TE-0117 Island Road Marsh Creation and Nourishment Project

Coastal Wetland Planning, Protection, and Restoration Act PPL 23

95% Design Report

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ABBREVIATIONS

ASTM	American Society of Testing and Materials
BOC	Bottom of Cut
CC	Conveyance Corridor
CDS	Center for Dredging Studies
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
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPMS	National Pipeline Mapping System
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.

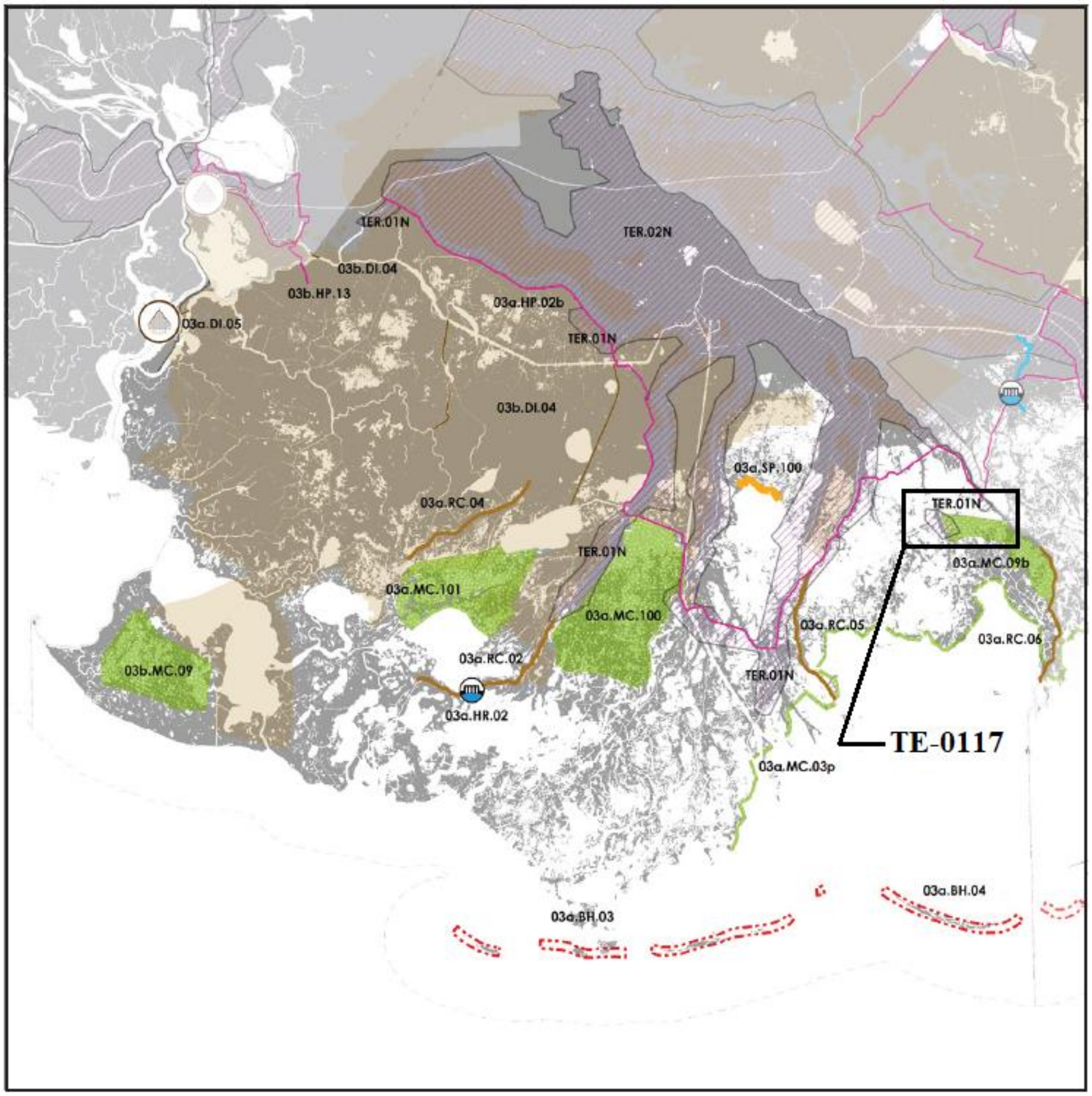


Figure 1: 2017 Master Plan Projects in Terrebonne Parish

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.

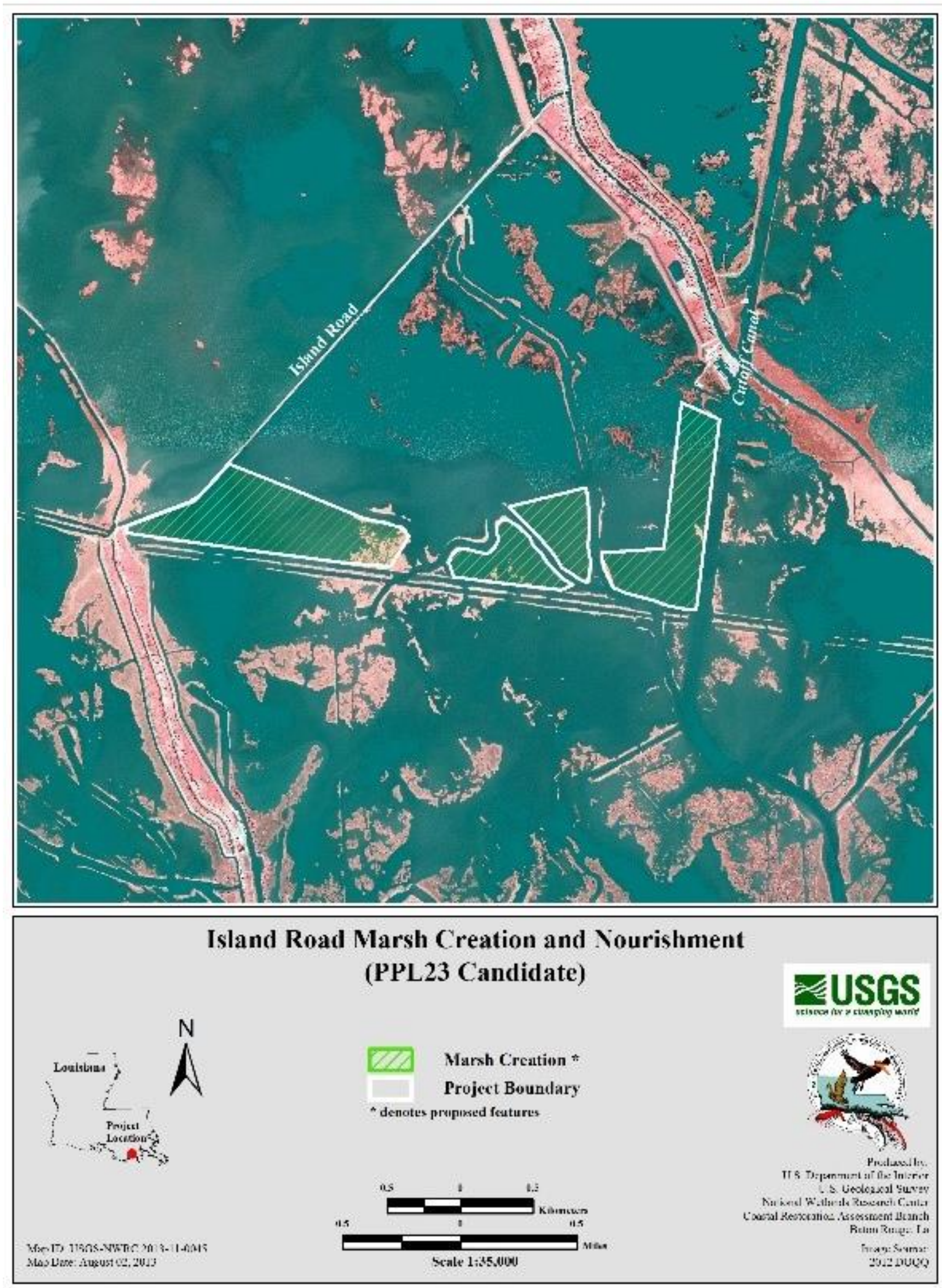


Figure 2: TE-0117 Phase 0 Authorized Project Map

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.

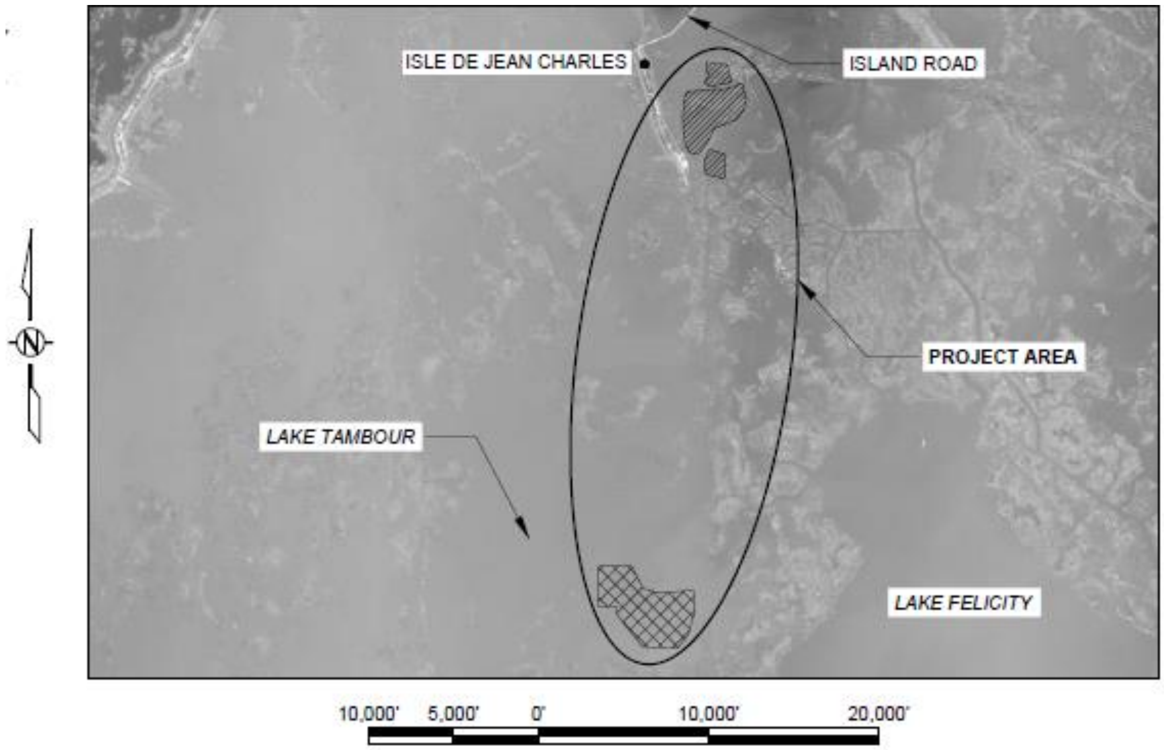


Figure 3: TE-0117 Site Vicinity

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, along with a map showing the updated 95% Design polygons.

<u>General Phase 0 and Phase 1 Goals</u>

- 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 land building from hydraulic dredging and disposal

Between Phase 0 and 30% design, 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.

Between 30% design and 95% design, modifications were made resulting in three (3) total marsh creation cells totaling 295 acres located in the same vicinity as 30%. The reduction in total number of marsh creation cells was due to the combination of the previously identified MCA2 and MCA4 into one (1) cell, renamed MCA2 for 95% design. A modification to MCA3 also occurred, where the southernmost portion was eliminated to exclude a significantly deep portion also calling for a sheetpile closure along the containment dike alignment.

The steps taken during the early stages of design and during a screening process and alternatives analyses are captured in **Section 3.0**. Design methodology is discussed in **Section 8.0**. Discussion on anticipated construction duration, cost, and other related information is available in **Section 9.0**. Modifications between Phase 0 approval and 30% design are discussed in **Section 10.0**, and modifications between 30% design and 95% design are discussed in **Section 11.0**.

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 water bottoms 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, Dennis Cenac, III et al., and the State of Louisiana. **Figure 4** contains a land ownership map of the entire project area.

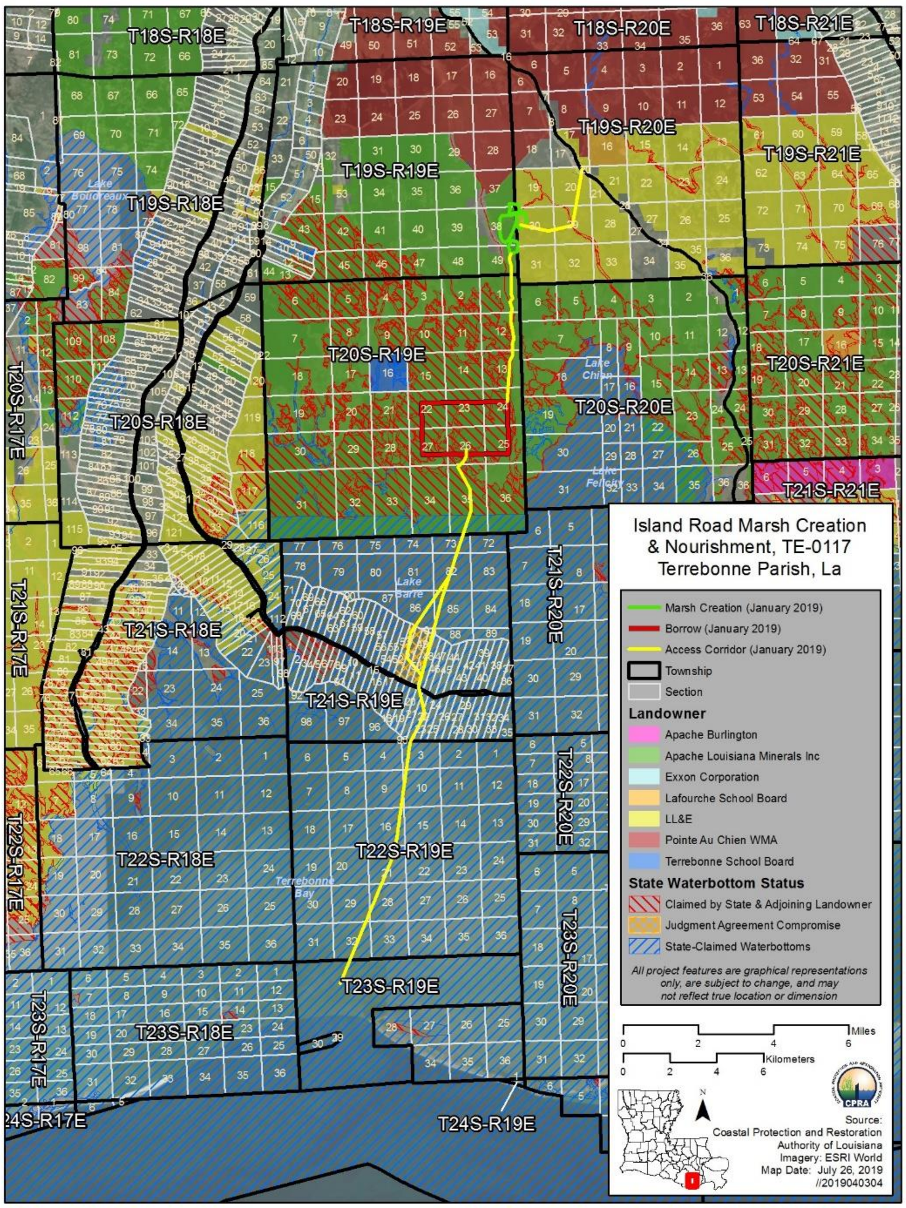


Figure 4: Land Ownership Map

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 (SONRIS) database, the National Pipeline Mapping System (NPMS) database, and other Geographic Information Systems (GIS) databases 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**.

Leading up to 95% design, a total of 35 oyster leases were identified that fall within the project footprint. Between 95% and Phase II, it is expected that approximately 900 acres will need to be assessed. These numbers are approximate and will be finalized as the design phase progresses past 95%.

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. NOAA-NMFS submitted a letter to SHPO on October 29, 2019, to cover the 30% designed features including project-specific cultural resource surveys. Final coordination with SHPO is pending.

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, respectively.

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. 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 completed
2020	• 95% 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 was a 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 potential project area to the Phase 0 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**.

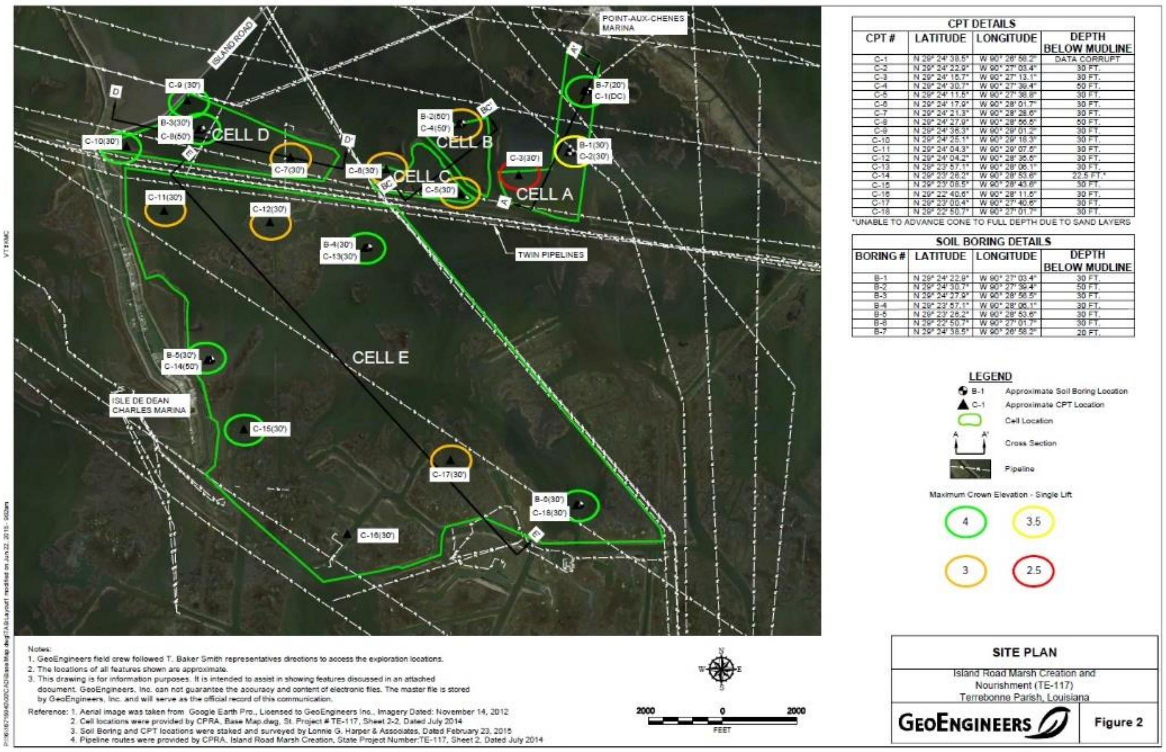


Figure 5: Exploratory Geotechnical Investigation Coverage Area

In 2015, based on a preliminary geotechnical findings, it was decided to collect survey data in the general area to the south of Twin Pipelines. This led to further project development in this region. **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**.

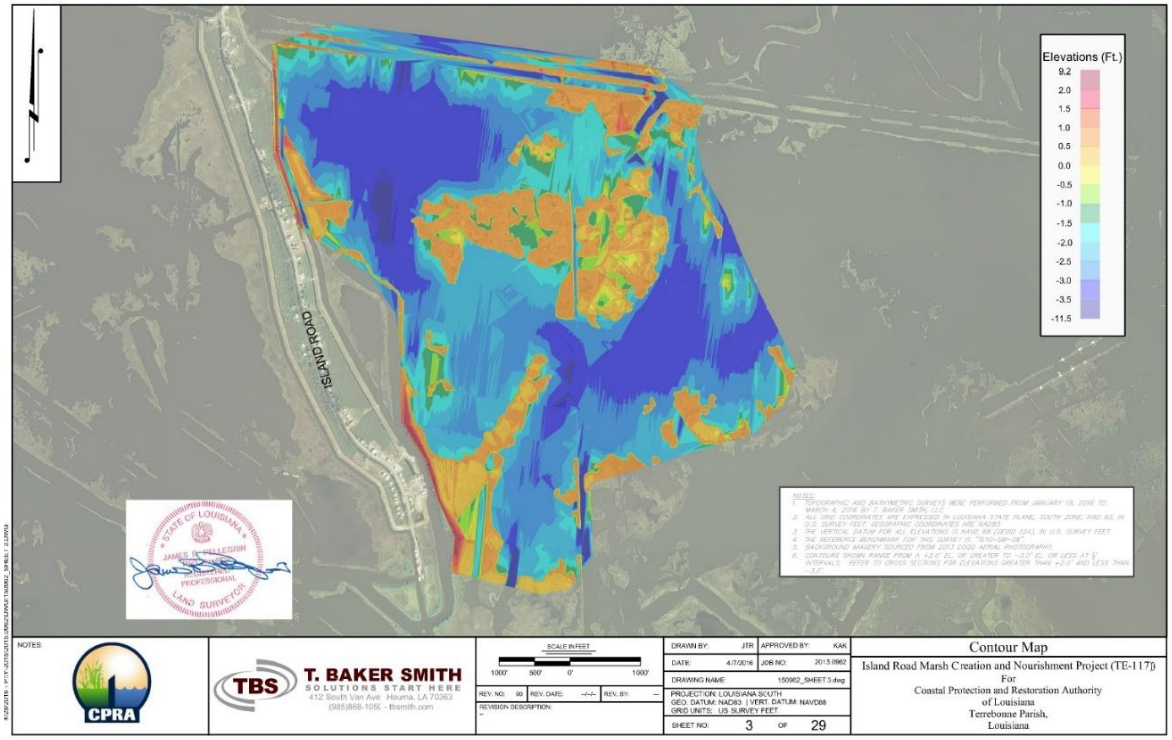


Figure 6: TE-0117 Survey Data Collection Coverage Area

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

In total, five (5) marsh creation alternatives and five (5) borrow alternatives were evaluated to develop the 95% design configuration.

The below sections focus on the 95% project design and modifications made post 30%; however, the 30% design report can be viewed for a more detailed account of past alternatives.

3.4.2 Marsh Creation Area Project Feature Development and Alternatives Analysis

A total of six (6) alternative alignments were evaluated including configurations of marsh creation cells to the north and to the south of the Twin Pipelines. Error! Reference source not found. and **Figure 8** show the 30% and 95% marsh creation area configurations, respectively. See the 30% design report for more information on past alternatives.

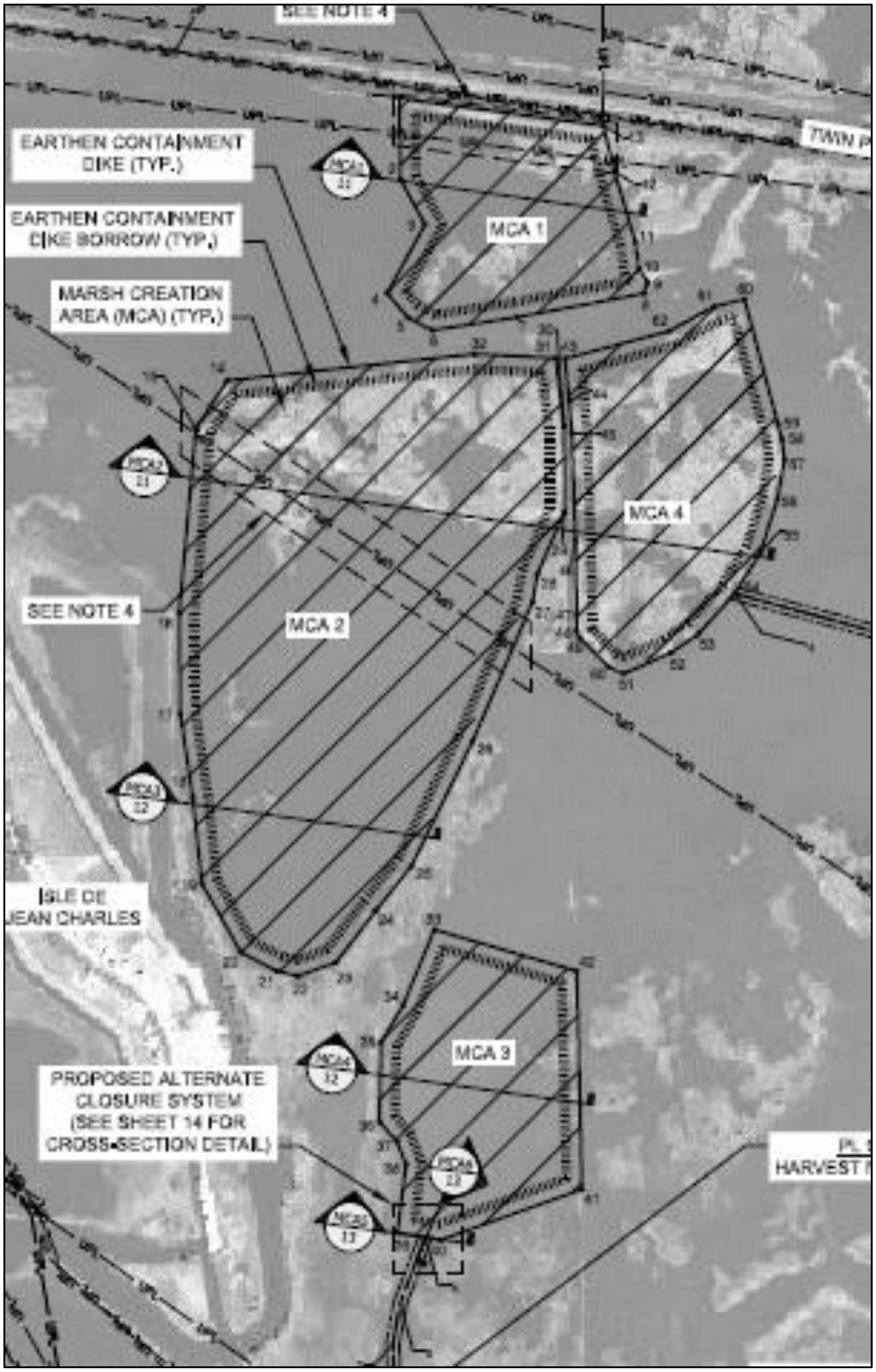


Figure 7: Marsh Creation Area Alternatives, 30% Design

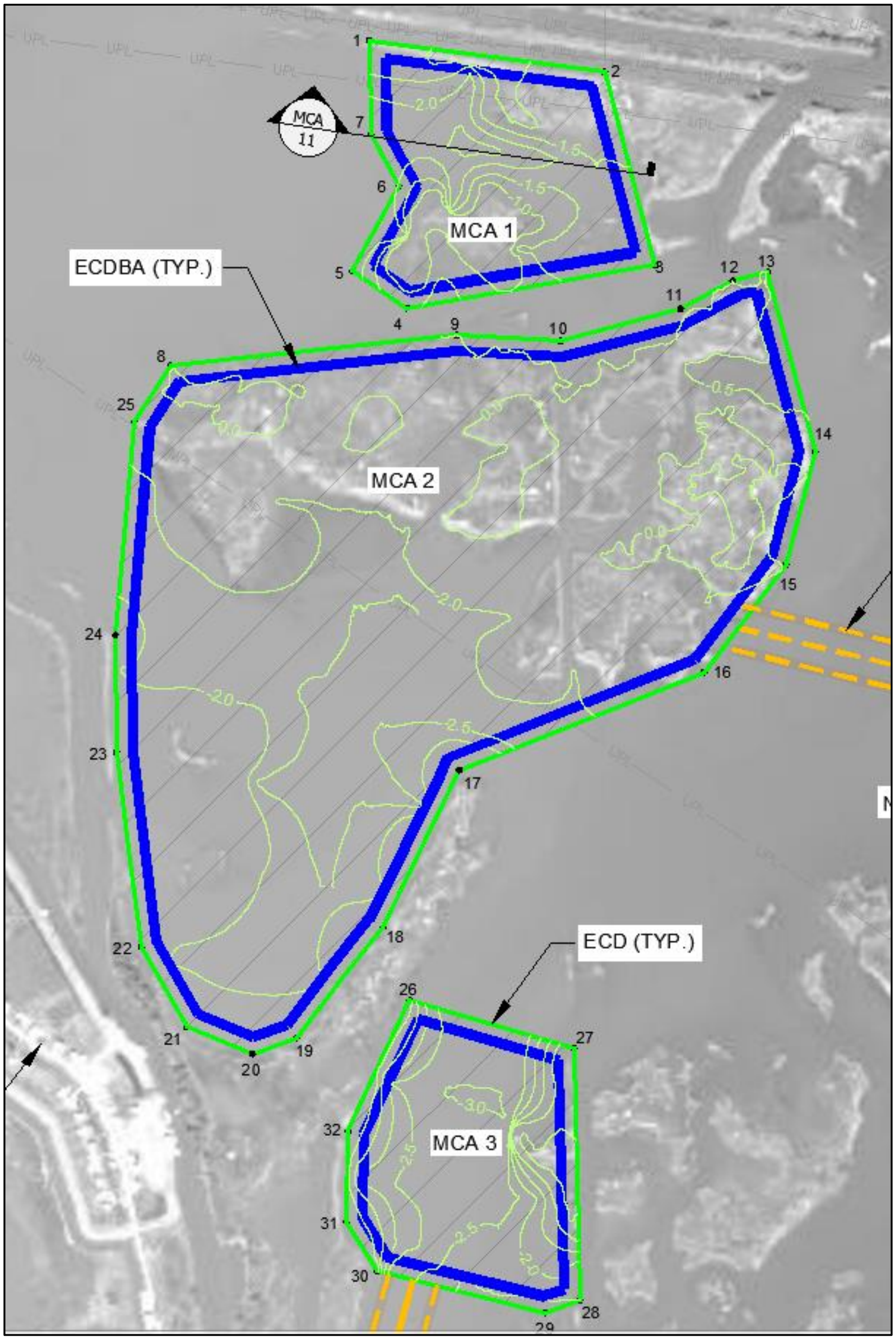


Figure 8: Marsh Creation Area Alternatives, 95% Design

3.4.3 Borrow Area Project Feature Development and Alternatives Analysis

A total of seven (7) borrow area configurations were evaluated. **Figure 9** shows the 95% borrow area configuration. See the 30% design report for more information on past alternatives.

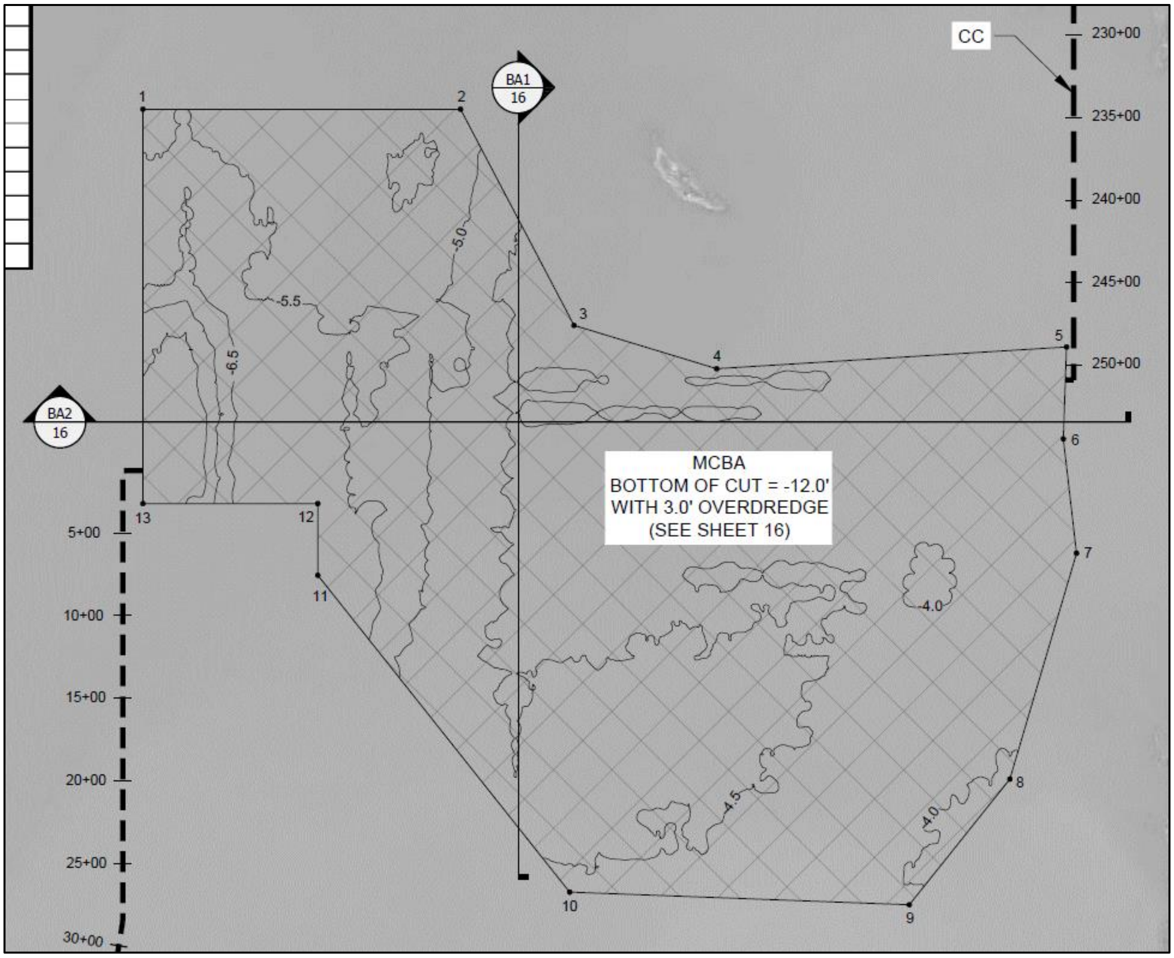


Figure 9: Borrow Area Alternatives, 95% Design

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 second configuration was developed, where the original four marsh creation cells were kept (north of Twin Pipelines), along with an additional fifth cell (south of Twin Pipelines) • Due to complications with the norther four cells, a third configuration of marsh creation alternatives was developed eliminating all options north of Twin Pipelines • An analysis of geotechnical conditions and water depths for containment dike constructability resulted in a fourth configuration of marsh creation cells in the area to the south of Twin Pipelines, which was presented at 30% (see **Figure 7**) • Modifications were made to the 30% alternative, and a fifth and final configuration was developed for 95% design (see **Figure 8**)

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 Error! Reference source not found.)
	• 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 and final alternative, which was developed based on the following (see Error! Reference source not found.):
	  ○ 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 30% design marsh creation area configuration is available in **Figure 7**, with **Figure 8** showing that of 95%. The borrow area (unchanged between 30% and 95%) is shown in **Figure 9**. See **Section 8.0** for additional discussion on the design process for TE-0117.

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 Constructed Marsh Fill Elevation (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 March 1, 2015 through April 21, 2020, 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 10** 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	+1.04	-0.25	+0.40	1.29
CRMS0341	+1.04	-0.30	+0.37	1.34
Average	**+1.04**	**-0.28**	**+0.38**	**1.31**

1. FT stands for "US Survey Foot".

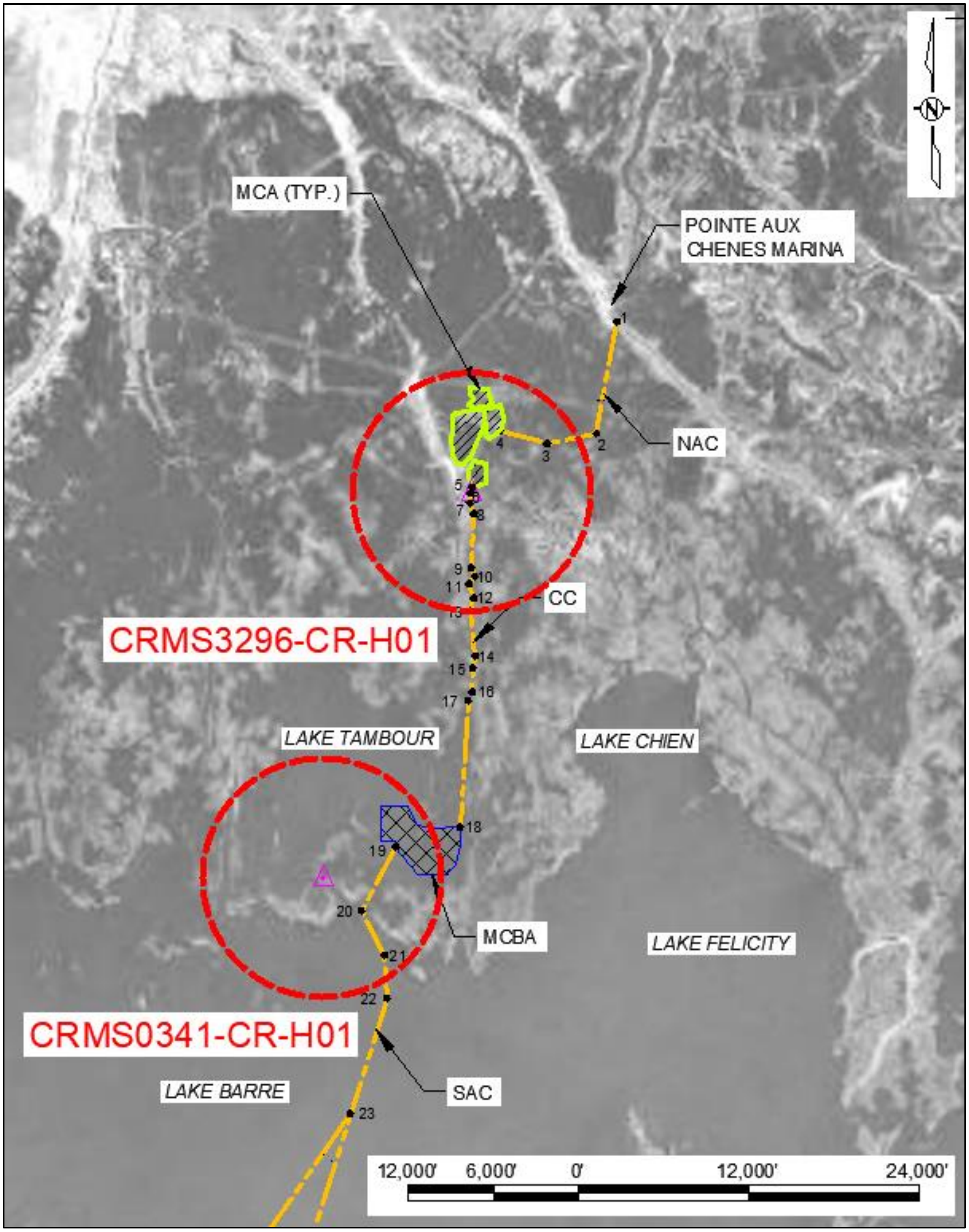


Figure 10: Locations of CRMS Continuous Recorders at TE-0117

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.

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. Given a 20-year project design life beginning in 2023 (TY0), the average annual rate of increase in ESLR under this scenario is approximately 0.30 in/yr (7.7 mm/yr), or 0.50 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. According to these sources, the TE-0117 project area experiences a subsidence rate of 6.4 mm/yr, which over the 20 year project life would be 128 mm, or 5.04 in (0.42 ft). When combined with 0.50 ft of ESLR, this amounts to 0.92 ft of RSLR over the project life. See **Figure 11** for the regional subsidence figure utilized from the 2017 Master Plan.

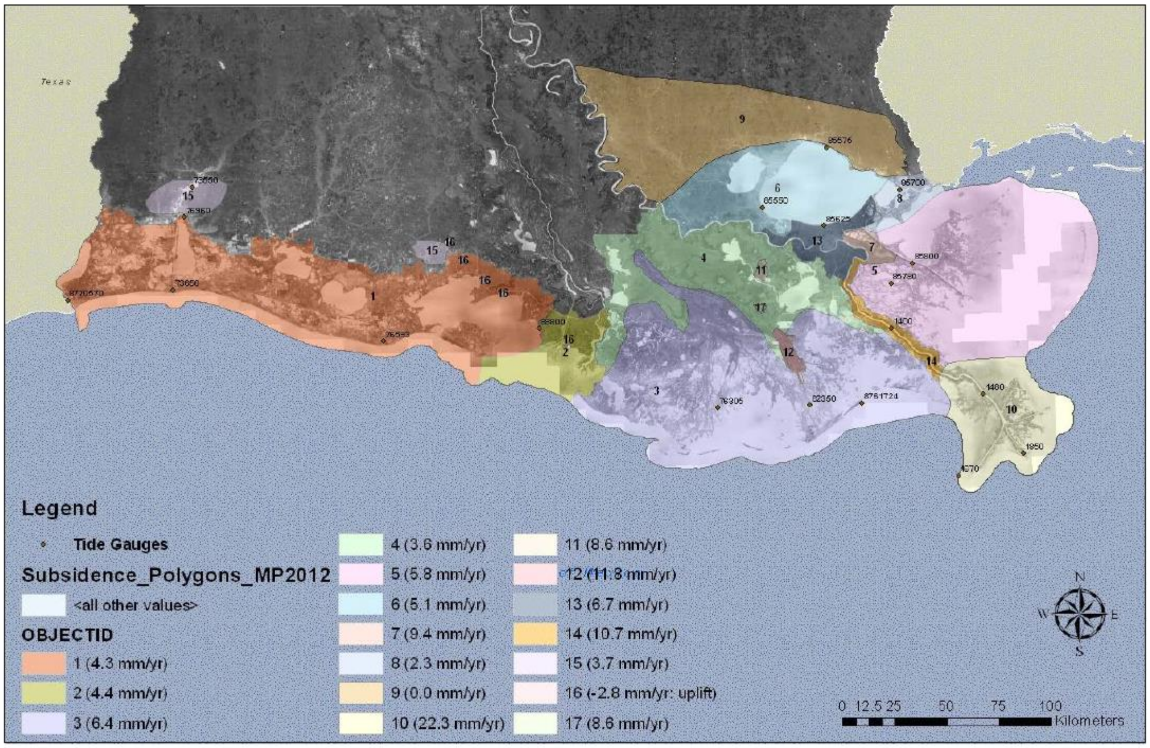


Figure 11: 2017 Master Plan Subsidence Rates by Region

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]
2023 (TY0)	0.0000	0.0000	0.0000
2024	0.0210	0.0213	0.0423
2025	0.0420	0.0430	0.0850
2026	0.0630	0.0653	0.1283
2027	0.0840	0.0879	0.1719
2028	0.1050	0.1109	0.2159
2029	0.1260	0.1342	0.2602
2030	0.1470	0.1581	0.3051
2031	0.1680	0.1824	0.3504
2032	0.1890	0.2070	0.3960
2033	0.2100	0.2320	0.4419
2034	0.2310	0.2572	0.4882
2035	0.2520	0.2831	0.5351
2036	0.2730	0.3094	0.5823
2037	0.2940	0.3360	0.6299
2038	0.3150	0.3629	0.6778
2039	0.3360	0.3904	0.7264
2040	0.3570	0.4180	0.7449
2041	0.3780	0.4462	0.8241
2042	0.3990	0.4747	0.8737
2043 (TY20)	0.4199	0.5039	0.9239

4.3 Percent Inundation Determination

Three methods were considered for hydrologic design of TE-0117, with the Percent Inundation Method being the primary hydrologic design method. These three methods were:

- Percent Inundation Method
- Traditional Tidal Datum Calculation (MHW/MLW)
- $50^{th}/80^{th}$ Percentile Method

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.

CPRA marsh creation projects are typically designed with the Percent Inundation Method, which was utilized for TE-0117. Also considered during the design phase was a third method, in which the 50^{th} and 80^{th} percentiles of reference marsh elevation surveys were obtained and applied to hydrologic design curves. See the 30% Design Report for more information.

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 saline 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 12** 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	+2.10	+2.60
10	+1.23	+1.73
MHW	+1.04	+1.54
20	+0.96	+1.46
80	-0.12	+0.38
MLW	-0.25	+0.25
90	-0.44	+0.06
99	-1.30	-0.80

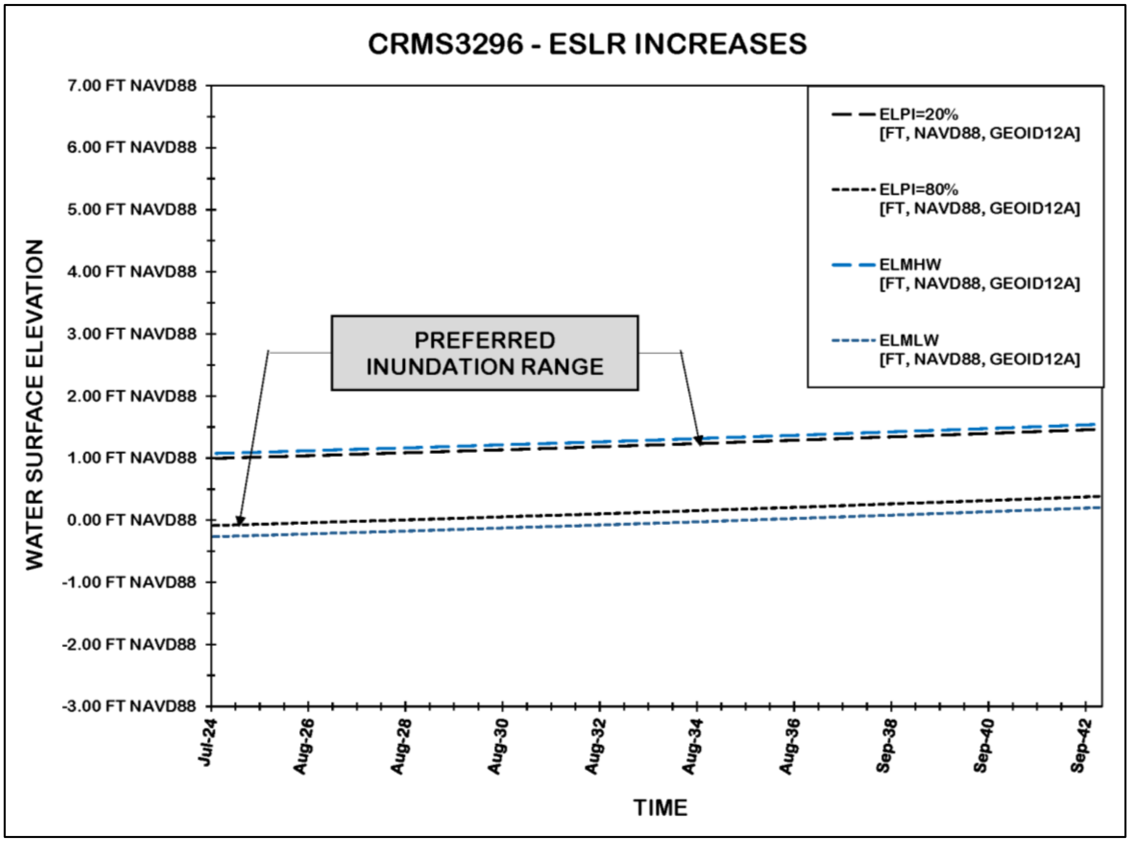


Figure 12: Percent Inundation and MHW/MLW for TE-0117

Vertical elevation gains due to accretion is another physical process that is sometimes considered in marsh creation project design. For TE-0117, the project team decided to avoid factoring in vertical gains in the marsh platform due to accretion processes, due to uncertainty in the implementation of accretion methodology on CWPPRA marsh creation projects.

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 13** 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.

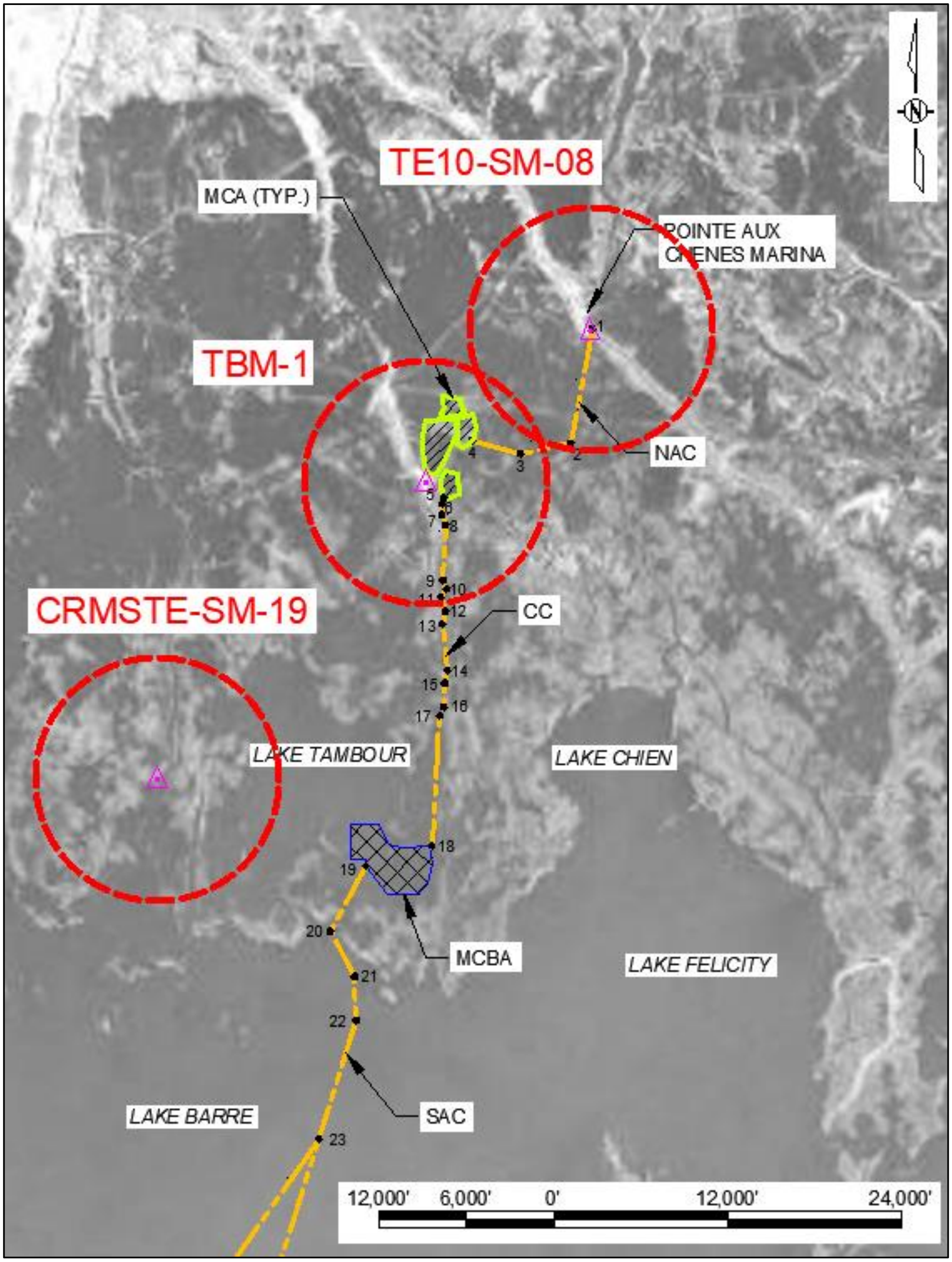


Figure 13: Locations of Survey Control Points at TE-0117

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 14** contains the topographic and bathymetric survey layout map provided by TBS.

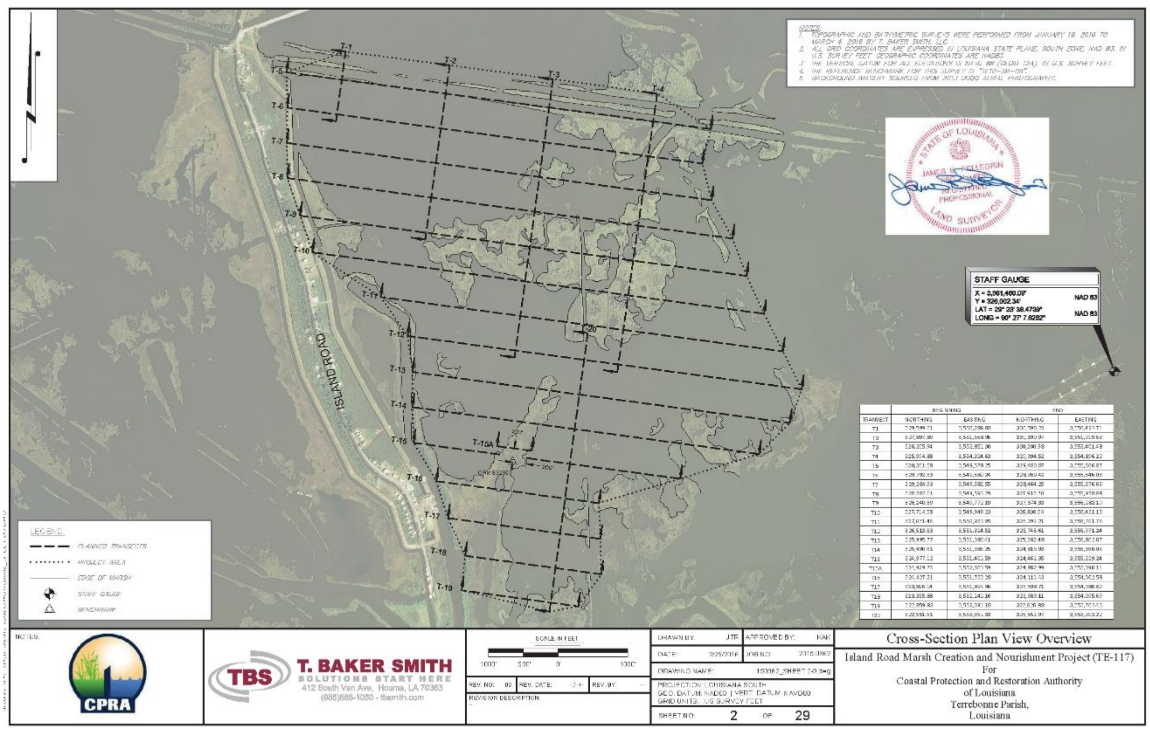


Figure 14: Marsh Creation Area Topo/Bathy Survey Layout

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 15** contains the magnetometer survey layout map provided by TBS.

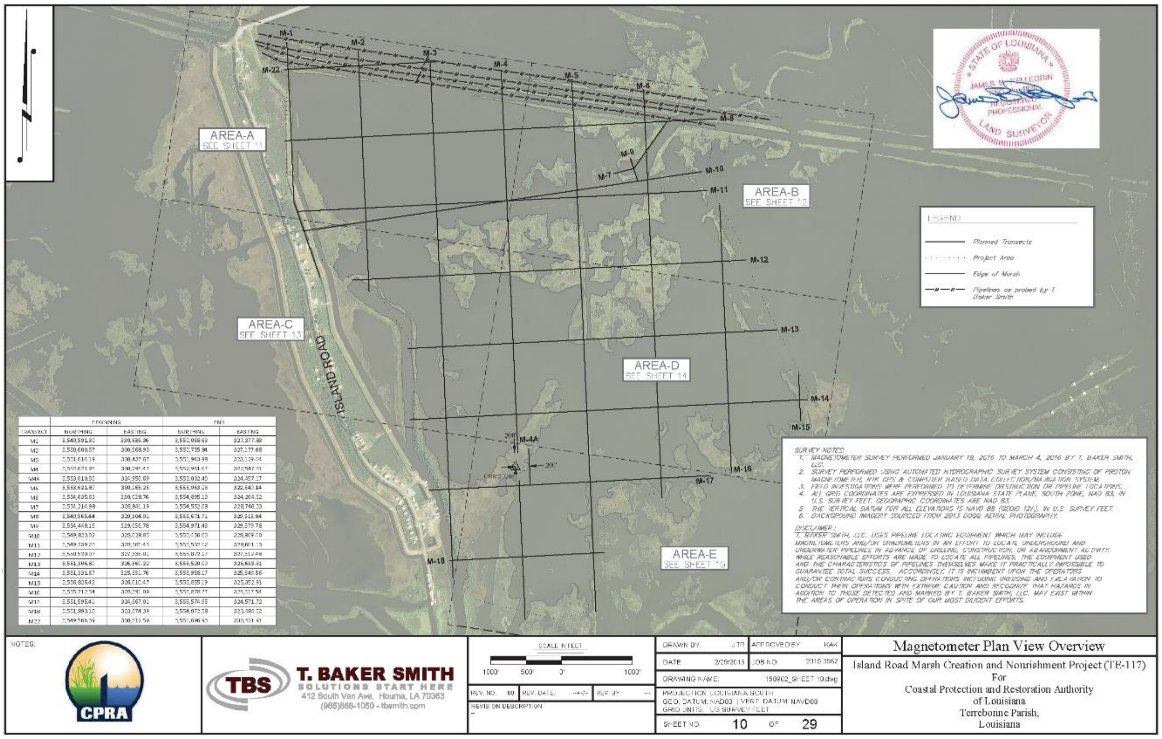


Figure 15: Marsh Creation Area Magnetometer Survey Layout

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 16** contains the reference marsh elevation survey layout map provided by TBS.

Table 6: Reference Marsh Elevations

Location	Average Elevation [FT NAVD88 GEOID12A]	Corresponding Percent Inundation
AV1	+0.50	47%
AV2	+0.64	38%
AV3	+0.57	43%
AV4	+0.55	44%
AV5	+0.52	46%
Average (All)	**+0.56**	**43%**

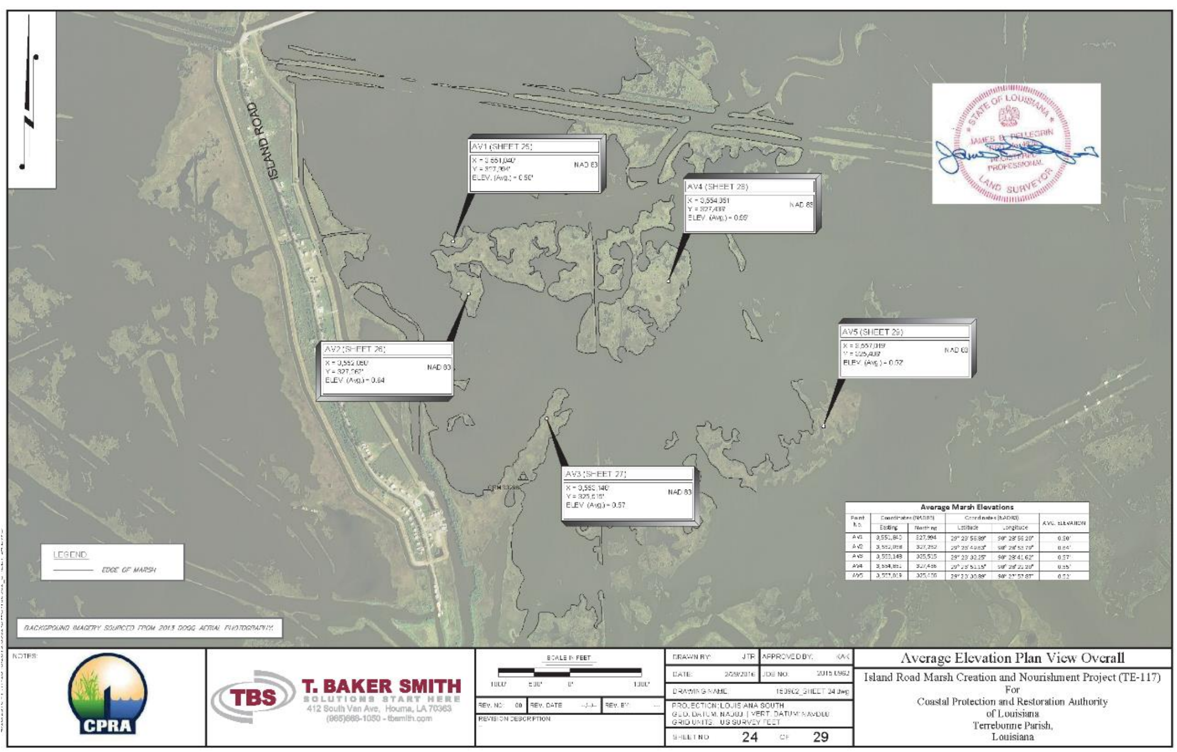


Figure 16: Reference Marsh Elevation Survey Layout

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 17** 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.

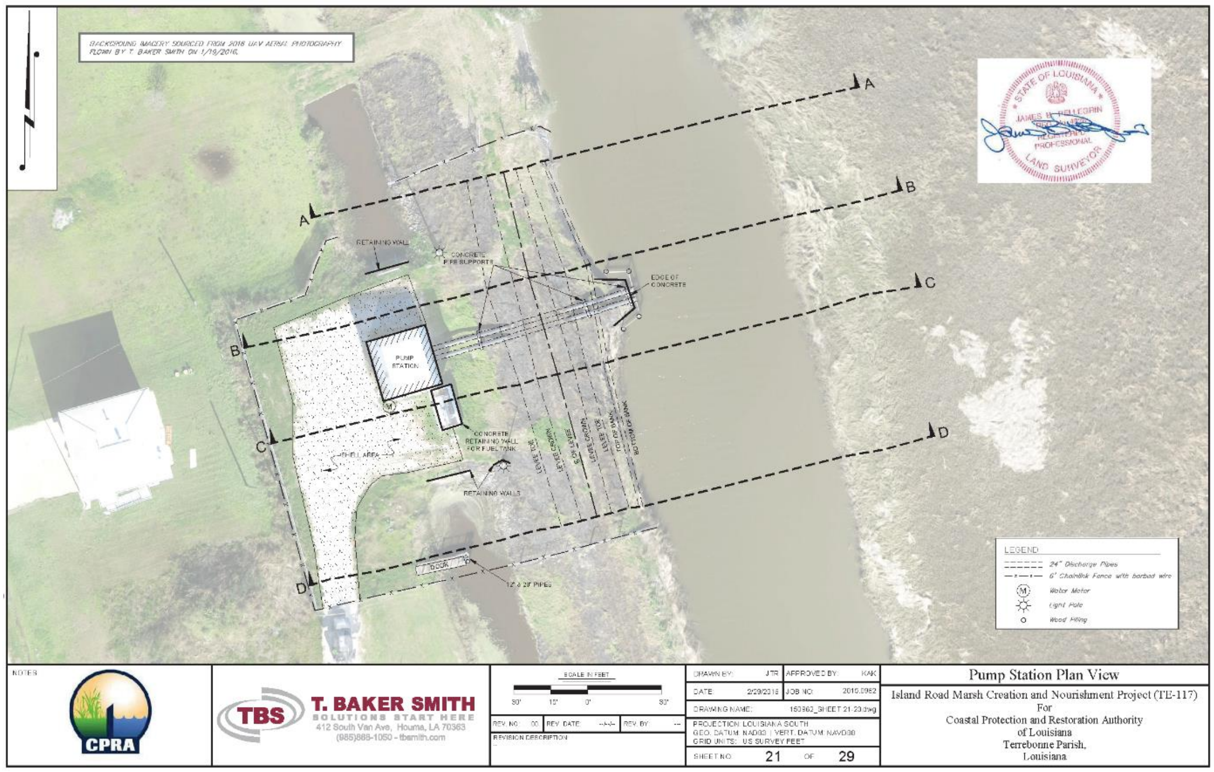


Figure 17: Isle de Jean Charles Pump Station Survey Layout

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 18** contains the borrow area survey layout map provided by CHF.

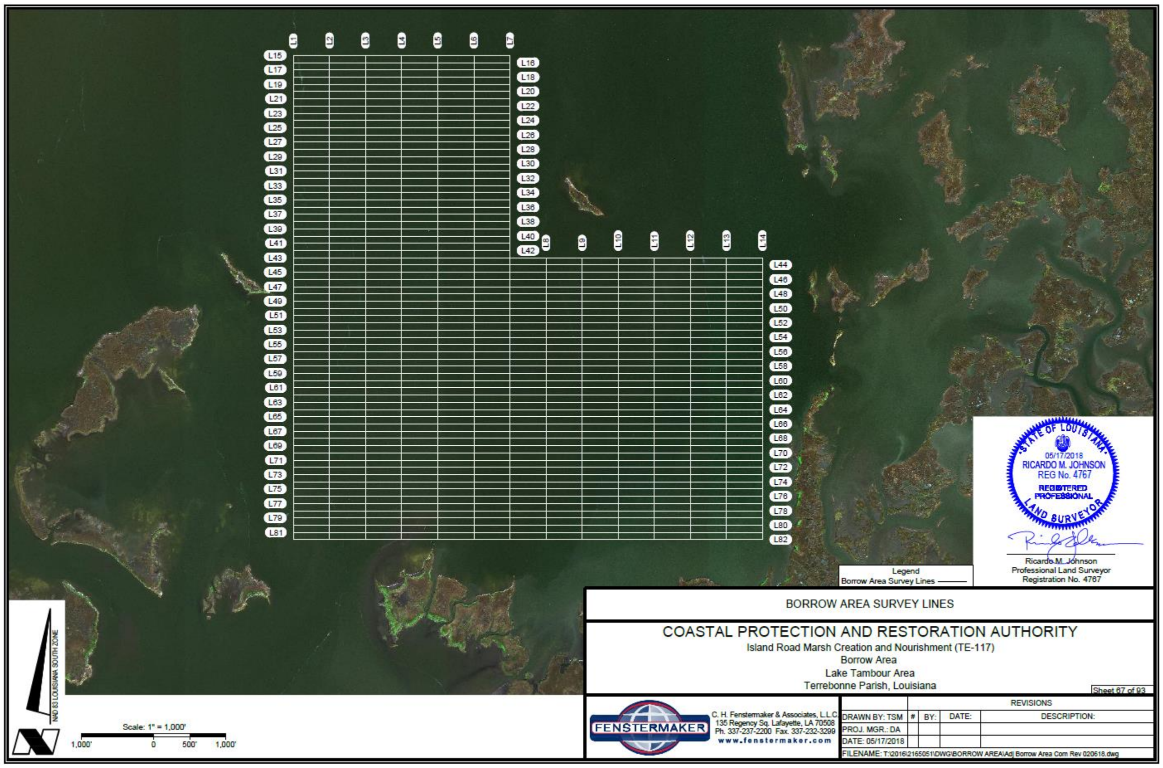


Figure 18: Borrow Area Topo/Bathy/Mag Survey Layout

Magnetometer survey data was collected along the same transect layout as shown in **Figure 18**. Based on the interpretation of magnetometer findings, no significant anomalies were interpreted for the data collected within the borrow area. In particular, no pipelines were encountered. All magnetic detections were reported as being associated with non-hazardous articles of ferrous debris.

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 19** 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 19: 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 off-center. 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 20** contains the topographic, bathymetric, and magnetometer survey layout map of the NAC and CC, while **Figure 21** contains that of the SAC and SAC SPUR.

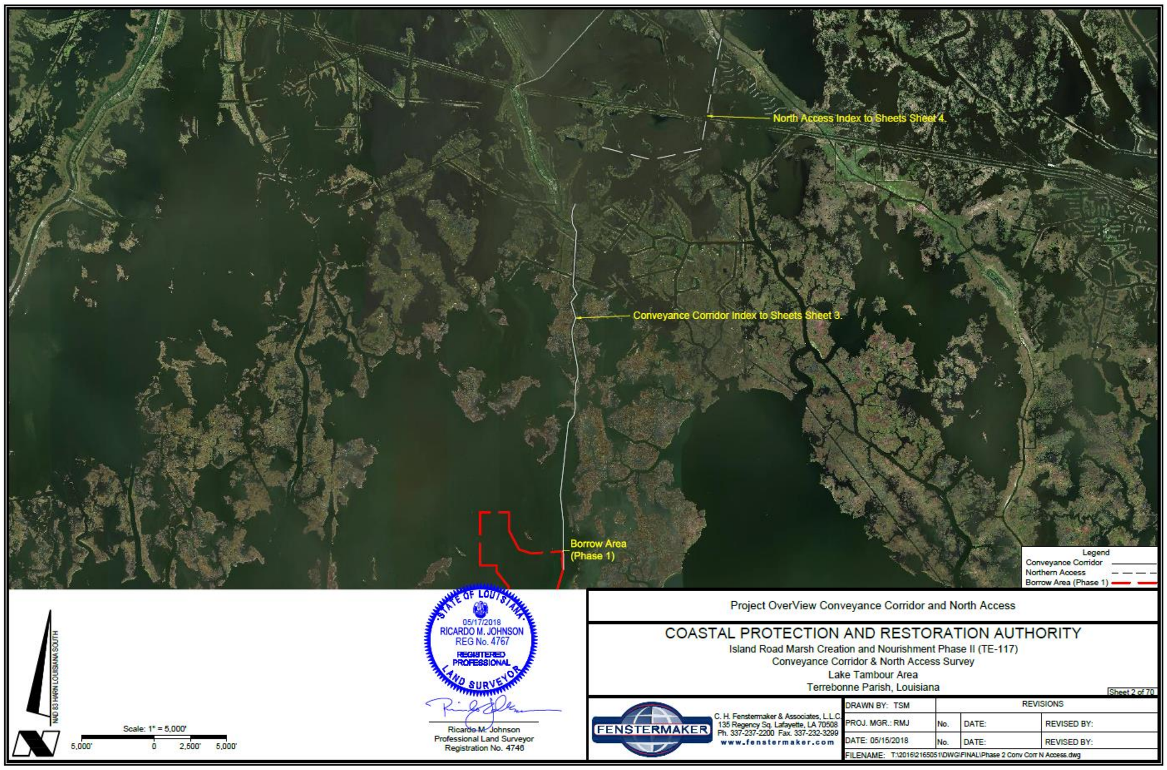


Figure 20: Access Corridor Centerline Transect Survey Layout (NAC, CC)

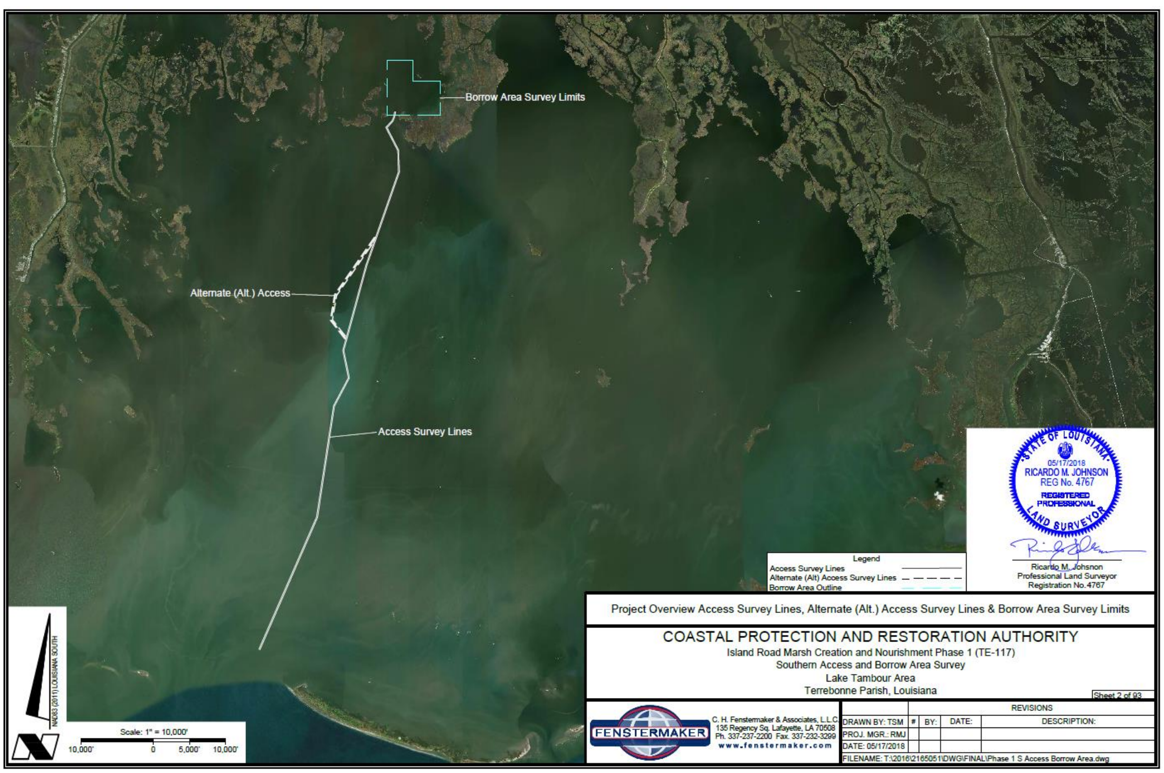


Figure 21: Access Corridor Centerline Transect Layout (SAC, SAC SPUR)

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 20** and **Figure 21**. For each magnetic anomaly detected, the anomaly was analyzed to determine if it was associated with a pipeline or other significant hazard. Based on the interpretation of these findings, the CHF crew executed additional investigation techniques such as probing and/or real time kinematic surveying 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” Unknown Pipeline Owner	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

***Pipeline information obtained is not guaranteed to be accurate and is not for construction. CPRA is actively in the process of QCing all pipeline information.**

Table 8: CHF Pipeline Identification for TE-0117

Pipeline Crossing ID	Pipeline/Flowline Identification	Applicable EAC CL Stationing	Excavation Proposed?	TOP EL [FT NAVD88]
1	Harvest Natural Gas Pipeline	NAC – STA 7+02	N	SIG**
2	Williams Energy Natural Gas PL	NAC – STA 9+01	N	SIG**
3	Unknown Pipeline Owner	NAC – STA 38+00	N	-15.0
4	Unknown Pipeline Owner	NAC – STA 54+00	N	-15.0
5	Koch Natural Gas Pipeline	NAC – STA 56+00	N	SIG**
6	Columbia Gulf Natural Gas PL	NAC – STA 57+00	N	SIG**
7	Genesis Petroleum Pipeline	NAC – STA 100+00	N	-9.0
8	Harvest Natural Gas Pipeline *Pipeline Partially Exposed*	CC – STA 6+60	N	-4.4
9	Southern Natural Gas Pipeline *Pipeline Partially Exposed*	CC – STA 18+89	N	-8.0
10	Hilcorp Pipeline	SAC – STA 243+28	N	-12.0
11	Unknown Pipeline Owner	SAC – STA 264+90	N	-11.5
12	Hilcorp Pipeline	SAC – STA 303+02	N	-10.5
13	24" Kinetica/36" Tennessee Gas Pipelines	SAC – STA 314+56	N	-12.5
14	Harvest/Hilcorp Pipelines	SAC – STA 641+56	N	-10.5

***Pipeline information obtained is not guaranteed to be accurate and is not for construction. CPRA is actively in the process of QCing all pipeline information.**
****Detected by signal only and observed to be sufficiently deep.**

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 14 pipeline crossings. 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. The prospective contractor will be required to abide by specification language on establishing proper demarcation of these pipeline crossings. 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. **Figure 22** and **Figure 23** below show the respective locations of the pipelines encountered for TE-0117. Note that **Figure 22** corresponds to the information in **Table 7**, with **Figure 23** corresponding to **Table 8**. See the design drawings in **APPENDIX M** for more in-depth graphical information on pipeline crossings.

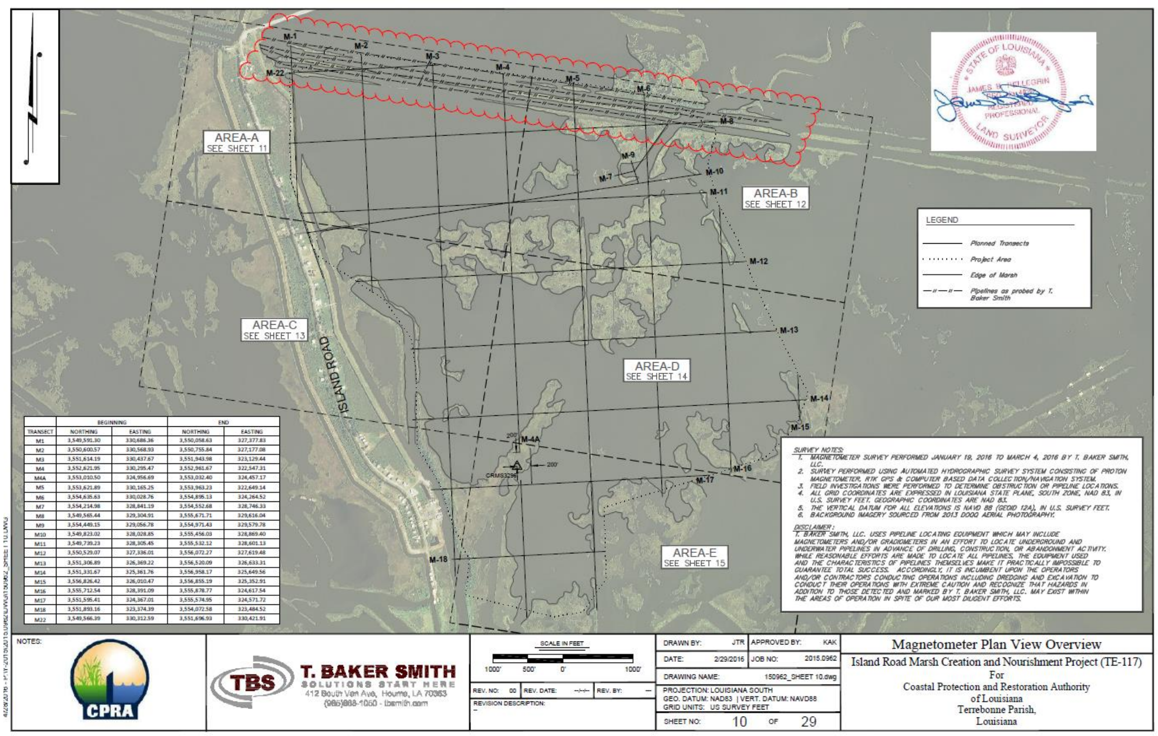


Figure 22: Pipelines Discovered During TBS Survey (shown in red cloud)

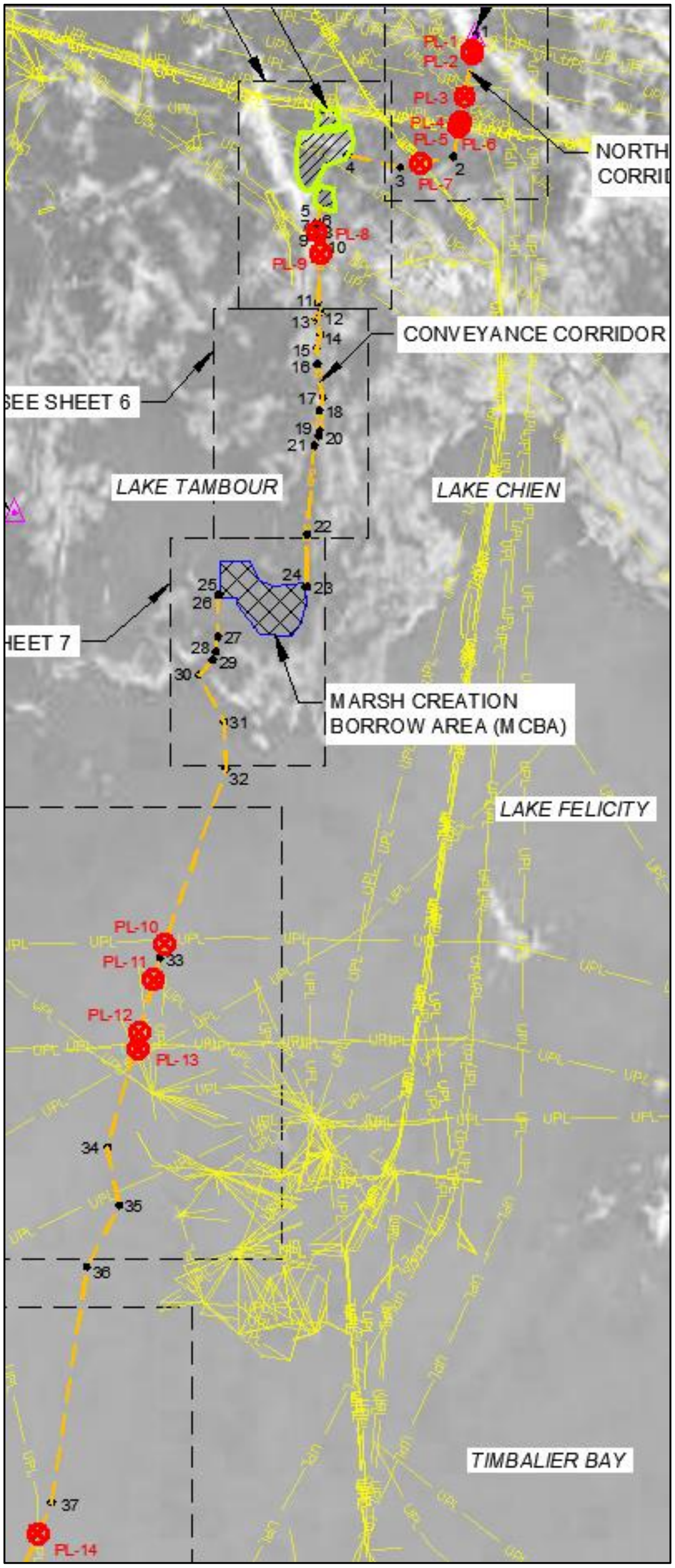


Figure 23: Pipelines Discovered During CHF Survey (denoted by "⊗" symbol)

5.5 Correspondence with Pipeline Owners

The TE-0117 team began correspondence with pipeline owners while working on 95% design, in order to evaluate any risks of necessary redesigns due to pipeline restrictions. No such restrictions were presented that required any redesign of the project. Below is an account of key correspondence.

For the pipelines identified in **Table 7**, although no excavation or project feature overlap is proposed, encroachment guidelines were collected from some of the identified pipeline companies. The 24” Columbia Gulf pipeline, which is located approximately 75 FT from the northernmost boundary of the project, contains encroachment guidelines that may require a Columbia Gulf representative to be onsite when operating within 500 FT of the right of way. All pipeline information collected during correspondence does not indicate a need to redesign any project feature. The TE-0117 team plans to continue correspondence with all known pipeline operators moving towards construction, and construction-phase monitoring is anticipated when operating within the vicinity of all pipelines.

For the pipelines identified in **Table 8**, a total of 14 pipeline crossings were identified in the three access corridor features. Encroachment guidelines were also collected from some of the identified pipeline companies. While equipment is expected to traverse these pipeline crossings, all pipeline information collected does not indicate a need to redesign any project feature. The TE-0117 team plans to continue correspondence with all known pipeline operators moving towards construction, and construction-phase monitoring is anticipated when operating within the vicinity of all pipelines. In particular, the two pipeline crossings determined to be partially exposed, are expected to require specific coordination with owners and further development of pontooning/floathose design to traverse these two crossings in the CC.

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. 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 non-cohesive in situ soil strata expected near bayous and historical waterways. Project literature on existing surface features and infrastructure were also reviewed for geotechnical information, as discussed in **Section 2.2**.

6.2 Geotechnical Field Investigations

6.2.1 General Scope

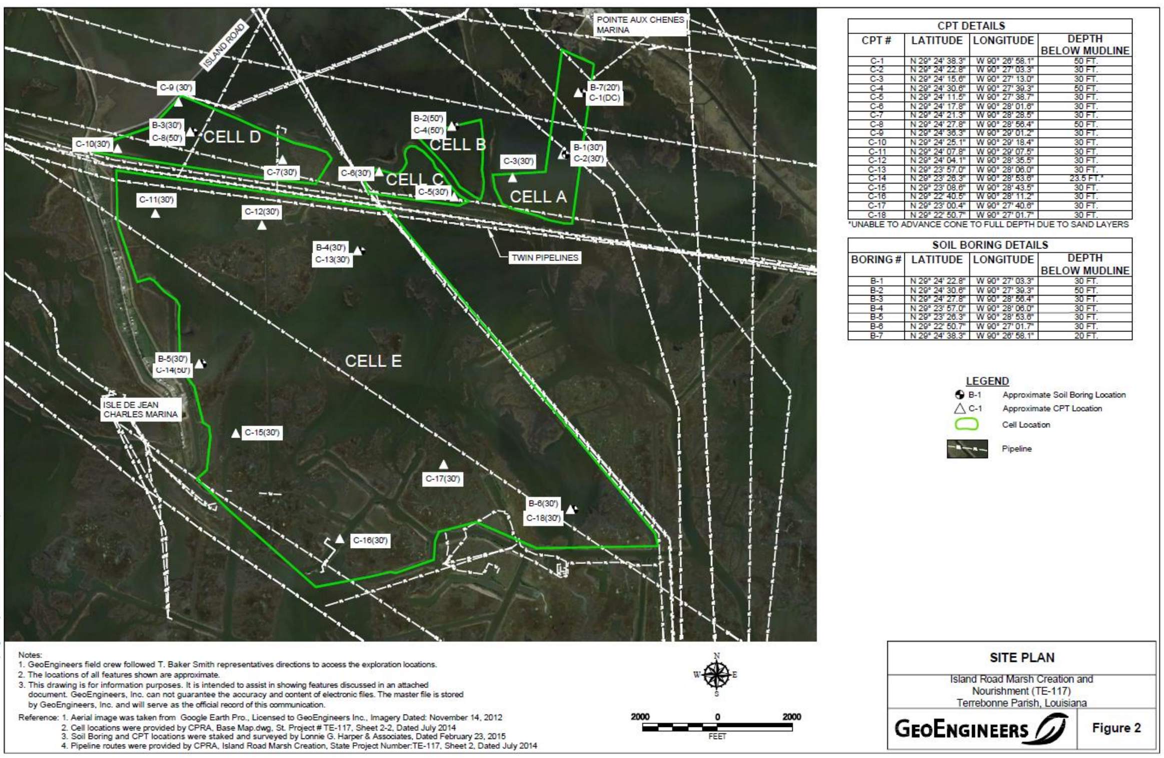
Table 9 contains a breakdown of information pertaining to geotechnical data collection investigations carried out for TE-0117. All geotechnical sampling, including soil sample identification, classification, storage, transport, and electronic data logging, were performed according to the most applicable standard as part of American Society for Testing and Materials (ASTM) standard methods and to the provisions stated in MCDG for geotechnical investigations.

Table 9: 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 drill rig 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. Soils encountered generally consisted of high moisture content peat and organic clay, underlain by predominantly very soft clay and silty clay soils, with some silts also encountered. A silty sand zone was also encountered throughout most of the investigation area, which was observed from elevation -7 to -12 FT NAVD88. **Figure 24** 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 24: 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 drill rig 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. Soils encountered generally consisted of very soft peat or organic clay, underlain by very soft clay, silt, and organic soils. A silty sand zone was also encountered throughout most of the investigation area, which was observed from elevation -7 to -12 FT NAVD88. **Figure 25** contains the supplementary marsh creation area geotechnical sampling layout map provided by GEO.

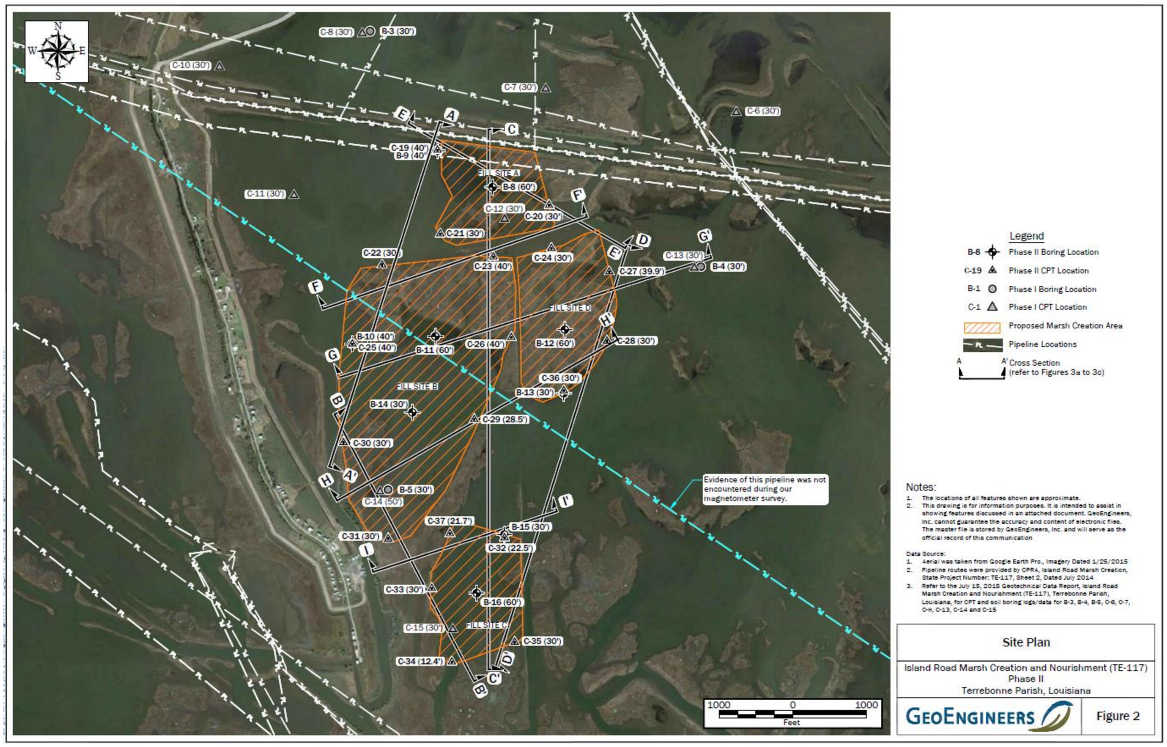


Figure 25: Supplementary Marsh Creation Area Geotechnical Sampling Layout

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. Soils encountered generally consisted of peat and organic clay. Within the interior of the borrow area, a silty sand zone of various thickness 4 FT to 10 FT) was encountered between elevation -10 FT NAVD88 to -20 FT NAVD88. **Figure 26** contains the borrow area geotechnical sampling layout map provided by GEO.

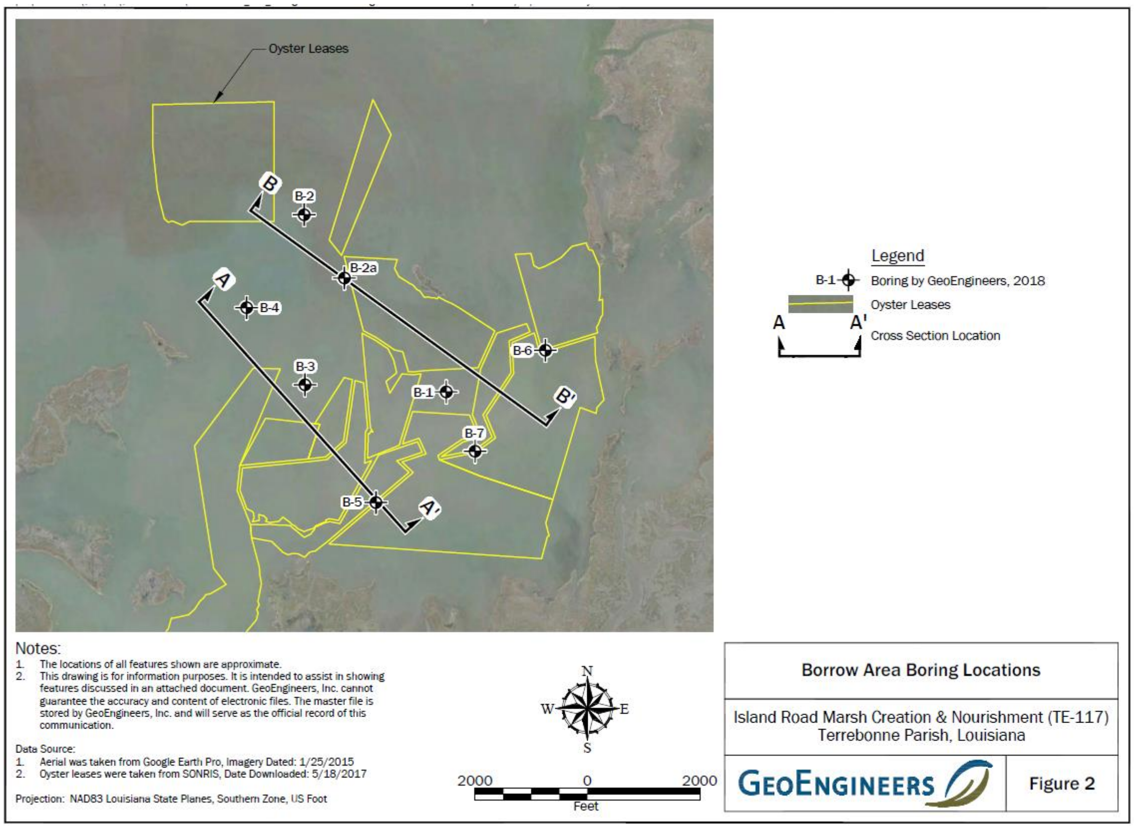


Figure 26: Borrow Area Geotechnical Sampling Layout

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.

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 27** and **Figure 28** contain geology maps provided by GEO.

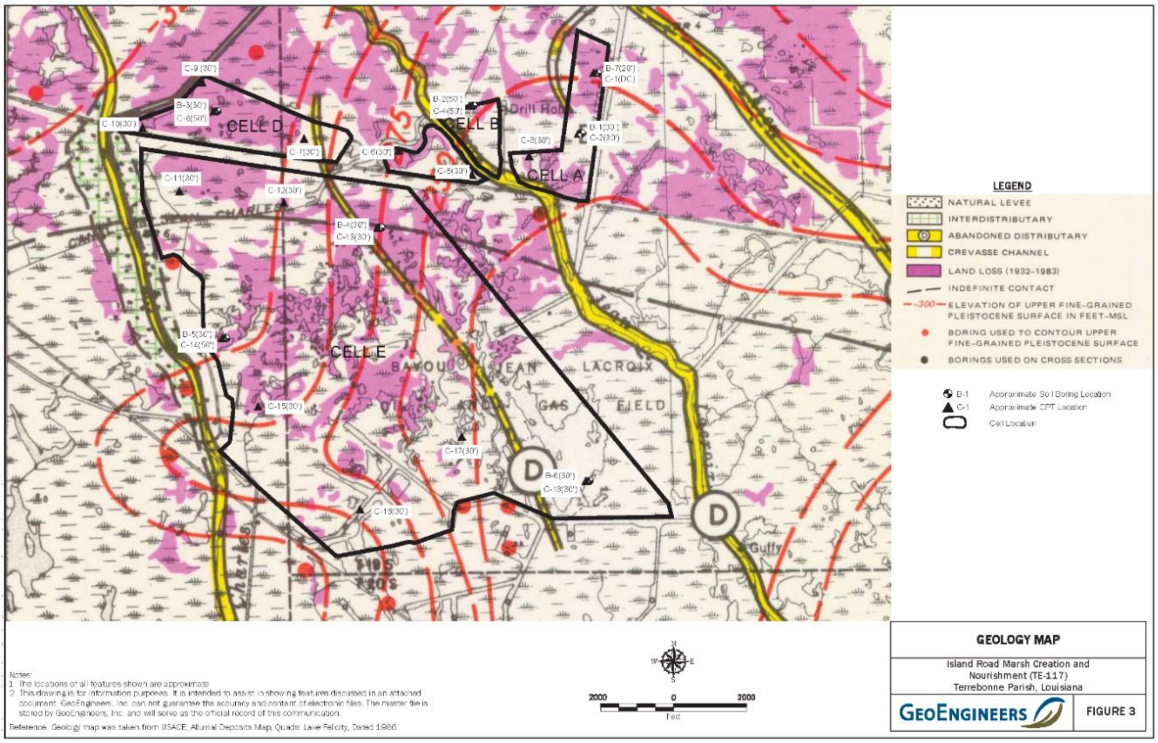


Figure 27: Geology Map, Exploratory Geotechnical Effort

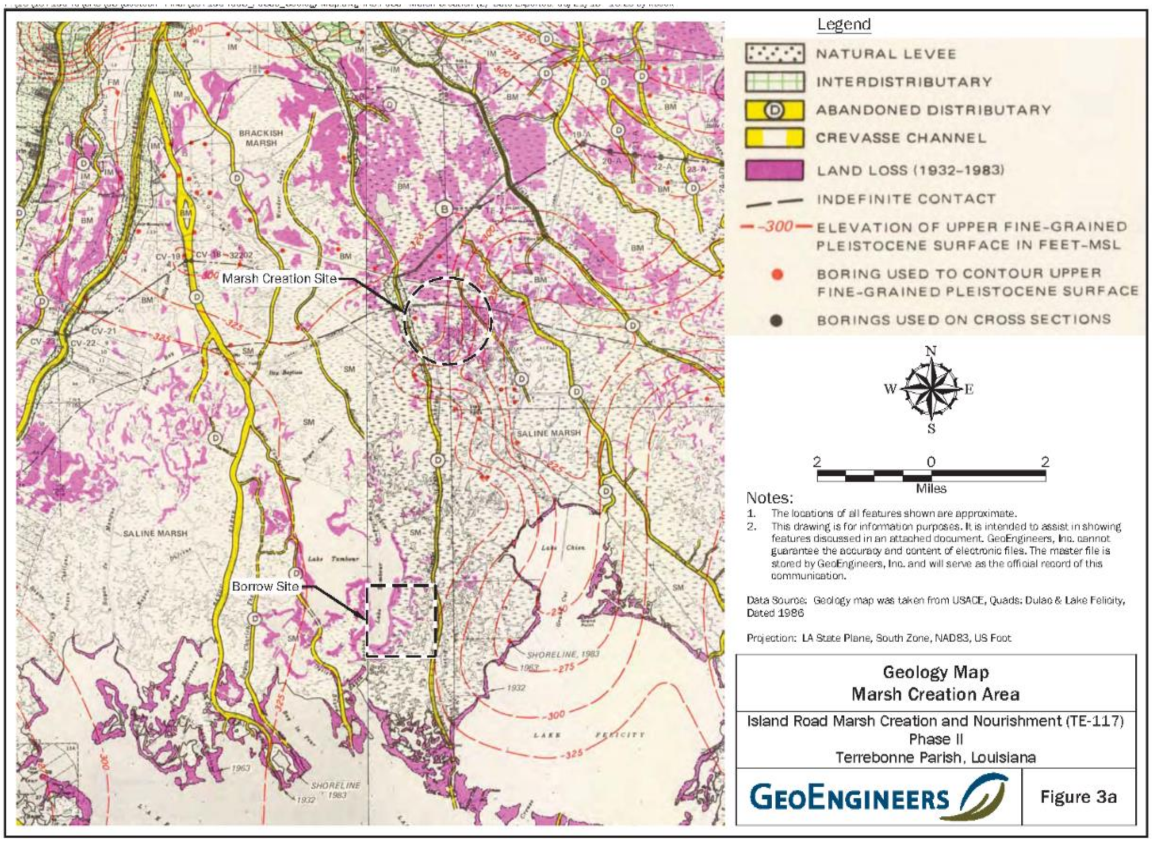


Figure 28: Geology Map, Supplementary Geotechnical Effort

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 the settlement curves shown below.

During 30% design, several settlement curves were analyzed; however, those curves did not maintain adequate intertidal elevation throughout the project life. As a result, additional analyses were completed during 95% to determine CMFEs and construction methods that would produce a successful design. The settlement analyses shown in this report include only those curves analyzed during the 95% design phase. See the TE-0117 30% design report for more information on the previous analyses.

Table 10 below contains summary information for the five (5) settlement analyses presented in this report, with **Figure 29** through **Figure 33** containing all five settlement curves. From Settlement Curve 1 of 5 to 5 of 5, modifications were made iteratively to better understand the effects of varying pump elevation, infill rate, and multiple lift construction strategies.

Table 10: Settlement Curve Summary Information

Settlement Curve No.	Preconstruction Mudline Elevation	End of Construction Pump Elevation	TY20 Settled Elevation	Infill Duration	Multiple Lift?
1 of 5	-3.0	+4.0	+0.12	30-day	N
2 of 5	-3.0	+4.0	+0.64	45-day	N
3 of 5	-2.0	+3.0	+0.52	45-day	N
4 of 5	-3.0	+3.0	+0.01	45-day	N
5 of 5	-3.0	+3.0	+0.64	45-day*	Y

Notes: All elevations shown in units of FT NAVD88.
Percent inundation elevations for TY20 are +1.46 (20%) and +0.38 (80%); see Table 5 for more information.
***Utilized 45 day duration for first lift, and then instantaneous duration for second lift.**

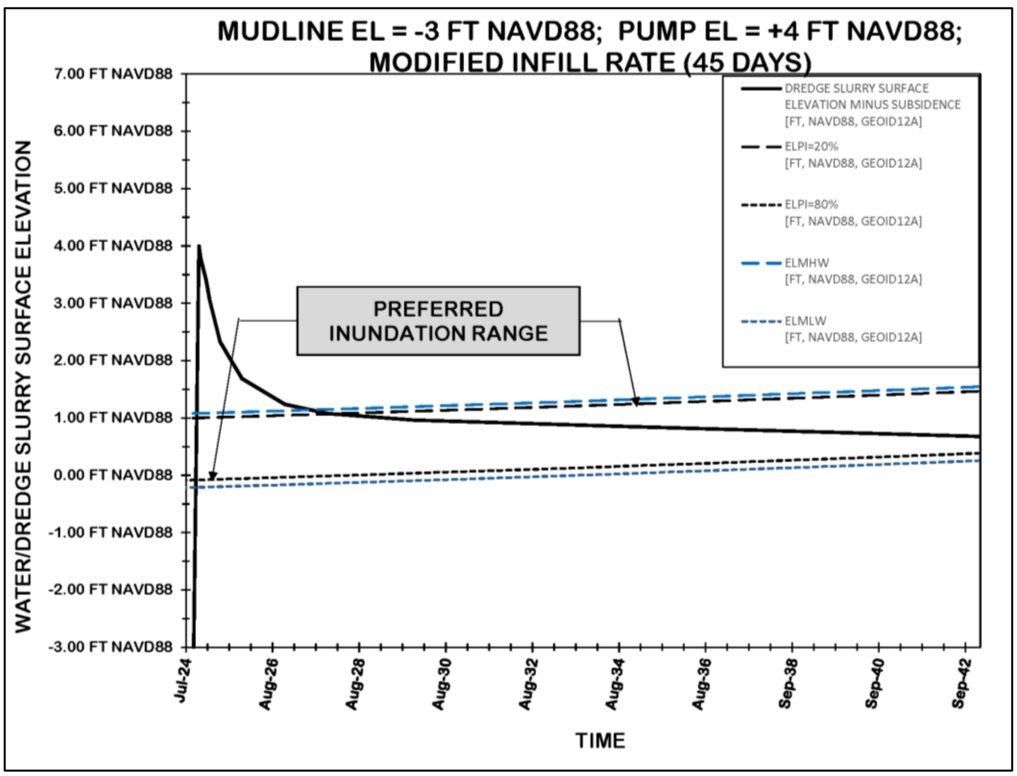


Figure 29: Settlement Curve 1 of 5

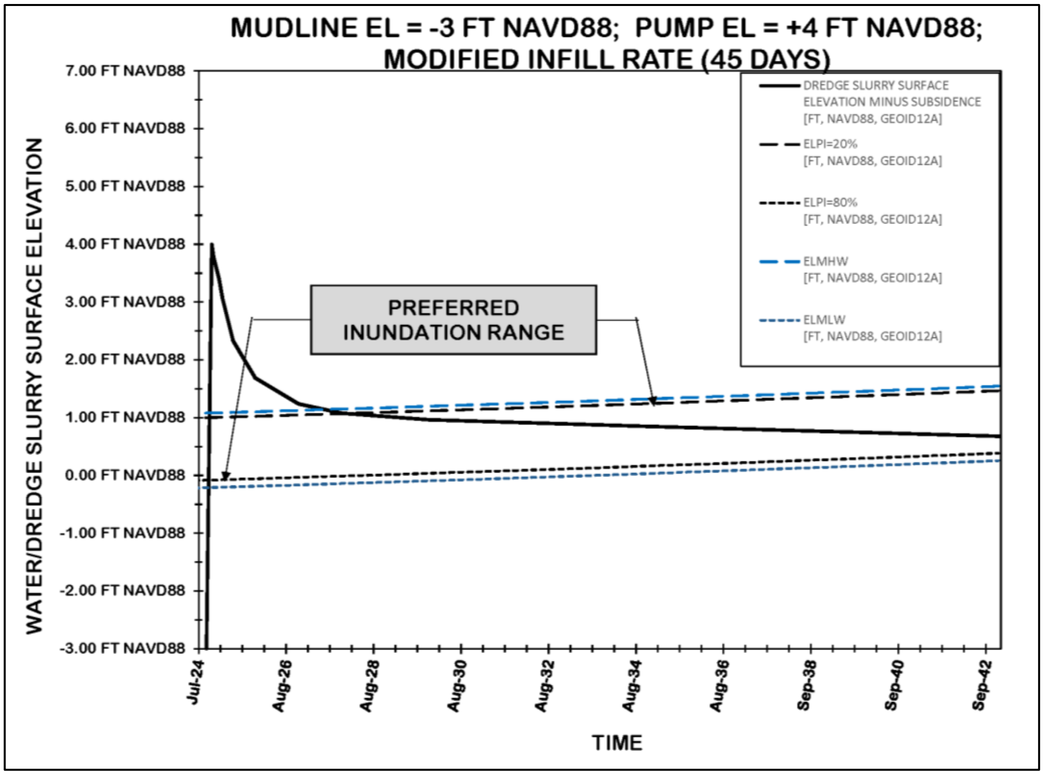


Figure 30: Settlement Curve 2 of 5

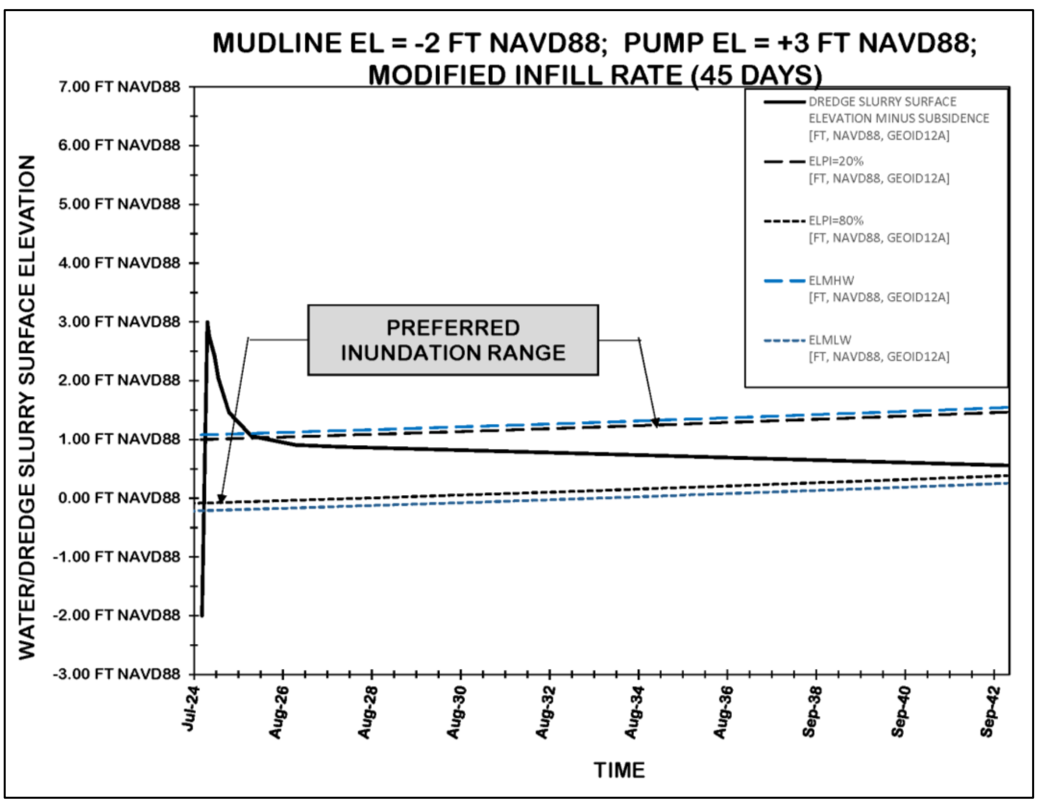


Figure 31: Settlement Curve 3 of 5

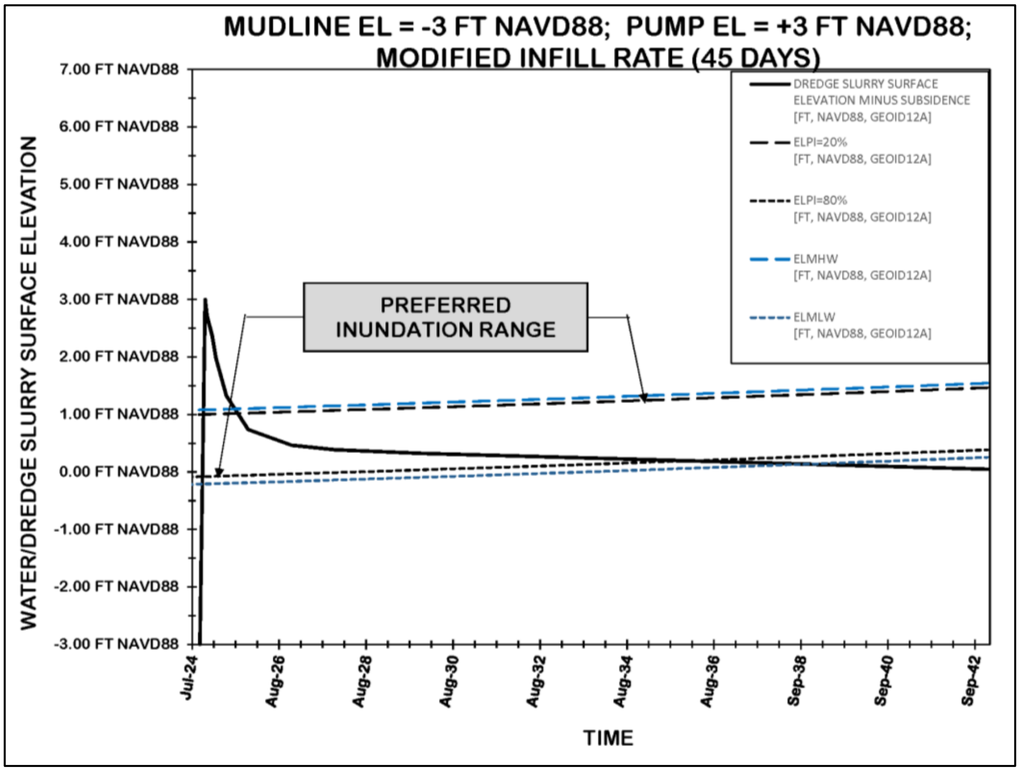


Figure 32: Settlement Curve 4 of 5

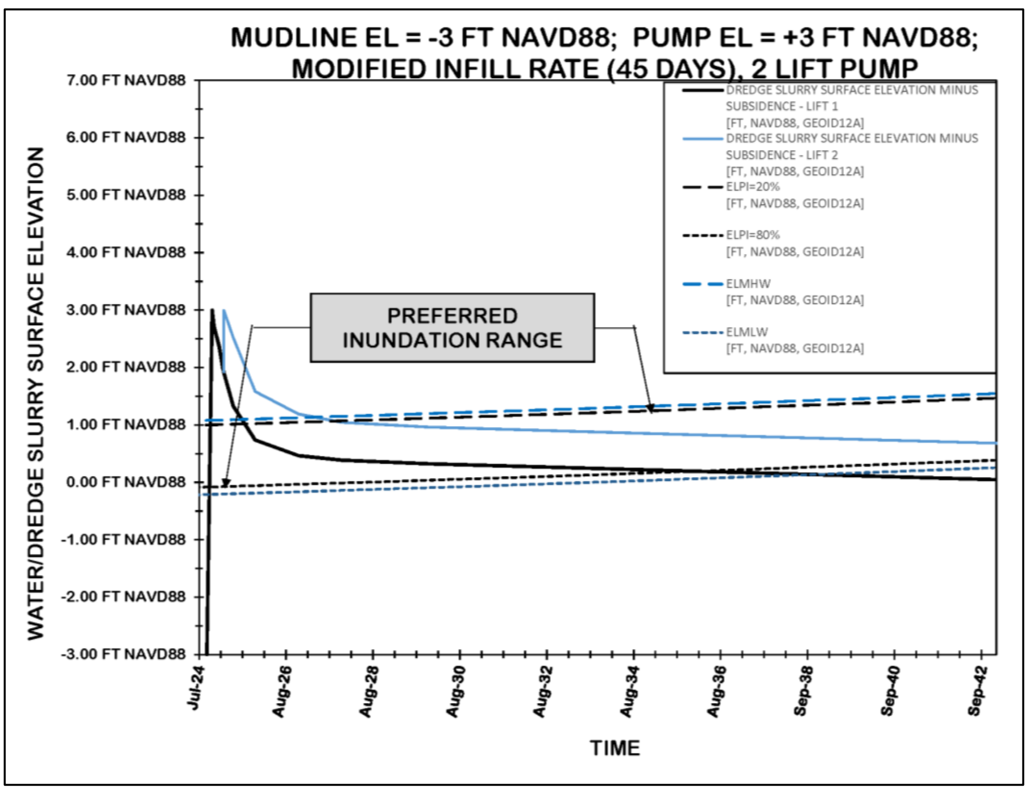


Figure 33: Settlement Curve 5 of 5

As indicated by the TBS color spectrum figure shown on **Figure 6**, settlement curves corresponding to preconstruction mudline elevations of -2 FT NAVD88 and -3 FT NAVD88 represent the majority of the existing bathymetric conditions across the project site. As such, the -2 FT NAVD88 to -3 FT NAVD88 preconstruction mudline elevations were of interest during these analyses. An interpolated settlement curve is included below (Figure 34).

Figure 29 and **Figure 30** both show the performance of a +4 FT NAVD88 pump elevation with a preconstruction mudline elevation of -3 FT NAVD88. Although the -3 FT NAVD88 contour does not represent the majority of the preconstruction mudline elevations across the project site, this was analyzed first as a critical case. Settlement Curve 2 of 5 differs only from Settlement Curve 1 of 5 in that a longer infill period of 45 was utilized rather than the 30 day period used in Curve 1. This was based on an analysis of hydraulic dredging production rates for past CPRA projects using a smaller dredge size as is expected for TE-0117 project site. Comparing between **Figure 29** and **Figure 30**, the modification of the infill rate parameter from a 30-day infill period to a 45-day infill period resulted in an increase in TY20 settled elevation of approximately 0.5 FT (see Table 10).

The first two settlement analyses assisted the team in better understanding the sensitivity of the infill rate parameter. Also during this time, GEO had begun performing preliminary containment dike slope stability analyses, to vet the feasibility of constructing containment dikes that would support high pump elevations, such as +4 FT NAVD88. This is further discussed in **Section 6.4.5**. As discussed in **Section 8.3**, a target CMFE of +3.0 FT NAVD88 was ultimately selected for design, which is best represented in **Figure 31** and **Figure 32**. Note that both of these analyses utilized the modified infill rate parameter of 45 days, to better represent likely hydraulic dredge production, due to the access limitations at the TE-0117 project site. Past CPRA projects show that 3-4 FT of access depth can support mobilization of low production hydraulic cutterhead dredge, such as 16-18" dredges and plant. These typically have production rate of around 5,000 t 10,000 CY/day.

Although shown to achieve a TY20 elevation within the desired percent inundation range, a multiple lift analysis was done for Settlement Curve 5 of 5 (**Figure 33**). GEO was instructed to perform this final settlement analysis by utilizing a period of inactivity between lifts of 100 days. This was done to represent a possible construction scenario, where a second lift may be applied to one of the marsh creation cells containing a few isolated locations of deep mudlines (-3 FT NAVD88). The 100 day period of inactivity was selected based on assumed hydraulic dredge production throughout the remaining portions of the project site. The thought process for Settlement Curve 5 of 5 was to perform such an analysis on a sufficiently late implementation of a possible second lift, to see if the TY20 settled elevation would be above the 20% inundation threshold. As shown, this was not the case.

As discussed in this section, the settlement curves shown in **Figure 31** (+3 FT NAVD88 pump, -2 FT NAVD88 mudline) and **Figure 32** (+3 FT NAVD88 pump, -3 FT NAVD88 mudline) are the most representative of site conditions. To better represent the settlement regime across the project site, **Figure 34** below shows an interpolated settlement curve, where the settled elevations between both runs were averaged for each timestep. This curve corresponds to a -2.5 FT NAVD88 preconstruction mudline elevation, with a +3 FT NAVD88 pump elevation.

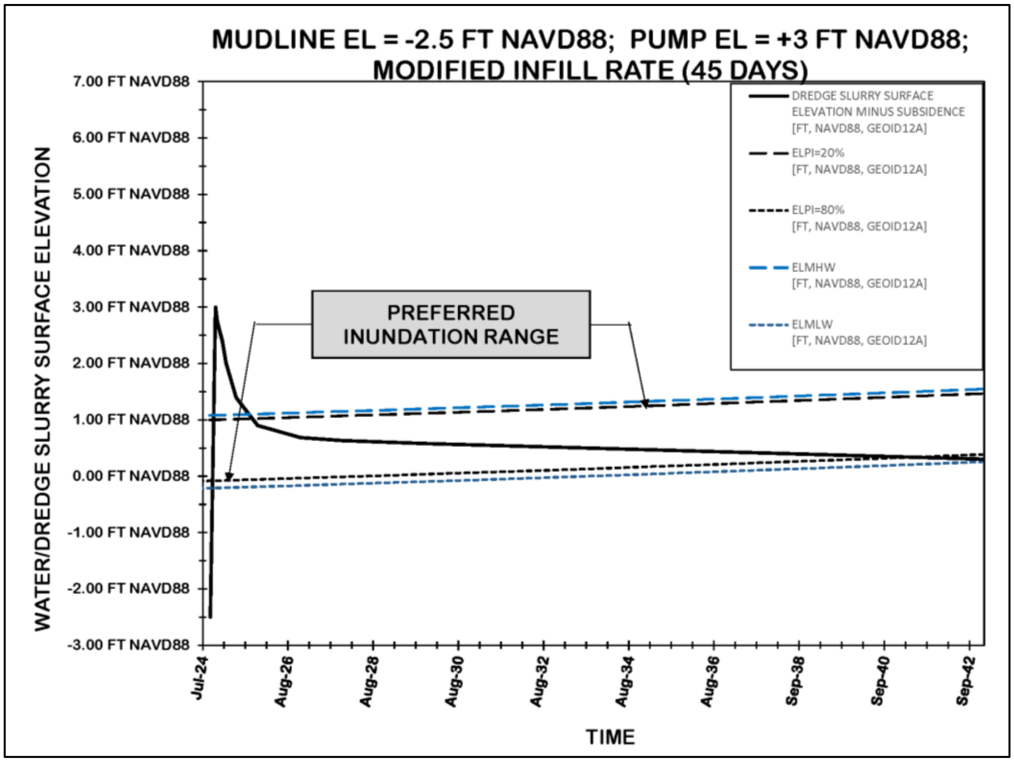


Figure 34: Interpolated Settlement Curve

The supplementary marsh creation area geotechnical engineering report included in **APPENDIX K** contains more in-depth information on the settlement analyses performed by GEO, along with the Addendum Report submitted in 2021.

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 35** 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.

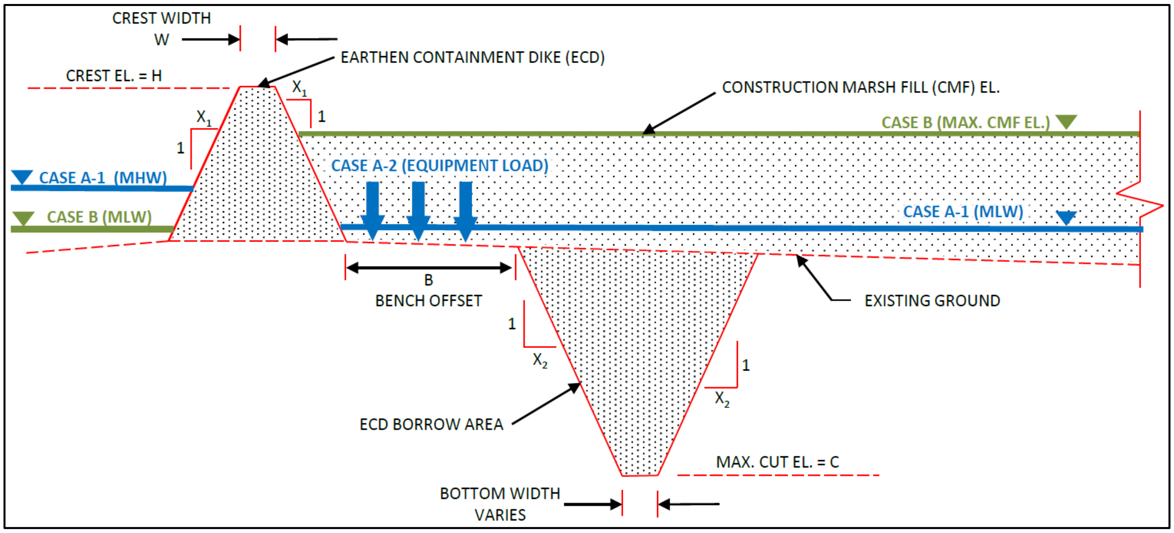


Figure 35: ECD Typical Section

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.

For 30% design, two (2) optimized ECD designs were presented, which differed only in the recommended bench offset distance. This difference was based on the two (2) subsurface design profiles developed by GEO (discussed in **Section 6.4.2**, see also **APPENDIX K**), which represented portions of the project site containing different surficial soil strata—with one design profile showing higher strengths and greater stability due to the presence of silts, while the other showed lower strengths due to thicker layers of weak and compressible soils. This approach was later refined in 95% design, in order to better design for containment dike alignments proposed along the weaker portions of the project site. See the TE-0117 30% design report for more details on the previously proposed ECD dike design.

Containment dike stability analyses were performed iteratively, similar to marsh fill settlement analyses. Although some portions of the project site showed constructible dikes up to crest elevations of + 5 FT NAVD88, a crest elevation of +4.5 FT NAVD88 was determined to be the governing maximum dike build across the project site. Note that the iterative process used for containment dike slope stability analyses was occurring while marsh fill analyses were ongoing, which assisted in the selection of target CMFE.

For the majority of the project site, containment dike side slopes of 1V:4H up to +4.5 FT NAVD88 crest elevations satisfied the minimum factor of safety criterion of 1.2, as per the CPRA MCDG, Appendix B. For two (2) reaches of containment dike along the north and west sides of MCA2, analyses demonstrated that side slopes of 1V:4H did not meet the 1.2 factor of safety. GEO re-analyzed these sections at side slopes of 1V:5H up to +4.5 FT NAVD88, and factors of safety were met. These two (2) 1V:5H side slope dike sections were located in the weaker portions of the project site, as discussed above. Additionally, these two (2) 1V:5H side slope dike sections were designed with symmetrical external borrow to be utilized, which also met CPRA's factor of safety requirements. **Figure 36** below shows sample output from SLOPE-W analysis software during geotechnical analysis. **APPENDIX K** contains more in-depth information on the ECD slope stability analyses performed by GEO.

Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Cohesion Fn	Phi' (°)
CH (-10 to -20)	Spatial Mohr-Coulomb	104		130 psf to 215 psf	0
CH (-20 to -23)	Spatial Mohr-Coulomb	97		215 psf to 240 psf	0
CH (-23 to -40)	Mohr-Coulomb	97	240		0
CH (-40 to -50)	Mohr-Coulomb	108	240		0
CH (-5 to -7)	Mohr-Coulomb	85	80		0
CH (-7 to -10)	Mohr-Coulomb	85	110		0
Containment Dike	Mohr-Coulomb	71	60		0
PT (GS to -5)	Spatial Mohr-Coulomb	72		0 psf to 80 psf	0
PT (GS to -5) (mudwave)	Mohr-Coulomb	72	0		0

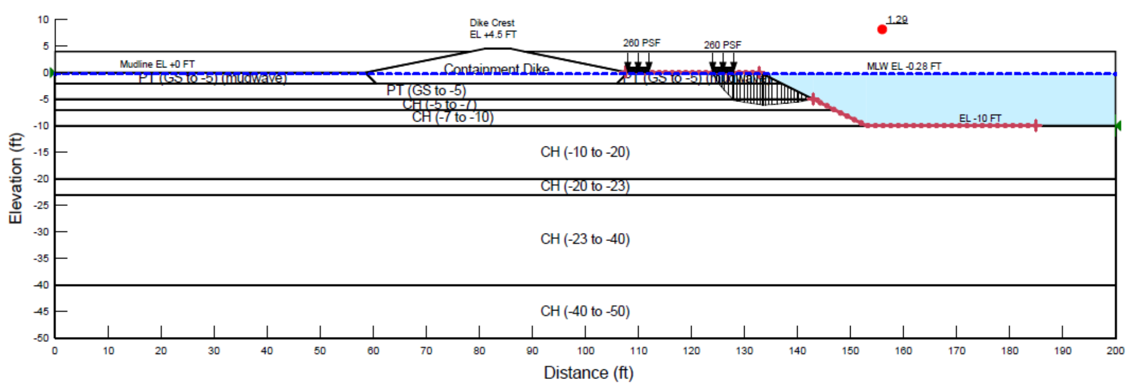
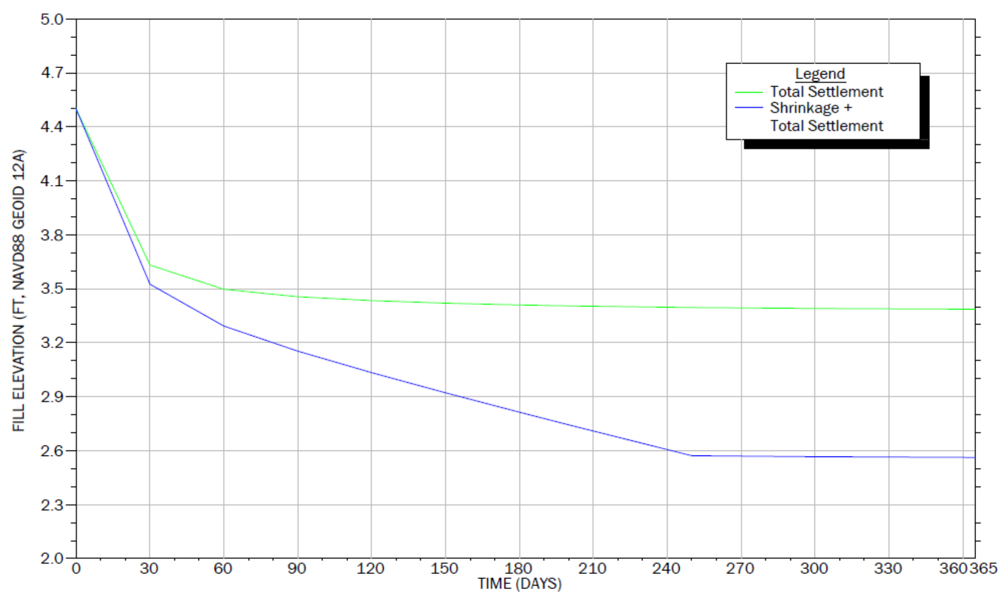


Figure 36: Sample SLOPE-W Output

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. ECD elevations of +4.5 FT NAVD88 were analyzed for earthen containment dike settlement. **Figure 37** and **Figure 38** show sample settlement curve outputs for ECD settlement.



FILL ELEVATION (FEET NAVD88)							
	INITIAL FILL PLACEMENT	6 MONTHS	1 YEAR	3 YEARS	5 YEARS	10 YEARS	20 YEARS
TOTAL SETTLEMENT	4.5	3.4	3.4	3.4	3.4	3.4	3.4
SHRINKAGE + TOTAL SETTLEMENT	4.5	2.8	2.6	2.6	2.6	2.6	2.6

ECD Crown Elevation vs. Time
Mudline El. 0 ft., Crown El. +4.5 ft.

Island Road Marsh Creation and Nourishment
(TE-117)
Terrebonne Parish, Louisiana

GEOENGINEERS **Figure C-1**

Figure 37: Sample ECD Settlement – 1 of 2

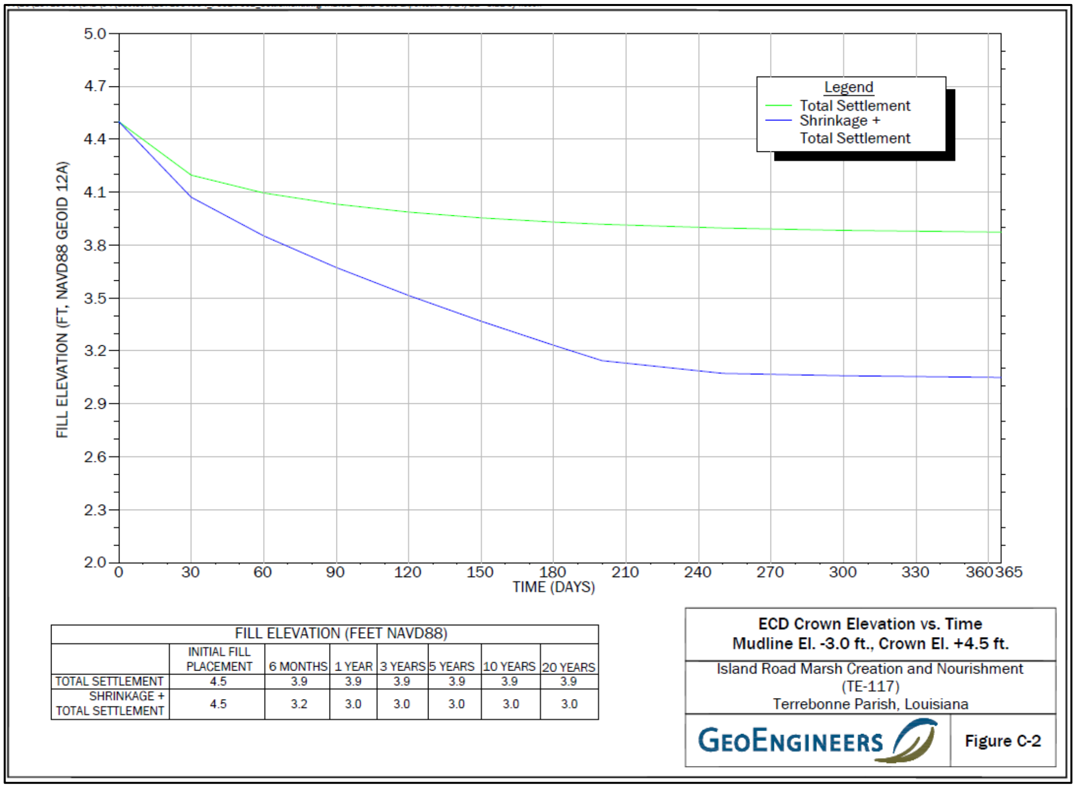


Figure 38: Multiple Lift ECD Sample Settlement Curve Array, TY0 – TY3

6.4.6 Alternate Gap Closure System Geotechnical Engineering Analyses

During 30% design, a sheetpile/embedment sand closure was designed to close off a -11 FT NAVD88 segment of containment dike reach. At 95% design, it was decided to eliminate the location in MCA3 that called for the alternate closure system design. See the 30% design report for more information.

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 26**). 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. Once findings were available from pilot tests, full scale settling column testing could then be executed to complete the long-term dredge slurry settling column analysis. This was a direct contributor to the settlement analyses performed, by using this laboratory data in determining the self-weight consolidation characteristics of the assumed dredge slurry.

6.5 Cut-to-Fill Recommendations

6.5.1 General

The below sections detail out the design decision-making involving cut-to-fill ratios utilized for TE-0117 project design.

6.5.2 Cut-to-Fill Ratios Utilized for 30% Design

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.

During 30%, a cut-to-fill ratio was 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.

A cut-to-fill ratio was also applied for all hydraulic dredging. 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.

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-fill ratio of

0.25:1) can occur. In the case of TE-0117, geotechnical conditions 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. However, the unknown in all projects is the role that fine-grained dredge fill particles play in attributing losses during dewatering. See **APPENDIX J** and **APPENDIX K** for more information on cut-to-fill ratios.

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 three (3) separate marsh creation areas shown in the figure below by hydraulically dredging sediment from an open water borrow area in Lake Tambour. The 95% 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, borrow area design, and equipment access/dredge pipe corridor design. See **Figure 39**.

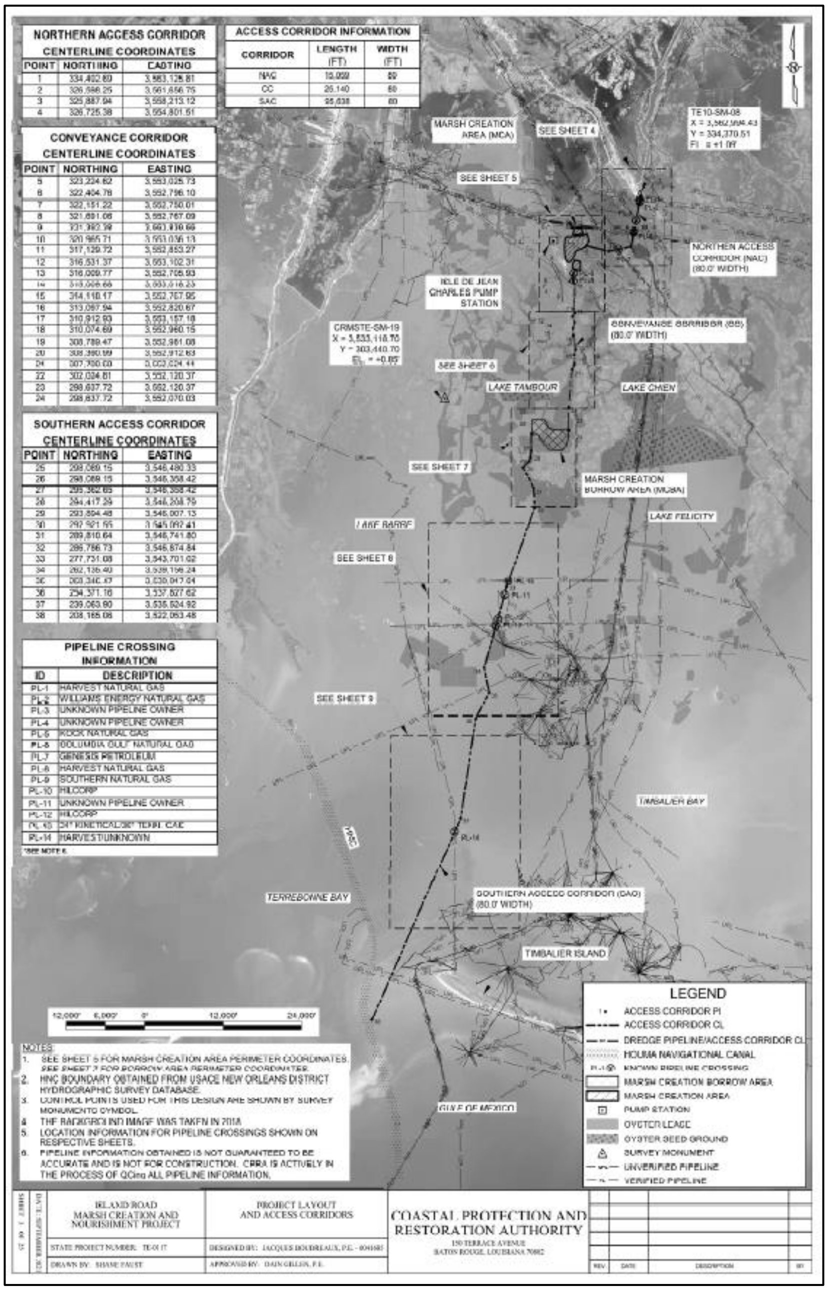


Figure 39: TE-0117 Project Layout

8.2 Engineering and Design Methodology

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 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;
- 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
- 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.

8.3 Marsh Creation Area Design

The configuration of the marsh creation areas went through five (5) alternative layouts during Phase I before arriving at the current configuration shown in the 95% Design Drawings (**APPENDIX M**, **Figure 8**). The first four alternatives are discussed more in-depth in the TE-0117 30% Design Report.

Marsh creation area design involved determining an appropriate CMFE. CMFE is governed by several factors including the tidal range, percent inundation, elevations of reference marsh plots within the site vicinity, 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. This entailed 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, the preferred percent inundation range is expected to rise approximately 0.5 FT, as discussed in **Section 4.3**.

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.

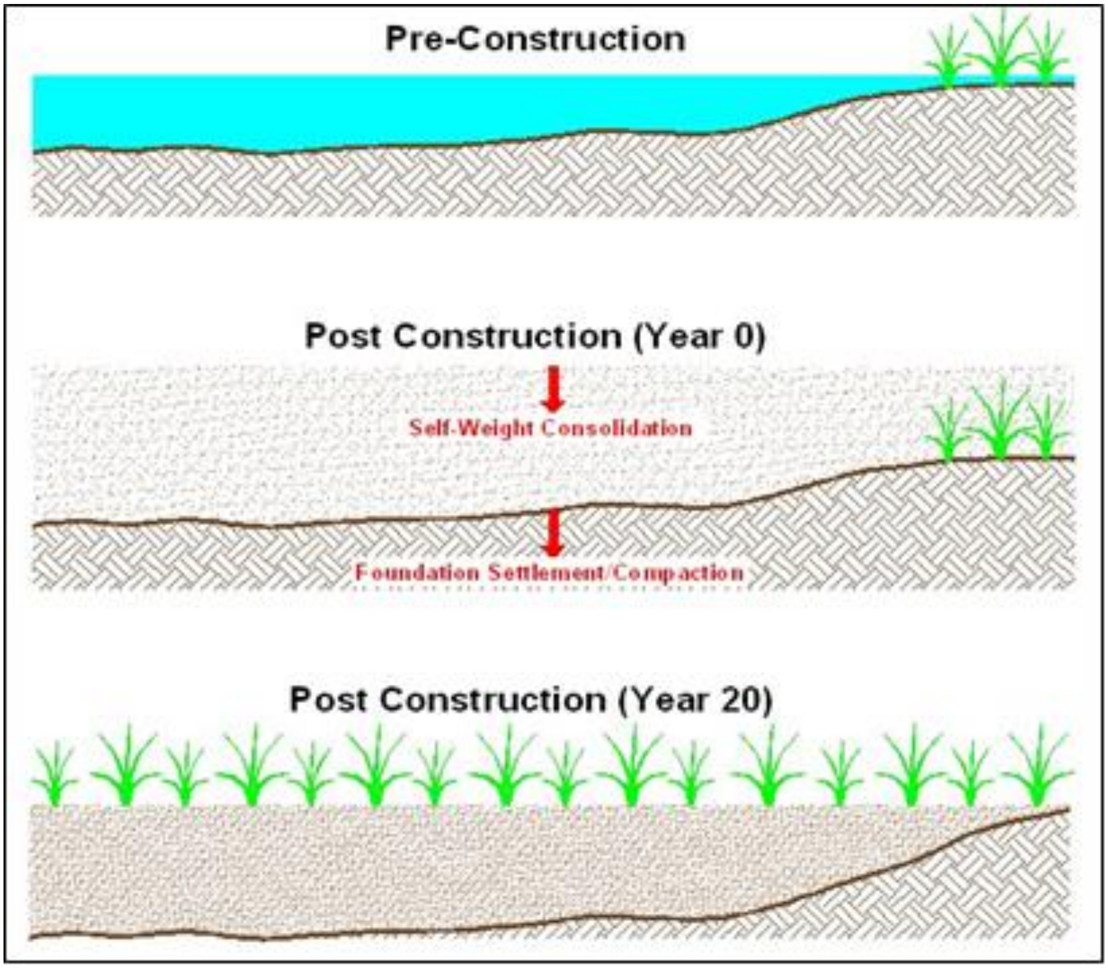


Figure 40: Marsh Fill Settlement Schematic

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 areas will be pumped to a target CMFE of +3.0 FT NAVD88. Note that the 95% design drawings call for a +/- 0.25’ construction tolerance, meaning the marsh fill could be pumped anywhere between +2.75 and +3.25 FT NAVD88.

The currently proposed marsh creation area layout calls for a total of three (3) 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 43**.

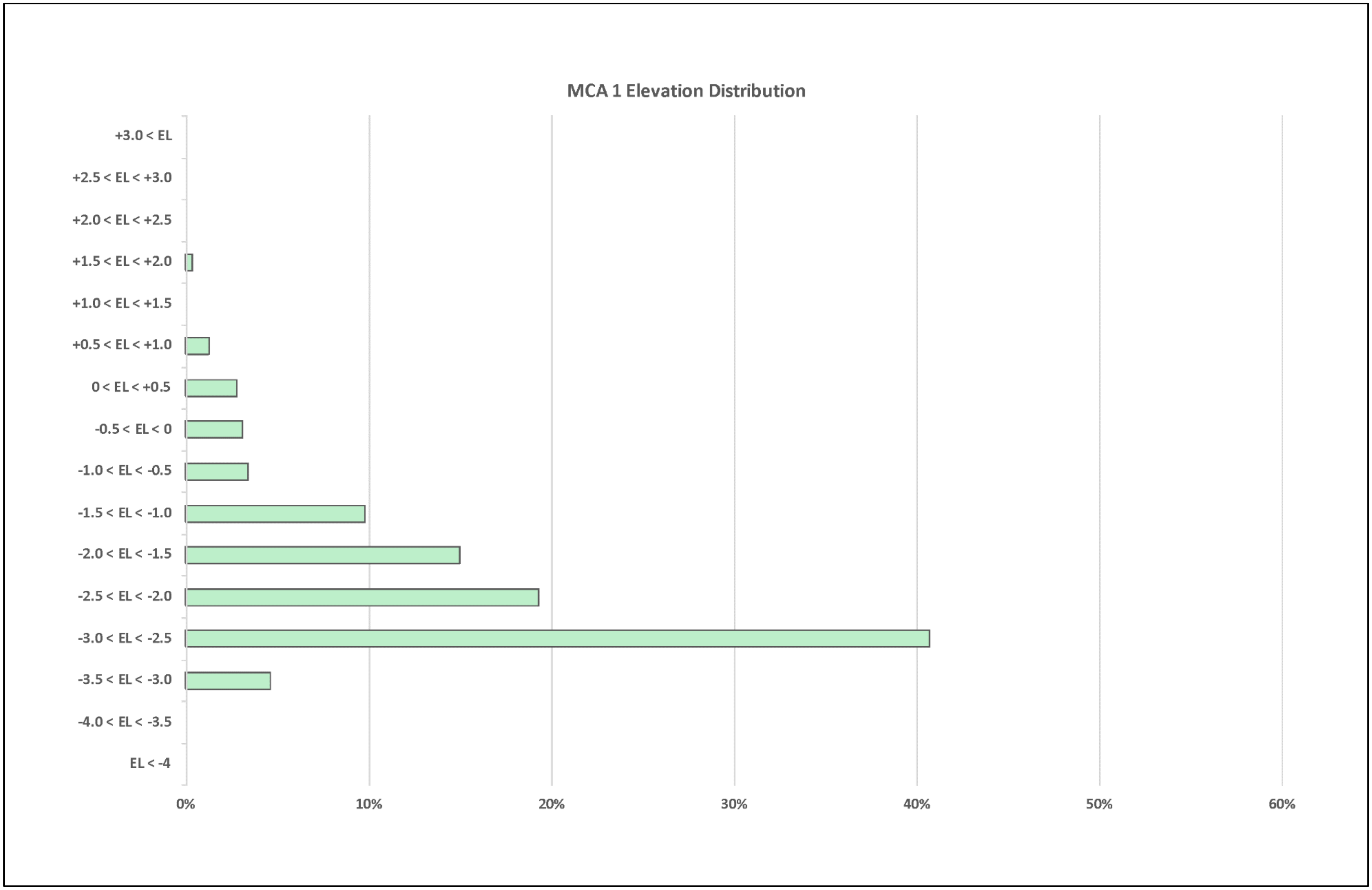


Figure 41: MCA1 Histogram of Existing Mudline Elevations

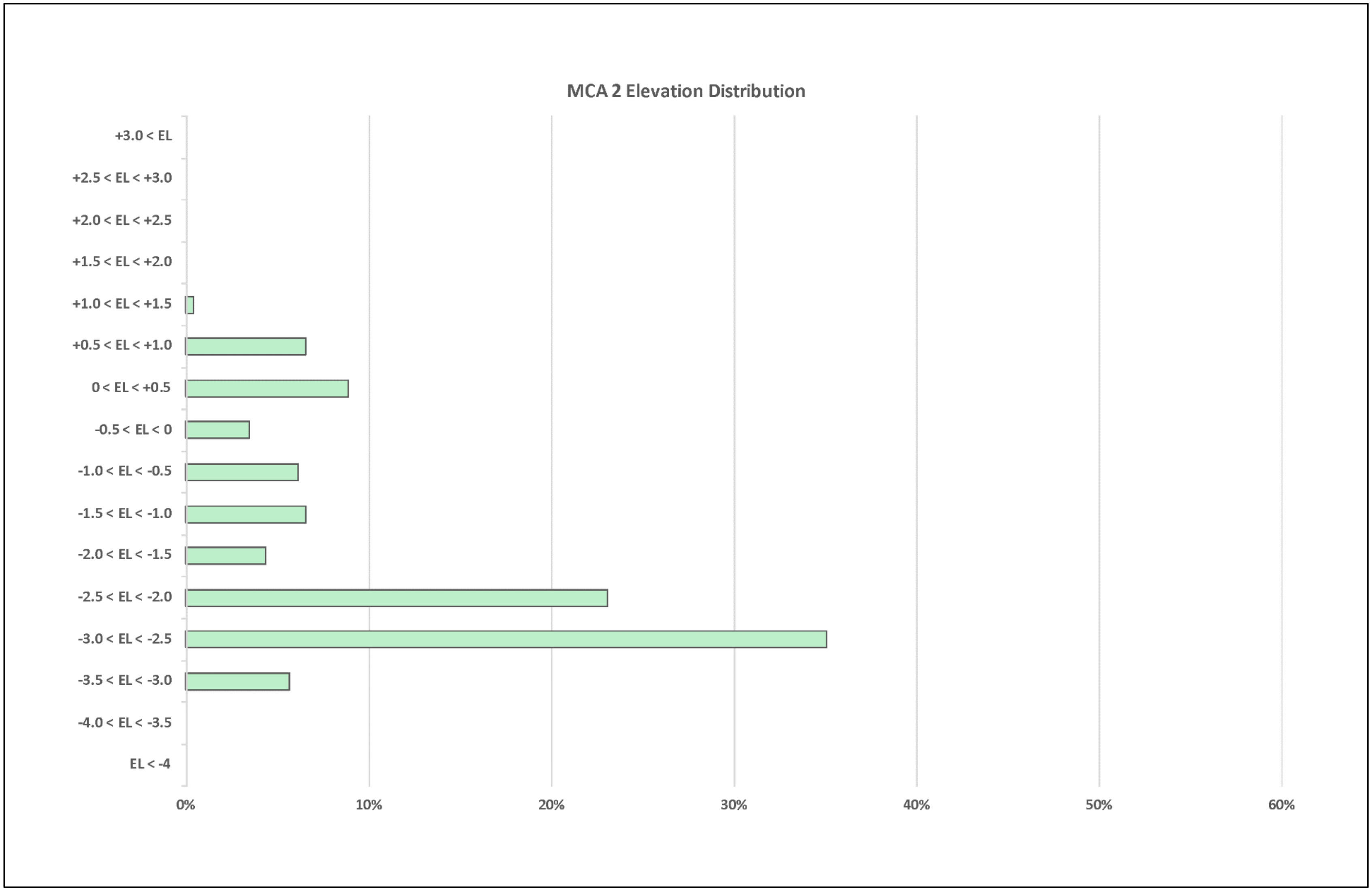


Figure 42: MCA2 Histogram of Existing Mudline Elevations

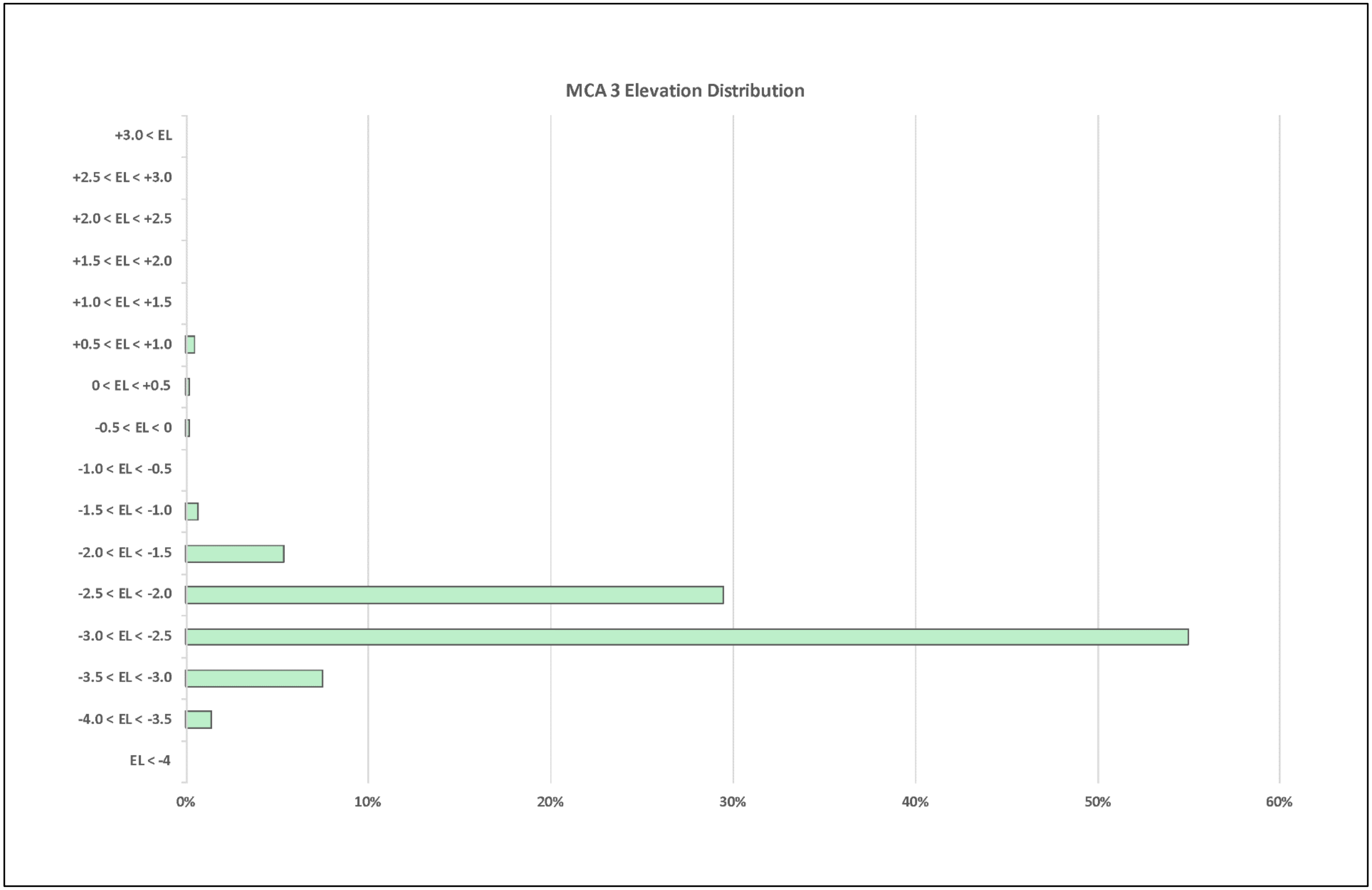


Figure 43: MCA3 Histogram of Existing Mudline Elevations

As observed from the above-shown figures, the majority of the existing mudline elevations are between the -2.5 FT NAVD88 and -3.0 FT NAVD88 elevation contours. As shown below in **Table 11**, the mean and median are provided for each marsh creation area along with cumulative average mean and median elevation values.

Table 11: Statistical Elevation Values for Existing Mudline Elevations

MCA ID	Mean Elevation [FT NAVD88]	Median Elevation [FT NAVD88]
MCA1	-2.12	-2.50
MCA2	-1.95	-2.50
MCA3	-2.58	-2.60
Cumulative Avg.	**-2.22**	**-2.53**

In order to calculate volumes, it was necessary to select a representative preconstruction mudline elevation for each marsh creation area. Based on the above information, a preconstruction mudline elevation of -2.5 FT NAVD88 was deemed acceptable for all marsh creation areas.

Though the final constructed fill elevation of the marsh fill area will be +3.0 FT NAVD88, volume calculations were determined at 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. In order to do this, the PSDDF output for the TY20 settled elevation was used to determine the final settled CMFE.

As shown in **Section 6.4.3**, several geotechnical settlement curves were analyzed throughout design. **Figure 31** and **Figure 32** depict two settlement analyses, both having pump elevations of +3.0 FT NAVD88, with **Figure 31** showing a preconstruction mudline elevation of -2 FT NAVD88, while **Figure 32** shows -3 FT NAVD88. In order to calculate volumes for the selected preconstruction mudline elevation of -2.5 FT NAVD88, an interpolation was performed between the two TY20 settled elevations. Interpolating between the two TY20 settled elevations, a settled elevation of +0.68 FT NAVD88 was utilized for volume calculations. Note this value does not factor in subsidence.

As shown in the above-mentioned settlement curves, 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.

Foundation soil settlement was also factored into the volume calculations. GEO determined that *up to* 0.4 FT of subgrade settlement could be seen for the two settlement cases of interest. 0.32 FT of subgrade settlement was selected for use in TE-0117 design, which was consistent with the estimated magnitudes of subgrade settlement provided by GEO. Adding 0.32 FT to the +0.68 FT NAVD88 settled elevation, volume computations were performed using AutoCAD Civil software for a settled elevation of +1.0 FT NAVD88.

Since the interior containment borrow must be also be refilled, dike backfill material was also incorporated into the volume computation. This was done by obtaining the containment dike fill template in AutoCAD and then multiplying the in-place dike volume by a 1.5:1 cut-to-fill ratio.

Next, the sum of in-place marsh fill volume (excluding subgrade settlement and dike backfill), assumed dike backfill volume, and assumed subgrade settlement were computed for each cell. The final step was then to multiply these sums by the hydraulic dredging cut-to-fill ratio of 1.2:1. Cut volumes for each marsh creation area are shown in **Table 12**, along with the final estimated contract volume for each cell. See **Figure 44** through **Figure 46** for plan and profile drawings of the marsh creation areas for TE-0117.

Table 12: Marsh Creation Area Design Quantities

MCA ID	Acreage [AC]	In-Place Marsh Fill Volume Plus Subgrade Settlement (Excluding Dike Backfill) [CY]	Dike Backfill Volume (C:F = 1.5:1) [CY]	Sum of In-Place + Dike Backfill [CY]	Total Cut Volume (C:F = 1.2:1) [CY]	Estimated Contract Volume [CY]
MCA1	38	141,645	41,607	183,252	219,902	220,000
MCA2	219	718,903	118,820	837,723	1,005,268	1,005,000
MCA3	38	186,245	36,818	223,063	267,675	278,000
Total	**295**	**1,046,793**	**197,245**	**1,244,038**	**1,492,845**	**1,503,000**

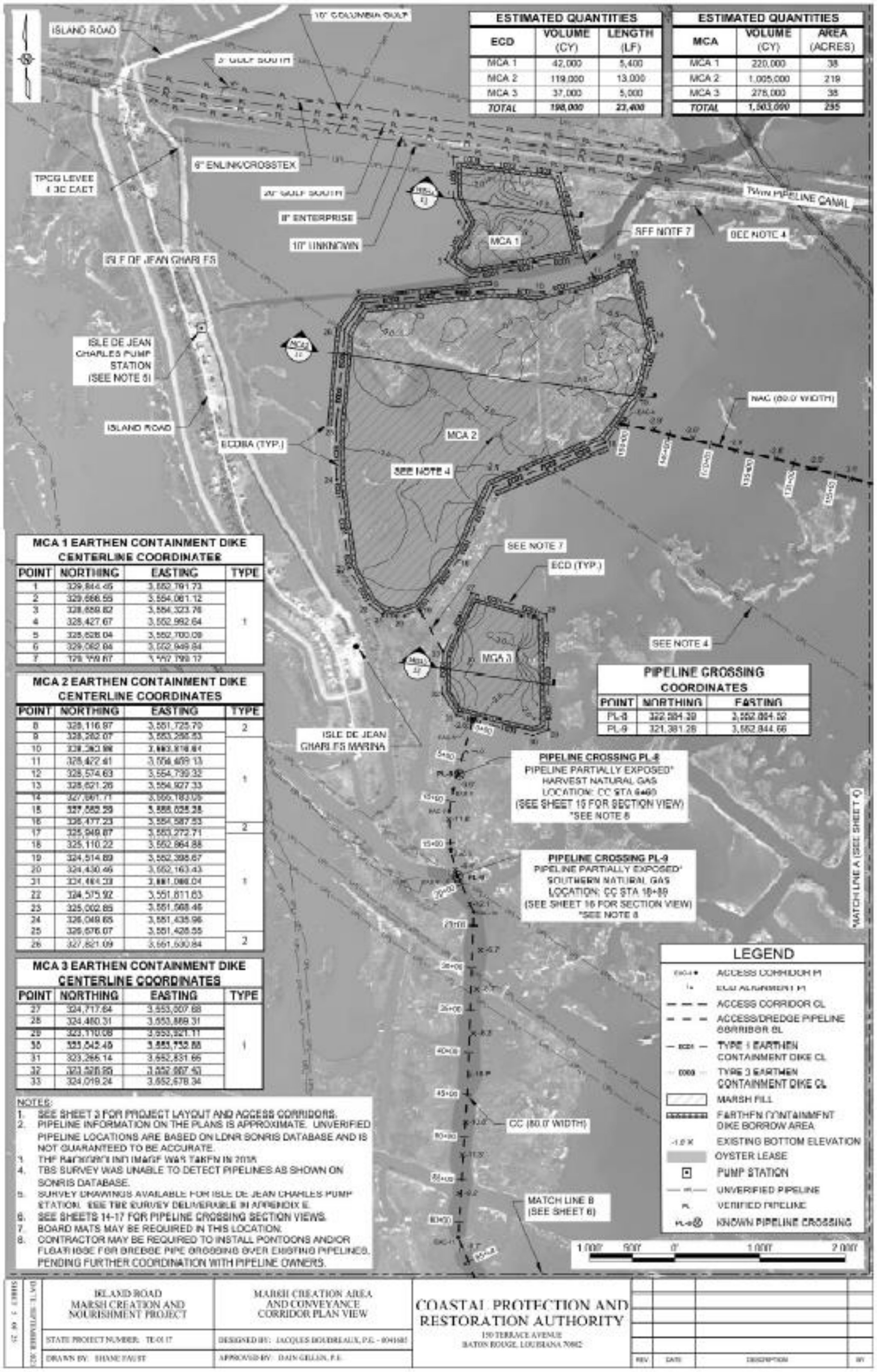


Figure 44: Marsh Creation Area Design, Plan View

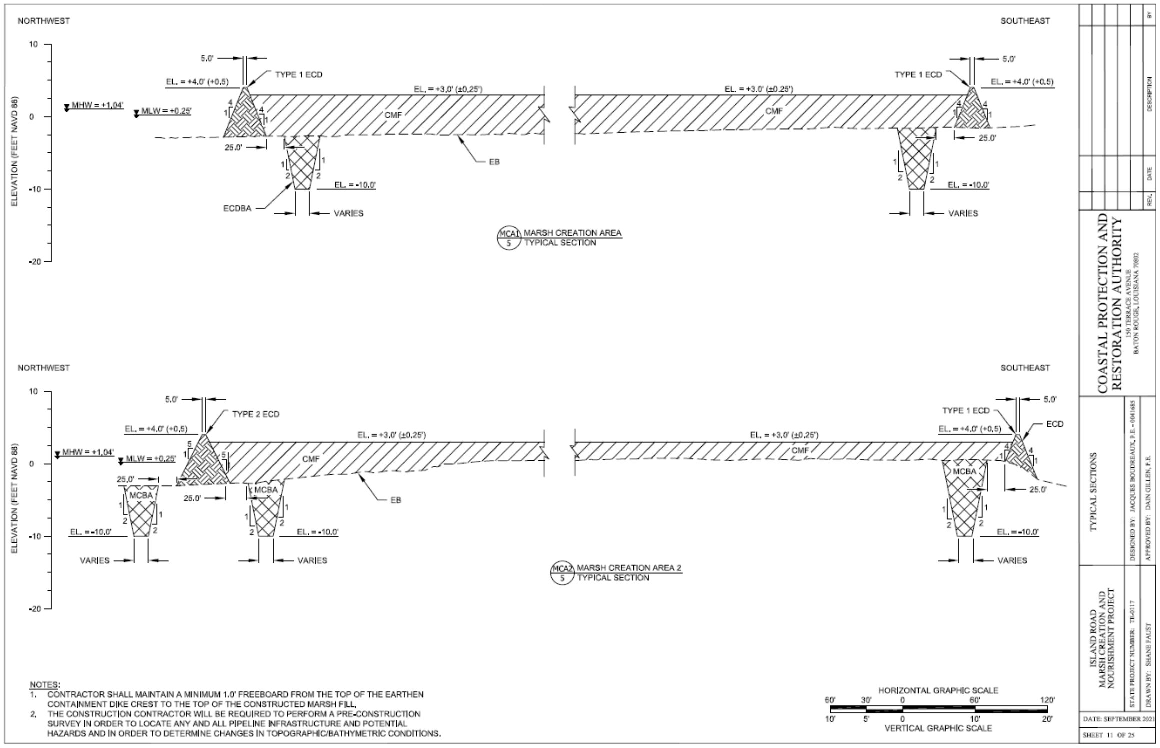


Figure 45: Marsh Creation Area Design, Typical Sections (1 of 2)

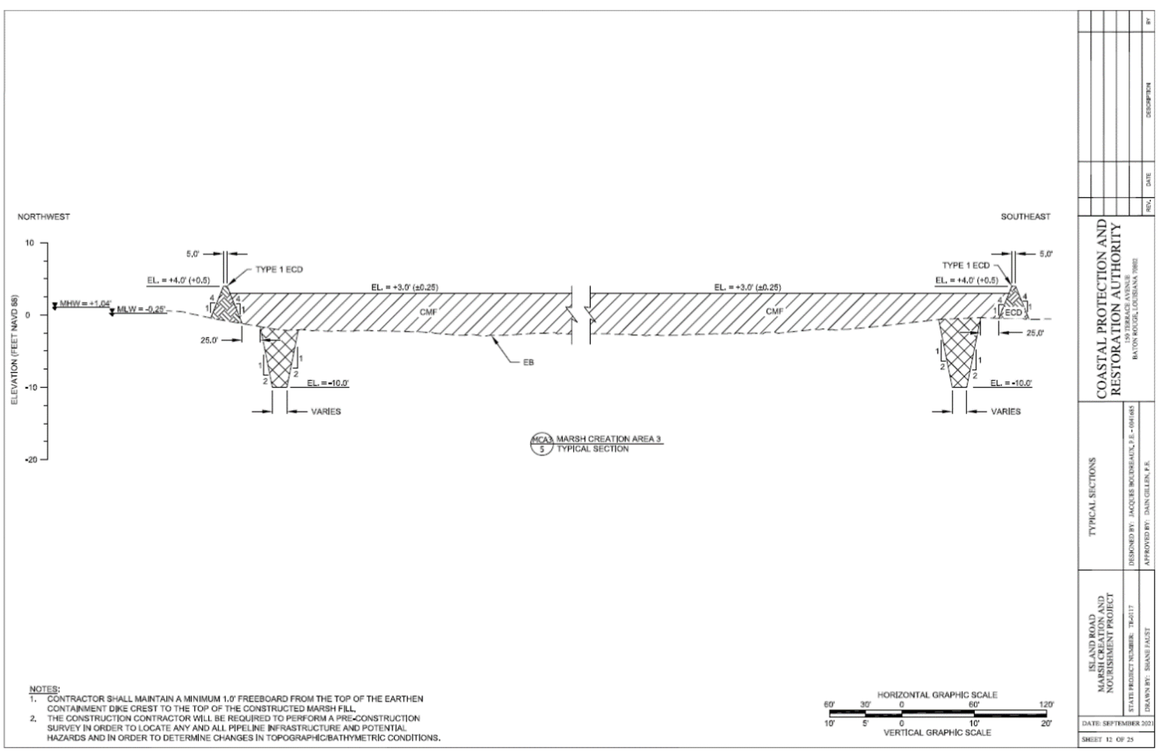


Figure 46: Marsh Creation Area Design, Typical Sections (2 of 2)

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 1.0 FT 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 target ECD crest elevation is +4.0 FT NAVD88, with an allowable positive 0.5 FT tolerance, meaning a maximum dike build of +4.5 FT NAVD88. The crown width will be 5 FT.

For sections shown throughout the project site as TYPE 1 containment dike, the design calls for side slopes of 1V:4H (4 feet horizontal for every foot of vertical rise). Interior dike borrow separated by a 25' stability berm is required. For sections shown throughout the project site as TYPE 2 containment dike, the design calls for 1V:5H side slopes with dual interior/exterior borrow, also to require a 25' stability berm for both borrow pits. **Figure 45** and **Figure 46** contain typical section drawings that depict the ECD design for TE-0117. Note the shown containment dike types in the typical section for MCA2 in **Figure 45**.

8.4 Borrow Area Design

As shown in **Table 12**, the total required borrow volume needed to create the as-proposed marsh creation is approximately 1.50M CY. This value was obtained by multiplying the sum of the total in-place marsh creation area volume, including dike backfill volume and foundation soil settlement, 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. Note that a significant amount of volumetric contingency is offered by the as-designed borrow area. **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)	1,503,000
-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

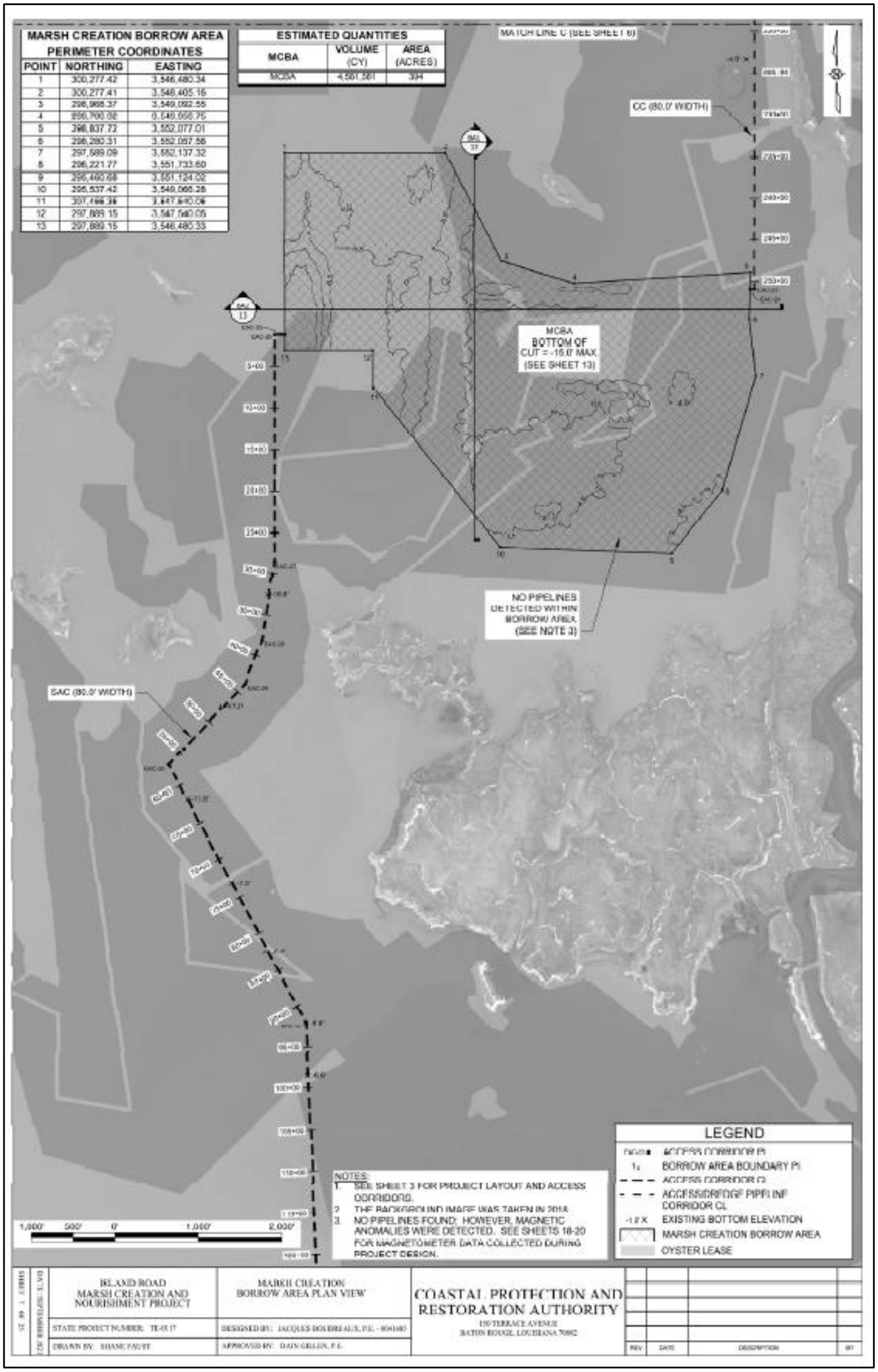


Figure 47: Borrow Area Design, Plan View

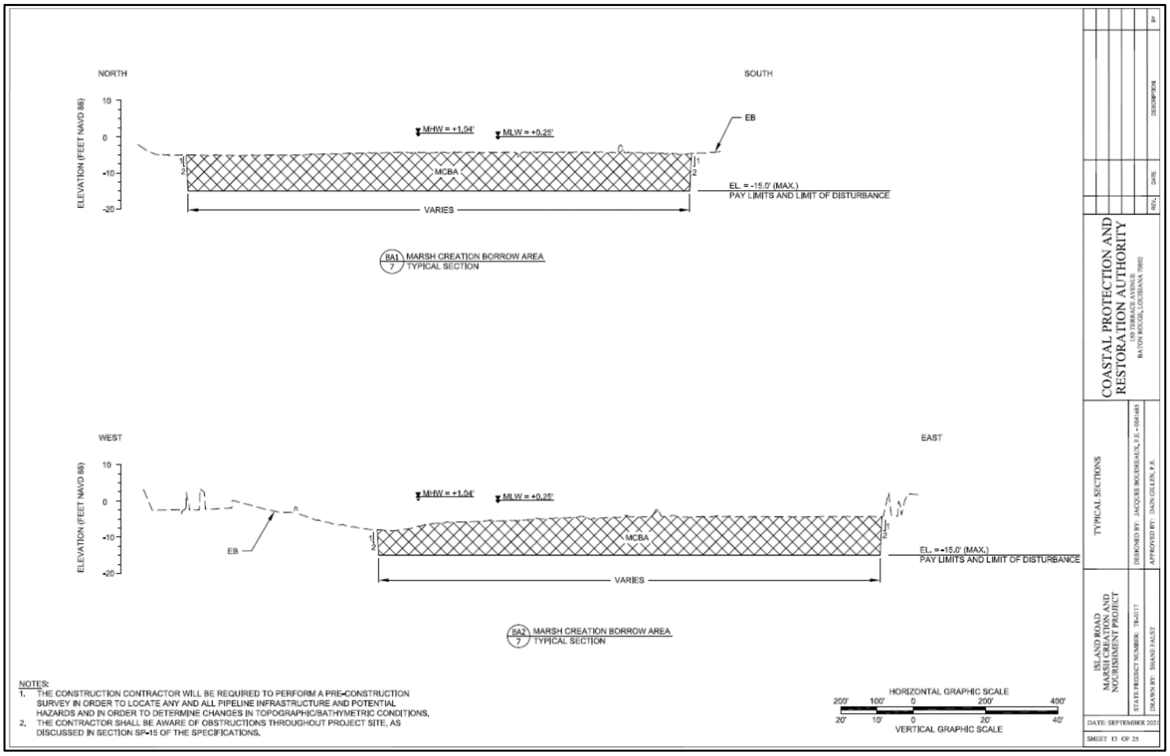


Figure 48: Borrow Area Design, Profile View

8.5 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). During 30%, extensive access dredging was proposed. This has been eliminated for 95% due to the draft depth limitations allowing only 16-18" hydraulic cutterhead dredges and plant, as a way to achieve the slower infill rates analyzed in the settlement analyses. There are also a total of 14 pipeline crossings identified along the various access corridors of TE-0117. This will require careful coordination and will further the need for equipment with low draft. 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.) • Includes a total of seven (7) pipeline crossings; see **Section 5.4** for pipeline information
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 • Includes a total of two (2) pipeline crossings; see **Section 5.4** for pipeline information
Southern Access Corridor (SAC)	• Intended for use as deep drafting vessel access corridor such as draglines, hydraulic dredge • Access from borrow area to HNC and navigable waters in Terrebonne Bay/Gulf of Mexico • Includes a total of five (5) pipeline crossings; see **Section 5.4** for additional information

9.0 CONSTRUCTION

9.1 Duration

An approximate construction duration was developed using the University of Texas Agricultural and Mechanical College Center for Dredging Studies (CDS) Dredge Production and Cost Estimation Software and Microsoft Project. Assuming a 16-18 inch hydraulic cutter suction head dredge and incorporating weather days, a total construction time from mobilization to demobilization is approximately 424 days. Previously, an analysis was done assuming production rates commensurate with 24 inch hydraulic dredging capability, which yielded approximately 400 days. Note that mobilization, demobilization, and mechanical dredging was also incorporated into this estimate of construction duration.

9.2 Cost Estimate

An Engineer's Estimate of Probable Construction Cost Plus Contingency was prepared for this project using the CWPPRA PPL 31 spreadsheet, CPRA Bid Tabulations of past projects, the CDS Dredge Unit Rate Cost Estimation Spreadsheet, and additional CPRA developed cost estimation spreadsheets. The estimated construction cost has been provided to the CWPPRA Engineering Workgroup in the current PPL 31 format.

9.3 Draft Construction Specifications

As per CWPPRA Standard Operating Procedures (SOP), it is required to submit as part of a 95% design submittal a draft set of construction specifications. This has been provided to NOAA as part of 95% design review.

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 the Twin PIpelines to present a more constructible project for consideration of Phase II funding. Specific modifications include the relocation of marsh creation areas, relocation of the borrow area, and a revision to the equipment access and dredge pipe corridor alignments. The reasons for modifications since Phase 0 are mudline elevations, soils, pipelines and utilities, inlet/outlet for a pumping station, pumping distance, and avoidance of oyster resources. The project area has been reduced from 383 acres to 295 acres and the estimated net acres have been reduced from 312 to 206 (-34%). A similar amount of reduction in cost occurred. Pursuant to Section 6.h.(2) of the CWPPRA Standard Operating Procedures (ver. 27), a change in request appears necessary for the TE-0117 project. A change in scope request is proposed for the September 3, 2021, Technical Committee meeting.

11.0 MODIFICATIONS FROM 30% DESIGN

Throughout Phase I, the TE-0117 project underwent several changes to all project features. Between the 30% milestone and the 95% milestone, refinement was made to the marsh creation area configuration that resulted in a reduction in number of marsh creation cells from a total of four (4) separate cells to a total of three (3). This was performed in order to eliminate a parallel dike configuration between two previously proposed cells, thereby conjoining the two into one larger cell. Additionally, modifications to fill site geometries were made such that unnecessary points of inflection were eliminated, as well as an elimination of a portion along MCA3 that called for an alternate sheeptile closure structure. Access dredging, having been previously proposed during 30% design, was eliminated for 95%. The benefit acreage increased from 292 acres at 30% design to 295 acres at 95% design. The cost also decreased between 30% and 95% design.

See **APPENDIX N** for all comments received following the TE-0117 30% design conference. The TE-0117 project team's responses are also included.

12.0 REFERENCES

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