Coastal Protection and Restoration Authority of Louisiana

State of Louisiana
Coastal Protection and Restoration Authority

2017 Operations, Maintenance, and Monitoring Report

for

Bayou Sauvage National Wildlife Refuge Hydrologic Restoration, Phase 2 (PO-18)

State Project Number PO-18
Priority Project List 2

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Orleans Parish

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Preface

The Bayou Sauvage National Wildlife Refuge Hydrologic Restoration, Phase 2 (PO-18) project was funded through the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA) on the 2nd Project Priority List with the United States Fish and Wildlife Service (USFWS) as the federal sponsor. The 2017 Operations, Maintenance, & Monitoring (OM&M) report for the PO-18 project is the first and final OM&M report for this project, which includes monitoring data collected throughout the life of the project (1996-2016) and Operations and Maintenance activities through 2016. Additional documents pertaining to the PO-18 project may be accessed on the Coastal Protection and Restoration Authority (CPRA) website at http://coastal.la.gov/ resources/library/ .

I. Introduction

The Bayou Sauvage National Wildlife Refuge Hydrologic Restoration, Phase 2 (PO-18) project is located within the Bayou Sauvage National Wildlife Refuge (NWR), approximately 13 miles (21 km) east of downtown New Orleans. The 6,838-ac (2,767 ha) project area is bounded by U.S. Interstate 10 to the north, the Maxent Canal levee to the west, the Lake Pontchartrain Hurricane Protection Levee to the east, and U.S. Highway 90 to the south (Figure 1). The PO-18 project area encompasses Water Management Units 3 and 4 of the Bayou Sauvage NWR, which is managed by the United States Fish and Wildlife Service (USFWS) (USFWS 2013). Water Management Units 3 and 4 are separated by U.S. Highway 11, but are hydrologically connected via culverts. The PO-18 project area is adjacent to the Bayou Sauvage NWR Hydrologic Restoration, Phase 1 (PO-16) project along the Hwy 90 boundary, and these two projects share a reference area, which is located between the PO-18 project area and Lake Pontchartrain.

As a result of construction of the Lake Pontchartrain Hurricane Protection Levee in 1956, the PO-18 project area became hydrologically isolated from the surrounding estuary, thereby creating a large impoundment with precipitation as the major water source. Two sets of flap-gate structures, which required significant head differential to operate, were installed along the Hurricane Protection Levee but were inefficient at draining the area (USFWS 1991). Approximately 95 ac/yr (38 ha/yr) of marsh habitat were lost from 1952 to 1991 within the 13,000 impounded acres of the refuge for a total loss of 3,800 acres (1,538 ha) (USFWS 1992). These losses were directly attributed to impounded rainfall and loss of daily tidal exchange which resulted in extended periods of inundation during the growing season. The PO-18 project and the adjacent PO-16 project were proposed as a means for removing excess water throughout the year, particularly during spring and summer, to enhance fresh marsh habitats in the project area and to promote the re-establishment of emergent marsh vegetation.

Prior to impoundment, the area containing the PO-18 project was described as ‘brackish three-cornered grass marsh’ and ‘saw grass marsh’ by O’Neil (1949); however, a shift from brackish to intermediate marsh occurred in the years following impoundment as observed through aerial surveys (Chabreck and Linscombe 1978, 1988, 1997). According to habitat

analysis data (NWRC 1993), the project area transitioned from over 90% non-fresh marsh (intermediate or brackish) in 1956 to 30% fresh and 14% non-fresh marsh in 1988. During this same time period, open water increased from 6% in 1956 to 30% in 1988. The loss of the non-fresh marsh has resulted in large open-water ponds, some over 1 mi (1.6 km) wide and approximately 1 ft (0.3 m) deep. The large fetch-to-depth ratio results in high wave action and fluid-fine particle size of the soils results in high turbidity, which together have accelerated the decline of the marsh and submersed aquatic habitats. By the time of project development, the project area was described as impounded fresh marsh (USFWS 1991) with dominant species including *Spartina patens* (saltmeadow cordgrass), *Cyperus spp.* (flatsedge), *Echinochloa spp* (cockspur grass), and *Bacopa spp* (waterhyssop), and approximately 10% of the area was dominated by aquatic plants [*Cabomba caroliniana* (Carolina fanwort) and *Ceratophyllum demersum* (coon's tail)]. A 1996 habitat analysis showed that the PO-18 project area contained approximately 3,288 acres open water (48%), 2,026 acres fresh/intermediate marsh (30%), 1,367 acres forested wetland (20%), and 99 acres scrub shrub (1.4%) (Appendix D-2).

The main objective of the PO-18 project was to reduce water levels in order to enhance revegetation of the marsh. The project-specific goals were (1) to lower water levels to within -0.5 - 0 ft below marsh elevation during the spring and summer and to within 0 - 0.5 ft above marsh elevation during the fall and winter; and (2) to promote the reestablishment of emergent marsh vegetation. To reach these objectives a dual pump station was installed housing two 33-inch diameter Patterson single stage axial flow vertical drainage pumps, with 42-inch diameter discharges, 34,000 GPM capacities, and two 42-inch diameter smooth-steel discharge pipelines. Construction was completed in May 1997 and subsequent operation of the pumps has been conducted by USFWS personnel. The US Army Corps of Engineers (USACE) began work to replace the pumps in December 2011 with two 36-inch diameter pumps as a result of the Hurricane and Storm Damage Risk Reduction System (HSDRRS) levee enlargement.

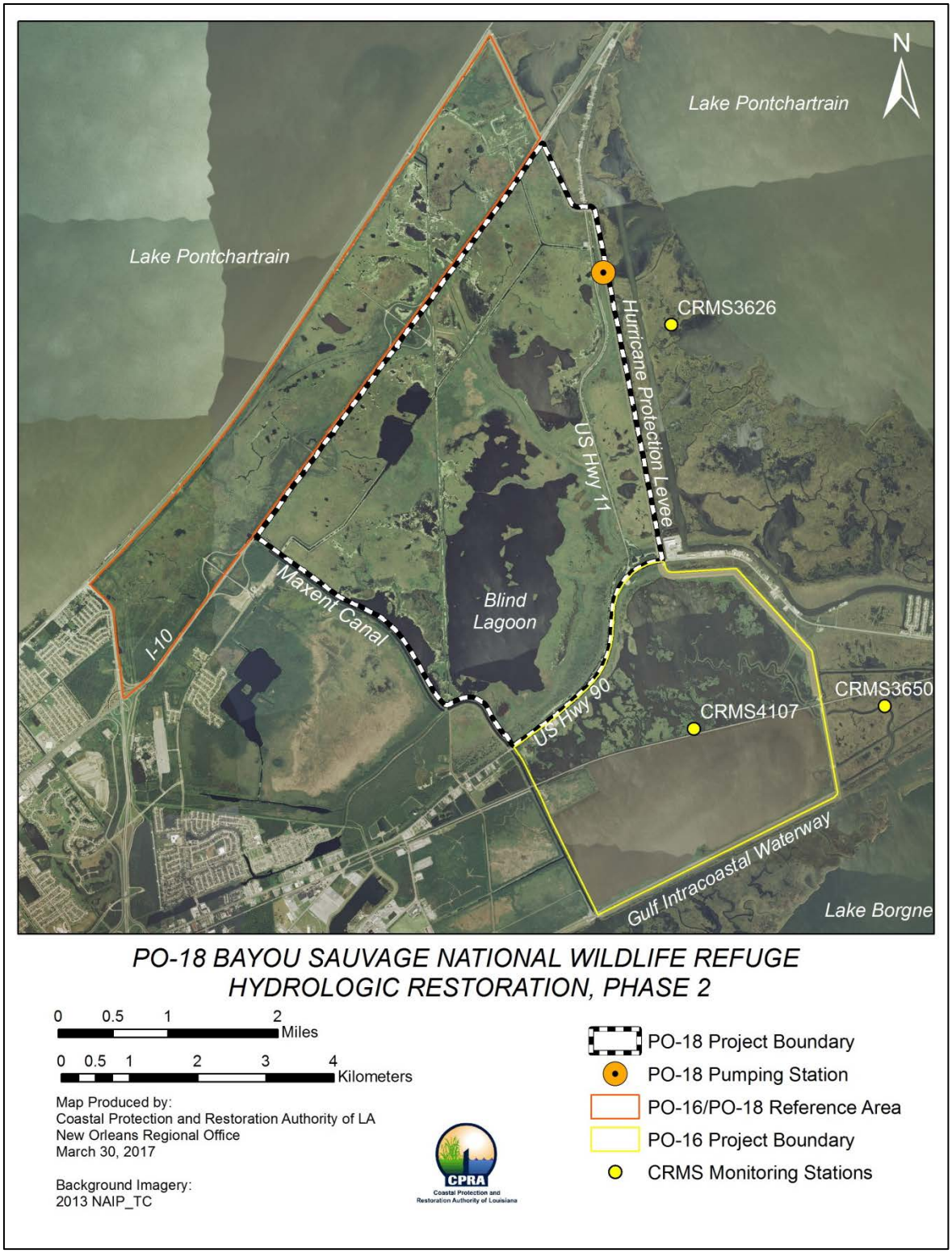

Figure 1. Bayou Sauvage National Wildlife Refuge Hydrologic Restoration, Phase 2 (PO-18) project area and features.

II. Maintenance Activity

a. Project Feature Inspection Procedures

The purpose of the annual inspection of the Bayou Sauvage NWR Hydrologic Restoration Project, Phase 2 (PO-18) 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. Should it be determined that corrective actions are needed, the CPRA shall provide a detailed cost estimate for engineering, design, supervision, inspection, and construction contingencies, and an assessment of the urgency of such repairs (LDNR 2004).

The most recent inspection of the Bayou Sauvage Refuge Restoration Project, Phase 2 (PO-18) was held on November 13, 2017 by Barry Richard and Clay Worley of CPRA and Pon Dixon and Shelley Stiaes of USFWS. Photographs of that inspection are included in Appendix A of this report.

b. Inspection Results

Pump #3

The pump is working as designed.

Pump #4

The pump is working as designed.

c. Maintenance Recommendations

At this time only preventative maintenance is needed.

i. Immediate/ Emergency Repairs

- None at this time.

ii. Programmatic/ Routine Repairs

- Periodically check pump stations for any maintenance needs.

d. Maintenance History

Due to the Hurricane and Storm Damage Risk Reduction System (HSDRRS) work to improve the levee system in this area, the discharge pipes and pumps were replaced by the US Army Corps of Engineers (USACE). The PO-18 project paid

$50,000 toward this work and the USACE paid the remaining costs. These improvements were completed in early 2012 and levee enlargement activities continued through 2014. Operational control of the new pumps was transferred back to the USFWS in August 2015.

The USFWS and CPRA requested a 6-year time extension on the 20-year project life due to the inoperability of the pumps following Hurricane Katrina and during the repair work by the USACE. CWPPRA granted this extension which moves the end of project life to the year 2023.

III. Operation Activity

Operation of the PO-18 pumps began in May 1997 and was conducted by USFWS personnel for the duration of the project life. CPRA has received limited operations records from the USFWS to determine if operations were conducted in accordance with the O&M Plan (LDNR 2004). Operations records were sent to CPRA (then LDNR) for the periods from May 1997 to March 1998 and from December 2009 to January 2010, which showed that the pumps were run for the durations shown in Table 1. These are the only *known* operations, not a complete record of operations. Per the USFWS, post-Hurricane Katrina operations have mainly consisted of regular maintenance operations to ensure the equipment was in working order. There were two extended periods during the project life when the pumps were not operational: 1) September 2005 to August 2006 due to Hurricane Katrina damage, and 2) October 2010 to August 2015 due to HSDRRS levee enlargement by the USACE (Figure 2). Per the USFWS, the pumps were also not operated from August 2015 to October 2017. Therefore, the pumps were not operational for a total of 97 months or approximately 40% of the 20-year project life.

The pump stations were recently brought back online in November 2017 and are now operable as of the 2017 inspection. It is the intent of the Bayou Sauvage NWR personnel to run the pumps at least once every two weeks to assure they are operable and available to manage the water levels in the refuge as intended.

Table 1. Known operations (# hours) of the two PO-18 pumps. Operations during other time periods are unknown except for periods when pumps were not operational. The # of days shown were not consecutive and operation of the two pumps did not always occur simultaneously.

Known Operations of the PO-18 Pumps (# Hours)		
	Pump #1	Pump #2
Spring/Summer1997	8	8.6
Fall/Winter1997-98	316	339.4
Fall/Winter2009-10	72	72

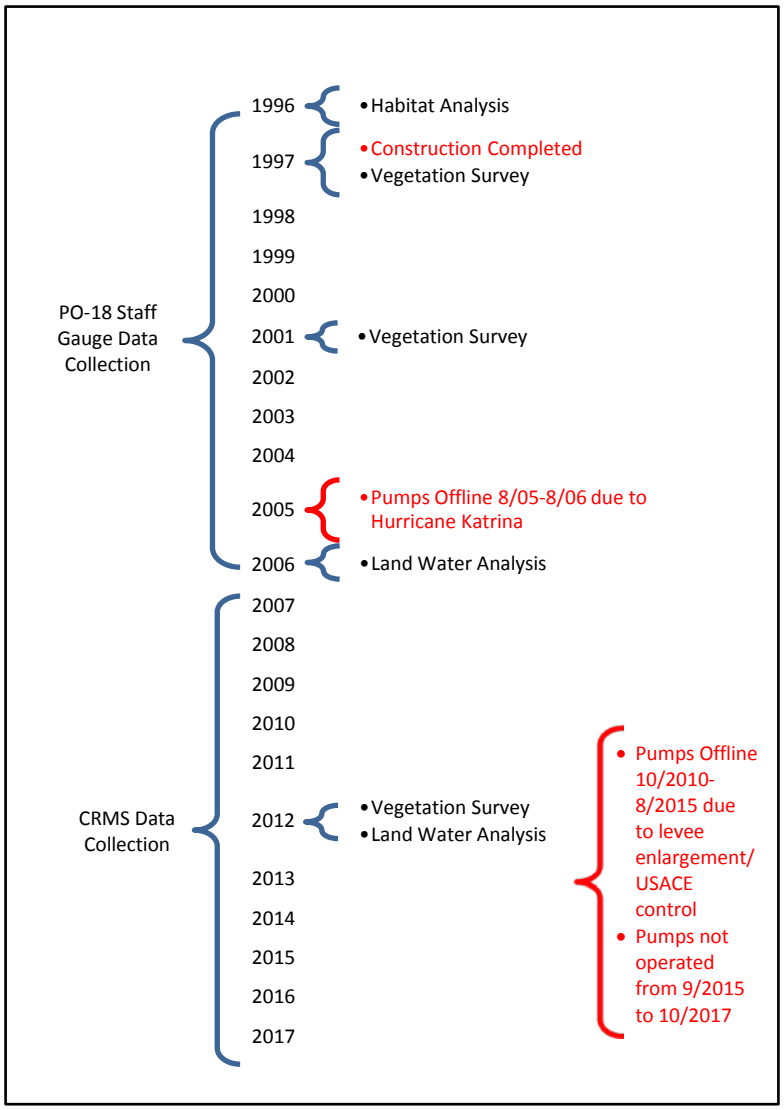

Figure 2. Timeline of construction and monitoring events associated with the Bayou Sauvage National Wildlife Refuge Hydrologic Restoration, Phase 2 (PO-18) project from 1996 to present.

IV. Monitoring Activity

Pursuant to a CWPPRA Task Force decision on August 14, 2003 to adopt the Coastwide Reference Monitoring System-*Wetlands* (CRMS) for CWPPRA, updates were made to the PO-18 Monitoring Plan to merge it with CRMS and provide more useful information for modeling efforts and future project planning while maintaining the monitoring mandates of the Breaux Act. Although there is no CRMS site within the PO-18 impoundment, there is one CRMS site (CRMS4107) located in the adjacent PO-16 project impoundment and two located immediately outside the impoundment (CRMS3626 and CRMS3650), which may be referred to for reference (Figure 1). Further information on data collection methods at the CRMS sites can be obtained in Folse et al. 2012.

a. Monitoring Goals

The following measurable goals were established to evaluate the effectiveness of the project:

1. Promote the reestablishment of emergent marsh vegetation.

2. Lower water levels to within -0.5 ft to 0.0 ft of marsh sediment elevation in the spring and summer and to within 0.0 to +0.5 ft of marsh sediment elevation throughout the rest of the year via the installation of pumps.

b. Monitoring Elements

The following monitoring elements will provide the information necessary to evaluate the goals listed above. A timeline of data collection events associated with these monitoring elements is shown in Figure 2.

Reference Area

An area north and west of I-10 and east of a levee along Paris Road was chosen as a reference area for the PO-18 project because it was impounded, had open-water areas with water levels within 1 to 2 feet, had fresh/intermediate marsh, bottomland hardwood and willow habitat, and had Clovelly and Lafitte muck soils similar to the project area (Figure 1); however, the reference area differs from the project area in that it has less open water pond areas and is sometimes subjected to tidal influence during the spring via gates connecting the area with Lake Pontchartrain.

Aerial Photography

To document marsh to open water ratios in the PO-18 project and reference areas, aerial photography was obtained in 1993 (reference area only), 1996, 2006 and 2012. Near-vertical, color-infrared aerial photography (1:12,000 scale, with ground control markers) was acquired and analyzed for changes in habitat type in 1993 and 1996 and for land to water ratios only in 2006 (Steyer et al. 1995, revised 2000). All remaining

habitat analyses were changed to land/water analyses upon the implementation of CRMS in 2003. In 2012, land to water ratios within the project and reference areas were derived from digital imagery with 1-meter resolution, acquired in October 2012 through the CRMS program. Considerable variability may exist in habitat and land/water classifications due to 1) clarity of the image; 2) water level at the time the image was taken; 3) seasonality; 4) difficulty in distinguishing submerged, floating, and emergent vegetation; and 5) in the case of floating marshes, variable mat buoyancy and frequent vegetative changes. Photography was always acquired in fall to early winter which adjusts for some seasonality differences. In addition to the PO-18 aerial photography analyses described above, land change between 1985−2010 was also evaluated for the PO-18 project area using Landsat Thematic Mapper (TM) data (Couvillion et al. 2011) through the CRMS program.

Vegetation

Emergent marsh vegetation sampling stations were established along seven transects within the project area and four transects within the reference area (Figure 3). Transects were chosen to intersect dominant habitat types, which included fresh marsh, *S. patens* marsh, *Salix nigra* (black willow) stands, and open water ponds. In the reference area, two transects were representative of *Spartina patens*-dominated intermediate marsh and two transects were open water. Five stations were located along each transect for a total of 35 project stations and 20 reference stations. The seven transects within the project area were first established and sampled using the line-intercept method by the USFWS in 1989 (Harris 1989). During the post construction period, species composition, percent cover, and relative abundance were evaluated within 4-m^2 plots along each transect using a modified Braun-Blanquet sampling method (Mueller-Dombois and Ellenberg 1974) in 1997, 2001, and 2012. Emergent marsh vegetation was also sampled annually at CRMS4107 within the adjacent PO-16 project area from 2007 to present. At CRMS4107, ten 4-m^2 sampling plots were randomly located along a 288-m transect and sampled using the same method described above. Percent coverage data from the PO-16 stations and CRMS stations were summarized according to the Floristic Quality Index (FQI) method utilized by CRMS (Cretini et al. 2011), where cover is qualified by scoring species according to their tolerance to disturbance and stability within specific habitat types.

Marsh Inundation

Water level was measured using staff gauges at five locations within the project area (three in the northern project area, and two in the southern project area) and at three locations within the reference area (Figure 3). The location and number of staff gauges were determined by USFWS personnel using information gathered during field investigations of water flow throughout the areas, and the collection of weekly staff gauge readings was the responsibility of USFWS personnel. Staff gauges and marsh surface elevation within the project and reference areas were surveyed relative to NAVD 88, feet (Geoid99) in 2003 (John Chance Land Surveys 2004). An earlier survey of the gauges was deemed to be suspect. Weekly gauge readings began in

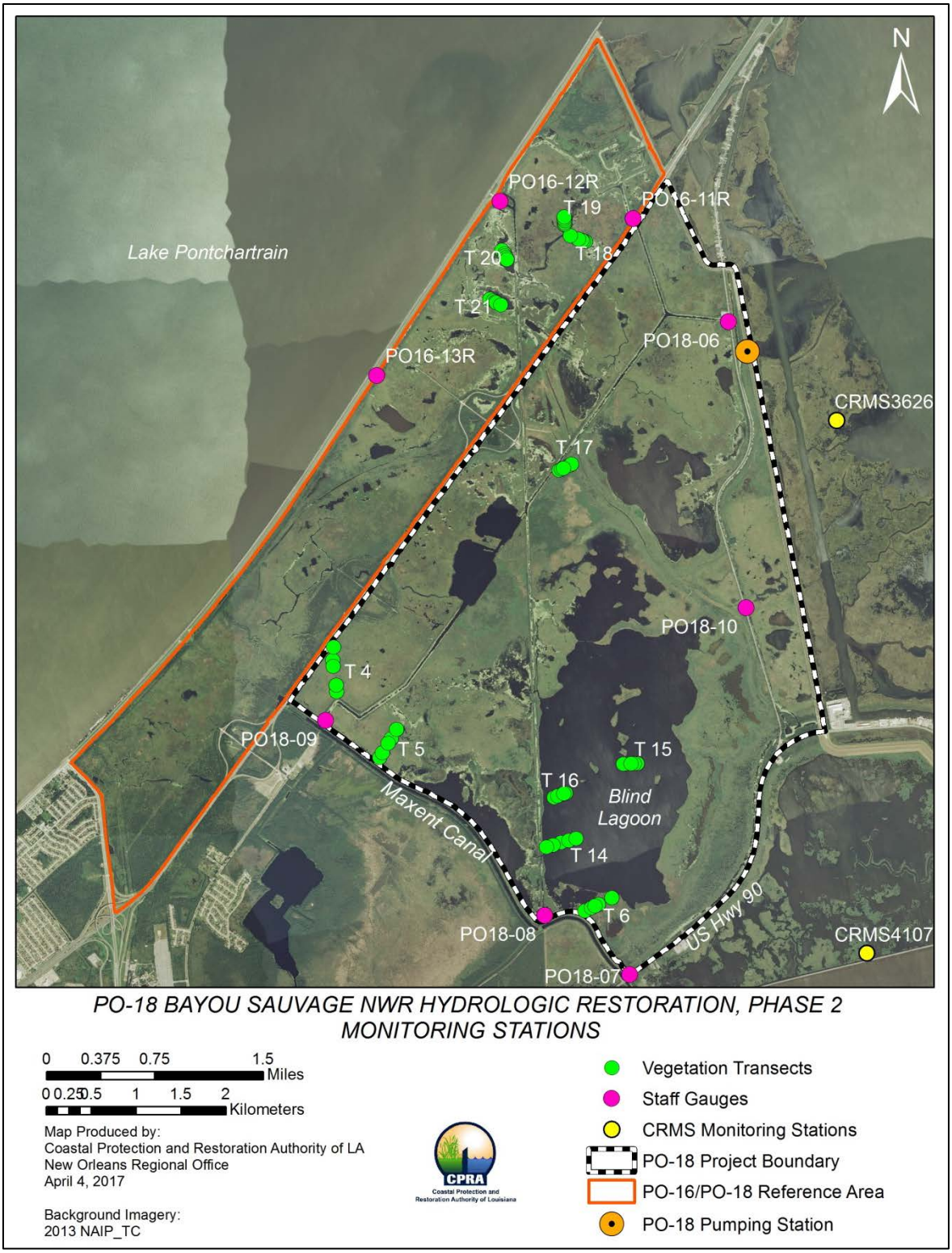

Figure 3. Location of monitoring stations within the PO-18 project and reference areas.

February 1997 and were to be continued through 2004, although intermittent gauge readings continued to be collected through 2014.

Hourly water level and salinity has been sampled at CRMS4107 in the adjacent PO-16 project area from November 2007 to present using methods described in Folse et al. 2012. The continuous recorder is mounted on a wooden post in open water with sufficient water depths to inundate the recorder year round. The station is serviced approximately once every month to clean and calibrate the recorder and to download the data. A staff gauge is installed next to the continuous recorder to compare recorded water levels to a known datum (NAVD88, ft). During processing, the data are examined for accuracy and loaded to the CPRA database, and are available for download from the CRMS website (http://www.lacoast.gov/crms2).

c. Monitoring Results and Discussion

i. Aerial Photography

Photography analyses of the PO-18 project and reference areas are presented in Appendix D for years 1993 (reference area only), 1996 (pre-construction), 2006 (9 years post-construction), and 2012 (15 years post-construction). One of the specific goals of the project was to promote the reestablishment of emergent marsh vegetation within the project area. More specifically, the wetland value assessment (WVA) predicted that the project would allow for the maintenance of existing emergent marsh and for the conversion of 700-800 acres of shallow open water to emergent marsh over the life of the project (USFWS 1991). Trends in land change were compared between the project and reference areas from 1993 to 2012 (Figure 5, Table 2). Land/water analyses showed a 7% land increase of 452 acres in the PO-18 project area from 1996 (Year -1) to 2012 (Year 16), with percent land within the project area increasing from 52% in 1996 to 59% in 2012 (Figure 4). In the reference area, land acreage was highly stable from 1993 to 2012, with an initial 3% decrease in the pre-construction period (1993 to 1996), and a subsequent 2% increase (53 acres) over the PO-18 project period (1996 to 2012).

An analysis of multi-temporal satellite data from 1985 to 2010 (Couvillion et al 2011) also showed a land gain within the PO-18 project area during the post-construction period, although the gain was smaller than observed through aerial photography analyses. The satellite data revealed a weak negative trend (r^2=0.02) of land loss overall from 1985 to 2010 (Figure 5); however, there was a weak positive trend (r^2=0.0043) of land gain in the PO-18 post-construction period only (1995 to 2010).

Although the project area did exhibit a 452-acre land gain by Year 16 post-construction, this gain was 248 acres less than the 700-acre target predicted in the WVA. Extreme climatological events occurring during this period included a severe drought in 1999 through early 2000 (Figure 6) and Hurricane Katrina in 2005, which

may have slowed the conversion rate of shallow water to marsh within the project area. In addition, the lack of operations data (see Section III. Operation Activity) make it impossible to determine whether the observed land gain is attributable to PO-18 project effects.

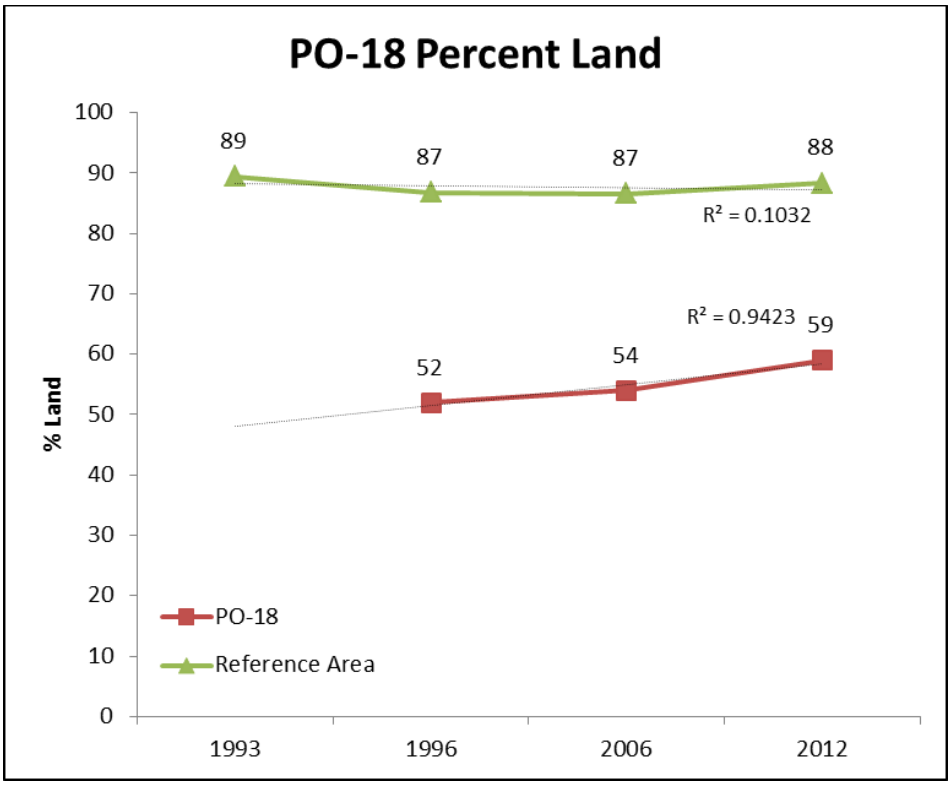

Figure 4. Trends in % land change within the PO-18 project and reference area from 1993 to 2012.

Table 2. Land acreage changes within the PO-18 project and reference area from 1993 to 2012.

Time Period	Project Area			Reference Area		
	Land Change (ac)	% Change	Change Rate (ac/yr)	Land Change (ac)	% Change	Change Rate (ac/yr)
1993—1996 (Pre-construction)	--	--	--	-85	-3%	-28
1996—2006 (Year 0 through 10)	+146	+2%	+15	-6	-<1%	-<1
2006—2012 (Year 10 through 16)	+306	+5%	+51	+59	+2%	+10
Overall (1996—2012)	+452	+7%	+28	+53	+2%	+3

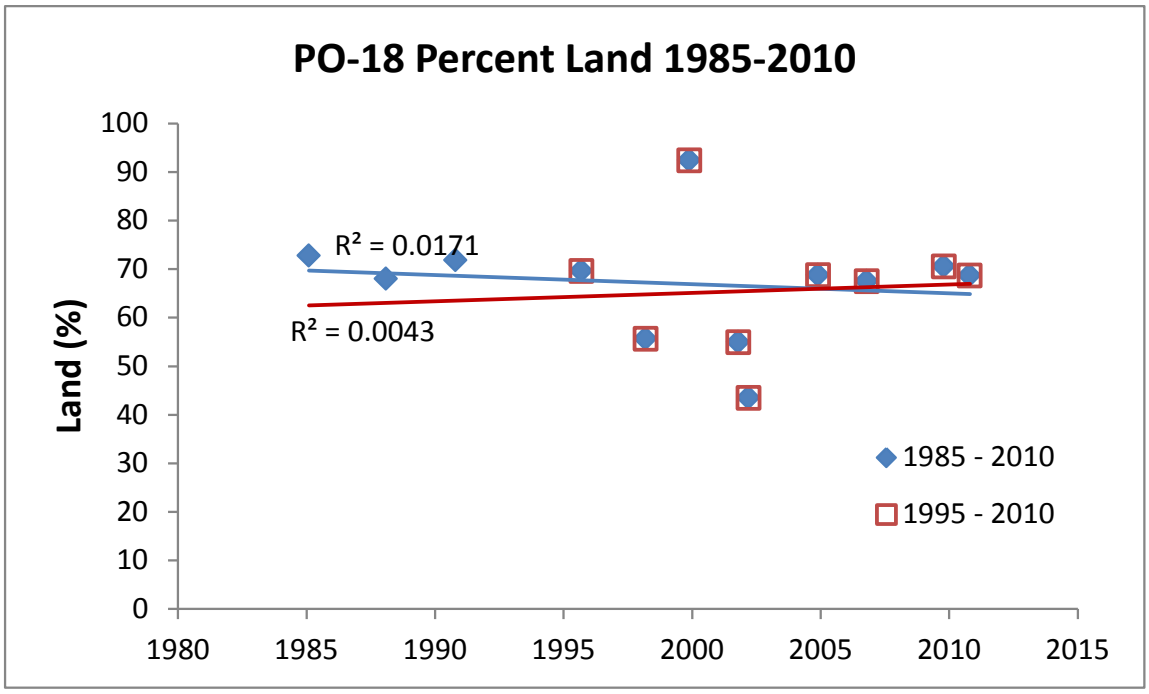

Figure 5. Trends in % land change within the PO-18 project area during the periods 1985-2010 and 1995-2010 based on land/water analyses of multi-temporal satellite data (Couvillon et al. 2011). Data points from post-storm periods in 2005 and 2008 were excluded.

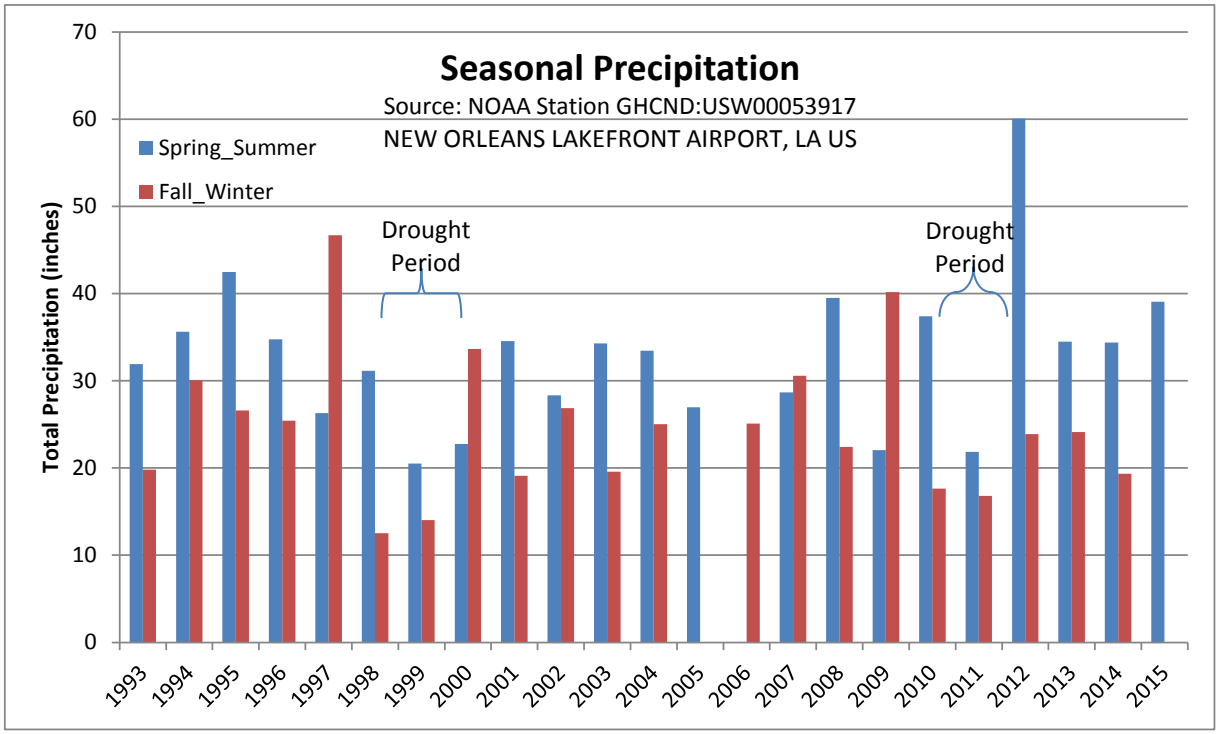

Figure 6. Total seasonal precipitation (in) from 1993 to 2015 observed at Lakefront Airport, New Orleans, LA (NOAA, GHCND:USW00053917).

ii. Vegetation

The goal to promote reestablishment of emergent marsh vegetation within the PO-18 project area was not achieved based on the vegetative plots sampled in 1997, 2001 and 2012. The intent of the project was that drawdown of water levels during optimal periods via the installed pumps would promote germination of marsh vegetation seeds on exposed mudflats. In 1996, four vegetation transects with 5 sample plots per transect were established in the PO-16/18 reference area for a total of 20 reference plots, and in 1997, seven transects were established in the PO-18 project area for a total of 35 project plots (Figure 3). Transects 14 and 16 were established in shallow, open water within Blind Lagoon with the expectation that these areas would become vegetated, and Transect 15 was established on a small island within Blind Lagoon. Eight plots on the Blind Lagoon transects and all plots on Transects 20 and 21 in the reference area (Figure 3), remained open water through the entire sampling period from 1996 to 2012. Only one open water plot in the project area became vegetated by 2012, while three plots which were initially vegetated in 1997 converted to open water. For the purpose of describing changes in the vegetative community over time within the project and reference areas, plots which were unvegetated for the entire sample period were not included in the analysis. The plots included in the analysis within the project area (n=27) were located on Transects 4 (n=5), Transect 5 (n=5), Transect 6 (n=5), Transect 14 (n=1), Transect 15 (n=4), Transect 16 (n=2), and Transect 17 (n=5). Plots analyzed in the reference area (n=10) were located on Transect 18 (n=5) and Transect 19 (n=5) (Figure 3). Due to access issues, Transect 17 was sampled in 2013; however, for analysis purposes these data were aggregated with the 2012 data collected at the other transects.

The vegetation community within the project area plots was indicative of a diverse fresh to intermediate marsh in all years sampled with *Bacopa monnieri* (herb of grace) and *Spartina patens* (saltmeadow cordgrass) as the dominant species (Figure 7). Total percent cover of vegetation within the project area plots showed a sharp decline from 1997 to 2001, which was observed across all transects except Transect 17 located in the northern project area (Figures 8 to 12). This decline may be attributed to severe drought which persisted from late 1998 through early 2000 (Figure 6). A similar decline in total vegetative cover was not observed in the reference area during this period, although *S. patens* abundance declined sharply and was replaced by *B. monnieri* as the dominant species. The adjacent PO-16 project (Figure 1), which is also a pump-controlled impoundment, also showed a significant decline in vegetative cover during this period (Hymel 2017). From 2001 to 2012, vegetative cover increased within the PO-18 project area, but decreased in both the reference area and PO-16 project area. Although vegetative cover rebounded in the PO-18 project area during this period, it did not recover to levels observed in 1997.

Differences were observed in the vegetative community among the project area transects. Transects 4 and 5 in the western project area are dominated by *S. patens*, although Transect 5 showed a sharp decrease in *S. patens* coverage in 2001 (Figures 8

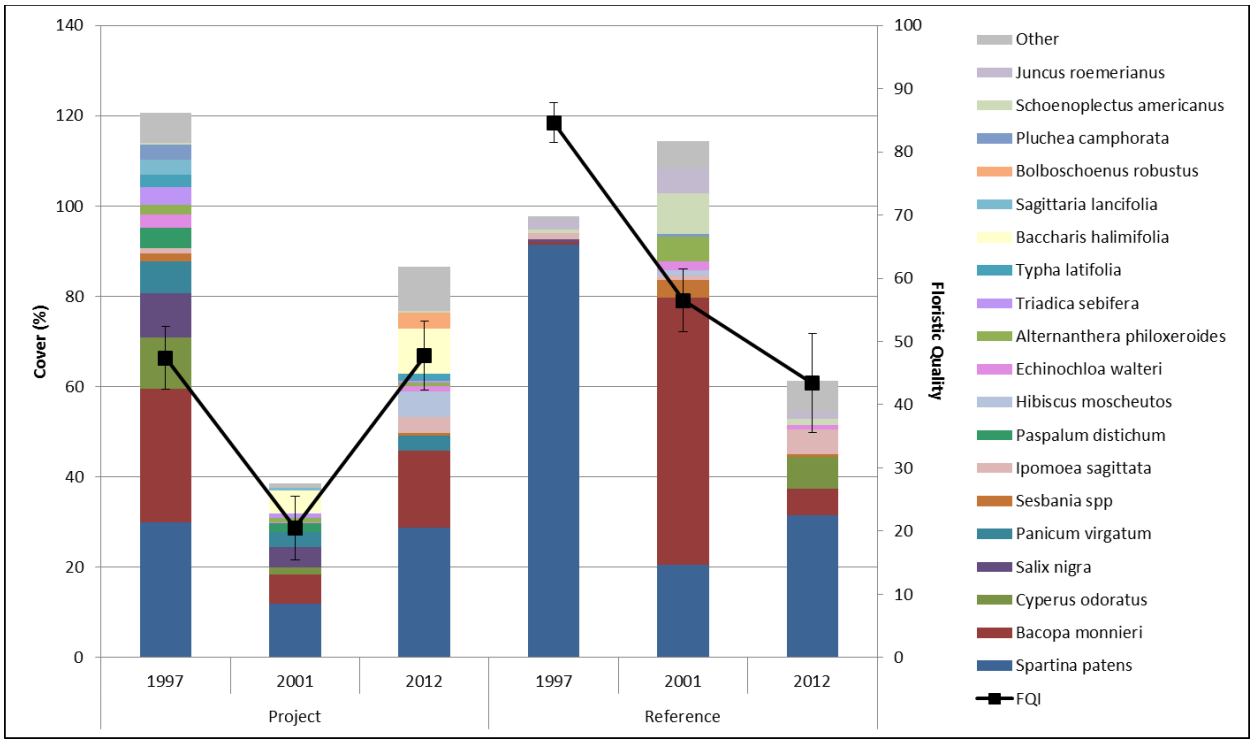

Figure 7. Mean percent cover of species within the PO-18 project and reference areas and the Floristic Quality Index (FQI) score for each year sampled.

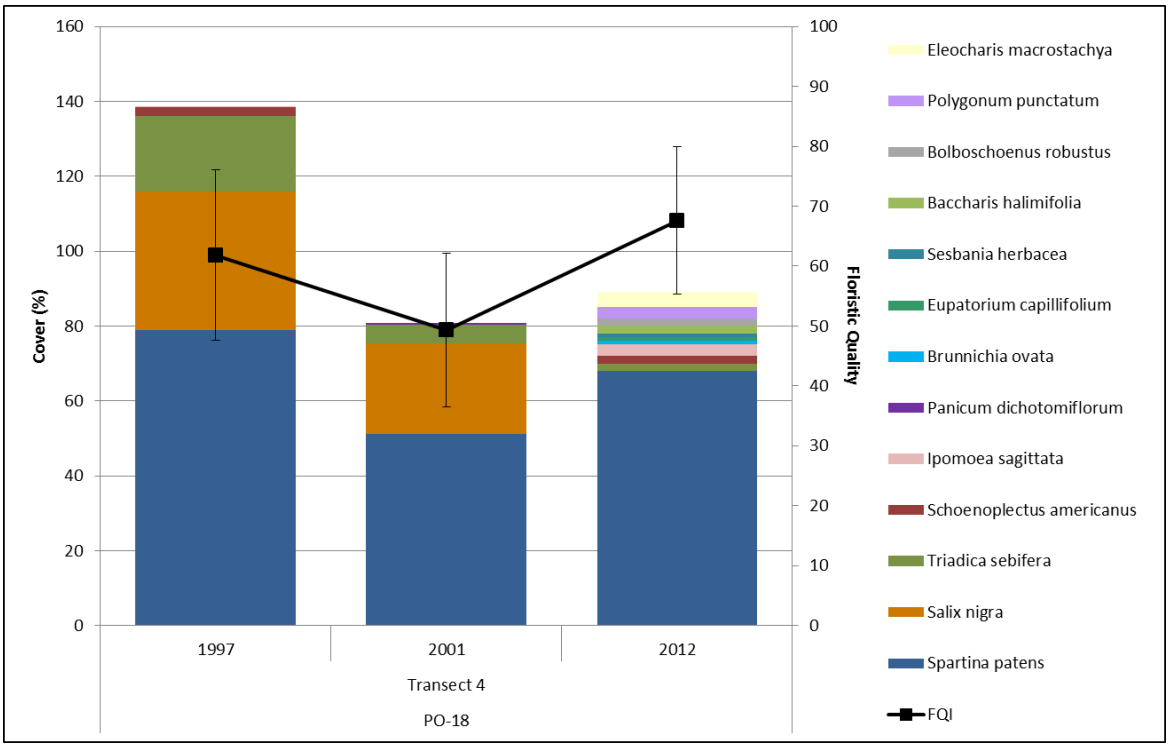

Figure 8. Mean percent cover of species and Floristic Quality Index (FQI) score from 1997 to 2012 along Transect 4 (n=5) within the western PO-18 project area.

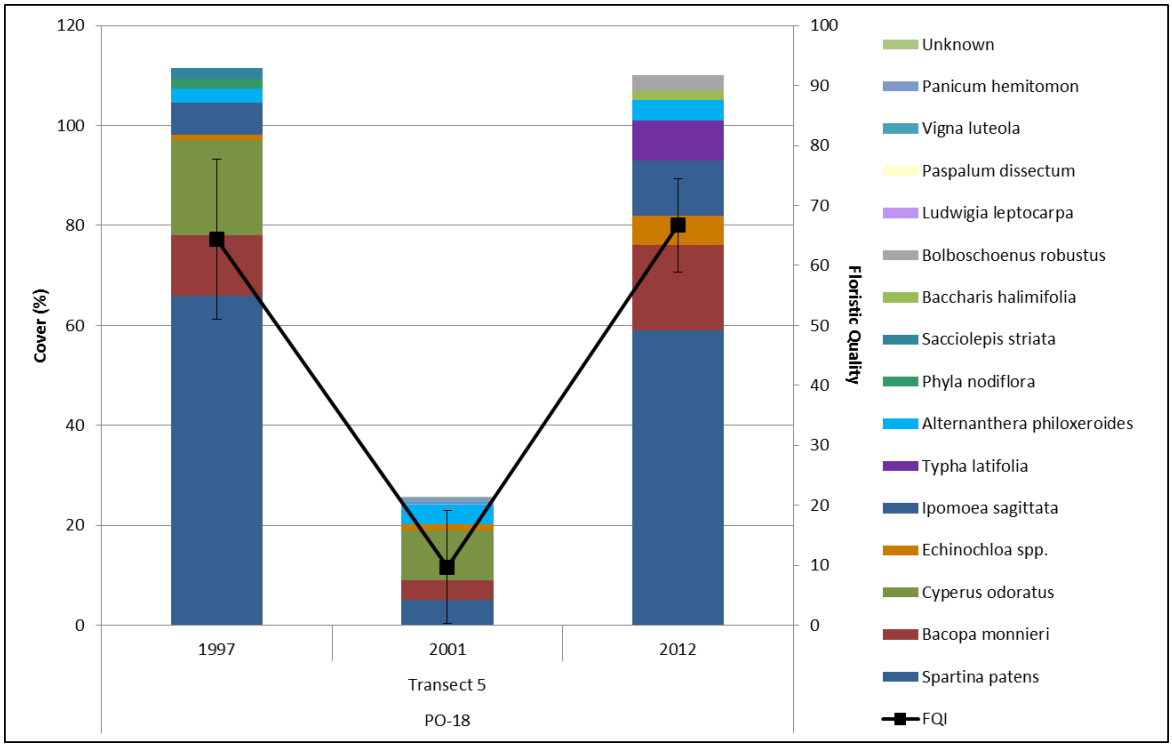

Figure 9. Mean percent cover of species and Floristic Quality Index (FQI) score from 1997 to 2012 along Transect 5 (n=5) within the western PO-18 project area.

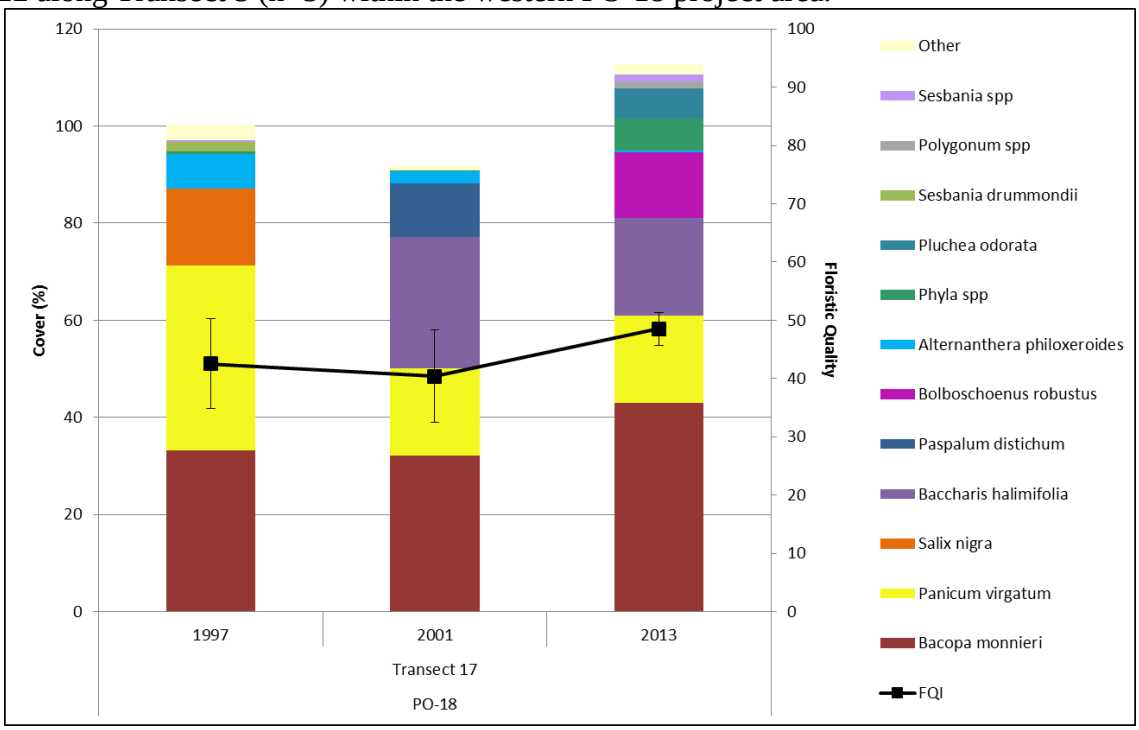

Figure 10. Mean percent cover of species and Floristic Quality Index (FQI) score from 1997 to 2013 along Transect 17 (n=5) within the northern PO-18 project area.

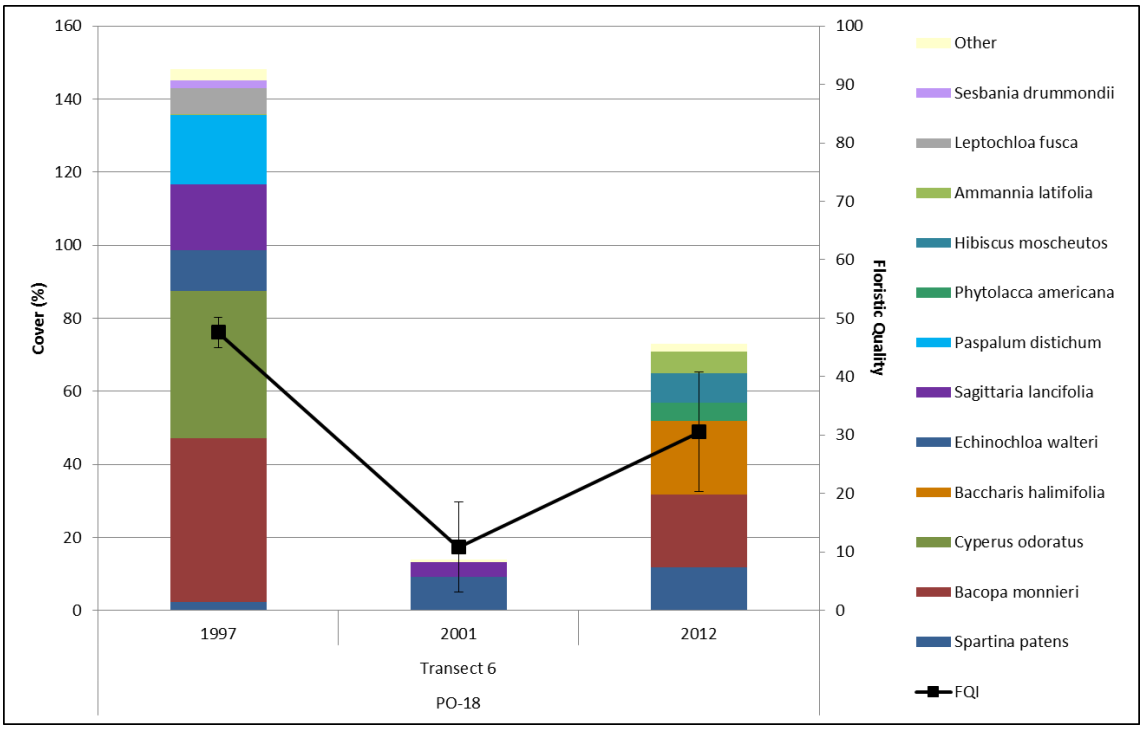

Figure 11. Mean percent cover of species and Floristic Quality Index (FQI) score from 1997 to 2012 along Transect 6 (n=5) within the southern PO-18 project area.

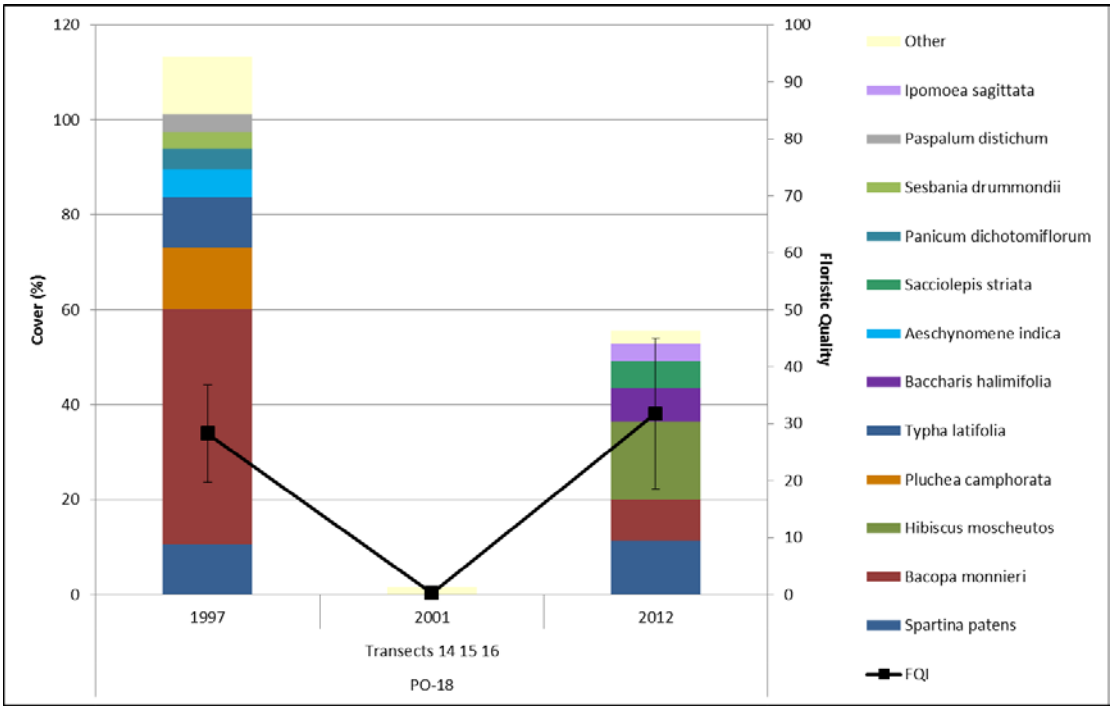

Figure 12. Mean percent cover of species and Floristic Quality Index (FQI) score from 1997 to 2012 along Transects 14, 15, and 16 (n=7) within Blind Lagoon in the southern PO-18 project area.

and 9). A stand of *Salix nigra* (black willow) was present along Transect 4 in 1989 (Harris 1989), 1997 (37% mean cover) and 2001 (24% mean cover), but was not present by 2012. Transect 17 in the northern project area was the most stable over time (Figure 10) with dominant species *B. monnieri, Panicum virgatum* (switchgrass) and *Baccharis halimifolia* (eastern baccharis). The southern project area (Figures 11 and 12) represented by Transects 6, 14, 15, and 16 showed the greatest decrease in percent cover between 1997 and 2001. Vegetation in this area was dominated by *B. monnieri* in 1997, with *Cyperus odoratus* as a co-dominant species at Transect 6. By 2012, vegetative cover was about 50% less than observed in 1997 with dominant species *B. monnieri* and *B. halimifolia* at Transect 6 and dominant species *Hibiscus moscheutos* (crimsoneyed rosemallow) at the Blind Lagoon transects. The vegetative community within the reference area plots was typical of a *Spartina patens*-dominated intermediate marsh and was most similar to Transects 4 and 5 in the project area. Species richness in the project area was higher than the reference area in all years sampled (Figure 13).

Several climatic events occurred during the project life which potentially induced vegetative stress within the Bayou Sauvage marshes. Extreme drought occurred in southeastern Louisiana in 1999-2000 and in 2011 (Figure 6) causing excessive drying and oxidation of soils. Salinity was not measured within the PO-18 project area, but salinity measured within the PO-16 impoundment at CRMS4107 in July 2011 reached a high of 25 ppt as evaporation occurred. By comparison, salinity at nearby CRMS3626 and CRMS3650 outside of the impoundment was less than 3 ppt during the same time period. Several major storms also impacted the project area including Hurricane Katrina in August 2005, which led to an influx of brackish water into the impounded areas. Retention of storm surge floodwaters for up to 3 weeks within the Bayou Sauvage impoundments was estimated by Howard (2012) to cause nearly 68% mortality of overstory and understory trees within the refuge, and likely contributed to the disappearance of the tree community at Transect 4 between 2001 and 2012. Differences in the plant community between the project and reference areas may explain the differing response to these events over the study period. In 1997, 48% and 85% of the PO-18 and PO-16 project area plots, respectively, were characterized as fresh marsh based on the species present (Figure 14), while the reference plots were 80% intermediate/20% brackish. The more intermediate species within the reference area may have been more resilient to salinity stressor events during the 1997-2001 sample period, as vegetative cover increased in the reference area during this period but decreased sharply in the PO-16 and PO-18 project areas. Over time, the PO-18 project area showed a reduction in fresh marsh plots and an increase in intermediate and brackish plots, but did not experience the conversion to open water as observed in the PO-16 project area (Figure 14).

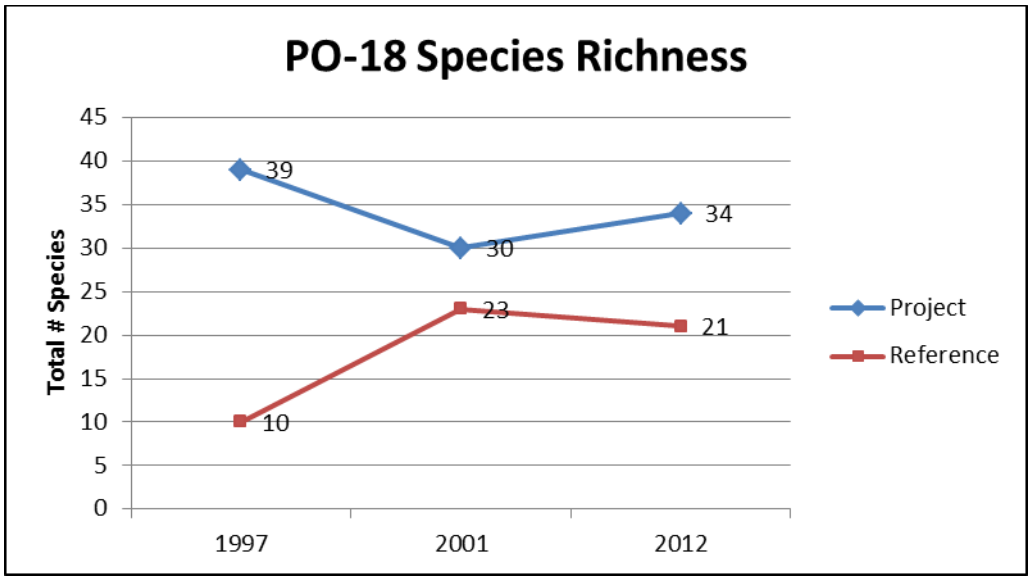

Figure 13. Total number of species observed within the PO-18 project and reference areas over time.

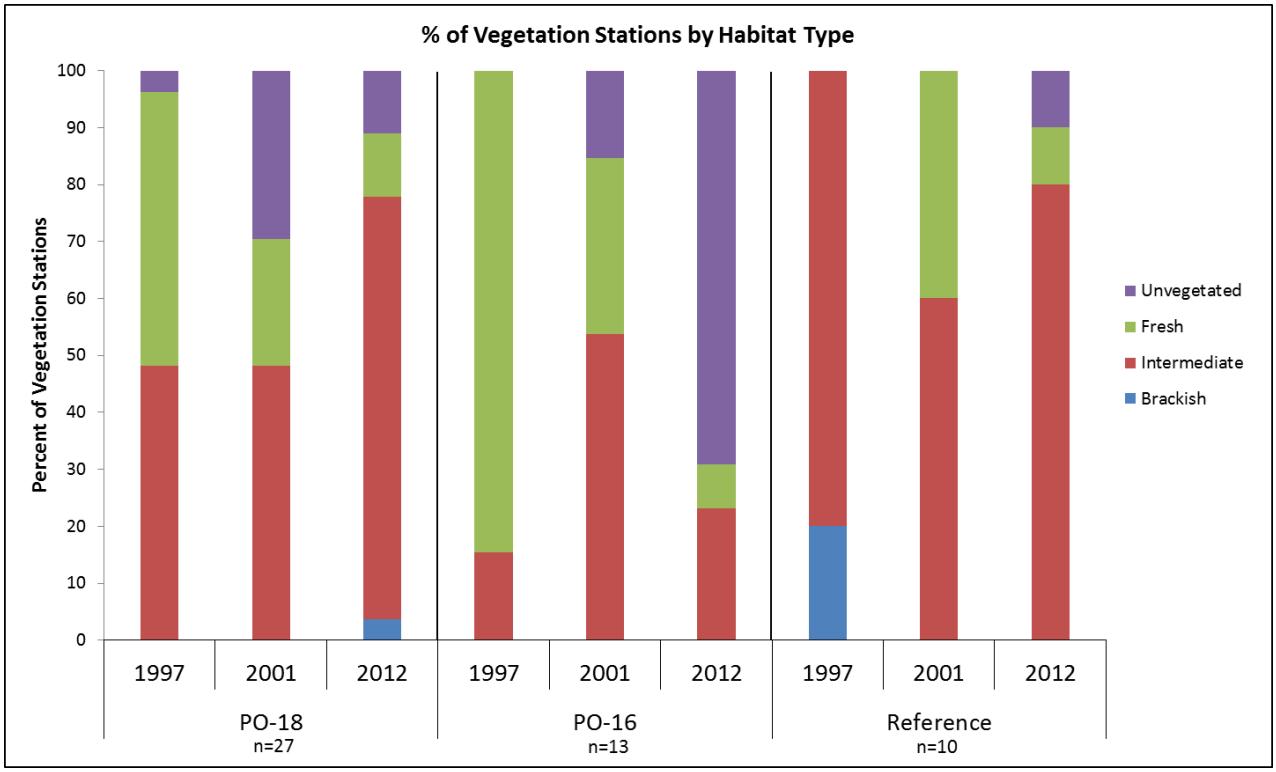

Figure 14. Percent of vegetation stations by habitat type as determined by species present in the PO-18 project area, PO-16 project area, and reference area in 1997, 2001, and 2012.

One tool that has been used to assess the quality of the vegetation community at the CRMS sites is the Floristic Quality Index (FQI) (Cretini et al. 2011). The FQI score is calculated by assigning each species a CC score, or coefficient of conservatism, which is scaled from 1 to 10 and reflects a species' tolerance to disturbance and habitat specificity. The modified FQI equation for Louisiana's wetland plant species takes into account not only the CC scores, but also the percent covers of species at a site, and the resulting FQI score is scaled from 0 to 100. FQI scores greater than 71 are classified as 'good', less than 39 are 'poor', and between 39 and 71 are considered 'fair'. Mean FQI scores were calculated for the PO-18 project and reference areas for each of the sampling years (Figures 7-12). FQI score for the reference area was initially higher than the PO-18 project area due to the high occurrence of *S. patens* which has a high CC score of 9, but decreased in each subsequent sampling year. FQI score within the PO-18 project area was nearly the same in 1997 and 2012 after showing a sharp drop in 2001, and was below the ideal range for fresh/intermediate marsh in all years sampled. FQI score within the project and reference areas was similar in the most recent sampling year (2012) at 48 and 43, respectively. According to the FQI scores calculated by transect, the vegetation community is the most stable in the western project area (Transects 4 and 5).

In summary, the project goal to promote re-establishment of vegetation was not achieved based on the plots sampled. Significant vegetative decline was observed in 2001, presumably due to severe drought. Recovery occurred between 2001 and 2012, but vegetative abundance did not reach levels measured at the beginning of the project life and open water plots did not vegetate as intended. As recovery occurred, the project area has demonstrated a shift from a fresh/intermediate to a primarily intermediate marsh community, which may provide some resilience to future high salinity events. Although the project goal was not achieved based on the plots sampled, the land gain observed through aerial land/water analysis indicates that the changes in the vegetative community have not translated to an overall loss of land within the project area.

iii. Marsh Inundation

Water level and operations data are essential in determining whether the PO-18 project has successfully met the target inundation levels stated in the project goals, which were to lower water levels within -0.5 ft to 0.0 ft of marsh sediment elevation in the spring and summer and within +0.5 ft of marsh sediment elevation in the fall and winter. During the staff gauge data collection period from 1997—2004, problems were encountered with data quality issues and frequency of staff gauge readings. Annual data completeness of staff gauge readings was acceptable from 1997-1999 at 92% or greater and several meetings were held between then-LDNR and USFWS to address data quality. From 2000 to 2004, however, annual data completeness ranged from 15% to 73%. The lack of pump operation records during the period of staff gauge data collection also hinders the evaluation of the project. Operations data were only

provided for two periods: 1) May 1997 to March 1998 and 2) October 2009 to April 2010 (Table 1), although it is known that the pumps were offline for two extended periods: 1) August 2005 to August 2006 following Hurricane Katrina and 2) October 2010 to April 2015 for USACE levee enlargement.

Additional problems were encountered with the initial survey of the project and reference area staff gauges to NAVD (ft), which was determined to be suspect. Weekly gauge readings began in February 1997 but a follow-up survey to correct the gauges did not occur until October 2003 (John Chance Land Surveys 2004). A correction factor was provided by the surveyor for the existing gauges, which was used to correct the 1997-2003 data. PO18-07 (Figure 3) was knocked over prior to the 2003 survey and therefore data for that station could not be back-corrected. PO18-08 showed a suspiciously high correction factor of 1.58 ft at the time of the 2003 survey and it is possible that this gauge was compromised sometime prior to the survey. Due to the issues with these two sites, the analysis will utilize PO18-06 in the northern project area, PO18-09 in the western project area, and PO18-10 in the eastern project area. Mean marsh elevation was surveyed in 2003 along four transects in the PO-18 project area and one transect in the Reference Area, and was calculated by averaging all points described by the surveyor as 'Vegetated Marsh'. Mean marsh elevation in the PO-18 project area was -0.56 ft NAVD, and the difference between the four transects surveyed was less than 0.1 ft. The Reference Area showed a higher mean marsh elevation of -0.16 ft NAVD, which was more similar to the marsh elevation observed in the PO-16 project area (-0.20 ft NAVD).

Mean seasonal inundation was calculated from the weekly gauge readings for the PO-18 project and reference area (Figure 15). The shaded area in Figure 15 represents the target area of -0.5 – 0 ft inundation in the spring/summer and 0 – 0.5 ft inundation in fall/winter relative to a marsh elevation of -0.6 ft NAVD in the project area and -0.2 ft NAVD in the reference area. Inundation was not calculated for seasons with less than three weekly readings. Trends in seasonal inundation were similar between the project and reference areas. A comparison of weekly inundation using the matched pairs t-test (JMP 11.0.0) showed that there was no significant difference in inundation between stations PO18-06 and PO18-09 (p=0.71); however, both of these stations were significantly different from PO18-10 (p<0.0001) (Table 3a). Inundation was about 0.1 ft lower at PO18-10, which appears to be less hydrologically connected due to the remnant spoil banks of Turtle Bayou. There was no significant difference in inundation between the three project stations and the two reference stations PO16-11R and PO16-12R (p>0.05); however, PO16-13R was significantly different from all other stations (p<0.01).

Operations data show that the pumps were run regularly from May 1997 to March 1998 for the durations presented in Table 1. A matched pairs t-test limited to this known operations period shows that water levels were significantly lower at the three project area stations than at reference stations PO16-11R/12R (p<0.05) (Table 3b).

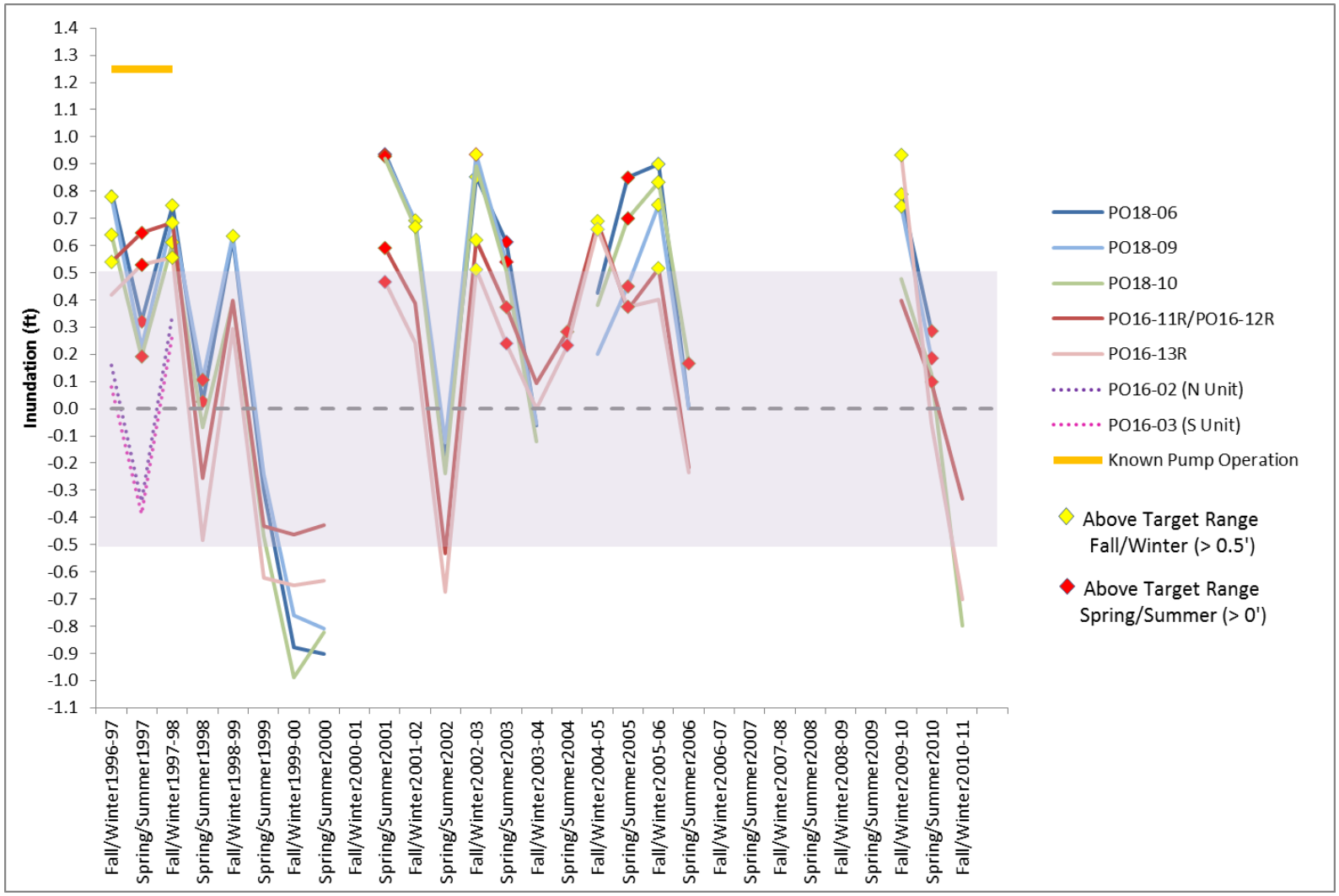

Figure 15. Mean seasonal inundation within the project and reference area of the Bayou Sauvage NWR Hydrologic Restoration project, Phase 2 (PO-18) based on weekly gauge readings. The shaded area represents the target inundation of -0.5 – 0 ft in the spring/summer and 0 – 0.5 ft in the fall/winter relative to a marsh elevation of -0.6 ft NAVD (project area) and -0.20 ft NAVD (reference area).

The greatest difference, however, was observed during the Spring/Summer 1997 season when the pumps were only run for 8 hours. The period of most frequent known pump operation (+300 hours) was the Fall/Winter season of 1997-98, during which the second highest precipitation level was recorded (47 inches) at the Lakefront Airport from 1993 to present (Figure 6). During this period, inundation in both project and reference areas were similar and ranged from 0.6 to 0.7 ft. By contrast, in the neighboring PO-16 project, the pumps in that impoundment were successful in lowering water levels during this operational period by over half a foot (Figure 15) (Hymel and Richard 2017).

Table 3. Results of Matched Pairs t-test comparisons of weekly inundation data between PO-18 project and reference stations. The p-values in red indicate significantly different results (p<0.05).

Matched Pairs t-test Results--*p* values

a) All Weekly Inundation Data, 1997-2014 (n=247)

	PO18-06	PO18-09	PO18-10	PO16-11R	PO16-12R	PO16-13R
PO18-06		0.71	<.0001	0.28	0.22	<.0001
PO18-09			<.0001	0.31	0.24	<.0001
PO18-10				0.06	0.10	0.0013
PO16-11R					0.47	<.0001
PO16-12R						<.0001
PO16-13R						

b) Known Operation Period Only, May 1997 - March 1998 (n=43)

	PO18-06	PO18-09	PO18-10	PO16-11R	PO16-12R	PO16-13R
PO18-06		0.0005	0.0004	0.0171	0.0262	0.82
PO18-09			0.13	0.0004	0.0007	0.11
PO18-10				<.0001	<.0001	0.0062
PO16-11R					0.42	<.0001
PO16-12R						<.0001
PO16-13R						

Following this early period of operation, it is unknown how often the pumps were operated except for periods where the pumps were known to be offline. Within the project area there were 7 spring/summer seasons and 7 fall/winter seasons identified where the mean inundation was above target range and presumably could have triggered pump operation. The percentage of weeks relative to the inundation target was calculated from an average of inundation at PO18-06 and PO18-09 for the project area and an average of the three reference sites for the reference area (Figure 16). Although there was a high percentage of missing data since 2001, the staff gauge

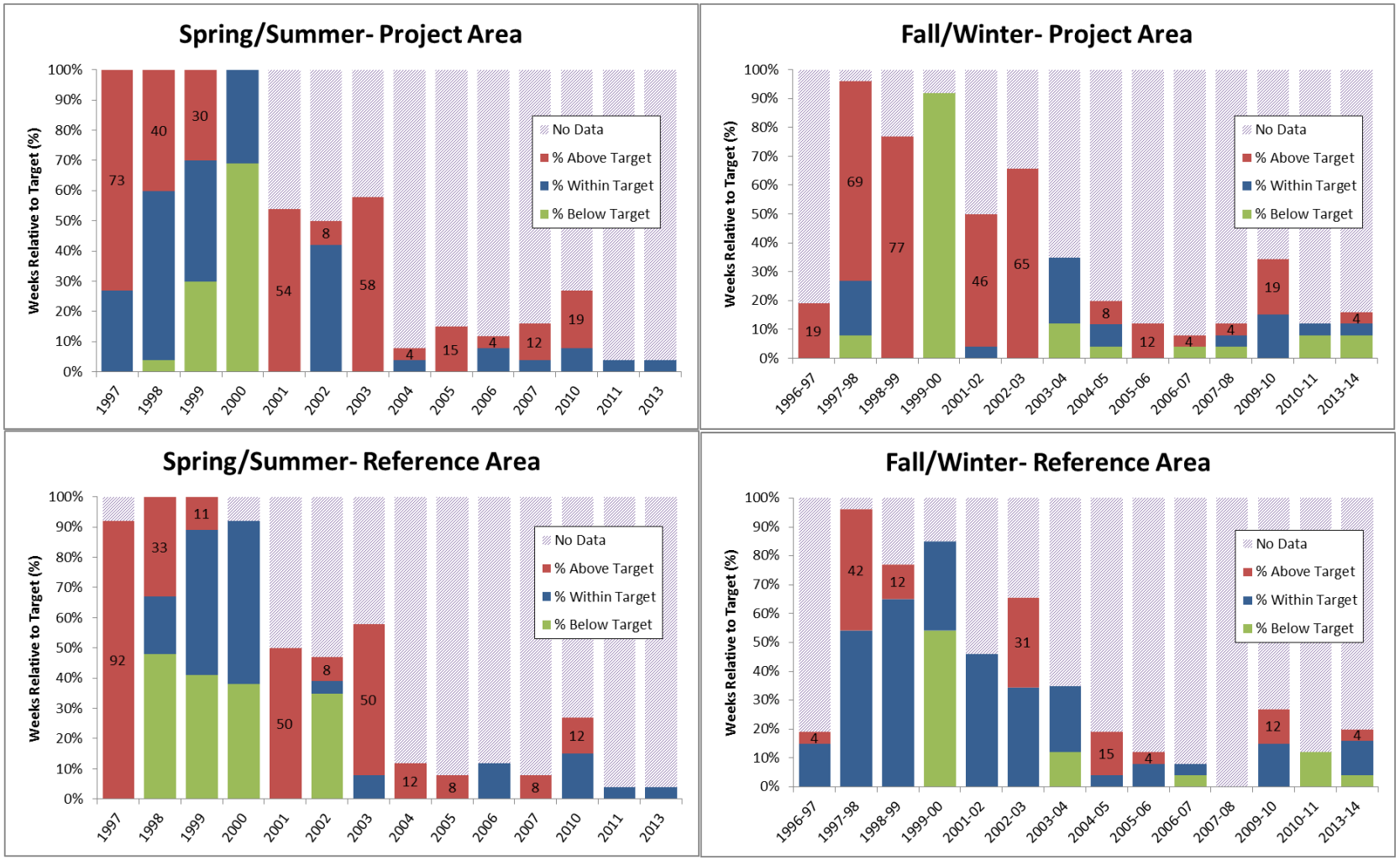

Figure 16. The percentage of weeks relative to the inundation target (within -0.5 to 0 ft in spring/summer and within 0 to 0.5 ft in fall/winter) within the PO-18 project and reference areas.

readings were normally collected at project and reference gauges on the same day. During the early period of known operation from 1997 to 1999, the percentage of weeks above target level was higher in the reference area than in the project area only during the Spring/Summer 1997 season. In 8 out of the 14 spring/summer and fall/winter seasons with available data (57%), the % of weeks above target level (inundation>0) was higher in the PO-18 project area than the reference area.

Although there is no CRMS site located in the PO-18 project area, water level has been sampled continuously at CRMS4107 in the adjacent PO-16 project area since November 2007. During this period, the PO-16/PO-18 pumps were not operational for approximately seven years (fall 2010 to fall 2017). The PO-16 marsh was flooded approximately 62% of the time relative to the CRMS4107 mean marsh elevation (0.39 ft) and 89% of the time relative to the PO-16 mean marsh elevation (-0.20 ft) (Figure 17). Inundation was above the seasonal target level 45% of the time relative to the CRMS4107 marsh elevation. During only the periods where the pumps were operational, inundation was above the seasonal target level 60% of the time. The only documented operations activity conducted in the fall/winter season of 2009 (Figure 17) appear to be associated with maintenance activities (addition of fuel conditioner). The fall/winter season of 2009 was a period of relatively high precipitation (Figure 6) and the CRMS4107 water level was still above the fall/winter target level (>0.5 inundation) when the pumps were turned off in January 2010 (relative to CRMS4107 or PO-16 marsh elevation).

Trends in soil elevation data at several CRMS sites within the Bayou Sauvage NWR indicate that marshes within the refuge impoundments may be increasingly vulnerable to submergence in the future. Over five years of RSET (rod-surface elevation table) and accretion data were used to calculate elevation trends at CRMS4107 (within the PO-16 impoundment) and at three unimpounded sites (CRMS0002, CRMS3626, CRMS3650). Data show that accretion rates are nearly double at sites outside of the impoundment (Figure 18). RSET measurements at the three unimpounded sites also showed positive elevation change rates of 0.4-0.5 cm/yr, while CRMS4107 had a negative elevation change rate of -0.71 cm/yr. Although CRMS soil elevation data is not available for the PO-18 impoundment, these data indicate that proper management and operation of the pumps may be increasingly critical for the health of the refuge impoundments if elevation trends are similar to those observed at CRMS4107.

In summary, it appears that although there was initial success in lowering water levels through pump operation early in the project life, inundation in the project area was above target range more often than the reference area in a majority of seasons where data are available. In addition to the pumps being offline for approximately 28% of the project life, it appears that there were several seasons where pump operation could potentially have occurred to reduce water levels within the project area.

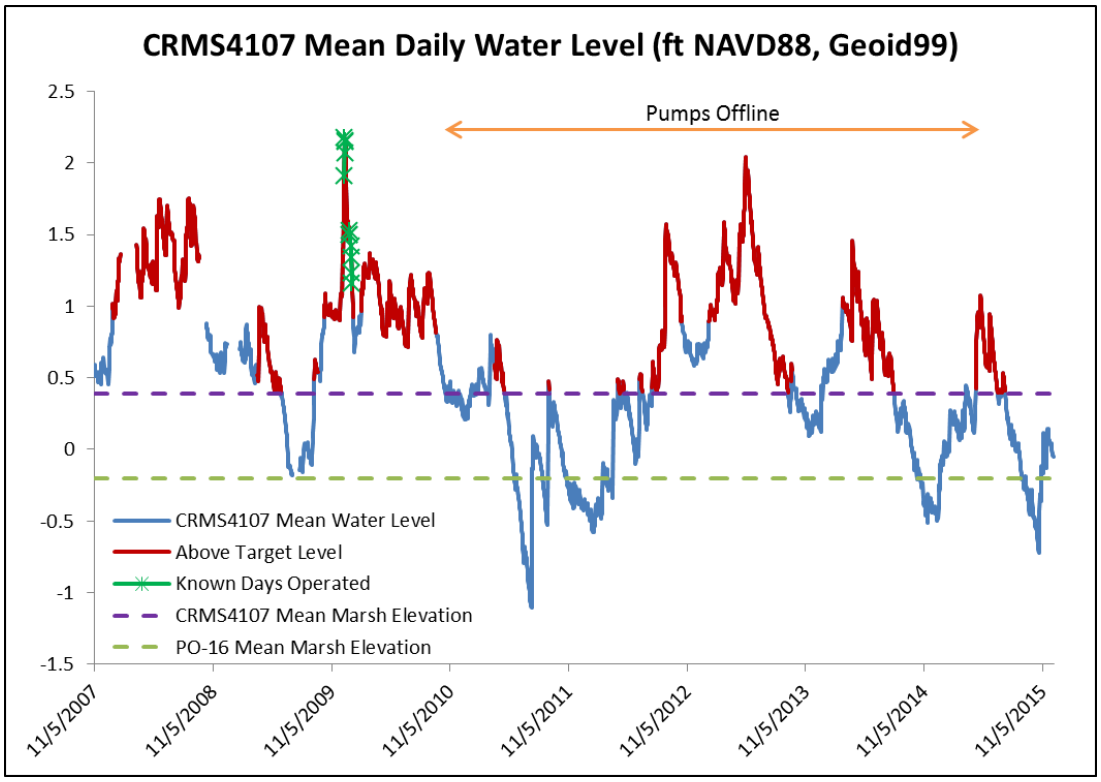

Figure 17. Mean daily water level at CRMS4107 from November 2007 to December 2015 relative to CRMS4107 marsh elevation (0.39 ft) and overall PO-16 marsh elevation (-0.20 ft). Mean water level above target inundation level (in red) is relative to the CRMS4107 mean marsh elevation.

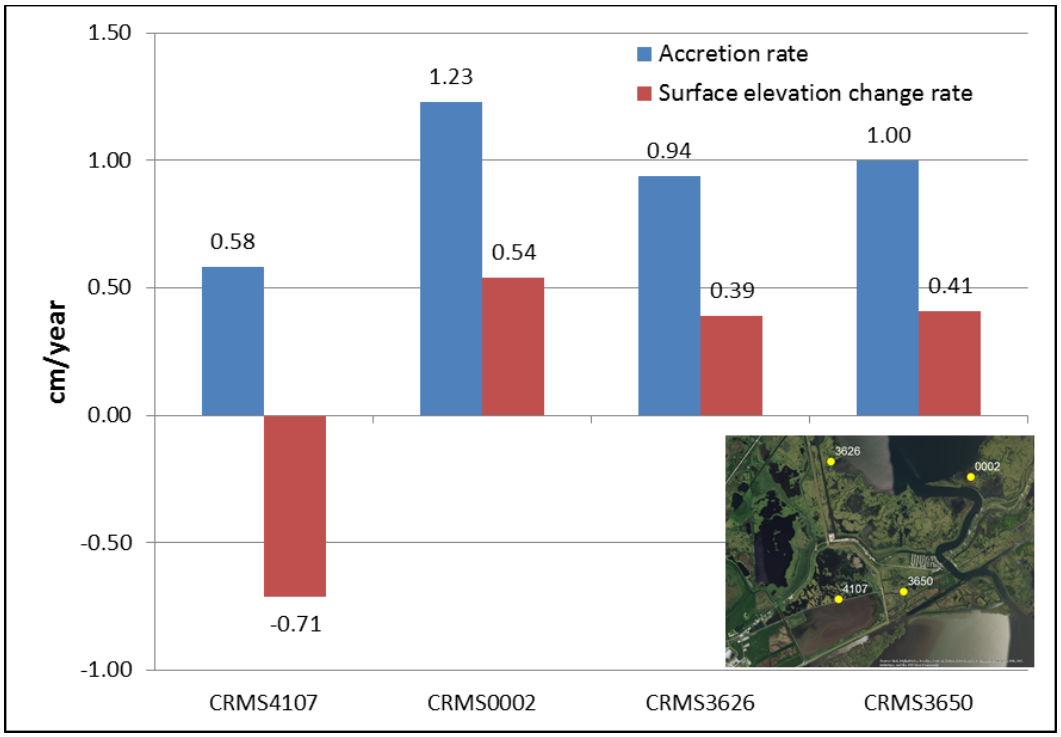

Figure 18. Long-term accretion and surface elevation change rates (cm/yr) at four CRMS sites within the Bayou Sauvage NWR. CRMS4107 is the only impounded site.

V. Conclusions

a. Project Effectiveness

The ability to measure the effectiveness of the PO-18 project was compromised by a lack of operations data for much of the project life. Changes in monitoring variables were evaluated over time, but those changes cannot be definitively attributed to project operations, or lack thereof. The first project goal, to promote the reestablishment of emergent marsh vegetation, was not achieved based on vegetation sampling conducted from 1997 to 2012; however, a 7% increase in land was observed through aerial photography analyses by Year 16 of the project life. Total percent cover of vegetation within the PO-18 project area showed a sharp decline from 1997 to 2001. This decline was likely due to severe drought and was also observed in the reference area and PO-16 project area. By 2012, vegetative cover rebounded in the PO-18 project area but not to levels observed in 1997. As recovery occurred, vegetation within the project area has demonstrated a shift from a fresh/intermediate to a primarily intermediate marsh community, which may provide some resilience to future high salinity events. Although the project area did exhibit a 452-acre land gain (7%) by Year 16 post-construction based on aerial photography, this gain was 248 acres less than the 700-acre target predicted in the WVA.

Based on the available staff gauge and operations data, it does not appear that water levels were consistently lowered within the impounded areas to -0.5 ft to 0.0 ft of marsh sediment elevation in the spring and summer and to within +0.5 ft of marsh sediment elevation throughout the PO-18 project life. A period of operation early in the project life showed some success in reducing water levels compared to the reference area; however, in the years that followed the percentage of weeks above the target inundation level was more often higher in the project area than the reference area. In addition to the pumps being offline for approximately 40% of the project life, it appears that there were several seasons where pump operation could potentially have occurred to reduce water levels within the project area.

b. Recommended Improvements

The following action items are recommended to improve the future operation of the PO-18 pumps:

1) Marsh Elevation/ Staff Gauge Survey – An updated survey of average marsh elevation of the PO-18 project area and PO-18 staff gauges is recommended.

2) Define Water Level Trigger — Based on the updated marsh elevation, a target water level reading should be defined that would trigger pump operation in the spring/summer and fall/winter seasons.

3) Documentation of Operations — A detailed log should be kept of all operations activity including the water level at the beginning and end of each operation

period.

4) Documentation of Maintenance — A detailed log should be kept of all maintenance activity both regularly scheduled and major events.

c. Lessons Learned

Evaluation of the PO-18 project was hindered by lack of operations records which should have been addressed early on through increased communication between the USFWS and CPRA. Target inundation levels consistent with the PO-18 project goals are listed in the Habitat Management Plan for the Bayou Sauvage NWR (USFWS 2013) but it is unknown how often the pumps were operated to achieve these targets. Greater collaboration between the USFWS and the CPRA regarding specific target water levels being used to trigger pump operations may have improved management of pump operations.

VI. References

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Appendix A
(Inspection Photographs, 11/13/2017)

Photo #1 – Pump Platform

Photo #2 – Discharge Pipes

Photo #3 – Levee

Photo #4 – Pump Engine

Photo #5 – Pump Engine

Photo #6 – Pump Gear

Photo #7 – Pump Gear

Photo #8 – Fuel Tank

Appendix B
(Field Inspection Notes)

FIELD INSPECTION CHECK SHEET

Project No. / Name: Bayou Sauvage Refuge (Phase 2) PO-18

Date of Inspection: 11/13/2017 Time: 10:00 AM

Structure No.

Inspector(s): LDNR: Richard, Worley
USFWS: Dixon, Stiaes

Structure Description: Dual-Pump Station Platform

Water Level: Normal Outside: Normal

Type of Inspection: Annual

Weather Conditions: Clear, mild

Item	Condition	Pysical Damage	Corrosion	Photo #	Observations and Remarks
Platform	Good	None	Moderate	1	
Trash Rack	Good	None	N/A		
Fuel tank	Good	None	None	8	
Pump Drive Engines	Good	None	None	4, 5	Both engines started and ran.
Pump gear boxes	Good	None	None	6, 7	A little rough to engage but both worked.
Piping	Good	None	None	2, 3	

Appendix C
(Three Year O&M Budget Projection)

Bayou Sauvage Refuge Wetland Restoration Phase II (PO-18)

Federal Sponsor: USFWS

Construction Completed : May, 1997

PPL 2

Current Approved O&M Budget January, 2005	Year 0 FY98	Year - 1 FY99	Year -2 FY00	Year -3 FY01	Year -4 FY02	Year -5 FY03	Year -6 FY04	Year -7 FY05	Year -8 FY06	Year -9 FY07	Year -10 FY08	Year -11 FY09	Year -12 FY10	Year -13 FY11	Year -14 FY12	Year -15 FY13	Year -16 FY14	Year - 17 FY15	Year -18 FY16	Year -19 FY17	Year -20 FY 18	Year -21 FY 19	Year -22 FY 20	Year -23 FY 21	Year -24 FY 22	Year -25 Fy 23	Project Life Budget	Currently Funded
State O&M																											$417,239	$417,239
Corps Admin																											$0	$0
Federal S&A																											$0	$0
Total																											$417,239	$417,239

Projected O&M Expenditures																											Remaining Project Life	Current 3 yr Request
Maintenance Inspection								$3,174.00	$0.00	$3,341.00	$3,428.00	$3,517.00	$3,609.00	$0.00	$0.00	$0.00	$0.00	$0.00	$4,209.00	$4,319.00	$4,431.00	$4,546.00	$4,664.00	$4,785.00	$4,909.00	$5,036.00	$28,371	$13,641
General Operations and Maintenance								$11,108.00	$0.00	$11,693.00	$11,998.00	$12,310.00	$12,631.00	$0.00	$0.00	$0.00	$0.00	$0.00	$14,732.00	$15,125.00	$15,518.00	$15,921.00	$16,335.00	$16,760.00	$17,196.00	$17,643.00	$99,373	$47,774
Surveys																											$0	$0
Sign Replacement																											$0	$0
Federal S&A																											$0	$0
Maintenance/Rehabilitation																											$0	$0
E&D																											$0	$0
Construction								$24,080.00							$0.00												$0	$0
Construction Oversight																											$0	$0
Total					$0	$0	$0	$38,362	$0	$15,034	$15,426	$15,827	$16,240	$0	$0	$0	$0	$0	$18,941	$19,444	$19,949	$20,467	$20,999	$21,545	$22,105	$22,679	$127,744	$61,415

O&M Expenditures from COE Report	$243,125
State O&M Expenditures not submitted for in-kind credit	$0
Federal Sponsor MIPRs (if applicable)	$0
Total Estimated O&M Expenditures (as of April 2017)	$243,125

Current O&M Budget less COE Admin	$417,239
Remaining Available O&M Budget	$174,114
Incremental Funding Request Amount FY18-FY20	**-$112,699**

Current Project Life Budget less COE Admin	$417,239
Total Projected Project Life Budget	$370,869
Project Life Budget Request Amount	**-$46,370**

Appendix D
(Aerial Photography Analyses)

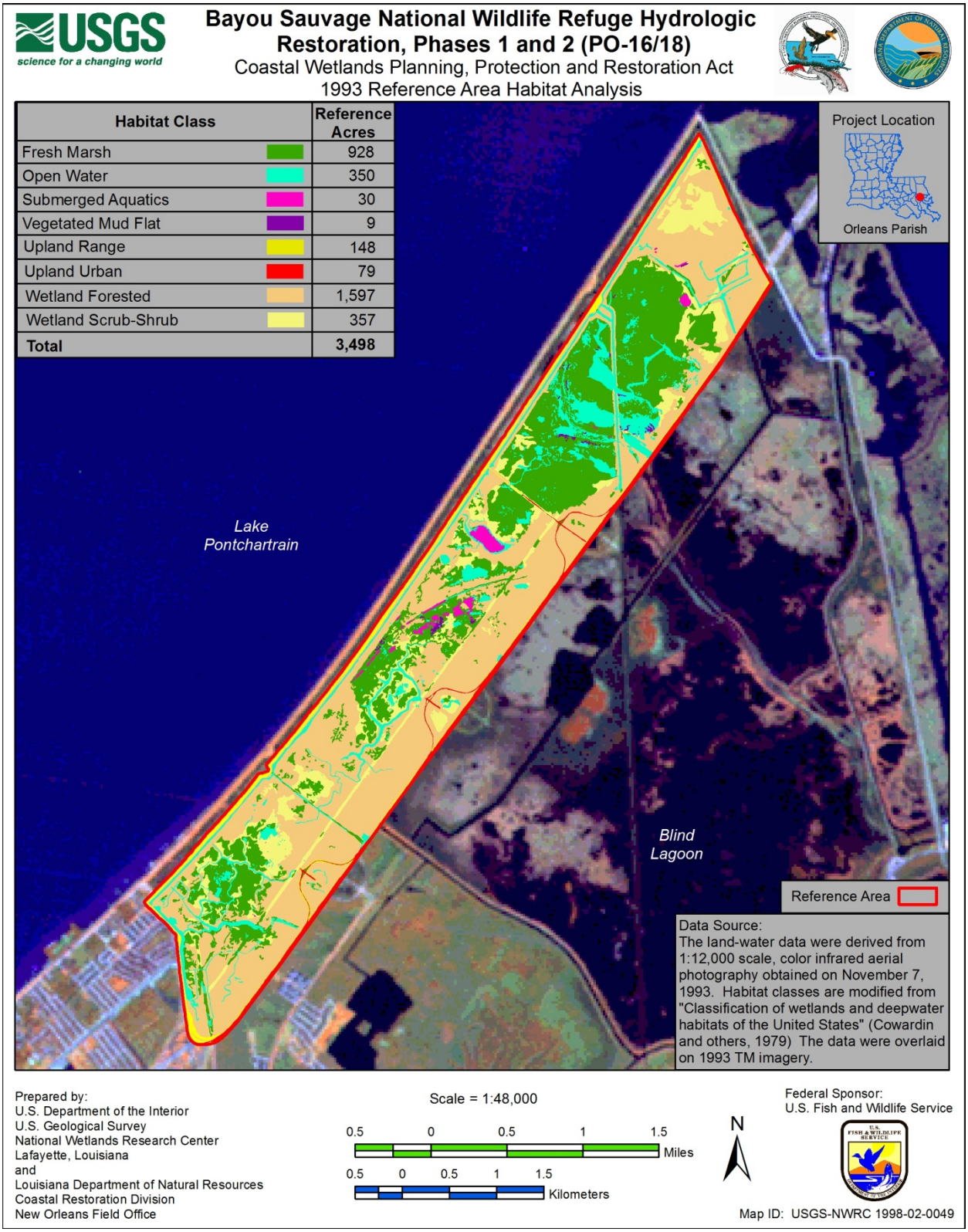

Figure D-1. 1993 habitat analysis of the Bayou Sauvage NWR Hydrologic Restoration (PO-16/18) reference area.

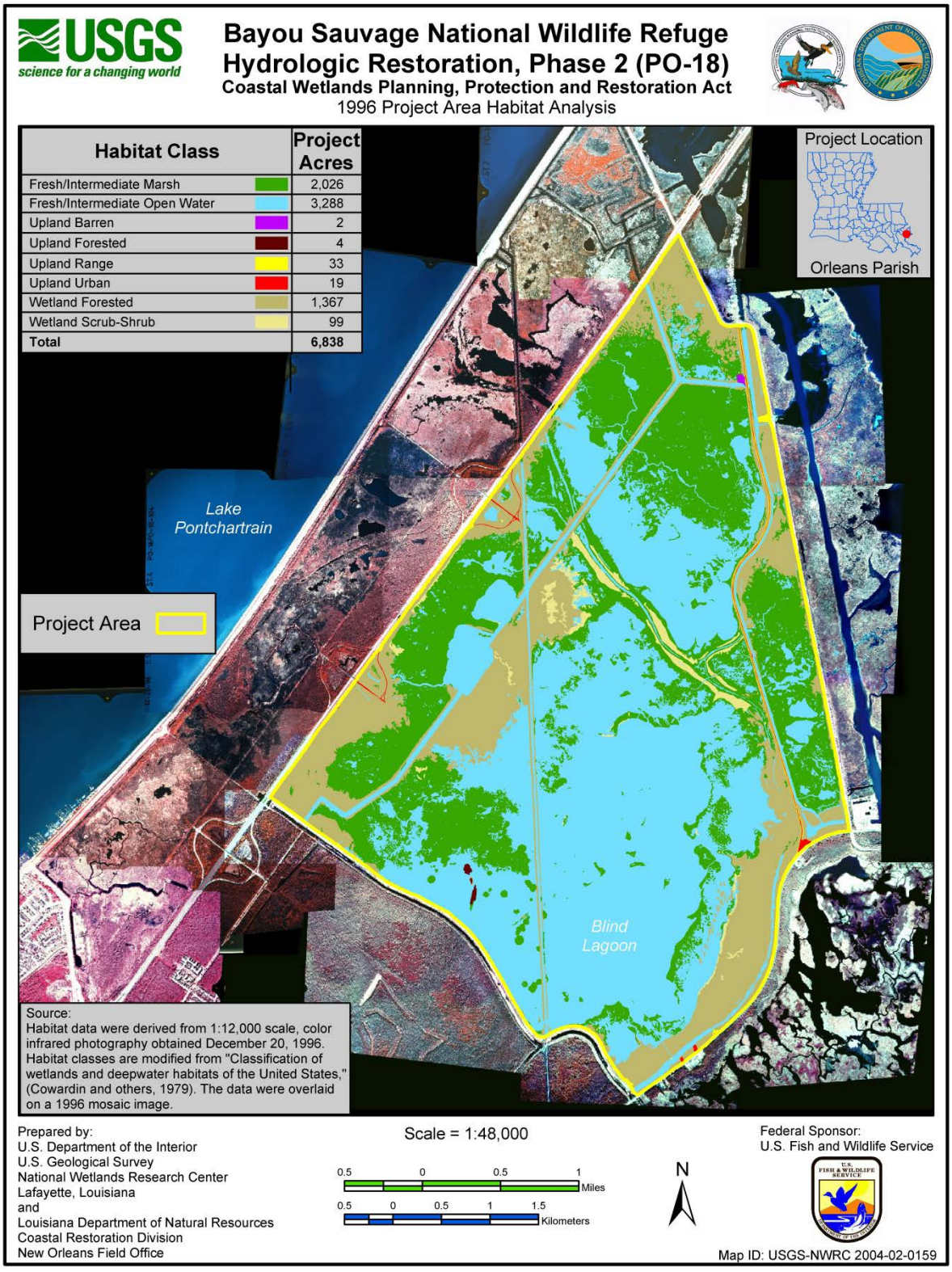

Figure D-2. 1996 habitat analysis of the Bayou Sauvage NWR Hydrologic Restoration, Phase 2 (PO-18) project area.

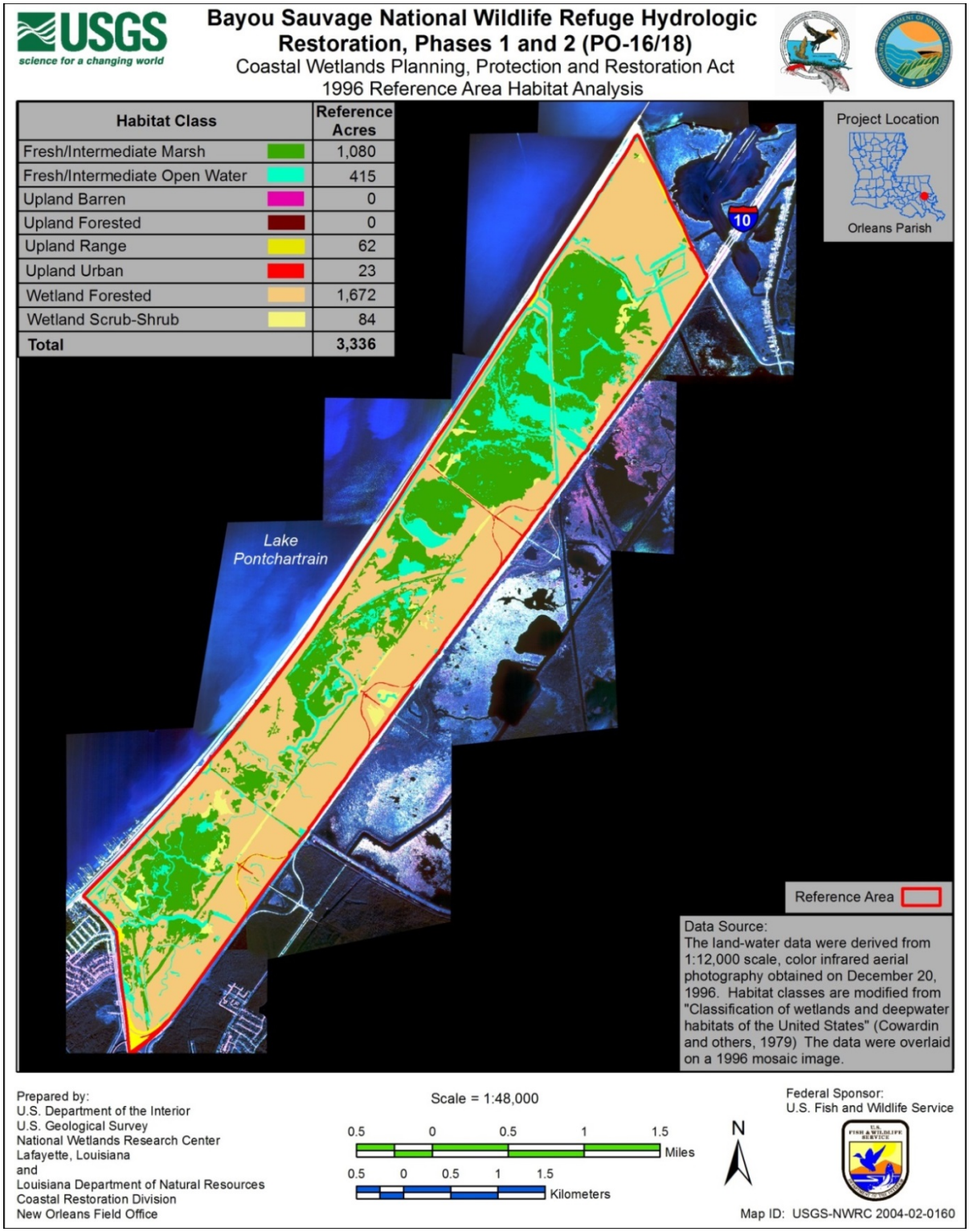

Figure D-3. 1996 habitat analysis of the Bayou Sauvage NWR Hydrologic Restoration (PO-16/18) reference area.

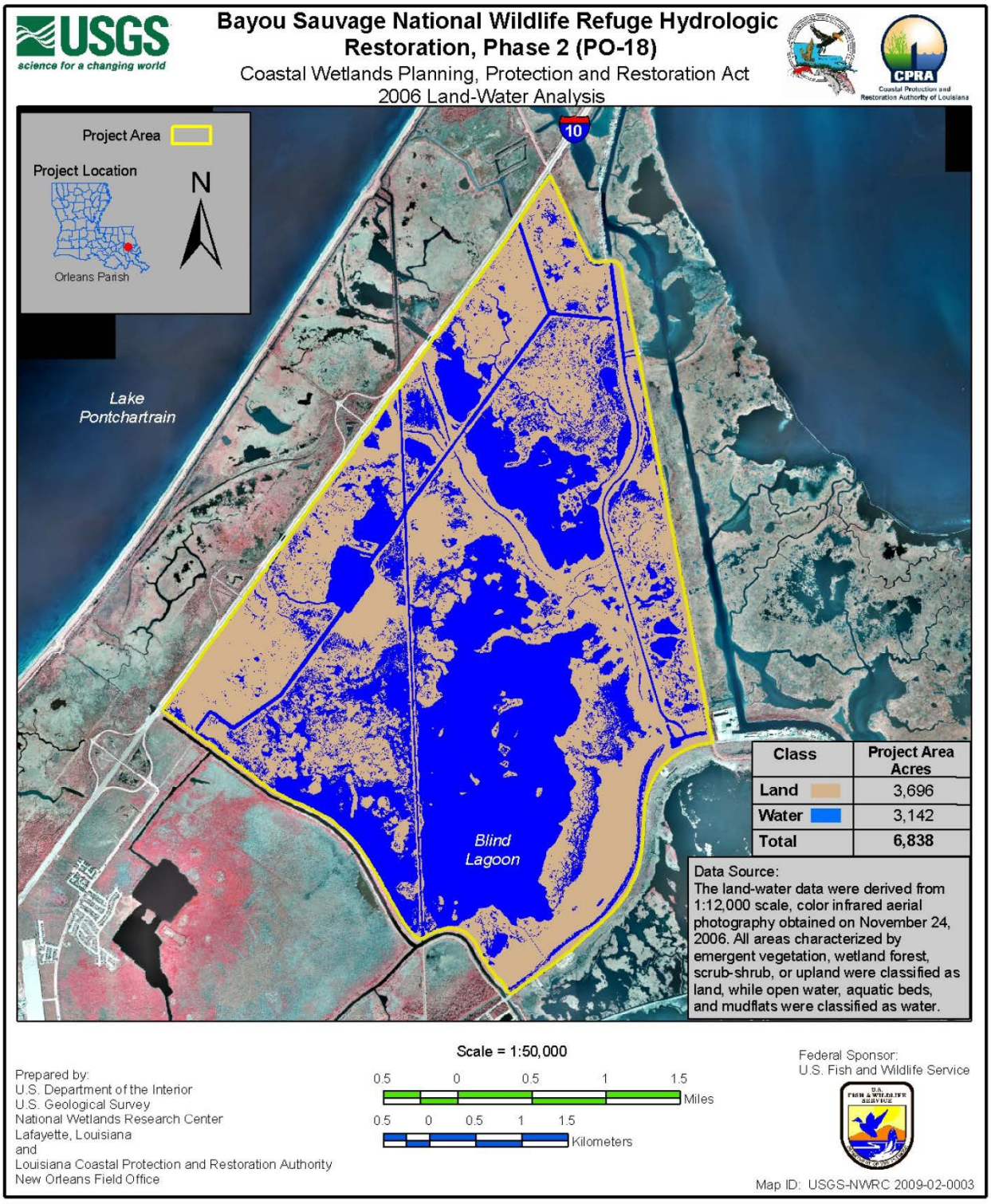

Figure D-4. 2006 land/water analysis of the Bayou Sauvage NWR Hydrologic Restoration, Phase 2 (PO-18) project area.

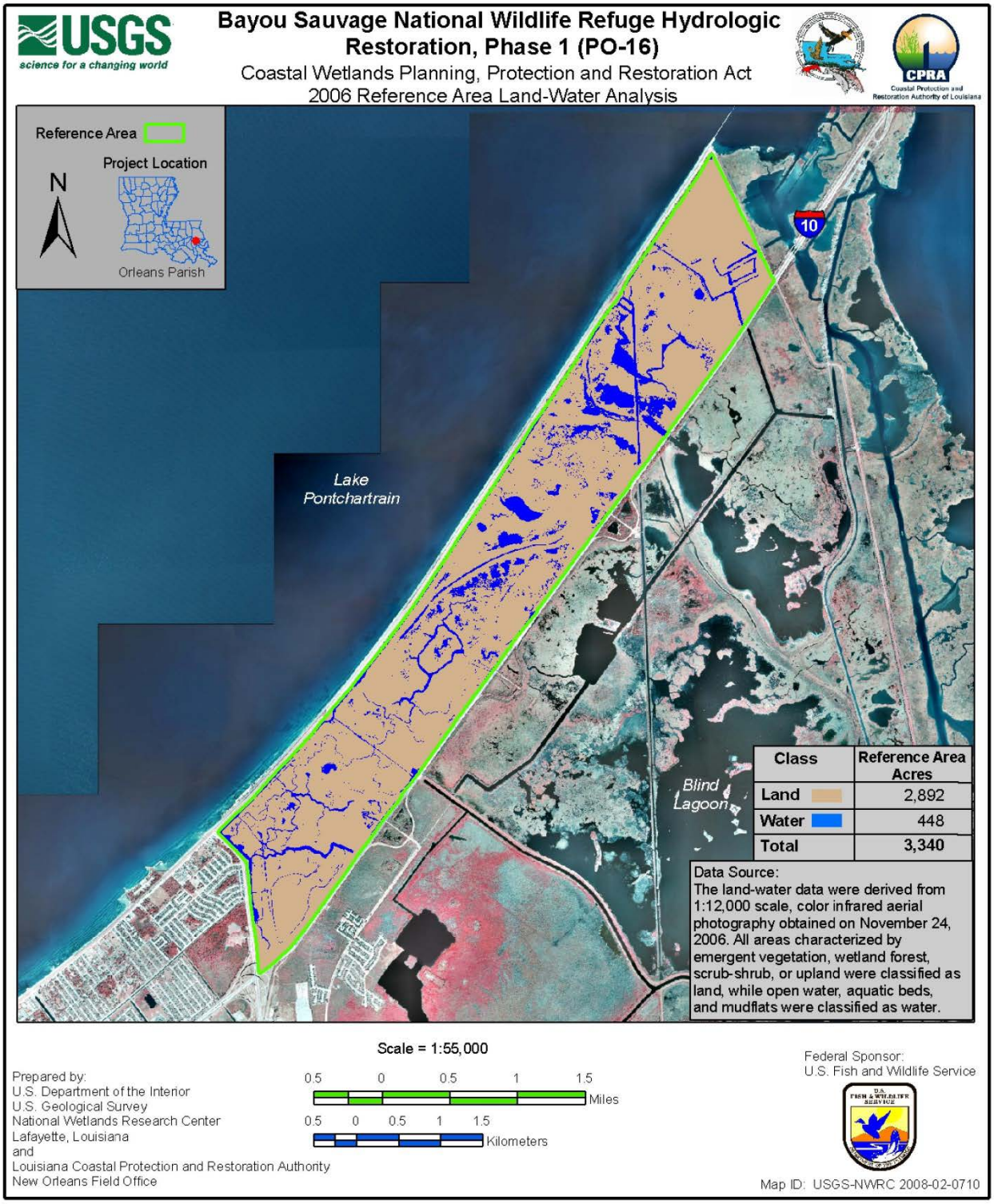

Figure D-5. 2006 land/water analysis of the Bayou Sauvage NWR Hydrologic Restoration (PO-16/18) reference area.

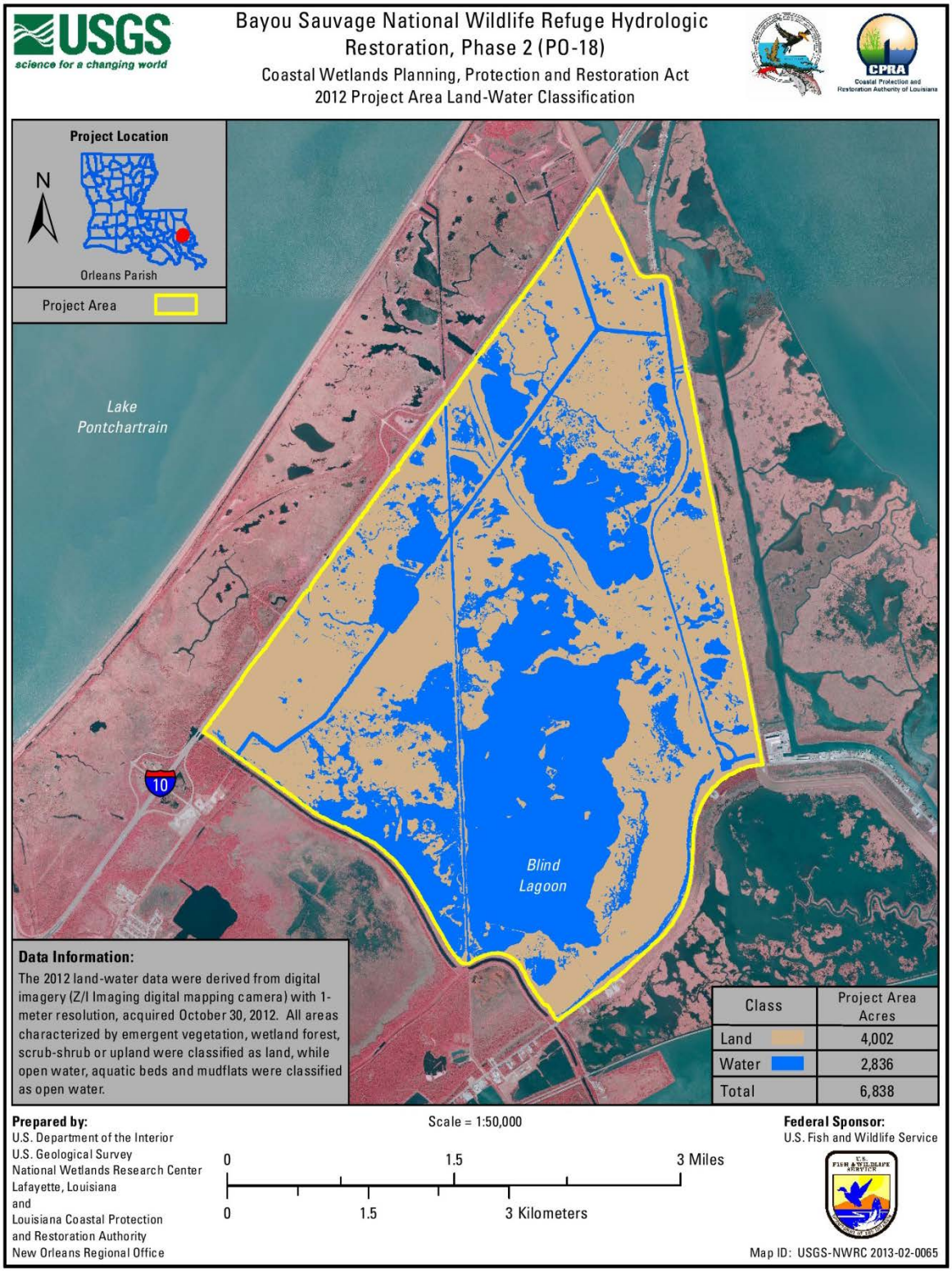

Figure D-6. 2012 land/water analysis of the Bayou Sauvage NWR Hydrologic Restoration, Phase 1 (PO-18) project area.

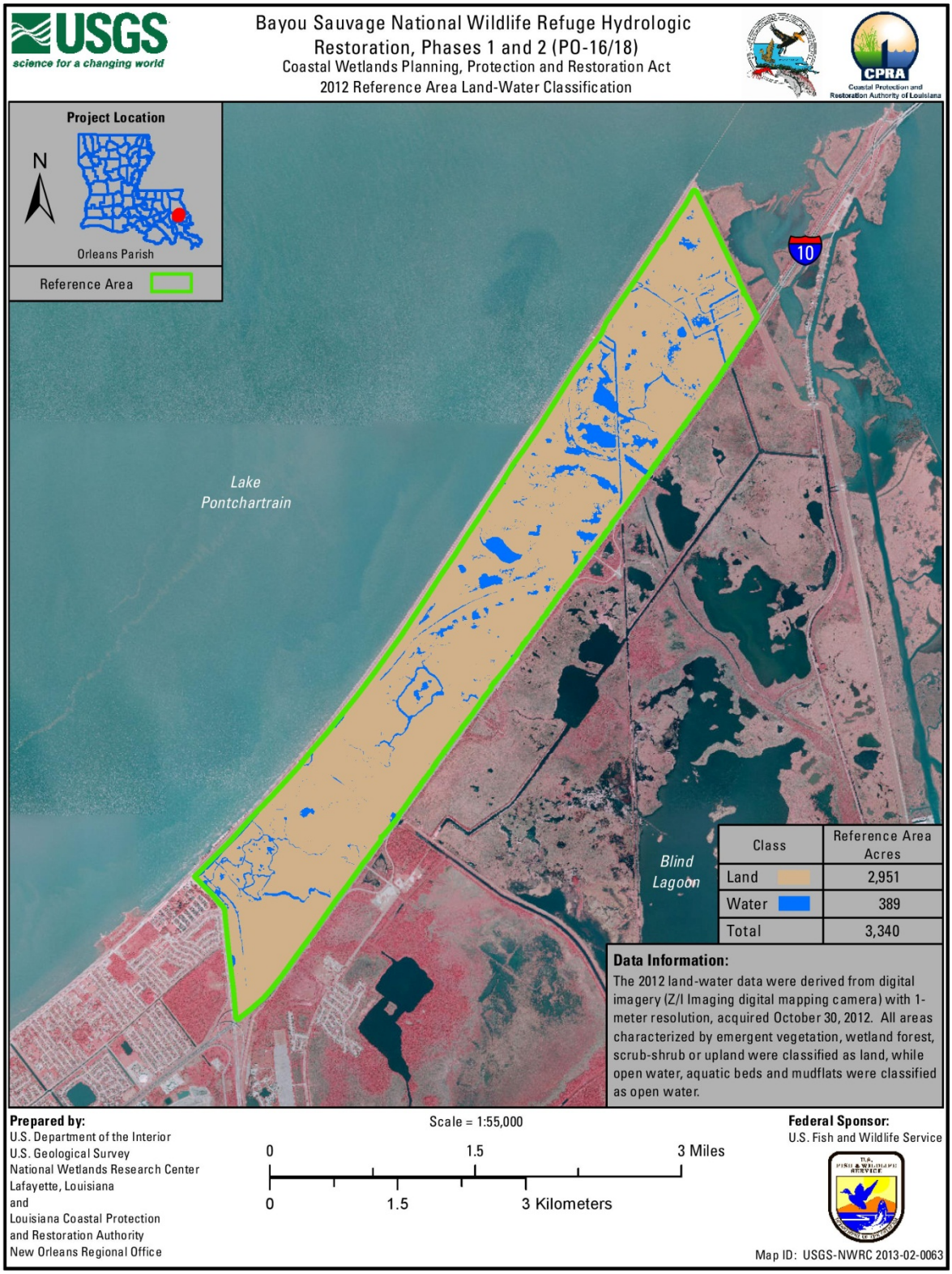

Figure D-7. 2012 land/water analysis of the Bayou Sauvage NWR Hydrologic Restoration (PO-16/18) reference area.