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THREE-YEAR COMPREHENSIVE MONITORING REPORT

COAST 2050 REGION 4
CAMERON CREOLE PLUG PROJECT
CS-17

Second Priority List Marsh Management Project
of the Coastal Wetlands Planning, Protection, and Restoration Act
(Public Law 101-646)

Leigh A. Sharp[1], Dona K. Weifenbach[1], and Norma M. Clark[2]

[1]Louisiana Department of Natural Resources
Coastal Restoration Division
P.O. Box 44027
Baton Rouge, La 70804-4027

[2] United States Geological Survey
700 Cajun Dome Blvd.
Lafayette LA 70506

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ABSTRACT

The response of emergent vegetation, submerged aquatic vegetation, frequency and duration of flooding, and salinity to hydrologic alterations in the Calcasieu/Sabine Basin were evaluated at the Cameron Creole Watershed Borrow Canal Plug project area located in Cameron Parish, Louisiana. The Cameron Creole Watershed consists of 64,000 acres bounded by a levee and five water control structures along the eastern side of Calcasieu Lake. The levee was constructed in 1989 to protect the brackish and intermediate marsh to the east of the lake. Two sheet metal plugs were installed in 1997 in the borrow canal excavated for the construction of the levee. The northern plug was designed to moderate the strong counterclockwise circulation of water through Grand Bayou and the intermediate marshes to the north. The southern plug was designed to reduce water levels and ponding of water in the southern end of the watershed. During the post-construction monitoring period, percent cover and species richness of emergent vegetation decreased, while maximum stem height increased. Changes in emergent vegetation were most likely due to climatic stressors including drought and flood and not necessarily the plugs installed during the project as similar trends were seen throughout the Calcasieu/Sabine watershed. Submerged aquatic vegetation decreased in both frequency of occurrence and species richness at all sites as drought conditions including high salinity and low water level continued. Pre-construction water level data were recorded during flood periods due to Hurricane Dolly and Tropical Storm Josephine and post-construction data were collected during periods of drought making the impact of the plugs on water circulation in the watershed and on ponding in the marshes south of the lake difficult to determine. It was not possible to differentiate ecological responses due to the project plugs and the pre-existing water control structures, and it may not be possible to duplicate conditions for measurement of water level, salinity, and water flow because preconstruction samples were taken during the worst drought in 20 years. Therefore, we recommend that monitoring for this project as written in the monitoring plan be discontinued and future monitoring of the Cameron-Creole Watershed and the Calcasieu Basin be conducted through CRMS-*Wetlands* monitoring approach.

INTRODUCTION

Louisiana possesses more than 40% of the total coastal wetland acreage in the United States. These wetlands are in a severe state of degradation due to natural and anthropogenic causes (Turner 1990; Boesch et al. 1994). Rates of relative sea level rise have increased across the Louisiana coast (Penland et al. 1989). The problem has been exacerbated by human interference with marsh ecosystem processes. Dredging of oil and gas access canals beginning in the 1940's led to landscape scale ecosystem change in coastal Louisiana (Myers et al. 1995; Reed and Rozas 1995).

The Chenier Plain developed approximately 4,000 years ago through westward littoral transport of Mississippi River delta sediments, combined with deposition of local fluvial sediments (Howe et al. 1935; Van Lopik and McIntire 1957; Byrne et al. 1959; DeLaune et al. 1983). The development of cheniers (recessional beach ridges) coincided with eastward shifts in the course of the Mississippi River (Byrne et al., 1959; Gould and McFarlan, 1959; DeLaune et al., 1983). Intervening mudflats (marshes) are associated with westward shifts in the river's course. The Calcasieu River has historically maintained a channel through the central portion of Calcasieu Lake (Van Sickle 1977).

The Cameron-Creole Watershed, on the Chenier Plain, consists of 64,000 acres (25,900 ha) of brackish, intermediate, and fresh marsh located along the east side of Calcasieu Lake in the Calcasieu/Sabine Basin in Cameron Parish, Louisiana (figure 1). This area is part of the Sabine National Wildlife Refuge. Since 1871, the Calcasieu Ship Channel (CSC) has been intermittently dredged, from 32.8 ft (10 m) deep in 1937, to 39.4 ft (12 m) in 1946, and deepened in 1963 to 49.2 ft (15 m) with a final width of 400 ft (122 m) (USACE 1971). The channel allowed salt water to flood the interior marshes surrounding Calcasieu Lake (figure 2). As a result, approximately 63,000 acres (25,496 ha) of brackish, intermediate, and fresh marsh on the east side of Calcasieu Lake were lost between 1950 and 1970 (Delany 1991). Most of the impacted marsh turned to open water while some was converted to brackish and salt marsh.

In 1989, a levee and five (5) water control structures (three variable-crest and two fixed crest weirs with vertical slots) were constructed by the Soil Conservation Service (SCS), now Natural Resources Conservation Service (NRCS), along the eastern shore of Calcasieu Lake (figure 2). The structures were intended to reduce the movement of salt water into the watershed. A borrow canal was also constructed along the wetland side of the levee to further prevent saltwater intrusion into the marsh.

Management of the five water control structures is controlled by the United States Fish and Wildlife Service (USFWS) including Sabine Refuge personnel. The structures are managed to prevent the introduction of saltwater into the Cameron-Creole Watershed. The five water control structures along Calcasieu Lake are operated in two phases. Phase I emphasizes slowing marsh erosion and reclaiming emergent marsh by implementing a partial drawdown to 0.5 ft (0.15 m) below marsh elevation from February 15 - July 15 each year. At least one of the vertical slots in each structure remains open during this time. Phase II, or the maintenance phase, emphasizes

Figure 1. Hydrologic basins of the Chenier Plain, Louisiana.

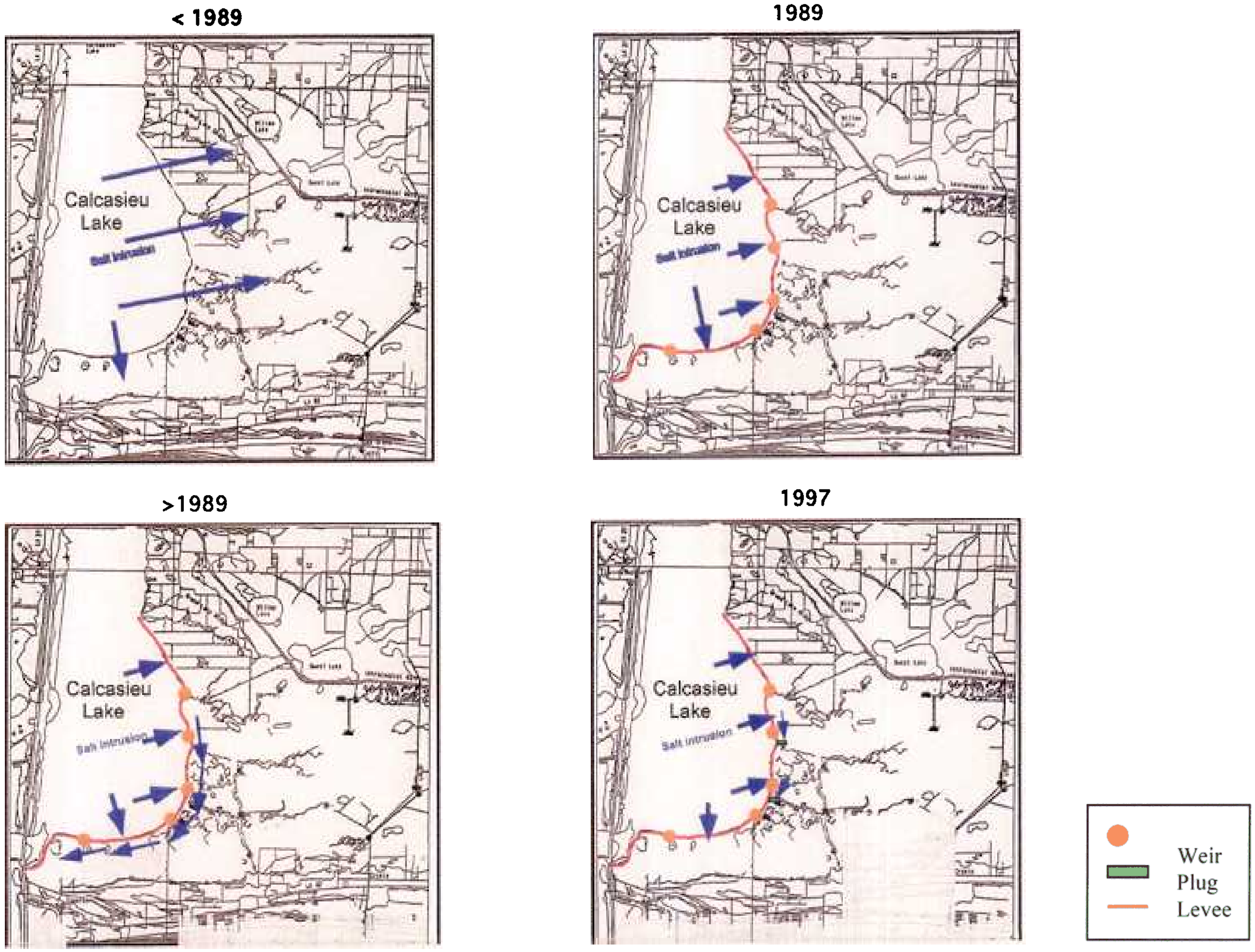


Figure 2. Historical alterations of Cameron Creole watershed hydrology and associated water circulation patterns.

slowing marsh erosion with secondary emphasis on improving fisheries habitat, maintaining and improving wildlife habitat, and increasing species diversity in emergent marsh plants. The crests of all structures are set at 0.5 ft (0.15 m) below marsh level with all slots and the boat bay at Grand Bayou open. Temporary closures of the boat bay and slots depend on salinity in Calcasieu Lake and in the marsh at East Prong (figure 3). The structures are closed when salinity at the confluence of Grand Bayou, North Prong and East Prong exceeds 12 ppt.

Changes in the water circulation patterns on the Cameron-Creole Watershed have not occurred as anticipated since the water control structures were installed and the management plan implemented in 1989. Saline water continues to move through the structures, and through the borrow canal, resulting in excessive accumulation of saline water in the southern end of the watershed (Delany 1991). In the northern end of the watershed, water moves rapidly in a counter-clockwise circulation pattern through the Peconi (Bois Connine) Bayou system (figure 2). In order to increase control of water flow, isolate management areas, and prevent further saltwater intrusion in the Cameron-Creole Watershed, two plugs were placed in the borrow canal in 1997. One was placed south of Grand Bayou and one south of Mangrove Bayou (figures 2 and 3).

The Cameron-Creole Watershed Borrow Canal Plug (CS-17) project is comprised of 14,471 acres (5,858 ha) of wetlands divided into three project areas and two reference areas (figure 4). The plug south of Mangrove Bayou (figure 5), set at 1.5 ft (0.46 m) National Geodetic Vertical Datum (NGVD), was intended to influence 6,082 acres (3,462 ha) in the northern project area. The vegetated marsh in this area was composed of *Spartina patens* (marshhay cordgrass), *Schoenoplectus pungens* (Olney's three-cornered grass), *Paspalum vaginatum* (joint grass), *Typha* spp. (cattail), and *Phragmites australis* (roseau cane) when the plugs were installed. Soils over the majority of the northern project area are classified as Bancker and Clovelly soil types, except in the northeast corner area, where a small percentage of Gentilly Muck is present (USDA 1995). In order to investigate the effect of the plug south of Mangrove Bayou on the surrounding marshes, water flow and the response of emergent vegetation percent cover, maximum height, and species richness were measured in the northern project area.

The plug south of Grand Bayou, set at 1.0 ft (0.3 m) NGVD, was intended to allow for separate operation of the Grand Bayou and Lambert Bayou structures, and was expected to affect 6,606 acres (2,675 ha) of brackish marsh in the southern project area (figure 4). The vegetated marsh in this area was composed of *S. patens, Distichlis spicata* (saltgrass), and *Spartina alterniflora* (smooth cordgrass). Soils are classified as Bancker, Clovelly, and Allmends Muck. In order to determine if the borrow canal plugs reduced water level in the southern project area, duration of flooding and the response of emergent vegetation cover, height, and richness was measured.

The plugs were also expected to affect 1,783 acres (720 ha) of broken marsh and shallow open water ponds from 0.5 ft to 2.0 ft (0.15-0.61 m) deep to the east of Grand Bayou. The ponds support stands of submerged aquatic vegetation (SAV) including *Ruppia maritima* (widgeon grass), *Myriophyllum spicatum* (Eurasian watermilfoil), and *Ceratophyllum demersum* (coontail). Underlying soils include Bancker, Gentilly, and Allemands Muck. The ponds in the eastern

Figure 3. Cameron-Creole Plugs Project area map with weirs, plugs, bayou names and watershed boundary.

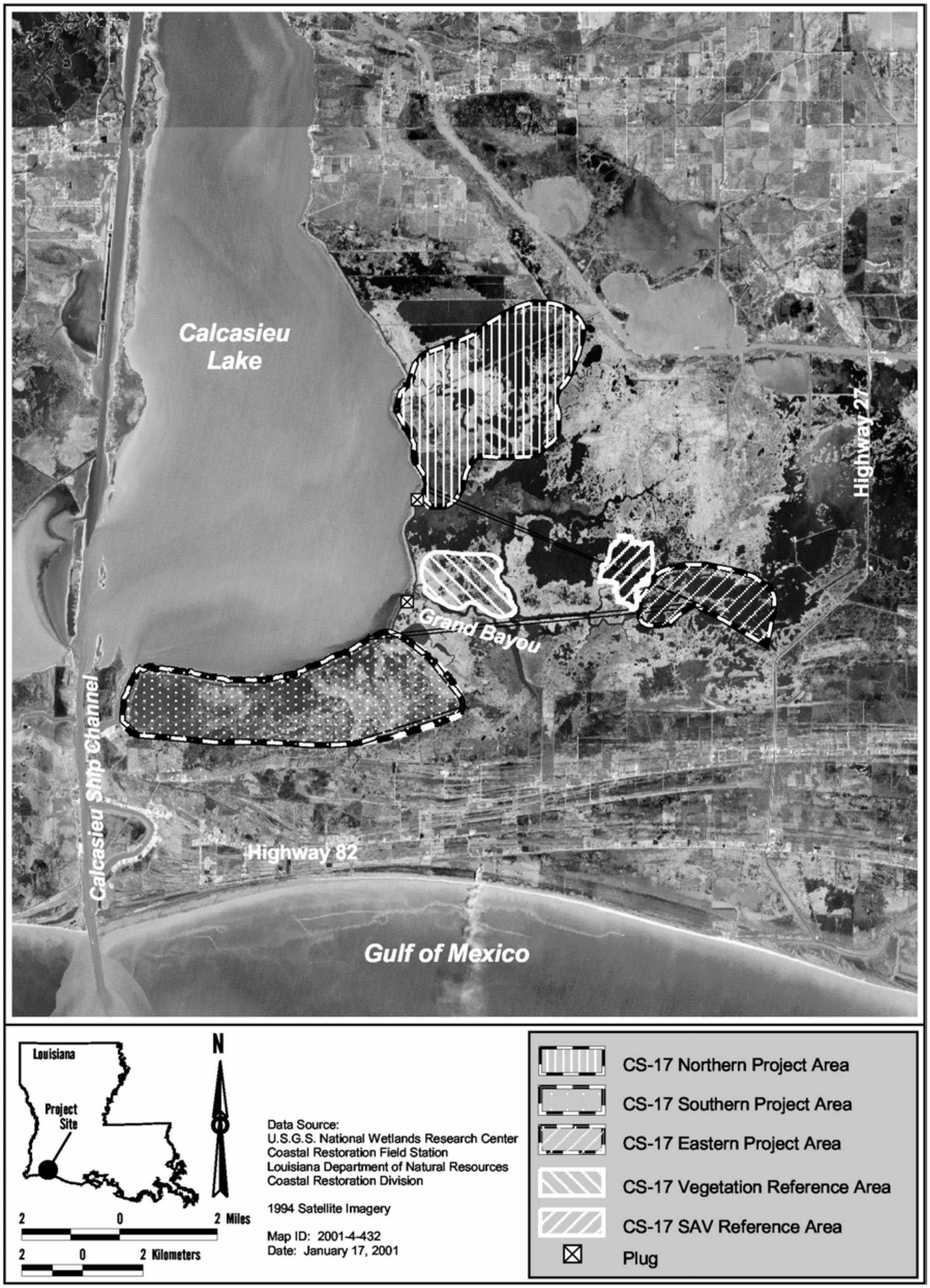


Figure 4. Cameron Creole Plug project map depicting project and reference areas.

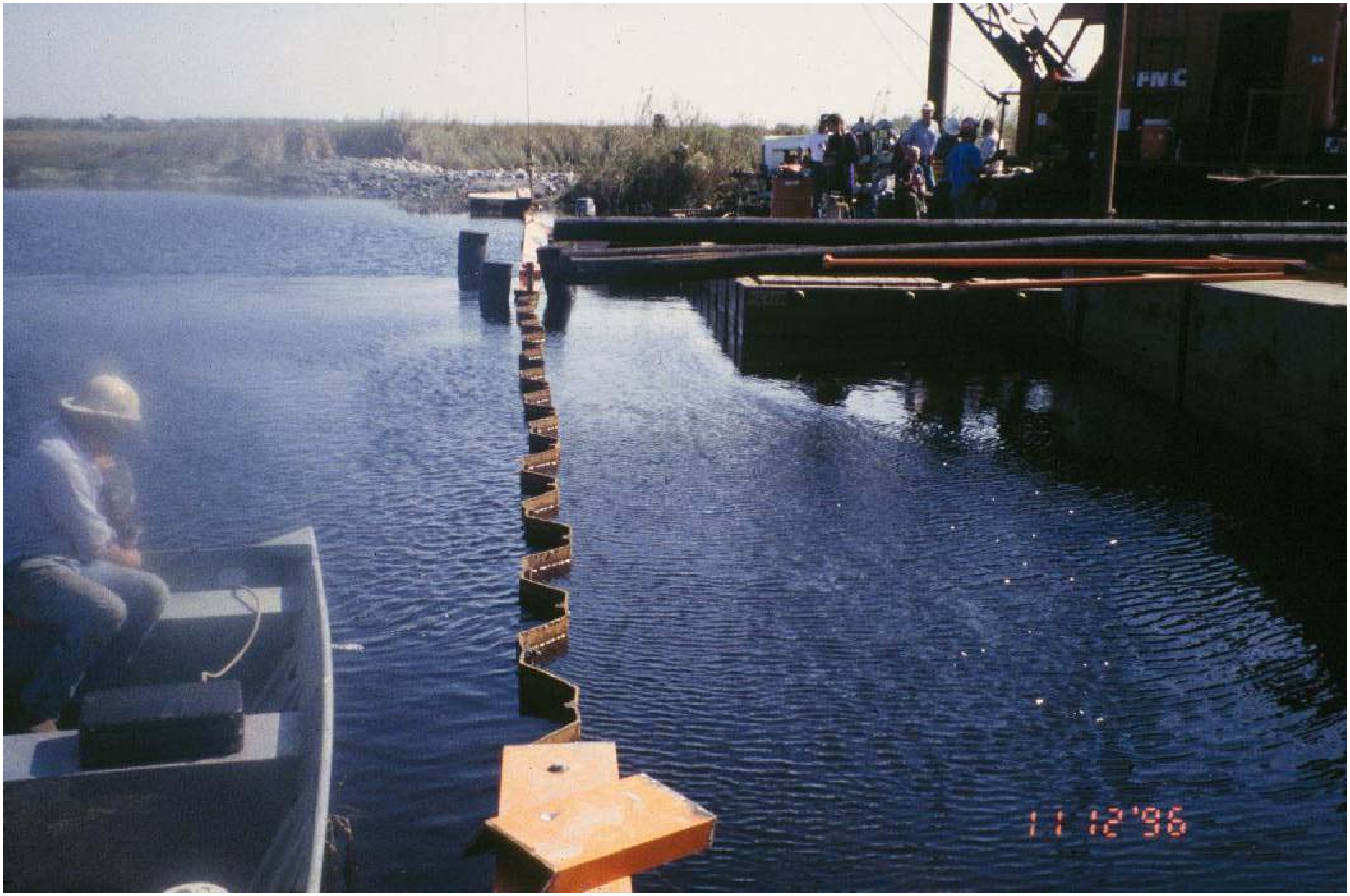


Figure 5. Photograph of plug installation south of Mangrove Bayou in November, 1996.

project area were monitored for effects of the plug project on the frequency of occurrence and species richness of SAV. Construction of the plugs in the borrow canal on the east side of Calcasieu Lake was completed in February 1997. The objectives of the project were to enhance and improve marsh condition in the northern, southern, and eastern project areas, and to improve structural management capabilities. The specific project goals were to reduce duration of flooding in the southern project area, reduce water flow in the borrow canal in the northern project area, increase coverage of emergent marsh plants in both the northern and southern project areas, and to increase the relative frequency of occurrence of SAV in the eastern project area.

METHODS

A detailed description of the monitoring design can be found in Weifenbach (1995).

Habitat mapping: 1:24,000 scale color-infrared aerial photography was classified and photo interpreted to measure wetland to open water ratios and to map habitat types in the project area. Pre-construction photography was obtained on November 1, 1993 and post-construction photography is scheduled for 2010. Information was analyzed at the USGS National Wetland Research Center (NWRC).

To determine land to open water ratios, the aerial photographs were scanned at 300 pixels per inch and georectified using ground control data collected with a global positioning system (GPS) capable of submeter accuracy. These individually georectified frames were then mosaicked to produce a single image of the project and reference areas. Using geographic information systems (GIS) technology, the photo mosaic was classified according to pixel value and analyzed to determine land to water ratios in the project and reference areas. All areas characterized by emergent vegetation were classified as land, while open water, aquatic beds, and mud flats were classified as water. An accuracy assessment comparing the GIS classification of 100 randomly chosen pixels to aerial photography determined an overall classification accuracy of 96%.

Using the National Wetlands Inventory (NWI) classification system, the photography was photo interpreted by NWRC personnel and classified to the subclass habitat level (Cowardin et al. 1992). The habitat delineations were transferred to 1:6,000 scale Mylar base maps, digitized, and reviewed for quality and accuracy.

The NWI classification system identifies habitat types by system, subsystem, class, and subclass. The estuarine system includes all tidal habitats in which waters consist of at least 0.5% ocean-derived salt and are diluted at least occasionally by freshwater runoff from the land. Palustrine habitats are nontidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens, and all wetlands that occur in tidal areas where ocean-derived salinities are less than 0.5% (Cowardin et al. 1992). Urban habitats are those whose areal coverage consists of less than 30% vegetation or other cover. Upland shrub-scrub habitats consist of at least 30% shrub-scrub, and upland forested habitats consist of at least 3% forest (Anderson et al. 1976). When describing both upland and wetland habitats, the term “shrub-scrub” refers to woody vegetation less than 20 ft (6m) in height. The term “forested” refers to woody vegetation taller than 20 ft. Where more than one class of vegetation exists, the uppermost layer of vegetation with areal coverage greater than 30% determines the NWI habitat type.

Soils: Soils were sampled in the plots used for vegetation monitoring and analyzed for field moist bulk density, percent organic matter, and soil salinity. Cores were taken with a Swensen corer, refrigerated and analyzed by personnel at the Louisiana State University (LSU) Agronomy Department where samples were first air dried and then oven dried at approximately 100^{o} C for 24-48 hours. Soil condition was monitored post-construction in 1997 coinciding with vegetative monitoring. Field moist bulk density is calculated as dry sample weight divided by volume of field moist sample.

Water Quality: Water quality data were collected using YSI 6000 continuous recorders at four stations, one in the northern project area (11), one in the southern project area (12), one in the vegetation reference area (borrow canal) (2R), and one outside of the levee surrounding the watershed in Calcasieu Lake (1R) (figure 4 and figure 6). Stations 1R, 2R, and 11 were established in September 1993, and station 12 was established in March 1995. Water level (ft North American Vertical Datum, NAVD), salinity (ppt), temperature (°C), and specific conductance ($\mu S/cm^3$) 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 due to biofouling was calculated at the time of retrieval by comparing dirty and clean discrete readings to those taken with a calibrated instrument. Missing data are usually due to instrument malfunction or inaccessibility to the site.

Discrete salinity readings were taken by refuge personnel at 25 existing USFWS monitoring stations, 6 located inside the project areas, and 19 located outside the project areas (figure 6) every two weeks (bi-weekly) from January 1990 to December 1999. Some data are missing due to inaccessibility. Maximum and minimum salinity of monthly means were calculated for each station over the entire sampling period. Monthly means of continuous water level data, collected from January 1996 to December 2000 and salinity data collected from March 1995 to December 2000 were calculated for all four continuous recorder stations.

Six staff gauges (three located within the project area and three located outside the project area) surveyed to NAVD 88 were monitored bi-weekly by USFWS personnel. Four of the staff gauges were located at the continuous recorder stations, where marsh surface elevation relative to the NAVD 88 datum was determined. Water level data were used to estimate frequency and duration of marsh inundation in the southern project area (station 12) compared to the vegetation reference area along the borrow canal (station 2R), from hourly data collected before construction between February 23, 1995 and December 16, 1996 and after construction between February 5, 1997 and July 20, 2000. Approximately 7,000 hours of pre-construction data and 26,000 hours of post-construction data were analyzed.

Hourly water level and salinity data from continuous recorders at stations 12 (southern project area) and 2R (vegetation reference in the borrow canal) were compared to hourly data from continuous recorders (12m and 2m) temporarily installed in the adjacent marsh from August 1997 to October 1997. Data were collected to test the assumption that continuous recorders in canals, which is where they are commonly placed, reflect conditions in the adjacent marsh.

Water flow: Water flow was measured at four sites in the northern project area, each in a different channel denoted by the letters A-D (figure 6). Channel A is a shallow, manmade pipeline canal approximately 3 ft deep x 80 ft wide x 2.5 mi long (0.9 m x 24.4 m x 4 km) running northeast to southwest. Channel B is a deep borrow canal approximately 9.1 ft deep x 165 ft wide x 10 mi long (2.8 m x 50.3 m x 16 km) running north/south at the sampling point. Channel B was excavated in 1989 to construct the levee along the east shoreline of Calcasieu

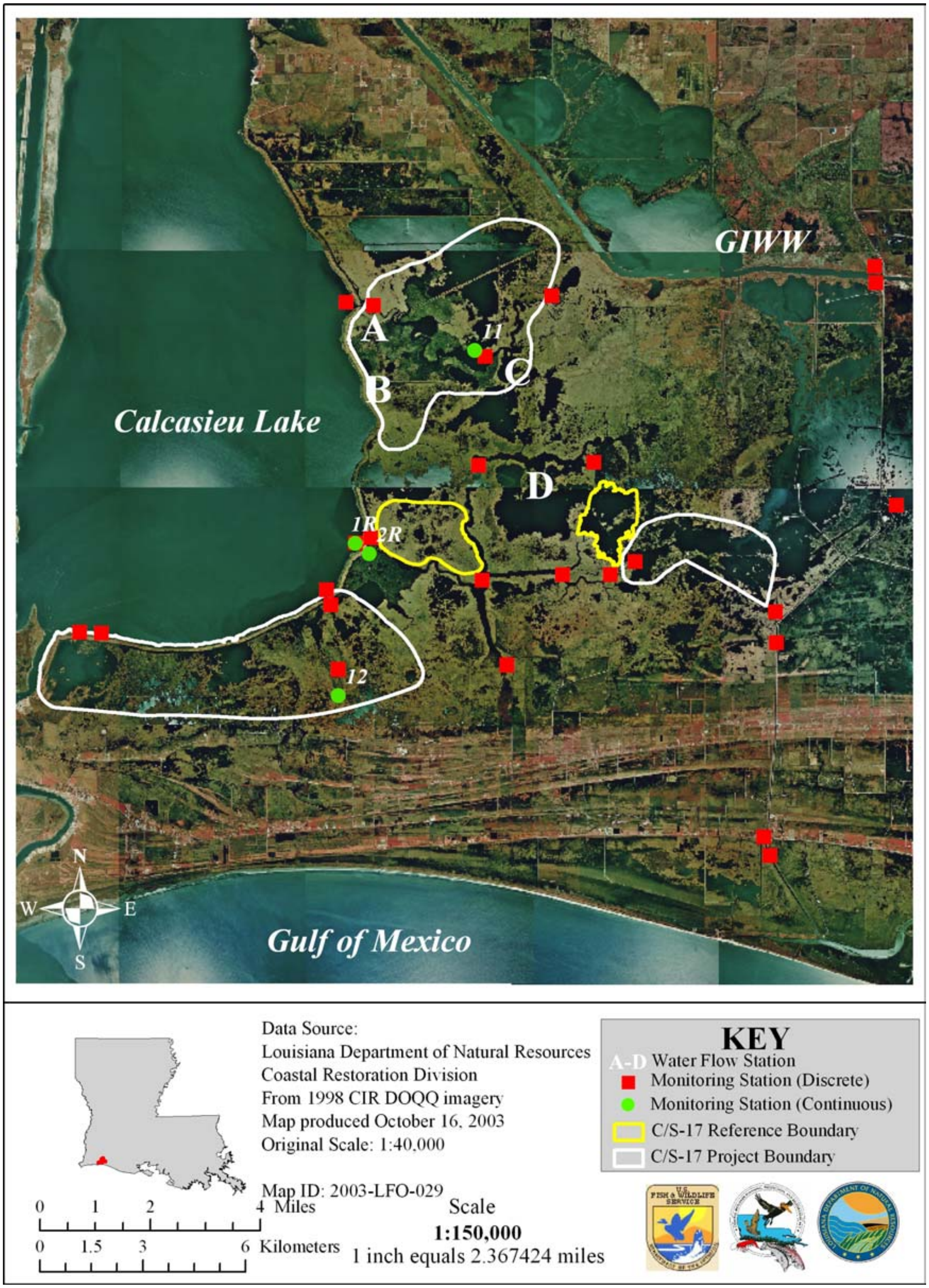


Figure 6. Map depicting sampling station locations and project and reference areas.

Lake. Channel C is a natural trenasse running north/south approximately 5.6 ft deep x 73 ft wide x 600 ft long (1.7 m x 22.3 m x 183 m) connecting North Prong to marshes in the northeast section of the watershed. Channel D is a short natural cut 4.3 ft deep x 42 ft wide x 300 ft long (1.3 m x 12.8 m x 91.5 m) running north/south, connecting two large bodies of shallow open water.

Cross-channel transect sampling was conducted using Marsh-McBirney Model 2000 portable hand-held flow meters to characterize the vertical and horizontal flow structure (Boon 1978; Kjerfve et al. 1981). According to the manufacturer's specifications, the sensor has an accuracy of ± 2% with a threshold of 19.99 ft/sec (6.1 m/s). The instantaneous volume flux through the channel was calculated by multiplying the velocity times the channel cross-sectional area. The cross channel transects were profiled every 2 hours from 7:30 am to 4:30 pm for a 72-hour period. Weather during the sampling period was characterized from data provided by the Louisiana Office of State Climatology (LOSC 1996). Monitoring was performed in 1996 (pre-construction). Mean flow was calculated for each station.

Emergent vegetation: Sites to monitor existing vegetation were selected using a systematic transect pattern in which transect lines were drawn in a northwest to southeast configuration from the Calcasieu Lake shoreline across the project and reference areas. Species composition, percent cover, and maximum height of dominant plants in 2 m^2 vegetation plots (1.4 m x 1.4 m) were determined at sixty sampling points (25 in the northern portion, 25 in the southern portion, and 10 in the vegetation reference area (figure 7), using the modified Braun-Blanquet method outlined in Steyer et al. (1995). Emergent vegetation data were collected pre-construction in October 1996 and post-construction in October 1997 and September 2000. Means of maximum dominant vegetation height, percent cover of important species, species richness, and surface salinity were determined for each area and were compared using Analysis of Variance (ANOVA). Species richness is defined as the number of species occurring in one sampling plot at a given time.

Submerged aquatic vegetation: Species composition and relative frequency of occurrence were determined for SAV in two ponds in the eastern project area and two ponds in a SAV reference area (figures 4 and 7). Presence or absence of SAV was recorded at no less than 25 random points along two transects in each pond, using the rake method (Chabreck and Hoffpauir 1962; Nyman and Chabreck 1996). SAV was monitored pre-construction in October 1996 and post-construction in October 1997 and September 2000. Means of relative frequency of occurrence of each species, species richness, and water depth and salinity were calculated and compared in the Eastern project and SAV reference areas using Analysis of Variance.

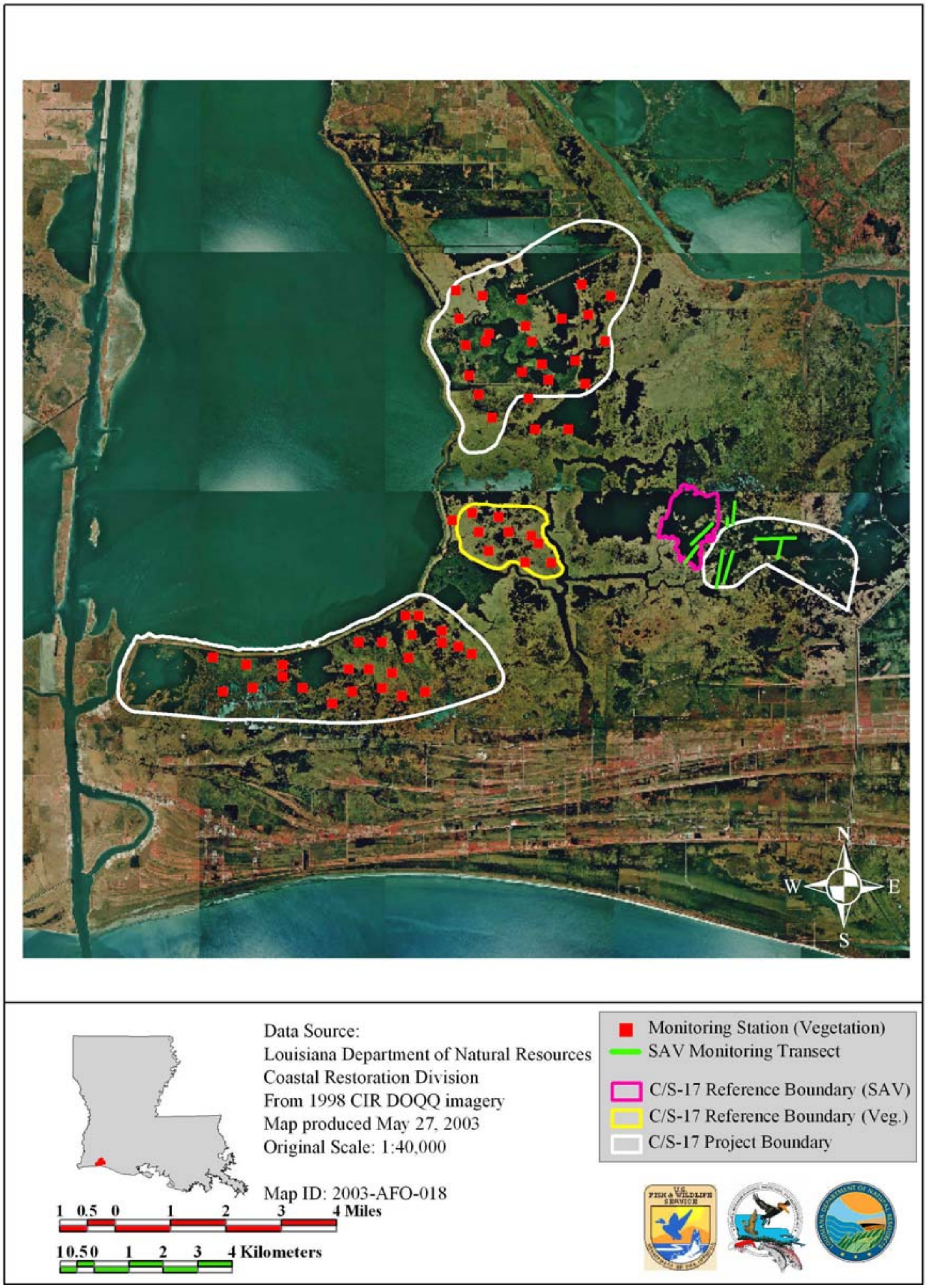


Figure 7. CS-17 Watershed map depicting sampling stations and transects for emergent vegetation and submerged aquatic vegetation.

RESULTS

Structure Operations: Operational changes of the Calcasieu Lake water control structures were carried out by USFWS personnel according to the resource management plan devised for the Cameron-Creole Watershed project and permit specifications. The most severe drought in 20 years (LOSC 1996) occurred in 1996, optimizing conditions for drawdown (figure 8). The drought occurred prior to construction of the plugs, but had an impact on the collection of pre-construction monitoring data as documented below. Structures were operated to allow water to drain from the marsh. After the drawdown was achieved drought conditions persisted past the scheduled July 15, 1996 opening date. Structure closures were extended due to prolonged high salinity in Calcasieu Lake coupled with extremely low water levels in the marsh. The drawdown was terminated August 30, 1996.

In late September and October of 1996 structures were operated to drain excess water due to elevated water levels in the project area and precipitation from Hurricane Dolly and Tropical Storm Josephine. Concurrent tropical storms in the fall of 1998 (tropical storms Charley, Earl, and Frances) caused similar high water conditions. Conversely, drought conditions caused structure closures during the first half of 1997 and 1999, and all of 2000 to prevent intrusion of high salinity water from Calcasieu Lake.

Habitat Mapping: Both the northern and southern project areas differed from the vegetation reference area in type and extent of marsh habitat in 1993 when the pre-construction aerial photography was obtained (figure 9, table 1). Both the northern and southern project areas had similar percentages of open salt water and salt marsh habitat based on total acreage. The vegetation reference area (which was the reference for the northern and southern project areas) had almost 25% less open water and 25% more salt marsh than the project areas (figure 9, table 1). The SAV reference and eastern project areas were similar to each other, both with a large percentage of open water and a small area of salt marsh. Salt marsh and open salt water were the dominant habitats in each of the project and reference area units.

Soils: Soil samples were to be collected in September 1996 and October 1997. However, soil samples were not collected in September 1996 due to the fluidity of the soil. Soil salinity was sampled at that time. Soil samples were, however, collected in October 1997 and were representative of the conditions during the post-construction period. Means and standard error for percent organic matter, bulk density, and soil salinity in the northern and southern project areas, as well as the vegetation reference area were calculated (table 2). Pre-construction soils data are not available for comparison to this post-construction data.

Analysis of data from 1997 indicates that soil salinity differed among the project and vegetation reference areas at that time ($F = 5.41$, $df_{2, 57}$, $p = 0.0071$). Post-ANOVA comparisons with least square means indicate that soil salinity was similar in the northern and southern areas, but was lower in the vegetation reference area. Analysis of the combined 1996 and 1997 soil salinity data indicate that salinity increased in the southern project area but did not change in the other two areas ($F = 10.72$, $df_{2, 57}$, $p = 0.0001$).

Figure 8. Photograph of an exposed mudflat during extreme low water in the 1996 drought.

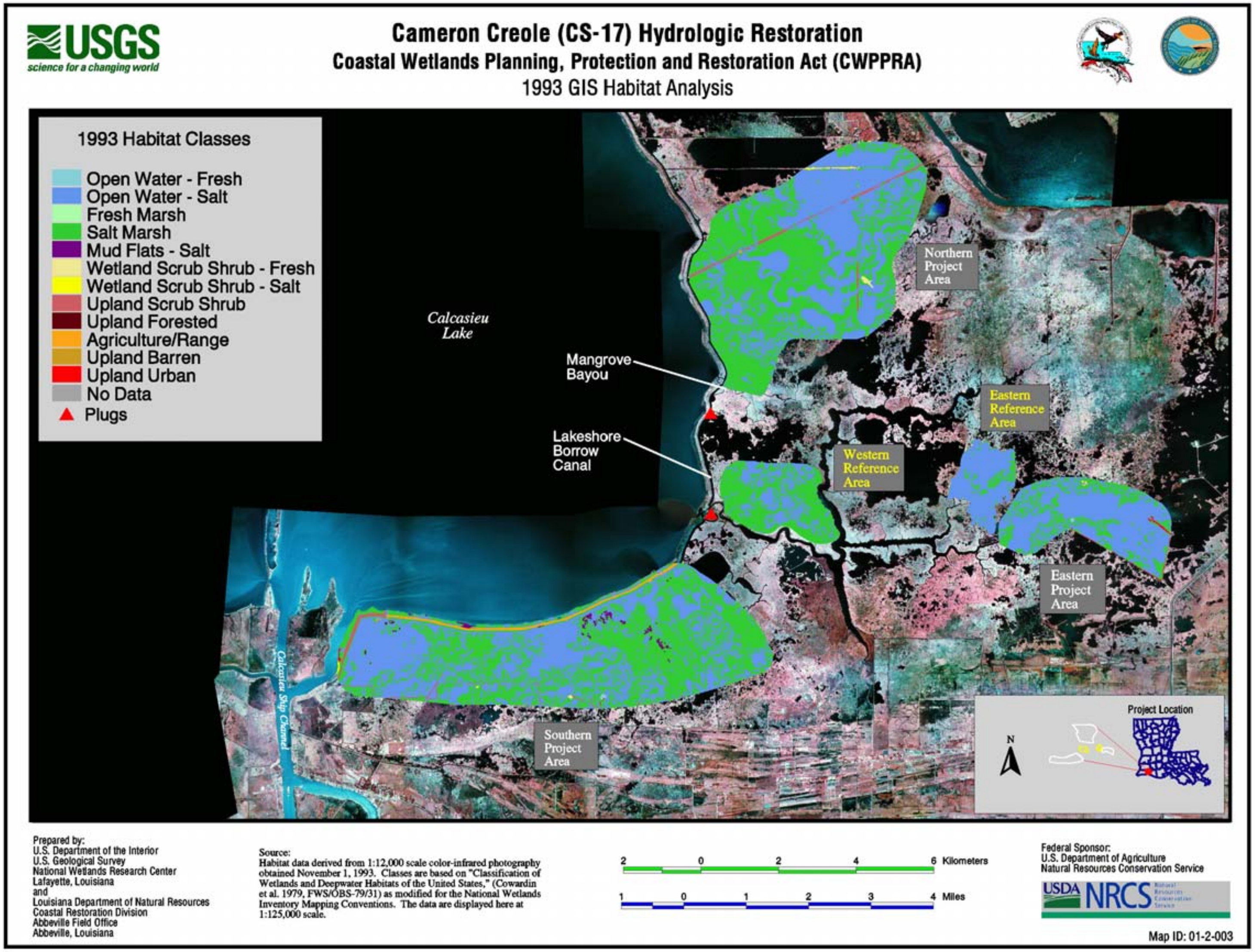


Figure 9. Habitat analysis in the Cameron Creole Watershed Borrow Canal Plug project (CS-17) and reference areas based on aerial photography obtained November 1, 1993

Table 1. Area of each habitat and percent land and water derived from photo interpretation of the 1993 aerial photography in the Cameron-Creole (CS-17) project and reference areas.

Habitat Class	Northern Project Area Acres (Hectares) % of total area	Southern Project Area	Vegetation Reference Area	Eastern Project Area (SAV)	SAV Reference Area
Open Water – Fresh	0	3 (1.2) <0.01%	0	1.7 (0.7) <0.01%	0
Open Water – Salt	2718 (1100.8) 45.10%	3151 (1276.2) 47.70%	565.1 (228.9) 90.10%	1302.2 (527.4) 73.70%	310.6 (125.8) 27.20%
Fresh Marsh	0	0.2 (0.1) <0.01%	0	0	0
Salt Marsh	3233.2 (1309.4) 53.70%	3220.4 (1304.3) 48.70%	62.2 (25.2) 9.90%	453.5 (183.7) 25.70%	831.6 (336.8) 72.80%
Mud Flats – Salt	0	35.9 (14.5) 0.50%	0	0	0
Wetland Shrub Scrub – Fresh	7.9 (3.2) <0.01%	1.5 (0.6) <0.01%	0	0	0
Wetland Shrub Scrub – Salt	8.6 (3.5) <0.01%	2.6 (1.1) <0.01%	0	1.1 (0.4) <0.01%	0
Upland Shrub Scrub	57.5 (23.3) 1%	58 (23.5) 0.90%	0	0	0
Upland Forested	0.5 (0.2) <0.01%	0	0	0	0
Agriculture/ Range	0.6 (0.2) <0.01%	125.2 (50.7) 2%	0	0	0
Upland Barren	0	5.5 (2.2) <0.01%	0	0	0
Upland Urban	0	3 (1.2) <0.01%	0	8.2 (3.3) 0.60%	0
TOTAL	6026.3 (2440.7)	6606.3 (2675.6)	627.3 (254.1)	1766.7 (715.5)	1142.2 (462.6)
% Open Water % Land	45.1 54.9	48.3 51.7	90.1 9.9	73.8 26.2	27.2 72.8

Table 2. Mean ± Std Err of soil variables for data collected October1997, in the Cameron Creole Watershed Borrow Canal Plug (CS-17) project.

Site	N	Soil Salinity (ppt)	Organic Matter %	Field Bulk Density (gm/cm^3)
Northern project area	25	5.0 ± 0.7	48.3 ± 3.7	0.13 ± 0.01
Southern project area	25	8.3 ± 0.6	59.3 ± 4.1	0.11 ± 0.01
Eastern reference area	10	2.8 ± 0.4	62.6 ± 4.7	0.11 ± 0.01

Salinity: Discrete water salinity data were collected bi-weekly from 1990 to 1999 by personnel from USFWS. Mean high and low salinity was calculated at each of the 25 USFWS sampling stations (figures 10 and 11). Salinity was highest in Calcasieu Lake and was lowest in the interior marsh.

Monthly mean salinity calculated for four continuous recorder stations from March 1994 to December 2000 indicate that salinity remained predominantly below 15 ppt at interior stations 2R, 11 and 12 until September 1999 when drought conditions combined with low rainfall and high tides elevated salinity to 20-25 ppt for the remainder of 1999 and most of 2000 despite structure closures (figure 12). Mean salinity values at station 1R, located in Calcasieu Lake, were higher than at stations 2R, 11, and 12, located in the managed marsh, for the majority of the sampling period.

Water Level: Marsh elevation (NAVD 88) was determined at continuous recorders in both November 1997 and June 2000 (table 3). Monthly mean water level for the four continuous recorder stations was calculated from March 1996 to December 2000. Water levels remained at or below average marsh elevation from March 1996 to late August 1996, from June 1997 to December 1997, and from December 1998 to December 2000 at all interior stations (figure 13). In July 1996, stations 2R and 11 reached the lowest level (0.09 ft NAVD). Station 12 water level data are unavailable for most of this drought period because the water level remained below the depth probe throughout the drought. Water level remained below the marsh surface again from July to November, 1997, and January 2000 through the end of the study, November, 2000.

The continuous water level data collected pre-construction cannot be used to quantify the effects of the CS-17 plug project (figure 13). Pre-construction data are only available from times when the marsh was extremely flooded due to Hurricane Dolly and Tropical Storm Josephine. Thus, this information does not serve as a valid comparison to the periods of drought that occurred after construction. The only month that data were available for every year was February. Mean water elevation was compared for February for each year and it was evident that there was no consistent trend in water level in response to the plugs (figure 13).

Water Level in Marsh vs. in Channels

To test the assumption that continuous recorders in canals reflected conditions in the adjacent marsh, data from paired water level recorders were analyzed. The data were collected from two pairs of recorders between 21 August, 1997 and 9 October, 1997. The two pairs were analyzed separately; 2m (marsh) and reference station 2R (channel) were compared, and 12m (marsh) and 12 (channel) were compared. First, graphs of weekly means (and standard errors) of channel and marsh salinity were compared. Second, repeated measures analysis of variance (ANOVA) was used to determine if average salinity, salinity variability, and depth variability differed between marsh and channel locations. Variance was used as the measure of depth variability but the coefficient of variability was used as the measure of salinity variability because salinity variance increases as salinity increases. Average depth was not compared between marsh and channel because the elevation of the marsh recorders were unknown. Finally, regression and correlation

Figure 10. Monthly mean high salinity values from 25 discrete USFWS monitoring stations measured biweekly from 1990-1999 in the Cameron Creole Watershed.

Figure 11. Monthly mean low salinity values from 25 discrete USFWS monitoring stations measured biweekly from 1990-1999 in the Cameron Creole Watershed.

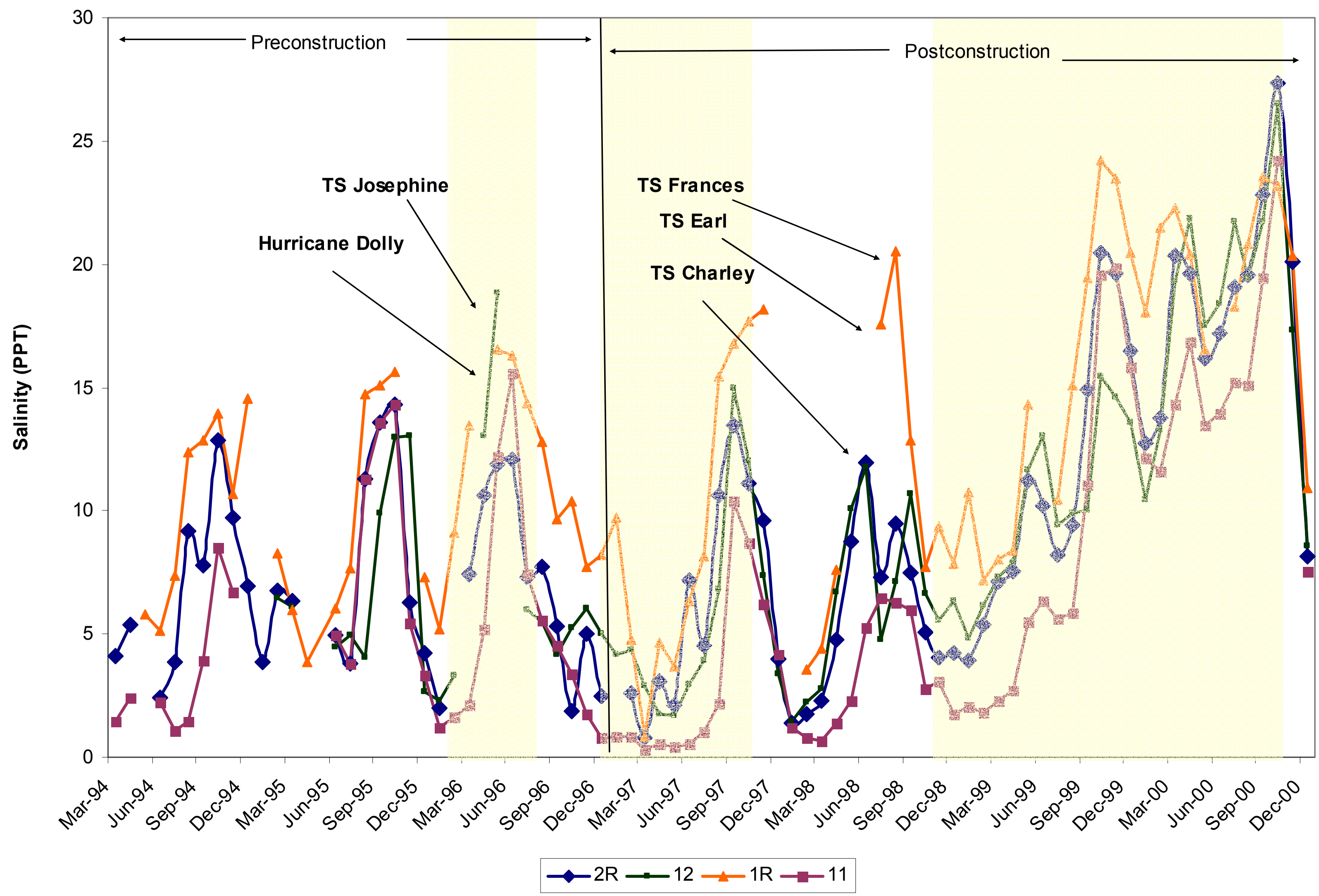


Figure 12. Monthly mean salinity values for all continuous recorder stations pre and post construction from March 1994 to December 2000 in the Cameron-Creole Watershed. Tropical storms and hurricanes are noted and periods of drought are shaded.

Table 3. Marsh elevation (ft NAVD 88) at continuous recorder stations. Elevation from survey conducted in 1997.

Study Area	Recorder	Marsh Elevation (m)
Northern Project	11	0.95
Southern Project	12	1.03
Reference (Borrow Canal)	2R	0.92

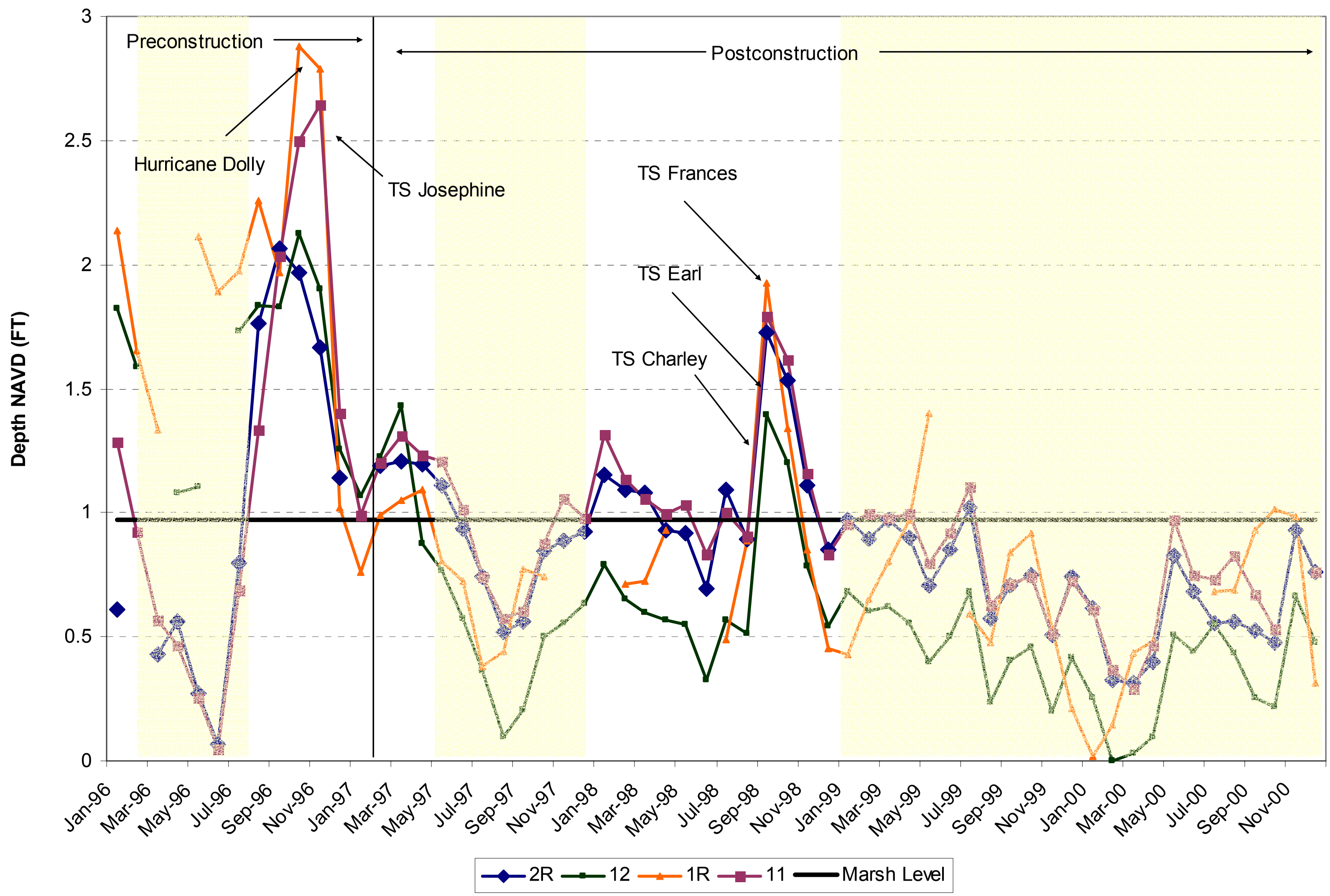


Figure 13. Monthly mean water level values for all continuous recorder stations pre and post-construction from January 1996 to December 2000 in the Cameron-Creole Watershed. Tropical storms and hurricanes are noted and periods of drought are shaded.

analyses were used to determine if marsh salinity could be predicted from channel salinity. Eighty percent of the hourly data were used to develop a regression equation that could be used to predict marsh water salinity from channel water salinity. The resulting equation and the remaining hourly data were used to test if observed marsh water salinity differed from marsh water salinity predicted from channel water salinity.

Comparison of the 2m and 2R pair of recorders indicated the following. Salinity averaged 12.3 ppt in the marsh and 12.1 ppt in the channel. The daily coefficient of variability for salinity averaged 5.8 in the marsh and channel. The daily variance of water level averaged 0.003 in the marsh and channel. Visual comparison of hourly data suggested virtually no differences in water level variability and only occasional differences in salinity between marsh and channel locations (figures 14 and 15). Daily variability did not differ between the marsh and channel for depth ($P_{site} = 0.9043$) or salinity ($P_{site} = 0.0545$). Daily mean salinity differed between the marsh and channel location on some days ($P_{site*day} = 0.0216$). Those differences were common and occurred in both directions. Regression analyses indicated a relationship between marsh and channel salinity (P = 0.0001). The relationship between marsh (y) and channel (x) salinity was described by the equation:

$$y = 1.2 + 0.9\,x \pm 0.02x$$

The relationship between predicted salinity and observed salinity was significant ($r^2 = 0.64$, $P < 0.0001$) but the predicted salinity was accurate only to within 2 to 4 ppt.

Comparison of the 12m and 12 pair of recorders indicated that salinity averaged 9.3 ppt in the marsh and 13.7 ppt in the channel. The daily coefficient of variability for salinity averaged 6.0 in the marsh and 5.4 in the channel. The daily variance of water level averaged 0.003 in the marsh and 0.002 in the channel. Visual comparison of hourly data suggested large differences in salinity between marsh and channel locations but little difference in water level variability between marsh and channel locations (figures 16 and 17). Daily variability differed between the marsh and channel for depth ($P_{site} = 0.0027$) but not salinity ($P_{site} = 0.6456$). Water levels were more variable in the channel than in the marsh except for a few days when variability was unusually high. Daily mean salinity differed between the marsh and channel location ($P_{site*day} = 0.0008$). This difference was great. Regression analyses indicated a relationship between marsh and channel salinity (P = 0.0001). The relationship between marsh (y) and channel (x) salinity was described by the equation:

$$y = 12.0 - 0.2\,x \pm 0.02x$$

The relationship between predicted salinity and observed salinity was significant (r = 0.21852, $P < 0.0007$) but the predicted salinity was accurate only to within 3 to 5 ppt.

<u>Water Flow</u>: Pre-construction water flow data were collected April 14-16, 1996 (table 4). The data were collected in the middle of what became a severe drought and did not reflect normal watershed conditions. No post-construction data are available for comparison. Therefore,

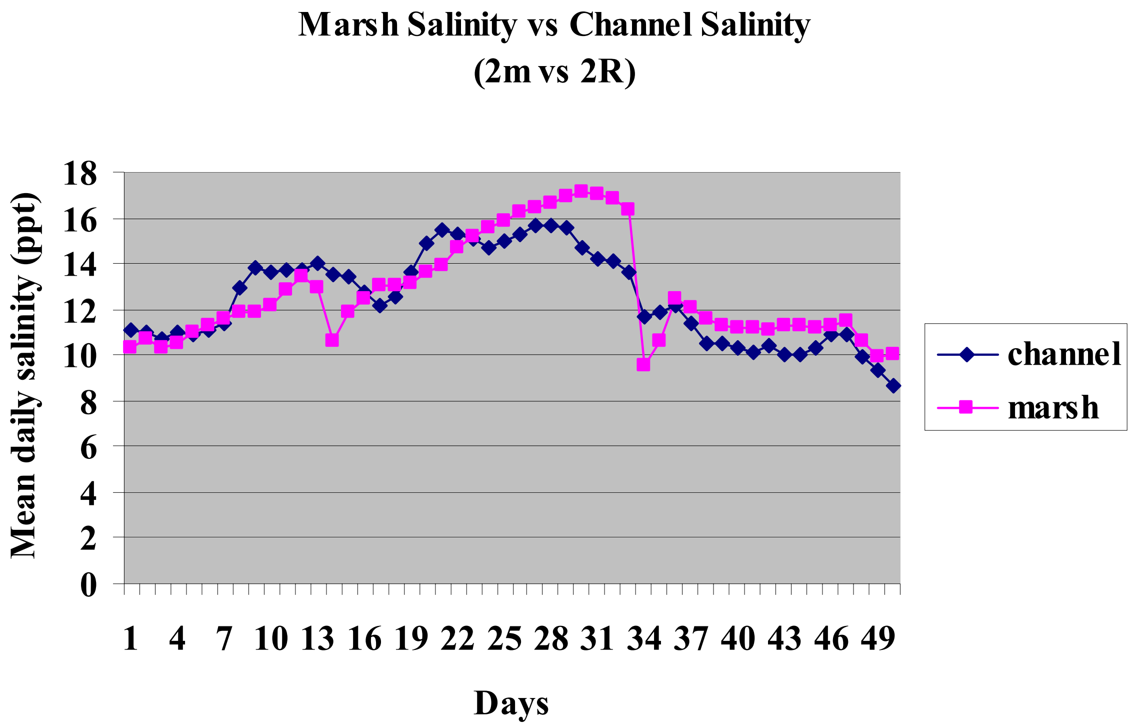


Figure 14. Comparison of salinity in marsh and channel continuous recorders.

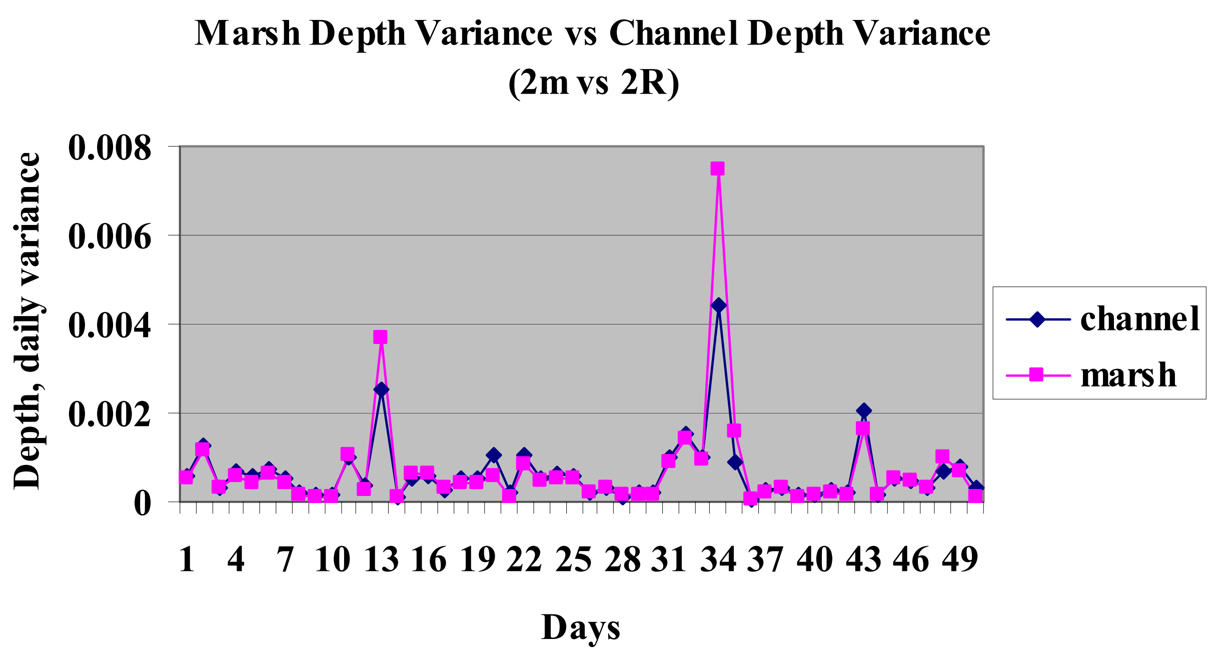


Figure 15. Comparison of water depth in marsh and channel continuous recorders.

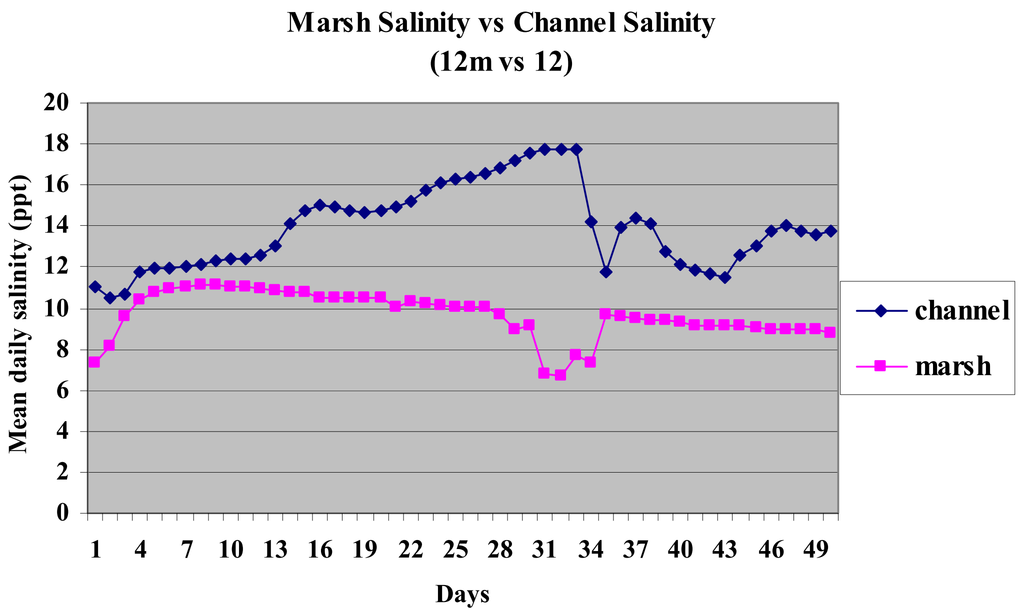


Figure 16. Comparison of salinity in marsh and channel continuous recorders.

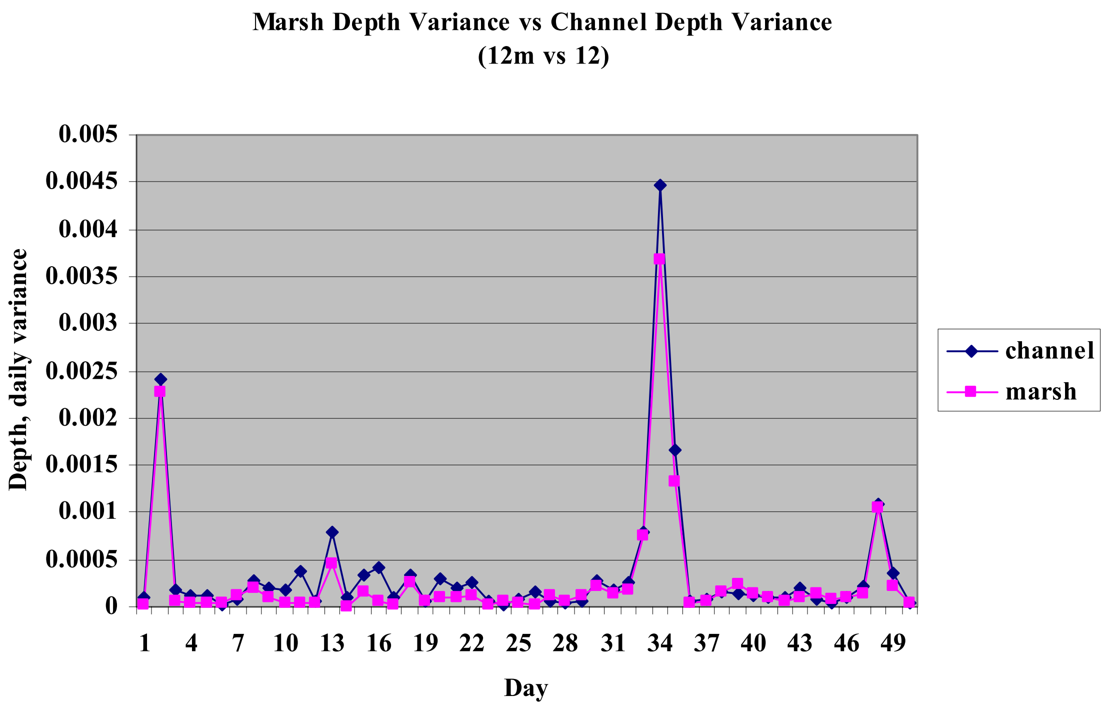


Figure 17. Comparison of water depth in marsh and channel continuous recorders.

Table 4. Pre-construction water flow in four channels (figure 6).

CS-17 Pre-construction channel flow May 14-16, 1996			
Channel	Transect	Flow per Transect (cfs)	Flow per Channel (cfs)
A	1	3.04	17.26
A	2	11.56	
A	3	2.66	
B	1	34.47	81.44
B	2	30.03	
B	3	16.94	
C	1	22.12	126.90
C	2	54.93	
C	3	49.85	
D	1	21.94	60.95
D	2	18.42	
D	3	20.59	

whether or not the plugs altered water circulation in the Northern project area cannot be determined from these data.

Emergent Vegetation: The dominant species in all three project areas was *Spartina patens* (saltmeadow cordgrass). Other species that occurred frequently include *Schoenoplectus pungens* (common threesquare), *Schoenoplectus robustus* (saltmarsh bulrush), and *Vigna luteola* (deerpea) in the northern project area, *Spartina alterniflora* (saltmarsh cordgrass), *S. pungens*, and *Distichlis spicata* (seashore saltgrass) in the southern project area, and *S. pungens* in the vegetation reference area.

Percent cover of each species found in 2 m^2 sampling plots during the three sampling years, 1996, 1997, 2000, was quantified (figures 18, 19, and 20, table 5). *Spartina patens*, the dominant species for each of the areas of interest, showed similar trends in the northern and southern project area and the vegetation reference area. In all three areas, cover of *S. patens* decreased between 1997 and 2000. Post ANOVA comparisons showed that differences in percent cover of *S. patens* between years are significant ($F = 4.46$, $df_{2,2,}$ $p = 0.0132$) (figure 21). However, changes in percent cover were similar in both of the project areas (figure 22). There was no response in percent cover of *S. patens* to the construction of plugs. The decrease in cover from 1997 to 2000 was most likely due to drought conditions as shown by the reduction in both the reference and project areas.

Mean maximum stem height for each species in sampling plots was calculated yearly. Mean stem height of the dominant species, *S. patens,* was significantly lower in 1996 than in 1997 and 2000 ($F = 24.33$, $df_{2,2}$, $p < 0.0001$) (Figure 23). There was no significant difference between the project and vegetation reference areas for stem height of *S. patens* (Figure 24). Low stem heights in 1996 may be attributed to drought stress.

There was no significant difference in species richness over time in the northern and southern project areas and vegetation reference area. The mean number of species in 2m^2 vegetation plots in each of the areas was relatively the same, about 2 species per plot (table 6).

Submerged Aquatic Vegetation: Submerged aquatic vegetation data were collected pre-construction in September 1996 and 1-yr and 3-yr post-construction in October 1997 and September 2000 in the eastern project area and SAV reference area. Variables include relative frequency of occurrence of species, species richness, depth, and salinity (table 7).

Analysis of Variance showed that there were several significant terms in the SAV model (table 8). Significant differences in frequency of occurrence of SAV were found between years, species, year species interaction, and year area species interaction. The number of species present decreased from 1996 and 1997 to 2000 when *Ceratophyllum demersum*, *Myriophyllum spicatum*, and *Najas caroliniana* were not present. Each species showed a different pattern from 1996 to 1997 and all species decreased in frequency of occurrence from 1997 to 2000, during a drought period (figure 25, table 9).

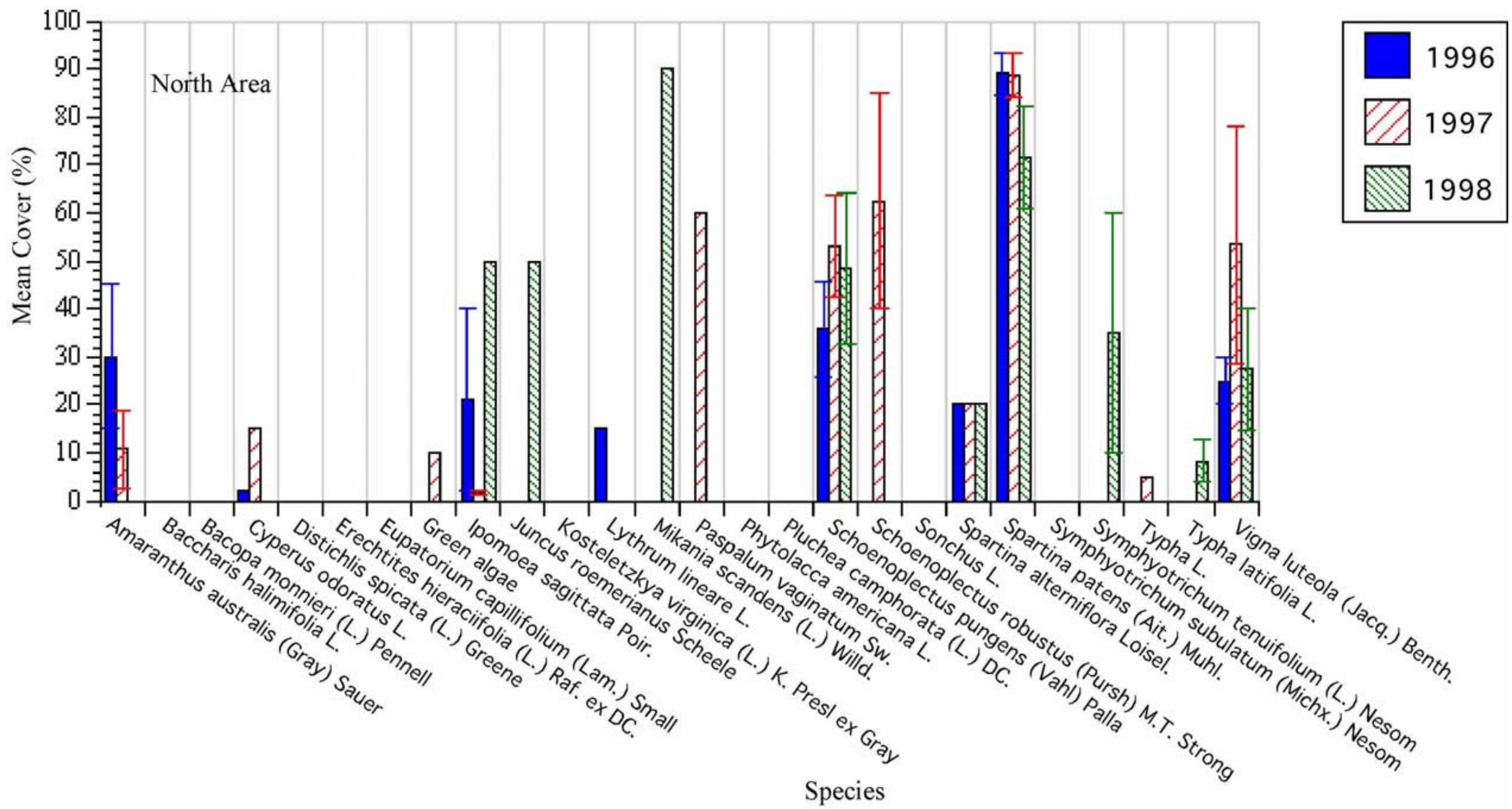


Figure 18. Mean % Cover in the northern project area for each species present in 1996, 1997, and 2000.

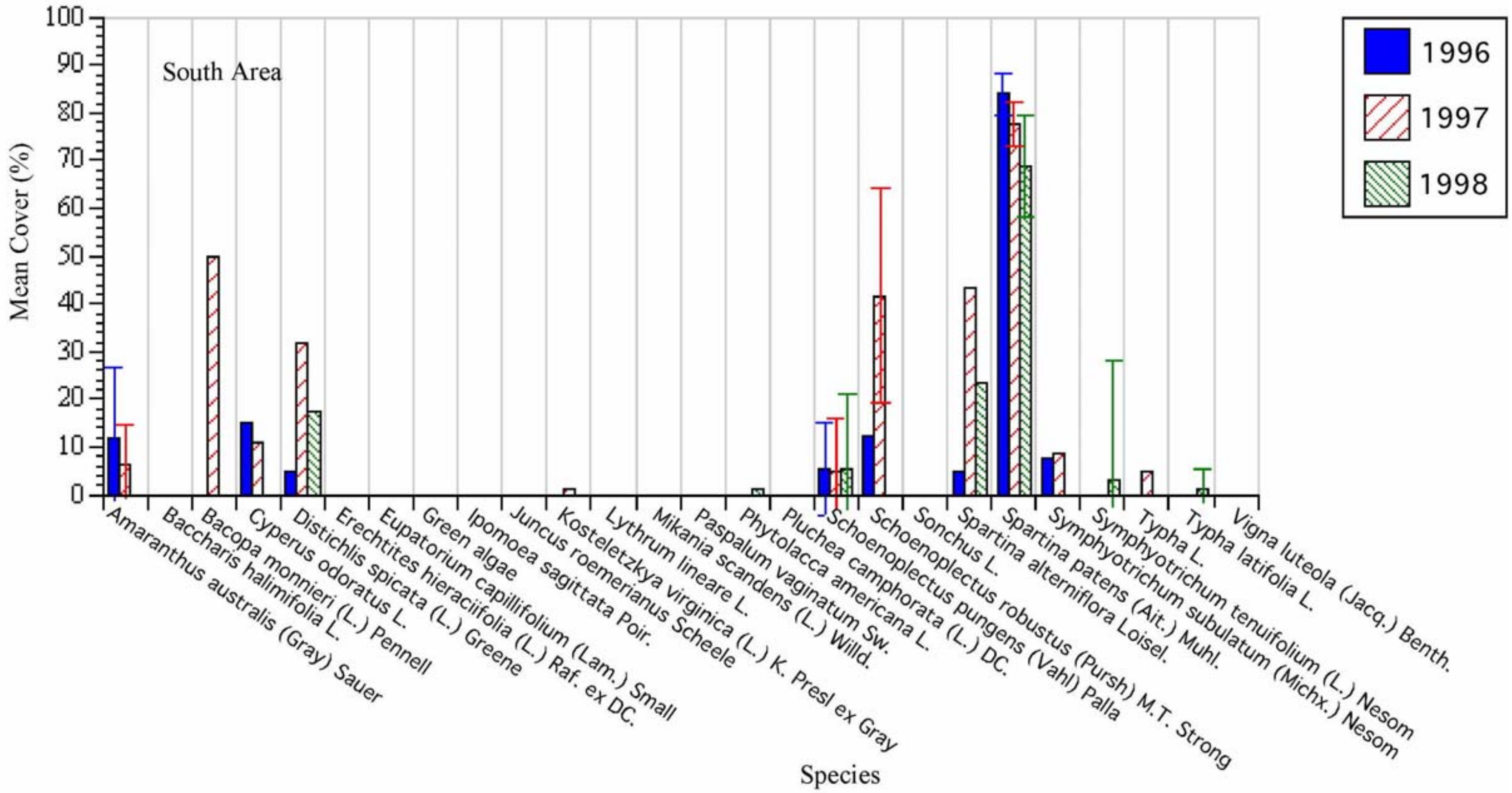


Figure 19. Mean percent cover in the southern project area for each species present in 1996, 1997, and 2000.

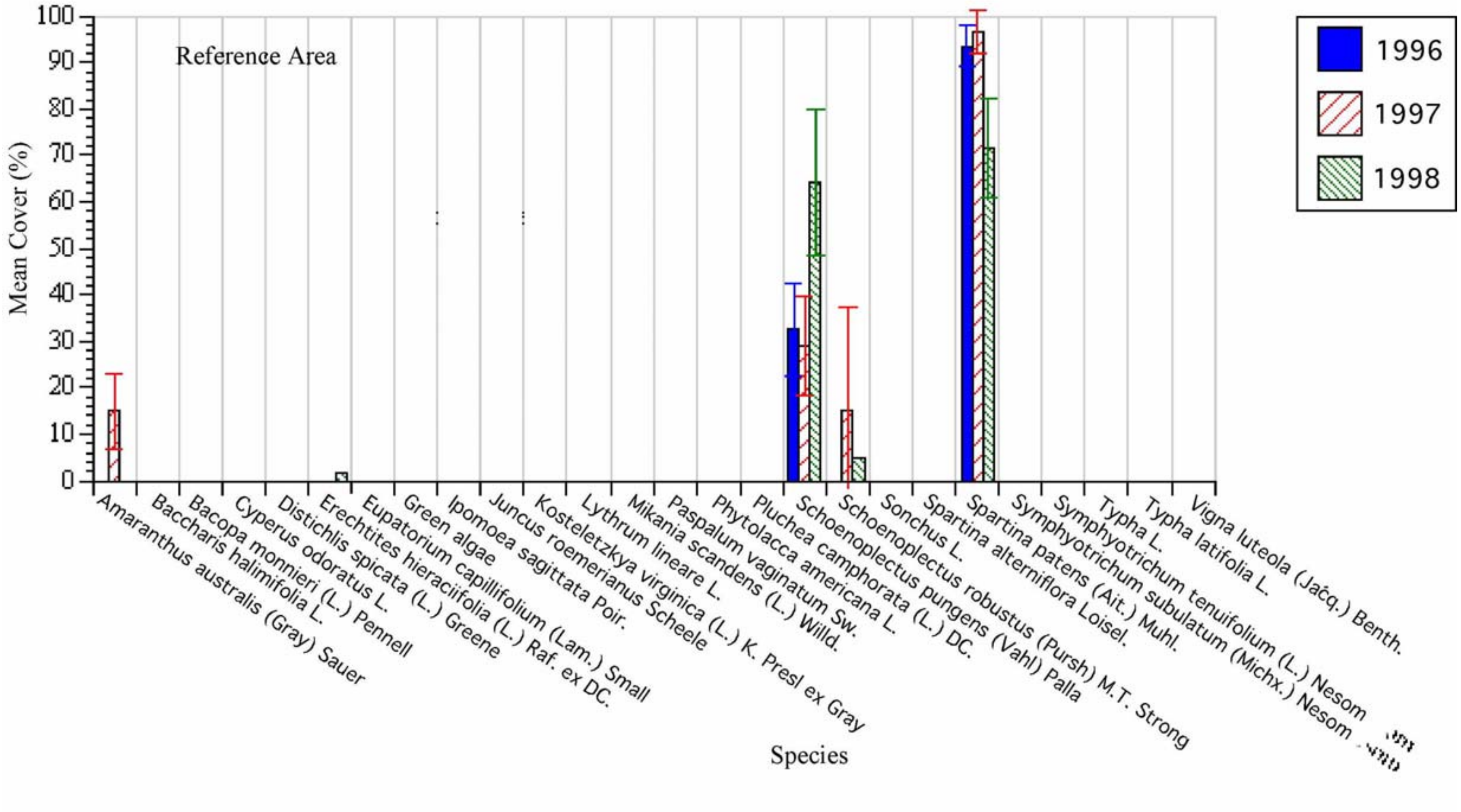


Figure 20. Mean percent cover in the vegetation reference area for each species present in 1996, 1997, and 2000.

Table 5. Percent cover (Mean ± SD) of emergent vegetation in the Cameron Creole Plugs (CS-17) project and reference areas based on data collected at monitoring stations (n=60) pre- and post-construction.

Species	Northern Project Area			Southern Project Area			Reference Area		
	1996	1997	2000	1996	1997	2000	1996	1997	2000
Andropogon virginicus	0.02 ± 0.1								
Amaranthus australis		1.7 ± 7			1.3 ± 3.5			1.5 ± 4.7	
Aster spp.	2.4 ± 9.4		4.4 ± 15	1.4 ± 4.5		0.4 ± 1.1			
Bacopa monnieri					2 ± 10				
Cyperus odoratus		0.6 ± 3			2.2 ± 5.2				
Distichlis spicata					7.7 ± 18.4	2.8 ± 7.9			
Eleocharis sp.	1.7 ± 8								
Erechtites hieracifolia					0.04 ± 0.2				0.2 ± 0.4
Ipomoea sagittata		0.1 ± 0.4	3.13 ± 12.5	0.6 ± 3					
Iva frutescens	0.04 ± 0.1	0.2 ± 1		2 ± 10			0.1 ± 0.2		
Juncus roemerianus		0.4 ± 2	3 ± 12.5						
Kosteletzkya virginica					0.04 ± 0.2				
Lythrum lineare							0.1 ± 0.2		
Mikania scandens		0.04 ± 0.2	5.6 ± 22.5						
Paspalum vaginatum		2.4 ± 12		0.4 ± 1.4					
Phragmites australis				0.6 ± 2.2		0.3 ± 1.1			
Phytolacca americana						0.1 ± 0.2			
Pluchea camphorate		0.04 ± 0.2			0.04 ± 0.2				
Rumex crispus				0.02 ± 0.1					
Ruppia maritime	2 ± 7.1								
Scirpus americanus .		20.8 ± 33.7	24 ± 39		0.2 ± 1	0.8 ± 2.4		20.4 ± 24.9	56.9 ± 37
Scirpus robustus	11.8 ± 22.5	5 ± 18.5		0.2 ± 1	5 ± 16.1		18.9 ± 25.3	1.5 ± 4.7	0.56 ± 1.7
Scirpus tabernaemontani	0.2 ± 0.8			1 ± 4.1					
Setaria magna		0.04 ± 0.2							
Sesbania drummondii				0.04 ± 0.1			0.1 ± 0.3		
Solidago sempervirens var.*mexicana*	0.6 ± 3						0.1 ± 0.3		
Spartina alterniflora				11.9 ± 32.8	6 ± 18.2	8 ± 13.3			
Spartina cynosurioides				1.2 ± 4.2			1 ± 2.1		
Spartina patens	86.5 ± 27.4	84.5 ± 29.1	72.6 ± 41.1	69.9 ± 35	71.1 ± 37.8	65.9 ± 36.3	93.1 ± 10.3	95.7 ± 7.8	70.8 ± 32.9
Spartina spartinae						0.8 ± 3.4			
Typha sp.		2 ± 1	2.1 ± 5.4		0.4 ± 1.4	0.1 ± 0.2			
Vigna luteola		6.4 ± 21.4	6.9 ± 16.7						
Mean Cover (%)	94.2 ± 8.9	95.7 ± 10	92.1 ± 24.6	83.5 ± 20.9	79.8 ± 30.8	80.7 ± 23.9	95.9 ± 5.9	98.1 ± 2.9	98.6 ± 1.3

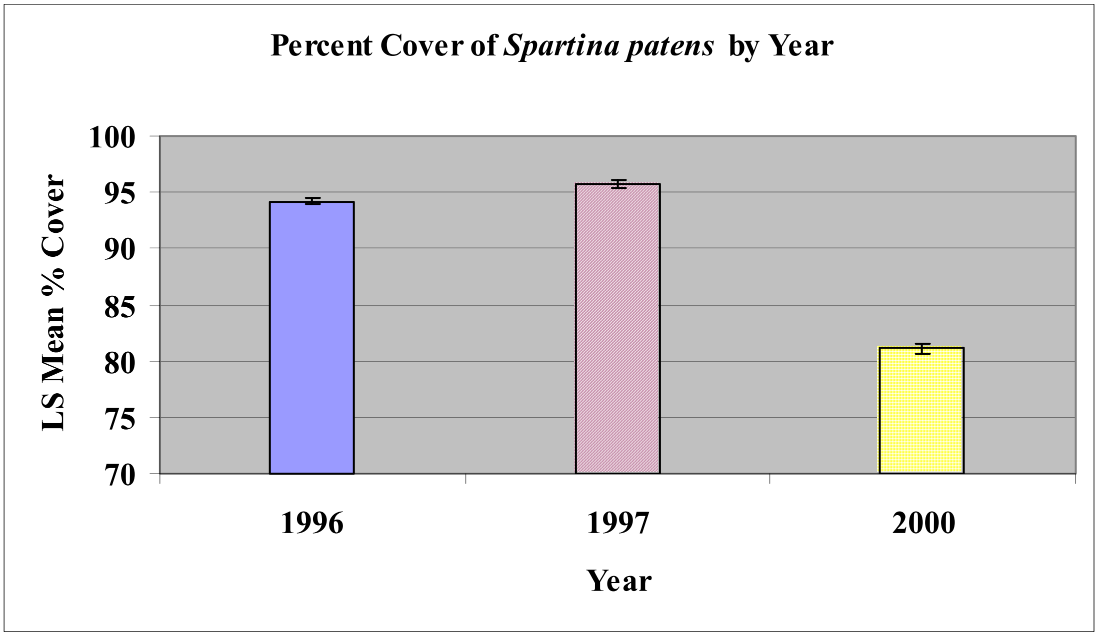


Figure 21. Least squares means of percent cover of *S. patens* by year. The graph represents all of the data for each year from all of the project and reference areas.

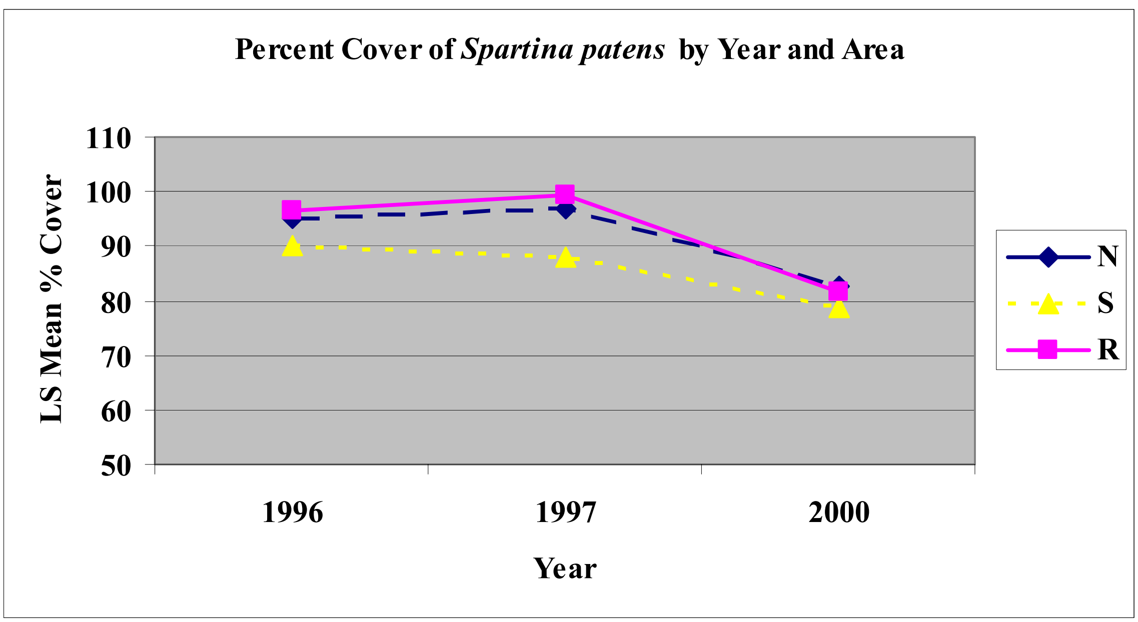


Figure 22. Least squares means of percent cover of *S. patens* for each year by area.

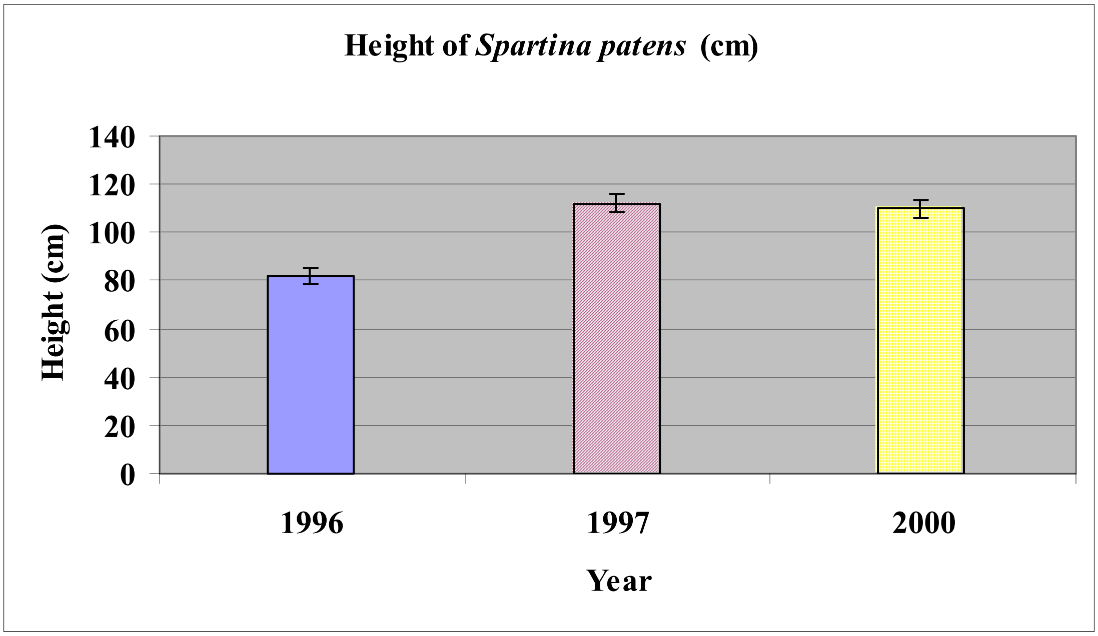


Figure 23. Least squares means of stem height of *S. patens* by year. The graph represents all of the data for each year from all of the project and reference areas.

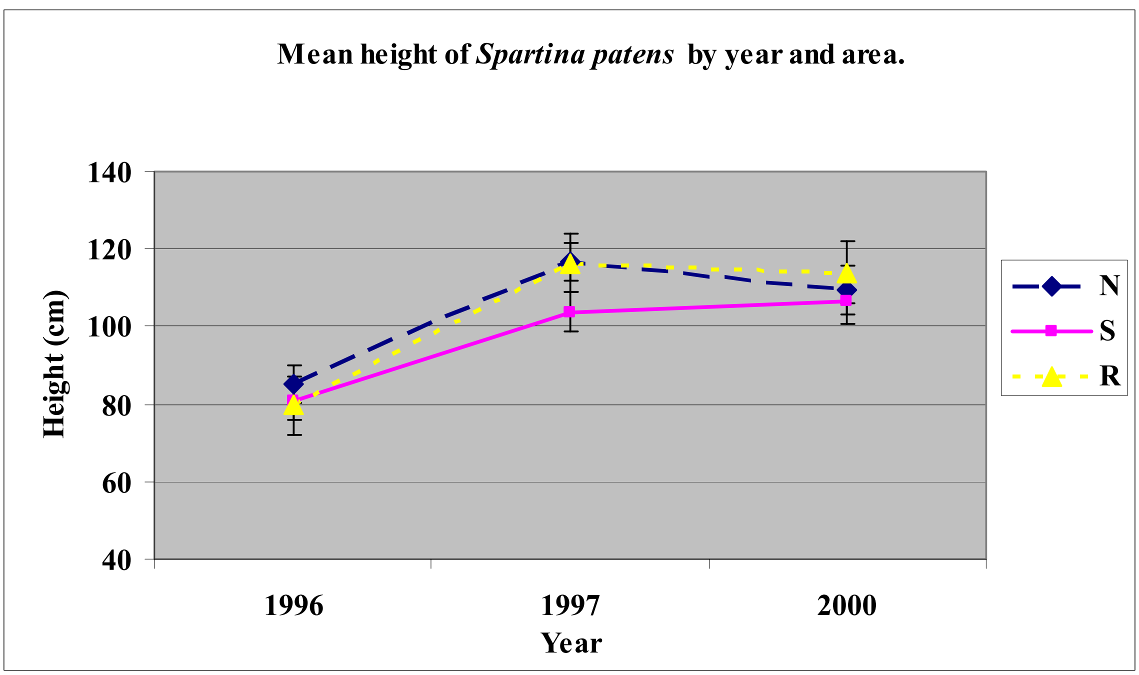


Figure 24. Least squares means of stem height of *S. patens* by year and area.

Table 6. CS-17 Emergent Vegetation Species Richness.
Note that means do not differ significantly.

Project Area	Year	LS Mean Richness	SE
Northern	1996	1.85	0.19
Northern	1997	2.00	0.19
Northern	2000	2.25	0.25
Southern	1996	1.71	0.20
Southern	1997	2.33	0.20
Southern	2000	1.89	0.22
Reference	1996	2.10	0.31
Reference	1997	2.00	0.31
Reference	2000	2.22	0.33

Table 7. Relative frequency of occurrence and species richness (Mean ± Std Dev) of submerged aquatic species, along with mean depth and salinity in the Cameron Creole Watershed Borrow Canal Plug (CS-17) project and reference areas from data collected pre-construction in October 1996 and post-construction in October 1997 and September 2000.

	Project Area			Reference Area		
Species or variable	1996	1997	2000	1996	1997	2000
Ruppia maritima	44.0 ± 19.13	1.5 ± 1.91	11.25 ± 11.56	45.75 ± 17.75	0 ± 0	3.24 ± 2.5
Vallisneria americana	14.75 ± 14.72	23.25 ± 17.46	0.50 ± 1.0	23.0 ± 10.98	69.5 ± 5.0	0 ± 0
Najas guadalupensis	18.75 ± 17.5	41.75 ± 33.51	0 ± 0	42.25 ± 22.81	32.5 ± 14.64	0 ± 0
Myriophyllum spicatum	2.5 ± 3.0	1.0 ± 2.0	0 ± 0	0 ± 0	1.5 ± 3.0	0 ± 0
Algae	36.5 ± 5.74	53.5 ± 54.0	9.75 ± 10.34	63.25 ± 20.77	28.5 ± 27.05	26.75 ± 2.06
Species Richness	4.25 ± 0.95	3.5 ± 0.58	1.75 ± 1.26	4 ± 0.0	3.0 ± 0.81	1.75 ± 0.5
Depth (ft)	2.43 ± 0.1	1.77 ± 0.2	1.49 ± 0.32	2.35 ± 0.12	1.71 ± 0.24	1.4 ± 5.91
Salinity (ppt)	1.65 ± 0.06	6.85 ± 0.53	18.15 ± 0.96	1.65 ± 0.06	6.3 ± 0.24	18.7 ± 0.16

Table 8. SAV ANOVA model. Significant terms are graphed (figures 25-30).

ANOVA for Frequency of Occurrence of SAV			
Term	F	df	p-value
year	29.20	2	<.0001
Area	0.06	1	0.8107
Species	15.98	5	<.0001
year*area	1.87	2	0.1587
year*species	8.38	10	<.0001
area*species	1.59	5	0.1698
year*area*species	2.73	10	0.0051

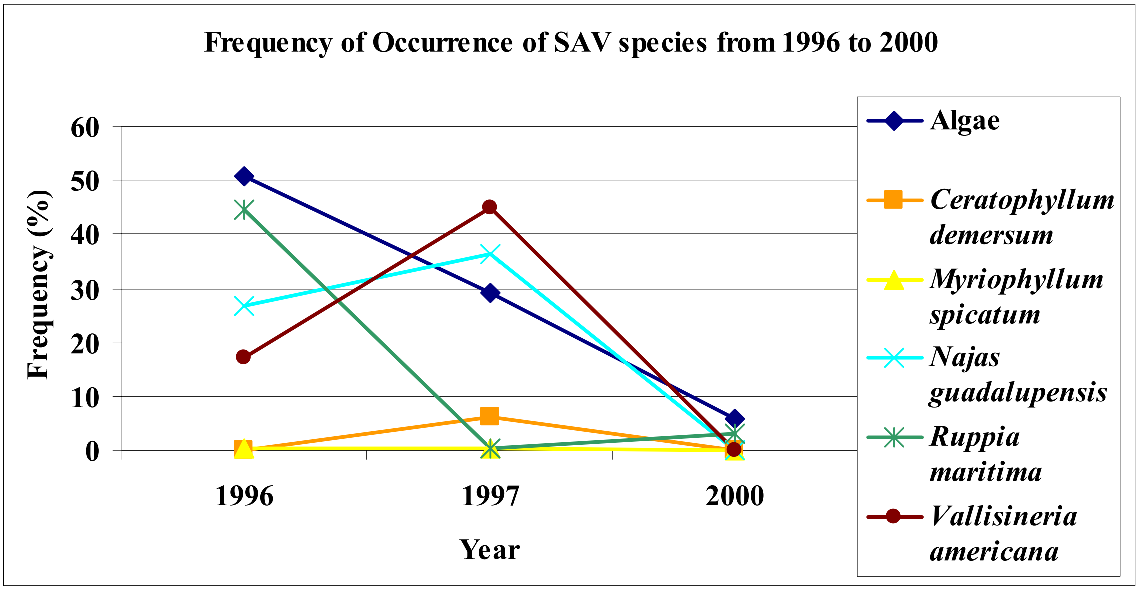


Figure 25. Frequency of occurrence of SAV species from 1996 to 2000.

Table 9. Frequency of occurrence of submerged aquatic vegetation species for each survey year over both the project and reference areas ($p<.0001$).

Year*Species			LS Mean Frequency	
Year	Species	Tukey *	of Occurrence (%)	Std Err
1996	Algae	A	50.87	1.14
1997	Algae	AB	29.17	1.14
2000	Algae	BCDE	5.77	1.14
1996	Ceratophyllum	E	0	1.14
1997	Ceratophyllum	BCDE	6.28	1.14
2000	Ceratophyllum	E	0	1.14
1996	Myriophyllum	DE	0.31	1.14
1997	Myriophyllum	DE	0.31	1.14
2000	Myriophyllum	BCDE	0	2.85
1996	Najas	ABC	26.67	1.14
1997	Najas	A	36.44	1.14
2000	Najas	E	0	1.14
1996	Ruppia	A	44.6	1.14
1997	Ruppia	DE	0.3	1.14
2000	Ruppia	CDE	3.04	1.14
1996	Vallisineria	ABCD	17.12	1.14
1997	Vallisineria	A	44.88	1.14
2000	Vallisineria	E	0.031	1.14

* Levels not connected by the same letter are significantly different.

Species richness decreased along with frequency of occurrence of SAV (table 7). No new species were found after the first sampling and several species disappeared before the last sampling in 2000. There was no significant difference between the project and vegetation reference area and both areas decreased in species richness at similar rates.

There was a difference between the reference and project area for some species over time. Algae decreased in the vegetation reference area from 1996 to 1997 while it increased in the project area (figure 26). Algae frequency decreased to the same low point in 2000 in both areas. *Vallisineria americana* increased in the reference area much more than in the project area from 1996 to 1997 and decreased to 0% in both areas in 2000 (figure 27). *Najas caroliniana* increased in the project area while it decreased in the vegetation reference area from 1996 to 1997 (figure 28). This species disappeared from both areas between 1997 and 2000. *Ceratophyllum demersum* (figure 29) and *Myriophyllum spicatum* (figure 30) showed the same trend in both the project and vegetation reference areas over time. Both had low frequencies of occurrence over the course of the project. Frequency of occurrence of *Ruppia maritima* followed the same trend in both the project and reference area, increasing from 1996 to 1997 and decreasing to less than 10% occurrence in 2000 (figure 31). Although the interaction effect of project area, species, and years were significant, the differences are most probably due to climatic events rather than the plug project itself. It has been determined that the vegetation reference area is not a valid reference for the project area since the two areas are spatially close together and are both affected by Calcasieu Lake and larger hydrologic forcing factors than the CS-17 plug project.

Figures 26 – 31. Frequency of occurrence of SAV for each species from 1996-2000.

Fig. 26. Algae

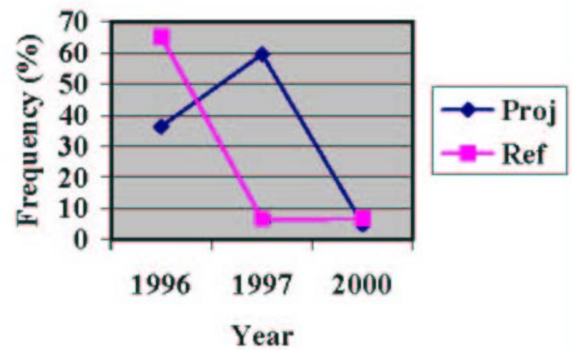


Fig. 27. *Vallisineria americana*

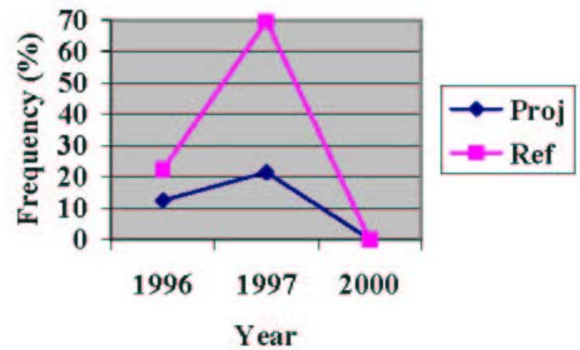


Fig. 28. *Najas caroliniana*

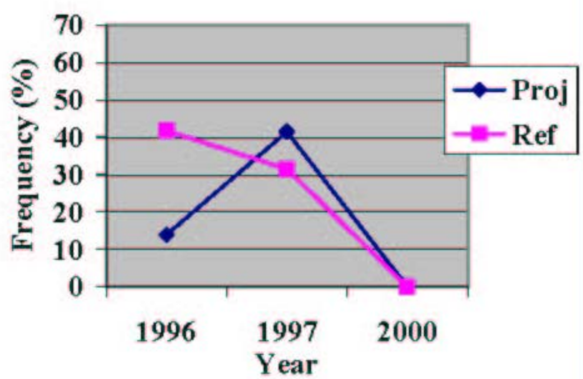


Fig. 29. *Ceratophyllum demersum*

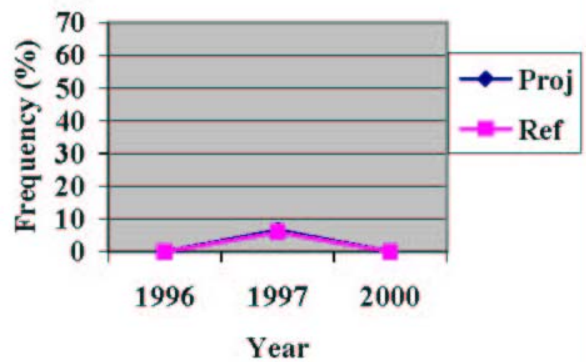


Fig. 30. *Myriophyllum spicatum*

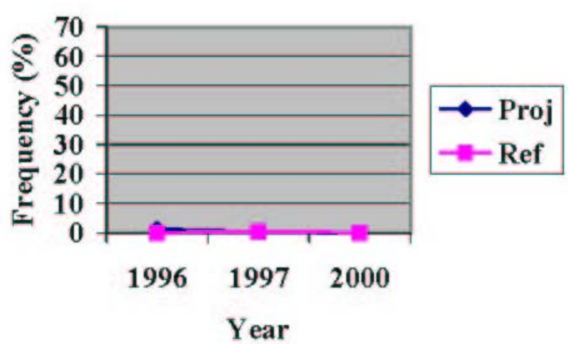
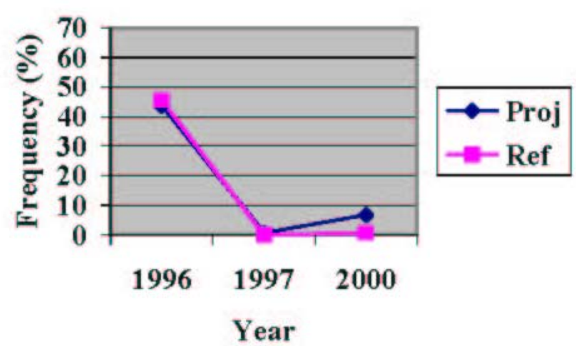


Fig. 31. *Ruppia maritima*



DISCUSSION

Drought and tropical storms were major hydrologic forcing factors for the entire sampling period which confounded the evaluation of project effectiveness. The period of March 1996 through September 1996 was reportedly the worst drought in 20 years in southwestern Louisiana (LOSC, 1996). In the fall of 1996, Hurricane Dolly and Tropical Storm Josephine were followed by a stalled front over the southwestern coast of Louisiana resulting in high water levels over the marsh for four months. In the summers of 1997 and 1998, low rainfall produced drought conditions. In the late summer of 1998, tropical storm Charley was followed by tropical storms Earl and Frances in September, causing a prolonged flooding event in the coastal marshes (figure 12). In January, 1999, a two year drought cycle began that continued through the end of the sampling period, December, 2000 (figure 13). These extreme environmental fluctuations hindered our ability to evaluate project effectiveness.

Discrete and continuous water quality data presented in this report follow historical trends indicating that high salinity waters enter the watershed at all five water control structures located in the east shoreline levee from Calcasieu Lake (figure 3). At the northernmost structure, salinity is reduced as Peconi Bayou twists and turns to the southeast. Grand Bayou is the major conduit for high salinity flow from the lake, north and south through the borrow canal, and easterly, with flow diminishing as North, East and South Prong become constricted. It cannot be determined at this time if the strong counterclockwise water circulation pattern through the northern project area has been moderated since pre-construction baseline flow data were collected during extreme, anomalous conditions. Pre-construction water flow readings were taken during a severe drought coupled with a drawdown. Similar environmental conditions have not been duplicated for post-construction comparisons.

Noname and Lambert bayous are nearest in proximity to the Calcasieu Ship Channel (figure 3) and contribute high salinity water to the southern end of the project where discharge opportunities are limited. The structures along the levee contribute to adequate drainage of the watershed when tides and Calcasieu Lake water levels allow. However, because the watershed relies on gravity drainage, and since four of the last five years have been in drought, it is not possible to examine if the plugs alone will keep water levels in an optimal range.

In a test of continuous recorders in channels and in adjacent marsh, statistically significant differences were detected between marsh and channel recorders. The difference at the 2R location might result from rainfall and evaporation having a greater impact at the marsh site than the channel site. The marsh and channel at site 12m and 12 appear to be more isolated from one another than the marsh and channel at the 2m location. These results suggest that there are differences in marsh and channel hydrology and channel recorders may not always represent marsh hydrology.

Submerged vegetation changed significantly in species composition and species richness over time. These changes possibly resulted from the drought and drawdown conditions, which caused water levels to reach record lows from April to July 1996 (figure 13). During this time, ponds that normally held water from 0.5 ft to 2 ft (0.15-0.61 m) deep were completely dry with surfaces exposed; continued drying over time caused deep fissures in the exposed mud (figure 8) which affected SAV survival in 2000.

Ruppia maritima can have an annual or perennial life cycle depending upon environmental stresses (Koch and Seeliger 1988). Although the plant may withstand prescribed drawdowns, excessive or irregular water level fluctuations that expose bottom soils for long durations may eliminate existing stands or cause great difficulty in establishing new stands (Joanen 1964; Joanen and Glasgow 1966). Drought conditions are efficient in causing seed coat breakage of *R. maritima* (Richardson 1980), promoting germination by increasing seed permeability to water. The prolonged drought of 1997 and 1998 may have caused an increase in germination of *R. maritima* seeds when the marsh was flooded in late summer of 1998, perhaps depleting the seed bank in the soil. In addition, water and soil salinities were high at this time, favoring *R. maritima* over *Vallisineria americana*. *R. maritima* tolerates a wider range of salinity than any other species of SAV (Brock 1979). These conditions would account for high percentages of *R. maritima* recorded in October 1996 and the slight comeback in 2000.

Although *Vallisineria americana* is capable of both asexual and sexual reproduction, it lives in a habitat where vegetative reproduction is apparently favored (Titus and Stone 1982). *V. americana* reproduces vegetatively by producing winter buds, called turions, at the end of the growing season. Buds may have sprouted in early spring when water was available, only to die back in late spring when soil surfaces were exposed, preventing new winter bud formation. In late summer, when water flooded the marsh surface, soil salinity was high while energy in the buds was low, perhaps causing low sprouting percentages. In 1997, there was adequate fresh water on the marsh all year, reducing salinity in the soil, providing optimal conditions for germination and growth of *V. americana*. Because of the drought of 1999 and 2000, by the fall of 2000 when sampling occurred, salinity had been elevated near 15 ppt for almost one year at most stations (figure 12). *Vallisneria americana* is unable to tolerate prolonged high salinity, as are *Najas guadalupensis, Myriophyllum spicatum,* and *Ceratopyllum demersum.* Water temperatures at shallow depths may also have been a factor in preventing the regrowth of submergent vegetation in fall of 2000.

CONCLUSION

Since the beginning of this project in 1996, the Cameron Creole watershed has been dominated by dramatic climatic patterns, including drought up to 2000, often followed by concurrent tropical systems in the fall. Consequently the changes that have been seen in the project area may be a result of these extreme patterns and not the result of the project features.

The cover of emergent vegetation remained stable over the duration of the project in each of the northern and southern project areas, and the vegetation reference area. Because both species richness and cover have been consistent over time and through seemingly adverse conditions, it appears that the emergent vegetation has become preconditioned to the dynamics of salinity and water level fluctuations over time. The levee and structure system was constructed only 11 years ago, resulting in a reversal from eroding marsh to a thriving, more stable emergent community.

Results from submergent aquatic vegetation community reveal how fast the SAV responded to stress factors such as salinity and water level. Species responded to rising salinity and dropping water levels. Although frequency of occurrence and species richness were low in 2000, field observations over the last few years have shown that submergent vegetation have regenerated as the watershed returned to more optimal salinity and water levels.

The occurrence of environmental extremes complicated effectiveness of the evaluation of the CS-17 Cameron-Creole Plug Project. Due to these complications, we have been unable to document significant ecological responses to the project design. The analyses suggest that either the project had minimal effect or that the data were confounded and not adequate for pre-post-construction comparisons. The reference areas for vegetation and SAV have been deemed inappropriate for the project areas because they are not independent of any possible effects of the plugs on vegetation and hydrology.

It was not possible to differentiate ecological responses due to the project plugs and the pre-existing water control structures, and it may not be possible to duplicate conditions for measurement of water level, salinity, and water flow because preconstruction samples were taken during the worst drought in 20 years. Therefore, we recommend that monitoring for this project as written in the monitoring plan be discontinued and future monitoring of the Cameron-Creole Watershed and the Calcasieu Basin be conducted through CRMS-*Wetlands* monitoring approach.

REFERENCES

Anderson, J. E., E. E. Hardy, J. T. Roach, and R. E. Witmer. 1976. A land use and land cover classification system for use with remote sensor data. U.S. Geological Survey Professional Paper no. 964. 28 pp. (As revised by L. Handley for habitat classification.)

Boesch, D. F., M. N. Josselyn, A. J. Mehta, J. T. Morris, W. K. Nuttle, C. A. Simestad, and D. J. P. Swift. 1994. Scientific assessment of coastal wetland loss, restoration, and management in Louisiana. Journal of Coastal Research, S.I. No. 20.

Boon, J. D., III 1978. Suspended solids transport in a salt marsh creek -an analysis of error in Estuarine Transport Processes (Kjerfve, B.J., ed.). The Belle W. Baruch Library in Marine Science, Number 7. University of South Carolina Press. Columbia, South Carolina. 331 pp.

Brock, M. A. 1979. Accumulation of proline in a submerged aquatic halophyte, Ruppia.Oecologia 51:217-19.

Byrne, J. V., Leroy, D. O., and C. M. Reilly 1959. The Chenier Plain and its stratigraphy, southwest Louisiana. Trans. Gulf Coast Association of Geological Societies, 9:237-260.

Chabreck, R. H., and C. M. Hoffpauir 1962. The use of weirs in coastal marsh management in coastal Louisiana. Proceedings of the Annual Conference of the Southeastern Association of Game Fish Commissioners. 16:103-12. Columbia, South Carolina.

Cowardin, L. M., V. Carter, F.C. Golet, and E.T. LaRoe. 1992. Classification of wetlands and deepwater habitats of the United States. Washington, D.C.: Fish and Wildlife Service, U.S. Department of the Interior. 131 pp.

Delany, B. 1991. Cameron-Creole Watershed Management, 1988-1990. Creole, Louisiana: unpublished report prepared for the USACE and LDNR/CMD.

DeLaune, R. D., Baumann, R. H., and J. G. Gosselink 1983. Relationships among vertical accretion, coastal submergence, and erosion in a Louisiana gulf coast marsh. Journal of Sedimentary Petrology 53(1):147-157

Gould, H. R. and E. McFarlan, Jr. 1959. Geologic history of the Chenier Plain, southwestern Louisiana. Transactions-Gulf Coast Association of Geological Societies 9:261-270.

Howe, H. V., Russel, R. J., McQuirt, J. H., Craft, B. C., and Stevenson, M. B. 1935. Reports on the geology of Cameron and Vermilion Parishes: Louisiana Geological Survey Bulletin. 6:242.

Joanen, T. 1964. A study of the factors that influence the establishment of natural and artificial stands of wigeongrass, *Ruppia maritima*, on Rockefeller Refuge, Cameron Parish, Louisiana, M.S. thesis, Baton Rouge, Louisiana State University. 86 pp.

Joanen, T., and L. L. Glasgow 1966. Factors influencing the establishment of wigeongrass stands in Louisiana. Proceedings of the Southeastern Association of Game Fish Commission. 19:78-92.

Kjerfve, B. J., L. H. Stevenson, J. A. Prohel, T. H. Chzranowski, and W. M. Kitchens 1981. Estimation of material fluxes in an estuarine cross-section: a critical analysis of spatial measurement density and errors. Limnology and Oceanography 26:325-35.

Koch, E. W., and U. Seeliger. 1988. Germination ecology of two *Ruppia maritima* L. populations in Southern Brazil. Aquatic Botany 31:321-27.

Louisiana Office of State Climatology (LOSC), Southern Regional Climate Center 1996. Louisiana Monthly Climate Review, Vol. 16, No. 5. Baton Rouge: LOSC, Southern Regional Climate Center. 12 pp.

Myers, R. S., G. P. Shaffer, and D. W. Llewellyn 1995. Bald cypress (*Taxodium distichum* (L.) (Rich.) restoration in southeast Louisiana: the relative effects of herbivory, flooding, competition, and macronutrients. Wetlands 15(2):141-148.

Nyman, J. A., and R. H. Chabreck 1996. Some effects of 30 years of weir-management on coastal marsh aquatic vegetation and implications in waterfowl management. Gulf of Mexico Science 14:16-25.

Penland S., K. E. Ramsey, R. A. McBride, T. F. Moslow, and K. A. Westphal. 1989. Relative sea level rise and subsidence in Louisiana and the Gulf of Mexico. Coastal Geology Technical Report No. 3. Louisiana Geological Survey. Baton Rouge, LA 70803.

Reed, D. J., and L. Rozas 1995. An evaluation of the potential for infilling existing pipeline canals in Louisiana coastal marshes. Wetlands 15(2):149-158.

Richardson, F. D. 1980. Ecology of *Ruppia maritima* L. in New Hampshire (U.S.A.) tidal marshes. Rhodora 82:403-439.

Steyer, G. D., R. C. Raynie, D. L. Steller, D. Fuller, and E. Swensen 1995. Quality managment plan for coastal Wetlands Planning, Protection, and Restoration Act monitoring program. Open file series no. 95-01. Revised June 2000. Baton Rouge: Louisiana Department of Natural Resources, Coastal Restoration Division. 97 pp.

Titus, J. E., and W. H. Stone. 1982. Photosynthetic response of two submersed macrophytes to dissolved inorganic carbon concentration and pH. Limnology and Oceanography 27:151-60.

Turner, R. E. 1990. Landscape development and coastal wetland losses in the northern Gulf of Mexico. American Zoologist 30:89-105.

U.S. Department of Agriculture (USDA) 1995. Soil Survey of Cameron Parish, Louisiana. Publication No. 1995-386-441/00020. Washington, D.C.: U.S. Government Printing Office. 135 pp, 122 maps. Scale 1:20,000.

U.S. Army Corps of Engineers (USACE) 1971. National Shoreline Study. Inventory Report-Lower Mississippi Region. New Orleans, LA. 58 pp.

Van Lopik, J. R., and W. G. McIntire. 1957. Cheniers of Vermilion Parish. Louisiana: their relation to Mississippi River delta chronology. Transactions of the Gulf Coast Association of Geological Societies. 4:302.

Van Sickle V. R., 1977. Coastal Louisiana oyster distribution and ecological change: Baton Rouge, Louisiana State University Center for Wetland Resources, Louisiana State University-SG-TD2-7-6(T).

Weifenbach, D. 1995. Cameron Creole Borrow Canal Plug Project (C/S-17) Monitoring Plan. Baton Rouge: Louisiana Department of Natural Resources, Coastal Restoration Division.

Prepared on December 1, 2003, by Leigh Anne Sharp.

LDNR Monitoring Manager:	Leigh Anne Sharp	(337) 482-0659
LDNR Project Manager:	Clay Menard	(337) 482-0683
Federal Sponsor:	USFWS/ Chris Pease	(337) 598-2216

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