**State of Louisiana**
**Coastal Protection and Restoration Authority**
**Office of Coastal Protection and Restoration**

# 2011 Closeout Report

for

# Mandalay Bank Protection Demonstration (TE-41) Project

State Project Number TE-41
Priority Project List 9

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2011 Closeout Report
For
Mandalay Bank Protection Demonstration
(TE-41)

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## Preface

This report includes monitoring data collected through June 2010, and the annual Maintenance Inspection from October 2009.

The 2011 report is the closeout report for this demonstration project. For additional information on lessons learned, recommendations and project effectiveness please refer to the 2004 and 2007 Operations, Maintenance, and Monitoring Reports on the LDNR web site.

## I. Introduction

The Mandalay Bank Protection Demonstration (TE-41) project is located along a 3.4-mi (5.5-km) segment of the Gulf Intracoastal Waterway (GIWW) inside the Mandalay National Wildlife Refuge (figure 1). It is approximately 6 mi (9.7 km) southwest of Houma, Louisiana, in the northeast portion of Terrebonne Parish. It is sponsored by the United States Fish and Wildlife Service (USFWS) and 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, Priority List IX). Vegetative communities in the project area include fresh marsh, scrub/shrub, seasonally flooded bottomland forest, and open-water areas with aquatic vegetation. The two types of fresh marsh, fresh bulltongue and fresh maidencane, have relatively high diversity (LDNR/CRD 2003).

From 1944 to 1983 the north and south shorelines in the project area have experienced an average land loss rate of approximately 13.17 ft $yr^{-1}$ (4.01 m $yr^{-1}$) (May and Britsch 1987). Frequent wave action along the waterway coupled with soft, unstable marsh sediments has resulted in bank erosion and an overall widening of the channel. Adjacent freshwater marshes remain vulnerable to the damaging effects of erosion. The stretch of GIWW within the project area experiences a substantial volume of marine vessel traffic (Segura 2001). The traffic is a mixture of recreational vessels, large barges and barge combinations, tug boats, supply vessels, and crew boats. The estimated mid-channel wave height in the GIWW generated by winds and large vessel wakes is approximately 3.0 ft (0.9 m) based upon calculations from preliminary design investigations (CEEC, Inc. 2001).

The objective of the Mandalay Bank Protection Demonstration (TE-41) project is to compare both the performance and the cost effectiveness of two off-bank and two blowout treatments. To achieve this objective the treatments ability to provide protection against shoreline erosion, promote sedimentation, and promote vegetation growth will be assessed in selected areas along the GIWW (figure 2).

The Mandalay Bank Protection Demonstration (TE-41) project was constructed in one phase beginning in April 2003 and completed in September 2003. The project had a demonstration period of five (5) years. Monitoring continued for five (5) years post-construction; however, structures were designed and constructed for a twenty (20) year life which began in September 2003. The project budget did not include any funding provision for the operation, maintenance, or rehabilitation of any of the project features other than for the performance of inspections of the project features. Inspections were performed after the first, third, and fifth years following construction completion.

The principal project features included (CEEC, Inc. 2004):

- Construction of approximately 1,223 ft (373 m) of submerged articulated concrete revetment mats. Three replicates of this treatment were installed.
- Construction of approximately 1,857 ft (566 m) of straight-walled fiberglass sheet pile. Three replicates of this treatment were installed.
- Construction of approximately 1,283 ft (391 m) of 24 inch (0.61 m) high A-Jacks® concrete blocks in an interlocking double row with two staggered rows of *Zizaniopsis miliacea* (Michx.) Doell & Aschers. (giant cutgrass) plantings on five foot centers between it and the shoreline. Three replicates of this treatment were installed.
- Construction of approximately 1,910 ft (582 m) of staggered treated lumber fencing with two staggered rows of *Z. miliacea* plantings on five foot centers between it and the shoreline. Three replicates of this treatment were installed.

Additional features include:

- Construction of approximately 501 ft (153 m) of concrete revetment armored plugs. Three replicates were installed.

Drawings of the Mandalay Bank Protection Demonstration (TE-41) structures are provided in appendix A.

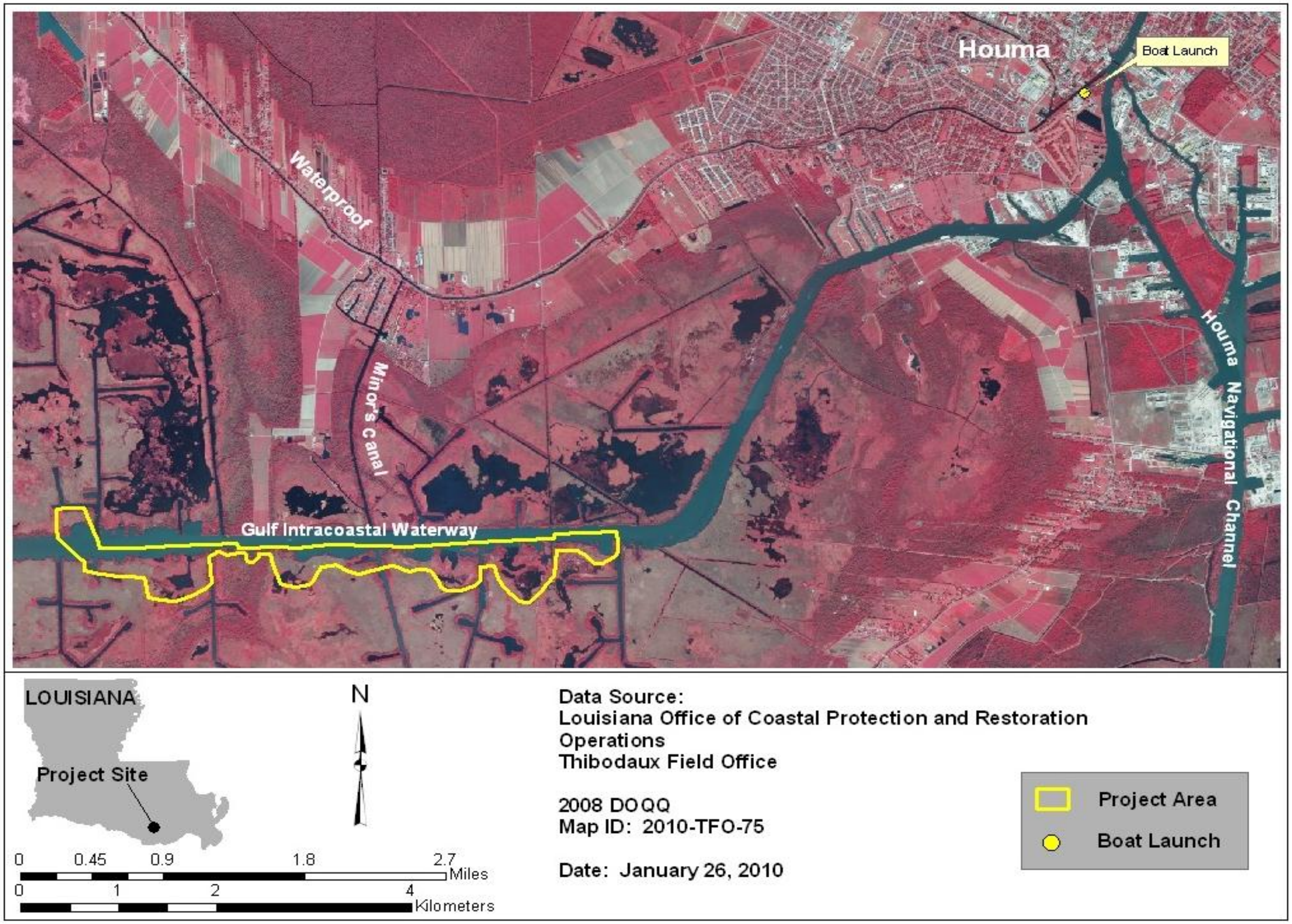


Figure 1. Location map with project boundary for the Mandalay Bank Protection Demonstration (TE-41) project.

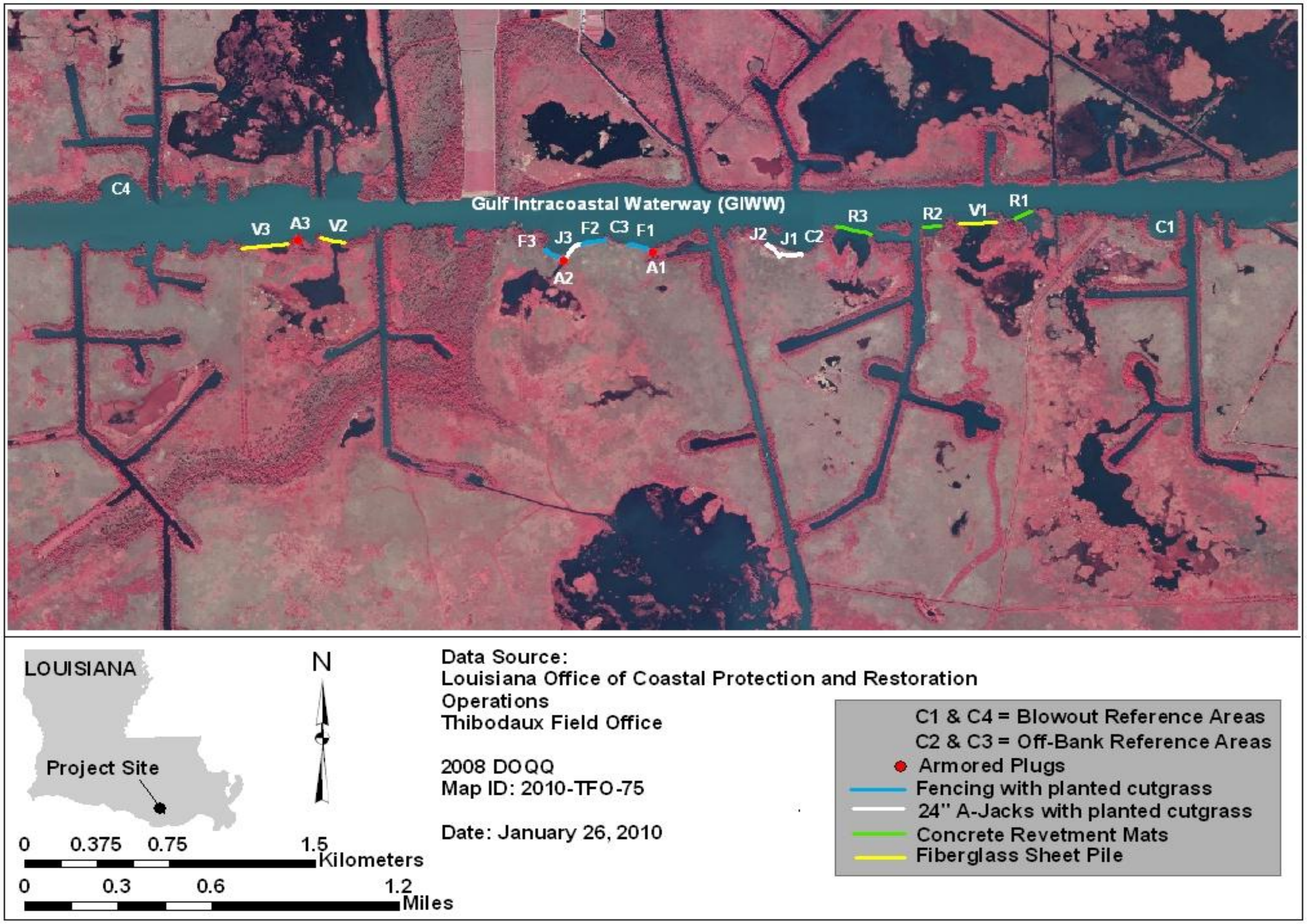


Figure 2. Location of treatments and reference areas for the Mandalay Bank Protection Demonstration (TE-41) project.

## II. Maintenance Activity

### a. Project Feature Inspection Procedures

The purpose of the inspection of the Mandalay Bank Protection Demonstration Project (TE-41) is to evaluate the constructed project features in order to determine the condition and effectiveness of the shoreline treatments and use the inspection results to prepare the final close-out report for the project. Included in the final close-out report is an evaluation of the condition of each shoreline treatment, photographs and estimated cost comparison of all four treatment types.

As described in the O&M Plan, three (3) project inspections are to be performed during the five (5) year demonstration period after the first, third, and fifth years following construction completion. This inspection will serve as the third and final of the three (3) project inspections.

The inspection of the Mandalay Bank Protection Demonstration Project (TE-41) was held on October 19, 2009. In attendance were Daniel Dearmond and Elaine Lear from OCPR. The boat was launched at approximately 8:30 a.m. at Cannon's Boat Launch on Southdown Mandalay Road along Bayou Black. From the launch, Minors Canal was then used to arrive at the GIWW. The water level taken from an existing gage located in Minors Canal near the project's secondary monument (TE-41-SM-01) was 1.48' (8:45am) at the start of inspection and 1.35' (1:05pm) at the conclusion. It should be noted that the timber piling that the gage is installed on was slightly out of plumb (less vertical than in 2005), and therefore the recorded reading is a little higher than the actual water level. The inspection of the project features began at the Fiberglass Sheet Pile Double Wall (Site V3), the western-most feature, and proceeded eastward along the GIWW to the Elevated Shoreline System Revetment Mats (Site R1), the eastern-most feature.

The field inspection included a complete visual inspection of the entire project site. Photographs were taken at each project feature (Appendix B).

### b. Inspection Results

<u>Blowout Treatments</u>

**<u>Sites R1, R2, and R3 – Revetment Mats / Elevated Shoreline (CPE Pipe) System</u>**

At Sites R1 and R2, increased settlement has occurred in two locations along the revetment mat / pipe system at each site. At the R1 Site, the two low areas are located approximately 40' east of the settlement plate and near the west end. At Site R2, the two low areas are located approximately 25' east of the settlement plate and near the west end. Much of the system west of the settlement plate was just below water elevation at the time of the survey. It should be noted that in these locations of observed settlement at Sites R1 and R2, fill material had to be placed in order to level the bottom before placement of the fabric, pipe, and mats during construction. No noticeable damage to the structures was apparent. The settlement plate riser pipes appeared to be in good condition. While the settlement plate riser pipe at Site R3 is visually out of plumb, this riser pipe was leaning upon installation. The warning signs and support piles at the three sites were in excellent condition. The bank tie-ins were in good condition with some bank erosion noted. Overall, the revetment mat structures appear to be intact and do not require any maintenance (Photos 48-58, 65-69; Appendix B).

Approximately 75 feet to the east of the east tie-in of Site R1, an existing breach in the bank was plugged with dredged material from the GIWW during construction. This earthen plug has now been breached leaving the bank open again (Photo 70, Appendix B).

**Sites V1, V2, and V3 – Straight-walled Fiberglass Sheet Pile System**

During the inspection, water levels were such that approximately 6 to 9 inches of the sheet pile structures were exposed. No noticeable breaching or major damage to the structures was apparent, and the earthen fill material placed between the double walls did not show signs of erosion. Some minor cracks, splits, and missing tops of sheet pile above the timber waler were observed. Timber walers appeared to be in good condition at all three sites. The galvanized tie rods and timber waler hardware were in good condition with only a minimal amount of corrosion present. The warning signs and support piles were in excellent condition. The bank tie-ins appeared in to be in good condition. Overall, the sheet pile structures appear to be intact and do not require any maintenance (Photos 2-6, 12-16 and 59-64; Appendix B).

Off-Bank Treatments

**Sites J1, J2, and J3 – Concrete Armor Units (24" A-Jacks) with Giant Cutgrass**

At the adjacent Sites J1 and J2, accretion has occurred, and the A-Jacks (double row) are now covered by well-vegetated, accumulated material. The depth of cover over the A-Jacks was found to be 1' to 2' in some locations (2007 inspection). The extent of vegetated accretion appears to be greater than 200' in some locations as it extends from the old shoreline behind the A-Jacks northward toward the GIWW beyond the warning signs at the two sites. The accreted material is densely vegetated. At Site J3, the water level was just below the tops of the A-Jacks. No accretion has occurred except at the west tie-in where the structure ties into the Site A2 plug. In fact, it appears as if the shoreline may have continued to experience some measure of erosion at this site. The survival rate of the plantings at Site J3 still appears to be the lowest (out of the three sites) as noted in the previous inspection reports. The tie-ins appeared to be in good condition at the three sites. The warning signs and support piles at the three sites were in excellent condition. No maintenance is recommended for the concrete armor unit sites at this time (Photos 27-28, 31-32 and 42-47; Appendix B).

**Sites F1, F2, and F3 – Fencing with Giant Cutgrass**

In general, the timber fencing and galvanized hardware at the three sites appeared to be in good condition with no signs of damage. One location of damage was noted however. At Site F2, approximately 7 or 8 fence spans were missing near the middle of the structure. It appears as if a barge struck the fence here. From communication with field personnel, it is believed this occurred in early May 2006. Most of the bank tie-ins were in good condition. The bank has eroded approximately 2' away from the west end of the fence at Site F2. The warning signs and support piles were in excellent condition at Sites F1 and F3. The warning sign support pile at Site F2 was struck by the barge as well and is now leaning with the sign partially submerged. At Site F3, significant accretion has occurred (an average of 10' in front of the structure and up to the bottom of the top cross timber on the structure). This fence site is adjacent to plug Site A2 where extensive accretion of material has occurred. In some locations material has accreted greater than 50' from the old shoreline behind the fence out to the warning sign. In the vertical direction the material has reached the second timber on the fence or higher. As noted in previous inspections, the survival rates of the planted giant cutgrass associated with Fencing Sites appears to still be very low. The only immediate maintenance need is the warning sign at Site F2. Also, consideration should be given to replacement of the damaged fence sections at Site F2. The damage to these sections as well as the length of time since the occurrence should be noted in the demonstration project results (Photos17-22, 29-30, and 33-40; Appendix B).

Additional Features

**Sites A1, A2, and A3 – Armored Earthen Plugs**

The concrete revetment mats appeared to be in good condition. Material has accreted in front of the Sites A1 and A2. The most accretion has occurred at Site A2 where the extent of vegetated accretion reaches well beyond the warning sign. The bank tie-ins were also in good condition. The warning signs and support piles were in excellent condition. Overall, the armored plugs appear to be intact and do not require any maintenance (Photos 7-11, 23-26 and 41; Appendix B).

## III. Operation Activity

### a. Operation Plan

None of the project features require operations.

### b. Actual Operations

None of the project features require operations.

## IV. Monitoring Activity

### a. Monitoring Goals

The objective of the Mandalay Bank Protection Demonstration (TE-41) project is to compare both the performance and the cost effectiveness of two off-bank and two blowout treatments. To achieve this objective the treatments ability to provide protection against shoreline erosion, promote sedimentation, and promote vegetation growth will be assessed in selected areas along the GIWW (LDNR/CRD 2003).

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

1. Stop shoreline erosion in specified areas along the south shores of the GIWW.
2. Increase elevation in shallow open water behind treatments along the GIWW.
3. Maintain/increase the frequency of occurrence of submerged aquatic vegetation (SAV) within shallow open water blowouts along the GIWW.
4. Increase mean cover of *Z. miliacea* to 50% or greater after five growing seasons in planted areas adjacent to eroding shorelines of the GIWW.
5. Increase mean cover of emergent vegetation within shallow open water blowouts along the GIWW.
6. Evaluate the cost effectiveness of different treatments in selected areas along the GIWW.
7. Evaluate the integrity of the structures associated with treatments in selected areas along the GIWW.

### b. Monitoring Elements

The final data collection year for this project was slated for the 2008 fall season. In agreement with the federal sponsor (USFWS), OCPR did not conduct sampling due to monitoring budget shortfalls. OCPR did however conduct a comprehensive qualitative field inspection of the entire project area's vegetation in August 2008 and a final topographic and bathymetric monitoring survey was completed in June 2010. In addition, a final structure inspection for the project was conducted in October 2009.

All data has been collected for this project and analyzed. Results for Vegetation, Percent Survival, and Submerged Aquatic Vegetation (SAV) were presented in the 2007 Operations, Maintenance, and Monitoring Report (Lear et al. 2007) and will be presented for purposes of this comprehensive closeout report. All additional data such as shoreline position data, elevation data, and qualitative vegetation observations collected beyond the 2007 report will also be presented.

**<u>Shoreline Survey</u>**

To document the rate of shoreline retreat or progradation in blowout and off-bank treatments, shoreline position (outward edge of emergent vegetation) was surveyed in all treatment and reference areas (Shaw® Coastal, Inc. 2004, 2006, and 2010). To determine shoreline position, three transect lines inside each treatment and reference area were surveyed by professional surveyors to a permanent benchmark established in the project area (figure 3). The survey lines coincided with vegetation plot transects and sedimentation elevation transects in each area.

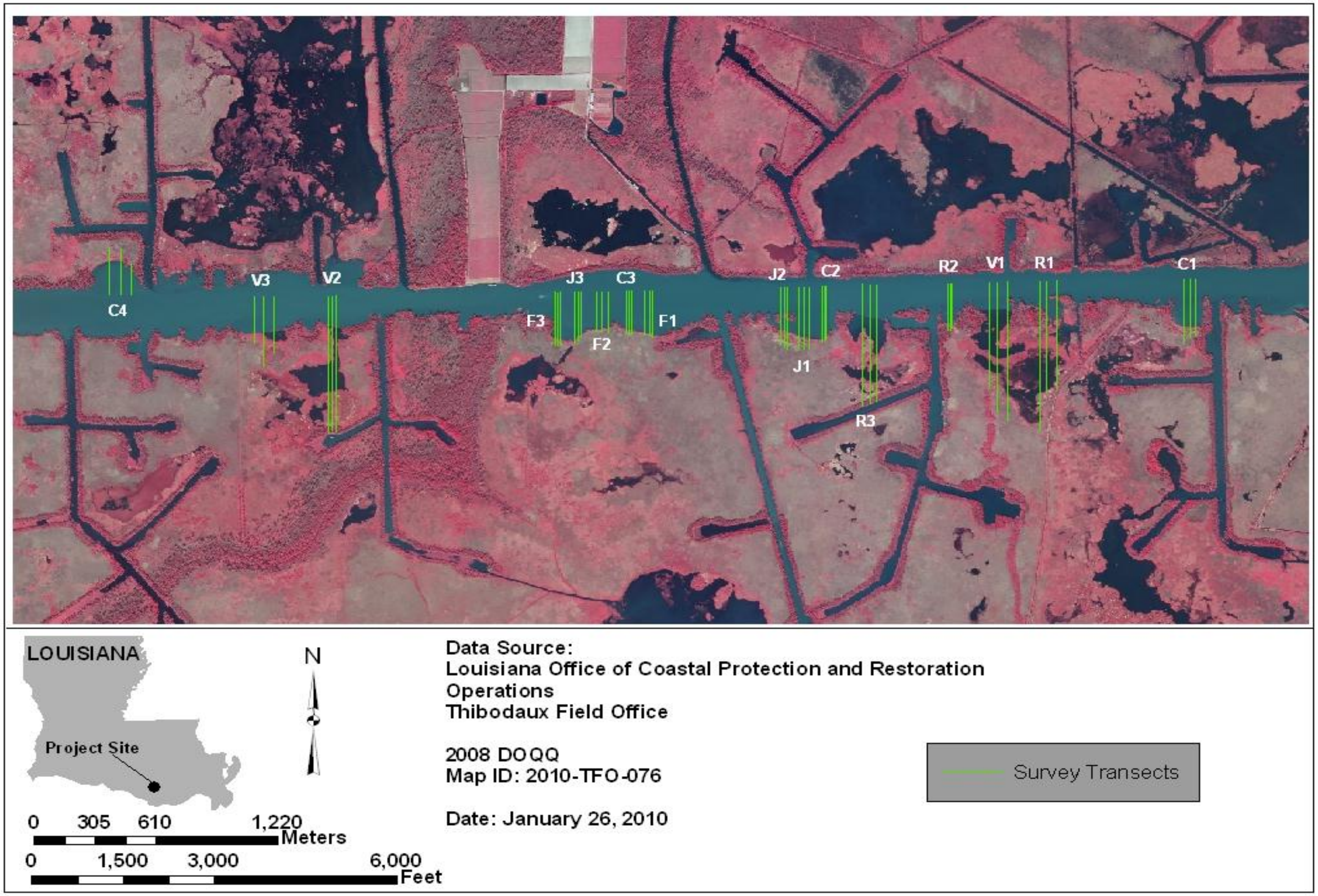


Figure 3. Transect location map for shoreline position, elevation, and vegetation monitoring activities on the Mandalay Bank Protection Demonstration (TE-41) project.

Shoreline position was documented in December 2003 (as-built) and post-construction in October 2005 and June 2010.

## Elevation

Bathymetric and topographic surveys were employed by professional surveyors (Shaw® Coastal, Inc. 2004, 2006, and 2010) to document elevation and volume changes inside the Mandalay Bank Protection Demonstration (TE-41) project area. As-built (December 2003), and post-construction (October 2005 and June 2010) elevation data were collected using three (3) cross sectional transects per treatment and real time kinematic (RTK) survey methods. The elevation transects began in the center of the GIWW and extended landward onto the marsh surface crossing over the structures and the shoreline (figure 3). Elevation data collected during these surveys recorded benthic and marsh elevations over time. In addition, points along the transects were also established to demarcate structure elevations and shoreline positions. All survey data were established using or adjusted to tie in with the Louisiana Coastal Zone (LCZ) GPS Network.

Survey data were re-projected horizontally and vertically to the UTM NAD83 coordinate system and the NAVD 88 vertical datum in meters using Corpscon® software. The re-projected data were imported into ArcView® GIS software for surface interpolation. Triangulated irregular network models (TIN) were produced from the point data sets. Next, the TIN models were converted to grid models (2.0 $m^2$ cell size), and the spatial distribution of elevations were mapped. The grid models were clipped to the sixteen TE-41 treatment polygons (12 structure and 4 reference area) to estimate elevation and volume changes.

Elevation changes from December 2003-October 2005 and December 2003-June 2010 in the structure and reference areas 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-41 structure and reference areas were mapped in half meter elevation classes. Lastly, volume changes in the structure and reference 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 the elevation grid models, the TE-41 treatments were also partitioned into foreshore [the area immediately in front of the structures (structure treatments) and the shoreline (reference treatments)] and leeward [the area immediately behind the structures (structure treatments) and the shoreline (reference treatments)] grids to delineate the effects of coastal structures and the shoreline planform on sedimentation patterns near the treatments. The foreshore and leeward subdivisions utilized the previously created grid models (December 2003, October 2005, and June 2010) and were clipped with 30.5 m wide polygons. However, the fencing treatments (F1, F2, and F3) and the third a-jack treatment (J3) were clipped with smaller width polygons because of spatial constraints imposed by their grids. Next, elevation changes were calculated for each subdivision for the December 2003-October 2005 and December 2003-June 2010 intervals using the aforementioned method. Volumes changes were calculated but are not reported because of differences in grid area between treatments.

The elevation points taken on the TE-41 structures during the December 2003, October 2005, and June 2010 surveys were used to determine structure settlement over time. New elevation grid models were created for all 12 structures and these grids were clipped with their matching structure polygons. Structure elevation changes were calculated by subtracting the December 2003-October 2005 and December 2003-June 2010 structure grid models using the methods described in the previous paragraphs. Volumes changes were not calculated for the structures because structure settlement was the parameter investigated.

**Vegetation**

To determine changes in percent (%) cover of emergent vegetation, plots were randomly established along three line transects running north to south in each treatment and reference area (figure 3). For blowout treatments, four plots were randomly placed along each transect. Three of the plots were randomly placed within one of three zones based upon plot distance from the proposed structure (if it was a treatment plot) or channel (if it was a reference plot). A fourth plot per transect was established on the marsh surface at a randomly chosen distance from the vegetated shoreline. Zones were determined by dividing the longest transect in each treatment or reference area into three equidistant areas. For off-bank treatment and reference areas, one plot per transect was established in the water at a random distance (from the treatment or channel). Two additional plots were placed along each transect on the marsh surface at a random distance from the vegetated shoreline. A modification of the Braun-Blanquet method (Mueller-Dombois and Ellenberg 1974) was used to determine total percent cover as well as individual species cover within the plots using a 6.6 ft x 6.6 ft (2 m x 2 m) square placed over the southeast corner pole. Vegetation data was collected twice during pre-construction in the fall of 2001 and 2002, once in the fall of 2003 (as-built), and once in the fall of 2005 (post-construction).

It is important to note that where corner poles could not be relocated during subsequent sampling periods, the field crew deemed these plots inactive and re-established new plots as close to the missing ones as possible using both a Differential Global Positioning System (DGPS) receiver and hand-held Wide Area Augmentation System (WAS)-enabled equipment. A re-established plot was considered different and distinguishable from the inactive plot it replaced. Where plots became open water due to shoreline erosion, new plots were re-established using a randomized distance from the vegetated shoreline. Each plot was assigned a unique station name. All vegetation monitoring station maps are located in appendix C, figures 1-7 of this report.

**Percent Survival**

To determine the survival of planted *Z. miliacea* behind off-bank treatments, the original planting scheme consisted of 18 permanent vegetation plots representing approximately 10% of the planted vegetation to be established among the off-bank treatments. Plots were to contain 12 plants planted in two staggered rows. The rows would have been spaced 5 ft apart with plants within each row spaced 5 ft apart. However, this scheme was modified during the installation of the plants. Percent survival was determined in the fall of 2003 (one month post-planting) and once in the fall of 2005 (post-construction).

When the monitoring field crew proceeded with the 2003 as-built survival data collection behind the fencing and the A-Jacks® treatments, it was determined that the planting scheme outlined in the project design was not adhered to. There were treatments with one, two, three, or four staggered rows instead of the anticipated design. The following procedure was used to determine percent survival: 1) a plot was established between the shoreline and treatment at each elevation transect (N = 3 transects per treatment replicate); 2) the number of rows established behind each treatment was determined by visual inspection since it did not adhere to the design; 3) standing on the shoreline and facing each treatment, plantings to the left of the observer were selected; and 4) three plants per row were counted based upon the assumed 5-ft staggered spacing of the design and percentages of survival were determined for each treatment.

**Submerged Aquatic Vegetation (SAV)**

To determine the frequency of occurrence of SAV, open water areas inside blowout treatments and reference sites were randomly sampled (figure 4). Each blowout was sampled at random points along transects using the rake method (Chabreck and Hoffpauir 1962; Nyman and Chabreck 1996). The number of random points and transects was determined based upon the size and configuration of the blowout. Frequency of SAV occurrence was determined for each area from the number of points at which SAV occurred and the total number of points sampled. SAV was monitored twice pre-construction in the fall of 2001 and 2002, during the fall of 2003 (as-built), and once post-construction during the fall of 2005.

### c. Preliminary Monitoring Results

**Shoreline Survey**

In order to determine if goal 1 was met, three elevation surveys were conducted which included the documentation of shoreline position. The first one was an as-built survey in fall 2003, the second one was two years post-construction in fall 2005, and the third survey was conducted during spring 2010.

Goal #1: Stop shoreline erosion in specified areas along the south shores of the GIWW

This closeout report provides a 6.5 year post-construction picture of the shoreline segments. For the analysis, shoreline change rates were calculated instead of shoreline gain/loss. A clearer

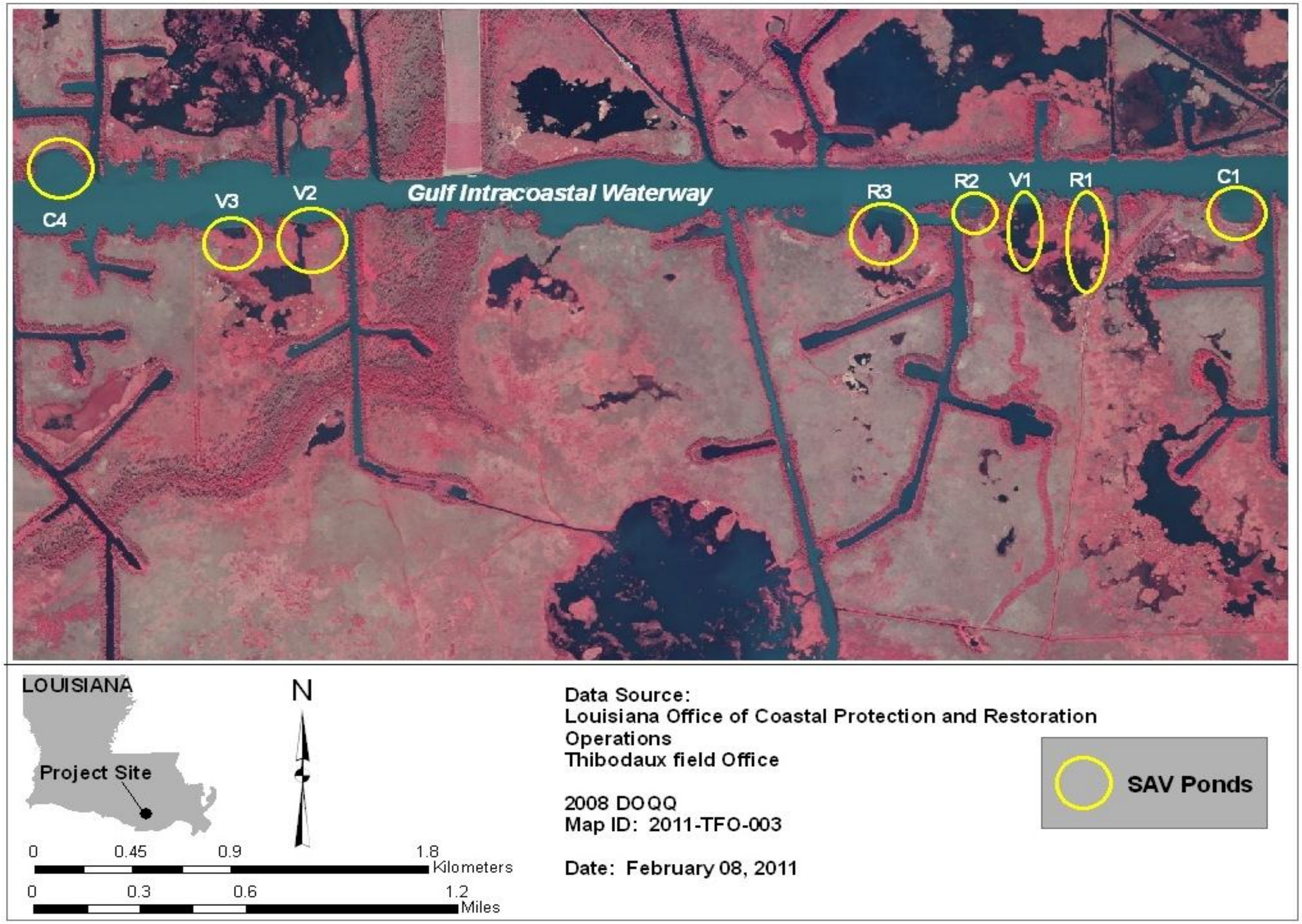


Figure 4. Location map of submerged aquatic vegetation (SAV) ponds for the Mandalay Bank Protection Demonstration (TE-41) project.

picture has emerged as a result of the re-examination of the 2003 and 2005 surveys which resulted in the inclusion of more replicates for analysis than in the 2007 OM&M report. The exception was with fiberglass sheetpile treatment V1 where the shoreline locations were still not discernible, so only two shoreline segments for this treatment were analyzed. Table 1 contains a ranking of treatment and reference types based upon this analysis. Additionally, a comparison was made between the blowout and off-bank treatment and reference shoreline segments (figure 5).

Table 1. A ranking of treatment and reference types based upon the average post-construction shoreline change rate along transects, for the Mandalay Bank Protection Demonstration (TE-41) project (Shaw®Coastal, Inc. 2004, 2006, and 2010).

| **Shoreline Segments** | **Treatment/Reference Type** | **Rank** | **Post-Construction Shoreline Change Rate ft/$^{yr-1}$(m/$^{yr-1}$)*** ** |
|---|---|---|---|
| C1, C4 | Blowout Reference | 1 | 13.17 (4.01) |
| J1, J2, J3 | A-Jacks® with Cutgrass | 2 | 11.18 (3.41) |
| V2, V3 | Fiberglass Sheetpile* | 3 | 8.52 (2.62) |
| F1, F2, F3 | Fencing with Cutgrass** | 4 | 1.15 (0.35) |
| R1, R2, R3 | Concrete Revetment Mat | 5 | 0.72 (0.22) |
| C2, C3 | Off-Bank Reference | 6 | -4.89 (-1.49) |

*Only two replicates due to lack of distinguishable shoreline in blowout V1

** F2 fencing structure was partially damaged due to a barge accident in spring 2006

***Date range is 11/22/2003 - 05/05/2010

The highest shoreline change rates occurred along the blowout reference shoreline segments (C1 and C4), the off-bank treatment shoreline segments (J1, J2, and J3), and the blowout treatment shoreline segments (V2, and V3). There were still gains for the remaining treatment types but not as large, while the off-bank reference shoreline segments experienced a loss (table 1; figure 5).

Interestingly, off-bank reference shorelines C2 and C3 both experienced negative shoreline changes (table 1). Shoreline erosion was visually confirmed and documented in the 2008 vegetation assessment as evidenced by the loss of the two marsh plots on the eastern transect (TE41-532R) of C2, one marsh plot on the western transect (TE41-530R), and fifty percent of the marsh plot closest to the shoreline on the middle transect (TE41-531R) to open water. For reference C3, erosion claimed both marsh plots along its western transect (TE41-518R).

The average change rate for the three fencing treatment shoreline segments was low because F3 was the only segment to prograde. The F3 shoreline segment had a very similar orientation

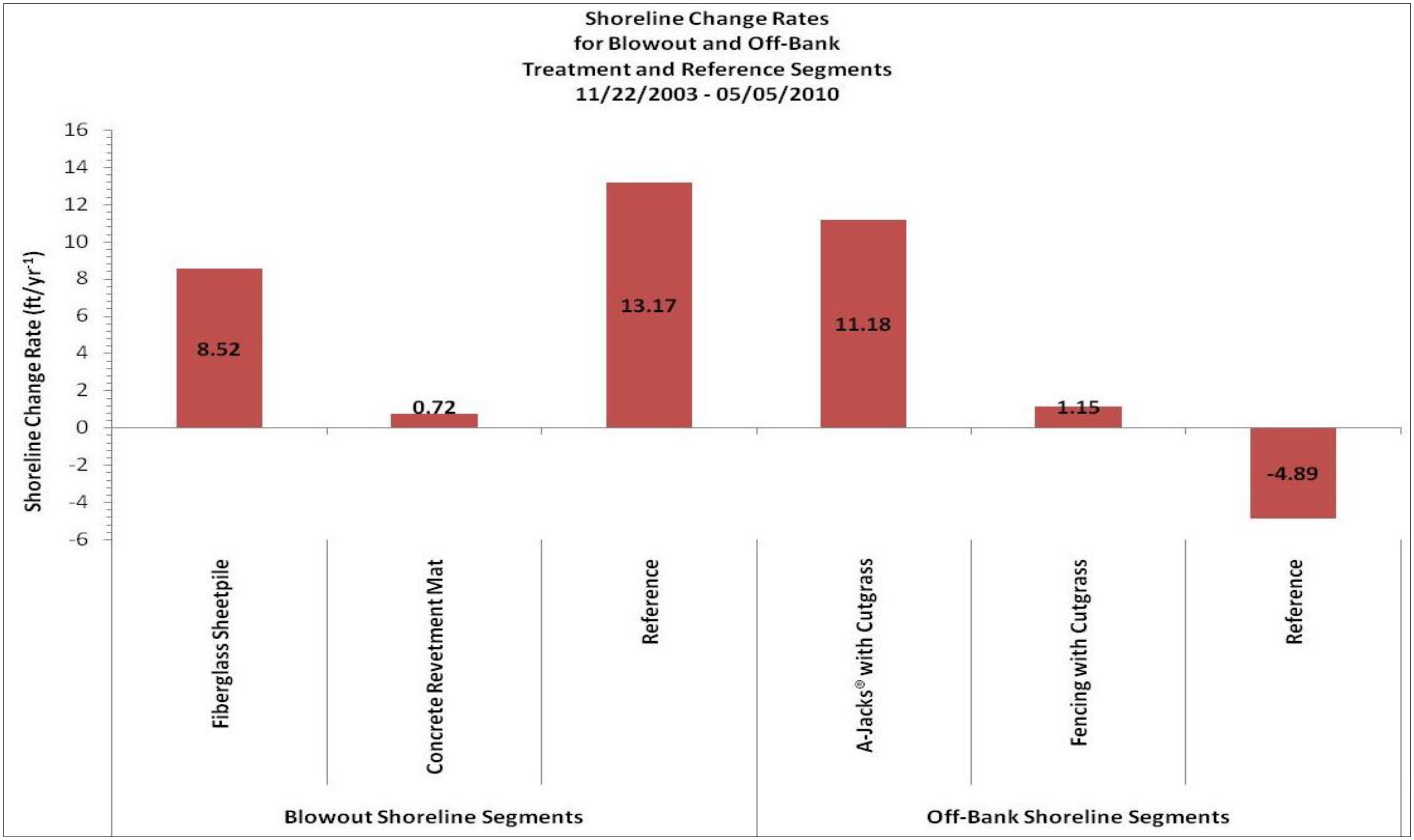


Figure 5. Average shoreline change rate by treatment and reference shoreline segments, for the Mandalay Bank Protection Demonstration (TE-41) project.

and location to the J1 and J2 segments which may have contributed to its success. One factor which differed between the two was that the planted species behind the F3 fencing was scattered in its configuration rather than in a solid line along the original shoreline.

The blowout shoreline segments associated with the fiberglass sheetpile treatments and the concrete revetment mat treatments had positive average shoreline change rates, however they were less than the rates for the blowout reference shoreline segments. The shape and distance from the open waterway may have contributed to the success of the two blowout references (C1 and C4). Both shoreline segments were located a distance from the waterway inside of large open features. The change rates for the concrete revetment mat replicates (R1, R2, and R3) were comparatively lower than the reference blowouts.

**Elevation**

Goal #2: Increase elevation in shallow open water behind treatments along the GIWW

The Mandalay Bank Protection Demonstration (TE-41) project area experienced small volume reductions since construction was completed in 2003. Elevation change and volume distributions for the TE-41 project area are shown in figure 6 (December 2003-October 2005) and figure 7 (December 2003-June 2010). Elevation grid models for the December 2003, October 2005, and June 2010 surveys are also provided in appendix D. During this post-construction period, sediment volume decreased by 12,859 $yd^3$ (9,831 $m^3$) from December 2003 to October 2005 (figure 6) and by 28,085 $yd^3$ (21,473 $m^3$) from December 2003 to June 2010 (figure 7). These volume reductions lowered marsh and channel contours by -0.10 ft (-0.03 m) from 2003 to 2005 and -0.25 ft (-0.08 m) from 2003 to 2010 (figures 6 and 7). Only the grid models for F2, R2, and V1 gained sediment volume from 2003 to 2005. The F2 and R2 grid models gained most of their volume in the center of the GIWW while the V1 elevation change grid model showed small volume increases in the embayment behind the structure and in the GIWW channel (figure 6). Conversely, R3, R1, and C4 grid models recorded the greatest volume losses for the 2003 to 2005 interval. R3 exhibited sediment volume declines in the marsh and in the GIWW channel, R1 displayed its largest sediment volume loss on the eastern edge of this structure due to detachment of the structure from the shoreline, and C4 revealed sediment volume losses in the GIWW channel (figure 6). For the period from 2003 to 2010, C1 (gained at shoreline) and R2 (gained behind structure) gained sediment volume whereas V2 (GIWW channel losses), V3 (losses in channel and at structure), and J2 (loss on small islands in front of structure) had the largest sediment volume losses (figure 7).

The Mandalay Bank Protection Demonstration (TE-41) structure and reference areas sustained differential sedimentation patterns since construction was completed in 2003. The

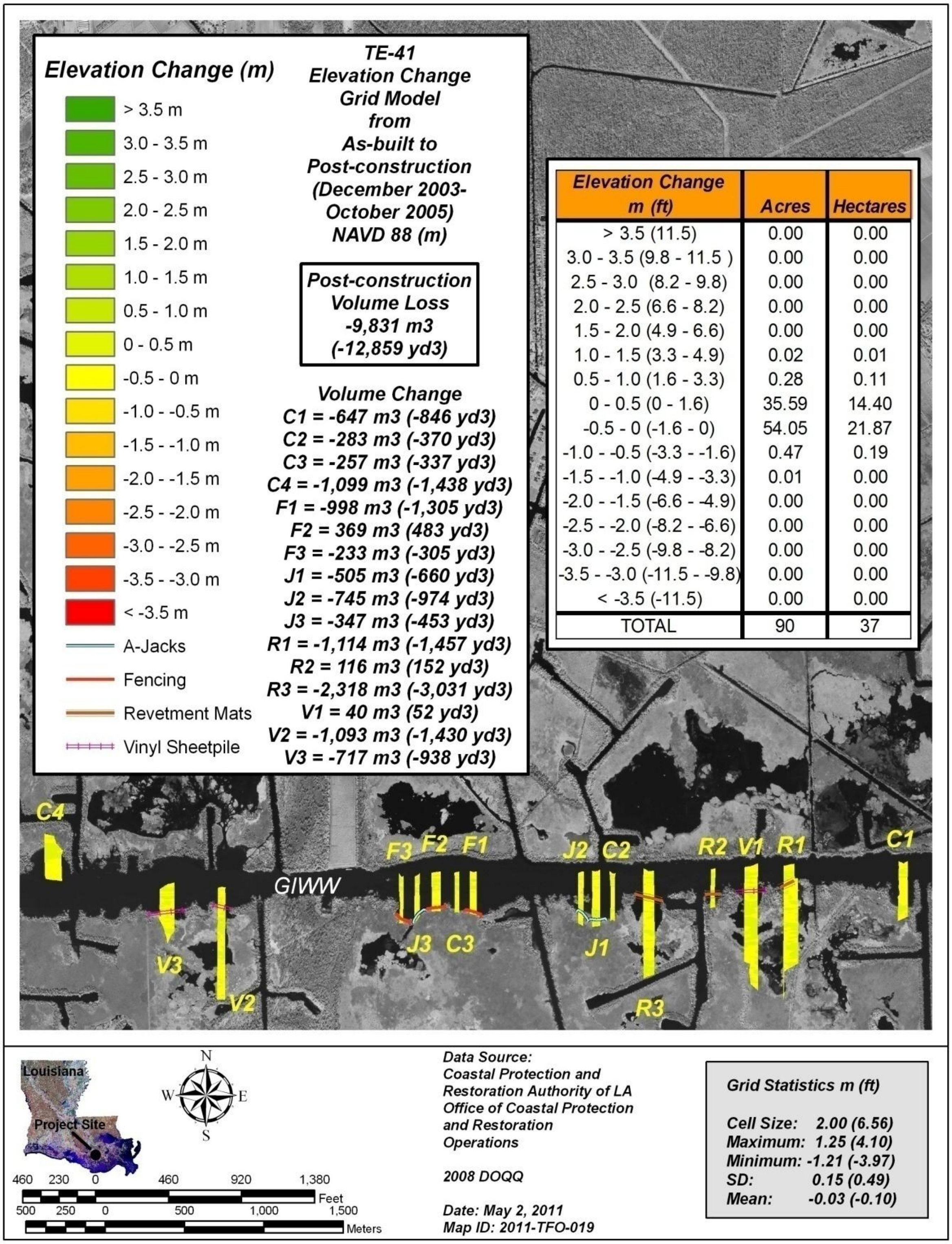


Figure 6. Elevation change and volume distributions from December 2003 through October 2005, for the Mandalay Bank Protection Demonstration (TE-41) project.

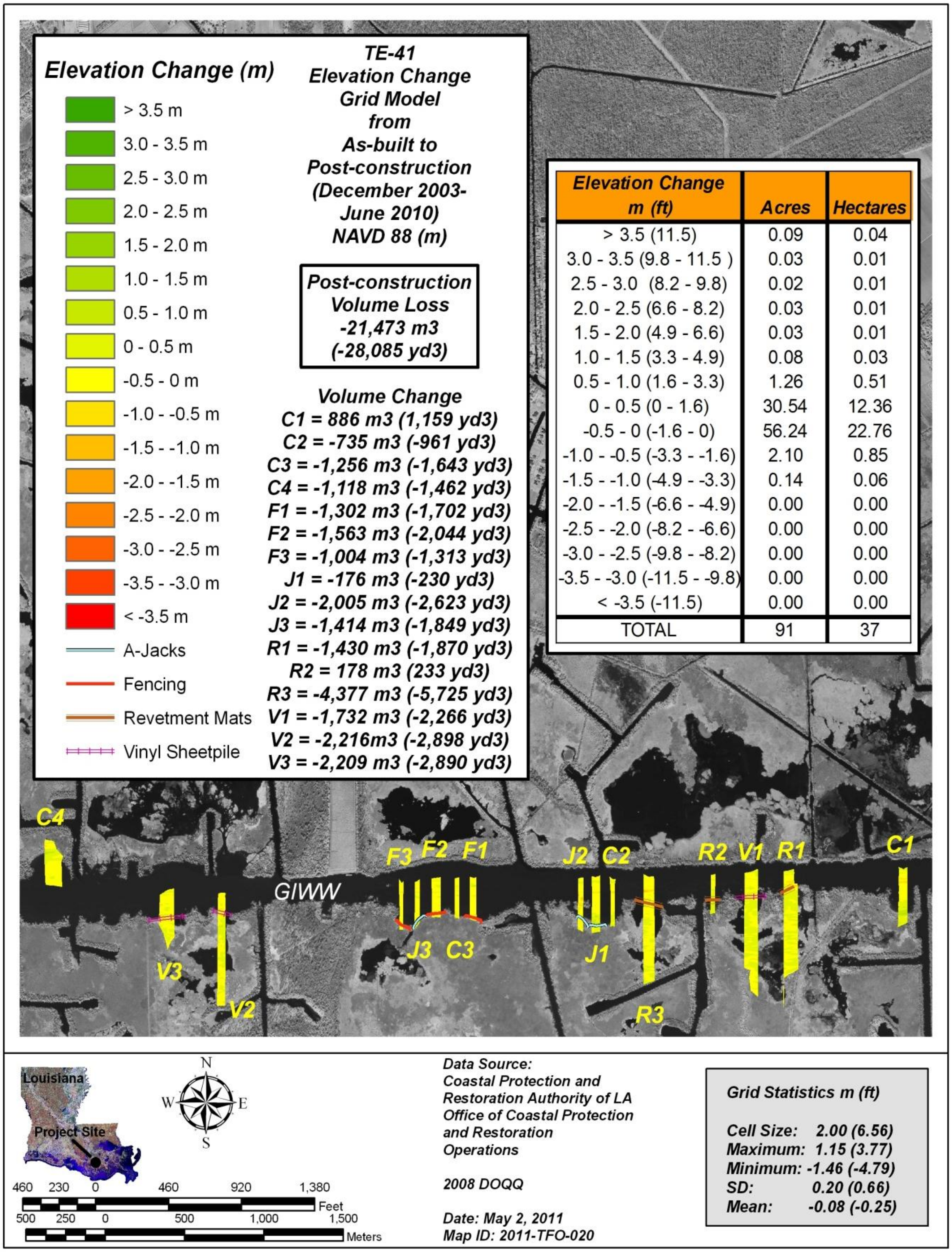


Figure 7. Elevation change and volume distributions from December 2003 through June 2010, for the Mandalay Bank Protection Demonstration (TE-41) project.

initial sedimentation response (2003-2005) to the structures showed nominal elevation changes in the foreshore (in front of the structures) and leeward (behind the structures) positions. At this time, sediments aggraded by 0.01±0.10 ft (0.004±0.03 m) in the foreshore position and 0.10±0.10 ft (0.03±0.03 m) in the leeward position (table 2). Subsequent analysis (2003-2010) of all the structures also revealed that only small changes in sedimentation were occurring in front of and behind the TE-41 structures. The mean elevation changes were -0.03±0.20 ft (-0.01±0.06 m) in the foreshore position and 0.03±0.13 ft (0.01±0.04 m) in the leeward position (table 2). The reference areas also recorded small

Table 2. Mean elevation change in front of (foreshore) and behind (leeward) the Mandalay Bank Protection Demonstration (TE-41) structures from 2003 to 2005 and 2003 to 2010.

| ***Structure*** | ***Foreshore Elevation Change 2003-2005 ft (m)*** | ***Leeward Elevation Change 2003-2005 ft (m)*** | ***Foreshore Elevation Change 2003-2010 ft (m)*** | ***Leeward Elevation Change 2003-2010 ft (m)*** |
|---|---|---|---|---|
| *F1* | -0.66 (-0.20) | -0.16 (-0.05) | -0.26 (-0.08) | -0.62 (-0.19) |
| *F2* | 0.03 (-0.01) | 0.72 (0.22) | -0.10 (-0.03) | -0.13 (-0.04) |
| *F3* | 0.07 (0.02) | 0.33 (0.10) | 0.00 (0.00) | 0.10 (0.03) |
| *J1* | 0.83 (0.26) | 0.43 (0.13) | 1.74 (0.53) | 0.40 (0.12) |
| *J2* | 0.49 (0.15) | -0.16 (-0.05) | -0.30 (-0.09) | -0.23 (-0.07) |
| *J3* | -0.13 (-0.04) | -0.16 (-0.05) | -0.59 (-0.18) | -0.16 (-0.05) |
| *R1* | -0.30 (-0.09) | 0.07 (0.02) | -1.21 (-0.37) | 0.16 (0.05) |
| *R2* | (-0.005) | 0.33 (0.10) | 0.10 (0.03) | 1.08 (0.33) |
| *R3* | -0.30 (-0.09) | 0.03 (0.01) | -0.07 (-0.02) | -0.07 (-0.02) |
| *V1* | 0.13 (0.04) | 0.0003 (0.0001) | 0.13 (0.04) | -0.10 (-0.03) |
| *V2* | 0.03 (0.01) | 0.20 (0.06) | -0.07 (-0.02) | 0.20 (0.06) |
| *V3* | -0.01 (-0.003) | -0.30 (-0.09) | 0.23 (0.07) | -0.40 (-0.12) |
| *Mean* | 0.00 (0.00) | 0.10 (0.03) | -0.03 (-0.01) | 0.03 (0.01) |
| *SE* | 0.10 (0.03) | 0.10 (0.03) | 0.20 (0.06) | 0.13 (0.04) |

increases in sedimentation for the 2003 to 2005 interval with gains of 0.07±0.13 ft (0.02±0.04 m) in the foreshore position and 0.13±0.23 ft (0.04±0.07 m) in the leeward position (table 3). Sedimentation increased in the reference areas for the 2003 to 2010 interval aggradating the foreshore position by 0.33±0.40 ft (0.10±0.12 m) and the leeward position by 0.40±0.49 ft (0.12±0.15 m) (table 3).

The majority of treatment types displayed variable sedimentation responses. The treated lumber fencing [-0.20±0.23 ft (-0.06±0.07 m) (foreshore) and 0.30±0.26 ft (0.09±0.08 m) (leeward)], revetment mat [-0.20±0.10 ft (-0.06±0.03 m) (foreshore) and 0.13±0.10 ft (0.04±0.03 m) (leeward)], fiberglass sheet pile [0.07±0.03 ft (0.02±0.01 m) (foreshore) and -0.03±0.13 ft (-0.01±0.04 m) (leeward)], and off-bank reference area [0.03±0.13 ft (0.01±0.04

Table 3. Mean elevation change in front of (foreshore) and behind (leeward) the Mandalay Bank Protection Demonstration (TE-41) reference areas from 2003 to 2005 and 2003 to 2010.

| *Reference Area* | *Foreshore Elevation Change 2003-2005 ft (m)* | *Leeward Elevation Change 2003-2005 ft (m)* | *Foreshore Elevation Change 2003-2010 ft (m)* | *Leeward Elevation Change 2003-2010 ft (m)* |
|---|---|---|---|---|
| *C1* | -0.16 (-0.05) | 0.40 (0.12) | 1.35 (0.41) | 1.21 (0.37) |
| *C2* | 0.13 (0.04) | -0.20 (-0.06) | 0.26 (0.08) | 0.13 (0.04) |
| *C3* | -0.10 (-0.03) | -0.33 (-0.10) | -0.49 (-0.15) | -0.92 (-0.28) |
| *C4* | 0.36 (0.11) | 0.62 (0.19) | 0.13 (0.04) | 1.12 (0.34) |
| *Mean* | 0.07 (0.02) | 0.13 (0.04) | 0.33 (0.10) | 0.40 (0.12) |
| *SE* | 0.13 (0.04) | 0.23 (0.07) | 0.40 (0.12) | 0.49 (0.15) |

m) (foreshore) and -0.26±0.07 ft (-0.08±0.02 m) (leeward)] treatments alternately demonstrated gains and losses of sediment during the initial response while the a- jacks [0.40±0.30 ft (0.12±0.09 m) (foreshore) and 0.03±0.20 ft (0.01±0.06 m) (leeward)] and blowout reference area [0.10±0.26 ft (0.03±0.08 m) (foreshore) and 0.52±0.13 ft (0.16±0.04 m) (leeward)] treatments exhibited increased sedimentation in both positions. For the 2003 to 2010 period, the sedimentation responses of the treatments were also variable. The revetment mat [-0.40±0.43 ft (-0.12±0.13 m) (foreshore) and 0.40±0.36 ft (0.12±0.11 m) (leeward)] and fiberglass sheet pile [0.10±0.10 ft (0.03±0.03 m) (foreshore) and -0.10±0.16 ft (-0.03±0.05 m) (leeward)] treatments alternately gained and declined in sediment elevation. The treated lumber fencing [-0.13±0.07 ft (-0.04±0.02 m) (foreshore) and -0.23±0.20 ft (-0.07±0.06 m) (leeward)] and the off-bank reference area [-0.13±0.40 ft (-0.04±0.12 m) (foreshore) and -0.40±0.52 ft (-0.12±0.16 m) (leeward)] treatments displayed sediment reductions in all positions. The a-jacks treatment moderately aggraded the foreshore position [0.30±0.72 ft (0.09±0.22 m)] and documented no change in sedimentation in the leeward position. However, all the sedimentation occurring at the a-jacks treatment was the result of shoaling of the J1 replicate. The J2 and J3 replicates did not aggrade any position (table 2). The blowout reference areas showed shoaling in both the foreshore [0.75±0.62 ft (0.23±0.19 m)] and leeward [1.18±0.07 ft (0.36±0.02 m)] positions. Therefore, the blowout reference areas were most successful in promoting sedimentation and raising channel contours. In general, changes in sedimentation at each treatment were the result of large gains or deficits at one replicate while the other replicates recorded small changes in sedimentation.

The shoreline geometry seems to have influenced the sedimentation patterns at the Mandalay Bank Protection Demonstration (TE-41) project. The treatments placed in blowout areas (C1, C4, R1, R2, R3, V1, V2, and V3) and shallow off-bank embayments (C2, J1, and J2) seem to be more efficient at capturing sediments and raising shoreline contours than the treatments placed along the linear segments (C3, F1, F2, F3, and J3) of the shoreline. The treatments in the blowout and embayment areas had a net increase in sedimentation in the foreshore

[0.10±0.10 ft (0.03±0.03 m) (2003-2005) and 0.13±0.10 ft (0.04±0.03 m) (2003-2010)] and leeward [0.20±0.23 ft (0.06±0.07 m) (2003-2005) and 0.33±0.16 ft (0.10±0.05 m) (2003-2010)] positions for both sampling intervals (table 4). Conversely, the linear treatments recorded sediment deficits for the foreshore position from 2003 to 2005 [-0.16±0.13 ft (-0.05±0.04 m)], the foreshore position from 2003 to 2010 [-0.30±0.10 ft (-0.09±0.03 m)], and the leeward position from 2003 to 2010 (-0.11±0.06 m). The leeward position of the linear segments had a small net increase in sedimentation [0.07±0.20 ft (0.02±0.06)] for the 2003-2005 interval (table 5). Therefore, trends in the data show that shoreline geometry influenced sedimentation in front of and behind the TE-41 treatments.

Table 4. Mean elevation change for treatment and reference segments along blowouts and off-bank embayments at the Mandalay Bank Protection Demonstration (TE-41) project.

| ***Treatment*** | ***Foreshore Elevation Change 2003-2005 ft (m)*** | ***Leeward Elevation Change 2003-2005 ft (m)*** | ***Foreshore Elevation Change 2003-2010 ft (m)*** | ***Leeward Elevation Change 2003-2010 ft (m)*** |
|---|---|---|---|---|
| *C1* | -0.16 (-0.05) | 0.40 (0.12) | 1.35 (0.41) | 1.21 (0.37) |
| *C2* | 0.13 (0.04) | -0.20 (-0.06) | 0.26 (0.08) | 0.13 (0.04) |
| *C4* | 0.36 (0.11) | 0.62 (0.19) | 0.13 (0.04) | 1.12 (0.34) |
| *J1* | 0.83 (0.26) | 0.43 (0.13) | 1.74 (0.53) | 0.40 (0.12) |
| *J2* | 0.49 (0.15) | -0.16 (-0.05) | -0.30 (-0.09) | -0.23 (-0.07) |
| *R1* | -0.30 (-0.09) | 0.07 (0.02) | -1.21 (-0.37) | 0.16 (0.05) |
| *R2* | -0.02 (-0.005) | 0.33 (0.10) | 0.10 (0.03) | 1.08 (0.33) |
| *R3* | -0.30 (-0.09) | 0.03 (0.01) | -0.07 (-0.02) | -0.07 (-0.02) |
| *V1* | 0.13 (0.04) | 0.0003 (0.0001) | 0.13 (0.04) | -0.10 (-0.03) |
| *V2* | 0.03 (0.01) | 0.20 (0.06) | -0.07 (-0.02) | 0.20 (0.06) |
| *V3* | -0.01 (-0.003) | -0.30 (-0.09) | 0.23 (0.07) | -0.40 (-0.12) |
| *Mean* | 0.10 (0.03) | 0.13 (0.04) | 0.20 (0.06) | 0.33 (0.10) |
| *SE* | 0.10 (0.03) | 0.10 (0.03) | 0.23 (0.07) | 0.16 (0.05) |

Table 5. Mean elevation change for treatment and reference segments placed along linear segments of the shoreline at the Mandalay Bank Protection Demonstration (TE-41) project.

| *Treatment* | *Foreshore Elevation Change 2003-2005 ft (m)* | *Leeward Elevation Change 2003-2005 ft (m)* | *Foreshore Elevation Change 2003-2010 ft (m)* | *Leeward Elevation Change 2003-2010 ft (m)* |
|---|---|---|---|---|
| *C3* | -0.10 (-0.03) | -0.33 (-0.10) | -0.49 (-0.15) | -0.92 (-0.28) |
| *F1* | -0.66 (-0.20) | -0.16 (-0.05) | -0.26 (-0.08) | -0.62 (-0.19) |
| *F2* | 0.03 (-0.01) | 0.72 (0.22) | -0.10 (-0.03) | -0.13 (-0.04) |
| *F3* | 0.07 (0.02) | 0.33 (0.10) | 0.00 (0.00) | 0.10 (0.03) |
| *J3* | -0.13 (-0.04) | -0.16 (-0.05) | -0.59 (-0.18) | -0.16 (-0.05) |
| *Mean* | -0.16 (-0.05) | 0.07 (0.02) | -0.30 (-0.09) | -0.36 (-0.11) |
| *SE* | 0.13 (0.04) | 0.20 (0.06) | 0.10 (0.03) | 0.20 (0.06) |

Goal #7: Evaluate the integrity of the structures associated with treatments in selected areas along the GIWW

The Mandalay Bank Protection Demonstration (TE-41) structures have incurred differences in secondary settlement since construction was completed in 2003. The treated lumber fencing and fiberglass sheet pile structures did not sustain any secondary settlement. The fencing structures experienced very small increases in elevation from 2003 to 2005 [0.036±0.016 ft (0.011±0.005 m)] and 2003 to 2010 [0.010±0.020 ft (0.003±0.006 m)]. Likewise the fiberglass sheet pile structures also had a nominal elevation increase [0.007±0.036 ft (0.002±0.011 m)] from 2003 to 2005 and settlement [-0.003±0.043 ft (-0.001±0.013 m)] from 2003 to 2010. These minimal elevation differences are probably the result of small survey position errors and infer that the treated lumber fencing and fiberglass sheet pile structures are maintaining their vertical position and are not settling. In contrast, the revetment mat and a-jacks structures did sustain some secondary settlement. The revetment mat structures settled -0.118±0.049 ft (-0.036 ± 0.015 m) from 2003 to 2005 and -0.417±0.180 ft (-0.127±0.055 m) from 2003 to 2010 while the a-jacks structures settled -0.725±0.184 ft (-0.221 ±0.056 m) from 2003 to 2005 and -0.866±0.194 ft (-0.264±0.059 m) from 2003 to 2010. Therefore, the a-jacks structures settled at twice the rate of the revetment mat structures. These results are not that surprising because the a-jacks were the heaviest structure installed followed by the revetment mats and these structures produced a greater overburden on the underlying soils than the treated lumber fencing and fiberglass sheet pile structures.

## Vegetation

Vegetation cover and species composition data were collected from 234 stations established along 48 transects during the fall of 2001, 2002, 2003, and 2005 (appendix C, figures 1-7).

Data analysis results and discussions for species reported inside the 6.6 ft (2 m) x 6.6 ft (2 m) station plots are presented in this report (figures 8 - 11).

Goal #5: Increase mean cover of emergent vegetation within shallow open water blowouts along the GIWW

Vegetation sampling targeted emergent vegetation rooted in the marsh substrate. *Eichhornia crassipes* (Mart.) Solms (water hyacinth) is a floating aquatic which was reported in numerous open-water blowout plots as well as in some off-bank marsh plots. Though this species was included in the "others" category during data analysis, it occurred in large transient floating mats in the open-water plots. Its occurrence in plots on the marsh surface was due to high water events which deposited it when the water receded.

Blowout Treatment and Reference Areas:

The relative mean percent cover of bare ground for fiberglass sheetpile treatment areas and the associated blowout reference areas increased in 2002 but substantially decreased by 2005 (figure 8). The relative mean cover for all species combined increased from 20% in 2002 to 78% in 2005. In the treatment vegetation plots, species diversity increased from 22 to 25 reported species between 2001 and 2002, respectively. The number of reported species decreased in 2003 to 23 but substantially increased to 38 species in 2005.

The relative mean percent cover of bare ground for concrete revetment mat treatment areas and the associated blowout reference areas increased in 2002 but substantially decreased by 2005 (figure 9). *Salix nigra* Marsh. consistently had the highest relative cover for any species in this treatment type between 2001 and 2005. This is probably because most of the plots for the blowout treatments were in open water yet the majority of vegetated plots were shoreline plots which ended up on or near spoil banks with a heavy tree canopy. In the treatment vegetation plots, diversity steadily increased from 16 species in 2001 to 31 species in 2005, along with a substantial increase in relative mean vegetative cover for all species combined from approximately 25% in 2002 to 70% in 2005.

In the blowout reference plots, species diversity increased from 7 species in 2002 to 17 species in 2003 and 16 species in 2005 (figures 8-9). Although the reported number of species remained similar in the reference plots, the relative mean vegetative cover for all species combined increased from 19% in 2002 to 57% in 2005. The majority of vegetated plots in the reference blowouts were on floating marsh shorelines with no tree cover, unlike the treatment blowouts.

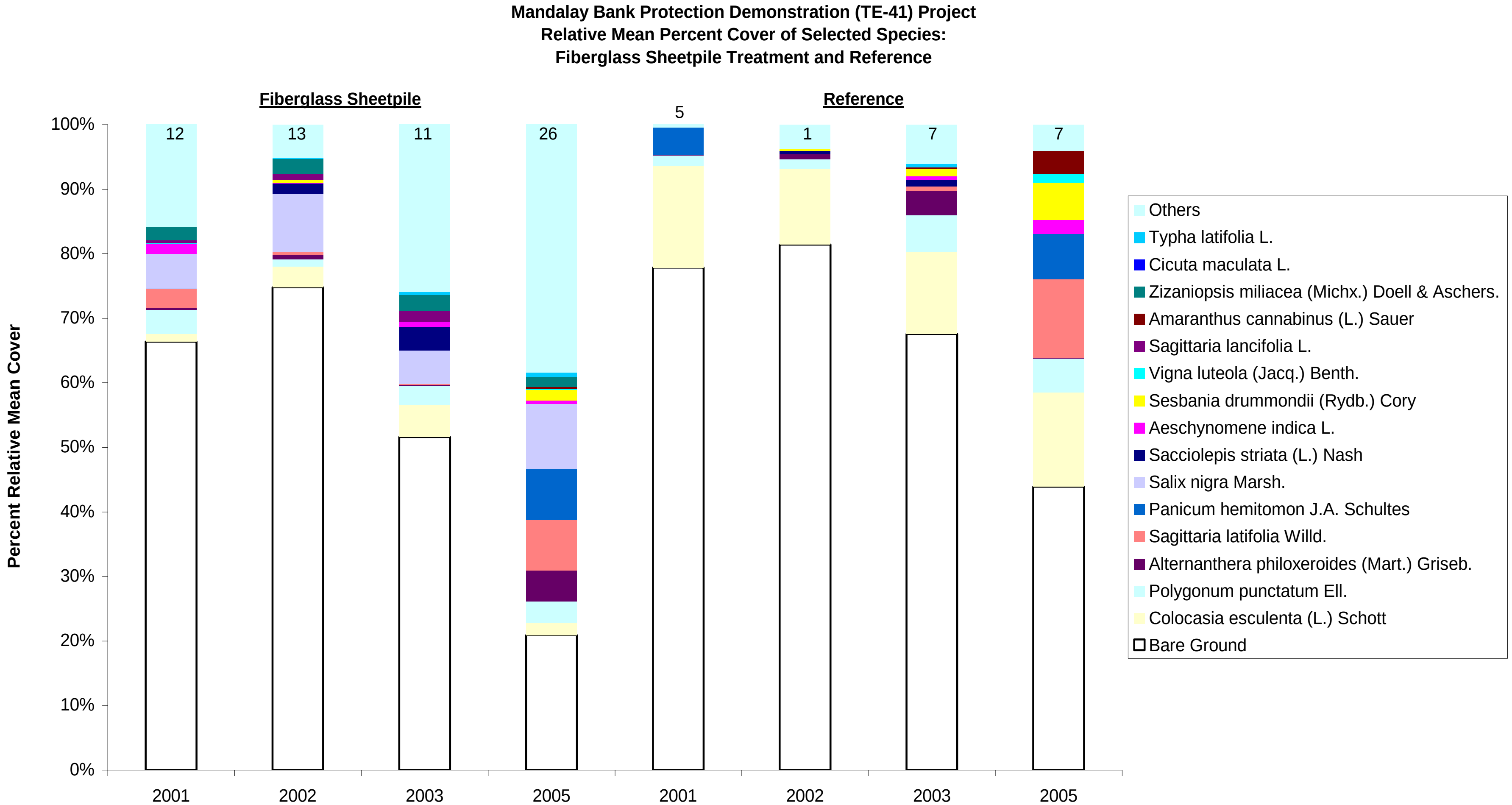


Figure 8. Relative mean percent cover of selected species inside the 2m x 2m Braun-Blanquet vegetation plots in blowouts for the Mandalay Bank Protection Demonstration (TE-41) project where years 2001 and 2002 represent pre-construction data, year 2003 represents as-built data, and year 2005 represents two years post-construction.

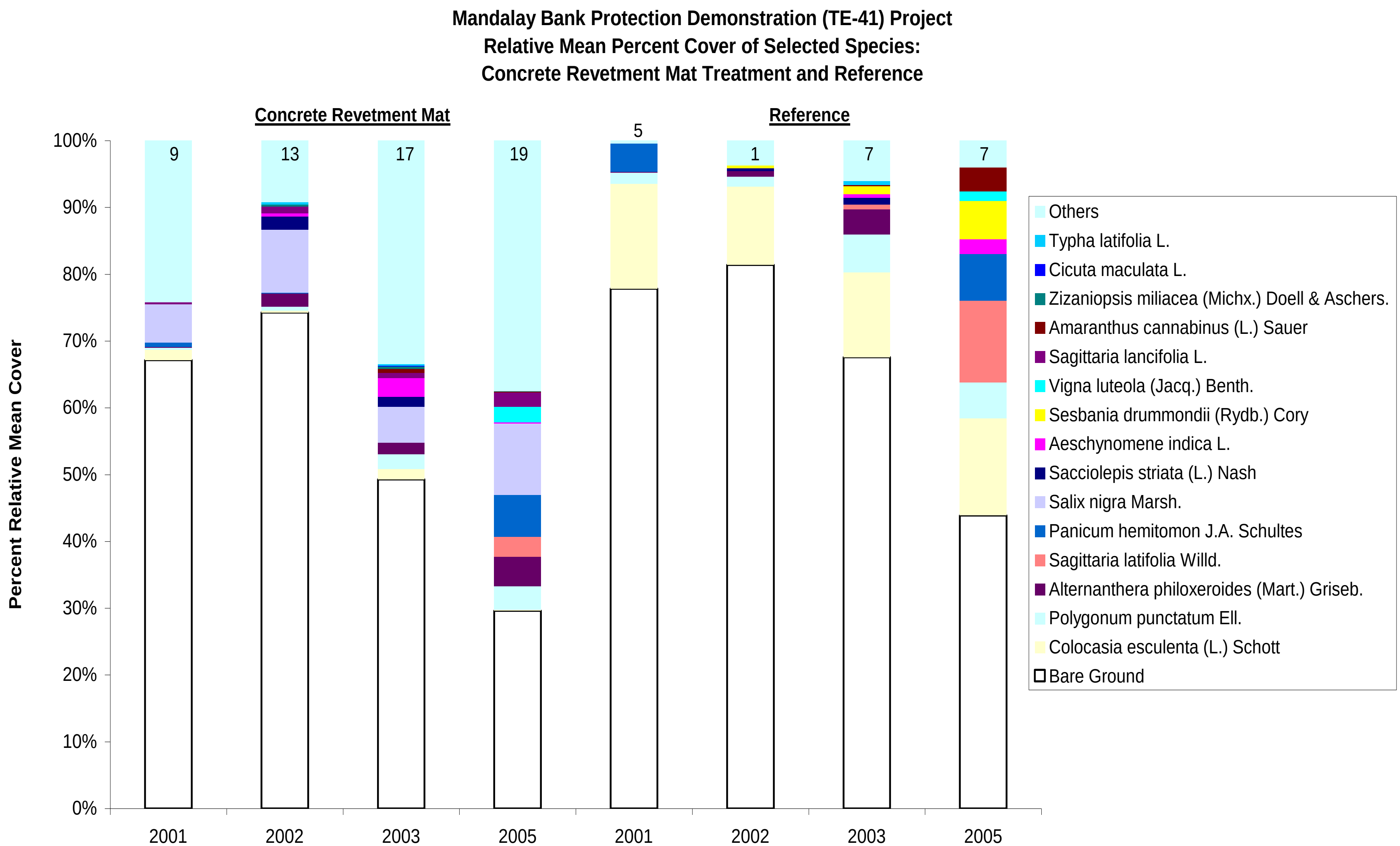


Figure 9. Relative mean percent cover of selected species inside the 2mx2m Braun-Blanquet vegetation plots in blowouts for the Mandalay Bank Protection Demonstration (TE-41) project where years 2001 and 2002 represent pre-construction data, year 2003 represents as-built data, and year 2005 represents two years post-construction.

Off-bank Treatment and Reference Areas:

For the fencing with cutgrass treatments, relative mean vegetative cover increased from a low of 29% in 2002 to high of 72% in 2005 while the species diversity increased from 19 in 2002 to 25 in 2005 (figure 10).

Relative mean vegetative cover for the A-Jacks® with cutgrass treatments steadily and substantially increased from approximately 63% to approximately 88% between 2001 and 2005 (figure 11). The number of species reported between 2001 and 2005 increased from 18 to 24 species with a slightly higher number of 26 reported during the 2003 sampling period.

In the off-bank reference areas species diversity increased from 20 reported species in 2001 to 28 species in 2005 (figures 10-11). Overall, relative mean vegetative cover remained stable from 2001 at approximately 64% to approximately 68% in 2005.

Relative percent cover of bare ground in all treatment and reference areas tended to exhibit similar patterns from one sampling period to the next, with the exception of the off-bank treatment fencing with cutgrass in 2002. In this case, more plots of this treatment type were either washed out or partially eroded when compared to the A-Jacks® treatments with no eroded plots. Also, the shoreline along the fencing treatments was mostly bare ground and badly balled up in most of the plots. Some of those fencing treatment plots also had large wracks of storm debris inside of them. Since the project structures were not installed until 2003, the possibility exists that the storm effects from Hurricane Lili coupled with shoreline orientation may have had some bearing on the cover values.

Though cover estimates could not be documented in 2008 due to a monitoring budget shortfall, species composition was documented in the fall for the entire project area along the vegetation transects, but not inside of individual plots already established from prior years. Based upon these observations, species composition was compared to the previous data collections (figure 12). All species documented both inside and outside of the vegetation plots within a 15 ft (4.57 m) from years 2001, 2002, 2003, and 2005 were included in this count.

Species diversity for the off-bank treatment and off-bank reference areas dipped slightly in 2002, possibly due to the prolonged drought which ended in 2001, coupled with the damage observed to the marsh from hurricane Lili in 2002. Diversity increased by the time of construction in 2003. In 2005, two years post-construction, it increased in the reference areas, yet decreased inside the treatment areas, though it was still more diverse than the years previous to construction. Finally, the lowest species diversity occurs in 2008, five years post-construction. Though qualitative field observations indicated healthy vegetative cover in

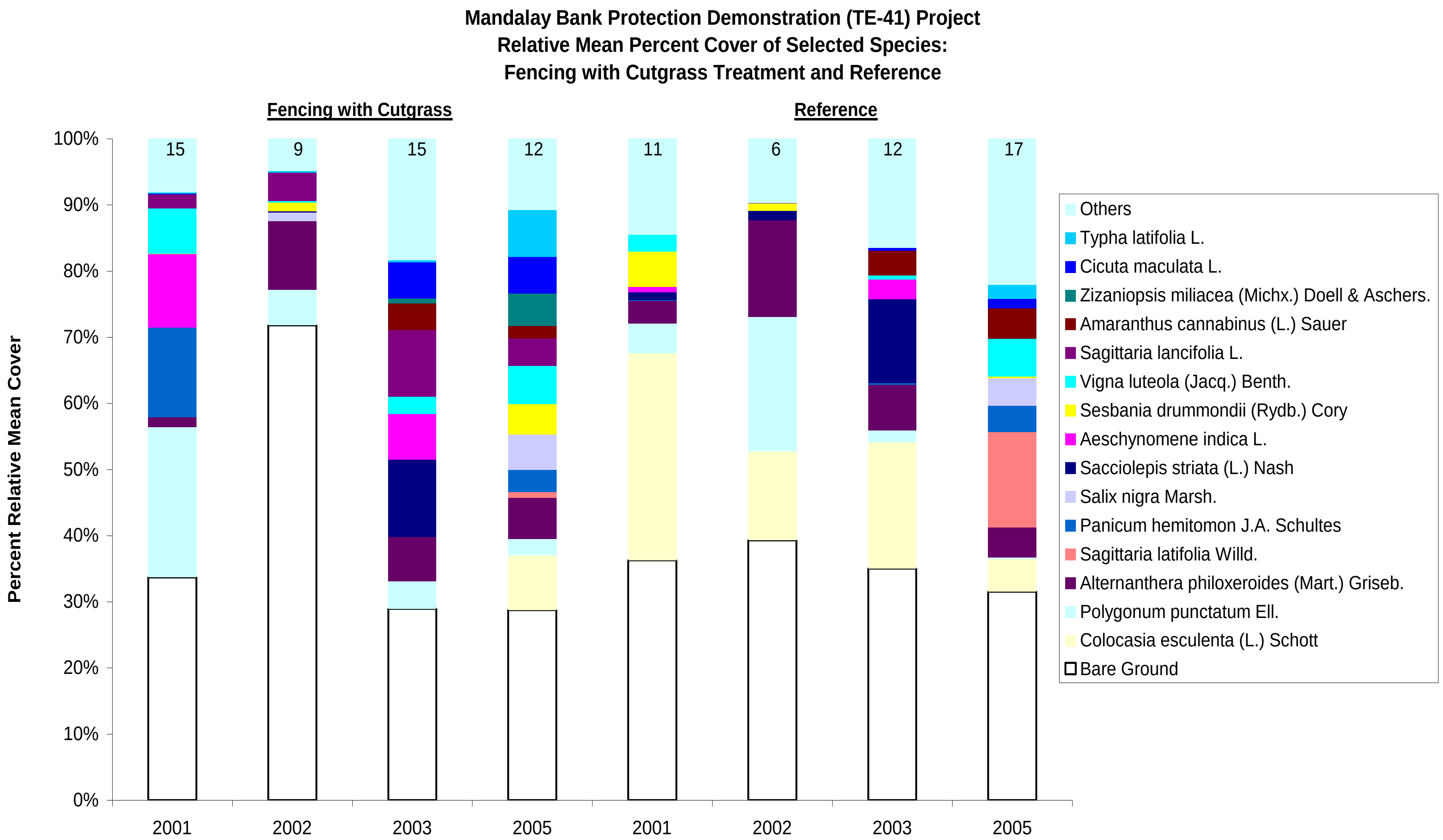


Figure 10. Relative mean percent cover of selected species inside the 2m x 2m Braun-Blanquet vegetation plots for off-bank areas for the Mandalay Bank Protection Demonstration (TE-41) project where years 2001 and 2002 represent pre-construction data, year 2003 represents as-built data, and year 2005 represents two years post-construction.

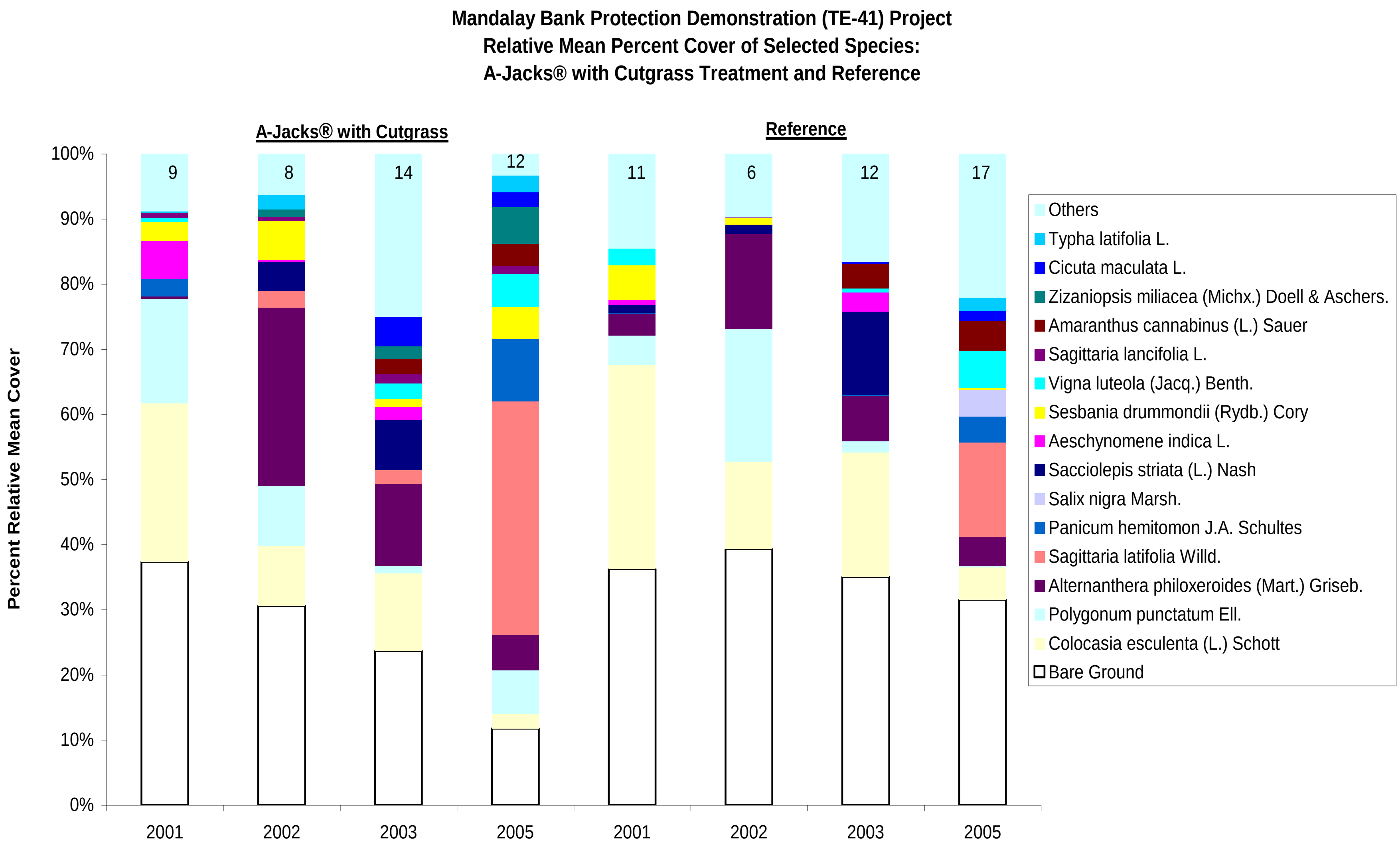


Figure 11. Relative mean percent cover of selected species inside the 2m x 2m Braun-Blanquet vegetation plots for off-bank areas for the Mandalay Bank Protection Demonstration (TE-41) project where years 2001 and 2002 represent pre-construction data, year 2003 represents as-built data, and year 2005 represents two years post-construction.

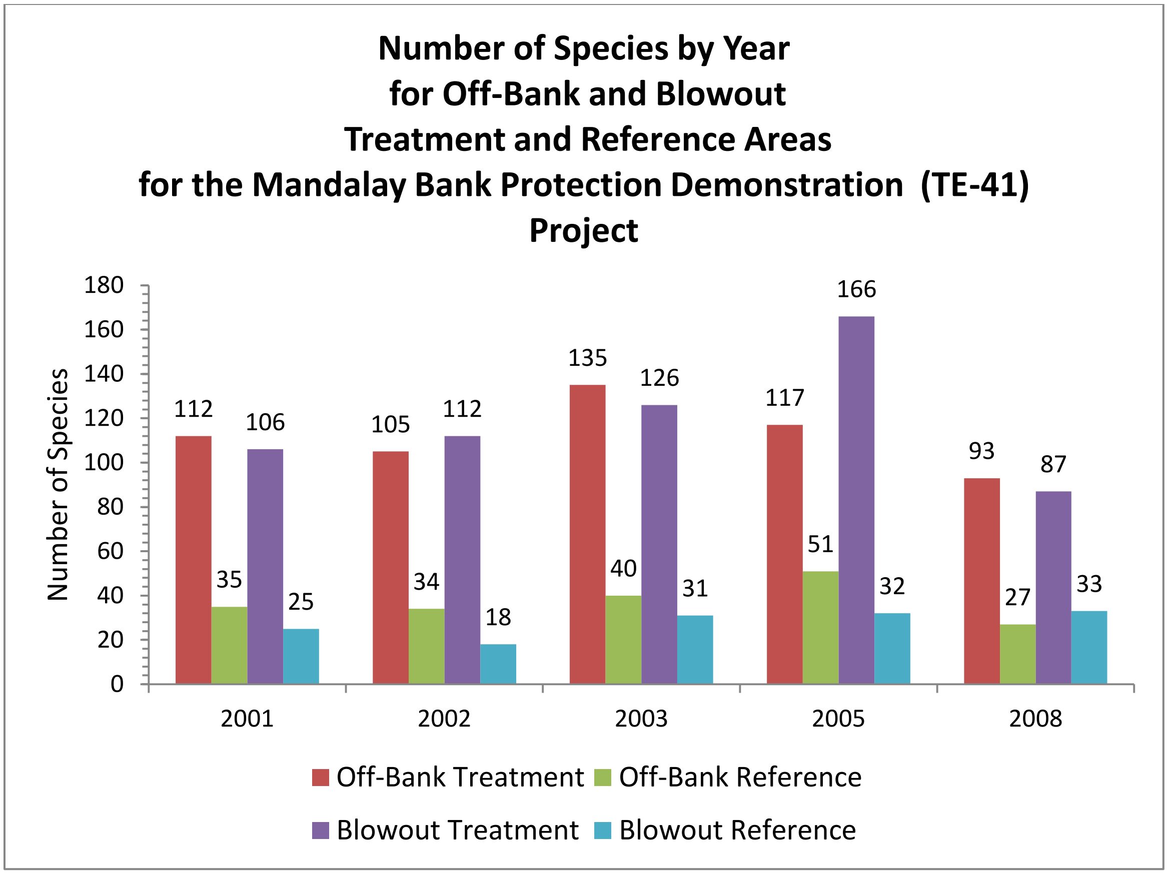


Figure 12. The total number of emergent vegetation species documented along vegetation transects of the off-bank and blowout treatment and reference areas for the Mandalay Bank Protection Demonstration (TE-41) project.

2008, it is possible that hurricanes Gustav and Ike had some effect on species diversity in these areas.

For the blowout treatments species diversity steadily increased from 2001 through 2005 where it peaked, then sharply decreased by 2008. The reference areas followed a similar trend through 2003, however it appears diversity remained the same after construction. The 2005 vegetation sampling schedule straddled the time period between the landfalls of hurricanes Katrina and Rita. The majority of the data for the blowout treatments was collected prior to Rita's landfall, while most of the data for off-bank treatment areas was collected following her landfall. This may explain why diversity was so high for the blowout treatment and reference areas. Based upon field observations, damage from Katrina's landfall two weeks prior to the 2005 vegetation sampling was not as marked as were Rita's impacts due to the prolonged exposure of lower Terrebonne parish marshes to high water levels and high winds. Katrina's landfall had greater impacts to the east of Terrebonne parish, while Rita pushed wind and water from offshore on its trek to the western portion of the state.

## Percent Survival

In order to determine if the planted species *Z. miliacea* (Michx.) Doell & Aschers increased in cover, percent cover and percent survival data was collected in the fall 2003 (N = 18 plots) one month post-planting, and in the fall 2005 (N = 17) two years post-planting. Only the treatments with plantings required this type of data collection (table 6). Comparative analysis between the existing data is presented in this report (tables 7-9).

Goal #4: Increase mean cover of Z.miliacea to 50% or greater after five growing seasons in planted areas adjacent to eroding shorelines of the GIWW

Table 6. 2003 and 2005 stations where percent survival data were collected in addition to percent cover and species composition data.

| Treatments | 2003 Stations | 2005 Stations |
|---|---|---|
| F1 | TE41-164, TE41-165, TE41-166 | TE41-164, TE41-165, TE41-166 |
| F2 | TE41-170, TE41-171, TE41-172 | TE41-170, TE41-171, TE41-172 |
| F3 | TE41-176, TE41-177, TE41-184 | TE41-176, TE41-177, TE41-184 |
| J1 | TE41-158, TE41-159, TE41-160 | TE41-158, TE41-159, TE41-160 |
| J2 | TE41-161, TE41-162, TE41-163 | TE41-161, TE41-163 |
| J3 | TE41-173, TE41-174, TE41-175 | TE41-173, TE41-174, TE41-175 |

*TE41-162 could not be relocated due to missing corner pole therefore it was inactivated.

Table 7. Percent survival of planted giant cutgrass inside of fencing and A-Jacks® treatments for fall 2003 vegetation monitoring one month post-planting.

| Fencing with Giant Cutgrass | | | | A-Jacks with Giant Cutgrass | | | |
|---|---|---|---|---|---|---|---|
| Treatment | Planted | Alive | Percent Survival | Treatment | Planted | Alive | Percent Survival |
| F1 | 24 | 9 | 37.5 | J1 | 18 | 12 | 66.7 |
| F2 | 24 | 9 | 37.5 | J2 | 24 | 11 | 45.8 |
| F3 | 27 | 12 | 44.4 | J3 | 18 | 3 | 16.7 |
| Total | 75 | 30 | 40 | Total | 60 | 26 | 43.3 |

Table 8. Percent survival of planted giant cutgrass inside of fencing and A-Jacks® treatments for fall 2005 vegetation monitoring one month post-planting.

| Fencing with Giant Cutgrass | | | | A-Jacks with Giant Cutgrass | | | |
|---|---|---|---|---|---|---|---|
| Treatment | Planted | Alive | Percent Survival | Treatment | Planted | Alive | Percent Survival |
| F1 | 24 | 1 | 4.2 | J1 | 18 | Indeterminate | Indeterminate |
| F2 | 24 | 1 | 4.2 | J2 | 24 | ? | ? |
| F3 | 27 | 7 | 25.9 | J3 | 18 | 1 | 5.6 |
| Total | 75 | 9 | 12 | Total | 60 | ? | ? |

The percent survival of planted giant cutgrass inside the fencing treatments decreased by 28% between the two sampling periods (tables 7-8). Percent survival of planted giant cutgrass inside the A-Jacks® treatments could not be determined for two reasons. First, the planted species inside of treatment J1 station TE41-158 grew into a solid line so that the parent plants could not be distinguished from the newer ones making a count impossible. Second, the exact location of station TE41-162 inside of treatment J2 could not be determined during the 2005 sampling period due to a missing corner pole. This station was inactivated and data was not collected.

Vegetation stations used to analyze plant survival were also analyzed for the mean percent cover of *Z. miliacea* (Michx.) Doell & Aschers (giant cutgrass). The A-Jacks® treatment had a higher average percent cover than the fencing (table 9). The monitoring goal was to achieve 50% cover by year 2008. Mean cover was not documented in 2008 due to monitoring funds shortfalls, therefore it could not be determined if this goal was met.

Table 9. Mean percent (%) cover of giant cutgrass inside of established vegetation plots located behind the structures.

| Fencing with Giant Cutgrass | | | A-Jacks with Giant Cutgrass | | |
|---|---|---|---|---|---|
| **Treatment** | **2003** | **2005** | **Treatment** | **2003** | **2005** |
| F1 | 0 | 8.33 | J1 | 0 | 53.33 |
| F2 | 1.67 | 0.67 | J2 | 0 | 5 |
| F3 | 6.67 | 23.33 | J3 | 0 | 13.33 |
| Average | 2.78 | 10.78 | Average | 0 | 23.89 |

## Submerged Aquatic Vegetation (SAV)

SAV was monitored twice pre-construction in the fall of 2001 and 2002, during the fall of 2003 (as-built), and once post-construction during the fall of 2005. Sampling only occurred in the blowout treatment and blowout reference areas. Table 10 shows a complete list of the species collected by year and treatment/reference.

Goal #3: Maintain/increase the frequency of occurrence of submerged aquatic vegetation (SAV) within shallow open water blowouts along the GIWW

In order to address goal 3, treatment and reference blowouts were analyzed for relative frequency of occurrence of all SAV species for the four years of data collection.

The October 2001 pre-construction sampling period for SAV occurred approximately four months after the end of a drought which lasted roughly from September 1999 through June 2001. The reference blowouts had the highest relative frequency of occurrence of empty pulls, yet they also had the species with the highest relative frequency of occurrence, *V. Americana* Michx. (figure 13). Conversely, the fiberglass sheetpile treatments had the lowest relative frequency of occurrence of empty pulls yet they contained all nine of the species documented across all of the treatment and reference blowouts. Also, out of those nine species, only three occurred inside all blowout treatments and references.

Table 10. Complete species list of SAV species reported during the 2001, 2002, 2003, and 2005 sampling periods for the Mandalay Bank Protection Demonstration (TE-41) project.

| Scientific Name | 2001 | 2002 | 2003 | 2005 |
|---|---|---|---|---|
| Empty Pull | M, S, R | M, S, R | M, S, R | M, S, R |
| Alga | S, R | M, S, R | M, R | M, S |
| Alternanthera philoxeroides (Mart.) Griseb. | | M | S | M, S, R |
| Brasenia schreberi J.F. Gmel. | | | S | |
| Cabomba caroliniana Gray | | M | | M |
| Ceratophyllum demersum L. | M, S, R | M, S, R | M, S, R | M, S |
| Cyperus L. | | S | | |
| Egeria densa Planch. | | R | | |
| Eichhornia crassipes (Mart.) Solms | | R | M, S | M, S, R |
| Hydrilla verticillata (L.f.) Royle | M, S | M, S, R | M, S, R | M, S, R |
| Hydrocotyle umbellata L. | | | | M |
| Lemna minor L. | | | M, S, R | M |
| Limnobium spongia (Bosc) L.C. Rich. Ex Steud | | M | M, S | |
| Luziola fluitans (Michx.) Terrell & H. Robin | | | M | |
| Myriophyllum spicatum L. | M, S | | S | M, S, R |
| Najas guadalupensis (Spreng.) Magnus | | | S | M |
| Nelumbo lutea Willd. | M, S | | M, S | M |
| Nuphar lutea (L.) Sm. | | | M | |
| Oxycaryum cubense (Poepp. & Kunth) Lye | | S | | |
| Paspalum fluitans (Ell.) Kunth | | | M, S | |
| Pistia stratiotes L. | | | | M |
| Potamogeton diversifolius Raf. | | | M | |
| Ruppia maritima L. | M, S, R | M, S, R | M, S, R | |
| Salvinia minima Baker | M, S | M, S, R | M, S | M, S |
| Utricularia L. | S | S | | |
| Vallisneria americana Michx. | M, S, R | M, S, R | M, S, R | M, S, R |

Note: M represents Revetment Mat, S represents Fiberglass Sheetpile, and R represents Reference

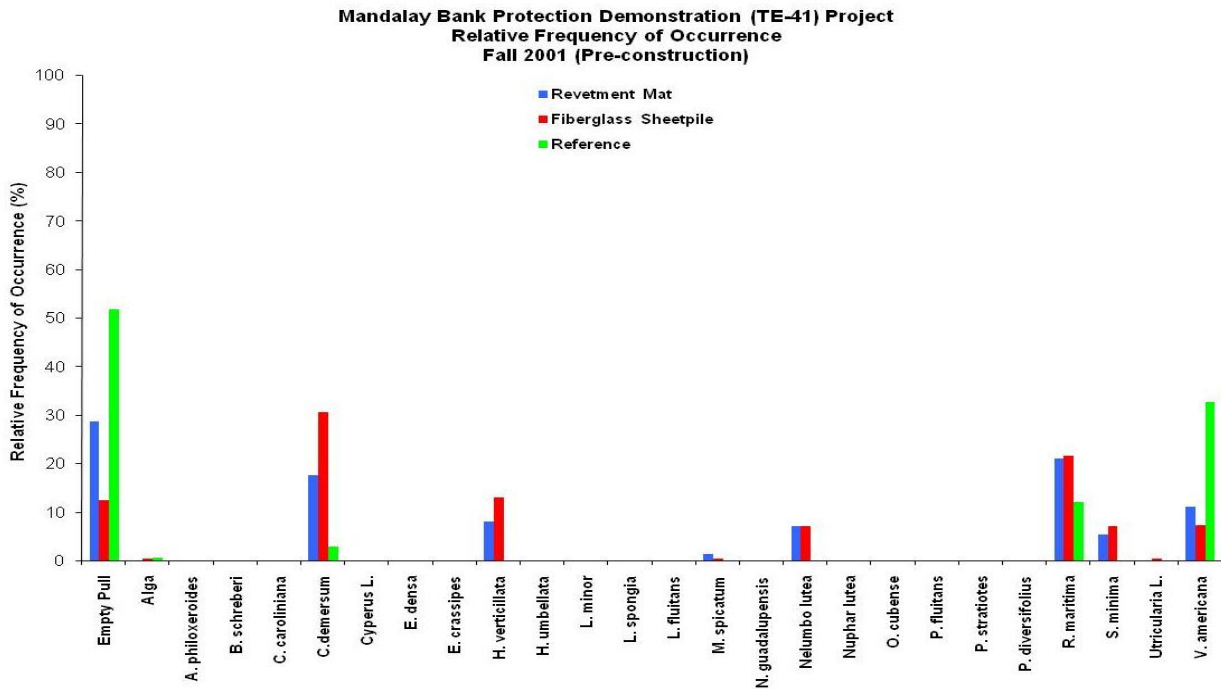


Figure 13. Relative frequency of occurrence of SAV in 2001 for the Mandalay Bank Protection Demonstration (TE-41) project.

The November 2002 pre-construction sampling period for SAV occurred shortly after hurricane Lili made landfall. Like the 2001 sampling period, the highest relative frequency of occurrence of empty pulls was in the reference blowouts (figure 14), as well as the species with the highest relative frequency of occurrence, *V. americana* Michx. Interestingly, in the reference blowouts the empty pulls occurred at a higher relative frequency than in 2001 and *V. americana* Michx. occurred at a lower relative frequency. The lowest relative frequency of occurrence of empty pulls was in the revetment mat treatments, yet this was almost two times higher than in 2001. Out of the 14 reported species during the 2002 sampling period, six of those occurred inside all blowout treatments and references.

The first post-construction sampling period was in 2003. The highest relative frequency of occurrence of empty pulls was inside the reference blowouts, approximately 16% higher than the 2002 sampling period (figure 15) however, unlike the previous two sampling periods, relative frequency of occurrence of *V. Americana* Michx. was lowest in the blowout references. This species still had the highest relative frequency of occurrence but this was inside the fiberglass sheetpile treatments. The revetment mat and fiberglass sheetpile treatment blowouts both had the lowest relative frequency of occurrence of empty pulls, and both had more than twice the total number of species documented in 2003. Out of 18 reported species, five of those occurred across all blowout treatments and references.

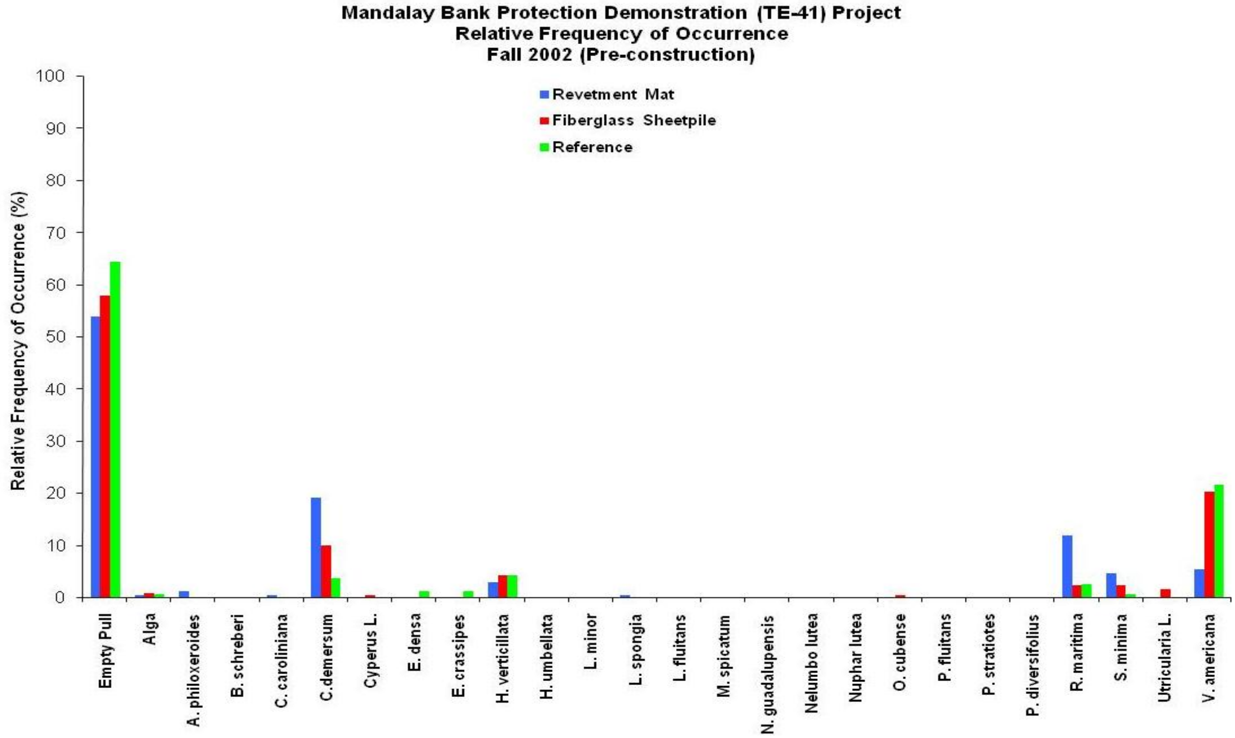


Figure 14. Relative frequency of occurrence of SAV in 2002 for the Mandalay Bank Protection Demonstration (TE-41) project.

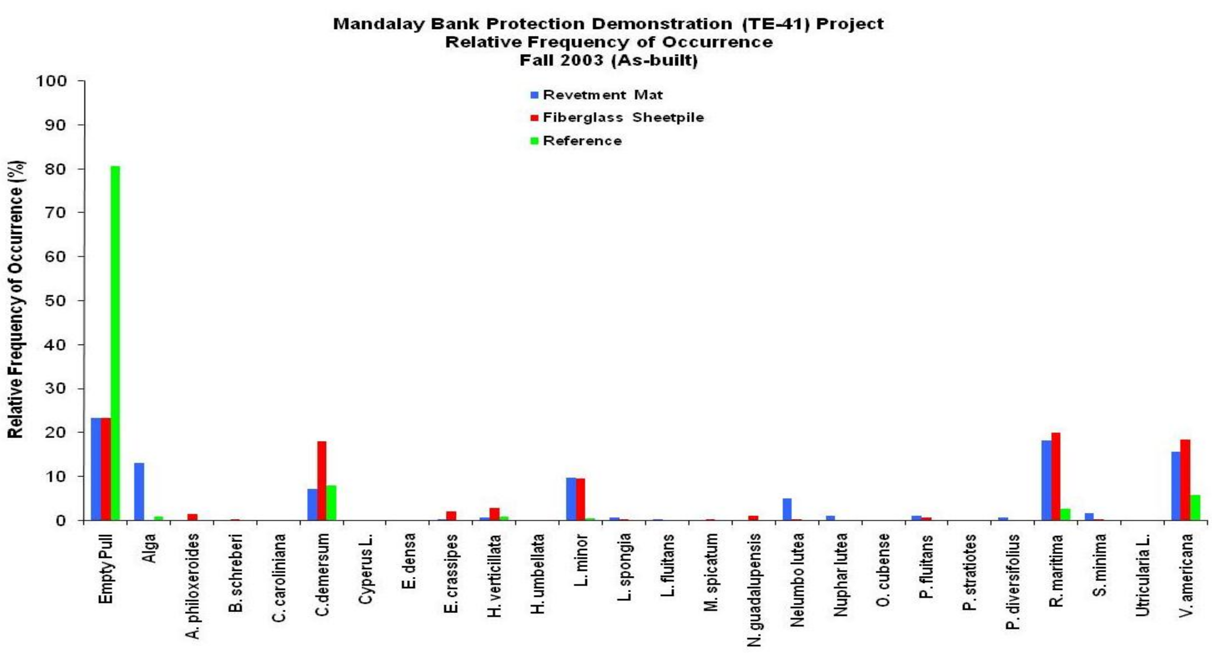


Figure 15. Relative frequency of occurrence of SAV in 2003 for the Mandalay Bank Protection Demonstration (TE-41) project.

Two major hurricanes, Katrina and Rita, made landfall just prior to the October 2005 post-construction sampling period. The highest relative frequency of occurrence of empty pulls was once again inside the reference blowouts, approximately 13% higher than the 2003 sampling period (figure 16). There was also a marked increase in empty pulls inside the concrete revetment mat and fiberglass sheetpile treatments. The species with the highest relative frequency of occurrence was *C. demersum* L. inside the fiberglass sheetpile treatments. Out of the 14 reported species, five of those occurred across all blowout treatments and reference blowouts during the 2005 sampling period.

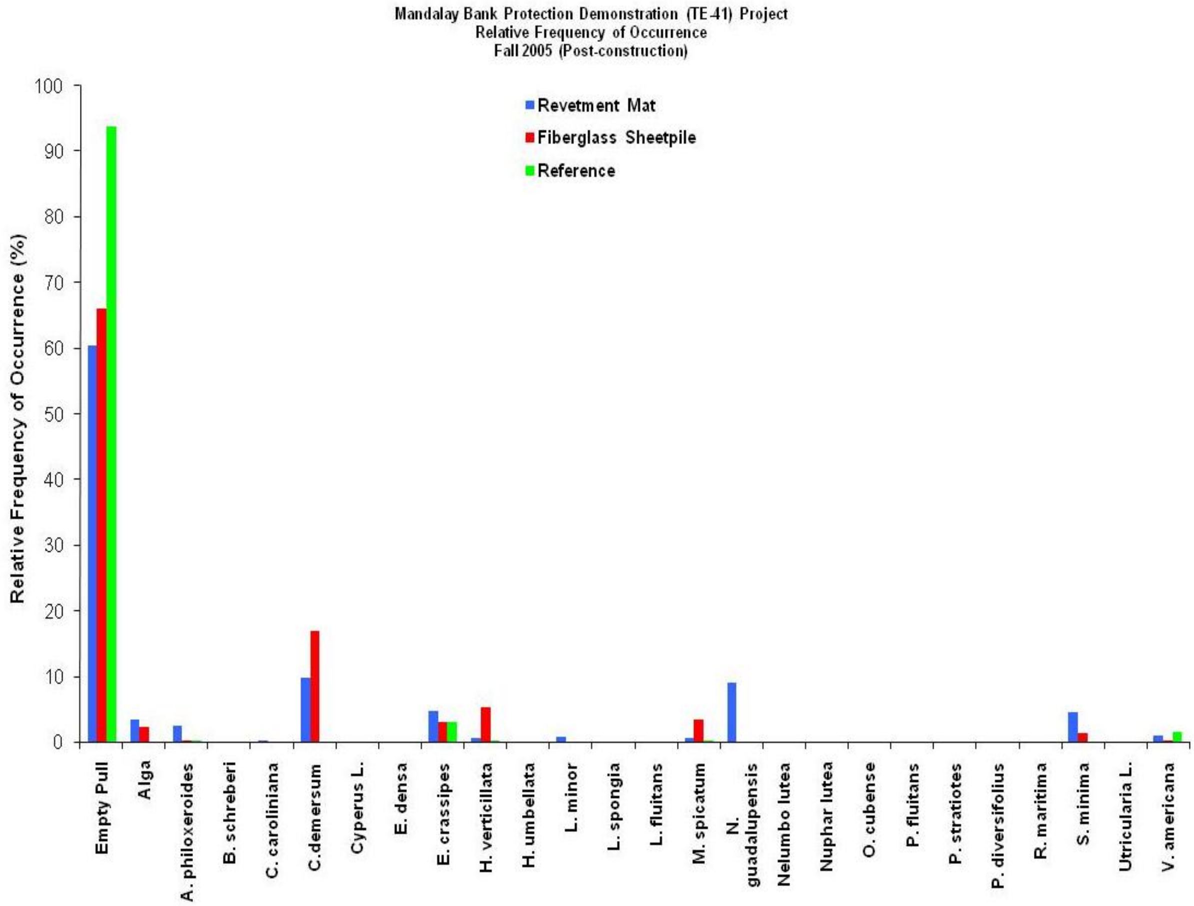


Figure 16. Relative frequency of occurrence of SAV for 2005 for the Mandalay Bank Protection Demonstration (TE-41) project.

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## Cost Effectiveness

Goal #6: Evaluate the cost effectiveness of different treatments in selected areas along the GIWW

In order to evaluate the cost effectiveness (goal #6) of the off-bank and blowout treatments, cost comparisons were compiled by the OCPR Thibodaux field office engineer, Brian Babin. Table 9 lists the 2002 as-built cost per linear foot (meter) for each treatment type, as well as the projected costs were the treatments built in 2011. Estimated 2011 costs are also listed for conventional treatments had they been used in lieu of those constructed for this project. In order to see how these figures were derived, expanded itemized costs for each treatment type are presented in appendix E. The shoreline change rate for each treatment type and reference type was included in table 11 to assist in the evaluation of this goal.

Table 11. Cost comparisons for project treatments.

| Treatments | Constructed Linear ft/m | 2002 Approximate Structure Cost $/ft ($/m) | Post-Construction Shoreline Change Rate $ft/yr^{-1}(m/yr^{-1})$ | 2011 Approximate Structure Cost $/ft ($/m) |
|---|---|---|---|---|
| **Off-Bank Treatments** | | | | |
| A-Jacks® with Cutgrass | 1,283 (391) | 163 (535) | 11.18 (3.41) | 284 (932) |
| Fencing with Cutgrass | 1,910 (582) | 64 (210) | 1.15 (0.35) | 129 (423) |
| Off-Bank References | 0 | 0 | -4.89 (-1.49) | 0 |
| **Blowout Treatments** | | | | |
| Concrete Revetment Mats | 1,223 (373) | 298 (978) | 0.72 (0.22) | 535 (1755) |
| Fiberglass Sheetpile | 1,857 (566) | 296 (971) | 8.52 (2.62) | 508 (1667) |
| Blowout References | 0 | 0 | 13.17 (4.01) | 0 |
| **Conventional Treatments** | | | | |
| Rock Dike | 1,000 (305) | NA | NA | 457 (1499) |
| Rock Dike With Lightweight Aggregate Core | 1,000 (305) | NA | NA | 487 (1598) |

The most cost effective project treatment type was the off-bank A-Jacks® with planted *Z. miliacea*, with the highest shoreline gains and the second lowest construction cost of all treatment types. Shoreline gains were substantially lower behind the fencing with planted *Z. miliacea* treatment type, though it cost the least to construct. Additionally, the off-bank references were the only shoreline segments to experience an overall shoreline loss.

For blowouts, the shoreline segments behind the fiberglass sheetpile treatments experienced substantial gains, the second highest of all the treatment types. However, this was the second costliest of all four treatment types to construct. The concrete revetment mats were the least effective and the costliest of all the treatment types. The shoreline segments behind these mats experienced the least gains. Though the blowout treatment shorelines experienced gains, the blowout reference shoreline gains were higher, the highest of all of the project shoreline segments.

### d. Discussion

*Shoreline:*
The goal (#1) to stop shoreline erosion in specified areas along the south shores of the GIWW has resulted in variability among the structure and reference types. When the data for the replicates representing each treatment and type were averaged, all of the structure shoreline segments exhibited positive change rates. The off-bank reference areas were the only treatment to show a negative shoreline change rate, and the blowout reference treatments had the highest average positive shoreline change rate. Since the structure and reference areas were established in floating marsh habitat, delineating shoreline position proved to be difficult. Therefore, a portion the variability within and between treatment types may have been derived from floating marsh movement.

Qualitative field observations over the 6.5 years of monitoring support some of the data presented. During the February 2007 structure inspections and the August 2008 vegetation assessment the field crews observed shoreline progradation at off-bank shoreline segments J1, J2, and F3. In 2007 field crews noted off-bank treatments J1 and J2 had accreted material which had completely vegetated and buried the double row of A-Jacks® by 1 to 2 ft (0.3 to 0.6 m) in depth. A high water event associated with tropical storm Bill in August 2003 May have contributed to this. It left substantial muddy deposits behind the structures. Since this accretion occurred between the time of construction and the as-built shoreline survey, there is no quantitative data to match the early field observations.

By 2008 the warning sign which was formerly in open water in front of the J1 and J2 structures stood in marsh approximately 50 ft (15 m) behind the newly formed shoreline. The *Z. miliacea* had grown into a solid stand where it was planted during construction just in front of the original shoreline, which was a considerable distance behind the new shoreline. The success of the J1 and J2 treatments may be partially attributed to their location and orientation with relation to the waterway. They were somewhat separated from it behind two small pieces of broken marsh, located in a small cove-like feature and not as directly impacted by boat wakes. The shoreline segment at off-bank treatment F3 also showed gains. The fencing structure was not visible under all of the thick vegetation which had grown over the accreted material which was strong enough for a person to stand and walk on top of it. The F3 shoreline segment accreted beyond the fencing and the warning sign toward the waterway.

The orientation, distance from the waterway, and shape of the blowout reference shoreline segments may have contributed to sediment aggregation and shoreline progradation. The U-shaped geometry of these blowout treatments seemed to promote deposition along these reference shorelines. Increased sedimentation inside these embayments was probably initiated during flooding or storm events. The comparatively lower change rates behind the concrete revetment mat blowout treatments may be partly attributed to the erosion of the earthen bankline to the east of the R1 east tie-in. The breach in this bankline allowed a large exchange of water in and out of the treatment area, likely increasing scouring effects as well as erosion to take place.

*Elevation:*

The goal (#2) to increase elevation in shallow open water behind treatments along the GIWW met with mixed results among the treatments. The TE-41 structure treatments collectively exhibited a very small increase in elevation immediately behind the structures (table 2). The reference areas incurred considerably larger elevation gains along their shorelines (table 3). The blowout reference area was the most successful treatment in promoting sedimentation for the duration of the project. Both the C1 and C4 replicates experienced shoaling on their shorelines (table 3). The revetment mat treatment also showed elevated sedimentation increases behind these structures due to aggradation behind the R2 structure. The a-jacks treatment sedimentation response averaged zero because of variability between replicates (table 2). The fiberglass sheet pile treatment slightly lowered contours behind these structures. The treated lumber fencing treatment recorded modest sediment deficits in the lee of these structures from 2003 to 2010. Scouring behind the F1 replicate contributed to this shoreline response (table 2). The off-bank reference area treatment displayed the largest sediment deficit primarily due to scouring along the C3 shoreline (table 3). In general, changes in sedimentation at each treatment were the result of large gains or deficits at one replicate while the other replicates recorded small changes in sedimentation.

The shoreline geometry seems to have influenced the sedimentation patterns at the Mandalay Bank Protection Demonstration (TE-41) project. The treatments placed in blowout areas (C1, C4, R1, R2, R3, V1, V2, and V3) and shallow off-bank embayments (C2, J1, and J2) seem to be more efficient at capturing sediments and raising shoreline contours than the treatments placed along the linear segments (C3, F1, F2, F3, and J3) of the shoreline. The treatments in the blowout and embayment areas had a net increase in sedimentation in the leeward position for the 6.5 year duration of the project (table 4). Conversely, the linear treatments recorded sediment deficits for the leeward position from 2003 to 2010 (table 5). Therefore, trends in the data show that shoreline geometry influenced sedimentation behind the TE-41 treatments. Moreover, the location and configuration of the structure and reference area treatments probably predicated the shoreline response.

*Vegetation:*

The goal (#5) to increase mean cover of emergent vegetation within shallow open water blowouts along the GIWW has been successful. Although the ratio of open water plots to marsh plots differed between blowout areas and off-bank areas (3:1 for blowouts and 1:2 for off-banks), relative mean cover followed similar trends between 2001 and 2005 in the treatment and reference areas. Vegetation cover increased from 2001 to 2005 while bare ground conversely decreased. The exception to this was in 2002 with the off-bank fencing with cutgrass treatments, where vegetative cover decreased substantially before recovering during the next growing season.

Between 2001 (as-built) and 2005 (post-construction) species diversity increased inside the blowout treatment and blowout reference vegetation plots, but more so inside of the treatment plots. When species composition included vegetation outside of the plots, and when 2008 vegetation assessments were included, the results were the same.

Species diversity increased inside the off-bank reference vegetation plots, increased slightly for the A-Jacks® treatments, but decreased slightly for the fiberglass sheetpile treatments between 2001 and 2005. When species composition included vegetation outside of the plots, and when 2008 vegetation assessments were included, species diversity decreased for both the treatments and references.

The goal (#4) to increase the mean cover of *Z. miliacea* to 50% or greater after five growing seasons in the planted areas adjacent to eroding shorelines of the GIWW was successful along the A-Jacks® treatment J1 shoreline only. It is important to note that although the goal of 50% mean cover was not met for the majority of the treatments, between 2003 and 2005 it increased behind all off-bank treatments except for fencing treatment F2 (table 9). Another consideration when examining this data is that the analysis only deals with what was inside of the plots, therefore no consideration was given to anything outside of them. There were qualitative observations made of the planted species during field trips which indicated that by 2008 very robust plants were present in the vicinity of the off-bank treatments, but they were reconfigured by tropical weather systems. It is entirely possible that these stands will continue to spread in the future.

*Survival:*

Percent survival of the planted species was most successful behind the A-Jacks® treatment J1 where the plants grew into a solid stand over the entire shoreline segment. Overall, however there was a substantial decrease in the number of plants inside of the remaining off-bank plots between 2003 and 2005. This does not take into consideration all of the very robust plants noted outside of these plots during the 2008 field trip, all of which have the potential to colonize the areas in the future.

Field observations made during annual structure inspections and data collection trips through the years has confirmed that weather systems have had an impact on survival of the planted species. During the 2005 fall vegetation data collection and during the February 2007 annual structure inspections, field personnel noticed that the planting scheme was drastically reconfigured for some of these treatments as a result of the powerful Hurricanes Katrina and Rita which impacted our coastline in 2005. During the February 2007 annual inspection, areas of progradation found in front of structures J1, J2, and F3 were fully vegetated and the field crew found that they were firm enough to walk on. By the August 2008 vegetation assessment the off-bank treatment J1 had a solid line of the planted species *Z. miliacea* where the old shoreline was located. At off-bank treatment F3 survival of the planted species, *Z. miliacea* could not be quantitatively expressed because the original planting scheme was not recognizable. The giant cutgrass plantings no longer remained in the as-built rows, but were scattered in very healthy vigorous clumps in a zone approximately 40 ft (12 m) deep beginning at the new shoreline. An explanation for the widespread disarray of the plantings is that this resulted when the plants were uprooted and tumbled by the waves from tropical systems. They rooted themselves where they were deposited. At off-bank treatment J2 the planted species had a scattered configuration very similar to J1 until one walked back to the old shoreline where there was a solid line of healthy giant cutgrass.

*Submerged Aquatic Vegetation:*
The goal (#3) to maintain/increase the frequency of occurrence of submerged aquatic vegetation within shallow open water blowouts along the GIWW was successful until powerful hurricanes impacted the project area. The relative frequency of *Vallisneria americana* Michx. progressively decreased in the reference blowouts between 2001 and 2005, but gradually increased in all treatment blowouts until it drastically decreased in 2005, a likely response to Hurricanes Katrina and Rita. In the reference blowouts, relative frequency of *Ceratophyllum demersum* (L.) steadily increased between 2001 and 2003, yet it was completely absent in 2005. Its frequency fluctuated inside both treatment types between 2001 and 2005 but eventually decreased. Between 2001 and 2005 the relative frequency of empty pulls steadily increased from 52% to 94% in the reference blowouts, while it fluctuated between 29% and 61% in the concrete revetment mat treatment blowouts, and between 12% and 66% in the fiberglass sheetpile treatment blowouts.

*Structure Integrity:*
The goal (#7) to evaluate the integrity of the structures associated with treatments indicates that the structures remained intact with a few exceptions. There was damage to one structure as well as the formation of a significant breach near the tie-in of another structure during the monitoring of this demonstration project. At structure F2, several fence spans were missing near the middle of the structure where it was struck by a barge. From communications with field personnel, this occurred prior to early May 2006 and sometime after the October 2005 hurricane impact inspection. Additionally, approximately 75 ft (23 m) to the east of the east tie-in of structure R1 an existing breach in the bank was plugged with dredged material during construction in September 2003 in order to create a separation between the blowout and the Gulf Intracoastal Waterway. Inspections from February and March 2005 indicate that the plug

was heavily eroded. At its narrowest point only 3 ft (0.9 m) of the plug remained between the blowout and the waterway. During the October 2005 inspection in the aftermath of hurricanes Katrina and Rita, the Thibodaux field office engineer noticed a 2 ft (0.6 m) breach in the plug. The breach was significantly larger [approximately 25 ft (8 m) wide] when observed during the August 2008 vegetation assessment, and the October 2009 inspections. The breach in this bankline was close enough to the east tie-in of structure R1 to allow for sediment volume losses next to that structure.

According to the 2005 and 2009 inspection reports, there were minor dips in the articulated concrete revetment mat structures at R1 and R2, and in the fiberglass sheetpile structure V2, but not enough to interfere with their intended function. These structures dampened wave energy while still allowing for water exchange and sediment deposition during high water events as evidenced by the sedimentation pattern changes throughout the years of monitoring. Finally, the staggered wooden fencing and the parallel fiberglass sheetpile structures had no secondary settlement. The 24” double stacked A-Jacks® structures experienced greater secondary settlement than the articulated concrete revetment mat structures.

*Cost Effectiveness:*

Cost of the treatment structures was not the sole consideration in determining which of the four project treatment types was the most effective. Depending on the variable analyzed, some treatments were more effective than others. For instance, the most cost-effective treatment based upon shoreline position analysis was the A-Jacks® with planted cutgrass, with the second-lowest construction cost and the highest shoreline position gains. One of the replicates (J1) for this treatment type also had the second highest post-construction leeward sediment elevation gains, as well as the highest plantings survival rate. However, it also experienced the highest post-construction secondary settlement rate. The geometry, orientation, and position behind small marsh islands of this replicate likely contributed to its success.

The fiberglass sheetpile structures were the second costliest to construct, they contributed to the second-highest shoreline position gains, and one of the replicates (V2) experienced the third highest post-construction gain in leeward sediment elevation. This treatment type also had a nominal secondary settlement rate.

The fencing with cutgrass treatments contributed to small shoreline position gains, very minor leeward sediment elevation gains behind one of its replicates (F3) during post-construction, and it was the lowest in cost to construct. Percent survival of the planted species behind this treatment type dropped to less than half of the original number. This treatment type also had nominal secondary settlement rate during post-construction.

The concrete revetment mat treatments were the costliest to construct. This treatment type contributed the smallest shoreline position gains out of all four of the treatment types. Two out of three replicates (R1 and R2) experienced leeward sediment elevation gains during post-construction, R2 having the highest out of all treatment replicates in the project. The structures experienced the second-highest settlement rate of all treatment types.

## V. Conclusions

### a. Project Effectiveness

The goal of stopping shoreline erosion in specified segments along the GIWW resulted in some variability among the treatment and reference areas. All of the treatment shoreline segments experienced positive changes when the transect data were averaged with the off-bank A-Jacks® with cutgrass segments experiencing the largest positive change rate. Among the reference areas, the highest positive shoreline change rate occurred along the blowout reference shoreline segments while the off-bank reference segments experienced the only negative change. The lowest positive shoreline changes occurred along the concrete revetment mat segments. Indications are that the breach in the earthen bankline to the east of blowout treatment segment R1 contributed to the low average. The size, shape, orientation, and distance from the GIWW of the segments in all likelihood contributed to shoreline gains and losses.

The cumulative effect of the structure treatments was incremental sediment elevation increases behind the constructed features, and considerably larger increases in the reference areas. In general, changes in sedimentation at each treatment were the result of large gains or deficits at one replicate while the other replicates recorded small changes in sedimentation. As a result, the shoreline response was decidedly variable. In addition, the treatments placed in blowout areas (C1, C4, R1, R2, R3, V1, V2, and V3) and shallow off-bank embayments (C2, J1, and J2) seem to be more efficient at capturing sediments and raising shoreline contours than the treatments placed along the linear segments (C3, F1, F2, F3, and J3) of the shoreline. Therefore, trends in the data show that shoreline geometry influenced sedimentation behind the TE-41 treatments. Moreover, the location and configuration of the structure and reference area treatments probably predicated the shoreline response.

Vegetation analysis reveals similar overall trends in both off-bank and blowout treatment and reference areas. Mean vegetation cover has increased steadily, while bare ground has conversely decreased between the 2001 and 2005 sampling periods. Also, species diversity has increased within this time period. During the 2008 vegetation assessment trip the overall project species diversity remained high, with the highest diversity behind the off-bank treatments. The project area continues to exist as a floating marsh with a mixture of freshwater species such as *Colocasia esculenta* (L.) Schott, *Polygonum punctatum* Ell., *Sagittaria latifolia* Willd., and *Panicum hemitomon* J.A. Schultes.

Percent survival of the planted species, *Z. miliacea* (Michx.) Doell & Aschers. substantially decreased from 40% in 2003 to 12% in 2005 behind the wooden fencing. Percent survival behind the A-Jacks® in 2003 was 43.3%. Survival could not be determined for 2005 behind the A-Jacks® because the plantings behind one of the treatments successfully grew into a solid line of plants from which the parent plants could not be distinguished, and because one of the plots could not be located. Noticeable damage to the plantings and reconfiguration of the planting scheme was observed following Hurricanes Katrina and Rita.

The relative frequency of occurrence of SAV inside the blowout reference areas steadily decreased between 2001 and 2005. Behind the blowout treatments it fluctuated from year to year, though it eventually decreased drastically in 2005, due to hurricanes Katrina and Rita. Prior to these weather systems the relative frequency of occurrence behind the treatments was on the rise by 2003, but decreased in the reference areas, indicating a positive project effect.

Structure elevation analysis and inspection field observations contributed to the evaluation of structure integrity associated with treatments for this project. With the exception of barge damage to fencing structure F2 and the breach to the east of the R1 tie-in, all of the structures have remained intact over the course of the 6.5 years of monitoring. The largest changes in structural elevations occurred with the heaviest of the treatments, the 24 inch interlocking A-Jacks® structures and the articulated concrete revetment mats. This can be attributed to secondary settlement. The structures experiencing very little to no settlement were those driven to resistance during construction and included the staggered wooden fencing and the parallel double walled fiberglass sheetpile.

Depending upon the analysis, there was some variability in the determination of cost-effectiveness among the treatment types. Also, the geometry, orientation, distance from the GIWW, and size of some of the treatment areas contributed to the success of the replicates within the treatments. Overall, the A-Jacks® with cutgrass treatments were the second lowest in costs to construct yet contributed to the highest shoreline gains, a high percent survival of plantings, and gains in sediment elevation behind one of the replicates. However this treatment type experienced the largest secondary settlement rate. The concrete revetment mats were the costliest treatments to construct, experienced the lowest shoreline position gains, and had the second highest structure settlement rates, yet one of the three replicates contributed to the highest leeward sediment elevation gains.

### b. Recommended Improvements

Two improvements are recommended for future shoreline protection demonstration projects. The first improvement is to standardize the size and configuration of the treatments. The dimensions of nearly all of the blowout treatments and replicates were different. This led to volume calculation difficulties (different areas) and probably influenced the sedimentation patterns. In addition, the off-bank treatments were placed along linear and embayment (curved) segments of the shoreline causing sedimentation patterns to differ. Therefore, the dissimilar size and configuration of the treatments resulted in high variability among and within treatment types making assessment of structure performance problematic and not definitive. The second improvement is elevation surveys of shoreline protection structures should be shorter and denser. The length of the surveys, extending to the center of the GIWW, did not aid in comparing treatments. These data only illustrated that bedload transport was occurring in the center of the GIWW. The surveys should also have shorter transect intervals and point spacing to lower uncertainty and increase repeatability of elevation data collection.

### c. Lessons Learned

Four monitoring lessons were learned from the Mandalay Bank Protection Demonstration (TE-41) project. The first lesson is that sedimentation patterns along the GIWW shorelines seem to be governed by the shoreline geometry. Blowout and embayment segments of the shoreline tend to aggrade while linear shoreline reaches tend to have reduced sedimentation. The second lesson learned is that determining shoreline position in a floating marsh can be challenging. Demarcating the shoreline position in this environment is difficult because floating marshes are easily eroded or relocated by wind, waves, and currents and the GIWW is a very dynamic navigation channel especially during storm events. The third lesson is that as-built information for the plantings was not collected. As-built drawings and associated GPS files for the plantings should be provided for projects of this type as they are important tools for monitoring percent survival. The fourth lesson is that pre-construction survey data should be available for comparison with as-built and post-construction survey data to aid in the assessment of elevation and shoreline position changes.

One structure stability lesson was learned from the Mandalay Bank Protection Demonstration (TE-41) project. This lesson is that the structures were relatively durable. Only the R1 structure breached. This breaching occurred on an earthen embankment on the edge of the structure. The actual sheet pile structure did not breach. In addition, some of the revetment mat structures (R1 and R2) experienced small amounts of differential settlement. Finally, the treated lumber fencing and fiberglass sheet pile treatments did not display any secondary settlement.

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## Appendix A

## Structure Designs

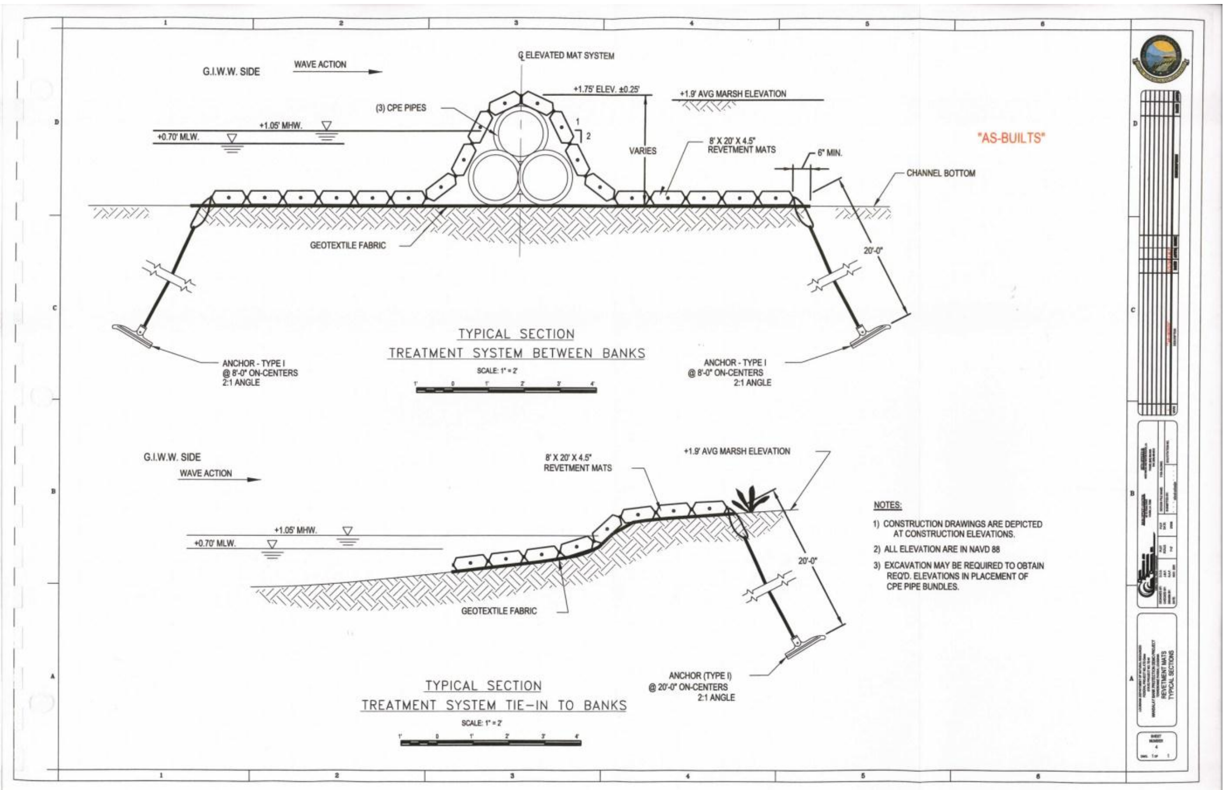



Figure 1. Typical cross sections showing the Mandalay Bank Protection Demonstration (TE-41) project's submerged articulated concrete revetment mat (R) structures.

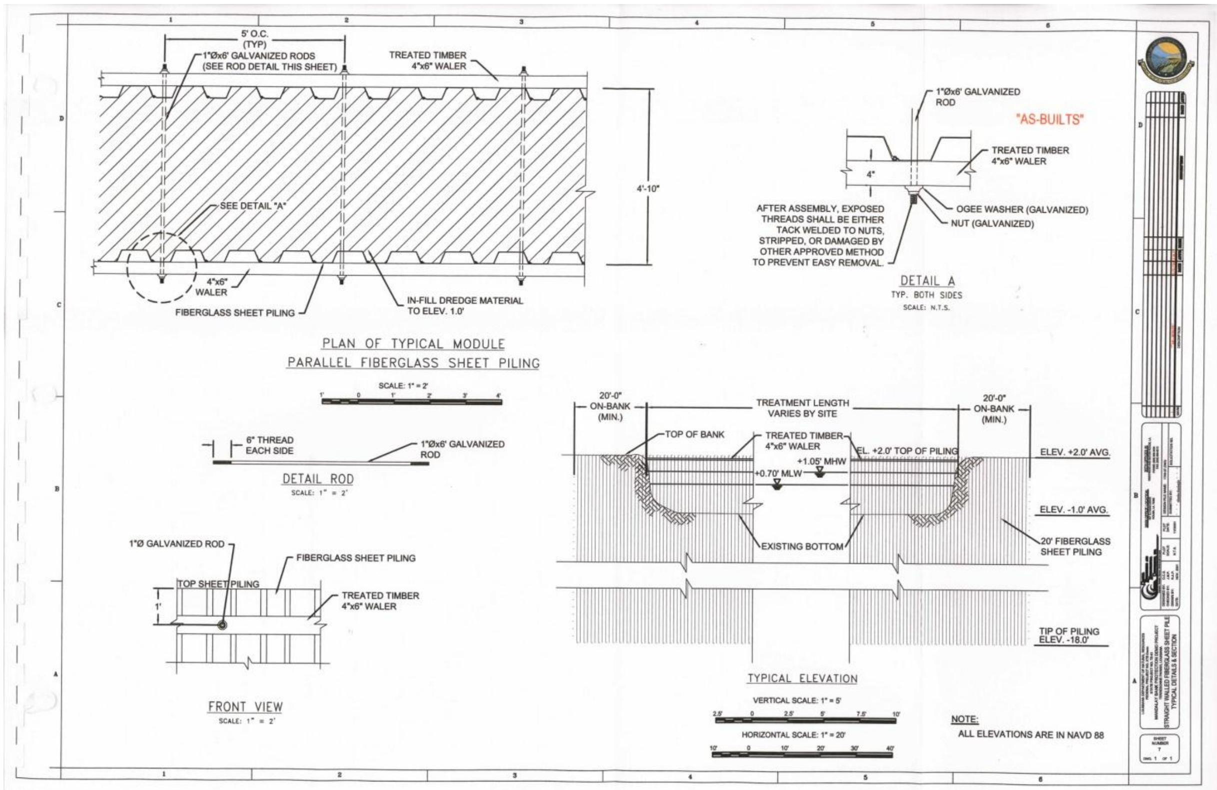



Figure 2. Typical cross section and aerial view depicting the Mandalay Bank Protection Demonstration (TE-41) project's straight-walled fiberglass sheet pile (V) structures.

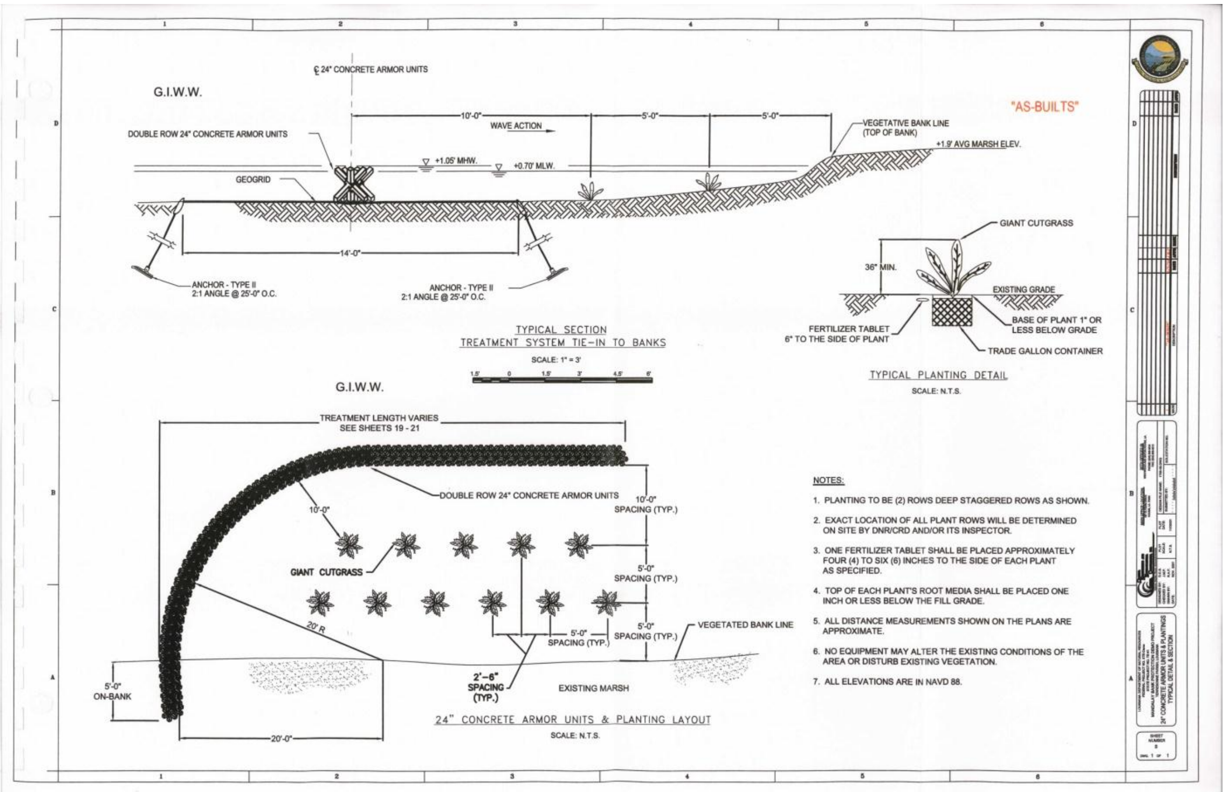



Figure 3. Typical cross section and aerial view depicting the Mandalay Bank Protection Demonstration (TE-41) project's A-Jacks (J) structures.

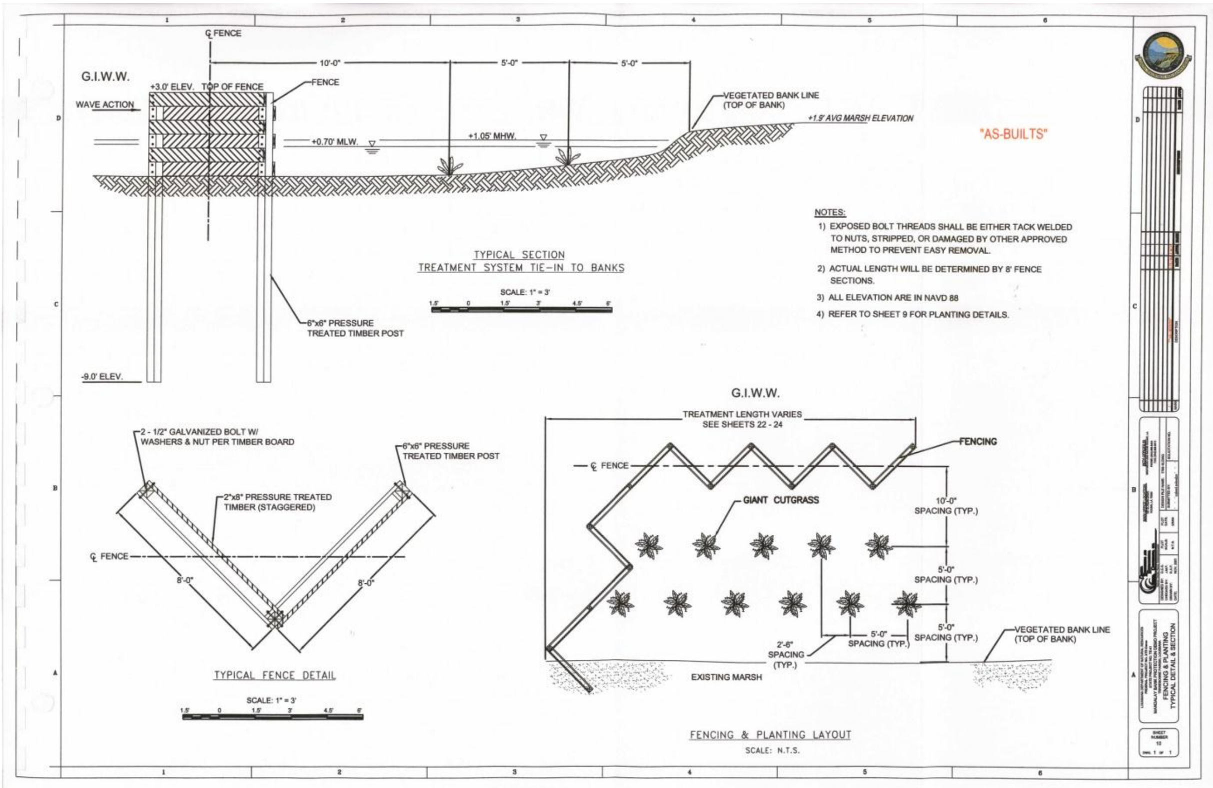



Figure 4. Typical cross section and aerial view depicting the Mandalay Bank Protection Demonstration (TE-41) project's treated lumber fencing (F) structures.

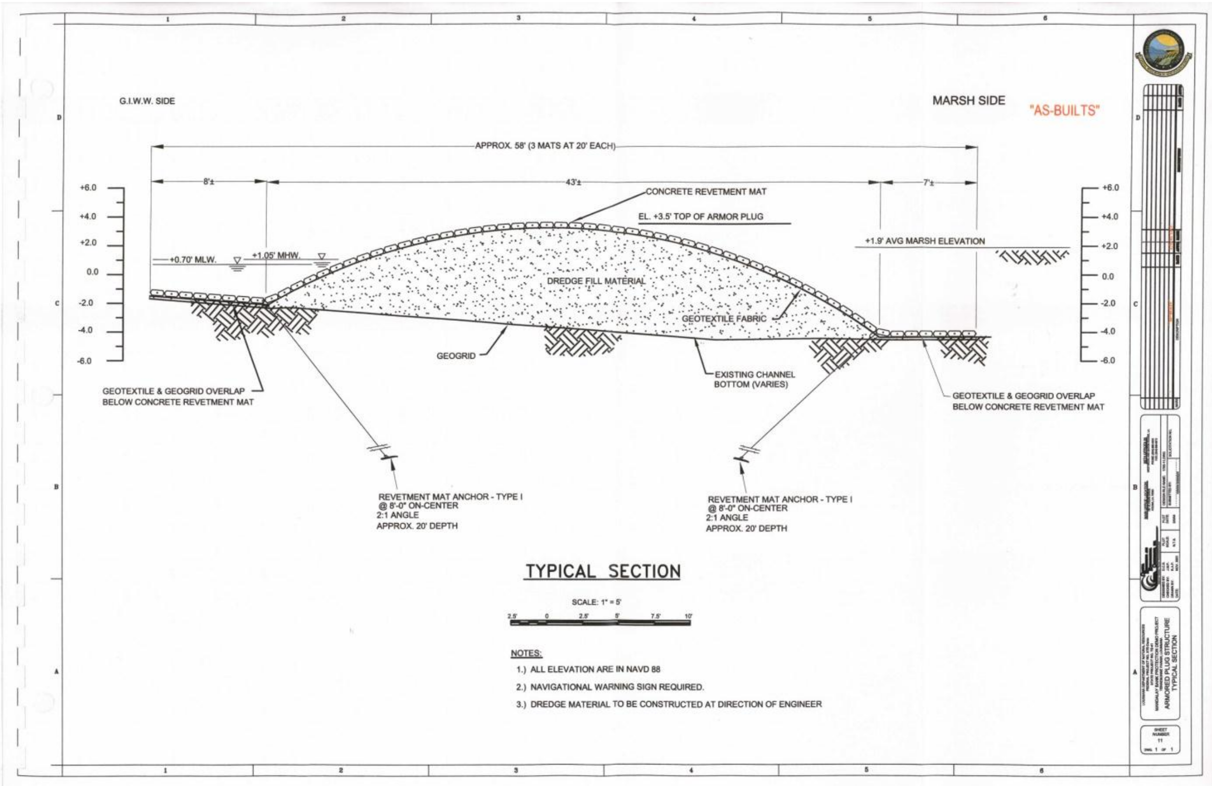



Figure 5. Typical cross sections showing the Mandalay Bank Protection Demonstration (TE-41) project's concrete revetment armored plugs.

**Appendix B**

**Inspection Photographs**


Photo No.1 –tide gage located along Minors Canal near the north bank of the GIWW.


Photo No.2 - Site V3 – warning sign in front of fiberglass sheet pile (double) wall structure.


Photo No.3 – Site V3 – bank tie-in at the west end of the fiberglass sheet pile (double) wall.


Photo No.4 – Site V3 – view of fiberglass sheet pile (double) wall structure looking east.


Photo No.5 - Site V3 – bank tie-in at the east end of the fiberglass sheet pile (double) wall.

Photo No.6 – Site V3 – close-up view of fiberglass sheet pile (double) wall structure.


Photo No.7 – Site A3- view of warning sign on the GIWW side of the armored earthen plug.

Photo No. 8 – Site A3 – close-up of the articulated concrete mats covering the earthen plug.


Photo No.9 – Site A3 – view of debris covering the armored earthen bank structure.


Photo No.10 – Site A3 – view of vegetation covering the armored earthen plug.


Photo No.11 – Site A3 - view of marsh behind (south side) of armored earthen plug.


Photo No.12 – Site V2 –warning sign on north side of the fiberglass sheet pile (double) wall.


Photo No.13 – Site V2 – fiberglass sheet pile tie-in to bank on the west side of the structure.


Photo No.14 – Site V2 - fiberglass sheet pile wall along south bank of GIWW looking east.


Photo No.15 – Site V2 – fiberglass sheet pile wall tie-in to bank on the east end of the structure.

Photo No.16 - V2 - fiberglass sheet pile wall tie-in to bank on the east end of the structure.


Photo No.17 – Site F3 – warning sign on north side (GIWW) of timber fence structure.


Photo No.18 – Site F3 – timber fence tie-in the bank line on the west side of the structure.


Photo No.19 – Site F3 – view of the timber fence structure along south bank line of GIWW.


Photo No. 20 – Site F3 – view of heavy vegetation and accretion around timber fence structure.


Photo No.21 – Site F3 – accretion in front and up to the top of the timber fence structure.


Photo No. 22 – Site F3 – close-up view of accretion around timber fence structure.


Photo No.23 - Site A2 - armored earthen plug tie-in the bank line on the west end of structure.


Photo No.24 – Site A2 – view of vegetative growth through the armored earthen plug structure.

Photo No. 25 – Site A2 – armored earthen plug tie-in to bank on the east side of the structure.


Photo No. 26 – Site A2 – warning sign on the GIWW waterway side of the armored plug.


Photo No.27 – Site J3 – Double row A-Jacks  units along the shoreline below water surface.


Photo No. 28 – Site J3 – Double row A-Jacks near bank tie-in.


Photo No.29 – Site F2 – timber fence and vegetation growth on the west end of the structure.


Photo No.30 – Site F2 – Timber fence treatment looking east.


Photo No. 31 – Site J3 – view of submerged double row concrete armoring units.


Photo No.32 – Site J3 – view of submerged double row concrete armoring units.


Photo No.33 – Site F2 – view of sign and fence damage by apparent boat collision.


Photo No.34 – Site F2 - view of damaged fence units where a boat collided with the structure.


Photo No.35 – Site F2 – timber fence unit tie-in to bank on the west end of structure.


Photo No.36 – Site F1 – timber fence tie-in to bank on the west end of the structure.


Photo No.37 – Site F1 – timber fence unit and vegetation behind structure looking east.


Photo No.38 – Site F1 – warning sign and timber fencing unit along south bank of GIWW.


Photo No.39 – Site F1 – close-up of timber fence unit tie-in to bank on west side of structure.


Photo No.40 – Site F1 – timber fencing units and vegetation along shoreline looking west.


Photo No.41 – Site A1 – site view of armored earthen plug covered with vegetation.


Photo No. 42 - Site J2 – view of double row concrete armoring system and vegetative cover.


Photo No.43 – Site J2 – view of vegetation covering concrete armoring units.


Photo No. 44 - Site J2 – view of warning sign and vegetative accretion in front of armoring units.


Photo No. 45 - Site J1 – view of vegetation and accretion in front of concrete armoring units.


Photo No. 46 – Site J1 – view of accretion in front of double row concrete armoring units.

Photo No. 47 – Site J1 & J2 – site location of double row concrete armoring units.

Photo No.48 – Site R1 – view of elevated shoreline system and warning sign looking south.


Photo No.49 – Site R1 – elevated system tie-in to bank on the west side of structure.


Photo No.50 – Site R1 – view of submerged revetment mats and CPE pipe looking east.


Photo No. 51 – Site R1 – elevated shoreline system tie-in to bank on east side of structure.


Photo No.52 – Site R1 – elevated shoreline system tie-in to bank on the east side of structure.


Photo No.53 – Site R1 – view  along revetment mats and  CPE pipes looking west.


Photo No.54 – Site R2 – view of warning sign and elevated shoreline system.


Photo No. 55 – Site R2 – Elevated shoreline system to bank tie-in on the west side of structure.


Photo No. 56 – Site R2 – view of settled areas along the elevated shoreline system.


Photo No.57 – Site R2 – Elevation shoreline system (revetment & CPE) tie –in on the east side.


Photo No.58 – Site R2 – view of settled areas long the elevated shoreline system looking west.


Photo No. 59 – Site V1 – view of warning sign in front of fiberglass sheet pile double wall.


Photo No.60 – Site V1 – fiberglass sheet pile double wall tie-in on the west side of the structure.


Photo No.61 – Site V1 – view along fiberglass sheet pile double wall looking eastward.


Photo No. 62 – Site V1 – fiberglass sheet pile double wall tie-in on east side of structure.


Photo No.63 – Site V1 – fiberglass sheet pile double wall looking westward.


Photo No. 64 – Site V1 – fiberglass sheet pile double wall tie-in to bank on east side of structure.

Photo No. 65 – Site R1 – settled area along elevated shoreline system (revetment mats and CPE).

Photo No.66 – Site R1 – elevated shoreline system tie-in to bank on west side of structure.


Photo No.67 – Site R1 – elevated shoreline system (revetment & CPE) looking eastward.


Photo No. 68 – Site R1 – elevated shoreline system tie-in to bank on east side of structure.


Photo No. 69- Site R1 – Areas that settled along Elevated Revetment Mats and CPE pipes.


Photo No. 70 – Breach in the bank near the earthen plug east of elevated shoreline unit R1.

**Appendix C**

**Vegetation Station Location Maps**

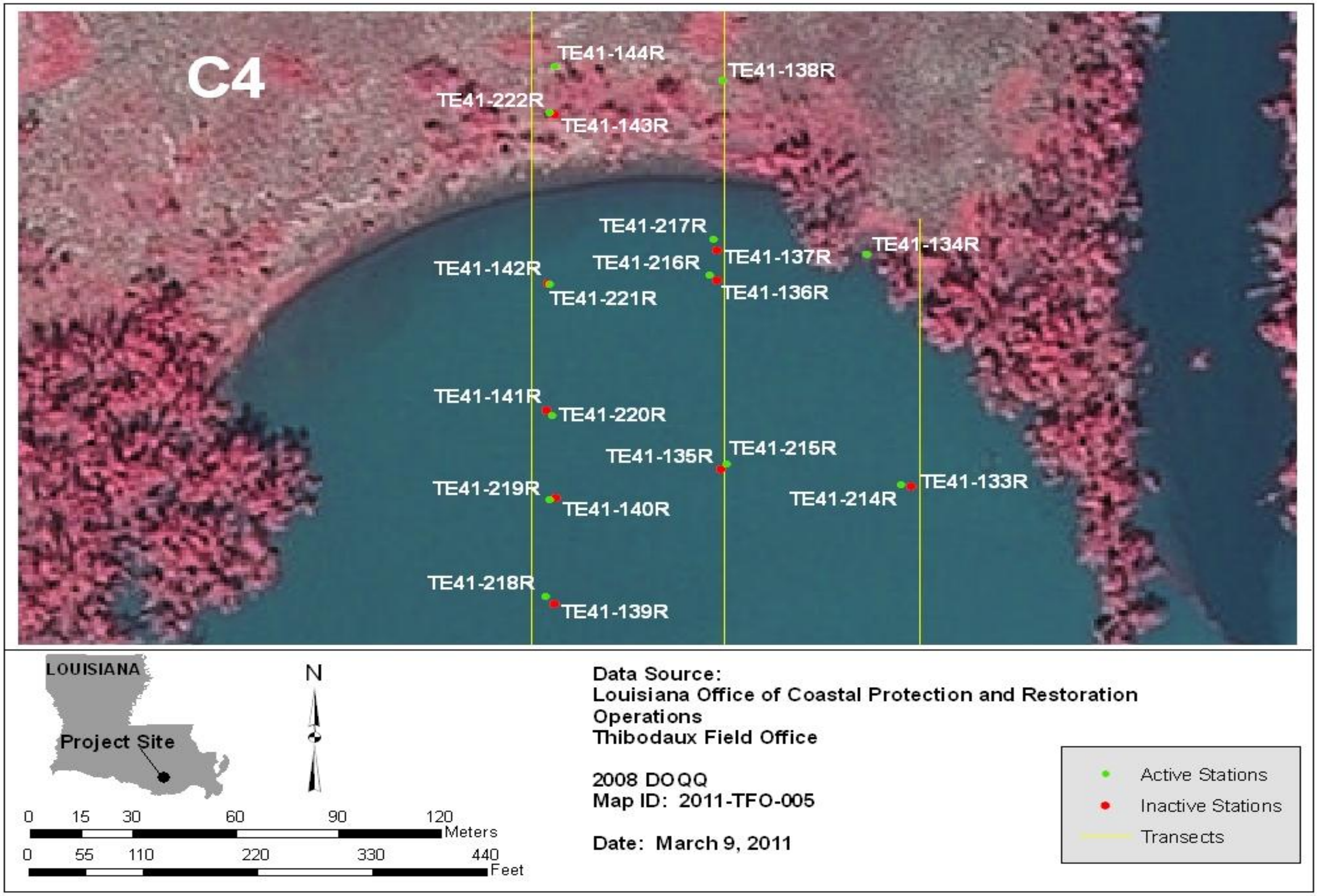



Figure 1. Location map of vegetation monitoring stations along transects inside the reference blowout C4, for the Mandalay Bank Protection Demonstration (TE-41) project.

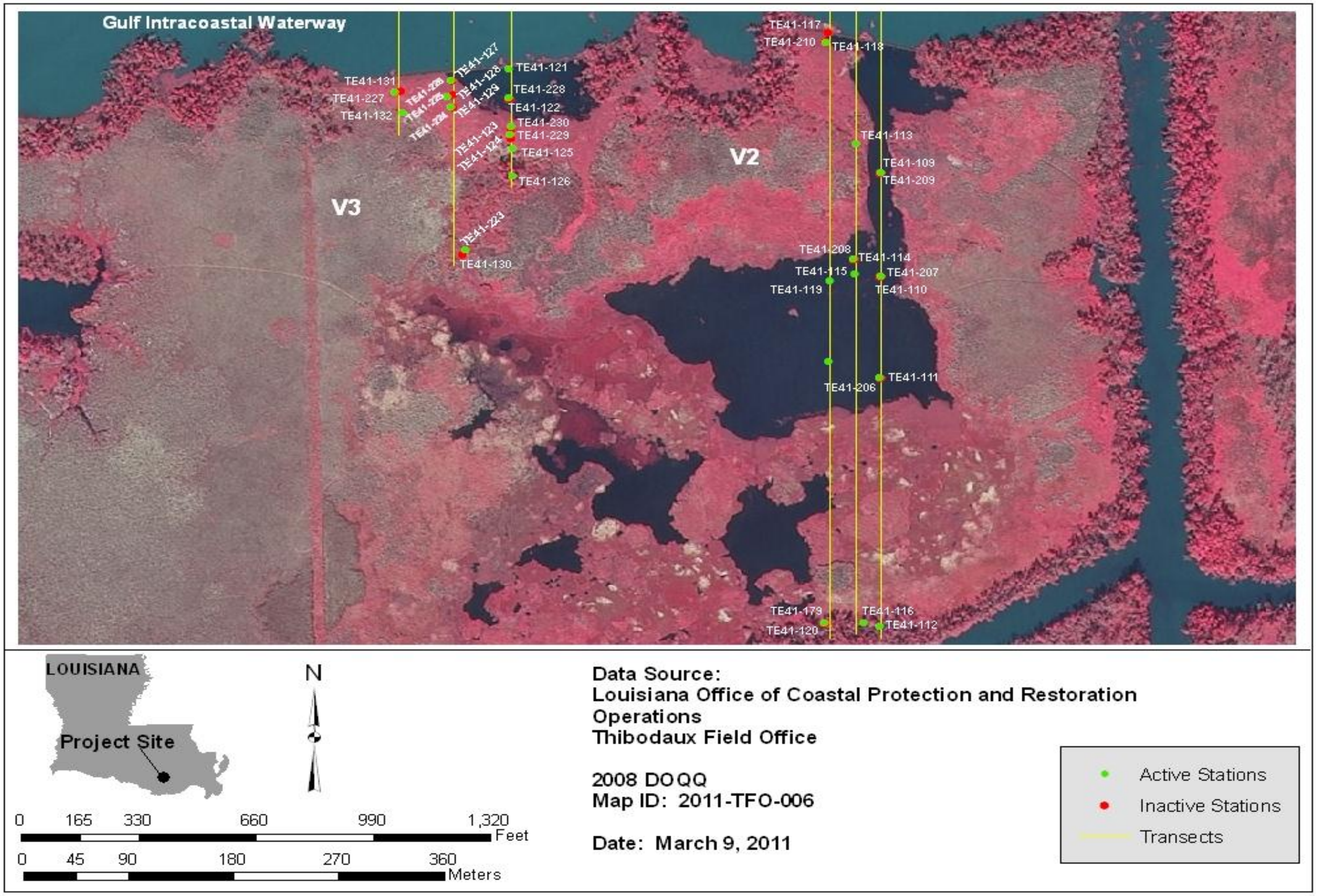



Figure 2. Location map of vegetation monitoring stations along transects inside blowout treatments V3 and V2, for the Mandalay Bank Protection Demonstration (TE-41) project.

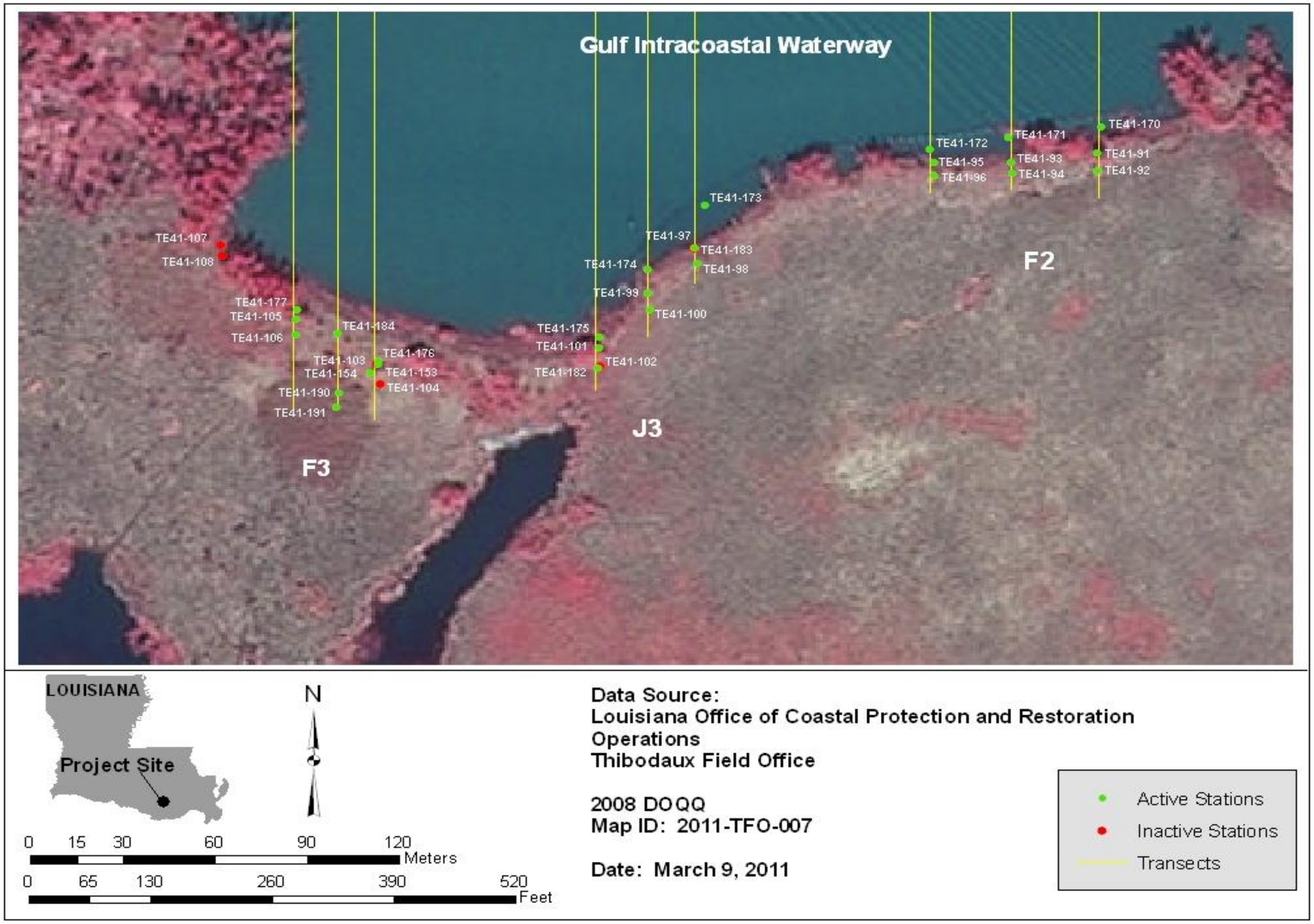



Figure 3. Location map of vegetation monitoring stations inside off-bank treatments F3 and F2, for the Mandalay Bank Protection Demonstration (TE-41) project.

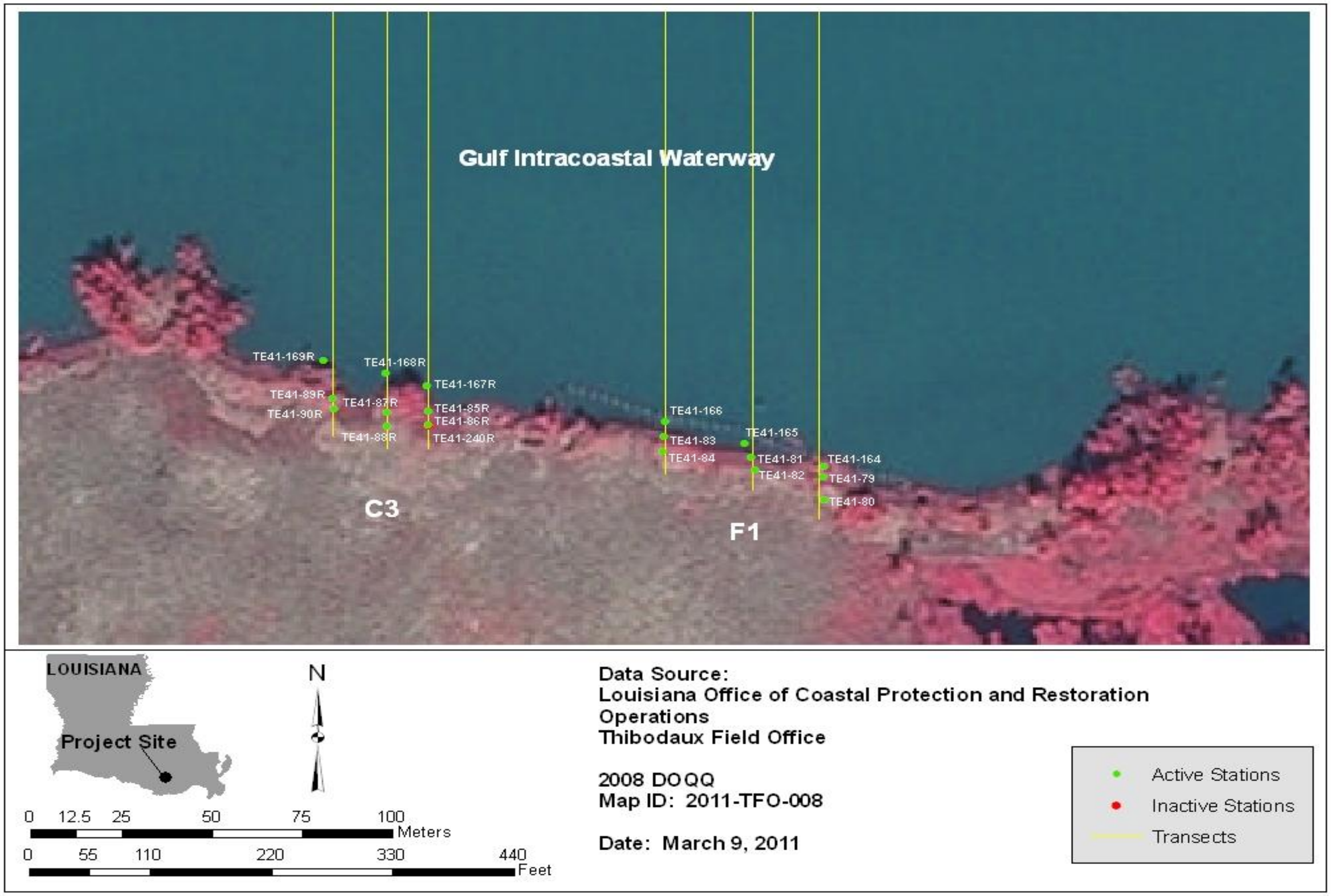



Figure 4. Location map of vegetation monitoring stations along transects within the off-bank reference C3 and the off-bank treatment F1, for the Mandalay Bank Protection Demonstration (TE-41) project.

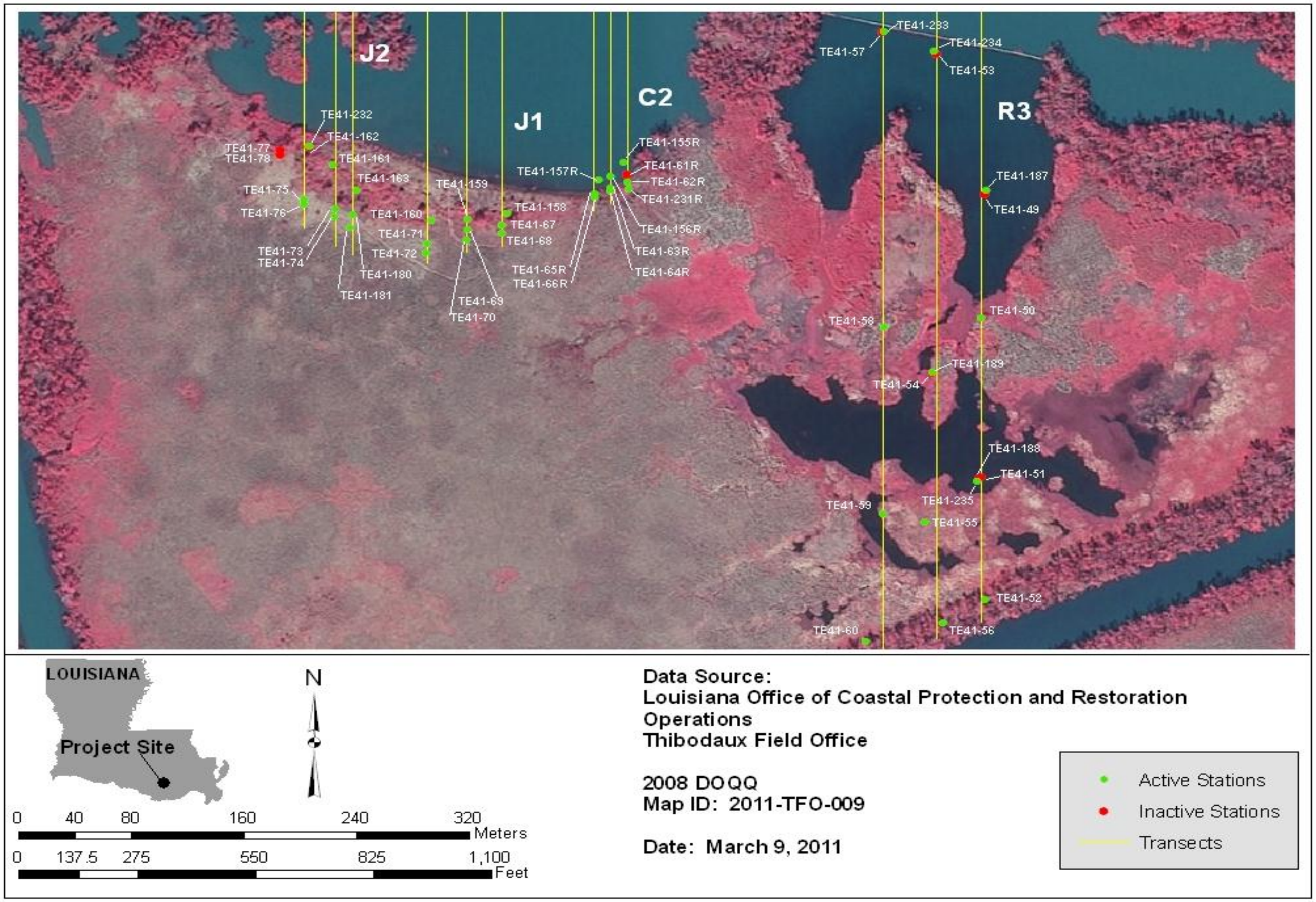



Figure 5. Location map for vegetation monitoring stations along transects within the off-bank treatments J2 and J1, the off-bank reference C2, and the blowout treatment R3, for the Mandalay Bank Protection Demonstration (TE-41) project.

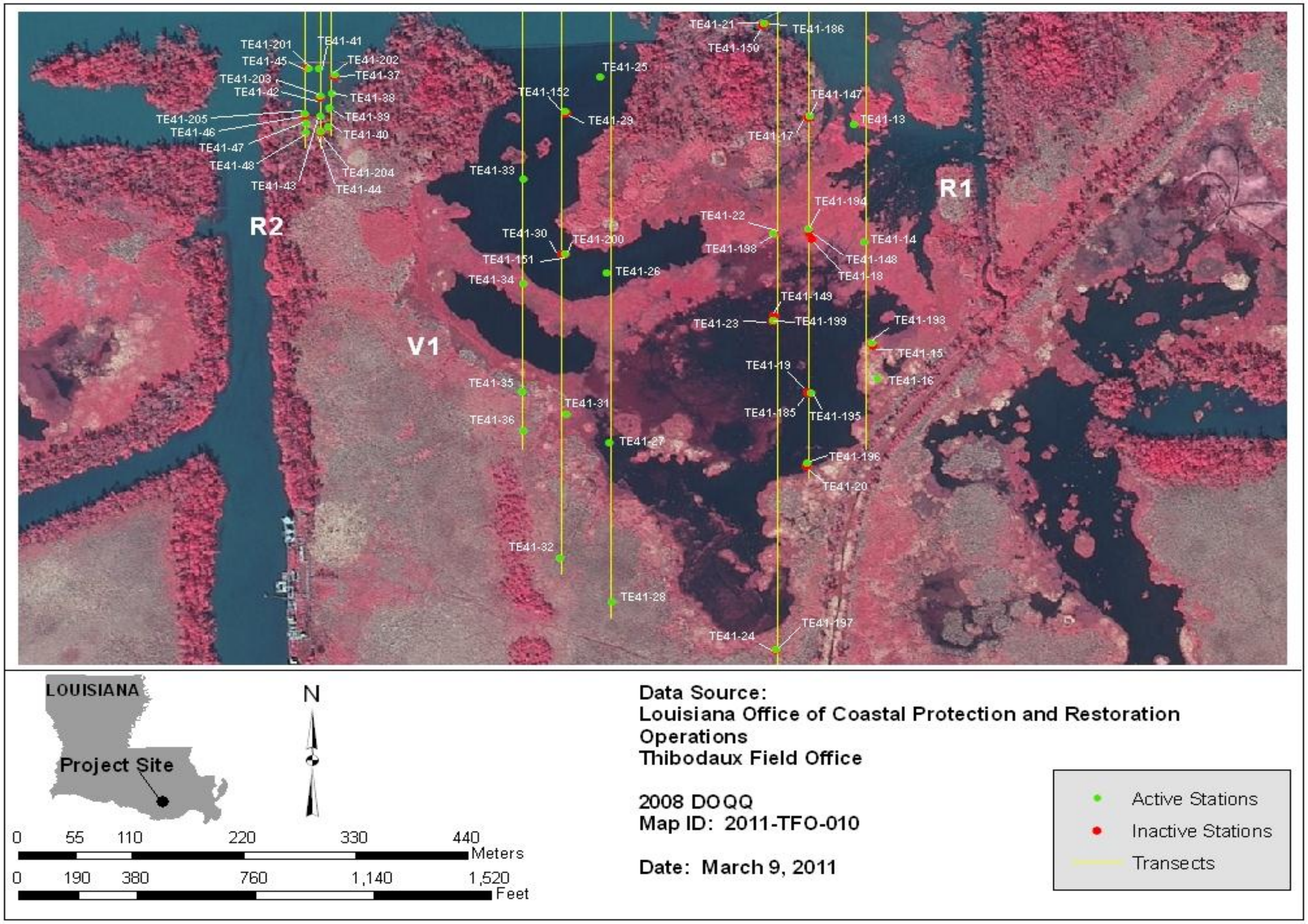



Figure 6. Location map of vegetation monitoring stations along transects inside the blowout treatments R2, V1, and R1, for the Mandalay Bank Protection Demonstration (TE-41) project.

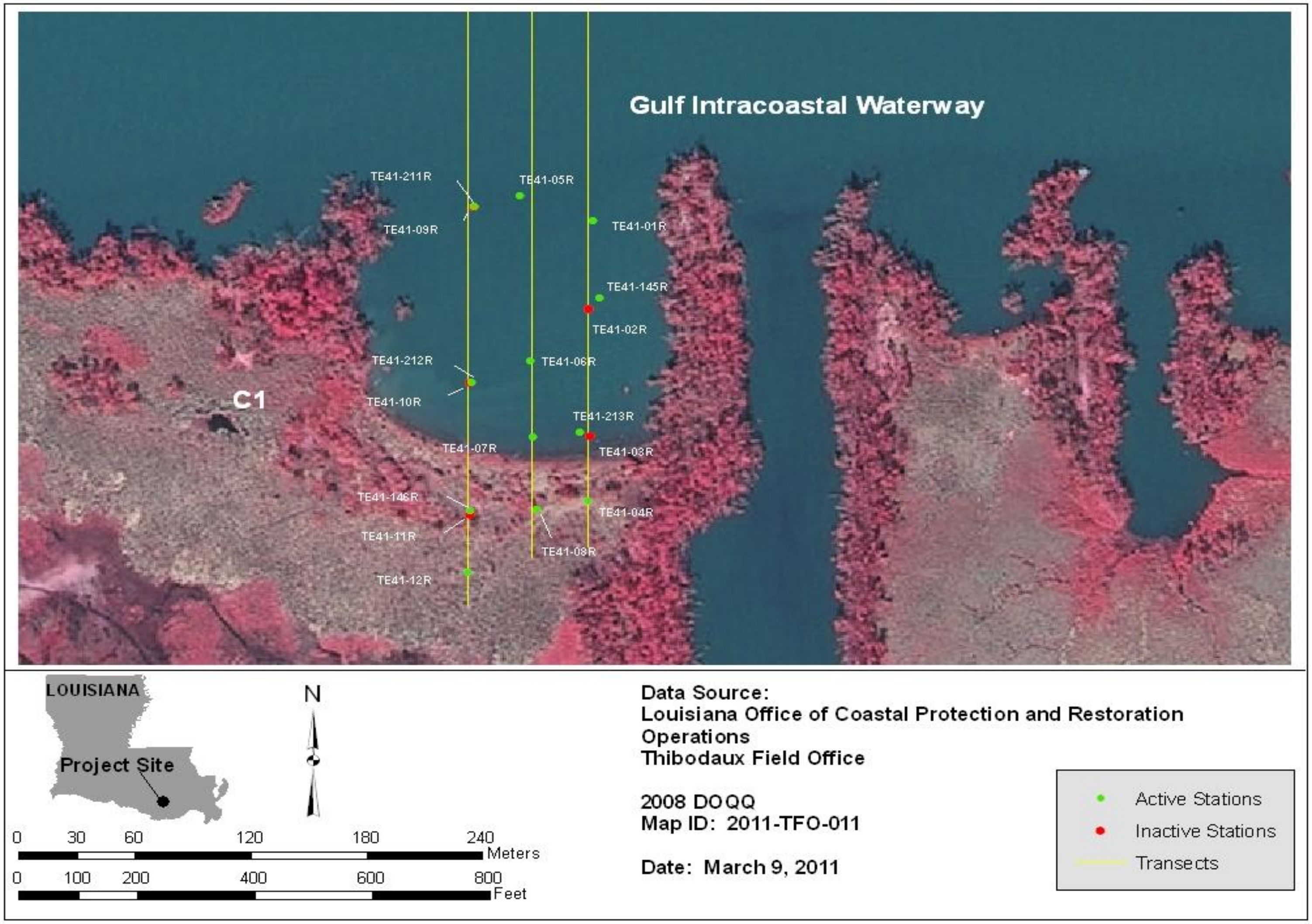



Figure 7. Location map for vegetation monitoring stations along transects inside blowout reference C1, for the Mandalay Bank Protection Demonstration (TE-41) project.

## Appendix D

## Elevation Survey Maps

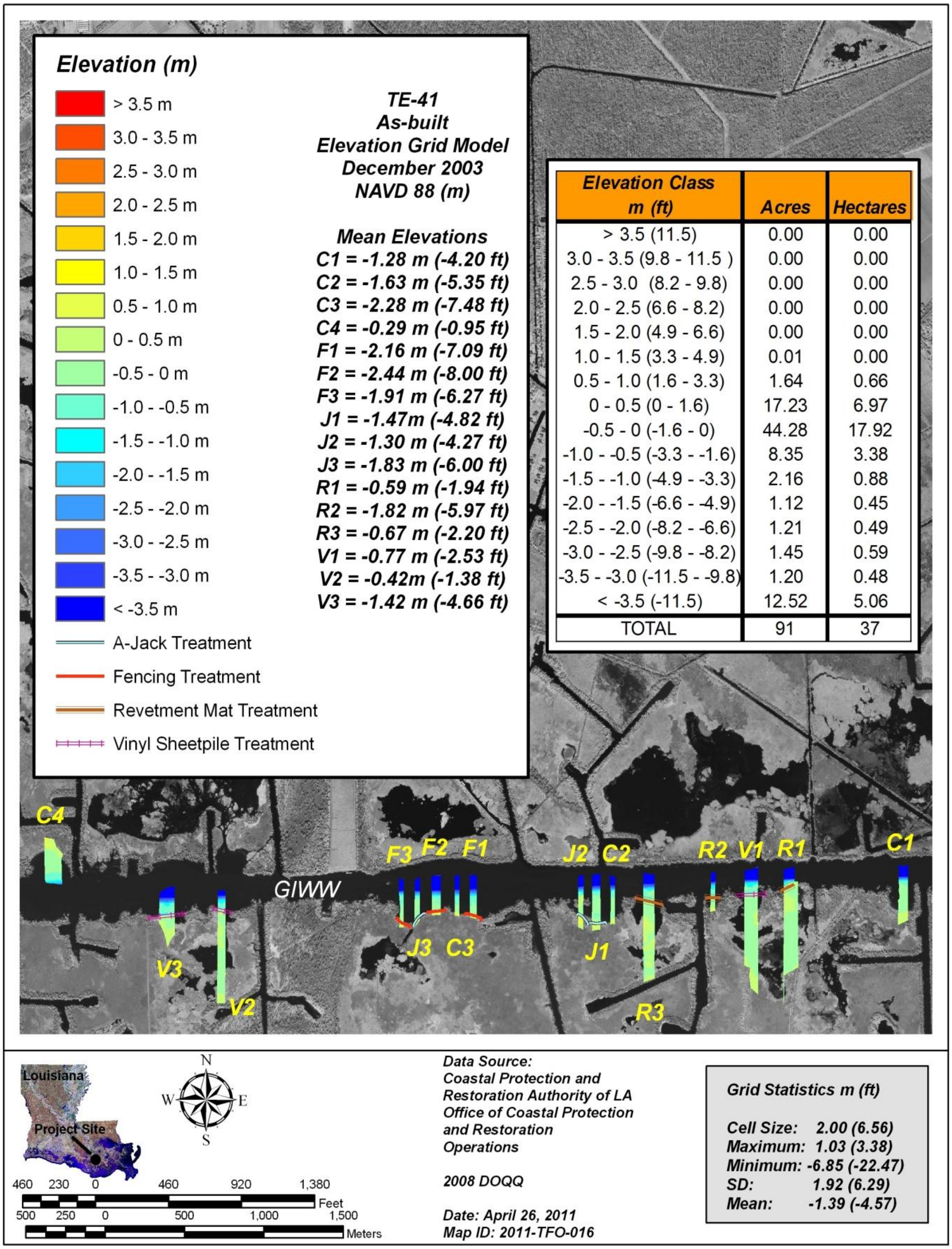



Figure 1. Elevation grid model from the December 2003 survey, for the Mandalay Bank Protection Demonstration (TE-41) project.

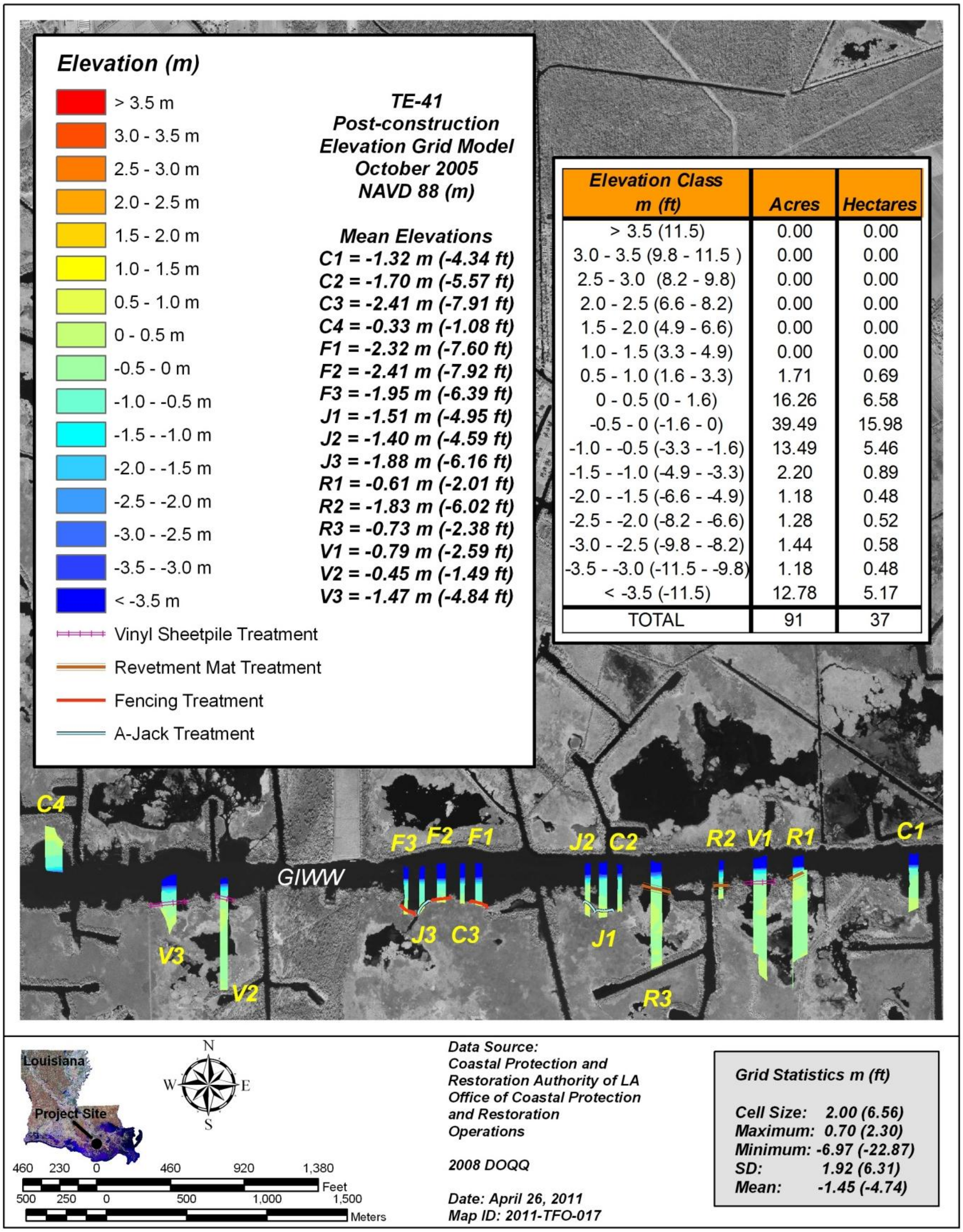
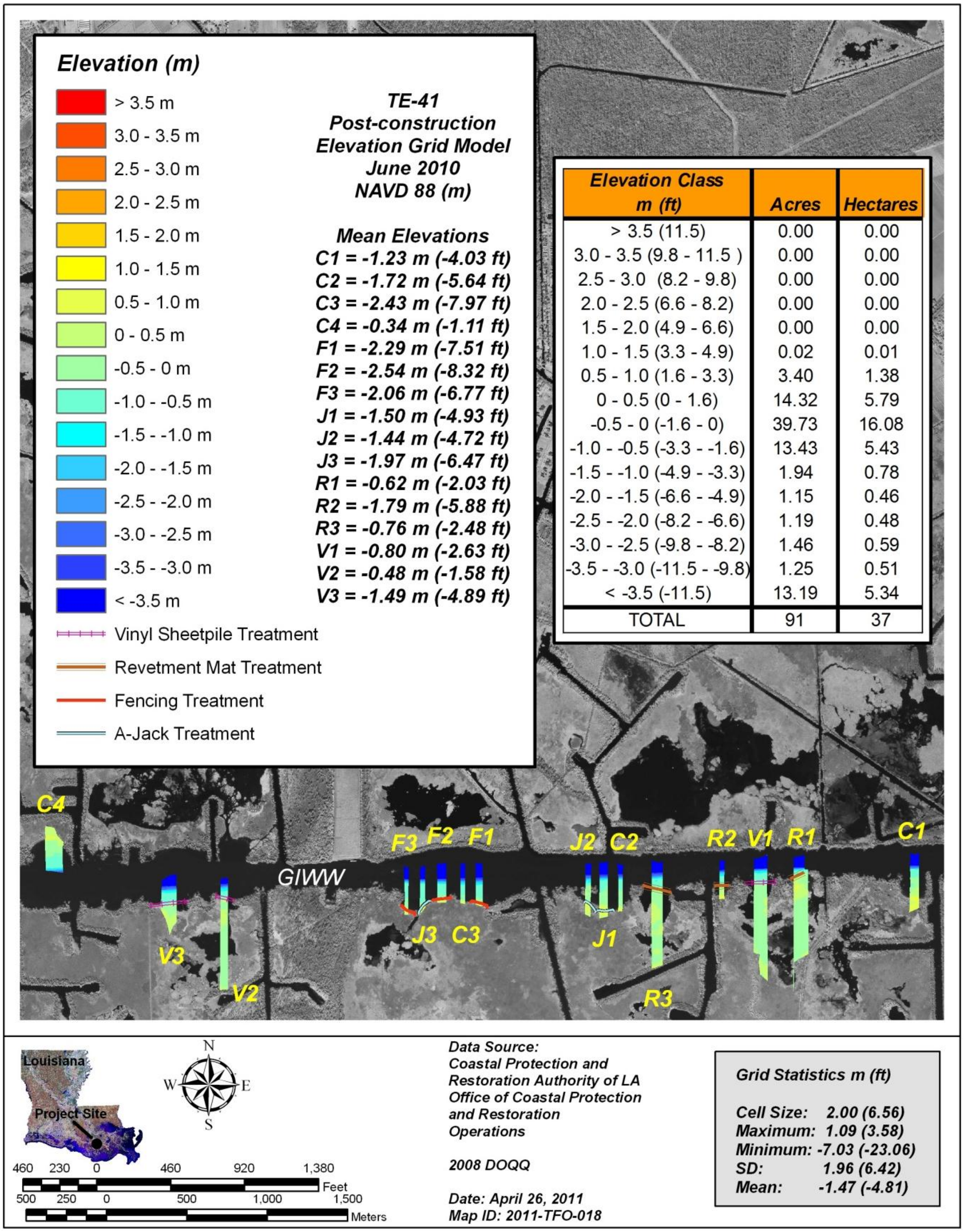



Figure 2. Elevation grid model from the October 2005 survey, for the Mandalay Bank Protection Demonstration (TE-41) project.




| Elevation Class m (ft) | Acres | Hectares |
|---|---|---|
| > 3.5 (11.5) | 0.00 | 0.00 |
| 3.0 - 3.5 (9.8 - 11.5 ) | 0.00 | 0.00 |
| 2.5 - 3.0 (8.2 - 9.8) | 0.00 | 0.00 |
| 2.0 - 2.5 (6.6 - 8.2) | 0.00 | 0.00 |
| 1.5 - 2.0 (4.9 - 6.6) | 0.00 | 0.00 |
| 1.0 - 1.5 (3.3 - 4.9) | 0.02 | 0.01 |
| 0.5 - 1.0 (1.6 - 3.3) | 3.40 | 1.38 |
| 0 - 0.5 (0 - 1.6) | 14.32 | 5.79 |
| -0.5 - 0 (-1.6 - 0) | 39.73 | 16.08 |
| -1.0 - -0.5 (-3.3 - -1.6) | 13.43 | 5.43 |
| -1.5 - -1.0 (-4.9 - -3.3) | 1.94 | 0.78 |
| -2.0 - -1.5 (-6.6 - -4.9) | 1.15 | 0.46 |
| -2.5 - -2.0 (-8.2 - -6.6) | 1.19 | 0.48 |
| -3.0 - -2.5 (-9.8 - -8.2) | 1.46 | 0.59 |
| -3.5 - -3.0 (-11.5 - -9.8) | 1.25 | 0.51 |
| < -3.5 (-11.5) | 13.19 | 5.34 |
| TOTAL | 91 | 37 |

Figure 3. Elevation grid model from the June 2010 survey, for the Mandalay Bank Protection Demonstration (TE-41) project.

## Appendix E

## Treatment Cost Analysis

## 2002 Cost Analysis

**Submerged Articulated Concrete Revetment Mats (1,223 linear feet)**

| | | |
|---|---|---|
| Mobilization/Demobilization (1 mob/demob) | $11,500 lump sum | $ 11,500 |
| Clearing, Grubbing and Shaping | $6,250/Lump Sum | $ 6,250 |
| Articulated Concrete Mats (152 Mats) | $1,300/each | $197,600 |
| Geotextile Fabric (3,939 sq.yds) | $3.50/sq.yd. | $ 13,787 |
| PVC Pipes (24" – 1,129 lft.) | $45/lft. | $ 50,805 |
| Anchors (Type 1 – 284 anchors) | $275/ each | $ 78,100 |
| Permanent Warning Signs (3 signs) | $1,000/each | $ 3,000 |
| Settlement Plates (3 plates) | $1,000/each | $ 3,000 |

Construction Cost for Submerged Articulated Concrete Revetment Mats: $364,042

**Cost per linear foot: $297.66/lft.**

**Straight-Walled Fiberglass Sheetpile (1,857 linear feet)**

| | | |
|---|---|---|
| Mobilization/Demobilization (1 mob/demob) | $11,500/Lump Sum | $ 11,500 |
| Clearing, Grubbing and Shaping | $6,250/Lump Sum | $ 6,250 |
| Fiberglass Sheet piles (72,960 sq.ft.) | $7.00/sq.ft. | $510,720 |
| Dredge Material (est. 1,000 cu.yds) | $15/cu.yd. | $ 15,000 |
| Permanent Warning Signs (3 Signs) | $1,000/each | $ 3,000 |

Construction Cost for Straight-Walled Fiberglass Sheet Pile: $549,970

**Cost per linear foot: $296.16/lft.**

**24" A-Jacks Concrete Blocks (1,283 linear feet)**

| | | |
|---|---|---|
| Mobilization/Demobilization (1 mob/demob) | $11,500 Lump Sum | $ 11,500 |
| Clearing, Grubbing and Shaping | $6,250/ Lump Sum | $ 6,250 |
| Geogrid (2,000 sq.yds) | $6.00/sq.yds. | $ 12,000 |
| Anchors (Type II) (206 Each) | $275/each | $ 56,650 |
| Plantings (454 plants) | $9/each | $ 4,086 |
| Permanent Warning Signs (3 Signs) | $1,000/each | $ 3,000 |
| A Jack Blocks(1,283 linear feet) | $90/lft. | $115,470 |

Construction Cost for A-Jacks Concrete Blocks: $208,956

**Cost per linear foot: $162.86/lft.**

**Staggered Treated Lumber Fencing (1,910 linear feet)**

| | | |
|---|---|---|
| Mobilization/Demobilization (1 mob/demob) | $11,500 lump sum | $ 11,500 |
| Clearing, Grubbing and Shaping | $6,250/Lump Sum | $ 6,250 |
| Timber Fencing (1,910 lft.) | $60/linear ft. | $114,600 |
| Plantings (454 Plants) | $9/each | $ 4,086 |
| Permanent Warning Signs (3 Signs) | $1,000/each | $ 3,000 |

Construction Cost for Staggered Treated Lumber Fencing $ 121,686

**Cost per linear foot: $63.71/lft.**

**2011 Cost Analysis**

**Submerged Articulated Concrete Revetment Mats (1,223 linear feet)**

| | | |
|---|---|---|
| Mobilization/Demobilization (1 mob/demob) | $30,000 lump sum | $ 30,000 |
| Clearing, Grubbing and Shaping | $10,000/Lump Sum | $ 10,000 |
| Articulated Concrete Mats (152 Mats) | $2,400/each | $364,800 |
| Geotextile Fabric (3,939 sq.yds) | $8.00/sq.yd. | $ 31,512 |
| PVC Pipes (24" – 1,129 lft.) | $75/lft. | $ 84,675 |
| Anchors (Type 1 – 284 anchors) | $400/ each | $113,600 |
| Permanent Warning Signs (3 signs) | $3,000/each | $ 9,000 |
| Settlement Plates (3 plates) | $3,500/each | $ 10,500 |

Construction Cost for Submerged Articulated Concrete Revetment Mats: $654,087

**Cost per linear foot: $534.82/lft.**

**Straight-Walled Fiberglass Sheetpile (1,857 linear feet)**

| | | |
|---|---|---|
| Mobilization/Demobilization (1 mob/demob) | $30,000/Lump Sum | $ 30,000 |
| Clearing, Grubbing and Shaping | $10,000/Lump Sum | $ 10,000 |
| Fiberglass Sheet piles (72,960 sq.ft.) | $12/sq.ft. | $875,520 |
| Dredge Material (est. 1,000 cu.yds) | $25/cu.yd. | $ 25,000 |
| Permanent Warning Signs (3 Signs) | $3,000/each | $ 3,000 |

Construction Cost for Straight-Walled Fiberglass Sheet Pile: $943,520

**Cost per linear foot: $508.09/lft.**

**24" A-Jacks Concrete Blocks (1,283 linear feet)**

| | | |
|---|---|---|
| Mobilization/Demobilization (1 mob/demob) | $30,000 Lump Sum | $ 30,000 |
| Clearing, Grubbing and Shaping | $10,000/ Lump Sum | $ 10,000 |
| Geogrid (2,000 sq.yds) | $12/sq.yds. | $ 24,000 |
| Anchors (Type II) (206 Each) | $450/each | $ 92,700 |
| Plantings (454 plants) | $15/each | $ 6,810 |
| Permanent Warning Signs (3 Signs) | $3,000/each | $ 9,000 |
| A Jack Blocks(1,283 linear feet) | $150/lft. | $192,450 |

Construction Cost for A-Jacks Concrete Blocks: $364,960

**Cost per linear foot: $284.46/lft.**

**Staggered Treated Lumber Fencing (1,910 linear feet)**

| | | |
|---|---|---|
| Mobilization/Demobilization (1 mob/demob) | $30,000 lump sum | $ 30,000 |
| Clearing, Grubbing and Shaping | $10,000/Lump Sum | $ 10,000 |
| Timber Fencing (1,910 lft.) | $100/linear ft. | $191,000 |
| Plantings (454 Plants) | $15/each | $ 6,810 |
| Permanent Warning Signs (3 Signs) | $3,000/each | $ 9,000 |

Construction Cost for Staggered Treated Lumber Fencing $ 246,810

**Cost per linear foot: $129.22/lft.**

**Additional 2011 Cost Analysis**

**Conventional Rock Dike**

**Rock Dike (4' top width, 3:1 side slopes, -2.0 contour, elevation +3.0' – assume 1,000 ft. length)**

Quantity: 5,805 tons

| | | |
|---|---|---|
| Mobilization/Demobilization (1 mob/demob) | $50,000 lump sum | $ 50,000 |
| Clearing, Grubbing and Shaping | $10,000/Lump Sum | $ 10,000 |
| Rock Rip Rap (5,805 tons) | $65/ton | $377,325 |
| Geotextile Fabric (4,445 sq.yds) | $8.00/sq.yd. | $ 35,560 |
| Permanent Warning Signs (3 signs) | $3,000/each | $ 9,000 |
| Settlement Plates (3 plates) | $3,500/each | $ 10,500 |

Construction Cost for Submerged Articulated Concrete Revetment Mats: $456,825

**Cost per linear foot: $456.83/lft.**

**Conventional Rock Dike w/ Light-weight aggregate core**

**<u>Rock Dike (4' top width, 3:1 side slopes, -2.0 contour, elevation +3.0' – assume 1,000 ft. length)</u>**

| | | |
|---|---|---|
| Quantity | Rock: | 3,600 tons |
| | Aggregate: | 1,250 cy. |

| | | |
|---|---|---|
| Mobilization/Demobilization (1 mob/demob) | $50,000 lump sum | $ 50,000 |
| Clearing, Grubbing and Shaping | $10,000/Lump Sum | $ 10,000 |
| Rock Rip Rap (3,600 tons) | $65/ton | $234,000 |
| Light weight aggregate core (1,250 cy.) | $110/cy. | $137,500 |
| Geotextile Fabric (4,445 sq.yds) | $8.00/sq.yd. | $ 35,560 |
| Permanent Warning Signs (3 signs) | $3,000/each | $ 9,000 |
| Settlement Plates (3 plates) | $3,500/each | $ 10,500 |

Construction Cost for Submerged Articulated Concrete Revetment Mats: $486,560

**Cost per linear foot: $486.56/lft.**