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Coastal Protection and Restoration Authority of Louisiana (CPRA)

2017 Operations, Maintenance, and Monitoring Report

for

Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37)

State Project Number BA-37
Priority Project List 11

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Prepared by:
Glen P. Curole
and
Benjamin J. Hartman

Operations Division
Thibodaux Field Office
1440 Tiger Drive, Suite B
Thibodaux, LA 70301

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Operations, Maintenance, and Monitoring Report
for
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(BA-37)

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Preface

This report includes monitoring data collected through December 2016, and annual Maintenance Inspections through July 2017. The Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) project is federally sponsored by the National Marine Fisheries Service (NMFS) and locally sponsored by the Coastal Protection and Restoration Authority of Louisiana (CPRA) under the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA, Public Law 101-646, Title III). BA-37 is listed on the 11th CWPPRA Priority Project List (PPL-11).

The 2017 report is the 3rd in a series of OM&M reports since the end of project construction in February 2007. This Operations, Maintenance, and Monitoring Report as well as earlier reports (Curole and Dearmond 2010; Curole and Ledet 2012) in this series are posted on the Coastal Protection and Restoration Authority of Louisiana (CPRA) website at *http://cims.coastal.louisiana.gov/DocLibrary/DocumentSearch.aspx* and on the official CWPPRA website at http://www.lacoast.gov/new/Projects/Info.aspx?num=BA-37 .

I. Introduction

The Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) project is a shoreline protection, marsh creation, and marsh nourishment restoration project located in the southwestern portion of the Barataria Basin in Lafourche Parish, LA (Figure 1). The project area consists of 556 ha (1,374 acres) of intermediate marsh and open water habitat found along the southern lake rim of Little and Round Lakes. The shoreline protection phase of this restoration project extends for 7,917 m (25,976 ft) from the eastern bank of the Breton Canal to the western bank of John the Fool Bayou along the southern shoreline of Little and Round Lakes (Figure 2). The marsh creation and nourishment phase of the BA-37 project forms its eastern border with the western bank of John the Fool Bayou, its western border with the eastern bank of the Tennessee Gas Pipeline Canal, and its northern border with the southern Round Lake shoreline (Figure 2). The Bayou L'Ours Ridge lies directly south of the project, and the Louisiana Offshore Oil Port's (LOOP) oil storage caverns and brine retention pond are situated southwest of the project (Figure 2).

The Bayou L'Ours subdelta was formed during the Lafourche deltaic lobe period (Gagliano and Wicker 1989). During this time, Bayou Lafourche and its network of distributaries comprised the main channel of the Mississippi River. Nutrient rich sediments were deposited along the banks of these distributaries primarily through overbank flooding (Sasser and Evers1995). As a result, a ridge network (natural levees) was established along these channels creating enclosed basins encircled by elevated ridges (Gagliano and Wicker 1989).

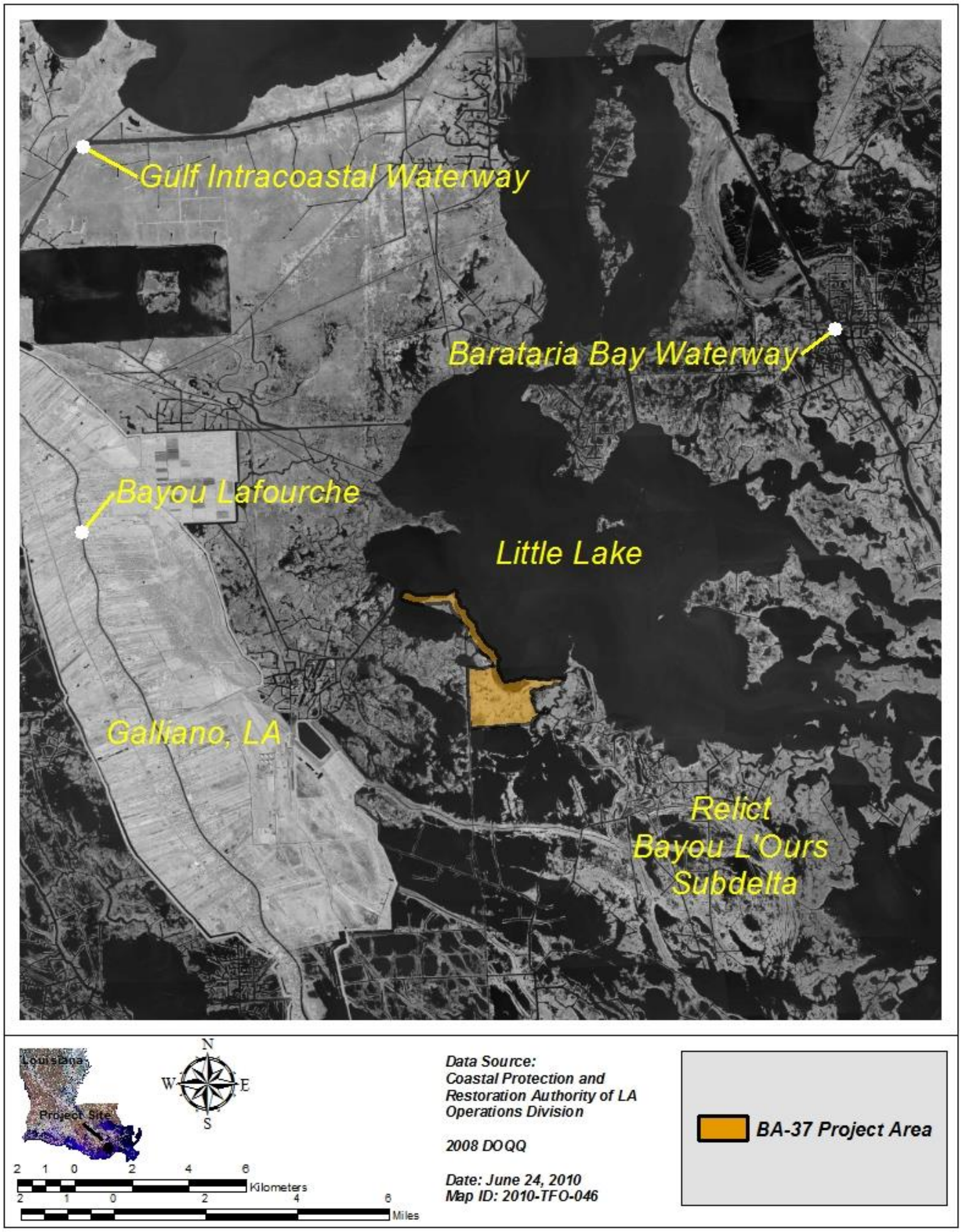


Figure 1. Location and vicinity of the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) project.

Figure 2. Location of the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) project area.

In the years since the creation of the Lafourche delta, the sediment and freshwater supply to the Bayou L'Ours subdelta has decreased considerably. The Mississippi River changed its course to form the Plaquemine and Balize deltaic lobes, a dam was placed at the junction of the Mississippi River and Bayou Lafourche in 1904, and the Mississippi River was channelized by the construction of artificial levees along its banks. In addition, Bayou L'Ours has become a relict distributary of Bayou Lafourche (Sasser and Evers 1995). Therefore, the hydrology of the Barataria Basin as well as the Bayou L'Ours subdelta has been altered by natural and anthropogenic changes in freshwater and sediment distributions.

The reduced freshwater and sediment supply has been a major influence in the formation of highly organic freshwater and intermediate marshes surrounded by slowly subsiding ridges and lake rims composed of mineral sediment deposits (Gagliano and Wicker 1989; Sasser and Evers 1995). These impounded organic marshes formed a floating marsh mat (flotant) overlying a layer of peat and organic muck (Gagliano and Wicker 1989; Sasser and Evers 1995). Sediment-poor organic soils accrete vertically predominately through slow oxidation of decaying plant matter and vegetative growth (root elongation) (Nyman et al. 1993; Delaune et al. 1993).

The soils found in the BA-37 project area are composed of a Lafitte-Clovelly association. These organic soils are generally found in very poorly drained brackish marshes (USDA 1984). Chabreck and Linscombe classified the project area as intermediate marsh in 1997, brackish to intermediate marsh in 1988, and brackish marsh in 1978. The area was also classified as brackish marsh by Chabreck et al. in 1968 and as floating three corner grass marsh by O'Neil in 1949. This area has been mapped as *Spartina patens* (saltmeadow cordgrass) and *Schoenoplectus americanus* (chairmaker's bulrush) brackish marsh (Sasser and Evers 1995; USDA 1984). *Eleocharis parvula* (dwarf spikerush), *Bacopa monnieri* (herb of grace), and *Ipomoea sagittata* (saltmarsh morning-glory) have also been found to inhabit Lafitte-Clovelly association soils (USDA 1984).

There was very little marsh degradation in the Bayou L'Ours basin until the advent of canal dredging for pipeline construction and oil field access in the 1940's (Gagliano and Wicker 1989). During the 1950's and 1960's, several rather deep access canals were allowed to breach the Bayou L'Ours ridge creating large gaps in the ridge which significantly altered the hydrology in the semi enclosed basin (Gagliano and Wicker 1989; Sasser and Evers 1995). These canals decreased the marsh surface elevations of the highly organic marsh mats, and introduced saltwater into a fresh and intermediate marsh environment. Tidal scouring of organic sediments, vegetation die-back, and subsidence resulted in extensive interior wetland loss (Gagliano and Wicker 1989; Sasser and Evers 1995). Land loss data indicate that wetland area in the Bayou L'Ours basin decreased by 6,085 acres (2,434 ha) and total open water increased by 6,197 acres (2,509 ha) during the period from 1945 to 1989 (Sasser and Evers 1995). Specifically, the marshes between the Bayou L'Ours ridge and the Little and

Round Lake rims showed considerable interior wetland loss from 1956 to 1978 (Sasser and Evers 1995). The marsh creation and nourishment area continued to experience large scale inland wetland loss from 1978 to 1990 (Figure 3) (Barras et al. 1994). These marshes are reportedly subsiding at a rate of 0.006-0.011 m/yr (0.021-0.035 ft/yr) (Sweeney 2001). The Little and Round Lake rims have continually transgressed from 1956 to1990 and are reportedly eroding at a rate of 6-12 m/yr (20-40 ft/yr) (Sweeney 2001).

The Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) project consist of two major features, a shoreline protection structure and marsh creation and nourishment area. A 7,917 m (25,976 ft) foreshore rock dike was constructed along the -0.6 m (-2 ft) NAVD 88 contour of Little and Round Lakes (Figure 3). The rock dike was constructed by placing rocks on top of a geotextile foundation. The dike was constructed using three lifts. All segments of the 7,917 m (25,976 ft) dike received the first two rock lifts, and 5,804 m (19,041 ft) of the dike was recapped during the third lift (Figure 3). Approximately, 145,528 tons of 250 lbs class rocks were used to construct the first two lifts and 29,762 tons of R650 class rocks were used to construct the third lift. The two lift segments of the dike were built to an elevation of 0.8 m (2.5 ft) NAVD 88 while the third lift segments were built to elevations of 1.1 m (3.5 ft) NAVD 88 and 1.2 m (4.0 ft) NAVD 88. Fish dips (breaches in the rock structure) were installed in the foreshore rock dike every 305 to 457 m (1,000 to 1,500 ft) for fisheries access. Construction of the BA-37 foreshore rock dike began on March 21, 2006 and was completed by February 11, 2007.

The marsh creation and nourishment phase of this project consisted of three project features: containment dikes, marsh creation in open water areas, and marsh nourishment over existing marsh. Several earthen containment dikes were placed along the border of the marsh creation and nourishment area (Figure 3). These structures were built to an elevation of 1.1 m (3.5 ft) NAVD 88. The sediments dredged from Little Lake were pumped into the marsh creation and nourishment disposal area (Figure 3). Approximately, 372 ha (920 acres) of marsh platform were created and nourished during construction. These constructed marshes were raised to a 0.72 m (2.36 ft) NAVD 88 elevation. After sediment consolidation, the containment dike was gapped in several locations. Construction of the BA-37 marsh creation and nourishment area began on November 26, 2005 and ended on August 14, 2006.

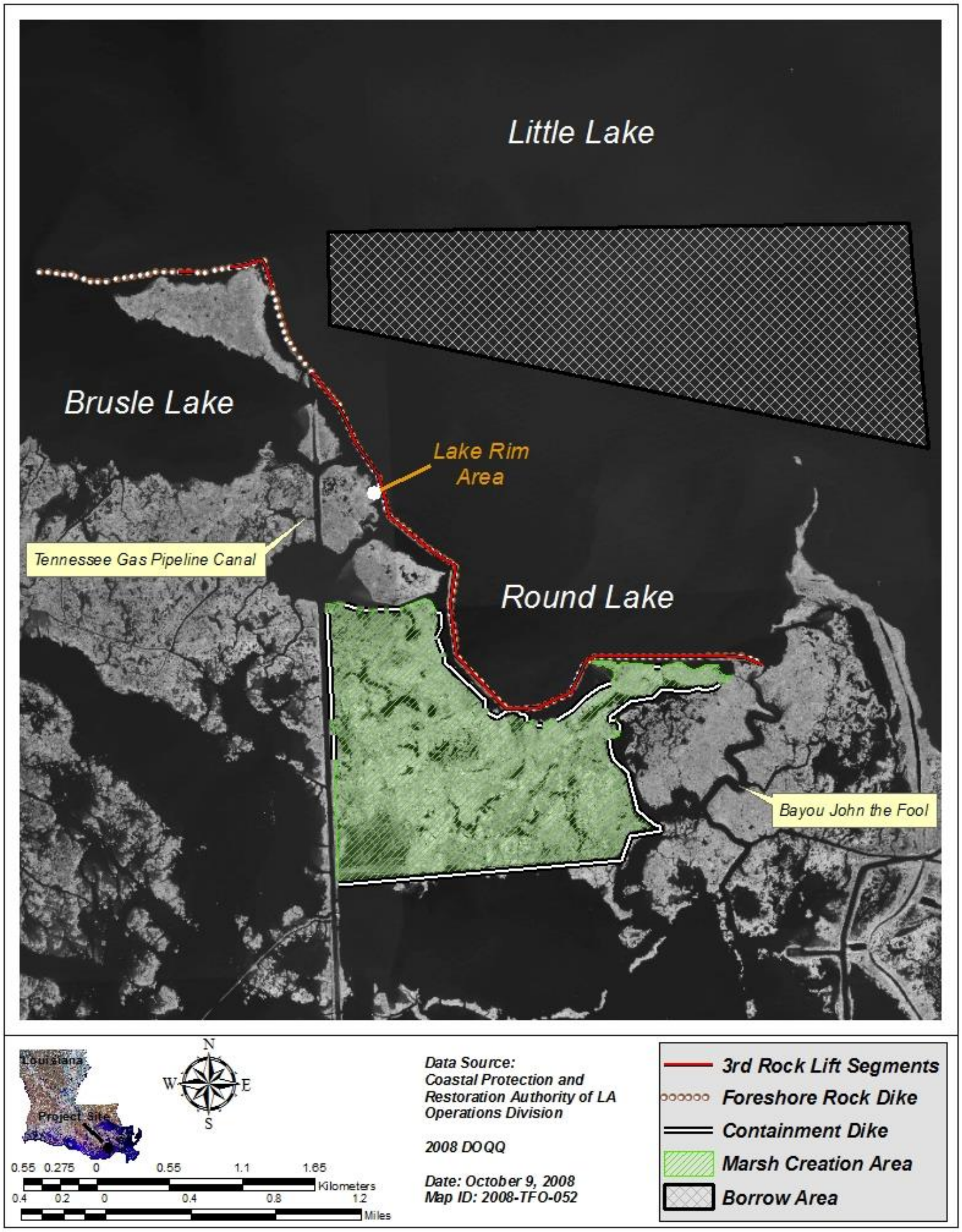


Figure 3. Location of the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) project features.

II. Maintenance Activity

a. Project Feature Inspection Procedures/Results

Rock Segments 1 – 24 (Photos 1 – 30, Appendix A)

All rock segments were visually inspected by boat. It appears that all rock segments have experienced some degree of settlement with the most obvious settlement on the western end of the project (Segments 1 through 8), where only two (2) rock lifts were made during construction. Segments 10 through 24 received a third lift during construction and appear to be in good to fair condition.

Currently, Rock Segments 1 and 2 have no marsh or vegetation along its southern edge, only open water. The fringe marsh that once separated Brusle Lake and Bay L'Ours, located just south of Segments 1 and 2 had eroded following Hurricane Katrina in 2005. This land loss occurred during construction of the project and the rock segments were installed as designed and contracted. Due to the liability associated with the rock dike being below the water surface during high tides and the lack of existing marsh behind the structure, NMFS and CPRA had decided to degrade Segment 1 and part of Segment 2, because the eastern edge of Segment 2 still protects the marsh behind Segment 3 from wave action. In the 2015 inspection report, CPRA had decided against recovering the rock riprap and installing at another location, instead electing to degrade the rock dike to a safe elevation along the lake bottom. This method was seen as more cost effective than recovering the rock riprap. However, 2016 discussions between the NOAA representative and CPRA rehashed the possibility of recovering the rock and building a Perpendicular Rock Dike branching off Segment 2 where the degrading terminates. The increased cost (although shared) of additional surveying and obvious alternative construction has been considered and deemed justifiable. The last survey of the entire rock shoreline was conducted in 2011. A complete Pre-Design survey of the rock on Segments 1 & 2 was concluded in February 2016 and additional surveying conducted in November 2016. The cost of construction of this project feature is reflected in the 3-year budget.

The spoil material broadcasted behind the rock dike segments during construction appear to be in good condition and has fully vegetated. Also, it appears that the SAV (submerged aquatic vegetation) behind the rock segments continues to increase from past inspections.

Marsh Creation Area (Photos 27 – 30, Appendix A)

We were only able to visually inspect the marsh creation area from the perimeter of the project and marsh fringe along Round Lake and the southern containment dike. The fill material in the marsh creation area appeared to be in very good condition and fully vegetated. The latest post-construction survey of the fill area was completed in 2016. Below is a table showing the average grid elevations from 2006, the year construction was completed, through 2016. The final post-construction survey of the marsh fill area was conducted in 2016 and is shown in Figure 1. In 2016, CPRA conducted design surveys for degrading Segment 1 and 2 dikes in conjunction with the marsh surveys previously planned for 2017, with cost savings from eliminating additional administrative & mobilization/demobilization costs.

The average grid elevations for the marsh creation area surveys are shown in the table below.

Table 1. **Average Marsh Grid Elevation by Year.**

Survey	Average Grid Elevation (FT, NAVD88)
As-Built (May-Aug 2006)	2.2
Post-Construction (May 2007)	1.49
Post-Construction (May 2008)	1.40
Post-Construction (June 2009)	1.14
Post-Construction (July 2010)	1.23
Post-Construction (July 2011)	1.18
Post-Construction (November 2016)	1.27

b. Maintenance History/Recommendations

i. Maintenance History

Below is a summary of completed maintenance projects and operation tasks performed since completion of the Little Lake Shoreline Protection/Dedicated Dredging near Round Lake Project (BA-37).

May 2008 – Survey of marsh creation area was performed by Shaw Coastal, Inc. The marsh elevations at the grid points within the marsh creation area as well as top elevations of the 24 rock dike settlement plates were collected. This survey represents the first of the scheduled O&M surveys to be performed but is actually the second post-construction survey. The first post-construction survey was performed by Shaw Coastal, Inc. in May 2007 with remaining construction funds immediately following acceptance of the project. The actual surveying consultant costs associated with the 2008 survey was $36,007.28.

July 2009 – Survey of marsh creation area was performed by Shaw Coastal, Inc. The marsh elevations at the grid points within the marsh creation area as well as top elevations of the 24 rock dike settlement plates were collected. This survey represents the second of the scheduled O&M surveys to be performed but is actually the third post-construction survey. The actual surveying consultant costs associated with the 2009 survey was $42,590.40.

July 2010 – A survey of marsh creation area was performed by Morris Hebert, Inc. The marsh elevations and the grid points within the marsh creation area as well as the top elevations of the rock dike settlement plates were collected. This survey represents the third of the scheduled O&M surveys to be performed but is actually the fourth post-construction survey. The actual surveying consultant costs associated with the 2010 survey is $23,500.

September 2011 – Survey of the marsh creation area, rock dike, and settlement plates was performed by Morris Hebert, Inc. The marsh elevations and the grid points within the marsh creation area, the profile of the rock dike sections, as well as the tops elevations of the rock dike settlement plates were collected. This survey represents the last of the scheduled O&M surveys to be performed post-construction. The actual surveying consultant cost associated with the 2011 survey was $60,013.23.

November 2016 – Survey of the marsh creation area, rock dike 1 & 2, and settlement plates was performed by Morris Hebert, Inc. The marsh elevations and the grid points within the marsh creation area, the profile of the rock dike sections, as well as the tops elevations of the rock dike settlement plates were collected. A magnetometer survey of the area around Rock Dike No. 1 and 2 was also conducted. The actual surveying consultant cost associated with the 2016 survey was $67,799.10.

ii. Maintenance Plan/Recommendations

Winter 2017 – As observed during post-construction surveys and visual inspections of the rock dike structure along the southern marsh of Little Lake and Round Lake, all of the rock dike segments have experienced some settlement. Over time, the settlement of the rock dike in the vicinity of Segments 1 and 2 has presented potential hazardous navigation conditions because the dike extends out into open water in an area without land behind it. A combination of high tides causing the rock dike to become submerged and the lack of a marsh shoreline behind both segments has resulted in a decision by NMFS and CPRA to degrade Segment 1 and part of Segment 2. Design surveys for degrading these segments were completed in February 2016. The current plan is to recover the rock rip rap for beneficial use in the construction of a "Perpendicular Rock Dike" near Segment 3 which will provide protection to adjacent land and reduce navigational hazards. The rock will be degraded to -2.0 ft NAVD88 (previous natural water bottom contour) on all of Rock Dike No. 1 and 870.00' of Rock Dike No. 2. Additional surveys for the creation of the new feature were completed in November 2016. Construction is anticipated to start in December 2017. The staff gage will also be repaired during this winter 2017-2018 maintenance event.

The marsh creation area appears to be completely vegetated and the post-construction surveys indicate elevations are approaching the average marsh elevation for the area. The final post-construction survey for the marsh creation area is scheduled for year 15 (2022) of the project life. There are no other funds allocated for the marsh creation portion of the project other than the surveying of the area grid points.

III. Operations Activity

a. Operation Plan

Other than the alterations proposed on Rock Dike Segment No. 1 and No. 2 plus the creation of the Perpendicular Rock Dike, there are no plans for future operation.

b. Actual Operations

There are no features of this project that requires operation from CPRA.

IV. 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 BA-37 Monitoring Plan 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 is one CRMS site located in the project area, CRMS6303. This site was added to the marsh creation and nourishment area after construction on October 24, 2008.

a. Monitoring Goals

The specific project strategies of the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) project are (1) to construct a foreshore rock dike along the Little and Round Lake shorelines to reduce the marsh edge erosion rate, (2) to place dredged sediments in confined openwater disposal areas to create intermediate or brackish marsh, (3) to plant *Spartina alterniflora* (smooth cordgrass) plugs to stabilize marsh creation disposal areas and increase emergent marsh vegetation cover, and (4) to place dredged sediments above the marsh surface to nourish existing marsh. The construction of a foreshore rock dike will slow erosion along the southwestern Little Lake shoreline by damping wind-induced wave energy. The placement of dredged material and subsequent establishment of vegetation is expected to result in the direct creation and nourishment of marsh habitat at an elevation of 1.0 ft (0.3 m) NAVD 88 by the 5th year of the post-construction period (Belhadjali and Cowan 2003).

The specific measurable goals established to evaluate the effectiveness of the project are:

1. Reduce the marsh edge erosion rate along the Little and Round Lake shorelines.

2. Create approximately 551 acres (223 ha) of marsh at suitable elevations for growth and establishment of intermediate or brackish emergent vegetation.

3. Nourish approximately 406 acres (164 ha) of existing marsh to enhance the growth and establishment of intermediate or brackish emergent vegetation.

4. Maintain 799 acres (323 ha) of emergent marsh at the end of the 20-year project life.

b. Monitoring Elements

The following monitoring elements provide the information necessary to evaluate the specific goals listed above:

Elevation

Topographic surveys were employed to document elevation and volume changes inside the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) project area. Pre-construction (December 2005), and as-built (August 2006) elevation data were collected in the marsh creation area using cross sectional (500-ft intervals) and real time kinematic (RTK) survey methods. Subsequent post-construction topographic surveys were performed in June 2007, May 2008, August 2009, August 2010, October 2011, and November 2016. In addition, twenty-four (24) settlement plates were surveyed using RTK methods to estimate foreshore rock dike subsidence. The settlement plates were surveyed during installation (March to November 2006), during the second rock lift (August 2006 to January 2007), during the as-built survey (February 2007), and during the post-construction period in May 2008, August 2009, July 2010, September 2011, April 2014, and November 2016. All survey data were established using or adjusted to tie in with the Louisiana Coastal Zone (LCZ) GPS Network.

Survey data were re-projected horizontally and vertically to the UTM NAD83 coordinate system and the NAVD 88 vertical datum in meters using Corpscon® software. The re-projected data were imported into ArcView® GIS software for surface interpolation. Triangulated irregular network models (TIN) were produced from the point data sets. Next, the TIN models were converted to grid models (2.0 m^2 cell size), and the spatial distribution of elevations were mapped. The grid models were clipped to the BA-37 marsh creation area and settlement plate polygons to estimate elevation and volume changes.

Elevation changes from December 2005-August 2006, August 2006-June 2007, August 2006-May 2008, August 2006-August 2009, August 2006-August 2010, August 2006-October 2011, and August 2006-November 2016 in the marsh creation area were calculated by subtracting the corresponding grid models using the LIDAR Data Handler extension of ArcView® GIS. Settlement plate elevation changes were calculated using the aforementioned procedures in November 2006-January 2007, November 2006-February 2007, November 2006-May 2008, November 2006-August 2009, November 2006-July 2010, November 2006-September 2011, November 2006-April 2014, and November 2006-November 2016. After the elevation change grid models were generated, the spatial distribution of elevation changes in the BA-37 marsh creation area and on the settlement plates were mapped in quarter-meter elevation classes. Lastly, volume changes in the marsh creation area were calculated in cubic meters (m^3) using the Cut/Fill Calculator function of the LIDAR Data Handler extension of ArcView® GIS. Volumes changes were not calculated for the settlement plates because foreshore rock dike subsidence was the parameter investigated. Note, these elevation and volume calculations are valid only for the extent of the survey area.

Shoreline Change

Shoreline position data were analyzed to estimate shoreline changes inside the BA-37 project area using the Digital Shoreline Analysis System (DSAS version 2.1.1) extension of ArcView® GIS (Thieler et al). Pre- and post-construction change rates were calculated for the marsh creation area and the lake rim area (project shoreline outside of marsh creation area) (Figures 2 and 3) independently. Shoreline positions were determined by digitizing aerial photographs at a 1:800 scale as per the Steyer et al. (1995) method, which defines shoreline position as the edge of the live emergent vegetation. The resulting polylines established the shoreline positions in UTM NAD 83 coordinates. Pre-construction and post-construction aerial photographs were acquired over an eleven-year period to discern the foreshore rock dike's effect on shoreline erosion rates. Pre-construction aerial photographs were collected on February 4, 1998; April 15, 2003; January 25, 2004; and November 1, 2005 while post-construction aerial photographs were captured on September 20, 2007 (6 months post-construction) October 29, 2008 (1.5 years post-construction), July 12, 2010 (3.5 years post-construction), November 1, 2012 (5.5 years post-construction), and November 1, 2016 (9.5 years post-construction). All images were georectified using UTM NAD 83 horizontal datum.

The February 1998, April 2003, January 2004 and November 2005 shorelines were created in ArcView® GIS software to establish pre-construction shoreline change rates, and the September 2007, October 2008, July 2010, November 2012, and November 2016 shorelines were created to establish post-construction shoreline change rates. Secondly, an offshore baseline was generated from an offset of the February 1998 shoreline. Thirdly, the DSAS attribute editor was populated by identifying shorelines and the baseline and dating shorelines. Next, 1000 m (3280 ft) simple transects were cast from the baseline at 50 m (164 ft) intervals producing shoreline change, intersect, and transect shapefiles. These shapefiles were edited by eliminating transects that intersect the shorelines at irregular angles. Finally, shoreline change data were imported into Excel® to calculate annual erosion rates for each period. Shoreline change rates were assessed for the ensuing periods February 1998-April 2003, April 2003-January 2004, January 2004-November 2005, September 2007-October 2008, October 2008-July 2010, July 2010-November 2012, and November 2012-November 2016 for the area behind the 7,925 m (26,000 ft) BA-37 foreshore rock dike. Shoreline analyses consisted of one-way ANOVA's. The statistical package used was JMP (v13).

Lake Rim Area

Pre-construction (February 1998, April 2003, January 2004 and November 2005) and post-construction (September 2007, October 2008, July 2010, November 2012, and November 2016) aerial photographs were utilized to delineate the area of lake rim portion (Figures 2 and 3) of the BA-37 project over time. The areal extent of the lake rim area was estimated by drawing polygons around the subaerial land within the lake rim area at a 1:5,000 scale. Once drawn the area inside the polygons were calculated using the Calculate Area function of ArcGIS®.

Land/Water

As previously mentioned one CRMS-*Wetlands* site (CRMS6303) is located in the BA-37 marsh creation area and will be used to characterize the structure of the project area marshes. Land/water, vegetation, and hydrological data extracted from this site will be employed to classify the constructed marsh structure. Land/water analysis was performed on a 1.0 km^2

(0.4 mi^2) portion of the marsh creation area at the CRMS6303 site (Figures 2 and 4). The U.S. Geological Survey's National Wetlands Research Center (USGS/NWRC) obtained 1.0 m (3.3 ft) resolution color infrared (CIR) aerial photography to delineate land and water habitats over time. A pre-construction aerial image was captured on November 1, 2005 and a post-construction image was captured on October 29, 2008. These images were analyzed, interpreted, processed, and verified for quality and accuracy using protocols established Folse et al. (2014). Specifically, habitats in the 1 km^2 (0.4 mi^2) were condensed to a land or water classification. Land was considered to be 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 acreages of land and water were calculated. After the analysis was complete, the classification data and the photomosaic were mapped to spatially view the data. The percentages of land and water and the land-to-water ratios were also determined to summarize the data.

Vegetation

Vegetation data was collected in the BA-37 marsh creation area at the CRMS6303 site (Figure s 2 and 4) to document species composition and percent cover over time. Ten (10) plots were placed inside the 200 m^2 (239 yd^2) square, which is nested within the 1.0 km^2 (0.4 mi^2) square, as per Folse et al. (2014) (Figure 7). Vegetation data were collected in October 2008 (2 year post-construction), July 2009 (3 years post-construction), June 2010 (4 years post-construction), and July 2011 (5 years post-construction) 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 4 m^2 plot were identified, and cover values were ocularly estimated. After sampling the plot, the residuals within a 5 m (16 ft) radius were inventoried. Mean percent cover was calculated to summarize the vegetation data and was grouped by year. Floristic quality index (FQI) was also estimated using the Cretini and Steyer (2011) protocol. Site FQI assessments were derived using mean percent cover values and coefficient of conservatism (CC) scores.

Hydrology

Hydrologic data is being collected at CRMS6303 in the BA-37 marsh creation area (Figure s 2 and 4). One (1) continuous recorder station was installed in the BA-37 project area to collect temperature (°C), specific conductance (μS/cm), salinity (ppt), and water level (ft) data on an hourly interval. The station was deployed and serviced, and the data was processed and verified for quality and accuracy in accordance with the Folse et al. (2014) protocol. The continuous recorder station was established on October 24, 2008 and has been under constant operation since that time. Daily mean water level and salinity data were calculated to summarize the data collected from this hydrologic monitoring station during the period from October 2008 to February 2012. In addition, annual hydrologic indexes (HI) were calculated for this site using mean salinity, percent time flooded, and the intermediate marsh classification. The HI scores are computed for a given water year, which begins October 1 and ends the following September 30.

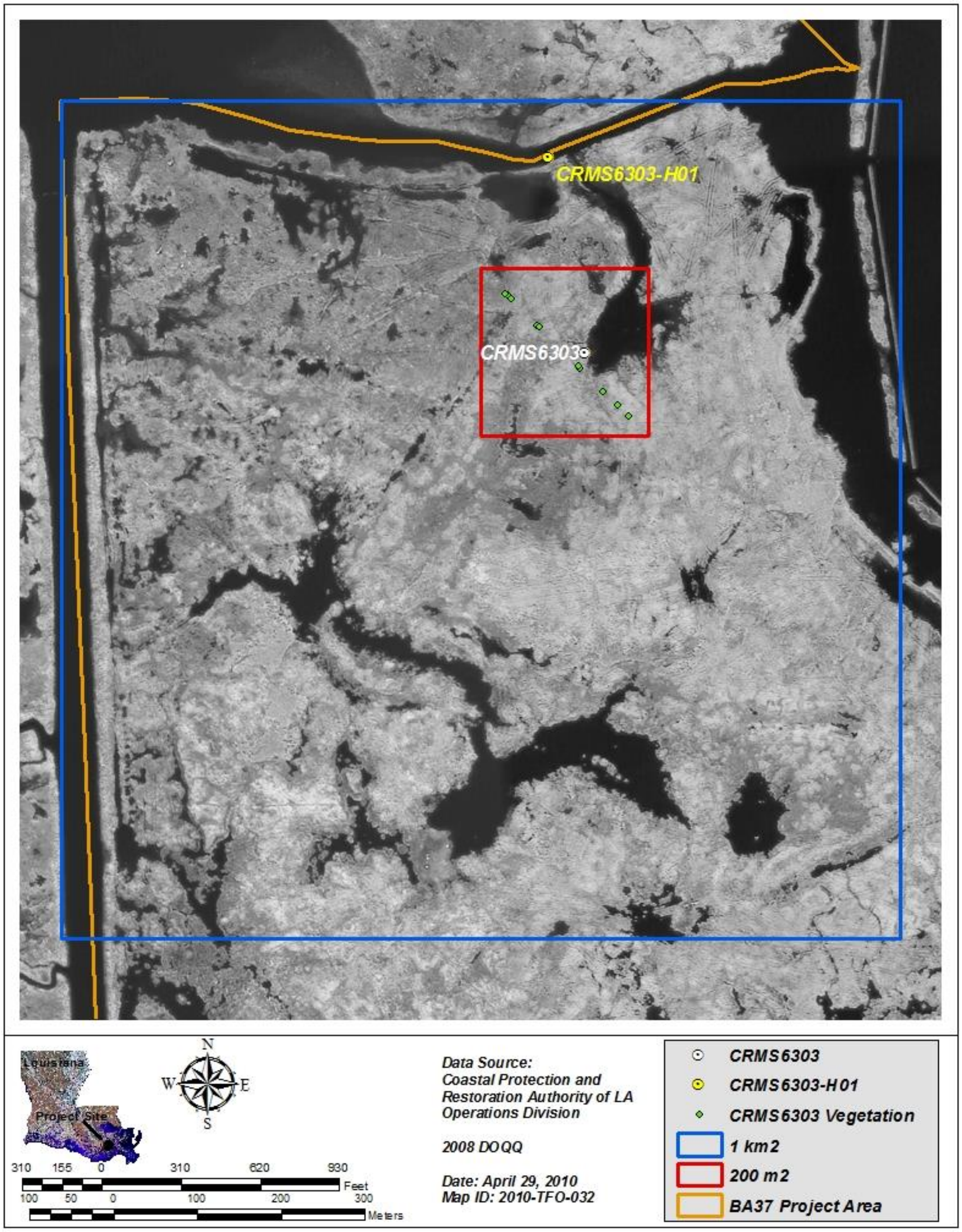


Figure 4. Location of CRMS6303 inside the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) project.

c. Monitoring Results and Discussion

Elevation

The Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) marsh creation and nourishment area experienced volume reductions since construction was completed in 2006. Elevation change and volume distributions for the BA-37 marsh creation area are shown in Figure 5 (Dec 2005-Aug 2006), Figure 6 (Aug 2006-Jun 2007), Figure 7 (Aug 2006-May 2008), Figure 8 (Aug 2006-Aug 2009), Figure 9 (Aug 2006-Aug 2010), Figure 10 (Aug 2006-Oct 2011), and Figure 11 (Aug 2006-Nov 2016). Elevation grid models for the Dec 2005, Aug 2006, Jun 2007, May 2008, Aug 2009, Aug 2010, Oct 2011, and Nov 2011 surveys are also provided in Appendix C. The volume and mean elevation changes inside the BA-37 constructed marsh are also plotted in Figure 12. Approximately 2,739,280 m^3 (3,582,843 yd^3) of sediment were deposited in the marsh creation area during construction (Figures 5 and 12). In the post-construction period, sediment volume decreased by 29% from Aug 2006 to Jun 2007 (Figures 6 and 12), by 35% from Aug 2006 to May 2008 (Figures 7 and 12), by 44% from Aug 2006 to Aug 2009 (Figures 8 and 12), by 41% from Aug 2006 to Aug 2010 (Figures 9 and 12), by 44% from Aug 2006 to Oct 2011 (Figures 10 and 12), and by 40% from Aug 2006 to Nov 2016 (Figures 11 and 12). The total sediment volume loss in the marsh creation area from Aug 2006 to Nov 2016 was approximately 1,102,050 m^3 (1,441,427 yd^3). While the volume has declined by 40% since construction, a substantial volume of sediments remain in place [1,637,230 m^3 (2,141,416 yd^3)], and the rate of volume loss has been relatively flat since 2009 (Figure 12). The corresponding post-construction mean elevation change inside the marsh creation area is graphically shown in Figures 12 and 13 and the grid models in Appendix C. Comparing the measured mean elevation changes to estimated values derived from consolidation curves (Eustis 2003) for fill elevations of 0.55 m (1.80 ft), 0.64 m (2.10 ft), 0.72 m (2.36 ft), and 0.91 m (3.00 ft) reveal that the marsh creation area is settling and subsiding at a slightly slower rate than its fill elevation consolidation curve, 0.72 m (2.36 ft) (Figure 13). These preliminary results provide evidence suggesting that marsh creation area is condensing at a sustainable rate. Therefore, the goals to create marsh at suitable elevations and nourish existing marsh were achieved, and the goal to maintain emergent marsh at the end of the 20-year project life is still attainable.

The BA-37 foreshore rock dike has incurred minor settlement since construction was completed in 2007. Elevation changes for the foreshore rock dike are delineated in Figure 14 (Mar 2006-Feb 2007), Figure 15 (Mar 2006-May 2008), Figure 16 (Mar 2006-Aug 2009), Figure 17 (Mar 2006-Jul 2010), Figure 18 (Mar 2006-Sep 2011), and Figure 19 (Mar 2006-Nov 2016). The rock dike settled 0.61 m (2.00 ft) during construction. This primary settlement of the dike occurred from settlement plate installation to the as-built survey (Mar 2006-Feb 2007) (Figure 14). Post-construction secondary settlement of the foreshore rock dike was 0.06 m (0.23 ft) from Feb 2007 to May 2008 (Figure 15), 0.09 m (0.30 ft) from Feb 2007 to Aug 2009 (Figure 16), 0.09 m (0.30 ft) from Feb 2007 to Jul 2010 (Figure 17), 0.13 m (0.44 ft) from Feb 2007 to Sep 2011 (Figure 18), and 0.17 m (0.56 ft) from Feb 2007 to Nov 2016 (Figure 19). The rate of secondary settlement is more

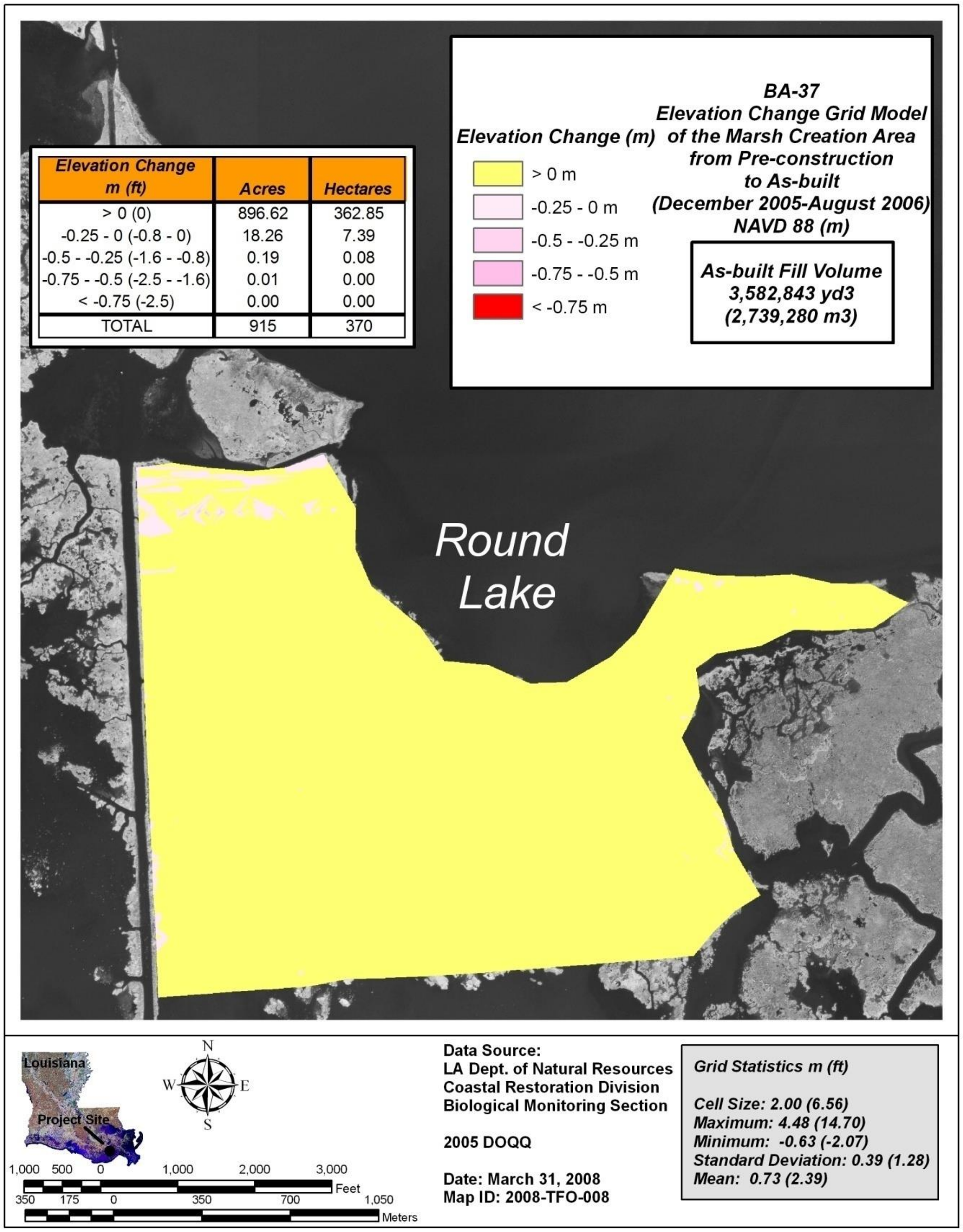


Figure 5. Elevation and volume change grid model from pre-construction (Dec 2005) to as-built (Aug 2006) at the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) project.

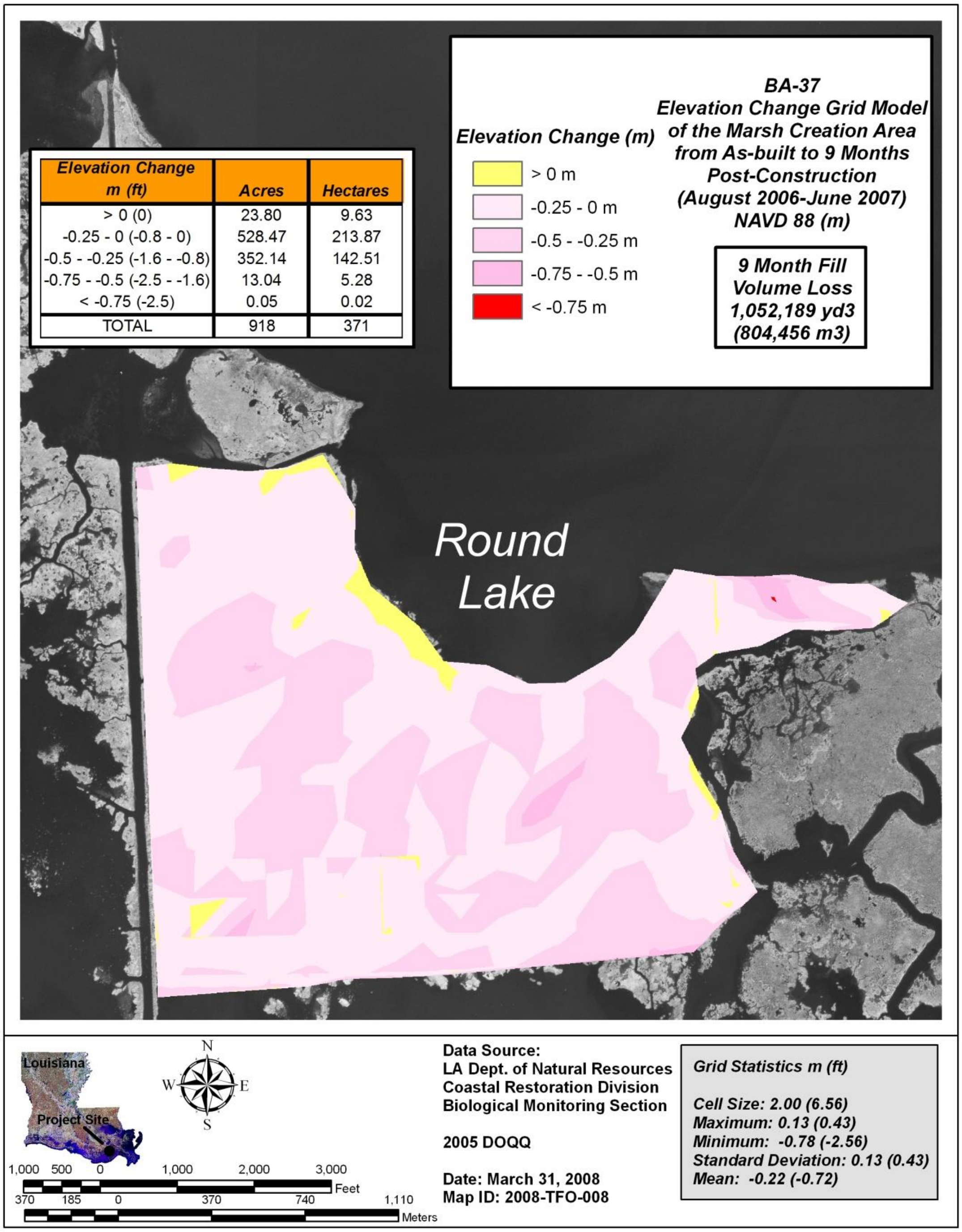
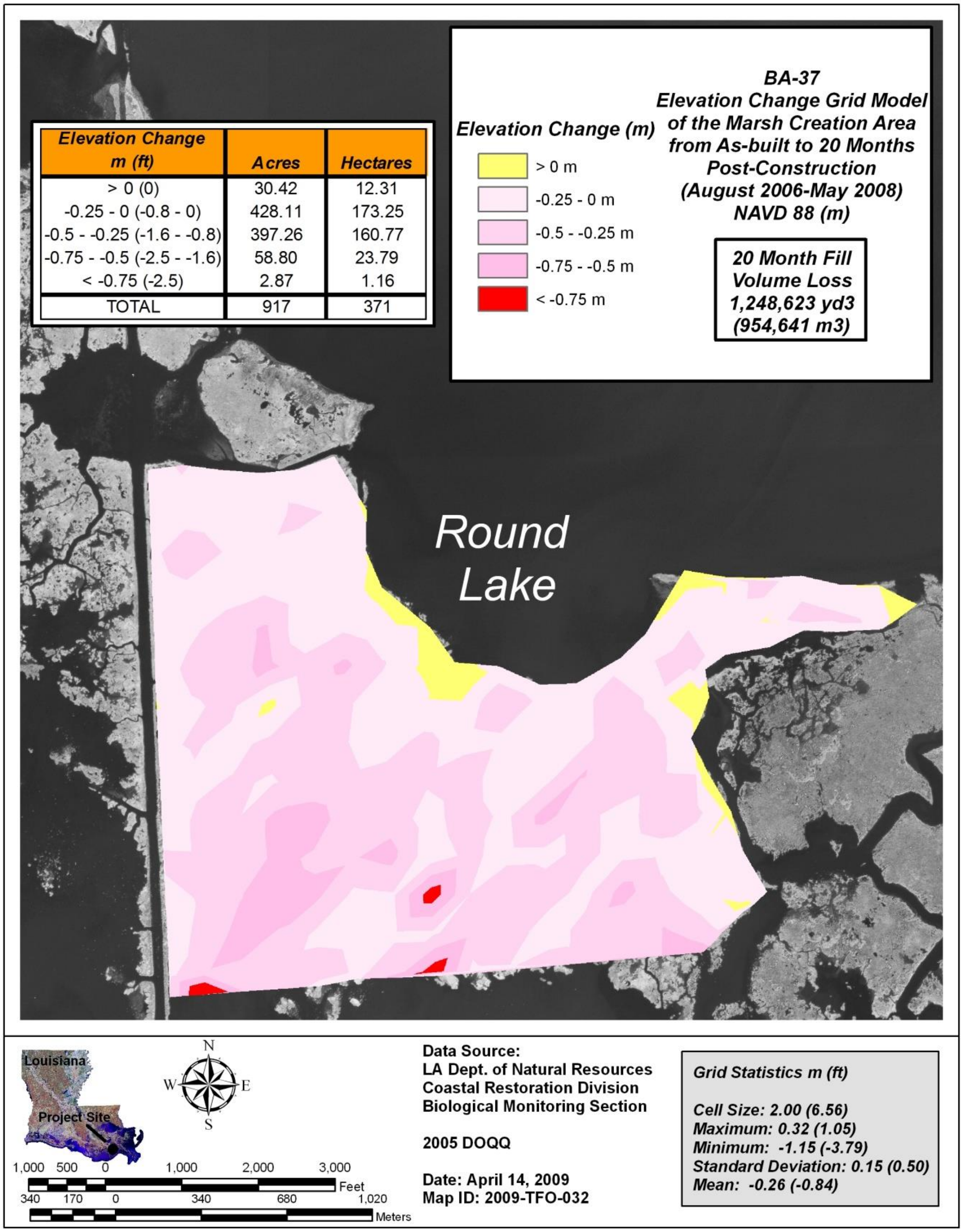


Figure 6. Elevation and volume change grid model from as-built (Aug 2006) to post-construction (Jun 2007) at the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) project.



Elevation Change m (ft)	Acres	Hectares
> 0 (0)	30.42	12.31
-0.25 - 0 (-0.8 - 0)	428.11	173.25
-0.5 - -0.25 (-1.6 - -0.8)	397.26	160.77
-0.75 - -0.5 (-2.5 - -1.6)	58.80	23.79
< -0.75 (-2.5)	2.87	1.16
TOTAL	917	371

Figure 7. Elevation and volume change grid model from as-built (Aug 2006) to post-construction (May 2008) at the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) project.

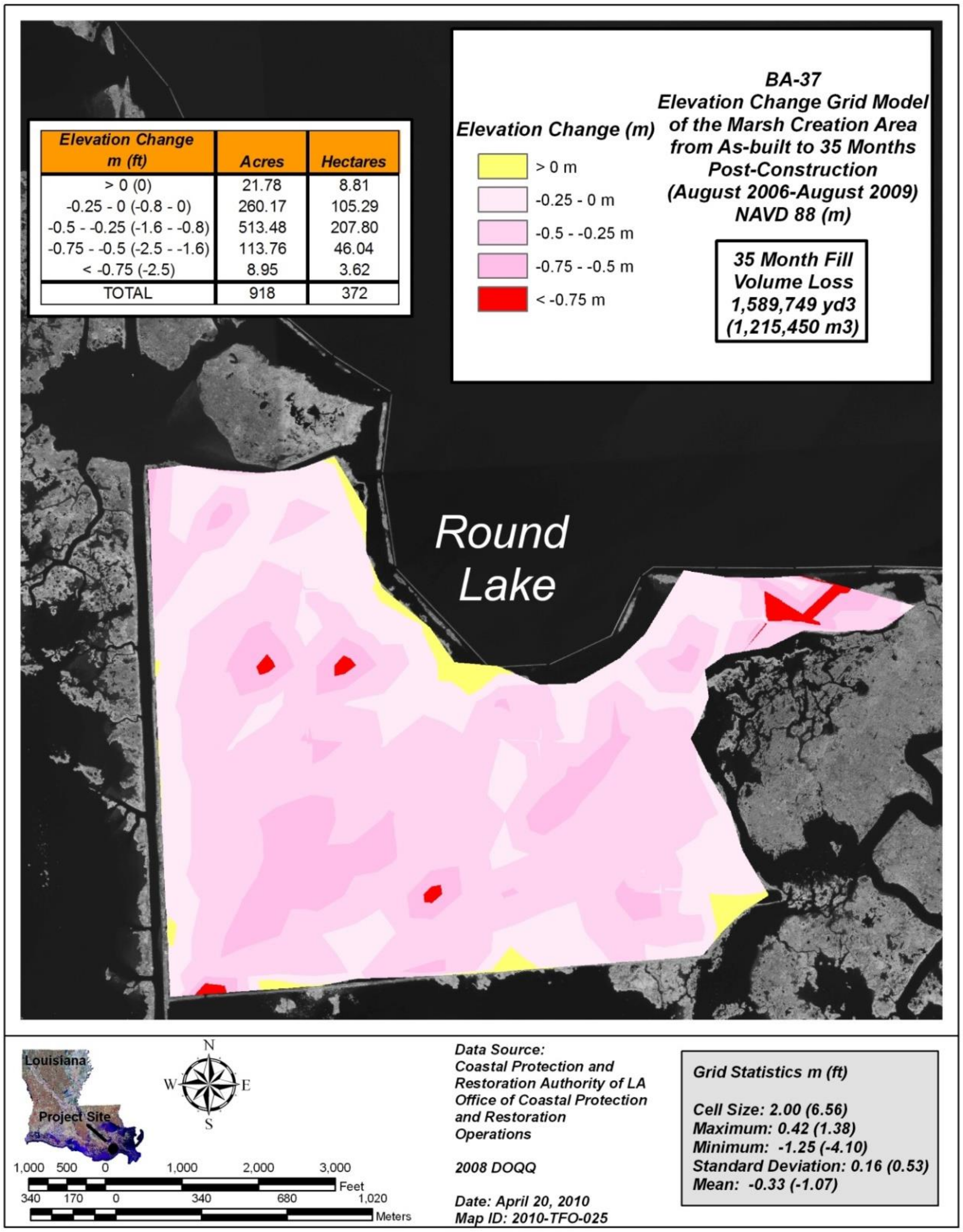


Figure 8. **Elevation and volume change grid model from as-built (Aug 2006) to post-construction (Aug 2009) at the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) project.**

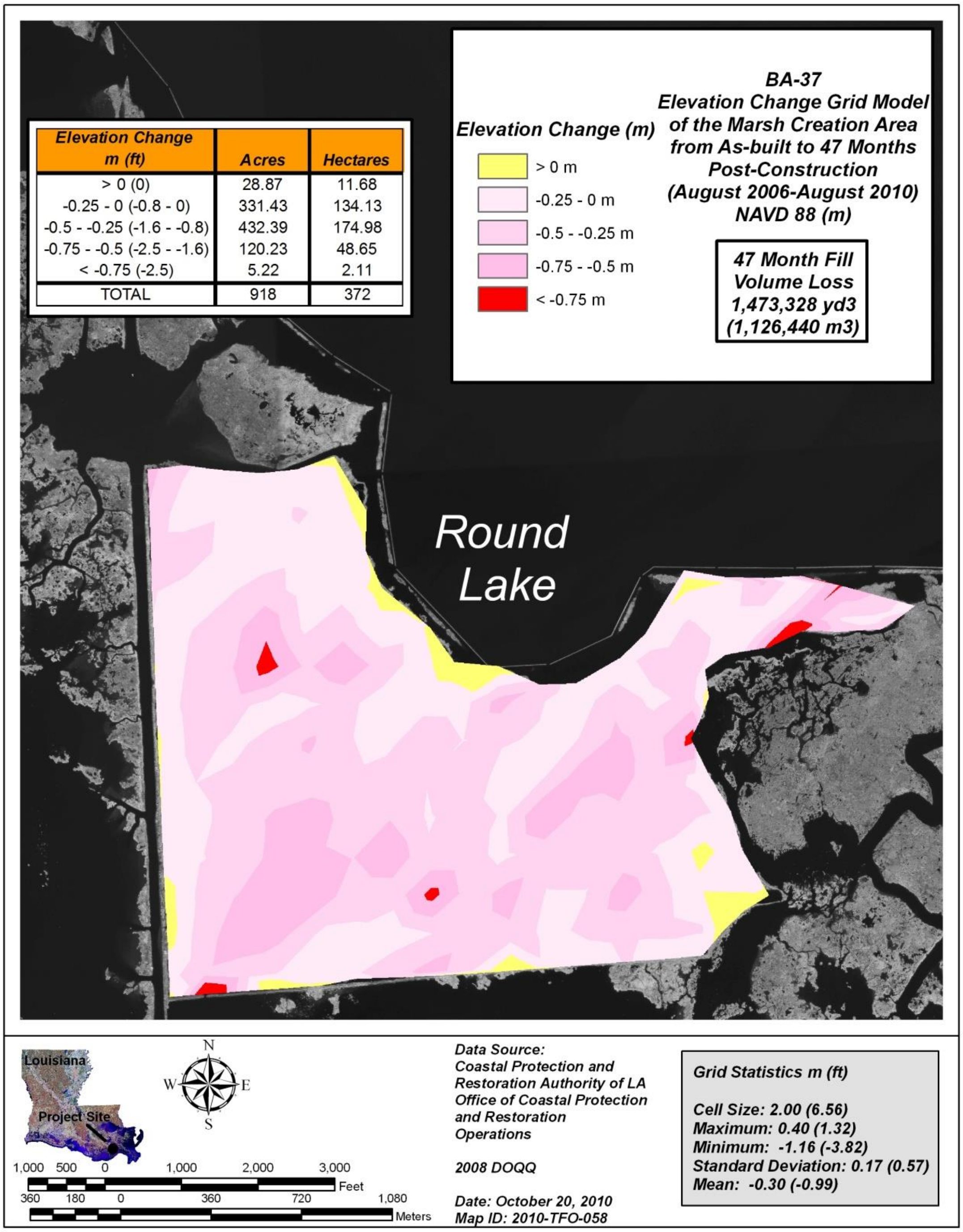


Figure 9. **Elevation and volume change grid model from as-built (Aug 2006) to post-construction (Aug 2010) at the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) project.**

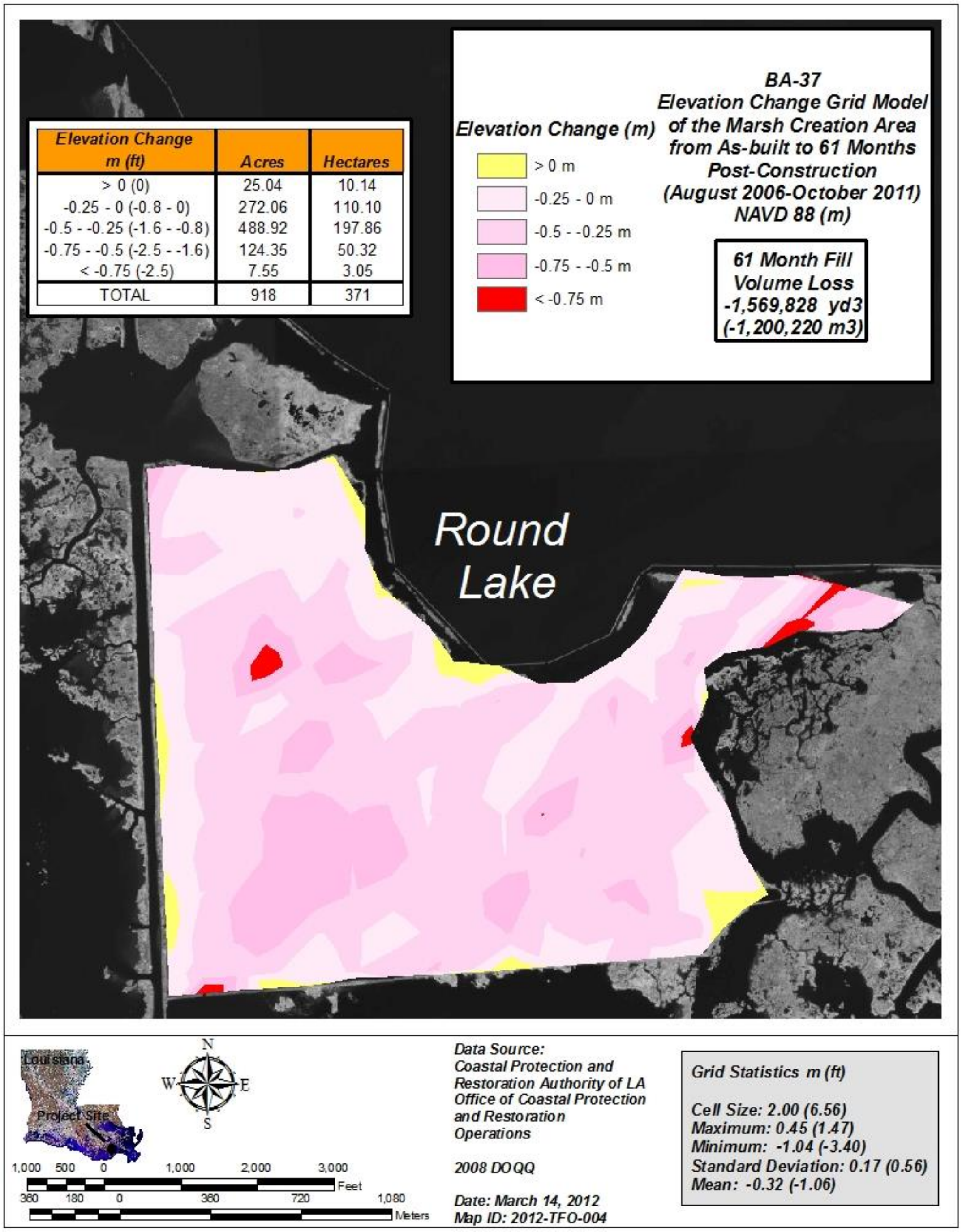


Figure 10. Elevation and volume change grid model from as-built (Aug 2006) to post-construction (Oct 2011) at the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) project.

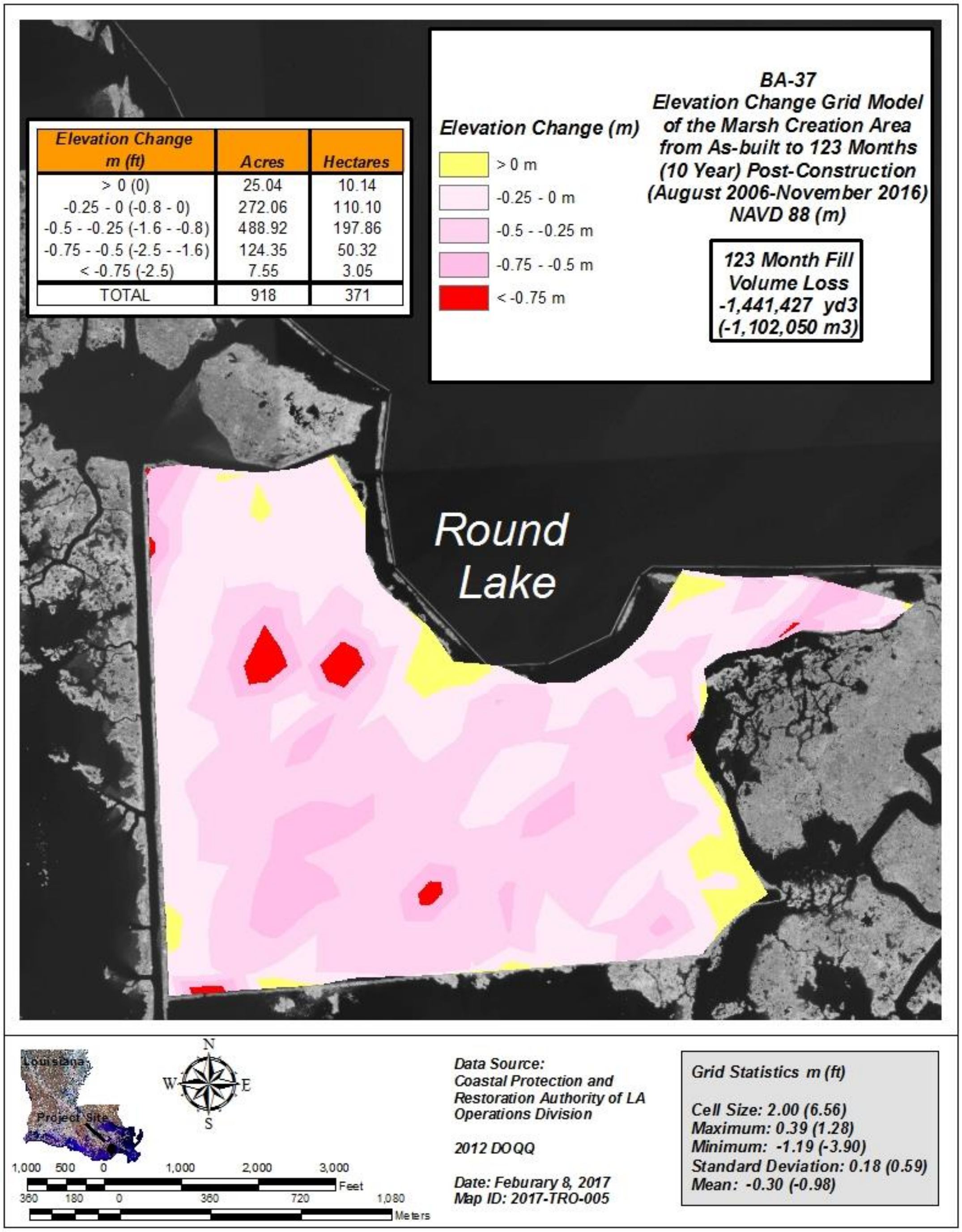


Figure 11. Elevation and volume change grid model from as-built (Aug 2006) to post-construction (Nov 2016) at the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) project.

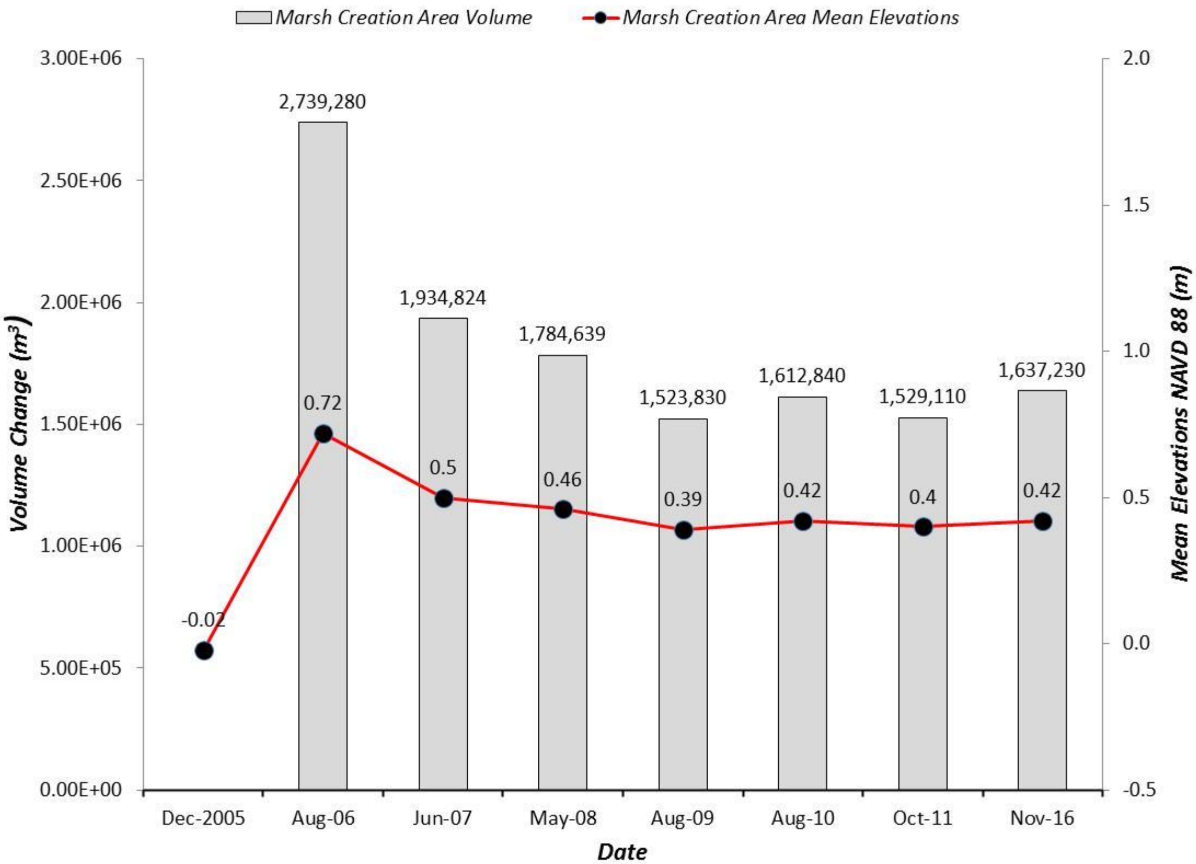


Figure 12. **Sediment volumes and mean elevations over time inside the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) marsh creation and nourishment area.**

aggressive than the predicted rock dike settlement curve established by Eustis (2003) during pre-construction. The actual value of secondary settlement is moderately larger than the estimated value (Figure 20). However, the measured rate of secondary settlement has decreased from May 2008 to Nov 2016 (Figures 16, 17, 18, and 19), and is starting to converge with the predicted settlement curve (Figure 20). The most probable reason for the rock dike's deviation from the settlement curve is the addition of 28,762 tons of rock to 5,804 m (19,041 ft) (73%) of the dike. This third rock lift was necessitated by primary settlement of the dike during construction and added a load of 1.56 tons/ft to the sections of the rock dike that were recapped. The total overburden on the underlying soils below the third lift portions of the dike is 7.16 tons/ft while the dike segments only receiving two lifts have an overburden of 5.60 tons/ft. Future settlement plate surveys will monitor the post-construction settlement rate of the foreshore rock dike.

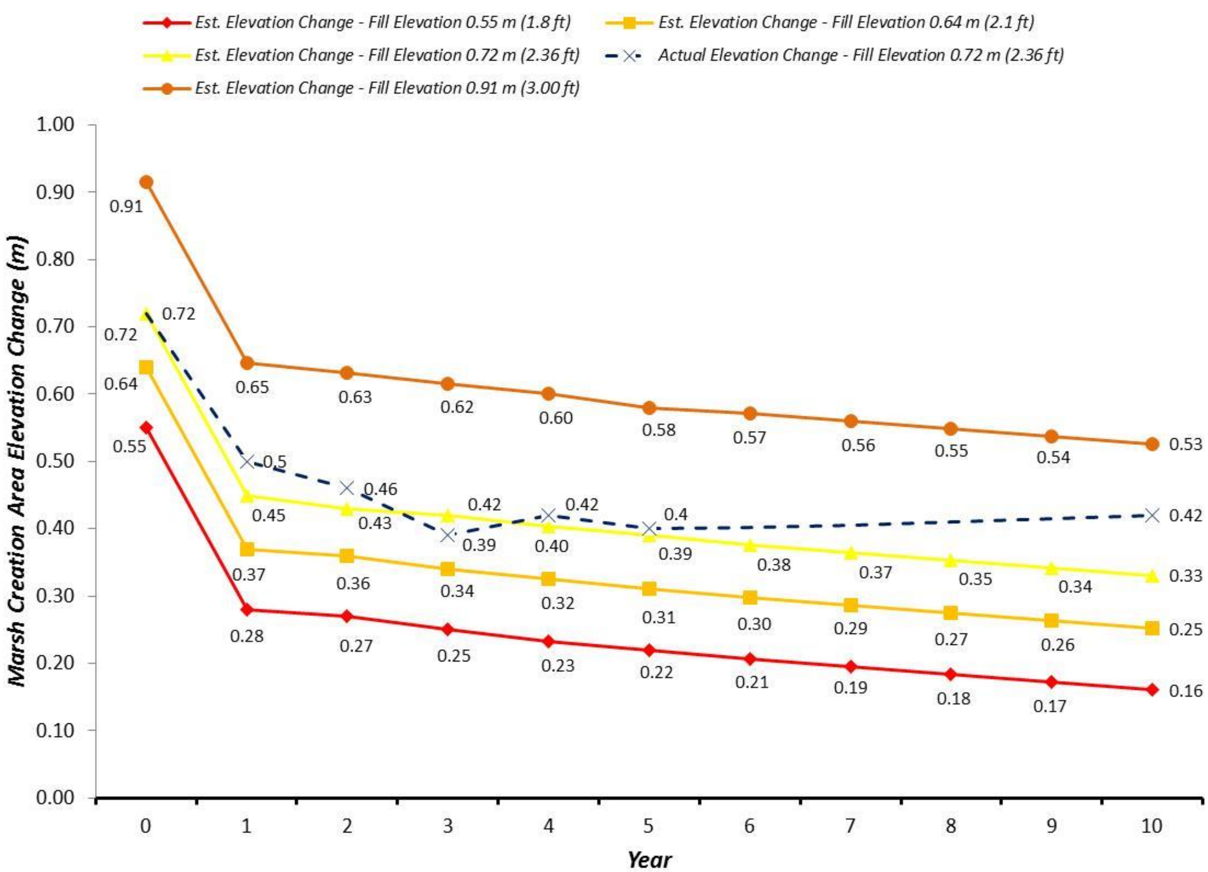


Figure 13. Estimated and actual sediment consolidation inside the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) marsh creation and nourishment area.

Shoreline Change

Preliminary pre- and post-construction shoreline position data indicate that the foreshore rock dike has reduced shoreline erosion rates in the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) project area since construction was completed in Mar 2007. Pre-construction shoreline erosion rates averaged -3 m/yr (-11 ft/yr) in the marsh creation area and -18 m/yr (-59 ft/yr) in the lake rim area from Jan 1998 to Nov 2005 (8 years) (Appendix D). Post-construction results for the period from Sep 2007 (6 months post-construction) to November 2016 (9.5 years post-construction) show average erosion rates of -0.2 m/yr (-1 ft/yr) (marsh creation area) and -2 m/yr (-7 ft/yr) (lake rim area) behind the foreshore rock dike (Appendix D). Although the pre-construction erosion rate in the lake rim area is considerably larger than the post-construction rate, the lake rim shoreline transgressed at a high rate from 2007 to 2008 [-10 m/yr (-33 ft/yr)] (Figure 21) primarily due to the effects of tropical storm activity on the shoreline. However, subsequent post-construction shoreline analyses in the lake rim area show sizable reductions in erosion rates. The low rates during these intervals are likely derived from the absence of high energy tropical systems.

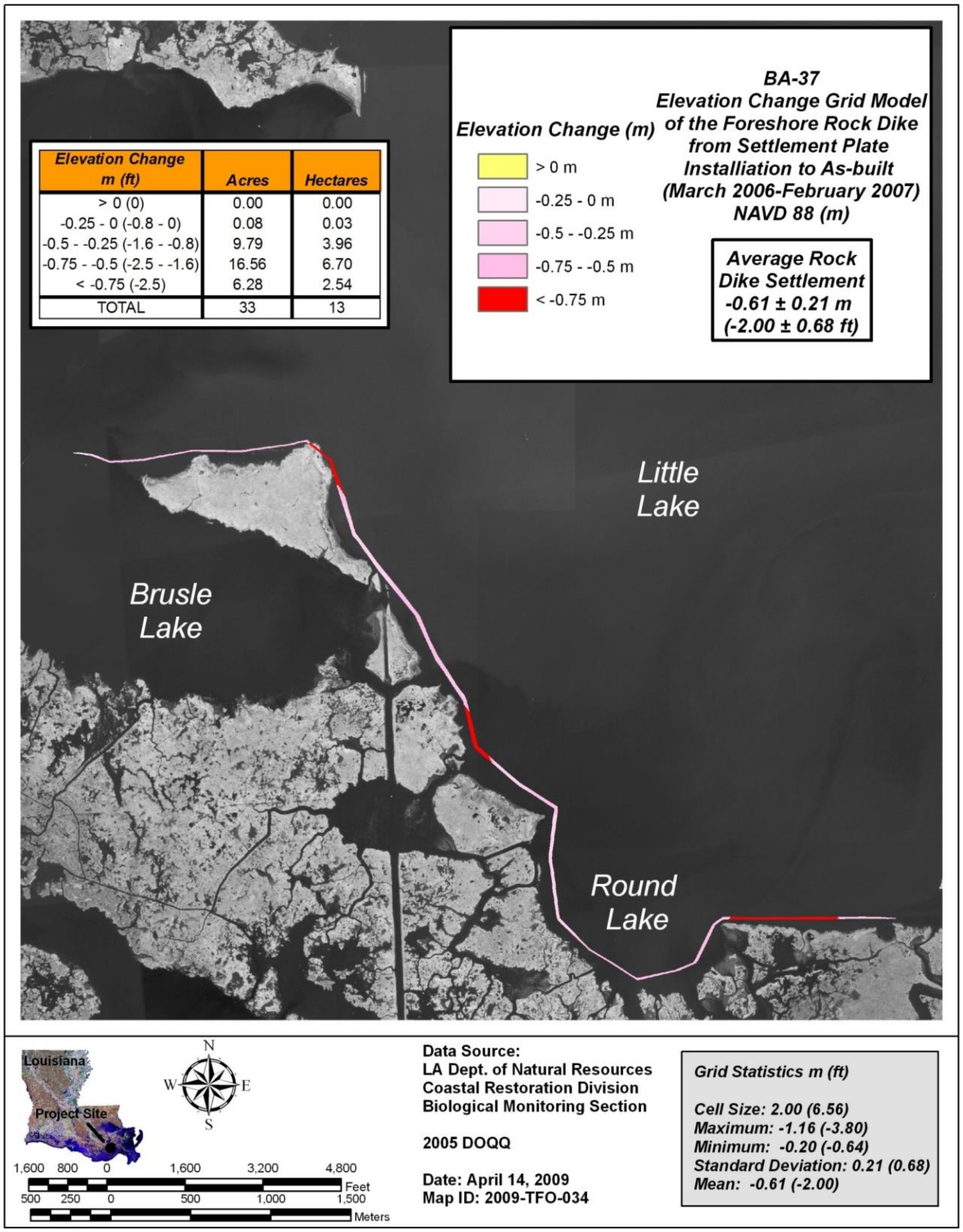
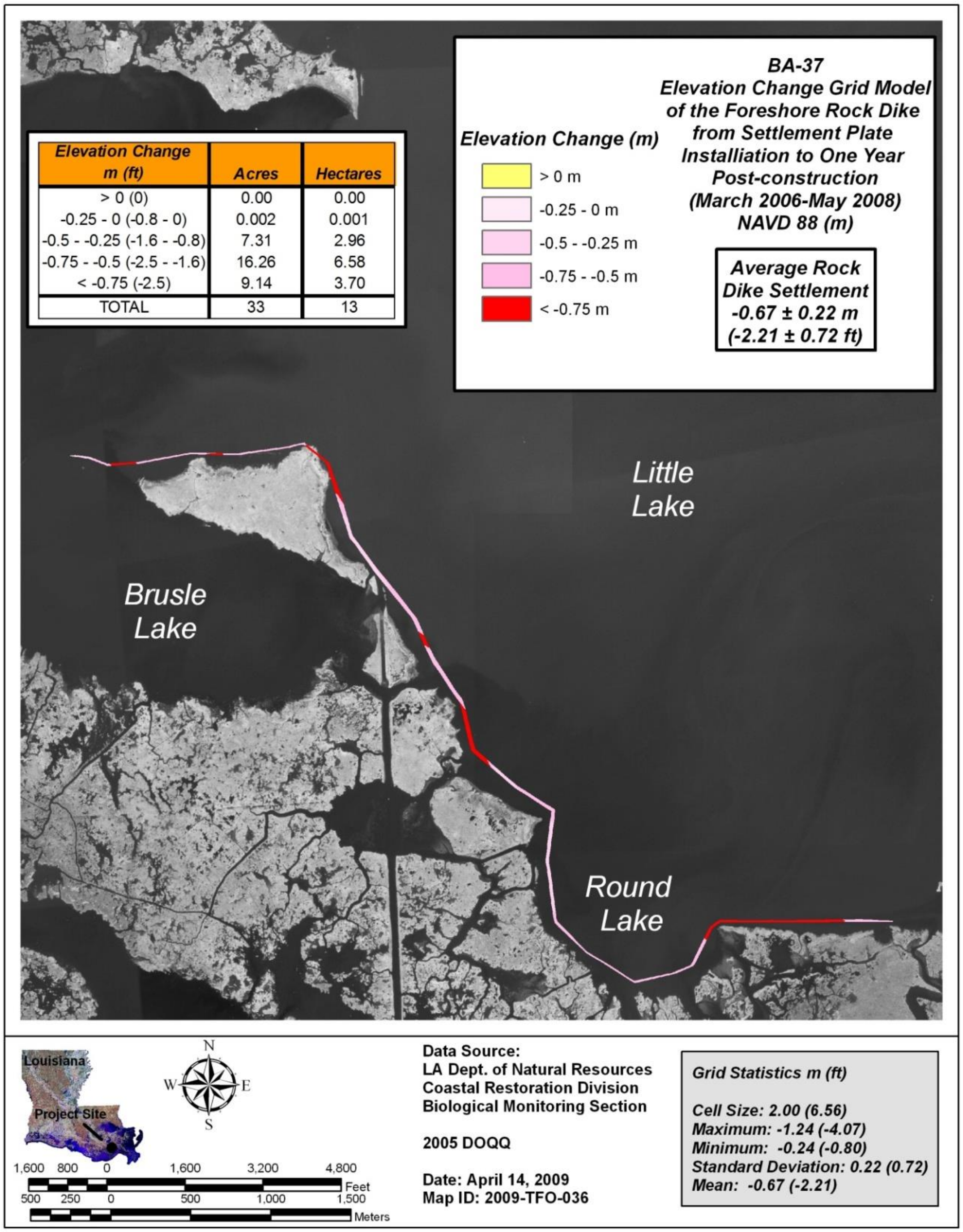


Figure 14. Elevation change grid model of the foreshore rock dike from settlement plate installation (Mar 2006) to as-built (Feb 2007) at the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) project.



Elevation Change m (ft)	Acres	Hectares
> 0 (0)	0.00	0.00
-0.25 - 0 (-0.8 - 0)	0.002	0.001
-0.5 - -0.25 (-1.6 - -0.8)	7.31	2.96
-0.75 - -0.5 (-2.5 - -1.6)	16.26	6.58
< -0.75 (-2.5)	9.14	3.70
TOTAL	33	13

Figure 15. Elevation change grid model of the foreshore rock dike from settlement plate installation (Mar 2006) to post-construction (May 2008) at the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) project.

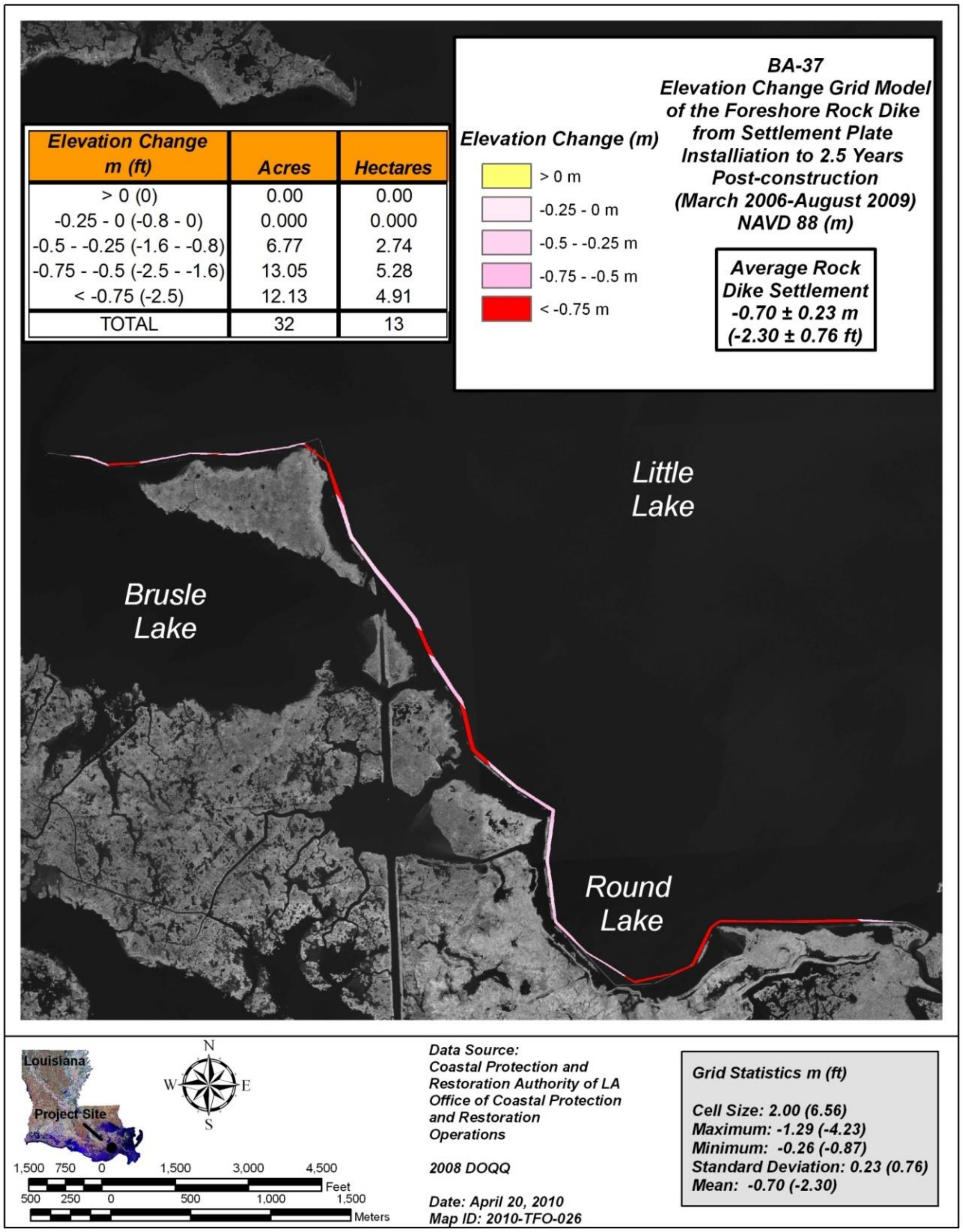


Figure 16. Elevation change grid model of the foreshore rock dike from settlement plate installation (Mar 2006) to post-construction (Aug 2009) at the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) project.

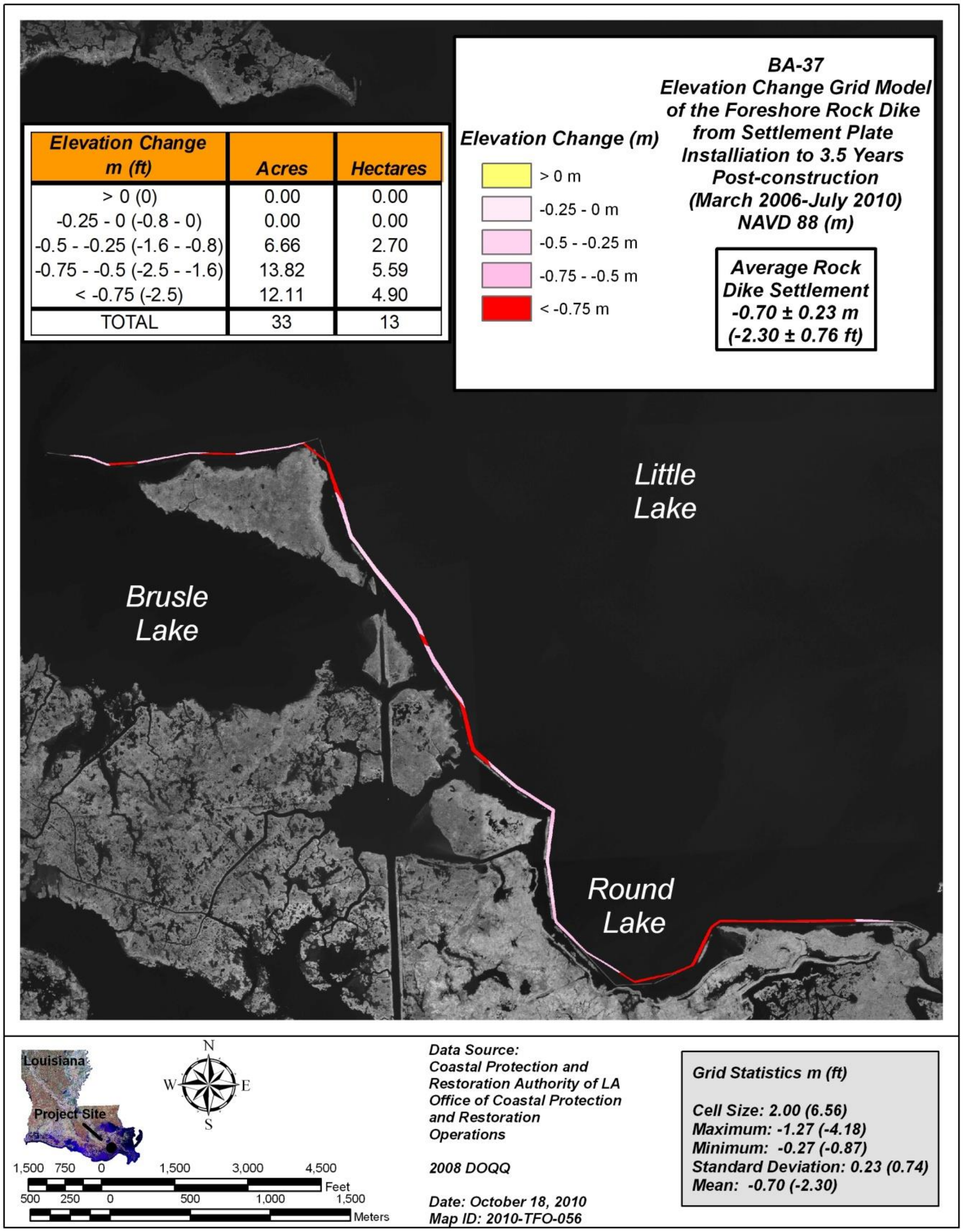


Figure 17. Elevation change grid model of the foreshore rock dike from settlement plate installation (Mar 2006) to post-construction (Jul 2010) at the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) project.

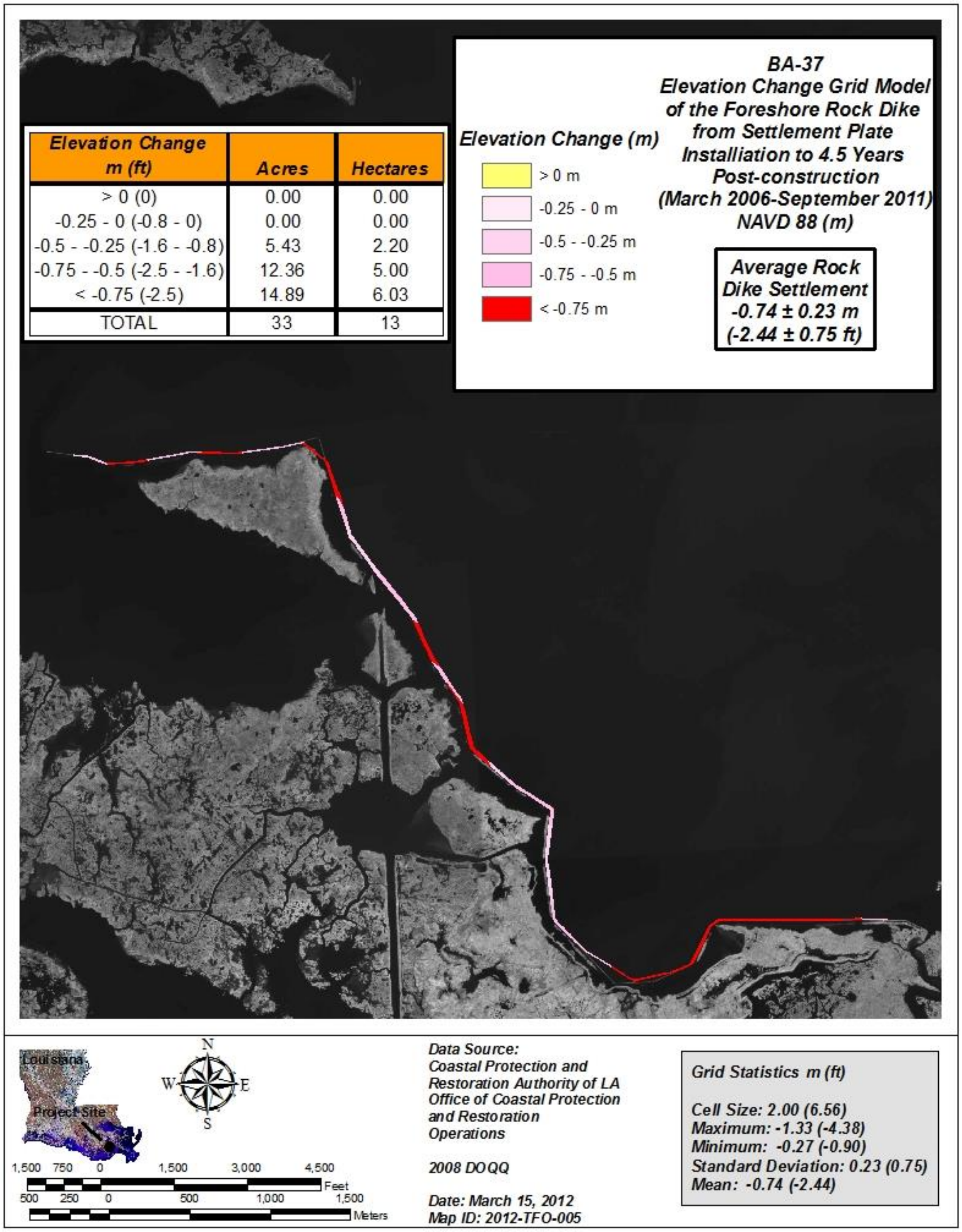


Figure 18. Elevation change grid model of the foreshore rock dike from settlement plate installation (Mar 2006) to post-construction (Sep 2011) at the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) project.

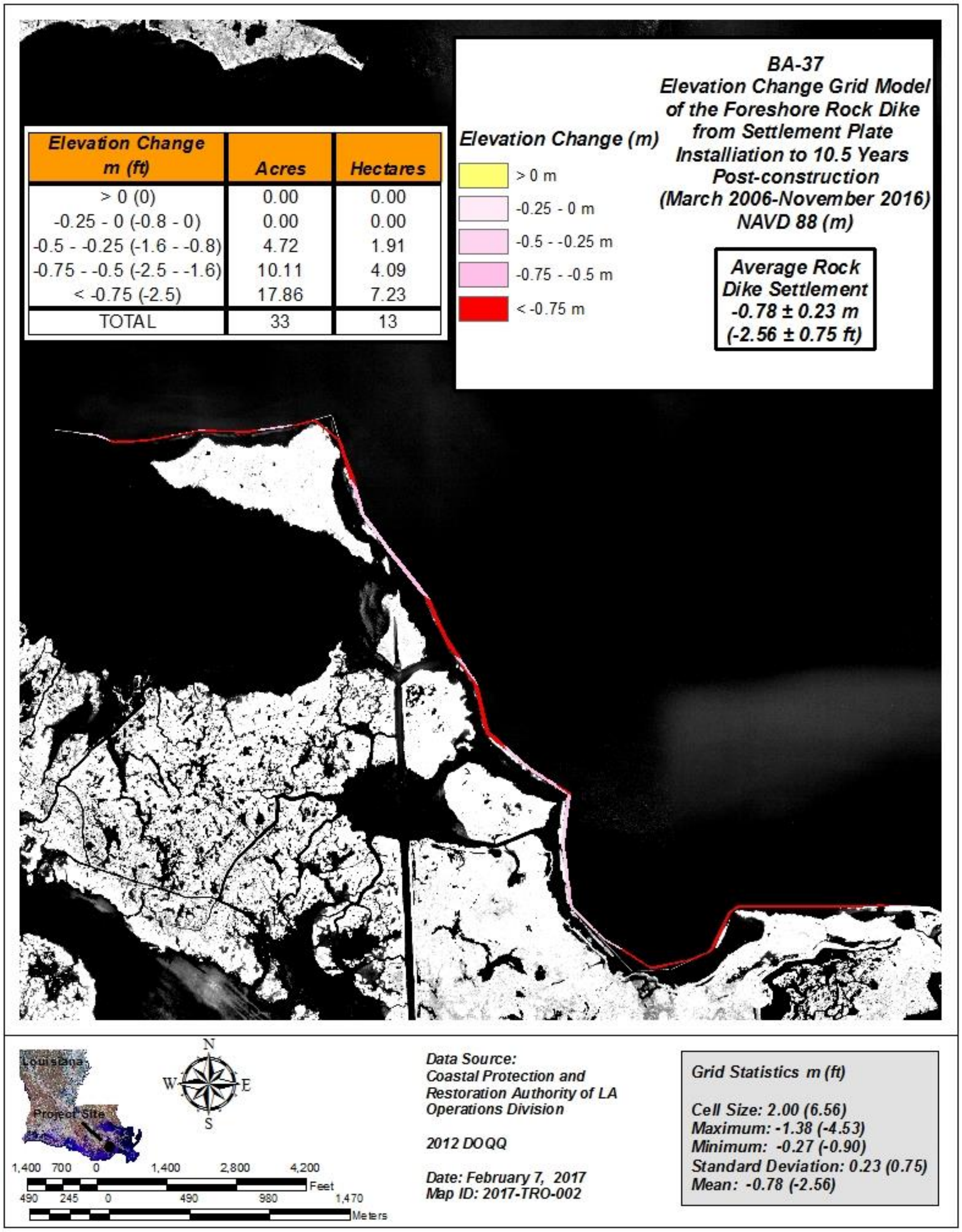


Figure 19. **Elevation change grid model of the foreshore rock dike from settlement plate installation (Mar 2006) to post-construction (Nov 2016) at the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) project.**

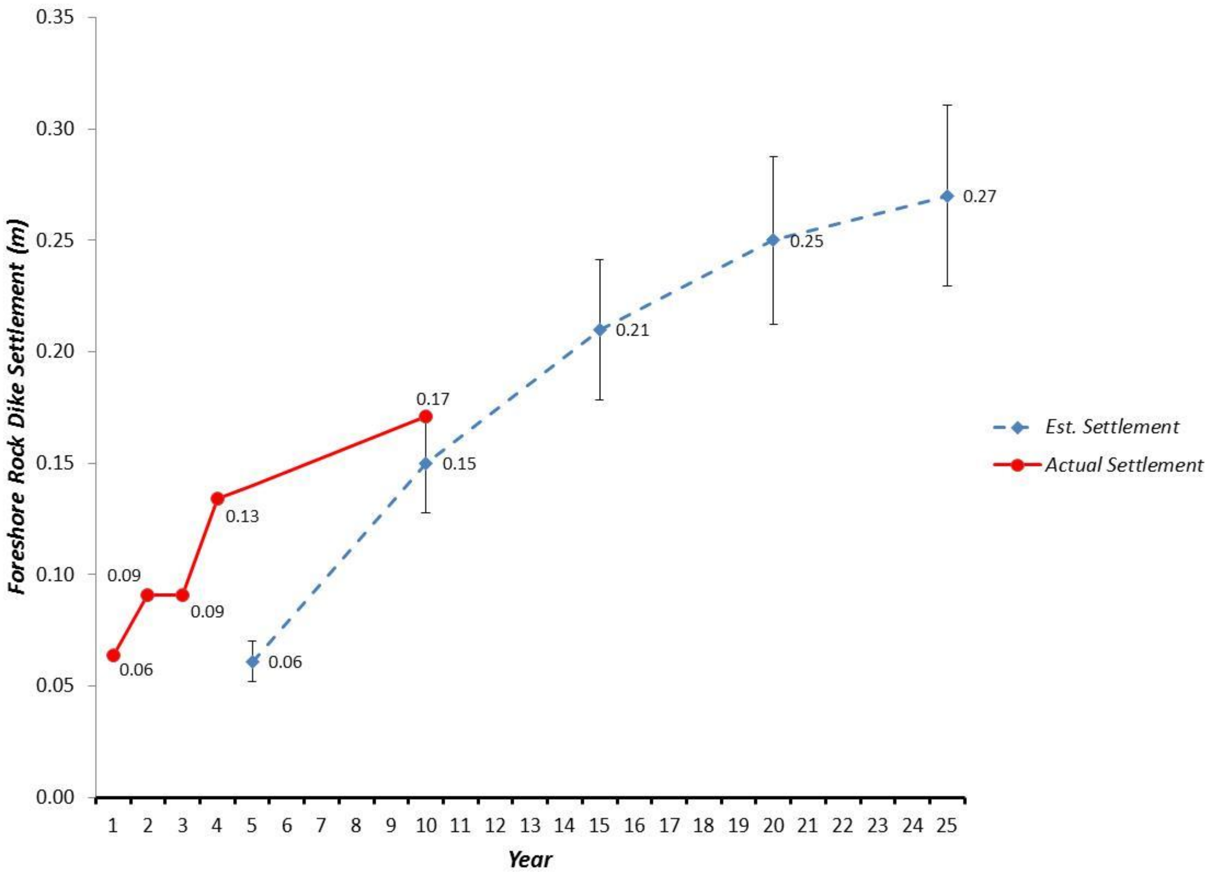


Figure 20. **Estimated and actual secondary settlement of the foreshore rock dike at the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) project.**

Pre-construction data reveals that the BA-37 shoreline was transgressing at a rapid rate. The marsh creation area shoreline eroded at rates of -2 m/yr (-7 ft/yr) from 1998 to 2003, -6 m/yr (-19 ft/yr) from 2003 to 2004, -6 m/yr (-21 ft/yr) from 2004 to 2005 (Figure 19), and -3 m/yr (-11 ft/yr) from 1998 to 2005 (Appendix D). The lake rim shoreline eroded at rates of -11 m/yr (-36 ft/yr) from 1998 to 2003, -7 m/yr (-24 ft/yr) from 2003 to 2004, -42 m/yr (-138 ft/yr) from 2004 to 2005 (Figure 22), and -18 m/yr (-59 ft/yr) from 1998 to 2005 (appendix D). During the 8 year pre-construction interval, the project area shoreline receded -103 m (-339 ft). It is apparent from the shoreline erosion data that the 2005 hurricane season significantly altered and reshaped the project area shorelines (Figure 21). The passage in quick succession of Hurricanes Cindy (Jul 2005), Katrina (Aug 2005) and Rita (Sep 2005) in close proximately to the project area (Figure 22) probably eroded large sections of shoreline and aided in the removal of 640 m (2,100 ft) of shoreline from the western extent of the project (Appendix D). Therefore, the 2005 hurricanes hastened the shoreline retreat in the pre-construction project area and intensified the land loss along the Little Lake and Round Lake rims. The pre-construction erosion rates were significantly different ($P < 0.05$) for intervals with and without high energy tropical storm events.

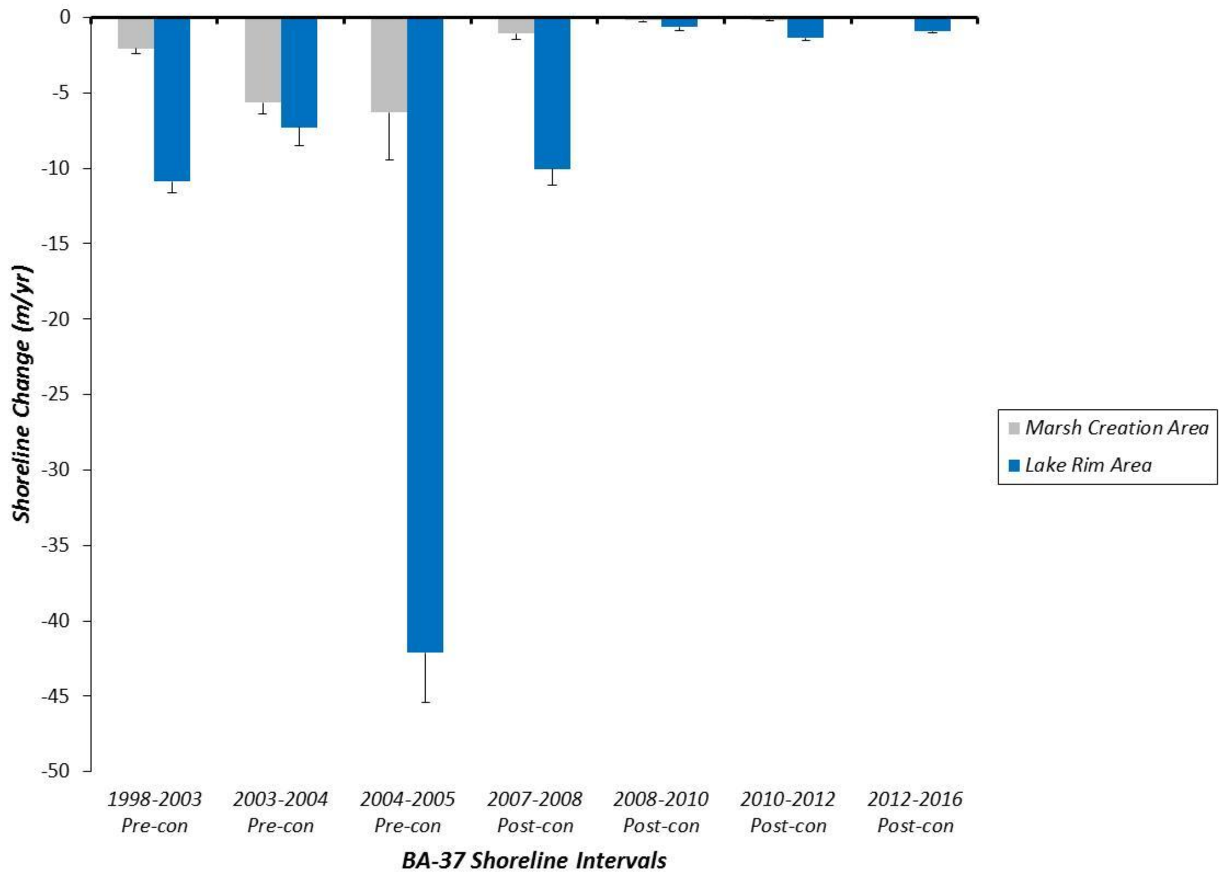


Figure 21. Pre (1998-2005) and post-construction (2007-2010) shoreline change at the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) project. Note the considerable erosion induced during the 2005 hurricane season.

Since construction of the foreshore rock dike, the marsh edge erosion rate has declined in the project area. Moreover, the pre- and post-construction shoreline change rates were significantly different ($P < 0.05$) (Figure 21). However, the initial post-construction shoreline analysis suggests that the lake rim shoreline was transgressing at the pre-2005 rate. The average shoreline erosion rate behind the rock dike was -10 m/yr (-33 ft/yr) from Sep 2007 to Oct 2008 (Figure 21) practically equivalent to the 1998-2003 (Figure 19) and 1998-2004 (Appendix D) erosion rates. The shoreline fronting the marsh creation area (Figures 2 and 3) incurred minimal shoreline erosion [-1 m/yr (-4 ft/yr)] during the initial post-construction analysis (Figure 21). Subsequent post-construction shoreline analysis show that the erosion rates in the marsh creation and lake rim areas have been considerably reduced since 2008. The marsh creation area transgressed at a rate of -0.2 m/yr (-1 ft/yr) from 2008 to 2010, -0.2 m/yr (-0.5 ft/yr) from 2010 to 2012, and -0.01 m/yr (-0.04 ft/yr) from 2012 to 2016 while the lake rim area transgressed at -0.6 m/yr (-2 ft/yr), -1 m/yr (-4 ft/yr), and -1 m/yr (-3 ft/yr) for the same intervals (Figure 21). The differences between these two areas were significant ($P < 0.05$). These disparities between the marsh creation and lake rim erosion rates are probably related to differences in fetch and sediment additions to the marsh creation area shoreline.

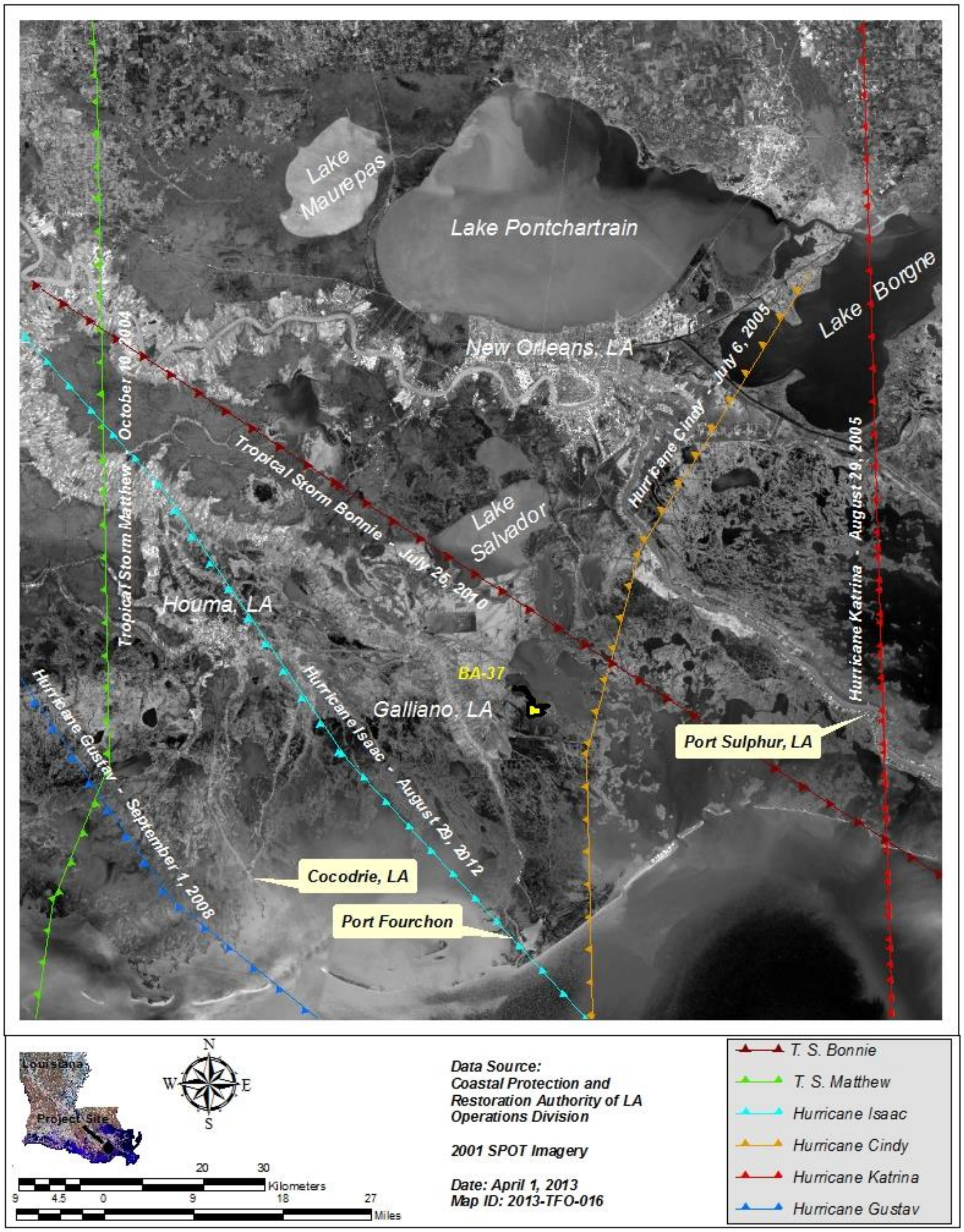


Figure 22. Pre-construction (2005) and post-construction (2008) hurricanes impacting the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) project area shoreline. Hurricanes Ivan (2004), Rita (2005), Ike (2008), and Tropical Storm Lee (2011) are not shown because the eye wall of these storms traveled further to the south (off the map).

The lake rim area has a larger fetch [88 ± 4 m (288 ± 14 ft)] than the marsh creation area [57 ± 10 m (186 ± 32 ft)], and the input of mineral sediments has strengthened the marsh creation area shoreline. The larger fetch behind the lake rim reach of the rock dike also likely contributed to the higher erosion rates behind this rock structure because waves have been shown to regenerate during high velocity winds when a large fetch lies between a coastal structure and a shoreline (Stone et al. 1999). Conversely, the marsh creation area shoreline fetch was substantially smaller. The increased erosion in the lake rim area could have been initiated by the massive erosion that incurred during the 2005 hurricane season (Figure 21) because remaining fragments of the historic mineral lake rim (Gagliano and Wicker 1989) possibly eroded leaving organic soils exposed. Moreover, the input of mineral sediments has strengthened the marsh creation area shoreline facilitating a stable and perhaps sustainable shoreline position. Although hurricanes have been found to erode coastal marshes (Guntenspergen et al. 1995; Stone et al. 1997; Watzke 2004; Trosclair 2013), cold fronts (Watzke 2004; Trosclair 2013) and wind generated waves (Stone et al. 1999; Curole et al. 2002; Watzke 2004; Trosclair 2013) have also been shown to cause marsh edge erosion. However, the underlying cause of the high post-construction erosion rate in the lake rim area appears to be Hurricane Gustav (Sep 2008) (Figure 22) because the passage of this storm seems to have coincided with substantial shoreline transgressions during the 2007-2008 period (Figure 21). In the absence of large scale tropical storms, the lake rim shoreline seems to incur low erosion rates. Statistical analysis of the shoreline data reinforces this assumption because erosion rates for the 2007-2008 interval were significantly different ($P < 0.05$) than later post-construction intervals. Future shoreline position data should clarify if the erosion rates behind the structure were induced solely by hurricane activity. Currently, the goal to reduce the marsh edge erosion rate is being attained because the marsh creation and lake rim shorelines seem to be maintaining their positions.

Lake Rim Area

The area of the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) lake rim (Figures 2 and 3) has declined over time. The vast majority of these acreage decreases transpired prior to construction of the BA-37 project. During the eight-year period before construction (1998-2005), the lake rim area acreage decreased by 64 ha (157 acres). Approximately, half of this pre-construction land loss occurred during the 2004-2005 interval and was likely induced by the 2005 hurricanes (Table 2). In the post-construction period (2007-2016), the areal extent of the lake rim area was reduced by only 9 ha (23 acres) (Table 2). In addition, a substantial portion of the post-construction lake rim area loss is occurring along the Brusle Lake shorelines (Figures 2 and 3), which are not protected by the BA-37 rock structure. Therefore, it is apparent that the foreshore rock dike has influenced the land loss rates in the lake rim area. The lake rim area analysis also confirms that pre-construction land-loss rates were intensified during periods of heightened hurricane activity.

Table 2. **Mean area of the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) lake rim area over time.**

Year	*Lake Rim Area Hectare (Acres)*	*Change Interval*	*Lake Rim Area Change Hectare (Acres)*
1998	160 (397)	*1998-2003*	30 (74)
2003	131 (323)	*2003-2004*	3 (8)
2004	127 (315)	*2004-2005*	30 (75)
2005	97 (240)	*2005-2007*	1 (3)
2007	96 (237)	*2007-2008*	3 (8)
2008	93 (229)	*2008-2010*	2 (4)
2010	91 (225)	*2010-2012*	2 (4)
2012	89 (221)	*2012-2016*	3 (7)
2016	87 (214)	*1998-2016*	74 (182)

Land/Water

The Land/Water classification of CRMS6303 showed that a 1.0 km^2 (0.4 mi^2) square portion of the BA-37 project increased in land area since construction. In Nov 2005 the marsh creation area consisted of nearly equal parts land and water. This analysis revealed that the 1.0 km^2 (0.4 mi^2) square enclosed 53 ha (131 acres) of land habitat and 47 ha (117 acres) of water habitat (Appendix E). The percentage of land in the 1.0 km^2 (0.4 mi^2) square was 53% during this time (Figure 23). This percentage corresponds to a land to water ratio of 1:1. After construction (Oct 2008) of the BA-37 marsh creation area, the land acreage inside the 1.0 km^2 (0.4 mi^2) square increased by 23 ha (57 acres) for a 23% increase in land area (Figure 23). Therefore, two years post-construction the CRMS6303 1.0 km^2 (0.4 mi^2) square consisted of 76 ha (188 acres) of land habitat (Appendix E), which corresponds to a land to water ratio of 3:1. The land area in the CRMS site was enlarged by 3 ha (7 acres) in Nov 2012, six years after construction, for a total post-construction land gain of 26 ha (64 acres), a 26% enhancement. The land area in 2012 was of 79 ha (195 acres), which translates to a land to water ratio of 4:1 or 79% land (Figure 23).

Vegetation

The CRMS6303 vegetation data confirms the classification of Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) marsh creation area as intermediate or brackish marsh. The dominant species from 2008 to 2011 were *Spartina patens* (saltmeadow cordgrass), *Paspalum vaginatum* (seashore paspalum), *Schoenoplectus americanus* (chairmaker's bulrush), and *Spartina alterniflora* (smooth cordgrass) (Figure 24). *S. patens*, *P. vaginatum*, and *S. americanus* are common inhabitants and indicator species for intermediate or brackish marsh. While *S. alterniflora* is ubiquitous in salt marsh communities, this species is also known to populate brackish and intermediate communities (Chabreck and Condrey 1979). The cover disparities between the 2008 sampling and the next

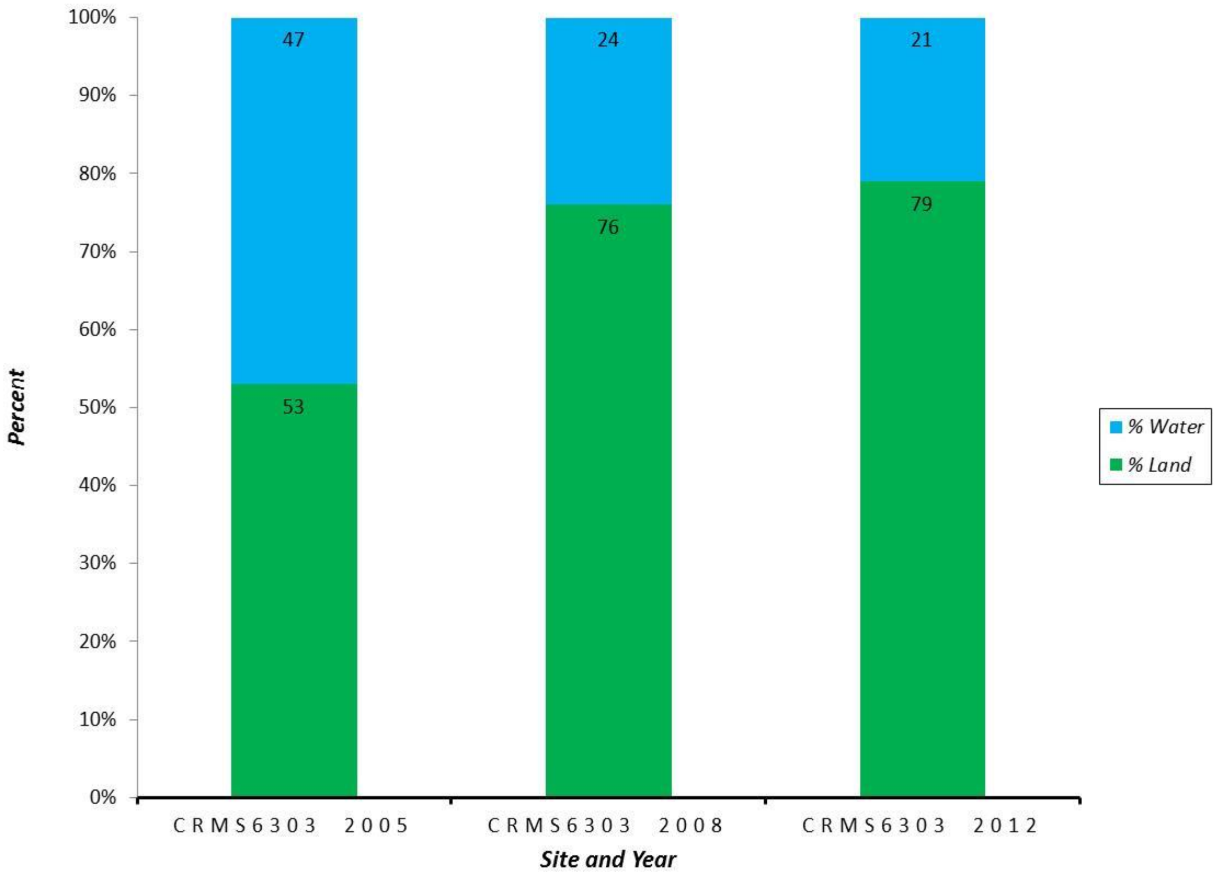


Figure 23. Percentage of land and water inside the CRMS6303 1.0 km2 (0.4 mi2) square in 2005 (pre-construction), 2008 (post-construction), and 2012 (post-construction).

three sampling events are probably due to seasonal variations in species growth. The 2008 vegetation sampling occurred in October and the 2009, 2010, and 2011 data were collected in June and July (Figure 24). Some *Spartina* species have been shown to have seasonal standing crops (Kirby and Grosselink 1976). As a result, their cover values are also cyclic and vary by season. *Vigna luteola* (Jacq.) Benth. (hairypod cowpea) began to expand its presence at the site in 2012 and has continued to be the dominant species since that time (2012-2016). The species richness also increased for this period while the cover of the original dominants declined (Figure 24). The slight dip in FQI values for this period is likely a result of these changes in species cover (Figure 24 and 25). Although the FQI was slightly reduced, the values remained above the mean of their marsh class (Figure 25) when compared to other CRMS sites (Figure 25). The species inhabiting this site along with the relatively high FQI and mean cover values consistently measured (Figure 24 and 25) signify that this CRMS site is structurally intermediate or brackish marsh habitat. In addition, the large cover of *V. luteola* from 2012 to 2016 infers that the site is well drained and salinities are low enough to fall within intermediate or brackish marsh classifications (USDA 2003). Therefore, it is highly likely that a considerable portion of the marsh creation area is composed of

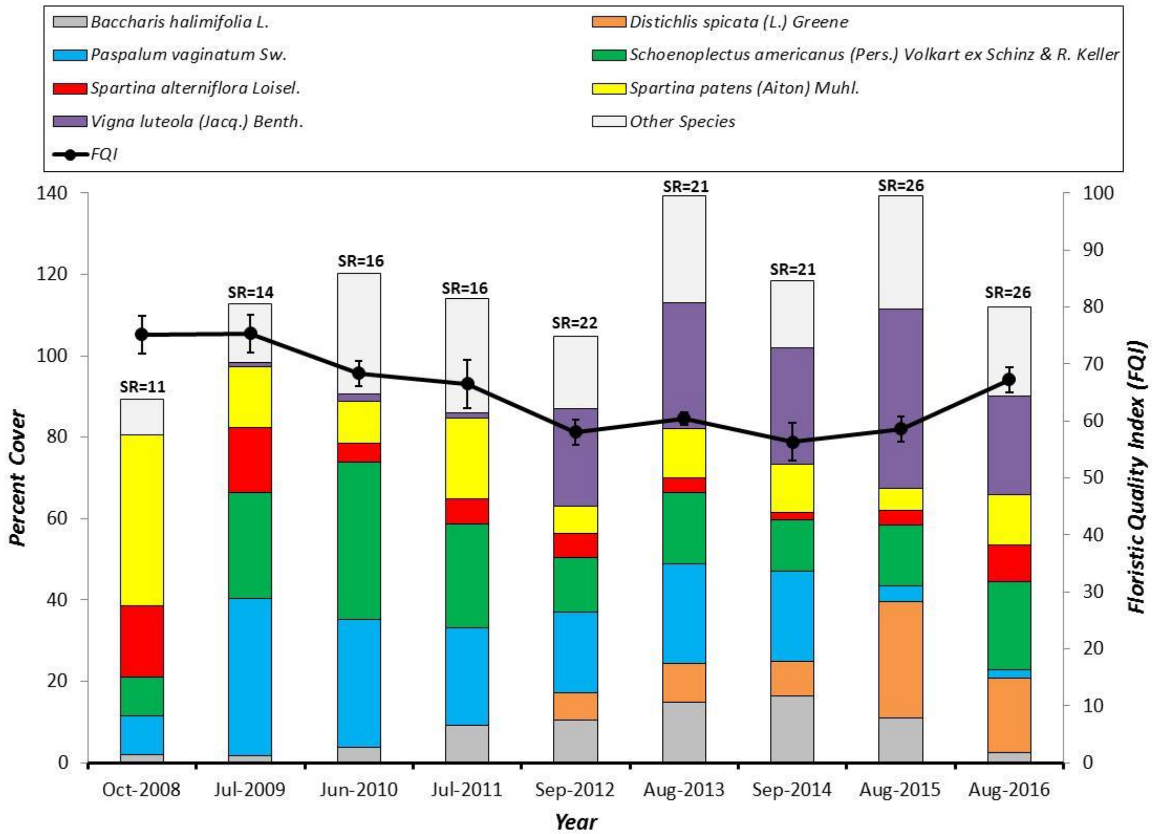


Figure 24. **Mean percent cover and floristic quality index (FQI) for vegetation species populating the CRMS6303 200 m2 (239 yd2) square from 2008 to 2016.**

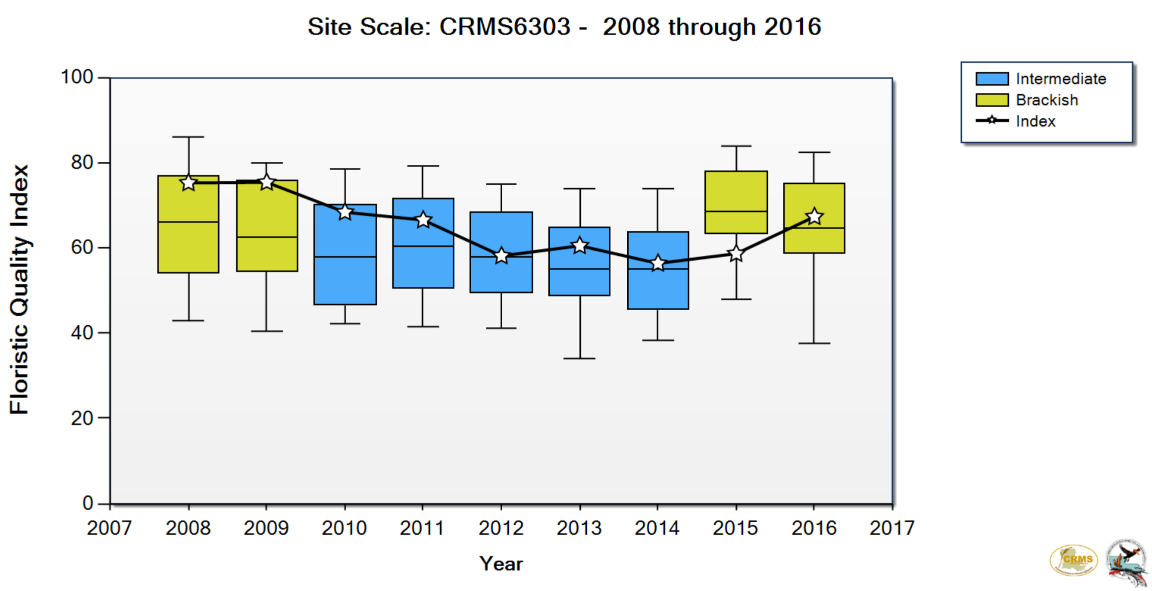


Figure 25 **Floristic quality index (FQI) for the CRMS6303 site over time. Note that this site is currently being classified as intermediate marsh, but prior to 2010 CRMS6303 was classified as brackish marsh.**

intermediate or brackish marshes. In closing, the CRMS6303 vegetation data support the assumption that the BA-37 marsh creation and nourishment goals are being attained.

Hydrology

The CRMS6303 hydrologic data confirms the classification of Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) marsh creation area as intermediate or brackish tidal marsh. The mean salinity and water level for the period from Oct 2008 to Dec 2016 were 3.12 ± 0.01 ppt and 1.27 ± 0.002 ft (0.39 ± 0.001 m) NAVD 88. The daily mean salinities, the salinity frequency distributions, and the daily mean water levels are shown in Figures 26, 27, and 28. The daily mean salinities ranged from 0.25 ppt (Jan 2010) to 16.96 ppt (Jun 2011). Though the salinity did spike above 10 ppt during the fall and spring of every year, the mean yearly salinity generally remained below or slightly above 3 ppt (Figure 27). However, in 2011 the mean yearly salinity escalated to 5.66 ± 0.04 ppt. The site experienced a persistent heightened salinity level from Feb to Jul. The rise in salinity in 2011 seems to be an anomaly for this site because the yearly mean never approached this value before or after 2011 (Figure 27). The 2011 increase in salinity also resulted in a

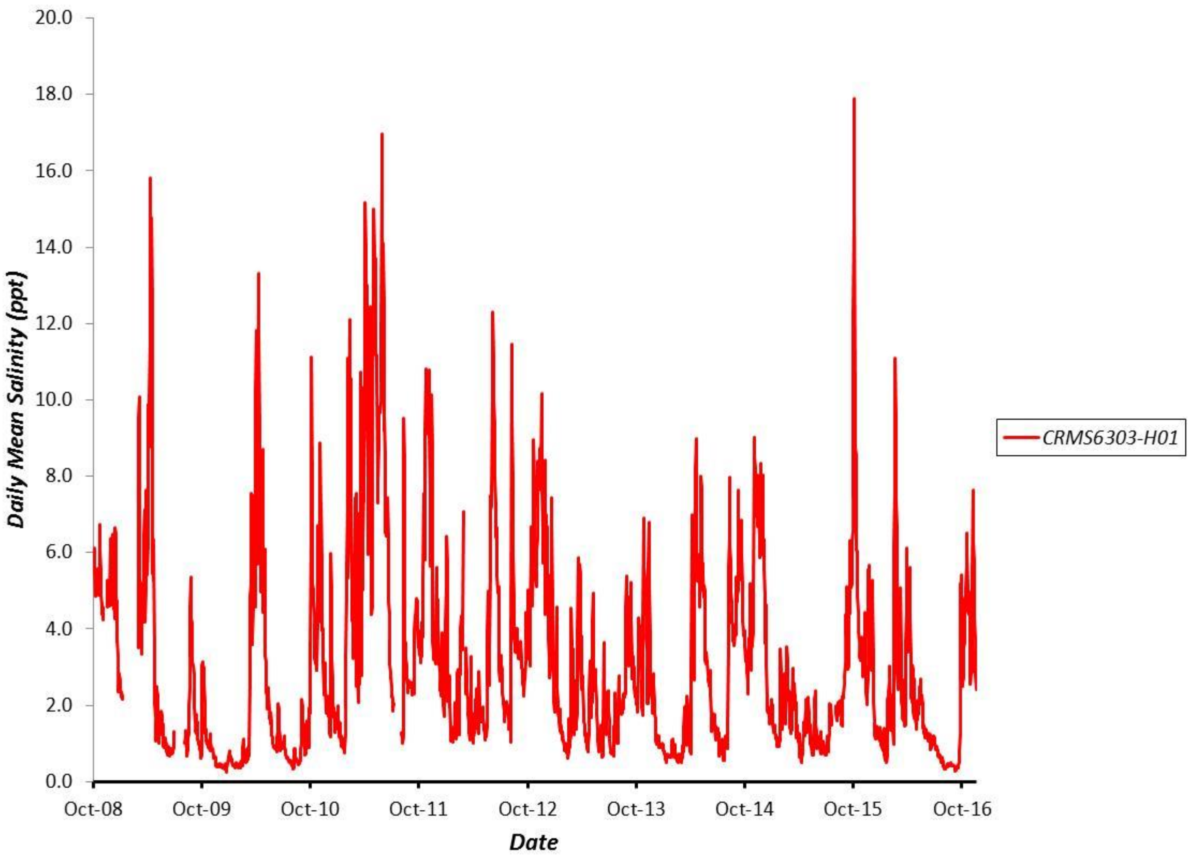


Figure 26. **Post-construction mean daily salinity (ppt) inside the CRMS6303 1 km square and the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) marsh creation and nourishment area.**

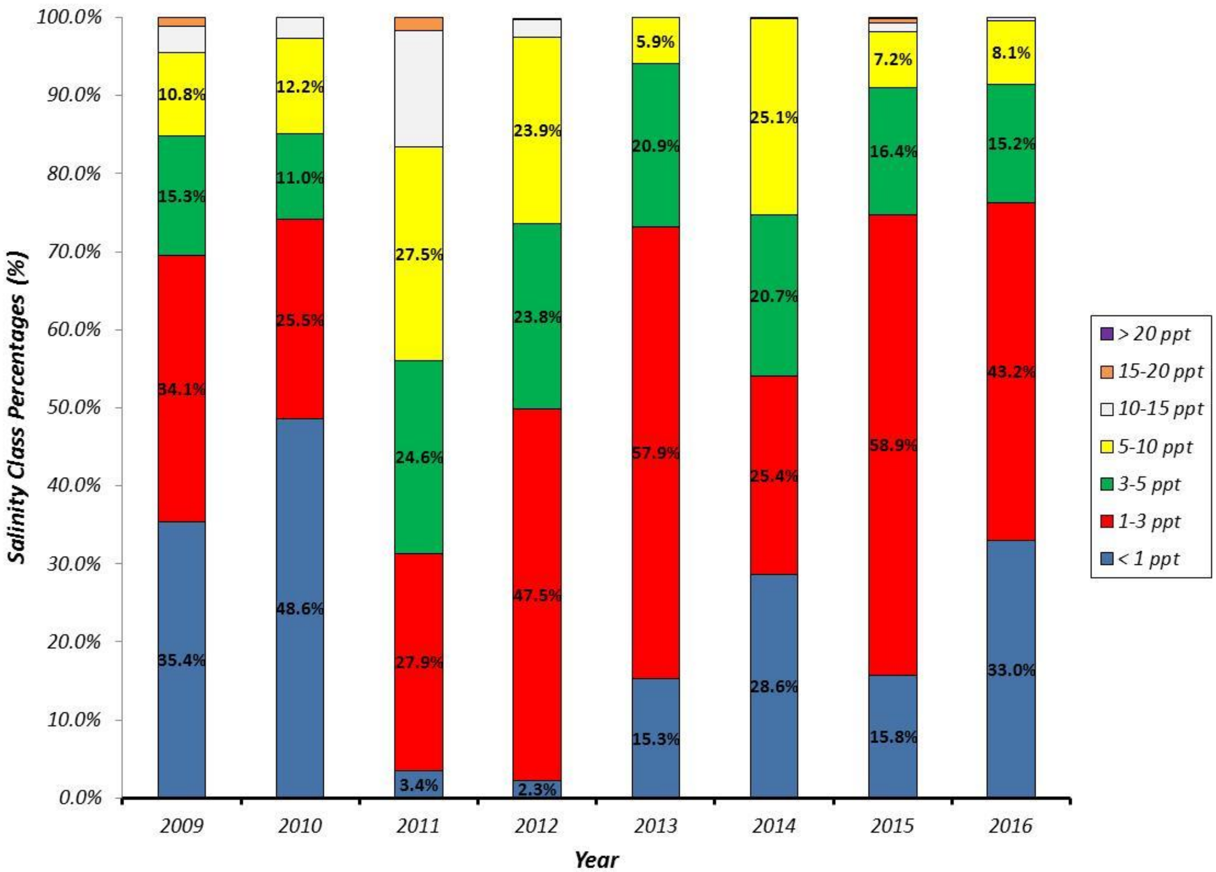


Figure 27. **Post-construction salinity (ppt) frequency distributions inside the CRMS6303 1 km square and the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) marsh creation and nourishment area.**

decrease in the site hydrologic index (HI). The 2010 HI score was 90 and the 2011 score was 27. In 2010 and after 2011, the site HI score was above the mean for its marsh class (Figure 29). Although the HI score never approached 90 again, it must be noted that 2010 was a very low salinity year. In fact, it was the lowest salinity year recorded for the sampling period (Figure 27). HI scores were not calculated for 2008, 2009, and 2016 since the site's yearly percent completeness fell below the threshold value of 70%. Because intermediate marshes have been classified as having salinities ranging from approximately 0.5 to 5 ppt and brackish marshes salinities overlap the high end of the intermediate range (Cowardin et al. 1979), the CRMS6303 hydrologic data validates an intermediate or brackish marsh classification.

The daily mean water levels are outlined in Figure 28. These daily means ranged from -0.57 ft (-0.17 m) (Dec 2010) to 4.90 ft (1.50 m) (Aug 2012). The rise in water levels in Sep 2011 and Aug 2012 were induced by Tropical Storm Lee and Hurricane Isaac, respectively (Figures 22 and 28). These storms caused extensive coastal inundation in the southern Barataria Basin. The marsh elevation in the vicinity of CRMS6303 has been documented as having a 1.40 ft (0.43 m) NAVD 88 elevation. Therefore, the marshes are flooded only when the water level

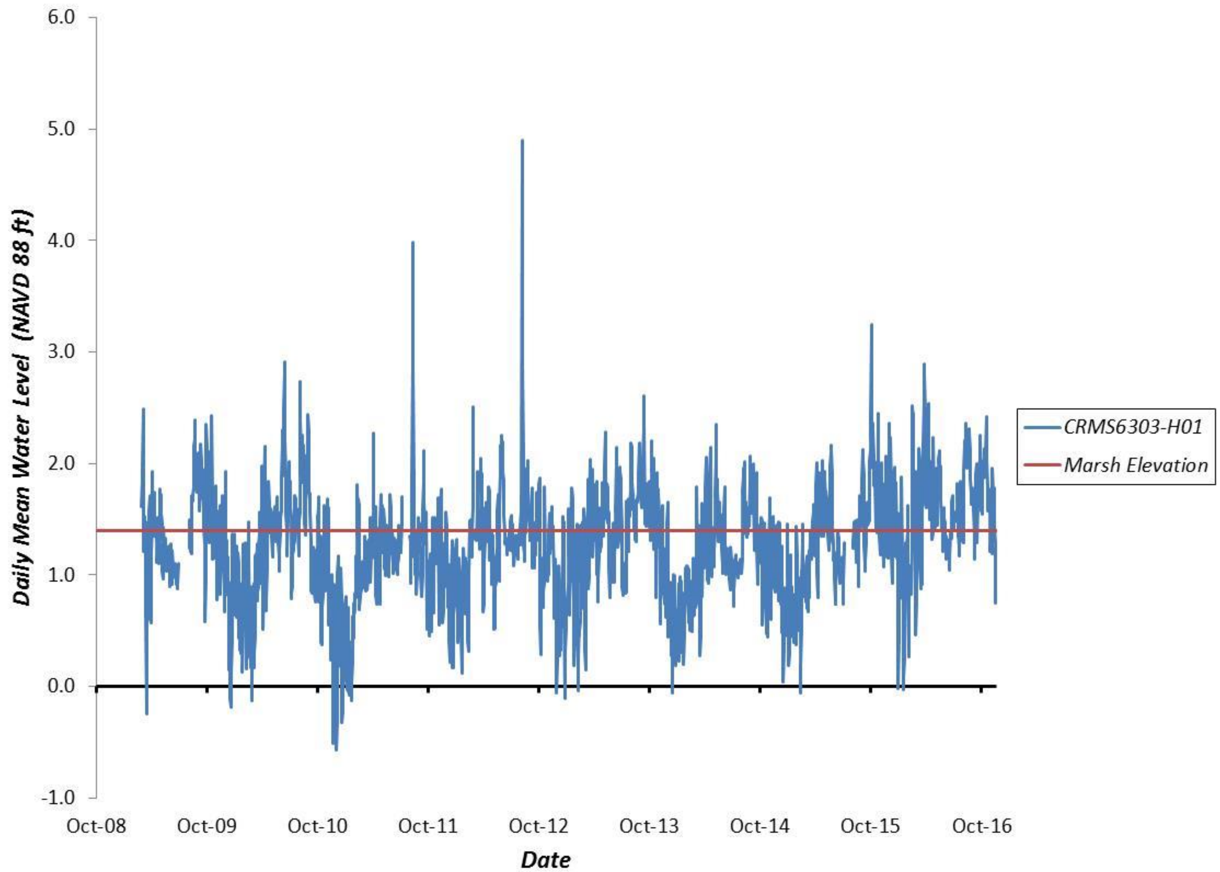


Figure 28. **Post-construction mean daily water levels (NAVD 88 ft) inside the CRMS6303 1 km square and the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) marsh creation and nourishment area.**

exceeds the mean water level. For the duration of the hydrologic data collection, the project area marshes were only flooded 40% of the time. In summary, the CRMS6303 hydrologic data endorse the BA-37 marsh creation and nourishment goals.

The CRMS data show that productive intermediate or brackish marsh communities were established within the marsh creation area and hydrologic and elevation conditions support these habitats. The vegetation community that formed in this area has had fairly persistent cover values and the species richness is expanding (Figure 24). This stability in the vegetation community was probably influenced by the slow rate of elevation change and the tidal regime. Although the salinity did spike to brackish and saline salinities, the mean salinity generally remained within the intermediate range. The tidal amplitude and elevation of the marsh creation area encourage the vegetative growth in this plant community because the marshes are periodically drained during low tides (Eleuterius and Eleuterius 1979; McKee and Patrick 1988). Therefore, the goals to create marsh at suitable elevations and nourish existing marsh are supported by the CRMS data.

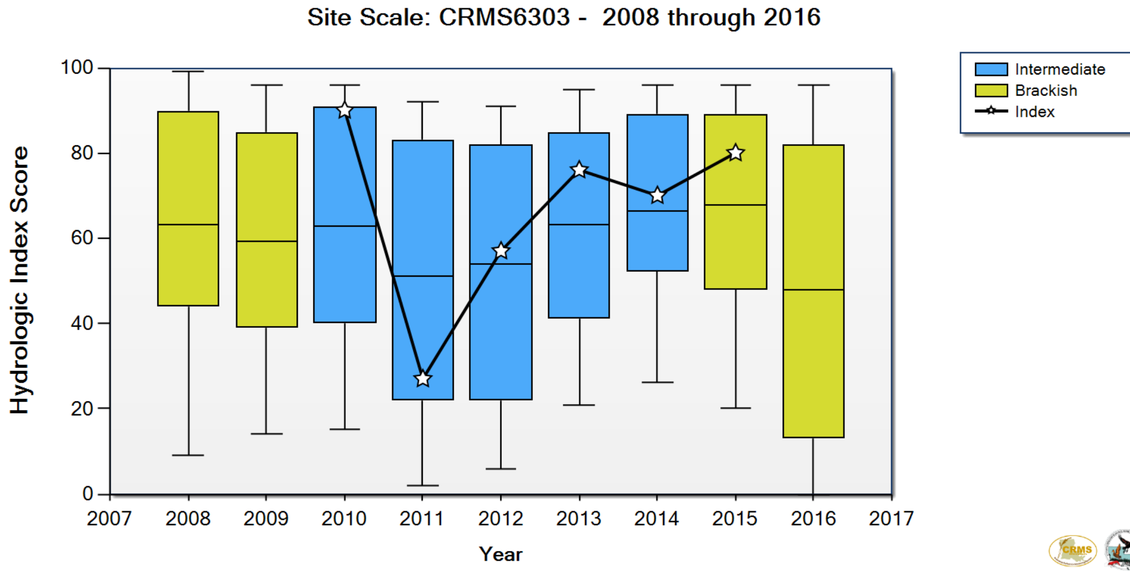


Figure 29. **Hydrologic index (HI) for the CRMS6303 site over time. Note that this site is currently being classified as brackish marsh, but from 2010 to 2014 CRMS6303 was classified as intermediate marsh.**

V. Conclusions

a. Project Effectiveness

The results of the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) reveal that three of the project goals were attained to date. The first goal to reduce the marsh edge erosion rate along the Little and Round Lake shorelines was realized because the shorelines fronting the marsh creation and lake rim areas have incurred reduced shoreline erosion rates since 2008. However, prior post-construction erosion rates showed that the lake rim shoreline was transgressing at the pre-2005 rate. The disparities between the marsh creation and lake rim erosion rates are probably related to differences in fetch and sediment additions to the marsh creation area shoreline. The input of mineral sediments may have strengthened the marsh creation area shoreline facilitating a stable and perhaps sustainable shoreline position. In contrast, the increased erosion in the lake rim area could have been initiated by the massive erosion that incurred during the 2005 hurricane season because remaining segments of the historical mineral lake rim likely eroded leaving organic soils exposed. The large fetch behind the lake rim reach of the rock dike also likely contributed to the high erosion rate behind this rock structure because waves have been shown to regenerate during high-velocity winds when a large fetch lies between a coastal structure and a shoreline (Stone et al. 1999). However, the high post-construction shoreline erosion rate in the lake rim area is probably an effect of Hurricane Gustav, which impacted the Louisiana coast in Sep 2008 (Figure 22). In the absence of large-scale tropical storms, the lake rim shoreline seems to incur low erosion rates.

The second and third goals to create and nourish intermediate or brackish marshes were attained. Approximately, 372 ha (920 acres) of marsh were created or enhanced through construction of the BA-37 project, and the CRMS6303 vegetation and hydrologic data support an intermediate or brackish marsh classification. Furthermore, the constructed marsh is settling and subsiding in compliance with the projected consolidation curve. Therefore, these results provide evidence suggesting that marsh creation and nourishment area is condensing at a sustainable rate.

The fourth goal to maintain emergent marsh at the end of the 20-year project life appears to be attainable because the marsh creation and nourishment area is settling at a slightly slower rate than the anticipated consolidation curve and has suffered only minor acreage losses since construction. At the midway point (10 year) in the project's life cycle, it seems highly likely that the BA-37 project will realize this goal. Therefore, the project is following a trajectory to maintain constructed marshes past the end of the project life.

b. Recommended Improvements

Based on the visual observations during the annual inspection and the settlement plate data from the post-construction surveys, the rock dike segments have experienced some settlement. Settlement is typical and anticipated for a rock dike structure of this type. We have reviewed the data from the 2016 survey, and by comparing the survey profile of all 24 rock dike segments to their constructed height, we have determined that a rock lift is not necessary at this time. The settlement data show that the rate of rock dike settlement is slowing and converging with the predicted settlement curve. Therefore, a rock lift is not necessary at this time. Further recommendations regarding potential rock lifts will be re-evaluated after annual visual inspections and review of the elevation data obtained from the year 15 survey. While no rock lift is scheduled, a rock dike maintenance event is scheduled to occur during the fall of 2017. This event will relocate the first two segments of the rock dike for safety and liability concerns. These rock segments are protruding into Brusle and Little Lakes and will be rotated over 100° eastward (counter clockwise) to protect the western edge of the lake rim area (Figure 3).

The marsh creation area appears to be completely vegetated and the surveys indicate its elevations are approaching the average marsh elevation for the area. There are no funds allocated for the marsh creation portion of the project other than the surveying of the area grid points. We recommend following the survey schedule in the O&M Plan, which calls for one additional elevation survey in year 15 of the project. The survey data along with the annual visual inspections will monitor the consolidation and settlement of the fill material and the resulting elevations within the marsh creation area.

c. Lessons Learned

Three lessons were learned from the first five years of the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) project. The first lesson is that the marsh creation and nourishment area could have been expanded to include marsh creation along the lake rim reach extending southward from the southern end of the Little Lake marsh creation area to the mouth of Breton Canal, although this would have increased the project cost considerably. The area surrounding the BA-37 project consists of large acreages of broken and subsided marsh. These areas have low contours that are conducive to marsh creation and nourishment. Nourishing the lake rim shoreline with mineral sediments may have been a viable alternative to lowering the shoreline erosion rates in the lake rim area. Adding mineral sediments to the lake rim shoreline may have reduced erosion rates along this reach because inputs of mineral sediments have substantially reduced the erosion rate along the marsh creation area shoreline.

The second lesson is that the marsh creation and nourishment area is settling in agreement with its consolidation curve. Although the actual rate of settlement appears to have slowed and slightly deviated from the curve, the earlier results followed the curve more closely. Nevertheless, the flat rate of constructed marsh settlement is encouraging and point toward marsh sustainability into the future. The aggressive post-construction elevation survey schedule allowed for this and has proven to be an excellent tool for estimating sustainability. One replicate survey was conducted for the first five post-construction years and at year ten. A seventh survey will be undertaken during post-construction year fifteen. As a result, another iteration of empirical evidence will be available to corroborate and validate the settlement curve. It is anticipated that this trend in settlement will continue and the future outcome of the project has already been predicted by the curve. Consolidation data is site specific and dependent on many factors including soil type. The ability to accurately forecast the mean elevation in a constructed marsh twenty years after the project is built would allow engineers and scientists to build marsh creation projects to higher elevations and let them settle and subside to the desired elevation over time. This would increase the longevity and sustainability of the constructed marshes.

The last lesson is that habitat mapping or land/water classification data should have been collected to monitor habitats over time. The constructed marsh created several diverse plant communities that are only being assessed through elevation data. Habitat data could have qualitatively and quantitatively estimated changes in these communities during the 20-year project life.

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Appendix A
(Inspection Photographs)

Photo 1: Beginning of the rock dike (Segment 1) near Sta. 10+00 at the entrance of Breton Canal.

Photo 2: Beginning of rock dike (Segment No.2) looking southward.

Photo 3: Low area along the rock dike (Segment No.2) near Sta. 23+93.

Photo 4: View of the end of rock dike (Segment No.2)

Photo 5:   View of the rock dike Segment No.3 looking north (inspection went through fish dip)

Photo 6:   View of land remnants behind rock dike Segments No. 2 & No. 3.

Photo 7: View of beginning of rock dike Segment No. 3.

Photo 8: View of the rock dike (Segments No. 3 & No. 4) and warning sign looking eastward.

Photo 9: View of the rock dike (Segments No. 4 & No. 5) looking south

Photo 10: View of the rock dike (Segment No. 6 & No. 7) and warning sign looking southwest.

Photo 11: View of the rock dike (Segment No. 7 & No. 8) looking south.

Photo 12: View of the rock dike (Segment No. 9) looking southwest.

Photo 13: View of the rock dike (Segment No. 9 & No. 10) looking southwest.

Photo 14: View of the rock dike and bent warning sign (Segment No. 10 & No. 11) looking southwest.

Photo 15: View of the rock dike (Segment No. 11 & No. 12) looking southwest.

Photo 16: View of the rock dike (Segment No. 12 & No. 13) looking southwest.

Photo 17: View of the rock dike and warning sign between Segment No. 13 & No. 14.

Photo 18: View of the rock dike (Segment No. 14) looking southward.

Photo 19: View of the rock dike (Segment No. 14 & No. 15) looking southward.

Photo 20: View of the rock dike near Segment No. 15 & No. 16 looking southward.

Photo 21: View of the rock dike (Segment No. 16) looking southwest.

Photo 22: View of the rock dike between Segment No. 16 & No. 17 looking southwest.

Photo 23: View of the rock dike between Segment No. 17 & No. 18 looking southwest.

Photo 24: View of the rock dike (Segment No. 18) looking southward.

Photo 25: View of the rock dike between Segment No. 19 & No. 20 looking southward.

Photo 26: View of the rock dike between Segment No. 20 & No. 21 looking eastward.

Photo 27: View of the rock dike between Segment No. 21 & No. 22 looking eastward.

Photo 28: View of the rock dike between Segment No. 22 & No. 23 looking southeast.

Photo 29: View of the rock dike & warning sign between Segment No. 23 & No. 24 looking south.

Photo 30: View of the rock dike, marsh, and open water just inside the opening of the southern containment dike (Segment No. 24) looking southward.

Appendix B
(Three Year Budget Projection)

LITTLE LAKE SHORELINE PROTECTION & DEDICATED DREDGING / BA37 / PPL11

Three-Year Operations & Maintenance Budgets 07/01/2017 - 06/30/2020

Project Manager	O & M Manager	Federal Sponsor	Prepared By
	Hartman	NMFS	Babin

	2017/2018	2018/2019	2019/2020
Maintenance Inspection	$ -	$ 22,097.00	$ 22,760.00
Administration (CPRA)	$ 42,918.00	$ -	$ -
Administration (NMFS)	$ 4,500.00	$ 10,000.00	$ 10,000.00

Maintenance/Rehabilitation

17/18 Description: Degrade 1900' of rock dike on the northern end of project near Breton Canal. Inpection included in CPRA Administration

E&D/Survey	$ 9,270.00
Construction	$ 667,700.00
Construction Oversight	$ 65,700.00
Sub Total - Maint. And Rehab.	$ 742,670.00

18/19 Description:

E&D	$ -
Construction	$ -
Construction Oversight	$ -
Sub Total - Maint. And Rehab.	$ -

19/20 Description:

E&D	$ -
Construction	$ -
Construction Oversight	$ -
Sub Total - Maint. And Rehab.	$ -

	2017/2018	2018/2019	2019/2020
Total O&M Budgets	$ 790,088.00	$ 32,097.00	$ 32,760.00

O&M Budget (3-yr Total)	$ 854,945.00
Unexpended O&M Funds	$ 1,106,801.00
Remaining O&M Budget (Projected)	$ 251,856.00

OPERATIONS & MAINTENANCE BUDGET WORKSHEET

Project: **BA-37 Little Lake Shoreline Protection / Dedicated Dredging Near Round Lake**

FY 17/18 –

Administration (NMFS)		$ 4,500
CPRA Administration:		$ 42,918
Maintenance:		$742,670
E&D:	$ 9,270	
Pre-Design Survey:	$ ~~31,250~~	
Marsh Survey:	$ ~~31,250~~	
Construction:	$667,700	
Construction Oversight:	$ 65,700	

Operation and Maintenance Assumptions:

Maintenance Event No.1 - to degrade approximately 1,900 linear (Segment No.1 and 2) of existing rock dike from Breton Canal southward.

Construction:	
Mobilization/Demobilization: (Lump Sum)	$ 55,000
Rock Recovery/Placement: (9,000 tons @ $50/ton)	$450,000
Flotation Dredging: (Lump Sum)	$ 20,000
Geotextile Fabric: (4,500 sq.yd. @ $5/sq.yd.	$ 22,500
Warning Signs:	$ 14,000
Settlement Plates:	$ 500
Surveys:	$ 50,000
Construction Cost:	$607,000
Contingency (10%):	$ 60,700
Total Estimated Construction Cost:	**$667,700**

Engineering, Design and Construction Oversight:	
Engineering/Design:	$ ~~46,350~~ 80% Completed ($9,270 remaining)
(7.5% Construction)	
Surveying:	$ ~~27,000~~ Completed

(Field Work – 7 days @ $3,250/Day)
(Data Processing/Report: - 50 hrs @ $85/hr.)
Permitting: $ ~~3,000~~ Completed
($3,000)
Construction Inspection: $ 49,500
(450 hrs @ $110/hr.)
Construction Admin: $ 16,200
(120 hrs. @ $135/hr.)
NMFS Admin: $ 4,500
(30 hrs @ $150/hr.)
Total Engineering/Design, Construction Oversight: **$ 79,470**

CPRA Direct Costs

Maintenance Event No.1:

Engineer 4 – 80 hrs. @ $60/hr. =	$ 4,800
Engineer 6 – 20 hrs. @ $73/hr. =	$ 1,460
Engineer 7 – 10 hrs. @ $79/hr. =	$ 790
	$ 7,050
Inspection:	
CPRA Engineer 3 – 12 hrs. @ $60/hr.:	$ 720
CPRA Engineer 6 – 12 hrs. @ $73/hr.	$ 876
CPRA Scientist 4 – 10 hrs. @ $50/hr.	$ 500
	$ 2096
Report:	
CPRA Engineer 6 – 60 hrs. @ $73/hr.	$ 4,380
Total Direct CPRA Costs:	**$13,625**

CPRA Indirect Costs

Maintenance Event No.1:

Engineer 4 – 80 hrs. @ $127/hr. =	$10,160
Engineer 6 – 20 hrs. @ $155/hr. =	$ 3,100
Engineer 7 – 10 hrs. @ $168/hr. =	$ 1,680
	$ 14,940
Inspection:	
CPRA Engineer 3 – 12 hrs.@ $127/hr.:	$ 1,528
CPRA Engineer 6 – 12 hrs. @ $155/hr.	$ 1,856
CPRA Scientist 4 – 10 hrs. @ $168/hr.	$ 1,676
	$ 5,060
Report:	
CPRA Engineer 6 – 60 hrs. @ $155/hr.	$ 9,293
Total Indirect CPRA Costs:	**$29,293**

FY 18/19 –

Administration (NMFS)			$ 10,000
O&M Inspection & Report			$ 22,097
CPRA Administration:			$ 0
Maintenance:			$ 0
E&D:	$	0	
Construction:	$	0	
Construction Oversight:	$	0	

Operation and Maintenance Assumptions:
Increase of 3% for inflation on inspection/report.

<u>CPRA Direct Costs</u>

Inspection:
$2,159 x 3% inflation = $2,224
Report:
$4,511 x 3% = $4,646
Total Direct CPRA Costs: **$6,870**

<u>CPRA Indirect Costs</u>

Inspection:
$5,212 x 3% = $ 5,368
Report:
$9,572 x 3% = $ 9,859

Total Indirect CPRA Costs: **$15,227**

FY 19/20 –

Administration (NMFS)			$ 10,000
O&M Inspection & Report			$ 22,760
CPRA Administration:			$ 0
Maintenance:			$ 0
E&D:	$	0	
Construction:	$	0	
Construction Oversight:	$	0	

Operation and Maintenance Assumptions:
Increase of 3% for inflation on inspection/report.

<u>CPRA Direct Costs</u>

Inspection:
$2,224 x 3% inflation = $2,291
Report:
$4,646 x 3% = $4,785
Total Direct CPRA Costs: **$7,076**

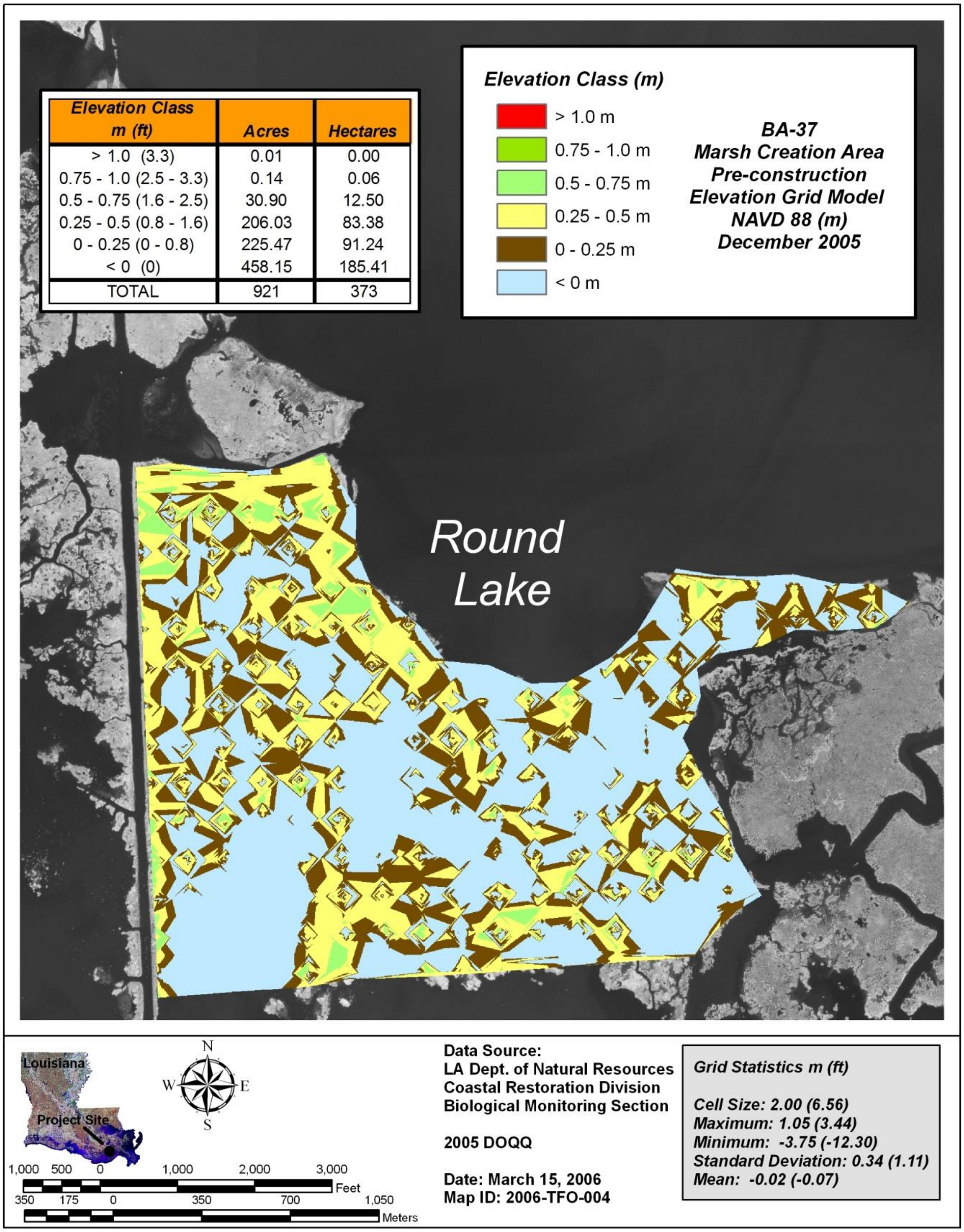
<u>CPRA Indirect Costs</u>

Inspection:	
$5,368 x 3% =	$ 5,529
Report:	
$9,859 x 3% =	$10,155
Total Indirect CPRA Costs:	**$15,684**

2017-2020 Accounting

Approved CWPPRA Budget (LANA Report):	**$ 1,498,723**
Total Expenditures (LaGov):	**$ 391,922**
Unexpended Funds:	**$ 1,106,801**

Appendix C
(Elevation Grid Models)



Elevation Class m (ft)	Acres	Hectares
> 1.0 (3.3)	0.01	0.00
0.75 - 1.0 (2.5 - 3.3)	0.14	0.06
0.5 - 0.75 (1.6 - 2.5)	30.90	12.50
0.25 - 0.5 (0.8 - 1.6)	206.03	83.38
0 - 0.25 (0 - 0.8)	225.47	91.24
< 0 (0)	458.15	185.41
TOTAL	921	373

Figure C-1. Pre-construction (Dec 2005) elevation grid model at the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) project.

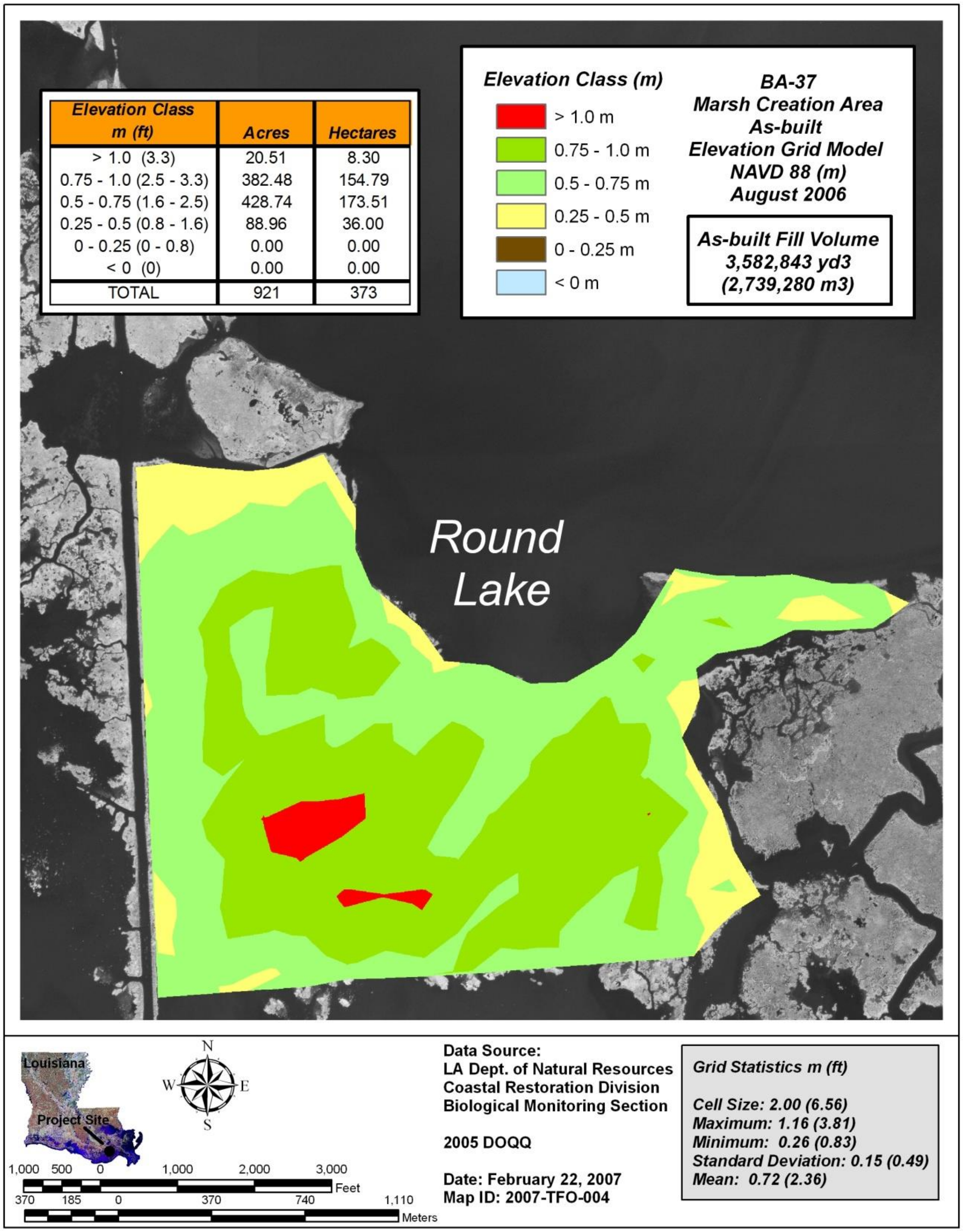


Figure C-2. As-built (Aug 2006) elevation grid model at the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) project.

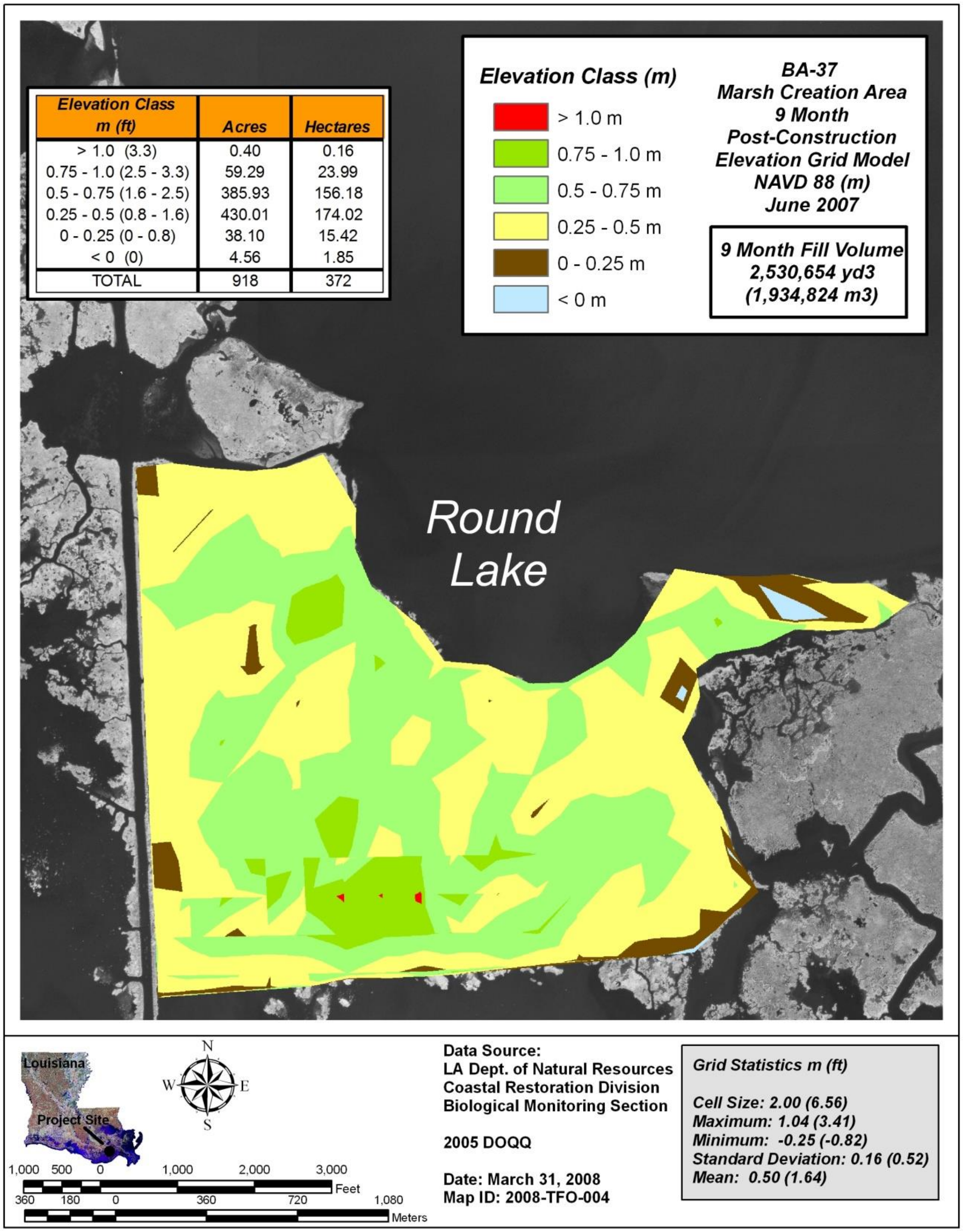


Figure C-3. **Post-construction (Jun 2007) elevation grid model at the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) project.**

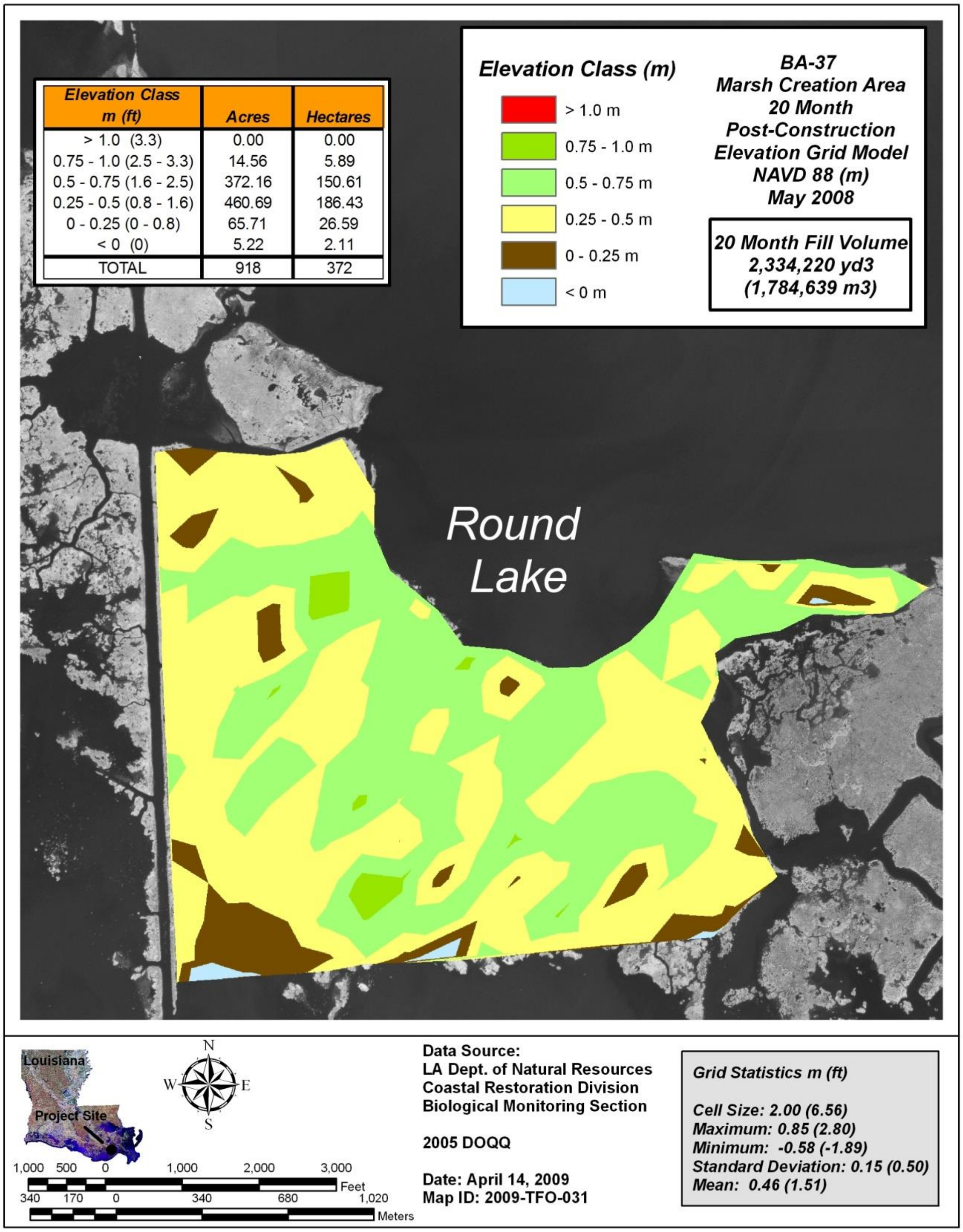


Figure C-4. Post-construction (May 2008) elevation grid model at the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) project.

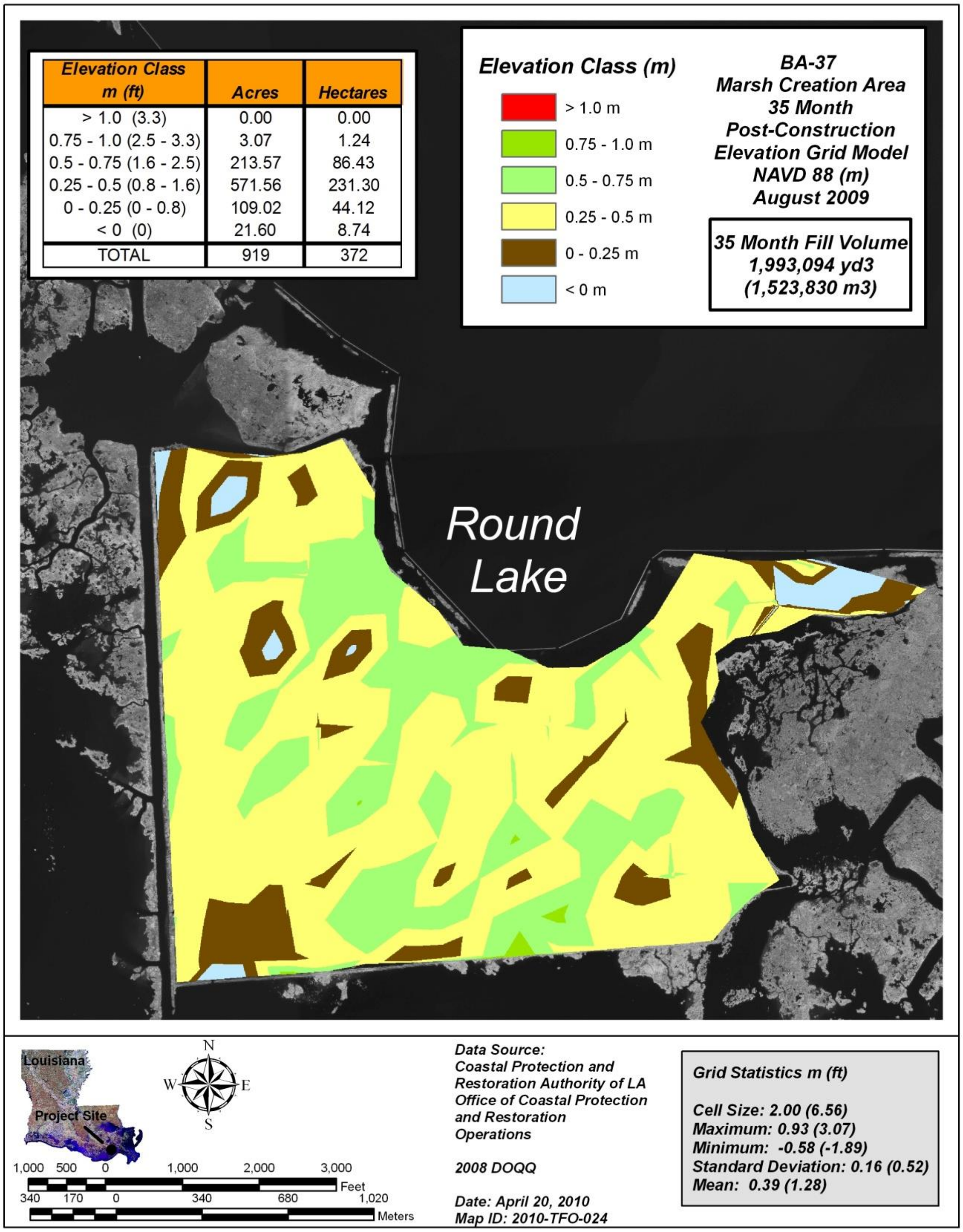


Figure C-5. **Post-construction (Aug 2009) elevation grid model at the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) project.**

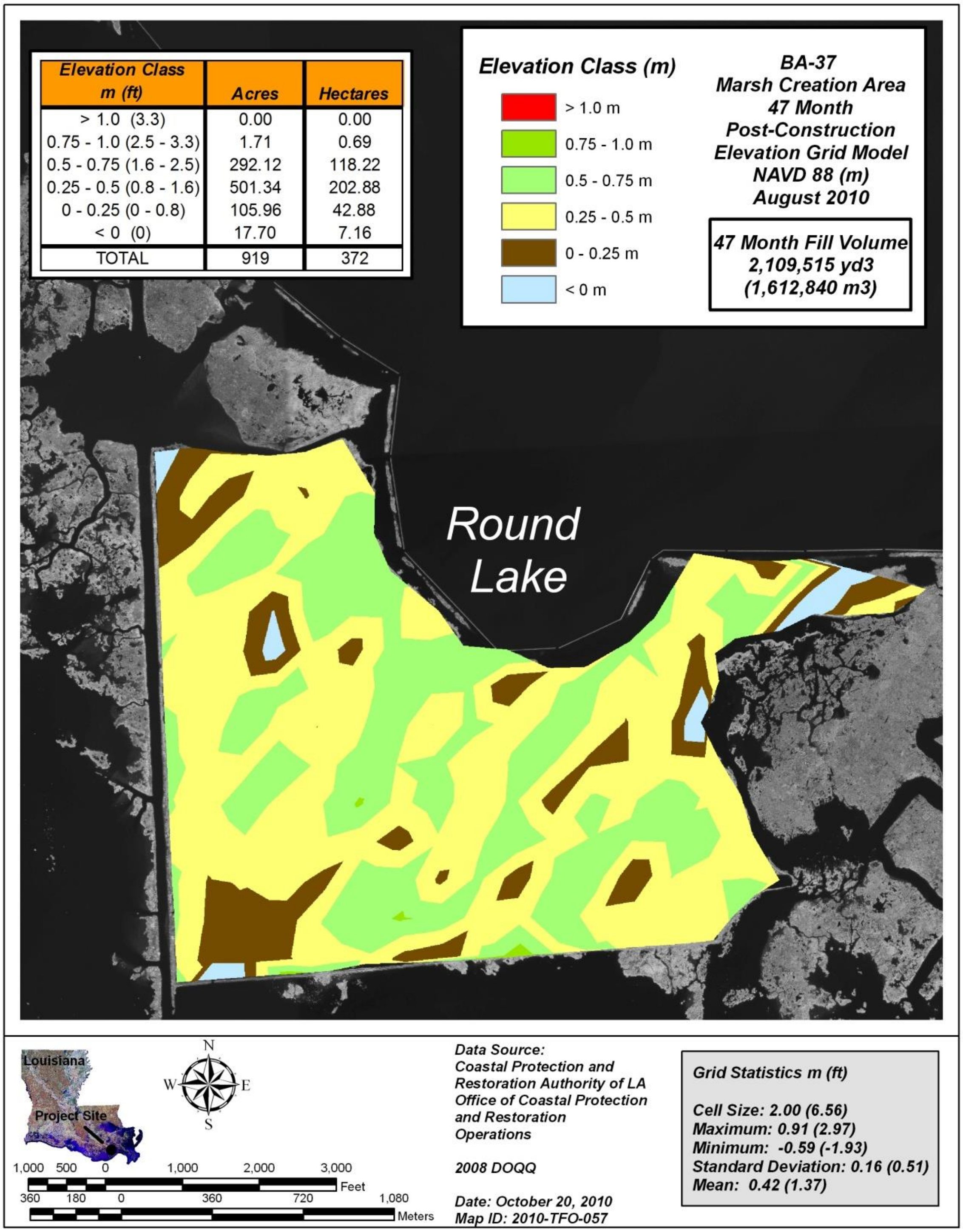


Figure C-6. Post-construction (Aug 2010) elevation grid model at the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) project.

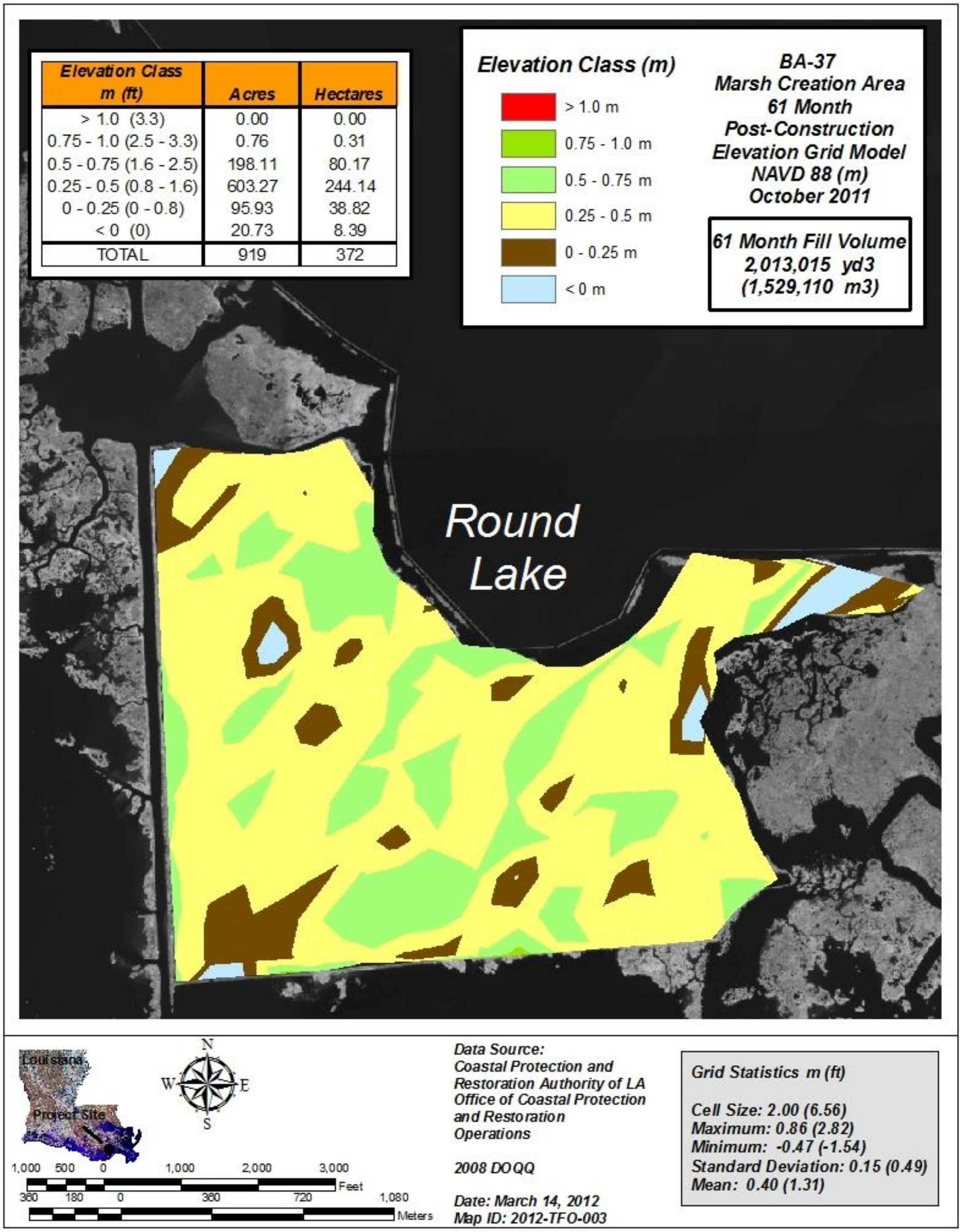


Figure C-7. Post-construction (Oct 2011) elevation grid model at the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) project.

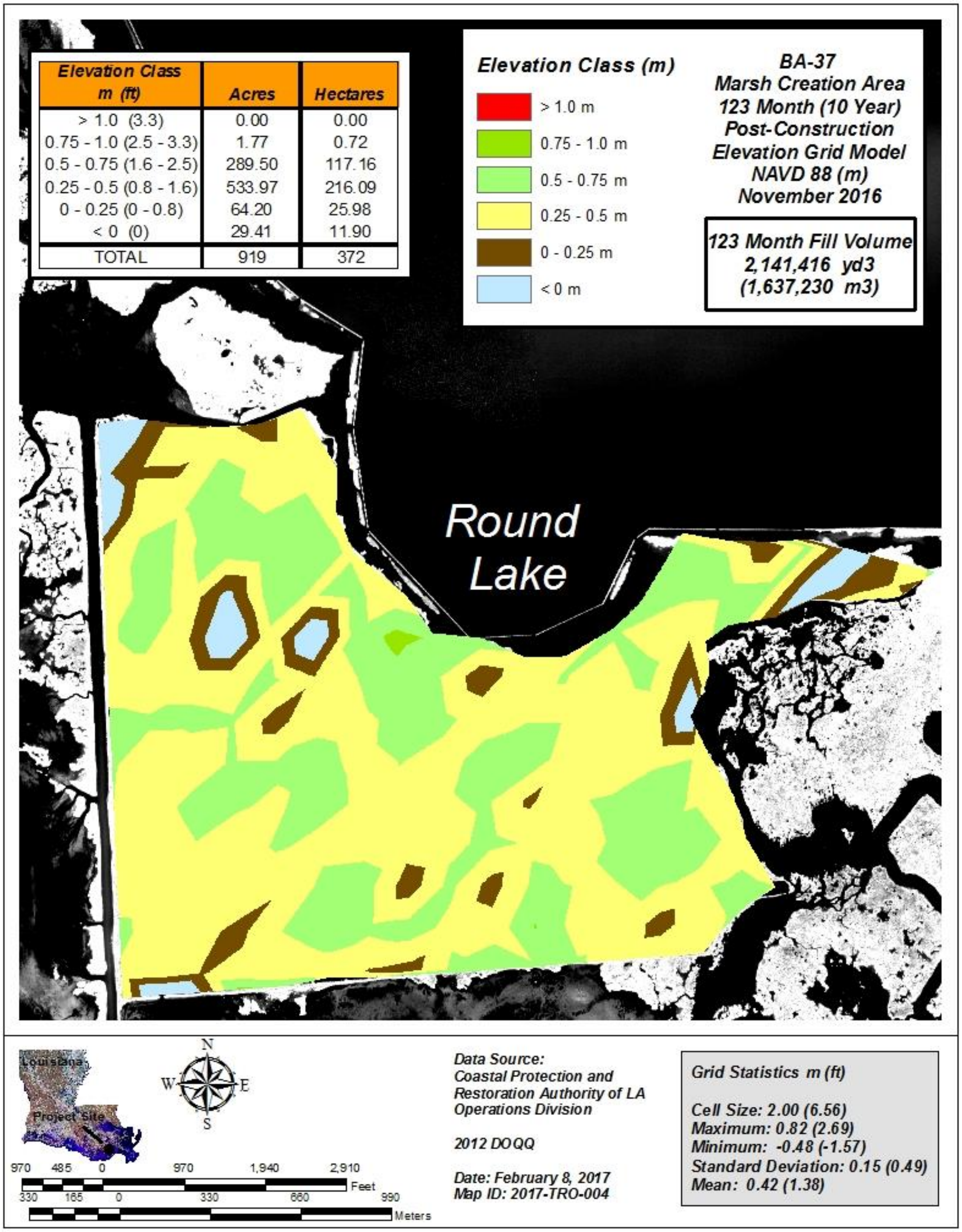


Figure C-8. Post-construction (Nov 2016) elevation grid model at the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) project.

Appendix D
(Shoreline Change Graphics)

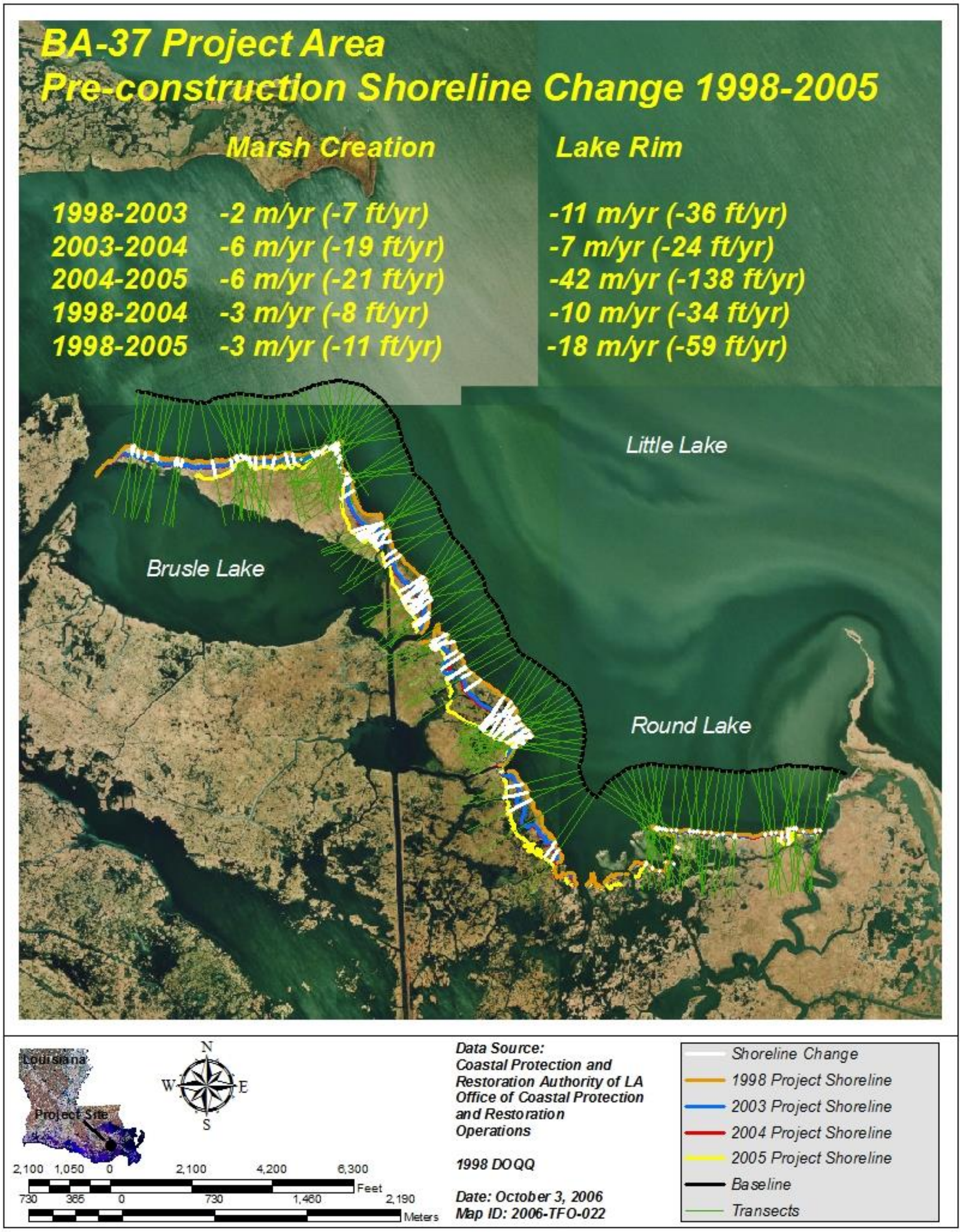


Figure D-1. **Pre-construction (1998-2005) shoreline change at the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) project.**

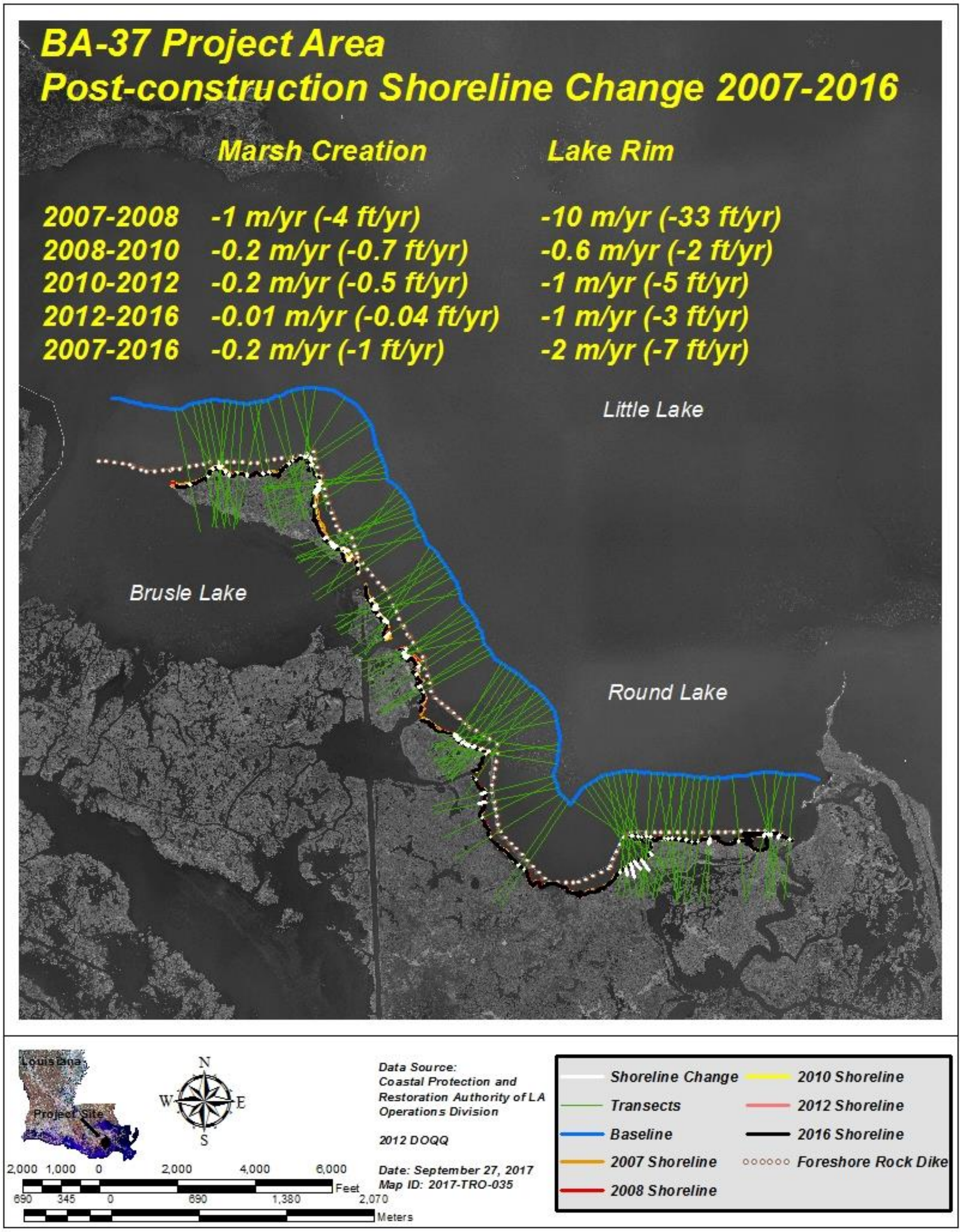


Figure D-2. **Post-construction (2007-2016) shoreline change behind the foreshore rock dike at the Little Lake Shoreline Protection/Dedicated Dredging Near Round Lake (BA-37) project.**

Appendix E
(Land/Water Maps)

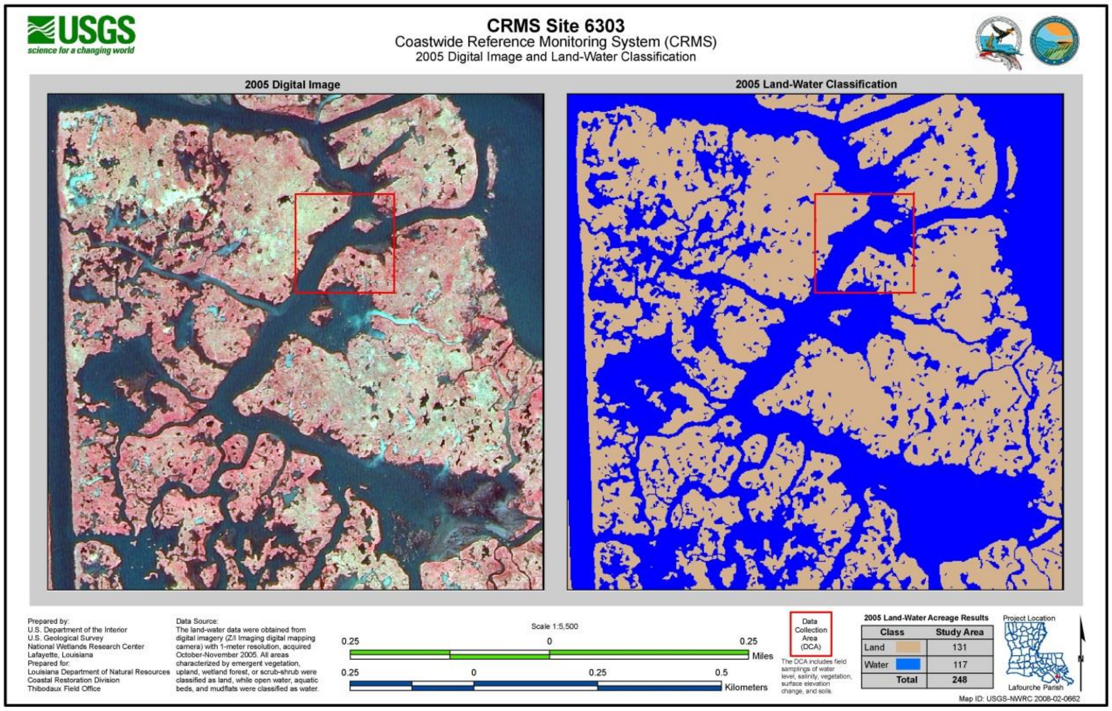


Figure E-1. **2005 land/water classification of the CRMS6303 1 km square.**

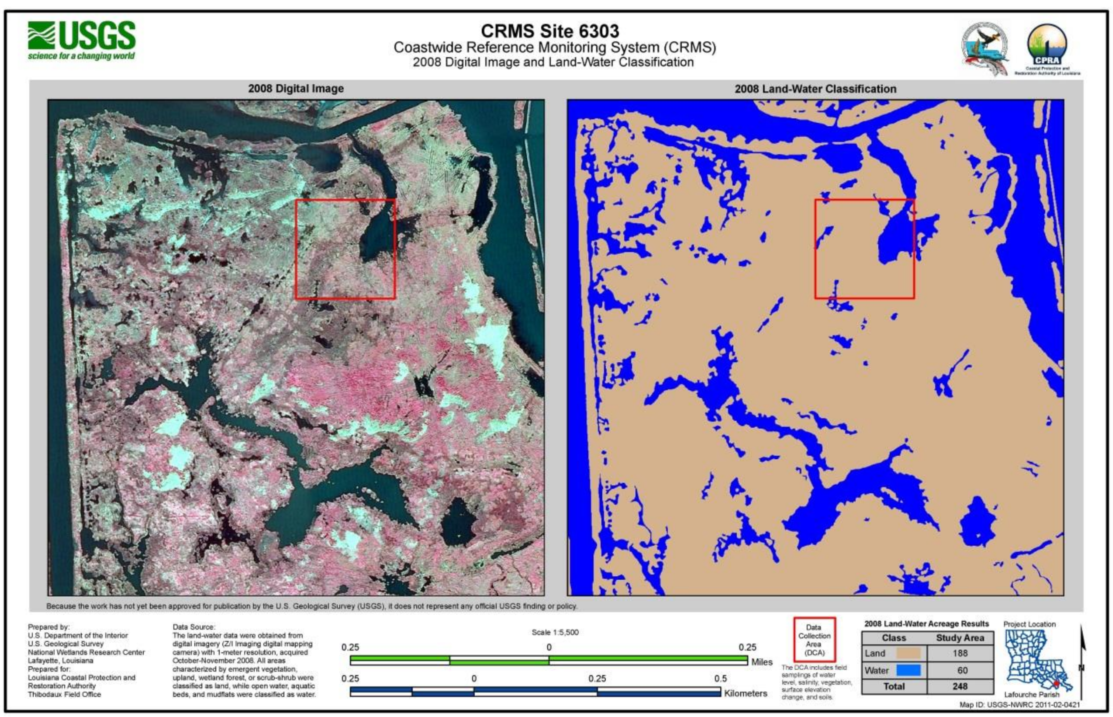


Figure E-2. **2008 land/water classification of the CRMS6303 1 km square.**

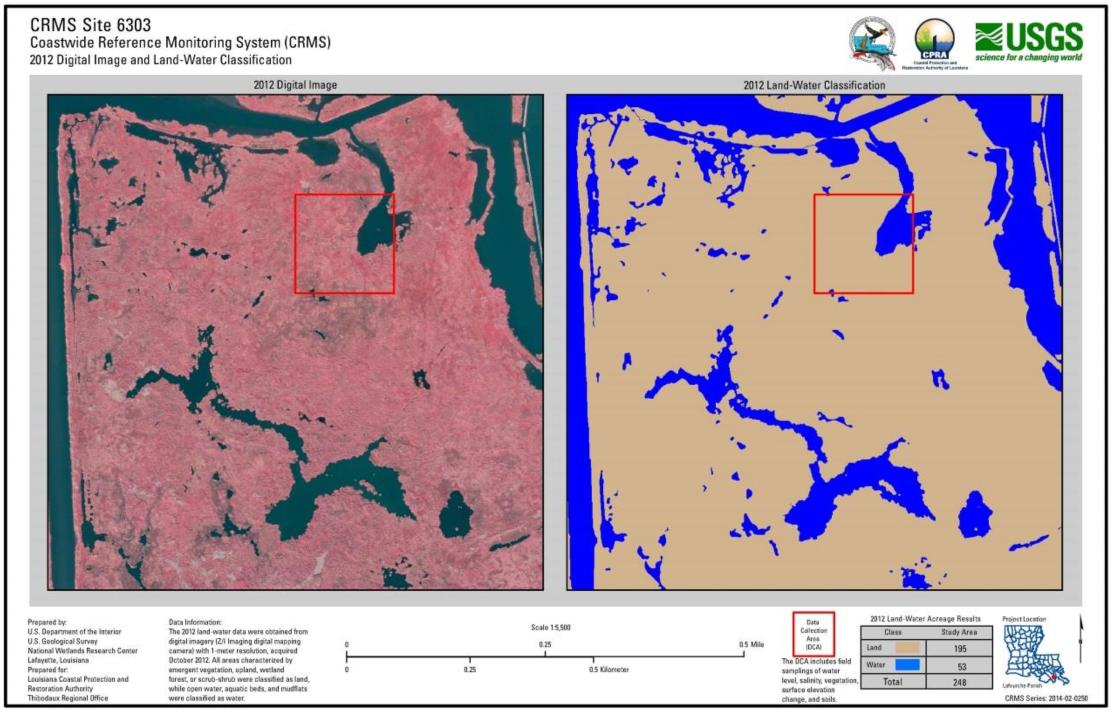


Figure E-3. 2012 land/water classification of the CRMS6303 1 km square.