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Department of Natural Resources
Coastal Restoration Division and
Coastal Engineering Division

2007 Operations, Maintenance, and Monitoring Report

for

GIWW (GULF INTRACOASTAL WATERWAY) to CLOVELLY HYDROLOGIC RESTORATION

State Project Number BA-02
Priority Project List 1

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Lafourche Parish

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2007 Operations, Maintenance, and Monitoring Report
For
GIWW (Gulf Intracoastal Waterway) to Clovelly Hydrologic Restoration (BA-02)

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I. Introduction

The GIWW (Gulf Intracoastal Waterway) to Clovelly Hydrologic Restoration (BA-02) project is located in Lafourche Parish, Louisiana, southeast of the GIWW, east of Bayou Lafourche, and north of the Superior Canal (figure 1). The project area totals 14,840 acres (6,006 hectares) of wetlands (81% land/marsh, 19% water) and is part of the last contiguous marsh tracts in the Barataria Basin.

Within the GIWW (Gulf Intracoastal Waterway) to Clovelly Hydrologic Restoration (BA-02) project the average rate of change from marsh habitat to non-marsh habitat (including wetland loss to both open water and commercial development) has been increasing since the 1950's. The mean wetland loss rates were 0.36%/year between 1945 and 1956, 1.03%/year between 1956 and 1969, and 1.96%/year between 1969 and 1980 (Sasser et al. 1986). Impacts from the numerous oilfield canals constructed in the GIWW to Clovelly Hydrologic Restoration (BA-02) project area include changes in hydrology, marsh impoundments, reduction in sediment accretion, and saltwater intrusion (Turner et al. 1984; Swenson and Turner 1987; Wang 1988; Turner 1990). The Clovelly Canal is connected to Little Lake on the eastern end and likely facilitates the transport of more saline waters from Little Lake to western regions of the project area.

Since 1949, marsh types have changed throughout the project, especially in the southern area. The entire project area was characterized as fresh marsh and floating three corner grass by O'Neil in 1949 (Coastal Environments, Inc. 1989). Since 1968, areas of intermediate and brackish marsh have encroached into the project area from the east, and by 1978, the project area contained almost entirely intermediate marsh with some brackish marsh along the Little Lake shoreline. In 1988, none of the project area was characterized as fresh marsh (Chabreck et al. 1968; Chabreck and Linscombe 1988), but the 1997 survey showed some pockets of fresh marsh in the northwest portion with the remainder of the project area as intermediate marsh. In 2001, the areas of fresh marsh in the northwest remained, some brackish marsh occurred in pockets in the southeast, but intermediate marsh was still predominate. It is unclear whether the changes in these areas have been due to an increase in salinity, a change in the water level regime, or a combination of the two. Increasing land loss rates for the Cut Off area (1932-1985: 0.10%; 1983-1990: 0.25%) (Dunbar et al. 1992), along with the changes in marsh types, are raising concerns that the quality of the marsh is declining and marsh will be converted to open water.

The project objective is to protect intermediate marsh in the project area by restoring natural hydrologic conditions that promote greater use of available freshwater and nutrients. This will be accomplished through structural measures aimed at limiting rapid water level changes, slowing water exchange through over-bank flow, reducing rapid salinity increases, and reducing saltwater intrusion (Lear 2003).

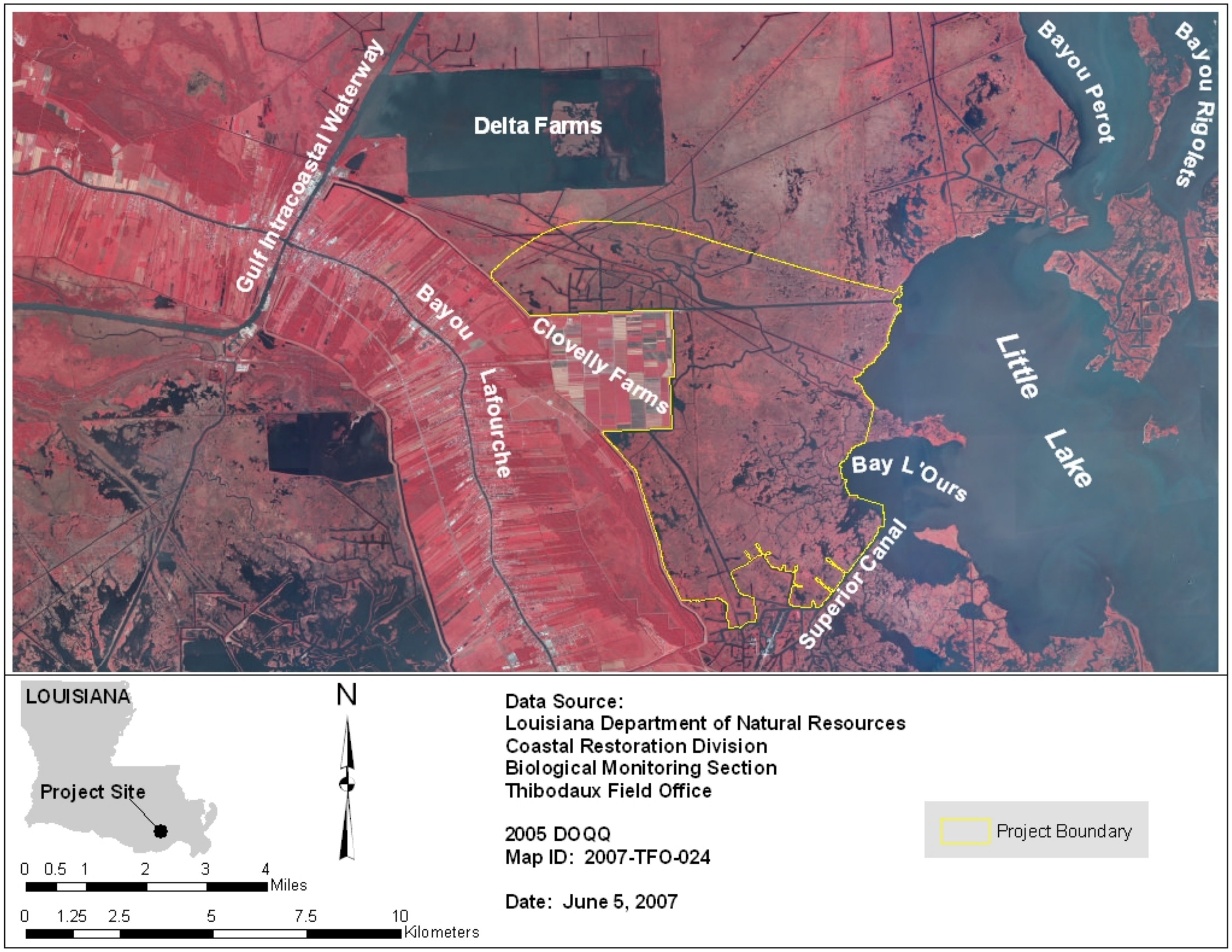

Figure 1. Location map with project boundary for the GIWW (Gulf Intracosastal Waterway) to Clovelly Hydrologic Restoration (BA-02) project.

Construction of project features occurred in two construction units. Construction Unit No. 1 has a twenty-year (20-yr) project life that began in November 1997, and Construction Unit No. 2 has a twenty-year (20-yr) project life that began in October 2000.
Project features include (LDNR et al. 2002):

Construction Unit No. 1

- Construction of three (3) fixed crest rock weirs with boat bays, from 200 pound class rock riprap cap on top of geotextile with a crest elevation approximately 3.8 to 4.0 ft (1.2 m) NAVD88, and a crest width approximately 8 to 8.9 ft (2.6 m) (figure 2; Structures 2, 4, and 7). Weir lengths varied depending upon their locations.
- Construction of two rock riprap channel plugs on top of geogrid. The plugs varied in crest elevation and length depending upon their locations (figure 2; Structures 43 and 4A).
- Construction of one rock riprap weir with a boat bay (figure 2; Structure 8).
- Construction of one 102 linear ft (36.6 m) rock-filled channel plug with a crest elevation of 3.2 ft (1.0 m) NAVD88, with a 36 inch diameter 10 gauge pile supported corrugated aluminum pipe through the plug embankment, and a 36 inch aluminum flap gate (figure 2; Structure 91).

Construction Unit No. 2

- Construction of approximately 5,665 linear ft (1,727 m) of lake-rim shoreline protection from 650 pound class rock riprap on top of geotextile with a design crest elevation of +2.0 ft (+0.6 m) and an average constructed crest elevation of 3.0 ft (0.9 m) NAVD88, and a crest width of 4 ft (1.2 m), along the southwestern shorelines of Little Lake, Bay L'Ours, and Brusle Lake (figure 2).
- Construction of approximately 5,023 linear ft (1531 m) of bank stabilization from 200 pound class rock riprap on top of earthen and rock fill on top of geotextile with a design crest elevation of +2.0 ft (+0.6 m) NAVD88, an average constructed crest elevation of +3.0 ft (+0.9 m) NAVD88, and a crest width of 4 ft (1.2 m), along the northern shoreline of Breton Canal (figure 2).
- Construction of approximately 11,711 linear ft (3,570 m) of earthen bank stabilization on top of geotextile with a design crest elevation of 2.0 ft (0.6 m) NAVD88, an average constructed elevation of +3.0 ft (+0.9 m) NAVD88, and a crest width of 4 ft (1.2 m) to 14 ft (4.3 m), along dead-end oilfield canals on the northern edge of Breton Canal (figure 2).
- Construction of one 263 linear ft (80 m) fixed crest weir from rock riprap with a 20 ft (6.1 m) barge bay from rock riprap with a crest elevation of 4.0 ft (1.2 m) NAVD88 and the invert of the barge bay set at -6.4 ft (-1.9 m) NAVD88 (figure 2; Structure 1).
- Construction of one 1,665 linear ft (507.5 m) fixed crest rock riprap weir with an 80 ft (24.4 m) barge bay, with a crest elevation of 4.0 ft (1.2 m) NAVD88 and the

invert of the boat bay at an elevation of -6.5 ft NAVD88 (-2.0 m) (figure 2; Structure 14A).

- Construction of one 511 linear ft (155.8 m) rock riprap channel plug with a crest elevation of 3.5 ft (1.1 m) NAVD88 (figure 2; Structure 4 A and B).
- Construction of one 213 linear ft (64.9 m) rock riprap channel plug with a crest elevation set at 4.0 ft (1.2 m) NAVD 88 (figure 2; Structure 90).
- Construction of one 80 linear ft (24.4 m) sheet pile variable crest weir with a 10 ft (3 m) wide variable crest section containing a 10 ft (3 m) wide stop log bay containing 12 stop logs. The stop logs can be adjusted from 1.0 ft to -3.0 ft (0.3 m to -0.9 m) NAVD88 using a movable crane with a hand winch. The fixed crest section of the structure was constructed with earthen wing walls to a crest elevation of 2.89 ft (0.88 m) NAVD88 on either side of the weir (figure 2; Structure 35).

II. Maintenance Activity

a. Project Feature Inspection Purpose and Procedures

The purpose of the annual field inspection of the GIWW (Gulf Intracoastal Waterway) to Clovelly Hydrologic Restoration (BA-02) project is to evaluate the constructed project features, identify any deficiencies, and prepare a report detailing the condition of such features, and to recommend corrective actions needed, if any. Should it be determined that corrective actions are required, the Louisiana Department of Natural Resources (LDNR) shall provide, in report form, a detailed cost estimate for engineering, design, supervision, inspection, construction, construction contingencies, and an assessment of the urgency of such repairs (LDNR and Pyburn and Odom, Inc. 2002). The Operation, Maintenance, and Monitoring report also contains a summary of maintenance projects undertaken since the constructed features were completed and an estimated project budget for the upcoming three (3) years for operation, maintenance and rehabilitation. The three (3) year projected budget is shown in Appendix A and a summary of past operation and maintenance projects is outlined in Section II.b of this report.

An inspection of the GIWW (Gulf Intracoastal Waterway) to Clovelly Hydrologic Restoration (BA-02) project was held on February 13, 2007, under cloudy skies and windy conditions. In attendance were Brian Babin, Shane Triche, and Elaine Lear with LDNR and Warren Blanchard and Bob Payton with the Natural Resources Conservation Service (NRCS). The inspection began at 10:30 a.m. following a field inspection of the Barataria Landbridge Project (BA-27) and ended at 1:30 p.m.

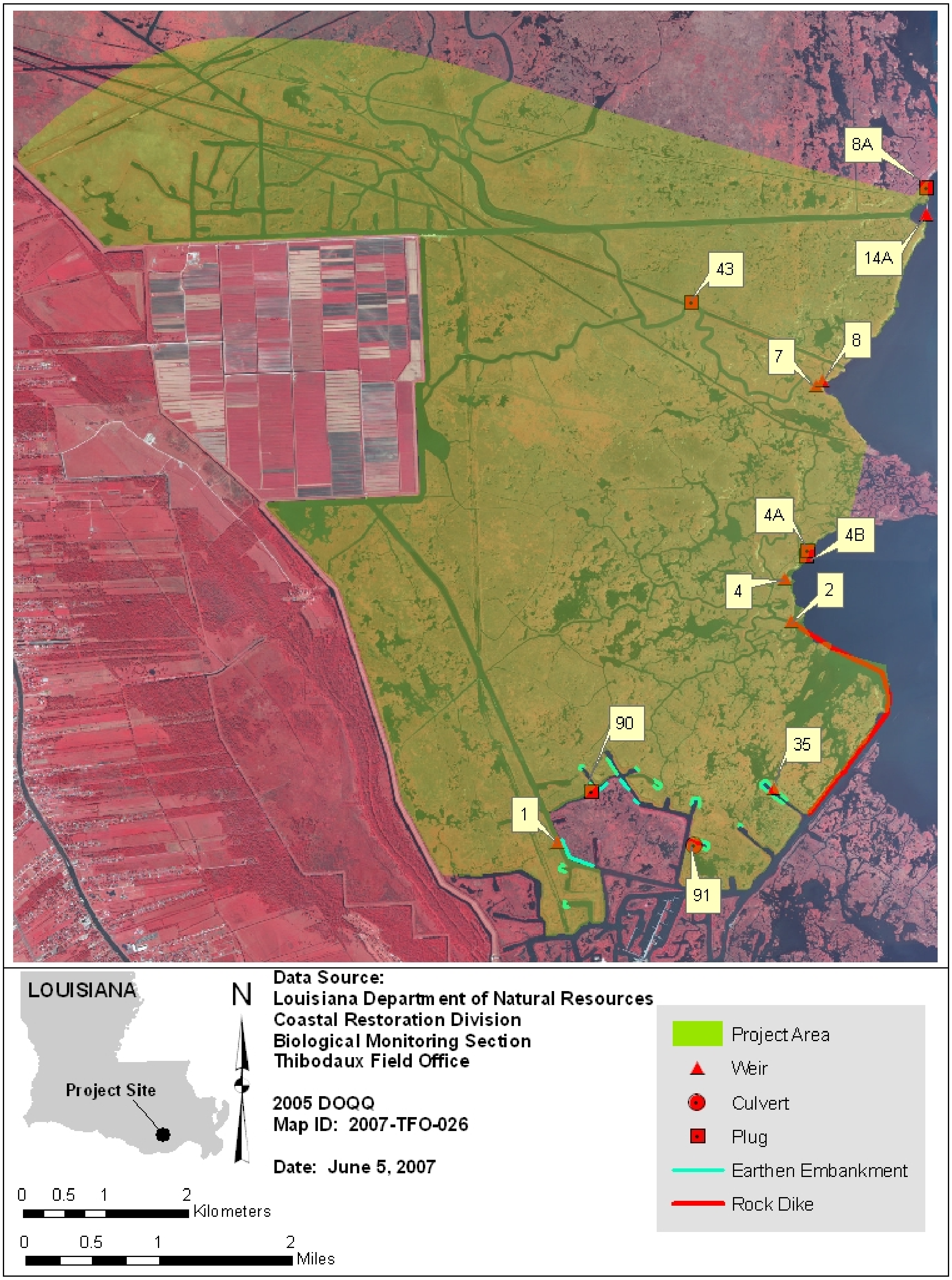

Figure 2. Project infrastructure map for the GIWW (Gulf Intracoastal Waterway) to Clovelly Hydrologic Restoration (BA-02) project.

b. Summary of Past Operation and Maintenance Projects

<u>2006 Structure Operations</u>

In accordance with the operation schedule outlined in the Operations and Maintenance Plan, Structure 35 has been operated during the months of April and November of each year since April 3, 2002. Structure 35 has not been operated since November 2005 due to the movement of marsh material behind the structure in the aftermath of Hurricanes Katrina and Rita. On February 9, 2007, acting as agent to Lafourche Parish, the LDNR Thibodaux Field Office (TFO) received a Programmatic General Permit to clean out the marsh debris behind Structure 35 to reopen the channel to the interior marsh. LDNR-TFO is currently working on plans and specifications to perform this work along with breach repairs at four (4) separate locations within the project area.
Navigational Aid Maintenance: Since the completion of the GIWW (Gulf Intracoastal Waterway) to Clovelly Hydrologic Restoration (BA-02) project, the navigational aids, adjacent to the barge bay at Structure 14A, have been serviced on several occasions. Below is a short description of repairs, dates, costs, and ongoing tasks associated with the maintenance of navigational aids:

5/16/02 Automatic Power of Larose, La., performed maintenance service to repair navigation lights at Structure 14A. Seventeen (17) bulbs were replaced at a total cost of $421.50.

12/16/03 Automatic Power performed maintenance on Structure 14A, replacing battery and bulbs in all four (4) navigation lights at a total cost of $2,189.80.

11/4/04 Automatic Power serviced navigation lights at Structure 14A, replacing one (1) lamp changer, one (1) battery and bulbs at a total cost of $922.23.

11/29/06 LDNR received bids for a State-wide Navigation Maintenance Contract for the inspection, diagnostic testing, and maintenance of twenty-seven (27) navigational aid systems at ten (10) different locations state-wide. The low bidder for this contract was Automatic Power, Inc., offering a bid in the amount of $83,424. This maintenance contract is a one (1) year contract with an option to extend for another two (2) years. The contact was awarded to Automatic Power and inspections began in February 2007.

12/11/06 Construction began to replace an existing timber pile cluster (dolphin) supporting the navigational aids and signage on the northeast side of the barge bay at Structure 14A. The timber dolphin was demolished by a large vessel accessing the barge bay opening. The timber pile cluster replacement project included the removal of the existing structure below the mud line and installing four (4) 60 ft (18.3 m) long, 2.5 CCA treated timber piles with navigation light and signage. The total replacement cost of this structure was $14,000. All engineering services including construction administration was provided by LDNR-TFO. Tidewater

Dock, Inc. of Galliano, La., was awarded the construction contract to replace the structure on 12/6/06 and completed the work on 12/20/06.

General Maintenance

Since the construction of the GIWW (Gulf Intracoastal Waterway) to Clovelly Hydrologic Restoration (BA-02) project was completed in 1999, no general maintenance needs or serious deficiencies were identified that required a maintenance event until Hurricanes Katrina and Rita. A post storm inspection of the project features revealed an obstruction of a channel located behind Structure 35 and several breaches in the earthen embankments on the southern end of the project area. LDNR-TFO is currently preparing plans and specifications to address the channel obstruction and breaches. The estimated cost for this maintenance event is approximately $110,000.

c. Inspection Results

CONSTRUCTION UNIT NO. 1

Structure No. 1 – Fixed crest rock weir with barge bay

The rock weir structure with barge bay at Structure No.1 appeared to be in good condition with no noticeable settlement along the length of the structure. The signs, supports, and earthen embankment tie-ins were also in good condition. As noted on previous inspections, we observed that several of the timber pile clusters on each side of the barge bay supporting the navigation aids and signage were slightly damaged and scarred from large vessels rubbing the timbers while accessing the barge bay. Although there is visible damage to the timber pile supports, LDNR and NRCS do not believe that the structural integrity of the pile supports are compromised by the damage present. The inspection team will continue to monitor the condition of the timber dolphin system. (Appendix B, Photos 1–3)

Structure No. 2 – Rock weir

The rock weir at this location appeared to be in fair condition with moderate settlement on the north side of the structure. The south side of the weir was in good condition with no noticeable change from previous inspections. Signs and supports were also in good condition with no obvious damage. The inspection team will continue to monitor the condition of the north side of the weir. (Appendix B, Photos 4–7)

Structure No. 4 – Fixed crest rock weir with boat bay

As documented on previous inspections, the north side of the rock weir had experienced severe settlement, below the elevation of the waterline estimated at 0.0 ft (0.0 m) NAVD88 at the time of the 2007 inspection. The warning sign installed in the center of the rock dike on the north side was missing. The south side of the rock weir appeared to be in good condition with no apparent change from the previous year's inspection. (Appendix B, Photos 8 and 9)

Structure No. 7– Fixed crest rock weir with boat bay

As reported on previous inspections, the south side of the structure had settled some since the rock weir was completed in 1997. It appears that settling has stabilized over the past few years with no noticeable change from the previous inspections. The signs and supports remain intact and are in good condition. (Appendix B, Photo 10)

Structure No. 8– Rock riprap weir

The small rock weir and earthen embankment tie-ins located adjacent to Structure No. 7 behind an existing camp was in good condition with no signs of damage or settlement. The gate crossing the boat bay and signage were also in good condition. (Appendix B, Photo 11)

Structure No. 43 – Rock riprap channel plug

On previous inspection cycles, it has been documented that a 10 ft (3 m) wide section of the rock plug was breached on the east side of the structure, allowing water exchange from the canal to the interior marsh during high water events. It appears that this section of the rock plug has stabilized and no exchange of water was noticed during the 2007 inspection. Due to the low elevation of the earthen banks along the channel adjacent to the structure, there would possibly be little benefit in repairing the structure since the marsh would flood on high water events, bypassing the rock plug. (Appendix B, Photo 12)

Structure No. 91 – Rock plug with culvert and flap gate

The rock plug at this location appeared to be in very good condition with no settlement or displacement of ri rap. The signs and supports along the structure were also in good condition. An inspection of the corrugated culvert and flap gated structure through the plug revealed moderate corrosion and excessive barnacle growth in and around the gate. The presence of barnacle growth in and around the gate does not appear to be affecting the gate operations. (Appendix B, Photos 13 and 14)

CONSTRUCTION UNIT NO. 2

Structure No. 4 A and B – Rock riprap channel plug

The channel plug along the west bank of Little Lake appeared to be in good condition with no visible damage or structure settlement. The marsh on both sides of the structure appeared to be thin with very little stable marsh remaining near the marsh tie-ins. From 2005 post storm assessments, this area experienced high erosion rates during Hurricanes Katrina and Rita, exposing the structure to potential breaching at both ends. The inspection team will continue to monitor the erosion and marsh conditions in this area. (Appendix B, Photo 15)

Structure No. 14A – Fixed crest rock weir with barge bay

The rock weir with barge bay along Clovelly Canal was in good condition with no visible settlement or damage. However, a small section of the rock weir near the south end of the barge bay was displaced during the 2005 hurricane season, leaving a gap at the opening of the barge bay. The inspection team agreed that the damage is minor and will not affect the integrity of the structure or alter the overall performance of the project. As noted in previous reports, the elevation of the marsh tie-ins on the south side of the structure is very low and has eroded further during Hurricanes Katrina and Rita, leaving a low-lying bank opened to the marsh behind the structure.

We did note that one (1) of the timber pile clusters on the northwest side of the structure was struck by a vessel accessing the barge bay, leaving a longitudinal crack in the timber piling. The inspection team is confident that the damage to the timber piling will not affect the integrity of the timber dolphin and do not believe that maintenance or replacement of the piling is necessary at this time. The inspections, diagnostic testing, and maintenance repairs of the four (4) navigational aids at this location have been contracted to Automatic Power, Inc. of Larose. The maintenance contract period began in January 2007 and will continue through January 2010. (Appendix B, Photos 16 and 17)

<u>Structure No. 35 – Variable crest weir, water control structure</u>

The variable crest weir structure was in good condition with minor paint chipping along the channel cap and hand railing on the bulkhead and walkway. The lifting boom was operational and signage in good condition. The stop logs have not been adjusted since 2005 due to large sections of marsh blocking the conveyance channel to the interior marsh as a result of Hurricane Katrina. LDNR-TFO has prepared plans and specifications to clean out marsh material blocking the channel beginning at Structure No. 35 and repair three (3) breaches in the spoil bank along existing oilfield location canals between Structures No. 35 and No. 91 near the southern boundary of the project area. Construction should begin sometime in late summer. Normal operations will continue once the marsh plug is removed and hydrologic connections are re-established. (Appendix B, Photos 18 and 19)

<u>Structure No. 90 – Rock riprap channel plug</u>

The rock plug at this location is in very good condition, with no settlement or displacement of riprap. The signs and timber supports are also in good condition. No maintenance required at this time. (Appendix B, Photos 20–22)

<u>Lake Rim Restoration</u>

As noted on previous inspections, we observed several areas along the rock dike of the lake rim that have settled below the design elevation. Areas with moderate settlement are Sta. 7+00 to Sta. 13+00 at approximately 1.5 ft (0.5 m) NAVD88, and 36+00 to 41+00 from 1.0 ft to 1.5 ft (0.3 m to 0.5 m) NAVD88. The original armored rock dike was constructed to an elevation of +2.0 ft (+0.6 m) NAVD88. Due to the settlement of the lake rim and rock weirs observed over the past several years, we are recommending a profile survey to evaluate the extent of settlement prior to the 2008 annual inspection. Once this data is collected, an informed decision can be made regarding maintenance needs of all rock features within the GIWW to Clovelly Hydrologic Restoration (BA-02) project. (Appendix B, Photos 23 and 24)

<u>Earthen Bank Stabilization</u>

Overall, the earthen embankment constructed along several oilfield canals near the southern boundary of the project appeared to be in good condition, with the exception of four (4) breaches identified during the post storm inspections completed in late 2005. The four (4) breaches are located in the southern portion of the project area and range between 10 ft (3.0 m) and 30 ft (9.1 m) wide. The LDNR-TFO is currently finalizing plans and specifications and acquiring necessary permits to repair these breaches and clean out marsh debris behind Structure No. 35. (Appendix B, Photos 25–28)

d. Maintenance Recommendations/Navigation Aids Maintenance:

i. Immediate/Emergency

Immediate maintenance recommendations resulting from the 2007 inspections include repairing four (4) breaches in southern project area resulting from Hurricanes Katrina and Rita and cleaning out marsh material behind Structure No. 35 to open the conveyance channel to the interior marsh. These repairs are included in a maintenance project initiated by LDNR and should be completed by December 2007.

ii. Programmatic/Routine

Programmatic/ routine repairs include inspections, diagnostic testing, and repair of four (4) navigational aids located at Structure No. 14A. LDNR awarded a maintenance contract to Automatic Power, Inc. of Larose, La., to inspect and repair navigational aids statewide. Inspections began in February 2007.

III. Operation Activity

a. Operation Plan

The water management plan for the GIWW (Gulf Intracoastal Waterway) to Clovelly Hydrologic Restoration (BA-02) project required the active operations of a single variable crest weir structure located northwest of Breton Canal near the southern boundary of the project area (Structure No. 35). Normal operations include manipulating the stop logs twice a year in accordance with the following operation schedule:

The stop logs are set at 0.5 ft (0.1 m) BML (Below Marsh Level) from April to November and removed from November to April (weir sill level = 2.0 ft [0.6 m] BML) to allow for sediment and nutrient inflow during the spring.

b. Actual Operations

Scheduled structure operations in September 2005 were canceled due to damage caused by Hurricanes Katrina and Rita. A maintenance project has been initiated by LDNR to remove large sheets of marsh blocking the conveyance channel behind Structure No. 35, prohibiting flow through the weir. Normal structure operations will resume upon completion of the maintenance project in December 2007.

IV. Monitoring Activity

a. Monitoring Goals

Specific objectives of the GIWW (Gulf Intracoastal Waterway) to Clovelly Hydrologic Restoration (BA-02) project are (1) to protect and maintain approximately 14,948 acres (6,049 hectares) of intermediate marsh by restoring natural hydrologic conditions that promote greater freshwater retention and utilization, prevent rapid salinity increases, and reduce the rate of tidal exchange; and (2) to reduce shoreline erosion through shoreline stabilization (Lear 2003).

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

1. Increase or maintain marsh to open water ratios.
2. Decrease salinity variability in the project area.
3. Decrease the water level variability in the project area.
4. Increase or maintain the relative abundance of intermediate marsh plants.
5. Promote greater freshwater retention and utilization in the project area.
6. Reduce shoreline erosion through shoreline stabilization.
7. Increase or maintain the relative abundance of submerged aquatic vegetation (SAV).

b. Monitoring Elements

<u>Habitat Mapping</u>

To document vegetated and non-vegetated areas and marsh loss rates, color-infrared aerial photography (1:24,000 scale with ground control markers) was obtained by the National Wetlands Research Center/United States Geological Survey (NWRC/USGS) for the project area. For each flight, the photography was geo-rectified, photo-interpreted, mapped, ground-truthed, and analyzed with GIS by NWRC personnel using techniques described in Steyer et al. (1995, revised 2000). Photography was obtained prior to construction in November 1993 and in December 1996, and after construction in December 2002.

Based on the CRMS-Wetlands (Coastwide Reference Monitoring System) review, land-water analysis instead of habitat mapping will be performed on photography collected in 2008 and 2015. A revision of the habitat analysis data was completed in March 2005 upon the request of LDNR personnel. NWRC personnel reviewed the most recent vegetation, water level, and salinity data to assess the photography for revisions.

Water Level

To monitor water level variability, seven (7) continuous recorder stations were located within the project area; however, two (2) stations (BA02-58 and BA02-59) were discontinued due to severe scouring around the instruments. Discrete water levels were measured monthly at five (5) stations inside the project area using techniques described in Steyer et al. (1995, revised 2000). Staff gauges located adjacent to the continuous recorders were surveyed to the North American Vertical Datum of 1988 (NAVD88) in order to tie recorder water levels to the Louisiana Coastal Zone GPS network. Marsh elevation was surveyed and used in conjunction with continuous recorders to determine duration and frequency of flooding.

Based on the CRMS-Wetlands review, discrete water level readings were discontinued in January 2004, and continuous water level readings from stations BA02-53, BA02-54, and BA02-55 were discontinued in March 2004.

Salinity

To monitor salinity variability, seven (7) continuous recorder stations were located within the project area; however, two (2) stations (station BA02-58 and BA02-59) were discontinued due to severe scouring around the instruments. Discrete salinity was measured monthly at 25 stations inside the project area using techniques described in Steyer et al. (1995, revised 2000).

Based on the CRMS-Wetlands review, discrete salinity readings were discontinued at the project stations in January 2004, and continuous salinity readings from stations BA02-53, BA02-54, and BA02-55 were discontinued in March 2004.

Vegetation

Species composition and relative abundance were evaluated inside the project area using a modification of the Braun-Blanquet method (Mueller-Dombois and Ellenberg 1974). Twenty-five (25) plots were established and sampled in the project area during the 1996 sampling event. Eight (8) of these plots in the northern portion of the project area were dropped from monitoring in late spring 1997 due to land rights issues. Vegetation species composition and relative abundance were evaluated once prior to construction in 1996, once in 1999 after Construction Unit No. 1 was completed, and three times after Construction Unit No. 2 was completed in 2000, 2002, and 2005. Additional data collection will commence at years 2008, 2012, and 2016.

Soil Samples

To evaluate effects of freshwater retention and saltwater intrusion, soil samples were taken to determine percent organic matter, bulk density, and soil porewater salinity using techniques described in Steyer et al. (1995, revised 2000). Twenty-five (25) plots were established and sampled in the project area during the 1996 sampling event. Eight (8) of these plots in the northern portion of the project were dropped from monitoring in late spring 1997 due to land rights issues. Soil samples from the remaining seventeen (17) project area plots were evaluated once prior to construction in 1996, once in 1999 after Construction Unit No. 1 was completed, and three times after Construction Unit No. 2 was completed in 2000, 2002, and 2005. Additional data collection will commence at years 2008, 2012, and 2016.

Shoreline Change

To evaluate marsh edge movement along the shoreline protection structures placed in Bay L'Ours and along the oil and gas access canal at the southern border of the project area, controlled sub-meter accurate Differential Global Positioning System (DGPS) equipment was used by LDNR personnel to document marsh edge position using techniques described in Steyer et al. (1995, revised 2000). This equipment was used to acquire the coordinates for each shoreline point within 21 randomly selected 300 ft (91.4 m) shoreline segments. DGPS measurements were taken pre-construction in 1993 and 1998, and in 2000, and 2003 post-construction. In 2005 another survey was conducted by Shaw Coastal, Inc., also using sub-meter accurate equipment described in the preliminary monitoring results and discussions section of this report for shoreline change. Measurements will also be taken in 2008, 2012, and 2016.

Submerged Aquatic Vegetation (SAV)

The frequency of occurrence of SAV was analyzed for the project area. Ten (10) ponds inside the project area and five (5) ponds inside the reference area were sampled once in the fall of 1996 (November) pre-construction. Three (3) ponds in the northern portion of the project area as well as the five ponds in the reference area were dropped from monitoring in the late spring 1997 due to land rights issues. Data collection on the remaining seven (7) ponds occurred four times after Construction Unit No. 1 was completed; during spring 1999, fall 1999, spring 2000, and during fall 2000. Post-construction data collection occurred during fall 2002 and fall 2005. Based upon the CRMS-Wetlands review, all future SAV data collection has been discontinued.

c. CRMS-Wetlands

In 2003, the Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA) Task Force adopted the Coastwide Reference Monitoring System (CRMS)-Wetlands program to evaluate the effectiveness of each constructed restoration project. CRMS-Wetlands provides a network or "pool" of reference sites that can be used to not only evaluate the effectiveness of individual projects but also hydrologic basins and entire coastal ecosystems. Each 1 km^2 CRMS-Wetlands site is monitored consistently according to a "Standard Operating Procedures" document with the following parameters collected at each site: hourly hydrographic (includes salinity, water level, and water temperature), monthly soil porewater salinity, semi-annual surface elevation and sediment accretion, annual emergent vegetation, land:water ratio estimated from aerial photography taken every three to four years, and soil properties collected once at each CRMS site.

CRMS-Wetlands is currently in the implementation stage (i.e., securing land rights, site characterizations, and site construction) and not all sites are fully operational. However, data collection has begun at over half of the sites and data will be used to help support project-specific monitoring as soon as it becomes available. The GIWW (Gulf Intracoastal Waterway) to Clovelly Hydrologic Restoration (BA-02) project has one CRMS-Wetlands monitoring site within its project boundary, CRMS0190, and a few sites surrounding the project (figure 3). Data collected from these CRMS-Wetlands sites along with future project-specific data collection efforts will provide a broader evaluation of project effectiveness.

d. Preliminary Monitoring Results and Discussion

Habitat Mapping

USGS/NWRC personnel completed scanning, georectification, and the production of habitat analysis maps for the aerial photography obtained prior to construction in November 1993 (figure 4) and in December 1996 (figure 5), and post-construction in December 2002 (figure 6). Photography was scanned in at 300 dots per inch on a sharp JX-610 scanner using WscanNT® software and stored as .TIFF images. ERDAS Imagine®, an image processing and geographic information systems (GIS) software package, was used to georectify individual frames of photography. The scanned images were assembled into a photomosaic and overlaid onto a georeferenced image (such as SPOT imagery and DOQQ imagery) of the same area to rectify it. Photointerpretation of the project and reference areas was completed, habitat classifications were hand digitized and their acreages calculated, and draft hard copies of the maps were produced and sent to the Louisiana Department of Natural Resources, Coastal Restoration Division, Thibodaux Field Office (LDNR/CRD/TFO) for review. Comments were sent back to NWRC and edits were made to the preliminary drafts. Final maps were sent to LDNR/CRD/TFO in 2003.

In 2004 upon the request of LDNR personnel, NWRC re-examined the photography from all three flights as well as the most recent vegetation and salinity data available. Revisions were made to the habitat classification data as a result of this review and updated maps were completed in March 2005. Revised data is presented in this report.

Using the 1993 and 1996 habitat analysis maps with tables (figures 4 and 5), the land acreage in the project area (figure 7) increased by 7 acres (2.8 hectares) (<1%). A more thorough examination reveals that it actually experienced a loss of 71 acres (28.7 hectares) and 78 acres (31.6 hectares) of marsh and wetland shrub/scrub, respectively, while there was a gain of 163 acres (66.0 hectares) in wetland forest community. The marsh community shifted towards a more freshwater community with a 752 acre (304 hectare) decrease in intermediate marsh and an increase of 681 acres (276 hectares) of fresh marsh. The reference area experienced a total loss of 46 acres (18.6 hectares) of land (1.2%) with a loss of 65 acres (26.3 hectares) from the marsh community but a gain of 24 acres (9.7 hectares) from the wetland scrub/shrub (4 acres [1.6 hectares]) and the wetland forest (20 acres [8.1 hectares]) community. The marsh community exhibited the same trend towards a more freshwater community with the intermediate marsh community decreasing by 77 acres (31.1 hectares) and fresh marsh increasing by 12 acres (4.9 hectares).

Using the 1996 and 2002 habitat analysis maps with tables (figures 5 and 6), the land acreage in the project area (figure 7) increased by 21 acres (8.5 hectares) (<1%). More specifically, the area gained 40 acres (16.2 hectares) of marsh and 23 acres (9.3 hectares) of wetland forest, but lost 34 acres (13.8 hectares) of wetland scrub/shrub. The marsh community shifted towards a more intermediate marsh with a 498 acre (210.5 hectare) increase and a decrease of 458 acres (185,3 hectares) in the fresh marsh community. The reference area experienced a total loss of 7 acres (2.8 hectares) of land (<1%). There was a loss of 17 acres (6.9 hectares) of marsh, a 5 acre (2.0 hectare) gain of wetland scrub/shrub, and a 4 acre (1.6 hectare) gain of wetland forest. The

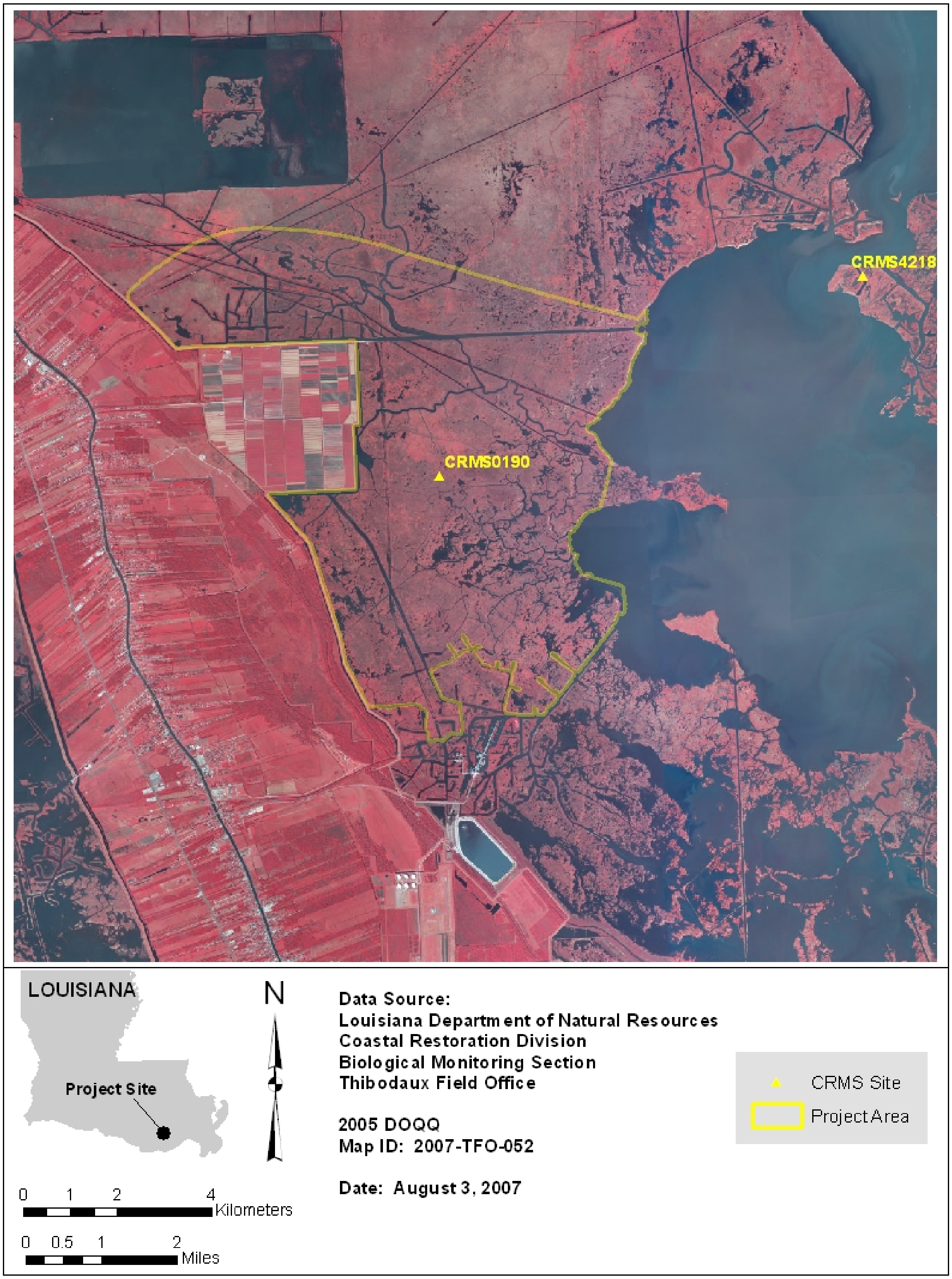

Figure 3. CRMS-Wetlands sites within and in the vicinity of the GIWW (Gulf Intracoastal Waterway) to Clovelly Hydrologic Restoration (BA-02) project.

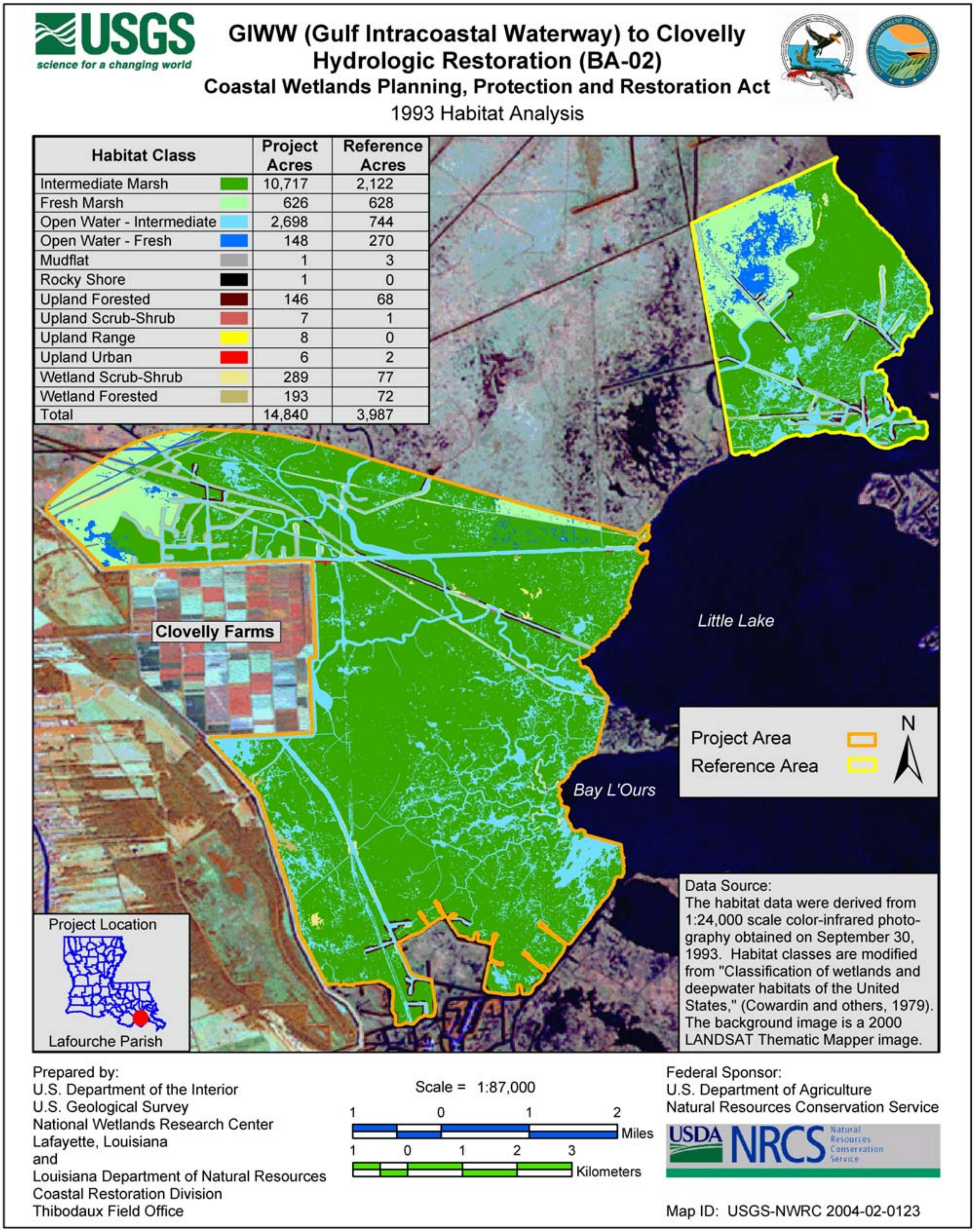

Figure 4. 1993 habitat analysis map for the GIWW (Gulf Intracoastal Waterway) to Clovelly Hydrologic Restoration (BA-02) project.

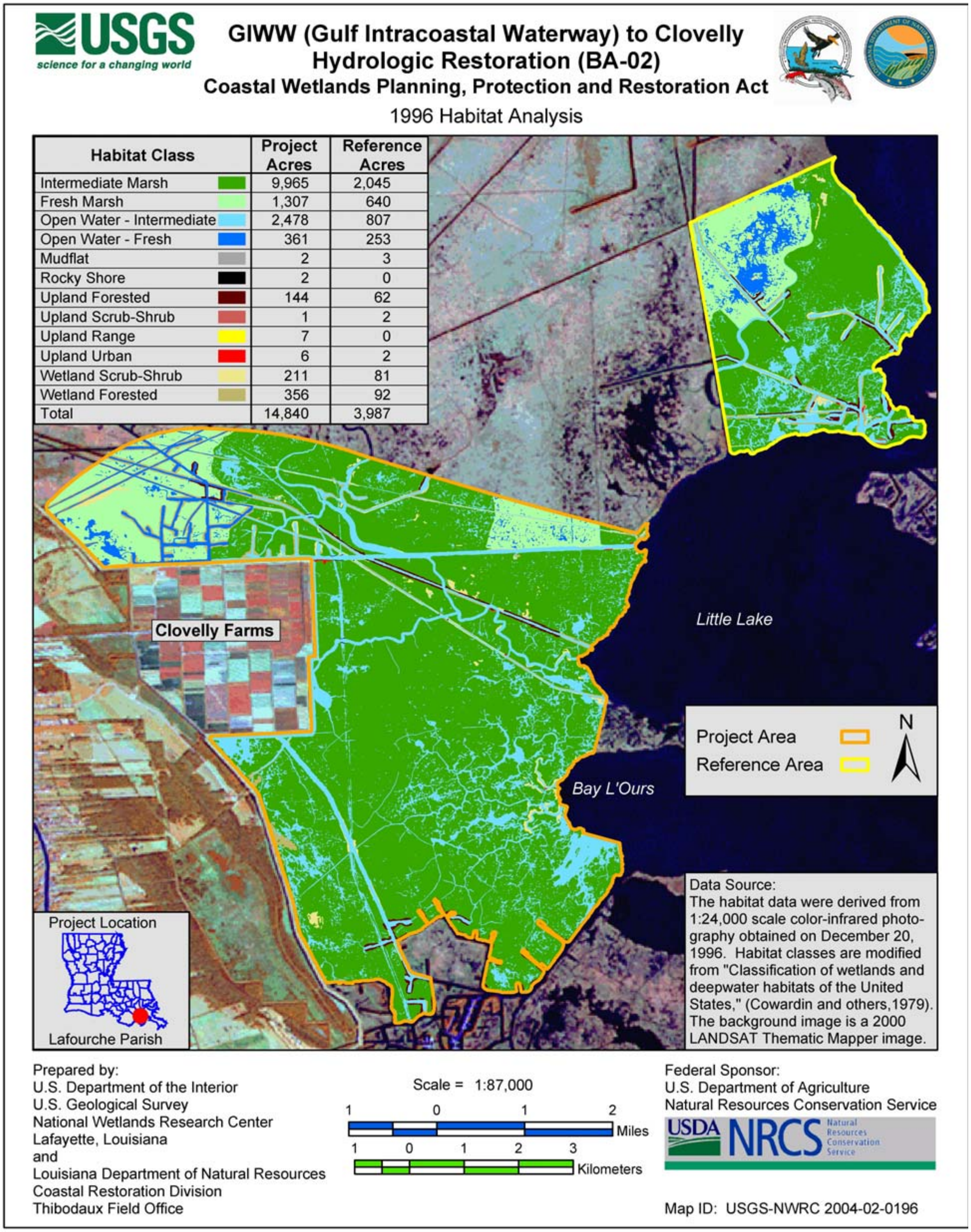

Figure 5. 1996 habitat analysis of the GIWW (Gulf Intracoastal Waterway) to Clovelly Hydrologic Restoration (BA-02) project.

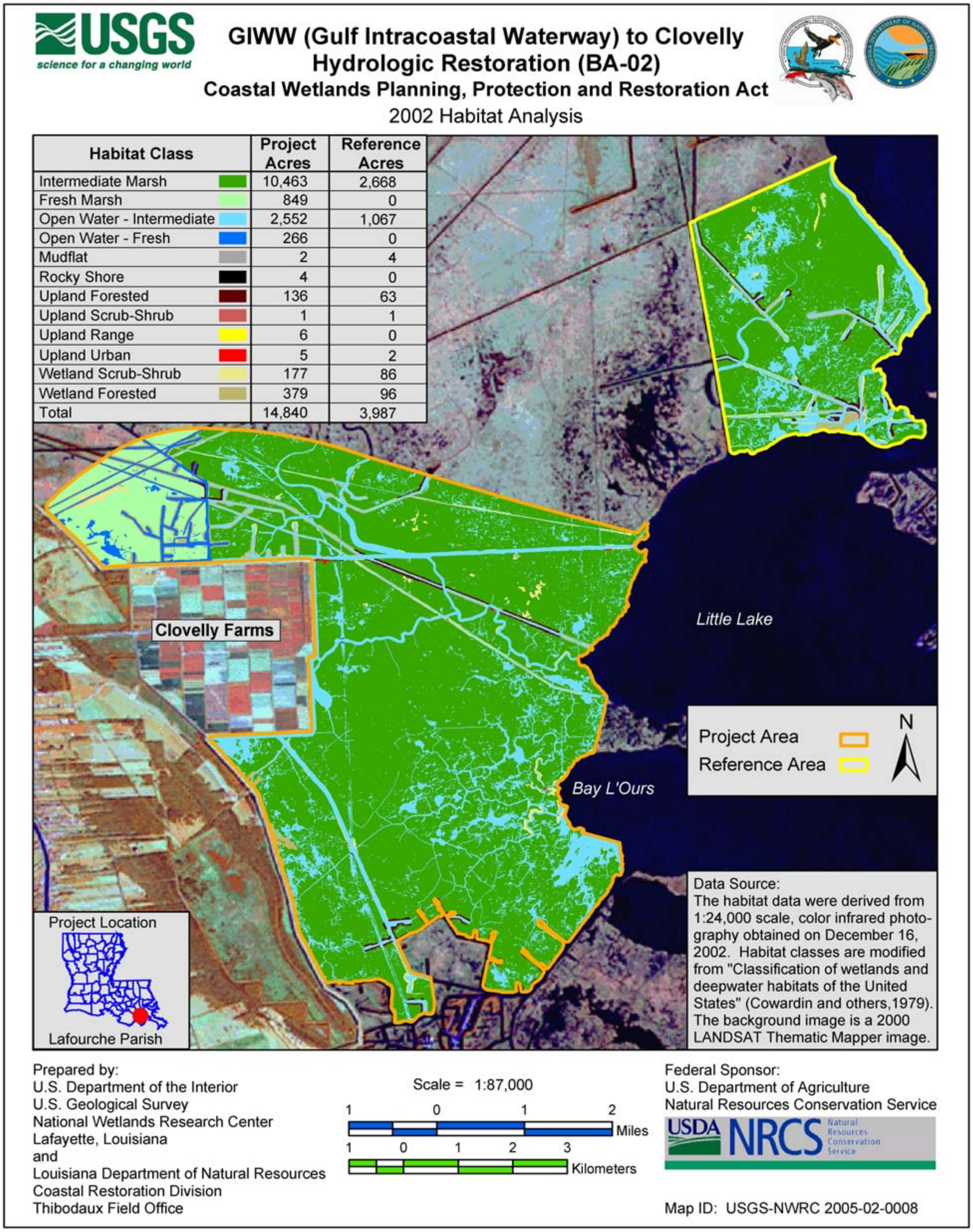

Figure 6. 2002 habitat analysis for the GIWW (Gulf Intracoastal Waterway) to Clovelly Hydrologic Restoration (BA-02) project.

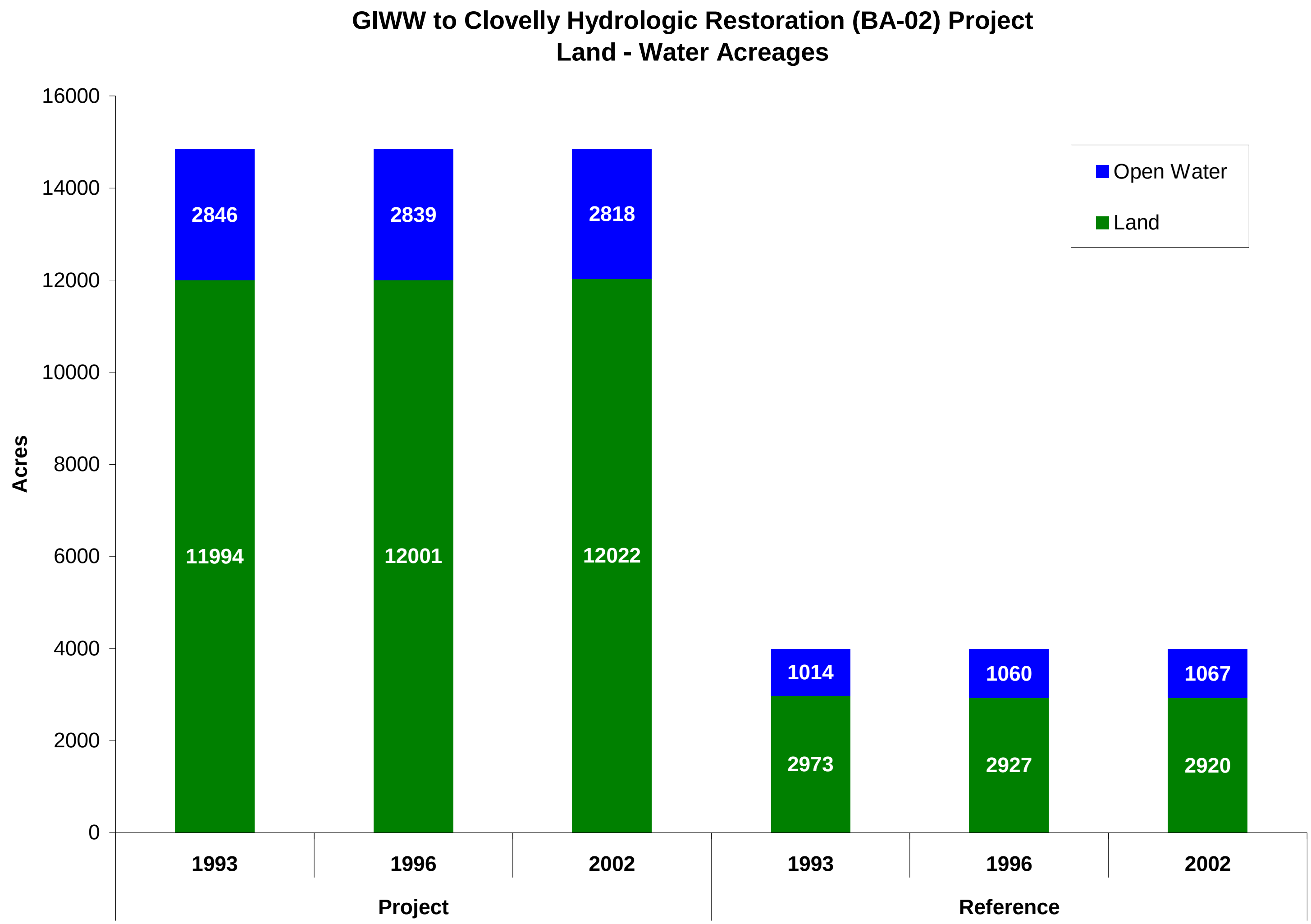

Figure 7. 1993, 1996, and 2002 Land to water acreages by project and reference area for the GIWW (Gulf Intracoastal Waterway) **to Clovelly Hydrologic Restoration (BA-02) project.**

marsh community exhibited the same trend towards an intermediate marsh with an increase of 623 acres (252 hectares) in intermediate marsh community and a loss of 640 acres (259 hectares) of fresh marsh. The 640 acre loss of fresh marsh represents an entire loss of the fresh marsh community in the reference area.

From the land–water analysis (figure 7), the project area increased by 21 acres (8.5 hectares) while the reference area lost 7 acres (2.8 hectares) between 1996 and 2002. During this period, both construction units of the project were completed and one of the worst droughts (August 1999–May 2001) was recorded in southeastern Louisiana. Despite the 22-month drought, the project area maintained a fresh marsh community while the reference area lost the fresh marsh community.

Water Level

Since project construction was completed in two construction units and only a portion of the structures were in place when the monitoring equipment was installed or in use, continuous water level data and discrete water quality data were broken into periods of partial and post-construction. One of the continuous recorder stations (station BA02-59) was gone, presumed to be scoured out, during pre-construction; therefore, there are no comparative post-construction data available for this station. Also, due to the CRMS-Wetlands review, stations BA02-53, BA02-54, and BA02-55 were discontinued in 2004. Finally, reference areas selected to the north and northeast of the project boundary were eliminated due to land rights issues during late spring 1997, leaving only the USGS Little Lake Data Collection Platform (DCP) station to the east of the project for reference data collection. Continuous recorder stations where hourly water level data have been collected are (table 1; figure 8):

Table 1. Continuous recorder stations and their data collection durations for the GIWW (Gulf Intracoastal Waterway) to Clovelly Hydrologic Restoration (BA-02) project.

Station	Data Collection Period
BA02-53	07/01/1997 - 03/23/2004
BA02-54	07/02/1997 - 03/23/2004
BA02-55	06/24/1997 - 03/23/2004
BA02-56	06/24/1997 - 10/25/2006
BA02-57	07/01/1997 - 10/25/2006
BA02-58	07/01/1997 - 07/24/2002
BA02-59	07/01/1997 - 10/12/1998

*Continuous recorder stations BA02-58 and BA02-59 were lost due to scouring of the channel bottoms where the stations were located.

Changes in water level values are measured on a continuous basis (defined as hourly, unless otherwise stated by the LDNR/CRD) where water depths remain deep enough to continually submerge the sensors. These variables are measured using a pressure transducer and a salinity meter (Steyer et al. 1995, revised 2000). The LDNR/CRD utilizes the YSI 6920, YSI 600XLM, or equivalent continuous recorder with a vented cable as the basic model that can measure water level via a pressure transducer, as well as salinity, specific conductance, and water temperature. Likewise, a YSI 30 or equivalent can measure salinity, specific conductance, and water

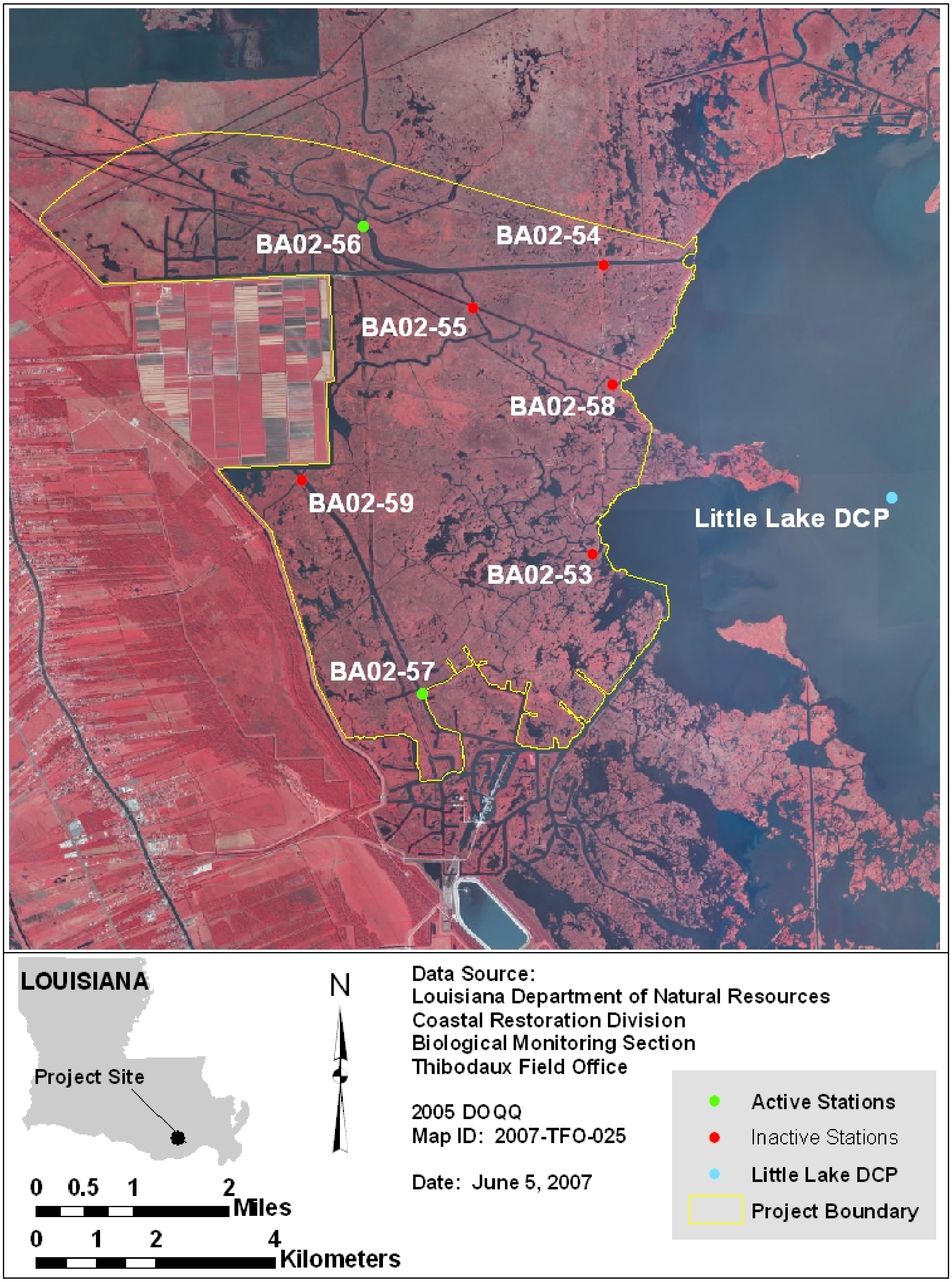

Figure 8. The GIWW (Gulf Intracoastal Waterway) to Clovelly Hydrologic Restoration (BA-02) project continuous recorder station locations.

temperature at discrete locations and to assure the data logger is properly calibrated (Folse and West 2005).

For this project, the actual continuous recorder stations consist of a water level support pole for deployment of the continuous recorder, and a separate support pole for a staff gauge within a few feet of the continuous recorder. Each station was located in a canal or natural bayou adjacent to the marsh edge where boat access was possible. At each station a continuous recorder was mounted onto a 16 ft (4.9 m) long 4 in x 4 in (0.1 m x 0.1 m) treated wooden post which was driven into the water bottom to resistance. An elevation point was established on the data recorder post by a professional surveyor to the vertical datum, North American Vertical Datum of 1988, U.S. Survey Feet (NAVD88, Feet). The measured distance from the elevation point to the constant recorder's depth sensor, establishes the sensor's elevation to datum (NAVD88, Feet). The staff gauge was mounted onto a separate 21 ft (6.4 m) long, 2 in (0.05 m) diameter galvanized iron pipe which was driven into the water bottom to resistance. Approximately 3.5'± of the pipe was left protruding above the water. The protruding end had a 2 in (0.05 m) pipe cap fastened to it with a benchmark located at the center of the cap established to NAVD88 Feet. Water level readings between the data recorder and the permanent staff gauge were compared to verify that the data recorder was recording the correct water level.

A differential global positioning system (DGPS) unit was utilized to collect the horizontal position of each continuous recorder setup as well as each staff gauge setup. The unit was also used to collect the station coordinate using the Universal Transverse Mercator (UTM), North American Datum of 1983 (NAD83), Meters coordinate system.

Data Analysis Methods for Water Level:
Full continuous monitoring started only after seven of the water control structures had already been built. There is therefore no empirical basis on which to assess the impact of the entire project. In order to assess impact of only the second phase of the construction, the analysis divides the time line into a partial construction period (December 1, 1997 – October 31, 2000) and a post-construction period (November 1, 2000 – December 31, 2006).

Reference areas selected to the north and northeast of the project boundary were dropped from the study when LDNR lost access to the property, leaving only the Little Lake DCP station as a source of reference data. Ideally, a reference area should resemble these original ones: a marsh location not affected by the project but subject to every other hydrological influence. The Little Lake DCP station does not meet these criteria perfectly. Little Lake is subject to the same hydrological influences – it *constitutes* a major influence – but it is not an interior marsh location. This does not prohibit comparisons with the project stations, but places some constraints (see "Constancy of Differences" in Stewart-Oaten and Murdoch 1986).

Water levels tended to vary similarly among all stations and with the Little Lake DCP. Although the Little Lake DCP water levels are reported in reference to a different vertical datum, the analysis uses changes in the differences between project stations and the Little Lake DCP. An absolute reference is not needed for these comparisons, only a consistent one. This consistency was lost in 2005 when the Little Lake DCP was damaged by a hurricane.

Results were analyzed over two intervals, with both intervals containing the same partial construction period. One set of analyses included all stations for the interval beginning December 1997 and ending in March 2004 when three of the five project stations (BA02-53, BA02-54, BA02-55) stopped recording. These tests are referred to here as the 2004 analysis.

The second set of analyses, referred to here as the 2005 analysis, used data from the two project stations (BA02-56 and BA02-57) that continued recording through October 25, 2006. This analysis reports water levels up to the last quarter of 2006 (October 2006), but the statistical tests use only data up to the third quarter of 2005 (August 2005), when the elevation of the Little Lake DCP station shifted abruptly during a hurricane.

Both sets of analyses compared water levels during the partial construction period to water levels during the post-construction period using the Little Lake DCP station as a reference. The statistical models follow a 2X2 and a 2X5 factorial analysis of variance (ANOVA) in which an interaction between the main effects (*period* and *location*) is tested for statistical significance. These are applications of the BACI paired series designs discussed in Stewart-Oaten and Murdoch (1986), Underwood (1994), and Smith (2002).

The statistical model depends on simultaneity of measurements among the various stations. For this reason, hourly water level measurements were aggregated into weekly means, one week being enough time to average out temporal lags among the stations during tidal and meteorological events. Another advantage to using weekly means is that they exhibit less serial correlation than hourly means; an important underlying assumption of the statistical model is sample independence.

The analysis was run using Proc GLM in SAS© Version 9.1. Distributional assumptions necessary to the statistical models were validated using exploratory data analysis and by performing the same hypothesis tests using *randomization testing*, a very robust, but computer-intensive resampling technique. Reference distributions generated from 10,000 trials yielded nearly identical p-values to those of the parametric tests.

<u>2004 Analysis:</u>
Figures 9 and 10 show water level as a time series of quarterly means from 1997 to 2004. Stations BA02-56 and BA02-57, the ones used for the 2005 analysis, are not shown in figure 9, although they were used in the 2004 analysis. Figures 11 and 12 show water level as period means (partial/post) and as period means for differences with the reference station.

Hourly measurements were aggregated into weekly means on which the statistics are based. No transformations were needed to meet the distributional assumptions of the statistical tests. The analysis compared water level during the partial construction period to water level during the post-construction period using the Little Lake DCP station as a reference. The statistical model

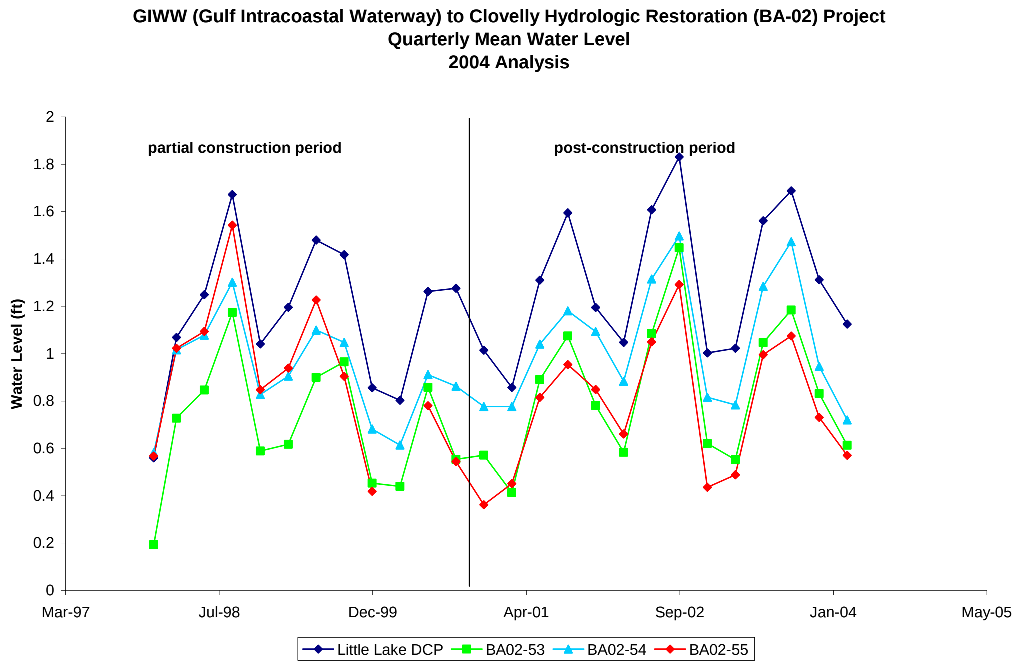

Figure 9. Partial and post-construction water levels as quarterly means. Stations BA02-56 and BA02-57 are included in the analysis but are not shown.

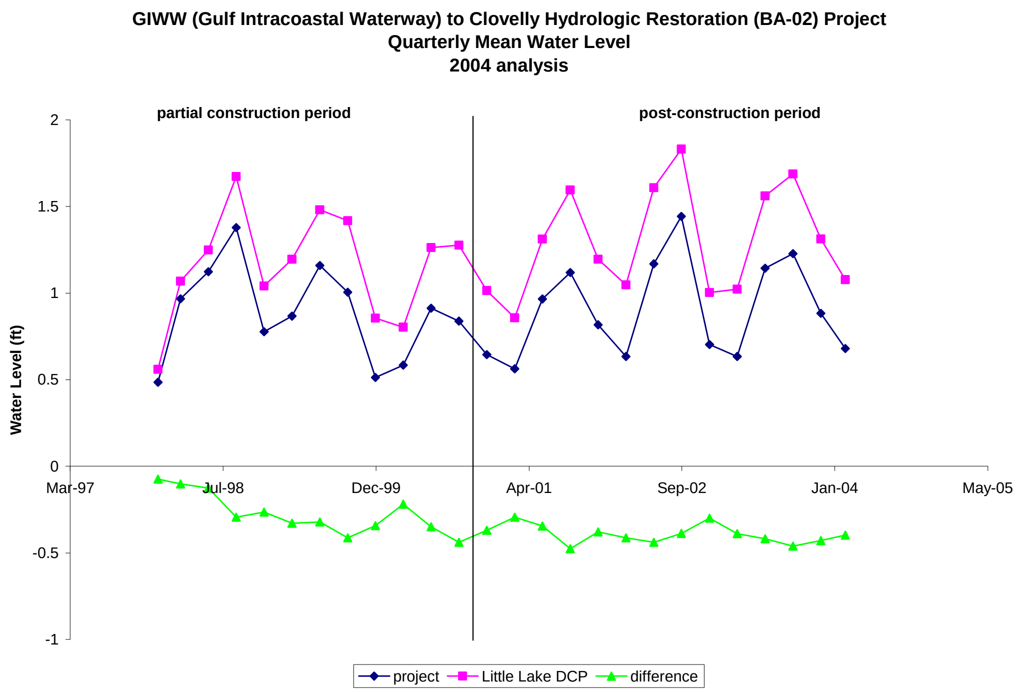

Figure 10. Partial and post-construction project and reference (Little Lake DCP) water levels as quarterly means. The trace labeled "project" is the average of stations BA02-53, BA02-54, BA02-55, BA02-56, and BA02-57.

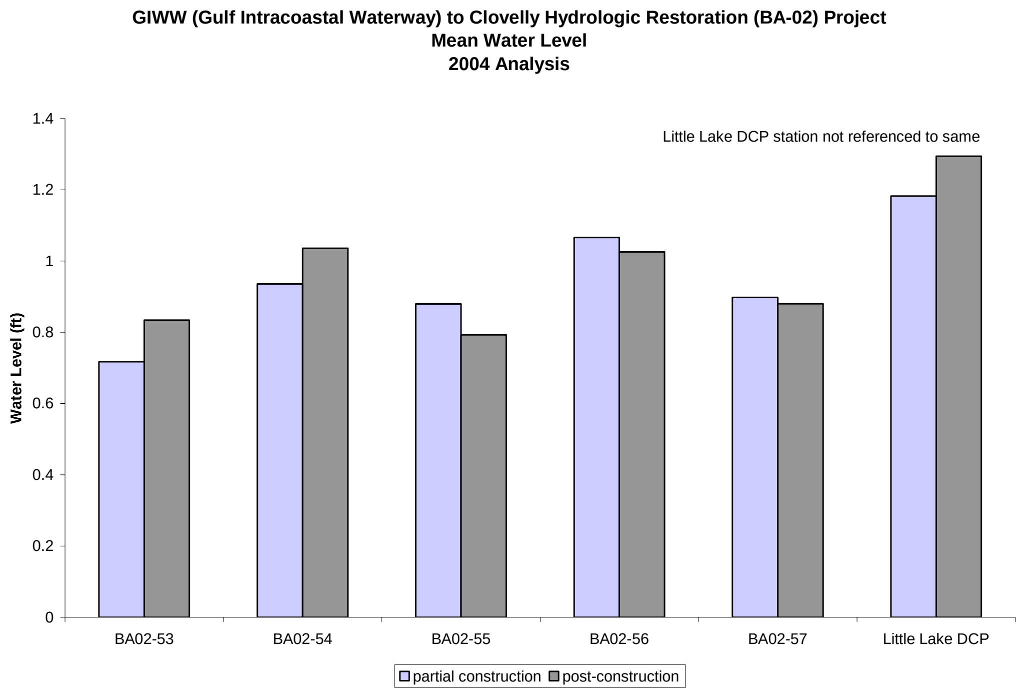

Figure 11. Partial and post-construction mean water levels by station.

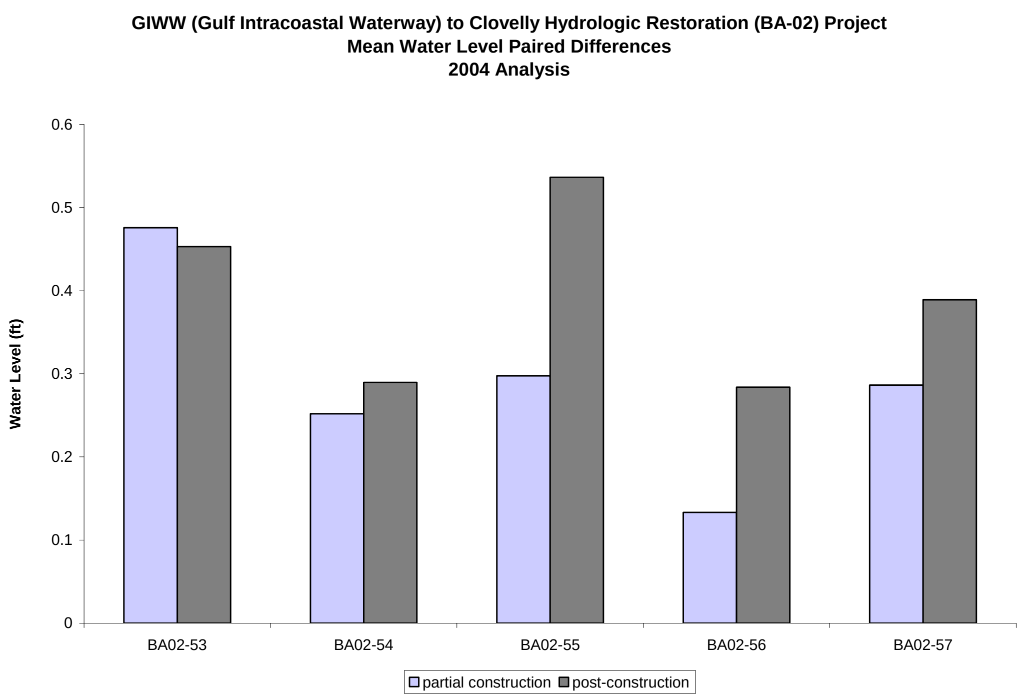

Figure 12. Partial and post-construction period means of paired differences in weekly means of water levels, reference (Little Lake DCP) minus station.

follows a factorial analysis of variance (ANOVA) in which an interaction between the main effects (*period* and *location*) is tested for statistical significance. In this case, the ANOVA F-test for interaction is equivalent to a two-sample t-test on partial construction paired differences vs. post-construction paired differences with

$$H_0\text{: (mean difference)}_{\text{partial}} = \text{(mean difference)}_{\text{post}}$$

and

$$\text{difference} = \text{(water level)}_{\text{project}} - \text{(water level)}_{\text{reference}}\ .$$

Because all five project stations are paired with the same reference station, considerations of sampling independence required that the weekly means of the project stations be averaged into a single weekly project mean. This makes the model into the 2X2 BACI paired series model in table 5 in Smith (2002).

A test on the *location*period* interaction showed no statistically significant impact (p =0.222). Lines slightly out of parallel in figure 13 show a change within the range of what can be attributed to chance.

Another type of BACI ANOVA was performed on the water level data, this time without using the Little Lake DCP station as a reference. In this arrangement, a 2X5 factorial model, the five stations were compared with each other, with *location* as a random effect and with no single station designated purely as a reference station. The only additional assumption needed is that if the project had an impact it would apply unevenly among the five stations. Conditions in the project area support this assumption (Meselhe et al. 2006). The design matches the one described in table 1.b of Underwood (1994). The test showed an impact on water level in the form of a statistically significant interaction (p < 0.0001), although no station registered a change in water level greater than 0.12 ft (0.04 m). What the interaction reports is that water level increased slightly at stations BA02-53 and BA02-54 while it decreased elsewhere (figure 11)..

2005 Analysis:

Figures 14 and 15 show water level as a time series of quarterly means from 1997 to 2006. Comparisons with the Little Lake DCP station end in 2005 when a hurricane shifted the station elevation (USGS has re-surveyed the station, but an abrupt shift still exists in the available data.). Figures 16 and 17 show water level as period means (partial/post) and as period means for differences with the reference station. As the bar charts show, mean water levels within the project did not track the slight increase (0.15 ft [0.05 m]) registered at the reference station.

Weekly means of water level at stations BA02-56 and BA02-57 were averaged into weekly project means paired with the weekly reference means, just as was done with five project stations in the 2004 analysis. The same 2X2 BACI paired series ANOVA yielded a marginal degree of.

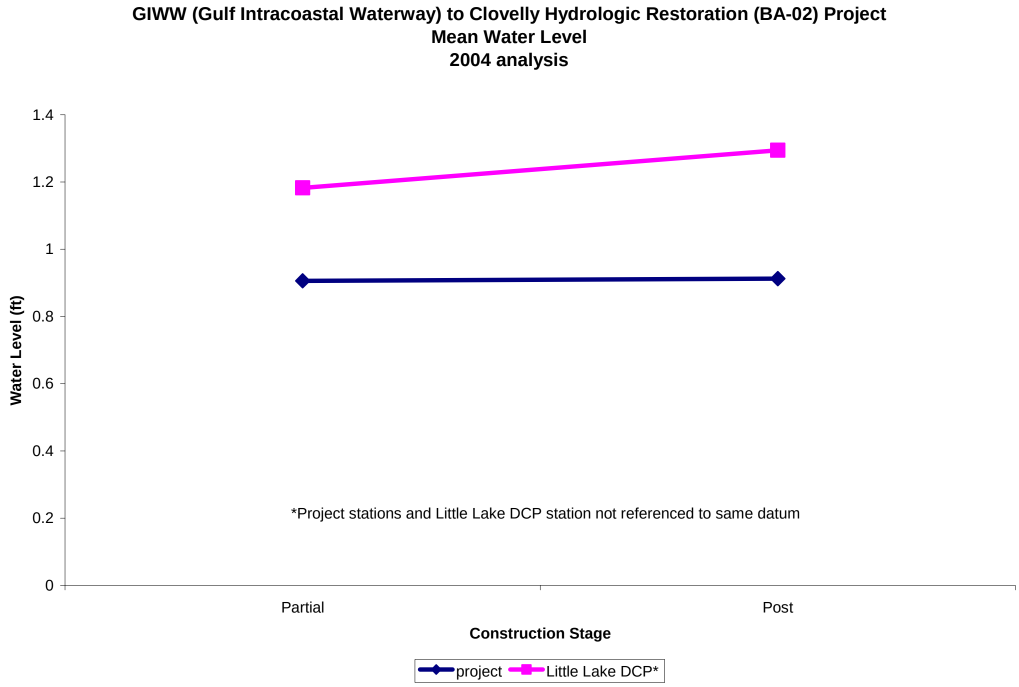

Figure 13. Period means of project and reference water levels. The project mean is the average of weekly means for stations BA02-53, BA02-54, BA02-55, BA02-56, and BA02-57.

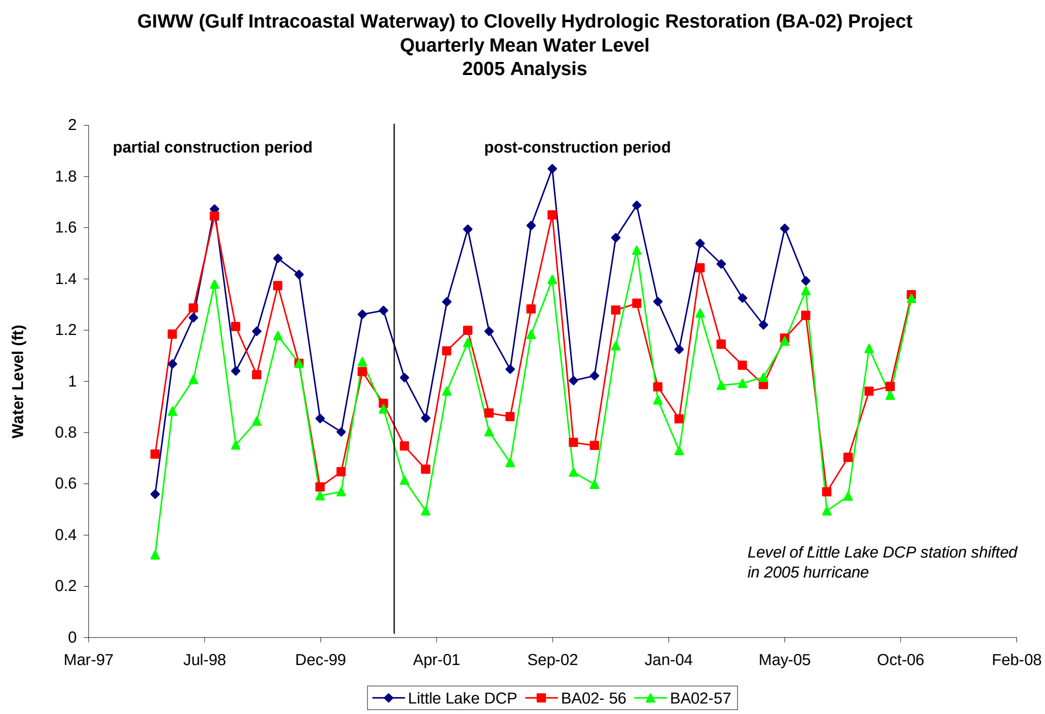

Figure 14. Partial and post-construction water levels as quarterly means. Little Lake DCP station is not referenced to same datum as project stations.

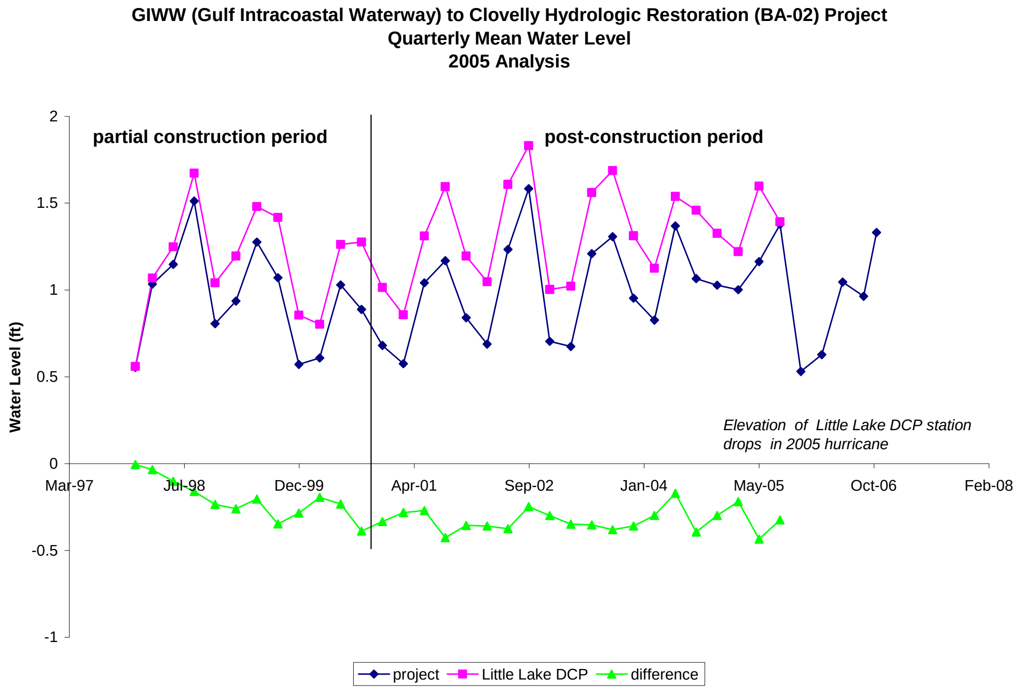

Figure 15. Partial and post-construction water levels as quarterly means. The trace "project" is the mean of stations BA02-56 and BA02-57. Little Lake DCP station not referenced to same datum as project stations.

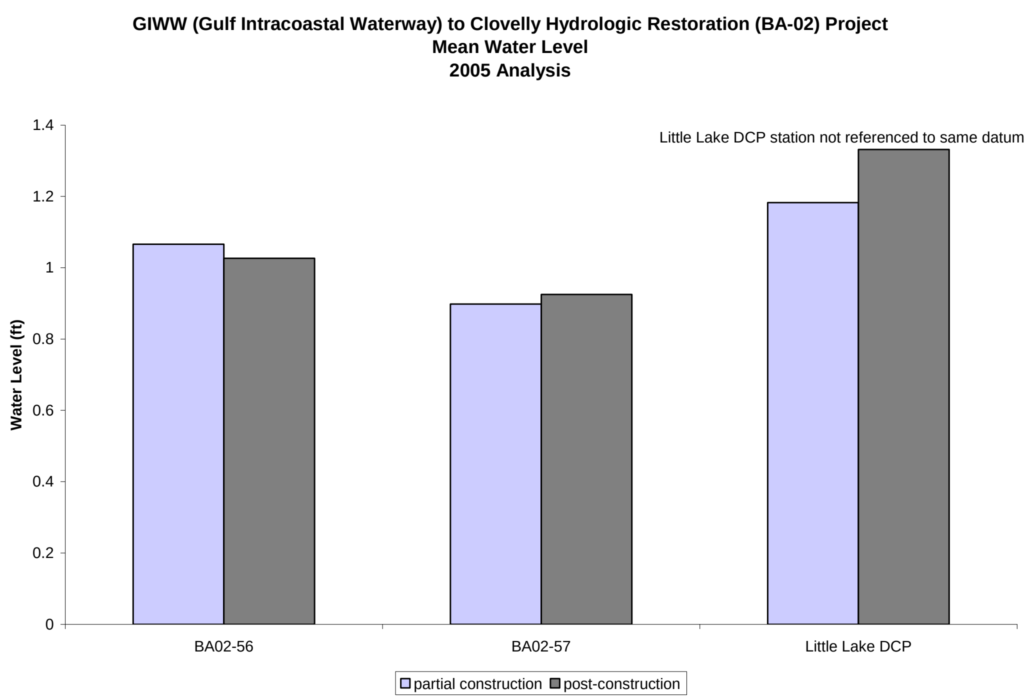

Figure 16. Partial and post-construction mean water levels.

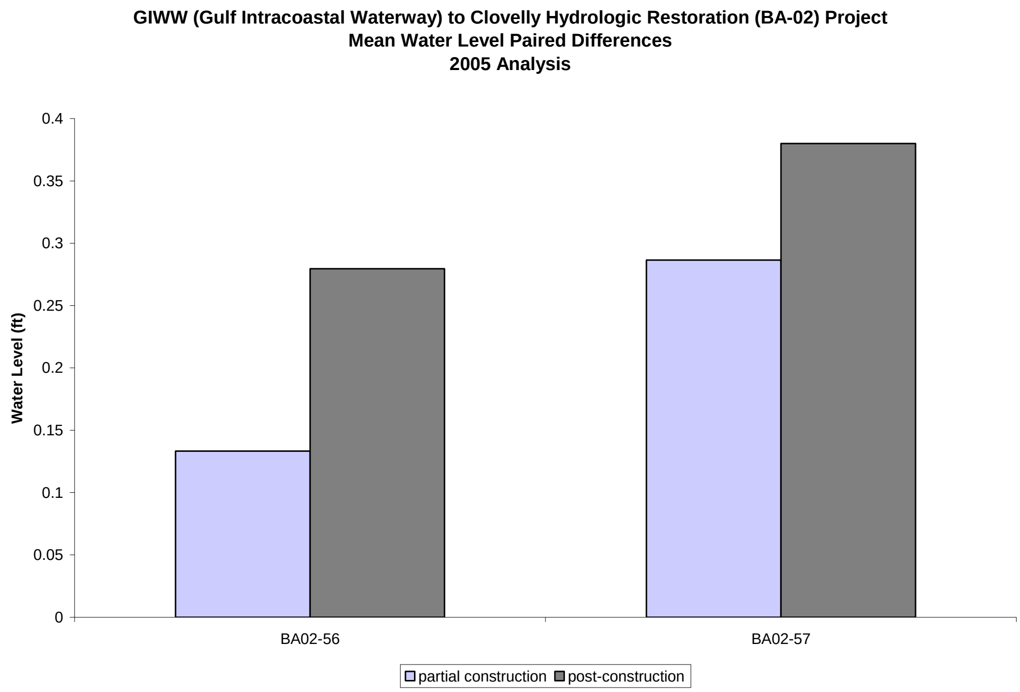

Figure 17. Partial and post-construction mean water levels of paired differences with reference, by station.

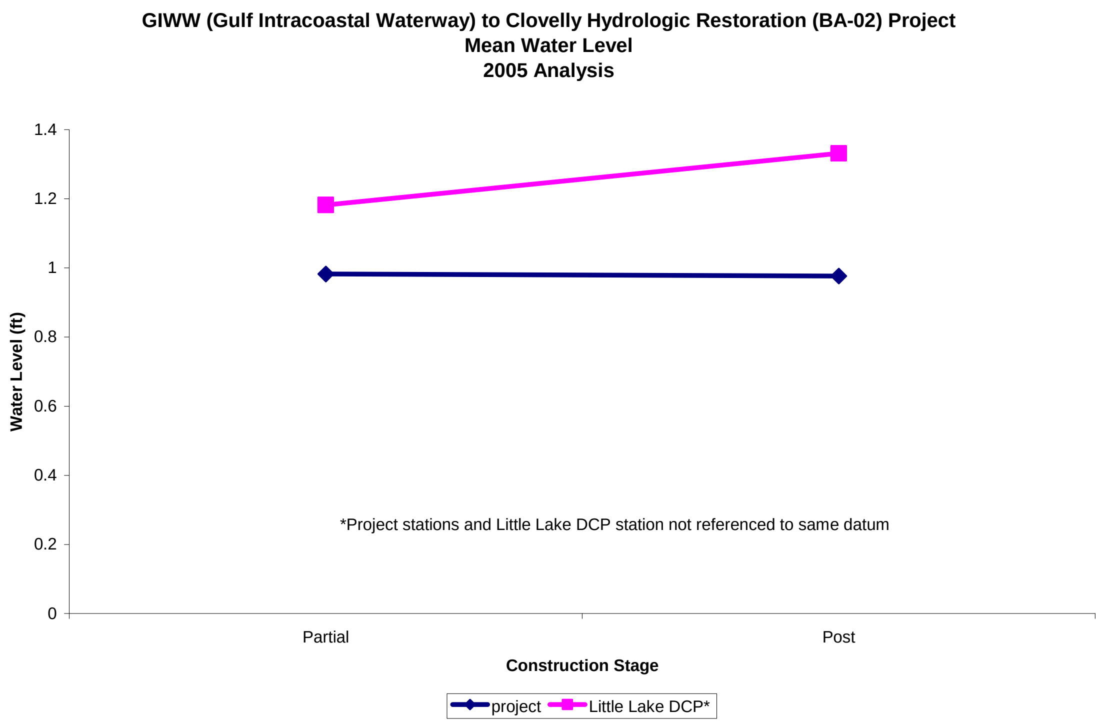

Figure 18. Period means of project and reference water levels. The project mean is the average of weekly means for stations BA02-56 and BA02-57.

statistical significance in the *location*period* interaction ($p = 0.0599$). This shows up graphically as lines slightly out of parallel in figure 18

Variability in Water Level:
One of the stated goals of the project was to reduce variability in water level.

The purest estimate of the variability of a measurement is the second central moment of its distribution, also known as the variance. Because hourly and daily periods are considered too brief to apply much stress to marsh vegetation (Visser 2007), a variance estimate of a weekly mean water level gives a more meaningful statistic. The partial construction water level variance of a project-wide weekly mean was compared to the post-construction variance using the folded F-test feature of Proc T-test in SAS© Version 9. The 2000-2004 post-construction variance (s^2 = $(0.4315 \text{ ft})^2$) was not significantly different ($p = 0.1909$) from the partial construction variance (s^2 = $(0.0.3928 \text{ ft})^2$). No significant difference occurred at the reference station either (p = 0.5504).

Impact on Vegetation by Flooding:
A study by Visser (2007) of the Coastal Ecology Institute of the LSU School of the Coast and Environment estimated the effect of flooding on the dominant vegetation (in this case, *Spartina patens*) by means of a flooding stress index, described in the following excerpt:

> A stress level of 0.5 was assigned to flood events that lasted between one and seven days. A stress level of 1 was assigned to flooding events that lasted more than seven days. Flooding events of less than one day were assumed to provide no stress to the plants (stress level = 0). The period stress index was calculated by multiplying the stress level by the percentage of time in the quarter that the stress level occurred and the percentage of productivity that occurred during that quarter. The yearly stress index was then calculated as the sum of all period stress levels.

The study found a statistically significant increase in the stress index at two stations, as summarized in table 2 below. ("Before" here refers to the 1997-2000 partial construction period; given the lack of pre-construction data, no impact estimate was possible for the entire project.) Two factors must inform interpretation of these results:

First, the Visser study did not attempt to assess impact at BA-02 or any other individual projects, but instead addressed the broader question of whether hydrologic restoration as a general strategy has had an impact in Louisiana. The two questions require different kinds of replication. (See the discussion under "The Statistical Population and Parameters in Question" in Stewart-Oaten and Murdoch 1986.)

Second, the Little Lake DCP station, located in open water and not surveyed to the same datum, is not a suitable reference site to assess impact in terms of flooding stress. Without a suitable reference, it cannot be known if the changes reported in table 2 resulted from completion of construction or from large scale fluctuations in the Barataria Basin.

Table 2. Period (partial and post-construction) average flooding stress index with standard deviation and significance (p) values for the GIWW (Gulf Intracoastal Waterway) to Clovelly Hydrologic Restoration (BA-02) project.

Project	Gauge	Stress Index Before Average (Std. Dev.)	Stress Index After Average (Std. Dev.)	p-value
BA-02	53	0.03 (0.04)	0.04 (0.03)	0.70
	54	0.13 (0.07)	0.32 (0.11)	**0.04**
	55	0.34 (0.09)	0.40 (0.20)	0.68
	56	0.38 (0.02)	0.42 (0.16)	0.72
	57	0.36 (0.08)	0.47 (0.06)	**0.06**

Salinity

See table 1 and figure 8, pages 20 and 21 under ”Water Level,” for station locations and data collection durations. The same continuous recorder equipment used to collect water level data was used to collect salinity data. Establishment of each continuous recorder setup and the water quality variables collected are described under the ”Water Level” data collection section of this report (page 20).

Data Analysis Methods for Salinity:

Analysis of the salinity data followed the same procedures used for the water level data with the difference that it used more data. Since the salinity sensors were not affected by the hurricanes of 2005, salinity data was available up to the last quarter of 2006. Refer to the water level data analysis method section for more details. As was the case with water level, lack of observations prior to construction means that the impact on salinity by the entire project is empirically unknowable. The statistical analysis below only assesses impact by the second construction unit.

2004 Analysis:

Figures 19 and 20 show salinity as a time series of quarterly means from 1997 to 2004. Not shown but also used in the 2004 analysis are stations BA02-56 and BA02-57, the ones used for the 2006 analysis. Figures 21 and 22 show salinity as period means (partial/post) and as period means for differences with the reference station. At every project station, post-construction salinity was slightly lower, but the decrease was less than that experienced by the reference station.

Hourly salinity measurements were transformed into common logarithms in order to meet assumptions of normal distribution and uniform variance. These log salinities were then aggregated into weekly means on which the statistics are based.

The analysis compared salinity during the partial construction period to salinity during the post-construction period using the Little Lake DCP station as a reference. The statistical model follows a factorial analysis of variance (ANOVA) in which an interaction between the main effects (*period* and *location*) is tested for statistical significance. In this case, the ANOVA F-test for interaction is equivalent to a two-sample t-test on partial construction paired differences vs. post-construction paired differences with

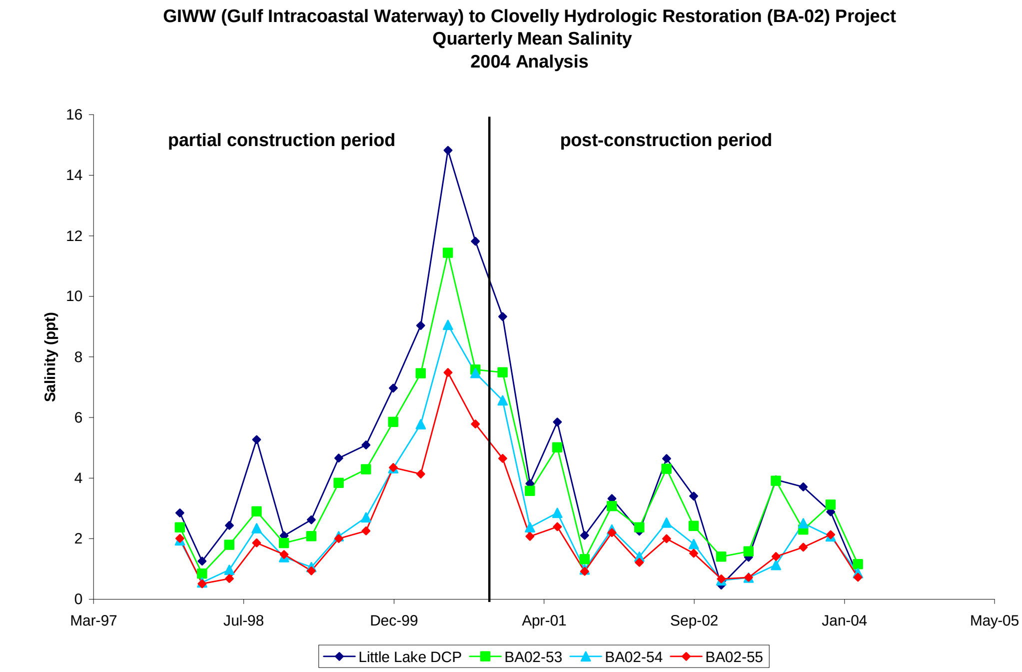

Figure 19. Partial and post-construction salinity as quarterly means. Stations BA02-56 and BA02-57 are included in the 2004 analysis but are not shown.

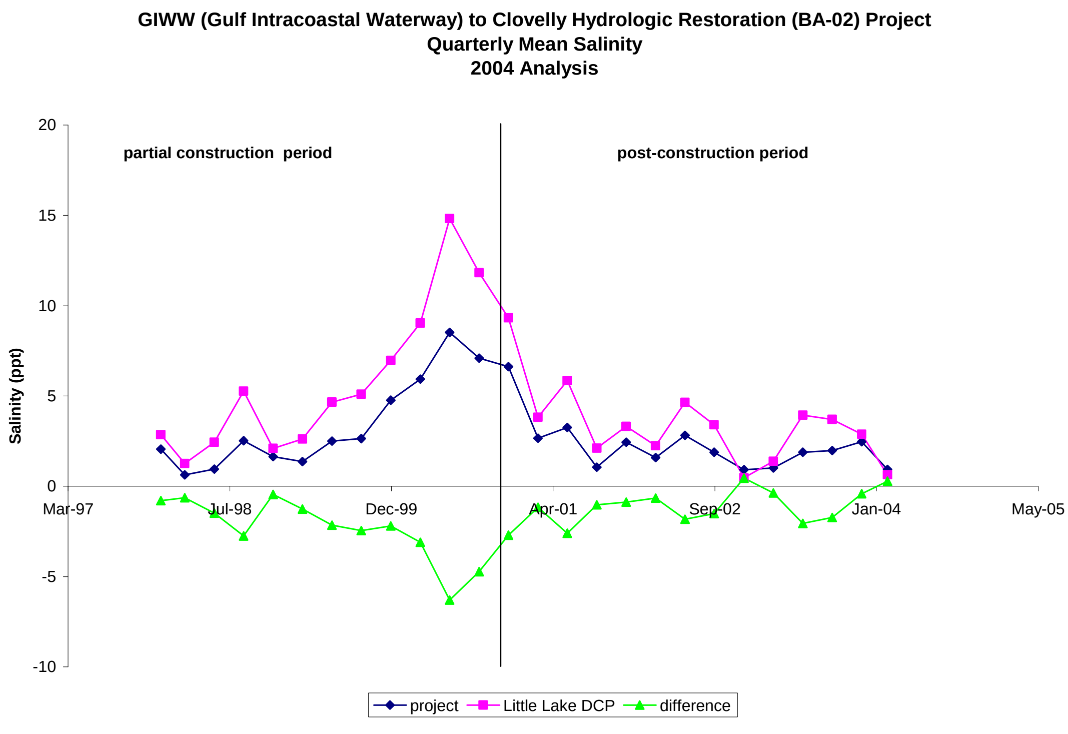

Figure 20. Partial and post-construction salinity as quarterly means by location. Trace labeled "project" is mean of stations BA02-53, BA02-54, BA02-55, BA02-56, and BA02-57.

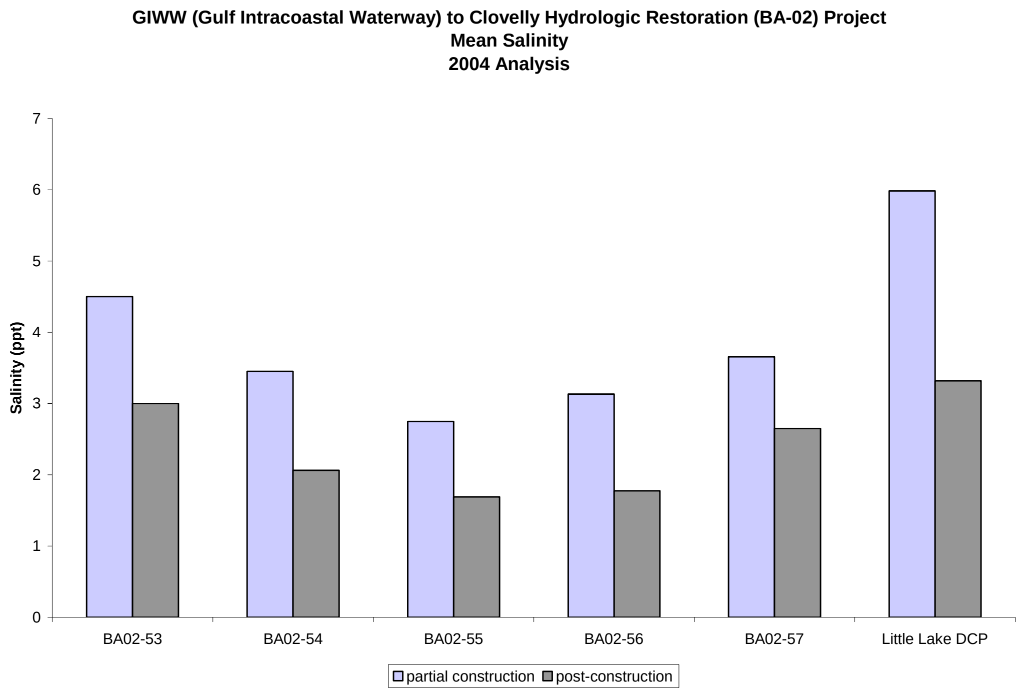

Figure 21. Partial and post-construction mean salinity by station.

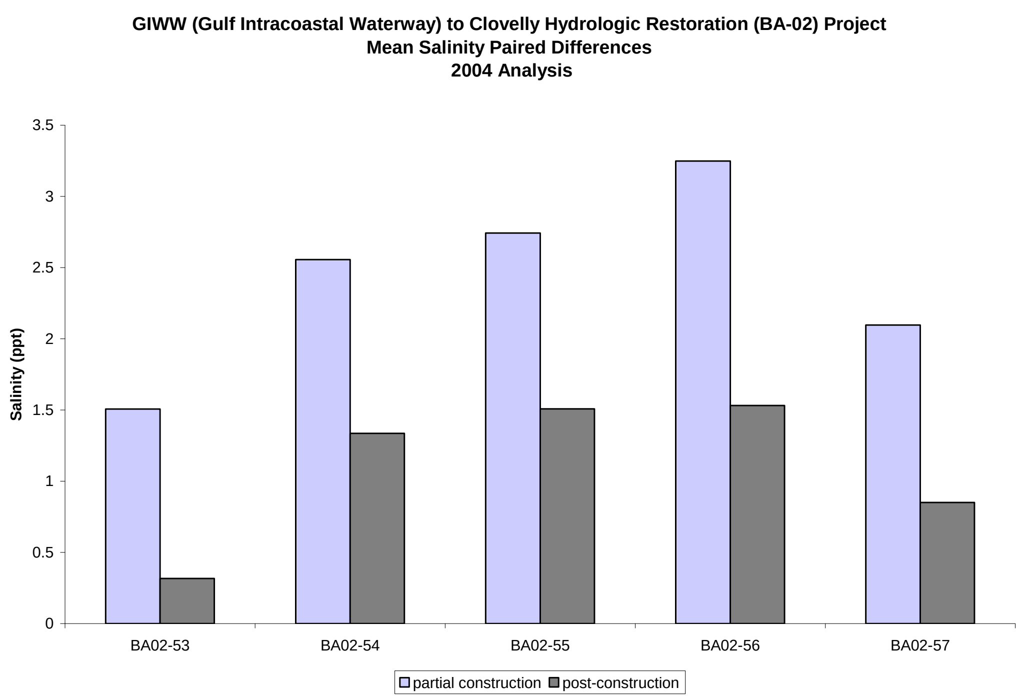

Figure 22. Partial and post-construction means of paired differences in weekly means of salinity, reference (Little Lake DCP) concentration minus station concentration.

$$H_0\text{: (mean difference)}_{partial} = \text{(mean difference)}_{post}$$

and

$$\text{difference} = \log10(\text{salinity} + 1)_{project} - \log10(\text{salinity} + 1)_{reference} .$$

Because all five project stations are paired with the same reference station, considerations of sampling independence required that the weekly means of the project stations be averaged into a single weekly project mean. This makes the model into the 2X2 BACI paired series model in table 5 in Smith (2002).

A test on the *location*period* interaction showed a statistically-significant impact ($p < 0.0001$). This shows up graphically as lines out of parallel in figure 23. Although salinity decreased throughout, salinity decreased less inside the project than at the reference site. This highly significant p-value reflects the size of the data set, not the size of the impact, which amounted to a difference in salinity less than 0.5 parts per thousand from what would be expected had there been no impact, an outcome with only small biological significance.

This observed convergence in salinity (figure 23) between project stations and the reference might be judged an artifact of a high salinity episode associated with a record-setting drought of 2000-2001. As may be seen in figures 19, 20, and 24, the project-to-reference salinity difference tends to increase during times of high salinity. This event, the kind of nuisance variability that the original reference stations could have controlled for, did not divide its influence evenly between the partial and post-construction periods, calling into question the statistical design and results. The log transformation compensates for this difference in response amplitude (see discussion under "Constancy of Differences" in Stewart-Oaten and Murdoch 1986) but the 2X2 BACI was nonetheless repeated with 11 consecutive high-salinity months, February to November of 2000, deleted from the record. As before, the *station*period* interaction tested significant ($p < 0.0001$).

Another type of BACI ANOVA was performed on the same data, this time without using the Little Lake DCP station as a reference. In this arrangement, a 2X5 factorial model, the five stations were compared with each other, with *location* as a random effect and with no single station designated purely as a reference station. The only additional assumption needed is that if the project had an impact it would apply unevenly among the five stations. Conditions in the project area support this assumption (Meselhe et al. 2006). The design matches the one described in table 1.b of Underwood (1994). Result: $p = 0.0019$. Again, a highly significant statistical result corresponding to a very modest impact. The impact shows up graphically (figure 19) as post-construction station BA02-53 exceeding the other stations by more than it had during the partial construction period.

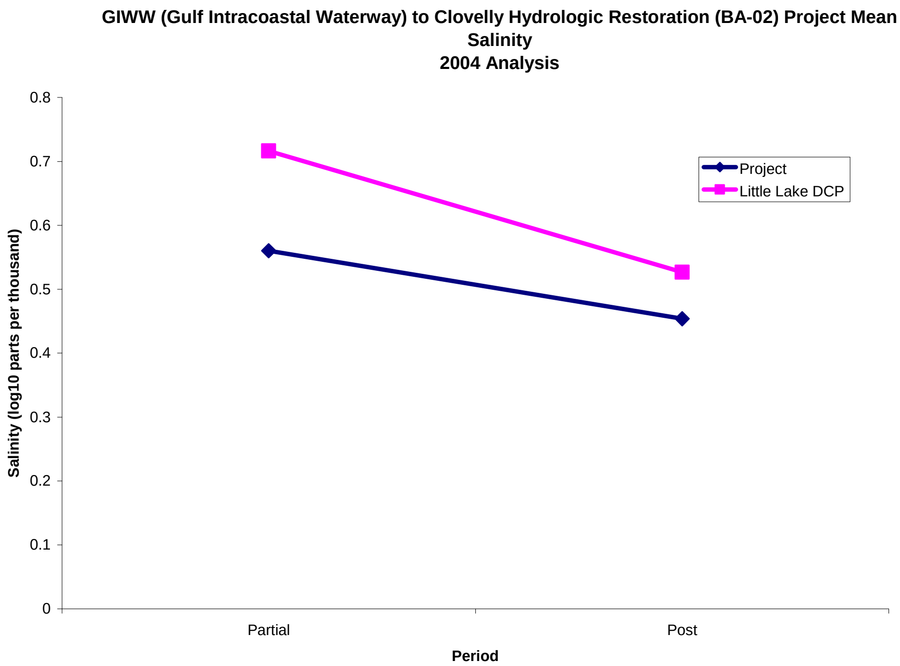

Figure 23. Period means of project and reference salinity. The project mean is the average of weekly means for stations BA02-53, BA02-54, BA02-55, BA02-56, and BA02-57.

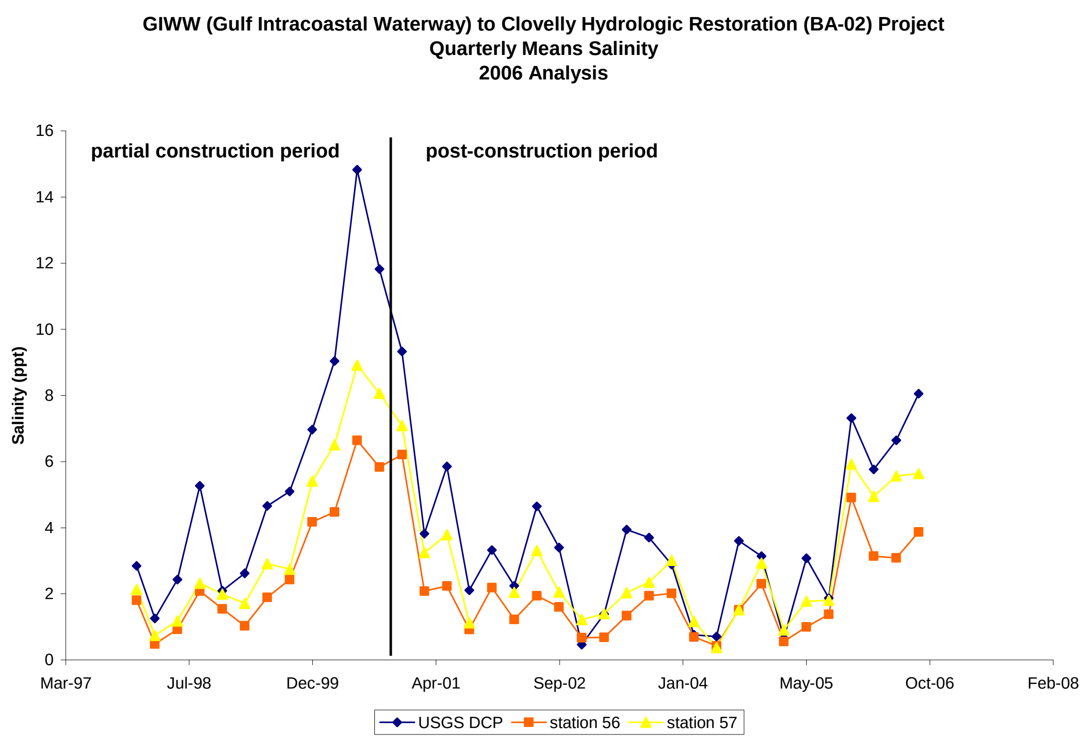

Figure 24. Partial and post-construction salinity as quarterly means.

2006 Analysis:

Figures 24 and 25 show salinity as a time series of quarterly means from 1997 to 2006. The analysis used data only from the reference station and stations BA02-56 and BA02-57, the two project stations that recorded data over the entire 1997-2006 period. Figures 26 and 27 show salinity as period means (partial/post) and as period means for differences with the reference station. At both project stations, post-construction salinity was slightly lower, but the decrease was less than that experienced by the reference station. The same result was obtained on the log scale.

Weekly means of log salinities at the two project stations were averaged into weekly project means paired with the weekly reference means, just as was done with five project stations in the 2004 analysis. The same 2X2 BACI paired series ANOVA yielded a statistically significant *location*period* interaction ($p < 0.0001$). This shows up graphically as lines out of parallel in figure 28. As with the 2004 analysis, this highly significant p-value reflects the size of the data set, not the size of the impact, which amounted to a difference in salinity less than 0.5 parts per thousand from what would be expected had there been no impact, an outcome with only small biological significance. Deleting the 11-month high salinity episode resulted in $p = 0.0027$.

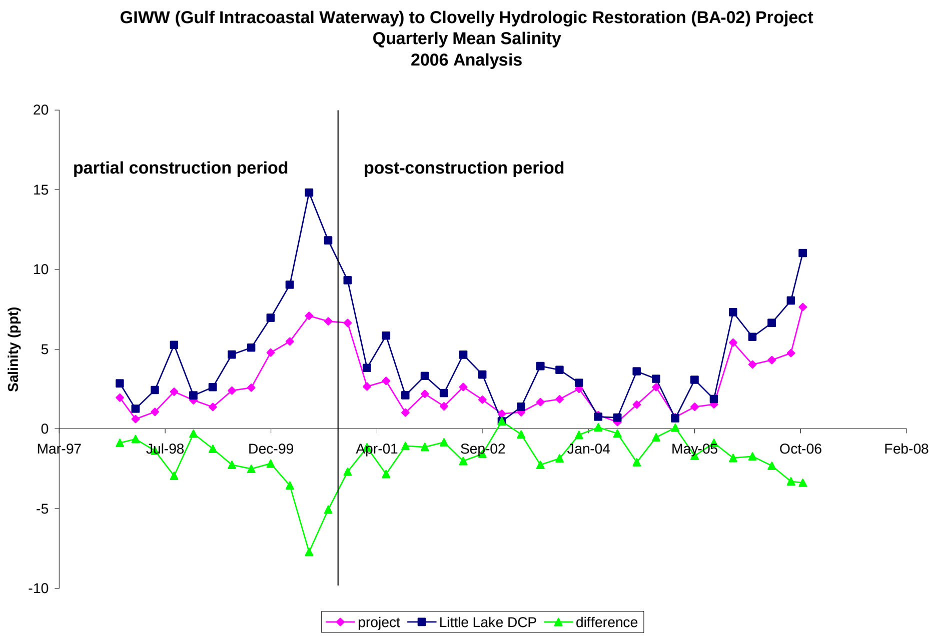

Figure 25. Partial and post-construction salinity as quarterly means. The trace "project" is the mean salinity at stations BA02-56 and BA02-57.

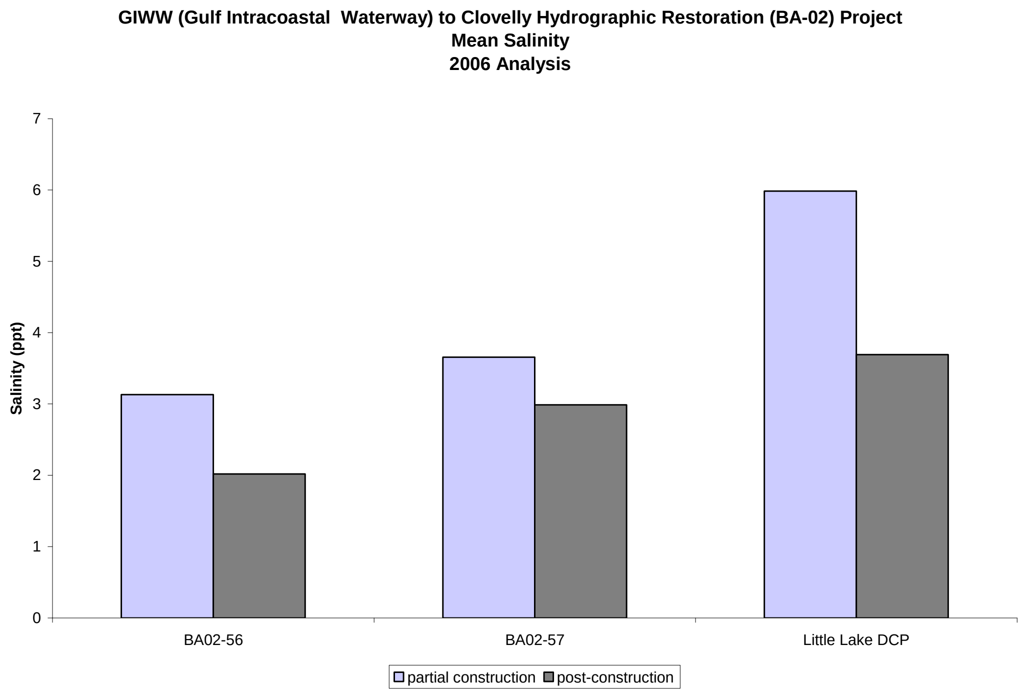

Figure 26. Partial and post-construction salinity by station.

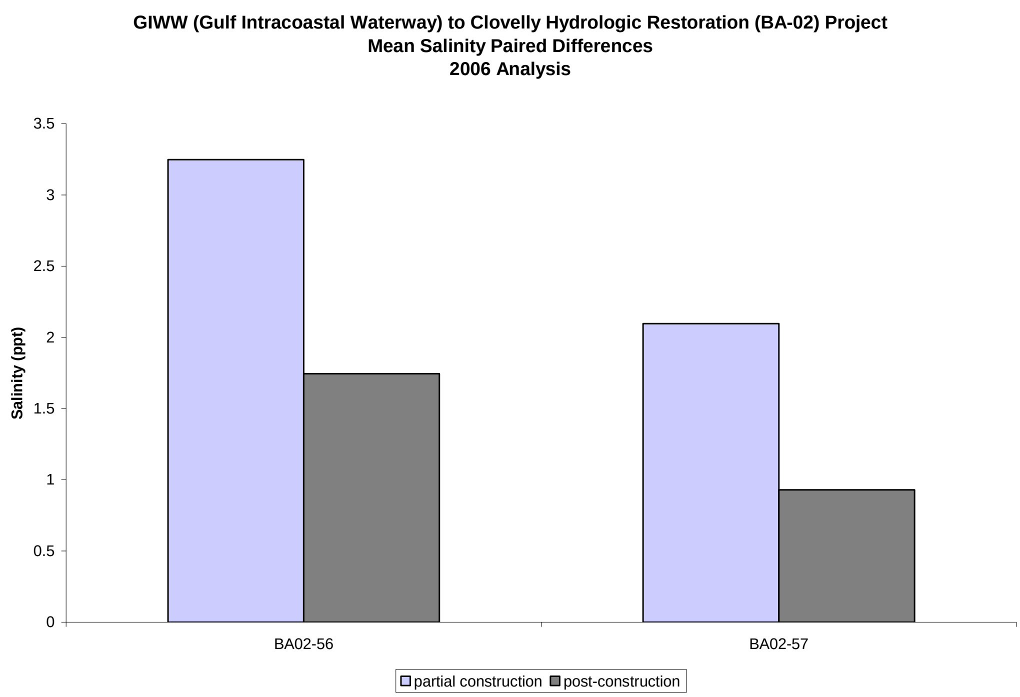

Figure 27. Partial and post-construction means of paired differences in weekly means of salinity, reference (Little Lake DCP) concentration minus station concentration.

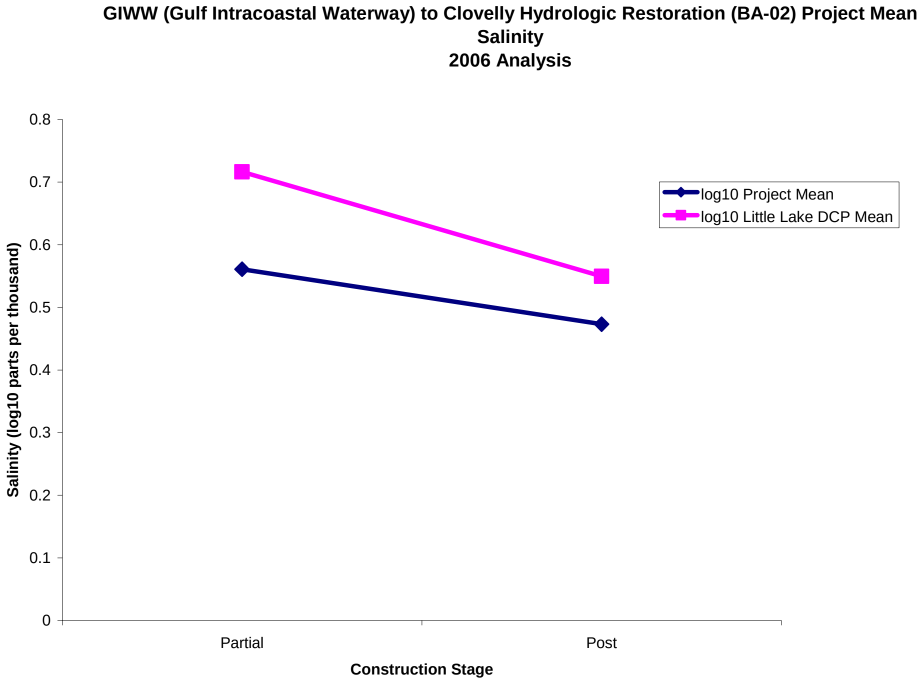

Figure 28. Period means of project and reference salinity. The project mean is the average of weekly means for stations BA02-56 and BA02-57.

<u>Modeling Results:</u>

The statistical results need to be reconciled with the findings of a hydrological model by C. H. Fenstermaker and Associates (Meselhe et al. 2006). The text of the report mentions salinity reductions as large as 3-4 ppt in the southern project area and 4-5 ppt in the Clovelly Canal.

These results need some interpretation. Little Lake, the source of salinity in the project area, has had an average post-construction salinity of only 3.7 ppt while station 56, the least saline station inside the project, averaged 2.0 ppt, concentrations that would preclude any overall reduction in mean salinity greater than 1.7 ppt.

The explanation is that the model did not estimate impact on overall mean salinity. Figures 3.5, 3.9, 3.11, 3.13, 3.15, 3.17, and 3.19 of the Fenstermaker report show the model results as distributions. The model yielded impacts in the ranges of 3-4 and 4-5 ppt, but these were transient events representing the lower percentiles of the events modeled. Table 3, which summarizes some of the model results, can be summarized by saying that (except for station 56) about twenty percent of the time the project structures achieved salinity reductions equaling or exceeding about one part per thousand.

Table 3. Project Impact (with structures vs. without) as Salinity Reduction, parts per thousand

station	scale	10th percentile	20th percentile	50th percentile
54	hourly	1.8	0.9	<0.1
54	monthly	1.3	0.9	0.4
58	hourly	1.5	0.9	0.1
58	monthly	1.1	0.9	0.3
55	hourly	1.3	0.9	<0.1
55	monthly	1.1	0.7	0.3
56	hourly	<0.1	<0.1	<0.1
56	monthly	0.1	<0.1	<0.1
end of C. Canal	hourly	1.7	1.1	0.1

Furthermore, Figures 3.6, 3.10, 3.12, 3.14, 3.16, and 3.18 of the Fenstermaker report indicate that these reductions were achieved mainly during high salinity episodes. This is an impact consistent with one of the project objectives, which is to prevent rapid salinity increases.

In summary, the statistical analysis addressed only the impact of the second construction unit on overall mean salinity, while the hydrological model addressed the impact of both construction units on specific events at specific locations.

An upper limit to the project impact on overall mean salinity is easy to estimate. The post-construction (2006) mean salinity in Little Lake is 3.7 ppt and the post construction mean salinity within the project is estimated at 2.5 ppt, giving a difference of 1.2 ppt, a number that approaches the resolution limit of the model.

<u>Variability in Salinity:</u>
One of the stated goals of the project was to reduce variability in salinity. The purest estimate of the variability of a measurement is the second central moment of its distribution, also known as the variance. Vegetation can more easily recover from hourly or daily exposures to stressful salinity levels (Visser 2007), so a variance estimate of the weekly mean salinity was used for the analysis. Partial construction salinity variance of a project-wide weekly mean was compared to the post-construction variance using the folded F-test feature of Proc T-test in SAS© Version 9. The 2000-2004 post-construction variance (s^2 = (1.89 ppt)^2) was significantly lower (p < 0.0001) than the partial construction variance (s^2 = (2.92 ppt)^2). This is probably a reflection of conditions at the reference station in Little Lake, where the effect was more drastic (3.38^2 versus 5.08^2, $p < 0.0001$).

<u>Impact on Vegetation by Salinity:</u>
Visser (2007) of the Coastal Ecology Institute of the LSU School of the Coast and Environment estimated the effect of salinity on the dominant vegetation (in this case, *Spartina patens*) by means of a salinity stress index. The index uses a stress level based on impaired production scaled to the length of the period of exposure to that stress level and scaled to a seasonal production factor:

$$\text{Salinity Stress Index} = \sum_{ij} Level_i \times Period_{ij} \times Production_j$$

Where: $Level_i$ = stress level i, $Period_{ij}$ = proportion of time level i was experienced during quarter j, $Production_j$ = proportion of production occurring in quarter j

The study found no significant change in the stress index, as summarized in table 4 below. ("Before" here refers to the 1997-2000 partial construction period.) All stress index values are less than 0.50, meaning that on average the dominant vegetation was estimated to achieve better than 50% of optimal production throughout the project.

Table 4. Period (partial and post-construction) average salinity stress index with standard deviations and significance (*p*) values. For the GIWW (Gulf Intracoastal Waterway) to Clovelly Hydrologic Restoration (BA-02) project.

Project	Gauge	Stress Index Before Average (Std. Dev.)	Stress Index After Average (Std. Dev.)	p-value
BA-02	53	0.42 (0.08)	0.42 (0.02)	0.91
	54	0.31 (0.17)	0.23 (0.07)	0.50
	55	0.29 (0.18)	0.22 (0.07)	0.56
	56	0.29 (0.18)	0.24 (0.06)	0.68
	57	0.37 (0.11)	0.31 (0.09)	0.44

As mentioned in the discussion of inundation stress (above), "before" refers to the 1997-2000 partial construction period; given the lack of pre-construction data, no impact estimate was possible for the entire project.

And, as with inundation stress, the Visser study did not attempt to assess impact at BA02 as an isolated project, but instead addressed the broader question of whether hydrologic restoration as a general strategy has had an impact on salinity stress in Louisiana. These results therefore supply information on the trajectory of salinity stress at BA02 but lack the degree of experimental control needed to assess local impact.

Discrete Salinity Data:

Discrete salinity data were collected at stations throughout the project area from September 1997 through January 2004 (table 5; figure 29). Discrete data collection took place in the same location each time; however, there were no station establishment materials associated with this type of sampling. The monthly readings took place in the same location of water bodies (lakes, bayous, navigational channels, marsh ponds), with no need to establish any distinctive markings. Repeated measures were obtained by using global positioning systems to ensure the readings were occurring in the same locations. Discrete samples included water quality readings collected

Table 5. Data collection stations and date ranges for monthly discrete salinity data at the GIWW (Gulf Intracoastal Waterway) to Clovelly Hydrologic Restoration (BA-02) project.

Station	Years	Collection Dates
BA02-02	1993 - 1995	01/22/93 - 06/20/95
BA02-03R	1993 - 1995	01/22/93 - 06/20/95
BA02-04R	1993 - 1995	01/22/93 - 06/20/95
BA02-05R	1993 - 1995	01/22/93 - 06/20/95
BA02-06	1993 - 1995	01/22/93 - 06/20/95
BA02-07	1993 - 1995	01/22/93 - 06/20/95
BA02-08	1993 - 1995	01/22/93 - 06/20/95
BA02-09	1993 - 1995	01/22/93 - 06/20/95
BA02-11	1993 - 1995	03/31/93 - 06/20/95
BA02-18	1993 - 1995	06/01/93 - 06/20/95
BA02-21	1993, 1997	06/01/93, 07/13/93, 07/27/93, 07/22/97
BA02-22R	1993 - 1995	06/01/93 - 06/20/95
BA02-23R	1993 - 1995	06/01/93 - 06/20/95
BA02-24R	1993 - 1994	06/01/93 - 09/20/94
BA02-25	1993	06/01/93, 07/13/93, 07/27/93
BA02-26	1993	06/01/93, 06/15/93, 07/13/93, 07/27/93
BA02-27R	1993 - 1995	06/15/93 - 06/20/95
BA02-28R	1993 - 1995	07/13/93 - 06/20/95
BA02-31	1993 - 1995, 1997 - 2004	01/22/93 - 06/20/95, 07/22/97 - 01/22/04
BA02-32	1997	07/22/97, 08/13/97, 09/15/97
BA02-33	1997 - 2004	07/22/97 - 01/22/04
BA02-34	1997 - 2000	07/22/97 - 06/08/04
BA02-35	1997 - 2004	08/18/97 - 01/22/04
BA02-35R	1993 - 1995, 1998 - 2004	03/31/93 - 06/20/95, 03/23/98 - 01/22/04
BA02-36	1997 - 2004	07/22/97 - 01/22/04
BA02-37	1997 - 2004	07/22/97 - 01/22/04
BA02-38	1997 - 2004	07/22/97 - 01/22/04
BA02-39	1997	08/13/97, 09/15/97, 09/15/97
BA02-40	1993 - 1995, 1997 - 2004	03/31/1993 - 06/20/1995, 07/22/97 - 01/22/04
BA02-41	1997	07/22/97, 08/13/97, 09/15/97
BA02-42	1993 - 1995, 1997 - 2004	03/31/93 - 06/20/95, 07/22/97 - 01/22/04
BA02-43	1993 - 1995, 1997 - 2004	03/31/93 - 06/20/95, 07/22/97 - 01/22/04
BA02-44	1993 - 1995, 1997 - 2004	03/31/93 - 06/20/95, 07/22/97 - 01/22/04
BA02-45	1993 - 1995, 1997	03/31/93 - 06/20/95, 08/13/97, 09/15/97

Table 5. (continued)

Station	Years	Collection Dates
BA02-46	1997 - 2002	07/22/97 - 07/24/02
BA02-47	1993 - 1995, 1997 - 2004	06/01/93 - 06/20/95, 07/22/97 - 01/22/04
BA02-48	1993 - 1995, 1997 - 2003	06/01/93 - 06/20/95, 07/22/97 - 10/07/03
BA02-49	1997 - 2004	07/22/97 - 01/22/04
BA02-50	1997 - 1998	07/22/97, 08/13/97, 09/15/97, 03/03/98, 03/23/98
BA02-51	1997 - 2004	07/22/97 - 01/22/04
BA02-52	1997 - 2000	07/22/97 - 10/04/00
BA02-53	1997 - 2004	07/22/97 - 01/22/04
BA02-53R	1997 - 2004	09/16/97 - 01/22/04
BA02-54	1997 - 2004	07/22/97 - 01/22/04
BA02-55	1997 - 2004	07/22/97 - 01/22/04
BA02-56	1993, 1997 - 2004	06/15/93, 07/22/97 - 01/22/04
BA02-57	1993 - 1995, 1997 - 2004	03/31/93 - 06/20/95, 07/22/97 - 01/22/04
BA02-58	1997 - 2004	07/22/97 - 01/22/04
BA02-58R	1998 - 2004	05/04/98 - 01/22/04
BA02-59	1997 - 2004	07/22/97 - 01/22/04
BA02-95	1998 - 2003	05/04/98 - 10/07/03
BA02-102	2000 - 2004	08/01/00 - 01/22/04

on a monthly basis from the same locations randomly selected by the LDNR/CRD for special sampling within the project and reference area. These water quality readings were taken with a portable, hand-held instrument (YSI 30 or equivalent) that provided the user with water temperature (°C), specific conductance (μS/cm), and salinity (ppt). Estimated water depth (ft) readings were obtained at each location using the graduated cable on the YSI 30 or equivalent. Before readings were taken in the field with a hand-held water quality meter, the meter was calibrated for quality assurance. Since the meter is capable of measuring a wide range of salinity concentrations, the instrument is calibrated with a solution that is relatively close to the conditions in the field (Folse and West 2005).

Data Analysis Method for Discrete Salinity:

Analysis was performed on discrete salinity data colleted from January 1993 through January 2004. Discrete salinity data collection was discontinued in January 2004 due to recommendations based upon the CRMS-Wetlands project review. All field data were entered to an electronic format where LDNR/CRD personnel followed quality assurance/quality control (QA/QC) procedures prior to data analysis as stated in Folse and West (2005).

Discrete stations that possessed pre-construction, partial construction and post-construction data were graphed in figure 30 to show the mean bottom salinity readings for each time period. Of the fifty-two (52) stations, only nine (9) stations have data for all three time periods which are in the project area. Results show that five (5) stations during the pre-construction time period (n=21) had a mean of less than 0.5 ppt, which is the salinity concentration for freshwater marshes. All stations during the partial and post-construction time period (n=27-34 and 18-24, respectively) had a mean salinity (2.1-4.0 ppt) in the oligohaline marsh type, which is 0.5-5.0

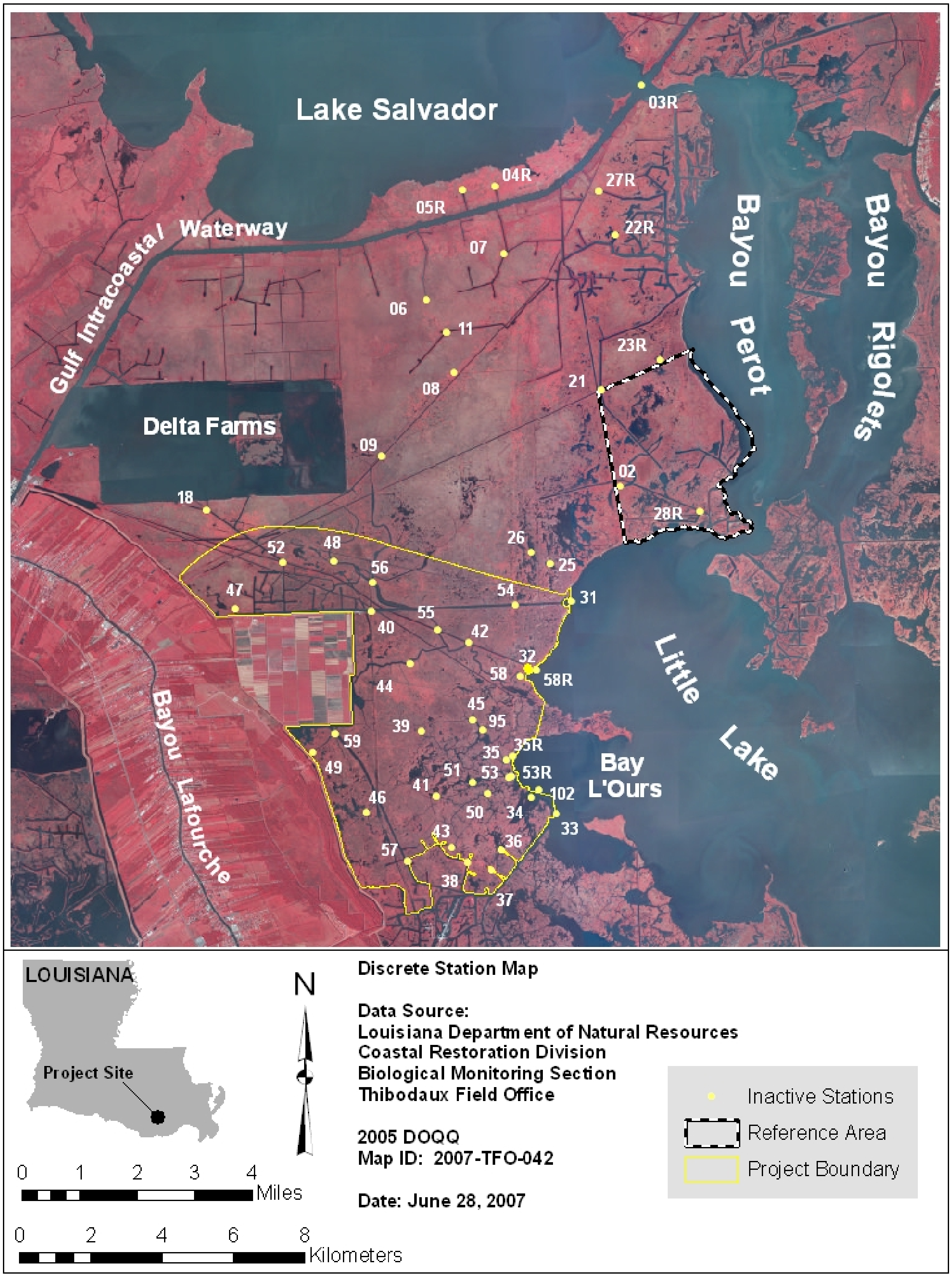

Figure 29. Location map of discrete salinity stations for the GIWW (Gulf Intracoastal Waterway) to Clovelly Hydrologic Restoration (BA-02) project. All stations were inactivated as a result of the CRMS-Wetlands project review.

ppt. The higher mean salinity readings are spatially distributed closer to Little Lake while the lower salinity stations are farthest away – the northwest portion of the project area.

When examining the project location, one would expect the northwest portion of the project to have a lower salinity since it is influenced more by the GIWW while the eastern and southern parts of the project are more influenced by the more saline waters of Little Lake. The unexpected result is the increase of the mean salinity during the partial and post-construction; however, the partial constructed period can be explained by a severe drought period that south Louisiana experienced at the same time. For the post-construction period, the discrete readings, although only monthly, show a pattern very similar to the closest continuous recorder station. Because there were no continuous recorder stations in the project area during the pre-construction period, it is difficult to conclusively determine the cause for the salinity increase.

Vegetation

Project-specific vegetation data were collected during the fall of 1996, 1999, 2000, 2002, and 2005 (table 6; figure 31). Each sampling station was marked with a PVC pole at the southeast corner to mark the plot which would allow for revisiting over time. Station coordinates were collected at the southeast corner pole with a Differential Global Positioning System (DGPS) to facilitate repeat sampling of the same stations over time. The corner pole position for each station was recorded in the Universal Transverse Mercator (UTM), North American Datum of 1983 (NAD83), Meters coordinate system. A 6.6 ft x 6.6 ft (2 m x 2 m) Braun-Blaunqet grid was placed over the southeast corner pole and oriented so that each side faced a cardinal direction while data collection took place. Species composition, percent cover by species and total percent cover data were recorded for the area inside the grid using ocular estimates.

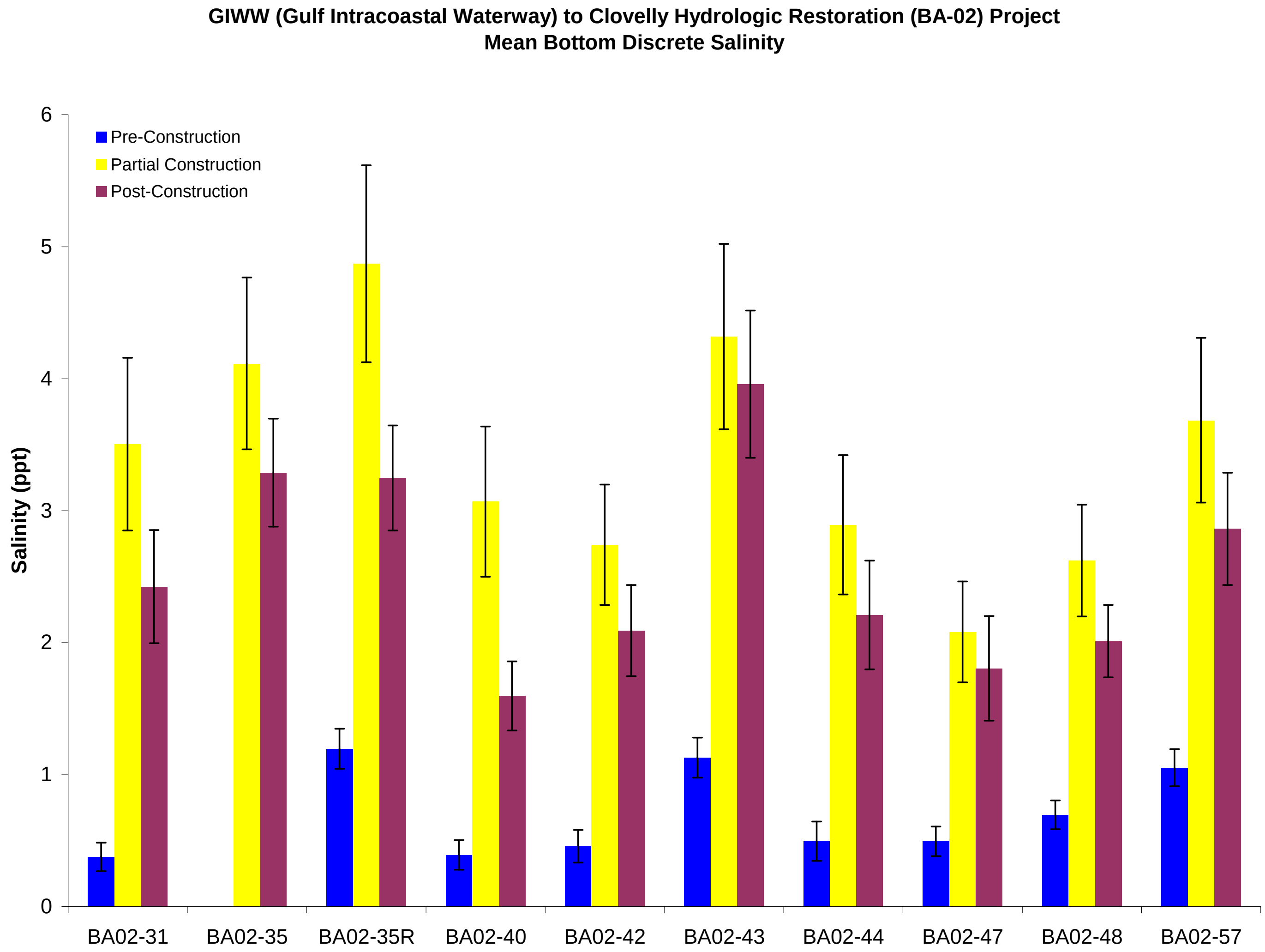

Figure 30. Mean monthly discrete bottom salinity pre-, partial, and post-construction.

Table 6. Sampling stations and date ranges for vegetation data collection at the GIWW (Gulf Intracoastal Waterway) to Clovelly Hydrologic Restoration (BA-02) project.

Station	1996	1999	2000	2002	2005	Replacement
BA02-60	Yes	Dropped	Dropped	Dropped	Dropped	None
BA02-60R	Yes	Dropped	Dropped	Dropped	Dropped	None
BA02-61	Yes	Dropped	Dropped	Dropped	Dropped	None
BA02-61R	Yes	Dropped	Dropped	Dropped	Dropped	None
BA02-62	Yes	Dropped	Dropped	Dropped	Dropped	None
BA02-62R	Yes	Dropped	Dropped	Dropped	Dropped	None
BA02-63	Yes	Dropped	Dropped	Dropped	Dropped	None
BA02-63R	Yes	Dropped	Dropped	Dropped	Dropped	None
BA02-64	Yes	Dropped	Dropped	Dropped	Dropped	None
BA02-64R	Yes	Dropped	Dropped	Dropped	Dropped	None
BA02-65	Yes	Dropped	Dropped	Dropped	Dropped	None
BA02-65R	Yes	Dropped	Dropped	Dropped	Dropped	None
BA02-66	Yes	Dropped	Dropped	Dropped	Dropped	None
BA02-67	Yes	Dropped	Dropped	Dropped	Dropped	None
BA02-68	Yes	Yes	Yes	Yes	No	BA02-150
BA02-69	Yes	Yes	Yes	Yes	Yes	None
BA02-70	Yes	Yes	Yes	Yes	Yes	None
BA02-71	Yes	Yes	Yes	Yes	Yes	None
BA02-72	Yes	Yes	Yes	Yes	Yes	None
BA02-73	Yes	Yes	No	No	No	BA02-100
BA02-74	Yes	Yes	Yes	Yes	Yes	None
BA02-75	Yes	Yes	Yes	Yes	Yes	None
BA02-76	Yes	Yes	Yes	Yes	No	BA02-152
BA02-77	Yes	Yes	Yes	Yes	No	BA02-151
BA02-78	Yes	Yes	Yes	Yes	Yes	None
BA02-79	Yes	Yes	No	No	No	BA02-101
BA02-80	Yes	Yes	Yes	Yes	Yes	None
BA02-81	Yes	Yes	Yes	Yes	Yes	None
BA02-82	Yes	Yes	Yes	Yes	Yes	None
BA02-83	Yes	Yes	Yes	Yes	Yes	None
BA02-84	Yes	Yes	Yes	Yes	Yes	None
BA02-100	No	No	Yes	Yes	Yes	None
BA02-101	No	No	Yes	Yes	Yes	None
BA02-150	No	No	No	No	Yes	None
BA02-151	No	No	No	No	Yes	None
BA01-152	No	No	No	No	Yes	None

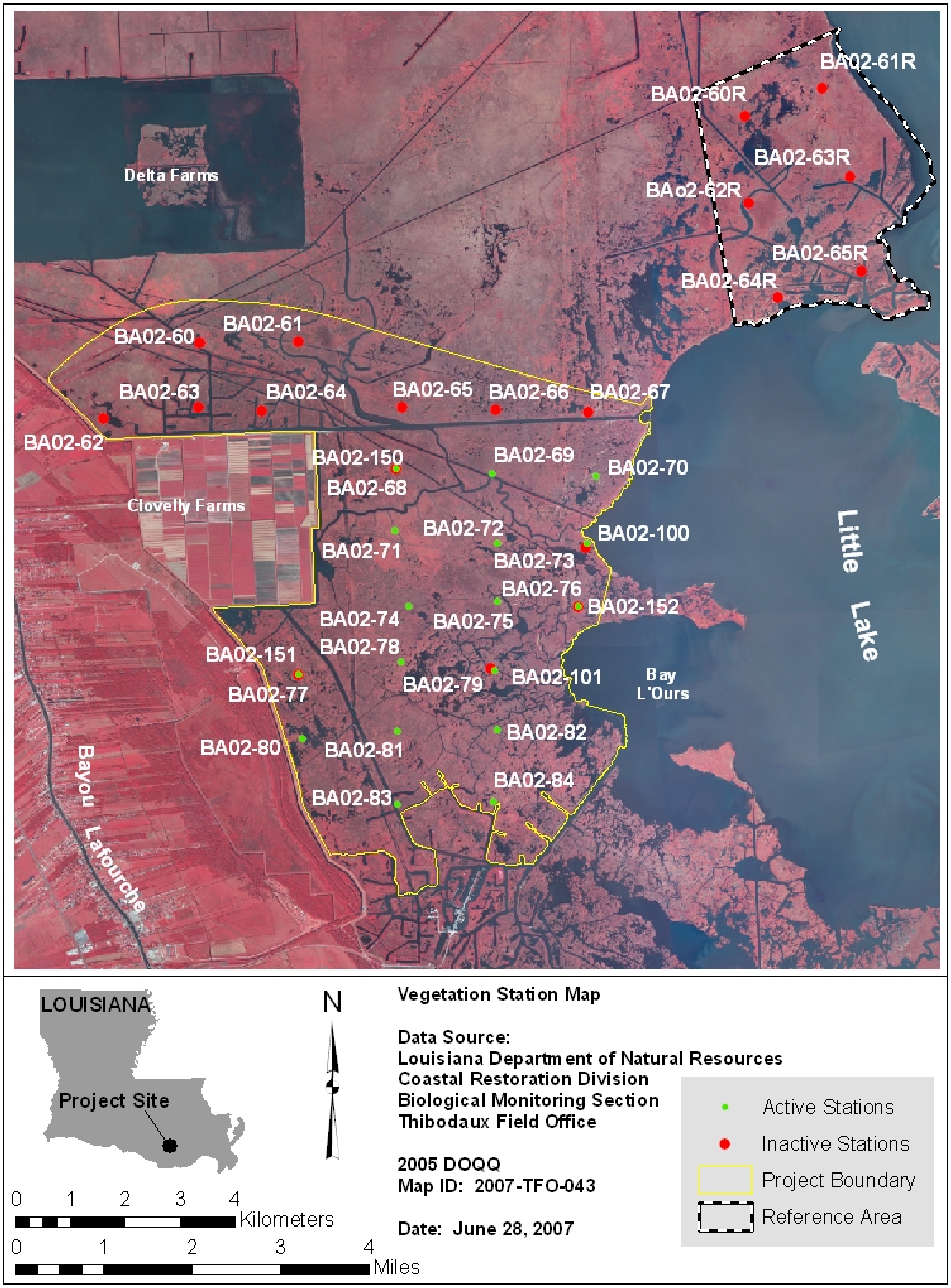

Figure 31. Project-specific vegetation and soils data collection stations for the GIWW (Gulf Intracoastal Waterway) to Clovelly Hydrologic Restoration (BA-02) project.

Data Analysis Methods for Vegetation:

Field data were entered into an electronic format where LDNR/CRD personnel followed QA/QC procedures prior to data analysis as stated in Folse and West (2005).

Data in figure 32 is presented as the relative mean percent of selected species found during sampling. SAS was used to sum the percent cover for each individual species across all stations sampled during that year. Then the sum of each percent cover was totaled. The sum of the percent cover for each species was divided by the totaled amount (giving a fraction) then multiplied by 100 to give the relative mean cover for each species. The total relative mean for each species sums to 100 percent as illustrated in the figure. This analysis provides an estimation of each species throughout the entire project area.

The increase in relative cover for *S. patens* (Ait.) Muhl. in 2000 and 2002 (figure 32) could possibly be a biological response to an increase in salinity coupled with an overall lower water level during a drought which lasted from September 1999 through June 2001. Salinity peaked around 15 ppt in the middle of the drought in June 2000. Additionally, the combined mean water level for all of the project continuous recorders remained relatively low for the duration of the drought (figure 9) in comparison to previous and consequent years. The main salinity tolerance mechanism for *S. patens* (Ait.) Muhl. is a strong salt tolerance at the cellular level (Li-Xianggan et al. 1995); however, since it lacks aerenchyma tissue it is not able to oxygenate its roots in anoxic soils (Bertness 1991). This could explain its positive response to higher salinity levels and lower water levels associated with the drought. Conversely, marsh species less tolerant of high levels of salinity would negatively respond to the aforementioned conditions, such as *Sagittaria lancifolia* L., which prefers medium to low salinities and saturated to moist soils. Although the species present during the 2000 and 2005 sampling periods continued to be diverse, the relative cover of all of these species made up a small portion of the overall cover compared to *S. patens* (Ait.) Muhl.

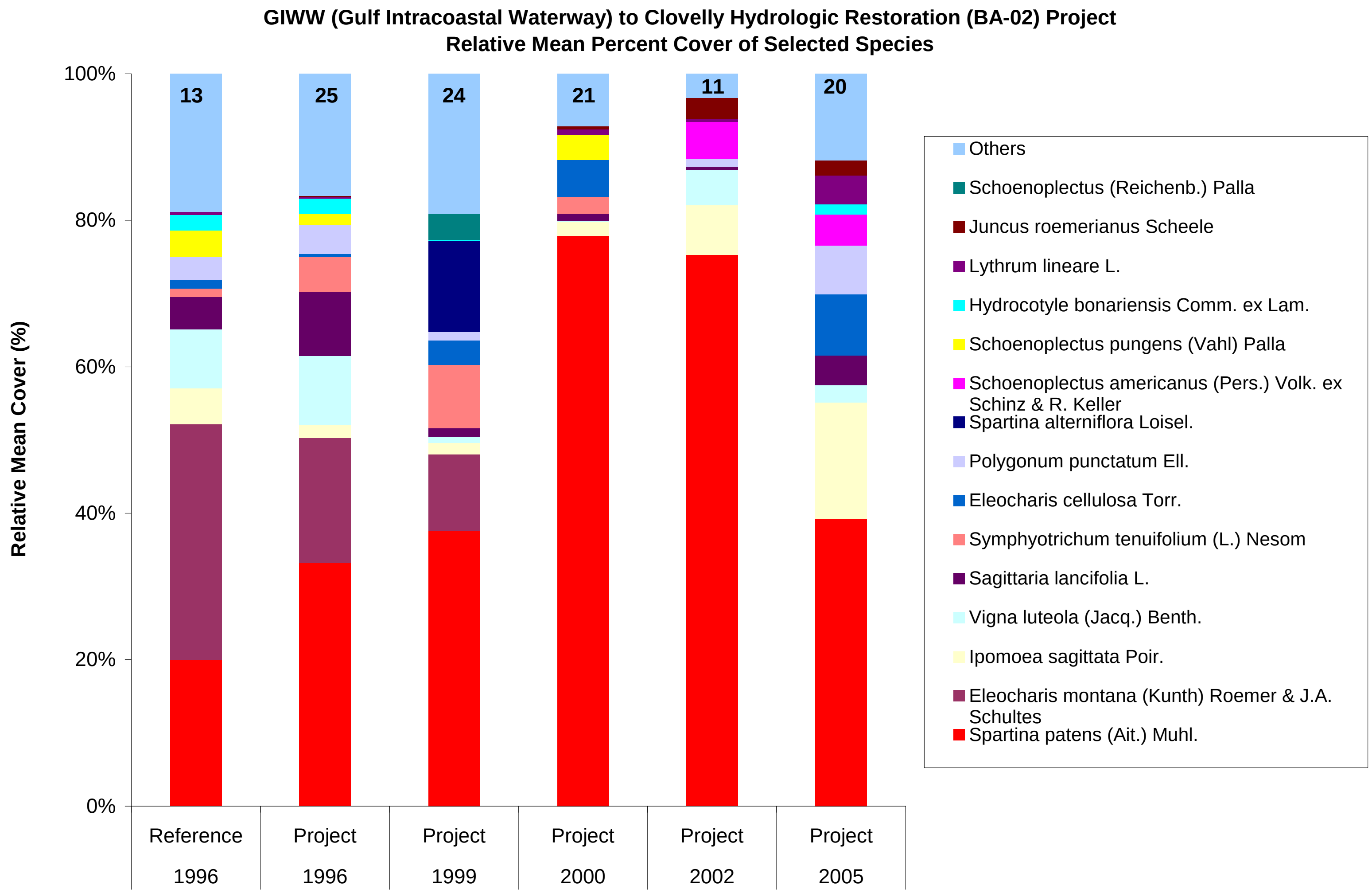

Figure 32. Relative mean percent cover of selected plant species.

Soils

Project specific soils data were collected concurrent to vegetation sampling during the fall of 1996, 1999, 2000, 2002, and 2005. Soils data collection stations as well as sampling years are the same as those used for vegetation monitoring (table 6; figure 31). For the years 1996, 1999, 2000, and 2002 simple grab samples were collected by LDNR personnel just outside of the 6.6 ft x 6.6 ft (2 m x 2 m) vegetation plots and delivered to the Louisiana State University (LSU) agricultural center agronomy department soils lab. One grab sample was taken at each station. Once the spot was selected for the sample, vegetation was clipped back to the marsh surface and all loose detritus was removed. Each sample, approximately 3.9 in (10 cm) deep and approximately 3.9 in (10 cm) in diameter, was taken from the marsh. The samples were placed in plastic Ziploc® bags, labeled, and stored in an ice chest on ice for the duration of the sampling trip. Once delivered to the field office, the samples were held in refrigeration no longer than 48 hours before delivery to the soils lab. The cores were processed in order to determine the g/cm^3 bulk density, percent organic matter content, and percent moisture content.

In 2005 LDNR contracted with Coastal Estuary Services (CES), LLC in Houma, Louisiana, for soils data collection and processing. Soil samples were taken with an 11.8 in (30 cm) stainless steel Meriwether corer, with an inside tube diameter of 4 in (10.1 cm) to a depth of 5.9 in (16 cm) using the protocol set forth in Folse and West (2005). The cores were transferred to individual Ziploc® bags, labeled, and placed in an ice chest on ice for the duration of the sampling trip. Once delivered to the field office, the samples were held in refrigeration no longer than 48 hours before delivery to the soils lab. Soil cores were analyzed for wet pH, dry pH, specific conductance (µS/cm), salinity (ppt), moisture content (%), bulk density (g/cm^3), wet volume (cm^3), and dry volume (cm^3).

Data Analysis Methods for Soils:

Soils data were received by LDNR/CRD and individual station results were totaled and divided by the number of stations to determine the mean values for the three (3) variables that were consistently collected. These variables included organic matter content (figure 33), moisture content (figure 34), and bulk density (figure 35).

Soil organic matter content is the percent of the soil that contains decomposed plant and animal residue and other organic compounds. Since organic matter is combustible, the Loss-On-Ignition method (Henri et al. 2001) is used to determine the percentage within the sample. Four of the five sampling years had a mean soil organic matter content greater than 60% while in 2002 the content was about 40%. These soils in the project area are considered organic soils, which is typical of a wetland.

Soil moisture content is the percentage of moisture in the sample. The soil moisture content for 4 of the 5 sample years was between 75 and 95% while the 2002 sample had a mean of 45%. These ranges are also common for wetland areas.

Soil bulk density is the dry weight of soil material per unit of volume. In 1996, the reference area soils averaged 0.85 g/cm^3, and project area soils averaged 1.02 g/cm^3, which is more

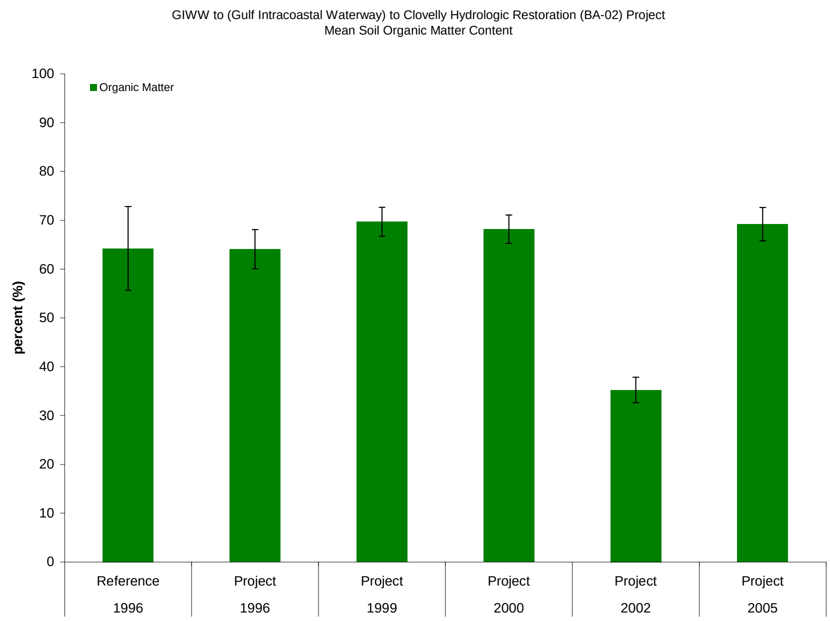

Figure 33. Percent organic matter in soil samples collected inside the GIWW (Gulf Intracoastal Waterway) to Clovelly Hydrologic Restoration (BA-02) project.

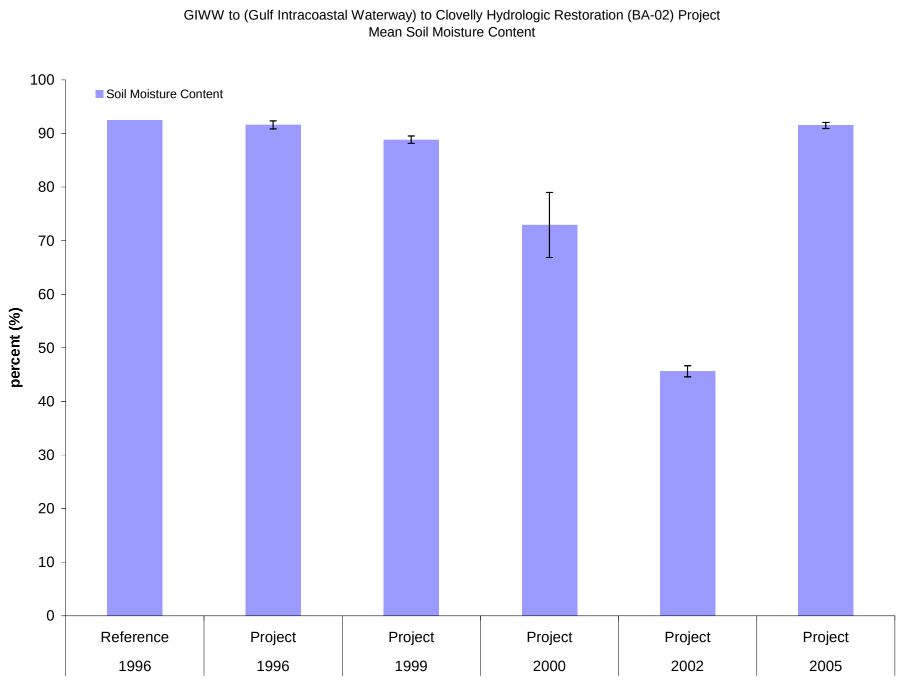

Figure 34. Mean percent soil moisture in soil samples collected inside the GIWW (Gulf Intracoastal Waterway) to Clovelly Hydrologic Restoration (BA-02) project.

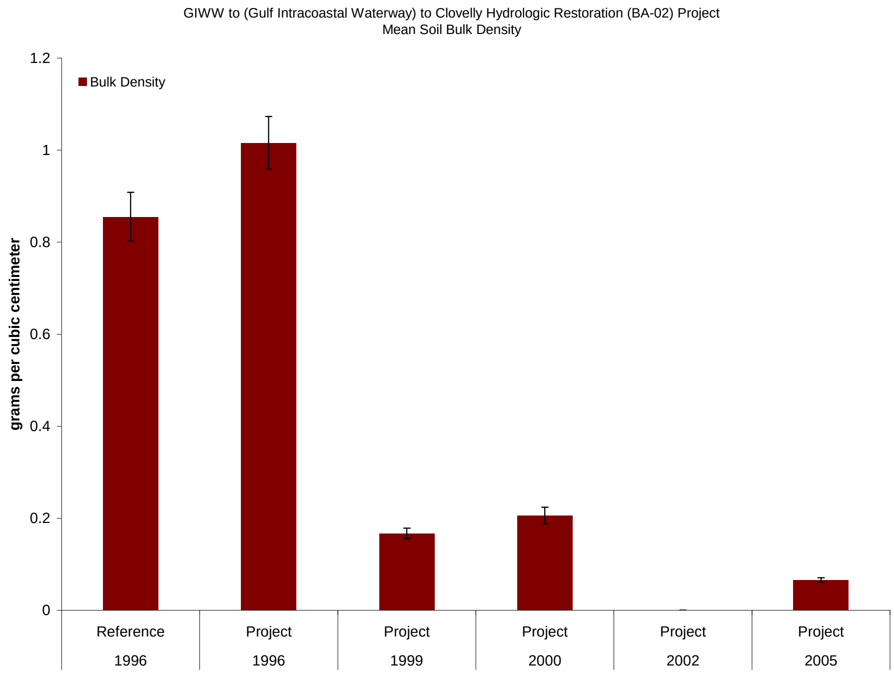

Figure 35. Bulk density for soil samples collected inside the GIWW (Gulf Intracoastal Waterway) to Clovelly Hydrologic Restoration (BA-02) project.

characteristic of mineral soils. The remaining samples averaged 0.17 g/cm^3 in 1999, 0.21 g/cm^3 in 2000, and 0.07 g/cm^3 in 2005. The soils laboratory did not perform bulk density measurements in 2002. Organic soils generally have a bulk density of 0.2 to 0.3 g/cm^3 but can be as low as 0.04 g/cm^3 in a peatland soil (Mitsch and Gosselink 2000).

All mean values presented are typical of a wetland soil in south Louisiana and with the project area, except for the 1996 bulk density measurements. It is believed that this data is an outlier and should be overlooked since there are no longer any LDNR/CRD employees that can provide insight for this occurrence.

Shoreline Change

Shoreline position data for the GIWW (Gulf Intracoastal Waterway) to Clovelly Hydrologic Restoration (BA-02) project was collected pre-construction by LDNR personnel in 1993, and 1998, as well as 2000 and 2003 post-construction. Also, Shaw Coastal, Inc. was contracted by LDNR to document shoreline position data in 2005. LDNR personnel utilized sub-meter accurate DGPS equipment to collect the shoreline points along 21 randomly selected 300 ft (91.4 m) segments (figures 36-41). The same segments were revisited for each subsequent survey. Shaw Coastal, Inc. personnel utilized a Trimble 5700 RTK base station with a Trimble 5800 rover unit; the data stored in a Trimble TSCe data collector (Shaw Coastal, Inc. 2005).

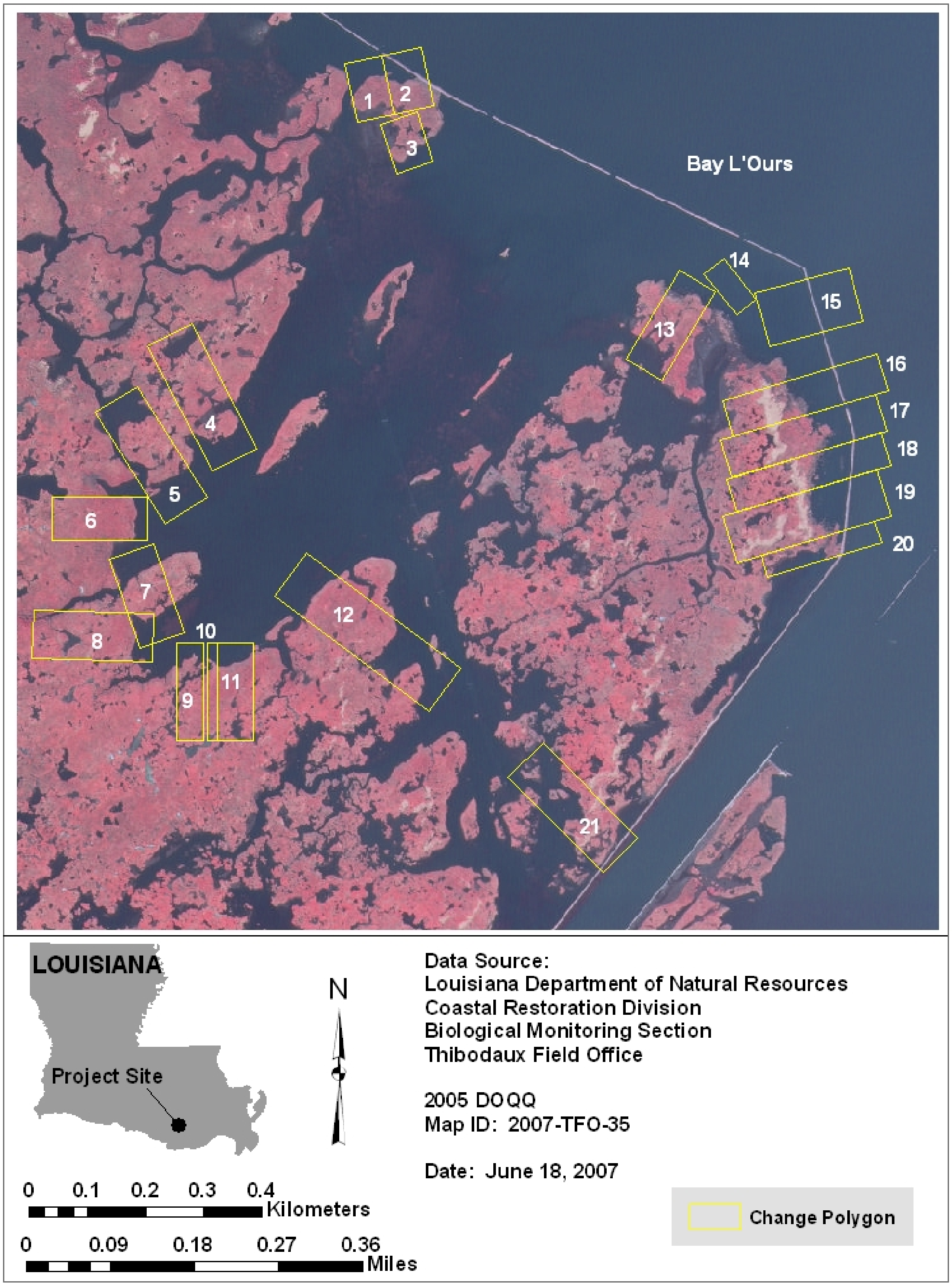

Figure 36. Change polygons for randomly selected shoreline segments 1-21 for the GIWW (Gulf Intracoastal Waterway) to Clovelly Hydrologic Restoration (BA-02) project. Construction for the shoreline protection rock dike was completed in October 2000.

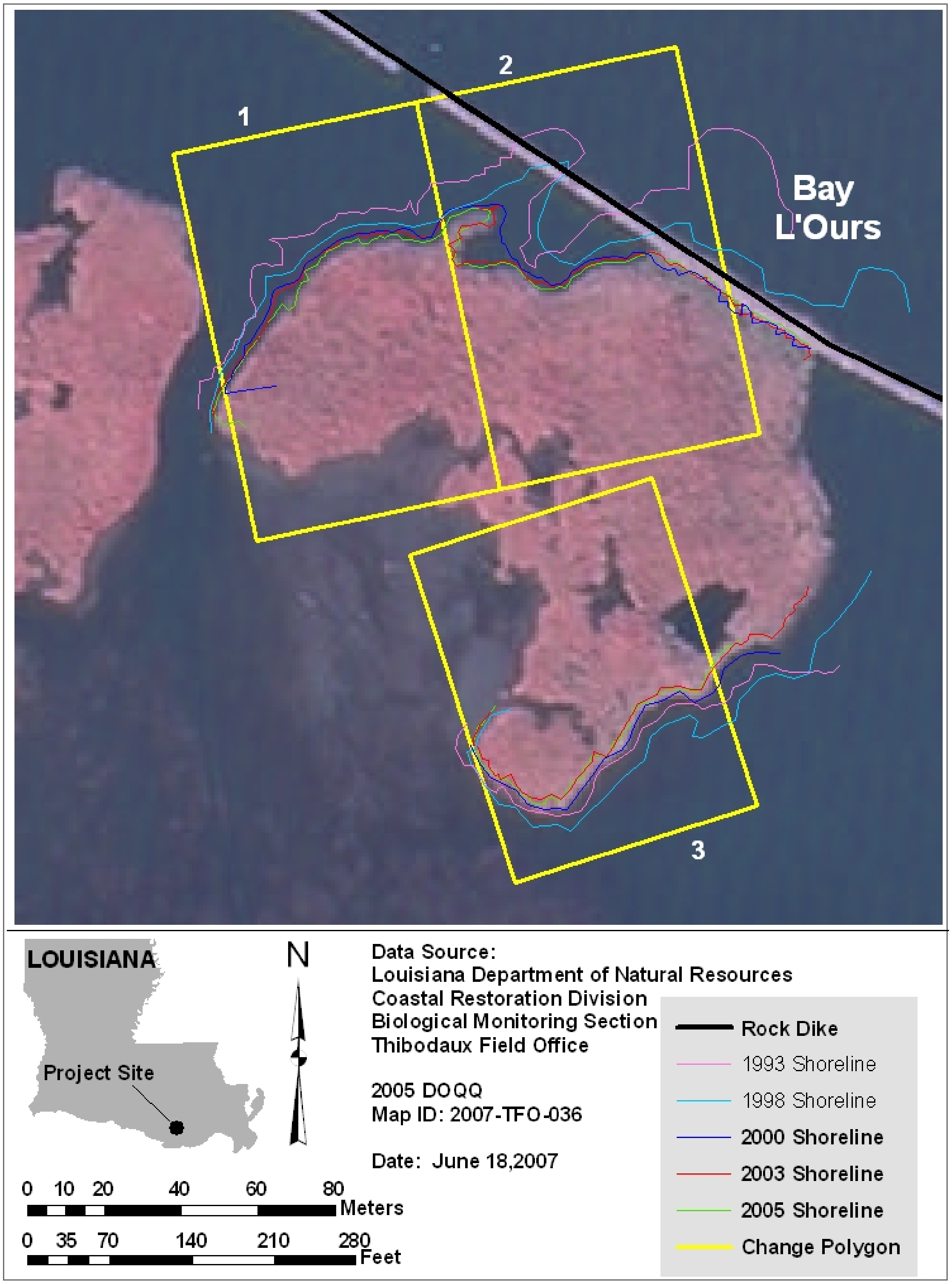

Figure 37. Location of 1993, 1998, 2000, 2003, and 2005 shoreline segments 1-3 for the GIWW (Gulf Intracoastal Waterway) to Clovelly Hydrologic Restoration (BA-02) project. Construction for the shoreline protection rock dike was completed in October 2000.

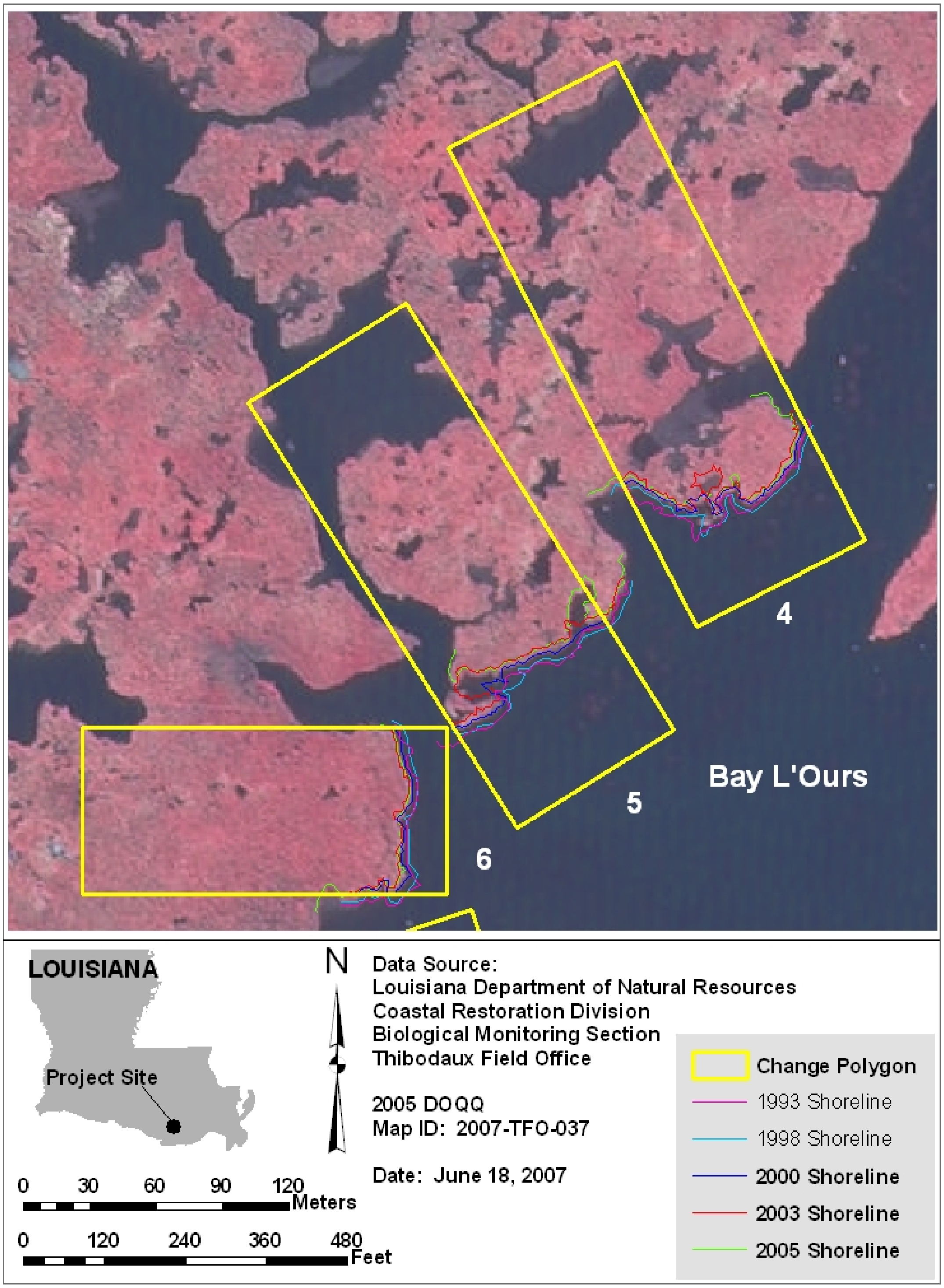

Figure 38. Location of 1993, 1998, 2000, 2003, and 2005 shoreline segments 4-6 for the GIWW (Gulf Intracoastal Waterway) to Clovelly Hydrologic Restoration (BA-02) project. Construction for the shoreline protection rock dike was completed in October 2000.

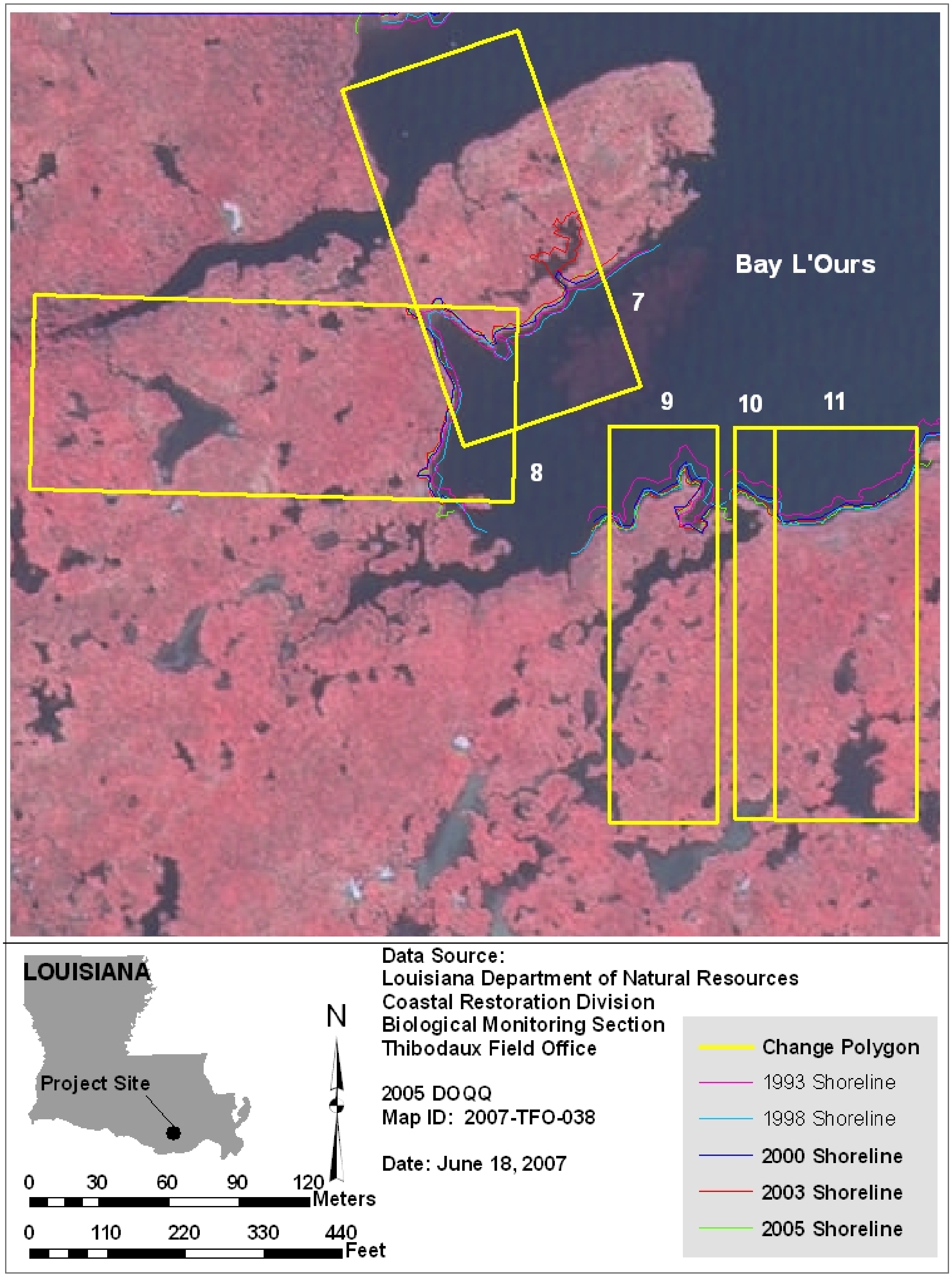

Figure 39. Location of 1993, 1998, 2000, 2003, and 2005 shoreline segments 7-11 for the GIWW (Gulf Intracoastal Waterway) to Clovelly Hydrologic Restoration (BA-02) project. Construction for the shoreline protection rock dike was completed in October 2000.

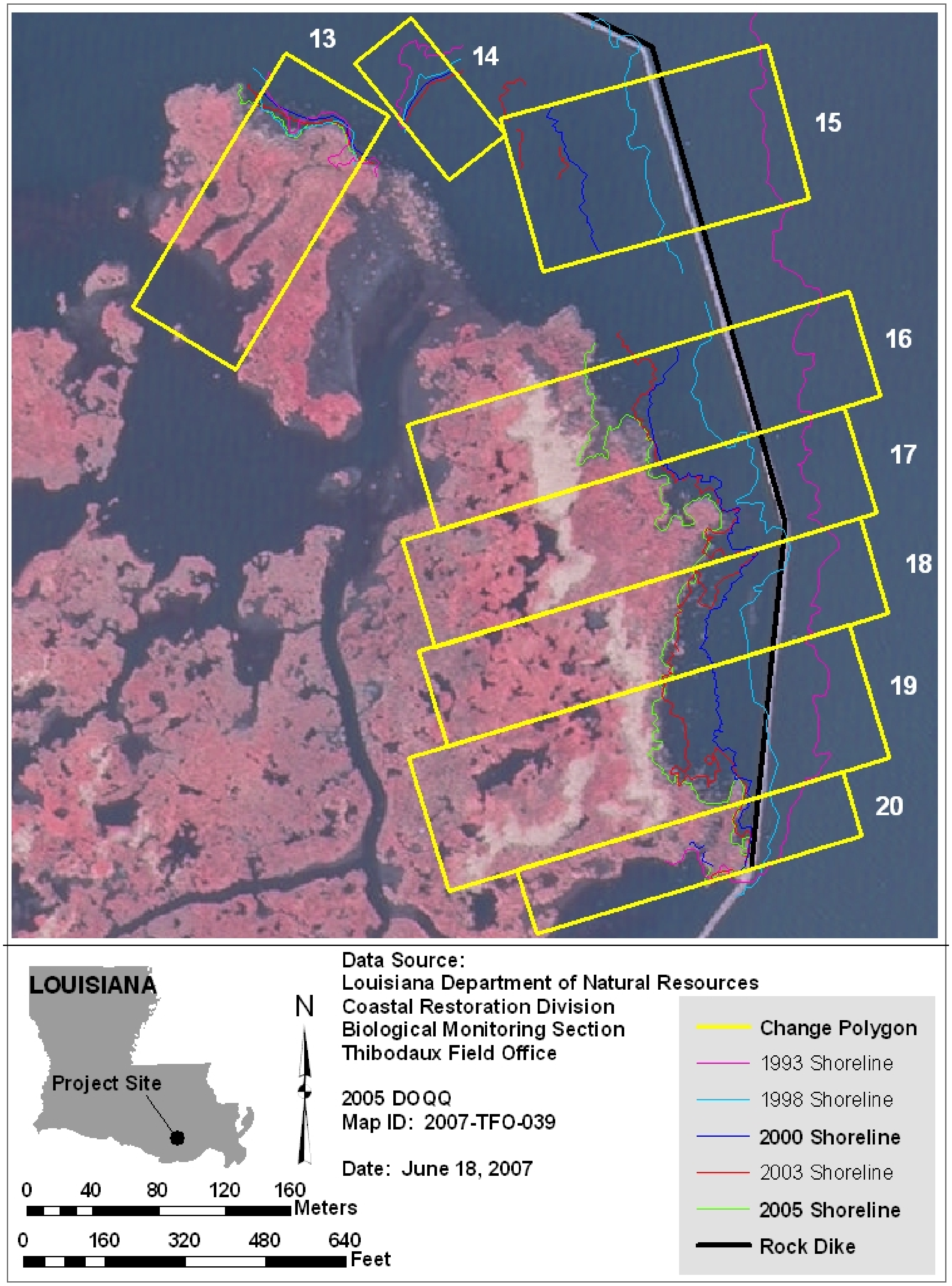

Figure 40. Location of 1993, 1998, 2000, 2003, and 2005 shoreline segments 13-20 for the GIWW (Gulf Intracoastal Waterway) to Clovelly Hydrologic Restoration (BA-02) project. Construction for the rock dike was completed in October 2000.

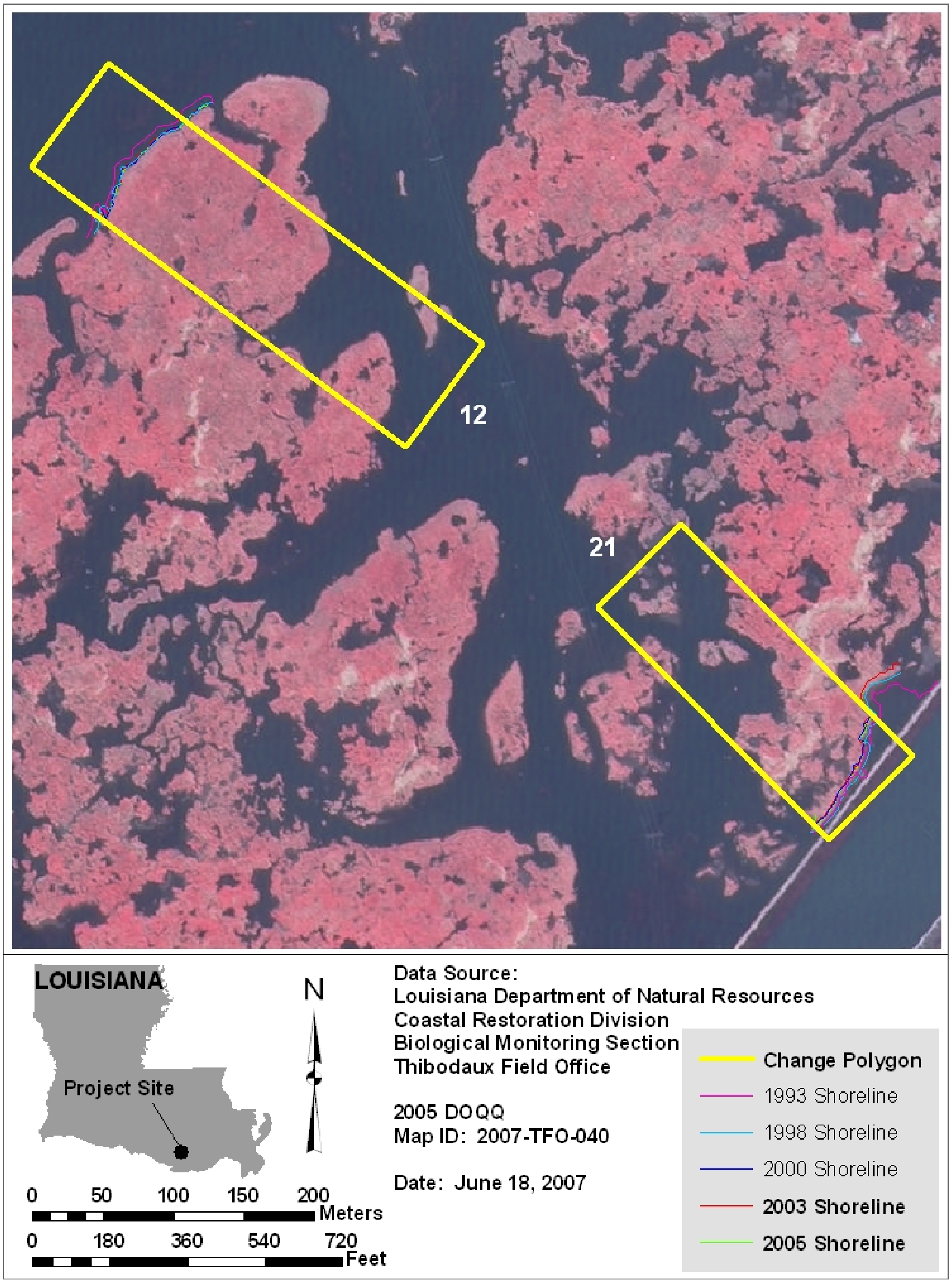

Figure 41. Location of 1993, 1998, 2000, 2003, and 2005 shoreline segments 12 and 21 for the GIWW (Gulf Intracoastal Waterway) to Clovelly Hydrologic Restoration (BA-02) project. Construction for the shoreline protection rock dike was completed in October 2000.

Data Analysis Methods for Shoreline Change:

Georectified DGPS shoreline segments from each survey year were entered into ArcView GIS® Version 3.2 and converted to shapefiles. Polygons were created from these segments in order to have a pre-existing standardized area from which to calculate area and linear changes with polygons created from each data collection year. Shoreline segments for each year were also entered into ArcView GIS® Version 3.2 as shapefiles. Each shapefile was entered into Autodesk Map © 2004 where polygons were created for the segments. Area and distance calculations were made between the polygons and segments for each year using the area command function in Autodesk Map© 2004. Data generated from these calculations were entered into a Microsoft®Excel 2002, Version 10.43 worksheet and additional calculations were performed to determine the change rate per year for each shoreline segment. A bar chart was created for graphic representation of the data (figure 42).

The methods used to determine shoreline position from survey to survey allowed personnel to determine changes occurring between a five year pre-construction time range and a five year post-construction time range to determine project effects. Also, because the DGPS equipment used for these surveys was sub-meter accurate, the shoreline segments could be georectified to aerial photography, which made it possible to generate data and produce images showing the shoreline changes.

In order to calculate the change rate per year for a given span of years, the land area inside the standardized polygon created for each shoreline segment was first determined for each survey year. The difference between the areas inside the polygon for a given span of years represented the change in the area.

Year 2000 Area (m^2) - Year 2005 Area (m^2) = Area Change (m^2)

Next, an average change rate was calculated by taking the area change inside the shoreline segment polygon and dividing it by the shoreline segment length.

Area Change (m^2) ÷ Shoreline Segment Length (m) = Avg. Change Rate (m)

Finally, the average change rate was divided by the number of days within the span of the two surveys being compared, and then multiplied by 365.25 days to determine the change rate per year.

(Avg. Change Rate (m) ÷ # of Days between surveys) x 365.25 days = Change Rate/Year (m/yr^{-1})

Note: The 365.25 day count was used to make allowances for leap years.

Results indicate that the rock dike reduced the erosion rates for segments 1, 2, 9-12, and 16-20 (figure 42). While the erosion rate increased for segments 3-7 and 13. Segments 14 and 15 are not used for comparison since the entire land mass in these segments disappeared between 2003

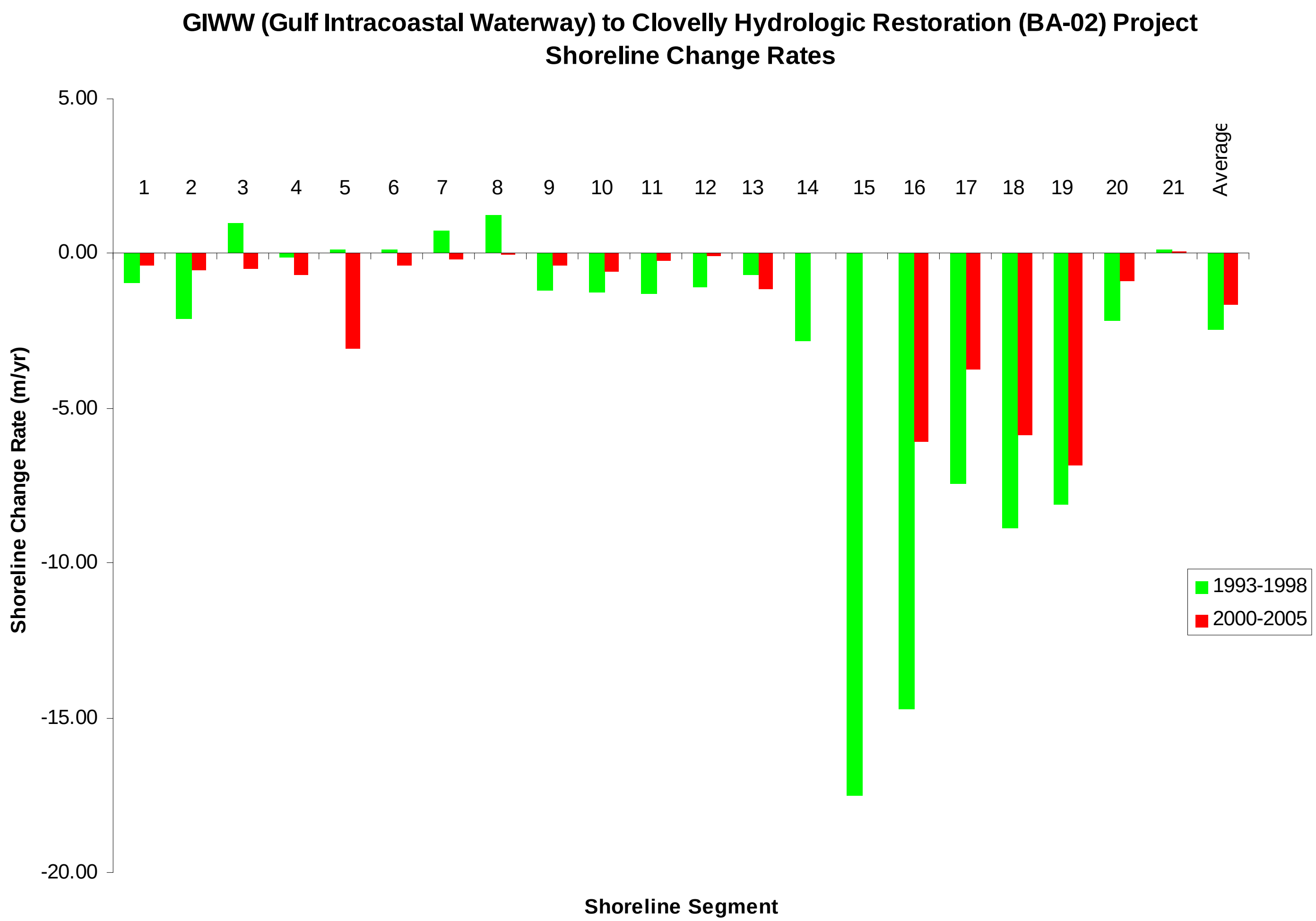

Figure 42. Shoreline change rates and the average shoreline change rate for each randomly selected shoreline segment pre- and post-construction. Note: Construction ended October 31, 2000. Segments 14 and 15 were not calculated into the "Average" change rate because they eroded completely away.

and 2005. The average shoreline erosion rate for 1993-1998 was 3.19 m/yr including segments 14 and 15, and 2.46 m/yr excluding segments 14 and 15. For the time period 2000-2005, the average shoreline rate was 1.66 m/yr excluding segments 14 and 15. Therefore, the average rate of erosion was reduced by 0.57 m/yr as a result of the rock dike. Several factors may attribute to the increase and decrease of erosion rates, which include, but are not limited to, orientation along the shoreline, proximity to the rock dike, and the amount of open water causing more frequent and larger wave action.

Submerged Aquatic Vegetation (SAV)

SAV data were collected during the fall of 1996, 1999, 2000, 2002, and 2005. Initially, fifteen (15) ponds were selected for data collection; however, three (3) ponds in the northern portion of the project were dropped due to land rights issues, as well as five (5) reference area ponds, leaving seven (7) ponds for SAV sampling (table 7; figure 43). Each pond was sampled at random points along transects using the rake method (Chabreck and Hoffpauir 1962; Nyman and Chabreck 1996). The number of random points and transects was determined based upon the size and configuration of the pond. Frequency of SAV occurrence was determined for each area from the number of points at which SAV occurred and the total number of points sampled.

Table 7. Sampling ponds and date ranges for SAV data collection at the GIWW (Gulf Intracoastal Waterway) to Clovelly Hydrologic Restoration (BA-02) project.

Station	1996	1999	2000	2002	2005
BA02-34	Yes	Yes	Yes	Yes	Yes
BA02-39	Yes	Yes	Yes	Yes	Yes
BA02-41	Yes	Yes	Yes	Yes	Yes
BA02-85	Yes	Yes	No	Yes	Yes
BA02-86	Yes	Yes	Yes	Yes	Yes
BA02-90	Yes	Yes	Yes	Yes	Yes
BA02-91	Yes	Yes	Yes	Yes	Yes
BA02-92	Yes	Dropped	Dropped	Dropped	Dropped
BA02-93	Yes	Dropped	Dropped	Dropped	Dropped
BA02-94	Yes	Dropped	Dropped	Dropped	Dropped
BA02-95R	Yes	Dropped	Dropped	Dropped	Dropped
BA02-96R	Yes	Dropped	Dropped	Dropped	Dropped
BA02-97R	Yes	Dropped	Dropped	Dropped	Dropped
BA02-98R	Yes	Dropped	Dropped	Dropped	Dropped
BA02-99R	Yes	Dropped	Dropped	Dropped	Dropped

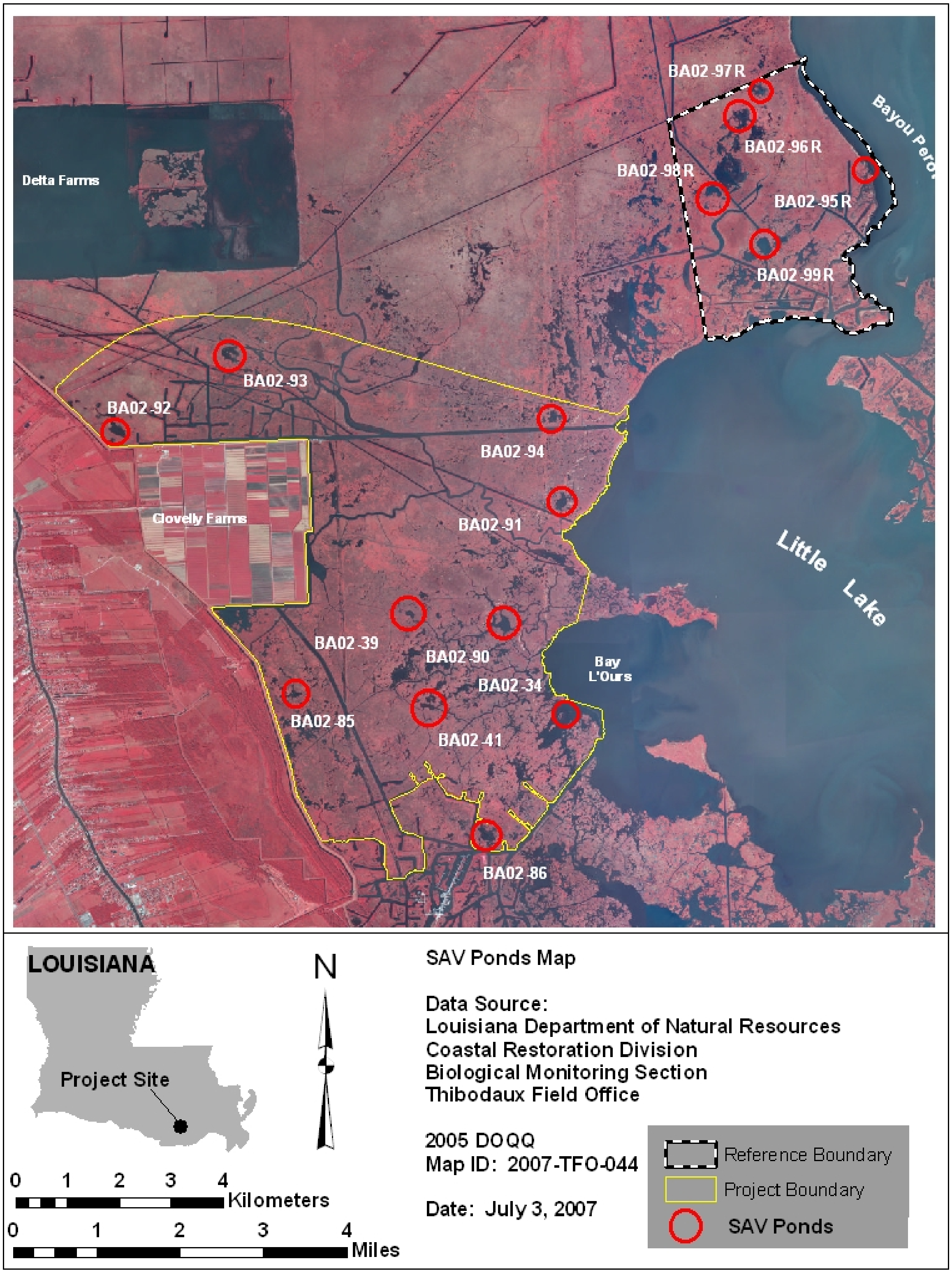

Figure 43. **Location map for the SAV ponds inside the GIWW (Gulf Intracoastal Waterway) to Clovelly Hydrologic Restoration (BA-02) project and reference area.**

Data Analysis Methods for SAV:

Field data were entered into an electronic format where LDNR/CRD personnel followed QA/QC procedures prior to data analysis as stated in Folse and West (2005).

Submerged aquatic vegetation sampling has occurred seven (7) times in five (5) different years (figure 44). In 1999 and 2000, data collection occurred in the spring and fall. Both spring sampling events show fewer empty pulls than the fall sampling. The larger difference is between the spring and fall 2000 sampling periods, when the drought may have had an impact on SAV abundance. Salinity was on the rise during the spring sampling period; however, the maximum salinity was recorded after the spring period, which may have affected the vegetation. The 2002 and 2005 results may be attributed to the passing of Hurricanes Lili (2002) and Katrina and Rita (2005).

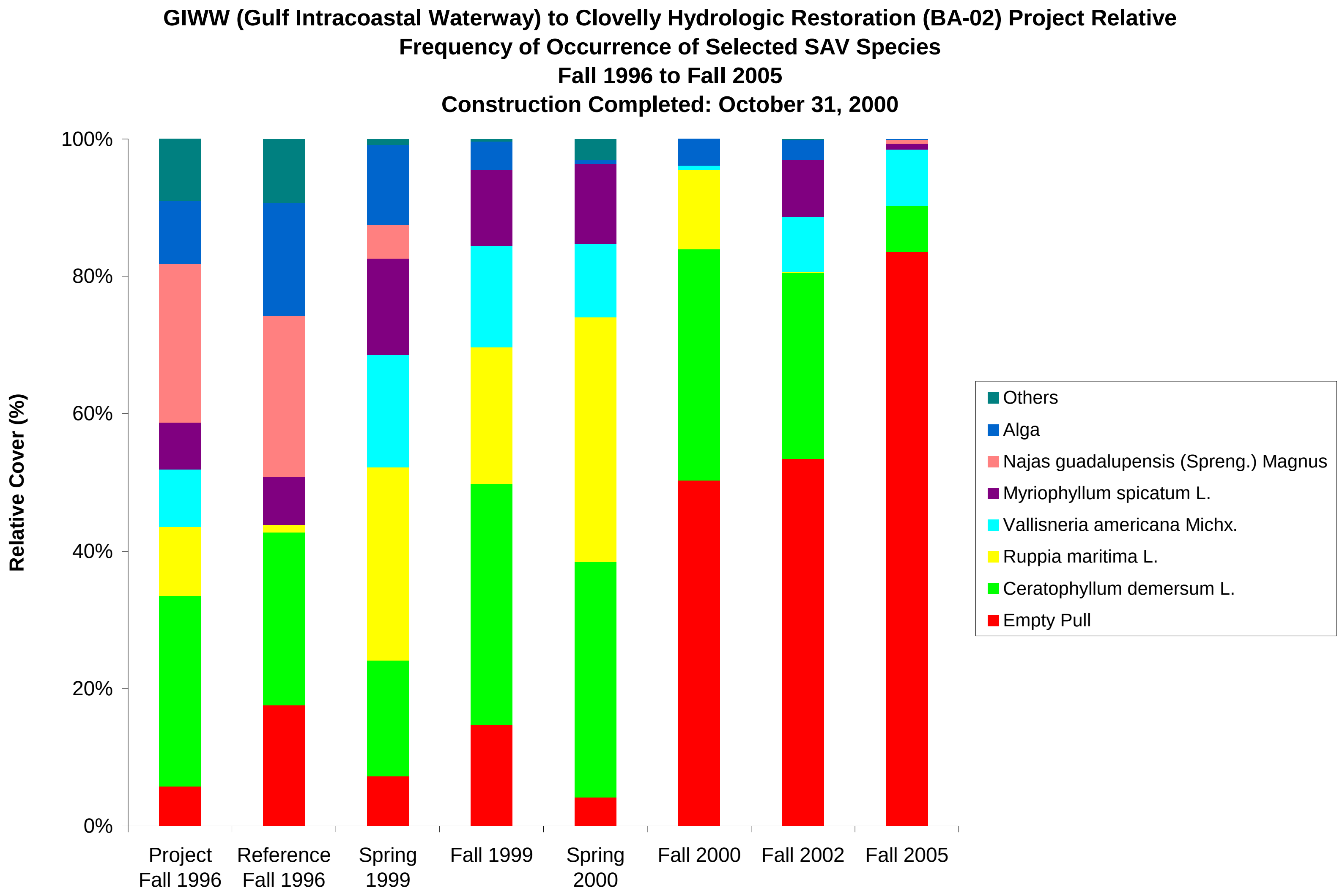

Figure 44. Relative frequency of occurrence of selected submerged aquatic vegetation species by project and reference area.

V. Conclusions

a. Project Effectiveness

Nine (9) years after the end of Construction Unit No. 1 and six (6) years after the end of Construction Unit No. 2, the project features have provided varying degrees of effectiveness within the project area. The ability to conclusively determine the project's effectiveness is limited by the fact that there is a lack of a true reference area collecting the same monitoring variables as the project area, and no pre-construction data. Continuous hydrographic data collection began during the construction of Construction Unit No. 1. However, it is anticipated that with the implementation of the CRMS-Wetlands project the project will be compared to adjacent marshes or marshes having the same classification throughout the coastal region.

The land-water analysis has shown a 21 acre (8.5 hectare) increase in land acreage between 1996 and 2002 while the reference area showed a 7 acre (2.8 hectare) loss of land to open water. During this period, the project's two construction units were completed and southeastern Louisiana experienced its worse drought on record. The reference area lost all of the fresh marsh community, which mostly converted to intermediate marsh, while the project area retained 65% of the 1996 fresh marsh community in 2002.

Without pre-construction water level and salinity data nor any continuous recorder stations in a reference area, project effectiveness determination is not conclusive. However, as the results of several analyses present illustrate the project area has not drastically changed marsh classifications. Data show the area to be classified as an oligohaline marsh (0.5 – 5.0 ppt).

Stress analysis for the dominant plant species, *Spartina patens*, show no significant increase in stress as it relates to salinity at any of the stations within the project area from the partial to post-construction period. On the other hand, one station (BA02-54) has shown a significant increase in plant stress as it relates to water levels. However, this was only determined for one of the five stations.

The only variable that has pre-construction, partial, and post-construction data is the discrete data. These data were collected at nine (9) stations and show a dramatic increase in salinity as time progressed. Figure 29 illustrates the mean bottom salinity readings collected during all time periods. The pre-construction data within the project area was in the freshwater (<0.5 ppt) and lower end of the oligohaline marsh classification whereas the post-construction data shows the mean salinity in the mid to upper ranges of the oligohaline marsh classification. Since data for all time periods have not been collected outside of the project area, project effectiveness cannot be determined since this may be a region response and not a project response.

The emergent vegetation in the project area seems to respond to changes in the salinity. As the mean salinity increases, the total number of species decreases and the mean percent cover of *Spartina patens* increase. Conversely, as the mean salinity decreases, the total number of species increases and the mean percent cover of *S. patens* decreases.

Similar effects occur with the submerged aquatic vegetation within the project area. As salinity increases, the total number of species and the relative frequency of species decreases.

The rock dike has reduced the average shoreline erosion rate in the immediate vicinity of its position. There were two (2) sampling areas that have been lost during the sampling time frame; however, the overall rate of erosion has decreased.

In an attempt to resolve the uncertainty of the biological response in relation to the current hydrologic conditions, LDNR contracted Fenstermaker & Associates to perform a hydrodynamic and salinity model of the GIWW to Clovelly Hydrologic Restoration (BA-02) project. The hydrodynamic model was completed in May 2006 and included an evaluation of constructed project features along the shoreline of Little Lake and an assessment of whether or not the constructed project features will remain as they are or will need design modifications. The hydrodynamic model showed that installing the structures does not have an impact on the salinity reduction north of the Clovelly Canal due to the existing ground slope in the project area, a decreasing slope southwards, forcing the water to flow from north to south. However, south of the Clovelly Canal, model results indicated that having all the structures in place reduced salinity in the project area "in the magnitude of 3-4 ppt on average at BA02-55 and BA02-58" (Meselhe et al. 2006). The model also yields a salinity reduction of "4-5 ppt" in the Clovelly Canal at BA02-54. Salinity reductions this large have been hard to reconcile with empirical evidence as discussed previously in section IV.d. of this report ("Salinity").

b. Recommended Improvements

Recommended improvements resulting from the 2007 annual inspection include repairing four (4) breaches located along existing oilfield canals on the southern end of the project area and removing existing marsh debris blocking the conveyance channel behind Structure No. 35. LDNR has initiated a maintenance project to address these deficiencies.

Other deficiencies noted in the inspection results of this report include moderate to severe settlement of the rock weirs along the shoreline of Little Lake and Bay L' Ours (Structures No. 2, 4, and 7) and moderate settlement of the rock dike along the lake rim. Prior to the 2008 annual inspection, we are recommending that a profile survey of all rock features be conducted to evaluate the extent of settlement and to determine which structures may require maintenance and/or rehabilitation.

c. Lessons Learned

Under the current design criteria for CWPPRA projects, most Hydrologic Restoration (HR) projects are designed with the aid of a hydrodynamic model to actively manage coastal restoration projects. Since the GIWW to Clovelly Hydrologic Restoration (BA-02) project was implemented in the early stages of the CWPPRA program, hydrologic modeling was not performed during the design phase. Evaluation of the initial post-construction data did not result in a conclusive determination regarding project effectiveness; therefore, a post construction hydrodynamic model was developed on a subset of project features to determine if the constructed features were providing the anticipated reduction in salinity and tidal exchange, and to assess whether the project features required design modifications. "The results of the model illustrated that the constructed features reduced salinity in the project area on the order of 3 to 4 ppt on average with no modifications. Modifications to the largest structure along Clovelly Canal revealed that an additional 2 to 3 ppt reduction in salinity levels could be attained by reducing the size of the barge bay opening" (Meselhe et al. 2006). From the limited modeling effort completed on this project, we have learned that biological data collection alone does not always provide the conclusive results in determining project effectiveness, and that biological data collection along with hydrodynamic modeling can be utilized to analyze goals and objectives of HR projects.

Land rights for both the project area and reference area need to be acquired prior to the construction of the project in areas that represent the project area. This was one of the first projects; land rights are currently acquired much earlier in the process than they were at the start when this project started..

Data collection stations need to be located in the proper areas both within the project area and—more importantly—in the reference area. Without a reference area, it is much more difficult to determine the effectiveness of the project features.

Data collection stations should not be inactivated until substitute stations are established and active. As with the CRMS-Wetlands project the anticipated timeline for station construction and activation was delayed due to several external factors. Project-specific stations should have remained active until the CRMS-Wetlands were active so there would be no data gaps.

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Appendix A

Three Year Budget Projections

GIWW TO CLOVELLY, PHASES 1 & 2 / BAO2 / PPL1

Three-Year Operations & Maintenance Budgets 07/01/2007 - 06/30/10

Project Manager	O & M Manager	Federal Sponsor	Prepared By
	B. Babin	NRCS	B. Babin

	2007/2008	2008/2009	2009/2010
Maintenance Inspection	$ 5,408.00	$ 5,569.00	$ 5,736.00
Structure Operation	$ 8,000.00	$ 8,000.00	$ 8,000.00
Administration	$ 8,000.00	$ 5,500.00	$ 5,500.00
Maintenance/Rehabilitation			

07/08 Description Major maintenance: Structure #35 clean-out and breach repairs

Routine Maintenance: navigation aid repairs, structure repairs, Assessment Survey of lake rim and rock weirs.

	2007/2008	2008/2009	2009/2010
E&D	$ 49,350.00		
Construction	$ 79,000.00		
Construction Oversight	$ 18,000.00		
Sub Total - Maint. And Rehab.	$ 146,350.00		

08/09 Description: Routine Maintenance: navigation aid repairs and miscellaneous maintenance

	2007/2008	2008/2009	2009/2010
E&D		$ -	
Construction		$ 5,000.00	
Construction Oversight		$ -	
	Sub Total - Maint. And Rehab.	$ 5,000.00	

09/10 Description: Routine Maintenance: navigation aid repairs and miscellaneous maintenance

	2007/2008	2008/2009	2009/2010
E&D			$ -
Construction			$ 5,000.00
Construction Oversight			$ -
		Sub Total - Maint. And Rehab.	$ 5,000.00

	2007/2008	2008/2009	2009/2010
Total O&M Budgets	**$ 167,758.00**	**$ 24,069.00**	**$ 24,236.00**
Total O&M Budget 2007 through 2010			**$ 216,063.00**
Unexpended O&M Budget			**$ 1,101,118.00**
Remaining O&M Budget (Projected)			**$ 885,055.00**

OPERATIONS & MAINTENANCE BUDGET WORKSHEET

Project: BA-02 GIWW to Clovelly Hydrologic Restoration Ph. 1 & 2

FY 07/08 –

Administration		$ 8,000*
O&M Inspection & Report		$ 5,408
Operation:		$ 8,000
Maintenance:		$110,000
E&D:	$ 13,000**	
Construction:	$ 74,000***	
Construction Oversight:	$ 18,000****	
General Maintenance:	$ 5,000***	

Operation and Maintenance Assumptions:

Structure Operations: water control structure operated twice annually for a total of $4,000 per operation. (2)($4,000) = $8,000 plus ($2,000 for LDNR administration.)*

General Maintenance: Water control structure, navigation aids repair. (Construction : $5,000)***. (Administration: $3,500)*

Maintenance: earthen embankment repairs and clean out behind Structure No. 35. The estimated construction cost is outlined below:

Mobilization & Demob:	$ 20,000	
Earthen embankment repairs:	$ 25,000	
Clean out Structure No. 35	$ 12,500	
	$ 57,500	
Contingency (20%)	$ 16,500	
Total Construction Cost:		$74,000***
Surveying (NRCS):	$ 3,000**	
Engineering & Design (LDNR):	$ 8,500**	
Construction Inspection:	$13,000****	
(IDIQ Contract: 200 hrs @ $65/hr.)		
LDNR Admin (Permit):	$ 1,500**	
Construction Admin LDNR:	$ 5,000****	
NRCS Admin:	$ 2,500*	
		$ 33,500
Overall Project Budget:		**$102,500**

FY 08/09 –

Administration		$ 5,500
O&M Inspection & Report		$ 5,569
Operation:		$ 8,000
Maintenance:		$ 5,000
E&D:	$ 0	
Construction:	$ 5,000	
Construction Oversight:	$ 0	

Operation and Maintenance Assumptions:

Structure Operations: water control structure operated twice annually for a total of $4,000 per operation. (2)($4,000) = $8,000 plus $2,000 for LDNR administration.

General Maintenance: Water control structure, navigation aids repair. Construction : $5,000. Administration: $3,500

FY 09/10 –

Administration		$ 5,500
O&M Inspection & Report		$ 5,736
Operation:		$ 8,000
Maintenance:		$ 5,000
E&D:	$ 0	
Construction:	$ 5,000	
Construction Oversight:	$ 0	

Operation and Maintenance Assumptions:

Structure Operations: water control structure operated twice annually for a total of $4,000 per operation. (2)($4,000) = $8,000 plus $2,000 for LDNR administration.

General Maintenance: Water control structure, navigation aids repair. Construction : $5,000. Administration: $3,500.

Appendix B

Inspection Photos

Photo No.1 – (Structure No.1) – rock weir with barge bay located along Superior Canal looking north.

Photo No. 2 – (Structure No.1) – view of slight damage to timber pile cluster at Structure No.1.

Photo No. 3 – (Structure No. 1) – view of timber pile cluster located on the northeast side of the structure.

Photo No. 4 – (Structure No. 2) – north side of rock weir with boat bay looking east.

Photo No. 5 – (Structure No. 2) – south side of rock weir w/boat bay looking southwest from Bay L'Ours.

Photo No. 6 – (Structure No. 2) – view of rock weir with boat bay from edge of Bay L' Ours.

Photo No. 7 – (Structure No. 2) – view of rock weir with boat bay from Bay L' Ours looking southwest.

Photo No. 8 – (Structure No. 4) – south side of rock weir with boat bay looking southeast.

Photo No. 9 – (Structure No. 4) – photo of rock weir with boat bay looking east from Bay L' Ours.

Photo No. 10 – (Structure No. 7) – north side of rock weir with boat bay looking east.

Photo No. 11 – (Structure No. 8) – small rock channel plug adjacent to Structure 7 looking north.

Photo No. 12 – (Structure No. 43) – rock channel plug on the interior of project area looking northeast.

Photo No. 13 – (Structure No. 91) – rock plug with flap gated structure located off of location canal.

Photo No. 14 – (Structure No. 91) – view of rock plug with flap gate and interior marsh side of structure.

Photo No. 15 – (Structure 4A & 4B) – rock riprap channel plug located along bank of Bay L' Ours.

Photo No. 16 – (Structure No. 14A) – barge bay opening looking southwest from Little Lake.

Photo No. 17 – (Structure No. 14A) – rock weir along the bank of Little Lake looking northwest.

Photo No. 18 – (Structure No. 35) – view of marsh plug behind Structure No. 35 along oilfield location canal.

Photo No. 19 – (Structure No. 35) – view of steel sheet pile wall of water control structure southeast side.

Photo No. 20 – (Structure No. 90) – south side of rock channel plug on location canal to Superior Canal.

Photo No. 21 – (Structure No. 90) – view of rock channel plug looking southwest to Superior Canal.

Photo No. 22 – (Structure No. 90) – view of rock channel plug looking southwest towards Superior Canal.

Photo No. 23 – (Lake Rim) – rock bank stabilization along the west shoreline of Bay L' Ours.

Photo No. 24 – (Lake Rim) – view of lake rim restoration along the north bank Brenton Canal.

Photo No. 25 – (Breach 1) – located along second oilfield canal from Bay L' Ours to Benton Canal..

Photo No. 26 – (Breach 2) –located on location canal south of Structure No. 91.

Photo No. 27 – (Breach 3) – located along same canal as Breach 2 but farther northward on the west bank.

Photo No. 28 – (Breach 4) – located along oilfield canal leading to Structure No, 91 on the west bank.

Appendix C

Field Inspection Reports

MAINTENANCE INSPECTION REPORT CHECK SHEET

Project No. / Name: **BA-02 GIWW / Clovelly Hydrologic Restoration** — Date of Inspection: February 13, 2007

Structure No. Site No. 1 — Inspector(s): B. Babin, S. Triche, E. Lear, W. Blanchard, B. Payton

Structure Description: Rip-Rap Cannel Plug — Water Level Inside:______ Outside: ______

Type of Inspection: Annual, Post Storm, other _Annual — Weater Conditions: M. Cloudy and Windy

Item	Condition	Pysical Damage	Corrosion	Photo #	Observations and Remarks
Signage /Supports	Good			25 thru 27	Rock weir was in good condition with no signs of settlement or displaced rock. All signage was also in good condition. We did notice, as reported in previous reports, that the timber pile clusters at the entrance and exit of the barge bay are slightly damaged from barges rubbing and scarring the timber piling while acessing the barge bay. The cable wraps on the pile cluster was loose on several dolphins. It is apparent that the timber pile clusters are not damaged to the extent that failure is eminent. We will continue to monitor the condition of these piles on future site visits.
Eathern Embankment	Good				
Rip Rap Weir	Good				
Timber piling and hardware	Fair	slight damage to timber piling and loose cable wraps			

Construction Unit No.2
Structure Description: 259 linear ft. rock rip-rap fixed crest weir with a 20 ft. boat bay across Superior Canal located east of the west fork of Bayou L'Ours, south of Clovelly Farms, Clovelly Canal and Site No.90, and west of Brusle Lake. The crest of the weir is set at 3.0 ft. elevation. The invert of the boat bay is set at -5.0' elevation. Two (2) navigation aid and warning signs are located on each side of the structure at the entrance of the boat bay.

MAINTENANCE INSPECTION REPORT CHECK SHEET

Project No. / Name: **BA-02 GIWW / Clovelly Hydrologic Restoration** — Date of Inspection: February 13, 2007

Structure No. Site No. 2 — Inspector(s): B.Babin, S. Triche, E. Lear, W. Blanchard, B. Payton

Structure Description: Fixed Crest Rock Weir w/ Boat Bay — Water Level Inside:

Type of Inspection: Annual, Post Storm, other Annual — Weater Conditions: Cloudy and windy

Item	Condition	Pysical Damage	Corrosion	Photo #	Observations and Remarks
Signage /Supports	Good			10 thru 13	The overall condition of the rock weir was good with significant settlement noticed on north side of the structure. We believe that the rock structure is still functioning as intended. Should the rock weir section on the north settle below the mean water level in the lake or bayou, our assessment would change and recommendation for maintenance may be necessary.
Eathern Embankment	Good				
Rock Weir	Fair				

Construction Unit No. 1
Structure Description: 200 linear ft. rock rip-rap fixed crest weir with a 15 ft. barge bay located south of Clovelly Canal, west of Bay L'Ours and northeast of Superior Canal and Site 91. The crest is set at an elevaiton of 2.3 ft. The invert of the boat bay is set at -5.1 ft. Aluminum warning signs are located on either side of the structure.

Marsh elevation: 1.36 ft.

MAINTENANCE INSPECTION REPORT CHECK SHEET

Project No. / Name: **BA-02 GIWW / Clovelly Hydrologic Restoration**

Date of Inspection: February 13, 2007

Structure No. Site No. 4A & B

Inspector(s): B. Babin, S. Triche, E. Lear, W. Blanchard, B. Payton

Structure Description: Rock Rip-Rap Channel Plug

Water Level Inside: N/A Outside: N/A

Type of Inspection: Annual, Post Storm, other Annual

Weater Conditions: Cloudy and Windy

Item	Condition	Pysical Damage	Corrosion	Photo #	Observations and Remarks
Timber Piles / Timber Wales	Good			8 & 9	The rock channel plug appeared to be in good condition with not signs of settlement
Galv. Pile Caps					The marsh on each side of the plug was thin at the tie-ins. This area experienced
Signage /Supports	Good				significant erosion from Hurricanes Katrina and Rita. No breaching is occuring at this time. We will continue to monitor the condition of the tie-ins.
Eathern Embankment	Fair	marsh thin around on each side of tie-ins.			
Rip Rap Channel Plug	Good				

Construction Unit No. 1

Structure Description: 90 linear ft. rock rip-rap channel plug located along the bank of Little Lake northeast of Site No.4. The Channel plug has an 8 ft. wide crest with 3:1 side slopes. The crest is set at +2.0 ft. AML (above marsh level). Marsh level was determined to be +1.47 ft. Prior to placement of rip-rap, the existing channel bottom was lined with a 84ft. X 30ft. Geogrid mat.

Marsh Level: +1.51'

MAINTENANCE INSPECTION REPORT CHECK SHEET

Project No. / Name: **BA-02 GIWW / Clovelly Hydrologic Restoration**

Date of Inspection: February 13, 2007

Structure No. Site No. 4

Inspector(s): B. Babin, S. Triche, E. Lear, W. Blanchard, B. Payton

Structure Description: Fixed Crest Rock Weir w/ Boat Bay

Water Level Inside:

Type of Inspection: Annual, Post Storm, other Annual

Weater Conditions: M. cloudy and windy

Item	Condition	Pysical Damage	Corrosion	Photo #	Observations and Remarks
Signage /Supports	Good			6 and 7	During the inspection of Structure No.4, we observed that the north side of the rock weir had settled below the water level estimated at 0.0'. The sign on the north side
Eathern Embankment	Good				was missing. The south side of the rock weir was in good condition with no noticeable settlement. We will re-evaluate the condition of the rock weir on the norht at a later date and discuss possible maintenance to raise the elevation of the north side with
Rock Weir	Fair				NRCS.

Construction Unit No.1

Structure Description: 160 linear ft. rip-rap fixed crest weir with a 20 ft. boat bay located shouth of Clovelly Canal, west of Bay L'Ours, just north of Site 2, and northeast of Superior Canal and Site 91. The crest of the weir was set at 2.4 ft. The invert of the boat bay is set at -3.9'. Aluminum warning signs are located in the center of the rock weir sections.

Marsh Level: +1.35'

MAINTENANCE INSPECTION REPORT CHECK SHEET

Project No. / Name: **BA-02 GIWW / Clovelly Hydrologic Restoration** Date of Inspection: February 13, 2007

Structure No. Site No. 7 Inspector(s): B.Babin, S. Triche, E. Lear, W. Blanchard, B. Payton

Structure Description: Fixed Crest Rock Weir w/ Boat Bay Water Level Inside:

Type of Inspection: Annual, Post Storm, other Annual Weater Conditions: M. Cloudy and Windy

Item	Condition	Pysical Damage	Corrosion	Photo #	Observations and Remarks
Signage /Supports	Good			4	**Observation:**
					The north side of the rock weir has experienced slight settlement since placement.
Eathern Embankment	Good				of rip-rap. Overall, the rock weir was in good condition with only minor settlement noted. The signs and supports were also in good condition.
					No maintenance will be required at this time.
Rock Weir	Fair				

Construction Unit No. 1

Structure Description: 200 linear ft. rip-rap fixed crest weir with a 20 ft. boat bay located south of Clovelly Canal, west of Little Lake and north of Site 4 in Bayou De La Gauche. The crest of the weir is set at and elevation of 2.4 ft. The invert of the boat bay is set at and elevation of -4.4'. Aluminum warning signs are located in the center of the rock weir sections.

Marsh Level: +1.42'

MAINTENANCE INSPECTION REPORT CHECK SHEET

Project No. / Name: **BA-02 GIWW / Clovelly Hydrologic Restoration** Date of Inspection: February 13, 23007

Structure No. Site No.8 Inspector(s): B. Babin, S. Triche, E. Lear, W. Blanchard, B. Payton

Structure Description: Rock Lined Channel Water Level Inside: N/A Outside: N/A

Type of Inspection: Annual, Post Storm, other Annual Weater Conditions: M. Cloudy and Windy

Item	Condition	Pysical Damage	Corrosion	Photo #	Observations and Remarks
				5	
					Observation:
Signage /Supports	Good				The small rock weir adjacent to Structure No.7 was in good condition with no indication of damage or settlement. The gate and signage was also in good condtion.
					No maintenance required at this time.
Eathern Embankment	Good				
Rock rip rap weir	Good				

Construction Unit No.1

Structure Description: 65 linear ft. rock rip-rap fixed crest weir with a 8' wide boat bay located in a pipeline channel south of the Clovelly Canal and west of Little Lake. The crest of the weir was set at +1.0 ft. AML (above marsh level). Marsh level was determined to be 1.8 ft. The invert of the boat bay was constructed at an elevation of -3.5 ft. Aluminum warning signs supported by galvanized pipes are located at the entrance of the pipeline canal.

Marsh Level: +1.8'

MAINTENANCE INSPECTION REPORT CHECK SHEET

Project No. / Name: **BA-02 GIWW / Clovelly Hydrologic Restoration** Date of Inspection: February 13, 2007

Structure No. Site 14A Inspector(s): B. Babin, S. Triche, E. Lear, W. Blanchard, B. Payton

Structure Description: Fixed crest rock weir with barge bay Water Level Inside: N/A Outside: N/A

Type of Inspection: Annual, Post Storm, other Annual Weater Conditions: Cloudy and windy

Item	Condition	Pysical Damage	Corrosion	Photo #	Observations and Remarks
Timber Piles /		Slight damage to			**Observation:**
Timber Wales	Fair	timber dolphin		1 & 2	Rock weir was in good condition with no noticeable settlement along the length of
Galv. Pile Caps		system NW side			the structure. As noted in hurricane assessment report, a small area of the rock
Cable /					weir on the south side of the barge bay was displaced by Hurricane Katrina.
Hardware etc.	Fair	Loss cables on			The damage to the rock weir is considered minimal and not affecting the overall
		several dolphins			effectiveness of the structure. Continue to monitor on future trips.
Signage					
/Supports	Good				We did notice that one (1) of the timber pile supports on the northwest side of the
					structure was damaged from apparent collision with water vessel or barge.
Eathern		moderate erosion			The damage does not appear to compromsie the structure intergrity of the structure.
Embankment	Fair	on south side of			continue to monitor on quarterly inspections by Automatic Power.
		structure			
Rock Weir					
	Good				Automatic Power of Larose has been awarded a maintenance contract to
					perform quarterly inspections and maintenance of these four (4) navigation lights.
					As noted in previous reports, the elevation of the marsh tie-in on the south side of the
					structure is very low and has eroded over the years leaving a low lying bank open
					to the marsh behind the structure. Although noticeable erosion has taken place in this
					area, no breaches have been identified.

Construction Unit No.2

Structure Description: 1,644 linear ft. rock rip-rap weir with 80 ft. barge bay crossing Clovelly Canal west of Little Lake. The crest of the weir is set at 3.0 ft. The invert of the 80 ft. barge bay is set at -6.5'. Galvanized warning signs and navigation lights supported by timber piles are located at the entrance of the barge bay.

Marsh elevation:

MAINTENANCE INSPECTION REPORT CHECK SHEET

Project No. / Name: **BA-02 GIWW / Clovelly Hydrologic Restoration** Date of Inspection: February 13, 2007

Structure No. Site No. 35 Inspector(s): B. Babin, S. Triche, E. Lear, W. Blanchard, B. Payton

Structure Description: Variable Crest Weir Structure Water Level Inside: Outside:

Type of Inspection: Annual, Post Storm, other Annual Weater Conditions: M. Cloudy and Windy

Item	Condition	Pysical Damage	Corrosion	Photo #	Observations and Remarks
Steel Bulkhead					
/ Caps	Good	None	Paint	16 & 17	Structure #35 was in good condition with minor paint chipping of the channel caps
			Chipping		and handrailing on the bulkhead and walkway. The lifting boom and signage was
Stop Logs					also in good condition. The channel leading to the interior marsh behind the structure
	Good	None			is still clogged with marsh material from Hurricane Katrina and Rita. LDNR is expected
					to receive bids for the clean-out of the marsh material in late June 2007.
Handrails					
Grating	Good		Paint		The variable crest weir had not been operated since the storms. Normal operations
Hardware etc.			Chipping		will continue once the marsh behind the structure is removed and hydrologic
Timber Piles /					connections re-established.
Timber Wales	Good				
Galv. Pile Caps					
Cable /					
Hardware etc.	Good				
Signage					
/Supports	Good				
Eathern					
Embankment	Good				

Construction Unit No.2

Structure Description: 80 linear ft. sheet pile variable crest weir with an eitght (8) ft. wide variable crest weir section located in a pipeline canal off of the Brenton Canal, south of Clovelly Canal, east of Superior Canal. The structure consist of an eight (8) ft. wide stop log bay with eight (8) 4" x 6" stop logs secured by guide channels. The stop logs can be adjusted from 1.0 ft. to -3.0 ft. On either side of the variable crest section is steel bulkhead set at an elevation of 3.0' along with steel deck and rotatable crane and winch to remove and replace stop logs.

MAINTENANCE INSPECTION REPORT CHECK SHEET

Project No. / Name: **BA-02 GIWW / Clovelly Hydrologic Restoration**

Date of Inspection: February 13, 2007

Structure No. Site No. 43

Inspector(s): B.Babin, S. Triche, E. Lear, W. Blanchard, B. Payton

Structure Description: Rock rip-rap channel plug

Water Level Inside: N/A Outside: N/A

Type of Inspection: Annual, Post Storm, other Annual

Weater Conditions: M. Cloudy and Windy

Item	Condition	Pysical Damage	Corrosion	Photo #	Observations and Remarks
Signage /Supports	Good			3	The rock weir was in good condition with a 10' section of the rock plug on the east side was low. We did not notice any water flow over the plug at this location.
Eathern Embankment	Fair	10' section on east side is low			The low area on the east side of the plug has been reported on previous reports and does not appear to have worsened. No maintenance at this time.
Rip Rap Channel Plug	Fair	low and thin			The earthen embankment tie-ins on both side of the plug were in fair condition with no breaching. The earthen tie-ins did appear to be low and thin in areas.
					No immediate maintenance required at this site.

Construction Unit No.1

Structure Description: 85 linear ft. rock rip-rap channel plug located in a pipeline channel south of the Clovelly Canal, east of Clovelly Farms, and west of Little Lake. The crest of the plug is set at elevation of 2.45 ft. Aluminum warning signs are located through the rock embankment on both sides of the structure.

Marsh elevation: +1.47'

MAINTENANCE INSPECTION REPORT CHECK SHEET

Project No. / Name: **BA-02 GIWW / Clovelly Hydrologic Restoration**

Date of Inspection: February 13, 2007

Structure No. Site No. 90

Inspector(s): B. Babin, S. Triche, E. Lear, W. Blanchard, B. Payton

Structure Description: _Rip-Rap Cannel Plug

Water Level Inside: Outside:

Type of Inspection: Annual, Post Storm, other _Annual

Weater Conditions: Cloudy and Windy

Item	Condition	Pysical Damage	Corrosion	Photo #	Observations and Remarks
Signage /Supports	Good			21 thru 23	The rock plug at this location was very high and in good conditon. No even the slightest settlement noticed. The signs and timber supports was in good condition.
Eathern Embankment	Good				No maintenance require at Structure 90.
Rip Rap Channel Plug	Good				

Construction Unit No.2

213 linear ft. rock rip-rap channel plug located across a pipline channel north of Site No. 1, south of Clovelly Farms and Clovelly Canal, and west of Brusle Lake. The crest of the plug is set at an elevation of 3.0 ft. Three (3) aluminum warning signs are located adjacent to the structure.

MAINTENANCE INSPECTION REPORT CHECK SHEET

Project No. / Name: **BA-02 GIWW / Clovelly Hydrologic Restoration**

Date of Inspection: February 13, 2007

Structure No. Site No. 91

Inspector(s): B. Babin, S. Triche, E. Lear, W. Blanchard, B. Payton

Structure Description: Rip-Rap Cannel Plug

Water Level Inside:________ Outside: ________

Type of Inspection: Annual, Post Storm, other Annual

Weater Conditions: M. Cloudy and Windy

Item	Condition	Pysical Damage	Corrosion	Photo #	Observations and Remarks
Signage /Supports	Good			19 & 20	the rock plug and earthen embankments at Structure 91 was in very good condition
					with no apparent settling of the structure or wash-outs of the earthen tie-ins.
Eathern Embankment	Good				The culvert and flap gate appreared to be experiencing minor corrosion by still in working condition. No maitnenance require at this site.
Rip Rap Channel Plug	Good				
Culvert / Flap Gate	Fair		Minor		

Construction Unit No.1

Structure Description: 120 linear ft. rock rip-rap channel plug located in a pipeline canal off of Superior Canal, south of Clovelly Canal, west of Brenton Canal and east of Superior Canal. The structure consist of a 10 gauge corrugated aluminum pipe (36" dia.) through the plug embankment. The invert of the pipe is set at elevation -2.87' The pipe is approximately 44 ft. long supported by 8-12" diameter creosote timber piles 50 ft. long. The aluminum flap gate is attached to the canal side of the structure. A 16' x 21' rock rip-rap scour pad 2' thick is located at the opening of the canal.

MAINTENANCE INSPECTION REPORT CHECK SHEET

Project No. / Name: **BA-02 GIWW / Clovelly Hydrologic Restoration**

Date of Inspection: February 13, 2007

Structure No. No number assigned

Inspector(s): B.Babin, S Triche, E. Lear, W. Blanchard, B. Payton

Structure Description: Earthen Embankment Stabilization

Water Level ________ Inside: ________

Type of Inspection: Annual, Post Storm, other Annual

Weater Conditions: cloudy and windy

Item	Condition	Pysical Damage	Corrosion	Photo #	Observations and Remarks
Earthen Embankment	Good	4 breaches			In the Hurricane Assesement Report and Inspection performed post Katrina and Rita,
					four (4) breaches were identified as a result of the storms. These four (4) breaches
					remain in similar condition. Below are the coordinates for each locations.
					Coordinates in State Plane (ft.)
					Breach 1
				Unavailable	3,631,076 (Easting)
					360,907 (Northing)
					Breach 2
				28	3,629,808 (Easting)
					360,153 (Northing)
					Breach 3
				30	3,629,556 (Easting)
					359,963 (Northing)
					Breach 4
				24 & 29	3,626,317 (Easting)
					359,652 (Northing)
					The repair of these four (4) breaches are included in the 2006 Maintenance Project
					along with clean-out of Structure #35 which is scheduled to bid sometimes in late June.
					Several of photos taken the day of the inspection did not come out and are no good.
					We have included photos of the breaches taken after Hurricane Katrina and Rita.

Construction Unit No. 2

Structure Description: 18,400 linear ft. of rock armored earthen embankment along Brenton Canal, Bay L Ours and various oil field canals.

MAINTENANCE INSPECTION REPORT CHECK SHEET

Project No. / Name: **BA-02 GIWW / Clovelly Hydrologic Restoration**

Date of Inspection: February 13, 2007

Structure No. No number assigned

Inspector(s): B.Babin, S Triche, E. Lear, W. Blanchard, B. Payton

Structure Description: Lakerim Stabilization

Water Level ________________ Inside: _____________

Type of Inspection: Annual, Post Storm, other Annual

Weater Conditions: cloudy and windy

Item	Condition	Pysical Damage	Corrosion	Photo #	Observations and Remarks
Signage /Supports	Good			14 and 15	As observed in previous annual inspectons, several locations of the armored embankment along the lake rim Bay L' Ours are low and have settled since construction. These include area near Sta. 9+00 to Sta. 13+00, Sta. 36+00 to Sta. 41+00 and Sta. 50+00. It is difficult to determine exactly how much settlement has occurred without a survey profile of the entire lake rim. This is something that LDRN and the federal sponser may consider. At this time, we will continue to monitor these areas on future visits.
Rock Armored Embankment	Fair to Good	Low in several locations			
Settlement Plates	Good				
					Within the last month, BP Pipeline has removed a rock dike protecting and exposed length of pipeline in Bay L' Ours near the mouth of Benton Canal. With consent from LDNR and NRCS, a portion of this rock rip rap removed from the dike was used to shore up low areas of the lake rim section on the north side of Benton Canal.

Construction Unit No. 2

Structure Description: 18,400 linear ft. of rock armored earthen embankment along Brenton Canal, Bay L Ours and various oil field canals.