed ground boundaries
	    ○ Maintained at least 1,000 ft from existing marsh edge
	    ○ Hydrodynamic modeling showed no significant impacts to wave energies post dredging

3.4.5 Phase I Revised Project Features

Following the alternatives analysis, the team was able to proceed with the development of the revised TE-0117 project features in design. The following sections discuss the data collection and detailed design utilized to arrive at the as-proposed project features. Additional documentation on the alternatives analysis procedures utilized can be found in **APPENDIX C**. The final restoration area concept is available in **Figure 9**, with additional discussion in **Section 8.0**.

4.0 HYDROLOGIC SITE CONDITIONS

4.1 Tidal Conditions

The tidal datum is a standard elevation defined by a certain phase of the tide and is used to measure local water levels and establish design criteria. Typically, the primary objective for computing the tidal datum is to establish the CMFE that maximizes the duration that the restored marsh will be at intertidal elevation throughout the 20 year project life. The tidal datum for TE-0117 was established and utilized in the early stages of preliminary design for surveys, geotechnical analysis, and assessing 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), mean tide level (MTL), and mean tidal range (MTR) over a specified period of time. MHW is the arithmetic mean of all daily high water surface elevations observed over one tidal epoch. MLW is the arithmetic mean of all daily low water surface elevations observed over one tidal epoch. MTL is the mean of MHW and MLW for that time period, and MTR is the difference between MHW and MLW.

Coastwide Reference Monitoring System (CRMS) monitoring stations CRMS3296 (located near marsh creation and nourishment area) and CRMS0341 (located near borrow area at southern access corridor approach) were utilized to obtain water surface elevation datasets. These control stations were selected because of their proximity to project features and because both stations were able to produce datasets corresponding to the elapsed time from October 1, 2013 through March 21, 2019, recording over a 5-year analysis period. The most recent five year period with data available was used to better reflect present-day and early construction-era mean sea level, which is consistent with NOAA guidance literature involving the use of the modified national tidal datum epoch to offset the inaccuracies of older portions of water level datasets experiencing eustatic (global) sea level rise (ESLR) (NOAA CO-OPS 2003). A detailed summary of the tidal datum calculations is shown in the Calculations Packet in **APPENDIX D**. The results of the tidal datum determination for the TE-0117 project are shown in **Table 3**. **Figure 13** depicts the spatial orientation of these two CRMS stations at the TE-0117 site in relation to the as-proposed project features.

Table 3: Tidal Datum Evaluation

CRMS Station	MHW [FT[1], NAVD88, GEOID12A]	MLW [FT[1], NAVD88, GEOID12A]	MTL [FT[1], NAVD88, GEOID12A]	MTR [FT[1]]
CRMS3296	+0.8037	-0.3586	+0.2226	1.1623
CRMS0341	+0.9048	-0.4490	+0.2279	1.3538
Average	**+0.8542**	**-0.4038**	**+0.2252**	**1.2580**

1. FT stands for "US Survey Foot".

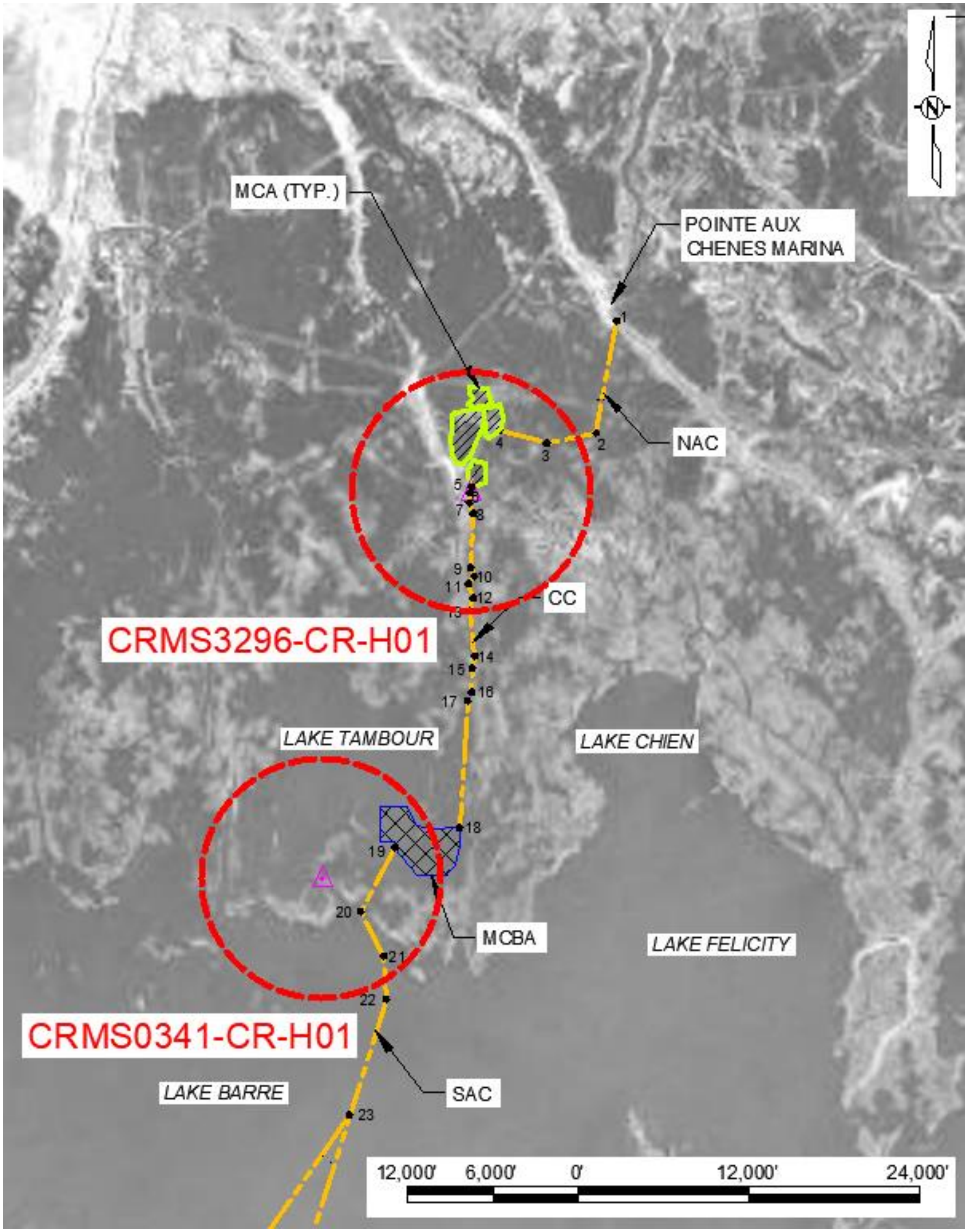


Figure 13: Locations of CRMS Continuous Recorders at TE-0117

4.2 Sea Level Rise Conditions

All projects funded through CWPPRA are designed and constructed based on a 20-year project life. In order to properly design TE-0117 and ensure it is built and performs according to the objectives laid out as discussed in **Section 1.0**, certain natural processes such as ESLR and subsidence must be assessed. The combination of these two processes, termed relative sea level rise (RSLR), was analyzed for the purposes of the TE-0117 project.

ESLR is defined as the global change in water level that accounts for a number of variables such as thermal expansion, the loss of glaciers and ice caps, and runoff from thawing permafrost, to name a few. CPRA's Planning & Research Division has produced guidance literature for use in forecasting ESLR rates of change consistent with the 2017 Master Plan. These rates are parameterized across multiple sea level rise scenarios that range from 0.5 total meters of sea level rise predicted by 2100 to 1.98 total meters of sea level rise by 2100 to account for uncertainty. It is recommended by the CPRA Planning & Research Division to use the 1.0 meter (medium) scenario for the purposes of marsh creation project design having a 20 year design life. The annual rate of increase in ESLR under this scenario is approximately 0.29 in/yr (7.3 mm/yr). In the case of TE-0117, this accounts to 0.56 ft of ESLR over the 20 year project life.

Subsidence is defined as the local decrease (settlement) in land surface elevation relative to a fixed datum. For the TE-0117 project area, the expected rate of subsidence was determined using information from the 2017 Master Plan and guidance literature produced by CPRA's Planning & Research Division. Based on the information provided in the MRHDM (in conjunction with the 2017 Master Plan and recommendations from CPRA's Planning & Research Division), the TE-0117 project area experiences a subsidence rate of 6.4 mm/yr and a corresponding 1.06 ft of RSLR for the "0.5-m by the year 2100" scenario, which is shown on **Figure 14**.

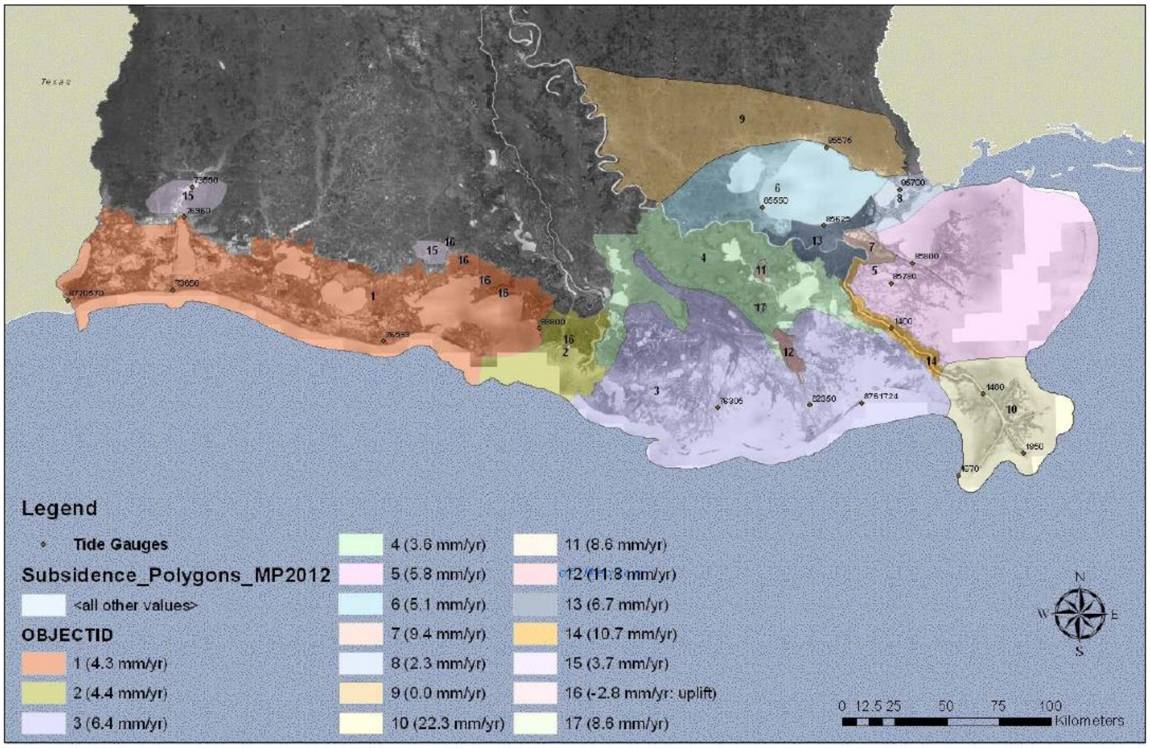


Figure 14: 2017 Master Plan Subsidence Rates by Region

ESLR rates were used to project expected increases in tidal datum values calculated. **Table 4** contains an array of these values combined with the expected rates of subsidence applied to predict RSLR across the TE-0117 design life.

Table 4: Subsidence, ESLR, and RSLR According to TY

Target Year (TY)	Subsidence [FT]	ESLR [FT]	RSLR [FT]
2016	0.0000	0.0000	0.0000
2017	0.0210	0.0186	0.0396
2018	0.0420	0.0376	0.0796
2019	0.0630	0.0571	0.1201
2020 (TY0)	0.0840	0.0769	0.1609
2021	0.1050	0.0971	0.2021
2022	0.1260	0.1177	0.2437
2023	0.1470	0.1387	0.2857
2024	0.1680	0.1601	0.3281
2025	0.1890	0.1819	0.3709
2026	0.2100	0.2042	0.4141
2027	0.2310	0.2268	0.4577
2028	0.2520	0.2498	0.5017
2029	0.2730	0.2732	0.5461
2030	0.2940	0.2970	0.5909
2031	0.3150	0.3121	0.6361
2032	0.3360	0.3458	0.6817
2033	0.3570	0.3708	0.7277
2034	0.3780	0.3962	0.7741
2035	0.3990	0.4220	0.8209
2036	0.4199	0.4482	0.8681
2037	0.4409	0.4747	0.9157
2038	0.4619	0.5017	0.9637
2039	0.4829	0.5291	1.0121
2040 (TY20)	0.5039	0.5569	1.0609

4.3 Percent Inundation Determination

Historically the tidal range between MHW and MLW has been the accepted range for marsh creation design. However, this approach only takes into account the tidal influences on 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 observed water levels in any given region. In order to account for tidal and non-tidal influences, observed tide elevations, versus predicted tide elevations, are considered.

An additional method to bracket the marsh elevation range is the Percent Inundation Method, which was utilized. For TE-0117 design, a third proxy was utilized in determining the 50th and 80th percentiles of reference marsh elevation surveys. Accretion is another physical process that has the potential to affect marsh creation design. In environments where alluvial deposition of sediments are anticipated, marsh creation design calls for the assumption of some elevation change resulting from accretion rates. In the case of TE-0117, while there do exist some hydrologic and alluvial deposition sources, the TCPG 4-3C levee system located to the west and Island Road located to the north are not anticipated to yield any attributable accretion rates. Therefore, the design team has opted to design without considering accretion for TE-0117 for 30% design status. However, in order to more accurately design for accretion in dedicated nourishment areas, the application of acceptable rates of accretion is anticipated in dedicated nourishment areas.

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). Percent inundation refers to the percentage of the year a certain elevation of wetlands is expected to be inundated and has become utilized as a proxy for marsh inundation occurrence in addition to tidal range. To determine percent inundation, percentiles were calculated based on data gathered from CRMS3296 that was then ranked statistically. In consult with CPRA Marsh Creation Design Guidelines (MCDG), the optimal percent inundation for vegetative brackish marsh function, which is the marsh type classification for the project area, is between 20% and 80% (Snedden and Swenson 2012). **Table 5** presents the results of the percent inundation determination along with MHW and MLW for the design life of TE-0117. **Figure 15** shows a graphical representation of the preferred inundation range for TE-0117; MHW and MLW are also depicted. A detailed summary of the percent inundation calculations is available in the Calculations Packet in **APPENDIX D**.

Table 5: Percent Inundation Calculated Values

Percentile	TY0 Percent Inundation Elevation [FT NAVD88 GEOID12A]	TY20 Percent Inundation Elevation [FT NAVD88 GEOID12A]
1	+1.98	+2.45
10	+1.16	+1.63
MHW	+0.80	+1.36
20	+0.80	+1.36
80	-0.11	+0.36
MLW	-0.36	+0.20
90	-0.44	+0.03
99	-1.25	-0.78

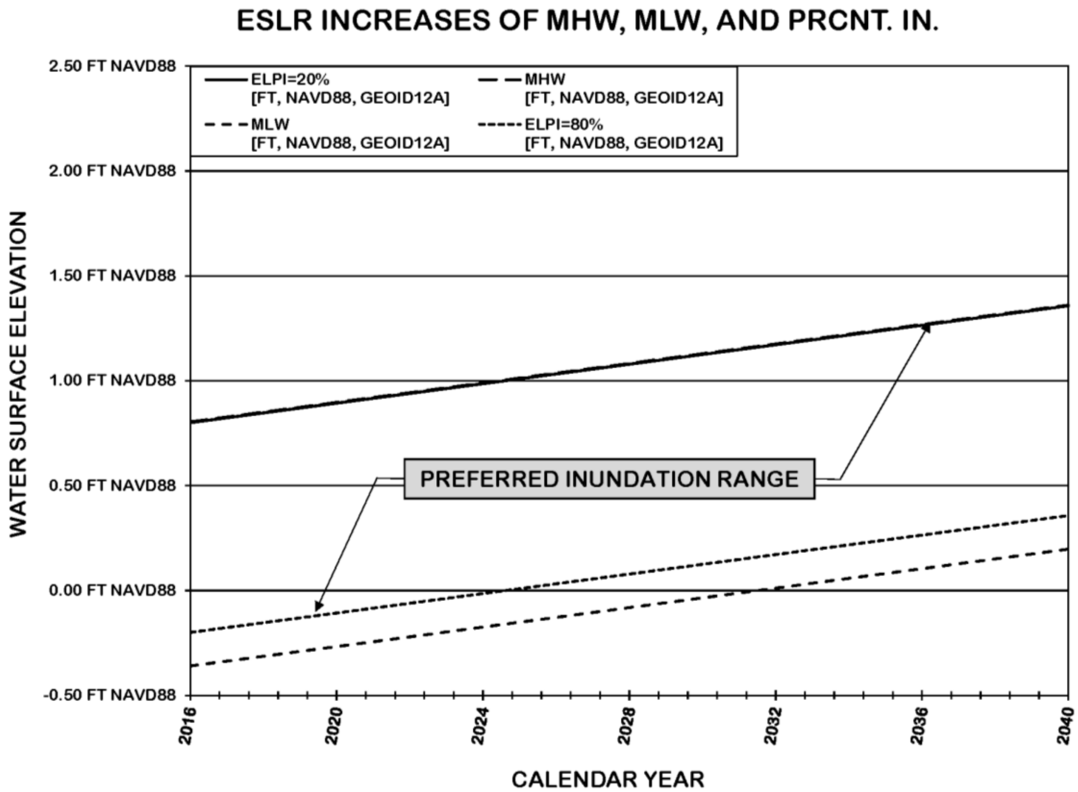


Figure 15: Percent Inundation and MHW/MLW for TE-0117

5.0 SURVEYS

5.1 General Scope

Topographic, bathymetric, magnetometer, and geophysical survey data were collected within the marsh creation area, proposed borrow area, access corridors, and potential dredge pipeline corridor alignments in a step-wise manner to facilitate the design of the project. The marsh creation area design survey effort was performed November 2015 through April 2016 by TBS. The deliverables received by CPRA as part of the TBS task are available in **APPENDIX E**. The borrow area, access corridors, and dredge pipeline corridor survey effort was performed August 2016 through September 2018 by CHF. The deliverables received by CPRA as part of the CHF task are available in **APPENDIX F**. 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.

5.2 Horizontal and Vertical Control

A National Geodetic Survey monument 2525A (also named and hereinafter referred to as TE10-SM-08) exists in the vicinity of the marsh creation area. TE10-SM-08 is located at the end of LA HWY 665 in the parking lot of the Pointe-aux-Chênes Marina in Terrebonne Parish. TBS used TE10-SM-08 as the primary control point for their survey activities. A State of Louisiana monument CRMSTE-SM-19 exists in the vicinity of the borrow area to the west of Lake Tambour in Terrebonne Parish and was used for control by CHF. One temporary benchmark TBM-1 was set by CHF on January 9, 2017 in the parking lot at the Isle de Jean Charles Marina in Terrebonne Parish. CHF utilized CRMSTE-SM-19 as the primary control point for their survey activities, and TBM-1 as well as TE10-SM-08 were also utilized as temporary benchmarks for a portion of their survey activities. **Figure 16** depicts the spatial orientation of TE10-SM-08, CRMSTE-SM-19, and TBM-1 at the TE-0117 site in relation to the as-proposed project features.

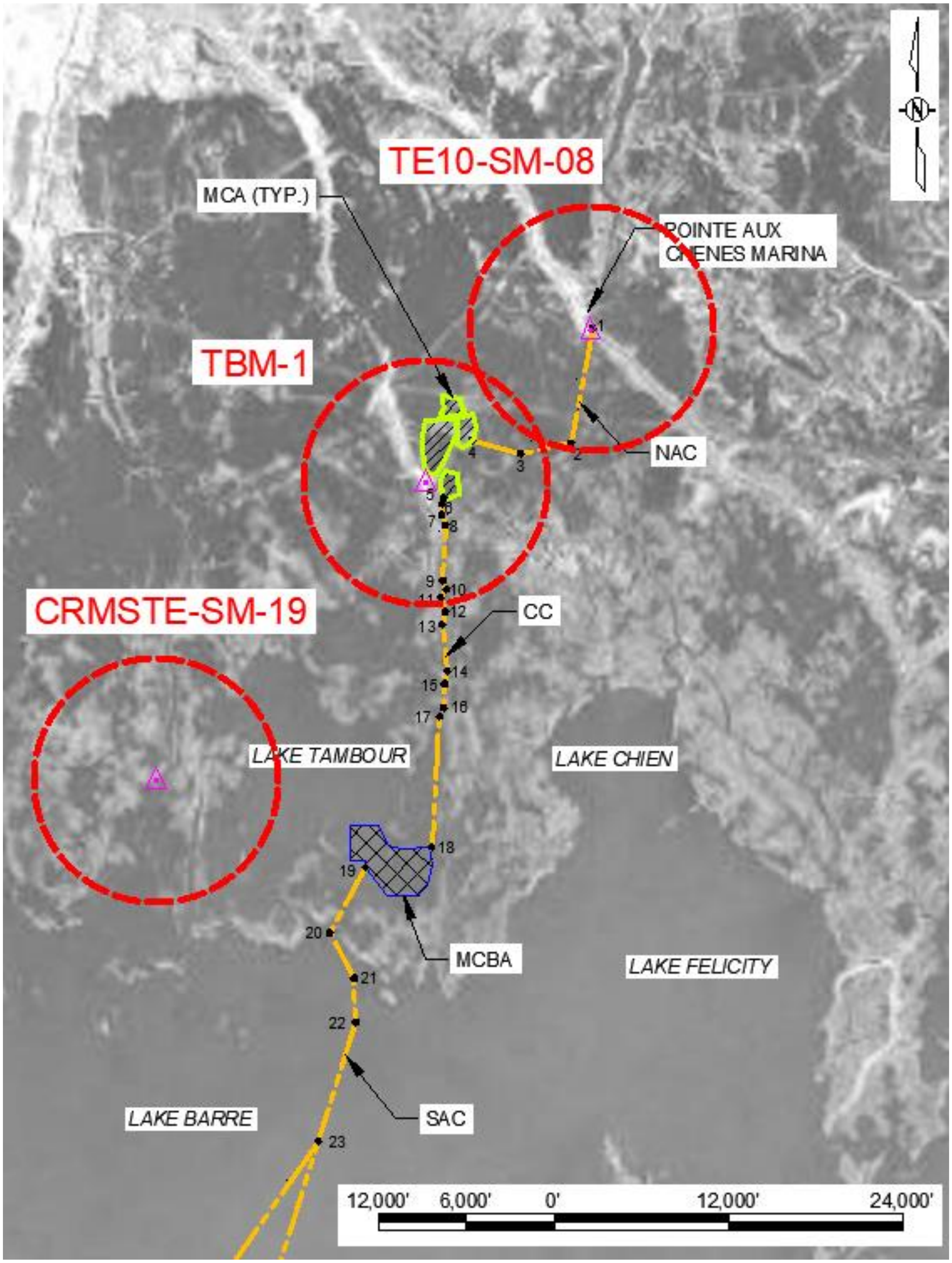


Figure 16: Locations of Survey Control Points at TE-0117

5.3 Topographic, Bathymetric, and Magnetometer Surveying

5.3.1 Marsh Creation Area Surveys

Topographic and bathymetric survey data were collected along transects spaced 250 and 500 feet parallel spanning the marsh creation area and vicinity. The majority of the transects were oriented along a northwest to southeast bearing and spaced 200 feet, while the remaining transects were laid out so as to capture perpendicular cross-tie alignments within the marsh creation area vicinity and were spaced 500 feet. Position, elevation, and water depths were recorded every 25 feet along each transect or where elevations changes were observed to occur greater than 0.5 feet. Topographic and bathymetric survey methods were used as applicable to obtain data along all transects and were consistent with the CPRA MCDG, Appendix A: *A Contractor's Guide to the Standards of Practice*. The topographic portions were overlapped with the bathymetric portions a minimum of 50 feet. Sideshots were taken as necessary to pick up variations in topographic features (highs and lows) such as trenasses, meandering channels, broken marsh areas, and any other existing features such as utility lines, pipelines, wellheads, and warning signs. A fixed height aluminum rod with a 6 inch diameter metal plate attached to the base of the rod was used to prevent the rod from sinking during topographic survey data collection. **Figure 17** contains the topographic and bathymetric survey layout map provided by TBS.

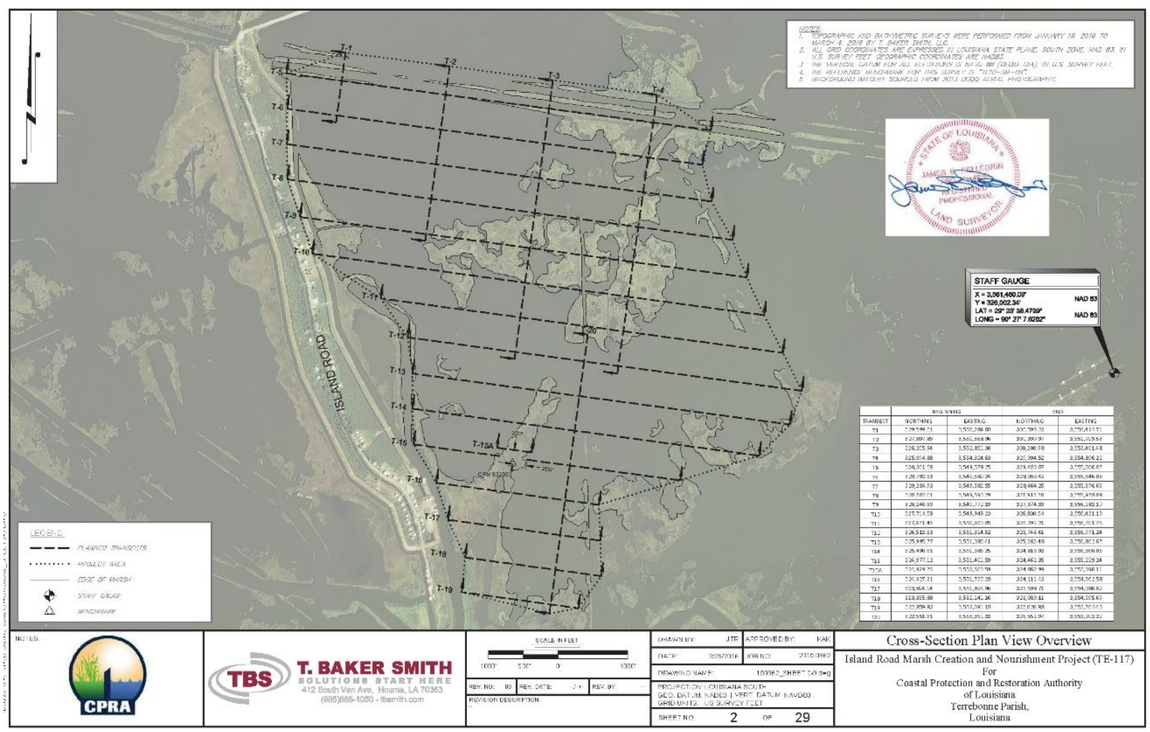


Figure 17: Marsh Creation Area Topo/Bathy Survey Layout

Magnetometer survey data was collected in a 500 ft spaced grid formation spaced spanning the marsh creation area and vicinity. For each magnetic anomaly detected during the initial magnetometer survey, a second magnetometer survey was performed around each anomaly in a smaller 50 by 50 ft rectangular grid formation. Probing techniques were also used to determine if metallic objects such as pipelines were present. No significant anomalies were detected within the marsh creation area and vicinity. However, a total of six (6) pipeline sections were discovered, all of which being located within Twin Pipelines to the northern extents of the survey coverage area and out of any proposed excavation or marsh creation construction. **Section 5.4** contains an additional information on pipelines encountered during the TBS survey effort as well as the CHF survey effort. **Figure 18** contains the magnetometer survey layout map provided by TBS.

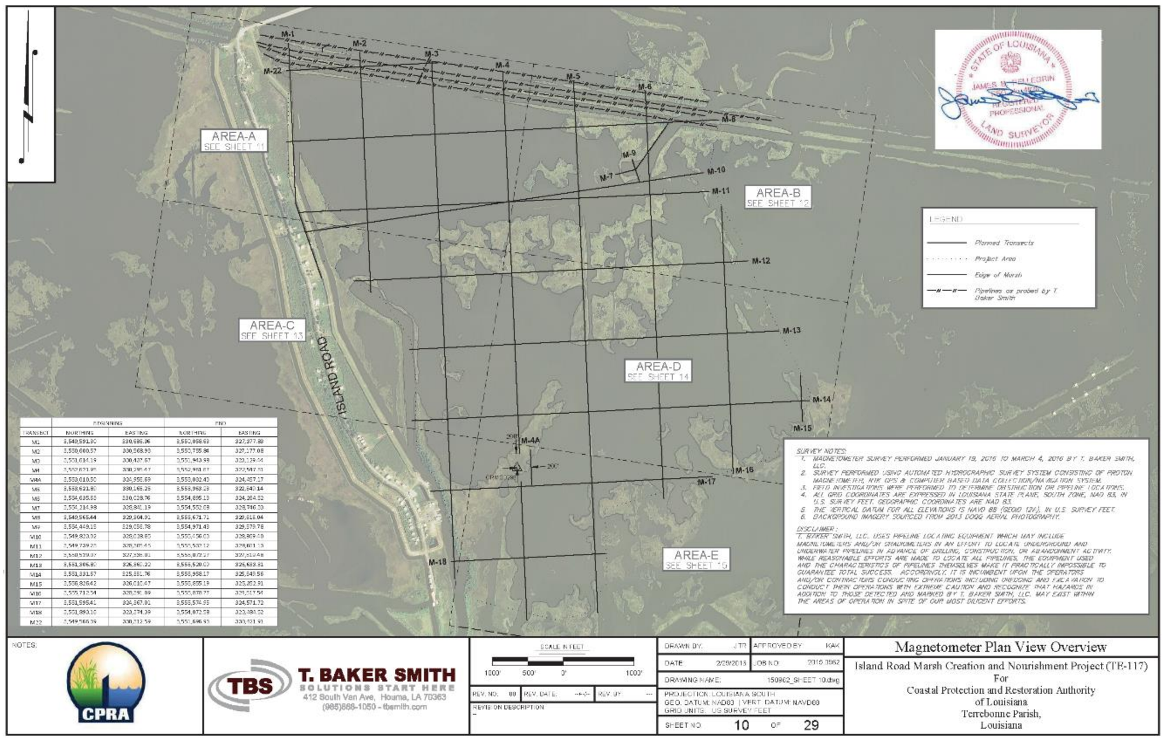


Figure 18: Marsh Creation Area Magnetometer Survey Layout

5.3.2 Water Surface Elevation and Staff Gage Surveys

To accurately measure daily water level fluctuations during the TBS survey effort, a staff gage was set near the project area on Marsh 22, 2016 at an approved location by CPRA. A 4 in by 4 in treated post 12 ft long was set and surveyed, and a ceramic staff gage was fastened using a 60d nail, in accord with the provisions stated in *A Contractor's Guide to the Standards of Practice*. Water surface elevation shots were taken near the staff gage, as well as taped measurements taken from the top of post to the 60d nail, from the top of post to the water surface, and from the top of post to the +3 FT NAVD88 mark on the staff gage. Upon comparison with CRMS3296 water level data, TBS reported an average comparison difference of 0.02 FT NAVD88 GEOID12A.

5.3.3 Reference Marsh Elevation Surveys

To better understand what elevations coincide with remaining, productive marsh habitat in the marsh creation area, average marsh elevations were gathered at select locations on March 3, 2016 under the supervision of a field biologist from the CPRA Thibodaux

Regional Office. Selection of locations was informed based on aerial photography and site observations of what visually appeared to be more vigorous marsh vegetation. Upon observing marsh quality, field locations were specified to the TBS field crew and five (5) locations were selected for reference marsh elevation surveys. Approximately 20 elevation shots were taken for each of the 5 reference marsh sites, and the average elevations for each site were computed and presented to CPRA. **Table 6** contains the average reference marsh elevation computations for each of the five sites. Comparing against the percent inundation calculated values shown in Table 5, the reference marsh elevations are all within the optimal inundation range and close to the average value of +0.39 FT NAVD88 GEOID12A corresponding to the average of the calculated 20% and 80% inundation elevations. **Figure 19** contains the reference marsh elevation survey layout map provided by TBS.

Table 6: Reference Marsh Elevations

Location	Average Elevation [FT NAVD88 GEOID12A]
AV1	+0.50
AV2	+0.64
AV3	+0.57
AV4	+0.55
AV5	+0.52
Average (All)	**+0.56**

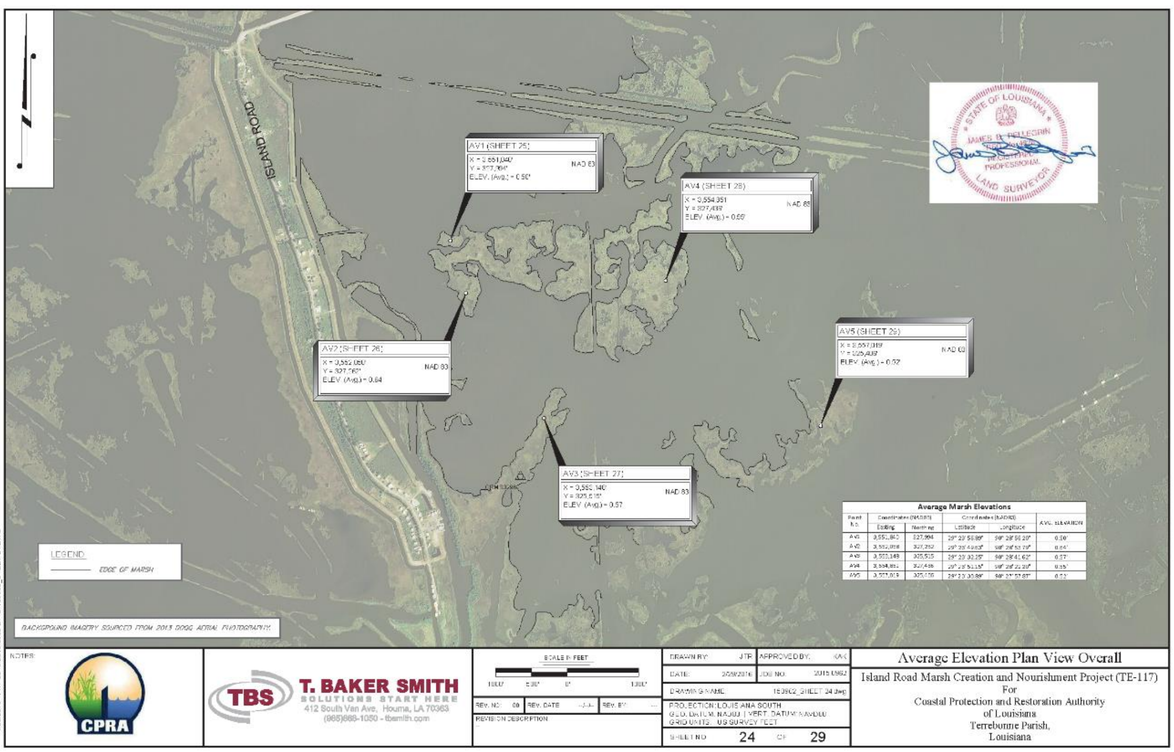


Figure 19: Reference Marsh Elevation Survey Layout

5.3.4 Surface Features and Infrastructure Surveys

To properly account for surface features and infrastructure present within the area, topographic features such as fences, gates, lightpoles, building corners, levee toes and crowns, concrete pipe supports, and discharge pipes were collected around the extents of the marsh creation area as applicable and in particular at the pump station located on Island Road in Isle de Jean Charles. Marsh creation banklines were also surveyed and delineated at the water's edge and shown in the survey drawings produced by TBS. **Figure 20** contains a survey layout map of the pump station and surrounding area. Examples of these surface features identified by TBS are: pump station outfall pipes, fencelines, pump station structures, and marsh banklines.

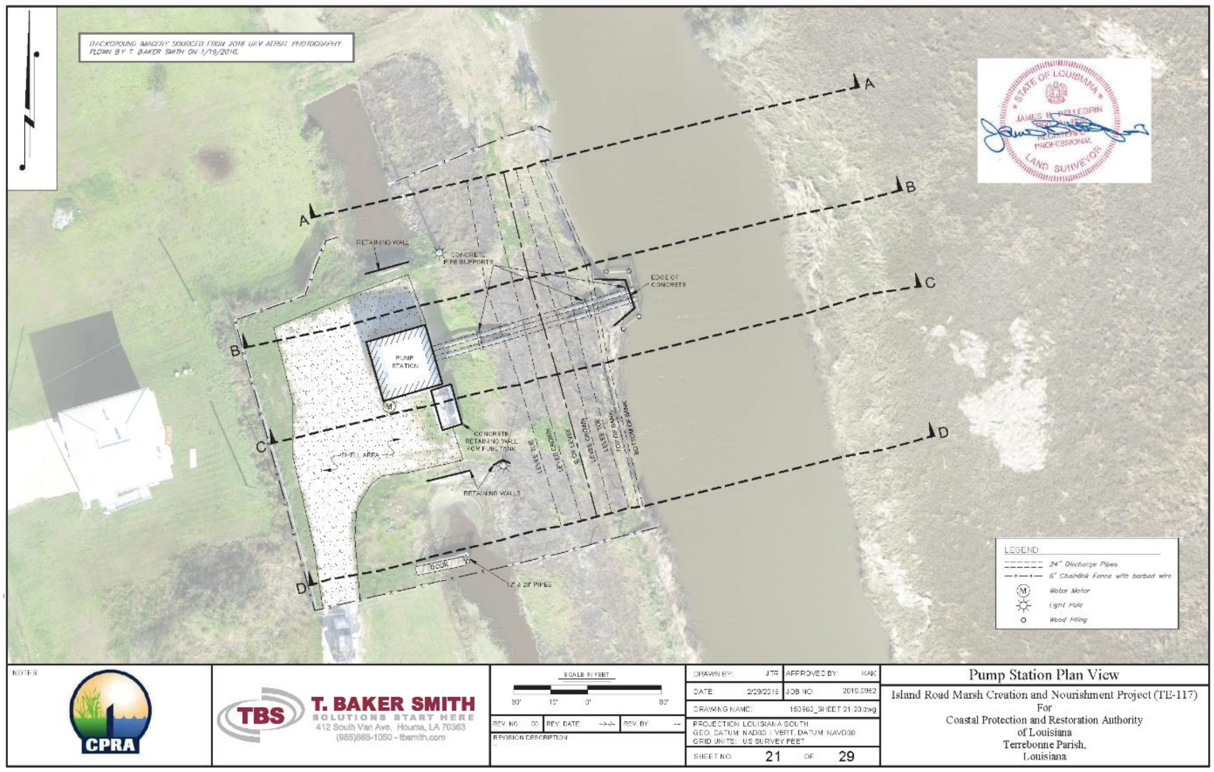


Figure 20: Isle de Jean Charles Pump Station Survey Layout

5.3.5 Borrow Area Surveys

Survey transects of the borrow area were taken predominantly in a north-south orientation every 98 feet. East-west transects were spaced 500 feet apart and oriented so as to capture cross-tie alignments within the borrow area. 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 were used as applicable to obtain data along all transects and were consistent with the CPRA MCDG, Appendix A: *A Contractor's Guide to the Standards of Practice*. **Figure 21** contains the borrow area survey layout map provided by CHF.

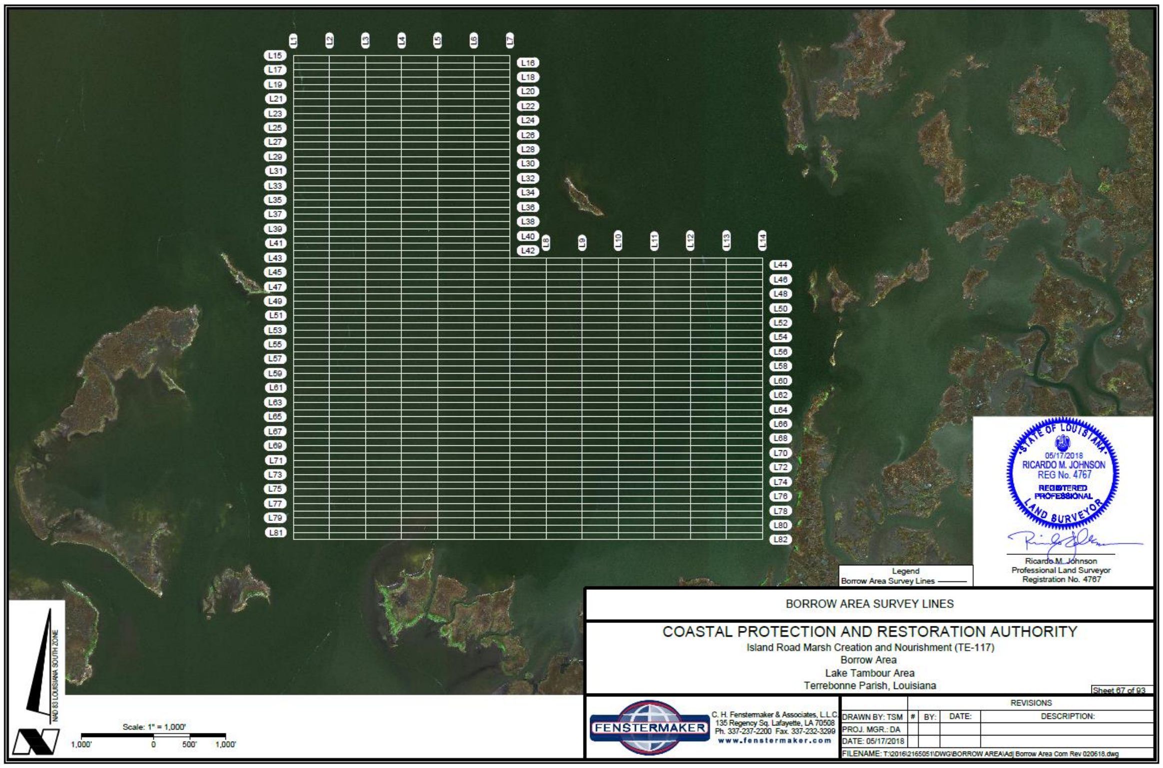


Figure 21: Borrow Area Topo/Bathy/Mag Survey Layout

Magnetometer survey data was collected along the same transect layout as shown in **Figure 21**. For each magnetic anomaly detected, findings were observed and presumed to represent articles of nonsignificant ferrous anomalies which were either buried below the mudline or were too small to be acoustically detected and probably associated with debris. Based on the interpretation of these findings, no significant anomalies were believed to be detected within the borrow area.

In addition to borrow area bathymetric and magnetometer surveys, CHF and associated subcontractors were tasked with performing geophysical and archaeological investigations in the TE-0117 borrow area. In order to thoroughly vet the TE-0117 as-proposed borrow area from any culturally sensitive artifacts, a geophysicist from Oceaneering International, Inc. and a marine archaeologist from Earth Search, Inc. accompanied the survey crew to perform sub-bottom profiling and archaeological surveying, respectively. Another critical component of the borrow area surveying task performed by CHF was to perform marsh bankline surveys of the lake rim at the southeastern extents of Lake Tambour in a manner similar to the TBS survey effort discussed in **Section 5.3.4**. This survey data was later used to inform borrow area computational wave modeling discussed in **Section 7.0**. Note that slope stability analyses were also performed on borrow area in situ soil samples, which are further described in **Section 6.0**. **Figure 22** contains a photograph of marsh bankline surveying field activities. More information pertaining to the geophysical, archaeological, marsh bankline surveying, survey data acquisition methods, and survey results is available in **APPENDIX F**.

Figure 22: Marsh Bankline Surveying in Lake Tambour, Pictured Aug. 2017

5.3.6 Conveyance Corridor and Equipment Access Corridor Surveys

Singlebeam bathymetric surveying was performed in the northern access corridor (NAC), conveyance corridor (CC), and southern access corridor (SAC) along a centerline transect and two offsets to the east and west spaced approximately 150 feet offcenter. Crossties were also laid out according to field fit and were surveyed using singlebeam bathymetric survey equipment as well. CPRA also tasked CHF with surveying an alternate corridor for a segment of the SAC, where infrastructure literature reviews indicated the possibility of some critical pipeline crossings located approximately 5 miles to the south of the borrow area. An alternate access corridor (hereinafter termed the SAC SPUR) was also surveyed with singlebeam bathymetric methods utilizing a centerline corridor with east and west offsets. Following hydrographic surveying, the CHF field crew performed topographic surveys to locate existing pipeline signs, bulkheads, pilings, and powerpoles along the NAC, CC, and SAC. Position, elevation, and water depths were recorded every 25 feet along each transect or where elevations changes were observed to occur greater than 0.5 feet. Topographic and bathymetric survey methods were used as applicable to obtain data along all transects and were consistent with the CPRA MCDG, Appendix A: *A Contractor's Guide to the Standards of Practice*. The topographic portions were overlapped with the bathymetric portions a minimum of 50 feet. Sideshots were taken as necessary to pick up variations in topographic features (highs and lows) such as trenasses, meandering channels, broken marsh areas, and any other existing features such as utility lines, pipelines, wellheads, and warning signs. Between August 21st and August 25th, 2017, the low sag of the existing overhead powerline on the west side of Cutoff Canal was surveyed using a reflectorless total station in order to determine the minimum clearance (approximately 37 ft) between low sag of the powerline at the NAC crossing and the water surface elevation during the survey (+0.5 FT NAVD88 GEOID12A). **Figure 23** contains the topographic, bathymetric, and magnetometer survey layout map of the NAC and CC, while **Figure 24** contains that of the SAC and SAC SPUR.

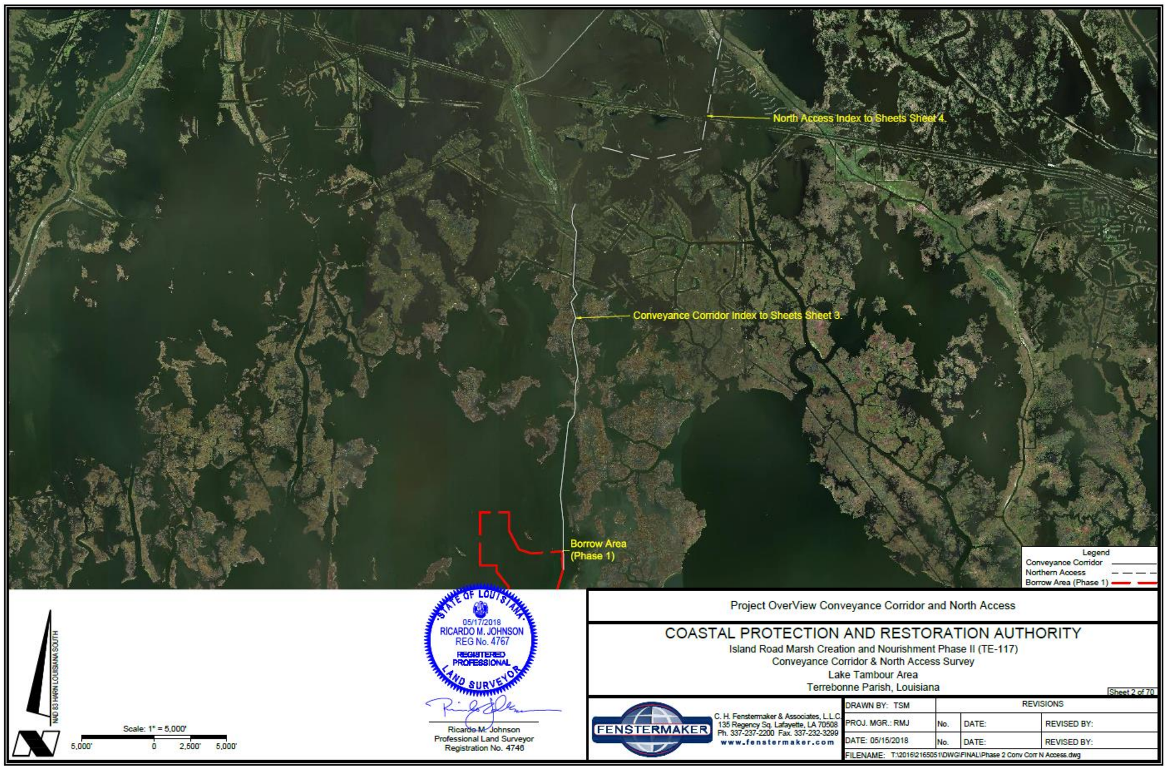


Figure 23: Access Corridor Centerline Transect Survey Layout (NAC, CC)

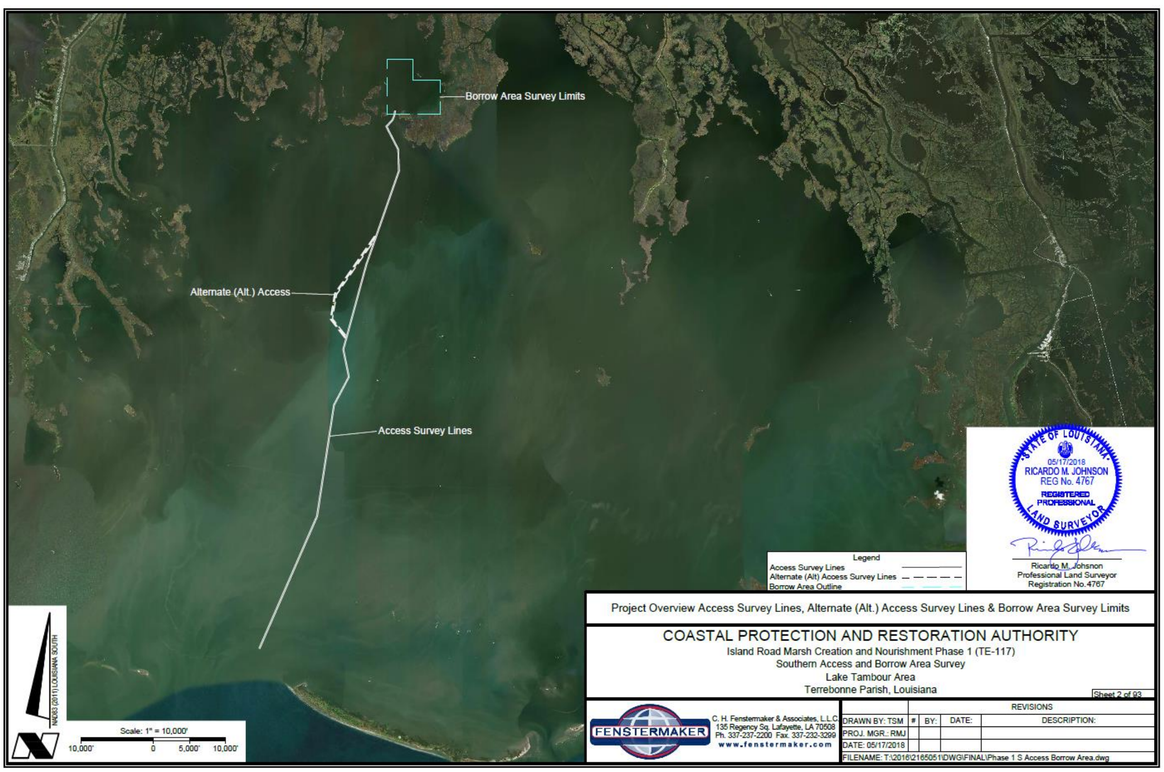


Figure 24: Access Corridor Centerline Transect Layout (SAC, SAC SPUR)

Magnetometer survey data was collected along the same centerline and offset transect configuration that was laid out for topographic/bathymetric surveying and as shown in **Figure 23** and **Figure 24**. For each magnetic anomaly detected, findings were first observed and determinations were made as to the potentiality of significant magnetic findings such as pipelines. Based on the interpretation of these findings, the CHF crew executed additional investigation techniques such real time kinematic surveying in the vicinity of significant findings and probings to determine whether or not any potential pipelines were exposed and if so to ascertain mudline elevation, depth of cover, and possible pipeline diameter in addition to other information. **Section 5.4** contains an additional discussion on pipelines encountered during the TBS survey effort as well as the CHF survey effort.

5.4 Pipeline Information

Table 7 contains a list of all pipeline information identified for the TE-0117 project as informed through the TBS survey effort. **Table 8** contains a list of all pipeline information identified for the TE-0117 project as informed through the CHF survey effort.

Table 7: TBS Pipeline Identification Information for TE-0117

Pipeline/Flowline Identification	Location in Relation to Project Features, Potential for Impact	Excavation Proposed?
6” Enlink/Crosstex Pipeline	Twin Pipelines (north of MCA), No Impact	N
20” Gulf South Pipeline	Twin Pipelines (north of MCA), No Impact	N
8” Enterprise Pipeline	Twin Pipelines (north of MCA), No Impact	N
10” Unidentified Pipeline	Twin Pipelines (north of MCA), No Impact	N
3” Gulf South Pipeline	Twin Pipelines (north of MCA), No Impact	N
10” Columbia Gulf Pipeline	Twin Pipelines (north of MCA), No Impact	N
20” Gulf South Pipeline	Twin Pipelines (north of MCA), No Impact	N

Table 8: CHF Pipeline Identification for TE-0117

Pipeline Crossing ID	Pipeline/Flowline Identification	Location in Relation to Project Features, Applicable CL[1] Stationing	Excavation Proposed?	TOP[2] EL[3] [FT[4]]	BOC[5] EL[3] [FT[4]]
1	Harvest Natural Gas Pipeline	NAC – Cutoff Canal Near PAC, STA 7+00	N	SIG[6]	N/A[7]
2	Williams Energy Natural Gas PL[8]	NAC – Cutoff Canal Near PAC, STA 9+00	N	SIG[6]	N/A[7]
3	Unknown Pipeline	NAC – Cutoff Canal, STA 38+00	N	-16	N/A[7]
4	Unknown Natural Gas Pipeline	NAC Crossing @ Twin Pipelines, STA 54+00	N	SIG[6]	N/A[7]
5	Koch Natural Gas Pipeline	NAC Crossing @ Twin Pipelines, STA 56+00	N	SIG[6]	N/A[7]
6	Columbia Gulf Natural Gas PL[8]	NAC Crossing @ Twin Pipelines, STA 57+00	N	SIG[6]	N/A[7]
7*	Genesis Petroleum Pipeline	NAC – Near MCA4, STA 100+00	Y	-9	-5
8*	Harvest Natural Gas Pipeline	CC – Near MCA 3, STA 247+00	Y	-7	-5
9*	Gulf South Natural Gas Pipeline	CC – Near MCA 3, STA 232+00	Y	SIG[6]	-5
10	Hillcorp Pipeline	SAC – Open Water @ SAC SPUR, STA 576+00	N	-12	-8

Table 8 (Continued from Previous Page): CHF Pipeline Identification for TE-0117

Pipeline Crossing ID	Pipeline/Flowline Identification	Location in Relation to Project Features, Applicable CL[1] Stationing	Excavation Proposed?	TOP[2] EL[3] [FT[4]]	BOC[5] EL[3] [FT[4]]
11	Unknown Pipeline	SAC – Open Water @ SAC SPUR, STA 550+00	N	-11	-8
12	Hillcorp Pipeline	SAC – Open Water @ SAC SPUR, STA 517+00	N	-10	-8
13	24” Kinetica Pipeline / 36” Tennessee Gas Pipeline Cluster	SAC – Open Water @ SAC SPUR, STA 504+00	N	-12	-8
14	Harvest Pipeline / Hillcorp Pipeline Cluster	SAC – Open Water Towards HNC[9] STA 177+00	N	-10	-8
15*	Hillcorp Pipeline	SAC SPUR, STA 140+00	Y	-12	-8
16*	24” Kinetica Pipeline / 36” Tennessee Gas Pipeline Cluster	SAC SPUR, STA 54+00	N	-16	-8

*Notes that excavation is proposed and that a minimum of 2 FT of cover is expected during the course of all construction operations.

1. CL stands for “centerline”.
2. TOP stands for “top of pipe”.
3. EL stands for “elevation”.
4. Units are FT relative to NAVD88, GEOID12A.
5. BOC stands for “bottom of cut”.
6. SIG is an abbreviation for signal detect only. Pipeline verified based on signal only and believed to be at significant depth below surface and out of impact zone of mechanical dredging operations.
7. BOC not applicable, as BOC elevation is greater than existing elevation at this location.
8. PL stands for “pipeline”.
9. HNC stands for “Houma Navigation Canal”.

As informed through survey data collection, the as-proposed hydraulic dredging operations in the borrow area as well as the as-proposed mechanical dredging operations in the marsh creation area are expected to be free of pipeline concerns. Also as informed through survey data collection, the as-proposed access and conveyance corridor project features currently call for a total of 16 pipeline crossings; however, all crossings are proposed in such a manner that a minimum of two (2) feet of cover is expected to be maintained under maximum allowable access dredging scenarios. In a future construction scenario, the prospective construction contractor will be required to perform a preconstruction magnetometer survey in order to more accurately reflect future construction-era conditions, with particular respect to pipeline crossings. As is required via standard construction permit conditions for CPRA projects, all access dredging is expected to be restored to pre-project conditions following construction operations. Additional pipeline identification information, as determined by TBS and CHF, is available in **APPENDIX E** and **APPENDIX F**, respectively. The TE-0117 design team has also discussed formulating a plan for early engagement of pipeline/utility owners between the 30% and 95% design status milestones.

5.5 Key Findings and General Conclusions

Table 9 contains a summary of surveying findings established for the TE-0117 project.

Table 9: TE-0117 Breakdown of Surveyed Elevations of Note

Project Feature (Specific Location/Case)	Apprx Preconstruction EL [FT NAVD88 GEOID12A]
NAC (Outside Cutoff Canal)	-4.0
MCA, Interior Cell (High Case)	+1.0
MCA, Interior Cell (Low Case)	-3.0
MCA, ECD[1] Alignment (Low Case)	-3.5
MCA, ECD[1] Alignment (Extreme Low Case, MCA3)	-11.0
CC (Midway Along CL)	-6.0
BA (Centrally Located)	-5.0
SAC (Upper, Near BA)	-7.0
SAC (Lower, Near HNC)	-12.0

1. ECD stands for “earthen containment dike”.

6.0 GEOTECHNICAL INVESTIGATIONS

6.1 Literature Review and Existing Conditions

Prior to the authorization of any data collection task orders, CPRA performed a literature review to obtain a general understanding of the geologic and geotechnical conditions within the TE-0117 vicinity. With the large amount of infrastructure in the area, it was discovered that several geotechnical engineering reports had been authored. Available information was reviewed, and discussions were conducted with geotechnical engineering firms and local government representatives who were familiar with the southeast Terrebonne area. Highly organic and soft clay layers were expected with the possibility of more granular and noncohesive in situ soil strata expected near bayous and historical waterways. Existing features that are understood to have had an impact on site hydrology, such as roads and canals, are also understood to likely have altered the geologic properties of the site. Similarly, the existence of additional infrastructure was also understood to potentially impact site hydrology and geology, and, therefore, all available information was collected and reviewed, as discussed in **Section 2.2**.

6.2 Geotechnical Field Investigations

6.2.1 General Scope

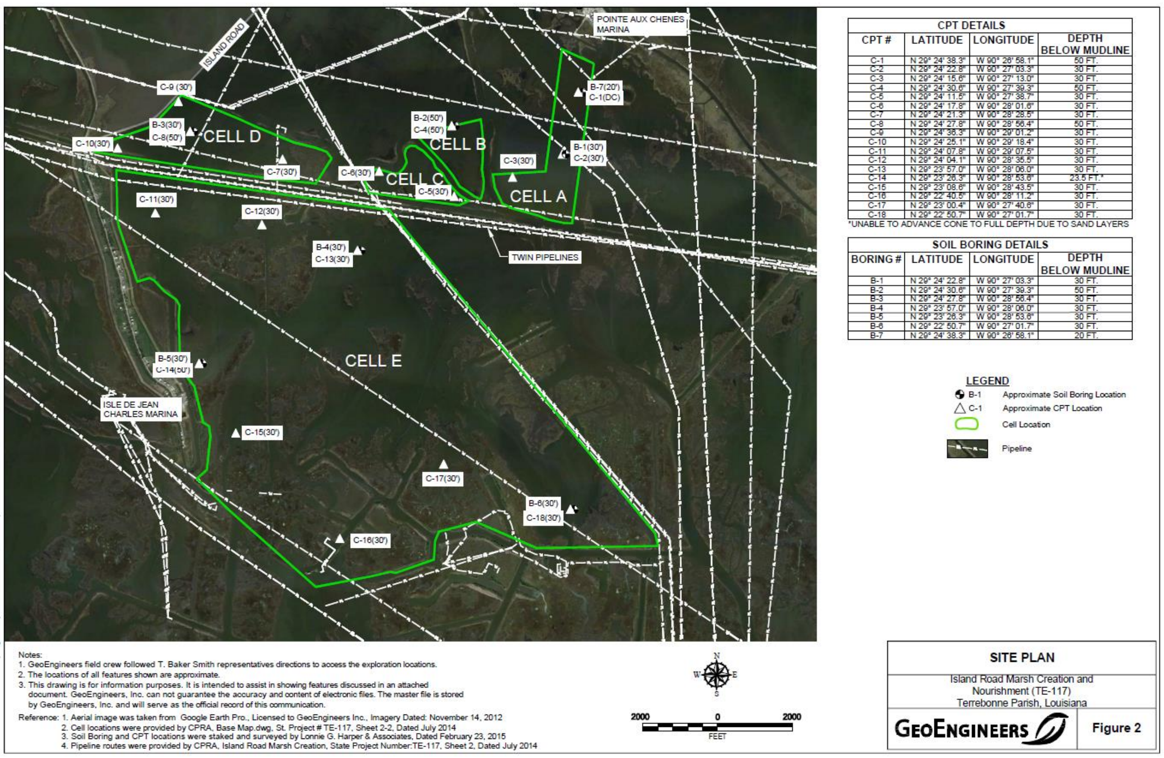
Table 10 contains a breakdown of information pertaining to geotechnical data collection investigations carried out for TE-0117. All geotechnical sampling, including soil sample identification, classification, storage, transport, and electronic data logging, were performed according to the most applicable standard as part of American Society for Testing and Materials (ASTM) standard methods and to the provisions stated in MCDG for geotechnical investigations.

Table 10: Breakdown of TE-0117 Geotechnical Investigations

Investigation No.	Timeframe	Sampling	Additional Details
1	2014 - 2015	7 borings, 18 CPTs	• marsh creation area in situ sampling only • high coverage area (total area ≈ 1,500 AC) • high sample density (coverage ≈ 70 AC/sample) • laboratory testing program executed • various engineering analyses conducted
2	2016 - 2018	12 borings, 19 CPTs	• marsh creation area in situ sampling only • borrow area sett. col. testing performed • medium coverage area (total area ≈ 400 AC) • high sample density (coverage ≈ 20 AC/sample) • laboratory testing program executed • various engineering analyses conducted
3	2017 – 2018	8 borings, 0 CPTs	• borrow area in situ sampling only • medium coverage area (total area ≈ 400 AC) • med sample density (coverage ≈ 50 AC/sample) • limited laboratory testing executed • limited engineering analyses conducted

6.2.2 Exploratory Marsh Creation Area Geotechnical Investigation (Investigation No. 1)

Soil conditions were evaluated in the marsh creation area and vicinity by extracting seven (7) borings at depths ranging 20 to 30 feet below the existing mudline and by advancing 18 CPTs at depths ranging 20 to 50 feet below the existing mudline. CPT soundings were completed using Geoprobe equipment mounted on an airboat, while the soil borings were completed using a drillrig mounted on an airboat. Prior to soil sampling operations, water depth and mudline elevation, location coordinates, and magnetometer clearance surveys were conducted by a professional land surveyor serving as a subcontractor to GEO. As an additional precaution, the GEO field crew probed around each soil boring and CPT prior to the commencement of sampling. An oyster biologist was also onsite observing field operations. **Figure 25** contains the exploratory marsh creation area geotechnical sampling layout map provided by GEO.



CPT DETAILS

CPT #	LATITUDE	LONGITUDE	DEPTH BELOW MUDLINE
C-1	N 29° 24' 38.3"	W 90° 26' 58.1"	50 FT.
C-2	N 29° 24' 22.8"	W 90° 27' 03.3"	30 FT.
C-3	N 29° 24' 15.6"	W 90° 27' 13.0"	30 FT.
C-4	N 29° 24' 30.6"	W 90° 27' 39.3"	50 FT.
C-5	N 29° 24' 11.5"	W 90° 27' 38.7"	30 FT.
C-6	N 29° 24' 17.8"	W 90° 28' 01.6"	30 FT.
C-7	N 29° 24' 21.3"	W 90° 28' 28.5"	30 FT.
C-8	N 29° 24' 27.8"	W 90° 28' 56.4"	50 FT.
C-9	N 29° 24' 36.3"	W 90° 29' 01.2"	30 FT.
C-10	N 29° 24' 25.1"	W 90° 29' 18.4"	30 FT.
C-11	N 29° 24' 07.8"	W 90° 29' 07.5"	30 FT.
C-12	N 29° 24' 04.1"	W 90° 28' 35.5"	30 FT.
C-13	N 29° 23' 57.0"	W 90° 28' 06.0"	30 FT.
C-14	N 29° 23' 26.3"	W 90° 28' 53.6"	23.5 FT.*
C-15	N 29° 23' 08.6"	W 90° 28' 43.5"	30 FT.
C-16	N 29° 22' 40.5"	W 90° 28' 11.2"	30 FT.
C-17	N 29° 23' 00.4"	W 90° 27' 40.6"	30 FT.
C-18	N 29° 22' 50.7"	W 90° 27' 01.7"	30 FT.

*UNABLE TO ADVANCE CONE TO FULL DEPTH DUE TO SAND LAYERS

SOIL BORING DETAILS

BORING #	LATITUDE	LONGITUDE	DEPTH BELOW MUDLINE
B-1	N 29° 24' 22.8"	W 90° 27' 03.3"	30 FT.
B-2	N 29° 24' 30.6"	W 90° 27' 39.3"	50 FT.
B-3	N 29° 24' 27.8"	W 90° 28' 56.4"	30 FT.
B-4	N 29° 23' 57.0"	W 90° 28' 06.0"	30 FT.
B-5	N 29° 23' 26.3"	W 90° 28' 53.6"	30 FT.
B-6	N 29° 22' 50.7"	W 90° 27' 01.7"	30 FT.
B-7	N 29° 24' 38.3"	W 90° 26' 58.1"	20 FT.

Figure 25: Exploratory Marsh Creation Area Geotechnical Sampling Layout

6.2.3 Supplementary Marsh Creation Area Geotechnical Investigation (Investigation No. 2)

Following an analysis of results from the exploratory effort, soil conditions were again evaluated in the revised marsh creation area by extracting nine (9) borings at depths ranging 30 to 60 feet below the existing mudline and 19 CPTs at depths ranging 15 to 40 feet below the existing mudline. CPT soundings were completed using an airboat-mounted hydraulic ram. Borings were completed using a drillrig mounted to a single engine airboat. As was performed for the exploratory effort, all sampling locations were staked out and surveyed to collect water depth, elevation, location, and also surveyed via closed loop magnetometer path to identify and avoid potential hazards. **Figure 26** contains the supplementary marsh creation area geotechnical sampling layout map provided by GEO.

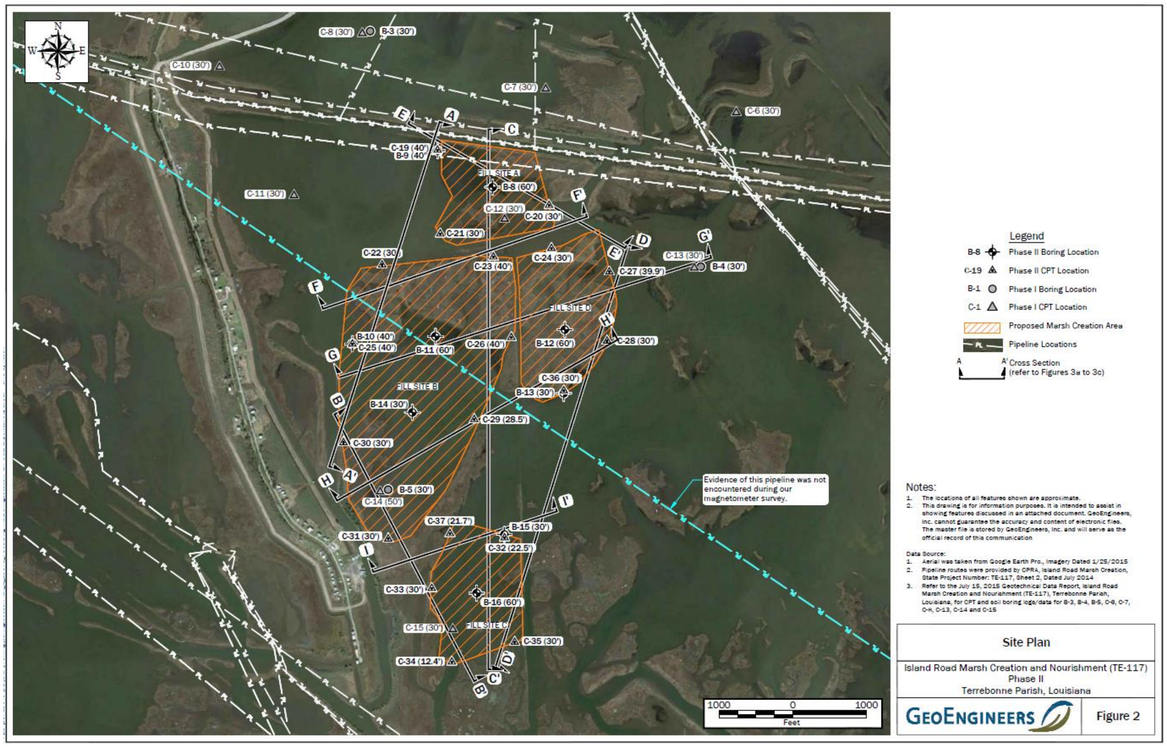


Figure 26: Supplementary Marsh Creation Area Geotechnical Sampling Layout

6.2.4 Borrow Area Geotechnical and Investigation (Investigation No. 3)

In conjunction with the CHF surveying task discussed in **Section 5.3.5**, soil conditions were evaluated in the borrow area by extracting eight (8) borings all to depths of 20 feet below the existing mudline. Prior to the arrival of the geotechnical sampling crew and equipment, stakeout and magnetometer surveys were conducted to verify that no magnetic hazards were believed to exist prior to soil sampling. **Figure 27** contains the borrow area geotechnical sampling layout map provided by GEO.

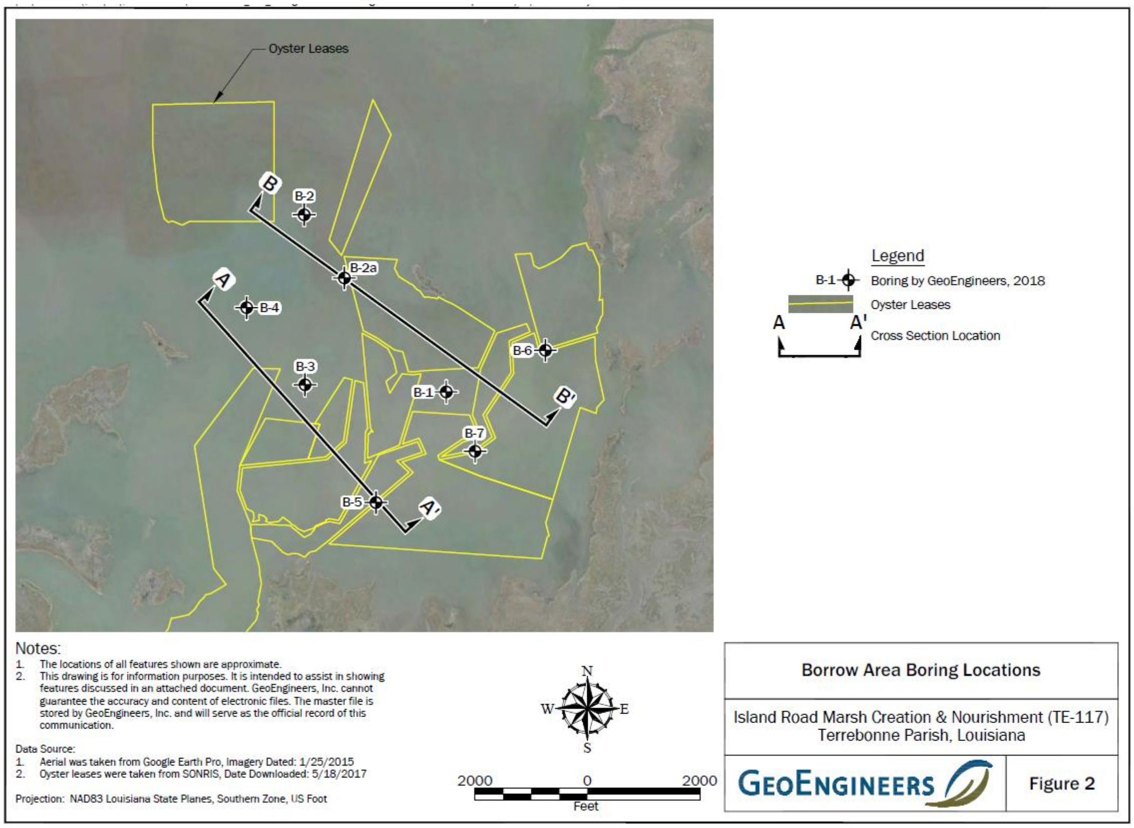


Figure 27: Borrow Area Geotechnical Sampling Layout

6.3 Geotechnical Laboratory Testing Program

All geotechnical engineering laboratory procedures were performed according to the most applicable standard as required by ASTM standard language and to the provisions stated in the MCDG for geotechnical laboratory testing. Note that settling column testing was performed based on the sample preparation and test procedure presented in the United States Army Corps of Engineers (USACE) Confined Disposal of Dredged Material engineer manual (EM 1110-2-5027), with modifications made under the supervision of a geotechnical engineer licensed by the Louisiana Professional Engineering and Land Surveying Board and with specialized training and experience in geotechnical engineering.

6.4 Geotechnical Engineering Analyses

6.4.1 General Geologic Evaluations

At the commencement of the exploratory marsh creation area geotechnical investigation, an assessment was made on geologic conditions at the project site by first reviewing historical geology maps obtained from *USACE, Alluvial Deposits Map, Quads: Lake Felicity, Dated 1986*. **Figure 28** and **Figure 29** contain geology maps provided by GEO.

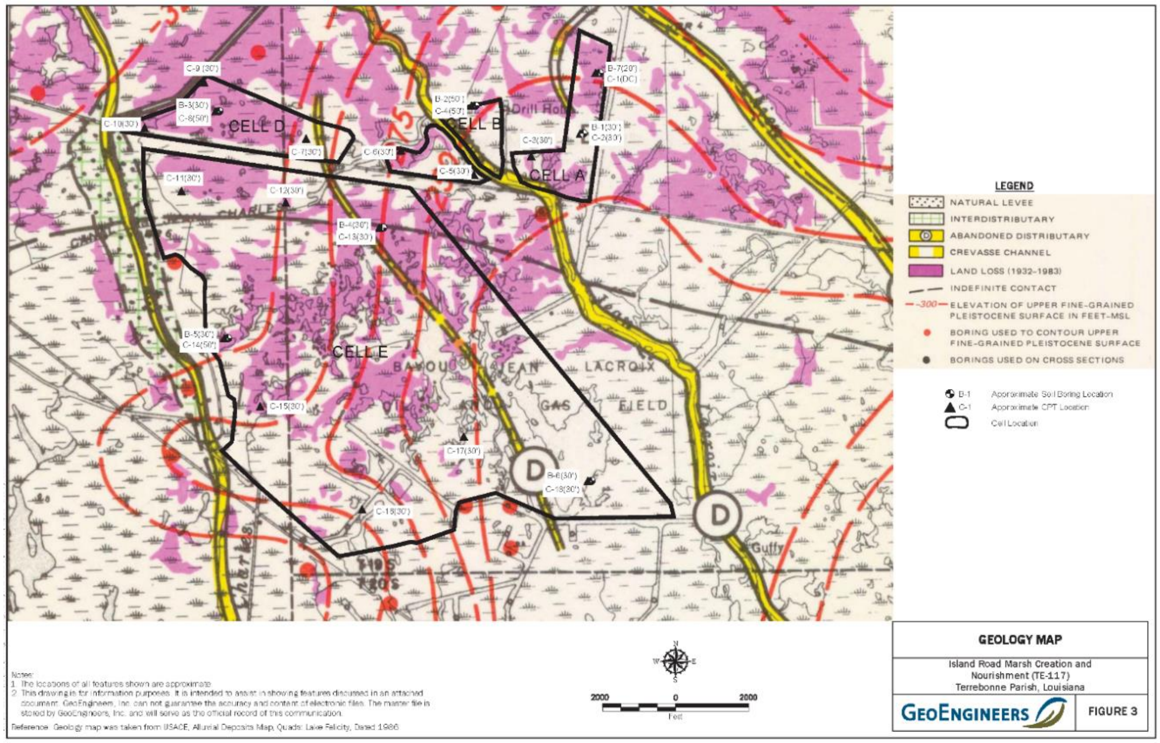


Figure 28: Geology Map, Exploratory Geotechnical Effort

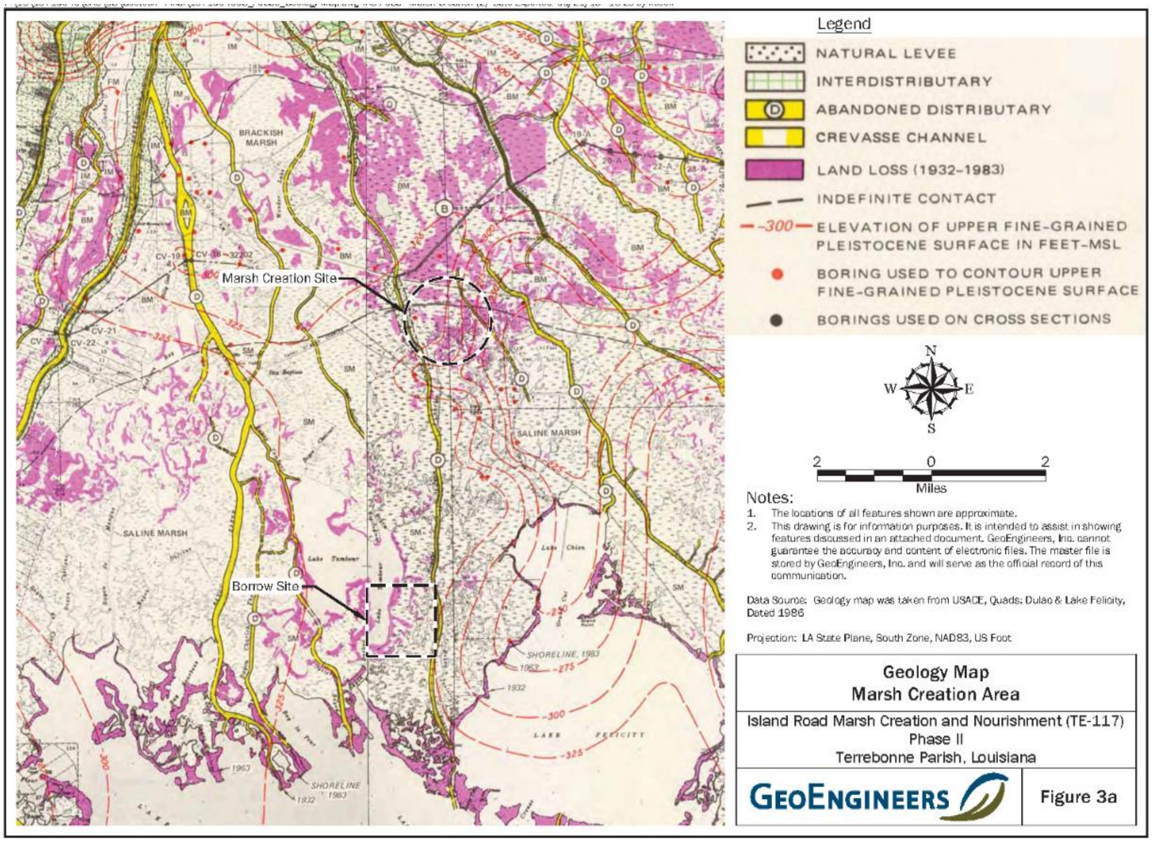


Figure 29: Geology Map, Supplementary Geotechnical Effort

GEO estimated that Pleistocene-era deposits are in existence approximately 225 to 325 feet below grade within most areas across the project site. However, natural levee deposits coming from historical bayous and waterways, while not having been created by Pleistocene-era sediment transport, are understood to provide more stable subsurface soil strata in the upper portions of the geologic profile than their marsh deposit counterparts located away from natural waterways and bayous. While the borrow area geologic conditions were analyzed based on historical USACE geology maps, soil conditions were anticipated to be relatively similar to that of the marsh creation area, with the governing constraint being to select geotechnical sampling so as to avoid impacts to oysters during geotechnical sampling operations and future construction.

6.4.2 Generation of Subsurface Design Profiles

Subsurface design profiles for the marsh creation area were generated using in situ soil sample characteristics that facilitated the geotechnical design of ECD slope stability and dike design dimensions, the geotechnical design of sheetpile-sand berm gap closure system, and the geotechnical design of marsh creation area fill settlement. Subsurface design profiles for the borrow area were also generated using in situ soil sample characteristics to better understand the nature of borrow material and to analyze slope stability of the post-dredge face of the borrow area edge. Additional information on subsurface design profiles is available in **APPENDIX J** and **APPENDIX K**.

6.4.3 Marsh Fill Settlement Analyses and Target Pump Elevation Determination

Settlement analyses were performed to determine the optimal CMFE of the marsh creation areas and the total volume of fill material required to meet CMFE and long-term project goals for settlement. The final elevation of the marsh creation area (at TY20) is governed by two forms of settlement: (1) the settlement of in situ soils in the marsh creation area caused by the applied loading of hydraulic dredge slurry deposition; and (2) the self-weight consolidation of the dredged material itself. Note that desiccation is considered as well, but is often considered to be secondary to the items (1) and (2). Data from settling column tests and low pressure consolidation tests was used to estimate the total magnitude of settlement and the time-rate of settlement of the slurry, and data from traditional consolidation testing was used to determine the settlement of the underlying soils within the marsh creation area cells. Note that subsidence has also been factored into settlement analyses and is depicted on settlement curves shown below.

The existing mudline elevations assumed for marsh fill settlement analysis can greatly affect the required construction elevation to achieve TY20, as well as the type of marsh fill operation that is required to meet said elevation. In the case of the TE-0117 project, GEO performed a settlement analysis for the governing case of in situ soil design profiles across three existing mudline elevation conditions as follows:

Condition 1) Preconstruction Mudline Elevation = +0 FT NAVD88

Condition 2) Preconstruction Mudline Elevation = -2 FT NAVD88

Condition 3) Preconstruction Mudline Elevation = -3 FT NAVD88

With the exception of the +0 FT NAVD88 condition, the settlement analyses produced by GEO call for 2-lift construction to a CMFE of +3.0 FT NAVD88 in order to meet TY20 settlement criteria. **Figure 30**, **Figure 31**, and **Figure 32** contain settlement curves corresponding to differing preconstruction mudline elevations across the total design life of 20 years. The settlement curve array corresponding to Condition 2) is shown below as the most representative condition for preconstruction mudline elevations across the marsh creation area, as indicated by the TBS color spectrum figure shown on **Figure 6**. The supplementary marsh creation area geotechnical engineering report included in **APPENDIX K** contains more in-depth information on the settlement analyses performed by GEO.

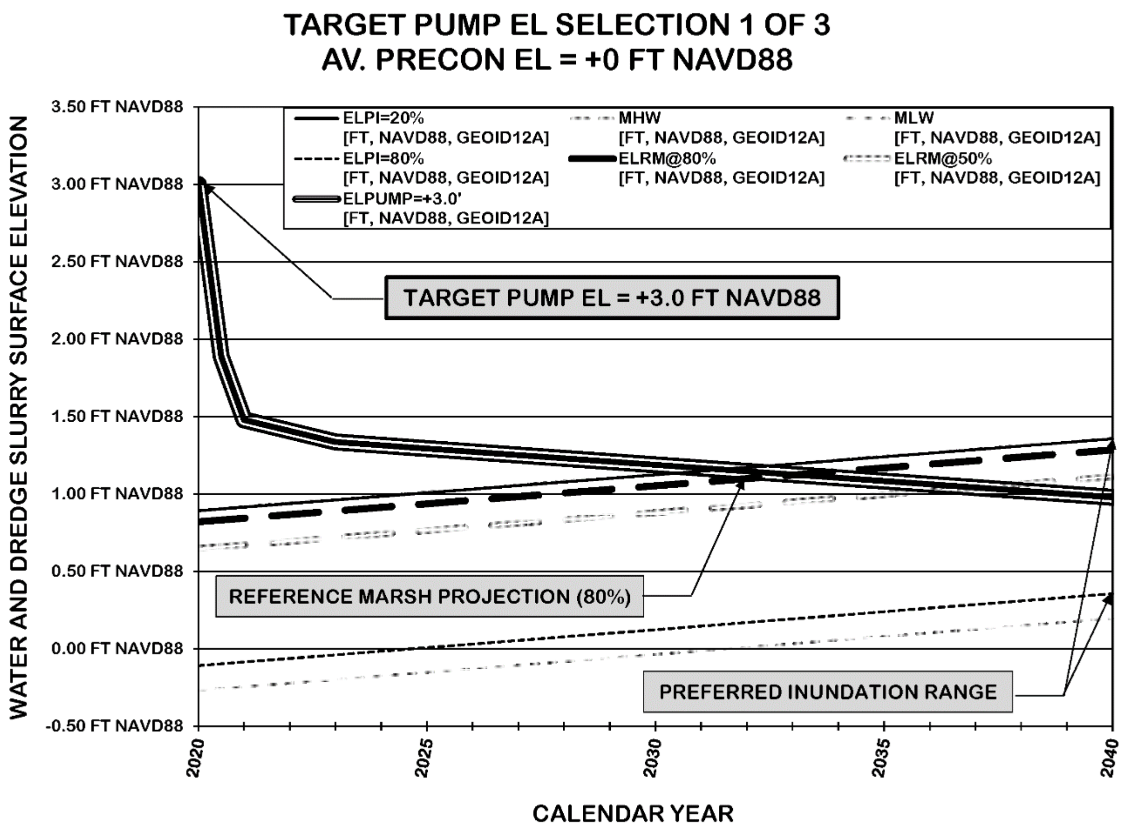


Figure 30: Settlement Curve Array, Mudline EL = 0 FT NAVD88

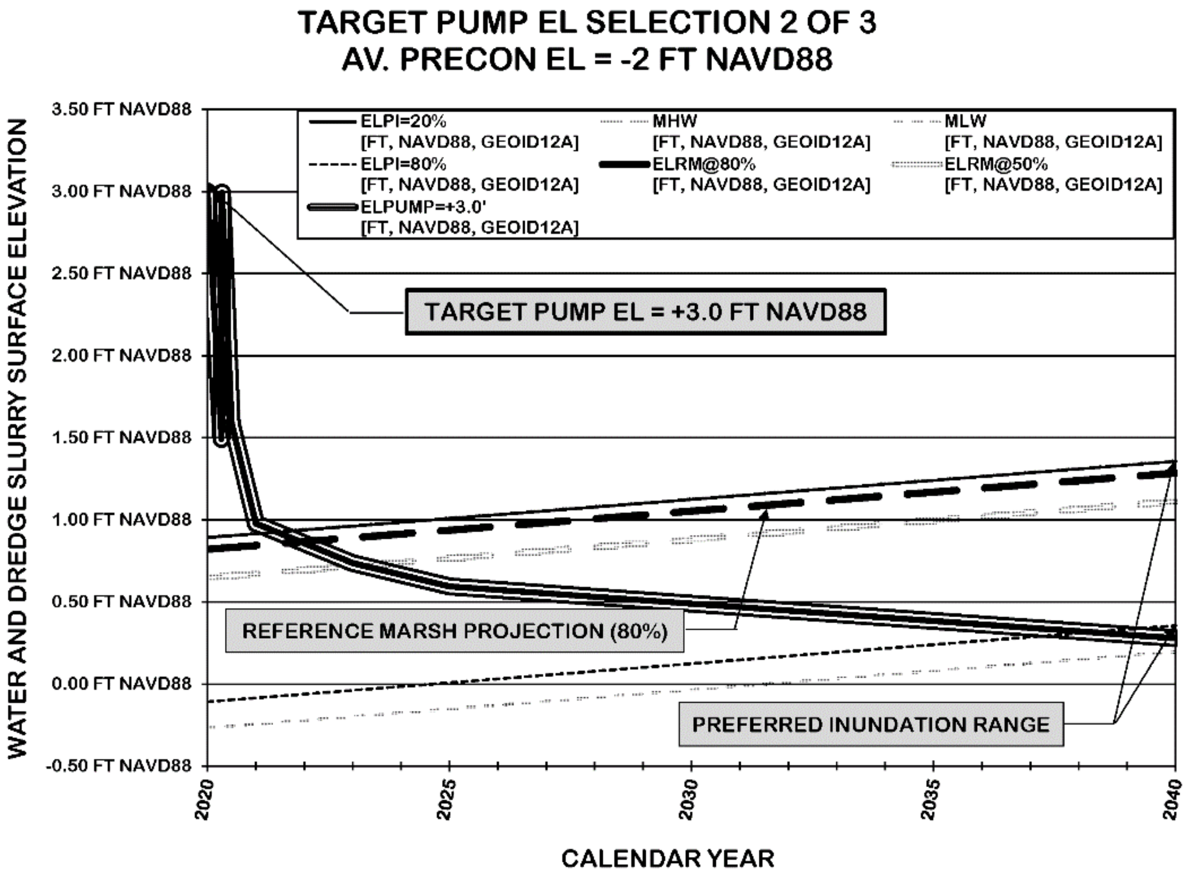


Figure 31: Settlement Curve Array, Mudline EL = -2 FT NAVD88

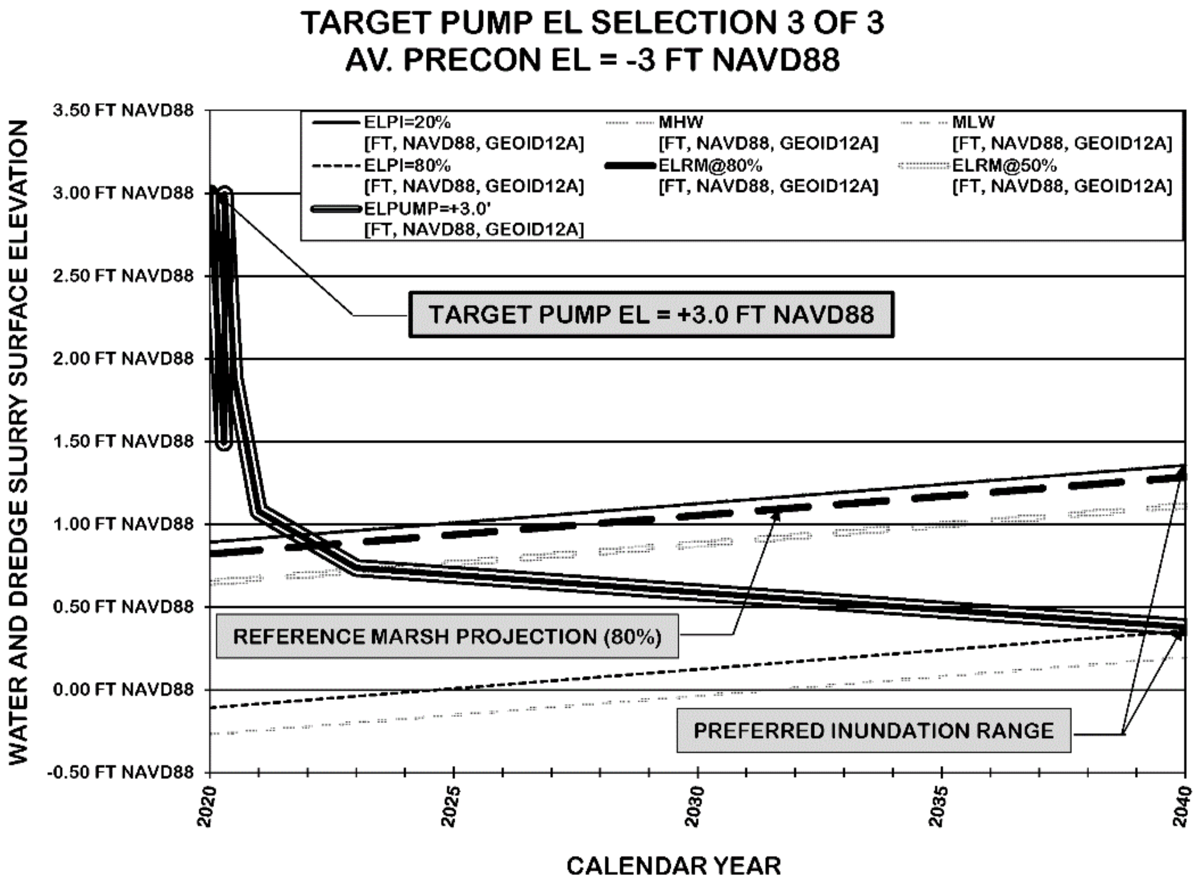


Figure 32: Settlement Curve Array, Mudline EL = -3 FT NAVD88

6.4.4 Earthen Containment Dike Slope Stability Analyses

Global and local slope stability analyses were performed on various ECD cross-sectional configurations at different crown elevations and dike design geometries in accordance with the CPRA MCDG, Appendix B Figure B-5 (shown as **Figure 33** below) in order to produce an optimized final ECD design. The slope stability of a typical ECD has two types of driving forces: (1) forces induced by the weight of soil; and (2) 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 and soil parameters of the proposed features. GEO performed stability analyses that computed factors of safety against potential failure based on limit equilibrium theory.

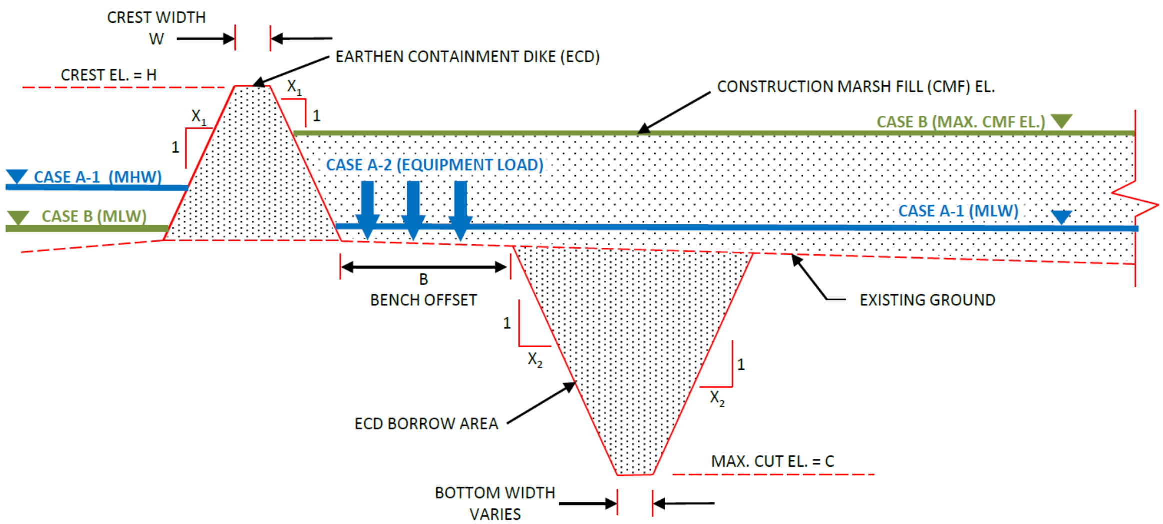


Figure 33: ECD Typical Section

For this project, multiple scenarios were run based on the governing constraints supplied to GEO in the form of preconstruction mudline elevations and percent inundation guidance documentation. Stability runs were performed and were evaluated across five (5) stability cases as follows:

Case 1)	Internal failure of ECD, no marsh fill placed.
Case 2)	Global failure of ECD into borrow channel, no marsh fill placed.
Case 3)	Failure of borrow channel, no marsh fill placed, construction equipment modeled.
Case 4)	Internal failure of ECD, marsh fill placed.
Case 5)	Global failure of ECD into exterior borrow channel, marsh fill placed.

As a result of the slope stability analyses, two (2) optimized ECD cases were developed by GEO which were based on each of the two in situ soil design profiles ("Design Profile 1" corresponding to subsurface soil conditions lacking coarse-grained deposits and "Design Profile 2" which contain more coarse-grained soils in shallow layers of strata). Side slopes of 1V:4H were incorporated based on experience and can be increased if necessary, provided the stability berm minimum width dimension is exceeded (30 ft for Design Profile 1, 25 ft for Design Profile 2). A minimum slope stability factor of safety of 1.2 was deemed acceptable by the design professional, as per the CPRA MCDG, Appendix B. **Figure 34** depicts the two optimized ECD cross-section designs produced for the TE-0117 project. These optimized sections correspond to the two design profiles developed across the site along with the change in mudline elevation. For the purposes of the 30% design milestone, the upper cross-section applies to the entirety of containment dike reaches for the current layout. The supplementary marsh creation area geotechnical engineering report included in **APPENDIX K** contains more in-depth information on the ECD slope stability analyses performed by GEO.

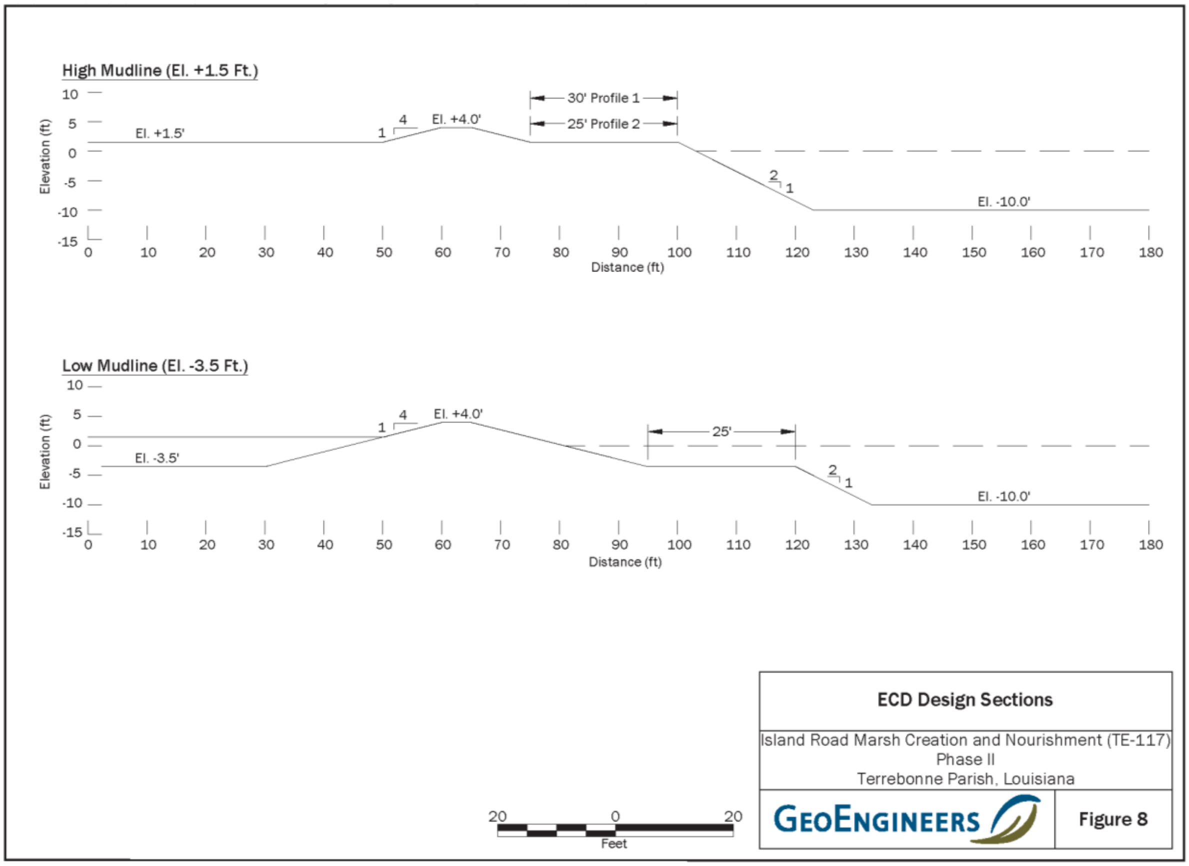


Figure 34: Optimized ECD Cross-Sectional Designs

6.4.5 Earthen Containment Dike Settlement Analyses

Consolidation settlement of the foundation soils beneath the ECDs was computed based on the dike geometries determined from slope stability analyses and the soil properties of the in situ soils near the proposed dike alignments. Total settlement factors include regional subsidence and elastic settlement of the in situ soils. Note that shrinkage and self-weight consolidation of the ECD soils also factor into ECD settlement calculations. Elastic settlement (construction settlement) of the in situ soils is expected to occur quickly and will likely result in an increase in the quantity of fill volume required to reach the design construction elevation. Multiple cases of ECD settled elevations were analyzed, with a construction ECD crown elevation of +4.0 FT NAVD88 GEOID12A being required to provide necessary freeboard during construction and all marsh fill operations, given the marsh fill settlement analyses discussed in **Section 6.4.3**. Note that multiple lift ECD construction was determined to be necessary to achieve this construction elevation and stability as discussed in **Section 6.4.4**, with dikes expected to provide at least 1 ft of freeboard during all times of construction. **Figure 35** contains a sample settlement curve array for ECD settlement bracketed between two (2) preconstruction mudline elevations of +1.5 FT NAVD88 and -3.5 FT NAVD88 representing dike construction on existing marsh and dike construction in open water over 20 years. **Figure 36** shows the same dataset focused on the first four years of the settlement curve.

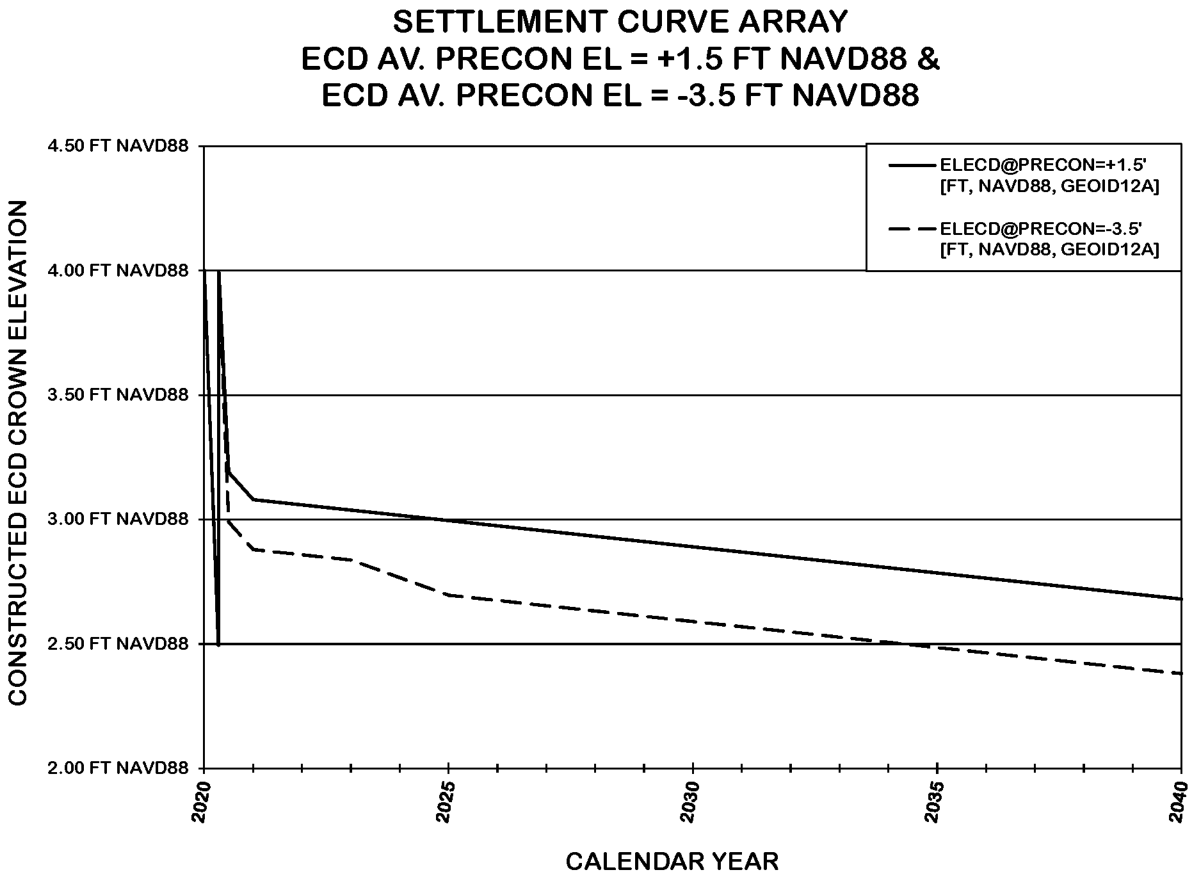


Figure 35: Multiple Lift ECD Sample Settlement Curve Array, TY0 – TY20

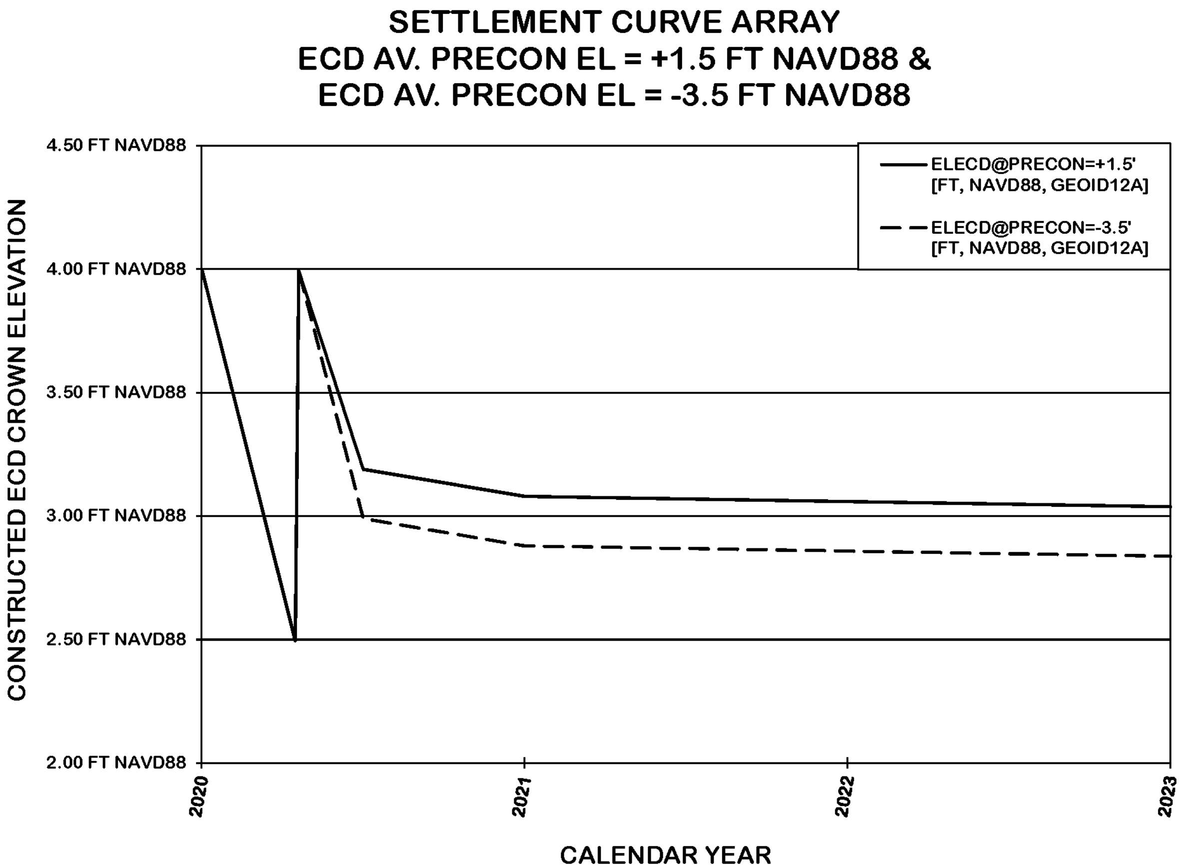


Figure 36: Multiple Lift ECD Sample Settlement Curve Array, TY0 – TY3

6.4.6 Alternate Gap Closure System Geotechnical Engineering Analyses

The marsh creation area vicinity was understood to have existing mudline elevations ranging from approximately +1.0 FT NAVD88 to -4 FT NAVD88, with the exception of a 100 ft segment at the very southernmost portion of the site that was approximately -11 FT NAVD88. Because conventional in situ ECD construction is not feasible, GEO was tasked with analyzing an alternate gap closure design. The use of PZ22/PZ27 sheetpile embedment into imported sand was analyzed. **Figure 37** shows the as-proposed alternate gap closure system design.

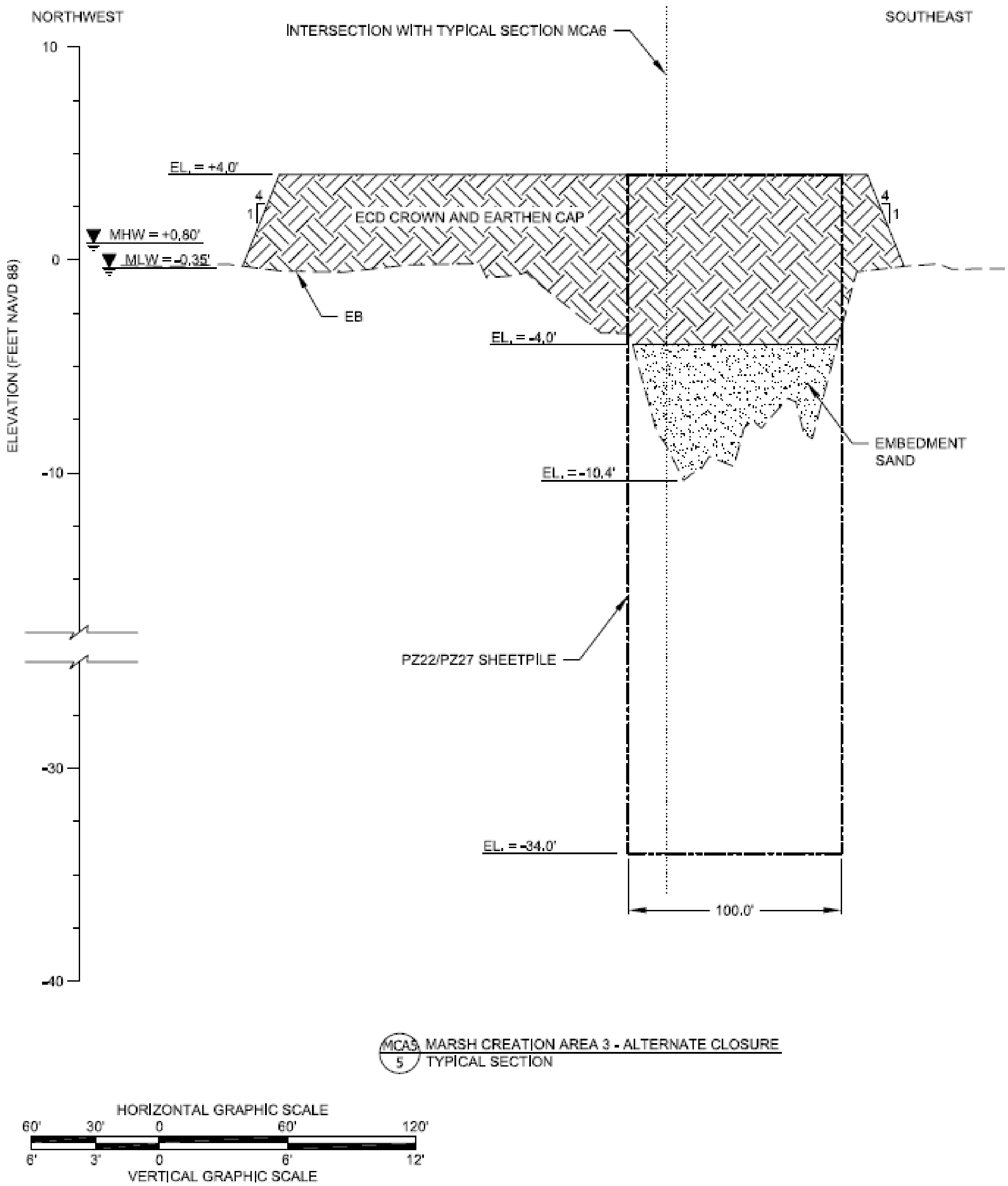


Figure 37: Alternate Closure System Design

6.4.7 Borrow Area Material Properties Assessment, Slope Stability Analysis, and Settling Column Testing

As discussed in **Section 6.2.4**, eight (8) borrow area borings were extracted and then later processed by GEO in their Baton Rouge, LA laboratory. Index property testing as well as select strength testing were performed on the in situ soil samples prior to composite mixing and preparation for settling column testing, which was later performed in a separate settling column testing laboratory. Following undisturbed sample testing, composite sample homogenization was performed by mixing in situ samples with water samples also obtained from Lake Tambour. Small specimens from these composite samples were then taken and prepared for further testing, while the remaining composite sample mixes were sent off to the settling column testing facility. Four (4) low stress consolidation tests were performed on these representative dredge slurry specimens. Using in situ soil strength data and the other pre-homogenization index soil properties, GEO was also able to perform analyses recommending that borrow area side slopes be designed to 1V:3H.

After low stress consolidation testing was performed by GEO, further processing was initiated on the two (2) separate composite samples: "Composite Sample 1" using borings B-2, B-2a, B-3 and B-4; and "Composite Sample 2" using borings B-1, B-5, B-6, and B-7 (borrow area boring layout shown in **Figure 27**). Pilot tests were first performed in accordance with the provisions stated in the CPRA MCDG, Appendix B, Section 2.7 (USACE EM 1110-2-5027) to obtain data on the two main phases of particulate settling—zone settling and compression settling. Then, full scale settling column testing was executed to complete the long-term dredge slurry settling column analysis. **Figure 38** contains a sample settling column test output provided by SCTCS Group, LLC (subconsultant to GEO).

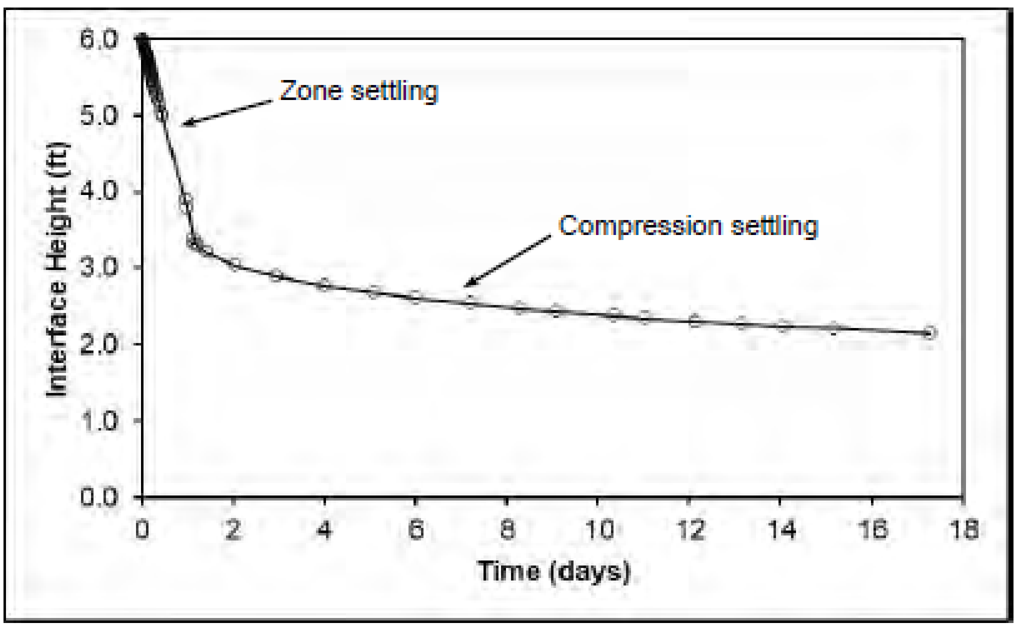


Figure 38: Sample Settling Column Test Output

6.6 Cut-to-Fill Recommendation

Cut-to-fill ratios were by recommended by GEO and CHF in order to provide volumetric contingencies for losses during hydraulic dredging and disposal, containment, and dewatering, as well as mechanical dredging and sidecasting/placement of ECD borrow material.

As proposed for TE-0117, a cut-to-fill ratio has been applied for all mechanically dredged ECD borrow material. In the past, mechanical dredging and sidecasting/placement of borrow material for ECD construction has been estimated using cut-to-fill ratios that ranged from approximately between 1.2:1 to 2.0:1. GEO has recommended a cut-to-fill ratio of 2.0:1 for all ECD alignments. For this project a cut-to-fill of 1.5:1 is being used for mechanical dredging and construction of ECDs. Upon review of the geotechnical engineering report in **APPENDIX K**, it is understood that the recommended C:F is based on the expectation to encounter up to 10 ft of peat material across the site. While this an adequate description of certain portions of the site, a cursory review of the geotechnical conditions along the as-proposed containment dike reaches show less peat constituency, and in some locations none at all. The deviation from the recommended 2.0:1 value to a reduced value of 1.5:1 is also based on a review of past projects of similar geotechnical conditions. Moving forward past the 30% milestone, the relocation of marsh creation areas and containment dike alignments is expected to further optimize containment dike design into shallower and more geotechnically constructible areas.

A cut-to-fill ratio has also been applied for all as-proposed hydraulic dredge fill material. This ratio is being factored in to account for three main sources of uncertainty: (1) losses near the cutterhead; (2) bulking of the sediments during the hydraulic dredging and disposal process; and (3) losses through the weirs and/or spill boxes in the confined marsh creation cells during the dewatering process. In the past, hydraulic dredging and disposal of borrow material for marsh creation has been estimated using cut-to-fill ratios that ranged from 1.0:1 to 1.5:1. However, past CPRA projects similar in scope and scale to TE-0117 have experienced large degrees of percent error with respect to contract volume versus total volume cut and total volume placed in a marsh creation project application, possibly as a result of misappropriation of excessively large cut-to-fill ratios.

During a hydraulic dredging operation, losses are known to occur near the cutterhead, as observed on numerous CPRA projects. Based upon the borrow area characteristics on typical projects, a bulking factor of 2 (cut-to-fill ratio of 0.5:1) to 4 (cut-to-fil ratio of 0.25:1) can occur. In the case of TE-0117, however, the in situ void ratios of the borrow soils compared to those of the near surface portions of representative healthy marsh soil samples were observed to be relatively close in value—with the in situ soils of the marsh creation area being slightly lower. However, the unknown in all projects is the role that fine-grained dredge fill particles play in attributing losses during dewatering. For smaller confined disposal cells (100 acres or less), which equate to less retention time, losses can be upwards of 50% whereas large cells typically exhibit lower losses such as approximately 10%. With the exception of MCA2 (approximately 155 AC), the marsh creation cells in this project are all significantly less in terms of acreage (approximately 40 – 50 AC), therefore a higher loss rate is assumed. GEO has recommended a cut-to-fill ratio of 1.2:1. CHF has recommended a cut-to-fill ratio of 2.0:1. For this project, a cut-to-fill ratio of 1.2:1 is being used for hydraulic dredging and disposal of marsh fill. There is no deviation from the recommended C:F presented by GEO.

7.0 BORROW AREA COMPUTATIONAL MODELING

7.1 Data Collection Requirements

As stated in **Section 5.3.5**, the design team was interested in developing an understanding of any potential effects to wave energy and increased susceptibility of the marsh bay rim to erosion during and after excavation of the proposed TE-0117 borrow area. As such, computational modeling was conducted as part of a borrow area impact analysis. This analysis was executed under the borrow area development data collection task order for which a two-dimensional hydrodynamic modeling exercise would assist the TE-0117 project team in informing design decisions of the borrow area feature.

7.2 Numerical Modeling Methodology

7.2.1 Model Setup

As identified by ULL, the overarching theme behind performing borrow area wave modeling is determining if historical wave energy patterns are adversely altered by bathymetry changes from hydraulic dredging. ULL developed a proposal to perform an analysis of these potential impacts associated with the borrow area to the surrounding marsh system in terms of water velocity (i.e., potential effects to the average speed of surface water surface currents) and wave energy (i.e., potential effects to significant wave height) at the TE-0117 site. The Danish Hydraulic Institute MIKE21 (hereinafter referred to as MIKE21) and the Delft University Simulating WAves Nearshore (SWAN) numerical modeling platforms were implemented to generate both preconstruction current and wave energy profiles, as well as postconstruction "after-dredge" current and wave energy profiles, and the difference between both simulations.

Using theoretical physics principles of conservation of energy, differential equations for depth-averaged conservation of continuity and momentum, and other equations such as hydrodynamic advection/reaction energy balance equations, a two-part numerical assessment was performed to assess potential impacts to wave and current hydrodynamics. See **APPENDIX L** for a more detailed account of model setup activities executed on behalf of the TE-0117 project.

7.2.2 Model Calibration and Validation

Topographic/bathymetric data, water level data, meteorological data, wave data were gathered from public information sources. CHF provided TE-0117 survey data and the proposed maximum borrow area dredge templates of interest in the form of plan and profile survey drawings and associated survey data.

Using historical water level data obtained from NOAA and CRMS databases, offshore water wave data obtained from the Coastal Studies Institute, and wind rose data obtained from a station in Grand Isle, LA, boundary conditions were input into SWAN and MIKE21, and modeled conditions versus observed conditions were compared. **APPENDIX L** contains a more in-depth synopsis of model calibration/validation.

7.2.3 Model Results and Documentation

According to the ULL modeling report, 84 computational modeling simulations were executed. The model results suggest that the average wave height increases did not exceed 0.06 ft and the average tidal velocities did not exceed 0.08 ft/s. Based on the interpretation of the model results, simulated impacts to future “after-dredge” borrow area wave and average surface water velocity conditions were of near negligible magnitudes. See **APPENDIX L** for more information.

7.3 Summary of Key Findings

As stated in the preceding sections of this report, **APPENDIX F** contains the entirety of the CHF borrow area development services deliverables. The ULL TE-0117 Borrow Region Wave and Velocity Impact Analysis Modeling Report has been included separately as **APPENDIX L**.

8.0 DESIGN

8.1 General Scope

The TE-0117 project proposal is to create marsh in four (4) separate marsh creation areas shown in the figure below by hydraulically dredging sediment from an open water borrow area in Lake Tambour. The 30% Design Drawings are available in **APPENDIX M**. The TE-0117 project design is broken up into the following subsections: marsh creation area design, earthen containment dike design, alternate gap closure system design, borrow area design, and equipment access/dredge pipe corridor design. See **Figure 39**.

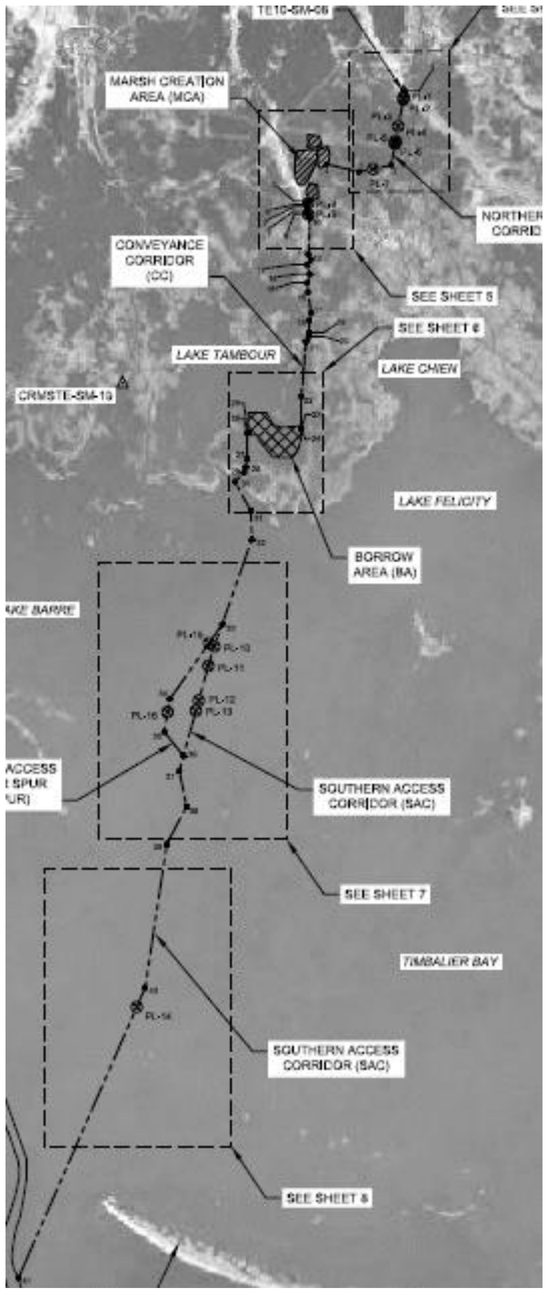


Figure 39: TE-0117 Project Layout

8.2 Engineering and Design Methodology

8.2.1 Design Goals and Objectives

The overarching CWPPRA Phase I objective of the TE-0117 project is to explore restoration options consistent with the project goals discussed in **Section 1.4** and as outlined in the CWPPRA PPL 23 Project Fact Sheet (**APPENDIX A**).

In order to produce a marsh creation project design solution capable of meeting the goals listed in **Section 1.4**, the specific engineering and design objectives, as stated throughout the Calculations Packet in **APPENDIX D**, are as follows:

- Compute the design tidal datum;
- Establish a preferred range of percent inundation elevations, analyze reference marsh survey elevations, and identify target settled marsh fill elevations for TY20;
- Determine required target pump elevation for marsh creation design via the generation of geotechnical settlement curves;
- Generate an optimized cross-sectional design for ECDs and one (1) sheetpile-sand berm gap closure;
- Produce a general civil layout for marsh creation and nourishment area/ECD geometric design, calculate the total proposed creation acreage, and calculate the total required in-place fill volume quantity;
- Produce a general civil layout for equipment access and dredge pipe corridor geometric design, and calculate the total estimated access dredging quantity required; and
- Produce a general civil layout for borrow area geometric design, calculate the total available borrow area acreage, and calculate the total available borrow volume quantity.

8.2.2 Design Constraints and Limitations

As discussed in **Section 3.3**, the TE-0117 project team recognized that producing a viable marsh creation project design in southeast Terrebonne Parish would be constrained by site conditions based primarily on geotechnical conditions and water depths. To address these constraints, the design team adopted a step-wise design approach to develop a constructible design solution in the vicinity of Island Road, Cutoff Canal, Twin Pipelines, and the community of Isle de Jean Charles.

The highly compressible and underconsolidated upper Holocene soil deposits and weak in situ soils at the marsh creation area present challenging soil conditions. The prevailing soil profile is characterized by soft, compressible peats underlain by highly organic, high plasticity clays at the restoration area and vicinity. While borrow area soil characteristics also present challenges, Lake Tambour soils are not expected to adversely affect project performance to a significant degree. Throughout a step-wise design solution process, ECD construction, ECD settlement, marsh fill settlement, and alternate gap closure system construction are anticipated to achieve adequate factors of safety. However, this is only possible under specific construction scenarios having high degrees of risk and uncertainty.

In addition to challenging soil conditions, water depths across the site are also identified as a design constraint. As depicted in the color spectrum map in **Figure 6**, the general trend is that most of the TE-0117 marsh creation and nourishment areas contain roughly 40 - 50% of the total collected survey data existing at mudline elevations between -2 FT NAVD88 and -3 FT NAVD88, with approximately 5% or more at or below the -3 FT NAVD88 elevation contour as well (see also **Figure 41** through **Figure 44**). Based on target pump elevations determined through geotechnical settlement analyses, design and construction of stable containment dikes in deep areas is a significant challenge. There is a strong influence of mudline elevation on feature layout, with no more than 1,000 LF (less than 4% of the total 27,000 LF) of containment dike reach currently proposed at or below the -3 FT NAVD88 contour, this being a minimal amount to optimize total creation acreage as well. In an inverse way, shallow water depths result in a total access dredging quantity currently proposed for approximately 68,000 LF (12.92 MI).

8.2.3 Design Limitations and Assumptions

The major design limitations are as follows:

- Containment dike stability is only achievable under specific site conditions and thus affects marsh creation area design directly; borrow area sizing is also indirectly affected.
- Containment dike design will need to be further refined past the 30% milestone, and as such further project feature revisions will need to take place.
- Target pump selection for marsh fill design is based on borrow area geotechnical characteristics as well as in situ soil settlement characteristics in the marsh creation area, and in some cases is not able to provide emergent land for the entire 20 year period of analysis depending upon success criteria metrics and location across the project site.
- Borrow area soil characteristics are highly plastic and may result in dewatering and settlement challenges in a hydraulic dredging and disposal construction scenario.
- Equipment access for deep drafting vessels may require extensive (up to 10 MI) of access dredging to fully deploy in the borrow area and potential booster pump locations.

For a more in-depth account of governing assumptions and calculation methodology, **APPENDIX D** contains the accompanying 30% Design Calculations Packet with dedicated sections discussing problem identification, assumption declaration, methodology discussion, and solution presentation for the following design elements.

- Tidal Datum Determination (see page D-8 of the calculations packet)
- Percent Inundation Selection and Reference Marsh Elevation Comparison (see page D-14 of the calculations packet)
- Settlement and Target Pump Elevation Determination (see page D-18 of the calculations packet)

- Earthen Containment Dike and Alternate Closure System Design Calculations (see page D-24 of the calculations packet)
- Marsh Creation and Nourishment Area Design Calculations (see page D-32 of the calculations packet)
- Access and Conveyance Corridor Design Calculations (see page D-35 of the calculations packet)
- Borrow Area Design Calculations (see page D-40 of the calculations packet appendix)

The sections that follow summarize the design process for each feature. See **APPENDIX M** for more in-depth information on the engineering and design methodology utilized.

8.3 Marsh Creation Area Design

The configuration of the marsh creation areas went through four (4) alternative layouts during Phase I before arriving at the current configuration shown in the 30% Design Drawings (**APPENDIX M**, **Figure 9**).

The next step in the marsh creation area design involved determining an appropriate CMFE. CMFE is governed by several factors including the tidal range, percent inundation, healthy marsh elevation, physical properties of borrow material, and bearing capacity of foundation soils within the marsh creation area. Determination of CMFE was based on consideration of the average marsh elevation over the life of the project. Maximizing the time period that the marsh platform has an elevation within the saline marsh inundation range (20%-80% inundated). The range of MLW to MHW also helps inform the range of intertidal marsh function, as does the reference marsh elevation surveys taken during data collection. Over the 20-year project life, including sea level rise and subsidence conditions stated in **Section 4.2**, the preferred percent inundation range is expected to rise from -0.11 FT NAVD88 and +0.89 FT NAVD88 (80% inundation at TY0 and 20% inundation at TY20, respectively) to +0.36 FT NAVD88 and +1.36 FT NAVD88 (80% inundation at TY20 and 20% inundation at TY20, respectively). The average MLW is expected to rise from -0.36 FT NAVD88 to +0.20 FT NAVD88 (TY0 and TY20, respectively), while the average MHW is expected to rise from +0.20 FT NAVD88 to +1.36 FT NAVD88 (TY0 and TY20, respectively). The MLW suggests that elevations lower than those yielded from the 20% inundation can provide substantive intertidal function. Alternatively, the MHW suggests that elevations higher than the 80% inundation can similarly provide function.

Settlement analyses are performed to determine the construction marsh fill elevation of the marsh creation areas and the total volume of fill material required for construction. The final year 20 elevation of the marsh creation area is governed by two forms of settlement: (1) the settlement of 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. **Figure 40** contains a schematic of the marsh fill settlement process.

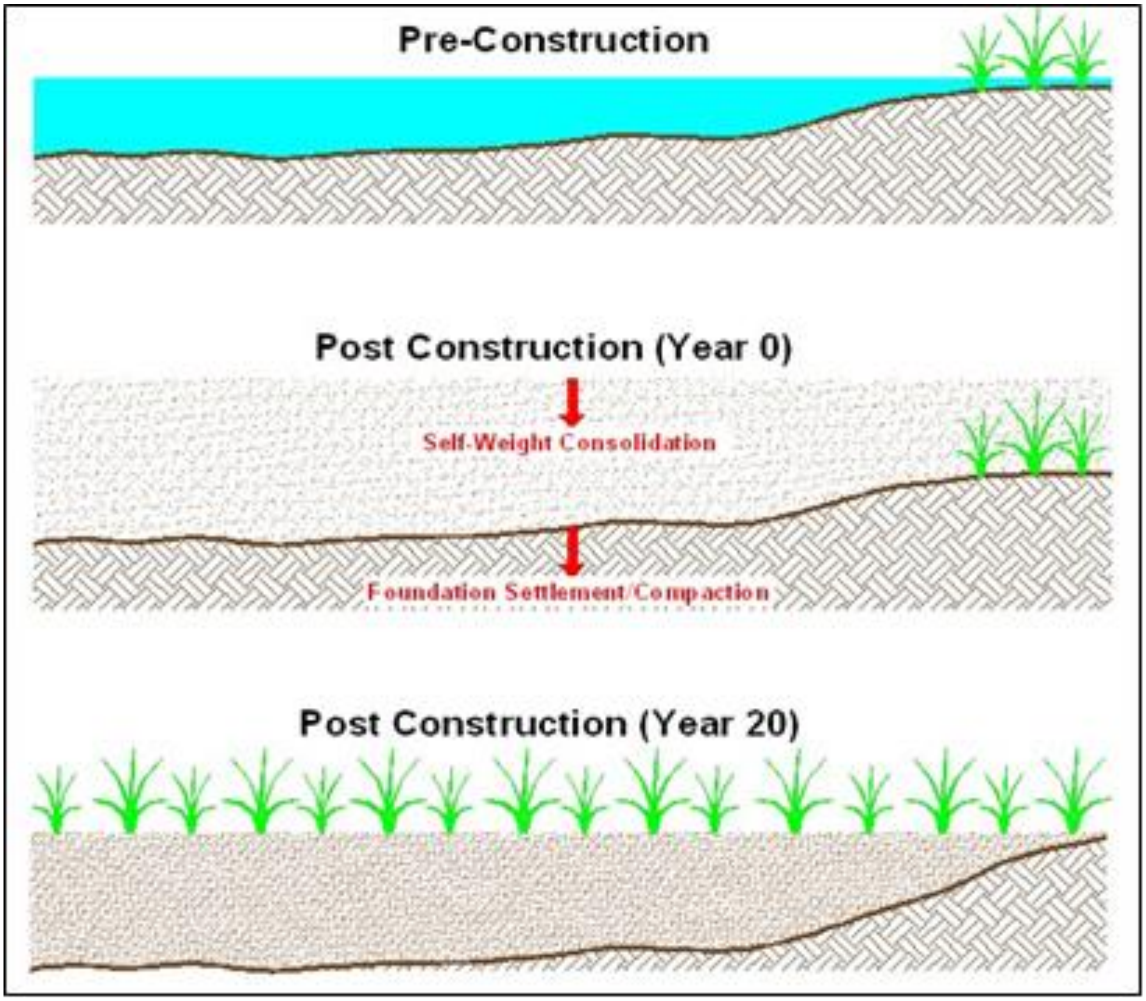


Figure 40: Marsh Fill Settlement Schematic

To achieve the project goals, the dredge slurry will need to initially be placed to a constructed fill elevation above the intertidal saline marsh range and settle into the range over the design life. To satisfy these conditions, the marsh creation are will be pumped to an elevation of +3.0 FT NAVD88, allowed to settle during the construction phase (settlement curve predictions state that the first lift settled elevations will become lowered to +1.5 FT NAVD88 within the preferred wait period of 60 days), and the repumped to +3.0 FT NAVD88 for the second lift.

The currently proposed marsh creation area layout calls for a total of four (4) separate cells. Having separate marsh creation area polygons requires analyzing the predicted settlement for each marsh creation area based on the collected samples and mudline elevations pertaining to each marsh creation area. The existing mudline elevation used for marsh fill settlement analysis can greatly affect the required construction elevation to achieve end of project 20-year elevations. The goal is to find an elevation that is representative of the entire marsh creation are while also accounting for deeper areas. Determining the existing mudline elevation to analyze for each marsh creation area involved looking at the survey points that fell within each marsh creation area. See **Figure 41** through **Figure 44**.

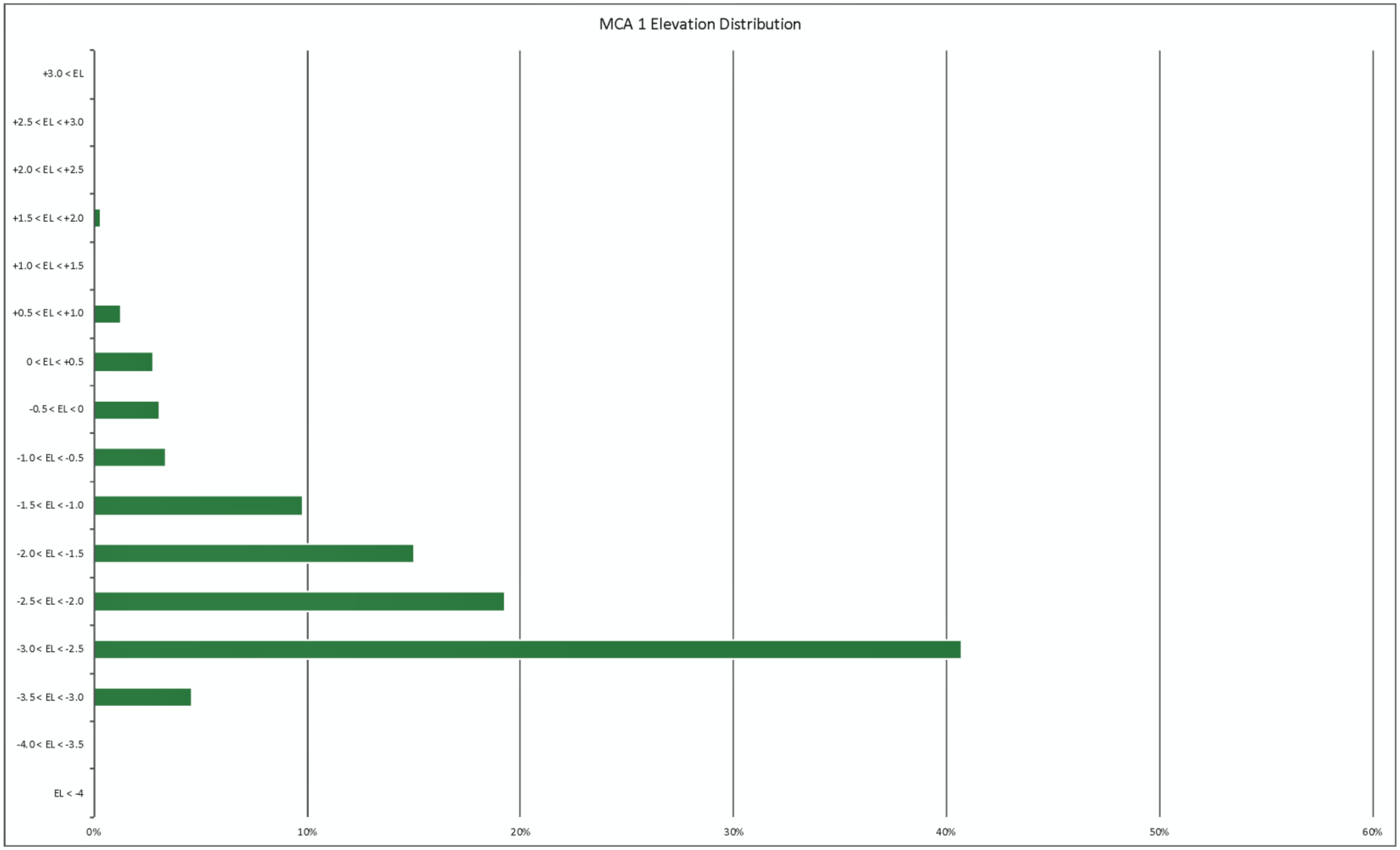


Figure 41: MCA1 Histogram of Existing Mudline Elevations

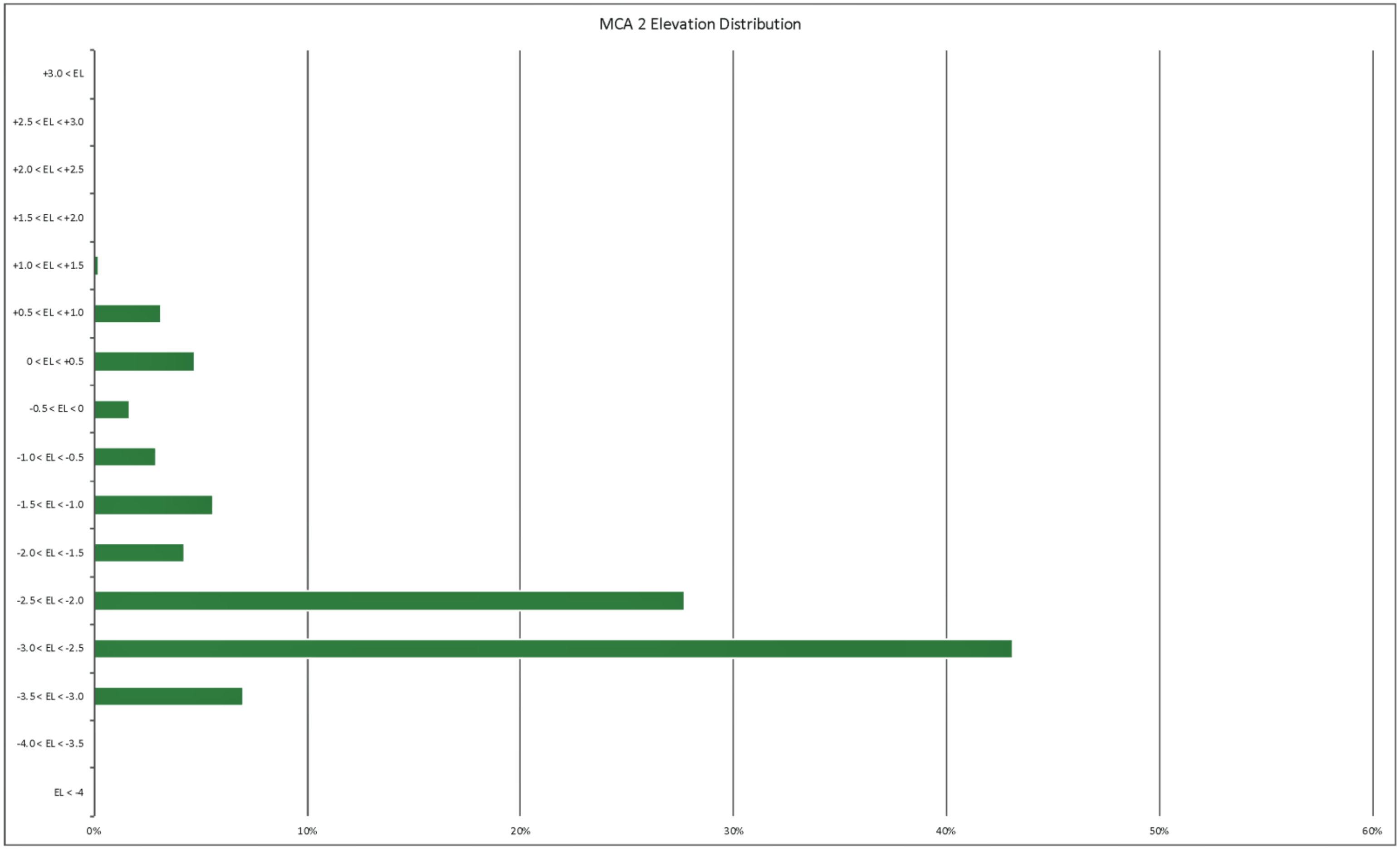


Figure 42: MCA2 Histogram of Existing Mudline Elevations

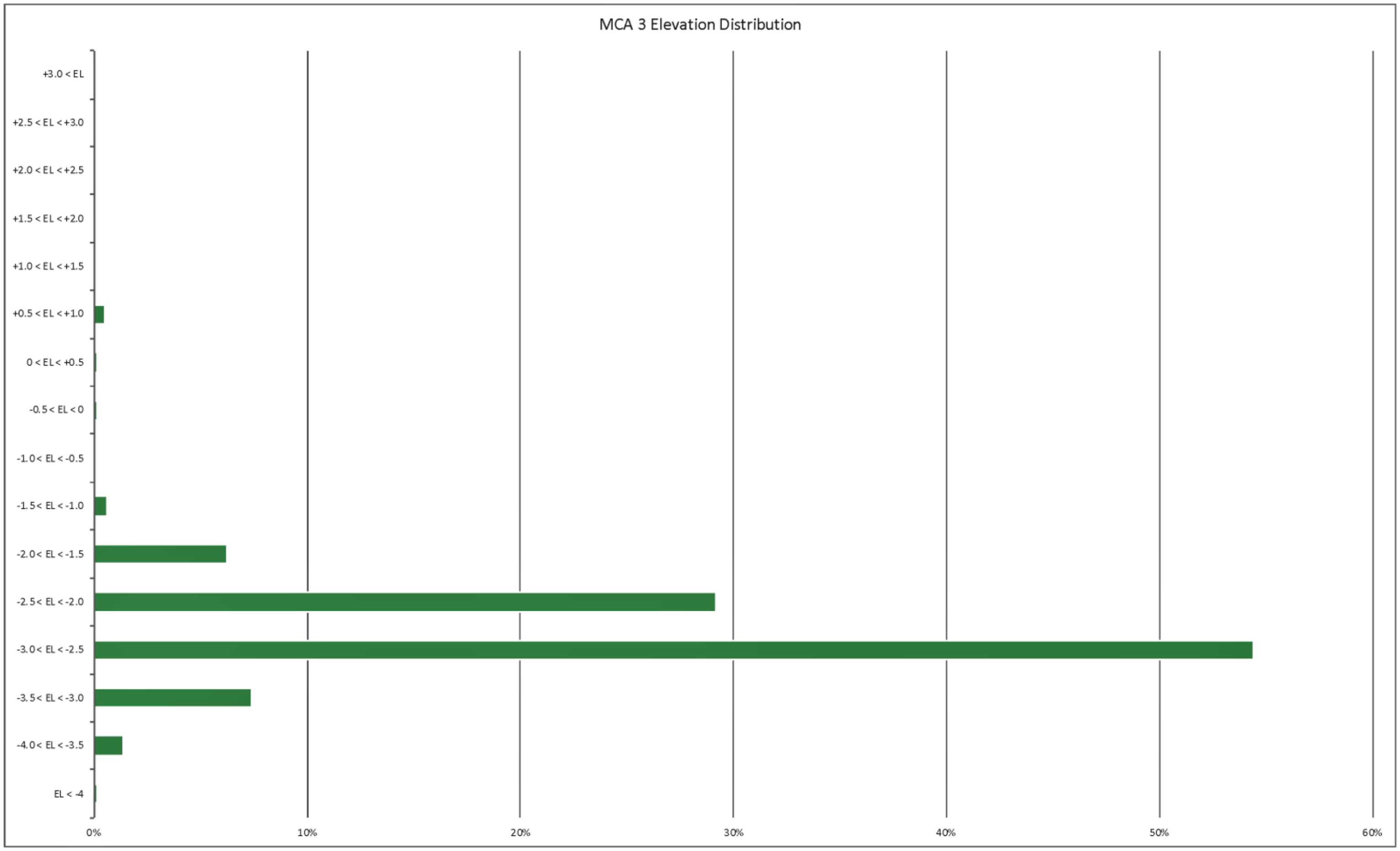


Figure 43: MCA3 Histogram of Existing Mudline Elevations

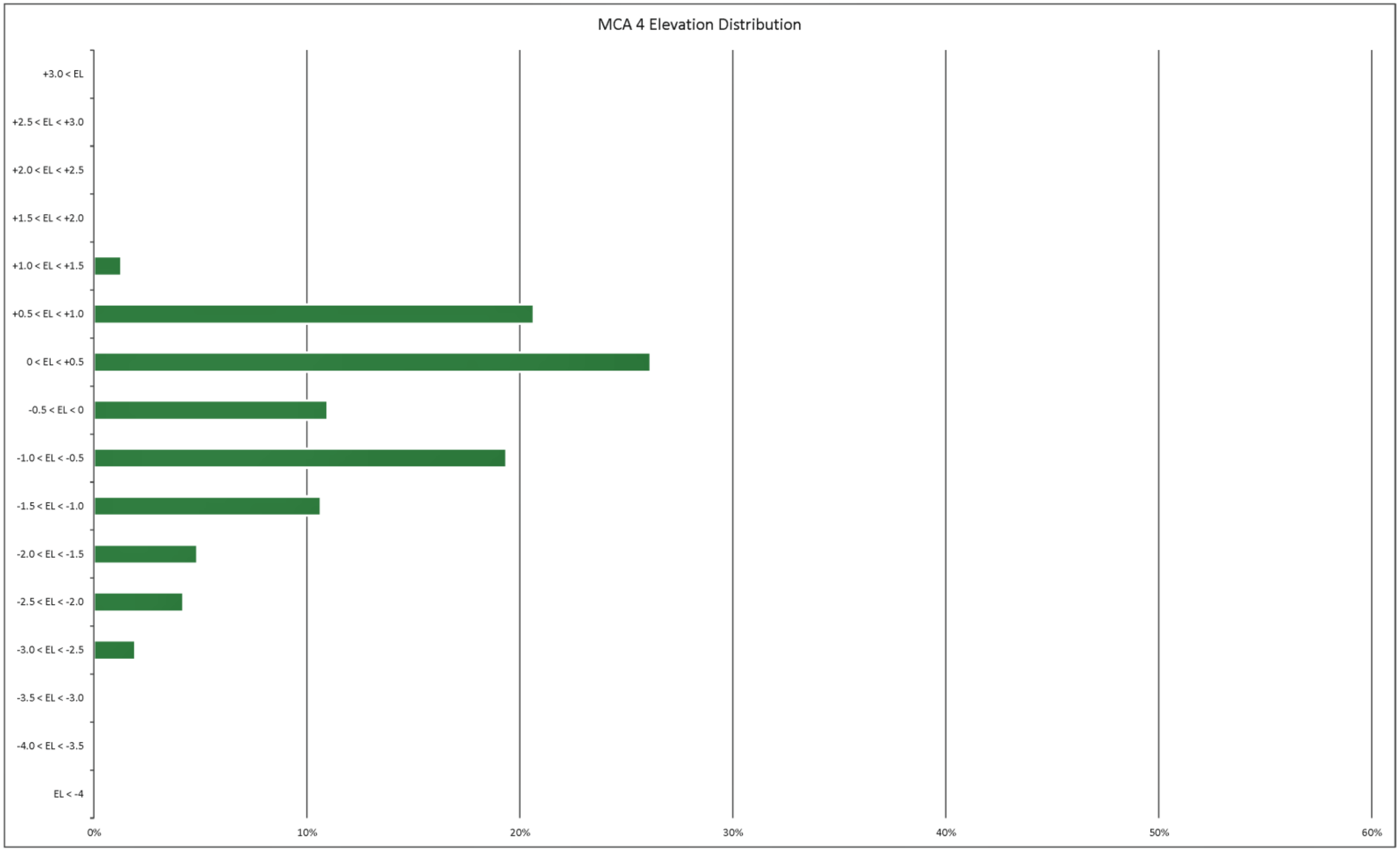


Figure 44: MCA4 Histogram of Existing Mudline Elevations

As observed from the above-shown figures, the majority (MCA1, MCA2, and MCA3 all containing at least 40% of the total amount of data) of the existing mudline elevations are between the -2.5 FT NAVD88 and -3.0 FT NAVD88 elevation contours. As an exception to this trend, the mudline elevations in MCA4 is contain approximately 25% of the total amount of data points between the 0 FT NAVD88 and -0.5 FT NAVD88 elevation contours.

Though the final constructed fill elevation of the marsh fill area will be +3.0 FT NAVD88, volume calculations were determined near the final settled CMFE to allow for primary consolidation settlement of the fill to occur. This process accounts for the decrease in voids, primarily water, as the material dewaters and begins to consolidate. As shown in the settlement curve for the +3.0 FT NAVD88 pump elevation in **Figure 30**, **Figure 31**, and **Figure 32**, 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 porewater. Near the completion of primary consolidation settlement, the material has dewatered giving a more accurate estimate of the actual contract volume of dredged material needed to achieve the target marsh elevation.

After determining the CMFE, the total volume of the marsh creation area was calculated using AutoCAD Civil software. Since the interior containment borrow must be also be refilled, a worst-case ECD borrow pit geometric design was similarly imported into AutoCAD in that was sized utilizing an ECD cut-to-fill ratio of 1.5:1. A volume computation was then performed, with the sum of the dike backfill volume and the highest observed TY20 CMFE (corresponding to a +1.0 FT NAVD88 settled material elevation) with foundation settlement factored in being taken as the total in-place volume. The sum of these three volumes are shown in **Table 11**.

Table 11: Marsh Creation Area Design Quantities

MCA ID	In-Place Volume [CY]	Acreage [AC]
MCA1	240,528	39.3
MCA2	782,450	155.7
MCA3	297,657	43.6
MCA4	218,132	52.8
Total	**1,538,767**	**291.3**

8.4 Earthen Containment Dike Design

The primary design parameters associated with the ECD design include crown elevation, crown width, and side slopes. A minimum of one (1) 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. The proposed ECDs for the TE-

0117 project will include crest elevations of +4.0 FT. The crown width will be 5 FT, with side slopes of 1V:4H (4 feet horizontal for every foot of vertical rise). Note that the previously discussed Design Profile 1 was incorporated for the entire ECD design, which calls for a 30 ft stability berm width. As proposed, the entirety of the approximately 27,000 LF of containment dike construction is to be built with interior in situ borrow. **Table 12** contains applicable ECD design values of note. **Figure 45** contains a depiction of an ECD construction typical section.

Table 12: Earthen Containment Dike Design Quantities

Marsh Creation Area ID	ECD Length Along CL [LF]	ECD In-Place Volume[1] [CY/LF]	ECD Borrow Pit Availability[1] [CY/LF]	FS_{MIN}[2]
MCA1	5,382	9.17	14.00	1.52
MCA2	10,540	9.17	14.00	1.52
MCA3	5,471	9.17	14.00	1.52
MCA4	6,055	9.17	14.00	1.52
Total	**27,448**	**N/A**	**N/A**	**N/A**

1. Per LF quantity assumed for worst case multiple lift ECD construction.
2. "FS_{MIN}" stands for minimum factor of safety, and in this instance is indicative of slope failure. See **APPENDIX K**.

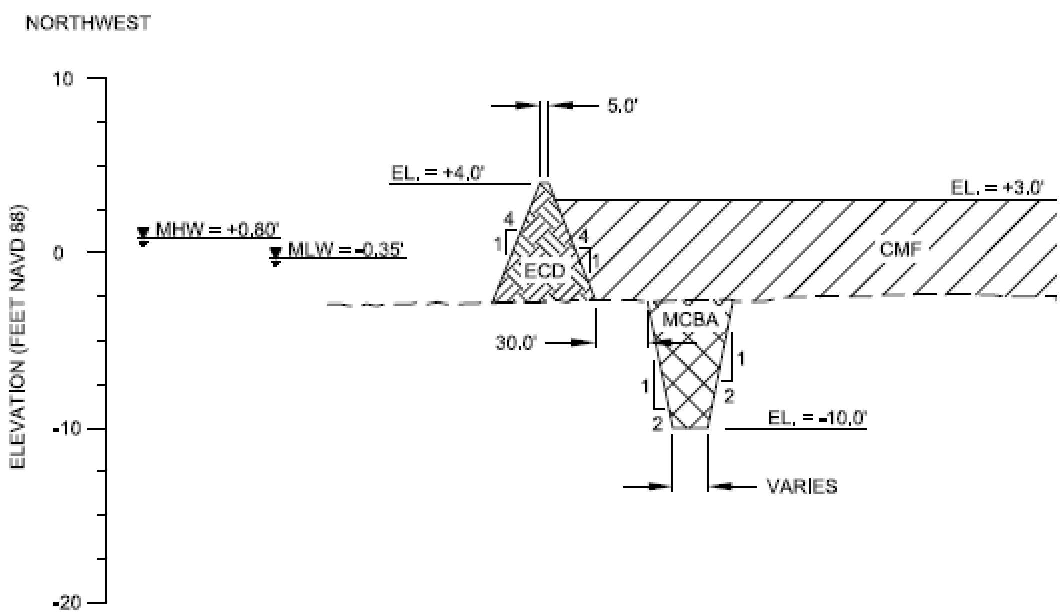


Figure 45: ECD Design

As discussed in **Section 6.5.6**, 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 are shown in **APPENDIX K**. The results show that a minimum of one (1) foot of freeboard will be present at all times during construction and throughout the anticipated construction phase. As shown, no additional construction tolerance has been analyzed for slope stability.

8.5 Alternate Gap Closure System Design

As discussed in **Section 6.5.7**, an approximately 100 FT-long portion of marsh creation area perimeter spans a deep pit-like feature. In this location, a sheetpile-embedment sand closure system is proposed. GEO performed a detailed geotechnical design exercise to produce the below-shown cross-sectional design in **Figure 46**. For more detailed information, see **APPENDIX K**. Note post-30% design, the TE-0117 team anticipates a containment dike/marsh fill cell reconfiguration such that alternate gap closure is expected to be eliminated.

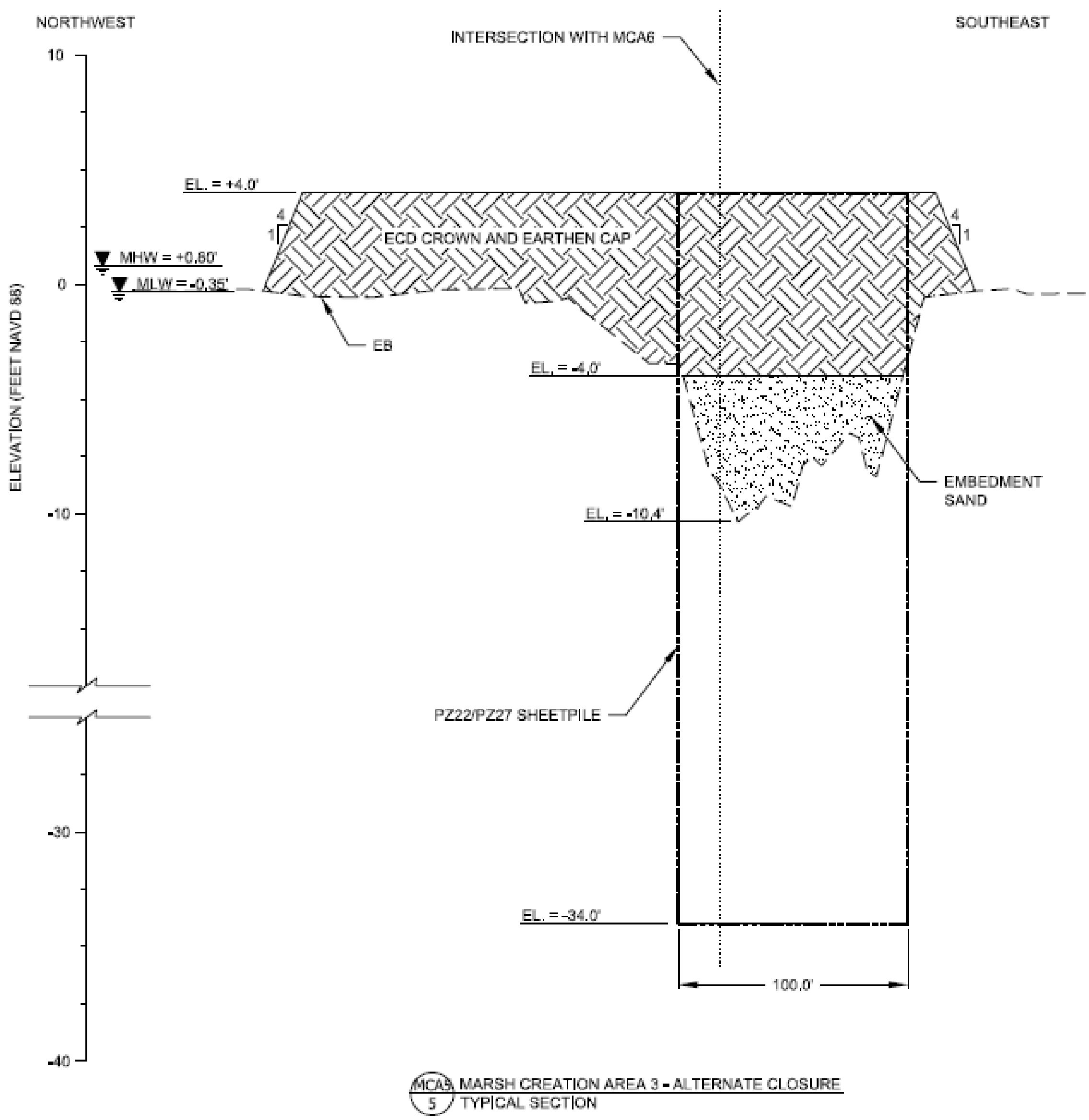


Figure 46: Alternate Gap Closure System Design

8.6 Borrow Area Design

As shown in **Table 11**, the total required borrow volume needed to create the as-proposed marsh creation is approximately 1.85M CY. This value was obtained by multiplying the total in-place marsh creation area volume (approximately 1.54M CY) by the design C:F ratio. As discussed in **Section 6.6**, a cut-to-fill ratio of 1.2:1 is being utilized for design and for use in sizing an appropriate borrow area. Using the borrow area delineation produced by CHF, along with an as-proposed -12 FT NAVD88 bottom of cut contour and 1V:2H side slopes, the following values apply as shown in **Table 13**. **Figure 47** and **Figure 48** contain plan and profile drawings for the borrow area.

Table 13: Borrow Area Design Quantities

Volumetric Feature	Volume [CY]
Total Volume Demand (C:F = 1.2:1)	1,846,521
-10’ NAVD88 Total Borrow Availability (394 AC)	3,307,155
-12’ NAVD88 Total Borrow Availability (394 AC)	4,561,581
-15’ NAVD88 Total Borrow Availability (394 AC)	6,911,180

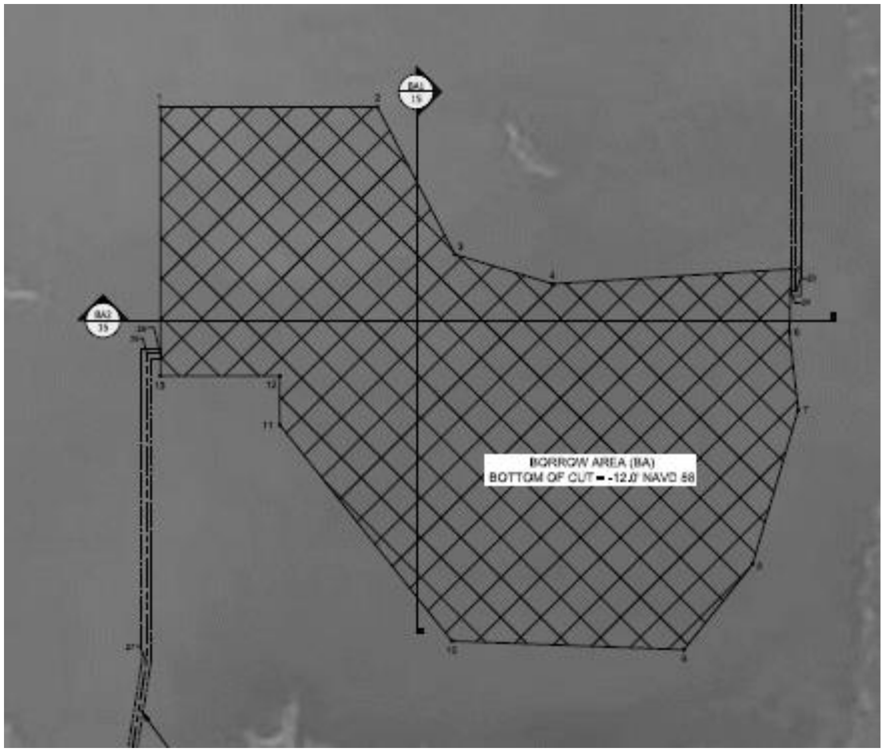


Figure 47: Borrow Area Design, Plan View

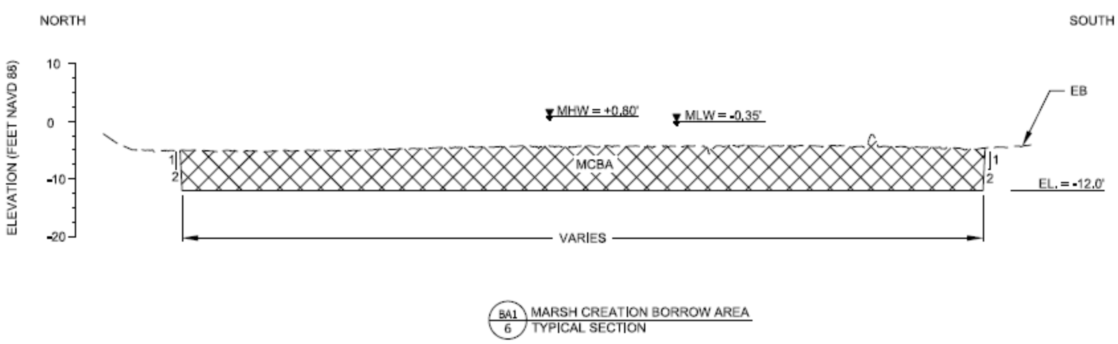


Figure 48: Borrow Area Design, Profile View

8.7 Equipment Access and Dredge Pipe Corridor Design

Figure 39 in **Section 8.1** depicts the TE-0117 project layout, with equipment access corridors and dredge pipe corridors shown. The total length of combined access and dredge pipe corridor, as measured along the as-proposed corridor centerlines, is approximately 132,000 LF (approximately 25 miles). The width of access and dredge pipe corridors is 80 FT, measured along the bottom of cut elevation contour (-5 FT NAVD88 or -8 FT NAVD88, depending on location, as discussed below), or otherwise along the mudline, is 80 FT. The 80 FT dimension is depicted in this design in preparation of construction permit drawings. However, it is likely that this value will be reduced with further refinement of the access corridor design, such that strategic locations will maintain the 80 FT bottom width, while the majority of the access dredging will be reduced for cost savings. The following terminology has been developed for the TE-0117 project equipment access and dredge pipe corridor design, as described in **Table 14**.

Table 14: Equipment Access and Dredge Pipe Corridor Information

Corridor	Details
Northern Access Corridor (NAC)	• Intended for use as shallow drafting vessel access corridor • Access from marsh creation areas to PAC Marina and parking lot for crew/project team member usage during construction • Envisioned for routine delivery of construction supplies (i.e., gasoline deliveries via fuel trucks, septic services to collect and dispose of trash and human waste, etc.) • Pipeline crossings allow for at least 2 ft of cover to top of identified pipelines
Conveyance Corridor (CC)	• Intended for dual use as shallow drafting vessel access corridor and dredge pipe corridor • Envisioned for booster pumps to be placed and operated in the southern region • Envisioned for use as crew transport corridor from northern extents of project site to borrow area/hydraulic dredge/southern access points • Pipeline crossings allow for at least 2 ft of cover to top of identified pipelines
Southern Access Corridor (SAC)	• Intended for use as deep drafting vessel access corridor • No anticipated need for access dredging (mudline elevations approaching -10 FT NAVD88) • Access from borrow area to HNC and navigable waters in Terrebonne Bay/Gulf of Mexico • Pipeline crossings allow for at least 2 ft of cover to top of identified pipelines
Southern Access Corridor Spur (SAC SPUR)	• Intended for use as deep drafting vessel access corridor • Pipeline crossings allow for at least 4 ft of cover to top of identified pipelines • Note: pipeline crossings at SAC have higher top of pipe elevations than SAC SPUR

The as-proposed NAC calls for a total 15,545 LF of access corridor. This corridor is intended for land-based access to the project site via Pointe-aux-Chênes Marina as well as smaller marine vessels to access the eastern extents of the marsh creation area via navigable waterways located to the east. A bottom of cut elevation of -5 FT NAVD88 is proposed for all access dredging required in the NAC. Also as shown, the proposed CC calls for a total 21,286 LF of centerline access corridor required. The entirety of the CC is proposed for access dredging, with the southern region calling for a bottom of cut elevation of -8 FT NAVD88 and the northern region having a bottom of cut elevation of -5 FT NAVD88. This is done in order to allow enough floatation for the placement of heavy equipment such as booster pump vessels and associated plant to the necessary location in the CC. There are also two pipeline crossings (shown as crossing IDs 8 and 9 in **Table 8**) which are not expected to be impacted due to TE-0117 construction operations. Also as shown, the as-proposed SAC calls for a total of 79,110 LF of access. Of this total, the northernmost 18,900 LF call for access dredging with a bottom of cut elevation of -8 FT NAVD88. All corridors are proposed with 80 FT of maximum bottom of cut width and side slopes of 1V:2H. The total linear footage and corresponding worst case (using maximum mudline elevations uniformly across corridor, further explained in **APPENDIX D**) cubic yardage of anticipated access dredging required for all corridors are shown in **Table 15**.

Table 15: NAC, CC, SAC, and SAC SPUR Design Quantities

Corridor ID	Total Required Navigable Corridor Distance [LF (MI)]	Total Required Access Dredging Corridor Distance [LF] (MI)	Total Required Access Dredging Volume [CY]
NAC	15,545 (2.94)	6,900 (1.31)	168,156
CC (-5' CUT)	21,286 (4.03)	7,901 (1.50)	23,996
CC (-8' CUT)		18,000 (3.41)	234,667
SAC	79,110 (14.98)	18,900 (3.58)	117,600
SAC SPUR	16,508 (3.13)	16,500 (3.12)	102,667
Total	**132,449 (25.09)**	**68,201 (12.92)**	**647,086**

8.8 Temporary Erosion Control Measures Considerations

In an effort to maintain consistency with other projects of similar scope and scale, and in order to deliver constructible solutions for marsh creation design, the TE-0117 design team has discussed the potential utility of temporary erosion control measures on ECDs during construction. While the TE-0117 project site is not understood to be a highly erosive environment due to wave and fetch-generated wave energies, the design team wishes to address risk of this possibility by requiring that the future construction contractor be required to maintain cross-sectional dike dimensions during all times of active marsh creation during construction. Following the 30% milestone, the TE-0117 design team has discussed formulating a plan to reduce owner-assumed risk of ECD construction and operation moving forward to construction bid document assembly.

8.9 Future Engineering and Design

With regard to post 30% engineering and design for the TE-0117 project, the following is recommended for consideration.

- The requirement to specify interior or exterior preferred containment dike borrow pit usage is critical for E&D completion. Additional geotechnical engineering and design will be required to verify slope stability of exterior and/or interior borrow for containment dike construction.

- Access dredging design is in need of refinement.
- The possibility of requiring containment dike construction to be completed in a certain, predetermined sequence, in order to allow geotechnical strength gains according to the containment dike reaches most critically in need and in a logically-prescribed manner is encouraged.
- The possibility of abandoning the alternate gap closure system, being informed by design optimization supported with cost-benefit analysis to be conducted in further E&D, is recommended.
- The use of geotextile foundation material has previously been recommended for consideration by GEO and it has been previously conveyed to CPRA that certain areas in the proposed ECD reaches may require additional stability with reinforcement fabric or matting.
- Consideration should be taken to refine the geometric layout of fill cell geometries so as to optimize creation acreage while minimizing geotechnical stability concerns with ECD construction.
- Caution has been exercised to minimize impacts to the hydrologic conditions in and around the open channel feature known as Canal St. Jean Charles. This canal receives outflow from the TPCG 4-3C EAST project's pumping system. A review of TBS survey data does not indicate any presence of any trapezoidal open channel in this area. However, future E&D activities should continue to be cautious in regard to any alteration to site hydrology, especially in this immediate vicinity.
- There is a possibility that unidentified O&G, utility, or otherwise subsurface infrastructures could exist in areas currently shown for proposed earthwork via mechanical dredging in and around ECD and alternate gap closure system borrow channels. The project team should be cognizant of this possibility if using deep-penetrating sheetpile closures elsewhere.

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 suction head dredge and incorporating weather days, a total construction time from mobilization to demobilization is approximately 490 days. Note that mobilization, demobilization, and mechanical dredging was also incorporated into this estimate of construction duration.

9.2 Cost Estimate

An Estimate of Probable Construction Cost Plus Contingency was prepared for this project using a modified version of the CWPPRA PPL 23 spreadsheet and historic project bid data. The estimated construction cost is available as a government cost estimate retained by NOAA-NMFS.

10.0 MODIFICATIONS FROM PHASE 0 APPROVAL

As a result of Phase I activities, the features originally approved in Phase 0 have been relocated to the south of Twin Pipelines to present a more constructible project for consideration of Phase II funding. Specific modifications include the relocation of marsh creation and nourishment areas, relocation of borrow area, relocation of conveyance corridors, and increases in previously estimated access dredging. The approximately 100 acre reduction in project footprint from the approved Phase 0 footprint is outside of the 25% CWPPRA Standard Operating Procedures (SOP). As per the CWPPRA SOP, a scope change request will be necessary due to the reduced marsh creation acreage. If the project sponsors concur to proceed to the 95% design level, a change in scope request will be made as early as the December Technical Committee meeting of propose to inactivate the project.

11.0 REFERENCES

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