CWPPRA ADAPTIVE MANAGEMENT: ASSESSMENT OF FIVE BARRIER ISLAND RESTORATION PROJECTS IN LOUISIANA

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EXECUTIVE SUMMARY

Transgressive barrier island systems surround the Mississippi River delta plain and provide important protection to the estuarine-based natural resources and the human infrastructure found landward of these critical shorelines. Through the Coastal Wetland Planning, Protection and Restoration Act (CWPPRA) of 1990, Louisiana has embarked on a program of large-scale barrier island protection and restoration projects. To date CWPPRA has invested more than $35 million in barrier island restoration in Louisiana. After a decade of implementation, CWPRRA has initiated an Adaptive Management process to assess and learn from the implementation of the restoration projects built to date. West to east along Louisiana's coast, the five CWPPRA barrier island restoration projects being assessed by this report include: 1) Raccoon Island (TE-29), 2) Whiskey Island (TE-27), 3) Trinity Island (TE-24), 4) East Island (TE-26), and 5) East Timbalier Island (TE-25/30). A variety of barrier island construction methods were used to restore these protective coastal features from a rubble mound seawall with dunes and backbarrier marshes to segmented detached breakwaters, and dunes with backbarrier marshes. This report investigates the benefits of these different restoration methods as to environmental enhancement, island longevity and construction costs as well as the challenges faced during the construction of the projects. The results of this Adaptive Management review demonstrate the use of dredged material and vegetation to restore barrier island dunes and backbarrier marsh is the most effective in terms of ability and costs to manage and control the long-term trends of erosion. The use of segmented breakwaters and rubble mound seawalls are less effective and more costly than the use of dredge material and vegetation. Improvements need to be made to the final design templates to ensure the correct slopes and elevations for backbarrier marsh creation.

INTRODUCTION

Louisiana is recognized as experiencing the most catastrophic coastal land loss conditions in the United States (Penland et al., 1992; Commission on the Future of Coastal Louisiana, 2002). Between 1932 and 1990, the Mississippi River delta plain lost over 680,000 acres of land (Britsch and Kemp, 1990). Over the last century, more than 50% of the area of Louisiana's barrier islands has been lost to erosion (Penland and Boyd, 1981; McBride et al., 1992). Coastal land loss is a complex environmental phenomenon in the Mississippi River delta plain (Penland, et al., 2002). Coastal land loss occurs in many forms and is a result of many different processes that drive this coastal crisis (Penland et al., 2000a and b).

In response to Louisiana's coastal land loss problem, the U.S. Congress enacted the Coastal Wetland, Planning, Protection, and Restoration Act (CWPRRA) of 1990 (Boesch et al., 1994). CWPRRA has provided more than $600 million to fund the restoration of Louisiana's deteriorating coast. CWPPRA engages in a variety of construction methods from freshwater diversion, marsh creation to barrier island restoration to combat coastal land loss (Raynie and Beasley, 2000).

Since 1990, CWPRRA has sought to restore five major barrier islands, along Louisiana's coast: Raccoon Island (TE-29), Whiskey Island (TE-27), Trinity Island (TE-24), East Island (TE-20) and East Timbalier Island (TE-25/30) (Figure 1). In 2002, the CWPRRA program decided to conduct an assessment of barrier island restoration methods in order to better understand the challenges and successes of project construction, performance, and cost-effectiveness. This assessment is termed Adaptive Management and this is a report on the barrier island restoration project review.

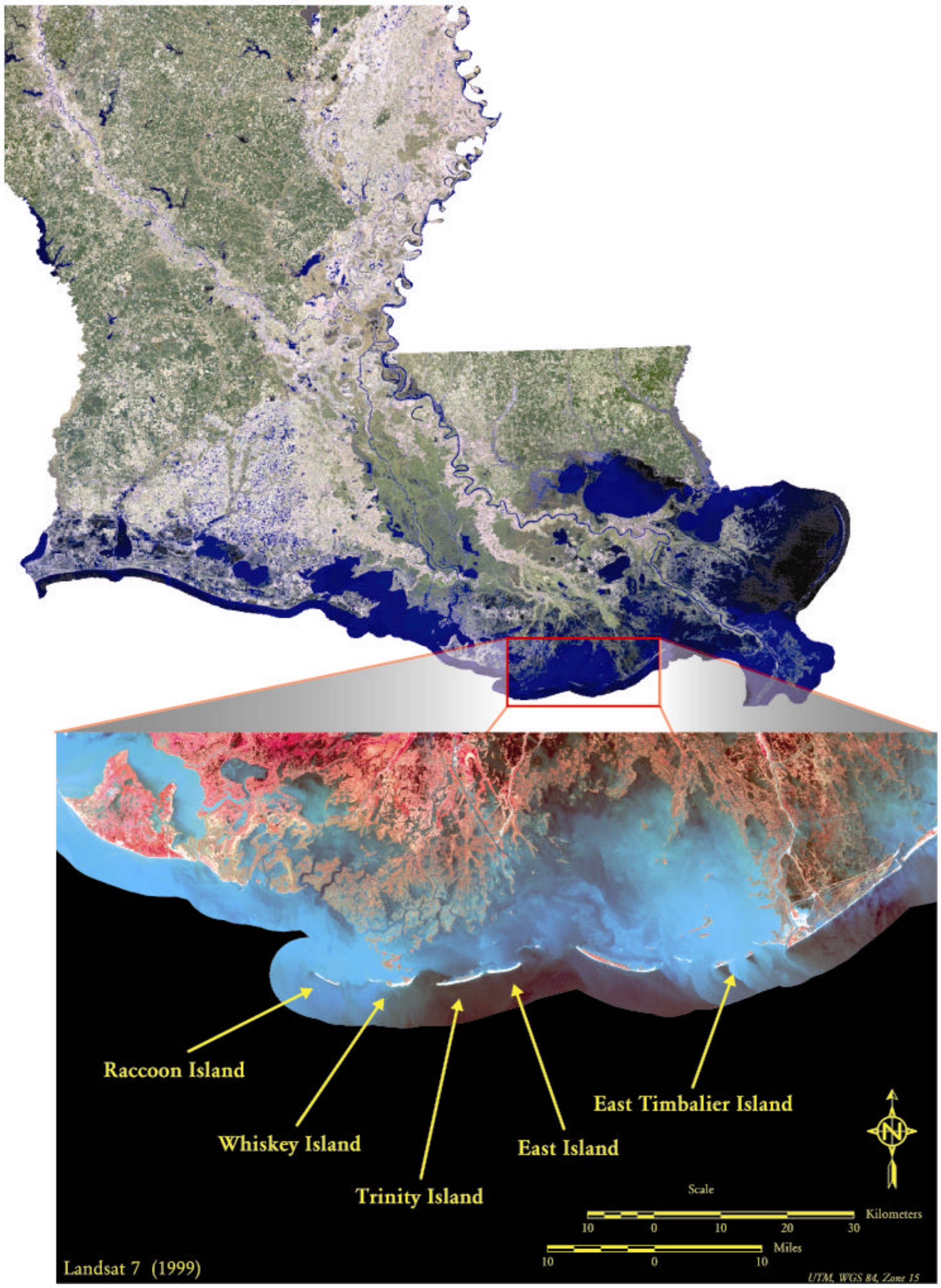

Figure 1. Location map of the five CWPPRA barrier island restoration projects under Adaptive Management Review: Raccoon Island (TE-29), Whiskey Island (TE-27), Trinity Island (TE-24), East Island (TE-20), and East Timbalier Island (TE-25/30).

BARRIER ISLAND FORMATION AND IMPORTANCE

Louisiana's barrier islands are unique in that they are deltaic in origin and are tied to the delta complex switching process of the Mississippi River delta plain (Frazier, 1967; Penland et al., 1981). The Mississippi River has built it's delta plain by the delta complex switching process, since the end of the Holocene Transgression (Figure 2). Delta Switching builds a new, more efficient delta complex and abandons the older, less efficient delta complex. Riverine processes no longer dominate the abandoned delta complex and coastal marine processes begin to rework its seaward margin forming barrier island systems (Penland et al., 1988a). Louisiana's barrier island systems evolve through 3 evolutionary stages as the coastal marine transgression reworks the abandoned, subsiding delta complex. Immediately after delta complex abandonment, barrier islands begin to form. This is termed Stage 1: Erosional Headland with Flanking Barrier Islands (Figure 3). Transgressive submergence erodes and reworks the abandoned regressive distributary and beach-ridge sediments into beaches, recurved spits, and barrier islands. Eventually due to submergence and erosion, Stage 1 evolves into Stage 2: Transgressive Barrier Island Arc. Continual Transgressive submergence leads to the formation of the Stage 3: Inner Shelf Shoal. East Timbalier Island represents a young Stage 1 barrier island. East Island, Trinity Island, Whiskey Island and Raccoon Island of the Isles Dernieres represent older Stage 2 barrier islands.

Louisiana's barrier islands are valued as the first line of defense against coastal storms, particularly hurricanes (Penland et al., 1988b; Stone and McBride, 1988). These barrier islands are critical to maintaining the seaward framework of the Mississippi River delta plain estuaries. Without the barrier islands, the estuaries would deteriorate and the higher salinity Gulf of Mexico waters would invade the lower salinity interior wetlands and the estuarine gradient between them would collapse and its productivity would be destroyed. These islands are not only important to wildlife and fishery resources, they provide critical protection to the human infrastructure landward of them (Louisiana Coastal Wetland Conservation and Restoration Task Force and the Wetlands Conservation and Restoration Authority, 1998). The protection of our Nation's most important domestic oil and gas industry is dependent on the presence of Louisiana's barrier islands as well as the safety of the surrounding low lying population centers within the massive system of hurricane protection levees found in southeast Louisiana, including the City of New Orleans are at risk as the barrier islands erode away.

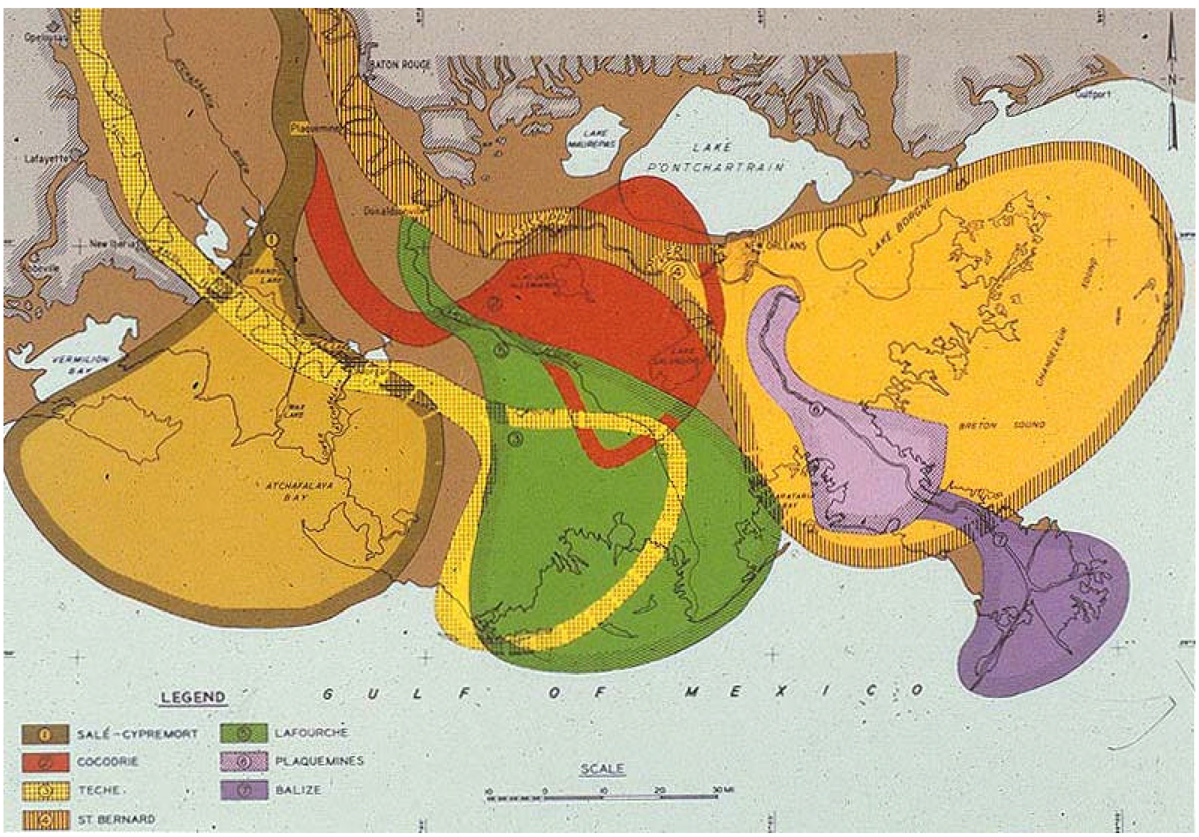

Figure 2. Delta switching model for the Mississippi River delta plain (Kolb and van Lopik, 1958).

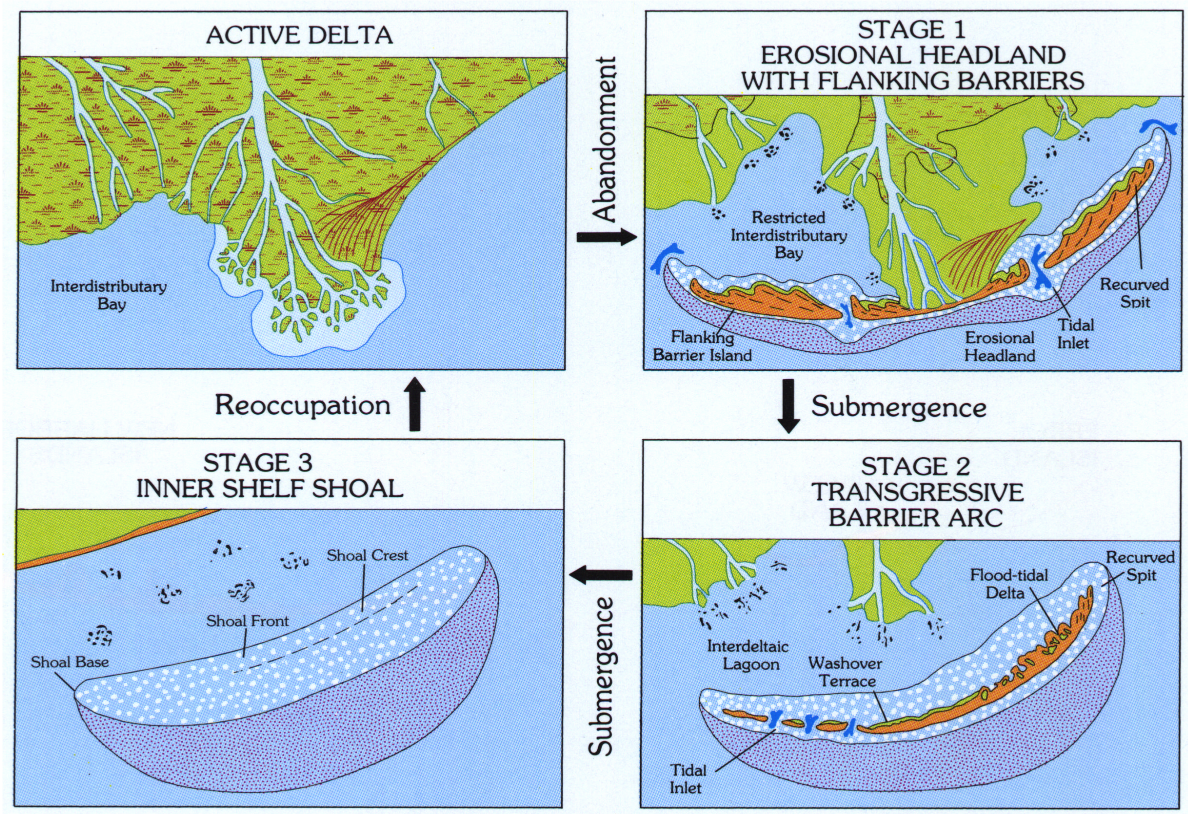

Figure 3. Three-stage Transgressive barrier island evolution model of the Mississippi River delta plain (Penland et al., 1988a).

BARRIER ISLAND CHANGE AND RESTORATION

Raccoon Island (TE-29)

Raccoon Island is the westernmost island in the Isles Dernieres barrier island arc (Figure 1). Raccoon Island represents the remnant of the western recurved spit of the historic Isles Dernieres of 1853 (Williams et al., 1992). The morphology of the Raccoon Island Gulf shoreline consists of undulating dunes and washover terraces with hummocky isolated sand dunes 3-5 feet in elevation on the east end of the island (Ritchie et al., 1988; Ritchie and Penland, 1990). Towards the west, Raccoon Island becomes lower and is more vulnerable to overwash, as a consequence the dune and washover terraces grade into lower washover flats. The backbarrier marshes are the widest on the east end of the island and narrow towards the west end (Figure 4).

The Raccoon Island (TE-29) project consists of 8-segmented breakwaters placed along the eastern end of this barrier island. The dominant littoral drift is to the west. The objective of this demonstration restoration project is as follows (www.lacoast.gov):

- Reduce the rate of shoreline retreat,
- Promote sediment deposition along the beach, and
- Protect seabird habitat.

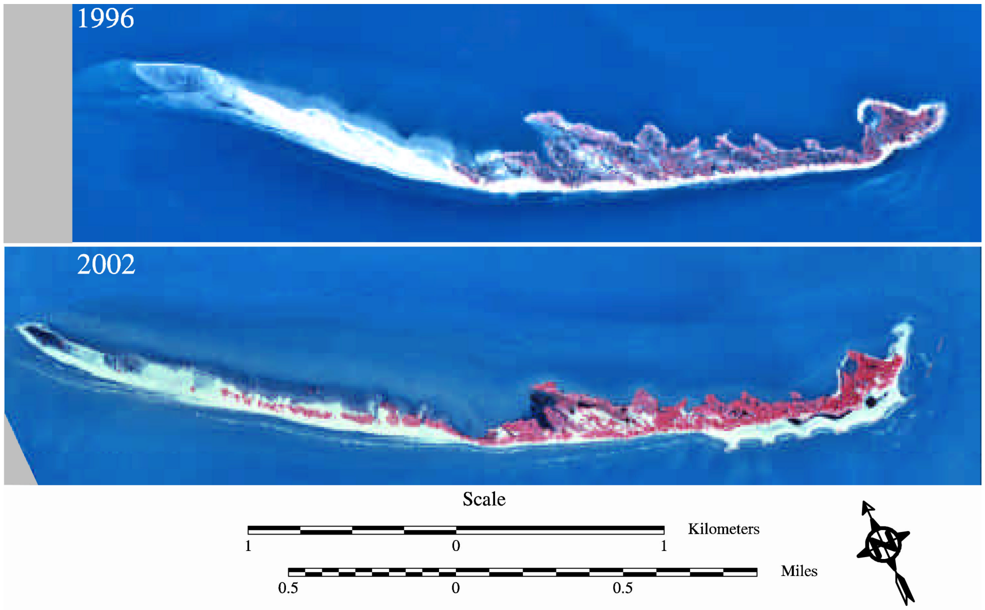

Figure 4. Aerial photo mosaic of Raccoon Island in 1996 (pre-construction) and 2002 (post-construction).

The 8 breakwaters were constructed in June and July of 1997, and were constructed about 300 ft offshore of the southeastern shore of Raccoon Island (Figure 5). The dimensions of the individual breakwaters are 300 ft in length, 10 ft crest height, and 10 ft crest width, with 3:1 slopes (Figure 6). The spacing gap between them is 300 ft. The breakwaters were built on the seafloor adjacent to Pass Colin to the east. The water depths ranged from 2 to 6 ft. This is an area of active landward sediment transport onshore from the Pass Colin. Construction was completed on July 16, 1997. The total project construction cost as of April 7, 2003 was $1,728,453 (www.lacoast.gov).

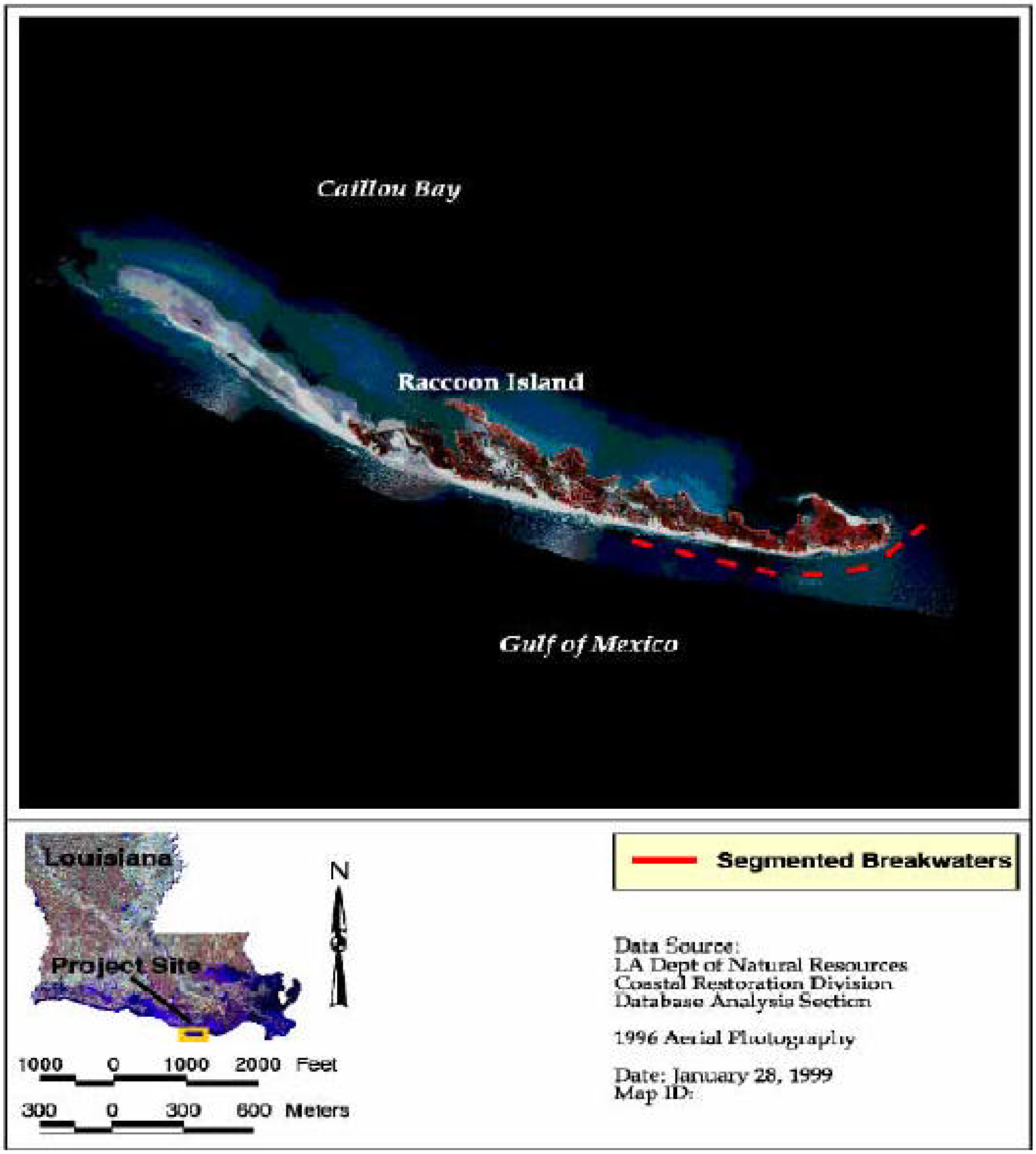

Figure 5. Location of the proposed Raccoon Island demonstration segmented breakwater system.

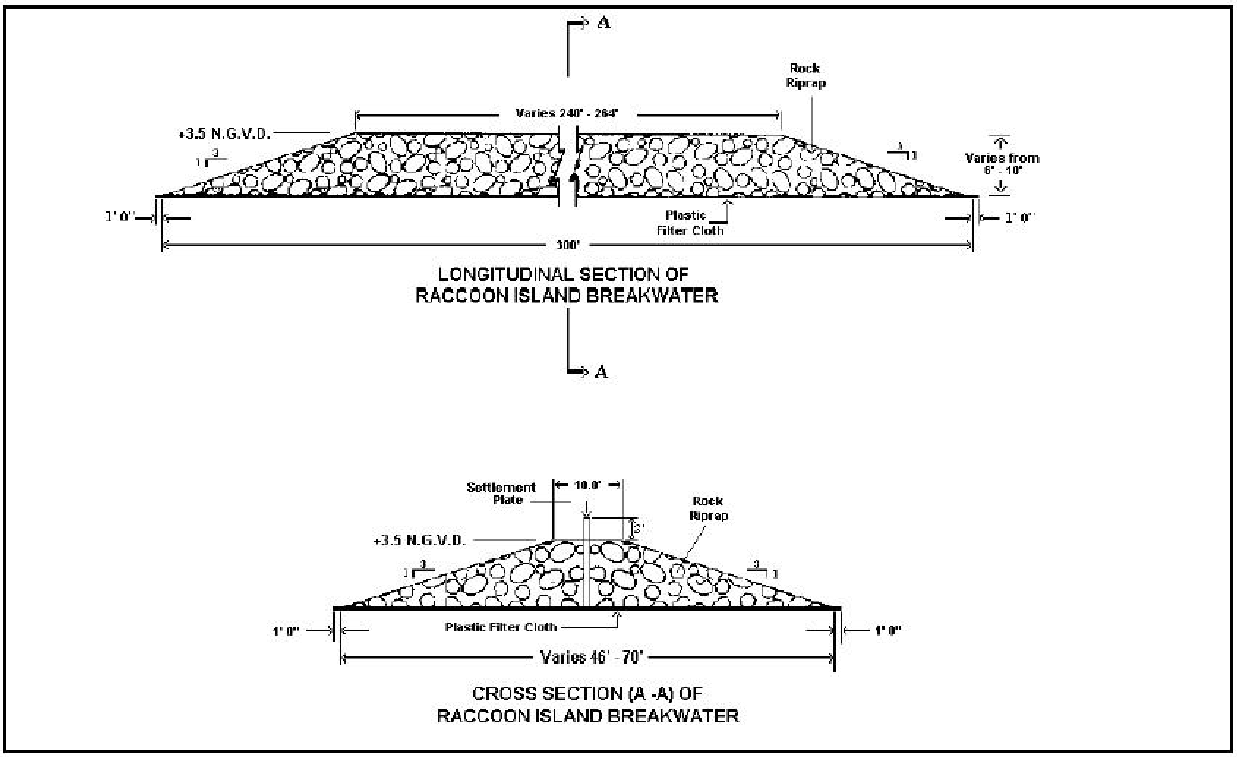

Figure 6. A schematic diagram of a typical Raccoon Island segmented breakwater showing structure dimensions.

Since 1978, Raccoon Island has rapidly decreased in area (Table 1). From 1978 to 1988, Raccoon Island reduced in size from 368.2 acres to 200.2 acres (Figure 7). During this 1978 – 1988 time-period, multiple hurricane impacts occurred in 1979 (Bob and Claudette) and in 1985 (Danny, Elena, and Juan). From 1988 to 1992, Raccoon Island further decreased in area from 200.2 acres to 167.8 acres. With the Hurricane Andrew impact of 1992, the area of Raccoon Island decreased even further to 112.8 acres. By 1993, Raccoon Island further reduced in area to 99.2 acres. The FEMA restoration project of 1994 reversed the trend of island area reduction and the size of Raccoon Island increased to 127.2 acres by 1996. Prior to breakwater construction in 1996, Raccoon Island consisted of 53.0 acres of beach, 4.8 acres of bare land, and 69.4 acres of marsh.

Table 1. CWPPRA Barrier Island Areas[1]: 1978-2002

Island	1978[2]	1988[3]	1992[4,5]	1992 [4,6]	1993 [4,7]	1996[8]	2002[8]
1. Raccoon Island	368.2	200.2	167.8	112.8	99.2	127.2	145.5
2. Whiskey Island	904.4	564.2	505.6	440.8	428.4	474.8	642.8
3. Trinity Island	1317.1	894.6	796.5	678.5	651.4	617.4	710.1
4. East Island	368.2	202.2	173.4	93.4	88.5	193.1	380.4
5. East Timbalier Island	1223.2	588.1	533.7	350.9	316.3	226.2	334.7

[1]Area in acres
[2]McBride et al., 1991
[3]McBride et al., 1992
[4]Penland et al., in press
[5] Pre-hurricane Andrew: 1-24-92
[6] Post-hurricane Andrew 10-12-92
[7] Post-hurricane Andrew 1-16-92
[8] Penland et al., 2003

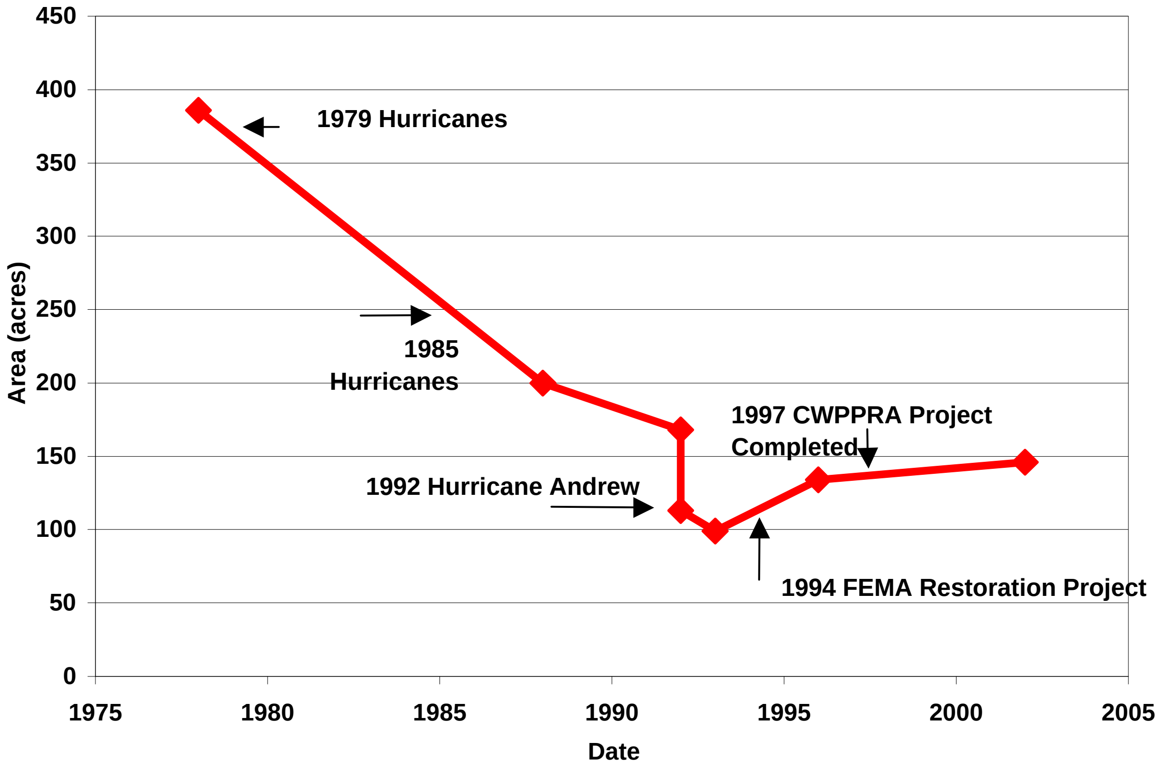

Figure 7. A time-series documenting the historical area changes in Raccoon Island between 1978 and 2002. Significant shoreline events are illustrated along the area time-series line.

The CWPRRA Raccoon Island demonstration segmented breakwater project was completed in 1997 and by 2002, the area of Raccoon Island increased to 145.5 acres. After breakwater construction, the area of beach increased to 67.8 acres due to accumulation behind the breakwaters and the extension of Raccoon Point, the area of bare land increased to 9.0 acres and the vegetated land decrease to 68.7 acres.

The template of this restoration project consisted of 8-segmented breakwaters constructed of stone rubble along the southeastern end of Raccoon Island (Figure 5). The goals of the project were to reduce the rate of shoreline erosion, promote sediment deposition, and protect seabird habitat. Between 1993 and 1994, the FEMA (DESA) restoration project was constructed using beach nourishment to repair the damages of Hurricane Andrew and the size of Raccoon Island increased by 28 acres or 28% in area. Between 1996 and 2002, the CWPPRA Raccoon Island demonstration breakwaters were constructed and the size of Raccoon Island increased by +18.3 acres or 14% in area (Figure 8).

In terms of the project goals, the Raccoon Island demonstration segmented breakwaters did reduce shoreline retreat, promote sediment deposition, and protect seabird habitat immediately landward of the breakwater structures. The segmented breakwaters accumulated sediment to create 17.1 acres of new beach (Figure 9). Of the 8 breakwaters constructed, 6 achieved the project objectives. However, the 2 easternmost breakwaters were ineffective in achieving any of the 3 project objectives identified. From a Raccoon Island coastal systems perspective, the 6 breakwaters that achieved their goal of protecting 3,000 feet of shoreline along Raccoon Island did affect areas further to the west. The 6 breakwaters disrupted sediment transport to the west creating an erosional shadow downdrift (Figure 9).

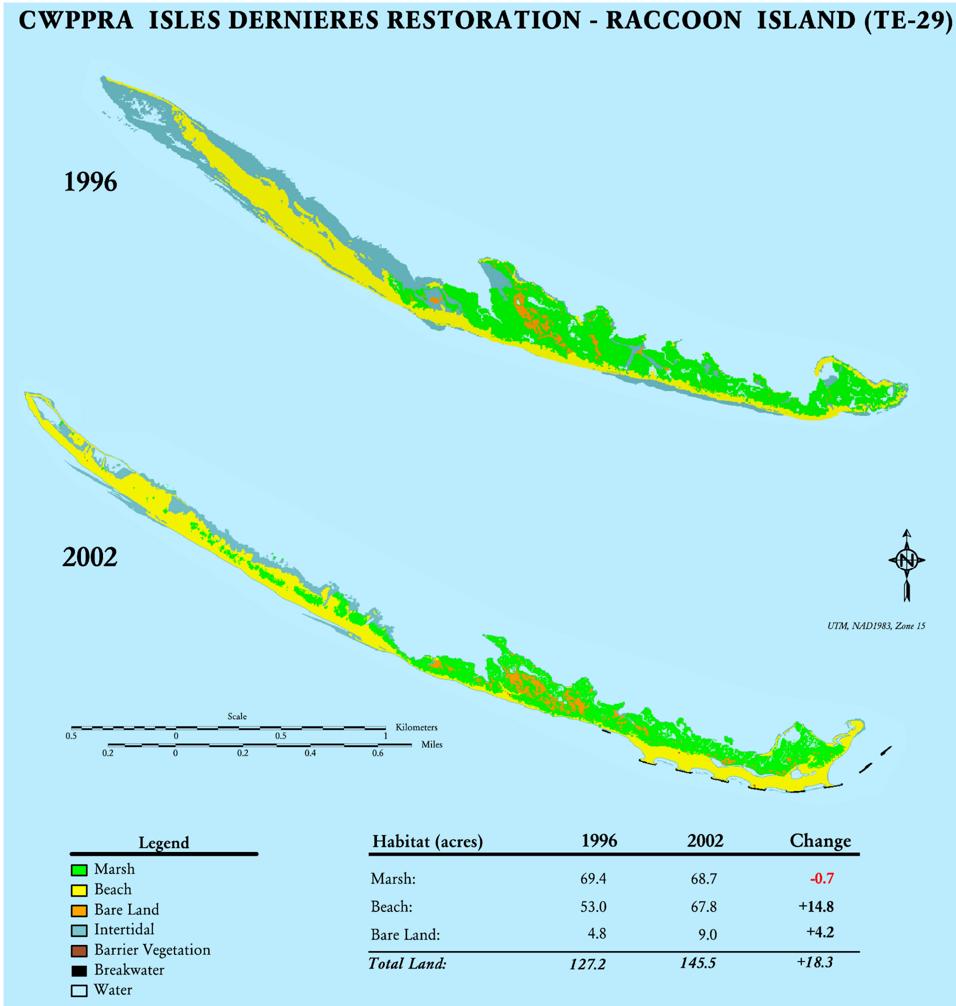

Figure 8. The 1996 pre-construction and 2002 post-construction habitats found at Raccoon Island (TE-29).

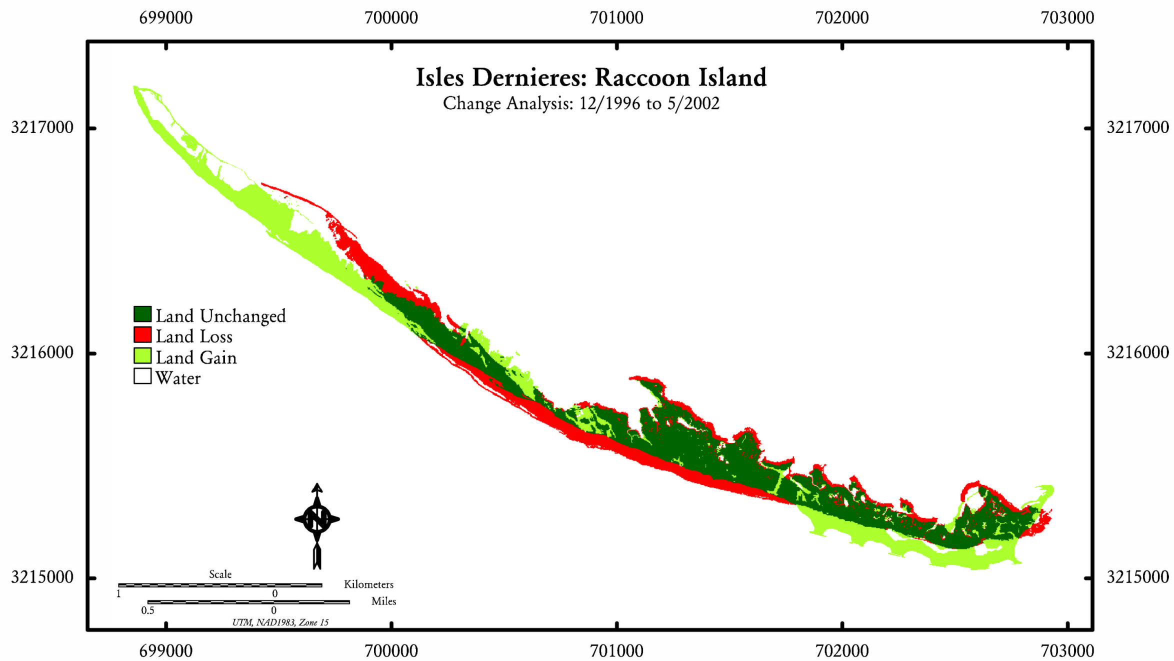

Figure 9. A map that depicts land gain, land loss, and land unchanged at Raccoon Island between 1996 and 2002.

The erosional shadow measured approximately 8,900 feet in length and resulted in the loss of 19.3 acres of Raccoon Island to accelerated shoreline retreat. The downdrift erosional shadow of the Raccoon Island segmented breakwaters accelerated shoreline retreat, promoted the loss of sediment from the beach, and damaged habitat in an area larger than the area protected by the segmented breakwaters. As a demonstration project, the Raccoon Island segmented breakwaters were successful when viewed in terms of the immediate area landward of them. However, the Raccoon Island segmented breakwaters proved to be unsuccessful from a larger coastal systems perspective because the positive benefits of the segmented breakwaters did not outweigh the negative benefits produced by the erosional shadow of the breakwaters. As of April 7, 2003, the total project construction cost was $1,788,184.

Whiskey Island (TE-27)

Whiskey Island is located immediately east of Raccoon Island (Figure 1). The morphology of the Gulf shoreline of Whiskey Island is characterized by a narrow beach backed by washover terraces and flats (Ritchie et al., 1988; Ritchie and Penland, 1990). The shoreline connects two marsh island remnants of the Mississippi River delta plain (Figure 10). The goal of the Whiskey Island restoration project is as follows (www.lacoast.gov):

- Create 328 acres of backbarrier marsh,
- Close the Coupe Nouvelle breach,
- Plant dune vegetation, and
- Construct sand fencing to trap sediment.

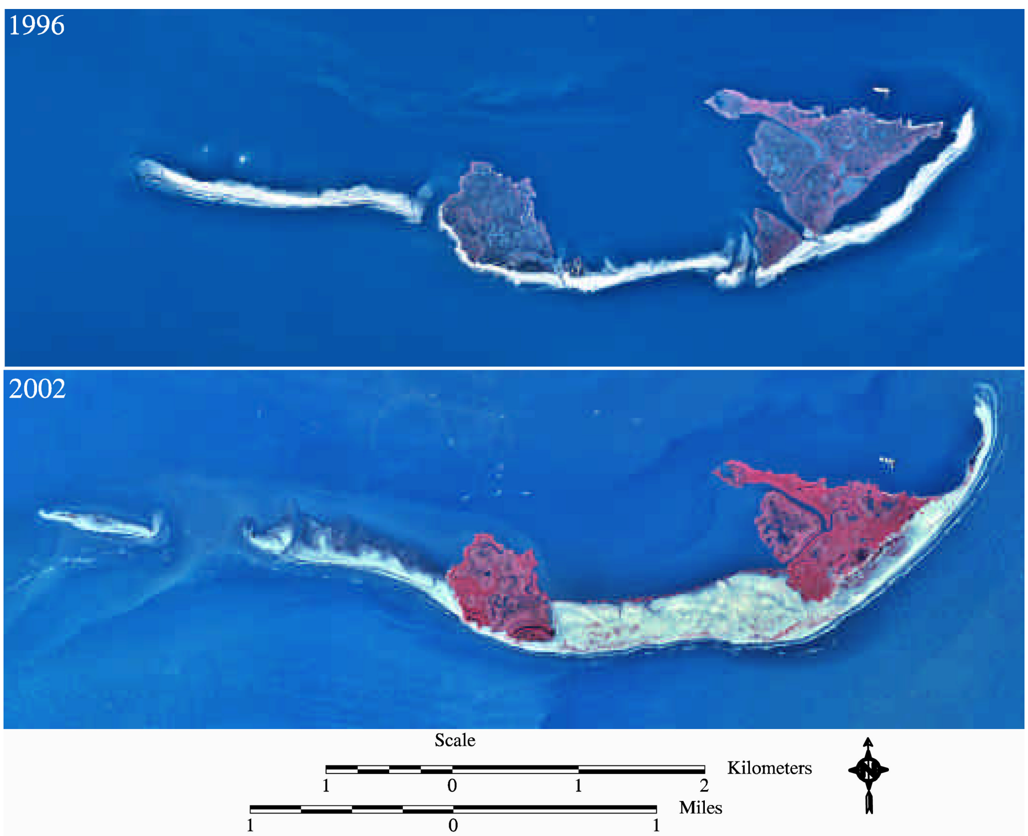

Figure 10. Air photo mosaics of Whiskey Island (TE-27) in 1996 (pre-construction) and 2002 (post-construction).

The Whiskey Island (TE-27) restoration project consisted of two design templates. The Coupe Nouvelle reach containment area was located along the southeastern shore of Whiskey Island and consisted of a +3 ft NAVD dune crest with a Gulfward slope of 1:100 and a bayward slope that varied to the natural contour of the backbarrier marsh (Appendix A). The width of the dune crest varied 200-300 ft by cross-section. The Coupe Nouvelle reach was designed as a backbarrier marsh creation project. The Whiskey Island reach area is located along the central shoreline of this island between the two main marsh islands and consisted of a +4 ft NAVD dune crest with a Gulfward slope of 1:100 and a bayward slope that varied towards Lake Pelto (Appendix A). The crest of the dune varied 300-500 ft in width by cross-section. The Whiskey Island section was designed as a breach closure and backbarrier marsh creation project. The natural dune line of the gulf shoreline served as containment to the south. The containment dike was designed with an elevation of +3 ft NAVD, and was to be placed along the Lake Pelto shoreline. The flanking dunes and backbarrier marsh surfaces to the east and west also served as containment features.

The Whiskey Island restoration project reach used a combination of unconfined and confined dredge material placement to construct the restoration template. Approximately 9,120 linear feet of containment dike was constructed for dredge material placement. Four areas containing greater than 70% sand was identified for use in project construction (Figure 11). These areas were identified as F1, F2, F3, and K. The dredge used to construct the Whiskey Island (TE-27) barrier restoration project was the Dredge Tom James which is a 30” diameter cutter head dredge that moved 2,850,000 cubic yards of dredge material from the borrow area into the Whiskey Island reach and Coupe Nouvelle reach containment areas (Figure 12).

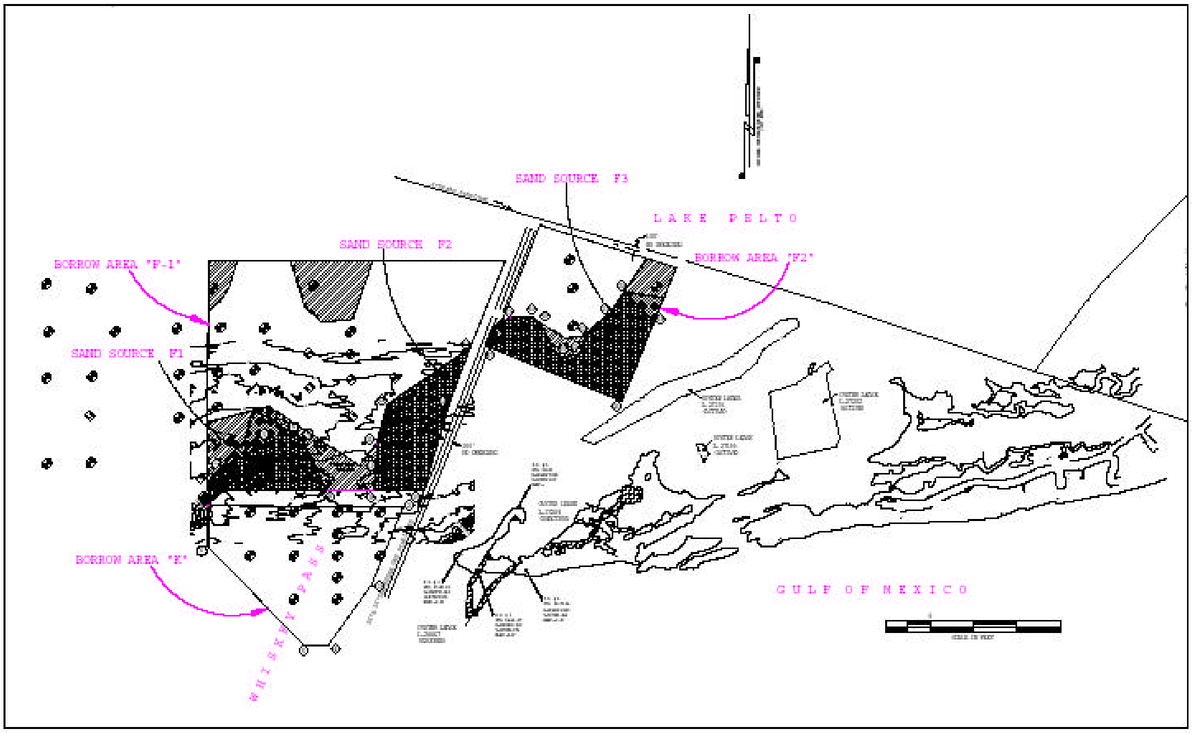

Figure 11. The proposed sediment borrow areas for Whiskey Island (TE-27) are identified as F1, F2 and K.

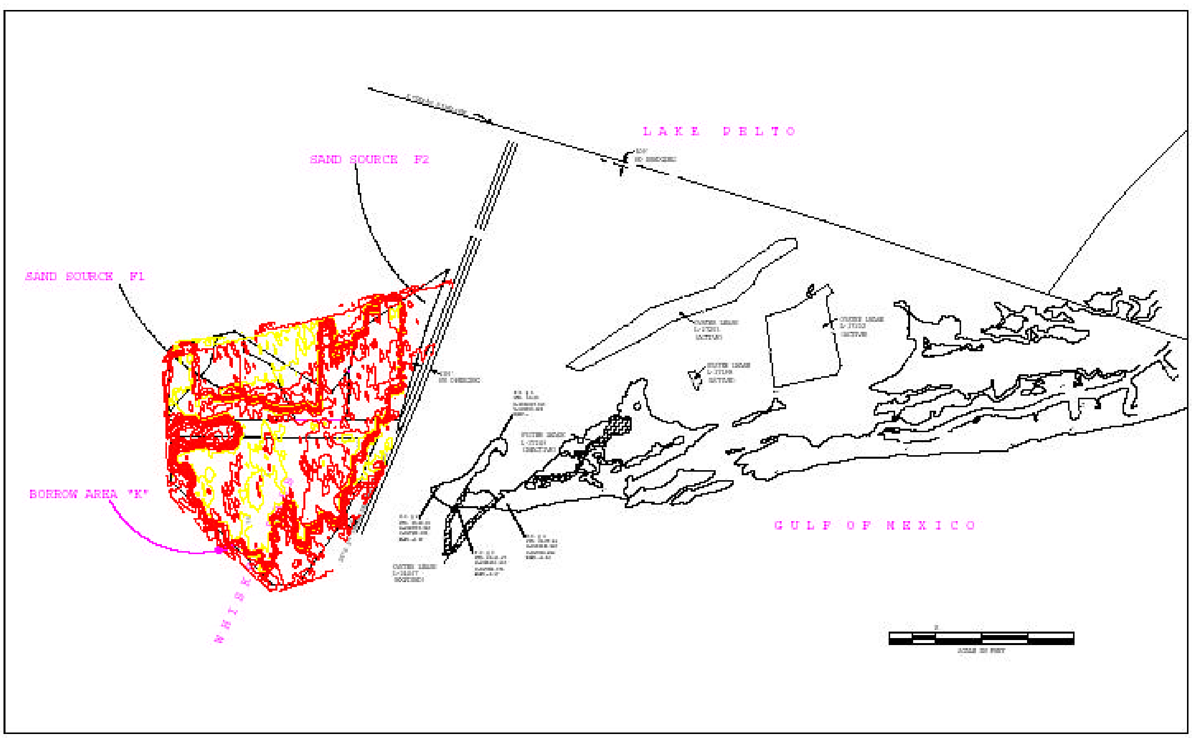

Figure 12. A post-construction survey map of the borrow areas excavated by the Dredge Tom James in borrow areas F1, F2, and K in the vicinity of Whiskey Pass.

After the dredge material had sufficiently dewatered, it was minimally graded and shaped into the final construction template. Vegetation was initially planted in July 1998 along the shoreline of Lake Pelto. Additional plantings were carried out in May and June of 1999, and sand-fencing construction was completed in June 2000. As of April 7, 2003, the total project construction cost was $7,299,482 (www.lacoast.gov).

Prior to restoration, Whiskey Island was rapidly eroding and decreasing in area (Table 1). Between 1978 and 1988, Whiskey Island decreased in area from 904.4 acres to 564.2 acres (Figure 13). This was a time period when multiple hurricanes impacted the area in 1979 (Bob and Claudette) and 1985 (Danny, Elena and Juan). By 1992, Whiskey Island had decreased to 505.6 acres. During the 1992 hurricane season, Hurricane Andrew impacted this area dramatically reducing Whiskey Island to 440.8 acres and by 1993 it further decreased in area to 428.4 acres. Post-storm recovery processes increased the area of Whiskey Island to 474.8 acres by 1996. Prior to restoration in 1996, Whiskey Island was comprised of 165.0 acres of beach, 2.5 acres of bare land, 304.1 acres of marsh and 83.2 acres of barrier vegetation (Table 2; Figures 14 and 15). Construction of Whiskey Island began in February 1998 and was completed in August 1998.

Table 2. CWPPRA Barrier Island Habitat Area: 1996-2002[1]

Island	Beach	Bare Land	Marsh	Barrier Vegetation	Area
Whiskey Island: 1996	165.0	2.5	304.1	3.2	474.8
Whiskey Island: 2002	102.2	196.5	296.7	47.5	642.9
Trinity Island: 1996	188.3	14.4	386.3	28.4	617.4
Trinity Island: 2002	89.8	272.1	268.1	80.1	710.1
East Island: 1996	136.5	0.6	39.6	16.4	193.1
East Island: 2002	111.2	213.4	18.2	37.6	380.4
East Timbalier Island: 1996	77.1	1.9	135.9	11.3	226.2
East Timbalier Island 2002	83.7	80.4	153.9	16.7	334.7

[1] Acres

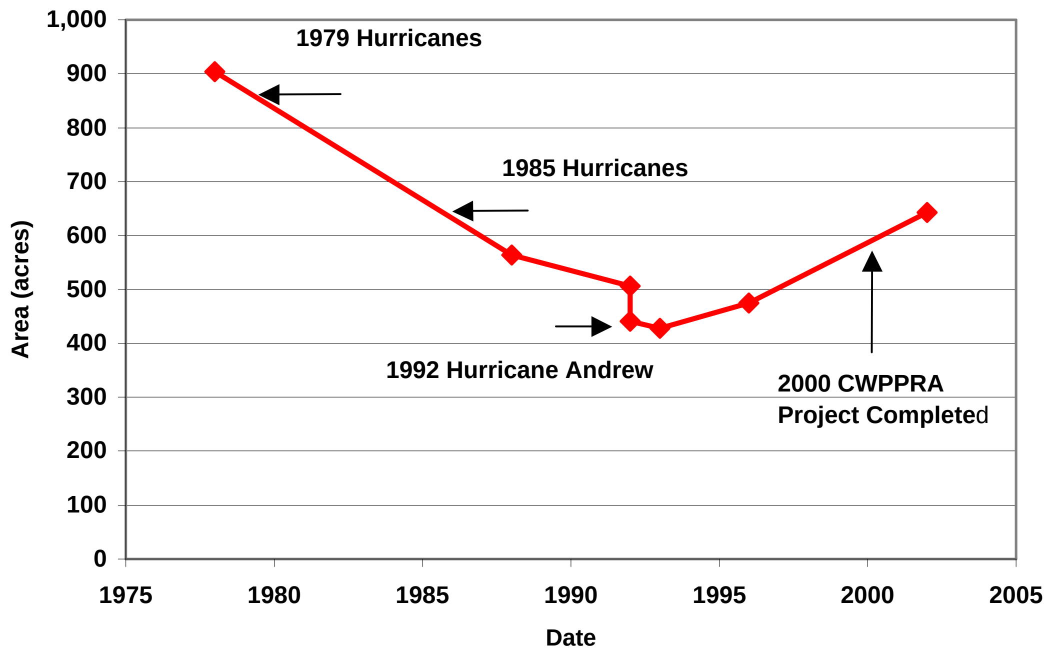

Figure 13. A time-series documenting the historical area changes in Whiskey Island (TE-27) between 1978 and 2002. Significant shoreline events are illustrated along the area time-series line.

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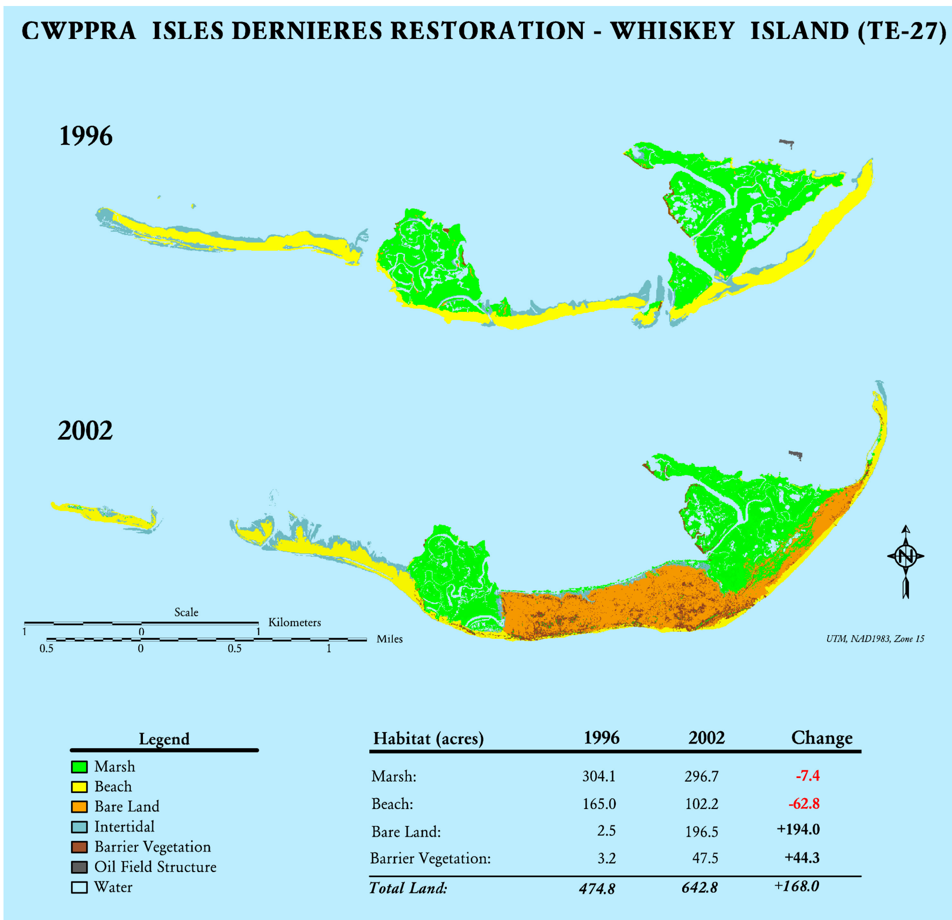
By 2002, the area of Whiskey Island had increased to 642.8 acres, a 36% increase in area (Figures 14 and 15). After restoration and by 2002, Whiskey Island was comprised of 102.2 acres of beach, 196.5 acres of bare land, 296.7 acres of marsh and 47.7 acres of barrier vegetation. The decrease in the beach habitat class is a result of filling and the switching of the beach habitat to bare land. The increase in bare land is a result of new land creation and/or filling. The decrease in marsh habitat is a result of burial by fill material and habitat switching. The increase in barrier vegetation is a result of land creation combined with vegetative plantings and recruitment increasing the area of this habitat type.



Habitat (acres)	1996	2002	Change
Marsh:	304.1	296.7	-7.4
Beach:	165.0	102.2	-62.8
Bare Land:	2.5	196.5	+194.0
Barrier Vegetation:	3.2	47.5	+44.3
Total Land:	*474.8*	*642.8*	*+168.0*

Figure 14. The 1996 pre-construction and 2002 post-construction habitats found at Whiskey Island (TE-27).

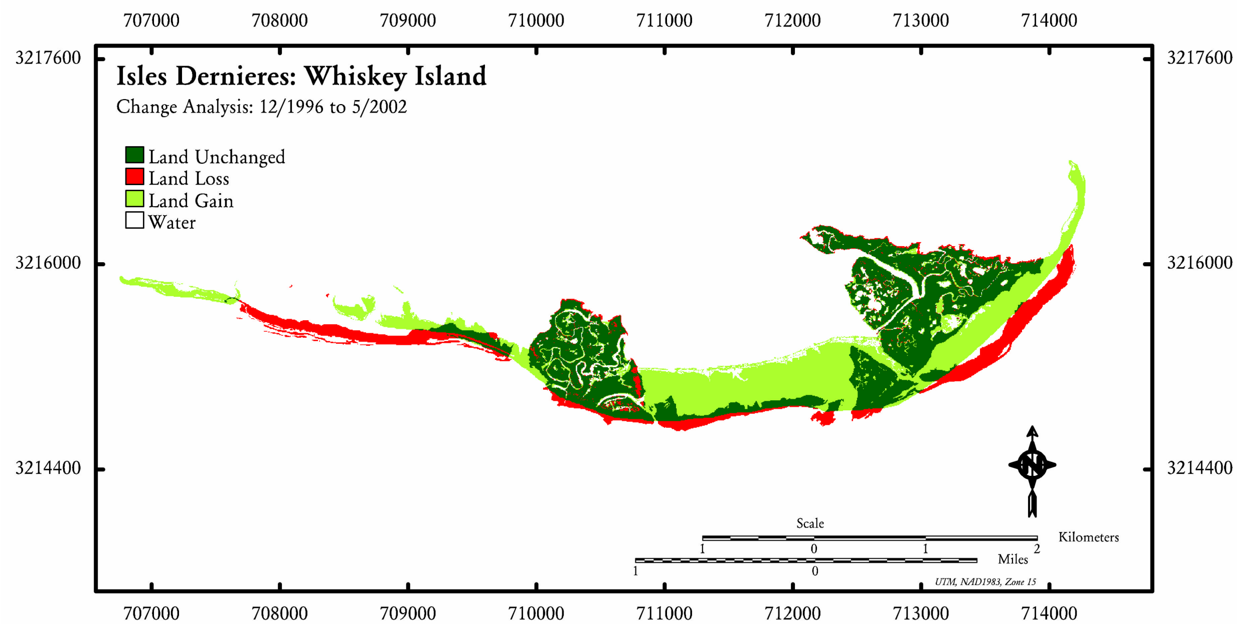


Figure 15. A map that depicts land gain, land loss, and land unchanged at Whiskey Island (TE-27) between 1996 and 2002.

The as-built drawing of the Whiskey Island restoration reach shows the dune sloping steeply towards the Gulf of Mexico shoreline and sloping steeply towards Lake Pelto (Appendix B). The Coupe Nouvelle restoration reach was designed for a +3 ft NAVD dune crest (Appendix A). The construction as-built shows the elevations as high as +6 ft NAVD near Whiskey Pass and decreasing from +5 ft to +4 ft NAVD to the west. Containment was planned for the Coupe Nouvelle reach area. The quality of the material in the F1 and F2 borrow area was poorer than predicted and the contractor had to build a containment dike in order to get the dredge material to stack. The +6 ft NAVD high area near Whiskey Pass was the initial location of the dredge pipe outfall. As the Coupe Nouvelle reach was constructed, the outfall pipe was moved further and further to the west. The breach that separated the Coupe Nouvelle reach and the main Whiskey Island reach was closed using unconfined dredge material placement with higher quality sediment from borrow area K. Further west, the natural shoreline was used as the gulfside containment dike and an earthen containment dike was constructed along the bay margin of Lake

Pelto. This containment dike maintained its integrity during construction due to the shelter provided by the surrounding marsh from the wave energy of Lake Pelto. As the Dredge Tom James moved further south into borrow area K, the quality of material continued to improve and the construction of the Whiskey Island reach was completed in August 1998.

In terms of meeting the stated Whiskey Island restoration project goals, the Coupe Nouvelle breach was closed, vegetation was planted and sand fencing was constructed. However, this restoration project did not construct 328 acres of new backbarrier marsh as proposed. This project created 168.1 acres of new land of which a small percentage was backbarrier marsh. The Whiskey Island restoration project missed its construction objective by –159.9 acres. One of the most probable reasons for the Whiskey Island project not achieving its target area may be the fact that the contractor's goal was to create a dredge hole of a specific size for payment. Payment was not based on the criteria to create 328 acres of new backbarrier marsh. The majority of new land created was not backbarrier marsh because the elevation was too high and the slope too steep. The majority of the new land created exceeded +2 ft NAVD (Appendix B). In most cases the proposed project elevations were exceeded and the construction as-built restoration template appears to be overfilled when compared to the design template. If the dredge material had been spread at the design elevation and slope, the area of land creation would have been larger with a higher probability for backbarrier marsh creation. If the project had been designed with a lower dune and a wider backbarrier marsh platform at +2 ft NAVD or less in elevation, the post-construction restoration template would have been closer to reaching the target of 328 acres of backbarrier marsh. Another consideration in not achieving the target area and habitat type is the quality of the dredge material in borrow areas F1 and F2. The project was originally designed to use containment dikes in the Coupe Nouvelle reach. Along the bayside of the Whiskey Island reach, the elevation and slope to Lake Pelto also exceeded the template design. The final construction template of Whiskey Island was higher in elevation and greater in slope than the original design template. This situation also indicates the importance of the contractor to adhere to the design template. It also points to the question of how the alignment of the containment dikes was determined and how the volume of hydraulic fill needed was calculated, because this will ultimately control the final as-built elevation and slope which will in turn control the area and the habitat type created. Another important point is the correct elevation for backbarrier marsh creation. The original design template could have never achieved the creation of backbarrier marsh because the project elevation was too high. The optimum elevation for marsh creation is ± 0-2 ft NAVD.

Trinity Island (TE-24)

Trinity Island is the largest island of the Isles Dernieres barrier island arc and is located immediately to the east of Whiskey Island (Figure 1). The morphology of the gulf shoreline of Trinity Island is characterized by a low hummocky dune terrace with isolated dunes of up to 3-4 feet in elevation (Ritchie et al., 1988; Ritchie and Penland, 1990). At the west and east ends of Trinity Island, the elevation decreases and overwash is more frequent resulting in the occurrence of washover flats (Figure 16). The goals of the Trinity Island restoration project are as follows (www.lacoast.gov):

- Restore Trinity Island dunes,
- Restore Trinity Island marshes,
- Create approximately 353 acres of island,
- Enhance the physical integrity of the island,
- Protect the Terrebonne estuary and vegetated wetlands against the direct exposure to the Gulf of Mexico, and
- Increase technical information on the restoration of barrier islands.

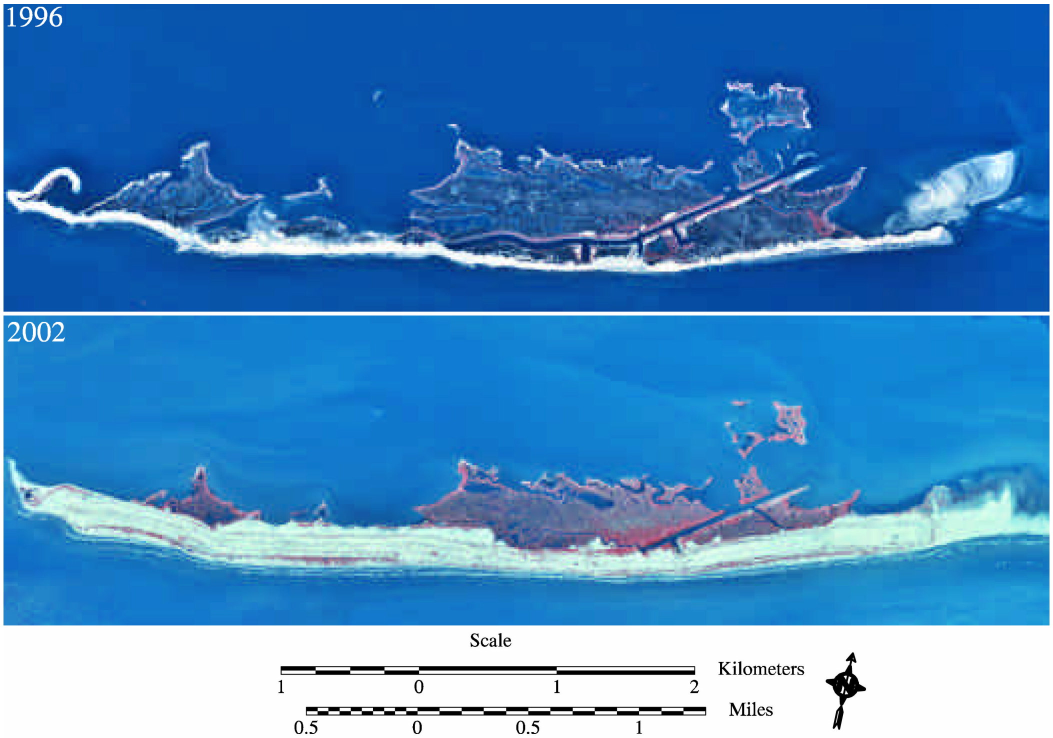


Figure 16. Air-photo mosaics of Trinity Island (TE-24) barrier island restoration project in 1996 (pre-construction) and 2002 (post-construction).

The Trinity Island restoration project was constructed after the completion of Whiskey Island and East Island. The Dredge Tom James, a 30” cutterhead dredge, moved from Whiskey Island after construction was completed to the west end of Trinity Island. The Dredge Arkansas, a 24” cutterhead dredge, moved from East Island after construction was completed to the east end of Trinity Island to begin the construction of this coastal restoration project.

The Trinity Island final restoration template was constructed into two phases. First, two major containment dikes were constructed to manage the initial placement of hydraulic fill. Both the gulfside and bayside containment dikes were constructed to +6 ft NAVD (Appendix C). The hydraulic fill was placed at a +5 ft NAVD elevation within the containment dikes. At Trinity Island there were 36,676 linear of land containment and 6,900 feet of water containment constructed. The majority of the hydraulic fill was placed on top of Trinity Island with a lesser amount in Lake Pelto. A series of 5 borrow areas of sand were identified to restore Trinity Island, F1, F2, K, H1, and H2. All borrow areas were predicted to contain more than 70% sand Figure 17). A total of 2,950,000 cubic yards of hydraulic fill was placed in the containment area of Trinity Island from the borrow sites (Figure 18). After containment dike construction and fill placement, the project area was cut, graded, and shaped into its final construction template.

The Trinity Island design template consisted of a +8 ft NAVD dune crest measuring 300 ft in width (Appendix C). The gulfside of the dune had a 1:10 slope to +6 ft NAVD with a varying slope to the backshore of the natural shoreline. The elevation of the natural shoreline was +2-3 ft NAVD. The bayside of the +8 ft NAVD dune had a 1:10 slope to +4 ft NAVD and a variable slope to Lake Pelto. This final construction template was achieved by cutting, grading and shaping. During construction, the water-based containment dikes kept being undermined by wave erosion from Lake Pelto. In response, visquene or plastic sheeting served as a temporary solution to stabilize the water-based containment dikes. The Dredge Tom James was mobilized in January 1998 and completed dredging by September 1998. Grading and shaping of the final construction template followed (Appendix D). Vegetative plantings and the installation of 22,500 linear feet of sand fencing were installed by the summer of 1999. As of April 7, 2002, the total cost of Trinity restoration was $10,785,706 (www.lacoast.gov).

Prior to restoration, Trinity Island was rapidly eroding and decreasing in area (Table 1). Between 1978 and 1988, Trinity Island decreased in area from 1317.1 acres to 894.6 acres (Figure 19). This was a time period of multiple hurricanes in 1979 (Bob and Claudette) and 1985 (Danny, Elena, and Juan). By 1992, Trinity Island further decreased to 796.5 acres.

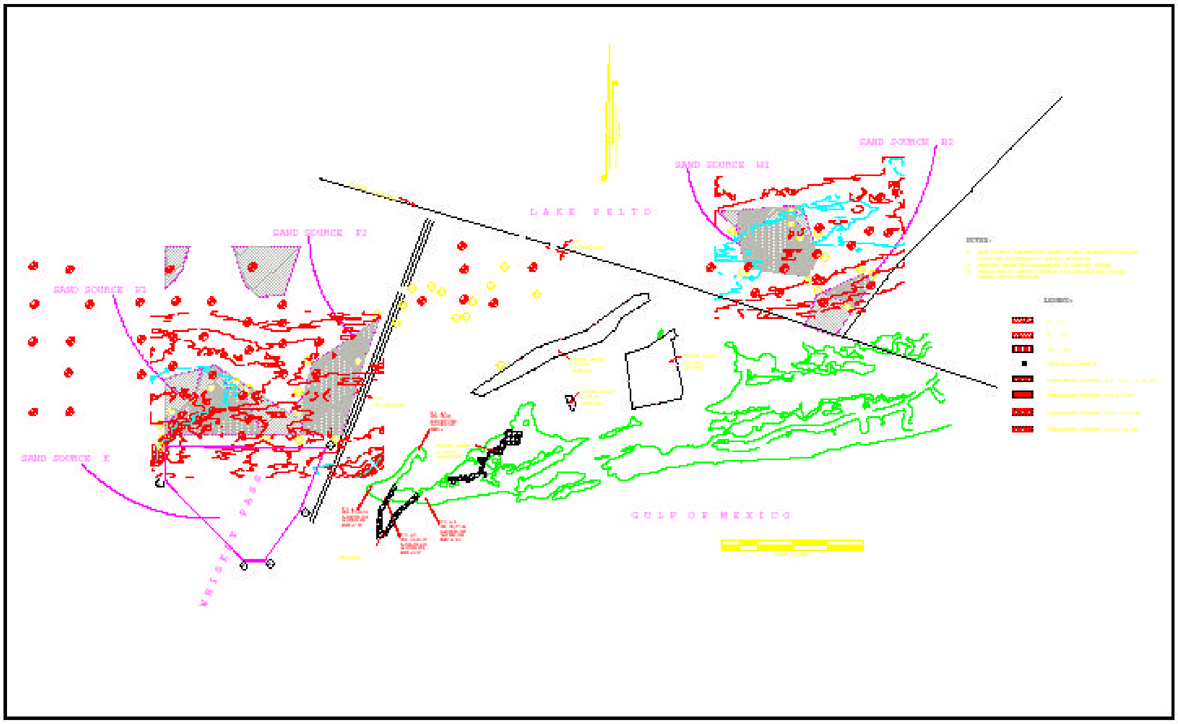


Figure 17. The proposed sediment borrow areas for Trinity Island are identified as H1, H2, F1, F2, and K.

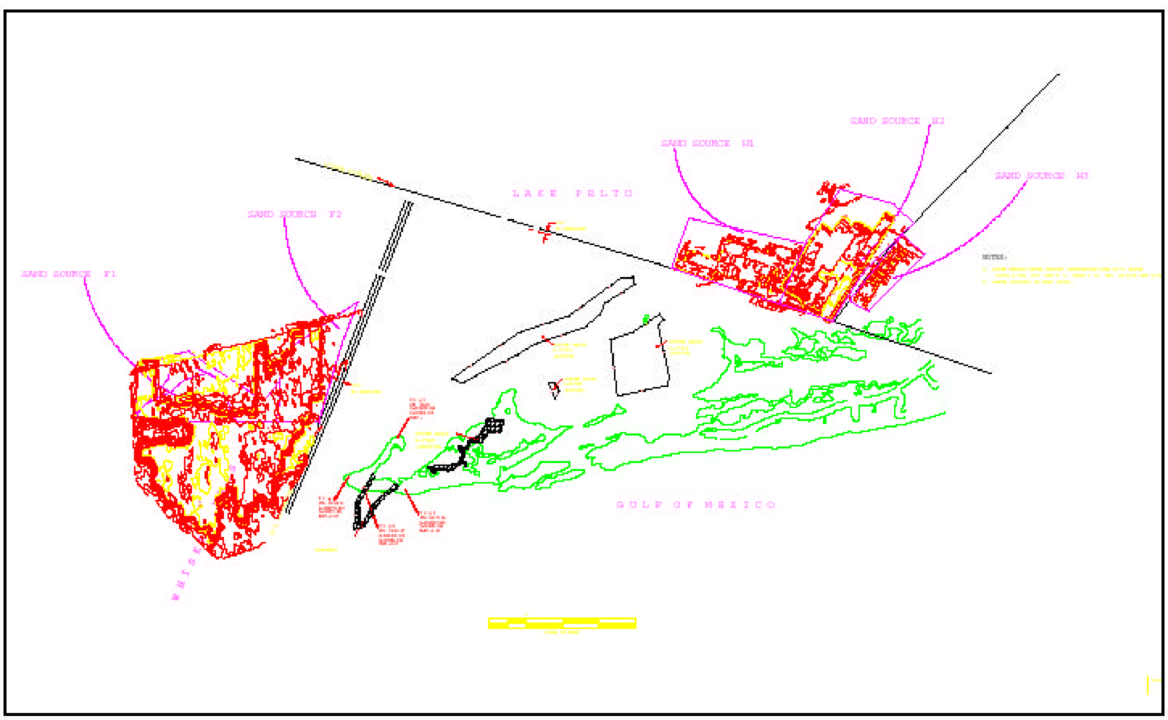


Figure 18. A post-construction survey of the H1, H2, H7, F1, F2 and K borrow areas used to construct the Trinity Island (TE-24) restoration project.

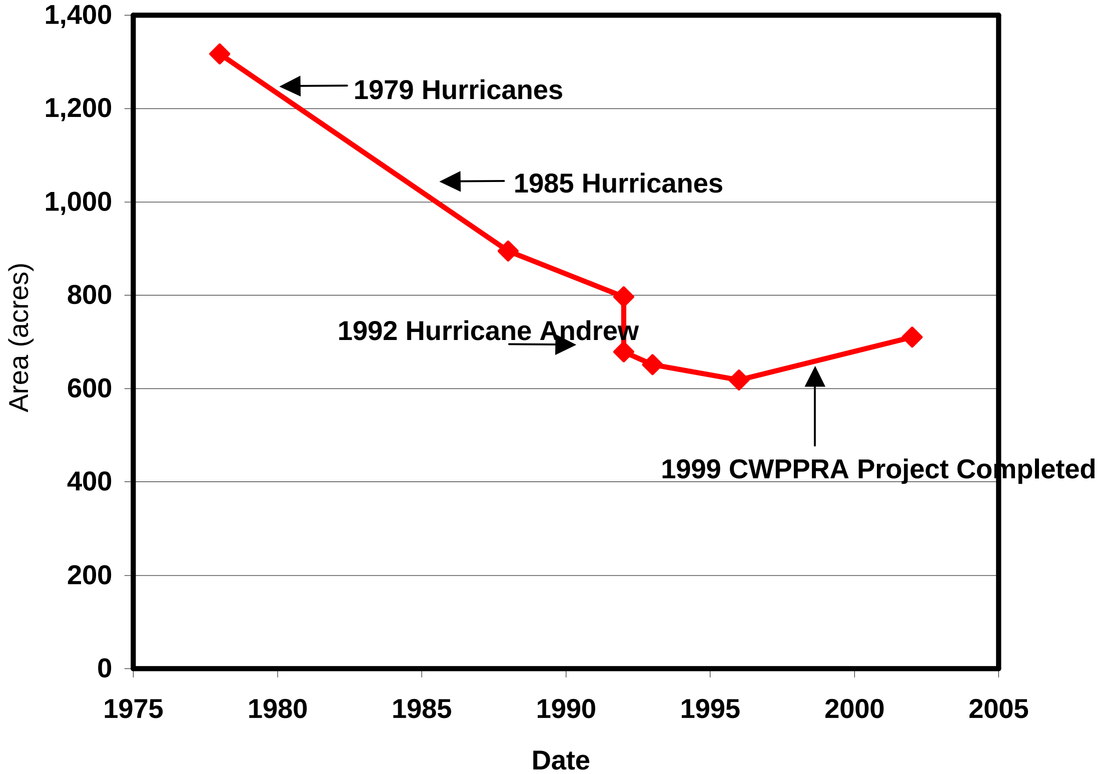


Figure 19. A time-series documenting the historical area changes in Trinity Island (TE-24) between 1978 and 2002. Significant shoreline events are illustrated along the area time-series line.

During the 1992 hurricane season, Hurricane Andrew impacted this area reducing Trinity Island to 678.5 acres and by 1993, this island decreased further to 651.4 acres. By 1996, the area of Trinity Island continued to decrease to 617.4 acres. Prior to restoration, this island consisted of 188.3 acres of beach, 14.4 acres of bare land, 386.3 acres of marsh and 28.4 acres of barrier vegetation (Table 2; Figures 20 and 21).

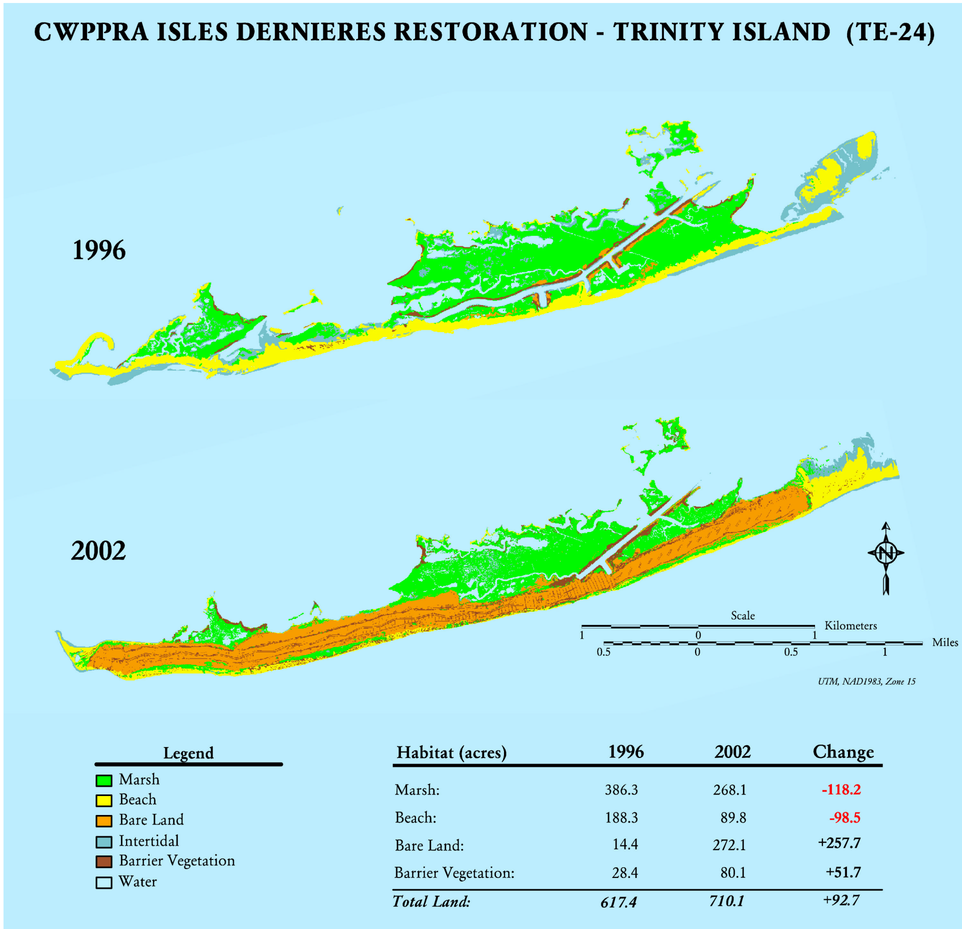


Figure 20. The 1996 pre-construction and 2002 post-construction habitats found at Trinity Island (TE-24).

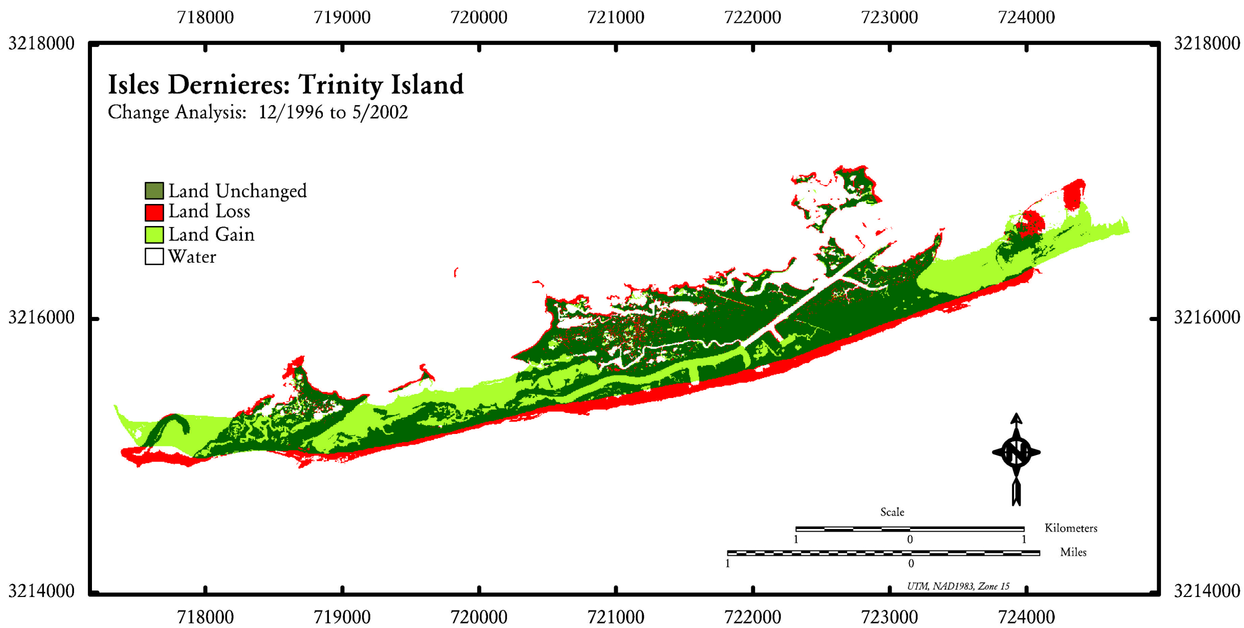


Figure 21. A map that depicts land gain, land loss, and land unchanged at Trinity Island (TE-27) between 1996 and 2002.

After restoration, Trinity Island increased in area from 617.4 to 710.1 acres by 2002. The beach class decreased from 188.3 acres to 89.8 acres after restoration (Table 2; Figure 20). This decrease is a function of filling and habitat switching to bare land. The marsh class decreased from 386.3 acres to 268.1 acres due to filling. The bare land dramatically increased in area from 14.4 acres to 272.1 acres as a result of direct filling. The barrier vegetation class increased from 28.4 acres to 80.1 acres due to vegetative plantings and growth of existing barrier vegetation.

The construction as-built drawings of the Trinity Island project shows the dune steeply sloping towards the Gulf of Mexico shoreline and steeply sloping towards Lake Pelto (Appendix D). The overall final Trinity Island dune meets the restoration template design. The vegetative plantings were completed in June 1999. However, the backbarrier slopes were too high and steep to achieve the desired project goal of marsh restoration. A review of the as-built in Appendix B show that slope of the backbarrier marsh platform is 1:10 and the majority of the elevation is greater than +4 ft NAVD. This configuration for the backbarrier marsh platform prohibited the establishment of extensive backbarrier marsh habitat.

A review of the project goals show that the Trinity Island restoration project achieved mixed results. The goal to restore the dunes of Trinity Island is questionable. The natural dunes found there were only +2-5 ft in elevation and supported a diverse variety of habitat and wildlife. There was never a continuous +8 ft high dune documented on Trinity Island. The +8 ft NAVD artificial dune lacks the natural biodiversity of a natural Louisiana dune system. The project goal to restore the dunes of Trinity Island was not achieved, nor was the goal to create or restore the marshes of Trinity Island achieved. The project buried 143.0 acres of high quality salt marsh and black mangrove habitat only to have it converted into bare land. The next goal to create approximately 353 acres of new island area was not achieved. Since the majority of the containment dikes and hydraulic fill are on the subaerial areas of Trinity Island, the area of this island increased only by +92.6 acres or +15%. Therefore, this goal missed its target area of 353 acres by 260.4 acres. The goal to enhance the integrity of Trinity Island was achieved by building the +8 ft NAVD high artificial dune parallel to the shore. The goal to protect the estuary and vegetated wetlands from the direct exposure of the Gulf of Mexico was achieved if this goal was only related to storm conditions. Trinity Island, restoration pre-restoration already protected the Terrebonne estuary and vegetative wetlands from the direct exposure of the Gulf of Mexico. The goal to increase technical information on the restoration of barrier islands was also achieved.

East Island (TE-20)

East Island is the easternmost island of the barrier island arc (Figure 1). Low hummocky dune and washover terraces along the majority of the shoreline characterize the morphology of the island with elevations ranging from +3-5 ft (Ritchie et al., 1988; Ritchie and Penland, 1990). A large recurved spit extends into Wine Island Pass on the east end of East Island and a continuous dune ridge to +6 ft high parallels the shoreline (Figure 22). The highest elevations on East Island occur just west of the Wine Island Pass spit where the Terrebonne Parish Consolidated Government built the first restoration project in the Isles Dernieres in 1984 (Penland et al., 1988b). In 1996, FEMA constructed a barrier island restoration project contiguous to the east end of the Terrebonne Parish project. At this location, elevations reached +7-8 feet. The goal of the East Island restoration project were as following (www.Lacoast.gov):

- Restore East Island dunes,
- Restore East Island wetlands,
- Create approximately 266 acres of island,
- Enhance the physical integrity of the island,
- Protect the lower Terrebonne estuary and associated vegetated wetlands against direct exposure to the Gulf of Mexico, and
- Increase technical information on the restoration.

East Island was restored before Trinity Island and concurrently with Whiskey Island. The final design template for East Island was constructed in two phases. First, the restoration project constructed two major containment dikes to manage the initial placement of hydraulic fill. Both the gulf and bayside containment dikes were constructed to +6 ft NAVD (Appendix C). The hydraulic fill was placed at a +5 ft NAVD within the East Island containment area.

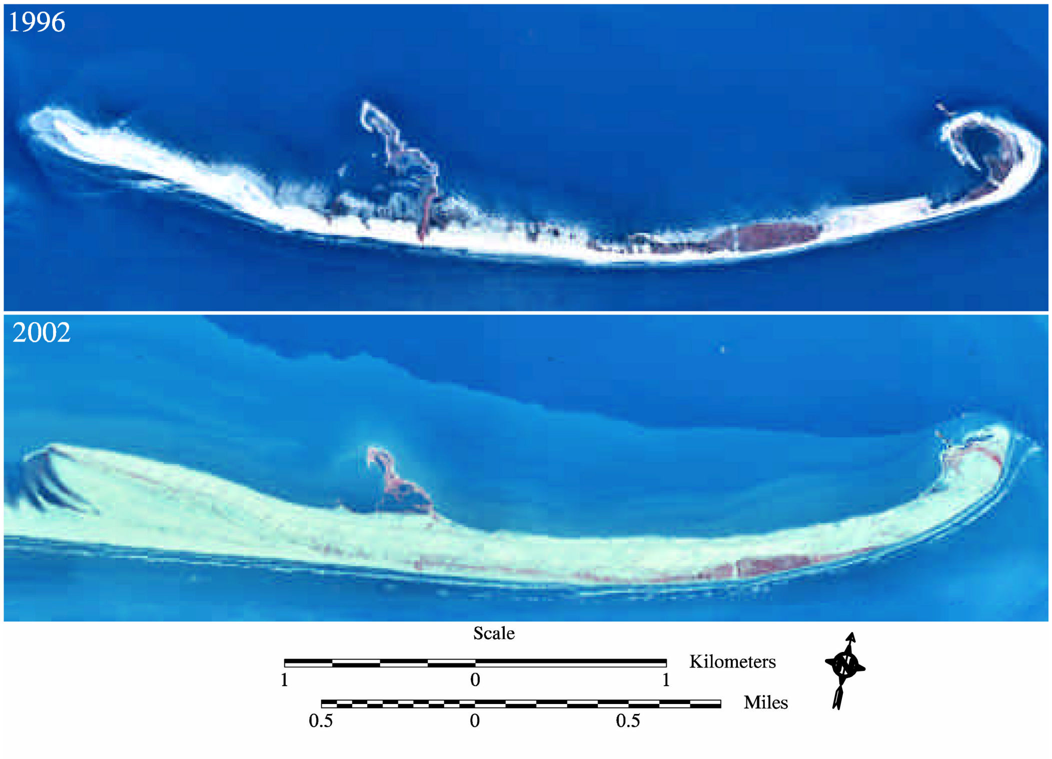


Figure 22. Aerial photo mosaic of East Island (TE-20) in 1996 (pre-construction and 2002 (post-construction).

The East Island restoration consisted of 16,500 linear feet of land containment on the Gulfside and 16,553 linear feet on the bayside water containment dikes in Lake Pelto. During construction the water based containment dikes experienced erosion due to the high-energy conditions of Lake Pelto during storm passages. In response, the contractor used visquene or plastic sheeting to stabilize and protect the backbarrier dikes. Two borrow areas were identified for use in the restoration of East Island; they were identified as J-1 and J-2. These borrow areas were located near Wine Island Pass and were reportedly characterized to contain 70% sand (Figure 23).

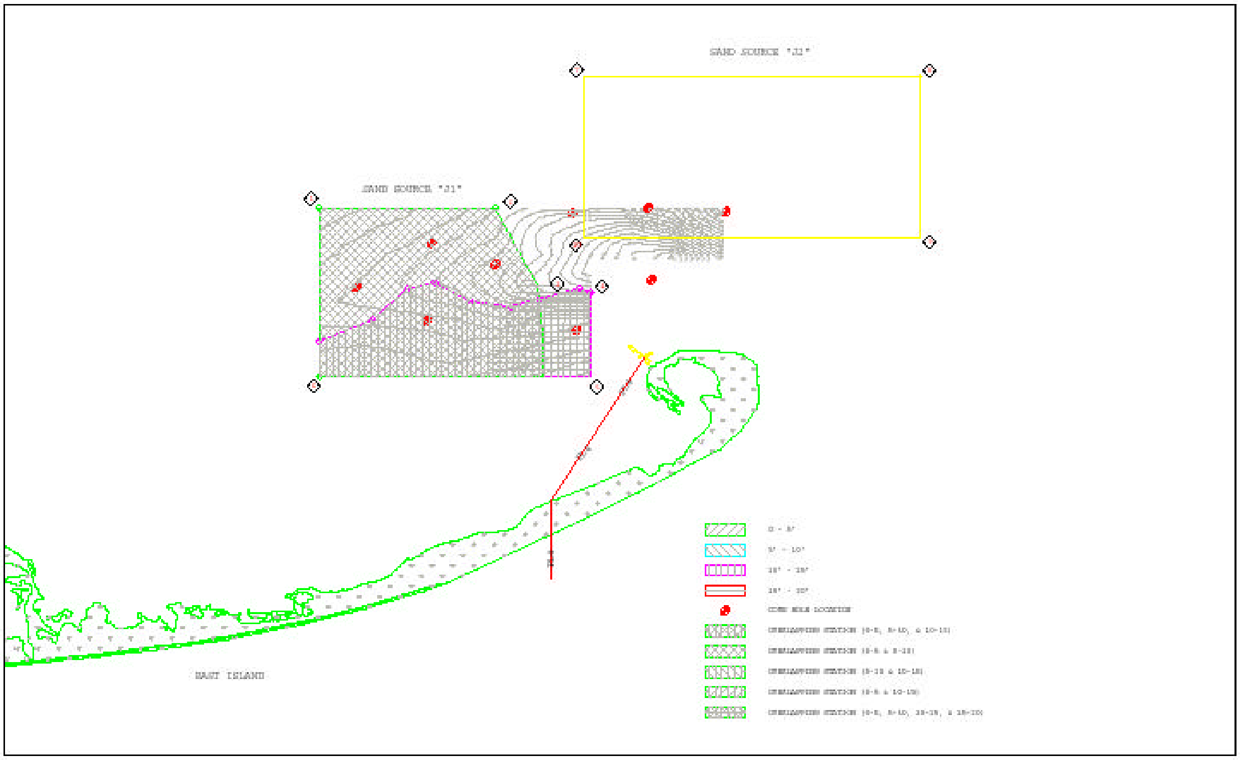


Figure 23. The locations of the proposed J1 and J2 borrow areas for use in the restoration of East Island.

Initially, the Dredge Arkansas was scheduled to start the restoration construction at East Island. However, it had mechanical problems and could not start on time. As a consequence, the Dredge Tom James moved onto the job site to begin construction. The quality of borrow material was thought to be of such good caliber that this material would stack unconfined. When the Dredge Tom James started mining the borrow site, the material was of such unexpected poor quality, the material would not stack. As a result, the Dredge Tom James moved onto Whiskey Island to allow time to build the necessary containment dikes to confine the unanticipated poor quality borrow material at East Island. Subsequently, after being repaired, the Dredge Arkansas moved onto the job site at East Island and began construction.

Once the containment dike construction and placement was complete, the next phase of restoration involved cutting, grading and shaping the final construction template. This process involved cutting material from the toe of each containment dike and shaping this material into a +8 ft NAVD dune crest 300-500 ft wide. The Gulf side of this dune had a crest elevation of +8 ft NAVD with a 1:10 slope to the +6 ft NAVD contour that would then vary in slope to the backside of the natural beach. The bayside of the +8 ft NAVD dune had a slope of 1:10 to the +4 ft NAVD contour and then the slope would vary to the Lake Pelto shoreline.

A total of 3,935,000 cy^3 of hydrologic fill was placed in the East Island containment structure. During construction, J1 and J2 borrow areas provided poor to moderate quality material for construction (Figure 24). Construction started at East Island in January 1998 and was completed in September 1998. Vegetative planting was completed by June 1999. The current project cost as of April 2, 2003 was estimated at $8,745,210 (www.Lacoast.gov).

Prior to the restoration, East Island was rapidly eroding and decreasing in area (Table 1). In 1978, East Island was 368.2 acres in area and by 1988 it decreased in size to 202.2 acres (Figure 25). During this period of time multiple hurricane impacts occurred in 1979 (Bob and Claudette) and in 1985 (Danny, Elena and Juan). By 1992, East Island continued to lose land and measured 173.4 acres in size. After Hurricane Andrew made landfall in 1992, East Island was further reduced to 93.4 acres and this continued into 1993 with East Island reaching 88.5 acres in size. Following Hurricane Andrew, FEMA did an emergency restoration project east of the former Terrebonne Parish restoration site resulting in East Island enlarging from 88.5 acres in 1993 to 193.1 acres in 1996. Prior to CWPPRA restoration, East Island consisted of 136.5 acres of beach, 0.6 acres of bare land, 39.6 acres of marsh, and 16.4 acres of barrier vegetation (Table 2; Figures 26 and 27).

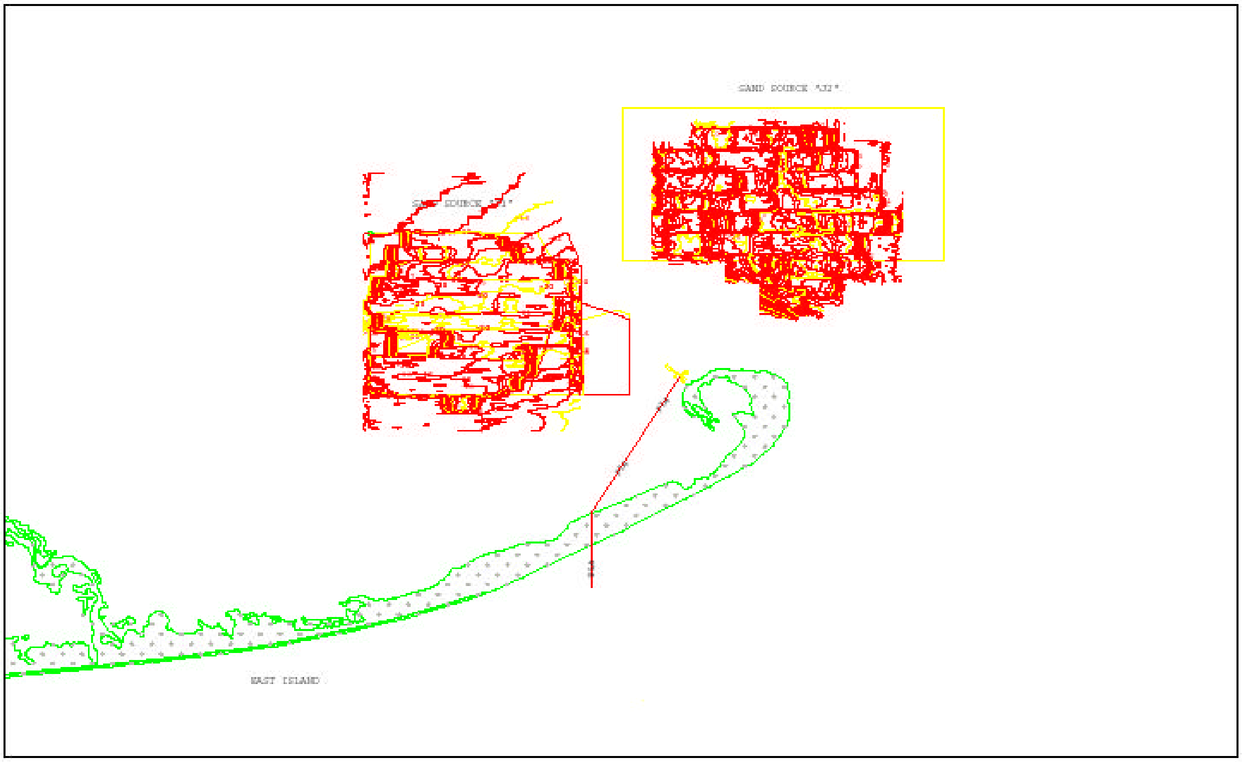


Figure 24. Post-dredging surveys of the J-1 and J-2 borrow areas used to construct the East Island (TE-27) restoration project.

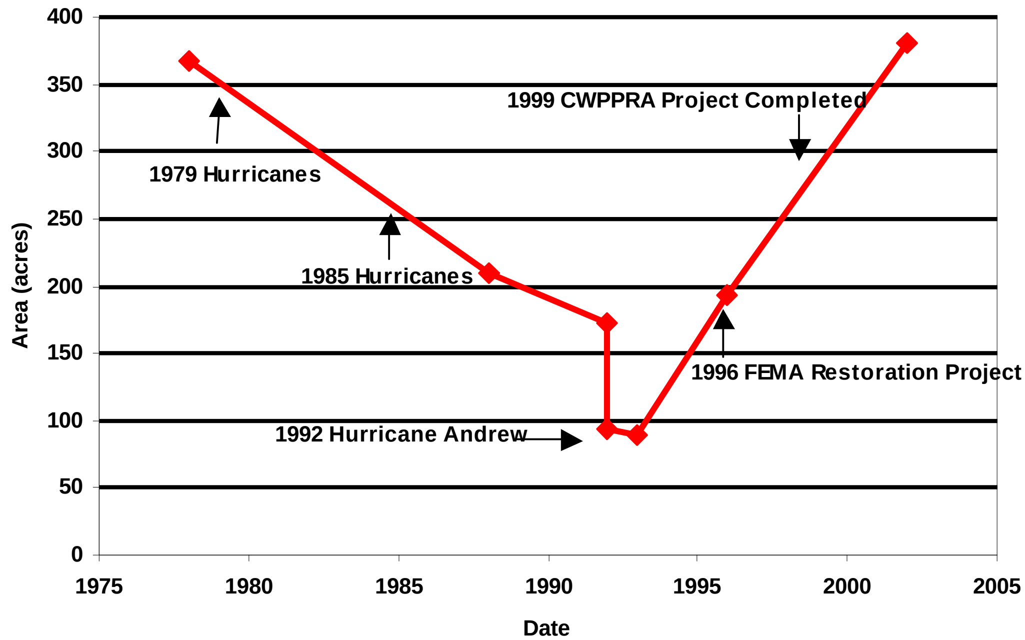
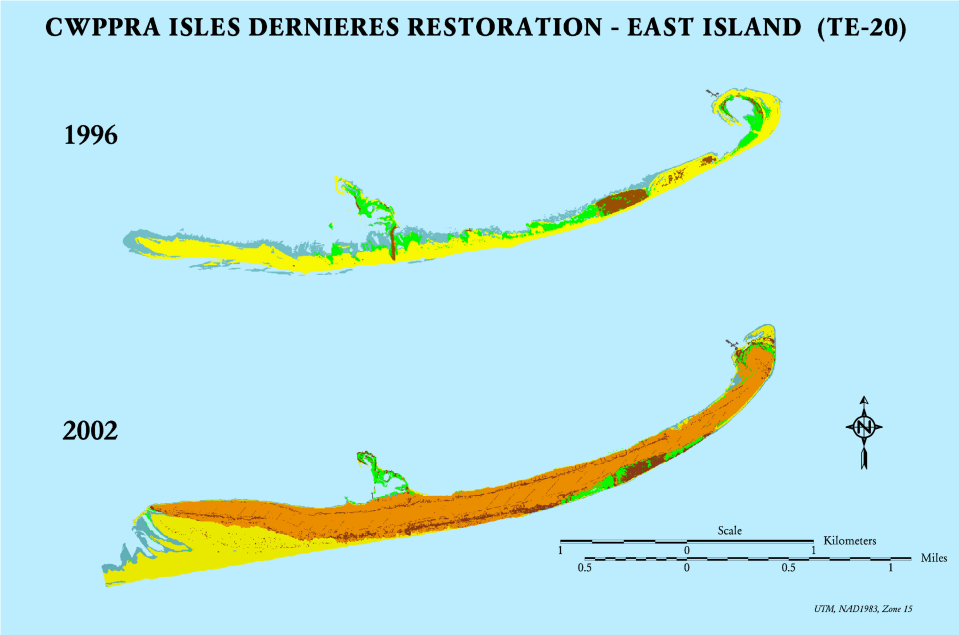


Figure 25. Time-series of the area of East Island from 1978 to 2002. Significant shoreline events are depicted on the timeline.



Habitat (acres)	1996	2002	Change
Marsh:	39.6	18.2	-21.4
Beach:	136.5	111.2	-25.3
Bare Land:	0.6	213.4	+212.8
Barrier Vegetation:	16.4	37.6	+21.2
Total Land:	*193.1*	*380.4*	*+187.3*

Figure 26. The 1996 pre-construction and 2002 post-construction habitats found at East Island (TE-20).

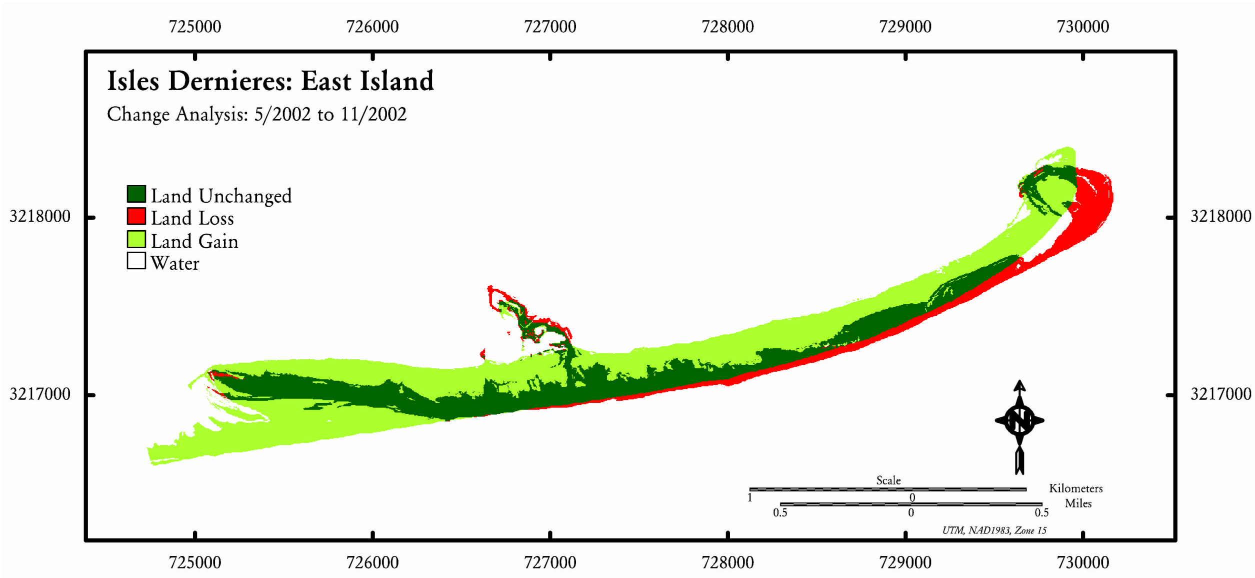


Figure 27. A map depicting land gain, land loss, and land unchanged for East Island (TE-20) between 1996 and 2002.

The CWPPRA East Island restoration was completed in 1998, and the area of the island increased from 193.1 acres to 380.4 acres by 2002. The beach habitat class was reduced to 111.2 acres, due to fill and bare land creation (Table 2; Figure 26). The area of the bare land class increased from 0.6 acres to 213.4 acres due to fill placement. The marsh class slightly decreased from 39.6 acres to 18.2 acres due to fill placement. The barrier vegetation class increased from 16.4 acres to 37.6 acres due to planting and recruitment.

In terms of project goal attainment, East Island was the most successful of the Isles Dernieres projects. In terms of dune restoration, this project did build a +8 ft NAVD artificial dune. Prior to restoration, the natural dunes on East Island were low, diverse in habitats and susceptible to storms. The new artificial dune is less susceptible to storms but in terms of habitat diversity, its environmental quality is less than that of the original lower natural dunes. The construction as-built drawing in Appendix E depict the post-construction shoreline configuration and dune variability. In terms of marsh, there was a loss of 21.4 acres due to filling. The construction as-built drawings indicate the area available for backbarrier marsh construction is very limited due to the higher elevations and steep bayside slope (Appendix E). There is very little land area below +2 ft NAVD for the establishment of marsh. In terms of creating 266 acres of new land, this project did not. This CWPPRA project built 187 acres of new island, missing its target by 97 acres. This project did increase the area of East Island by 97% and this fact is very important and technically significant because it demonstrated that this restoration method could significantly increase barrier island area in Louisiana using dredging and hydraulic fill technology. East Island definitely increased our technical information on barrier island restoration. Clearly, the final constructed template enhanced the physical integrity of the island. The constructed dune will provide improved protection during stronger storms such as hurricanes to landward areas.

East Timbalier Island (TE-25/30)

East Timbalier Island lies between Raccoon Pass and Little Pass Timbalier within the Bayou Lafourche barrier shoreline (Figure 1). The morphology of East Timbalier Island has been modified by extensive oil and gas operations (Figure 28). A large rubble mound seawall parallels the Gulf shoreline and numerous smaller rock dikes crisscross the interior of East Timbalier Island. Access canals, pits, and hydrocarbon production support facilities are common on East Timbalier Island. Landward of the seawall, hummocky washover terraces and flats are found (Ritchie and Penland, 1990; Ritchie et al., 1995). A combination of broken marsh and tidal flats are found throughout the backbarrier area of East Timbalier Island (www.lacoast.gov). The goal of the East Timbalier Island CWPPRA restoration project was as follows:

- Dredge 2,900,000 cy^3 of sediment to establish a 200 ft wide dune and a 500 ft wide marsh along the length of the island,
- Increase the size of the island by 216 acres, and
- Increase the island's life expectancy.

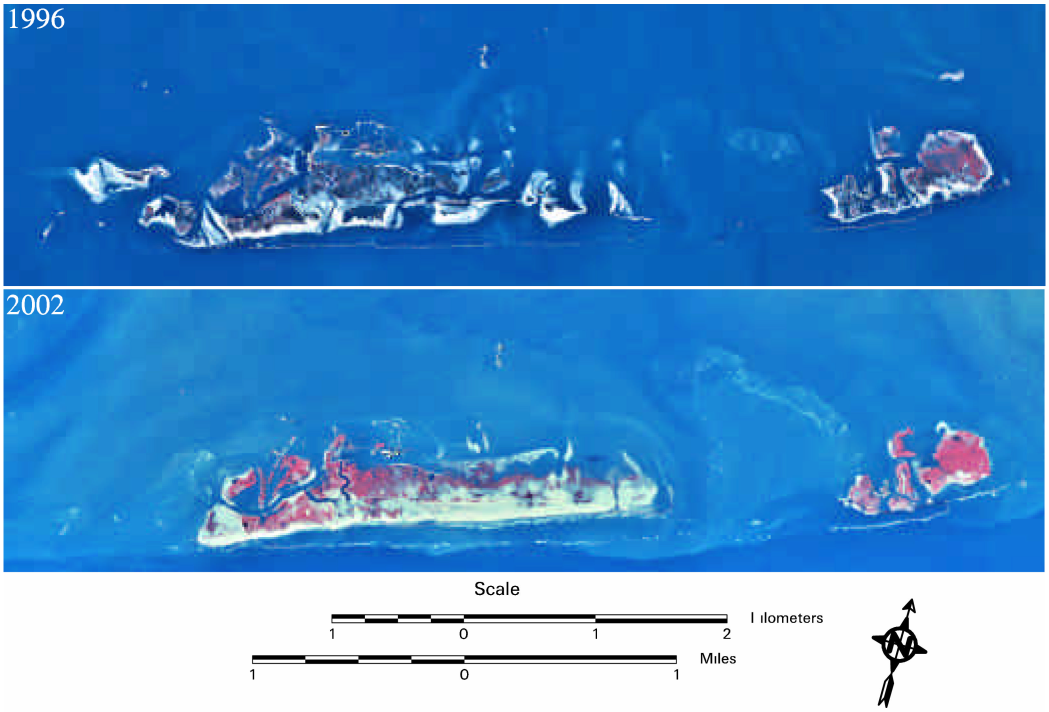


Figure 28. Air photo mosaics of East Timbalier Island 1996 (pre-construction) and 2002 (post-construction).

The restoration design template was constructed in two phases. The first phase involved building front and back containment dikes +5ft NAVD in elevation (Appendix F). These dikes were subsequently filled to an elevation of +3.5 ft NAVD. Three potential borrow areas were delineated within Little Pass Timbalier and are identified as sand sources, A, B, and C (Figure 29). Once the containment areas were hydraulically filled the material was allowed to settle before shaping. The marsh platform area was cut from +3.5 ft NAVD to +2 ft NAVD with the marsh platform tapering to the bay. The dune was designed with an elevation of +5 ft NAVD.

Figure 29. Sediment resource areas A, B, and C identified for East Timbalier Island (TE-25/30) restoration.

Prior to restoration, East Timbalier Island was eroding and rapidly decreasing in area (Table 1). In 1978, East Timbalier was 1,223.3 acres in area and by 1988 it decreased to 588.1 acres (Figure 30). During the period of 1978 and 1988, two periods of multiple hurricanes impacted the area, one in 1977 (Bob and Claudette), and one in 1985 (Danny, Elena, and Juan). By 1992, East Timbalier had been reduced in area to 533.7 acres. Hurricane Andrew impacted the area and the size of East Timbalier Island drastically decreased to 350.9 acres and by 1993 it had further decreased to 316.3 acres. In 1996, East Timbalier Island measured 226.2 acres. Prior to restoration, East Timbalier Island was comprised of 77.1 acres of beach, 1.9 acres of bare land, 135.9 acres of marsh, and 11.3 acres of barrier vegetation (Table 2; Figure 31).

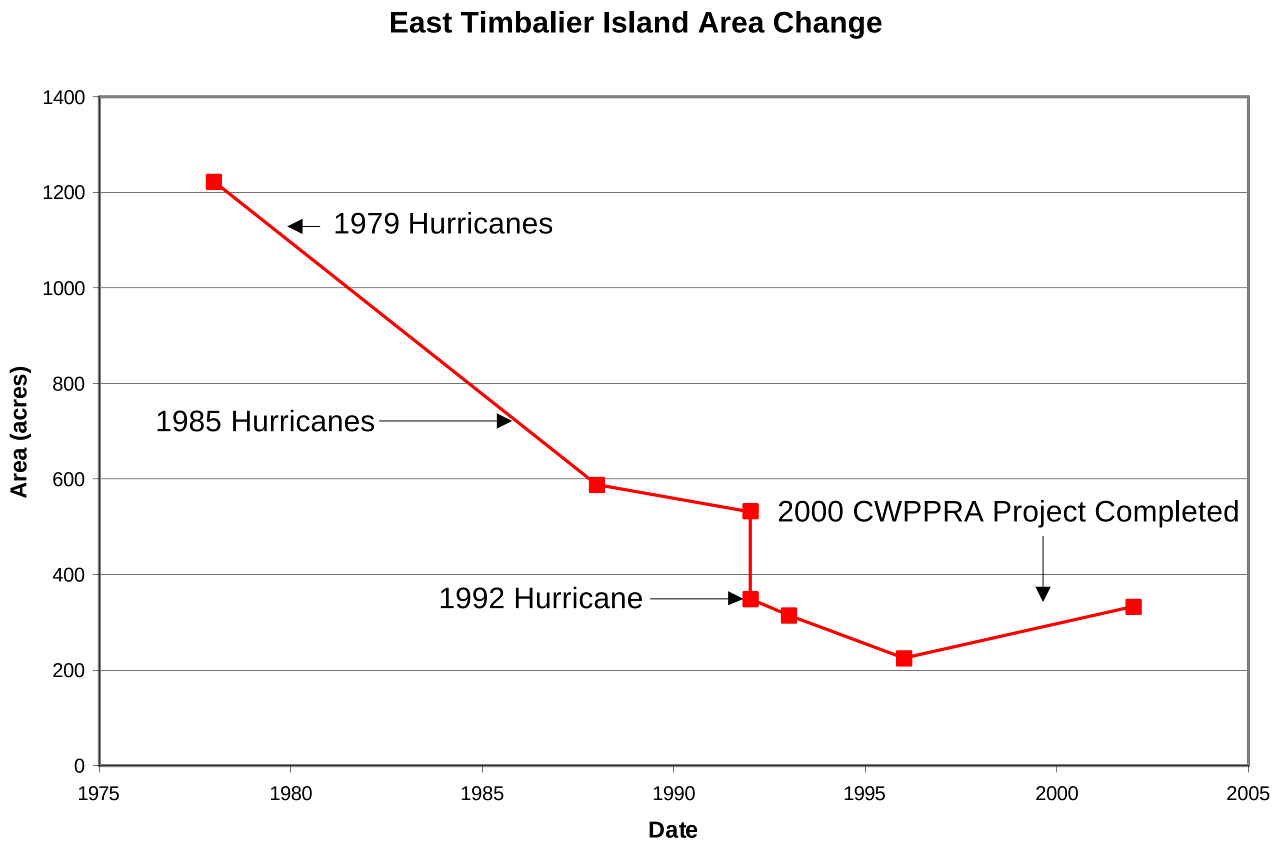
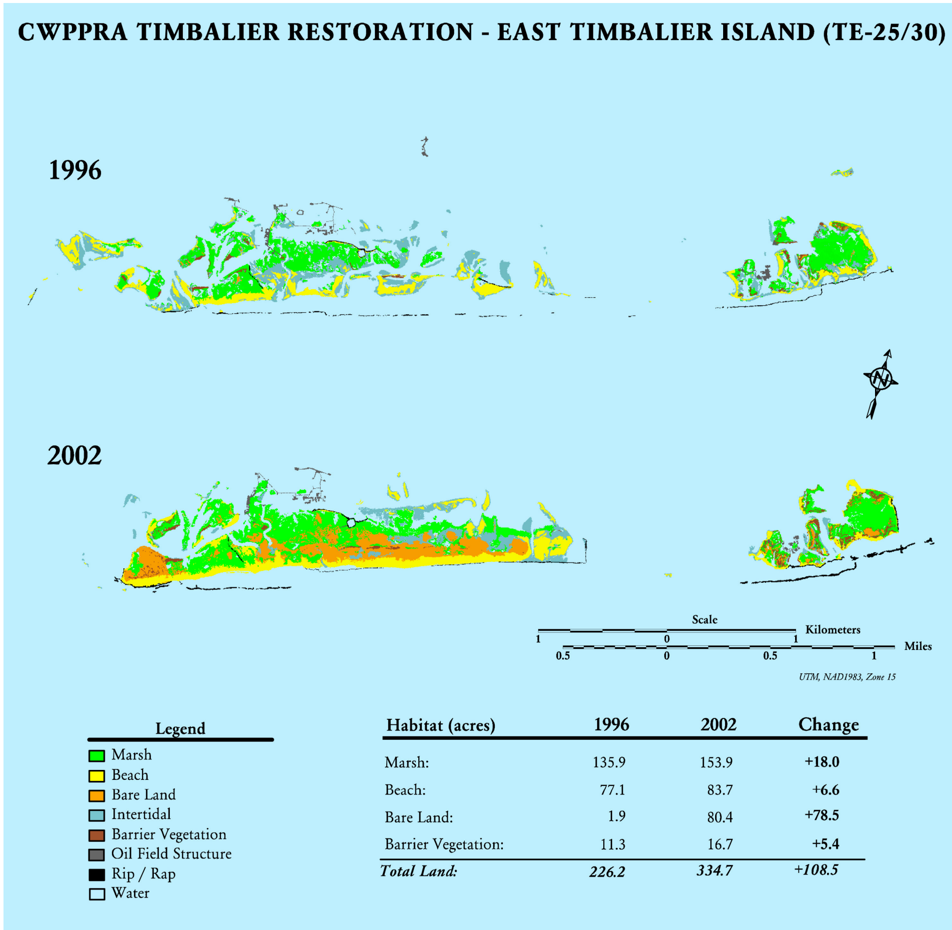


Figure 30. A time-series of the area of East Timbalier Island between 1978 and 2002. Significant events that have impacted the area of East Timbalier Island are depicted.



Habitat (acres)	1996	2002	Change
Marsh:	135.9	153.9	**+18.0**
Beach:	77.1	83.7	**+6.6**
Bare Land:	1.9	80.4	**+78.5**
Barrier Vegetation:	11.3	16.7	**+5.4**
Total Land:	***226.2***	***334.7***	***+108.5***

Figure 31. The 1996 pre-construction and 2002 post-construction habitats found at East Timbalier Island (TE-25/30).

Restoration construction began in 1999 and was completed in 2000. Approximately 7,000 ft of rubble mound seawall was constructed along the Gulf shoreline. In 2000, 13,000 ft of sand fencing was installed and in 2001, 13,000 plugs of Bitter Panicum were planted. As of April 7, 2003, the total project costs have been $17,805,743 (www.lacoast.gov). After restoration, the area of East Timbalier Island increased from 226.2 acres in 1996 to 334.7 acres, an increase of 108.5 acres or +48% in area (Figures 31 and 32). The area of beach habitat increased to +83.7 acres due to wave reworking of the hydraulic fill. The bare land class increased to +80.4 acres due to filling. The marsh habitat class increased to 153.9 acres due to burial by hydraulic fill. The barrier vegetation class increased to +16.7 acres due to planting and vegetative recruitment.

In terms of project goals, the first goal was to dredge 2,800,000 cy^3 of material and place this material on East Timbalier Island. The construction as-built placement amount was 2,627,111 cy^3, therefore attaining 94% of this restoration endpoint (Appendix G). In terms of the second and third restoration goals of creating a linear dune and backbarrier marsh built of 216 acres of land, this project fell slightly short at 107.5 acres or 82% attainment of this restoration endpoint. This CWPPRA barrier island restoration project did increase the life expectancy of East Timbalier Island. The low elevation of the backbarrier profile at $\pm$ 2 ft was at the optimum elevation to lead to the establishment of extensive backbarrier marshes over time (Appendix G).

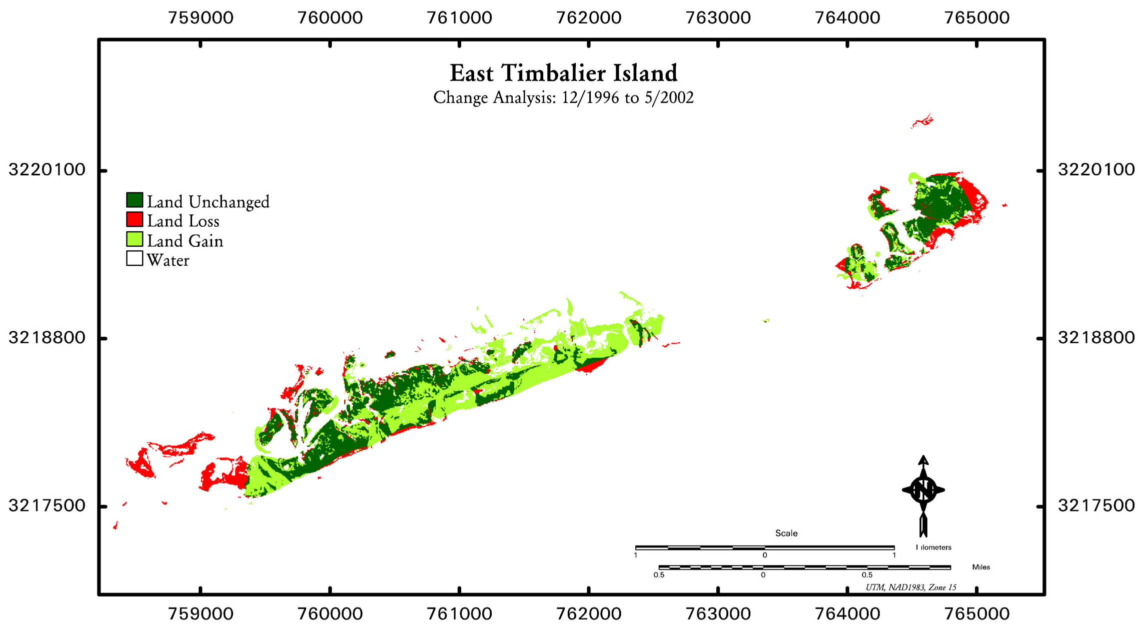


Figure 32. A map that depicts land gain, land loss, and land unchanged at East Timbalier Island (TE-25/30) between 1996 and 2002.

DISCUSSION

The Adaptive Management Review of these 5 CWPPRA barrier island restoration projects give great insight for planning future and developing new Gulf Shoreline restoration strategies and projects as CWPPRA matures and the Louisiana Coastal Area (LCA) Comprehensive Study moves forward with a programmatic WRDA Authorization to Congress. These five CWPPRA barrier island restoration projects provided a very important benchmark for Gulf shoreline restoration in Louisiana in that they proved we can reverse the trend of long-term Gulf shoreline erosion. We have learned important lessons from the Adaptive Management Review that can only make future Gulf Shoreline project planning, engineering design, and restoration construction more effective. This discussion will focus on the following points:

- Direct unit area cost,
- Direct benefit area cost,
- Target area endpoint,
- Design template vs. construction template,
- Geologic framework and sediment resources,
- Containment dikes,
- Ecological restoration, and
- Barrier island survivability

Direct Unit Area Cost

The cost per unit area is an important number because it gives a mesure for assessing the cost of project design, construction, and habitat creation. The direct cost per acre is influenced by many factors. We have some control over these factors, such as the source and quality of construction material, engineering design, construction management, and cost of plant materials.

Factors that we have little or no control of are the weather, unanticipated poor quality borrow material, the behavior of containment dike material and the general risk of constructing projects in the coastal marine environment. In light of all of these risks, CWPPRA built five barrier island restoration projects that were successful and increased the area of all five projects. Table 3 lists the island, area increase, construction cost and cost per acre.

Table 3. Direct Unit Area Cost for Gulf Shoreline Restoration

Island	Area Increase[1]	Percent Increase	Construction Costs	Cost Per Acre Direct Cost[2]
Raccoon Island	+18.3	+ 14 %	$ 1,788,184	$98,975
Whiskey Island	+168.0	+ 36 %	$ 7,299,482	$ 43,449
Trinity Island	+92.7	+ 15 %	$10,785,706	$116,476
East Island	+187.3	+ 97 %	$ 7,931,835	$ 42,416
East Timbalier Island	+108.5	+ 49 %	$17,805,740	$163,355

[1] in acres
[2] Direct Unit Area Cost for Restoration

Of the five barrier island projects reviewed, East Island (TE-20) was the most cost-effective in creating new land at $42,416/acre. The East Island (TE-20) barrier island restoration project consisted of a +8 ft NAVD dune with a narrow backbarrier marsh. This project increased the area of East Island by 187.3 acres that represent an area increase of 97%. CWPPRA restoration almost doubled the size of East Island because most of the construction took place in containment dikes located in open water within Lake Pelto. An additional factor for the low project cost is East Island's dredge material costs were the lowest of all of the hydraulic dredge and fill projects reviewed at $2.02 cy^3.

The Whiskey Island (TE-27) restoration project was the second most cost-effective at $43,449/acre. The Whiskey Island restoration project was designed with a +3 - 4 ft NAVD cross-section that was actually built to +4-6 ft NAVD. There was less construction within open water containment dikes in Lake Pelto than at East Island, and yet Whiskey Island increased in area by 168 acres, which is a +36% area increase. Another higher cost factor is the dredge material cost was the highest at \$2.57, East Island the next at \$2.02 cy^{-3} and Trinity Island was at \$2.23 cy^{-3}.

Next in cost were the demonstration segmented breakwaters at Raccoon Island (TE-29). Using the assumption that the accretion of +18.3 acres at Raccoon Island between 1996 and 2002 is attributed to the segmented breakwaters, and then the cost per acre of new land is \$98,795. However, a careful inspection of the analysis of the shoreline changes found at Raccoon Island demonstrates several points that need to be recognized. First, the longshore sediment transport is to the west. Next, it is very apparent in Figure 9 that an erosional shadow extends from the western side of the breakwaters for 8,900 feet. In this erosional shadow, the shoreline has eroded, valuable shorebird habitat has been impacted, and sediment has been lost from this shoreline. Knowing these facts indicate that the Raccoon Island project was likely more damaging than helpful to this barrier island system. However, it is true that immediately landward of the segmented breakwaters, sediment accumulated, erosion rates were reduced, and shorebird habitat was protected. Understanding and knowing the risks associated with hard coastal structures and their erosional shadow indicates extreme caution should be taken in choosing a solution that removes sediment from one part of the natural littoral system and starves the downdrift area resulting in an erosional shadow which is usually larger than the area benefited updrift. Using a conservative estimate of land gain and assigning all land gain on Raccoon Island between 1996-2002 to the segmented breakwaters, the per acre cost for Raccoon Island is \$98,975.

Next in the price per acre for barrier island restoration is Trinity Island (TE-24). This project consisted of a +8 ft NAVD dune built directly on Trinity Island with very little construction in open water. The cost per acre of new land is $116,476. The area of Trinity Island increased by 92.7 acres, which is an increase of 15%. This project produced very little quality habitat and buried 118.2 acres of high quality marsh and black mangrove. The cost per cy^{-3} of dredge material placement was $2.23.

East Timbalier Island (TE-25/30) lies within the erosional shadow of the Belle Pass jetties. The construction of this large barrier island rubble mound seawall was started by Gulf Oil, and subsequently maintained by Chevron, Greenhill Petroleum, and now Pioneer Natural Resources evidences the struggle between man and nature within the largest erosional shadow in Louisiana. The connection between the Bayou Lafourche headland and the Timbalier Islands is critical to the preservation of the Terrebonne estuary and the protection of the extensive oil fields landward of them and yet, the Belle Pass jetties are threatening the very existence of these islands and the inshore oil and gas fields. This CWPPRA project consisted of a 150-200 ft wide dune with an elevation of +5 ft NAVD and a 600 ft wide marsh with an elevation of +2 ft NAVD. Hydraulic fill combined with 7000 ft of rubble mound containment was used to build this project at a cost of $163,355 per acre. The high per acre cost of the East Timbalier Island (TE-25/30) restoration project is a result of the combined use of low-cost dredge material, high cost hard coastal structures, and unforeseen complications of sediment quality problems in the borrow areas. Strategically, East Timbalier Island is one of the most important barrier islands in the Terrebonne Estuary.

A review of the construction methods of these 5 CWPPRA barrier island projects indicate that the most cost-effective direct unit area cost restoration approach would be to focus on making the islands larger by using dredged material placement.

Direct Benefit Area Cost

The construction cost per acre captures the direct barrier island restoration foot print cost. The fundamental basis for barrier island restoration is that these islands form our first line of defense against waves, salinities, and storms from the Gulf of Mexico. Louisiana's barrier islands form the seaward framework of the estuaries that our society is dependent upon for renewable and non-renewable resources. Therefore, the direct restoration construction cost per acre do not capture the true area benefited landward of the barrier islands and therefore a truer measure of the cost-effectiveness of barrier island restoration, should be termed the direct area benefited cost per acre. The direct benefit area cost concept distributes the direct unit area cost landward to capture the service area of the 5 CWPPRA barrier projects reviewed by this Adaptive Management report. The average direct unit area cost for the restoration of the 5 CWPPRA barrier island projects reviewed in this report is $102,189 per acre with a range of $42,416 to $163,355. Stone et al., 2003 recently concluded that the barrier islands in the Terrebonne basin provide wave and storm protection for areas more than 20 miles inland. Assuming these 5 CWPPRA barrier island restoration projects restored 12.2 miles of Gulf shoreline and the landward limit of protection is 10 miles, then these projects protect approximately 78,080 acres of backbarrier estuarine areas including the human infrastructure. Based upon the results of the Stone et al., 2003 report, when the area of barrier island restoration is combined with the backbarrier areas protected, the average direct benefit area cost is $584 per acre versus the average direct unit area cost of $102,189. If the benefited area is extended 20 miles inland the average direct benefit area cost drops to $292 per acre. This comparison shows the importance of understanding and assessing the construction and benefit costs of barrier island restoration in order to gain a true economic understanding of the cost-effective nature of Gulf shoreline restoration.

Target Area

All of the CWPPRA barrier island projects had a construction target area except Raccoon Island (TE-29). East Timbalier Island (TE-25/30) had the best on target area of 108.5 acres aiming for 130 acres (Table 4). East Timbalier Island was 84% on target area. East Island (TE-20) was the next at 187.3 acres or 62% on target area. Whiskey Island (TE-27) at +168 acres was 33% on the target area. Trinity Island (TE-24) was the worst on target area at 92.7 acres out of a projected 353 acres or an on target value of only 26%. It's hard to find a good explanation for the great variability in missing the projected target area. East Timbalier Island (TE-25/30) missed its target area only slightly due to encountering poor quality hydraulic fill. In contrast at Trinity Island (TE-24) the sediment quality problems had been worked out and this project worked the best in terms of construction. Whiskey Island (TE-27) was another poor performer at 33% on target area. In one way, East Island (TE-20) looks great from a total area created standpoint with an area increase of 97%. However, this project was 72% on target. There are several potential explanations for the short-fall: 1) the design template was built too high and steep, 2) there was a disconnect between the size of the containment area and the anticipated performances of the selected borrow material, 3) the payment of the dredging operations on the cut were not producing the required volume of fill to be placed on the job site, and 4) there is a disconnect between particular cut and fill ratios and the sediment type found in borrow areas for construction.

Table 4. CWPPRA Barrier Island Restoration Target Areas

Island	Target Area[1]	Area Created	Acres off target	Percent on target
Raccoon Island	N/C	+ 18.3	N/C	N/C
Whiskey Island	328	+168.0	160.0	49%
Trinity Island	353	+ 92.7	-260.3	26%
East Island	266	+187.3	-78.7	71%
East Timbalier Island	216	+108.5	-107.5	50%

[1]acres

Design Template vs Constructed Template

A review of the design templates and construction templates using the construction as-builts for East Island (TE-20), Trinity Island (TE-24), and Whiskey Island (TE-27), all showed the construction cross-sections were either too high, too steep, or both for backbarrier marsh creation. The exception was East Timbalier Island (TE-25/30) where the design templates and construction templates were very consistent in the construction as-builts (Appendix A-F).

The implications of constructed template irregularities with the design templates are two fold. First, when built too high, material is wasted from making the project spatially larger and ecologically on target. This is the case for Whiskey Island (TE-27) where the Coupe Nouvelle reach was designed at +3 ft NAVD and built to +5-6 ft NAVD (Appendix B). If this project had been built to the design template, then more material would be available to make the island larger. The unanticipated need for containment dikes due to poor sediment quality resulted in this situation. Secondly, when the construction template is too steep in slope and the slope too high in elevation, the zone to establish backbarrier marshes is severely restricted. Appendices C, D, and E show the design and constructed templates for Trinity Island (TE-24) and East Island (TE-20) respectively. The elevations of the backbarrier slopes are so steep that only a narrow band of marsh can develop. This is also the case for Whiskey Island (TE-27). It is important to note that creating backbarrier marshes were cited as major benefits for all of the barrier island restoration projects, except Raccoon Island. East Timbalier Island (TE-25/30) did the best job in limiting the elevation for the development of a broad marsh platform. Backbarrier salt marsh cannot grow above +2 ft NAVD. There appears to be a major disconnect between what is being proposed and benefits accrued after construction. With all of the investment by CWPPRA in these barrier island backbarrier marsh creation projects that ended up with scrub/shrub or bare land habitat instead, it may be wise to return to these islands and mechanically re-grade and re-shape them in order to increase island size, improve backbarrier marsh elevation, and plant salt marsh vegetation.

Geologic Framework and Sediment Resources.

The key to successfully restoring the Gulf Shoreline of Louisiana is a thorough understanding of the geological framework of the barrier islands and mainland shorelines and the character of the sediment available to support shoreline restoration project planning and construction. East Island (TE-20) and Whiskey Island (TE-27) both had unanticipated experiences with poorer quality sediment than expected. Borrow sites J1 and J2 required containment for this material, but the original plan expected the material to be self-stacking without containment. When the Dredge Tom James encountered poor quality material at the East Island (TE-20) J1 and J2 borrow sites, it moved offsite to Whiskey Island to allow time for containment dike construction while the Dredge Arkansas was in the shipyard for repair. When the Dredge Tom James moved to Whiskey Island (TE-27), it encountered the same problem again. The material from F1 and F2 would not stack and containment dikes had to be constructed. It was only after borrow area K, H1, H2 and H7 were confirmed to contain better material than J1, J2, F2, and F2 that the construction of Whiskey Island (TE-27), Trinity Island (TE-24) was completed. East Timbalier Island (TE-25/30) encountered similar problems at borrow areas A, B, and C in Little Pass Timbalier.

A review of the borings or vibracores used to delineate the borrow areas indicates the number of samples are severally inadequate. The front-end geologic framework and sediment resource work should not be limited. This geotechnical information is important and critical to the successful planning and construction of Gulf shoreline restoration projects. Just a review of how the problems related to the sediment quality adversely impacted Whiskey Island (TE-27), Trinity Island (TE-24), East Island (TE-20), and East Timbalier Island (TE-25/30) construction demonstrates the need for thorough geotechnical investigations to support the planning and engineering design process. A sediment resource database tied to a GIS is needed to adequately support CWPPRA and LCA future Gulf shoreline restoration planning, design, and construction.

Sediment resource management needs become more proactive on a regional scale than the project-by-project scale in the past. First, a well-supported sediment resource database program needs to be undertaken building on existing geotechnical data. This database program needs to be tied to a GIS system that provides the maximum utility of this information. The U.S. Geological Survey has started a pilot program to address sediment resource issues in Louisiana. Next, geotechnical standards need to be established so that future sediment resource investigators collect, analyzed, and format this data in a compatible framework with a sediment resource database and GIS. The Gulf shoreline needs to be prioritized where future restoration will take place and in what sequence. After this is determined, a regional sediment resource survey should take place at the planning scale independent of future projects. This will allow a much-improved database for project planning. Once the project is designed, a more detailed construction sediment resource can be conducted to reduce the risk of unforeseen sediment quality programs.

Containment Dikes

There appears to be a consensus that containment dikes should always be used if the potential exists to encounter unanticipated poor quality sediments. Containment dikes reduce risk and provide greater control over the stacking of dredged material. A review of the project as-builts suggests that containment dikes can lead to dredge material being stacked higher than the design template. In this case, during construction careful inspections should be made to ensure the design template is not exceeded in elevation. This is particularly true when constructing backbarrier marsh platforms where the maximum elevations cannot exceed +2 ft NAVD. Careful post-fill grading and shaping can assist to ensure the correct elevations and slopes are achieved for marsh creation.

Thorough geotechnical investigations should provide the guidance for the need for containment dikes for dredged material placement. When using borrows areas such as Ship Shoal or incised Pleistocene valleys offshore of west Louisiana, the quality of the material may be such that containment should not be necessary.

Ecological Restoration

All 5 CWPPRA barrier island restoration projects reviewed increased the size of these individual islands. A review of project goals and an inspection of each of these restoration sites suggest there is not a good connection between land gain and ecological restoration. Raccoon Island (TE-29) created the most natural land of all of the 5 restoration projects. Beaches and dunes are very similar to natural ones developed after segmented breakwater construction. At

East Timbalier Island, a low five-foot dune was built and backed by a wide ± 2 ft NAVD marsh platform. These were the 2 projects with the best ecological restoration.

The Whiskey Island (TE-27), Trinity Island (TE-24) and East Island (TE-20) restoration all increased the size of the islands. However, the backbarrier marsh components were built primarily above +2 ft NAVD that is too high for marsh creation. Artificial dunes were successfully built however they lacked the environmental quality and biodiversity of lower natural dunes. These three projects created large back barrier platforms for scrub/shrub development.

Future barrier island design templates need to be reviewed in light of these observations to ensure that backbarrier marsh platforms are designed and built at ± 2 ft NAVD. Future work needs to address development of techniques that will aid in the implementation of successful ecological dune restoration.

Barrier Island Survivability

The 5 CWPPRA barrier island restoration projects reviewed were predicted to disappear early during the 21st century. In theory, the restoration of these barrier islands should improve the survivability and push back the date of predicted disappearance. Tables 5, 6 and 7 lists the pre-restoration predicted disappearance date and post-restoration disappearance date. The variability in the barrier island disappearance rates is a function of the amount of land created and the background rate of erosion. The fundamental information provided by Tables 5, 6 and 7 is that the more new land that is created relative to the background loss rate increased to survivability and longevity of a restored barrier island.

Table 5. CWPPRA Barrier Island Survivability.

Island	Pre-restoration Disappearance Date[1]	Rate of Acres Lost/yr	Acres Created	Post-Restoration Disappearance Date	Added Survival Years
Raccoon Island (TE-29)	2006	-13.4	+18.3	2013	+7
Whiskey Island (TE-27)	2016	-23.9	+168.0	2029	+13
Trinity Island (TE-24)	2012	-40.0	+92.7	2020	+8
East Island (TE-20)	2016	-9.8	+187.3	2041	+25
East Timbalier Island (TE-25/30)	2001	-55.4	+108.5	2008	+7

[?] McBride, et.al., 1992

Table 6. Historical Isles Dernieres Barrier Island Arc Areas: 1887-2002.

YEAR	Area (acres)	Area (km^2)	Area ($miles^2$)
1887[2]	8338.5	33.8	13.0
1934[2]	4838.3	19.6	7.5
1956[2]	3602.8	14.6	5.6
1978[2]	2957.9	12.0	4.6
1988[3]	1861.2	7.5	2.9
1992[4,5]	1643.3	6.7	2.6
1992 [4,6]	1325.5	5.4	2.1
1993 [4,7]	1267.5	5.1	2.0
1996[8]	1412.5	5.7	2.2
2002[8]	1878.8	7.6	2.9
2002[9,10]	1555.9	6.3	2.4

Table 7. CWPPRA Historical Barrier Island Areas[1]: 1887-2002.

Islands	1887[2]	1978[2]	1988[3]	1992[4,5]	1992 [4,6]	1993 [4,7]	1996[8]	2002[8]	2002[9,10]
Raccoon Island	2058.6	368.2	200.2	167.8	112.8	99.2	127.2	145.5	74.5
Whiskey Island	6279.9	904.4	564.2	505.6	440.8	428.4	474.8	642.8	529.4
Trinity Island		1317.1	894.6	796.5	678.5	651.4	617.4	710.1	662.6
East Island		368.2	202.2	173.4	93.4	88.5	193.1	380.4	289.3
E Timbalier Island	476.9	1223.2	588.1	533.7	350.9	316.3	226.2	334.7	234.7

[1]Area in acres
[2]McBride et al., 1991
[3]McBride et al., 1992
[4]Penland et al., in press
[5] Pre-hurricane Andrew: 1-24-92
[6] Post-hurricane Andrew: 10-12-92
[7] Post-hurricane Andrew: 1-16-92
[8] Penland et al., 2003
[9] Post-storm Isidore and Lili: 11-07-02
[10] Connor et al., in press

CONCLUSIONS

1. The 5 CWPPRA barrier island restoration project reviewed, Raccoon Island (TE-29), Whiskey Island (TE-27), Trinity island (TE-24), East Island (TE-20) and East Timbalier Island (TE-25/30), all stopped the long-term trend of Gulf shoreline erosion.
2. The direct unit acre cost for barrier island restoration ranged between $42,416 and $163,355.
3. Hydraulic fill is the most cost-effective barrier island restoration technique when the majority of the dredge material is placed in open water to increase island area.
4. Hydraulic fill barrier island projects decrease in their cost-effectiveness when the majority of the dredge material is directly placed on existing land.
5. Hard coastal structures such as segmented breakwaters and rubble mound seawalls are the most expensive barrier island restoration techniques and their performance is questionable.
6. When considering costs, the direct footprint of barrier island appears expensive. However, when the area landward benefited by the barrier island restoration footprint is calculated into the project costs, barrier island restoration becomes very inexpensive. For example, a $100,000 per acre project footprint decreases to $250-500 per acre when the area benefited is included in project costs.
7. All of the hydraulic fill barrier island restoration projects missed their target area endpoint. East Timbalier Island (TE-25/30) performed the best at achieving its target end at 84% followed by East Island (TE-20) at 62%, Whiskey Island (TE-27) at 25%, and Trinity Island (TE-24) at 18%.

8. East Timbalier Island (TE-25/30), East Island (TE-20), and Trinity Island (TE-27) were the only hydraulic fill restoration projects to achieve their design template configurations.

9. Whiskey Island (TE-27) exceeded its design template elevation by + 2-3 ft NAVD.

10. East Timbalier Island (TE-25/30) was the only hydraulic fill restoration project that achieved a +2 ft NAVD backbarrier marsh platform elevation.

11. Major components of the Whiskey Island (TE-27), Trinity Island (TE-24), and East Island (TE-20) design templates called for backbarrier marsh platforms at an elevation of +2-4 ft NAVD. This elevation is too high to establish a backbarrier marsh. Future hydraulic fill restoration projects that require a backbarrier marsh must not exceed a platform elevation of + 2 ft NAVD.

12. The concept of dune restoration must be revisited because the natural dune elevations are typically less than +6 NAVD in Louisiana. Artificial dunes at +8 ft or higher in elevation such as found at Trinity Island (TE-27) and East Island (TE-20) appear not to provide the same ecological diversity as found in lower natural dunes at +3-6 ft in elevation.

13. The sediment resource investigations supporting the planning and design of the hydraulic fill restoration projects all over estimated the quality of the available sediment resulting in project delays and cost.

14. Geotechnical investigations for future barrier island restoration planning and design efforts need to decrease the spacing or increase density of vibracores and seismic lines to ensure the confidence of these surveys. The results of the surveys associated with Whiskey Island (TE-27), Trinity Island (TE-27), East Island (TE-20), and East Timbalier Island (TE-25/30) document the need for more thorough sediment resource investigations.

15. The use of containment dikes are critical in successful hydraulic fill barrier island restoration projects because they increase the performance of design template construction.

16. Inspections of Whiskey Island (TE-27), Trinity Island (TE-24) and East Island (TE-20) projects documented the island area and elevation increased, but the ecological restoration of these islands was limited. The diversity of flora and fauna appears less on the restored barrier islands landscapes than natural ones.

17. All of the 5 CWPPRA barrier island restoration projects reviewed increased the survivability or date of island disappearance. Hydraulic fill barrier island restoration projects were more effective in increasing the survivability of these islands than the use of hard structures.

18. Three important design principals were learned by this Adaptive Management Review of these 5 barrier island restoration projects.

    A. If the barrier island is getting smaller, make it larger.

    B. The optimum elevation for backbarrier marsh creation is $\pm$ 0-2 ft NAVD.

    C. Conduct robust sediment resource investigations in advance of project planning, conduct further sediment resource investigations in support of project design, and conduct site-specific sediment resource investigations in support of project construction.

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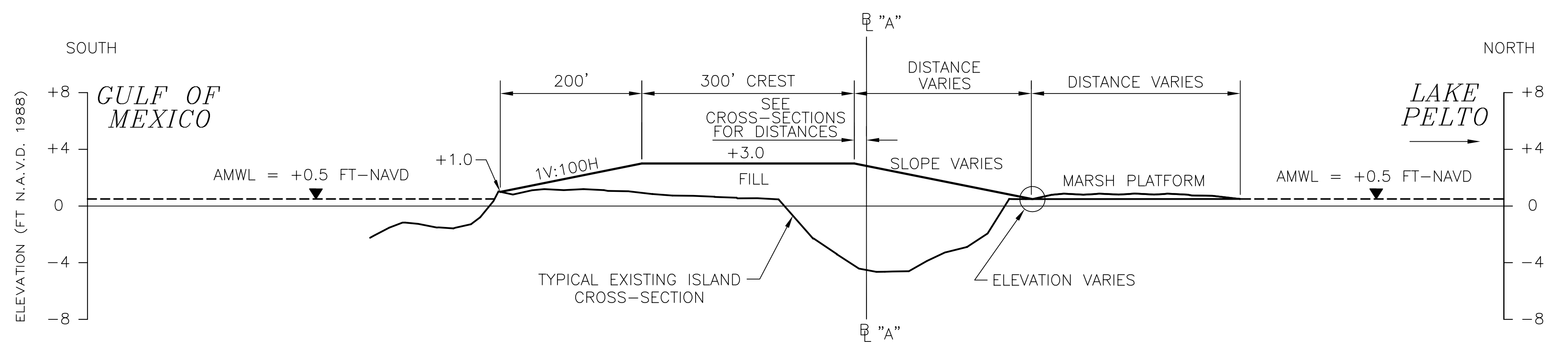
APPENDIX A

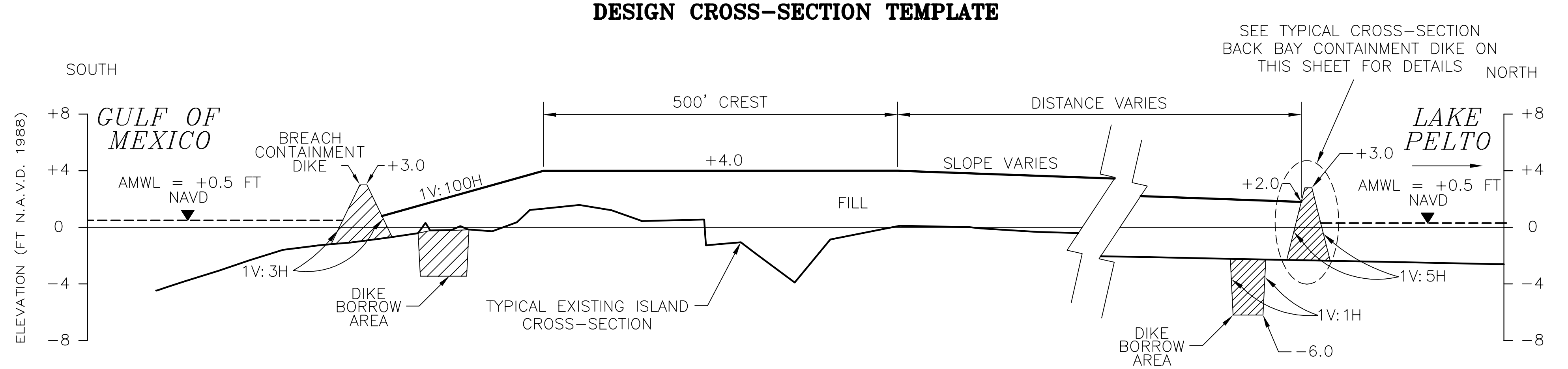
The design templates for the Whiskey Island (TE-27) barrier island restoration project.

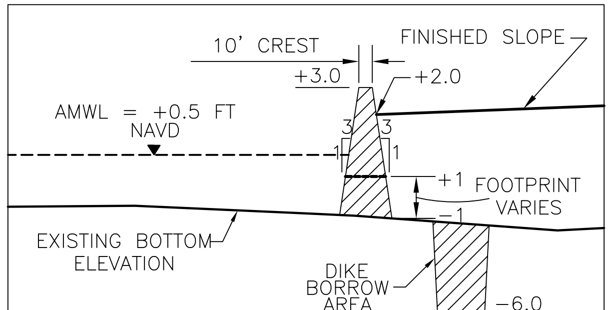
FEDERAL PROJECT NO.	STATE PROJECT NOS.	PARISH	SHEET NO.
PTE15bii	TE-27	TERREBONNE	4

COUPE NOUVELLE CONTAINMENT AREA
DESIGN CROSS-SECTION TEMPLATE



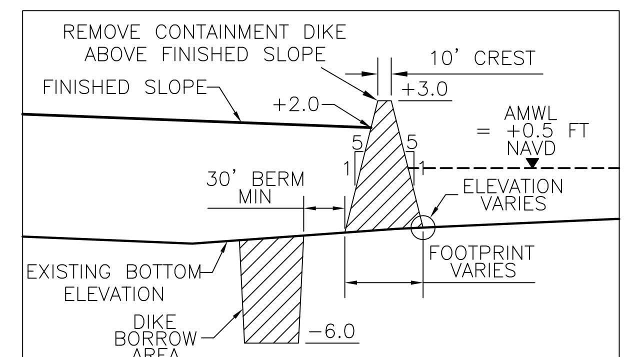
BACK BAY AND BREACH CONTAINMENT AREA
DESIGN CROSS-SECTION TEMPLATE





BREACH CONTAINMENT DIKE TYPICAL CROSS-SECTION

(NOT TO SCALE)



BACK BAY CONTAINMENT DIKE TYPICAL CROSS-SECTION

(NOT TO SCALE)

AS-BUILT

Ref: Picciola and Associates Survey Drawings "Hydrographic and Topographic Survey, Whiskey Island Restoration Project Part1 (TE-27/PTE15bii), Terrebonne Parish, LA" Dated 8/14/97, Sheets 1-13.

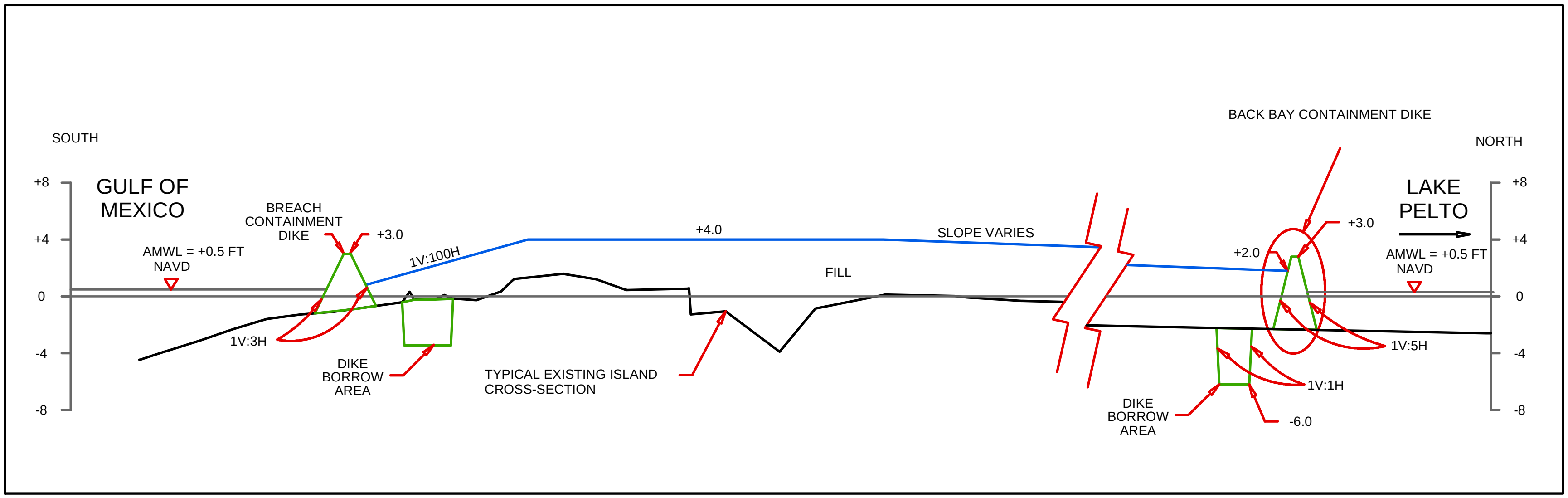
DATE	REVISIONS	APPROVED
09/10/98	As-built drawings	MJR

DRAWN BY: HJT/JDF
APPROVED BY: DBK/ALL
DATE : 9/15/97
SCALE : HORZ. 1" = 100' VERT. 1" = 5'

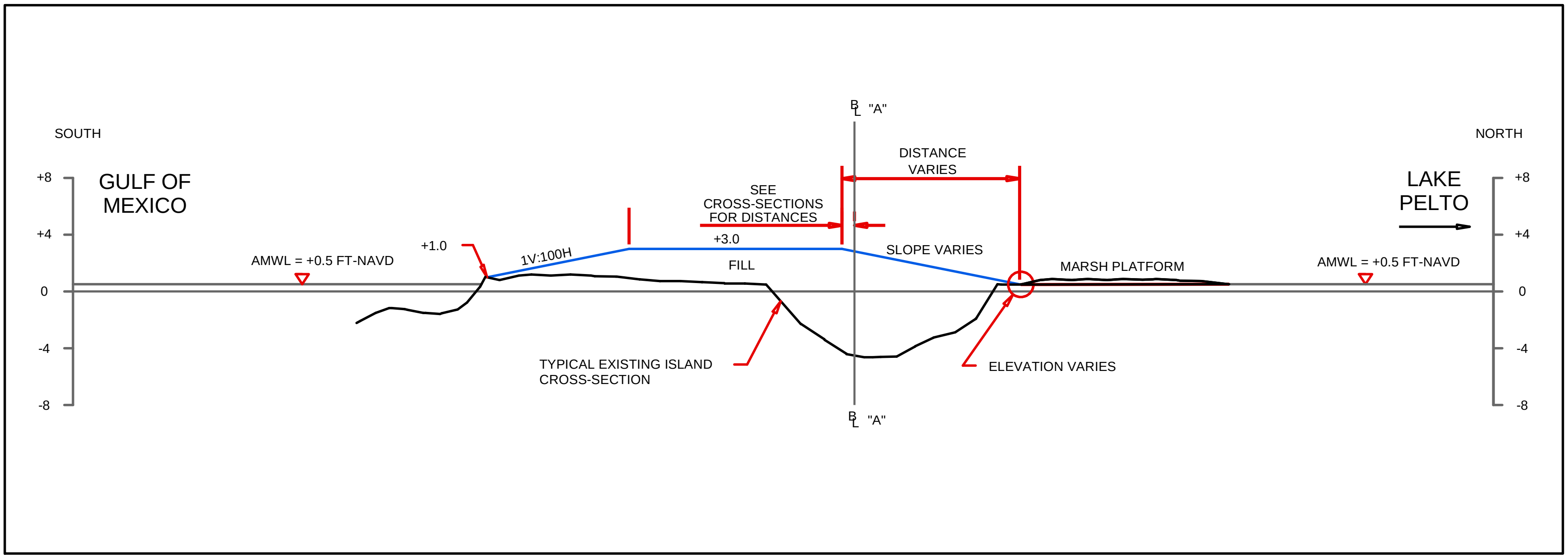
STATE OF LOUISIANA
DEPARTMENT OF NATURAL RESOURCES
COASTAL RESTORATION DIVISION
NICHOLLS STATE UNIVERSITY
P.O. BOX 2079
THIBODAUX, LOUISIANA 70310

WHISKEY ISLAND RESTORATION PROJECT - PHASE 1
TE-27 / PTE15bii

TYPICAL CROSS-SECTIONS & EROSION PROTECTION DETAILS



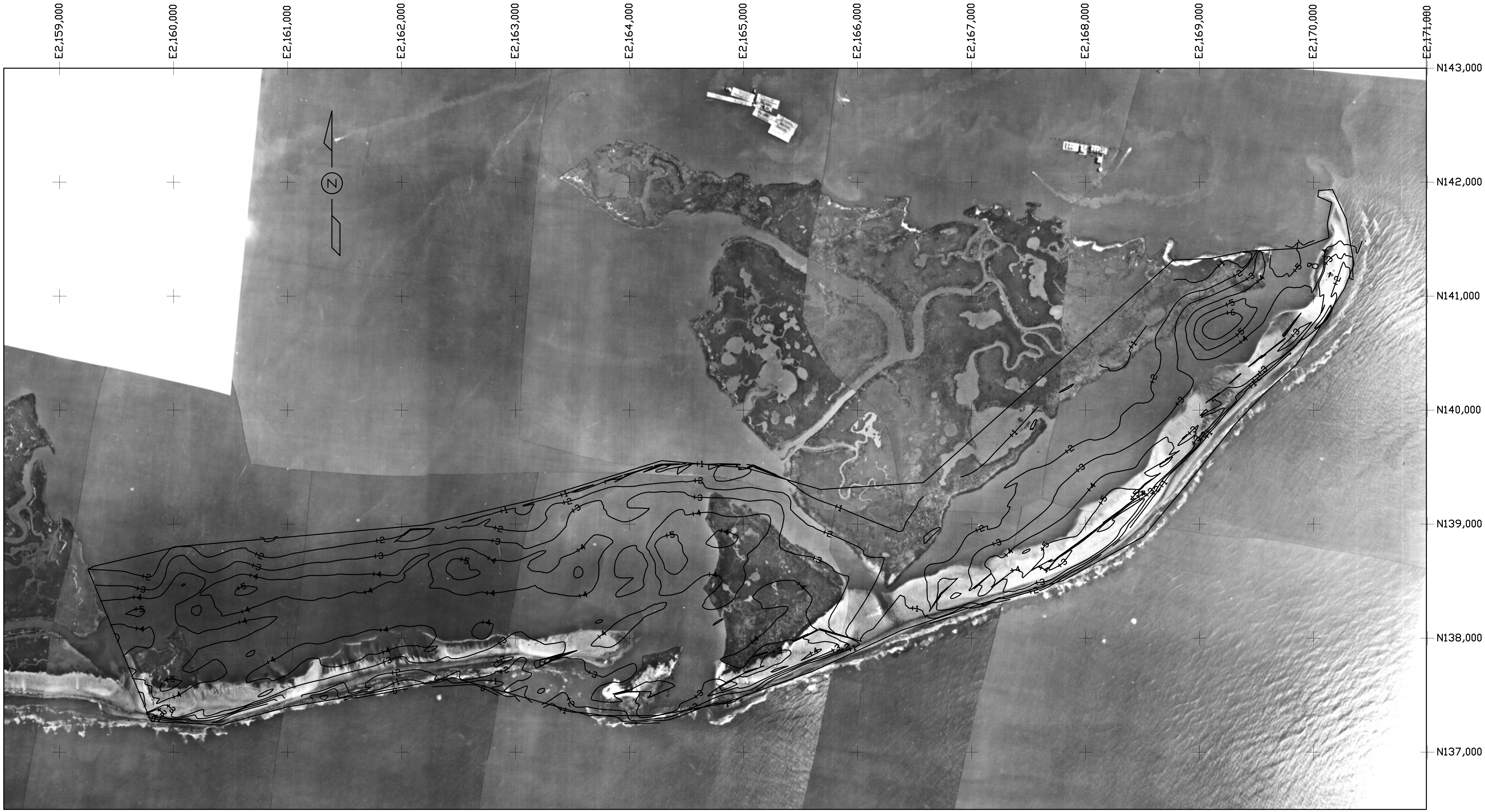
BACK BAY CONTAINMENT DIKE
SOUTH
NORTH
+8
+4
0
-4
-8
GULF OF MEXICO
LAKE PELTO
BREACH CONTAINMENT DIKE
+3.0
AMWL = +0.5 FT NAVD
1V:100H
+4.0
SLOPE VARIES
FILL
+2.0
+3.0
AMWL = +0.5 FT NAVD
1V:3H
DIKE BORROW AREA
TYPICAL EXISTING ISLAND CROSS-SECTION
1V:5H
1V:1H
DIKE BORROW AREA
-6.0


SOUTH
NORTH
B L "A"
DISTANCE VARIES
SEE CROSS-SECTIONS FOR DISTANCES
GULF OF MEXICO
LAKE PELTO
+8
+4
0
-4
-8
+3.0
+1.0
1V:100H
FILL
SLOPE VARIES
MARSH PLATFORM
AMWL = +0.5 FT-NAVD
AMWL = +0.5 FT-NAVD
TYPICAL EXISTING ISLAND CROSS-SECTION
ELEVATION VARIES
B L "A"

APPENDIX B

The construction as-built drawings depicting the configuration, elevational contours, and project cross-sections of the Whiskey Island (TE-27) restoration project.

FEDERAL PROJECT NO.	STATE PROJECT NOS.	PARISH	SHEET NO.
PTE15bii	TE-27	TERREBONNE	3



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SCALE: 1" = 400'

Ref: Picciola and Associates Survey Drawings "Hydrographic and Topographic Survey, Whiskey Island Restoration Project Part1 (TE-27/PTE15bii), Terrebonne Parish, LA" Dated 8/14/97, Sheets 1-13.

Topographic surveys shown done by T. Baker Smith & Son, Inc. 6/98.

DATE	REVISIONS	APPROVED
09/10/98	As-built drawings	MJR

DRAWN BY: HJT/JDF
APPROVED BY: DBK/ALL
DATE : 9/15/97
SCALE : 1" = 400'

STATE OF LOUISIANA
DEPARTMENT OF NATURAL RESOURCES
COASTAL RESTORATION DIVISION
NICHOLLS STATE UNIVERSITY
P.O. BOX 2079
THIBODAUX, LOUISIANA 70310

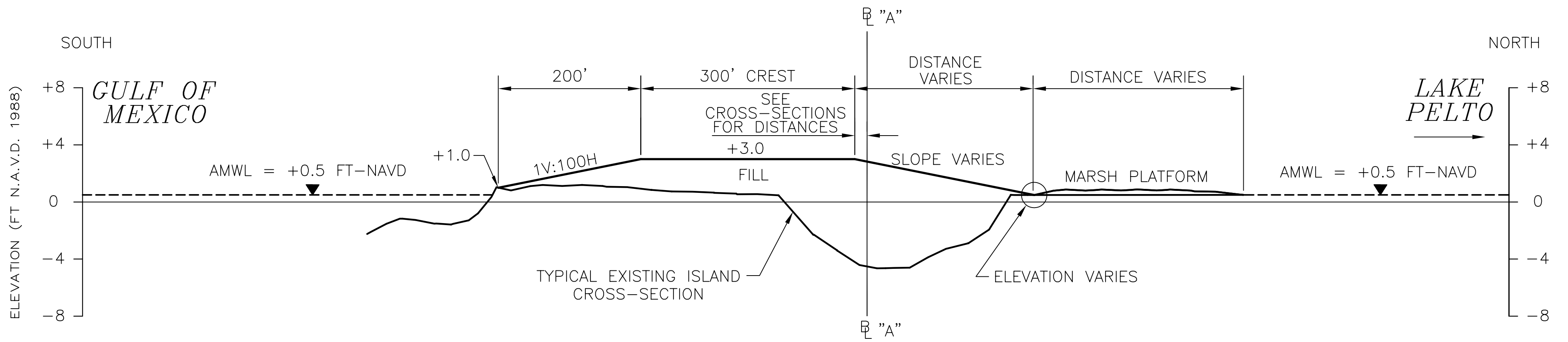
AS-BUILT

WHISKEY ISLAND RESTORATION PROJECT - PHASE 1
TE-27 / PTE15bii

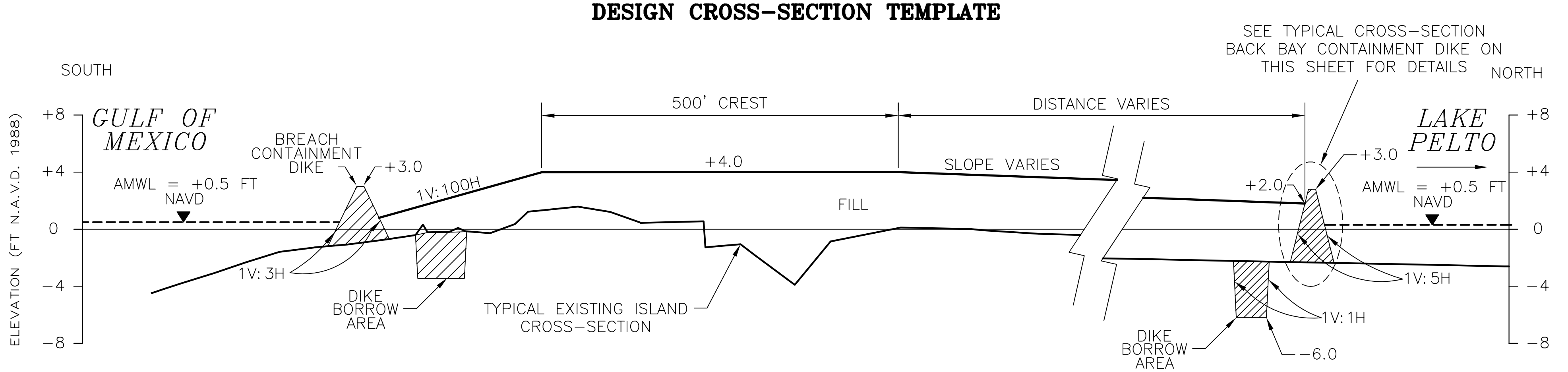
PROJECT AREA
TOPOGRAPHIC SURVEY

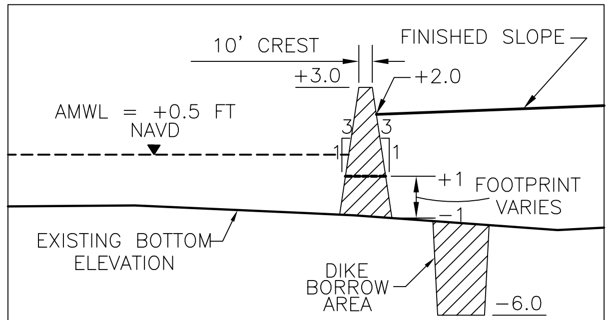
FEDERAL PROJECT NO.	STATE PROJECT NOS.	PARISH	SHEET NO.
PTE15bii	TE-27	TERREBONNE	4

COUPE NOUVELLE CONTAINMENT AREA
DESIGN CROSS-SECTION TEMPLATE



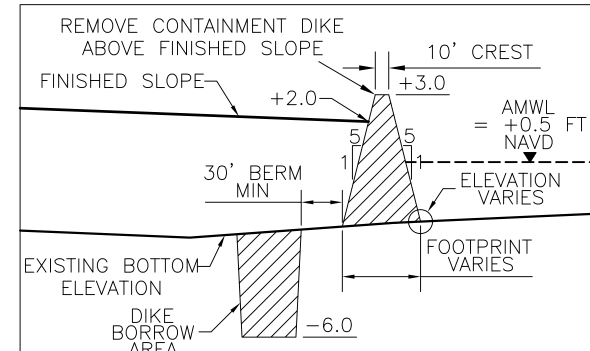
BACK BAY AND BREACH CONTAINMENT AREA
DESIGN CROSS-SECTION TEMPLATE





BREACH CONTAINMENT DIKE TYPICAL CROSS-SECTION

(NOT TO SCALE)



BACK BAY CONTAINMENT DIKE TYPICAL CROSS-SECTION

(NOT TO SCALE)

AS-BUILT

Ref: Picciola and Associates Survey Drawings "Hydrographic and Topographic Survey, Whiskey Island Restoration Project Part1 (TE-27/PTE15bii), Terrebonne Parish, LA" Dated 8/14/97, Sheets 1-13.

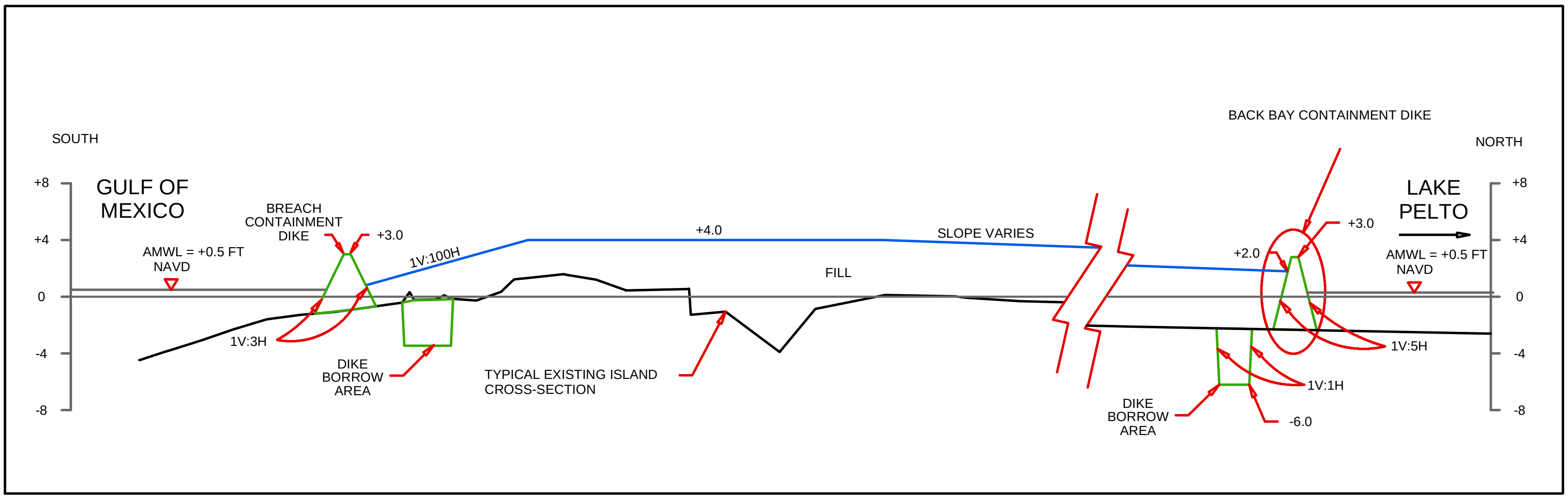
DATE	REVISIONS	APPROVED
09/10/98	As-built drawings	MJR

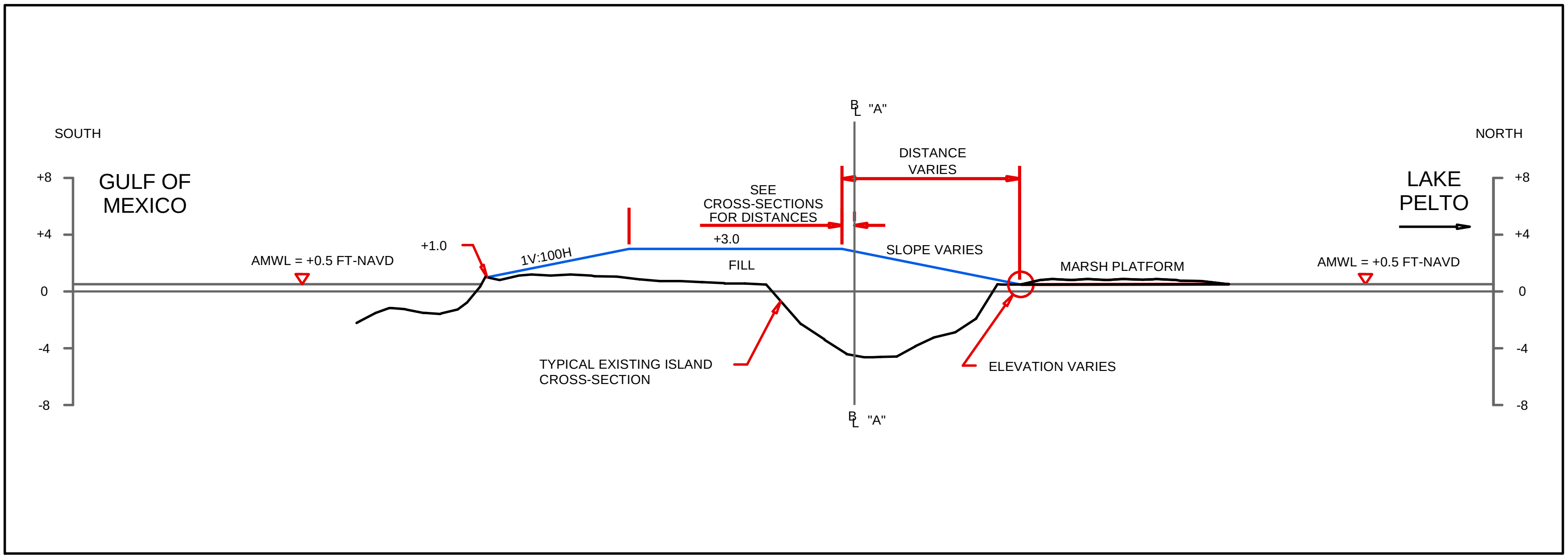
DRAWN BY:	HJT/JDF
APPROVED BY:	DBK/ALL
DATE :	9/15/97
SCALE :	HORZ. 1" = 100' VERT. 1" = 5'

STATE OF LOUISIANA
DEPARTMENT OF NATURAL RESOURCES
COASTAL RESTORATION DIVISION
NICHOLLS STATE UNIVERSITY
P.O. BOX 2079
THIBODAUX, LOUISIANA 70310

WHISKEY ISLAND RESTORATION PROJECT - PHASE 1
TE-27 / PTE15bii

TYPICAL CROSS-SECTIONS & EROSION PROTECTION DETAILS


SOUTH
NORTH
BACK BAY CONTAINMENT DIKE
GULF OF MEXICO
LAKE PELTO
BREACH CONTAINMENT DIKE
+3.0
1V:100H
+4.0
SLOPE VARIES
FILL
+2.0
+3.0
AMWL = +0.5 FT NAVD
AMWL = +0.5 FT NAVD
1V:3H
DIKE BORROW AREA
TYPICAL EXISTING ISLAND CROSS-SECTION
1V:5H
1V:1H
-6.0
DIKE BORROW AREA
+8
+4
0
-4
-8

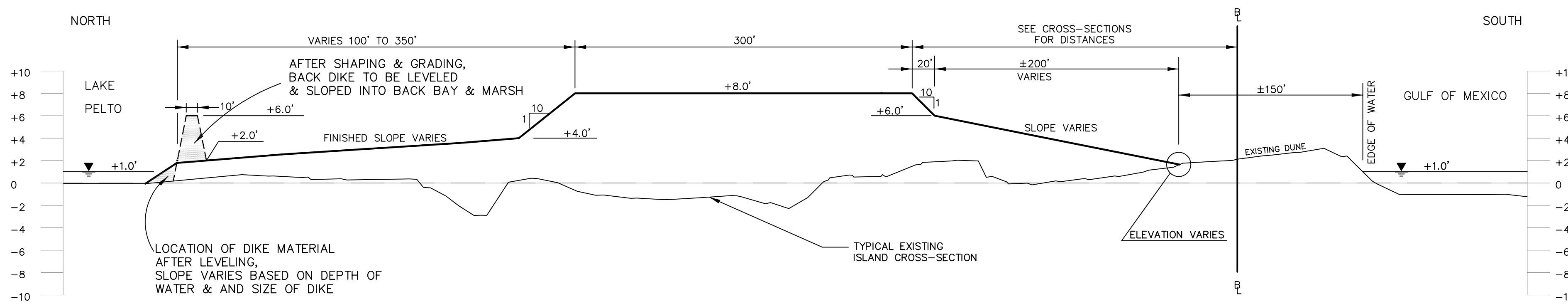


SOUTH
NORTH
B
L
"A"
GULF OF
MEXICO
LAKE
PELTO
+8
+4
0
-4
-8
DISTANCE
VARIES
SEE
CROSS-SECTIONS
FOR DISTANCES
+3.0
+1.0
1V:100H
FILL
SLOPE VARIES
MARSH PLATFORM
AMWL = +0.5 FT-NAVD
AMWL = +0.5 FT-NAVD
TYPICAL EXISTING ISLAND
CROSS-SECTION
ELEVATION VARIES

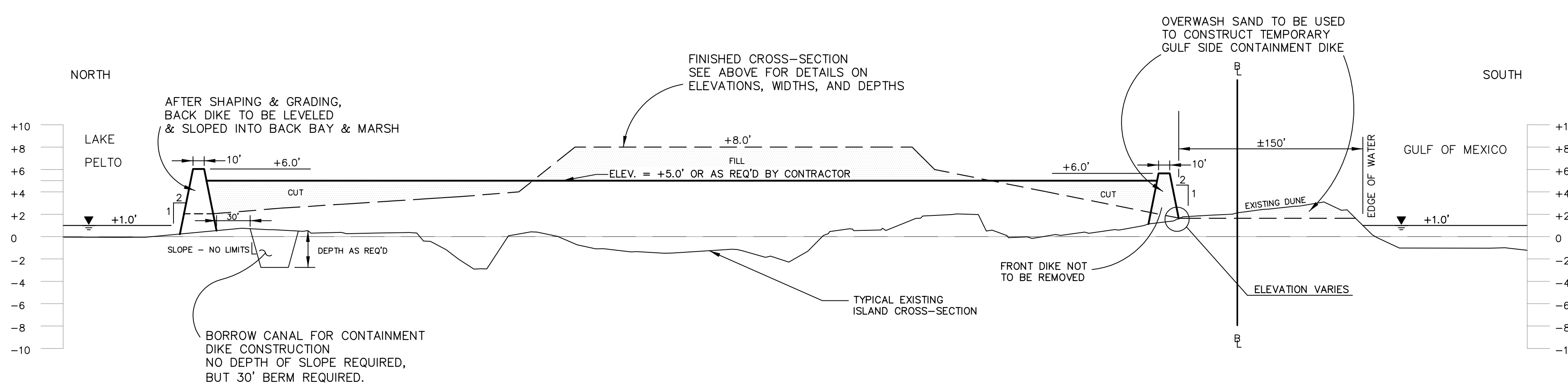
APPENDIX C

The design template for Trinity Island (TE-27) and East Island (TE-20) barrier island restoration projects.

FEDERAL PROJECT NOS.	STATE PROJECT NOS.	ENGINEERING CONTRACT NO.	PARISH	SHEET NO.
TE-20 XTE-41	TE-20 TE-24	435CW-97-13	TERREBONNE	6



DESIGN CROSS SECTION TEMPLATE AFTER GRADING AND SHAPING



CONSTRUCTION CROSS SECTION TEMPLATE

SCALE: HORIZ. 1" = 60'
VERT. 1" = 6'

AS-BUILT

DATE	DESCRIPTION	BY
12/16/98	AS-BUILT DRAWINGS	CDL

REVISIONS

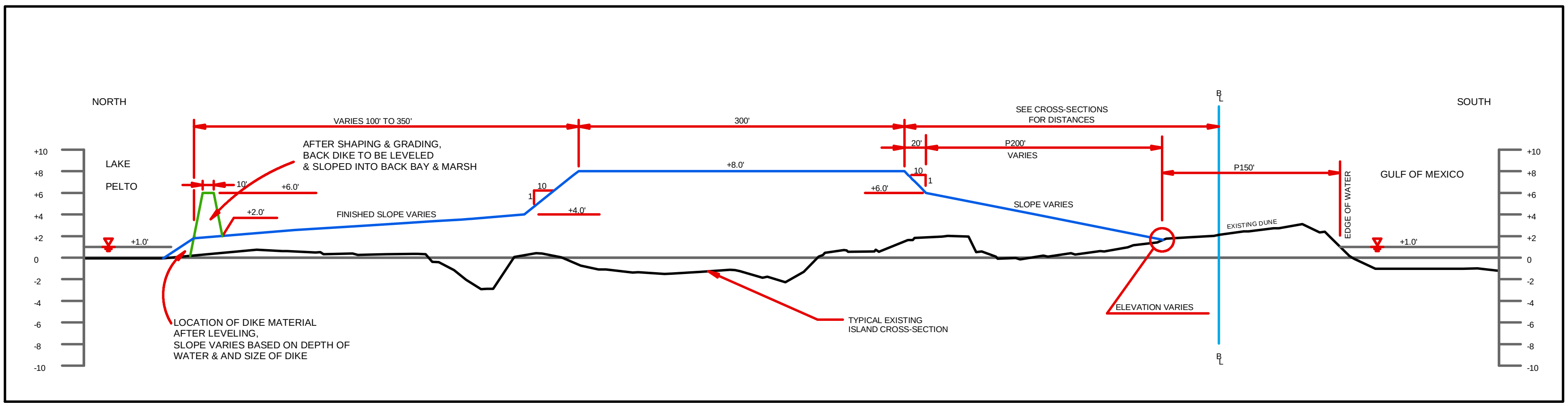
TYPICAL CROSS-SECTION & EROSION PROTECTION DETAILS

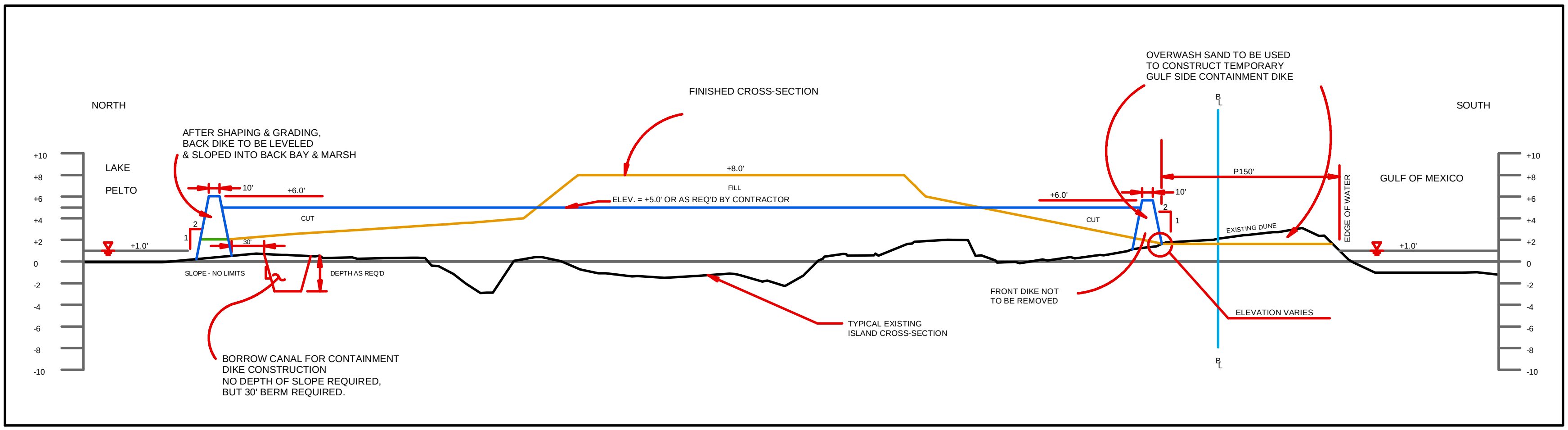
STATE OF LOUISIANA
DEPARTMENT OF NATURAL RESOURCES
COASTAL RESTORATION DIVISION

ISLE DERNIERES RESTORATION PROJECT
TRINITY ISLAND – PHASE 1 & EAST ISLAND PHASE 0

T. BAKER SMITH & SON, INC.
CIVIL ENGINEERS - SURVEYORS - ENVIRONMENTAL SERVICES
P.O. BOX 2266 HOUMA, LOUISIANA 70361

DRAWN	KAP	DRAWING SHEET6ASBUILT	DATE AUGUST, 1997
CHECKED	MJR	JOB No. 578-96	SCALE 1 = 60


NORTH
SOUTH
VARIES 100' TO 350'
300'
SEE CROSS-SECTIONS
FOR DISTANCES
20'
P200'
VARIES
P150'
+10
+8
+6
+4
+2
0
-2
-4
-6
-8
-10
LAKE
PELTO
AFTER SHAPING & GRADING,
BACK DIKE TO BE LEVELED
& SLOPED INTO BACK BAY & MARSH
10'
+6.0'
+2.0'
FINISHED SLOPE VARIES
10
1
+4.0'
+8.0'
+6.0'
SLOPE VARIES
+1.0'
GULF OF MEXICO
EDGE OF WATER
EXISTING DUNE
LOCATION OF DIKE MATERIAL
AFTER LEVELING,
SLOPE VARIES BASED ON DEPTH OF
WATER & AND SIZE OF DIKE
TYPICAL EXISTING
ISLAND CROSS-SECTION
ELEVATION VARIES

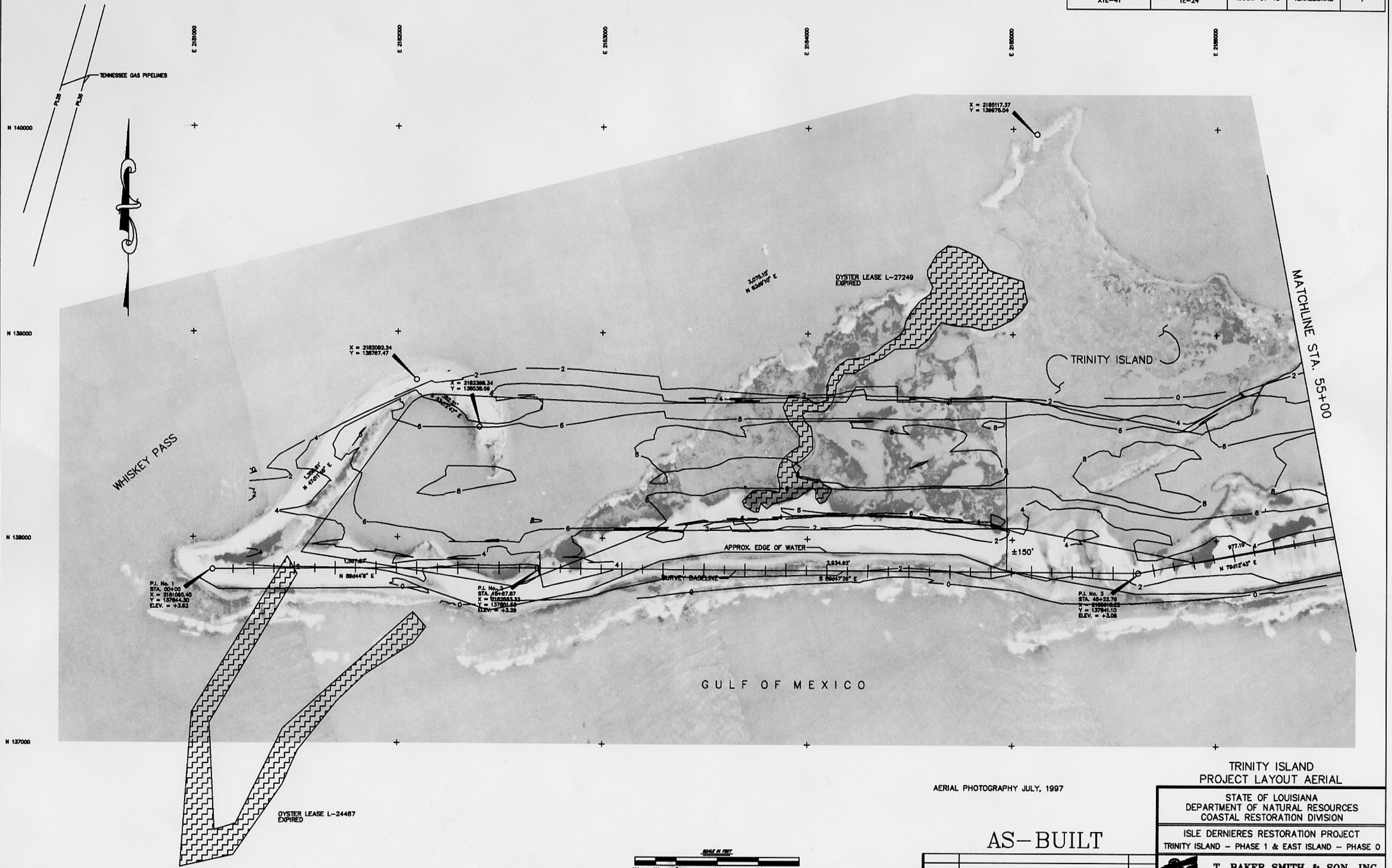


NORTH
SOUTH
LAKE
PELTO
GULF OF MEXICO
FINISHED CROSS-SECTION
AFTER SHAPING & GRADING, BACK DIKE TO BE LEVELED & SLOPED INTO BACK BAY & MARSH
OVERWASH SAND TO BE USED TO CONSTRUCT TEMPORARY GULF SIDE CONTAINMENT DIKE
+8.0'
FILL
+6.0'
10'
CUT
ELEV. = +5.0' OR AS REQ'D BY CONTRACTOR
30'
+1.0'
SLOPE - NO LIMITS
DEPTH AS REQ'D
BORROW CANAL FOR CONTAINMENT DIKE CONSTRUCTION NO DEPTH OF SLOPE REQUIRED, BUT 30' BERM REQUIRED.
TYPICAL EXISTING ISLAND CROSS-SECTION
FRONT DIKE NOT TO BE REMOVED
P150'
EDGE OF WATER
EXISTING DUNE
ELEVATION VARIES
+10
+8
+6
+4
+2
0
-2
-4
-6
-8
-10

APPENDIX D

The Trinity Island (TE-24) as-built construction template depicting the shoreline configuration and elevation contours.

FEDERAL PROJECT NOS.	STATE PROJECT NOS.	ENGINEERING CONTRACT NO.	PARISH	SHEET NO.
TE-20 XTE-41	TE-20 TE-24	435CW-97-13	TERREBONNE	7



TRINITY ISLAND
PROJECT LAYOUT AERIAL

AERIAL PHOTOGRAPHY JULY, 1997

STATE OF LOUISIANA
DEPARTMENT OF NATURAL RESOURCES
COASTAL RESTORATION DIVISION

ISLE DERNIERES RESTORATION PROJECT
TRINITY ISLAND – PHASE 1 & EAST ISLAND – PHASE 0

AS–BUILT

DATE	DESCRIPTION	BY
12/16/98	AS–BUILT DRAWINGS	CDL
	REVISIONS	

T. BAKER SMITH & SON, INC.
CIVIL ENGINEERS – SURVEYORS – ENVIRONMENTAL SERVICES
P.O. BOX 2266 HOUMA, LOUISIANA 70361

DRAWN	DFB	DRAWING	SHEET7ASBUILT	DATE	AUGUST, 1997
CHECKED	MJR	JOB No.	578–96	SCALE	1 = 200

FEDERAL PROJECT NOS.	STATE PROJECT NOS.	ENGINEERING CONTRACT NO.	PARISH	SHEET NO.
TE-20 XTE-41	TE-20 TE-24	435CW-97-13	TERREBONNE	8

TRINITY ISLAND
PROJECT LAYOUT AERIAL

STATE OF LOUISIANA
DEPARTMENT OF NATURAL RESOURCES
COASTAL RESTORATION DIVISION

ISLE DERNIERES RESTORATION PROJECT
TRINITY ISLAND – PHASE 1 & EAST ISLAND – PHASE 0

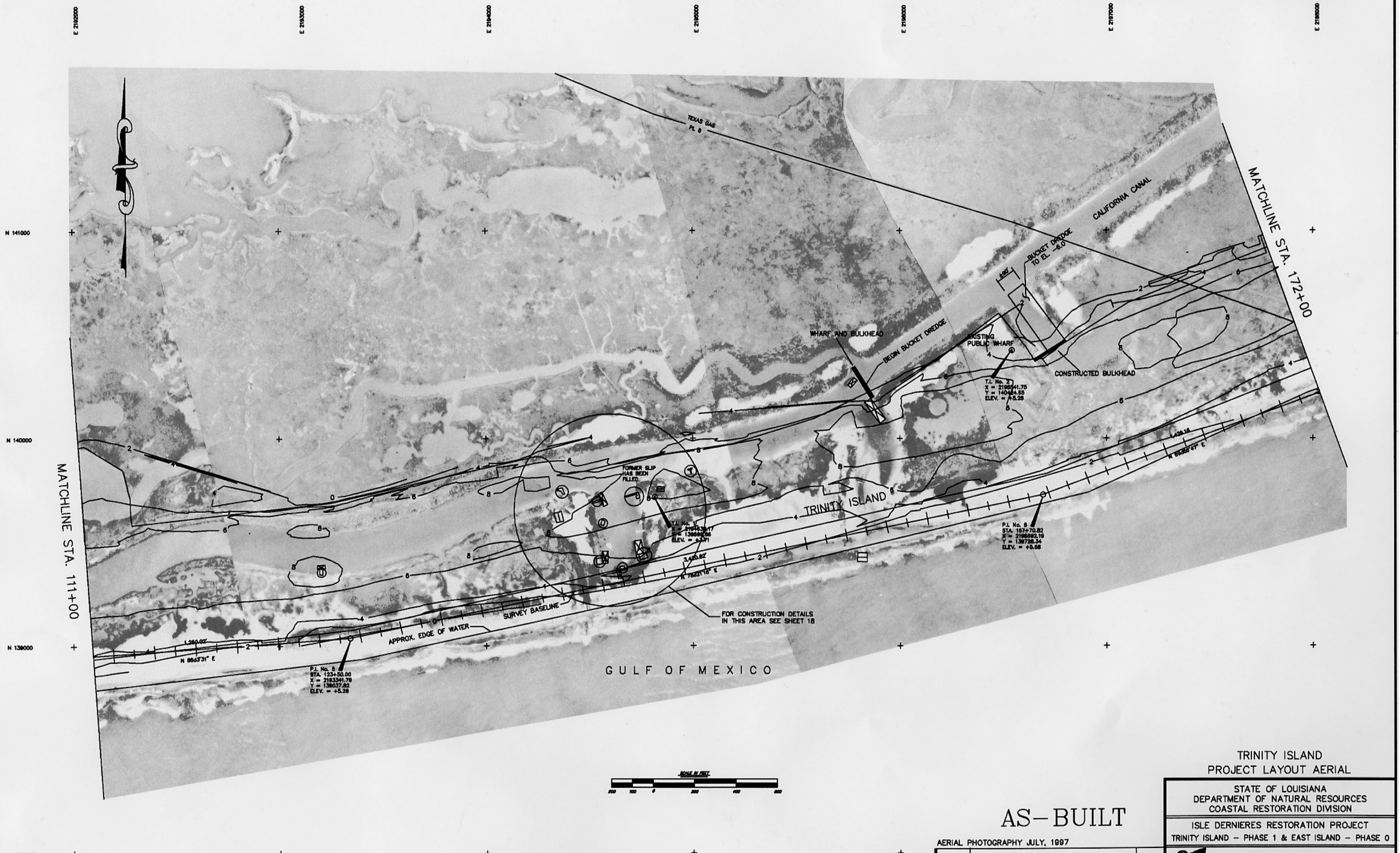
AS–BUILT

12/16/98	AS-BUILT DRAWINGS	CDL
DATE	DESCRIPTION	BY
	REVISIONS	

T. BAKER SMITH & SON, INC.
CIVIL ENGINEERS – SURVEYORS – ENVIRONMENTAL SERVICES
P.O. BOX 2266 HOUMA, LOUISIANA 70361

DRAWN	DFB	DRAWING SHEET8ASBUILT	DATE AUGUST, 1997
CHECKED	MJR	JOB No. 578-96	SCALE 1 = 200

FEDERAL PROJECT NOS.	STATE PROJECT NOS.	ENGINEERING CONTRACT NO.	PARISH	SHEET NO.
TE-20 XTE-41	TE-20 TE-24	435CW-97-13	TERREBONNE	9



TRINITY ISLAND
PROJECT LAYOUT AERIAL

AS-BUILT

AERIAL PHOTOGRAPHY JULY, 1997

STATE OF LOUISIANA
DEPARTMENT OF NATURAL RESOURCES
COASTAL RESTORATION DIVISION

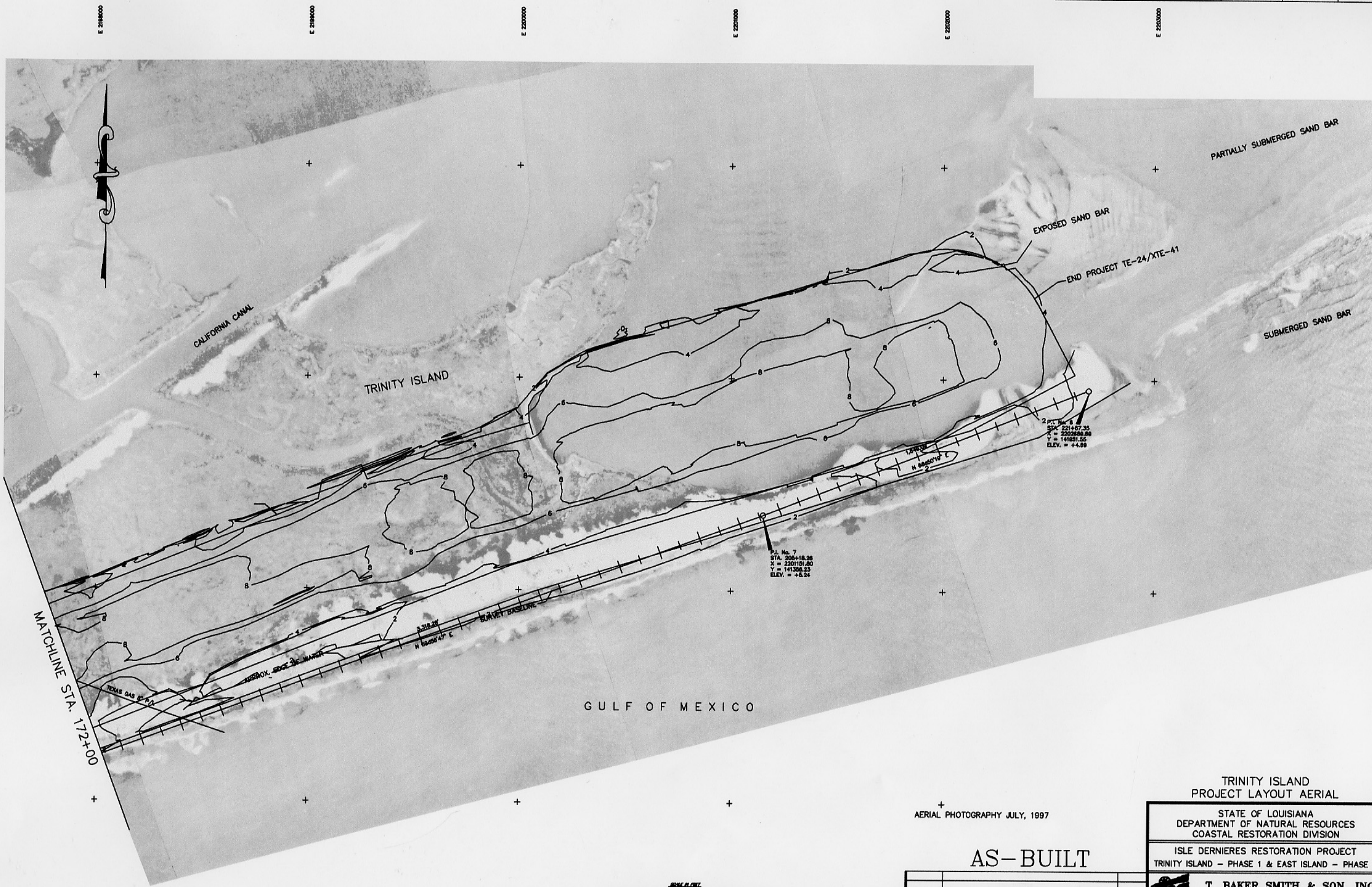
ISLE DERNIERES RESTORATION PROJECT
TRINITY ISLAND – PHASE 1 & EAST ISLAND – PHASE 0

T. BAKER SMITH & SON, INC.
CIVIL ENGINEERS – SURVEYORS – ENVIRONMENTAL SERVICES
P.O. BOX 2266 HOUMA, LOUISIANA 70361

DATE	DESCRIPTION	BY
12/16/98	As-built drawings	CDL
REVISIONS		

DRAWN	DFB	DRAWING SHEET9ASBUILT	DATE AUGUST, 1997
CHECKED	MJR	JOB No. 578-96	SCALE 1 = 200

FEDERAL PROJECT NOS.	STATE PROJECT NOS.	ENGINEERING CONTRACT NO.	PARISH	SHEET NO.
TE-20 XTE-41	TE-20 TE-24	435CW-97-13	TERREBONNE	10



AERIAL PHOTOGRAPHY JULY, 1997

AS-BUILT

TRINITY ISLAND
PROJECT LAYOUT AERIAL

STATE OF LOUISIANA
DEPARTMENT OF NATURAL RESOURCES
COASTAL RESTORATION DIVISION

ISLE DERNIERES RESTORATION PROJECT
TRINITY ISLAND – PHASE 1 & EAST ISLAND – PHASE 0

T. BAKER SMITH & SON, INC.
CIVIL ENGINEERS - SURVEYORS - ENVIRONMENTAL SERVICES
P.O. BOX 2266 HOUMA, LOUISIANA 70361

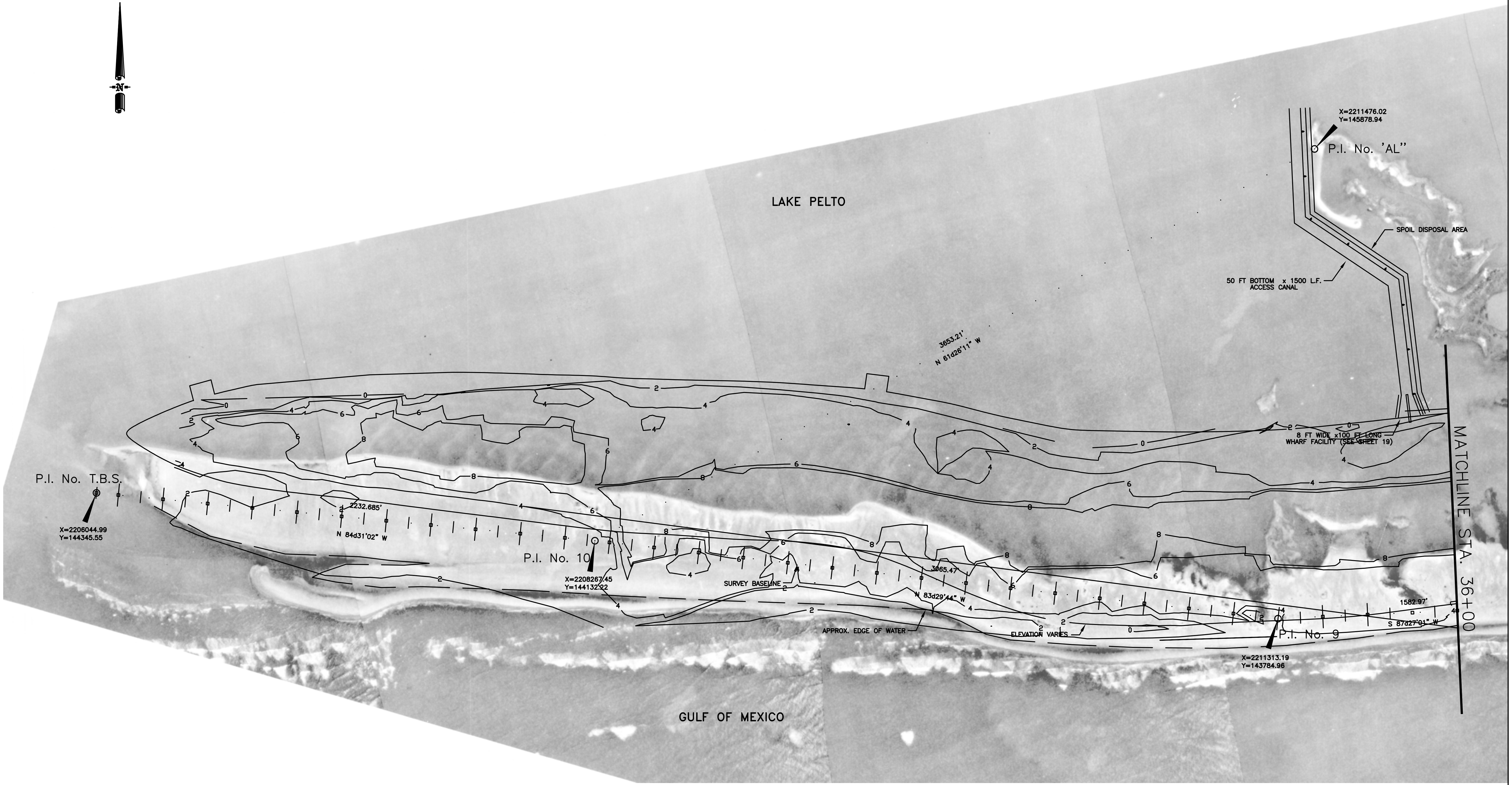
DATE	DESCRIPTION	BY
12/16/98	AS-BUILT DRAWINGS	CDL
	REVISIONS	

DRAWN	DFB	DRAWING SHEET10ASBUILT	DATE AUGUST, 1997
CHECKED	MJR	JOB No. 578-96	SCALE 1 = 200

APPENDIX E

The construction as-built drawing of the East Island (TE-20) CWPPRA restoration project depicting the shoreline configuration and elevation contours.

FEDERAL PROJECT NOS.	STATE PROJECT NOS.	ENGINEERING CONTRACT NO.	PARISH	SHEET NO.
TE-20 XTE-41	TE-20 TE-41	435CW-97	TERREBONNE	11



SCALE IN FEET

200 100 0 200 400 600

AS-BUILT

PROJECT LAYOUT AERIAL

STATE OF LOUISIANA
DEPARTMENT OF NATURAL RESOURCES
COASTAL RESTORATION DIVISION

ISLE DERNIERES RESTORATION PROJECT
EAST ISLAND – PHASE 0

T. BAKER SMITH & SON, INC.
CIVIL ENGINEERS – SURVEYORS – ENVIRONMENTAL RESEARCH
P.O. BOX 2266 HOUMA, LOUISIANA 70361

DATE	DESCRIPTION	BY
12/16/98	AS-BUILT DRAWINGS	CDL

REVISIONS

DRAWN:	DRAWING: SHEET11ASBUILT	DATE: 09-04-98
CHECKED: MJR	SCALE: as-shown	JOB No.: 578-96

FEDERAL PROJECT NOS.	STATE PROJECT NOS.	ENGINEERING CONTRACT NO.	PARISH	SHEET NO.
TE-20 XTE-41	TE-20 TE-41	435CW-97	TERREBONNE	12

SCALE IN FEET

200 100 0 200 400 600

AS-BUILT

PROJECT LAYOUT AERIAL

STATE OF LOUISIANA
DEPARTMENT OF NATURAL RESOURCES
COASTAL RESTORATION DIVISION

ISLE DERNIERES RESTORATION PROJECT
EAST ISLAND - PHASE 0

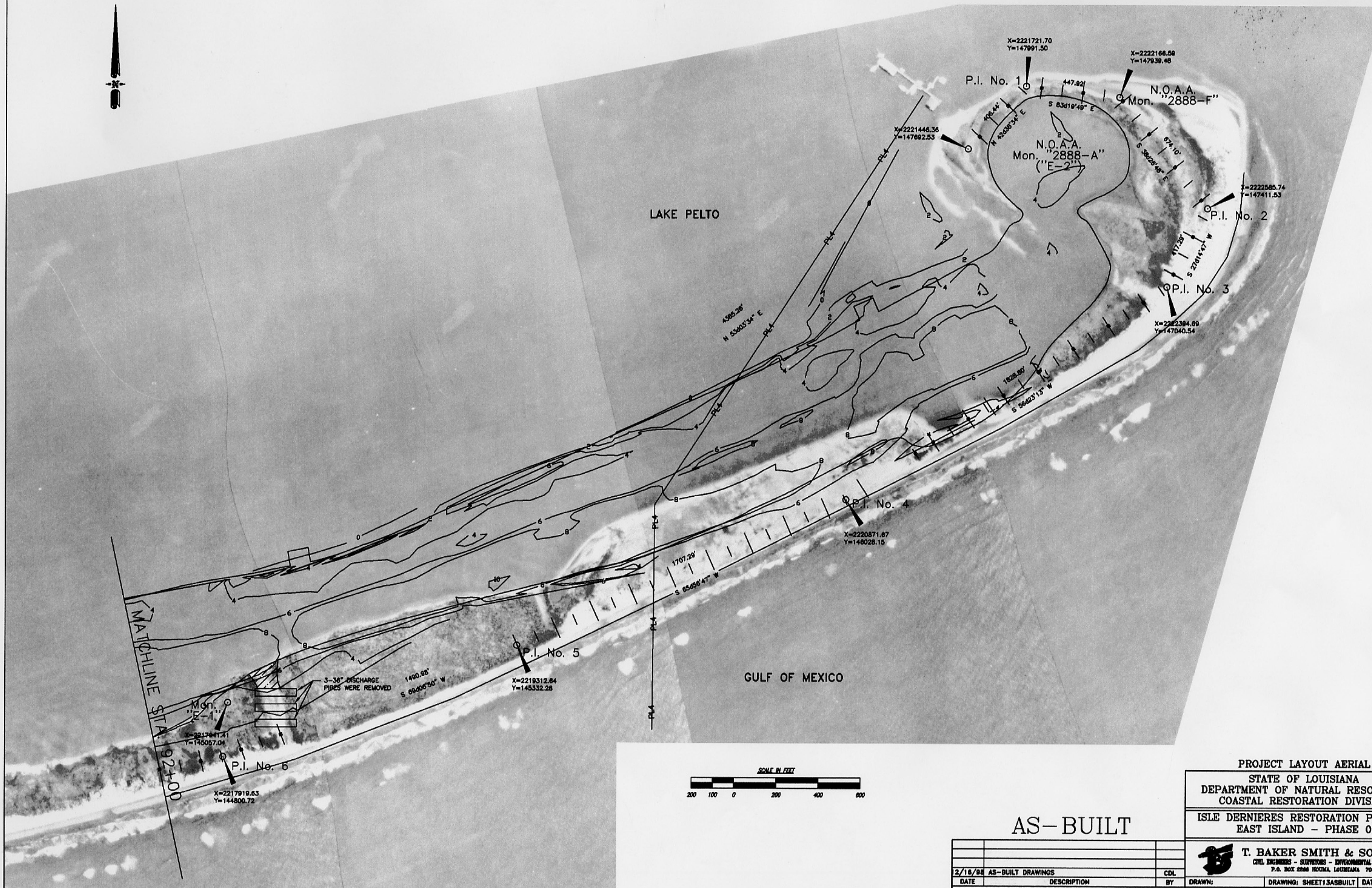
T. BAKER SMITH & SON, INC.
CIVIL ENGINEERS - SURVEYORS - ENVIRONMENTAL RESEARCH
P.O. BOX 2266 HOUMA, LOUISIANA 70361

DATE	DESCRIPTION	BY
12/16/98	AS-BUILT DRAWINGS	CDL

REVISIONS

DRAWN:	DRAWING: SHEET12ASBUILT	DATE: 09-04-97
CHECKED: MJR	SCALE: as-shown	JOB No.: 578-96

FEDERAL PROJECT NOS.	STATE PROJECT NOS.	ENGINEERING CONTRACT NO.	PARISH	SHEET NO.
TE-20 XTE-41	TE-20 TE-41	435CW-97	TERREBONNE	13



AS-BUILT

PROJECT LAYOUT AERIAL

STATE OF LOUISIANA
DEPARTMENT OF NATURAL RESOURCES
COASTAL RESTORATION DIVISION

ISLE DERNIERES RESTORATION PROJECT
EAST ISLAND – PHASE 0

T. BAKER SMITH & SON, INC.
CIVIL ENGINEERS – SURVEYORS – ENVIRONMENTAL RESEARCH
P.O. BOX 2266 HOUMA, LOUISIANA 70361

DATE	DESCRIPTION	BY
12/16/98	AS-BUILT DRAWINGS	CDL

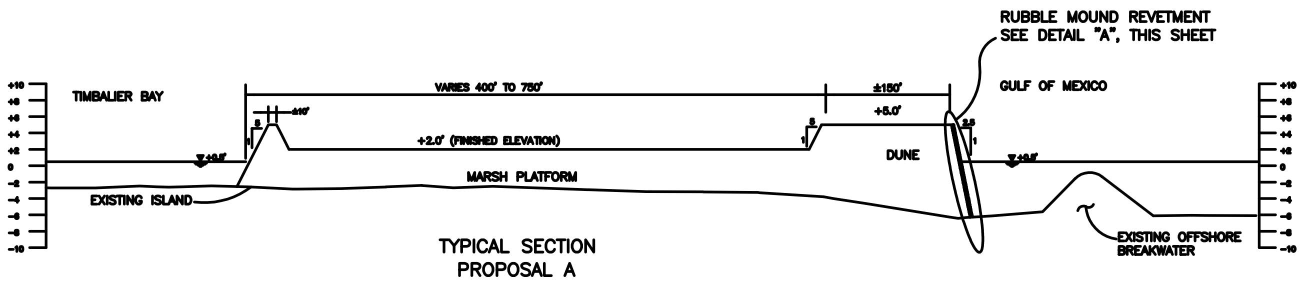
REVISIONS

DRAWN:	DRAWING: SHEET13ASBUILT	DATE: 09-04-97
CHECKED: MJR	SCALE: as-shown	JOB No.: 578-96

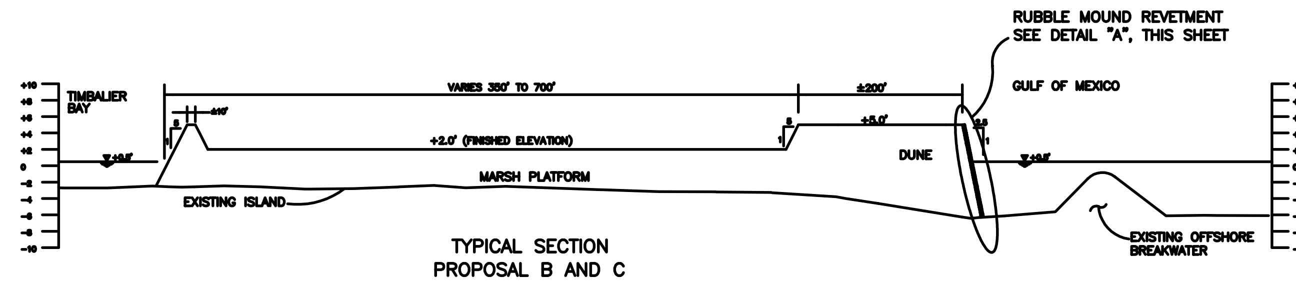
APPENDIX F

The design template for East Timbalier Island (TE-25/30) barrier island restoration project.

FEDERAL PROJECT NOS.	STATE PROJECT NOS.	ENGINEERING CONTRACT NO.	PARISH
XTE-67 XTE-45-67B	TE-25 TE-30	435CW-97-10	LAFOURCHE



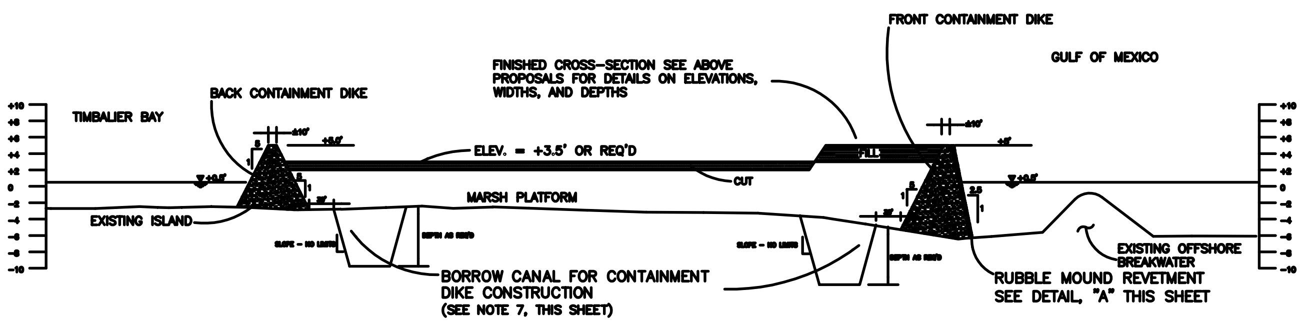
TYPICAL SECTION
PROPOSAL A



TYPICAL SECTION
PROPOSAL B AND C

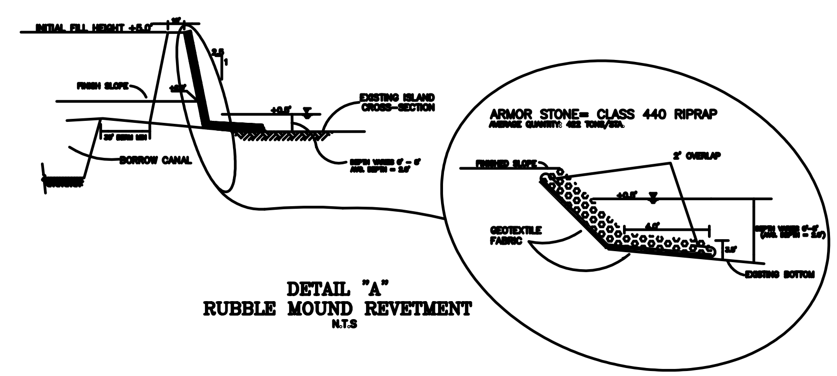
DESIGN CROSS-SECTION TEMPLATES AFTER GRADING AND SHAPING

SCALE – HORZ.: 1" = 100'
VERT.: 1" = 10'



SUGGESTED CONSTRUCTION
CROSS-SECTION TEMPLATE

SCALE – HORZ.: 1" = 100'
VERT.: 1" = 10'



DETAIL "A"
RUBBLE MOUND REVETMENT
N.T.S

NOTES:

1. RUBBLE MOUND REVETMENT TO BE CONSTRUCTED FROM STATION 96+91.99 TO STATION 159+11.62 FOR PROPOSAL A AND PROPOSAL B.
2. RUBBLE MOUND REVETMENT TO BE CONSTRUCTED FROM STATION -4+30.76 TO STATION 7+49.04 AND FROM STATION 96+91.99 TO STATION 159+11.62 FOR PROPOSAL C
3. REVETMENT ARMOR STONE: SHALL BE CLASS 440 RIPRAP.
4. GEOTEXTILE FABRIC TO OVERLAP A MINIMUM OF 2 FEET

NOTES:

1. RUBBLE MOUND REVETMENTS MUST BE SATISFACTORILY COMPLETE PRIOR TO COMMENCEMENT OF HYDRAULIC FILL.
2. AT THE CONTRACTOR'S REQUEST, APPROVAL TO BEGIN HYDRAULIC FILL PRIOR TO COMPLETION OF THE RUBBLE MOUND REVETMENT MAY BE MADE BY THE OWNER AT THE CONTRACTOR'S RISK.
3. CONTRACTOR IS RESPONSIBLE FOR MAINTAINING THE INTEGRITY OF THE CONTAINMENT DIKES DURING HYDRAULIC FILL.
4. ALL NOTES AND REQUIREMENTS ARE APPLICABLE FOR ALL PROPOSALS.
5. ALL ROCK QUANTITIES BASED ON AVERAGE WATER DEPTH.
6. EXISTING OFFSHORE BREAKWATER SHALL REMAIN UNDISTURBED THROUGHOUT CONSTRUCTION.
7. NO DEPTH OR SLOPE REQUIRED ON BORROW CANAL, HOWEVER, CANAL MUST BE OFFSET A MINIMUM OF 30' FROM BASE OF CONTAINMENT DIKE.
8. CONTRACTOR MAY FILL CONSTRUCTION TEMPLATE TO GRADE.

AS BUILT NOTE:

1. FOR INFORMATION ON AS BUILT CROSS SECTIONS AND TEMPLATES (SEE SHEETS 15 THRU 24).

AS BUILT

REVISIONS:

DATE:	REMARKS:
10-6-98	RE-ADVERTISEMENT
1-18-00	AS BUILT

STAMP:

PICCIOLA & ASSOCIATES
CONSULTING ENGINEERS & SURVEYORS
CUT OFF, LOUISIANA

DESIGNED BY:	DRAWN BY:	CHECKED BY:
TBS, INC.	T.P.C.	D.B.R.

DATE: 02/23/98

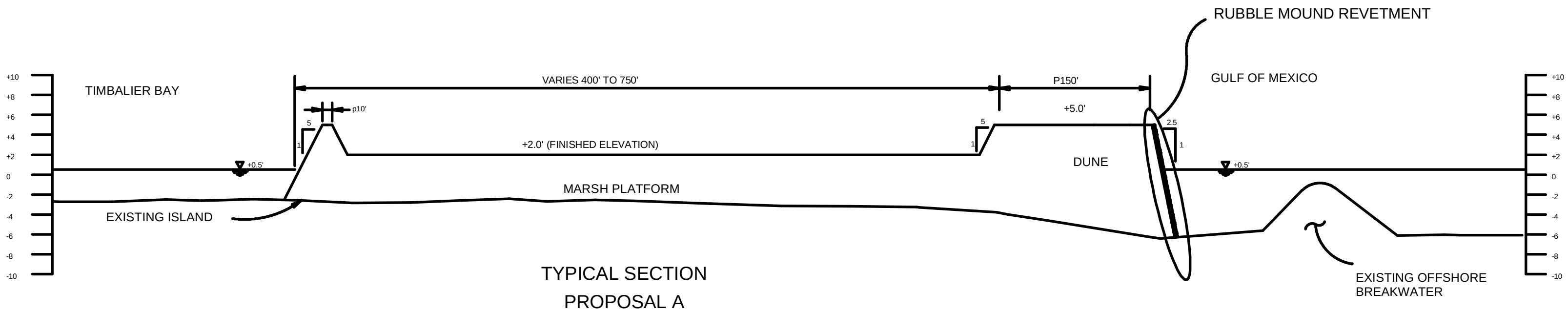
SCALE: AS SHOWN

DEPARTMENT OF NATURAL RESOURCES
COASTAL RESTORATION DIVISION

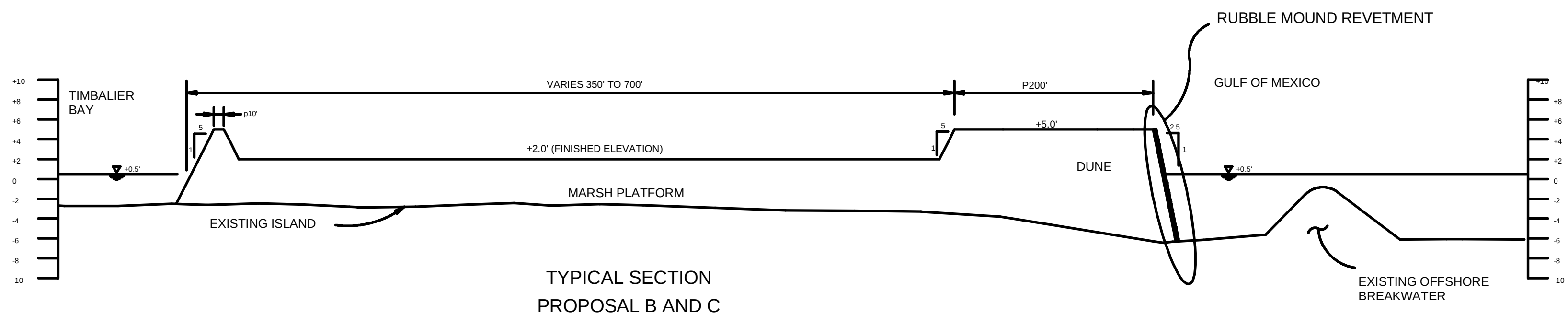
EAST TIMBALIER ISLAND SEDIMENT RESTORATION PROJECTS
TYPICAL CROSS-SECTION
AND
EROSION PROTECTION DETAILS

SHEET NO. 5 OF 24

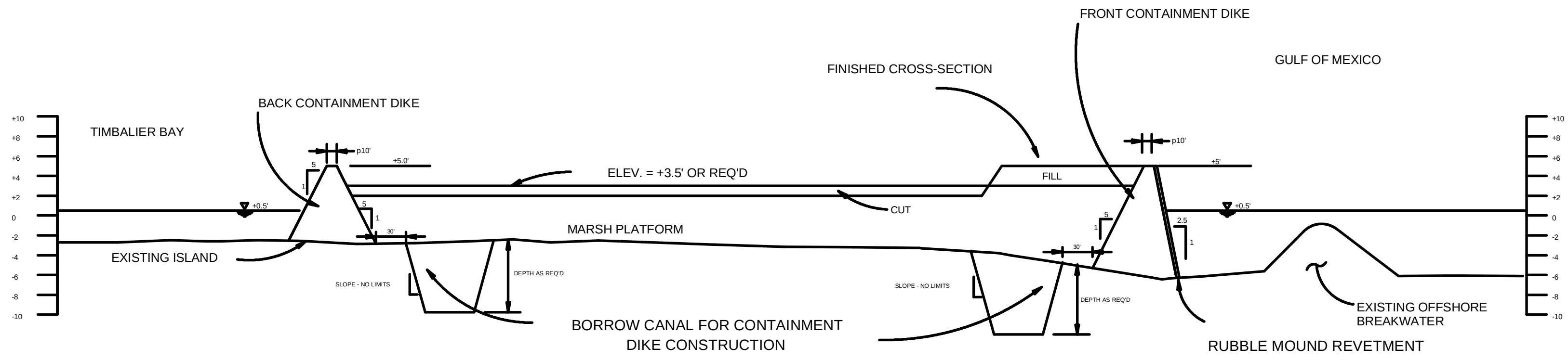
571-98: TYPSEC1.DWG



TYPICAL SECTION
PROPOSAL A



TYPICAL SECTION
PROPOSAL B AND C



SUGGESTED CONSTRUCTION
CROSS-SECTION TEMPLATE

SCALE - HORZ.: 1" = 100'
VERT.: 1" = 10'

APPENDIX G

The as-built of the East Timbalier Island (TE-25/30) restoration project depicting the shoreline configuration and elevational contours.

FEDERAL PROJECT NOS.	STATE PROJECT NOS.	ENGINEERING CONTRACT NO.	PARISH
XTE-67 XTE-45-67B	TE-25 TE-30	435CW-97-10	LAFOURCHE

POINT	AS BUILT COORDINATE LIST	
1	X = 2319432.02	Y = 144554.88
2	X = 2319432.02	Y = 144554.88
3	X = 2319831.02	Y = 144809.28
4	X = 2318624.96	Y = 144522.56
5	X = 2319145.22	Y = 144688.18
6	X = 2319507.38	Y = 144858.06
7	X = 2319810.53	Y = 144851.58
8	X = 2318538.11	Y = 145301.39
9	X = 2319009.13	Y = 145427.84
10	X = 2319243.62	Y = 145402.54

AS BUILT NOTE:

1. LAYOUT IS FOR AS BUILT.
2. REVETMENT WIDTH IS NOT TO SCALE. SEE TYPICAL SECTION SHEET 5 OF 24.

AS BUILT

REVISIONS:

DATE:	REMARKS:
10-5-98	RE-ADVERTISEMENT
1-15-00	AS BUILT

STAMP:

PICCIOLA & ASSOCIATES
CONSULTING ENGINEERS & SURVEYORS
CUT OFF, LOUISIANA

DESIGNED BY:	DRAWN BY:	CHECKED BY:
TBS, INC.	T.P.C.	D.B.R.

DATE: 02/23/98

SCALE: 1" = 200'

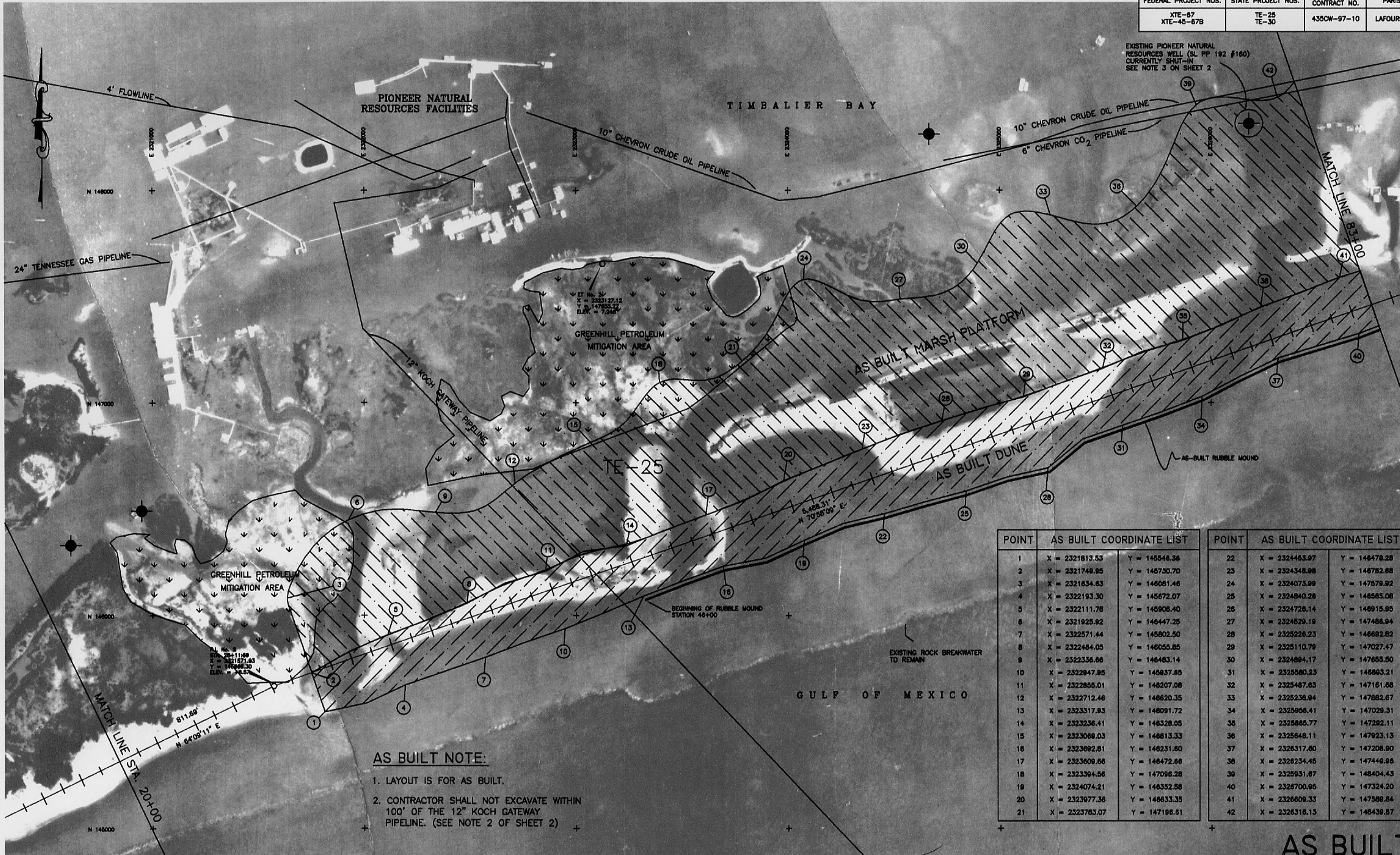
DEPARTMENT OF NATURAL RESOURCES
COASTAL RESTORATION DIVISION

EAST TIMBALIER ISLAND SEDIMENT RESTORATION PROJECTS
PROJECT LAYOUT AERIAL

SHEET NO. 6 OF 24

571-97: ET-PLAN1.DWG

FEDERAL PROJECT NOS.	STATE PROJECT NOS.	ENGINEERING CONTRACT NO.	PARISH
XTE-67 XTE-45-67B	TE-25 TE-30	435CW-97-10	LAFOURCHE



POINT	AS BUILT COORDINATE LIST	
1	X = 2321813.53	Y = 145546.36
2	X = 2321749.95	Y = 145730.70
3	X = 2321634.63	Y = 146081.46
4	X = 2322193.30	Y = 145672.07
5	X = 2322111.78	Y = 145906.40
6	X = 2321925.92	Y = 146447.25
7	X = 2322571.44	Y = 145802.50
8	X = 2322484.05	Y = 146055.85
9	X = 2322336.66	Y = 146483.14
10	X = 2322947.95	Y = 145937.65
11	X = 2322855.01	Y = 146207.08
12	X = 2322712.46	Y = 146620.35
13	X = 2323317.93	Y = 146091.72
14	X = 2323236.41	Y = 146328.05
15	X = 2323069.03	Y = 146813.33
16	X = 2323692.81	Y = 146231.60
17	X = 2323609.66	Y = 146472.66
18	X = 2323394.56	Y = 147098.28
19	X = 2324074.21	Y = 146352.58
20	X = 2323977.36	Y = 146633.35
21	X = 2323783.07	Y = 147196.61

POINT	AS BUILT COORDINATE LIST	
22	X = 2324453.97	Y = 146478.28
23	X = 2324348.98	Y = 146782.68
24	X = 2324073.99	Y = 147579.92
25	X = 2324840.26	Y = 146585.08
26	X = 2324726.14	Y = 146915.95
27	X = 2324529.19	Y = 147486.94
28	X = 2325226.23	Y = 146692.82
29	X = 2325110.79	Y = 147027.47
30	X = 2324894.17	Y = 147655.50
31	X = 2325580.23	Y = 146893.21
32	X = 2325487.63	Y = 147161.68
33	X = 2325238.94	Y = 147882.67
34	X = 2325956.41	Y = 147029.31
35	X = 2325865.77	Y = 147292.11
36	X = 2325648.11	Y = 147923.13
37	X = 2326317.60	Y = 147208.90
38	X = 2326234.45	Y = 147449.96
39	X = 2325931.67	Y = 148404.43
40	X = 2326700.95	Y = 147324.20
41	X = 2326609.33	Y = 147589.84
42	X = 2326316.13	Y = 148439.87

AS BUILT NOTE:

1. LAYOUT IS FOR AS BUILT.
2. CONTRACTOR SHALL NOT EXCAVATE WITHIN 100' OF THE 12" KOCH GATEWAY PIPELINE. (SEE NOTE 2 OF SHEET 2)

AS BUILT

REVISIONS:

DATE:	REMARKS:
10-5-98	RE-ADVERTISEMENT
1-15-00	AS BUILT

STAMP:

PICCIOLA & ASSOCIATES
CONSULTING ENGINEERS & SURVEYORS
CUT OFF, LOUISIANA

DESIGNED BY: TBS, INC. | DRAWN BY: T.P.C. | CHECKED BY: D.B.R.

DATE: 02/23/98

SCALE: 1" = 200'

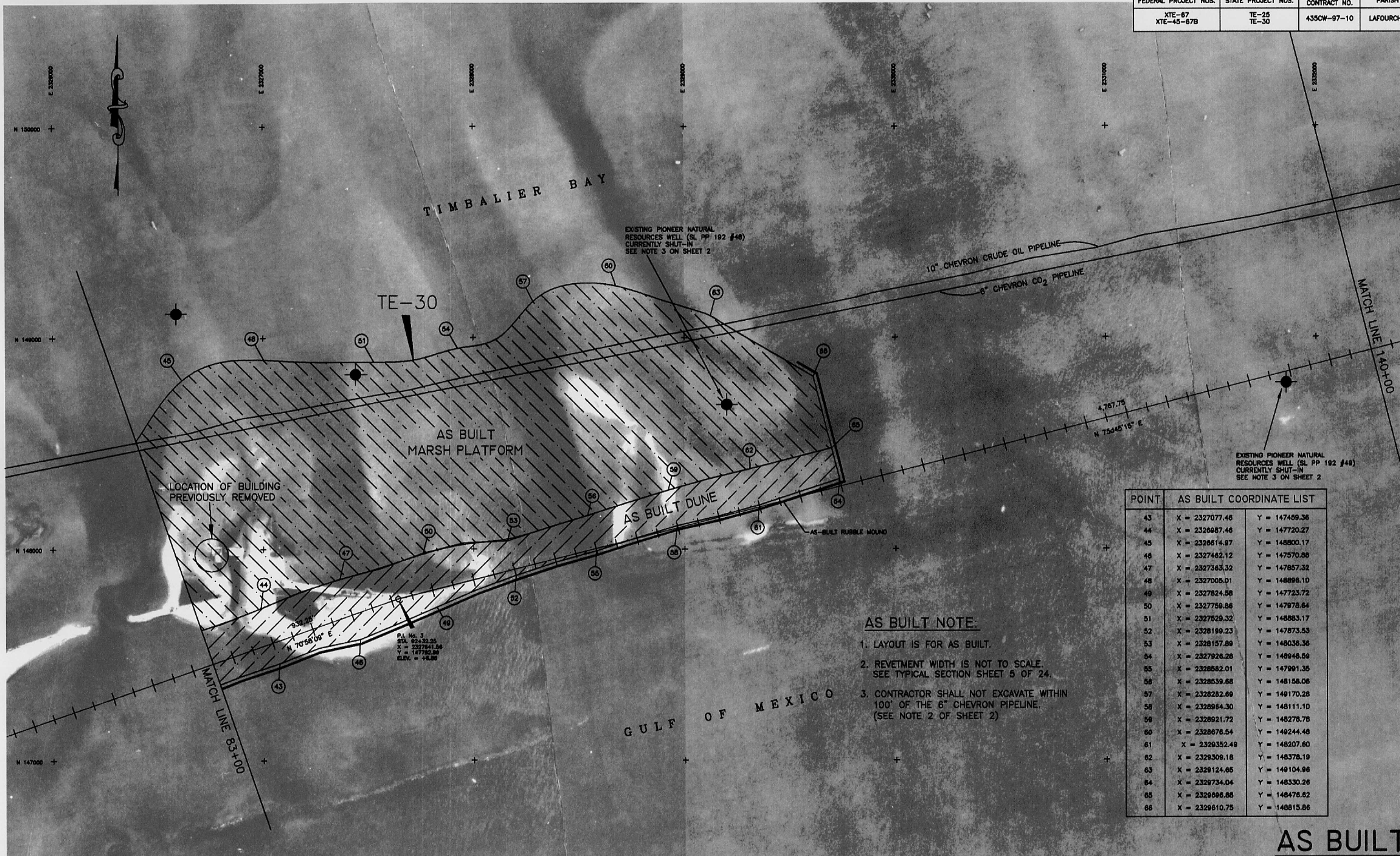
DEPARTMENT OF NATURAL RESOURCES
COASTAL RESTORATION DIVISION

EAST TIMBALIER ISLAND SEDIMENT RESTORATION PROJECTS
PROJECT LAYOUT AERIAL

SHEET NO. 7 of 24

571-97: ET-PLAN2.DWG

FEDERAL PROJECT NOS.	STATE PROJECT NOS.	ENGINEERING CONTRACT NO.	PARISH
XTE-67 XTE-45-67B	TE-25 TE-30	435CW-97-10	LAFOURCHE



POINT	AS BUILT COORDINATE LIST	
43	X = 2327077.46	Y = 147459.36
44	X = 2326987.46	Y = 147720.27
45	X = 2326614.97	Y = 148800.17
46	X = 2327462.12	Y = 147570.86
47	X = 2327363.32	Y = 147857.32
48	X = 2327005.01	Y = 148896.10
49	X = 2327824.56	Y = 147723.72
50	X = 2327759.86	Y = 147978.64
51	X = 2327529.32	Y = 148883.17
52	X = 2328199.23	Y = 147873.53
53	X = 2328157.89	Y = 148036.36
54	X = 2327926.26	Y = 148946.59
55	X = 2328582.01	Y = 147991.35
56	X = 2328539.68	Y = 148158.06
57	X = 2328282.69	Y = 149170.28
58	X = 2328964.30	Y = 148111.10
59	X = 2328921.72	Y = 148278.78
60	X = 2328676.54	Y = 149244.48
61	X = 2329352.49	Y = 148207.60
62	X = 2329309.16	Y = 148378.19
63	X = 2329124.65	Y = 149104.96
64	X = 2329734.04	Y = 148330.26
65	X = 2329696.86	Y = 148476.62
66	X = 2329610.75	Y = 148815.86

AS BUILT NOTE:

1. LAYOUT IS FOR AS BUILT.
2. REVETMENT WIDTH IS NOT TO SCALE. SEE TYPICAL SECTION SHEET 5 OF 24.
3. CONTRACTOR SHALL NOT EXCAVATE WITHIN 100' OF THE 6" CHEVRON PIPELINE. (SEE NOTE 2 OF SHEET 2)

AS BUILT

SCALE IN FEET

200 100 0 200 400 600

REVISIONS:	
DATE:	REMARKS:
10-5-98	RE-ADVERTISEMENT
1-15-00	AS BUILT

STAMP:

PICCIOLA & ASSOCIATES
CONSULTING ENGINEERS & SURVEYORS
CUT OFF, LOUISIANA

DESIGNED BY: TBS, INC. | DRAWN BY: T.P.C. | CHECKED BY: D.B.R.

DATE: 02/23/98

SCALE: 1" = 200'

DEPARTMENT OF NATURAL RESOURCES
COASTAL RESTORATION DIVISION

EAST TIMBALIER ISLAND SEDIMENT RESTORATION PROJECTS
PROJECT LAYOUT AERIAL

SHEET NO. 8 OF 24

571-97: ET-PLAN3.DWG