Coastal Protection and
Restoration Authority of Louisiana

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Office of Coastal Protection and Restoration

2013 Operations, Maintenance, and Monitoring Report

for

Raccoon Island Shoreline Protection/Marsh Creation (TE-48)

State Project Number TE-48
Priority Project List 11

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Terrebonne Parish

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Operations, Maintenance, and Monitoring Report
For
Raccoon Island Shoreline Protection/Marsh Creation
(TE-48)

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Preface

This report includes monitoring data collected through December 2012, and annual Maintenance Inspections through June 2013.

The 2013 report is the 2nd report in a series OM&M reports. For additional information on lessons learned, recommendations and project effectiveness please refer to the 2010 Operations, Maintenance, and Monitoring Report on the CPRA web site.

I. Introduction

The Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project is a barrier island shoreline protection and marsh creation restoration project. This project is located on Raccoon Island, which lies within the Louisiana Department of Wildlife and Fisheries (LDWF) administered Isle Dernieres Barrier Islands Refuge. Raccoon Island is positioned approximately 25 mi (40 km) southwest of Cocodrie in Terrebonne Parish, Louisiana (Figure 1) and is an important nesting colony for brown pelican (*Pelecanus occidentalis*) and other species of colonial wading and shore birds. The TE-48 project area consists of 502 acres (203 ha) of supratidal, intertidal, and subtidal habitat found on Raccoon Island (Figure 2). The project was federally sponsored by the Natural Resources Conservation Service (NRCS) and locally sponsored by the Louisiana Coastal Protection and Restoration Authority (CPRA) under the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA, Public Law 101-646, Title III). The shoreline protection phase extended the breakwater field 4,000 ft (1,219 m) along the Gulf of Mexico shoreline and added a 926 ft (282 m) terminal groin to the eastern end of the Raccoon Island. The marsh creation phase of the TE-48 restoration project elevated the subtidal area behind Raccoon Island to an intertidal elevation. Raccoon Island is separated from other islands in the Isle Dernieres barrier island arc via the greater than 3 mi (5 km) wide Coupe Colin tidal inlet (Figure 1). This barrier island also forms its southern border with the Gulf of Mexico and its northern border with Caillou Bay (Figures 1 and 2).

Raccoon Island and the other Isle Dernieres barrier islands were formed during the Teche and the early Lafourche delta complexes by creation of the Caillou Headland (Peyronnin 1962; Frazier 1967). Abandonment of the Grand Caillou subdelta 600 to 800 years B.P. shaped this headland using delta front sheet sands and sediment transport processes (Frazier 1967; Bird 2000). Headland detachment and inlet formation facilitated the fragmentation of Caillou Headland into the Isle Dernieres barrier island arc (Penland et al. 1985; McBride et al. 1989; Saucier 1994; Reed 1995).

The soils on Raccoon Island are composed of Scatlake muck and Felicity loamy fine sand soils. The Scatlake muck soil is a very poorly drained mineral soil that is located in the back barrier marsh areas of the island while the Felicity loamy fine sand soil is

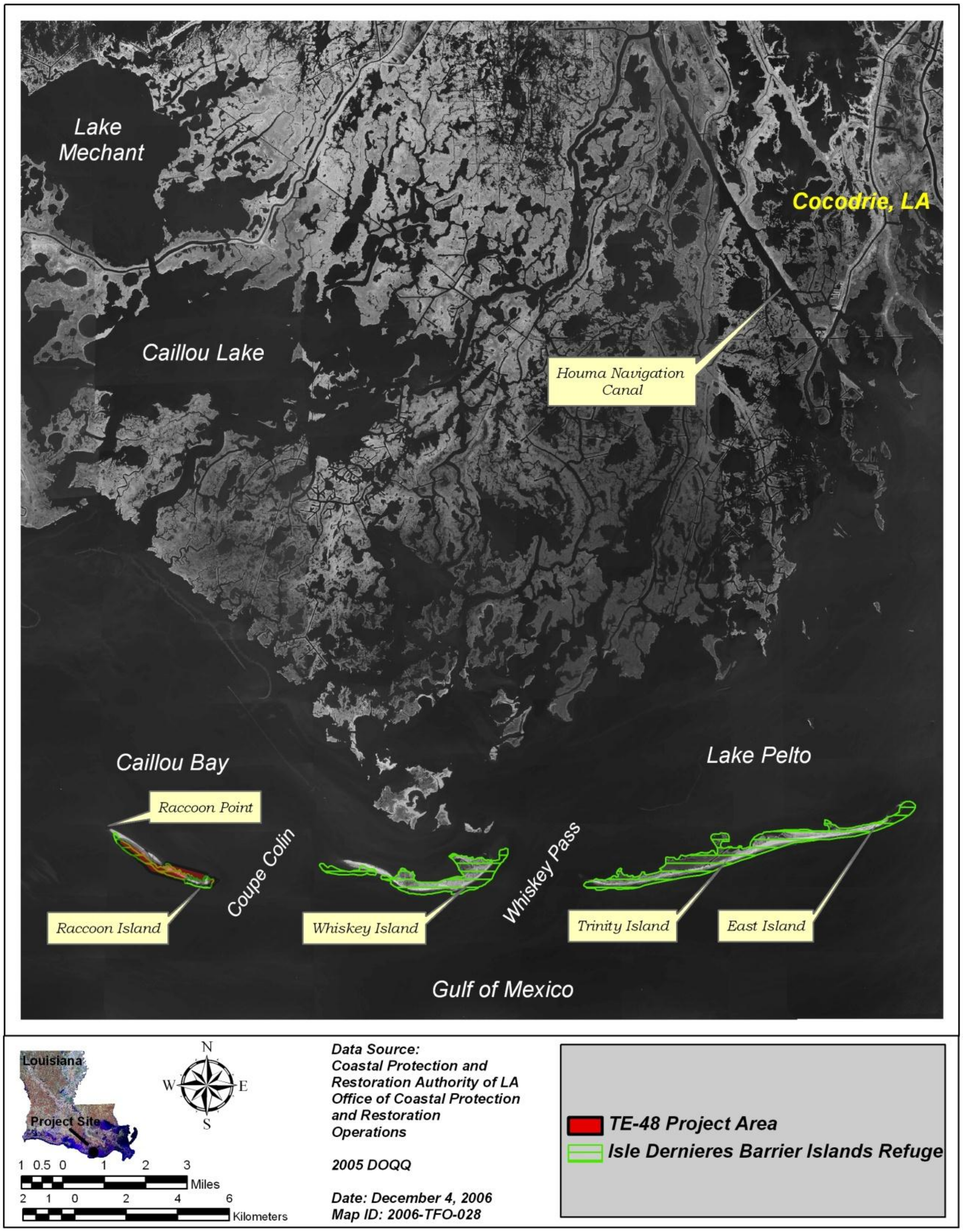


Figure 1. **Location and vicinity of the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project.**

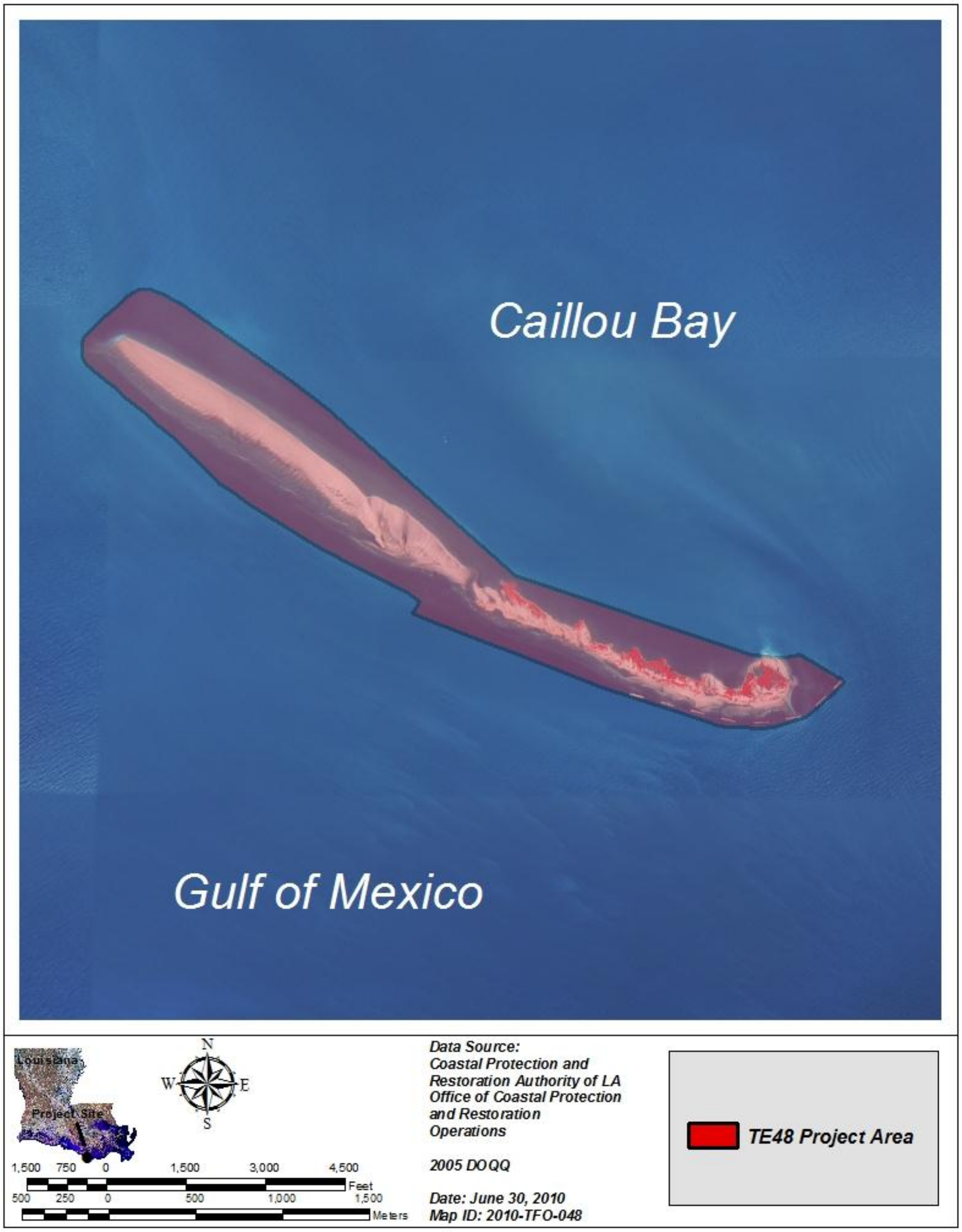


Figure 2. **Location of the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project area.**

distributed along the island's shoreface, beach, and supratidal habitats and consists of a somewhat poorly drained sandy soil (USDA 2007).

Raccoon Island habitats have been recently classified as consisting of intertidal flat, marsh, and beach environments. Typically, intertidal flat and beach habitats do not support extensive vegetative cover (Fearnley et al. 2009). The back barrier marsh area has been mapped as *Spartina alterniflora* Loisel. (smooth cordgrass) and *Avicennia germinans* (L.) L (black mangrove) saline mineral marsh (USDA 2007; Fearnley et al. 2009). On Raccoon Island *A. germinans* forms critical habitat for brown pelican nesting. Slightly elevated areas of this marsh have been found to be dominated by *Distichlis spicata* (L.) Greene (seashore saltgrass) and *Sporobolus virginicus* (L.) Kunth (seashore dropseed) (USDA 2007). *Spartina patens* (Ait.) Muhl. (marshhay cordgrass), *Baccharis halimifolia* L. (eastern baccharis), and *Distichlis spicata* (L.) Greene (seashore saltgrass) have been documented as the primary vegetation species occupying Felicity loamy fine sand soils (USDA 2007). Sasser et al. (2008) classified Raccoon Island as salt marsh habitat.

Delta switching, longshore transport, and tropical storms and cold fronts have increased subsidence and shoreline transgressions on Raccoon Island. The creation of the Plaquemine and Modern delta lobes substantially reduced the sediment supply to the Isle Dernieres barrier islands (Peyronnin 1962; Frazier 1967; Boyd and Penland 1981; Saucier 1994; Reed 1995; Pilkey and Fraser 2003). The sediment deficit contributes to the more than 0.4 in/yr (1.0 cm/yr) subsidence rate experienced in the area (Coleman and Smith 1964; Penland and Ramsey 1990; Roberts et al. 1994). Moreover, subsidence has been postulated as the main cause of back barrier marsh loss (Peyronnin 1962). The sediment deficit and subsidence have also contributed to the considerable wetland loss in the marshes north of Isle Dernieres (Reed 1995) by enlarging bays and increasing the tidal volume. This expanded tidal prism has resulted in the formation of more frequent and wider tidal inlets along the Isle Dernieres barrier island arc (Miner et al. 2009a). Net longshore transport flows in a western direction on Raccoon Island transporting sediment to the spit and eventually off the island (Peyronnin 1962; Stone and Zhang 2001; Thomson et al. 2004; Georgiou et al. 2005). In addition, the longshore transport is localized on Raccoon Island due to the presence of a wide tide dominated inlet and the islands position at the terminal end of the Isle Dernieres barrier island arc (Levin 1993). As a result, the tidal passes with increasing ebb shoals act as sediment sinks and increase the rate of shoreline erosion (Miner et al. 2009a). On Raccoon Island, a considerable volume of sediments has been transported to the Raccoon Point shoreface (Figure 1) over the last 125 years (Miner et al. 2009a).

The shoreline change rate on Raccoon Island has been estimated to be -27.9 ft/yr (-8.5 m/yr) historically (1855-2005), -23.5 ft/yr (-7.2 m/yr) in the long-term (1904-2005), -12.2 ft/yr (-3.7 m/yr) in the short-term (1996-2005), and -106.0 ft/yr (-32.3 m/yr) in the near-term (2004-2005) (Martinez et al. 2009). Numerous tropical storms (Peyronnin 1962; Stone et al. 1993; Stone et al. 1997; Georgiou et al. 2005) and cold fronts (Boyd and Penland 1981; Dingler and Reiss 1990; Georgiou et al. 2005) have elevated water levels high enough to cause partial or total overwash along this low profile barrier island. Therefore, tropical storms and cold fronts have altered the geomorphology of Raccoon Island through cross-shore sediment transport. In addition, Miner et al. (2009a) reported that a significant amount of sediments were removed from the Isle Dernieres lower shoreface during storm events. Due to the above processes, Raccoon Island has experienced reductions in sediment volume and island narrowing (Penland et al. 1985; McBride et al. 1989). From 1978 to 2005, the subaerial acreage of Raccoon Island was reduced by approximately 300 acres (121 ha). By 2005, only 95 acres (38 ha) of Raccoon Island remained subaerial (Martinez et al. 2009). Moreover, Penland et al. (2003) surmised that Raccoon Island would become subaqueous by 2006 while a later analysis by Coastal Engineering Consultants, Inc. (2013) projected a pre-breakwater island year of disappearance in 2000.

In 1997, the Louisiana Coastal Protection and Restoration Authority (CPRA) and the Natural Resources Conservation Service (NRCS) initiated the Raccoon Island Breakwaters Demonstration (TE-29) project. This project constructed eight (8) detached breakwaters (#0-#7) along the eastern shoreface of Raccoon Island (Figure 3). These rock breakwaters were positioned approximately 300 ft (91 m) from the shoreline, were 300 ft (91 m) in length, had 300ft (91 m) gaps, and were built to a 4.5 ft (1.4 m) NAVD88 crown elevation (Armbruster 1999; Belhadjali 2004). The TE-29 project was successful in increasing the sediment volume behind nearly all of the breakwaters due to the presence of a nearby sand shoal (Armbruster 1999; Stone et al. 2003). However, a channel formed in the lee of breakwaters #0 and #1 reducing the sediment volume behind these structures. The breakwaters also contributed to shoreline transgressions and habitat loss west of these structures by causing a disruption in the longshore transport (Penland et al. 2003; Stone et al. 2003). Aerial photographs showing the performance of these breakwaters over time are illustrated in figures 4, 5, and 6. Construction of the TE-29 project began on April 21, 1997 and was completed by July 31, 1997.

The Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project was originally conceived as a single restoration project. However, TE-48 was divided into two phases to facilitate the construction of the shoreline protection part of the project (Phase A). The back barrier marsh creation portion of the project (Phase B) was delayed due to difficulties in securing a sediment borrow site in federal waters. The shoreline protection phase of the TE-48 project extended the TE-29 breakwater field 4,000 ft (1,219 m) to the west by constructing eight additional rock breakwaters (#8-#15) and constructed a rock groin on the eastern edge of Raccoon Island (Figure 3). The eight TE-48 breakwaters were designed to be positioned approximately 250 ft (76 m) from the shoreline, to be 300 ft (91 m) in length, to have gaps widths that vary from 160-300 ft (49-91m), and to be built to a 4.5 ft (1.4 m) NAVD88 crown elevation. Note the gap widths were designed to be narrowed in cumulative 20 ft (6.1 m) increments from east to west (Thomson 2004). The groin was designed to extend 926 ft (282 m) into the shoreface and have a 4.5 ft (1.4 m) NAVD88 crown elevation (Figure 3). Project construction began on January 24, 2006 and was not completed until September 16, 2007 because of substantial delays incurred following the passage of severe weather events. Figure 7 shows Raccoon Island before (2005) and during construction (2006) while Figure 8 displays the island immediately after construction of Phase A in 2007 (as-built). Phase B, the back barrier marsh creation part of the TE-48 project, began construction on September 27, 2012 and was completed on April 23, 2013. Phase B created 63 acres (26 ha) of back barrier marsh beginning on the eastern terminus of Raccoon Island and extended westward (Figure 3).

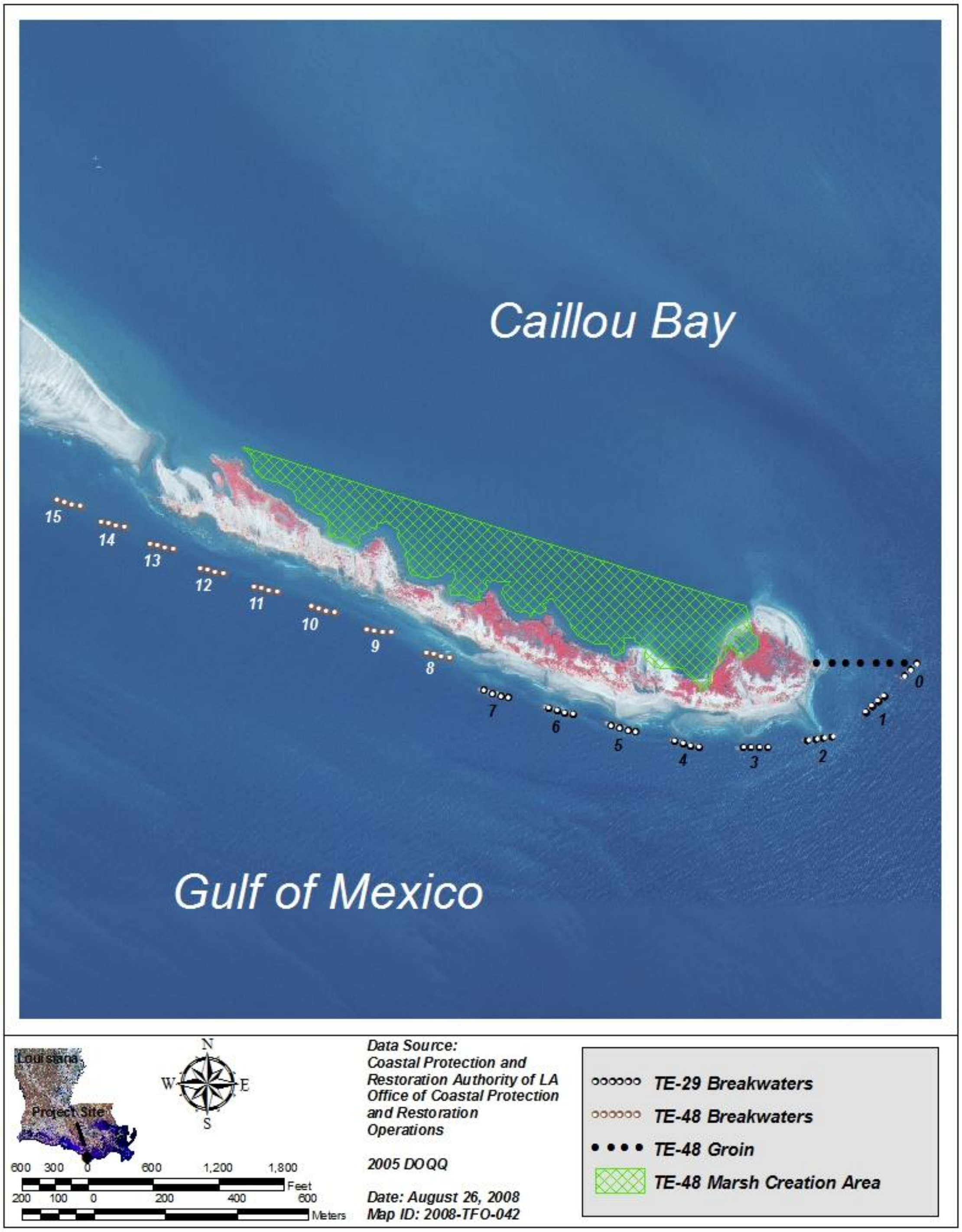


Figure 3. Location of the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project features. The TE-48 breakwaters and groin constitute phase A of the project. Phase B of the TE-48 project consists of the marsh creation area.

Figure 4. **Aerial photography (1998 and 2001) showing the performance of the Raccoon Island Breakwaters Demonstration (TE-29) project. Note the tombolo formations behind breakwaters 2 through 7 in 2001.**

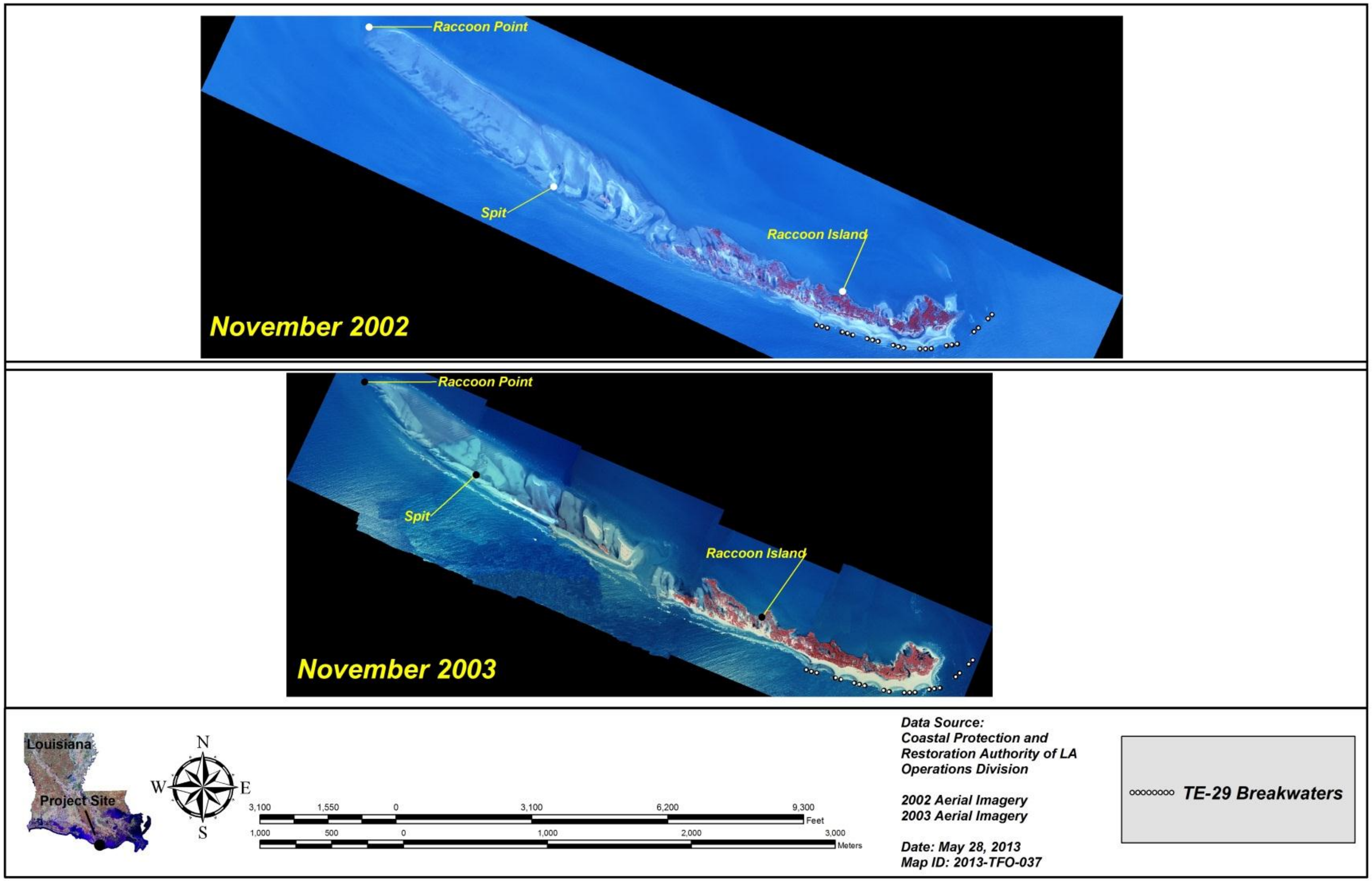


Figure 5. **Aerial photography (2002 and 2003) showing the performance of the Raccoon Island Breakwaters Demonstration (TE-29) project. Note the erosion induced by the 2002 (T. S. Isidore and Hurricane Lili) and 2003 (T. S. Bill) hurricane seasons. Overwash events occurred during both hurricane seasons and a breach separated Raccoon Island from the spit in 2003.**

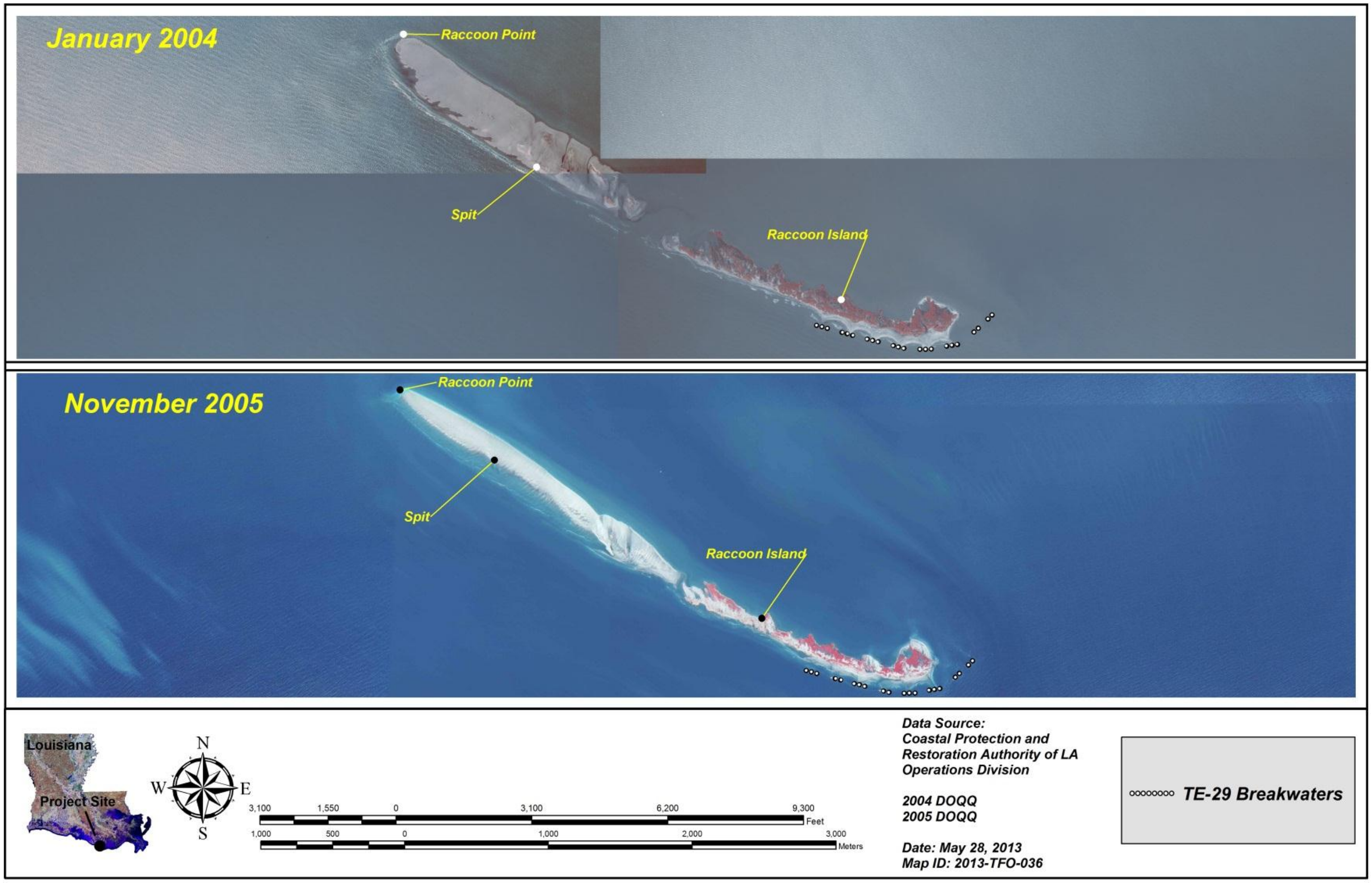


Figure 6. **Aerial photography (2004 and 2005) showing the performance of the Raccoon Island Breakwaters Demonstration (TE-29) project. Note the expansion (2004) and then partial closure (2005) of the breach during this interval.**

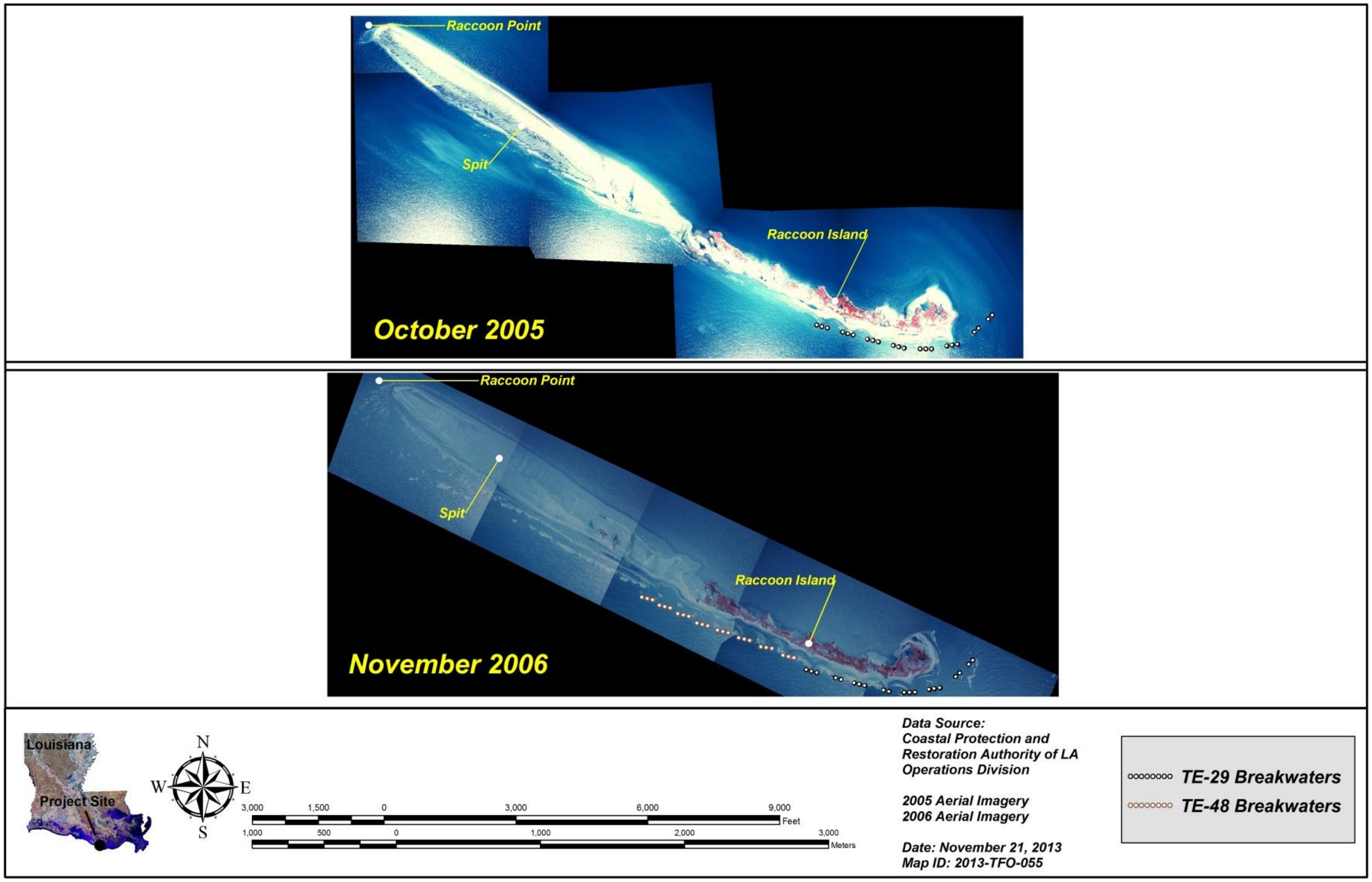


Figure 7. **Aerial photography (2005 and 2006) showing Raccoon Island before and during construction of the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project. Note the decreasing diameter of the breach in 2005. The 2006 image shows the complete closure of the breach, partial construction of the TE-48 breakwaters, and then absence of the groin.**

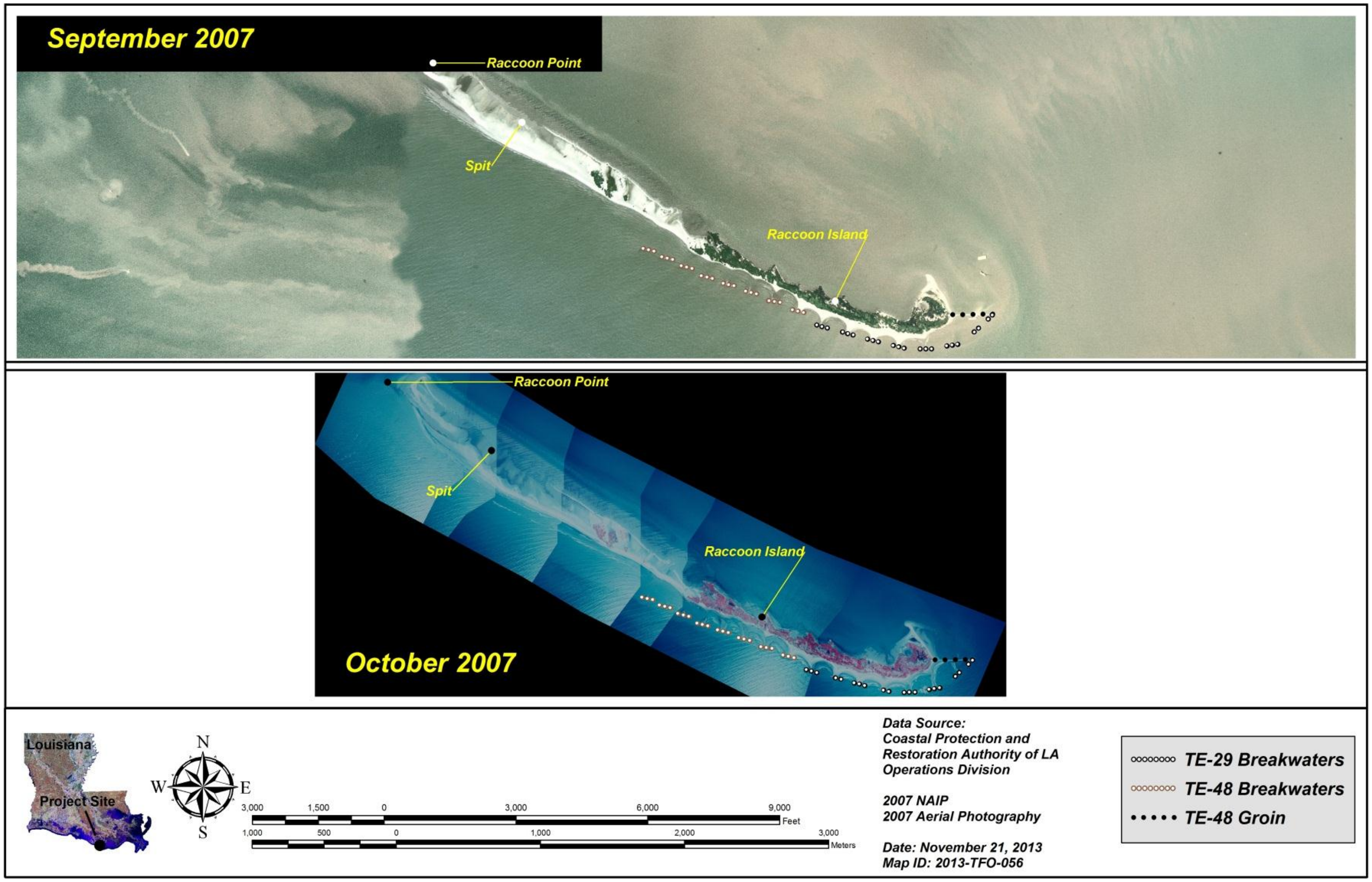


Figure 8. **Aerial photography (Sep 2007 and Oct 2007) showing the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project immediately after construction of Phase A. Note the geomorphic features forming behind the TE-48 structures.**

II. Maintenance Activity

a. Project Feature Inspection Procedures

The purpose of the annual inspection of the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project is to evaluate current conditions of the project features and develop recommendations for future actions in regards to both this project and future projects. The most recent inspection of Raccoon Island was conducted on June 4, 2013 and participants were Glen Curole, Darin Lee, and Jason Curole (CPRA), Loland Broussard (USDA - NRCS), and Tyson Crouch (Louisiana Department of Wildlife & Fisheries [LDWF]). The assessment began at approximately 10:00 am and proceeded from the western end of the island (near breakwater 15) easterly to the east end of the island at the terminal groin. The back marsh fill area was then accessed from the back dike near the eastern end and the back dike was traversed to the western end.

b. Inspection Results

The June 4, 2013 inspection included visual observation of the project features with as-built features. Below are general observations made during the assessment, as well as recommendations and costs for possible corrective actions. Photos taken during the assessment, with comments, are found in Appendix A.

1. Two of the original TE-29 breakwaters (#3 & #4) have crest elevations lower than the other breakwaters, and shoreline configurations behind these structures indicate that these lower elevations are affecting the performance (Appendix A).

2. All other breakwaters appear to be of sufficient height and width, with minimal change from design criteria (Appendix A).

3. The back marsh area created in 2013 has settled to approximately 3.5 ft or lower based on the settlement gages within the fill area, with the western end toward the outfall structure showing the lower elevations. The area also shows continued settlement (Appendix A).

4. Recent vegetative plantings within the fill area are severely stressed at the time of this inspection; however, there is some indication of new growth. These plantings should be accessed again to determine issues before new plantings are attempted (Appendix A).

c. Maintenance Recommendations

i. Immediate/ Emergency Repairs

Due to the obvious deterioration of the two TE-29 breakwaters and their effect on sediment processes and volume capture within the breakwater field, CPRA recommends recapping these and any other breakwaters found below design heights, as soon as an approved O&M plan is completed. A complete survey of the breakwaters, both TE-29 and TE-48 should be conducted and plans should be developed to repair any deficiencies necessary. These project features have accomplished the CWPRRA goals set forth and should be maintained in order to perform as designed within overall State Master plan goals for Raccoon Island.

ii. Programmatic/ Routine Repairs

None.

d. Maintenance History

No maintenance has been done on either the TE-29 or TE-48 projects.

III. Operations Activity

a. Operation Plan

Due to the recent completion of the TE-48 phase 2 portion of this project, an O&M plan has not been finalized. As-built information, once provided by NRCS, will be used to finalize a maintenance plan. Budget projections will be made and possible repairs to breakwaters mentioned previously will be pursued based on the completed O&M plan.

b. Actual Operations

None.

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-48 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. Barrier Islands were considered separate from other ecosystems and not incorporated into the CRMS-*Wetlands* design. Therefore, there are no CRMS sites located in the project area.

The Barrier Island Comprehensive Monitoring Program (BICM) was initiated in 2002 to provide a comprehensive approach to barrier shoreline monitoring similar to CRMS-*Wetlands* (Troutman et al. 2003). The decided advantage of BICM over project specific monitoring is that it provides long term data on all of Louisiana's barrier shorelines and is not limited to areas with constructed projects. As a result, a greater amount of long-term data is available to evaluate constructed projects, to facilitate planning and design of future barrier island projects in numerous other programs (CWPPRA, LCA, WRDA, CIAP), to assist with O&M activities, and to determine storm impacts. Because data are collected for the entire barrier island system concurrently and with identical methodologies, these data are more consistent, accurate, and comprehensive than previous barrier island data collection efforts.

Implementation of the BICM program began in 2005 because of the need to establish a new coastal baseline dataset after the impacts of hurricanes Katrina and Rita. Initial datasets collected include: 1) post-storm damage assessment photos and video, 2) shoreline positions, 3) habitat composition, 4) land/water analysis, 5) topography, 6) bathymetry, and 7) sediment characteristics. Additionally, these data have been compared to standardized historic data and they are provided digitally to user groups for future use.

The BICM program data has been incorporated with CWPPRA collected project specific data, as well as other available datasets, to evaluate the goals and objectives of the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project.

a. Monitoring Goals

The specific project strategies of the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project are (1) to install 8 additional breakwaters to reduce shoreline erosion rates by approximately 60% [from 52 feet/year to 21 feet/year, as estimated by model calculations performed by Thomson et al. (2004) and (2) to create 60 acres of intertidal wetlands to extend the longevity of the northern back bay areas and expand bird habitat. The construction of the segmented breakwaters will reduce wave energy on the Raccoon Island shore and the groin will reduce tidal impacts behind the eastern TE-29 breakwaters. The placement of dredged material and subsequent establishment of vegetation is expected to result in the creation of intertidal and supratidal marsh habitat.

The specific measurable goal established to evaluate the effectiveness of the project is:

1. Reduce shoreline erosion to protect habitats sustaining Raccoon Island rookery and sea bird colonies.

b. Monitoring Elements

The following monitoring elements will provide the information necessary to evaluate the specific goals listed above as well as assessement of the overall elevation and volume changes associated with placement of additional breakwaters:

Shoreline Change

Gulf of Mexico shoreline change data was analyzed for the breakwater field area (shorelines behind the TE-29 and TE-48 structures) using the Digital Shoreline Analysis System (DSAS version 2.1.1) extension of ArcView® GIS (Thieler et al. 2003). Shoreline positions were determined by creating contour lines from established elevation grid models at half foot intervals. The procedures utilized to create the grid models and contour lines are described in the elevation methodology that follows. The shoreline positions were created from the 0 ft (0 m) NAVD88 contour of the December 2005, February 2008, November 2009, and November 2012 elevation grid models. Once the shorelines were delineated a baseline was generated and simple transects were cast at 164 ft (50 m) intervals. Shoreline change rates were assessed for the ensuing periods December 2005-February 2008, February 2008-November 2009, and November 2009-November 2012.

Shoreline position data were also calculated to estimate shoreline changes along the Gulf of Mexico and Caillou Bay spit shorelines using the Thieler et al. (2003) method and contour lines. Shoreline positions were created from the 0 ft (0 m) NAVD88 contour of the December 2005, February 2008, August 2008, May 2009, November 2009, and November 2012 elevation grid models. Shoreline change rates were evaluated for the following periods December 2005-February 2008, February 2008-August 2008, August 2008-May 2009, May 2009-November 2009, and November 2009-November 2012 via the simple transect procedure from the preceding paragraph.

Elevation

Topographic and bathymetric surveys were employed to document elevation and volume changes inside the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project area. Pre-construction (December 2005) and as-built (February 2008) elevation data were collected using traditional cross sectional and real time kinematic (RTK) survey methods. Subsequent post-construction surveys were conducted in August 2008, May 2009, November 2009, and November 2012. These surveys were essentially split into 2 surveys, a breakwater field survey and a spit survey (Figure 9). The breakwater field survey [750 ft (229 m) intervals] extended from the -7 ft (2 m) contour of the Gulf of Mexico shoreface to the vegetated portion of the island while the spit survey [1,500 ft (457 m) intervals] extended from the -7 ft (2 m) contour of the Gulf of Mexico shoreface to the to the -4 ft (1 m) contour of Caillou Bay (Figure 9). Only the spit portion of Raccoon Island was surveyed in August 2008 and May 2009. All survey data were established or adjusted to tie in with the Louisiana Coastal Zone (LCZ) GPS Network using the benchmark COON. All data surveys were referenced to LA State plane South Zone 1702, and vertical elevations were referenced to GEOID99.

The December 2005, February 2008, August 2008, May 2009, November 2009, and November 2012 survey data were re-projected horizontally and vertically to the UTM NAD83 coordinate system and the NAVD88 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 [3.3 ft^2 (1.0 m^2) cell size], and the spatial distribution of elevations were mapped in one foot elevation classes. The grid models were clipped to the TE-48 polygons to estimate elevation and volume changes within the breakwater field and spit areas.

Elevation changes from December 2005-February 2008, February 2008-August 2008, February 2008-May 2009, February 2008-November 2009, and February 2008-November 2012 were calculated by subtracting the corresponding grid models using the LIDAR Data Handler extension of ArcView® GIS. After the elevation change grid models were generated, the spatial distribution of elevation changes in the TE-48 shoreface were mapped in half foot elevation classes. Lastly, volume changes in the breakwater field and spit areas were calculated in cubic meters (m^3) using the Cut/Fill Calculator function of the LIDAR Data Handler extension of ArcView® GIS. Note, these elevation and volume calculations are valid only for the extent of corresponding survey areas.

In addition to the holistic analysis of elevation grid models, the TE-48 project area was also partitioned into six static subdivisions (polygons) to delineate the effect of the coastal structures and tropical and extratropical storms on the different segments of Raccoon Island. All the subdivisions utilized the previously created grid models (December 2005, February 2008, August 2008, May 2009, November 2009, and November 2012) that were clipped to fit the following areas. The subdivisions consisted of the subaerial spit, the TE-29 breakwaters, the TE-48 breakwaters, the spit shoreface, the TE-29 shoreface, and the TE-48 shoreface (Figure 10). The static subaerial spit is the portion of the Raccoon Island Spit that extends above the December 2005 0 ft (0 m) NAVD88 contour. The TE-29 breakwaters segment encircles the TE-29 breakwaters and the TE-48 groin. The TE-48 breakwaters segment encircles the TE-48 breakwaters. Both the breakwater segments form their northern border on the edge of the elevation grid models, form their southern border 50 ft (15 m) south of the structures, and extend 150 ft (46 m) past their terminal

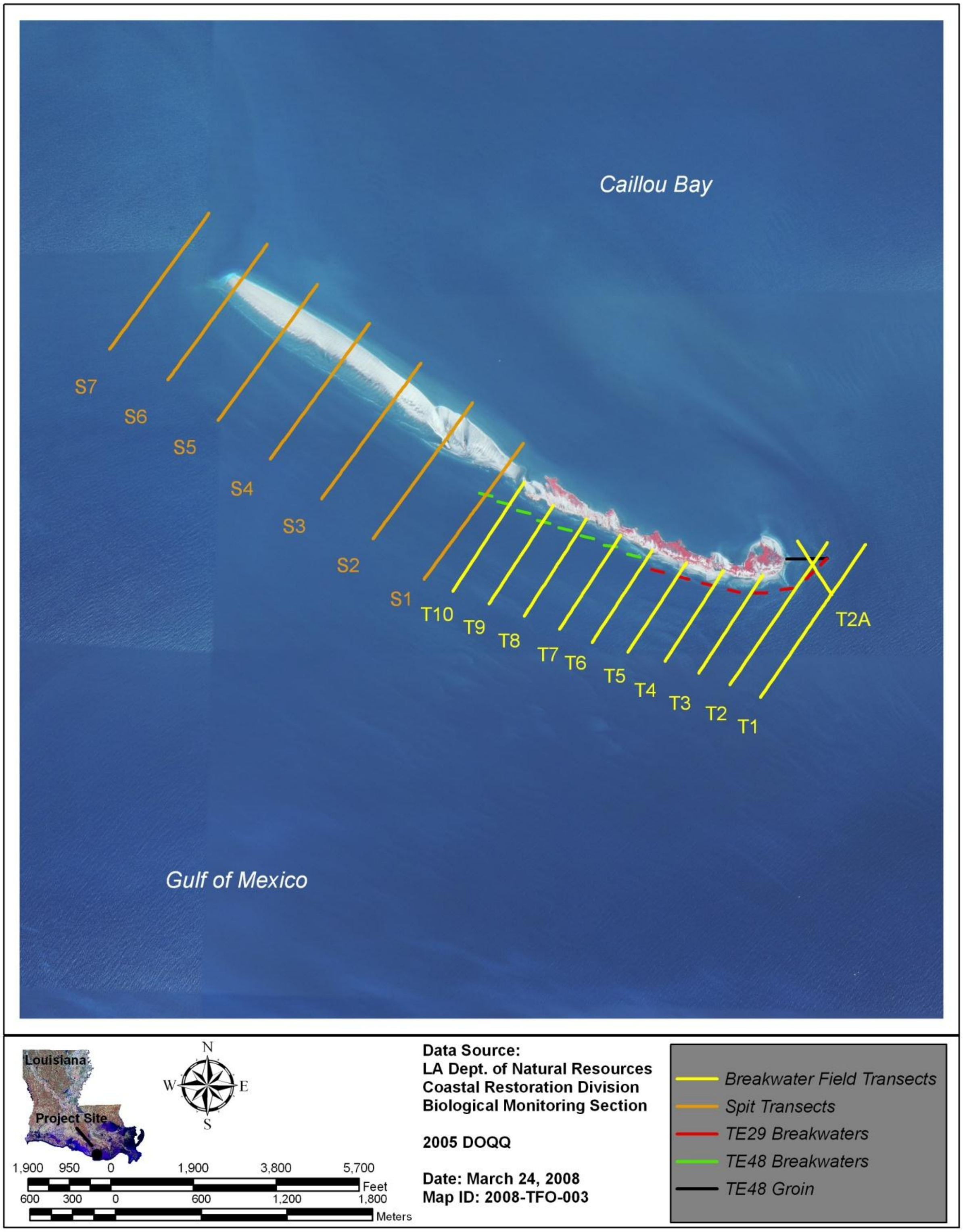


Figure 9. Location of the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project's topographic and bathymetric survey transects.

structures (Figure 10). All of the shoreface segments (Spit, TE-29, and TE-48) form their southern borders on the edge of the elevation grid models and extend northward. The static spit shoreface segment extends to the December 2005 0 ft (0 m) NAVD88 contour of the spit while the TE-29 and TE-48 shoreface segments extend to positions 50 ft (15 m) south of their respective structures (Figure 10). Once the elevation grid models were clipped to their subdivision borders, the mean elevation for each time period was calculated. The August 2008 and May 2009 analysis were performed only for the spit segments because these surveys did not extend to the breakwater field part of Raccoon Island. Next, volume change was calculated for each subdivision for the December 2005-February 2008, February 2008-August 2008, February 2008-May 2009, February 2008-November 2009, and February 2008-November 2012 intervals using the aforementioned method. Additionally, volume change was also calculated for the August 2008-May 2009, May 2009-November 2009, and November 2009-November 2012 static spit subdivision intervals to enhance temporal resolution.

A second spit elevational analysis was employed using variable partitions (polygons) to discern trends in the spit evolution over time. This method demarcated the 0 ft (0 m) NAVD88 contour for the December 2005, February 2008, August 2008, May 2009, November 2009, and November 2012 time periods using the previously created grid models (Figure 11). Hence, the spatial extent of the subdivisions changed for each time period depending on the location of the 0 ft (0 m) NAVD88 contour. All elevations above the 0 ft (0 m) NAVD88 contour were included in the subaerial spit subdivision for that interval while the elevations below the 0 ft (0 m) NAVD88 contour were contained within the spit shoreface subdivision (Figure 11). The polygons were drawn and the analyses were conducted using the procedures detailed in the preceding paragraphs. Volume change was calculated for each subdivision for the December 2005-February 2008, February 2008-August 2008, February 2008-May 2009, February 2008-November 2009, February 2008-November 2012, August 2008-May 2009, May 2009-November 2009, and November 2009-November 2012 intervals.

Spit subaerial spit area and subaerial spit width were also calculated by demarcating the 0 ft (0 m) NAVD88 contour of the Raccoon Island Spit using the December 2005, February 2008, August 2008, May 2009, November 2009, and November 2012 elevation grid models. The subaerial spit area was calculated for each interval by drawing a polygon around the 0 ft (0 m) NAVD88 contour of the spit at a 1:800 scale. Once drawn the area inside the polygon was calculated. The subaerial spit width was calculated for each interval by measuring the width of the subaerial part of the S1 to the S6 transects (Figure 4) [0 ft (0 m) NAVD88 contour surrounding the spit] at a 1:800 scale. The widths were then averaged for each period.

Volumes were calculated to determine the amount of sediment required to close the breach between the spit and Raccoon Island. This procedure delineated the area of the breach, clipped the Feb 2008 and Nov 2012 grid models to this area, and subtracted the grid models to calculate the fill volume and depth. To estimate elevation and

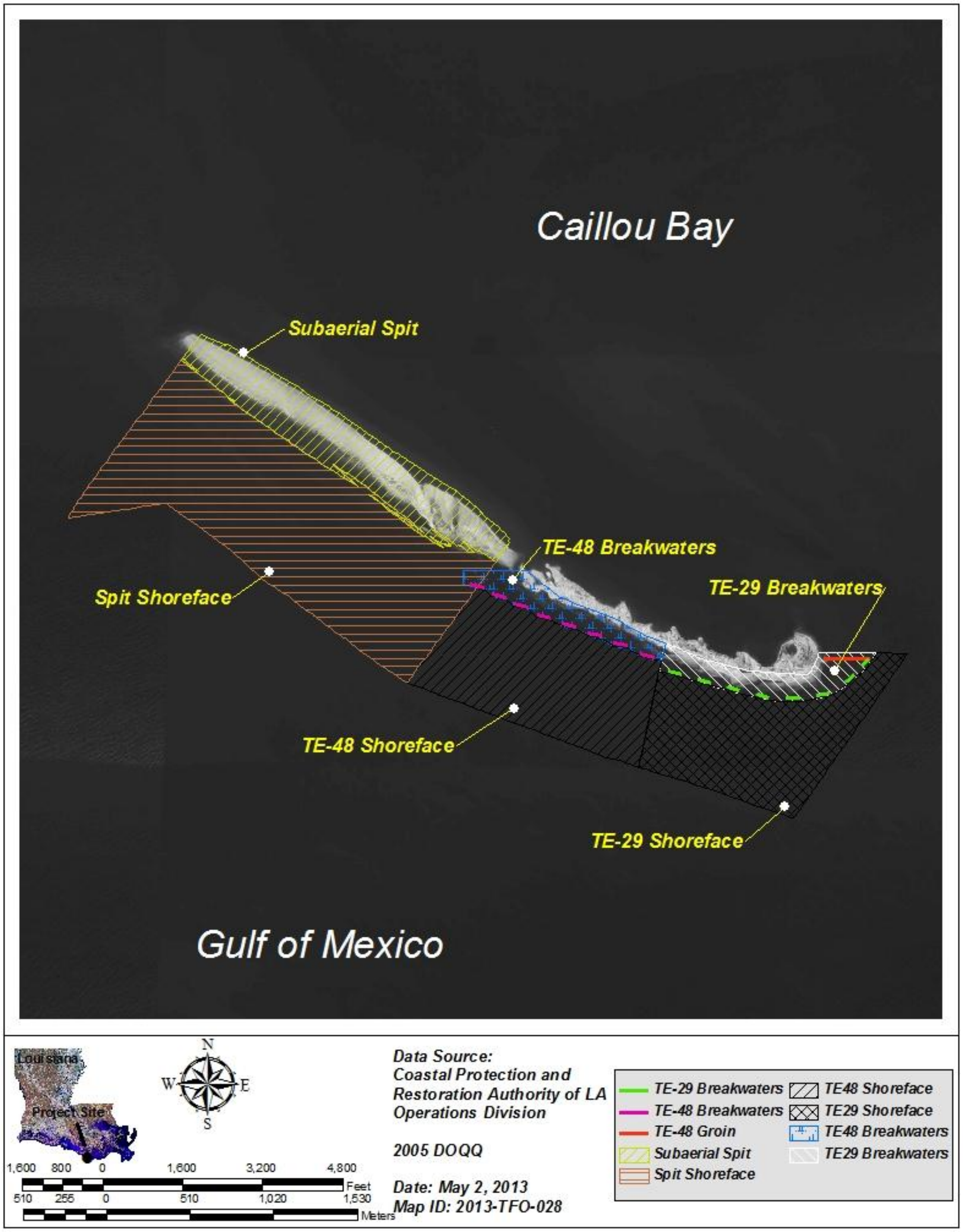


Figure 10. Location of the six static subdivisions (polygons) at the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project. These subdivisions were used to calculate volume changes in predefined areas.

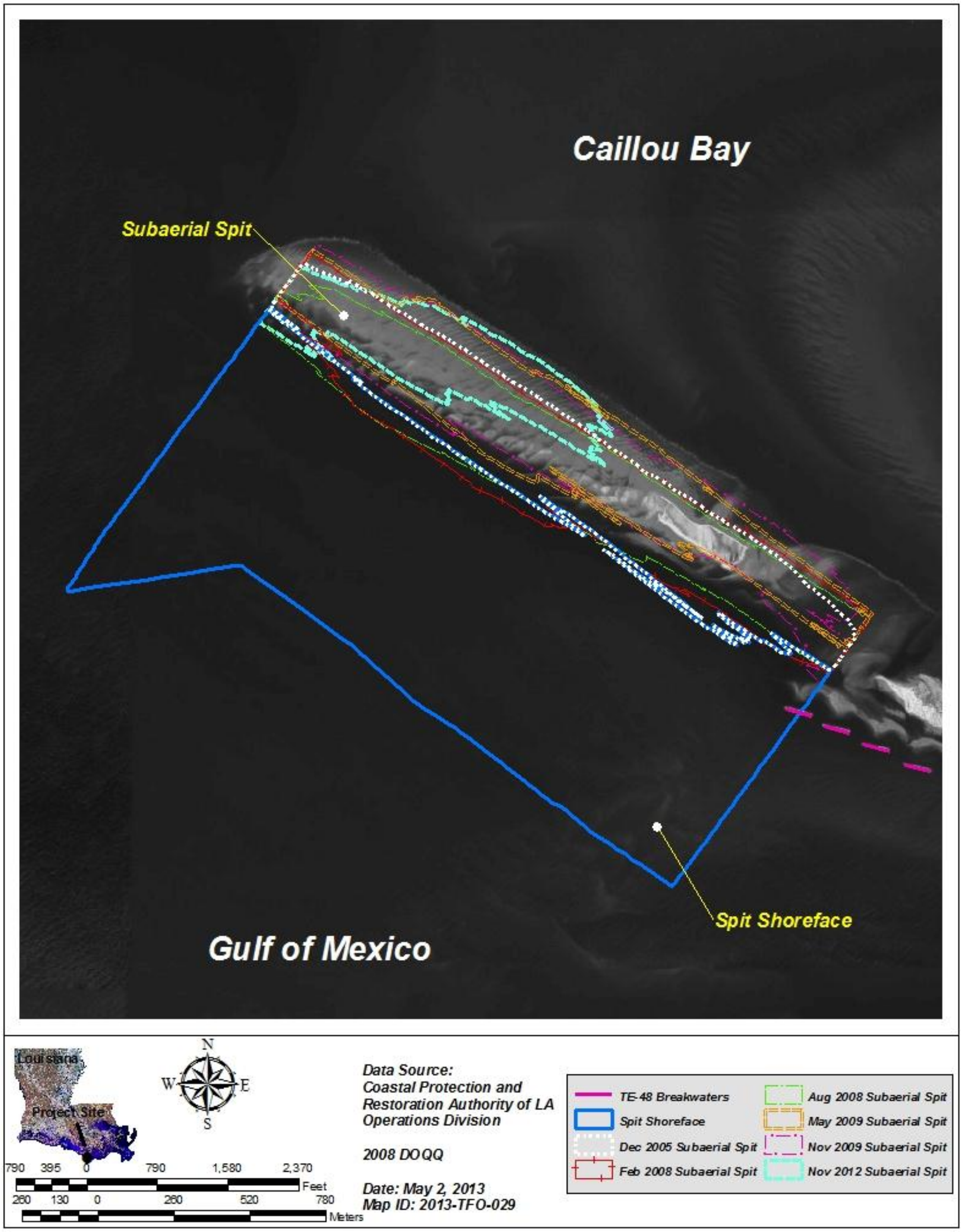


Figure 11. Location of the variable spit subdivisions (polygons) at the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project. These subdivisions were used to calculate volume changes above (subaerial spit) and below (spit shoreface) the 0 ft (0 m) NAVD88 contour. For clarity only the Dec 2005 spit shoreface polygon is shown.

volume changes required to fill the breach to ubiquitous elevations, 2012 survey elevations were transformed to 0.0 ft (0.0 m), 1.0 ft (0.30 m), 2.0 ft (0.61 m), 2.5 ft (0.76 m), and 3.0 ft (0.91 m) elevations, and volumes and depths were calculated using the previously described methodology.

Sediment Properties

Ponar grabber (subaqueous) and hand scoop (subaerial) sediment samples were obtained along six (6) cross-shore transects for the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project in July 2008 to characterize the median grain size (D50) and grain size distributions in the shoreface and other barrier island habitats. These sediment transects were separated on 3000 ft (914 m) intervals and were funded through the Barrier Island Comprehensive Monitoring (BICM) program (Troutman et al. 2003; Kulp et al. 2011a). One sample was collected from each distinguishable location: -15 ft (-5 m) contour, middle of shoreface, upper shoreface at mean low water, beach berm, dune, and back-barrier marsh. A second set of BICM sediment samples is scheduled to be collected on Raccoon Island in 2013.

b. Preliminary Monitoring Results

Shoreline Change

The Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project area incurred shoreline expansions and transgressions over the monitoring period (2005-2012). CPRA analyzed the BICM data (Martinez et al. 2009) and calculated historic shoreline change rates for the pre-breakwater time period (1887 – 2004) and the Raccoon Island shoreline change rate was -25.5 ft/year (-7.8 m/year), and when the data is parsed into future breakwater field versus the "unprotected spit", the rates remain similar, indicating that the island eroded at a similar rate along its length through this historic record. Additionally, the short-term (1996 – 2005) BICM shoreline change rate is similar to the pre-1996 rates, at -23.9 ft/year (-7.3 m/year), but when the short-term shoreline change rates are calculated within specific areas, the shore behind the existing TE-29 breakwaters accreted at 17.5 ft/year (5.3 m/year), while the still unprotected TE-48 area and the spit had increased erosions rates of -47.9 and -46.4 ft/year (-14.6 and -14.1 m/year), respectively. Thomson (2004) also reported an increased shoreline erosion post-construction of the TE-29 breakwaters, with the shoreline erosion west of the TE-29 breakwaters increasing 62%, to -42.0 ft/year (-12.8 m/year). These change rates point to both the benefit of the TE-29 breakwaters to the shoreline they were protecting, as well as possible impacts to the down drift shoreline. Monitoring data between December 2005 and February 2008, show the shoreline behind the existing TE-29 breakwaters and the TE-48 area eroded (Table 1) at approximately -8.31 ft/year (-2.53 m/year), a rate less than the BICM short-term erosion rate reported for Raccoon Island (Martinez et al. 2009). This reduced rate possibly notes the early impacts of the TE-48 breakwaters as construction progresses thru this time period. Note, the zero foot contour lines utilized to measure erosion rates along the breakwater field and spit shorelines can be viewed in appendix B.

Conversely, the post-construction shoreline positions behind the complete breakwater field sustained considerable progradation in some areas (Table 1), with the shorelines in the vicinity of the groin and the behind the western TE-48 breakwaters (Figure 3) accreting at the fastest rates. Moreover, the progradation that occurred in these areas sizably extended shoreline positions to the south. As a result, the goal to reduce shoreline erosion is currently being attained with an overall shoreline change rate of 22.7 ft/year (6.9 m/year) since project construction (Table 1).

However, the breakwater field has shown considerable variation in the average shoreline positions since 2005. While the overall shoreline position has shown accretion as discussed, it should be noted that an engineering assessment of the barrier islands (CEC, Inc. 2013) thru February 2011, indicates that since 2005 the TE-29 breakwaters have shown erosion in the areas from breakwaters #3 – 6, indicating possibly more than the effects of the two settled breakwaters (Appendix B). Shorter term analysis from October 2007 thru February 2011, mirror the longer-term analysis, but also show that overall the breakwater field may now be only holding the shoreline (CEC, Unpublished data) (Appendix B). We want to point out that the groin area is not analyzed due to the fact that there was no shoreline in that area during the 2007 time period and future analysis should show large accretion in this area. Also, the CEC,Inc. analysis indicates that the western end of the TE-48 breakwaters have not held the shoreline and it has continued to erode, most likely due to the breach and its continued expansion. These data sets support the monitoring data in that the breakwaters have achieved their goal of reducing the shoreline erosion rate, but as usual it is a complex area with multiple processes that must be considered in evaluating success and managing the island.

In addition to the complexities of shoreline change within the breakwater field, the Raccoon Island spit, down drift, shows a dramatic increase in the erosion rate when compared to historic and short-term change rates. During the total post construction analysis period (February 2008 thru November 2012) the spit has eroded a total distance of -534.3 feet (-162.9 m) since the as-built survey, showing an average yearly shoreline change rate of -118.7 ft/year (-36.2 m/year) (Table 2). This rate is more than double the erosion rate from the short-term BICM data (Martinez et al. 2009), which includes Hurricanes Katrina and Rita.

Within the spit area, CPRA was able to measure both the Gulf of Mexico and Caillou Bay shoreline change rates. During the pre-construction interval, both the gulf and bay spit shorelines moderately advanced their positions (Table 2), indicating post-storm recovery after the 2005 Hurricanes. For the post-construction intervals, the spit's Gulf of Mexico shoreline showed highly variable shoreline changes.

During the immediate post-construction period (February thru August 2008), the spit's gulf shoreline began to erode at a rate of approximately -72.4 ft/yr (-22.1 m/yr), while the Caillou Bay shoreline during this period experienced substantial transgressions (Table 2), indicating major rollover. During the second post-construction interval (August 2008 thru November 2009), Hurricanes Gustav and Ike impacted the project area. Both the gulfside and bayside shorelines were relocated to the north (Table 2) and the island was breached at the geographic beginning of the spit as it was most recently in 2003 (Figure 5). After the 2008 hurricane season, the spit's shoreline was relocated considerably further into the bay causing the island and it's spit to be offset. Table 2 illustrates this translocation of the spit's shoreline through the massive amount of erosion on the gulf shoreline and the massive amount of progradation on the bay shoreline of the spit for the August 2008 to May 2009 interval.

Following the 2008 hurricane season (May 2009-November 2009), the spit's Gulf of Mexico shoreline change rate actually showed accretion thru summer 2009. However, this post-storm recovery appears to be ephemeral because the spit shoreline could not sustain this progradation rate and went into another period of erosion from November 2009 thru November 2012 (Table 2). Tropical and extratropical storms, the expanding breach and offset shoreline, and the probable interruption of longshore sediment transport likely influenced this renewed spit erosion. The bayside shoreline after breaching also changes in that it no longer moves in concert with the gulf side of the spit. Bayside movement is to the north during time periods post 2008 storms, but the shore moves very little compared to the gulf (Table 2), indicating a reduced sediment volume by passing the large breach and no longer feeding the spit. Again, the CEC, Inc data (Appendix B) supports the monitoring data on the spit in that there has been erosion within the spit area, but like the breakwater field it is not constant temporally or spatially.

Table 1. Gulf of Mexico shoreline change behind the Raccoon Island Breakwater Field over time.

Breakwater Field Shoreline Change	*Dec 2005 Pre – Feb 2008 As-blt*	*Feb 2008 As-blt - Nov 2009 2Yr Post*	*Nov 2009 2Yr Post - Nov 2012 5Yr Post*
Gulf of Mexico Change (ft)	-17.92	40.23	68.79
Gulf of Mexico Change Rate (ft/yr)	-8.31	22.56	22.70

Table 2. Shoreline change along the Raccoon Island Spit's Gulf of Mexico and Caillou Bay shorelines over time.

Subaerial Spit Shoreline Change	*Dec 2005 Pre - Feb 2008 As-blt*	*Feb 2008 As-blt - Aug 2008 1Yr Post*	*Aug 2008 1Yr Post - May 2009 1.5Yr Post*	*May 2009 1.5Yr Post - Nov 2009 2Yr Post*	*Nov 2009 2Yr Post - Nov 2012 5Yr Post*
Gulf of Mexico Change (ft)	30.17	-37.69	-325.77	45.46	-216.32
Gulf of Mexico Change Rate (ft/yr)	13.99	-72.43	-440.40	86.86	-71.39
Caillou Bay Change (ft)	14.00	-85.06	273.09	-1.21	-22.24
Caillou Bay Change Rate (ft/yr)	6.49	-163.44	369.18	-2.32	-7.34

Elevation

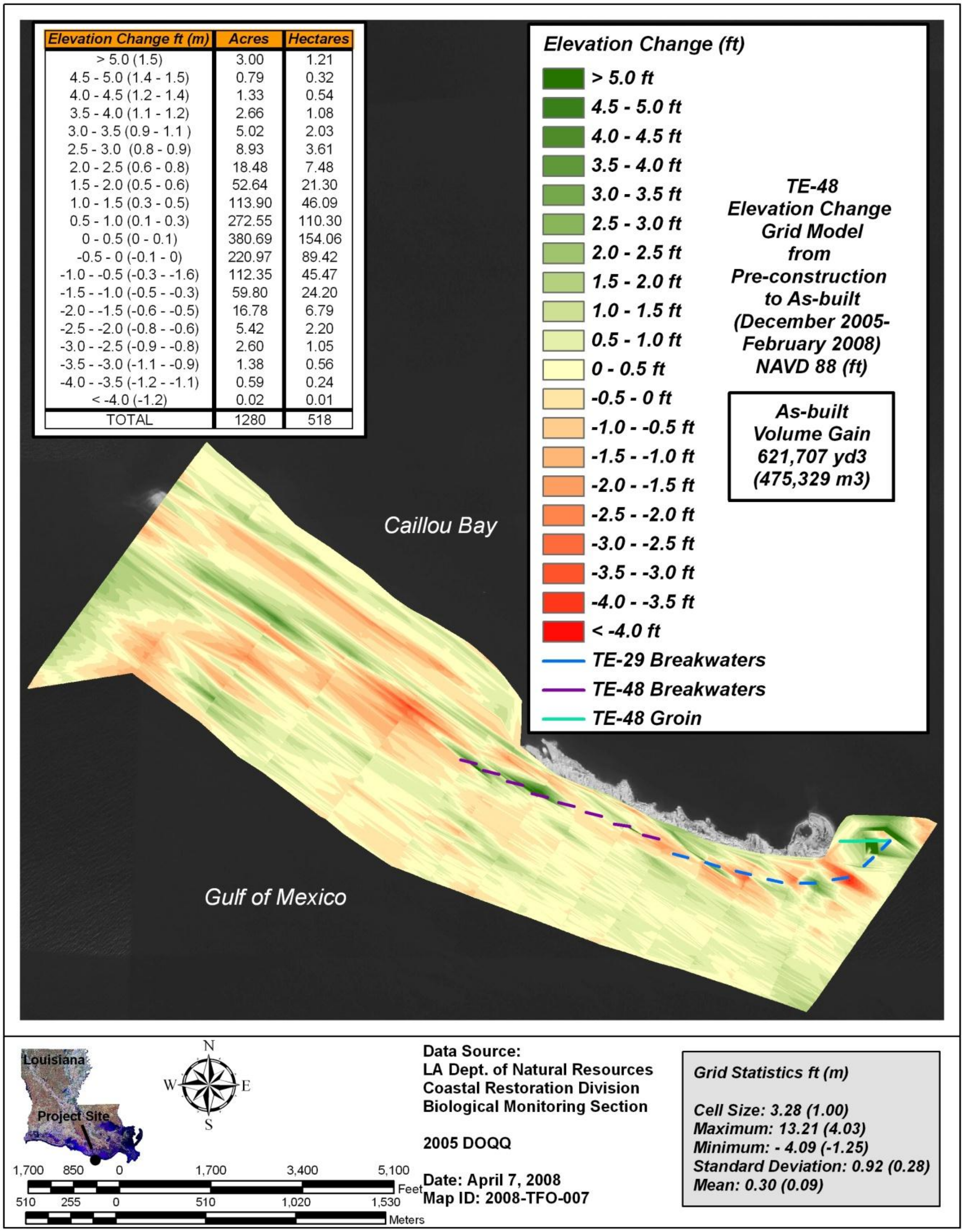
The Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project area experienced volume changes and shoreline modifications since construction was completed in 2007. Volume changes over the period of the study are summarized in Table 3. Elevation change and volume distributions for Raccoon Island (breakwater field and spit) are shown in Figure 12 (Dec 2005-Feb 2008), Figure 13 (Feb 2008-Nov 2009), and Figure 14 (Feb 2008-Nov 2012). In addition, elevation change and volume distributions for the Raccoon Island Spit are shown in Figure 15 (Feb 2008-Aug 2008) and Figure 16 (Feb 2008-May 2009). Supplementary elevation change grid models for the Raccoon Island Spit are displayed in appendix C. Elevation grid models for all survey periods are also provided in appendix D. The TE-48 volume and mean elevation changes are also graphically shown in Figure 17 (Raccoon Island) and

Figure 18 (spit only). Approximately, 621,707 yd^3 (475,329 m^3) of sediment were naturally deposited on Raccoon Island during construction through physical processes (Figures 12, 17, and Table 3). Thirty-seven percent or 231,315 yd^3 (176,853 m^3) of the sediment gain occurred on the Raccoon Island Spit and sixty-three percent or 390,482 yd^3 (298,545 m^3) of the sediment gain occurred in the Raccoon Island Breakwater Field (Figure 18 and Table 3). In the post-construction period, the spit lost 827,364 yd^3 (632,565 m^3) of sediment from Feb 2008 to Aug 2008 (Figures 15, 18, and Table 3) and gained 414,881 yd^3 (317,199 m^3) of sediment from Aug 2008 to Nov 2009 (Figures 13, 15, 18, and Table 3). However, only 19,470 yd^3 (14,886 m^3) of these spit volume gains were retained by Nov 2012 (Figures 14, 15, 18, and Table 3). The breakwater field gained a relatively large volume during the pre-construction period and displayed modest volume gains in the post-construction period (Table 3). Moreover, pre-construction volume gains suppressed post-construction volume losses on the spit and exaggerated post-construction volume gains in the breakwater field (Table 3). The total tabulated sediment volume of Raccoon Island declined by 751,168 yd^3 (574,309 m^3) in the post-construction period (Figure 14 and Table 3). Tables 4-5 and Figures 12-14 show that the TE-48 breakwaters gained elevation and volume since construction and the TE-29 breakwaters also gained elevation and volume in 2012 due to the placement of the TE-48 groin. The shoreface components of Tables 4-5 and Figures 12-14 display a net transport of sediment to the west and a net loss of sediment since Feb 2008. Tables 4-5 also illustrate that the shoreface segments of the TE-48 project either enhanced or degraded volume estimates in the spit and breakwater field reaches (Figures 12, 13, 14, 15, 16, 17, 18, and Table 3).

Table 3. Pre- and post-construction sediment volume changes on the Raccoon Island Spit and in the Breakwater Field. The third row shows the combined breakwater field and spit volume changes. Note that the volume changes include both the subaerial segments of the island and the shoreface.

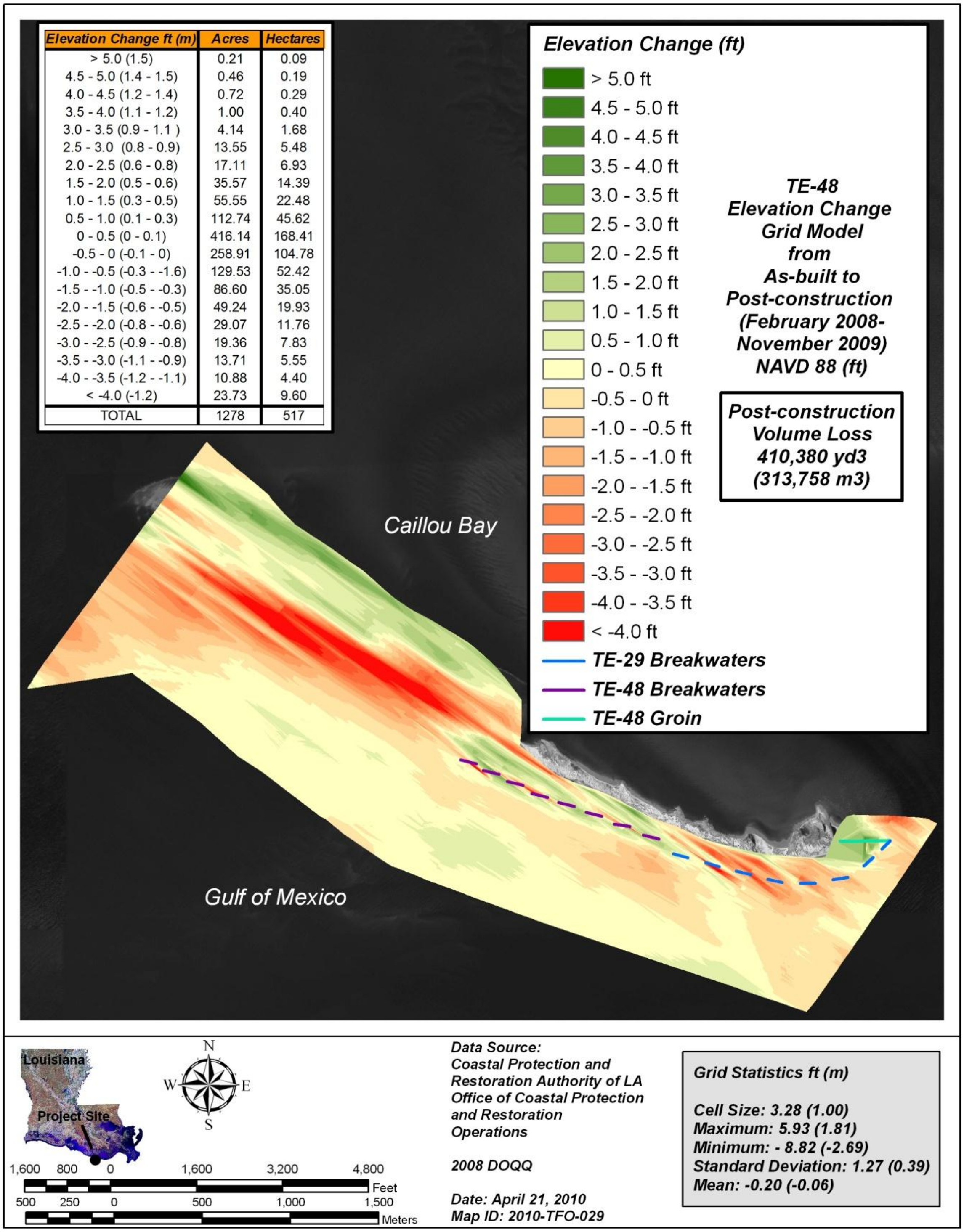
Volume Change (yd3)	Dec 2005 Pre– Feb 2008 As-blt	Feb 2008 As-blt– Aug 2008 1Yr Post	Aug 2008 1Yr Post- May 2009 1.5Yr Post	May 2009 1.5Yr Post- Nov 2009 2Yr Post	Feb 2008 As-blt- Nov 2009 2Yr Post	Nov 2009 2Yr Post- Nov 2012 5Yr Post	Post-con Total Feb 2008 - Nov 2012	Pre- & Post-con Total Dec 2005 - Nov 2012
Spit	231,315	-827,364	173,699	241,182	-412,483	-395,411	-807,894	-576,579
Breakwater Field	390,482	-	-	-	2,169	54,228	56,397	446,879
Breakwater Field & Spit	621,707	-	-	-	-410,380	-340,788	-751,168	-129,461

In the following discussion, note that the variable subarerial spit elevations and volumes are considerably different than their static counterparts because they are derived from different extents. The variable portion (rows 1 & 2 of Tables 4 & 5) expands and contracts with changes in elevation while the static measurements are derived from the subaerial portion (≥ 0 ft contour) of the spit in Dec 2005 (Figure 11,



Elevation Change ft (m)	Acres	Hectares
> 5.0 (1.5)	3.00	1.21
4.5 - 5.0 (1.4 - 1.5)	0.79	0.32
4.0 - 4.5 (1.2 - 1.4)	1.33	0.54
3.5 - 4.0 (1.1 - 1.2)	2.66	1.08
3.0 - 3.5 (0.9 - 1.1)	5.02	2.03
2.5 - 3.0 (0.8 - 0.9)	8.93	3.61
2.0 - 2.5 (0.6 - 0.8)	18.48	7.48
1.5 - 2.0 (0.5 - 0.6)	52.64	21.30
1.0 - 1.5 (0.3 - 0.5)	113.90	46.09
0.5 - 1.0 (0.1 - 0.3)	272.55	110.30
0 - 0.5 (0 - 0.1)	380.69	154.06
-0.5 - 0 (-0.1 - 0)	220.97	89.42
-1.0 - -0.5 (-0.3 - -1.6)	112.35	45.47
-1.5 - -1.0 (-0.5 - -0.3)	59.80	24.20
-2.0 - -1.5 (-0.6 - -0.5)	16.78	6.79
-2.5 - -2.0 (-0.8 - -0.6)	5.42	2.20
-3.0 - -2.5 (-0.9 - -0.8)	2.60	1.05
-3.5 - -3.0 (-1.1 - -0.9)	1.38	0.56
-4.0 - -3.5 (-1.2 - -1.1)	0.59	0.24
< -4.0 (-1.2)	0.02	0.01
TOTAL	1280	518

Figure 12. Elevation and volume change grid model for the breakwater field and spit from pre-construction (Dec 2005) to as-built (Feb 2008) at the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project.



Elevation Change ft (m)	Acres	Hectares
> 5.0 (1.5)	0.21	0.09
4.5 - 5.0 (1.4 - 1.5)	0.46	0.19
4.0 - 4.5 (1.2 - 1.4)	0.72	0.29
3.5 - 4.0 (1.1 - 1.2)	1.00	0.40
3.0 - 3.5 (0.9 - 1.1)	4.14	1.68
2.5 - 3.0 (0.8 - 0.9)	13.55	5.48
2.0 - 2.5 (0.6 - 0.8)	17.11	6.93
1.5 - 2.0 (0.5 - 0.6)	35.57	14.39
1.0 - 1.5 (0.3 - 0.5)	55.55	22.48
0.5 - 1.0 (0.1 - 0.3)	112.74	45.62
0 - 0.5 (0 - 0.1)	416.14	168.41
-0.5 - 0 (-0.1 - 0)	258.91	104.78
-1.0 - -0.5 (-0.3 - -1.6)	129.53	52.42
-1.5 - -1.0 (-0.5 - -0.3)	86.60	35.05
-2.0 - -1.5 (-0.6 - -0.5)	49.24	19.93
-2.5 - -2.0 (-0.8 - -0.6)	29.07	11.76
-3.0 - -2.5 (-0.9 - -0.8)	19.36	7.83
-3.5 - -3.0 (-1.1 - -0.9)	13.71	5.55
-4.0 - -3.5 (-1.2 - -1.1)	10.88	4.40
< -4.0 (-1.2)	23.73	9.60
TOTAL	1278	517

Figure 13. **Elevation and volume change grid model for the breakwater field and spit from as-built (Feb 2008) to post-construction (Nov 2009) at the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project.**

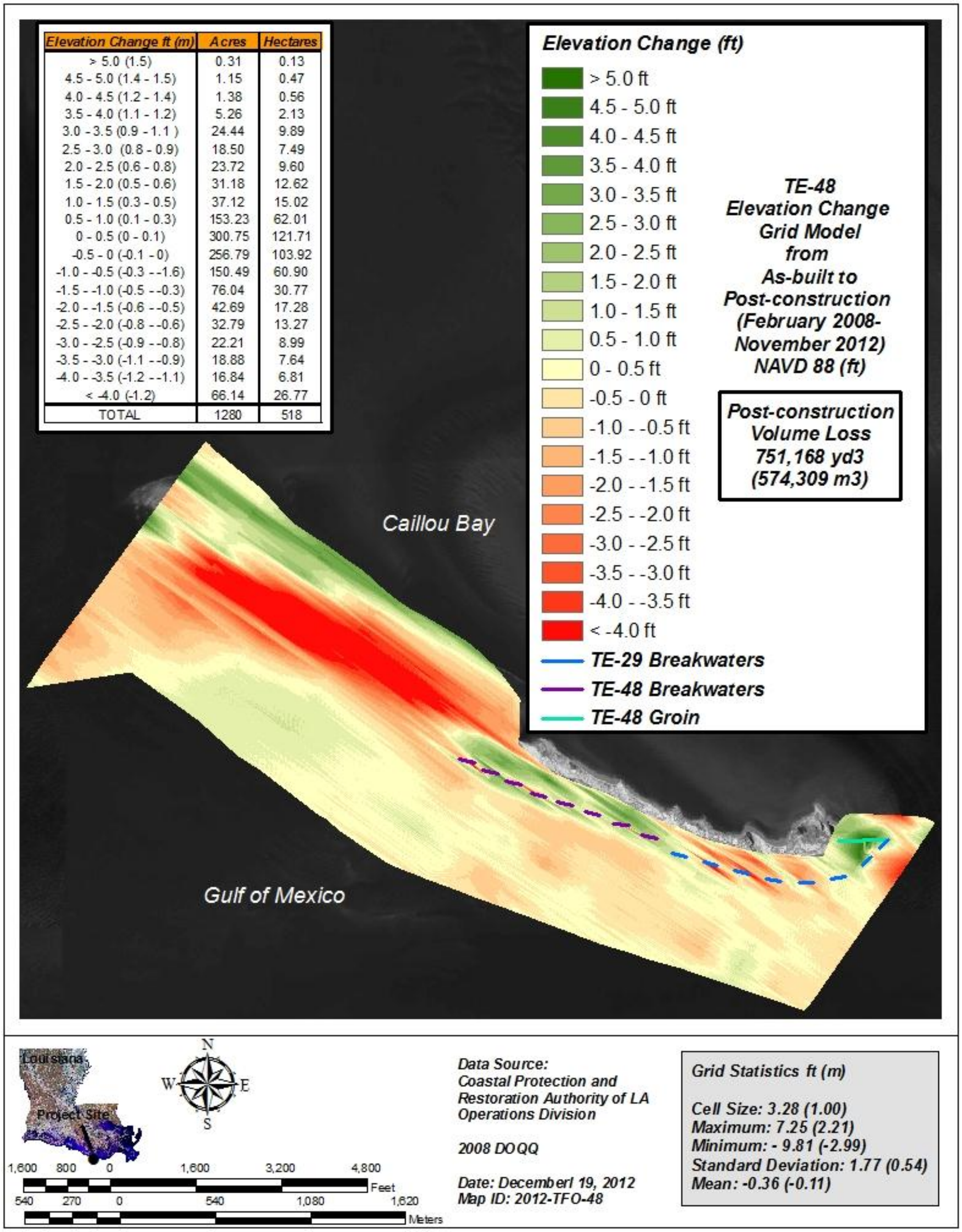


Figure 14. **Elevation and volume change grid model for the breakwater field and spit from as-built (Feb 2008) to post-construction (Nov 2012) at the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project.**

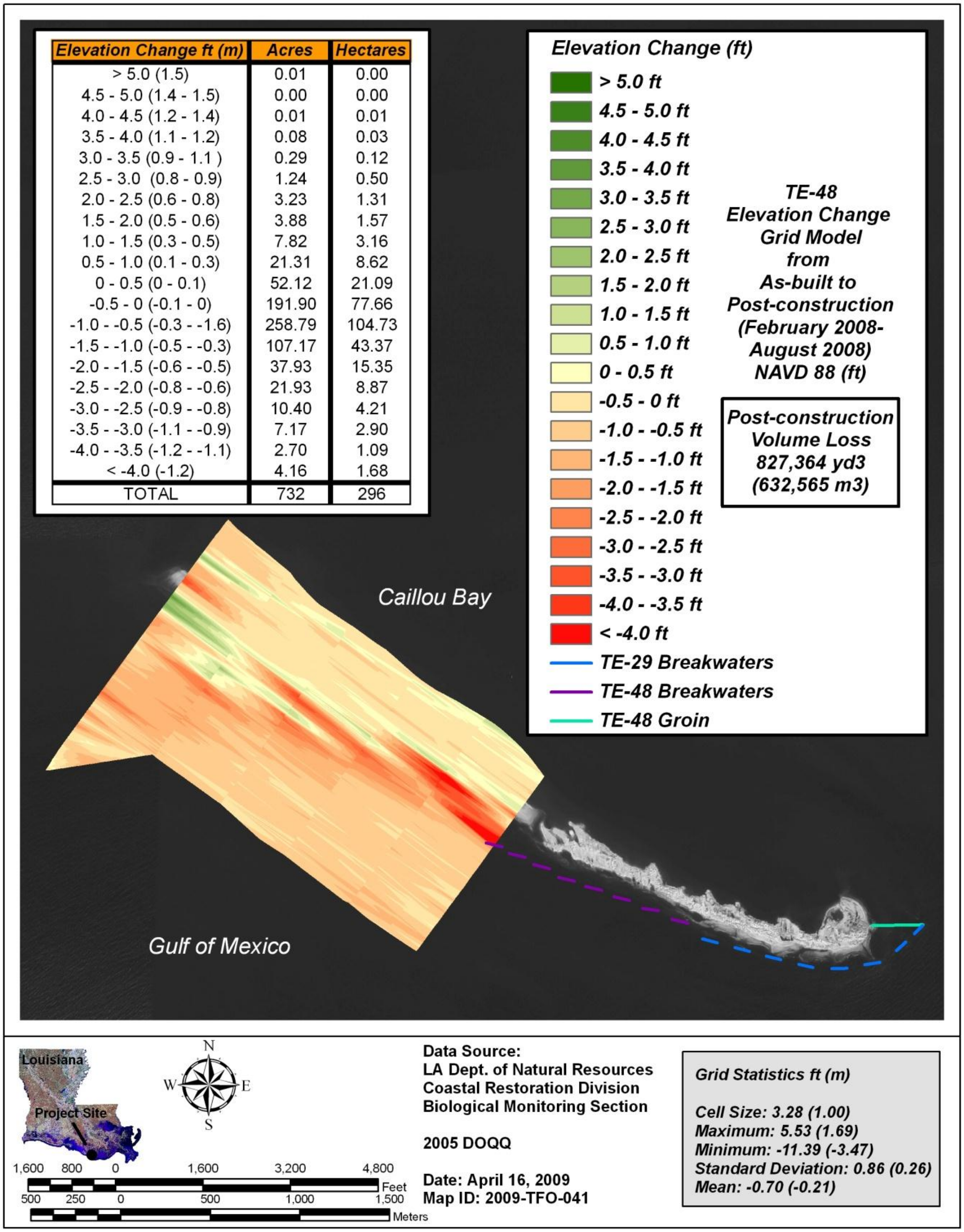


Figure 15. Elevation and volume change grid model for the spit from as-built (Feb 2008) to post-construction (Aug 2008) at the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project.

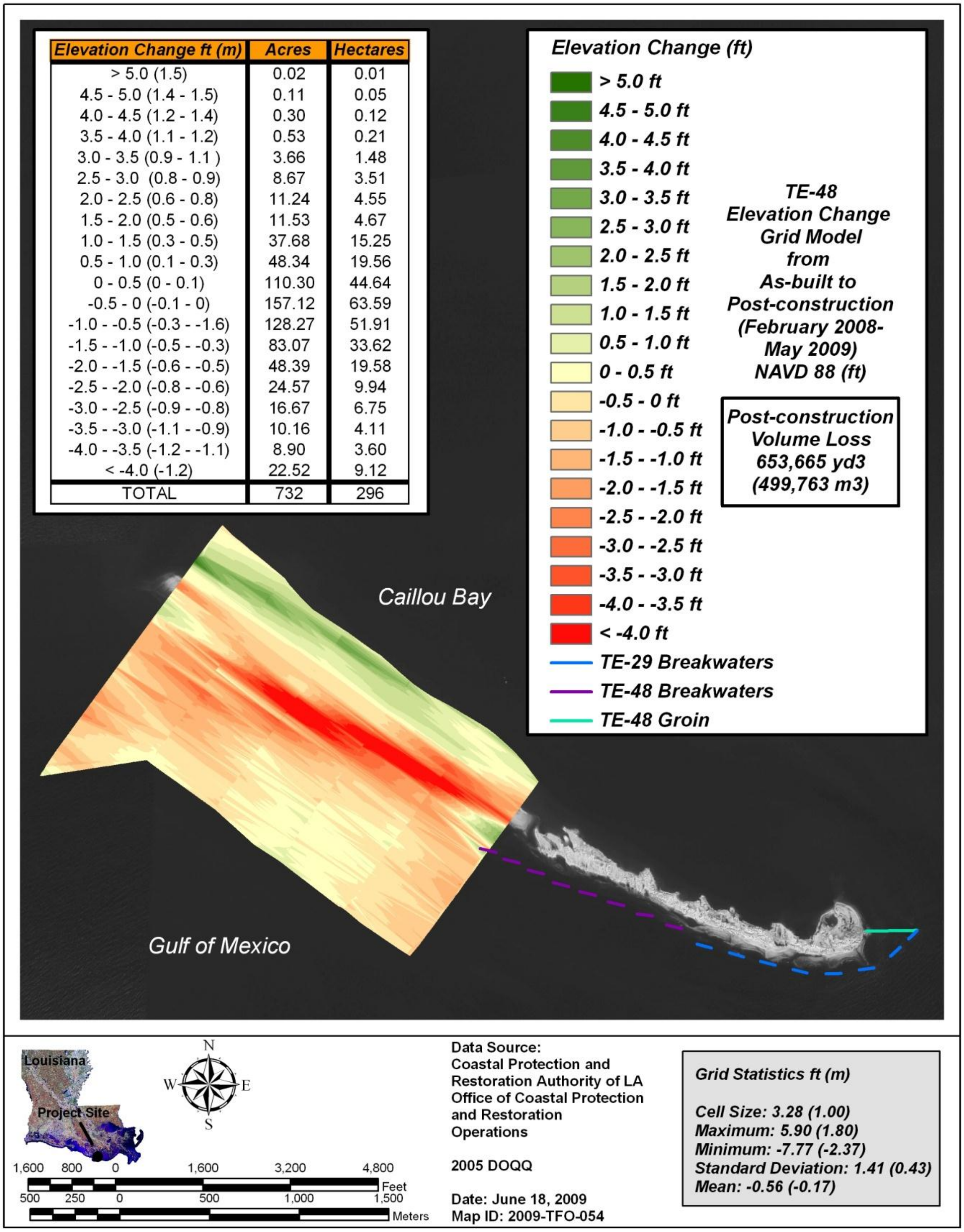


Figure 16. **Elevation and volume change grid model for the spit from as-built (Feb 2008) to post-construction (May 2009) at the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project.**

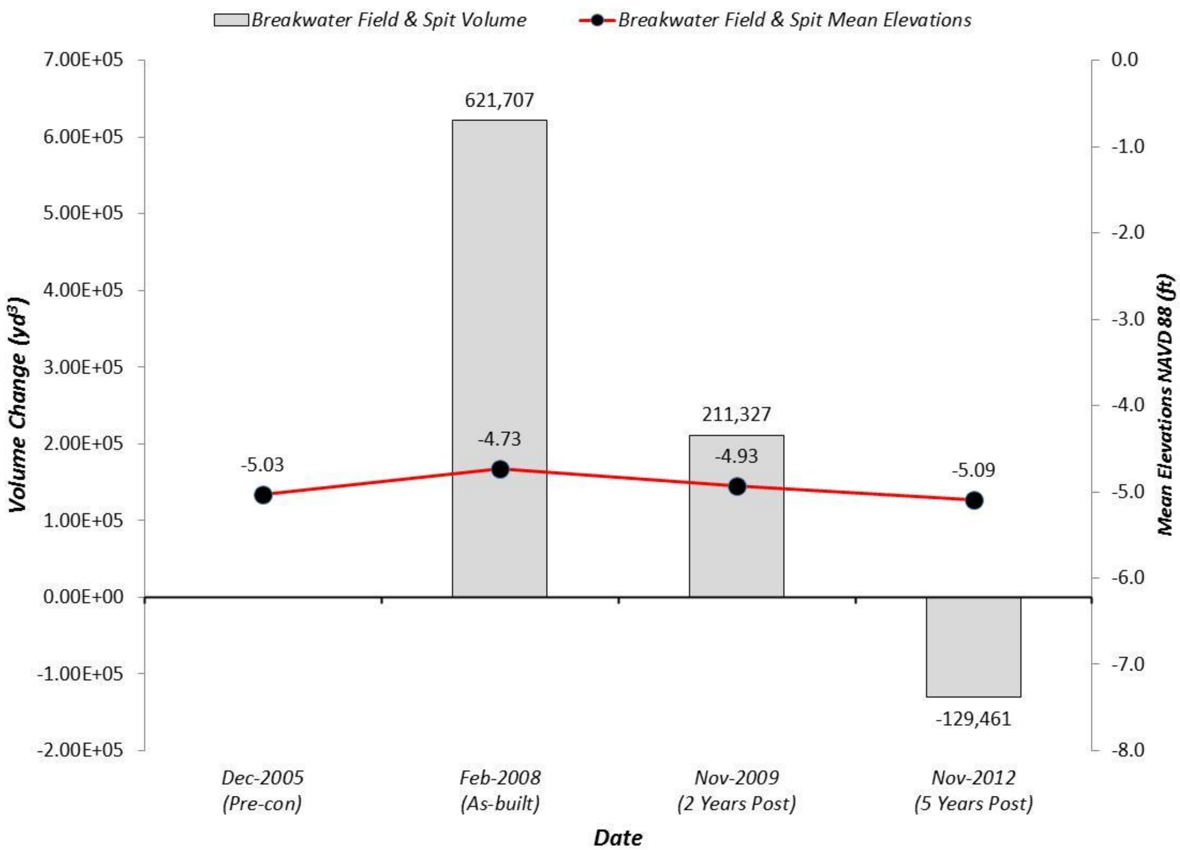


Figure 17. **Sediment volume change and mean elevations over time along the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project's breakwater field and spit areas.**

Tables 4 and 5). For example, the mean elevations (Table 4) and volumes (Table 5) for the variable subarerial spit subdivisions are always greater than their static counterparts because their grid models only include elevations greater than or equal to zero in an area that is increasingly contracting. Likewise, the variable spit shoreface volume for the Nov2009-Nov2012 interval shows a large loss because the subaerial portion of the spit has transgressed and the breach has expanded (Table 5 and Figure 14).

The TE-48 structures have been successful in capturing sediment and aggrading shoreline positions (Table 1). The construction of the groin caused considerable volume increases (Figures 12, 13, and 14), expanded the eastern tip of the island by approximately 665 ft (203 m) (Figures 19, 20, and 21), and closed the greater than 10 ft (3 m) deep channel that developed behind breakwaters #0 and #1 (Figures 12, 13, and 14) as postulated by Stone et al. (2003). In addition, the tombolo that formed behind breakwater #1 in 2010 has transgressed slightly; however, this geomorphic feature is still a very prominent salient (Figures 13, 14, and 22). While the area surrounding the groin gained volume, the volume behind breakwaters #2 through #6

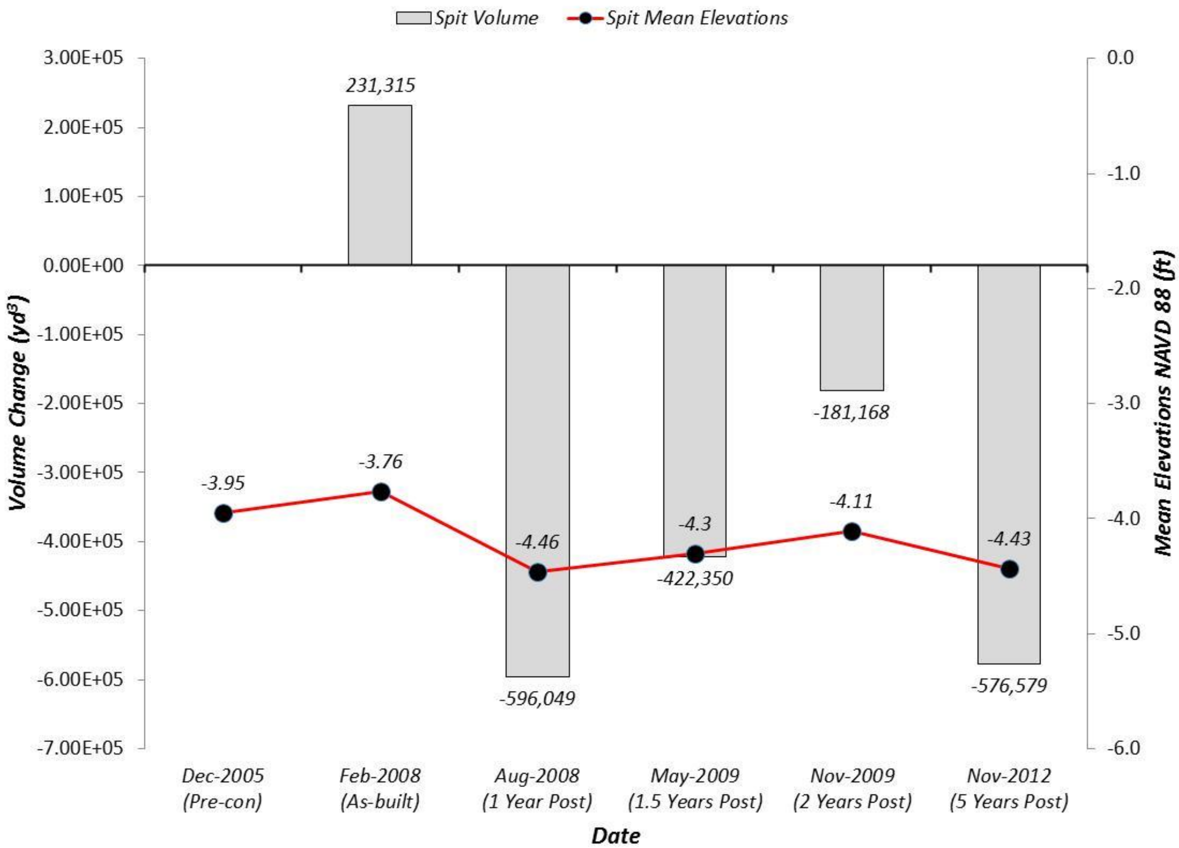


Figure 18. **Sediment volume change and mean elevations over time along the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project's spit.**

declined (Figure 13 and Table 5) and breakwater #2 lost volume immediately after construction (Figure 12). Breakwater #2's volume has modestly increased over time; however, breakwaters #3 to #6 continue to display volume losses (Figure 14). In addition, breakwaters #3 and #4 have settled and are probably not functioning at optimal levels (Figure 21). Therefore, it seems that some of the volume gained in the groin area was redistributed from the TE-29 breakwaters. Likewise, all the TE-48 breakwaters (#8-#15) showed increases in volume (Figure 13 and Table 5). The volumes behind the TE-48 breakwaters have not only increased but salients or tombolos have formed behind five of these structures (breakwaters #8 through #12) (Figure 20). The shoreline response behind the structures reaffirms the volume change data (Table 1). Shoreline positions behind the TE-29 and TE-48 structures have experienced considerable progradation since construction. The shoreline segments that sustained the greatest gains were the segments in the vicinity of the groin and on the western end of the breakwater field while the segments incurring the largest shoreline transgressions were behind breakwaters #3 to #6 as illustrated in figures 13

Table 4. Mean elevations inside six predefined (static) Raccoon Island subdivisions over time. Also, included (first two rows) are the spit elevations above (spit) and below (shoreface) the zero ft contour. These contours vary spatially over time due to variation in subaerial spit elevations.

Mean Elevation (NAVD88 ft)	*Dec-2005 Pre*	*Feb-2008 As-blt*	*Aug-2008 1 Yr Post*	*May-2009 1.5Yr Post*	*Nov-2009 2 Yr Post*	*Nov-2012 5 Yr Post*
Subaerial Spit (≥0 ft Contour)	1.40	1.40	1.24	0.76	1.06	1.11
Spit Shoreface (<0 ft Contour)	-5.95	-5.91	-6.79	-5.97	-5.9	-5.69
Subaerial Spit	1.40	1.32	0.86	0.09	0.31	-1.27
Spit Shoreface	-5.95	-5.76	-6.66	-6.51	-6.3	-6.28
TE-48 Shoreface	-8.23	-7.91	N/A	N/A	-7.78	-7.99
TE-29 Shoreface	-7.49	-7.03	N/A	N/A	-7.18	-7.13
TE-48 Breakwaters	-1.4	-0.73	N/A	N/A	-0.20	0.65
TE-29 Breakwaters	-1.03	-0.57	N/A	N/A	-0.78	-0.35

Table 5. Volume change inside six predefined (static) Raccoon Island subdivisions over time. Also, included (first two rows) are the spit volume changes above (spit) and below (shoreface) the zero ft contour. These contours vary spatially over time due to variation in subaerial spit elevations.

Volume Change (yd3)	*Dec 2005 Pre– Feb 2008 As-blt*	*Feb 2008 As-blt– Aug 2008 1Yr Post*	*Feb 2008 As-blt– May 2009 1.5Yr Post*	*Feb 2008 As-blt- Nov 2009 2Yr Post*	*Feb 2008 As-blt- Nov 2012 5Yr Post*	*Aug 2008 1Yr Post- May 2009 1.5Yr Post*	*May 2009 1.5Yr Post- Nov 2009 2Yr Post*	*Nov 2009 2Yr Post- Nov 2012 5Yr Post*
Subaerial Spit (≥0 ft Contour)	57,124	-34,773	2,384	89,227	19,274	-20,962	76,359	18,422
Spit Shoreface (<0 ft Contour)	97,240	-697,677	-508,697	-343,102	-311,626	152,945	144,658	-128,632
Subaerial Spit	-20,572	-116,576	-312,276	-254,986	-655,075	-195,986	57,448	-398,939
Spit Shoreface	149,960	-684,441	-568,721	-409,990	-398,444	116,150	158,644	11,766
TE-48 Shoreface	115,027	N/A	N/A	46,049	-26,390	N/A	N/A	-72,720
TE-29 Shoreface	150,367	N/A	N/A	-50,302	-35,806	N/A	N/A	14,356
TE-48 Breakwaters	52,002	N/A	N/A	41,011	107,781	N/A	N/A	66,662
TE-29 Breakwaters	40,082	N/A	N/A	-17,925	19,015	N/A	N/A	36,932

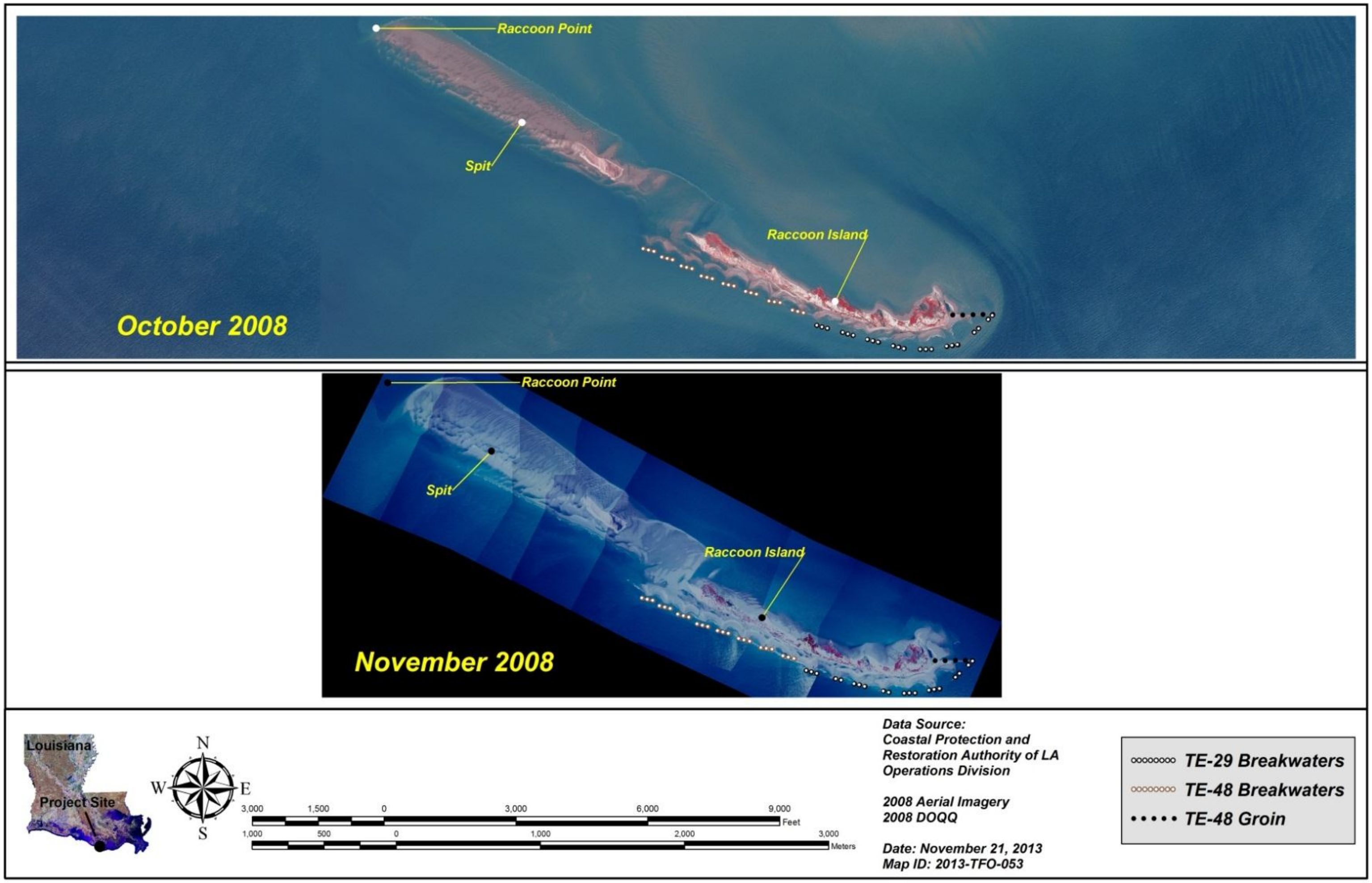


Figure 19. **Aerial photography (Oct 2008 and Nov 2008) showing the performance of the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project after Hurricane Gustav. Note the breach expansion, the spit shoreline transgressions, the development of salients behind all the TE-48 breakwater (2008), and the expansion of the groin shoreline.**

Figure 20. **Aerial photography (2010 and 2012) showing the performance of the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project. Note the breach enlargement and aggradation behind the TE-48 structures in 2012.**

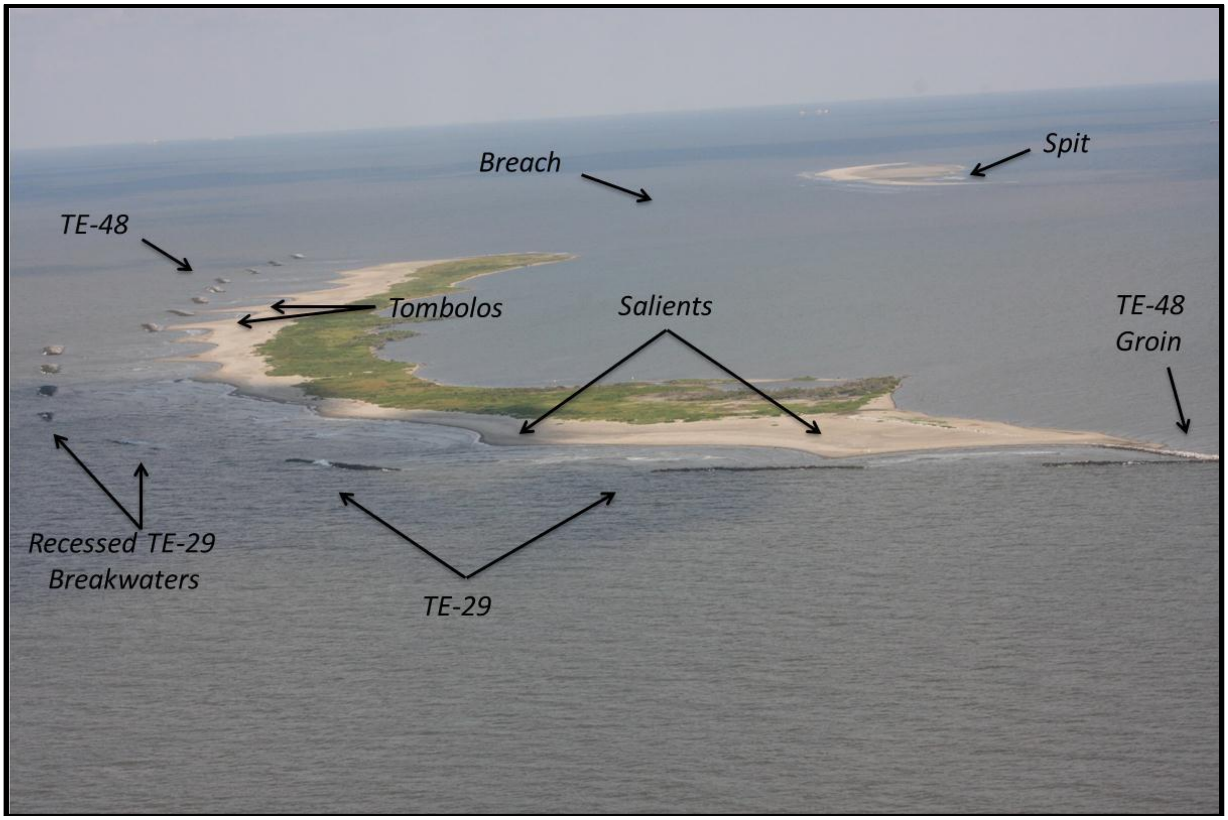


Figure 21. View of Raccoon Island from the SE showing the project and geomorphic features. Oblique aerial photograph was taken one month after the passage of Hurricane Isaac on September 26, 2012. Note the large expanse between Raccoon Island and the spit.

and 14. Surprisingly, the detached salients that formed behind breakwaters #13 through #15 in the aftermath of the 2008 hurricane season (Figure 19) do not appear by 2012 (Figure 20) but the contours behind these structures aggraded (Figures 13 and 14) denoting that the breach between the island and the spit and/or the northerly retreat of this shoreline (Figures 3, 19, and 20) are influencing sedimentation behind these structures. Also, the TE-48 breakwaters seem to have been designed to the correct dimensions to promote salient development (Suh and Dalrymple 1987; McCormick 1993; Ming and Chiew 2000). However, breakwaters #14 and #15 were placed further offshore than the 250 ft (76 m) design (Figure 3) and salients formed behind these structures. This is probably due to the fact that the structures were within the Ming and Chiew (2000) tolerance for salient development, and the gaps between the structures decreased towards the west (Suh and Dalrymple 1987). Interestingly, all the TE-48 structures (breakwaters and the groin) have progressively aggraded the shorelines in their lee over time (Figures 12, 13, 14, and Tables 4 and 5). Moreover, breakwaters #13 to #15 have raised contours that are considerable distances from the shoreline. The TE-48 structures have not only slowed the rate of erosion but also

Figure 22. **Oblique photographs showing the area behind breakwater 1 in 2010 (Panel A) and 2013 (Panel B). Note the tombolo formation in 2010 and transgression into a salient in 2013.**

prograded Raccoon Island's shoreline position and in doing so abated shoreline erosion directly behind them. Therefore, the TE-48 goal is currently being achieved. However, these structures are also sequestering sand resources, thereby, limiting resource availability to the downdrift spit (Table 5), and possibly contributing to the dramatically increased shoreline erosion along the spit.

Hurricane Gustav (Sep 2008) can be attributed with causing part of the post-construction volume losses. This storm which passed within 20 mi (32 km) of Raccoon Island (Figure 23) transgressed the spit shoreline 326 ft (99 m) (Table 2), reopened the breach separating Raccoon Island and the spit leaving an approximate 1,500 ft (457 m) divergence (Figures 5, 6, 7, 19, and 24), and damaged brown pelican nesting habitat (Figure 25).

Since this tropical event, the breach has expanded to an estimated 3,100 ft (945 m) width and steepened to a -2.36 ft (-0.72 m) NAVD88 contour (Figures 14, 20, and 21).

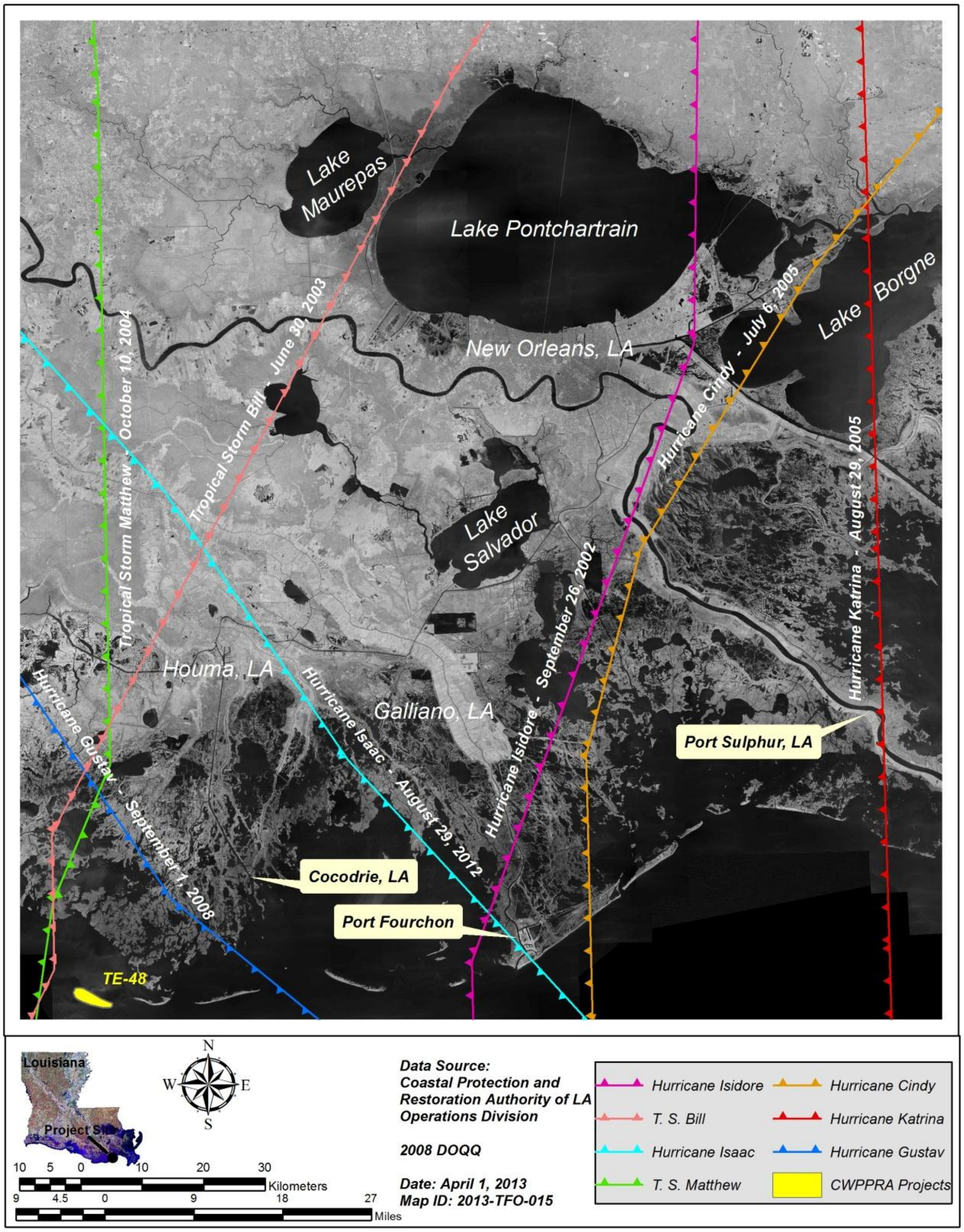


Figure 23. Pre-construction (2002, 2003, 2004, & 2005) and post-construction (2008 & 2012) hurricanes impacting the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project area shoreline. Hurricanes Lilli (2002), Ivan (2004), Rita (2005), Ike (2008), and Tropical Storm Lee (2011) are not shown because the eye wall of these storms traveled further to the south outside the extent of the map.

Table 6. Mean width, length, and area of the subaerial portion of the Raccoon Island Spit over time.

Subaerial Spit Summary Statistics	*Dec-2005 Pre (n=6)*	*Feb-2008 As-blt (n=6)*	*Aug-2008 1Yr Post (n=6)*	*May-2009 1.5Yr Post (n=6)*	*Nov-2009 2Yr Post (n=6)*	*Nov-2012 5Yr Post (n=3)*
Mean Width (ft)	849	929	803	776	813	772
Length (ft)	7465	7432	7490	7456	7303	3929
Area (Acres)	157	167	147	137	149	65

The scouring of the breach has caused 125 acres (51 ha) of the spit to become subaqueous. In Feb 2008 this area had an average elevation of 1.54 ft (0.47 m) NAVD88 elevation (Appendix C). To fill the breach to its former elevation would require 786,693 yd^3 (601,470 m^3) of sand resources (Figures 14, 20, and 21). Due to the progressive development of the breach, it seems that this gap may evolve into an inlet (Levin 1993; McBride et al. 1989).

After Hurricane Gustav, the spit gained volume in May 2009 (Figures 16, 18, and Table 3) and Nov 2009 (Figures 13, 18, and Table 3). However, the gains in spit volume were primarily a function of gains in the spit shoreface, which has recorded increases in sedimentation over time (Table 5). The subaerial spit volume did increase in Nov 2009 displaying a partial recovery from the Hurricane Gustav loss. Louisiana delta plain barrier islands typically recover incompletely from large scale storm events due to the microtidal climate and low wave energy of the northern Gulf of Mexico (Penland et al. 1985). This subareial spit volume increase was short lived, though, because by Nov 2012 this area incurred substantial losses in volume (Table 5). These volume changes are reaffirmed by Tables 1, 5, and 6, which exhibit partial reclamation (Nov 2009) and subsequent declines (Nov 2012) in elevation, position, length, and area. Moreover, a drastic reduction in spit length and areal extent was noted in Nov 2012 (Figures 20 and 21) and the spit width was an average of three transects due to spit truncation (Table 6). Although the volume of the spit has decreased considerably, portions of the sand and sediment resources were conserved outside the study area due to the continued northwest migration of the spit (Figures 14 and 20). Inlet formation has been found to considerably reduce the area of barrier islands (McBride et al. 1989). The establishment and expansion of the breach on Raccoon Island reaffirms this point. The enlargement of the breach is likely a result of tropical storm (Peyronnin 1962; Stone et al. 1993; Stone et al. 1997; Georgiou et al. 2005; Morton and Barras 2010) and cold front (Boyd and Penland 1981; Dingler and Reiss 1990; Georgiou et al. 2005) forcing since the Nov 2009 survey. Tropical Storm Lee (2011) and Hurricane Isaac (2012) have impacted Raccoon Island since 2010 (Figure 23) and probably influenced the broadening of the breach. The historical record also supports tropical storm breaching (Figure 5) and cold front enlargement (Figure 6) of the spit. Although the spit sustained large volume deficits over time, a portion of the spit's

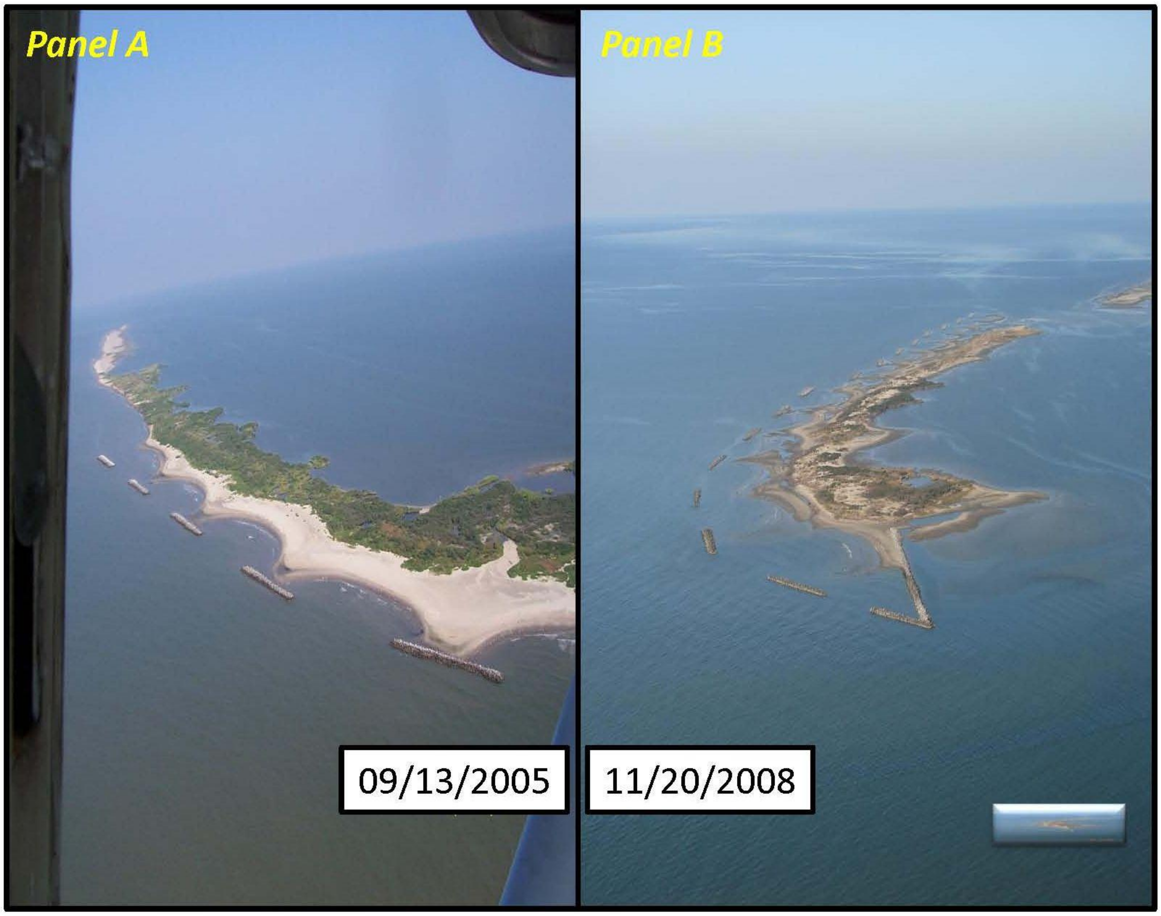


Figure 24. Oblique aerial views of Raccoon Island after Hurricane Katrina in 2005 (Panel A) and the 2008 (Panel B) hurricane season. Note the breaching of the spit and the stressed habitats in 2008. Also, note the downdrift impacts occurring in the immediate lee of the TE-29 breakwater field. These impacts are illustrated in the 2005 aerial.

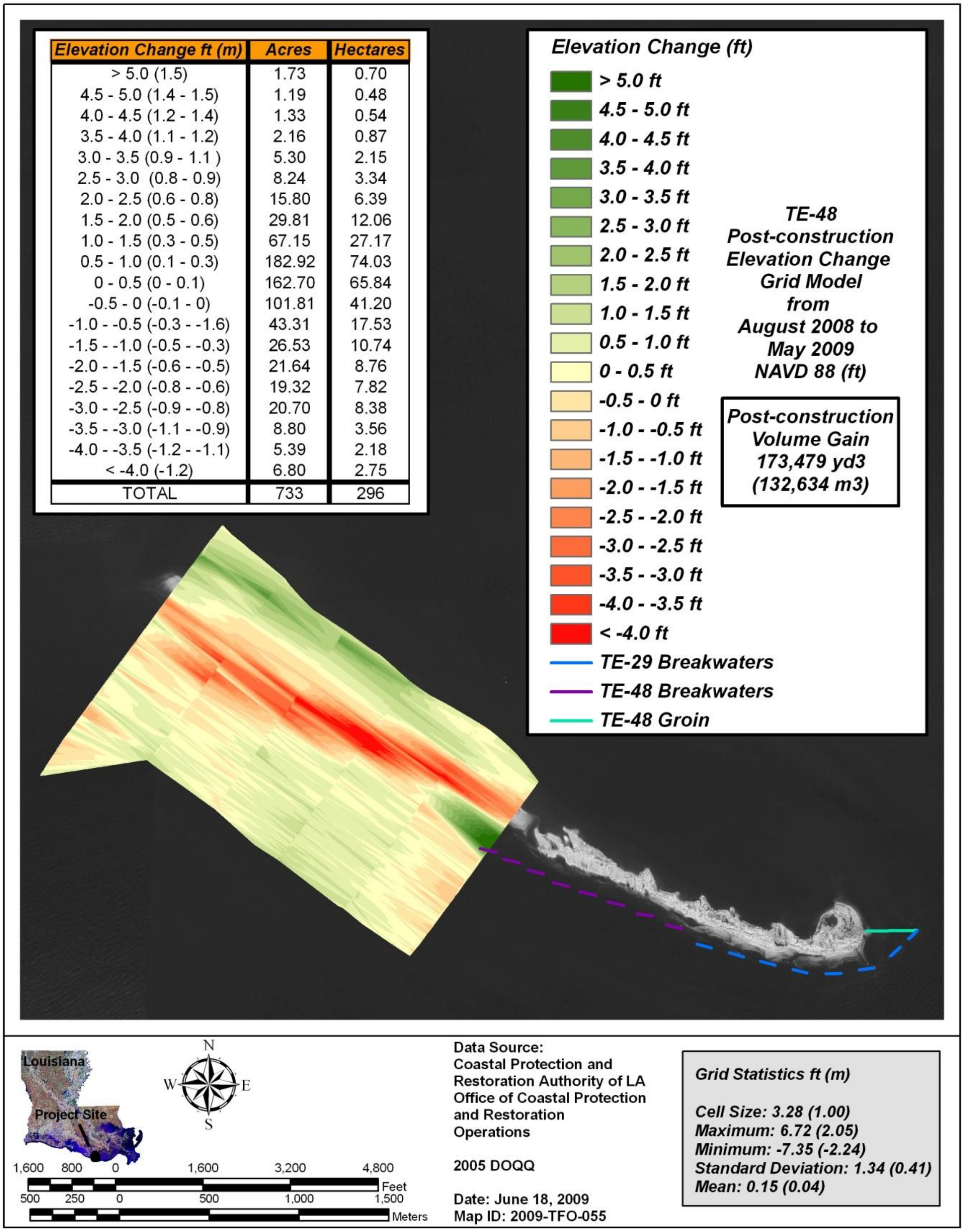
volume was conserved and elevations were raised in the shallow reaches of Caillou Bay (Figures 13, 14, 16, 26, and Table 2). Moreover, the large volume gain behind breakwater #15 immediately after HurricaneGustav (Figure 26) aggraded a part of the shoreface that appeared to scoured by the breakwaters (Figure 15), and brown pelican nesting habitat partially recovered from Hurricane Gustav damage by 2013 (Figure 25). In contrast, the spit exhibited negligible subaerial expansion to the west having migrated only 3.41 acres (1.38 ha) from Feb 2008 to Nov 2012.

The volume loss that transpired on the Raccoon Island Spit before the 2008 hurricane season (Figures 15, 18, and Tables 3, 5) illustrates that downdrift impacts of the breakwater field were occurring in the immediate lee of the breakwaters not long after construction. Although a considerably greater proportion of the volume losses occurred in the spit shoreface subdivision (Table 5), a sizeable volume of sediments [-116,576 yd^3 (-89,129 m^3)] were removed from the subaerial part of the spit (Table 5).

Figure 25. Oblique photographs showing Raccoon Island in 2010 (Panel A) and 2013 (Panel B). Note the stressed condition of the brown pelican nesting habitat in 2010 and the partial recovery of these habitats by 2013.

The spit shoreface losses are likely due to winter storms and longshore transport processes. The mean width (Table 6), area (Table 6), and elevation (Table 4) of the subaerial portion of the spit all declined immediately after construction (August 2008). Table 2 also illustrates that both the Gulf of Mexico and the Caillou Bay spit shorelines transgressed from February 2008 to August 2008. Furthermore, spit shoreline transgressions in the immediate lee of the TE-48 breakwaters are apparent as early as Feb 2008 (Figure 12) and continue to intensify over time (Figures 13, 14, 15, and 16). Downdrift volume losses are common on segmented breakwaters and have been well documented (Armbruster 1999; Underwood et al. 1999; Penland et al. 2003; Stone et al. 2003; Thomalla and Vincent 2003; Edwards 2006).

The low contour sand shoal identified by Armbruster (1999) and Stone et al. (2003) does not appear on the grid models (appendix D) or elevation change models (Figures 12, 13, and 14) suggesting that the shoreface has steepened on the eastern edge of Raccoon Island. Tables 4 and 5 also provide evidence showing that the shoreline



Elevation Change ft (m)	Acres	Hectares
> 5.0 (1.5)	1.73	0.70
4.5 - 5.0 (1.4 - 1.5)	1.19	0.48
4.0 - 4.5 (1.2 - 1.4)	1.33	0.54
3.5 - 4.0 (1.1 - 1.2)	2.16	0.87
3.0 - 3.5 (0.9 - 1.1)	5.30	2.15
2.5 - 3.0 (0.8 - 0.9)	8.24	3.34
2.0 - 2.5 (0.6 - 0.8)	15.80	6.39
1.5 - 2.0 (0.5 - 0.6)	29.81	12.06
1.0 - 1.5 (0.3 - 0.5)	67.15	27.17
0.5 - 1.0 (0.1 - 0.3)	182.92	74.03
0 - 0.5 (0 - 0.1)	162.70	65.84
-0.5 - 0 (-0.1 - 0)	101.81	41.20
-1.0 - -0.5 (-0.3 - -1.6)	43.31	17.53
-1.5 - -1.0 (-0.5 - -0.3)	26.53	10.74
-2.0 - -1.5 (-0.6 - -0.5)	21.64	8.76
-2.5 - -2.0 (-0.8 - -0.6)	19.32	7.82
-3.0 - -2.5 (-0.9 - -0.8)	20.70	8.38
-3.5 - -3.0 (-1.1 - -0.9)	8.80	3.56
-4.0 - -3.5 (-1.2 - -1.1)	5.39	2.18
< -4.0 (-1.2)	6.80	2.75
TOTAL	733	296

Figure 26. **Elevation and volume change grid model for the spit from post-construction (Aug 2008) to post-construction (May 2009) at the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project.**

subdivision (TE-29 Shoreface) containing the shoal has steepened and recorded volume losses since construction. Moreover, this shoal has been recognized (Stone et al. 2003) as the source of the sediment volume increases behind the TE-29 breakwaters. Stone et al. (2003) also provided evidence showing that small tropical storms caused the volume of this shoal to be slightly reduced. Consequently, the passage of the massive 2005 and 2008 hurricanes—Hurricane Katrina (Aug 2005), Hurricane Rita (Sep 2005), Hurricane Gustav (Sep 2008), and Hurricane Ike (Sep 2008) (Figure 23)—might have contributed to the erosion of this shoal (Penland et al. 1985McBride et al. 1989; Georgiou et al. 2005; Miner et al. 2009a). Comparing the earlier Stone et al. (2003) grid models [-2 ft (-0.61 m) NAVD88] with the latest elevation data (Nov 2012) [-6 ft(-1.8 m) NAVD88] (Figure 14) suggest that approximately 4 ft (1.2 m) of the sand shoal has eroded from the shoreface. Stone et al. (2003) also estimated the sand thickness of the shoal to be 9.35 ft (2.85 m). Therefore, approximately 5.35 ft (1.63 m) of the sand shoal remains in place. However, a considerable quantity of this sand volume may be unavailable for littoral transport because the depth of closure for Raccoon Island is -6 ft (1.8 m) NAVD88 (Thomson et al. 2004). As a result, the erosion of the sand shoal could be the major cause of the sediment volume loss behind breakwaters #2 through #6 (Figures 13 and 14). If the shoal has been significantly eroded, it may be necessary to consider a beach nourishment event to add sand resources to Raccoon Island. Beach nourishment events have been shown to enhance and stabilize other breakwater projects (Thomalla and Vincent 2003; Edwards 2006).

The volume and transport of sand facies are the primary factors contributing to the high volume loss rate encountered on Raccoon Island. Barrier island arcs in Louisiana, like Isle Dernieres, have insufficient sand resources to sustain their length, width, area, and elevation (Penland et al. 1985; McBride et al. 1989). On Raccoon Island the longshore current is localized because negligible sand resources are believed to be conveyed across the Coupe Colin Inlet (Figure 1) (Stone and Zhang 2001). Additionally, shoreface subsidence has been postulated as a mechanism for removing sand facies available for longshore transport and profile lowering (Penland et al. 1985; McBride et al. 1989; Dean 1997). Moreover, Raccoon Island has a low contour depth of closure (Thomson et al. 2004). Hurricanes and tropical storms have also been implicated in removal of granular sediments from the littoral systems of Louisiana's delta plain shorelines (Penland et al. 1985; McBride et al. 1989; Georgiou et al. 2005; Miner et al. 2009a). Furthermore, Miner et al. (2009a) confirm that volume loss along these sandy shorelines is accelerated during periods of frequent and/or intense tropical storm activity. These researchers and Miner et al. (2009b) also point out that a portion of this volume is being transported to Raccoon Point (Figures 1, 4, 5, 6, 7, 8, 19, and 20) and aggrading the terminal end of the Isle Dernieres system (Figure 27). However, the composition (sand, silt, or clay) of the sediments sequestered inside Raccoon Point's inner shelf shoal is currently not known. In the recent past, Raccoon Island has been impacted numerous times by tropical storms and hurricanes (Figures 5, 6, 19, 20, and 23) and incurred sediment deficits as a result. For these reasons, a

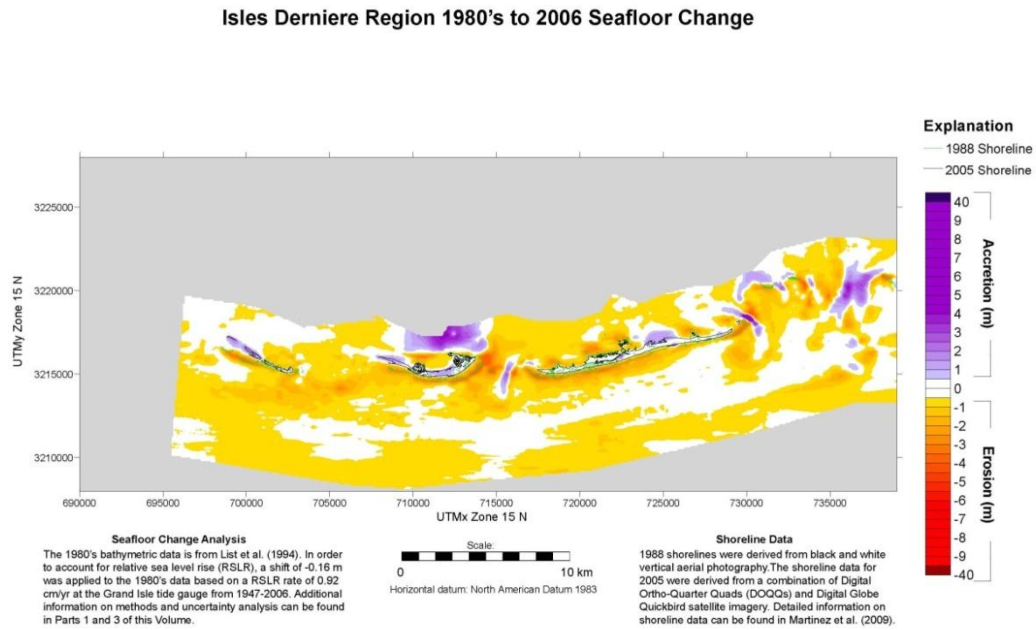


Figure 27. **Inner shelf aggradation of the Raccoon Point shoal from the 1980's to 2006. The graphic was obtained from BICM (Miner et al. 2009b).**

additional sand resources should be added to the Raccoon Island system through breach closure and beach nourishment event to increase island length and natural process development (Penland and Suter 1988; Feagin et al. 2010). In addition, a terminal groin structure placed on the western edge of the spit (Dean 1997) and marsh constructed behind the breach closure area should be considered to enhance the retention of sediment. Marsh creation behind the breach closure area and the spit would increase the area, width, and sediment volume of Raccoon Island. It would also provide a platform to retain cross-shore sediments, establish an additional barrier to resist erosion and breaching, and increase the habitat available for brown pelican nesting. Table 7 lists the volumes and depths required to close and fill the breach to predefined elevations. Note, the 1.54 ft (0.47 m) NAVD88 elevation listed in Table 7 is the average orthometric height of the breach area in Feb 2008.

In conclusion, preliminary results indicate that the TE-48 goal to reduce shoreline erosion behind the breakwaters to protect Raccoon Island habitats is currently being attained because sediment volume increased behind all the TE-48 structures and the breakwaters and the groin protected and the shoreline from tropical storm and cold front activity. Moreover, these structures have not only protected the shoreline but

Table 7. Estimated fill volumes and depths required to close and aggrade the breach to predefined fill elevations at the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project.

Fill Elevation NAVD88 ft	*Fill Volume yd^3*	*Fill Depth ft*
0.00	476,808	2.36
1.00	678,710	3.36
1.54	786,693	3.90
2.00	880,612	4.36
2.50	981,583	4.86
3.00	1,082,514	5.36

they have also caused considerable progradation of the shorelines in their lee. However, the structures appeared in the intervening time to have negative downdrift impacts to the spit and the breach expanded substantially over time, indicating that a more systematic approach to barrier island management is needed when considering projects and structural approaches. In addition, the apparent erosion of the eastern sand shoal to the depth of closure could influence future distributions of sand behind the structures.

Sediment Properties

The results of the sediment properties analysis demonstrate that surficial sand deposits were present along the Raccoon Island shoreface, the Coupe Colin Inlet, and the Raccoon Point inner shelf shoal in July of 2008 (Kulp et al. 2011a; Kulp et al. 2011b). The sand content of the Raccoon Island samples ranged from 90 to 100% (Figure 28), and the grain size ranged from 125–250 µm (Figure 29). This grain size translates to a fine sand classification. Although the distribution of sand resources appears favorable, Isle Dernieres Barrier Islands have been characterized as having a thin sand layer overlying silt and/or clay substratums (Penland et al. 1985) and the surface samples were collected before the 2008 hurricane season. The enlargement of the breach and erosion of the spit and eastern shoal signify low quantities of sand facies available for longshore transport. Moreover, sand resource availability is vital to success or failure of breakwater projects (Dean and Dalrymple 2002). While the 2013 BICM sediment grab samples will discover if the spatial distribution of littoral sand resources has been altered since 2008, sediment cores should be extracted to establish a detailed sediment budget for Raccoon Island. These cores should extend 15-20 ft (5-6 m) below the ground surface (bgs) and stretch from Coupe Colin Inlet to Raccoon Point.

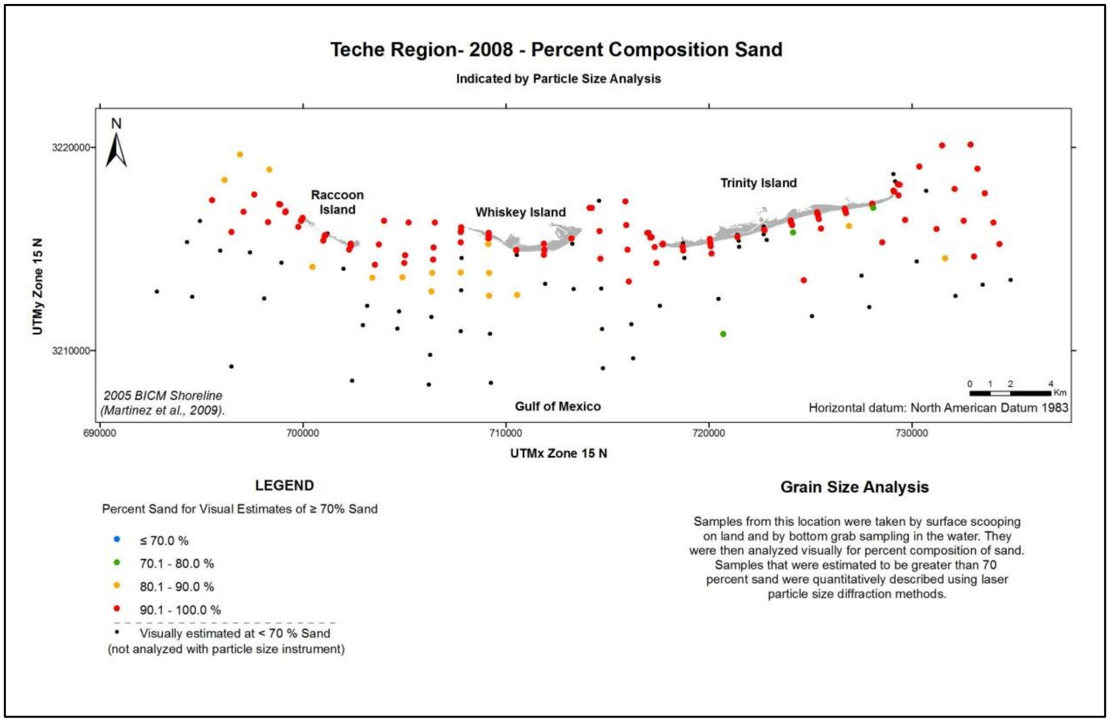


Figure 28. Percent sand for the Isle Dernieres Barrier Arc in 2008. The graphic was obtained from BICM (Kulp et al. 2011b).

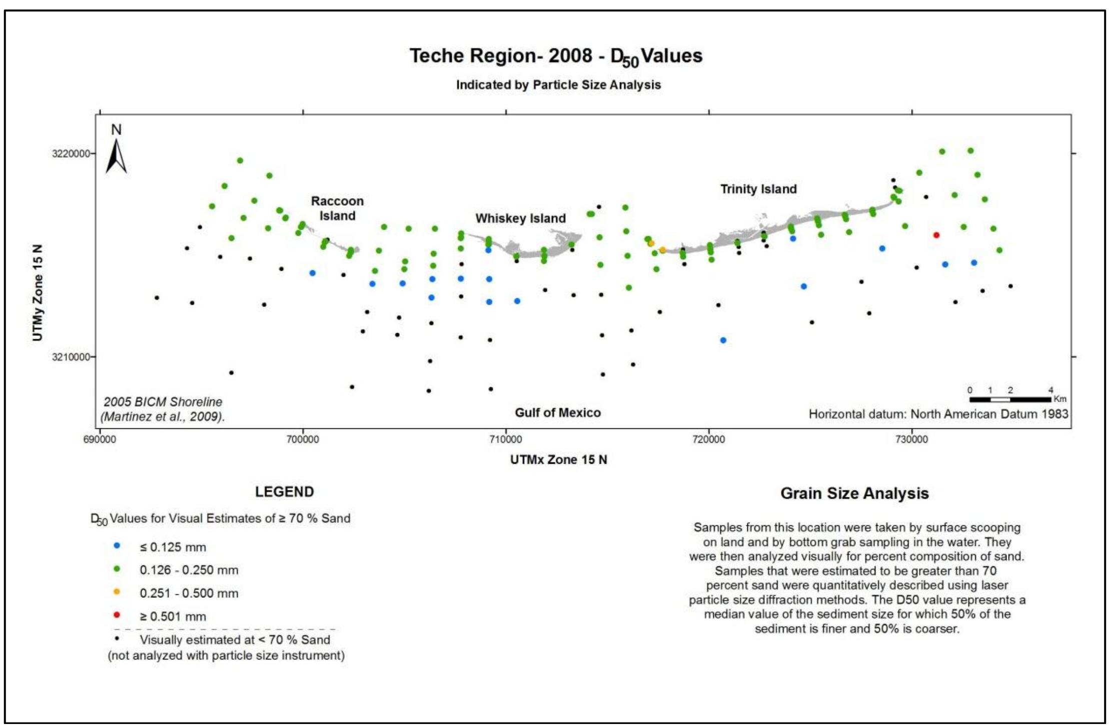


Figure 29. Grain size distribution for the Isle Dernieres Barrier Arc in 2008. The graphic was obtained from BICM (Kulp et al. 2011b).

V. Conclusions

a. Project Effectiveness

The results of Phase A of the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project reveal that the project goal of reducing the shoreline erosion is being attained at the present time behind the breakwaters. The goal to reduce shoreline erosion to protect habitats sustaining the Raccoon Island rookery and sea bird colonies was achieved because all TE-48 structures gained sediment volume and advanced the shoreline position. The groin expanded the shoreline and gained considerable volume. The large volume increase surrounding this structure initiated salient formation behind TE-29 breakwaters #1 and #2 and closed a channel that developed behind TE-29 breakwaters #0 and #1. The TE-48 breakwaters all showed volume gains and breakwaters #8 through #12 displayed tombolo or salient formations. Additionally, the CEC, Inc. (2013) projected pre-restoration and post-restoration year of disapperance (YOD), and found that the restoration efforts have extended the projected year of Raccoon Island disappearance by 17 years, which is slightly better than the overall Terrebonne Basin system wide assessment, of an additional 13 years due to restoration.

However, during this evaluation, the spit recorded a large shoreline erosion rate as well as a large volume loss, post-construction and prior to Hurricane Gustav due to a combination of winter storms, reduced longshore transport across the breach, and downdrift impacts of the TE-48 breakwaters. During Hurricane Gustav, the spit shoreline transgressed appreciably, and the breach between Raccoon Island and the spit expanded substantially. Since Hurricane Gustav, the spit volume has continued to decline and the breach has expanded considerably while the TE-48 breakwaters have continued to sequester volume updrift of the spit.

The eastern shoreface of Raccoon Island seems to have steepened because the large sandy shoal that Armbruster (1999) and Stone et al. (2003) identified could not be located with bathymetric data. Moreover, this shoal has been recognized (Stone et al. 2003) as the source of the sediment volume increases behind the TE-29 breakwaters. Approximately, a 4 ft (1.2 m) thick portion of the sand shoal has eroded from the shoreface. A large portion of the remaining sand volume may be unavailable for littoral transport because Raccoon Island is reported to have a very shallow depth of closure (Thomson et al. 2004). As a result, the erosion of the sand shoal could be the major cause of the sediment volume loss behind breakwaters #3 through #6. Although there are sand resource deficiencies, the project is protecting the shoreline updrift of the spit and will be monitored into the future.

The marsh creation area was too recently constructed to make any conclusions. The area is filled and looks suitable for habitat development, but only time will tell. The BICM program will develop habitat data from the 2012 CRMS-Wetlands photography, but this is pre-construction. Additional habitat mapping is expected through the BICM program in 2017.

b. Recommended Improvements

Several improvements would enhance the sustainability and analysis of the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project. First, TE-29 breakwaters #3 and #4 have settled and should be repaired. These structures have recessed and are only partially exposed during higher tides affecting the shoreline response. Currently, no salients are being produced in the lee of these structures and with reduced sediment input due to the erosion of the eastern shoal these breakwaters should be repaired to insure they perform to their maximum efficiency. Once as-built information for the phase B portion of the project is provided and a final O&M plan is approved, a complete survey of the breakwaters themselves, including settlement plates should be conducted and plans for repairs should be developed.

Secondly, sediment cores should be extracted to establish a detailed sediment budget for Raccoon Island. These cores should extend 15-20 ft (5-6 m) below the ground surface (bgs) and stretch from Coupe Colin Inlet to Raccoon Point.

Thirdly, as called for in the States Master Plan (CPRA 2012) additional sand resources should be added to the Raccoon Island system through a breach closure and beach nourishment event to increase island length and natural process development (Penland and Suter 1988; Feagin et al. 2010). Adding sand resources to the Raccoon Island littoral system via breach closure and beach nourishment would enrich the response of the shoreline to coastal structures and prolong the longevity of the island and spit. In addition, a terminal groin structure placed on the western edge of the spit should be considered to improve sediment retention (Dean 1997).

Lastly, although the back barrier marsh creation component (Phase B) of the TE-48 project was recently constructed, creating additional marsh behind the breach closure area and the spit would increase the area, width, and sediment volume of Raccoon Island. It would also provide a platform to retain cross-shore sediments, establish an additional barrier to resist erosion and breaching, and increase the habitat available for brown pelican nesting. As a result, additional back barrier marsh creation areas behind the breach and spit would enhance the sustainability of Raccoon Island and the brown pelican colony.

c. Lessons Learned

Four lessons were learned from the first five years of Phase A of the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project. The first lesson is that the TE-48 structures have been effective in capturing and retaining sediments. The groin has progressively advanced the shoreline position on the eastern tip of the island and caused infilling of the former channel behind breakwaters #0 and #1. As a result, the placement of the groin in its current location has increased volumes and extended shoreline positions in the lee of breakwaters #0 and #1 stabilizing the eastern margin of the Raccoon Island. Similarly, all the TE-48 breakwaters have raised shoreline contours in their lee. These shoreline positions have continued to evolve over time through sediment aggradation. The placement of the TE-48 breakwaters closer to the shore and the narrowing western gap widths has enhanced the performance of the structures while the earlier breakwaters are not as efficient because they were placed further offshore and have wider gap widths. However, the sediment induced volume expansions in the vicinity of the groin and behind the TE-48 breakwaters have come to the detriment of the Raccoon Island Spit and breakwaters #3-#6 (TE-29) which have recorded sediment deficits since construction of the TE-48 structures. Consequently, the retention and continued aggradation of sand resources by the TE-48 structures have lowered the quantity available to nourish the Raccoon Island Spit and the shorelines in the lee of breakwaters #3-#6. Although tropical and extra tropical storms are the primary cause of the large spit volume loss, the sequestering of limited sand resources by the TE-48 structures has impacted volumes on the downdrift spit and in the lee of breakwaters #3-#6.

The second lesson is that the entire shoreface (breakwater field and spit) should have been topographically and bathymetrically surveyed during all sampling events. The Aug 2008 and May 2009 surveys only collected data on the spit portion of the island. Since Hurricane Gustav made landfall in Sep 2008, no data is available to assess the function of the breakwater and groin structures immediately before or after the storm. Moreover, the placement of these hard structures affects the sediment budget for whole island not just the breakwater field. Therefore, the elevation surveys should have mapped the breakwater field and the spit contours to verify changes in the shoreface.

The third lesson learned is the large sandy shoal that Armbruster (1999) and Stone et al. (2003) identified should have been re-assessed after the 2008 hurricanes and a new sediment budget established. The volume and location of sand resources should have been quantified and mapped. This geotechnical data could have forecast the sustainability of the TE-48 project and Raccoon Island as a whole.

The fourth lesson is that project goals and objectives need to be better defined and quantified as well. As is noted here, the goal; is based strictly on shoreline erosion with no measureable definition and no mention of the marsh creation area goals. This is a continuing CWPPRA issue and this project is an example of a whole component not assessed due to a lack of specific measurable goals.

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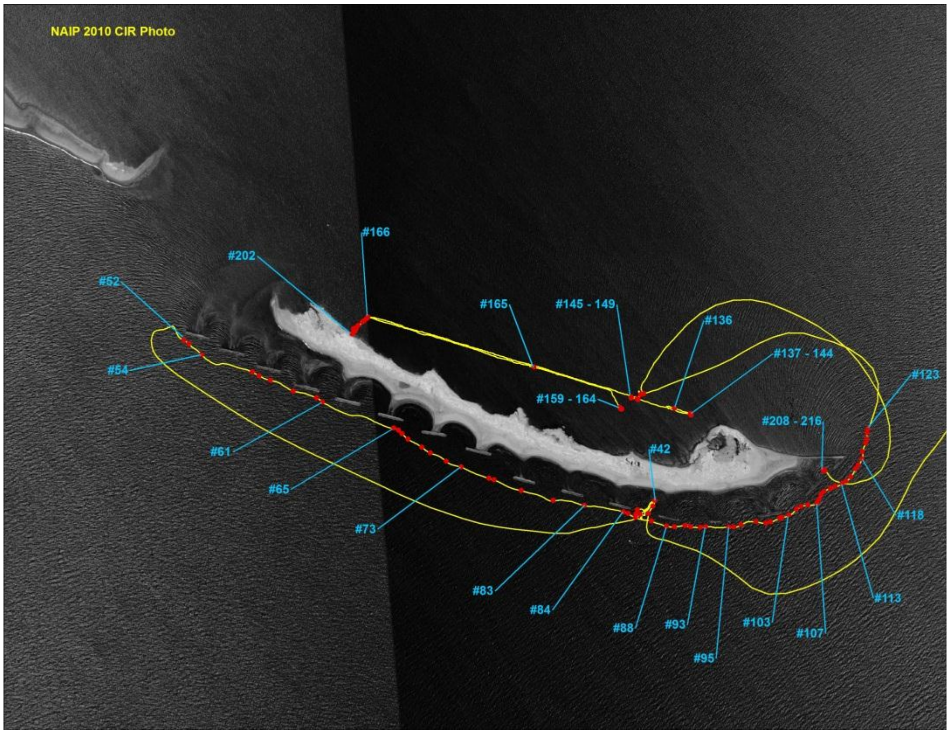
Appendix A
(Inspection Photographs)



Map: Location of CPRA photos from the June 04, 2013 inspection.

Photo 1: Gulf Shoreline near TE-29 breakwater #4 looking east (Raccoon_038). Note low elevation of TE-29 breakwater 4 and 3 in background.

Photo 3: Behind TE-29 breakwater #5 looking west (Raccoon_042). Note higher crest elevation of breakwaters, and wave diffraction from breakwaters and salients.

Photo 4: Gulfward of TE-29 breakwater #5 looking west (Raccoon_046). Note high elevation of TE-29 breakwaters and existing settlement plates. TE-48 breakwaters in far distance closer to shoreline.

Photo 5: West end of TE-48 breakwater #15 looking west (Raccoon_052). Note high crest elevation of breakwaters, and intact settlement plates.

Photo 6: Gulfside of TE-48 breakwater field looking east (Raccoon_053). Note high elevation of breakwaters and existing settlement plates.

Photo 7: TE-48 breakwater #14 looking north (Raccoon_052). Note breach in background with obvious shallow shoal.

Photo 8: Western end of TE-48 breakwater #12 looking east (Raccoon_056). Note salient formation behind breakwater and wave diffraction. Also nearest settlement plate appears to be slightly in front of the breakwater.

Photo 9: Close-up of tombolo formation behind TE-48 breakwater #11 looking east (Raccoon_059). Note heavy shorebird use of the island and bird research efforts in the background.

Photo 10: TE-48 breakwater #9 looking north (Raccoon_068). Note salient formation behind breakwater and narrow existing vegetation behind which is the unvegetated TE-48 marsh platform containment dike.

Photo 11: TE-29 breakwater #4 looking northeast (Raccoon_088). Note low elevation, leaning settlement plates, and lack of wave diffraction behind the breakwater.

Photo 12: TE-29 breakwater #3 looking north (Raccoon_068). Note low elevation, leaning settlement plates, and lack of wave diffraction behind the breakwater. Also, note higher elevation of breakwater #1 and #2 in background.

Photo 13: TE-29 breakwater #3 looking north (Raccoon_095). Note low elevation, lack of wave diffraction behind the breakwater, and no evidence of salient formation.

Photo 14: TE-29 breakwaters #2 – 0 and TE-48 eastern terminal groin looking north (Raccoon_098). Note high elevation, significant salient formation.

Photo 15: TE-29 breakwater #0 and TE-48 eastern terminal groin looking west (Raccoon_120). Note high elevation and significant sand accumulation along groin.

Photo 16: TE-48 marsh creation back dike looking east (Raccoon_131). Note geotextile coverage of the back dike in an attempt to postpone degradation until sediments consolidate and vegetative plantings spread. Also, note geotubes in background as the first attempt to protect the back dike.

Photo 17: TE-49 marsh creation back dike eastern tie in looking southeast (Raccoon_141). Note slight low spot in fill area due to pipe wash out.

Photo 18: TE-48 marsh creation area back dike looking east (Raccoon_143). Note geo-tubes in as the first attempt to protect the back dike.

Photo 19: TE-49 marsh creation area looking south (Raccoon_148). Note persons walking on fill beyond locations plantings contractor could access on previous attempts indicating good settlement and compaction.

Photo 20: TE-48 marsh creation area back dike looking west (Raccoon_150). Note geotextile cover on dike and first plantings along inside, indicting where contractor could access.

Photo 21: TE-49 marsh creation area plantings looking west along back dike (Raccoon_158). Note dry cracked soils and stressed plants. Also, note low borrow ditch in background.

Photo 22: TE-48 marsh creation area settlement gage #14 (Raccoon_164). Note persons could access by walking and settlement indicated approx. 3.5 ft elevation.

Photo 23: TE-49 marsh creation area outfall area on western end of island looking west (Raccoon_166). Note shallow flat habitat outside the fill area created by fill and sediment dewatering.

Photo 24: Typical containment borrow channel for the TE-48 marsh creation area (Raccoon_179). Note differential settlement after filing creates lower elevations in pre-dug areas.

Photo 25: TE-49 marsh creation area outfall area on western end of island looking west (Raccoon_166). Note shallow flat habitat outside the fill area created by fill and sediment dewatering.

Photo 26: TE-48 marsh creation area western end containment tie-in (Raccoon_178). Note spill box still in place currently provides water exchange while sediment consolidates.

Appendix B
(Shoreline Change Graphics)

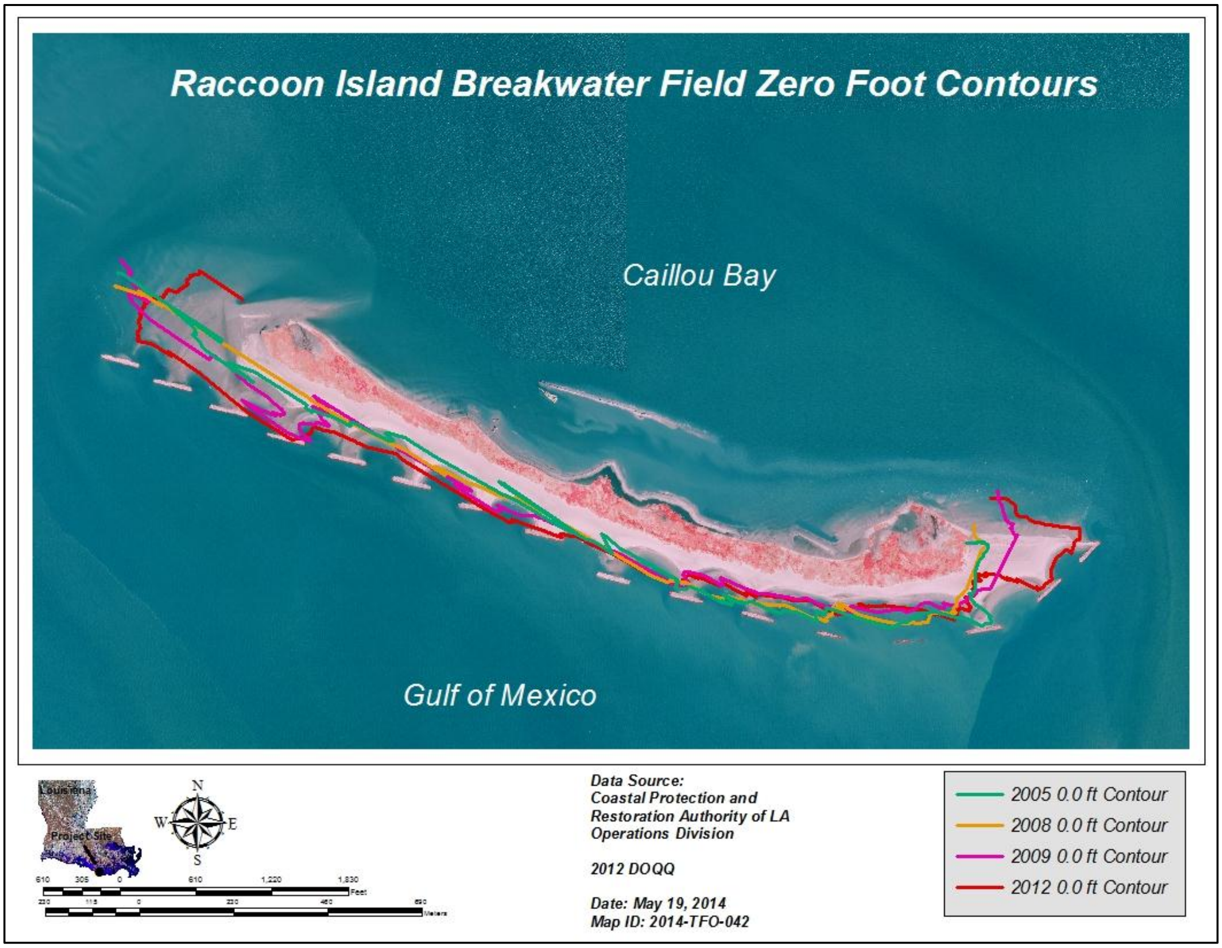


Figure B-1. **The zero foot contour lines used to delineate the shoreline position of the breakwater field in Dec 2005, Feb 2008, Nov 2009, and Nov 2012 at the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project.**

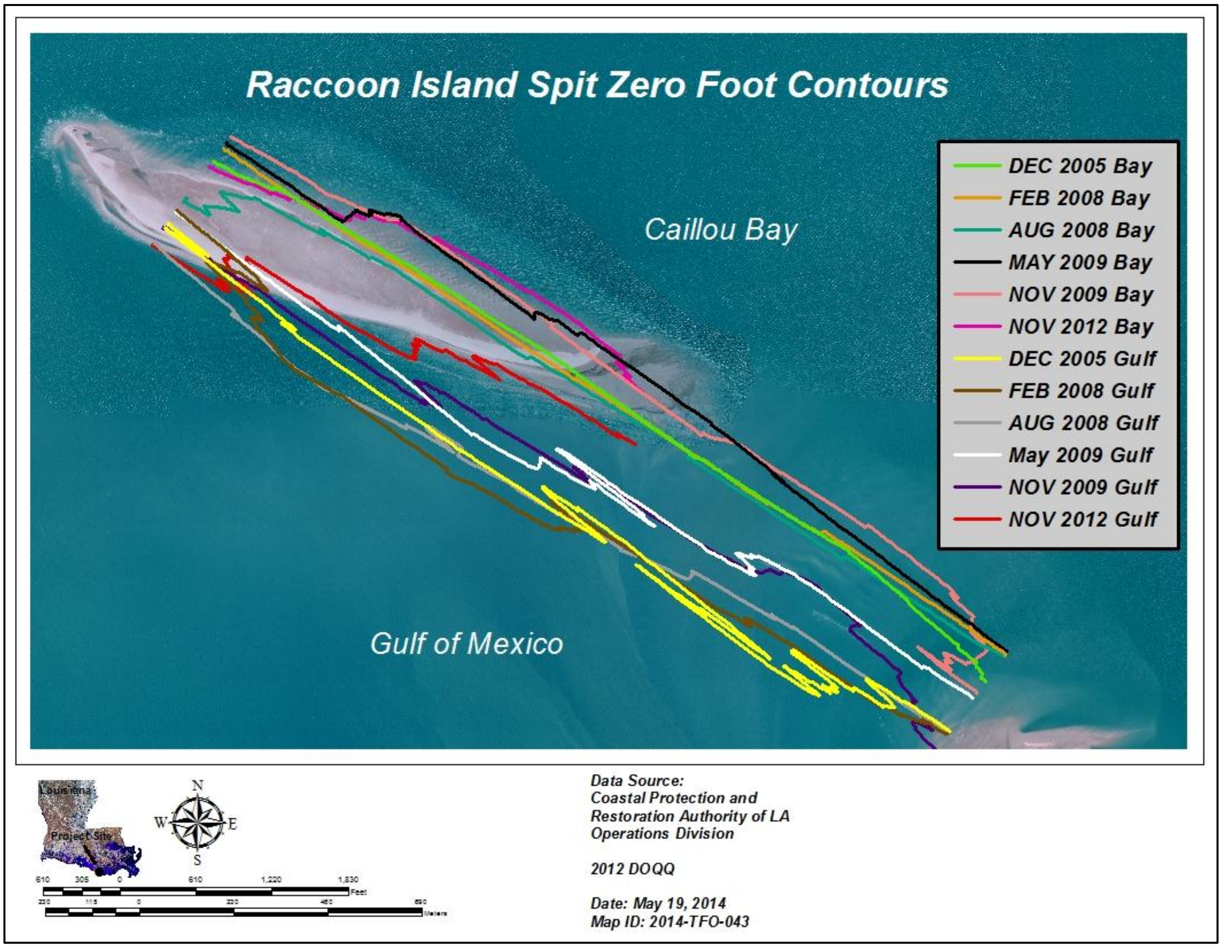


Figure B-2. **The zero foot contour lines used to delineate the shoreline position of the spit field in Dec 2005, Feb 2008, Aug 2008, May 2009, Nov 2009, and Nov 2012 at the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project.**

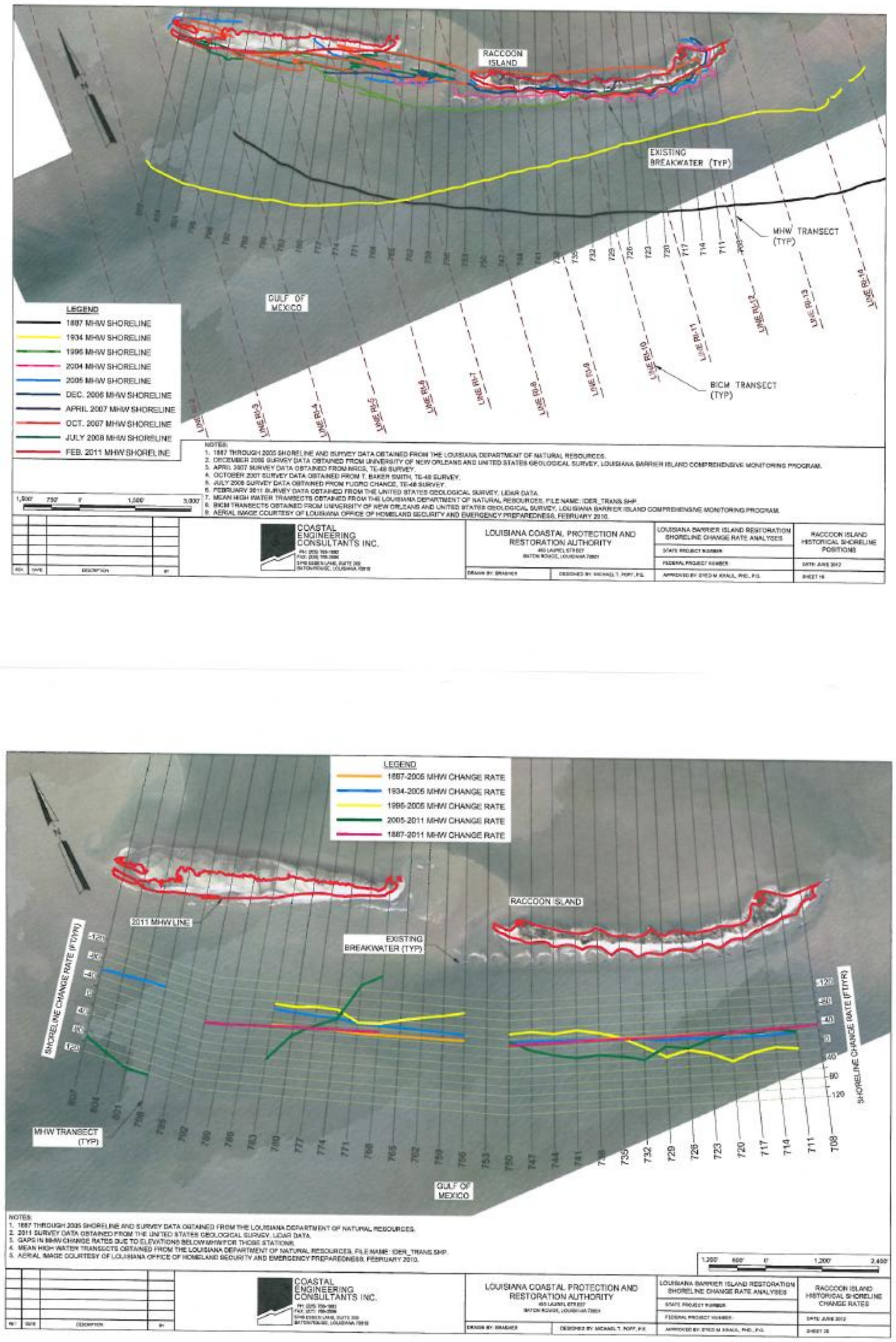
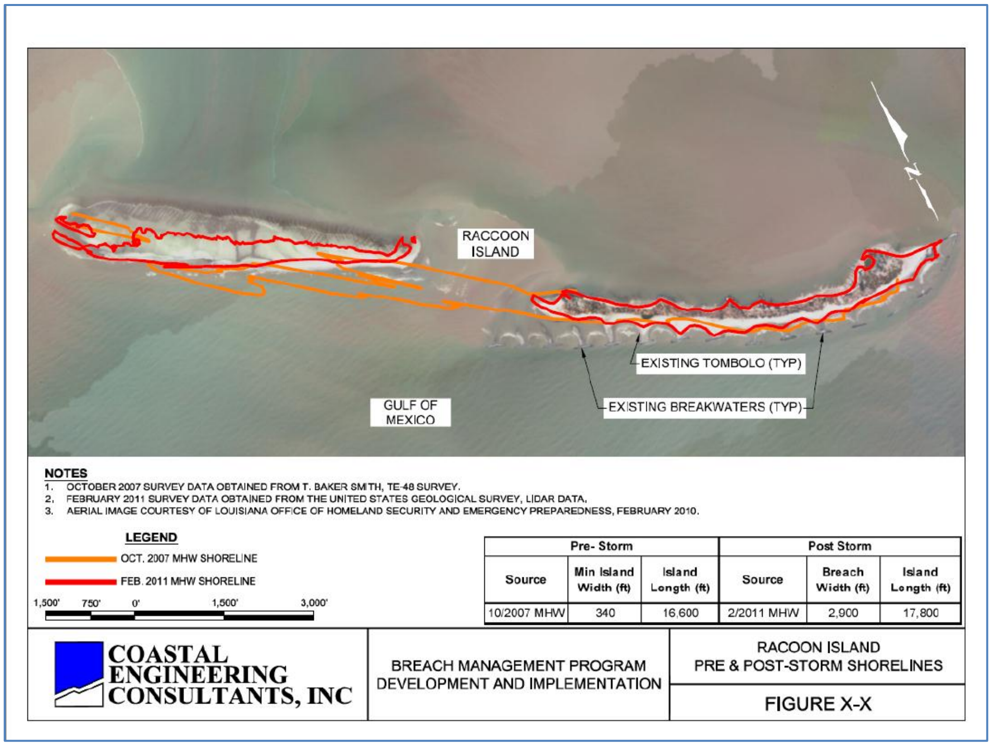


Figure B-3. Historical shoreline positions and change rates on Raccoon Island.



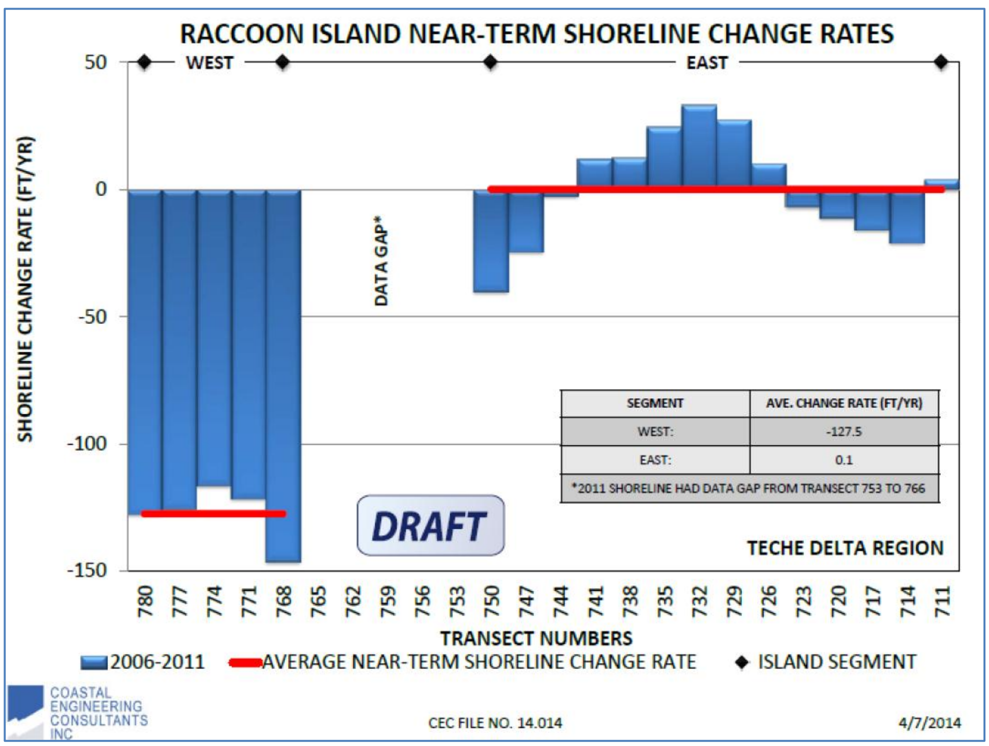


Figure B-4. **The Raccoon Island Breach Management Program and near term shoreline change rates.**

Appendix C
(Spit Elevation Change Graphics)

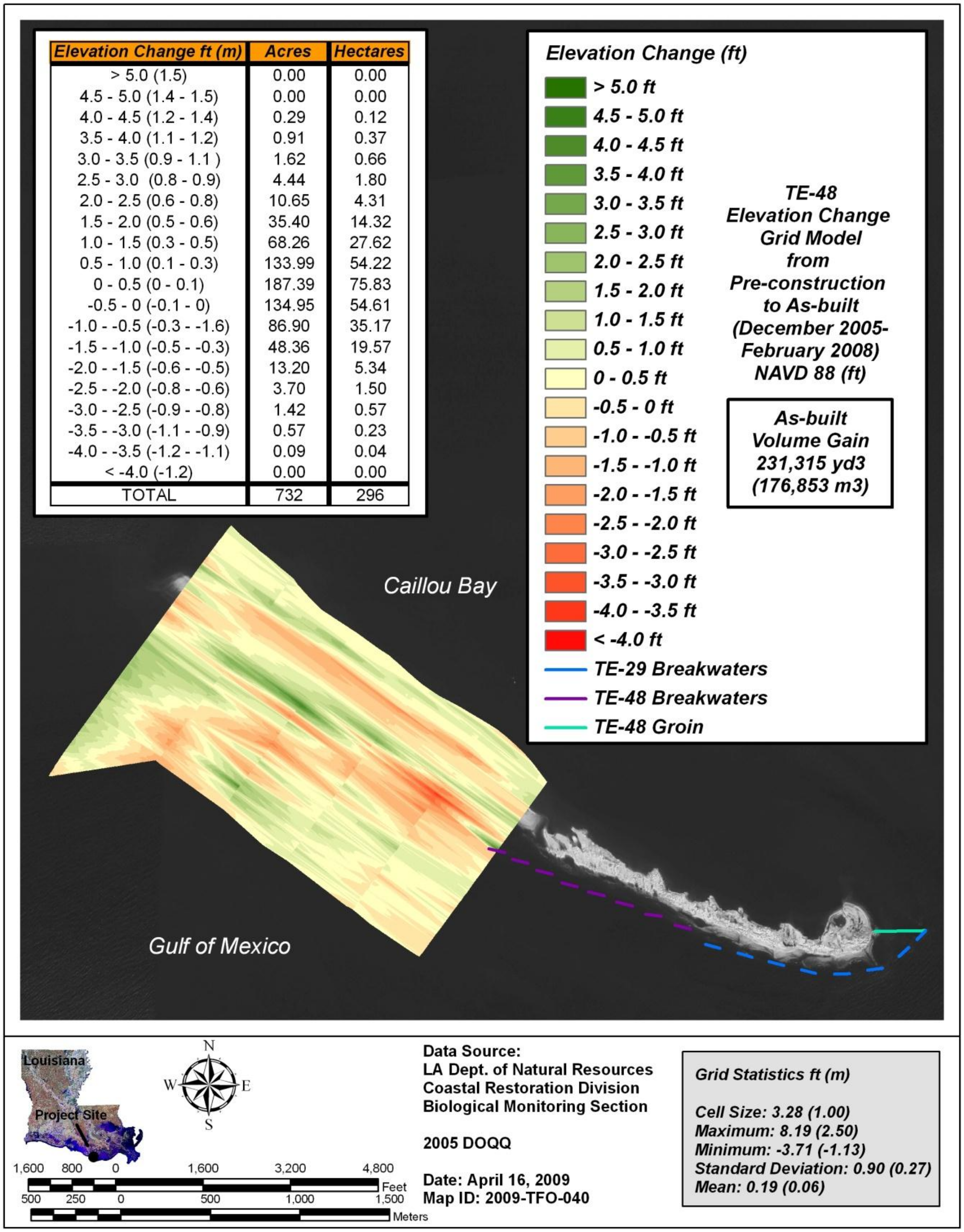


Figure C-1. **Elevation and volume change grid model for the spit from pre-construction (Dec 2005) to as-built (Feb 2008) at the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project.**

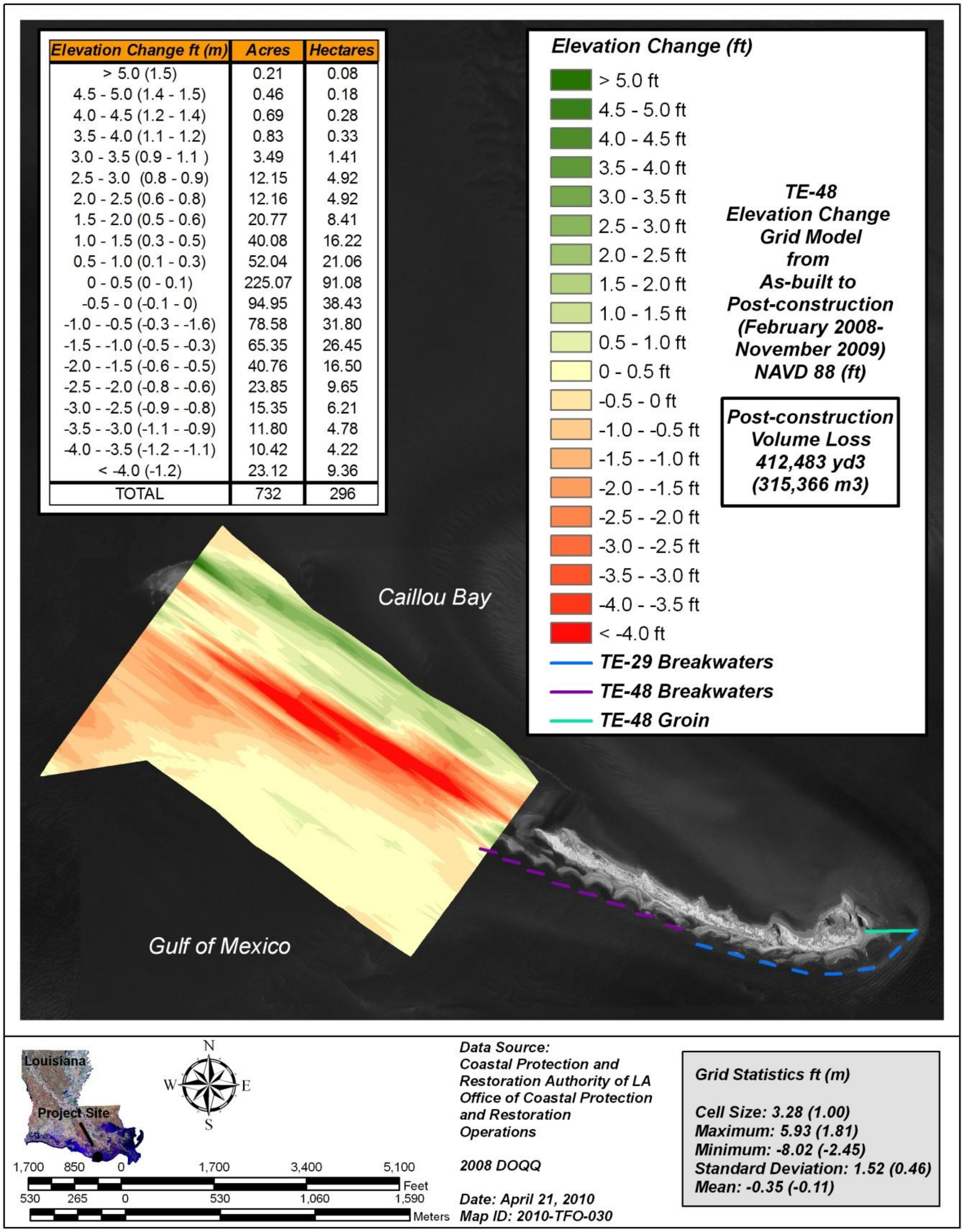
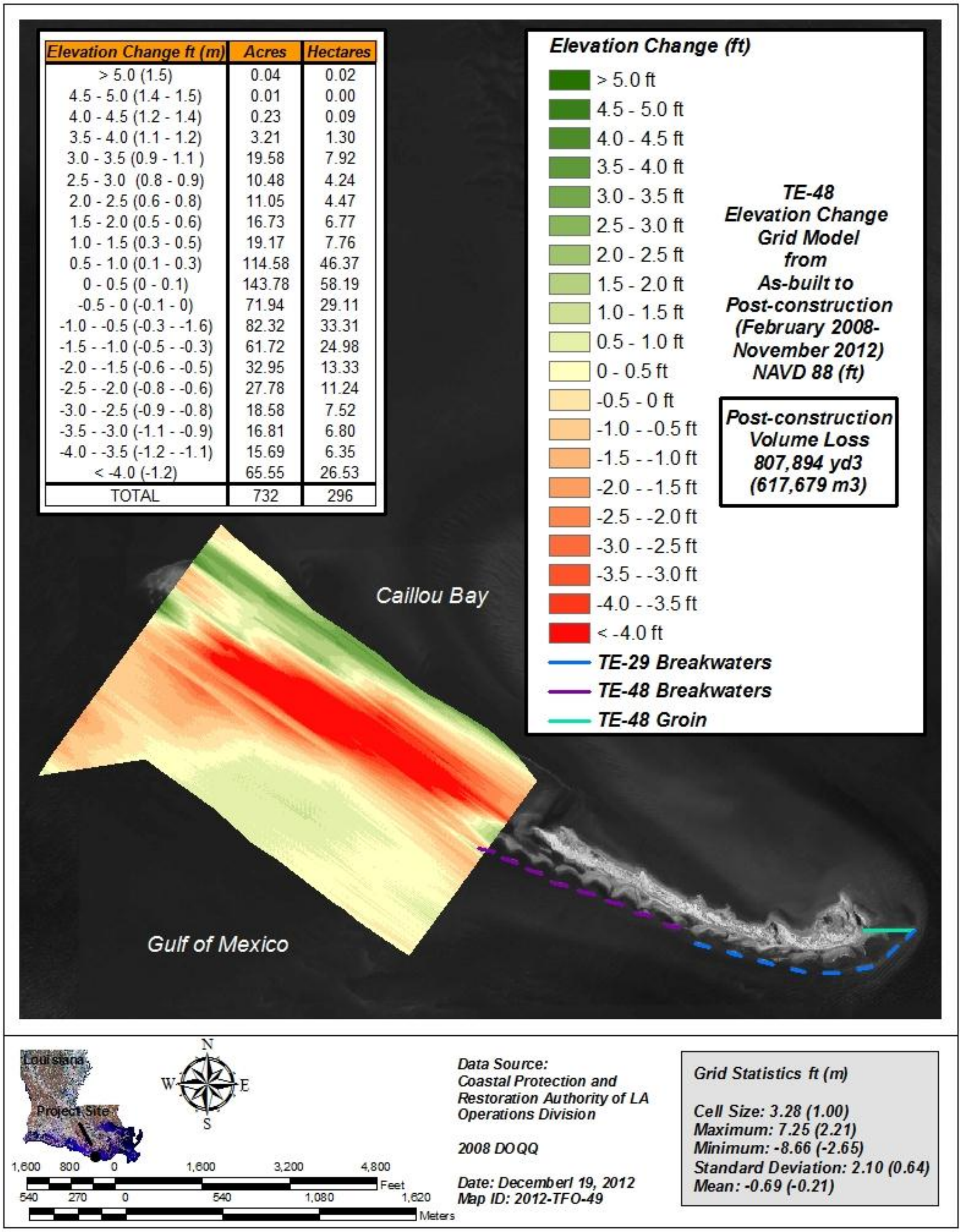


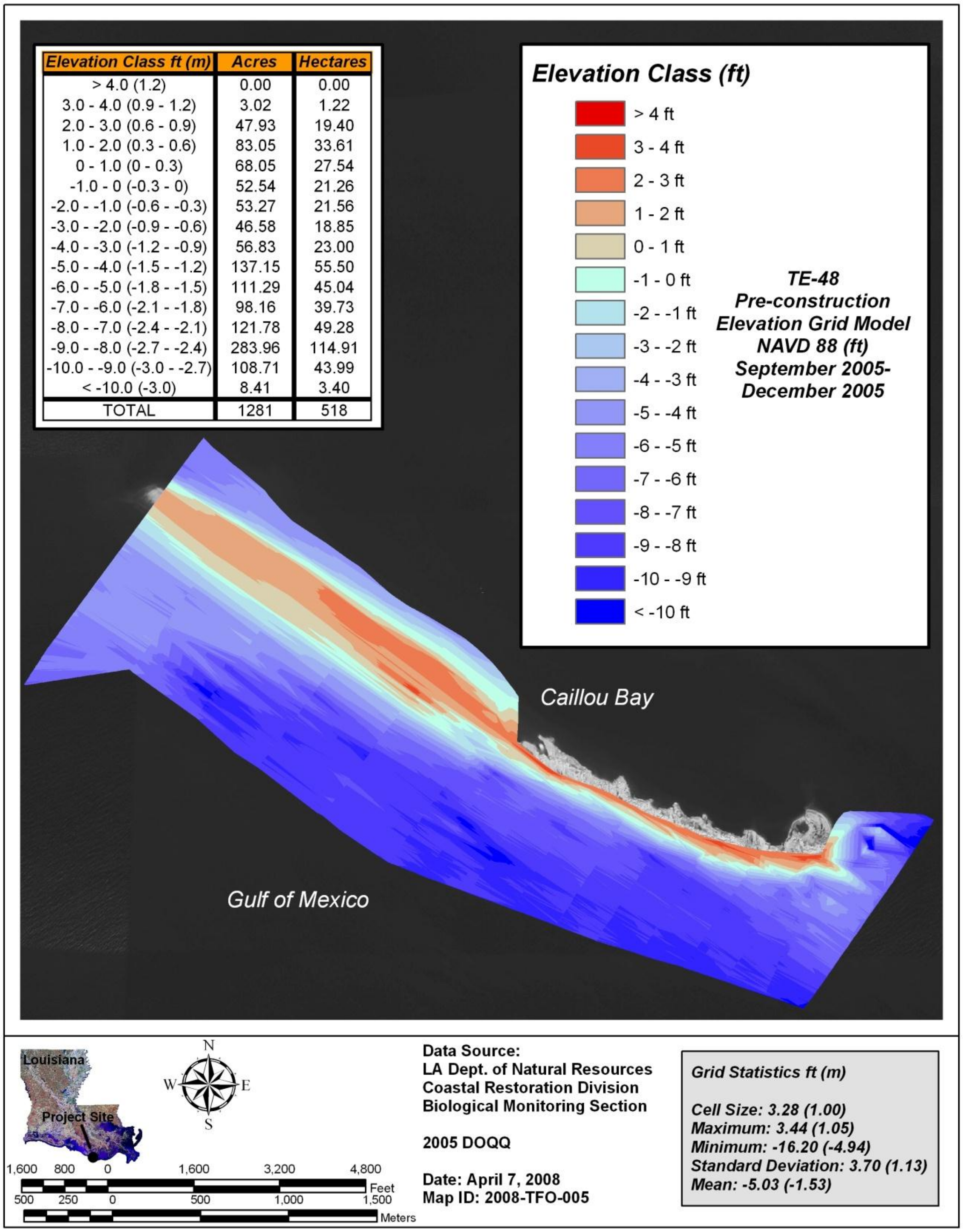
Figure C-2. **Elevation and volume change grid model for the spit from as-built (Feb 2008) to post-construction (Nov 2009) at the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project.**



Elevation Change ft (m)	Acres	Hectares
> 5.0 (1.5)	0.04	0.02
4.5 - 5.0 (1.4 - 1.5)	0.01	0.00
4.0 - 4.5 (1.2 - 1.4)	0.23	0.09
3.5 - 4.0 (1.1 - 1.2)	3.21	1.30
3.0 - 3.5 (0.9 - 1.1)	19.58	7.92
2.5 - 3.0 (0.8 - 0.9)	10.48	4.24
2.0 - 2.5 (0.6 - 0.8)	11.05	4.47
1.5 - 2.0 (0.5 - 0.6)	16.73	6.77
1.0 - 1.5 (0.3 - 0.5)	19.17	7.76
0.5 - 1.0 (0.1 - 0.3)	114.58	46.37
0 - 0.5 (0 - 0.1)	143.78	58.19
-0.5 - 0 (-0.1 - 0)	71.94	29.11
-1.0 - -0.5 (-0.3 - -1.6)	82.32	33.31
-1.5 - -1.0 (-0.5 - -0.3)	61.72	24.98
-2.0 - -1.5 (-0.6 - -0.5)	32.95	13.33
-2.5 - -2.0 (-0.8 - -0.6)	27.78	11.24
-3.0 - -2.5 (-0.9 - -0.8)	18.58	7.52
-3.5 - -3.0 (-1.1 - -0.9)	16.81	6.80
-4.0 - -3.5 (-1.2 - -1.1)	15.69	6.35
< -4.0 (-1.2)	65.55	26.53
TOTAL	732	296

Figure C-3. **Elevation and volume change grid model for the spit from as-built (Feb 2008) to post-construction (Nov 2012) at the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project.**

Appendix D
(TE-48 Elevation Grid Models)



Elevation Class ft (m)	Acres	Hectares
> 4.0 (1.2)	0.00	0.00
3.0 - 4.0 (0.9 - 1.2)	3.02	1.22
2.0 - 3.0 (0.6 - 0.9)	47.93	19.40
1.0 - 2.0 (0.3 - 0.6)	83.05	33.61
0 - 1.0 (0 - 0.3)	68.05	27.54
-1.0 - 0 (-0.3 - 0)	52.54	21.26
-2.0 - -1.0 (-0.6 - -0.3)	53.27	21.56
-3.0 - -2.0 (-0.9 - -0.6)	46.58	18.85
-4.0 - -3.0 (-1.2 - -0.9)	56.83	23.00
-5.0 - -4.0 (-1.5 - -1.2)	137.15	55.50
-6.0 - -5.0 (-1.8 - -1.5)	111.29	45.04
-7.0 - -6.0 (-2.1 - -1.8)	98.16	39.73
-8.0 - -7.0 (-2.4 - -2.1)	121.78	49.28
-9.0 - -8.0 (-2.7 - -2.4)	283.96	114.91
-10.0 - -9.0 (-3.0 - -2.7)	108.71	43.99
< -10.0 (-3.0)	8.41	3.40
TOTAL	1281	518

Figure D-1. **Pre-construction (Dec 2005) elevation grid model of the breakwater field and spit at the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project.**

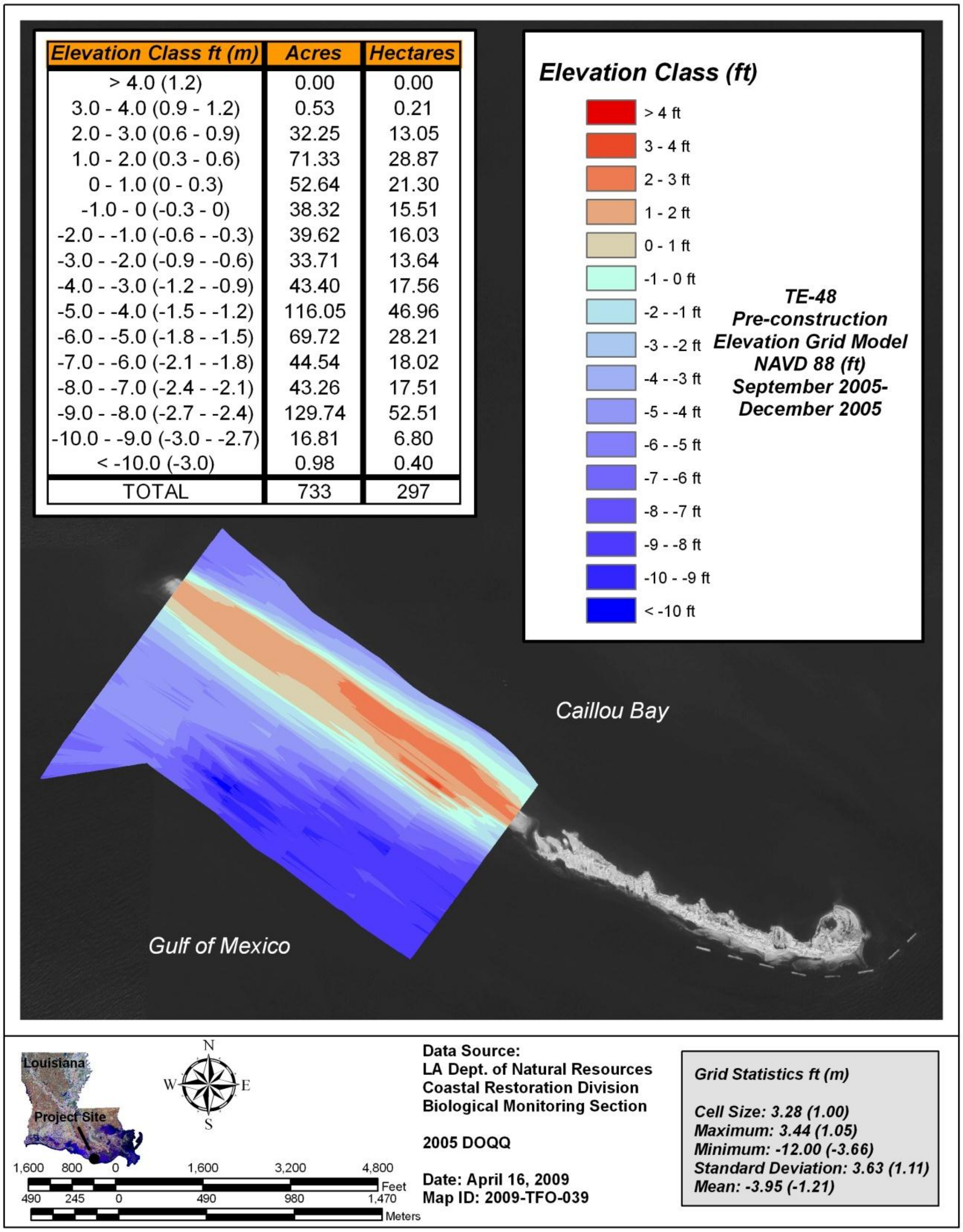
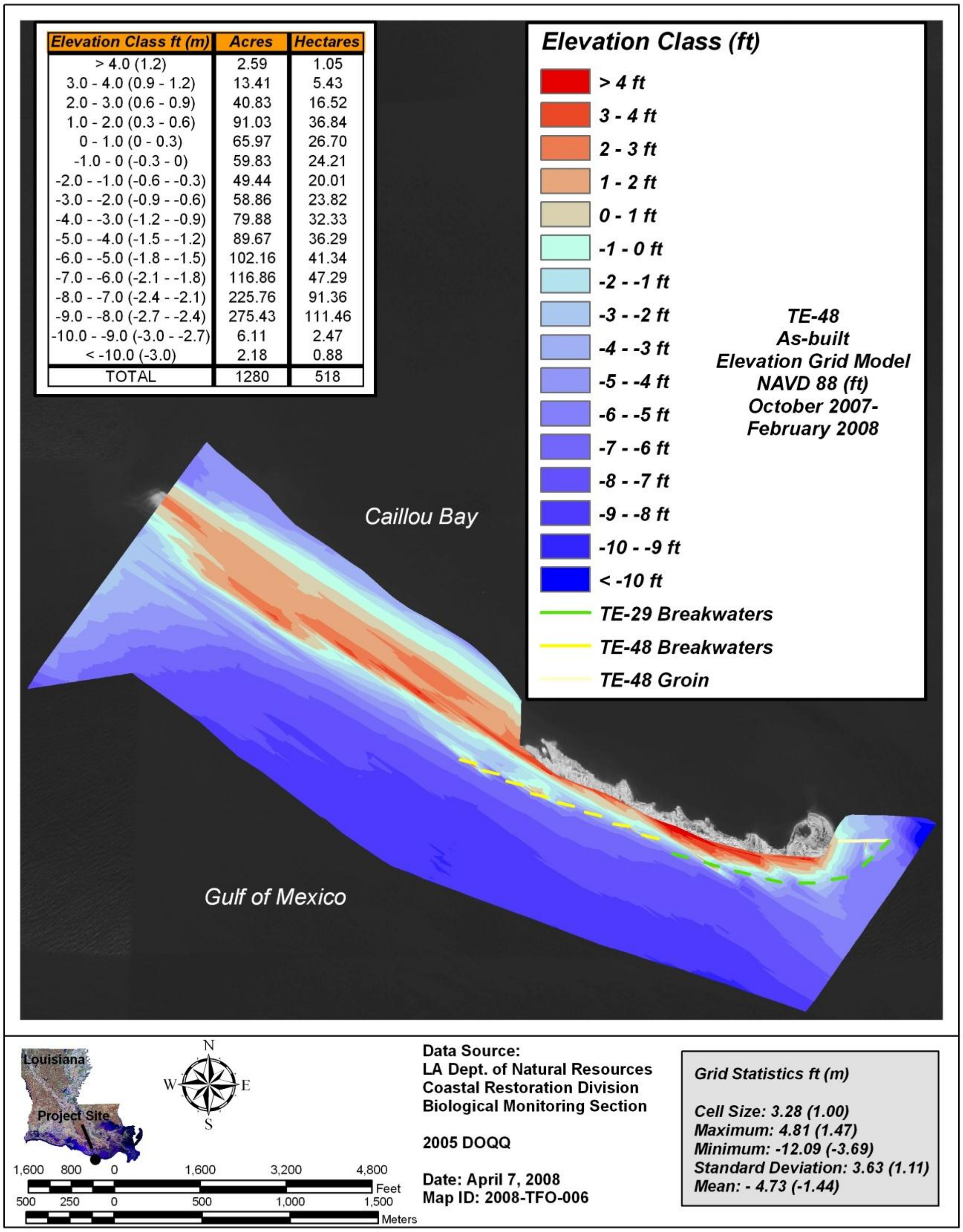
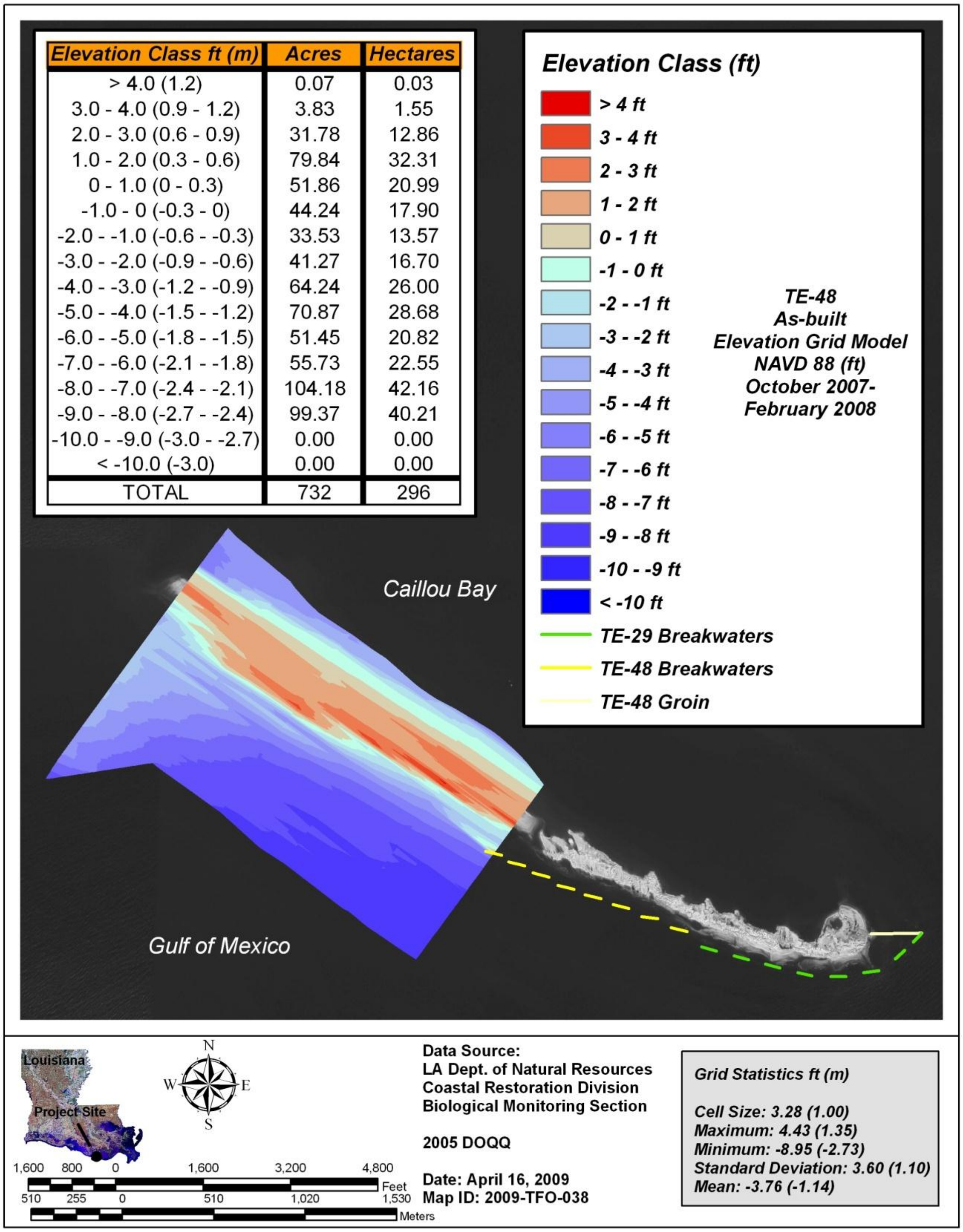


Figure D-2. Pre-construction (Dec 2005) elevation grid model of the spit at the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project.



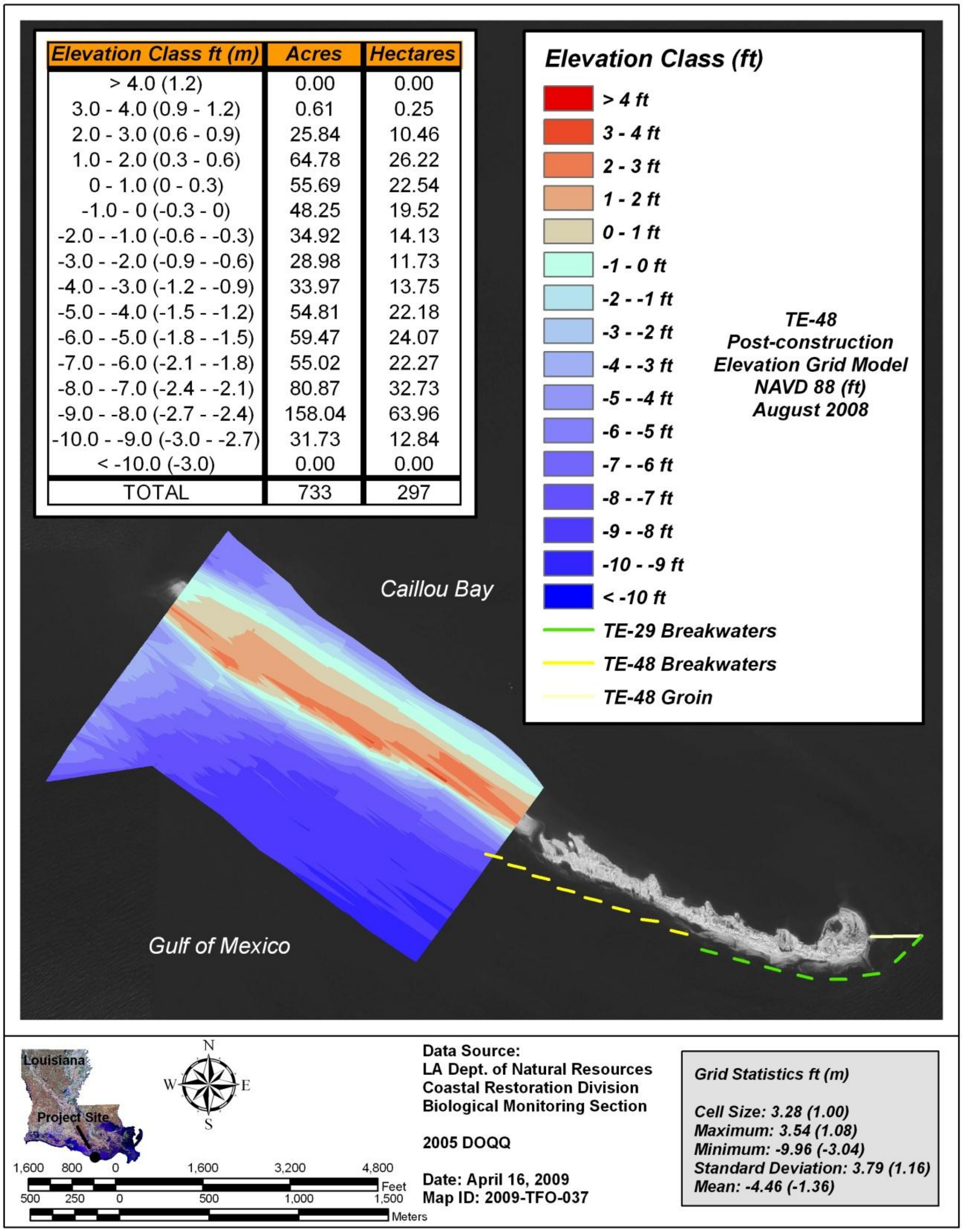
Elevation Class ft (m)	Acres	Hectares
> 4.0 (1.2)	2.59	1.05
3.0 - 4.0 (0.9 - 1.2)	13.41	5.43
2.0 - 3.0 (0.6 - 0.9)	40.83	16.52
1.0 - 2.0 (0.3 - 0.6)	91.03	36.84
0 - 1.0 (0 - 0.3)	65.97	26.70
-1.0 - 0 (-0.3 - 0)	59.83	24.21
-2.0 - -1.0 (-0.6 - -0.3)	49.44	20.01
-3.0 - -2.0 (-0.9 - -0.6)	58.86	23.82
-4.0 - -3.0 (-1.2 - -0.9)	79.88	32.33
-5.0 - -4.0 (-1.5 - -1.2)	89.67	36.29
-6.0 - -5.0 (-1.8 - -1.5)	102.16	41.34
-7.0 - -6.0 (-2.1 - -1.8)	116.86	47.29
-8.0 - -7.0 (-2.4 - -2.1)	225.76	91.36
-9.0 - -8.0 (-2.7 - -2.4)	275.43	111.46
-10.0 - -9.0 (-3.0 - -2.7)	6.11	2.47
< -10.0 (-3.0)	2.18	0.88
TOTAL	1280	518

Figure D-3. **As-built (Feb 2008) elevation grid model of the breakwater field and spit at the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project.**



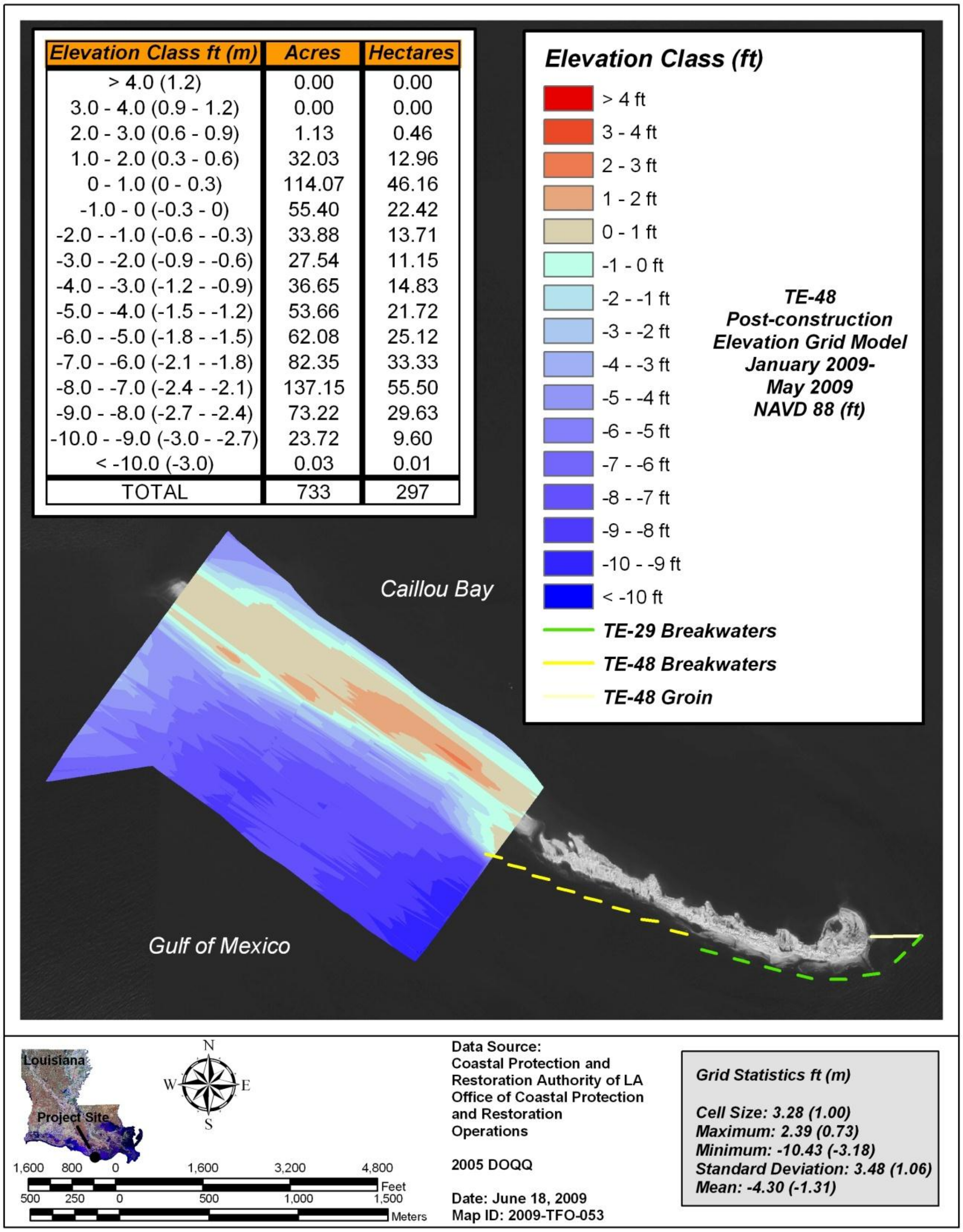
Elevation Class ft (m)	Acres	Hectares
> 4.0 (1.2)	0.07	0.03
3.0 - 4.0 (0.9 - 1.2)	3.83	1.55
2.0 - 3.0 (0.6 - 0.9)	31.78	12.86
1.0 - 2.0 (0.3 - 0.6)	79.84	32.31
0 - 1.0 (0 - 0.3)	51.86	20.99
-1.0 - 0 (-0.3 - 0)	44.24	17.90
-2.0 - -1.0 (-0.6 - -0.3)	33.53	13.57
-3.0 - -2.0 (-0.9 - -0.6)	41.27	16.70
-4.0 - -3.0 (-1.2 - -0.9)	64.24	26.00
-5.0 - -4.0 (-1.5 - -1.2)	70.87	28.68
-6.0 - -5.0 (-1.8 - -1.5)	51.45	20.82
-7.0 - -6.0 (-2.1 - -1.8)	55.73	22.55
-8.0 - -7.0 (-2.4 - -2.1)	104.18	42.16
-9.0 - -8.0 (-2.7 - -2.4)	99.37	40.21
-10.0 - -9.0 (-3.0 - -2.7)	0.00	0.00
< -10.0 (-3.0)	0.00	0.00
TOTAL	732	296

Figure D-4. As-built (Feb 2008) elevation grid model of the spit at the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project.



Elevation Class ft (m)	Acres	Hectares
> 4.0 (1.2)	0.00	0.00
3.0 - 4.0 (0.9 - 1.2)	0.61	0.25
2.0 - 3.0 (0.6 - 0.9)	25.84	10.46
1.0 - 2.0 (0.3 - 0.6)	64.78	26.22
0 - 1.0 (0 - 0.3)	55.69	22.54
-1.0 - 0 (-0.3 - 0)	48.25	19.52
-2.0 - -1.0 (-0.6 - -0.3)	34.92	14.13
-3.0 - -2.0 (-0.9 - -0.6)	28.98	11.73
-4.0 - -3.0 (-1.2 - -0.9)	33.97	13.75
-5.0 - -4.0 (-1.5 - -1.2)	54.81	22.18
-6.0 - -5.0 (-1.8 - -1.5)	59.47	24.07
-7.0 - -6.0 (-2.1 - -1.8)	55.02	22.27
-8.0 - -7.0 (-2.4 - -2.1)	80.87	32.73
-9.0 - -8.0 (-2.7 - -2.4)	158.04	63.96
-10.0 - -9.0 (-3.0 - -2.7)	31.73	12.84
< -10.0 (-3.0)	0.00	0.00
TOTAL	733	297

Figure D-5. Post-construction (Aug 2008) elevation grid model of the spit at the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project.



Elevation Class ft (m)	Acres	Hectares
> 4.0 (1.2)	0.00	0.00
3.0 - 4.0 (0.9 - 1.2)	0.00	0.00
2.0 - 3.0 (0.6 - 0.9)	1.13	0.46
1.0 - 2.0 (0.3 - 0.6)	32.03	12.96
0 - 1.0 (0 - 0.3)	114.07	46.16
-1.0 - 0 (-0.3 - 0)	55.40	22.42
-2.0 - -1.0 (-0.6 - -0.3)	33.88	13.71
-3.0 - -2.0 (-0.9 - -0.6)	27.54	11.15
-4.0 - -3.0 (-1.2 - -0.9)	36.65	14.83
-5.0 - -4.0 (-1.5 - -1.2)	53.66	21.72
-6.0 - -5.0 (-1.8 - -1.5)	62.08	25.12
-7.0 - -6.0 (-2.1 - -1.8)	82.35	33.33
-8.0 - -7.0 (-2.4 - -2.1)	137.15	55.50
-9.0 - -8.0 (-2.7 - -2.4)	73.22	29.63
-10.0 - -9.0 (-3.0 - -2.7)	23.72	9.60
< -10.0 (-3.0)	0.03	0.01
TOTAL	733	297

Figure D-6. Post-construction (May 2009) elevation grid model of the spit at the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project.

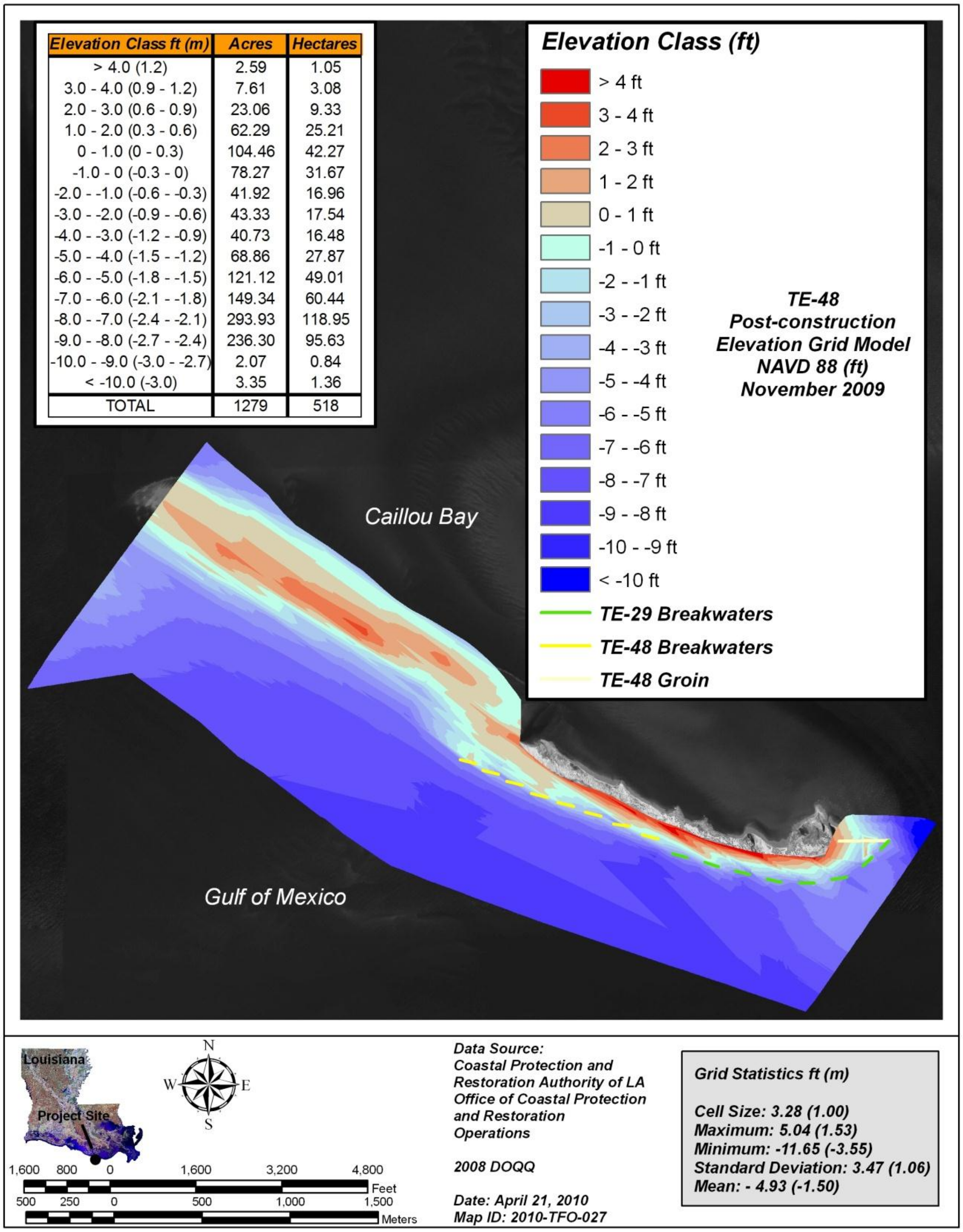


Figure D-7. Post-construction (Nov 2009) elevation grid model of the breakwater field and spit at the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project.

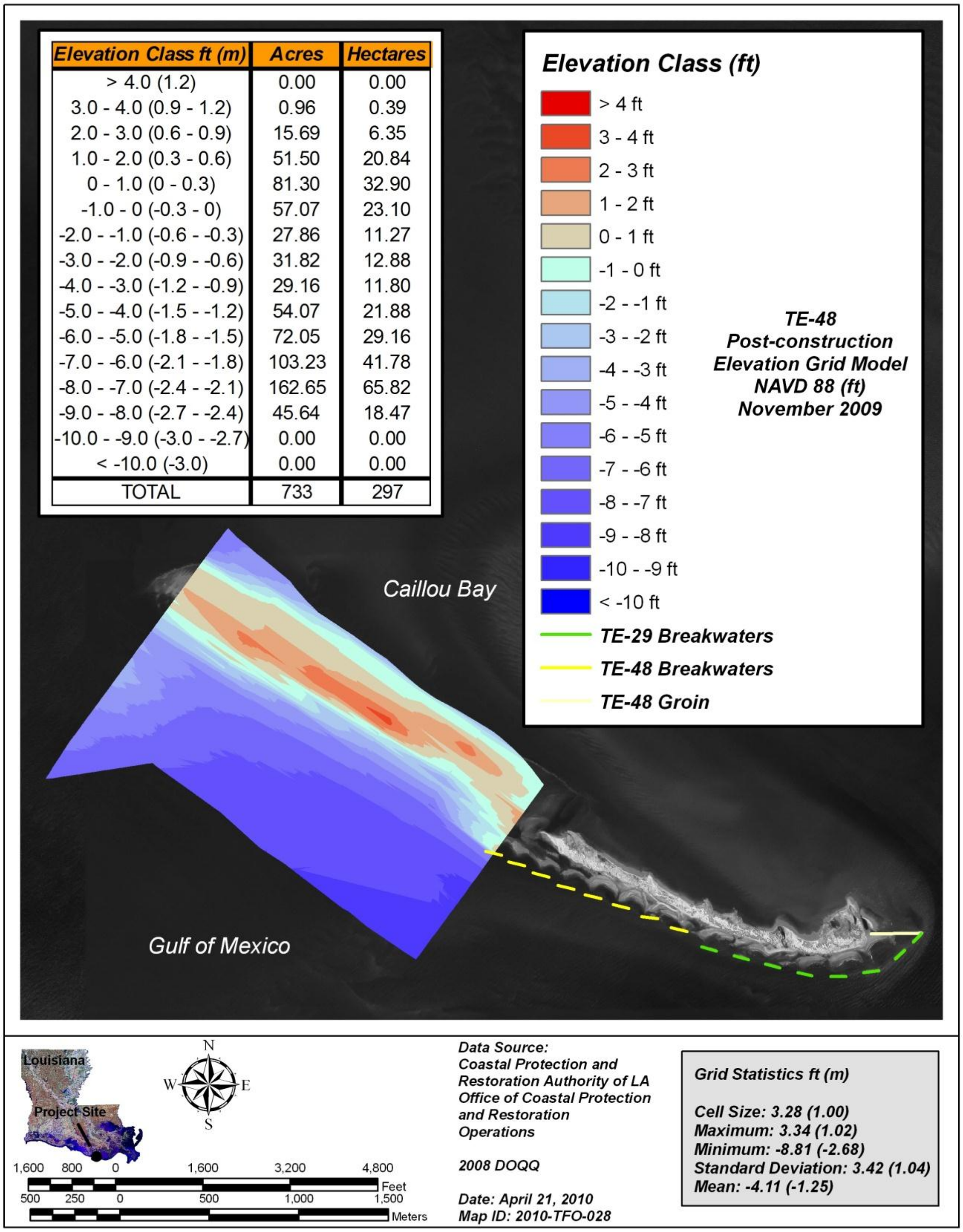
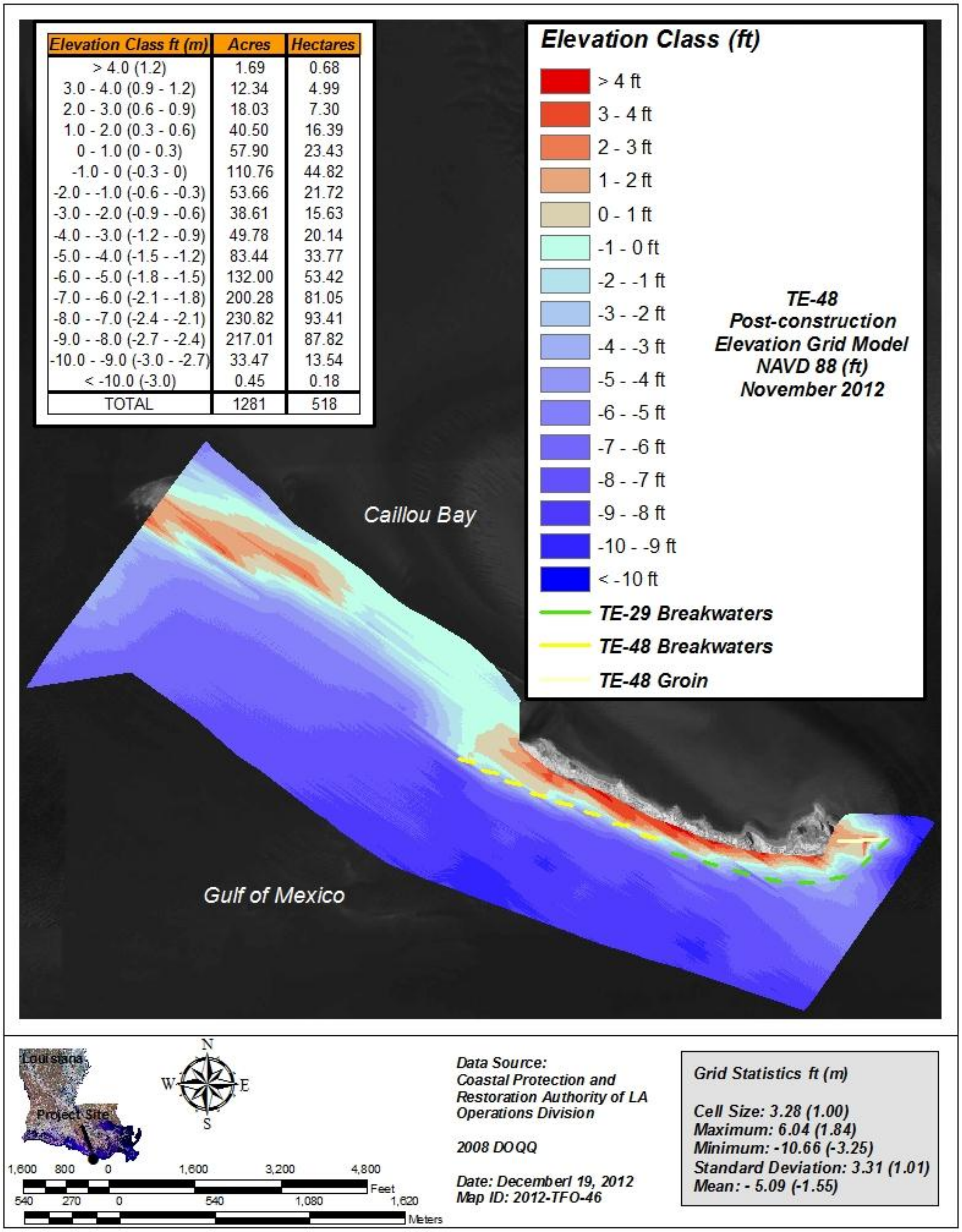
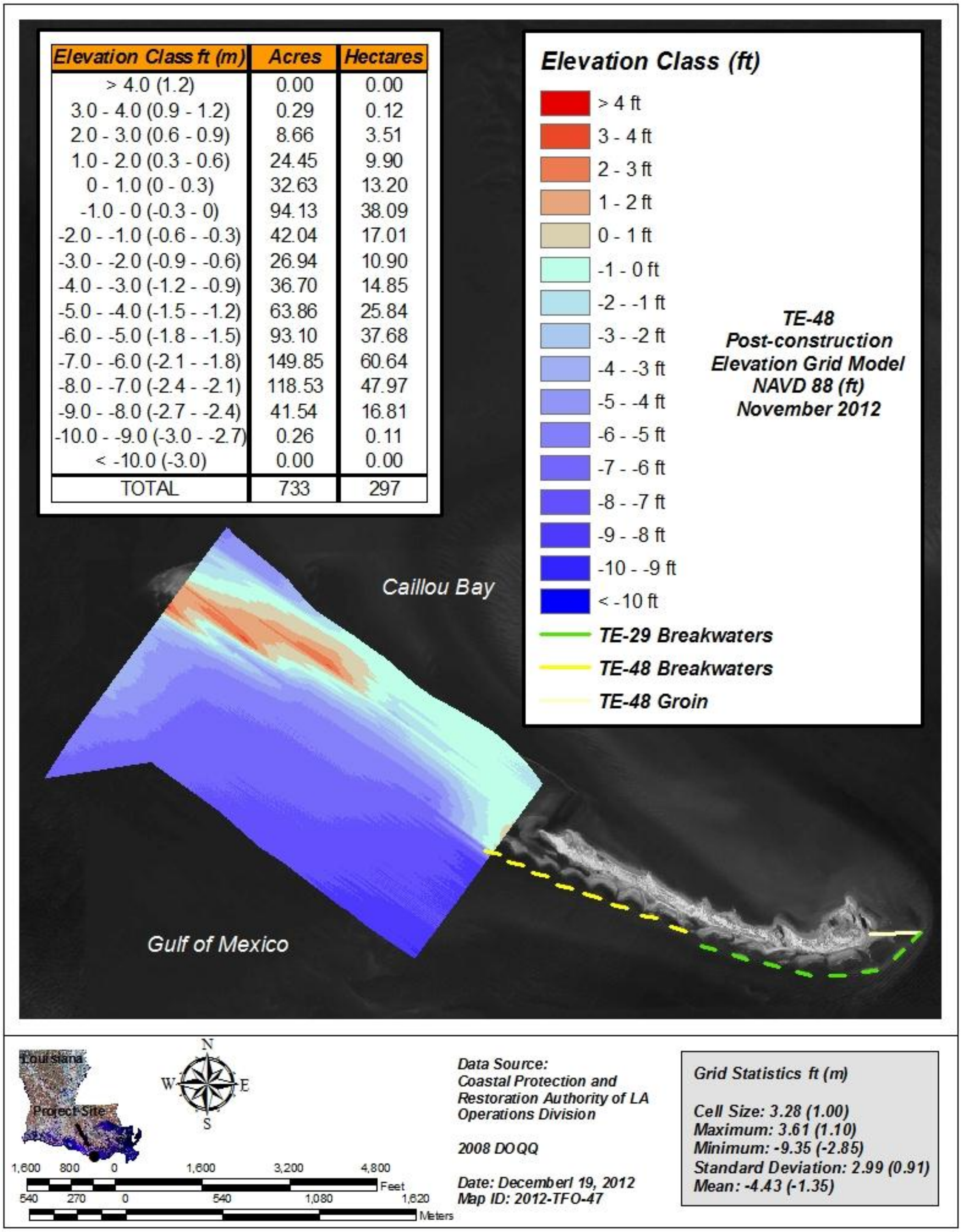


Figure D-8. Post-construction (Nov 2009) elevation grid model of the spit at the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project.



Elevation Class ft (m)	Acres	Hectares
> 4.0 (1.2)	1.69	0.68
3.0 - 4.0 (0.9 - 1.2)	12.34	4.99
2.0 - 3.0 (0.6 - 0.9)	18.03	7.30
1.0 - 2.0 (0.3 - 0.6)	40.50	16.39
0 - 1.0 (0 - 0.3)	57.90	23.43
-1.0 - 0 (-0.3 - 0)	110.76	44.82
-2.0 - -1.0 (-0.6 - -0.3)	53.66	21.72
-3.0 - -2.0 (-0.9 - -0.6)	38.61	15.63
-4.0 - -3.0 (-1.2 - -0.9)	49.78	20.14
-5.0 - -4.0 (-1.5 - -1.2)	83.44	33.77
-6.0 - -5.0 (-1.8 - -1.5)	132.00	53.42
-7.0 - -6.0 (-2.1 - -1.8)	200.28	81.05
-8.0 - -7.0 (-2.4 - -2.1)	230.82	93.41
-9.0 - -8.0 (-2.7 - -2.4)	217.01	87.82
-10.0 - -9.0 (-3.0 - -2.7)	33.47	13.54
< -10.0 (-3.0)	0.45	0.18
TOTAL	1281	518

Figure D-9. Post-construction (Nov 2012) elevation grid model of the breakwater field and spit at the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project.



Elevation Class ft (m)	Acres	Hectares
> 4.0 (1.2)	0.00	0.00
3.0 - 4.0 (0.9 - 1.2)	0.29	0.12
2.0 - 3.0 (0.6 - 0.9)	8.66	3.51
1.0 - 2.0 (0.3 - 0.6)	24.45	9.90
0 - 1.0 (0 - 0.3)	32.63	13.20
-1.0 - 0 (-0.3 - 0)	94.13	38.09
-2.0 - -1.0 (-0.6 - -0.3)	42.04	17.01
-3.0 - -2.0 (-0.9 - -0.6)	26.94	10.90
-4.0 - -3.0 (-1.2 - -0.9)	36.70	14.85
-5.0 - -4.0 (-1.5 - -1.2)	63.86	25.84
-6.0 - -5.0 (-1.8 - -1.5)	93.10	37.68
-7.0 - -6.0 (-2.1 - -1.8)	149.85	60.64
-8.0 - -7.0 (-2.4 - -2.1)	118.53	47.97
-9.0 - -8.0 (-2.7 - -2.4)	41.54	16.81
-10.0 - -9.0 (-3.0 - -2.7)	0.26	0.11
< -10.0 (-3.0)	0.00	0.00
TOTAL	733	297

Figure D-10. Post-construction (Nov 2012) elevation grid model of the spit at the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project.