Coastal Protection and Restoration Authority of Louisiana

State of Louisiana
Coastal Protection and Restoration Authority

2019 Operations, Maintenance, and Monitoring Final Report

for

Lake Chapeau Sediment Input and Hydrologic Restoration, Point Au Fer Island (TE-26)

State Project Number TE-26
Priority Project List 3

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For
Lake Chapeau Sediment Input and Hydrologic Restoration,
Point Au Fer Island
(TE-26)

Table of Contents

Preface

This report includes TE-26 project specific monitoring data collected from April 1997 through January 2016, and the annual maintenance inspection. The Lake Chapeau Sediment Input and Hydrologic Restoration, Point Au Fer Island (TE-26) project is a Coastal Wetlands, Planning, Protection, and Restoration Act (CWPPRA, Public Law 101-646, Title III, Priority List I) project administered by the National Marine Fisheries Service (NMFS) and the Coastal Protection and Restoration Authority of Louisiana (CPRA).

The 2018 report is the fifth and final (closeout report) in a series of reports containing Operations, Maintenance and Monitoring data. For information on lessons learned, recommendations, project effectiveness, and data collected throughout the project's economic life refer to the 2004, 2007, 2011, and 2016 Operations, Maintenance, and Monitoring Reports on the CPRA web site at https://cims.coastal.louisiana.gov.

I. Introduction

The 2016 project area contains 7,654 acres (3097 hectares) of brackish to intermediate marsh plus 6,156 ac (2491 ha) of open water (Appendix A, Figure 5). This project, located on Point Au Fer Island, is bound to the northwest by Atchafalaya Bay, to the northeast by Four League Bay, and to the south by the Gulf of Mexico. It is located approximately 13 mi (20.9 km) southeast of the mouth of the Atchafalaya River in Terrebonne Parish, Louisiana (Figure 1).

Marsh loss rates throughout Point Au Fer Island between 1932 and 1974 peaked at 45.45 ac/yr (18.4 ha/yr) and occurred as a direct result of oil exploration activities (NMFS 1994). The rate of interior marsh loss has decreased since that time and was estimated to be 20.14 ac/yr (8.15 ha/yr) (1983-1990). Shoreline erosion along Point Au Fer Island throughout time (1880s-2015) was -16.91 (ft/yr), historically (1930s-1950s) was -15.1 (ft/yr), long-term (1950s-1998) was -16.4 (ft/yr), short-term (1996-2015) was -18.7 (ft/yr), and near-term (2004-2012) was -20.1 (ft/yr) (Byrnes 2018). The land loss rate inside the TE-26 project boundary was approximately 106.9 ac/yr (43.3 ha/yr) between 1988 and 2000. Oil and gas access canals cut into the interior of Point Au Fer Island have deteriorated the hydrologic separation between the Locust Bayou and Alligator Bayou watersheds and dramatically altered the island's natural drainage pattern (NMFS 1994). Sheet flow and over bank flow were drastically reduced by artificial levees, which in turn impounded marsh and led to degradation due to soil water logging. Due to unnatural hydrologic patterns the abundant sediment load generated by the Atchafalaya River circulating through the island's interior have not been effectively utilized. Additional assumed causes of land loss have been attributed to natural subsidence and natural shoreline erosion.

The objectives of the Lake Chapeau Sediment Input and Hydrologic Restoration, Point Au Fer Island (TE-26) project are to 1) convert approximately 168 acre (105 hectares) of open water to

Figure 1. Lake Chapeau Sediment Input and Hydrologic Restoration, Point Au Fer Island (TE-26) project and reference area boundaries.

marsh at final elevation of 0.5 feet (0.15 meters) National Geodetic Vertical Datum of 1929 (NGVD29) or 0.346 feet (0.105 meters) North American Vertical Datum of 1988 (NAVD88) west of Lake Chapeau between Locust Bayou and Alligator Bayou using sediment mined from Atchafalaya Bay (Figure 2), and 2) restore natural sediment and hydrologic pathways by plugging canals in the project area. By plugging man-made canals the inland marshes would be preserved and protected from marine influences while reestablishing the original hydrologic regime (NMFS 1998). Creating marsh north and west of Lake Chapeau would reestablish the hydrologic separation of the Locust Bayou and Alligator Bayou watersheds.

The final design of the Lake Chapeau project consisted of three (3) components, with additional project features added to address problems encountered during and after construction:

1. To re-establish a land bridge between Locust Bayou and Alligator Bayou, the first component was to hydraulically dredge approximately 721,931 cubic yards of material from the Atchafalaya Bay and spread to an average of two (2) feet thick to create approximately 168 acres of marsh between these two bayous (D. Burkholder, Final Report n.d.).

2. The second component of the project (hydrologic restoration) consisted of the construction of seven (7) rock weirs in man-made canals around the perimeter of Lake Chapeau and gapping existing spoil banks in one channel. The rock weirs and spoil bank gapping's are designed to help restore the natural circulation and drainage pattern within the central portion of Point au Fer Island (D. Burkholder, Final Report n.d.). The principle project features of this component are:

    - Site No. 1 – Rock weir – 150 linear feet (LF)
    - Site No. 3 – Rock weir – 229 LF
    - Site No. 4 – Rock weir – 174 LF
    - Site No. 5 – Rock weir – 70 LF
    - Site No. 6 – Rock weir – 145 LF
    - Site No. 7 – Rock weir – 157 LF
    - Site No. 9 – Rock weir – 240 LF

3. The third component of the project consisted of dredging a 6,700 foot long silted section of Locust Bayou to its original navigable depth. This was done to accommodate the increase flows resulting from the re-establishment of the island's natural drainage patterns. A total of 59,218 cubic yards of material was dredged and placed in 1.5 feet high by 80 feet wide spoil banks on both sides of the bayou. The spoil banks were gapped periodically so not to impede the flow of natural waterways and drainage (D. Burkholder, Final Report n.d.)

Construction for the Lake Chapeau Sediment Input and Hydrologic Restoration, Point Au Fer Island (TE-26) project began on September 14, 1998, and was completed on May 18, 1999. The project has a 20-year life, which began in May 1999.

The principal project features constructed include (Figures 2 - 3):

- Dredging approximately 78 acres (32 hectares) of Atchafalaya Bay water bottom to approximately -11.1 feet (-3.4 meters) NAVD88 and pumping the 721,931 yd^3 (551,956 m^3) of sediment into a containment area approximately 193.6 acres (78 hectares) in size to an initial target elevation of +1.5 feet (0.46 meters) NGVD29 or 1.3 feet (0.40 meters) NAVD88, with a final target elevation of 0.5 feet (0.15 meters) NGVD29 or 0.346 feet (0.105 meters) NAVD88 after consolidation.
- Construction of seven rock weirs across man-made oil access canals located along the fringes of the project area. Six of the weirs were built to a top elevation of 0.00 feet (0.0 meters) NGVD29 or -0.15 feet (-0.05 meters) NAVD88 with a crest width of 10 feet (3.0 meters). One of the weirs included a boat bay constructed to an elevation of -4.0 feet (-1.2 meters) NGVD29 or -4.17 feet (-1.27 meters) NAVD88 with a fixed crest elevation of 0.0 feet (0.0 meters) NGVD29 or -0.17 feet (-0.05 meters) NAVD88. All of the weirs were constructed with a core of reef shell wrapped in a geotextile woven fabric layer, and then topped with 2 feet (0.61 meters) of 250 lb (113.3 kg) class rock riprap.
- Construction of a 167 feet (60 meters) rock plug with a crest height of 5 feet (1.5 meters) NGVD29 or 4.8 feet (1.5 meters) NAVD88 along a shoreline breach created by the dredge pipeline along the east shoreline of the Atchafalaya Bay. The plug was built from 250 lb (113.3 kg) class rock riprap core placed on top of a geotextile fabric layer.
- Dredging approximately 6,400 linear feet (1951 meters) of Locust Bayou to a bottom elevation of -4.2 feet (-1.3 meters) NGVD29 or -4.4 feet (-1.3 meters) NAVD88 with an average width of 70 feet (21 meters). Several 25 feet (7.62 meters) gaps were cut into the spoil banks to allow for natural bank overflow and high water events.
- Note: All elevation conversions from NGVD29 to NAVD88 were calculated using Corpscon 6.0.

The following project feature was not part of the original project design but was added in May 1999, one growing season after dredge material placement, because of low natural recruitment of vegetation from the marshes surrounding the fill area:

- Installation of 46,980 vegetative plugs of *Spartina alterniflora* Loisel.(smooth cordgrass) throughout the fill area (Figure 3), placed on 5 feet (1.5 meters) center spacings along randomly located paired rows also spaced 5 feet (1.5 meters) apart (Coastal Environments 2000).

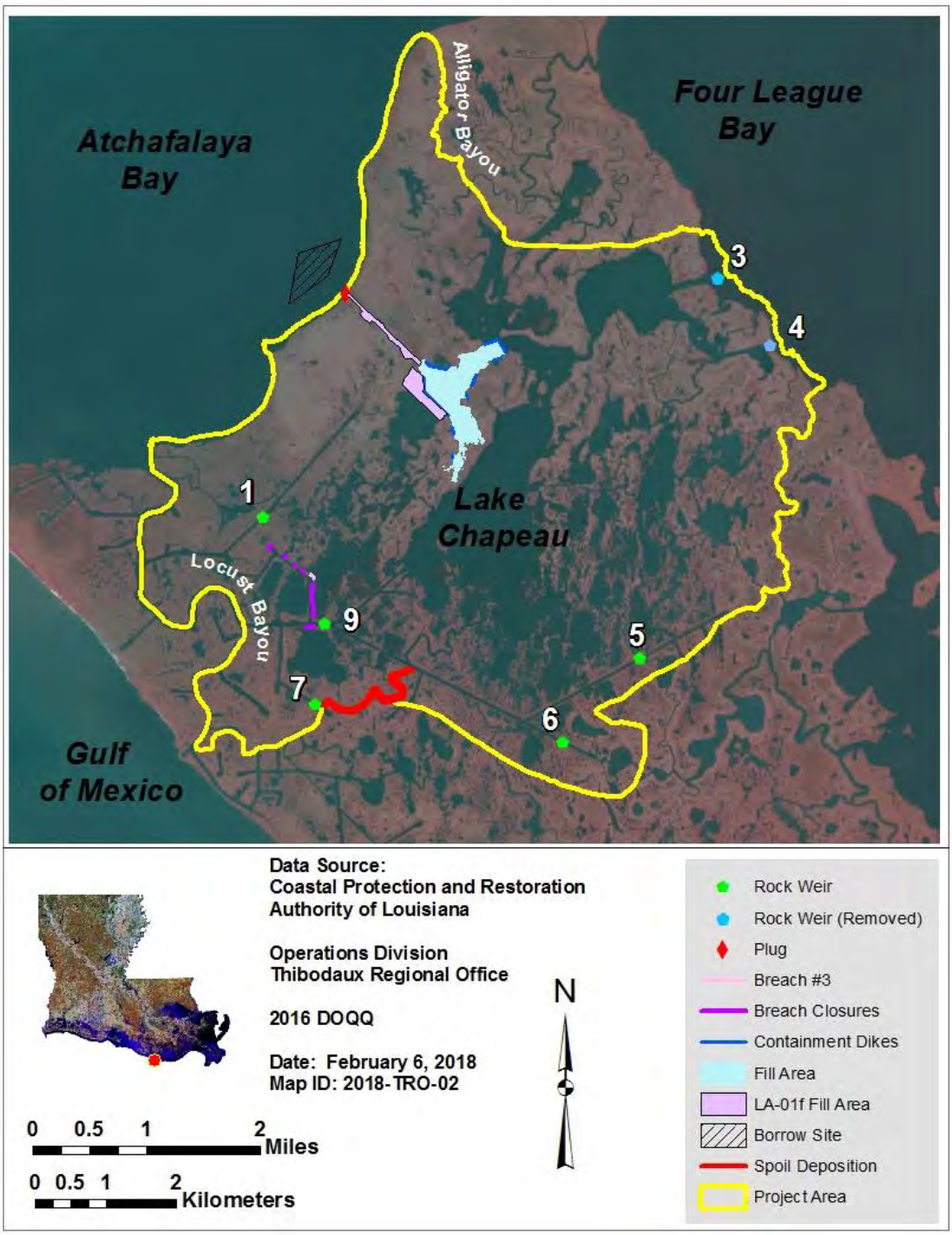

Figure 2. Lake Chapeau Sediment Input and Hydrologic Restoration, Point Au Fer Island (TE-26), project boundary and features.

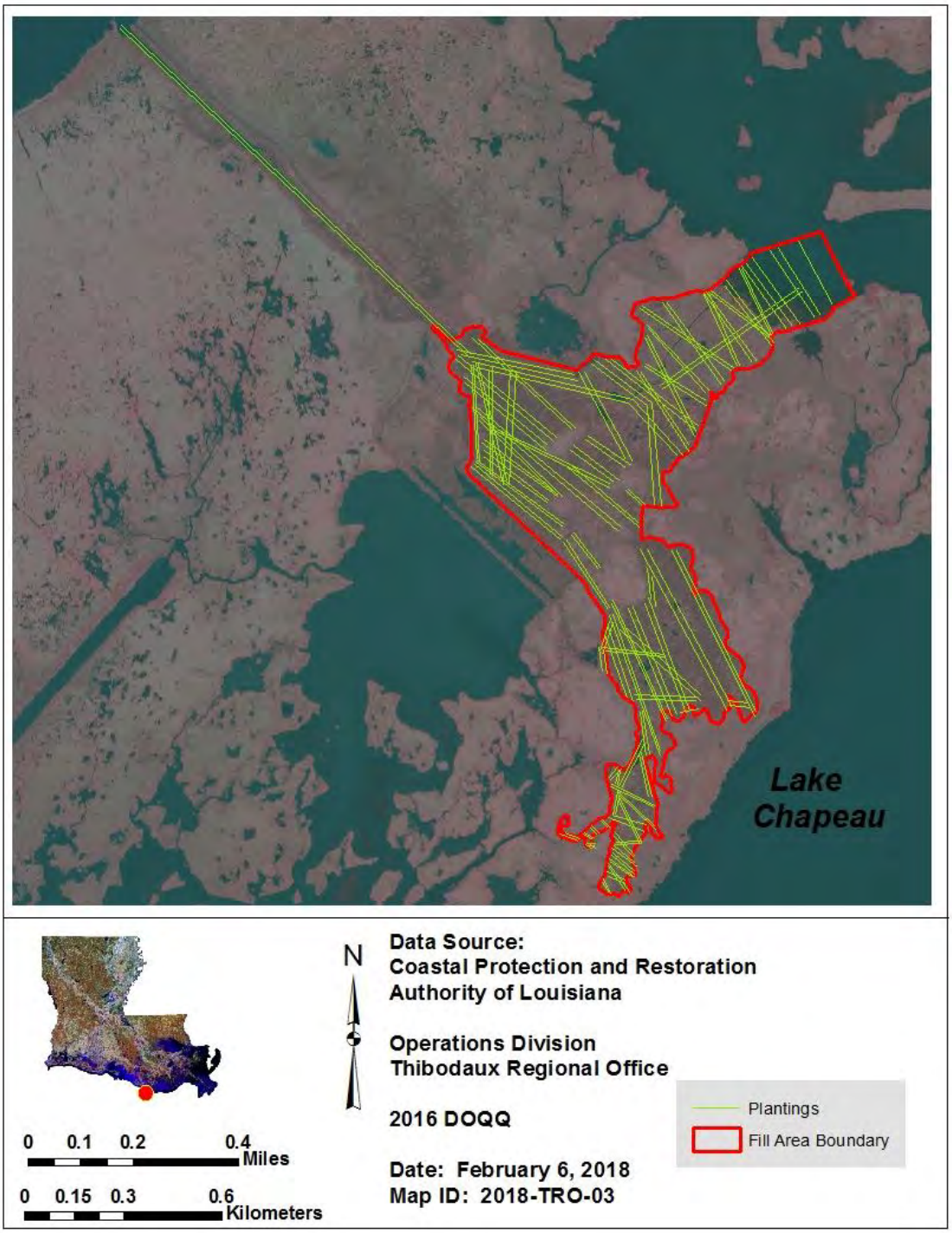

Figure 3. Location map indicating as-built plantings of *Spartina alterniflora* on the dredge material fill area for the Lake Chapeau Sediment Input and Hydrologic Restoration, Point Au Fer Island (TE-26) project.

II. Maintenance Activity

a. Operation, Maintenance and Rehabilitation Procedures

Through the Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA) program, the Coastal Protection and Restoration Authority (CPRA) and the NOAA- National Marine and Fisheries Service (NMFS) were tasked with developing an Operation and Maintenance Plan (O&M Plan), which required CPRA and NMFS to performing annual inspections, provide an inspection report, and maintain constructed project features through 2019, the twenty (20) year life of the project. The O&M Plan (LDNR 2002) was completed and signed by both parties in February 2003. The project features included in the O&M Plan consisted of seven (7) rock riprap weirs across several channels on the interior of the island and incidental features such as warning signs and barricades.

The purpose of the annual inspections of the Lake Chapeau (TE-26) project was to evaluate the constructed project features and identify any deficiencies, prepare a report detailing the condition of these features, and recommend corrective actions if needed. If corrective actions were needed and recommended, CPRA provided in the report a detailed cost estimate for engineering, design, construction, supervision, inspections and contingencies as well as an assessment of the urgency of recommended maintenance repairs.

b. Summary of Past Operation and Maintenance Projects

June 2000 – The first maintenance event was to repair breaches in existing spoil banks along an existing location canal southwest of Lake Chapeau just west of Site No.9 by constructing a rock weir at one location and dredging material from the canal to plug an additional five (5) other locations. This work was completed by Jonny F. Smith Truck and Dragline Service, Inc. of Slidell, La. as part of the Point au Fer (TE-22) Phase III construction contract.

October 2004 – The second maintenance event on the Lake Chapeau project consisted of the removal and replacement of existing warning buoy system. The purpose of this maintenance project was to remove the floating buoy system that prone to damage and frequently vandalized, and provide a more rigid barricade system at six (6) of the seven (7) weir sites for navigation safety and to prevent passage around the structure. The timber barricade system included timber piles driven every 20 feet across the existing channels with 4-inch diameter horizontal steel piping connecting the vertical timber piling. Each structure was marked with warning signs and reflective tape to allow visibility at night. The project was designed by Picciola and Associates of Cut Off, La. and constructed by Dupre Brothers Construction Co., Inc. of Houma, La. The project was completed in October 2004 at a total cost of $330,745.50 (Includes: Engineering, Design, Bidding, Construction Administration, Inspection, and Construction).

September 2005 – The third maintenance event included a breach repair on the south side of Site No. 3. The purpose of the project was to extend the rock weir by 50 linear feet on the south

side of the structure. Articulated concrete mats were also used on the south side to slow future shoreline erosion and potential breaching. This work was performed in conjunction with maintenance work on the Point au Fer project (TE-22) maintenance project,

November 2007 – Dedicated Dredge Program – Point au Fer Island
The Louisiana Department of Natural Resources (LDNR) Dedicated Dredge Program was initiated in FY 98/99 and is funded 100% by the State of Louisiana through its statutorily dedicated Wetlands Conservation and Restoration Fund. The goal of this program is to use a small, mobile hydraulic dredge to move sediment from small inland waterways within the coastal zone of Louisiana and deposit the material to nourish and/or rebuild the threatened coastal marsh that are located immediately adjacent to those waterways.

The Point au Fer Island Dedicated Dredge Project (LA-01f) is located on Point au Fer Island between the Atchafalaya Bay and Lake Chapeau in Terrebonne Parish (Figure 2). The project consisted of dredging approximately 295,000 cubic yards to fill a 60 acre site adjacent to the original Lake Chapeau dredge site and the linear corridor connecting the proposed fill area to the Atchafalaya Bay. The LDNR Engineering Division performed the engineering, design, and bidding. Construction Oversight services were provided by Gulf South Engineers, Inc. of Houma. The total project cost including construction oversight was $2,598,079.

May 2011 – The fourth maintenance event involved the demolition of the rock weir at Site No. 3 along the east shoreline of Four League Bay. Due to the high rate of erosion along the shoreline (-14.1 feetperyear, Martinez 2009) in the area of Site No. 3, a large breach, approximately 250 feet wide, formed around the north end of the rock dike. The breach made the structure ineffective to the project goals and no longer feasible to maintain, in addition to becoming a navigational hazard. The purpose of this maintenance project was to degrade the structure to an elevation of -8.0 feet NAVD88 to remove any navigational hazard the weir may pose to boat traffic in the area. The construction was performed by Great Southern Dredging, Inc. Royal Engineers and Consultants, LLC. provided design, engineering, bidding and construction oversight services under the direction of CPRA. The project was completed in May 2011 at a total cost of $188,872.72 (Includes: construction, engineering & design, surveys, and administration costs).

August 2018 – the fifth maintenance event involved the demolition of the rock weir at Site No. 4 along the east shoreline of Four League Bay. As with the rock weir at Site No. 3, the erosion along the shoreline was slowly overtaking the structure and breaching around the rock weir was imminent, making the structure ineffective and a potential navigational hazard in the future. The purpose of the project was to remove the timber barricade system that was installed in 2004 and degrade the rock weir to an elevation below -8.0 feet NAVD88. LeBlanc Marine, LLC. was awarded the construction contract and began construction in August 2018. Engineering and bidding was performed in-house by the CPRA Thibodaux Regional Office. Construction was completed on August 19, 2018 at a total construction cost of $130,000(Lear 2014).

c. Budget Approvals and Estimated Final Expenditures

Original O&M Approved Budget:	$ 429,720
2006 Budget Increase:	$ 225,869
2008 Budget Increase:	$ 326,764
2009 budget Increase:	$ 915,192
Total Approved O&M Budget:	$1,897,545
Total Estimated CPRA Expenditures:	**$1,099,081**
Total Estimated Remaining O&M Funds:	**$ 789,464**

d. Conclusion

The final inspection of the Lake Chapeau (TE-26) Hydrologic Restoration and Marsh Creation project was conducted on May 25, 2016 with CPRA, NMFS and the landowner representative. It was determined that all of the rock weir features on the interior of the island appeared to be in good condition with no obvious settlement, displacement, or erosion. The only deficiencies noted during the inspection were the "bleaching" of the signage on the structures causing color contrast to fade and missing or corroded sheet metal caps on the timber piling. The signs and sheet metal caps on all of the structures were replaced in 2018 as part of a maintenance event that included several other projects. With the repairs of the signage, sheet metal caps, and the demolition of the Rock Weir at Site No.4, CPRA and NMFS agree that the project is currently in a satisfactory condition and project closeout procedures can proceed through CWPPRA.

III. Monitoring Activity

Pursuant to a CWPPRA Task Force decision on August 14, 2003 to adopt the Coastwide Reference Monitoring System-*Wetlands* (CRMS-*Wetlands*) for CWPPRA, updates were made to the TE-26 Monitoring Plan (Lear 2003) to merge it with CRMS-*Wetlands* and provide more useful information for modeling efforts and future project planning while maintaining the monitoring mandates of the Breaux Act. There are no CRMS sites located in the project area; however, nearby sites CRMS0293, CRMS0305, and CRMS0309 data collected June 2006 through December 2017 will be used as references.

a. Monitoring Goals

The objectives of the Lake Chapeau Sediment Input and Hydrologic Restoration, Point Au Fer Island (TE-26) project are to convert approximately 168 acres* (67.98 hectares) of open water to marsh at a mean elevation of 0.346 feet (0.105 meters) NAVD88 west of Lake Chapeau between the Locust Bayou and Alligator Bayou using sediment mined from Atchafalaya Bay, and to restore natural sediment and hydrologic pathways by plugging canals in the project area.

The following goals will contribute to the evaluation of the above objectives:

1. Create approximately 168 acres (67.98 hectares) of marsh west of Lake Chapeau.
2. Decrease the water level variability within the project area.

* The monitoring plan (Lear 2003) states a goal of 168 acres (67.98 hectares) of marsh creation; however, the polygon built for analyzing this data has an area of 193.6 acres (78.3 hectares). This polygon is used for land-water analysis and for the topographic survey in the marsh creation portion of the project. The polygon used is the fill area boundary in Figure 3, which uses the containment dikes and the marsh edge features built or used during construction.

b. Monitoring Elements

i. Habitat Mapping and Land Water

Color-infrared aerial photography (1:24,000 scale) was obtained for project and reference areas in order to document vegetated and non-vegetated areas, changes in vegetative community type, and submerged aquatic vegetation. The photography was photo-interpreted, scanned, mosaicked, geo-rectified, and analyzed by United States Geological Survey (USGS) Wetland and Aquatic Research Center (WARC) personnel according to the standard operating procedure described in Steyer et al. (1995, revised 2000). Photography was obtained pre-construction in 1994 and 1997 as well as post-construction in 2001, 2008, and 2016. Habitat mapping was conducted on the 1994, 1997, and 2001 photography for the project and reference areas. Land-water analysis was conducted on the fill area in the 1994 and 2001 photography. Based upon recommendations from the CRMS review, only a land-water analysis was conducted on the 2008 and 2016 photography. The 2008 photography replaced the 2010 photography and the 2016 photography replaced the 2015 photography and was the last in the series for this project (Appendix A).

For the CRMS-*Wetlands* sites land-water analysis was performed on a 1.0 km^2 (0.4 mi^2) grid, which encompassed each site. The USGS/WARC obtained 1.0 meter (3.3 feet) resolution color infrared (CIR) aerial photography to delineate land and water habitats over time. An aerial image was captured between October and November in 2005, 2008, 2012, and 2016 for each site (Appendix A). This image was analyzed, interpreted, processed, and verified for quality and accuracy using protocols established in Folse et al. (2018). Specifically, habitats in the 1 km^2 (0.4 mi^2) were condensed to a land or water classification. Land was considered a combination of emergent marsh, scrub-shrub, wetland forested, and upland habitats. The open water, beach/bar/flat, and submerged aquatics (SAV) habitat classes were considered water. Once grouped into these two classes, the percentage of land and water and the land to water ratio were calculated. After the analysis was complete, the classification data and the photomosaic were mapped to spatially view the data.

ii. Water Level

To monitor water level variability, two continuous recorders were located within the project area and one continuous recorder was located in each of the two reference sites (Figure 4). Data was collected using the Folse et al (2018) methodology. Water level was recorded hourly. Hourly water level has been monitored continuously prior to construction in 1997-1998 and after construction in 1999 through December 2017. The locations of two of the four continuous recorder stations have been adjusted based upon requests from the federal sponsor following the CRMS-*Wetlands* review, and for logistical reasons. Three CRMS-*Wetlands* sites (CRMS0293, CRMS0305, and CRMS0309) in the vicinity of the project will be used as references, since there are no *CRMS-Wetlands* sites inside the TE-26 project or reference boundaries (Figure 4).

iii. Salinity

This monitoring element is not one of the project goals; however, it is important ecologically in understanding the vegetative composition of the project's marshes over time. To monitor salinity variability, two continuous recorders were located within the project area and one continuous recorder was located in each of the two reference sites (Figure 4). Data was collected using the Folse et al (2018) methodology. Salinity was recorded hourly. Mean daily water salinity has been monitored continuously prior to construction in 1997-1998 and after construction in 1999 through December 2017. The locations of two of the four continuous recorder stations have been adjusted based upon requests from the federal sponsor following the CRMS-*Wetlands* review, and for logistical reasons. Three CRMS-*Wetlands* sites (CRMS0293, CRMS0305, and CRMS0309) in the vicinity of the project will be used as references, since there are no *CRMS-Wetlands* sites inside the TE-26 project or reference boundaries (Figure 4).

iv. Vegetation

Dredge placement in the project area was completed in February 1999; however, vegetative plantings were not part of the original project design. Upon final inspection of the dredge material disposal area in May 1999, NMFS and CPRA personnel noted very little natural recruitment of vegetation and recognized the need for plantings. CPRA monitoring personnel randomly selected five 2 x 2 meter plots on the fill area and seven 2 x 2 meter plots in the natural marsh adjacent to the fill area in the fall of 1999 to begin monitoring vegetation. As a result of the May 1999 inspection, a total of 46,980 *Spartina alterniflora* Loisel(smooth cordgrass) plugs were installed in April 2000 to establish vegetation on the exposed fill area (Figure 5).

Figure 4. Location map of project-specific and CRMS-Wetlands continuous hydrographic stations, for the Lake Chapeau Sediment Input and Hydrologic Restoration, Point Au Fer Island (TE-26) project.

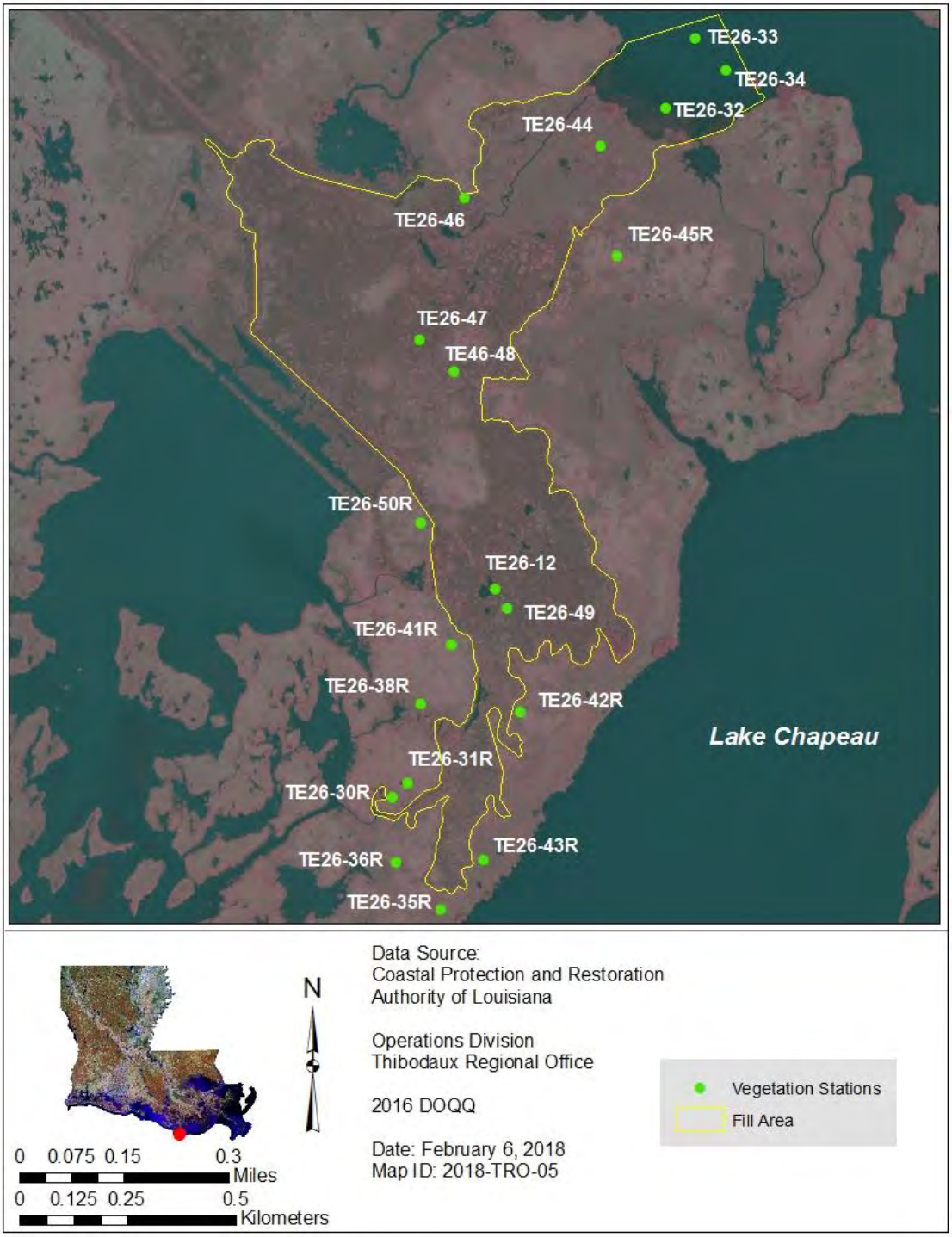

Figure 5. Vegetation Station locations for the Lake Chapeau Sediment Input and Hydrologic Restoration, Point Au Fer Island (TE-26) project.

Species composition and percent cover were documented using the Braun-Blanquet method (Steyer et al. 1995; revised 2000) inside of 12 randomly selected $4m^2$ plots to monitor the plantings (Figure 5). Seven reference plots and five project plots were sampled in 1999, 2001, 2004, 2007, 2008, 2010, 2013, and 2016 according to the standard operating procedure described in Folse et al. (2018). During the 2010 vegetation data collection period, five new project stations and five new reference stations were randomized in order to replace those with missing PVC corner poles and to increase the number of data collection stations for project monitoring.

The plots were evaluated in the late summer or early fall (from July 15 to September 15), prior to plant senescence. Each plot was marked with a PVC pole on the southeast corner to allow personnel to revisit them over time. The 2008 data collection period was not part of the original monitoring plan however, it was necessary to conduct damage assessment after hurricane Katrina's landfall. Final vegetative data collection occurred in October 2015. Three CRMS-*Wetlands* sites (CRMS0293, CRMS0305, and CRMS0309) in the vicinity of the project will be used as references, since there are no *CRMS-Wetlands* sites inside the TE-26 project or reference boundaries (Figure 4).

Vegetation data was collected in 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, and 2015 via the semi-quantitative Braun-Blanquet method (Mueller-Dombois and Ellenberg 1974; Sawyer and Keeler-Wolf 1995; Barbour et al. 1999). Plant species inside each $4m^2$ plot were identified, and ocular estimates of cover values estimated using Braun-Blanquet units (Mueller-Dombois and Ellenberg 1974). After sampling the plot, the residuals within a 5 meters (16 feet) radius were inventoried. The data were analyzed for relative cover.

During the 2015 vegetative data collection an additional 17 stations were sampled to help characterize the vegetation of the project area. These extra sites were located in the vicinity of the Chabreck and Linscombe samplings established in 1997 (Figure 6.)

v. Topographic and Bathymetric Elevation Surveys

Originally, the monitoring plan included collection of sediment staff gauge data for the dredge material fill area; however, the gauges were never installed so monitoring for this variable was replaced with topographic and bathymetric elevation surveys. To document elevation changes in the dredge material fill area, the dredge borrow area, and a portion of the Locust Bayou channel bottom where dredging occurred, topographic and bathymetric elevation surveys were conducted twice in 1999 (pre-construction and as-built), and again in 2004 (five years post-construction).

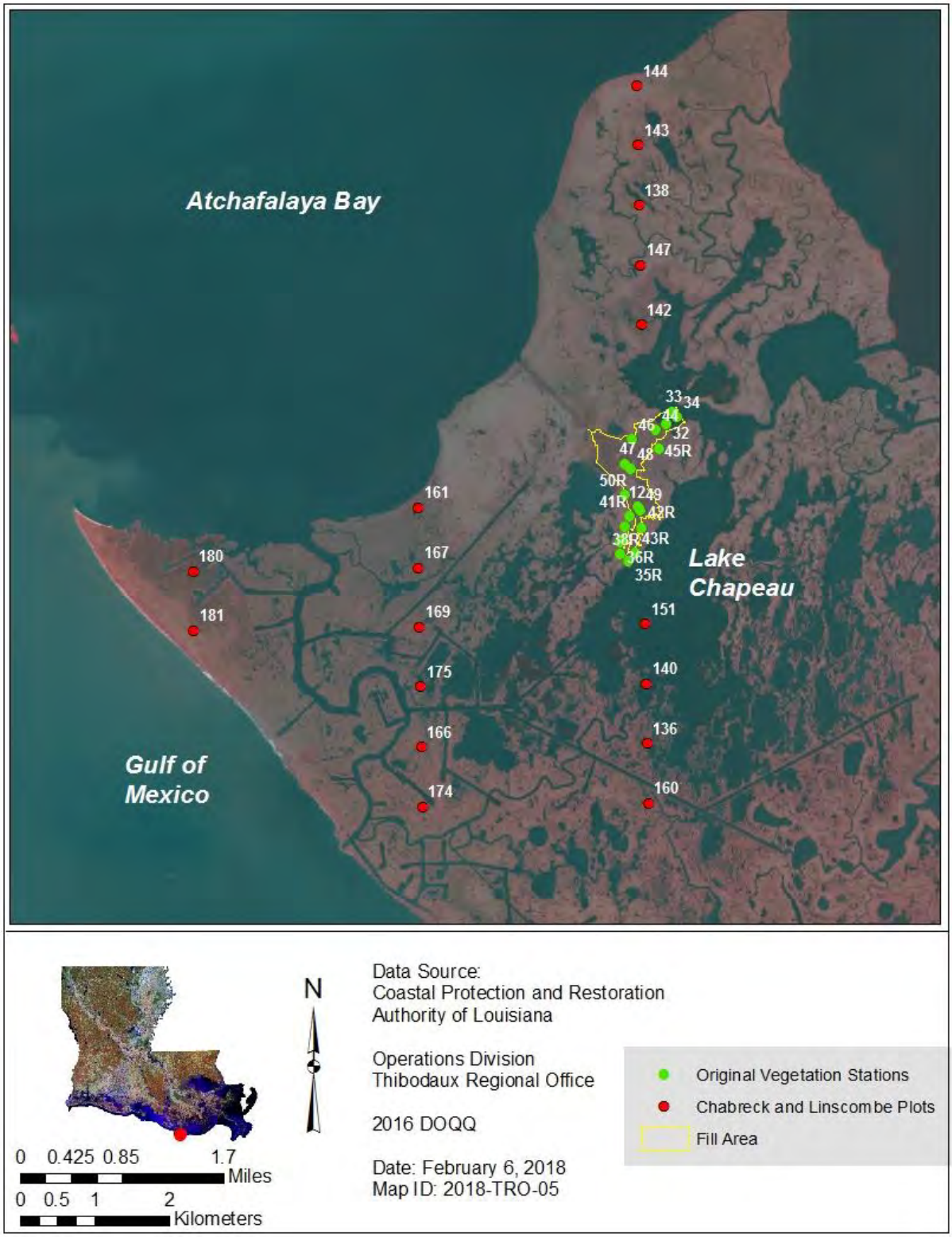

Figure 6. Additional vegetation station locations sampled during the fall 2015 sampling for the Lake Chapeau Sediment Input and Hydrologic Restoration, Point Au Fer Island (TE-26) project.

c. Monitoring Results and Discussion

i. Habitat Mapping and Land Water

The USGS/WARC personnel completed scanning, geo-rectification and production of photomosaics for aerial photography flown in 1994, 1997, 2001, 2008, and 2016 (Appendix A; Figures 1-5). Habitat analysis was conducted on the 1994, 1997, and 2001 photography and yielded pre-construction and post-construction acreages for the habitat classes found in the project and reference areas. Habitat analysis was replaced with land-water analysis for the 2008 and 2016 photography.

For this report, the 1994, 1997, and 2001 habitat classes were consolidated into land or water acreages using the Steyer et al. (1995 revised 2000) protocol so that comparisons could be made to the 2008 and 2016 land-water data in both the project and reference areas. Land was considered a combination of non-fresh marsh, upland barren, agriculture/range, upland scrub-shrub, urban, non-fresh wetland scrub-shrub, and fresh wetland scrub-shrub. The non-fresh mud flat and non-fresh open water habitat classes were considered water. Once grouped into land or water classes, the acreages of land and water for each year of photography were calculated. The annual change rates were calculated using the acreages, the number of days between photography and the number of days in a year (Tables 1-2).

Table 1. Land-water analysis inside the project area indicating change rates between each year of photography as well as the post-construction period.

	Project Change Rates ac/yr (ha/yr)				
Interval	**1994-1997**	**1997-2001**	**2001-2008**	**2008-2016**	**2001-2016**
Land	-61.8 (-25.0)	52.9 (21.4)	-66.8 (-27.03)	-2.25 (-0.9)	-31.4 (-12.7)

Table 2. Land-water analysis inside the reference areas indicating change rates between each year of photography as well as between the first and last year of photography.

	Reference Areas Land Change Rates ac/yr (ha/yr)				
Interval	**1994-1997**	**1997-2001**	**2001-2008**	**2008-2016**	**2001-2016**
Ref 1	-16.5 (-6.7)	1.7 (0.69)	-21.5 (-8.7)	-7.25 (-2.9)	-13.6 (-5.5)
Ref 2	-1.2 (-0.49)	-7.4 (-2.99)	-13.1 (-5.30)	-4.25 (-1.72)	-8.2 (-3.3)

Prior to construction in 1999, there was land to water conversion inside the project and reference areas from 1994 through 1997. Conversely, there was a substantial change from water to land in the project area between 1997 and 2001, primarily due to the creation of the fill area in May 1999. Reference area 1 also experienced a minimal land gain while reference area 2 continued to convert to open water (Tables 1 and 2). Between 2001 and 2008, then continuing in 2008 through 2016 the conversion of land to water was still apparent in all areas. The large declines in land area in the project and reference areas during the 2001-2008 interval (Tables 1 and 2) is likely a result of the intense and frequent hurricane activity that occurred in 2005 (Hurricanes Katrina and Rita) and 2008 (Hurricanes Gustav and Ike). For the 2008-2016 interval, land loss rates were considerably lower in all areas (Tables 1 and 2) and tropical storm activity was also reduced. Although the TE-26 project and reference areas experienced declines in land habitat during the post-construction period, the fill area shows minor signs of change (Appendix A Figure 5).

In addition to the USGS/WARC habitat and land-water analyzes, CPRA performed a land-water analysis for the fill area on the 1994 and 2001 photography. This analysis indicates that the acreage of land increased by 139.5 ac (56.5 ha) acres between 1994 and 2001, while the acreage of water correspondingly decreased (Appendix A; Figures 6-7). The increase can be attributed to the addition of dredge material.

ii. Water level

In addition to six project-specific stations, three nearby *CRMS-Wetlands* continuous recorder stations were established in 2006; CRMS0293-H01, CRMS0305-H01, and CRMS0309-H01. CRMS-*Wetlands* stations were used as reference stations for purposes of data analysis. Date range data collection histories for all recorders are shown in Table 3.

In this report, analysis will include continuous water level data from all project-specific and CRMS-*Wetlands* continuous recorders active from January 2007 through December 2015 (Table 3).

Table 3. Project-specific and CRMS-*Wetlands* continuous recorder stations data collection date range histories, for the Lake Chapeau Sediment Input and Hydrologic Restoration, Point Au Fer Island (TE-26) project.

Station	Data Collection Period
Project-Specific Stations	
TE26-01R	04/14/1997 - 1/27/2015
TE26-02R	04/24/1997 - 11/28/2007
TE26-03	04/24/1997 - 09/24/2008
TE26-05	01/20/1998 - 1/27/2015
TE26-06	02/08/2008 - 1/27/2015
TE26-07	02/12/2009 - 1/27/2015
CRMS-*Wetlands* Stations	
CRMS0293-H01	06/07/2006 - 12/05/2017
CRMS0305-H01	12/06/2006 - 12/05/2017
CRMS0309-H01	06/15/2006 - 12/05/2017

Since Stations TE26-02R and TE26-03 were deactivated on November 28, 2007 and September 24, 2008 respectively, data from January 1, 2007 up to these deactivation points are included. Stations TE26-06 and TE26-07 were activated on February 8, 2008 and February 12, 2009, respectively. All other stations were continuously active during the report period. Hourly readings were averaged over each day and these daily means were averaged to obtain weekly means (Figures 7-8). Analysis of weekly means minimizes variation due to diurnal tides that occur in the project area. Tidal cycles often span more than one day; consequently, analyzing data on a daily basis does not account for the tidal cycle. Sites were split into two groupings based on geographical proximity, an East group (Group 1) and a South group (Group 2). Group 1 included stations TE26-01R, TE26-06, and CRMS0305-H01. Group 2 included stations TE26-02R, TE26-03, TE26-05, TE26-07, CRMS0293-H01, and CRMS0309-H01. Tukey's tests were performed on each group to determine differences in the mean water levels for all possible pairwise comparisons.

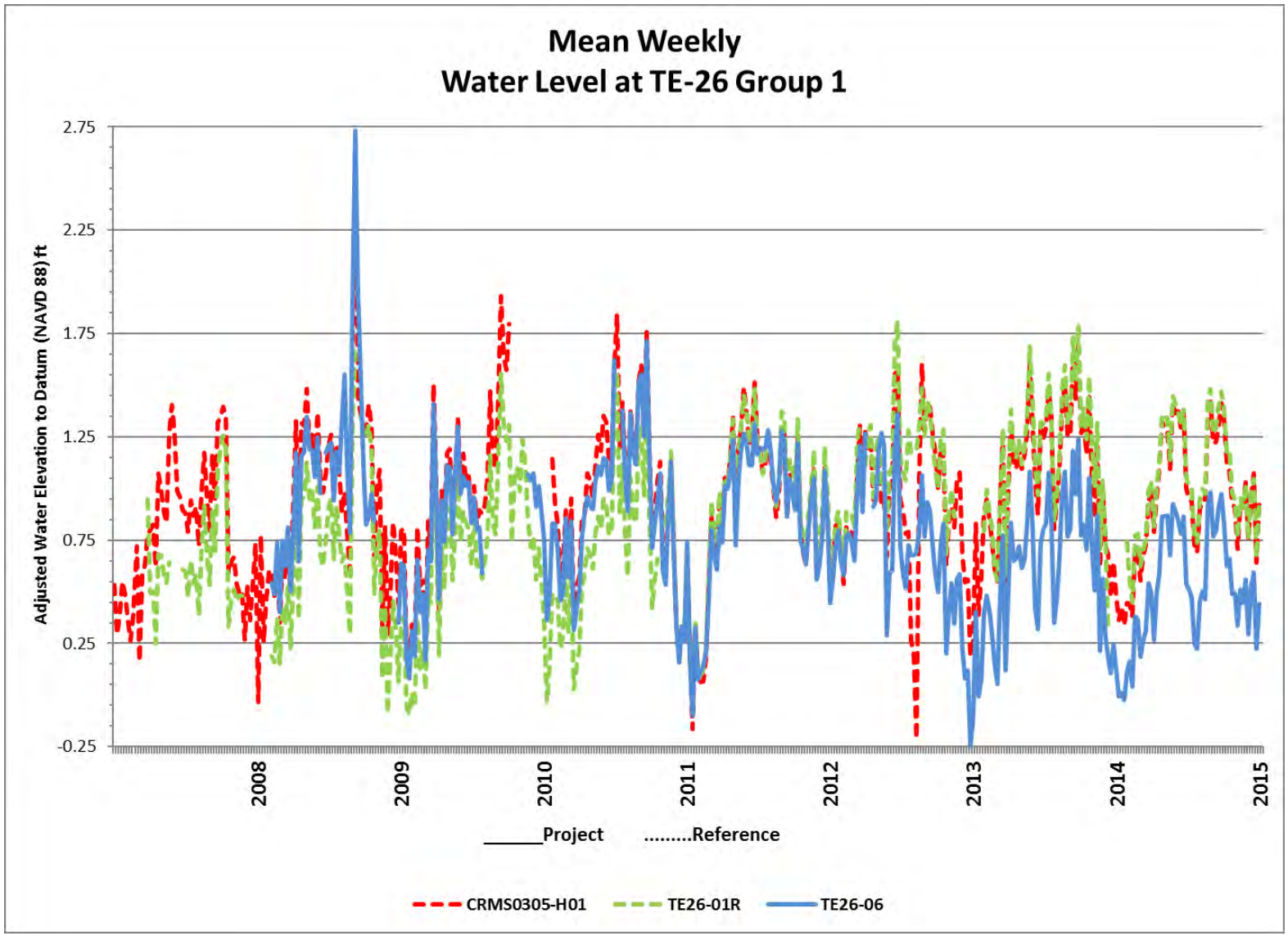

Figure 7. Comparative mean weekly water levels for project-specific and reference continuous recorders, as well as the CRMS-*Wetlands* reference continuous recorder in data analysis group 1. For the Lake Chapeau Sediment Input and Hydrologic Restoration, Point Au Fer Island (TE-26) project.

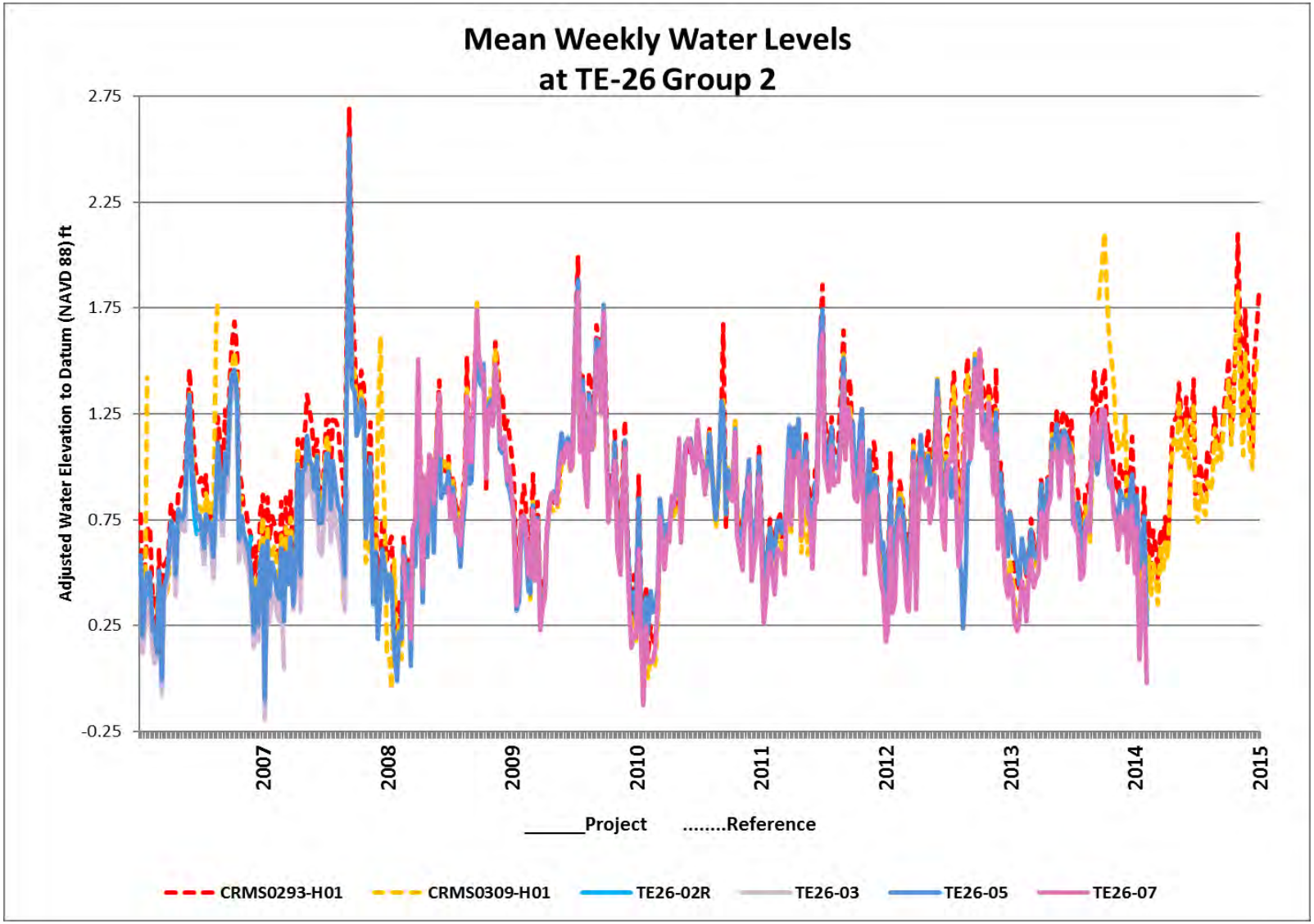

Figure 8. Comparative mean weekly water levels for project-specific and reference continuous recorders, as well as the CRMS-*Wetlands* reference continuous recorders in data analysis group 2. For the Lake Chapeau Sediment Input and Hydrologic Restoration

Within Group 1, mean water level was significantly different (P<0.05) for all three pairwise comparisons of stations. The CRMS-*Wetlands* site CRMS305-H01 had the highest average water level, followed by project site TE26-01R which was 0.13 feet lower. Compared with reference site TE26-01R, the average water level difference was smaller than CRMS305-H01 but greater than TE26-06; CRMS0305-H01 was on average significantly higher by 0.13 feet, while TE26-06 was significantly lower by 0.12 feet. The project stations were significantly different (P<0.05) from each other.

Within Group 2 mean water level was significantly different for all of the fifteen pairwise comparisons. CRMS0293-H01 had mean water levels significantly higher (P<0.05) than all of the project stations (range: 0.06 - 0.4 feet). It also exceeded the CRMS0309-H01 mean water level by 0.06 feet, and it was significantly higher (P>0.05). Mean water levels for CRMS0309-H01 were significantly higher (P<0.05) than all project stations (range: 0.09 feet - 0.34 feet). Stations TE26-05 and TE26-07 had significantly higher (P<0.05) mean water levels than TE26-02R and TE26-03 (range: 0.01-0.24 feet). Based upon this analysis, mean water levels ranked from highest to lowest as follows; CRMS0293, CRMS0309, TE26-05, TE26-07, TE26-02R, and TE26-03.

iii. Salinity

Station locations and data collection durations for salinity data are the same as those presented under the "Water Level" data collection section of this report (Figure 4 and Table 3). The same CRMS-*Wetlands* continuous recorder stations used to collect water level data were used to collect salinity data.

Results presented in the 2007 OM&M report for this project included data collected from the four original project-specific continuous recorders for the time period from April 1997 through December 2006 (Lear et all 2007). Continuous recorder hourly data was analyzed for mean weekly salinity, which was adjusted for biofouling and hourly salinity variation.

In this report, analysis includes adjusted salinity data from all project-specific and CRMS-*Wetlands* continuous recorders active from January 2007 through December 2015 (Table 3; Figures 9-10). Hourly readings were averaged over each day and these daily means were averaged to obtain weekly means. The use of average weekly means helped to reduce the effects of diurnal tides. Sites were split into two groupings based on geographical proximity, an East group (Group 1) and a South group (Group 2). Group 1 included stations TE26-01R, TE26-06, and CRMS0305-H01. Group 2 included stations TE26-02R, TE26-03, TE26-05, TE26-07, CRMS0293-H01, and CRMS0309-H01. Tukey's tests were performed on each group to determine differences in the mean salinities for all possible pairwise comparisons.

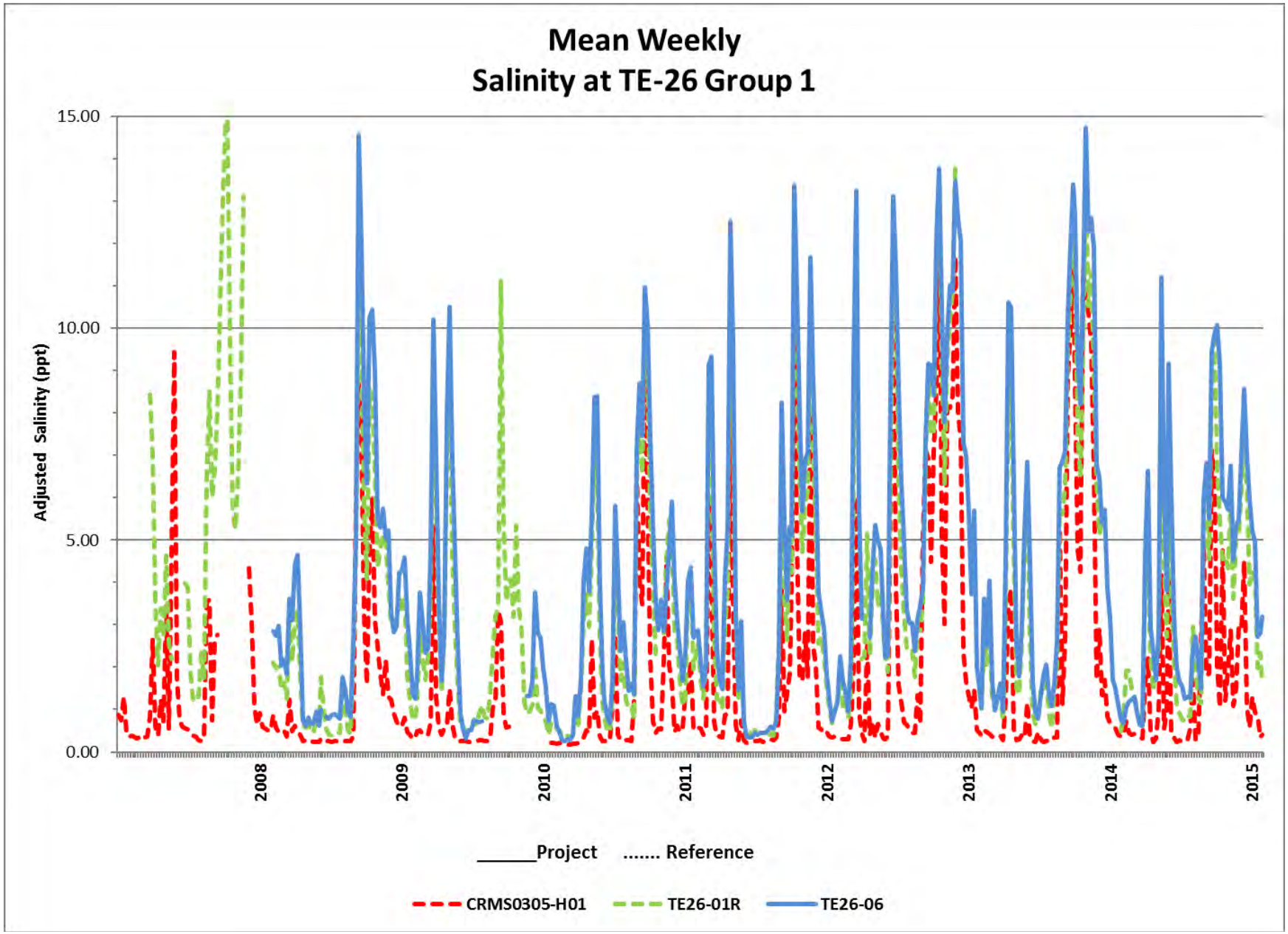

Figure 9. Comparative mean weekly salinities for project-specific and reference continuous recorders, as well as the CRMS reference continuous recorder in data analysis group 1. For the Lake Chapeau Sediment Input and Hydrologic Restoration

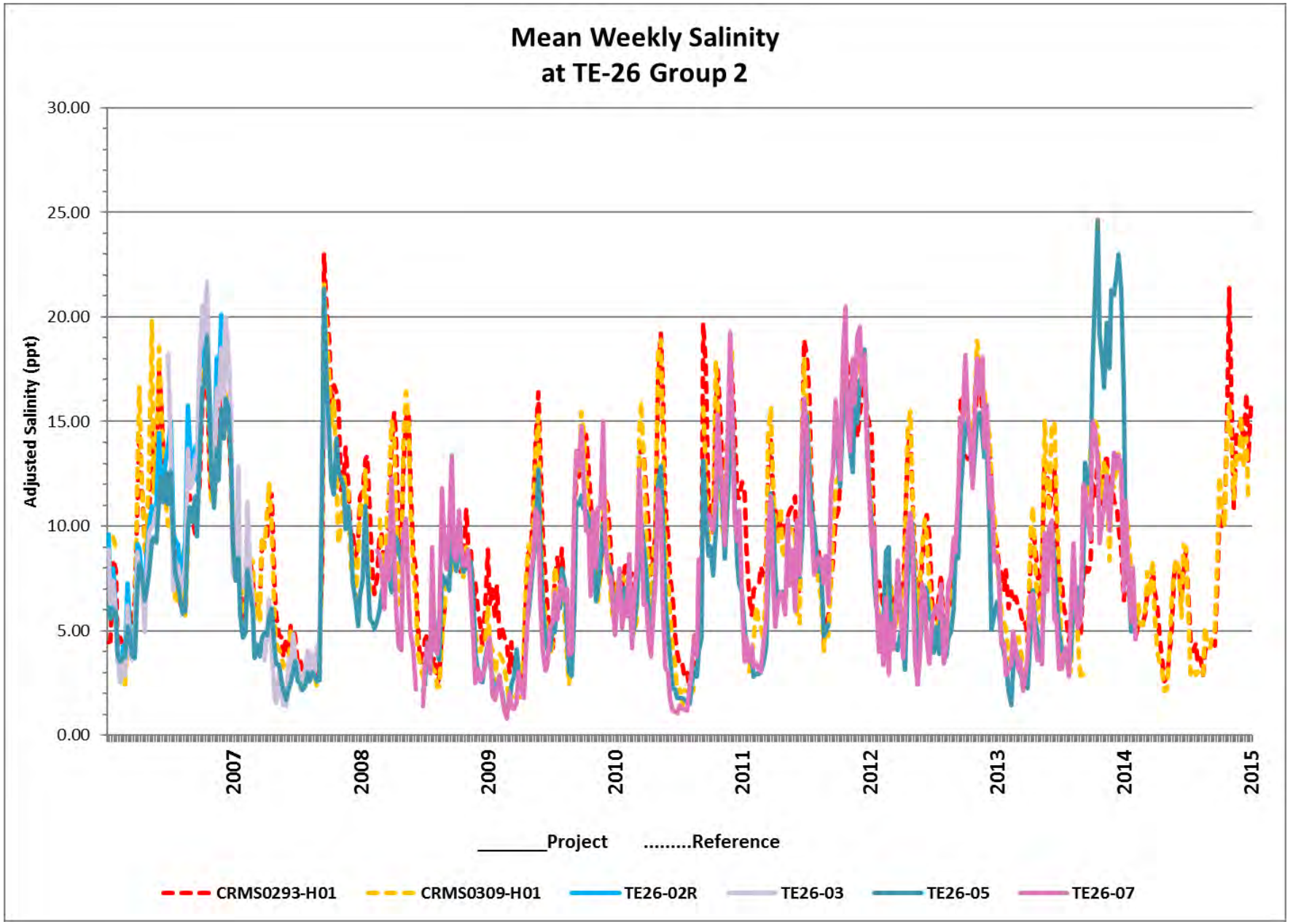

Figure 10. Comparative mean weekly salinities for project-specific and reference continuous recorders, as well as the CRMS reference continuous recorders in data analysis group 2. For the Lake Chapeau Sediment Input and Hydrologic Restoration.

Significant variation was present among the sites in both Group 1 ($p<10^{-16}$) and Group 2 ($p<10^{-10}$) for mean weekly salinity. Within Group 1 salinity was significantly different for all of the three pairwise comparisons. Both the TE-26 reference site (TE26-01R) and project site (TE26-06) were significantly more saline than the CRMS305-H01 reference site (on average 1.8 and 2.5 ppt greater, respectively). In contrast, the two TE-26 sites were similar, but not significantly so, with the project site TE26-06 having a slightly higher salinity than the reference site TE26-01R (on average 0.6 ppt).

Within Group 2 mean adjusted salinity differences were significant for fourteen of the fifteen pairwise comparisons between stations. The project reference station TE26-02R had the highest mean salinities compared with all other sites (range of differences: 1.5 - 2.9 ppt). Site TE26-07 had lower mean salinities than all other sites (range of differences: 0.06 - 2.9 ppt). Those differences were significant except for TE26-05. Project site TE26-03 fell somewhat it the middle with mean salinities significantly greater than TE26-05 and TE26-07 (range of differences: 0.60 and 0.66 ppt, respectively), and significantly lower than CRMS0293 and CRMS0309 (range of differences: 0.71 and 0.26 ppt respectively). Based upon this analysis, the sites ranked from highest mean salinity to lowest as follows; TE26-02R, CRMS0293, CRMS0309, TE26-03, TE26-05, and TE26-07.

As with water levels, salinities are yet another important ecological component which has contributed to the success of the marshes in the dredge material fill area and its immediate surroundings. Based upon the vegetation analysis in section c. iv. of this report, the mean cover and species composition constitutes what is representative of healthy, low-salinity intermediate to brackish marshes in the coastal zone of Louisiana as described by Chabreck, Linscombe, and Visser in Mac et al. (1998).

iv. Vegetation

Project-specific vegetation data were collected during the fall of 1999, 2001, 2004, 2007, 2008, 2010, 2013 and 2015 inside and adjacent to the fill area. The data were analyzed for mean cover (Figure 11).

The 1999 vegetation sampling did not find vegetation within the project area plots. The reference plots outside of the fill area were dominated by *Spartina patens* (Figure 11). By 2001, two growing seasons post-planting, mean percent cover of the planted species *S. alterniflora* had reached 100% in the project plots and it was the only species present. By comparison, the reference area plots showed substantial natural recruitment of the planted species. The mean percent cover of *S. alterniflora* decreased by 2007 in both the fill area and reference area plots but rebounded by 2008, and though *S. patens* was the dominant species in the reference area it was still absent from the adjoining fill area altogether (Figure 11). *S. patens* and *Distichlis. spicata* were found in the fill area plots in 2010, which indicated natural recruitment of species from the surrounding reference area marsh. Combined mean cover of all species in both the fill area and reference area plots increased in 2010, though the mean cover for the planted species decreased.

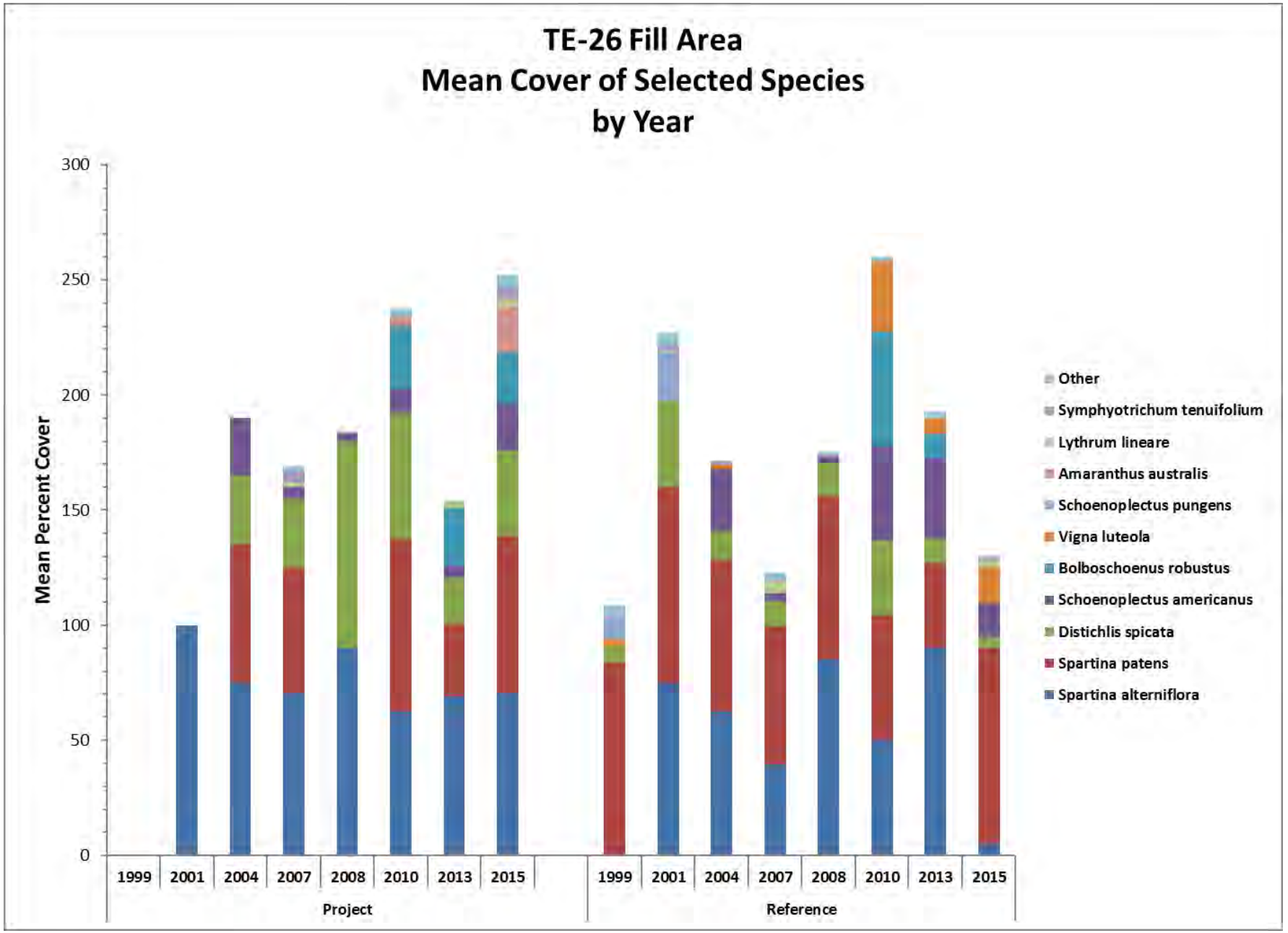

Figure 11. Mean percent cover for selected species to date, inside of project and reference 4 m^2 Braun-Blanquet vegetation plots. For the Lake Chapeau Sediment Input and Hydrologic Restoration, Point Au Fer Island (TE-26) project.

In 2013, twelve growing seasons post-planting, *S. alterniflora* remained the dominant species in the fill area. In addition, diversity increased in the fill area in 2013. Also, by 2013 the planted species had spread into all reference plots and experienced its highest mean cover than in all previous years of sampling (Figure 11).

In 2015 (15 growing seasons past planting) and the last project vegetation sampling *S. alterniflora* remained dominant but the diversity and mean percent cover increased in the fill area. Although present in the reference area, *S. alterniflora* cover drastically declined while *S. patens* expanded its coverage in the reference area (Figure 11).

v. Topographic and Bathymetric Elevation Surveys

Elevation data from the topographic and bathymetric surveys taken in 1999 (pre-construction and as-built) by River Road Construction, Inc. were adjusted to the post-construction survey taken in 2004 by Acadian Engineers and Environmental Consultants, Inc. The data was entered into ArcMap® version 9.1 where grids were created for the borrow area, the fill area, and the Locust Bayou dredge channel. Elevation statistics were calculated from the grids for the areas inside the boundary polygons. Contour elevation maps were created in ArcViewGIS® version 3.2 and placed in Appendix C of the 2011 OM&M report. Change grids were produced in ArcViewGIS® version 3.2 by subtracting the contour grids produced in ArcMap® version 9.1. Elevation statistics were calculated from these change grids for the areas inside the boundary polygons and elevation change maps were produced in ArcViewGIS® version 3.2 (Lear et all 2011).

IV. Conclusions

a. Project effectiveness

The habitat, land-water, vegetation, and elevation data presented reveal that the goal to create 168 acres (67.98 hectares) of marsh at a target elevation of 0.346 feet (0.105 meters) NAVD88 was partially realized. Only 139.5 acres (56.5 hectares) of marsh were created in the fill area, primarily due to the northeast corner of the fill area remaining subaqueous. However, the marsh that was created has resisted erosion and remains considerably above the target elevation. Though the dominant species in the created marsh is the planted species *Spartina alterniflora*, the diversity has increased with the introduction of additional species from the surrounding natural marshes, and vegetation cover continues to be robust and sustainable these sixteen years post-construction. The acreage created in the fill area may have created enough of a hydrologic separation of the Alligator Bayou and Locust Bayou to restore the historical hydrology; however, this remains inconclusive.

Between January 2007 and December 2015 the project stations were significantly different ($P<0.05$) from each other in both mean weekly water level and salinity variation. They were also significantly different ($P<0.05$) from the surrounding CRMS-*Wetlands* stations. The exception to this were TE26-05 and TE26-07 experienced similar mean weekly salinities. The

differences could be attributed to freshwater influx from the Atchafalaya River and tidal influences from the Gulf of Mexico due to the distances between stations. While the majority of stations were significantly different ($P<0.05$), the differences in average water level were relatively minor and likely due to the strong statistical power resulting from the large number of observations. Therefore, at this time it appears that the structures are not meeting the goal of reducing variability in the water level elevations. From an ecological standpoint, the water levels and salinities have maintained the fill area marshes and the adjacent natural marshes as healthy intermediate-brackish low-salinity marshes.

The installation of *S. alterniflora* proved beneficial and effective in establishing rapid vegetative cover on the created marsh platform. The 1999 as-built vegetation data indicated an absence of vegetation in the marsh creation area; however in 2015, sixteen years after planting, mean percent cover was approximately 85% and several species were present where the elevation was conducive for plant growth. Conversely, those areas that did not increase in elevation or meet the target elevation have no emergent vegetative growth, as evidenced at TE26-32, TE26-33, and TE26-34 where they remain in open water.

b. Monitoring Lessons Learned

- The budget should have included money for surveying the marsh creation and borrow area to conclusively determine if the target elevation was met. Surveying Locust Bayou would indicate how long the channel maintained the target depth, which was dredged to restore the historic hydrology of the area.
- Hourly continuous recorders were placed south (outside) of the weirs. Placing the recorders inside of the weirs and some distance away would have provided a more definitive answer about project effectiveness as it relates to the hydrology portion of the project.
- In order to accurately determine if the project has altered flow patterns to a more natural state, the proper instrumentation should have been deployed prior to construction and after construction. Flow meters would better determine the change in hydrology along with continuous water level recorders. The information from both instruments would have been used for a hydrologic model.
- CRMS stations or CRMS like stations inside of the project area would have made for a more robust comparison to the CRMS stations located outside of the project area and across the CRMS network.

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Appendix A
(Habitat and Land-Water Maps)

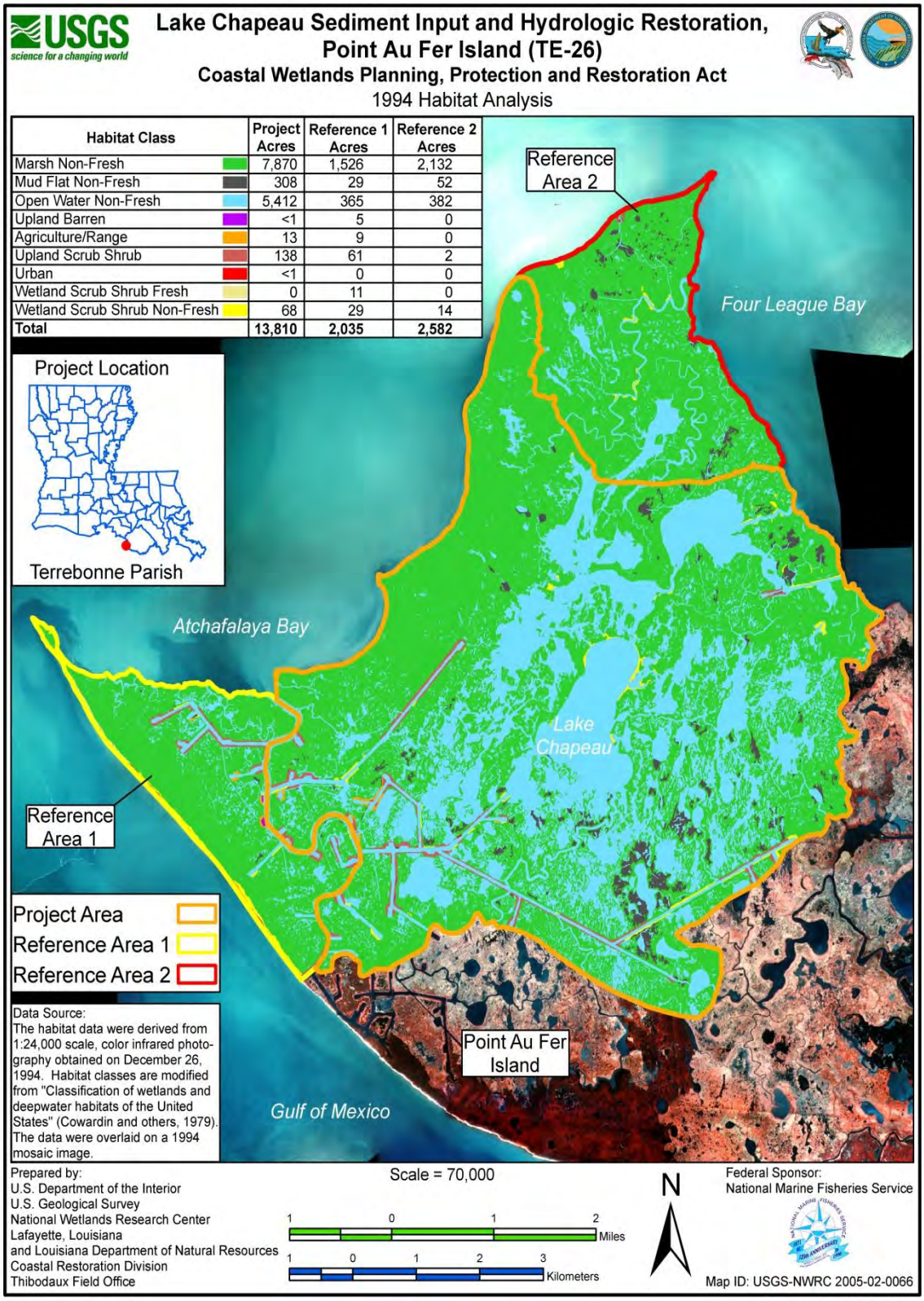


Figure 1. 1994 habitat analysis map of the TE-26 project and reference areas.

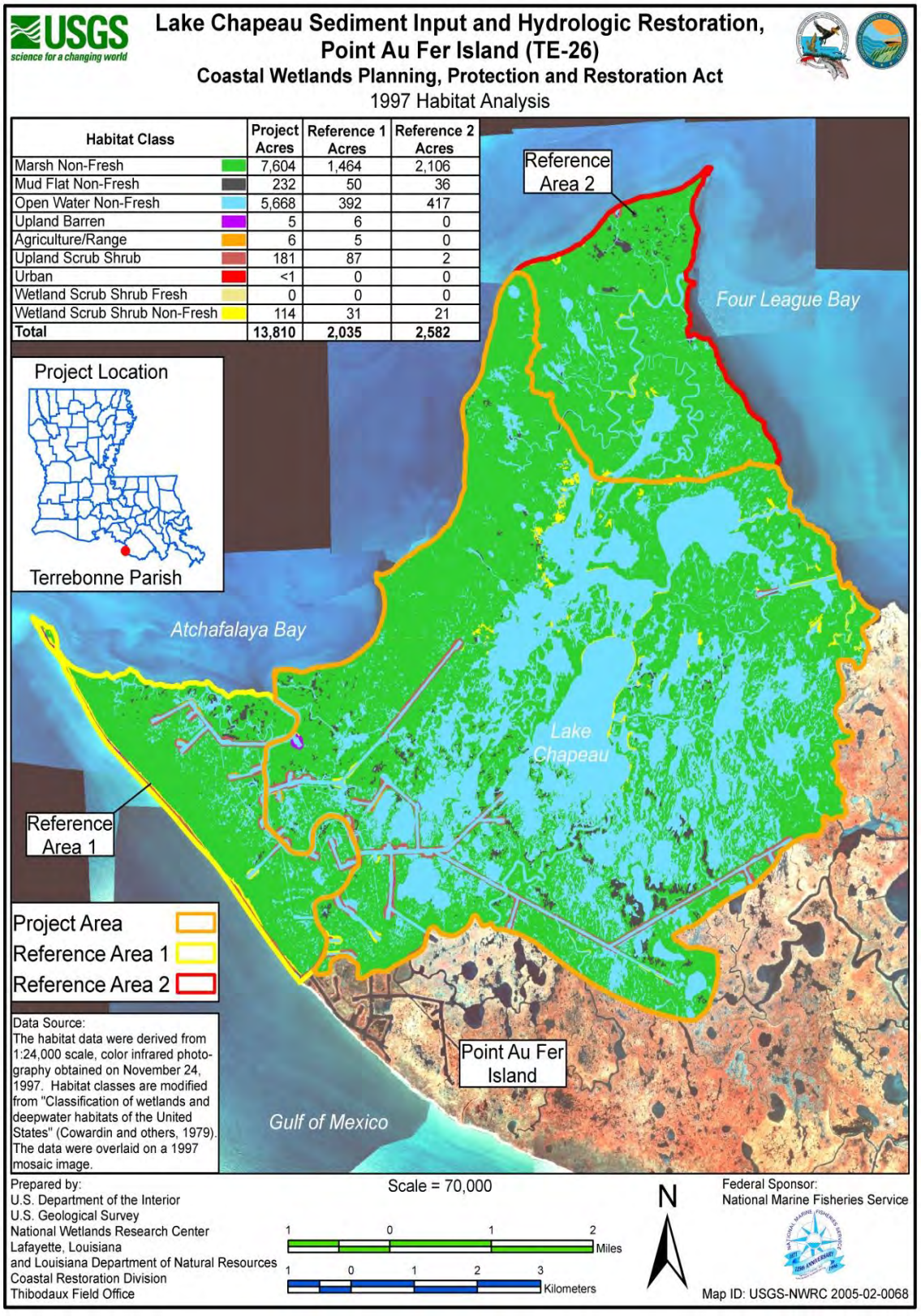


Figure 2. 1997 habitat analysis map of the TE-26 project and reference areas.

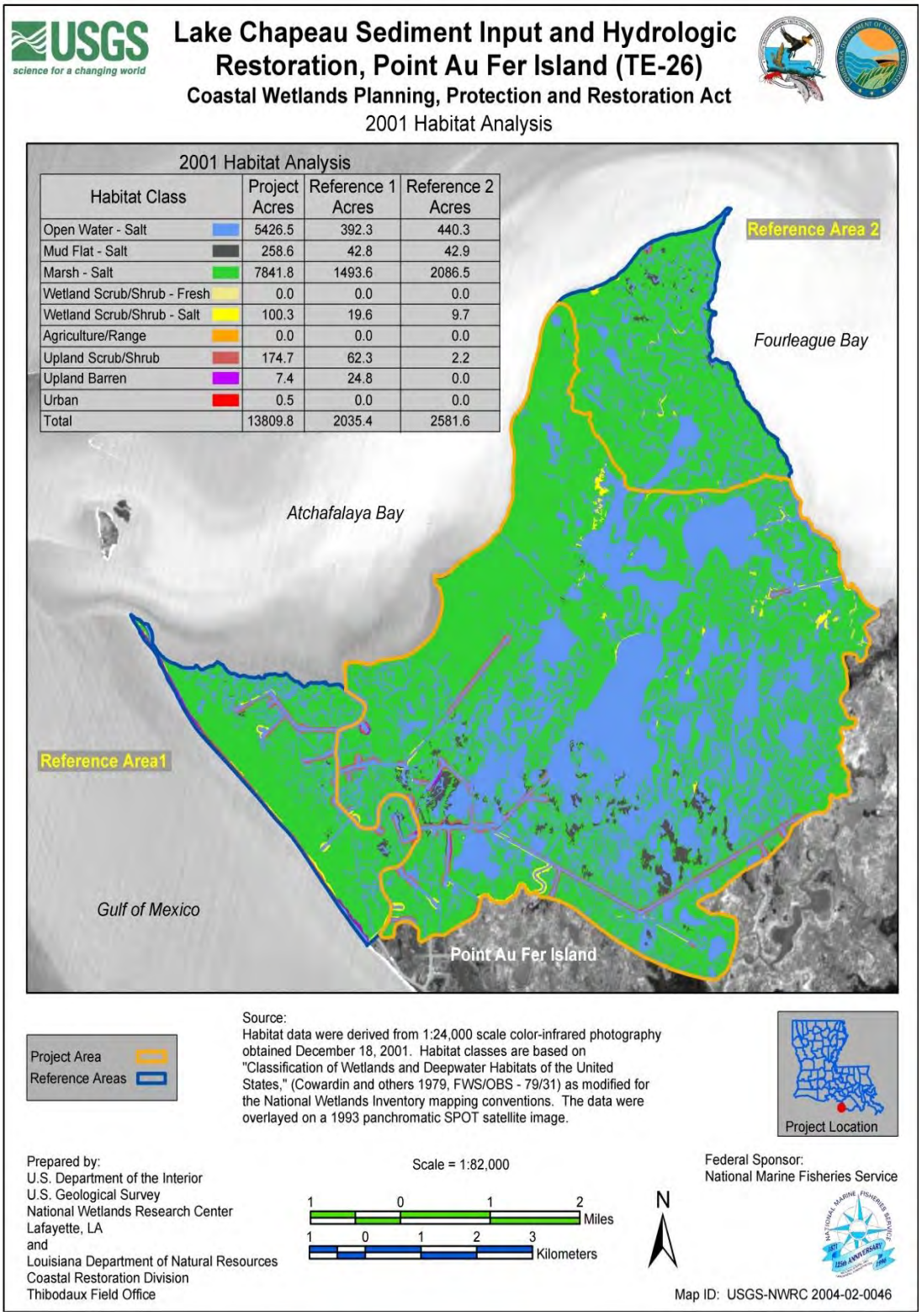


Figure 3. 2001 habitat analysis map of the TE-26 project and reference areas.

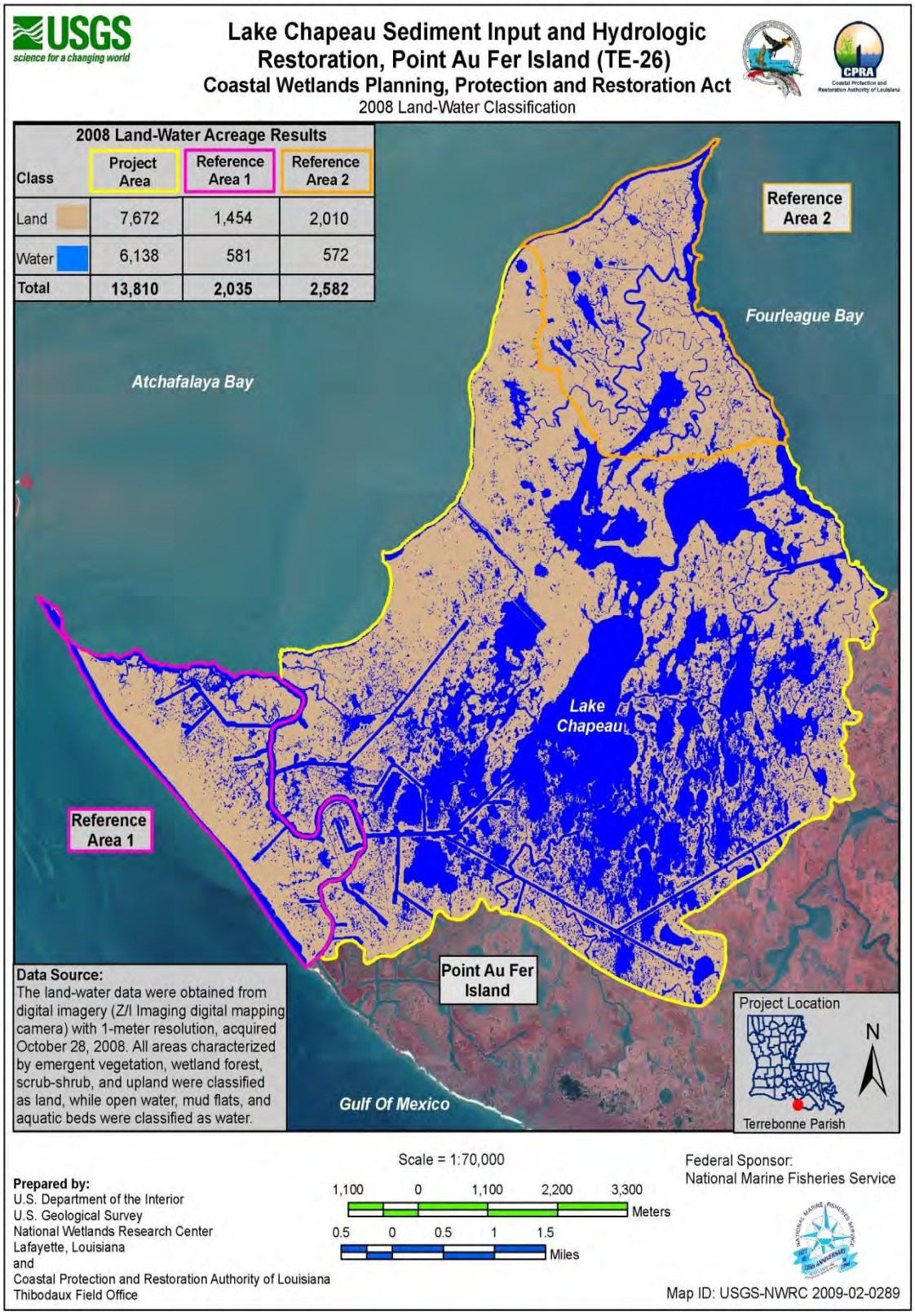


Figure 4. 2008 land-water analysis map of the TE-26 project and reference areas.

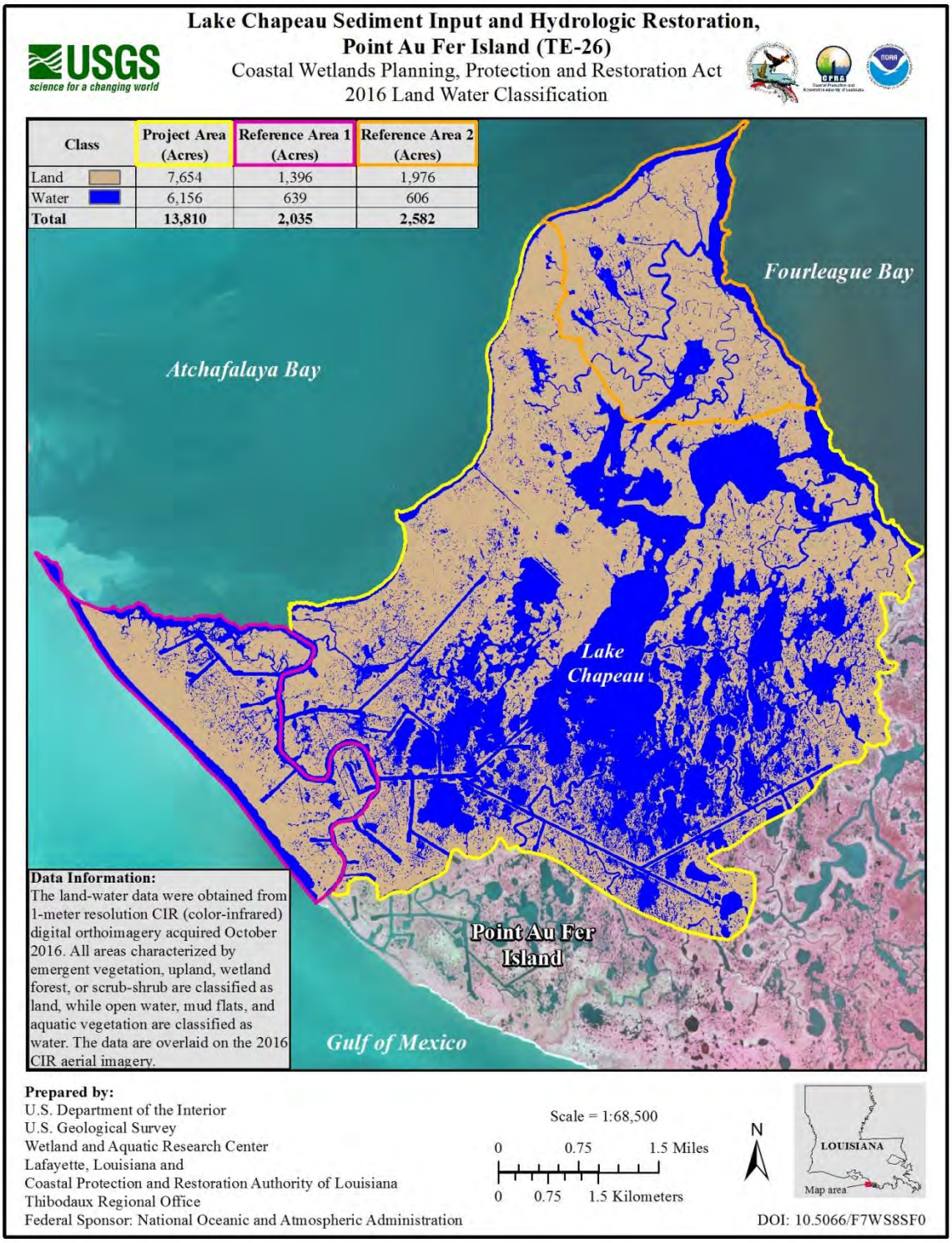
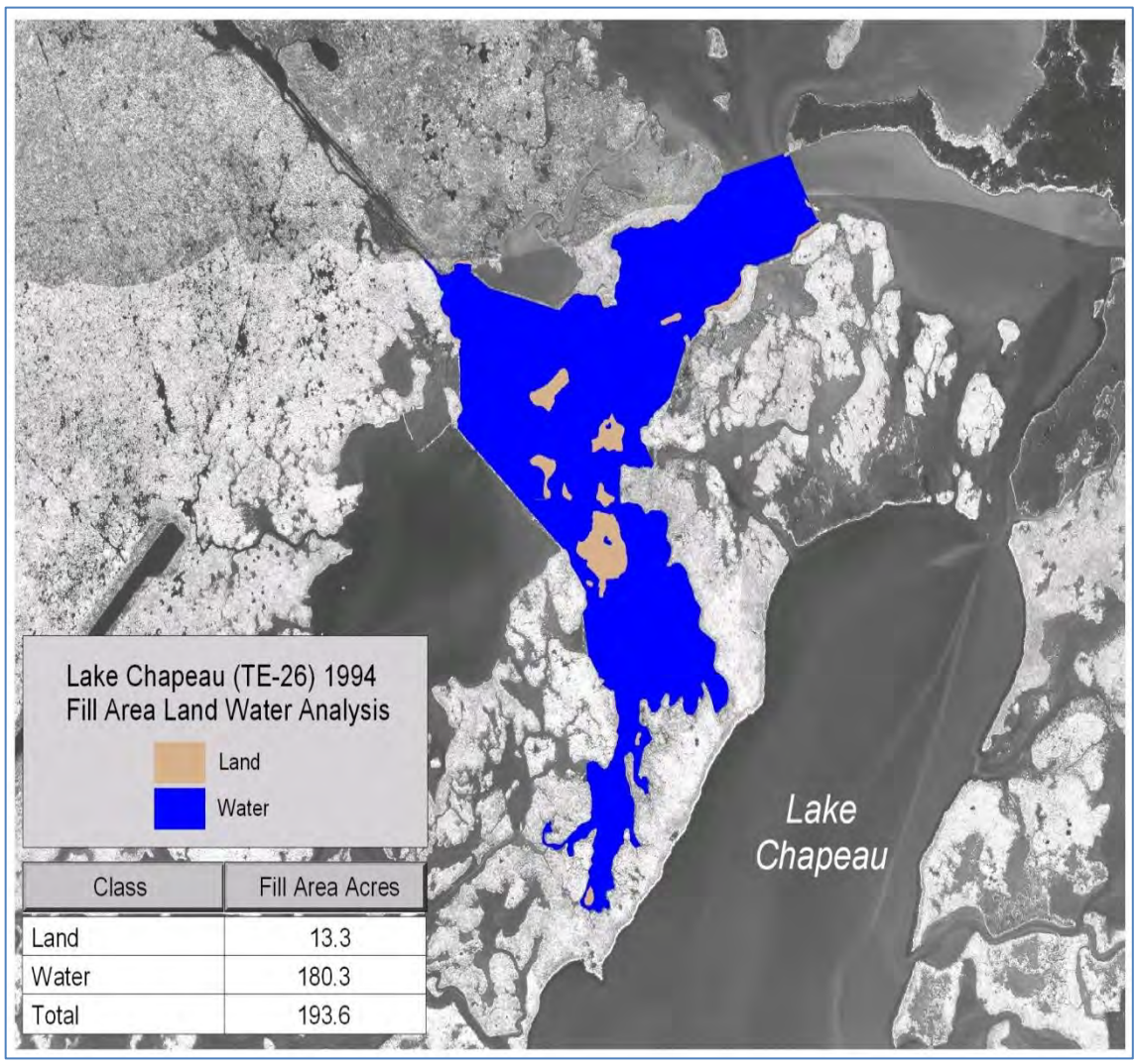
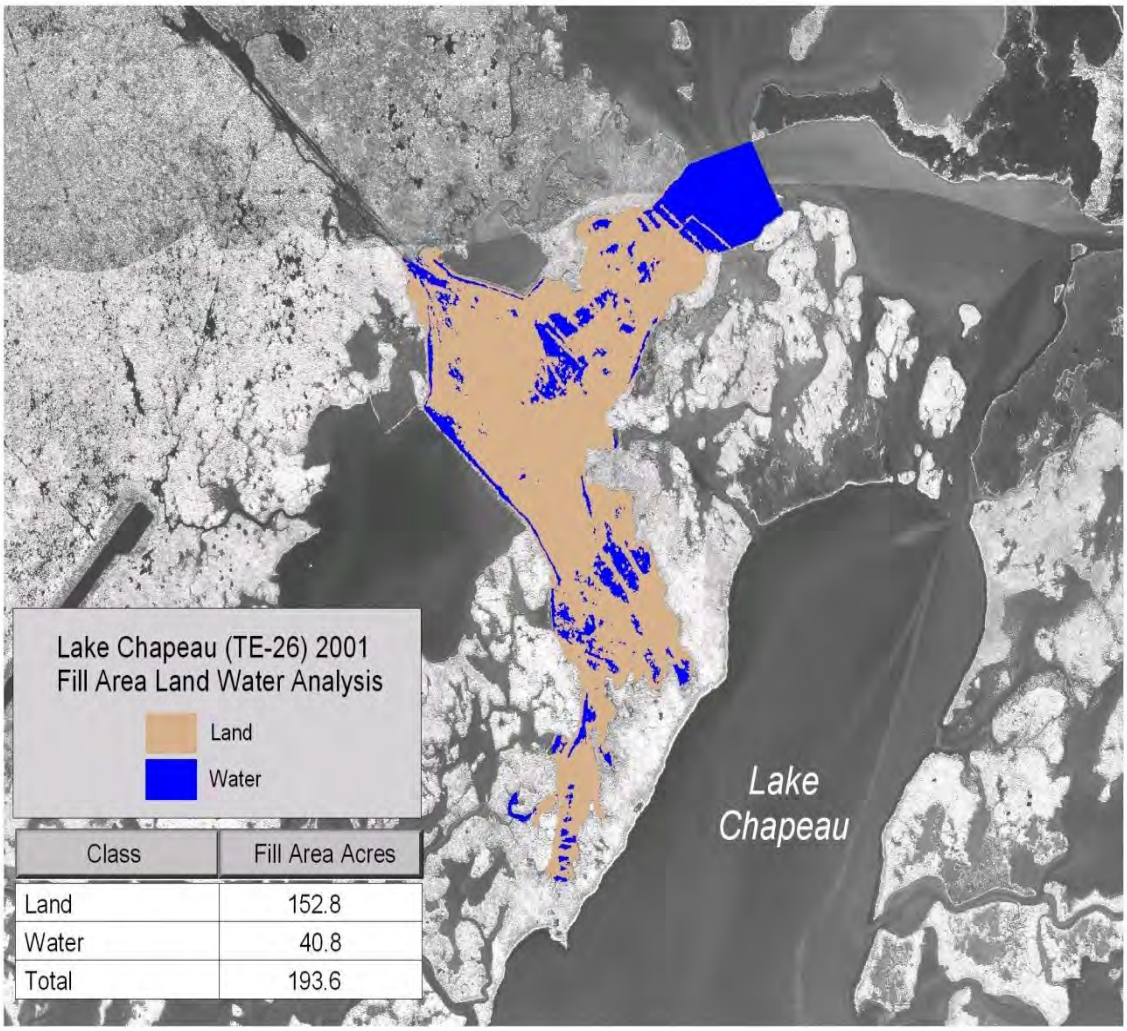


Figure 5. 2016 land-water analysis map of the TE-26 project and reference areas.



Class	Fill Area Acres
Land	13.3
Water	180.3
Total	193.6

Figure 6. 1994 land-water analysis map of the TE-26 fill area.



Class	Fill Area Acres
Land	152.8
Water	40.8
Total	193.6

Figure 7. 2001 land-water analysis map of the TE-26 fill area.

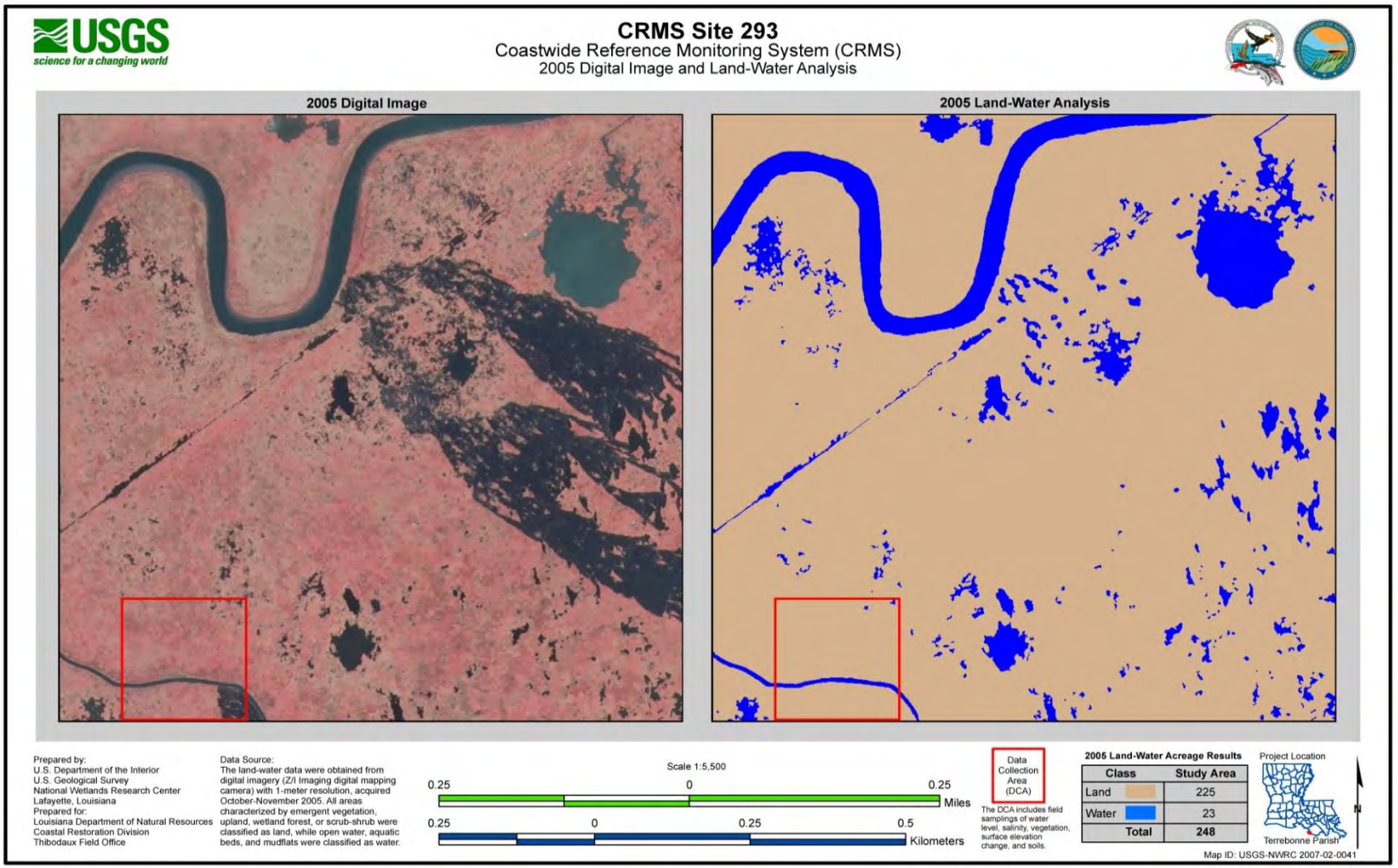


Figure 8. 2005 land-water analysis map for CRMS-Wetlands site CRMS0293 located in the southeast portion of Point Au Fer Island.

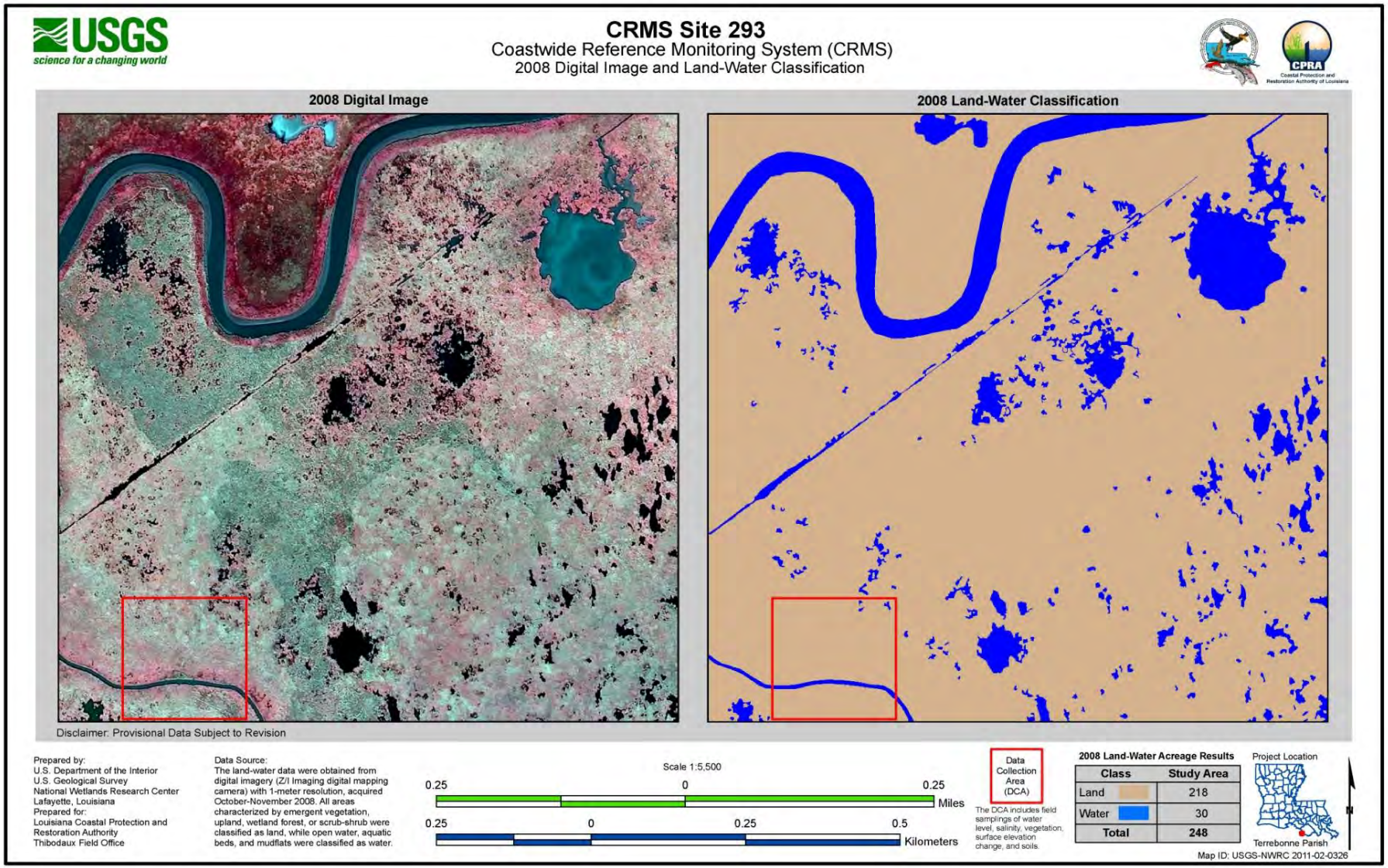


Figure 9. 2008 land-water map of the CRMS-*Wetlands* site CRMS0293 located in the southeast portion of Point Au Fer Island.

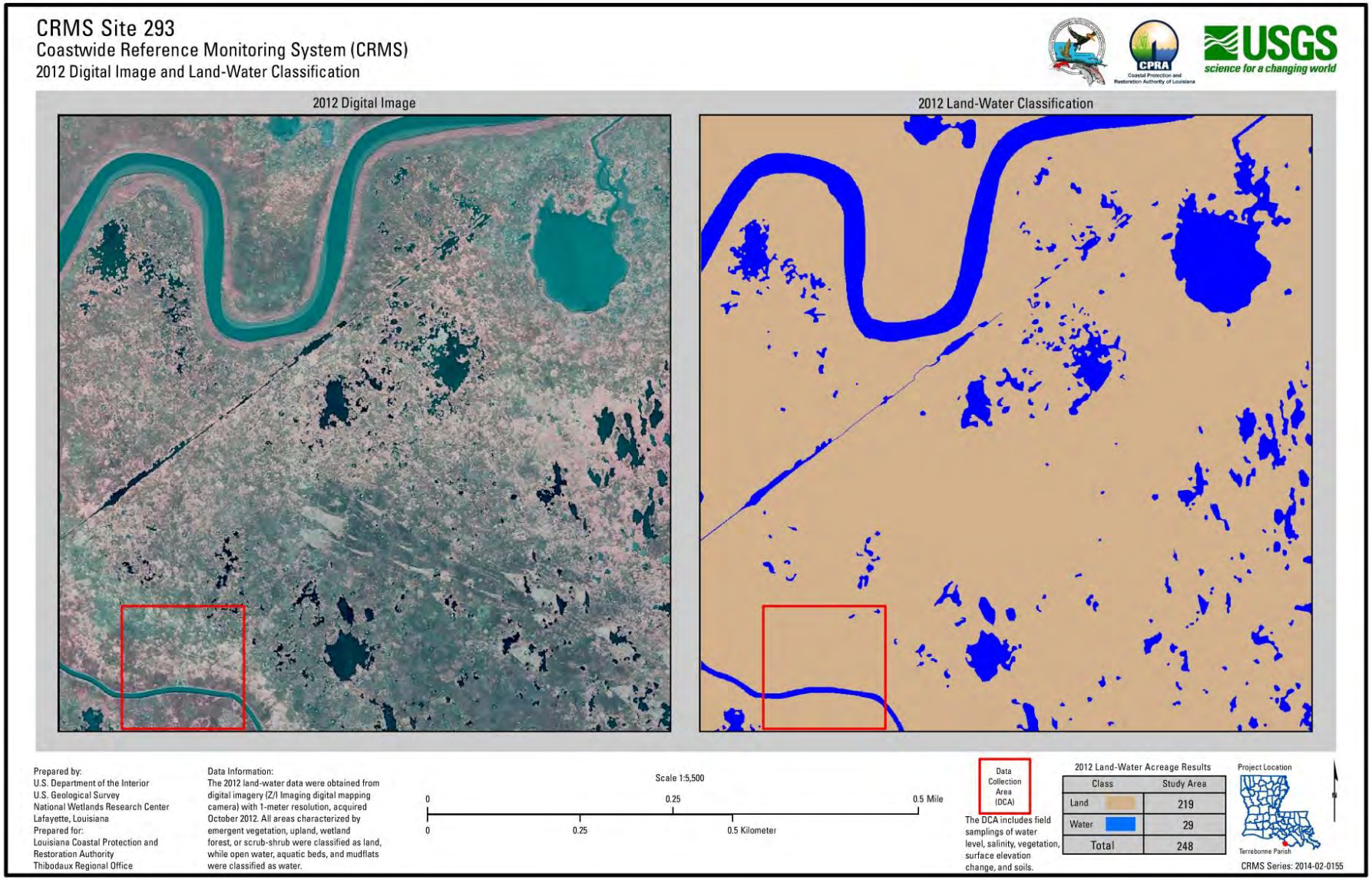


Figure 10. 2012 land-water map of the CRMS-Wetlands site CRMS0293 located in the southeast portion of Point Au Fer Island.

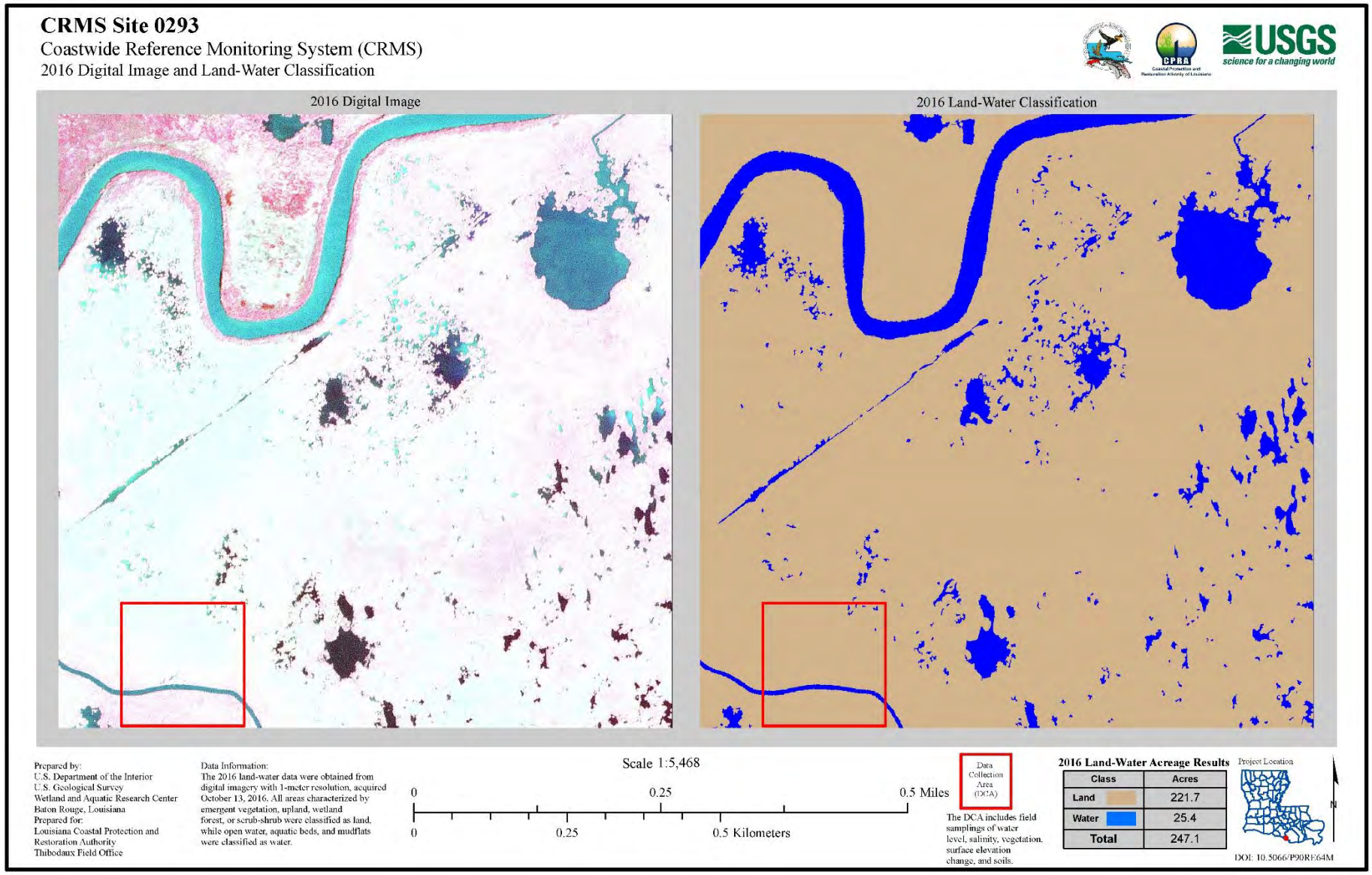


Figure 11. 2016 land-water map of the CRMS-Wetlands site CRMS0293 located in the southeast portion of Point Au Fer Island

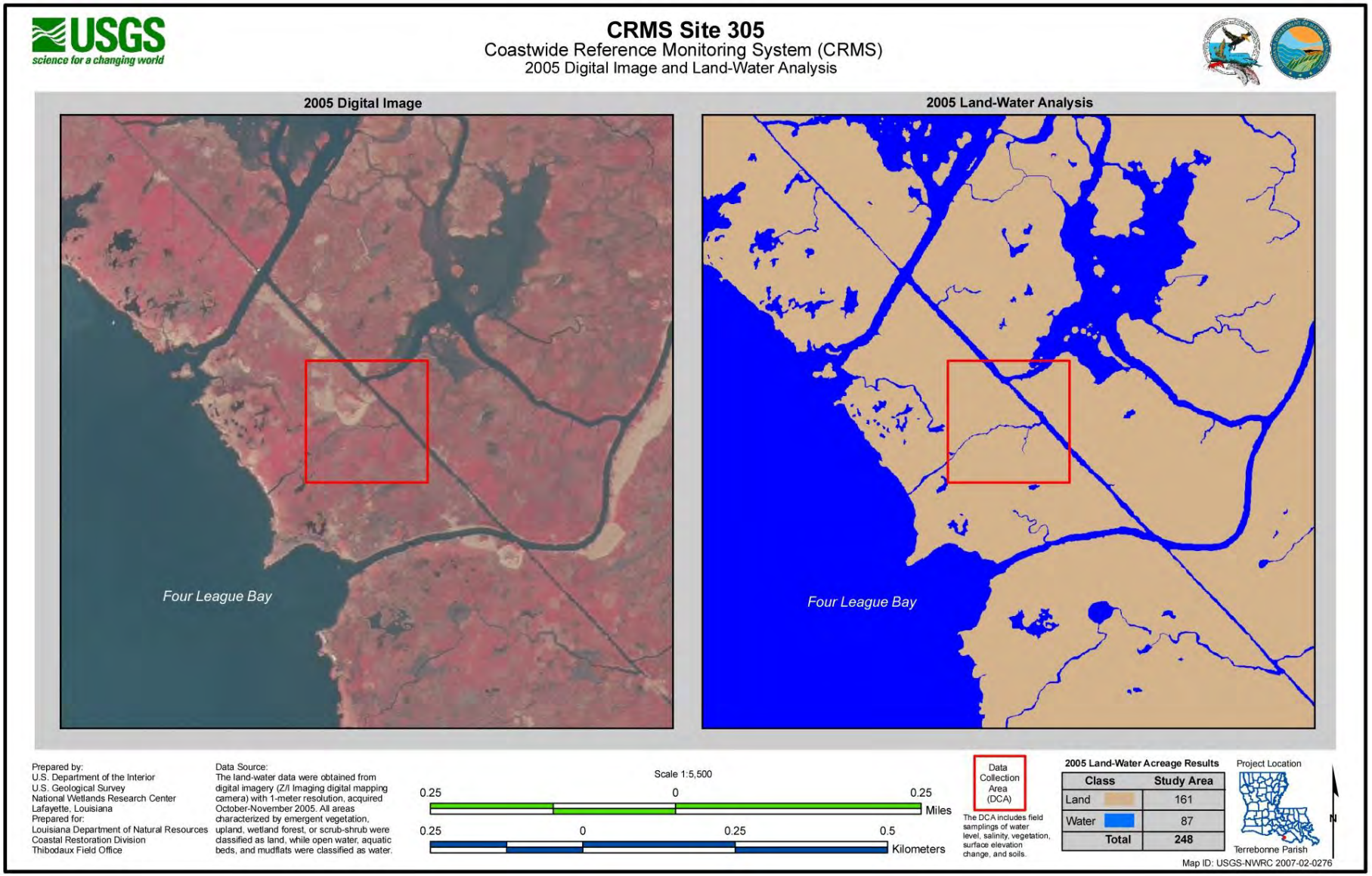


Figure 12. 2005 land-water analysis map of CRMS-Wetlands site CRMS0305 located just east of the Atchafalaya river delta on the northern shoreline of Four League Bay.

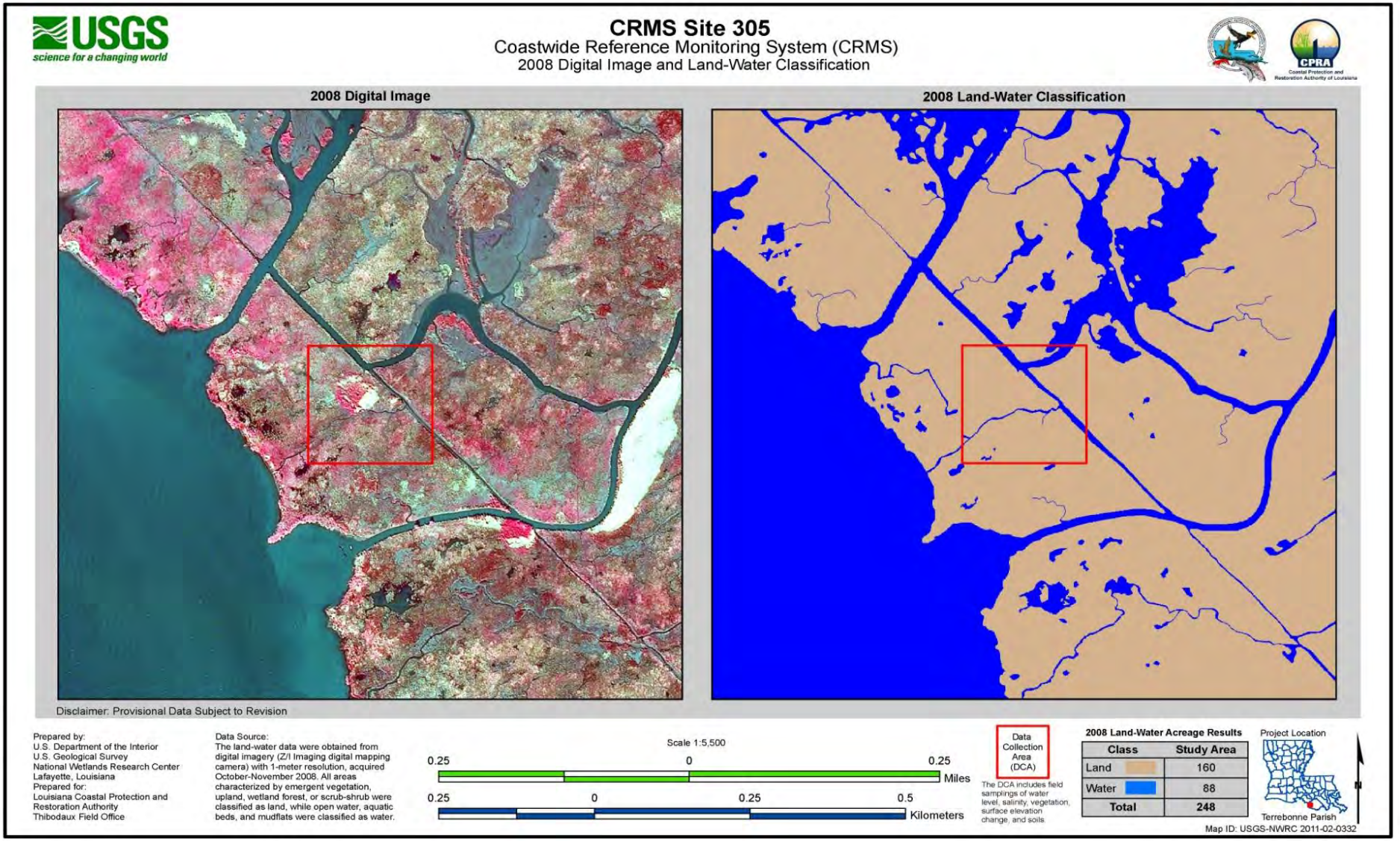


Figure 13. 2008 land-water analysis map of CRMS-Wetlands site CRMS0305 located just east of the Atchafalaya river delta along the northern shoreline of Four League Bay.

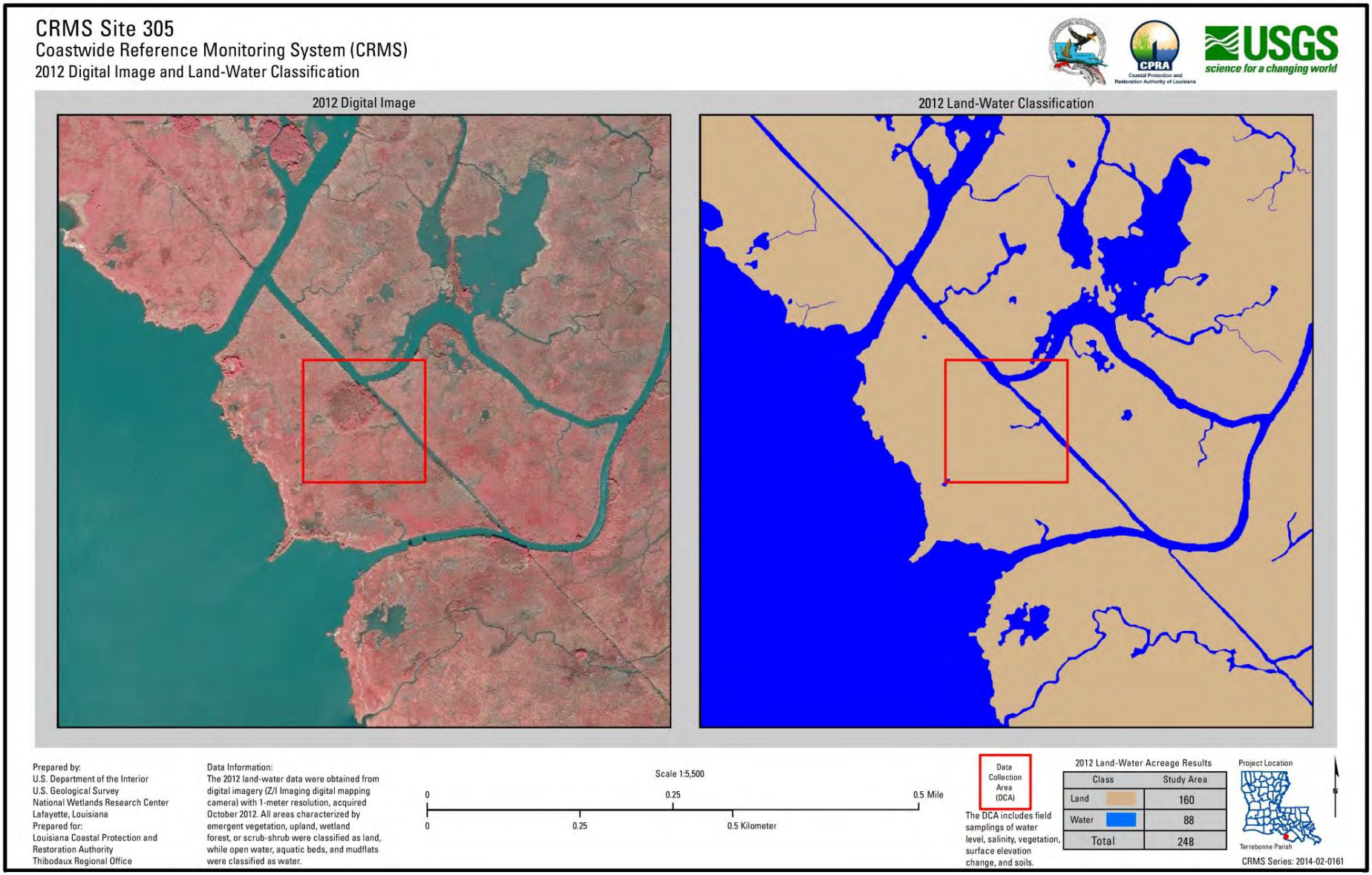


Figure 14. 2012 land-water analysis map of CRMS-Wetlands site CRMS0305 located just east of the Atchafalaya river delta along the northern shoreline of Four League Bay

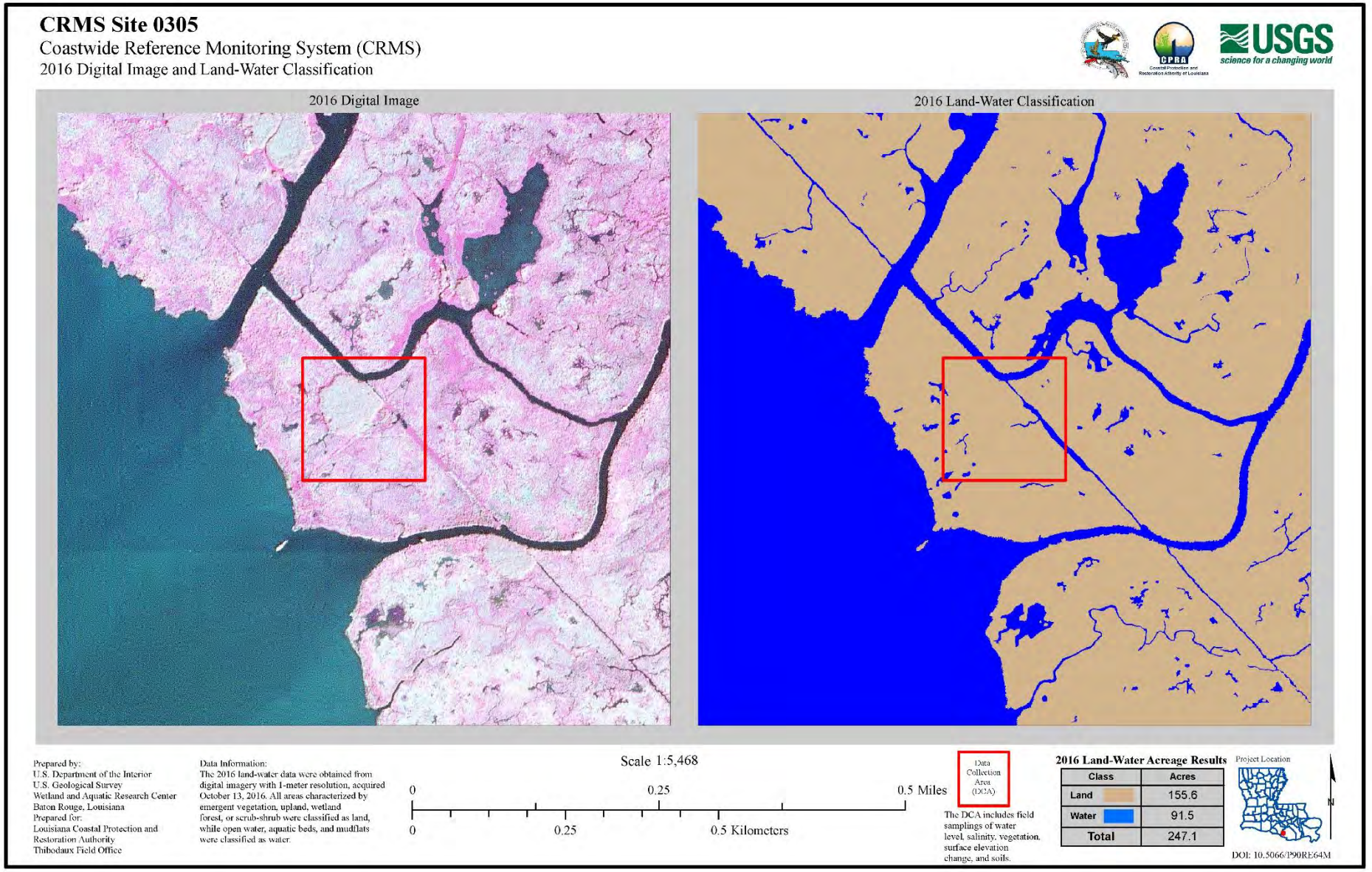


Figure 15. 2016 land-water analysis map of CRMS-Wetlands site CRMS0305 located just east of the Atchafalaya river delta along the northern shoreline of Four League Bay.

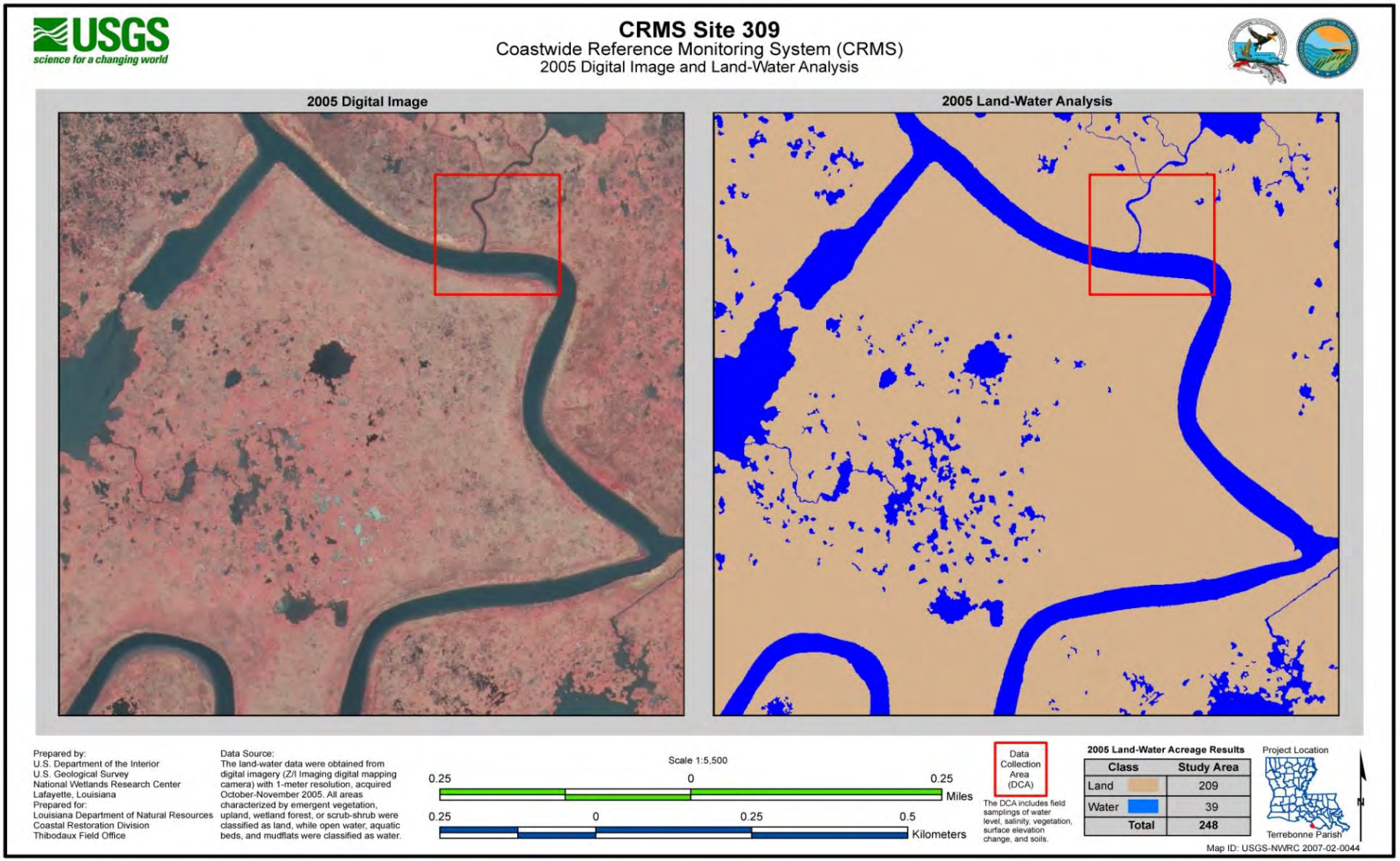


Figure 16. 2005 land-water analysis map for CRMS-*Wetlands* site CRMS0309 located in the southeast portion of Point Au Fer Island**.**

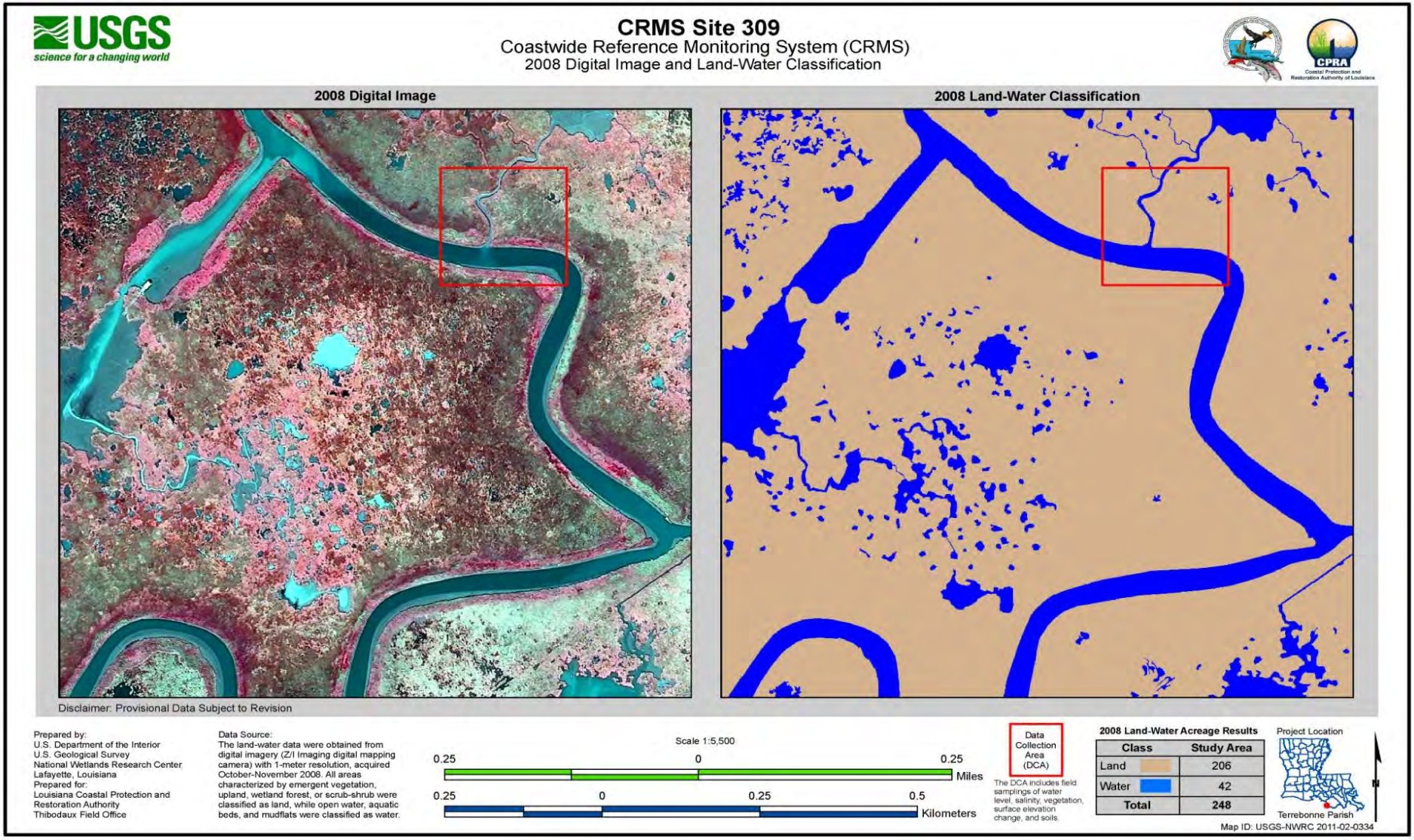


Figure 17. 2008 land-water analysis map of CRMS-Wetlands site CRMS0309 located in the southeastern portion of Point Au Fer Island

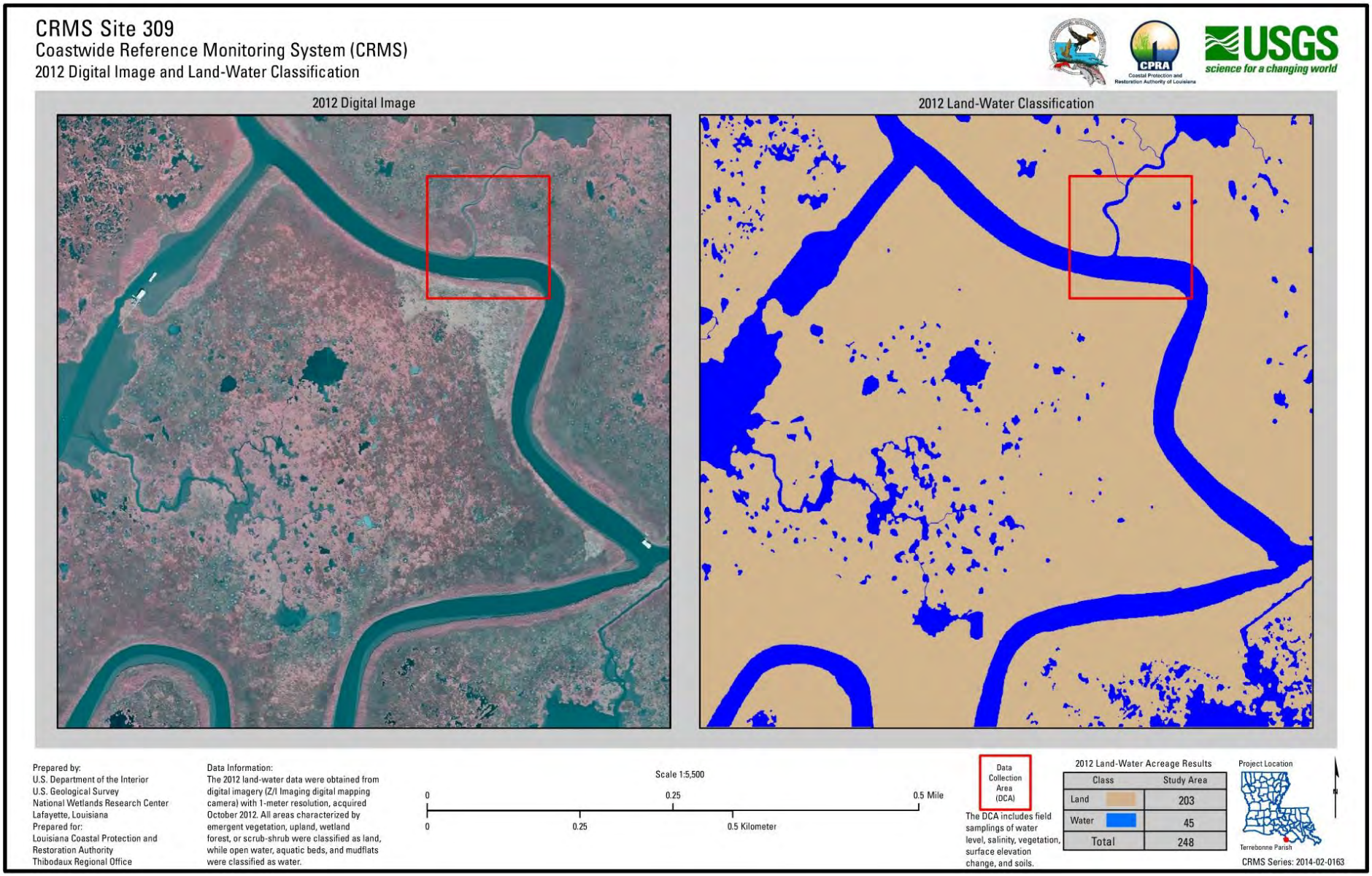


Figure 18. 2012 land-water analysis map of CRMS-Wetlands site CRMS0309 located in the southeastern portion of Point Au Fer Island.

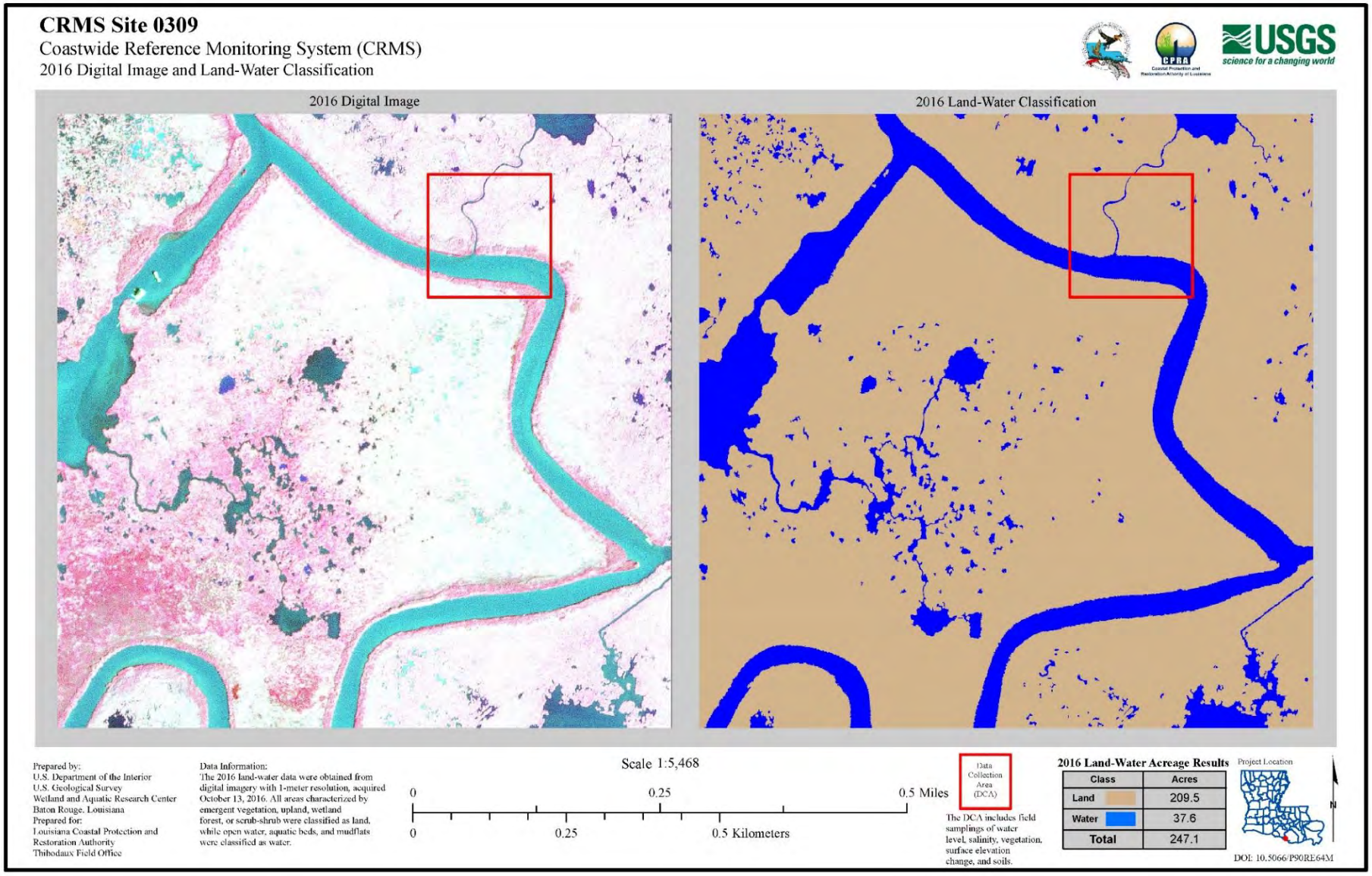


Figure 19. 2016 land-water analysis map of CRMS-Wetlands site CRMS0309 located in the southeastern portion of Point Au Fer Island

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