CHAPTER 3 AFFECTED ENVIRONMENT

This chapter first describes the coastal system processes that have shaped the Louisiana coastal ecosystem then presents the historic and existing conditions for significant natural environment and human environment resources. Significant resources presented include: soils; offshore sand resources; salinity regimes; barrier systems — barrier shorelines, headlands, and islands; barrier reef resources; coastal vegetation resources; wildlife resources — birds, mammals, amphibians, and reptiles; plankton resources; benthic resources; fisheries resources; essential fish habitat; threatened and endangered species; hydrology; water quality resources; historic and cultural resources; recreation resources; aesthetic resources; air quality; noise; hazardous, toxic, and radioactive waste (HTRW); and socioeconomic and human resources (population; infrastructure; employment and income; commercial fisheries; oyster leases; oil, gas, and minerals; pipelines; navigation; flood control; hurricane protection levees; agriculture; forestry; and water supply). Information regarding gulf hypoxia is also presented.

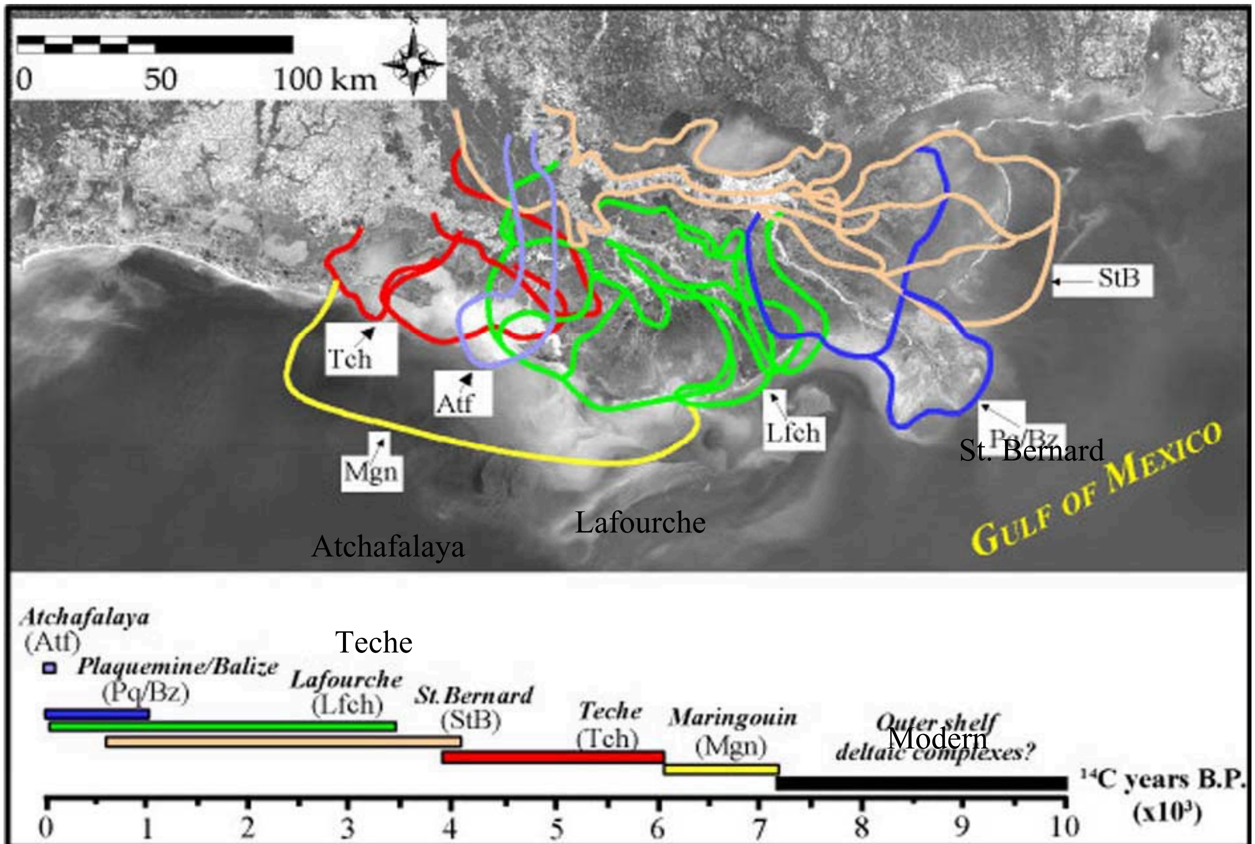
3.1 COASTAL SYSTEM PROCESSES

3.1.1 The Deltaic Cycle

Important contributions to the understanding of the geologic history of the lower Mississippi alluvial valley and the Louisiana coastal plain have been made by Fisk (1944, 1952, 1955), Fisk and McFarlan (1955), McFarlan (1961), Kolb and van Lopik (1966), and Frazier (1967). More recent work by Smith et al. (1986), Boyd and Penland (1988), and Coleman (1988) focuses in detail on the historical development of the Deltaic Plain.

The geologic development of coastal Louisiana is closely related to shifting Mississippi River courses. The Mississippi River has changed its course several times during the last 7,000 years, leading to the development of the Mississippi River Deltaic and Chenier Plains. The Deltaic Plain is composed of six major delta complexes: two prograding and four degrading (see **figure 3-1**). Within a delta complex there may be several major distributaries contributing to the development of individual delta lobes. Frazier (1967) was able to subdivide the Mississippi's delta complexes into 16 separate delta lobes.

In contrast to the Deltaic Plain, the Chenier Plain formed to the west, away from active deltaic growth. When the Mississippi River was in a more westward position, fine silts and clays were transported by westward flowing nearshore currents and deposited as mudflats along the existing shoreline. When Mississippi River deposition ceased or declined, as the river shifted eastward, these mudflats were reworked by marine processes, concentrating the coarser grained sediments and shell material into shore-parallel ridges called "cheniers." Introduction of new sediments by the next westward shift of the Mississippi River resulted in isolation of these ridges by accretion of mudflats gulfward of the ridges. Numerous cycles of deposition and erosion are responsible for creating the alternating ridges separated by marshlands characteristic of the Chenier Plain.



By at least 10,000 years B.P. deltaic sequences were being constructed on the upper shelf during times of relative sea-level stability in the overall rising sea level (Boyd et al. 1989). Following sea-level highstand at approximately 4,000 years B.P., deltaic progradation switched to the east, migrating through distributary switching processes to the west and eventually to the modern Birdfoot Delta (Balize depocenter). Net result of the migrating depocenters is a vertically stacked and offset sedimentary package of primarily deltaic deposits that have created the extensive fluvial networks and wetlands of southern Louisiana. Following abandonment of individual delta lobes the deltaic depocenters became submerged and reworked by marine processes. The depocenters then formed transgressive coastlines, barrier island systems, and ultimately submerged sand shoals on the continental shelf.

Figure 3-1. The Mississippi River Deltaic Plain with locations of major delta complexes. The Atchafalaya and Modern Delta complexes are active and the Teche, Lafourche, and St. Bernard complexes are inactive (*modified from Frazier 1967*)**.**

Recognition that the Deltaic and Chenier Plains are formed by an orderly progression of events related to shifting Mississippi River courses led to the identification and characterization of the deltaic cycle. The delta cycle is a dynamic and episodic process alternating between periods of seaward progradation of deltas (regressive deposition) and the subsequent landward retreat of deltaic headlands as deltas are abandoned, reworked, and submerged by marine waters (transgressive deposition). **Figure 3-2** illustrates the stages in the development of a major delta lobe through its regressive and transgressive phases, from stream capture to submarine shoals (Roberts 1997). Key components of each phase are discussed in the following sections.

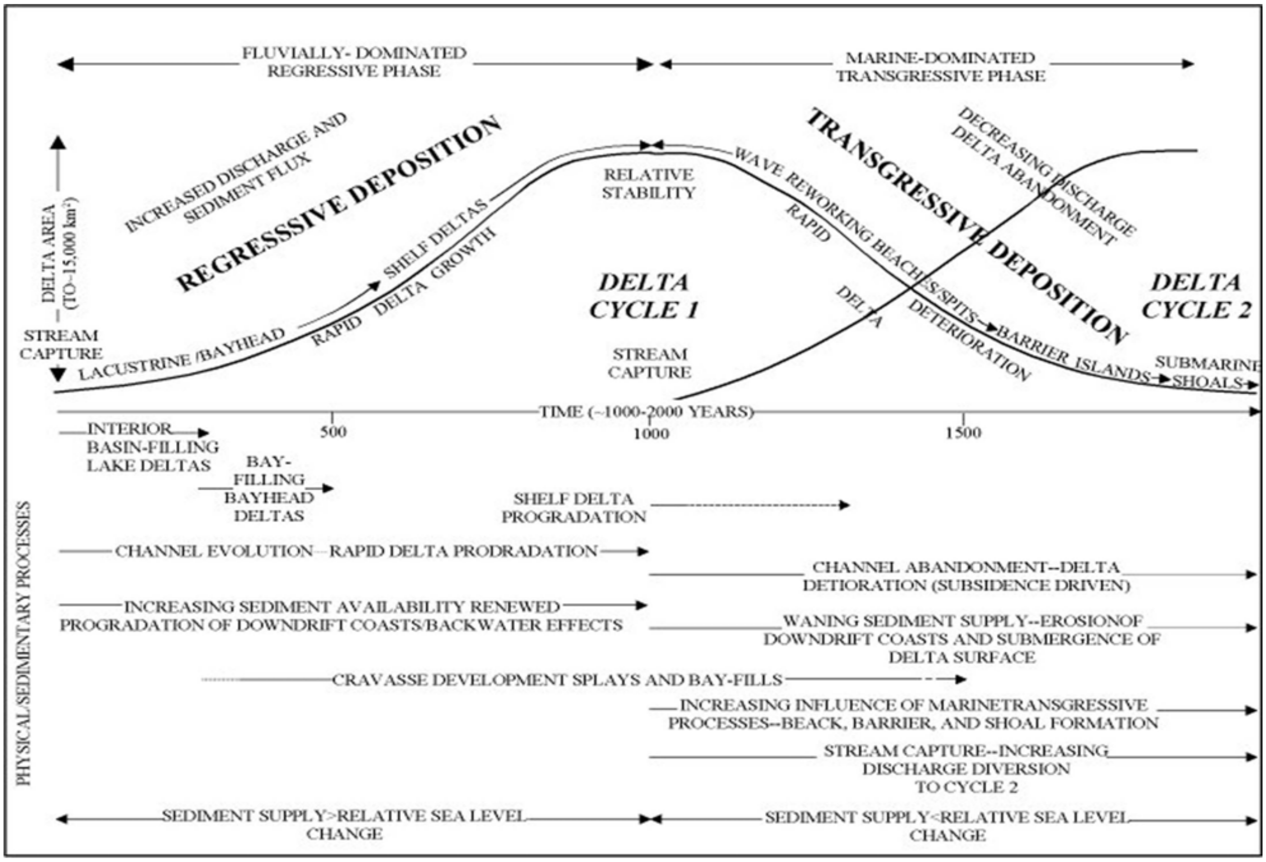


Figure 3-2. Graph of the delta cycle showing the growth and decay of individual delta lobes through processes of fluvial switching and relative sea level change *(from Roberts 1997).*

3.1.1.1 Delta Advancement

The fluvial dominated regressive phase of the deltaic cycle begins with the progressive capture of the primary flow and sediment source by a geologically younger or more efficient channel (**figure 3-2**). This stream capture initiates the filling of inland lakes. Interior lakes fill rapidly with lacustrine, lacustrine delta, and swamp deposits. Fluvial processes dominate this phase with little or no marine influence. Flow into the Atchafalaya River and subsequent Atchafalaya Basin filling is an example of this phase. As the interior basin fills, more fluvial sediments are delivered to the coast by distributaries, resulting in bayhead delta development. Shallow bays are filled with fine sand, silts, and clays resulting in the formation of laterally extensive subaerial delta lobes. The thickness of bayhead deltas is largely dependent on accommodation space (the area available to receive sediments).

The Wax Lake and Atchafalaya Deltas are examples of bayhead deltas. Atchafalaya River sediments reaching the coast are also being carried westward and are deposited as progradation mudflats along the eastern Chenier Plain, thus representing a new episode of the Chenier Plain development process (Huh et al. 1991). As bayhead deltas prograde seaward, shelf stage delta development begins.

3.1.1.2 Delta Abandonment

As the receiving basin fills, there is a reduction in stream gradient and a loss of hydraulic efficiency, which ultimately leads to a new stream capture upriver. The abandoned delta shifts from the fluvial-dominated, progradation phase to the marine-dominated, transgressive phase of the deltaic cycle. During this phase, sediment deposition is reduced or eliminated, and compaction and reworking of the delta lobe lead to land loss and marine transgression (see **figure 3-3**).

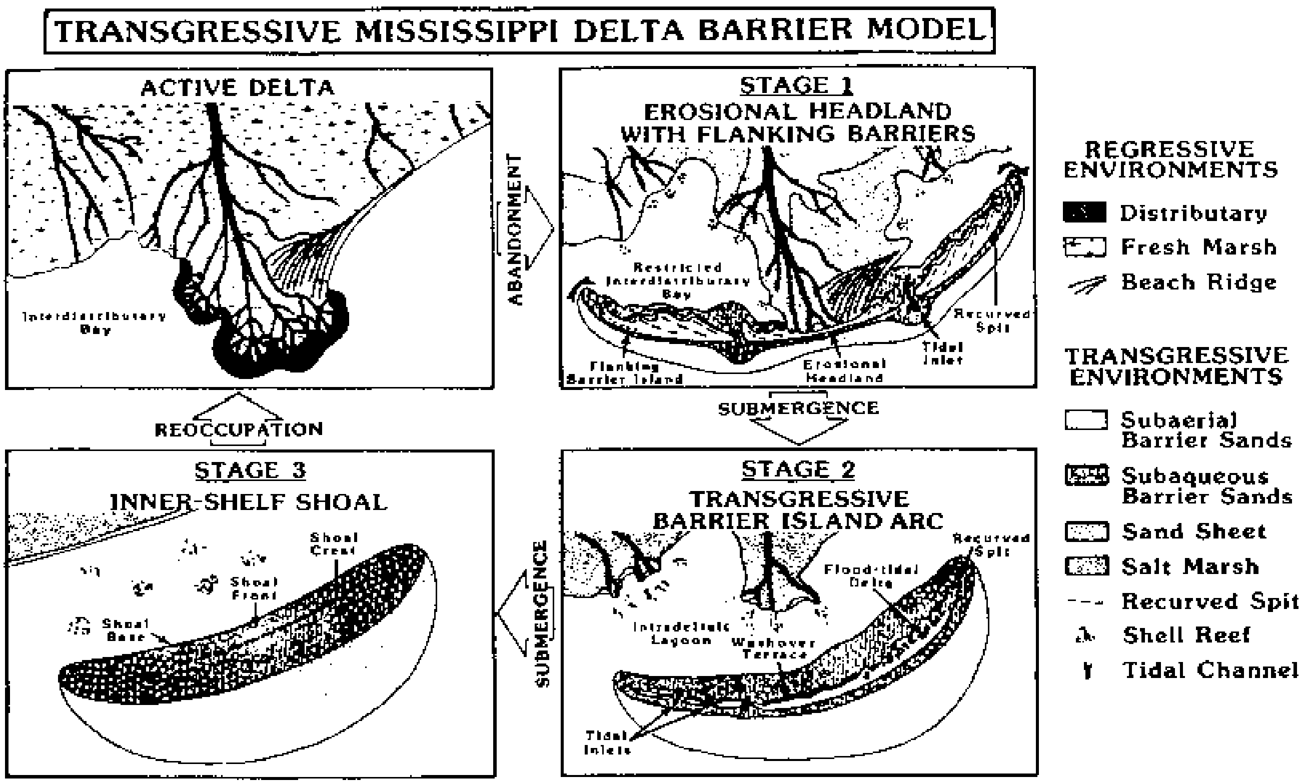


Figure 3-3. Three-stage geomorphic model summarizing the genesis and evolution of transgressive depositional systems in the Mississippi River Deltaic Plain. It begins with stage 1, erosional headland with flanking barriers *(from Penland and Boyd 1981; Penland et al. 1988).*

3.1.2 Deltaic Geomorphology

3.1.2.1 Delta Switching

Delta switching is responsible for constructing the Louisiana coastal plain over the last 7,000 years. The "delta cycle" is controlled by this switching and is characterized by a fluvially-dominated, regressive phase and a marine-dominated, transgressive phase. Many variables act to determine the phase of the "delta cycle" active at any one location. Time, sediment supply, accommodation space, relative sea level change, and rate of discharge are some of the variables responsible for development of the Deltaic and Chenier Plains of coastal Louisiana.

Throughout most of the last 7,000 years the "delta cycle" has created more land by building deltas (regressive phase) than was destroyed by relative sea level change and erosional processes (transgressive phase). Since the early 1900s humans have had a major influence on many of the key elements controlling the delta cycle. The Old River Control Structure has eliminated the delta switching process by maintaining the river in its current position. Flood protection levees built in the early 1900s contain the flow of the river eliminating overbank flooding and the nutrients and sediment that accompany these floods. Also, the sediment load of the Mississippi River has declined by approximately 50 percent between the 1930 to 1952 period and the 1963 to 1982 period (Kesel 1988). This decline has been attributed to bank stabilization by revetments, dams constructed on the Missouri River and other large tributaries, and other erosion control measures. This reduction in sediment load means that even if the delta switching process were restored, delta development would likely be less robust when compared to former deltas.

As the natural delta-building process was restrained, relative sea level rise and erosion (transgressive processes) began to dominate the coastal landscape. Within this environment of diminished delta building, man began a period of extensive development in the coastal zone beginning in the 1950s. Man-made alterations to the natural landscape such as dredging of navigation and access canals, construction of roads and levees within the wetlands, and drainage projects altered the natural hydrology compounding the negative effects of relative sea level change and erosion. Land loss rates exceeding 40 mi^2/yr were documented for the period from 1958 to 1974 and elevated rates of loss continue today.

Coastal Louisiana is characterized by depositional environments and shoreline configurations representing various phases of the delta cycle. Presently, most of the Louisiana coastal zone is in the marine-dominated, transgressive phase of the delta cycle. Only the Modern and Atchafalaya Deltas are in the fluvially-dominated, regressive phase. However, both of these deltas are limited in their development by human influences. The Atchafalaya River flow is limited to 30 percent of the Mississippi River flow, retarding growth of the Atchafalaya and Wax Lake Deltas. Much of the deposition at the mouth of the Modern Mississippi River Delta has been forced into deep water by confining its flow. Shelf edge deltas build less subaerial land mass and contribute less sediment to the nearshore littoral system for nourishing downdrift wetlands than inner shelf deltas.

In the past, areas of the coast experiencing transgression and erosion were ultimately renourished with sediments and nutrients by the next episode of delta switching and progradation. The land loss resulting from erosion and relative sea level change served as a receiving area for these new delta lobes. Without the delta switching process, natural introduction of significant volumes of sediment and nutrients to degraded coastal areas is difficult. Controlling the natural delta-building processes has extended the marine-dominated, transgressive phase longer than would be expected for large areas of the coast. Without significant introduction of sediment and nutrients, those declining delta lobes within the coast will continue to deteriorate at a rapid rate.

3.1.2.2 Biologic Diversity and Delta Switching

The deltaic cycle of growth, abandonment, and degradation is paralleled by the cycle of biological diversity and productivity (**figure 3-4**). However, this second cycle peaks slightly after the geologic cycle. The biological diversity and productivity of the Mississippi Deltaic Plain is linked to the extensive diversity of coastal habitats in this geographically distinct central Gulf coast region. The biological productivity cycle is at its highest during the early degradation phase of the geologic cycle. In this phase, the marshes are fragmented by channels, ponds, lakes, and bays and thus, have an increasing amount of "edge" (land-water interface). Net primary plant productivity and fishery productivity are the highest in this phase. The inshore shrimp harvest is especially correlated to the edge in a delta (Turner 1979).

In addition, estuaries in general and coastal wetlands in particular, tend to produce an excess of organic material, some of which is exported seaward where it represents a major energetic pathway and supports coastal fisheries (Day et al. 1989). This is known as the "outwelling" hypothesis (Odum 1980).

As the delta degradation phase continues, biological diversity and productivity also eventually declines (**figure 3-4**). Generally, there is no longer the natural interplay of the various stages of the delta cycle across coastal Louisiana to offset delta degradation or losses in one area with delta progradation or increase in other areas. Consequently, both land-building and biological diversity and productivity continue to peak and decline.

From an ecosystem restoration perspective, a "return" to an earlier part of the delta phase would initially have an associated reduction in biological productivity and habitat diversity for that basin. Hence, restoration of coastal Louisiana requires consideration of the trade-offs between the land building via the river versus the potential impacts to biological productivity and habitat diversity. From a coast wide perspective, the Louisiana coastal area is a dynamic system, and while one area may be land building with resultant reduction in biological productivity and habitat diversity, there remain many other areas that will continue to suffer land loss and associated increases in biological diversity and productivity. Hence, coast wide, there would continue to be a dynamic interplay of the many different habitats that characterize the Louisiana coastal area with different ranges of biological diversity and productivity, which would be similar to what has been experienced over the past.

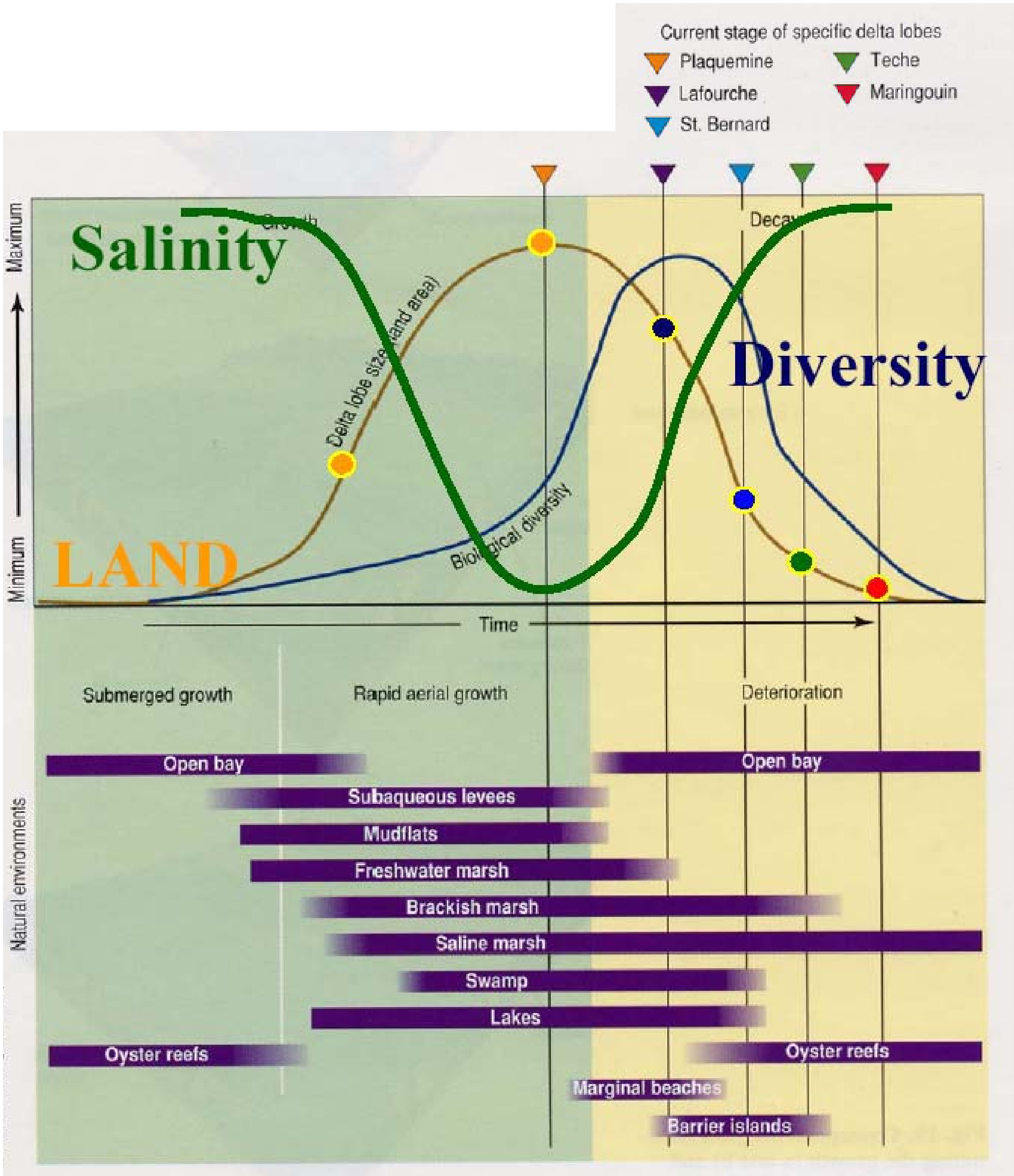


Figure 3-4. Graphical depiction of the growth and degradation of a delta lobe *(adapted from Gagliano and van Beek 1975; and Neill and Deegan 1986).*

3.1.2.3 Relative Sea Level Change

The entire Louisiana coastal zone is experiencing relative sea level rise (RSLR). RSLR is defined here as the net effect of numerous processes that result in the downward displacement of the land surface relative to sea level. RSLR is controlled by several major factors that include eustatic sea level, geosynclinal downwarping, compaction of Holocene deposits, and faulting (currently estimated to be between 0.6 and 1.3 m^3/yr). Recent studies have shown that subsurface fluid withdrawal may be a contributor to RSLR, but the magnitude of its contribution is not well understood (Morton et al. 2002).

Eustatic sea level refers to the global fluctuations in sea level primarily due to changes in the volume of major ice caps and glaciers, and expansion or contraction of seawater in response to temperature changes. Past studies based on worldwide tide gauges estimate the rate of eustatic sea level rise at 0.12 m^3/yr (0.04 inch/yr) (Gornitz et al. 1982). More recent studies have predicted an increase in this rate to 0.34 m^3/yr (0.13 inch/yr) for the next 100 years due to global warming (USEPA 1995).

Downwarping (regional subsidence of the earth's crust) of the Gulf Coast Geosyncline accounts for a small percentage of the observed RSLR in coastal Louisiana. For millions of years, fine sediments have been deposited along the continental margin, downwarping the basement and creating a gradually subsiding trough. The downwarping continues as new sediments are added to the basin. Kolb and van Lopik (1958) estimate the rate of downwarping at 0.02 m^3/yr (0.008 inch/yr) over the last 60 million years, with the greatest downwarping occurring during periods of maximum deposition.

Compaction of Holocene deposits is considered the primary contributor to RSLR in the coastal plain. The three major components of Holocene sediment compaction include 1) primary consolidation, 2) secondary compression, and 3) oxidation of organic matter (Terzaghi 1943; Roberts 1985). Primary consolidation occurs as the volume of the soil mass is reduced due to dewatering under a sustained load. Secondary compression results from a decrease in soil volume due to rearrangement of the internal soil structure. Oxidation of organic matter through chemical reactions reduces the soil volume.

Compaction of Holocene sediments varies widely throughout the coastal zone and is closely linked to the thickness and age of deposits. Fine-grained deposits with high water contents characterize the coastal zone. The thicker the deposits, the more interstitial water is available for removal, which leads to high rates of RSLR as they compact. Older deposits have already undergone most of the primary consolidation and secondary compression and therefore exhibit lower RSLR rates than recently deposited sediments. The age, thickness, and to some extent the type of deposits, are responsible for the variability in RSLR rates across the coast.

Movement on the downthrown side of deep-seated fault blocks is a well-documented process in coastal Louisiana. However, the effects on the shallow subsurface and surface are poorly understood. A recent investigation by Gagliano et al. (2003) identified likely areas of fault-induced subsidence, but the magnitude and spatial extent of their impact are still being determined. Morton et al. (2002) proposed that extraction of oil and gas from deep reservoirs in south Louisiana may result in accelerated rates of RSLR at the surface. A minor amount of movement along fault planes can have major impacts on wetlands where accretion barely exceeds RSLR.

An important man-made contributor to RSLR is drainage of wetlands for agriculture, flood protection, and development. Forced drainage results in lowering the water table, resulting in accelerated compaction and oxidation of organic material. RSLR of up to several feet has been documented in developed areas of Jefferson and Orleans Parishes, and large areas of coastal land loss are found associated with failed land reclamation projects.

Marsh accretion plays a critical role in the existence of marsh habitat by maintaining elevation within a given tidal range. Accretion takes place through a combination of mineral sediment and organic matter accumulation (Hatton et al. 1983). Marsh surfaces must vertically accrete to keep pace with the rate of RSLR or they will be submerged. Hydrologic modifications resulting from the construction of levees, navigation channels, and access canals have reduced the amount of mineral sediments available to the marshes. In general, marsh accretion rates vary from approximately 0.5 m^3/yr (0.2 inch/yr) to 1.3 m^3/yr (0.5 inch/yr), depending on proximity to the source of sediment. In many locations the accretion rate is not great enough to equal or exceed the RSLR rate.

3.2 SOILS

3.2.1 Historic and Existing Conditions

This resource is institutionally significant because of: the CEQ memorandum of August 11, 1980, entitiled "Analysis of Impacts on Prime or Unique Agricultural Lands in Implementing the National Environmental Policy Act (NEPA);" Executive Order 11990 - Protection of Wetlands; and the Agriculture and Food Act of 1981 (Public Law 97-98) containing the Farmland Protection Policy Act (PL 97-98; 7 U.S.C. 4201 *et seq*.).

Coastal land loss is directly and inextricably linked to the five factors of soil formation. There are six general soil groups in the Louisiana coastal zone. These groups align with physiographic sub-regions identified in Agricultural Handbook 296. The following subsections present a description of the soil formation factors that are key elements for restoration efforts.

3.2.1.1 Factors of Soil Formation

Soil is a natural, three-dimensional body that forms on the earth's surface. The five main factors that influence the process of soil formation include: climate; formation of the soil material from the parent material; the physical and chemical composition of the original parent material; the kinds of plants and other organisms living in and on the soil; the relief of the land and its effect on runoff and erosion; and the length of time the soil has to form. The effect of any one factor can differ from place to place, but the interaction of all the factors determines the kind of soil that forms. Interaction of the factors results in differences among the soils and has an effect on the type of properties expressed in soils at any given site.

Parent Material: The soils in the Louisiana coastal zone formed in either alluvial sediments or loess, and many have accumulations of organic material in the upper part. Some soils are organic throughout, and some, nearest to the coast, formed in marine sediments. The alluvium is from distributary streams of former deltas of the Mississippi River (Saucier 1974).

Bordering the stream channels are low ridges called natural levees. These levees are highest next to the channels and slope gradually into backswamps further from the channels. The levees are shaped by waters that overspread the stream banks. When the water slows, it drops sand, then silt, and finally, clay particles. Thus, the soils on the highest parts of natural levees generally formed in loamier parent materials. These soils are generally lighter in color, more permeable, and better drained than the soils on the lower part of the natural levees and in the backswamps. The soils on the lower part of the natural levees and in the backswamps beyond the natural levees generally formed in more clayey parent materials that were deposited by slowly moving water or stagnant backwater.

Organic material accumulates in areas that are continuously saturated or flooded. Water prevents the complete oxidation and decomposition of the plant residue. Water, vegetation, and time, coupled with a change in sea level and land subsidence, created conditions where thick layers of organic material accumulated in the marshes. Historically, the buildup of organic material kept pace with land subsidence and sea level change during the advancement phase of the delta cycle.

Climate: The Louisiana coastal zone has a humid subtropical climate characteristic of areas near the Gulf of Mexico. The warm, moist climate promotes rapid soil formation by determining water availability for weathering minerals, transporting the materials released, and through its influence on temperature that determines the rate of chemical weathering in the soil.

Plants and Other Organisms: This factor includes plants, bacteria, fungi, and animals. The native plants, and their associated complex communities of bacteria and fungi, generally have a major influence on soil formation. Additionally, human activities, such as cultivating crops, channel construction, burning, draining, diking, flooding, paving, and land smoothing, affect the soil. Some soils in the coastal zone have been changed drastically through artificial drainage that de-watered and made firm the formerly semi-fluid clay layers in those soils.

Relief**:** Relief and the landscape position have influenced the formation of the different soils. Relief and other physiographic features mainly influence soil formation processes by affecting internal soil drainage, runoff, erosion and deposition, salinity levels, and exposure to the sun and wind. In the coastal zone, sediment historically accumulated at a much faster rate than erosion removed sediments. This accumulation of sediment throughout the active Deltaic Plain occurred at a faster rate than many of the processes of soil formation. This is evident in the distinct stratification in lower horizons of some soils. Levee construction and other water-control measures may have reversed this trend for some soils. Soil slope and rate of runoff on the alluvial soils are low enough that erosion is not a major problem. However, the slope and rate of runoff on the terrace uplands are high enough to be an erosion hazard.

Differences in the content of organic matter in the soils are related to the length of time the soils remain saturated, and consequently, to relief. The content of organic matter generally increases as the length of time the soil remains saturated increases, and at some point, a layer of partially decomposed organic matter begins to accumulate on the surface. Soils on higher positions of the landscape have better surface runoff, internal drainage, and aeration. This allows more rapid and complete oxidation of organic matter to take place. The soils on lower positions of the landscape receive runoff from those on higher positions; thus, the soils on lower positions remain saturated nearer to the surface for longer periods. In many areas, suitable outlets do not exist for the water to readily leave these areas.

The overall surface elevation in the coastal zone relative to sea level is slowly changing because the soils are on a low-lying, slowly subsiding landmass. In addition, post-depositional sediment compaction can result in some subsidence, and local deposition of sediment can contribute to similar, but more localized changes.

Time: In general, the soils of the coastal zone formed in various kinds of parent material, ranging in age from the most recent deposits along distributary channels and in swamps and marshes to the late Pleistocene sediments that form the core of the terrace uplands.

3.2.1.2 Soil Formation

Processes that result in development of soil structure have occurred in most of the mineral soils. Plant roots and other organisms contribute to the rearrangement of soil material into secondary aggregates. The decomposition products of organic residue and the secretions of organisms serve as cementing agents that help stabilize structural aggregates. Alternate wetting and drying, as well as shrinking and swelling, contribute to the development of structural aggregates and are particularly effective in soils that have appreciable amounts of clay. Consequently, soil structure is typically most pronounced in the surface horizon, which contains the most organic matter, and in clayey horizons that alternately undergo wetting and drying.

3.3 OFFSHORE SAND RESOURCES

Potential sand resources suitable for coastal restoration purposes include the major offshore sand shoals, near-shore sand bodies, and sand rich shoreline depositional areas such as distributary mouth-bar deposits, tidal inlets, and tidal deltas. Of these, the offshore sand shoals and the larger nearshore sand bodies represent potential sources for the millions of tons of sand sediment that would be necessary for coast wide restoration. These offshore sand resources are especially essential for the restoration of the barrier shorelines, headlands, and islands. Louisiana's four major sand shoals are described in the following subsections, followed by a description of the nine near-shore sand bodies located off the Barataria barrier shoreline.

3.3.1 Historic and Existing Conditions

3.3.1.1 Trinity Shoal, Outer Shoal, St. Bernard Shoals, and Ship Shoal

Penland et al. (1986), Williams et al. (1989), Suter et al. (1991), Kulp et al. (2002), and Williams et al. (2002) describe Louisiana's major sand shoals that contain large volumes of high sand content sediment suitable for coastal restoration. These shoals, the reworked remnants of former deltaic lobes, include: Trinity Shoal, Outer Shoal, St. Bernard Shoals, and Ship Shoal (see **figure 3-5**).

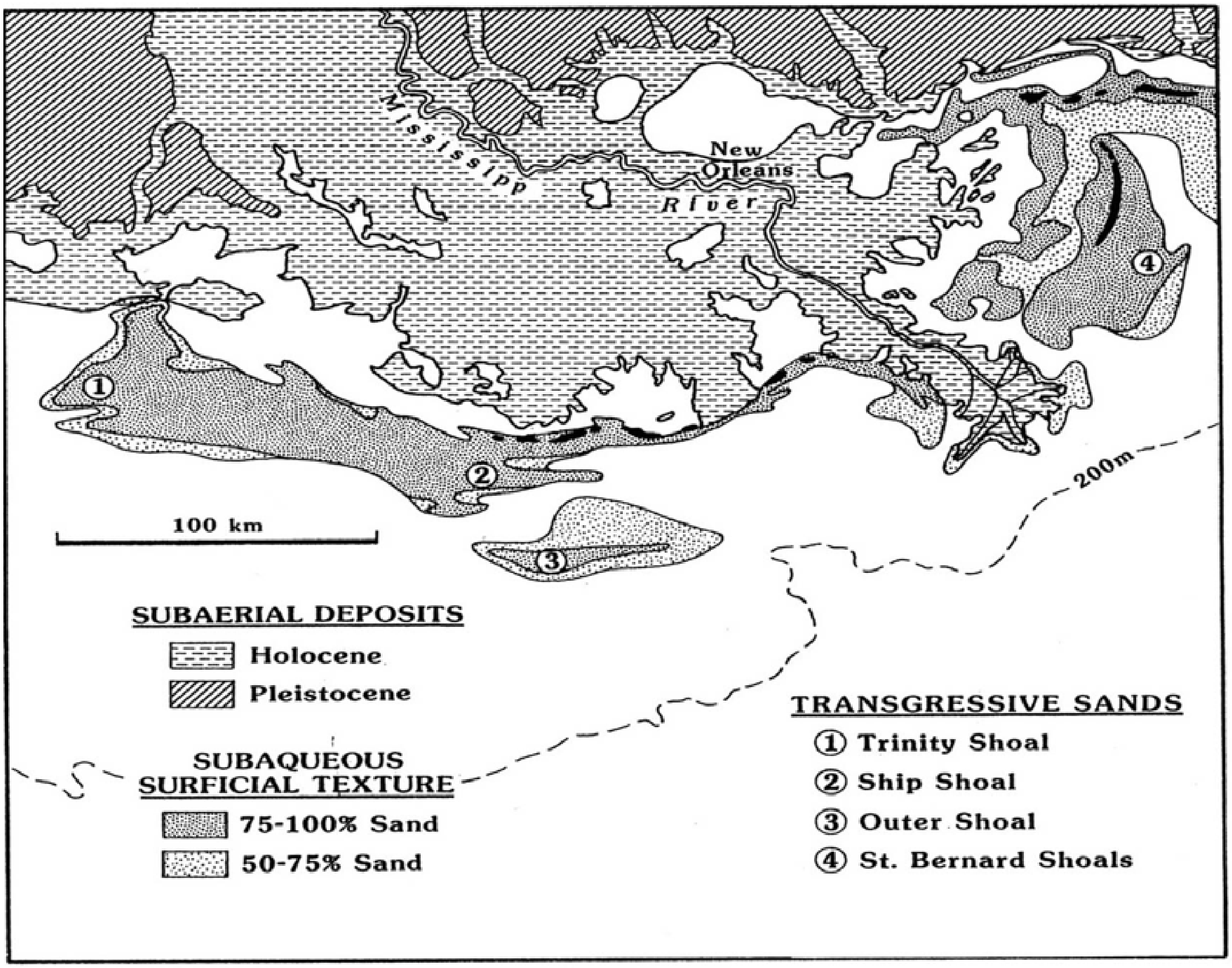


Figure 3-5. Louisiana offshore sand sources: Trinity Shoal, Ship Shoal, Outer Shoal, and St. Bernard Shoals *(from Penland et al. 1986).*

Trinity Shoal is a large, isolated shoal located on the western Louisiana shelf offshore of Marsh Island and Cheniere Au Tigre. This shoal, approximately 18 miles (29 km) long and 3 to 6 miles (4.83 km) wide, is covered by approximately 23 to 32 ft (7 to 10 meters (m)) of water and has 6 to 12 ft (1.8 to 3.6 m) of relief relative to the surrounding seafloor.

Outer Shoal is approximately 21.75 miles (35 km) long, 3.11 to 6.21 miles (5 to 10 km) wide, and lies approximately 15.53 miles (25 km) seaward of Ship Shoal on a platform lying between the –18 to –20 m (–19.6 to –21.8 m) isobaths (an imaginary line or one drawn on a map connecting all points of equal depth below the surface of a body of water).

The St. Bernard Shoals, a set of smaller 3 to 4 mile (4.8 to 6.4 km) wide shoals within a larger inner shelf sand body, are located approximately 20 miles (32.2 km) offshore of the Chandeleur barrier islands.

Ship Shoal, the largest submerged shoal off Louisiana, is a Holocene sand body located on the south-central Louisiana inner shelf about 9.32 miles (15 km) seaward of the Isles Dernieres. Ship Shoal is approximately 31.07 miles (50 km) long and 3.11 to 7.46 miles (5 to 12 km) wide, with relief of up to 11.81 ft (3.6 m). It lies in a water depth of 19.69 to 29.53 ft (6 to 9 meters) and is composed primarily of well-sorted quartz sand, a benthic substrate not commonly found on the Louisiana inner shelf (Stone 2000). The geologic framework and character of Ship Shoal and the surrounding area has been described from the results of several studies that involved the collection of seismic reflection and vibracore data. Penland et al. (1986) and Cuomo (1984) provide relatively comprehensive descriptions of Ship Shoal area geology and the in situ sand resource.

Resource estimates for the volumes of sand comprising the Ship Shoal structure are 1.2 billion cubic meters (m^3) (15.6 billion cy) ranging from very fine to medium sand, 112 million m^3 (151 million cy) in the shoal crest, 430 million m^3 (580 million cy) in the shoal front, and 640 million m^3 (864 million cy) within the shoal base. An additional 123 million m^3 (166 million cy) of sand is estimated to be contained as distributary channel fill deposits under the shoal (Penland et al. 1986).

3.3.1.2 Offshore Meteorology and Physical Oceanography

The Louisiana inner shelf is an example of a low-energy environment where significant hydrodynamic activity is generated almost exclusively by local storms, including both tropical (summer) and extratropical (winter) storms. The degree to which Ship Shoal mitigates the wave climate along the Isles Dernieres and the central Louisiana coast has been studied in recent years by researchers from LSU through a cost-sharing arrangement between LSU and the U.S. Minerals Management Service. These efforts have provided baseline information relative to wind and wave conditions, as well as bottom currents in and around the Ship Shoal area.

3.3.1.2.1 *Meteorology of Ship Shoal Area*

Stone (2000) recently completed a three-year field study of the Ship Shoal area that involved the deployment of bottom-mounted instrumentation to collect data relative to bottom currents and sediment transport. However, a primary focus of the work was to investigate the influence of meteorological conditions and, in particular, high-energy wind events (storms) on inner shelf processes in Louisiana. Wind records indicate that, annually, average wind speed in coastal Louisiana is approximately three meters/second (m/s) (9.8 ft/s) from the southeast. Hourly wind data during the deployment period were obtained from the National Oceanographic and Atmospheric Administration (NOAA) station located on Grand Isle, Louisiana at 29^{o}27' N, 89^{o}96' W (Station GDIL1). These measurements were supplemented by daily national weather maps obtained from the National Weather Service, which were inspected visually to verify the occurrence of cold front passages.

Wind speed during the deployment averaged 4.8 m/s (15.7 ft/s) and had a mean direction toward the southwest (228^{o}). Hourly wind speed and direction for the deployment period are shown in **figures 3-6** and **3-7,** which clearly demonstrate the increases in wind speed characteristic of extratropical storms, as well as the clockwise rotation of wind direction during their passage.

Spectral analysis of the wind speed over the 61-day deployment period shows a statistically significant peak in energy at a frequency of roughly every five days, or approximately the same as that of extratropical storm passages (**figure 3-8**). This suggests that extratropical storms were responsible for most of the variability in wind speed during this time, a result consistent with other published research for the northern Gulf of Mexico.

Nine storms occurred during the 61-day deployment, a frequency of one every 6.8 days. Mean wind speed and direction were 8.1 m/s (26.5 ft/s) and 174^{o}during storms and 3.8 m/s (12.4 ft/s) and 293^{o} during fair weather. On the whole, storms during the period were characterized by strong winds blowing toward the south, while the mean wind direction during fair weather was westerly.

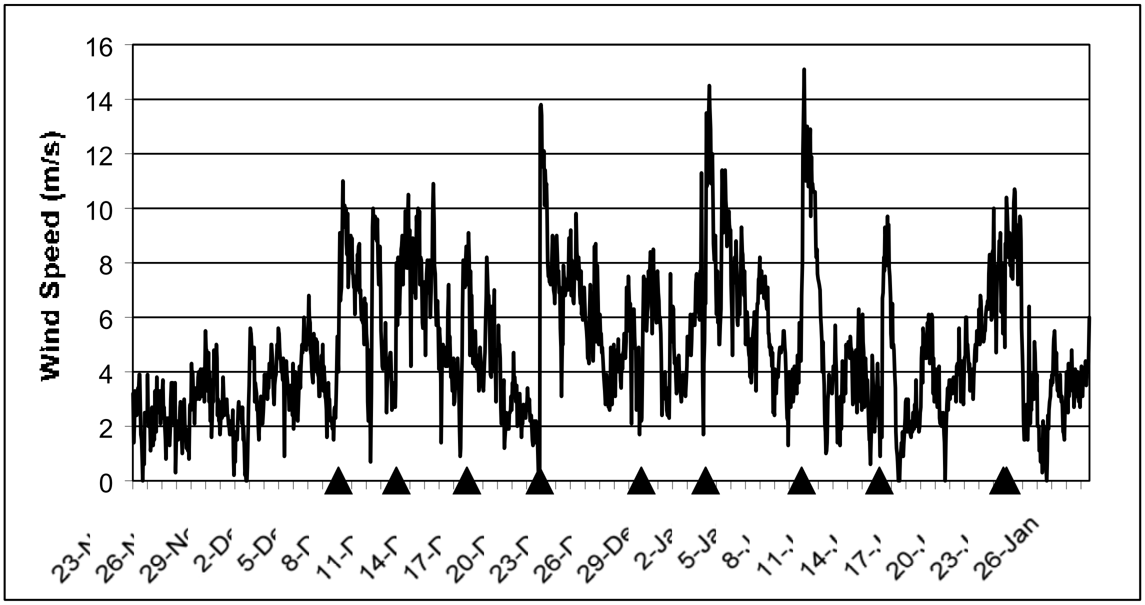


Figure 3-6. Wind speed during the instrumentation deployment period for the Stone (2000) study. Black arrows indicate the time of the cold front passages associated with extratropical storms.

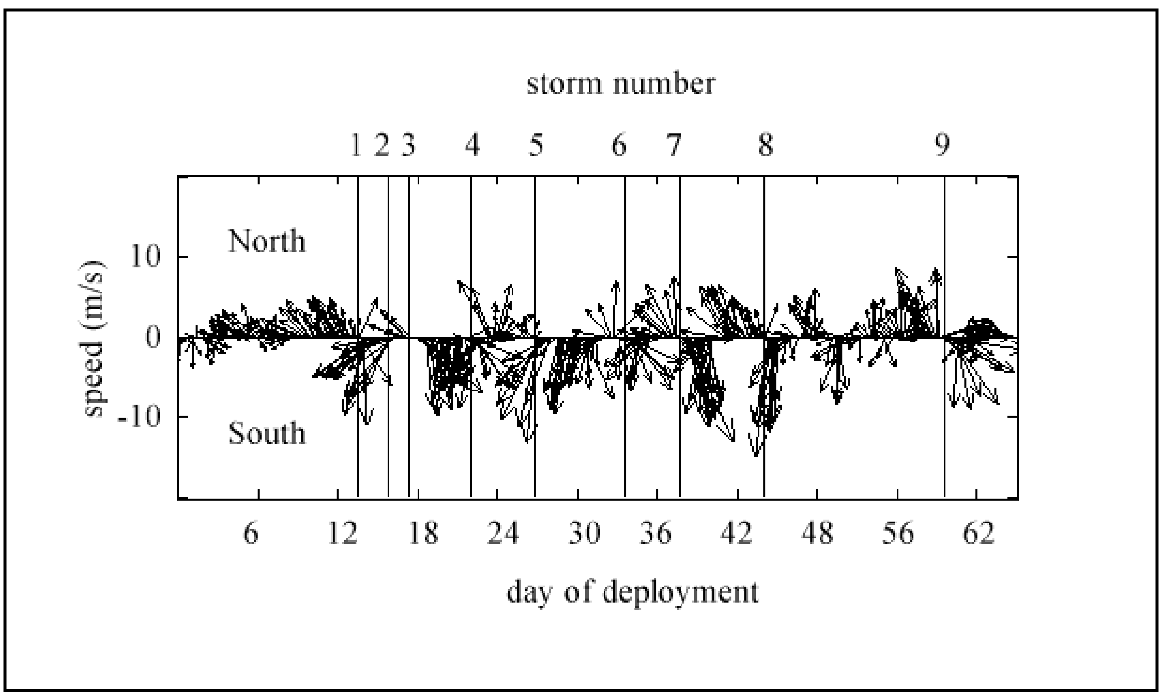


Figure 3-7. Feather plot of hourly wind vectors during the instrumentation deployment period for the Stone (2000) study.

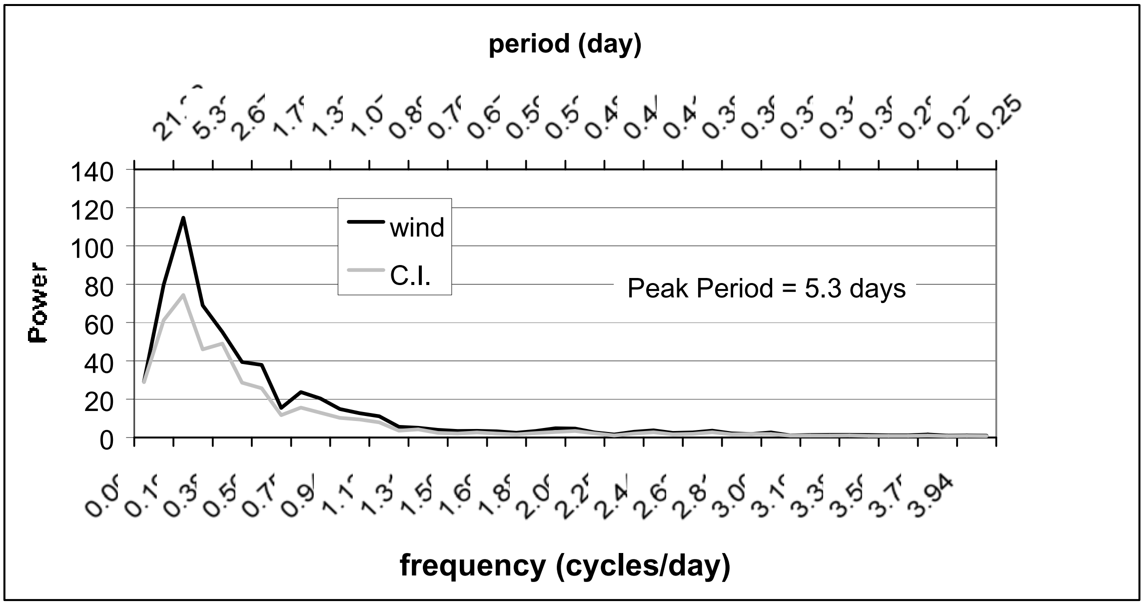


Figure 3-8. Power spectrum of wind speed during the instrumentation deployment period for the Stone (2000) study. C.I. represents the 90 percent confidence interval.

3.3.1.2.2 *Physical Oceanography of the Ship Shoal Area*

The recently completed three-year field study of wave climate, wave-current interactions, bottom boundary layer dynamics, and sediment transport in the Ship Shoal area, landward to the inner shelf adjacent to the Isles Dernieres conducted by Stone (2000) gives the most complete picture of the wave and current climate in the Ship Shoal area to date. The study was a follow-up effort to a numerical modeling effort completed in October 1996 (Stone and Xu 1996). **Figure 3-9** shows the location of the field effort and the location of bottom-mounted instrumentation.

The project involved: (1) directional wave spectra measured simultaneously at two geographical locations to check the numerically modeled results obtained from the wave modeling effort; (2) direct field measurements of temporally- and spatially-varying directional wave spectra at two proposed locations conducted under different wave conditions (storms, fair weather, etc.) to facilitate numerical model output checking and to develop a quantitative wave climate for the study area; and (3) direct field measurements of bottom boundary layer hydrodynamic processes and suspended sediment transport. The data analysis indicates that massive and rapid sediment movement occurs on Ship Shoal during storm events. This sediment movement is important in understanding the dynamics of the shelf/shoal complex.

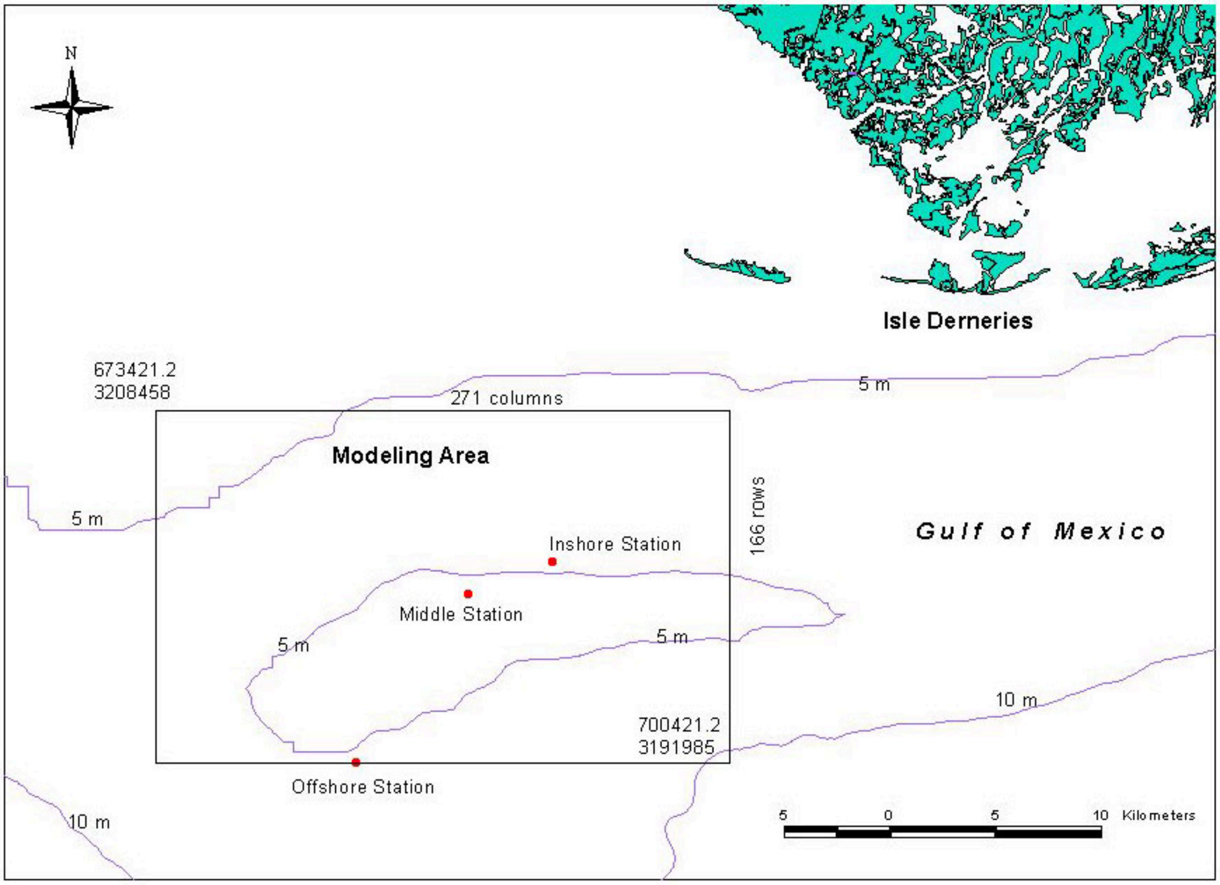


Figure 3-9. Location of the Stone (2000) field effort and bottom-mounted instrumentation. Site 1 = Offshore Station, Site 2 = Inshore Station. An additional site (Middle Station) was established for the 2000 deployment.

3.3.1.2.3 *Wave Climate*

The wave climate in and around the Ship Shoal area can be characterized using both hindcast and measured data. **Table 3-1** shows the location of hindcast and actual data stations. In a 20-year (1956–1975) hindcast Wave Information Study (WIS) conducted by the USACE (Hubertz and Brooks 1989), statistics from the hindcast stations adjacent to the study area indicated an annual-mean significant wave height of 1.0 ± 0.2 m (3.28 ± 0.6 ft) and mean peak period of 4.5–6.0 seconds. The maximum hindcast wave heights at the same stations exceeded 5 m (16.4 ft), and the wave peak period associated with the largest wave exceeded 11 seconds. The monthly mean significant wave heights in winter months (December - March) were 0.2–0.6 m (0.6–1.9 ft) higher than that of the rest of the year. The data also show that the predominant wave directions were from the southeastern quadrant.

Despite the dominant low wave energy environment in the study area, tropical storms and hurricanes influence sea state significantly. The 20-year hindcast of hurricane waves shows that the significant wave height for a 50-year return period is greater than 15 m (49.2 ft). The 5-year return period significant wave height is approximately 6–7 m (19.6–22.9 ft).

Table 3-1. Sources of wave climate data.

Sources	Lat. (N)	Long. (W)	Water Depth (m)
WIS 19	28.5^o	91.0^o	33
WIS 20	28.5^o	90.5^o	38
WIS 21	28.5^o	90.0^o	91
NDBC 42017	27.5^o	90.5^o	407
LATEX 16	28.9^o	90.5^o	21

3.3.1.2.4 *Bottom Currents at Ship Shoal*

Table 3-2 presents an overall summary of hydrodynamic parameters for the entire deployment for the Stone (2000) study. The data indicate that Ship Shoal has an important effect on regional hydrodynamics; an influence that is presumably also significant on any inner shelf that includes submerged sand bodies or other prominent bathymetric features. Furthermore, this has important implications for bottom boundary layer dynamics and sediment transport on the south-central Louisiana inner shelf. In particular, storm events resulted in significant increases in wave height and current velocities, supporting prior observations that the area is a storm-dominated one. Significant wave height during the observed storm events was several times the mean fair weather value and was clearly higher at Site 1 (offshore) than at Site 2 (nearshore), supporting the conclusion that Ship Shoal is responsible for measurable wave energy attenuation. Dramatic increases in both mean and wave-driven flow tended to accompany storms (**figures 3-10** and **3-11**). F**igure 3-12** illustrates the observed current speed relative to direction at Site 1.

Table 3-2. Summary of hydrodynamic parameters recorded by the systems throughout the deployment for the Stone (2000) study.

Location		***Site 1 (Offshore)***		***Site 2 (Nearshore)***
System	***Statistic***	***1A (ADV)***	***1B (WADMAS)***	***2A (ADV)***
Total Depth (m)	Mean	8.8	9.0	7.3
	Minimum	8.2	8.4	6.7
	Maximum	9.2	9.5	7.8
Hs (m)	Mean	n/a	0.61	0.45
	Minimum	n/a	0.07	0.10
	Maximum	n/a	2.80	1.53
Tp (s)	Mean	n/a	5.3	5.0
	Minimum	n/a	3.6	3.6
	Maximum	n/a	9.1	9.1
Orbital Velocity (cm/s)	Mean	11.7	10.6	9.9
	Minimum	2.6	0.8	0.0
	Maximum	35.9	53.1	36.5
Current Speed (cm/s) (~0.3m above bed)	Mean	5.8	4.6	6.3
	Minimum	0.1	0.1	0.0
	Maximum	44.8	34.2	47.6
Current Speed (cm/s) (~1m above bed)	Mean	12.4	8.0	13.9
	Minimum	0.1	0.1	0.0
	Maximum	72.4	53.2	62.3
Current Direction	Mean	245	240	292

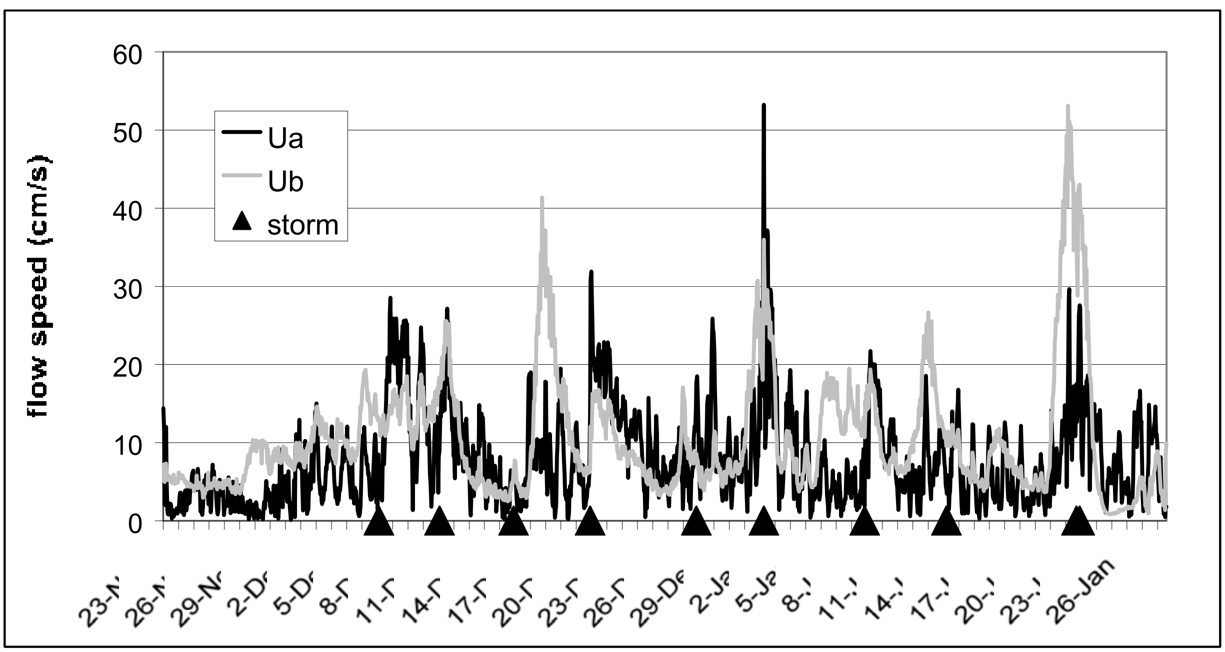


Figure 3-10. Flow speed of mean (Ua) and orbital (Ub) currents at Site 1 (Stone and Xu 1996).

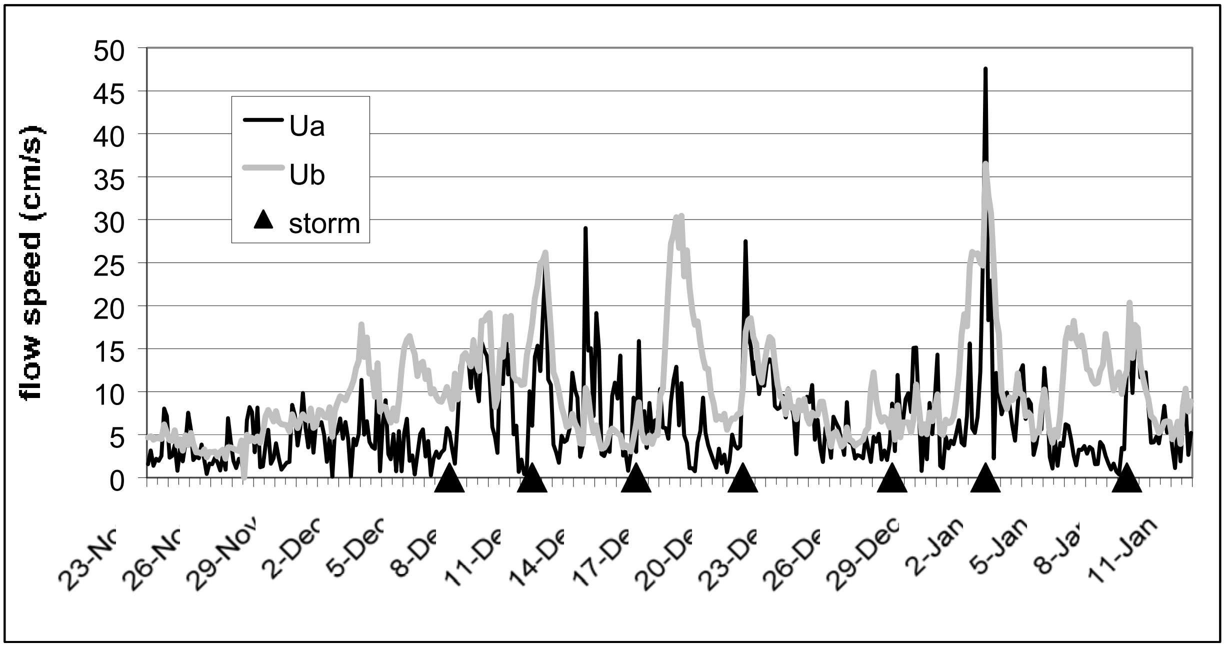


Figure 3-11. Flow speed of mean (Ua) and orbital (Ub) currents at Site 2 (Stone 2000).

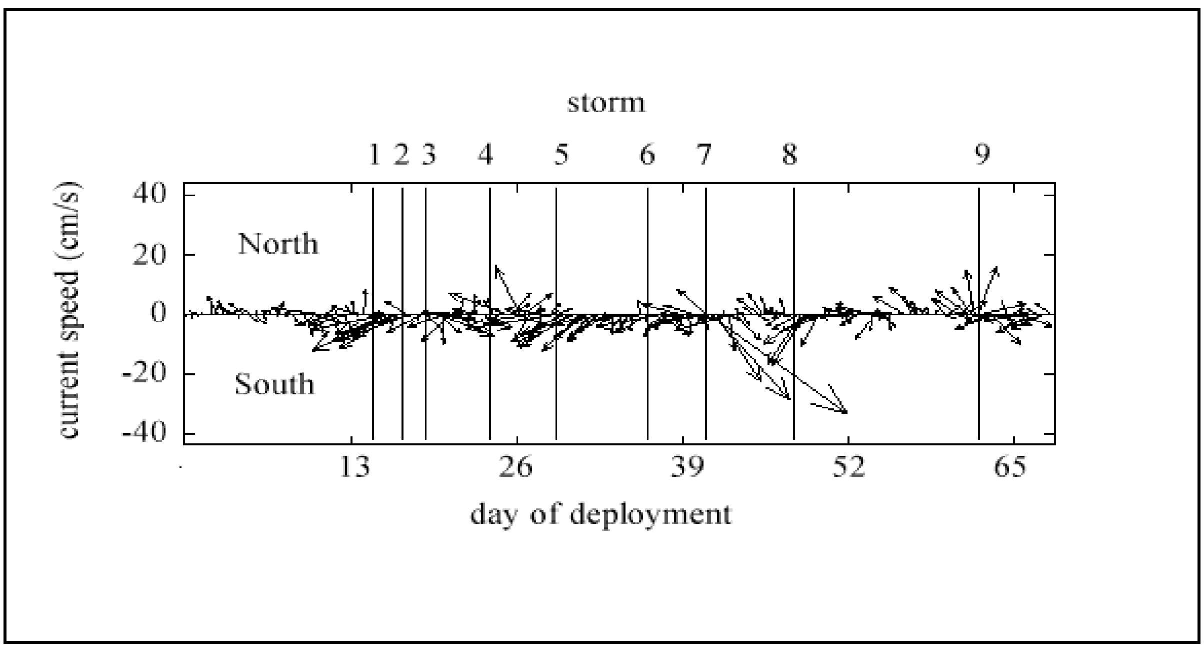


Figure 3-12. Vector plot of mean current direction at Site 1 during the deployment (Stone 2000).

3.3.1.2.5 *Bottom Boundary Layer Parameters*

Stone (2000) observed episodic increases in current and wave-current shear velocity associated with storm activity (**figures 3-13** and **3-14**). Shear velocity was particularly high during the period of strong wave-orbital flow for three of the observed storm events, when mean flows were particularly strong.

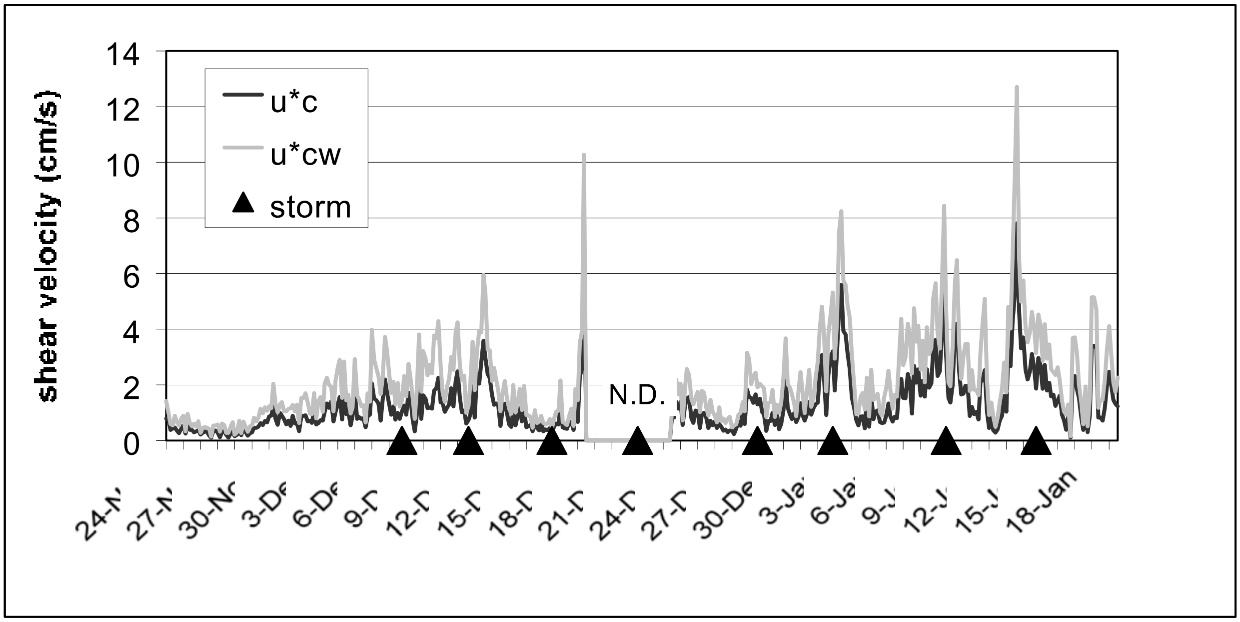


Figure 3-13. Current and combined wave-current shear velocity as measured at Site 1 (Stone 2000).

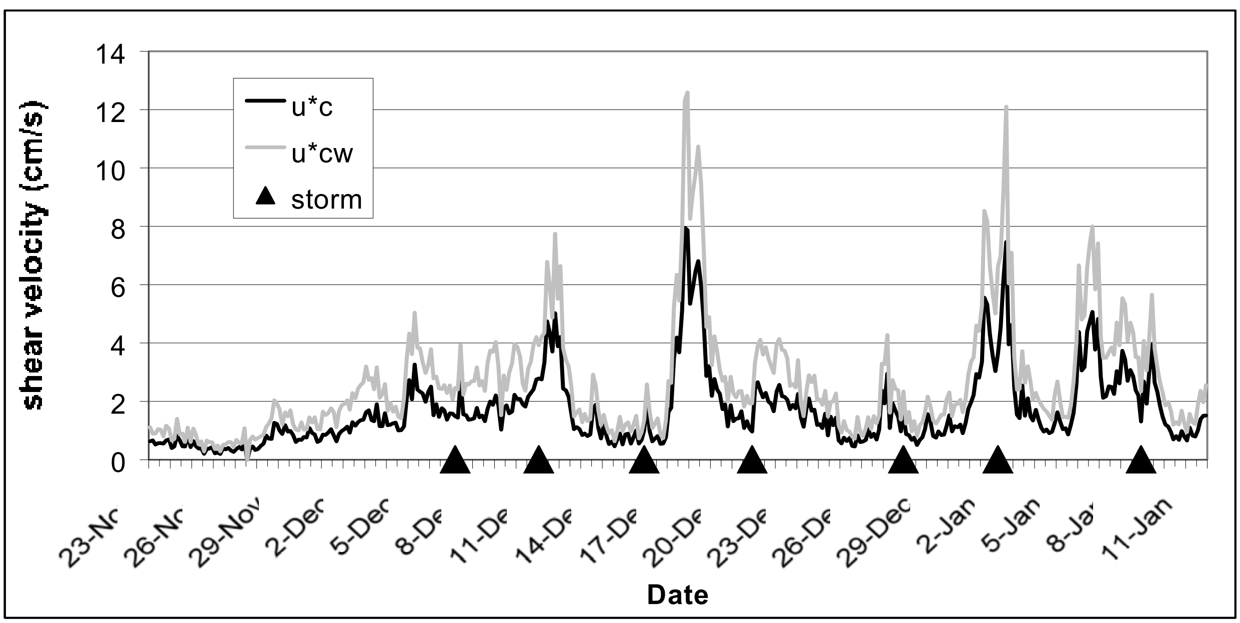


Figure 3-14. Current and combined wave-current shear velocity as measured at Site 2 (Stone 2000).

3.3.1.2.6 *Sediment Transport at Ship Shoal*

Four high sediment transport events were noted during the Stone (2000) study, and were generally associated with storms. Sediment transport direction varied considerably between storms as well as during individual storms. Two of the most significant storms were characterized by opposing trends in sediment transport direction – while onshore and eastward (i.e., NE) transport dominated during one of the storms, offshore and westward (i.e., SW) transport dominated during another storm event. Within these storms, transport direction fluctuated by 180^{o} on a very short time scale (i.e., several times per storm). This may have been related to diurnal fluctuations resulting from either tidal or inertial current flow, or to other variations in relative wave and current energy and direction.

3.3.1.2.7 *Summary of the Physical Oceanographic Regime of Ship Shoal*

Based on the data collected and analyzed by Stone and Xu (1996), a picture of the physical oceanographic regime within the Ship Shoal area emerges:

1. Hydrodynamic, bottom boundary layer, and sedimentary variability on the Louisiana inner shelf during the winter is episodic, and is largely the result of recurring extratropical storm passages.

2. Considerable variability between storms, as well as during storms themselves, is reflected in hydrodynamic, bottom boundary layer, and sedimentary parameters. Some indices are several orders of magnitude greater during strong storms than during fair weather, while in the case of weak storms, the same parameters may actually be weaker.

3. Despite this considerable variability, storms are generally characterized by increases in wave height, near-bed orbital and mean current speed, shear velocity, suspended sediment concentration, and sediment transport. Decreases in wave period and apparent bottom roughness are also apparent.

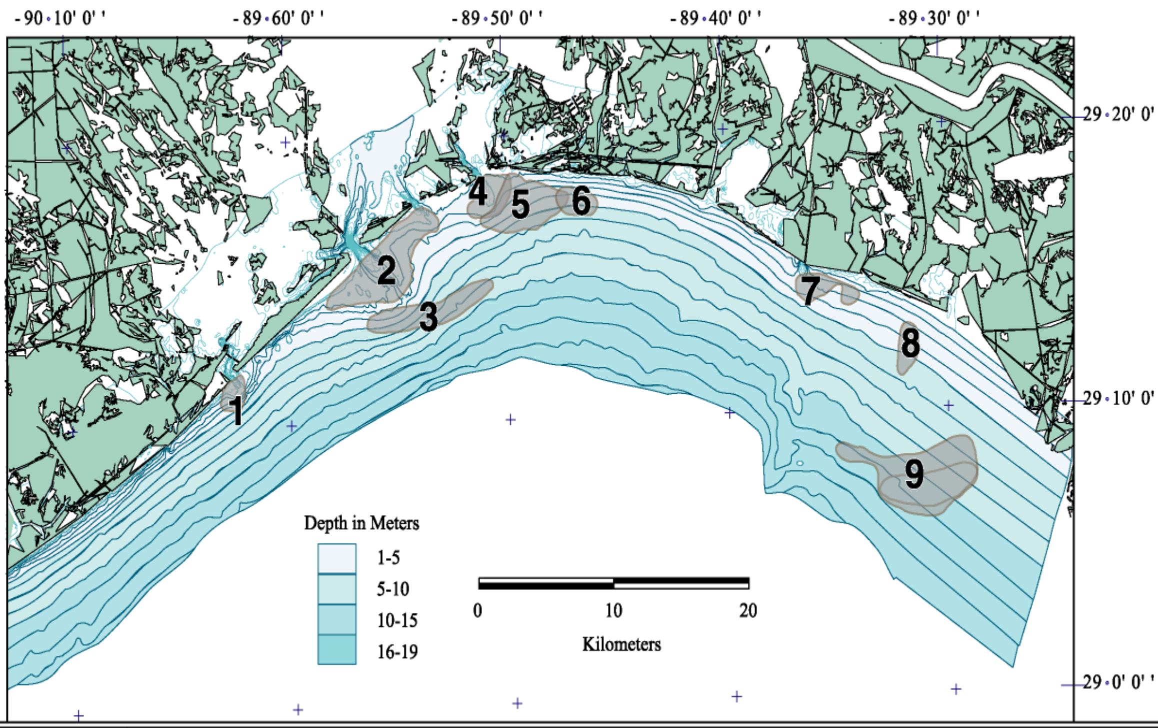
4. Sediment transport during the winter is dominated by the strongest storms, when net sediment flux tends to be seaward.

5. Differences between the seaward and landward flanks of Ship Shoal are apparent. Waves tend to be higher and longer in period on the seaward side, while mean currents are generally higher landward, where they are directed onshore, in comparison with the seaward currents that predominate at the offshore site. It is apparent, therefore, that Ship Shoal exerts a significant influence on regional hydrodynamics, reducing wave energy and modulating current velocity.

6. The long-term evolution of Ship Shoal appears to be the result of a balance between fair weather influences, which cause erosion, and winter storm influences, which cause accretion. Superficially, this closely follows the commonly held notions of nearshore storm/fair weather sediment transport on barred, but direct parallels are avoided for the moment since the details of process and response require further investigation.

3.3.1.3 Barataria Nearshore Sand Resources

Kulp and Penland (2001), Kindinger et al. (2001), and Kulp and Penland (2002) investigated several sand resource sites located adjacent to the Barataria Basin barrier shoreline for use in its potential restoration during the ongoing Barataria Basin Barrier Shoreline Restoration feasibility study (see **figure 3-15**). Seismic and sonar interpretations verified geologic samples (vibracores and borings) that there are nine nearshore sand body areas that meet or exceed the minimum criteria for potential mining sites (**figure 3-15**). The nine sand bodies potentially contain between 396 and 532 million cy and can be characterized into three surfical and six buried sites. However, while these nine potential sand sources consist primarily of fine sand, a full 90 percent of the sand body areas would need almost 570 million cy of overburden removed if the entire resource is mined. Kindinger et al. (2001) recommend using the sand for barrier island shore face restoration and the overburden to build back-barrier platforms for marsh restoration.



Target Site	Surface Area (Mi.^{2})	Depth to Target (ft below MSL)	Thickness of Overburden (ft)	Est. Target Thickness (ft)	Percent Sand %	Grain size range (phi)	Est. Vol. Sand (low) (yd^3)	Est. Vol. Sand (high) (yd^3)
1. Caminada	1.24	5-10	0	4	60-80	2.5-4.7	3,060,924	4,081,233
2. Barataria (inshore)	8.80	5-10	0	4-9	60-85	2.5-4.7	35,436,544	50,201,771
3. Barataria (offshore)	4.96	25-40	10-15	7-9	60-80	2.5-5.5	24,563,918	32,751,891
4. Quatre Bayou (shallow)	2.45	10	0	5-10	60-80	2.5-4.7	11,406,726	15,208,968
5. Quatre Bayou (deep)	5.32	22-45	7-15	5-22	70-100	2-5.5	53,832,158	76,903,083
6. Quatre Bayou (D2)	1.70	45-47	30-40	7+	50-80	3-5	7,372,288	9,829,717
7. Empire	2.10	17-25	3-10	3-6	60-80	2-3.5	5,854,464	7,805,952
8. Scoffield	1.50	30	9	6+	80-90	2.5-5.5	7,434,240	8,363,520
9. Sandy Point	11.60	40-48	8-13	20-30	60-80	2.5-5.5	179,660,800	239,547,733

Figure 3-15. Barataria nearshore sand resources *(from Kindinger et al. 2001).*

3.3.1.4 Sand Suitability

To determine the suitability of a specific sand source for beach nourishment, the mean grain size of the source material should be close to or slightly larger than that occurring at the in situ or target beach. The term "beach quality" sand commonly infers a significant or a high degree of similarity between the sediment textural parameters of the sand source (shoal or deposit) and the sand target (coastal beach). However, estimates of beach quality are often considered by assessing an "overfill factor." James (1975) examined criteria that would indicate the probable behavior of borrow material on a natural beach. The overfill factor concept and determination methodology were developed to describe a measure of the amount of source material that would need to be placed on a target beach to compensate for the losses that occur from natural winnowing processes along the shoreface. The overfill factor, R_A, represents the number of m^3 of material required to create one m^3 of in situ beach when the beach is in a condition compatible with the native material. Overfill factors are expressed as a ratio of a unit volume of natural, or in situ beach, to a volume of source material required; the factor is commonly listed as the unit of fill volume required. McBride et al. (1989) used James' overfill factor formula to calculate an overfill factor for the Isles Dernieres shoreline using sand from Ship Shoal. The calculated overfill factor is determined to be 1:1.03, or 1.03. Based on that overfill factor, Ship Shoal sand constitutes an excellent source of sand for Isles Dernieres beach nourishment projects. These calculations would be needed for determining suitability of other shoals and sand bodies.

3.4 SALINITY REGIMES

3.4.1 Historic and Existing Conditions

Salinity measurement has traditionally been an important parameter for estuarine hydrology and habitat potential. Orlando et al. (1993) describe the importance of understanding salinity:

- Salinity is a direct measure of the relative influence of the sea and the freshwater sources in an estuary.
- Salinity is an excellent hydrographic tracer, indicating the movement and exchange of water masses.
- Salinity, as a hydrodynamic variable, dominates the density structure of an estuary and therefore exerts important controls on currents and turbulence.
- Salinity is an essential element in determining estuarine habitat. It directly affects distribution, abundance, and composition of biological resources.
- Salinity is easily measured using various techniques and historical information available.

Salinity is the predominant factor responsible for change of fresh, intermediate, brackish and saline habitats. For example, Flynn et al. (1995) indicate that extreme salinities may lead to conversion of fresh and intermediate marshes to open water.

Perret et al. (1971) provide one of earliest comprehensive descriptions of salinity regimes across coastal Louisiana (see **figure 3-16**). They present the 10, 15, and 20 percent isohaline (salinity) lines for the Louisiana coast for the period of April 1968 through March 1969.

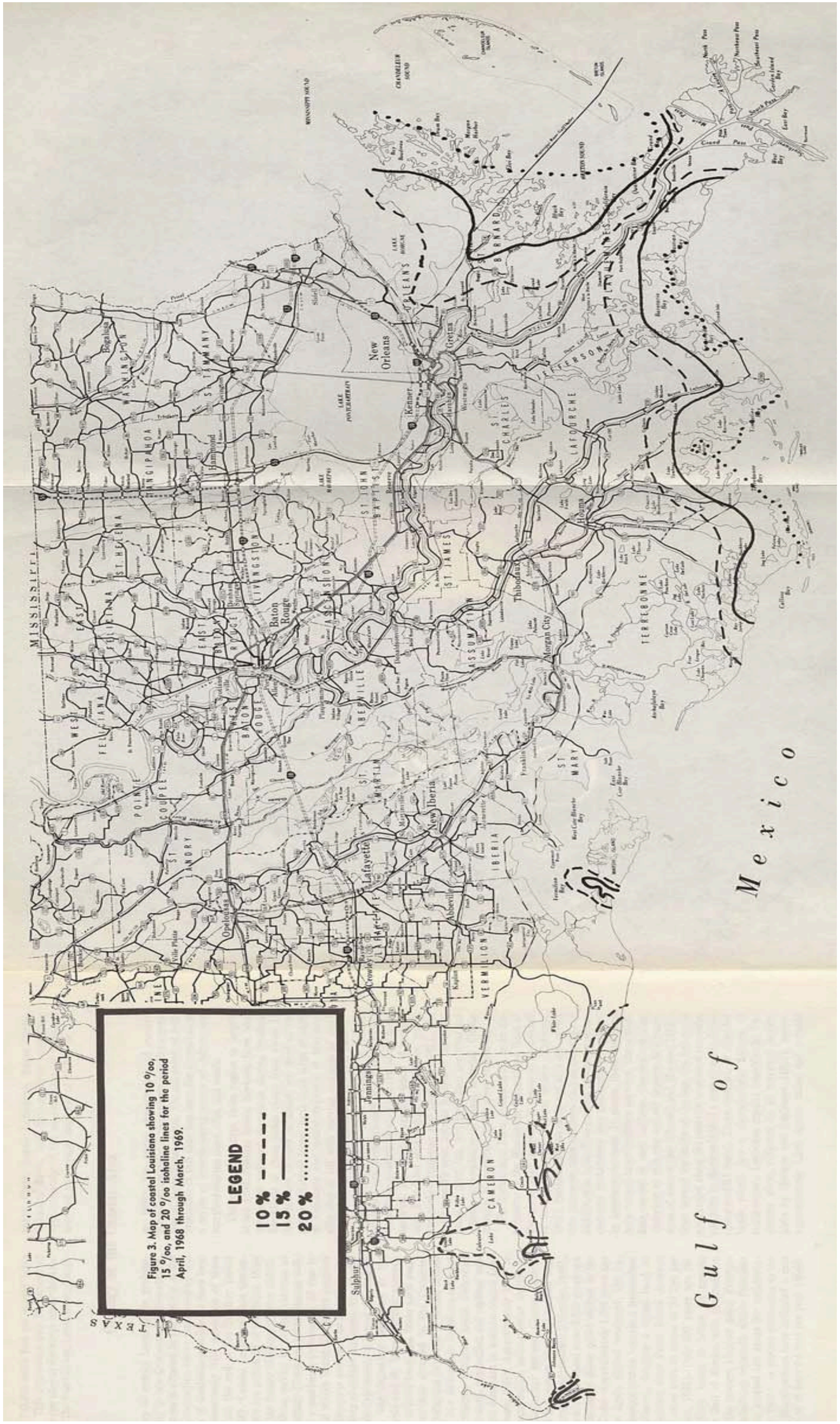


Figure 3-16. Map displaying 10, 15, and 20 percent isohaline lines from 1968-1969 coastal Louisiana (*from Perret et al. 1971*).

3.4.1.1 Coastal Louisiana Estuarine Salinity Patterns – Existing Conditions

As part of NOAA's National Estuarine Inventory, Orlando et al. (1993) provided a comprehensive synthesis of salinity information for 26 principal gulf estuaries. Those sections of Orlando et al. (1993) pertaining to Louisiana's coastal basins are incorporated by reference. Orlando et al. (1993) indicate that besides being a critical factor that determines habitat, salinity provides a direct measure of estuarine transport behavior. An estuary's ability to retain, flush, and mix pollutants is determined by the same processes affecting how freshwater inputs combine with seawater, which is directly measured by salinity. Orlando et al. (1993) utilized a time series of records of freshwater inflow and salinity, in conjunction with available background information on tides, wind, and other factors to quantify salinity variability. Representative three-month seasonal averaging periods were used to reflect the normal range of high- and low-salinity regimes under typical and present-day hydrologic conditions.

According to Orlando et al. (1993), the salinity patterns throughout the major basins of coastal Louisiana may be influenced by the following forcing mechanisms: freshwater inflow, tides, wind, and coastal shelf processes. Coastal Louisiana estuaries' seasonal freshwater discharge source and timing of delivery vary between estuaries as well as within estuaries. Generally, the high-inflow/low-salinity periods are typically from late winter to late spring. The low-inflow/high-salinity periods are typically from late spring to late fall. With the exception of the Atchafalaya estuary, most of Louisiana's estuarine systems are shallow, wind-driven systems with small tidal action that prevents salinity stratification. In the Atchafalaya, prevailing seasonal winds and entrainment of diluted gulf waters are secondary modifiers of the salinity structure in this basin.

Figures 3-17 through **3-20** display modeling results for salinity patterns under the base conditions (and Future Without-Project conditions, see section 4.3, SALINITY REGIMES) for each subprovince. Models are based on simplifying assumptions, subject to uncertainty and error, and are only approximations of real conditions. The models used in this study have not been fully validated and their results should be considered within that context. Appendix C, HYDRODYNAMIC AND ECOLOGICAL MODELING of the Main Report provides a more detailed presentation of the numerical model results of salinity distributions. These models are static images (snapshots) of typical salinity distributions.

The base, or existing conditions, mean salinity distributions for Subprovince 1 are displayed in **figure 3-17**. The hydrologic model assumed that Caernarvon freshwater diversion structure would be running all year at 235 cfs. The freshest mean salinities, 0 to 2 parts per thousand (ppt), would be found in the interior-most portions of the subprovince in the vicinity of Lake Maurepas (boxes IA and IB) and in the general vicinity south of the Mississippi River Gulf Outlet (MRGO) and Caernarvon (boxes VA and VB). Lake Pontchartrain would grade from 2-4 ppt in the western portions to 4-6 ppt in the eastern portions of the lake. The southern portions of the Lake Borgne area (box IIIA) would have a mean salinity range of 6–8 ppt with the northern portions of the lake ranging from 8–10 ppt (box IIIB). The eastern portion of the Mississippi River Delta (box VE) would have a mean salinity range of 2–4 ppt. The remainder of the subprovince, Chandeleur Sound and Breton Sound (boxes IV, VC, and VD), would have the greatest mean salinity ranges of greater than 10 ppt.

The base, or existing conditions, mean salinity distributions for Subprovince 2 are displayed in **figure 3-18**. The hydrologic model assumed that the Davis Pond Diversion would be running all year at 5,000 cfs. At the present time, such an operational scheme is not authorized. The interiormost portions of the subprovince (boxes 1A, 1B, 2A, 2B, 3A, and 3B) would have the freshest mean salinity range of 0–2 ppt. The region east of the Barataria Bay Waterway, extending from Myrtle Grove south to the western portion of the Mississippi River Delta (box 4B), would have a mean salinity range of 4–6 ppt. The Caminada Bay and headland area (box 4A) would have the highest mean salinity range of greater than 10 ppt.

The base, or existing conditions, mean salinity distributions for Subprovince 3 are displayed in **figure 3-19**. The freshest portions of the subprovince would be the interior portions of Terrebonne Parish (box I) with a mean salinity range of 0-2 ppt. The areas adjacent to the Atchafalaya River, Wax Lake Delta, and regions surrounding East and West Cote Blanche Bays would have a mean salinity range of 2-4 ppt (boxes IV, VIII, and IX). The area extending from Caillou Lake in the east to Point au Fer in the west (box V) and the area surrounding Vermilion Bay (box VII) would have a mean salinity distribution of 4-6 ppt. The interior portion of Terrebonne Bay (box II) would have a mean salinity distribution of 6-8 ppt. The area from Terrebonne Bay in the east to Caillou Bay in the west (boxes III and VI) would have the highest mean salinity range of greater than 10 ppt.

The base, or existing conditions, mean salinity distributions for Subprovince 4 are displayed in **figure 3-20**. The interior regions of the subprovince, extending from Freshwater Bayou in the eastern portion of the subprovince, north of Louisiana State Highway 82, and west of Grand Lake (boxes 2C1, 2C2, 2A1, 2B1, 2B2, 2A2, 2A4, 2A3, and 3E5) and the isolated areas west of Calcasieu Lake (boxes 3E6, 301, 306, and 3C2) would have the lowest mean salinity range from 0-2 ppt. The area south of White Lake (boxes 1C2 and 1B2), east of Calcasieu Lake (box 3E4), bordering the Sabine River (boxes 3B1, 3B2, 3B3, and 3B4) and bordering the western gulf shoreline (box 3A2) would have a mean salinity range of 4-6 ppt. The areas bordering the gulf shoreline from Freshwater Bayou, west to Lower Mud Lake (boxes 1B3, 1B1, and 1A1), and the area west of Calcasieu Lake (boxes 3C1, 3C4, and 3C5) would have a mean salinity range of 6-8 ppt. The area at the mouth of the Sabine River (box 3A1) and west of Calcasieu Lake (boxes 3D2 and 3D3) would have a mean salinity range of 8-10 ppt. The Calcasieu Lake and immediate surrounding area (boxes 3E1, 3E2, 3E4, and 3D4) would have the greatest mean salinity range of greater than 10 ppt.

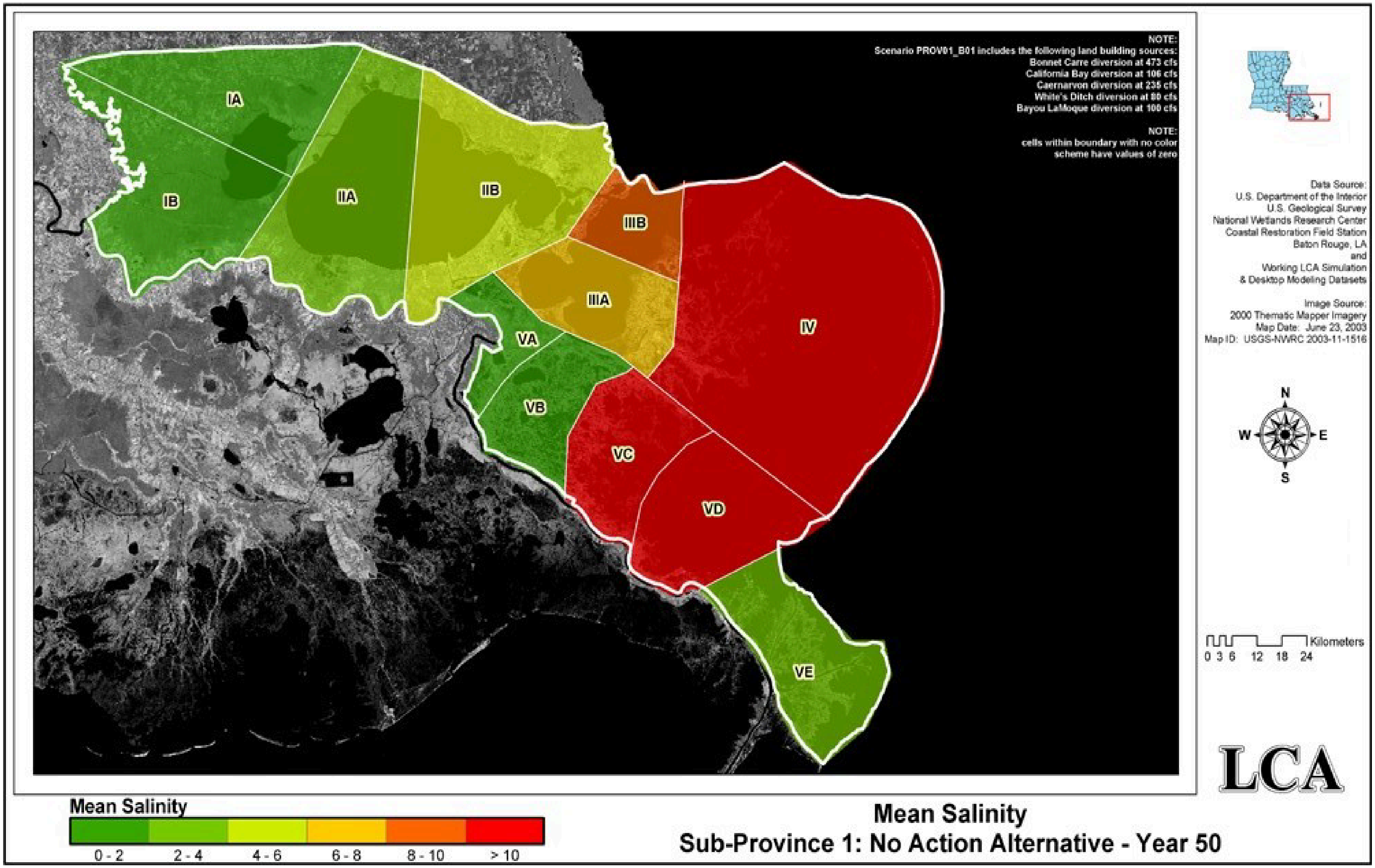


Figure 3-17. Modeling outputs displaying mean salinity under base and Future Without-Project conditions in Subprovince 1.

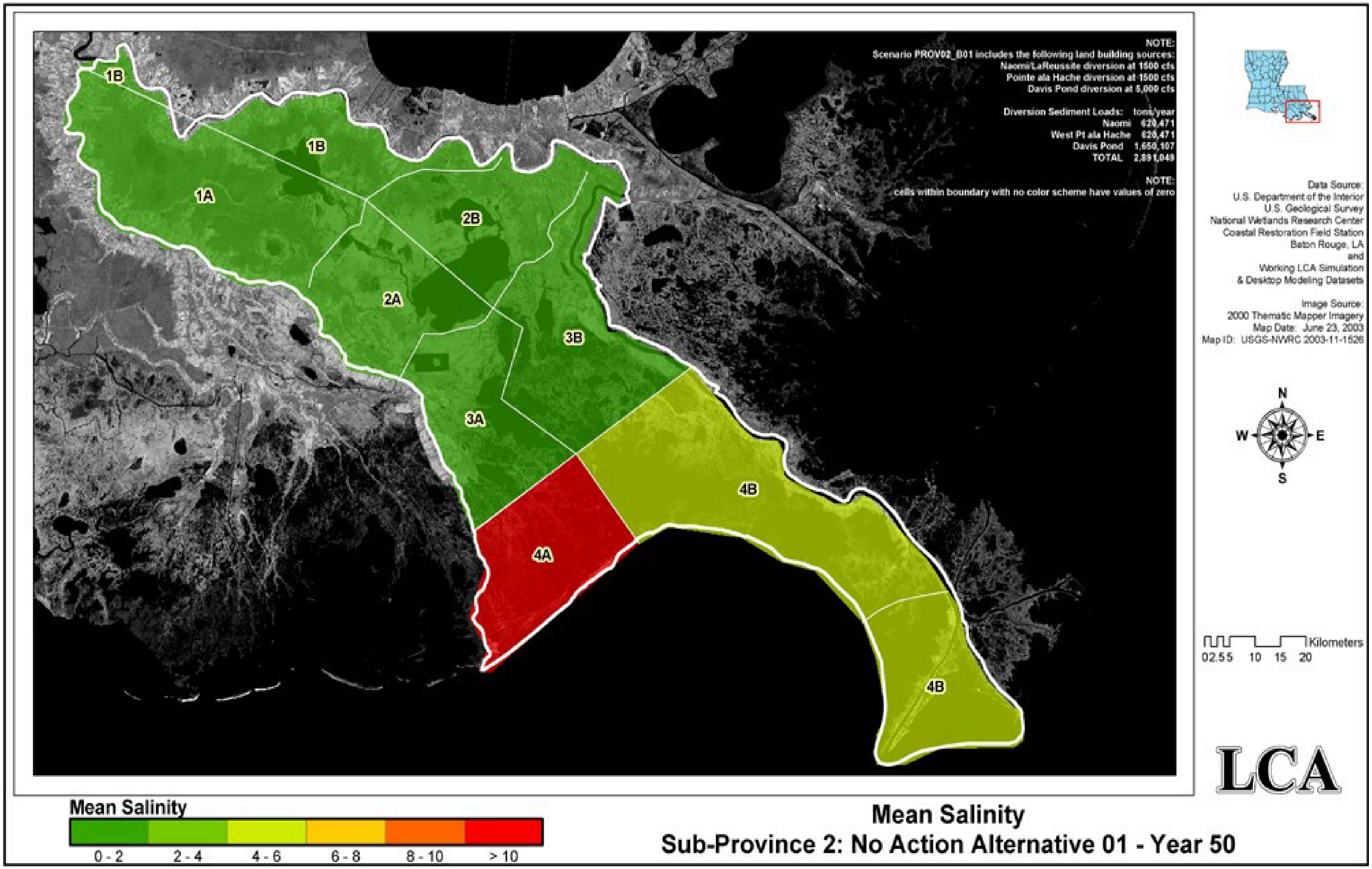


Figure 3-18. Modeling outputs displaying mean salinity under base and Future Without-Project conditions in Subprovince 2.

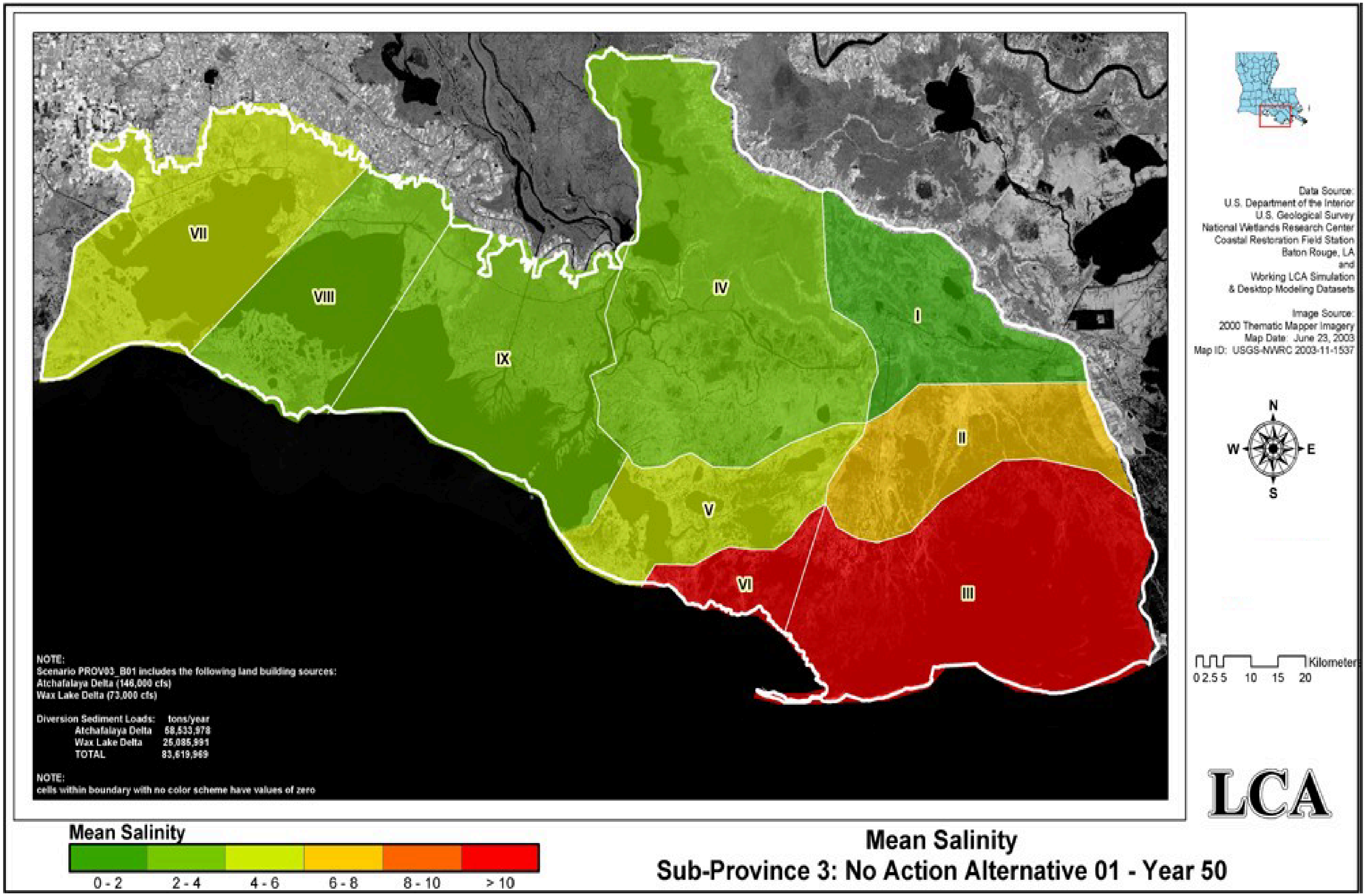


Figure 3-19. Modeling outputs displaying mean salinity under base and Future Without-Project conditions in Subprovince 3.

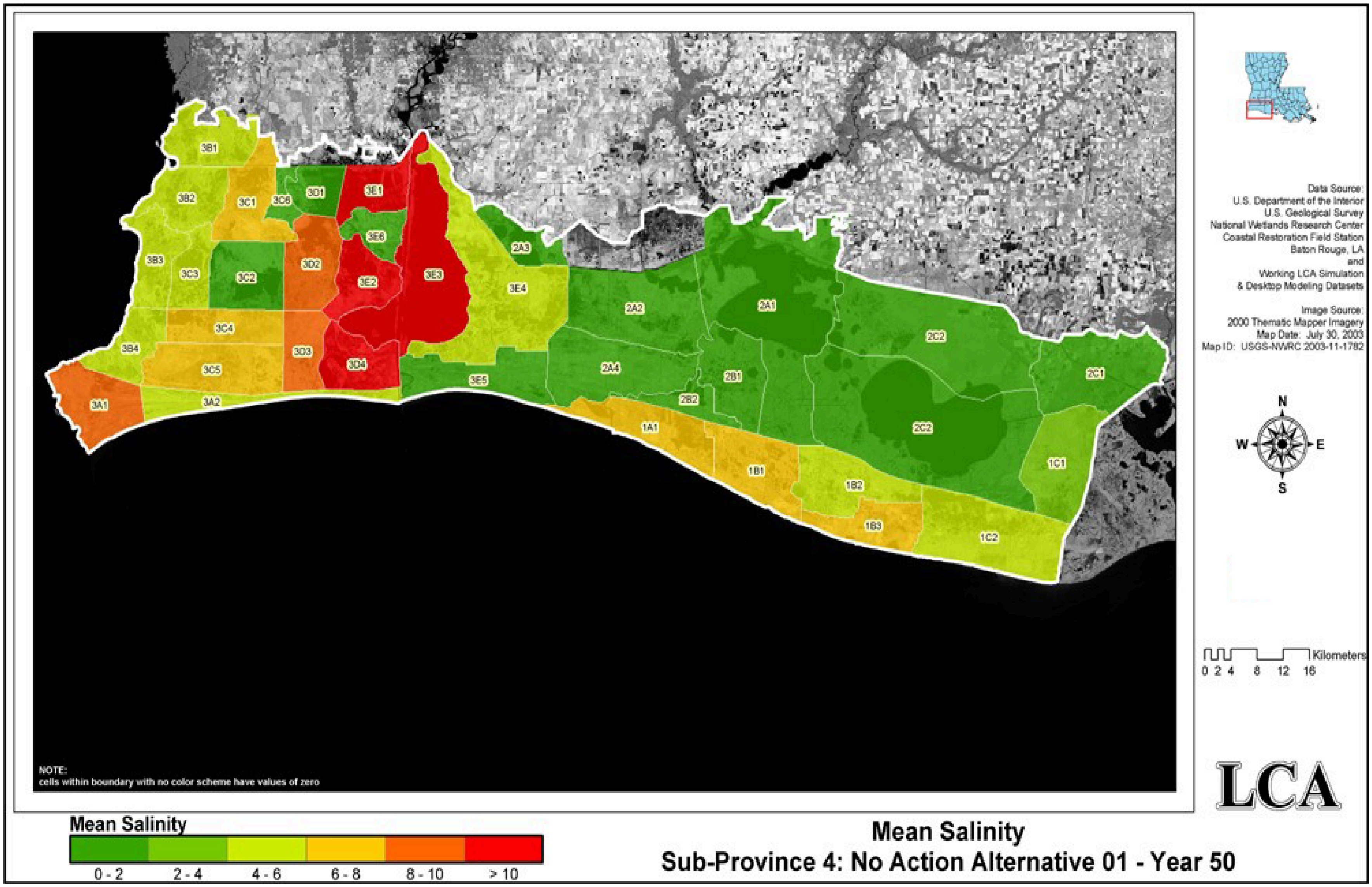


Figure 3-20. Modeling outputs displaying mean salinity under base and Future Without-Project conditions in Subprovince 4.

3.5 BARRIER SYSTEMS: BARRIER SHORELINES, HEADLANDS AND ISLANDS

3.5.1 Importance of Louisiana's Barrier Systems

A more detailed description of barrier system resources is provided in appendix D LOUISIANA GULF SHORELINE RESTORATION REPORT of the Main Report. These resources are institutionally recognized by the Coastal Barrier Resources Act of 1990 (16 U.S.C. §§3501-3510). Section 3501 of the act describes the Congressional statement of findings that:

- Coastal barriers provide habitats for migratory birds, wildlife, finfish, shellfish and other aquatic organisms;
- Coastal barriers contain resources of extraordinary scientific, recreational, natural, historic, and ecologic importance;
- Coastal barriers serve as natural storm protective buffers and are generally unsuitable for development because they are vulnerable to hurricane and other storm damage and because natural shoreline recession and the movement of unstable sediments undermine human structures;
- Certain actions and programs of the Federal Government have subsidized and permitted human development on coastal barriers and the result has been the loss of barrier resources, threats to human life, health, and property, and the expenditure of millions of tax dollars each year; and
- A program of coordinated Federal, state, and local governments is critical to the more appropriate use and conservation of coastal barriers.

Barrier systems provide protection of the wetlands, bays, and estuaries behind the islands. Barrier systems help reduce wave energy at the margins of coastal wetlands, thereby limiting mechanical erosion; additionally, they limit storm surge heights and retard saltwater intrusion (Williams et al. 1992). Barrier islands and shorelines mark a transition between land and sea. They are not only geologic entities, but also biological entities whereby the biological vigor reflects physical diversity (Britton and Morton 1989). On May 3, 2001, the USFWS designated critical habitat for wintering populations of the endangered piping plover, which includes most of the Louisiana barrier islands. Appendix D LOUISIANA GULF SHORELINE RESTORATION TEAM REPORT of the Main Report presents a more detailed discussion of this resource.

Louisiana's barrier systems contain about 300 miles (483 km) of shoreline that stretch from the Chandeleur Islands southeast of the Pearl River and the Louisiana/Mississippi border west to Sabine Pass on the Texas/Louisiana border. The barrier system helps protect the area behind the coastline that is affected by coastal processes in the Gulf of Mexico, such as waves, salinity, water levels, and storms.

Louisiana's barrier systems are the first line of defense against the storms and hurricanes that impact coastal Louisiana; they dampen the impacts of waves and surges before they move landward toward more fragile inland estuarine and wetland areas. They also protect the inshore oil and gas extraction infrastructure that is not built to withstand the gulf waves.

Louisiana's barrier systems regulate the exchange of higher salinity gulf waters with the lower salinity waters of the interior coastal areas. This is seen in the estuarine gradient of progressively fresher vegetation zones as one travels inland from the saline marshes near the gulf, landward to less saline brackish marshes, intermediate marshes, freshwater marshes, and swamps (see also section 3.7, COASTAL VEGETATION RESOURCES).

The diversity and abundance of natural resources in Louisiana's barrier systems plays a major role in making this unique area "A Working Coast." This "working coast" is also a rich fishery, recreational or "sportsman's paradise", and coastal and offshore petroleum production area. In addition to providing critical habitat for threatened and endangered species, such as the piping plover, brown pelican, and sea turtles, Louisiana's barrier systems protect what many consider to be critically imperiled human habitat (see appendix D LOUISIANA GULF SHORELINE RESTORATION TEAM REPORT of the Main Report).

Louisiana's barrier systems are experiencing some of the highest land loss rates in the Nation, due to both natural and man-made factors. The following sections describe the historic and predicted land loss of this area.

3.5.2 Historic and Existing Conditions

Deltaic Plain Barrier Systems

Louisiana's barrier systems are located principally in the Deltaic Plain region and include the Chandeleur, Plaquemines, Bayou Lafourche, and Isles Dernieres barrier systems. More detailed descriptions of Louisiana's barrier islands, especially land loss comparisons over the past 100 years, is provided in Williams et al. (1992), "Atlas of Shoreline Changes in Louisiana from 1853 to 1989." A series of reports prepared by the Louisiana Geological Survey entitled "The Coastal Sand Dunes of Louisiana: An Inventory" provides the most comprehensive description of Louisiana's vanishing barrier islands. This series of publications includes: the Isles Dernieres (Ritchie et al. 1989), the Plaquemines Shoreline (Ritchie et al. 1990), the Chandeleur Islands (Ritchie et al. 1992), and the Bayou Lafourche Barrier Shoreline (Ritchie et al. 1995).

Chandeleur Barrier System: At over 46.60 miles (75 km) long, the Chandeleur barrier system is the oldest transgressive barrier island arc on the Deltaic Plain. These islands enclose Breton Sound and Chandeleur Sound in St. Bernard and Plaquemines Parishes. The Chandeleur Islands are part of the Breton National Wildlife Refuge (NWR), a large portion of which is a designated wilderness area. The Chandeleur Barrier System include the following islands: Chandeleur, New Harbor Islands, North Islands, Freemason Islands, Curlew, Errol, Grand Goosier, and Breton Islands.

Plaquemines Barrier System: This 24.85 to 31.07 miles (40 to 50 km) long barrier system forms the seaward geologic framework for the eastern Barataria Basin and lies about 31.07 miles (50 km) northwest of the active Mississippi River Delta. Historic Fort Livingston is situated upon West Grand Terre, the largest island in this system. The Plaquemines barrier system consists of remnant barrier spits and islands defined either by a tidal pass, or the entrance to a bayou. These islands include: Cheniere Ronquille, Bay La Mer Gulf Shore, Bay Joe Wise Gulf Shore, Shell Island, Pelican Island, and Dry Cypress Bayou Gulf Area.

Bayou Lafourche Barrier System: The Bayou Lafourche barrier system stretches over 37.28 miles (60 km) from Barataria Pass near Grand Isle to Cat Island Pass. This barrier system forms the seaward geologic framework of western Barataria Basin and the eastern Terrebonne Basin. This barrier system consists of the only commercially developed barrier island in Louisiana, Grand Isle. The 12.43-mile (20 km) Caminada-Moreau headland, with some of the highest rates of shoreline loss in coastal Louisiana, is the landfall site of many oil and gas pipelines, including the Louisiana Offshore Oil Port (LOOP) facilities. The westernmost islands in this barrier system include Timbalier Island and East Timbalier Island. These islands have experienced more lateral morphological change than any others in Louisiana (Williams et al. 1992).

Isles Dernieres Barrier System: At over 16.84 miles (30 km) long, the Isles Dernieres barrier system forms the seaward geologic framework for the western Terrebonne Basin. In 1853, this barrier system was a continuous shoreline system, except for Wine Island (Williams et al. 1992). Today, this barrier system consists of five main islands: Wine Island, East Island, Trinity Island, Whiskey Island, and Raccoon Island.

Chenier Plain Barrier Shoreline

The Chenier Plain of southwestern Louisiana, with elevations of approximately 6 to 20 ft (2 to 6 m), extends from Sabine Pass, Texas to Southwest Point, Louisiana. A chenier plain consists of multiple shore-parallel, sand-rich ridges that are perched on and physically separated from one another by relatively finer-grained, clay-rich sediments. Oak trees (“cheniers” in French) grew on these ridges and gave the region its name. The Chenier Plain evolved during the Holocene as a sequence of progradational mudflats that were intermittently reworked into sandy or shelly ridges to form the modern physiography. Numerous cycles of deposition and erosion created alternating ridges separated by marshlands. These processes concentrated the coarse-grained sediments and formed shore-parallel ridges called “cheniers” (Gould and McFarlan 1959; Byrne et al. 1959). Introduction of new sediment by westward shifts of the Mississippi River Delta resulted in the isolation of these ridges by accretion of new material on the existing shoreline (**figure 3-21**). Thus, repeated seaward growth and retreat along the Chenier Plain is a consequence of deltaic deposition farther east as well as the periodic cessation of sediment supply to the Chenier Plain as deltaic depocenters were abandoned. Currently, the Atchafalaya River is supplying the Chenier Plain with fine sediments by westward-directed longshore transport of fine-grained material.

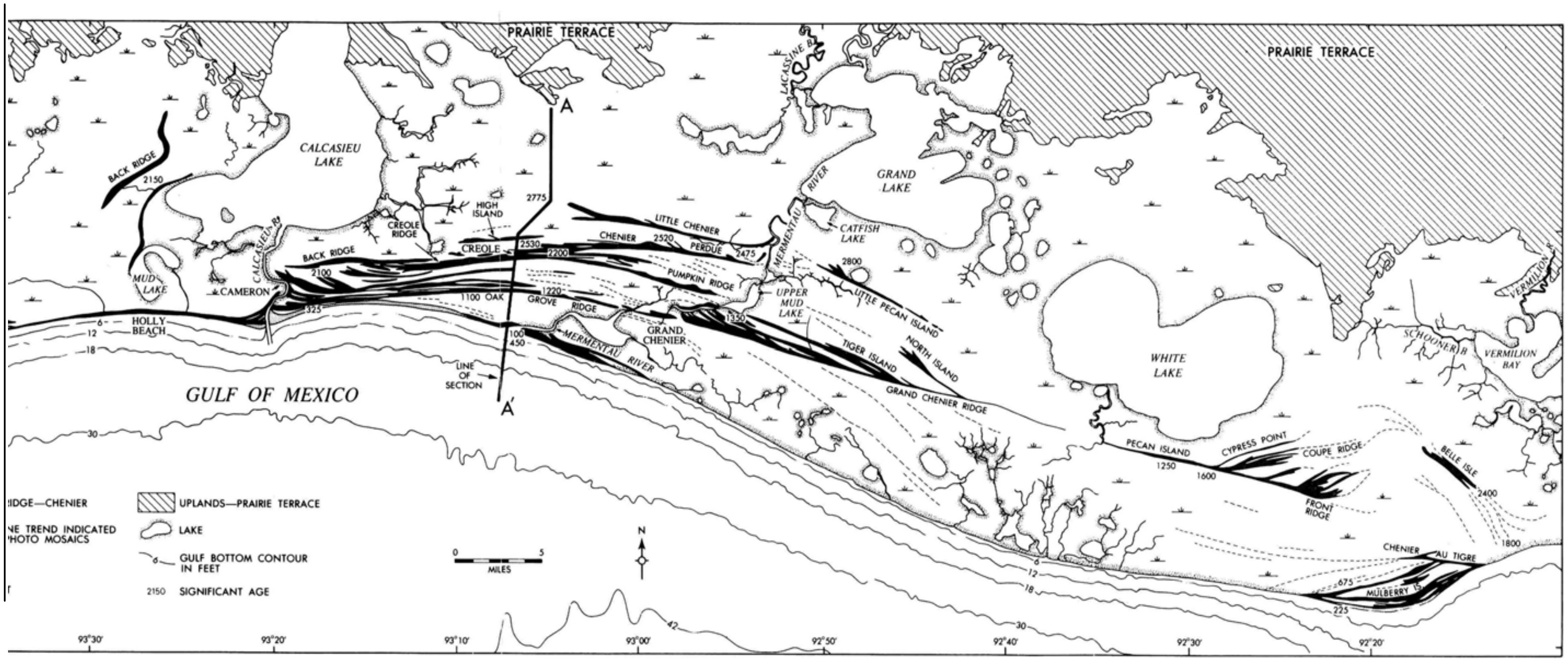


Figure 3-21. Regional geomorphologic framework of the southwestern Louisiana Chenier Plain. Note the shore-parallel distribution of sandy ridges separated by ridge-elongate mud flats and marshlands. Ages on ridges indicate their radiometrically-determined times of formation (by Gould and McFarlan 1959)

3.5.3 Barrier Island Erosion

The high rates of coastal erosion and wetland loss in Louisiana have been recognized and documented since the 1950s (Morgan and Larimore 1957; Gagliano and van Beek 1970; Adams et al. 1978; Gosselink et al. 1979; Wicker 1980; Walker et al. 1987; Britsch and Kemp 1990; Dunbar et al. 1990; Penland et al. 1990; Williams et al. 1990; Williams et al. 1992). Williams et al. (1992) wrote in the " Louisiana Barrier Island Erosion Study":

The physical processes that cause barrier island erosion and wetlands loss are complex, varied, and poorly understood. There is much debate in technical and academic communities about which of the many contributing processes, both natural and human-induced, are the most significant. There is further controversy over some of the proposed measures to alleviate coastal land loss.

Dingler and Reiss (1990) recognized the importance of cold-front driven storm erosion and overwash in the central part of the Isles Dernieres. More recently, Morton (2002) describes that about once every seven to ten days from November to April, winter storms related to the passage of a cold front occur throughout the Louisiana coastal region. These winter storms act like pumps that cause rapid changes in water levels and associated wave erosion. Preceding passage of a cold front, low barometric pressure generates strong onshore winds that set water up along the coast, flooding open ocean and mainland beaches and exposing the shores to strong wave attack. As the front passes the coast, strong winds are directed offshore driving water onto the back barrier flats and away from the ocean beaches. The frequent oscillation in water levels and waves erodes both sides of barrier islands as well as mainland and bay shores. Such Gulf Coast winter storms cause much less land loss or property damage than do hurricanes, so they are not ranked or given names like severe northeasters of the Atlantic coast.

Our knowledge of barrier system restoration has since increased over the ensuing years, particularly with the several barrier island restoration projects constructed under the CWPPRA program. However, the knowledge of ecosystem and coast wide-level restoration is still in its formative stage, thereby requiring an adaptive management approach for restoration and site-specific evaluation.

Over the last century, the rate of erosion along Louisiana's gulf shoreline has progressively increased, threatening the health of coastal Louisiana. Using historical maps and aerial photography, the patterns and rates of shoreline change are mapped. **Figure 3-22** displays the long-term shoreline change history of the Louisiana gulf shoreline from the 1880s to 2002 (from Connor et al. 2004). **Figure 3-23** displays the short-term shoreline change history of the Louisiana gulf shoreline from the 1880s to 2002 (from Beall et al. 2004).

Figure 3-22. Long-term shoreline change history of Louisiana gulf shoreline from 1880s to 2002 *(from Connor et al. 2004).*

Figure 3-23. Short-term shoreline change history of Louisiana gulf shoreline from 1880s to 2002 *(from Beall et al. 2004).*

The gulf shoreline is divided into 31 reaches based on the geomorphology, change trends, existence of man-made structures, and/or a combination of these factors. Reaches 1-10 make up the Chenier Plain; reaches 11-31 make up the Deltaic Plain gulf shoreline.

The average rate of long-term (greater than 100 years) shoreline change is –19.9 ft/yr (6.1 m/yr). The average short-term (less than 30 years) rate of shoreline change is 30.9 ft/yr (9.4 m/yr). The highest rates of erosion are often found in the erosional shadows of hard coastal structures, such as navigation jetties, seawalls, and breakwaters. Beach nourishment, dune construction, and backbarrier marsh creation are the only project types that built new land and reversed gulf shoreline erosion.

3.6 BARRIER REEF RESOURCES

A massive complex of intertidal oyster reefs once spanned the interface between the Gulf of Mexico and the bays and wetlands of the Atchafalaya and Teche/Vermilion Basins (see **figure 3-24**). This reef complex is about 44 miles (70.8 km) long and can be separated into 3 reef zones. The first is the Point Au Fer reef that is about 27 miles (43.5 km) long, which forms the lower boundary of Atchafalaya Bay and separates the bay from the gulf. The second zone is a smaller reef field that developed on the submerged natural levees of Bayou Sale, which extends from Point Chevreuil on the mainland southwesterly towards Shell Keys at the gulf for a distance of 18 miles (28.9 km). Only the lower portion of this discontinuous reef field contributes to the barrier complex; the upper portion forms the boundary between Atchafalaya Bay and East Cote Blanche Bay. The third zone lies adjacent to and gulfward of Marsh Island and is a continuous reef field for a distance of about 15 miles (24.1 km). This extensive assemblage of reefs is recognized as a unique ecological feature of the Louisiana coast (Burk and Associates, Inc. 1976) and a natural barrier to coastal erosion (Morgan and Morgan 1983). It is a significant resource considering its value to protecting existing wetlands and to enhancing the formation of new wetlands in the Atchafalaya Delta.

3.6.1 Historic and Existing Conditions

This massive barrier reef complex likely flourished until the late 1800s when the Atchafalaya River discharge altered the salinity conditions making the area unfavorable for oysters. Today, the Atchafalaya–Vermilion estuary is the freshest estuary along the northern Gulf of Mexico (Orlando et al. 1993). By the early 1900s commercial oyster production had greatly declined on the reefs east of Marsh Island. It was then that the State of Louisiana began leasing the Point Au Fer and Point Chevreuil reefs for shell mining. This leasing and mining continued through much of the 20th century, resulting in the removal of most of the barrier reef between Point Au Fer Island and Marsh Island. Presently, shell mining (or shell dredging) no longer occurs in coastal Louisiana.

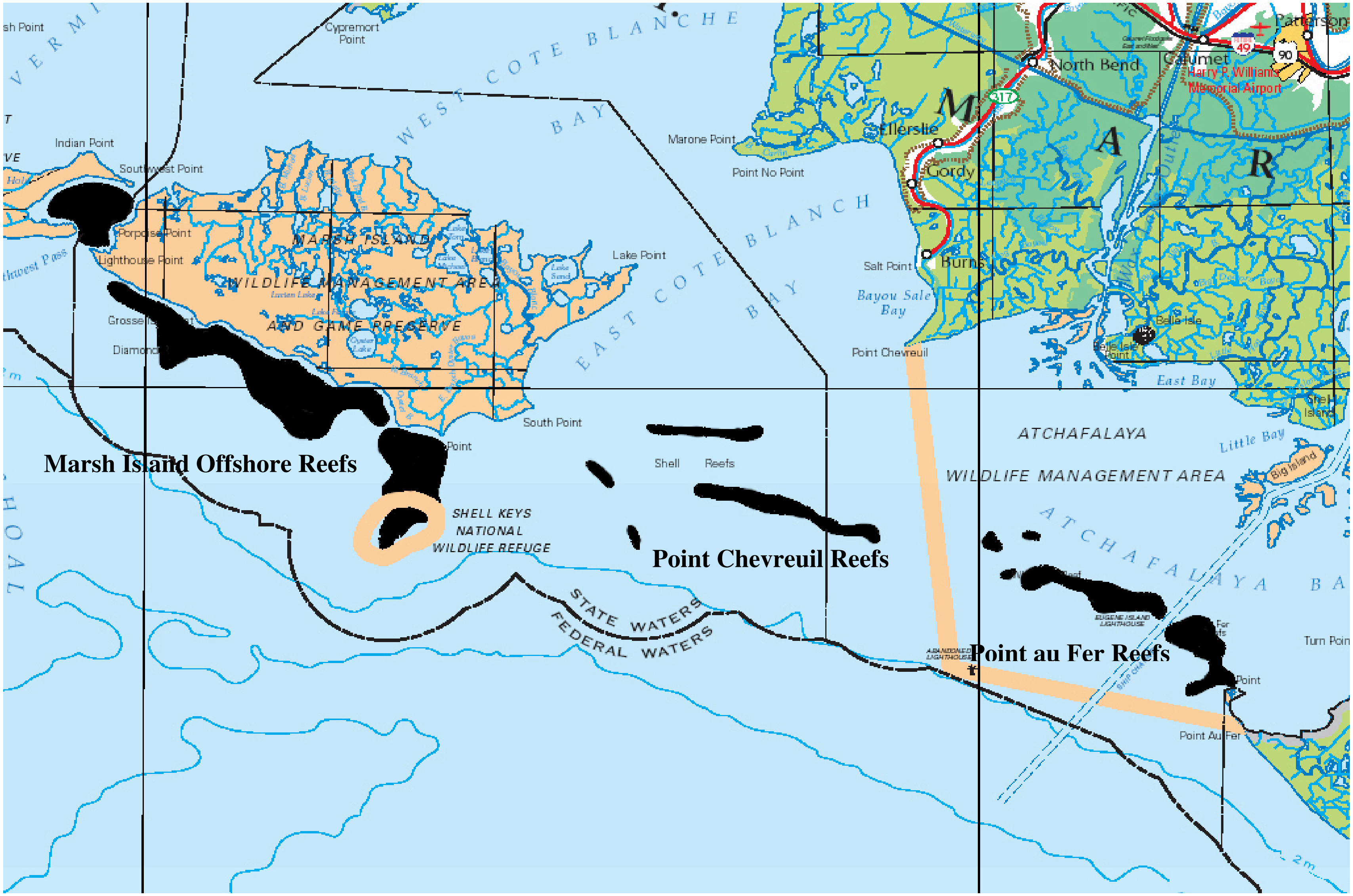


Figure 3-24. Louisiana barrier reefs (filled in black).

Point Au Fer Reef: Only remnants of this barrier reef complex remain and it is partially encompassed by the Atchafalaya Delta Wildlife Management Area (WMA), which is administered by the Louisiana Department of Wildlife and Fisheries (LDWF). The water bottoms of the reef area, along with those of Atchafalaya Bay and the bays in the Teche/Vermilion Basin, have been designated as seed oyster grounds by LDWF. Only the waters close to Marsh Island experience salinity regimes necessary for oyster production. These salinity regimes occur during periods of drought and/or low Atchafalaya River discharge. The remaining areas are usually too fresh to produce harvestable oysters.

Point Chevreuil Reef: Like the Point Au Fer reef, most of the reefs have been mined. Several years ago shell was added to Rabbit Island, a once prominent emergent shell island in this reef field located near Point Chevreuil. It is one of the few remaining remnant reefs that are popular recreational saltwater fishing areas. Again, like the Point Au Fer reef complex, only the areas close to Marsh Island experience salinity regimes necessary for oyster production.

Marsh Island Offshore Reefs: These reefs have largely survived the shell mining decades and are still commercially productive. This reef complex is located far enough from the Atchafalaya River that it is not affected by the freshening that occurs in the easterly portions of the barrier reef complex. The Marsh Island reef complex effectively reduces offshore wave energies to protect the Marsh Island shoreline. Marsh Island is a WMA administered by LDWF.

Shell Keys National Wildlife Refuge: Shell Keys, located at the southeastern boundary of the barrier reef complex and about three miles (4.8 km) south of Marsh Island, is a NWR. Wave action and water circulation patterns maintain the narrow keys by winnowing shell fragments from nearby oyster reefs. The 5 to 7-acre (2.0 to 2.8 ha) Shell Keys NWR was established in 1907. By executive order, the refuge was "... reserved and set apart...as a reserve and breeding ground for native birds." The refuge is located in Iberia Parish, Louisiana, in the offshore waters to the west of the Atchafalaya River Delta, and south of Marsh Island WMA. The refuge is composed of a few small shell spits or islands that are continually being built up and then eroded and moved by storm events. The area has large concentrations of shorebirds and colonial sea birds. The refuge is a bird sanctuary and is closed to all public use.

3.7 COASTAL VEGETATION RESOURCES

3.7.1 Historic Conditions

The inherent oscillating nature of the formation processes drove domination of coastal ecosystems back and forth between riverine and marine influence. Over time, a variety of distinct combinations of environmental conditions that regulate vegetative succession waxed and waned across the coast. As a result, the history of Louisiana coastal vegetative communities is one of continuous development and adaptation, change or loss throughout the coastal formation period. These circumstances provided the ingredients necessary for the development of an ecosystem with an abundant and highly diverse vegetative tableau overlaying the coastal landscape.

Louisiana's coastal wetlands comprise a variety of environments formed by spatially and temporally varying conditions that continually influence and change the vegetative landscape. The environmental factors and their innumerable combinations that regulate the occurrence and distribution of plant species and associations include, but are not limited to, soil and water salinity, soil type, elevation, hydrology and flooding regime, tidal influence, and climate. Competition, especially from invasive species, herbivory pressure, and man-made disturbance, such as burning or hydrologic modification, are other forces that can impact vegetative species.

Each plant species adapts to a definite range of environmental conditions, and those species that are adapted to similar conditions form communities or associations that are best able to grow and successfully compete for a particular site. Wherever the prevailing environmental conditions are similar, analogous communities with comparable species composition and dominance tend to occur. When environmental conditions change, succession can occur where plant species or whole communities are replaced by others more suited to the new conditions (O'Neil 1949; Chabreck 1972a).

In habitats with restricted variation in conditions, such as those with extreme salinity, species diversity is reduced. Since the source of salinity in coastal Louisiana is the Gulf of Mexico, salinity levels exist along a gradient, which declines as the saltwater moves inland. A zonation of plant species that differ in salinity tolerance exists along that gradient, with the species diversity of those zones increasing from salt to fresh environments (see **table 3-3**).

Table 3-3
Salinity ranges for the four coastal wetland types.

Wetland Type	Range (ppt)	Mean (ppt)	Typical Range (ppt)
Fresh	0.1 – 6.7	<3.0	0 – 3
Intermediate	0.4 – 9.9	3.3	2 – 5
Brackish	0.4 – 28.1	8.0	4 – 15
Saline	0.6 – 51.9	16.0	12+

(Source: Chabreck 1972; Louisiana Coastal Wetlands Conservation and Restoration Task Force; and the Wetlands Conservation and Restoration Authority 1998)

Louisiana's coastal vegetative landscape is characterized by a diversity of plant communities that have been previously classified and mapped according to major association or type (Penfound and Hathaway 1938; O'Neil 1949; Chabreck et al. 1968; Chabreck 1970, 1972b; Cowardin et al. 1979; Chabreck and Linscombe 1978, 1988; Visser et al. 1998, 1999, 2000; and Chabreck et al. 2001).

The combination of salinity, elevation, and organic substrate gradients contributes to distinct zonation in Louisiana's coastal wetland communities. The dominant zonation, with increasing distance from the coast, is salt, brackish, intermediate, and freshwater organic marshes, and swamp and bottomland hardwood communities, which have been well described by Penfound and Hathaway (1938), Chabreck (1970, 1972b); Visser et al. (1998, 1999, 2000); and Visser and Sasser (1998).

The types and productivity of vegetative communities are greatly influenced by the same factors responsible for coastal land loss. Furthermore, the persistence of a vegetative community is dependent upon its ability to adapt to changing conditions. The loss of wetlands has and continues to impact all vegetative community types from the barrier islands, headlands, and salt marshes at the coastal shore to the interior fresh marshes, swamps and bottomland forests.

There is difficulty in assessing trends in vegetative community changes coast wide because of high variability within the coastal landscape. Successional changes have been bi-directional, illustrating that there is no single factor that can explain trends at a coast wide scale. In many areas, transitions in habitat types toward more salt tolerant communities have been recorded over the past 50 years (O'Neil 1949; Chabreck et al. 1968; Chabreck and Linscombe 1978 and 1988; and Linscombe et al. 1997a and 1997b). In others, fresh marsh vegetation types did not show a predicted change to more salt-tolerant communities, but did reflect significant changes in species dominance (Visser et al. 1999).

Sequential mapping of habitats based on coast wide surveys of vegetative communities has been described by O'Neil (1949), Chabreck et al. (1968), Chabreck and Linscombe (1978 and 1988), and Linscombe et al. (1997a and 1997b). Differences in mapping areas and survey approaches between each mapping period make direct acreage comparison of habitat types between maps inappropriate (G. Linscombe, LDWF, 2002 – personal communication). The variability of the coastal vegetation community habitat over time is illustrated on **figures 3-25** and **3-26**.

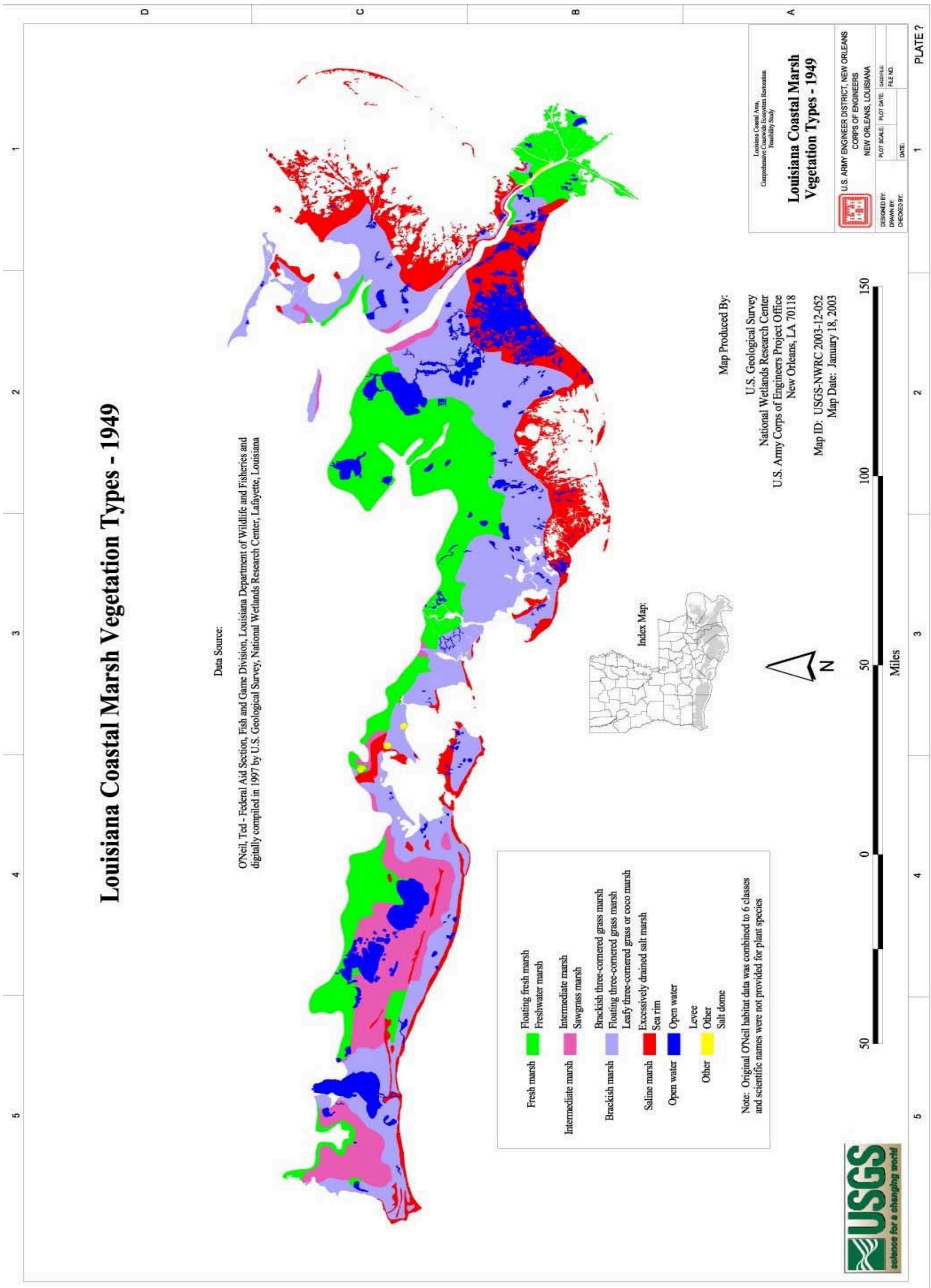


Figure 3-25. Louisiana Coastal Marsh Vegetation in 1949.

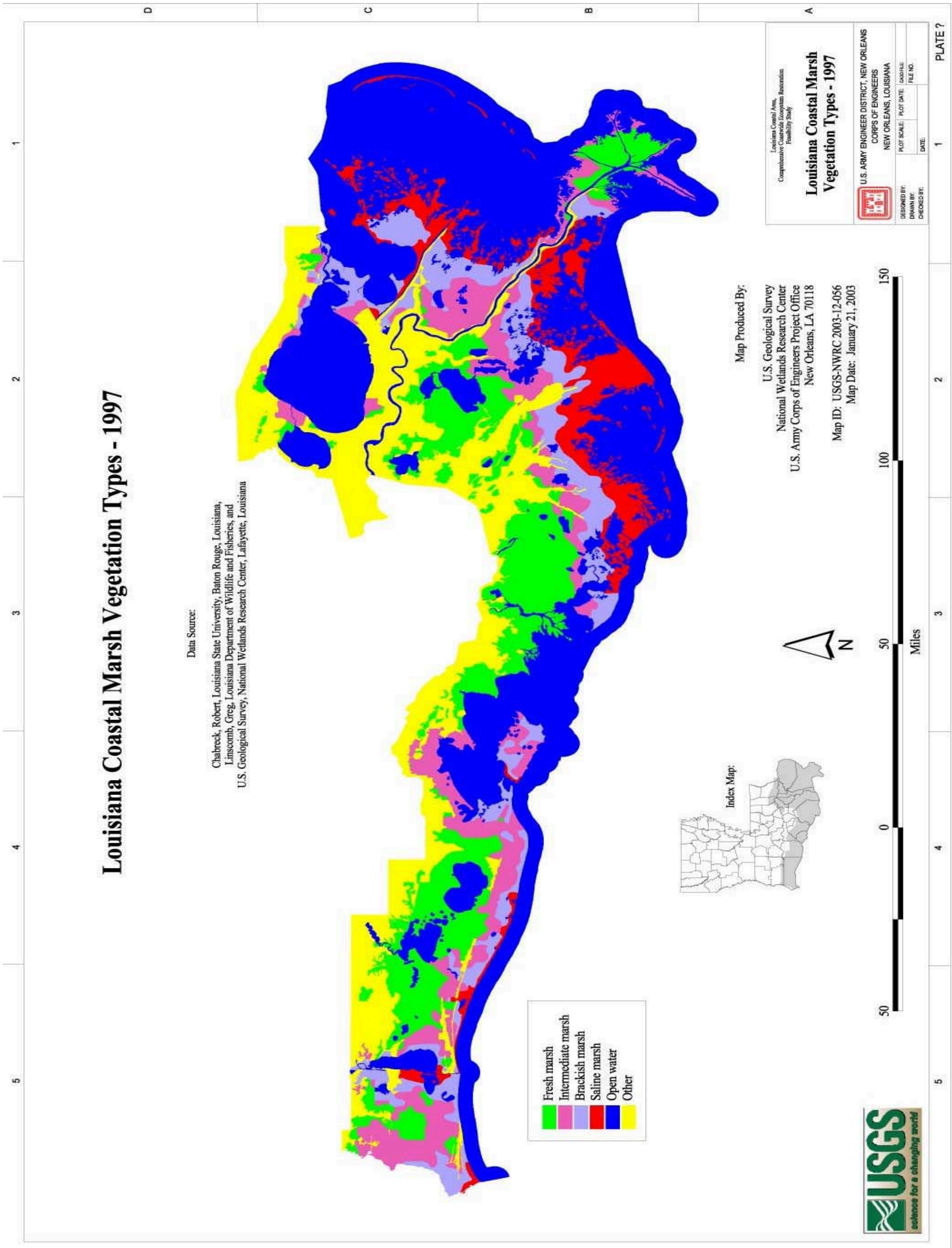


Figure 3-26. Louisiana Coastal Marsh Vegetation in 1997.

3.7.1.1 Major Mechanisms of Vegetative Change

Just as varying combinations of predominant environmental conditions influenced the distribution and successional patterns of vegetation communities during Louisiana's coastal formation, alteration of those conditions brought about by modern landscape changes, land loss, and other events affects the continued existence of wetland vegetation. It is important to understand the major mechanisms of how vegetation is impacted in the course of landscape alteration and by land loss and other factors to develop effective and efficient means to protect and rehabilitate Louisiana's coastal wetlands. Moreover, while many coastal wetland plant species are resilient to single stressor events, there is a growing body of evidence that suggests the combined effects of multiple stressors occurring simultaneously are the most detrimental to plant communities (Webb and Mendelssohn 1996; Baldwin and Mendelssohn 1998; DeLaune et al. 1987). If change is too rapid or at a magnitude beyond the tolerance limits of plant species to allow succession, conversion to open water can occur. The major mechanisms of vegetative change include the following:

- Accretion and Submergence: The vertical accumulation of wetland soils is achieved by accretion of mineral sediment inputs and/or organic accumulation resulting from above- and below-ground plant productivity (DeLaune et al. 1983a; DeLaune et al. 1990a). The survival and productivity of marshes is reliant on these soil-building processes to offset submergence, which results from subsidence and soil oxidation-decomposition losses, and to maintain the marsh surface elevation with respect to sea level change (DeLaune et al. 1978; DeLaune et al. 1979; DeLaune et al. 1990b).
- Flooding: Wetland plants employ different physical and/or metabolic mechanisms that enable them to tolerate and grow in flooded soils. However, in almost all cases plants are dependent on the maintenance of soil surface elevation to sustain the flooding regime to which they are adapted. Increases in flooding, depth, and duration, and salinity levels stress plants by altering metabolic function, and negatively impacting productivity, survival, and regeneration.
- Salinity: Wetland plant species have evolved different levels of tolerance to salinity and respond to salinity with different mechanisms. Numerous studies have demonstrated that elevated salinity can negatively affect all wetland species and can contribute to large-scale vegetation dieback (Chabreck and Linscombe 1982; McKee and Mendelssohn 1989).

3.7.1.2 Factors Driving Changes in Vegetative Resources

Levee System: Since the 18th century, levee construction has interrupted overbank flows and halted the large-scale dissemination of sediment to wetlands. Many of the interior marshes coast wide no longer receive sufficient sediment and associated nutrient input to support vigorous plant productivity and vertical accretion (DeLaune et al. 1990c). This modern environment of sediment deprivation now exists while compaction and subsidence of the coastal area continues as part of the natural degradation of abandoned delta lobes. Descending marsh surface elevation and the resulting increase of flooding, erosion, and saltwater intrusion drove habitat shifts toward more salt tolerant plant communities or conversion to open water that continues today.

Channelization: Construction of canals for oil and gas production and deep navigation channels has affected wetland vegetation by changing the marsh hydrology, interrupting sheet flow, inhibiting drainage, altering sediment movement patterns, causing impoundment and flooding, and facilitating saltwater intrusion and increased tidal exchange.

Drainage for Development and Agricultural Use: Sizable tracts of fresh wetland vegetative communities were also converted for development or agronomic use early in the last century. Wetland soils are not suitable for typical long-term cropping or pasture improvement without establishing significant hydrologic control, so many large expanses of marshes converted for development or agricultural use were leveed and managed with pump-drainage systems (USDA 1977; Okey 1918a; Okey 1918b).

Other Hydrologic Alteration: Installation of other infrastructure, such as municipal drainage systems and road and railroad embankments, has also been associated with wetland deterioration and loss due to accelerated drainage, interruption of natural drainage and impoundment, and physical removal for borrow material.

Fire: Marsh burns, either conducted for management or occurring as a natural phenomenon, have also affected species distribution and successional patterns of plant communities.

Herbivory: Muskrat, nutria, and sometimes geese have been the reported culprits of damage across the coastal area due to "eat-outs," where all marsh vegetation in an area, including the root system, is consumed (O'Neal 1949; T. Vincent, Audubon Refuge 1995 – personal communication; Linscombe and Kinler 1997).

Invasive Species: The aggressive spread of invasive species decreases stands of native plants in many areas, thus rapidly altering ecosystem function. Different ecosystem types vary in the species that pose problems and the degree to which they are currently impacted or threatened by invasive species (USGS 2000). Disturbed ecosystems are more vulnerable to invasive species than stable ecosystems. Invasive plant species often increase and spread rapidly because the new habitat into which they are introduced is often free of insects and diseases that are natural controls in their native habitats. Invasive species frequently out-compete native plants and alter ecosystem function. Ecosystems vary in their vulnerability to invasion (USGS 2000). In coastal Louisiana water hyacinth (*Eichhornia crassipes*), alligator weed (*Alternanthera philoxeroides*), and hydrilla (*Hydrilla verticillata*) are well-known invasive plants. More recently, common salvinia (*Salvinia minima*), giant salvinia (*Salvinia molesta*), and variable-leaf milfoil (*Myriophyllum heterophyllum*) also have become invasive, displacing native aquatic species and degrading water quality and habitat quality.

Invasive aquatic species frequently change local ecology and hinder the growth and reproduction of native aquatic plants (Chabreck 1972a). In many cases invasive plant species interfere with drainage and flood control and impede navigation and recreational activities (Westbrooks 1998). For example, due to the physical and ecological problems created by water hyacinth, anglers, boaters, SCUBA divers and swimmers are just a few of the groups that are adversely impacted. Water hyacinth degrades water quality, which reduces fishing opportunities. When water hyacinth takes over a waterway, it physically limits the use of that waterway and makes conditions very difficult for boaters and swimmers. Also, when mats of water hyacinth are formed, underwater visibility and biodiversity are reduced, and SCUBA divers are unable to enjoy various underwater features.

Chinese tallowtree (*Triadica sebifera*, formerly *Sapium sebiferum*) and sea-side cedar (*Tamarix gallica*), because of their tolerance to flooding and salt stress, rapidly colonize higher disturbed open ground and interrupt the natural succession of native prairie, scrub-shrub, and woody species. Escaped populations of Chinese tallowtree have established extensive, self-replacing monocultures that have radically altered ecosystems (USGS 2000). Barrow et al. (2000) illustrates how the invasive Chinese tallowtree, in crowding out native species, provides less food for migrating birds.

Cogongrass (*Imperata cylindrica*) is a fast-growing perennial grass that is infesting gulf coast wetlands, savannas, and forests. Considered one of the top-ten worst weeds in the world, cogongrass invades dry to moist natural areas and forms dense colonies with extensive root/rhizome systems that displace native plant and animal species. Cogongrass has been recorded in parts of Louisiana (Center for Aquatic & Invasive Plants 2000), and recently has been found to be locally abundant in a few areas (J. Pitre, USDA NRCS, 2002 - personal communication).

Climate: Wetlands already weakened by extreme weather conditions may be more vulnerable to damage from subsequent events as plant communities become stressed beyond their ability to recover or shift toward communities with more tolerant species. Prolonged periods of drought can also impact coastal vegetation, such as the "brown marsh" phenomenon in 2000 where damage or dieback was reported in areas of unprecedented size in the Terrebonne and Barataria saline marshes.

3.7.2 Existing Conditions

Chabreck et al. (1968), Chabreck (1970, 1972), Chabreck and Linscombe (1978, 1988), and Chabreck et al. (2001) subdivided and mapped Louisiana coastal wetlands into four zones on the basis of Penfound and Hathaway’s (1938) descriptions of the major vegetation types within salinity zones. This classification of marsh vegetation is widely recognized and often used in broadly describing coastal wetlands. The four vegetation types are fresh, intermediate, brackish, and saline, and occur in zones that generally parallel the coast (**figure 3-27**).

Coast wide, the range of salinity within each of these vegetation zones can vary drastically; however, as shown in the Coast 2050 report, the ranges of salinity that occur most frequently are typically much more narrow (**table 3-3).**

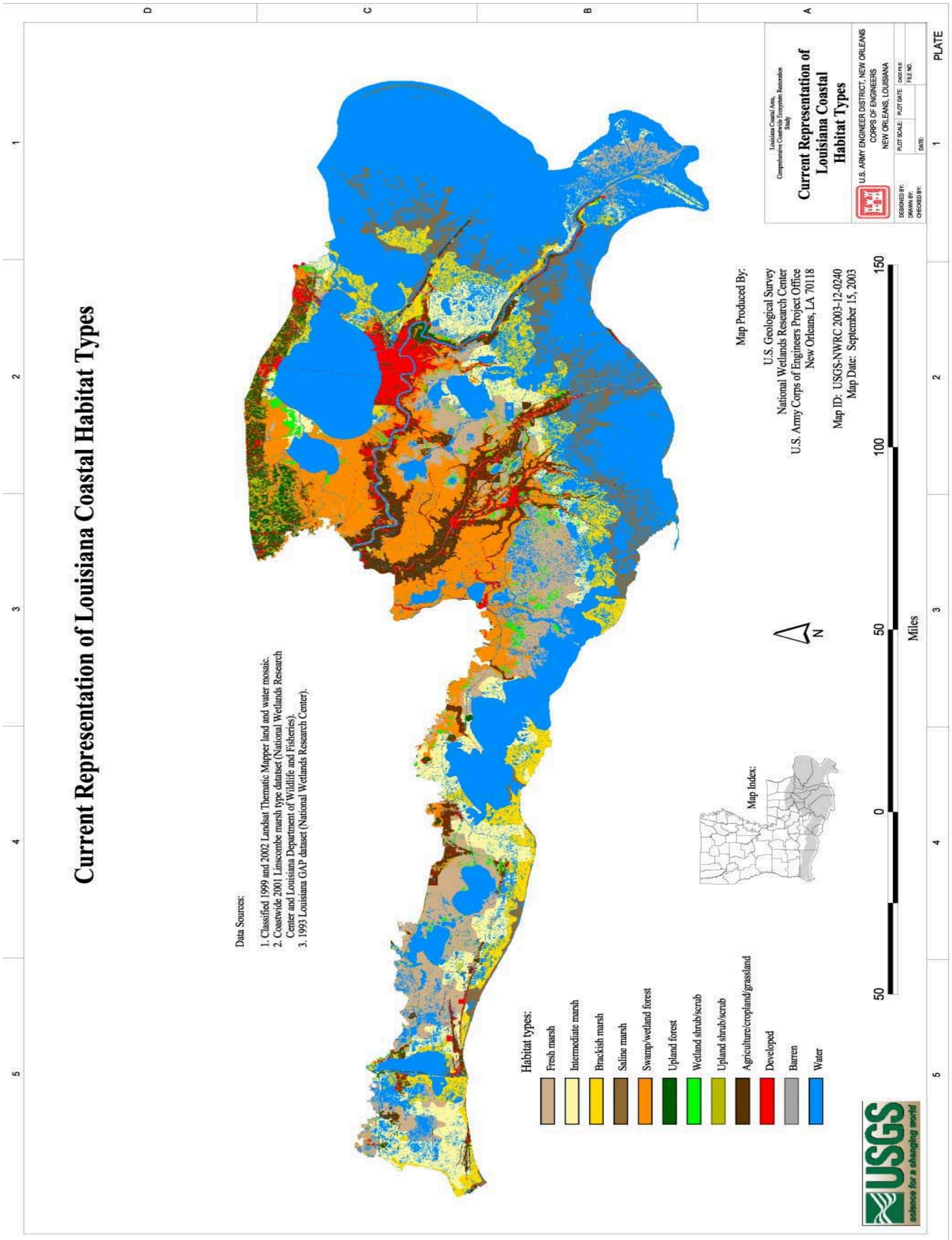


Figure 3-27. Louisiana Coastal Area Vegetative and Other Habitat Types.

In a coast wide survey, Chabreck (1972) recorded a total of 118 species of vascular plants in all marsh types. The species found in the greatest amount overall was marshhay cordgrass (*Spartina patens*), making up about one-fourth of the vegetation in the coastal marshes. Within the broad groupings of major vegetative habitat types found coast wide, such as described above, additional subdivisions of vegetative communities or associations exist (O'Neil 1949). Penfound and Hathaway (1938) acknowledged that there are many associations within which are several "specialized" subgroups that have developed in correlation with specific local differences in environmental factors. It is likely, because of the number and variation of environmental factors that exist and the potential combinations thereof, that division and subdivision of vegetative communities based on characteristic differences could continue until almost every community could be partitioned based on a unique attribute. For practical reasons, this level of division is not warranted, but to protect the diversity in Louisiana, conservation efforts must take this phenomenon into account (Smith 1988).

Using recent GIS analysis and classification by USGS NWRC for LCA Study planning, the desktop model output of one square kilometer resolution provides a current summary of the acreages of fresh, intermediate, brackish, and saline marsh types, and swamp/wetland forest based on a subdivision of the Louisiana coastal zone by subprovince (**table 3-4**).

Table 3-4
Wetland Habitat Acreage by Subprovince in Louisiana Coastal Zone
(from Desktop Model Analysis)

Habitat Classes (Acres)	Sub Province 1	Sub Province 2	Sub Province 3	Sub Province 4	Total LCA Area
Fresh Marsh	71,279	180,876	341,733	346,923	940,811
Intermediate Marsh	160,752	85,267	193,569	284,702	724,290
Brackish Marsh	180,441	65,337	201,216	137,529	584,523
Saline Marsh	113,149	117,809	113,513	30,307	374,778
Swamp/Wetland Forest	353,904	294,397	388,811	3,674	1,040,786
Total*	879,525	743,687	1,238,841	803,135	3,665,188

NOTE: Wetland Shrub/Scrub acreage has been distributed among the broader habitat classes used by the desktop model.
* All acreage figures provided for all habitat types exclude habitat that occurs within fastlands because they are hydrologically disconnected from areas that would be affected by LCA Plan restoration actions and are not included in the areas analyzed by the LCA Study desktop model.

The model aggregated the acreage of many distinct vegetative communities according to local environmental conditions (salinity and water levels) into the larger wetland habitat classifications of Fresh Marsh, Intermediate Marsh, Brackish Marsh, Saline Marsh, Swamp/Wetland Forest, and Upland and other non-wetland classes (see appendix C HYDRODYNAMIC AND ECOLOGICAL MODELING). For instance, wetland scrub/shrub habitat was distributed according to the appropriate broader habitat classification within which it occurred, and barrier island communities were aggregated into saline habitat, as delineated in Linscombe's 2001 dataset (see Data Source list in **figure 3-27**). Although important, unique vegetative communities such as Coastal Dune Grasslands or Mangrove Thicket on barrier islands were not specifically distinguished or delineated by the model. Also, the model did include Upland habitat acreage that was not located within fastlands; however, the model assumed no change in Upland acreage over the 50-year period of analysis.

The primary focus of Chabreck's (1972) and Chabreck and Linscombe's (1978, 1988, 2001) classification is the vegetative species of the natural marshes and interior water bodies of the coastal area. However, it is important to recognize that within those broadly delineated zones of marsh habitat types, other wetland areas with distinctive surface features and vegetative communities occur in association with the marshes. The following are descriptions of other major habitat types that comprise and illustrate the diversity of the LCA Study area:

- Swamp and Wetland Forests: Of the approximately 1,031,868 acres of swamp/wetland forests in the LCA Study area (Barras 2002, unpublished), the three major communities are swamp forest, bottomland forest, and wet pine flatwood forest. Cypress and cypress-tupelo swamps with fairly open canopies sometimes support fresh marsh and scrub/shrub species as groundcover, and very often the water surface in cypress-tupelo swamps is covered by floating vegetation. Extensive coastal swamps are found in the Pontchartrain, Barataria, Terrebonne, and Atchafalaya basins where they generally occupy the area between fresh marshes and developed areas of higher elevation. Healthy cypress swamps occur only in freshwater areas experiencing minimal daily tidal action and where the salinity range does not normally exceed two ppt. Both the bottomland hardwood forests and wet pine flatwoods occur only in fresh areas. Bottomland hardwood forests exist primarily in broad floodplains and distributary ridges of the Atchafalaya River and on the distributary ridges of the Mississippi River. Wet pine flatwoods within the LCA Study area are generally found on poorly drained flats and depressional areas in the "Florida Parishes" (Smith 1986). Wet pine flatwoods also contain a very diverse herbaceous community that can include many state rare species and, within in the LCA Study Area, may include the endangered species Louisiana quillwort (*Isoetes louisianensis*).
- Scrub/Shrub: There are approximately 121,314 acres of wetland scrub/shrub habitat, and 84,725 acres of upland scrub/shrub habitat in the LCA Study Area (Barras 2002, unpublished). Scrub/shrub habitat is found along bayou ridges and on dredged material embankments, and is typically bordered by marsh at lower elevations and by cypress-tupelo swamp or bottomland hardwoods (in fresh areas) or developed areas at higher elevations. Scrub/shrub communities are found associated with all four marsh types, from salt marsh to fresh marsh.
- Upland Forests: There are approximately 172,025 acres of upland forests in the LCA Study area (Barras 2002, unpublished). Three major communities of upland forest in the

area include chenier/maritime forest, mixed hardwood forest, and mixed pine-hardwood forest (Craig et al. 1987).

- Cropland/grassland: There are approximately 481,824 acres of cropland/grassland in the LCA Study area (Barras 2002, unpublished). Predominant crops include sugarcane (*Saccharum* sp.) (about 440,000 acres), rice (*Oryza* sp.) (about 306,000 acres) soybeans (*Glycine* sp.) (about 72,000 acres), and hay/grass (about 58,000 acres) (LSU Agricultural Center / Louisiana Cooperative Extension Service 2001).
- Urban areas: There are approximately 262,536 acres of urban area in the LCA Study area (Barras 2002, unpublished), including fringing suburbs, built-up areas of metropolitan communities, man-made structures, and associated disturbances that may or may not include vegetation.
- Barren: There are approximately 1,350 acres of barren area in the LCA Study area (Barras 2002, unpublished). Barren areas consist primarily of exposed, unvegetated (less than 25 percent vegetation) areas that are inundated annually and typically associated with rivers, streams, lakes, ponds, and impoundments. Barren areas occur within upland and wetland zones.
- Water: There are approximately 4,491,105 acres of water in the LCA Study area (Barras 2002, unpublished), including the Gulf of Mexico, coastal bays and lakes, lagoons, ponds, impoundments, canals, rivers, and streams. Excluding the Gulf of Mexico, coastal bays and large lakes, such as Lake Pontchartrain, there are approximately 984,366 acres of water.

3.7.2.1 Chenier and Deltaic Plains

Louisiana's coastal zone can be divided into two areas based on geologic origin: the Chenier and Deltaic Plains. Although these are two very large areas and both contain the habitat types described above, some differences in wetland vegetative communities can be found between the plains. Visser et al. (1998) conducted quantitative analyses of vegetation data collected by Chabreck and Linscombe in 1997 to determine naturally occurring vegetation associations in the Louisiana coastal zone marshes. The Visser et al. (1998) vegetative type analysis used species dominance and species association as the primary criteria to classify marsh areas, rather than species composition, which was used to delineate the four habitat types described by Chabreck (1972). Of the 12 vegetation associations occurring within four salinity regimes that Visser et al. identify, 11 are found in the Deltaic Plain, but only six are found in the Chenier Plain. While the Deltaic Plain hosts more types of associations, especially in the fresh and intermediate regimes, species richness is somewhat higher in the fresher regimes in the Chenier Plain associations. Also, in the association types that are found to occur both in the Chenier and Deltaic Plains, the dominant species are the same in both regions, but the overall species composition is notably different.

3.7.2.2 Rare, Unique, and Imperiled Vegetative Communities

Further subdivision of each subprovince by hydrologic basin provides a focus on the unique vegetative communities associated with distinctive local environmental factors (Louisiana Natural Heritage Program (LNHP) 2002) (see **figure 3-28).**

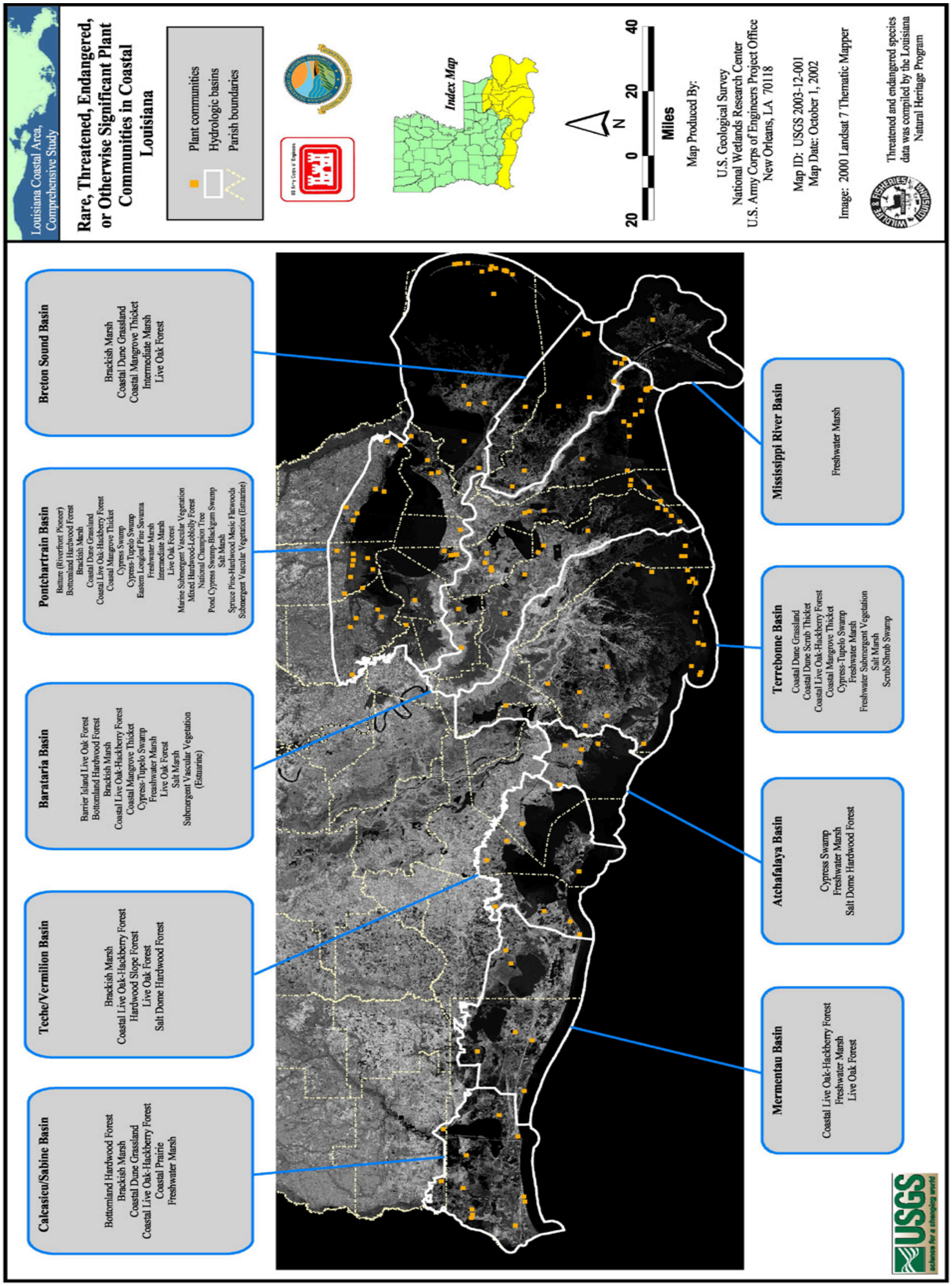


Figure 3-28. Rare, threatened, endangered, or otherwise important plant communities in coastal Louisiana *(from LNHP).*

Some examples of the unique communities include floating marshes, barrier island and coastal dune communities, and maritime forests (Craig et al. 1987; Sasser 1994). The LNHP classification system (Craig et al. 1987) provides descriptions of coastal Louisiana's natural plant communities, their dynamics, locales, and a community status ranking. Each identified community is assigned a ranking according to its relative occurrence and/or level of security or endangerment within the state. Many unique communities in coastal Louisiana are listed by the LNHP as imperiled or critically imperiled because of their rarity or vulnerability to extirpation (local extinction). The following are LNHP descriptions of communities occurring in the Louisiana coastal area that have been designated as imperiled or critically imperiled. The wide range of these communities provides an illustration of the extent of the recognized threat to Louisiana's rich habitat diversity.

The following unique communities, nestled within the broader vegetative habitats, are important in that they contribute to the extensive diversity of the coastal ecosystem, are the basis for its productivity, and are essential to the stability of the bionetwork. Overall, plant communities provide protection against substrate erosion and contribute food and physical structure for cover, nesting, and nursery habitat for wildlife and fisheries. Continued degradation and loss of existing wetland areas, in concert with truncation of replenishing processes, will accelerate decline in the interdependent processes of plant production and vertical maintenance necessary for a stable ecosystem.

- Marine Submergent Vascular Vegetation Communities: Also known as seagrass beds, occur in shallow, relatively clear offshore marine systems with unconsolidated substrate. The primary community species listed are turtle grass (*Thalassia testudinum*), manatee grass (*Syringodium filiforme*), sea grass (*Halophila engelmanii*), shoal grass (*Halodule wrightii*), and widgeon grass (*Ruppia maritima*).
- Estuarine Submergent Vascular Vegetation Communities: Composed primarily of water celery (*Vallisneria americana*), widgeon grass, southern naiad (*Najas guadalupensis*), and horned pondweed (*Zannichellia palustris*). These brackish communities grow in sand/mud bottom substrates in shallow, protected waters with low turbidity. Activities that cause long-term increase in turbidity in the waters surrounding the beds are a serious threat to their viability. This community is ranked as imperiled.
- Coastal Mangrove Thicket: Dominated by black mangrove (*Avicennia germinans*), this estuarine community has several important ecological functions - he extensive root systems stabilize shorelines and reduce erosion, provide cover and food, improve surrounding water quality by filtering nutrients and suspended sediments, and provide nesting areas for colonial water birds.
- Coastal Dune Grassland: Also known as maritime grasslands, occurs on beach dunes, relatively elevated backshore areas above intertidal beaches on barrier islands, and mainland shores. The frequent flooding, erosion, and shifting dune substrate constantly influence the dynamic community composition. Marshhay cordgrass is usually the dominant species, but saltgrass (*Distichlis* sp.), seashore paspalum (*Paspalum vaginatum*), beach panicgrass (*Panicum amarum*), seacoast bluestem (*Schizachyrium maritimum*), and broomsedges (*Andropogon* sp.) are common associates.

- Coastal Dune Shrub Thicket: Occur on stabilized sand dunes and beach ridges on barrier islands and mainland coast. It is of very limited extent in Louisiana due to relatively poorly developed coastal dunes. This community normally appears as a relatively dense stand of shrubs that usually include wax myrtle (*Myrica cerifera*), yaupon (*Ilex vomitoria*), marsh elder (*Iva frutescens*),eastern baccharis (*Baccharis halimifolia*), and occasionally acacia (*Acacia smallii*) and toothache tree (*Zanthoxyllum clava-herculis*).
- Barrier Island Live Oak Forest: In 1999, the LNHP designated a separate community classification, barrier island live oak forest, to describe the single known extant live oak (*Quercus virginiana*) community on Grand Isle, a Louisiana barrier island.
- Vegetated Pioneer Emerging Delta: These communities are dynamic, forming primarily within the actively building delta region at the mouth of the Atchafalaya River. Zonation of species occurs on the newly accreted land. This very diverse community is successional in nature, changes rapidly with time, and is restricted to one region of Louisiana.
- Coastal Prairie: The coastal prairie was once very extensive in southwestern Louisiana, but today, of the approximately 2.5 million original acres, less than 100 acres remain and are relegated to small remnant parcels. The coastal prairie is extremely diverse and dominated by grasses, sedges, rushes, and a wide variety of forbs. Fire is a major contributor to the maintenance of the prairie, and its suppression allows certain woody species to invade.
- Live Oak Forest: Occurs principally in southeastern Louisiana on natural levees, ridges, or frontlands, and on islands within marshes and swamps in the coastal zone. Live oak dominates the stand, but water oak (*Quercus nigra*), American elm (*Ulmus americana*), sugarberry (*Celtis laevigata*), red maple (*Acer rubrum*), and green ash (*Fraxinus pennsylvanica*) are usually prominent community members. There are only a small number of populations known to exist and they are vulnerable to extirpation (local extinction).
- Salt Dome Hardwood Forest: This community is a variable mixed forest that occurs on the elevated salt domes near the coast. The natural community includes live oak, various elms (*Ulmus* sp.), and other species not typical of hardwood slope forests above the coastal zone.
- Coastal Live Oak-Hackberry Forest: Also known as chenier maritime forest, this is a natural community that formed on abandoned beach ridges primarily in southwest Louisiana, although abandoned beach ridges and stream levees in the southeast are also locally known as cheniers. Live oak and hackberry (also referred to as sugarberry) are the dominant canopy species, and other common species are red maple, sweet gum (*Liquidambar styraciflua*), water oak, green ash, and American elm. These species populate ridges composed primarily of reworked sand and shell that are normally four to five feet (1.2 to 1.5 m) above sea level. Cheniers serve as natural hydrologic buffers, providing some protection for the interior marshes against saltwater intrusion.
- Live Oak-Pine-Magnolia Forest: Also known as maritime mesophytic forest, this vegetation type principally occurs in sandy soil within two miles (3.2 km) of Lake Pontchartrain where the Pleistocene prairie terrace meets the lake. This community

exhibits site-to-site variation in species composition, and may experience exposure to salt spray and saltwater inundation associated with storm events.

- Fresh Marsh: Although the fresh marshes, as previously described, compose a large amount of the entire coastal marsh acreage, the LNHP ranks this community as imperiled because it has undergone the largest reduction in acreage of any of the marsh types over the past 20 years due to saltwater intrusion. In general, this community occurs on substrates with the highest organic matter content of any marsh type, making it more vulnerable to loss through erosion and subsidence.
- Floating Fresh Marsh: Also known as flotant marsh, it is included within the LNHP's overall fresh marsh classification and therefore is not described or ranked separately as a distinct community subclass. Nevertheless, it is discussed separately in this writing for two reasons. First, in North America the largest areas of floating marsh appear to be in the freshwater marshes of the Louisiana Deltaic Plain (Mitsch and Gosselink 1993). Second, in the last decade work by Sasser (1994) and Visser et al. (1999) brought to light that the extensive maidencane (*Panicum hemitomon*)-dominated, thick mat flotant described by O'Neil in 1949 has been drastically reduced.

3.8 WILDLIFE RESOURCES: BIRDS, MAMMALS, AMPHIBIANS, AND REPTILES

3.8.1 Historic and Existing Conditions

This resource is institutionally significant because of the Fish and Wildlife Conservation Act of 1980, the Fish and Wildlife Coordination Act of 1958, as amended, the Migratory Bird Conservation Act, the Migratory Bird Treaty Act, the Endangered Species Act of 1973 (ESA), and Executive Order 13186 Migratory Bird Habitat Protection. Wildlife resources are technically significant because they are a critical element of the various coastal habitats, they are an indicator of the health of various coastal habitats, and many wildlife species are important commercial resources. Wildlife resources are publicly significant because of the high priority that the public places on their esthetic, recreational, and commercial value.

The biodiversity characterizing coastal Louisiana is nationally significant. Coastal Louisiana contains an estimated 40 percent of the vegetated estuarine wetlands in the contiguous United States. Louisiana's coastal wetlands provide important habitats for various life cycle phases for over 50 rare, threatened, or endangered species including: piping plover (*Charadrius melodus*), bald eagle (*Haliaeetus leucocephalus*), brown pelican (*Pelicanus occidentalis*), Kemp's Ridley sea turtle (*Lepidochelys kempii*), loggerhead sea turtle (*Caretta caretta*), diamondbacked terrapin (*Malaclemys terrapin*), Gulf sturgeon (*Acipenser oxyrinchus desotoi*), and Louisiana black bear (*Ursus americanus luteolus*). In the Barataria-Terrebonne estuary alone, one of the most degraded but most productive and diverse estuary complexes of coastal Louisiana, it is estimated that 353 species of birds are known to occur, of which 185 species are annual returning migrants. In total, approximately 735 species of birds, finfish, shellfish, reptiles, amphibians, and mammals spend all or part of their life cycle in the estuary (http://www.btnep.org).

The wetlands and associated habitats of coastal Louisiana are of national importance and provide essential habitat to diverse and abundant wildlife resources, including a wide range of resident and migratory birds as well as critical habitat for the wintering populations of the piping plover. Coastal Louisiana has the Nation's largest concentrations of colonial nesting wading birds and seabirds. One hundred ninety-seven colonies of wading birds and seabirds (representing 215,249 pairs of nesting birds), were observed in coastal Louisiana during a 2001 survey (Michot et al. 2003). Louisiana coastal marshes provide habitat to 14 species of ducks and geese (those species for which data is available), including approximately 50 percent of the wintering duck population of the Mississippi Flyway (Michot 1996).

Coastal Louisiana's marshes, swamps, and associated habitats support millions of neotropical and other migratory avian species such as rails, gallinules, shorebirds, wading birds, and numerous songbirds. The rigors of long distance flight require most migratory birds to rest and refuel several times before they reach their final destination. Louisiana coastal wetlands provide migratory birds essential stopover habitat on their annual migration route. During the spring, many of these birds are on their way to nesting areas further north. Migration in the fall is important since it provides resting and refueling habitat prior to crossing the Gulf of Mexico. These advantages certainly enhance survival of individual migrating birds, increases in population size, and in time, survival potential for the species as a whole.

Reincke et al. (1989) describe the importance of the Mississippi alluvial valley for migrating and wintering waterfowl. Continuing losses of wintering habitat (Tiner 1984; Forsythe 1985) and a better appreciation of the interdependence of waterfowl requirements throughout the annual cycle (Anderson and Batt 1983) have led to a more balanced concern for the conservation of breeding, migration, and wintering habitats. The North American Waterfowl Management Plan (NAWMP) (Canadian Wildlife Service [CWS] and USFWS 1986), a multi-nation agreement for the management of waterfowl, proposes to restore prairie nesting areas and protect migration and wintering habitat for waterfowl and other migratory bird populations in the lower Mississippi River and Gulf Coast regions, among others. The NAWMP identifies coastal Louisiana as part of one of the most important regions in North America for the maintenance of continental waterfowl populations.

Coastal Louisiana has been a leading fur-producing area in North America. Common furbearers include nutria (*Myocastor coypus*), mink (*Mustela vison*), muskrat (*Ondatra zibethica*), raccoon (*Procyon lotor*), and river otter (*Lutra canadensis*). The coastal marshes and swamps also support game mammals such as white-tailed deer (*Odocoileus virginianus*) and swamp rabbit (*Sylvilagus aquaticus*) and smaller mammals such as bats, mice, and squirrels. Louisiana marshes provide abundant habitat for many reptiles, most notably the American alligator (*Alligator mississippiensis*). Coastal Louisiana supports approximately 1.5 million alligators, for which sport and commercial hunting is strictly regulated. The swamps and fresh/intermediate marshes support many amphibians, especially various frog species.

The following information is taken from the Coast 2050 report and appendices B – F (specifically, tables 1-4), which provide the most recent information about wildlife functions, status, trends, and projections for the entire LCA Study area. A general discussion is presented for those instances where species or species groups have been decreasing or increasing in abundance over the last 10 to 20 years.

3.8.1.1 Subprovince 1 – Pontchartrain Basin, Breton Basin, and Eastern Mississippi River Delta

Wintering waterfowl use is high in parts of the upper subprovince, including the La Branche area, Bayou Sauvage, and Delta National Wildlife Refuges (NWR); Pass a Loutre Wildlife Management Area (WMA); and the Chandeleur Islands. Dabbling duck and diving duck numbers are increasing in the vicinity of freshwater diversions, such as in the Caernarvon area. However, numbers have somewhat declined where the MRGO has had a negative influence. Wading bird colonies are present in suitable habitat throughout the area and have been steady or increasing in those areas. The outer saline marshes and the Chandeleur Islands contain several seabird colonies that have been decreasing as those marshes continue to decline.

Game mammals and furbearers are generally associated with forested wetlands. The wetlands of this subprovince were an important area for the production of furbearers. In recent history, fur production has been on a downward trend. This decline is largely attributed to saltwater intrusion and a corresponding reduction in carrying capacity for fur animals such as the muskrat and nutria (Kerlin 1979).

American alligator abundance has been increasing in the upper portions of the subprovince and decreasing in the lower portions, but overall has declined as fresh marsh converted to intermediate and brackish marsh. According to Dundee and Rossman (1989), several amphibians and reptiles occupy a wide variety of habitats throughout the subprovince.

3.8.1.2 Subprovince 2 – Barataria Basin and Western Mississippi River Delta

Over the past 10 to 20 years, duck numbers have declined in the brackish and saline marshes and increased in the vicinity of freshwater diversions. The decline is a result of marsh loss and a conversion to saltier marsh types as marine forces increasingly penetrate into the interior marshes of this basin. The abundance of seabirds, wading birds, shorebirds, and other birds using marsh and open water habitats is declining in areas of high land loss. There are nearly 100 waterbird nesting colonies known within the area in every habitat type from cypress swamp to barrier islands. Brown pelican and bald eagle abundance is increasing, primarily as a result of improved nesting success in other parts of the coast.

Furbearer, alligator, and game mammal populations have decreased in areas of land loss, mainly the lower basin. Populations appear steady in the rest of the subprovince.

3.8.1.3 Subprovince 3 – Terrebonne, Atchafalaya, and Teche/Vermilion Basins

The bald eagle has increased in numbers over the past 10 to 20 years as a result of increased nesting in and around this subprovince. Over the last 10 to 20 years, dabbling ducks, wading birds, shorebirds, seabirds, furbearers, and alligators have experienced decreasing populations in eastern Terrebonne Basin as a result of marsh loss and a conversion to saltier marsh types. Across this subprovince, the greatest loss of coastal wetlands has occurred in the fresh and intermediate marshes of the Terrebonne Basin. Terrebonne Basin fresh and intermediate marshes and swamp represent a major fall staging and wintering area for migratory waterfowl.

With steady growth of emergent wetlands occurring since 1973, the Atchafalaya Basin has experienced an increase in wildlife usage and provides excellent habitat for most wildlife species/species groups. Atchafalaya Delta WMA provides some of the highest quality habitat for wintering waterfowl in coastal Louisiana. Beneficial use of dredged material has created nesting habitat in the Atchafalaya Delta WMA that has become important for nesting colonial seabirds in Louisiana (Carloss 1997 and Leberg et al. 1995). Wading bird nesting colonies exist on both the Wax Lake Delta and the Main Delta. Neotropical migrants use forested areas extensively during migration. There are numerous waterbird nesting colonies within the subprovince, the most significant on Raccoon Island.

Consistent with the stable wetland conditions and freshening across the Teche/Vermilion Basin, the trend for most wildlife species/species groups has been one of stable or, in some cases, increasing populations.

3.8.1.4 Subprovince 4 – Calcasieu-Sabine and Mermentau Basins

The most recent trend toward marsh stability and the diversity of marshes in the area have led many species to exhibit increasing or stable population trends over the past 10 to 20 years. Increasing populations of the American alligator have been associated with fresh and intermediate marshes, while several groups of birds, such as waterfowl, have also been increasing in population. Stable populations of furbearers, seabirds, coots, rails, and game mammals also exist in this subprovince. This subprovince generally provides high quality habitat for waterbirds and wading birds. Several amphibians and reptiles are common to the Mermentau and Calcasieu/Sabine Basins and occupy a variety of habitats.

3.8.2 Invasive Mammalian Species

The following information is taken from LDWF et al. (2003). The two mammals identified as invasive species in Louisiana are the nutria and feral hogs (*Sus scrofa*).

Nutria are large, rodent-like, herbivorous, aquatic mammals with large orange incisor teeth. They were introduced to Louisiana from Argentina between 1900 and 1940 for fur farming. However, when some fur farms failed, the nutria were released into the wild, and it was thought they would act as a biocontrol for invasive water hyacinth (LeBlanc 1994).

Nutria are prolific breeders and they exacerbate coastal wetland loss by digging into soft wetland soils and eating the roots of marsh vegetation. As the vegetation dies, the soft soils become open water; these holes in the marsh are called “eat-outs” (USGS 2000). Historically, fur demand meant that hunters and trappers kept populations somewhat in check. After the price of nutria pelts plummeted in 1989, however, nutria populations began to grow unbounded (USGS 2000).

The Coastwide Nutria Control Program, approved under CWPPRA in 2002, is designed to remove approximately 400,000 nutria annually through an incentive payment program designed to encourage nutria harvesting. Thus far, the program has collected 308,160 nutria tails from 342 participants. The preliminary results indicate that the 2002-2003 harvest overlaps with nutria damage (vegetative eat outs) from 2002.

Feral hogs are actually a combination of purebred wild boars, purebred domestic livestock, and hybrids of those two species (Aguirre and Poss 1999). Besides competing with deer, bears, rabbits, and other native species for habitat and food resources, feral hogs can pose a serious risk to Louisiana residents. In their quest for food, feral hogs damage hurricane protection levees with their snouts and hooves (Jensen 2001). Weakening hurricane protection levees is a very serious problem in Louisiana; without levees, low-lying areas are more prone to floods from storm surges caused by heavy winds, such as in a hurricane.

3.9 PLANKTON RESOURCES

3.9.1 Historic Conditions

Plankton communities serve an important role in the coastal waters of Louisiana. The plankton are composed of three groups, the bacterioplankton, phytoplankton, and zooplankton (Knox 2001). The phytoplankton are the primary producers of the water column, and form the base of the estuarine food web. The zooplankton provide the trophic link between the phytoplankton and the intermediate level consumers such as aquatic invertebrates, larval fish, and smaller forage fish species (Day et al. 1989). Microzooplankton appear to be important consumers of bacterioplankton, which are typically enumerated primarily by culture and microscopic techniques. Culture techniques are selective and invariably underestimate bacterial densities (Day et al. 1989).

"The Cooperative Gulf of Mexico Estuarine Inventory and Study, Louisiana," prepared by the Louisiana Wildlife and Fisheries Commission in 1971, provides a summary of plankton across the coastal estuaries of Louisiana in the late 1960s (Perret et al. 1971).

The dominant member of the zooplankton community throughout that study was the copepod *Acartia tonsa*. The greatest concentrations of zooplankton were encountered in Breton Sound. The lowest concentrations were encountered in Chandeleur Sound and Lake Borgne east of the Mississippi River, Lakes Barre and Raccourci, and Terrebonne and Timbalier Bays. Species diversity was greatest in the Breton Sound and Mississippi River, East Bay, Garden Island Bay, and West Bay areas. Historically, salinity appears to be the chief controlling factor in the number of species present, while temperature, competition, and predation control the number of individuals present. In addition, the abundance of certain zooplankton may be indicative of good fishing areas.

3.9.2 Existing Conditions

3.9.2.1 Phytoplankton

Phytoplankton are tiny, single-cell algae that drift with the motion of water. The dominant groups are diatoms and dinoflagellates, and other important groups include cryptophytes, chlorophytes (green algae), and chrysophytes (blue-green algae). In Louisiana, eutrophic conditions can lead to noxious blooms of blue-green algae, often dominated by single species of the genus *Anabaena* or *Microcystis.* Some species produce toxins, and large scale blooms can lead to hypoxic conditions, which results in fish kills in some cases. Such blooms tend to occur in fresh or oligohaline waters, up to approximately 7 ppt salinity.

In recent years, blooms of blue-green algae have been observed in several coastal lakes in Louisiana. Large-scale blooms occurred in Lake Pontchartrain in 1993 and 1997, with smaller blooms observed in other years. The 1997 bloom occurred after a month-long opening of the Bonnet Carre Spillway, which introduced up to 240,000 cfs of Mississippi River water into Lake Pontchartrain. Blooms in the lake are not unusual in July or August, when light winds allow for low turbidity. This in turn allows for light penetration into the water column, and in combination with high nutrient concentrations and high temperatures, conditions are optimal for phytoplankton growth. Lake Pontchartrain, Lac Des Allemands, and various other coastal lakes that receive runoff high in nutrients experience algal blooms under such conditions. Runoff from fertilized areas, including lawns, golf courses, agricultural fields, and both treated and untreated sewerage provide nutrients that cause such lakes to be eutrophic. Such water bodies tend to be high in primary productivity, which fuels the estuarine food web. Abundant growth of green algae can be observed in healthy water bodies. Phytoplankton production is the major source of autochthonous organic matter (produced within the system) in most estuarine systems (Day et al. 1989). However, too much productivity can be detrimental to a lake's ecology when blooms, particularly blooms of blue-green algae, occur.

Lane et al. (1999) studied water quality impacts of the Caernarvon Freshwater Diversion Project, which diverted approximately 740 to 7,500 cfs of water from the Mississippi River into the Breton Sound, depending on the month of the year. The authors concluded that "there was no significant impact of the diversion at all of the water quality monitoring stations for $NO_2 + NO_3$." Specifically, they stated that rapid reduction of $NO_2 + NO_3$ seemed to occur, indicating that "the Breton Sound wetlands and shallow waters were acting as a strong sink for $NO_2 + NO_3$." The study also concluded that the total nitrogen and total phosphorus levels did not have a significant impact due to the diversion.

In south central Louisiana, Rabalais et al. (1995) found that the sediment record (from the Barataria and Terrebonne salt marshes) indicates that the wetlands adjacent to the estuarine system incompletely buffer the effects of increased nutrient loading on water quality and that the ability of the wetlands to absorb additional amounts of nutrients is much less than 100 percent.

Phytoplankton in more saline environments can cause a different kind of bloom; *Karenia breve* (formerly known as *Gymnodinium breve*), for example, is a dinoflagellate that has been associated with red tides. Red tides are so named because the prolific growth stains the water red. Toxins associated with red tides are capable of killing fish and shellfish. Red tide populations well below the fish kill level pose a serious problem for public health through shellfish contamination. Bivalve shellfish, especially oysters, clams, and coquinas, can accumulate so many toxins that they become toxic to humans. Public health concerns also emerge from studies that show that the presence of airborne toxins have an impact on the human respiratory system (Mote Marine Lab website: http://www.marinelab.sarasota.fl.us/~mhenry/WREDTIDE.phtml). Freshwater diversion has been utilized in some instances to attempt to reduce the spread of red tides into coastal waters.

3.9.2.2 Zooplankton

Zooplankton are faunal components of the plankton, including small crustaceans such as copepods, ostracods, euphausiids, and amphipods; the jellyfishes and siphonophores; worms, mollusks such as pteropods and heteropods; and the egg and larval stages of the majority of benthic and nektonic animals (Rounsefell 1975). Zooplankton are weakly swimming animals comprised of two broad categories: holoplankton, which are planktonic species as adults, and meroplankton, which are organisms that occur in the plankton during early life stages before becoming benthic or nektonic (most common are immature forms of benthic invertebrates). Zooplankton serve as food for a variety of estuarine consumers, but also are important for their role in nutrient cycling.

Although there are no clear general patterns of zooplankton abundance in estuaries, some regional seasonal patterns have been described (Day et al. 1989). The zooplankton of many estuarine water bodies are dominated by copepods of the genus *Acartia.* Cyclopoid copepods and cladocerans are often abundant in low salinity waters of Louisiana (Hawes and Perry 1978). Zoeae (a larval stage in some crustaceans) can make up a large component of the meroplankton. Zooplankton in Louisiana waters are in some cases dominated by zoeae of the mud crab *Rithropanopeus harrisii*.

While some zooplankton are euryhaline, others have distinct salinity preferences. Therefore, introduction of river water into estuarine systems can have dramatic short-term impacts on plankton populations in adjacent coastal waters (Hawes and Perry 1978).

3.10 BENTHIC RESOURCES

3.10.1 Historic and Existing Conditions

The bottom estuarine substrate (benthic zone), regulates or modifies most physical, chemical, geological, and biological processes throughout the entire estuarine system via what is commonly called a "benthic effect" (Day et al. 1989). Within a salt marsh, less than 10 percent of the above-ground primary production of the salt marsh is grazed by aerial consumers. Most plant biomass dies and decays and its energy is processed through the detrital pathway. The major consumer groups of the benthic habitat include: bacteria and fungi, microalgae, meiofauna, and microfauna (Mitsch and Gosselink 1993).

Benthic community structure is not static, it provides a residence for many sessile, burrowing, crawling, and even swimming organisms. The benthic community is a storehouse of organic matter and inorganic nutrients, as well as a site for many vital chemical exchanges and physical interactions. Day et al. (1989) describe the functional groups of estuarine benthic organisms. These groups include: macrobenthic (e.g., molluscs, polychaetes, decapods); microbenthic (e.g., protozoa); meiobenthic (e.g., nematodes, harpacticoid copepods, tubillaria), epibenthic; infauna (e.g., most bivalves); interstitial fauna (e.g., beach meiofauna, tardigrades); suspension-feeders (e.g., bryozoa and many bivalves); filter-feeders (e.g., porifera, tunicates, bivalves); non-selective deposit feeders (e.g., gastropods); selective deposit feeders (e.g., nematodes, sand dollars, fiddler crabs); raporial feeders and predators (e.g., star fish and gastropod drills); and parasites and commensuals (e.g., parasitic flatworms and copepods, pea crabs).

According to Mitsch and Gosselink (1993), the salt marsh is a major producer of detritus for both the salt marsh system and the adjacent estuary. They point out that the detritus material exported from the marsh is more important to the estuary than the phytoplankton-based production in the estuary. Detritus export and the shelter found along marsh edges make salt marshes important nursery areas for many commercially important fish and shellfish. Salt marshes have been shown at times to be both sources and sinks of nutrients, particularly nitrogen.

3.10.2 Outer Continental Shelf Benthic Resources

3.10.2.1 Benthic Environment of the Ship Shoal Area

As described in section 3.3 OFFSHORE SAND RESOURCES, offshore sand shoals and the larger nearshore sand bodies represent potential sources for the millions of tons of sand sediment that would be necessary for coast wide restoration. With its extensive oil and gas activities, the benthic resources on Ship Shoal have been extensively studied. The following is a summary of the benthic resources on Ship Shoal provided by the MMS.

Ship Shoal is a Holocene sand body located on the south-central Louisiana inner shelf 15 kilometers seaward of the Isles Dernieres. It is approximately 50 km (31 miles) long and 12km (7 miles) wide. It lies in a water depth of six to nine meters and is composed primarily of well-sorted quartz sand, a benthic substrate not commonly found on the Louisiana inner shelf (Stone 2000).

The benthic communities are threatened by two natural environmental perturbations that occur on the Louisiana continental shelf (LCS), anoxic to hypoxic bottom conditions and tropical cyclones. The change from anoxic to hypoxic conditions occurs annually with inconsistent intensities and ranges (Rabalais et al. 1993). On average, one tropical cyclone visits the LCS once every four years, which can vary in intensity (Stone 2000). It can take anywhere from one to two years for the benthic communities to recover from either of these events (Baker et al. 1981).

In a Southwest Research study conducted by Baker et al. in 1981, samples from the LCS, including Ship Shoal, were studied to determine the ecological effects of petroleum production platforms in the central Gulf of Mexico. The sampling stations for Ship Shoal were located roughly 27km (17 miles) from the shore, in approximately six meters of water. Results from this study indicated that the benthic communities of the Ship Shoal varied from that found throughout the LCS.

The taxonomic composition of meiofauna on Ship Shoal varied significantly from the meiofauna found in the LCS. Foraminefera, which were found to be high in both species richness and diversity in benthic communities on the LCS, only comprised 0.2 percent of all meiofauna found on Ship Shoal (**table 3-5**). Only *Bolvina lowmani*, one of the four dominant species of foraminefera located on the LCS, was found in significant abundance on Ship Shoal. Conversely, the distribution of taxa Nematoda, which were not found high in species richness on the LCS, comprised 97.7 percent of the total meiofauna, and included predominantly Cyantholaimidae, Theristus, Sabatieria, Linhomoe, Choniolaimade and Chromadoriade (Baker et al. 1981). The high taxonomic composition of Nematoda on Ship Shoal can most likely be attributed to the high sand content of the shoal and is an indication that sand on Ship Shoal is non-polluted (Baker et al. 1981).

Macroinfauna Polychaeta was found in similar taxonomic composition on both Ship Shoal and the LCS. Polychaeta consisted of 62.6 percent of the total macroinfauna on Ship Shoal and 69.0 percent on the entire LCS (Baker et al. 1981). The density and diversity of taxa Polychaeta on the LCS were found to be higher than those seen on Ship Shoal, except in areas where the sediment composition was similar to that of Ship Shoal (sand). Polychaetes are known to favor a less sandy substrate, explaining the low values of diversity and density of Polychaeta on ship Shoal.

Table 3-5. Percent taxonomic composition of meiofauna, macroinfauna and macroepifauna for the Baker et al. (1981) study.

Category and Taxa	Ship Shoal (%)	Louisiana Continental Shelf (%)
Meiofauna		
Formineferia	0.2	55.3
Nematoda	97.0	34.7
Macroinfauna		
Polychaeta	62.6	69.0
Macroepifauna		
Osteichytes	69.3	32.8
Decapoda	30.7	25.7

Results from the Southwest Research Institute study indicated that the prevailing macroepifauna and demersal fish on Ship Shoal are located in the taxa Osteichytes (69.3 percent) and Decapoda (30.7 percent) (**table 3-5**). Taxa Decapoda, although similar in taxonomic composition to that found on the LCS, was lower in diversity on Ship Shoal. The taxa Osteichytes was found to be particularly higher in taxonomic composition (69.3 percent) of the total macroepifauna, but lower in diversity when compared to the entire LCS. Shallower water depths such as those found on Ship Shoal were correlated to a larger abundance of taxa Osteichytes and would explain the increased taxonomic composition (Baker et al. 1981). The biomass of demersal fish on Ship Shoal was found to be much higher than those of the LCS on average. The biomass on Ship Shoal was recorded at 68.7 kg/hr (151.8 pounds/hr) in comparison to an average of 19.6 kg/hour (43.3 pounds/hr) throughout the LCS (Baker et al. 1981). These results suggest that Ship Shoal is an extremely productive ground for demersal fish in the context of the LCS.

The diversity, taxonomic composition, and presence of opportunistic species indicate that the fauna residing on Ship Shoal and the LCS are stressed. This slightly depressed state may remain constant because of the periodic perturbations and recovery time needed by benthic communities. Even though the benthic communities of the LCS are stressed they still resemble the assemblages of similar environments. Results from the Southwest Research Study found that the benthic assemblages on the LCS and Ship Shoal were similar to those found offshore of Texas and the eastern United States despite their depressed state (Baker et al. 1981; Vittor 1987).

3.11 FISHERIES RESOURCES

3.11.1 General

This resource is institutionally significant because of the Magnuson-Stevens Fishery Conservation and Management Act of 1976, as amended (Magnuson-Stevens Act), the Fish and Wildlife Coordination Act of 1958, as amended, and the Endangered Species Act of 1973 (ESA). Fisheries resources are technically significant because they are a critical element of many valuable freshwater and marine habitats, they are an indicator of the health of various freshwater and marine habitats, and many fish species are important commercial resources. Fisheries resources are publicly significant because of the high priority that the public places on their esthetic, recreational, and commercial value.

Louisiana's vast and biologically diverse coastal area serves as an important gulf coast estuarine system, which functions as a nursery, feeding, spawning, and growout area for many aquatic organisms. Louisiana ports produce a catch comparable to that of the entire Atlantic seaboard, and more than triple that of the remaining gulf states (NMFS 2001). Four Louisiana ports have ranked among the top 10 in value of commercial fisheries landings throughout the U.S. since 1981 (NMFS 2003a). Louisiana's commercial landings have been over one billion lbs/yr for over 20 years, with a value exceeding $400 million in 2000. White shrimp (*Litopenaeus setiferus)*, brown shrimp (*Farfantepenaeus aztecus*), and gulf menhaden (*Brevoortia patronus*) account for the majority of commercial harvest by value (personal communication from NMFS Statistics and Economics Division).

The term fish, as used in this document, includes a variety of finfish and shellfish. There are several ways to profile this diverse collection of organisms. For the purpose of this DPEIS, the general salinity preference of an organism for the freshwater, estuarine, or marine environment is used.

Freshwater species inhabit lakes, rivers, and backwaters where salinities remain low. Lagoons, bayous, and ponds throughout Louisiana provide excellent freshwater habitat for species such as largemouth bass (*Micropterus salmoides*), crappie (*Pomoxis* spp.), various other sunfish species, and catfish (*Ictalurus* sp.).

The majority of the LCA Study area is considered estuarine habitat; therefore, estuarine aquatic organisms are a significant resource within the project area. Estuarine fishery species may be resident (species residing in the estuary throughout their life cycle), such as killifishes (*Cyprinodontidae*), or transient (species that use estuaries during their life cycle), such as gulf menhaden, blue crab (*Callinectes sapidus*), and shrimp.

Marine species are found in offshore waters throughout the gulf coast and generally do not depend on coastal estuaries to complete any part of their life cycle. These species are in some ways dependant on the health and productivity of coastal estuaries, in that their prey often are made up of estuarine dependant species. In addition, some marine species frequently inhabit the lower reaches of estuaries, where productivity is high.

The American oyster (*Crassostrea virginica*) is indigenous to coastal Louisiana, and provides a rich ecological and commercial resource. This organism is unique in that it does not migrate like other estuarine species. Salinity plays a key role in oyster sustainability. Typically, they proliferate in salinities ranging from 5 to 15 parts per thousand. Fresher waters fail to support biological function, and more saline waters promote disease and predation.

3.11.2 Historic and Existing Conditions

Louisiana commercial landings have increased significantly since the early 1900s and recreational harvests have been relatively stable for the past 10 years. Coastal habitats that support Louisiana fisheries have been impacted over the last 50 years by subsidence, sea level change, channelization of bayous, dredging of canals, and intensive management of marshes for wildlife and waterfowl. **Table 3-6** provides a 10-year average value for the most economically important species in Louisiana, and their value relative to the Gulf of Mexico and United States landings.

Table 3-6
The Top Four Valued Fisheries in Louisiana for the 10-year Period 1992-2001

Fishery	10-year Average Dollars	% of Gulf Value	% of U.S. Value
Shrimp	163,261,317	35%	29%
Menhaden	56,125,930	85%	54%
Blue Crab	27,365,792	70%	20%
Oyster	24,857,736	58%	26%

Personal communication from the National Marine Fisheries Fisheries Statistics and Economics Division, Silverspring, MD

Even though extensive areas of marsh have been lost in coastal Louisiana, commercial harvest and recreational catches of most species have not diminished (NMFS Statistics and Economics Division – personal communication). It is important to note that recreational catch and commercial landings are fishery dependent data. The increase in Louisiana landings may reflect the expansion of the commercial fishing industry, the growing efficiency in harvest technologies, and the growing demand for seafood over the past century. One hypothesis to explain continued high fisheries production is that as marshes have deteriorated, tremendous amounts of organic detritus have been released into the estuarine system, consequently driving high levels of primary productivity. High primary productivity increases the resources available for secondary productivity. Additionally, an increase in marsh to water interface (i.e., marsh edge), and the formation of shallow, protected lagoons and ponds, has resulted in prime areas for growth and development of estuarine species (Browder et al. 1985; Browder et al. 1989; Minello and Rozas 2002). At the same time, saltwater intrusion into previously low-salinity areas has increased the amount of estuarine area available to estuarine and marine fishery species (Chesney et al. 2000; Zimmerman et al. 2000). However, this intrusion can exacerbate marsh loss in those areas (Chabreck and Linscombe 1982; McKee and Mendelssohn 1989).

Production of oysters in Louisiana has been relatively stable for the last 50 years, with harvest from public beds replacing the decreasing harvest from private leases. The Louisiana oyster industry has been experiencing many stressors over the past several decades that threaten the long-term sustainability of both the industry and the resource. Increasing coastal land loss is reducing the amount of marsh that provides shelter to reefs, and saltwater intrusion is exacerbating disease and predation. In addition, the industry is faced with changing environmental conditions, fluctuating market demands, public perception issues, and increased competition.

Current and future fishery population trends are described in the Coast 2050 report (Louisiana Coastal Wetlands Conservation and Restoration Task Force and the Wetlands Conservation and Restoration Authority 1998), and were used to evaluate existing trends and future projections over the LCA Study area. The Coast 2050 report projects fishery population to the year 2050 based on land loss predictions. The selected species represent a group of species similar in habitat requirements, seasonal occurrence in the estuary, salinity preference, and spawning or migratory season. **Figure 3-29** represents a summary of the Coast 2050 report on fisheries population trends and projections for estuarine species.

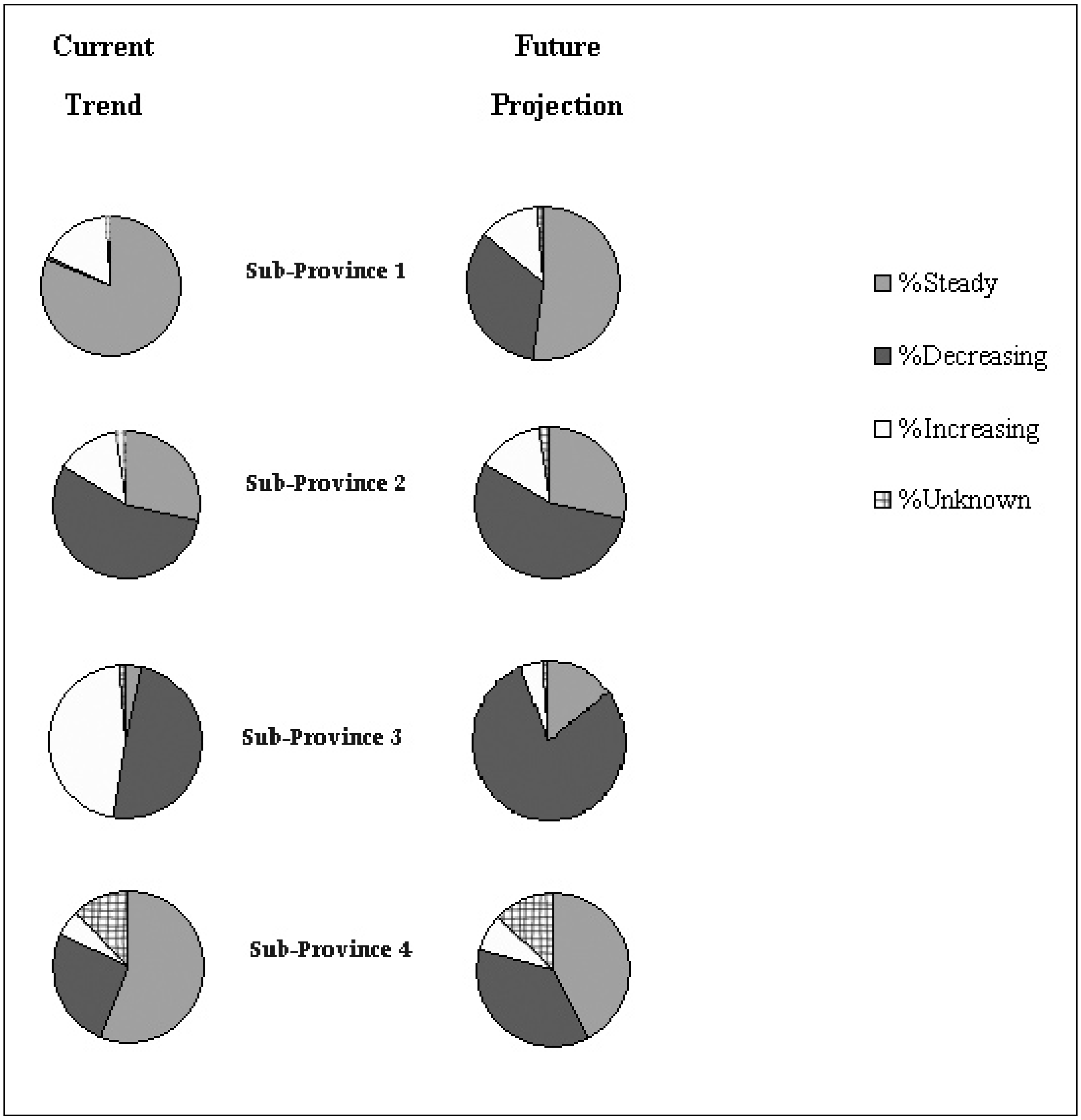


Figure 3-29. Estuarine Fisheries Population Trends and Projections by Subprovince. (*Data from: Louisiana Coastal Wetlands Conservation and Restoration Task Force and the Wetlands Conservation and Restoration Authority 1998)*

3.12 ESSENTIAL FISH HABITAT

This resource has statutory significance because of the Magnuson-Stevens Act (P.L. 104-297), which intended to promote the protection, conservation, and enhancement of Essential Fish Habitat (EFH). The EFH designation is an important component of building and maintaining sustainable marine fisheries through habitat protection. The Magnuson-Stevens Act defines EFH for Federally managed fish species as “those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity.” A summary of EFH requirements for species managed by the Gulf of Mexico Fishery Management Council (GMFMC), and for which EFH has been designated in Louisiana, is in **table 3-7**.

Table 3-7
Summary of the Magnuson-Stevens Fishery Conservation and Management Act (P.L. 104-297) designation of Essential Fish Habitat for Coastal Louisiana*

Species	Life Stage	EFH
Brown shrimp *Farfantepenaeus aztecus*	eggs larvae postlarvae/ juvenile subadult adult	(Marine system) < 110 m, demersal (Marine system) < 110 m, planktonic (Estuarine system) marsh edge, submerged aquatic vegetation, tidal creeks, inner marsh (Estuarine system) mud bottoms, marsh edge (Marine system) < 110 m, silt sand, and muddy sand
White shrimp *Litopenaeus setiferus*	eggs larvae postlarvae/ juvenile, subadult adult	(Marine system) < 40 m, demersal (Marine system) < 40 m, planktonic (Estuarine system) marsh edge, submerged aquatic vegetation, marsh ponds, inner marsh, oyster reefs (Marine system) < 33 m, silt, soft mud
Red drum *Sciaenops ocellatus*	eggs, larvae postlarvae/ juvenile subadult adult	(Marine system) planktonic (Marine and Estuarine systems) submerged aquatic vegetation, estuarine mud bottoms, marsh/water interface (Estuarine system) mud bottoms, oyster reefs (Marine and Estuarine systems) Gulf of Mexico & estuarine mud bottoms, oyster reefs
Red snapper *Lutijanus campechanus*	larvae, postlarvae/juvenile adult	(Marine system) structure, sand/mud; 17-183 m (Marine system) reefs, rock outcrops, gravel; 7-146 m
Vermilion snapper *Rhomboplites aurorubens*	juvenile	(Marine system) reefs, hard bottom, 20-200 m
Spanish mackerel *Scomberomorus maculatus*	larvae juvenile adult	(Marine system) <50 m isobath (Marine and Estuarine system) offshore, beach, estuarine (Marine system) pelagic
Bluefish *Pomatomus saltatrix*	postlarvae/juvenile adult	(Marine and Estuarine systems) beaches, estuaries, and inlets (Marine and Estuarine systems) Gulf, estuaries, pelagic

*Detailed information on Federally managed fisheries and their EFH is provided in the 1998 generic amendment of the Fishery Management Plans for the Gulf of Mexico prepared by the Gulf of Mexico Fishery Management Council (GMFMC).

Proposed activities are unlikely to impact EFH for red snapper and vermilion snapper. Therefore, there will be no further discussion of these species in relation to impacts on EFH. Primary categories of EFH that could be impacted as a result of restoration efforts in the LCA Study area include, but are not limited to, estuarine wetlands (e.g., marsh edge, inner marsh, marsh ponds, and tidal creeks); submerged aquatic vegetation; seagrasses; mud, sand, shell, and rock substrates (e.g., oyster reefs and barrier island flats); mangrove wetlands; and estuarine water column. Any activities that may adversely affect EFH should be avoided, minimized, or mitigated to conserve EFH.

Fish and most macro-crustaceans are highly mobile, and they rely on a variety of habitats for different functions (Miller and Dunn 1980). The characteristics of coastal Louisiana waters essential to fish are not static. There are a number of fish species that are Federally managed, with a variety of life stage requirements. The Magnuson-Stevens Act requires a conservative approach to designating EFH. For these reasons, EFH is not confined to isolated locations. All of the estuarine and marine portions of the LCA Study area are considered EFH and are an important consideration in the development of any restoration plan.

3.12.1 Historic and Existing Conditions

As conditions along Louisiana's coast have changed, effects to different categories of EFH have varied. For example, as the marsh has been lost, it has generally been replaced with other categories of EFH, such as submerged aquatic vegetation or mud bottoms. In contrast, in areas where active delta growth is occurring, the opposite may have happened (e.g., mud bottoms have been replaced with marsh). It is important to have a balance between different categories of EFH for the various life stages of Federally managed fishery species in the LCA Study area. The general trend in the recent past has been one of conversion of highly productive categories of EFH, such as inner marsh and marsh edge, to less productive estuarine water column; and mud, sand, or shell substrates. If this trend continues, it is likely to result in less complex, biologically diverse habitats and unsustainable fishery productivity.

All tidally influenced waters and substrates within the subprovinces, including the sub-tidal and tidal vegetation (seagrasses, algae, marshes, and mangroves) are designated as EFH. There are over 8 million acres (3.24 million ha) of marsh and water habitat, of which over 4.4 million acres (1.7 million ha) are surface water. Over half of the waters are between 0 and 1.8 m (0–5.9 ft) in depth (Perret et al. 1971). Sediments are mud, sand, and silt across the coast (Barrett et al. 1971). Submerged vegetation occurs along the coast, but no acreage figure is available, except for Lake Pontchartrain, where an estimated 20,000 acres (8,094 ha) exist (Gulf of Mexico Fishery Management Council 1998).

EFH alterations of particular concern are the marsh loss experienced along the Louisiana coast, as described in section 3.9 PLANKTON RESOURCES. Land/water interface has been shown to be more important to fishery production than total wetland acreage (Faller 1979; Gosselink 1984; Zimmerman et al. 1984).

3.13 THREATENED AND ENDANGERED SPECIES

Within the State of Louisiana there are 25 animal and 3 plant species (some with critical habitats) under the jurisdiction of the USFWS and/or NMFS (see **table 3-8**), which are presently classified as threatened or endangered (see **figure 3-30**). The USFWS and NMFS share jurisdictional responsibility for sea turtles and the gulf sturgeon. Of the animals and plants under USFWS and/or NMFS jurisdiction, only 16 animal and 1 plant species are within the study area. Those species outside of the study area will not be affected by the proposed restoration plans. For a complete description of those species, their critical habitat geographic designations, management objectives, and current recovery status, refer to the USFWS endangered species web site at http://endangered.fws.gov and the NMFS endangered species web site at http://www.nmfs.noaa.gov/prot_res/overview/es.html. In addition, the USFWS has published the "Report to Congress On The Recovery Program For Threatened And Endangered Species, 1996, Appendix" (USFWS 1996). This report assigns each species a Listing Status, Lead Region, Population Status, Recovery Plan, Plan Stage Recovery Achieved, and Recovery Priority (http://endangered.fws.gov/recovery/96apndx.pdf).

Informal coordination with the USFWS and NMFS was initiated to determine potential impacts of conceptual, programmatic restoration alternatives to threatened and endangered species and their critical habitats. Generally, formal coordination and preparation of any necessary documentation such as Biological Assessments, if necessary, would be initiated with either or both of these agencies on a specific project-by-project basis as required. Portions of this section concerning organisms under the jurisdiction of the USFWS was prepared with input from members of the USFWS, Lafayette Field Office, Endangered Species Section. Portions of this section concerning organisms under the jurisdiction of NMFS was prepared with input from members of the Endangered Species regional office in Florida.

3.13.1 Historic and Existing Conditions

From a programmatic standpoint, historic and existing conditions for threatened and endangered species relevant to the LCA Study area principally stem from the alteration, degradation, and loss of habitats; human disturbance and exploitation; and pollution. Louisiana's unabated coastal land loss continues to reduce available coastland resources. This creates increased competition among and between the various threatened and endangered species for scarce coastal resources. A more detailed description of the historic and existing conditions for those threatened and endangered species that may be found in the study area is provided in appendix B1 PROGRAMMATIC BIOLOGICAL ASSESSMENT.

Table 3-8
Threatened and Endangered Species in Louisiana.
(E=Endangered; T= Threatened; C=Candidate)
(Species in bold are those found within the study area)

Species Under Jurisdiction of the USFWS
Status Common Name *Scientific Name*

Mammals
E[1] -- Florida Panther (*Felis concolor coryl*)
E[1] -- Red wolf (*Canis rufus*)
E -- West Indian manatee (*Trichechus manatus*)
T -- Louisiana black bear (*Ursus americanus luteolus*)

Birds
E[2] -- Bachmans's warbler (*Vermivora bachmanii*)
E -- Brown pelican *(Pelecanus occidentalis*)
E[1] -- Eskimo curlew (*Numenius borealis*)
E[1] -- Ivory-billed woodpecker (*Campephilus principalis*)
E -- Least tern; interior population (*Sterna antillarum*)
E -- Red-cockaded woodpecker (*Picoides borealis*)
T -- Bald eagle (*Haliaeetus leucocephalus*)
T -- Piping plover (*Charadrius melodus*)

Reptiles
E -- Hawksbill sea turtle (*Eretomchelys imbricata*)
E -- Kemp's (Atlantic) ridley sea turtle (*Lepidochelys kempii*)
E -- Leatherback sea turtle (*Dermochelys coriacea*)
T(S/A)[3] --American alligator (*Alligator mississippiensis*)
T -- Gopher tortoise (*Gopherus polyphemus*)
T -- Green sea turtle (*Chelonia mydas*)
T -- Loggerhead sea turtle (*Caretta caretta*)
T -- Ringed sawback turtle (*Graptemys oculifera*)
C -- Snake, Louisiana pine (*Pituophis ruthveni*)

Fish
E -- Pallid sturgeon (*Scaphirhynchus albus*)
T -- Gulf sturgeon (*Acipenser oxyrinchus desotoi*)

Invertebrates
E – Mussel, Fat pocketbook (*Potamilus capax*)
E -- Pink pearlymussel Mucket (*Lampsilis abrupta*)
T -- Inflated (Alabama) heelsplitter (*Potamilus inflatus*)
T -- Louisiana pearlshell (*Margaritifera hembeli*)

Plants
E -- American chaffseed (*Schwalbea americana)*
E -- Louisiana quillwort (*Isoetes louisianensis*)
T -- Earth fruit (*Geocarpon minimum*)

Species Under Jurisdiction of NMFS
Status Common Name *Scientific Name*

Marine Mammals
E -- Sperm whale (*Physeter macrocephalus*)
E -- Sei whale (*Balaenoptera borealis*)
E -- Humpback whale (*Megaptera novaeangliae*)
E -- Finback whale (*Balaenoptera physalus*)
E -- Blue Whale (*Balaenoptera musculus*)

Sea Turtles[4]
E -- Hawksbill sea turtle (*Eretomchelys imbricata*)
E -- Kemp's (Atlantic) ridley sea turtle *Lepidochelys kempii*)
E -- Leatherback sea turtle (*Dermochelys coriacea*)
T -- Green sea turtle (*Chelonia mydas*)
T -- Loggerhead Sea Turtle (*Caretta caretta*)

Fish
T -- Gulf sturgeon (*Acipenser oxyrinchus desotoi*)

Candidate Species[5]
Dusky shark (*Carcharhinus obscurus*)
Sand tiger shark (*Odontaspis taurus*)
Night shark (*Carcharinus signatus*)
Speckled hind (*Epinephelus drummondhayi*)
Saltmarsh topminnow (*Fundulus jenkensi*)
Jewfish (*Epinephelus itajara*)
Warsaw grouper (*Epinephelus striatus*)

E[1] The Florida panther, red wolf, Eskimo curlew, and ivory-billed woodpecker are presumed to be extinct in the state.
E[2] There has been no confirmed Bachman's warbler U.S. nesting ground sighting since the mid-1960s, however, several sightings of the species have occurred on wintering grounds during the last decade. This species may be extirpated in Louisiana.
T(S/A) [3] For law enforcement purposes, the alligator in Louisiana is classified as "Threatened due to Similarity of Appearance." They are biologically neither endangered nor threatened. Regulated harvest is permitted under state law.
[4] The USFWS and NOAA share jurisdictional responsibility for sea turtles and the gulf sturgeon.
[5] Candidate species are not protected under the ESA, but concerns about their status indicate that they may warrant listing in the future. Federal agencies and the public are encouraged to consider these species during project planning so that future listings may be avoided.

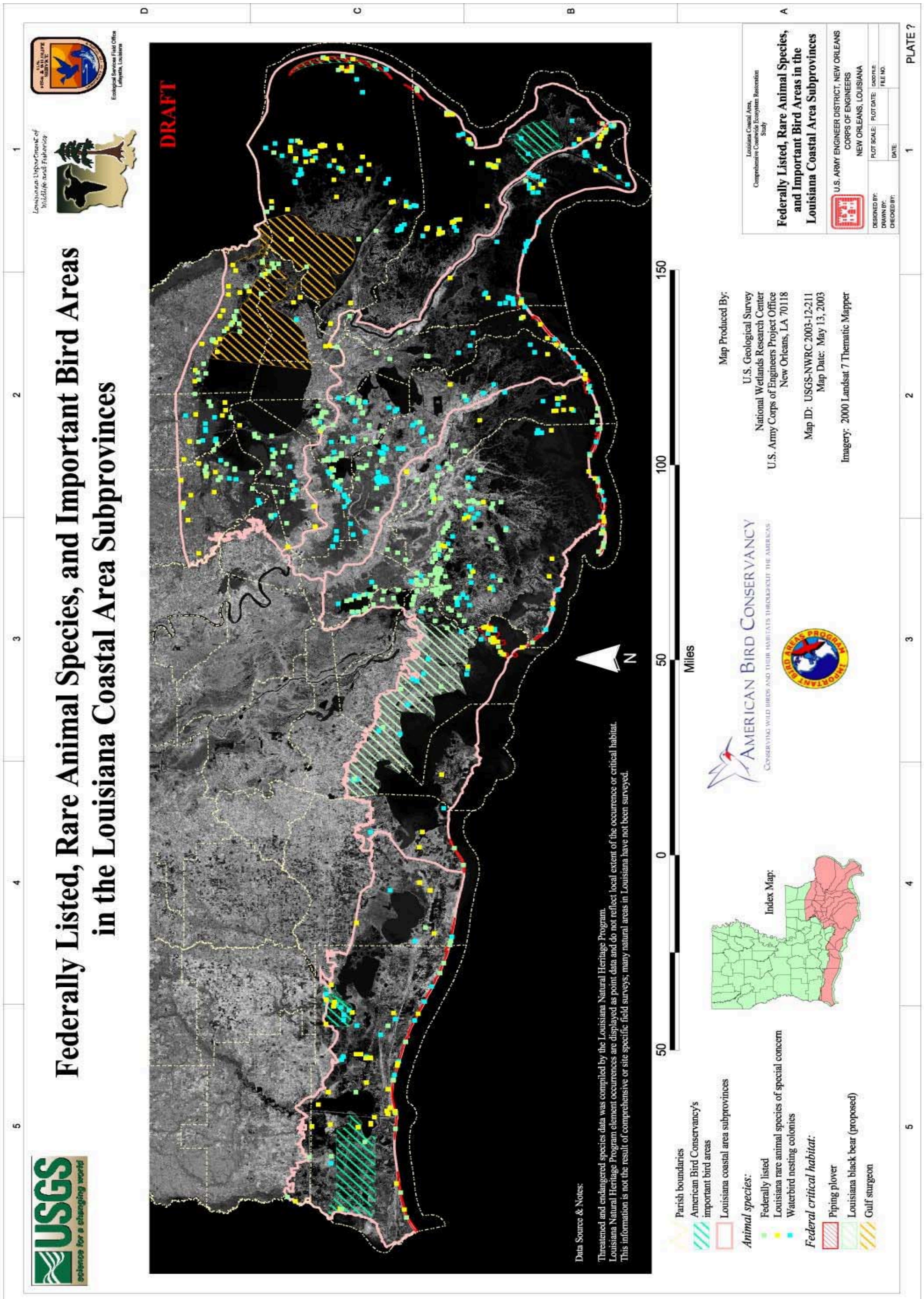


Figure 3-30. Federally listed rare animal species and important bird areas in the subprovinces *(from LNHP).*

3.14 HYDROLOGY

3.14.1 Flow and Water Levels

3.14.1.1 Historic and Existing Conditions

The hydrology of today's Mississippi River alluvial flood plain evolved from the formation of the different deltas and has been altered by human activity. In the shallow water deltas, such as the Teche, Lafourche, and St. Bernard, there was one main channel and numerous distributaries. As the delta evolved, the banks of the channels built up, rainfall runoff and overflow moved away from the channel and crevasses formed in the banks.

Beginning with human development in the 1700s and until present day, the Mississippi River was leveed and water levels in the river rose as a result. As documented earlier, during this time, numerous crevasses occurred along the Mississippi River and formed channel networks away from the main channel, thus flooding adjacent land and bringing in sediment. The flood control improvements along the Mississippi and Atchafalaya Rivers eliminated crevasses and other natural overflow. Today, flow exits the main channel through controlled structures such as the Bonnet Carre Spillway, Caernarvon, Whites Ditch Siphon, Bohemia Spillway, and Bayou Lamoque, which subsequently convey water into Subprovince 1; Davis Pond, the Naomi Siphon, and West Pointe a La Hache Siphon into Subprovince 2; and Old River Control Complex and Morganza Floodway into Subprovince 3.

In the lower portion of the river, near Head of Passes, crevasses in the channel banks formed subdeltas such as the one at West Bay. Channels within the subdelta conveyed water and sediment, thereby forming new land in the receiving area. Channels lengthened and energy slopes flattened, thus reducing sediment delivery. When slopes approached the slope of the Mississippi River, sediment delivery could no longer keep up with subsidence. That is likely the reason that the subdeltas today still convey a measurable portion of Mississippi River flow, yet land loss is occurring. The deep water delta distributary channels, Southwest Pass, South Pass, and Pass a Loutre convey about 65 percent of the river flow, with Grand Pass, Baptiste Collette, and Cubits Gap conveying the rest.

The flood control works have lowered peak flood stages along the Mississippi River in the New Orleans area and south. The operation of the dams along the Mississippi River and its tributaries has increased low flow volumes. Currently, the minimum annual flow in the Mississippi River is higher than it was in the 1930s.

Subprovince 1 - Mississippi River, Lake Pontchartrain, and Breton Basins

In Subprovince 1, the main basins are the eastern portion of the lower Mississippi River Delta, Lake Pontchartrain, and Breton Basins. Lake Pontchartrain, Lake Maurepas, and Lake Borgne are the major lakes in the subprovince. Rivers that drain into the lakes, in order of magnitude of average annual flow, are the Pearl, Amite, Tangipahoa, Tickfaw, and Tchefuncte. Predominant land use varies from agriculture and forestry to petroleum and fisheries. Runoff, in general, has increased over time due to urbanization. The Ross Barnett Reservoir on the Pearl River, completed in 1962, influences flow rates in the Pearl River, generally lowering peak stages and extending the duration of the runoff event. The operation of the Bonnet Carre Spillway can greatly increase the flow into Lake Pontchartrain.

Numerous navigation channels, drainage canals, and access canals, ranging in size from the Mississippi River deep draft channel to the MRGO to an oil well access canal, have altered the hydrology of the basins within the subprovince. These channels can confine freshwater flow, cross natural drainage boundaries, or convey gulf waters inland. The erosion of channel banks, due to waves generated from vessel traffic, can also change flow patterns.

Subprovince 2 – Mississippi River and Barataria Basin

In Subprovince 2, the main basins are the western portion of the lower Mississippi River and Barataria. Major water bodies are Barataria Bay, Lake Salvador, Lake Cataouatche, and Lac Des Allemands. The predominant land use is agricultural along ridges. Wetlands make up the majority of the subprovince. The Naomi and West Pointe a la Hache Siphons convey water from the Mississippi River into the subprovince. Flow from the Lower Atchafalaya River is also conveyed into Subprovince 2 via the GIWW. Historically, until completion of the closure at Donaldsonville in 1904, Bayou Lafourche was a source of freshwater supply to the rural population, the sugar cane industry, and the mills along the bayou. In 1955, a pumping station was placed in operation to provide a source of freshwater supply.

Drainage canals, roads, access canals, and navigation channels, including the GIWW and the Barataria Bay Waterway, have altered the hydrology of the subprovince. Channels and roads cross natural drainage boundaries, thus restricting or redirecting water movement. Channels can also convey gulf waters inland.

Subprovince 3 – Teche/Vermilion, Atchafalaya, and Terrebonne Basins

The Atchafalaya Basin Floodway System hydrologically divides Subprovince 3 and is also the major source of freshwater. The main basins to the east of the Atchafalaya are Lake Verret and Terrebonne. To the west, the main basins are the Teche and Vermilion Rivers. Major water bodies in the subprovince are Lake Verret, Lake Palourde, Terrebonne Bay, Timbalier Bay, and Four League Bay to the east; and Lake Fausse Pointe, Lake Dauterive, Vermilion Bay, and East and West Cote Blanche Bays to the west. Atchafalaya Bay is at the southern end of the Atchafalaya Basin Floodway. Channels that drain into the Terrebonne Basin include Bayou Boeuf and Bayou Black. The Bayou Black ridge restricts the flow of water along the northern boundary of the Terrebonne Basin. Channels that drain into the bays west of the Atchafalaya include the Vermilion River, Charenton Drainage Canal, and Bayou Teche. Land use is predominantly agricultural along the ridges.

The Atchafalaya Basin Floodway; GIWW; Atchafalaya River; Bayous Chene, Boeuf, and Black Navigation Channel; Houma Navigation Canal; and Houma area levees and pump systems, drainage canals, and access canals have altered the hydrology of the subprovince. Historically, annual flow volumes have increased into the Atchafalaya; however, flow increased from less than 10 percent of the combined Mississippi and Red River flow in the 1850s to 30 percent today. Within the last 30+ years, the GIWW has been discharging increasing amounts of Atchafalaya freshwater and sediments to the coastal area throughout Subprovince 3, mainly during the annual spring flood. The Houma Navigation Canal conveys almost two thirds of the Atchafalaya water in the GIWW (the GIWW channel through the Houma area restricts the movement of water farther east). Backwater effects can slow drainage through the Bayou Black ridge, thus affecting the duration of high water levels in the Lake Verret area.

Subprovince 4 – Calcasieu/Sabine and Mermentau Basins

The main basins of Subprovince 4 are the Sabine, Calcasieu, and Mermentau. Major water bodies are Calcasieu Lake, Sabine Lake, White Lake, and Grand Lake. The largest rivers that drain into the coastal area are Sabine, Calcasieu, and Mermentau. Land use is wildlife refuges and agricultural along the high ground.

Drainage canals, control structures, navigation channels (such as the Calcasieu and Sabine-Neches Ship Channels and the GIWW), and access canals have altered the hydrology of the subprovince. Water movement is in the east-west direction, as well as to the south. Water levels, or flow patterns, are controlled by structures such as the Schooner Bayou Control Structure and the Leland Bowman Lock. Refuge areas have been developed in the subprovince with individual water management areas.

3.14.2 Sediment

3.14.2.1 Historic and Existing Conditions

The major sources of sediment to the entire LCA Study area are the Mississippi and Atchafalaya Rivers. The Engineer Research and Development Center (ERDC) and Richard Kesel of LSU conducted two definitive studies of the suspended sediment regime and bed material gradation of the Mississippi River Basin in the early 1980s (Keown et al. 1981; Kesel 1988). These reports identify several cultural impacts over the past two centuries that have shaped the present character of the Mississippi main-stem suspended sediment regime in coastal Louisiana. In the late 1800s to early 1900s, land use in the Mississippi River Basin changed from primarily forest and grassland to agricultural activities. The Old River Control Complex, completed in 1963, regulates the flow between the Mississippi and Atchafalaya Rivers. Dams and other sediment retention structures were constructed on the Mississippi River system between 1953 and 1967 and on the Arkansas River system between 1963 and 1970. Construction of channel improvement features began in the 1800s. Kesel (1988) also attributed the New Madrid Earthquake of 1811-12 with altering the suspended sediment regime in the early 1800s.

For the Mississippi River in Louisiana, average suspended sediment loads decreased 25 percent between the late 1800s and 1950, and 40 to 60 percent since 1950, for a total of 79 percent from 1851 to present (Keown et al. 1981; Kesel 1988). The percentage of suspended sand load has also decreased by 45 percent since the late 1800s (Kesel 1988).

In the subprovinces, sediment enters the areas with freshwater inputs and with gulf waters. For existing conditions, the Atchafalaya River, Wax Lake Outlet, and Lower Atchafalaya River have average suspended sediment concentrations and grain sizes similar to the Mississippi River. The other rivers and channels in the subprovinces such as Calcasieu River and Mermentau River have concentrations significantly lower than the Mississippi River and grain sizes considerably finer.

Sediment deposition occurs in most channels within coastal Louisiana and in some estuary areas such as Vermilion Bay and Lake Verret. Navigation channels experience significant shoaling, and dredging is performed. In the Mississippi River navigation channel, over the past 20 years, an average of 15 to 20 million cy (11.4 to 15.2 million m^3) of material is annually dredged from the Head of Passes and Southwest Pass areas. Approximately 30 percent of the material dredged is used beneficially. The material removed by cutterhead dredges is used beneficially. In Southwest Pass, dangerous turns, coupled with deep draft traffic, make it unsafe to use the current cutterhead dredge fleet; therefore, hopperhead dredges are used instead. Under the present authority, the material from the hopperhead dredges cannot be used beneficially in a cost effective manner.

3.14.3 Water Use and Supply

3.14.3.1 <u>Historic and Existing Conditions</u>

Fresh ground and surface water is abundant in southern Louisiana. Prior to the 1900s, water used for most purposes was from surface sources. Many households collected rainwater for domestic uses and farmers generally relied on rainfall and irrigation ditches to provide water to their crops. During the late 1800s, water wells began to come into common usage and quickly proliferated in areas where fresh groundwater was available. The use of groundwater allowed farmers to plant crops in areas where sources of fresh surface water were unreliable or unavailable. In coastal areas of southeastern Louisiana, groundwater supplies are generally limited and surface water is primarily used. Large amounts of fresh groundwater are generally available and groundwater is used for most purposes.

During 2000, about 3,000 million gallons per day (Mgal/d) (11,370 million liters per day[Ml/d]) of freshwater were withdrawn for various uses in the LCA Study area. Of this water, about 97 percent was from surface sources and about 3 percent was from groundwater sources. Most of this use was in southeastern Louisiana in parishes that border or straddle the Mississippi River.

The Mississippi River and some of its distributaries were the largest sources of surface water, contributing 96 percent (2,800 Mgal/d [10,612 Ml/d]) of the total surface withdrawals. Other major sources included Bayou Lafourche (52 Mgal/d [197 Ml/d), the GIWW (10 Mgal/d [37.9 Ml/d]), Mermentau River (10 Mgal/d [37.9 Ml/d]), and Bayou Lacassine (7 Mgal/d [26.5 Ml/d]). Surface water was used for various purposes, including industry (1,340 Mgal/d), power generation (1,240 Mgal/d [4,699 Ml/d]), public supplies (310 Mgal/d [1,174 Ml/d]), and agriculture (47 Mgal/d [178 Ml/d]). Withdrawals for power generation and industry were primarily from the Mississippi River and used for once-through cooling and much of the water was returned to the source. Industrial withdrawals were primarily for petroleum refining and chemical manufacturing. In southwestern Louisiana, large amounts of fresh groundwater are available, and groundwater is used for most purposes.

3.14.4 Groundwater

3.14.4.1 Historic and Existing Conditions

Southern Louisiana generally has very abundant fresh groundwater supplies. However, aquifers along the coast typically contain saltwater that extends inland as a wedge along the base of the aquifer. Coastward, the saltwater wedge typically thickens and the overlying freshwater thins until the entire thickness of the aquifer contains saltwater. Salty groundwater is often defined as water containing a chloride concentration greater than 250 mg/L or a dissolved solids concentration greater than 1,000 mg/L. Saltwater can move into freshwater parts of the aquifer by lowering freshwater levels through pumping. Such movement of saltwater or the saltwater wedge is known as saltwater encroachment. Saltwater can move laterally or vertically in an aquifer. The USGS, in cooperation with the Louisiana Department of Transportation and Development, maintains a loose network of wells designed to monitor saltwater encroachment in coastal aquifers.

The water table is at or near the surface throughout most of the coastal zone. The silt- and sand-rich depositional environments such as point bar, intradelta, natural levee, beach, and near shore gulf are generally connected hydraulically to the adjacent water body (i.e., river, lake, distributary channel) and the elevation of the water table in these deposits reflects the level/stage of the adjacent water body. This is especially true in deposits adjacent to the Mississippi and Atchafalaya Rivers. Any potential connectivity should be investigated to determine its influence on uplift pressures, design of dewatering systems, and groundwater migration.

Three major aquifer systems are present in the coastal areas of Louisiana: the Southern Hills, Chicot, and New Orleans aquifer systems. In southeastern Louisiana, along the northern extent of Subprovince 1 and the Pontchartrain Basin, the Southern Hills aquifer system extends southward from southwestern Mississippi into southeastern Louisiana and contains freshwater as far south as the Baton Rouge fault. The Baton Rouge fault, which extends approximately from Baton Rouge eastward across the northern part of Lake Pontchartrain, is generally considered the southern limit of the Southern Hills aquifer system because most of the 30 aquifers that comprise the Southern Hills aquifer system contain saltwater south of the fault. The Southern Hills aquifer system is the principal source of freshwater in southeastern Louisiana north of the Baton Rouge fault and is used for most purposes. The base of freshwater in the Southern Hills aquifer system in the LCA Study area is about 3,000 ft (914.4 m) below sea level.

South of the Southern Hills aquifer system and the Baton Rouge fault, the New Orleans aquifer system consists of four aquifers that supply fresh groundwater to the southern parts of the Pontchartrain Basin in Subprovince 1, and the northern parts of the Barataria Basin in Subprovince 2. The aquifers that comprise the New Orleans aquifer system contain saltwater in many areas and only limited groundwater supplies are available in most areas. Because of this, surface water generally is used for public supplies and other major uses in the Barataria and southern Pontchartrain Basins. However, limited amounts of groundwater from the New Orleans aquifer system are withdrawn for public supply, industry, power generation, and other uses. The base of freshwater in the New Orleans aquifer system averages about 500 ft (152.4 m) below sea level in the LCA Study area.

The Chicot aquifer system is present throughout southwestern Louisiana and is the principal source of water to the Teche/Vermilion Basin in Subprovince 3, and the Calcasieu/Sabine and Mermentau Basins in Subprovince 4. Prior to development of the Chicot aquifer system, which began in the late 1800s, groundwater flow in the system was from north to south and water discharged upwards into springs in coastal areas from Calcasieu Parish to St. Mary Parish. By the late 1940s, pumping from the system had lowered water levels and altered flow gradients, and the springs disappeared. Flow in the system beneath coastal areas is now northward towards pumping centers in the central parts of southwestern Louisiana.

Groundwater from the Chicot aquifer system is used for all purposes, though most of the water pumped from the aquifer system within the LCA Study area is used for rice irrigation, public supplies, and industrial purposes. The Chicot aquifer system is completely salty in most of western Cameron Parish, southern St. Mary Parish, and the southern edges of Cameron and Vermilion Parishes. Saltwater extends inland as a wedge along the base of the Chicot aquifer system and present at some depth in the aquifer system throughout Subprovinces 3 and 4. The base of freshwater in the Chicot aquifer system within the LCA Study area averages about 500 ft (152.4 m) below sea level.

About 77 Mgal/d (291.8 Ml/d) of groundwater were withdrawn in the LCA Study area in 2000. Most of the withdrawals were withdrawn from the Southern Hills and Chicot aquifer systems near the northern edge of the study area. About 21 Mgal/d were withdrawn from the Southern Hills aquifer system in the study area and primarily used for public supplies. The same amount was withdrawn from the Chicot aquifer system, but was primarily used for rice irrigation and crawfish farming. About 28 Mgal/d (106 Ml/d) were withdrawn from the New Orleans aquifer system and was primarily used for shipbuilding, sugar refining, and chemical manufacturing. About 16 Mgal/d were withdrawn from the Mississippi River alluvial aquifer in the study area and was also used for chemical manufacturing and sugar refining.

No major sources of fresh groundwater are available in the Breton Sound and Mississippi River Delta Basins of Subprovince 2 or the Atchafalaya and Terrebonne Basins of Subprovince 3. Fresh groundwater is also not available in the eastern Pontchartrain Basin or all but the extreme northern part of the Barataria Basin. Parishes in these basins, including Assumption, Jefferson, Lafourche, Orleans, Plaquemines, St. Bernard, St. Charles, St. James, and Terrebonne, where little or no fresh groundwater is present, use large amounts of surface water for public supply and other uses.

3.15 WATER QUALITY RESOURCES

3.15.1 Historic and Existing Conditions

Historic and current water quality issues for rivers and streams in coastal Louisiana include the transport of nutrients, pesticides, synthetic organic compounds, trace elements, suspended sediment, and bacteria. The database for the Mississippi River at St. Francisville and the Atchafalaya River at Melville is extensive, with comprehensive water quality datasets beginning in the mid-1970s. Historically, sites have been operated in cooperation with the USACE and the Louisiana Department of Transportation and Development. These two sites are currently sampled as part of the USGS National Stream Quality Accounting Network (NASQAN). The database for the Mississippi River is extensive enough that several general conclusions can be made concerning its suitability for coastal restoration efforts:

1. Trace elements, including heavy metals, are generally not considered a water quality issue in the Mississippi River.
2. Nitrate concentrations average around 1.4–1.6 mg/L in the lower Mississippi River. This is the result of natural and human inputs, particularly agricultural fertilizers in the mid-continent. Nitrate at these concentrations can cause excessive algal growth and eutrophication in coastal water bodies and contribute to the hypoxia problem in the Gulf of Mexico.
3. Fecal coliform bacteria in the lower Mississippi River have declined dramatically with more effective sewage treatment at Baton Rouge and New Orleans since the mid- to late-1980s.
4. The primary pesticides detected in the Mississippi River are the herbicides atrazine, metolachlor, and acetochlor.
5. Per LDEQ's database[1], organic compounds are typically not detected in the Mississippi River.
6. For conventional parameters in LDEQ's database[1], there is essentially no difference in water quality spatially along the length of the Mississippi River between Pointe a la Hache and the Louisiana State line.

[1]LDEQ performs collection and analysis for 29 conventional parameters and fecal coliform through the Surface Water Monitoring Program with a priority pollutant scan quarterly at the Mississippi River sites.

The most common individual designated uses in the coastal plain of Louisiana include primary contact recreation, secondary contact recreation, fish and wildlife propagation, shellfish propagation, and drinking water supply. Primary contact recreation is defined by LDEQ as any recreational activity that involves or requires prolonged body contact with the water, such as swimming, water skiing, tubing, snorkeling, and skin-diving. Secondary contact recreation is defined as any recreational activity that may involve incidental or accidental body contact with the water and during which the probability of ingesting appreciable quantities of water is minimal, such as fishing, wading, and recreational boating. Fish and wildlife propagation is defined as the use of water for preservation and reproduction of aquatic biota such as indigenous species of fish and invertebrates, as well as reptiles, amphibians, and other wildlife associated with the aquatic environment. This also includes the maintenance of water quality at a level that prevents contamination of aquatic biota consumed by humans. Shellfish propagation is the use of water to sufficiently maintain biological systems that support economically important species of oysters, clams, mussels, or other mollusks so that their productivity is preserved and the health of human consumers of these species is protected. See **table 3-9** for water quality issues throughout the LCA Study area.

Table 3-9
Water-quality issues, locations, and possible causes in the LCA Study Area

AREA	ISSUE	LOCATION	POSSIBLE CAUSES	COMMENTS
Subprovince 1	Pesticide pulse Nutrient pulse Eutrophication	Entire subprovince	Hydrologic modification of Miss. River Agriculture	Midcontinent pulses of pesticides (particularly atrazine) and fertilizers are a national concern. Levees throughout the Mississippi River system funnel these pulses to the Louisiana coastal area.
	Bacterial contamination	Entire subprovince	Inadequate waste treatment Unsewered camps	Fecal bacteria arise from both point and nonpoint sources, from humans and animals (mammals, birds).
	Potential sediment contamination in urban & industrial areas	Urban and industry centers: Bayou Bonfouca (known example that has been remediated)	Abandoned creosote plant Urbanization	Bed sediments from small tributaries and canals in this subprovince, especially the Lake Pontchartrain Basin, should be sampled before utilization.
Subprovince 2	Pesticide pulse Nutrient pulse Eutrophication	Entire subprovince	Hydrologic modification of Miss. River Agriculture	Midcontinent pulses of pesticides (particularly atrazine) and fertilizers are a National concern. Levees throughout the Mississippi River system funnel these pulses to the Louisiana coastal area.
	Bacterial contamination	Entire subprovince	Inadequate waste treatment Unsewered camps	Fecal bacteria arise from both point and nonpoint sources, both human and animal (mammals, birds).
	Potential sediment contamination in urban & industrial areas Trace elements	Harvey Canal Algiers Canal Bayou Lafourche	Light industry, boat repair, maintenance Urbanization	Trace elements and synthetic organic compounds. Use of canals for diversions or hydrologic restoration should take into consideration potential for resuspension of contaminants.
Subprovince 3	Pesticide pulse Nutrient pulse Eutrophication	Mostly Terrebonne; less severe westward	Hydrologic modification of Miss. River Agriculture	Midcontinent pulses of pesticides (particularly atrazine) and fertilizers are a National concern. Levees throughout the Mississippi River system funnel these pulses to the Louisiana coastal area.
	Bacterial contamination	Entire Subprovince; Terrebonne most severe	Inadequate waste treatment Unsewered camps	Fecal bacteria arise from both point and nonpoint sources, both human and animal (mammals, birds).
Subprovince 4	Potential sediment contamination in urban & industrial areas	Calcasieu	Petrochemical Agrichemical	Trace metals and synthetic organic compounds, particularly hexachlorobenzene, in the Calcasieu River just north of the LCA Study boundary.

Note: Gulf of Mexico waters off of all coastal parishes are under a fish consumption advisory due to mercury contamination.

The Louisiana Department of Health and Hospitals (LDHH) coordinates with LDEQ, the Louisiana Department of Wildlife and Fisheries, and the Louisiana Department of Agriculture and Forestry to issue water body advisories aimed at protecting the public's health. These include fish and shellfish consumption advisories and swimming advisories. Fish and shellfish consumption advisories employ a risk-based method to advise the public to limit or avoid the intake of certain species of fish and shellfish that have unsafe contaminant levels in their tissues. Swimming advisories may be issued for a water body due to fecal coliform or other types of contamination. The Gulf of Mexico waters off of all coastal parishes is under a fish consumption advisory related to mercury contamination (See section 4.14.2 for a brief discussion on methylmercury). This information comes from the latest publications on LDHH and LDEQ's websites in July 2004. Advisories for specific water bodies are discussed below in their respective subprovince.

The LCA project team has developed boundaries for the subprovinces of the coastal region. For this document, the applicable water quality subsegments from each basin as developed by LDEQ and presented in the "2002 Water Quality Management Plan, Water Quality Inventory, Section 305(b)" were identified that fall within each of the four subprovinces. The water quality data and references of each subsegment reviewed for this document follow the basin delineations. Below are the basins that fall within each subprovince.

Subprovince 1

- Portion of Lake Ponchartrain Basin (including Breton Sound)
- Eastern half of Mississippi River Delta Basin
- Western half of Mississippi River Delta Basin (spatially within Subprovince 2, but discussed under Subprovince 1)
- Lower portion of Pearl Basin

Subprovince 2

- Barataria Basin

Subprovince 3

- Terrebonne Basin (Coastal Area)
- Atchafalaya Basin (Coastal Area)
- Teche/Vermillion Basin (Coastal Area)

Subprovince 4

- Mermentau Basin (Coastal Area)
- Calcasieu Basin (Coastal Area)
- Sabine Basin (Coastal Area)

Subprovince 1 – Mississippi River, Lake Pontchartrain, and Breton Basins.

Of the 81 water body segments in the Pontchartrain Basin assessed in the LDEQ's "2002 Water Quality Management Plan, Water Quality Inventory, Section 305(b)" report (2002 305(b) report), 24 are fully supporting their designated uses. Forty-nine water body segments are partially supporting their designated uses, while eight are not supporting any of their designated uses. The major causes of impairment are fecal coliform, nutrients, dissolved oxygen (DO; refers to the amount of oxygen contained in water, which defines the living conditions for oxygen-requiring (aerobic) aquatic organisms), suspended solids, turbidity, oil and grease, and mercury. Suspected sources of impairment include on-site wastewater treatment systems, sanitary sewer overflows, municipal and industrial point sources, urban runoff, dairies, flow alterations, and land development.

Swimming advisories are in effect for the Lake Pontchartrain south shore, the Bogue Falaya River, Tangipahoa River, and Tchefuncte River. Those water bodies are under advisory due to bacteria counts that exceed the primary contact recreation water quality standard for swimming. A swimming advisory, due to organic chemical contamination (creosote), is in effect for Bayou Bonfouca.

Fish and shellfish consumption advisories, due to mercury contamination, are in effect for the Bogue Falaya River, Tchefuncte River Tangipahoa River, Bogue Chitto River, Pearl River, Bayou Liberty, Blind River, Amite River Drainage Basin, and Tickfaw River.

For the western and eastern portions of the Mississippi River Delta Basin, the 2002 305(b) report assessed that the Mississippi River from Monte Sano Bayou to Head of Passes was fully supporting the designated uses of secondary contact recreation and drinking water supply; however, this subsegment was assessed as not supporting primary contact recreation or fish and wildlife propagation. The suspected causes of impairment include nitrogen, phosphorus, and total fecal coliform from suspected sources of municipal point source discharges and upstream sources. The Mississippi River Basin Coastal Bays and gulf waters were assessed as not supporting fish and wildlife propagation due to mercury from atmospheric deposition. This subsegment was not assessed for the other designated uses due to insufficient data.

The 2002 Water Quality Inventory Section 305(b) Report assessed that the three water quality subsegment water bodies in the Pearl River Basin were fully supporting the designated uses of primary and secondary contact recreation, but not supporting fish and wildlife propagation. The suspected causes of impairment range from metals such as mercury, copper, and lead to pathogens and turbidity. The suspected sources of impairment include unknown sources, atmospheric deposition, and sand/gravel/rock mining or quarries.

Subprovince 2 – Barataria Basin

The water quality of the Barataria Basin is primarily adversely affected by periodic nutrient overloading (eutrophication) in selected parts of the upper- and mid-basin. Generally, there are no problems with trace metals in the basin, with the single documented exception of the Harvey Canal area. Fecal coliform concentrations can exceed designated uses, particularly after storms overwhelm local sewage treatment areas. Improper or untreated sewage from camps and boats is also a problem. The herbicide atrazine can consistently be detected throughout the Barataria Basin. Sources include both local use, particularly on sugarcane, and inputs from the mid-continent. Overall, the occurrence and amount of atrazine in the Barataria Basin does not appear to be a concern for human health.

Subprovince 3 - Teche/Vermilion, Atchafalaya, and Terrebonne Basins

According to the 2002 305(b) report, the Vermilion Bay was listed as fully supporting all of the designated uses, while the Vermilion-Teche River Basin Coastal Bays and gulf waters were assessed as fully supporting all designated uses except fish and wildlife propagation. The suspected source of impairment is mercury due to atmospheric deposition. The West Cote Blanche Bay and the East Cote Blanche Bay are both fully supporting the designated uses.

The 2002 305(b) report assessed the Lower Atchafalaya River as fully supporting its designated uses of primary contact recreation, secondary contact recreation, and fish and wildlife propagation. The report assessed the Atchafalaya Bay and Delta as not supporting its designated use of fish and wildlife propagation while it was not assessed for primary contact recreation, secondary contact recreation, or shellfish propagation. Mercury was the suspected cause of impairment in the Atchafalaya Bay and Delta. The Wax Lake Outlet, from U.S. Highway 90 to the Atchafalaya Bay, and the GIWW, from the Bayou Boeuf Lock to Bayou Sale, were not assessed for the 2002 305(b) report.
According to the 2002 305(b) report, the Terrebonne Basin Coastal Bays and gulf waters were listed as fully supporting all designated uses except fish and wildlife propagation. The suspected causes of impairment include phosphorus, nitrogen, and mercury. The suspected sources of impairment are upstream sources and atmospheric deposition. The Timbalier Bay is fully supporting all designated uses.

Subprovince 4 - Calcasieu/Sabine and Mermentau Basins

According to the 2002 305(b) report, the Calcasieu River Basin-Coastal Bays and gulf waters are fully supporting all designated uses except fish and wildlife propagation, due to mercury from atmospheric deposition. The 2002 305(b) report lists many of the coastal water body subsegments of the basin as not assessed. Caution is advised by LDHH on fish consumption from the Calcasieu Estuary due to low levels of chemical contamination including hexachlorobenzene, hexachloro-1-3-butadiene, and PCBs. Also, a fish and shellfish consumption advisory due to mercury contamination is in effect for the Calcasieu River Drainage Basin.

According to the 2002 305(b) report, the Sabine River Basin Coastal Bays and gulf waters are not supporting fish and wildlife propagation due to mercury from atmospheric deposition. There are approximately five other subsegments within the LCA near-term course of action project boundary that are not currently assessed.

The water quality in the coastal zone area of the Mermentau River Basin is primarily adversely affected by a small number of trace metals, agriculture runoff, and periodic eutrophication in selected parts of the upper coastal zone of the basin. The Mermentau River Basin Coastal Bays and gulf waters were assessed in the 2002 305(b) Report as not supporting fish and wildlife propagation. The suspected causes of impairment include carbofuran and mercury from atmospheric deposition, crop production, and unknown sources. Grand Lake and White Lake are not supporting fish and wildlife propagation due to turbidity, chlorides, ammonia nitrogen, sedimentation, and total suspended solids. Again, crop production is the suspected source of the impairment, as well as natural conditions.

3.16 HISTORIC AND CULTURAL RESOURCES

Coastal Louisiana contains numerous historic and prehistoric archeological sites as well as standing historic properties. These archaeological sites and historic properties span the human occupation sequence of the state and represent Louisiana's long cultural heritage. Over 3,000 archeological and historical sites have been recorded for the 20 parishes in the LCA Study area. In addition to these sites, more than 200 historic properties are listed on the National Register of Historic Places.

3.16.1 Historic and Existing Conditions

3.16.1.1 Types of Cultural Resources

Historic and prehistoric sites in the LCA Study area tend to be located along the natural levees of rivers and bayous that were used as transportation routes. The offshore borrow sites, such as Ship Shoal, also have the potential to contain historic shipwrecks.

The Mississippi River was the main means of transportation and its natural levees were the choice location for settlement. The surrounding coastal lakes and areas were gradually explored for natural resources and utilized as well. As the population along the Mississippi River increased, land along its natural levees became scarce. Settlers began to move further outward following waterways such as Bayou Lafourche, Bayou Teche, Bayou Terrebonne, the Vermilion River, and other bayous and rivers in the coastal area.

Prehistoric sites include hunting and food processing camps, hamlets, and village sites. Native Americans relied on hunting, fishing, and gathering of plants. Types of historic sites include domestic buildings, plantation sites, farmsteads, military sites, commercial sites, industrial sites, boat landings, and hunting and fishing camps along the coast. In addition to terrestrial historic sites, the project area has the potential to contain historic shipwrecks. Bayou Barataria, Bayou Lafourche, Bayou Teche, and the Atchafalaya, Vermilion and Calcasieu Rivers, as well as the other bayous in the study area, have been a major means of transportation in the Louisiana "bayou country" since prehistoric times. The smaller bayous that connect to Bayou Lafourche were also used by the local Native Americans as well as by trappers, hunters, and fishermen. Watercraft from all time periods could be present in the study area. Most of the vessels used historically in this area were vernacular watercrafts.

In the early 1900s, various subsistence activities that were initially developed prior to the 20th century became more commercial in nature. Moss, first gathered for the making of beds and as filler in the construction of houses, was commercially processed and sold to the upholstery business as stuffing for furniture and car seats. Following World War II, the moss industry declined as the result of the wide availability of foam rubber and the increased cost of gathering moss. The lumber industry that had flourished in the late 1800s continued to grow with the harvesting of cypress throughout south Louisiana. Lumber towns and sawmills dotted the landscape until most of the virgin cypress forests were cut and the lumber companies moved westward.

The trapping of animals in south Louisiana began with Native Americans and continued on into the 1900s. Otter, muskrat, and nutria were trapped in the marshes and provided furs for the garment industry all over the world. Hunting camps and processing stations were located throughout the marsh. The demand for furs has declined over the years. Nutria are trapped today for food and bounties, to keep the population from expanding and destroying the marsh, or from causing problems in municipal canals.

Seafood, one of the most important natural resources in south Louisiana, has continued to become more important to the economy of Louisiana. In the middle of the 19th century, methods of preservation (such as the drying of shrimp and canning of oysters) made it possible to export seafood. The introduction of the gasoline motor and refrigeration allowed fishermen greater access to markets in New Orleans and the larger towns inland from the coast. Seafood processing camps that had been established all over the coast in the 1800s, including Manila Village, Bayou St. Malo, and the Isle de Caminada, were abandoned after being hit by numerous tropical storms and hurricanes. In the 1900s, many of these fishermen established new settlement and seafood processing businesses along the major waterways leading away from the coast. Fishing remains a major economic activity in south Louisiana.

Rice and sugar remained major cash crops across the coastal parishes. By the eve of World War II, large sugar companies had developed after bad weather, plant diseases, and economic policies had almost destroyed sugar production in south Louisiana. Truck farming of vegetables and citrus to towns and cities provided fresh vegetables at local markets. Cameron and Vermilion Parishes are, today, the top two cattle producing parishes in Louisiana.
Other industries developed in south Louisiana in the 1900s that have shaped the economy of the state. The oil industry began in the early 1900s and continues to be a major industry. Large oil fields are located in the marshy areas of south Louisiana and offshore. Pockets of sulfur and salt are located across south Louisiana. The extraction of these natural resources became major industrial activities.

All of these economic activities have contributed to the constructed environment of south Louisiana. In addition to the residential homes, public buildings, and commercial buildings, these industries have contributed to the south Louisiana landscape and to the heritage of the area. Historic standing structures, archaeological sites, and landscape features associated with man's activities in the coastal area may be significant cultural resources. The Division of Archaeology maintains information on over 12,000 archaeological sites and thousands of historic standing structures.

3.16.1.2 Impacts Affecting Cultural Resources

The diverse resources available in coastal Louisiana have led to a diverse history and rich culture in the Louisiana coastal ecosystem. As a result, cultural resources are abundant in the area. Over the last 50 years, as land loss has progressed and saltwater intrusion has increased, many of these cultural resources have been put at risk or lost to erosion, inundation, and construction of navigation channels and canals.

Cultural resources in the LCA Study area are subject to a variety of natural and human impacts. Factors influencing archeological site preservation are presented in the following discussion. A thorough recognition of these factors is crucial in understanding archaeological site preservation. Many of the cultural resources located within the study area were reported as having been disturbed in the initial site forms on file with the Louisiana Division of Archaeology. Some of these sites were impacted by construction activities conducted prior to the implementation of regulations governing the treatment of cultural resources. Unfortunately, destruction of cultural resource sites from man-made actions continues in coastal Louisiana.

Factors that influence site preservation within the study area are essentially those that influence land loss and erosion in the coastal zone. Natural influences include subsidence, saltwater intrusion, and the frequency, magnitude, and duration of storms. Subsidence, compaction, and erosion accelerate the conversion of marsh to open water. Saltwater intrusion, coupled with subsidence, is resulting in the landward encroachment of the gulf. These processes are deleterious to archeological sites located in proximity to various lakes, bays, sounds, canals, and other water bodies.

Other factors influencing site preservation are related to the climate and topography of the area. The climate in this area is influenced by air masses, which result in severe storms during the summer months and sporadic, high energy disturbances during the winter months. The effects of severe wind and rain are enhanced by the low topography common throughout the area.

The actions of man are also major factors influencing site preservation in the area. Natural levees and their adjacent waterways represent important features to the region historically. Distributary channels formed important routes of transportation while the adjacent levees provided suitable landforms for settlements, fortifications, and access to the area's abundant natural resources. Prehistoric settlements focused on these high ridges and natural levees. The high ground was also preferred for historic settlements. Some of the first agricultural concessions in the area were granted along the Mississippi River and the major bayous of the study area. This focus on suitable dry land adjacent to navigable watercourses continues to the present and increased commercial/industrial developments influences site preservation.

The construction of various flood and water control structures is another factor that has influenced site preservation in the coastal zone. Levees have been constructed to prevent flooding and control the flow of water in some areas. These projects affect both sediment transport and deposition in the area. They have also been known to obliterate any evidence of, as well as destroy, cultural resources directly during construction. Excavation and maintenance dredging of canals for the extraction of mineral resources and for navigation has accelerated erosion and has dug into archeological sites. Many archaeological sites in the study area have subsided and were exposed during dredging activities for these canals. Other archeological sites were split by canals and subsequently eroded, resulting in the loss of cultural deposits. Another major source of destruction of archaeological sites is wakes from boats utilizing the waterways.

Since the passage of the National Historic Preservation Act of 1966, NEPA, and other National laws, Federal agencies are required to examine and avoid impacts to significant cultural resources. In cases where the site cannot be avoided, mitigation measures are developed either to retrieve significant data on the cultural resource or to compensate for the impact.

The land in the study area is eroding rapidly. The protection of these lands by some of the ongoing CWPPRA or other restoration projects, such as disposal of borrow material adjacent to archaeological sites, may actually protect these sites in the long-term by stopping or slowing land erosion. Depending on the restoration feature, the proposed actions could help to restore the surrounding wetlands, thus protecting the land and whatever sites that may be located in the area.

Past construction actions in the study area have had an adverse impact on significant cultural resources. These actions include:

- Dredging material from borrow areas, which impacts submerged cultural resources such as shipwrecks.
- The construction of plugs, shoreline protection devices, levees, etc. could all affect recorded and unrecorded cultural resources.
- Increased sediment flows have caused direct impacts on sites throughout the study area, while in some cases sediment flows have helped protect cultural sites by preventing further erosion.
- Depositing sediment on top of a known site has changed the environment in which a site has survived. This has, in some instances, caused adverse impacts.
- Dredging waterways has impacted prehistoric sites and historic shipwrecks in the study area.
- Construction of erosion control devices, such as weirs and dikes, and the building and removal of canal banks, have also adversely impacted prehistoric and historic sites in the study area.

3.16.1.3 Offshore Archaeological Resources

Archaeological resources are defined as any prehistoric or historic site, building, structure, object, or feature that is man-made or modified by human activity. The new MMS Archaeological Resource Regulation at 30 CFR 250.194(b) grants specific authority to the Regional Director to require archaeological resources surveys and reports. Surveys are required prior to any sea floor disturbing activities on leases within the archaeological high-probability areas (NTL 98-06).

3.16.1.3.1 *Historic*

With the exception of Ship Shoal Lighthouse, historic archaeological resources on the outer continental shelf (OCS) consist of shipwrecks. A 1977 MMS archaeological baseline study for the northern Gulf of Mexico indicated that 2 percent of the pre-20th century shipwrecks and 10 percent of all wrecks reported lost between 1500 and 1945 have known and/or verified locations (CEI 1977). An MMS-funded study by Texas A&M University (Garrison et al. 1989) updated the shipwreck database. Statistical analysis of over 4,000 potential shipwrecks in the northern Gulf indicated that many of the OCS shipwrecks occur in cluster patterns related mainly to natural geological navigation hazards, storms, and port entrances.

The management of potential historic shipwreck resources on the OCS has been accomplished through the establishment of a high-probability zone for the occurrence of historic shipwrecks. This high-probability zone consists of three subzones - (1) shoreline to 10 km from the shore; (2) 21 half-degree-square quadrates associated with cultural and geographic features including historic ports, barrier islands, and reefs; and (3) specific nine-lease-block high-probability search polygons associated with shipwrecks located outside of the two aforementioned zones. The Ship Shoal Area has one of the densest concentrations of shipwrecks in the Gulf of Mexico. The Texas A&M University study (Garrison et al. 1989) indicated there were 33 known wrecks (10 of which are historic), 13 unknown wrecks and two underwater bottom obstructions recorded within the Ship Shoal Area. The 33 known shipwrecks and their presumed Block locations are presented in **table 3-10.**

The Texas A&M study also examined variables affecting shipwreck site formation process and shipwreck preservation potential. Ship Shoal Block 88 falls within the MMS Central Planning Area (CPA). In general, the study concluded that there is a high degree of shipwreck preservation potential in the eastern portion of the CPA where there is a thick deposit of Holocene deltaic sediments. There is a lower potential for preservation in the central and western part of the CPA, where sedimentation rates are thinner and were slower to develop. Block 88 falls near the Middle of the CPA and, based on the Texas A&M study, the shipwreck preservation potential would be moderate to high. Ship Shoal Block 88 is located within one of the MMS high-probability search polygons and will require a 50-m (164 ft) marine remote-sensing instrument survey.

Table 3-10 Shipwrecks in the Ship Shoal Area
Source: MMS database.

Vessel Name	Lease Area	Lease Block
EMMA LOUIS	SS	0004
CHANCELLOR	SS	0006
TWIN BROTHER	SS	0013
MARJORIE	SS	0019
MARIAN S	SS	0023
G. MO. MARCONI	SS	0036
MISS LIBERTY	SS	0039
VALKYRE	SS	0045
MISS ELLEN	SS	0063
SEA DUKE	SS	0067
SHIP SHOAL	SS	0067
JO ANN	SS	0074
MINNIE	SS	0086
GOLDEN ISLE	SS	0090
BIG ELEVATOR	SS	0093
GULF OF MEXICO	SS	0093
BRETON ISLAND	SS	0093
SALLY GALE	SS	0093
HELEN BUCK	SS	0097
DAHLIA	SS	0099
CARDINAL ELEVATOR	SS	0107
ATLAS	SS	0109
BLUE WAVE	SS	0109
BRETON ISLAND	SS	0114
MISS MORGAN CITY	SS	0128
G.C.T. CO.16	SS	0159
JOSEPH H. DAVI	SS	0167
R W GALLAGHER	SS	0207
KERR MCGEE 11055	SS	0214
HEREDIA	SS	0216
ANDY MARTIN	SS	0221
LIL TEXAN	SS	0235
JEFF DAVIS	SS	0258

3.16.1.3.2 *Prehistoric Conditions of the Offshore Area*

The migration of early man into the Gulf of Mexico region is currently accepted to be around 12,000 years before the present (B.P.) (Aten 1983). Sea level curves developed for the northern Gulf of Mexico by Coastal Environments, Inc. (CEI 1982) indicate that sea level at 12,000 years B.P. would have been approximately 45 m (147.6 ft) below present sea level. Therefore, the prehistoric archaeological high-probability zone is a contiguous area between the Federal/state boundary and the 45-m (147.6 ft) bathymetric contour.

Based on their 1977 baseline study, CEI proposed that prehistoric sites analogous to the type of sites frequented by Paleo-Indians on land can be identified on the now-submerged continental shelf. Geomorphic features that have a high probability for associated prehistoric sites include barrier islands and back-barrier embayments, rivers channels and associated floodplains and terraces, and salt-dome features. Recent investigations in Louisiana and Florida indicate that mound building activities by prehistoric inhabitants may have occurred as early as 6,200 years B.P. (Hagg 1992; Russo 1992). Therefore, man-made features, such as mounds, may also exist in the shallow inundated portions of the OCS. Remote-sensing surveys performed by the oil and gas industry have been very successful in identifying these types of geographic features that have a high probability for associated prehistoric sites.

Regional geology studies for the Ship Shoal area by Fisk and McFarlan (1955) and Frazier (1974) indicate that this area is underlain by a portion of the abandoned and drowned Maringouin delta complex. This is a subdeltaic mass deposited from about 7,500 to 6,000 years B.P. by the Mississippi River when rising sea level followed the late Wisconsin glacial peak. Subsequently in this area, the Teche and LaFourche deltas, which were active from about 3,500 to 2,500 years B.P. and 1,000 to 300 years B.P., respectively (Kolb and van Lopik 1958), deposited a sequence of deltaic and marine sediments on the Maringouin subdelta. Typical deltaic sequences were deposited as sheets of sand at river mouth bars, with sand and coarser silt remaining nearshore and finer silt and clay were carried offshore by prevailing currents. As the Teche and LaFourche courses were abandoned by the Mississippi River, the massive deltaic sand bodies to the west-southwest were reworked by current action into an elongated shoal, Ship Shoal, which overlies the downwarped, subaerially weathered Prairie formation.

Floyd (1995) performed a geoarchaeological analysis of the Ship Shoal area, Block 72 and 87 geohazard survey. Block 87 borders on the western edge of Ship Shoal 88 and is germane to the prehistoric site potential of Block 88. Floyd (1995) states that this portion of the inner continental shelf was above sea level for thousands of years prior to conversion into a marine environment. He continues with an analysis of the subbottom profiles from Blocks 72 and 87, stating they were examined for relict landforms that may have supported prehistoric human groups prior to complete conversion of this region into an offshore environment (Floyd 1995). Regional geologic information indicates that the post-transgressive, Holocene Age deposits are approximately 110 feet (33.5 m) thick (Bernard 1970). The upper Holocene soil unit covers the Western Wall of the former Mississippi Canyon, which was entrenched during the low sea level cycle. Further, any archaeological sites associated with prehistoric human occupation of this Pleistocene Age river valley are buried beyond reasonable recovery depths (115 feet [35.1 m]). However, there may have been archaeological sites along the subaerial levees of the Holocene Age deltas (e.g., Teche and LaFourche deltas) that aggraded in this region over the past 6,000 years.

Ship Shoal Block 88 falls within the MMS prehistoric high-probability zone (e.g. 45-m [147.6 ft] bathymetric contour) and is subject to prehistoric archaeological clearance prior to any sea floor disturbance.

3.17 RECREATION RESOURCES

While individual significance or value of recreation may differ greatly, nationally it is very significant. This is clarified in the 1999 report drafted by the National Recreation Lakes Study Commission, which states "recreation constitutes 10.5 percent of all consumer spending and contributes more than $350 billion annually to the Gross Domestic Product" (1999).

The following is a "programmatic" survey of Recreational Resources in the LCA Study area. Due to the programmatic nature of the LCA Plan and FPEIS, the ability to do site-specific investigations and surveys in the study area is limited. For this FPEIS, existing reports, studies, and inventories are being compiled and used to compose the historic and existing conditions of recreational resources in the study area. As specific projects are identified and scheduled, impacts to resources specific to each project site/area would need to be assessed.

Much of the recreation data has been extracted from the 1993 – 1998 Louisiana Statewide Comprehensive Outdoor Recreation Plan (SCORP), which is updated at five-year intervals (SCORP 1998). The SCORP not only inventories statewide recreation resources, but also identifies and prioritizes the areas of need. While regions defined in the SCORP do not fit perfectly within the LCA Study area boundaries, the SCORP regions and LCA Study areas do generally coincide. Recreation data was also obtained from the 2000 U.S. Census and National Survey of Fishing, Hunting, and Wildlife-Associated Recreation (FHWAR) by the U.S. Census Bureau, and the 2001 FHWAR completed by USFWS.

3.17.1 Historic Conditions

For the first inhabitants of southern Louisiana, and those who followed, recreation outings were times to practice customs and traditions learned from forefathers. The means by which Louisiana's early residents lived, hunting and fishing for food, utilizing high ground for camps, and building vessels for transportation, shaped what is now recognized as traditional recreation in southern Louisiana.

3.17.2 Existing Conditions

The present day recreational activities are deeply rooted in historic vocational and cultural traditions of southern Louisiana. Vocations centuries old have become today's avocations. Greatly exemplifying this are the hundreds of festivals celebrated throughout the coastal zone, many of which focus on harvests of rice, sugar cane, shrimp, crawfish, oyster, and alligator, and celebrating cultures and heritage such as Cajun, Creole, Isleno, and many European cultures.

The LCA Study area is rich in recreational resources, with nearly half of Louisiana's campgrounds, state historic sites, National historic parks, NWRs, WMAs, state parks and commemorative areas, important bird areas, and other sites of interest scattered throughout the coastal zone. From the Texas coast on the west to the Mississippi state line on the east, the recreating public has access to fresh, estuarine and marine resources for fishing, hunting, boating, swimming, camping, crabbing and crawfishing. Traditional non-consumptive recreation includes, but is not exclusive to, tennis, golf, zoos, aquariums, baseball, picnicking, biking, hiking, wildlife viewing, photography, and other activities.

Sportspersons and wildlife watchers spend $110 billion annually, 1.1 percent of the Nation's gross domestic product. Preliminary findings in the State of Louisiana, from the USFWS 2001 FHWAR, show that 970,000 sportspersons participated in fishing with expenditures of $694,978 and 333,000 participated in hunting with expenditure of $416,953. Wildlife-watching participants numbered 802,000 resident and 314,000 nonresident with expenditures of $165,746. In this region of the country, 19 percent of the population are anglers, 9 percent are hunters, and 25 percent participate in wildlife-watching activities.

Americans traveling to Louisiana spent approximately $8.1 billion in 2001. This supported over 113,000 jobs in the state with annual income of about $1.8 billion. Tax revenues associated with recreation and tourism in Louisiana were about $1.1 billion for all levels of government. Thus, tourism is an important resource in the State of Louisiana.

The Louisiana SCORP included some general needs and needs for specific regions. Some of the general needs included the need for more quality accommodations and camping facilities with more activities; the need to improve access to lakes for the average public; the need to enlarge buffer strips of timber along streams, roads, and lakes to preserve plant communities; the need for more and improved local recreational opportunities; the need for more intense trail systems; the need for more regional promotion and packaging of outdoor recreation; the need for urban wilderness parks; and the need for public education on conservation and facility use. **Table 3-11** displays Federal, state, and other important recreational resources.

Table 3-11
Federal, state, and other areas of important recreational resources

Wildlife/Recreation Areas	State Total	LCA Total	LCA Study Area			
			Delta Plain			Chenier Plain
			Subprovince 1	Subprovince 2	Subprovince 3	Subprovince 4
USFWS National Wildlife Refuges	16	9	3		3	3
Jean Lafitte National Historic Parks and Preserves	6	4	2	1	1	
Louisiana Wildlife Management Areas and Refuges	36	16	5	3	6	2
LA State Parks	17	8	3	2	2	1
State Historic Sites	12	2	1		1	
Important Bird Areas	15	10	3	1	1	5
Scenic Byways	16	7	2	1	2	2
Annualized Unit Day Value (UDV) *	$4.05 billion	$661.3 million	$55.6 million	$66.1 million	$72.3 million	$467.3 million

3.17.2.1 Subprovince 1: Eastern Mississippi River Delta, Lake Pontchartrain, and Breton Sound Basin

The Louisiana SCORP inventoried over 282,000 acres (114,210 ha) of recreational facilities (these are public facilities and acres, and do not account for private lands and leases) for SCORP Region 1 (roughly, Subprovince 1). While some of these facilities are tied more to urban settings, much is tied directly to the coastal zone. More than 196,000 acres (79,380 ha) are available for hunting. The region also has 142 boat lanes at 123 boat ramps; 395 acres (160 ha) with 1,833 tables for picnicking; 10 beaches equating to 11 acres (4.5 ha); and 320 acres (129.6 ha) for camping, with 263 tent sites and 1,739 trailer sites. These resources alone are conservatively estimated to have an annualized Unit Day Value (UDV) of over $120 million.

The SCORP prioritized needs in this region/subprovince, which include the need for improved access to roadside areas to enable fishing and boating, the need to include consumptive and non-consumptive activities on all public recreation areas with adequate funding for both user groups, the need for more wilderness/primitive camping opportunities, the need to identify and acquire large tracts of waterfront lands for large scale parks, and the need to address the dwindling state of marine resources.

3.17.2.2 Subprovince 2: Western Mississippi River and Barataria Basin

The Louisiana SCORP inventoried over 104,000 acres (42,120 ha) of recreational facilities (these are public facilities and acres, and do not account for private lands and leases) for SCORP

Region 3 (roughly, Subprovince 2). More than 107,000 acres (43,335 ha) are available for hunting. How can you have more acres for hunting than were inventoried (107,000 acres vs. 104,000 acres)? The region also has 194 boat lanes at 105 boat ramps; 131 acres (53.1 ha) with 365 tables for picnicking; 1 beach of 37 acres (14.9 ha); and 71 acres (28.7 ha) for camping with 34 tent sites and 422 trailer-sites. These resources alone are conservatively estimated to have an annualized UDV of over $286 million.

The SCORP prioritized needs in this region/subprovince, which include the need to maintain cultural heritage while increasing benefits associated with outdoor recreation and tourism, the need to promote and improve upon what is there (e.g., Terrebonne, fishing, marsh, foods, etc.), the need for more public access to marshes, the need to protect the barrier islands, and the need to provide aid to recreation-related businesses.

3.17.2.3 Subprovince 3: Teche, Vermilion, Atchafalaya, and Terrebonne Basins

The Louisiana SCORP inventoried over 690,000 acres (279,450 ha) of recreational facilities (these are public facilities and acres, and does not account for private lands and leases) for SCORP Region 4 (roughly, Subprovince 3). While some of these facilities are tied more to urban settings, much is tied directly to the coastal zone. More than 523,000 acres (211,815 ha) are available for hunting. The region also has 218 boat lanes at 138 boat ramps; 607 acres (245 ha) with 1,441 tables for picnicking; 16 beaches equating to 8 acres (3.2 ha); and 443 acres (179 ha) for camping, with 498 tent sites and 2,391 trailer sites. These resources alone are conservatively estimated to have annualized UDV of over $119 million dollars.

The SCORP prioritized needs in this region, which include the need for full funding for State Parks Capital Improvement Plan, the need for better roads and signage to recreation areas, the need to educate the public about conservation/ethical usage of land, the need to make the public aware that recreation is part of tourism and is an economic development tool, the need to educate users (locals and tourists) to the uniqueness of the region (Tabasco, salt domes, Atchafalaya Delta, swamps, etc.); the need to provide recreation to improve the quality of life, and the need to promote and interact between local, state, Federal, and private recreation programs to keep users/tourists in the area longer.

3.17.2.4 Subprovince 4 – Calcasieu/Sabine and Mermentau Basins

The Louisiana SCORP inventoried over 383,000 acres (155,115 ha) of recreational facilities (these are public facilities and acres, and do not account for private lands and leases) for SCORP Region 5 (roughly, Subprovince 4). While some of these facilities are tied more to urban settings, many are tied directly to the coastal zone. More than 134,000 acres (54,270 ha) are available for hunting. The region also has 115 boat lanes at 89 boat ramps; 153 acres (62 ha) with 1,054 tables for picnicking; 10 beaches equating to 363 acres (147 ha); and 154 acres (62.4 a) for camping, with 282 tent sites and 825 trailer sites. These resources alone are conservatively estimated to have an annualized UDV of over $2.6 billion.

The SCORP prioritized needs in this region, which include the need to promote southwest Louisiana, birding, public hunting, cycling, and hunting of underutilized species; the need to provide more and improved access to water-based recreation (roads, parking, facilities, ramps, piers, bank fishing, and improve existing wharfs); the need for more public restrooms and picnic facilities; and the need to identify cultural sites.

3.18 AESTHETIC RESOURCES

3.18.1 Historic and Existing Conditions

This resource's institutional significance is derived from laws and policies that affect visual resources, most notably NEPA. The 1988 USACE Visual Resources Assessment Procedure (VRAP) provides a technical basis for identifying the project's significant impacts. Public significance is based on public perceptions and professional analysis of the project's visual impacts (Smardon et al. 1988).

The VRAP was developed for use in the planning process as input to plan formulation, design, and operations. The VRAP is organized as a process, as if the USACE had a database on the existing visual quality of the District's area of responsibility and could draw on this to assess the impacts to aesthetics caused by various civil works projects. As this is not the case, use of the procedure to place a value on existing visual resources requires developing the information leading up to the existing visual quality conditions (i.e., the Management Classification System (MCS)).

The timing of MCS implementation, the level of detail at which visual resource information is collected and analyzed, and the nature of the MCS end products are varied considerably in response to the District's planning needs. The MCS would be done at the regional level (Chenier and Delta Plains) during the detailed planning process of any proposed LCA Plan projects.

The type of public input for aesthetics, as well as environmental issues in general, varies with the project. Indirect sources of public opinion, such as the National and state recognized scenic byways and rivers are identified and used in the professional assessments of aesthetic values representative of the Chenier and Deltaic Plains. Examples include the Louisiana Scenic Byway, River Road Scenic Byway, San Bernardo Scenic Byway, Lafourche/Terrebonne Scenic Byway, Bayou Teche Scenic Byway, Promised Land Scenic Byway, Jean Lafitte Scenic Byway, and the Creole Nature Trail. Aesthetic values of aquatic areas are derived from the natural characteristics of a particular area. Aesthetic values may include such parameters as the visual distinctiveness of the elements present, which may result from prominence, contrasts due to irregularity of form, line, color, and pattern; the diversity of elements present, including topographic expression; shoreline complexity; landmarks; vegetative pattern diversity; and waterform expression.

Historical accounts of the visual character of the Louisiana coastal area detail how hydrologic modifications due to the service needs of various industries - petroleum, maritime, agriculture and timber - and man's settlement patterns have forever changed the landscape character of the Louisiana coastal area. The most intensive petroleum development in the Nation's coastal area and Federal offshore area has been concentrated in Louisiana. Since 1926, when production was first recorded in the coastal zone, a large portion of the state's total oil and gas has been produced in this part of the state. Therefore, as the proposed coastal restoration projects approach design implementation, environmental assessment of the project's effects to existing visual resources would be utilized on an individual project basis, taking into account historical conditions.

3.19 AIR QUALITY

This resource is institutionally significant because of the Clean Air Act of 1963, as amended (CAA), and the Louisiana Environmental Quality Act of 1983, as amended (LEQA). Air quality is technically significant because of the status of regional ambient air quality in relation to the National Ambient Air Quality Standards (NAAQS). It is publicly significant because of the desire for clean air expressed by virtually all citizens.

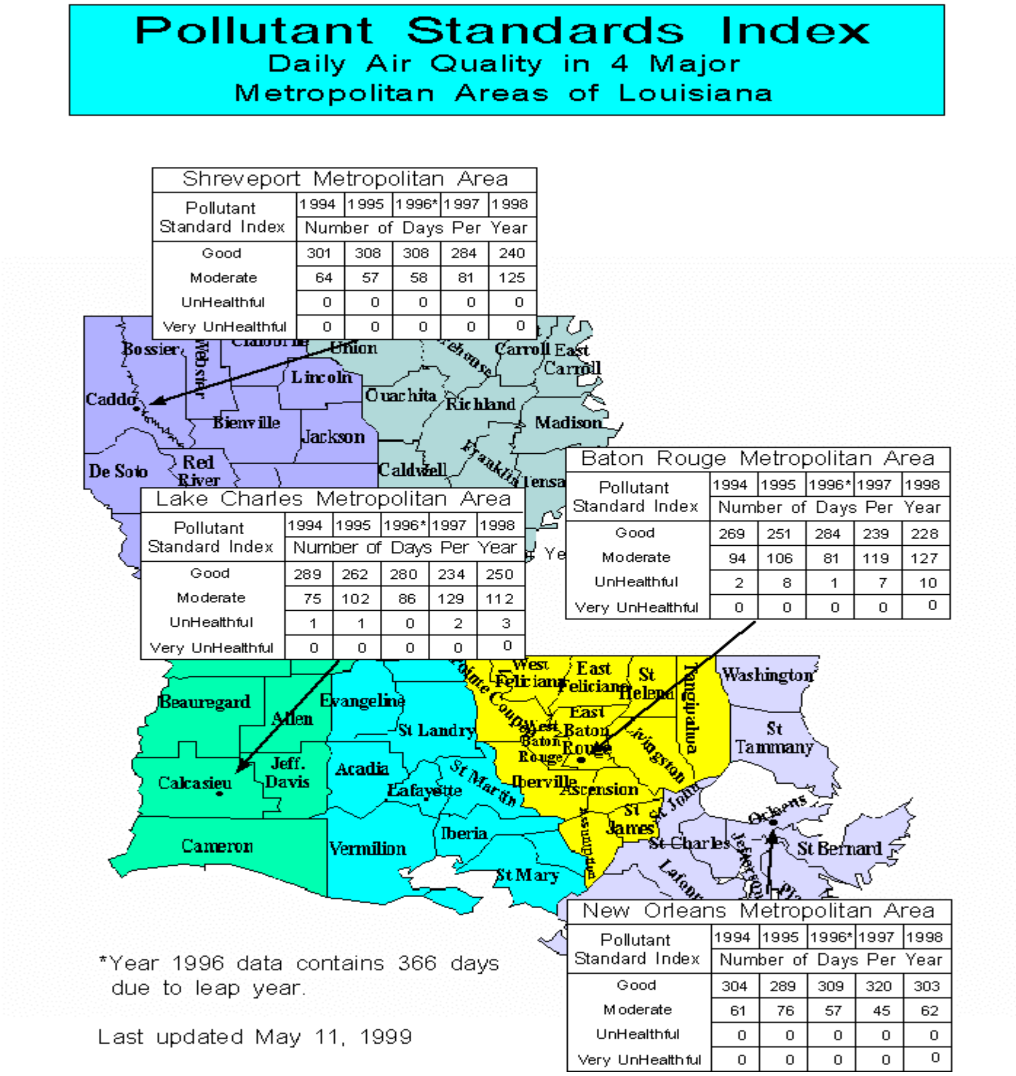
3.19.1 Historic and Existing Conditions

3.19.1.1 Criteria Pollutant Reporting

The USEPA has set national air quality standards for six common pollutants (also referred to as "criteria" pollutants). They include ozone (O_3), particulate matter, carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2) and lead (pB). States are required by the Code of Federal Regulations (CFR) to report to the USEPA annual emissions estimates for point sources (major industrial facilities) emitting greater than, or equal to, 100 tons (per year of volatile organic compounds (VOCs), NO_2, SO_2, particulate matter less than 10 microns in size (PM-10); 1,000 tons per year of CO; or 5 tons per year of Pb. Since O_3 is not an "emission," but the result of a photochemical reaction, states are required to report emissions of VOCs, which are compounds that lead to the formation of O_3. **Figure 3-31** displays pollutant standards in four major metropolitan areas of Louisiana (LDEQ - personal communication).

In accordance with the CAA, USEPA set NAAQS for pollutants considered harmful to public health and the environment. The CAA established two types of national air quality standards. Primary standards set limits to protect public health, including the health of "sensitive" populations such as asthmatics, children, and the elderly. Secondary standards set limits to protect public welfare, including protection against decreased visibility, damage to animals, crops, vegetation, and buildings.

Generally, addressing potential air quality impacts concerns would be accomplished on a project-by-project basis and in coordination with the LDEQ. As required by LAC 33:III.1405 B, an air quality applicability determination would be made for each specific project. This would include consideration of each separate project item of the proposed action for the category of general conformity, in accordance with the Louisiana General Conformity, State Implementation Plan (SIP; LDEQ 1994).



Shreveport Metropolitan Area

Pollutant Standard Index	1994	1995	1996*	1997	1998
	Number of Days Per Year				
Good	301	308	308	284	240
Moderate	64	57	58	81	125
UnHealthful	0	0	0	0	0
Very UnHealthful	0	0	0	0	0

Baton Rouge Metropolitan Area

Pollutant Standard Index	1994	1995	1996*	1997	1998
	Number of Days Per Year				
Good	269	251	284	239	228
Moderate	94	106	81	119	127
UnHealthful	2	8	1	7	10
Very UnHealthful	0	0	0	0	0

Lake Charles Metropolitan Area

Pollutant Standard Index	1994	1995	1996*	1997	1998
	Number of Days Per Year				
Good	289	262	280	234	250
Moderate	75	102	86	129	112
UnHealthful	1	1	0	2	3
Very UnHealthful	0	0	0	0	0

New Orleans Metropolitan Area

Pollutant Standard Index	1994	1995	1996*	1997	1998
	Number of Days Per Year				
Good	304	289	309	320	303
Moderate	61	76	57	45	62
UnHealthful	0	0	0	0	0
Very UnHealthful	0	0	0	0	0

Figure 3-31. Pollutant standards in four major metropolitan areas of Louisiana *(Source: LDEQ).*

An air quality determination would be calculated for each project, based upon direct and indirect air emissions. Direct emissions include those resulting directly from construction of the proposed action. Generally, since no other indirect Federal action, such as licensing or subsequent actions would likely be required or related to the restoration construction actions, it is likely that indirect emissions, if they would occur, would be negligible. Therefore, the air applicability determination analysis would be based upon direct emission for estimated construction hours. Typically, however, consideration of total emissions for each work item separately (or even when all work items are summed) generally do not exceed the threshold limit applicable to VOCs for parishes where the most stringent requirement (50 tons per year in serious non-attainment parishes) is in effect, (see General Conformity, SIP, section 1405 B.2), the VOC emissions for the proposed construction would be classified as de minimus and no further action would be required.

3.19.2 Improving Air Quality via Coastal Restoration

The effects of vegetation, especially trees, on air quality is exemplified by research conducted by David J. Nowak, Project Leader, USDA Forest Service, Northeastern Research Station, 5 Moon Library, SUNY-CESF, Syracuse, NY 13210. Nowack and his associates found that urban trees remove gaseous air pollution primarily by uptake via leaf stomata as well as at the plant surface. Trees also remove pollution by intercepting airborne particles. Nowak found that air quality improvement in New York City, due to pollution removal by trees during daytime of the in-leaf season averaged 0.47 percent for particulate matter, 0.45 percent for O_3, 0.43 percent for SO_2, 0.30 percent for NO_2, and 0.002 percent for CO. In 1994, trees in New York City removed an estimated 1,821 metric tons of air pollution at an estimated value to society of $9.5 million. Air pollution removal by urban forests in New York was greater than in Atlanta (1,196 tons; $6.5 million) and Baltimore (499 tons; $2.7 million), but pollution removal per m^2 of canopy cover was fairly similar among these cities (New York: 13.7 $g/m^2/yr$; Baltimore: 12.2 $g/m^2/yr$; Atlanta: 10.6 $g/m^2/yr$).

These standardized pollution removal rates differ among cities according to the amount of air pollution, length of in-leaf season, precipitation, and other meteorological variables. Large healthy trees greater than 77 cm (30.03 in) in diameter remove approximately 70 times more air pollution annually (1.4 kg/yr [3.1 pounds/yr]) than small healthy trees less than 8 cm (3.1 in) in diameter (0.02 kg/yr [0.04 pounds/yr]). With regard to emission of VOCs, Nowak found that emissions by trees can contribute to the formation of O_3 and CO. However, in atmospheres with low nitrogen oxide concentrations (e.g., some rural environments), VOCs may actually remove O_3. Because VOC emissions are temperature dependent and trees generally lower air temperatures, increased tree cover can lower overall VOC emissions and, consequently, O_3 levels in urban areas. VOC emission rates also vary by species. Nine genera that have the highest standardized isoprene emission rate, and therefore the greatest relative effect among genera on increasing O_3, are beefwood (*Casuarina* sp.); *Eucalyptus* sp.; sweetgum ; black gum (*Nyssasylvatica*); sycamore (*Platanus* sp.); poplar (*Populus* sp.); oak (*Quercus* sp.); blacklocust (*Robiniapsuedoacacia*); and willow (*Salix* sp.). However, due to the high degree of uncertainty in atmospheric modeling, results are currently inconclusive as to whether these genera will contribute to an overall net formation of O_3 in cities (i.e., O_3 formation from VOC emissions are greater than O_3 removal). Some common genera in Brooklyn, NY, with the greatest relative effect on lowering O_3 were mulberry (*Morus* sp.); cherry (*Prunus* sp.); linden (*Tilia* sp.); and honey locust (*Gleditsiatriacanthos*).

Studies of the effects of common wetland plants and trees, such as those found in coastal Louisiana, on air pollution have yet to be done. However, it is reasonable to extrapolate from these existing studies that similar effects on air quality improvement would be likely, especially for restoration of fresh swamp and bottomland hardwood forests (David J. Nowak, Project Leader, USDA Forest Service, Northeastern Research Station, 5 Moon Library, SUNY-CESF, Syracuse, NY 13210 - personal communication)

3.20 NOISE

3.20.1 Historic and Existing Conditions

Noise, or unwanted sound, may be objectionable in terms of the health or nuisance effects it may have upon humans and the human environment, as well as upon the animals and ecological systems in the natural environment. The Noise Control Act of 1972 declares the policy of the United States to promote an environment for all Americans free from noise that jeopardizes their health or welfare. It is the purpose of the act to establish a means for effective coordination of Federal activities in noise control and to provide information to the public regarding the noise emissions.

Noise concerns are directly related to its potential negative effects upon humans and animals, and may range from annoyance to adverse physiological responses, including permanent or temporary loss of hearing, disruption of colonial nesting birds, and other types of disturbance to humans and animals. Noise is typically associated with human activities and habitations, such as operation of commercial and recreational boats, water vessels, air boats, and other recreational vehicles; operation of machinery and motors; and human residential-related noise (air conditioner, lawn mower, etc.). Generally, noise is a localized phenomenon throughout the LCA Study area.

3.21 HAZARDOUS, TOXIC, AND RADIOACTIVE WASTE

A Phase I Initial Site Assessment (ISA) is required for all USACE Civil Works Projects to facilitate early identification and appropriate consideration of potential HTRW problems. Engineer Regulation ER 1165-2-132 and Division Regulation DIVR1165-2-9 describe the policies for conducting HTRW reviews for USACE Civil Works Projects. HTRW includes any material listed as a "hazardous substance" under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), and any material listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA). Other regulated contaminants include those substances that are not included under CERCLA and RCRA, but may pose a potential health or safety hazard, and are regulated by other statutory authorities. Examples include, but are not limited to, many industrial wastes; naturally occurring radioactive materials (NORM); many products and wastes associated with the oil and gas industry; herbicides; and pesticides. If dredged material and sediments beneath navigable waters are within the boundaries of a site designated by the USEPA or the state for a response action under CERCLA, or if they are part of a National Priority List site under CERCLA, they will qualify as HTRW and will be treated accordingly. However, dredged material and sediments beneath navigable waters that do not qualify as HTRW, as defined in the preceding, would be evaluated for suitability for placement in waters of the U.S. in accordance with the Section 404 (b)(1) guidelines as mandated by Section 404 of the CWA, or the criteria established in Section 103 of the Marine Protection, Research, and Sanctuaries Act.

The purpose of the Phase I ISA is to ensure that HTRW and contamination issues are properly considered in project planning and implementation. The ISAs generally consist of a review of all properties in a project area to determine the potential for HTRW concerns on each property. In addition, a complete review of appropriate state and Federal environmental enforcement agencies' records is conducted, prior to a site reconnaissance, to identify any potential hazardous situation. The results of the ISA provide early detection of HTRW, and determine viable options to avoid HTRW problems and establish procedures for resolution of HTRW concerns, issues, or problems. Early detection of HTRW sites of concern within the project area would be accomplished during early planning phases, prior to land acquisition, and initiation of construction activities. HTRW problem areas would be avoided where practicable.

Should an ISA discover HTRW problems within a project area, a Phase II assessment would be conducted to further investigate areas of concern identified by the Phase I ISA. A Phase II assessment consists of sampling and testing various media (e.g., oil, water, air, soil, containers, substances, etc.), which were identified in the ISA as areas of concern. Sampling and testing would confirm the presence, characteristics, and extent of contamination. The Phase II assessment would also present recommendations on what removal and/or control actions would be necessary to mitigate potential hazards. Where HTRW contaminated areas or impacts cannot be avoided, response or remediation actions must be acceptable to the EPA and state regulatory agencies.

3.21.1 Historic Conditions

Development of oil and gas resources in the Louisiana coastal zone began in the 1920s, and in the 1940s on the outer continental shelf (OCS). Since 1921, about 75 percent of all state lands leased for petroleum development has been in the coastal zone. As the early oil and gas industry flourished, transportation and storage became a problem. Pipelines were built to the railroads, where tank cars were filled and transported. Storage presented difficulties because shipping could not keep up with production. Some elevated wooden tanks were built to store oil, but large earthen storage pits were also often dug to hold millions of barrels. In addition to these oil storage pits, earthen pits were also used to store drilling muds, brine, and by-products from daily oil and gas activities. Pipelines were later constructed to connect offshore oil and gas production platforms with onshore facilities. Today, several thousand miles (over 10 thousand km) of pipeline systems extend to virtually all points in the state.

In addition to the emergence of the oil and gas industry, two discoveries in the 19th century laid the foundation for the development of the petrochemical industry in Louisiana in the 20th century. Salt was discovered at Avery Island in 1862 and sulfur was discovered near Lake Charles around the mid- to late-nineteenth century. Brine in salt domes is used to make chlorine for bleach and water purification, computer discs, and polyvinyl chloride (PVC). Sulfur is used in making fertilizer and paper, among other products. Other industries in Louisiana produce potential HTRW substances, including synthetic rubber, refrigerants, and oxygen. A large portion of the petrochemical industry is located along major Louisiana waterways (e.g., Mississippi and Calcasieu Rivers) where there is a source of water for production activities and transportation.

3.21.2 Existing Conditions

A review of Federal and state agencies' databases reveals numerous HTRW sites of concern within the parishes in the coastal Louisiana study area. The Federal agencies' databases revealed numerous sites under the National Priority List (Superfund); CERCLA; RCRA waste generators; RCRA Corrective Action (CORRACTS) list; RCRA non-CORRACTS treatment, storage or disposal facilities; and sites listed under the National Response center for incidents involving oil and chemical spills. The state databases also revealed numerous inactive and abandoned sites, landfills, and leaking underground storage tanks. In addition to these known areas of concern, a large number of unknown/unidentified environmental sites of concern are likely located within the coastal Louisiana study area.

Compilation of a list of sites of concern for the entire LCA Study area is not practicable at this time in light of the large number of sites, funding limitations, and current time constraints. As restoration alternative plans become more defined, detailed HTRW analyses will be performed to evaluate and eliminate, where possible, potential HTRW problem sites from consideration. Addressing existing HTRW sites of concern for proposed LCA Plan projects will include a review of site-specific as well as project specific information and plans. However, preliminary sites of concern were compiled from a number of state and Federal databases. **Figure 3-32** shows the locations of a superfund site, several inactive and abandoned sites, open dumpsites, and leaking underground storage tanks known to be present within the Louisiana study area.

The USCG – National Response Center recorded over 60,000 reports of crude oil and natural gas spills in the entire state of Louisiana from 1990 to 2002. **Figure 3-33** shows the approximate locations of the spills. This figure is for HTRW information purposes only. The source of the information used in displaying spills was developed by the Louisiana Oil Spill Coordinator's Office (LOSCO)/Office of the Governor. The geographic location accuracy is highly variable from a hundredth of a mile (hundredth of km) to over one hundred miles (over 161 km), and in some cases derivation of a geographic location is not possible. The information provided is presented "as is" without warranty of any kind (contact LOSCO for the complete legal distribution liability disclaimer).

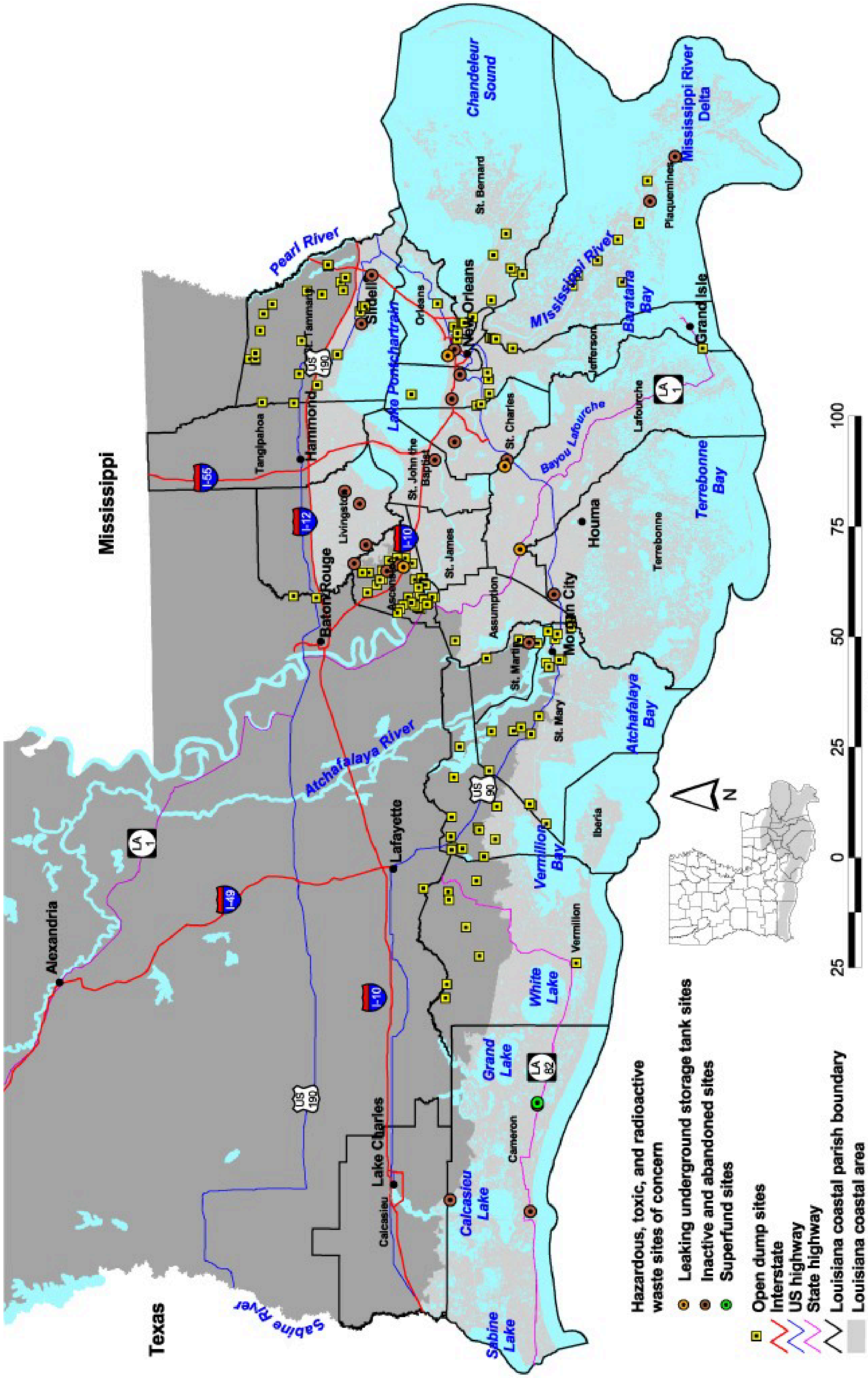


Figure 3-32. Hazardous, toxic, and radioactive waste sites of concern within the coastal Louisiana study area.

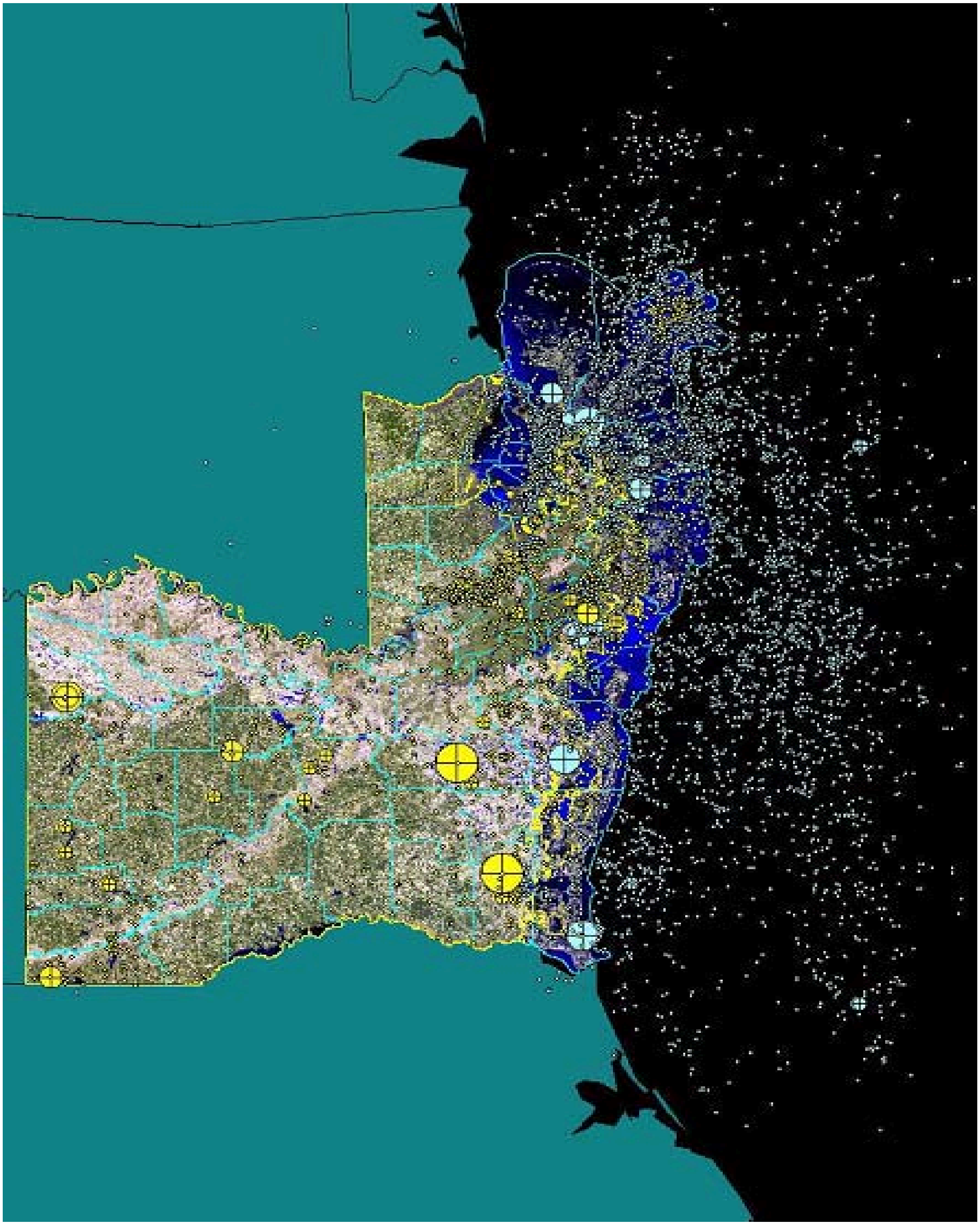


Figure 3-33. Crude oil and natural gas spills in the entire State of Louisiana from 1990 to 2002 *(from LOSCO).*

3.22 SOCIOECONOMIC AND HUMAN RESOURCES

Nearly two million people, representing approximately 43 percent of the state's population, reside within the LCA Study area. The rich soil conditions, mild climate, natural waterways, and abundance of water and other natural resources have long attracted and supported economic development in coastal Louisiana. The diversified economy that exists in the region today includes oil and gas production and transportation, navigation, commercial fishing, agriculture, recreation, and tourism. Employment has varied widely with periods of rapid growth and contraction; in 2000 there were more than 800,000 jobs in coastal Louisiana. The most influential industries for the study area's economy include oil, gas and pipeline; navigation; commercial and recreational fishing and hunting; and agriculture, all of which are essential for supporting Louisiana's economy. The following socioeconomic profile addresses historic and existing conditions within 17 Louisiana parishes of the LCA Study area. A general background of population, infrastructure, socioeconomic and human resources, commercial fisheries, oyster leases, petroleum, navigation, flood control, pipelines, hurricane protection, agriculture, forestry, and water supply are discussed below. Environmental justice issues will be assessed on a project-specific basis during follow-up feasibility level analyses. Reference to compliance with Executive Order 12898 regarding environmental justice is described in section 6.1.1.11.

3.22.1 Population

3.22.1.1 <u>Historic and Existing Conditions</u>

Population in the 20-parish study area increased from 1,556,965 to 2,247,344 from 1960 to 2000, with approximately 50.2 percent of Louisiana's population residing in the coastal area. Population in coastal parishes has remained fairly stable as a share of state population over this period. Every parish in the study area has increased in population over the period except Orleans Parish, which decreased.

3.22.2 Infrastructure

3.22.2.1 <u>Historic and Existing Conditions</u>

Table 3-12 is a summary of the infrastructure in the portions of the study area that are considered at risk.

Table 3-12
Summary of the Valuation of Assets in the LCA Study Area
(*source: Waldemar S. Nelson & Co 2003)*

Asset Category	Value
Oil and Gas Production Facilities	$3,207,180,000
Pipelines	3,203,947,000
Highways	5,981,038,000
Railroads	385,770,000
Navigable Waterways	3,639,743,000
Ports	869,376,000
Industrial and Manufacturing Facilities	30,818,728,000
Transmission Lines	416,844,000
Municipal and Parish Utility Infrastructure	4,295,777,000
Municipal and Parish Private Buildings	42,756,136,000
Agricultural Interests –Lands	160,680,000
Agricultural Interests –Products	163,424,000
Total Asset Value	$95,898,643,000

The estimation methods used include replacement costs (for pipelines, highways, and railroads) and fair market value (for agriculture and private buildings). Also, the value of the navigable waterways in the study area was calculated by using operation and maintenance costs. It was assumed that the costs paid for the navigable waterways in the system are justified (i.e., that the value of the waterways system is equal to what is being paid to maintain them). The estimated total asset value that would be at greater risk if coastal erosion continues is between $95 billion and $100 billion.

3.22.3 Employment and Income

3.22.3.1 <u>Historic and Existing Conditions</u>

Employment in the study area has varied widely, with several periods of rapid growth and shrinkage as the job base varied. For example, strong growth in the early 1980s was followed by sharp job declines during the mid and late 1980s. This decline was brought about by shrinkage in oil field production and employment, caused by dropping oil prices.

The diversification of the southern Louisiana economy increased after the local recession of the late 1980s, as resources were channeled from the oil and gas industry into other areas, including tourism. However, many jobs still depend on the oil and gas industry. For example, much of the construction employment is oil and gas dependent, since a lot of construction activity is done in support of that industry. The leading employers are transportation; oil and gas; seafood; tourism; and the finance, insurance, and real estate sectors.

The highest income parishes in the area are consistently those in the New Orleans metropolitan statistical area (MSA), including St. Tammany, Jefferson, St. Charles, and Orleans Parishes. The most influential industries for the study area economy, and the ones most likely to be impacted by coastal wetland losses, include oil, gas, and pipeline; navigation (transportation); and commercial and recreational fishing and hunting. These industries are covered in the following sections, along with flood control, which is a major issue for study area inhabitants.

3.22.4 Commercial Fisheries

3.22.4.1 Historic and Existing Conditions

Louisiana's coastal wetlands are the richest estuaries in the country for fisheries production. Commercially and recreationally important species such as brown and white shrimp, blue crabs, eastern oysters, and menhaden are abundant, but these species populations are threatened if land loss continues. Louisiana has historically been an important contributor to the Nation's domestic fish and shellfish production, and is one of the primary contributors to the Nation's food supply for protein. While Louisiana has long been the Nation's largest shrimp and menhaden producer, it has also recently become the leading producer of blue crabs and oysters.

Total landings in Louisiana were 1.2 billion pounds (0.54 billion kg)in 2001. The percentage contribution of total landings for the gulf region was 74 percent and for the Nation was 12.5 percent. Dockside revenues for commercial fisheries in coastal Louisiana were $343 million in 2001 (NMFS 2003b). These revenues were the largest for any state in the contiguous United States, second only to Alaska. **Figure 3-34** shows the trend in total landings for Louisiana, the gulf region, and the Nation attesting to the substantial productivity of Louisiana's coastal marshes (NMFS 2003b).

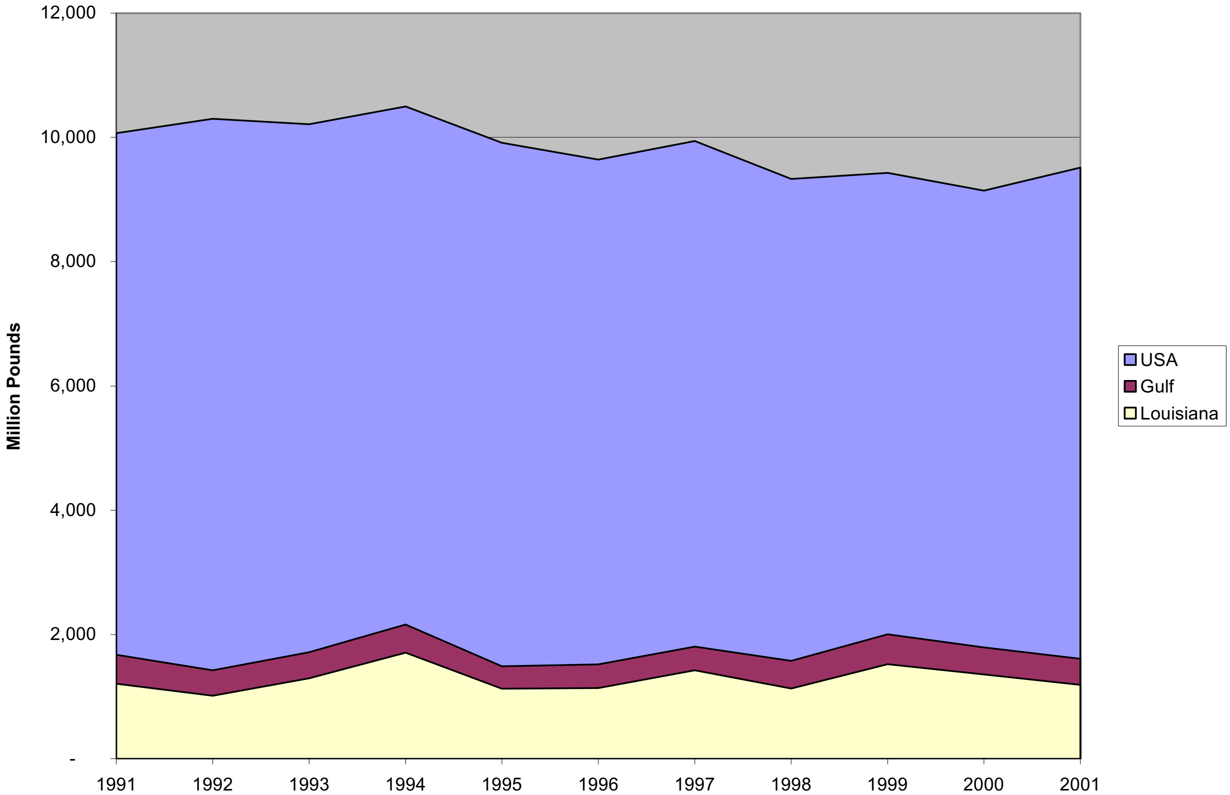


Figure 3-34. Historical trend in commercial landings for Louisiana, the gulf region and the Nation (*source: NMFS 2003b*).

The most important species, in terms of Louisiana dockside revenue in 2001, was shrimp. Louisiana caught approximately 125 million pounds (56.3 million kg) of shrimp in 2001, which is over 45 percent of United States' total landings, and more than what was caught in any other state. In 2000, the gulf region landed over 77 percent of the total United States' shrimp catch and Louisiana landed over 57 percent of shrimp caught in the gulf. Almost all of the shrimp caught in Louisiana and along the gulf coast have spent an important part of their life living and growing in the Louisiana coastal marshes.

Another important species harvested in the area is menhaden. Menhaden is processed to produce both fishmeal and fish oil. Fishmeal is used as a high protein animal feed. The broiler (chicken) industry is currently the largest user of menhaden meal, followed by the turkey, swine, pet food, and ruminant (cattle/livestock) industries. The Louisiana menhaden fisheries landings were the largest in the Nation, landing twice as much as the next closest state. The percent of dockside value from Louisiana to that of the rest of the Nation was over 57 percent.

In 2002 alone, Louisiana had 44 percent of the Nations oyster catch (58 percent of the Nation's eastern oysters) by pounds with 36 percent of the value (or 49 percent of the value for the Nation's eastern oysters). Louisiana also has led the United States in eastern oyster production, contributing just under half of the U.S. production. Louisiana also produced about 26 percent of the Nation's blue crabs in 2001. As with eastern oyster production, the trend has been for Louisiana to become the largest producer of blue crabs in the Nation, surpassing other states that were the dominant producers in the 1990s. The dockside value for blue crabs landed in Louisiana in 2001 was $35.9 million for landings of 41.7 million pounds (18.7 million kg).

3.22.5 Oyster Leases

3.22.5.1 Historic Conditions

In 1892, Act 206 established the first public oyster grounds open to all Louisiana residents. Act 206 also adjusted the closed season, increased the size of a lease to 10 acres (4 ha), and authorized the office of oyster inspector to enforce the laws. Ten years later, Louisiana's first comprehensive oyster law was passed with the Act of 1902. The Louisiana Department of Conservation issued the first private oyster lease in 1903 in Plaquemines Parish (Laiche 1993).

3.22.5.2 Existing Conditions

Louisiana is the top producer of the eastern oyster (*Crassostrea virginica*) in the United States, averaging approximately 11.4 million pounds (5.1 million kg) per year, with an average value of $25.8 million. The fishery has two main sources - privately leased grounds, and public seed grounds. The State of Louisiana owns the water bottoms, and leases out acreage to oyster fishermen. The public grounds are open to harvesting by all licensed fishermen, but are only open during the public season, which runs from September through March. Oysters can be harvested from the private grounds throughout the year.

The LDWF and the Louisiana Wildlife and Fisheries Commission manage over 1 million acres (over 405,000 ha) of public grounds. Extensive reefs are located on the east side of the Mississippi River, particularly in Black Bay, Lake Borgne, and the Biloxi Marsh. Special areas in the public grounds are managed as Oyster Seed Reservations, which generally have more strict harvest limitations. These are located in Bay Gardene, Hackberry Bay, Sister Lake, and Bay Junop. Vast areas of public seed grounds are located in Vermilion Bay, East and West Cote Blanche Bays, and a special tonging-only area is located in Calcasieu Lake.

These public grounds provide seed oysters (less than 3 inches [7.6 cm]) that can be transplanted to leases to grow up to legal sacking size. The public grounds also provide sack oysters that can be brought directly to market. Prior to 1993, sales from private leases comprised around two thirds of the total oyster production. Beginning in 1993, approximately half of the oysters brought to market in Louisiana now come from public grounds. In recent years, the market for oysters has been stagnant, which is in part due to illness associated with the consumption of raw oysters. The Louisiana Oyster Task Force has contracted with a marketing firm to try to expand the market for Louisiana oysters, and counteract negative publicity.

Approximately 420,000 acres (170,100 ha) are currently under lease in Louisiana, compared to less than 250,000 acres (101,250 ha) during the mid 1970s and early 1980s (Diagne and Keithly 1998). The leases have 15-year terms and are leased from the state for $2 per acre per year. Using data from NMFS for the period from 1985 through 2001, the average value of the harvest from private leases is $17,149,464. Dividing this number by the average total acreage leased over this same period gives the annual harvest per acre. Assuming 360,172 acres (145,869 ha), the average acre of oyster lease produces approximately 27 pounds (12.2 kg) of oysters and $48 in gross sales. However, the quality of water bottoms varies widely, with the harder substrates generally providing the better oyster productivity. In a recent bottom side-scan sonar survey of 9,600 acres (3,888 ha) of leases in the Barataria Basin, approximately 6.6 percent of the leased area was found to have a suitable bottom for growing oysters (Wilson and Roberts 2000). The remainder of the leased area lacked enough hard bottom to support commercial farming of oysters. It is unknown if this leased area is representative of the entire leased area in the state.

Leasing in the Barataria Basin has shown a northward trend over the years, with an increased acreage being leased in the upper estuary as salinities increased (van Sickle et. al. 1976). Oysters in high salinity waters are susceptible to infection with *Perkinsus marinus*, or "dermo," a parasitic protozoan. Predation by the oyster drill (*Stramonita haemastoma*) and other predators also causes increased oyster mortality in high salinity water. Leases are presently located as far north as Little Lake, Turtle Bay, Round Lake, and Lake Laurier. Areas east of the Mississippi River, and the Barataria Basin dominate oyster production in Louisiana. St. Bernard and Plaquemines Parishes encompass virtually all of the oyster producing areas east of the river, and Plaquemines Parish also includes part of the Barataria Basin. From 1988 through 1997, these two parishes accounted for approximately 50 percent of the oysters landed in Louisiana, and approximately 47 percent of landings from private leases in Louisiana. Monitoring data from the existing Caernarvon diversion structure has shown that production of both oysters and menhaden has increased.

The feasibility and cost of creating oyster habitat can be examined through past experience of the LDWF. The LDWF has conducted numerous shell plants over the years in areas that have favorable growing waters. Barges of clamshell or other suitable cultch material are towed slowly across the area, and the shell is pushed off of the barges by high-pressure hose. Such shell plants can be highly productive for many years. The cost of LDWF's 1994 and 1995 shell plants was approximately $2,000 per acre.

A more recent effort was made to estimate the cost of preparing water bottoms for oyster cultivation for cases where the water bottom used would not necessarily be a firm one, as was typically used by LDWF for shell plants. The cost was estimated to be approximately $7,200 per reef acre. The difference in cost is related to the higher volume of cultch used per acre (185 cy/acre vs. 81 cy/acre), and the increased cost of cultch since 1995 ($37.35/cy vs. $24/cy).

3.22.6 Oil, Gas, and Minerals

3.22.6.1 Historic and Existing Conditions

The petroleum industry in the state accounts for almost 25 percent of the total state revenues and employs more than 116,000 people (about 6 percent of the state's total workforce). These workers earn almost 12 percent of the total wages paid in Louisiana. Indirect employment levels in support industries make this economic sector more important than is indicated by the direct employment figures.

Dependence on imported oil and gas is driven by domestic petroleum production and consumption. Until the 1950s, the United States produced nearly all of the petroleum it needed. The gap between production and consumption began to widen, so that imported petroleum has become a major component of the U.S. petroleum supply. The U.S. produces less crude oil than it did 20 years ago and from 1993 onward, the U.S. has imported more petroleum than it produced. In 2000, U.S. petroleum net imports reached an annual record level of 10.6 million barrels per day (3.8 billion barrels per year).

Louisiana plays an important part in the production of crude oil for the Nation. Louisiana's production of crude oil has declined by about 30 percent since 1980, although production in the Louisiana OCS has increased steadily since 1990 and now greatly exceeds the onshore production rate. In 2000, Louisiana produced more crude oil than any other state. Louisiana's oil resources come from wells on land, from state waters within three miles (4.8 km) of shore, and from Federal waters greater than three miles (3.8 km) from shore. The amount of oil produced by Louisiana can be put into perspective by comparing it to what is consumed by the entire Nation. Energy consumption can be divided into five sectors: transportation, industrial, electric power generation, residential, and commercial. Over the past 20 years, Louisiana crude oil production alone has been greater than what has been consumed nationally in three of these sectors: residential, commercial, and electric power generation (LDNR and U.S. Department of Energy 2001). Louisiana production has increased in the past 10 years so that in 2000 it produced enough crude oil to meet the needs of all three of these sectors. Louisiana provides over 27 percent of the total oil produced in the U.S. If Louisiana did not produce oil, the U.S. would have to import 30 percent more oil from the Organization of the Petroleum Exporting Countries (OPEC) than it currently does. Any significant decrease in Louisiana production would affect citizens in all states.

Natural gas has been the second largest source of energy for the U.S. since 1988. The United States had large natural gas reserves until the late 1980s when consumption began to significantly outpace production. Imports rose to make up the difference, nearly all coming by pipeline from Canada. Three states (Texas, Louisiana, and Oklahoma) account for over half of all natural gas produced in the U.S. The amount of natural gas produced by Louisiana can be put into perspective by comparing it to what is consumed by the entire Nation in five economic sectors. Over the past 20 years, Louisiana's gas production has been greater than what has been consumed in four of the five sectors: transportation, commercial, electric power, and residential sectors (LDNR and U.S. Department of Energy 2001). Louisiana currently provides over 26 percent of the total natural gas produced in the U.S. Over the past 20 years, Louisiana has produced more natural gas than what was imported by the Nation. If Louisiana did not produce natural gas at the same level of consumption, the U.S. would have to import 133 percent more gas from other countries than it currently does. Any significant decrease in Louisiana's natural gas production would have a significant impact on the U.S. economy.

Based on a recent study entitled "Economic Impact Assessment Louisiana Coastal Area Comprehensive Coastwide Ecosystem Restoration Study" conducted jointly by the USACE and the LDNR, drilling and production activities in the state amount to a direct economic impact of over $730 million per year.

Indirect impacts equal about $250 million per year. The direct economic impacts create 3,400 jobs with an average wage of $42,330 per year (total annual direct impact wages of $144 million). The indirect impact jobs create another 3,100 jobs at an average wage of $27,300 per year (total annual indirect impact wages of $84 million).

All of the oil and gas produced along Louisiana’s coast and wetlands comes from a highly interdependent network of core and supporting industries. The core businesses, along with their suppliers, contractors, services and research departments sprung up around each other and formed a huge cluster of businesses linked to each other and to other industries throughout the region. Port Fourchon is the geographic and economic hub of this cluster. Hundreds of offshore drilling rigs in the Gulf of Mexico send oil and gas to the mainland through Port Fourchon. For example, Port Fourchon alone supports a number of businesses ranging from restaurants that provide food and catering to offshore workers, shipbuilders that fabricate drill ships and oil well service vessels, air and water transportation firms, as well as petroleum extraction companies. Most major and independent oil and gas companies operating in the gulf have a presence at Port Fourchon. Damage to infrastructure caused by increased storm surge impacts and associated land losses would threaten the supply base that keeps these offshore facilities operating at peak efficiency and reliability.

The total net collections by the Louisiana Department of Revenue have been in the $5.5 to $6 billion range. Since the value of the direct and indirect economic impacts is nearly $1 billion, this means that the oil and gas industry contributes approximately 17 percent of the total revenue collected each year. Since these collections fund all state operations, an impact to the oil and gas industry would have a significant negative impact on the state.

3.22.7 Pipelines

3.22.7.1 Historic and Existing Conditions

The total assessed value of interstate pipelines alone in Louisiana is over $600 million and the pipeline industry employs 4,855 persons with an annual payroll of $250 million. Louisiana is laced with thousands of pipelines conveying oil, gas, and other liquid and gaseous materials for short and long distances. Included are 25,000 miles (40,250 km) of pipe moving natural gas through interstate pipelines; 7,600 miles (12,236 km) of pipe carrying natural gas through intrastate pipelines to users within the state’s boundaries; 3,450 miles (5,554 km) of pipe transporting crude oil and crude oil products; and thousands of miles of flowlines carrying oil and gas from the wellhead to separating facilities. Some of the most prominent sites related to oil and gas interests lie within the state, notably the Henry Hub where the national price of natural gas is set, the Louisiana Offshore Oil Port, and two of the major components of the Nation’s Strategic Petroleum Reserve. Louisiana is home to two of the four Strategic Petroleum Reserve storage facilities: West Hackberry in Cameron Parish and Bayou Choctaw in Iberville Parish. Louisiana's oil production is currently equivalent to 30 percent of OPEC imports to the U.S. If Louisiana did not produce oil, the U.S. would have to import 30 percent more oil from OPEC countries than it currently does.

Of interest to the coastal degradation issue are those pipelines that exist within the coastal areas that are vitally important as a conveyance means to move oil, gas, or chemical products from point of production to refineries, gas plants, and intrastate and interstate pipelines. Many thousands of miles of pipelines can be found in coastal Louisiana ranging from small gathering lines connecting production wells with storage tanks to larger pipelines carrying very large quantities of gas or oil.

Louisiana has 13 major crude oil pipelines, 9 major product pipelines, and 13 Liquefied Petroleum Gas pipelines in the state. Eighteen petroleum refineries distill a combined crude oil capacity of more than 2.7 million barrels per calendar day - the second highest in the Nation after Texas. Louisiana's oil production affects all states. It provides a significant portion of total U.S. production, and its production is equivalent to a significant portion of total imports and total OPEC imports. Any reduction of Louisiana oil would have obvious adverse effects on all U.S. consumers.

3.22.8 Navigation

3.22.8.1 Historic and Existing Conditions

Annual U.S. port tonnage statistics consistently rank the Ports of New Orleans, South Louisiana, and Baton Rouge fourth, first, and ninth, respectively. Primary inbound cargos at the Port of Baton Rouge are petroleum and chemicals. Outbound cargos are grain, chemicals, and petroleum products. Primary inbound cargos at the Port of South Louisiana are crude oil and petroleum products, while corn, wheat, and animal feed dominate the port's exports. At the Port of New Orleans, principal inbound cargos consist of steel, crude, and refined petroleum products and outbound cargos include grain, forest products, and steel.

The major waterways in the study area are:

The Louisiana portion of the GIWW, stretches from the Texas – Louisiana state line in the west to the Louisiana – Mississippi state line in the east. The GIWW Alternate Route operates from Port Allen to Morgan City. This waterway totals 366.4 miles (589.9 km). The GIWW is the lifeline for industries in Louisiana, with both small and large craft using the route to reach channels flowing into the gulf. It is at the Port of New Orleans where the GIWW has its major connection with the interior of the country. There, it joins with the Mississippi River system. Combined, the Mississippi River ports of south Louisiana are rated number one in the Nation in total tonnage and number one in the world in grain exports. When ranked by waterborne tonnage, Louisiana is number one when compared to other states.

The MRGO connects the Gulf of Mexico with its inner harbor docks, as well as providing access to the Mississippi River through the Inner Harbor Navigation Canal lock. The MRGO is coterminous with the GIWW for the innermost reaches, thus it serves as a vital link for inland navigation traffic. The channel is authorized at 36 feet (10.9 m) deep by 500 feet (805 km) wide from mile 0 to mile 66. Peak traffic for the channel was realized in 1978, when 9.4 million short tons were reported. Annual tonnage for the year 2002 was 3.3 million short tons.

Bayou Lafourche is located about 60 miles (96.6 km) upstream from New Orleans near Donaldsonville, Louisiana, and empties into the Gulf of Mexico approximately 100 miles (161 km) west of the Mississippi River Delta. In 1904, a dam was placed across the distributary as a flood protection measure for Donaldsonville (Doyle 1972). While the dam fulfilled its authorized purpose to help prevent flooding in the city, its construction severed what remained of the hydrologic connection between the Mississippi River and the wetland of Barataria Basin and eastern Terrebonne Basin. Port Fourchon is situated near the mouth of this bayou where the oil and gas industry, and both recreational and commercial fishermen work side by side. The Port of Fourchon serves as a terminal for much of the oil activities in South Louisiana. Supply boats, oil drilling vessels, oil field personnel, repair docks, and labor crews all work out of this area.

The Barataria Bay Waterway, which is located in southeast Louisiana, is approximately 41 miles (66 km) from the GIWW to the Gulf of Mexico with a side channel to Grande Isle, Louisiana. Similar to Bayou Lafourche, marine traffic on this waterway primarily services oil company activities in south Louisiana, as well as the commercial fishing industry.

The Calcasieu River and Pass, which is located in southwest Louisiana, is approximately 110 miles (177 km) long beginning at Phillips Bluff, Louisiana and ending at the 42-foot (12.8 m) contour in the Gulf of Mexico. Located on the waterway is the Port of Lake Charles, the 11th largest seaport in the United States, accommodating 4.5 million tons of cargo annually at its public facilities.

The Sabine-Neches Waterway serves the Ports of Port Arthur, Beaumont, and Orange in Jefferson and Orange Counties, Texas. The Sabine-Neches Waterway is attributed with 128 million short tons of freight traffic cargo in 2001, ranking fourth in the U.S. in tonnage volume. Over 90 percent of this cargo is associated with petroleum and chemical products. Sixty-three percent of the 2001 tonnage consisted of deep-draft ocean-going movements. This waterway extends from the Gulf of Mexico for 86.8 miles (139.7 km) into turning basins at West Port Arthur, Beaumont, and Orange, Texas. The deepest channel, Sabine Pass, is maintained at 40 feet (12.2 m), with Port Arthur and Beaumont channels maintained at 37 and 39 feet (11.3 and 11.8 m), respectively.

The megaports of New Orleans, South Louisiana, and Baton Rouge line 172 miles (277 km) of both banks of the lower Mississippi River. The Port of Lake Charles is located on the Calcasieu River and Pass in southwest Louisiana.

There are four additional Federal navigation projects and related waterways that have an impact on the LCA Study area. These are the Lower Atchafalaya River; Bayous Chene, Boeuf, and Black; Houma Navigation Canal; and Acadiana Gulf of Mexico Access Channel (Port of Iberia to the gulf). These waterways, along with Bayou Lafourche and Barataria Bay Waterway, have considerable marine activity, but do not carry cargo. The relevant commerce is derived from oil and gas rig fabrication, delivery, and offshore services.

3.22.9 Flood Control

3.22.9.1 Historic and Existing Conditions

Prior to the construction of the Mississippi River Levee (MRL) system, periodic floods from the Mississippi River caused tremendous damage to residents, industry, and public infrastructure. The construction of the MRL and a series of other riverine flood control systems have largely reduced this level of damages, but at the expense of reducing sediment distribution into the alluvial plain. Flood losses currently occur mainly as a result of rainfall events. The typical pattern has been for these damages to increase as development continues since increases in development densities tends to reduce flood storage areas while increasing the stock of assets at risk to flooding.

3.22.10 Hurricane Protection Levees

3.22.10.1 Historic and Existing Conditions

Over one million people currently live within areas protected by existing hurricane protection projects. Numerous communities exist in the study area dominated by the Greater New Orleans metropolitan area. The deltaic area is subject to rainfall, tidal, and hurricane flooding, which results in structural, agricultural, and environmental damages. The relatively flat terrain, and large urbanized areas at or below sea level aggravate flood damages. The study area is very low in elevation, comprised primarily of sea-level marsh, swamp, and open water, with relief provided by the alluvial ridges of the present and abandoned courses and distributaries of the Mississippi River. The elevations vary from as low as –10 feet (–3.1 m) NGVD in developed areas that have been protected by levees and drained by pumps, to about +25 feet (+7.6 m) NGVD along the ridges of the Mississippi River. St. Tammany Parish, located on the north shore of Lake Pontchartrain, has ground elevations of up to +200 feet (60.9 m) NGVD. An extensive system of Federal and local levees has been constructed in southern Louisiana to protect against hurricane surge and flooding from the Mississippi River.

The study area contains five existing authorized hurricane protection projects plus three hurricane studies that are in various stages of the study process. The existing authorized projects are Lake Pontchartrain, Louisiana and Vicinity; New Orleans to Venice, Louisiana; West Bank and Vicinity, Louisiana; Larose to Golden Meadow, Louisiana; Morgan City and Vicinity, Louisiana, and Grand Isle and Vicinity, Louisiana. Ongoing studies include Morganza to the Gulf feasibility study; Lake Pontchartrain west shore feasibility study; and Donaldsonville to the Gulf reconnaissance study. Because none of these existing hurricane protection projects provide protection against Category 4 or 5 storms, mass evacuations are required when hurricanes threaten the area.

Although there are five existing hurricane protection projects in the study area, these projects were not designed to protect against Category 4 or 5 storms. In 1998, Hurricane Georges caused great concern in the southeast Louisiana area and forced the evacuation of hundreds of thousands of people. Although this storm did not strike the study area directly, its close passage made many people aware of the potential disastrous impact of a high strength storm. Based on the

Southeast Louisiana Hurricane Preparedness report completed by the USACE in 1994, a slow moving Category 3 hurricane would put approximately 1,131,369 people at risk that would need to evacuate. A Category 5 storm would put 1,154,700 people at risk in southeast Louisiana that would need to evacuate. After Hurricane Georges, it was estimated that 300,000 people evacuated. For Hurricane Ivan, in September 2004, which was projected to hit as a Category 4 or 5, state and local officials estimate that 600,000 people evacuated. Both of these evacuations severely stressed the highway systems. There is great potential for catastrophic loss of life due to a major hurricane storm surge.

3.22.11 Agriculture

3.22.11.1 Historic and Existing Conditions

Agriculture is an important component of coastal Louisiana's economy. More than $2.8 billion of crops and livestock were produced in Coastal Louisiana in 2001. The rich deltaic soil and mild climate are conducive to the production of a wide variety of crops, including sugar cane, rice, and soybeans. Approximately 20 percent of the Nation's rice and 37 percent of the Nation's sugar are produced in Louisiana. Most of this production is in the coastal areas of the state and many of these areas are experiencing either direct land loss or increasing salinities of waters that are used for crop irrigation.

Agricultural production in the study area is dominated by sugar cane in the eastern portion and rice in the western portion. Significant income is also derived from livestock production, primarily cattle and horses. Rice production in the area has traditionally been supported by water obtained from local bayous. These bayous have recently begun to experience higher salinity levels, which is detrimental to crop production. Much of the saltwater intrusion has taken place because of navigation channels and oil and gas canals. In the sugar producing areas, production has been hampered by subsidence resulting in flooding and drainage problems. Even in areas where saltwater intrusion has not occurred, the loss of adjacent wetlands makes croplands more susceptible to storm damages.

3.22.12 Forestry

3.22.12.1 Historic and Existing Conditions

Timber production in Louisiana's forested wetlands is an important renewable resource. The forest products industry is the second largest manufacturing employer in Louisiana, employing about 26,000 people with earnings of more than $900 million (Louisiana Forestry Association 2000). The harvest and transportation of timber provides jobs for an additional 8,000 people. Bottomland forests in southern Louisiana serve as a source for lumber. In 1996, the south delta region of Louisiana (Stratton and Westbrook 1996) produced about 22 million cubic feet (660,000 million cubic meters) of lumber. Presently, Louisiana's forestland covers about 13.8 million acres (5.6 million ha), which is about 2,000,000 acres (810,000 ha) less than the early 1960s forestland area. Private, non-industrial companies own over 60 percent of Louisiana's forestland, while forest-product industries and the public own the remaining 40 percent of forestland. Louisiana forests landowners received $680 million in 1999 from the sale of timber.

3.22.13 Water Supply

3.22.13.1 Historic and Existing Conditions

While coastal Louisiana has abundant sources of freshwater, increases in salinity due to coastal erosion could have serious economic effects in some areas. Of the water used in the LCA Study area in coastal Louisiana, about 97 percent is from surface sources and about 3 percent is from groundwater sources. The Mississippi River and its distributaries are the largest source of surface water, contributing 96 percent of the total surface withdrawals. Other major sources include Bayou Lafourche, the GIWW, Mermentau River, and Bayou Lacassine. Surface water is used for various purposes, including industry (46 percent), power generation (42 percent), public supplies (11 percent), and agriculture (2 percent). Industrial withdrawals are primarily for petroleum refining and chemical manufacturing. Withdrawals for agricultural use are primarily in southwestern Louisiana. Of the three percent of water use in the LCA Study area coming from groundwater supplies, most of this supply was used for chemical manufacturing, sugar refining, and shipbuilding.

3.23 GULF HYPOXIA

Hypoxia exists when dissolved oxygen (DO) concentrations are less than those necessary to sustain animal life (operationally defined as < 2mg/L). Hypoxia results when oxygen consumption during decomposition of organic material exceeds oxygen production through photosynthesis and replenishment from the atmosphere (CENR 2000). Organic matter comes primarily from within the marine ecosystem through algal growth, stimulated by nutrients. Hypoxia in the northern Gulf of Mexico is caused primarily by excess nitrogen delivered from the Mississippi-Atchafalaya River Basin in combination with stratification of gulf waters (CENR 2000).

Gulf ecosystems and fisheries are affected by hypoxia. Mobile organisms leave the hypoxic zone for waters with higher dissolved oxygen concentrations, and those that cannot leave die or are seriously harmed. Fish, shrimp, and zooplankton are less abundant in hypoxic waters (CENR 2000), as are aerobic benthic organisms in sediments under hypoxic waters.

Hypoxia is a major environmental problem affecting coastal Louisiana and the northern Gulf of Mexico. It is also a problem of National importance, which will require action throughout the Mississippi River Basin to solve. While hypoxia is not a cause of land loss in coastal Louisiana, it is highly relevant to the broader coastal Louisiana ecosystem. The January 2001, "Action Plan for Reducing, Mitigating, and Controlling Hypoxia in the Northern Gulf of Mexico" (Mississippi River/Gulf of Mexico Watershed Nutrient Task Force 2001) describes a National strategy to reduce the frequency, duration, size and degree of oxygen depletion in the northern Gulf of Mexico. The Action Plan describes, in general, actions that are needed throughout the Mississippi River Basin to address gulf hypoxia, including restoring de-nitrification and nitrogen retention in the coastal plain of Louisiana.

Although the primary purpose of the LCA Plan is to address Louisiana's coastal wetland loss crisis, it also has the potential to contribute to National efforts to reduce gulf hypoxia. By restoring the flow of Mississippi River waters to deltaic wetlands, the LCA Plan could provide these wetlands with the freshwater, sediment, and nutrients they need to become productive again, while also making use of the wetland capacity to remove nutrients that cause hypoxia. It should be noted, however, that uncertainty remains regarding the efficacy of diversions with respect to nutrient removal, as well as the potential for adverse water quality impacts. Further assessment of this nutrient retention capacity and the potential for adverse effects would be conducted during the development and review of specific projects.

3.23.1 Historic Conditions

Gulf hypoxia has been monitored consistently on an annual basis since 1985 (Rabalais et al. 1999). For the period 1985 to 1992, the bottom area of the hypoxic zone averaged 2,730 to 3,510 mi^2. Bottomwater hypoxia was continuous across the Louisiana shelf in mid-summer 1993 to 1997, and the bottom area was twice as large as the 1985 to 1992 average (Rabalais et al. 1999). **Figure 3-35** displays the frequency of occurrence of hypoxia that has been mapped from mid-summer "snapshots" obtained by sampling a 60- to 80-station grid in the gulf annually from 1985 to 1999 (Rabalais et al. 1999).

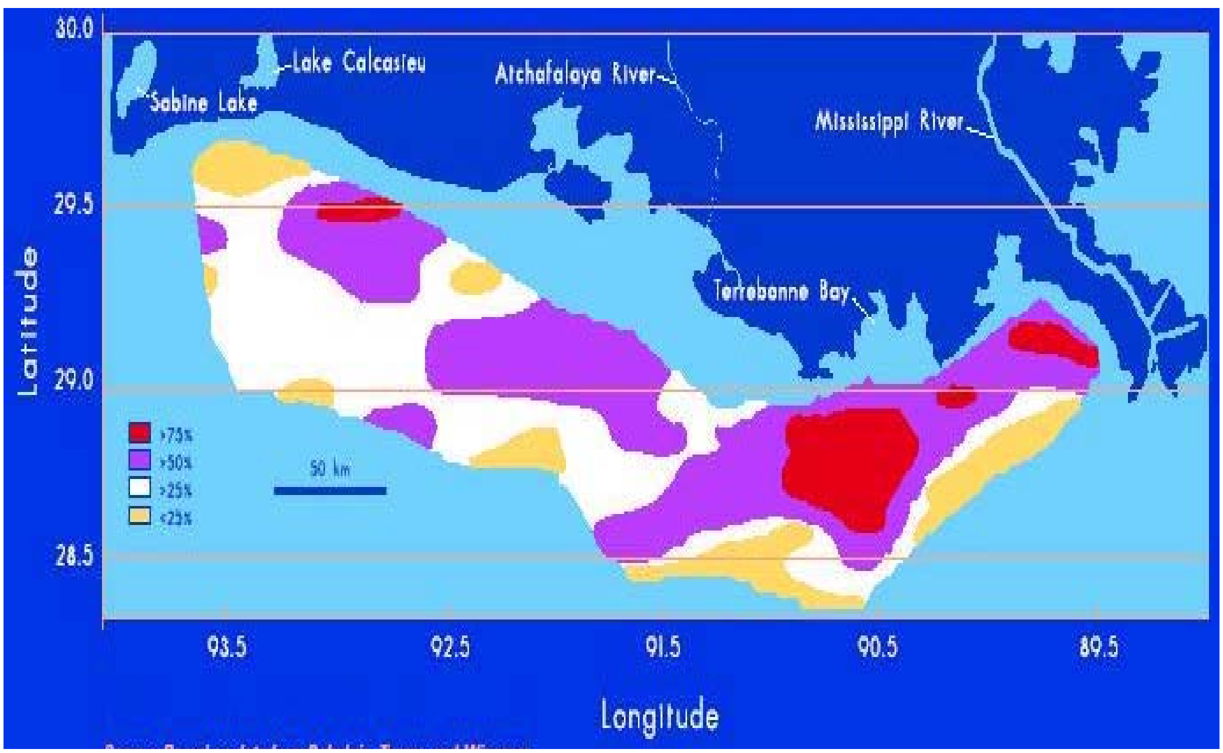


Figure 3-35. The frequency of occurrence of hypoxia has been mapped from mid-summer "snapshots" obtained by sampling a 60- to 80-station grid in the gulf annually from 1985 to 1999 (*Source: Rabalais et al. 1999***).**

Sediment cores from the hypoxic zone show that algal production and deposition, as well as the area of low DO, were much less (smaller) in the early 1900s, and that significant increases occurred in the latter half of the 20th century (CENR 2000). During this period, there were three major changes in the drainage basin affecting the river nutrient flux (CENR 2000). First, landscape alterations, such as deforestation and artificial agricultural drainage, removed most of the river basin's nutrient buffering capacity. Second, most of the river channelization for flood control and navigation was completed prior to the 1950s. Third, major increases in fertilizer nitrogen input to the basin occurred between the 1950s and 1980s. Since 1980, the Mississippi and Atchafalaya Rivers have discharged, on average, about 1.6 million metric tons of total nitrogen to the gulf each year (CENR 2000). Total nitrogen load has increased since the 1950s, due primarily to an increase in nitrate nitrogen. Nitrate flux to the Gulf of Mexico almost tripled between the periods of 1955 to 1970 and 1980 to 1996 (CENR 2000).

3.23.2 Existing Conditions

In general, the size of the hypoxic zone continues to hover near its historic maximum, but with much year-to-year variation. For example, during the summer of 2002, the bottom area of the hypoxic zone was the largest ever measured, over 8,500 mi^2, roughly the size of the State of New Hampshire (Rabalais 2002). During the summer of 2003, it was only half as large as the average over the previous 10 years (3,300 mi^2) (Rabalais 2003). Such year-to-year variations are typically due to variation in stratification of the water and to variations in river discharge. No trend in dissolved inorganic nitrogen or total nitrogen flux has been observed since 1980, but these fluxes have become highly variable, depending on river discharge (CENR 2000).

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