SYNERGISTIC APPROACH TO RESTORING THE CAMINADA HEADLAND

A. Taylor\textsuperscript{1}, S. Dartez\textsuperscript{2}

ABSTRACT

The Caminada Headland is a 13 mile long beach, dune, and back barrier marsh located southeast of Port Fourchon in Barataria Basin and serves as a vital piece of protection for one of the nation’s top ports. Years of storm impacts exacerbated the already high beach loss rate and significant prolonged breaches greatly increased the net export of sediment from the headland. In addition to the shoreline migration, the interior marshes were quickly being converted to open water resulting in more loss of sediment as the beach and dune continue to migrate landward. Beginning in the early 2000s, plans began to restore the beach, dune, and interior marshes. Due to funding limitations, restoration of the Headland was segmented into four different projects. Two beach and dune restoration projects totaling approximately 10 million cubic yards of sand and two back barrier marsh creation projects totaling approximately 2.6 million cubic yards of mixed sediment were designed and either constructed or will be constructed within the next year.

This case study will focus on the challenges of the design and construction of the beach and dune projects and on the design and upcoming construction of the back-barrier marsh creation components and lessons learned throughout the process.

Keywords: Hydraulic dredging, beach and dune restoration, marsh creation, Ship Shoal, Barataria Basin Barrier Shoreline Restoration Study

INTRODUCTION

The Caminada Headland is a barrier headland that has evolved through the years of deltaic evolution, reforming a coastal feature created by deposition of Mississippi River sediment carried to the Gulf of Mexico by several distributaries, primarily Bayou Moreau, that meandered across the Lafourche Delta lobe prior to its abandonment about 1,000 years before present. After active delta growth slowed and ceased, normal coastal processes became dominant, and the shoreline-shaping activity shifted to an erosional phase, reworking the sediment deposits by lateral transport, aeolian transport, and overwash (CEC, 2012). Due to the impacts from tropical storms and hurricanes and subsidence and sea level rise, the beach and dune developed numerous breaches over time allowing for saline water to intrude upon historic freshwater lakes and marshes. Much of this marsh that lies between the headland and Louisiana Highway 1, the main hurricane evacuation route for the city of Grand Isle, is now interrupted by larger areas of open water. As the beach and dune continues to migrate landward, overwashed sediments are lost into the newly formed open water and land loss rates are exacerbated (CEC, 2012).

Restoration plans for the Caminada Headland began as part of the Barataria Basin Barrier Shoreline Restoration Study (BBBS), a large-scale joint study between the USACE New Orleans District and the State of Louisiana. This area was deemed essential for restoration because of its ability to act as protection for interior coastal wetlands, providing significant ecosystem value for wildlife and fish, and providing the foundation for economically valuable commercial and recreational fisheries (SJB, 2008 and USACE, 2011). The continued deterioration of the Caminada Headland and the associated back barrier marshes threatened thousands of acres of critical wetland habitat as well as existing infrastructure such as Port Fourchon, LA Highway 1, and the lower Lafourche levee system (CEC 2012). Figure 1 shows the basis of design for the beach, dune and back barrier marshes from the BBBS preferred alternative.

\textsuperscript{1} Project Engineer, Louisiana CPRA, 150 Terrace Avenue, Baton Rouge, LA 70802, USA, T: 225-342-9419, Fax: 225-342-6801, Email: amanda.taylor@LA.GOV.

\textsuperscript{2} Managing Engineer, Coastal Engineering Consultants, Inc., 8570 Anselmo Lane, Baton Rouge, LA 70810, USA, T:225-768-1982, Email: sdartez@ceci-la.com
The goals of the beach and dune projects are to restore approximately 12 miles of beach and dune with sand dredged from Ship Shoal, which is approximately 27 nautical miles away, to restore the barrier shoreline from Belle Pass to Caminada Pass. The restored barrier shoreline is used to reduce wave energy and saltwater intrusion into the back barrier environments, including chenier ridges, marshes, and bays. Restoration of the Headland barrier shorelines provides a sediment source to sustain barrier beaches along the Headland (CEC, 2012).

Funding for the design and construction of the two increments of the beach and dune projects came from two different funding sources. The first increment was authorized for design and construction through the Coastal Impact Assistance Program (CIAP) and 2008 State of Louisiana Surplus funds. The second increment was authorized for design and construction through the National Resource Damage Assessment (NRDA). Coastal Engineering Consultants, Inc. (CEC) served as the designer and Engineer of Record for both increments of the project.

**Caminada Beach and Dune Increment 1**

CEC evaluated three templates for increment one of the beach and dune in order to optimize project performance and maximize ecosystem restoration benefits. Numerical modeling was used to quantify sediment transport along the Headland over a long-term period as well as storm erosion losses and storm damage reduction benefits (CEC, 2012). The final template was determined based on the BBBS template, the numerical modeling, and fiscal restraints. Figure 2 shows the final template designed and constructed.
Caminada Beach and Dune Increment 1 Design

The data collection effort for increment one of the beach and dune involved topographic and bathymetric surveys, geotechnical analysis of the headland and the borrow area, and a review of the various coastal processes that have effects on the behavior of the sediment placed such as wind, wave, currents, tides, sea level rise, and sediment transport. This information was then utilized to determine the fill template, including the beach width, dune width, dune height, and volume needed to fill the template, the borrow area, and the conveyance corridors.

Since the entire BBBS footprint included restoring nearly 13 miles of beach and dune, the main driver behind the design of increment one was available budget. Alternative analyses were performed by CEC on the three alternatives utilizing the Generalized Model for Simulating Shoreline Change (GENESIS) and the Steady State Spectral Wave (STWAVE) model to evaluate performance of different fill templates over time. Based on the models, the preferred alternative maintained a wider beach on average and was sustainable longer than the other two alternatives. Since sediment transport is a major factor in the overall performance of the beach and dune, the preferred alternative placed a higher quantity of sand along the barrier shoreline reaches exhibiting the highest erosion rate compared to the other templates (CEC 2012). The design summary of the construction fill template is shown in Table 1. The construction template included a one-foot tolerance to account for initial construction compaction, consolidation, and settlement. Additionally, a gulfward beach slope construction tolerance of 1V:40H was provided from mean low water seaward to account for construction inaccuracies, sediment variability, and profile adjustment (CEC, 2012).
Table 1. Beach and Dune Increment 1 Fill Template Summary

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (ft)</td>
<td>25,500</td>
</tr>
<tr>
<td>Dune Typical Width (ft)</td>
<td>290</td>
</tr>
<tr>
<td>Beach Typical Width (ft)</td>
<td>65</td>
</tr>
<tr>
<td>Target Dune Elevation (ft NAVD88)</td>
<td>+7.0</td>
</tr>
<tr>
<td>Target Beach Elevation (ft NAVD88)</td>
<td>+4.5</td>
</tr>
<tr>
<td>Required Fill Volume (MCY)</td>
<td>2.88</td>
</tr>
</tbody>
</table>

The borrow area design included two sand lease blocks in the eastern end of Ship Shoal. Ship Shoal is an east-west elongated sand body approximately 40 miles in length and varies between two and six miles in width, and is the remnant of a barrier headland and island deposited during a previous Mississippi River delta-building event (CEC, 2013). Though the borrow area is approximately 27 nautical miles away, it was chosen largely for its geotechnical properties, which include having approximately 98% sand with a mean grain size of 0.19 mm on average and having sediments highly compatible with the native beach sediments (CEC, 2012). Utilizing the fill template sand quantity calculations, a design dredge cut of -43 ft NAVD88 with a 2 foot allowable overdredge was delineated within these sand lease blocks. Two potentially cultural sensitive areas and multiple pipelines were excluded from the borrow area yielding the borrow area shown in Figure 3.

![Figures 3. South Pelto Borrow Area in Ship Shoal.](image)

Due to the distance between the proposed borrow area and the fill template, it was impractical to assume material could be directly pumped to the Headland; therefore, five areas near the restoration area were designed and designated as potential pump-out areas. These areas would allow for hopper dredges or scow barges to move sand from the pump-out area to the Headland using sediment re-handlers. Design for these areas included mainly surveys to ensure the area was deep enough to allow access for a fully-loaded hopper or scow without access dredging and to ensure no pipelines, wells, or culturally sensitive areas were present within the pump-out area or the conveyance corridor (CEC 2013).
**Caminada Beach and Dune Increment 1 Construction**

Construction on increment one began in March 2013 and was completed in January of 2015. Throughout the construction duration, many obstacles and firsts were encountered for the project team. As previously mentioned, the borrow area was located approximately 27 nm from the restoration area, so multiple excavation and transportation methods were used to convey the material. The first method used a cutterhead dredge in the Ship Shoal borrow area to excavate material and place it into scow barges that were then towed to the restoration area and offloaded using a hydraulic unloader to place the material on the Headland. The second method was utilizing a hopper dredge to excavate material from the borrow area, transport the material to one of the pump-out areas, and pump it to the Headland (CEC, 2015).

Multiple challenges needed to be overcome during construction including navigational traffic, a tropical storm, nesting birds, and existing projects and features in the restoration area. Due to the close proximity of the restoration area to Port Fourchon, extra precautions were taken to ensure the pump-out area within Belle Pass was adequately outside of the vessel navigational channel. Coordination between the Contractor and the Port was required to ensure safe travel for both the vessels and the scows.

During construction, a tropical storm made landfall near the project site. Since the project was in construction when the storm made landfall, a new pre-construction survey was required and the template design had to be reevaluated. The analysis determined that the impacts were minimal with an estimated volume loss of approximately 81,000 CY (CEC, 2015).

The Caminada Headland has historically been a productive habitat for several migratory and wintering birds, and specifically the Lease Tern (CEC, 2015). During the nesting period, approximately February to September, abatement methods such as windmills, decoys, or noises needed to be used to ensure birds would not nest near the active construction zone. If a bird nest was discovered, a buffer would have been enforced and no work would have been allowed within the buffer. Coordination between CPRA, CEC, and USFWS was had to determine when an area was clear for construction. Fortunately, only one nesting incident impacted the construction but had no impact on the timeline of the project.

The final as-built features included 3.6 MCY placed along approximately 31,000 linear feet of shoreline. Habitat acreage increased from approximately 240 acres to 375 acres as a result of the construction (CEC, 2015). Vegetative plantings were performed along the dune by a CPRA contractor in July 2015.

**Caminada Beach and Dune Increment 2**

As with increment one, CEC was contracted as the designer and Engineer of Record for the second increment of the beach and dune. Increment two’s footprint started where increment one’s footprint ended and continued approximately 7.4 miles eastward to Elmer’s Island as shown in Figure 4.
Caminada Beach and Dune Increment 2 Design

Shortly before the survey of increment two, Hurricane Isaac made landfall near the project area. Topographic and bathymetric surveys were not only taken in the increment two footprint but also along the increment one footprint, which was finalizing design and would begin construction early the next year. Geotechnical investigations were conducted by GeoEngineers in support of the project design. Consolidation curves were developed for the fill design template and compared to results of nearby projects to determine the profile evolution over time (CEC, 2013).

Based on the data collected from increment one and increment two, four major modifications were incorporated into the final design of the restoration area. First, part of the western segment of the preliminary design for the second increment was built with increment one. Second, due to the effects of Hurricane Isaac, the template had to reconfigured to address the erosion that had occurred. Third, a background erosion of two years was computed to account for the uncertainties in construction timing. Lastly, a fill extension was designed to complete the full beach and dune design template on the eastern end of the restoration area to allow for flexibility at the time of bidding if funding is available (CEC, 2013). The design summary of the construction fill template is shown in Table 2.

Table 2. Beach and Dune Increment 2 Fill Template Summary

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (ft)</td>
<td>39,000</td>
</tr>
<tr>
<td>Dune Typical Width (ft)</td>
<td>290</td>
</tr>
<tr>
<td>Beach Typical Width (ft)</td>
<td>65</td>
</tr>
<tr>
<td>Target Dune Elevation (ft NAVD88)</td>
<td>+7.0</td>
</tr>
<tr>
<td>Target Beach Elevation (ft NAVD88)</td>
<td>+4.5</td>
</tr>
<tr>
<td>Required Fill Volume (MCY)</td>
<td>4.94</td>
</tr>
</tbody>
</table>
All but one of the increment two pump-out areas and conveyance corridors were utilized for increment one. The borrow area was contiguous with the borrow area for increment one with similar permitted dredge depths. Due to various potential cultural resource targets and identified oil and gas infrastructure, the borrow area footprint is irregularly shaped as shown in Figure 5 and was estimated to have over six million cubic yards.

Figure 5: Increment 2 Ship Shoal borrow area.

Caminada Beach and Dune Increment 2 Construction

Construction on increment two began in February 2015 and was completed in January 2017. The same two transportation methods utilized for increment one was used for increment two since the borrow area was in roughly the same location as the first increment.

Many of the challenges present during increment one construction were present for increment two’s construction. The most notable difference, however, was the impacts from Hurricane Isaac. Increment one was surveyed along with the increment two template to determine what design changes, if any needed to occur as result of the hurricane. It was discovered that the fill template adjusted to a natural angle of repose of 1V:25H, which gave the designer the ability to reduce the needed fill quantity by approximately 300,000 CY (CEC, 2017).

The other big issue that came up during construction was public access. Elmer’s Island to the east of the project area was open to the public during daylight hours. Historically, vehicle access was allowed to the beach, but since construction was ongoing, access was limited to pedestrian access only (CEC, 2017).

The final as-built features for the beach and dune included utilizing 5.2 MCY of sand to construct approximately 39,000 feet of shoreline. Habitat acreage increased from 460 acres to approximately 690 acres as a result of the construction of the second increment (CEC, 2017). Vegetative plantings of the dune was completed in June 2017 through a CPRA contract to further improve the longevity of the project.

Lessons Learned

Since there were two increments of the beach and dune, lessons from increment one’s construction were implemented for increment two. Based on the construction methods and material properties of increment one, a slope adjustment
was designed to reduce the fill volume needed. The reduction in fill volume allowed for the same fill template originally designed to be built more efficiently. Similarly, fill requirements were optimized for increment two in the vicinity of existing projects or existing features due to experiences on increment one (CEC, 2018).

Due to the beach and dune projects being the first project to utilize Ship Shoal as a borrow area, design and construction restrictions were put in place to minimize potential impacts to the environment and species living near it. Since the borrow is in federal waters, a sand lease has to be procured from BOEM (Bureau of Ocean Energy Management). This lease allows for work to be done within the leased area for 2-years. One of the other main restrictions in place when working particularly with the hopper dredge was the sea turtle relocation trawling. Coordination between CPRA, BOEM, and NMFS resulted in stipulations set in place to handle relocation of sea turtles encountered near the borrow area while using the hopper dredge (CEC, 2018).

Experience gained by the project team, contractor, and other stakeholders will be used for future beach and dune projects to implement Louisiana’s Coastal Master Plan.

**BACK BARRIER MARSH CREATION**

The goals of the back barrier marsh creation projects are the create and nourish approximately 1,000 acres of intertidal marsh with sediment dredged from an offshore borrow area to create a platform for which the newly-constructed beach and dune can migrate, reducing the likelihood of breaching, improving the longevity of the barrier shoreline, and protecting wetlands and infrastructure to the north and west. In addition to providing protection, the back barrier marshes will provide critical habitat for many bird, animal, and plant species native to coastal Louisiana.

Due to funding limitations, the back barrier marsh creation design was separated into two Coastal Wetland Planning, Protection, and Restoration Act (CWPPRA) projects. In both projects, the Environmental Protection Agency (EPA) served as the Federal Sponsor and CPRA served as the designer/Local Sponsor. The basis of design for both projects was the BBBS and the CPRA Marsh Creation Design Guidelines (CPRA, 2017).

**Caminada Back Barrier Increment 1**

The original goals for the increment one project included restoring approximately 420 acres of intertidal marsh adjacent to increment one of the beach and dune project. The footprint included filling the marshes closest to Port Fourchon and Bayou Lafourche, a large portion of the historic Bay Champagne, and the southern extent of Bayou Moreau. In addition to filling these areas, two pipeline canals run parallel through the project area. Surveys of these canals showed that the northernmost canal was greater than five (5) feet deep in many areas throughout the footprint. Consequently, this canal was excluded from the final footprint in order to maximize acreage created with funding limitations. By excluding the canal and analyzing the geotechnical data, the final footprint for increment one was increased to 471. Figure 6 shows the spatial changes to the footprint from original design to present.
Caminada Back Barrier Increment 1 Data Collection

Since extensive data collection and work has been performed in the past along the Headland, the data collection efforts were greatly reduced. Through the use of CPRA’s consultant contracts, surveys, geotechnical data, and borrow area modeling were performed to fill in any data gaps identified after review of existing data.

Topographic, bathymetric, and magnetometer surveys of the proposed fill area and areas outside of the fill area were completed by Morris P. Hebert to identify potential design and construction obstacles such as deep areas along the proposed containment dike alignment, pipelines and wells, and natural or man-made features. Topographic and bathymetric surveys identified multiple design challenges such as areas where mudlines were -4 ft NAVD88 and deeper as well as many rock dikes and wooden barriers installed by landowners and pipeline companies. The magnetometer survey verified the existence of three pipeline corridors, and the pipelines within each corridor were probed for depth of cover, which ranged from approximately 5 foot of cover to 8 feet of cover. A cultural resource investigation was performed on the proposed fill area, and no known culturally significant areas were identified (MPH, 2016).

As a part of the BBBS, a 500 acre area in the Gulf of Mexico approximately 1.5 miles from the shoreline was investigated for potential use for borrow, and as part of the beach and dune projects, two dredge pipeline corridors
were identified from the borrow to the fill area. A cultural resource investigation was performed for the borrow area and dredge pipeline corridors, and no known culturally significant areas were identified. As part of the back barrier marsh creation projects, bathymetric and magnetometer surveys were performed on these previously-identified features, and multiple pipelines and significant magnetometer anomalies were discovered in the middle of the 500 acre proposed borrow area. Due to the depth of the water in the borrow area probing of the pipelines for depth of cover was not practical.

In addition to the survey efforts, two geotechnical exploration efforts were completed to aid in the design. Eustis Engineering collected ten vibracores in the borrow area, classified the material, and performed Atterberg limits and moisture content tests. The borrow material was found to be comprised mainly of clays and silts with few sand lenses (Eustis 2015). Settlement characteristics of the borrow material was then tested using the settling column test and the low-stress consolidation test. This effort was coupled with the fill area geotechnical analysis performed by GeoEngineers, which comprised of eight soil borings, to determine the total settlement of the foundation and slurry. Settlement curves were calculated using the USACE’s PSDDF program for use in design.

GeoEngineers was also tasked with evaluating the stability and settlement of the earthen containment dikes. Twenty-seven Cone Penetrometer Tests (CPTs) were taken along the alignment of the proposed earthen containment dikes. CPTs are a cheaper, quicker alternative to tradition soil borings to determine strength properties of the soil as well as give a good estimate of the soil classification; however, a soil boring must be nearby to correlate the CPT readings (GeoEngineers, 2016). In coordination with CPRA, GeoEngineers utilized the soil strength data and the GeoSlope program, Slope/W to determine stable configurations of the earthen containment dikes. Stable configurations are defined as having a minimum factor of safety of at least 1.2 in each of the cases shown in Table 2 (CPRA, 2017, GeoEngineers, 2016). Settlement of the earthen containment dikes was computed using the Settle3D program, and that information was used to design appropriately sized earthen containment dike borrow areas.

Table 2: Slope stability example for each of the three stability cases.

<table>
<thead>
<tr>
<th>Case</th>
<th>Description</th>
<th>Factor of Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Global stability during borrow excavation</td>
<td>1.317</td>
</tr>
<tr>
<td>B</td>
<td>Global stability during marsh construction</td>
<td>1.209</td>
</tr>
<tr>
<td>C</td>
<td>Local stability during borrow excavation with equipment surcharge</td>
<td>1.255</td>
</tr>
</tbody>
</table>

In addition to the survey of the borrow area, a wave modeling effort was completed by Coastal Engineering Consultants to analyze the potential effects to the shoreline from mining the proposed offshore borrow area. The collected bathymetric data along with water elevations, wave heights, wave period and direction, wind speed and direction, and sediment characteristics were utilized to calibrate the Delft3D model to model wave refraction, sediment transport patterns, and morphological changes along the Headland. Multiple scenarios were run depending on probability of occurrence, and the results concluded that excavation of the proposed borrow area would not have an adverse effect on the Headland (CEC, 2016).
Caminada Back Barrier Increment 1 Design

The collected data was used in the design of the four main components of marsh creation projects: the fill area, the earthen containment dikes, the borrow area, and the dredge pipeline corridors. Figure 7 shows the final project features.

Beginning with the marsh creation fill area, the primary goals are to create a platform which functions as a healthy marsh while providing that platform for the overwashed sediments. The governing factor in achieving these goals is determining the appropriate constructed marsh fill elevation (CMFE). Determining the CMFE takes into account the water levels in the area, relative sea level rise, and the settlement characteristics of the subgrade and dredged slurry. Water level calculations include determining the tidal range as well as the optimal inundation range for the marsh type being created. These values are then added to the projected eustatic sea level rise that will occur over the 20-year project design life. Table 3 details the water level calculations at the time of construction as well as including the eustatic sea level rise.

<table>
<thead>
<tr>
<th>Table 3: Water level results for target year 0 and target year 20.</th>
</tr>
</thead>
<tbody>
<tr>
<td>TY0</td>
</tr>
<tr>
<td>MHW (+0.84 ft, NAVD 88)</td>
</tr>
<tr>
<td>MLW (-0.59 ft, NAVD88)</td>
</tr>
</tbody>
</table>

The other parameter needed to determine the appropriate CMFE is the projected settlement, which was calculated as part of the geotechnical investigation task. Subsidence calculations are typically added to the settlement calculations; however, due to the overwash nature of the Headland and looking at historical data, that component was excluded. The appropriate CMFE was determined to be +2.2 ft NAVD88 in order to achieve both short-term and long-term goals. Volume calculations for the needed fill quantity was based on this CMFE and is detailed in Table 4.

<table>
<thead>
<tr>
<th>Table 4: Construction Summary for Increment 1.</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMFE (ft, NAVD88)</td>
</tr>
<tr>
<td>2.2</td>
</tr>
</tbody>
</table>
Once a CMFE was determined, the earthen containment dike design was finalized. Utilizing the stability and settlement calculations performed during the geotechnical investigation, crown elevations and side slopes were determined to provide a stable configuration that provided a minimum of one foot of freeboard above the dredged slurry. Due to the existence of weaker clays in certain reaches of the earthen containment dike alignment, geotextile fabric is needed to be placed within the containment dike section as shown in Figure 8. Upon completion of the project, the earthen containment dike will be degraded to allow for natural tidal flow to resume (CPRA, 2016).

![Figure 8: Earthen containment dike typical containing geotextile fabric.](image)

The final two features involved in the marsh creation design are the borrow area and the dredge pipeline corridors. The most important factor in the design of those features for this particular project was the presence of multiple pipelines. The 500 acre borrow area was delineated into two 200 acre borrow areas each having more than 3 MCY of material, which is well more than the needed fill quantity. The dredge pipeline corridors were delineated to allow the Contractor flexibility to work and place his dredge pipe within the 300 foot wide corridor. Restrictions regarding existing pipelines include the requirement to float the dredge pipe over the pipeline and the right of way in order to not disturb the soils. The corridor was restricted to 50 foot wide at the beach and dune to limit the impact footprint to the newly constructed beach and dune (CPRA, 2016).

**Caminada Headland Back Barrier Marsh Creation Increment 2**

The original goals for the increment two project included restoring approximately 440 acres of intertidal marsh adjacent to increment two of the beach and dune project. As with increment one, the northern pipeline canal was excluded due to deeper mudline elevations. In addition to physical barriers present, the original footprint included an area of cultural significance. Special care and design considerations were made to ensure the cultural site would not be disturbed during construction activities. As with increment one, analyzing the geotechnical data allowed for the footprint to be increased while remaining within the allowable budget. The final footprint for increment two was increased to 542. Figure 9 shows the spatial changes to the footprint from original design to present.

![Figure 9: Spatial changes for the Caminada Back Barrier Marsh Creation Increment 2.](image)
Caminada Headland Back Barrier Marsh Creation Increment 2 Data Collection

Due to the close proximity of the increment one project and the relatively short time between increment one’s data collection and increment two’s data collection, much of the data collected for the first effort was able to be used for the second. The borrow area and dredge pipeline corridors were already surveyed and delineated due to the efforts of BBBS and increment one, so the data collection efforts were focused mainly on the marsh fill area.

CPRA tasked HydroTerra Technologies to complete a topographic, magnetometer, and bathymetric survey in the fill area as well as in the marshes exterior to the fill area between the fill area and Elmer’s Island Road. Extension of the survey transects allowed for the possibility to extend the fill area if conditions were favorable (i.e. funding availability, material properties, etc.) allowing for the full template of the BBBS to be completed. As with increment one, multiple pipelines, rock dikes, and man-made structures were identified as a result of the survey. The depth of cover over the pipelines were comparable to the ones identified in increment one, so many of the same design requirements remained in place. A cultural resource investigation yielded one culturally significant site near the northern boundary of the proposed fill area. A buffer around the site was imposed for design and construction.

Since an extensive geotechnical analysis was performed for increment one and that information was able to be utilized, a much smaller effort was tasked to Ardaman & Associates to collect and analyze the soils in the increment two footprint. This effort consisted of mainly CPTs with only a couple of soil borings to correlate the CPTs. Due to the variant nature in which the marshes were created, the subsurface soils of increment two were not similar to the subsurface soils in increment one. Full analysis of the settlement characteristics of the marsh fill was reevaluated, and the resulting settlement curves were calculated.

Earthen containment dike stability and settlement calculations were performed with the same methodology as was performed for increment one. As before, Slope/W was used to determine stable configurations of the earthen containment dike in accordance with the CPRA Marsh Creation Design Guidelines (CPRA, 2017). Table 5 shows the results of the earthen containment dike slope stability analysis (Ardaman, 2017).

<table>
<thead>
<tr>
<th>Case</th>
<th>Description</th>
<th>Factor of Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Global stability during borrow excavation</td>
<td>1.37</td>
</tr>
<tr>
<td>B</td>
<td>Global stability during marsh construction</td>
<td>1.29</td>
</tr>
<tr>
<td>C</td>
<td>Local stability during borrow excavation with equipment surcharge</td>
<td>1.33</td>
</tr>
</tbody>
</table>

Caminada Back Barrier Increment 2 Design

Utilizing the collected data, the marsh creation fill area and earthen containment dikes were designed. The footprint of the marsh creation area is shown in Figure 9 and the footprint of the borrow areas and dredge pipeline corridors can be found in Figure 7. As with increment one, the main goals of the marsh fill area are to create a functioning marsh platform as well as a platform for which the newly created beach and dune can roll back upon. Due to the difference in soil properties between the two increments, the CMFE had to be reevaluated to determine the appropriate construction elevation and the fill quantities were recalculated. Calculations for eustatic sea level rise were updated for the adjusted project design life. Table 6 shows the design water levels for increment two at the construction year and at the end of the 20-year design life. Settlement curves were overlaid on top of the water level data to determine the appropriate CMFE. In order to maximize the benefits of the marsh fill, a CMFE of +2.5 ft NAVD88 was determined and subsequent volume calculations were performed (CPRA, 2018).

<table>
<thead>
<tr>
<th>TY0</th>
<th>TY20</th>
</tr>
</thead>
<tbody>
<tr>
<td>MHW</td>
<td>+0.74 ft, NAVD88</td>
</tr>
<tr>
<td>MLW</td>
<td>-0.18 ft, NAVD88</td>
</tr>
</tbody>
</table>

The calculated quantities for increment two can be found in Table 7.

<table>
<thead>
<tr>
<th>CMFE (ft, NAVD88)</th>
<th>Area (Acres)</th>
<th>Volume (CY)</th>
</tr>
</thead>
<tbody>
<tr>
<td>+2.5</td>
<td>542</td>
<td>1,180,911</td>
</tr>
</tbody>
</table>

Table 5: Slope stability example for each of the three stability cases.

Table 6: Water level results for target year 0 and target year 20.
Once marsh fill elevations were determined, the earthen containment dike design was finalized. Soil conditions along the earthen containment dike alignment of increment two are considerably stronger than those of increment one. Therefore, additional measures, such as the geotextile fabric needed in increment one, were not needed to construct stable containment dikes having at least a minimum of one foot of freeboard above the dredged slurry. As with increment one, the dikes will be gapped or degraded completely to allow for tidal exchange within the newly-created marsh.

Increment two will utilize the borrow area and dredge pipeline corridor delineated for increment one.

**Lessons Learned**

As with many designs, unforeseen challenges occur throughout the design process that require adaptability. One of the biggest challenges of working in an ever-changing environment is the multiple environmental concerns needing to be addressed during design. The back barrier marshes are home to multiple protected species including the piping plover and the lease tern. During data collection, nests were identified in the proposed project area, and data could not be collected within a set radius of the nest. This requirement forced the designer to modify the design based on the limited data or to make correlations in accordance with the CPRA Geotechnical Standards to complete the designs (CPRA, 2017).

Construction in the vicinity of pipelines is something almost every project in coastal Louisiana has to deal with. In the case of the back barrier marsh projects, two main pipeline canals are found parallel through the fill areas, and the Louisiana Offshore Oil Pipelines (LOOP) run perpendicular to the fill area. Designing containment in the vicinity of active pipelines requires multiple considerations for protecting those involved. Multiple alternatives were considered for construction for increment one including hay bale cores, sand cores, and multi-lift construction in the vicinity of the pipeline. Ultimately, the design included excavation of material outside of the pipeline right of way and double handling the material to build the containment over the pipeline. This option proved to be the cheapest and preferred option in coordination with the pipeline operators (CPRA, 2018).

Lessons learned through the design of the back barrier marshes will be utilized for future marsh designs to implement the Louisiana Coastal Master Plan.

**Back Barrier Marsh Construction**

Construction of the back barrier marsh projects has not commenced at this time; however, plans and specifications are being developed to construct both projects under one contract to allow for the entire template to be functioning marsh at the same time. Benefits to this method of construction include being able to fully complete the template for storm protection, capturing the overwash sediments from the beach and dune, and potentially being able to construct the projects for a cheaper cost overall due to not having to bid out two separate projects years apart.

Monitoring the performance of the marsh platform would be greatly benefitted by the projects being constructed simultaneously. Instrumented settlement plates will be placed within the marsh and water level data as well as data regarding the soil pressures will be monitored throughout construction as well as in the few years post-construction. Having the entire template placed at once allows for more accurate monitoring and allows for comparisons to be drawn between the two projects.

**CONCLUSIONS**

The construction of the four Caminada Headland restoration projects presented many challenges and learning opportunities that will be carried forward into future designs and construction. The use of new technologies and construction methods allow for better constructed projects, more efficient designs, and better monitoring techniques to shape the future of coastal restoration projects in Louisiana.

**REFERENCES**


**CITATION**