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Coastal Protection and Restoration Authority of Louisiana

Office of Coastal Protection and Restoration

2010 Operations, Maintenance, and Monitoring Report

for

East Mud Lake Marsh Management (CS-20)

State Project Number CS-20
Priority Project List 2

December, 2010
Cameron Parish

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I. Introduction

The East Mud Lake Marsh Management Project (CS-20) area consists of 8,054 acres (3259 ha) located in the Calcasieu/Sabine Basin in Cameron Parish, Louisiana (figure 1). The project is bounded by LA Hwy 82 to the south, LA Hwy 27 to the west, Magnolia Road to the north, and an existing levee and property line near Oyster Bayou to the east.

The CS-20 project area is physiographically complex with three wetland habitat types (Deep, Shallow, and Meadow Marsh; after USDA-SCS 1951) and has been characterized as brackish marsh since the first vegetation map of 1949 (O'Neil 1949). Adjacent marshes to the west and northwest have freshened to intermediate marsh over time (Chabreck et al. 1968, Chabreck and Linscombe 1988, Visser et al. 2000) while the project area has remained brackish. The south end of Mud Lake contained dense stands of *Ruppia maritima* (widgeon grass) prior to 1960; however, hydrologic conditions have changed causing elevated water levels, rapid water-level fluctuations, high salinities, and wide salinity fluctuations (USDA-SCS 1994). The percent of land has deteriorated from 99% in 1953 to 57% by 1992 (USDA-SCS 1992).

Tidal flow into and out of the project area has historically been from the north (LCWCRTF 2002). Oyster Bayou and Mud Pass provide outlets from the area on the east and south. Fresh water historically entered the area from the west via sheet flow and input from First and Second Bayous; however, the installation of LA Hwy 27 and its associated borrow canals has restricted freshwater input from the west (figure 1). Second Bayou has silted in since 1957 and now provides little or no freshwater flow. First Bayou remains the main source of freshwater introduction into the area; however, it is also silting in, and much of the remaining fresh water is diverted by the LA Hwy 27 borrow canal.

Several human induced hydrologic changes have increased tidal fluctuations further into the coastal wetlands and led to the deterioration of the marsh over the years on a basin-wide scale, highlighted by the installations and channel bottom maintenance of the Calcasieu (permanently opened to the Gulf of Mexico in 1903, deepened to 30 ft and widened to 250 feet in 1941, deepened to 40 ft [12.2 m] and widened to 400 ft [122 m] over time to current dimensions by 1968) and Sabine-Neches (commissioned to 9 ft [2.7 m] deep and 100 ft [305 m] wide in 1908, deepened to 25 ft [7.6 m] in 1916, deepened to 40 ft [12.2 m] and widened to 400 ft [122 m] over time to current dimensions in 1972) Ship Channels and the Gulf Intracoastal Waterway between the Sabine and Calcasieu Rivers (5 ft [1.5 m] deep by 40 ft [12.2 m] wide channel installed 1913-1915, deepened to 30 ft [9.1 m] and widened to 125 ft [38 m] in 1927, depth maintained at 12 ft [3.7 m] since 1949) (see LCWCRTF 2002). Specific to the project area, Mud Lake and its adjacent marshes suffer from increased flooding and salinity via the Calcasieu Ship Channel/Pass and isolation/fragmentation from adjacent marshes. The project area is connected by water to the Calcasieu Ship Channel (CSC) via Mud and Oyster Bayous to the east and the West Cove Canal to the north. Because the CSC/Pass has been maintained at a depth of 40 ft (12.2 m) and bottom width of 400 ft (122 m) without obstruction since 1968, high tidal amplitudes and salt water from the Gulf of Mexico are drawn into the project area. In addition, high water levels are impounded over the marsh

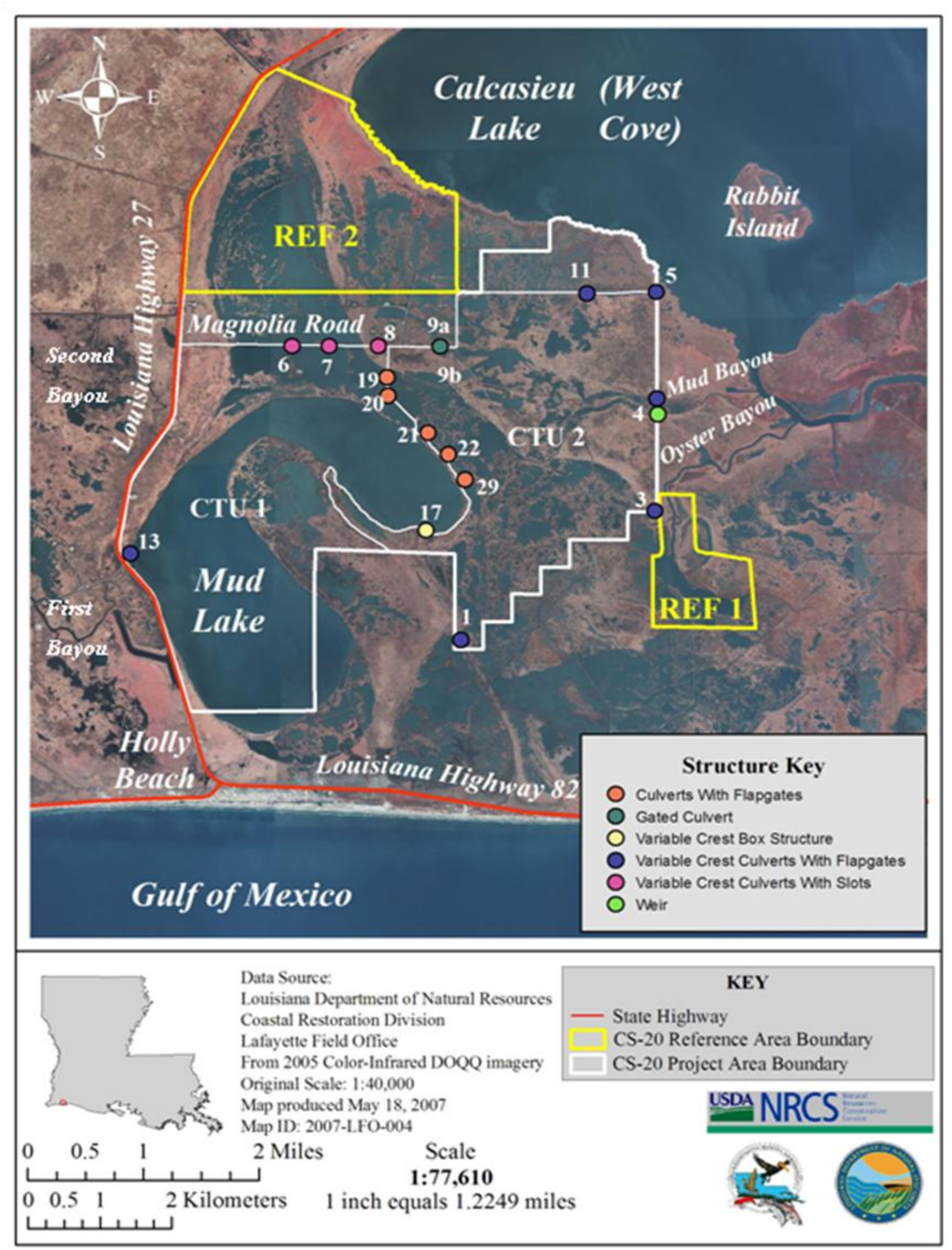


Figure 1. East Mud Lake (CS-20) project map depicting project boundaries, conservation treatment unit boundaries, reference area boundaries, and project features.

and are slow to recede in this area because of LA Highways 82 to the south and 27 to the west, the levees demarking property lines to north, east, and south, and several ring levees and roads within the project area. This combination of sustained high water levels and increased salinity stress has deteriorated the vegetation and led to "ponding" (USDA-SCS 1994). In addition, the subsidence rate and sea level rise has led to a 0.25 inch (0.64 cm) water level increase per year from 1942-1988 (Penland et al 1989) which results in even less suitable conditions for vegetative production.

The East Mud Lake Marsh Management Project (CS-20) is designed to reduce wetland degradation by reducing rapid fluctuations in water and salinity levels and prolonged periods of marsh inundation in the project area and by enhancing regeneration of desired emergent and submergent vegetation. This project will increase vegetative occurrence by reducing salinity-induced stress and alleviating excessive water levels while not creating tidal scour problems (Louisiana Coastal Wetlands Conservation and Restoration Priority List, 1992).

The project area is divided into two, independently managed, Conservation Treatment Units (CTUs). CTU #1 contains Mud Lake and will be managed passively. Structures and features present in this unit consist of shoreline repair, vegetative plantings, earthen plugs, culverts with flapgates, and variable crest culverts. CTU #2 will be actively managed for drawdown capabilities in order to encourage shallow areas to revert to emergent vegetation (figure 1).

CS-20 involves installing and maintaining water control structures, repairing and constructing levees, and planting vegetation, as components of a marsh management plan for the two CTUs that make up the project area. Construction was completed in June 1996. The structures are designed to reduce the extreme fluctuations in salinity and water levels while providing adequate water flow to create a hydrology conducive to the establishment of brackish emergent and submergent vegetation to minimize marsh deterioration. Vegetative plantings will aid in reverting shallow open waters less than 0.5 feet (0.15 m) deep to emergent marsh. The vegetative plantings will also help stabilize and protect eroding shorelines.

The types and numbers of structures and features of the project are as follows:

1.	Variable Crest Culverts with Flapgates	6
2.	Variable Crest Culverts With Slots	3
3.	Gated Culvert	1
4.	Culverts with Flapgates	5
5.	Variable Crest Box Structure	1
6.	Earthen Plugs	2
7.	Shoreline Repair	2
	(Total = 25,153 cubic feet of dredged material)	
8.	Levee Repair	1
	(66,461 cu yds of dredged material needed to shore up the step levee on the north, east, and southeast sides of CTU#2)	

II. Maintenance Activity

a. Project Feature Inspection Procedures

The purpose of the annual inspection of the East Mud Lake Marsh Management Project (CS-20) is to evaluate the constructed project features to identify any deficiencies and prepare a report detailing the condition of project features and recommended corrective actions needed. Should it be determined that corrective actions are needed, OCPR shall provide, in the report, a detailed cost estimate for engineering, design, supervision, inspection, and construction contingencies, and an assessment of the urgency of such repairs. The annual inspection report also contains a summary of maintenance projects, if any, which were completed since completion of constructed project features and an estimated projected budget for the upcoming three (3) years for operation, maintenance and rehabilitation. The three (3) year projected operation and maintenance budget is shown in Appendix B.

Construction to replace structure ES-4, repair ES-1,ES-3, ES-5, ES-6, ES-7, ES-8, ES-9 a&b, ES-11, ES-13, and add rock revetment to scoured areas throughout the CS-20 perimeter was ongoing throughout 2009-2010; therefore, an inspection of CS-20 was not conducted.

b. Inspection Results

c. Maintenance Recommendations

i. Immediate/ Emergency Repairs

ii. Programmatic/ Routine Repairs

d. Maintenance History

General Maintenance: Below is a summary of completed maintenance projects and operation tasks performed since April 1996, the construction completion date of (CS-20).

December 1999 Maintenance Project – LDNR: This maintenance project included the installation of approximately 600 tons of stone riprap around ES-4, aluminum fabrication and installation of flap gate lifting devices and a stop log channel repair at ES-4, approximately 950 linear feet of earthen levee repair, and placement of approximately 100 tons of stone riprap at ES-6, 7, 8, 9a & 9b. Construction was completed in December 1999. The costs associated with the engineering, design and construction of CS-20 are as follows:

Construction:	$113,848.21
Engineering & Design:	$ In house
Construction Oversight/As built surveys:	$ 11,902.28

TOTAL CONSTRUCTION COST: $125,750.49

(Does not include costs associated with in-house design.)

III. Operation Activity

a. Operation Plan

The project area is divided into Conservation Treatment Unit (CTU) #1 and CTU #2. Operational plans and procedures for CTU #1 are designed to stabilize salinity and water levels. Operational plans and procedures for CTU #2 are designed to expose mud flats for seed germination and planting (Phase I, 1996-1997). Once vegetative plantings are established, operations and procedures for CTU #2 are designed to gradually increase water levels to maintain and enhance vegetative growth for optimum waterfowl and furbearer utilization and to stabilize salinity (Phase II, 1998-present).

CTU #1 – Water Management Scheme – January 1, 1996 to present

1. Structures ES-#6, ES-#7, and ES-#8 – The stop logs will be set no higher than 6-inches below marsh level. The vertical slots in the structures will remain open except to protect marsh vegetation during the periods of high salinity. These slots will be closed when salinity inside the marsh exceeds 15 ppt, 100 feet south of structure ES-#7.

2. Structures at ES-#13 (First Bayou) – Set stop logs 6-inches below marsh level. Lock flap gates open except when salinity exceeds 7 ppt in the road ditch on the west side of LA Highway 27 at the Drainage District's Structure.

CTU #2 – Water Management Scheme Phase I – Revegetation Phase 1a
February 15 – May 31 (or to July 15), 1996 and 1997

1. Remove all stop logs and allow flap gates to operate at structures ES-#1, ES-#3, ES-#4, ES-#5, ES-#9a, and ES-#11.

2. Screw gate open and allow flap gate to operate at structure ES-#9b.

3. Allow flap gates to operate at structures ES-#19, ES-#20, ES-#21, ES-#22 and ES-#29.

4. Set stop logs at 12-inches above marsh level at structure ES-#17.

CTU #2 – Water Management Scheme Phase I – Revegetation Phase 1b
May 31 (or July 15) – February 14 +/- 2 weeks, 1996 and 1997

1. Set stop logs 6-inches below marsh level and lock flap gates open at structures ES-#1, ES-#3, ES-#4, ES-#9a and ES-#11.

2. Set the weir crest of one 5-foot wide bay at 12-inches below marsh level and the crest of the other 5-foot wide bay at 6-inches below marsh level and lock flap gate open at ES-#5.

3. Screw gate open and lock flap gate open at structure ES-#9b.

4. Lock flap gates open at ES-#19, ES-#20, ES-#21, ES-#22 and ES-#29.

5. Remove all stop logs at structure ES-#17.

CTU #2 – Water Management Scheme Phase II – Maintenance Phase
January 1, 1998 to present

1. Set stop logs 6-inches below marsh level and lock flap gates open at structures ES-#1, ES-#3, ES-#4, ES-#9a and ES-#11.

2. Set the weir crest of one 5-foot wide bay at 12-inches below marsh level and the weir crest of the other 5-foot wide bay at 6-inches below marsh level and lock flap gates open at structure ES-#5.

3. Screw gate open and lock flap gate open at structure ES-#9b.

4. Lock flap gates open at structures ES-#19, ES-#20, ES-#21, ES-#22 and ES-#29.

5. Remove all stoplogs at structure ES-#17.

Safety Provisions

1. Storms: Immediately following heavy rain storms or tidal surges, all gates and weirs shall be opened as needed, to provide normal gravity drainage for the area as well as to protect the integrity of the levee system.

2. Water Salinity: Water salinity will be managed to maintain the area as brackish marsh. To protect marsh vegetation during periods of high salinity, the ingress gates will be closed when salinity inside CTU #2 exceeds 15 ppt at ES-#3 or ES-#5. The water salinity provision is adaptable to long-term weather conditions such as drought; at which time, the structures will be adaptively managed as agreed upon by the landowner (Apache Louisiana Minerals, Inc.) and OCPR.

b. Actual Operations

In accordance with the operation schedule outlined in the Operation and Maintenance Plan and USACE Permit, structures were manipulated as required by Apache Louisiana Minerals, Inc. personnel who are under contract with OCPR (Table 1). Copies of the quarterly reports that are provided as well as a copy of the operations contract between OCPR and Apache Louisiana Minerals, Inc. are attached in the "Structure Operations" section of the CS-20 East Mud Lake Marsh Management Operation & Maintenance Plan.

Table 1. Summary structure operations (2005-2009) compiled from reports delivered by the land owner of CS-20, Apache Louisiana Minerals, Inc. Stoplogs are typically set at 0.5' below marsh level (BML).

Date	CTU 1 Structure (ES 6, 7, 8, 13)	CTU 2 Structures (ES 1, 3[a], 4[b], 5, 9, 11)	Remarks
7/15/2005	Stoplogs at 0.5' BML	Flaps Closed	
9/25/2005	Hurricane Rita - Not able to lock flaps after Hurricane Rita		
10/10/2005	Removed all stop logs to drain storm surge except ES3 & 4 b/c debris		
4/3/2006	Stoplogs replaced to 0.5' BML after storm drainage. ES 3 & 4 still damaged.		
9/29/2006	Hurricane Rita debris removed from ES 6, 7, 8, and 9.		
1/30/2007	Stoplogs at 0.5' BML	Flaps Locked Open	Flush CTU 2 with low salinity water
3/20/2007	Stoplogs at 0.5' BML	Stoplogs removed	
5/16/2007	Stoplogs at 0.5' BML	Stoplogs returned and Flaps Closed	
3/4/2008	Stoplogs at 0.5' BML	Flaps Locked Open	Flush CTU 2
Thru 12/2009	No operation changes during Hurricane Ike. Flaps have remained open despite salinity > 15 ppt to encourage water exchange (flushing).		

[a]Structure 3 was damaged during Hurricane Rita; the flap gate was ajar with low water flow. Structure 3 was repaired in fall 2010.

[b]Structure 4 was partially sunken prior to Hurricane Rita, partially functioning, and vandalized to keep flaps open for shrimping. Structure 4 was replaced in winter 2010.

IV. Monitoring Activity

Pursuant to a CWPPRA Task Force decision on August 14, 2003 to adopt the Coastwide Reference Monitoring System-*Wetlands* (CRMS) for CWPPRA, updates were made to the CS-20 Monitoring Plan to merge it with CRMS-*Wetlands* and provide more useful information for modeling efforts and future project planning while maintaining the monitoring mandates of the Breaux Act. There are two CRMS sites in the CS-20 project area (CRMS0672 and CRMS0655) and references are made to basin-marsh type (Cal/Sab-brackish marsh) scale averages of CRMS sites. Given the age and rigorous monitoring design for CS-20, CRMS data (which only begins in 2006) will be used to provide a regional scale context where applicable. Applicable data used in this report is the Floristic Quality Index vegetation data from 2006-2009.

a. Monitoring Goals

The objectives of the East Mud Lake Management Project are:

1. Prevent wetland degradation in the project area by reducing vegetative stress, thereby improving the abundance of emergent and submergent vegetation. This will be achieved through hydrologic structural management to reduce water levels and salinities.

2. Stabilize shoreline of Mud Lake through vegetative plantings.

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

1. Decrease rate of marsh loss.

2. Increase vegetative cover along shoreline of East Mud Lake.

3. Increase coverage of emergent vegetation in shallow open water areas.

4. Increase abundance of vegetation in presently vegetated portions of project area.

5. Reduce water level and salinity fluctuations to within target ranges for brackish vegetation. Target range for salinities is less than or equal to 15 ppt and 6" below marsh level to 2" above marsh level for water levels.

6. Decrease duration and frequency of flooding over marsh.

7. Decrease mean salinity in Conservation Treatment Unit #2.

8. Increase accretion in Conservation Treatment Unit #2.

*9. Maintain fisheries abundance.

*Note: This is not a specific goal as addressed in the project documentation. However, due to concerns regarding potential fishery impacts, it has been included in the monitoring plan.

b. Monitoring Elements

Habitat mapping: At the US Geological Survey – National Wetlands Reseach Center (NWRC), 1:12,000 scale color infrared aerial photography obtained in 1994 (December 26), 2000 (November 27), and 2006 (November 11) was classified photo-interpreted, and georectified to measure areas of and map habitat types in the project (CTU 1 and CTU 2) and reference (REF 1 and REF 2) areas pre-(1994) and post-(2000 and 2006) construction. An accuracy assessment comparing the GIS classification of 100 randomly chosen pixels to aerial photography determined an overall classification accuracy of 96%. In addition, NWRC produced habitat analysis maps of the project and reference areas from the classic habitat analyses of 1956, 1978, and 1988.

Habitat classifications were combined into larger land and water (includes unvegetated mudflats) categories. For each time period, land area was calculated into percent land for the project and reference areas. Regressions of percent land over time were plotted and land change rates were calculated for each area. The regressions and rates were divided into historical preconstruction (1956-1994) and post construction (1994-2006). The 2000-2006 Land-Water Change Analysis Map, produced by NWRC, displays where recent change has occurred.

Vegetation plantings: The *S. alterniflora* plantings were divided into three land types due to different stress factors from boat wakes, wave energy, and herbivory. The canal plantings, located on a long, straight canal in CTU 2 are subject to herbivory from cattle year-round. The step levee plantings are located in CTU 2 on short canals where plants were installed at a farther distance from the shoreline. Lakeshore plantings are located on the shoreline of East Mud Lake in CTU 1 and subject to high wave energy due to the long north-south fetch across the lake. To document planting success, 5% of the plants along the step levee and canal, and 5% of the plants along the East Mud Lake shoreline were sampled. Nineteen plots along the step levee, seventeen plots along the canal, and 4 plots along the shoreline, consisting of 10 plants spaced 5 ft (1.5 m) apart, were selected and sampled. Parameters measured included, percent survival of planted vegetation, species composition of encroaching vegetation, and percent cover for each species present. Monitoring stations were placed every 1,000 ft (305 m). The 1-mo, 6-mo, 1-year, and 4-year postplanting sampling was conducted in July 1996, December 1996, August 1997, and June 2000, respectively. A Kruskal – Wallis test was used to compare percent survival and percent cover of *S. alterniflora* among the three planting locations (step levee, canal, and lake shoreline) for each sampling time. Chi – Square tests were considered significant at $p < 0.05$.

Existing vegetation: Stations to monitor existing vegetation were selected using a systematic transect pattern in which five transect lines were drawn in a northwest to southeast configuration from the Calcasieu Lake/West Cove shoreline in the project area and reference area 2. Five stations were chosen at equally spaced points along each transect line, for a total of 25 stations in CTU 2 (project area) and 20 stations in REF 2 (reference area), to obtain an even distribution of stations throughout the marsh (figure 2). Percent cover, height of dominant species, and species composition were monitored in 1.0 m^2 vegetation plots in 1995 and 1997, and in 4 m^2 plots in 1999 – 2009. Emergent vegetation data were collected in July 1995 (preconstruction) and after construction in July 1997, June 1999, July 2003, December 2005 (special post hurricane Rita sample), June 2006, September 2007, September 2008, and August 2009. Floristic Quality Index (FQI), a grading index based on the quality of species composition for a vegetation type and percent coverage of species, was calculated for each station during each sampling period (Cretini et al. 2009). The intent is to assess the condition of existing vegetation, specifically; therefore, stations that were converted to open water are not included in this analysis (six stations were lost in the reference area during Hurricane Rita). An Analysis of Variance (ANOVA) was used to test for differences among areas (project v reference), years, and the area × year interaction for the response variables percent cover and FQI.

<u>Water level and salinity</u>: Data were collected using seven (7) YSI 6000 or YSI 6920 continuous recorders at five stations inside the project area and 2 stations in the reference areas (figure 2). Water level (ft, NAVD), salinity (ppt), water temperature (^{o}C), and specific conductance (ΦS/cm) were recorded hourly at these stations. All continuous recorder data were shifted when necessary due to biofouling when error at time of retrieval exceeded 5%. Percent error caused by biofouling was calculated at the time of retrieval by comparing dirty and clean discrete readings to those taken with a calibrated instrument. Water depth, salinity, and temperature were measured monthly at 27 stations, 15 located inside the project area, and 12 in the reference areas. Monthly staff gauge readings were taken at 11 stations located within the project area and 10 in the reference areas. Some data are missing due to inaccessibility to sites at some sampling times. Hydrologic data was collected by Coastal Estuary Services, LLC during the timeframe of this 2010 OM&M report (2006-2009).

Water level data relative to marsh surface (1.01 ft NAVD) were presented on a yearly basis through 2009 from representative stations of comparable project/reference areas (station 3 of CTU 2/ station 14R of REF 1; station 7 of CTU 1/ station 15R of REF 2). The percent of hourly water level measurements lower, higher, or within the target zone of 2 inches above average marsh level (1.18 ft NAVD) and 6 inches below marsh level (0.51 ft NAVD) were calculated for all years in the above mentioned stations. Yearly mean salinity data was presented through 2009 from the above mentioned stations to evaluate the goal of decreasing mean salinity in CTU 2. The percent of hourly salinity measurements greater than 15 ppt at the above mentioned stations during each year of operation was calculated to determine if the project was effective at maintaining salinities less than or equal to 15 ppt.

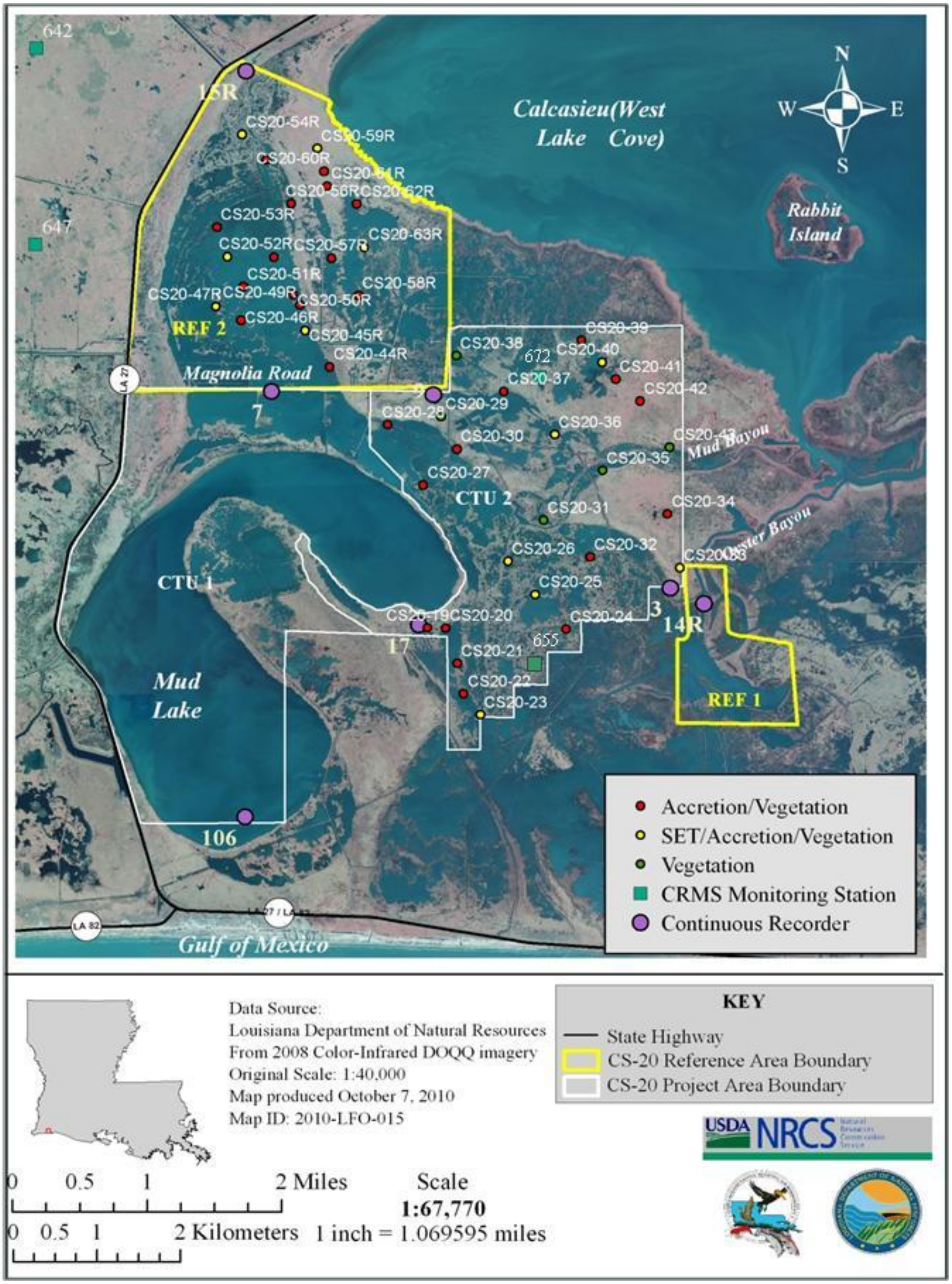


Figure 2. East Mud Lake (CS-20) project map depicting continuous hydrologic recorder, marsh sampling (Surface Elevation Table (SET), accretion, and vegetation), and CRMS stations.

Marsh Elevation Change: Elevation change data was collected from 12 Surface Elevation Table (SET) sites (6 in project area CTU 2 and reference area REF 2) and 40 Vertical Accretion (VA) sites (20 in the same project and reference areas as the SET sites) in July 1996 (baseline SET measurements and original establishment of VA horizon layers), December 1996, July 1997, December 1997, June 1998, June 2000, July 2003, December 2005 (post hurricane Rita subset), June 2006, and August 2009 (figure 2, details of installation and data collection are below). Multiple VA sites were matched to the SET sites to create functional elevation change units based on wetland habitat/soil types (Deep Marsh/Banker Muck, Shallow Marsh/Creole Mucky Clay, and Meadow Marsh/Mermentau Clay) (Table 2). Cumulative change (VA and SET) of the units were averaged by area for each time interval to present the pattern of change over type. Distinct differences over time in CS-20 are defined by the hurricanes in 2005 (Rita) and 2008 (Ike); therefore, change rates (slopes from VA and SET over time) were calculated from the time periods before the hurricanes (1996-2003) and over the life of the project (1996-2009) for each site. Shallow marsh subsidence (SS) rate was then calculated from the difference of VA and SET rates (SS = VA – SET). Marsh elevation change rates (VA, SET, SS) are compared in an area (project v reference) × time period (prehurricane v overall) full factorial ANOVA with Student's t-test to describe differences within the interaction effects.

Table 2. Distribution of Surface Elevation Table (SET) and Vertical Accretion (VA) sites within CS-20 areas and wetland habitat/soil types.

Area	SET Site	VA Sites	Wetland Habitat/Soil Types
Project (CTU 2)	CS20-23	CS20-20,21,22,23	Deep Marsh/Banker Muck
	CS20-25	CS20-24,25,32	Deep Marsh/Banker Muck
	CS20-26	CS20-26,27,28	Deep Marsh/Banker Muck
	CS20-36	CS20-30,36,37	Shallow Marsh/Creole Mucky Clay
	CS20-40[1]	CS20-39,40	Shallow Marsh/Creole Mucky Clay
	CS20-33[1]	CS20-33,34,42,43	Meadow Marsh/Mermentau Clay
Reference (REF 2)	CS20-45R	CS20-44R,45R,49R	Deep Marsh/Banker Muck
	CS20-47R	CS20-46R,47R,51R	Deep Marsh/Banker Muck
	CS20-52R[2]	CS20-48R,52R,53R	Deep Marsh/Banker Muck
	CS20-54R[2]	CS20-54R,55R,56R	Shallow Marsh/Creole Mucky Clay
	CS20-63R	CS20-57R,58R,63R	Shallow Marsh/Creole Mucky Clay
	CS20-59R	CS20-59R,60R,61R,62R	Meadow Marsh/Mermentau Clay

[1]SET pipe was damaged prior to August 2009 sampling; only prehurricane data is analyzed.
[2]Site was converted to open water by Hurricane Rita; only prehurricane data is available.

Vertical accretion – We used the marker horizon technique to measure soil accumulation over time. A marker horizon that contrasts with the marsh soil (Feldspar clay) was placed in 0.5 x 0.5 m plots marked with 2 PVC poles at opposing corners to enable location of the feldspar over time, and cores from randomly selected locations within each plot were taken with a cryogenic corer (Knauss and Cahoon 1990). Vertical accretion (soil depth above the feldspar) was measured to the nearest millimeter at 1-4 locations on each core. A maximum of 3 cores per plot were taken at each sampling period, however, feldspar was not always clearly visible on any of the three cores. Feldspar stations (2 plots per site) were established at 20 sites in both the project area (CTU 2) and the reference area (REF 2) (figure 2). In July 1996, 14 sites in CTU 2 and 16 stations in REF 2 were originally established while sites that were inaccessible in July were established in December 1996 (CTU 2 – 6 sites; REF 2 – 3 sites). New feldspar plots were systematically reestablished at all sites in December 1997, and the original plots were abandoned; subsequently, sites were reestablished on an as-needed basis (could not find stations or feldspar layer). Some sites were not visited during sampling periods due to inaccessibility.

For each sample date, the core measurements from each station were averaged per site. To keep the data "cumulative" over uneven time periods, the data was manipulated to have a common establishment date (July or December 1996) by adding the last measurement of the previous establishment period to measurements from subsequent reestablishment periods. Vertical Accretion sites were then grouped with corresponding SET sites (as described above, Table 2); grouping VA sites per SET site compensated for missing data at individual VA sites during a given sample date.

Surface elevation - Surface elevation table (SET) sites were established in August 1995 at 12 (6 in CTU 2; 6 in REF 2) of the 40 feldspar and vegetation sites to detect changes in marsh surface elevation due to subsidence and accretion/erosion combined (figure 2). Detailed procedures for the SET installation and data collection are documented in Steyer et al. (1995). During each sample date, nine pin height measurements (length of pin over the SET) were taken in four directions at each of the sites. A cumulative pin height difference for a sample date was calculated for each individual pin by subtracting the baseline pin height (t_0) from the current pin height (t_i) (Cumulative pin height = $t_i - t_0$). Pin height differences for each direction were averaged, and the directions were averaged for each site per sample date. Cumulative elevation changes per site were used to calculate sample date intervals and rates. Marsh surface elevation was originally measured preconstruction in December 1995; however, only 10 of the 12 SET station sites were accessible for the first two measurements, and a different SET was used to start the postconstruction period. Therefore, only postconstruction data is used in this report.

Soils: Soil cores from vegetation monitoring stations in the project and reference areas were collected in July 1996 (preconstruction), July 1999 (postconstruction), and June 2006 (post-Hurricane Rita). Cores were taken from with a Swensen corer (10 cm deep), refrigerated, and delivered to Louisiana State University (LSU) Agronomy Department (LSU Ag) to analyze soil characteristics. At LSU Ag the soil cores were air dried and then oven dried at approximately 100 ^{o}C until constant mass to determine BD (grams of dry field sample/volume of field sample). The dried soil was ground and subsampled to determine %MM via loss on ignition from which %OM was calculated:

% Mineral Matter = (weight of ash/weight of subsample) × 100 (1)

% Organic Matter = 100 - % Mineral Matter. (2)

Organic and mineral density of the dry soil was calculated based on bulk density to determine the actual amount of each component:

Mineral Density = Bulk Density × (% Mineral Matter/100) (3)

Organic Density = Bulk Density × (% Organic Matter/100). (4)

Fisheries: Fisheries monitoring was conducted to estimate abundance and species composition in the project and reference areas to determine whether the project affected fish abundance. Thirty samples each were collected from CTU 2 in the project area and reference area 2, concurrently, during each sampling period with a 1-m^2 throw trap with 1-m high walls constructed of 1.6 mm mesh nylon netting (Kushlan 1981). A 0.25 in (0.64-cm) diameter steel bar, bent into a square, was attached to the bottom of the net to make it sink rapidly in the water. A floating collar of plastic pipe 0.75 in (1.91-cm) diameter was attached to the top of the net to keep the throw trap vertical in the water column after deployment. Additional samples were collected randomly using a 20-ft (6.1 m) minnow seine with 3/16 in (0.48 cm) mesh to compensate for the potential deficiency of the throw traps for determining species composition. A minimum of three seine pulls were conducted in the project area and both reference areas at each sampling event to determine whether throw traps adequately depict species composition. Mean density, relative abundance, and total biomass (dry weight in grams) of each species were recorded. A water sample was collected at each site and measurements taken for water temperature (^oC), salinity (ppt), dissolved oxygen (mg/l), water depth (cm) and distance to the marsh edge (m). At each site, presence or absence of SAV was noted. Sampling locations were randomly chosen from a grid pattern for each sampling trip. Personnel from LDNR/CRD conducted sampling in June 1995, October 1995, April 1996 (during drawdown), October 1996, and March 1997. National Marine Fisheries Service (NMFS) personnel and the LDNR/CRD monitoring manager conducted sampling in April 1997 (during drawdown), September 1997, April 2001, and November 2001. NMFS analyzed data from June and October 1995 and April 1996 and determined that throw trap sampling depicted species composition of the area at least as well as seine sampling, and seine sampling was discontinued.

Density and biomass means and standard errors for each fish and crustacean species were calculated for the project and reference area for each sampling period. Means and standard errors for all environmental variables collected were calculated for the project and reference area per sampling period. Although construction was not completed until after the April 1996 sampling time, access to the project area was disturbed by the ongoing construction and April 1996 was thus considered postconstruction. Two factor ANOVAs with interaction were used to compare mean animal densities and environmental variables between the project and reference areas for preconstruction sampling times to estimate the suitability of the reference area. The specific environmental variables tested were salinity, temperature, dissolved oxygen, depth, and distance to edge and the animal variables were total fishes, total crustaceans, transient fishes, transient crustaceans, resident fishes, and resident crustaceans. The same set of environmental and animal variables were then compared between preconstruction and postconstruction sampling times with a one-way ANOVA for each area separately (Appendix A). Prior to statistical analyses, Hartley's F-max test was used to determine if variances in the treatment cells were equal (Milliken and Johnson 1992). We performed a ln(x+1) transformation on the density, species richness, and biomass data, because cell means were positively related to standard deviations. In cases where cell means were positively related to variances (i.e., salinity, water temperature, dissolved oxygen concentration, water depth, distance to edge), a square root transformation was used prior to analyses. These transformations generally reduced the relationships between means and standard deviations or variances. However, F-max tests still indicated heterogeneity for some variables. Despite this failure to meet the assumption of homogeneity of variances in all cases, ANOVA tests were conducted on transformed data because the test is considered robust, and failure to correct heterogeneity does not preclude its use (Green 1979, Underwood 1981). An alpha level of 0.05 was used to determine statistical significance for all ANOVA tests.

c. Preliminary Monitoring Results and Discussion

Land to Water Ratio and Habitat mapping: Before the hydrologic modifications made by the CS-20 project, historical land-loss rates (1956-1994) were similarly high in CTU 2 (1.00% y^{-1}) and REF 2 (0.96% y^{-1}), twice as low in REF 1, and three times lower in CTU 1; a pattern which reflected the percent of land in each area in 1956 (figure 3a). Land-loss rates were approximately doubled in the time increment prior to project construction (1988-1994) in CTU 2 (2.44% y^{-1}), REF 2 (1.79% y^{-1}), and REF 1 (0.87% y^{-1}) while CTU 1 slightly increased (0.44% y^{-1}). By the time CS-20 was constructed in 1996, CTU2, REF 1, and REF 2 had about the same percentage of land (~60%); where as, CTU 1 had ~30% land coverage. Following construction, land-loss rates reduced substantially (actually gained land) in CTU 2, moderately in REF 1 and 2, and remained the same in CTU 1 from 1994-2006 (figure 3b). Land area dynamics in the two time intervals within the postconstruction period were defined by different weather anomalies; 1994-2000 included three significant droughts, and 2000-2006 included Hurricane Rita. Land loss in CTU 1, REF 1, and REF 2 significantly slowed to <0.1% y^{-1} from 1994-2000 while CTU 2 went from the area losing the most land preconstruction to reversing land-loss as it gained land from 1994-2000 (0.70% y^{-1}) which included managed drawdowns (1996 and 1997) in addition to the droughts. The low water levels and more oxygenated soils allow vegetation to expand from shorelines and into broken marsh. Land loss increased across all areas from 2000-2006 resulting from the scour energy and prolonged flooding from Hurricane Rita. REF 2 (1.54% y^{-1}) and CTU 1 (0.64% y^{-1}) experienced the greatest loss rates while REF 1 (0.39% y^{-1}) and CTU 2 (0.30% y^{-1}) had lower loss rates from 2000-2006.

Much of the land loss from 2000-2006 has occurred in large swaths in CTU 1 (on the exposed tip of the peninsula in a passively managed area) and REF 2; where as, gains occurred primarily in the headwaters from the West Cove Canal in REF 2 and sparsely throughout broken marsh into shallow water (figure 4). Coincidental to the pattern of large scale areas of land loss is the distribution of Bancker Muck which is described as poorly drained, typically low-elevation soil (1.01' NAVD88 in CTU 2); where as, the stable land areas are typically coincidental with Mermentau Clay which are associated with higher elevation ridges (1.45' NAVD88 in CTU 2). Another soil type, Creole Muck, found throughout the CS-20 project areas is intermediate in elevation and is often dynamic in terms of land change. These soil types are distributed evenly among CTU 1, CTU 2, and REF 2, while REF 1 does not have Banker Muck.

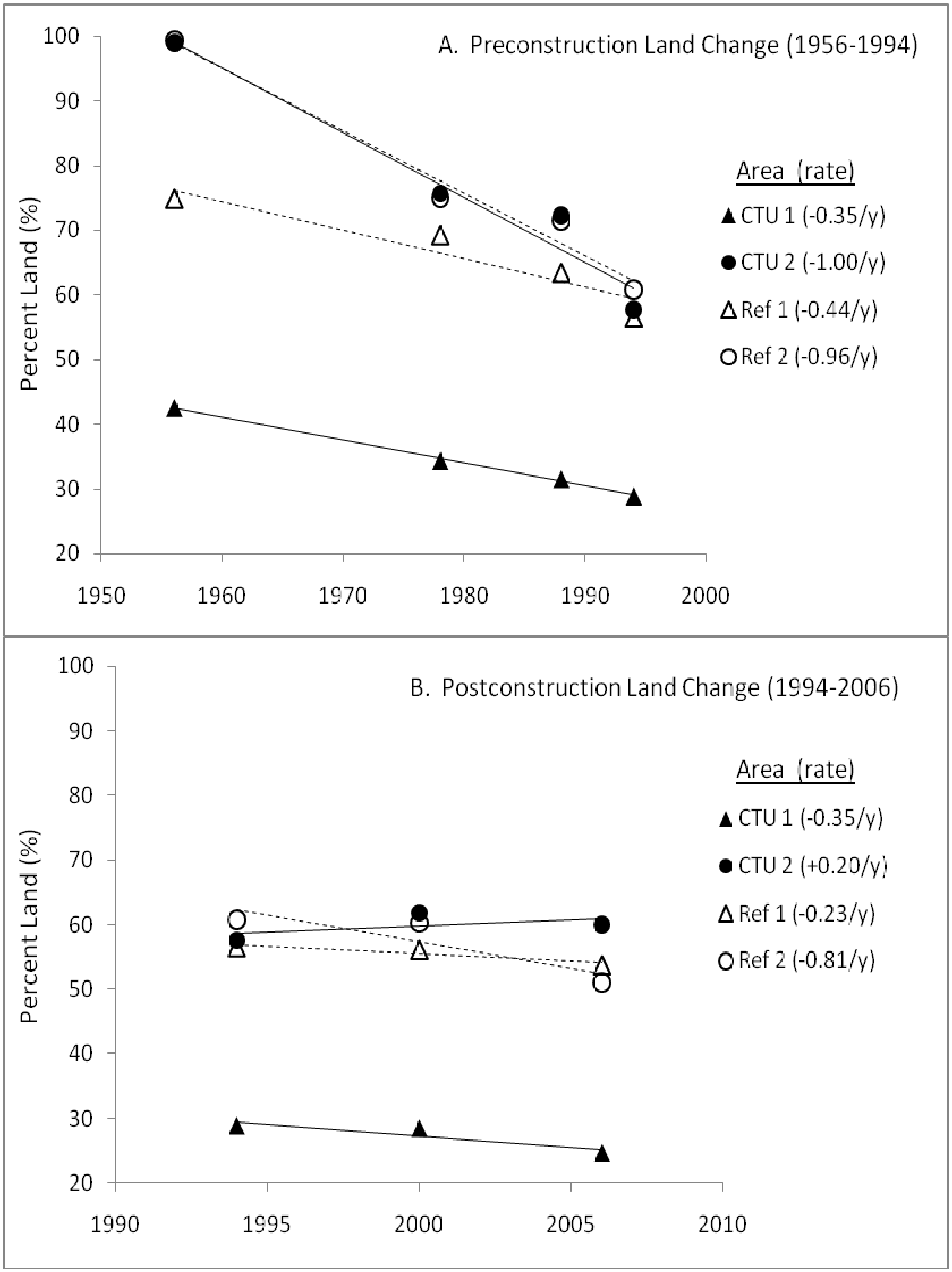
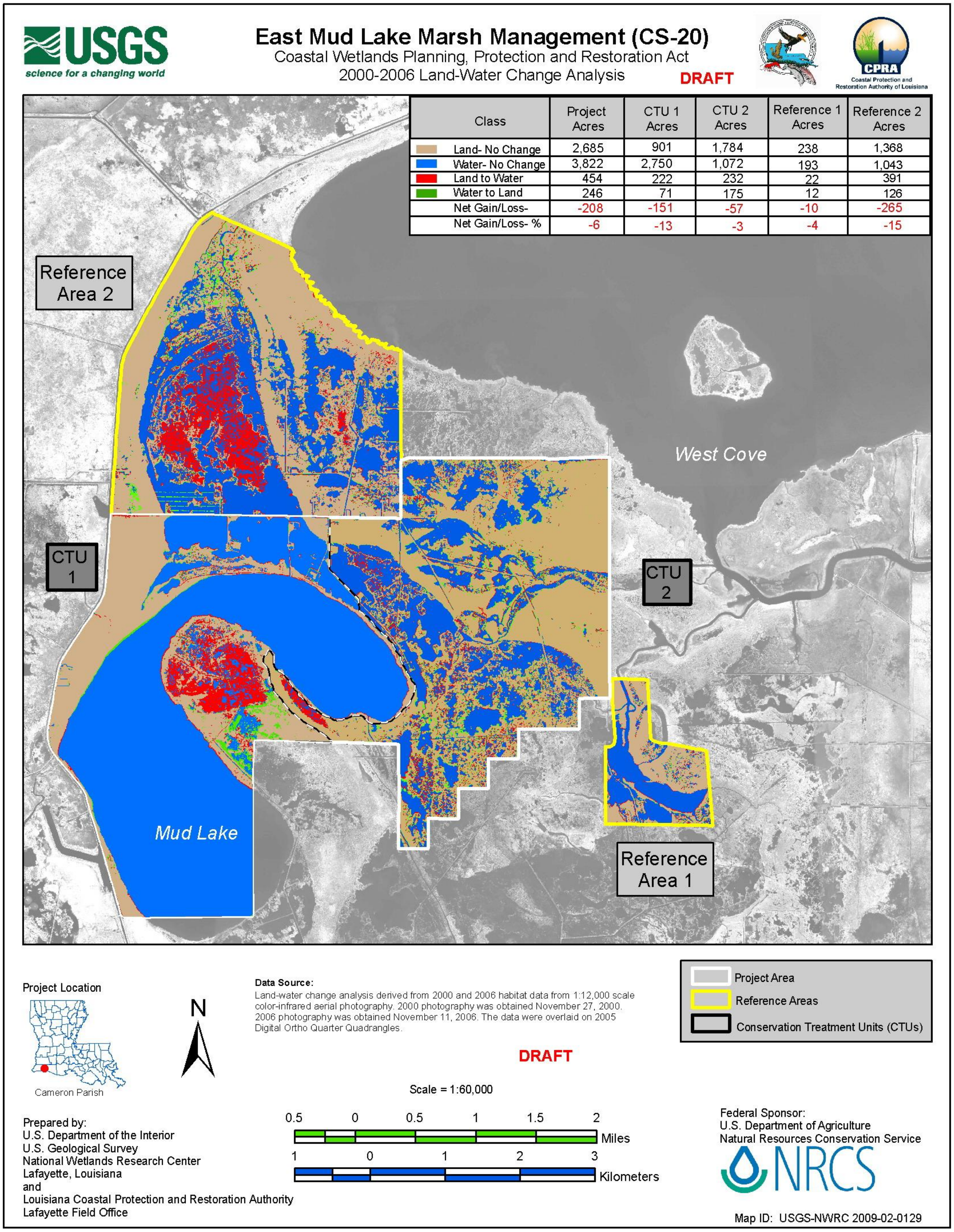


Figure 3. Percent vegetated land coverage of each CS-20 area with trend lines and rates over preconstruction (**A**) and postconstruction (**B**) time periods compiled from USGS-NWRC habitat analyses.



Class	Project Acres	CTU 1 Acres	CTU 2 Acres	Reference 1 Acres	Reference 2 Acres
Land- No Change	2,685	901	1,784	238	1,368
Water- No Change	3,822	2,750	1,072	193	1,043
Land to Water	454	222	232	22	391
Water to Land	246	71	175	12	126
Net Gain/Loss-	-208	-151	-57	-10	-265
Net Gain/Loss- %	-6	-13	-3	-4	-15

Figure 4. Land to water change analysis from 2000-2006 at CS-20 produced by USGS-National Wetlands Research Center.

Vegetative Plantings: The following is a summary of percent cover change and marked plant survival detailed in the CS-20 Three Year Comprehensive Report; no additional data has been collected. Vegetative cover along the shoreline of East Mud Lake (CTU 1) was not increased by vegetative plantings; however, about 50% of plantings along the canal (east border of CTU 2) and step levee (southeast border of CTU 2) areas remained four years after planting, and maintained over 20% cover. The original plan to install all plantings on the lakeshore was modified because of unexpected difficulty securing suitable planting substrate. A small portion of the plantings on the lake shoreline survived well for six months but did not increased in cover; however, no plants survived by our last sampling in 2000. Land gains along the lake could be due to protection of the shoreline made possible by the short fetch in that narrow part of the lake allowing for deposition of suspended sediment that existing vegetation could have colonized. The new land could also be the result of the expansion of existing vegetation into previously unvegetated mudflat that had not been detected by earlier aerial photography. Native species colonizing the shoreline and step levee were indicative of drier/saltier conditions and included *Distichlis spicata* (salt grass), *S. patens*, *Heliotropium currassivicum* (seaside heliotrope), *Lycium carolinianum* (salt matrimony-vine), and *Salicornia bigelovii* (glasswort). Marked individuals of *Spartina alterniflora* from plantings survived longer along the canal and step levee than the shoreline of East Mud Lake over a four year period (July 1996 – June 2000). Plant survival was greater than 90% after 6 mos across all land types. Along the canal plant survival was greater than 90% thru 12 mos and then decreased to 55% after 48 mos. Along the step levee survival decreased to 45-50% after 12 mos and maintained thru 48 mos. Along the East Mud Lake Shoreline, plant survival sharply declined to 15% from 6 to 12 mos, and no marked plants from the plantings survived to 48 mos. Typical plant turnover or stress caused plant survival decreases along the Canal and Step Levee; where as, planting were physically removed by wave energy along East Mud Lake.

Existing Vegetation: The goal to increase coverage of emergent vegetation in shallow, unvegetated, open water areas was achieved, but the amount is difficult to quantify. The drawdown phase of the project was intended to allow germination of marsh vegetation seeds and expansive tillering. Because our formal emergent vegetation sampling only incorporated existing vegetated areas, the only way to attempt to evaluate this goal was through analysis of aerial photography and through observations during field trips. CTU 2 gained land from 1994-2000, and we believe it is due mainly to vegetative expansion at the marsh/water interface in broken marsh. Evidence of this new vegetation first became apparent during vegetation sampling after the drawdown and drought in 1996. Subsequently, land-loss rates from 2000-2006, which included Hurricane Rita in 2005, were the lowest in CTU 2.

Patterns in the percent cover of species (% cover) and Floristic Quality Index (FQI) were distinctly different before and after the hurricanes at sampling stations (fig 5). Just prior to construction (1995), both project (CTU 2) and reference (REF 2) areas had high % cover, FQI, and were dominated by *Spartina patens* (the project area had higher species richness). Just following construction (spring 1996), the region was struck by severe drought (1996-1997) followed by prolonged flooding following Hurricane Francis (1998). Vegetation in REF 2 responded to these conditions with slight, but consistent, declines in % cover and FQI through 1999 as % cover fell to ~80% and FQI dipped to ~70 ("Fair" score). Both % cover and FQI rebounded to “Good” levels prior to Hurricane Rita. In addition to the regional weather conditions, CTU 2 also had managed drawdowns in 1996 and 1997 which intensified the drought effect as vegetation in responded with sharp declines in % cover (~60%) and FQI (~ 40, “Poor” score) in 1997 as lower quality, disturbance species became established and *S. patens* declined by about half. By 2003, % cover rebounded 20% and FQI slightly increased into the "Fair” range as *S. patens* remained repressed and other more salt tolerant species encroached. Both areas were heavily impacted by Hurricane Rita (September 1995) as both areas lost about 70 % of their vegetative cover and FQI scores dropped to the “Poor” range (<25). Both areas had similar recoveries by September 2008 (>95% cover and “Good” FQI scores) and relatively small set-backs following Hurricane Ike. Both areas have higher species richness and experienced a community shift towards more salt tolerant species such as *Distichlis spicata*, *Schoenoplectus robustus*, and *Spartina alterniflora* since project construction. According to CRMS data (2006-2009), FQI of 47 brackish marsh sites in the Cal/Sab basin averaged a “Fair” 53.5 (25^{th} quartile was a “Poor” 41.9; 75^{th} quartile was a “Fair” 67.2. During the CRMS timeframe, both the project and reference areas approached the 75^{th} quartile with an average FQI of 61.0 (project) and 60.4 (reference).

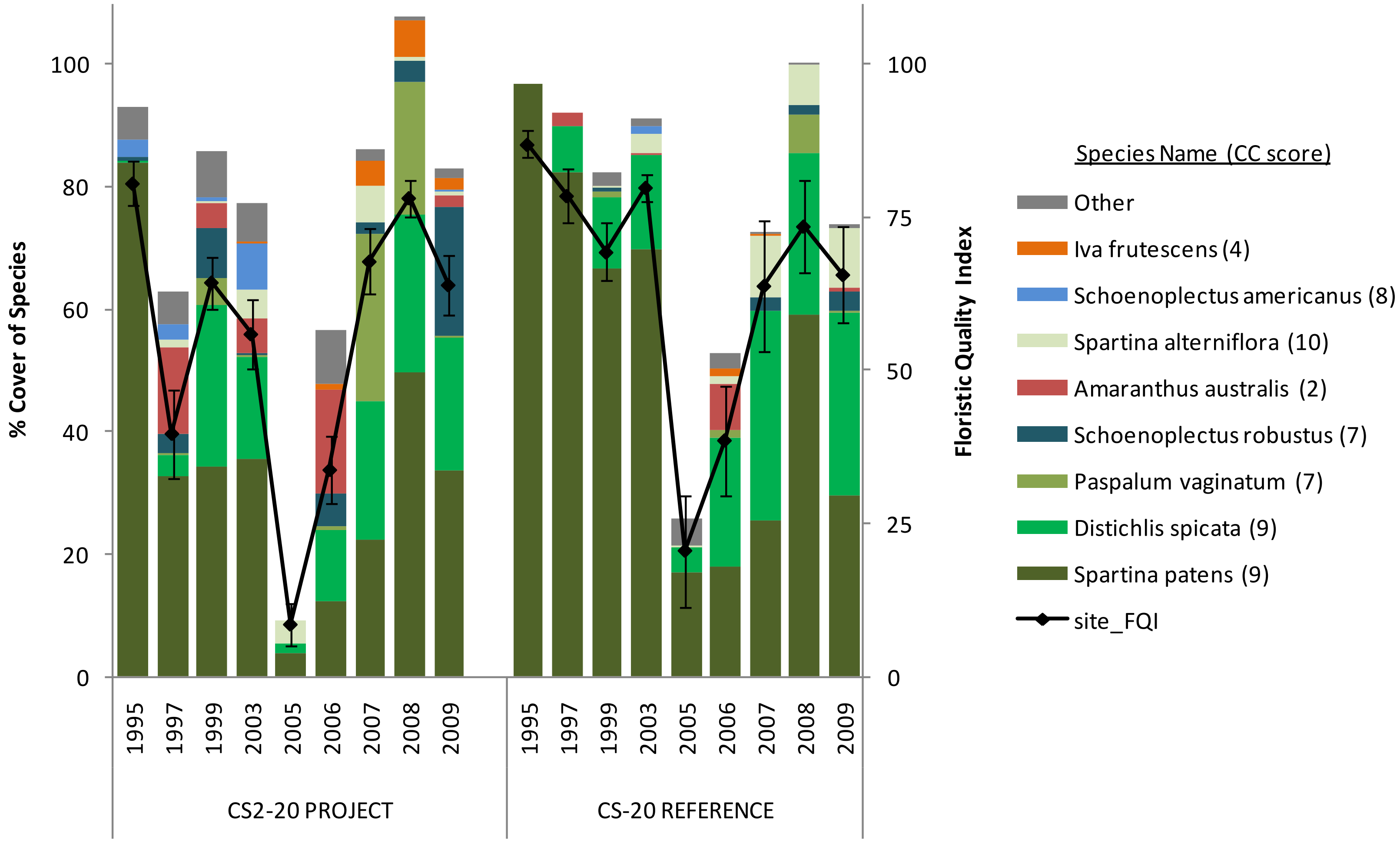


Figure 5. Percent cover of species (% cover) and Floristic Quality Index (FQI) was collected over the life of CS-20 in project (CTU 2) and reference (REF 2) areas. The stacked columns represent % cover of species listed in the legend (primary y-axis). The overlaid line graph represents the FQI score (secondary y-axis) which is calculated from the cumulative Conservation Coefficient (CC) scores in the legend weighted by % cover of each species. Values are means and standard areas from vegetation stations within areas for each sampling date.

Water Level and Salinity: Water levels were less variable at the project stations than reference stations through 2005. Water levels were much more sporadic post Hurricane Rita in 2006, as yearly water levels ranged from 15" above marsh elevation (REF 1) to 18" below (REF 2) in the reference areas and, a more moderate range, 7 ½" above marsh elevation (CTU 2) to 6" below (CTU 1) in the project areas (figure 6). A similar pattern held for percent time relative to water level target (2" above to 6" below marsh elevation of 1.01' NAVD88). REF 1 was flooded over the target range for nearly 100% of 2006 (figure 7) while station 3 (CTU 1) was flooded about 90% of the year (figure 8). Conversely, REF 2 and CTU 1 were drier in 2006. Station 7 (CTU 1) spent about 60% of 2006 below the target water level (figure 9) while water levels at station 15R (REF 2) were about three times lower as it spent 95% of 2006 below the target water level (figure 10). From 2007-2009 water levels stabilized at a higher level than typical as all areas averaged > 2" above marsh elevation per year (figure 6) and both project areas were flooded ~50% of the time (figures 7 and 9). Effects of Hurricane Ike in 2008 were not as evident as Hurricane Rita as water levels returned to "normal" after about 3 weeks.

Overall, salinity increased sharply from 2004 to 2006 approaching concentrations existing during the drought of 1999-2000 (figure 11) as all stations spent over 60% of the days above the maximum target of 15 ppt by 2006 (figure 12). Salinity receded in 2007, though not to pre-Rita concentrations, then increased through 2009 as a result of Hurricane Ike, especially CTU 1, with Station 14R (REF1) remaining the saltiest station, overall (figure 11). During "calmer" times (2001-2004) the project areas were above 15 ppt less than 25% of the time and less than their paired project areas (figure 12). CTU 1 spends the most time below 15 ppt during "calm" periods but holds higher salinities following events (1999/2000 drought and post hurricanes in 2006 and 2008) as structure 13 prevents water from flowing west into fresher areas across Hwy 27.

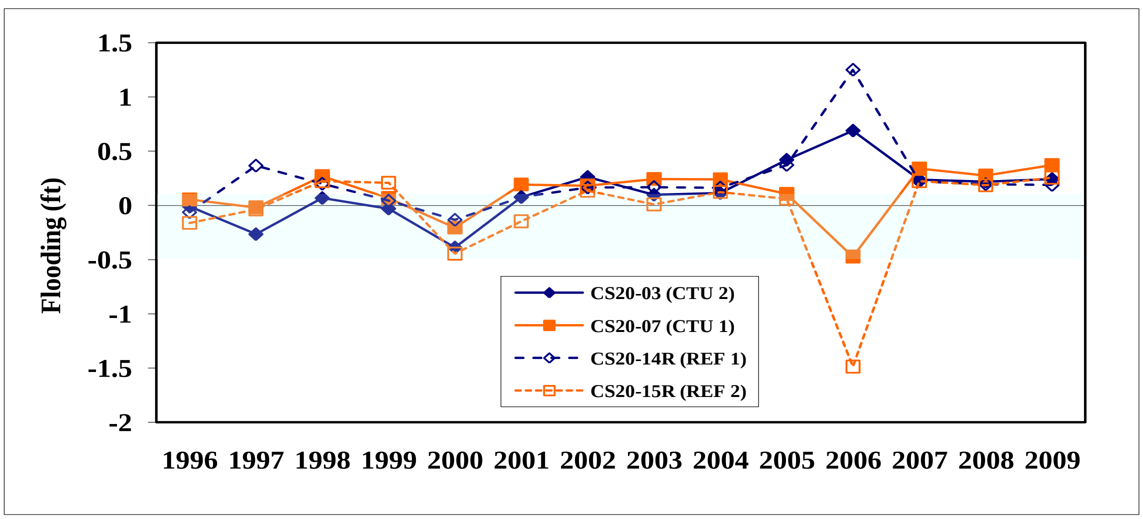


Figure 6. Mean water level relative to marsh elevation (1.01 ft NAVD88) per year collected by continuous water level recorders within the project (solid lines) and reference (dashed lines) areas. The colors represent comparable stations (project/reference). Shaded area is the targeted range (<2" above and <6" below marsh) for water level for the project areas.

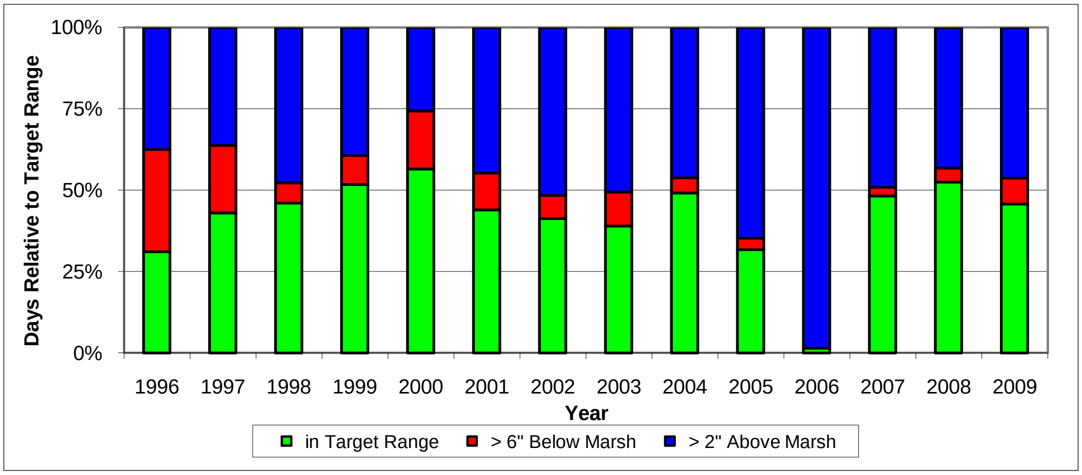


Figure 7. Percent days per year at CS20-14R in REF 1 of water levels relative to target range (2" above to 6" below marsh level) since construction. Marsh level is averaged at 1.01 ft NAVD.

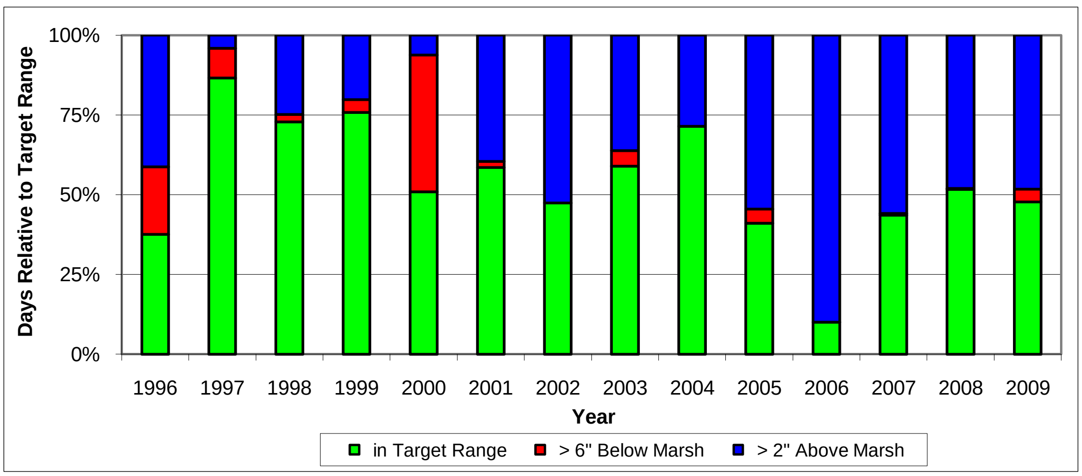


Figure 8. Percent days per year at CS20-03 in CTU 2 of water levels relative to target range (2" above to 6" below marsh level) since construction. Marsh level is averaged at 1.01 ft NAVD.

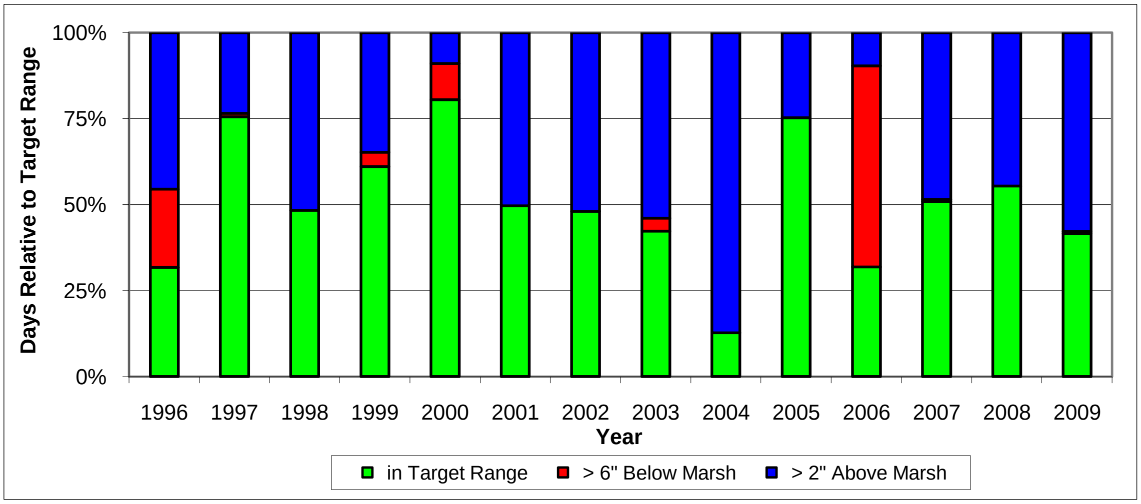


Figure 9. Percent days per year at CS20-07 in CTU 1 of water levels relative to target range (2" above to 6" below marsh level) since construction. Marsh level is averaged at 1.01 ft NAVD.

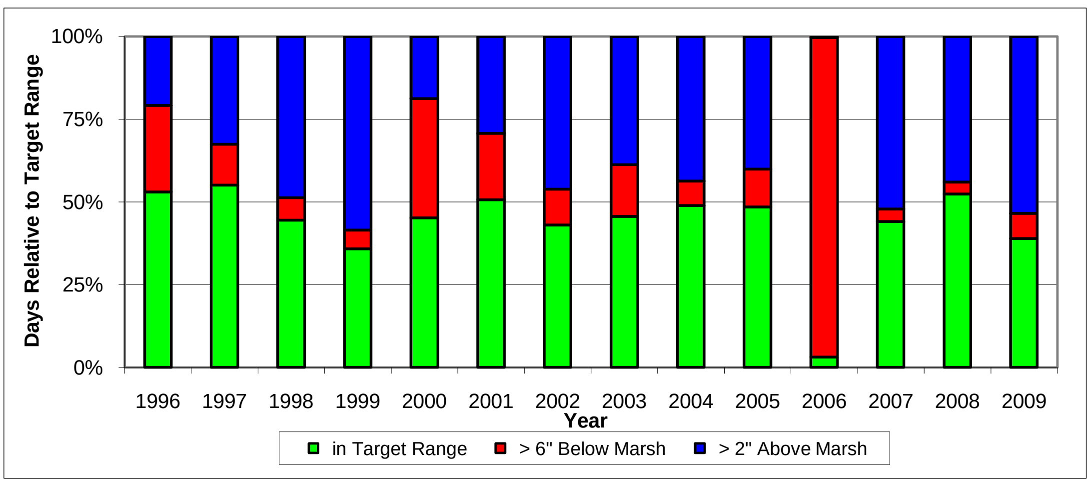


Figure 10. Percent days per year at CS20-15R in REF 2 of water levels relative to target range (2" above to 6" below marsh level) since construction. Marsh level is averaged at 1.01 ft NAVD.

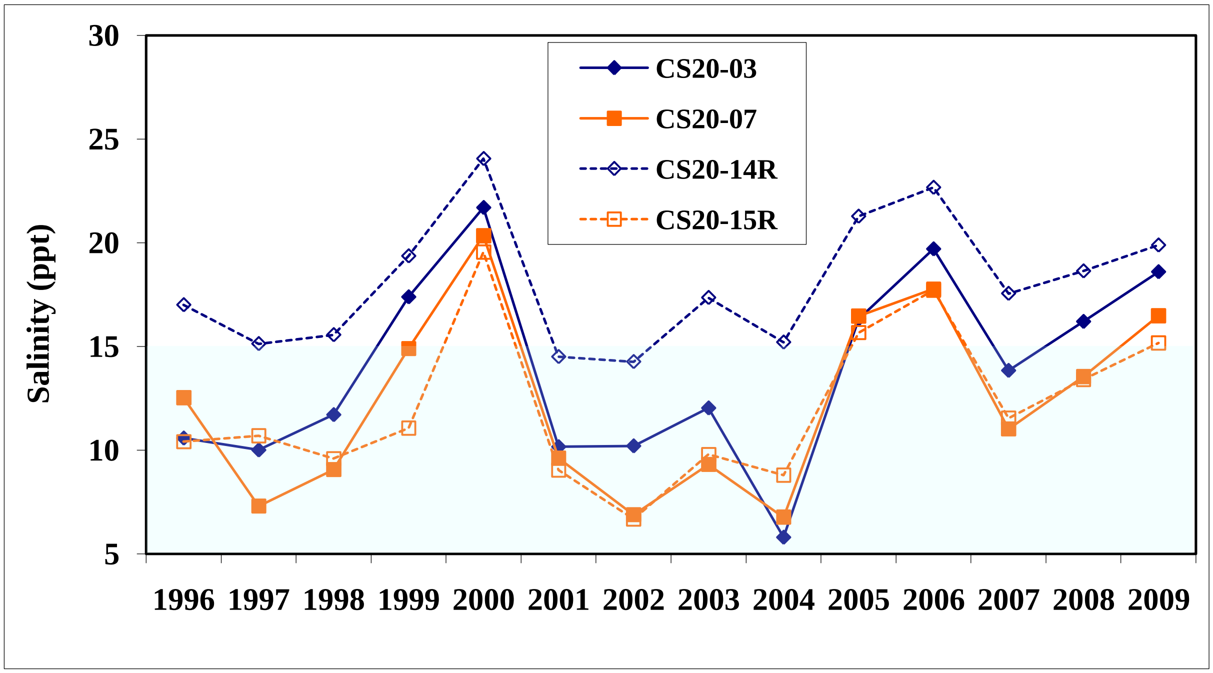


Figure 11. Mean water salinity per year collected by continuous water level recorders within the project (solid lines) and reference (dashed lines) areas. The targeted salinity for the managed areas is below 15 ppt (shaded area).

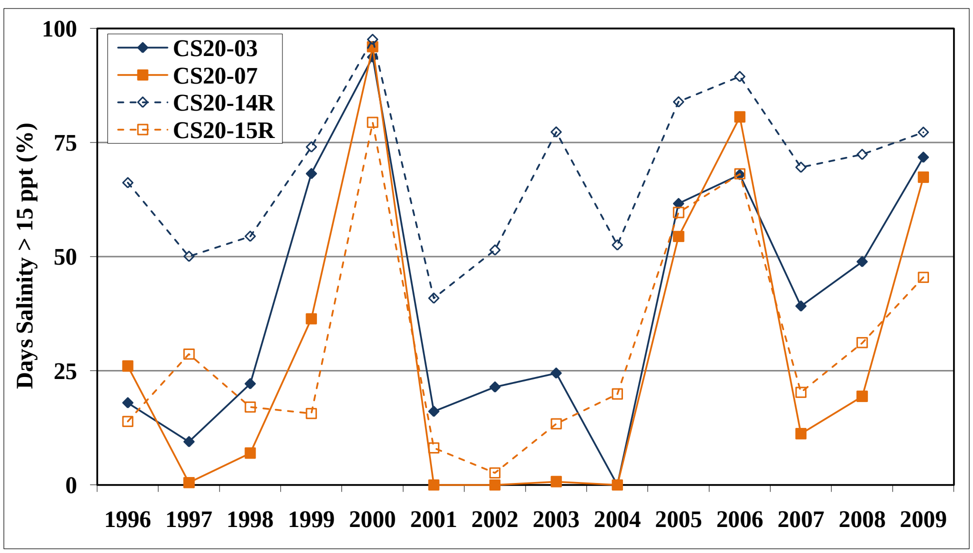


Figure 12. Percentage of days that salinity was greater than 15 ppt per year collected by continuous water level recorders within the project (solid lines) and reference (dashed lines) areas. Paired comparisons are CS20-03 (CTU 2) v CS20-14R (REF 1) and CS20-07 (CTU 1) v CS20-15R (REF 2).

Marsh Elevation Change: Distinct differences over time in CS-20 are defined by the hurricanes in 2005 (Rita) and 2008 (Ike) (figure 13); therefore, change rates (slopes from VA, SET, and SS over time) were calculated from the time periods before the hurricanes (1996-2003) and over the life of the project (1996-2009) for each site (Table 3). Many stations were converted to open water during the hurricanes in the reference area and a couple of SET stations were damaged before the 2009 sampling; therefore, analyses were conducted with 6 units for the prehurricane time period and 4 units for the overall time period. Vertical Accretion and SET rates were statistically greater overall than prehurricane as VA rate doubled and SET rate quadrupled. Prior to the hurricanes, elevation change was greater in the reference area; however, elevation change was greater in the project area over the whole project life as the rate increased twice as much in the project area than the reference area (Table 3). Much of the difference in elevation change between the areas is the result of increased subsidence in the reference area or reworking/displacement of surface sediment in the project area following the hurricanes

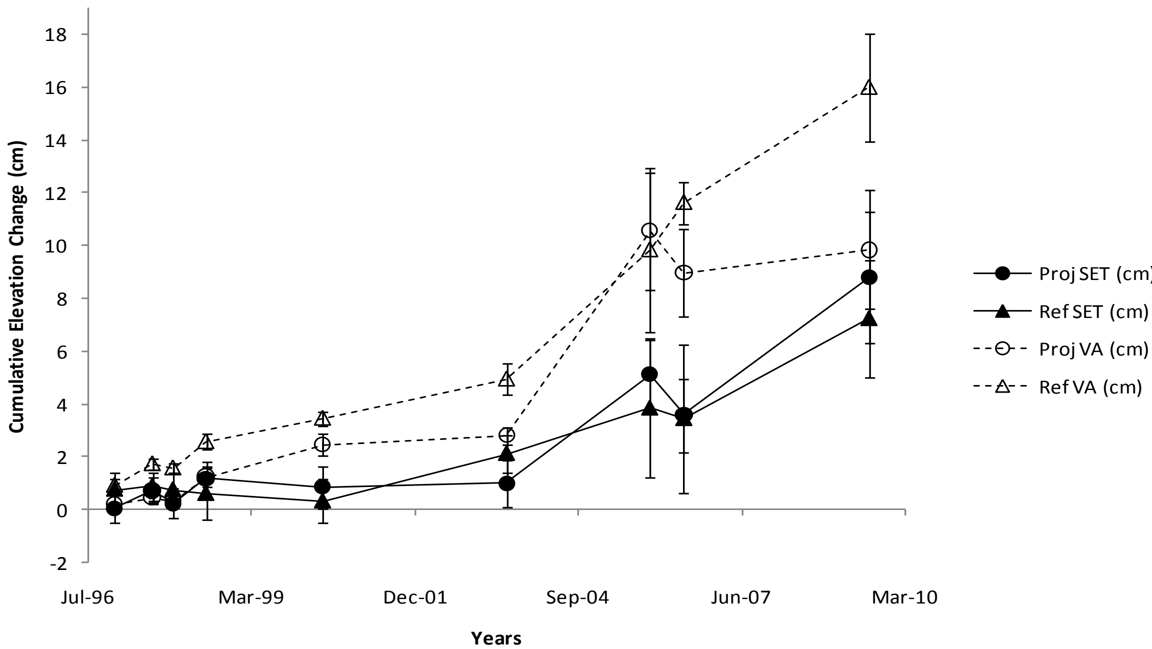


Figure 13. Surface elevation change (SET) and vertical accretion (VA) was collected at CS-20 project (Proj – CTU 2) and reference (Ref – REF 2) areas over time (Jul 1996 – Aug 2009). Values are means and standard errors of SET sites in the areas.

Table 3. Vertical Accretion (VA), Surface Elevation (SET), and Shallow Subsidence (SS) rates prior to the hurricanes and over the life of the project collected in CS-20 project and reference areas (Jul 1996 – Aug 1999) for the project. Different letters indicate statistical differences over time and area within each rate type (no statistical difference within SS rates).

			Rates of Change (cm/yr ± 1 SE)		
Time Period	Area	n	VA	SET	SS
Pre-Hurricanes	Project	6	0.44 ± 0.05^{A}	0.09 ± 0.11^{A}	0.35 ± 0.24
(Dec 1996–Jul 2003)	Reference	6	0.61 ± 0.09^{A}	0.17 ± 0.05^{AB}	0.44 ± 0.24
Overall	Project	4	1.03 ± 0.21^{B}	0.66 ± 0.12^{C}	0.37 ± 0.06
(Dec 1996–Aug 2009)	Reference	4	1.06 ± 0.07^{B}	0.46 ± 0.18^{BC}	0.60 ± 0.06

Soils: Project (CTU 2) and reference (REF 2) areas were similar to one another in terms of bulk density (BD) and organic components (density [OD] and percentage [%OM]) as surface soils (top 10 cm) changed over the three sampling periods (figures 14). From 1996-1999 (pre- to post-construction), BD decreased about 55% with a slighter decrease of about 20% in %OM during the drought and flooding events. A net loss in soil organic matter typically occurs when organic matter decomposition outpaces production (root productivity)/accumulation (sedimentation) (Nyman and DeLaune 1990). From 1999 to 2006 (pre- to post Hurricane Rita), BD sharply doubled with a proportional increase in mineral density (note decrease in %OM) resulting from the large sediment input during the storm surge of Hurricane Rita in 2005. Although OD increased, the soils converted from organic (>30% OM) to mineral (<30% OM) after Hurricane Rita. Soil properties are scheduled to be collected in 2012.

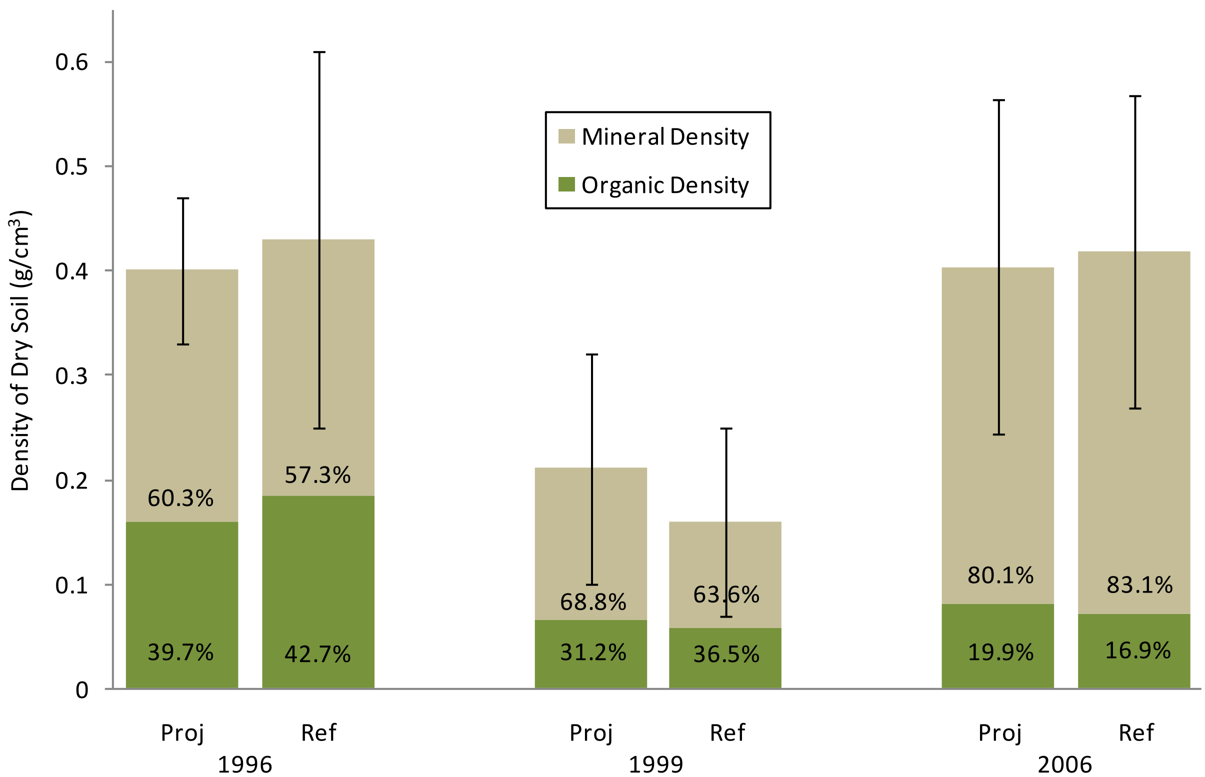


Figure 14. Bulk (full column), organic, and mineral density of dry soil (g/cm^3) of the top 10 cm from Proj (n=25) and Ref (n=20) sites collected preconstruction (1996), postconstruction (1999), and post Hurricane Rita (2006). Values are means of densities (columns) and mineral and organic percentages (text on bars); error bars are standard deviations of bulk density.

<u>Fisheries</u>: Fisheries aspects were collected in the CTU 2 (project area) and REF 2 (reference area). In order to accurately describe the most important differences in fisheries species abundances, resident and transient species are treated separately. Resident species spend most of their life cycle within the estuary, whereas transient species spawn in nearshore or offshore waters and use shallow estuarine habitats as nursery areas.

The most abundant resident fish species included *Poecilia latipinna* (sailfin molly), *Gambusia affinis* (western mosquitofish), *Menidia beryllina* (inland silversides), and *Cyprinodon ariegates* (sheepshead minnow), while *Brevoortia patronus* (gulf menhaden) and *Anchoa mitchilli* (bay anchovy) were two of the most abundant transient fish species. The most abundant resident decapod taxa include *Palaemonetes intermedius* (brackish grass shrimp), *P. pugio (*daggerblade grass shrimp), and *Palaemonetes* sp., while *Penaeus setiferus* (white shrimp), *P. aztecus* (brown shrimp), and *Callinectes sapidus* (blue crab) represent most abundant transient decapod species.

Before and after project construction, transient fishes and crustaceans were generally more abundant in the reference area (REF 2) than the project area (CTU 2) (figures 15 and 16) while resident fishes and crustaceans were generally more abundant in the project area than the reference area (figures 17 and 18). This likely indicates a previous and present access restriction for transient species to the project area caused by ring levees which is more suitable habitat for resident species. Fisheries species densities were temporally variable in both areas, and despite a trend toward higher crustacean densities after project construction in both areas, the project did not have a significant effect on total fisheries species densities. Although transient crustacean densities did increase significantly postconstruction in the project area, there was a much greater significant postconstruction increase in the reference area in total, transient, and resident crustacean densities, which means that even if the project effects contributed to an increase in animal numbers it was overshadowed by other (likely natural) causes.

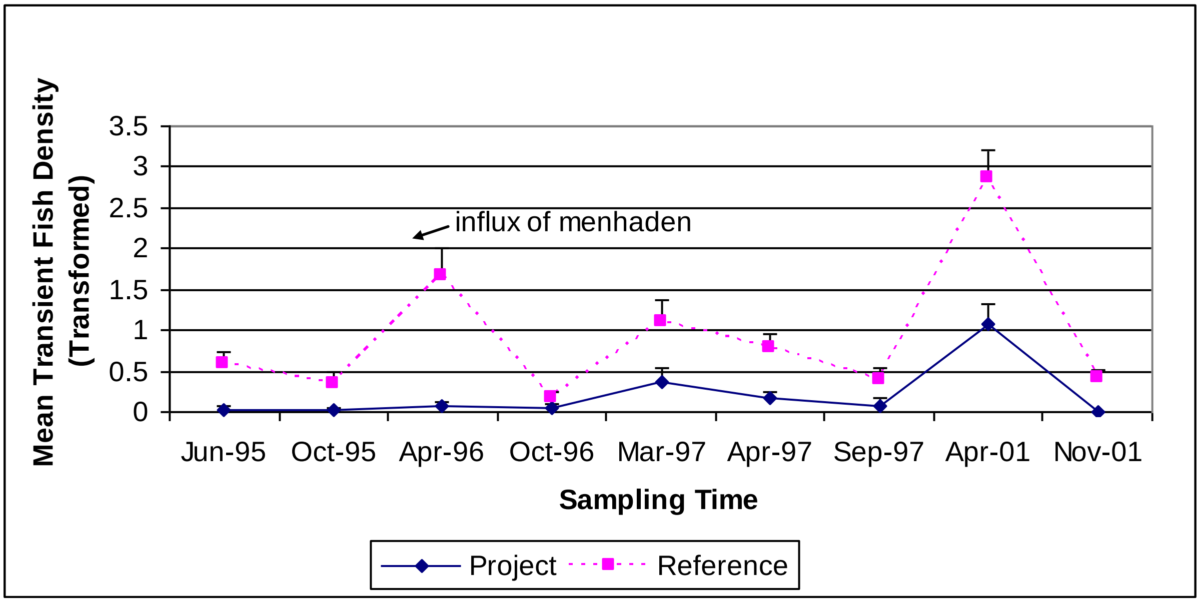


Figure 15. Transformed mean density per square meter of transient fish species collected in the East Mud Lake (CS-20) project and reference areas at sampling dates between June 1995 and November 2001**.**

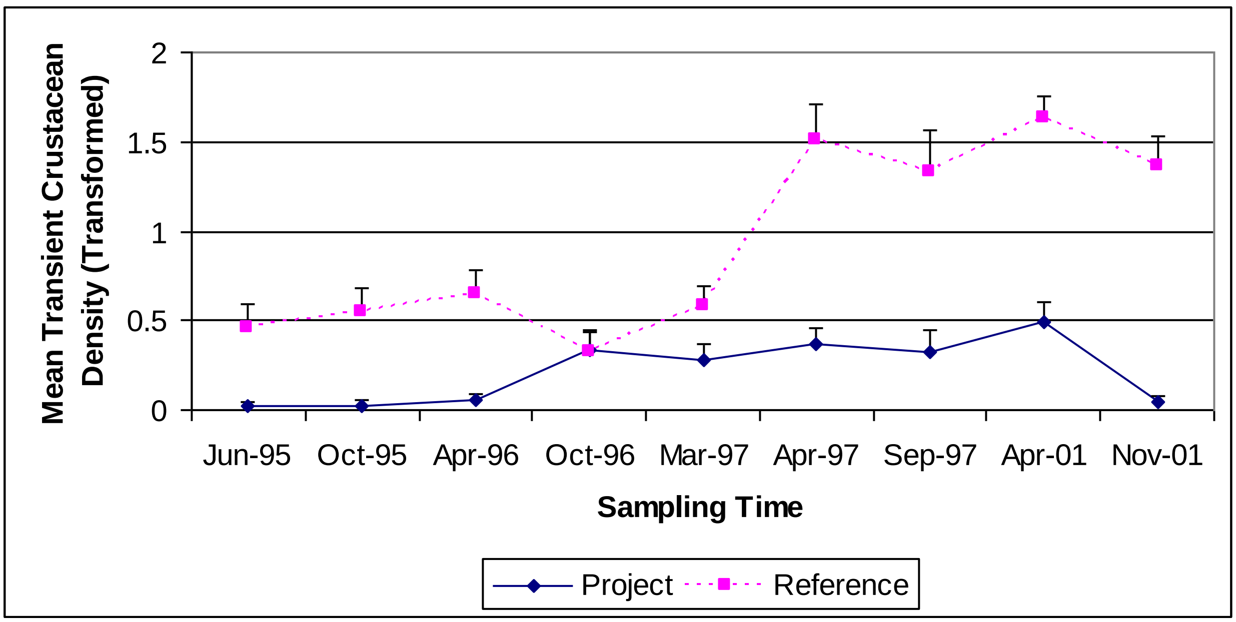


Figure 16. Transformed mean density per square meter of transient crustacean species collected in the East Mud Lake (CS-20) project and reference areas at sampling dates between June 1995 and November 2001.

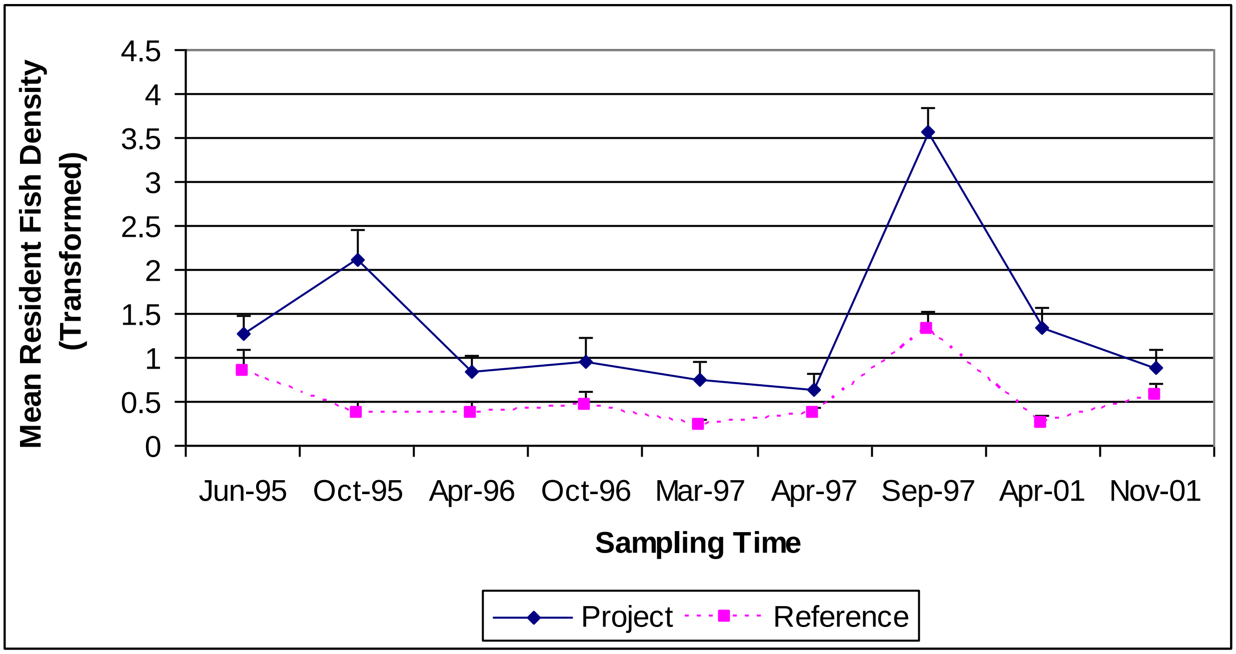


Figure 17. Transformed mean density per square meter of resident fish species collected in the East Mud Lake (CS-20) project and reference areas at sampling dates between June 1995 and November 2001**.**

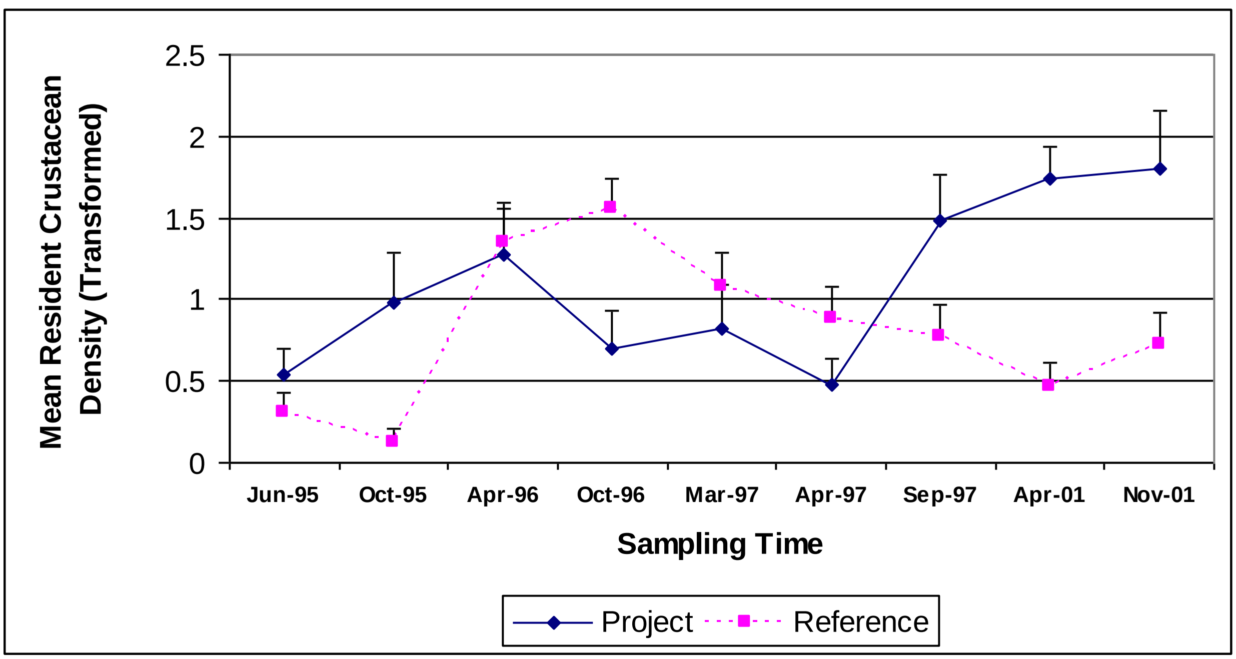


Figure 18. Transformed mean density per square meter of resident crustacean species collected in the East Mud Lake (CS-20) project and reference areas at sampling dates between June 1995 and November 2001**.**

V. Conclusions

a. Project Effectiveness

The CS-20 project has been effective at decreasing the rate of marsh loss. Land loss rates decreased substantially after construction in CTU 2 which is the project area with the greatest acreage of marsh and is actively managed. CTU 2 went from having the highest historical rate of land loss among project and reference areas (1956-1996) to being the only area to gain land after construction (1996-2000). In addition, CTU 2 had the lowest percentage of marsh loss resulting from Hurricane Rita (2000-2006). Following construction (1996-2006), marsh loss remained steady in CTU 1 and decreased slightly in the reference areas relative to historical rates of marsh loss (1956-1996).

Operation of water control structures coupled with the previous impoundment of the area moderates water levels and attenuates the high salinities that occur outside the project area during normal weather conditions. But, even when operated correctly, strong weather/climate patterns dominate control of water level and salinities inside and outside of project area as demonstrated by the high salinity during the 1999-2000 drought that was not controlled by the structures. Unfortunately, it is extreme weather/climate patterns, rather than normal conditions, that impact coastal marshes the most. As a result of Hurricanes Rita (September 2005) and Ike (September 2008), water levels were highly variable among the areas as water levels remained above the target in CTU 2 and water dropped below the target in CTU 1, and salinities were above 15 ppt for more than 65% of 2006 in both project areas. From 2006-2009 (including Hurricane Ike impacts), water levels and salinities remained elevated in the project and reference areas. In a positive note for the project, water levels in the project areas were closer to the target than the reference areas following Hurricane Rita. The ability to determine project effects on water level and salinity are confounded by the operational status of the water control structures (storm damage, vandalism, and length of time for maintenance) and the decision to keep the structures open since March 2008 in order to keep high salinity water circulating through the project area rather than trapping it in the project area. Recent maintenance of ES 3 and replacement of ES 4 will facilitate improved drainage of CTU 2; also, planned maintenance of ES 13 should resume freshwater input to CTU 1. Unfortunately, siltation has been a chronic problem at ES 13 because of low flow rates from First Bayou; efforts to restore flow to First Bayou by Ducks Unlimited, Inc. (DU) should improve water exchange at ES 13.

Overall, the CS-20 project has been effective at increasing emergent vegetation into shallow open-water areas in CTU 2. Initially, vegetative cover at sampling stations in the project area declined in 1997 (1996 drawdown, drought, flood), then rebounded by 2003; where as, the vegetative cover in the reference area (no drawdown) was consistently high through 2003. After Hurricane Rita (Sept 2005), cover in both the project and reference areas was decimated. Both areas had similar recoveries by September 2008 (>95% cover and "Good" floristic quality index [FQI] scores) and relatively small set-backs following Hurricane Ike. Dominant species composition changed over time, especially in the project areas, as vegetation type shifted to more saline plants (oligohaline wiregrass to mesohaline mixtures) since the flood in 1996 and Hurricanes Rita and Ike. Currently on a regional scale, the both project and reference vegetation sites in CS-20 had FQI scores approaching the 75th quartile of brackish marsh CRMS sites in the Cal/Sab basin from 2006-2009.

Increasing the land to water ratio by encouraging vegetation growth on the marsh edge is a worthwhile effort and a goal of the project, but it will only last if the marsh elevation is maintained or increased. Overall, components of elevation change are less variable in the project than the reference areas; this is attributable to the water control structures and the pre-existing ring levees around CTU 2. The project area receives less allochthonous input than the reference area because of the pre-existing ring levees; recently, however, it appears that the accretion rates of the two areas are similar so it is doubtful that the lack of suspended material input is the only factor influencing marsh elevation change. Prior to the hurricanes, elevation change was greater in the reference area; however, elevation change increased twice as much in the project area over the whole project life as the reference area. Much of the difference in elevation change between the areas is the result of increased subsidence in the reference area following the hurricanes. Sedimentation from the hurricanes was relatively large, greater than years or even decades of normal deposition, which was reflected in the soil properties as bulk density sharply increased with an influx of mineral matter. Although the different areas had the similar general patterns in elevation change and physical soil properties, the patterns were more pronounced in the reference than the project area. However, the newly introduced sediments are very unconsolidated and the thickness of the new layer will likely decrease over time. More sampling over time will tell us how much elevation we have truly gained from these hurricanes.

Fisheries species were sampled in CTU 2 and reference area 2. The project had maintained fisheries abundance prior to Hurricane Rita. Resident fishes and crustaceans were generally more abundant in the project area, and transient fishes and crustaceans were generally more abundant in the reference area prior to and 5 years after project construction. This indicates the pre-existing ring levee has restricted access of transient species to the project area and provides a more suitable habitat for resident species in the project area. We have not monitored fisheries abundance since Hurricane Rita.

Large changes over time are driven by climatic conditions (droughts, flooding, hurricanes) occurring on a regional scale rather than project effects. During “calmer times” between regional scale events, differences among project and reference areas are more distinctive as the project areas typically have more moderate (less fluctuations) water levels and lower salinity. Although more moderate than the reference areas, effects in the project areas since Hurricane Rita are confounded by operation problems of water control structures that are either sunken CTU 2 (ES 4) or have debris stuck in the flapgates (ES 3 and 13). Also, operations adapted to hurricane conditions by leaving the structures open more often to allow the project area to flush. Repairs, replacement, and improvements of and around hydrologic structures completed in 2010 will impact the overall performance and effectiveness of CS-20. In addition, recent projects to the west and east of CS-20, sponsored by DU, are predicted to positively influence hydrologic conditions in the vicinity. To the west, First Bayou was dredged and disconnected from a large location canal; this will allow more fresh water to drain from marshes west of Hwy 27 into East Mud Lake through ES 13. To the east, the channel of

Oyster Bayou, which is connected to the Calcasieu Ship Channel, was restricted; this will limit the exchange of higher salinity water through ES 3.

b. Recommended Improvements

The following operation and maintenance (O&M) events were completed by the end of 2010 and will improve the operation of CS-20 East Mud Lake Marsh Management Project.

- ES-6 – rock rip rap for bank erosion, replace padlocks and metal pile caps, clean out culverts.
- ES-7 – rock rip rap for bank erosion, replace padlocks and metal pile caps, replace staff gages, clean out culverts.
- ES-8 – rock rip rap for bank erosion, replace padlocks and metal pile caps.
- ES-9a – replace metal pile caps, clean out culvert, replace staff gages, replace padlocks and repair flapgate handle.
- ES-9b – replace gear box and stem cover, replace seat flange on flapgate, clean out culvert, replace padlocks and metal pile cap covers, repair flapgate handle.
- ES-11 – rock rip rap for bank erosion, extend boardwalk, replace metal pile cap covers and padlocks, replace staff gages.
- ES-5 – rock rip rap for bank erosion, replace metal pile cap covers, replace padlocks, replace boardwalk, and replace staff gages.
- ES-4 – replace structure, abandon existing structure in place.
- ES-3 – rock rip rap for bank erosion, clean out culvert, replace boardwalks, replace padlocks and staff gages.
- ES-1 – rock rip rap for bank erosion, extend boardwalk, replace metal pile cap covers and padlocks, replace staff gages.
- ES-17 – replace warning sign, replace pile cap on sheet pile wall, replace staff gage, replace metal pile cap covers, padlocks and locking tabs.
- ES-13 – replace warning sign, replace metal pile cap covers, replace staff gages, clean out debris, replace padlocks, replace metal pile cap on sheet pile wall.
- Levee/Step canal – repair levees and remove trash/debris and silt from canal.

Most of the damages resulting in the above maintenance and repairs were sustained during Hurricanes Rita in 2005 and were originally scheduled to be addressed in FY2007. A mechanism to reduce the time required for maintenance would benefit the project, as damages to the structures affect the hydrology of the project by inhibiting operation to achieve water level and salinity targets.

In light of the recent O&M events and recent DU projects in adjacent areas affecting the hydrology of the project area, revisions of the monitoring plan to extend hydrologic monitoring to 2015 and add a sampling event in 2015 is recommended. A request for additional funding from CWPPRA was awarded in 2010.

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Appendix A
(Inspection Photographs)

No inspection was performed during 2009-2010 due to ongoing maintenance on this project.

Appendix B
(Three Year Budget Projection)
E. MUD LAKE/ CS-20 / PPL 2
Three-Year Operations & Maintenance Budgets 07/01/2010 - 06/30/11

Project Manager	O & M Manager	Federal Sponsor	Prepared By
Pat Landry	*Pat Landry*	*NRCS*	*Pat Landry*

	2010/2011	2011/2012	2012/2013
Maintenance Inspection	$ 5,909.00	$ 6,086.00	$ 6,269.00
Structure Operation	$ 6,500.00	$ 6,500.00	$ 6,500.00
Administration	$ -		$ -

Maintenance/Rehabilitation

10/11 Description:

E&D	$ -
Construction	$ -
Construction Oversight	$ -
Sub Total - Maint. And Rehab.	$ -

11/12 Description:

E&D	
Construction	
Construction Oversight	
Sub Total - Maint. And Rehab.	$ -

12/13 Description:

E&D	$ -
Construction	$ -
Construction Oversight	$ -
Sub Total - Maint. And Rehab.	$ -

	2010/2011	2011/2012	2012/2013
Total O&M Budgets	**$ 12,409.00**	**$ 12,586.00**	**$ 12,769.00**

O &M Budget (3 yr Total)	**$ 37,764.00**
Unexpended O & M Budget	**$ 932,545.00**
Remaining O & M Budget (Projected)	**$ 894,781.00**

OPERATION AND MAINTENANCE BUDGET WORKSHEET 07/01/2010-06/30/2011

E. MUD LAKE / PROJECT NO. CS-20 / PPL NO. 2

DESCRIPTION	UNIT	EST. QTY.	UNIT PRICE	ESTIMATED TOTAL
O&M Inspection and Report	EACH	1	$5,909.00	**$5,909.00**
General Structure Maintenance	LUMP	1	$0.00	**$0.00**
Engineering and Design	LUMP	1	$0.00	**$0.00**
Operations Contract	LUMP	1	$6,500.00	**$6,500.00**
Construction Oversight	LUMP	1	$0.00	**$0.00**

ADMINISTRATION

LDNR / CRD Admin.	LUMP	1	$0.00	$0.00
FEDERAL SPONSOR Admin.	LUMP	1	$0.00	$0.00
SURVEY Admin.	LUMP	0	$0.00	$0.00
OTHER				$0.00
			TOTAL ADMINISTRATION COSTS:	**$0.00**

MAINTENANCE / CONSTRUCTION

SURVEY

SURVEY DESCRIPTION:					
	Secondary Monument	EACH	0	$0.00	$0.00
	Staff Gauge / Recorders	EACH	10	$0.00	$0.00
	Marsh Elevation / Topography	LUMP	0	$0.00	$0.00
	TBM Installation	EACH	0	$0.00	$0.00
	OTHER				$0.00
				TOTAL SURVEY COSTS:	**$0.00**

GEOTECHNICAL

GEOTECH DESCRIPTION:					
	Borings	EACH	0	$0.00	$0.00
	OTHER				$0.00
				TOTAL GEOTECHNICAL COSTS:	**$0.00**

CONSTRUCTION

CONSTRUCTION DESCRIPTION:						
	Rip Rap	LIN FT	TON / FT	TONS	UNIT PRICE	
	Rock Armor at 1, 3, 5, 11	0	0.0	1,363	$0.00	$0.00
	Rock Armor at 6, 7, 8	0	0.0	246	$0.00	$0.00
		0	0.0	0	$0.00	$0.00
	Filter Cloth / Geogrid Fabric		SQ YD	0	$0.00	$0.00
	Navigation Aid		EACH	0	$0.00	$0.00
	Signage		EACH	0	$0.00	$0.00
	General Excavation / Fill		CU YD	0	$0.00	$0.00
	Dredging		CU YD	0	$0.00	$0.00
	Sheet Piles (Lin Ft or Sq Yds)			0	$0.00	$0.00
	Timber Piles (each or lump sum)			0	$0.00	$0.00
	Timber Members (each or lump sum)			0	$0.00	$0.00
	Hardware		LUMP	1	$0.00	$0.00
	Materials		LUMP	1	$0.00	$0.00
	Mob / Demob		LUMP	1	$0.00	$0.00
	Contingency		LUMP	1	$0.00	$0.00
	General Structure Maintenance		LUMP	1	$0.00	$0.00
	Replace Structure No. 4		LUMP	1	$0.00	$0.00
	Levee Repair		CU YD	19,120	$0.00	$0.00
	Clean Wrack & Debris		LUMP	0	$0.00	$0.00
					TOTAL CONSTRUCTION COSTS:	**$0.00**

TOTAL OPERATIONS AND MAINTENANCE BUDGET: **$12,409.00**

OPERATION AND MAINTENANCE BUDGET 07/01/2011-06/30/2012

E. MUD LAKE/CS-20/PPL2

DESCRIPTION	UNIT	EST. QTY.	UNIT PRICE	ESTIMATED TOTAL
O&M Inspection and Report	EACH	1	$6,086.00	**$6,086.00**
General Structure Maintenance	LUMP	1	$0.00	**$0.00**
Engineering and Design	LUMP	1	$0.00	**$0.00**
Operations Contract	LUMP	1	$6,500.00	**$6,500.00**
Construction Oversight	LUMP	1	$0.00	**$0.00**

ADMINISTRATION

LDNR / CRD Admin.	LUMP	0	$0.00	$0.00
FEDERAL SPONSER Admin.	LUMP	0	$0.00	$0.00
SURVEY Admin.	LUMP	0	$0.00	$0.00
OTHER				$0.00
			TOTAL ADMINISTRATION COSTS:	**$0.00**

MAINTENANCE / CONSTRUCTION

SURVEY

SURVEY DESCRIPTION:					
	Secondary Monument	EACH	0	$0.00	$0.00
	Staff Gauge / Recorders	EACH	0	$0.00	$0.00
	Marsh Elevation / Topography	LUMP	0	$0.00	$0.00
	TBM Installation	EACH	0	$0.00	$0.00
	OTHER				$0.00
				TOTAL SURVEY COSTS:	**$0.00**

GEOTECHNICAL

GEOTECH DESCRIPTION:					
	Borings	EACH	0	$0.00	$0.00
	OTHER				$0.00
				TOTAL GEOTECHNICAL COSTS:	**$0.00**

CONSTRUCTION

CONSTRUCTION DESCRIPTION:						
	Rip Rap	LIN FT	TON / FT	TONS	UNIT PRICE	
		0	0.0	0	$0.00	$0.00
		0	0.0	0	$0.00	$0.00
		0	0.0	0	$0.00	$0.00
	Filter Cloth / Geogrid Fabric		SQ YD	0	$0.00	$0.00
	Navagation Aid		EACH	0	$0.00	$0.00
	Signage		EACH	0	$0.00	$0.00
	General Excavation / Fill		CU YD	0	$0.00	$0.00
	Dredging		CU YD	0	$0.00	$0.00
	Sheet Piles (Lin Ft or Sq Yds)			0	$0.00	$0.00
	Timber Piles (each or lump sum)			0	$0.00	$0.00
	Timber Members (each or lump sum)			0	$0.00	$0.00
	Hardware		LUMP	1	$0.00	$0.00
	Materials		LUMP	1	$0.00	$0.00
	Mob / Demob		LUMP	1	$0.00	$0.00
	Contingency		LUMP	1	$0.00	$0.00
	General Structure Maintenance		LUMP	1	$0.00	$0.00
	OTHER				$0.00	$0.00
	OTHER				$0.00	$0.00
	OTHER				$0.00	$0.00
					TOTAL CONSTRUCTION COSTS:	**$0.00**

TOTAL OPERATIONS AND MAINTENANCE BUDGET: **$12,586.00**

OPERATION AND MAINTENANCE BUDGET 07/01/2012-06/30/2013

E. MUD LAKE/CS-20/PPL2

DESCRIPTION	UNIT	EST. QTY.	UNIT PRICE	ESTIMATED TOTAL
O&M Inspection and Report	EACH	1	$6,269.00	**$6,269.00**
General Structure Maintenance	LUMP	1	$0.00	**$0.00**
Engineering and Design	LUMP	1	$0.00	**$0.00**
Operations Contract	LUMP	1	$6,500.00	**$6,500.00**
Construction Oversight	LUMP	1	$0.00	**$0.00**

ADMINISTRATION

LDNR / CRD Admin.	LUMP	1	$0.00	$0.00
FEDERAL SPONSER Admin.	LUMP	1	$0.00	$0.00
SURVEY Admin.	LUMP	1	$0.00	$0.00
OTHER				$0.00
			TOTAL ADMINISTRATION COSTS:	**$0.00**

MAINTENANCE / CONSTRUCTION

SURVEY

SURVEY DESCRIPTION:

Secondary Monument	EACH	0	$0.00	$0.00
Staff Gauge / Recorders	EACH	0	$0.00	$0.00
Marsh Elevation / Topography	LUMP	0	$0.00	$0.00
TBM Installation	EACH	0	$0.00	$0.00
OTHER				$0.00
			TOTAL SURVEY COSTS:	**$0.00**

GEOTECHNICAL

GEOTECH DESCRIPTION:

Borings	EACH	0	$0.00	$0.00
OTHER				$0.00
			TOTAL GEOTECHNICAL COSTS:	**$0.00**

CONSTRUCTION

CONSTRUCTION DESCRIPTION:

Rip Rap	LIN FT	TON / FT	TONS	UNIT PRICE	
	0	0.0	0	$0.00	$0.00
	0	0.0	0	$0.00	$0.00
	0	0.0	0	$0.00	$0.00

Filter Cloth / Geogrid Fabric	SQ YD	0	$0.00	$0.00
Navagation Aid	EACH	0	$0.00	$0.00
Signage	EACH	0	$0.00	$0.00
General Excavation / Fill	CU YD	0	$0.00	$0.00
Dredging	CU YD	0	$0.00	$0.00
Sheet Piles (Lin Ft or Sq Yds)		0	$0.00	$0.00
Timber Piles (each or lump sum)		0	$0.00	$0.00
Timber Members (each or lump sum)		0	$0.00	$0.00
Hardware	LUMP	1	$0.00	$0.00
Materials	LUMP	1	$0.00	$0.00
Mob / Demob	LUMP	1	$0.00	$0.00
Contingency	LUMP	1	$0.00	$0.00
General Structure Maintenance	LUMP	1	$0.00	$0.00
OTHER			$0.00	$0.00
OTHER			$0.00	$0.00
OTHER			$0.00	$0.00
			TOTAL CONSTRUCTION COSTS:	**$0.00**

TOTAL OPERATIONS AND MAINTENANCE BUDGET: **$12,769.00**

Appendix C
(Field Inspection Notes)

No inspection was performed during 2009-2010 due to ongoing maintenance on this project.