CPRA
Coastal Protection and Restoration Authority of Louisiana

State of Louisiana Coastal Protection and Restoration Authority

2014 Operations, Maintenance, and Monitoring Report

for

Bayou LaBranche Wetland Creation (PO-17)

State Project Number PO-17
Priority Project List 1

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St. Charles Parish

Prepared by:
Danielle C. Richardi

CPRA Operations Division
New Orleans Regional Office
CERM, Suite 309
2045 Lakeshore Dr.
New Orleans, Louisiana 70122

COASTAL WETLANDS PLANNING, PROTECTION, AND RESTORATION ACT

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Table of Contents

Preface

The 2014 Operations, Maintenance, and Monitoring (OM&M) Report for the Bayou LaBranche Wetland Creation project (PO-17) includes the presentation and analysis of monitoring data collected from November 1993–December 2013. This report is the fourth and final OM&M report for this project, with previous OM&M reports written in 2004, 2008 and 2011. Monitoring reports for PO-17 were written following a different format annually between 1995–1999 and in 2003. The PO-17 project was included on the first Coastal Wetlands Planning, Protection and Restoration Act (CWPRRA) priority project list (PPL 1) that was proposed in 1991. The United States Army Corps of Engineers (USACE) is the federal sponsor and the Coastal Protection and Restoration Authority (CPRA), previously the Louisiana Department of Natural Resources, Coastal Restoration Division (LDNR,CRD), is the state sponsor. Documents pertaining to PO-17, including the monitoring plan, monitoring reports, and the project completion report, are available through CPRA's online library at *http://coastal.la.gov/resources/library*.

I. Introduction

Bayou LaBranche Wetland Creation (PO-17) was the first restoration project constructed through CWPPRA and is consequently the first project to complete its 20-year monitoring lifespan. The PO-17 project involved hydraulically dredging sediment from the bottom of Lake Pontchartrain to construct a neighboring 436-acre marsh platform south of the lake in St. Charles Parish, Louisiana (Figure 1). The aim of the project was to create marsh habitat in an area of critical need that was becoming increasing susceptible to shoreline breaching and the subsequent exposure of interior wetlands to wave energy and higher salinity water from Lake Pontchartrain.

<u>Location</u>

The PO-17 project area is bordered by Lake Pontchartrain (north), Interstate 10 and the Illinois Central Gulf Railroad (south/southwest), an unnamed pipeline canal (east) and Bayou LaBranche (west). To the east of the project area is a 515-acre reference area that consists primarily of open water (Figure 2). Prior to construction, the project area was mostly shallow, open-water estuarine habitat with a mean water depth of 1.0 foot (USACE 1992). A narrow band of intermediate marsh extended along the northern project boundary, separating the project area from the lake. The close proximity of the project area to a plentiful sediment source, the existence of partial containment, and a shallow water depth made PO-17 an ideal candidate for marsh creation with dredged sediment.

<u>Need</u>

A combination of events initiating in the 1800s contributed to a nearly complete loss of marsh in the area and a subsequent conversion to open water. The construction of the Illinois Central Railroad in 1830 significantly altered the local hydrology by creating a barrier to drainage and sheet flow across the marsh. Hydrology in the area was further altered in the early 1900s when marsh habitat was drained for farming, but the success of this project was short-lived. In September 1915, storm surge breached the levee surrounding the property (Hawes, date unknown) and agricultural pursuits were subsequently abandoned in the flooded farmland. In the 1960s, canals were excavated through the LaBranche wetlands for the construction of Interstate 10. These canals provided a direct conduit for saltwater intrusion from Lake Pontchartrain into the interior marsh (USACE 1992). Saltwater flooding from Hurricane Betsy (September 1965) is noted as having negatively impacted vegetation in the area with a 12-foot storm surge that stressed the freshwater marsh vegetation and bald cypress (USACE 1992). The construction of the Mississippi River Gulf Outlet (MRGO), completed in 1968, may have contributed towards wetland loss in the area by facilitating the influx of high salinity water and storm surge from the Gulf of Mexico into Lake Pontchartrain. Hurricane Katrina (August 2005) highlighted the dangers of storm surge through the MRGO, which prompted the closure of the waterway through the construction of a rock barrier that was completed on July 9, 2009 (USACE 2011). Subsidence and shoreline erosion have also contributed to land loss in the area. Pierce et al. (1985) estimated that subsidence was 0.39 in/yr (0.99 cm/yr) in the LaBranche wetlands. Erosion of the Lake Pontchartrain shoreline was estimated to be 9.5 ft/yr (2.9 m/yr) between 1955 and 1972 (Coastal Environments, Inc. 1984).

Construction

Construction of the Bayou LaBranche Wetland Creation project began in January 1994 and was completed by the end of April 1994. Earthen containment dikes were built between January 6, 1994–February 29, 1994, to a height of five feet above the marsh to contain the dredged sediment as it dewatered and consolidated. A z-wall closure and a concrete weir were constructed in the spoil bank that divides the eastern and western cells of the project area (Figure 2). The removal of several segments of the z-wall and the opening of the weir allows for hydrologic exchange between these two areas. Three weirs and four box culverts were constructed in the containment berm to allow water to flow into and out of the project area (Figure 2).

Sediment delivery began on March 7, 1994, and ended on April 2, 1994, with approximately 2,800,000 yd^3 of sediment dredged from the lake (Lauto 1994). Discharge of the sediment was restricted from within 1000 feet of Interstate 10 due to concerns over compromising the foundation. Because of this restriction, the dredged sediment was discharged primarily in the northern project area and was distributed southward. This method of sediment delivery resulted in a larger volume of sediment deposition in the north and a higher localized elevation. The maximum elevation for sediment in the project area was established at +4.0′ NGVD (+3.8′ NAVD88), with an expected settlement to approximately +1.5′ NGVD (+1.3′ NAVD88) after six to eight months (Broussard and Dickson 1995). Further settlement to approximately +1.0′ NGVD (+0.8′ NAVD88) was predicted at nine to twelve months post-construction (USACE 1992). Continued settlement of the newly created marsh platform was expected to result in the creation of approximately 360 acres of intermediate wetlands during the project’s 20-year CWPPRA lifespan, with elevation ranging from +0.5′ to +1.5′ NGVD (+0.3′ to +1.3′ NAVD88) (Broussard and Dickson 1995).

In order to help stabilize the newly-deposited sediments, the PO-17 project area was aerially seeded in July 1994 with 7,140 pounds of *Echinochloa frumentacea* (billion dollar grass), provided by the National Resources Conservation Service and St. Charles Parish and 1000 pounds of soybean screenings, provided by the Soil Conservation Service (LDNR/CRD, data unknown). Soybean screening is the weed seed that is filtered from soybean seeds during harvesting. The soybean screening was described as containing a variety of native seed that was well-suited for planting in the PO-17 project area. Approximately two years later on May 28, 1996, 1600 trade gallons of *Schoenoplectus californicus* (California bulrush) were planted through the Louisiana Department of Agriculture and Forestry Vegetative Planting Program. The vegetation was planted in the project area just north of Interstate 10 along the edge of the marsh to enhance the development of emergent marsh vegetation and further stabilize the marsh edge (Crescent SWCD 1996).

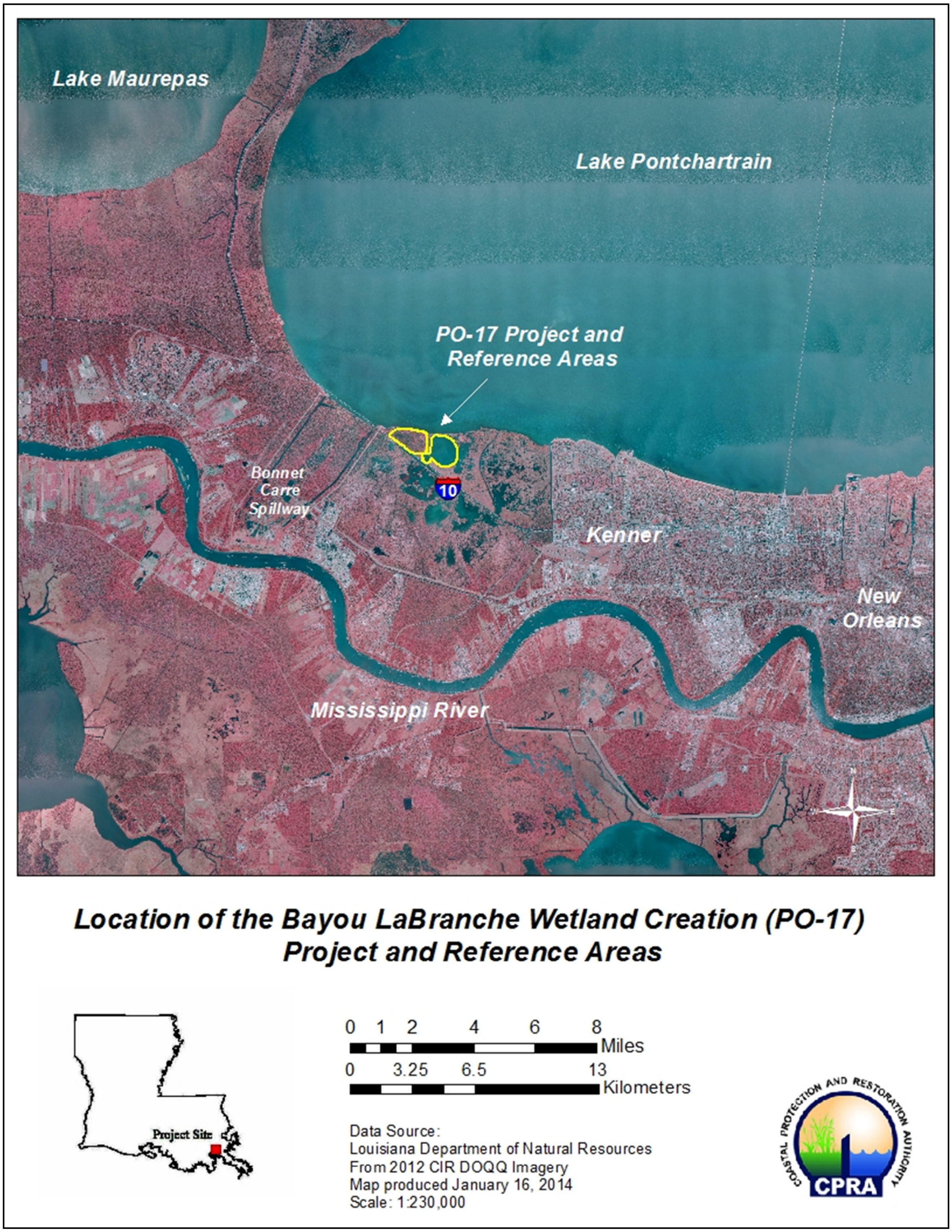

Figure 1. Location of the Bayou LaBranche Wetland Creation (PO-17) project area. The site is located between Lake Pontchartrain (northern boundary) and I-10 (southern boundary) and is approximately 18 miles northwest of New Orleans, Louisiana.

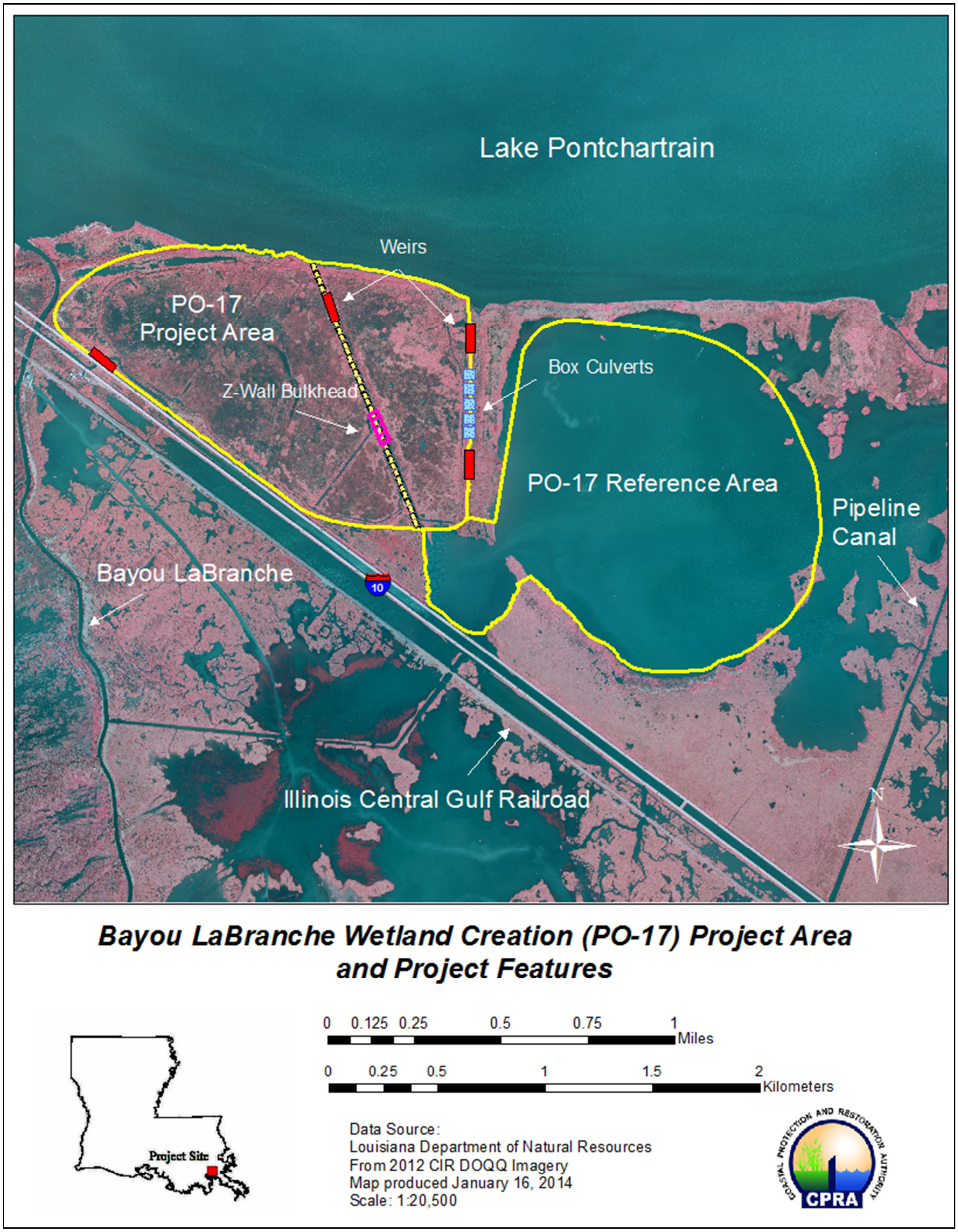

Figure 2. Project boundary for the Bayou LaBranche Wetland Creation (PO-17) project area and reference area and the associated project features.

II. Maintenance Activity

No maintenance activities are associated with PO-17.

III. Operation Activity

No operations activities are associated with PO-17.

IV. Monitoring Activity

A. Monitoring Goal

The goal of the Bayou LaBranche Wetland Creation project was to create new vegetated wetlands in the Bayou LaBranche area utilizing dredged sediments. The following objectives were developed to evaluate the success of attaining the project's goal:

1. Create approximately 305 acres (123 ha) of shallow-water habitat conducive to the natural establishment of emergent wetland vegetation.

2. Increase the marsh to open-water ratio in the project area to a minimum of 70% emergent marsh to 30% open water after five years following project completion.

The 305 acres of shallow-water habitat (objective 1) equate to the minimum 70% emergent marsh target (objective 2).

B. Monitoring Elements

Monitoring of the PO-17 project was conducted at both project-specific stations and at Coastwide Reference Monitoring System (CRMS) sites. Data collection for PO-17 occurred solely at project-specific stations until 2008, when CRMS6299 was installed in the project area and CRMS2830 was installed in the reference area. Monitoring at CRMS sites follows CRMS protocols as outlined in Folse et al. 2012. Due to the lack of marsh habitat within the designated reference area, the project-specific reference vegetation and sediment sampling stations and the topographic survey transects were established in natural marsh in the surrounding area (Figure 3).

<u>Land-Water Analysis</u>

Land-water analysis of color infrared aerial photography was conducted to measure land to open water ratios in the project and reference areas. Photography at 1:12,000 scale was taken November 7, 1993 (pre-construction) and November 17, 1997. Additional photography (1:30,000 scale) was acquired on February 10, 2001, with funding provided by the United States Geological Survey (USGS). Analysis of this photography is included in this report, although it was not scheduled as part of the PO-17 monitoring plan. The final aerial photography was taken on November 9, 2012, as part of the CRMS coast-wide aerial photography flights using a Z/I Imaging digital mapping camera with 1-meter resolution (approximately 1:16,000 scale).

Topographic Surveys

Elevation surveys were conducted to assess whether the project area was settling as expected to support marsh vegetation through the project's lifespan. Transects in the reference area were also surveyed to compare elevation and settlement between the created and natural marsh. Topographic surveys were conducted of the project area in 1996, 2002 and 2013 and of the reference area in 2002 and 2013. The 1996 and 2002 data are not included in this report due to uncertainties regarding what benchmarks and geoids were used for the surveys.

Sediment Elevation (Staff Gauges)

Staff gauges (NAVD 88) were installed in the project area to monitor the elevation of the deposited dredged sediments. In 1994, seven temporary staff gauges were installed around the perimeter of the area. In 1996, these temporary gauges were replaced by 19 permanent staff gauges that were installed along north-south transects at the vegetation stations. Sediment elevation data were collected four times in 1994, three times in 1995, five times in 1996 and 1997, twice in 1999 and 2000, and annually in 1998, 2001, 2002, 2004, 2005, 2007 and 2010 to coincide with vegetation surveys.

Habitat Analysis

The aerial photography used for land-water analysis (1993, 1997 and 2012) was further classified to differentiate and quantify land and water areas into specific habitats (marsh, scrub-shrub, forest, aquatic bed etc.). Habitat analysis allowed for an evaluation of the project's success of creating emergent marsh. Habitat analysis was not conducted on the supplemental aerial photography that was acquired in 2001.

Vegetation

Vegetation data were collected to assess species composition and cover in the project area and to compare the vegetative community in the created marsh to that of the neighboring natural marsh. Species composition and relative abundance of emergent vegetation were quantified at 18–20 (varied between years) project-specific vegetation stations in the project area and 13 project-specific vegetation stations in the reference area using techniques described in Steyer et al. (1995, revised 2000). Prior to 2001, stations were 1 m x 1 m paired plots. Starting in 2001, a single 2 m x 2 m plot was surveyed at each station. Stations were surveyed pre-construction in 1994 and post-construction in 1996, 1997, 1998, 2001, 2002, 2004, 2005, 2007, 2010 and 2013. Annual vegetation monitoring began in 2008 at CRMS6299 in the project area and CRMS2830 in the reference area. At each CRMS site, surveys are conducted at ten 2 m x 2 m stations aligned along a 288 m diagonal transect within a 200 m x 200 m square.

Salinity

Salinity data were used to characterize the spatial and temporal variation of salinity within the project and reference areas. Salinity was recorded hourly at project-specific stations PO17-43 in the project area and PO17-44R in the reference area from April

1996–June 2003 (Figure 3). The collection of hourly salinity data resumed in January 2008 with the installation of CRMS6299 in the project area and CRMS2830 in the reference area.

Water Elevation

Water elevation data were used to characterize the spatial and temporal variation of water elevation (NAVD88) within the project and reference areas. Water level was recorded hourly at project-specific stations PO17-43 in the project area and PO17-44R in the reference area from April 1996–June 2003 (Figure 3). Staff gauges were established and surveyed at each continuous recorder station in August 1997, allowing for the conversion of water level data to NAVD88. The collection of hourly water elevation data resumed in January 2008 with the installation of CRMS6299 in the project area and CRMS2830 in the reference area.

Soil Properties

Sediment cores were collected at the vegetation stations with a Swenson corer (Swenson 1982) to characterize soil composition in the project area and to compare the soil properties of the project area to that of the reference area. Soil samples (~50 cm^3) were taken to coincide with vegetation surveys in 1996, 1997, 1998, 2001, 2002, 2004, 2005, 2007, 2010 and 2013. Sediment cores were also collected from the vegetation reference area sites starting in 2002, with the exception of 2005. The cores were analyzed to determine percent organic matter and bulk density (g/cm^3).

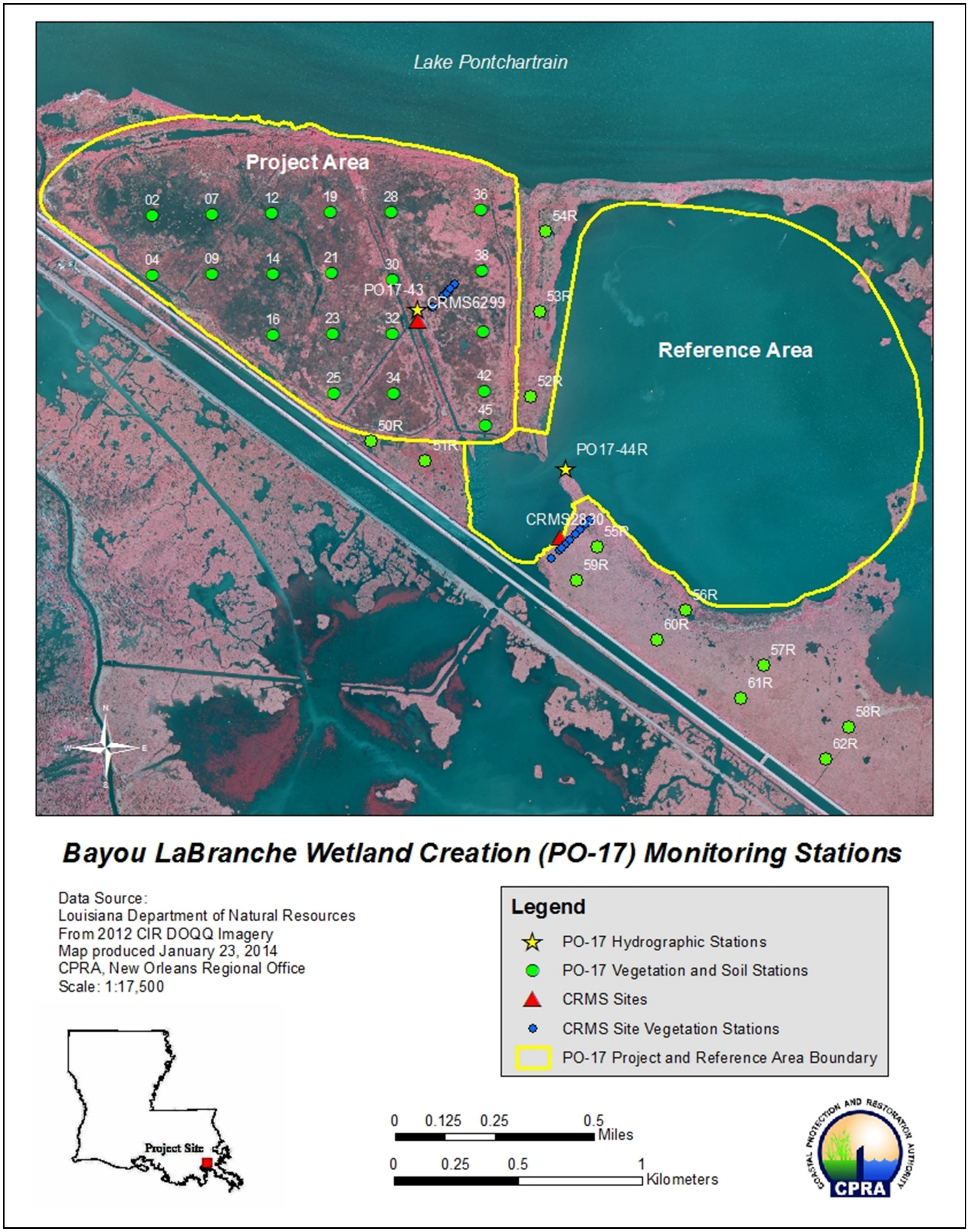

Figure 3. Location of PO-17 project-specific monitoring stations and CRMS monitoring sites associated with PO-17. An 'R' after a station name designates a reference station.

C. Monitoring Results and Discussion

i. Land-Water Analysis

Land-water analysis is important in marsh creation projects to determine the success of the initial project construction and to assess the sustainability of the project over time. Areas that have converted from open water to land, or alternately, areas that have converted from land to open water, can be differentiated and mapped. Pre-construction land-water analysis of aerial photography taken November 7, 1993, showed that both the PO-17 project and reference areas were primarily open water and contained only 19% land (81 acres) and 2% land (12 acres) respectively (Table 1, Figure 4). Post-construction land-water analyses of the PO-17 project between 1997 and 2012 have demonstrated an increase in the percentage of land in the project area over time, while the percentage of land in the reference area has remained nearly stable (Table 1).

The first post-construction land-water analysis for PO-17 was conducted on imagery acquired November 17, 1997, approximately 3.5 years after the project was constructed. The percentage of land in the project area increased to 82% (356 acres), with the remaining open water located primarily in the southeastern region of the project area. The percentage of land in the reference area remained constant at 2% (11 acres) (Table 1, Figure 5).

Land-water analysis was also conducted on aerial photography taken February 10, 2001, as part of an additional data collection effort supported by the USGS. The photography was flown at 1:30,000, a lesser resolution than the 1:12,000 or 1:16,000 scale that was flown for the other analyses. While not directly comparable to the higher resolution photography, the imagery is still useful to identify trends. According to the 2001 imagery, the percentage of land in the project area increased to 87% (380 acres), while the percentage of land in the reference area remained stable at 2% (10 acres) (Table 1, Figure 6).

The final land water analysis for PO-17 was conducted on imagery acquired November 9, 2012. The percentage of land in the project area increased to 94% (408 acres), which amounts to the creation of 327 acres of land since the 1993 pre-construction imagery. The majority of area still classified as water in the project area (6%, 27 acres) is restricted to canals. Since project construction, the percentage of land in the reference area has remained at 2%, with a slight decrease from 12 acres in 1993 to 10 acres in 2012 (Table 1, Figure 7).

Table 1. Results from land-water analyses between 1993 and 2012 for the PO-17 project and reference areas. * The 2001 imagery was flown at a 1:30,000 resolution.

Date of Aerial Photography Acquisition	PROJECT AREA					REFERENCE AREA				
	Land (acres)	Land (%)	Water (acres)	Water (%)	Total (acres)	Land (acres)	Land (%)	Water (acres)	Water (%)	Total (acres)
11/07/1993 (pre-construction)	81	19	355	81	436	12	2	504	98	516
11/17/1997	356	82	80	18	436	11	2	504	98	516
02/10/2001 *	380	87	56	13	436	10	2	505	98	515
11/09/2012 (project end)	408	94	27	6	435	10	2	505	98	515

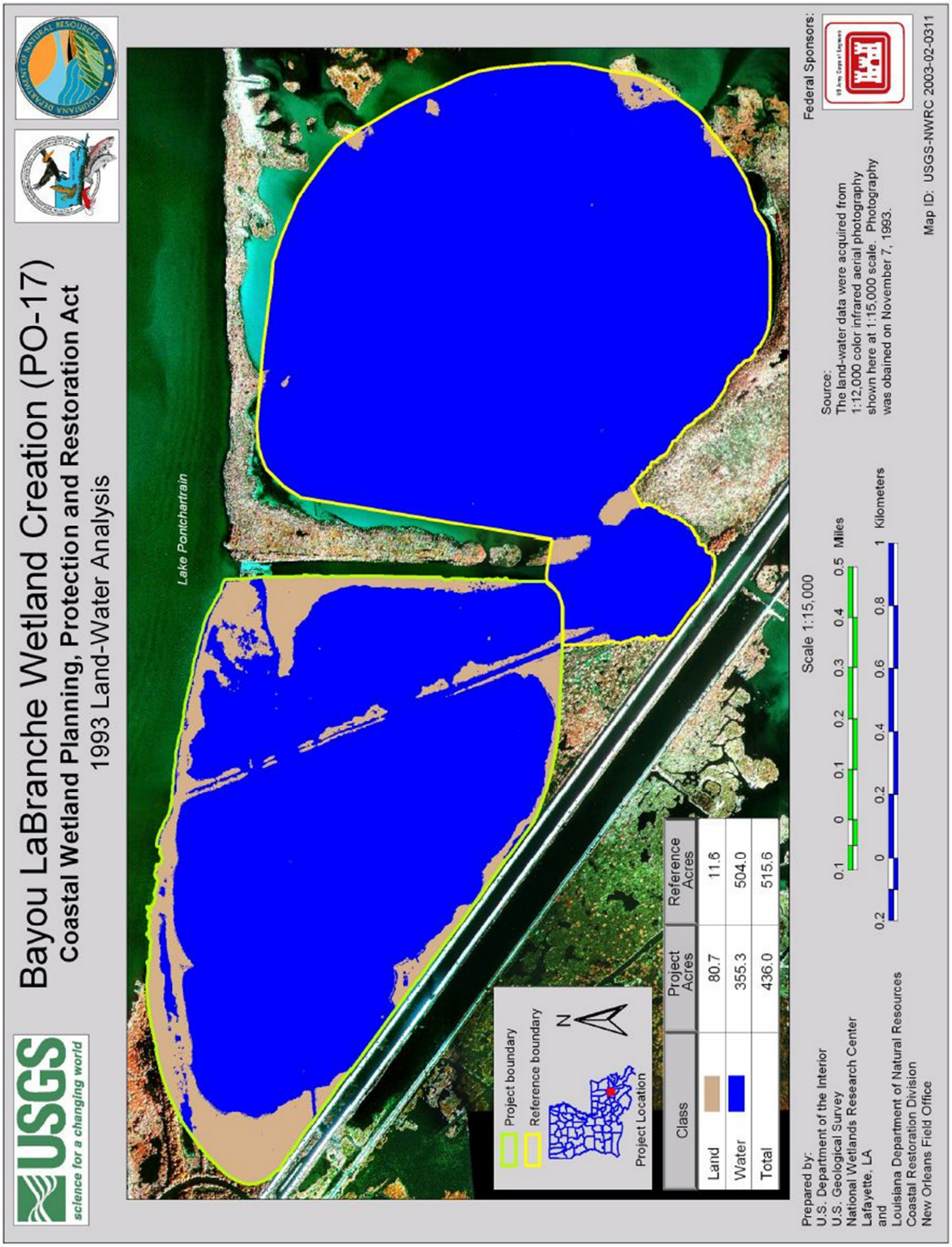

Figure 4. Land-water classification of the PO-17 project and reference areas using aerial photography acquired pre-construction on November 7, 1993.

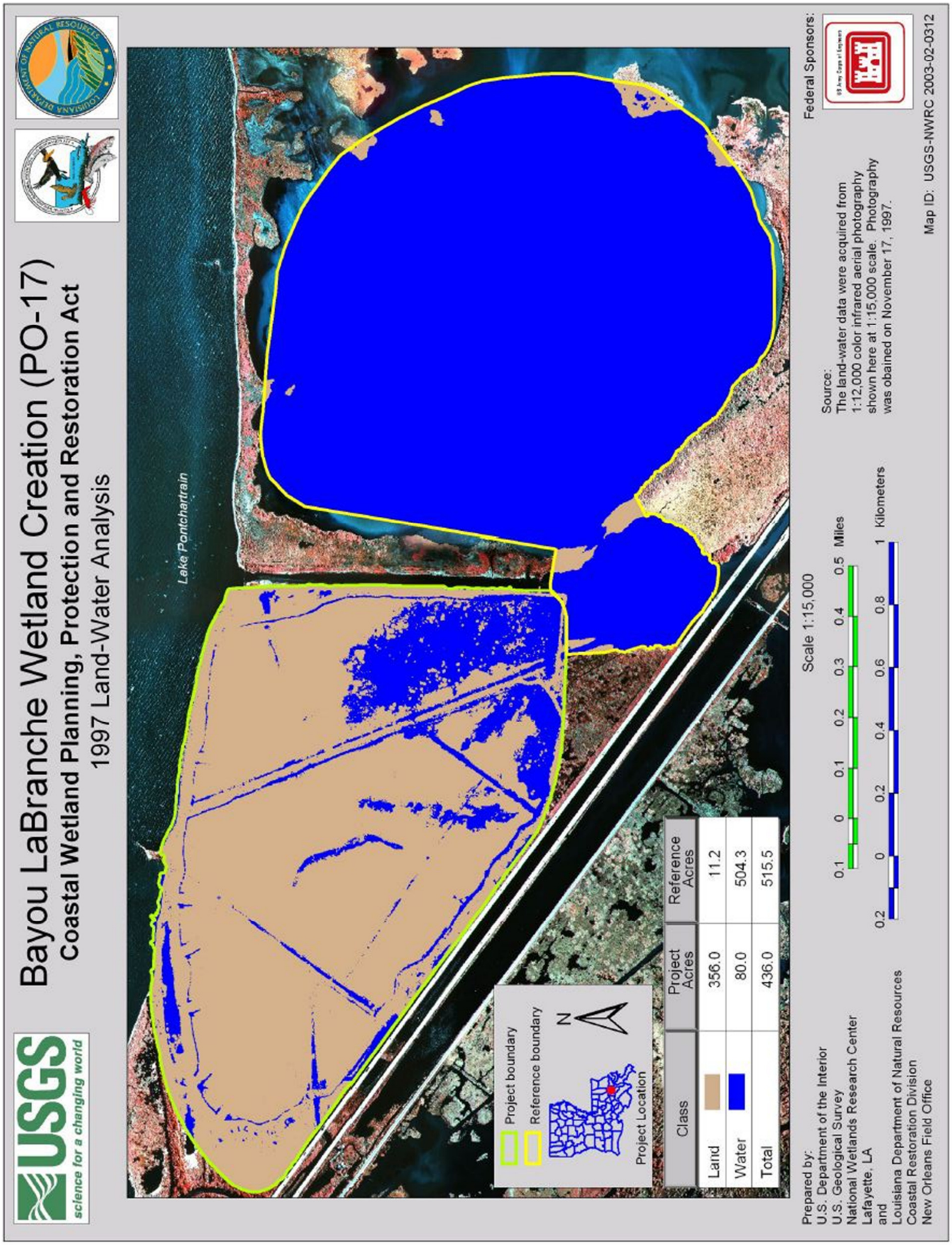

Figure 5. Land-water classification of the PO-17 project and reference areas using aerial photography acquired post-construction on November 17, 1997.

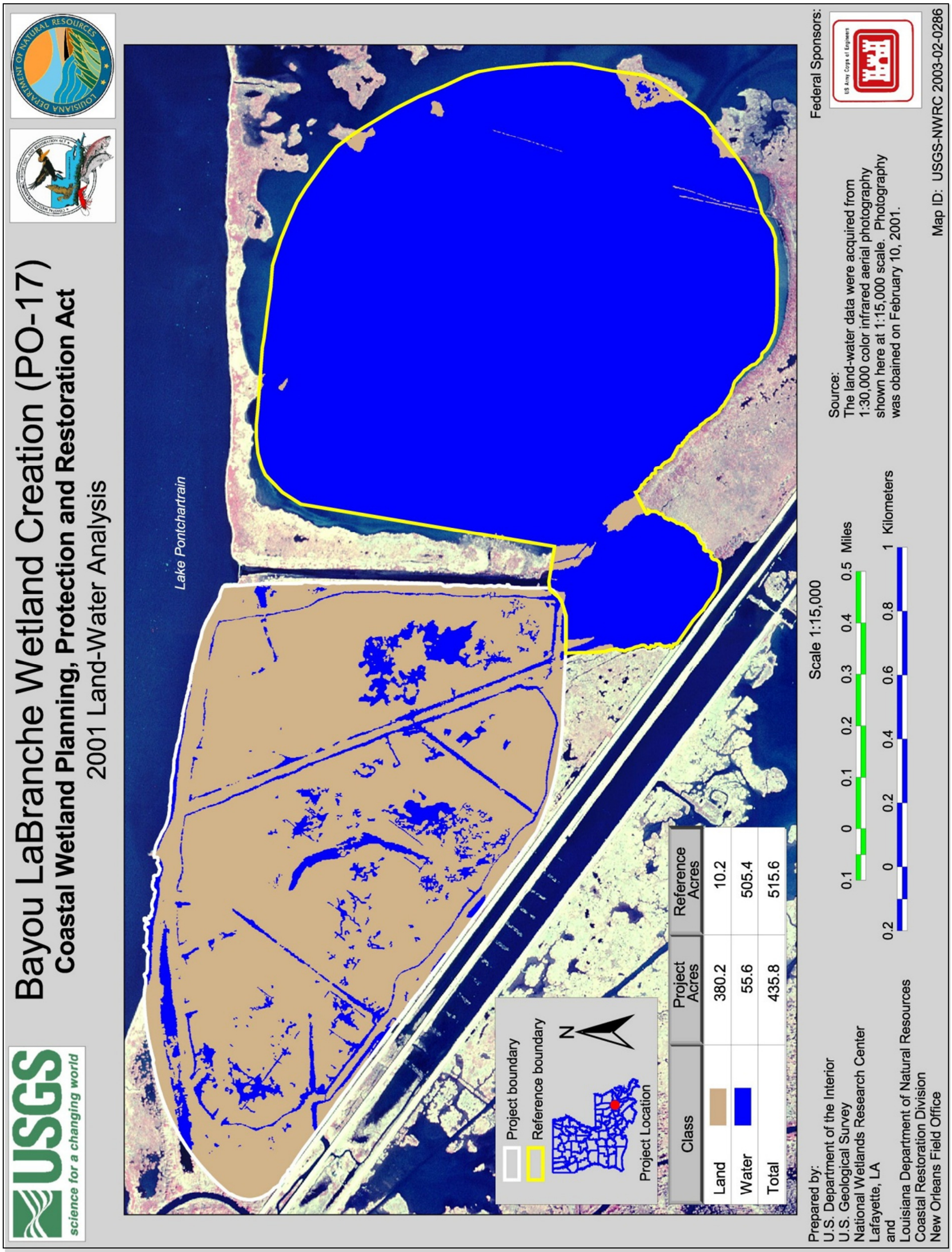

Figure 6. Land-water classification of the PO-17 project and reference areas using aerial photography acquired on February 10, 2001.

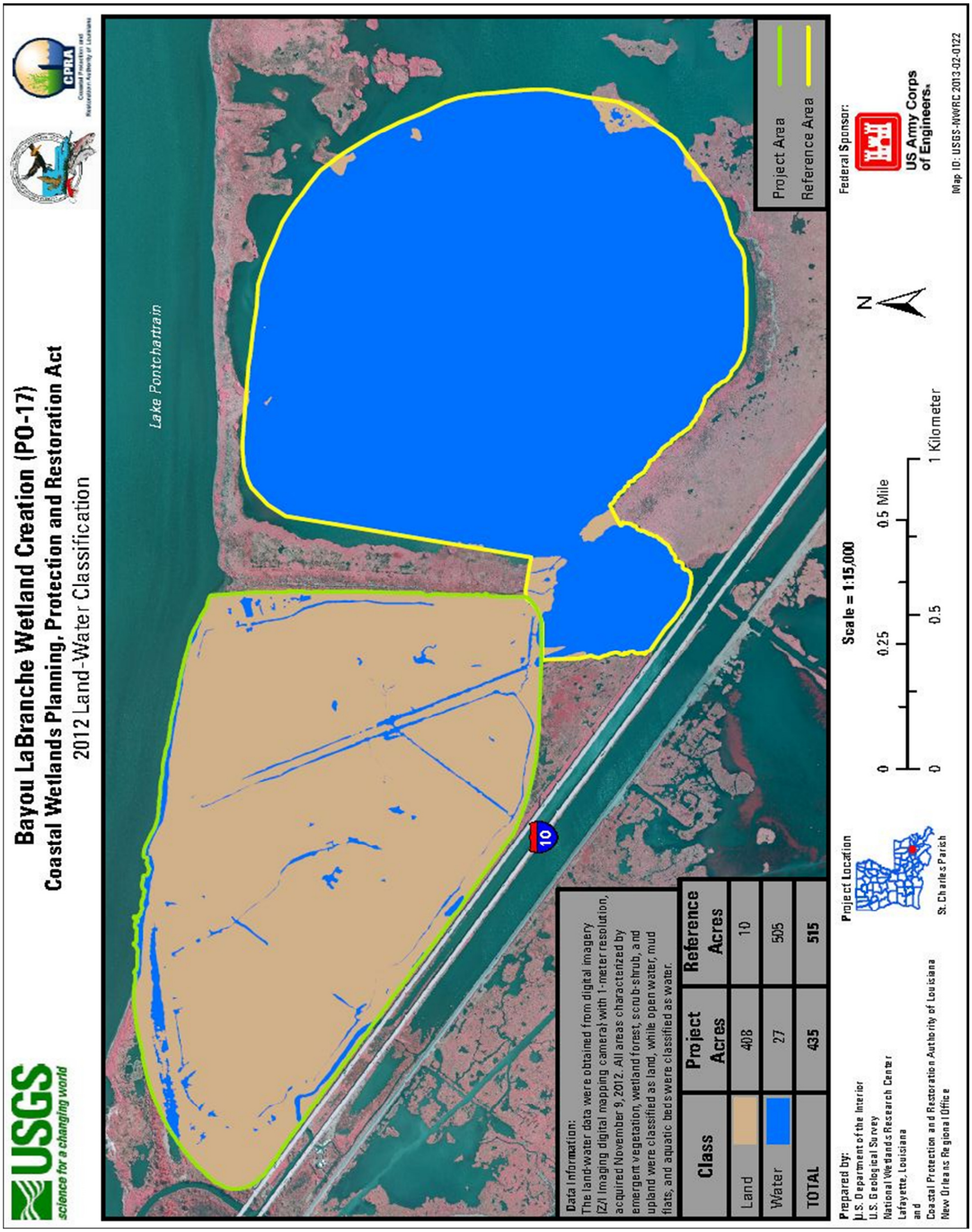

Figure 7. Land-water classification of the PO-17 project and reference areas using aerial photography acquired on November 9, 2012.

ii. Topographic Surveys

Elevation surveys are useful to indicate whether a marsh creation project was constructed to the specified elevation, is settling at the predicted rate, and falls within an elevation range that supports the hydrology necessary for the development of marsh habitat. Survey data also allow for a comparison of elevation between created marsh and natural marsh in the area. Topographic surveys were conducted of the PO-17 project area in 1996, 2002 and 2013 and of the reference area in 2002 and 2013. Due to the inability to identify a common benchmark between the surveys and to determine the geoid and ellipsoid used for the 1996 and 2002 surveys, only the 2013 survey data are included in this report.

The 2013 survey was conducted in NAVD88, using geoid 12A and ellipsoid GRS 80. Transects in the project area were spaced approximately 800 feet apart, with the exception of transect column 6, which was spaced approximately 1200 feet from transect column 5 (Figure 8). Elevation points were collected approximately every 50 feet along each transect. Four reference transects were surveyed in natural marsh neighboring the project area to provide a comparison to elevation in the created marsh (Figure 8). A surface contour map of the project area was generated using AutoCAD 2010 to estimate total surface elevation and provide a visual representation of topography. AutoCAD interpolates between survey points to create a surface elevation grid; therefore, the maps are a useful tool for assessment and visualization, but they are only as accurate as the robustness of the dataset.

The maximum constructed elevation for sediment in the project area was established at +4.0′ NGVD (+3.8′ NAVD88), with an expected settlement to approximately +1.0′ NGVD (+0.8′ NAVD88) at nine to twelve months post-construction (USACE 1992). During the 20-year CWPPRA lifespan, the project area was predicted to settle to within an elevation range of +0.5′ to +1.5′ NGVD (+0.3′ to +1.3′ NAVD88) (Broussard and Dickson 1995). Based on analysis of the 2013 survey data, approximately 77% of the project area (290 acres) has settled to within this predicted range. However, since the analysis is divided into 0.5′ increments, this value is likely an over-estimation because it covers an elevation range of +0.0′ to +1.5′ NAVD88, rather than +0.3′ to +1.3′ NAVD88 (Figure 9).

As of 2013, the greatest percentage of the project area (64%, 238 acres) was at a marsh elevation between +1.49′ to +1.00′ NAVD88. The highest elevation was in the north, where elevation ranged between +1.50′ to +1.99′ NAVD88, with a smaller area retaining a higher elevation of +2.00′ to +2.49′ NAVD88. The lowest marsh elevation (excluding canals) was in the central to south-central project area and ranged between +0.50′ to +0.99′ NAVD88 (Figure 9). As discussed in the Introduction, the dredged sediment was discharged in the northern project area due to discharge restrictions near Interstate 10. The sediment was not distributed evenly after delivery, resulting in a higher elevation in the north.

The elevation of survey points along individual transects were averaged to provide a representation of elevation in the project area without interpolation and allow for a comparison to elevation in the reference area. Survey points along spoil banks and in waterways were removed from the data set prior to averaging. The mean elevation of the project area was +1.21′ NAVD88, which was a tenth of a foot lower than the mean elevation in the reference area of +1.31′

NAVD88. The elevation along reference transect AD1, just south of the project area, was notably lower than that of the other reference transects. Transect AD1 had a mean elevation of +1.01′ NAVD88, while the other three transects ranged from +1.35′ to +1.47′ NAVD88 (Figure 10). The mean elevation along the transects in the project area corresponds well to the interpolated data on the contour map, with elevation highest in the north (Row A), and lowest in the south/central project area.

Shortly after the construction of PO-17, concerns arose regarding the delayed settlement of the project area. The created marsh platform had been projected to settle to within the range of the surrounding natural marshes by one year after construction. However, as of April 1995, the elevation of the project area was reported at approximately 1.5 feet higher than the surrounding marsh and was noted as being populated more with upland vegetation than with species that are associated with a marsh habitat. Based on the 2013 elevation survey data, the project area had settled to an elevation that was similar to the surrounding natural marsh. Additionally, while habitat analysis from 1997 confirms the presence of significant scrub-shrub habitat, the 2012 analysis indicated that the project area had transitioned to primarily emergent marsh. Settlement of the project area appears to have taken longer than expected, but this outcome has resulted in a greater project longevity with the continuing existence of emergent marsh habitat past the project's 20-year lifespan.

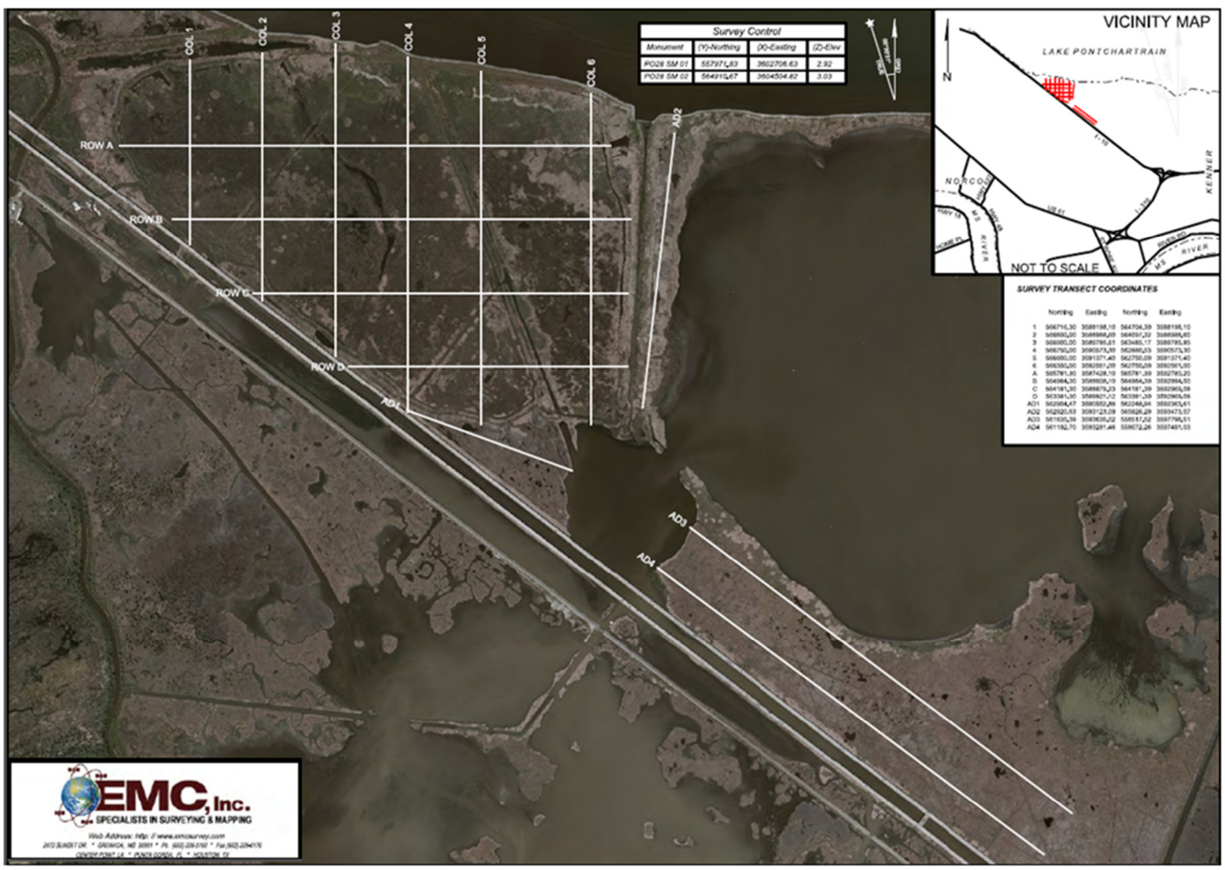

Figure 8. Location of the PO-17 project area and reference area (AD) elevation survey transects.

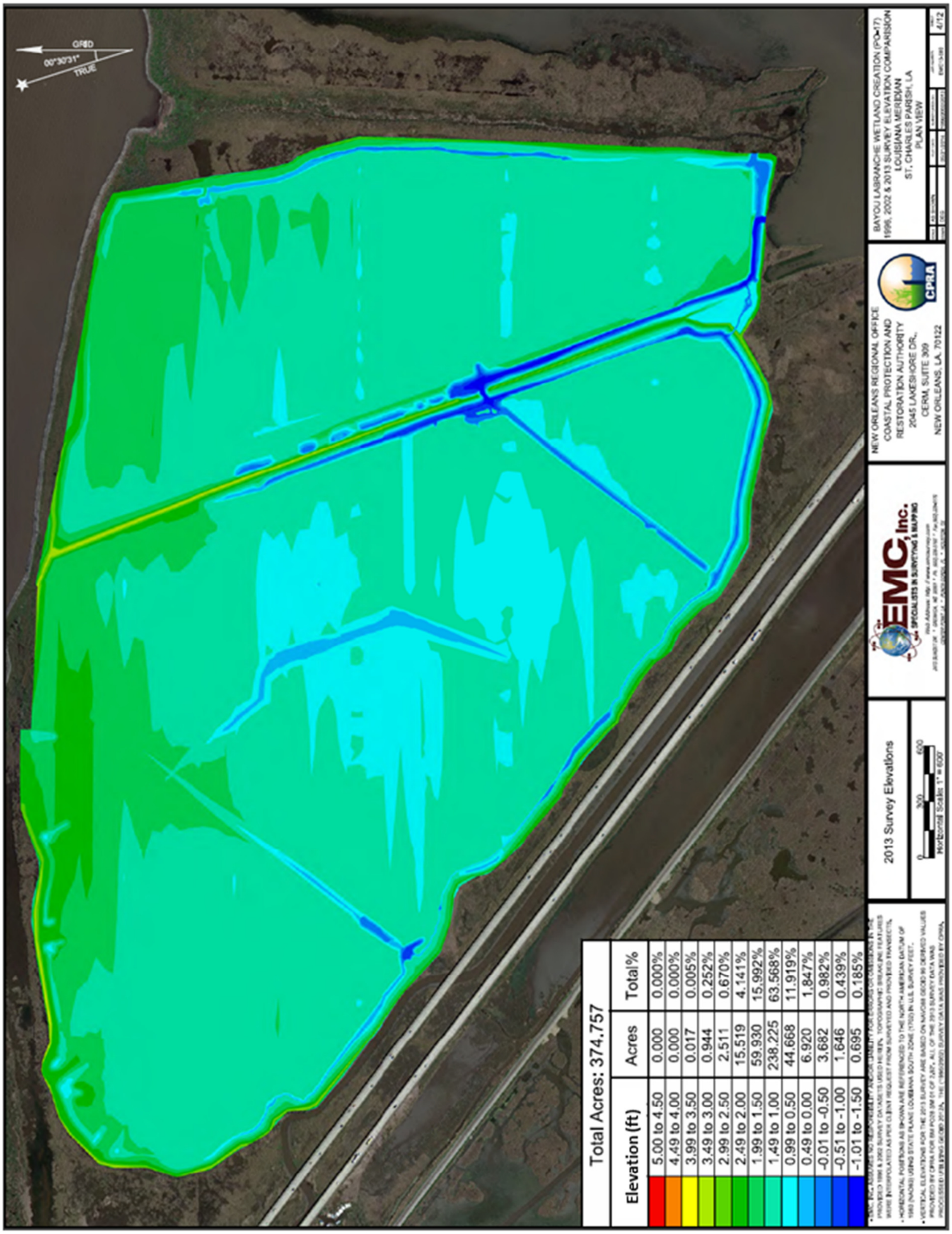

Figure 9. Surface elevation of the PO-17 project area as surveyed between October 2013 and November 2013. Elevation is delineated by 0.50-foot increments.

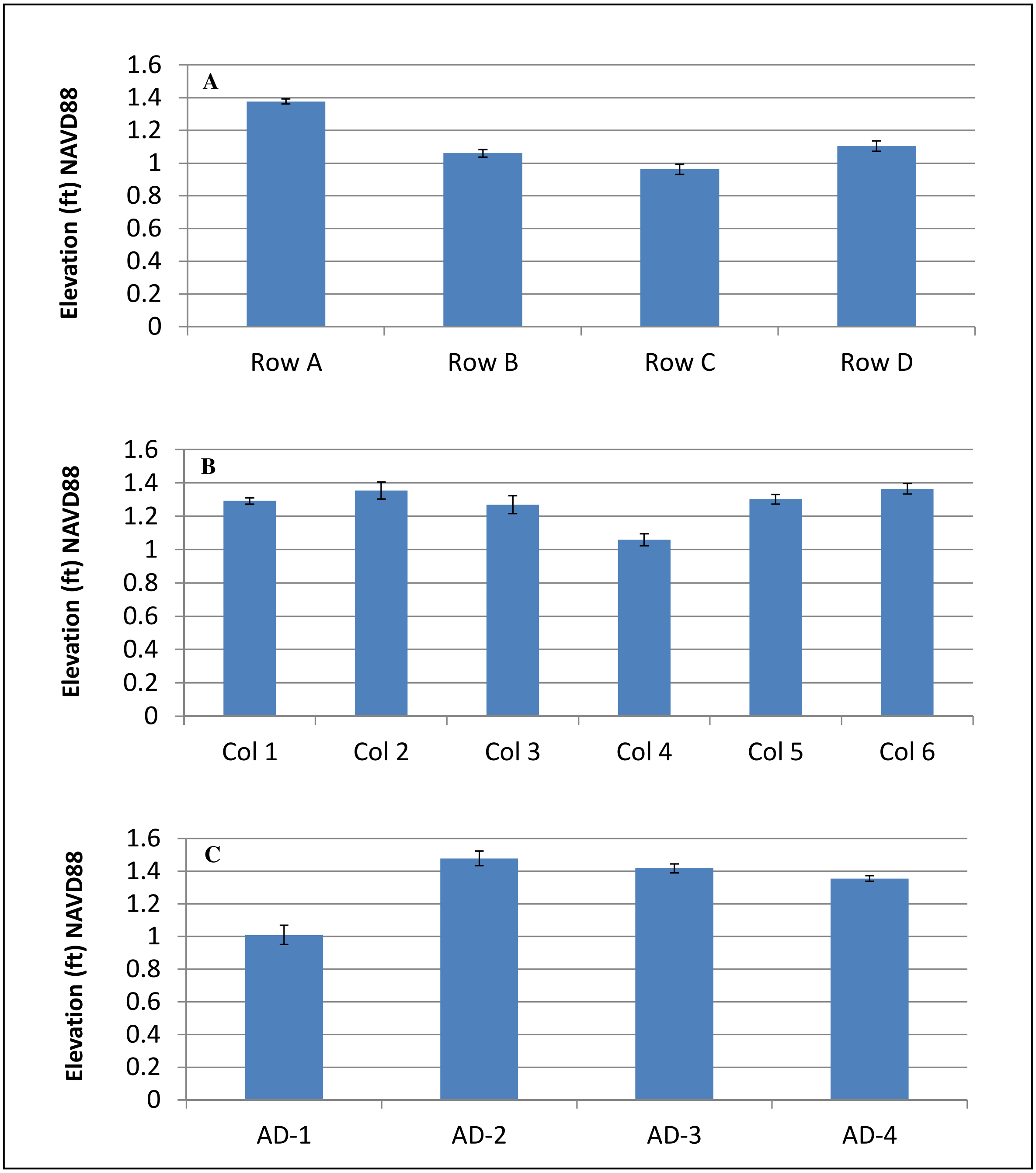

Figure 10. Average elevation (± SE) of each PO-17 project and reference area transect as surveyed between October 2013 and November 2013. **A:** project area row transects, **B:** project area column transects, **C:** reference area transects.

iii. Sediment Elevation (Staff Gauges)

Sediment staff gauges were installed in the project area to supplement the more precise and expansive, but less frequent topographic surveys and to provide a general estimation of settlement of the dredged material. After project construction in 1994, the sediment was too unconsolidated to allow predictable access to interior portions of the project area; therefore, temporary staff gauges were installed around the project's perimeter. Elevation data recorded from six staff gauges between October 1, 1994, and March 9, 1995, indicated that the sediment settled from a mean elevation of +1.92′ ± 0.22 SE to +1.00′ ± 0.50 SE (NAVD88) (Figure 11). Based on these data, the highest recorded rate of sediment consolidation in the project area occurred during this period.

By 1996, the sediment had adequately consolidated and 19 permanent staff gauges were installed at the vegetation stations in the project area. One dataset was selected from each of the years with multiple surveying periods to coincide most closely with a year of separation from the next surveying event. Data collected during 1994 and 1995 from the temporary staff gauges were not included in the statistical analyses. Data were analyzed using an ANOVA in Proc GLM, $\alpha = 0.05$, with a Tukey post-hoc test (SAS Institute Inc., Cary, NC, version 9.1).

Mean sediment elevation for PO-17 between 1996–2010 was significantly different between years ($df = 10$, $F = 7.95$, $P < 0.0001$) (Figure 11). Sediment elevation in the project area declined between 1997 and 1998 but was followed by an extended period of stabilization from 1998–2004, when it ranged between +0.70′ to +0.75′ (NAVD88). Between 2005–2010, mean sediment elevation increased from +0.77′ ± 0.06 SE to +0.92′ ± 0.05 SE (NAVD88). The increase in elevation could be due to the sinking of the staff gauges or differences in measurement techniques between years. Photographs that were taken during the 2005 survey show several stations that were unvegetated and located in open water or at the marsh edge, but photographs and vegetation data collected during subsequent surveys in 2007 and 2010 show a transition of the open water plots to a vigorous *Spartina alterniflora* (smooth cordgrass) marsh. An increase in vegetative belowground biomass at these plots, as well as the trapping of sediments and wrack brought in from storms, could potentially account for some of the rise in elevation at these sites.

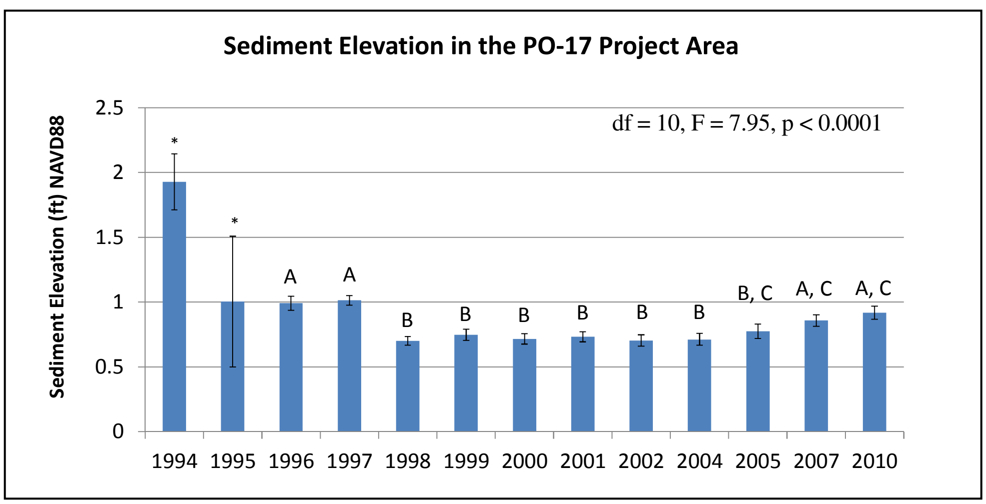

Figure 11. Mean annual sediment elevation (±SE) in the PO-17 project area between 1994–2010. * Data from 1994 and 1995 are not included in the statistical analysis. Different letters indicate significant differences between years ($\alpha = 0.05$). Data were averaged from 19 staff gauges all years except 1994 and 1995 (6 gauges), 1996 (17 gauges) and 2010 (16 gauges).

iv. Habitat Analysis

Habitat analysis was used to further delineate land and water in the PO-17 project and reference areas into specific habitats. This analysis was necessary to assess whether the project's objectives of creating 305 acres of shallow water habitat and a minimum of 70% emergent marsh after five years were attained. Habitat analysis was done in conjunction with land-water analysis in 1993, 1997, and 2012. Due to the spacing of the analyses, there is no assessment of the habitat types at year five (1999), the target assessment year to attain 70% emergent marsh. However, the 2012 analysis shows that the project objectives were attained during the project's life and have been sustained through the end of its 20-year CWPPRA lifespan. The 2012 habitat analysis classified 83% (356 acres) of the project area as emergent marsh, with a significant percentage of this marsh developing in areas that were classified in 1997 as scrub-shrub and open water habitats (Figure 12).

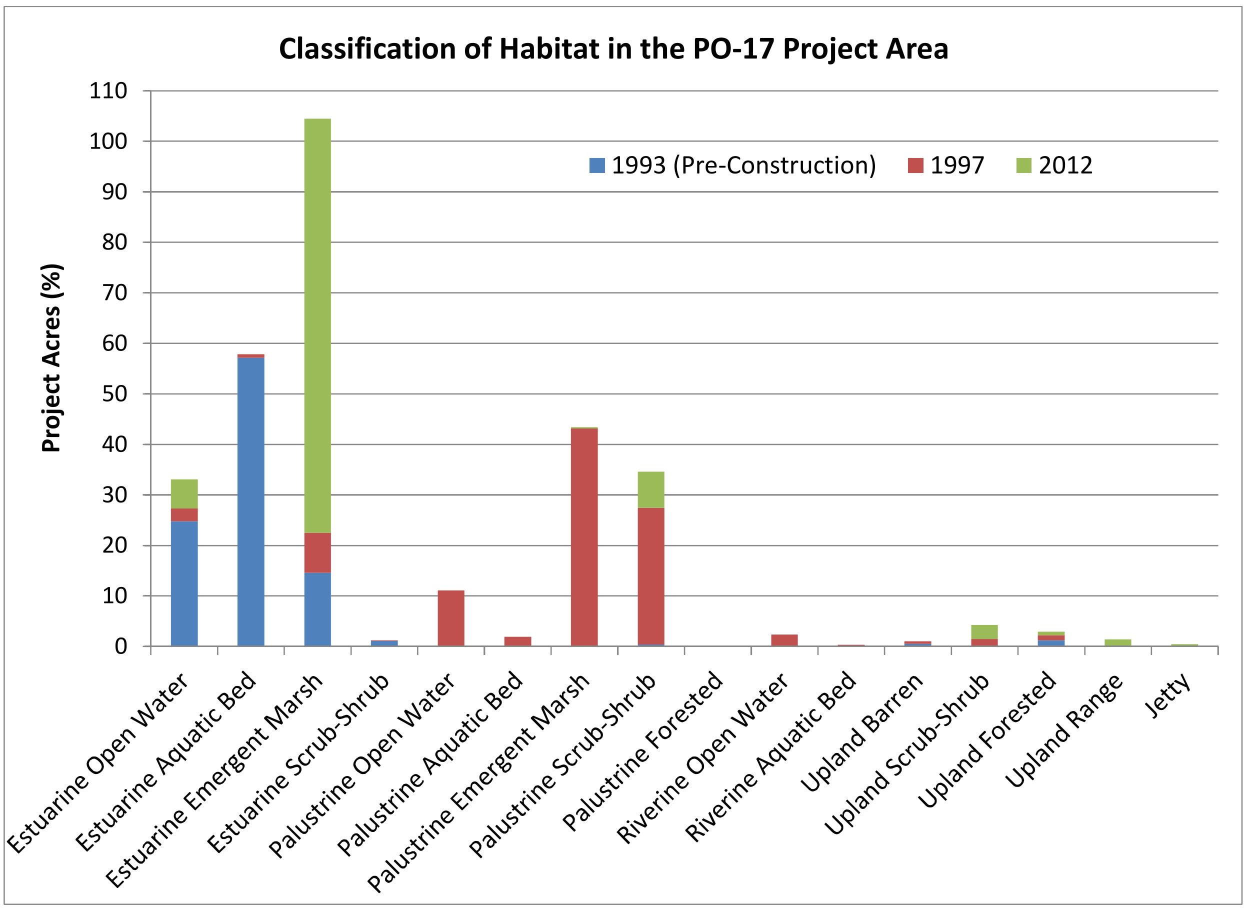

Figure 12. Percentage of each habitat within the PO-17 project area for the November 7, 1993, November 17, 1997 and November 9, 2012 habitat analyses. The project area transitioned to primarily estuarine emergent marsh habitat by 2012.

The 1993 pre-construction habitat analysis identified nearly all habitat in the project area as estuarine (98%) (Figure 13). The USGS National Wetlands Institute (NWI) classification system used for these analyses describes an estuarine system as all tidal habitats in which waters consist of at least 0.5% ocean-derived salt and are diluted at least occasionally by freshwater runoff from the land (Cowardin et al. 1979). Within the estuarine system, the majority of habitat was identified as aquatic bed (57%), with open water (25%) and emergent marsh (15%) having a lesser representation (Figure 13). The reference area was classified almost entirely as estuarine open water (97%). Aquatic bed habitat is dominated by plant species that grow primarily below or on the surface of the water, while emergent marsh habitat is characterized by the prevalence of emergent herbaceous angiosperms (flowering plants) (Cowardin et al. 1979).

The 1997 post-construction habitat analysis indicated that the project area had transitioned from an estuarine to a palustrine system (83%), with the elevation of the dredged sediment influencing the development of fresher and less tidally-influenced habitats (Figure 14). The USGS NWI classification system defines a palustrine system as non-tidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens, and all wetlands that occur in tidal areas where ocean-derived salinities are less than 0.5% (Cowardin et al. 1979). Within this palustrine system, emergent marsh was the dominant habitat (43%), followed by scrub-shrub (27%) and open water (11%) habitats (Figure 14). Scrub-shrub habitat is defined by a dominance of woody vegetation, with shrubs and small trees that are less than 20 feet tall (Cowardin et al. 1979). Estuarine and palustrine emergent marsh comprised 51% of the project area, not yet reaching the objective of 70% emergent marsh that was targeted for year five. The majority of scrub-shrub habitat was located in the northern project area, where sediment elevation was still too high to favor the development of emergent marsh. The reference area showed little habitat change between years, with 96% of the area still classified as estuarine open water (Figure 14).

The final habitat analysis in 2012 indicated that the project area had settled to an elevation that again promoted the development of an estuarine system, with estuarine emergent marsh comprising 82% of the habitat (Figure 15). The scrub-shrub habitat declined in the project area from 29% in 1997 to 10% in 2012, due to settlement in some of the higher elevation regions that previously restricted the development of marsh habitat. The remaining scrub-shrub habitat was primarily in the far northern project area and along spoil banks. The large area of open water that remained in the southeastern portion of the project area in 1997 transitioned to emergent marsh by 2012. The classification of habitat types in the reference area remained relatively unchanged, with 97% of the habitat classified as estuarine open water (Figure 15).

Figure 13. Habitat classification of the PO-17 project and reference areas using aerial photography taken pre-construction on November 7, 1993.

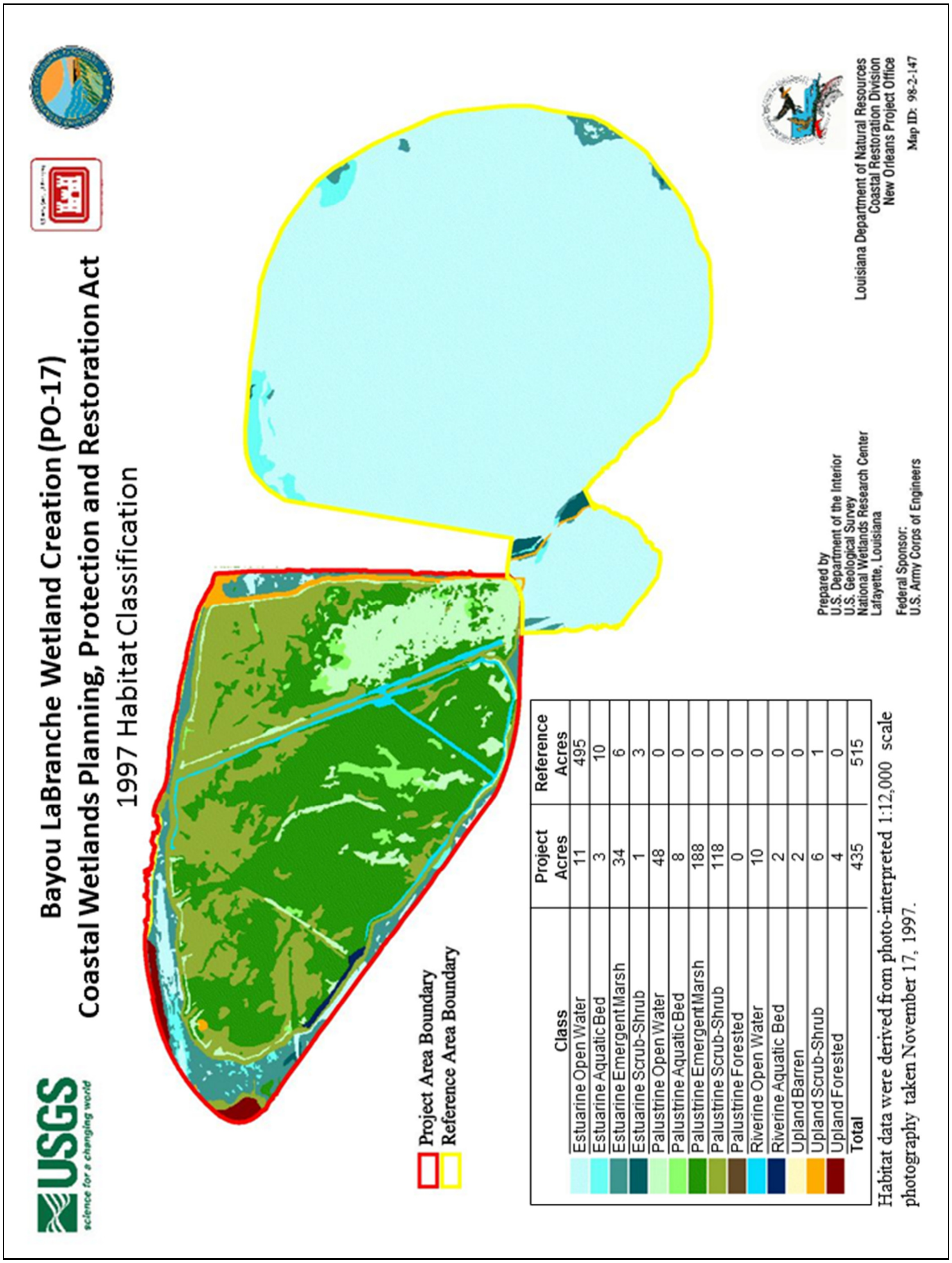

Figure 14. Habitat classification of the PO-17 project and reference areas using aerial photography taken approximately 3.5 years post-construction on November 17, 1997.

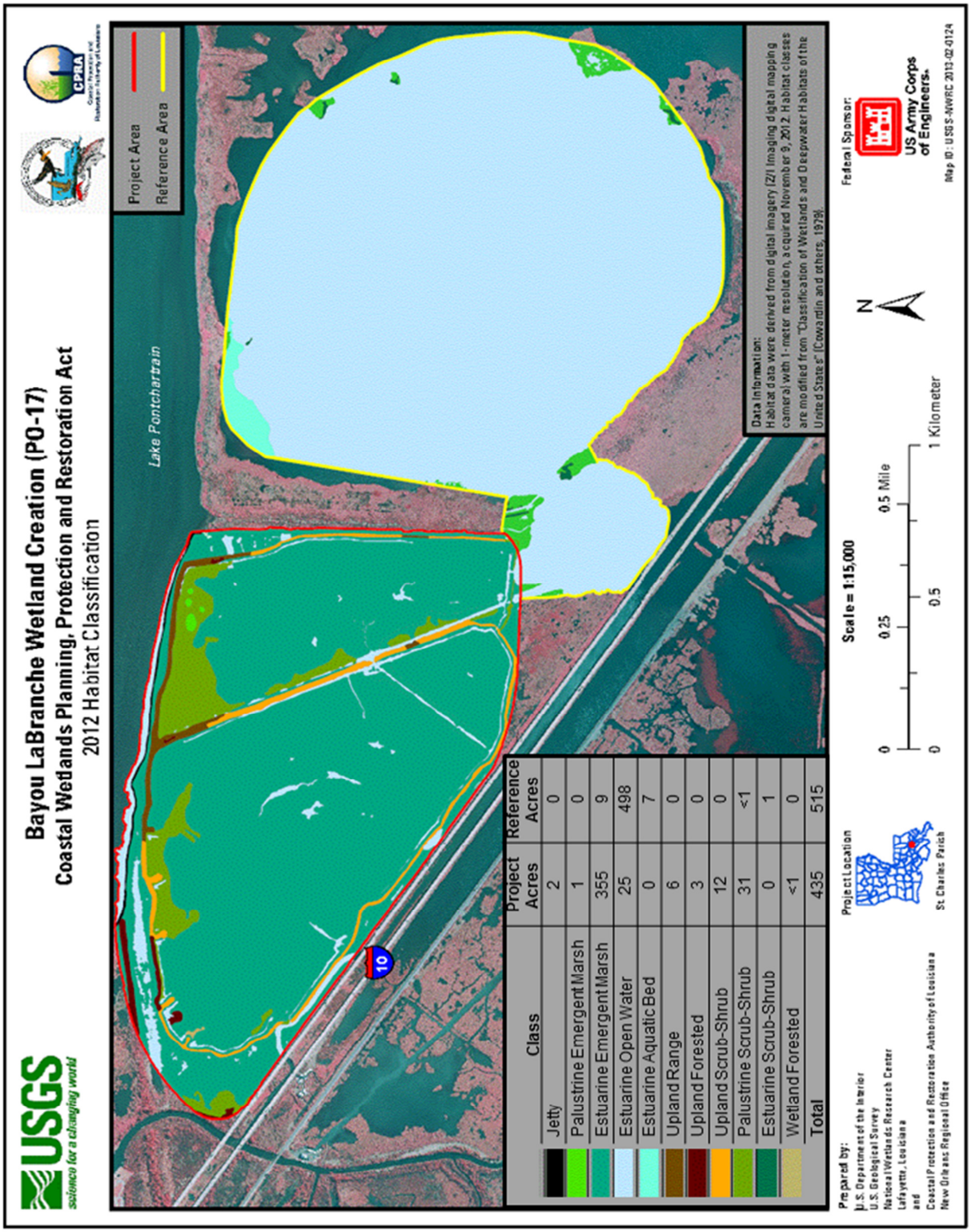

Figure 15. Habitat classification of the PO-17 project and reference areas using aerial photography taken approximately 18.5 years post-construction on November 09, 2012.

v. Vegetation

Vegetation surveys provided a detailed characterization of the species comprising habitats in the PO-17 project and reference areas. Analyses focused on examining how the species cover and composition in the project area changed over time, and on how the community in the project area compared to that in the reference area.

Total Percent Cover

Total percent cover is a single estimation of live vegetative cover that is visually assessed at each station and ranges from 0%–100%. The collection of total cover data did not begin in the project area until 2001, and therefore excluded the early colonization years. Mean total percent cover in the project area was compared over years at the project-specific stations using an ANOVA in Proc GLM (SAS Institute Inc., Cary, NC, version 9.1). Since 2001, total percent cover has not been significantly different between years (DF = 6, F = 2.09, $p = 0.058$). The lowest total percent cover occurred in 2005 (50.2%) and was followed by the highest total percent cover in 2007 (81.8%) (Figure 16).

The 2005 vegetation survey was conducted in October, less than two months after the storm surge from Hurricane Katrina inundated the project area with saline water. Field notes from this survey indicated that most of the vegetation was not severely damaged; however, species at some plots appeared salt stressed. *Schoenoplectus sp.* (bulrush), *Symphyotrichum sp.* (aster), and *Iva frutescens* (Jesuit's bark) were described as showing browning and die-back. It was also noted that the more salt-tolerant species *Spartina alterniflora* (smooth cordgrass) and *Spartina patens* (saltmeadow cordgrass) appeared to fare better (LDNR 2005). Based on the individual species covers, the relatively high vegetative cover in 2007 is due to a pronounced increase in *S. alterniflora*, which although surveyed two years after the hurricane, likely benefited from the influx of higher salinity water and the resulting decrease in competition from less salt-tolerant species (Figure 17).

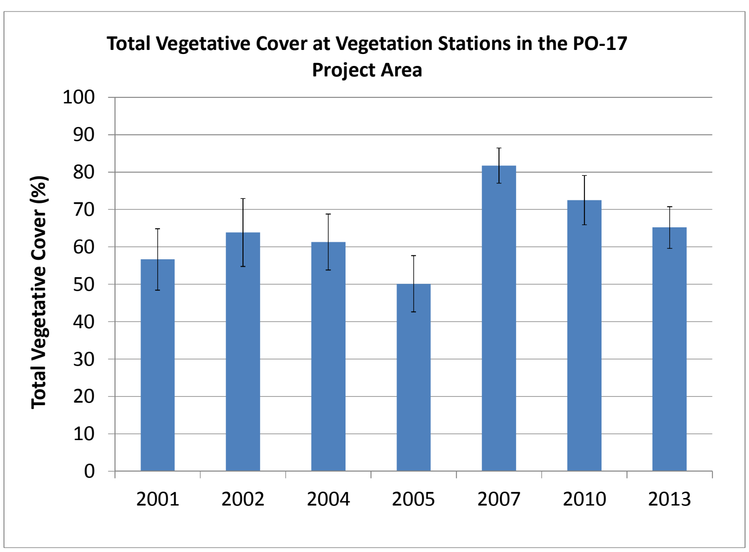

Figure 16. Total percent vegetative cover (±SE) in the PO-17 project area. Nineteen project-specific stations were surveyed in 2004; twenty stations were surveyed for all other years.

Species Percent Cover and Floristic Quality Index

Species percent cover is the visual estimation of the live cover for each species of vegetation at a station. Because the covers for species can overlap due to different heights and growth forms, the sum of the individual species' covers can exceed 100%. Vegetation-monitoring guidelines were still being refined during the early vegetation surveys; therefore, the species cover data between 1996 and 1998 are suspect in comparison to the later years' data. However, they do accurately represent the dominant species present at the stations.

In addition to providing general descriptive information about the vegetative community at a station, species cover data are used to calculate the Floristic Quality Index (FQI). The FQI equation 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 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 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 characterizes a vigorous coastal wetland (e.g. *Spartina alterniflora*). A station with a high FQI score represents a community with a low percentage of invasive and disturbance species that is dominated by species that are found in a stable marsh community in Louisiana. The ideal FQI range for marshes in an inactive deltaic plain in Louisiana is > 80 (Cretini et al. 2011).

Project Area

Abundant submerged aquatic vegetation was noted in the project area during a pre-construction vegetation survey conducted in February 1994. The species with the greatest prevalence included *Myriophyllum spicatum* (Eurasian watermilfoil), *Najas guadalupensis* (southern waternymph), *Ruppia maritima* (widgeongrass) and *Ceratophyllum demersum* (coon's tail). The only emergent vegetation recorded was *Eleocharis parvula* (dwarf spikerush).

Post-construction vegetation surveys at PO-17 project-specific stations between 1996 and 2013 demonstrated a significant change in the species composition, with a transition from a community of disturbance, pioneer species to one populated by species more indicative of a stable, mature marsh. This trend is reflected by the increasing FQI score, which ranged from a low of 7.1 in 1997, to a high of 70.5 in 2007 (Figure 17). Low FQI values are common for newly-constructed marsh sites, since cover will be sparse and the area will initially be populated by aggressive, disturbance species with low CC scores. The upwards trend for the FQI score largely correlates to an increase in the cover of *S. alterniflora* (CC=10) and *S. patens* (CC=9) (Figure 17).

The species with the highest mean covers in the project area over years were *S. alterniflora*, *Bacopa monnieri* (herb of grace) and *S. patens*, with 15.3%, 6.6% and 6.2% cover, respectively (Figure 17). However, the covers of these species varied considerably between years and were not indicative of the community composition throughout the project's lifespan. The first post-construction survey in May 1996 revealed a community of primarily disturbance species including *Ranunculus* sp. (buttercup) and *Solidago sempervirens* (seaside goldenrod) (Figure 17). While the prevalence of these two species was short-lived, the early colonizing *B. monnieri* and the shrub *Baccharis halimifolia* (eastern baccharis) formed a more enduring part of the vegetative community (Figure 17). *Baccharis halimifolia* has declined over years, reflecting the overall reduction in scrub-shrub habitat as the higher elevation areas of PO-17 settled to an elevation with a flooding regime that promoted the growth of emergent marsh habitat.

A notable change in the marsh community occurred in 2004, with the first significant documentation of *S. alterniflora* at vegetation stations (Figure 17). Since 2004, *S. alterniflora* has had the highest percent cover each year, ranging from a low of 13.3% in 2005, to a high of 47.8% in 2007. *Spartina alterniflora* was planted by the Soil Conservation Service in the LaBranche wetlands in May 1984 due to its ability to tolerate high salinity and tidal variability and its success at stabilizing shorelines. Prior to this planting, *S. alterniflora* had not been documented in the area (Talbot and Ensminger 1989). This species has declined in the project area since 2007, possibly due to greater competition from species such as *Schoenoplectus robustus* (sturdy bulrush), a brackish species that has been shown in field studies to out-compete *S. alterniflora* in fresher environments (Crain et. al). *Schoenoplectus robustus* was recorded in the 1997 and 1998 surveys, but it was not until 2004 that it also became a consistent, prominent component of the marsh community. The percent cover of *S. robustus* has increased for each survey since 2007. These two species, along with *S. patens*, have largely defined the marsh community since 2004 (Figure 17).

Annual vegetation surveys began in 2008 at CRMS6299 in the project area. The dominant vegetation at this site closely resembled that of the project-specific stations during the same period, with *S. alterniflora*, *S. robustus* and *S. patens* comprising a mean percent cover over years of 56.2%, 34.8% and 14.4%, respectively (Figure 18). *Spartina patens,* a species more associated with high marsh and less adapted to prolonged, deep flooding, was not recorded in 2013. The absence of this species may be in response to increased competition from *S. robustus*, but may also be due to increased flooding. The frequency of flooding was higher in 2013 at CRMS6299 than in previous years, and the depth equaled the highest on record (Table 4, page 36). Data from future surveys are necessary to see if the absence of this species is temporary or if this will be a more enduring change in the vegetative community. The FQI score for CRMS6299 in the project area averaged 79.2 over years, ranging from a low of 65.3 in 2012 to a high of 87.2 in 2010 (Figure 18). The FQI remained above 80.0 and in the ideal range from 2008–2011, but then declined in 2012, primarily due to the decrease in *S. alterniflora* cover. The decline in the percent cover of *S. alterniflora* mirrors the decline at the project specific sites and may also be related to increased competition from *S. robustus*.

Reference Area

Spartina patens was the dominant species at project-specific stations in the PO-17 reference area, averaging 60.4% cover over years (Figure 19). The vine *Ipomoea sagittata* (saltmarsh morning glory) was the second most abundant species, averaging 7.0% cover over years. Other species, such as *Polygonum punctatum* (dotted smartweed), *Polygonum hydropiperoides* (swamp smartweed), and *S. robustus*, had single years with high percent covers, but otherwise were insignificant components of the marsh community. While *S. alterniflora* was the dominant species in the project area, it was not present at stations in the reference area. The FQI score averaged 67.5 over years and ranged from a low of 42.0 in 2010 to a high of 81.8 in 2005 (Figure 19).

Annual vegetation surveys conducted since 2008 at CRMS2830 in the reference area indicate a vegetative community that closely resembled the community at the project-specific reference sites. *Spartina patens* was the dominant species over years, averaging 52.4% cover, followed by *I. sagittata*, which averaged 34.9% cover. Other than these two species, only *P. punctatum* had a notable presence at CRMS2830, with peaks of 28.3% cover in 2010 and 22% cover in 2011. The FQI for CRMS2830 in the reference area has been relatively stable, averaging 72.5 between years and ranging from a low of 66.7 in 2013 to a high of 76.7 in 2012 (Figure 20).

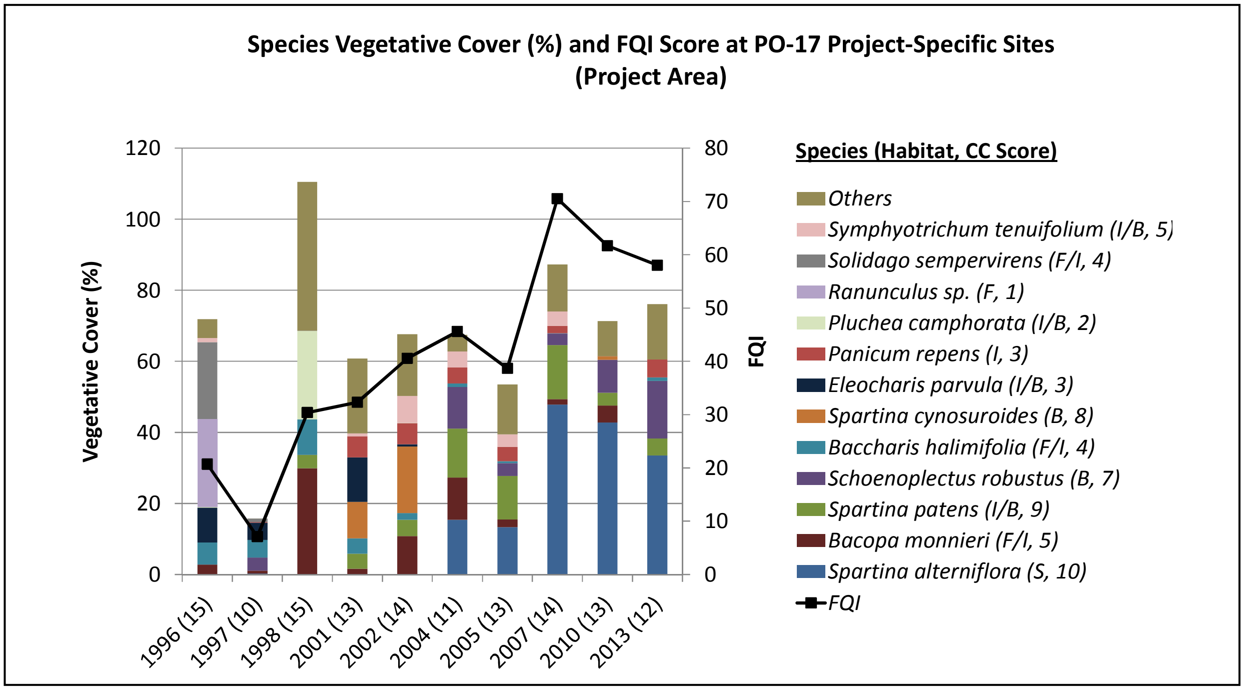

Figure 17. Mean percent cover of vegetative species and FQI score at project-specific stations in the PO-17 project area. The marsh habitat where the species typically grows and the CC score are listed after the species name. F = fresh, I = intermediate, B = brackish, S = salt. Eighteen stations were sampled in 1997, 19 in 1996 and 2004, and 20 in all other years. The number after the year corresponds to the number of species surveyed.

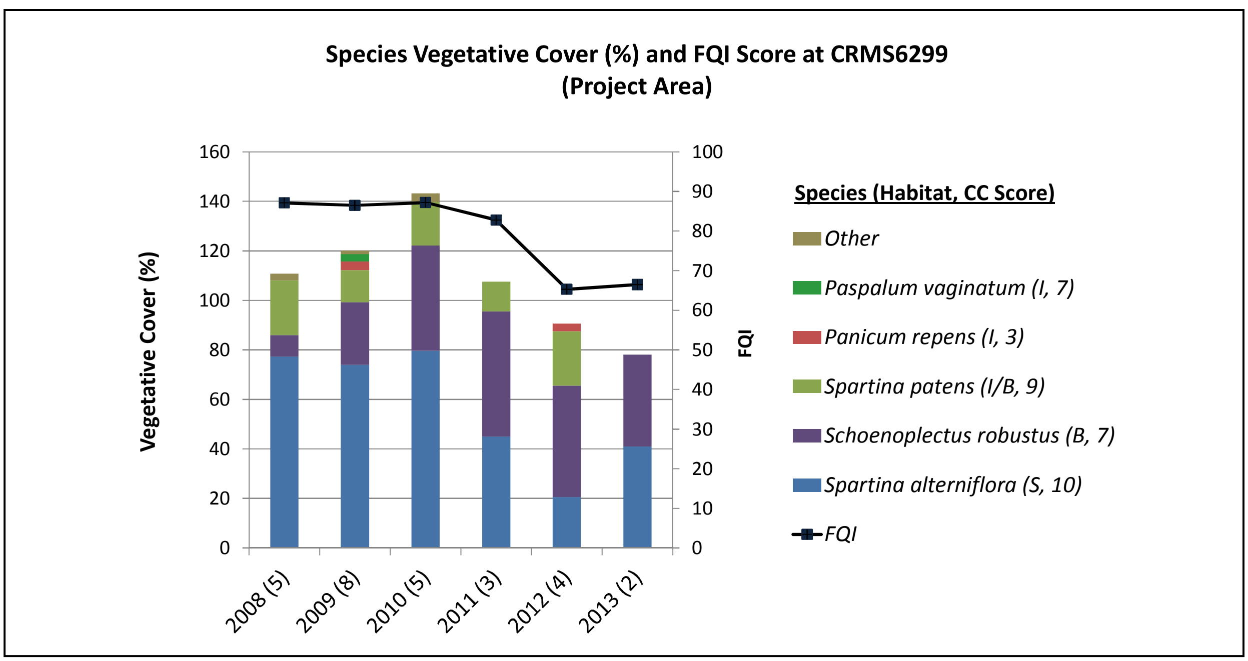

Figure 18. Mean percent cover of vegetative species and FQI score at CRMS6299 in the PO-17 project area. The marsh habitat where the species typically grows and the CC score are listed after the species name. F = fresh, I = intermediate, B = brackish, S = salt. Ten stations were surveyed each year. The number after the year corresponds to the number of species surveyed.

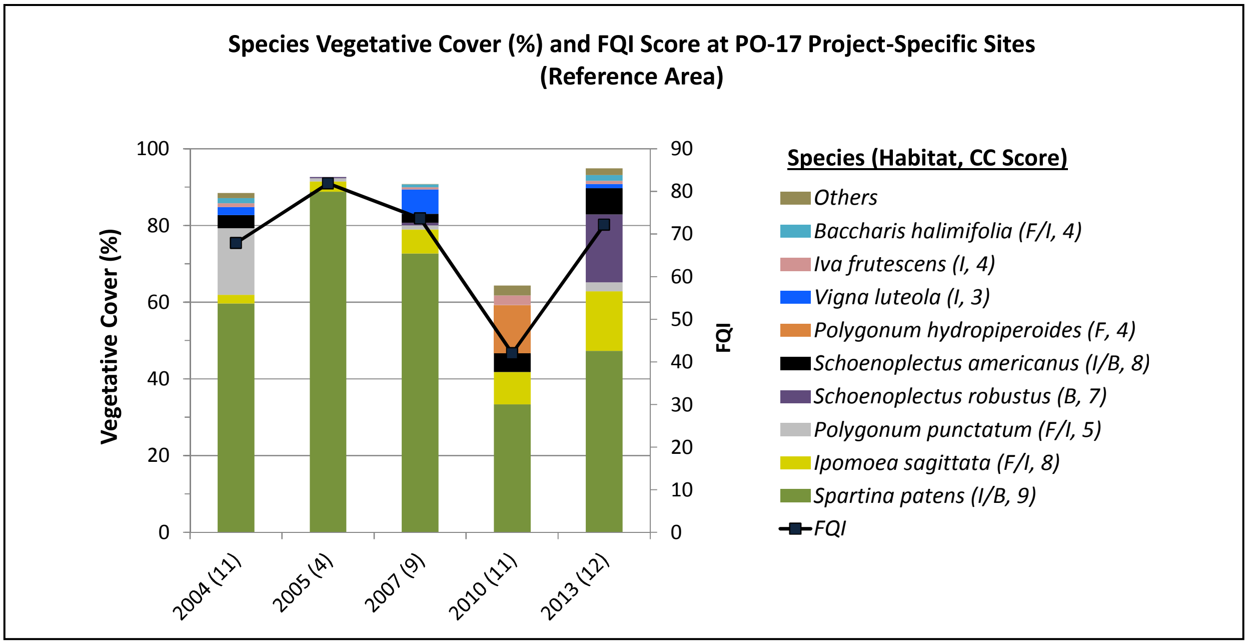

Figure 19. Mean percent cover of vegetative species and FQI score at project-specific stations in the PO-17 reference area. The marsh habitat where the species typically grows and the CC score are listed after the species name. F = fresh, I = intermediate, B = brackish, S = salt. Thirteen stations were surveyed each year. The number after the year corresponds to the number of species surveyed.

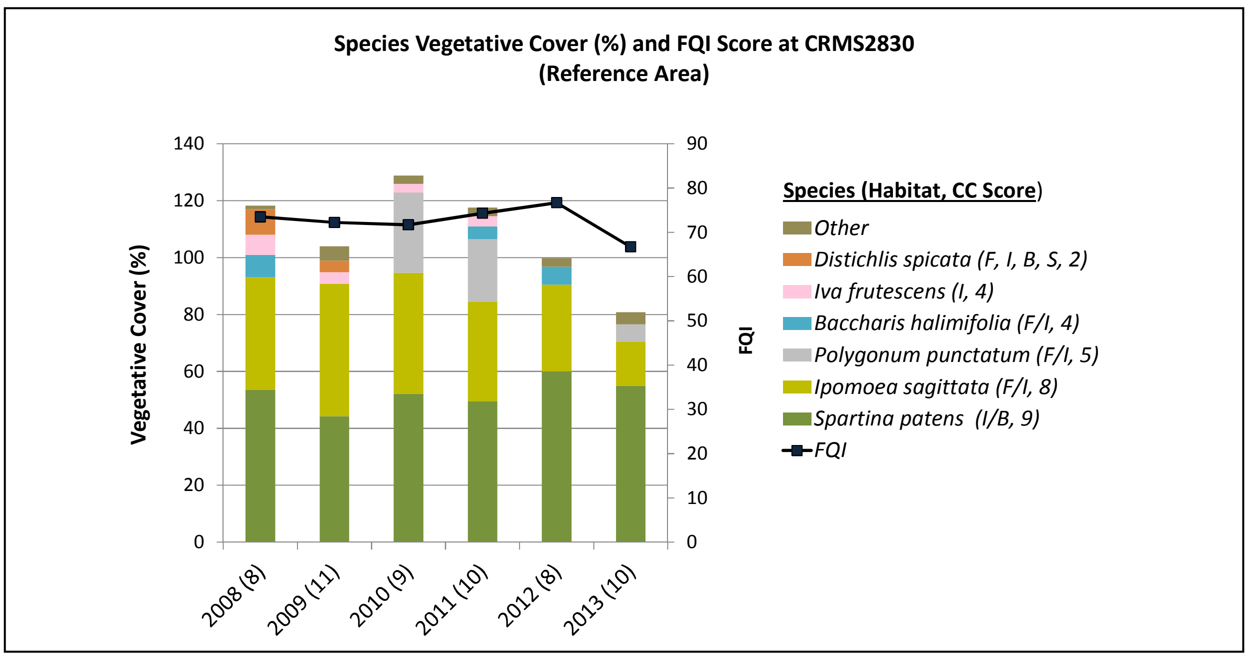

Figure 20. Mean percent cover of vegetative species and FQI score for CRMS2830 in the PO-17 reference area. The marsh habitat where the species typically grows and the CC score are listed after the species name. F = freshwater, I = intermediate, B = brackish, S = saltwater. Ten stations were surveyed each year. The number after the year corresponds to the number of species surveyed.

Species Distribution

Species distribution data provide a more complete picture of the vegetative community by indicating if a species' distribution is patchy, or if it is occurring more widely throughout the project area. Generally, in both the project and reference areas, the species with the highest covers were also the species with the widest distribution.

Project Area

Spartina alterniflora had the widest distribution among project-specific stations, occurring at an average of 30% of stations over years and an average of 59% of stations since 2004. *Bacopa monnieri* occurred at an average of 27% of stations over years and was the second most widely distributed species. This species has experienced a steady decline in distribution since 2004 and was not recorded in the project area in 2013 (Table 3A). A possible explanation for this decline is greater competition from *S. alterniflora* and *S. robustus*. Similar to *S. alterniflora*, *S. robustus* had a limited distribution prior to 2004, but by 2010, it had expanded to 75% of stations, making it the most widely distributed species that year. In 2013, it equaled *S. alterniflora* in distribution, occurring at 70% of stations. With the exception of 2013, the distribution of *S. patens* has been trending upwards, occurring at an average of 17% of stations over years. The total number of species recorded at stations in the project area ranged from a high of 15 in 1996 and 1998, to a low of 10 in 1997 (Table 3A).

At CRMS6299 in the project area, *S. alterniflora* occurred at 100% of stations each year. *Schoenoplectus robustus* and *S. patens* were the most widely distributed species after *S. alterniflora*, occurring at 82% and 43% of stations between years, respectively (Table 3B). In 2013, the distribution of *S. patens* declined at the project-specific stations to 15%; this decline was even more pronounced at CRMS6299, where *S. patens* was not recorded. The total number of species recorded at CRMS6299 ranged from a high of eight in 2009, to a low of two in 2013 (Table 3B).

Reference Area

Spartina patens occurred at 100% of project-specific stations in the reference area each year. *Ipomoea sagittata* was also widely distributed, occurring at an average of 69% of stations between years. The number of species surveyed in the reference area ranged from a high of 13 species in 2013, to a low of four species in 2005. *Iva frutescens*, *B. halimifolia*, *S. americanus* and *Vigna luteola* (hairy pod cowpea) were commonly recorded in the reference area over years, but were absent from the 2005 survey, likely due to salt stress from the Hurricane Katrina storm surge (Table 3C).

The distribution of species at CRMS2830 in the reference area was similar to that at the project-specific reference stations. *Spartina patens* and *I. sagittata* both occurred at 100% of stations each year. *Polygonum punctatum* was the next widely distributed species, occurring at an average of 42% of stations between years. The number of species surveyed at stations ranged from a high of 11 in 2009, to a low of eight in 2008 and 2012 (Table 3D).

Table 3. Percent of vegetation stations where each species occurred in the PO-17 project and reference areas. **A**. PO-17 vegetation stations in the project area, **B**. CRMS6299 (project area), **C**. PO-17 vegetation stations in the reference area, **D**. CRMS2830 (reference area). * This table includes all species with a mean occurrence of > 10% over years. The complete list of species is included in Appendix I. N = number of stations. *Habitat* = the marsh habitat where the species most commonly occurs. F = fresh, I = intermediate, B = brackish, S = salt.

A Scientific Name	Common Name	% of Project Area Stations Where Species Occurred											
		1996	1997	1998	2001	2002	2004	2005	2007	2010	2013	Average	Habitat
		N=19	N=18	N=20	N=20	N=20	N=19	N=20	N=20	N=20	N=20		
Spartina alterniflora	smooth cordgrass		6				47	45	70	65	70	30	S
Bacopa monnieri	herb of grace	26	61	50	20	35	42	20	10	5		27	F/I
Schoenoplectus robustus	sturdy bulrush		11	5			26	15	10	75	70	21	B
Spartina patens	saltmeadow cordgrass			5	5	10	26	30	35	40	15	17	I/B
Eleocharis parvula	dwarf spikerush	42	22		40	20						12	I/B
Solidago sempervirens	seaside goldenrod	79	33	5								12	F/I
Baccharis halimifolia	Eastern baccharis	32	17	20	15	10	5	5	5		5	11	F/I
Iva frutescens	Jesuit's bark			5	5	5	16	10	30	10	25	11	I
Total Number of Species*		**15**	**10**	**15**	**13**	**14**	**11**	**13**	**14**	**13**	**12**		

B Scientific Name	Common Name	% of CRMS6299 Stations Where Species Occurred (N = 10)							Habitat
		2008	2009	2010	2011	2012	2013	Average	
Spartina alterniflora	smooth cordgrass	100	100	100	100	100	100	100	S
Schoenoplectus robustus	sturdy bulrush	50	80	90	90	90	90	82	B
Spartina patens	saltmeadow cordgrass	40	50	50	70	50		43	I/B
Total Number of Species*		**5**	**8**	**5**	**3**	**4**	**2**	**5**	

C Scientific Name	Common Name	% of Reference Stations Where Species Occurred (N = 13)						Habitat
		2004	2005	2007	2010	2013	Average	
Spartina patens	saltmeadow cordgrass	100	100	100	100	100	100	I/B
Ipomoea sagittata	saltmarsh morning-glory	62	69	77	69	69	69	F/I
Polygonum punctatum	dotted smartweed	69	23	15		31	28	F/I
Schoenoplectus robustus	sturdy bulrush		8	23		69	20	B
Vigna luteola	hairypod cowpea	31		38		23	18	I
Schoenoplectus americanus	chairmaker's bulrush	15		8	15	23	12	I/B
Iva frutescens	Jesuit's bark	15		15	23	8	12	I
Baccharis halimifolia	eastern baccharis	31		15		15	12	F/I
Total Number of Species*		**11**	**4**	**9**	**11**	**12**	**9**	

D Scientific Name	Common Name	% of CRMS2830 Stations Where Species Occurred (N = 10)							Habitat
		2008	2009	2010	2011	2012	2013	Average	
Spartina patens	saltmeadow cordgrass	100	100	100	100	100	100	100	I/B
Ipomoea sagittata	saltmarsh morning-glory	100	100	100	100	100	100	100	F/I
Polygonum punctatum	dotted smartweed		10	90	100	20	30	42	F/I
Iva frutescens	Jesuit's bark	20	50	20	10		30	22	I
Baccharis halimifolia	eastern baccharis	30	10	10	10	30	10	17	F/I
Cuscuta pentagona	fiveangled dodder	10	10	10	10	20	10	12	F
Pluchea odorata	sweetscent		40		20	10		12	I/B
Total Number of Species*		**8**	**11**	**9**	**10**	**8**	**10**	**9**	

Difference in Community Composition Between Project and Reference Areas

The difference in vegetative communities—dominance of *S. alterniflora* in the project area as compared to dominance of *S. patens* in the reference area—is likely due to differences in marsh elevation and flooding. With the exception of the northern PO-17 project area, the marsh elevation is lower in much of the project area than in the reference area, and as a result, the marsh is flooded more deeply and at a greater frequency than the reference area. The semi-impoundment of the project area, especially in the early years of the project's life, also contributed to the establishment of more flood-tolerant species. These conditions would favor the growth of *S. alterniflora* and *S. robustus* in the project area, while the higher elevation and less frequent flooding in the reference area would favor the growth of the higher marsh species *S. patens*. The greater cover of the shrubs *B. halimifolia* and *I. frutescens* in the reference area also indicate conditions that are favorable for higher marsh/scrub-shrub species.

vi. Salinity

Salinity data were used to assess any differences between the project and reference areas and to identify the localized effects of significant climactic and flood control events. Hourly salinity data were recorded at project-specific hydrographic stations PO17-43 (project area) and PO17-44R (reference area) from April 1996–June 2003 and at CRMS6299 (project area) and CRMS2830 (reference area) from January 2008–December 2013.

Over the life of the project, daily mean salinity was higher at PO17-43 in the project area (5.07 ppt ± 0.06 SE) than at PO17-44R in the reference area (4.44 ppt ± 0.05 SE). Daily mean salinity was also higher at CRMS6299 in the project area (2.98 ppt ± 0.03 SE) than at CRMS2830 in the reference area (2.86 ppt ± 0.03 SE) (Figure 21). Differences in salinity between the project and reference areas during the same period are small, especially between the CRMS sites, and the ecological impact of that difference on the marsh community may be negligible. The higher salinity recorded during the period of project-specific monitoring (1996–2003) is largely due to the freshwater evaporation and concentration of salt during the extended drought that occurred in the region from September 1999 through December 2000 (Figure 22).

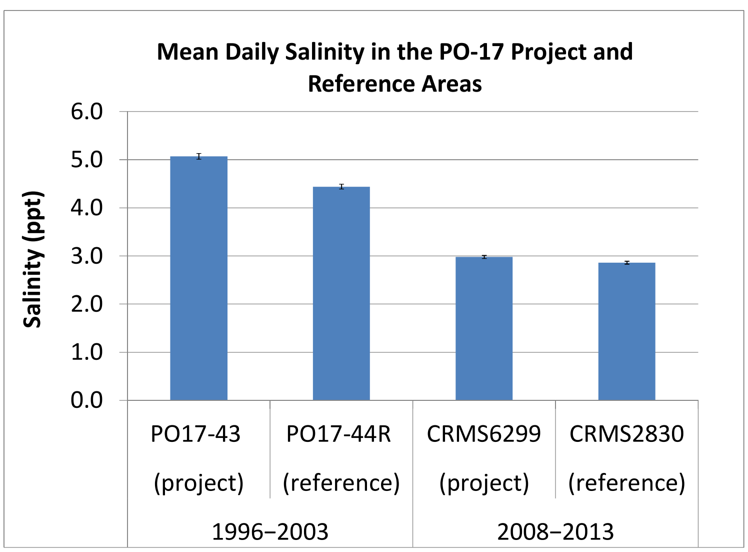

Figure 21. Mean daily salinity measured at hydrographic stations in the PO-17 project and reference areas. Salinity was measured at project-specific stations PO17-43 and PO17-44R from April 1996–June 2003 and at the CRMS stations from January 2008–December 2013.

The highest monthly mean salinity (12.16 ppt) was recorded in the project area August 2000 at PO17-43 during the previously mentioned drought. In addition to the drought, storm surge from significant weather events, most notably Hurricanes Gustav and Ike (August/September 2008) also elevated salinity in the project and reference areas (Figure 22). Pronounced reductions in salinity occurred after the opening of the Bonnet Carré Spillway in April 2008 and May 2011 and as a result of high monthly rainfall that occurred in the New Orleans area January 1998 (19.28 inches) and December 2009 (25.92 inches) (Figure 22).

The higher salinity observed in the project area, in particular during the early project years, may be the result of reduced hydrologic exchange due to semi-impoundment. Containment berms were constructed around the perimeter of the project area to confine the dredged sediments as they dewatered and consolidated. The berms could have delayed the outflow of saline water after tidal inundation from storm surge and hindered the flushing of salts that became concentrated in the surface water and sediment as freshwater evaporated. The possibility of impoundment resulting from the berms was realized at the time of construction and drainage culverts were installed to allow for water flow into and out of the project area. Their function was impeded during winter months, presumably by duck hunters who blocked the culverts to enhance ponding for waterfowl. These obstructions were reportedly washed out by 1999 (Raynie and Visser 2002) and no longer influenced water exchange.

The similarity between salinity at the CRMS project and reference sites indicates that hydrologic exchange has likely increased in the project area over time (Figure 22). According to firsthand observations, the southern opening to the canal where the project area hydrographic stations were located has widened over years (personal comm. W. Boshart), increasing connectivity between the canal and the open water reference area (Figure 3). Continued settlement of the project area and containment berm has also likely resulted in greater hydrologic exchange. It should be noted that the CRMS stations were not installed in the exact locations of the project-specific stations, but they were installed at nearby locations with similar habitat and hydrology (Figure 3).

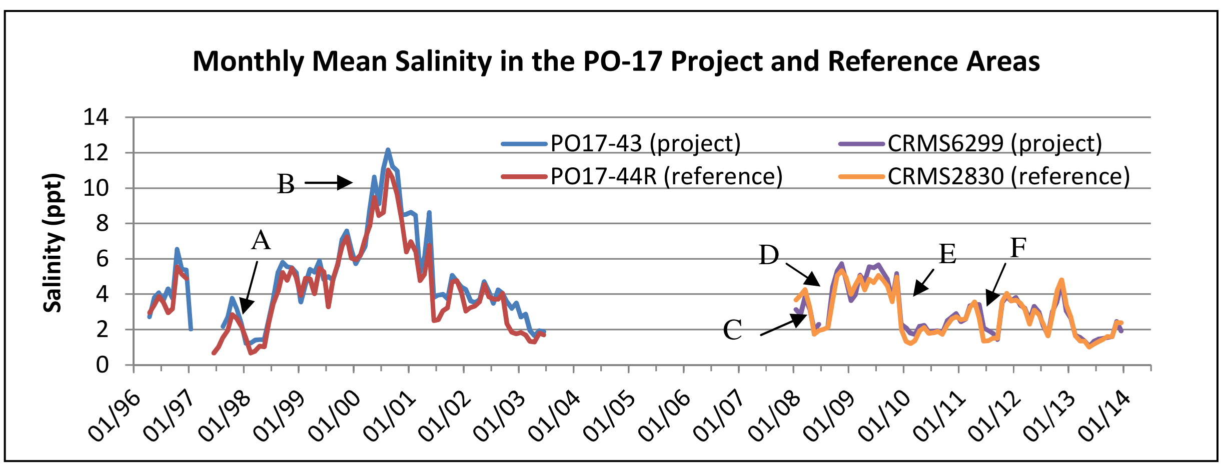

Figure 22. Monthly mean salinity in the PO-17 project and reference areas 04/1996–12/2013. **A:** monthly rainfall of 19.28 inches in New Orleans (01/1998), **B:** drought: 09/1999–12/2000 **C:** Bonnet Carré Spillway opening (04/11/2008–04/29/2008, **D:** Hurricanes Gustav (08/25/2008–09/04/2008) and Ike (09/01/2008–09/14/2008), **E:** monthly record rainfall of 25 inches (12/2009), **F:** Bonnet Carré Spillway opening (05/09/2011–06/20/2011).

vii. Water Elevation

Water level data were used to assess any differences between the project and reference areas, to identify the localized effects of significant climactic and flood control events, and to calculate the frequency, depth and duration of flooding on the marsh surface. Hourly water level data were recorded at stations PO17-43 in the project area and PO17-44R in the reference area from April 1996–June 2003. Water level data collected prior to August 7, 1997 for PO17-43 and prior to June 11, 1997 for PO17-44R were excluded from analyses due to recording errors. The collection of hourly water level data resumed in January 2008 and continued through December 2013, with the installation of CRMS6299 in the project area and CRMS2830 in the reference area.

Mean daily water elevation (NAVD88) from 1997–2003 was higher at PO17-43 in the project area (1.04′ ± 0.01 SE) than at PO17-44R in the reference area (0.89′ ± 0.01 SE). The higher elevation in the project area may be due to the partial impoundment that was reported early in the project's life. The difference in mean daily water elevation between the project and reference areas was not evident later in the project's life at the CRMS stations. Water elevation from 2008–2013 was 1.21′ ± 0.01 SE at CRMS6299 (project area) and 1.20′ ± 0.01 SE at CRMS2830 (reference area) (Figure 23). As previously mentioned, hydrologic exchange has likely increased with time in the project area; however, the CRMS reference site still appears to drain to a slightly greater depth than the project site (Figure 24).

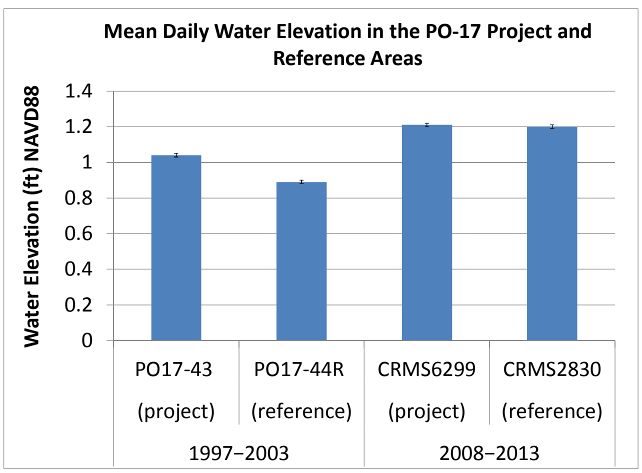

Figure 23. Mean daily water elevation (NAVD88) measured at hydrographic stations in the PO-17 project and reference areas. Water elevation was analyzed at PO17-43 from June 1997–June 2003, at PO17-44R from August 1997–June 2003, and at the CRMS stations from January 2008–December 2013.

No individual event had as dramatic a long-term affect on water elevation as the drought had on salinity; however, the drought likely did serve to keep water elevation lower during its duration (09/1999–12/2000). The highest mean monthly water elevation in the project area (2.56′ NAVD88) was recorded for August 2008 as a result of storm surge from Hurricanes Gustav and Ike. Storm surge had the greatest noticeable impact on water elevation in the area during the project's life (Figure 24). Water elevation remained unusually high during late fall 2012 through winter 2013, when water levels typically decline seasonally in the project area (Figure 24). Total precipitation measured at the New Orleans Louis Armstrong International Airport January 2012–February 2012 was higher in 2013 (13.32″) than during the same period for other years of CRMS monitoring. A rainy 2013 winter may have resulted in higher than average water elevation in the region. Wind is also a significant factor that affects flooding in the LaBranche wetlands and may have contributed to the higher water elevation during this time.

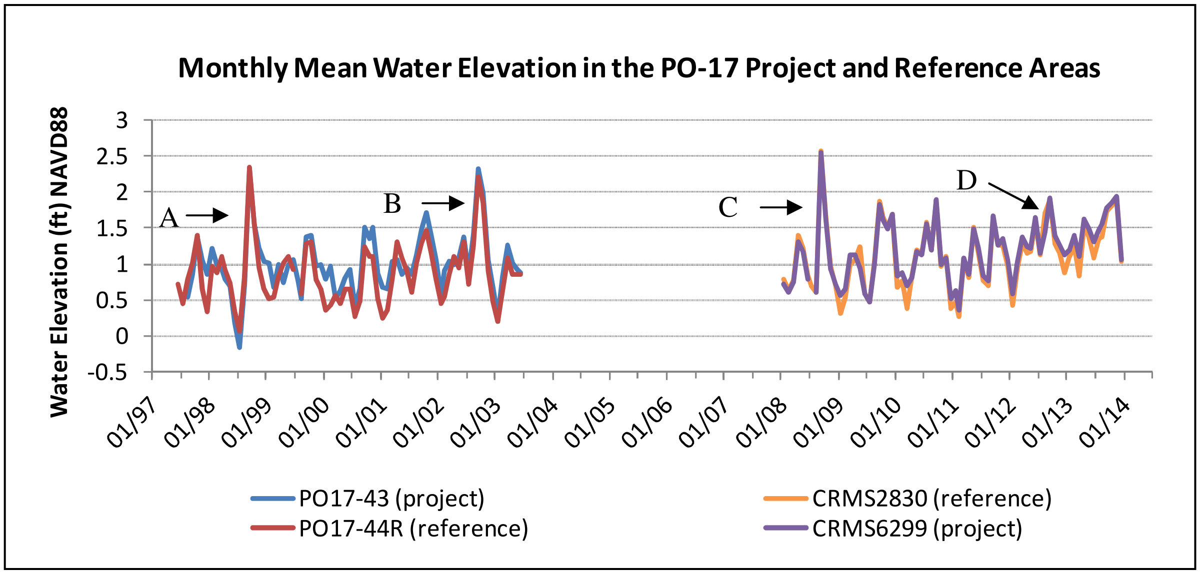

Figure 24. Monthly mean water elevation at PO-17 project-specific and CRMS hydrographic stations in the PO-17 project and reference areas. **A:** Tropical Storm Frances: 09/08/98–09/13/98, **B:** Hurricane Isidore: 09/14/02–09/27/02; Hurricane Lili: 09/21/02–10/04/02, **C:** Hurricanes Gustav (08/25/08–09/04/08) and Ike (09/01/08–09/14/08), **D:** Hurricane Isaac (08/21/2012–09/01/2012).

Frequency, Depth and Duration of Flooding

Frequency, depth and duration of flooding were analyzed at the CRMS sites in the project and reference areas to compare flooding of the marsh. The project area was flooded for a greater mean percentage of time over years than in the reference area—65.3% at CRMS6299 (project area), as compared to 26.8% at CRMS2830 (reference area) (Table 4). Both sites were flooded more frequently in 2013 than in previous years due to the higher water elevation recorded in the project and reference areas that year (Figure 24).

Not only was the project area site flooded for a longer time than the reference area site, it was also flooded at a greater depth. The annual flooding depth at CRMS6299 averaged 0.63 feet over years, as compared to 0.50 feet at CRMS2830 (Table 4). The mean number of flooding events were slightly more numerous in the project area over years and lasted for a longer duration than in the reference area (CRMS6299: 19 events/16.1 days; CRMS2830 (15 events/6.6 days) (Table 4). A flooding event is defined as an event that lasts at least one day (24 hours) and is separated from another event by a least one day of non-flooded conditions.

The elevation data used for these analyses are specific to these monitoring sites and flooding conditions in other parts of the project and reference areas are reflected by the marsh elevation and hydrology specific to that region. It can be assumed that flooding in the project area is less frequent in the north, where marsh elevation is higher than in the south. The marsh elevation at CRMS6299 (0.89 ft NAVD88) is lower than at CRMS2830 (1.48 ft NAVD88). Since water elevation was similar between sites, the lower elevation in the project area explains the higher calculated flooding at this location.

Table 4. Frequency, depth and duration of flooding at CRMS monitoring sites in the PO-17 project and reference areas from 01/29/2008-010/24/2013. Marsh elevation at CRMS6299 is 0.89 ft NAVD88 and at CRMS2830 is 1.48 ft NAVD88.

	CRMS6299 (Project Area) Marsh Elevation: 0.89 ft NAVD88						**CRMS2830 (Reference Area)** Marsh Elevation: 1.48 ft NAVD88					
YEAR	N (Days)	# of Days Flooded	# of Flood Events	% of Time Flooded	Mean Depth (ft) ± SD	Mean Duration of Flood (Days) ± SD	N (Days)	# of Days Flooded	# of Flood Events	% of Time Flooded	Mean Depth (ft) ± SD	Mean Duration of Flood (Days) ± SD
2008	286	148	18	51.7	0.73 ± 0.78	8.2 ± 13.6	338	73	9	21.6	0.70 ± 0.86	8.1 ± 9.1
2009	287	185	11	64.5	0.66 ± 0.45	16.8 ± 30.8	347	116	16	33.4	0.40 ± 0.37	7.3 ± 8.0
2010	338	204	27	60.4	0.51 ± 0.43	7.6 ± 9.4	365	66	11	18.1	0.44 ± 0.37	6.0 ± 5.8
2011	356	198	23	55.6	0.55 ± 0.55	8.6 ± 9.7	365	63	11	17.3	0.51 ± 0.62	5.7 ± 7.2
2012	351	266	18	75.8	0.60 ± 0.55	14.8 ± 12.9	362	98	19	27.1	0.53 ± 0.78	5.2 ± 4.5
2013	326	274	17	84.0	0.73 ± 0.43	15.4 ± 27.2	365	158	21	43.3	0.42 ± 0.30	7.5 ± 6.9
Average	**324**	**213**	**19**	**65.3**	**0.63**	**16.1**	**357**	**96**	**15**	**26.8**	**0.50**	**6.6**

viii. Soil Properties

Organic matter (%) and bulk density (g/cm^3) were analyzed for sediment cores collected at PO-17 vegetation stations in the project area between 1996–2013. Forty-two samples (two from each station) were collected in 1996 and 1997, and 18–22 samples were collected for other years. The duplicate samples were averaged for each station prior to analysis. The sediment cores were extracted from the marsh surface down to 10 cm and total volume was approximately 50 cm^3. Sediment cores were also collected in the PO-17 reference area at the thirteen vegetation stations between 2002–2013, with the exception of 2005. Data collected in 2002 and 2004 were not included in the analyses due to potential errors with reporting. A non-parametric Kruskal-Wallis test was used to test for differences among years ($\alpha = 0.05$) (SAS Institute Inc., Cary, NC, version 9.1).

Percent organic matter of the sediment collected from the project area was significantly different among years, with a trend towards increasing organic matter ($\chi^2 = 122.63$, df = 7, $P < 0.0001$) (Figure 25). The sediment dredged from the bottom of Lake Pontchartrain was primarily of mineral composition and an increase in organic matter would be expected to occur over time with vegetative growth and decomposition. Organic matter ranged from a mean high of 13.19% in 2010, to a low of 2.88% in 1998. Between 2005–2013, percent organic matter has shown signs of stabilization, averaging 11.92% ± 0.60 SE (Figure 25). Organic matter in the reference area averaged 31.20% ± 2.08 SE and was not significantly different between years ($P = 0.5791$). Twenty years after project construction, the percent organic matter in the created marsh was still considerably lower than in the natural marsh. However, based on the habitat and vegetation surveys conducted during the project's life, it has been within a range that has supported the growth of emergent marsh habitat.

Bulk density of sediment in the project area was also significantly different among years; however, it showed a declining trend over years ($\chi^2 = 106.32$, df =7, $P < 0.0001$) (Figure 26). The bulk density of the sediment in the project area ranged from a high of 1.62 g/cm^3 in 1996, to a low of 0.44 g/cm^3 in 2010. Bulk density declined in the project area between 1996 and 2005, but was generally stable between 2005–2013, averaging 0.54 g/cm^3 ± 0.03 SE over years. A decrease in bulk density can be expected with an increase in organic content, which promotes a higher porosity of the soil (USDA NRCS 2008). Bulk density in the reference area averaged 0.24 g/cm^3 ± 0.03 between 2007–2013 and was not significantly different between years (P = 0.9411) (Figure 26). As of 2013, bulk density remained higher in the created marsh than in the natural marsh. Despite the difference in bulk density between the created and natural marsh, bulk density has been within a range that has fostered the expansion of emergent marsh vegetation in the project area.

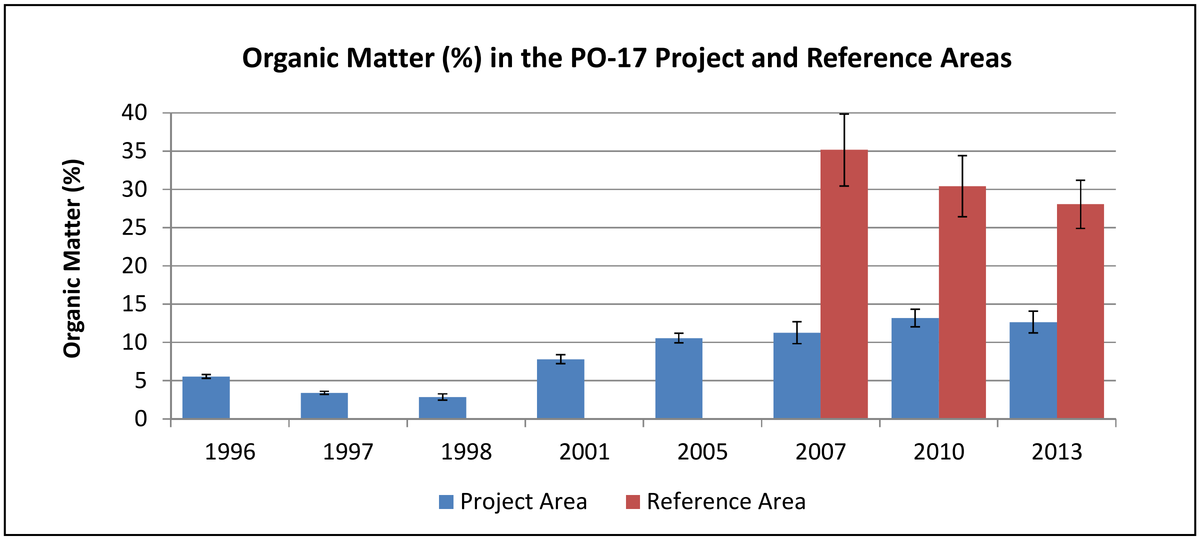

Figure 25. Percent organic matter of sediment (± SE) in the PO-17 project and reference areas between 1996–2013.

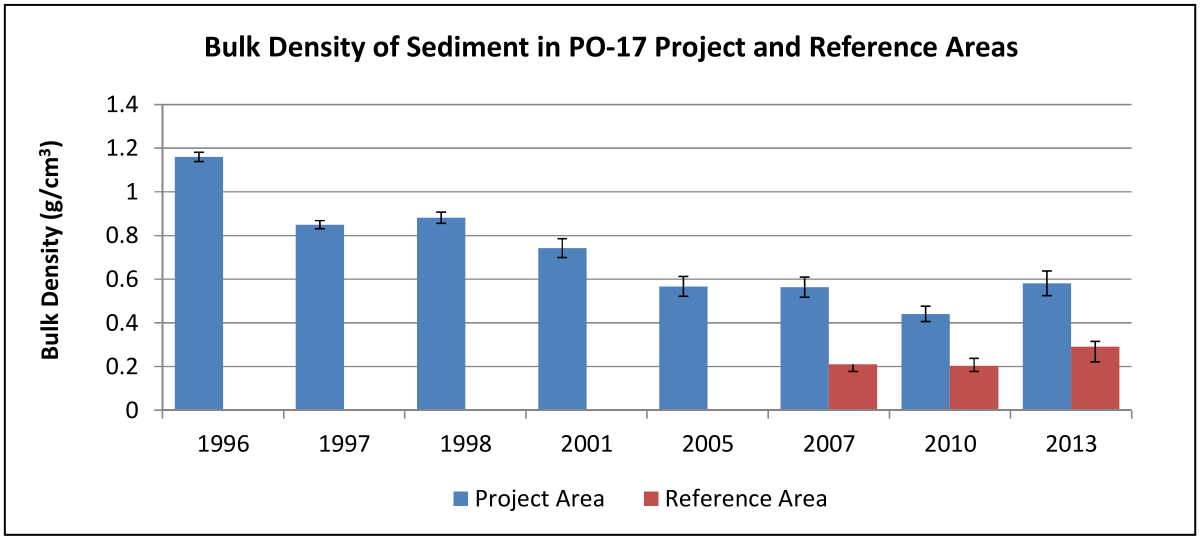

Figure 26. Bulk density of sediment (± SE) in the PO-17 project and reference areas between 1996–2013.

V. Conclusions

A. Project Effectiveness

The goal of the Bayou LaBranche Wetland Creation project was to create new vegetated wetlands in the Bayou LaBranche area utilizing dredged sediments. This goal was attained. Prior to project construction, the project area was classified as primarily estuarine aquatic bed and estuarine open water habitat; as of 2012, the project area was classified as primarily estuarine emergent marsh.

The specific objectives of the project were as follows:

1. Create approximately 305 acres (123 ha) of shallow-water habitat conducive to the natural establishment of emergent wetland vegetation.

2. Increase the marsh:open-water ratio in the project area to a minimum of 70% emergent marsh to 30% open water after five years following project completion.

As of November 2012, there were 408 acres of land in the project area, of which 356 acres were classified as emergent marsh. Estuarine emergent marsh comprised 82% (355 acres) of the habitat, and palustrine emergent marsh comprised 1% (1 acre) of the habitat. Both objectives for the project were met and sustained through the end of the project's life; however, the attainment of a minimum of 70% emergent marsh to 30% open water likely took longer than five years (1999). Habitat analysis conducted in 1997 indicated that 51% (222 acres) of the project area was emergent marsh and 29% (125 acres) was scrub-shrub habitat. The higher elevation in the northern area of the project fostered the development of scrub-shrub habitat during the early project years, but as the sediment settled and the land received greater inundation, the scrub-shrub habitat transitioned into emergent marsh.

B. Recommended Improvements

Bayou LaBranche Wetland Creation (PO-17) reached the end of its 20-year CWPPRA life in 2014. This project has been successful at achieving its goal and no new recommendations are being made at this time. However, the following recommendations were made in the 2004 OM&M Report (Boshart 2004), and were included in all future OM&M reports. These recommendations are addressed in respect to the project's end-of–life status.

1. <u>Create additional gaps in the containment dikes to improve hydrologic exchange.</u>

   Impoundment due to the containment dikes and insufficient drainage features appears to have been an issue within the project area, especially early in the project's life. Unauthorized modifications to drainage of the project area (blockage of culverts) exacerbated the retention of water during this time. Creating additional gaps in the containment dikes early in the project's life would have increased hydrologic exchange, but based on the hydrographic data, impoundment was not as great of an issue as to require it. Hydrographic data also indicate that differences in water elevation and salinity have decreased between the project and reference area monitoring stations. Continued settlement of the project area and the containment dikes, and expected natural degradation of the containment dikes over time, has likely led to increased hydrologic exchange in the project area.

2. Continue to monitor marsh elevation to assess further settlement in the project area.

   This recommendation was implemented and a final elevation survey of the project and reference areas was conducted in 2013. Elevation surveys are crucial to determine settlement rates and to assess if the project elevation is suitable to support the desired habitat. Surveys of the project area and a reference area also allow for a comparison between elevation and settlement rates in created and natural marsh. Elevation surveys scheduled throughout a project's life are now standard for CWPPRA marsh creation projects and continue to provide valuable information that is useful for future marsh creation projects.

3. Add dredged sediment to the project area to prevent open water conversion (if necessary).

   The 2012 land-water analysis had the highest percentage of land for any years surveyed; therefore, this action was not required to sustain land throughout the project's 20-year lifespan.

C. Lessons Learned

1. Marsh creation using dredged sediment is an effective restoration strategy to use in coastal Louisiana that can provide benefit beyond the 20-year CWPPRA project lifespan.

2. Post-construction elevation surveys of the project area were conducted in 1996, 2002, and 2013. The intention of this data collection effort was to compare the sediment elevation over time to measure settlement of the created marsh. Unfortunately, because it is unknown what geoids and ellipsoids were used for the 1996 and 2002 surveys, the data cannot be accurately compared. Surveying protocols have advanced considerably in the last decade, and documentation of surveying parameters is now standard procedure. In order to ensure consistency and accuracy with surveys, CPRA has published a surveying guide of minimum standards, with the latest revision in January 2013 (CPRA 2013). One important lesson learned from this project is to ensure that surveys conducted throughout the project's life will be comparable to one another.

3. Discharge of the sediment was restricted from within 1000 feet of Interstate 10 due to concerns over compromising the foundation. Because of this restriction, the dredged sediment was discharged primarily in the northern project area, which resulted in a larger volume of sediment deposition in the north and a higher localized elevation. Greater effort should have been made to distribute the sediment evenly in the project

area to attain the target elevation. The higher elevation in the north fostered the development of scrub-shrub habitat, rather than the desired marsh habitat and delayed the attainment of the 70% marsh habitat goal established for five years post-construction.

4. Efficient and detailed record-keeping is essential to maintain the vast quantity of correspondence, reports, and data collected throughout a project's life. Information regarding a project needs to be stored in a central location that will be accessible to the changing personnel involved with a project from its conception to completion—a period that can last well over 25 years.

5. While this project benefitted from rigorous data collection, during the early years, the monitoring program would have benefitted from an equally rigorous documentation of procedures and quality control and assurance. Significant improvements to monitoring protocols, data management and quality control have been implemented since monitoring for this project was initiated in 1994.

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APPENDIX 1

Vegetation Tables for Bayou LaBranche Wetland Creation (PO-17)

Table 1. Percent of stations where each vegetative species occurred at project-specific vegetation stations in the PO-=17 project. N = number of stations surveyed. *Habitat* is the marsh habitat where the species is most commonly found. F = freshwater, I = intermediate, B = brackish, S = saltwater.

		Percent of PO-17 Project Area Stations Where Species Occurred											
Scientific Name	**Common Name**	**1996**	**1997**	**1998**	**2001**	**2002**	**2004**	**2005**	**2007**	**2010**	**2013**	**Average**	**Habitat**
		N=19	N=18	N=20	N=20	N=20	N=19	N=20	N=20	N=20	N=20		
Spartina alterniflora	smooth cordgrass		6				47	45	70	65	70	30	S
Bacopa monnieri	herb of grace	26	61	50	20	35	42	20	10	5		27	F/I
Schoenoplectus robustus	sturdy bulrush		11	5			26	15	10	75	70	21	B
Spartina patens	saltmeadow cordgrass			5	5	10	26	30	35	40	15	17	I/B
Eleocharis parvula	dwarf spikerush	42	22		40	20						12	I/B
Solidago sempervirens	seaside goldenrod	79	33	5								12	F/I
Baccharis halimifolia	Eastern baccharis	32	17	20	15	10	5	5	5		5	11	F/I
Iva frutescens	Jesuit's bark			5	5	5	16	10	30	10	25	11	I
Pluchea camphorata	camphor pluchea	11		65		15						9	I/B
Panicum repens	torpedo grass		6		20	10	16	10	15	5	5	9	I
Ranunculus sp.	buttercup	84										8	F
Symphyotrichum tenuifolium	perennial saltmarsh aster	11			15	25	11	5	15			8	F
Distichlis spicata	saltgrass			5	20	20		5	5	15	5	8	B/S
Spartina cynosuroides	big cordgrass				30	40				5		7	B
Schoenoplectus pungens	common threesquare				40	25						7	F
Symphyotrichum subulatum	eastern annual saltmarsh aster			35	20							6	I
Lemna minor	common duckweed		28									3	F
Cyperus odoratus	fragrant flatsedge	5			5	5	11					3	I
Amaranthus australis	southern amaranth				5				10		10	2	I/B
Schoenoplectus californicus	California bulrush						5	5	5	5		2	I
Eleocharis sp.	spikerush							20				2	I
Symphyotrichum divaricatum	southern annual saltmarsh aster										20	2	F
Amaranthus sp.	pigweed	11		5								2	
Amaranthus cannabinus	tidalmarsh amaranth									15		2	I/B
Ipomoea sagittata	saltmarsh morning-glory										15	2	F/I
Sesbania drummondii	poisonbean			15								2	F
Paspalum vaginatum	seashore paspalum	5								5		1	I
Cuscuta indecora	bigseed alfalfa dodder								5		5	1	I
Echinochloa walteri	coast cockspur grass			10								1	I
Vigna luteola	hairypod cowpea								5	5		1	I
Schoenoplectus americanus	chairmaker's bulrush							5			5	1	I/B
Leptochloa fusca	malabar sprangletop					10						1	I
Azolla caroliniana	Carolina mosquitofern		6									1	F
Setaria pumila	yellow foxtail		6									1	I/B
Echinochloa sp.	cockspur grass	5										1	F/I
Packera glabella	butterweed	5										1	F
Paspalum dissectum	mudbank crowngrass						5					1	F
Polygonum punctatum	dotted smartweed	5										1	F/I
Polypogon interruptus	ditch rabbitsfoot grass	5										1	F
Sesbania herbacea	bigpod sesbania	5										1	I
Cuscuta sp.	dodder									5		1	F/I
Panicum capillare	witchgrass			5								1	F
Panicum sp.	panicgrass								5			1	.
Paspalum sp.	crowngrass			5								1	F/I
Sesuvium maritimum	slender seapurslane			5								1	B/S
Leptochloa sp.	sprangletop							5				0	F/I
Sorghum halepense	johnsongrass					5						0	F
Total Number of Species		**15**	**10**	**15**	**13**	**14**	**11**	**13**	**14**	**13**	**12**		

Table 2. Percent of stations where each vegetative species occurred at CRMS6299 in the PO-17 project area. Ten stations were surveyed each year. *Habitat* is the marsh habitat where the species is most commonly found. F = freshwater, I = intermediate, B = brackish, S = saltwater.

Scientific Name	Common Name	Percent of CRMS6299 Stations Where Species Occurred (N = 10)							Habitat
		2008	2009	2010	2011	2012	2013	Average	
Spartina alterniflora	smooth cordgrass	100	100	100	100	100	100	100	S
Schoenoplectus robustus	sturdy bulrush	50	80	90	90	90	90	82	B
Spartina patens	saltmeadow cordgrass	40	50	50	70	50		43	I/B
Panicum repens	torpedo grass	10	10	10		20		8	I
Amaranthus australis	southern amaranth		20					3	I/B
Paspalum vaginatum	seashore paspalum		10	10				3	I
Paspalum sp.	crowngrass	10						2	F/I
Pluchea odorata	sweetsecent		10					2	I/B
Symphyotrichum subulatum	eastern annual saltmarsh aster		10					2	I
Total Number of Species		**5**	**8**	**5**	**3**	**4**	**2**		

Table 3. Percent of stations where each vegetative species occurred at PO-17 project-specific reference vegetation stations. Thirteen stations were surveyed each year. *Habitat* is the marsh habitat where the species is most commonly found. F = freshwater, I = intermediate, B = brackish, S = saltwater.

Scientific Name	Common Name	Percent of PO-17 Reference Area Stations Where Species Occurred (N = 13)						Habitat
		2004	2005	2007	2010	2013	Average	
Spartina patens	saltmeadow cordgrass	100	100	100	100	100	100	I/B
Ipomoea sagittata	saltmarsh morning-glory	62	69	77	69	69	69	F/I
Polygonum punctatum	dotted smartweed	69	23	15		31	28	F/I
Schoenoplectus robustus	sturdy bulrush		8	23		69	20	B
Vigna luteola	hairypod cowpea	31		38		23	18	I
Schoenoplectus americanus	chairmaker's bulrush	15		8	15	23	12	I/B
Iva frutescens	Jesuit's bark	15		15	23	8	12	I
Baccharis halimifolia	eastern baccharis	31		15		15	12	F/I
Polygonum hydropiperoides	swamp smartweed				46		9	F
Cyperus odoratus	fragrant flatsedge	31			8		8	I
Symphyotrichum tenuifolium	perennial saltmarsh aster	23			8		6	I/B
Solidago sempervirens	seaside goldenrod	8		8			3	F/I
Alternanthera philoxeroides	alligatorweed					8	2	F/I
Amaranthus australis	southern amaranth					8	2	I/B
Amaranthus cannabinus	tidalmarsh amaranth				8		2	I/B
Cuscuta sp.	dodder				8		2	F/I
Distichlis spicata	saltgrass				8		2	B/S
Eleocharis cellulosa	Gulf Coast spikerush					8	2	F/I
Leptochloa fusca	Malabar sprangletop				8		2	I
Panicum hemitomon	maidencane	8					2	F
Typha domingensis	southern cattail					8	2	I
Total Number of Species		**11**	**4**	**9**	**11**	**12**		

Table 4. Percent of stations where each vegetative species occurred at CRMS2830 in the PO-17 reference area. Ten stations were surveyed each year. *Habitat* is the marsh habitat where the species is most commonly found. F = freshwater, I = intermediate, B = brackish, S = saltwater.

Scientific Name	Common Name	% of CRMS2830 Stations Where Species Occurred (N = 10)							Habitat
		2008	2009	2010	2011	2012	2013	Average	
Spartina patens	saltmeadow cordgrass	100	100	100	100	100	100	100	I/B
Ipomoea sagittata	saltmarsh morning-glory	100	100	100	100	100	100	100	F/I
Polygonum punctatum	dotted smartweed		10	90	100	20	30	42	F/I
Iva frutescens	Jesuit's bark	20	50	20	10		30	22	I
Baccharis halimifolia	eastern baccharis	30	10	10	10	30	10	17	F/I
Cuscuta pentagona	fiveangled dodder	10	10	10	10	20	10	12	F
Pluchea odorata	sweetscent		40		20	10		12	I/B
Vigna luteola	hairypod cowpea	30	10	10	10			10	I
Alternanthera philoxeroides	alligatorweed	10				20	20	8	F/I
Schoenoplectus robustus	sturdy bulrush		10		10		20	7	B
Bacopa monnieri	herb of grace		10			10	10	5	F/I
Amaranthus australis	southern amaranth			20				3	I/B
Distichlis spicata	saltgrass	10	10					3	B/S
Kosteletzkya virginica	Virginia saltmarsh mallow						10	2	F/I
Symphyotrichum sp.	aster			10				2	*
Symphyotrichum subulatum	eastern annual saltmarsh aster				10			2	I
Total Number of Species		**8**	**11**	**9**	**10**	**8**	**10**	**9**	