Coast 2050: Toward a Sustainable Coastal Louisiana

Federal State Local

PARTNERSHIP

COAST 2050

Louisiana Coastal Wetlands Conservation and Restoration Task Force
and the
Wetlands Conservation and Restoration Authority

This document is one of three that outline a jointly developed, Federal/State/Local, plan to address Louisiana's massive coastal land loss problem and provide for a sustainable coastal ecosystem by the year 2050. These three documents are:

- Coast 2050: Toward a Sustainable Coastal Louisiana,
- Coast 2050: Toward a Sustainable Coastal Louisiana, An Executive Summary,
- Coast 2050: Toward a Sustainable Coastal Louisiana, The Appendices.

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COAST 2050

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Coast 2050:
Toward a Sustainable Coastal Louisiana

report of the

Louisiana Coastal Wetlands Conservation and Restoration Task Force

and the

Wetlands Conservation and Restoration Authority

Louisiana Department of Natural Resources
Baton Rouge, La. 1998

We, the undersigned, do affix our signatures below, as representatives of the Federal Louisiana Coastal Wetlands Conservation and Restoration Task Force established in accordance with the Coastal Wetlands Planning, Protection and Restoration Act of 1990 ("Breaux Act"), in testimony of our unanimous support of the Coast 2050 Plan.

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We, the undersigned, do affix our signatures below, as representatives of Louisiana's State Wetlands Conservation and Restoration Authority established in accordance with the Louisiana Coastal Wetlands Conservation and Restoration Act of 1989 ("Act 6"), in testimony of our unanimous support of the Coast 2050 Plan.

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Written resolutions of support were also received from all of Louisiana's twenty coastal parishes for the strategies affecting their respective areas and for the Coast 2050 model of parish involvement. These resolutions are presented in the appendix.

prepared by

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CHAPTER 1

COAST 2050: THE NEED FOR ACTION

The Problem: System Collapse in Coastal Louisiana

The rate of coastal land loss in Louisiana has reached catastrophic proportions. Within the last 50 years, land loss rates have exceeded 40 square miles per year, and in the 1990's the rate has been estimated to be between 25 and 35 square miles each year. This loss represents 80% of the coastal wetland loss in the entire continental United States.

The reasons for wetland loss are complex and vary across the state. Since the scale of the problem was recognized and quantified in the 1970's, much has been learned about the factors that cause marshes to change to open water and that result in barrier island fragmentation and submergence. The effects of natural processes like subsidence and storms have combined with human actions at large and small scales to produce a system on the verge of collapse.

System collapse threatens the continued productivity of Louisiana's bountiful coastal ecosystems, the economic viability of its industries, and the safety of its residents. If recent loss rates continue into the future, even taking into account current restoration efforts, then by 2050 coastal Louisiana will lose more than 630,000 additional acres of coastal marshes, swamps, and islands. The loss could be greater, especially if worst-case scenario projections of sea-level rise are realized, but in some places there is nothing left to lose.

Along with the loss of acreage goes the loss of the various functions and values associated with the wetlands: commercial harvests of fisheries, furbearers and alligators; recreational fishing and hunting, and ecotourism; habitats for threatened and endangered species; water quality improvement; navigation corridors and port facilities; flood control, including buffering hurricane storm surges; and the intangible value of land settled centuries ago and passed down through generations. The public use value of this loss is estimated to be in excess of $37 billion by 2050, but the losses associated with cultures and heritage are immeasurable.

Coastal planning efforts in Louisiana began in earnest in the mid-1970's. Since then, many plans and studies have been developed by technical experts, citizens' groups, and State and Federal agencies.

Primary efforts to prevent catastrophic land loss have been implemented under the Federal Coastal Wetlands Planning, Protection and Restoration Act (hereafter, "Breaux Act") in partnership with Louisiana's efforts through Act 6 (LA. R.S. 49:213 *et seq.*). Between 1990 and 1997, almost $250 million was allocated through the Breaux Act toward projects expected to prevent 13% of this loss. Two separately funded larger projects, the Caernarvon and Davis Pond Freshwater Diversions, with a combined construction cost of approximately $130 million, will divert fresh water from the Mississippi River into adjacent coastal basins for salinity control and will also improve conditions within the coastal marshes. These projects, combined with Breaux Act efforts, should prevent up to 22% of the loss projected to occur by 2050 (Figs. 1-1, 1-2). The Breaux Act projects and the two large diversions demonstrate that we have the ability to prevent ecosystem collapse, and show that larger projects can be very effective.

What is needed now is a program that assures that all the best projects are built in the most efficient and timely manner. As noted by the Coalition to Restore Coastal Louisiana (1998), restoration requires a single coastal plan with a clear, overarching strategic vision, a process for ensuring effective public input to restoration planning, and integration of restoration projects into the overall coastal management system.

Coast 2050: A NEW Approach

Coast 2050 is a planning effort inspired by the severity of the problems facing south Louisiana, as well as an increased level of confidence in our ability to understand the ecosystem and to implement effective restoration projects. The plan combines elements of all previous efforts, along with new initiatives from private citizens, local governments, State and Federal agency personnel, and the scientific community.

For the first time, as explicitly called for by the Coalition to Restore Coastal Louisiana in 1997, diverse groups have come together to develop one shared vision for the coast expressed in this overarching goal: ***to sustain a coastal ecosystem that supports and protects the environment, economy and culture of southern Louisiana, and that contributes greatly to the economy and well-being of the nation.***

The first step in achieving this goal is to produce a technically sound plan based upon managing ecosystems with three clear strategic objectives:

- To sustain a coastal ecosystem with the essential functions and values of the natural ecosystem,
- To restore the ecosystem to the highest practicable acreage of productive and diverse wetlands, and
- To accomplish this restoration through an integrated program that has multiple use benefits; benefits not solely for wetlands, but for all the communities and resources of the coast.

Important new information has been developed in this innovative approach to planning. Among other contributions, the Coast 2050 Plan provides new quantitative techniques for projecting land loss patterns into the future, the first coastwide assessment of subsidence rates and patterns, and the first

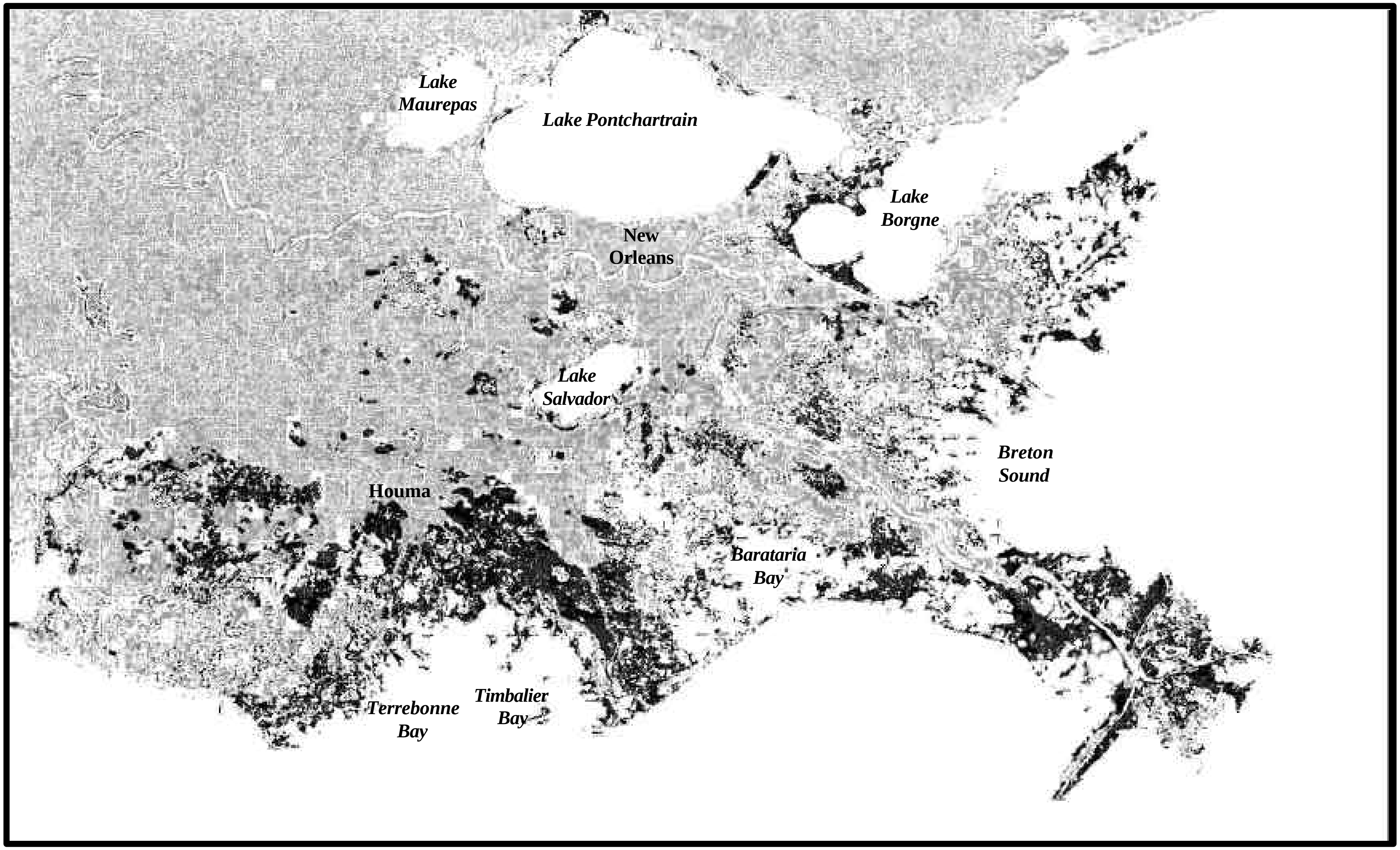


Figure 1-1. Wetlands projected to be lost in the Deltaic Plain (shown in black) between 1993 and 2050 (adapted from LSU Natural Systems Engineering Laboratory, 1998).

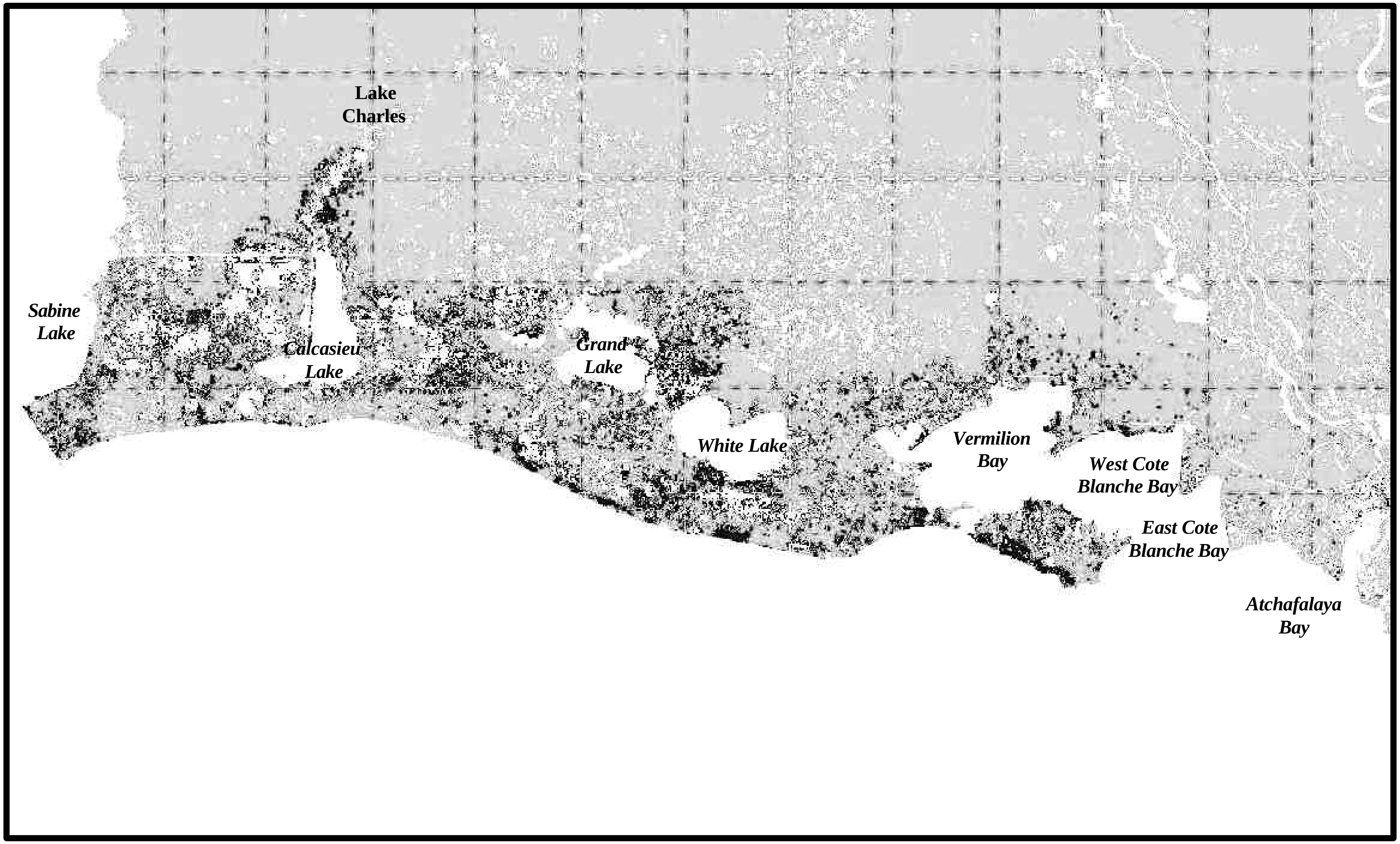


Figure 1-2. Wetlands projected to be lost in the Chenier Plain (shown in black) between 1993 and 2050 (adapted from LSU Natural Systems Engineering Laboratory, 1998).

comprehensive consideration of changes in fish and wildlife populations.

Also new is the extent to which the planning process has involved the affected public at the local level. Indeed, many of the ecosystem restoration strategies included in this plan are not new, but recently they have received far wider understanding and endorsement. The participation of local governments and private citizens in plan development has made an essential contribution to the plan.

The level of citizen support for this new approach to restoration planning in coastal Louisiana is demonstrated by one astonishing fact: councils and police juries of all 20 coastal parishes have passed resolutions in support of the Coast 2050 ecosystem strategies.

The Coast 2050 Plan

The information in this document has been organized to include the essential details supporting the need for action in coastal Louisiana and the specific strategies to accomplish success. Each chapter stands alone, with an organization as follows:

- The 18-month process used to build the plan is described in Chapter 2,
- Chapters 3-6 detail the landscape of coastal Louisiana and the problems it faces, the implications of these changes for fish and wildlife populations, and the severe economic and human consequences of continuing on the current path,
- Chapter 7 outlines the ecosystem management strategies essential to the survival of coastal Louisiana and expected costs and benefits associated with implementation of the plan,
- Chapters 8 and 9 address broader institutional issues and scientific and technological needs, and
- The final chapter outlines how this plan should lead to actions that will save the coast.

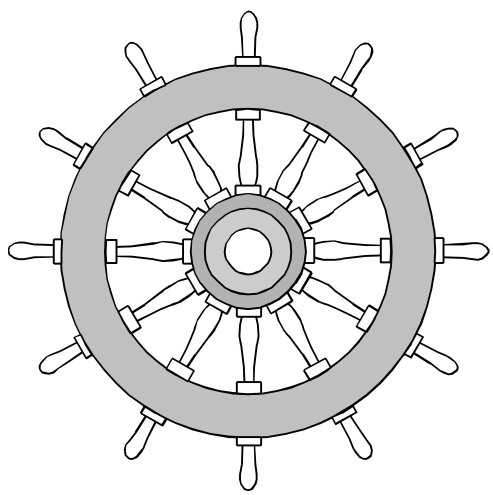
A separate document contains the appendices that record much of the detailed work that went into preparation of the plan. These appendices explain the new methods used to inventory existing conditions and to project future conditions. They also detail the public involvement in the planning process.

Summary

Coast 2050 has been a truly collective effort among Federal, State, and local governments. The effort has been affirmed by the adoption of the plan by the Louisiana Coastal Wetlands Conservation and Restoration Task Force and the Wetlands Conservation and Restoration Authority as their official restoration plan, the transmission of this plan to the U.S. Department of Commerce by the State of Louisiana to incorporate it into the Louisiana Coastal Resources Program Guidelines, and resolutions of support from 20 coastal parish councils and police juries.

The Coast 2050 Plan is based upon the best available, albeit imperfect, understanding of both the causes of loss and the effectiveness of restoration measures. There is a recognized need to continue the study of the system, to learn from those measures that have already been implemented, and to learn from the successes and failures of other major coastal ecosystem restoration programs. This plan should be the start of coastal restoration in Louisiana at the ecosystem scale, and the restoration effort must grow and adapt through time.

Those responsible for restoration decisions expect and welcome the fact that the plan will be revised in the future as new knowledge becomes available, as new opportunities arise, as new restoration technology develops, and perhaps as new landscape problems occur. Addressing the collapse of Louisiana's coastal ecosystem, however, must move forward in the face of such uncertainty or it will be too late for the marshes, the swamps, the industries, and the people.



CHAPTER 2

COAST 2050: THE PLAN

Before Coast 2050

Coastal land loss in Louisiana began to exceed levels normally associated with the delta cycle and natural coastal ecosystem change during the 1950's (Britsch and Dunbar 1993). The magnitude of the changes in the landscape and their pervasive nature became clear during the 1970's when the first of several mapping studies (Gagliano and van Beek 1970) quantified the scale of the problem. The recognition of the problem led to growing public concern that coastal land loss be addressed. Governmental response was in the form of legislation and planning programs which have changed in perspective in the last 30 years (Table 2-1). While all the milestones in Table 2-1 have contributed to restoration, those that provided the primary legal impetus for action are Act 361 of 1978, Act 41 of 1981, Act 6 of 1989, and the Breaux Act of 1990.

The Breaux Act called for the development of a comprehensive *Louisiana Coastal Wetlands Restoration Plan* (Public Law 101-646§303.b). The first such plan was completed in 1993 and has been in use since that time. In addition, the Governor's Office of Coastal Activities Science Advisory Panel prepared a plan for the coast in 1994 for the Wetlands Conservation and Restoration Authority (State Wetlands Authority), constituted under Act 6 (R.S. 49:213.1 *et seq.*). At about the same time, other plans were developed as the need for action became widely apparent (Table 2-1).

The Coast 2050 plan has been developed under the legislative mandates described above and is a result of recognition by Federal, State, and local agencies that a single plan is needed. Such a plan must incorporate a clear vision for the coast, build on previous work, integrate coastal management and coastal restoration approaches, and adopt a multiple-use approach to restoration planning. The Coast 2050 Plan will serve as the joint coastal restoration plan of the Breaux Act Task Force and the State Wetlands Authority.

The Mission of Coast 2050

The Coast 2050 plan was developed based on the following mission statement:

> "*In partnership with the public, develop by December 22, 1998, a technically sound strategic plan to sustain coastal resources and provide an integrated multiple use approach to ecosystem management*."

The essential components of this mission were accomplished by adhering to the three principles outlined below.

- The partnership with the public was facilitated by the direct involvement of parish government Coastal Zone Management representatives, briefings to local elected officials, and public meetings (Appendix A). The numerous town meetings and Regional Planning Team meetings held during the plan formulation stage demonstrate the level of effort to allow public involvement (Table 2-2). Another important aspect of public participation was the involvement of the Barataria-Terrebonne National Estuary Program and several nongovernmental organizations such as the Coalition to Restore Coastal Louisiana, the Lake Pontchartrain Basin Foundation, the Acadiana Bay Association, and the Vermilion Rice Growers Association.

- To be technically sound, the plan must be based on the current state of knowledge of our coastal system. Therefore, academic and private coastal scientists were involved in every step of this planning process. They played key roles on the Planning Management Team and the Regional Planning Teams and added to the scientific and technical expertise of the Federal and State agency personnel.

- The multiple use approach required that coastal wetlands were not the only coastal resource considered during the course of this planning effort (Appendices B-F). Information regarding other coastal uses and resources such as infrastructure, fish and wildlife resources, public safety, and navigation was also collected and carefully considered in developing objectives and strategies.

The Coast 2050 mission will continue into the future, reflecting the public commitment shown by unanimous parish support, ongoing and expanded efforts in research and development, and integration of the plan into the Coastal Zone Management program.

Coast 2050 Structure

The organizational structure of the Coast 2050 planning effort (Fig. 2-1) is indicative of the guiding philosophy of this effort. The structure reflects an interactive planning network in which scientific and technical matters were developed by the Strategic Working Group, while the public acceptability and coastal resource objectives were the responsibility of the Coastal Zone Management Working Group. These two groups were jointly constituted by the Breaux Act Task Force and the State Wetlands Authority. The Strategic Working Group consisted of the State Wetlands Authority members and the Breaux Act Technical Committee members. The Breaux Act agencies represented were the U.S. Army Corps of Engineers, the U.S. Environmental Protection Agency, the U.S. Department of Agriculture's Natural Resources Conservation Service, the

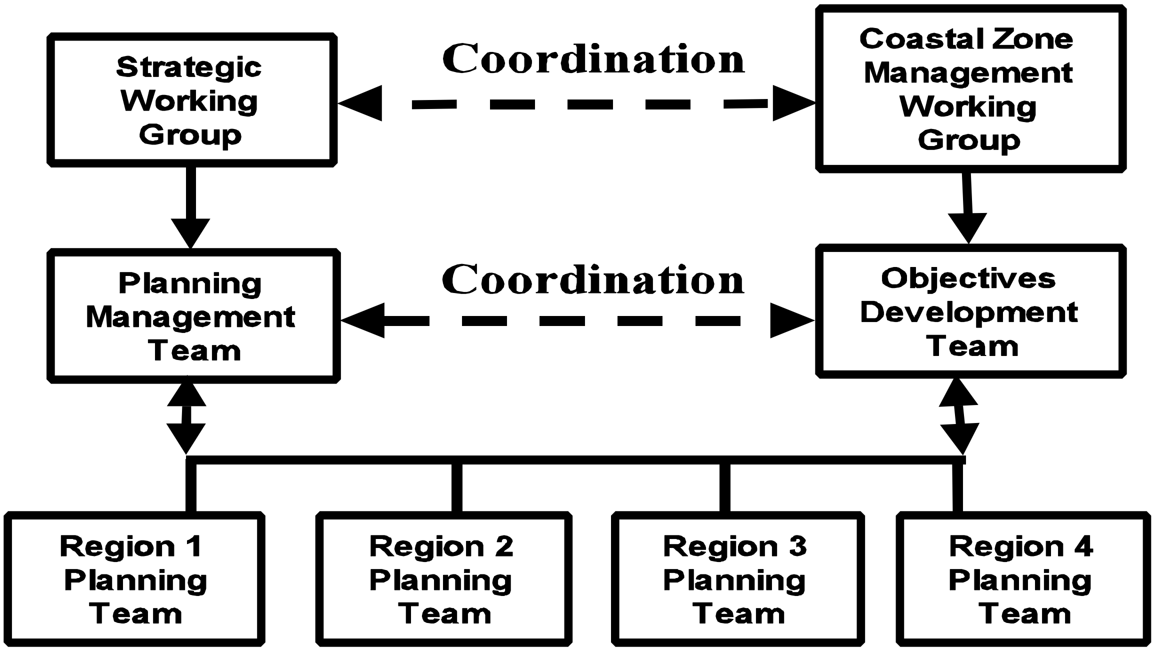


Figure 2-1. Coast 2050 organization.

Department of the Interior's U.S. Fish and Wildlife Service, and the Department of Commerce's National Marine Fisheries Service. The Louisiana State agencies represented on the Strategic Working Group were the Office of the Governor, the Department of Natural Resources, the Division of Administration, the Department of Wildlife and Fisheries, the Department of Environmental Quality, the Department of Transportation and Development, and the State Soil and Water Conservation Commission of the Department of Agriculture and Forestry. The Planning Management Team was appointed by the Strategic Working Group and was responsible for both coordinating the planning effort and writing this planning document.

The Coastal Zone Management Working Group consisted of parish government representatives and parish Coastal Zone Management Advisory Committees. This working group was largely responsible for public involvement: this outreach to the public via local governments proved to be a particularly effective facet of the Coast 2050 planning process. The Objectives Development Team was responsible for carrying out the policies established by the Coastal Zone Management Working Group and soliciting use and resource objectives from parish governments, Coastal Zone Advisory Committees, and the Regional Planning Teams.

The coast was divided into four regions based on hydrologic basins (Fig. 2-2). For planning purposes, each region was broken into mapping units (*see* Chapter 7).

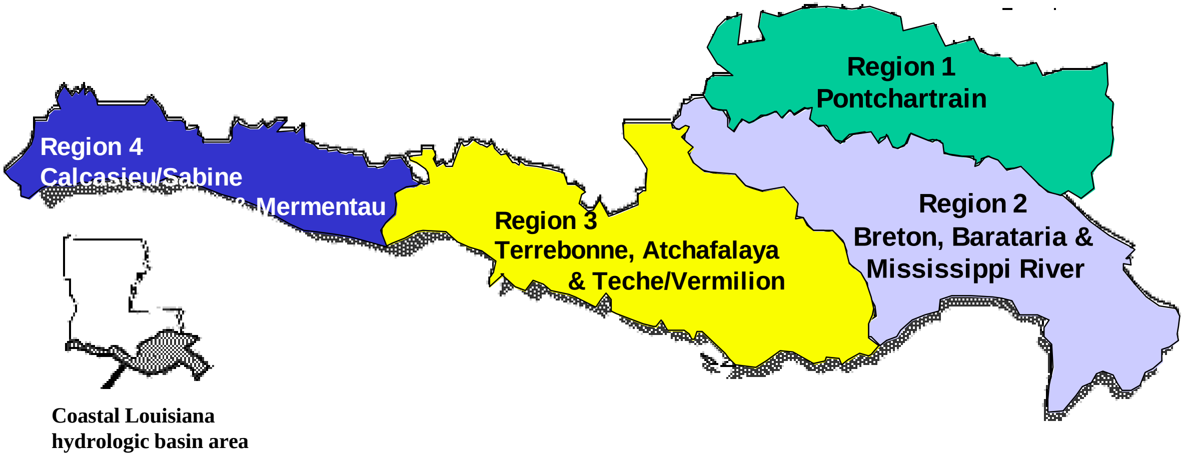


Figure 2-2. Regions used in the Coast 2050 plan.

Four Regional Planning Teams were established in order to develop strategies and provide input on coastal use and resource objectives. They furnished this to the Planning Management Team and to the Objectives Development Team. The Regional Planning Teams consisted of State and Federal agency staff, academic representatives, parish governments, Louisiana Cooperative Extension Service/LSU Sea Grant staff, and local volunteers.

The Coast 2050 Process

The planning process was built around a paradigm of consensus building to maximize the strategies that were considered to be both technically sound and publicly acceptable (Fig. 2-3). The consensus building was achieved over 18 months and involved a series of public scoping meetings, regional team meetings and other gatherings to achieve consensus concerning the best strategies to implement on the coast (Appendix A).

Four public scoping meetings were held, one per region, during July and August of 1997 in order to further develop the process and scope of the plan. Regional Planning Team meetings were initiated on a monthly basis in all four regions. From October 1997 until May of 1998, many important issues were reviewed concerning strategies and objectives, such as past plans, infrastructure, and resource trends (Appendices B-F).

In order to take advantage of previous coastal restoration planning efforts, each Regional Planning Team was provided a matrix that listed all previously proposed projects and strategies by mapping unit (Appendices C-F). This matrix was compiled from the plans listed in Table 2-1. The Regional Planning Teams received and discussed local technical input and public concerns; generated most of the mapping unit-scale local, common, and programmatic strategies; and developed many other work products.

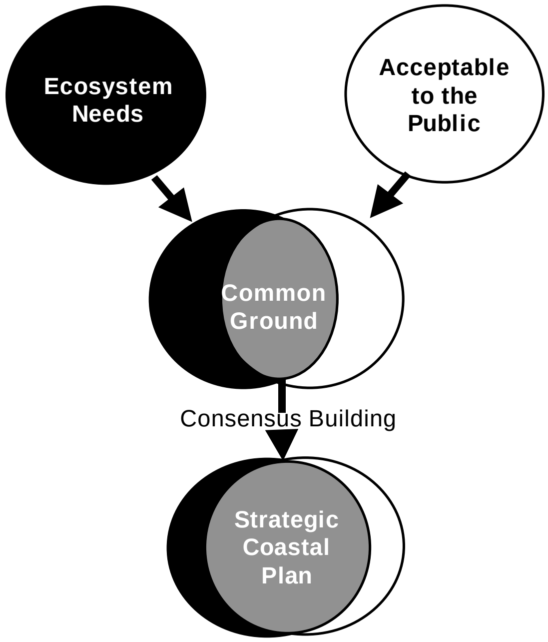


Figure 2-3. Coast 2050 development process.

The Planning Management Team also met monthly to review input received from regional meetings, to develop regional strategies and other plan components, and to prepare this document.

In June and July 1998, 11 town meetings were held across coastal Louisiana to give the public an update on the planning process and to solicit their responses to the proposed strategies and objectives (Table 2-2). By August 1998, a draft strategic plan was completed by the Planning Management Team and the Regional Planning Teams. In September 1998, a second set of four regional meetings was held to discuss this draft plan with the public. At this stage, all the coastal parishes involved in the development of the plan expressed their support for the Coast 2050 strategies by passing resolutions.

Coast 2050 is the first coastal restoration plan for Louisiana to receive the explicit support of all 20 coastal parish governments.

On October 20, 1998, the State Wetlands Authority and the Breaux Act Task Force jointly discussed the recommended strategies and objectives along with the public comments received during the final four regional meetings. Both groups unanimously adopted the Coast 2050 strategies and objectives. The main report of the plan (this document) was distributed for final review by the Breaux Act Task Force and the State Wetlands Authority in December of 1998.

The Role of the Plan

The Coast 2050 Plan was developed in partnership with the public, parish governments, and State and Federal agencies. It is based on technically sound strategies designed to sustain coastal resources. The plan is an overall template which will provide program-neutral guidance for the development and implementation of coastal restoration projects.

The synergy of the strategies and program guidance is intended to provide continued effectiveness to meet the challenges of coastal land loss at the scale that is now devastating coastal Louisiana. The Coast 2050 Plan represents our vision for Louisiana's coast for the year 2050 and provides a comprehensive strategic plan for achieving this vision.

Table 2-1. Milestones concerning coastal restoration in Louisiana.

Hydrologic and Geologic Studies of Coastal Louisiana is an 18-report series completed between 1970 and 1973. Results reported include: (l) first measurements and identification of the coastal land loss problem; (2) identification of ecosystem components and processes; (3) evaluation of causes of loss and deterioration; (4) recommendations for size and location of freshwater diversions and subdeltas; and (5) development of multiple use planning approach. The final report, entitled *Environmental Atlas and Multi-Use Management Plan for South-Central Louisiana,* has become the prototype for restoration planning in coastal Louisiana.
Act 35 of the 1971 Louisiana Legislature established the Louisiana Advisory Commission on Coastal and Marine Resources to determine the needs and problems of coastal and marine resources. They published three major reports: *Louisiana Government and the Coastal Zone—1972; Wetlands '73: Toward Coastal Zone Management in Louisiana;* and *Louisiana Wetland Prospectus* in 1973.
The Federal Coastal Zone Management (CZM) Act of 1972 encouraged coastal states to assume coastal planning, permitting, Federal consistency, and conflict resolution. (Administered by U.S. Department of Commerce.)
Act 361 of 1978 of the Louisiana Legislature or the "State and Local Coastal Resources Management Act" (LA. R.S. 49:214.21 *et seq.*) established Louisiana's CZM Program, pursuant to the CZM Act of 1972, including: CZM boundary, coastal use permitting, local programs, and Federal consistency determinations. (Administered by the Louisiana Department of Natural Resources.)
Act 41 of the Second Extraordinary Session of 1981 of the Louisiana Legislature created a one-time $35 million fund for conducting applied research and physical projects to address coastal restoration. The Act also resulted in the formation of the Coastal Protection Task Force which recommended five projects and a study in a report to Governor Treen in 1982, and a *Coastal Master Plan* that focused on barrier islands and shorelines. (Made obsolete by "Act 6" of 1989.)
Saving Louisiana's Coastal Wetlands: The Need for a Long-term Plan of Action was published in April, 1987 (EPA-230-02-87-026). It was a report of the Louisiana Wetland Protection Panel. It provided a comprehensive review of causes of wetland loss and projects authorized at the time. It also proposed the development of a strategic plan that would serve to outline necessary actions to preserve coastal wetlands.
The Coalition to Restore Coastal Louisiana (CRCL) was incorporated in 1988. It was established to advocate the restoration and preservation of Louisiana's coast. It played a major role in the passage of Act 6 and the Breaux Act. CRCL is made up of local and national environmental groups, civic and religious organizations, businesses, industry groups, local governments and concerned citizens.
Coastal Louisiana: Here Today and Gone Tomorrow? was published by the CRCL in 1989. It advocated a grass-roots initiative intended to result in the near-term implementation of sediment diversions and other structural measures such as barrier island restoration, marsh creation with dredged materials, and regulatory actions such as establishment of special management areas, full mitigation of all primary and secondary wetland impacts, and institutional initiatives such as increased funding for coastal restoration programs.

Table 2-1. Milestones concerning coastal restoration in Louisiana (Cont.).

Act 6 of the Second Extraordinary Session of 1989 of the Louisiana Legislature, or the Louisiana Coastal Wetlands Conservation, Restoration, and Management Act (LA. R.S. 49:213*et seq.),* created the Wetlands Conservation and Restoration Authority which has oversight of the annual Coastal Wetlands Conservation and Restoration Plan. The act also created a renewing fund for restoration efforts authorized in the plan. The first annual coastal plan was completed in April 1990. The first plan to cost-share on Breaux Act projects was completed in March 1992. Each annual plan provides site-specific project recommendations.
The Lake Pontchartrain Basin Foundation (LPBF) was established in 1989. It is a nonprofit citizen's organization, established by the Louisiana Legislature to expedite the clean-up, restoration and preservation the Pontchartrain Basin. LPBF has led many initiatives to clean up the lake, including opposition to shell dredging and the development of a LPBF Comprehensive Management Plan.
The Coastal Wetlands Planning, Protection and Restoration Act, Pub. L. No. 101-646 (1990), is also known as the "Breaux Act." It resulted in an annual $33 million (approx.) for federal restoration project match and $5 million for planning, and has resulted in annual "Priority Project Lists" since 1992. The Breaux Act also provided for the *Louisiana Coastal Wetlands Restoration Plan* and the *Louisiana Coastal Wetlands Conservation Plan. (* Administered by the Louisiana Coastal Wetlands Conservation and Restoration Task Force.)
The Barataria-Terrebonne National Estuary Program was established in 1990. The program completed and submitted its *Comprehensive Conservation and Management Plan* (CCMP) in 1996. A Program Office has been established to support the Management Conference, which consists of citizens' groups, landowners, businesses, agencies, etc. The Management Conference is responsible for implementing this plan, which addresses estuarine quality and biological sustainability. The CCMP development is a model of effective public input for extensive planning.
Act 637 of 1991 of the Louisiana Legislature (LA. R.S. 49:214.32(F)) requires the Louisiana Department of Natural Resources to develop rules and regulations for implementation of a *Long Term Management Strategies Plan.* This plan consists of a comprehensive protocol for the beneficial use of dredge materials. The statute requires beneficial use of any materials dredged from or deposited in coastal waters from the maintenance of any channel longer than one mile or where more than 500,000 cubic yards of material are moved.
A Long-term Plan for Louisiana's Coastal Wetlands was completed in 1993 by S. M. Gagliano and J. L. van Beek for the Louisiana Department of Natural Resources. It provides for comprehensive offensive and defensive strategies to be carried out in two 25-year phases. Key elements include the establishment of a "Hold Fast Line," reallocation of Mississippi River flow with the establishment of phased subdeltas, estuarine management and an orderly retreat seaward of "Hold Fast Line," and succession management of freshwater basins landward of the "Hold Fast Line." Volume Two lists possible sources of funding for plan implementation.
The Louisiana Coastal Wetlands Restoration Plan was completed in 1993 by the Louisiana Coastal Wetlands Conservation and Restoration Task Force. It provided a comprehensive approach to restore and prevent the loss of coastal wetlands. Using a basin planning approach, a number of needed projects were identified and the implementation of major strategies was called for, such as the abandonment of the present Mississippi River Delta, multiple diversions into Barataria, reactivation of old distributary channels, rebuilding barrier island chains, seasonal increases down the Atchafalaya, reversal of negative hydrologic modifications, and controlling tidal flows in large navigation channels.

Table 2-1. Milestones concerning coastal restoration in Louisiana (Cont.).

A Long-term, Comprehensive Management Plan for Coastal Louisiana to Ensure Sustainable Biological Productivity, Economic Growth, and the Continued Existence of its Unique Culture and Heritage was completed in 1994 by Dr. van Heerden. This plan "attempts to simulate natural delta growth processes by creating river diversions and reestablishing former distributaries ... [and] restoration of Louisiana's barrier islands."
An Environmental-Economic Blueprint for Restoring the Louisiana Coastal Zone: The State Plan was completed in 1994. This is a report of the Governor's Office of Coastal Activities Science Advisory Panel Workshop. It provides a "long range blueprint for restoring Louisiana's coastal wetlands, which includes several key provisions. The most important of these are: (1) diverting Mississippi River water and sediments into key locations; (2) restoring, protecting, and sustaining barrier islands; and (3) modifying major navigation channels to reduce saltwater intrusion and storm surge entry."
Scientific Assessment of Coastal Wetland Loss, Restoration and Management in Louisiana was published in 1994. It was authored by Dr. Boesch, et al. and funded by the W. Alton Jones Foundation, Inc. Its purpose was to assess the then-current restoration approaches and wetland loss processes, and provide scientifically based recommendations to improve restoration efforts. It determined that the Breaux Act was off to a good start, but that (1) region-wide strategies need better integration with small-scale ones, (2) better technical and policy review was needed, (3) private land rights should be balanced with greater public interests, and (4) financing for large-scale introduction of alluvial materials should be obtained.
The Louisiana Coastal Wetlands Conservation Plan was completed in May 1997 as authorized by the Breaux Act. The Louisiana Department of Natural Resources developed this plan in conjunction with the U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, and U.S. Environmental Protection Agency in order to achieve no net loss of coastal wetlands due to development activities. Recommended actions include public education, innovative technology development, and landowner assistance. Also, implementation resulted in a reduction in the required percentage of state matching funds, as provided for in the Breaux Act.

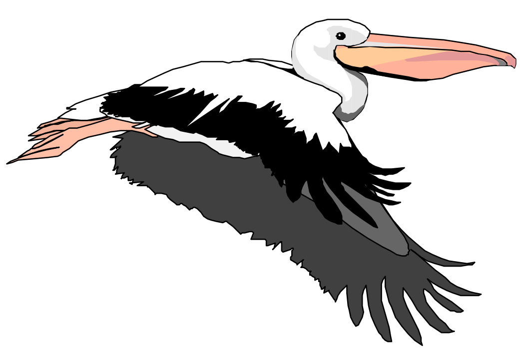


Table 2-2. Coast 2050 public meetings.

Date(s)	Reg.	Location	Meeting type	Purpose	Attend.
7/15-16/97	1	USACE Building, New Orleans	Kick-off Regional Meeting	Obtain Feedback on Process and Issues for Coast 2050	46
7/24-25/97	3	Nicholls State Univ., Thibodaux	Kick-off Regional Meeting	Obtain Feedback on Process and Issues for Coast 2050	68
7/29-30/97	2	Yenni Bld., Metairie	Kick-off Regional Meeting	Obtain Feedback on Process and Issues for Coast 2050	60
8/14-15/97	4	Cameron Police Jury Building	Kick-off Regional Meeting	Obtain Feedback on Process and Issues for Coast 2050	60
9/18/97	2	USACE Building, New Orleans	RPT Meeting	Status and Trend Compilation and Evaluation	25
9/19/97	3	Morgan City Municipal Audit.	RPT Meeting	Status and Trend Compilation and Evaluation	30
9/22/97	1	USACE Building, New Orleans	RPT Meeting	Status and Trend Compilation and Evaluation	26
9/23/97	4	Cameron Police Jury Building, Cameron	RPT Meeting	Status and Trend Compilation and Evaluation	26
10/07/97	1	USACE Building, New Orleans	RPT Meeting	Status and Trend Compilation and Evaluation	47
10/15/97	4	Cameron Police Jury Building, Cameron	RPT Meeting	Status and Trend Compilation and Evaluation	23
10/17/97	3	Abbeville Cooperative Office	RPT Meeting	Status and Trend Compilation and Evaluation	23
10/27/97	2	USACE Building, New Orleans	RPT Meeting	Status and Trend Compilation and Evaluation	50
11/05/97	4	Cameron Police Jury Building, Cameron	RPT Meeting	Status and Trend Compilation and Evaluation	23
11/21/97	4	Cameron Police Jury Building, Cameron	RPT Meeting	Status and Trend Compilation and Evaluation	20
12/11/97	1	USACE Building, New Orleans	RPT Meeting	Status and Trend Compilation and Evaluation	25
12/12/97	2	USACE Building, New Orleans	RPT Meeting	Status and Trend Compilation and Evaluation	27
12/12/97	4	Cameron Police Jury Building, Cameron	RPT Meeting	Status and Trend Compilation and Evaluation	31

Table 2-2. Coast 2050 public meetings (cont).

12/15/97	4	Cameron Police Jury Building, Cameron	RPT Meeting	Status and Trend Compilation and Evaluation	9
1/08/98	2	USACE Building, New Orleans	RPT Meeting	Status and Trend Compilation and Evaluation	18
1/09/98	3	Abbeville Cooperative Office	RPT Meeting	Status and Trend Compilation and Evaluation	11
1/13/98	4	Cameron Police Jury Building, Cameron	RPT Meeting	Status and Trend Compilation and Evaluation	17
1/13/98	2	USACE Building, New Orleans	RPT Meeting	Status and Trend Compilation and Evaluation	21
1/14/98	4	Cameron Police Jury Building, Cameron	RPT Meeting	Status and Trend Compilation and Evaluation	16
1/15/98	3	Abbeville Cooperative Office	RPT Meeting	Status and Trend Compilation and Evaluation	26
1/20/98	3	Abbeville Cooperative Office	RPT Meeting	Status and Trend Compilation and Evaluation	38
1/21/98	1	USACE Building, New Orleans	RPT Meeting	Status and Trend Compilation and Evaluation	15
2/10/98	4	Cameron Police Jury Building, Cameron	RPT Meeting	Strategy and Objectives Meeting	19
2/10/98	2	Belle Chase	RPT Meeting	Strategy and Objectives Meeting	20
2/13/98	1	USACE Building, New Orleans	RPT Meeting	Strategy and Objectives Meeting	16
2/17/98	2	USACE Building, New Orleans	RPT Meeting	Strategy and Objectives Meeting	15
2/18/98	3	Abbeville Cooperative Office	RPT Meeting	Strategy and Objectives Meeting	28
2/19/98	3	Abbeville Cooperative Office	RPT Meeting	Strategy and Objectives Meeting	24
2/25/98	1	Slidell	RPT Meeting	Strategy and Objectives Meeting	8
2/25/98	2	Belle Chase	RPT Meeting	Strategy and Objectives Meeting	16
2/26/98	1	Hammond	RPT Meeting	Strategy and Objectives Meeting	25
3/03/98	2	USACE Building, New Orleans	RPT Meeting	Strategy and Objectives Meeting	19

Table 2-2. Coast 2050 public meetings (cont).

3/12/98	3	Nicholls State Univ., Thibodaux	RPT Meeting	Strategy and Objectives Meeting	22
3/13/98	3	Nicholls State Univ., Thibodaux	RPT Meeting	Strategy and Objectives Meeting	22
3/16/98	1	USACE Building, New Orleans	RPT Meeting	Update and Discussion Meeting	12
3/18/98	3	New Iberia	RPT Meeting	Update and Discussion	11
3/18/98	3	New Iberia	RPT Meeting	Atchafalaya Bay Assn.	23
3/19/98	3	New Iberia	RPT Meeting	Update and Discussion	18
3/23/98	2	USACE Building, New Orleans	RPT Meeting	Update and Discussion Meeting	29
3/31/98	4	Rockefeller State Wildlife Refuge	RPT Meeting	Update and Discussion Meeting	40
4/07/98	3	New Iberia	RPT Meeting	Final Strategies and Objectives Meeting	16
4/16/98	3	Morgan City Municipal Audit.	RPT Meeting	Needs List	9
4/20/98	1,2	Convent Court House, Convent	RPT Meeting	St. James Advisory Committee Meeting	14
5/12/98	3	Abbeville Cooperative Office	RPT Meeting	Vermilion Rice Growers Association	25
5/20-21/98	1, 2, 3, 4	USACE Building, New Orleans	SWG/CZMWG Joint Meeting	Review, Amend and Approve Strategies and Objectives	51
6/03/98	1, 2, 3, 4	Burden Research Center, Baton Rouge	Town Meeting	Present, Discuss, & Assess Results of Joint Meeting	26
6/04/98	1, 2, 3, 4	Yenni Building, Metairie	Town Meeting	Present, Discuss, & Assess Results of Joint Meeting	22
6/09/98	4	Cameron Police Jury Building, Cameron	Town Meeting	Present, Discuss, & Assess Results of Joint Meeting	21
6/10/98	3, 4	Abbeville Cooperative Office	Town Meeting	Present, Discuss, & Assess Results of Joint Meeting	93
6/11/98	3	Bayou Vista Civic Center, Bayou Vista	Town Meeting	Present, Discuss, & Assess Results of Joint Meeting	15
6/15/98	2, 3	Cut Off Youth Center, Cut Off	Town Meeting	Present, Discuss, & Assess Results of Joint Meeting	30

Table 2-2. Coast 2050 public meetings (cont).

6/16/98	3	Houma Municipal Auditorium, Houma	Town Meeting	Present, Discuss, & Assess Results of Joint Meeting	38
6/23/98	2	Port Sulphur Civic Center, Port Sulphur	Town Meeting	Present, Discuss, & Assess Results of Joint Meeting	20
6/24/98	1	SLU University Center, Hammond	Town Meeting	Present, Discuss, & Assess Results of Joint Meeting	19
6/25/98	1, 2	St. Bernard Govt Complex, Chalmette	Town Meeting	Present, Discuss, & Assess Results of Joint Meeting	42
7/07/98	2	Jean Lafitte Auditorium, Lafitte	Town Meeting	Present, Discuss, & Assess Results of Joint Meeting	27
7/21-22/98	1, 2, 3, 4	Holiday Inn Central-Holidome, Lafayette	SWG/CZMWG Joint Meeting	Review and Approval of Strategies and Objectives	34
9/09/98	4	Burton Coliseum, Lake Charles	Regional Meeting	Present, Discuss, & Assess Results of Joint Meeting	44
9/10/98	3	National Wetlands Research Center, Lafayette	Regional Meeting	Present, Discuss, & Assess Results of Joint Meeting	15
9/15/98	2	USACE Building, New Orleans	Regional Meeting	Present, Discuss, & Assess Results of Joint Meeting	27
9/16/98	1	SLU University Center, Hammond	Regional Meeting	Present, Discuss, & Assess Results of Joint Meeting	20
Total Meetings : 65					
Total Attendance: 1,756					

CHAPTER 3

COASTAL LOUISIANA TODAY

Coastal Louisiana is made up of two wetland-dominated ecosystems, the Deltaic Plain of the Mississippi River, which occupies Regions 1, 2, and most of 3, and the closely linked Chenier Plain, which lies within Region 4 and the western part of Region 3 (Fig. 3-1). Both are influenced by the Mississippi River, one of the great natural systems of North America. The rich renewable resource values related to the coastal wetlands are to a large extent the product of the dynamic nature of these systems. The Deltaic Plain and Chenier Plain ecosystems are shrinking in size and deteriorating in function because of natural changes and human intervention. The Deltaic Plain, in particular, has lost vital subsystem components and functions, and other components have been impaired to the extent that the system is in a condition of collapse.

Deltaic Plain Processes

The Deltaic Plain

Under natural conditions, a vast wetland area developed as a result of delta-building processes (Russell et al. 1936; Fisk 1944; Kolb and van Lopik 1965; Frazier 1967; and many others). This build-up occurred over a 5,000-year period during which sea level conditions were relatively stable (Fig. 3-2). During historic times, delta building has occurred in only a few areas along the Louisiana coast. One is the active Mississippi delta, where a birdfoot pattern of land extends out into deep water of the Gulf of Mexico (Russell et al. 1936). The second is the Atchafalaya Delta where, since about 1950, subdeltas have formed at the mouths of the Lower Atchafalaya River and the Wax Lake Outlet (Shlemon 1975; van Heerden and Roberts 1988; Roberts 1998).

The Delta Cycle

Delta building is cyclic. The delta cycle begins when an upstream diversion directs a distributary of an alluvial river toward some low-lying area of the coast (Scruton 1960; Coleman and Gagliano 1964). When the stream enters an open water body (coastal lake or bay) and the flow leaves the confines of the channel banks, there is a loss of velocity and consequentially a reduction in the stream's ability to transport sediment (sand, silt, and clay). Sediment is deposited to form bars and shoals, which in turn may cause the channel to branch (Russell et al. 1936; Welder 1959; Coleman et al. 1969). In an open basin of deposition (bay or open gulf) the stream splits or bifurcates (Fig. 3-3), sometimes rejoining. In a closed basin, (such as the lakes in the Atchafalaya Basin) the channel branches and rejoins

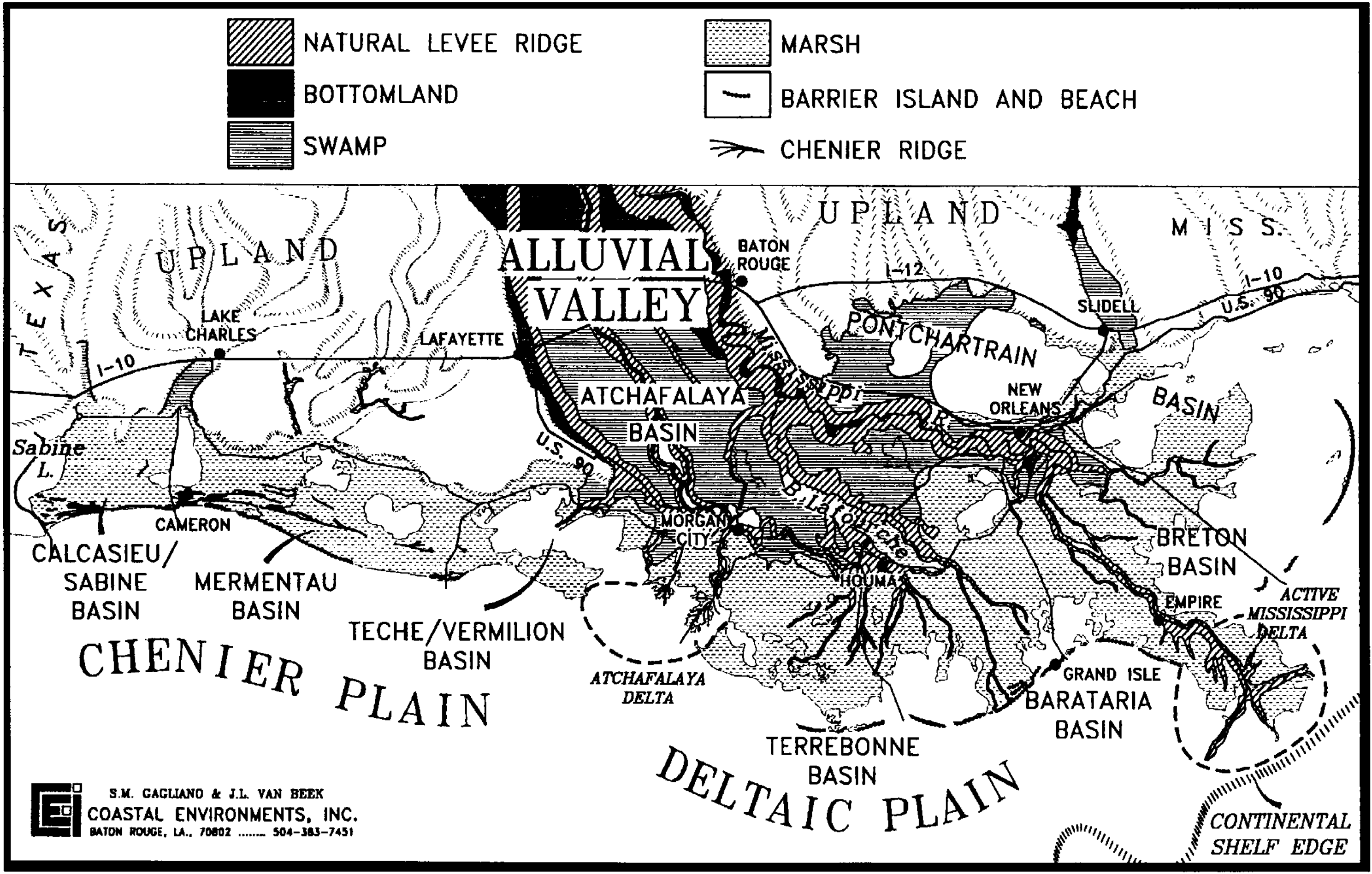


Figure 3-1. Map of major coastal Louisiana land forms (after Gagliano and van Beek 1993).

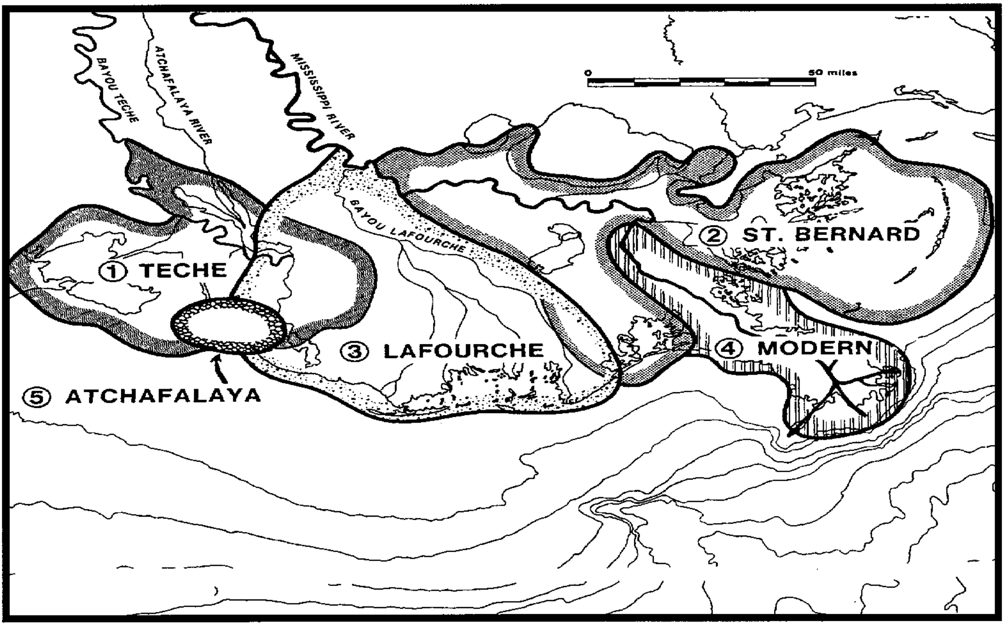


Figure 3-2. The deltaic plain landmass was built by a sequence of overlapping deltaic lobes which developed during the last 5,000 years (Teche = 6,000-350 B.P., St. Bernard = 5,000-500 B.P., Lafourche = 3,500-50 B.P., Modern = 1,000 B.P. to present, Atchafalaya = 50 B.P. to present) (modified from Frazier 1967).

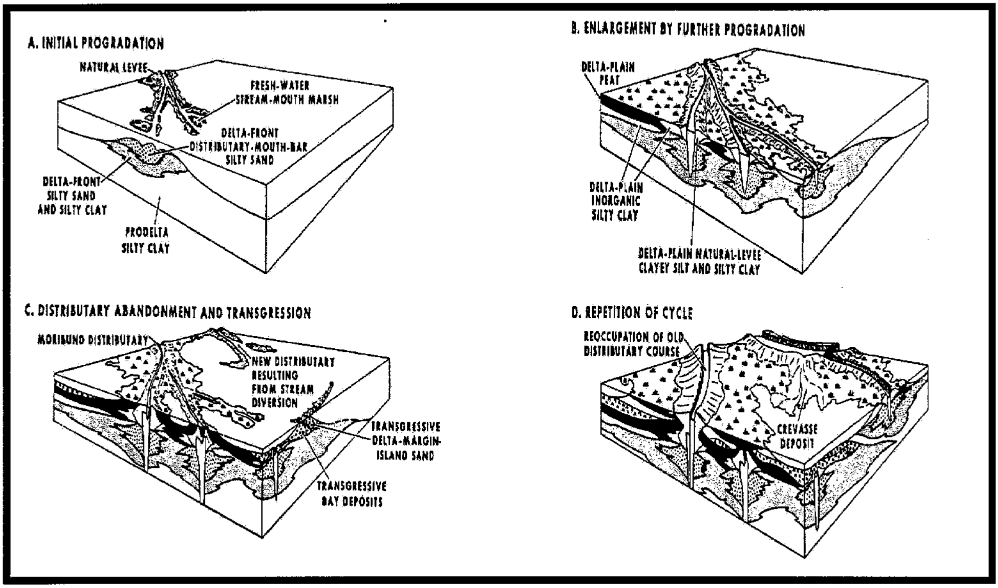


Figure 3-3. Land building in the vicinity of active distributary outlets (after Frazier, 1967).

to form a braided pattern. The bars and shoals build up through flood overflow of the banks (overbank processes) and gradually emerge as land when the stage falls. The newly formed land becomes colonized by wetland vegetation. The vegetation in turn reduces velocities of overbank flow and captures sediment to accelerate aggradation or build up. In this fashion a subdelta lobe forms and advances seaward (progrades). Major delta lobes are clusters of subdelta lobes emanating from a common major river distributary and form over a period of 500 to 1,000 years (Frazier 1967). Subdelta lobes form in 50 to 100 years (Coleman and Gagliano 1964). Thus, an induced subdelta formation is an achievable event within the time frame of the Coast 2050 Plan.

Active delta-building areas are dominated by fresh, turbid water. As the lobe increases in size, the spread and accumulation of vegetation become the dominant processes in the upper part of the system. In many instances, continuous unbroken mats of marsh grass form in basin areas between distributary channels. The vegetation impedes flow and chokes channels. Surface streams become rare, and drainage becomes sluggish and is largely restricted to sheet flow. Energy levels from water movement are very low, and water becomes anaerobic and stained by tannic acid. These conditions are conducive to preservation of organic particles and accumulation of peat deposits (Fisk 1958) as well as the formation of floating marshes in these interdistributary basins (Russell 1942; O'Neil 1949).

The delta builds up or aggrades through a combination of alluvial processes (overbank flooding, crevasses, lacustrine delta building), processes of vegetation growth (peat accumulation, flotant), and biochemical processes (reefs and shell beaches). Continuation of aggradational processes is essential to maintenance of the deltaic landmass. An equally important aspect of this land-building process occurs when a new subdelta lobe builds around the seaward end of an older lobe, providing protection to the older landmass from erosive forces of the gulf. As long as delta-building conditions remain favorable, the shore advances seaward and the delta builds coastal wetlands (regressive phase). In about 5,000 years, this process resulted in a landmass that was approximately 7,000 square miles (4.5 million acres) or more in extent by the early 1700's.

The deterioration phase begins with natural closure of distributary feeder channels at their heads (Fig. 3-3). The supply of fresh water and transported sediment is cut off and no longer reaches the seaward edge of the subdelta. The newly deposited deltaic sediments subside rapidly, and marine processes become dominant. Water conditions in the lower end of the system become brackish and saline. Waves and longshore currents erode the subdelta land mass (Fig. 3-4). These processes winnow out the fine sediment (clays, plant materials, and silts) and leave sand size mineral particles and shells to form beaches, barrier islands, spits, and shoals. These formations are progressively reworked by the waves and currents into barrier headlands and

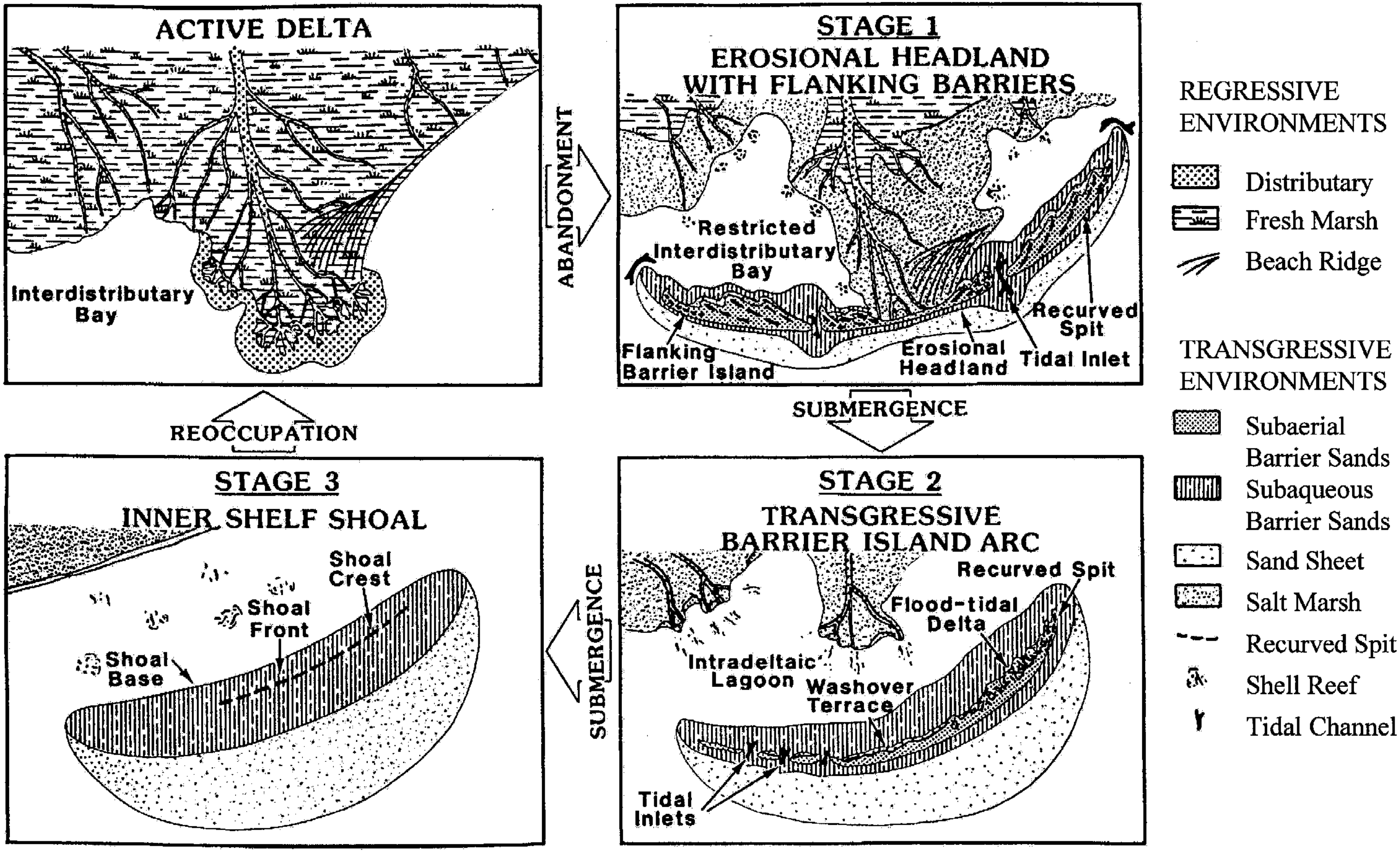


Figure 3-4. Barrier island cycle (after Penland and Boyd 1981).

island arcs, that curve around the fronts of deteriorating subdeltas.

Landward of the barrier islands other dramatic changes occur. Marine tidal invasion works its way landward into the extensive wetland areas lying between the distributaries. Under natural conditions, the invasion is slow and is driven by factors such as subsidence, storms, and animal eat-outs. The freshwater marshes and swamps undergo two changes. Soft substrate areas (floating marshes are particularly vulnerable) give way to ponds, which slowly enlarge into lakes and bays. Where the substrate is firm, freshwater plants are replaced by brackish water species. Brackish and saline marsh communities become established. This salinity gradient, from fresh through saline marshes, results in a high level of biodiversity. Through this process the interdistributary basins become more estuarine in character. At the same time that slow marine invasion and transformation are occurring in the lower (seaward) parts of the subdelta lobe, freshwater conditions continue to flourish in the upper (landward) parts of the lobe. The invasion process has been greatly accelerated by dredging of navigation channels and canals, which alter the natural hydrology of the system.

The advanced deterioration phase of the delta cycle is reached when the barrier islands begin to diminish in size and fragment, and the estuarine bays separating the barrier arc from the mainland remnants of the subdelta lobe become broad and open. Eventually, the barrier islands become shoals and the gulf shore moves inland to the heads of the estuarine bays. Freshwater conditions may persist in the landward remnants of the lobe from local precipitation, but the system no longer receives fresh water and sediment input through the original distributary system. The brackish and saline bays and marshes are extensive components of the current system.

Although a major part of the subdelta landmass reverts to open water conditions during this phase, geometry and bottom conditions of the shallow water bodies are a product of the delta building process. The shallow water areas are a mix of island remnants, shoals, tidal passes and reefs, which result in optimum conditions, however unstable, for a large assemblage of estuarine fish and shore birds. Shell-forming mollusks are particularly important during this phase, as they add coarse-grained sediment (calcium carbonate) to the deteriorating delta. These form reefs and wash up to contribute to islands and beaches (Gagliano et al. 1997). While the terminal stage of the delta cycle is productive, without renewal through new delta growth, erosion and deterioration would become the dominant processes. This would result in loss of the fringing wetlands, which are the basis for the productivity.

The delta cycle creates diversity, drives ecological succession and is the basic renewal process operating in the delta system (Gagliano and van Beek 1975; Gosselink 1984). Under natural conditions, at any one time different parts of the Deltaic Plain were in different stages of the delta cycle. This variety resulted in maximum diversity of fish and wildlife habitat and environmental conditions.

The Mudstream

Every active subdelta has a "mudstream" (Fig. 3-5a and 3-5b). This mudstream consists of the fine grained sediments (silts and clay) that stay in suspension beyond the immediate area of the active distributary outlets and move along the coast in response to coastal currents (Morgan et al. 1953; van Lopik 1955; Adams et al. 1978; van Heerden 1983; Wells and Roberts 1980; Kemp 1986; Roberts 1998). Twenty-five percent or more of the transported sediment escapes deposition in the immediate area of the distributary outlets and is carried away in the mudstream. If the subdelta is building into shallow waters of a bay or the inner continental shelf, these fine-grained sediments may be transported by longshore currents. If the mudstream flows along the fronts of barrier islands or the gulf shore, tidal action may move some of the turbid waters into interdistributary areas through tidal passes and tidal networks, but sediment transported by the mudstream is too fine grained to contribute to the sand budgets of the islands. Some of the mudstream sediment may eventually form mudflats along the open shore of the gulf. If the distributary outlets discharge into deep waters (far out on the continental shelf or beyond the shelf edge as in the case of the modern birdfoot delta) deposition resulting from the mudstream may be on the sea bottom of the shelf or into the depths of the gulf. In the latter instance, mudstream sediments are largely lost to the land building and maintenance processes.

Chenier Plain Processes

The Chenier Plain (Region 4 and the western part of Region 3) is a complex system influenced primarily by four coastal plain rivers, the intermittent longshore mudstream from the Mississippi River outlets, and the Gulf of Mexico. The landforms and geological history have been described by Howe et al. (1935) and Gould and McFarlan (1959) and the ecosystem by Gosselink et al. (1979). Byrnes et al. (1995) studied historic shoreline dynamics and change. The dominant longshore drift along the Louisiana coast is from east to west, and as a result, during intervals when the Mississippi is active along the western side of the Deltaic Plain, the mudstream moves fine-grained sediment towards the Chenier Plain and mudflats form. These are colonized by marsh grass and have added new wetlands to the coast. Conversely, when the Mississippi subdeltas have been on the east side of the Deltaic Plain, the gulf shore along the Chenier Plain has been subjected to erosion. The long-term result during the past 5,000 years has been episodes of shoreline progradation interrupted by episodes of retreat, but progradation has been greater than retreat. A new interval of land building along the eastern part of the Chenier Plain is now unfolding because extensive mudflats began to form about 1950 as a result of outgrowth of the Atchafalaya delta lobes. Since

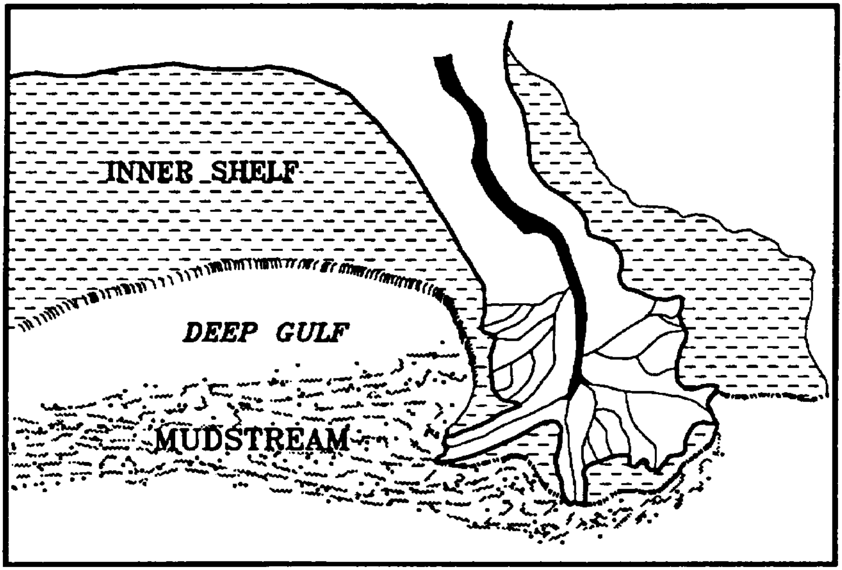


Figure 3-5a. Mudstream offshore. When delta building extends to the edge of the continental shelf or beyond, the mudstream flows offshore into the deep waters of the Gulf and has little effect on the shore zone (after Gagliano and van Beek 1993).

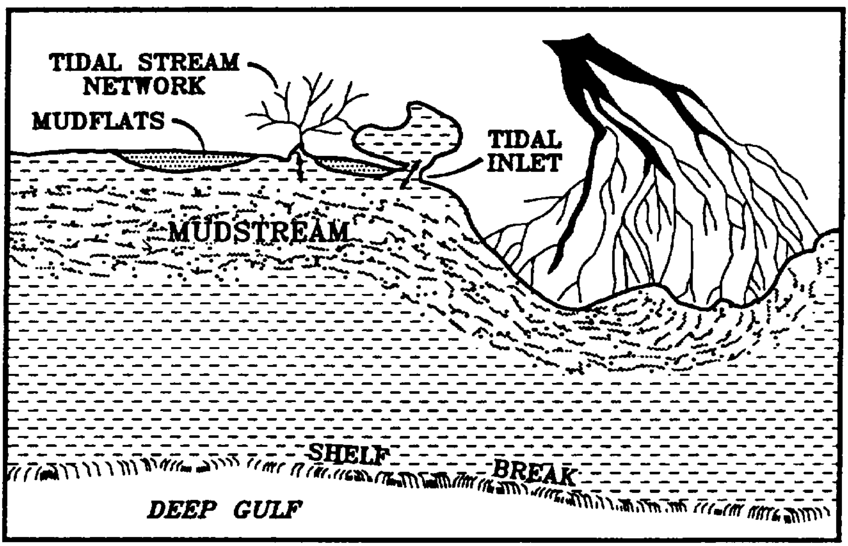


Figure 3-5b. Mudstream onshore. When delta lobes build into shallow water, fine grained sediment transported in the mudstream may be brought into coastal estuaries and marshes by tidal processes and storms and may be deposited along the shore to form mudflats (after Gagliano and van Beek 1993).

1950, the shoreline along the eastern end of the Chenier Plain has been prograding, and although the progradation is advancing toward the west, the rest is still eroding.

During the erosion intervals, fine-grained materials were winnowed out leaving lag deposits of sand and shell which form gulf beaches. The beach deposits were shaped by waves and coastal currents into ridge systems. A high percentage of the composition of the ridges is shell, reflecting the paucity of sand-sized mineral sediment in the mudflat and marsh sediment, which was eroded back. The geometry of the ridges is more complex where they meet the river mouth estuaries. Here, fans of accretion beaches and curved spits occur. Ridge systems became separated from the seashore during intervals of progradation. The relict shell beach ridges are covered with live oak trees and stand as linear islands in the marsh. These are the cheniers of southwestern Louisiana. Development of the beach ridges and cheniers blocked drainage and saltwater inflows. This blockage in turn resulted in the development of large freshwater basins on the landward side of the ridges.

The marshes and ridges are interrupted by Calcasieu and Sabine Lakes, which were initially formed as bays in the drowned river valleys of the Calcasieu and Sabine Rivers during the Holocene rise of sea level. The rivers form small deltas at the heads of these lakes. The lower ends were naturally blocked by bar formation, with only a small tidal pass outlet. Through time, two other large lakes, Grand Lake and White Lake, developed in the eastern part of this zone. The Mermentau River passes through Grand Lake on its way to the sea. Before the bars across the tidal passes were removed for navigation, the lakes and adjacent marshes were largely fresh. On the seaward side of the most prominent chenier trend, however, was a zone of brackish to saline marshes. Locally, tidal stream networks have developed in this zone.

Resulting Landscape

Uplands, Ridgelands, and Fastlands

High, firm land is rare in coastal Louisiana. Elevations of the wetlands are barely above mean gulf level and at best the soils are soft and poorly consolidated. In contrast to the wetlands, geologically older uplands bordering the Deltaic and Chenier Plains have higher elevations and firmer soils. Within the Deltaic Plain, finger-like patterns of narrow alluvial ridges, which reach out toward the gulf, are also higher and firmer. These natural levees, formed by overbank processes, occur along active and abandoned Mississippi River distributaries. In the Chenier Plain, the relict beaches constitute the highest land and are generally parallel to the gulf shore. In addition, there are human-made ridge features throughout the coastal lowlands, which include railroad and highway embankments, artificial levees, and dredged material ridges (“spoil banks”) along waterways.

The natural and man-made ridges form the skeletal framework to which the coastal wetlands are attached. They form hydrologic basin divides, and they are more resistant to erosion than the wetlands. Historically, human settlement and activity have been on the uplands and have followed the natural levee and chenier ridges. The alluvial soils of the higher ridges were fertile and well suited for agriculture and the ridges also provided corridors of access to the resources of the coastal wetlands, estuaries, and the gulf. Deltaic Plain cities such as New Orleans, Thibodaux, Houma, Morgan City, and Empire were initially established on the crests of natural levees. Chenier Plain communities located on old beach ridges include Cameron and Grand Chenier.

Fastlands are areas surrounded by artificial levees, which provide protection from river and storm flooding, and within which there is a system of drainage canals, ditches, and pumps. These forced drainage areas are usually located between natural levee ridges and adjacent backswamp areas. Within them lie most of the agricultural, urban, and industrial land of the coastal zone.

The need to use strategic locations close to the resources and water transportation routes has resulted in settlement of low-lying ridges outside of the protective fastland levees. Important unleveed corridors include Grand Chenier-Cameron, Lower Lafourche, Cocodrie, Lafitte-Barataria, Yscloskey, and Delacroix Island.

The landforms and human settlement pattern are well suited for multiple use. Infrastructure is located on the uplands, within the fastlands, and along unleveed corridors, while ecosystem management is appropriate and effective in the estuarine basins (Gagliano and van Beek 1975).

Estuarine Basins

The Coast 2050 Plan directs ecosystem management planning toward the vast interdistributary estuarine basins. The upper end of the Deltaic Plain basins are occupied by large freshwater swamps and marshes (Fig. 3-6). Each of these wetland types is represented by certain plant species (Table 3-1). These wetlands are not dependent upon the sea. They can occur far inland from the shore or be completely separated from the brackish and saline marshes by natural ridges or artificial levees. They may be subject to rise and fall of the tide, but not ebb and flow. These are low energy environments. They change slowly and have thick sequences of organic soils or floating grass root mats. They have isolated lakes and backswamp drainage channels, but water movement through the basins is largely unchannelized. The middle and lower ends of the estuary contain lakes and bays fringed by saline and brackish marshes. These are subject to the ebb and flow of the tides, and consequently the water is brackish to saline. They are higher energy areas increasingly dominated by tidal and marine processes in a seaward direction.

Saline grasses require a firm substrate. Such conditions occur in relict natural levees, over-wash on the bay side of barrier islands, rims of bays, banks of tidal streams and firm peat deposits that

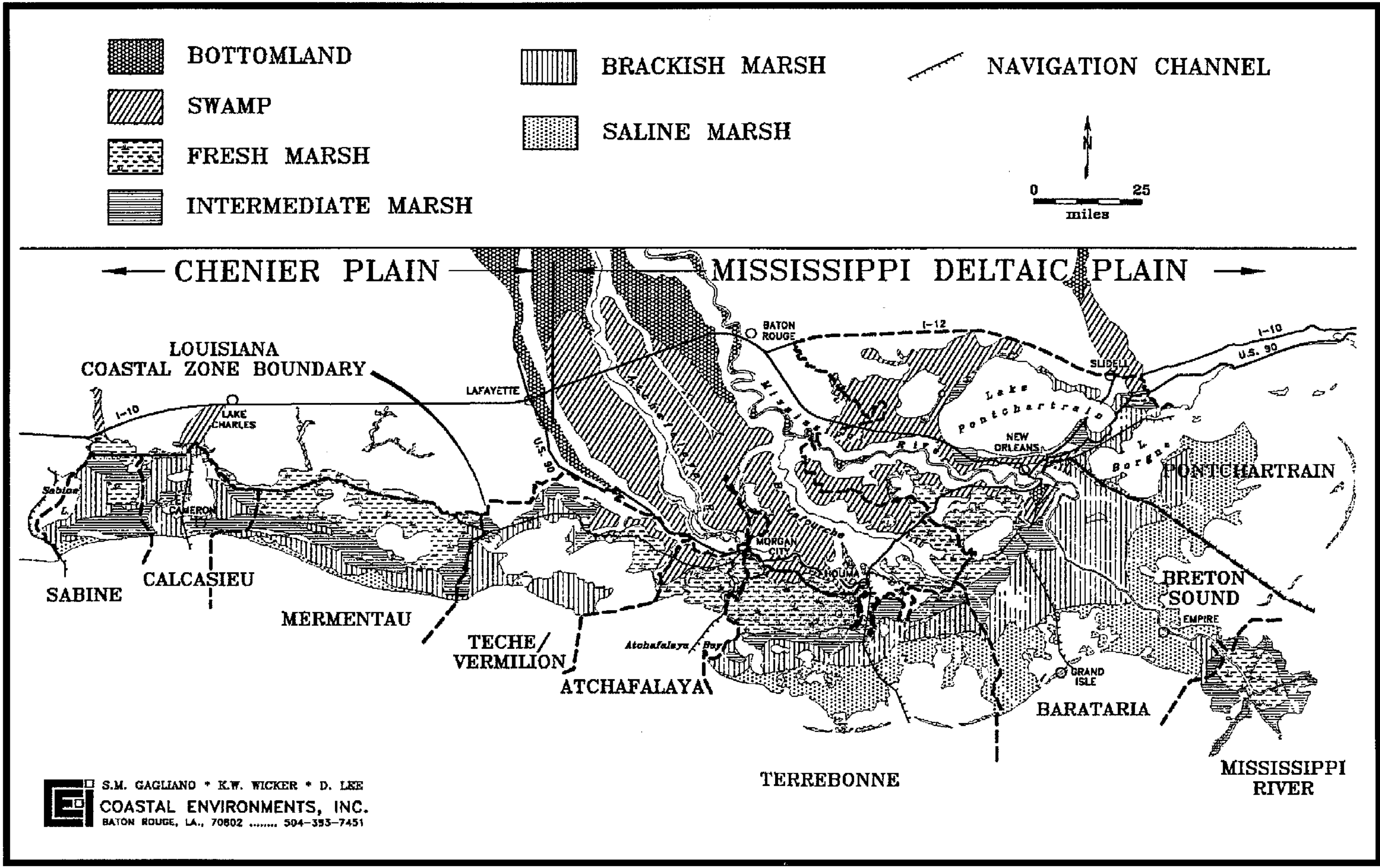


Figure 3-6. Coastal Louisiana vegetation zones (Gagliano and van Beek 1993, marsh after Chabreck and Linscombe 1978).

have accumulated initially as fresh marshes. In such instances, salt-tolerant vegetation is able to maintain a firm footing and can develop a tightly interwoven root mat that is resistant to erosion. Like their fresh marsh counterparts, salt marsh islands with favorable tidal exchange may remain viable for thousands of years, except for edge erosion.

Under natural conditions, there was a hydrologic balance within the basins which was a major factor in determining the distribution of wetland vegetation. Self-regulating mechanisms controlled outflow of freshwater runoff and inflow and interchange of tidal waters from the gulf. Change was driven by the delta cycle, but was slow and almost imperceptible.

Barrier Islands and Gulf Shore

Separating the basins from the open gulf are chains of barrier islands. The islands occur in four arcs, each of which fringes an abandoned delta lobe (Morgan and Larimore 1957; Penland and Boyd 1981). They initially formed from reworking of abandoned subdeltas by waves and currents. Since the sand budget of each arc is limited to sand which can be eroded from the old delta headlands, all are sand deficient and deteriorating (Williams et al. 1992; McBride and Byrnes 1995; Stone et al. 1997; Stone and McBride 1998).

Port Fourchon, an important offshore petroleum industry supply port, is located on a barrier headland, and Grand Isle, a beach resort and fishing village, is located on a barrier island. These gulf shore communities of the Deltaic Plain are linked to the mainland by La. Highway 1.

Along the Chenier Plain, segments of the gulf shore are made up of (1) mudflats, (2) shell and sand beaches, and (3) fans of accretion beaches at lake tidal passes. There are also beach resort communities in the Chenier Plain, such as Holly Beach and Peveto Beach, that can be reached by La. Highway 82.

Table 3-1. Swamp and marsh salinity ranges and major plant species.

Habitat type	Salinity range (ppt)	Major plant species
Fresh Swamp	0-1	*Taxodium distichum, Nyssa aquatica*
Fresh Marsh	0-3	*Panicum hemitomon, Sagittaria falcata*
Intermediate Marsh	2-5	*Sagittaria falcata, Spartina patens*
Brackish Marsh	4-15	*Spartina patens, Scirpus americanus*
Saline Marsh	12+	*Spartina alterniflora, Distichlis spicata*

CHAPTER 4

DETERIORATION OF THE LANDSCAPE

Rates and Patterns of Loss

The balance of Louisiana's coastal systems has been upset by a combination of natural processes and human activities. Massive coastal erosion, which began around 1890 and peaked during the 1950's and 1960's, has resulted in loss and deterioration of wetlands, barrier islands, and ridges (Fig. 4-1a,b,c). During a period of little more than 100 years, more than one million acres, or about 20% of the coastal lowlands (mostly wetlands), have eroded. Because it took about 5,000 years for the coastal lowlands to form, it follows that 1,000 years of natural land building was eroded in about one century. As a result, both the Deltaic and Chenier Plain systems are badly degraded. The Deltaic Plain has lost and continues to lose subsystem components and is approaching a condition of system collapse.

The distribution of the land loss sheds light on the causes (Fig. 4-2). The losses are not uniformly distributed, but rather are concentrated in a few areas. The two areas of highest loss are (1) within the Deltaic Plain in the lower Terrebonne and Barataria Basins and the Mississippi Basin, and (2) in the Chenier Plain in the vicinity of Calcasieu and Sabine Lakes.

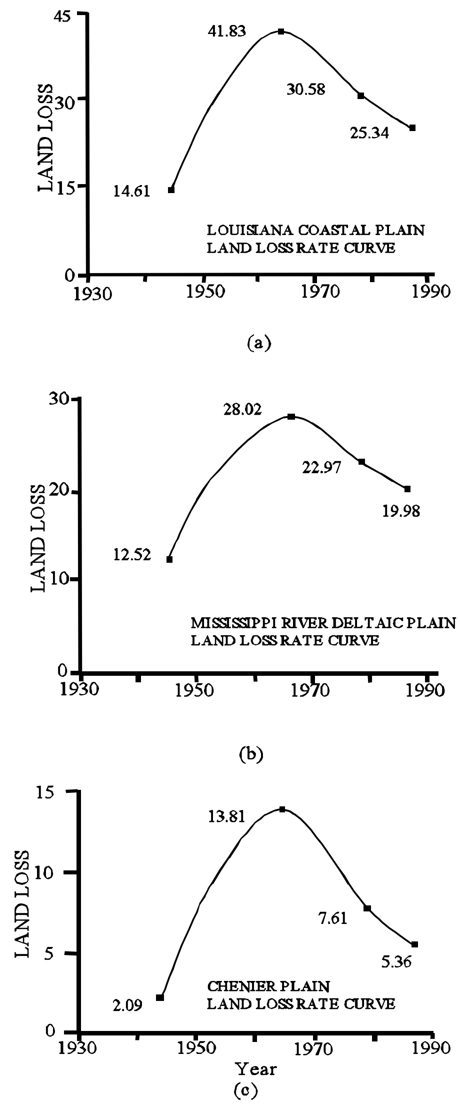


Figure 4-1. Loss rates of the entire Louisiana coastal area, Deltaic Plain, and Chenier Plain. Land loss rates are expressed in square miles per year (after Dunbar et al. 1992).

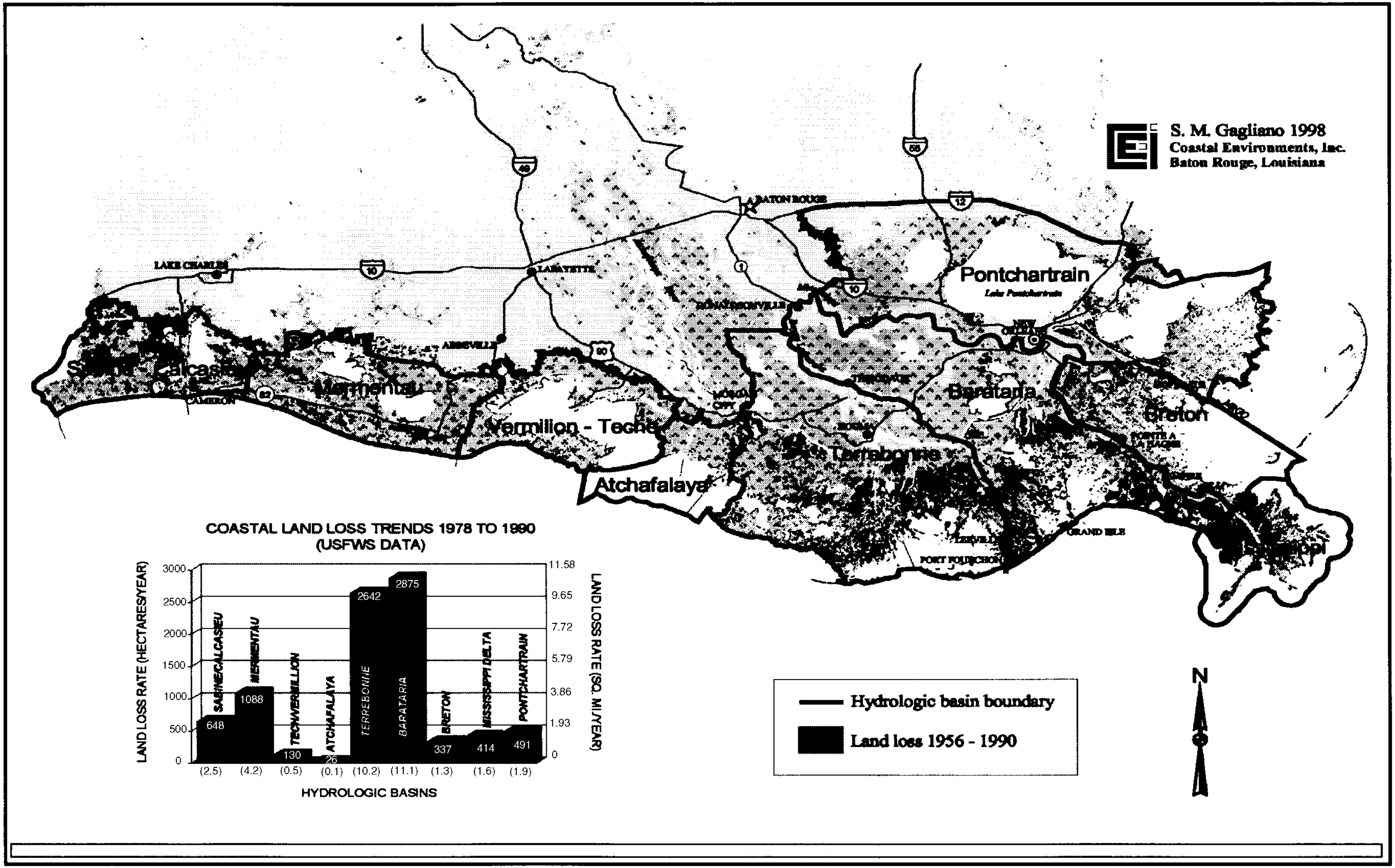


Figure 4-2. Distribution of land loss in the Louisiana coastal area (Gagliano 1998, adapted from Barras et al.1994).

There is no single cause for all of the wetland and land loss in coastal Louisiana. The sustainability of the coastal ecosystems is threatened, however, by the inability of many wetlands to maintain their surface elevation in the face of subsidence and sea level rise. A discussion of these issues and the other major causes of land loss follows.

Factors Controlling Marsh Sustainability

Sea Level Rise

The combined effect of the worldwide rise of sea level resulting from glacial melting and subsidence or land sinking results in relative changes between the elevation of the land and the sea (relative sea level rise).

The average rate of sea level rise is currently 0.39 ft/century (0.12 cm/year). Until recently, the sea level rise rate has been low, accounting for only a small component of the change along the Louisiana coast. Most of the recorded relative sea level rise has been related to subsidence. The best estimate of sea level experts is that the level of the world's oceans will increase 8 inches (20 cm) over the next 50 years (Fig. 4-3).

Subsidence

Subsidence is the combined effect of geological movement along faults and compaction of poorly consolidated sediments.

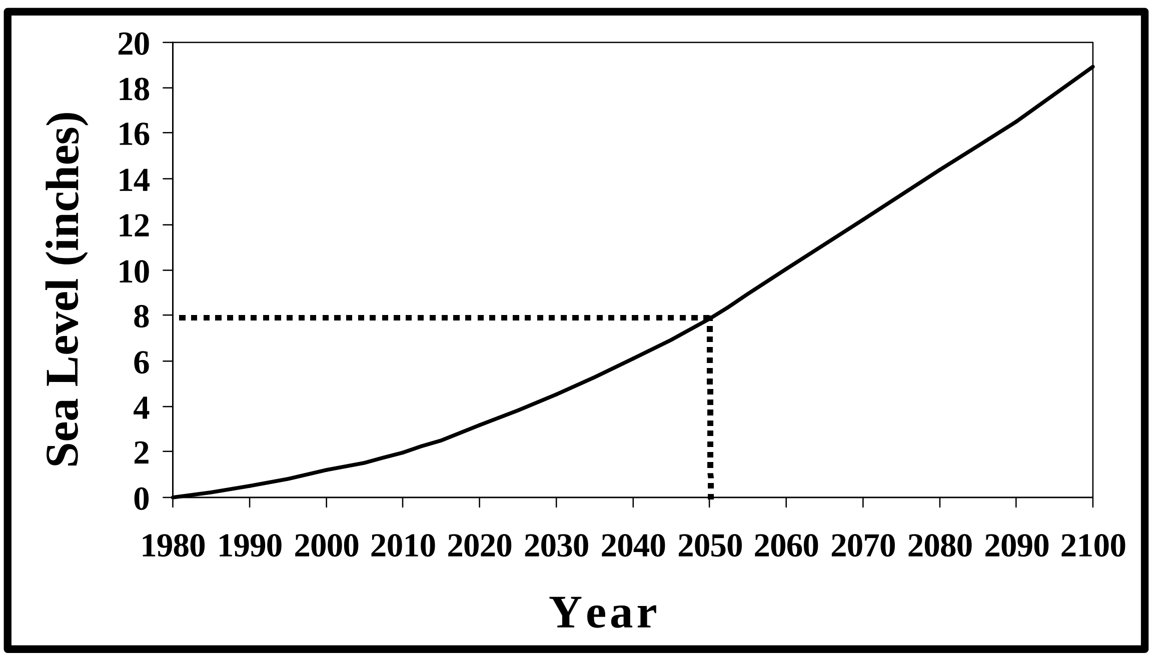


Figure 4-3. Projected best estimate of worldwide rise in sea level (Wigley and Raper 1992).

Compaction

Compaction is related to the type and thickness of Holocene Period (modern) sediment that has accumulated on top of the weathered surface of the Pleistocene formation during the past 5,000 years. This buried top of the Pleistocene is a continuation of the land surface of the uplands and before burial was exposed by low sea level stands during the last ice age. A prism of modern sedimentary deposits (sands, silts, clays, peat beds, and shell beds) accumulated above the weathered surface during the rise and the relative still-stand of the sea that followed glacial melting. The poorly consolidated clay and peat beds had higher water content at the time of deposition. They were compacted and lost volume after burial. This compaction process, which still continues, contributes to subsidence. Where these deposits are thick, compaction and subsidence rates are higher.

Sinking of Fault-bounded Blocks

Hundreds of faults have been mapped in the coastal area by petroleum geologists (Wallace 1957). The fault pattern is complex. Many faults are deep seated, and the most significant occur in trends and zones (Fisk 1944; Murray 1960; Fig. 4-4). These fault trends and zones define irregularly shaped blocks, which may be rising, subsiding, and/or tilting in relation to neighboring blocks (Gagliano and van Beek 1993).

All blocks within the coastal zone are subsiding. Upland areas bordering the coastal zone are generally rising in isostatic adjustment to sediment loading in coastal basins. Fault trends and zones separating rising blocks and sinking blocks are called hinge lines. Cities on upland rising blocks include Slidell, Mandeville, Ponchatoula, Baton Rouge, Lafayette, Abbeville, and Lake Charles.

The area of most intensive faulting occurs within a triangle in the Deltaic Plain, which is bounded by the NE-SW trending Thibodaux fault trend, the NW-SE trending Terre aux Boeufs fault trend and the Gulf of Mexico. Of the many fault trends cutting across this block, the Theriot-Golden Meadow-Forts fault trends are the most important and subdivide the block into a northern and southern component (Fig. 4-4).

Subsidence Rates

Data for calculating subsidence come from a number of sources. These data include: (1) depth of surfaces upon which human structures (prehistoric Indian village sites, lighthouses, forts, roads, etc.) were built; (2) radiometric dating of buried peat deposits; (3) tidal gauge records; and (4) sequential land surveying. The latter technique provides the best measure of present subsidence rates.

Studies conducted by Shea Penland and others (Ramsey and Moslow 1987; Penland et al. 1988; Penland et al. 1989; Penland and Ramsey 1990) have led to the conclusion that the subsidence rate for the Deltaic Plain is 3.0 to 4.3 ft/century (0.9 to 1.3 cm/yr) and for the

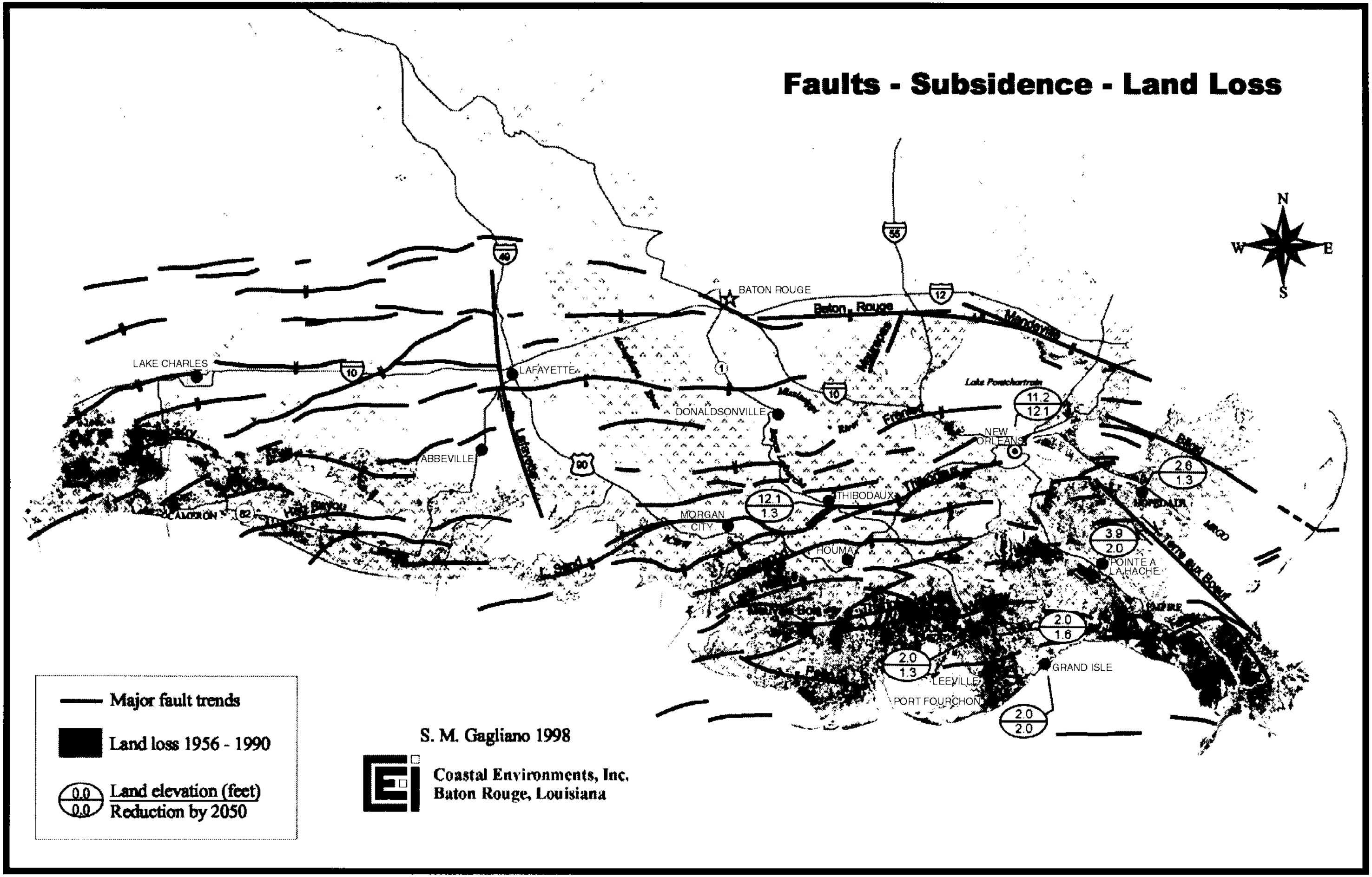


Figure 4-4. Major fault trends and future changes in land elevation of south Louisiana (Gagliano 1998).

Chenier Plain it is 1.3 to 2.0 ft/century (0.4 to 0.6 cm/yr).

Subsidence rates in some areas of coastal Louisiana have increased significantly during modern decades (Van Beek et al. 1986; Penland et al. 1988). A small part of this change can be attributed to worldwide increase in sea level. Based on sequential land surveying measurements, the combined subsidence/sea level rise rate in some of the most severe subsidence areas is more than 3.0 feet per century. Since the present world wide average rate of sea level rise is only 0.394 foot per century, it appears that the land elevation in some areas of coastal Louisiana is being reduced in elevation eight times faster than the sea level rise rate. The difference is related to the combined effects of fault movement and sediment compaction.

The areas of highest subsidence appear to be related to fault movement and are found in the lower Deltaic Plain within the fault-bounded triangle described above. Subsidence in the blocks bounded by these faults is high (2.1 – 3.5 ft/century). The area of highest rates (> 3.5 ft/century) is found in the lower delta below the Forts fault.

Patterns of Subsidence

Figure 4-5 shows patterns of subsidence rates by mapping unit. The rates shown are derived from sequential land surveying data, which have been extrapolated to the mapping units on the basis of fault patterns. The rates should be regarded as "best estimates." Most of the benchmarks where the measurements have been made are located on major natural levee ridges in the Deltaic Plain. Since none of the benchmark locations are aggrading, and the elevations are not referenced to tide gauges, the changes in elevations are true measures of subsidence. Little subsidence rate information is available for the Chenier Plain.

Bordering uplands are stable (Fig. 4-5). Subsidence rates in the Chenier Plain are classified as low (0-1 ft/century), with one exception. The area around Calcasieu Lake is classified as low to intermediate (0 – 2 ft/century). A second area of low subsidence is found along the north side of the Pontchartrain Basin, including the area north of Lake Maurepas, the Pontchartrain land bridge, and the Biloxi and St. Bernard marshes.

Intermediate subsidence rates occur in a broad band extending from Freshwater Bayou Canal to Chandeleur Sound. This includes Marsh Island and the Vermilion-West Cote Blanche, East Cote Blanche, Atchafalaya Bay, Penchant and Verret Basins, the upper Barataria Basin, the Maurepas Basin, and the corridor along Bayou La Loutre.

Relationship Between Faulting, Subsidence, and Land Loss

There appears to be a strong relationship between faulting, subsidence, and land loss (Penland et al. 1989; Gagliano and Van Beek 1993; Kuecher 1994). There are major fault trends and zones associated with areas of high land loss (Fig. 4-4). In the Deltaic Plain, the areas of highest subsidence occur within

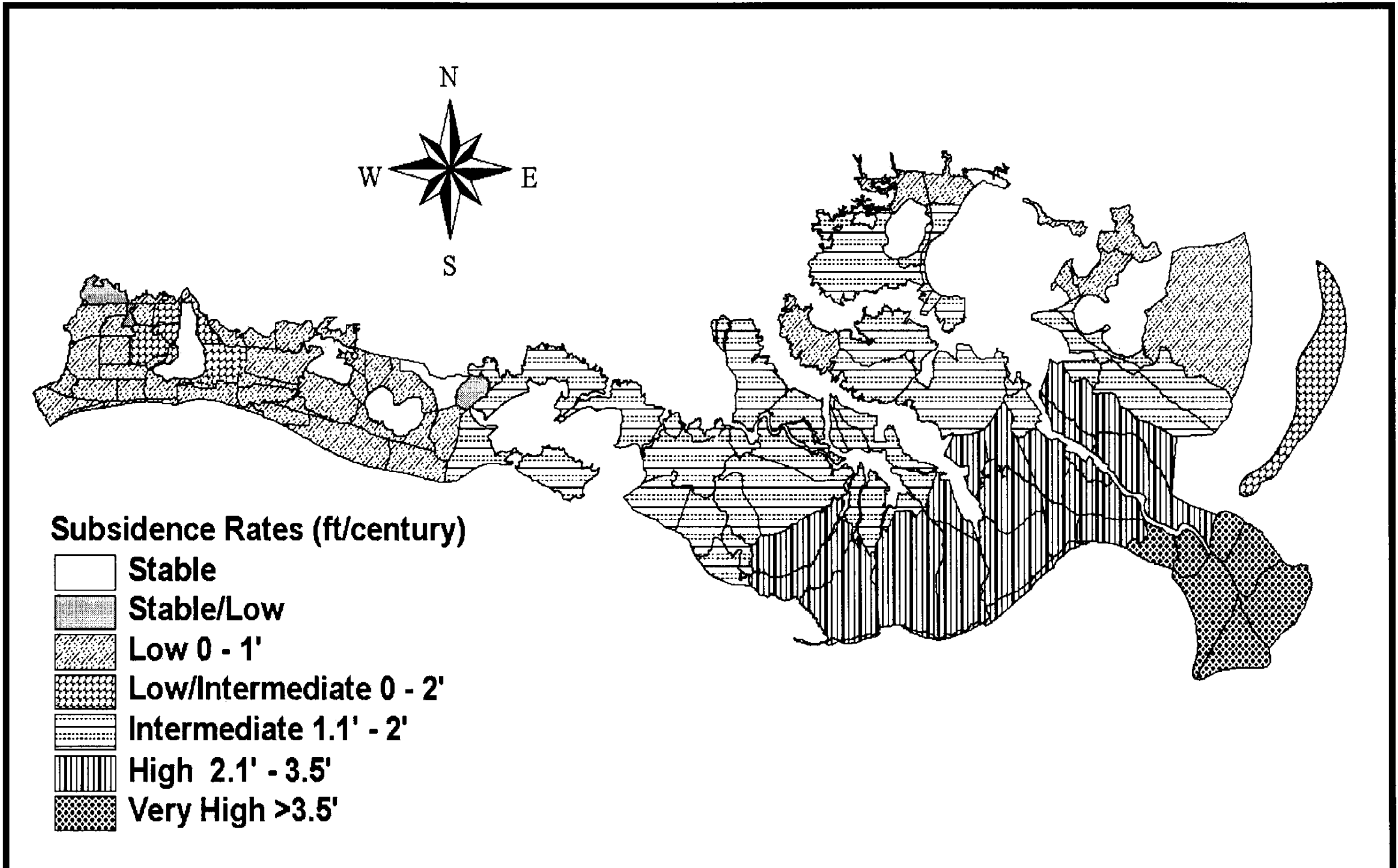


Figure 4-5. Subsidence rates in coastal Louisiana by mapping unit (Gagliano 1998).

the fault-bounded triangle and particularly south of the Theriot-Golden Meadow-Forts fault trends. Sixty percent or more of the total land loss for the entire coastal zone, and approximately 80% or more of the loss within the Deltaic Plain has occurred within this fault-bounded area. Three of the four barrier island arcs, as well as Golden Meadow, Leeville, Cocodrie, Port Fourchon, Grand Isle, Empire, and Venice, are on the fault-bounded blocks within this triangle. Relative sea level rise rates are expected to be 0.4-0.6 inches per year in this region by 2050.

Within the Deltaic Plain, between the hinge line and the fault bounded triangular block, is a zone of relatively low to moderate sinking rates and land loss rates. The cities of Chalmette, New Orleans, Houma, and Thibodaux are located within this zone.

Aggradation vs. Relative Sea Level Rise

The vulnerability of coastal systems to sea level rise is a combination of their sensitivity to the change and their ability to adapt to the change (Raper et al. 1996). The elevation of a coastal marsh surface in relation to the tide is critical to its survival and sustainability.

The combined stresses imposed on coastal marshes by subsidence and eustatic sea level rise require that vertical building of marsh soils must take place to prevent submergence and deterioration. The main processes controlling soil building are inorganic sediment deposition and organic matter accumulation. The relative importance of these processes varies across coastal Louisiana with physiographic setting and marsh type.

Inorganic Sediment Supply and Deposition

The average annual suspended load of the Mississippi River presently reaching the gulf is approximately 78 million cubic yards. This amount is approximately half of the sediment reaching the gulf prior to the 1950's when dams were placed on many tributaries of the river and extensive channel control works were implemented (Meade and Parker 1985, Meade et al. 1990). Artificial levees, which now line the lower river almost to the Gulf of Mexico, however, prevent even this smaller amount of sediment from being dispersed into the adjacent flood plain and wetlands by preventing overbank flow and crevasse splay formation. Most river sediments are now funneled to the mouth of the river where they are discharged off the continental shelf. There are few direct avenues for the input of suspended sediment from the Mississippi and Atchafalaya Rivers into the coastal wetlands of Louisiana. The isolation of the wetlands from riverine sediments impairs their ability to keep pace with relative sea level rise.

The main source of suspended sediment to the vast areas of coastal marsh that are isolated from the Mississippi and Atchafalaya Rivers is the reworking of sediments from the nearshore and coastal bays during storms (Reed 1989; Cahoon et al. 1995a). Some marshes close to the newly emerging Atchafalaya delta do receive sediments from riverine sources. In these areas vertical accretion rates for non-hurricane conditions are high (DeLaune et al. 1992; Childers and Day 1990; Baumann et al. 1984; Cahoon et al. 1995b). In addition, these marsh soils have much higher bulk densities than those of salt marshes in parts of the Mississippi Delta removed from riverine sediment inputs (Hatton et al. 1983, DeLaune et al. 1992).

Organic Matter Accumulation

The elevation of some marshes in coastal Louisiana with low sediment input is maintained by the accumulation of organic matter within the marsh soil. Organic matter accumulation is maximized in fresher marshes which produce more material and where limited tidal exchange reduces the export of plant material.

In areas of low subsidence, such as the Chenier Plain, marsh elevation is maintained through organic matter accumulation. In areas with higher rates of relative sea level rise, marsh survival may be due to the development of "flotant" or floating marshes. Floating marshes are described by Sasser (1994) as "wetlands of emergent vegetation with a mat of live roots and associated dead and decomposing organic material and mineral sediments, that moves vertically as ambient water levels rise and fall." That the mat can move in response to water level variations suggests that these marshes are unlikely to be stressed by gradual increases in relative sea level. O'Neil (1949) suggested that floating marshes form when natural "attached" organic marshes are subjected to subsidence or sea level rise and the buoyant organic mat is subjected to increasing upward tension. It eventually breaks free from its mineral substrate and floats. This adaptation to subsidence and sea level rise relies upon the buoyancy of the organic mat—a characteristic of marshes with minimal mineral sediment deposition. Thus the development of floating marshes is probably constrained to areas of low salinity, low mineral sediment inputs, a firm skeletal framework (natural levees, cheniers, spoil banks, lake rims, etc.) and low water energy conditions. These floating marshes are very susceptible to damage by hurricanes.

In brackish and fresh marshes, hydrologic changes which increase salinity or result in ponding of water on the marsh surface can cause plant deterioration. These changes reduce the production of organic matter and increase the sensitivity of the marshes to submergence. In addition, large, rapid increases in salinity may result in plant death in the less resilient intermediate and fresh marshes.

Survival or Submergence?

The factors controlling sediment delivery to coastal marshes depend on the extent of riverine influence and hydrologic reworking of coastal sediments. In addition, alterations to marsh hydrology can affect whether sediments within channels and bayous actually reach the marsh surface. Canal spoil banks and levee impoundments reduce the amount of sediment deposition on the marsh surface (Reed et al. 1997) and may ultimately reduce the ability of affected marshes to keep pace with subsidence and sea level rise. Organic matter accumulation varies with vegetative type, and the zonation of swamps, fresh, brackish and saline marshes across the coast reflects gradients in salinity. Variations in sediment supply combine with gradients in salinity to produce complex patterns that control whether marshes can survive relative sea level rise—whether they are sustainable in the long-term. At present, different marsh types are maintained by different processes and the resulting diversity of habitat types is an essential characteristic of the productive coastal ecosystem.

Other Major Causes of Losses

Altered Hydrology

Navigation channels and canals dredged for oil and gas extraction have dramatically altered the hydrology of the coastal area. North-south channels and canals brought salt water into fresh marshes where the salinity and sulfides killed the vegetation. Saltwater intrusion, caused by channel deepening, endangers the potable water supply of much of the coastal region (Fig. 4-6). Canals also increased tidal processes that impacted the marsh by increasing erosion. East-west canals impeded sheetflow, ponded water on the marsh, and led to stress and eventual loss. Jetties at the mouth of the Mississippi River directed sediment into deep waters of the gulf.

Storms

Much of the coastal loss has occurred during storm events, which include not only hurricanes, but also storms related to passages of fronts, which are most severe in winter months. Within several days, storms can cause major landform alterations to barrier islands and the gulf shore. Alterations may include removal and redistribution of sediment and creation and alteration of inlets. Hurricane impact is the single most important factor in erosion and alteration of barrier islands. Damage may be equally devastating to muddy shorelines, banks and the marshes. Creation of a number of large lakes as the result of rupture and stripping away of root mats in floating marsh have been documented. Surge scour may also tear away rooted marsh vegetation. Salt water and plant materials pushed and thrown inland by storm surge and tide have also greatly altered marsh vegetation communities. In the Chenier Plain, for example, in 1957 Hurricane Audrey brought saline water into fresh marshes and caused extensive loss.

Interior Marsh Loss

Much land loss and marsh deterioration along the Louisiana coast has occurred where fresh marshes and swamps have been subjected to marine tidal processes, usually the result of subsidence and exacerbated by canal dredging. In such areas the marshes are affected by several factors. First is the invasion of higher salinity water and related sulfide formation, which kills the fresh and intermediate vegetation that makes up the floating mats. In some instances, the fresh and intermediate grasses are replaced by more salt-tolerant, brackish vegetation, but such vegetation can only successfully colonize areas of firm substrate. Consequently, floating marshes and marshes with poorly consolidated substrate do not make the transition to brackish and saline marsh, but instead revert to unvegetated mud flats.

Secondly, if breaches occur in the skeletal framework of natural levee ridges and lake rims which hold the fresh and intermediate marshes together, a tidal pumping process quickly removes the fluid and semi-fluid soils and the barren mud flats are converted to ponds, lakes, and bays.

Edge Erosion

In the past 100 years, the total barrier island area in Louisiana has declined 55% (Fig. 4-7), at a rate of 155 acres per year (Williams et al. 1992), largely due to storm overwash and wave erosion. In many ways the shorelines of bays and lakes and the banks of canals and streams are even more vulnerable to erosion than the barrier islands. The Louisiana coast has approximately 350 miles of sandy shoreline along its barrier islands and gulf beaches; however, there are about 30,000 miles of land-water interface along the bays, lakes, canals and streams. Most of these consist of muddy shorelines and banklines, and virtually all are eroding. In many instances, rims of firmer soil around lakes and bays, and natural levees along streams have eroded away leaving highly organic marsh soils directly exposed to open water wave attack.

Herbivory

Nutria, accidently released in the 1930's, became unprofitable to trap in the 1980's. The nutria multiplied rapidly and grazed heavily on marsh plants. This grazing imposed additional stress on marsh plants, frequently resulting in mortality, as well as physically disrupting the substrate, thereby accelerating marsh loss. This destruction of wetland plants has been well documented in the Barataria and Terrebonne Basins.

Dredge and Fill Activities

Prior to the regulation of dredge and fill activities in wetlands, large areas of swamp and marsh were converted into fastlands for agricultural, residential and industrial uses. This practice has been almost completely halted, but dredge and fill for petroleum exploration, pipelines, canal developments, and industrial uses have directly and indirectly contributed to marsh destruction.

Consequences of Land Loss

The consequences of massive landscape change and ecosystem deterioration are real for all coastal communities. Some swamps and marshes are presently surviving relative sea level rise and provide the basis for our productive coastal fishery. Not all parts of the system can survive in this way.

The Human Landscape

Ridges only aggrade or build up when they are being formed along the banks of active distributaries or as active gulf beaches. Surface elevations of all relict natural levee ridges, chenier ridges, artificial ridges, embankments, levees, and fastlands become lower through time in response to subsidence. The protection levees around fastlands prevent aggradation; therefore, all fastland areas within the coastal zone are subsiding (Fig. 4-6). The problem of reduction of land surface elevation is exacerbated in forced drainage districts within fastlands, where drained soils shrink and compact. Surface elevations within some fastland areas in eastern New Orleans are more than 10 feet below mean gulf level. Surface elevations of the higher lands in selected coastal towns and cities are shown in Table 4-1. The projected reductions in surface elevation as a result of the combined effects of subsidence and sea level rise by the year 2050 and 2100 are also shown.

The levees that contain the fastlands are constructed of earth and cannot withstand marine erosive forces. Deterioration of coastal marshes means these levees are increasingly exposed to open water. Furthermore, all infrastructure along the unleveed corridors is subject to sinking and exposure to waves, tides, and storm surges.

Collapse of the Natural System

Outside of the fastlands, the coastal ecosystem is in a state of collapse. The combined effect of regional subsidence, alterations to hydrology at all scales, episodic storms, and local factors such as herbivory and canal bank erosion can lead to conditions across the coastal landscape which cause severe stress to wetland plants, and ultimately their death. Any alterations which allow marsh soils to be excessively waterlogged, either by preventing aggradation of the marsh surface or by physically ponding water within the wetlands, cause soil chemical changes which even the most resilient marsh plants cannot survive. Once plants die, roots no longer provide structure and integrity to marsh soils, and land loss results. The multiplicity of factors that contribute to loss and their complex interactions across the coast produce problems that are truly vast in scale.

The integrity of the coastal landscape is severely threatened. The salinity gradients within the estuarine basins support the diversity of habitats essential to the function of these systems. These gradients are maintained by the skeletal distributary ridges and cheniers and barrier shorelines at the gulf. Because the low-lying barrier islands and cheniers suffer overwash and fragmentation during storms (Fig. 4-7), many of them will probably be gone by 2050. If these vital components of the systems are allowed to disappear, the essential character of the estuarine basins will change drastically.

Within the basins, the loss of extensive marsh areas and the progressive degradation of upper-basin swamps mean that critical subsystem components are becoming massively diminished.

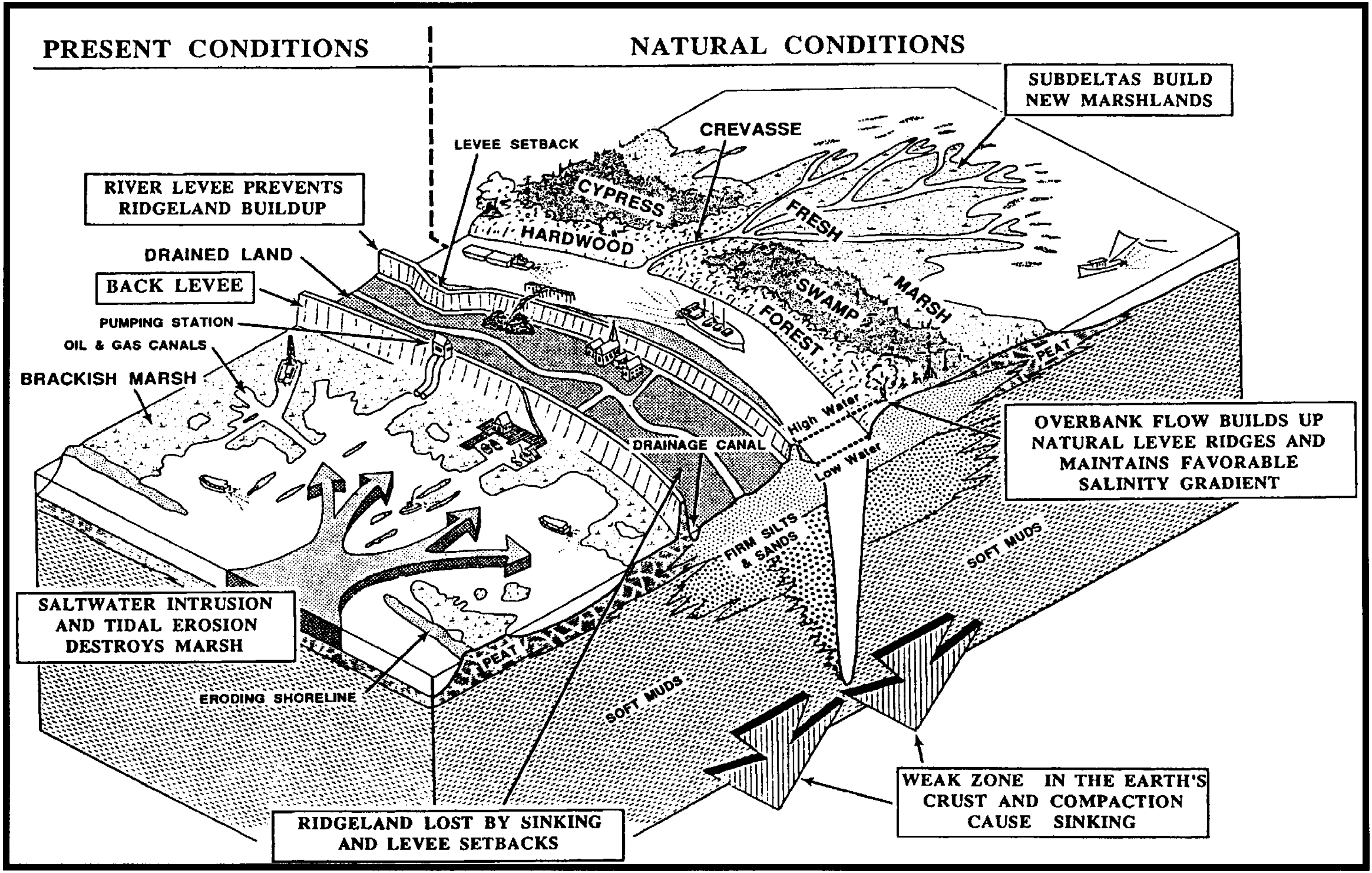


Figure 4-6. Natural and modified conditions along the Mississippi River corridor (after Gagliano 1989).

While open water habitat is a critical component of the natural coastal system in Louisiana, it must be interspersed with ridges, barriers, marshes, and swamps to provide sustainable productivity into the future.

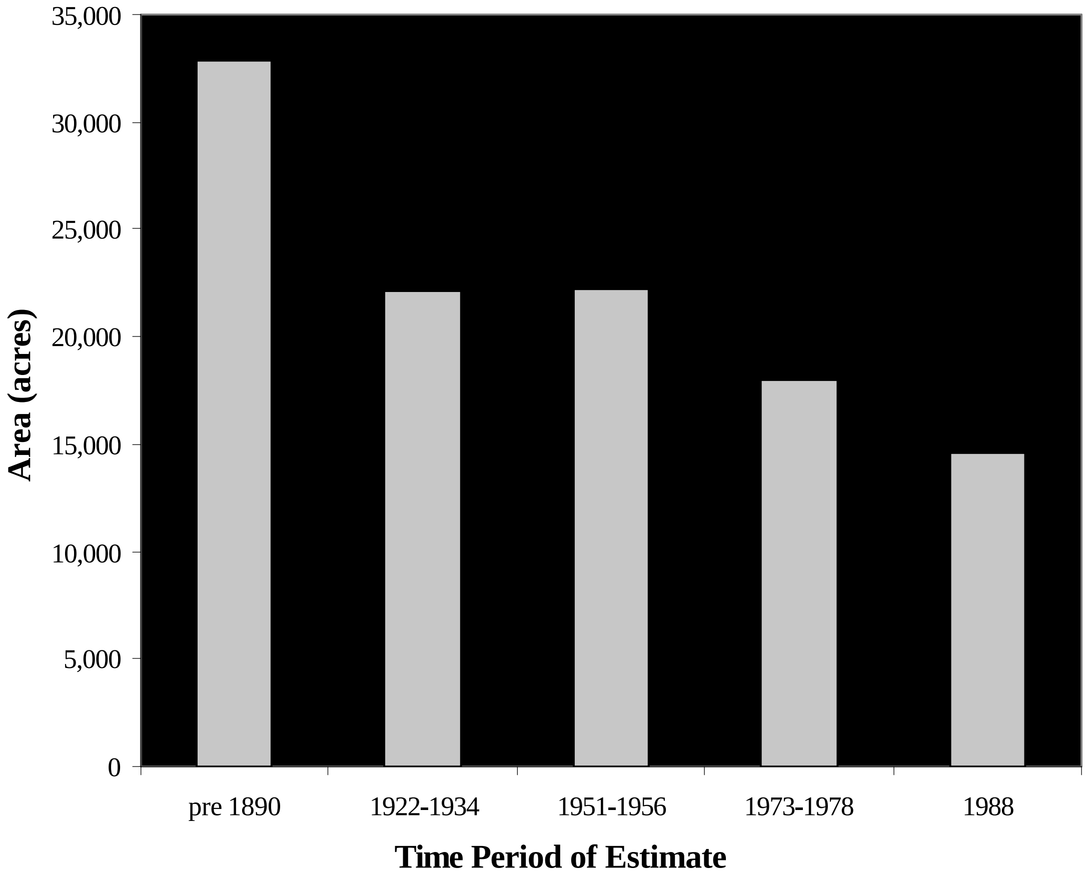


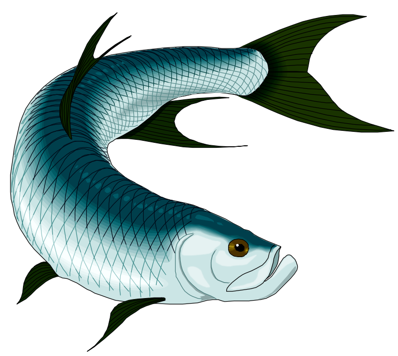
Figure 4-7. Estimates of Louisiana barrier island area (Wiliams et al. 1992).

Table 4-1. Subsidence of coastal cities and communities.

	Range of land elevation (feet)	Subsidence inches/year (50 Yr)	Subsidence plus sea level rise inches/year (50 Yr)	2050 elevation loss (feet)	2100 elevation loss (feet)
New Orleans*	-10.0 to +15.0	0.08	0.30	1.25	2.82
Thibodaux	+2.0 to +12.0	0.08	0.31	1.28	2.92
Hopedale	+1.0 to +2.5	0.09	0.32	1.35	3.02**
Golden Meadow*	-3.0 to +2.0	0.09	0.32	1.35	3.02**
Leeville	+1.0 to +2.0	0.12	0.39	1.61**	3.54**
Pointe a la Hache*	-3.0 to +4.0	0.15	0.44	1.84	4.00**
Grand Isle	+1.0 to +2.0	0.18	0.50	2.07**	4.60**

* Areas with forced drainage districts

** Areas where projected loss of elevation approaches or exceeds elevation of highest land.



CHAPTER 5

COASTAL LOUISIANA IN 2050

Historic Coastal Land Loss

Historic land loss was determined with the U.S. Army Corps of Engineers (USACE) land loss data base (Dunbar et al. 1992). This data base consists of eight maps that cover most of the Louisiana coastal area. Areas that changed from land to water are delineated for four time periods: 1932-56, 1956-74, 1974-83, and 1983-90. The land loss was determined for each of the four regions for each time period. Then, the Regional Planning Teams determined the major causes of loss within each region. Data from Penland et al. (1996) were used, in addition to knowledge gained from area residents familiar with the marsh (*see* Appendix B for methodology).

From 1932 to 1990, Region 1 lost approximately 74,800 acres of marsh out of a total of 322,000 acres (Appendix C). Overall, 23% of the 1932 marsh was lost. The construction of the Mississippi River Gulf Outlet (MRGO) in the early 1960's caused loss of marsh from both its "footprint" (area of direct impact) and the saline water it allowed to enter the basin once the La Loutre Ridge was breached. These events led to high loss in the areas surrounding the MRGO and in areas more removed such as the Pontchartrain/ Maurepas Land Bridge. Marshes in eastern New Orleans lost significant amounts of marsh because of ponding of water by levees. Other major causes of land loss in the region were shoreline erosion, subsidence, and altered hydrology. Much of the recent loss is due to shoreline erosion.

From 1932 to 1990, Region 2 lost nearly 360,000 acres of marsh, 35% of the marsh that existed in 1932 (Appendix D). Half of this loss was in brackish and saline marsh. About one third of the loss was fresh marsh. Altered hydrology and nutria herbivory contributed significantly to losses in upper Barataria. Marshes fringing large lakes and bays disappeared due to wind-induced shoreline erosion. In the southern and eastern portions of Barataria, high subsidence rates contributed to marsh loss. Excessive water on the marsh also caused loss along the lower Bayou Lafourche corridor. Saltwater brought in by navigation channels and oil and gas exploration also contributed to losses. Plaquemines Parish marshes west of the river were lost because of altered hydrology, saltwater intrusion, and faulting. Hurricane damage and the extremely high subsidence rates caused marsh loss in the active Mississippi River Delta. Saltwater intrusion and altered hydrology caused loss of interior marsh in the Breton Sound Basin.

From 1932 to 1990, Region 3 lost approximately 247,650 acres of marsh, or about 24% of the 1932 marsh (Appendix E). The central and eastern portions of the Terrebonne Basin experienced massive losses of fresh to brackish marshes. An intermediate to high natural subsidence rate and altered hydrology caused by canals are probably responsible for the losses. These two factors led to excessive flooding in these wetlands. Shoreline erosion was severe along the fringes of the bays and large lakes. Wetlands in western Terrebonne showed some loss during this period, but the rate was much less than in central and eastern Terrebonne, which is far removed from the influence of the Atchafalaya River. Even though these western Terrebonne wetlands have a low loss rate, many of them are stressed by excessive flooding and ponding of water.

From 1932 to 1990, Region 4 (excluding the four western mapping units south of the Gulf Intracoastal Waterway) lost about 226,000 acres of the original 893,300 acres that existed in 1932 (Appendix F). This equates to a loss of 25% of the 1932 marsh over the 58-year period. The four mapping units in the western portion of the Calcasieu-Sabine Basin are not in the USACE New Orleans District historical land loss data base. According to Barras et al. (1994), these four units lost 15,950 acres from 1978-90 or 18% of the 1978 marsh. The significant hydrologic alterations caused by major ship channels and the Gulf Intracoastal Waterway allow saltwater intrusion. Locks are often operated in a manner that is less than optimal for the marsh vegetation. These two factors are most commonly cited causes of historic wetland loss. Shoreline erosion along major lakes, bays and the Gulf of Mexico, especially in the vicinity of Rockefeller Refuge, is also a significant cause of ongoing loss.

Projected Land Loss Rates and Locations

The 1974-90 marsh loss rate for each mapping unit was projected into the future to estimate the acres of marsh lost by 2050. These numbers must be recognized as a "best estimate." Coastal Louisiana is estimated to lose nearly 514,460 acres of marsh by 2050—21% of today's marsh. If the benefits of freshwater diversions (49,000 additional acres by 2050) and the Breaux Act coastal restoration projects (nearly 66,000 additional acres by 2050) are included in the calculations, nearly 115,000 acres of that loss will be prevented. Thus, with current restoration efforts we should prevent about 22% of the predicted loss. Nevertheless, with the current level of restoration we will still lose nearly 400,000 acres of marsh. Table 5-1 shows the acres of marsh lost with and without restoration for various areas of the coast.

The location of the projected loss was identified by selectively modifying the 1993 LANDSAT image. The result is a map of coastal Louisiana that indicates where marsh might be lost by 2050 (Figs. 1-1 and 1-2).

Projected Habitat Conversions

To project the distribution of habitat types for 2050, the land loss projection maps described above were superimposed on the 1990 habitat maps. This methodology assumes that the location of future habitat zones will not shift. These zones have shifted both north and south in the past, so, that they will remain as they are is a simplistic assumption.

Table 5-2 shows the acreage of the existing habitat types in each region and the projected acreage by habitat type in 2050. The habitat type with the greatest projected marsh loss varies from region to region. In Region 1, 42% of the 1990 intermediate marsh is lost by 2050. In Regions 2 and 3, saline marsh shows the greatest loss with 32% of the saline marsh in these regions being converted to open water by 2050. The growing deltas in Atchafalaya Bay will allow fresh marsh in Region 3 to decrease by only 2%. In Region 4, brackish marshes show the greatest losses; 19% of the 1990 brackish marshes are projected to become open water.

Table 5-1. Wetland loss projections.

Region	Basin	Acres of marsh in 1990	Acres of marsh lost by 2050 without restoration	Acres of marsh preserved by the Breaux Act and diversions	Net acres of marsh lost by 2050 at current restoration levels	Acres of swamp in 1990	Acres of swamp lost by 2050 at current restoration levels
1	Pontchartrain	253,000	50,330	4,720	45,610	213,570	105,100
2	Breton Sound	171,100	44,480	17,900	26,580	0	0
2	Mississippi Delta	64,100	24,730	18,340	6,390	0	0
2	Barataria	423,500	134,990	42,420	92,570	146,360	80,090
3	Terrebonne	488,800	145,250	5,170	140,080	152,400	46,700
3	Atchafalaya	48,800	(30,030)*	8,080	(38,110)*	12,600	0
3	Teche/ Vermilion	234,300	32,160	3,360	28,800	18,390	0
4	Mermentau	441,000	61,710	2,600	59,110	370	0
4	Calcasieu/ Sabine	317,100	50,840	12,440	38,400	170	0
	Total	2,441,700	514,460	115,030	399,430	543,860	231,890

*Due to delta building, acres will be gained in the Atchafalaya Basin.

Table 5-2. Existing and projected habitat types in each Coast 2050 region.

	Fresh marsh acres	Intermediate marsh acres	Brackish marsh acres	Saline marsh acres	Total marsh acres
Region 1:					
Acreage in 1990	34,700	27,700	110,900	79,700	253,000
Projected acreage in 2050	30,100	16,000	99,900	61,400	207,400
Net acres lost by 2050*	4,600	11,700	11,000	18,300	45,600
Percent 1990 marsh lost	13%	42%	10%	23%	18%
Region 2:					
Acreage in 1990	220,100	73,000	214,500	151,100	658,700
Projected acreage in 2050	194,250	61,900	174,900	102,100	533,150
Net acres lost by 2050*	25,850	11,100	39,600	49,000	125,550
Percent 1990 marsh lost	12%	15%	18%	32%	19%
Region 3:					
Acreage in 1990	298,300	92,700	240,700	140,200	771,900
Projected acreage in 2050	292,330	69,100	184,800	94,900	641,130
Net acres lost by 2050*	5,970	23,600	55,900	45,300	130,770
Percent 1990 marsh lost	2%	25%	23%	32%	17%
Region 4:					
Acreage in 1990	354,600	171,700	198,600	33,200	758,100
Projected acreage in 2050	317,070	151,070	160,200	32,250	660,590
Net acres lost by 2050*	37,530	20,630	38,400	950	97,510
Percent 1990 marsh lost	11%	12%	19%	3%	13%

*includes acres preserved by Breaux Act Priority Lists 1-6 and Caernarvon and Davis Pond Diversions

CHAPTER 6

CONSEQUENCES OF LANDSCAPE DETERIORATION

Economic Setting

The economic well-being of Louisiana's coastal communities and the competitiveness of the coastal industries are important not only to the State but also to national growth and prosperity. To be competitive in the 21st century, the United States will continue to depend on Louisiana's rich coastal resources, and the nation will be called on to make substantial investments to insure that these resources are protected and remain productive over the long term.

Overview

Offshore oil and natural gas production, along with all its related service industries, continues to command the State's coastal economy. The fisheries industry, particularly shrimp, oysters, and menhaden, remains very important. Petrochemical processing and manufacturing, which dominate the industrial corridors on either side of the Mississippi River from below New Orleans to Baton Rouge, and the Calcasieu River in the vicinity of Lake Charles, are also of great importance. Industries related to navigation, such as ship- and boat-building and repair, are major activities along the principal navigable waterways, and millions of tons of cargo are shipped annually to and from foreign or inland U.S. locations. Rice, sugar cane, soybeans, and cattle are the most important agricultural commodities produced in the region. In fact, until the oil boom changed the region and State's economy, this area was largely an agrarian society where residents farmed, fished, and trapped extensively. Aquaculture, especially the pond aquaculture of crawfish, has become a significant regional economic activity since the 1970's. Extensive tourism and recreational activities revolve around the area's wildlife, fisheries, and wetland-based culture.

Most recently, the region's economy has rebounded from a 1980's downturn in the oil and gas industry that had resulted in a reduced population, as thousands of people migrated elsewhere to seek work. The main impetus for this recent resurgence has been the discovery of oil and gas in the deepwater fields of the central Gulf of Mexico. This discovery, along with deepwater royalty tax relief and new and improved technology, has brought about an increase in offshore and shore-based activities. The sheer volume of activity that has taken place in the last three or four years—and the forecast is for this situation to continue—has raised serious concerns about the coastal infrastructure's ability to handle current and additional growth.

The infrastructure needs, along with fisheries issues and coastal restoration, are the topics of greatest concern to coastal leaders, according to a 1998 study by the Economic Development Administration. These leaders have pointed out that recent economic growth has added pressure to a deteriorating infrastructure network. Coastal parishes and cities are having to rapidly respond to many deferred maintenance problems, while at the same time having to find the means for undertaking the additional public works projects urgently needed to cope with new developments.

Coastal leaders also contend that due to the many challenges facing commercial fisheries and the associated seafood production sector, there is a need to insure the industry's sustainability. Traditionally, thousands of Louisianians have depended on shrimp, menhaden, oysters, crabs, and commercial finfish harvesting and processing. But many challenges confront this industry and all the interests involved from Federal and State governments to harvesters, wholesalers, and even consumers will have to become proactive to insure the sector's continued importance in the coastal economy.

Coastal leaders have expressed great concern about the continued deterioration of coastal wetlands. Their consensus is that the problem has not only significant ecological implications, but also major economic ones. Many coastal communities and economic sectors are at risk, and undue delays in responding to the problem could result in grave economic and social consequences. For example, habitat loss and major changes in the balance of freshwater and saltwater in these ecosystems can lead to the loss of fisheries sensitive to this balance, significantly disrupting Louisiana's vitally important seafood production sector. Another example is agriculture. Citrus growers in Plaquemines Parish are experiencing crop losses caused by saltwater intrusion, and rice growers in central Acadiana are concerned about the continued supply of fresh water for their crops.

Coastal Communities and Demographics

Coastal Louisiana's residents represent a diversity of nationalities and cultures, including French, Spanish, Portuguese, German, Italian, English, Caribbean, Croatian, African, and American Indian. The largest and oldest immigrant group to colonize the wetlands is of French descent. New Orleans was founded by Bienville in 1718. Exiled Acadians from what is now Nova Scotia, Canada, began moving into the region beginning in the 1750's. According to Donald W. Davis (1994), all immigrants to Louisiana's wetland landscapes developed cultural practices tied to the annual-use cycle that is still linked to the region's natural resource base. Traditionally, thousands of coastal residents have been engaged in farming, hunting, trapping, shrimping, crabbing, oystering, and fishing.

Louisiana's coast is a flat coastal lowland characterized mainly by marshes, swamps, lakes, levees, cheniers, bays and bayous. The area also includes several metropolitan and mid-sized communities that serve as population, trade, and service centers. The 1997 population in the 20 coastal parishes was approximately 2 million residents, according to U.S. Census estimates, an increase of 84,000 persons since 1990. Louisiana had over 4.2 million residents in 1990 and gained about 131,600 persons between those same years. In other words, 64% of the State's population gain during the 7-year period took place within these parishes. In 1997, about 60% of this population resided in the four most populated parishes: Orleans, Jefferson, and St. Tammany in the eastern most part of the study area, and Calcasieu in the far western portion.

Physical Infrastructure

Description of Infrastructure

Physical infrastructure refers to capital facilities and land assets—private, State, Federal, parish or municipal—that are necessary to (1) support development and (2) protect public health, safety, and well-being. It includes, but is not limited to, water supply and wastewater disposal, transportation (ports, roads, bridges, airports, rail, navigation, highways), solid waste disposal, drainage, flood protection, industrial parks, electricity, oil and gas structures, and educational facilities and parks.

Louisiana ranks first in the nation in total shipping tonnage, handling over 450 million tons of cargo each year through the public and private installations located within the State's jurisdiction of six deep-draft ports: New Orleans, Greater Baton Rouge, Lake Charles, South Louisiana, Plaquemines Parish, and St. Bernard. These ports are the mainstays of Louisiana's maritime shipping industry, and have given the region both national and international prominence. In addition, the privately-owned Louisiana Offshore Oil Port offloads approximately 10-13% of the country's imported crude petroleum that eventually is moved via pipelines to refineries and consumers throughout the nation. Significant contributions to the State's economy are also made by the fifteen smaller ports that are situated within the coastal zone, primarily serving the oil and gas and fishing industries. The Gulf Intracoastal Waterway is a critical shallow-draft transportation link that carries an annual average of 70 million tons of freight (primarily liquid bulk items such as petroleum and petroleum products) between the Mississippi and Texas state lines. An alternate Gulf Intracoastal Waterway route, linking Morgan City and Port Allen, averages 25 million tons of cargo shipped per year.

In addition to the 3,000 miles of commercially navigable waterways, coastal Louisiana has railroad transportation, Interstate, U.S. and state highways, commercial and general aviation airports, and an extensive network of oil and gas pipelines. Southern Pacific, Kansas City Southern, Amtrak, Illinois Central, and Union Pacific are the main railroads serving the area, although several other smaller railway companies have emerged in recent years and serve some of the more remote parts of the region. Interstate

Highways 10 and 12, U.S. Highways 90 and 190, and La. Highway 82 are the main east-west routes. North-south service consists of Interstates 49, 55, and 59 along with U.S. Highways 51, 61, and 165, and La. Highway 1. Several state highways such as Highways 1, 23, 27, 39, and 82 serve as evacuation routes from the coastal zone. Some 14,000 miles of onshore and 2,000 miles of offshore pipelines are located in the region.

Concerns About Infrastructure

The most frequently identified public infrastructure concerns of coastal Louisiana involve roadways, navigation and ports, sanitation and water supplies, drainage and flood control, and coastal erosion prevention structures.

Roads, highways, and bridges, many of which are vital evacuation routes, are deteriorating and becoming more congested. Many coastal highways and roads are in poor or mediocre condition. Highway 82, for example, in Cameron Parish is being eroded by gulf waves. Between $20 million and $80 million are needed to prevent its structural failure in the next 5 years. Many bridges, particularly those referred to as off-system, are structurally deficient or functionally obsolete. In addition, state-run ferries that have served many communities in lieu of bridges are being turned over to local governments, who lack the resources to properly operate and maintain the systems.

Navigation and port interests are concerned about the continued development of port facilities and the replacement of several strategic navigation structures which have become obsolete. The navigation locks in the Gulf Intracoastal Waterway system, including the Inner Harbor Navigation Canal in the New Orleans area, are outdated and need to be replaced. Ports face severe access problems on both the water and land sides, and facilities are inadequate to meet the growing demands of international commerce and offshore services. Additional coastal deterioration will only exacerbate the problem.

The environmental infrastructure is also facing severe deterioration because of substantial under-funding, particularly for solid waste management, water supplies, and wastewater systems. Not only is compliance with State and Federal mandates a concern, but if water quality is not maintained, and in some localized instances restored, this situation will result in negative effects on certain sectors of the economy. Oyster production and harvesting, tourism, and outdoor recreation are only a few of the sectors that rely on the availability of clean, safe water supplies.

Local drainage and flood control infrastructure are a growing concern for local and parish governments. As protective marshes continue to disappear, long term maintenance costs will be prohibitive.

In an earlier study for La. Department of Natural Resources' Coastal Restoration Division, the Louisiana Sea Grant College Program at Louisiana State

University inventoried the major components of the State's coastal infrastructure and estimated its value to exceed $48 billion (Louisiana Sea Grant College Program 1998). This figure is considered conservative because (1) all public infrastructure components were not included in the inventory—for example, levees, public utilities, etc. were excluded, and (2) the per unit cost estimates that were used to arrive at the total amount were primarily "rules-of thumb" figures obtained from experts in the field, and extrapolated to apply throughout the Coast 2050 study region.

Storm Surge Protection

When a hurricane makes landfall in Louisiana, a large percentage of the infrastructure damage is caused by flooding associated with the storm surge and heavy rains. Wind related damage is also significant, and depending on the strength of the storm and the location of landfall, wind damage costs may be greater than the cost of flood damage. Hurricane damages to coastal communities can result in increased costs of living and doing business in flood prone areas with a concomitant regional economic decline. Historically, this has been followed by gradual emigration from coastal communities (Smith et al. 1998).

It is commonly acknowledged that barrier islands and coastal wetlands reduce the magnitude of hurricane storm surges and related flooding; however, there are scant data as to the degree of reduction. The best data available relating to this issue come from continuous water level recorders that were in place prior to Hurricane Andrew making landfall in St. Mary Parish at Point Chevreuil on August 26, 1992. Hurricane Andrew was a Category 3 storm on the Saffir-Simpson scale. Andrew's winds produced a positive storm tide in areas east of landfall and a negative storm tide west of landfall. The highest recorded water elevation during Andrew was 9.3 ft at Cocodrie (Lovelace 1994).

Hurricane Andrew gave direct evidence that the physiography of marshes where a storm makes landfall affects the degree to which the storm surge is dampened. The surge amplitude in the Terrebonne marsh system decreased from 9.3 ft above sea level in Cocodrie to 3.3 ft (Swenson 1994) in the Houma Navigation Canal approximately 23 miles due north. This equates to a reduction in surge amplitude of approximately 3.1 inches per linear mile of marsh and open water between Houma and Cocodrie. Similarly, the magnitude of the storm's surge was reduced from 4.9 ft at Oyster Bayou to 0.5 ft at Kent Bayou located 19 miles due north. This equates to a reduction in surge amplitude of approximately 2.8 inches per linear mile of fairly solid marsh between these sites.

It is important to bear in mind that these are data points from only one storm. The role of coastal marshes in ameliorating hurricane storm surges depends on a variety of factors including the physical characteristics of the storm, coastal geomorphic setting and the track of a storm when it makes landfall.

Quantitative computer simulation modeling of the effect of various barrier island configurations on hurricane storm surges (Suhayda 1997) has shown that changing coastal inlet geometry at the barrier shoreline can reduce storm surges in inland locations such as Cocodrie by over 3 ft. Clearly, the effect of storms on the human population and infrastructure in the coastal zone can be ameliorated by the maintenance of extensive coastal marshes and barrier islands.

Consumptive Uses of Wetlands

Louisiana's coastal wetlands are essential for numerous species of fish and wildlife, food production, habitat for fish and wildlife reproduction and nursery activities, and overall support of the food chain. National Marine Fisheries Service statistics for the last 20 years indicate that coastal Louisiana contributes about 20% of the nation's total commercial fisheries harvest. According to the Louisiana Cooperative Extension Service, in 1995 alone the gross commercial value of coastal fisheries and wildlife production exceeded $300 million. Value-added activities meant another $900 million to the State's economy. In 1996, the total economic effect of marine commercial fisheries was $2.2 billion, and $944 million for marine recreational fisheries (Southwick Associates 1997). Commercial fisheries resources also support a wide range of related seafood processors and similar operations, and help maintain between 50,000 and 70,000 jobs statewide in the processing, wholesaling, transporting, retailing, and services sectors.

Wild fur pelts continue to be harvested, and trappers annually receive approximately $1.3 million for the product, according to a report to the Fur and Alligator Advisory Council (Louisiana Department of Wildlife and Fisheries 1997). The same source reports that annually the harvest of wild alligators results in skins and meat worth over $9.3 million, and alligator farming yields approximately $11.5 million per year.

Coastal Louisiana also provides an excellent setting for outdoor activity. Use of outdoor recreation resources has grown considerably in recent years, and there are several major initiatives to attract more visitors to the region. The preliminary "1996 National Survey of Fishing, Hunting and Wildlife Associated Recreation" (U.S. Department of the Interior, Fish and Wildlife Service 1997) estimated that 1.2 million Louisianians enjoy the outdoors, and that between 1989 and 1995, the annualized growth rate in saltwater recreational fishing licenses was 6% (Louisiana Department of Wildlife and Fisheries 1996). Combination freshwater and saltwater recreational fishing licenses for residents and nonresidents for fiscal year 1997 totaled about 540,000. Charter fishing trips have also been increasing and the latest figures indicate that approximately 60,000 nearshore and inland saltwater charter fishing trips were taken in 1995.

The latest available figures from the Louisiana Department of Wildlife and Fisheries indicate that Louisiana had 275,000 registered boats in 1994. Over

49,000 (18%) were registered in the six Coast 2050 parishes that are contiguous to Lake Pontchartrain: Orleans, Jefferson, St. Tammany, St. John the Baptist, St. Charles, and Tangipahoa.

Louisiana’s coast is at the end of the Mississippi and Central flyways, and nearly 70% of the waterfowl migrating along these routes overwinter at sites in coastal Louisiana. If extensive healthy marsh habitats are not available, waterfowl would return to their nesting areas in a weakened condition, resulting in lower nesting success and decreased fall flights. Over 90,000 Louisiana residents and 14,000 non-residents purchased migratory bird hunting licenses in 1996. The U.S. Fish and Wildlife Service estimates over 860,000 migratory bird hunting days for 1996.

Nonconsumptive Uses of Wetlands

The coastal parishes, more than ever before, are deriving greater economic benefits from tourism development. Attractions, employment and income attributed to this sector have grown, tax revenues have increased, and virtually every coastal parish is fully organized for and has embarked on this type of development. Increased tourism is apparent from the U.S. Travel Data Center statistics that are compiled annually, by parish, for travel and tourism-related employment, expenditures, and payroll. Between 1990 and 1995, the number of persons employed by this industry grew by over 8%; expenditures, when adjusted for inflation, climbed by over 21%; and the adjusted payroll figures increased by 26%. This included over 800,000 visitors that engaged in “wildlife watching” or other nonconsumptive uses such as observing, photographing, and visiting public parks and other natural areas.

According to the 1993-98 Statewide Comprehensive Outdoor Recreation Plan (Louisiana Department of Culture, Recreation and Tourism 1993), 7 of the State’s 28 state parks and 2 of 12 commemorative areas are located in the region. Some 800,000 visitors made use of these facilities in 1994. Also, the Department of Wildlife and Fisheries and the U.S. Fish and Wildlife Service provide for recreational uses at wildlife management areas and refuges.

Major Case Studies and Smaller Vignettes

Louisiana contains numerous coastal communities at the end of natural levee ridges which are surrounded by marshes and estuaries. Examples include: Yscloskey, Venice, Port Fourchon, Isle de St. John Charles, Cocodrie, Theriot, and Intracoastal City. People have lived in these small communities for a number of generations and have traditionally relied on the region’s plentiful natural resource base. Five communities (Fig. 6-1) were chosen to illustrate how future marsh loss is expected to affect some of the communities, particularly the public infrastructure. The discussion of the South Lafourche Corridor is detailed because Port Fourchon is Louisiana’s

Figure 6-1. Communities discussed in case studies and vignettes (Larger stars indicate communities highlighted in case studies and vignettes, smaller stars are other communities mentioned).

primary port directly located on the Gulf of Mexico. New Orleans is discussed because it represents an area with high population levels. Three other communities (Yscloskey, Cocodrie, and Holly Beach/Constance Beach) are discussed as smaller case studies or vignettes. They were chosen because they typify the problems facing many of Louisiana's smaller coastal communities. More details on the public infrastructure values for each of these communities can be found in Appendices C-F. Coastal Louisiana communities share a basic connection to their surrounding environments—their cultures and economies are part land based and part water based, and most have become similarly threatened by the conversion of land to water. The human settlement of the region is a history of opportunities and constraints. It is very likely that the future loss of marsh will tip the balance toward the constraints in all of these communities.

Community at risk: South Lafourche Corridor

The South Lafourche development corridor is located in the central Louisiana coast region, in Lafourche and Jefferson Parishes (Fig. 6-1). It provides access through the coastal lowlands to the productive estuarine zones and the Gulf of Mexico. The corridor is in a strategic position, running along the Bayou Lafourche natural levee ridge through the Barataria and Terrebonne estuaries. Over the years, it has been one of the country's most productive oil and gas regions. The corridor's strategic position is enhanced by its role as a staging area for offshore services, waterborne commerce activities, and as a center for sport and commercial fishing.

Population

The population of Lafourche Parish, as estimated in 1995, was 87,625 persons. This translates to a parish-wide population density of approximately 81 persons per square mile. There are higher population concentrations in the Lafourche corridor, where there are approximately 364 residents per square mile (U.S. Census 1990, 1998). In effect, 85% of the parish's population lives on 18% of the land, an indication of the clustered linear settlement pattern of natural levee ridges.

Economy

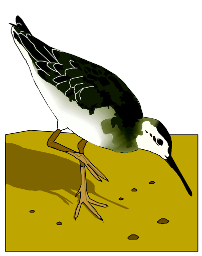
Renewable and nonrenewable resource extraction and use characterize the regional economy. The renewable resources are largely the products of the surrounding estuaries and wetlands: commercial fishing, hunting and trapping. Most nonrenewable extraction (oil and gas) takes place offshore and in the estuaries and is highly dependent on the area's infrastructure.

The total value of the Lafourche estuarine dependent industries in 1994 was almost half a billion dollars. The 1994 value of the renewable resources produced in Lafourche Parish was $70 million. Oil and gas extraction had a value of $388 million. This represents 81% of the parish's resource use economy (McKenzie et al. 1995; Industrial Economics 1996).

Population Settlement Balance

The opportunity/constraint balance in South Lafourche has fluctuated throughout its settlement history. In the 19th century, the opportunities were primarily fishing and agriculture. The main constraint was the proximity to the dangerous forces of the gulf. In the late 1800's, a significant south Lafourche fishing community called Caminadaville existed near the gulf on Cheniere Caminada, west of Grand Isle. The chenier had 1,470 inhabitants in 1893 when a hurricane destroyed the community. The settlement was abandoned and most of the surviving inhabitants moved farther inland to the area that would eventually become the towns of Leeville and Missville (Rogers 1985; McKenzie et al. 1995).

Facing another hurricane in 1909, Leeville and Missville residents took to their oyster luggers and sought more protected land. Though the towns were destroyed, the majority of residents rebuilt. Unfortunately, a stronger storm hit the region in 1915, inundating Leeville and Missville with 20 feet of water. Faced again with the destruction of the communities and substantial loss of life, the communities were abandoned and many of the survivors relocated still farther north along the bayou to the relative protection of Golden Meadow. The Golden Meadow ridge was the final stop on their retreat from the gulf (Rogers 1985).



New Opportunities

In the 1930's, oil was discovered along the Lafourche corridor. The once-abandoned Leeville community was resettled in 1931 and had 98 producing wells by 1937 (Woolfolk 1980). The economic opportunities of oil drew people back down the corridor to the places from where fisherfolk had only recently retreated. The tremendous economic opportunity of oil extraction made addressing the environmental constraints of the South Lafourche corridor feasible.

Changing Opportunities

Oil and gas activity within the corridor, the surrounding estuaries, and the State's offshore waters has been in a period of substantial decline. Meanwhile, the Federal offshore industry is presently projecting a 40-year production cycle, with 50% to 100% growth by the year 2000 (Cranswick and Regg 1997; Guo et al. 1998). With the industry moving offshore, the locations of service and support industries in Louisiana are becoming increasingly important. The land and the gulf are linked by two important complexes in the corridor—Port Fourchon and the Louisiana Offshore Oil Port.

Port Fourchon is one of Louisiana's port complexes closest to the Gulf of Mexico. Over $750 million of public and private investments have been made in this complex that primarily supports offshore oil and gas activities in the Gulf of Mexico. Over 100 businesses provide support for such services. Port development has barely kept up with the demand for waterfront property. There is a waiting list of tenants, and the third and final phase of the "E-slip" development that has served as the centerpiece for the port's growth is being fast-tracked and is scheduled to be completed in the next couple of years.

Louisiana Highway 1 is Port Fourchon's only land-based access. It is estimated that on a monthly basis, 30,000 trucks and over 200,000 passenger vehicles travel on this highway below Galliano. Traffic flow figures are predicted to continue to increase at a rate of somewhere between 3% and 6% annually in the next decade with the expansion of deepwater oil and gas activities. A major impediment, however, is the Leeville Bridge, which already is in a deteriorated condition. In fact, a recent report concludes that 21% of Highway 1 is in poor condition, and 98% is in need of some kind of improvement (Guo et al. 1998).

Located 21 miles south of Port Fourchon, the Louisiana Offshore Oil Port is the nation's only deepwater port, handling between 10% and 13% of the nation's imported oil supply. The offshore facility is connected by a 42-inch pipeline to the Clovelly Dome Storage Terminal, an underground salt cavern in the south Lafourche corridor. The storage terminal is connected by five pipelines to 30% of the national refining capacity. Recently connected to the Shell MARS production platform, the Louisiana Offshore Oil Port will handle domestic production as well as foreign imports.

According to preliminary findings of an Outer Continental Shelf (OCS) impacts study (Hughes 1998), OCS development may cause substantial growth in the south Lafourche corridor. Nearly 60% of the gulf's future offshore drilling in the next 30 years can be served from Port Fourchon. An 8-year conservative growth projection of almost 5,000 new jobs, with over $500 million in wages, is expected as a result of OCS expansion. While the recent growth of the industry has absorbed the existing regional labor pool, future growth may be hampered because the presently taxed infrastructure may limit growth (Hughes 1998). OCS operations use Port Fourchon mainly because it is the closest port to their activities (Falgout 1998). As OCS extraction pushes farther into the gulf, even Louisiana's central location becomes less strategic.

If the South Lafourche corridor continues to deteriorate, business investments will also deteriorate (White 1998). It has been estimated that if the deepwater oil support industry is not fully established at Port Fourchon by 2000, then oil companies will expand elsewhere, (Galveston or Mobile) and by 2004 will steadily pull out of the port altogether (White 1998). The economic losses to the region would be high, potentially worse than the oil downturn of the 1980's. Louisiana's network of 3,819 vendors that receive

$2.4 billion worth of annual business could lose their link to OCS activities with an accompanying devastating effect on their businesses. Undoubtably, some portion of the $3 billion annual revenue that Gulf of Mexico offshore oil and gas operations generate in Louisiana (Applied Technology Research Corp. 1998) would be lost.

Land Loss—The New Constraint

The threat of coastal land loss may impede the continued growth and/or sustainability of the south Lafourche corridor. The social and economic threats to the Lafourche corridor by 2050 from unabated land loss can be evaluated from two distinct perspectives.

1. Theoretical Approach—Impact of Land Loss on Infrastructure. Without positive human intervention, land loss caused by erosion, subsidence, and other factors will continue for the next 50 years, much as it has for the last century. It is projected that by 2050, more than 49 square miles of marsh will be lost just to the east of the corridor; over 50% of the adjacent marsh will be open water. Another 33 square miles of marsh just to the west will disappear, and nearly 70% of these existing marshes will be gone. Highway 1 will be breached in numerous places, rendering it impassable. The theoretical replacement cost, if the same type of road could be laid in the same place, would be approximately $20 million. Approximately 8.5 miles of secondary roads would be impacted as well, at a loss of over $24 million. The 119 currently active oil and gas wells, now surrounded by land, could find themselves in the water, a possible loss of $12.3 million of infrastructure. Approximately 8.3 miles of the ring levee in the vicinity of Golden Meadow would be sporadically exposed to open water and possibly breached, at a replacement cost of $4.2 million. The value of the lost wetlands, based on an estimated use value of $5,000 per acre (Industrial Economics 1996), would amount to $260 million in losses to recreation and ecosystem services to the region.

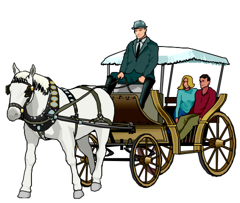
*2. Catastrophic Event Approach—Impact of Storms on People and Infrastructure***.** It is highly likely that a storm will strike the region and cause extensive damage to the weakened system. This could happen in the very near term, though each year that land loss continues unabated and infrastructure remains unprotected, the potential for storm damage increases. The Louisiana Department of Public Safety Services (1985) identified 12 comprehensive storm scenarios and mapped 62 distinct storm surge patterns. The region is exceptionally vulnerable to storm surge impacts. In the event of a category 3, 4, or 5 storm, approximately 35,000 people will need to evacuate from the area south of the Leeville bridge on the only evacuation route, Louisiana Highway 1 (Curole 1998). In addition to the possible loss of life and property, accelerated erosion, and cleanup costs typical of hurricane force storms, a breach in the highway or damage to the Leeville bridge would paralyze the largest portion of the corridor's economy until repairs could be made.

South Lafourche Corridor Conclusion

Human settlement has been drawn to the South Lafourche corridor for the past 1,000 to 2,000 years because of the estuary, the marshes, the Gulf of Mexico and the natural levee ridges. Land loss is not just a constraint to realizing the region's resource opportunities; it threatens the very existence of the opportunities. The marshes and transportation access to the gulf are threatened, and the dangers of the gulf have only become more dangerous to the corridor. The potential impact of land loss in the corridor is the eventual abandonment of the corridor as a viable community. Like Caminadaville in 1893, Leeville (and Missville) in 1909 and 1915, and other similar settlements along the gulf that have faced overbearing constraints, the choice is either to abandon the corridor or recognize the dangers and defend against them. Reversing the land loss is the first step in that defense.

Community at risk: New Orleans

All communities in Louisiana south of I-10 are threatened by coastal erosion, but New Orleans' potential losses are especially high. New Orleans lies at the center of a nearly 2,600 square mile metropolitan area containing 1.2 million people and five parishes (Fig. 6-1). Taxable real estate and property in the region are assessed at more than $5 billion, and fair market value of these assets exceeds $40 billion.



The Threat

The Mississippi River flows through the center of the metropolitan area. The northern boundary is Lake Pontchartrain and coastal wetlands surround the other margins. No other major city in the country is surrounded by so many flood-prone habitats. New Orleans is virtually an island already; as wetland loss continues, the amount of water around the city will increase. In addition, at least 45% of the metropolitan core is at or below sea level. In New Orleans, elevations vary from 10 feet below sea level in developed areas to 15 feet above sea level along the natural ridges of the Mississippi.

Today, New Orleans is protected from flooding rainwater, river water and seawater by 520 miles of levees and floodwalls, 270 floodgates, and 92 pumping stations connecting thousands of miles of drainage canals and pipes. The wetland buffer that now partially protects New Orleans from storm surges is disappearing. By 2050, the city will be closer to and more exposed to the Gulf of Mexico.

Hurricanes pose the worst threats.

C In 1965 the eye of Hurricane Betsy (a Category 3 storm) passed about 50 miles west of New Orleans and the tidal surge into St. Bernard and Orleans Parishes caused $2 billion in damages and 81 deaths.

C In 1985 Hurricane Juan (a Category 1 storm) caused higher tides than Betsy in some areas because of its slow movement. The West Bank of Jefferson Parish sustained $52 million in damage.

The current hurricane protection system, to be completed in 2002, protects the city from a storm surge associated with a fast moving Category 3 hurricane. But what if the storm is more intense (Hurricane Camille in 1969 was a Category 5) or the storm moves slowly, allowing more time for the storm surge to build? Storm surge models show that a hurricane could produce an 18-foot storm surge in Lake Pontchartrain, which could be topped with 10 foot waves. None of the current or planned protection measures would be effective under those circumstances.

The Possible Consequences

Unfortunately, storm surge heights will only increase as subsidence and sea-level rise continue and more wetlands are lost. A portion of the West Bank of Orleans and Jefferson Parishes, bounded by the Mississippi River and Harvey Canal, is a 22,500 acre urban area with substandard hurricane protection and 34,362 structures valued at more than $3 billion. The projected future for this area combines the effect of a 100-year return period hurricane on a landscape experiencing continued wetland loss. Some structures in this area, which in 1991 would flood with a 100-year event, by 2050 would flood with only a 50-year event. The cost of a 100-year hurricane for these structures, their contents, and vehicles in the area could increase by 280% in this area of the West Bank by 2050. The cost of flood damage from such a storm in 1991 would theoretically have been $629 million, by 2050 this could increase to $1.8 billion.

Community at risk: Yscloskey (St. Bernard Parish)

The small fishing village of Yscloskey lies in St. Bernard Parish about 25 miles east of New Orleans (Fig. 6-1). The village is at the intersection of Bayous La Loutre and Yscloskey and is entirely surrounded by marshes and estuaries. The area analyzed for this vignette includes all structures along Louisiana Highway 46 from its junction with Louisiana Highway 300 to the end of Highway 46 at the Mississippi River Gulf Outlet. These highways link the fishing communities of St. Bernard Parish with the New Orleans Metropolitan Area.

Approximately 325 permanent residents live in Yscloskey (Metrovision 1998). In addition, there are approximately 50 commercial establishments in the general vicinity. Fishing is the most important aspect of the local economy. A trip to the area reveals oyster luggers offloading sacks of oysters at the wholesale houses, and shrimp boats docked beneath moss covered oaks along the scenic bayous. Recreational fishing is also important, and several marinas cater to anglers. When the Mississippi River Gulf Outlet was built, the residents of Old Shell Beach had to be relocated and many moved west to Yscloskey.

The entire length of Highway 46 from Verret east lies outside the hurricane protection levees. Hurricane Betsy heavily damaged the corridor in 1965, and in 1969 Hurricane Camille destroyed many homes and boats.

The community's public infrastructure includes a fire station and a community hall. The transportation infrastructure includes 1.75 miles of paved road on Highways 46 and 624, one mile of asphalt road, and a lift bridge across Bayou La Loutre, built in 1957. A power substation, transmission lines, distribution lines, and transformers supply electricity. The water supply system consists of a water tower with corresponding supply lines.

Land loss in the vicinity of Yscloskey is moderate. The marshes to the south are benefitting from the Caernarvon Freshwater Diversion Project, but will still lose nearly 10 square miles by 2050. Thirteen percent of the existing marshes will be open water. To the east and north more than 34 square miles of marsh will be lost by 2050, causing nearly 16% of today's marshes to be converted to open water. This loss of land will mean that the infrastructure at Yscloskey is at even greater risk from storms and high waters.

The replacement cost of the bridge over Bayou La Loutre is estimated at between \$4 million and \$5 million, the paved highway at \$5.25 million, and the asphalt road at \$1 million. The total replacement cost of roads, highways, and bridges in the Yscloskey area is \$10.75 million. Electric lines and transformers would cost approximately \$98,000 to replace. The power substation has a replacement cost of \$1.3 million. The replacement of natural gas lines in Yscloskey would cost between \$116,000 and \$174,000. The water tower is valued at \$261,000, and its supply lines have a replacement cost of \$80,000. If the entire community infrastructure had to be replaced because of a combination of marsh loss and storm damage, it could cost as much as \$13 million. Marsh loss will also affect people's livelihoods. As significant areas of marsh are lost, there will be fewer oysters, shrimp, spotted seatrout, and red drum.

Community at risk: Cocodrie (Terrebonne Parish)

Cocodrie is a village located in the southern marshes of Terrebonne Parish between the Houma Navigation Canal and Bayou Petit Caillou (Fig. 6-1). The study area includes the lower 8.7 miles of Highway 56 ending at Point Cocodrie. Approximately 600 people live in the area (Metrovision 1998). There are 200 residential structures and approximately 20 commercial buildings located in the area. Cocodrie is entirely surrounded by marsh, and there is no hurricane protection for the area.

Cocodrie is an ideal location for recreational fishing. Recreational anglers, along with commercial fishing guides, operate out of local marinas. Several commercial fishing operations are also present. Cocodrie is the home of Louisiana Universities Marine Consortium (LUMCON), home of the W.J. DeFelice Marine Center. The marine center is a 75,000 square foot complex of research, instructional, housing and support facilities. It includes 26,000 square feet of laboratory, classroom, office, and library space. Dormitory rooms and apartments provide housing for up to 80 people. The only other public building in Cocodrie is a fire station at the northern extreme of the study area. There are 8.7 miles of pavement on Highway 56, five miles of gravel road, and a bridge just south of the fire station. The water supply system includes a water tower, a metering station, and supply lines. There are also natural gas lines serving the area. Cocodrie's public infrastructure is estimated to be worth over $53 million.

Land loss in the vicinity of Cocodrie is projected to be very severe. By 2050 over 55% of the marsh north of Cocodrie will be gone. Even more seriously, over 65% of the marsh to the east and 35% of the marsh to the west and south will have turned to open water. The barrier islands to the south will be tiny remnants of what they are today. Even if Cocodrie were to still exist by 2050, it would be an island community surrounded by water. The sport and commercial fisheries will be seriously reduced.

Loss of marsh will significantly impact the public infrastructure. Roads, highways, and bridges will have to be replaced and raised at an approximate cost of $27 million. The public utilities will be at much greater risk than they are today from hurricanes or even winter storms. The replacement cost of electrical utility infrastructure is estimated at almost $800,000. The cost estimate for replacing the water supply system is approximately $1 million. Natural gas lines would have to be replaced at a cost of nearly $580,000.

The replacement cost of LUMCON would be approximately $24 million. The fire station is valued at $150,000. If the entire infrastructure had to be replaced due to a combination of marsh loss and storm damage, it could cost up to $53 million.

Community at risk: Holly Beach/Constance Beach (Cameron Parish)

The Holly Beach/Constance Beach corridor is located in Cameron Parish (Fig. 6-1). It includes the area from the intersection of Louisiana Highways 27 and 82 westward for 10 miles along Highway 82 toward the town of Johnson's Bayou. The area contains some of the few sand beaches along Louisiana's Gulf of Mexico Coast. The small communities of Holly Beach, Constance Beach, Martin Beach, Peveto Beach, and Little Florida are clustered along the highway. Approximately 800 permanent residents live in the area. Proximity to Lake Charles and other communities in southwest Louisiana make this an ideal spot for a weekend vacation. There are approximately 400 residential structures in the area and nearly 100 commercial establishments. Many of the structures are small camps and motels that serve the area's recreational and tourism interests. Hunting, fishing, birding, and beach recreational activities are the major tourist attractions.

The community infrastructure includes a fire station and an ambulance building on Highway 27. There are approximately 10 miles of highway and seven miles of bituminous road in the area. Highway 82 is part of the Creole Nature Trail. Another highway of importance to the beaches lies outside the study area. Louisiana Highway 27 runs north from the gulf through the Sabine National Wildlife Refuge to high ground near Lake Charles. Highways 27 and 82 are the only hurricane evacuation routes from the beaches and the communities along the coast. There are no hurricane protection levees in the area. There is a power substation on Highway 82 and a transmission line runs the length of the highway. A water tower and 17 miles of supply lines bring water to the area.

In this area, coastal erosion has led to shoreline retreat such that La. Highway 82 is now at the Gulf of Mexico shoreline. The highway has been severely damaged during several winter and tropical storms and has been moved landward several times. It is now built on the last natural ridge, or chenier, before the marsh. Between 1991 and 1994 the Louisiana Department of Natural Resources constructed a series of 85 breakwaters along 8 miles of the coastline. The combined cost of these breakwaters and other road-protection measures has been over $12 million in the last 10 years. The breakwaters provide some protection to the highway, but more work is needed to prevent loss of the highway. It cannot be relocated farther inland because of the lack of suitable substrate in the marsh plain. If the highway can no longer be maintained and the chenier is breached, there will be interior marsh loss. La. Highway 82 is one of the two roads out of this area. By 2050, approximately 20% of the marshes north of this highway will become open water. If these marshes are not protected, the evacuation route will be more at risk. Shoreline erosion on the gulf side is already a problem, but as the interior marshes are lost, the ridge on which the road is built may be exposed to attack from the northern side as well (albeit of a lesser magnitude). If measures are not taken to protect the shoreline and to maintain the interior marshes, community infrastructure worth $300,000 will be at risk. More importantly, communities will need to relocate because their hurricane evacuation route, as well as their means of conducting everyday business, will be lost. The replacement cost of the roads would be $37 million. The utility infrastructure replacement cost would be $2.1 million.

Summary of Coastal Communities at Risk

The Fourchon corridor and the three isolated communities discussed in the vignettes all share a reliance on the wetlands surrounding them. They depend heavily on the fish and wildlife that, in turn, are dependent on the vanishing marshes. They rely on ecotourism that is based on the natural resources of the coast. Their livelihood depends on the oil and gas resources in the wetlands or offshore. People live in these communities to be near the bountiful resources of the coast. New Orleans sits astride the Mississippi River, surrounded by lakes and wetlands, and depends on shipping, tourism, and manufacturing. Its inhabitants recreate in the wetlands. The severe loss of the wetlands that is projected to occur in the future puts all these communities at risk.

In the past, people made decisions that are destroying the coastal resources: the wetlands, the fisheries and the wildlife. The opportunity now exists to slow the loss of wetlands, which will preserve the natural system while at the same time help these communities to continue to exist. It is a wiser decision to save the wetlands than to move communities or replace the infrastructure. By preserving the wetlands, we would help preserve a way of life and retain the economic viability of these coastal communities.

Fisheries

Loss of coastal wetlands in Louisiana has severe implications for the long-term sustainability of fisheries resources. The remarkable level of productivity of the State's marine systems is tied to both the quantity and quality of estuarine fisheries habitat. Recent high production has been linked to the amount of land-water interface, which is highest in marshes undergoing the early stages of subsidence and disintegration. A drastic downturn in the harvest of the majority of the most valued species of fish and shellfish is expected as open water replaces marsh in most areas. Coastal fisheries resource managers are looking toward coastal restoration for protection of existing wetlands and the creation of new marshes to replace some portion of those which have been lost.

Historic Trends in Fisheries Production

Methodology

To assess the recent trends and future projections of fishery populations within the Coast 2050 study area, four broad species assemblages were established based on salinity preferences. These assemblages were marine, estuarine dependent, estuarine resident, and freshwater. Within each of the four assemblages, "guilds" of fishery organisms were established. As used in this document, "guilds" are groupings of ecologically similar species identified by a single, representative species and, hereafter, the terms "guild" and "species" are used interchangeably. Fishery guilds common to coastal Louisiana, within each salinity-preference assemblage are:

- Spanish mackerel guild—marine,
- Red drum, black drum, spotted seatrout, gulf menhaden, southern flounder, white shrimp, brown shrimp, and blue crab guilds—estuarine dependent,
- American oyster guild—estuarine resident, and
- Largemouth bass and channel catfish guilds—freshwater.

In a broad sense, each of the 12 guilds is uniquely identified by the combination of the representative species' habitat preference, salinity preference, primary habitat function, seasonal occurrence in the estuary, and spawning or migratory seasons (Table 6-1). Habitat and life history information is based on available scientific literature specific to the northwestern Gulf of Mexico, but it is somewhat generalized to accommodate the establishment of guilds.

Once the species representing each fishery guild was identified, population changes of each species were assessed and displayed by using a matrix for each of the four coastal regions (*see* Appendix B for methodology, Appendices C-F for Regions 1-4, respectively). The matrices display mapping units and guilds and, within the mapping units, provide information on the population stability (recent change trends) and population projections for each species group. The discussion of fishery population projections follows this section. Most of the recent trend information was provided by biologists of the Louisiana Department of Wildlife and Fisheries (LDWF). The assessments were based on LDWF fishery-independent sampling data and personal observation of area fishery biologists, and generally span a period of 10 to 20 years. Staff members of LDWF believe that, because of selectivity of sample gear, the trend information is most reflective of recent changes in the subadult portion of each guild. Historic trend information represented in each coastal region matrix is summarized below.

Region 1 Trends

Within Region 1 (Appendix C), the freshwater assemblage, represented by largemouth bass and channel catfish guilds, occurs in the low salinity (generally less than 2 parts per thousand) to freshwater areas of the basin. In general, freshwater fishery populations have been steady over the past 10-20 years. Similarly, the Spanish mackerel guild, representing the marine fishery assemblage and found only in higher salinity waters on the perimeter of the basin, has exhibited stable population numbers.

The estuarine dependent species assemblage is found throughout Lake Pontchartrain and in the brackish to saline zones of the Lake Borgne and Chandeleur Sound areas. With the exception of the red drum guild, whose populations have increased in the eastern units of the region, recent population levels have been relatively steady for all guilds throughout the units in which they occur. The resident species assemblage, represented by the American oyster, has exhibited steady to declining populations.

Not included within the matrix is the gulf sturgeon, which is federally listed as a threatened or endangered species. Population levels in coastal Louisiana are unknown; however, recent records indicate that this anadromous species occurs in this region.

Region 2 Trends

Region 2 (Appendix D) exhibits mixed population trends among mapping units and species guilds. The freshwater assemblage occurs in the upper and mid-basin zones, the Mississippi River delta and in the vicinity of freshwater diversions. Largemouth bass exhibited generally steady population levels, as did channel catfish, except in several of the mid-basin mapping units where populations increased in response to freshwater input.

The marine assemblage guild (Spanish mackerel) showed steady population trends in the Mississippi River delta units. Within the lower estuary and barrier island units, populations showed patterns of increase.

Estuarine resident and dependent species do not occur in the uppermost units of Region 2. No guild showed a consistent pattern throughout all mapping units. In general, species within these guilds have shown decreasing numbers in units nearest the Gulf of Mexico, increasing levels in the vicinity of freshwater diversions, and steady populations in other mid-basin and Mississippi River delta mapping units.

Region 3 Trends

Region 3 (Appendix E) includes multiple estuarine basins, extending from the Terrebonne/Timbalier Bay complex to the Vermilion Bay estuary. Similar to Region 2, fish and shellfish within these basins exhibit mixed historic trends among mapping units and species guilds. The two guilds within the freshwater assemblage show stable population trends, except in the central basin area where populations have generally decreased.

Where the marine guild representative occurs, in the gulf fringe of the basin, populations have tended to increase in Region 3.

The estuarine resident, American oyster, shows both increasing and decreasing trends except in the western units where populations are reported to be stable. Upward and downward trends of the oyster appear to be related to recent habitat and salinity shifts, occurring between the barrier islands and the intermediate/brackish marsh zones of the Terrebonne estuary.

Estuarine dependent species also have an erratic pattern of change from steady population levels. An overall pattern of population decreases is noted for the barrier islands, Marsh Island, and the Terrebonne, Penchant, and Pelto marshes, while generalized increases are reported in the area of the Houma Navigation Channel and for the guild represented by red and black drum and blue crab. From the Atchafalaya subdelta west, generally steady population trends were noted.

Region 4 Trends

Region 4 (Appendix F) contains two estuarine basins: Mermentau and Calcasieu-Sabine. The two guilds representing the freshwater assemblage exhibit steady population levels in nearly all units providing suitable fresh to low salinity habitat in the basins. Exceptions occur in several units in the vicinity of

Black Lake and Sabine Pool, where population increases have occurred.

Spanish mackerel from the marine assemblage had limited occurrence within these basins. Present in the lower portions of Calcasieu Lake and near the gulf shoreline of the Rockefeller Refuge area, populations have been steady. Among the species representing the estuarine dependent assemblage, blue crab populations have been steady. White and brown shrimp have shown steady to declining patterns, with a greater number of units showing declines, especially in the Calcasieu-Sabine basin. Geographically, estuarine dependent species have tended to decline in the Grand Lake, Mud Lake, Southeast Sabine, Brown's Lake, West Black Lake, and Cameron-Creole mapping units, which are areas influenced by weirs and other types of water control structures. Other units, some of which are also subject to water level control, often reflected steady to increasing population patterns.

Projected Trends in Fisheries Production

The projection of possible future changes in fishery production for coastal Louisiana is based solely on landscape change model predictions previously discussed in Chapter 5. The key parameters in making those projections were percent and pattern of wetland loss in each mapping unit. It should be recognized that numerous other factors which could not be forecast, such as changes in water quality, fishery harvest levels, wetland development activities (e.g., dredging and filling), and blockages of migratory pathways also could negatively impact fishery production. Because of the potential for great inaccuracy in predicting land loss and fishery population changes 50 years into the future, especially when considered at a mapping unit scale, discussion of future changes is presented as a coastwide assessment with reference to specific units to exemplify those changes. Projected trends in production are presented for each guild and for each mapping unit in the Appendices C-F.

Marine Assemblage

Within the marine assemblage and dependent on individual species habitat requirements, habitats utilized by species of this assemblage are expected to expand as barrier islands submerge, land and land platforms subside, saline marsh deteriorates and retreats, tidal prisms increase, and higher salinity waters intrude farther inland. This habitat shift would increase the area of near shore habitat available for the marine assemblage. Accordingly, the future projections do not reflect adverse production impacts typically associated with land loss, and in a number of cases increases are forecast. As shallow marine habitat expands, however, it is likely that the forage base, composed partly of estuarine-dependent species, would diminish. It is possible that, even though habitat conditions would remain suitable, a reduction in populations of estuarine-dependent forage species would cause decreased production of the marine assemblage.

Estuarine Resident Assemblage

As barrier islands erode and wetland erosion and submergence continue over the next 50 years, it is likely that higher salinity levels will occur at more inland locations. To remain in preferred salinity zones, the estuarine resident assemblage will continue to be displaced northward as salinity shifts occur. The magnitude of population relocations will be related to the salinity tolerance and habitat preferences of individual species within the assemblage. The American oyster is especially sensitive to salinity changes because of its susceptibility to attack by predators and parasites as average salinities increase above 15 parts per thousand. Overall, as preferred wetland habitats deteriorate, detrital based food sources diminish, and zones of optimal salinity are reduced or shift to areas having otherwise unsuitable habitats, populations of species within the American oyster guild will decline.

Estuarine Dependent Assemblage

Guilds within the estuarine-dependent assemblage can tolerate a variety of salinity conditions, so salinity change alone should not significantly affect populations. Production of many of the guilds, however, is closely associated with the areal extent and interspersion of vegetated, intertidal wetlands. In areas such as the Terrebonne Wetlands mapping unit of Region 3, estuarine wetlands are already highly fragmented (high water-marsh interspersion). The predicted continued marsh loss within such mapping units would result in reduced wetland habitat availability and a decline in production. In areas where extensive marshes exist, the pattern of future marsh loss would influence how that loss impacts productivity. A gradual loss of marsh edge (enlargement of water bodies) should not have a major short-term effect.

Where land loss occurs in the form of internal marsh break-up (formation of numerous small water bodies in an otherwise continuous marsh), production could be enhanced by increased habitat accessibility and the export of nutrients and plant detritus. The Johnson's Bayou mapping units in Region 4 provide an example of such a loss pattern and associated fishery production increases. Even in these areas, however, as deterioration continues beyond the year 2050, production would decline. Overall, the matrices (Appendices C-F) indicate that wetland erosion and fragmentation will cause a reduction in the productivity of guilds within the estuarine-dependent assemblage.

Freshwater Assemblage

Freshwater assemblages have a low tolerance for salinity. They generally are found in coastal areas having salinities of 2 parts per thousand or less. As higher salinity water encroaches into previously fresh wetlands, species within the freshwater guilds would be displaced. The ability of these guilds to relocate to suitable habitat is restricted by land elevation. That is, at some point the freshwater aquatic habitats of the coastal area grade into nonaquatic habitat. Populations within the largemouth bass and channel catfish guilds may not be greatly affected in areas having a relatively low predicted rate of wetland loss. The total area of suitable, freshwater habitat, however, will diminish as marsh and barrier island buffers between the Gulf of Mexico and fresh to low salinity zones deteriorate. Reduction of the area available for use by the freshwater assemblage guilds would result in an overall reduction of those populations. Only in the area of Atchafalaya and East Cote Blanche Bays and in the vicinity of river diversion outfall sites is there an expected expansion of freshwater fishery habitat by 2050.

Summary

In general, populations within the marine assemblage should remain relatively steady unless there is a decline in food availability related to the loss of wetland habitat. Species within the estuarine resident and estuarine dependent assemblages will decline based on habitat loss predictions for the year 2050. The two guilds representing the freshwater assemblage are predicted to have steady to decreasing population levels except in those mapping units with significant freshwater inflows.

Wildlife

Louisiana's coastal wetlands, extending from the forested wetlands at the upper end to the barrier shorelines bordering the gulf, provide a diverse array of habitats for numerous wildlife communities. In addition to fulfilling all life cycle needs for many resident species, coastal wetlands provide wintering or stopover habitat for migratory waterfowl and many other birds. The bald eagle and brown pelican, protected by the Endangered Species Act, are recovering from very low populations experienced over the last three decades. Increasing populations for those two species are projected to continue in the future, independent of near-term wetland changes. The fate of other species groups in coastal Louisiana will be influenced by habitat conditions there. These groups include migratory birds, such as wintering waterfowl, which rely on the abundant food supply in coastal wetlands to store sufficient energy reserves for migration and nesting. The prediction of extensive land loss and habitat change by the year 2050 prompted an examination of the effect of such losses and changes in the abundance of wildlife.

Methodology

To assess the recent trends and future projections of wildlife abundance within the Coast 2050 study area (Appendices B-F), 21 prominent wildlife species and/or species groups were identified:
(1) brown pelican, (2) bald eagle,
(3) seabirds, (4) wading birds,
(5) shorebirds, (6) dabbling ducks,
(7) diving ducks, (8) geese, (9) raptors,
(10) rails, gallinules, and coots,
(11) other marsh and open water residents, (12) other woodland residents,
(13) other marsh and open water migrants, (14) other woodland migrants,
(15) nutria, (16) muskrat, (17) mink, otter, and raccoon, (18) rabbit,
(19) squirrel, (20) white-tailed deer, and
(21) American alligator. A matrix was developed for each region to present the function, status, trend (over last 10 to 20 years), and projection (through the year 2050) for the above listed species and/or species groups for each habitat type

within each mapping unit. Habitat types which occupied less than 5% of a given mapping unit were excluded unless that habitat type was viewed to be unique or unless it performed a critical function.

Information displayed in the matrices (*see* Appendices C-F for Regions 1-4, respectively) represents common understandings of the selected species and/or species groups, field observations, some data, and recent and projected habitat changes, all synthesized by wildlife biologists from the Louisiana Department of Wildlife and Fisheries, U.S. Fish and Wildlife Service, and the Natural Resources Conservation Service.

Because the amount of information contained in the matrices is quite extensive (21 species or species groups, 140 mapping units, and up to seven habitat types per mapping unit), a general discussion is presented, by region, of only those instances where species or species groups have been decreasing or increasing in abundance over the last 10 to 20 years, or are projected to decrease or increase in abundance through the year 2050. If a species or species group is not discussed within a region, the abundance of that species or species group has been generally steady over the last 10 to 20 years and is expected to remain generally steady through the year 2050.

The projection of wildlife abundance through the year 2050 is based almost exclusively on the predicted conversion of marsh to open water and the gradual relative sinking and resultant deterioration of forested habitat throughout the study area. Such predictions may or may not prove to be accurate. Additionally, numerous other factors including water quality, harvesting level, and habitat changes elsewhere in the species' range cannot be predicted and were not considered in these projections. Therefore, the projections presented below and in the Appendices are to be viewed and used with caution.

Region 1 Wildlife Trends and Projections

Trends

Brown pelican and bald eagle abundances are increasing. Wading bird abundance has increased in all but four mapping units which surround Lake Borgne. Dabbling duck, diving duck, rail, gallinule, and coot numbers are declining in Central Wetlands and South Lake Borgne. The abundance of raptors and other woodland species are increasing in forested wetlands. Alligator abundance has been increasing in the upper basin and decreasing in the lower basin.

Projections

Brown pelican and bald eagle numbers are projected to increase in areas presently occupied. Seabird abundance is expected to decrease in the lower basin and in the Bonnet Carré and LaBranche Wetland mapping units. Wading bird numbers are expected to decrease in the four mapping units which surround Lake Borgne. The numbers of dabbling ducks, diving ducks, geese, rails, gallinules, and coots are expected to decline in the Manchac and East Orleans Land Bridge areas, Central Wetlands, and South Lake

Borgne. The abundance of other birds utilizing marsh and open water habitats is expected to decrease in three units on the periphery of Lake Borgne and in the LaBranche Wetlands.

The abundance of raptors and other woodland species is expected to decrease in forested habitats. Raptor abundance is expected to decrease for five marsh-dominated units around Lake Pontchartrain and Lake Borgne. Furbearer and alligator numbers are expected to decrease in the lower basin. Alligator abundance in the upper basin is expected to increase. In mapping units surrounding Lake Maurepas, in Central Wetlands, and in South Lake Borgne, squirrel, rabbit, and white-tailed deer abundance are expected to decrease.

Region 2 Wildlife Trends and Projections

Trends

Brown pelican and bald eagle abundance are increasing. Seabird abundance is decreasing in areas of high land loss. Dabbling duck and diving duck numbers are declining in the brackish and saline marshes of the central and lower portions of Region 2, declining in the less active parts of the Mississippi River delta, and increasing in the vicinity of freshwater diversions. Goose numbers are declining in less active parts of the delta. Rail, gallinule, and coot trends are similar to that of dabbling ducks, except that Cataouatche/Salvador and Gheens have increasing numbers. The abundance of other birds using marsh and open water habitats is declining in areas of high land loss. Raptor abundance has increased in forested habitats and decreased in deteriorating marshes. Furbearer and alligator numbers are decreasing in areas experiencing high land loss.

Projections

Brown pelican and bald eagle numbers are projected to increase in areas presently occupied. Seabird abundance is expected to decrease in areas of high land loss. Wading bird and shorebird abundance are expected to decrease in the region except in areas influenced by river diversions. The numbers of dabbling ducks, diving ducks, rails, gallinules, and coots are expected to increase in the vicinity of freshwater diversions and decline in the other central and lower region marshes. Goose abundance is expected to decrease in the less active delta areas.

The abundance of other birds using marsh and open water habitats is projected to decrease in deteriorating wetlands and increase in projected land-building areas such as West Bay. Decreased numbers of raptors and other woodland birds are expected across the region except in areas influenced by river diversions. Furbearer and alligator numbers are projected to decrease in areas expected to experience high land loss. Squirrel abundance is expected to decline throughout Region 2. Rabbit and white-tailed deer numbers are expected to decline in much of the fresh swamp, hardwood forest, and central and lower marshes.

Region 3 Wildlife Trends and Projections

Trends

Brown pelican and bald eagle numbers are increasing. Seabird abundance has declined in the Terrebonne-Timbalier Bay area. Wading bird abundance has increased in stable wetlands and has decreased in deteriorated habitats. Shorebird abundance is decreasing in the Terrebonne-Timbalier mainland marshes. Goose numbers are increasing in the Penchant mapping unit and in the marshes near the Atchafalaya River. Rail, gallinule, and coot numbers are decreasing in areas where marshes are deteriorating. The abundance of raptors has increased in forested wetlands.

Furbearer numbers have decreased in the deteriorated wetlands of the Terrebonne-Timbalier Bay area and in the Mechant-de Cade mapping unit. Alligator abundance is increasing in marsh-dominated mapping units which are strongly influenced by the Atchafalaya River and is decreasing in units that have experienced high land loss.

Projections

Brown pelican and bald eagle numbers are projected to increase in areas presently occupied. The abundances of seabirds, wading birds, shorebirds, raptors, and other birds utilizing marsh and open water habitats are expected to decrease in deteriorating wetland areas. Dabbling duck, diving duck, goose, rail, gallinule, and coot numbers are expected to decline in the lower central Terrebonne, lower eastern Terrebonne, and Penchant marshes. The abundances of raptors and other birds utilizing hardwood forests are expected to decrease.

Furbearer and alligator populations are expected to decrease in deteriorating wetlands of the Terrebonne-Timbalier Bay area and in Mechant-de Cade. Squirrel abundance is expected to decline throughout Region 3, except in the Avoca mapping unit. Rabbit and white-tailed deer numbers are expected to decline in much of the fresh swamp and hardwood forest habitats and in the lower central Terrebonne, lower eastern Terrebonne, and Penchant marshes.

Region 4 Wildlife Trends and Projections

Trends

In the vicinity of the gulf, Calcasieu Lake, and Sabine Lake, brown pelican numbers are increasing. Bald eagles have shown a small but increased presence in the South White Lake unit. Wading bird abundance is increasing in marsh habitats. In the Mermentau Basin, dabbling duck and diving duck abundances have declined in mapping units surrounding Grand Lake and White Lake. In the Calcasieu-Sabine basin, duck abundance has been generally increasing. Goose abundance is increasing throughout much of Region 4. Alligator abundance is generally increasing in mapping units with low to moderate salinity regimes and low to moderate tidal energy.

Projections

Brown pelican and bald eagle numbers are projected to increase in areas presently occupied. Seabird abundance is projected to decrease in marsh habitats of the Calcasieu-Sabine Basin. Decreases in wading bird abundance are expected in marsh habitats of eight Calcasieu-Sabine Basin mapping units and six Mermentau Basin units. Decreased shorebird abundance is expected in marsh habitats in 11 Calcasieu-Sabine Basin mapping units and 11 Mermentau Basin mapping units. The abundances of dabbling ducks, diving ducks, geese, rails, gallinules, and coots are expected to decline in mapping units surrounding Grand Lake and White Lake, and in other mapping units throughout Region 4 where conversion of marsh to open water is expected. Decreased abundance of other birds utilizing marsh and open water habitats is expected in marsh habitats in 17 Calcasieu-Sabine basin mapping units and 12 Mermentau Basin mapping units. The abundances of raptors and other birds utilizing forested habitats are expected to decrease. The abundance of furbearers is expected to increase in the Cameron-Creole Watershed mapping unit. Alligator numbers are expected to increase in six low salinity mapping units and two mapping units where salinity and water level regimes are now manipulated (Cameron-Creole Watershed and West Black Lake). In mapping units with high land loss projections, rabbit and white-tailed deer numbers are expected to decline.

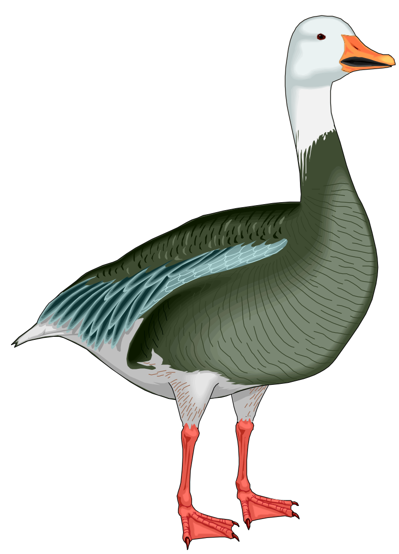


Table 6-1. Representative fish and invertebrate guilds of coastal Louisiana.

Species (guild) Life stage		Habitat preference				Salinity preference				Primary habitat function			Seasonal preference				
		EM	SH	DW	FS	F	I	B	SA	S	NU	FO	SP	SU	FA	WI	YR
Marine assemblage																	
Spanish mackerel	Adult																
	Juvenile																
Estuarine dependent assemblage																	
Red drum	Adult																
	Juvenile														*		
Black drum	Adult																
	Juvenile												*				
Spotted seatrout	Adult																
	Juvenile													*			
Gulf menhaden	Adult																
	Juvenile															*	
Southern flounder	Adult																
	Juvenile															*	
White shrimp	Subadult																
	Juvenile													*			
Brown shrimp	Subadult																
	Juvenile												*				
Blue crab	Adult																
	Juvenile												*	*			
Estuarine resident assemblage																	
American oyster													*	*			
Freshwater assemblage																	
Large mouth bass	Adult												*				
	Juvenile																
Channel catfish	Adult												*				
	Juvenile																

Habitat preference—EM=emergent marsh; SH=shallow water; DW=channel, open water > 6 ft; FS=fresh swamp
Salinity preference—F=fresh; I=intermediate; B=brackish; SA=saline
Primary habitat function—S=spawning; NU=nursery; FO=foraging
Seasonal preference—SP=spring; SU=summer; FA=fall; WI=winter; YR=year round
<All preferences denoted by block shading>
* Indicates immigration period for marine transient species and spawning season for resident species.

CHAPTER 7

ECOSYSTEM MANAGEMENT STRATEGIES

Strategic Goals

Because natural processes created the highly productive wetlands in coastal Louisiana, reestablishment of these processes is essential to achieve sustainability. Reestablishment does not imply controlling nature but does require constructive use of the forces that formed coastal Louisiana (the rivers, rainfall, and the gulf). Neither does reestablishment imply a return of the coastal system to a pristine condition, because too much has changed for that to occur. The intent is to design restoration strategies based on ecological principles so the future coast will have the productivity and other desirable features of a highly-valued natural system.

There are three strategic goals that must be achieved in order to restore the coastal ecosystem. Each goal is discussed below. The regional ecosystem strategies, described subsequently, are intended to accomplish these goals.

Goal 1: Assure vertical accumulation to achieve sustainability

The natural, long-term productivity of Louisiana's coastal wetlands has occurred because, over a large area and over time measured in centuries, the ecosystem maintained itself against the natural forces (such as subsidence and erosion) that cause marsh loss. Self-maintenance is the most essential attribute of "what the ecosystem needs." Failure to achieve self-maintenance in the system means either the system cannot be sustained, or the system must be maintained artificially with large ongoing investments of labor, energy, and materials.

To achieve self-maintenance, sustainable marshes must accumulate sediment and/or organic matter at a rate that equals or exceeds the combined effect of sea-level rise and subsidence. This upward growth in the land surface, to counteract sinking, is known as vertical accumulation. Delta building is one natural process of accumulation of new land. For established marshes, vertical accumulation occurs through periodic, gentle marsh flooding and drainage that promote healthy vegetation and large rates of organic production. It is also important to protect otherwise self-sustaining wetlands from excessive erosional forces.

Goal 2: Maintain estuarine gradient to achieve diversity

Following sustainability, a second essential characteristic that makes the natural system so productive is its diversity of habitats and the consequent diversity of fish and wildlife resources. These habitats include swamps, marshes of various salinities, and the more emergent landforms (natural and artificial levees, chenier ridges, and barrier islands). With diversity, the ecosystem is capable of providing a wide array of outputs and is resilient to adverse changes.

A dynamic salinity gradient in each estuary is the fundamental driving force that creates natural ecosystem diversity. Significant freshwater input must occur at the upper end of each estuary and must flow seaward to grade into increasingly saline and tidally dominated flow at the gulf end of the estuary, where the system is partially contained by emergent land (such as barrier islands or chenier ridges). With a salinity gradient comes the gradation of fresh-intermediate-brackish-saline vegetation and associated variations in fish and wildlife habitat. The other features of ecosystem diversity, such as the more emergent landforms, are natural outgrowths of the delta-building and chenier cycles.

Goal 3: Maintain exchange and interface to achieve system linkages

Ecosystem linkages are the pathways by which energy, materials, and organisms are transferred and mixed among the ecosystem components. Effective interconnections are needed to support a food chain that is diverse and highly productive. Examples include migration of saltwater organisms into comparatively fresher marshes as part of their natural reproductive cycle; the normal export of surplus organic marsh detritus to sustain the estuarine food chain; and overflow of fresh water (with nutrients and sediments) into marshes in a natural flow regime.

Optimal linkages require that the landforms and hydrology of the ecosystem allow for efficient exchange of energy and materials between the marshes and estuaries. In turn, this is achieved by habitats that have stable edges and that are naturally interspersed with other habitats, and by a hydrologic regime that maintains the natural rhythms of the coast—including tidal cycles, storms, and river floods.

The regional strategies discussed below apply these three strategic goals in different ways, depending on the specific needs of ecosystems in different areas. The relative role of the regional strategies in meeting the ecosystem needs is broadly categorized, according to the estimated amount of marsh benefitted, as minor (< 1,000 acres), moderate (1,000-5,000 acres), major (5,000-10,000 acres) or substantial (>10,000 acres). Further details about specific strategies follow; very broadly, any given strategy includes one or more of the following approaches.

- *Enhance the ecosystem by using resources more efficiently* . In some areas, especially those with strong and positive riverine influences, the integrity of the natural system is intact and the wetlands are considered sustainable through 2050 with little or no further intervention. Strategies are designed to make more effective use of the available resources.

- *Maintain the ecosystem by addressing known risks* . In some areas, the ecosystem is now thriving but is at risk of losing its sustainability by 2050. These ecosystems may be at risk from the predicted loss of adjoining wetlands, shorelines, barrier islands, or levee ridges that now provide integrity to the ecosystem. The risks may also relate to prospective changes in existing hydrologic management. In such areas, strategies aim to reduce risks and promote hydrologic conditions that are favorable to sustainability, diversity, and exchange.

- *Recover the ecosystem by reversing the loss process*. Large areas of the coast exist where the ecosystem has lost some of its integrity and the emergent wetlands are no longer self-maintaining. Where these areas have a platform of intact (but perhaps declining) vegetation, it is possible that the wetlands could return to self-maintaining conditions. The strategies are to recover sustainability through restoration actions that recreate the lost aspects of system integrity, reduce existing vegetation stresses, and/or stimulate vertical accumulation.

- *Rebuild the ecosystem by creating new wetlands*. Finally, in some parts of the coast, the ecosystem has degraded to the point that virtually all of the ecosystem integrity is lost and there is no vegetative substrate upon which to recover sustainable conditions. Consequently, if emergent wetlands are desired, they will need to be newly built, as through a new delta lobe or marsh creation project. Alternatively, such areas would exist and function as an open water system.

Coastwide Common Strategies

The coastwide common strategies were ubiquitous to practically every mapping unit, so they are simply defined one time, with the understanding that they would be implemented as appropriate. They are explicitly recommended for some mapping units where there is deemed to be a compelling and immediate need for such a strategy (Appendices C-F).

Beneficial Use of Dredged Material from Maintenance Operations

Five components are recognized: (1) inventory unused material, (2) assess suitability of material for beneficial use (e.g., grain size, contaminants), (3) identify sites to benefit from unused material, (4) address the Federal standard for beneficial use, and (5) secure funding to utilize unused material if beneficial use is more costly than the Federal standard. Some aspects of this beneficial use are programmatic in nature in that they do not result in project development and construction. The beneficial use strategies listed in the regional and mapping unit tables

(Appendices C-F) refer to the physical act of building wetlands with dredged material rather than the programmatic aspects, discussed later in this document (Chapter 8).

Dedicated Dredging for Wetland Creation

Wetland habitat creation using dredging technology is a viable strategy across the coastal zone to build land where traditional marsh building processes do not occur or are infeasible. This strategy differs from beneficial use of maintenance dredged material in that maintenance dredged material from navigation channels or other permitted activities is not the intended sediment source. As a strategy, the primary purpose of dedicated dredging is the utilization of dredged material to restore, create, or enhance coastal wetlands.

Herbivory Control

Nutria, and occasionally muskrat, populations can become so high in certain areas of Louisiana's coast that they actually destroy marsh, resulting in its conversion to open water. This strategy is aimed at reducing the severe levels of marsh destruction by increasing trapping incentives, developing better markets for nutria, etc.

Stabilization of Major Navigation Channels

The loss of wetlands resulting from the direct effects of bank erosion along Louisiana's nine major navigation channels in the coastal zone is estimated to be in excess of 35,000 acres. The need for stabilization in critical areas has been noted in all four Coast 2050 regions.

Maintenance of Bay and Lake Shoreline Integrity

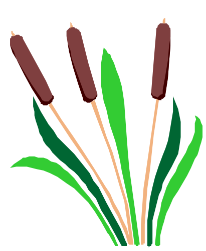
This strategy includes an array of shoreline protection technologies in locations where excessive erosion of bay and lake rims would expose interior marshes to increased rates of erosion or severe hydrologic change. The strategy is not intended to armor all shorelines or to prevent normal shoreline retreat and rollover.

Management of Pump Outfall for Wetland Benefits

As the number of pumps increases throughout the coast, so do the opportunities to benefit wetlands while improving the quality of the discharged water. Water quality improvement usually involves introducing the discharge into wetlands, rather than directly into waterways, in a controlled fashion for filtering.

Vegetative Planting

Planting projects have been used for over a decade in Louisiana with a high degree of success. Vegetative plantings can stabilize banks and reestablish wetlands in some areas. Added benefits include increased overall plant productivity in the area and creation of prime habitat for wildlife and fish.



Maintain or Restore Ridge Functions

Coastal ridges resulting from abandoned shorelines or natural levees are a critical structural component of our estuaries. The repair or maintenance of these to protect or improve the hydrology of the coast is recommended at numerous locations.

Terracing

Terracing, accompanied by vegetative planting, is an effective means of marsh habitat creation in areas with soils of suitable mineral content. Functions and values of terraces include nursery habitat, fetch reduction, and sediment trapping in addition to promoting conditions conducive to growth of submerged aquatic vegetation.

Region 1 Strategic Plan

Background

Region 1 encompasses the Lake Pontchartrain Basin, which extends from the Mississippi River on the west to the Chandeleur Islands on the east, and from the Prairie Terrace on the north to the Mississippi River Gulf Outlet (MRGO) on the south. It covers portions of the following parishes: Livingston, Tangipahoa, St. Tammany, St. Bernard, Orleans, Jefferson, St. Charles, St. John the Baptist, St. James, and Ascension.

The region can be divided into three subbasins. The Upper Basin consists of the 110,000 acres of bottomland hardwoods, 191,630 acres of swamps, 12,700 acres of fresh marshes, and about 400 acres of intermediate marshes that lie west of the Pontchartrain/Maurepas Land Bridge. The Middle Basin contains 21,850 acres of swamps, 20,000 acres of fresh marshes, 27,300 acres of intermediate marshes, and 42,000 acres of brackish marshes surrounding Lake Pontchartrain. The Lower Basin consists of 90 acres of swamps, 2,000 acres of fresh marshes, 68,900 acres of brackish marshes, and 79,700 acres of saline marshes around Lake Borgne and near Chandeleur Sound.

The region contains Lakes Pontchartrain, Maurepas, and Borgne, which govern hydrology and drainage patterns throughout the region. The Amite and Tickfaw Rivers, Bayou Manchac and other rivers drain into Lake Maurepas. These contribute to significant water movement within the area. Lake Pontchartrain is affected by freshwater inflows from Pass Manchac, North Pass, and the Tangipahoa, Tchefuncte, and Bogue Falaya Rivers, some bayous, and the Bonnet Carré Spillway. The lower basin contains many tidal channels. Major navigation channels include the MRGO and the Gulf Intracoastal Waterway.

Habitat Objectives

Generally, parish governments and citizens in Region 1 are more concerned with maintaining present habitats and current levels of productivity in the region than with making massive changes (Fig. 7-1, 7-2). Some conversion of intermediate and brackish marshes to fresh marshes is deemed

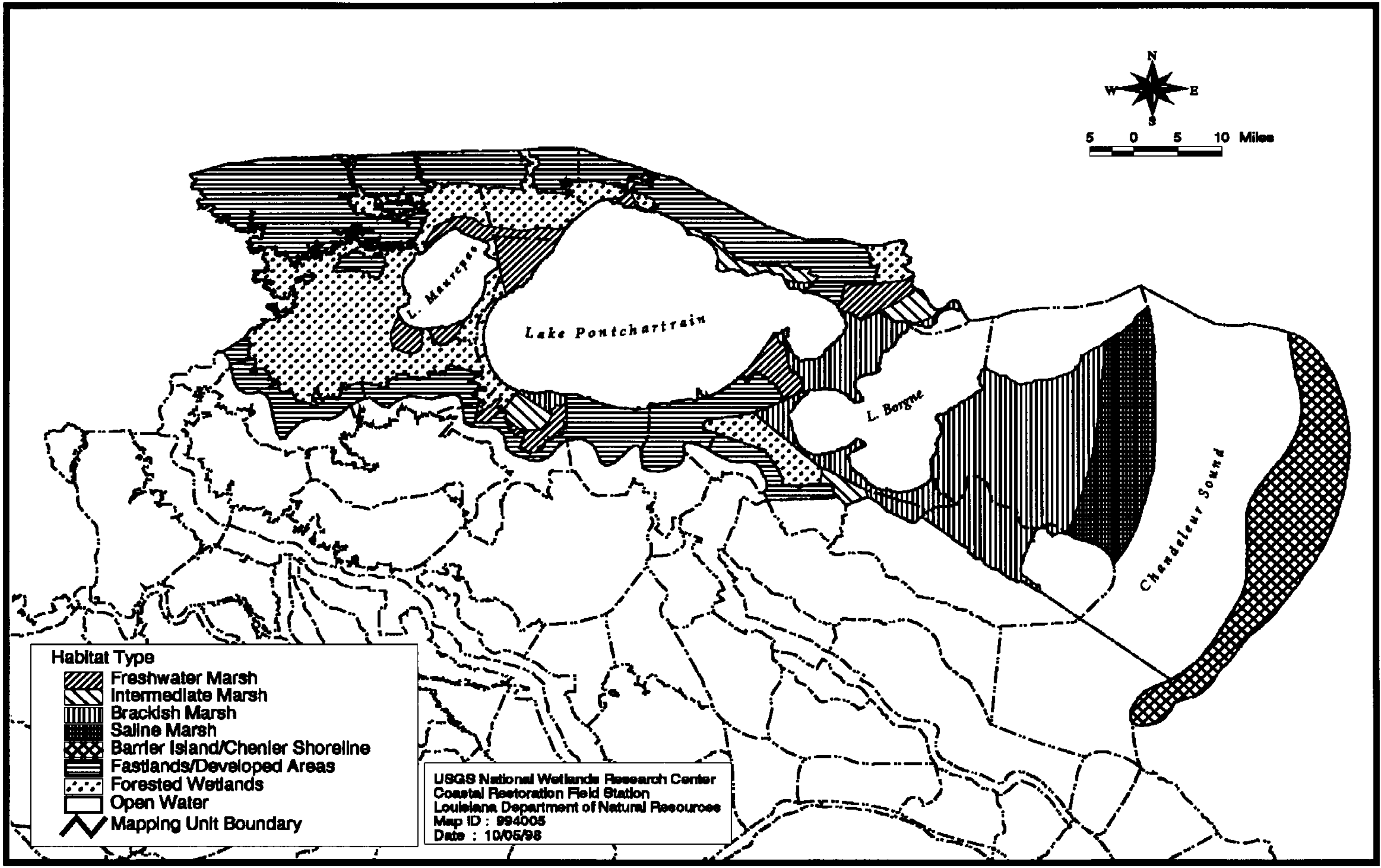


Figure 7-1. Coast 2050 habitat objectives for Region 1.

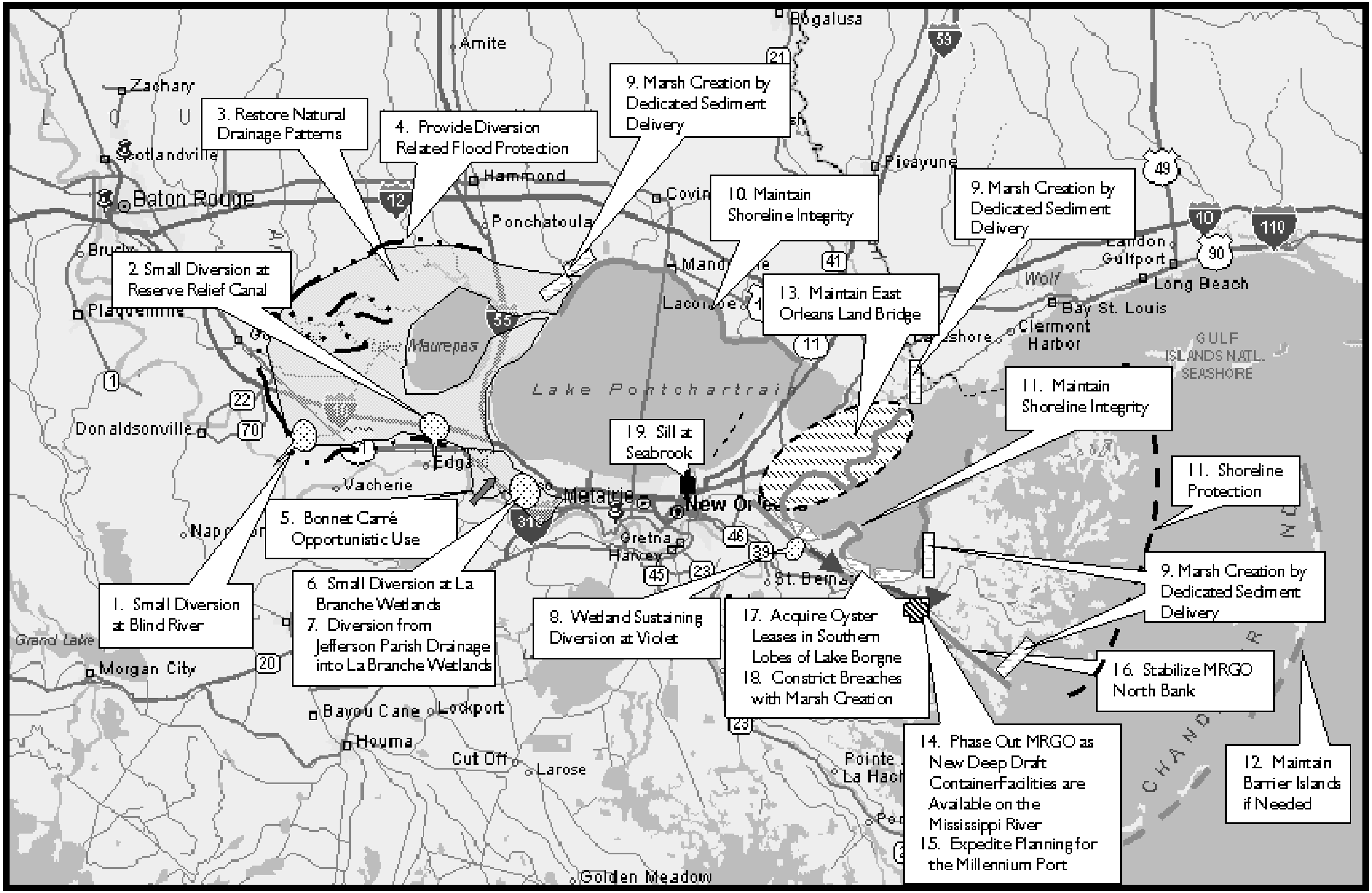


Figure 7-2. Coast 2050 Region 1 regional ecosystem strategies.

warranted in the Manchac and North Shore marshes and around the Pearl River mouth. Open water in the interior of the forested wetlands in and around Lake Maurepas is also recommended for reconversion to forest. Forested wetlands in the central wetlands, currently stressed by high salinity, are also denoted for expansion. Some of the saline marshes in the Biloxi Marsh mapping unit are recommended for conversion to brackish marsh.

Regional Ecosystem Strategies

Restore Swamps

1. Small Mississippi River diversion at Blind River with outfall management . The swamps in the Upper Basin are dying because they are subsiding, flooding, and lacking sediment and nutrients. A diversion of no greater than 2,000 cubic feet per second (cfs) at Blind River with outfall management (restoring natural drainage patterns by gapping spoil banks, plugging canals, and maintaining culverts) is proposed (Fig.7-2). This strategy is intended to preserve these swamps by reducing flooding and providing them with nutrients. At the present time, the extent of possible wetland benefits is uncertain.

2. Small Mississippi River diversion at Reserve Relief Canal with outfall management. A diversion of no greater than 2,000 cfs at the Reserve Relief Canal with outfall management is expected to preserve minor acreage in these swamps by reducing flooding and providing them with nutrients.

3. Restore natural drainage patterns . In areas of the Upper Basin where diversions are not built, natural drainage patterns would be restored by gapping spoil banks, plugging canals, and maintaining culverts. For instance, if the culverts under U.S. Highway 51 were properly maintained, the swamps to the west would be less stressed by ponded water. This strategy is projected to preserve minor amounts of swamp.

4. Provide diversion-related flood protection where needed . Additional flood protection and drainage would be provided to any developed areas in the Upper Basin that would be threatened by diversion-related flooding. Low levees would be provided at the wetland/nonwetland interface with pumped drainage. This strategy is necessary before any of the diversions can be built, and its benefits to wetlands will be indirect.

Restore/Sustain Marshes

5. Small diversion from the Mississippi River through the Bonnet Carré Spillway by opportunistically removing pins from the water control structure . The wetlands along the south shore of Lake Pontchartrain have a low loss rate, probably because the water diverted through the Bonnet Carré Spillway for flood control provides sediment and nutrients. Authorization would be sought for removing pins from the Bonnet Carré Flood Control Structure when the Mississippi River is high. The diverted water would provide additional nutrients and sediment to the wetlands adjoining Lake Pontchartrain. By removing pins early in the year, the fresh water and nutrients would be diverted to the lake before the warm temperatures could cause large algal blooms. Some of the additional water would be moved to the west, perhaps along the Old Hammond Highway borrow pit, to reach the Manchac wetlands. This strategy is expected to prevent the loss of a moderate amount of wetlands.

6. Small diversion of Mississippi River water into La Branche Wetlands. A small diversion from the Mississippi River could be made into the southern La Branche marshes. The diversion is likely to prevent the loss of a moderate amount of wetlands.

7. Diversion from Jefferson Parish drainage into La Branche Wetlands. Drainage water would be pumped into the swamps or marshes wherever feasible. Pumping water from the Jefferson Parish drainage canal is proposed to get additional fresh water and nutrients into the La Branche Wetlands. This strategy is expected to preserve a minor amount of wetlands.

8. Wetland sustaining diversion from the Mississippi River near Violet once the MRGO is closed. A 2,000 to 5,000 cfs diversion from the Mississippi River through the Violet Canal to sustain the Central Wetlands and Biloxi Marshes would be built. Such a diversion could not be effective until the MRGO is closed. This strategy is estimated to preserve moderate amounts of the marshes in the Central Wetlands and adjacent to Lake Borgne. These marshes provide significant hurricane buffering for the New Orleans metropolitan area.

9. Dedicated delivery of sediment for marsh building. Material could be pumped from adjacent lakes or rivers to create marsh in several units (Tchefuncte, Tangipahoa, and Pearl River mouths, Eloi Bay, and Biloxi marshes). This strategy is projected to create a moderate amount of marsh.

Protect Bay and Lake Shorelines

10. Maintain shoreline integrity of Lake Pontchartrain. Maintaining the shoreline integrity of Lake Pontchartrain needs to be addressed. Lake shoreline protection could be in the form of structural means (wave busters, gobi mats, rip-rap, etc.) or non-structural means (vegetative rolls or mats, vegetative plantings, etc.). This strategy is expected to preserve a minor amount of marsh.

11. Maintain shoreline integrity of Lake Borgne and protect shoreline of the Biloxi Marshes. Maintaining the shoreline integrity of Lake Borgne needs to be addressed. Lake shoreline protection could be achieved by structural means (wave busters, gobi mats, rip-rap, etc.) or non-structural means (vegetative rolls or mats, vegetative plantings, etc.). This strategy is projected to preserve a minor amount of marsh. Shoreline protection of the Biloxi Marshes is necessary because over 18% of the area will be lost by the year 2050 if nothing is done. Shoreline protection of the most seriously eroding areas is projected to preserve a moderate amount of marsh.

Restore and Maintain Barrier Islands

12. Maintain Chandeleur Islands if necessary. The Chandeleur Islands provide unique habitat in the basin: beaches, dunes, marshes, mudflats, and beds of submerged aquatic vegetation (SAV). The islands are fairly stable, but they breach regularly and are moving north and west. The islands were seriously damaged by Hurricane Georges in 1998. Portions of the Chandeleurs are protected with a wilderness designation that prevents any repair. Coordination with the U.S. Fish and Wildlife Service should occur and a request for a special exemption from Congress to allow island maintenance should be sought. Islands would be restored with material from offshore or from the maintenance of the MRGO. This strategy would maintain the 1990 acreage on the islands.

Maintain Critical Landforms

13. Maintain Eastern Orleans Land Bridge by marsh creation and shoreline protection. This land bridge protects the wetlands surrounding Lake Pontchartrain from higher salinity and higher energy waters. It is a fairly stable landform at the present time. If it appears that the land bridge is at risk, major efforts would be made to stabilize it. Marsh would be created and shoreline protected by dedicated dredging or beneficial use. Vegetative plantings could also be used. SAV beds would be restored. This strategy is estimated to preserve moderate amounts of marsh.

Special Problems—
Resolve the MRGO Problem

14. Close MRGO to deep draft navigation when adequate container facilities exist on the river. The MRGO is perceived as a major problem in the Pontchartrain Basin. Wave erosion causes a 15-foot per year loss along 37 miles of the north bank. When the MRGO was completed in the 1960's, salinity increased in the basin, causing massive environmental damage. Currently, the MRGO is the only access to container facilities on the Inner Harbor Navigation Canal. However, only 2-3 large ships per day use the waterway. Some container facilities have just been built on the Mississippi River in the New Orleans area, but they are generally fully booked.

A large new Millennium Port, including container facilities, is proposed in Plaquemines Parish. Once there are adequate container facilities on the river, the MRGO would be closed to deep draft navigation. The closure could be achieved by a structure (gate or weir) at the La Loutre ridge that would allow the passage of shallow-draft navigation but reduce salinities coming up the MRGO. In addition, the possibility of restoring the ridges at Bayous Bienvenue, Dupre, and Yscloskey should be studied. The strategy of actually closing the channel to deep draft shipping is expected to preserve minor amounts of marsh.

15. Expedite planning for the Millennium Port. The Millennium Port, a new deep draft port under consideration for construction in

Plaquemines Parish, would allow closure of the MRGO to large vessels. Planning for the Millennium Port should start immediately.

16. Stabilize the entire north bank of the MRGO. The U.S. Army Corps of Engineers (USACE) has placed some rock along the north bank of the MRGO under various authorities. Authorization and funding for more rock along the north bank would be sought. In addition, dredged material would continue to be used beneficially behind the rock. This strategy is projected to prevent the loss of a moderate amount of marsh.

17. Acquire oyster leases and create marsh in the southern lobes of Lake Borgne. Oyster leases in the two southern lobes of Lake Borgne (at Bayous Dupre and Yscloskey) would be purchased and marsh created in these lobes by beneficial use of dredged material. Rock dikes would contain the created marsh. The marsh would be maintained with maintenance material. This strategy is expected to create and preserve major amounts of marsh.

18. Constrict breaches between MRGO and Lake Borgne with created marshes . The rock needed to contain the created marsh would be placed so as to reduce the cross section of Bayous Dupre and Yscloskey. This constriction would reduce the salinity in Lake Borgne and the Biloxi Marshes. This strategy would improve the area slightly for oysters, but wetland benefits have not yet been estimated.

19. Construct a sill at Seabrook . During most summers, a large area of Lake Pontchartrain has very little dissolved oxygen at the bottom. This anoxic area is caused by salinity stratification due to the MRGO. This anoxic condition could be solved by constructing a sill at Seabrook. This strategy would improve fisheries in Lake Pontchartrain.

Sequencing of Regional Strategies

Near Term (1-5 years)

In the near term, easily constructed strategies should be implemented. Also, any strategies that are a necessary first step for other strategies should be built.

The possible benefits of the Mississippi River diversion at Blind River should be analyzed quickly because the cypress swamps west of Lake Maurepas are some of the most severely stressed in the basin. If the diversion is found to be feasible, the diversion-related flood protection must first be provided. This diversion and its outfall management should be closely monitored to verify its effectiveness.

Removing the pins from the Bonnet Carré Spillway when waters are high is a very easily implemented strategy and should be started as soon as authorization can be acquired. Pumping from the Jefferson Parish drainage canals into La Branche Wetlands should be started in the near term and monitored to see if this strategy is appropriate for additional areas. The small diversion from the Mississippi River into La Branche Wetlands should be built.

Continued use and management of the existing Violet siphon is recommended until the larger project is built. Critically eroding shorelines of Lakes Borgne and Pontchartrain, such as those along the shorelines of the East Manchac Land Bridge and the East Orleans Land Bridge, should be maintained, as should the eastern shoreline of Biloxi Marshes.

Construction of a sill at Seabrook should be accomplished in the near future. Dedicated delivery of sediment should be initiated in several units.

The north bank of the MRGO should be stabilized as soon as possible. Negotiations to purchase the oyster leases in the lobes of Lake Borgne should be initiated. Then, when the USACE needs new sites for beneficial use of dredged material, these areas will be available. Planning for the Millennium Port or alternatives should be expedited. Potential benefits, including public safety, of closing the MRGO should be evaluated.

Dialogue should be initiated with the U.S. Fish and Wildlife Service to determine the appropriateness of a specific change in the wilderness designation for Breton National Wildlife Refuge that would allow restoration of the Chandeleur Islands after severe damage such as that from Hurricane Georges in 1998.

Intermediate Term (6-15 years)

If the diversion at Blind River proves effective in restoring swamps, the Reserve Relief Canal diversion should be built. If land loss appears to be increasing on the Eastern Orleans Land Bridge, restoration should be initiated. Studies should be initiated on the 2,000-5,000 cfs diversion proposed for the Violet Canal. Plans should be made for the eventual closure of the MRGO with a sill or gate at La Loutre.

Long Term (16-50 years)

The MRGO should be closed to deep-draft navigation. The wetland sustaining diversion at Violet should be built. Possibilities for other freshwater diversions from the Mississippi River into swamps should be sought if the previous ones have proved effective.

Local and Common Strategies

There are some important local and common strategies in Region 1. Shoreline integrity could be maintained in all mapping units (Fig. 7-3) around Lakes Maurepas, Pontchartrain, and Borgne. Vegetative plantings of cypress and/or marsh grass could occur in nearly all units. Dedicated dredging from Lakes Maurepas, Pontchartrain, and Borgne could be used to create marsh on the West and East Manchac Land Bridges, in La Branche Wetlands, the East Orleans Land Bridge, in South Lake Borgne and along the south shore of Lake Pontchartrain near Lincoln Beach.

Beneficial use of dredged material from the Tangipahoa bar channel could occur. Dredged material from the MRGO could be used to create marsh in South Lake Borgne, the Biloxi Marshes, and Eloi Bay.

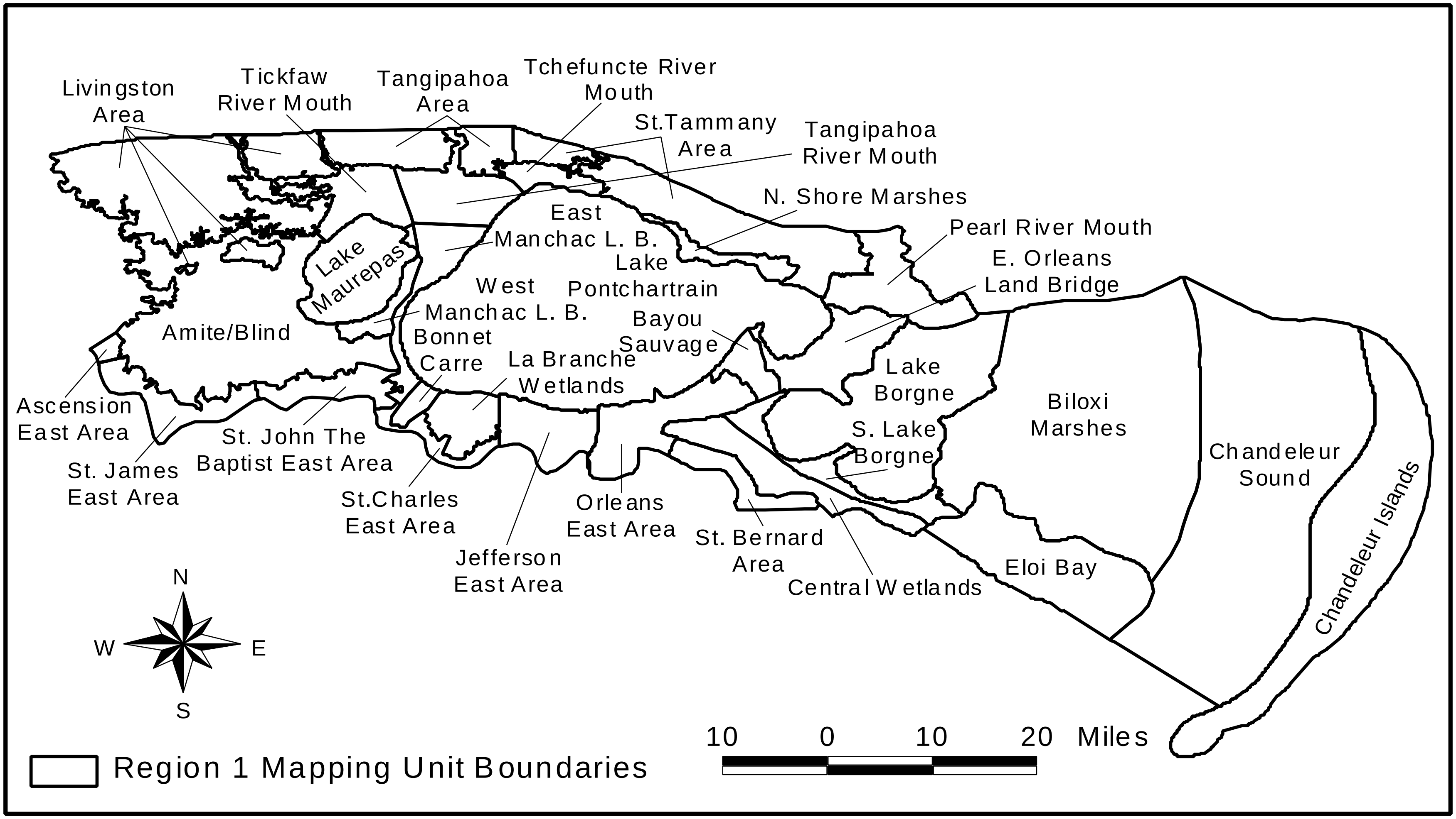


Figure 7-3. Region 1 mapping units.

Submerged aquatic vegetation could be restored in Lakes Pontchartrain and Maurepas, in ponds on the East Orleans Land Bridge and in Chandeleur Sound. Wave breaks and rubble mounds could maintain shoreline integrity and improve fisheries habitat in Lake Pontchartrain. In Lake Borgne and the Biloxi Marshes, reef zones could enhance oyster production. Hydrologic restoration could be accomplished on the Manchac Land Bridges East and West, the North Shore marshes, the La Branche Wetlands, East Orleans Land Bridge, Bayou Sauvage, the Central Wetlands, South Lake Borgne, the Biloxi Marshes, and Eloi Bay. See Appendix C for more details on these local and common strategies.

Region 2 Strategic Plan

Background

Region 2 includes the Breton Sound, Barataria Basin, and the Mississippi River Birdsfoot Delta. It stretches from the MRGO on the east, to Bayou Lafourche on the west, to the Mississippi River on the north and the Gulf of Mexico on the south. It covers all or part of the following parishes: St. Bernard, Plaquemines, Jefferson, Lafourche, St. Charles, St. James, St. John the Baptist, and Assumption.

It is an area with great habitat diversity. Extensive bottomland hardwood forests (90,000 acres) lie adjacent to the Mississippi River and Bayou Lafourche. Over 146,000 acres of cypress-tupelo swamps cover the upper Barataria Basin. South of the swamps, vast marshes extend to the Gulf of Mexico in the Mississippi Delta, Barataria and Breton Basins (220,100 acres of fresh marshes, nearly 73,000 acres of intermediate marshes, 214,500 acres of brackish marshes, and 151,100 acres of saline marshes). The fresh marshes are found in the north, with a band of intermediate marsh lying southward. The central portion of the basins contain brackish marshes; saline marshes fringe the Gulf of Mexico and Breton Sound. The southern end of the Barataria Basin is bounded by a series of barrier headlands, islands and shorelines.

Habitat Objectives

Habitat objectives for the year 2050 were first suggested by parish governments and representatives of local coastal zone advisory committees. Then, as the Regional Planning Team developed strategies, the habitat objectives were revised to correlate with the strategies. These revised objectives were approved by parishes. Because several large diversions into the Barataria Basin are proposed, the habitat objectives include fresh marsh extending south of Little Lake and across the basin through the Myrtle Grove unit (Figs. 7-4, 7-5).

Another objective is a new strip of fresh marsh parallel to the Mississippi River from West Point a la Hache to Venice and near the river in American Bay. A band of intermediate marsh gulfward of the fresh marsh with brackish marsh to its south is also desired. The only remaining saline marsh would be near Barataria Bay. The barrier islands and shorelines would be restored. Regional interested parties prefer the Mississippi River Birdsfoot Delta to remain as it is now.

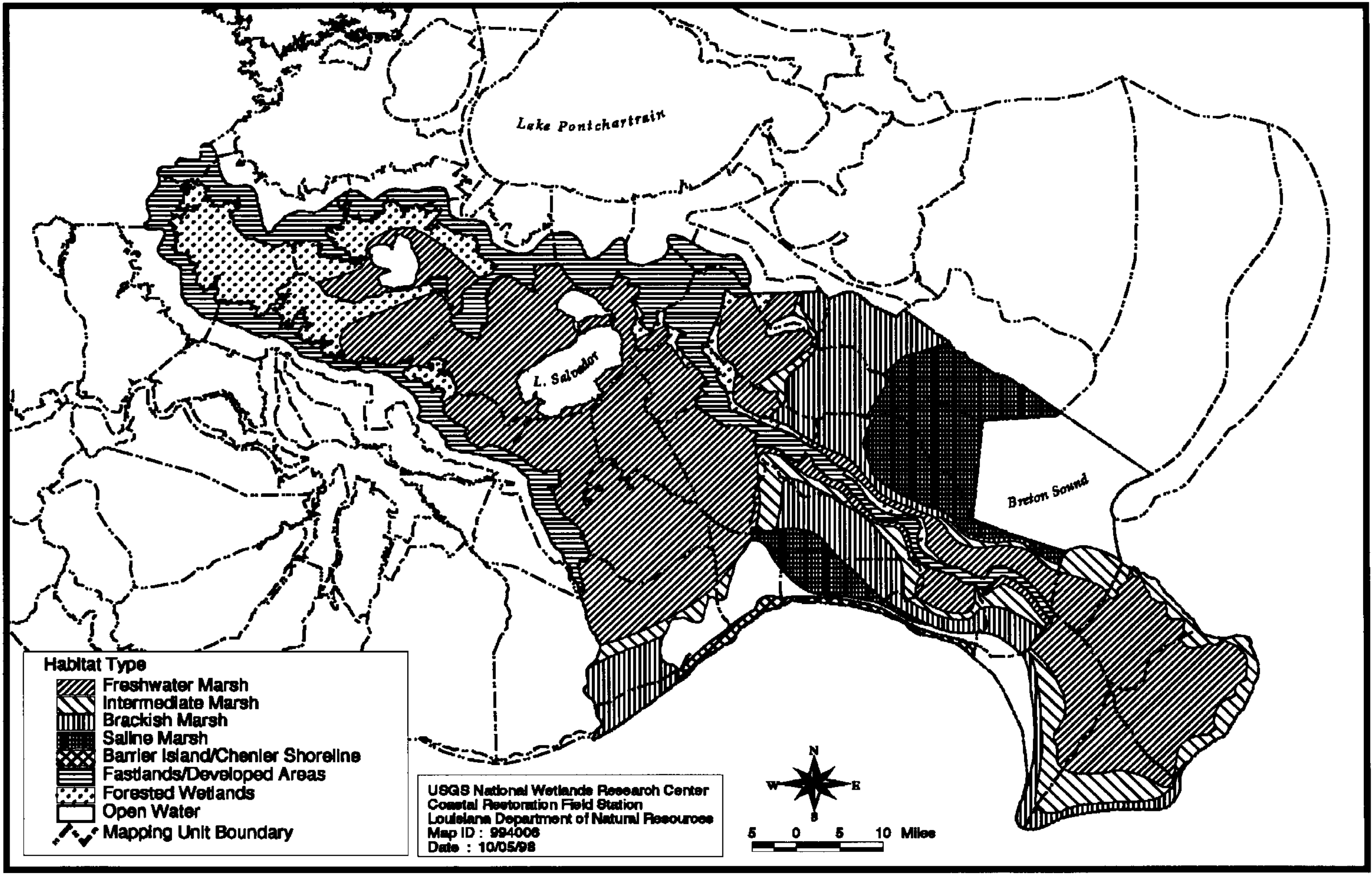


Figure 7-4. Coast 2050 habitat objectives for Region 2.

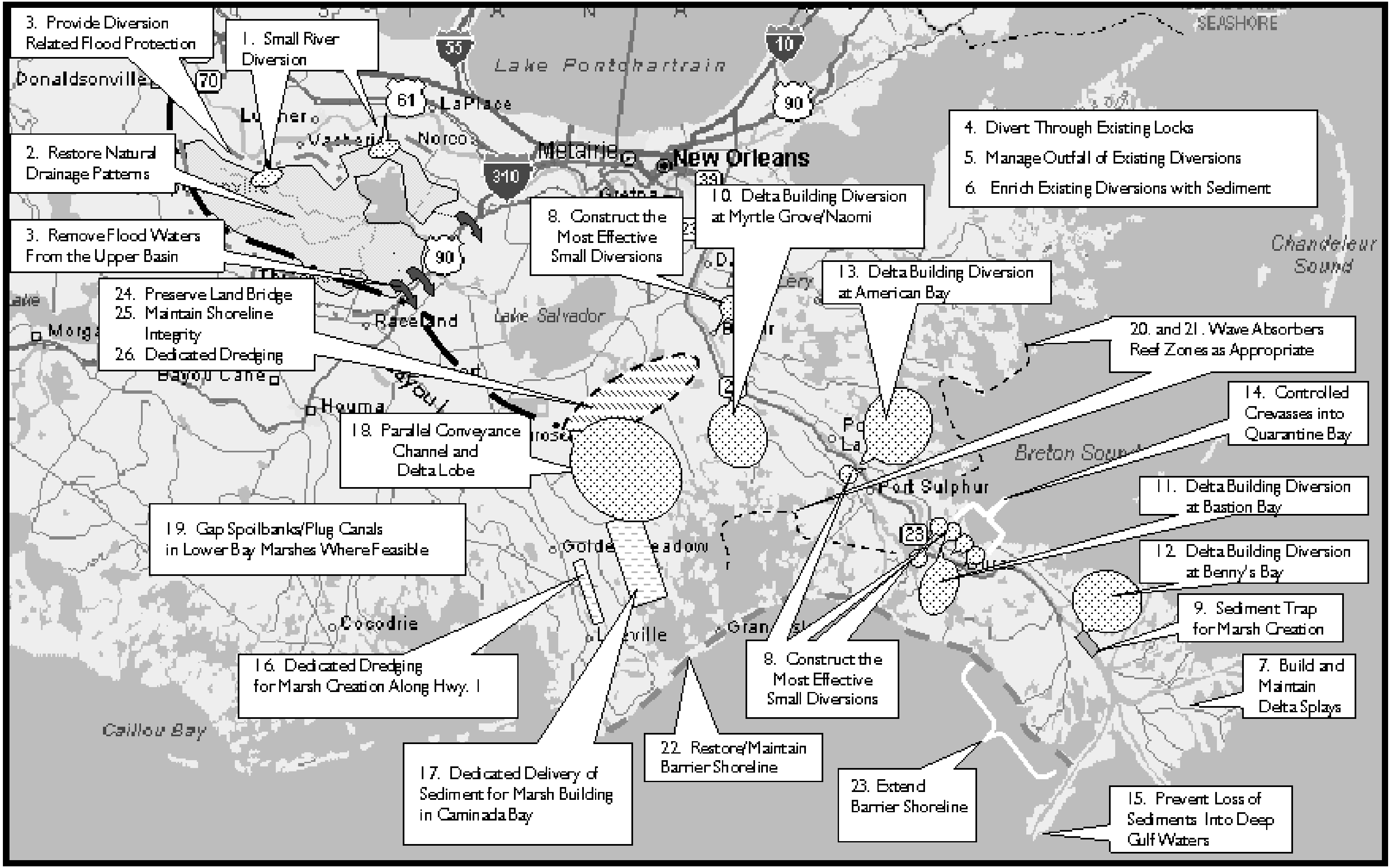


Figure 7-5. Coast 2050 Region 2 regional ecosystem strategies.

Regional Ecosystem Strategies

Restore Swamps

1. Construct small diversions with outfall management. A possible strategy to preserve the stressed upper basin swamps is to construct several small sediment-rich diversions from the Mississippi River. The outfall of the diversions should be managed to spread the water across the swamp, keep the water moving and prevent ponding. The nutrients and small amounts of sediment brought in by the river should slightly increase productivity and vertical accretion in the swamps. This strategy is projected to preserve a minor amount of swamp habitat.

2. Restore natural drainage patterns. Another strategy consists of restoring natural drainage by gapping spoil banks and plugging canals where these actions would not cause adverse effects. It would be implemented in swamps where it is not possible to provide freshwater diversions. It would be less effective in preventing swamp loss than the previous strategy which brought in fresh water.

3. Prevent diversion-related flooding and remove diverted waters from the upper basin. To add water to the swamps, flood protection must be provided for developed areas, and drainage improvements must be made so the water can exit the upper basin. Local forced drainage should be provided at the wetland/nonwetland interface so the swamps are separated from the developed regions. Environmentally sound pumping plans should be developed so storm water is filtered through the swamps. U.S. Highway 90 should be raised and sufficient flap-gated culverts should be installed so that rainfall and the additional river water could drain south by gravity.

Restore and Sustain Marshes

4. Use existing locks to divert Mississippi River water. The existing locks on the Mississippi River (Algiers and Empire) could be used to divert as much water as possible. At the present time, the USACE is releasing fresh water through the Algiers Lock whenever the stage is low on the marsh side. The existing Harvey Lock cannot be used for small diversions, but when a replacement lock is needed for navigation, it should be also designed so that small diversions would be feasible. Implementation of this strategy is projected to preserve a moderate amount of marsh by 2050.

5. Manage outfall of existing diversions. The siphons at Naomi and West Pointe a la Hache already have Breaux Act outfall management plans. These 20-year plans could be continued through 2050. The authorized outfall management plan at Caernarvon should be implemented. A plan should be developed for the Davis Pond diversion. This strategy is estimated to moderately reduce marsh loss by 2050.

6. *Enrich existing diversions with sediment*. This enrichment is difficult to engineer at the siphons because extra sediment could cause clogging. This concept should be pursued at Davis Pond and Caernarvon. Additional

sediment is expected to preserve a minor amount of marsh by 2050.

7. Continue building and maintaining delta splays. The Mississippi River is creating marsh naturally on the east bank, south of Bohemia and in the Birdsfoot Delta. The natural delta on the east bank should be maintained. The Breaux Act program of building and maintaining delta splays in the Birdsfoot Delta should be continued through 2050. This strategy is projected to create a moderate amount of new land.

8. Construct most effective small diversions . Several small diversions from the Mississippi River have been suggested as Breaux Act projects or are being studied in the Mississippi River Sediment, Nutrient, and Freshwater Redistribution Study. The most effective of these small diversions should be planned and built (Upper Oak River, Amoretta, east and west of Empire). The above-mentioned diversions are projected to prevent a moderate amount of marsh loss by 2050.

9. Construct sediment trap in the Mississippi River south of Venice . To reduce maintenance dredging in Southwest Pass, the USACE is studying the possibility of a sediment trap south of Venice. Material that would normally be dredged and "ocean dumped" could be used beneficially. The trap would be pumped out by a dustpan dredge and significant amounts of marsh are projected to be created in the Birdsfoot Delta.

10. Construct a delta-building diversion in Myrtle Grove/Naomi area (15,000 cfs). A delta-building diversion from the Mississippi River should be built in the vicinity of Myrtle Grove or Naomi. Such a diversion is estimated to have significant benefits by creating land and preventing loss in the central basin by 2050.

11. Construct delta-building diversion in Bastion Bay (about 15,000 cfs) . A delta-building diversion of about 15,000 cfs into Bastion Bay would create land and significantly reduce land loss in the vicinity. This strategy must address oyster lease issues. The strategy would also partially fill the borrow pit left from the construction of the New Orleans-to-Venice hurricane protection levee. Local interested parties are concerned that this pit is increasing marsh loss and causing increased salinities in the developed area.

12. Construct delta-building diversion into Benny's Bay (about 50,000 cfs) . A very large diversion in the Birdsfoot Delta between Main Pass and Baptiste Collette Bayou is projected to create a substantial amount of land and reduce future marsh loss.

13. Construct a delta-building diversion into American Bay (20,000 to 100,000 cfs). This strategy is projected to create/preserve a moderate amount of land with a small diversion and a significant amount with the large diversion. This strategy must address oyster lease issues.

14. Construct delta-building diversion through controlled crevasses into Quarantine Bay. This strategy consists of breaching the natural levee between Bayou Lamoque and Fort St. Phillip to allow about 40,000 cfs to enter Quarantine Bay. Most of the sediment would be kept in Quarantine Bay by a low levee from California Point to Sable Island. This diversion is projected to create a significant amount of marsh and reduce loss in the vicinity. This strategy should not significantly impact oysters.

15. Prevent the loss of bedload into deep gulf waters off the Continental Shelf by relocating the Mississippi River Navigation Channel.
One of the most significant ecological problems in coastal Louisiana is the loss of major amounts of Mississippi River sediments, including the bedload, into deep gulf waters. This strategy would dissociate riverine processes and navigation and thus allow the Mississippi River sediments to build and nourish marshes. Navigation would be handled by a new channel exiting to the east or west (but not north of Venice) with at least a double set of locks. The strategy is expected to create a significant amount of land in the long term.

16. Dedicated dredging to create marsh near Louisiana Highway 1 . This strategy would protect the vulnerable highway with a 1,000-acre band of marsh in the Caminada Bay unit.

17. Dedicated delivery of sediment for marsh building in Caminada Bay. The marshes adjacent to the southern end of Bayou Lafourche are deteriorating rapidly and are far from any riverine sediment. One possible solution involves pumping material from offshore to the deteriorating marsh-pond complex to create significant areas of marsh adjacent to Bayou Lafourche. This strategy would not be self-sustaining, but it is projected to result in creating a moderate amount of marsh by 2050.

18. Construct a large conveyance channel parallel to Bayou Lafourche to divert approximately 30,000 cfs to create a delta lobe in and near Little Lake. The potentially most effective alternative for rebuilding this collapsed wetland system is to initiate a new subdelta in the area. The subdelta could be accomplished by building a conveyance channel about one-third the size of the Wax Lake Outlet that would leave the Mississippi River south of Donaldsonville and parallel Bayou Lafourche at the Forty Arpent line (Gagliano and van Beek 1993; Gagliano and van Beek 1998).

One branch of the channel would cross Bayou Lafourche north of the Gulf Intracoastal Waterway and build a delta in the Bully Camp area of Region 3. The other branch would stay on the east side of the bayou and nourish marshes or build a delta in and near Little Lake. Small diversions from the conveyance channel could be directed into wetlands in the northern portion of the basin. The main conveyance channel could be used as a floodway when the Mississippi River is high.

After consolidation, material dredged from the channel might provide a base for a new State Highway 1. Any possible navigation features of this strategy must not impede the land-building capacity of the diversion.

This strategy is projected to create significant amounts of marsh in the Little Lake mapping unit, reduce marsh loss over the entire western portion of the Barataria Basin, and help preserve swamp in the upper basin.

19. Gap spoil banks and plug canals in lower bay marshes. Where determined to be appropriate and feasible, spoil banks would be gapped and canals plugged to maximize sediment deposition in marshes adjacent to the bays in the lower portions of Breton and Barataria Basins. This strategy is estimated to prevent a minor amount of loss.

Protect Bay and Lake Shorelines

20. Construct wave absorbers at the heads of bays. Low breakwaters would be built at the heads of bays, as described in the Barrier Shoreline Feasibility Study, to protect fringing marshes. The possibility of continuing these wave absorbers across the southern rim of the Lake Washington/Grand Ecaille unit and also across the mouth of the Breton Basin would also be considered. This strategy is projected to preserve a major amount of marsh.

21. Construct reef zones across bays. Reef zones would be constructed across bays. This strategy has no mappable marsh benefits but would enhance estuarine fisheries habitat.

Restore and Maintain Barrier Islands and Barrier Shorelines

22. Restore/maintain barrier headlands, islands, and shorelines . The Fourchon headland, barrier islands, and barrier shoreline are among the most rapidly retreating shorelines in the region. These areas would be restored by the most cost-effective of the sand alternatives from the Barrier Shoreline Feasibility Study. This strategy is projected to create moderate amounts of marsh and beach habitat by 2050. Additional unmappable benefits would be gained by protecting, restoring, or creating wooded areas critical for neotropical migrants.

23. Extend and maintain barrier shoreline from Sandy Point to Southwest Pass. The Plaquemines Parish Council has requested that the barrier shoreline be extended from Sandy Point to Southwest Pass. Material from the sediment trap (see Strategy 9) could possibly be used to build such a shoreline.

Maintain Critical Landforms - (Central Basin Land Bridge)

24. Build entire Breaux Act land bridge shore protection project . The southern portion of the Perot/Rigolettes unit must be kept intact to protect the marshes farther north. This project should be built and maintained through 2050. It is expected to preserve a moderate amount of marsh by 2050.

25. Preserve bay and lake shoreline integrity on the land bridge . The southern shores of Little Lake are in danger of breaching into interior marsh, and the Gulf Intracoastal Waterway is about to breach into Lake Salvador on the south shore of the lake. These shorelines should be stabilized. This strategy is projected to prevent the loss of a moderate amount of marsh.

26. Dedicated dredging to create marsh on the land bridge . This strategy consists of dedicated dredging to create about 1,000 acres of marsh north of the Bayou L'Ours ridge to help stabilize the land bridge.

27. Build the Bayou Lafourche siphon and pump project, if cost effective . The possibility of a small pumped diversion down Bayou Lafourche is being studied. The waters could be directed into the Clovelly area to preserve a minor amount of land bridge marshes.

Sequencing of Regional Strategies

Near Term (1-5 years)

Authority should immediately be obtained to create a strip of marsh adjacent to Highway 1. The USACE is initiating a Reconnaissance Report for the area from Donaldsonville to the Gulf of Mexico. This report will focus on flood control, wetland conservation and restoration, wildlife and fish, and navigation. Those responsible for implementing the Coast 2050 program should maintain close coordination with this effort so the upper basin swamps can be restored as quickly as possible.

When the Barrier Shoreline Feasibility Study is finalized, authority should be quickly sought to construct the recommended alternative. The barrier headlands, islands, and shoreline should be restored as soon as possible. Wave absorbers should be built to preserve marshes at the heads of bays.

Construction of a full Breaux Act land bridge project should be a high priority. Authority should be sought to stabilize the southern shorelines of Lake Salvador and Little Lake. Consideration should be given to a dedicated dredging project near the Bayou L'Ours ridge under Breaux Act authority. If the Bayou Lafourche Pumping project is cost effective, it should be built.

The relocation of the Mississippi River navigation channel to allow better utilization of river sediments to create marsh should be analyzed. Studies should be started immediately to determine methods to prevent loss of massive amounts of sediments off the Continental Shelf.

The marshes in lower Barataria Basin are no longer sustainable without a massive infusion of sediment from the Mississippi River. The Breton Basin and Birdsfoot Delta offer opportunities for delta building diversions. The Regional Planning Team reached consensus on the following sequenced set of strategies to utilize the river.

- The 50,000-cfs authorized Breaux Act diversion at West Bay in the Birdsfoot Delta should be built as soon as possible.

- Short studies should be done to determine the feasibility of using the existing locks to divert river water and enriching existing diversions with sediment. These strategies could be accomplished by the USACE under an existing authority such as Section 1135.

- Outfall management plans should be developed for the Davis Pond Diversion, possibly under the Breaux Act.

- The most effective small diversions should be considered as priority list projects for the Breaux Act.

Once the USACE completes the Mississippi River Sediment, Nutrient, and Freshwater Redistribution Feasibility Study, consideration should be given to immediately implementing the sediment trap concept and constructing a delta-building diversion in the Myrtle Grove/Naomi area. Monitoring the Myrtle Grove Diversion would provide information to aid in planning the next diversion.

There are several considerations involved in these diversions: oyster lease issues, land rights issues in terms of who owns mineral rights on the new land, and the possibility of increased maintenance dredging in the Mississippi River. Timing is another important consideration; one way to create an artificial delta would be to pulse large amounts of water into the area every few years.

Restoration of the barrier islands and river diversions act synergistically and are critical to the long-term sustainability of the estuarine ecosystem.

The only way to prevent the loss of the southwestern portion of the Barataria Basin adjacent to Bayou Lafourche is by importing massive amounts of sediment, either by dedicated dredging or by a conveyance channel from the Mississippi River parallel to Bayou Lafourche. A feasibility study should be initiated in the near term. Planning and construction phases would be very complicated because of the large project area and its expected impacts to existing uses such as land-based transportation, navigation, agriculture, drainage systems, harvest of estuarine species, and flood protection systems. While planning could begin in the near term, diversion implementation would likely be in the long term.

Intermediate Term (6-15 years)

The Regional Planning Team agreed that the following delta-building diversions should be built in sequence once the Myrtle Grove Diversion is complete: Bastion Bay from Buras, Benny's Bay, and Quarantine and American Bays.

Long Term (16-50 years)

The conveyance channel from the Mississippi River into the Little Lake area should be built, if feasible. The Breaux Act delta-splay project and the siphon outfall management projects should be continued from years 21-50.

During the regional meetings, some diversion scenarios were suggested that were not sequenced by the Regional Planning Team: major diversions at Amoretta and American Bay. The team preferred that these strategies be considered only after all other strategies had been built or rejected as infeasible.

Local and Common Strategies

Local strategies for Region 2 mapping units (Fig. 7-6) include restoring hydrology in the Myrtle Grove area by various methods. The depth of South Pass could be limited to that necessary for navigation, and more flow should be encouraged to exit through Pass à Loutre. A small freshwater diversion with outfall management could be built at Homeplace. Grand Pass could be enriched with sediment from the Mississippi River. Whenever the opportunity arises, the hurricane protection levee borrow canal that runs from near Venice to Empire could be filled to create marsh. Wave absorbers could be placed along the barrier shoreline. Either the Empire jetties could be removed or a sand bypass system built.

There are several common, coastwide strategies that could be adopted. Herbivory control could occur in the Baker, Cataouatche/Salvador, des Allemends, Naomi, and Perot/Rigolettes units. Maintaining shoreline integrity is especially important around Caminada Bay and Lake Cataouatche. Vegetative plantings could be considered.

The banks of the Gulf Intracoastal Waterway, the Barataria Bay Waterway, and the Southwest Louisiana Canal could be stabilized. The pumps connected with the Larose-to-Golden Meadow hurricane protection project could be relocated or redirected to place outfall into the marsh instead of canals. The function of the Bayou Barataria and Bayou L'Ours ridges could be maintained. The oak ridges on the barrier islands and shoreline could be reestablished. Dredged material from the Barataria Bay Waterway and from South, Baptiste Collette, Grand and Tiger Passes could be used to create marsh. Efforts should be made to beneficially use more material from the Mississippi River. Material could be dredged from offshore to build marsh in Barataria Bay, behind the barrier islands, and in Baptiste Collette, Pass a Loutre and East Bay units. Material from South Pass could be used to create a barrier to protect marshes along Southwest Pass. For a detailed matrix of local and common strategies by mapping unit, see Appendix D.

Region 3 Strategic Plan

Background

Region 3 encompasses the Terrebonne, Atchafalaya, and the Teche-Vermilion Basins. The region extends from Bayou Lafourche on the east, to Freshwater Bayou Canal on the west, and north to the boundary of coastal wetlands as defined in the Louisiana Coastal Wetlands Conservation Plan (La. Dept. of Natural Resources 1997). It covers all or part of the following parishes: Lafourche, Terrebonne, Assumption, Iberville, St. Martin, Iberia, St. Mary, Lafayette, and Vermilion.

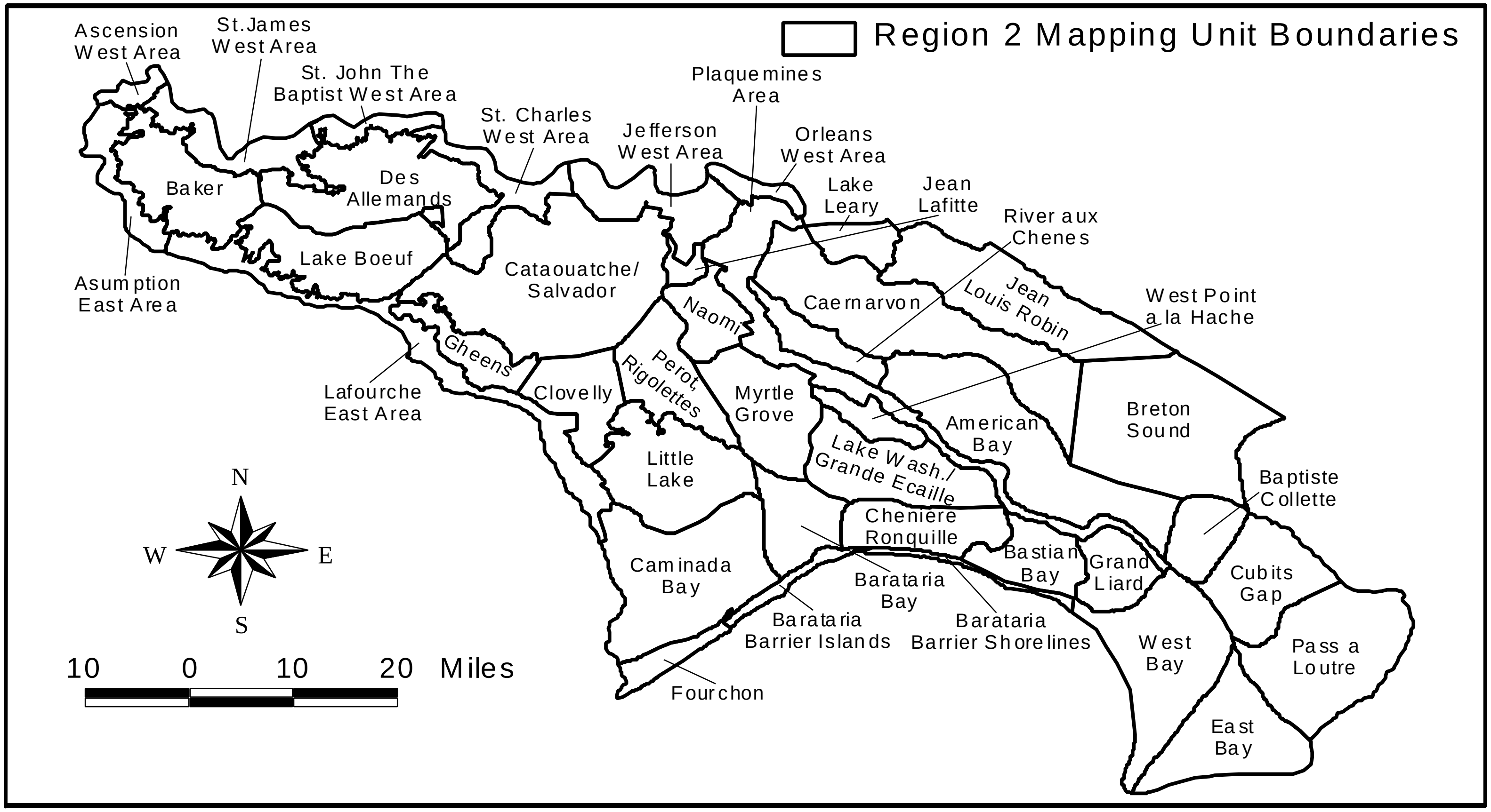


Figure 7-6. Region 2 mapping units.

This region covers 1,107,900 acres of vegetated wetlands. The region contains approximately 368,550 acres of cypress and bottomland forest. South of the forested wetlands lie 298,300 acres of fresh marsh, 92,700 acres of intermediate marsh, 240,700 acres of brackish marsh, and 140,200 acres of saline marsh.

The Region is divided into three basins (Terrebonne, Atchafalaya, and Teche-Vermilion). Terrebonne Basin is divided into four distinct subbasins. The Verret Subbasin is north of Bayous Boeuf and Black and west of Bayous Terrebonne and Lafourche. It contains forested wetlands and large lakes. The Fields Subbasin lies north and east of Bayou Terrebonne and north of Bayou Blue, and its wetlands are fresh marshes. The Penchant Subbasin is south of Bayous Boeuf and Black, east of the Atchafalaya River and Bay, west of Bayou Du Large, and includes Point au Fer Island. Penchant's major habitats range from large areas of highly organic fresh floating marshes to more mineral brackish marshes. The Timbalier Subbasin is south of Bayous Terrebonne and Blue, east of Bayou DuLarge and west of Bayou Lafourche. Timbalier's major habitat types range from organic fresh marshes through saline marshes to barrier islands. The Atchafalaya Basin includes Atchafalaya Bay and the northern marshes. The Teche-Vermilion Basin extends from Point Chevreuil to Freshwater Bayou Canal and includes the fresh to brackish East and West Cote Blanche Bays, Vermilion Bay, and the surrounding marshes.

Habitat Objectives

Habitat objectives for the year 2050 were first suggested by parish governments and representatives of local coastal zone advisory committees. Then, as the Regional Planning Team developed strategies, the habitat objectives were revised to correlate with the strategies. These revised objectives were approved by the parishes. Generally, parish governments and the public in Region 3 would like to maintain present habitats in areas above the Gulf Intracoastal Waterway and revert to past habitats in areas below the Gulf Intracoastal Waterway (Figs. 7-7, 7-8).

Regional Ecosystem Strategies

Restore Swamps

1. Improve hydrology and drainage in the Verret Subbasin . Implementation of a flood protection feature from the USACE Lower Atchafalaya River Reevaluation Study would alleviate the problems associated with chronic and excessive backwater flooding that is largely due to Atchafalaya River influence. This feature, known as the "Barrier Plan," would block water exchange from south to north at U.S. Highway 90 between Morgan City and Houma. Pumps would be installed to remove excess water from the Verret Subbasin. The effect of this action on floating marshes in the Penchant Subbasin is uncertain at this time, but the water should be distributed so as not to impact these wetlands. Additional measures, such as introducing

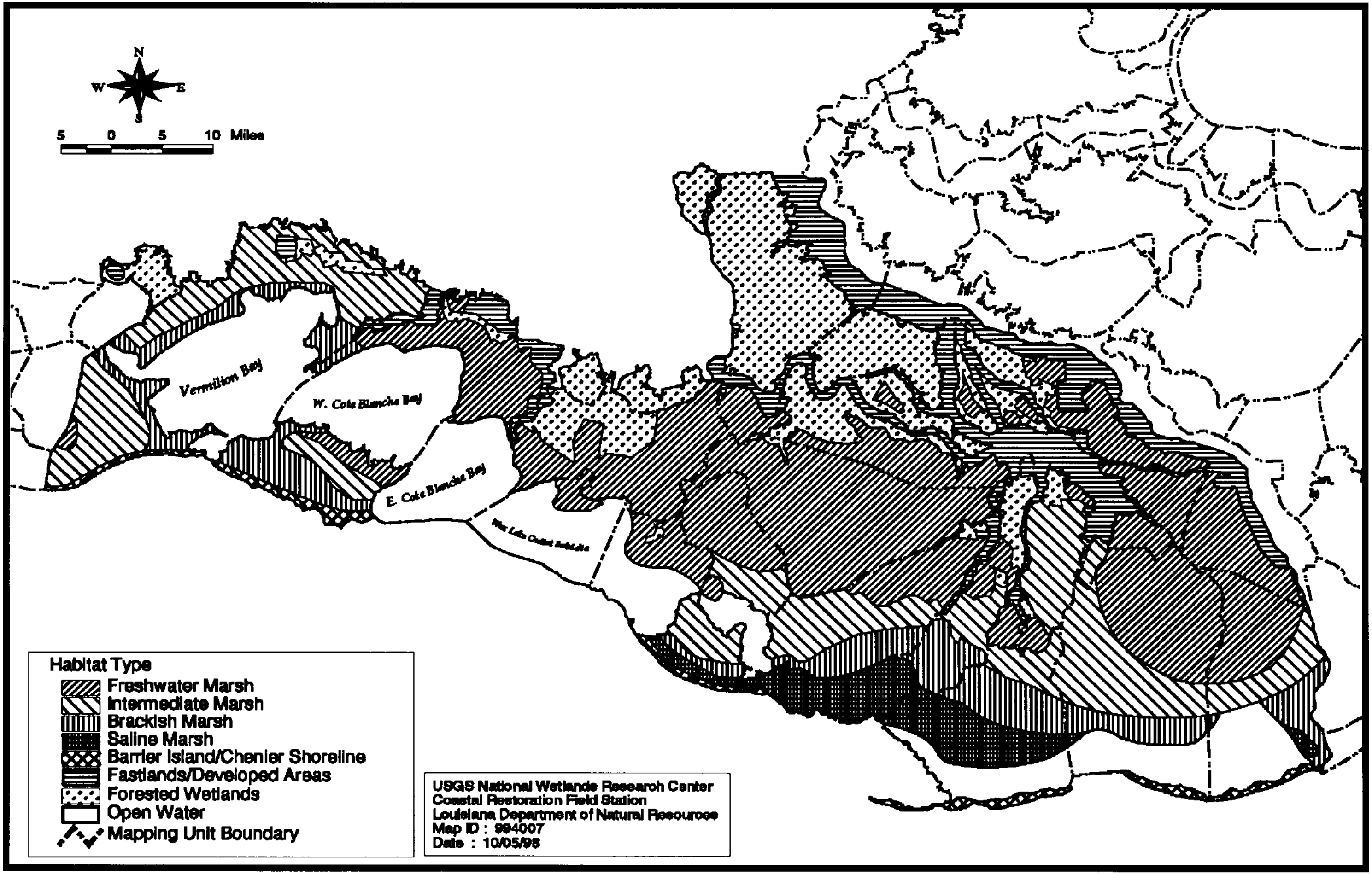


Figure 7-7. Coast 2050 habitat objectives for Region 3.

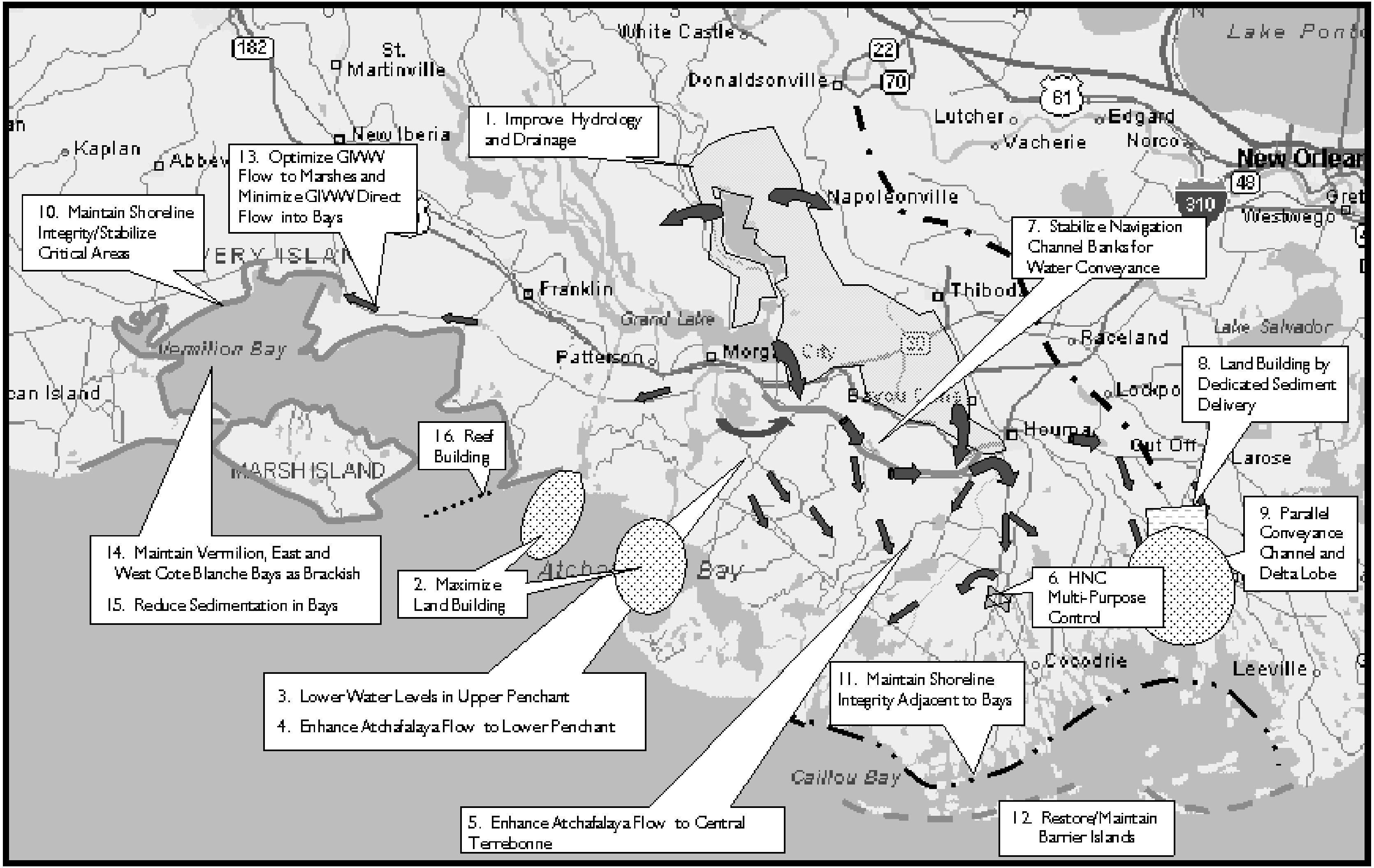


Figure 7-8. Coast 2050 Region 3 regional ecosystem strategies.

supplemental water from the Atchafalaya River or the Mississippi River to the Verret Subbasin during drought conditions to address water quality needs, would be considered. Implementation of this strategy would benefit about 200,000 acres of forested wetlands and prevent most future swamp loss. The strategy would protect the affected communities, industries, and agricultural lands from flooding.

Restore and Sustain Marshes

2. Maximize land building in Atchafalaya Bay. This strategy entails implementing a delta management plan in Atchafalaya Bay to maximize land building. One feature would be to separate navigation from the delta development zone, thereby allowing more efficient delta growth and reduced navigation channel maintenance. Another element of the strategy would be to train a delta lobe to extend toward Four League Bay to protect nearby mainland marshes from storm surges and to increase the amount of sediment available for transit into the marshes from storms. The delta management plan would attempt to contain land building sediments in Atchafalaya Bay rather than filling bays to the west. This strategy would maintain the processes that preserve the mainland wetlands in the Atchafalaya outlets area. This strategy is anticipated to create substantial amounts of marsh by 2050.

3. Lower water levels in upper Penchant marshes. Wetland stress in the upper Penchant Subbasin is associated with excessive flooding from the Atchafalaya River and the Verret Subbasin. Modifying water flow patterns to distribute the fresh water to other wetland areas, especially the lower Penchant marshes, would relieve the excessive flooding. Reducing water levels would reduce wetland losses in upper Penchant.

4. Increase transfer of Atchafalaya River water to lower Penchant tidal marshes. Tidal marshes adjacent to Four League Bay are strongly influenced by Atchafalaya River flows. These marshes are generally healthy whereas marshes farther east receive less Atchafalaya influence and are experiencing higher rates of loss. This strategy would implement measures to distribute more Atchafalaya flow to the tidal marshes in the vicinity of Lake Mechant and Caillou Lake. Wetland losses are anticipated to be reduced by the increased flow of fresh water and nutrients.

5. Enhance Atchafalaya River water influence to central Terrebonne marshes (Bayou Dularge to Bayou Terrebonne). Implementation of this strategy would expand the zone of beneficial influence by modifying water flow patterns to distribute Atchafalaya flow farther east and to adjust the north to south drainage in the area's watersheds as necessary to maximize wetland benefits. Wetland losses are expected to be reduced by the increased flow of fresh water and nutrients.

6. Establish multipurpose control of Houma Navigation Canal. A lock or gate on the Houma Navigation Canal is a feature in the ongoing Morganza-to-the-

Gulf Study that could aid in accomplishing the strategy for enhancing central Terrebonne marshes. The lock and connecting levees could allow more efficient use of Atchafalaya River water and sediment flow, aid in maintaining salinity regimes favorable to area wetlands, and provide hurricane protection to residents of Terrebonne Parish. More fresh water and less salt water north of the lock are anticipated to reduce wetland losses.

7. Stabilize banks of navigation channels for water conveyance . The Avoca Cutoff Channel, Bayou Chene, the Gulf Intracoastal Waterway (between the Atchafalaya River and Bayou Lafourche), and the Houma Navigation Canal would function as major conveyance channels for Atchafalaya flow distribution. Some of the banks have deteriorated. To perform a conveyance function, the deteriorated channel banks would need to be rebuilt and stabilized. This strategy acts synergistically with Strategies 3 through 6 above (lowering water levels in the upper Penchant marshes, increasing flow to lower Penchant tidal marshes, enhancing Atchafalaya influence to central Terrebonne marshes, and establishing multipurpose control of the Houma Navigation Canal). Taken together, these five strategies are anticipated to preserve a substantial amount of marsh through 2050.

8. Dedicated delivery of sediment for marsh building by any feasible means . This strategy could be used to rebuild wetlands on a small scale at sites across the region. Sediment could be transported by pipeline, barge, or truck when and where shown to be feasible. For instance, this strategy might be used to build a substantial amount of marsh in the lower Timbalier Basin.

9. Build land in upper Timbalier Subbasin by sediment diversion from the Mississippi River via a conveyance channel. The extremely high land loss in the Timbalier Subbasin is indicative of a collapsed wetland system. High subsidence rates, inadequate sediment supply, altered hydrology, and increased tidal exchange rates are largely responsible for this condition.

Potentially, the most effective alternative for rebuilding this wetland system may be to initiate a new subdelta building process in the area (Gagliano and Van Beek 1993; Gagliano 1994, 1998; Gagliano and Van Beek 1998). This subdelta could be accomplished by diverting flows from the Mississippi River, south and east of Donaldsonville, through a conveyance channel parallel to the developed Bayou Lafourche ridge. The diversion would be about 30,000 cfs, approximately one-third the size of the Wax Lake Outlet. A branch of the channel, carrying about half of the water, would cross Bayou Lafourche below Thibodaux and end in the Bully Camp area. Any project-related navigation features must not impede or interfere with the land building capacity of the channel. This strategy is anticipated to create substantial amounts of land and reduce loss in the Bully Camp and Terrebonne marshes.

Protect Bay and Lake Shorelines

10. Maintain shoreline integrity and stabilize critical areas of Teche-Vermilion Bay systems including the gulf shorelines. Shoreline erosion is a major cause of land loss in the Teche-Vermilion Basin. Relative to other coastal basins, interior wetland loss rates are low. By maintaining the shoreline integrity, this strategy is anticipated to preserve a moderate amount of marsh.

11. Maintain shoreline integrity of marshes adjacent to Caillou, Terrebonne, and Timbalier Bays. The irregular shorelines of the bays in the Timbalier Subbasin are retreating rapidly. Interior wetland loss rates are very high in this subbasin. Interior wetlands would benefit from measures that would absorb erosive wave energies and would aid in maintaining favorable hydrological conditions. This strategy is anticipated to preserve a moderate amount of marsh.

Restore Barrier Islands and Gulf Shorelines

12. Restore and maintain the Isle Dernieres and Timbalier barrier island chains. The Timbalier and Isles Dernieres barrier island chains have severely eroded. This strategy would restore the island chains to a condition suitable for maintaining the integrity of the estuarine system. The Barrier Shoreline Feasibility Study has evaluated alternative restoration measures, costs, and benefits of restoring the island chains. This strategy is anticipated to create moderate amounts of marsh and barrier beaches.

Special Concerns and Opportunities: Resolve Vermilion-Cote Blanche Bays Salinity and Turbidity

The Teche-Vermilion Basin is strongly influenced by the Atchafalaya River. River flow is transported westward into the basin by the Gulf Intracoastal Waterway, by exchange between Atchafalaya Bay and East Cote Blanche Bay, and by a diversion from the Atchafalaya into Bayou Teche and the Vermilion River. While this influence benefits wetlands and satisfies some agricultural irrigation needs, there are concerns about its adverse effects on navigation and estuarine fisheries. Managing the river's influence to sustain the basin's wetlands is a general strategy. Several measures that address aspects of this strategy are being evaluated in the USACE Lower Atchafalaya River Reevaluation Study. The following specific strategies include other measures that address basin needs.

13. Optimize Gulf Intracoastal Waterway flows into marshes and minimize direct flow into bays. With this strategy, Gulf Intracoastal Waterway flows would be routed through wetland areas before draining into the bays. Sediments and nutrients would be retained in the wetlands, and bay water temperatures would be increased. This strategy is anticipated to preserve a moderate amount of marsh.

14. Maintain Vermilion, East and West Cote Blanche Bays as brackish . While this strategy could be viewed as an objective, the sensitivity surrounding this issue required the statement be made a strategy. No specific measures have been identified to implement this strategy. The main expectation is to achieve the objective when planning other measures in the region that could affect bay salinities. Benefits for this strategy have not been estimated.

15. Reduce sedimentation in bays . Measures identified to implement Strategies 2, 13, and 16 (maximizing land building in Atchafalaya Bay, optimizing Gulf Intracoastal Waterway flows into marshes and minimizing direct flow into bays, and creating an artificial reef complex) would aid in accomplishing this strategy. Other measures to reduce Atchafalaya River influence to these bays are being evaluated in the USACE Lower Atchafalaya River Reevaluation Study. Benefits for this strategy have not been estimated.

16. Create an artificial reef complex including one from Point Chevreuil toward Marsh Island . An artificial reef would be constructed along the alignment of the natural reef that was mined earlier this century. Expectations are that the reef would restore some semblance of the former hydrology in East Cote Blanche Bay and adjacent wetlands. The reef would also enhance fisheries through reduction of turbidity and bay infilling. This strategy has no measurable marsh benefits.

Sequencing of Regional Strategies

Near Term (1-5 years)

This category includes strategies that require implementation prior to other restoration strategies because adverse hydrologic impacts could result from reversing the order. The urgency of flood protection must also be considered.

Improved hydrology and drainage in the Verret Subbasin in the near term would be required before Atchafalaya River resources could be optimized for wetland restoration in the Atchafalaya or Terrebonne Basins in the intermediate term.

In the Terrebonne wetlands, dedicated delivery of sediment would be an important strategy to maintain abandoned distributary ridges such as the natural levees of Bayous Lafourche, Pointe Au Chien, and Terrebonne. Furthermore, this strategy could be used to enhance flood protection by building wetlands adjacent to levees. This strategy could be implemented independently of, or concurrently with, other restoration or flood protection measures.

The potentially most effective way to prevent loss in the Timbalier Subbasin is by importing massive amounts of sediment to create a new subdelta. A feasibility study should be initiated to determine if a conveyance channel parallel to Bayou Lafourche is the most effective strategy. Planning and construction phases would be very complicated because of the large project area and its expected impacts to existing uses such as land-based transportation, navigation, agriculture, drainage systems, harvest of estuarine species, and flood protection systems. A network of flood protection systems would be necessary and would extend from the Mississippi River to the lower reaches of Bayous Lafourche, Terrebonne, and Pointe Au Chien. Some flood protection systems are in place and others are presently being planned. While planning could begin in the near term, diversion implementation would likely be in the intermediate to long term.

Barrier island restoration in the Terrebonne Basin and protection of the Rainey Marsh gulf shoreline could be implemented in the near term, before the islands and shoreline deteriorate further. These restoration measures could be implemented independently of other strategies and would enhance the effectiveness of other restoration strategies such as maintaining shoreline integrity and building a new delta lobe in the Timbalier Subbasin.

The strategies to maintain bay shoreline integrity in the Teche-Vermilion and Terrebonne Basins could be implemented independently of other strategies. Shoreline integrity maintenance is not limited to one point in time in a 50-year period, but maintenance as needed over the entire period. Thus, its logical place in sequencing is at the beginning of the 50-year period. These strategies can enhance other strategies or be enhanced by other strategies. For example, the dedicated delivery of sediment strategy could be a construction alternative for shoreline protection. The shoreline maintenance strategies would help to achieve the strategy to reduce sedimentation in Cote Blanche and Vermilion Bays.

The four strategies developed to address concerns over Atchafalaya River influence in the Teche-Vermilion Basin should be implemented in the near term, as river influence is expected to increase over time. These strategies would not conflict with other restoration strategies. Maximizing land building in Atchafalaya Bay in the intermediate term could be planned and implemented to facilitate the strategic objectives of sediment reduction and maintenance of a brackish salinity regime in the bays of the Teche-Vermilion Basin.

Intermediate Term (6-15 years)

This category includes strategies that require prior implementation of near-term strategies that would protect other wetlands and developed areas from increased water levels.

The first strategy in this category is to maximize land building in Atchafalaya Basin, primarily in Atchafalaya Bay. Accomplishment of this strategy would likely result in higher water levels in Terrebonne wetlands, thereby increasing river influence in that area.

Several regional strategies are interrelated hydrologically and involve optimizing Atchafalaya River influence to western and central Terrebonne wetlands. Bank stabilization along waterways would be necessary to improve their efficiency conveying Atchafalaya River water to central Terrebonne. Once in the central marshes, the water could be optimally distributed to wetlands in the vicinity of the Houma Navigation Canal, Lake Boudreaux, and lower Bayou La Cache. Establishing multipurpose control of the Houma Navigation Canal would greatly facilitate the management potential of river influence in the canal area.

Bank stabilization is also a precursor to lowering water levels between the Atchafalaya River and the central Terrebonne wetlands. Water levels can be lowered in the weakly tidal, fresh upper watershed area by distributing excess water across the ridges to the tidal, brackish lower watershed area. These strategies incorporate major hydrologic components of a watershed plan for the western and central Terrebonne wetlands.

Long-Term (16-50 years)

If determined to be feasible, the Bayou Lafourche conveyance channel would be built in the intermediate or long term.

Local and Common Strategies

There are only three local strategies in Region 3. In all mapping units (Fig. 7-9) with hurricane or protection levees, the local strategy is to protect against hurricanes and flooding by maintaining an apron of marshes outside the levees. In the Wax Lake Wetlands unit, the local strategy is to maintain the Wax Lake distributaries, for example Hog Bayou. Another Breaux Act project, the Jaws Terracing Project, should be maintained through the year 2050.

There are several common, coastwide strategies that could be adopted in Region 3. Banks of navigation channels such as the Houma Navigation Canal and the Gulf Intracoastal Waterway could be stabilized in all mapping units that contain such channels (St. Louis Canal, Terrebonne, Pelto Marshes, Fields and Devil’s Swamps, HNC Wetlands, Avoca, Gulf Intracoastal Waterway, Penchant, Mechant de Cade, Wax Lake Wetlands, North Wax Lake Wetlands, Atchafalaya Marshes, Rainey Marsh, Cote Blanche Wetlands, and Vermilion Bay Marsh). In addition, material dredged during maintenance of these navigation channels could be used beneficially in nearly every unit.

Bay, lake, and gulf shoreline integrity could be protected wherever these are eroding, and critical areas could be stabilized in an area that includes over two-thirds of the mapping units.

Establishing and protecting ridge functions are important in all units with such ridges (North and South Bully Camp, St. Louis Canal, Montegut, Terrebonne Marshes, Boudreaux, Caillou, Avoca, Penchant, Mechant de Cade, Rainey Marsh, Big Woods, Cote Blanche Wetlands, and Vermilion Bay Marsh). In the Verret Wetlands and Fields Swamps, a strategy of routing pump outfall through the wetlands could be adopted. For a detailed list of local and common strategies by mapping unit, see Appendix E.

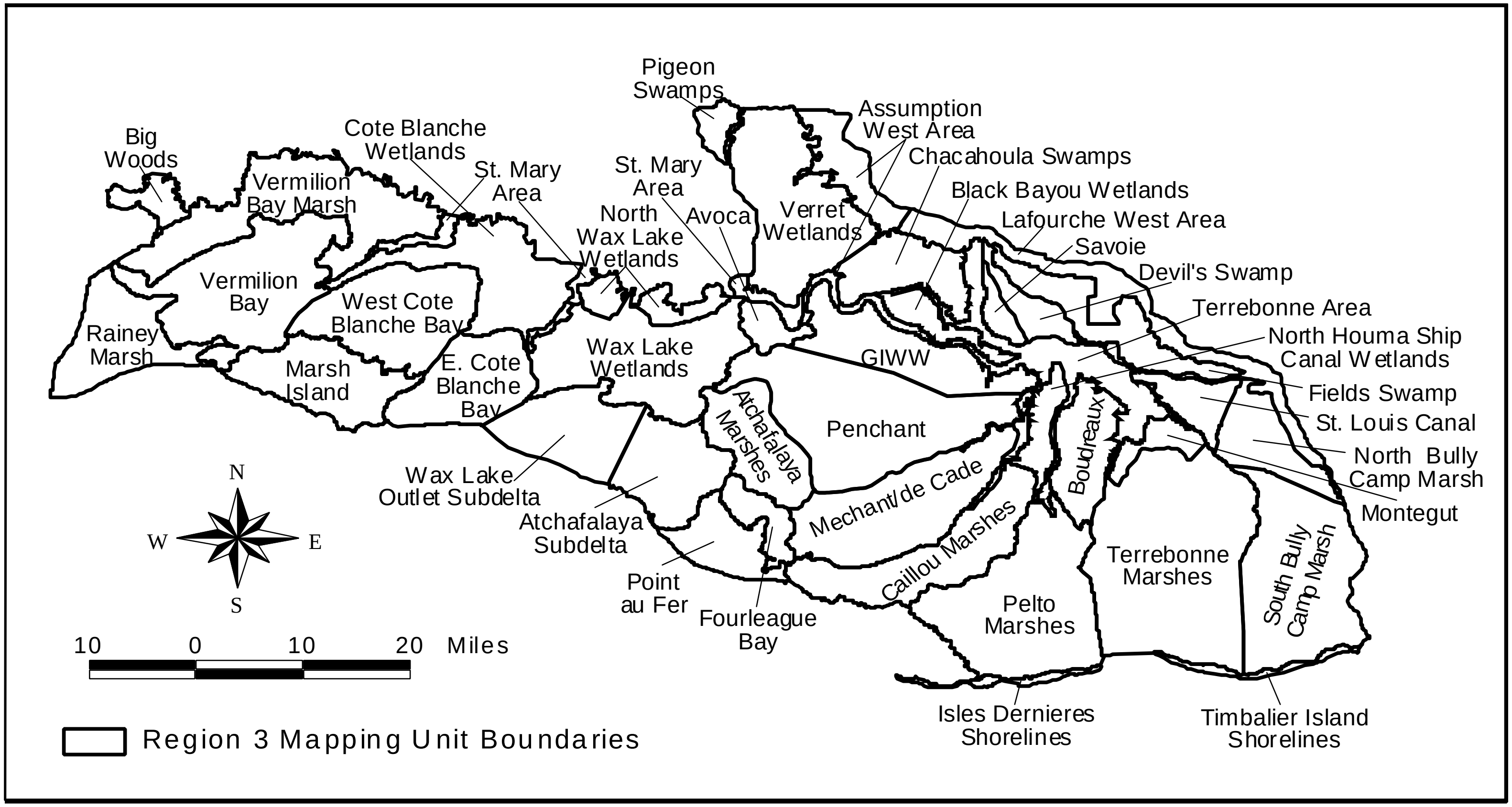


Figure 7-9. Region 3 mapping units.

Region 4 Strategic Plan

Background

Region 4 extends from the western bank of the Freshwater Bayou Canal westward to the Louisiana/Texas border in Sabine Lake, and from the marsh areas just north of the Gulf Intracoastal Waterway south to the Gulf of Mexico in Vermilion, Cameron, and Calcasieu Parishes. Region 4 comprises approximately 1,307,000 acres of marsh, open water, and chenier habitats. Marsh types and their associated acreage across the region are: 354,600 acres (45%) of fresh marsh, 171,700 acres (23%) of intermediate marsh, 198,600 acres (27%) of brackish marsh, and 33,200 acres (5%) of saline marsh.

Region 4 consists of two basins: the Mermentau and the Calcasieu-Sabine. The Mermentau Basin extends from Freshwater Bayou Canal westward to Highway 27 and is divided into two subbasins along an east-west line in the vicinity of the Pecan Island and Grand Chenier ridges. North of this line is the Lakes Subbasin, whose natural drainage has been interrupted by many canals and the placement of several water control structures. The subbasin now functions almost like a large freshwater impoundment. Areas immediately to the north of the region are used primarily for rice and crawfish farming. The Mermentau River, which runs diagonally (NE to SW) across the basin, supplies fresh water to the basin. Two large lakes, Grand and White Lakes, are located in the Lakes Subbasin. The Chenier Subbasin lies between the Gulf of Mexico and the Pecan Island/Grand Chenier ridge complex. Drainage can occur eastward to Freshwater Bayou Canal, southward to the Gulf of Mexico, and westward to the Mermentau River and Ship Channel.

The Calcasieu-Sabine Basin is a shallow coastal wetland system with freshwater input at the north end and a north-south circulation pattern through Calcasieu and Sabine Lakes and some east-west water movement which occurs through the Gulf Intracoastal Waterway and interior marsh canals (e.g., North Line Canal and South Canal on Sabine National Wildlife Refuge). Both lakes are connected to important shipping corridors and are used for recreational purposes as well. As in the Mermentau Basin, managed wetlands are a significant feature of the area, with structures in the Cameron-Creole Watershed, the Sabine National Wildlife Refuge, and on privately owned lands.

Habitat Objectives

The Region 4 Habitat Objectives for the year 2050 were developed by the Objectives Development Team consisting of parish government representatives and the local coastal advisory committees of Vermilion, Cameron, and Calcasieu Parishes. Generally, the habitat objectives map produced by the Objectives Development Team reflected a reduction of the salinities of the marsh habitats in the western and southern areas of Region 4 (Figs. 7-10, 7-11). The Lakes Subbasin is presently composed of fresh to intermediate marsh. The habitat

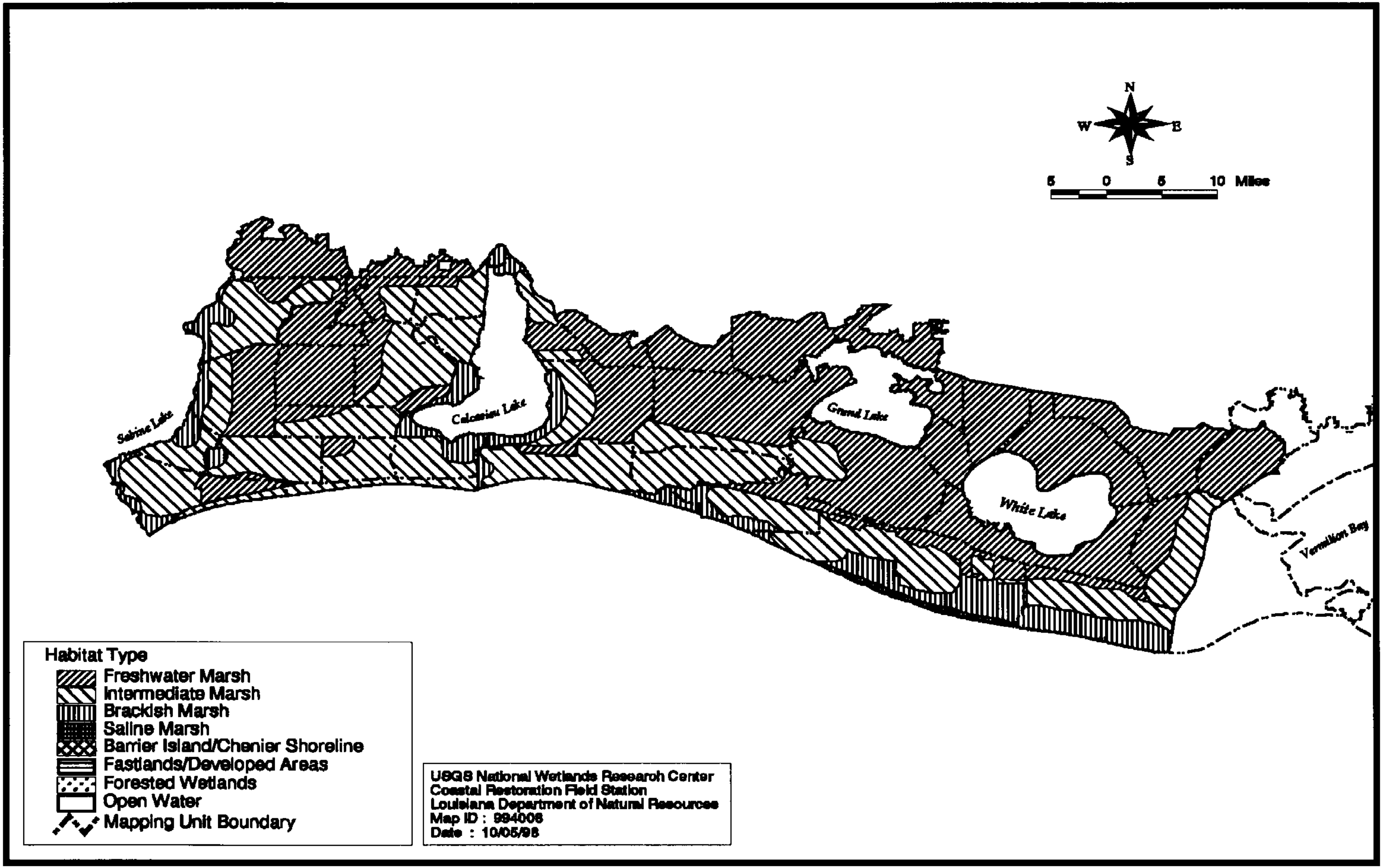


Figure 7-10. Coast 2050 habitat objectives for Region 4.

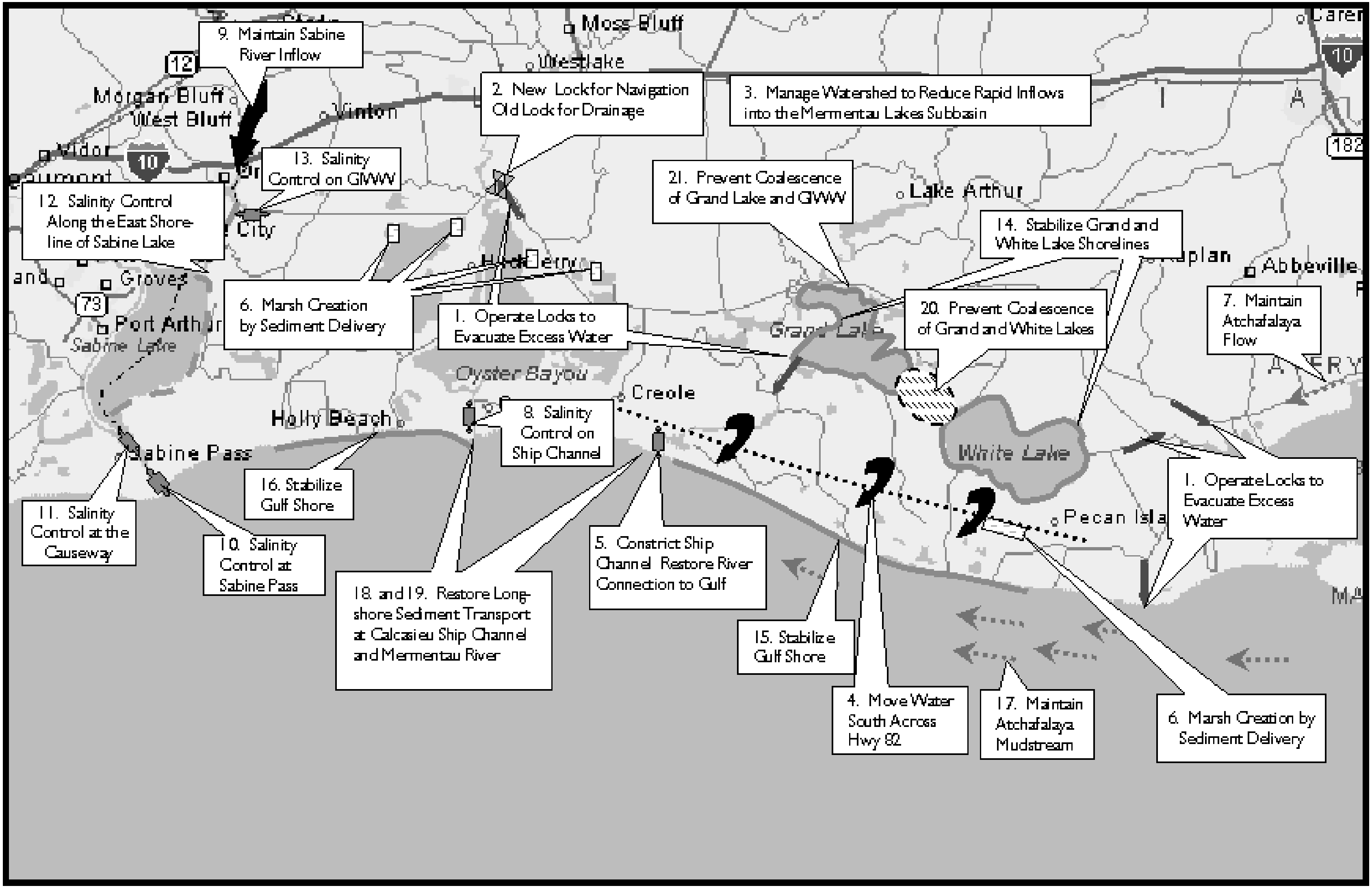


Figure 7-11. Coast 2050 Region 4 regional ecosystem strategies.

objective for this area is to convert most of the area to fresh marsh. The objective for the Chenier Subbasin is to convert the existing saline and brackish marshes to brackish and intermediate marshes by the year 2050. The objective for the Calcasieu-Sabine Basin is to create fresher conditions by the year 2050.

Regional Ecosystem Strategies

Because of the socioeconomic demands and opportunities which exist in this region, it is not realistic to return to "natural" conditions by taking actions such as restoring Calcasieu Pass or Sabine Pass to their pre-1900 conditions, filling in the Gulf Intracoastal Waterway, or filling in the myriad of smaller canals. In a manner which accommodates, better uses, and improves existing infrastructure, the goals of the regional strategies for Region 4 are: (1) to eliminate adverse hydrologic conditions, including elevated water levels and extreme salinity spikes, and (2) to reestablish or maintain the integrity of major natural landforms.

Restore and Sustain Wetlands

1. Operate locks to evacuate excess water from the Lakes Subbasin. By lowering water levels in a timely manner, inundation-related plant stresses could be relieved and lake shoreline erosion could be reduced. In recent years, this strategy has been partially implemented with some success. Continued and additional benefits could be derived by consistently operating structures 24 hours per day at all five control points (Calcasieu Lock, Leland Bowman Lock, Schooner Bayou Control Structure, Catfish Point Control Structure, and Freshwater Bayou Lock). Operation should strive to reduce the duration of marsh inundation during and after periods of high rainfall, achieve water elevations which are conducive to marsh vigor and health inside the lock system, and allow free outflow of water when inside water levels exceed target water levels and a drainage differential exists. This strategy is expected to preserve a moderate amount of marsh by 2050.

2. Operate existing Calcasieu Lock specifically to evacuate excess water, after building a new lock on a parallel channel specifically for navigation. The Calcasieu Lock site is thought to be the best of the existing sites for the evacuation of excess water. The new lock would allow water evacuation and navigation to function independently and without conflict. Operation goals would be as stated above. This strategy is anticipated to preserve a moderate amount of marsh by 2050 by lowering water levels.

3. Manage watershed to reduce rapid inflows into the Lakes Subbasin. Drainage improvements in the Mermentau River watershed allow water, particularly during and after high rainfall events, to reach the Lakes Subbasin very quickly, causing elevated water levels. Without impeding drainage from existing developed or agricultural lands, this strategy would slow the flow of water, perhaps through incentive programs, catch basins, or stream restoration. This strategy is expected to preserve a moderate amount of marsh by 2050.

4. Move water from north to south across Highway 82 with associated drainage improvements south of Highway 82. This strategy is two-fold: to evacuate excess water from the Lakes Subbasin, and to provide freshwater to the Chenier Subbasin. Water could be moved from north to south with a series of gravity drainage structures and/or pumps along Highway 82. A prerequisite for such structures or pumps would be to improve drainage south of Highway 82, perhaps establishing a flow-through system. This strategy is anticipated to preserve a major amount of marsh by 2050.

5. Restore the connection of the original Mermentau River to the Gulf of Mexico and constrict the width and depth of the Mermentau Ship Channel to its authorized dimensions. The purpose of this strategy is also two-fold: to allow better drainage of wetlands located along the lower 5 to 7 miles of the original Mermentau River, and to reduce the intrusion of salt water up the Mermentau Ship Channel. This strategy is anticipated to preserve a minor amount of marsh by 2050.

6. Dedicated dredging of sediment for wetland creation. This strategy consists of dredging material from channels or lakes to create marsh in rapidly eroding units such as Lacassine; Cameron Creole Watershed; Sweet and Willow Lakes; Big, Brown, and Black Lakes; and South Pecan Island. This strategy is projected to create a moderate amount of marsh.

7. Maintain Atchafalaya River water and sediment inflow through the Gulf Intracoastal Waterway. Presently, marshes in the Mermentau Basin seem to be deriving benefit from the flow of Atchafalaya River water and sediment through the Gulf Intracoastal Waterway. The purpose of this strategy is to discourage any curtailment of such flow through the Gulf Intracoastal Waterway.

Salinity Control in the Calcasieu Basin

8. Salinity control of the Calcasieu Ship Channel between the Gulf of Mexico and Calcasieu Lake. Salinity control could be established by installing a gate, lock, or other saltwater barrier. The primary goal of this strategy is to reduce peak salinities, probably limited to a seasonal basis. During nonpeak salinities, navigation would be unaffected. Should such control be established, perhaps the need for maintenance and/or intensive operation of lakeside control structures could be reduced in the future. This strategy is expected to preserve a major amount of marsh by 2050.

Salinity Control of the Sabine Basin *

9. Maintain Sabine River inflow. The primary focus of this strategy is to discourage implementation of the Trans-Texas Water Plan (TTWP) via proactive participation, including projection of future conditions, education regarding adverse effects, direct opposition to TTWP if appropriate, and development

*These strategies apply whether the TTWP is implemented or not, but are an absolute must if the TTWP is implemented.

of measures to mitigate the TTWP.

10. Salinity control at Sabine Pass . Salinity control could be established by installing a gate, lock, or other saltwater barrier in Sabine Pass. The primary goal of this strategy is to reduce peak salinities, probably limited to a seasonal basis. During nonpeak salinities, navigation would be unaffected. This strategy is expected to preserve a substantial amount of marsh by 2050 by reducing salinities.

11. Salinity reduction of Sabine Lake at the Causeway. Salinity reduction could be accomplished by a sill type structure that would allow small to medium boat navigation. Large boat navigation (barges, ships, etc.) through the Sabine-Neches Waterway would be unaffected. This strategy is anticipated to preserve a moderate amount of marsh by 2050.

12. Salinity control on the east shoreline of Sabine Lake . The primary goal of this strategy is to reduce the penetration of peak salinities into the interior marshes. This strategy is expected to preserve a major amount of marsh by 2050.

13. Salinity Control in the Gulf Intracoastal Waterway east of Sabine River. The primary goal of this strategy is to reduce the flow of high salinity water eastward from Sabine River, through the Gulf Intracoastal Waterway, and into the interior marshes. This strategy is anticipated to preserve a moderate amount of marsh by 2050.

Protect Bay and Lake Shorelines

14. Stabilize Grand Lake and White Lake shorelines. These two very large lakes are experiencing significant shoreline erosion. In many areas the historic shoreline rim is completely lost, exposing interior organic soil marshes to high wave energy. Shoreline stabilization should address the ongoing direct loss as well as increasing rates of loss for interior marshes which otherwise would be exposed to wave energy. This strategy is expected to preserve a major amount of marsh by 2050.

15. Stabilize Gulf of Mexico shoreline in the vicinity of Rockefeller Refuge . With a shoreline retreat rate of 35 feet per year, shoreline stabilization is necessary to address the direct loss of wetlands. This strategy is anticipated to preserve a major amount of marsh.

16. Stabilize Gulf of Mexico shoreline from Calcasieu Pass to Johnson's Bayou. In addition to the long-term threat to interior wetlands posed by potential shoreline breaches and saltwater intrusion, there is an immediate threat to sections of Highway 82 which would be addressed with this strategy of holding the shoreline in its current position. This strategy is expected to preserve a moderate amount of marsh by 2050.

17. Maintain Atchafalaya River mudstream in the Gulf of Mexico . Presently, certain reaches of the Gulf Mexico shoreline in Region 4 are prograding because of the Atchafalaya

River mudstream (*see* Fig. 3-5b). The purpose of this strategy is to discourage any curtailment of such a stream in the Gulf of Mexico.

18. Restore long-shore sediment flow across the mouth of Calcasieu Pass. Jetties installed for reducing sedimentation within the Calcasieu Ship Channel have interrupted long-shore sediment transport along the Gulf of Mexico shoreline. Sediment bypass mechanisms would help reduce shoreline retreat west of the Calcasieu Ship Channel, and could be implemented as part of Strategy 16 above. This strategy is anticipated to preserve a minor amount of marsh by 2050.

19. Restore long-shore sediment flow across the mouth of Mermentau Ship Channel. Jetties installed for the purpose of reducing sedimentation within the Mermentau Ship Channel have interrupted long-shore sediment transport along the Gulf of Mexico shoreline. Sediment bypass mechanisms would help reduce shoreline retreat west of the Mermentau Ship Channel. This strategy is likely to preserve a minor amount of marsh by 2050.

20. Prevent the coalescence of Grand Lake and White Lake. Individually, Grand Lake and White Lake are presently very large and are experiencing significant shoreline erosion. If allowed to coalesce, the fetch and probably erosion rates will increase tremendously. Additionally, if the lakes coalesce, water circulation patterns throughout the Lakes Subbasin will likely be altered and wind-induced water stacking will likely exacerbate marsh inundation, leading to increased interior marsh loss. This strategy is expected to preserve a major amount of marsh by 2050.

21. Prevent the coalescence of Grand Lake and the Gulf Intracoastal Waterway. If Grand Lake and the Gulf Intracoastal Waterway are allowed to coalesce, the north bank of the waterway will be exposed to the fetch of Grand Lake and water circulation patterns throughout the Lakes Subbasin will likely be altered. This strategy is anticipated to preserve a minor amount of marsh by 2050.

Sequencing of Regional Strategies

Near Term (1 to 5 years)

There are four regional strategies that simply call for using existing infrastructure or discouraging future human activities that may adversely affect wetlands. Implementation of these strategies by the appropriate entities should be pursued immediately. They include: operating locks to evacuate excess water from the Lakes Subbasin, maintaining Atchafalaya sediment inflow through the Gulf Intracoastal Waterway, maintaining Sabine River inflow, and maintaining Atchafalaya water and sediment stream in the Gulf of Mexico. Although not identified as a regional strategy, initiation of the Hydrologic Investigation of the Chenier Plain, funded by the Breaux Act, should proceed immediately so that the resulting information can be used to design specific projects called for in other strategies.

Additional strategies recommended for the near term include those for which there is a considerable body of knowledge; existing, "on-the-ground" projects which can be used to aid in the design of specific projects; and those which address an immediate threat to wetlands or critical infrastructure. These strategies include: moving water from north to south across Highway 82 with associated drainage improvements south of Highway 82, salinity control on the east shoreline of Sabine Lake, stabilizing Grand Lake and White Lake shorelines, stabilizing the Gulf of Mexico shoreline in the vicinity of Rockefeller Refuge, stabilizing the Gulf of Mexico Shoreline from Calcasieu Pass to Johnson's Bayou, restoring long-shore sediment flow across the mouths of Calcasieu Pass and the Mermentau Ship Channel, preventing the coalescence of Grand Lake and White Lake, preventing the coalescence of Grand Lake and the Gulf Intracoastal Waterway, and dedicated dredging for wetland creation.

Intermediate Term (6 to 15 years)

Strategies recommended for implementation in the intermediate term are those for which the existing body of knowledge is insufficient to confirm the merit, and/or determine the feasibility and optimal design. All of these strategies would benefit from the information gathered via the Hydrologic Investigation of the Chenier Plain. Furthermore, these strategies would require close coordination with interested user groups. This group of strategies includes: operating the existing Calcasieu Lock specifically to evacuate excess water after building a new navigation lock on a parallel channel, managing the watershed to reduce rapid inflows into the Lakes Subbasin, restoring the connection of the original Mermentau River to the Gulf of Mexico and constricting the width and depth of the Mermentau Ship Channel to its authorized dimensions; and salinity reduction of Sabine Lake at the Causeway.

Long Term (16-50 years)

Because of their magnitude, the need for feasibility analyses, and the potential effect on navigation and other uses, the following strategies are recommended for implementation in the long term: salinity control of the Calcasieu Ship Channel between the Gulf of Mexico and Calcasieu Lake, salinity control at Sabine Pass, and salinity control in the Gulf Intracoastal Waterway east of the Sabine River. If salinity control at Sabine Pass is feasible and receives funding, salinity control on the Gulf Intracoastal Waterway would probably not be necessary.

Local and Common Strategies

Hydrologic restoration is a local strategy recommended for nearly all of the Region 4 mapping units (Fig. 7-12). Local hydrologic restoration strategies involve the use of dams or water control structures to restore the altered hydrology in the various units.

These strategies would reduce saltwater intrusion or water levels and/or restore tidal flow and fisheries access to the

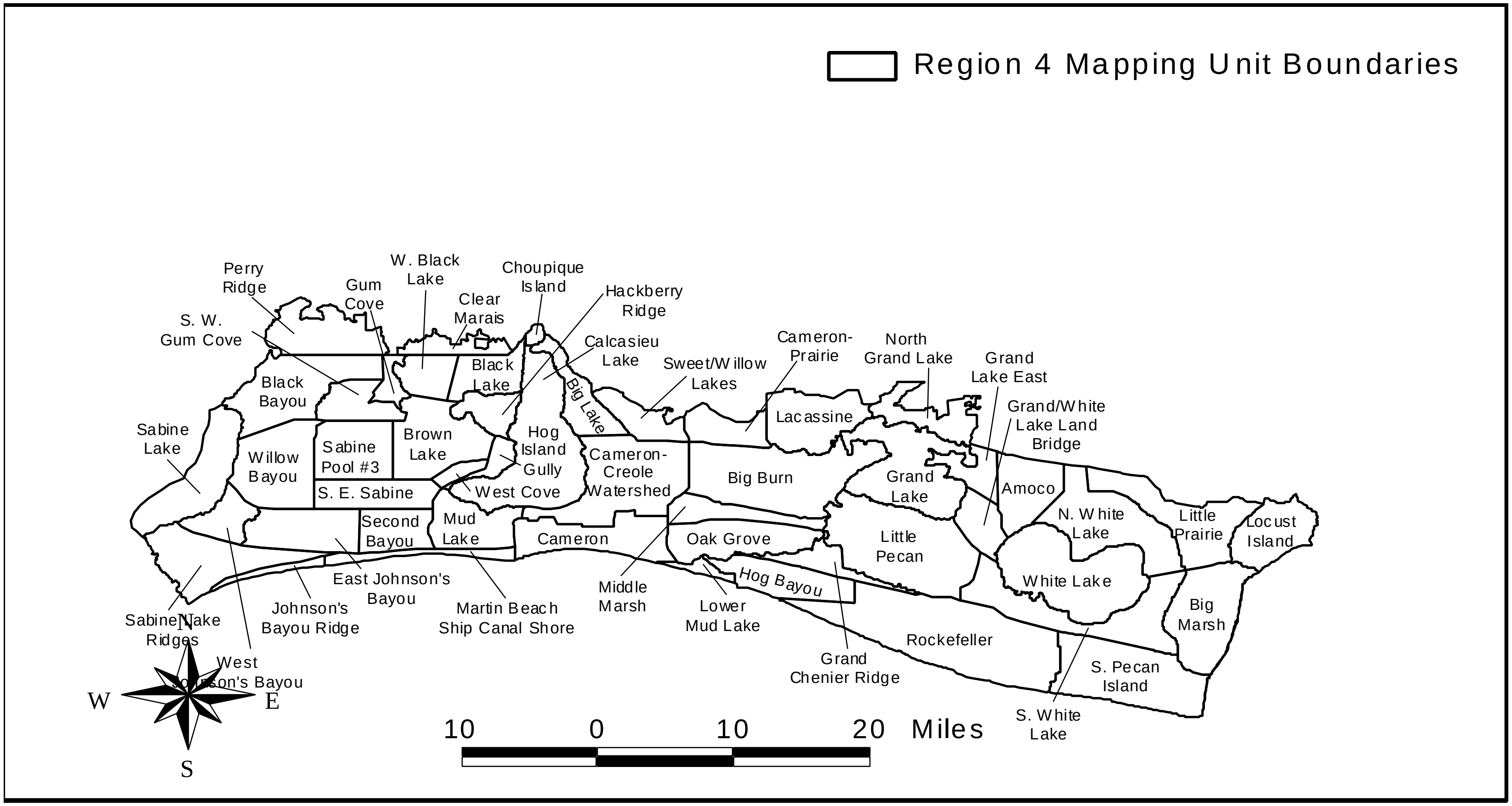


Figure 7-12. Region 4 mapping units.

marshes. Freshwater introduction strategies are found in Little Pecan, South Pecan Island and Hog Bayou, where there is a need for, and a source of, freshwater to counteract the effects of increased saltwater intrusion (Fig. 7-11). Maintaining drainage infrastructure is a local strategy for the Cameron unit. Maintaining "perched" marshes, where fresher marshes have formed on dredged material sites, is a strategy unique to the Choupique Island unit. General shoreline stabilization is a widespread common strategy for nearly every Region 4 mapping unit.

Terracing and vegetative plantings are common strategies that can be applied to any of the 50 Region 4 mapping units that contain substantial areas of shallow open water. This technique has already been applied on two wildlife refuges. The soil conditions in Region 4 are generally more conducive to terracing when compared to other regions. Maintain ridge function is another common strategy that is applicable to those mapping units with existing ridges or cheniers. Vegetative planting, apart from terracing, is a common strategy which can be applied to any mapping units which are composed of shallow water with little wave action.

Dedicated dredging has been recommended for the Grand and White Lakes Land Bridge and South Pecan Island mapping units, but it can be applied to any mapping unit in Region 4 which has critical shallow open water areas which are in danger of opening into larger lake or bay systems.

Beneficial use of dredged material is a strategy which can be applied to any Region 4 mapping unit which is adjacent to a major navigation channel such as the Calcasieu or Sabine Ship Channels, or Freshwater Bayou Canal. The Gulf Intracoastal Waterway crosses the entire region and is found in 20 of the region's 50 mapping units. Bank stabilization along the Gulf Intracoastal Waterway is a necessary common strategy.

Herbivory control is a common strategy that can be applied to problem areas in Region 4, including the Middle Marsh, East Johnson's Bayou, and Second Bayou mapping units. For a detailed matrix of local and common strategies by mapping unit, see Appendix F.

Costs and Benefits of Regional Ecosystem Strategies

Region 1 Benefits

Implementing the regional ecosystem strategies would achieve the overarching goal of Coast 2050: sustaining a coastal ecosystem that supports and protects the economy and culture of southern Louisiana and contributes greatly to the economy and well-being of the nation. Implementing all of the regional strategies proposed for the Lake Pontchartrain Basin is estimated to prevent approximately 74% of the marsh loss across the entire region by 2050, thereby saving 33,500 acres of marsh. The benefits of local and common strategies have not been estimated, but it can be assumed that implementation of some of these strategies could reduce loss slightly more.

Implementation of the regional strategies would have restored the highest practicable acreage, given the constraints placed on Mississippi River diversions by local interests. Vertical accretion in this basin would come mainly from small river diversions that provide nutrients. The marshes that would be preserved would have the functions and values of natural ecosystems. Many of the strategies will provide multiple-use benefits such as providing marsh to protect the New Orleans metropolitan area.

A good estuarine gradient will be achieved in Region 1, and there will be extensive habitat diversity. There will be essentially no barriers to exchange of energy and materials between the wetlands and the estuary.

Region 2 Benefits

Implementing the regional strategies would achieve the overarching goal of Coast 2050: sustaining a coastal ecosystem that supports and protects the economy and culture of southern Louisiana and contributes greatly to the economy and well-being of the nation. By 2050, it is projected that there would be 189,900 additional acres of marsh compared to what would exist without the strategies. Not only would no net loss be achieved in the region, but there would be a 51% gain by the year 2050. The highest practicable acreage would have been restored.

The marshes created and preserved by these strategies would have the functions and values of the natural ecosystem. Several of the strategies such as the Bayou Lafourche conveyance channel and river diversions in Plaquemines Parish, if feasible, would provide multiple-use benefits. The hurricane protection levees parallel to Bayou Lafourche and in Plaquemines Parish will be protected by adjacent marsh. Louisiana Highway 1 will have a strip of protective marsh to its east.

The ecosystem objective of vertical accumulation would be achieved by using the Mississippi River nutrients and sediments to increase vegetative plant growth and to create and preserve marsh. Extensive use of Mississippi River water would accentuate vertical accumulation but reduce the estuarine gradient by limiting future areas of saline marsh. This tradeoff is necessary to make opportunistic use of the nutrients and sediments of this river. Sequential operation of future diversions might reduce the adverse salinity impacts. The region would still have habitat diversity from bottomland hardwoods and swamps in the upper end through extensive marshes to barrier islands and shorelines near the gulf. There would be extensive exchange of energy and materials between the wetlands and the estuary.

Because of deteriorating marsh conditions, fisheries will diminish dramatically well before 2050 if no action is taken. While the proposed strategies may produce short-term adverse impacts to fisheries, such strategies are needed to prevent long-term significant decline or collapse in fisheries production. Short-term fisheries impacts would need to be addressed to render river-oriented strategies acceptable.

Region 3 Benefits

Implementing the regional strategies would achieve the overarching goal of Coast 2050: sustaining a coastal ecosystem that supports and protects the economy and culture of southern Louisiana and contributes greatly to the economy and well-being of the nation. By 2050, there would be 119,600 additional acres of marsh and 46,700 additional acres of swamp compared to what would exist without the strategies. No net loss would be achieved in swamps and 91% of the predicted marsh loss would have prevented. The highest practicable acreage would have been restored.

The marshes created and preserved by these strategies would have the functions and values of the natural ecosystem. Several of the strategies such as the Bayou Lafourche conveyance channel would provide multiple-use benefits to communities and infrastructure. The ecosystem objective of vertical accumulation would be achieved by using water and sediment from the Atchafalaya and Mississippi Rivers and by protecting the self-sustaining wetlands in the Teche-Vermilion system from bay and lake shoreline erosion.

The extensive use of Atchafalaya and Mississippi River waters would accentuate vertical accumulation but reduce the estuarine gradient by limiting future areas of saline marsh. This tradeoff is necessary to make opportunistic use of the nutrients and sediments of these two rivers. The region would still have extensive habitat diversity from bottomland hardwoods and swamps in the upper end through extensive marshes to barrier islands near the gulf. There would be extensive exchange of energy and materials between the wetlands and the estuary. There is a possibility that this exchange could have adverse impacts on floating marsh.

Region 4 Benefits

Implementing the regional strategies would achieve the overarching goal of Coast 2050: sustaining a coastal ecosystem that supports and protects the economy and culture of southern Louisiana and contributes greatly to the economy and well-being of the nation.

The major strategies in the Mermentau Basin involve removing water from the Lakes Subbasin. These strategies are projected to reduce future loss by 57% in this basin, resulting in an additional 34,730 acres being present in 2050 when compared to no additional restoration efforts. In the Calcasieu-Sabine Basin, major strategies involve controlling salinity. If the TTWP is not implemented, and salinity control is implemented along the lake shore in the near term and at Sabine Pass in the long term, the regional strategies are projected to reduce the Calcasieu-Sabine Basin loss by 61%, resulting in an additional 24,810 acres being present in 2050. If the TTWP is implemented, regional strategies are projected to reduce marsh loss by only 31% in the Calcasieu-Sabine Basin.

In this region, there is no significant source of sediments. Thus, vertical accumulation must be achieved predominately by the organic production which could take place if excess water can be removed and salinity can be controlled. This salinity control would allow simulation of the historic estuarine gradient and maintain large areas as fresh and intermediate marsh. While the projected exchange and interface in Region 4 may be less than in other regions, a healthy ecosystem which more closely resembles the historic condition and produces the highest practicable acreage would likely exist if these strategies were implemented. Water management actions should strive to allow, to the greatest extent practicable but without negative impacts to the ecosystem, detrital exchange and aquatic organism movement so as to optimize functions and values. The regional strategies will provide multiple-use benefits by preserving a band of marsh adjacent to highways and developed areas.

Costs

The costs of the regional ecosystem strategies have been roughly estimated. The total dollar figure is generally the present value of construction costs. Maintenance costs are included where maintaining the landform is a vital part of the strategy. Monitoring costs are not included. No estimates have been made for local or common strategies. The approximate cost of implementing all the regional ecosystem strategies across the entire coast is approximately $14 billion.

Benefits of Regional Strategies to Communities at Risk

As described earlier (Chapter 6), the very existence of many small coastal communities is threatened by marsh loss. The regional strategies described above would significantly improve the future of these communities.

South Lafourche Corridor

If the strategies in Region 2 and Region 3 are implemented, the South Lafourche Corridor is expected to have more marsh adjacent to it in 2050 than it does today. Land can be built immediately with dredged material to protect La. Highway 1. Wave absorbers and preservation of the land bridge will reduce loss to the east of the corridor. Then, once the Bayou Lafourche Conveyance Channel is constructed, it will build deltas that wrap around both sides of the corridor. The regional strategies are anticipated to allow the preservation of this vital corridor.

New Orleans Metropolitan Area

If the strategies in Regions 1 and 2 are implemented, the New Orleans metropolitan area will have more marsh adjacent to it than it does today. If nothing is done, 25% of the marshes west of the area will be gone by 2050. If the strategies are implemented, it is estimated that there will be no net loss in the La Branche area. There are presently extensive marshes stretching east from the metropolitan area to Chandeleur Sound. If no more marshes are restored, 41 square miles of these marshes will be gone by 2050. If the Region 1 strategies are implemented, it is anticipated that only 20 square miles of marsh will have been lost by 2050. Marshes to the south of the area also offer protection. If nothing is done, 19 square miles just south of the metropolitan area will be lost by 2050. If the Region 2 strategies are implemented, only nine square miles are expected to be lost. These regional strategies will provide significant protection to the New Orleans metropolitan area by preserving a marsh buffer that should reduce hurricane damage.

Yscloskey

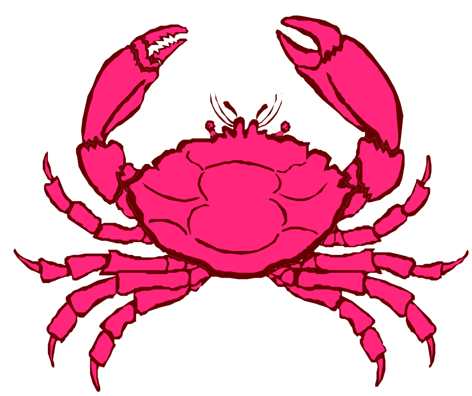
The regional strategies are expected to prevent some loss of marsh to the north and east of the community—only 21 square miles will be lost instead of 34. Stabilizing the north bank of MRGO and the shoreline of Lake Borgne should provide most of these benefits. There are essentially no regional strategies for the marshes to the south, so there would still be nearly ten square miles lost. Common strategies such as beneficial use of dredged material could, however, restore marshes in this area and help maintain Yscloskey as a viable community.

Cocodrie

The regional strategies for Region 3 are anticipated to preserve significant amounts of marsh in the vicinity of Cocodrie. Instead of 55% of the marshes to the north being gone by 2050, only 16% would be lost. To the east, instead of 64% of the marshes becoming open water, only 32% would be lost. The strategies do little for the marshes to the west, so there would still be about 35% lost. The strategies that provide most of the benefits are moving Atchafalaya River water to the lower tidal marshes, stabilizing the banks of the Houma Navigation Canal, and building a control structure in the canal. Once the Bayou Lafourche Conveyance Channel is built, it will provide significant benefits to the marshes to the east of Cocodrie. These strategies will contribute the continued existence of Cocodrie.

Holly Beach/Constance Beach

Regional strategies in Region 4 are expected to help reduce marsh loss north of these communities and will help protect La. Highway 82. Stabilizing the gulf shoreline and restoring longshore sediment flow across the mouth of Calcasieu Pass will protect the communities from direct attack by the gulf. These strategies should help preserve these beach communities.



CHAPTER 8

INSTITUTIONAL ISSUES

A priority in the Coast 2050 planning process has been to address institutional issues, which are issues arising from actions such as government funding and regulation. There are literally dozens if not hundreds of Federal, State, and local programs that can have an impact on wetlands. In the past, the efforts made to align these programs toward common goals have not been comprehensive, nor have they been uniformly effective. Directing government decisions to a common end is an essential step in effective restoration.

Breaux Act Coordination

Consistency among certain uses of coastal Louisiana's resources is a requirement addressed in the Breaux Act Section 303(d). Section 303(d)(1) requires that, "In implementing, maintaining, modifying, or rehabilitating navigation, flood control or irrigation projects, other than emergency actions, under other authorities, the Secretary, U.S. Army Corps of Engineers [USACE] in consultation with the Director (U.S. Fish and Wildlife Service) and the Administrator [USEPA], shall ensure that such actions are consistent with the purposes of the restoration plan submitted pursuant to this section" ("plan" refers to the Louisiana Coastal Wetlands Restoration Plan of 1993 or subsequent revisions of that plan).

The purpose as referenced in Section 303(b)(2), is as follows: "The purpose of the restoration plan is to develop a comprehensive approach to restore and prevent the loss of coastal wetlands in Louisiana. Such a plan shall coordinate and integrate coastal wetlands restoration projects in a manner that will ensure the long-term conservation of the coastal wetlands of Louisiana."

Breaux Act Consistency Requirements (P.L. 101-646, Sec. 303(d)(1))

No procedural guidance yet exists for carrying out the 303(d)(1) consistency requirement. Plans are underway in the New Orleans District of the USACE to develop interim procedural guidance in consultation with U.S. Fish and Wildlife Service and the U.S. Environmental Protection Agency. While this guidance is being implemented within the New Orleans District, the District will work with the Mississippi Valley Division to ensure that any USACE activity that would have an effect on Louisiana's coastal wetlands is consistent with 303(d)(1). As a minimum, actions covered under this requirement include planning, constructing, maintaining, modifying, and rehabilitating any USACE project whose purpose is navigation, flood control, or irrigation. Examples include maintenance of existing navigation projects such as the Gulf Intracoastal Waterway or the Mississippi

River Gulf Outlet. Ongoing planning under the Lower Atchafalaya Basin Reevaluation Feasibility Study presents a prime example for application of the Section 303 (d)(1) consistency requirement because of overlap in this system between management of flood flows and coastal wetland restoration. This consistency requirement also applies to any of the above-described actions if the project pertains to navigation, flood control, or irrigation within or affecting Louisiana's coastal wetlands.

Breaux Act Restoration Plan/Coastal Zone Provision (P.L. 101-646, Sec. 303(d)(2))

Existing procedures of the Coastal Management Division used in implementing Coastal Zone Management Act Federal Consistency would be available to the State for reviewing all federal actions after the Coast 2050 Plan is incorporated into the State's Coastal Zone Management Program.

Pursuant to 16 U.S.C. 3952(d)(2), the Governor of the State of Louisiana can request, and the Secretary of Commerce shall approve, the restoration plan described at P.L. 101-646 Section 303(b) as an amendment to the State's federally approved coastal zone management program. Upon receiving this approval, the restoration plan would then be incorporated into the Louisiana Coastal Resources Program (LCRP) and all enforceable policies and mechanisms of the State's coastal zone management program would be applicable under provisions of the Coastal Zone Management Act, 16 U.S.C. Section 1456. This document, *Coast 2050: Toward a Sustainable Coastal Louisiana*, represents such a restoration plan.

The Governor's request is to be made through the Secretary of Commerce and processed in accordance with the rules and procedures pertaining to amendments to federally approved coastal zone management plans at 36 CFR 923.80-84. Such a request has been made by the Governor of Louisiana in correspondence dated November 28, 1995 (Appendix A).

Once incorporated into the LCRP, activities of Federal agencies would be reviewed for consistency with the restoration plan pursuant to the Federal Consistency authority granted to the State by 16 U.S.C. 1456. This review would be conducted by using the current review procedures of the Louisiana Department of Natural Resources, Coastal Management Division.

Breaux Act Conservation Plan Implementation Requirements (P.L. 101-646, Sec. 304)

In November 1997, the State of Louisiana received federal approval of its Coastal Wetlands Conservation Plan, in accordance with Section 304 of the Breaux Act. This document details the State's ongoing efforts to achieve a "no-net-loss" of wetlands from all future development. The plan is based largely on public education, mitigation of unavoidable losses, and implementation of State-funded restoration projects and programs. An advanced data management system has been implemented to improve the State's ability to track wetland losses that occur through development as well as to track the results of mitigation implementation. Within 2 years, or by mid-2000, the approving Federal agencies must report to Congress whether the plan's implementation has achieved the "no-net-loss" goal. The State was granted a reduction from 25% to 15% cost share obligation on the Breaux Act construction projects upon approval of the plan in December 1997.

Losses of wetlands resulting from ongoing development present both ecological and regulatory complications. Both the USACE New Orleans District and the State of Louisiana Department of Natural Resources (DNR) carry out regulatory programs aimed at minimizing wetland losses and compensating for unavoidable wetland losses. Both agencies have evolving data management systems to track development in wetlands and mitigation actions to offset unavoidable losses. It is therefore important that both agencies coordinate their activities and share pertinent aspects of this information with the Coast 2050 Plan implementation process.

During the development of the Louisiana Coastal Wetlands Conservation Plan, DNR reported on development-related activities in wetlands, based on an account of the number of permits issued and resulting acreage of wetlands disturbed. The 15-year accounting period that started in 1980 showed a dominance of oil and gas activity in terms of permit numbers. It is important to consider the acreage of wetlands affected by each permit. For instance, levee construction or residential subdivision development may impact many more acres under one permit than the average impact per oil/gas permit. Over the reporting period, DNR reported an average annual impact to wetlands of 893 acres based on USACE information. It was noted, however, that the USACE regulates these wetland losses and requires compensatory mitigation in many cases. It is estimated that about 200 lost acres per year are unmitigated. It is important to recognize that little field data exist to verify these estimates. Through DNR's implementation of its Coastal Wetlands Conservation Plan, more exact tracking of wetland losses and gains related to development will be conducted. Reevaluation of the estimated losses shown above will occur annually and mitigation adjustments will be made as necessary. For more information about numbers of permits by activity type, see Appendices C-F.

Beneficial Use of Dredged Material

One activity that is often associated with the State's consistency program (although not exclusively so) is the beneficial use of material dredged to maintain navigation channels. Sediment represents one of the most important resources for building wetlands. Dredging activities in Louisiana, including maintenance of Federal navigation channels and permitted activities in Louisiana's coastal zone, account for the removal and redeposition of 90 to 120 million cubic yards of sediment annually. Current Federal policy, physical and chemical characteristics of the dredged material, logistics, and economics limit the beneficial use of this sediment to create and/or restore wetlands. The increased beneficial use of this dredged material resource must be an integral part of the plan to reduce Louisiana's yearly coastal land loss.

If one assumes a standard water depth of 5 feet with an allowance of one foot for subsidence/compaction, and a usable volume of material at 40 million cubic yards, one could possibly create about 6 square miles of subaerial wetlands each year. The approximate annual loss of wetlands in Louisiana is 30 square miles per year. Thus, the potential for the beneficial use of dredged material to address Louisiana's coastal land loss is significant.

Beneficial use of dredged material resources, as envisioned within the context of the Coast 2050 initiative, can take on any of several forms. Beneficial use is any use which would protect, enhance, or provide a platform for the restoration of vegetated wetlands. Such uses could include the impacting of some vegetated wetlands if the long-term result is the protection or net gain of vegetated wetlands.

Over the last decade there have been numerous examples of beneficial use of dredged material. The current status of this effort is described in Appendices C-F (Dredging Histories for Federally Maintained Navigation Channels). The USACE and the State of Louisiana have used dredged material resources to create over 7,000 acres of subaerial land which has become vegetated wetlands. This usage has occurred in conjunction with maintenance dredging of federally maintained navigation channels, as well as through jointly funded efforts utilizing USACE authorities (e.g., Section 204) matched by the state.

It has been the USACE's practice that, as long as the effort to achieve beneficial use is within the project's base plan or Federal standard cost, the USACE can and will make beneficial use of dredge material resources.

If, however, the cost exceeds the Federal standard or base plan, beneficial use will not be made unless additional funding from some other authority and/or source can be found to cover those costs which exceed the base plan costs.

Through its legislature, Louisiana has stated its policy with respect to beneficial use of dredged material resources in R.S.49:214.32(F):

> "the Secretary (of DNR) shall insure that whenever a proposed use or activity requires that dredging or disposal of five hundred thousand cubic yards or more of any water bottom or wetland within the coastal zone, the dredged material shall be used for the beneficial purposes of wetland protection, creation, enhancement or combinations thereof..."

Examples of additional sources of authority and funding for beneficial use include other USACE authorities, such as Section 204, Section 1135, Section 115, or nonfederal funds which are provided by local sponsors, including states, local government, port authorities, etc.

There are a number of strategies that, when used either singly or in concert, could lead to the beneficial use of more of this material resource. Some of these strategies are listed below.

- Seek additional Congressional authority and funds to allow USACE to perform more beneficial use during navigation channel maintenance.
- Seek Congressional assistance to have "Federal Standard/Base Plan" funding formula changed to include beneficial use.

- Seek Congressional/State authorization and/or funding for USACE to construct wetlands using dredged material resources.

- Seek funding through the Louisiana State Wetlands Authority and/or Breaux Act for a yearly supplement to fund beneficial use projects, either in concert with USACE supplemental funding, or as an "add-on" to maintenance events funded with state/Breaux Act funds.

- Seek Clean Water Action Plan support for increased beneficial use as a means of achieving a portion of the 100,000 acres/year increase in wetlands that it calls for by the year 2005.

- Seek additional funding for the USACE so that the materials currently being placed in ocean dredged material disposal sites can be used beneficially and then seek de-designation of all those sites.

- Seek additional funding and authority to require "compensatory" mitigation for dredged material not used beneficially from maintenance of Federal navigation channels and permitted activities in the Louisiana coastal zone.

Programmatic Strategies

During the course of the Coast 2050 planning initiative, many ideas were suggested by the Regional Planning Teams and the public that are programmatic rather than physical in nature. These concepts were carried through the entire process in a similar fashion as the regional and mapping unit strategies. They are presented below as recommendations that have the potential to improve implementation efficiency of authorized restoration projects, improve effectiveness of future restoration efforts, improve the coordination among existing environmental resource programs, or result in actions that may benefit coastal wetlands in other ways.

Coastwide Programmatic Recommendations

Coordinate mitigation with restoration plan objectives and priorities

During the permitting process, when compensatory mitigation for unavoidable impacts to coastal resources is being negotiated, regulatory authorities should, if within statutory limits, make certain that mitigation plans are consistent with restoration plan objectives. Compensatory mitigation projects have far-reaching potential for wetland creation, enhancement, and protection efforts in the coastal zone, and this strategy is designed to capture this potential.

Provide appropriate relocation costs and adequate flood control for impacts related to wetland restoration projects

This strategy is to ensure that wetland restoration projects include, at the outset, provisions to adequately mitigate for potential damages that may be incurred as a result of that project. Flooding impacts, both primary and secondary, from wetland restoration projects should be anticipated in the design phases of those projects. Projects should include specific, detailed provisions to address those impacts. For example, if a river diversion is likely to result in flooding, avoidance of damages or compensation for property damages should be included as a cost of the project. If appropriate, oyster lease issues should be addressed in accordance with Louisiana's laws and regulations (R.S. 56:432.1 et seq., and LAC 43:I§850-858).

Expedite permitting of coastal restoration projects

Despite efforts to streamline permitting of regulated activities in jurisdictional wetlands, securing the necessary authorizations can be time-consuming, even for those projects that are considered beneficial. Development of additional Federal and State general permits or perhaps special exemptions would reduce permitting time and allow beneficial projects to be implemented in a timely manner.

Impose and enforce wake limits in areas where bank erosion caused by wakes is severe

This strategy is designed to reduce boat wakes, thereby decreasing wave energy and reducing erosion on shorelines and banks. The strategy is to work with enforcement agents and post speed limits on portions of waterways most susceptible to erosion.

Implement best management practices to improve wetlands and associated aquatic habitats and address other water quality issues

This strategy would entail the coordination with other State and Federal agencies such as Department of Environmental Quality, Department of Transportation and Development, Natural Resources Conservation Service, Soil and Water Conservation Commission, Louisiana Department of Wildlife and Fisheries and U.S. Environmental Protection Agency to implement best management techniques for such practices as forestry, agriculture, marinas, urban development, and hydrologic modification.

Improve land rights acquisition procedures

This strategy involves working with landowners to secure rights to build restoration projects or to increase acreage of wetland habitats through donations, Federal and State incentive programs, easements, etc.

Increase wetlands though incentive-based programs

Marsh and swamp acreage could be increased by converting unused agriculture fields, pastures, and grazing areas to their original wetland habitats through such efforts as the Wetland Reserve Program, which is administered by the Natural Resources Conservation Service.

Identify funding sources that match the scale needed to adequately address the coastal land loss problems in Louisiana

This strategy involves determining additional levels of funding required to adequately offset Louisiana's coastal land loss and to implement appropriate actions to secure such funds.

Prevent the negative effects of shell dredging

Shell dredging should be administered in such a way that environmental damages, including but not limited to wetland effects, are avoided or mitigated.

Mitigate water hyacinth problems to reduce marsh erosion

Water hyacinth is an exotic plant that, under optimal growth conditions, can form floating mats of vegetation that can weigh many tons. When these huge rafts are blown or carried by currents against or onto a bank of emergent wetland vegetation, severe damage and ensuing erosion may be sustained. In instances where water hyacinth may be an important factor in erosion rates, steps should be taken to prevent associated problems from occurring.

Develop and support a comprehensive barrier shoreline/island initiative to expedite appropriate actions such as mitigation of damages and restoration of these critical areas

Barrier shorelines, headlands, and barrier islands are important for a number of reasons. Therefore, consideration should be given to the formation of an initiative that focuses on problems, potential solutions, and other issues related to these areas.

Regional and Mapping Unit Programmatic Recommendations

Region 1

In the Lake Pontchartrain mapping unit (Fig. 7-3), water quality improvements were suggested, particularly as related to sewer discharge. Three related concerns were also voiced: the desirability of a continued drilling moratorium, a continued ban on shell dredging, and improved management of fill material (Appendix C).

The Region 1 Regional Planning Team also suggested that in the Lake Borgne, Biloxi Marshes, and Eloi Bay mapping units, restrictions should be placed on oyster harvesting in the near-shore zone, so that extensive reefs might become established in these areas and protect the shorelines from erosion, provide shell hash to the system, and improve water quality.

The Regional Planning Team identified several tracts where opportunities may exist for the inclusion of additional lands protected as special status areas. These were areas in Lake Maurepas and Manchac Land Bridge West mapping units to be considered as National Estuarine Research Reserves; the Manchac Land Bridge East to be considered as an extension of the Joyce and Manchac Wildlife Management Areas; and the LaBranche Wetlands unit was recommended as an addition to the Bayou Sauvage National Wildlife Refuge.

The Tchefuncte River mouth was identified as an area where drainage and development of marsh lands should be reduced, while the Pearl River Mouth was suggested as an area where dredging should be restricted. In the North Shore Marshes, flood control measures were recommended to be coordinated with the Coast 2050 restoration strategies. In addition, a 36-foot draft limit was proposed for the Mississippi River Gulf Outlet.

Region 2

In the Baker and Des Allemands mapping units (Fig. 7-6), the Regional Planning Team recommended that selective harvesting of trees planted in mitigation banks be allowed. In the Lake Washington/Grand Ecaille and Bastion Bay mapping units, the Regional Planning Team recommended that the problem of salinity intrusion be studied, particularly the possibility of intrusion via the hurricane protection levee borrow canal (Appendix D).

Barrier island restoration and protection was an issue that was deemed to warrant programmatic consideration, e.g., the restriction of sand mining on islands and ridges in the Fourchon mapping unit. In Caminada Bay, it was suggested that alternative sources of sediment, such as red mud, compost, etc., be considered for restoration purposes.

Region 3

Several programmatic strategies originating in Region 3 were moved into the coastwide strategy section due to their widespread applicability, i.e., those dealing with shell dredging effects, river water studies, water hyacinth, and a barrier island/shoreline initiative.

In addition, the Regional Planning Team proposed a far-reaching recommendation to establish multipurpose control of the Houma Navigation Canal, including freshwater and sediment retention and distribution, salinity control, hurricane protection, and navigation facilitation. In the wetland area immediately adjacent to the Houma Navigation Canal, it was recommended that there be a wake limit established and enforced, that flood protection be established on both sides of the canal, and that the Falgout Canal project's water management plan be amended. The Field's Swamp mapping unit (Fig. 7-9) was another area where wake limits were suggested (Appendix E).

In the Timbalier Island Shorelines and Isles Dernieres Shorelines units, the Regional Planning Team suggested that new dredging of canals be eliminated, directional drilling be utilized to prevent new development footprints on the islands, and that mitigation efforts should be directed at restoring the islands.

In Mechant-de Cade, water quality and wastewater management were recommended. In Big Woods, the Regional Planning Team advocated the protection of the groundwater recharge area between Perry and Big Woods from salinity intrusion. In the St. Louis Canal unit, flood protection was cited as a recommendation, and in the Devil's Swamp mapping unit, levee maintenance and water quality improvement were recommended.

Region 4

In Region 4, the Regional Planning Team identified a number of programmatic recommendations, many of which are related to existing hydrologic and salinity problems, or additional problems considered likely should the proposed Trans-Texas Water Plan become a reality. In general, these strategies involve funding and undertaking a study or studies that would provide the needed information to accurately anticipate the potential effects of a Trans-Texas Water Plan scenario and to develop contingency plans that would mitigate these effects should the Trans-Texas Water Plan happen. Information is needed concerning the effects on year-round salinity patterns under various conditions, including drought; and to determine the ramifications of this on wetland loss and conversion rates, and resulting consequences on fish, wildlife, water supply, and other resources. Those mapping units (Fig. 7-12) the Regional Planning Team suggested may be most vulnerable to such adverse impacts are Black

Bayou, Perry Ridge, South West Gum Cove, Sabine Lake, Sabine Lake Ridge, Southeast Sabine, Willow Bayou, and West Johnson's Bayou (Appendix F).

Another major theme in Region 4 is to maintain the Grand Lake, White Lake, and South White Lake mapping units as low-salinity, fresh-to-intermediate ecosystems, in which water levels and hydroperiods would be controlled so as to reduce wetland loss resulting from extended flooding episodes, while at the same time protecting fresh water supplies for agriculture. These areas would provide limited estuarine access, and fisheries parameters would be monitored at key locations.

Other programmatic strategies include: addressing the severe bullwhip mortality problem in the East Johnson's Bayou and Second Bayou mapping units, maintaining ridge functions at Johnson's Bayou Ridge, and restricting sand mining at the Grand Chenier Ridge mapping unit. In the Little Prairie mapping unit, it was suggested that the "wiggles" on the Gulf Intracoastal Waterway be straightened out so as to improve navigation safety and thereby reduce the chances of accident-related adverse impacts to wetlands and dependent resources. In Sabine Lake, the Regional Planning Team suggested that pollution be reduced by "best management practices."

Compensation Issues

Abating the loss of wetland functions and values in the future may result in some limited near-term negative impacts. These negative impacts, to the extent they occur, are most likely to be experienced by people using the wetlands for income generation. Though the negative impacts associated with any given project may be temporary, with duration being related to that period needed for adjustment to the transition, the issue of compensation may arise. Compensation is an issue with the potential to alter project selection, construction, and operation. Consequently, a policy on compensation should be developed. This policy would include whether or not compensation should be extended to commercial harvesters other than those addressed in the currently proposed Oyster Lease Relocation Program.

Insight can be found by reviewing instances of public direct and indirect support of commercial harvesters. Indirect support occurs via incentive programs. At least two programs in Louisiana involve indirect incentives. The first, Act 164 (R.S. 47:297), was enacted to provide a tax credit against individual income tax for Louisiana gasoline and special fuel taxes paid for operating or propelling any commercial fishing boat. The second indirect incentive entitles commercial fishermen to receive a Louisiana State sales tax exemption certificate from the Department of Revenue and Taxation (R.S. 47:305.20). Both programs require that commercial fishing must be the exemption certificate holder's primary source of income. Though not related to a specific restoration project, such mechanisms could be a means of compensation. That is, a state policy of compensation would not have to be project specific. The policy could use the established programs in recognition of the statewide approach to restoring wetlands. Parts of the sales tax exemption removed in prior years could be restored. Qualification (licenses) and documentation (tax returns) programs need not be created as they are in place and familiar to agencies processing applications.

Other Louisiana programs such as the Commercial Fisherman's Gear Compensation Program involve direct payments. Damage to fishing gear and boats is compensated from a state-administered fund. To be eligible, applicants must receive 50% or more of their income from commercial fishing.

Compensation programs at the Federal government level are most often associated with natural disaster recovery efforts. An example is the Hurricane Andrew Disaster Payments Program to oyster lease holders and other commercial fishermen. Compensation after natural disasters is focused on returning the affected businesses to operation. Oyster leaseholders received funds from the U.S. Department of Agriculture's Agricultural Conservation and Stabilization Service headquartered in Alexandria, Louisiana. This program included payments to leaseholders as compensation for the loss of oysters and removal of debris from oyster reefs. Payments were made after leaseholders met qualification conditions related to the extent of losses. Among the relevant aspects of this program was the establishment of a threshold below which no payments were received. That is, damage had to first be demonstrated and then judged to be above the threshold prior to payment.

The program for other commercial fishermen did not attract many applicants in Louisiana. Other gulf states experienced a similar low application and subsequent approval rate. The excess funds were distributed to fishery agencies in gulf states for use in programs that could beneficially impact commercial fishermen. The most noteworthy Louisiana program is the use of the Federal funds by the Department of Natural Resources to identify and remove bottom obstructions deemed hazardous to both navigation and fishing gear use. This indirect approach may be suitable for restoration projects if governmental policy includes compensation. It may not be obstruction removal in the case of public projects but the activities could include: (1) improved navigation aids, (2) improved access via launching ramps, and (3) improved aquatic weed control.

Both Federal and State agencies have experience in developing and administering payment programs with varied purposes for the commercial fishing industry. Whether or not there are prospects of measurable damage and an obligation to abate impacts is a matter for government to determine. Experience with past programs does not suggest a specific program. There are components of such programs that must be discussed if programs are authorized, including:

- Establishing a single statewide program or developing programs for each project that meets compensation justification criteria,
- Identifying effects to be compensated,
- Establishing qualifications for those eligible,
- Identifying project impact areas, i.e., the affected area parallel of the Oyster Lease Relocation Program,
- Establishing criteria for documenting losses,

- Establishing agency procedures and costs associated with verification of claims,

- Establishing the open season period in which applications are received,

- Establishing the length of time in which damage should be compensated, and

- Establishing the source and estimate the amount of funds necessary for direct payment compensation.

CHAPTER 9

SCIENCE AND TECHNOLOGY

One of the challenges of implementing a plan as ambitious as Coast 2050 is the integration of the latest science and technology into the detailed planning and engineering phases of the resulting projects. Often, the planning phases of major landscape projects across the country take many years, during which time new information becomes available and the fundamental rationale of the project is called into question. The technical and scientific problems identified during a lengthy implementation process can be minimized by ensuring that appropriate research is accomplished and integrated into the planning process and project design. The Breaux Act restoration effort has made strides towards this goal by incorporating university scientists into some aspects of project selection (e.g., benefits analyses) and planning (e.g., modeling and feasibility studies), and by allocating funds for monitoring for the life of constructed projects. As implementation of ecosystem scale management strategies begins, outstanding scientific and technical questions should be addressed and monitoring data and restoration-oriented research results should be used in adaptive management and project planning decisions.

The Coast 2050 Plan is based on the current state of knowledge of Louisiana's complex coastal ecosystems. The technical aspects of this plan owe much to the efforts of coastal researchers, technical agency personnel, coastal land managers, and other local participants, but we need to enhance our capabilities to both manage coastal systems (technology) and to predict environmental response to those actions (science).

Research Needs and Improved Understanding

To fully achieve the ecosystem goals set forth in this plan, a better understanding of ecological and biogeomorphic processes and functions is needed. Critical questions still need answers, such as—What is the effect on ecosystem sustainability of a seasonal river diversion that increases the annual range of salinities within the receiving basin? How important to coastal marshes is nutrient input alone vs. freshwater and sediment delivery from the river? How does this vary with marsh type?

Clearly, there are still many restoration issues in coastal Louisiana that cannot be resolved without additional research. The research must then be integrated into the refinement of the strategies and the revision of the plan. Particular areas needing more research are:

- *Relative contribution of drainage improvements, nutrients and* *sediment supply in ameliorating the degradation of cypress-tupelo forests*.

- *Genesis of and factors controlling sustainability, sensitivity and resilience of floating marshes*.

- *Water quality impacts of Mississippi River water diversions through coastal wetlands, including the potential effects of nutrients on hypoxia in the gulf and in inshore receiving areas*. Many workers have argued that diversions of Mississippi River water through coastal wetlands will result in lower nutrient levels in the gulf, and less potential for hypoxia to develop. In contrast, some suggest that diversions into the coastal basins with restricted water movement may result in an inshore hypoxia problem.

- *Factors controlling long-term vertical accumulation and sustainability of the marsh surface—the role of storms, the interactions between sediment deposition, organic matter accumulation and vertical accretion, and the associated variability across marsh types and coastal physiographic settings*.

- *Short-term and long-term effects of coastal restoration projects on fisheries and wildlife production and distribution, and the relative merits of the different project types and features employed to these resources.*

Improved Technologies

Restoration Technology

Developments in restoration technology are required if the Coast 2050 Plan is to move forward. The plan recognizes that the resources of fresh water and sediments are critical to the sustainability of the coastal ecosystem. Managing natural flows and directing sediment to areas of need means manipulating a major river system on an unprecedented scale. The engineering design of structures, channels and gates must advance to facilitate the control of the river's resources to meet the ecosystem needs. For areas where fresh water and/or sediment are not available, however, additional techniques for maximizing vertical accumulation through organic matter production need to be developed.

Another area requiring attention is the study of the use of alternative marsh creation materials, such as fiber rolls, waste fill material, vegetative earth reinforcement mats, biodegradable wood fiber erosion control blankets, biodegradable erosion control mats, sod reinforcement fabrics, etc. Hard structures such as gobi-blocks, silt fences, and geotextile sheets, which might hold dredged soil in place to allow for vegetative plantings or natural revegetation, also need to be investigated. The effectiveness of these measures in different physical and ecological settings should be determined and the information disseminated to all involved in restoration work.

Predictive Tools

To effectively use existing knowledge and gain the increased understanding necessary to deal with the issues described above, it is essential that appropriate predictive tools are developed. The tools include numerical modeling approaches to predicting patterns of water level, salinity, and sediment distribution. Hydrologic models, which specifically encompass flows across marsh surfaces and through channels and structures, must be developed. Ecological models must address marsh accretion (mineral and organic), nutrient budgets, and soil biogeochemical processes.

Information Needs and Database Development

The Breaux Act has one of the best developed monitoring programs nationwide for wetland projects. Monitoring funds are routinely allocated for the life of constructed projects and monitoring plans for each project are developed to include statistical designs and the use of reference areas. Because of funding constraints, these monitoring efforts are limited to the environmental parameters expected to be affected by the projects and are confined to the area immediately affected by a project and an adjacent reference area if a suitable one can be located. As more projects are undertaken, monitoring databases for some essential variables such as water level and salinity data will cover extensive areas of the coast. These collective data will provide a good starting point to assess the cumulative spatial and temporal impacts of the numerous Breaux Act projects on the entire ecosystem.

The implementation of the Coast 2050 Plan must encompass monitoring at the ecosystem scale, including spatially and temporally linked coastwide data for attributes such as water levels, currents, salinities and suspended sediments, to aid in planning and to fully assess the rate of progress toward the goal of a sustainable coast. The concept of a coastwide monitoring program is being explored by Federal and State agencies; establishment of such a program should be a high priority. Analysis of this coastwide data should provide a better understanding of system processes.

A more immediate need is to gather current and accurate bathymetry of water bodies and topography of marshes and swamps. In the Barataria-Terrebonne National Estuary Program area, the determination of surface elevations has proved to be a useful planning tool, but the lack of detailed bathymetry remains problematic. A coastwide bathymetry and topography survey is essential to project, watershed, and ecosystem planning.

Fundamental databases that describe the contemporary environment should be developed in a manner that allows university scientists, agency personnel, land managers, and local interests to access and use available information. Such databases should provide access to: (1) coastwide data for attributes such as water levels, currents, salinities and suspended sediments, (2) project-specific monitoring data and evaluations, (3) GIS-based information regarding the current status of our coastal systems, especially the bathymetry of water bodies and topography of marshes and swamps, and the current, ever changing, land-water configuration of our coast, and (4) GIS-based information regarding infrastructure so that landscape restoration planners can readily determine the location of oil and gas pipelines, roads, levees, etc.

Integration of Science and Technology—Examples

Three feasibility studies currently underway have already demonstrated the value of combining talents in research, engineering, and planning to develop the information essential to major public works programs. The Barrier Shoreline Feasibility Study, Phase 1, and the Mississippi River Sediment, Nutrient and Freshwater Redistribution Study were both funded by the Breaux Act in 1996 in response to a call from the Governor of the State of Louisiana for the examination of system-scale restoration strategies. In addition, the USACE in response to flood control problems within the Atchafalaya Basin and coastal communities has funded the Lower Atchafalaya River Reevaluation Study. These studies represent a step forward for coastal restoration planning in Louisiana because they:

- Include input from active researchers,
- Use predictive modeling approaches to understanding process dynamics, and
- Examine how restoration strategies can result in benefits outside the immediate project area.

In addition, the Lower Atchafalaya River Reevaluation Study has involved data collection which has greatly increased our understanding of delta building and marsh rejuvenation using fresh water and suspended sediment. It is essential that such approaches be pursued as the Coast 2050 ecosystem scale strategies are refined by feasibility analyses into projects.

The Coast 2050 Science and Technology Challenge

Participants in the Coast 2050 planning process have enough understanding of coastal Louisiana and its problems to develop the strategies presented in this plan and know that the strategies can address some important issues. The challenge is to fill in the gaps of information, understanding, and technology so that the presented strategies can provide their potential benefit to the coast. To meet that challenge, (1) mechanisms to fund a coordinated program of coastal investigations to understand the longer term dynamics of the system must be developed, (2) research and demonstrations that specifically advance restoration technology must be conducted, (3) usable databases must be developed, and (4) mechanisms to integrate research results into the planning and design of restoration projects must be developed.

CHAPTER 10

REALIZING THE GOAL: PRINCIPLES FOR IMPLEMENTING THE COAST 2050 PLAN

Development of a detailed agenda for implementing the Coast 2050 Plan is the next important step in the Coast 2050 Program. The implementation program will be designed in 1999 and will be based on the principles set forth below. To move forward in the campaign to ensure sustainability of Louisiana's valuable coastal resources, challenges that presently delay project construction must be embraced and solved.

Some important issues will emerge as detailed planning is undertaken. The Breaux Act process and the ongoing efforts of the State of Louisiana and private landowners to restore the coast have already shown that there are some issues that need immediate attention. Some of these problems have been highlighted here. It has not thus far been the goal of the Coast 2050 planning effort to resolve these issues; rather, the purpose here is to point to the action items most critical to successful implementation of the Coast 2050 ecosystem strategies.

Measures of Success

Short Term

In the short-term, the success of the Coast 2050 Plan will be measured by two things. The first is the extent to which a large number of strategic restoration projects are quickly planned, implemented and operated effectively. The second is the extent to which regulatory and infrastructure programs are quickly and effectively aligned toward the Coast 2050 restoration goals.

Action Items:

- Ensure that existing Breaux Act funds are directed towards strategies included in the Coast 2050 Plan. The Breaux Act Task Force has already taken steps in this direction by ensuring that the next Priority Project List considers Coast 2050 strategies.

- Initiate review of regulatory programs to determine specific modifications needed to enhance implementation of Coast 2050 strategies.

Long Term

The Coast 2050 Plan seeks to provide the maximum productive acreage and productivity from the coastal ecosystem. In the long-term, success will be measured by the quantity, diversity, and quality of wetland acreage, and the resulting benefits from various services to Louisiana and the nation. These benefits include protection against storms and floods, production of fisheries and wildlife resources, protection of water supply and wastewater assimilation capacity, and support to activities such as oil and gas development, navigation, and ecotourism.

Action Item:

- C Develop a coordinated approach to evaluation of ecosystem value and restoration including, but not limited to, wetland acreage, measures of secondary productivity, biodiversity indices, and population/infrastructure development.

These measures—strategic projects, regulatory reform, and wetlands benefits—will be the focus of the implementation effort.

Scale of Success

The strategies set forth in this plan constitute the nation's (and world's) largest and most ambitious program of ecosystem restoration. One measure of the scale of this undertaking is to compare the investment that is now being made in coastal restoration to the amount of funds needed to accomplish Coast 2050.

Construction aspects of the Coast 2050 Plan would likely require spending $14 billion or more over the next 30 years. The current Breaux Act program invests less than 10% of that amount, which is a primary reason why it can achieve only limited and localized restoration benefits. **Thus, Coast 2050 envisions at least a tenfold increase in the effort that will be made to restore Louisiana's coastal wetlands.**

The large increase in effort is required because the current program will address only 22% of the land loss problems. The strategies put forth in Coast 2050 are larger, more ambitious, more productive, and more costly than projects that can be funded under the current program. The cost increase also reflects the fact that most small, inexpensive projects that contribute to restoration have already been funded. The implementation effort must emphasize steps needed to put large, strategic projects on the ground.

Action Items:

- C Identify potential funding mechanisms for key ecosystem strategies and embark upon preliminary reconnaissance studies to provide the information required by those mechanisms.

- C Quantify the resources and identify the source of cost-share funds and services.

Ingredients for Success

Coastal Louisiana is on the verge of ecosystem collapse. With that collapse comes an immeasurable cost to human communities and the national economy. Thus, the implementation plan must provide a **fast track to substantial accomplishments**, if we expect to reach the overarching goal of a sustained coastal ecosystem that supports and protects the regional and national economy. There are four essential foundation blocks for successful restoration. Getting each in place quickly will be the primary objective of the implementation program.

Commitment

Coast 2050 cannot succeed unless there is a public will to achieve large-scale restoration. The Breaux Act program was born from a fundamental commitment on the part of Louisiana citizens and their representatives that coastal restoration is among the highest of society's priorities. A substantially enlarged program will require these same citizens and representatives to renew and expand their commitment. The commitment must be shared at the national level.

Action Item:

- The State of Louisiana must show its legislative and fiscal commitment to ecosystem sustainability and challenge the Federal government to respond.

Knowledge

The unprecedented scale of action that is envisioned by the Coast 2050 Plan will test our ability to understand, predict, and manage the effects of restoration actions on coastal ecosystems. It will be imperative to support the Plan through an extensive program that acquires data on coastal resources and processes, that interprets these data through state-of-the-art hydrologic and ecological models, that develops safety net features to address risks and unintended consequences, and that applies the results of our knowledge through adaptive management of restoration projects and activities.

Action Item:

- The State and its Federal partners must demonstrate their commitment by directly supporting programs to increase the knowledge base, develop the predictive tools, and make the technological advances necessary to implement Coast 2050 strategies.

Process

Decisions on specific Coast 2050 actions will require a planning and implementation process that has extensive public involvement and effective incorporation of public values. This process must integrate the restoration program into the entire fabric of coastal activities and must ensure that restoration is accomplished with impacts on coastal communities and the coastal economy that are acceptable, or that are dealt with equitably through compensation and other programs.

Action Item:

- Impediments to the implementation of restoration projects such as determination of land ownership, resolution of surface-mineral rights conflicts, compensation for damages and access to public resources must be more efficiently addressed.

Resources

Finally and perhaps most fundamentally, implementing Coast 2050 will require a large increase in resources directed at coastal restoration. These include funding that is at least 10 times greater than now available to put the key strategies on the ground and the personnel needed to plan, develop, build, and manage large-scale projects and to streamline regulatory programs. Without such funding, the coast will be lost.

Urgency of the Coast 2050 Plan

Action must be fast. The Coast 2050 Plan was developed over 18 months and involved hundreds of people. The commitment of the public to this plan is based on the expectation that it ***will*** make a difference in the coastal landscape before it is too late. Lessons learned in this process need to be used to make future planning and implementation efforts more effective. All elements of the Coast 2050 Plan cannot be implemented within five or even ten years, and a detailed implementation plan still needs to be developed. However, there are many issues which local, State, and Federal interests can address immediately. *Without the commitment to take these first steps, the Louisiana coastal ecosystem will collapse*. ***The need for action is clear. The time for action is now.***

REFERENCES

Act 35 of 1971 of the Louisiana Legislature.

Act 361 of 1978 of the Louisiana Legislature (La. R.S. 49:214.21 *et seq.*).

Act 41 of the Second Extraordinary Session of 1981 of the Louisiana Legislature.

Act 6 of the Second Extraordinary Session of 1989 of the Louisiana Legislature (La. R.S. 49:213 *et seq.*).

Act 637 of 1991 of the Louisiana Legislature (La. R.S. 49:213.13).

Adams, R.D., P.J. Banas, R.H. Baumann, J.H. Blackmon, and W. G. McIntire. 1978. Shoreline erosion in coastal Louisiana: inventory and assessment. Final report to Louisiana Department of Transportation and Development. Baton Rouge, La. 139 p.

Applied Technology Research Corp. 1998. Impacts. Final report to Mid-Continent Oil and Gas Association. Internet URL: http://www.lmoga.com.

Barras, J.A., P.E. Bourgeois, and L.R. Handley. 1994. Land loss in coastal Louisiana 1956-90. National Biological Survey, National Wetlands Research Center Open File Report 94-01. 4 p., 10 color plates.

Baumann, R.H., J.W. Day, Jr., and C.A. Miller. 1984. Mississippi deltaic wetland survival: sedimentation versus coastal submergence. Science 224(8):1093-5.

Bernard, H.A., and R.J. LeBlanc. 1965. Resume of the Quaternary geology of the Northwestern Gulf of Mexico Province. Pages 137-185 *in* H.E. Wright, Jr., and D.G. Frey, editors, The Quaternary of the United States: A Review Volume for the VII Congress of the International Association for Quaternary Research. Princeton University Press, Princeton, N.J.

Boesch, D.F., M.N. Josselyn, A.J. Mehta, J.T. Morris, W.K. Nuttle, C.A. Simenstad, and D.J.P. Swift. 1994. Scientific assessment of coastal wetland loss, restoration and management in Louisiana. Journal of Coastal Research Special Issue No. 20. 103 p.

Britsch, L.D., and J.B. Dunbar. 1993. Land loss rates: Louisiana coastal plain. Journal of Coastal Research 9:324-338.

Byrnes, M.K., R.A. McBride, Z. Tao, and L. Duvic. 1995. Historical shoreline dynamics along the chenier plain of southwestern Louisiana. Transactions/Gulf Coast Association of Geological Societies 45(5):113-122.

Cahoon, D.R. 1991. A study of marsh management in coastal Louisiana. CoastWise 3(3):8-12.

Cahoon, D.R., D.J. Reed, J.W. Day, Jr., G.D. Steyer, R.M. Boumans, J.C. Lynch, D. McNally, and N. Latif. 1995a. The influence of Hurricane Andrew on sediment distribution in Louisiana coastal marshes. Journal of Coastal Research SI 18:280-94.

Cahoon D.R., D.J. Reed, and J.W. Day, Jr. 1995b. Estimating shallow subsidence in microtidal salt marshes of the southeastern United States: Kaye and Barghoorn revisited. Marine Geology 128:1-9.

Center for Business and Economic Research. 1995. Lafourche Parish Profile: 1995. Louisiana Department of Economic Development, Baton Rouge, La. Internet URL http://leap.net1.nlu.edu/PPROF96/LAFOURCH.HTM.

Chabreck, R.H. and G. Linscombe. 1978. Vegetative type map of the Louisiana coastal marshes. La. Wildlife and Fisheries Comm., Baton Rouge, La.

Childers, D.L., and J.W. Day, Jr. 1990. Marsh-water column interactions in two Louisiana estuaries. I. Sediment dynamics. Estuaries 13(4):393-403.

Coalition to Restore Coastal Louisiana. 1989. Coastal Louisiana: Here today and gone tomorrow? A citizen's program for saving the Mississippi River Delta region to protect its heritage, economy and environment. Baton Rouge, La. 70 p.

Coalition to Restore Coastal Louisiana. 1998. No time to lose: The future of Louisiana without full scale coastal restoration. Draft copy. Baton Rouge, La. 59 p.

Coastal Wetlands Planning, Protection and Restoration Act, Pub. L. No. 101-646 (1990).

Coleman, J.M., and S.M. Gagliano. 1964. Cyclic sedimentation in the Mississippi River Deltaic Plain. Transactions of the Gulf Coast Association of Geological Societies 14:67-80.

Coleman, J.M., S.M. Gagliano, and J.P. Morgan. 1969. Mississippi River subdeltas: Natural models of deltaic sedimentation. Pages 23-27 *in* Louisiana State University Studies, Coastal Studies Bulletin 3. Louisiana State University Press, Baton Rouge, La.

Costanza, R., R. d'Arge, R. de Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R.V. O'Neill, J. Paruelo, R.G. Raskin, P. Sutton, and M. van den Belt. 1997. The value of the world's ecosystems services and natural capital. Nature 387:253-260.

Craig, N.J., R.E. Turner, and J.W. Day, Jr. 1980. Wetland losses and their consequences in coastal Louisiana. Zeitschrift fur Geomorphologie Supplementband 34(May):225-241.

Cranswick, D., and J. Regg. 1997. Deepwater in the Gulf of Mexico: America's New Frontier. U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region.

Curole, W. 1998. South Lafourche Levee District and Office of Emergency Preparedness. Personal Communication, August 1998.

Davis, D.W. 1994. Who are the people of Louisiana's coastal zone? Coast & Sea 3(2):2-3.

Debrusschere, K., and J.L. van Beek. 1993. Development of a comprehensive coastal wetland restoration plan and implementation strategy. Vol. 2: Implementation Strategy. Coastal Environments, Inc., Baton Rouge, La.

DeLaune R.D., W.H. Patrick, Jr., and C.J. Smith. 1992. Marsh aggradation and sediment distribution along rapidly submerging Louisiana Gulf Coast. Environmental Geology and Water Sciences 20(1):57-64.

DeLaune, R.D. and C.J. Smith. 1984. The carbon cycle and the rate of vertical accumulation of peat in the Mississippi River Deltaic Plain. Southeastern Geology 25(2):61-69.

Dozier, M.D., J.G. Gosselink, C.E. Sasser, and J.M. Hill. 1983. Wetland change in southwestern Barataria Basin, Louisiana, 1945-1980. Report submitted to LOOP, Inc., New Orleans, Louisiana, by the Center for Wetland Resources, Louisiana State University, Baton Rouge, La.

Dunbar, J.B., L.D. Britsch, and E.B. Kemp, III. 1992. Land loss rates: report 3, Louisiana coastal plain. Technical Report GL-90-2, U.S. Army Corps of Engineers District, New Orleans, La. 28 p.

Elliott, D.O. 1932. The improvement of the Lower Mississippi River for flood control and navigation in three volumes. U.S. Waterways Experiment Station, Vicksburg, MS. 345 p. + 71 plates.

Falgout, T. 1998. Greater Lafourche Port Commission. Personal Communication, August 1998.

Federal Coastal Zone Management Act. 1972, as amended (P.L. 92-583, 92nd Congress, S. 3507).

Fisk, H.N. 1944. Geological investigation of the alluvial valley of the lower Mississippi River. U.S. Army Corps of Engineers, Mississippi River Commission, Vicksburg, MS.

Fisk, H.N. 1958. Recent Mississippi River sedimentation and peat accumulation. p. 187-199 *in* Compte rendu du quatrieme congres pour l'avancement des etudes de stratigraphic et de geologie du Carbonifere, Heerlen, The Netherlands.

Frazier, D.E. 1967. Recent deltaic deposits of the Mississippi River: their development and chronology. Transactions/Gulf Coast Association of Geological Societies 17:287-311.

Frazier, D.E., and A. Osanik. 1969. Recent Peat Deposits - Louisiana Coastal Plain. p. 63-85 *in* E.C. Dapples, and M. E. Hopkins, editors, Environments of Coal Deposition. Geological Society of America Special Paper 114.

Gagliano, M.H., S.M. Gagliano, and P.J. Moses. 1997. Bay Rambo Oyster Reef: an artificial oyster reef in the deltaic estuarine area of Louisiana. Report to the Lafourche Parish Council and the Gulf of Mexico Program. Coastal Environments, Inc., Baton Rouge, La. 30 p.

Gagliano, S.M. 1972. Proposed multiuse management plan for the Louisiana Coastal Zone. Louisiana Advisory Commission on Coastal and Marine Resources.

Gagliano, S.M. 1973. Canals, dredging, and land reclamation in the Louisiana Coastal Zone. Report 14. Center for Wetland Resources, Louisiana State University, Baton Rouge, La. 104 p.

Gagliano, S.M. 1989. Controlled diversions in the Mississippi River deltaic plain. p. 257-268 *in* Kusles, J.A. and Daly, S., editors, Proceedings of International Symposium (Wetlands and River Corridor Management, July 5-9, Charleston, South Carolina), Association of Wetland Managers.

Gagliano, S.M. 1994. An environmental-economic blueprint for restoring the Louisiana coastal zone: the state plan. Report of the Governor's Office of Coastal Activities, Science Advisory Panel Workshop. Coastal Environments, Inc., Baton Rouge, La.

Gagliano, S.M. 1998. Faulting, Subsidence, and Land Loss in Coastal Louisiana. Coastal Environments Inc., Baton Rouge, La.

Gagliano, S.M., P. Culley, P. Light, D. Earle, W. Daniel, Jr., A. Rowland, R. Shlemon, J.L. van Beek, L. Johannes, and C. Latiolais. 1972a. Environmental Atlas and multi-use management plan for south central Louisiana. Coastal Resources Unit, Center for Wetland Resources, Louisiana State University. Baton Rouge, La. 109 p.

Gagliano, S.M., H.J. Kwon, and J.L. van Beek. 1970. Deterioration and restoration of coastal wetlands. Coastal Studies Institute, Center for Wetland Resources, Louisiana State University, Baton Rouge, La. 14 p.

Gagliano, S.M., D. Lee, E. Fike, M. Gagliano, K. Wicker, L. Harkins, and C. Latiolais. 1994. Strategies for enhancing water-oriented recreation and ecotourism, eastern Orleans wetlands. Coastal Environments, Inc., Baton Rouge, La. 18 p.

Gagliano, S.M., P. Light, and R.E. Becker. 1972b. Controlled diversions in the Mississippi Delta system: an approach to environmental management. Report 8, Center for Wetland Resources, Louisiana State University, Baton Rouge, La. 146 p.

Gagliano, S.M., K.J. Meyer-Arendt, and K.M. Wicker. 1981. Land loss in the Mississippi River deltaic plain. Transactions/Gulf Coast Association of Geological Societies 31:295-300.

Gagliano, S.M., and D.W. Roberts. 1990. Restoration and conservation of the Terrebonne Parish, Louisiana coastal area. Report to the South Terrebonne Conservation and Tidewater District. Coastal Environments, Baton Rouge, La.

Gagliano, S.M., and J.L. van Beek. 1970. Geological and geomorphic aspects of deltaic processes, Mississippi delta system. Hydrologic and Geologic Studies of Coastal Louisiana, Report 1, Coastal Resources Unit, Center for Wetland Resources, Louisiana State University, Baton Rouge, La.

Gagliano, S.M., and J.L. van Beek. 1975. An approach to multiuse management in the Mississippi Delta system. p. 223-238 *in* M.L. Broussard, editor, Deltas, Models for Exploration. Houston Geological Society, Houston, TX.

Gagliano, S.M., and J.L. van Beek. 1976. Mississippi River sediment as a resource. p. 102-126 *in* Ram S. Saxena, editor, Modern Mississippi Delta—Depositional Environments and Processes.

Gagliano, S.M., and J.L. van Beek. 1993. A long-term plan for Louisiana's coastal wetlands. Louisiana Department of Natural Resources, Office of Coastal Restoration, Baton Rouge, La.

Gagliano, S.M., and J.L. van Beek. 1998. A third branch for the Mississippi River: the Lafourche conveyance channel. Coastal Environments Inc., Baton Rouge, La.

Gagliano, S.M., and R.Weinstein. 1985. The shifting deltaic coast of the Lafourche Country and its prehistoric settlement. p. 122-149 *in* Philip D. Uzee, editor, The Lafourche country: the people and the land. Lafourche Heritage Society, Lafayette, La.

Gagliano, S.M., and K.M. Wicker. 1988. Processes of wetland erosion in the Mississippi River deltaic plain. Coastal Environments, Inc., Baton Rouge, La. 20 p.

Gosselink, J.G. 1984. The ecology of delta marshes of coastal Louisiana: a community profile. U.S. Fish and Wildlife Service, Biological Services Program, FWS/OBS-84/09. 134 p.

Gosselink, J.G., C.L. Cordes, and J.W. Parsons. 1979. An ecological characterization study of the Chenier Plain coastal ecosystem of Louisiana and Texas. U.S. Fish and Wildlife Service, Office of Biological Services, FWS/OBS-78/11. 3 volumes.

Gould, H.R., E. McFarlan, Jr. 1959. Geologic history of the Chenier Plain, southwestern Louisiana. Transactions/Gulf Coast Association of Geological Societies 9:261-70.

Guo, J., D. Hughes, and W. Keithly. 1998. An analysis of Louisiana Highway 1 in relation to expanding oil and gas activities in the central Gulf of Mexico. Interim Report, U.S. Department of Interior, Minerals Management Service and Louisiana State University.

Hatton, R.S., R.D. DeLaune, and W.H. Patrick, Jr. 1983. Sedimentation, accretion, and subsidence in marshes of Barataria Basin, Louisiana. Limnology and Oceanography 28(3):494-502.

Howard, Needles, Tammen and Bergendoff, Inc. 1985. Program management manual for coastal protection master plan. Louisiana Department of Natural Resources, Geological Survey Division, Coastal Protection Section. Baton Rouge, La.

Howe, H.V., R.J. Russell, J.H. McGuirt, B.C. Craft, and M.B. Stephenson. 1935. Reports on the geology of Cameron and Vermilion Parishes. Geological Bulletin No. 6. Department of Conservation, Louisiana Geological Survey, New Orleans, La. 242 p.

Hughes, D. 1998. Louisiana State University Agricultural Center, Agricultural Economist. Personal Communication, August 1998.

Hughes, D., J.M. Fannin, W. Keithly, W. Olatubi, and J. Guo. 1998. Impact of the Gulf of Mexico Outer Continental Shelf (OCS) petroleum mining industry on the economy of and public service provision in Lafourche Parish, Louisiana. U.S. Department of the Interior, Minerals Management Service and Louisiana State University.

Industrial Economics, Inc. 1996. Economic value assessment for the Barataria-Terrebonne estuarine system. BTNEP Publ. No. 26 Barataria-Terrebonne National Estuary Program, Thibodaux, La.

Johnson, W.B., and J.G. Gosselink. 1982. Wetland loss directly associated with canal dredging in the Louisiana Coastal Zone. p. 60-72 *in* D.F. Boesch, editor, Proceedings of the Conference on Coastal Erosion and Wetland Modification in Louisiana: Causes, Consequences, and Options. Center For Wetland Resources, Louisiana State University, Baton Rouge, La.

Kaye, C.A., and E.S. Barghoorn. 1964. Late quaternary sea-level change and crustal rise at Boston, Massachusetts, with notes on the autocompaction of peat. Geological Society of America Bulletin 75:63-80.

Kemp, G.P. 1986. Mud deposition at the shoreface: wave and sediment dynamics on the Chenier Plain of Louisiana. Ph.D. dissertation, Louisiana State University, Baton Rouge, La. 148 p.

Kolb, C.R., and J.R. Van Lopik. 1965. Depositional Environments of the Mississippi River Deltaic Plain - southeastern Louisiana. P. 17-61 *in* M.L. Shirley, editor, Deltas in their geologic framework. Proceedings of the Fifteenth Annual Gulf Coast Association of Geological Societies Meeting. Houston Geological Society, TX.

Kosters, E.C., G.L. Chmura, and A. Bailey. 1987. Sedimentary and botanical factors influencing peat accumulation in the Mississippi Delta. Journal of the Geological Society, London 144:423-434.

Kuecher, G.J. 1994. Geologic framework and consolidation settlement potential of the Lafourche Delta, topstratum valley fill: implications for wetland loss in Terrebonne and Lafourche Parishes, Louisiana. Ph.D. dissertation, Louisiana State University, Baton Rouge, La. 346 p.

Lake Pontchartrain Basin Foundation. 1995. Comprehensive management plan. Metairie, La. 79 p.

List, J.H. 1994. Louisiana barrier island erosion study: atlas of sea-floor changes from 1878 to 1989. U.S. Department of the Interior, U.S. Geological Survey Miscellaneous Investigations Series I-2150-B. 81 p.

Louisiana Advisory Commission on Coastal and Marine Resources. 1972. Louisiana Government and the Coastal Zone - 1972. Baton Rouge, La.

Louisiana Advisory Commission on Coastal and Marine Resources. 1973. Coastal Resources Program: Louisiana wetland prospectus. Conclusions, recommendations and proposals of the Louisiana Advisory Commssion on Coastal and Marine Resources. La. Dept. of Transportation and Development, Baton Rouge, La. 346 p.

Louisiana Advisory Commission on Coastal and Marine Resources. 1973. Wetlands '73: Toward Coastal Zone Management in Louisiana. Baton Rouge, La.

Louisiana Coastal Wetlands Conservation and Restoration Task Force. 1993. Coastal Wetlands Planning, Protection, and Restoration Act: Louisiana Coastal Wetlands Restoration Plan. Main report and environmental impact statement. Louisiana Coastal Wetlands Conservation and Restoration Task Force, Baton Rouge, La.

Louisiana Department of Culture, Recreation, and Tourism, Office of State Parks, Division of Outdoor Recreation. 1993. Louisiana statewide comprehensive outdoor recreation plan, part 1, information base for executive decision. Baton Rouge, La.

Louisiana Department of Natural Resources. 1982. Coastal Protection Task Force report. Final report to Gov. David C. Treen, the Joint House and Senate Committee on Natural Resources, and the Legislative Budget Committee. Louisiana Department of Natural Resources. Baton Rouge, La.

Louisiana Department of Natural Resources, Office of Coastal Restoration and Management. 1997. Louisiana Coastal Wetlands Conservation Plan. Baton Rouge, La. 46 p. plus appendices.

Louisiana Department of Public Safety Services. 1985. Southeast Louisiana Storm Surge Atlas. Louisiana Department of Public Safety Services, Office of Emergency Preparedness, Baton Rouge, La. 53 p.

Louisiana Department of Wildlife and Fisheries. 1997. Report to the fur and alligator advisory council. Baton Rouge, La.

Louisiana Department of Wildlife and Fisheries, Office of Marine Fisheries. 1996. Recreational licenses sold. Baton Rouge, La.

Louisiana Oil Spill Coordinators Office (LOSCO). 1997. Oil spill response training course. Course content and training material. State of Louisiana, Office of the Governor, Baton Rouge, La. 727 p.

Louisiana Sea Grant College Program. 1997. Coastal economic strategy series. Louisiana State University. Baton Rouge, La.

Louisiana Sea Grant College Program. 1998. Analysis of Louisiana's coastal infrastructure. Louisiana State University. Baton Rouge, La.

Louisiana State University Natural Systems Engineering Laboratory. 1998. Land to be lost/gained between 1993 and 2050. Geo-referenced image provided by the Louisiana Department of Natural Resources, Louisiana State University for Coastal Wetlands, Planning, Protection and Restoration Act Task Force.

Louisiana Wetlands Protection Panel. 1987. Saving Louisiana's coastal wetlands: the need for a long-term plan of action. Baton Rouge, La.

Lovelace, J.K. 1994. Storm-tide elevations produced by Hurricane Andrew along the Louisiana Coast, August 25-27, 1992. U.S. Geological Survey Open File Report 94-371, Baton Rouge, La. 5 p.

McBride, R.A., and M.R. Byrnes. 1995. A megascale systems approach for shoreline change analysis and coastal management along the northern Gulf of Mexico. Gulf Coast Association of Geological Societies Transactions 45:405-414.

McKenzie, L.S. III, M.W. Wascom, W.R. Keithly, R.E. Emmer, W.H. Hudnall, M.T.C. Johnson, F. Niami, and B.A. Touchet. 1995. Land use and socioeconomic status and trends in the Barataria-Terrebonne estuarine system. BTNEP-23. Barataria-Terrebonne National Estuary Program, Thibodaux, La. 184 p.

Meade, R.H. and R.S. Parker. 1985. Sediments in rivers of the United States. National Water Summary 1984. U.S. Geological Survey, Water Supply Paper 2275.

Meade, R.H., T.R. Yuzyk, and T.J. Day. 1990. Movement and storage of sediment in rivers of the United States and Canada. In the Geology of North America, Vol. O-1, Surface Water Hydrology. The Geological Society of America. P. 255-279.

Melancon, E., Jr., T. Soniat, V. Cheramie, M. Lagarde, R. Dugas, and J. Barras. 1994. The oyster resource zones within Louisiana's Barataria and Terrebonne estuaries. Barataria-Terrebonne National Estuary Program Office BTNEP-15, Thibodaux, La. 184 p.

Mendelssohn, I.A., and K.L. McKee. 1988. *Spartina alterniflora* die-back in Louisiana: time-course investigation of soil waterlogging effects. Journal of Ecology 76:509-521.

Mendelssohn, I.A., R.E. Turner, and K.L. McKee. 1983. Louisiana's eroding coastal zone: management alternatives. Journal of Limnology 9(2):63-75.

Metrovision, Greater New Orleans Chamber of Commerce. 1998. Personal Communication.

Meyer-Arendt, K.J., and P.H. Templet. 1983. Restoration and management measures for Timbalier Island and Isles Dernieres, Terrebonne Parish. Coastal Environments, Inc., Baton Rouge, La. 45 p.

Moore, D.M. and R.D. Rivers, editors, 1996. The appendix: CCMP supplement content requirements and program support documentation, CCMP-Part 4. Barataria-Terrebonne National Estuary Program, Thibodaux, La.

Moore, D.M. and R.D. Rivers. 1996. The estuary compact: A public-private promise to work together to save the Barataria and Terrebonne basins, CCMP-Part 2. Barataria-Terrebonne National Estuary Program, Thibodaux, La.

Moore, D.M. and R.D. Rivers. 1996. The executive summary: Program objectives, action plans, and implementation strategies at a glance, CCMP-Part 1. Barataria-Terrebonne National Estuary Program, Thibodaux, La.

Moore, D.M. and R.D. Rivers, editors, 1996. The technical supplement: CCMP action plan details for plan implementation, CCMP-Part 3. Barataria-Terrebonne National Estuary Program, Thibodaux, La.

Morgan, J.P. 1972. Impact of subsidence and erosion on Louisiana coastal marshes and estuaries. P. 217-233 *in* R.H. Chabreck, editor, Proceedings of the Coastal Marsh and Estuary Management Symposium. Division of Continuing Education, Louisiana State University, Baton Rouge, La.

Morgan, J.P. and P.B. Larimore. 1957. Changes in the Louisiana shoreline. Transactions of the Gulf Coast Association of the Geological Society, 7:303-310.

Morgan, J.P., J.R. van Lopik, and L.G. Nichols. 1953. Marsh occurrence and development of mudflats along the western Louisiana coast. Coastal Studies Institute, Technical Report No. 2, Louisiana State University, Baton Rouge, La, 34 p.

Murray, G.E. 1960. Geologic framework of Gulf Coastal Province of United States. P. 5-33 *in* F.P. Shepard, F.B. Phleger, and T.H. van Andel, editors, Recent sediments, northwest Gulf of Mexico. American Association of Petroleum Geologists, Tulsa, OK.

National Geographic Society. 1987. Field guide to the birds of North America. National Geographic Society, Washington, D.C. 464 p.

Nyman, J.A., R.H. Chabreck, R.D Delaune, and W.H. Patrick, Jr. 1993. Submergence, salt-water intrusion, and managed gulf coast marshes. P. 1690-1704 *in* O.T. Magoon, W.S. Wilson, H. Converse, and L.T. Tobin, editors, Coastal Zone '93. Vol. 2. American Society of Civil Engineers, New York City, N.Y.

O'Neil, T. 1949. The muskrat in the Louisiana coastal marshes: a study of the ecological, geological, biological, tidal, and climatic factors governing the production and management of the muskrat industry in Louisiana. Louisiana Department of Wild Life and Fisheries, New Orleans, La. 152 p.

Penland, S., and R. Boyd. 1981. Shoreline changes on the Louisiana barrier coast: Proceedings of an international symposium. Oceans. New York: IEEE, p 209-229.

Penland, S., R. Boyd, and J.R. Suter. 1988. Transgressive depositional systems of the Mississippi Delta Plain: a model for barrier shoreline and shelf sand development. Journal of Sedimentary Petrology 58(6):932-49.

Penland, S., I. Mendelssohn, L. Wayne, and D. Britsch. 1996. Natural and human causes of coastal land loss in Louisiana - workshop summary. Baton Rouge: Coastal Studies Institute, Wetland Biogeochemistry Institute, Louisiana State University. Baton Rouge, La. 25 p.

Penland, S., and K.E. Ramsey. 1990. Relative sea-level rise in Louisiana and the Gulf of Mexico: 1908-1988. Journal of Coastal Research 6(2):323-342.

Penland, S., K.E. Ramsey, R.A. McBride, T. Mestayer, and K.A. Westphal. 1988. Relative sea level rise and delta-plain development in the Terrebonne Parish region. Coastal Geology Technical Report No. 4, Louisiana Geological Survey, Baton Rouge, La. 120 p.

Penland, S., K.E. Ramsey, R.A. McBride, T.F. Moslow, and K.A. Westphal. 1989. Relative sea level rise and subsidence in Louisiana and the Gulf of Mexico. Louisiana Geological Survey, Baton Rouge, La. 65 p.

Ramsey, K.E. and T.F. Moslow. 1987. A numerical analysis of subsidence and sea level rise in Louisiana. P. 1673-1688 *in* N.C. Kraus, editor, Coastal sediments '87: Proceedings of a specialty conference on advances in understanding of coastal sediment processes, New Orleans, La., May 12-14, 1987. American Society of Civil Engineers, New York City, N.Y.

Ramsey, K.E., T.F. Moslow, and S. Penland. 1985. Sea level rise and subsidence in coastal Louisiana. Coastal Geology Program, Louisiana Geological Survey, Baton Rouge, La. 11 p.

Raper, S.C., T.M. Wigley, and R.A. Warrick. 1996. Global sea level rise: past and future. P. 11 -45 *in* J.D. Milliman and B.U. Haq, editors, Sea-level Rise and Coastal Subsidence. Kluwer, Dordrecht, the Netherlands. P. 11-45.

Reed, D.J. 1989. Patterns of sediment deposition in subsiding coastal salt marshes, Terrebonne Bay, Louisiana: the role of winter storms. Estuaries 12(4):222-227.

Reed, D.J., N. DeLuca, and A.L. Foote. 1997. Effect of hydrologic management of marsh surface sediment deposition in coastal Louisiana. Estuaries 20(2):301-311.

Roberts, H.H. 1997. Dynamic changes of the Holocene Mississippi River Delta Plain: the delta cycle. Journal of Coastal Research 13(3):605-27.

Roberts, H.H. 1998. Delta switching: early responses to the Atchafalaya River diversion. Journal of Coastal Research 14(3):882-899.

Rogers, D.P. 1985. Retreat from the gulf: reminiscences of early settlers of lower Lafourche. The Lafourche country: the people and the land. P. 97-107 *in* Philip D. Uzee, editor, Lafourche Heritage Society, Lafayette, La.

Russell, R.J. 1942. Flotant. Geographical Review, XXXII (L): 74-98.

Russell, R.J., H.V. Howe, J.H. McGuirt, C.F. Dohm, W. Hadley, Jr., F.B. Kiffen, and C.A. Brown. 1936. Lower Mississippi River Delta: reports on the geology of Plaquemines and St. Bernard Parishes. Louisiana Geological Survey, Geological Bulletin 13, Louisiana Department of Conservation, New Orleans, La.

Sallenger, A.H., S.P. Penland, J.H. List, M.E. Hansen, J.R. Dingler, S.J. Williams. 1995. Hurricane and extreme storm impacts on the physical coastal environment. Page 108 *in* A.C. Hine, R.B. Halley, editors, Linked Earth system; congress program and abstrats; Vol. 1Society of Economic Paleontologists and Mineralologists, Tulsa, OK.

Sasser, C.E. 1994. Vegetation dynamics in relation to nutrients in floating marshes in Louisiana, USA. Center for Coastal, Energy, and Environmental Resources, Louisiana State University, Baton Rouge, La. 193 p.

Sasser, C.E., M.D. Dozier, J.G. Gosselink, and J.M. Hill. 1986. Spatial and temporal changes in Louisiana's Barataria Basin marshes, 1945-1980. Environmental Management 10(5):671-680.

Saucier, R.T. 1963. Recent geomorphic history of the Pontchartrain Basin. Coastal Studies Series 9, Louisiana State University Press, Baton Rouge, La. 114 p.

Scruton, P.C. 1960. Delta building and the deltaic sequence. P. 82-102 *in* F.P. Shepard, editor, Recent sediments, northwest Gulf of Mexico. American Association of Petroleum Geologists.

Shlemon, R.J. 1975. Subaqueous delta formation: Atchafalaya Bay, Louisiana. P. 209-221 *in* M.L. Broussard, editor, Deltas, Models for Exploration. Houston Geological Society, Houston, TX.

Southwick Associates. 1997. The economic benefits of fisheries, wildlife and boating resources in the state of Louisiana. Louisiana Department of Wildlife and Fisheries, Baton Rouge, La. 21 p.

Stone, G.W., and R.A. McBride. 1998. Louisiana barrier islands and their importance in wetland protection: forecasting shoreline change and subsequent response of wave climate. Journal of Coastal Research 14(3):900-915.

Stone, G.W., S.J. Williams, and A.E. Burrus. 1997. Louisiana's barrier islands: an evaluation of their geological evolution, morphodynamics and rapid deterioration. Journal of Coastal Research 13(3):591-592.

Suhayda, J.N. 1997. Modeling impacts of Louisiana barrier islands on wetland hydrology. Journal of Coastal Research 13: 686-693.

Suhayda, J.N., G.P. Kemp, R.S. Jones, and J. Peckham. 1991. Restoration of wetlands using pipeline transported sediments. p. 257-262 *in* GCS-SEPM Foundation Twelfth Annual Research Conference.

Swenson, E.M. 1994. Hurricane Andrew: the Inundation of the Louisiana Coastal Marshes. Report submitted to the Louisiana Department of Natural Resources, Baton Rouge, Louisiana. DNR Contract No. 256081-95-02. 62 p.

T. Baker Smith and Son, Inc. 1998. Barrier shoreline feasibility study, Step H: forecasted trends in economic resource conditions. Report submitted to Louisiana Department of Natural Resources, Baton Rouge, La. 62 p.

Templet, P.H., and K.J. Meyer-Arendt. 1988. Louisiana wetland loss: a regional water management approach to the problem. Environmental Management 12(2):181-192.

Turner, R.E. 1987. Relationship between canal and levee density and coastal land loss in Louisiana. U.S. Fish and Wildlife Service, Biological Report 85(14), Washington, D.C. 58 p.

U.S. Army Corps of Engineers, New Orleans District. 1982. Louisiana coastal area, Louisiana, freshwater diversion to Barataria and Breton Sound Basins: draft feasibility study. Vol. 1. Main Report [and] Environmental Impact Statement. U.S. Army Corps of Engineers, New Orleans, La.

U.S. Bureau of the Census. 1990. Census of the population, Summary Tape File 3a CD-ROM. Bureau of the Census, Washington, D.C.

U.S. Bureau of the Census. 1998. 1995 County Business Patterns for Lafourche, La. Bureau of the Census, Survey Processing and Products Branch, Washington, D.C. Internet URL: http://www.census.gov.

U.S. Department of Commerce, Bureau of Economic Analysis. BEA Regional Facts, Lafourche Louisiana 1994-95, 1985-95. Internet URL: http://www.bea.doc.gov.

U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region. 1997. Environmental impact statement: Gulf of Mexico OCS oil and gas lease sales 171, 174, 177 and 180 -- western planning area. OCS EIS/EA MMS 97-0032. Minerals Management Service, U.S. Department of the Interior, New Orleans, La. 429 p.

U.S. Environmental Protection Agency and Louisiana Geological Survey. 1987. Saving Louisiana's coastal wetlands: the need for a long-term plan of action. Report of the Louisiana Wetland Protection Panel. EPA-230-02-87-026. U.S. Environmental Protection Agency, Baton Rouge, La.

U.S. Fish and Wildlife Service, Department of the Interior. 1997. 1996 national survey of fishing, hunting and wildlife-associated recreation: state overview. Washington, D.C. 27 p.

van Beek, J.L., T.J. Duenckel, P.C. Howard, K.J. Meyer-Arendt, and S.M. Gagliano. 1986. Long-term management and protection of Plaquemines Parish. Coastal Environments, Inc., Baton Rouge, La. 249 p.

van Heerden, I.L. 1983. Sediment responses during flood and non-flood conditions, New Atchafalaya Delta, Louisiana. M.S. thesis, Louisiana State University, Baton Rouge, La. 76 p.

van Heerden, I.L. 1994. A long-term, comprehensive management plan for coastal Louisiana to ensure sustainable biological productivity, economic growth, and the continued existence of its unique culture and heritage. Center for Coastal, Energy, and Environmental Resources, Louisiana State University. Baton Rouge, La.

van Heerden, I.L., and H.H. Roberts. 1988. Facies development of Atchafalaya Delta, Louisiana: a modern bayhead delta. The American Association of Petroleum Geologists Bulletin 72(4):439-453.

van Lopik, J.R. 1955. Recent geology and geomorphic history of central coastal Louisiana. Coastal Studies Institute Technical Report 7, Louisiana State University, Baton Rouge, La. 88 p.

Wallace, W.E., Jr. 1957. Fault map of south Louisiana. Transactions/Gulf Coast Association of Geology Society 7:240.

Welder, F.A. 1959. Processes of deltaic sedimentation in the lower Mississippi River. Technical Report 12. Coastal Studies Institute, Louisiana State University, Baton Rouge, La. 87 p.

Wells, J.T., and H.H. Roberts. 1980. Fluid mud dynamics and shoreline stabilization: Louisiana chenier plain. P. 1382-1401*in* Proceedings of the 17th International Coastal Engineering Conference (ASCE), Sydney, Australia.

White, R. 1998. Vice President of Business Development, Edison Chouest Offshore. Personal Communication. 8/11/98.

Wigley, T.M. and S.C.B. Raper. 1992. Implications for climate and sea level of revised IPCC emission scenarios. Nature 357:293-300.

Williams, S.J., S. Penland, and A.H. Sallenger, Jr., editors, 1992. Louisiana Barrier Island Erosion Study: Atlas of shoreline changes in Louisiana from 1853 to 1989. Prepared by the U.S. Geological Survey in cooperation with the Louisiana Geological Survey. 103 p.

Woolfolk, Doug, editor. 1980. The longest street: A story of Lafourche Parish and Grand Isle. Moran Publishing Corporation, Baton Rouge, La.