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Coastal Protection and Restoration Authority of Louisiana

Office of Coastal Protection and Restoration

2010 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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Prepared by:
Glen P. Curole
and
Brian J. Babin

CPRA/Office of Coastal Protection and Restoration
Thibodaux Field Office
1440 Tiger Drive, Suite B
Thibodaux, LA 70301

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

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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 sea 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 Office of Coastal Protection and Restoration (OCPR) under the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA, Public Law 101-646, Title III). The shoreline protection phase will extend the breakwater field 4000 ft (1,219 m) along the Gulf of Mexico shoreline and add a 1000 ft (305 m) terminal groin to the eastern end of the Raccoon Island. The marsh creation phase of the TE-48 restoration project will elevate 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 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. The intertidal flat habitat sustains a very minimal 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 (*Pelecanus occidentalis*) 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

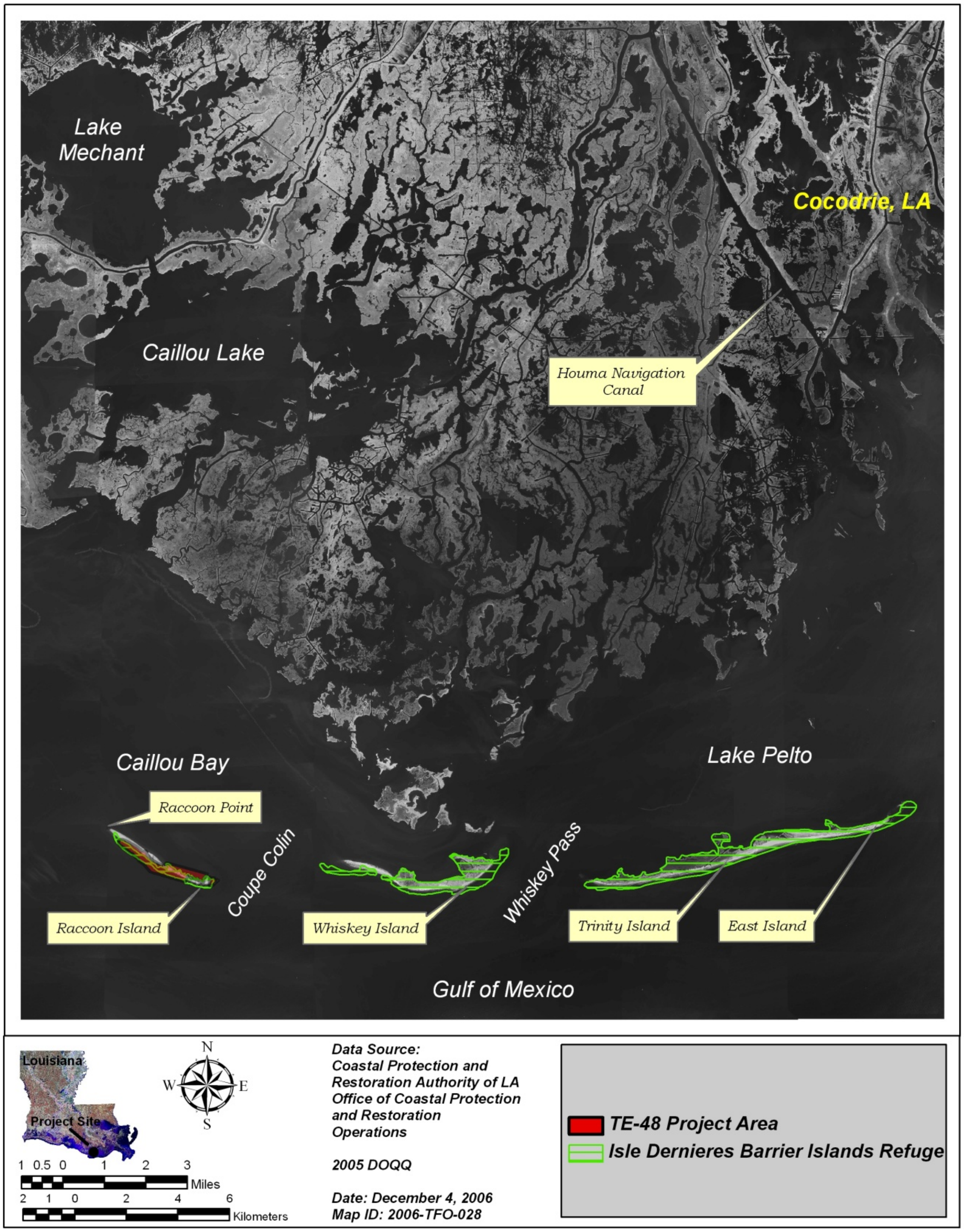


Figure 1. **Location and vicinity of the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project.**

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

dropseed) (USDA 2007). The beach habitat typically does not support extensive vegetative cover (Fearnley et al. 2009). However, *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) 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. 2009). Net longshore transport flows in a western direction on Raccoon Island transporting sediments to the spit (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 wave dominated tidal pass and the islands position at the terminal end of the Isle Dernieres barrier island arc (Levin 1993). As a result, the tidal passes act as sediment sinks and increase the rate of shoreline erosion. On Raccoon Island, a considerable volume of sediments have been transported to the Raccoon Point shoreface (figure 1) over the last 125 years (Miner et al. 2009). 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. (2009) 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).

In 1997, the Louisiana Office of Coastal Protection and Restoration (OCPR) 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) NAVD 88 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).

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) has been 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 4000 ft (1219 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, be 300 ft (91 m) in length, have gaps widths that vary from 160-300 ft (49-91m), and be built to a 4.5 ft (1.4 m) NAVD 88 crown elevation. Note the gap widths were designed to be narrowed in cumulative 20 ft (6.1 m) increments from east to west. The groin was designed to extend 952 ft (290 m) into the shoreface and have a 4.5 ft (1.4 m) NAVD 88 crown elevation (figure 3). Although the TE-48 breakwaters and groin were built, the exact specifications of these structures were not provided because the as-built drawings and project completion report have not been finalized. Also, the phase A construction timeline was not provided for the same reason. Project construction began in 2005 and was not completed until the latter part of 2007 because of substantial delays incurred following the passage of Hurricanes Katrina and Rita. Phase B, the back barrier marsh creation part of the TE-48 project (figure 3), has been designed and fully funded. However, a memorandum of agreement (MOA) between OCPR, NRCS, and the Bureau of Ocean Energy Management - Regulation and Enforcement (BOEMRE), formerly the Minerals Management Service (MMS), to utilize a benthic borrow site in federal waters has not been signed to date. When this document is authorized, the phase B part of the project should begin construction.

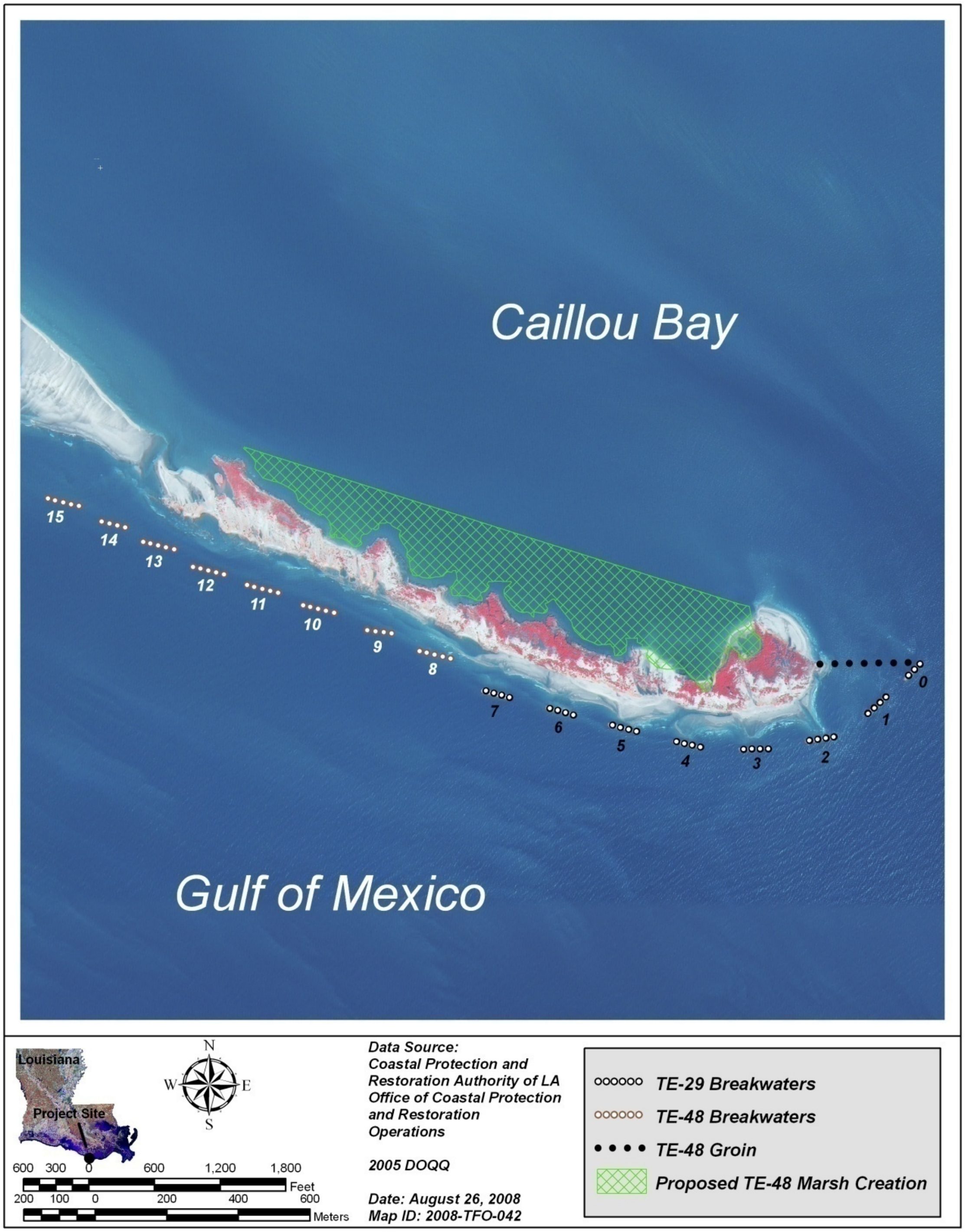


Figure 3. **Location of the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project features. The TE-48 breakwaters and groin constitute phase A of the project. Phase B of the TE-48 project consists of the proposed marsh creation area.**

II. Maintenance Activity

No maintenance activities have been performed for the TE-48 project since construction.

III. Operation Activity

No operation activities are required for the TE-48 project.

IV. Monitoring Activity

a. Monitoring Goal

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 goal listed above:

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, and November 2009. These surveys were essentially split into 2 surveys, a breakwater field survey and a spit survey (figure 4). 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 4). Only the spit portion of Raccoon Island was surveyed in August 2008 and May 2009. All survey data were established using or adjusted to tie in with the Louisiana Coastal Zone (LCZ) GPS Network.

The December 2005, February 2008, August 2008, May 2009, and November 2009 survey data were re-projected horizontally and vertically to the UTM NAD83 coordinate system and the NAVD 88 vertical datum in meters using Corpscon® software. The re-projected data were imported into ArcView® GIS software for surface interpolation. Triangulated irregular network models (TIN) were produced

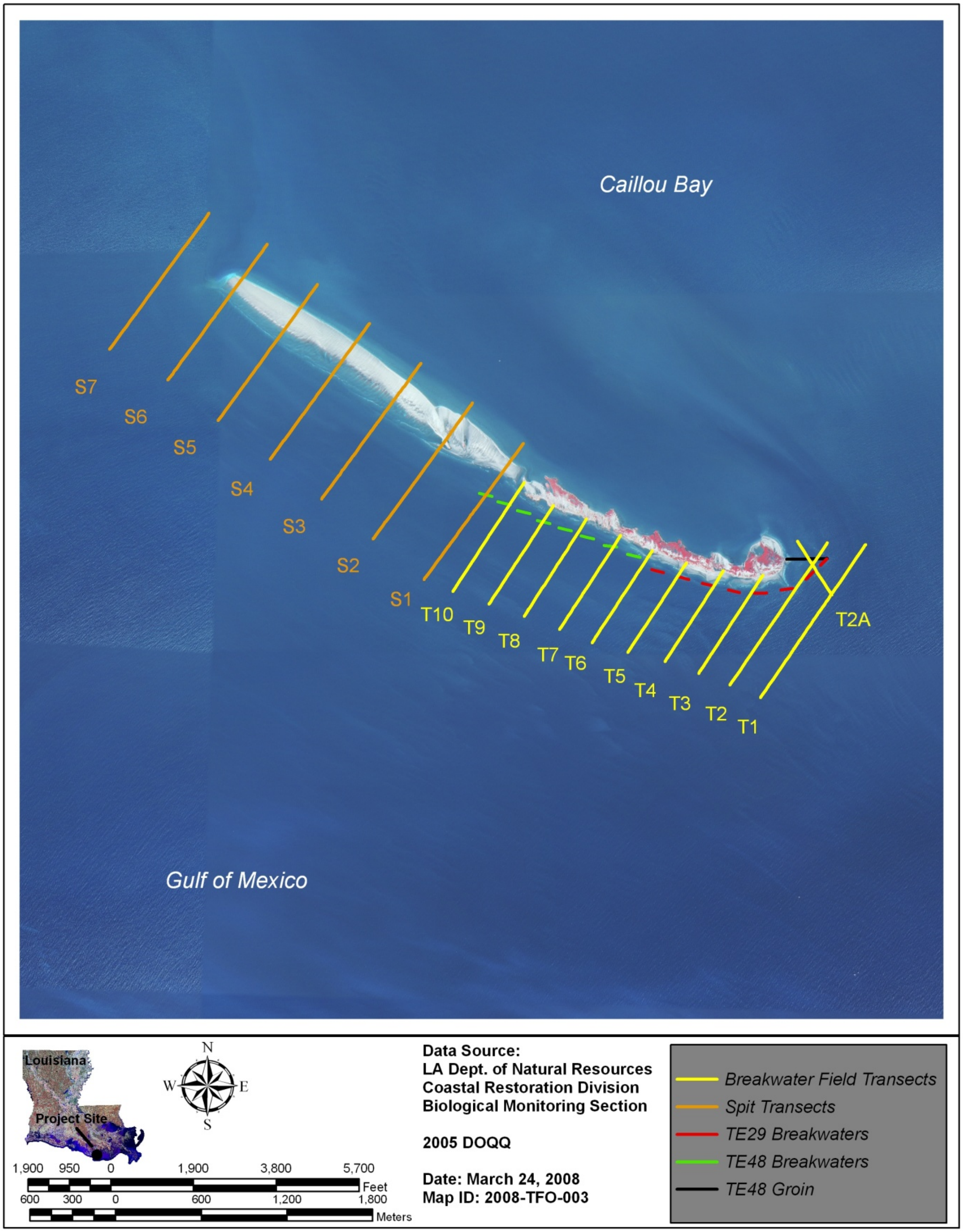


Figure 4. Location of the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project's topographic and bathymetric survey transects.

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, and February 2008-November 2009 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 the survey area.

In addition to the holistic analysis of elevation grid models, the TE-48 project area was also partitioned into six subdivisions to delineate the affect 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, and November 2009) 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. The subaerial spit is the portion of the Raccoon Island Spit that extends above the 0 ft (0 m) NAVD 88 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 there southern border 50 ft (15 m) south of the structures, and extend 150 ft (46 m) past their terminal structures. 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 spit shoreface segment extends to the 0 ft (0 m) NAVD 88 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. Once the elevation grid models were clipped to their subdivision borders, the mean elevations for each time period were calculated. The August 2008 and May 2009 analysis were only performed 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, and February 2008-November 2009 intervals using the aforementioned method.

Spit shoreline change, subaerial spit area, and subaerial spit width were also calculated by demarcating the 0 ft (0 m) NAVD 88 contour of the Raccoon Island Spit using the December 2005, February 2008, August 2008, May 2009, and November 2009 elevation grid models. Shoreline position data were analyzed to estimate shoreline changes along the Gulf of Mexico and Caillou Bay shorelines using the Digital

Shoreline Analysis System (DSAS version 2.1.1) extension of ArcView® GIS (Thieler et al. 2003). Shoreline positions were determined by digitizing previously established elevation grid models at a 1:800 scale. Once the shorelines were digitized a baseline was generated and simple transects were cast. Shoreline change rates were assessed for the ensuing periods December 2005-February 2008, February 2008-August 2008, August 2008-May 2009, and May 2009-November 2009. The subaerial spit area was calculated for each interval by drawing a polygon around the 0 ft (0 m) NAVD 88 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) NAVD 88 contour surrounding the spit] at a 1:800 scale. Once measured the widths were averaged for each time period.

Sediment Properties

Push core sediment samples were obtained along six (6) cross-shore transects for the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project in 2008 to characterize the median grain size 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). 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. However, no laboratory analysis has been performed on these sediment samples to date. In the future, the core samples will be analyzed to determine sediment grain size, sorting, percent sand and fines, organic matter content, and bulk density (Troutman et al. 2003).

b. **Preliminary Monitoring Results and Discussion**

Elevation

The Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project area experienced volume reductions and shoreline modifications since construction was completed in 2008. Elevation change and volume distributions for Raccoon Island (breakwater field and spit) are shown in figure 5 (Dec 2005-Feb 2008) and figure 6 (Feb 2008-Nov 2009). In addition, elevation change and volume distributions for the Raccoon Island Spit are shown in figure 7 (Dec 2005-Feb 2008), figure 8 (Feb2008-Aug 2008), figure 9 (Feb 2008-May 2009), and figure 10 (Feb 2008-Nov 2009). Elevation grid models for the Dec 2005, Feb 2008, Aug 2008, May 2009, and Nov 2009 surveys are also provided in appendix A. The TE-48 volume and mean elevation changes are also graphically illustrated in figure 11 (Raccoon Island) and figure 12 (spit only). Approximately, 621,707 yd^3 (475,329 m^3) of sediment were deposited on Raccoon Island (breakwater field and spit areas) during construction

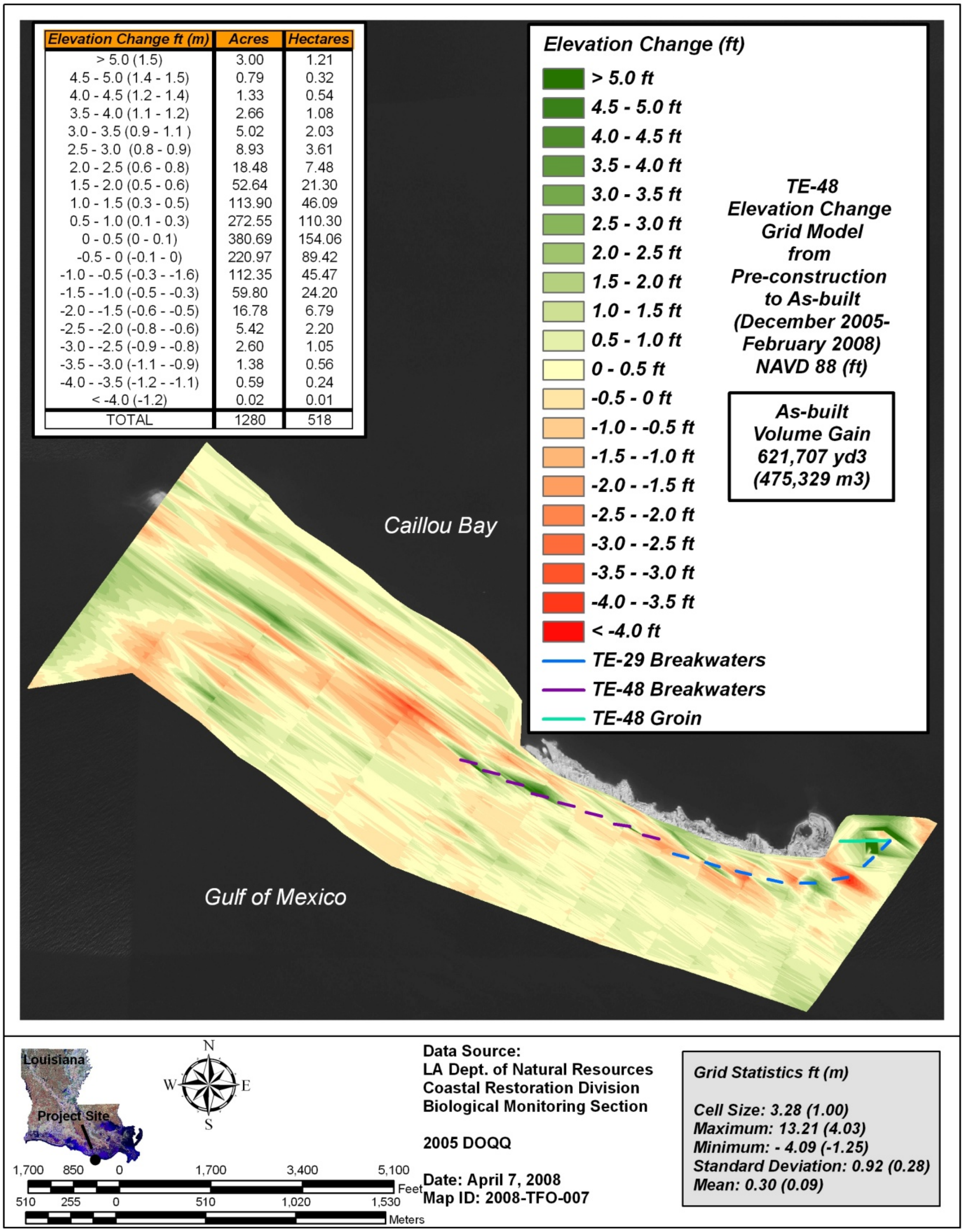


Figure 5. **Elevation and volume change grid model for the breakwater field and spit from pre-construction (Dec 2005) to as-built (Feb 2008) at the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project.**

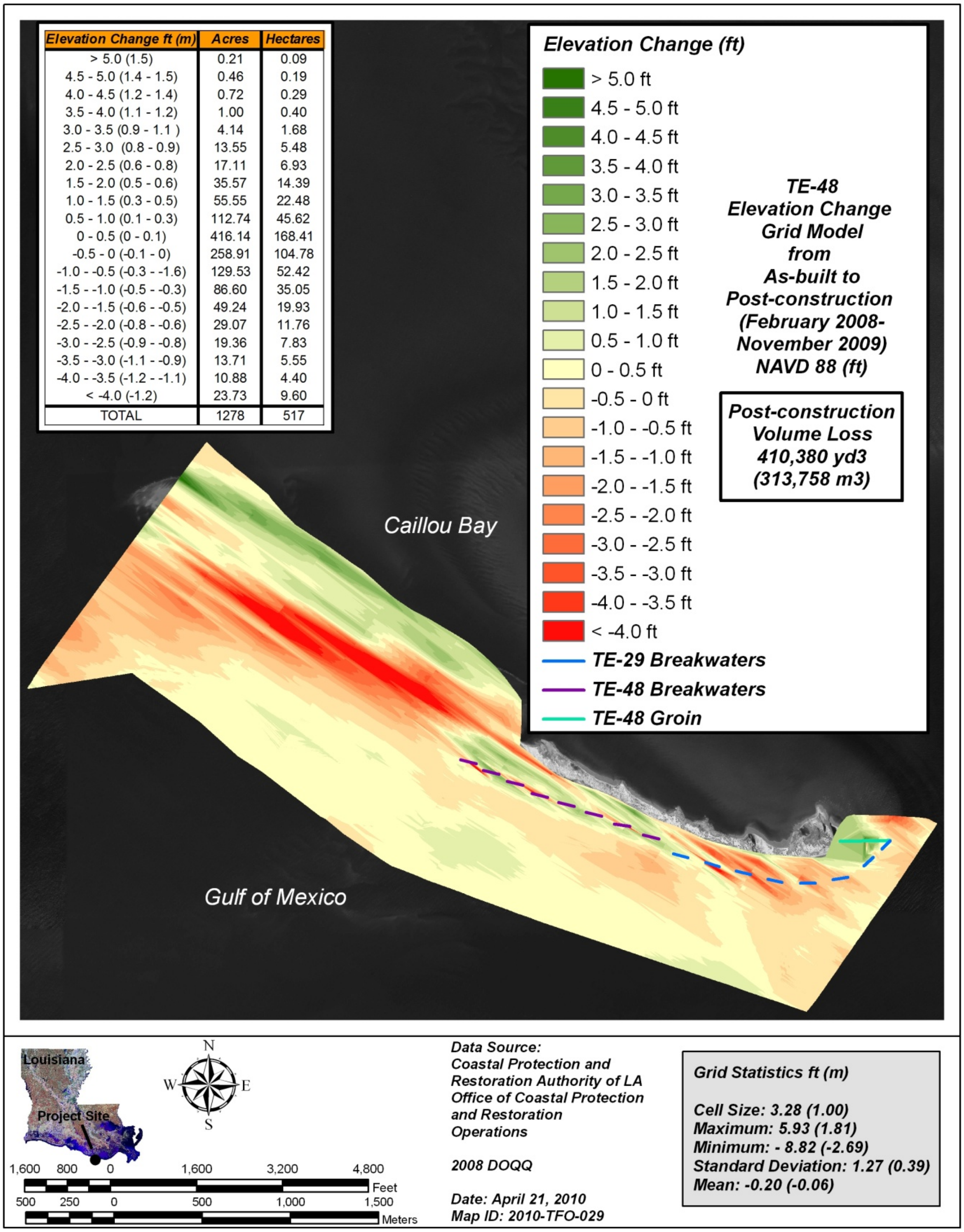
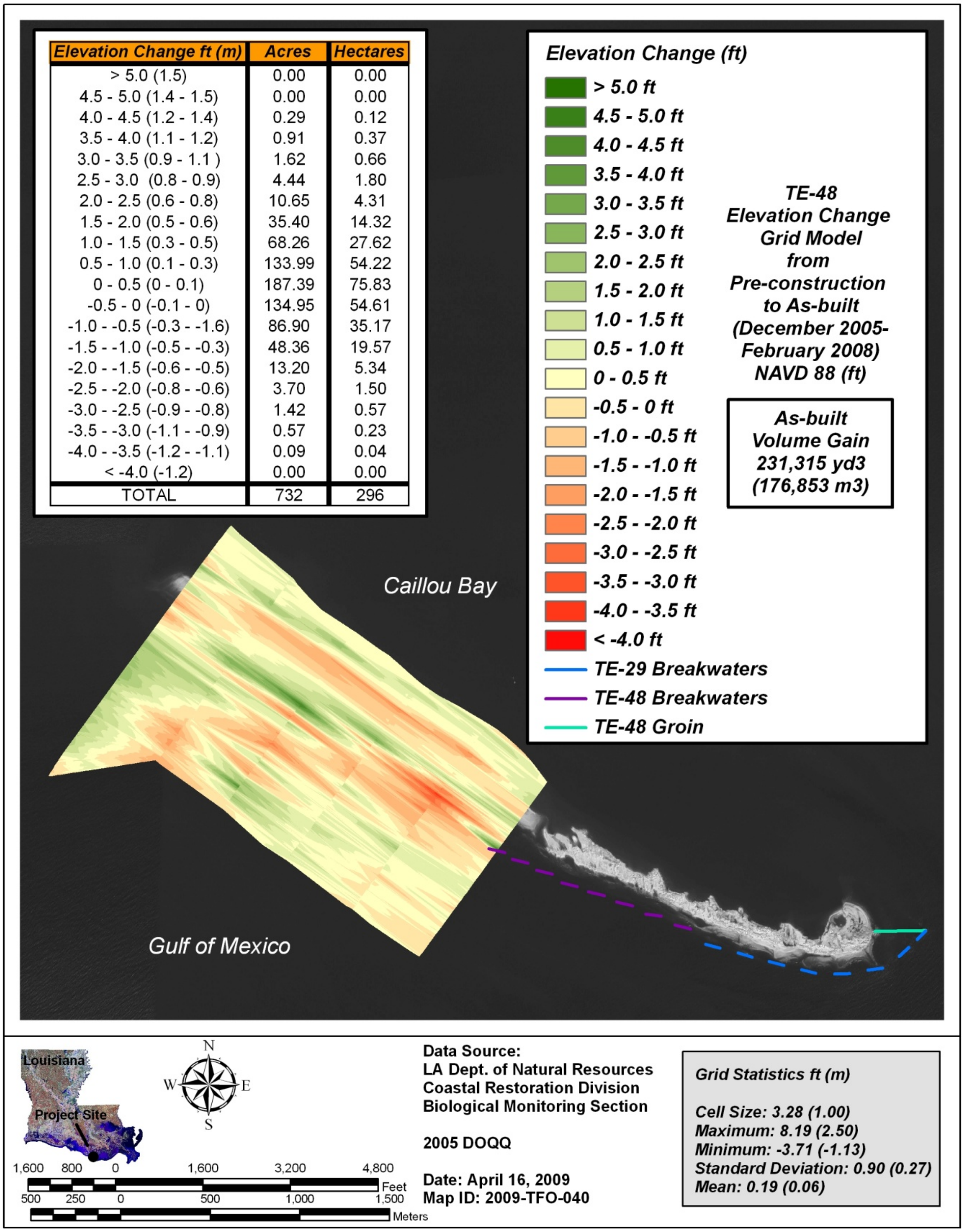


Figure 6. **Elevation and volume change grid model for the breakwater field and spit from as-built (Feb 2008) to post-construction (Nov 2009) at the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project.**



Elevation Change ft (m)	Acres	Hectares
> 5.0 (1.5)	0.00	0.00
4.5 - 5.0 (1.4 - 1.5)	0.00	0.00
4.0 - 4.5 (1.2 - 1.4)	0.29	0.12
3.5 - 4.0 (1.1 - 1.2)	0.91	0.37
3.0 - 3.5 (0.9 - 1.1)	1.62	0.66
2.5 - 3.0 (0.8 - 0.9)	4.44	1.80
2.0 - 2.5 (0.6 - 0.8)	10.65	4.31
1.5 - 2.0 (0.5 - 0.6)	35.40	14.32
1.0 - 1.5 (0.3 - 0.5)	68.26	27.62
0.5 - 1.0 (0.1 - 0.3)	133.99	54.22
0 - 0.5 (0 - 0.1)	187.39	75.83
-0.5 - 0 (-0.1 - 0)	134.95	54.61
-1.0 - -0.5 (-0.3 - -1.6)	86.90	35.17
-1.5 - -1.0 (-0.5 - -0.3)	48.36	19.57
-2.0 - -1.5 (-0.6 - -0.5)	13.20	5.34
-2.5 - -2.0 (-0.8 - -0.6)	3.70	1.50
-3.0 - -2.5 (-0.9 - -0.8)	1.42	0.57
-3.5 - -3.0 (-1.1 - -0.9)	0.57	0.23
-4.0 - -3.5 (-1.2 - -1.1)	0.09	0.04
< -4.0 (-1.2)	0.00	0.00
TOTAL	732	296

Figure 7. **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.**

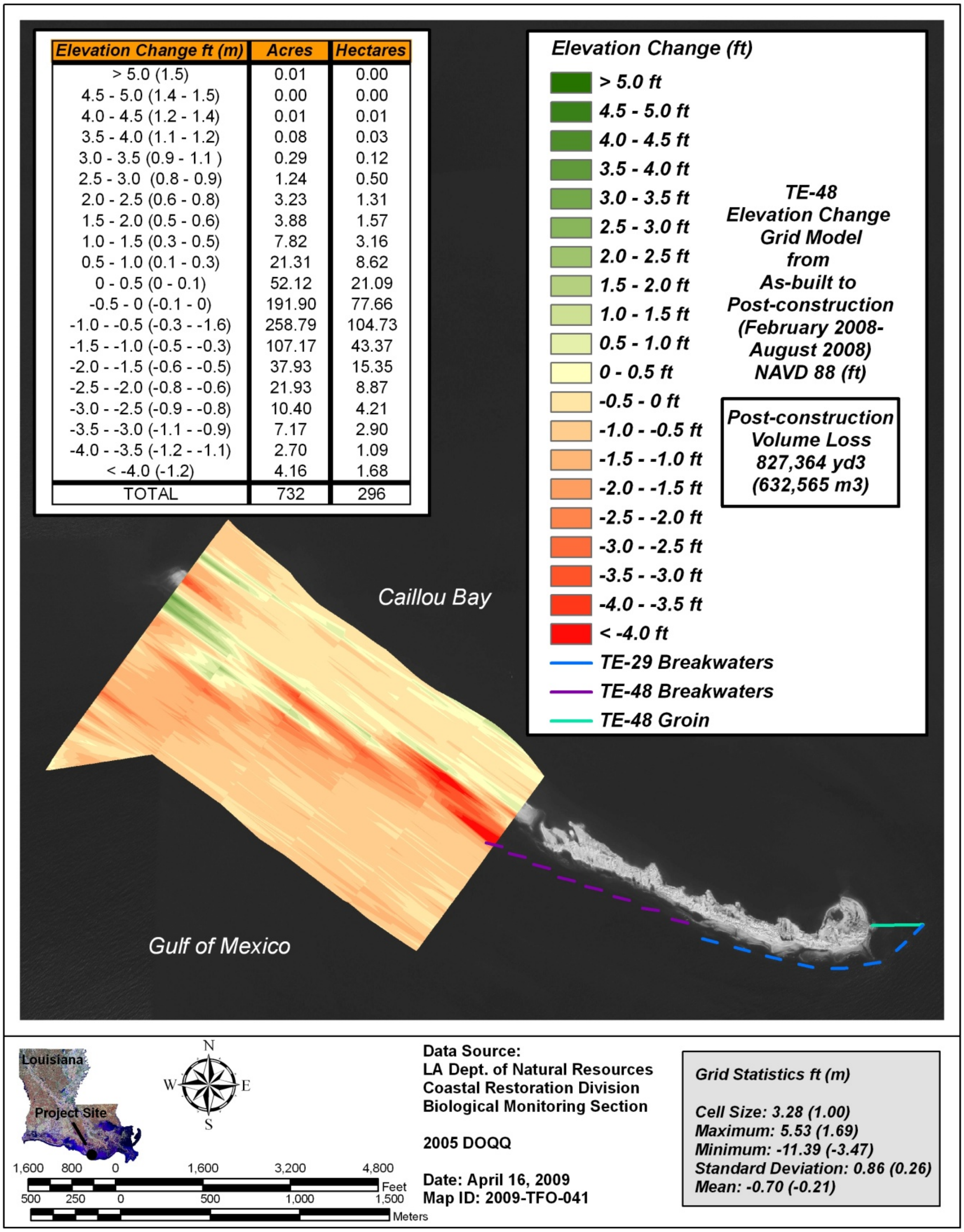


Figure 8. **Elevation and volume change grid model for the spit from as-built (Feb 2008) to post-construction (Aug 2008) at the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project.**

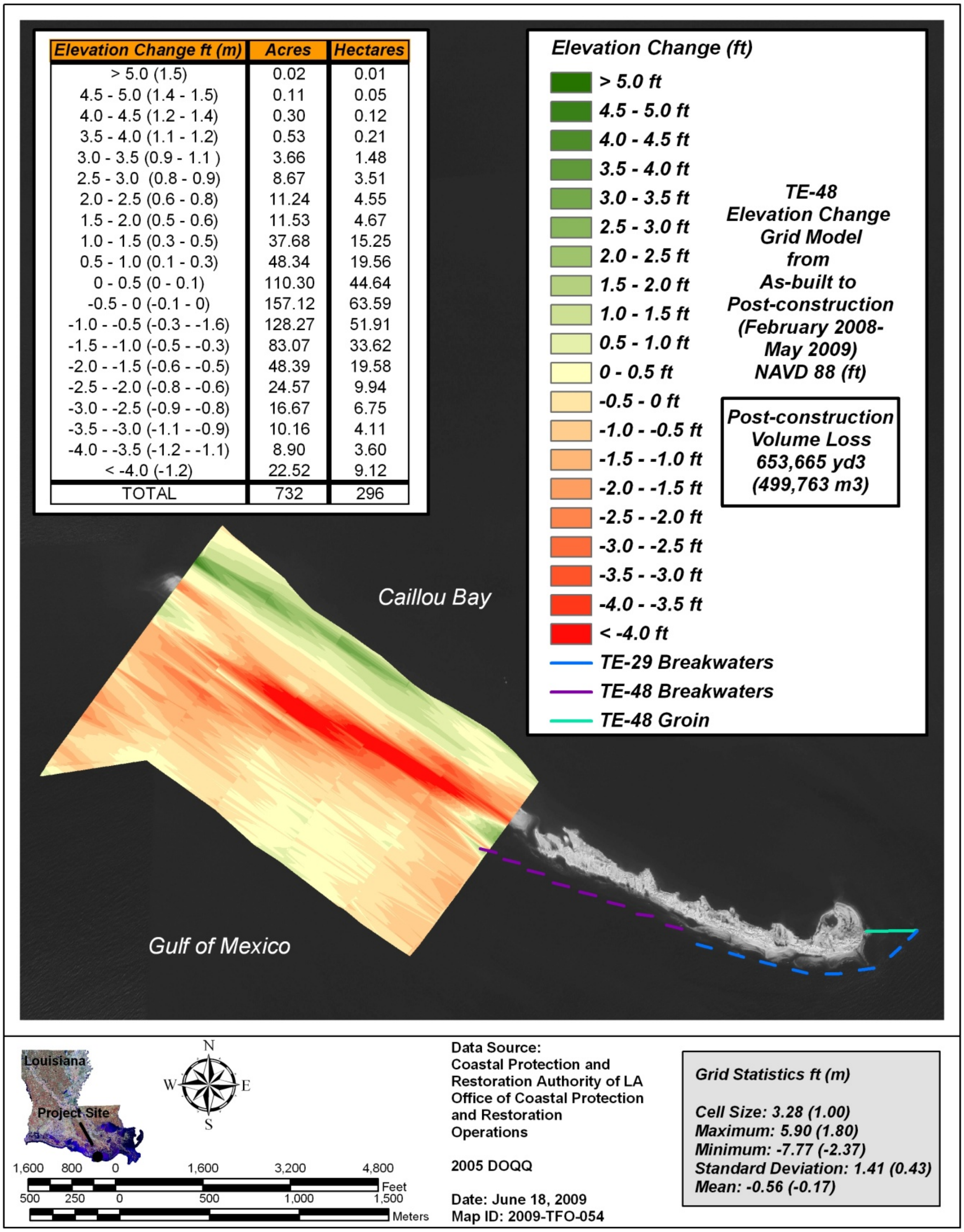
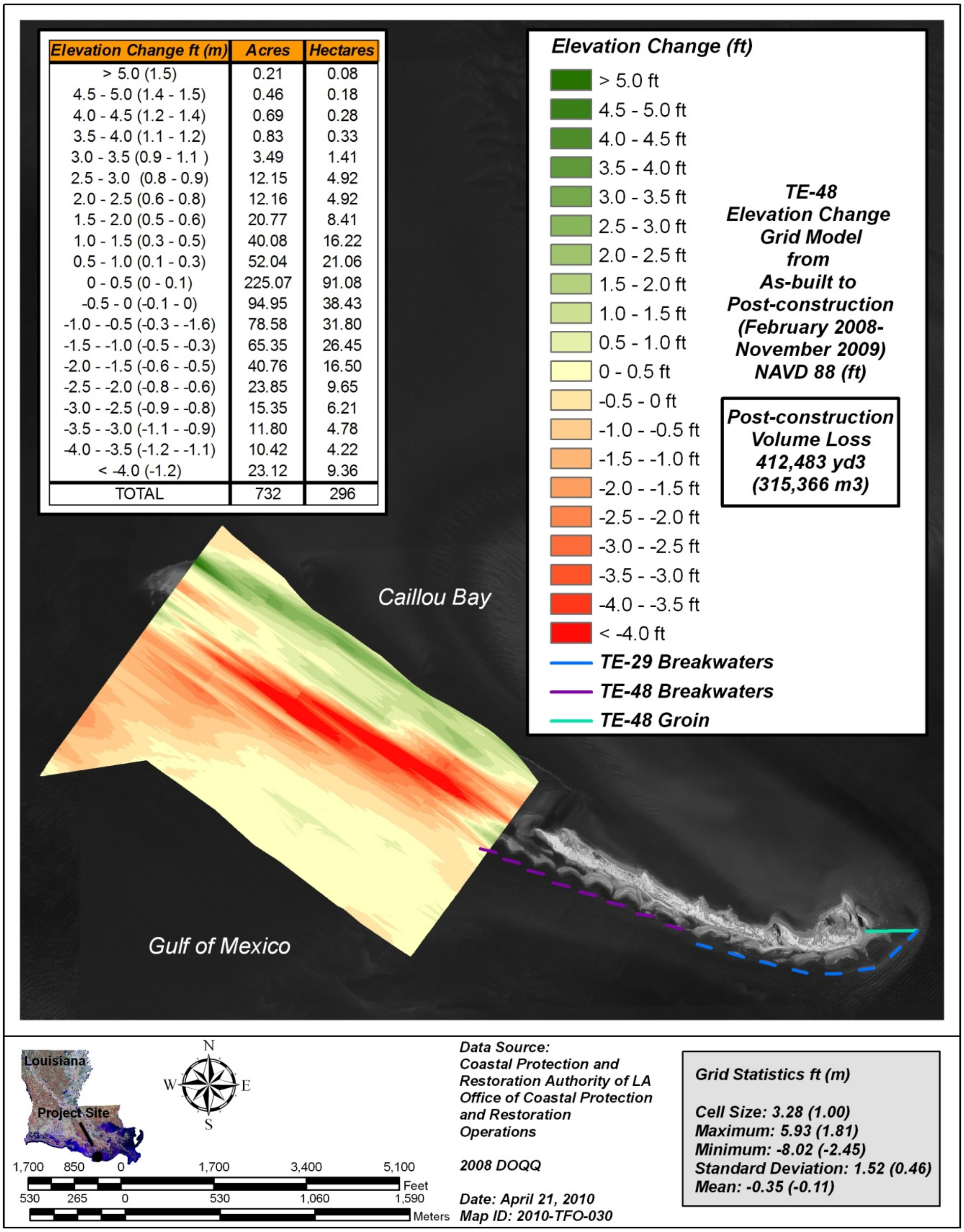


Figure 9. **Elevation and volume change grid model for the spit from as-built (Feb 2008) to post-construction (May 2009) at the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project.**



Elevation Change ft (m)	Acres	Hectares
> 5.0 (1.5)	0.21	0.08
4.5 - 5.0 (1.4 - 1.5)	0.46	0.18
4.0 - 4.5 (1.2 - 1.4)	0.69	0.28
3.5 - 4.0 (1.1 - 1.2)	0.83	0.33
3.0 - 3.5 (0.9 - 1.1)	3.49	1.41
2.5 - 3.0 (0.8 - 0.9)	12.15	4.92
2.0 - 2.5 (0.6 - 0.8)	12.16	4.92
1.5 - 2.0 (0.5 - 0.6)	20.77	8.41
1.0 - 1.5 (0.3 - 0.5)	40.08	16.22
0.5 - 1.0 (0.1 - 0.3)	52.04	21.06
0 - 0.5 (0 - 0.1)	225.07	91.08
-0.5 - 0 (-0.1 - 0)	94.95	38.43
-1.0 - -0.5 (-0.3 - -1.6)	78.58	31.80
-1.5 - -1.0 (-0.5 - -0.3)	65.35	26.45
-2.0 - -1.5 (-0.6 - -0.5)	40.76	16.50
-2.5 - -2.0 (-0.8 - -0.6)	23.85	9.65
-3.0 - -2.5 (-0.9 - -0.8)	15.35	6.21
-3.5 - -3.0 (-1.1 - -0.9)	11.80	4.78
-4.0 - -3.5 (-1.2 - -1.1)	10.42	4.22
< -4.0 (-1.2)	23.12	9.36
TOTAL	732	296

Figure 10. **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.**

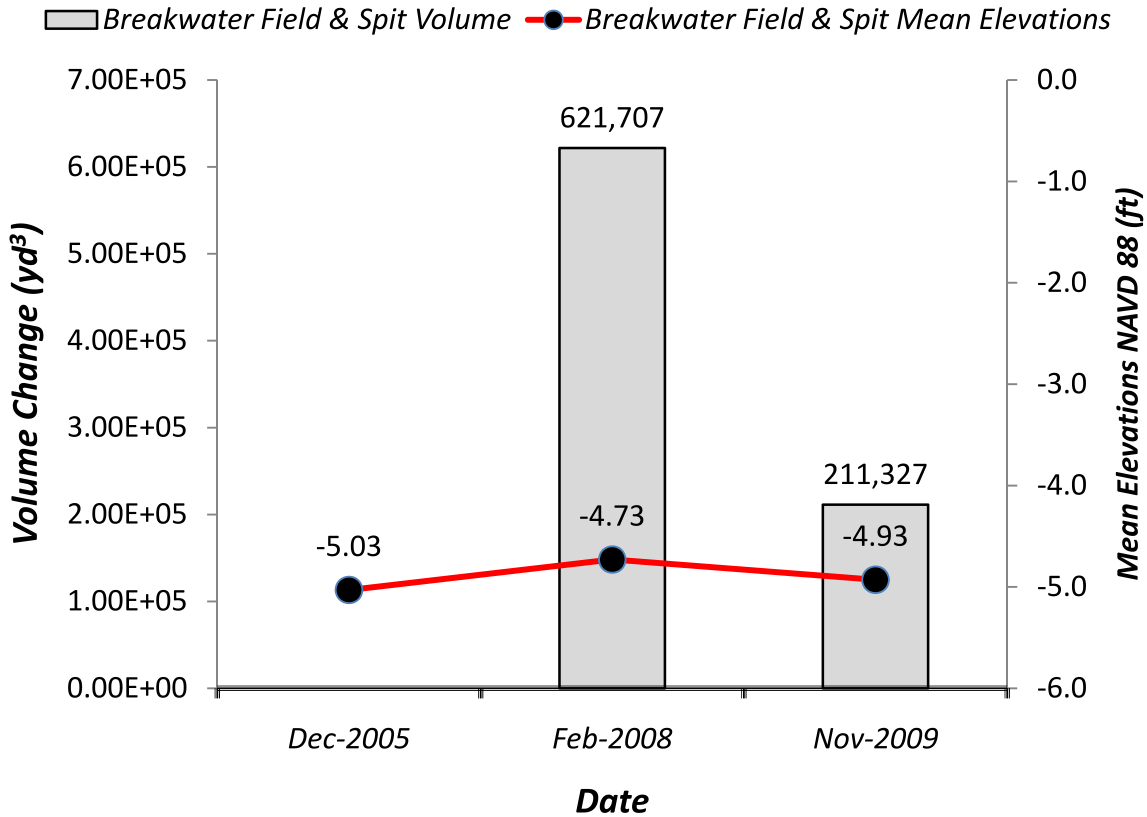


Figure 11. Sediment volume change and mean elevations over time along the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project's breakwater field and spit areas.

(figures 5 and 11). 231,315 yd^3 (176,853 m^3) of the sediment gain occurred on the spit portion of Raccoon Island (figures 7 and 12). In the post-construction period, sediment volume on Raccoon Island (breakwater field and spit) decreased by 66% from Feb 2008 to Nov 2009 (figures 6 and 11), and volume on the spit part of the island declined by 358% from Feb 2008 to Aug 2008 (figures 8 and 12), by 283% from Feb 2008 to May 2009 (figures 9 and 12), and by 178% from Feb 2008 to Nov 2009 (figures 10 and 12). Note that the spit lost 827,364 yd^3 (632,565 m^3) of sediments from Feb 2008 to Aug 2008 (figures 8 and 12) and gained 414,881 yd^3 (317,199 m^3) of sediments from Aug 2008 to Nov 2009 (figures 8, 10, and 12). The breakwater field gained approximately 2,103 yd^3 (1,608 m^3) of sediment during the interval from Feb 2008 to Nov 2009 (figure 6). Moreover, tables 1 and 2 show that the TE-48 breakwaters gained elevation and volume since construction while the TE-29 breakwaters volume and elevation declined.

Hurricane Gustav 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 13) transgressed the spit shoreline 326 ft (99 m) (table 3), expanded the breach separating

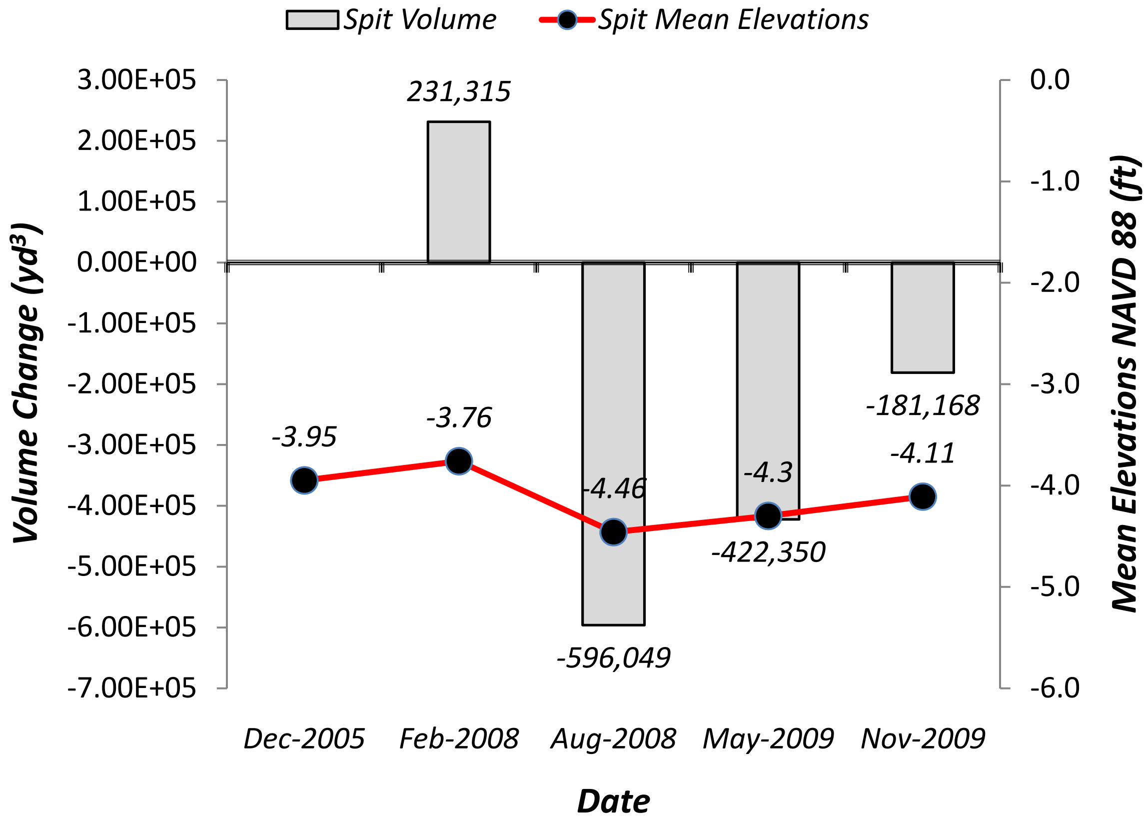


Figure 12. **Sediment volume change and mean elevations over time along the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project's spit.**

Raccoon Island and the spit from approximately 150 ft (46 m) to 1,500 ft (457 m), and damaged brown pelican (*Pelecanus occidentalis*) nesting habitats (figure 14). However, the substantial volume loss that transpired on the Raccoon Island Spit before the storm (figures 8, 12, and table 2) illustrate that downdrift impacts of the breakwater field were occurring in the immediate lee of the breakwaters not long after construction. The mean width (table 4), area (table 4), and elevation (table 1) of the subaerial portion of the spit all declined immediately after construction (August 2008). Table 3 also illustrates that both the Gulf of Mexico and the Caillou Bay shorelines transgressed from Feburary 2008 to August 2008. The spit shoreface also recorded very large volume losses in August 2008 (figure 8 and table 2). 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).

After Hurricane Gustav, the spit gained volume in May 2009 (figures 9, 12, and table 2) and Nov 2009 (figures 10, 12, and table 2). Moreover, a portion of the spit's volume was conserved and elevations were raised in the shallow reaches of Caillou Bay (figures 9, 10, 15, and table 3). However, the mean elevation of the subaerial

Table 1. Mean elevations inside six predefined Raccoon Island subdivisions over time.

Mean Elevation (NAVD 88 ft)	*Dec-2005*	*Feb-2008*	*Aug-2008*	*May-2009*	*Nov-2009*
Subaerial Spit	1.4	1.4	1.24	0.76	1.06
Spit Shoreface	-5.95	-5.91	-6.79	-5.97	-5.9
TE-48 Shoreface	-8.23	-7.91	N/A	N/A	-7.78
TE-29 Shoreface	-7.49	-7.03	N/A	N/A	-7.18
TE-48 Breakwaters	-1.4	-0.73	N/A	N/A	-0.2
TE-29 Breakwaters	-1.03	-0.57	N/A	N/A	-0.78

Table 2. Volume change inside six predefined Raccoon Island subdivisions over time.

Volume Change (yd3)	*Dec 2005-Feb 2008*	*Feb 2008-Aug 2008*	*Feb 2008-May 2009*	*Feb 2008-Nov 2009*
Subaerial Spit	57,124	-34,773	2,384	89,227
Spit Shoreface	97,240	-697,677	-508,697	-343,102
TE-48 Shoreface	115,027	N/A	N/A	46,049
TE-29 Shoreface	150,367	N/A	N/A	-50,302
TE-48 Breakwaters	52,002	N/A	N/A	41,011
TE-29 Breakwaters	40,082	N/A	N/A	-17,925

Table 3. Shoreline change along the Raccoon Island Spit's Gulf of Mexico and Caillou Bay shorelines over time.

Subaerial Spit Shoreline Change	*Dec 2005-Feb 2008*	*Feb 2008-Aug 2008*	*Aug 2008-May 2009*	*May 2009-Nov 2009*
Gulf of Mexico Change (ft)	30.17	-37.69	-325.77	45.46
Gulf of Mexico Change Rate (ft/yr)	13.99	-72.43	-440.40	86.86
Caillou Bay Change (ft)	14.00	-85.06	273.09	-1.21
Caillou Bay Change Rate (ft/yr)	6.49	-163.44	369.18	-2.32

Table 4. Mean width and area of the subaerial portion of the Raccoon Island Spit over time.

Subaerial Spit Summary Statistics	*Dec-2005*	*Feb-2008*	*Aug-2008*	*May-2009*	*Nov-2009*
Mean Width (ft)	849	929	803	776	813
Area (Acres)	157	167	147	137	149

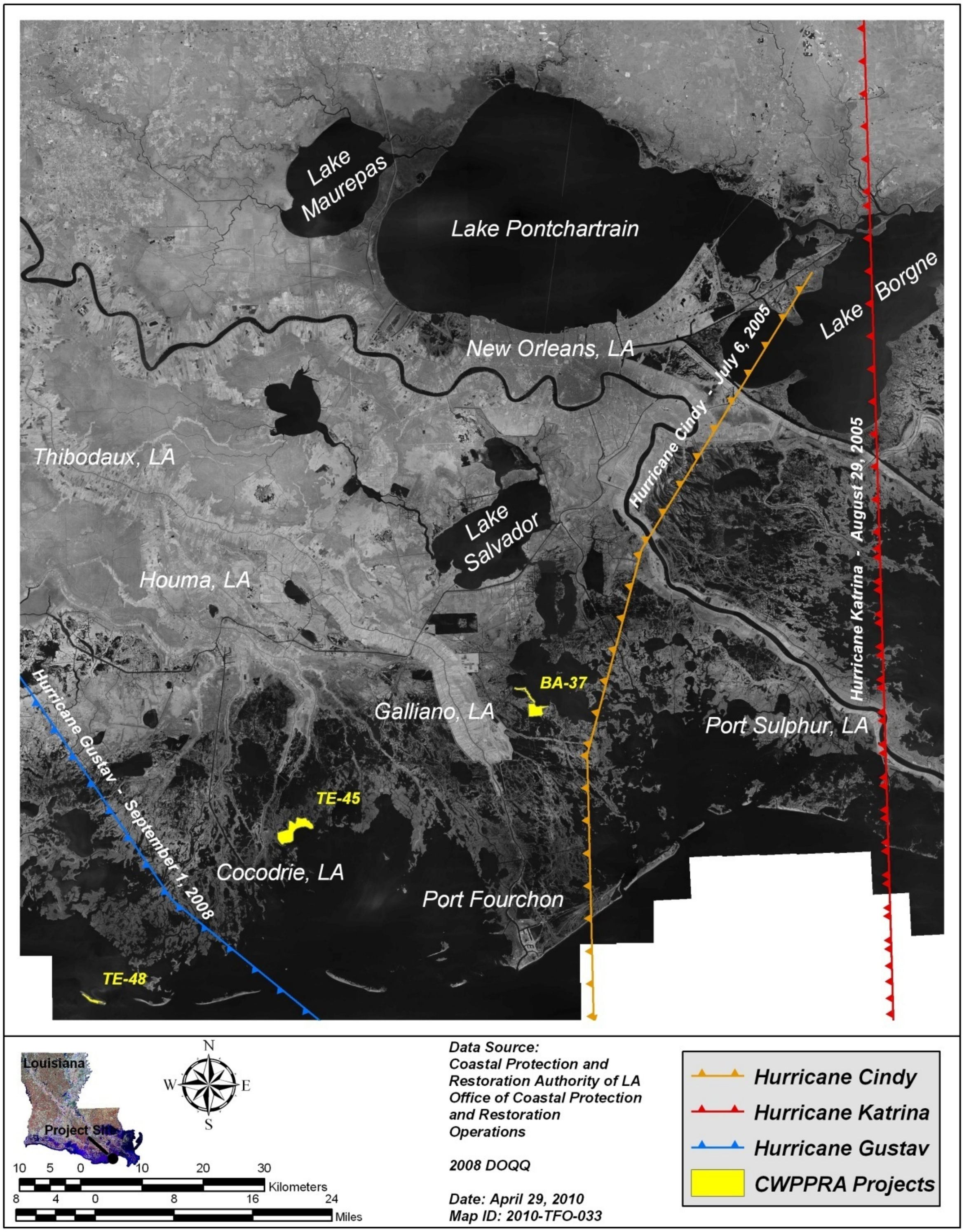


Figure 13. Pre-construction (2005) and post-construction (2008) hurricanes impacting the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project area shoreline.

Figure 14. **View of stressed brown pelican nesting habitat at the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project.**

portion of the spit was reduced significantly during this tropical event (table 1), and the width and area of the spit recorded their lowest dimensions after this storm (table 4). The large volume gain behind breakwater 15 immediately after Hurricane Gustav (figure 15) aggraded a part of the shoreface that appeared to be scoured by the breakwaters (figure 8) and could be a result of the storm.

The construction of the groin caused considerable volume increases (figures 5 and 6), expanded the eastern tip of the island by approximately 350 ft (107 m) (figure 16), and closed the channel that developed behind breakwaters 0 and 1 (figures 5 and 6) as postulated by Stone et al. (2003). In addition, a tombolo is currently forming behind breakwater 1 (figures 17 and 6). While the area surrounding the groin gained volume, the volume behind breakwaters 2 through 6 declined (figure 6 and table 2) and breakwater 2 lost volume immediately after construction (figure 5). Therefore, it seems that some of the volume gained in the groin area was redistributed from these breakwaters. Likewise, all the TE-48 breakwaters (8-15) showed increases in volume (figure 6 and table 2). The volumes behind the TE-48 breakwaters have not only

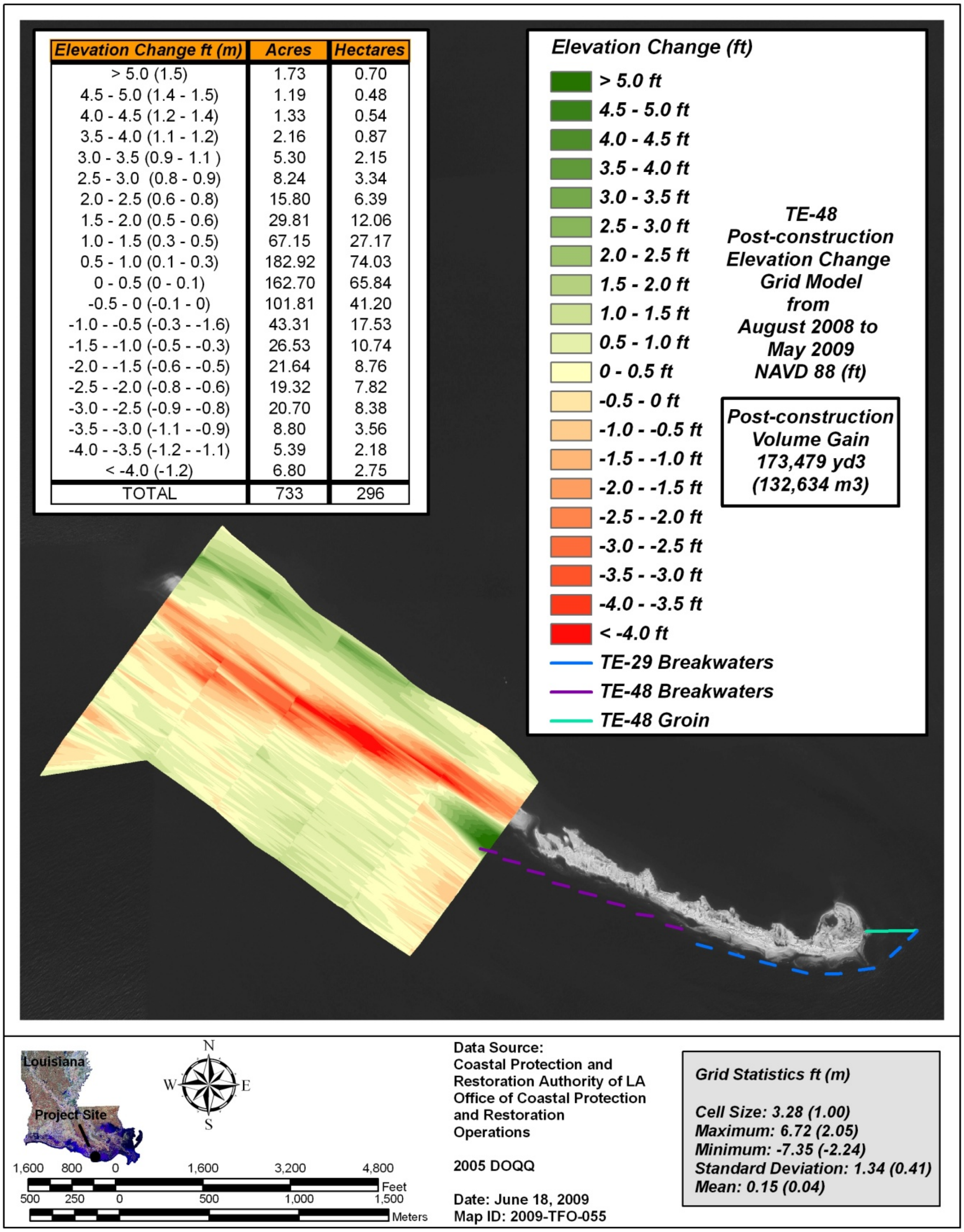


Figure 15. **Elevation and volume change grid model for the spit from post-construction (Aug 2008) to post-construction (May 2009) at the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project.**

Figure 16. **Aerial view of the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project's shoreline in Oct 2008. Note the development of salients behind all the TE-48 breakwaters and the expansion of the groin shoreline.**

Figure 17. **View of the tombolo forming behind breakwater 1 at the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project. Note the rock structure in the background is the groin.**

increased but salients have formed behind all theses structures (figure 16). Interestingly, the salients behind breakwaters 12 through 15 are separated from Raccoon Island (figure 16) denoting that the breach between the island and the spit and/or the northerly retreat of this shoreline (figures 3 and 16) are possibly 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 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).

The low contour sand shoal identified by Armbruster (1999) and Stone et al. (2003) does not appear on the grid models (appendix A) or elevation change models (figures 5 and 6) suggesting that the shoreface has steepened on the eastern edge of Raccoon Island. Tables 2 and 3 also provide evidence showing that the shoreline 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. The passage of the massive 2005 and 2008 hurricanes; Hurricane Katrina (Aug 2005) (figure 13), Hurricane Rita (Sep 2005), and Hurricane Gustav (Sep 2008) (figure 13); might have contributed to the erosion of this shoal. Comparing the earlier Stone et al. (2003) grid models [-2 ft (0.61 m) NAVD 88] with the latest elevation data (Nov 2009) [-6 ft (1.8 m) NAVD 88] 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 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) NAVD 88 (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 (figure 6). 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).

In conclusion, preliminary results indicate that the TE-48 goal to reduce shoreline erosion 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 the shoreline from Hurricane Gustav, a large category 3 tropical storm. However, the structures appeared in the intervening time to have negative downdrift impacts to the spit. In addition, the apparent erosion of the sand shoal to the depth of closure could influence future distributions of sand behind the structures.

Sediment Properties

The sediment cores collected by the BICM program have not been analyzed to date. When the soil data becomes available, the distribution of the sand resources will be mapped.

V. Conclusions

a. Project Effectiveness

The results of the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project reveal that the project goal is being attained at the present time. The goal to reduce shoreline erosion to protect habitats sustaining Raccoon Island rookery and sea bird colonies was achieved because all TE-48 structures gained sediment volume and protected the shoreline. The groin expanded the shoreline and gained considerable volume. The large volume increase surrounding this structure initiated tombolo formation behind breakwater 1 and closed a channel that developed behind breakwaters 0 and 1. The TE-48 breakwaters all showed volume gains and salient formations. However, the spit recorded a large volume loss prior to Hurricane Gustav. During this hurricane, the spit shoreline transgressed appreciably, and the breach between Raccoon Island and the spit expanded substantially. Since Hurricane Gustav, the spit has added volume but is still far short of the as-built volume (Feb 2008). 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. If the shoal has lost significant volume, a beach nourishment event could be warranted. While there are sand resource problems, the project is protecting the shoreline and will be monitored into the future. Therefore, these preliminary results suggest that the TE-48 project is currently accomplishing its goal.

b. Recommended Improvements

Several improvements would enhance the sustainability and analysis of the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project. First, the back barrier marsh creation component (phase B) of the TE-48 project needs to be constructed. Raccoon Island has narrowed considerably due to the persistent movement of tropical storms and cold fronts through the region. Constructing marsh on the bay side would increase the area, width, and sediment volume of Raccoon Island. It would also provide a platform to retain cross-shore sediments and increase the habitat available for brown pelican (*Pelecanus occidentalis*) nesting. As a result, the back barrier marsh creation area would enhance the sustainability of Raccoon Island and the brown pelican colony. Secondly, Raccoon Island Shoreline Protection/Marsh Creation (TE-48) as-built drawings, survey, and the project completion report need to be provided once they are finalized. The construction timeline and the dimensions of the structures need to be confirmed to analyze the effects of the structures. The TE-48 project was built over a long timeline (several years) primarily because of issues that developed in the aftermath of Hurricanes Katrina and Rita. Therefore, some of the structures were completed or partially built well before the project was completed. The specifications of breakwaters are especially important because structure length, gap width, and distance offshore can alter breakwater functioning and salient or tombolo development. As a result, it is essential that the project completion report and as-built information be distributed once they are finalized. Thirdly, the sustainability of the TE-48 project would be enhanced through beach nourishment. Sand resource availability is vital to success or failure of breakwater projects (Dean and Dalrymple 2002). Since the eastern shoreface of Raccoon Island seems to have steepened, a vibracore investigation to determine the volume and location of sand remaining in the shoal (Armbruster 1999; Stone et al. 2003) should be initiated. If the volume of the sand shoal has been reduced significantly, a beach nourishment event may be necessary. Adding sand resources to the Raccoon Island littoral system via beach nourishment would enhance the response of the shoreline to the coastal structures and the sustainability of the island.

c. Lessons Learned

Two lessons were learned from the first two years of the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project. The first 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 second lesson learned is the large sandy shoal that Armbruster (1999) and Stone et al. (2003) identified should have been re-assessed after the 2005 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.

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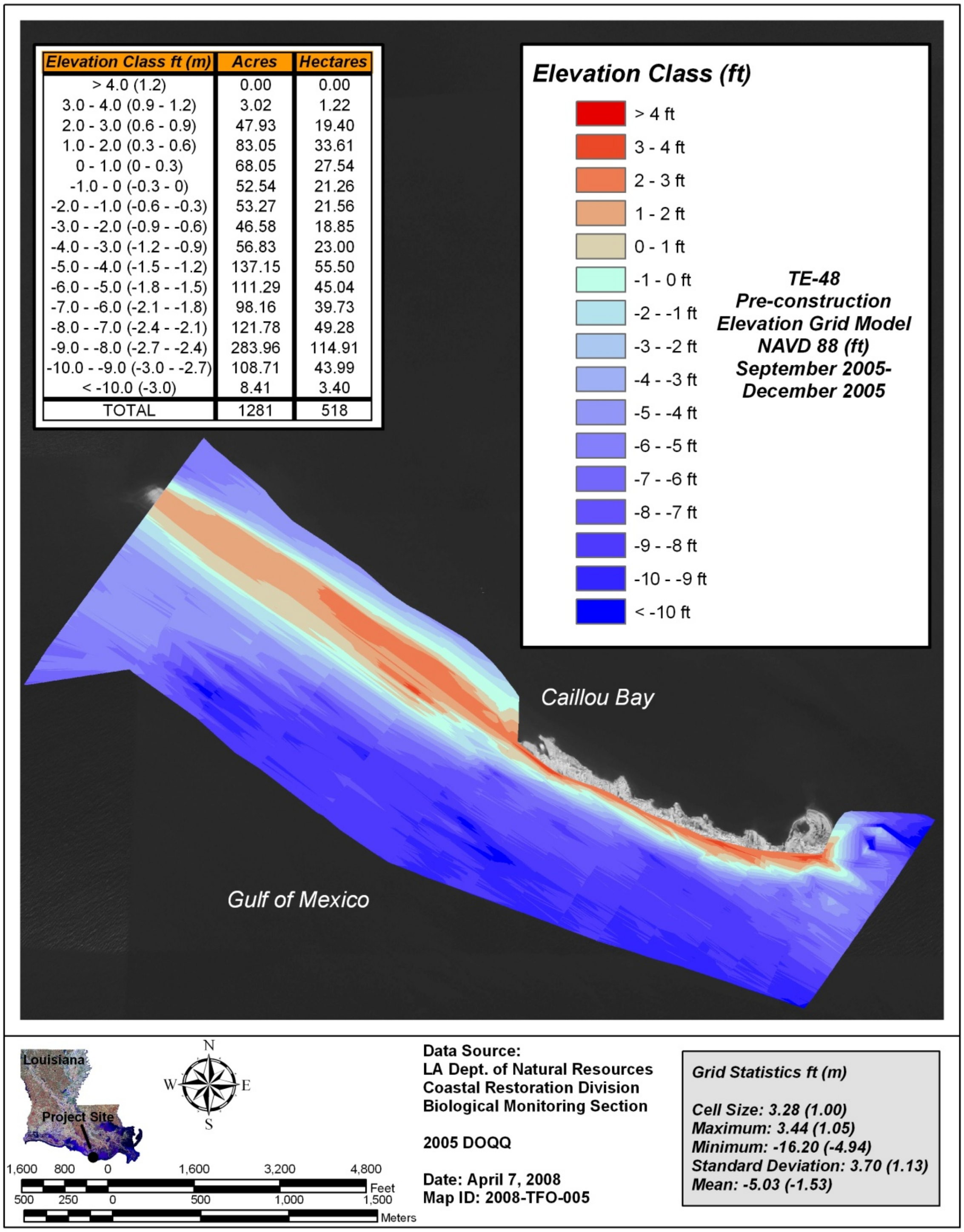
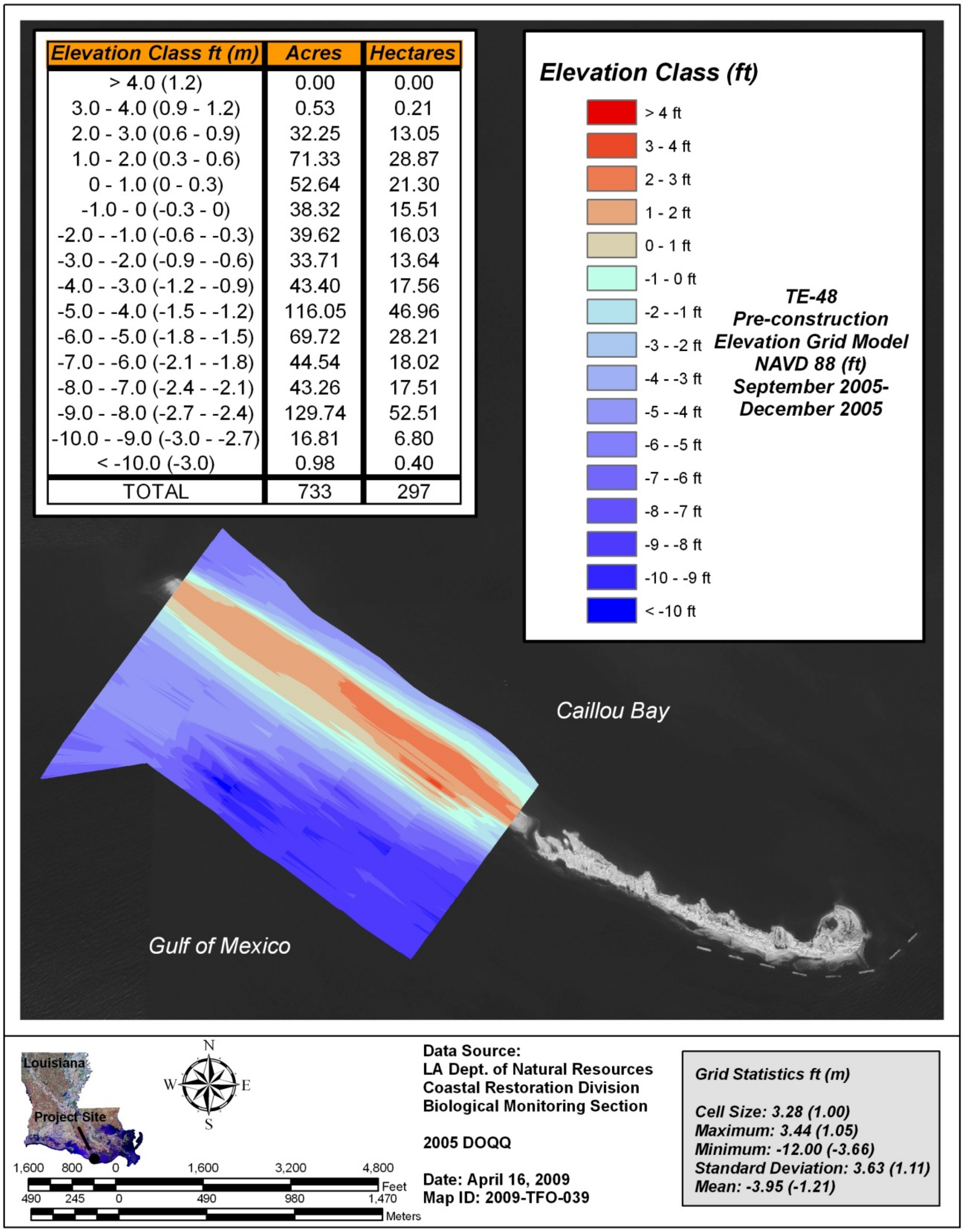
Appendix A

TE-48 Elevation Grid Models



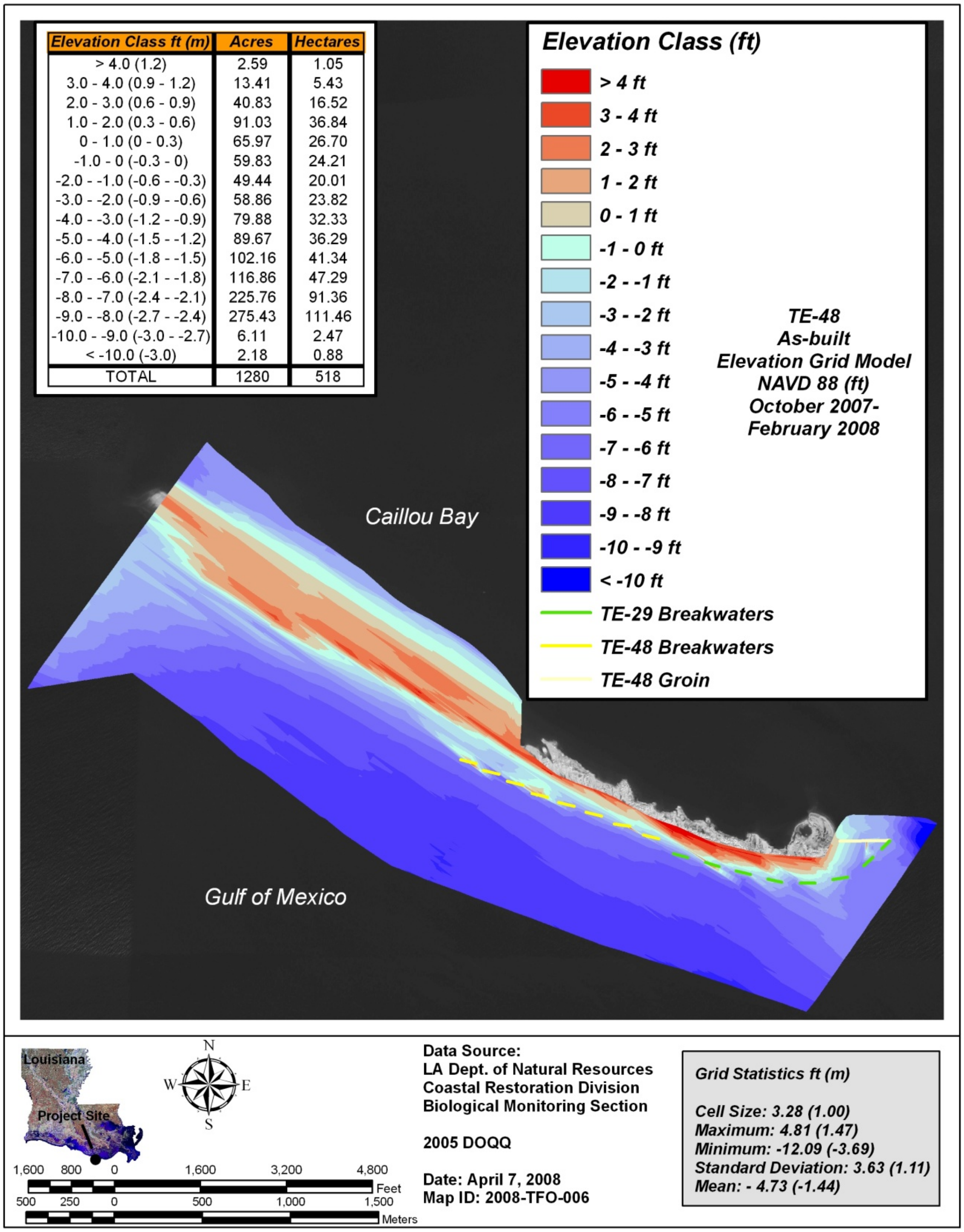
Elevation Class ft (m)	Acres	Hectares
> 4.0 (1.2)	0.00	0.00
3.0 - 4.0 (0.9 - 1.2)	3.02	1.22
2.0 - 3.0 (0.6 - 0.9)	47.93	19.40
1.0 - 2.0 (0.3 - 0.6)	83.05	33.61
0 - 1.0 (0 - 0.3)	68.05	27.54
-1.0 - 0 (-0.3 - 0)	52.54	21.26
-2.0 - -1.0 (-0.6 - -0.3)	53.27	21.56
-3.0 - -2.0 (-0.9 - -0.6)	46.58	18.85
-4.0 - -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. **Pre-construction (Dec 2005) 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)	0.53	0.21
2.0 - 3.0 (0.6 - 0.9)	32.25	13.05
1.0 - 2.0 (0.3 - 0.6)	71.33	28.87
0 - 1.0 (0 - 0.3)	52.64	21.30
-1.0 - 0 (-0.3 - 0)	38.32	15.51
-2.0 - -1.0 (-0.6 - -0.3)	39.62	16.03
-3.0 - -2.0 (-0.9 - -0.6)	33.71	13.64
-4.0 - -3.0 (-1.2 - -0.9)	43.40	17.56
-5.0 - -4.0 (-1.5 - -1.2)	116.05	46.96
-6.0 - -5.0 (-1.8 - -1.5)	69.72	28.21
-7.0 - -6.0 (-2.1 - -1.8)	44.54	18.02
-8.0 - -7.0 (-2.4 - -2.1)	43.26	17.51
-9.0 - -8.0 (-2.7 - -2.4)	129.74	52.51
-10.0 - -9.0 (-3.0 - -2.7)	16.81	6.80
< -10.0 (-3.0)	0.98	0.40
TOTAL	733	297

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

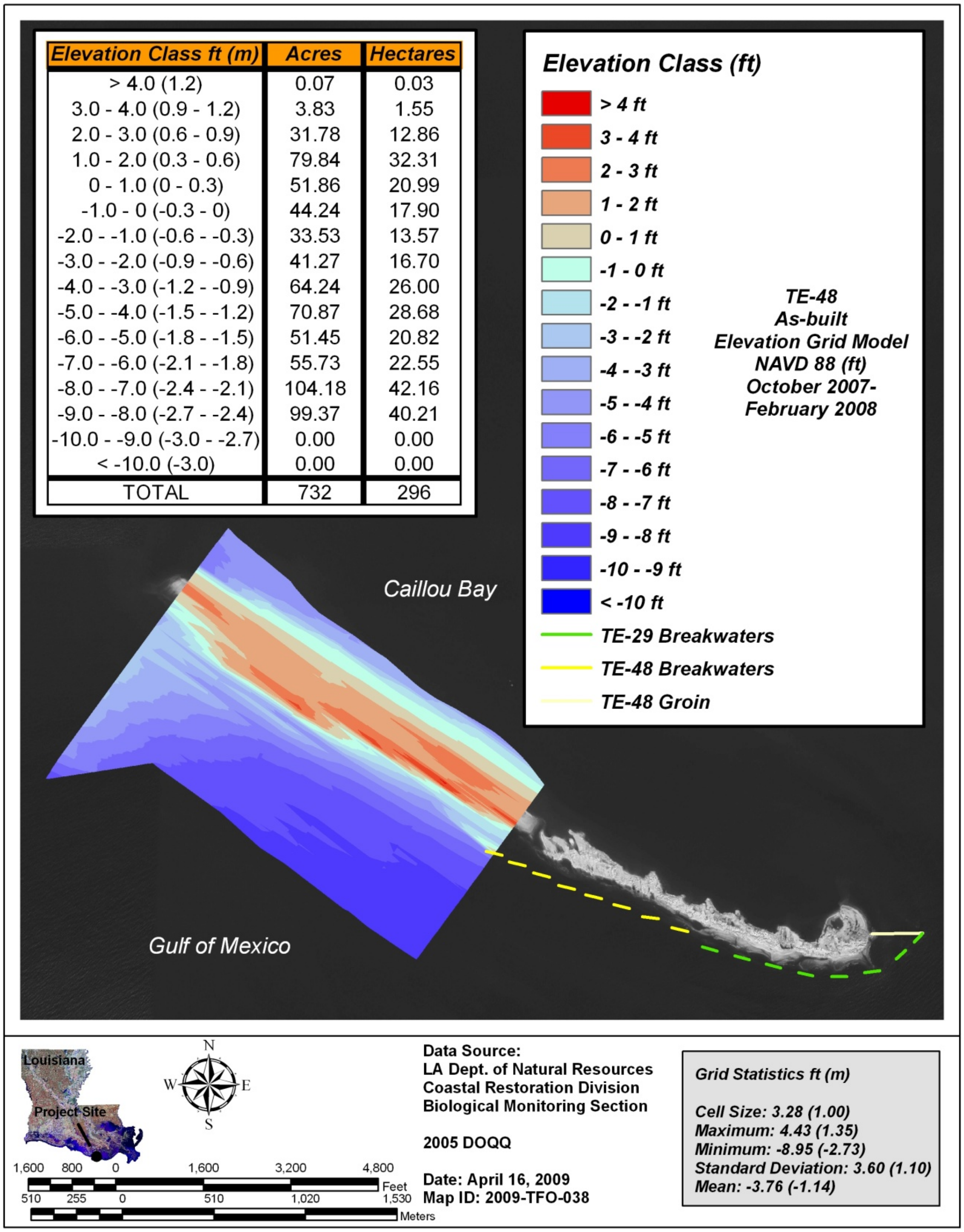
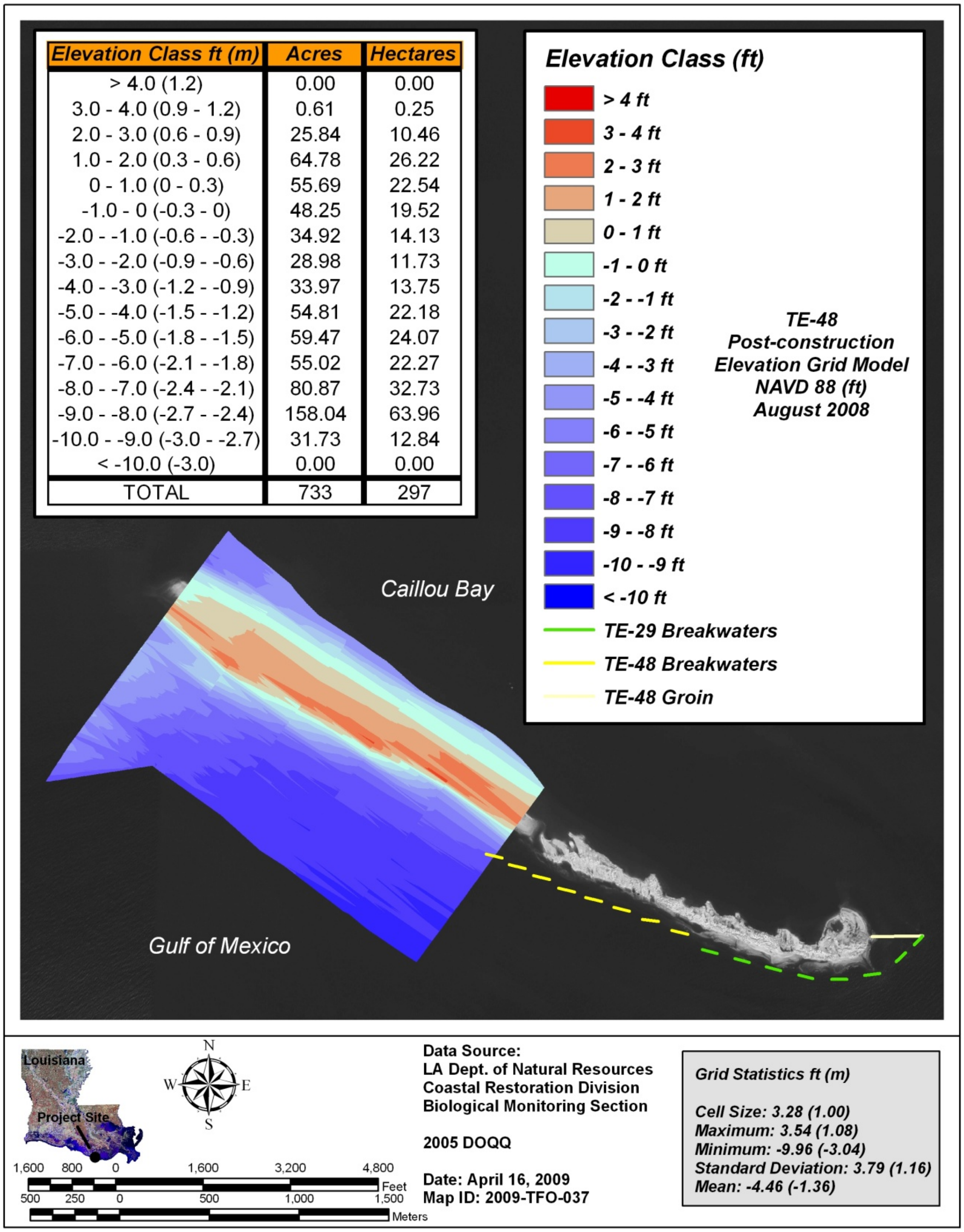
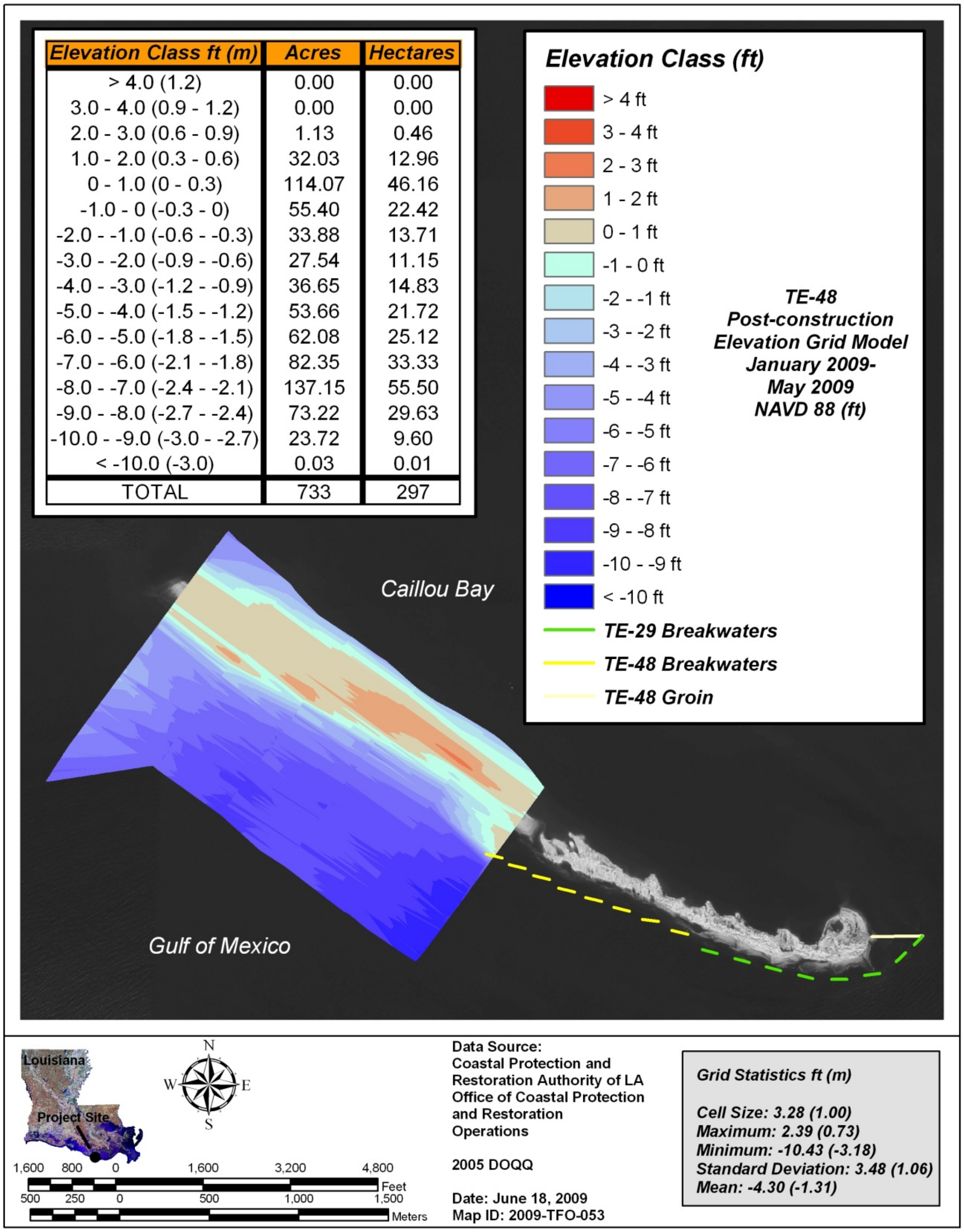


Figure. **As-built (Feb 2008) elevation grid model of the spit at the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project.**



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

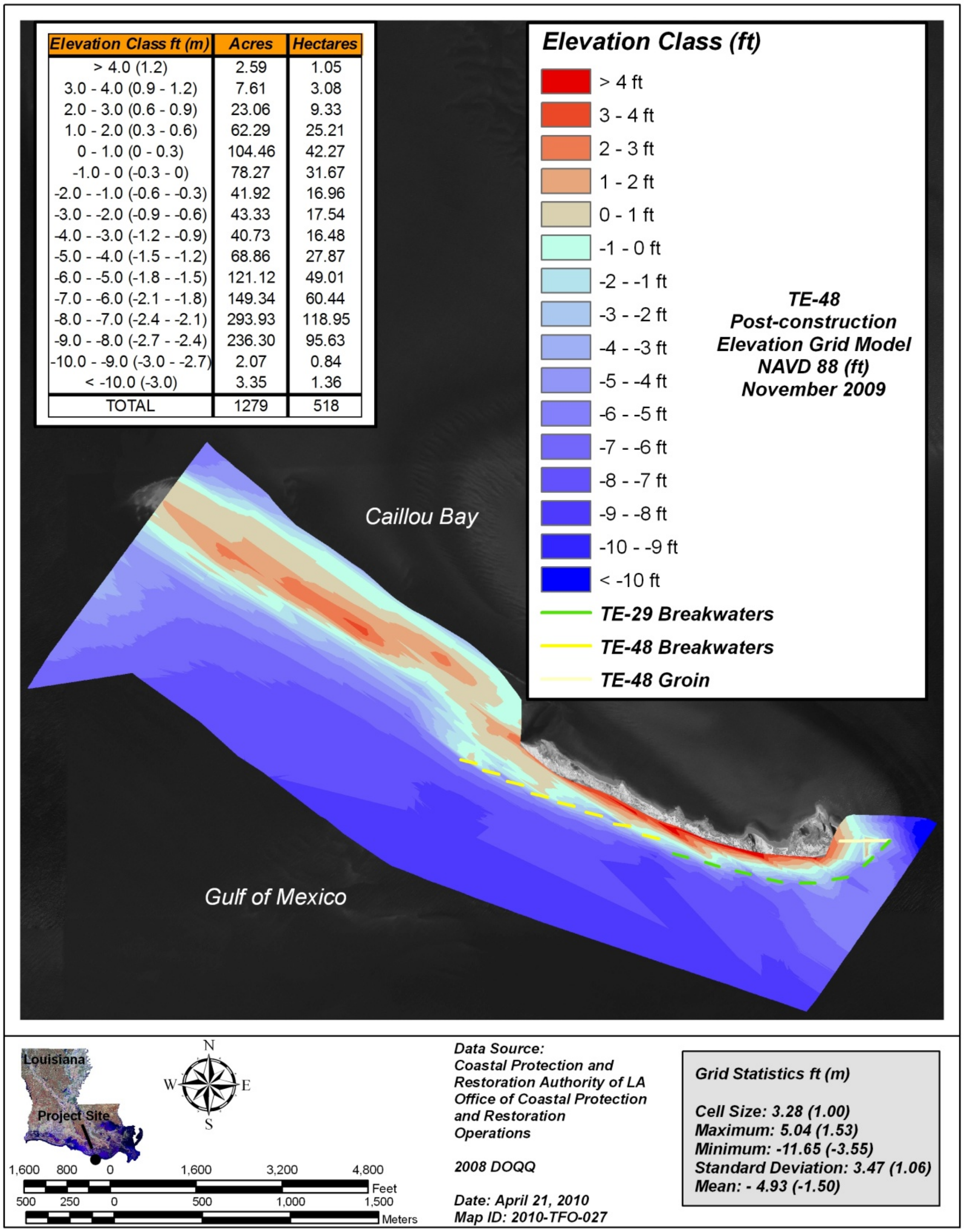
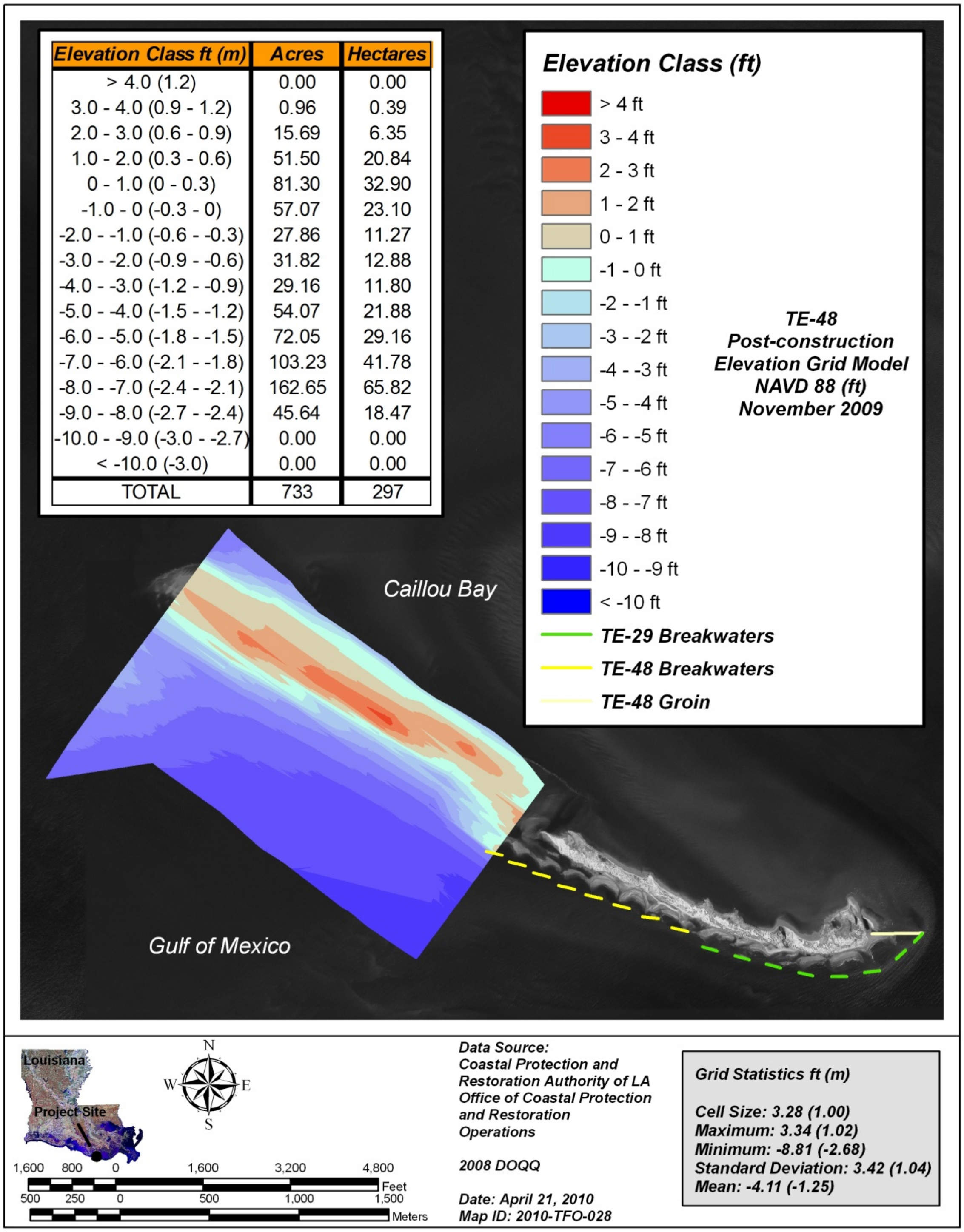


Figure. **Post-construction (Nov 2009) elevation grid model of the breakwater field and spit at the Raccoon Island Shoreline Protection/Marsh Creation (TE-48) project.**



Elevation Class ft (m)	Acres	Hectares
> 4.0 (1.2)	0.00	0.00
3.0 - 4.0 (0.9 - 1.2)	0.96	0.39
2.0 - 3.0 (0.6 - 0.9)	15.69	6.35
1.0 - 2.0 (0.3 - 0.6)	51.50	20.84
0 - 1.0 (0 - 0.3)	81.30	32.90
-1.0 - 0 (-0.3 - 0)	57.07	23.10
-2.0 - -1.0 (-0.6 - -0.3)	27.86	11.27
-3.0 - -2.0 (-0.9 - -0.6)	31.82	12.88
-4.0 - -3.0 (-1.2 - -0.9)	29.16	11.80
-5.0 - -4.0 (-1.5 - -1.2)	54.07	21.88
-6.0 - -5.0 (-1.8 - -1.5)	72.05	29.16
-7.0 - -6.0 (-2.1 - -1.8)	103.23	41.78
-8.0 - -7.0 (-2.4 - -2.1)	162.65	65.82
-9.0 - -8.0 (-2.7 - -2.4)	45.64	18.47
-10.0 - -9.0 (-3.0 - -2.7)	0.00	0.00
< -10.0 (-3.0)	0.00	0.00
TOTAL	733	297

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