Historical Causes of Landscape Change in the Mermentau Basin

A better understanding of the causes of land loss in the Mermentau Basin will improve our understanding of the factors that influence this ecosystem's stability. We decided that an efficient way to investigate causes of land loss and gain in the Mermentau Basin would be to interview the various experts in the fields of biology, ecology, and wildlife management who possess intimate historical knowledge of events that impacted biological and hydrological processes in this ecosystem. Although much of this information is anecdotal in nature, it provides an interesting perspective on the causes of landscape change in the Mermentau Basin.

We held a meeting in January 2000 to consult with: Alan Ensminger, Louisiana Landowners Association; Tom Hess, Louisiana Department of Wildlife and Fisheries (LDWF), Rockefeller Wildlife Refuge, assistant refuge manager; Ted Joanen, Miami Corporation; Guthrie Perry, LDWF, Rockefeller Wildlife Refuge manager; David Richard, Stream Properties, Inc.; and Paul Yackupzak, U.S. Fish and Wildlife Service, Cameron Prairie National Wildlife Refuge, refuge manager. Dr. Robert H. Chabreck of Louisiana State University contributed further review of the findings provided by our panel of experts.

Each expert shared knowledge of the causes of land loss at particular sites and when that loss occurred, over the periods 1956-78 and 1978-90. The group members then reached consensus on the various causes of landscape change. Each Mermentau Basin site discussed was assigned a number (Figure 19). We summarize these causes of landscape change, identifying each of these areas by its corresponding Coast 2050 mapping unit (LCWCRTF/WRCA 1998).

Area 1 (Cameron Prairie Unit):

In the 1950s, a large impoundment was constructed and the area was used to grow rice. The subsequent oxidation of the organic marsh substrate when the rice field was drained resulted in lower surface elevations. When rice farming was abandoned and the area re-flooded, substrate elevation was too low for re-colonization by emergent marsh. Currently, the area provides good waterfowl habitat and is expected to continue to be managed accordingly.

Area 2 (Western Big Burn Unit):

Land loss in the Western Big Burn Unit occurred in 1981 as a result of saltwater intrusion from the Calcasieu Ship Channel (CSC). Salinities as high as 20 ppt have been recorded in water flowing through the Welfare Bridge under Highway 27 (see Figure 4).

Area 3 (Middle Marsh Unit):

Most of the present-day ponds were historically saw grass marsh in this high marsh prairie. Most of the Middle Marsh Unit was opened up by extensive muskrat herbivory, as this area historically held one of the highest muskrat populations in the region. Losses in the eastern part of the unit are associated with saltwater intrusion

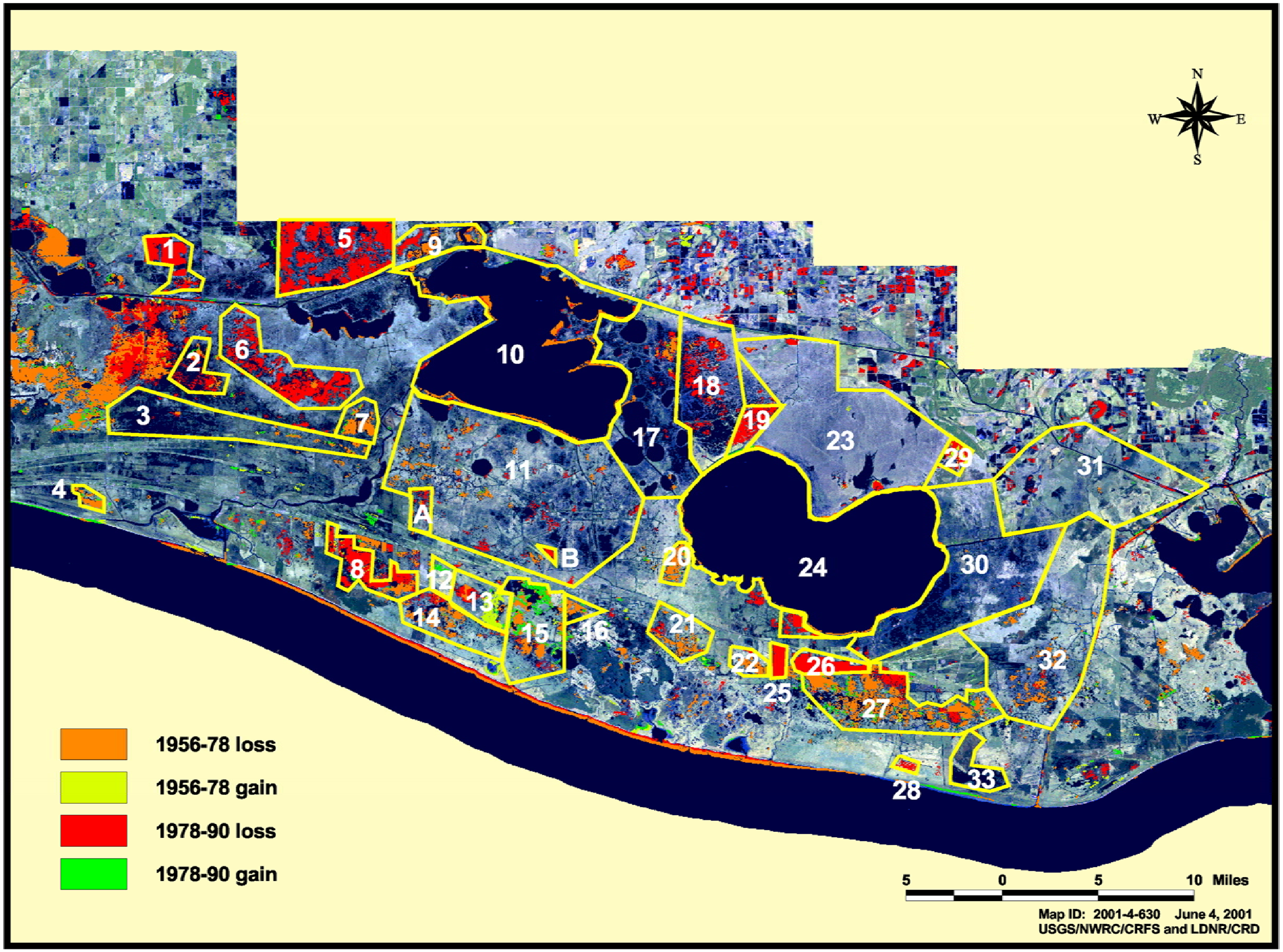

Figure 19. Historical trends in landscape change in the Mermentau Basin.

via a ditch dug across the unit. The area is presently under gravity drainage, with normal tidal flow, and estuarine fisheries access not allowed.

Area 4 (Cameron Unit - Creole Canal, north of old Mermentau River Channel):
O'Neil (1949) classified this as a brackish three-corner grass marsh. This area historically received a constant inflow of freshwater coming down the Mermentau River. When the Catfish Point Control Structure was built in 1951, it restricted these inflows. The Creole Canal and associated oil and gas canals allowed saltwater into the area, and because there was inadequate flushing to get it out, the habitat converted to open water. It later revegetated to salt marsh cordgrass, *Spartina alterniflora*, around the edges of the area.

Area 5 (Lacassine Unit):
This area was historically a saw grass marsh that was converted into a waterfowl impoundment in 1943. Water levels were intentionally held high to kill the saw grass marsh and create favorable conditions for waterfowl. Much of the loss shown in Figure 19 is not true land loss because the image was taken during a period of high water. A common management practice included drawdowns for the purpose of oxidizing soils to promote the growth of aquatic plants. This practice allowed managers to keep increased water levels with the objective of improving conditions for bass fishing and waterfowl. An unplanned consequence of this management strategy is that much of the maidencane (*Panicum hemitomon*) marsh was killed, which reduced the quality of nesting habitat for alligators.

Area 6 (Big Burn Unit):
The "Big Burn" in this area occurred during a drought in 1924-25. There are two suspected causes of the burn in what was then a saw grass marsh: a lightning strike, or alligator hunters who started the fire by burning the marsh in the summer to facilitate alligator hunting. Regardless, fire burned for two years and was eventually extinguished by heavy rains. Historical photography from the late 1950s reveals that over time, the area healed and the marsh closed up as a deep organic marsh expanded to fill the ponds formed by the burn. In the early 1960s, saltwater intrusion occurred, primarily from the CSC via the Welfare Bridge and secondarily from the Mermentau River and hurricanes Audrey and Carla. Thus saltwater effectively negated the healing that had occurred and the area returned to open water. Currently, this marsh seems to be recovering, probably as a result of the Cameron-Creole Watershed project.

Area 7 (Southeastern Big Burn Unit in the vicinity of the Humble Canal):
This loss is believed to have been caused by discharges of produced water from oil and gas exploration during the 1950s**.** Humble Canal also caused land loss through saltwater intrusion from the Mermentau River when the Humble Canal Structure failed.

Area 8 (Hog Bayou Unit):

Marsh loss in this area is attributed to the oxidation of fragile organic soils due to drainage for cattle grazing, saltwater intrusion from the Mermentau Ship Channel, and to the rapid intrusion of high salinity water as a result of the opening of Beach Prong channel.

Area 9 (Lacassine and North Grand Lake Units):

Marsh loss in this area is attributed to elevated Lakes Sub-basin water levels that caused the washout of some of the organic floating marsh near the mouth of Bayou Lacassine. Navigation in the GIWW also negatively impacted the area through boat wake-induced shoreline erosion. Some loss is believed to have been due to nutria herbivory.

Area 10 (Grand Lake Unit):

Shoreline erosion due to artificially elevated water is thought to be the leading cause of loss in this unit. High water levels were maintained in the Lakes Sub-basin beginning in 1951, with the installation of the Catfish Point Control Structure, through the mid-1970s. The USACE has managed water at a lower level since around 1994, but the lake rims are badly eroded. Consequently, the historical buffer from wave energy is also gone. Dredging for shells in Grand Lake may also have contributed to shoreline erosion.

Area 11 (Little Pecan Unit):

This area was once solid saw grass marsh but the saw grass died in the early 1950s and was virtually gone by the mid-1960s. When Hurricane Audrey made landfall in 1957, large rafts of living wiregrass marsh, *Spartina patens*, were transported over the Grand Cheniere Ridge with the storm surge and deposited in this unit. Over time, wiregrass became the dominant plant species in this area. Some of the ponds in this unit represent areas of marsh loss caused by large volumes of produced water that were discharged directly into the marsh by the petrochemical industry. The Mermentau Ship Channel may have also played a role in increased saltwater intrusion in these marshes. The Coast 2050 Region 4 Regional Planning Team believed excessive flooding due to altered hydrology to be a primary cause of loss in this unit (LCWCRTF/WCRA 1999).

Areas 11A and 11B (Little Pecan Unit):

These former marsh areas were impounded and converted to agricultural fields that were drained and maintained under pump. The organic marsh soils oxidized, resulting in elevation loss, and cattle grazing of the wiregrass caused a successional shift to less flood-tolerant species, such as seaside panicum (*Panicum amarum*) and Bermuda grass (*Cynodon* spp.). When pumping and levee maintenance were abandoned and the area re-flooded, the water was too deep for re-colonization by emergent marsh. Both of these areas now serve as high-quality habitat for waterfowl.

Area 12 (Rockefeller Unit 2):

Marsh gain in this area is due to water management that uses a lo-lift pump and 36-in stoplog flapgate water control structure.

Area 13 (Rockefeller Unit 3):

The marsh gain depicted is a result of managed water level drawdown. The land loss occurred prior to 1978 and is attributed to saltwater intrusion up Joseph's Harbor Canal from the gulf into the old saw grass marsh. In the early 1950s, the area was managed as a permanently flooded brackish impoundment. Management efforts began in the early 1970s to create fresher conditions and a vegetative community more suitable for waterfowl.

Area 14 (Southwest Rockefeller Unit 1 around Price Lake):

Refuge managers intentionally burned this brackish wiregrass marsh in the mid-1960s to create better waterfowl habitat. The burn was followed by a flooding event that resulted in the total die-off of the emergent marsh, resulting in pond formation.

Area 15 (Rockefeller Units 4 and 5):

Although not depicted as loss on the image (Figure 19), the open water shown was formerly a willow ridge that subsided prior to the 1950s. The area was historically a fresh saw grass marsh that was lost through saltwater and tidal intrusion from Joseph's Harbor Canal. A ditch dating back to the 1860s connected Grand Chenier and Pecan Island, which also connected the two isolated marsh areas. This ditch was also a conduit for saltwater from Joseph's Harbor Canal. Units 4 and 5 are currently managed as multi-use areas to provide controlled access to estuarine organisms. Unit 4 has a freshwater introduction structure on the north boundary line canal that provides freshwater, nutrients, and sediments to the area. Both units are subjected to periodic drawdowns to solidify the bottom substrate, improve the growth conditions for submerged aquatics, and improve waterfowl habitat.

Prior to the Joseph's Harbor Canal, Little Constance Bayou was the main drainage channel for the area. The bayou was blocked in the early 1960s and Joseph's Harbor Canal/Humble Canal became both the main drainage channel and a major point of saltwater intrusion. Humble Canal was constructed in 1940. The 65-ft-wide canal extended from the East End Camp to the Joseph Harbor Bayou, then two miles east to a drill prospect. In the winter of 1951-52, construction began on Superior Canal, which connected the Grand Lake system with Rockefeller Wildlife Refuge. Shortly after, the Deep Lake and Constance Bayou Oilfields were discovered. In 1954 the Property Line Canal was dug from Humble Canal to Superior Canal. Because of saltwater problems, the East End locks were constructed in 1959.

Area 16 (Rockefeller Unit 6):

This area was historically a saw grass marsh. Land loss in this area is attributed to saltwater and tidal intrusion from Joseph's Harbor Canal.

Area 17 (Grand/White Lake Land Bridge Unit):

This is currently a deep organic bulltongue marsh with scattered black willow (*Salix nigra*) and rattlebox (*Sesbania drumondii*), but historically the area was a saw grass marsh. During winter cold-front passages and strong northerly winds, the unit becomes completely inundated and resembles an ocean's rough waters. Erosion on the Grand and White Lake shorelines and excessive water levels are the primary causes of marsh loss in this area.

Area 18 (East Amoco Unit):

This is a healthy deep marsh dominated by maidencane and bulltongue. The land loss image (Figure 19) is inaccurate for this area because the image was acquired during a period of high water artificially and temporarily impounded to create better waterfowl habitat. The Coast 2050 Region 4 Regional Planning Team stated that significant losses continue to occur in the northern part of this unit but it seems probable that they misinterpreted false loss (LCWCRTF/WCRA 1999).

Area 19 (Southeast corner of the Amoco Unit):

This area is impounded and has oxidized to the extent that it is below marsh level. During periodic drawdowns, it is sometimes recolonized with annual species.

Area 20 (Western side of the South White Lake Unit):

This was a waterfowl management unit managed for the production of annual grasses and sedges that are good waterfowl foods. The areas of land loss on the map (Figure 19) are misclassified because of impounded water that was present when the 1978 image was acquired. It is not presently under management. The Coast 2050 Region 4 Regional Planning Team believed excessive flooding due to altered hydrology to be the primary cause of loss in this unit (LCWCRTF/WCRA 1999).

Areas 21 and 22 (North Central Rockefeller Unit):

These areas were historically saw grass marshes that were killed by saltwater intrusion, produced-water discharge, and nutria herbivory.

Area 23 (North White Lake Unit and some of the Amoco Unit):

This area is deep organic maidencane marsh that may float during high water conditions. O'Neil (1949) classified this as a floating fresh marsh. North of the GIWW from this unit is a peat mining operation located in this same marsh type, a testament to the organic productivity of maidencane marshes. Most of the loss in this unit is from shoreline erosion on White Lake and canal construction.

Area 24 (South White Lake Unit):

This area was placed under drainage for cattle grazing. Cattle grazing and soil oxidation resulted in the elimination of the natural *Spartina patens* community, with a successional shift to less flood-tolerant species such as seaside panicum (*Panicum amarum*) and Bermuda grass (*Cynodon* spp.). When the levees were no longer adequately maintained, the area became permanently flooded to a depth that prevented recolonization of emergent marsh.

Areas 25 and 26 (Northern portion of the South Pecan Island Unit):

This former marsh area was leveed off and drained for cattle pasture. It eventually suffered levee failure and became inundated by the same process that occurred in Area 24.

Area 27 (South Pecan Island Unit):

An Exxon facility built in the 1940s pumped produced water directly into the marsh, causing the loss of the historical saw grass marsh. Some of this loss is also associated with saltwater intrusion and organic matter export that occurred when the construction of the Freshwater Bayou, Louisiana Fur, Dewitt, and Rollover canals opened this area to increased tidal action.

Area 28 (South end of the South Pecan Island Unit):

The map image (Figure 19) misclassified the area as loss, due to a burn, and the area is actually a high marsh. It is also possible that the loss shown on this image is due to a muskrat eat-out that has since recovered. This is an area of historically large muskrat populations.

Area 29 (Part of the North White lake Unit):

This area is actually a burn that has since recovered and is classified incorrectly on the land loss image.

Area 30 (East side of the South and North White Lake Units):

The large ponds east of White Lake are actually bulltongue and maidencane marshes that are now inundated. Shoreline erosion due to water levels held artificially high in White Lake is also thought to be a cause of loss in this area.

Area 31 (Little Prairie Unit):

This is a high, fresh, prairie marsh dominated by black needlerush (*Juncus roemerianus*), switch grass (*Panicum vaginatum*), and hog cane (*Spartina cynosuroides*). It is a healthy marsh that has had relatively little historical loss. The biggest problem facing this marsh is its hydrologic connection with Little Vermilion Bay, which draws too much water into the area, resulting in prolonged flooding. The Coast 2050 Region 4 Regional Planning Team identified marsh impoundment for crawfish culture as a cause of loss in this unit (LCWCRTF/WCRA 1999).

Area 32 (Big Marsh Unit):

This area grades from fresh to brackish marsh. Areas of loss reflect the historical saw grass marshes that were killed by saltwater intrusion from the Freshwater Bayou Canal. It is currently under management.

Area 33 (Southeastern corner of the South Pecan Island Unit):

This large pond is the result of a historical burn and possibly a muskrat and snow goose eat-out.

In summary, most of the historical causes of landscape change in the Mermentau Basin can be traced to specific causes or combinations of events. Excluding the impact of Hurricane Audrey in 1957, nearly all land losses can be directly or indirectly tied to human-induced hydrologic alterations.

Mermentau Basin Coastal Change Analysis Program

Under funding from the National Oceanic Atmospheric Administration, the Spatial Analysis Branch of the U.S. Geological Survey National Wetlands Research Center conducted a Coastal Change Analysis Program (C-CAP). Landsat Thematic Mapper (TM) images with 25-m pixel resolution and collateral data sources were used to classify the land cover of the Mermentau Basin within the Chenier Plain of coastal Louisiana. Methods and detailed analyses for this program are presented in Appendix B.

Results

The largest spatial coverages for the entire study area in 1996 were associated with cultivated land (34%), grassland (9%), woody land forests (deciduous, evergreen, mixed, scrub shrub, 13%), woody wetland forests (deciduous, scrub shrub, 11%), wetland palustrine (7%) and wetland estuarine (6%) marshes, and water (17%). The remaining 3% was spread mostly between the developed high-intensity and developed low-intensity classes. It should be noted that there are inherent inaccuracies with any landscape classification scheme that are related to fluctuating water levels, image resolution, and spectral reflectance. Accuracy assessment for the change points from 1990 to 1996 resulted in an overall accuracy of 90%.

Changes in Land Cover

Small positive increases in land cover between 1990 and 1993, and between 1993 and 1996, substantiate the stable nature of mature forested wetlands in the Upland Sub-basin. Likewise, the minimal change in wetland estuarine and palustrine classes during both periods suggests a fairly stable marsh. Overall acreage shifts reflect relative stability in the Lakes and Chenier sub-basins. The net trend in wetland acreage from 1990 to 1996 shows a small increase of 2,458 ac and an increase in unconsolidated shore habitat of 3,443 ac. Small marsh gains and losses, however, reflect natural processes, management practices, and human-induced hydrologic alterations. We discuss here the most notable changes.

The largest interior marsh area showing a conversion from land to water is located in the marshes northwest of White Lake (Figure 20). This is an impoundment that is actively managed for waterfowl. Management practices include periodic drawdown of the marsh to stimulate the production of annual emergent marsh species that provide a food source for wintering waterfowl. The red area on the image reflects a change from marsh to water due to the presence of these annual species in 1990 and their absence in 1993 and 1996. The 1990 image was acquired during late fall, a time of year when the annual species were still alive.

The 1993 and 1996 images were acquired during winter, after the onset of senescence (Figures 21 and 22). Thus, the analysis technique inaccurately detects a change from vegetation to water, and consequently reports this as “marsh loss.” However, in reality, this managed area is undergoing an annual cycle of plant growth, senescence and decomposition, and is not actually experiencing “marsh loss.”

Two main “hot spots” of loss are notable on Figures 20-22. The largest of these is located on the south side of the Grand Chenier Ridge in the vicinity of Hog Bayou (Figure 22; see also Figure 4). This loss is probably due to reduced Mermentau River inflow and ongoing saltwater intrusion resulting from installation of the Catfish Point Control Structure and the Mermentau Ship Channel. Another possible cause for loss in this area is the construction of levees for cattle grazing and subsequent soil oxidation followed by flooding. Another hot spot of loss is located on the western edge of the basin adjacent to Louisiana Highway 27, between the Little Chenier Ridge and Chenier Purdue Ridge (Figure 22; see also Figure 4). The cause of marsh deterioration in this area is not clear, but it may be muskrat herbivory (this area has historically contained high muskrat populations) or impoundment-related flooding, or it may be false loss due to naturally high water conditions present at the time the image was acquired.

Other changes are located along the Gulf of Mexico shoreline. Shoreline accretion can be seen on the eastern edge of the basin immediately west of the Freshwater Bayou Canal (Figure 22). This accretion is due to mud flat progradation of Atchafalaya River sediments moving west with the dominant littoral drift. West of this area, erosion is the dominant process, as is evidenced by approximately 250 ft of shoreline lost between 1990 and 1996. Erosion is also evident along the shores of Grand and White lakes.

Land gain in the bays fringing the Rockefeller Wildlife Refuge is occurring and visible in these images (Figure 23). This accretion and marsh colonization are attributable to the combined effects of the Atchafalaya River mud stream and resuspended material from beachfront erosion that is carried into the bays with the tides and waves.

Determining Causes and Effects of Flooding in the Mermentau Basin

Over the past century, human activities have led to major hydrologic alterations to the Mermentau Basin. Related to agricultural practices, petrochemical exploitation, transportation and navigation corridors, and wetland management activities, these alterations have precipitated major shifts in composition and distribution of both plant and animal species. One result of these changes is that the heart of the Mermentau Lakes Sub-basin now functions more as a freshwater reservoir and less as the low-salinity estuary it once was.

We have concentrated here on the analysis of existing long- and short-term hydrographic records, supplemented with recent analyses of land cover change, and the contributed expertise of biologists and wetland managers who have worked in the region for nearly half of a century. In so doing, we have increased our understanding of basin hydrology, and hence our ability to make sound management decisions for the restoration

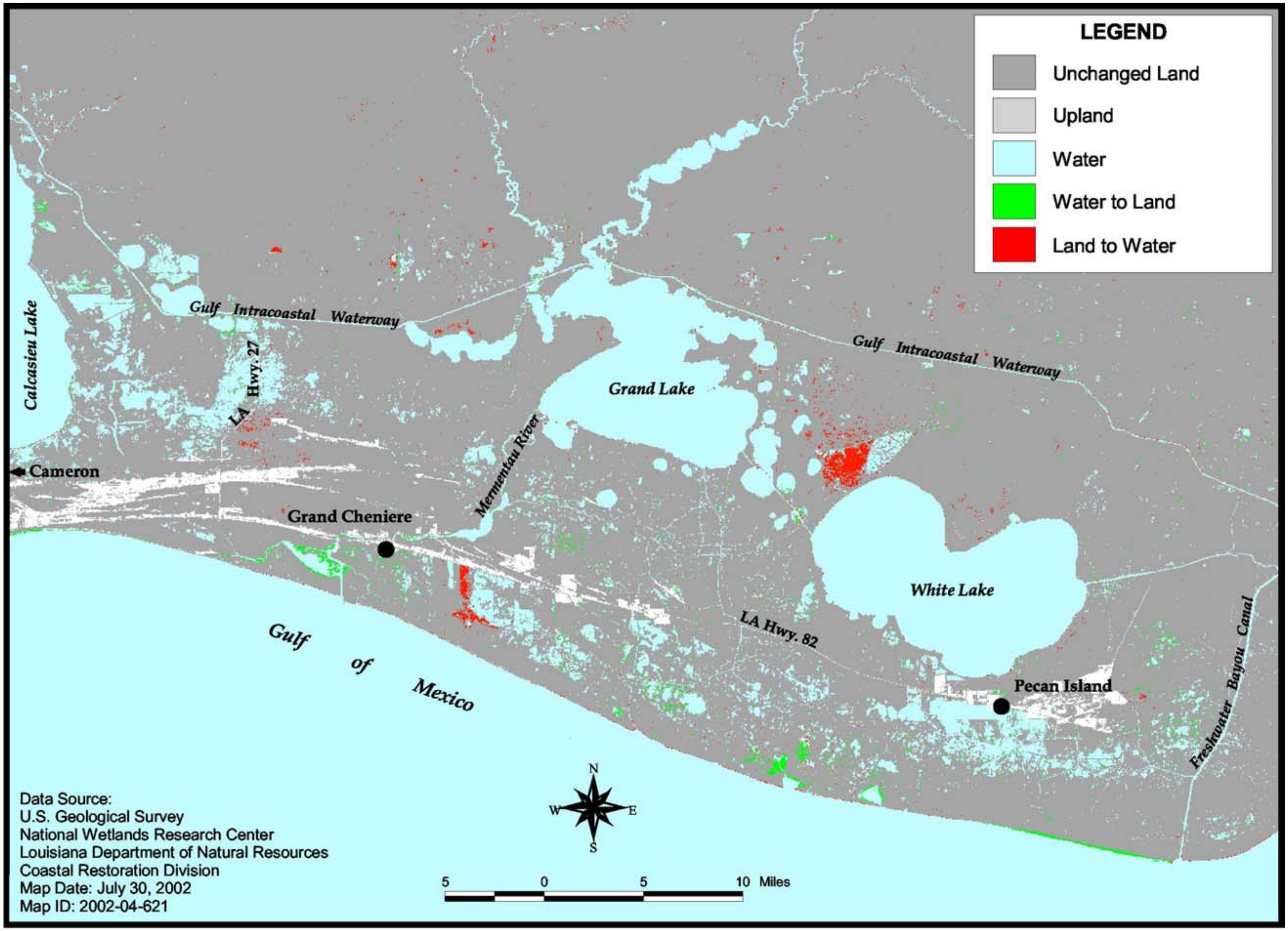

Figure 20. Mermentau Basin landscape changes, 1990-1993.

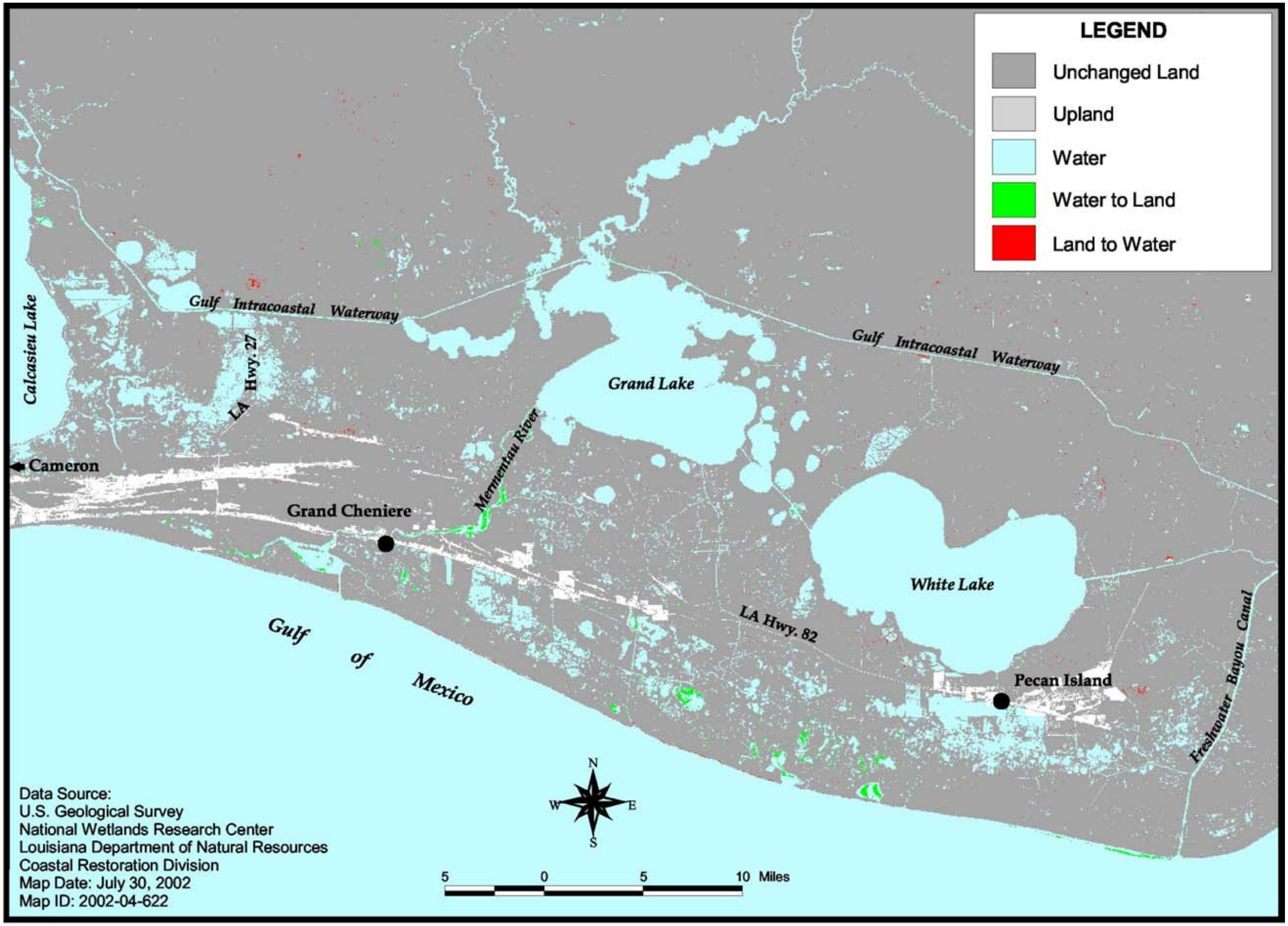

Figure 21. Mermentau Basin landscape changes, 1993-1996.

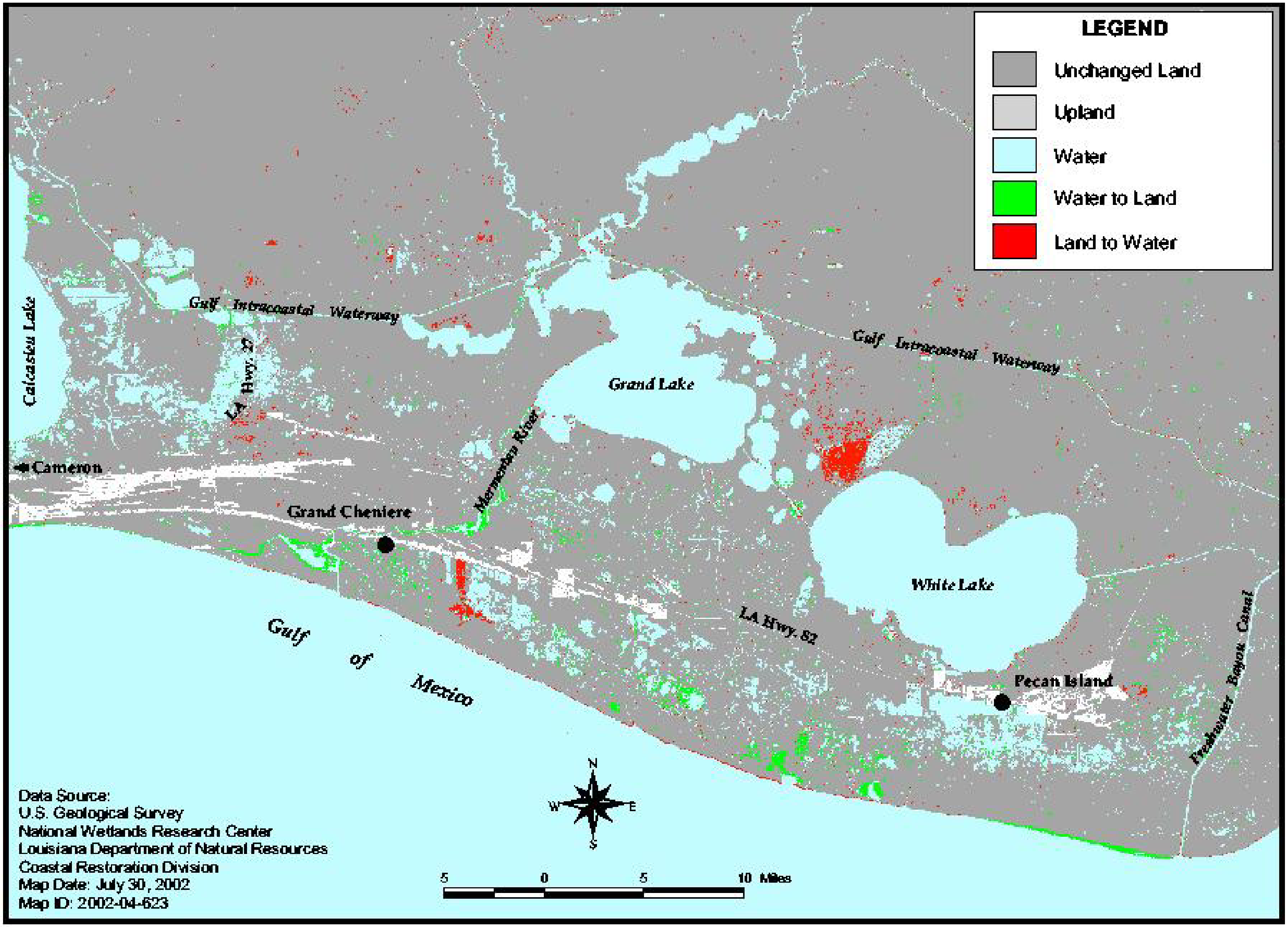

Figure 22. Mermentau Basin landscape changes, 1990-1996.

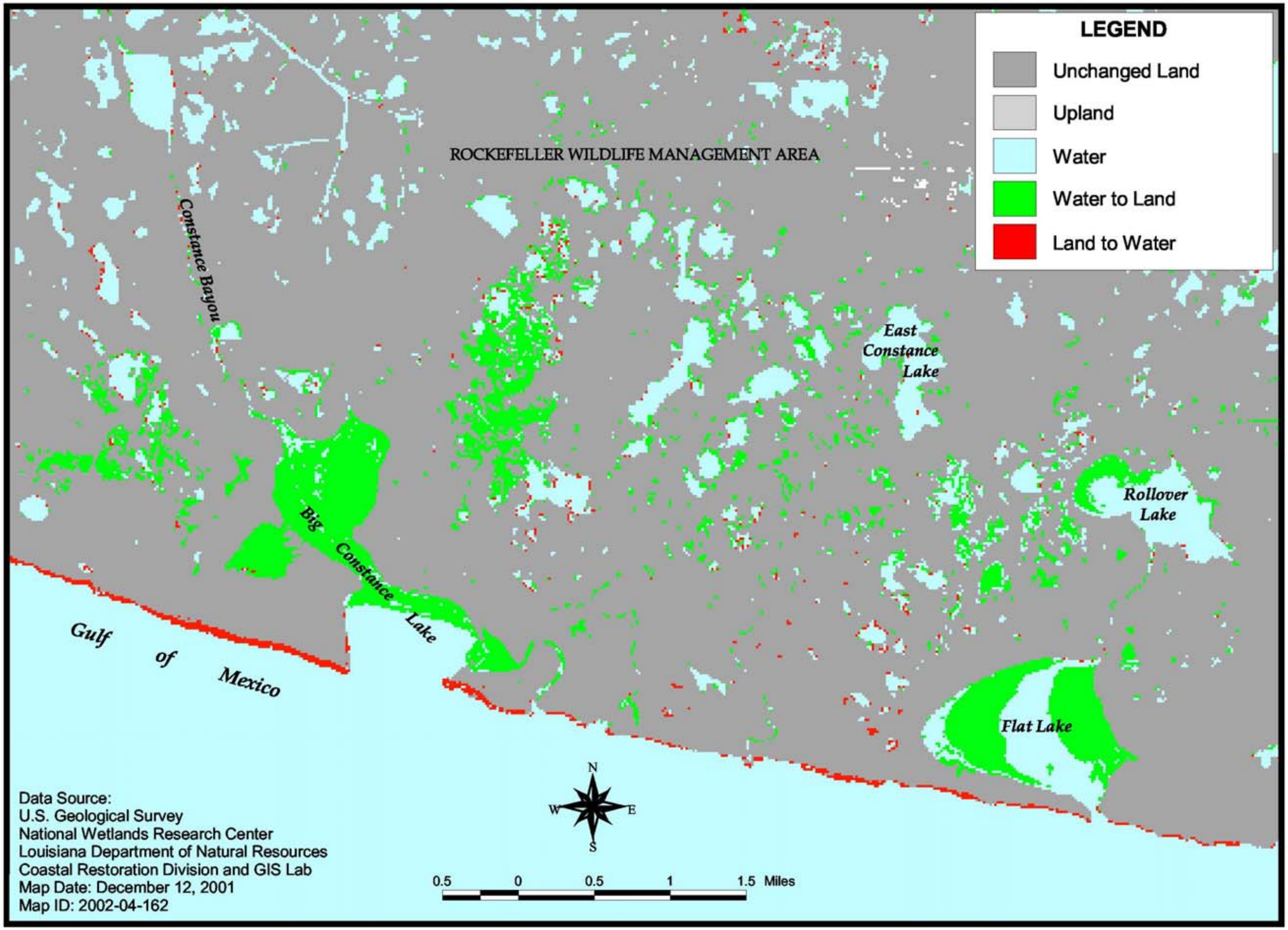

Figure 23. Shoreline changes in the Rockefeller Wildlife Refuge, 1990-1996.

and protection of the basin. Although much remains to be learned about basin hydrology, this is an important step toward understanding this region.

Analyses of data from the USACE water control structures that regulate hydrology within the Lakes Sub-basin indicate that water level is rising both inside and outside of the sub-basin. The rates of rise are irregular both over time and among the structures. The data indicate a rise averaging approximately 0.16 in/yr on the interior and approximately 0.27 in/yr on the exterior over a nearly 50-yr period of record. Such seemingly high rates of water level rise inside and outside of the Lakes Sub-basin have significant implications for the future. Two principal questions arise: How is the marsh responding to these changes? And, what are the implications for drainage of the system?

Many managers and scientists have long believed that the operations of five USACE perimeter control structures have resulted in elevated water levels, poor drainage, and prolonged marsh flooding, and that those conditions together are cumulatively drowning the marsh in the Lakes Sub-basin. Elevated water levels and prolonged marsh flooding have been named in several restoration plans and planning documents as the major causes of land loss in the Mermentau Basin (CWPPRA 1993; LCWCRTF/WRCA 1998; USDA 1997). Elevated water levels are presumed to cause or accelerate land loss through at least three main mechanisms: shore erosion along large bodies of water; floatant marsh washout; and interior marsh die-back due to prolonged marsh flooding. Still, no scientific evidence exists to document the occurrence of these phenomena on a systemic scale in this ecosystem.

There is anecdotal evidence that water levels were held higher during the 1950s - 80s than presently. It is also possible, albeit poorly documented, that drainage has been impeded through the combined effects of: 1) higher than normal rainfall and heavy rain events in the 1960s; 2) inefficient drainage through the lower Mermentau River (later "remedied" by the dredging and expansion of the ship channel); and 3) historical operation schedules for USACE control structures that resulted in interior water levels being held excessively high, thereby increasing shoreline erosion along Grand and White lakes. In addition to the prolonged flooding of marshes in the vicinity of the Catfish Point Control Structure, water level data from Evers et al. (1998) indicated marsh flooding in *Panicum hemitomon* marsh north of White Lake over an entire 1-yr data collection effort over the period March 1997 to March 1998. Additional evidence that water levels are somewhat higher in the Lakes Sub-basin than in the Chenier Sub-basin is indicated by the presence of a water level gradient going north to south most of the time (Swenson 2001). Over the past decade, however, the USACE has improved structure operation to facilitate system drainage. Nonetheless, lakeshore erosion still remains a cause of land loss in the Lakes Sub-basin.

Assessing the impact of elevated water level on floatant marsh in the region is difficult because the floating marshes have not been clearly identified. Floatant marsh may well exist in the basin, but no floatant mat movement has been documented in the scientific literature, though O'Neil (1949) indicated a large area north of White Lake as floatant. Marsh loss near the intersection of Bayou Laccassine and the GIWW is thought to have been caused by the washout of floatant marsh due to elevated water levels. The 1990-96 analysis of land cover change shows no evidence that this process continues to occur. We speculate that most or all of the highly erodible floatant marsh has already been lost. Research is ongoing to document the occurrence and spatial extent of floatant marsh in the Mermentau Basin.

Although the belief that prolonged marsh flooding causes interior wetland loss is widely held, rates of water level rise in the Lakes Sub-basin do not exceed the reported ability of fresh and intermediate marshes to maintain their elevation in response or relation to a rising sea (Delaune et al. 1983; Hatton et al. 1983; Baumann et al. 1984; Knaus and Van Gent 1989). This is corroborated by both our analysis of the causes of historical land loss and the apparent net stability of the basin, as evidenced by a small gain in basin marsh area revealed through the 1990-96 land cover change analysis.

The vegetative response to marsh flooding is largely determined by the flood tolerance of the species found in that marsh. The three major marsh communities that are prevalent in the Mermentau Basin (Visser et al. 1998)—oligohaline wiregrass, fresh bulltongue, and fresh maidencane—should be considered individually when evaluating the flood tolerance of these communities. Even then, solely evaluating community flood tolerance may fall short in areas that are exposed to periodic salinity stresses, as are the marshes of the southern and eastern Lakes Sub-basin. A scientific literature review illuminates the unresolved questions regarding the flood tolerance of the dominant marsh communities in the Lakes Sub-basin (Table 7). For example, in the fresh bulltongue marshes, *Sagittaria lancifolia* has proven to be extremely flood tolerant even when continually flooded for several months (Grace and Ford 1996). Field manipulations of marsh surface elevation indicate no significant differences in plant biomass production even when plants were lowered 10-20 cm below adjacent marshes over periods of several months (McKee and Mendelssohn 1989; Grace and Ford 1996). One study found that belowground biomass increased with flooding treatment, although it is possible that there were periods during that experiment when the treatment may not have been flooded (Howard and Mendelssohn 1995). Still another study has shown decreases in biomass and stem density with flooding (Webb and Mendelssohn 1996). McKee and Mendelssohn (1989) noted a decrease in biomass for maidencane (*Panicum hemitomon*) under flooded conditions with lowered sods in the field but not in the greenhouse.

Most studies of oligohaline and mesohaline wiregrass marshes dominated by *Spartina patens* have dealt with the combined effects of flooding and salinity. The scientific community generally agrees that flooding and salinity stresses can create anaerobic conditions resulting in a buildup of toxic metabolites such as hydrogen sulfide. This in turn can reduce nutrient uptake, with plant stress or death the result. How these marshes respond to flooding stress alone is unclear and has not been well documented. One hypothesis is that the semi-impounded nature of the Lakes Sub-basin keeps it relatively fresh, thus elemental sulfur, being virtually unlimited in seawater, may not be present at levels that will be stressful to the *Spartina patens*-dominated marsh. Although additional study is needed to either support or discredit this hypothesis, analysis of historical land cover change indicates that the oligohaline wiregrass marshes of the Lakes Sub-basin have remained generally stable over the past three decades.

Table 7. Summary of marsh flooding studies that relate to marshes in the Mermentau Lakes Sub-basin.

Citation	Study site	Depth and duration of flooding	Species	Change in biomass	Conclusions
Pezeshki et al. 1987	Greenhouse	5 cm, 45 days	*Sagittaria lancifolia*	N/A	Flooding decreased mean stomatal conductance and net photosynthesis.
McKee and Mendelssohn 1989	Southern end of Lac Des Allemands	10 cm, 5/86-9/86	*Panicum hemitomon* *Sagittaria lancifolia*	Decrease No Change	Effects of flooding on freshwater marsh communities may depend on the species composition and relative flood tolerance of the dominant species.
	Greenhouse	10 cm, 35 days	*Panicum hemitomon*	No Change	
Howard and Mendelssohn 1995	Jean Lafitte NHP (Jefferson Parish)	7.5 and 15 cm, 4/89-7/90	*Sagittaria lancifolia*	Increase (Belowground)	*S. lancifolia* not affected by increased water levels, as indicated by aboveground and total belowground biomass.
Baldwin et al. 1996	Greenhouse	5 cm, 48 days	*Spartina patens* *Paspalum vaginatum* *Sagittaria lancifolia* *Eleocharis parvula*	N/A	Flooding significantly reduced species richness and seedling numbers for most fresh marsh species, although *S. lancifolia* and *Eleocharis parvula* germinated well under flooding conditions.
Webb and Mendelssohn 1996	Adjacent to Grand Bayou Canal near Larose (Lafourche Parish)	15 cm, 4/30/93-10/1/93	*Sagittaria lancifolia*	Decrease	Flooding significantly reduced live biomass at the *S. lancifolia* marsh site.
Grace and Ford 1996	Pass Manchac (Tangipahoa and St. John the Baptist parishes)	20 cm 10/26/92-6/3/93	*Sagittaria lancifolia*	Increase	Increased flooding is insufficient to have long-term detrimental effects on *S. lancifolia*.
Lessmann et al. 1997	Greenhouse	39 cm, 58 days	*Panicum hemitomon*	N/A	Mean leaf elongation rates for both species decreased following flooding experiments. No significant population effect was identified in either species.
		39 cm, 57 days	*Spartina patens*	N/A	
Gough and Grace 1998	Pearl River WMA (St. Tammany Parish)	10 cm, 6/93-7/95	*Spartina patens* *Sagittaria lancifolia*	Decrease Decrease	*S. lancifolia* was relatively flood tolerant and the decrease in biomass may be attributed to increased dominance of *S. patens*.

Similarly, flood tolerance of the fresh maidencane marshes of the upper Lakes Sub-basin has received relatively little study, and findings are inconclusive. McKee and Mendelssohn (1989) found that flooding *Panicum hemitomon* with 4 in of water for four months resulted in significantly reduced stem density in the field but not in the greenhouse. The same experiment had no effect on *Sagittaria lancifolia.* Surveys indicate that these marshes are slightly higher in elevation than average, so presumably they are flooded less frequently than the fresh bulltongue and oligohaline wiregrass marsh communities.

Our analysis of the continuous water level recorder data at each of the control structures suggests that, with the exception of marshes in the vicinity of Catfish Point, marsh flooding does not appear to be excessive over the long term to the extent that it is causing land loss on a systemic scale. A review of the historical causes of landscape change, albeit somewhat anecdotal, points to causes of loss other than prolonged marsh flooding in the Lakes Sub-basin, such as produced-water discharge, saltwater intrusion, historical wetland and wildlife management practices (ones that are no longer employed), and shoreline erosion. Historically elevated water levels may have exacerbated shoreline erosion on Grand and White lakes, but this effect is hard to substantiate given that nearly all lake and bay shorelines in Louisiana have experienced significant erosion (Adams et al. 1978; Barras et al. 1994). The connection between historical water levels and lakeshore erosion is so unclear that we can neither prove nor disprove that elevated water levels have contributed substantially to lakeshore erosion.

As previously discussed, the record of historical water levels clearly indicates that marshes in the vicinity of Catfish Point experience extreme flooding. Despite this, land loss maps show very little change in these marshes over the period 1978-96. This leads us to speculate that these marshes are fairly tolerant of this extreme flooding. Moreover, we have been unable to find any evidence of marsh stress or marsh die-back in this area. The question remains as to why the marsh flooding regime in the vicinity of Catfish Point is so radically different from marshes around the other four USACE control structures. We believe it likely that hydrologic alterations over time - principally the construction of the GIWW, the CSC, the Catfish Point Control Structure, Calcasieu Lock, and Highway 27 - and the expansion of the lower Mermentau River channel and Cutoff Channel, have collectively altered the flow patterns such that the historical north-south tidal and freshwater inflows have shifted to an east-west flow pattern. We propose that the following series of hydrologic changes (Figure 24) explains the observed flooding regime in the marshes near Catfish Point:

1925-44

Construction of the GIWW bisected the Mermentau River and Bayou Laccassine, and redirected some of the freshwater inflow both east and west.

1936

Louisiana Highway 27 was built from Creole to just north of the GIWW. After this, nearly all hydrologic exchange between the Mermentau and Calcasieu basins has been via the GIWW.

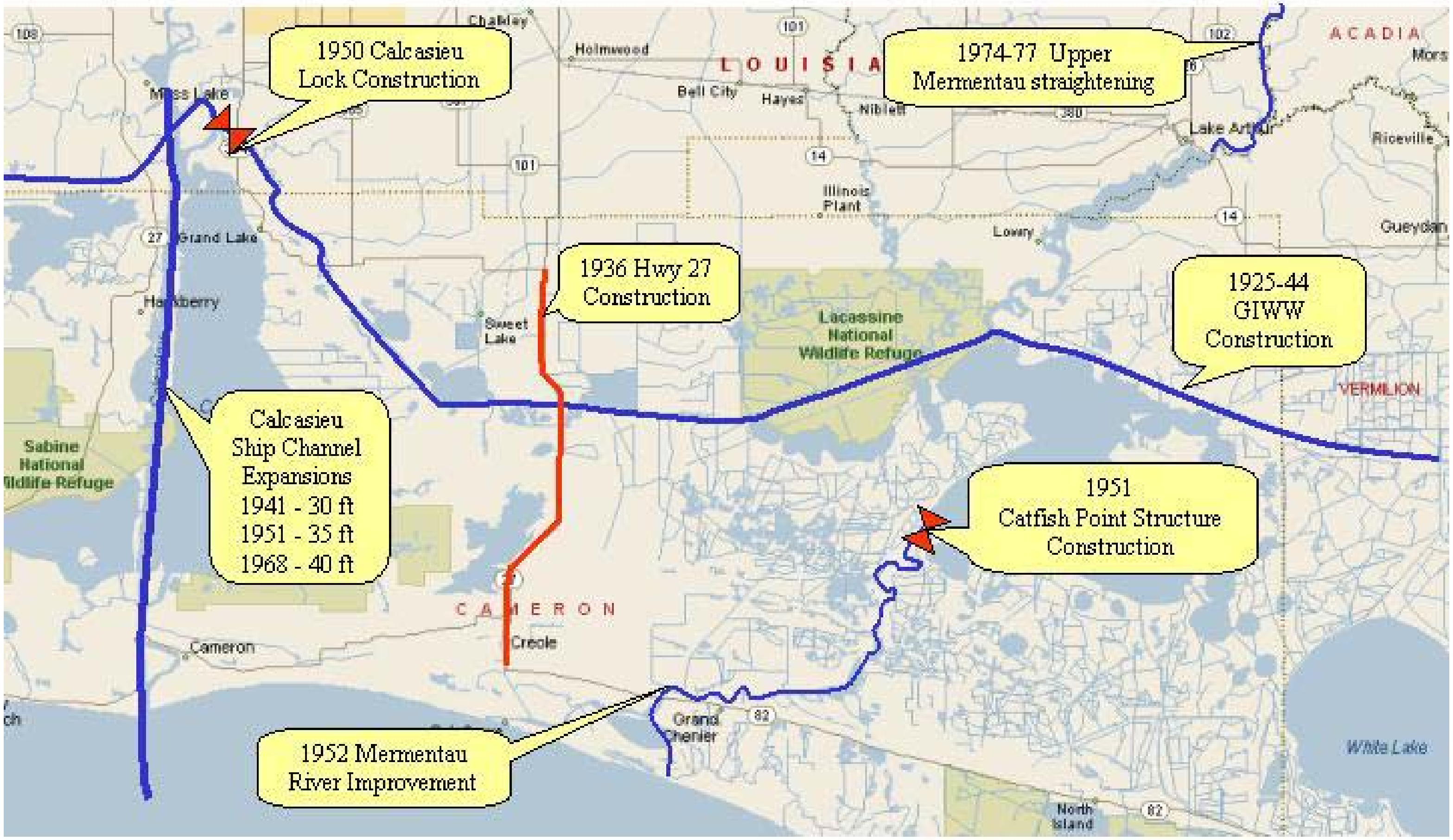

Figure 24. Historical hydrologic alterations that may have caused excessive marsh flooding in the vicinity of the Catfish Point Control Structure.

1941, 1951, 1968

During each of these years, the CSC was progressively deepened to 30 ft, 35 ft, and 40 ft, respectively. This increased the tidal amplitude and saltwater intrusion into a system that was historically dominated more by the Mermentau and Calcasieu rivers.

1950

Construction of the Calcasieu Lock largely halted CSC-induced saltwater intrusion into the Mermentau Basin via the GIWW. At the same time, deepening of the CSC increased tidal amplitude, resulting in higher high tides and lower low tides. Thus, when the tide ebbs, a greater head differential is established on either side of the Calcasieu Lock. This increase in head resulted in a more efficient drainage pathway for Mermentau River freshwater inflows because the drainage potential is so much greater there than at the Catfish Point Control Structure, where drainage opportunity is very limited (Figure 8).

1951

Construction of the Catfish Point Control Structure further reduced freshwater inflow south of the structure.

1952

Channel alterations on the lower Mermentau River to improve navigation increased the channel cross section, resulting in increased tidal amplitude and associated saltwater intrusion.

1974-1977

Construction of seven meander cutoffs straightened the upper Mermentau River. This resulted in more rapid freshwater inflow into the Lakes Sub-basin.

We propose that each of these hydrologic changes contributed to, and collectively are responsible for, the extreme flooding of marshes in the vicinity of Catfish Point. Prior to these hydrologic alterations, sufficient freshwater head existed, coupled with minimal tidal intrusion, to allow a natural north-south basin drainage pattern. Following these dramatic alterations to system hydrology, adequate freshwater head for drainage no longer exists because freshwater inflows are artificially diverted east and west (primarily west) at the GIWW. There, conditions have become established for unnatural tidal fluctuations, with “higher” high tides and “lower” low tides, resulting in a greater freshwater head and lower ebb tides at Calcasieu Lock, and more efficient outflow of freshwater following rain events and during ebb tides at Calcasieu Lock than at the Catfish Point Control Structure. The Superior Canal and the East End Locks on the Rockefeller Wildlife Refuge provide an avenue where water can exit the Lakes Sub-basin through Rockefeller Wildlife Refuge Unit 6. The volumes of Mermentau River freshwater that do get past the GIWW and into Grand Lake hit the Catfish Point Control Structure. At Catfish Point, drainage is inhibited by higher tide levels on the south side of the structure and nearly continuous spoil banks on the Mermentau River south of the structure. We propose that the water then has no place to go and pooling occurs in the marshes surrounding the Catfish Point Control Structure. The CWPPRA-funded Humble Canal Hydrologic Restoration Project is being designed to reduce water levels in these marshes and, to some extent, should alleviate marsh flooding during periods when gravity drainage is possible.

We have presented preliminary evidence that prolonged marsh flooding occurs in the vicinity of Catfish Point, but to date there are no clear research findings linking high water levels in the Lakes Sub-basin to marsh loss or to increased shoreline erosion in the Mermentau Basin. Currently, multiple projects under various phases of planning share, at least in part, the common goal of removing excessive water from the marshes in the Lakes Sub-basin. We recommend that, in light of our findings, the CWPPRA program proceed cautiously with these projects and evaluate other factors that may be causing landscape deterioration. The timing and duration of marsh flooding need to be understood at both the ecosystem scale and at the level of plant-substrate interaction. The general understanding of the relationship between marsh stability, marsh elevation, and surface flooding is, at best, inconclusive. Basic applied research is needed to document the chemical-physical relationship between marsh flooding and plant health in this area. This would be consistent with other ongoing programmatic efforts to improve project effectiveness, including the use of adaptive management, hydrodynamic modeling, and detailed ecological review during the project planning phase.