Coastal Protection and Restoration Authority of Louisiana

2023 Operations, Maintenance, and Monitoring Report

for

Bayou Dupont Sediment Delivery Marsh Creation #3 and Terracing (BA-0164)

State Project Number BA-0164
Priority Project List 22

January 2023

Prepared by:
Danielle Richardi, Dr. Theryn Henkel and Barry Richard

Operations Division
New Orleans Regional Office
2045 Lakeshore Drive, Suite 309
New Orleans, LA 70122

Suggested Citation:

Richardi, D.C., T.K. Henkel, and B.J. Richard. 2023. *2023 Operations, Maintenance, and Monitoring Report for Bayou Dupont Sediment Delivery Marsh Creation #3 and Terracing,* Coastal Protection and Restoration Authority of Louisiana, New Orleans, Louisiana. 34 pp. plus Appendices.

Operations, Maintenance, and Monitoring Report
For
Bayou Dupont Sediment Delivery Marsh Creation #3 and Terracing (BA-0164)

Table of Contents

Preface

The Bayou Dupont Sediment Delivery Marsh Creation #3 and Terracing project (BA-0164) was funded through the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA) on the 22th Priority Project List. The United States Environmental Protection Agency (EPA) is the federal sponsor for the project, and the Coastal Protection and Restoration Authority (CPRA) is the state sponsor. This 2023 Operations, Maintenance, & Monitoring (OM&M) report is the first in a series of reports that will summarize BA-0164 monitoring and O&M activities conducted during the 20-year OM&M life of the project. This report includes an assessment of BA-0164 monitoring data available through 2021, and observations from the November 2021 maintenance inspection. Additional documents pertaining to the BA-0164 project may be accessed on CPRA's website at: https://cims.coastal.louisiana.gov/outreach/projects/ProjectView?projID=BA-0164 or on the CWPPRA website at https://lacoast.gov/new/Projects/Info.aspx?num=BA-164.

I. Introduction

The Bayou Dupont Sediment Delivery Marsh Creation #3 and Terracing (BA-0164) project is located on the west bank of the Mississippi River in Jefferson and Plaquemines Parishes, west-northwest of the town of Myrtle Grove, Louisiana (Figure 1). The project area lies between the Plaquemines Parish flood protection levee to the east and Bayou Dupont to the southwest. The northern boundary of the marsh creation areas and the northwest boundary of the terrace field are adjacent to the CWPPRA-funded Mississippi River Sediment Delivery System−Bayou Dupont (BA-0039) marsh creation project, which is also sponsored by the EPA (Figure 1). The BA-0164 project is included in Louisiana's Comprehensive Master Plan for a Sustainable Coast under the Large-Scale Barataria Marsh Creation−Component E, 1st Period Increment (CPRA 2012).

Wetlands in the Barataria Basin were historically nourished by the fresh water, sediment and nutrients delivered by the Mississippi River and its many distributary channels. These inputs ceased following the creation of levees along the lower river for flood control and navigation. In addition, the construction of numerous oil and gas canals, along with subsurface oil and gas withdrawal, has exacerbated wetland loss in the area. From 1932 to 2016, the Barataria Basin lost over 276,000 acres of marsh (Couvillion et al 2017). The rate of land loss within the BA-0164 project area between 1985 and 2011 was -0.486% per year (USGS 2012).

The BA-0164 project used sediment hydraulically dredged from the Alliance Anchorage borrow site in the Mississippi River to build a 144-acre marsh platform in an area of the Barataria Basin that had converted from marsh to shallow open water (Figure 1). The Long-Distance Sediment Pipeline (BA-0043-EB, LDSP) was used to transport the dredged sediment slurry from the river to the project area. One terrace field, containing 14 earthen terraces, was also constructed as part of the BA-0164 project using sediment dredged from within the terrace field (*in situ*). An additional neighboring 128 acres of marsh were constructed with Mississippi River sediment using State surplus and Coastal Impact Assistance Program (CIAP) contingency funds from the BA-0043-EB project. The additional acres are being monitored as part of the BA-0164 project and for the purpose of this report, should be considered part of BA-0164 unless otherwise noted.

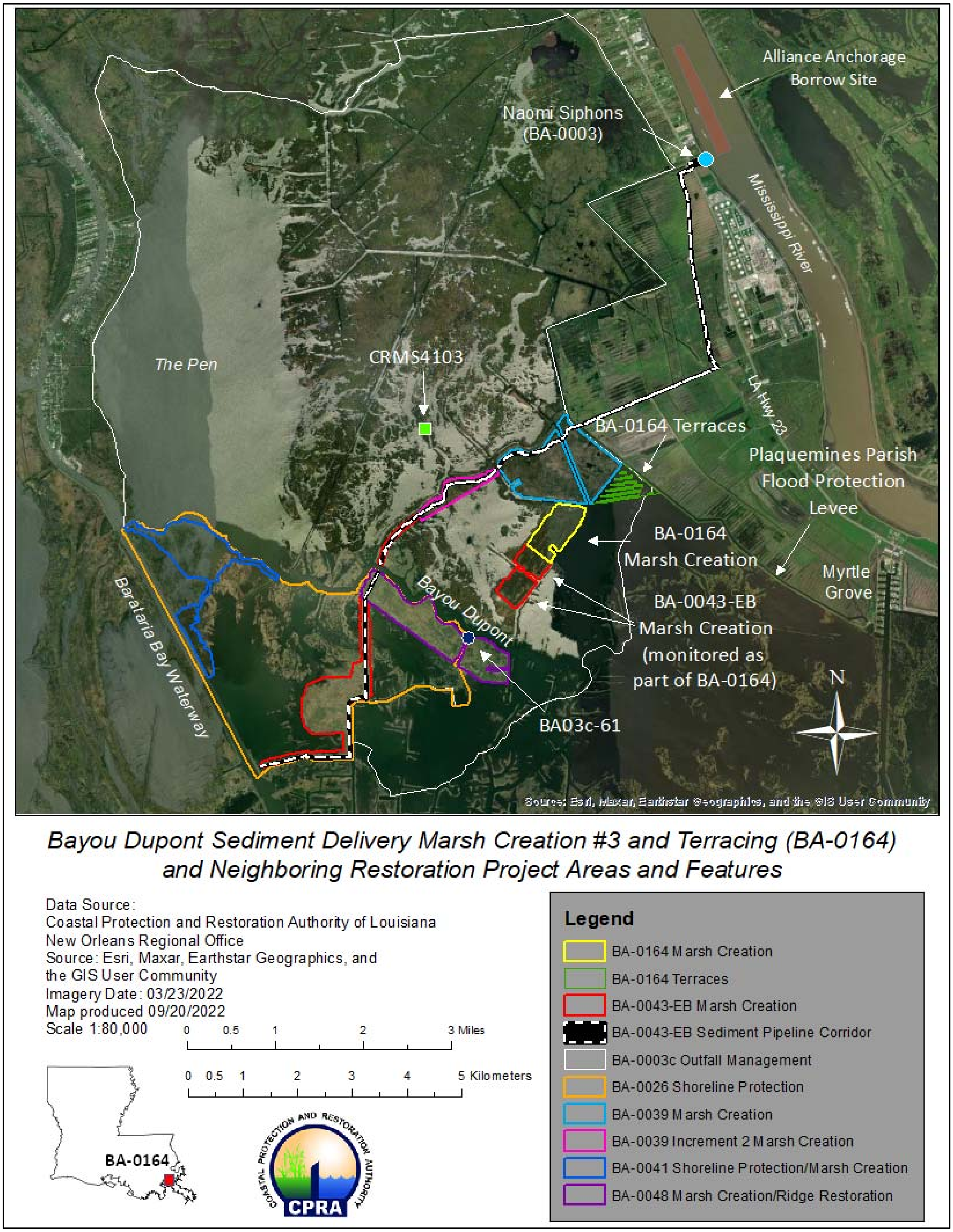


Figure 1. Location of the BA-0164 project area and other neighboring coastal restoration projects.

The goals of the BA-0164 project are to restore marsh in open water areas and reduce local wave energy with the construction of terraces. The specific project objectives are as follows:

1) Create and nourish approximately 137 acres of intermediate marsh using pipeline delivery of sediment dredged from the Mississippi River (as-built acres were slightly higher at 144 acres).

2) Create approximately 9,679 linear feet of earthen terraces using sediment dredged from within the project area.

The additional 128 acres of marsh creation funded with CIAP and State surplus funds increased the total created marsh to 265 acres. Ten acres of marsh were also created as part of the LDSP BA-0164 access corridor, but these acres are not part of the monitored footprint. Therefore, the revised objective for marsh creation is to create and nourish approximately 265 acres of intermediate marsh using pipeline delivery of sediment dredged from the Mississippi River.

<u>Construction Timeline and Project Features</u>

Marsh

Construction of the BA-0164 and BA-0043-EB marsh creation areas began April 21, 2016. Prior to the start of sediment delivery, the existing spoil bank along the northern and eastern boundary of the northern and southern cells (Figure 2), and the southern boundary of the northern cell were fortified and elevated with *in situ* sediment to contain the dredged river sediment as it dewatered and consolidated. This containment was constructed to a height of +3.5 ± 0.5 ft NAVD88 (Geoid03)*, with a five-foot wide crown and side slopes of 1(V):5(H) (Moffatt & Nichol 2014). The western boundary of both cells, and the southern boundary of the southern cell were left uncontained to provide a more natural shoreline and facilitate hydrologic exchange. The marsh creation platform was designed and constructed to an elevation of +2.5 ± 0.5 ft NAVD88 (Geoid03) and it is predicted to settle to approximately +0.8 ft at year 20 (GeoEngineers 2014a). Construction of the BA-0164 marsh was completed August 28, 2016, and construction of the BA-0043-EB marsh was completed one month later on September 24, 2016.

Terraces

The terrace field area was initially targeted for marsh creation, but geotechnical analyses determined that the underlying soils could not support the design elevation to maintain optimal marsh inundation through the 20-year project life (Moffatt & Nichol 2014). As an alternative, 14 terraces were constructed in the same location to reduce wave energy in the immediate area (Figure 2). Terrace construction began on February 28, 2017, and ended on June 19, 2017. The terraces were constructed to a height of +2.5 + 0.5 ft with sediment that was dredged from within the terrace field using two marsh buggy excavators. Rather than construct the terraces initially to the specified as-built elevation, the terraces were constructed in two lifts. The terraces were first built to an elevation of approximately +1.0 ft, and were then allowed to consolidate and dewater for around 25 days. After this period of stabilization, construction of the terraces resumed to the specified as-built elevation. The total as-built length (crown length) of the 14 terraces was 9,666 linear ft, with the individual terrace lengths ranging from 248 ft to 1017 feet. The terraces were constructed with a 10-foot-wide crown and side slopes of 1(V):5(H) (Moffatt and Nichol 2018). The terraces are predicted to settle to +1.8 ft at year 20; however, this elevation only considers consolidation settlement. Additional settlement from shrinkage due to drying could occur, potentially resulting in a lower elevation at year 20 (GeoEngineers 2014a).

**All elevations in this report are reported in feet and referenced to the vertical datum of NAVD88 and Geoid03.*

The slopes of the terraces were planted with *Spartina alterniflora* (smooth cordgrass) to help stabilize the soils and provide a protective vegetative barrier to wave-induced erosion. The first planting occurred in September 2017 and was conducted by the Coalition to Restore Coastal Louisiana (CRCL), with funding provided by Phillips 66. The CRCL's volunteers planted approximately 5000 *S. alterniflora* plugs on terraces 8–13, with two to three rows planted on the southern slopes and one row planted on the northern slopes (Figure 2). Plants were installed on 3-ft centers with rows approximately 2 ft apart. The planting was focused on the terraces that were most exposed to wave energy to provide early protection until the more extensive project planting could be completed.

The BA-0164 project-funded planting occurred late April–early May 2018, and included an additional 19,360 *S. alterniflora* plugs that were planted on the remaining terrace slopes on 3-ft centers with 2-ft spacing between rows. The terrace crowns were planted with 22,586 *Paspalum vaginatum* (seashore paspalum, four-inch containers), following the same spacing as *S. alterniflora*. The plans called for three rows of *S. alterniflora* on each slope and six rows of *P. vaginatum* on each crown; however, planting plans were adjusted in the field as necessary according to site conditions.

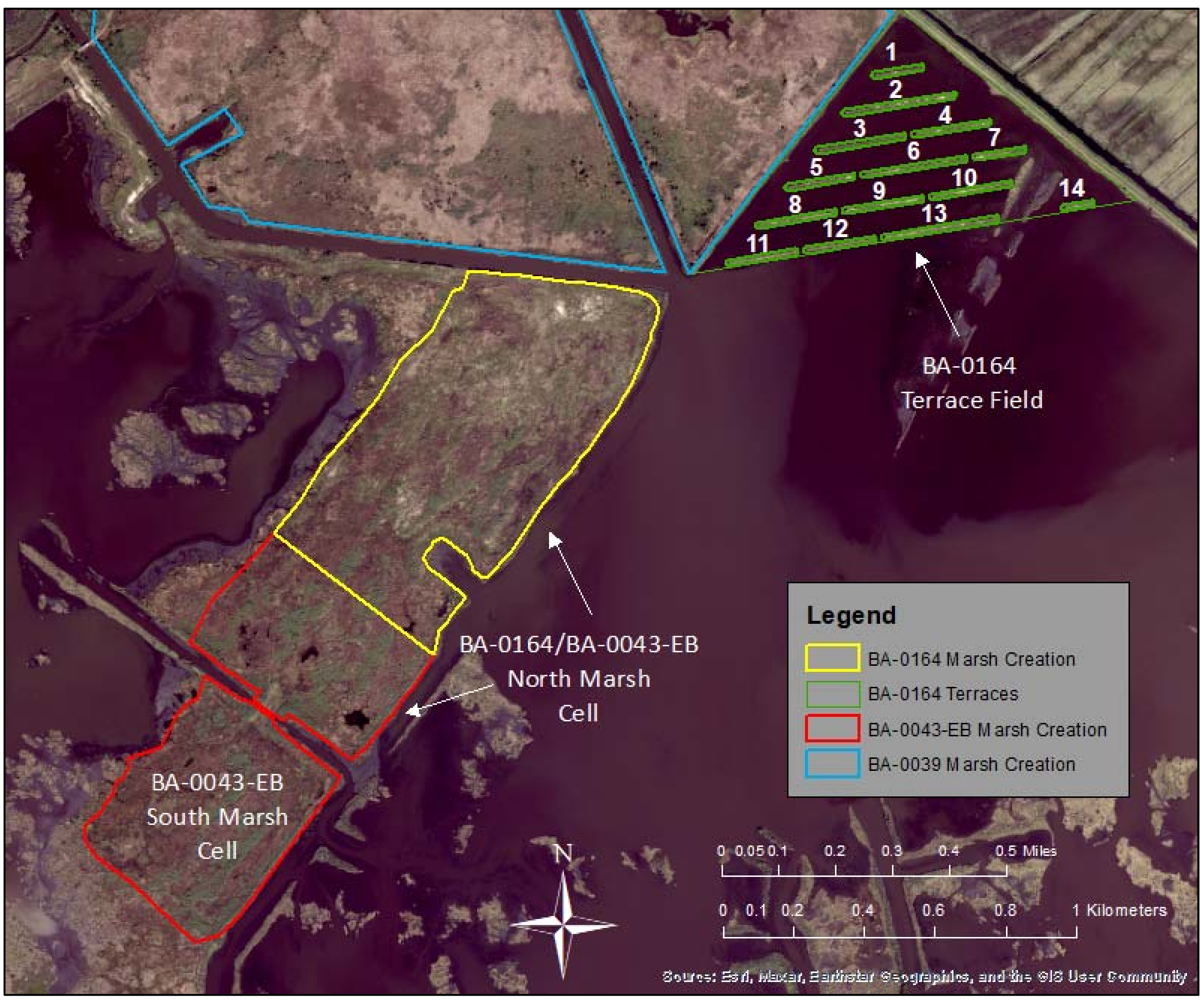


Figure 2. Project features monitored as part of the BA-0164 project. DOQQ imagery from 11/16/2018. The adjacent BA-0039 marsh creation project is also shown on the map.

II. Maintenance Activity

a. Project Feature Inspection Procedures

The purpose of annual inspections is to evaluate the constructed project features to identify any deficiencies and to prepare a report detailing the condition of project features and recommended corrective actions needed. The inspection procedure consists of a site visit, with a visual inspection of the project features. If corrective actions are required, CPRA shall provide in the report a detailed cost estimate for engineering, design, supervision, inspection, and construction contingencies, and an assessment of the urgency of such repairs. The annual inspection report also contains a summary of maintenance events and an estimated projected budget for the upcoming three years for operation, maintenance and rehabilitation. The three-year projected operation and maintenance budget is shown in Appendix A.

An inspection of the BA-0164 project was conducted on November 2, 2021, by Barry Richard, Danielle Richardi, and Theryn Henkel of the CPRA. The inspection was conducted to document any damage from Hurricane Ida, a Category 4 hurricane that made landfall in Port Fourchon, LA, on August 29, 2021. Photographs of the inspection are included in Appendix B of this report.

b. Inspection Results

Marsh Creation Areas
No visible signs of erosion or land loss was noted of the fill areas. The vegetation cover visually appears to be approximately 70–75%. There are locations where tidal exchange is occurring and appears sufficient for a healthy marsh.

Terrace Field
The terraces appeared to be in great condition. No visible signs of erosion were noted, although the dense vegetation (primarily *Spartina alterniflora*) on most of the terrace slopes obscured a more thorough inspection. The vegetative cover visually appears to be approximately 90%.

c. Maintenance Recommendations

Immediate/ Emergency Repairs

No immediate repairs are necessary.

Programmatic/Routine Repairs

No programmatic/routine repairs are necessary.

d. Maintenance History

There have been no maintenance events at this time.

III. Operation Activity

Operations are not required for this project.

IV. Monitoring Activity

a. Monitoring Goals

Monitoring data are used to assess the integrity of the BA-0164 constructed project features and their ability throughout the 20-year monitoring life to attain and sustain the intended habitats and functions. The specific project objectives are to create and nourish approximately 265 acres of intermediate marsh using pipeline delivery of sediment dredged from the Mississippi River, and to create approximately 9,679 linear feet of earthen terraces using sediment dredged from within the project area. The as-built acres of marsh increased to 272 acres (Moffatt and Nichol 2018), and this total acreage will be used for project assessment, which is outlined below and in the BA-0164 monitoring plan (Richardi 2018).

b. Monitoring Elements

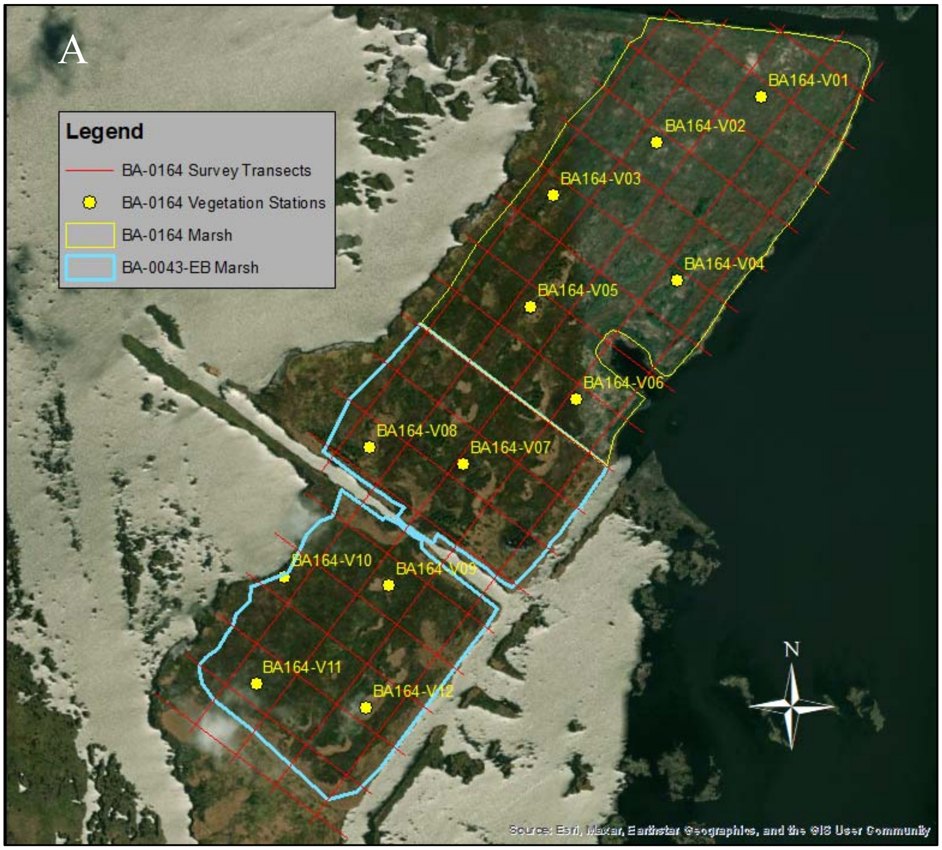
Land-Water Analysis

Analysis of aerial photography is being used to evaluate land to water ratios within the created marsh and terrace field over the life of the project. Land-water analysis was conducted by the United States Geologic Survey (USGS) Wetland and Aquatic Research Center (WARC) using 1-m resolution color infrared digital orthoimagery (Z/I Imaging digital mapping camera) acquired November 16, 2018, through the Coastwide Reference Monitoring System (CRMS) program. The analysis was conducted using standard operating procedures documented in Steyer et al. 1995 (revised 2000), in which all areas characterized by emergent vegetation, wetland forest, scrub-shrub, or upland are classified as land, while open water, aquatic beds, and non-vegetated mudflats are classified as water. Future aerial photography analyses are tentatively scheduled for 2024 (Year 8) and 2033 (Year 17).

Elevation

Surface elevation data from real-time kinematic (RTK) topographic/bathymetric surveys were used to determine if the marsh and terraces were constructed to the specified elevations, are settling at the predicted rates, and are maintaining elevations that promote healthy marsh habitat. A topographic/bathymetric survey was conducted in June 2016 to determine elevations prior to the start of project construction. An as-built survey was conducted in December 2016 for the marsh creation areas and in July 2017 for the terraces, and a subsequent survey of both features was conducted in October 2020. The surveys were conducted using the horizontal datum NAD83, vertical datum NAVD88, and US Survey Feet. Data were collected in Geoid03 (2004.65) for the pre-construction and as-built surveys. Data were collected in Geoid12b for the 2020 survey and post-processed in the Geoid03 (2004.65) model.

Marsh survey transects are spaced every 400 ft on a grid (Figure 3A), with elevation recorded every 50 ft along each transect. Terrace field transects are generally spaced every 300 ft vertically, with exceptions including a second transect that was added to terraces 7 and 14 and their borrow areas for the 2020 survey to better assess elevation of these features (Figure 3B). Horizontal terrace transects are established along the centerline of the terraces and terrace borrow areas, with a distance of 100 feet between each terrace row and the corresponding borrow area. Elevation was recorded a minimum of every 5 ft along each vertical terrace transect within the borrow areas and on the terraces to delineate elevation change within the features. Otherwise, elevation was recorded every 50 ft along each terrace field transect.



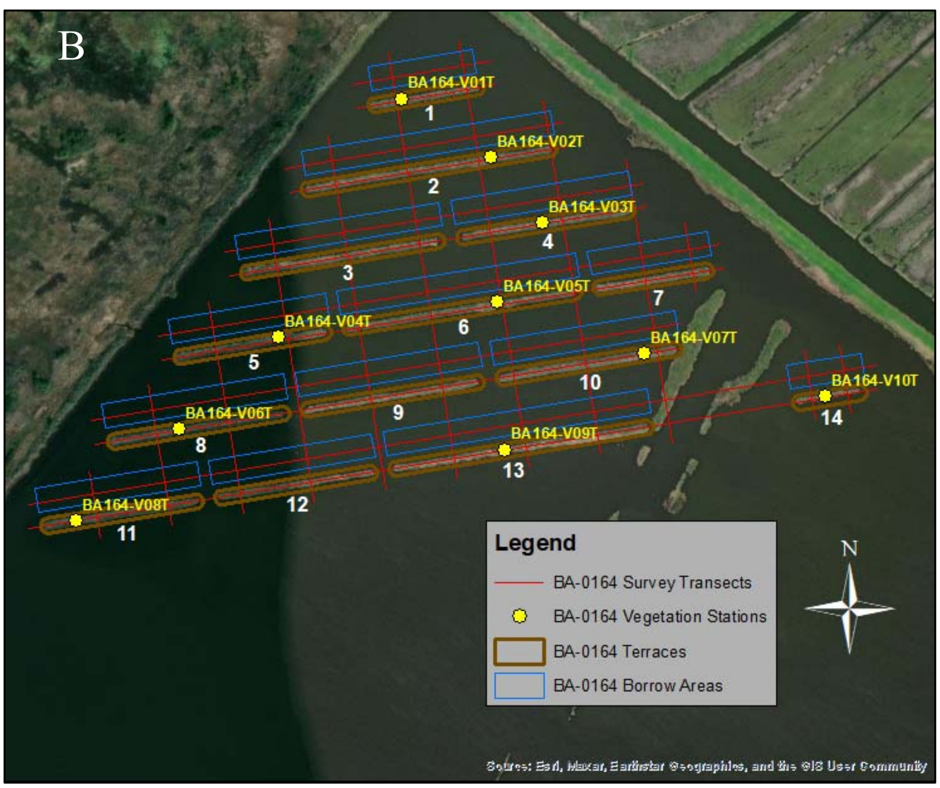


Figure 3: Location of the BA-0164 marsh (A) and terrace (B) elevation survey transects and vegetation monitoring stations.

Elevation data were processed and analyzed in ArcMap 10.5.1. Polygons that outlined the marsh only (excluding all containment dikes) were produced in order to constrain the analyses. For each survey year, elevation point shapefiles were imported into ArcMap and clipped to the marsh polygon. The "natural neighbor" tool was used to interpolate the points into an elevation surface using output cell size of 1.0. The interpolated surface was then clipped to the marsh polygons. The result was a marsh elevation surface for each survey year. These surfaces were then used to calculate elevation. Elevation difference was calculated using the "minus" tool in ArcMap, which compares two elevation surfaces, resulting in a new surface that indicates where and how much elevation was gained or lost between survey years. The elevation surfaces were also used to calculate the area of land that was within specific elevation contours (e.g. how much area was between 0.0 ft and +0.5 ft of elevation, etc.). The tool also calculates the mean elevation and standard deviation for each elevation surface. These data were used to compare to the predicted elevation settling rates that were developed during project design to determine if the marsh was settling as expected. The percent of time the marsh was inundated was calculated based on the mean marsh elevation and water elevation data from nearby CRMS4103. All of the above analyses were repeated for the separate northern and southern marsh creation cells.

The terrace elevation data were processed using the same methods as for the marsh. Polygons that outline the terraces themselves were used to constrain the elevation interpolation. For the pre-construction survey and the year 4 survey, elevation data were also captured along the centerline for the terrace borrow areas, but these data were not collected for the as-built survey. Therefore, only the 2020 post-construction borrow area elevations will be presented in this report. Measured settlement of the terraces was compared to the predicted settlement using elevation data collected only from the terrace crowns. The mean crown elevation and water elevation data from CRMS4103 were used to determine the percent of time the terraces were inundated.

Marsh and Terrace Vegetation

Vegetation data were collected within the marsh creation areas and on the terraces to assess the colonization and transition of vegetation, to compare the vegetation in the created marsh to local, natural marsh, and to gauge the quality and stability of the vegetative community. Emergent vegetation was sampled in August 2018 and June 2021 at twelve 2 m x 2 m stations in the marsh creation areas and ten 2 m x 2 m stations on the terraces (Figure 3) using a modified Braun-Blanquet sampling method (Mueller-Dombois and Ellenberg 1974) as described in Folse et al. 2020. Data collected at each station included an assessment of total percent cover, species present, percent cover of each species, average height of each vegetation layer, and depth of water on the marsh surface. Future vegetation surveys of the marsh and terraces are scheduled for 2026 (Year 10) and 2035 (Year 19).

Total percent cover, species richness, percent layer cover (herbaceous, shrub, tree and carpet), and Floristic Quality Index (Cretini et al. 2012) were analyzed by year and by feature (marsh and terrace) using ANOVA in RStudio (RStudioTeam 2016) or ANOVA, ProcGLM using SAS 9.4 software (SAS Institute, Cary NC). The BA-0164 marsh vegetation data were compared to the vegetation data at the adjacent BA-0039 marsh creation project (constructed in 2010 with Mississippi River sediment) to assess their similarities and differences shortly after construction. The vegetation community at BA-0164 and BA-0039 were also compared to the natural marsh community at nearby CRMS4103. At BA-0039, there were 30 vegetation stations (10 stations at each at the three CRMS-like monitoring sites), and at CRMS4103 there were 10 stations. All stations are 2 m x 2 m.

c. Monitoring Results and Discussion

The monitoring results and discussion for each monitoring element include BA-0164 data available between 2016 and 2021. These results will be updated with new data in subsequent OM&M reports that are scheduled to be written in 2027 and 2036, allowing for a continued assessment of project performance over the 20-year monitoring life. For the purpose of analysis, the BA-0164 and BA-0043-EB marsh creation areas will be referred to as BA-0164, unless otherwise specified. All means are reported with standard deviation (SD).

i. Land-Water Analysis

The BA-0164 marsh and terrace creation areas were mostly shallow, open water habitat prior to project construction (Figure 4). A 2010 pre-construction analysis of land and water acres in the proposed marsh creation footprint delineated 213 acres of water and only 10 acres of marsh (USGS 2012). The constructed marsh creation boundary changed slightly from the one utilized for the 2010 analysis; however, the changes would have had minimal impact on the assessment.

A post-construction land-water analysis of the BA-0164 project area was conducted using CRMS aerial imagery that was acquired on November 16, 2018. At the time of imagery acquisition, the BA-0164 marsh creation areas were just over two years old, and the terraces were almost 1.5 years old. The 2018 analysis indicated that the marsh creation area was nearly 100% land, with a classification of 271 acres of land and 1 acre of water (Figure 5). Analysis within the 101-acre terrace field quantified 14 acres of land (14% land) and 87 acres of water (86% water). In addition to the constructed terraces, the terrace field boundary contained the terrace borrow areas, a significant amount of shallow open water, and a few acres of pre-existing marsh. In order to limit the analysis to the terrace features, an additional land-water analysis was conducted using the terrace polygons that were used for elevation assessment (Figure 3B and Section IV.c.ii). Within the reduced, approximately 14-acre footprint, there were 9 acres of land (65% land) and 5 acres of water (35% water). This more constrained land-water analysis will allow for a better assessment of terrace land change over years.

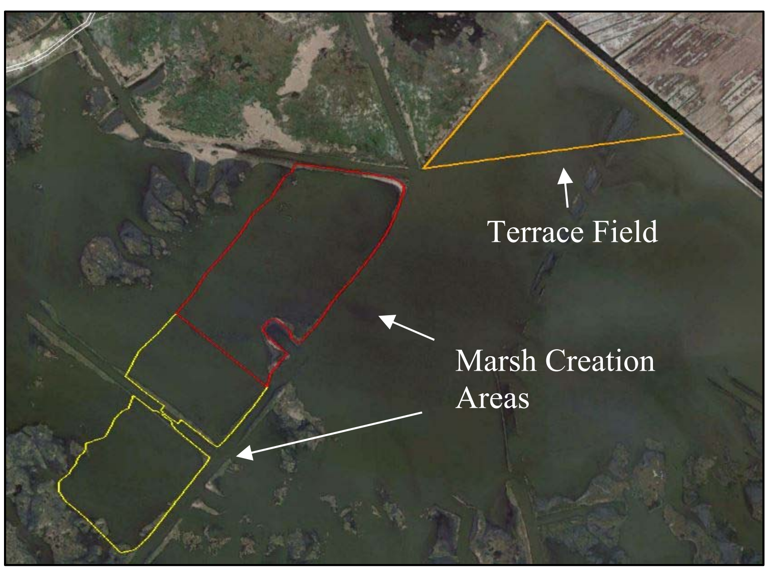


Figure 4. Google Earth aerial imagery from 10/29/2012, showing the open water BA-0164 and BA-0043-EB project areas prior to project construction.

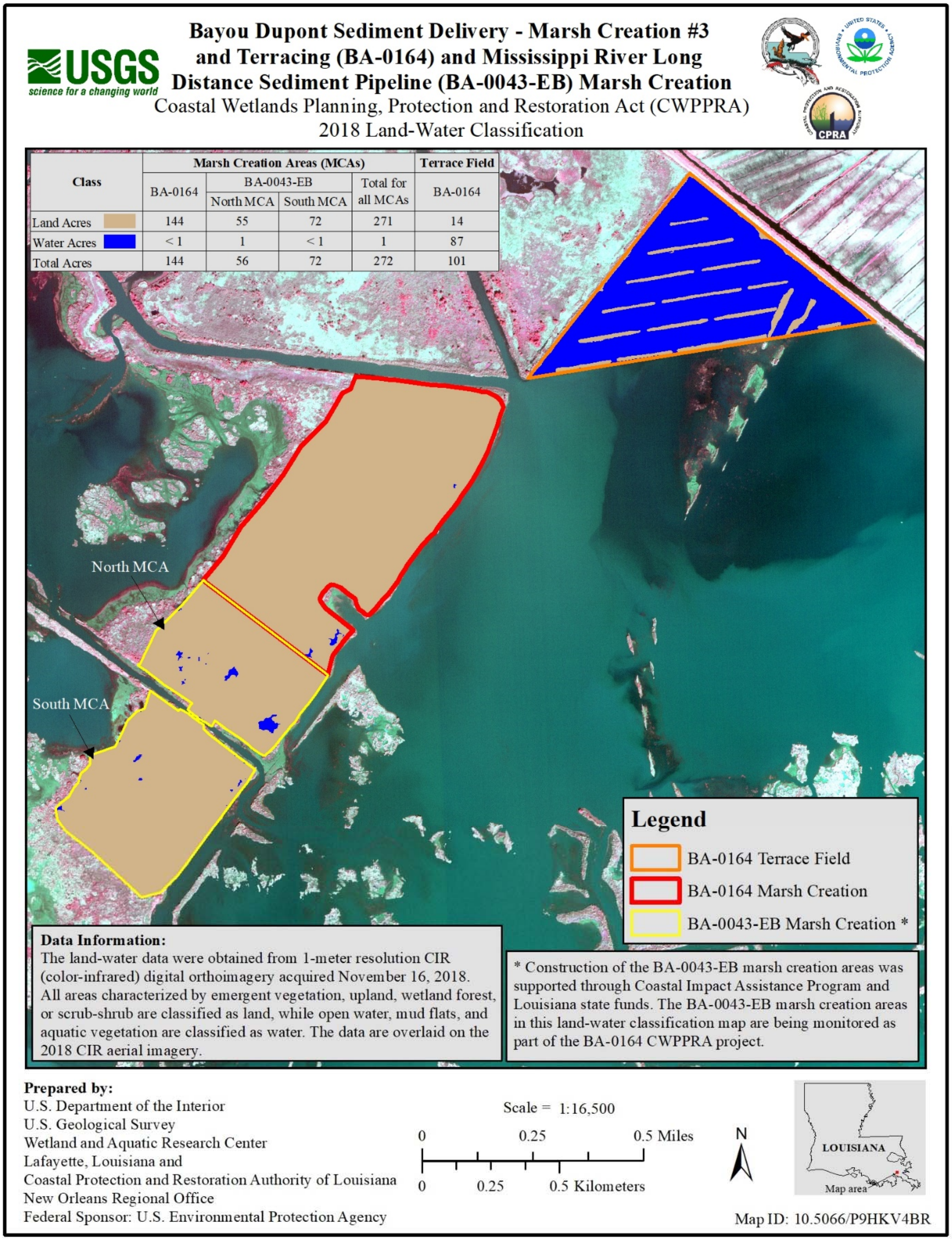


Figure 5. Land-water analysis of the BA-0164 and BA-0043-EB marsh creation areas and the BA-0164 terrace field using CRMS aerial imagery collected November 16, 2018.

ii. Elevation

Land-water analysis provides a general overview of how well marsh and terrace creation projects maintain their presence in a landscape over time. Elevation surveys add considerably to this knowledge, by allowing for an evaluation of whether project elevations can support marsh habitat, and whether project features are settling and functioning as predicted during project design. Four BA-0164 surveys are assessed in this report—a pre-construction elevation survey that was conducted in June 2016, an as-built survey that was conducted of the marsh in December 2016, an as-built survey that was conducted of the terraces in July 2017, and a survey that was conducted of both features in October 2020 to assess early project performance.

Marsh

The marsh project boundary that was used for elevation analysis contains approximately 246 acres and excludes all containment dikes and spoil banks to avoid a false inflation of marsh elevation. The mean elevation within the marsh boundary prior to construction (June 2016) was -2.0 ± 0.5 ft, with greater than half of the project area (55.4%) at an elevation between -2.0 ft and -2.5 ft (Table 1, Figure 6). Elevations ranged from a high of +1.1 ft (marsh), to a low of -3.6 feet. Most of the area below -2.5 ft was in the southern marsh cell, which had a slightly lower mean elevation than the northern cell at -2.3 ± 0.4 ft and -1.9 ± 0.4 ft, respectively.

The as-built survey (December 2016) was conducted approximately 2.5 months after the end of marsh construction. The mean as-built marsh elevation was +2.3 ± 0.4 ft, with the greatest percentage of the project area (42.9%) at an elevation between +2.0 ft and +2.5 feet (Table 1, Figure 6). Elevations ranged from a high of +4.3 ft to a low of 0.0 feet. Project specifications called for the marsh to be built to +2.5 ± 0.5 ft and 73.9% of the project area was within this elevation range shortly after construction. The southern cell had a slightly higher as-built elevation than the northern cell, at +2.5 ± 0.3 ft and +2.2 ± 0.4 ft, respectively. This initial difference may be related to the completion dates for the two cells. Construction of the northern cell was completed approximately one month earlier than the southern cell, resulting in a longer time for the northern cell to settle prior to the as-built survey.

A relatively lower elevation area in the northern cell was located just south of the small keyhole along the eastern project boundary (Figure 6). A section of the containment berm was difficult to construct in this area because elevations were low around a gap that was present in the pre-existing spoil bank. The containment berm did not reach the construction height specifications in this area and as a result, construction in the vicinity may have been impacted in order to reduce the potential loss of sediment.

For the 2020 elevation survey, mean marsh elevation was +1.3 ± 0.5 ft, indicating that the project area had declined approximately one foot since the 2016 survey (Figure 6). The highest percentage of the project area (35.4%) was at an elevation between +1.0 ft and +1.5 ft (Table 1, Figure 6) and elevations ranged from +3.6 ft to -0.7 feet. For the 2016 as-built survey, the northern cell had a lower mean elevation than the southern cell; however, this order reversed for the 2020 survey, with the southern cell now 0.5 feet lower than the northern cell, at +0.9 ± 0.4 ft and +1.4 ± 0.5 ft, respectively.

The highest elevations in the marsh (> +1.5 ft) were concentrated in the northern region of the north cell, which was constructed first and served as the staging area for project construction. As the Mississippi River sediment discharged into the northern project area, it displaced some of the underlying sediment southward, resulting in “mud waves” in the mid and southern reaches of the northern fill cell. Mud waves were also created while pumping sediment into the southern cell. The existing soils within the BA-0164 marsh and terrace construction sites were characterized as peat and organic clay, both of which are highly organic (GeoEngineers 2014a). The dredged river sediment has a higher mineral content, is heavier than these organic soils, and characteristically compacts and dewaters at a quicker rate. As a result, areas with a greater depth of fill from river sediment likely stabilized more rapidly during construction, while compaction and dewatering of the soils with a higher organic content occurred over a longer time period.

The lowest elevations (< 0.0 ft) for the 2020 survey were concentrated in the southern fill cell along the western boundary (Figure 6). The southern fill cell was constructed without containment on the western and southern boundaries and relatively lower elevations were already indicated along the western boundary for the 2016 as-built survey. It is possible that a loss of sediment through drainage along this boundary contributed to lower elevations in this area. Additionally, the characteristics of the underlying soils in the southern cell could explain the greater elevation decline. During the geotechnical investigation in 2014 as part of the design of this project, 10 cone penetration tests (CPTs) were performed in the two fill cells. Of the 10 CPTs taken, two were in the southern cell and eight were in the northern cell. Of the eight in the northern cell, six CPTs met refusal at a sand/silt layer well before reaching the probing depth of approximately 50 feet. Neither of the two CPTs in the southern cell met refusal (GeoEngineers 2014b). Therefore, it can be assumed that subsoil consolidation could be playing a part in the difference in elevation between the two cells.

In the four years between the 2016 (as-built) and 2020 surveys, the mean marsh elevation declined approximately 1.0 foot. The extent of settlement differed between the northern and southern marsh cells, with the northern cell declining 0.8 ft between surveys, and the southern cell declining 1.7 feet. While some areas in the southern cell lost greater than 2.0 ft in elevation, the largest percent of area (49.7%) within the BA-0164 marsh declined a lesser amount between 0.5 ft and 1 foot (Figure 7).

Table 1. Acres (%) by elevation interval for the 2016 pre-construction, 2016 as-built and 2020 BA-0164 marsh elevation surveys. The color corresponds to the color of the elevation interval in Figure 6.

Elevation (ft) NAVD88, G03	Color	Marsh Acres (%)		
		2016 (Pre-Con)	2016 (As-Built)	2020
-3.6 – -3.0		< 0.1		
-3.0 – -2.5		8.1		
-2.5 – -2.0		55.4		
-2.0 – -1.5		26.7		
-1.5 – -1.0		7.1		
-1.0 – -0.5		1.3		0.1
-0.5 – 0.0		0.7		1.2
0.0 – 0.5		0.5	< 0.1	5.2
0.5 – 1.0		0.2	0.2	23.8
1.0 – 1.5		< 0.1	3.1	35.4
1.5 – 2.0			19.9	27.0
2.0 – 2.5			42.9	6.9
2.5 – 3.0			31.0	0.4
3.0 – 4.4			2.8	< 0.1

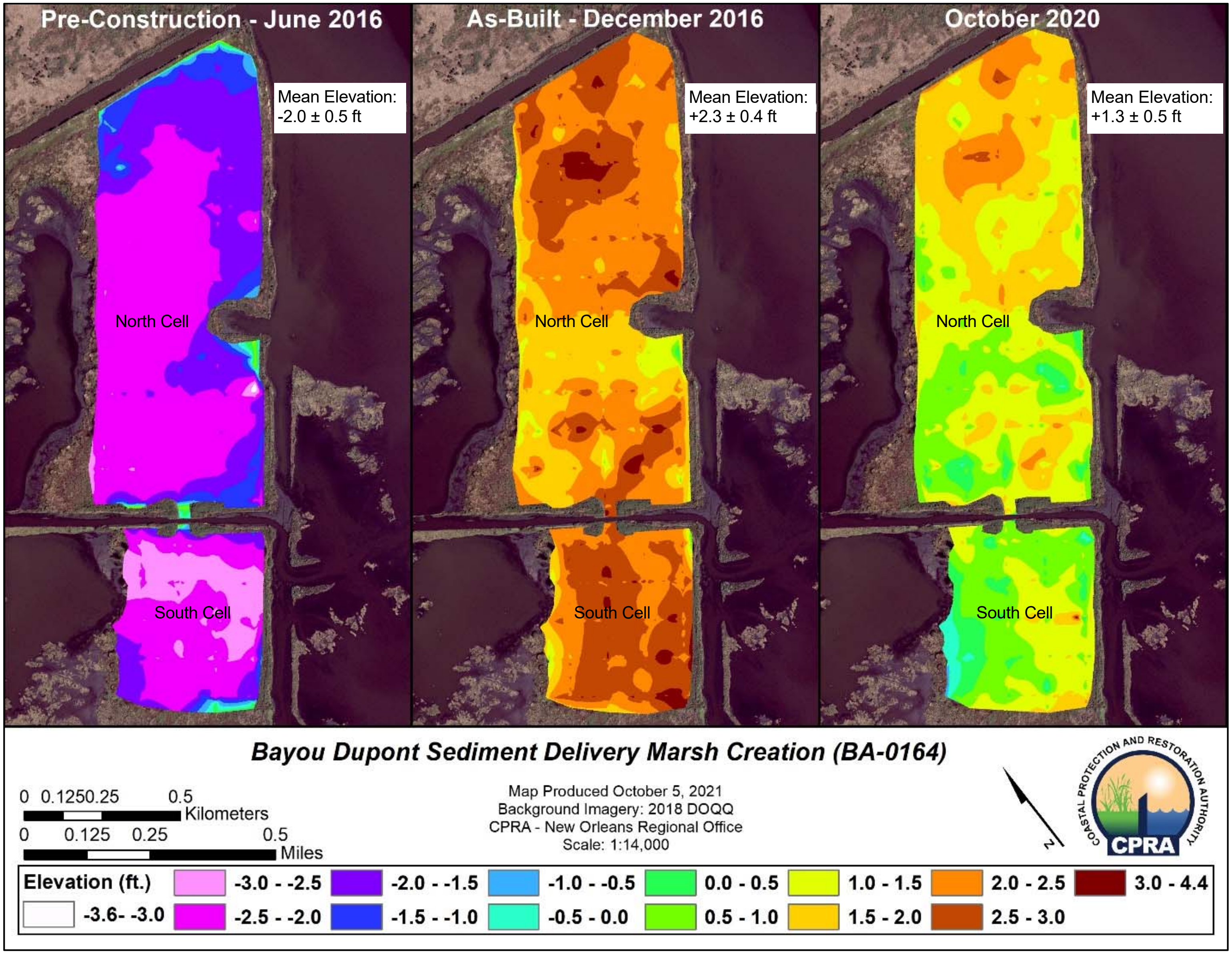


Figure 6. Interpolated surface elevation of the BA-0164 marsh for the pre-construction, as-built, and year 4 surveys.

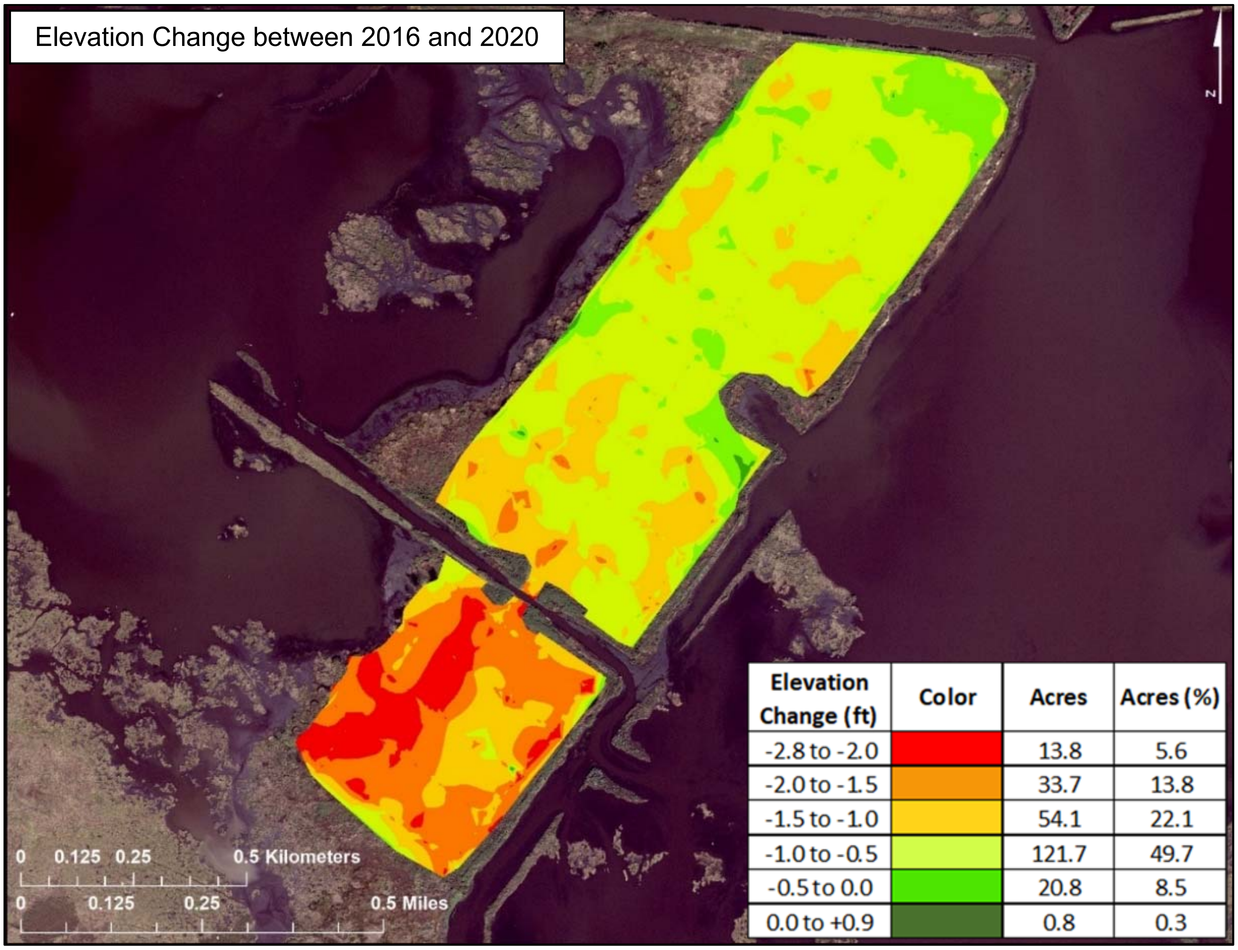


Figure 7. Elevation change in the BA-0164 marsh creation areas in the four years between the 2016 as-built and 2020 surveys.

Terraces

The area of the 14 terrace polygons that was used for elevation analysis sums to approximately 13.5 acres. Elevation analysis was conducted of the entire terrace features within these polygons (including both crown and slope) and of just the terrace crowns, with the latter analysis being used for comparison to the predicted settlement curve. Terrace transects include a centerline transect that runs lengthwise along the crown, as well as multiple shorter transects that cross the terraces perpendicularly and range from two to four transects per terrace (Figure 3B).

The pre-construction (2016) mean elevation within the terrace polygons was -1.7 ± 0.4 ft, with elevations ranging from +0.4 ft to - 2.4 feet. Greater than half of this area (59.4%) was at an elevation between -1.5 ft and -2.0 ft (Table 2, Figure 8). Construction of the terraces was completed in June 2017, and the as-built survey was conducted approximately one month later. The mean as-built elevation was +1.7 ± 0.9 ft; however, the greatest percentage of acres (29.9%) was at a higher elevation between +2.0 ft and +2.5 ft (Table 2, Figure 9). By the October 2020 survey, mean terrace elevation had declined to +0.4 ± 1.0 ft, with the greatest terrace area again within a higher elevation interval between +1.0 ft and +1.5 ft (27.2%). The lower range of elevation for the 2020 survey (< -2.5 ft) is largely due to the inclusion of a few survey points that extended further down the slope and outwards from of some of the terraces, but were still within the terrace polygons and were therefore used for analysis (Table 2). The high standard deviation for the post-construction mean elevations is explained by the terrace design, with a larger number of higher elevations along the terrace crowns, and a smaller number of lower elevations along the terrace slopes.

The number of acres by elevation interval may be skewed towards higher elevations by the crown transect data points and the limits of interpolation. This effect is discernable in Figures 9 and 10 by the clusters of higher interpolated elevations (> 2.0 ft) that are repeated along the length of the terraces. These higher elevation clusters are punctuated by lower elevation bands where the perpendicular transects crossed the terraces and captured the lower slope elevations. Additional transects along the terrace slopes could improve future elevation assessments of the terrace features.

In the three years between the 2017 (as-built) and 2020 (year 3) surveys, the mean terrace elevation declined approximately 1.3 feet. The majority of the area declined between 1.0 ft to 1.5 ft (37%) followed by 0.5 ft to 1.0 ft (30%) (Figure 11). Erosion appears to have occurred on some of the terrace slopes; however, the terrace crowns appear to be relatively stable.

Table 2. Acres (%) by elevation interval for the 2016 (pre-construction), 2017 (as-built) and 2020 BA-0164 terrace elevation surveys. Color corresponds to color of the elevation interval in Figures 8–10.

Elevation (ft) NAVD88, G03	Color	Terrace Acres (%)		
		2016 (Pre-Con)	2017 (As-Built)	2020
-4.3 – -2.5				1.1
-2.5 – -2.0		22.4	< 0.1	1.9
-2.0 – -1.5		59.4	0.2	3.0
-1.5 – -1.0		12.8	0.6	5.4
-1.0 – -0.5		3.8	1.3	7.6
-0.5 – 0.0		1.4	2.8	9.8
0.0 – 0.5		0.1	6.0	13.7
0.5 – 1.0			10.2	19.6
1.0 – 1.5			13.6	27.2
1.5 – 2.0			20.4	10.0
2.0 – 2.5			29.9	0.7
2.5 – 3.3			15.1	< 0.1

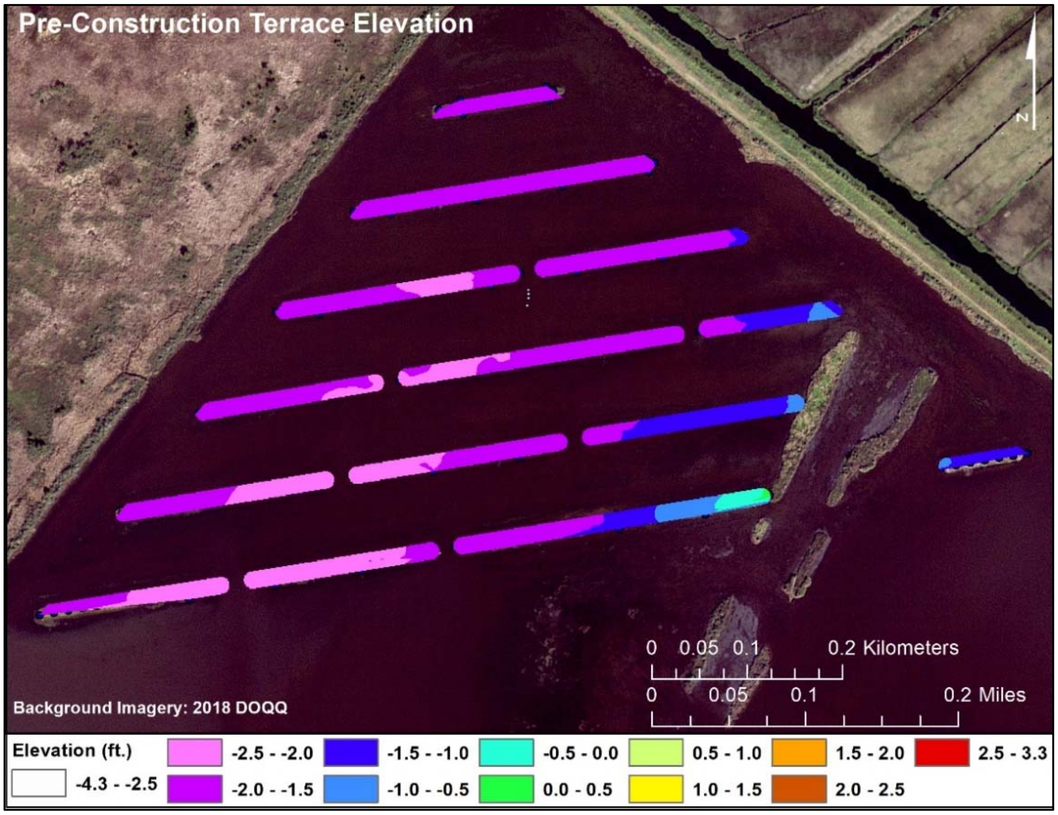


Figure 8. Pre-construction (2016) interpolated elevation within the BA-0164 terrace boundaries.

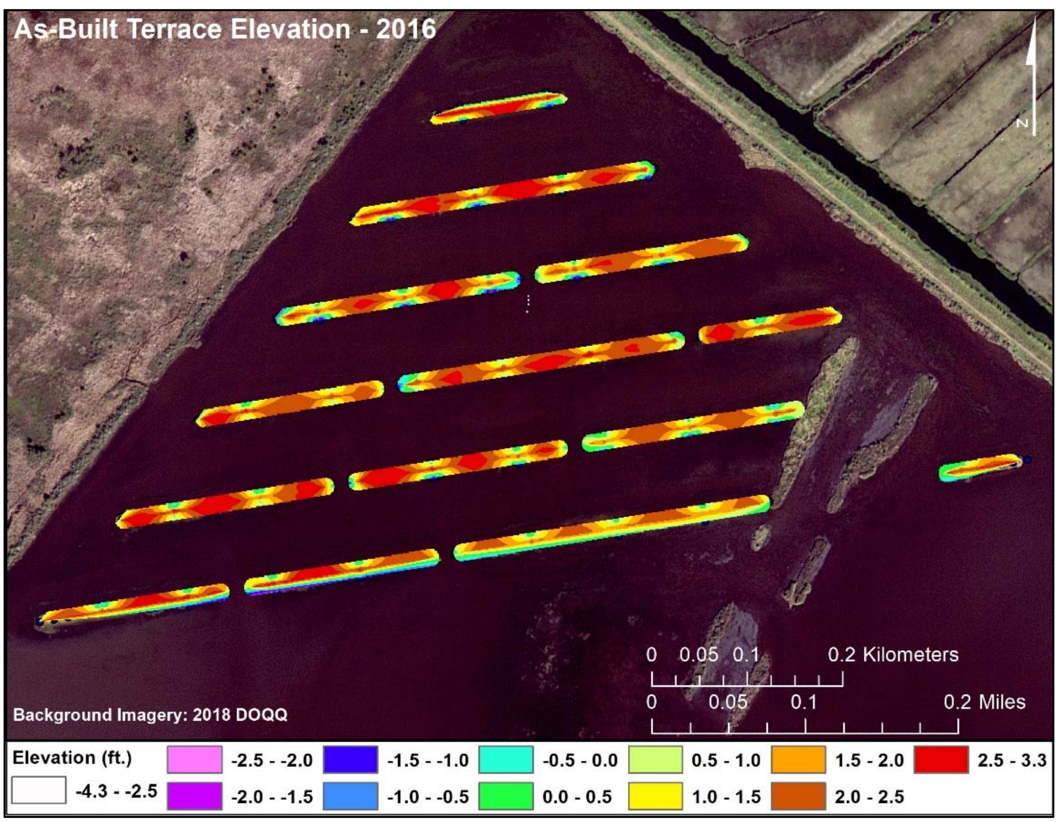


Figure 9. As-built (2017) interpolated elevation of the BA-0164 terraces.

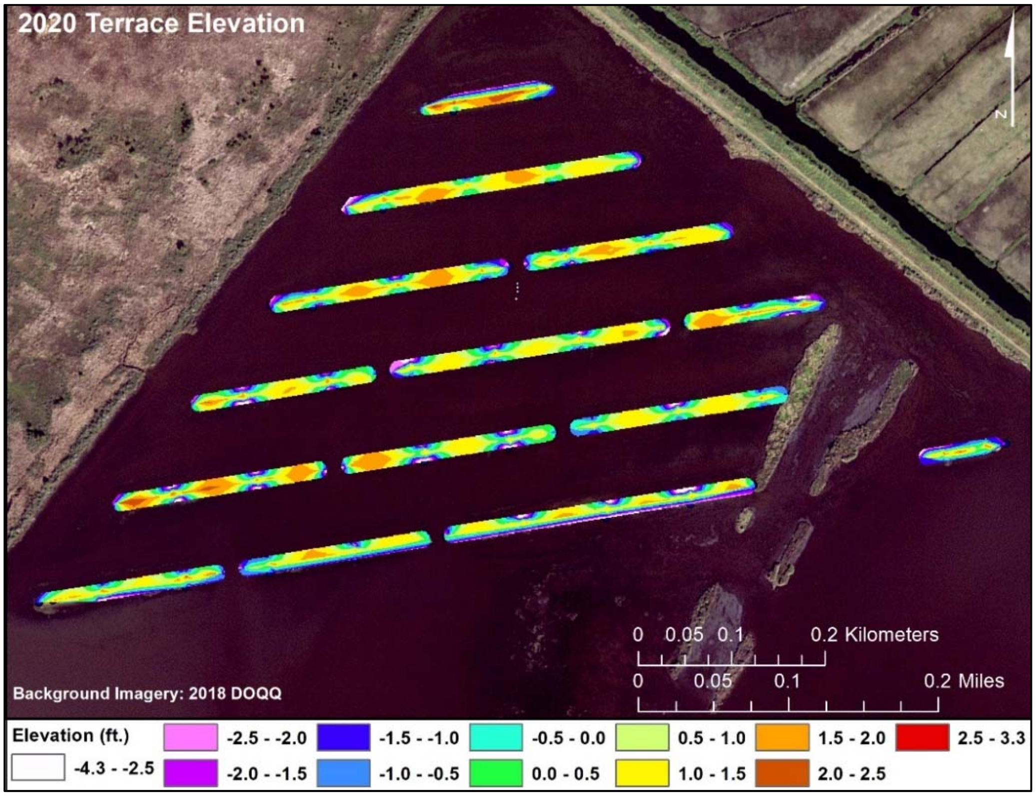


Figure 10. 2020 interpolated elevation of the BA-0164 terraces.

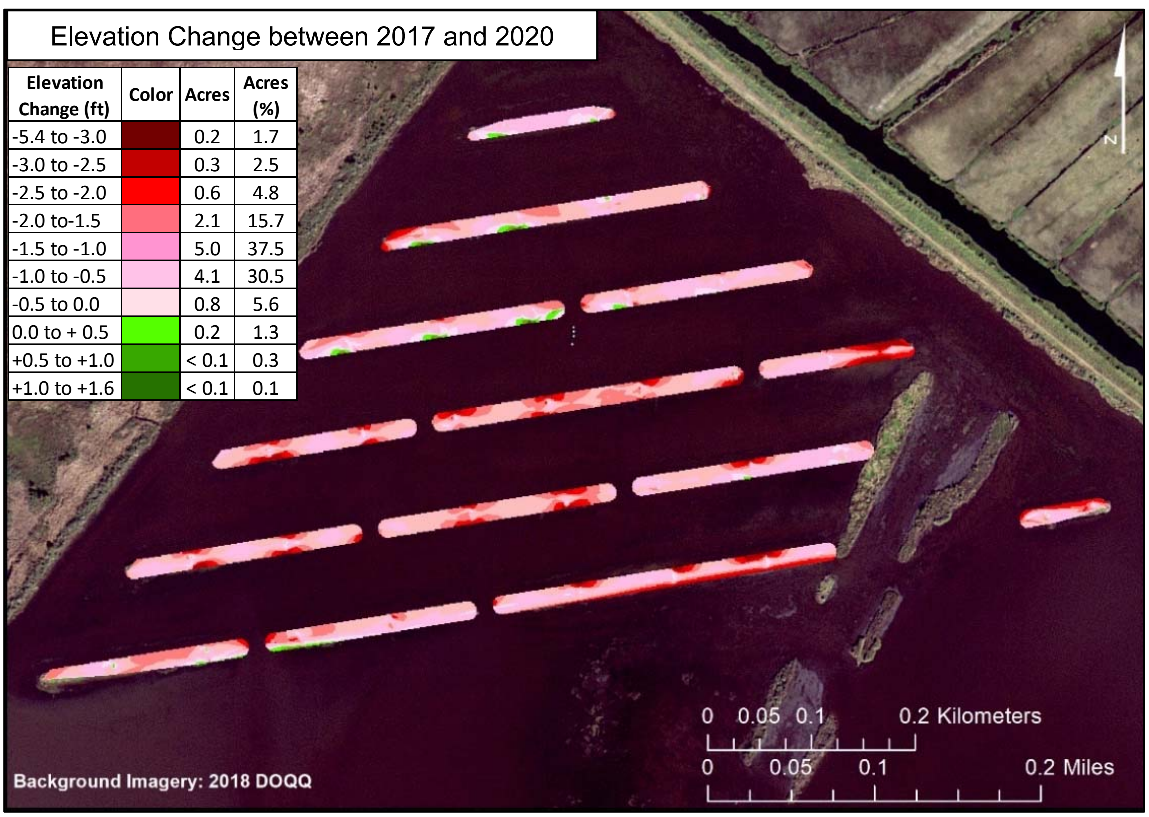


Figure 11. BA-0164 terrace elevation change between the 2017 as-built and 2020 surveys.

Terrace Borrow Area

The terraces were constructed with *in situ* sediment dredged from borrow areas parallel to and north of each terrace. Mean elevation within the 14 borrow areas prior to construction was -1.7 ± 0.3 ft, with elevations ranging from -0.5 ft to -2.4 feet. Within the larger terrace field, mean elevation was -1.6 ± 0.5 ft, and elevation ranged from +1.2 ft (marsh) to -2.4 feet. The 2017 as-built terrace elevation survey did not include centerline transects for the terrace borrow areas, and as a result, the point field of elevation data was not adequate to construct a surface elevation model. Therefore, only the 2020 post-construction elevation survey results are presented. Three years after excavation, the mean elevation within the borrow areas was -4.5 ± 1.4 ft, and elevation ranged from a high of -0.6 ft to a low of -8.7 ft (Figure 12). The greatest area (28.3%) was at an elevation between -5.0 ft and -6.0 feet. The next elevation survey is tentatively scheduled for fall 2023. Elevation data from this survey will be compared to the 2020 survey to assess rates of in-fill or erosion.

The narrow, elongated vertical bands of higher elevations repeated along the length of the borrow areas, especially evident along the northern borders, correspond to the survey transects that ran perpendicular through the terrace field (Figure 3B). These higher elevations capture the slope rise from the borrow areas, and indicate that the interpolated elevations are likely biased towards a lower elevation due to the influence of the centerline elevations in the interpolated surface model.

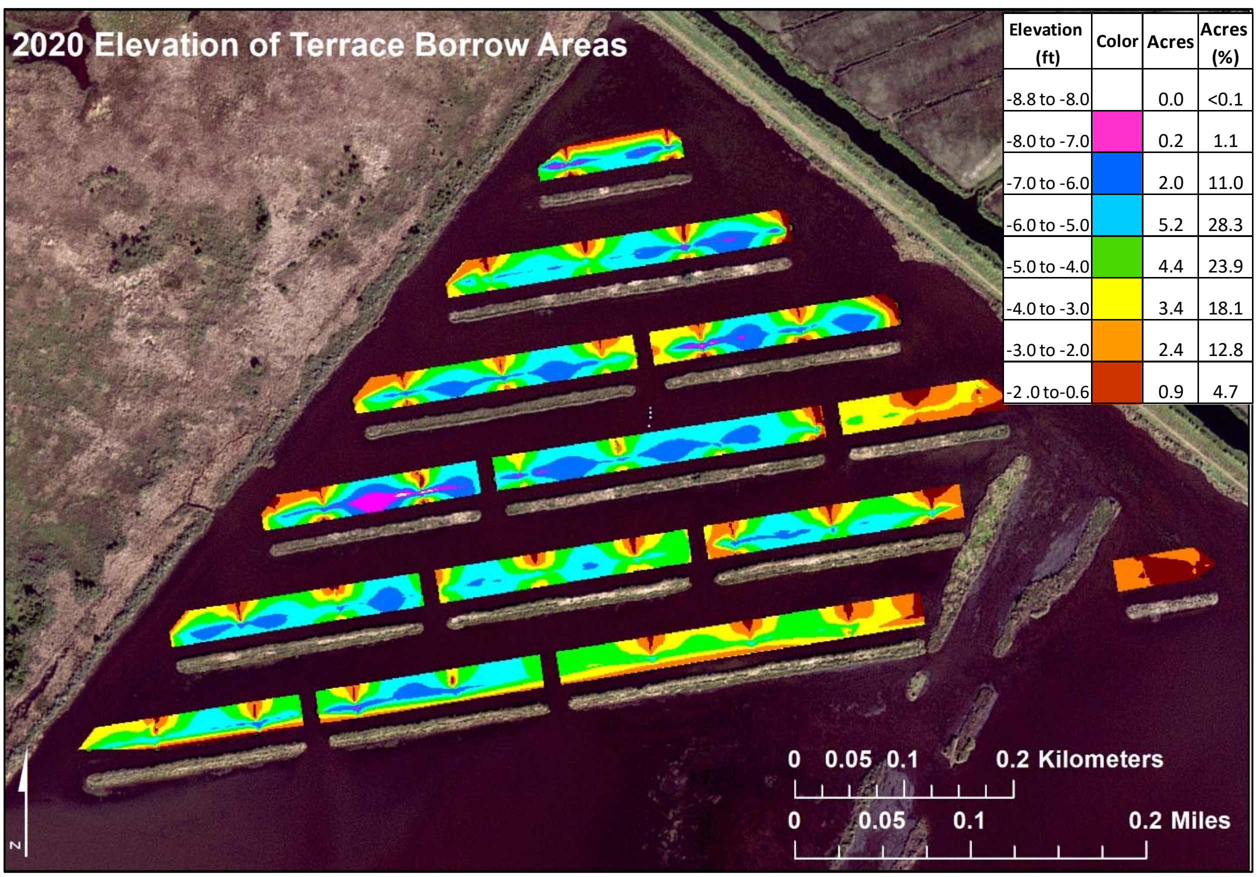


Figure 12. Elevation in the terrace borrow areas for the 2020 survey.

Settlement Curves

Marsh

During project design, settlement curves for different marsh elevations were developed to determine the best constructed elevation to provide long-term sustainability of the BA-0164 marsh. Settlement of the pumped dredge material and subsidence of the underlying soils were both factored into settlement calculations. A construction elevation of +2.5 ± 0.5 ft was chosen based on geotechnical analyses and an analysis of marsh inundation. The surveyed mean marsh elevation for the 2016 as-built and 2020 surveys were compared to the predicted settlement curve elevations to determine whether the project was performing as expected.

The 2016 as-built survey was conducted approximately 2.5 months after the end of construction. The mean marsh elevation was +2.3 ± 0.4 ft, approximately 0.7 ft higher than the predicted elevation of approximately +1.6 ft (Figure 13). The mean elevation of the northern cell was +2.2 ± 0.4 ft and of the southern cell was +2.5 ± 0.3 ft, which placed them 0.6 ft and 0.9 ft, respectively, above the predicted elevation. This initial elevation difference between cells may be related to the one-month earlier completion date for the northern cell. Marsh creation projects settle rapidly in the first few weeks after project construction, and the BA-0164 marsh was predicted to settle approximately 0.8 ft within the first two weeks.

By 2020, the mean surveyed marsh elevation had declined by one foot to +1.3 ± 0.5 ft, which was 0.4 ft higher than the +0.9 ft predicted elevation (Figure 13). The settlement rate was different between cells, with the northern cell declining 0.8 ft since 2016, and the southern cell declining 1.7 ft, over twice the amount, during the same time period. The 2020 mean elevation of the northern cell was +1.4 ± 0.5 ft, approximately 0.5 feet higher than predicted, while the southern cell was at the predicted elevation of +0.9 ± 0.4 feet. It is early in the 20-year project life; however, on the current trajectory, the northern cell is settling slower than predicted and the southern cell is settling as expected. As previously discussed, the extent of the containment berms and the characteristics of the soils may have contributed to the differences in elevation between the cells.

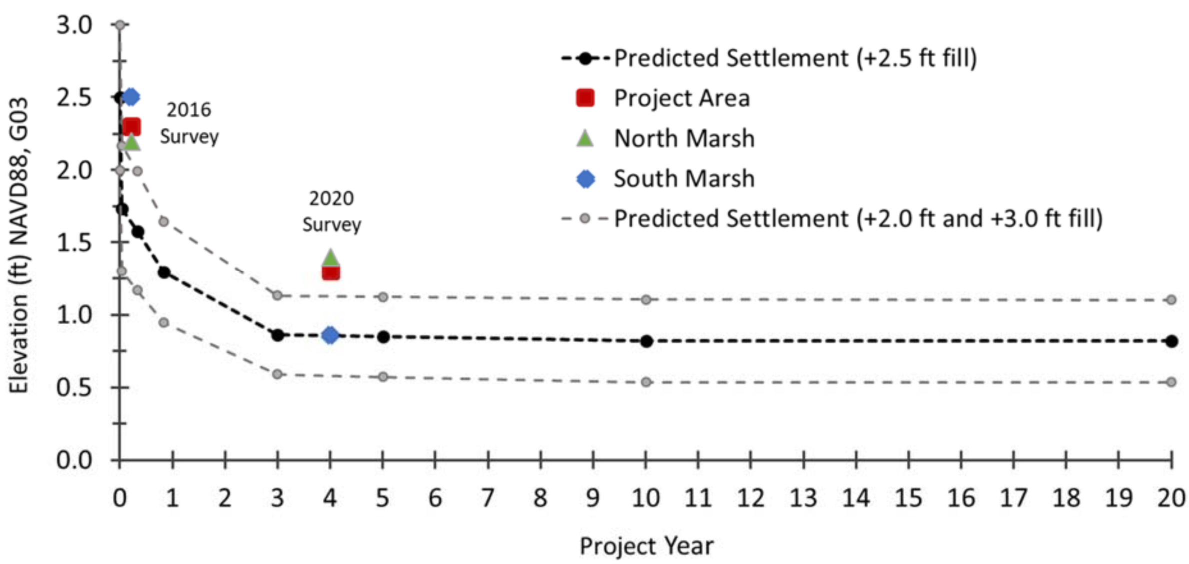


Figure 13. BA-0164 marsh settlement curve for a constructed elevation of +2.5 ± 0.5 feet. The curves for a +3.0 ft and +2.0 ft constructed elevation are included to show the construction tolerance (± 0.5 feet). The as-built and year 4 mean marsh surveyed elevations are included on the graph.

Terraces

Elevation data points collected only on the terrace crowns were used to compare mean terrace elevation to the predicted settlement curve. The settlement curve was developed considering compaction of the soils, but did not factor in shrinkage of fill due to drying of the sediments as they were placed above water (GeoEngineers 2014a). The 2017 as-built survey was conducted approximately 1 month after the end of construction. The mean as-built elevation of the terraces was +2.5 ± 0.3 feet, which was approximately 0.2 ft higher than the predicated elevation for that time. Between the 2017 and 2020 surveys, the mean elevation of the terraces declined 0.9 ft to an elevation of +1.6 ± 0.3 ft, slightly lower than the +1.9 ft predicted by the settlement curve (Figure 14). The difference between the predicted and measured settlement may be partially attributed to the shrinkage of soils, which was expected to occur between three and six months after construction. Based on a similar terrace design, but with a wider 15 ft crown, additional settlement from shrinkage during the 20-year project life was estimated to be an additional 0.3 feet (GeoEngineers 2014a). Future settlement of the terrace crowns is expected to be minimal through the remainder of the monitoring period, as the predicted settlement is < 0.1 foot between year 3 and year 20.

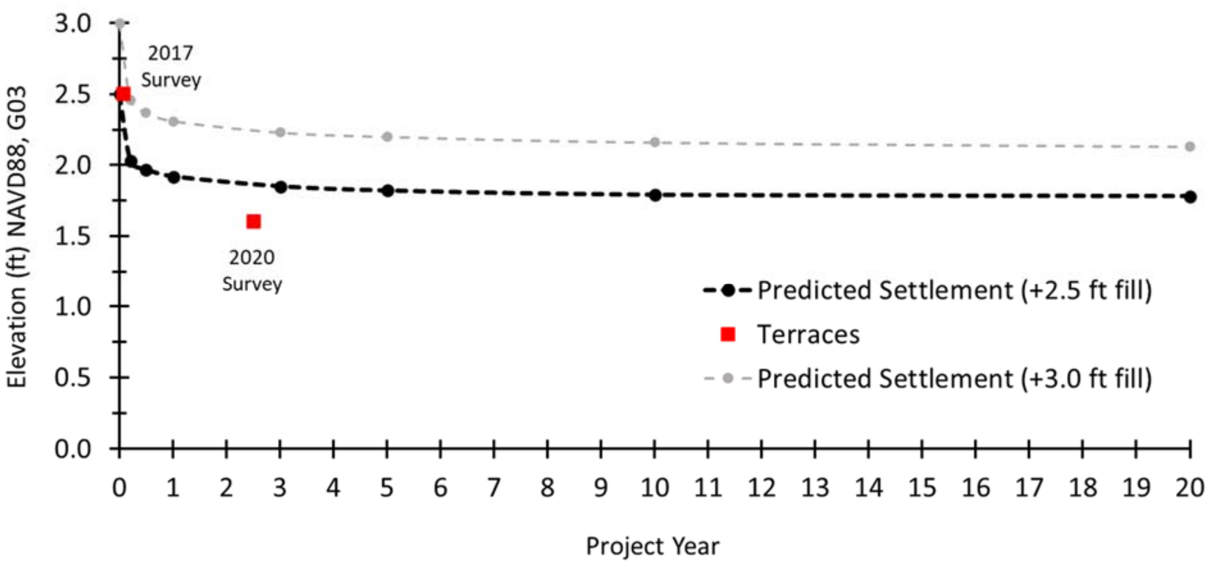


Figure 14. BA-0164 terraces settlement curve for a constructed elevation of +2.5 + 0.5 feet. The predicted elevations for a +3.0 ft constructed elevation is included to represent the construction tolerance (+ 0.5 feet). The as-built (2017) and year 2.5 (2020) mean surveyed elevations of the terrace crowns are included on the graph.

Inundation

When developing the settlement curves for the BA-0164 marsh and terraces, hydrographic station BA03-61 (Figure 1) was utilized to calculate percent inundation throughout the project's 20-year post-construction life. This station was discontinued in 2021; therefore, CRMS4103 (Figure 1) is being used as a surrogate due to its proximity to the project area (approximately 2.5 miles from BA-0164), more complete data record, and expected continuity through the 20-year monitoring life of the project. The full hourly CRMS4103 water elevation data record (through writing of this report) was used to calculate the percent of time the marsh and terraces were inundated based on their mean elevations. Hourly CRMS4103 water elevation data between 02/01/2008 and 10/26/2022 were converted to Geoid03 (from either Geoid99 or Geoid12a), using adjustments provided by the National Oceanic and Atmospheric Administration's National Geodetic Survey at https://geodesy.noaa.gov.

For both fresh and intermediate marsh in the Louisiana Coastal Zone, the optimal inundation range is between 10% and 90% (CPRA 2017). Marsh creation projects are initially constructed to a higher elevation that is outside of this inundation range due to the rapid initial settlement that occurs within the first few years. For the BA-0164 as-built surveys, the marsh and terraces were expectedly both at a mean elevation where inundation was occurring less than 1% of the time and would be limited to extreme flooding events (Figure 15). But by the 2020 survey, the southern marsh cell had settled to a mean elevation (+0.9 ± 0.4 ft) where it was tidally inundated approximately 37% of the time, well-within the optimal range for fresh/intermediate marsh. The northern marsh cell was still at a higher mean elevation (+1.4 ± 0.5 ft) for the 2020 survey that kept it just below the 10% inundation range.

As the elevation contour maps previously demonstrated, elevations within the marsh vary by location. For example, elevations in the northern cell were generally higher further north and lower further south for the 2020 survey. In order to better represent inundation that occurs within this range of elevations, inundation was calculated for the standard deviation (± SD) of the mean elevation for each feature. This range is represented by the ± bars for each mean inundation (%) in Figure 15. Inundation for the northern cell mean elevation ± SD (+1.9 ft to 0.9 ft) ranged between 2% and 37% for the 2020 survey, with inundation occurring at a greater frequency generally further south in the cell where elevations were lower (Figure 15, Figure 6).

The terrace crowns settled to a mean elevation of +1.6 ± 0.3 ft by the 2020 survey, and at that elevation, were inundated only 4% of the time (Figure 15). If the inundation range is calculated for the mean terrace elevation ± SD, inundation ranged between 13% and 2%. By remaining at a higher elevation in the landscape, the terraces are serving as speed bumps to reduce localized tidal energy. Figure 16 provides a visual representation of where the terraces and marsh cells lie in regards to CRMS4103 daily mean water elevation and the mean elevation of each feature.

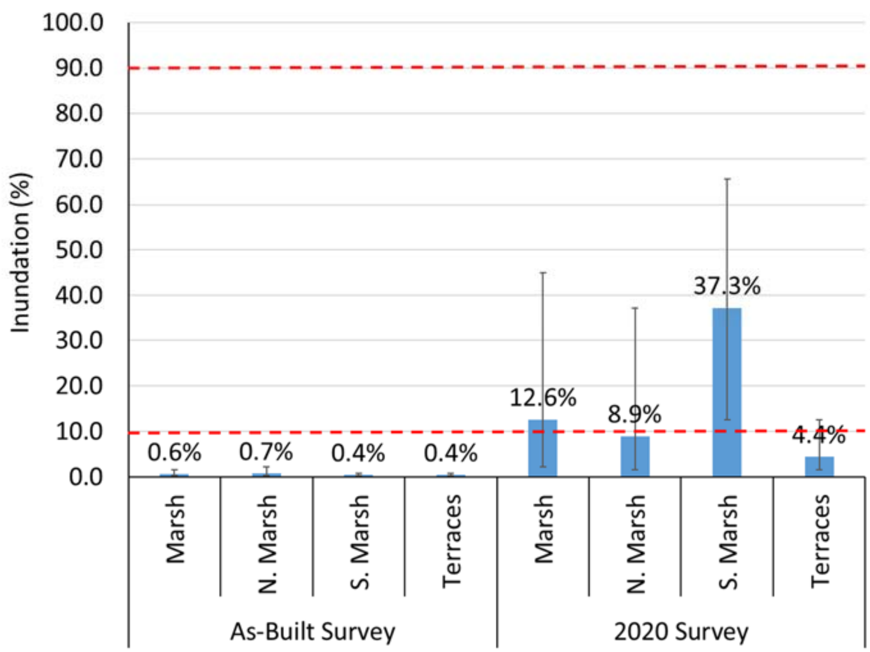


Figure 15. Calculated inundation (%) of the marsh and terraces for the as-built and 2020 elevation surveys. The dashed lines at 10% and 90% inundation represent the optimal inundation range for marsh. Inundation (%) is calculated based on the mean elevation of each feature, with the ± bars representing the inundation range calculated for the ± SD of the mean feature elevation.

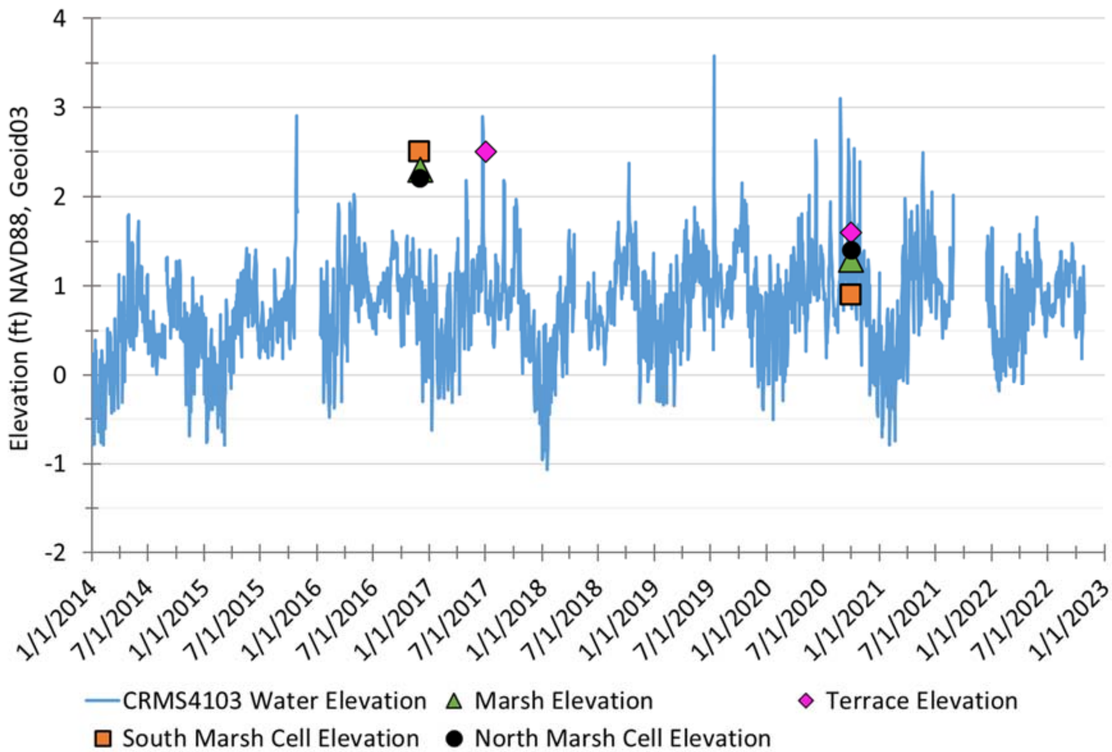


Figure 16. Mean daily elevation at CRMS4103 between 01/01/2014 and 12/28/2022, with mean elevation of the BA-0164 project features for the as-built and 2020 surveys.

iii. Vegetation

The vegetative communities of the BA-0164 marsh and terraces are analyzed separately in this report due to different construction timelines and sediment sources. Construction of the marsh was completed in September 2016 using Mississippi River sediment, while construction of the terraces was completed almost a year later in June 2017, using sediment dredged from within the terrace field. Additionally, the marsh platform was not planted, while the terraces were planted with *Paspalum vaginatum* (seashore paspalum) along the terrace crowns and *Spartina alterniflora* (smooth cordgrass) along the terrace slopes.

<u>Total Percent Cover</u>

Total percent cover is an assessment of the total live vegetative cover, with the maximum cover being 100%. A total percent cover of 100% means that if a station was viewed from above, no ground would be viewable beneath the vegetation. The BA-0164 marsh creation platform vegetated rapidly, with total cover measuring 80.8 ± 10.4% by the August 2018 survey that was conducted two years after construction (Figure 17). Total cover trended lower for the June 2021 survey, at 70.8 ± 24.2%, but cover was still high and the difference between the surveys was insignificant. For the terraces, the 2018 survey occurred only one year after construction, but cover was still considerable at 67.0 ± 20.0% (Figure 17). By the 2021 survey, the terrace cover had increased significantly to 88.5 ± 6.3% ($p = 0.0045$, $F = 10.50$), largely due to a pronounced increase in shrubs. The standard deviation was lower on the terraces in 2021 than in 2018, indicating the total cover of each surveyed terrace was more similar in 2021. This is opposite of the trend for the marsh, where the variability in coverage between monitoring stations increased in 2021.

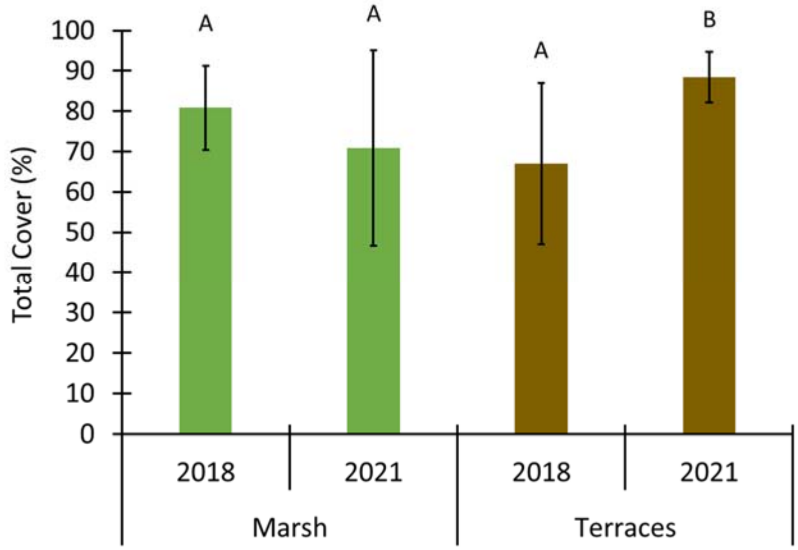


Figure 17. Total mean vegetative cover (%) ± SD at marsh and terrace monitoring stations for the 2018 and 2021 vegetation surveys.

<u>Layer Percent Cover</u>
Four vegetative layers—tree, shrub, herbaceous, and carpet—are assessed at each monitoring station (Folse et al. 2020). These layers are primarily differentiated by height and whether the species are herbaceous or woody (i.e., shrubs and trees). Each layer is assessed individually, allowing for an observation of changes to vertical structure and habitat within the community. Because layers can overlap, for example, taller shrubs can overlap shorter herbaceous vegetation, the sum of layer covers at a station can be greater than the total cover, which has a maximum value of 100%.

The herbaceous and shrub layers both contributed substantially to the vegetative cover in the marsh and on the terraces. In the marsh, the herbaceous layer was dominant in 2018 and 2021, at 60.0 ± 27.1% and 64.6 ± 20.4% cover, respectively. The shrub layer provided a lesser cover in 2018 and 2021, at 25.2 ± 32.7% and 17.5 ± 29.0%, respectively (Figure 18). On the terraces, the herbaceous layer composed nearly all of the vegetative cover in 2018 (67.0 ± 20.0%), with the shrub cover contributing only 4.4 ± 6.5% (Figure 18). For the 2021 survey, the terrace herbaceous cover declined to 49.5 ± 22.9%, but was not significantly different from the herbaceous cover in 2018. However, the terrace shrub layer increased significantly in 2021 to 56.0 ± 28.2% ($p < 0.0001$, F = 31.65), with shrubs being recorded at every terrace monitoring station. No carpet layer was recorded in the marsh or on the terraces for the 2018 or 2021 surveys, and only one marsh station had trees, with *Sabal minor* (black willow) being recorded during the 2021 survey.

For the 2021 survey, the shrub layer cover on the terraces was also significantly higher than the shrub layer cover in the marsh ($p = 0.0052$, F = 9.82). The 2020 mean elevation of the marsh was +1.3 ± 0.5 ft, while the mean elevation of the terraces was 0.3 ft higher at +1.6 ± 0.3 feet. The slightly higher terrace elevation may be encouraging greater shrub growth than in the marsh. Additionally, a greater shrub seed source in the terrace soils and a higher organic content may have fostered greater shrub development.

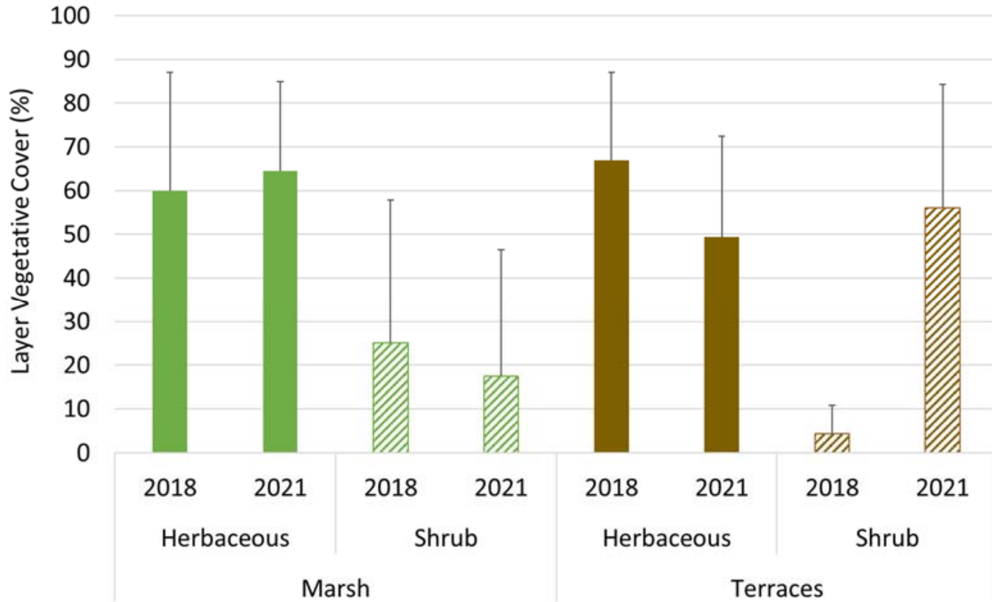


Figure 18. Herbaceous and shrub layer mean percent cover (+ SD) for the 2018 and 2021 vegetation surveys in the marsh and on the terraces.

<u>Individual Species Cover</u>

Marsh

The three species with the highest mean percent cover for the 2018 marsh vegetation survey were *Typha latifolia* (broadleaf cattail, 29.2%), *Baccharis halimifolia* (eastern Baccharis, 22.7%) and *Cyperus filicinus* (fern flatsedge, 8.3%) (Figure 19). *Typha latifolia* and *C. filicinus* are both herbaceous obligate species (OBL, only grow in wetlands), while *B. halimifolia* is a shrub and is a classified as facultative (FAC, grows in both wetland and non-wetland habitats). *Typha latifolia* and *C. filicinus* are likely colonizing relatively lower elevation areas within the young marsh that experience a greater depth and frequency of inundation; whereas *B. halimifolia* is colonizing higher elevation, less inundated areas of the marsh. A total of 28 plant species were identified at marsh stations in 2018, with two additional plants identified only to genus. Based on the species composition and covers, the marsh was categorized as fresh-intermediate, with nine stations being classified as fresh marsh and three stations being classified as intermediate marsh.

For the 2021 survey, *T. latifolia* and *B. halimifolia* remained in the top three species with highest covers, at 14.1% and 19.5%, respectively. *Solidago sempervirens* (seaside goldenrod) increased in cover from 8.2% in 2018 to 23.3% in 2021, making it the species with the highest cover that year (Figure 19). *Solidago sempervirens* is common in coastal Louisiana and can be found in grasslands, areas of transition (such as newly-created marsh habitats), marshes, and on dunes. It is classified as a facultative wetland (FACW) species, meaning it is usually found in wetlands, but can also be found in non-wetland habitats. A total of 31 species were identified in 2021, with one additional plant identified only to genus. As in 2018, the marsh was categorized as fresh-intermediate, with six stations being classified as fresh marsh and six stations being classified as intermediate marsh. The mean daily salinity between 02/01/2008 and 10/27/2022 was 1.9 ± 1.5 ppt at nearby intermediate marsh site CRMS4103. As tidal inundation of the marsh increases, the vegetative community can be expected to transition to a more uniform intermediate marsh habitat.

Terraces

The three species with the highest mean percent cover for the 2018 terrace vegetation survey were *Paspalum vaginatum* (OBL, seashore paspalum, 28.5%), *Panicum dichotomiflorum* (FACW, fall panicgrass, 10.3%), and *Symphyotrichum divaricatum* (OBL, southern annual saltmarsh aster, 10.3%), all herbaceous marsh species (Figure 20). *Paspalum vaginatum* was planted on the terrace crowns approximately three months prior to the survey to help stabilize soils; therefore, its relatively high cover and presence at 90% of the surveyed stations is not surprising. By the 2021 survey, two shrub species became dominant on the terraces, with *B. halimifolia* at 38.7% cover and *Iva frutescens* (FACW, Jesuit's bark) at 18.8% cover. *Solidago sempervirens* had the third highest cover (16.1%), and *P. vaginatum* had dropped to 14.8% (Figure 20). For the 2021 survey, *Baccharis halimifolia* and *S. sempervirens* were both found at 100% of the terrace stations, while *P. vaginatum* was found at 80%. Based on the species composition and covers, the terrace community was classified as intermediate marsh for both the 2018 and 2021 surveys.

Spartina alterniflora (OBL) was also planted on the terraces, but this species was planted on the terrace slopes due to its growth in more inundated marsh habitats and usefulness in reducing tidally-induced erosion. Despite all monitoring stations being located on the terrace crowns, *S. alterniflora* was identified at 30% of stations in 2018 and 60% of stations in 2021; however, cover was low at 1.3% in 2018 and 6.5% in 2021. Field observations have documented the vigorous growth and expansion of this species along the terrace slopes (Appendix B, Photos 4 and 5).

Photographs showing representative BA-0164 marsh and terrace vegetation communities are included in Appendix C. The complete list of all species recorded at marsh and terrace stations, along with their mean covers, distributions, and associated marsh habitats, is included in Appendix D.

<u>Floristic Quality Index (FQI)</u>

The Floristic Quality Index (FQI) goes beyond providing information on species cover and distribution by characterizing the quality and stability of the marsh. The calculation of the FQI was developed by Swink and Wilhelm (1979), but has been modified by Cretini et al. (2011) to more effectively describe the coastal community in Louisiana. The FQI score is calculated using the percent cover for each species and a value that is assigned to each species based on how indicative it is of a stable marsh community. This value is called the coefficient of conservatism (CC) and ranges from 0 to 10, with 0 being a species of lowest value (e.g., invasive species) and 10 being a species that is characteristic of a vigorous coastal wetland (e.g., *S. alterniflora*). A station with a high FQI score represents a community that has a low percentage of invasive and disturbance species and is dominated by species that are found in a stable marsh community. The FQI score for each station was averaged for the marsh and for the terraces to produce a mean FQI score for each habitat. An FQI score > 71 is considered good, < 39 is considered poor, and between these ranges is considered fair (based on a maximum score of 100) (CPRA 2022).

The marsh FQI score was stable for the 2018 and 2021 surveys, at 32.7 ± 10.8 and 32.2 ± 16.9, respectively (Figure 19). These values place the marsh vegetation community in the poor category. A low FQI score for a recently-created marsh is not surprising, since the vegetative community is still in transition and the FQI is crafted to measure the stability of a marsh. If individual station, rather than mean FQI scores are assessed, the percentage of stations in the fair category increased from 25% to 50% between surveys; however, a decline in the FQI score at other stations prevented an increase in the mean marsh FQI value. The terrace FQI score increased between years from 38.4 ±

10.3 to 46.5 ± 8.3, transitioning the terrace vegetation community from the poor to the fair category. The percentage of terrace stations in the fair category increased from 50% to 80% between surveys. The higher FQI score for the terraces in comparison to the marsh is largely attributed to the terrace plantings. Both planted species have high CC scores (*P. vaginatum*: CC = 7; *S. alterniflora*: CC = 10).

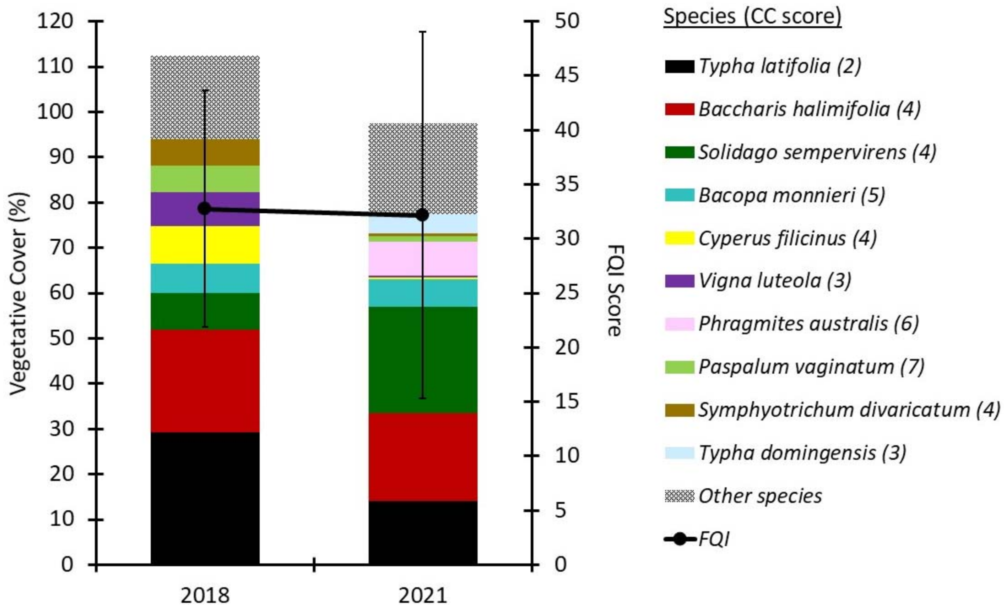


Figure 19. Mean species percent cover and FQI ± SD by survey year for BA-0164 marsh stations (n = 12). The graph shows the sum of the mean percent covers for each species. Due to the physical overlap of individual species at stations, this sum can be greater than 100%.

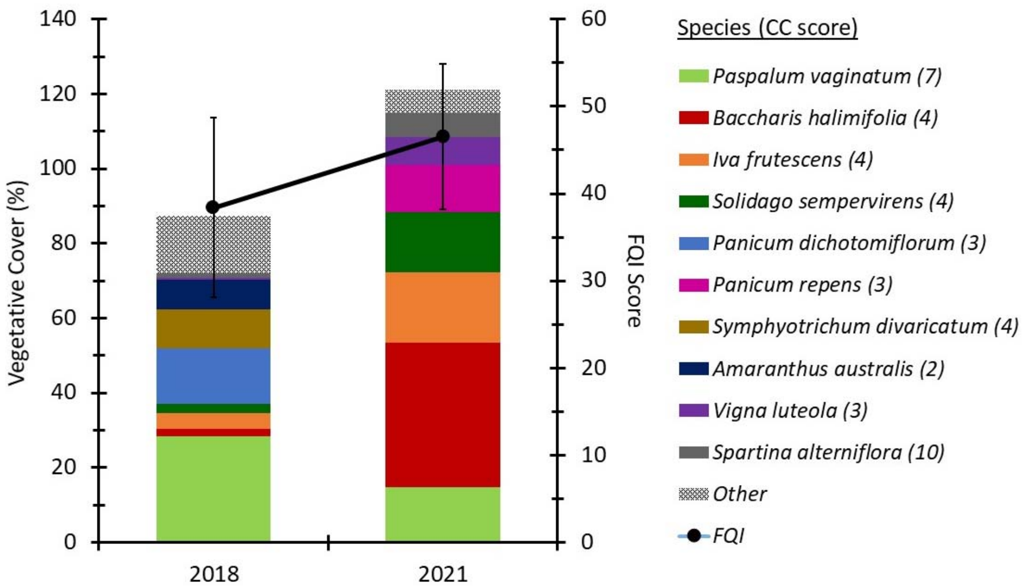


Figure 20. Mean species percent cover and FQI ± SD by survey year for BA-0164 terrace stations (n = 10). The graph shows the sum of the mean percent covers for each species. Due to the physical overlap of individual species at stations, this sum can be greater than 100%.

Vegetation Comparisons

The BA-0164 project is the third Bayou Dupont marsh creation project constructed through CWPPRA using Mississippi River sediment. It was constructed adjacent to BA-0039, the first Bayou Dupont marsh creation project that was completed in 2010. The early vegetative community at BA-0164 (marsh only) was compared to the early vegetative community at BA-0039 to see if it was following a similar trajectory. Both projects were also compared to the natural marsh community at CRMS4103, which is located less than 2.5 miles northwest of BA-0164. The BA-0164 vegetation surveys were conducted two and five years after marsh construction, while the BA-0039 surveys were conducted closer to one and four years after construction. For CRMS4103, data were averaged for the annual vegetation surveys that occurred 2009–2021 to provide a general characterization of the site. CRMS4103 is classified as intermediate marsh, the intended marsh habitat for BA-0164, with the next closest CRMS sites being classified as brackish to saline marsh. For BA-0039, there were three CRMS-like monitoring sites that contained 10 vegetation stations along each site transect (Richardi 2016). For BA-0164 there were 12 stations that were placed randomly throughout the marsh. CRMS4103 contained 10 vegetation stations along the site transect (Folse et al. 2020). All stations were 2 m by 2 m.

Total percent cover was similar between the BA-0164 and BA-0039 constructed marsh projects and CRMS4103 natural marsh (Figure 21). Within the vegetative layers, the herbaceous layer cover was also similar among all locations, but there was a difference among the shrub layer covers ($p = 0.0019$, F = 4.62). The BA-0164 shrub cover two years after construction (2018 survey) was higher than the BA-0039 shrub cover one year after construction (2011 survey) at 25.2% ± 32.7% and 0.3 ± 1.8%, respectively (Figure 22). The difference in the shrub covers may be due to the amount of time shrubs had to develop for each project between the end of construction and the first vegetation survey. The BA-0039 survey occurred just one year after project construction, preventing a significant amount of woody vegetative growth. However, the difference in shrub cover may also be partially due to different elevations of the marsh. Two years after the BA-0164 2018 vegetation survey, the mean marsh elevation was +1.3 ± 0.5 ft; whereas the BA-0039 mean marsh elevation in 2011, the same year as the BA-0039 vegetation survey, was slightly lower, at +1.0 ± 0.4 feet.

The FQI score was also different between sites ($p < 0.0001$, F = 6.21), with the BA-0164 FQI score being significantly lower both years than the FQI score at BA-0039 and CRMS4103 (Figures 23 and 24). While the two projects and CRMS4103 share many of the same marsh species, the dominant species are different between locations and explain the difference in FQI scores. For example, *T. latifolia* (CC = 2), *B. halimifolia* (CC = 4) and *S. sempervirens* (CC = 4), all low scoring species, were dominant at BA-0164. At BA-0039, *P. vaginatum* (CC = 7), *Bacopa monnieri* (CC = 5, herb of grace), and *Distichlis spicata* (CC = 2, saltgrass) had the greatest covers, while higher-scoring *Sagittaria lancifolia* (CC = 6, bulltongue arrowhead), *Spartina patens* (CC = 9, saltmeadow cordgrass) and *Ipomoea sagittata* (CC = 8, saltmarsh morning-glory) were dominant at CRMS4103 and explain why the natural marsh site had the highest mean FQI score (50.1).

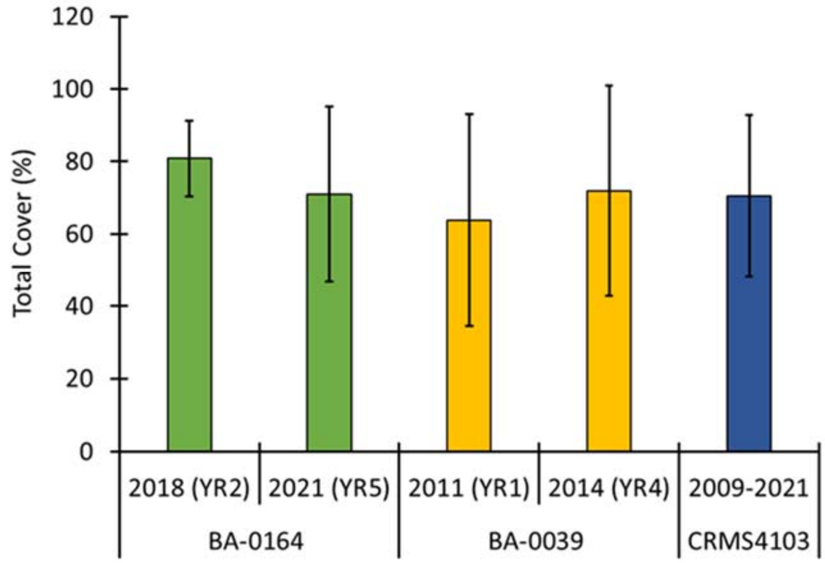


Figure 21. Comparison of total mean vegetative cover (%) ± SD at BA-0164, BA-0039 and CRMS4103.

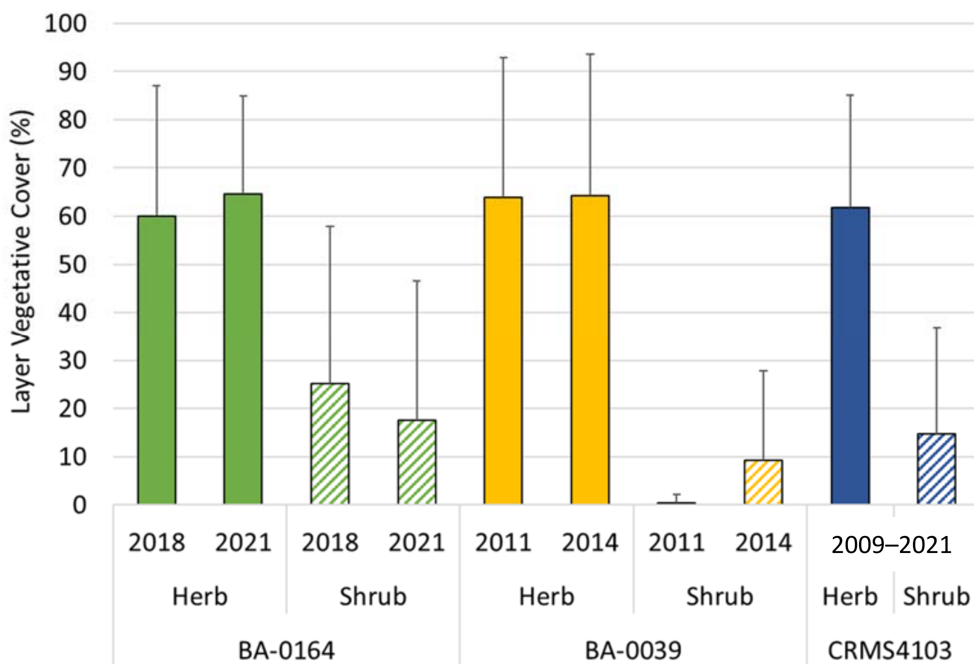


Figure 22. Comparison of herbaceous and shrub layer mean percent cover (+ SD) at BA-0164, BA-0039 and CRMS4103.

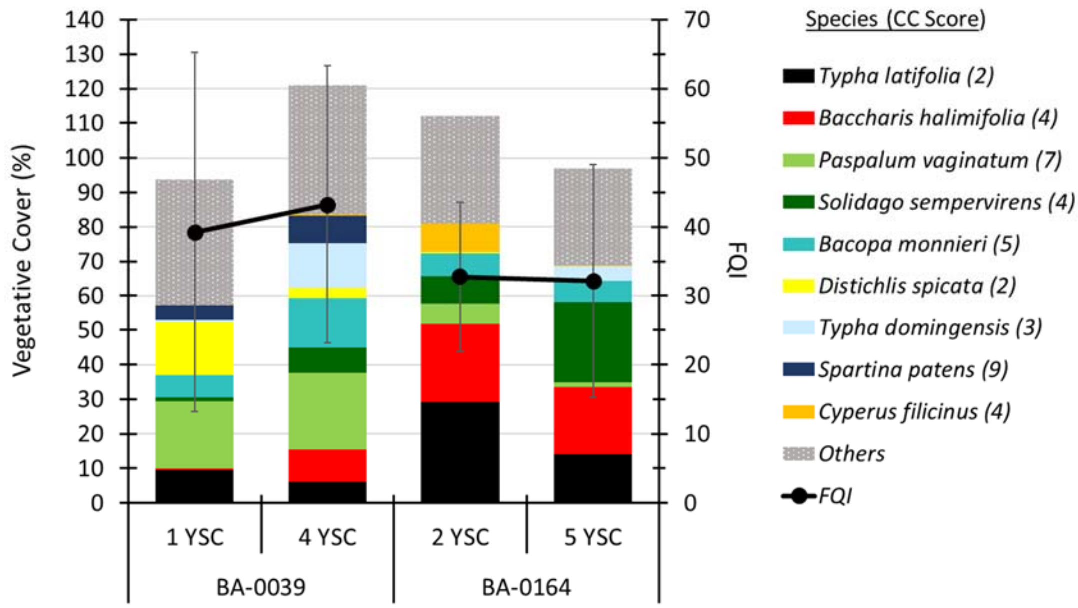


Figure 23. Mean species percent cover and FQI for the BA-0039 and BA-0164 marsh creation projects. YSC = Years Since Construction.

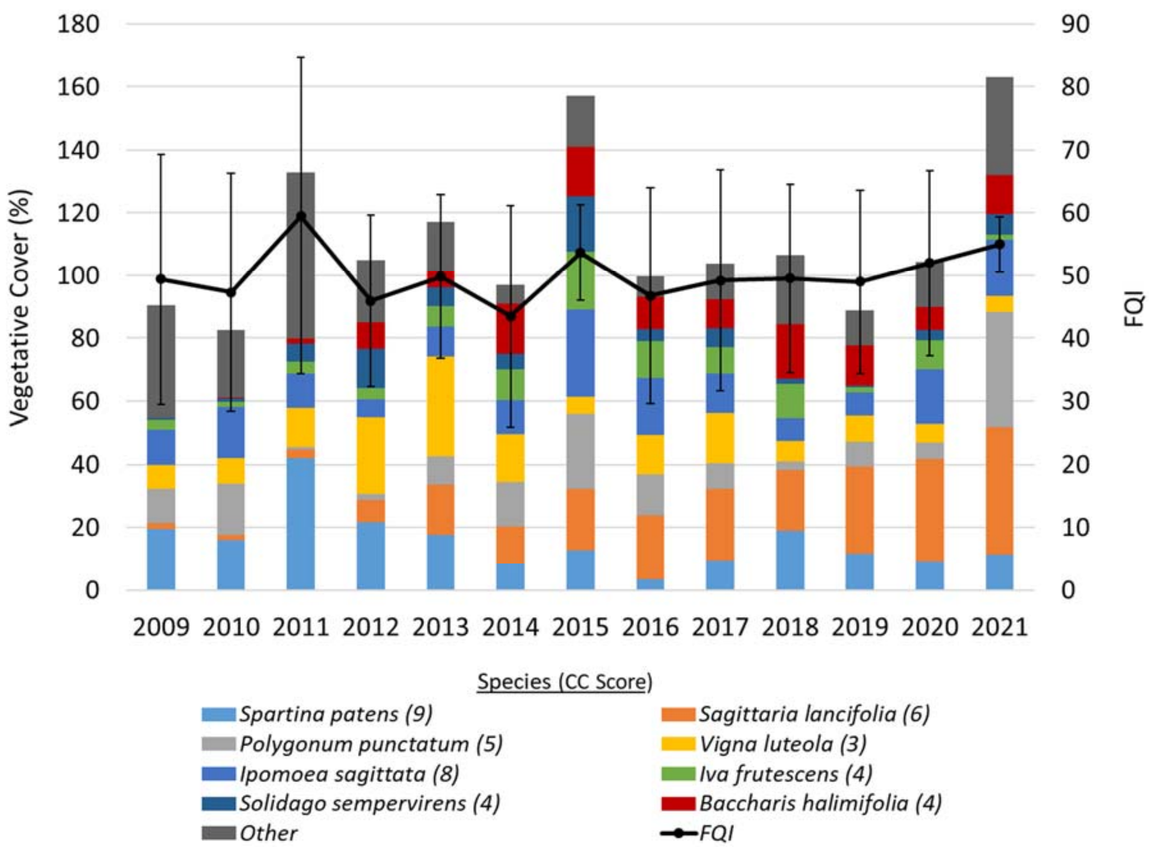


Figure 24. Mean species percent cover and FQI ± SD for CRMS4103.

V. Conclusions

The goals of the BA-0164 project are to restore marsh in open water areas and reduce local wave energy with the construction of terraces. The specific project objectives are to create and nourish approximately 265 acres of intermediate marsh using pipeline delivery of sediment dredged from the Mississippi River, and to create approximately 9,679 linear feet of earthen terraces using sediment dredged from within the project area. As detailed below, for the term of this OM&M report, the BA-0164 project has attained its goals. The objectives have also largely been met, with the only limit to full attainment being the marsh categorization of fresh-intermediate rather than intermediate habitat, as of the 2021 vegetation survey.

a. Project Effectiveness

Marsh

- Results of the 2018 land-water analysis classified the BA-0164 marsh creation area into 271 acres of land and only 1 acre of water. This assessment occurred just over two years after the completion of construction and indicates that early in the project life, the marsh creation feature is maintaining its integrity in the landscape.

- An analysis of marsh elevation from the 2016 and 2020 surveys shows that the northern marsh cell may be stabilizing at approximately half a foot higher than predicted by the settlement curve, while the southern marsh cell is settling as predicted. As of the October 2020 elevation survey, the mean elevation of the northern and southern marsh cells was +1.4 ± 0.5 ft and +0.9 ± 0.4 ft, respectively. Results for the 2020 elevation survey indicate that the marsh may remain at or above the predicted elevation at year 20. The next elevation survey, scheduled for fall 2023, will more clearly demonstrate whether settlement has stabilized and will provide a better indication of the longer-term elevation trend.

- The ideal inundation range for fresh and intermediate marsh is between 10% and 90%. By the year 4 (2020) elevation survey, the southern marsh cell had settled to a mean elevation between the 10% and 90% inundation zone, as intended, with the marsh being inundated approximately 37% of the time. The northern marsh cell was inundated less frequently at only 9% of the time, due to its higher mean elevation. The northern cell was characterized by higher elevations in the northern area of the cell, and lower elevations in the south. In order to better represent inundation that occurs within this range of elevations, inundation was calculated for the standard deviation (± SD) of the mean elevation for each feature. Inundation for the northern cell ranged between 2% and 37% for the 2020 survey, with inundation occurring at a greater frequency generally further south in the cell.

- The newly-constructed marsh platform vegetated rapidly without the need of plantings, with a total cover of 80.8 ± 10.4% in 2018, just two years after construction. This cover declined slightly to 70.8 ± 24.2% for the 2021 survey. The community is primarily composed of herbaceous marsh vegetation, with *Typha latifolia* and *Solidago sempervirens* being the two species with the highest herbaceous covers in 2021. The shrub *Baccharis halimifolia* had the second highest cover in 2021, and is likely colonizing the higher elevation areas of the marsh with lesser inundation.

- The marsh community is categorized as fresh-intermediate, based on the classification of each vegetation monitoring station. The marsh may be transitioning to a more consistently intermediate marsh (the intended habitat), with the number of vegetation stations classified as intermediate increasing between the 2018 and 2021 surveys from three to six. This transition in marsh habitat may be in response to an increase in tidal inundation with marsh settlement.

<u>Terraces</u>

- The 2018 terrace land-water analysis was conducted almost 1.5 years after their construction. Within the 101-acre terrace field boundary, 14 acres were classified as land and 87 acres were classified as water. The inclusion of natural marsh within the terrace boundary limited the scope of the analysis; therefore, an additional analysis was conducted on land and water acres within each of the 14 terrace polygons, which totaled approximately 14 acres. This analysis indicated that there were 9 acres of land and 5 acres of water. Future USGS land-water assessments will include this boundary to allow for a more refined evaluation of terrace land change over time.

- The goal of the terraces is to reduce local wave energy. Terrace elevation was analyzed for the terrace features (crown and slope), and just the terrace crowns, with the later used to compare to the settlement curve and determine percent inundation. Mean terrace elevation for the features was +0.4 ± 1.0 ft for the 2020 survey, which was conducted approximately 2.5 years after terrace construction. The mean crown height was +1.6 ± 0.3 ft, which was 0.3 ft lower than the +1.9 ft predicted crown elevation for the time of the survey. The settlement curve only considered consolidation settlement, and did not factor in settlement from shrinkage of the soils due to drying, which could account for the lower than predicted elevation. Future settlement of the terraces is expected to be minimal through the rest of the monitoring period, as the predicted additional terrace crown settlement is < 0.1 ft between year 3 and year 20.

- According to the BA-0164 project completion report, the as-built length of the terraces was 9,666 linear feet, which was close to the targeted constructed length of 9,679 linear feet (Moffatt and Nichol 2018). The as-built length represented the length of the crowns, and did not include the slopes on either end of the terraces. The 2020 elevation survey indicated that little erosion had occurred along the terrace crowns that would impact the length of the terraces. However, erosion was indicated along the slopes of some of the terraces by declines in elevation between the 2017 and 2020 surveys.

- The terrace crowns settled to a mean elevation of +1.6 ± 0.3 ft by the 2020 survey, and at that elevation, were inundated only 4% of the time. If the inundation range is calculated for the mean terrace elevation ± SD, inundation ranged between 13% and 2%. By remaining at a higher elevation in the landscape, the terraces are serving to reduce localized tidal energy.

- The terrace plantings of *Paspalum vaginatum* on the crown and *Spartina alterniflora* along the slopes were effective in quickly establishing vegetation on the terraces. *Spartina alterniflora* has proliferated where planted and is likely providing protection from wave-induced erosion.

b. Recommended Improvements

- Additional elevation transects should be established on the terrace slopes to allow for a better assessment of the terrace features and elevation change over time. Because of the narrow width of the terraces and the rapid change in elevation along the slopes, surface elevation models struggled with accurate interpolation. Increasing the point field on the terrace slopes will improve future analyses.

- Vegetative plantings of terraces should be included as part of the project construction phase. Plants should be ready for installation as soon as possible after the final construction of terraces to provide a timely method of erosion control.

c. Lessons Learned

- In the southern cell, sediment loss through the uncontained southern and western boundaries may have contributed to a greater decline in elevation. The northern cell is contained on three sides, which may have resulted in a more stable, and higher, marsh platform. Additional factors, including the depth of river sediment fill and the characteristics of the underlying soils, could have contributed to the differences in elevation between the two marsh creation cells.

VI. References

Coastal Protection and Restoration Authority of Louisiana. 2021. Coastwide Reference Monitoring System (CRMS) Basin Level Report Card: Barataria Basin, 2021. 13 pp. https://warcservices.usgs.gov/CRMS/ChartingAPI/dataCharting/Report_Cards/BA_2021_ReportCard.pdf

Coastal Protection and Restoration Authority. 2017. Marsh Creation Design Guidelines, Marsh Creation Projects. Version MCDG1.0. Appendix D. Marsh Inundation Methodology. 11p.

Coastal Protection and Restoration Authority of Louisiana (CPRA). 2012. Louisiana's Comprehensive Master Plan for a Sustainable Coast. Coastal Protection and Restoration Authroity, Baton Rouge, Louisiana, 188 p.

Couvillion, B.R., H. Beck, D. Schoolmaster, and M. Fischer. 2017. Land area change in coastal Louisiana 1932 to 2016: U.S. Geological Survey Scientific Investigations Map 3381, 16 p. pamphlet, https://doi.org/10.3133/ sim3381.

Cretini, K.F., J.M. Visser, K.W. Krauss, and G.D. Steyer. 2012. Development and use of a floristic quality index for coastal Louisiana marshes. *Environmental Monitoring and Assessment* 184:2389–2403.

Folse, T. M., T. E. McGinnis, L. A. Sharp, J. L. West, M. K. Hymel, J. P. Troutman, D. Weifenbach, W. M. Boshart, L. B. Rodrigue, D. C. Richardi, W. B. Wood, C. M. Miller, E. M. Robinson, A. M. Freeman, C. L. Stagg, B. R. Couvillion, and H. J. Beck. 2020. A standard operating procedures manual for the Coastwide Reference Monitoring System-Wetlands and the System-Wide Assessment and Monitoring Program: Methods for site establishment, data collection, and quality assurance/quality control. Louisiana Coastal Protection and Restoration Authority. Baton Rouge, LA. 252 pp.

GeoEngineers, Inc. 2014a. Geotechnical Engineering Report: Bayou Dupont Sediment Delivery Marsh Creation No. 3 (BA-164). File No. 16715-037-00. Prepared for Louisiana Coastal Protection and Restoration Authority. 10 pp. plus figures and appendices.

GeoEngineers, Inc. 2014b. Geotechnical Data Report: Bayou Dupont Sediment Delivery Marsh Creation No. 3 (BA-164). File No. 16715-037-00. Prepared for Louisiana Coastal Protection and Restoration Authority. 5 pp. plus figures and appendices.

Moffatt & Nichol. 2018. Bayou Dupont Sediment Delivery Marsh Creation #3 and Terracing (BA-164) Project Completion Report. Prepared for Louisiana Coastal Protection and Restoration Authority. 32 pp. plus appendices.

Moffatt & Nichol. 2014. Bayou Dupont Sediment Delivery Marsh Creation #3 (BA-164) 95% Design Report. Report prepared for the Coastal Protection and Restoration Authority of Louisiana, Baton Rouge, Louisiana. 40 pp. plus appendices.

Mueller-Dombois, D., and H. Ellenberg. 1974. Aims and methods of vegetation ecology. John Wiley and Sons, Inc. New York.

Richardi, D. 2018. Monitoring plan for Bayou Dupont Sediment Delivery Marsh Creation #3 and Terracing (BA-0164). Coastal Protection and Restoration Authority of Louisiana. 12 pp. https://cims.coastal.louisiana.gov/RecordDetail.aspx?Root=0&sid=21284

RStudioTeam. 2016. RStudio: Integrated Development for R. RStudio, Inc., Boston, MA http://www.rstudio.com/.

SAS Institute. 2002-2012. SAS for Windows, Release 9.4. The SAS Institute., Cary, NC, USA.

Steyer, G.F., R.C. Raynie, D.L. Steller, D. Fuller, and E. Swenson. 1995, revised 2000. Quality management plan for Coastal Wetlands Planning, Protection, and Restoration Act monitoring program. Open-file report no. 95-01. Louisiana Department of Natural Resources, Coastal Restoration Division, Baton Rouge, LA. 97 pp. plus appendices.

Swink, F. and G.S. Wilhelm. 1979. Plants of the Chicago region, third ed., revised and expanded edition with keys: Lisle, III. The Morton Arboretum.

USGS 2012. Information for WVA-Bayou Dupont Sediment Delivery – Marsh Creation #3.

Appendix A

Three-Year O&M Budget Projection

Bayou Dupont Sediment Delivery – Marsh Creation No. 3 (BA-164)

Federal Sponsor: EPA

Construction Completed : 7/2017

PPL 22

Current Approved O&M Budget	Year 0	Year - 1	Year -2	Year -3	Year -4	Year -5	Year -6	Year -7	Year -8	Year -9	Year -10	Year -11	Year -12	Year -13	Year -14	Year -15	Year -16	Year - 17	Year -18	Year -19	Project Life	Currently
	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32	FY33	FY34	FY35	FY36	FY37	Budget	Funded
State O&M	$3,523	$3,594	$91,421	$3,739	$8,068	$91,740	$3,968	$2,000	$2,000	$4,211	$2,000	$2,000	$4,469	$2,000	$2,000	$4,742	$2,000	$2,000	$5,032	$6,232	$246,738	$208,053
Corps Admin	$1,269	$1,295	$1,321	$1,347	$1,374	$1,402	$1,430	$1,458	$1,487	$1,517	$1,548	$1,578	$1,610	$1,642	$1,675	$1,709	$1,743	$1,778	$1,813	$3,389	$32,385	$10,896
Federal S&A	$3,523	$3,594	$3,666	$3,739	$3,814	$9,957	$3,968	$4,047	$4,128	$4,211	$4,295	$4,381	$4,469	$4,558	$4,649	$4,742	$4,836	$4,934	$5,032	$35,328	$121,871	$32,262
Total																					$400,994	$251,211

Projected O&M Expenditures																					Remaining Project Life	Current Budget
Maintenance Inspection		$3,594		$3,739			$3,968			$4,211			$4,469			$4,742			$5,032		$22,422	$3,968
State Admin (Non-Inspection FY)	$3,523		$3,666		$2,000	$2,000		$2,000	$2,000		$2,000	$2,000		$2,000	$2,000		$2,000	$2,000		$6,232	$24,232	$4,000
																					$0	$0
Surveys			$64,691			$89,740															$89,740	$89,740
Federal S&A	$3,523	$3,594	$3,666	$3,739	$3,814	$9,957	$3,968	$4,047	$4,128	$4,211	$4,295	$4,381	$4,469	$4,558	$4,649	$4,742	$4,836	$4,934	$5,032	$35,328	$103,536	$17,973
																					$0	$0
Containment Dike Gapping																					$0	$0
E&D			$5,832		$6,068																$0	$0
Construction			$17,232																		$0	$0
Construction Oversight																					$0	$0
Total	$3,523	$3,594	$91,421	$3,739	$8,068	$91,740	$3,968	$2,000	$2,000	$4,211	$2,000	$2,000	$4,469	$2,000	$2,000	$4,742	$2,000	$2,000	$5,032	$6,232	$136,394	$97,708

O&M Expenditures from COE Report	$11,967	Current O&M Budget less COE Admin	$240,315	Current Project Life Budget less COE Admin	$368,609
State O&M Expenditures not submitted for in-kind credit	$0	Remaining Available O&M Budget	$228,348	Total Projected Project Life Budget	$148,361
Federal Sponsor MIPRs (if applicable)	$0	**Add'l Funding amount needed**	**($130,640)**	**Project Life Budget Request Amount**	**($220,249)**
Total Estimated O&M Expenditures (as of June 2019)	$11,967				

Appendix B

Inspection Photographs
11/02/2021

Photo 1. Broken up marsh deposited by Hurricane Ida southeast of the BA-0164 marsh creation area. Despite significant damage to natural marsh in the area, the BA-0164 marsh appeared to weather the storm with little damage.

Photo 2. Looking northwest along the canal that divides the northern and southern BA-0164 marsh creation cells.

Photo 3. Eastern shoreline of the BA-0164 northern marsh creation cell. Some wrack deposited during Hurricane Ida is visible along the shoreline.

Photo 4. Terrace 8, showing shrubs growing on the crown and expanding, planted *Spartina alterniflora* growing along the base of the slope.

Photo 5. Terrace 12 is on the outermost terrace row, which is most exposed to wave energy. This photograph is taken from the southeastern side of the terrace, looking outwards and northwest from the terrace field.

Photo 6. Looking north between Terraces 3 and 4, with Terrace 2 in the background.

Appendix C

Vegetation Monitoring Photographs

Photo 1. Marsh community at vegetation monitoring station V02 in the northern BA-0164 project area during the 2021 survey. *Solidago sempervirens* (seaside goldenrod) had the greatest cover (60%) and the marsh was flooded at a depth of < 0.1 feet.

Photo 2. The vegetation community at monitoring station V04 had a high shrub cover during the 2021 survey, with *Baccharis halimifolia* (eastern baccharis) providing 65% cover. The tree *Salix nigra* (black willow) was also present and provided 35% cover. The marsh was not flooded at this station.

Photo 3. Vegetation monitoring station V07 is located in the southern area of the northern cell. For the 2021 survey, *Typha domingensis* (southern cattail) was the only species rooted in the plot. Water depth was 0.7 feet.

Photo 4. Vegetation monitoring station V09 was the only marsh station that had a high cover of *Phragmites australis* (common reed, 85%). This station is located in the southern cell and was not flooded during the 2021 survey.

Photo 5. *Baccharis halimifolia* (eastern Baccharis) grows along the crown of Terrace 1 during the 2021 survey. This dense coverage is representative of the shrub growth that was encountered at most of the terrace vegetation monitoring stations during the 2021 survey.

Photo 6. *Paspalum vaginatum* (seashore paspalum) covered 70% of the vegetation station on Terrace 11 during the 2021 survey. This species was planted shortly after construction to reduce erosion of soil from the terrace crowns.

Appendix D

Vegetation Tables

Table 1. Percent cover and occurrence of each species at marsh vegetation stations in the BA-0164 project area. Habitat is the marsh habitat where the species in most commonly found. F = freshwater, I = intermediate, B = brackish, S = saltwater.

Scientific Name	Common Name	BA-0164 2018		BA-0164 2021		Habitat
		% Cover	% of Stations	% Cover	% of Stations	
Alternanthera philoxeroides	alligatorweed			0.4	8.3	F/I
Amaranthus australis	southern amaranth	0.3	8.3	0.2	8.3	I/B
Ammannia latifolia	pink redstem	0.7	16.7			F/I
Andropogon glomeratus	bushy bluestem	0.1	8.3	0.9	16.7	F/I
Baccharis halimifolia	eastern baccharis	22.7	41.7	19.5	50.0	F/I
Bacopa monnieri	herb of grace	6.5	50.0	6.1	50.0	F/I
Borrichia frutescens	bushy seaside tansy			0.2	8.3	S
Conyza canadensis	Canadian horseweed	0.4	8.3			F
Cyperus elegans	royal flatsedge			0.4	8.3	F/I
Cyperus filicinus	fern flatsedge	8.3	25.0	0.4	8.3	F/I
Cyperus odoratus	fragrant flatsedge	0.2	8.3			I
Cyperus oxylepis	sharpscale flatsedge	2.5	8.3	0.8	16.7	F
Cyperus surinamensis	tropical flatsedge	0.9	16.7			F
Distichlis spicata	saltgrass	0.4	8.3			F/I
Echinochloa walteri	coast cockspur grass	0.4	8.3			I
Eleocharis cellulosa	Gulf Coast spikerush			0.4	8.3	F/I
Eleocharis flavescens	yellow spikerush			3.3	8.3	I/B
Eleocharis macrostachya	pale spikerush			0.4	8.3	I
Eleocharis vivipara	viviparous spikerush	0.2	8.3			F
Fimbristylis castanea	marsh fimbry			1.0	16.7	B
Hydrocotyle ranunculoides	floating marshpennywort			0.4	8.3	F
Hydrocotyle sp.	hydrocotyle	0.8	8.3	2.1	8.3	**F**
Ipomoea sagittata	saltmarsh morning-glory	0.4	8.3	0.2	8.3	F/I
Leptochloa fusca	Malabar sprangletop	2.8	25.0			I
Lythrum lineare	wand lythrum	0.2	8.3	1.1	25.0	I/B
Morella cerifera	wax myrtle			0.3	8.3	F
Panicum repens	torpedo grass			0.8	8.3	I
Paspalum urvillei	Vasey's grass	0.5	8.3	0.9	16.7	F
Paspalum vaginatum	seashore paspalum	5.8	8.3	1.3	16.7	I
Phragmites australis	common reed			7.5	16.7	I
Phyla nodiflora	turkey tangle fogfruit	0.8	16.7			F
Pluchea odorata	sweetscent	2.8	33.3	0.2	8.3	I/B
Polygonum punctatum	dotted smartweed	0.8	8.3			F/I
Sabatia stellaris	rose of Plymouth			1.0	16.7	B/S
Salix nigra	black willow	0.2	8.3	3.3	16.7	F
Schoenoplectus americanus	chairmaker's bulrush			1.0	16.7	I/B
Schoenoplectus tabernaemontani	softstem bulrush	0.2	8.3			I/B
Sesbania herbacea	bigpod sesbania	2.5	16.7	0.7	16.7	I
Solidago sempervirens	seaside goldenrod	8.2	58.3	23.3	66.7	F/I
Symphyotrichum divaricatum	southern annual saltmarsh aster	5.9	41.7	0.4	16.7	F
Symphyotrichum sp.	aster	0.3	8.3			
Typha domingensis	southern cattail			4.3	25.0	I
Typha latifolia	broadleaf cattail	29.2	75.0	14.1	66.7	F
Vigna luteola	hairypod cowpea	7.5	33.3	0.5	25.0	I

Table 2. Percent cover and occurrence of each species at terrace vegetation stations in the BA-0164 project area. Habitat is the marsh habitat where the species in most commonly found. F = freshwater, I = intermediate, B = brackish, S = saltwater.

Scientific Name	Common Name	BA-0164 2018		BA-0164 2021		Habitat
		% Cover	% of Stations	% Cover	% of Stations	
Alternanthera philoxeroides	alligatorweed			0.2	10	F/I
Amaranthus australis	southern amaranth	8	60			I/B
Baccharis halimifolia L.	eastern baccharis	1.8	70	38.7	100	F/I
Bolboschoenus robustus	sturdy bulrush			0.3	10	B
Calystegia sepium	hedge false bindweed			0.5	10	F
Conyza canadensis	Canadian horseweed	0.3	10			F
Cuscuta sp.	dodder			0.3	10	F/I
Cyperus filicinus	fern flatsedge	0.5	10			F/I
Cyperus odoratus	fragrant flatsedge	0.3	20			I
Distichlis spicata	saltgrass	5.5	10			F/I
Echinochloa walteri	coast cockspur grass	0.3	10			I
Eupatorium capillifolium	dogfennel	0.2	10			F
Ipomoea sagittata	saltmarsh morning-glory	2.6	30	0.4	20	F/I
Iva frutescens	Jesuit's bark	4.4	60	18.8	60	I
Kosteletzkya virginica	Virginia saltmarsh mallow			1	10	F/I
Leptochloa fusca	Malabar sprangletop	2	10			I
Panicum dichotomiflorum	fall panicgrass	14.9	60			F/I
Panicum repens	torpedo grass			12.5	80	I
Paspalum vaginatum	seashore paspalum	28.5	90	14.8	80	I
Phragmites australis	common reed			0.3	20	I
Pluchea odorata	sweetscent	2.5	20			I/B
Polygonum punctatum	dotted smartweed	0.8	20			F/I
Sesbania sp.	riverhemp			0.2	10	F/I
Solidago sempervirens	seaside goldenrod	2.4	60	16.1	100	F/I
Spartina alterniflora	smooth cordgrass	1.3	30	6.5	60	S
Spartina patens	saltmeadow cordgrass			3	10	I/B
Symphyotrichum divaricatum	southern annual saltmarsh aster	10.3	70			F
Symphyotrichum sp.	aster	0.2	10			
Typha domingensis	southern cattail			0.1	10	I
Vigna luteola	hairypod cowpea	0.5	20	7.5	80	I