FRESHWATER INFLOW ACTION AGENDA (3.1) FOR THE GULF OF MEXICO

GULF OF MEXICO PROGRAM

September 1993

Executive Summary

The Gulf of Mexico contains ecological and commercial resources matched by few other bodies of water. Yet its productive waters disguise the increasing environmental threats that endanger these resources. In recognition of the growing threats, Regions 4 and 6 of the U.S. Environmental Protection Agency (USEPA), which share jurisdiction over the five Gulf Coast States (Alabama, Florida, Louisiana, Mississippi, and Texas), initiated the Gulf of Mexico Program in August 1988. The goal of the Gulf of Mexico Program is to protect, restore, and enhance the coastal and marine waters of the Gulf of Mexico and its coastal natural habitats, to sustain living resources, to protect human health and the food supply, and to ensure the recreational use of Gulf shores, beaches, and waters--in ways consistent with the economic well being of the region.

The Gulf of Mexico Program is a cooperative partnership among federal, state, and local government agencies, as well as with people and groups who use the Gulf. During the early stages of Program development, eight priority environmental problems were identified and the following Issue Committees have been established to address each of these problems: Marine Debris, Public Health, Habitat Degradation, Coastal & Shoreline Erosion, Nutrient Enrichment, Toxic Substances & Pesticides, Freshwater Inflow, and Living Aquatic Resources. There are important linkages among these various Issue Committees, and the Gulf of Mexico Program works to coordinate and integrate activities among them.

The Freshwater Inflow Committee was charged with characterizing the problems associated with alterations to freshwater inflow into the Gulf and identifying appropriate ways to protect these resources. The Issue Committee has been meeting for more than three years--to review information and data collected by citizens and scientists, identify problem areas, discuss actions that can resolve the problems, and evaluate methods for achieving and monitoring results. The culmination of Issue Committee efforts is this Freshwater Inflow Action Agenda which specifies an initial set of activities needed to protect the Gulf of Mexico from freshwater inflow concerns. This Action Agenda is the first generation of an evolving series of Action Agendas that will be developed to meet the future needs of the Gulf of Mexico.

Chapter 1 of the Action Agenda provides an overview of Gulf of Mexico resources and the threats now facing those resources. In addition, Chapter 1 describes the structure of the Gulf of Mexico Program, including the Action Agenda development process.

Chapter 2 describes the functional role of freshwater inflows relative to the ecology of estuarine environments and the Gulf of Mexico.

Chapter 3 describes the legal and institutional framework currently in place in the Gulf of Mexico to address freshwater inflow issues and support efforts to provide sufficient quantities of freshwater needed to maintain a healthy marine ecosystem.

Chapter 4, **The Unfinished Agenda**, contains the goal, objectives, and specific activities established by the Gulf of Mexico Program to address freshwater inflow issues. The long-term goal established by the Issue Committee is to:

- ❑ Protect, preserve, restore, and, where feasible, enhance the freshwater inflow to the Gulf of Mexico and the associated bays and estuaries for the purpose of maintaining the ecological health and integrity of those systems.

For the purposes of this Action Agenda, "freshwater" includes surface water, ground water, springs, and precipitation.

Eighty-six action items have been developed to support the goal and these are grouped under four types of activity and seventeen objectives (see **Index of Freshwater Inflow Objectives**). The action items included in Chapter 4 have been screened by the Gulf of Mexico Program and represent those activities that are currently the most significant and most achievable. This is a fairly comprehensive, but not exhaustive list. This document begins an evolving process of Action Agendas in which action items are designated, implemented, and then reassessed as progress in the Gulf is made. In the future, new action items will be developed to meet the changing needs in the Gulf of Mexico.

Action items contained in Chapter 4 are not listed in priority order. Some of the actions may already be underway but not yet completed. Others are included because they will guide federal, state, and local government agencies and private sector organizations in allocating resources where they are most needed and in justifying future management strategies. This Action Agenda should prompt specific agencies and groups to become involved.

The Gulf of Mexico Program recently developed ten short-term environmental challenges to restore and maintain the environmental and economic health of the Gulf. Within the next five years (1993-1997), through an integrated effort that complements existing local, state, and federal programs, the Program has pledged efforts to obtain the knowledge and resources to:

- Significantly reduce the rate of loss of coastal wetlands.
- Achieve an increase in Gulf Coast seagrass beds.
- Enhance the sustainability of Gulf commercial and recreational fisheries.
- Protect the human health and food supply by reducing input of nutrients, toxic substances, and pathogens to the Gulf.
- Increase Gulf shellfish beds available for safe harvesting by ten percent.

- Ensure that all Gulf beaches are safe for swimming and recreational uses.
- Reduce by at least ten percent the amount of trash on beaches.
- Improve and expand coastal habitats that support migratory birds, fish, and other living resources.
- Expand public education/outreach tailored for each Gulf Coast county or parish.
- Reduce critical coastal and shoreline erosion.

This Freshwater Inflow Action Agenda supports these five year environmental challenges.

For the public, the Gulf of Mexico Action Agenda should serve three purposes. First, it should reflect the public will with regard to addressing freshwater inflow concerns. Second, it should communicate what activities are needed to address freshwater inflow concerns and provide the momentum for initiating these actions. Third, it should provide baseline information from which success can be measured.

This Action Agenda is a living document; therefore, the Gulf of Mexico Freshwater Inflow Committee intends to periodically revise and update this document.

Index of Freshwater Inflow Objectives

Policy, Planning & Implementation

Objective: Develop a process for assessing the range of freshwater needs for estuarine and coastal waters of the Gulf of Mexico and identify the quantity and quality of freshwater necessary to meet those needs.

Objective: Identify and evaluate Gulf of Mexico estuaries with freshwater inflow issues and select appropriate estuaries for management attention.

Objective: Develop a coordinated Gulfwide strategy to provide adequate freshwater inflows to the estuarine and coastal waters of the Gulf of Mexico.

Objective: Develop policy alternatives on the allocation of water among Gulf of Mexico estuaries.

Objective: Promote the watershed approach in national policy.

Research

Objective: Conduct research to improve the understanding of relationships among freshwater inflows, salinity patterns, nutrient delivery and uptake, sediment regimes, circulation and flushing times, estuarine productivity, and habitat (with an emphasis on major representative river systems) in the Gulf of Mexico.

Objective: Conduct research on the cumulative impacts of alterations on freshwater inflows to the Gulf of Mexico.

Objective: Conduct research on population and economic projections in the Gulf of Mexico related to freshwater needs and flows and related socio-political issues.

Index of Freshwater Inflow Objectives (continu d)

Monitoring & Assessment

Objective: Inventory all available data and identify data gaps relating to water quality and quantity, water use factors, and effects of freshwater inflow on Gulf of Mexico estuarine productivity–including salinity patterns, nutrient delivery and uptake, sediment regimes, land use and land use changes, biological parameters, geomorphology, and types of freshwater inflow (*e.g.*, surface water, ground water, and other sources).

Objective: Assess trends in freshwater inflows to the Gulf of Mexico.

Objective: Identify and evaluate causes of change in freshwater inflow quantity and quality relative to location, volume, and timing of change within an estuary or segment in the Gulf of Mexico.

Objective: Determine Gulf of Mexico estuarine resource-based salinity requirements based on existing knowledge and working hypotheses (inventory what has been done and identify what needs to be done for major representative ecosystems).

Objective: Identify linkages and assess relationships among freshwater inflows, salinity patterns, nutrient delivery and uptake, sediment regimes, estuarine productivity, other water quality parameters, and the adjacent Gulf of Mexico.

Objective: Develop a Gulfwide monitoring program to assess the effectiveness of freshwater management actions on an estuary specific (or estuary class) basis.

Public Education & Outreach

Objective: Promote the basin-wide public awareness of ecological, economic, and health impacts associated with alterations of freshwater inflows to estuarine systems and the cumulative role of those estuaries for sustaining the health of the Gulf of Mexico.

Objective: Promote the basin-wide awareness of federal, state, and local government officials and decision-makers of the ecological, economic, and health impacts associated with alterations of freshwater inflows to estuarine systems and the cumulative role of those estuaries for sustaining the health of the Gulf of Mexico.

Objective: Promote basin-wide public involvement to address the ecological, economic, and health impacts associated with alterations of freshwater inflows to estuarine systems and the cumulative role of those estuaries for sustaining the health of the Gulf of Mexico.

Table of Contents

List of Tables

List of Figures

1 OVERVIEW OF THE GULF OF MEXICO

The Gulf of Mexico - A Vast & Valuable Resource

Bounded by a shoreline that reaches northwest from Florida along the shores of Alabama, Mississippi, and Louisiana, and then southwest along Texas and Mexico, the Gulf of Mexico is the ninth largest body of water in the world. The Gulf's U.S. coastline measures approximately 2,609 km (1,631 miles)--longer than the Pacific coastline of California, Oregon, and Washington. The Gulf region covers more than 1.6 million km^2 (617,600 mi^2) and contains one of the nation's most extensive barrier-island systems, outlets from 33 major river systems, and 207 estuaries (Buff and Turner, 1987). In addition, the Gulf receives the drainage of the Mississippi River, the largest river in North America and one of the major rivers of the world. A cornerstone of the nation's economy, the Gulf's diverse and productive ecosystem provides a variety of valuable resources and services, including transportation, recreation, fish and shellfish, and petroleum and minerals.

Encompassing over two million hectares (five million acres) (about half of the national total), Gulf of Mexico coastal wetlands serve as essential habitat for a large percentage of the U.S.'s migrating waterfowl (USEPA, 1991). Mudflats, salt marshes, mangrove swamps, and barrier island beaches of the Gulf also provide year-round nesting and feeding grounds for abundant numbers of gulls, terns, and other shorebirds. Five species of endangered whales, including four baleen whales and one toothed whale, are found in Gulf waters. These waters also harbor the endangered American crocodile and five species of endangered or threatened sea turtles (loggerhead, green, leatherback, hawksbill, and Kemp's Ridley). The endangered West Indian (or Florida) manatee inhabits waterways and bays along the Florida peninsula. The anadromous Gulf sturgeon, recently designated as threatened, has been found in waters of the Gulf and many of its tributary rivers.

In addition, a complex network of channels and wetlands within the Gulf shoreline provides habitat for estuarine-dependent commercial and recreational fisheries. The rich waters yielded approximately 771 million kg (1.7 billion pounds) of fish and shellfish in 1991. Worth more than $641 million at dockside, this harvest represented 19 percent of the total annual domestic harvest of commercial fish (USDOC, 1992). The Gulf boasts the largest and most valuable shrimp fishery in the U.S and also contributed 41 percent of the U.S. total oyster production in 1991 (USDOC, 1992). Other Gulf fisheries include diverse shellfisheries for crabs and spiny lobsters and finfisheries for menhaden, herring, mackerel, tuna, grouper, snapper, drum, and flounder. The entire U.S. Gulf of Mexico fishery yields more finfish, shrimp, and shellfish annually than the South and Mid-Atlantic, Chesapeake, and Great Lakes regions combined.

The Gulf's bountiful waters draw millions of sport fishermen and beach users each year. It is estimated that the Gulf supports more than one-third of the nation's marine recreational fishing, hosting four million fishermen in 1985, who caught an estimated 42 million fish (USDOC, 1992). Popular nearshore catches include sea trout (weak fish), cobia, redfish, flounder, grouper, red snapper, mackerel, and tarpon; offshore catches include blue marlin, white marlin, sailfish, swordfish, dolphin, and wahoo. Tourism-related dollars in the Gulf Coast States contribute an estimated $20 billion to the economy each year (USEPA, 1991).

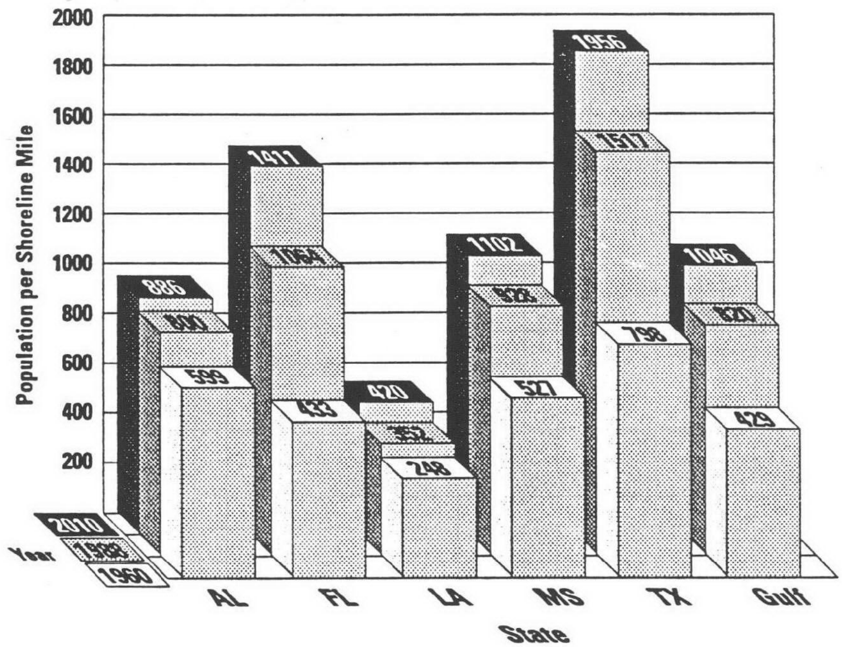
Gulf oil and gas production are equally valuable to the region's economy and are a critical part of the nation's total energy supply. In 1990, more than 1,600 Outer Continental Shelf (OCS) leases were in production, yielding approximately 90 percent of U.S. offshore production. These OCS royalties annually contribute about $3 billion to the Federal Treasury. Thirty-eight percent of all petroleum and 48 percent of all natural gas reserves in the U.S. are estimated to be in the Gulf of Mexico. The industry employs some 30,000 people in the region.

Approximately 45 percent of U.S. shipping tonnage passes through Gulf ports, including four of the nation's busiest: Corpus Christi, Houston/Galveston, Tampa, and New Orleans. The second largest marine transport industry in the world is located in the Gulf of Mexico. According to USEPA, vessel trips in and out of American Gulf ports and harbors exceeded an estimated 600,000 trips in 1986. The U.S. Navy is also implementing its Gulf Coast Homeporting Plan, designed to dock at least 25 vessels in Ingelside, TX, Pascagoula, MS, and Mobile, AL.

Millions of people depend on the Gulf of Mexico to earn a living and flock to its shores and waters for entertainment and relaxation. The temperate climate and abundant resources are attracting more and more people. The region currently ranks fourth in total population among the five U.S. coastal regions, accounting for 13 percent of the nation's total coastal population. Although the Gulf region is not as densely settled as others, it is experiencing the second fastest rate of growth; between 1970 and 1980, the population grew by more than 30 percent (USDOC, 1990a). According to the U.S. Department of Commerce, the Gulf's total coastal population is projected to increase by 144 percent between 1960 and 2010, to almost 18 million people. **Figure 1.1** shows the Gulf of Mexico coastal population density or population per shoreline mile projected to the year 2010. Florida's population alone is expected to have skyrocketed by more than 300 percent by the year 2010. The increasing coastal population is of concern because as the population increases, so do competing needs for freshwater.

The Gulf's resources and environmental quality are affected not only by the millions living and working in the region, but also by activities occurring throughout much of the nation. Over two-thirds of the land area of the contiguous U.S. drains into the Gulf. Maintaining sufficient freshwater inflows into the Gulf is vital to sustaining its vast and valuable resources.

Figure 1.1 ***Gulf of Mexico Coastal Population per Shoreline Mile***



(Source: USDOC, 1990a)

The Gulf of Mexico - A Resource At Risk

Increasing populations result in increased use and demands on Gulf of Mexico resources. Until recently, the Gulf was considered too vast to be affected by pollution and overuse. However, recent trends indicate serious long-term environmental damage unless action is initiated today. Potential problems or signs of increasing degradation throughout the Gulf system include the following (USEPA, 1991):

- ❑ Fish kills and toxic "red tides" and "brown tides" were an increasing phenomenon in Gulf waters during the 1980s.
- ❑ Alabama, Mississippi, Louisiana, and Texas are among those states that discharge the greatest amount of toxic chemicals into coastal waters.
- ❑ More than half of the shellfish-producing areas along the Gulf Coast are permanently or conditionally closed. These closure areas are growing as a result of increasing human and domestic animal populations along the Gulf Coast (USDOC, 1991b).
- ❑ Diversions and consumptive use for human activities have resulted in significant changes in the quantity and timing of freshwater inflows to the Gulf of Mexico.
- ❑ Louisiana is losing valuable coastal wetlands at the rate of approximately 14-66 km^2/year (5-25 mi^2/year) (Dunbar, *et al.*, 1992).
- ❑ Almost 1,800 kg/mi (2 tons/mi) of marine trash covered Texas beaches in 1988.
- ❑ Up to 9,500 km^2 (4,000 mi^2) of oxygen deficient (hypoxia) bottom waters, known as the "dead zone," have been documented off the Louisiana and Texas coasts (Rabalais, *et al.*, 1991).
- ❑ Gulf shorelines are eroding up to 30 m/year (100 ft/year). Few coastal reaches in the Gulf can be characterized as "stable" or "accreting."

The Gulf of Mexico Program - Goals & Structure

Problems plaguing the Gulf cannot be addressed in a piecemeal fashion. These problems and the resources needed to address them are too great. The Gulf of Mexico Program (GMP) was formed to pioneer a broad, geographic focus in order to address major environmental issues in the Gulf before the damage is irreversible or too costly to correct.

The program is part of a cooperative effort with other agencies and organizations in the five Gulf States, as well as with people and groups who use the Gulf. In addition to the U.S. Environmental Protection Agency (USEPA), other participating federal government agencies include: National Aeronautics and Space Administration (NASA), U.S. Army Corps of Engineers (USACE), U.S. Department of Agriculture (USDA), U.S. Department of Commerce (USDOC), U.S. Department of Defense (USDOD), U.S. Department of Energy (USDOE), U.S. Department of the Interior (USDOI), U.S. Department of Transportation (USDOT), U.S. Food and Drug Administration (USFDA), and Agency for Toxic Substances and Disease Registry (ATSDR).

The Gulf of Mexico Program also works in coordination and cooperation with five National Estuary Programs (NEPs) within the Gulf: Tampa Bay, Sarasota Bay, Galveston Bay, Corpus Christi Bay, and the Barataria-Terrebonne Estuarine Complex. The Gulf of Mexico Program supports and builds on certain activities of these programs, bringing a Gulfwide focus and providing a forum for addressing issues of Gulfwide concern.

By building on and enhancing programs already underway, as well as by coordinating new activities, the Gulf of Mexico Program will serve as a catalyst for change. The program's overall goals are to provide:

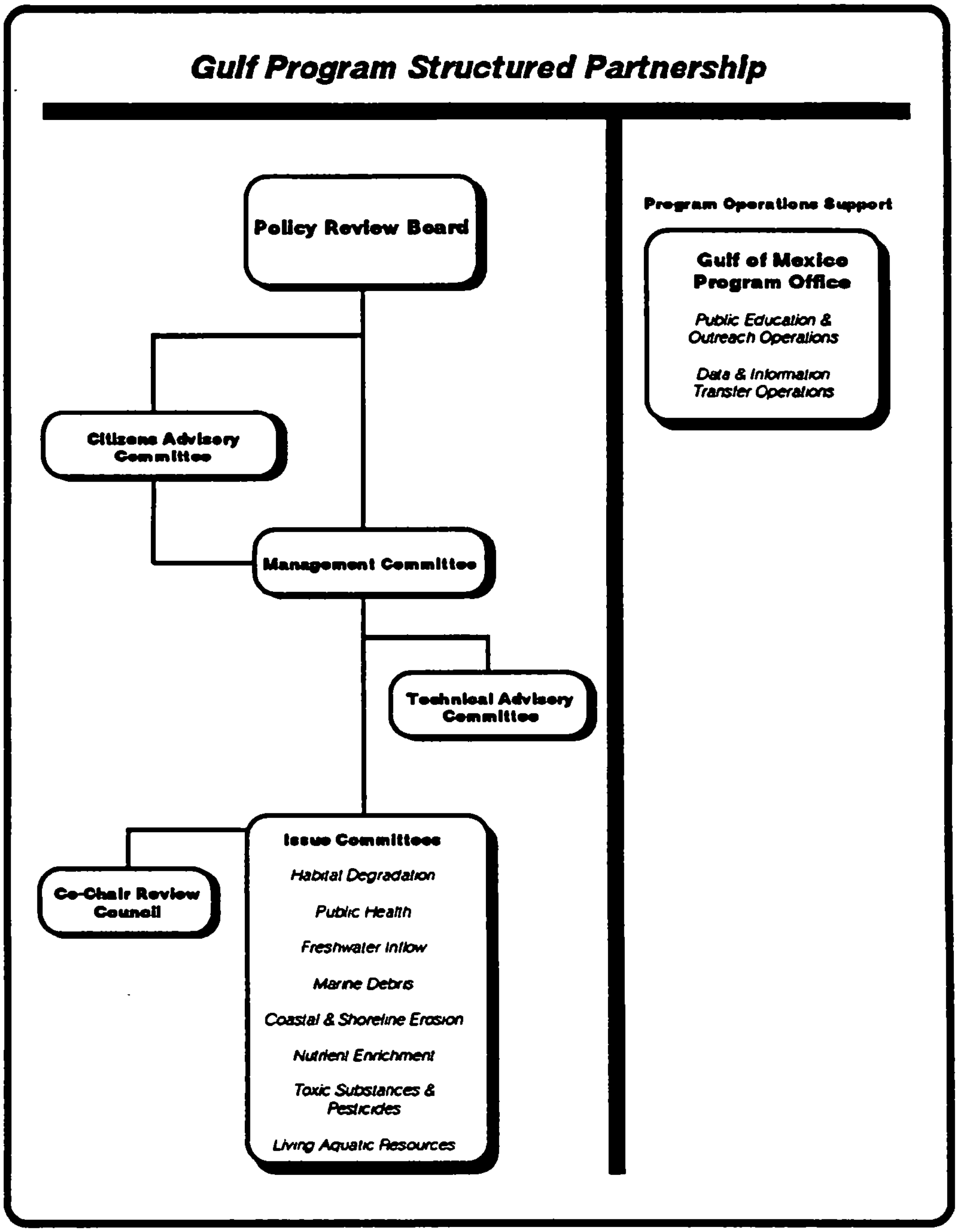
- ❑ A mechanism for addressing complex problems that cross federal, state, and international jurisdictional lines;
- ❑ Better coordination among federal, state, and local programs, thus increasing the effectiveness and efficiency of the long-term effort to manage and protect Gulf resources;
- ❑ A regional perspective to address research needs, which will result in improved transfer of information and methods for supporting effective management decisions; and
- ❑ A forum for affected groups using the Gulf, for public and private educational institutions, and for the general public to participate in the solution process.

The Gulf of Mexico Program is supported by four committees: Policy Review Board (PRB), Management Committee (MC), Citizens Advisory Committee (CAC), and Technical Advisory Committee (TAC) (see **Figure 1.2**). Composed of 20 senior level representatives of state and federal agencies and representatives of the technical and citizens committees, the Policy Review Board guides and reviews overall program activities. The Management Committee guides and manages Gulf of Mexico Program operations and directs the Action Agenda activities of the Issue Committees. The Citizens Advisory Committee is composed of five governor-appointed citizens who represent environmental, fisheries, agricultural, business/industrial, and development/tourism interests in each of the five Gulf Coast States. This committee provides public input and assistance in publicizing the Gulf of Mexico Program's goals and results. Representatives of state and federal agencies, the academic community, and the private and public sectors are members of the Technical Advisory Committee and provide technical support to the Management Committee.

The Gulf of Mexico Program has established the following eight Issue Committees, each co-chaired by one federal and one state representative, to address priority environmental problems:

- ❑ **Habitat Degradation** of such areas as coastal wetlands, seagrass beds, and sand dunes;
- ❑ **Freshwater Inflow** changes resulting from reservoir construction, diversions for municipal, industrial, and agricultural purposes, and modifications to watersheds with concomitant alteration of runoff patterns;
- ❑ **Nutrient Enrichment** resulting from such sources as storm water, industries, and agriculture;
- ❑ **Toxic Substances & Pesticides** contamination originating from industrial and agriculturally based sources;
- ❑ **Coastal & Shoreline Erosion** caused by natural and human-related activities;
- ❑ **Public Health** threats from swimming in and eating seafood products coming from contaminated water;
- ❑ **Marine Debris** from land-based and marine recreational and commercial sources; and
- ❑ **Living Aquatic Resources**.

Figure 1.2


Gulf Program Structured Partnership
Policy Review Board
Citizens Advisory Committee
Management Committee
Technical Advisory Committee
Co-Chair Review Council
Issue Committees
Habitat Degradation
Public Health
Freshwater Inflow
Marine Debris
Coastal & Shoreline Erosion
Nutrient Enrichment
Toxic Substances & Pesticides
Living Aquatic Resources
Program Operations Support
Gulf of Mexico Program Office
Public Education & Outreach Operations
Data & Information Transfer Operations

Two cross-cutting technical operating committees support the public education and information and resource management functions of the eight environmental Issue Committees. These are:

- ❑ **Public Education & Outreach Operations**
- ❑ **Data & Information Transfer Operations**

The action planning process used by each Gulf of Mexico Program Issue Committee includes the following key activities:

- ❑ Definition of environmental issues;
- ❑ Characterization of identified problems, including sources, resources, and impacts;
- ❑ Establishment of goals and objectives;
- ❑ Evaluation/assessment of corrective actions and control measures, including cost/benefit analysis;
- ❑ Selection of priority action items;
- ❑ Establishment of measures of success;
- ❑ Implementation of actions; and
- ❑ Evaluation of success and revision of the Action Agenda.

As the Issue Committees progress through each of these activities, ample opportunities are provided for public review and Policy Review Board endorsement is requested at appropriate points. The Gulf of Mexico Program will continuously work to integrate related activities of the eight Issue Committees. Through the consensus of Program participants, a coordinated response will be directed to the successful maintenance and enhancement of resources of the Gulf of Mexico.

Th Fr shwater Inflow Committe

The Co-Chairs and membership of the Freshwater Inflow Committee are as follows:

Co-Chairs:

Susan Rees	U.S. Army Corps of Engineers
Bruce Moulton	Texas Natural Resource Conservation Commission

Members:

Len Bahr	Louisiana Office of the Governor
Joan Browder	National Marine Fisheries Service
Fred Deegen	Mississippi Bureau of Marine Resources
Dick Eckenrod	Tampa Bay National Estuary Program
Ernie Estevez	Mote Marine Laboratory
David Hankla	U.S. Fish & Wildlife Service
Dave Smith	U.S. Fish & Wildlife Service/Gulf of Mexico Program
John Klein	National Oceanic & Atmospheric Administration
Larry Land	U.S. Geological Survey
Fritzi Pikes	Texas Natural Resource Conservation Commission--CAC
Don Waller	Mississippi Farm Bureau Federation--CAC
Janet Starnes	Northwest Florida Water Management District
Walter Stevenson, Jr.	Alabama Department of Economic & Community Affairs
Lon Strong	U.S. Soil Conservation Service
John Weber	U.S. Army Corps of Engineers

The Freshwater Inflow Committee developed the following goal for addressing freshwater inflow issues in the Gulf of Mexico:

- ❑ Protect, preserve, restore, and, where feasible, enhance the freshwater inflow to the Gulf of Mexico and the associated bays and estuaries for the purpose of maintaining the ecological health and integrity of those systems.

For the purposes of this Action Agenda, "freshwater" includes surface water, ground water, springs, and precipitation.

The Gulf of Mexico Policy Review Board endorsed this goal on November 8, 1990. In developing this Draft Action Agenda, the Freshwater Inflow Committee has sought input and advice from the other Issue Committees, as well as from organizations, interest groups, and private concerns outside of the Gulf of Mexico Program. An "Action Agenda Workshop" sponsored by the Issue Committee in New Orleans, LA, on April 15-16, 1993, to review an early version of the Action Agenda, was attended by approximately 40 persons comprising a mix of Program and non-Program participants. In addition to Gulf of Mexico Program participants, representatives from the following agencies and organizations attended the workshop: Lake Pontchartrain Basin Foundation, Trinity River Authority, Florida Department of Community Affairs, Southwest Florida Water Management District, U.S. Fish & Wildlife Service, Manatee County Public Works Department, Mississippi Farm Bureau Federation, Northwest Florida Water Management District, Louisiana State University, Texas Parks & Wildlife Department, Lower Colorado River Authority, U.S. Geological Survey, Mississippi State University, Mississippi Water Resources Research Institute, Texas Water Development Board, County Sanitation Districts of Orange County (California), Galveston Bay National Estuary Program, University of South Alabama, and University of Florida. This meeting generated a significant number of action items and comments that were addressed in the present document. (See **Appendix D: Participants in the Action Agenda Development Process.**)

2 FRESHWATER INFLOW IN THE GULF OF MEXICO

Role of Freshwater Inflows in Estuarine Ecosystems

Estuaries are by definition bodies of water that receive freshwater inflows. Estuaries function as transition zones between the freshwater of a river and the saline environment of the sea. The estuaries of the Gulf of Mexico are highly productive ecosystems that support wildlife and fisheries and contribute substantially to the economy of coastal areas. Estuarine-dependent species comprise more that 95 percent of the commercial fishery harvests from the Gulf of Mexico, and many important recreational fishery species also depend on estuaries during some part of their life cycle. The ability of an estuary to function as a nursery depends upon the quantity, timing, and input-location of freshwater inflows. Estuarine ecosystems are very vulnerable to disturbances by humans, primarily upstream withdrawals of water for agricultural, industrial, and domestic purposes; contamination by industrial and sewage discharges and agricultural runoff carrying pesticides and herbicides; and eutrophication caused by excessive nutrient inputs from a variety of nonpoint (agricultural drainage, faulty septic systems) and point sources (sewage treatment plants) (Rozengurt and Haydock, 1991).

Freshwater inflows provide the following important functions within an estuary:

- ❑ Provide a food supply by stimulating both photosynthesis and microbial decomposition;
- ❑ Deposit sediments that stabilize coastal wetlands against erosion, subsidence, and sea level rise;
- ❑ Drive estuarine circulation by establishing salinity gradients; and
- ❑ Create a range of salinities under which plants and animals with various salinity needs can thrive.

Diversions of freshwater inflows from estuarine ecosystems is one of the four highest priority threats to living marine resources nationwide (Chambers, 1991). The future of fisheries and wildlife in the Gulf depends upon recognizing and preventing the estuarine habitat degradation caused by freshwater inflow alterations.

As a result of the National Symposium on Freshwater Inflow to Estuaries (1980), the Texas Department of Water Resources reviewed its studies on six estuaries and observed that a 32 percent depletion of natural freshwater inflow to estuaries was the average maximum percentage that could be permitted if subsistence levels of nutrient transport, habitat maintenance, and salinity control were to be maintained (Clark and Benson, 1981).

Salinity Characteristics of Gulf of Mexico Estuari s

Salinity is an important environmental factor affected by alterations in freshwater inflow. A change to the salinity structure of an estuary may cause impacts throughout the system, at scales many times larger than the impacts of wetland loss or pollutant discharge. To a great extent, distributions of organisms in an estuary are determined by salinity, which in turn is determined by a complex suite of interacting factors including rainfall, river discharge, tides, wind, and basin configuration. Human alteration of river flow can significantly affect the salinity regime of an estuary, and thereby change its biota.

Salinity is a fundamental environmental factor because all organisms are 80 to 90 percent water, and internal salt concentrations must be maintained within a certain range in each species. Each species or life stage within a species is adapted to a particular external environment. Most estuarine organisms can tolerate a wider range of external salinities than oceanic species; however, even estuarine species have tolerance limits. Few estuarine species can function optimally within the entire salinity range from fresh to sea water. Most organisms are associated with either the higher end of the salinity range (25-36 ppt) or the middle range (10-25 ppt), but not both. Few estuarine organisms will tolerate salinity fluctuations greater than 15 or 20 ppt.

The range of salinity tolerance changes over an organism's lifetime. The typical pattern for an estuarine-dependent species is to spawn offshore in waters at, or near, seawater strength. Post larvae then move into an estuary and settle at the lowest optimal salinity. As it grows, the organism gradually moves into higher salinity water. Finally, as a late juvenile or early adult, the organism migrates offshore. Outside the optimal salinity range, a reduction in reproduction, growth, and survival is expected, even if the species is still present in that range.

Shifts in salinity distributions caused by changes in freshwater inflows can shut species out of formerly ideal refuges, feeding areas, and nursery grounds. Alterations in freshwater inflow can dramatically change the distribution of salinities across an estuary. For example, changes in freshwater inflow can shift the boundary between fresh and salt water (usually considered the one part per thousand isohaline) several miles up or down stream. The result may be a drastic area reduction of bottom types that are suitable for a given species. Although many organisms are mobile, movement does not benefit them if no suitable areas with favorable salinities are available or if such areas have become so small that crowding occurs. Because of the effect on salinity patterns alone, changes in freshwater inflow can reduce the overall carrying capacity of an estuary.

Because horizontal salinity gradients serve as physiological barriers for some organisms, salinity effectively screens potential predators from estuarine organisms tolerant of low and fluctuating salinities (Snedaker *et al.*, 1977). Human induced increases in estuarine salinities may eliminate this barrier and cause a change in resident species populations (Northwest Florida Water Management District, 1991). Increasing salinization of estuarine ecosystems also leads to saltwater intrusion and eventual destruction of natural seasonal gradients (Rozengurt and Haydock, 1991).

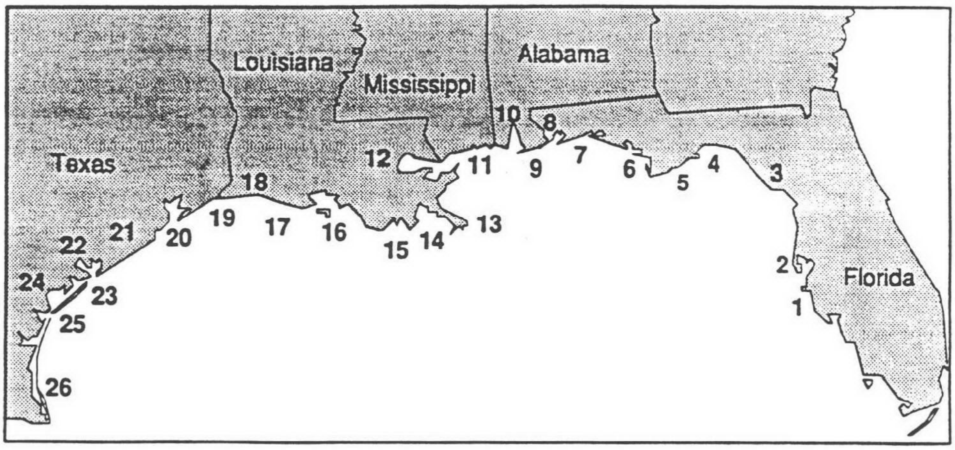
Freshwater river plumes discharging into the northern Gulf of Mexico reduce salinities of nearshore Gulf waters, especially in May and October (Cochrane and Kelly, 1986). These low-salinity waters generally drift westward, driven by southeasterly winds and the pressure gradients. The degree in which salinities in Texas estuaries are affected by these low-salinity waters depends on their proximity to major river plumes and to the year-to-year variability in river discharges, especially those of the Atchafalaya and Mississippi Rivers (Orlando, *et al.*, 1993). These plumes are also responsible for the high variability in shelf salinity off the Texas coast, compared to those off the Florida coast (Orlando, *et al.*, 1993).

NOAA's National Estuarine Inventory (Orlando, *et al.*, 1993) examined the salinity structure and variability of 26 Gulf of Mexico estuaries. (**Figure 2.1** provides a map illustrating the location of the estuaries discussed.) To the extent that data allowed, the salinity structure was represented by typical seasonal distributions existing under normal and present-day hydrologic conditions. This structure: 1) indicates the relative influence of seawater and freshwater sources in the estuary; 2) provides a common basis for comparisons between estuaries; and 3) becomes a reference point for salinity variability analysis. The following characterization uses temporal variability to differentiate functional differences between five estuary types having direct influence on resource distribution and water quality.

Variability Across the Region. The geographical proximity of Gulf estuaries suggests a certain degree of similarity in such features as morphology, hydroclimatology, and salinity structure. In general, five broad geographic groupings are recognizable. The extremes, represented by the shallow, arid, high salinity systems of the Florida peninsula and south Texas, sharply contrast with the broad, water-rich, low salinity embayments of the Mississippi and Atchafalaya River deltas. Intermediate conditions exist from the Florida panhandle to the Mississippi Sound and from western Louisiana to the Texas coastal bend. The former are relatively deep, receive moderate-to-high freshwater inflows, and have intermediate salinity concentrations, while the latter are typically shallow embayments that receive low-to-moderate freshwater volumes and have correspondingly higher salinities (Orlando, *et al.*, 1993).

While the geographic groups reflect Gulf of Mexico estuaries with certain common characteristics, important functional differences exist among many adjacent systems, due to variation in other controlling factors such as Gulf wind and bathymetric influences. The dynamic balance of these factors can be determined by characterizing estuarine salinity (Orlando *et al.*, 1993). **Figure 2.2 and Table 2.1** arrange the Gulf systems by combinations of salinity variability, expressed at weekly and seasonal time scales.

Figure 2.1 ***Gulf of Mexico Estuaries***



Eastern Gulf of Mexico	Central Gulf of Mexico	Western Gulf of Mexico
1 Sarasota Bay	11 Mississippi Sound	19 Sabine Lake
2 Tampa Bay	12 Lakes Pontchartrain/ Borgne & Chandeleur Sound	20 Galveston Bay
3 Suwannee River	13 Breton Sound	21 Brazos/San Bernard Rivers & Cedar Lakes
4 Apalachee Bay Estuaries	14 Barataria Bay	22 Matagorda Bay
5 Apalachicola Bay	15 Terrebonne/Timbalier Bays	23 San Antonio Bay
6 St. Andrew Bay	16 Atchafalaya/ Vermilion Bays	24 Aransas Bay
7 Choctawhatchee Bay	17 Mermentau River	25 Corpus Christi Bay
8 Pensacola Bay	18 Calcasieu Lake	26 Laguna Madre
9 Perdido Bay		
10 Mobile Bay		

(Source: Orlando *et al.*, 1993).

Figure 2.2 Estuary Types Based on Intra-Annual Salinity Variability

Type	Estuary	High- and Low-Salinity Periods: 3-month low-salinity period	High- and Low-Salinity Periods: 3-month high-salinity period	Magnitude of Salinity Variability: Days-Weeks	Magnitude of Salinity Variability: Months-Seasons	Magnitude of Salinity Variability: Year-Year	Average Annual Salinity (ppt): Surface	Average Annual Salinity (ppt): Bottom
1	Tampa Bay	Aug–Oct	Apr–Jun	L	L	L	25	26
	Corpus Christi Bay	Sep–Nov	Jun–Aug	L	VL	L	27	28
	Sarasota Bay	Aug–Oct	Apr–Jun	VL	VL	VL	32	33
	Laguna Madre	Sep–Nov	Jun–Aug	L	VL	L	NA	NA
2	San Antonio Bay		Apr–Jun; Jul–Sep	H	L	M	11	11
	Terrebonne/Timbalier Bays	Jan–Mar	Sep–Nov	M	L	L	12	12
	Aransas Bay	Sep–Nov	Jun–Aug	H	L	M	16	17
	Apalachee Bay Estuaries	Feb–Apr	Sep–Nov	M	L	M	16	18
	Barataria Bay	Apr–Jun	Sep–Nov	M	L	L	17	18
	Matagorda Bay	Apr–Jun	Aug–Oct	M	L	L	18	20
3	Suwannee River	Feb–Apr	Oct–Dec	M	H	M	3	NA
	Perdido Bay	Feb–Apr	Oct–Dec	M	H	M	8	14
	Apalachicola Bay	Feb–Apr	Sep–Nov	M	H	M	11	16
	Pensacola Bay	Feb–Apr	Sep–Nov	M	H	M	13	16
	St. Andrew Bay	Feb–Apr	Sep–Nov	M	M	L	16	21
	Mermentau River	Jan–Mar	Jun–Aug	M	M	L	NA	NA
4	Sabine Lake	Mar–May	Aug–Oct	L	M	M	5	7
	Mobile Bay	Feb–Apr	Aug–Oct	L	H	M	9	15
	Breton Sound	Mar–May	Sep–Nov	L	M	L	12	15
	Galveston Bay	Apr–Jun	Aug–Oct	L	M	M	12	16
	Choctawhatchee Bay	Feb–Apr	Sep–Nov	L	M	L	13	16
	Calcasieu Lake	Jan–Mar	Aug–Oct	L	M	L	13	14
	Brazos River & San Bernard River/ Cedar Lakes	Apr–Jun	Aug–Oct	L	M	M	NA	NA
5	Atchafalaya/Vermilion Bays	Mar–May	Sep–Nov	L	L	L	5	6
	Lakes Pontchartrain/Borgne and Chandeleur Sound	Feb–Apr	Aug–Oct	L	L	L	5	6
	Mississippi Sound	Feb–Apr	Aug–Oct	L	L	L	16	22

3-month low-salinity period (open bar)
3-month high-salinity period (solid bar)

Abbreviations: NA, not available; H, high; M, medium; L, low; VL, very low

(Source: Orlando *et al.*, 1993)

Table 2.1 ***Estuary Types Based on Intra-Annual Salinity Variability***

Type	Magnitude of Variability Weekly*	Seasonal	Average Annual Salinity
1	L	L	High (Seawater-dominated)
2	M	L	Intermediate
3	M	M	Intermediate
4	L	M	Intermediate
5	L	L	Low (Freshwater-dominated)

*L - low; M- medium

(Source: Orlando *et al.*, 1993).

This categorization is based on average annual salinity and its intra-annual variability *under normal hydrologic conditions.* Some estuaries may be inappropriately categorized due to the lack of data (*e.g.*, Suwannee River, Mississippi Sound, and Mermentau River) (Orlando *et al.*, 1993).

The resulting five estuarine types include a sampling of systems from around the Gulf with different morphological features. Despite this, estuaries within each type share a common relationship to salinity variability, mean estuarine salinities, and freshwater inflow. While seemingly discrete, the five estuary types actually lie along a continuum with considerable overlap between types 2 through 4 (Orlando *et al.*, 1993).

Types 1 and 5. These types are *stable.* They represent the extreme range of freshwater inflow to Gulf estuaries and, correspondingly, the extreme range of salinity behavior. At these extremes, a single mechanism dictates the salinity (in this case, average annual salinities) and precludes any significant intra-annual variability. In type 1 estuaries, which lack a dominant and continuous freshwater source, salinity is predominately near (or above) Gulf values and quite stable. In contrast, type 5 salinities are overwhelmed by a dominant and continuous freshwater inflow source. Even when variable, inflow is still so great that there is little salinity intrusion and, therefore, low variability. Consequently, low variability may be realized through either of two opposing scenarios: seawater dominance or freshwater dominance (Orlando *et al.*, 1993).

Types 2 through 4. These three estuary types are *variable*. They reflect intermediate freshwater inflow conditions, intermediate mean salinities, and a shift in both the magnitude and dominant time scale of salinity variability. In these systems, the salinity structure and variability are not determined solely by freshwater inflow, but also depend on the relative influence of other physical factors such as tidal exchange. Freshwater inflow generally increases and becomes more continuous from type 2 to type 4, progressively suppressing seawater intrusions and shifting the dominant time scale of salinity variability from weekly to seasonal. The magnitude of salinity variability, however, achieves a maximum at type 3 (*i.e.*, these systems experience medium variability at both the weekly and seasonal time scales), as neither seawater nor freshwater sources predominate. Because the range of inflow defining each of these intermediate types is somewhat overlapping, a given estuary can transition between types (Orlando *et al.*, 1993).

Oth r Factors Affected by Freshwater Inflow

Changes in nutrient and sediment loads associated with altered freshwater inflow can also disrupt the nursery function of an estuary by affecting food and habitat availability. Various studies have shown that changes in phytoplankton, zooplankton, and benthos, as well as fish and invertebrates, are associated with alterations in freshwater inflow. Freshwater inflow changes can affect such water quality parameters as suspended sediments, dissolved oxygen (DO), water temperature, and pH, which in turn affect biota.

Suspended sediments are usually deposited in estuaries, as the flow velocity of the river widens and slows. This natural process helps offset settling of deposited soils, erosion, and other processes removing solids. Suspended sediments are also commonly associated with nutrients. Some materials such as particles of decaying organic matter are obvious nutrient sources. Phosphorous is also commonly carried in soil sediments, as can be pesticides of various types. In the water column, sediments absorb sunlight, decreasing the level of light penetration. This causes stratified heating of the upper levels of water and inhibits the growth of benthic plants. Sediments can also carry bacterial populations.

The DO level in water is one of the primary factors determining the populations which can survive in those waters. Some of the most preferred game species require relatively high DO levels (more than 5 ppm), while some species (catfish) survive well at 2 ppm. As DO drops from 2 ppm to 0 ppm, the number of species surviving tends to shift rapidly to favor anaerobic bacterial populations. The primary cause of DO depletion is metabolism of nutrient loads, mostly by bacteria. The potential for this type of oxygen consumption is commonly measured as Biochemical Oxygen Demand (BOD). The primary sources of DO are surface mixing and photosynthesis of phytoplankton populations.

Water temperature determines not only which species are present in a population, but also much of the timing of their life cycles. Species demanding high DO are commonly associated with lower water temperatures since low temperatures allow more oxygen to be dissolved. The metabolic rate of most aquatic species is directly determined by the water temperature in a relationship where a change in water temperature of 10° C causes a doubling of the metabolic rate. Thus, higher water temperatures stimulate rapid growth, but can reduce the DO available to support it.

Water pH in the range of five to nine is usually regarded as acceptable for most species, with a pH around eight being preferred. Outside this range, pH becomes first a stress, then lethal. In natural waters, a low pH is commonly associated with outflow from watersheds rich in digestible carbon, such as forests and bogs. These produce tannic acids, as well as the carbonic acid formed by metabolism. High pH can be associated with high phytoplankton loads in poorly buffered waters, with pH rising as carbonic acid is removed through photosynthesis. The primary resistance to pH fluctuations in natural waters is the carbonate buffering system. Waters rich in carbonates and bicarbonates require massive additions of acid or alkaline to produce even modest changes in pH.

Freshwater inflow is also important for the process of circulation and flushing in estuaries. In some estuaries, such as Tampa Bay, horizontal density gradients established by freshwater inflows combine with winds and tides to drive circulation in the estuary. The resulting currents and related flushing rates not only influence water quality, but are also instrumental in transporting planktonic organisms throughout the estuary. Freshwater inflows also flush planktonic organisms and detritus into the Gulf of Mexico, providing food for those organisms that do not enter the estuaries.

The estuarine sediments of many river deltas slowly consolidate. Reduced freshwater inflow will invariably reduce or even eliminate significant sediment inflow. If sediment inflow is eliminated from such estuaries, wetland loss due to consolidative subsidence and erosion accelerates. This is particularly true of deltaic regions of the Louisiana Gulf coast.

Quantity of Freshwater Inflows to the Gulf of Mexico

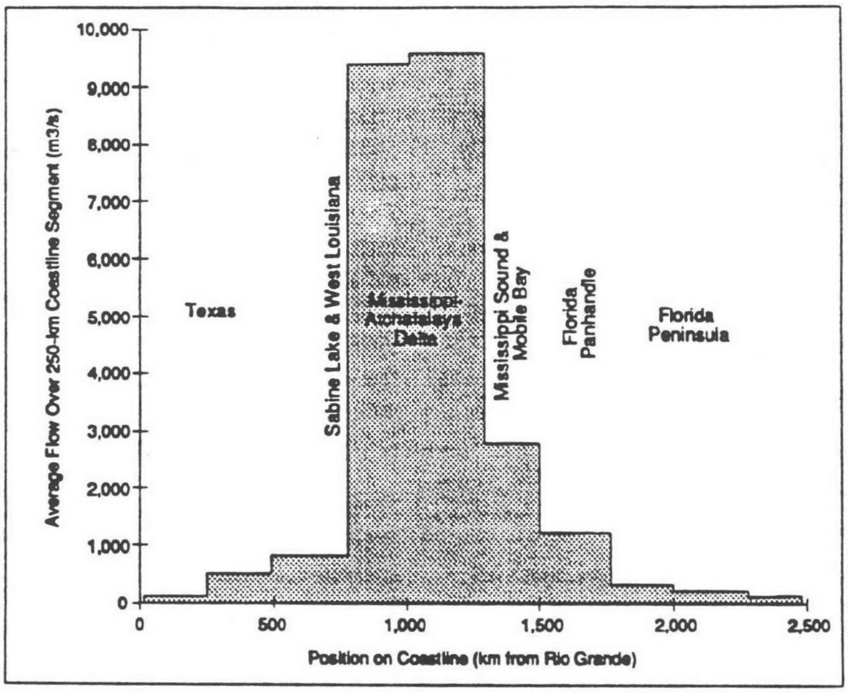
The Gulf of Mexico watershed represents over two-thirds of the drainage of the contiguous U.S. into the coastal ocean. This watershed is subject to nearly the full range of North American climates, corresponding to a wide range of inflows to its estuaries. **Figure 2.3** shows the inflow variation with distance around the Gulf coast (Orlando, *et al.*, 1993). This inflow is roughly symmetrical, centered on the Mississippi River Delta, with a range of over two orders of magnitude, from the arid segments of the Florida and Texas coasts to the water-rich Mississippi delta. [**Figure 2.3** depicts the general variation of the Gulf's river flow but should not be used to infer that the inflow is a smooth function of coastline position. River flow is concentrated in the principal drainage ways and would appear as spikes of inflow, separated by large distances with no inflow. **Figure 2.3** greatly smooths this variation by averaging over 250 km (155 mi) segments.]

The timing of freshwater delivery to Gulf of Mexico estuaries ranges from seasonal dominance in the central Gulf to isolated, short-duration, high intensity pulses in Florida and Texas (Orlando, *et al.*, 1993). The timing and fluctuation of river flow are further modified by reservoirs located on most major rivers flowing to Gulf estuaries (Orlando, *et al.*, 1993). The relationship of freshwater inflows to salinity distributions, habitat, water circulation patterns, and pollutant transport is dependent on both the volume and timing of delivery, as well as interaction with other physical forcing mechanisms. The influence of freshwater inflows varies between estuaries and within any given estuary.

The volume of instream flows is important not only to the receiving estuaries, but also to the rivers and streams that carry these flows. High flowing rivers and streams support more productivity on their river-sides and banks. In addition, high flowing rivers capture and transport more organic material and detritus from the productive river-side areas to estuaries for nourishment. The flushing of the cypress swamps and bottomland hardwood areas of the Wallisville Area on the Trinity River Delta to Trinity Bay is a good example of this.

The U.S. Geological Survey (USGS) reports on inflows provide data on inflows to rivers, not necessarily to estuaries. USGS reports investigate impoundment effects for selected rivers, but these results should not be applied to the unstudied ones, which may be smaller and more prone to local impoundment/diversion effects. Almost all of the data concerning the quantity and water quality of streamflow to the Gulf of Mexico are being collected by USGS and are available from computer storage.

Figure 2.3 ***General Variation of River Flow Around the Gulf***



(Source: Orlando, *et al.*, 1993)

Quantity and Water Quality of Streamflow to the Gulf. Long-term continuous streamflow records exist for almost all major streams that discharge directly to the Gulf of Mexico. Fifty-four streams, each with drainage areas greater than 518 km^2 (200 mi^2), that discharge directly to the Gulf of Mexico or its estuaries have been identified and classified as major streams (see **Table 2.2**). The total drainage area for these streams, almost 4.693 million km^2 (1.812 million mi^2), represents about 95 percent of the total drainage area to the Gulf (not including the contribution from Mexico). A compilation of drainage areas to the Gulf of Mexico and drainage areas gaged for streamflow is presented in **Table 2.3**; selected characteristics for data available from streamflow gages proximate to the Gulf of Mexico are presented by state in **Table 2.4** (USGS, 1992).

Daily values for dissolved solids are available at gages on 44 of the major streams and all but one of the major streams with drainage areas greater than 2,590 km^2 (1,000 mi^2) (see **Table 2.2**). The total drainage area of these gages is about 4.7 million km^2 (1.8 million mi^2). Selected characteristics of the dissolved-solids data base for streamflow gages within 320 km (200 mi) of the Gulf of Mexico are presented in **Table 2.4**.

Table 2.2 *Periods of Record for U.S. Geological Survey Daily Values of Water Quality & Streamflow for the Lower Reach of Major Streams That Discharge Directly to the Gulf of Mexico & Its Estuaries*

STREAM NAME (STATE)	DRAINAGE AREA (MI²)	PERIOD OF RECORD AND NUMBER OF YEARS OF DATA FOR: STREAMFLOW	DISSOLVED SOLIDS	SEDIMENT	DISSOLVED OXYGEN	pH	WATER TEMPERATURE
RIO GRANDE (TX)	335,500	1934-88 (55)	1966-88 (19)	1966-83 (18)	--	--	1967-83 (11)
SAN FERNANDO CREEK (TX)	507	1965-88 (24)	--	--	--	--	--
NUECES RIVER (TX)	16,660	1940-88 (49)	1942-88 (47)	1950-51 (2)	--	--	1948-88 (33)
ARANSAS RIVER (TX)	247	1965-88 (24)	--	--	--	--	--
MISSION RIVER (TX)	690	1940-88 (49)	1962-81 (20)	--	--	--	1961-81 (21)
SAN ANTONIO RIVER (TX)	3,921	1925-88 (53)	1960-88 (29)	--	--	--	1959-88 (30)
GUADALUPE RIVER (TX)	5,198	1936-88 (53)	1966-83 (18)	--	--	--	1967-83 (17)
LAVACA RIVER (TX)	817	1939-88 (50)	1978-81 (4)	--	--	--	1978-81 (4)
COLORADO RIVER (TX)	42,240	1939-88 (50)	1945-88 (44)	1957-73 (17)	--	--	1948-88 (36)
SAN BERNARD RIVER (TX)	727	1955-88 (34)	1978-81 (4)	--	--	--	1978-81 (4)
BRAZOS RIVER (TX)	45,007	1904-88 (68)	1942-88 (47)	1966-86 (21)	--	--	1951-88 (35)
BUFFALO BAYOU (TX)	317	1964-88 (17)	1979-88 (6)	--	1986-88 (3)	--	1979-88 (6)
TRINITY RIVER (TX)	17,186	1925-88 (64)	1942-88 (43)	1955-71 (4)	1975-88 (14)	1975-88 (14)	1950-88 (35)
PINE ISLAND BAYOU (TX)	336	1968-88 (21)	1968-81 (14)	--	--	--	1968-88 (21)
VILLAGE CREEK (TX)	860	1925-88 (51)	1968-70 (3)	--	--	--	1968-70 (3)
NECHES RIVER (TX)	7,951	1905-88 (69)	1948-88 (41)	--	--	--	1948-88 (30)
SABINE RIVER (TX)	9,329	1925-88 (64)	1946-88 (42)	--	1968-75 (8)	1968-75 (8)	1948-88 (34)
CALCASIEU RIVER (LA)	1,700	1923-88 (52)	1968-87 (12)	--	1968-77 (5)	1968-77 (5)	1968-87 (12)
BAYOU NEZPIQUE (LA)	527	1939-88 (50)	--	--	--	--	--
VERMILION RIVER (LA)	UNKNOWN	1968-88 (21)	1958-82 (20)	--	1971-82 (12)	1976-82 (7)	1949-82 (25)
ATCHAFALAYA RIVER (LA)	87,570	1935-88 (54)	1952-81 (16)	1973-85 (9)	--	--	1953-84 (12)
MISSISSIPPI RIVER (LA)	1,129,810	1934-88 (55)	1950-88 (39)	1950-75 (26)	1967-88 (22)	1968-88 (21)	1954-88 (33)
AMITE RIVER (LA)	1,280	1939-88 (50)	1968-81 (12)	--	--	--	1968-81 (11)
TANGIPAHOA RIVER (LA)	646	1939-88 (50)	1963-83 (6)	--	--	--	1963-83 (6)
BOGUE CHITTO (LA)	1,213	1938-88 (51)	1975-82 (8)	--	--	--	1975-82 (8)
PEARL RIVER (MS)	6,573	1939-88 (50)	1963-85 (13)	1967-87 (21)	1975-85 (11)	1975-85 (11)	1963-85 (13)
WOLF RIVER (MS)	308	1972-88 (17)	1978-81 (4)	--	--	--	1978-81 (4)
RED CREEK (MS)	441	1959-88 (30)	1985-86 (2)	--	--	--	1985-86 (2)
BLACK CREEK (MS)	701	1972-88 (17)	--	--	--	--	--
PASCAGOULA RIVER (MS)	6,590	1931-88 (58)	1970-81 (12)	--	--	--	1958-81 (13)
TOMBIGBEE RIVER (AL)	18,417	1929-88 (60)	1966-88 (21)	--	--	--	1963-88 (26)
ALABAMA RIVER (AL)	22,000	1931-88 (58)	1966-87 (17)	--	--	--	1966-87 (17)
PERDIDO RIVER (AL)	394	1942-88 (47)	1979-81 (3)	--	--	--	1979-81 (3)
ESCAMBIA RIVER (FL)	3,817	1935-88 (54)	--	--	--	--	--
BIG COLDWATER (FL)	237	1938-88 (49)	--	--	--	--	1960-60 (1)
BLACKWATER RIVER (FL)	205	1951-88 (38)	--	--	--	--	1961-69 (3)
YELLOW RIVER (FL)	624	1939-88 (50)	1965-72 (8)	--	--	--	1965-72 (8)
SHOAL RIVER (FL)	474	1939-88 (50)	--	--	--	--	--
CHOCTAWHATCHEE RIVER (FL)	4,384	1930-88 (59)	1964-83 (18)	--	--	--	1965-83 (17)
CHIPOLA RIVER (FL)	781	1922-88 (53)	1965-72 (8)	--	--	--	1965-72 (8)
APALACHICOLA RIVER (FL)	17,200	1929-88 (60)	1963-79 (17)	--	1974-79 (6)	1974-78 (5)	1965-79 (14)
OCHLOCKONEE RIVER (FL)	1,700	1927-88 (62)	1965-72 (8)	--	--	1965-72 (8)	1965-72 (8)
SAINT MARKS RIVER (FL)	535	1957-88 (30)	--	--	--	--	--
AUCILLA RIVER (FL)	747	1950-88 (39)	1979-81 (3)	--	--	--	1979-81 (3)
STEINHATCHEE RIVER (FL)	350	1951-88 (38)	1979-82 (4)	--	--	--	1979-82 (4)
SUWANNEE RIVER (FL)	9,640	1942-88 (47)	1966-77 (12)	--	--	--	1965-77 (13)
WACCASASSA RIVER (FL)	480	1964-88 (18)	--	--	--	--	--
WITHLACOOCHEE RIVER (FL)	2,020	1970-88 (19)	1950-83 (23)	--	--	1950-50 (1)	1950-83 (21)
HILLSBOROUGH RIVER (FL)	650	1939-88 (50)	1965-82 (11)	--	--	--	1965-82 (11)
ALAFIA RIVER (FL)	335	1933-88 (56)	1958-86 (22)	--	--	1964-70 (5)	1958-86 (21)
MYAKKA RIVER (FL)	229	1937-88 (52)	1963-81 (6)	--	--	--	1963-81 (7)
HORSE CREEK (FL)	218	1951-88 (38)	1965-67 (3)	--	--	--	1965-67 (3)
PEACE RIVER (FL)	1,367	1932-88 (57)	1962-81 (20)	--	--	1962-70 (7)	1962-81 (20)
CALOOSAHATCHEE RIVER (FL)	UNKNOWN	1967-88 (22)	1965-82 (17)	--	--	--	1964-83 (20)

Notes:
Daily-values data not collected where dashed.

(Source: USGS, 1992)

Table 2.3 Drainage Areas & Gaged Drainage Areas to the Gulf of Mexico

	AREA DESCRIPTION	SQUARE MILES
1.	Area of the 48 contiguous States	3,022,260
2.	Drainage area to the Gulf along United States boundaries, including the Rio Grande	1,901,499
3.	Drainage area to the Gulf from the Rio Grande	335,500
4.	Drainage area to the Rio Grande from the United States	133,000
5.	Drainage area to the Rio Grande from Mexico	202,500
6.	Drainage area for the 54 identified major streams that discharge to the Gulf	1,811,656
7.	Drainage area for the 44 identified long-term streamflow-gaging stations	1,804,151

DRAINAGE AREAS BY STATES (SQUARE MILES) AND PERCENTAGES OF TOTAL DRAINAGE

State	*Total Drainage to Gulf Along State's Border*	*Drainage for Identified Major Streams*	*Drainage for Identified Long-Term Streamflow Gage*
Texas	518,650	487,493 (97%)	485,540 (94%)
Louisiana	1,250,249	1,222,746 (98%)	1,222,973 (98%)
Mississippi	20,830	14,613 (70%)	13,163 (63%)
Alabama	44,650	40,811 (91%)	40,811 (91%)
Florida	67,120	45,993 (69%)	41,664 (62%)
TOTALS	1,901,499	1,811,656 (95%)	1,804,151 (95%)

Note: Three rivers join the Gulf along boundaries between the above states. For purposes of this study, the Sabine River is assumed to be in Texas, the Pearl River in Mississippi, and the Perdido River in Alabama.

Drainage areas for stream gages are taken from U.S. Geological Survey computer files for individual gages. Other drainage areas used throughout this report are aggregated from a computer file of hydrologic unit codes, descriptions, names, and drainage areas maintained by the U.S. Geological Survey. The file is published in:

Seaber, P.R, Kapinos, F.P., and Knapp, G.L., 1987, Hydrologic Unit Maps: U.S. Geological Survey Water Supply Paper 2294, 63 p.

(Source: USGS, 1992)

Table 2.4 ***Selected Characteristics of the U.S. Geological Survey Data Base for Daily Values of Streamflow & Dissolved Solids for Stream Gages Within 200 Miles of the Gulf of Mexico***

State	*Gaged Constituent*	*Number of Sites*	*Mean Value for*			*Maximum Years of Record*	*Minimum Years of Record*
			Years of Data	*Beginning Year*	*Ending Year*		
Texas	Streamflow	395	24	1956	1981	92	1
Louisiana	Streamflow	205	19	1957	1979	59	1
Mississippi	Streamflow	93	24	1950	1975	69	1
Alabama	Streamflow	284	15	1955	1973	70	1
Florida	Streamflow	219	17	1964	1982	67	1
Texas	Dis. Solids	77	15	1968	1982	46	1
Louisiana	Dis. Solids	68	9	1969	1977	56	1
Mississippi	Dis. Solids	30	4	1975	1978	15	1
Alabama	Dis. Solids	70	5	1977	1982	33	1
Florida	Dis. Solids	60	9	1969	1977	33	1

Note: Within about 200 miles of the Gulf, daily values of streamflow exist for 1196 gages and daily values for salinity of streamflow exist for 305 gages within the U.S. Geological Survey data base. Gages for the quantity and quality of streamflow are numbered in downstream order by the U.S. Geological Survey. The gage numbers included in this summary, by states, are as follows:

State	*Range of gage numbers*
Texas	08020000-08042500; 08064000-08078000; 08096500-08118000; 08150000-08212000; and 08451000-085555555
Louisiana	All gages
Mississippi	02441000-02999999; 07285500-07999999
Alabama	02000000-02999999
Florida	02291000-02310290; 02310900-02313265; 02313700-02370000

(Source: USGS, 1992)

Daily values for water temperature are available for most of the major streams (**Table 2.2**), while daily values for suspended sediment, dissolved oxygen, and pH are available for only some of the major streams. Periodic values for nutrients, physical organics and inorganics, indicator bacteria, inorganic-chemical constituents, minor elements, insecticides, and herbicides are available at many streamflow gages within 320 km (200 mi) of the Gulf of Mexico. These data are collected infrequently, commonly about four to eight samples per year, and thus would be difficult to use in quantitative analyses concerning water-quality loads or trends without the use of advanced statistical models.

Historical Streamflow to the Gulf. Almost every identified major stream that discharges directly to the Gulf of Mexico has been gaged for streamflow discharges by the U.S. Geological Survey. Selected characteristics for the long-term streamflow gages are presented in **Table 2.5**, and annual mean streamflow discharges from 1947 to 1986 are presented in **Tables 2.6**, **2.7**, and **2.8** (USGS, 1992).

Temporal Variation. The monthly and seasonal cumulative variation in freshwater inflows produces the most dramatic changes in bay-wide salinities in most Gulf of Mexico estuaries (Orlando, *et al.*, 1993). For most of the coast, the summer or fall is the low-flow season (Geraghty *et al.*, 1973). The high-flow season is dependent on large-scale climatological controls. For most of the Texas coast, spring is the high-flow season, driven by direct precipitation and by the interaction of continental and marine air. For the northern coast, from Louisiana to the Florida panhandle, the winter and early spring are the high-flow seasons, due to precipitation, snow melt, and river-channel transport in the great Midwestern watersheds. In Florida, summer and early fall are the high-flow seasons, due to air-mass thunderstorms in the peninsula's small watersheds. Also, in Florida, spring is frequently the low-flow season (Orlando, *et al.*, 1993).

Year-to-year variability in freshwater input to Gulf of Mexico estuaries is great, responding to large-scale climate fluctuations that produce flooding and drought. In some years, the high-flow period is pronounced and lengthy. In other years, it may be completely absent. Although river discharges in the low-flow period are pronounced and lengthy, in other years, they may be completely absent. Although river discharges in the low-flow period are less variable than those in the high-flow period, annual variability does occur. In some years, the low-flow period is shortened or eliminated by unusual runoff; in other years, it is prolonged (Orlando, *et al.*, 1993).

Table 2.5 *Selected Characteristics for Long-Term Streamflow Gages on Streams Discharging Directly to the Gulf of Mexico*

GAGE NO.	USGS GAGE NO.	STREAM NAME AND LOCATION	LATITUDE (DDMMSS)	LONGITUDE (DDMMSS)	PERIOD-OF-RECORD	YEARS OF RECORD	DRAINAGE AREA (MI)
1	08475000	RIO GRANDE NEAR BROWNSVILLE, TEXAS	255235	972715	1934-88	55	335,500
2	08211000	NUECES RIVER NR MATHIS, TEX.	280217	975136	1940-88	49	16,660
3	08189500	MISSION RIVER AT REFUGIO, TEXAS	281730	971644	1940-88	49	690
4	08188500	SAN ANTONIO RIVER AT GOLIAD, TEX.	283858	972304	1925-28,40-88	53	3,921
5	08176500	GUADALUPE RIVER AT VICTORIA, TEX.	284734	970046	1936-88	53	5,198
6	08164000	LAVACA RIVER NEAR EDNA, TEXAS	285735	964110	1939-88	50	817
7	08162500	COLORADO RIVER NR BAY CITY, TX	285826	960044	1939-88	50	42,240
8	08114000	BRAZOS RIVER AT RICHMOND, TX	293456	954527	1904-05,23-88	68	45007
9	08075000	BRAYS BAYOU AT HOUSTON, TX	294149	952443	1937-88	52	95
10	08074500	WHITEOAK BAYOU AT HOUSTON, TX	294630	952349	1937-88	52	86
11	08066500	TRINITY RIVER AT ROMAYOR, TX	302530	945102	1925-88	64	17,186
12	08041500	VILLAGE CREEK NR KOUNTZE, TEX.	302352	941548	1925-27,40-88	51	860
13	08041000	NECHES RIVER AT EVADALE, TEX.	302120	940635	1905-06,22-88	69	7,951
14	08030500	SABINE RIVER NR RULIFF, TX	301813	934437	1925-88	64	9,329
15	08015500	CALCASIEU RIVER NR KINDER, LA	303010	925455	1923-24,39-88	52	1,700
16	08012000	BAYOU NEZPIQUE NR BASILE, LA	302650	923755	1939-88	50	527
17	08010000	BAYOU DES CANNES NR EUNICE, LA	302900	922925	1939-88	50	131
18	07381490	ATCHAFALAYA RIVER AT SIMMESPORT, LA.	305857	914754	1935-88	54	87,570
19	07374000	MISSISSIPPI R. AT BATON ROUGE, LA	302929	911150	1934-88	55	1,129,810
20	07378500	AMITE RIVER NEAR DENHAM SPRINGS, LA.	302750	905925	1939-88	50	1,280
21	07375500	TANGIPAHOA RIVER AT ROBERT,LA	303023	902142	1939-88	50	646
22	07375000	TCHEFUNCTA RIVER NR FOLSOM, LA	303657	901455	1943-88	46	96
23	02492000	BOGUE CHITTO NR BUSH, LA	303745	895350	1938-88	51	1,213
24	02489500	PEARL R NR BOGALUSA, LA	304735	894915	1939-88	50	6,573
25	02479000	PASCAGOULA RIVER AT MERRILL, MS	305840	884335	1931-88	58	6,590
26	02469761	TOMBIGBEE R AT COFFEEVILLE L&D NR COFFEEVILLE AL	314530	880745	1929-88	60	18,417
27	02429500	ALABAMA RIVER AT CLAIBORNE AL	313248	873045	1931-88	58	22,000
28	02376500	PERDIDO RIVER AT BARRINEAU PARK, FL	304125	872625	1942-88	47	394
29	02375500	ESCAMBIA RIVER NEAR CENTURY, FL	305754	871403	1935-88	54	3,817
30	02368000	YELLOW RIVER AT MILLIGAN, FLA.	304510	863745	1939-88	50	624
31	02369000	SHOAL RIVER NR CRESTVIEW, FLA.	304150	863415	1939-88	50	474
32	02366500	CHOCTAWHATCHEE RIVER NR BRUCE, FLA.	302703	855354	1931-88	58	4,384
33	02359500	ECONFINA CREEK NEAR BENNETT, FLA.	302304	853324	1936-88	53	122
34	02359000	CHIPOLA RIVER NR ALTHA, FLA.	303202	850955	1922-27,30-31,44-88	53	781
35	02358000	APALACHICOLA RIVER AT CHATTAHOOCHEE FLA	304203	845133	1929-88	60	17,200
36	02330000	OCHLOCKONEE RIVER NR BLOXHAM, FLA.	302310	843859	1927-88	62	1,700
37	02324500	FENHOLLOWAY RIVER AT FOLEY, FLA.	300355	833429	1947-88	42	120
38	02323500	SUWANNEE RIVER NEAR WILCOX, FLA.	293522	825612	1942-88	47	9,640
39	02310000	ANCLOTE RIVER NR ELFERS, FLA.	281250	824000	1947-88	42	72
40	02304500	HILLSBOROUGH RIVER NR TAMPA, FLA.	280125	822540	1939-88	50	650
41	02301500	ALAFIA RIVER AT LITHIA, FLA.	275219	821241	1933-88	56	335
42	02300500	LITTLE MANATEE RIVER NR WIMAUMA, FLA.	274015	822110	1940-88	49	149
43	02298830	MYAKKA RIVER NR SARASOTA, FLA.	271425	821850	1937-88	52	229
44	02296750	PEACE RIVER AT ARCADIA, FLA	271319	815234	1932-88	57	1,367

(Source: USGS, 1992)

Table 2.6 *Annual Mean Streamflow, in Cubic Feet per Second, for Long-Term Gages in Texas, 1947-86*

YEAR	GAGE NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14
1947	2480	1273	131.0	966	2203	346.0	3090	8765	131	114	9681	1274	10000	11783
1948	2244	148	9.2	312	702	157.0	1246	2687	47	25	6167	448	4802	8193
1949	3895	1225	33.0	557	1204	146.0	1599	4645	67	45	5566	769	5030	8636
1950	1368	340	4.2	364	1061	126.0	2119	5783	170	129	11075	2248	11371	15944
1951	1008	583	38.0	306	542	47.0	700	1418	17	11	2387	265	2042	4374
1952	423	244	98.0	456	819	162.0	616	1820	23	18	2779	492	3718	6415
1953	525	741	42.0	353	1074	163.0	1273	4105	78	57	5511	1058	8177	12335
1954	641	465	19.0	143	648	23.0	651	2727	44	39	1694	309	2114	4097
1955	158	135	7.0	169	374	140.0	1014	2168	40	22	2935	402	3149	5574
1956	53	184	8.0	98	132	6.1	840	2158	23	13	1211	258	1608	3421
1957	88	1962	105.0	974	1973	244.0	5980	15288	51	37	12689	458	4607	9645
1958	123	1538	146.0	974	3541	514.0	6200	11865	81	70	11695	967	8465	12294
1959	8280	829	56.0	597	1580	306.0	2491	4450	114	90	4909	447	5162	6723
1960	505	602	87.0	429	1764	278.0	4827	8869	138	87	6621	524	4728	6545
1961	606	847	198.0	994	3865	966.0	5743	16125	176	167	10442	1561	10409	12410
1962	367	111	42.0	374	.914	234.0	1525	4508	71	55	4469	531	5174	7500
1963	172	109	11.0	196	565	63.0	706	2759	96	48	3495	339	2153	2831
1964	132	104	14.0	289	568	74.0	375	1715	65	38	1612	518	2603	3250
1965	161	787	46.0	676	1812	349.0	2051	10263	50	28	7333	220	1659	4081
1966	1137	452	126.0	383	1551	280.0	2081	8791	148	78	8946	708	3354	7553
1967	4284	2167	531.0	1165	1225	178.0	544	1866	55	28	1771	256	1812	1959
1968	2855	1232	203.0	1141	2921	516.0	4900	13227	152	75	11519	517	5126	4560
1969	383	136	83.0	538	1817	440.0	2000	8219	120	70	10387	788	9378	12324
1970	245	718	80.0	507	1797	289.0	3523	6459	140	69	4657	301	2362	4132
1971	1216	2139	371.0	354	860	221.0	929	1679	145	71	730	190	1128	2635
1972	3814	1780	233.0	995	2410	493.0	1808	4374	146	84	5377	833	2461	6465
1973	2539	714	247.0	1505	2667	856.0	2641	9283	283	178	11295	1790	9634	13342
1974	1482	1244	279.0	1385	2844	564.0	3088	7877	186	129	9970	1529	10396	12099
1975	3494	552	30.0	1149	3506	412.0	5862	13957	202	142	14661	1685	9905	14205
1976	3333	550	190.0	837	2199	209.0	1785	5816	168	98	5317	771	4432	5941
1977	3291	1455	235.0	1672	3937	573.0	3974	10741	177	109	7977	683	4742	5988
1978	381	307	78.0	826	1461	329.0	866	1893	150	91	2472	545	2325	3681
1979	4299	499	135.0	1366	3460	766.0	3056	11487	325	161	9968	2013	10265	12058
1980	378	771	118.0	552	1020	175.0	936	4307	180	98	5611	1060	7282	9010
1981	2171	1268	279.0	1084	3028	473.0	3012	5053	220	145	4393	688	2342	2890
1982	1103	479	241.0	649	1814	556.0	2400	7829	186	95	11626	461	3513	4251
1983	400	146	109.0	470	1124	409.0	1623	5462	346	212	6818	1415	8637	11800
1984	246	145	110.0	287	479	128.0	658	1403	173	89	3280	979	5417	6914
1985	262	376	77.0	647	1600	357.0	1892	6540	244	156	8094	736	5020	7069
1986	193	395	21.0	740	1827	195.0	1896	8379	239	158	10401	1015	6206	7516
MEAN	1516	744	122.0	687	1720	319.0	2313	6419	137	86	6689	801	5313	7561

(Source: USGS, 1992)

Table 2.7 *Annual Mean Streamflow, in Cubic Feet per Second, for Long-Term Gages in Louisiana, Mississippi & Alabama, 1947-86*

	GAGE NUMBER													
YEAR	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1947	3221	1067	307	194395	455981	2483	1515	234	2797	11738	13564	34499	36744	1109
1948	1788	623	213	173563	421691	2330	1459	227	2356	9229	12598	30221	34601	910
1949	3822	1036	260	219467	552844	3469	1915	313	3356	17926	19408	46694	53973	1059
1950	3972	870	331	278450	674326	2198	1212	169	2292	11562	9390	30528	25063	753
1951	1322	283	103	240881	607417	1858	1050	143	1760	8947	8176	31638	25923	600
1952	1968	477	165	215898	538380	929	604	83	995	4013	5428	19455	29542	552
1953	4589	1169	370	158635	383458	2781	1255	194	2081	9801	9025	24606	32034	579
1954	1470	330	87	88910	242644	1202	902	152	1233	4770	6494	14209	22008	550
1955	2609	1166	366	138219	364805	1880	922	90	1468	6907	5061	19428	22081	554
1956	1463	343	133	131592	340694	1548	910	119	1383	7734	6330	20687	23099	496
1957	2098	688	256	201265	470781	1146	746	102	1172	5678	4647	21317	28769	637
1958	3538	985	263	240767	537304	2218	1231	178	2089	12340	13215	36120	35393	670
1959	1883	778	305	148466	354118	1794	1035	138	1664	7191	8062	20447	23951	771
1960	1383	633	149	186813	447678	1405	914	111	1630	8450	9760	25382	28440	803
1961	3365	1280	367	208141	460603	2341	1594	230	2698	11288	15247	33557	40831	990
1962	2507	646	249	243621	523378	2342	1671	253	2775	14500	13929	38543	41423	886
1963	1220	384	165	126057	290290	869	525	77	919	3412	3718	14987	28988	569
1964	1731	769	319	90484	341481	1813	1082	144	1530	8462	8631	32795	43428	771
1965	1540	603	213	182038	411375	1859	949	123	1621	8286	8532	25548	31376	699
1966	2249	762	276	139792	378115	2445	1337	183	2116	9067	10571	20509	30286	726
1967	1921	551	268	157025	361263	1485	762	102	1241	4278	4704	14733	26548	608
1968	2230	635	196	218866	445552	965	555	82	1069	7859	6479	31112	33876	371
1969	2279	916	301	228299	460280	1584	920	117	1425	7244	8349	23183	26331	726
1970	788	323	146	203556	414926	970	554	75	928	5035	5160	23816	24235	670
1971	1790	792	317	196496	404345	1430	1071	129	1684	10157	10448	28774	37044	734
1972	2317	958	353	206030	413271	2224	1335	195	2282	10336	10148	23472	34631	446
1973	4517	1639	499	383427	729071	3063	1742	230	3184	15322	14253	42352	47626	783
1974	3407	1302	361	320455	632499	2600	1651	256	2954	17536	15391	40672	34489	824
1975	3832	1222	355	321197	598943	3158	1708	217	3141	16327	15842	40121	48726	1068
1976	1963	522	172	180123	403281	1343	718	93	1453	10774	9800	33940	48006	902
1977	1707	706	254	130951	312907	2713	1281	191	1943	10309	10864	29818	35492	692
1978	2012	719	186	218458	508030	2446	1313	182	2102	10698	9854	27690	33683	1064
1979	3337	1302	357	287973	663170	3104	1580	185	2519	16877	15432	40872	44259	960
1980	3556	1246	344	212046	489057	3562	1775	193	3081	18633	19380	48712	44757	1144
1981	1052	359	115	150671	352923	1287	798	91	1318	5603	6475	15986	18773	628
1982	1145	575	208	212011	501899	1387	900	97	1426	6528	6746	23909	30859	522
1983	4979	1412	523	298373	678918	4433	2258	291	3697	22555	18640	57425	45112	1050
1984	2866	836	240	254320	595650	1745	1000	134	1872	10661	9624	35415	43132	821
1985	2859	839	285	243419	564153	2074	1052	120	1837	8796	7436	21301	21139	648
1986	2308	876	271	215477	501975	1698	812	66	1490	5728	7466	11842	14441	732
MEAN	2489	813	266	206164	470737	2050	1165	157	1965	10069	10107	28908	33278	752

(Source: USGS, 1992)

Table 2.8 *Annual Mean Streamflow, in Cubic Feet per Second, for Long-Term Gages in Florida, 1947-86*

	GAGE NUMBER															
YEAR	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
1947	8588	1675	1372	9869	579	2021	23877	1797	52	9856	111.0	793	576	273	543	2403
1948	7494	1584	1516	11624	758	2977	33514	4516	223	24560	88.0	814	492	228	287	1678
1949	9803	1388	1461	11252	674	2066	35510	2293	107	12985	86.0	452	441	177	389	1759
1950	3630	808	970	5600	553	1221	16210	1001	21	7600	89.0	658	228	137	179	700
1951	3281	625	667	3930	497	868	12155	651	30	6704	29.0	333	202	144	98	999
1952	4653	773	681	5541	464	1179	20279	1401	99	9179	58.0	371	188	95	116	757
1953	4509	921	848	5656	480	1157	20891	1097	144	7496	113.0	852	532	271	390	2301
1954	5209	1308	1155	7259	525	1264	18696	1019	82	9290	71.0	781	480	220	294	2213
1955	3601	608	551	3493	379	613	11283	315	51	4281	32.0	264	236	140	160	714
1956	3055	726	703	3454	376	794	12442	640	60	4640	20.0	102	136	40	73	392
1957	5023	1279	880	6124	451	1048	15680	948	141	8201	87.0	588	442	171	299	1455
1958	5007	990	1004	6986	673	1874	22529	2626	199	13208	101.0	601	424	221	332	1482
1959	5532	1047	1173	6338	593	1504	20762	2109	177	13989	228.0	1546	792	411	579	2381
1960	8435	1388	1545	8402	626	1822	25068	2522	185	12934	200.0	1718	845	319	546	2571
1961	7913	1414	1279	7015	525	1329	23674	1810	126	10588	44.0	327	270	81	157	1014
1962	6156	1153	1023	6216	450	1179	22218	766	78	7142	36.0	484	346	203	302	910
1963	3549	888	876	5071	454	1159	17679	1153	117	7172	67.0	425	393	191	173	904
1964	6602	1585	1605	10982	634	2247	34643	2937	317	15045	135.0	937	383	133	183	972
1965	6758	1108	1325	8769	644	2158	31061	4325	170	19269	77.0	614	350	153	276	843
1966	6123	1010	1058	7422	596	1597	26875	2583	185	15043	57.0	696	395	124	200	1242
1967	4225	712	675	5162	482	1294	21139	1324	111	9549	49.0	422	375	159	232	722
1968	2889	610	766	4510	414	759	17671	430	75	5301	53.0	411	414	218	286	1257
1969	3515	803	797	4455	428	911	15896	1430	122	6335	75.0	499	369	160	292	1056
1970	6478	1363	1087	7271	531	1350	19180	2060	259	13297	112.0	742	450	149	319	1441
1971	7427	1157	987	8362	513	1264	26572	1488	104	9080	65.0	148	237	111	149	614
1972	4467	702	571	5390	454	1235	22108	1374	147	11919	21.0	119	259	150	215	640
1973	10348	1759	1331	10585	563	1952	33322	3082	180	15562	22.0	214	335	203	231	1000
1974	6708	1004	1232	6801	477	1213	23602	1378	123	8554	92.0	492	327	117	223	1059
1975	11695	2206	1661	10345	572	1927	32718	2413	109	12761	32.0	231	217	84	125	472
1976	9857	1784	1547	9390	550	1511	26452	1943	97	9546	57.0	343	324	57	169	824
1977	6146	1130	1137	7610	863	1523	24037	1959	157	12056	11.0	63	143	86	202	441
1978	8367	1746	1781	10842	614	1921	26096	1552	117	10872	46.0	337	256	188	277	1082
1979	7639	1307	1197	8035	637	1861	22374	1989	97	8657	95.0	328	472	164	204	910
1980	8504	1330	1163	8231	624	1864	25417	2001	147	10757	26.0	274	327	122	185	764
1981	3828	609	649	3941	484	606	12661	928	106	5612	8.9	80	179	155	191	298
1982	6302	888	896	5942	441	1192	18704	1378	146	8234	95.0	315	277	231	314	1362
1983	8864	1355	1321	8000	564	2011	29130	2197	192	13659	62.0	495	426	264	373	1479
1984	6413	1080	1021	7000	629	1930	29394	2880	183	17141	64.0	337	290	114	144	714
1985	4394	968	761	4076	470	785	14508	816	121	6887	37.0	159	139	75	93	307
1986	6001	940	1055	6002	614	1529	14303	2760	160	12517	65.0	310	193	108	102	528
MEAN	6175	1143	1083	7074	539	1473	22508	1797	133	10637	70.0	492	354	166	248	1116

(Source: USGS, 1992)

Annual Mean Discharge. Temporal changes in streamflow to the Gulf of Mexico were determined by statistically comparing annual mean streamflow values for early and late periods of the period of record. Values for annual mean streamflow represent annual volumes of streamflow to the Gulf of Mexico. Increases in streamflow for the later period occurred at 29 of the gages while decreases occurred at 15 of the gages. Eight of the streams had increases in discharge that exceeded 25 percent. Increases in streamflow for Brays and Whiteoak Bayou in Houston, TX, are probably related to increases in urbanization in those watersheds. The causes for increases at the other gages were not investigated. The largest percentages in decreased discharge occurred at gages in southern Florida. Decreased streamflow in west-central Florida is attributed to rainfall deficits in that area during the 1960 and 1970 decades. Rainfall deficits have continued in west-central Florida in the 1980s. However, flows in the Peace River in Florida have been declining in excess of that expected from rainfall deficits alone (USGS, 1992).

Annual Maximum and Minimum Discharge. Temporal changes in maximum and minimum streamflow to the Gulf were determined by comparing annual maximum and minimum daily mean discharges for early and late periods at each gage. This analysis is important because maximum and minimum discharges may impact marine life in the Gulf of Mexico as much as annual mean volumes (USGS, 1992).

Increases in annual maximum discharges for the later period occurred at 24 of the gages while decreases occurred at 20 of the gages. Large increases or decreases occurred at many of the gages. All but two of the gages with decreased maximum discharges are in Texas and Florida. Increases in maximum discharges exceeded 50 percent for the Mission River, Brays Bayou, and Amite and Tangipahoa Rivers. Decreases exceeded 20 percent for the Rio Grande, Brazos, Neches, and Sabine Rivers in Texas, and the Anclote, Hillsborough, Alafia, Little Manatee, Myakka, and Peace Rivers in Florida. Causes for decreased maximum discharges to the Gulf of Mexico from Texas streams were not investigated.

While the flow of the Hillsborough River may have decreased by more than 20 percent over the period of record, the record is based on gage data upstream of the City of Tampa's reservoir. Discharges of the reservoir to tidal waters have been much lower than instream flows above the dam (Eckenrod). Similarly, the annual mean flow of the Little Manatee River has not changed over the period of record, but minimum flows have increased significantly because of agricultural tail-water runoff. Farms use deep aquifer water that is highly mineralized, so the chemistry of dry-season river flows has been affected, as well as discharge rates (Eckenrod).

Increases in annual minimum discharges for the later period occurred at 27 of the gages while decreases occurred at 17 of the gages. Large increases occurred at many of the gages. Decreases exceeding 20 percent occurred for the Colorado River in Texas, and the Anclote, Hillsborough, and Peace Rivers in Florida.

Inflow to Central Gulf. The Louisiana estuaries on the west side of the Mississippi River are a series of bar-built systems in which freshwater is generally dispersed throughout the system by numerous small channels or bayous. The freshwater input into these systems is not well known. To the east of the Mississippi River, two major freshwater sources from rivers entering the Mississippi Sound on the western end include the Pearl and the Pascagoula Rivers, which supply about equal volumes of mean flow (USACE, 1983). Additional freshwater is also supplied from several smaller rivers in Mississippi, as well as several rivers entering Lake Pontchartrain, thus supplying freshwater to Lake Borgne through the tidal passes at the east end of Lake Pontchartrain. The picture is quite different on the eastern end of the Sound where the Mobile River supplies freshwater at an average rate of about 63,558 ft^3/second (1,800 m^3/second) (Isphording, *et al.*, 1983). The impact of these rivers on the salinities in both the estuaries and Mississippi Sound is large and in general follows a seasonal pattern, with highest salinities in summer and fall during low-river flows, and lowest salinities in winter and spring during high-river flows (Orlando, *et al.*, 1993).

Inflow to Eastern & Western Gulf. In the more arid sections of the Gulf of Mexico coast (*i.e.*, Texas and Florida), river flow is governed by surface runoff generated by storms, and this flow is highly variable so that rivers exhibit large, sudden excursions. The greater frequency and intensity of precipitation in estuaries of the Upper Texas and Florida panhandle coasts, along with the detention created by reservoirs, lead to considerable overlap in individual storm pulses. Hence, the freshwater inflow hydrography in these estuaries is typically manifested as a seasonal runoff surge of several weeks to a few months in duration. Further south in Texas and Florida, runoff pulses become more isolated in time, and the inflow appears as a series of nearly discrete flood pulses (Orlando, *et al.*, 1993).

Factors Relat d to Chang s in Streamflow

Freshwater inflows are altered in several ways. The amount of inflow can be decreased or increased. Decreases accompany impoundment projects and diversions for consumptive uses. Increases tend to be caused by flood control projects, deforestation, urbanization, and agricultural development. The inflows can be changed on an annual basis or seasonal basis. Inflows can also be altered in two other important ways. The timing of inflows can be changed, even if the amounts are not, and the location of inflows can be changed, even if the amount and time are not. Alterations in freshwater inflows that have occurred as part of land development and water management in watersheds influence the productive capacity of the estuaries downstream. Such alterations have occurred worldwide.

A number of anthropogenic changes have been made to the natural flow pattern within each watershed that flows into the Gulf of Mexico. Dams have been built on streams for flood control, water supply, and recreation. Water from streams is used to grow crops, lawns, shrubs, and flowers. Water is moved from one watershed to another to satisfy changing needs. In addition, drainage facilities have been built to move large amounts of water quickly to streams and bays. Also having a significant impact on water resources are roads, clear cutting of heavy vegetation, and development near water sources. Freshwater changes have caused a tremendous loss of marine productivity in many areas. Recent studies along the Texas coast indicate freshwater inflow rates affect the relative abundance of various species of phytoplankton and the relationship between estuarine chlorophyll concentrations.

Reservoirs are located on most of the major rivers flowing into Gulf of Mexico estuaries. The presence of reservoirs indicates diversion of water for human use, which may be important to the freshwater budget of an estuary. Reservoirs affect the timing and fluctuations of river flow. They can decrease the amount of flow variation of a river, particularly because natural peak flows are held back and released in smaller quantities over a longer period of time. In specific low-flow periods (*i.e.*, summer), the relative effect of the reservoirs may be much greater since the low-river is even further reduced (Orlando, *et al.*, 1993). For rivers in the more arid segments of the Gulf, it is arguable whether the natural river flow at low-flow levels could have any impact on salinities even without reservoirs (Orlando, *et al.*, 1993). The effect of these reservoirs on average estuarine salinities is controversial, but it is believed to be less important than other factors (*i.e.*, seasonal variation in marine and terrestrial climates, or the presence of navigation channels connecting estuaries with the Gulf) (Orlando, *et al.*, 1993). Reservoirs also reduce sediment loads delivered to estuaries.

Dredging of river channels to improve either navigation or drainage has reduced the flooding of and sediment distribution into those stream delta estuaries. This reduces the ability of the stream to naturally maintain elevations of subsiding wetlands and to offset wetland loss in those estuaries.

Impacts of Alterations in Freshwater Inflows

The historic approach of unlimited freshwater withdrawals from rivers eventually leads to chain reactions that destroy estuarine ecosystems (Rozengurt and Haydock, 1991). Fundamental relationships that are affected (see **Figure 2.4**) are as follows:

- ❑ Estuarine circulation is partly dependent upon freshwater inflows. This can be particularly important in estuaries experiencing low tides, such as those in the Gulf of Mexico.

- ❑ Coastal wetlands depend upon sediments carried by freshwater inflow to counteract coastal erosion and subsidence processes and sea level rise.

- ❑ Decreased freshwater inflow leads to increased salinization of coastal aquifers and soils. Saltwater intrusion also destroys freshwater wetlands.

- ❑ When coupled with increased nutrient loads from sewage and agricultural runoff, increased light penetration resulting from reduced silt loads promotes algal blooms.

- ❑ Effects of pollutants increase in the absence of sufficient fresh water for adequate dilution. High evaporation rates and poor mixing aggravate the problem with pollutants.

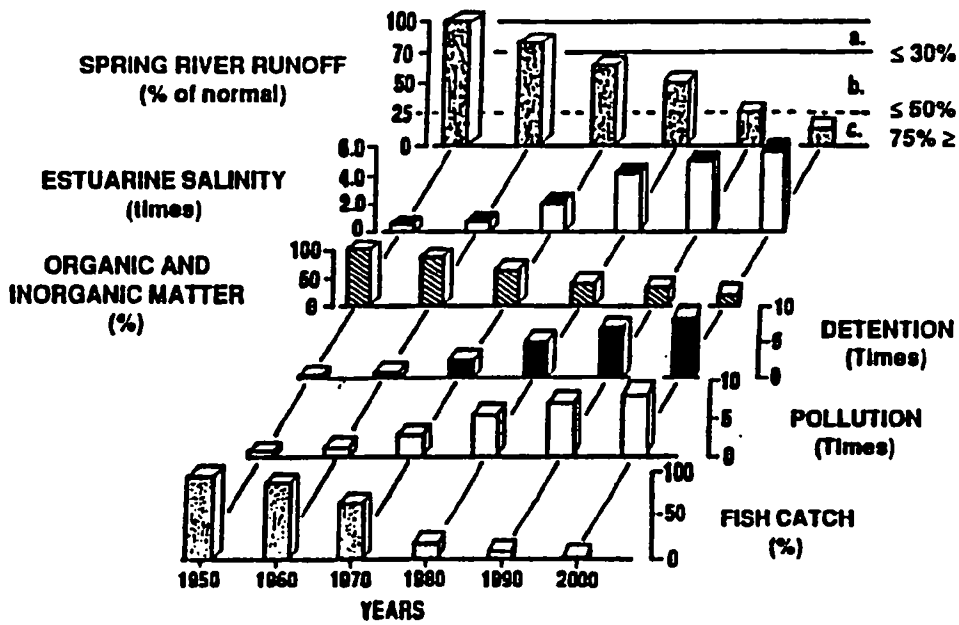
- ❑ The end result is a reduction in biological productivity and alarming decreases in landings of fish and shellfish (Rozengurt and Herz, 1981).

The clearest example of the ecological and economic effects of large scale diversion of freshwater inflows comes from the southern part of the former Soviet Union (Rozengurt and Herz, 1981; Rozengurt *et al.*, 1985; Rozengurt and Haydock, 1991). The USSR built 30 major dams on rivers flowing into the Black, Caspian, Azov, and Aral Seas. These dams hold back 30-97 percent of stream flow to these systems. The dams have destroyed fish migration routes and spawning and nursery grounds. They have eliminated 90-98 percent of the valuable species of commercial fish in all the major rivers and estuaries of the southern USSR (Rozengurt *et al.*, 1987). Attempts to restore fish stocks in these systems have failed. Within just 20 years, the Aral Sea changed from one of the most productive seas in the world to a virtual desert. Economic losses associated with the devastation to the lake and surrounding countryside amounted to $6.5 billion annually.

According to Rozengurt and Haydock (1991), the Gulf of Mexico already has been deprived of 40-90 percent of spring runoff from 44 rivers and 30 estuaries. In addition, agricultural runoff, industrial discharges, and traffic and other activities associated with six of the nation's top seaports stress the coastal Gulf of Mexico environment. The distortion of natural coastal dynamics caused by direct and indirect manipulation of freshwater flow may be responsible for oxygen deficient waters. Up to 9,500 km^2 (4,000 mi^2) of oxygen deficient (hypoxia) bottom waters, known as the "dead zone," have been documented off the Louisiana and Texas coasts (Rabalais, *et al.*, 1991).

Gulf of Mexico harvests of several high valued species, including red drum, red snapper, king mackerel, and pink shrimp declined in the 1980s (Browder *et al.*, 1991; Brown *et al.*, 1991), and some stocks still have not recovered. For instance, landings of pink shrimp from the Tortugas grounds of southern Florida are at an all-time low. Roughly 52 percent of the Gulf of Mexico's classified shellfish-growing areas are closed to harvest, at least in part because there is insufficient runoff to flush out natural and human-induced contaminants that have accumulated (Duke and Sullivan, 1990). Freshwater-related ecosystem degradation in South Florida and Texas is now so great that it threatens multi-billion dollar fishery and tourism industries.

Figure 2.4 ***Conceptual Chain Reaction Between Spring River Runoff & Some Major Chemical, Physical & Economic Parameters in Delta-Estuary-Sea Economy***



a. Range of natural limitations in spring freshwater diversions (≤30% of normal).
b. Detrimental range of spring diversions for living and non-living resources (50% of normal).
c. Range of residual spring runoff irrevocably damaging to environment and economics of ecosystems (75%≥ of normal).

(Source: Rozengurt and Herz, 1981)

State-by-Stat Ov rvi w

Alabama

The Alabama coastal zone is distinguished from both the Texas and Florida coastal zones by a much greater influx of freshwater (Orlando *et al.*, 1993). The Alabama coastal zone is characterized by a series of barrier islands and bays. However, these bays are surrounded only by fringing salt marshes as opposed to the extensive wetland systems found along the Louisiana coast.

General Description of Mobile Bay and the Alabama Gulf Coast. Mobile Bay is a submerged river valley estuary. The boundaries of the estuary are defined from the head of tide on the Alabama and Tombigbee Rivers at Claiborne and Coffeeville, respectively, to the estuary's terminus with the Gulf of Mexico at Main Pass and Pass aux Herons. Mobile Bay is oriented on a north-south axis, perpendicular to the Gulf of Mexico. The bay in general is relatively large, shallow, and wide. Mobile Bay is 50 km (31 mi) in length, 34 km (21 mi) in width, and has a depth of approximately 3 m (9.8 ft). The bay has a total drainage area of 115,510 km^2 (44,598 mi^2).

The Alabama coast line east of Mobile Bay on Dauphin Island consists of white sandy beaches backed by dunes. West of the Bay the coast line, which fronts the Mississippi Sound, is low and marshy with numerous bayous and tidal flats.

Freshwater Inflow. Major tributaries entering Mobile Bay are the streams in the Mobile River Delta, Dog and Fowl Rivers on the western shore, and Fish and Bon Secour Rivers on the eastern shore. The upper tidally influenced reaches of the system form an extensive delta region as the Mobile River enters the bay through these three major tributaries accounting for run-off associated with 90 percent of the drainage basin. The average daily flow (gaged at Claiborne and Coffeeville, AL) to Mobile Bay was 1,848 m^3/second (65,253 ft^3/second) for the period 1929-1983. The ungaged portion of the Mobile River System watershed is estimated to contribute an additional seven percent of freshwater inflow to the Bay.

Several patterns exist that affect freshwater inflow to the bay. First, over 95 percent of the freshwater enters the bay via the Mobile River System. Highest freshwater discharges occur generally from February to May, corresponding to periods of lowest bay-wide salinities. Second, water exchange with the Gulf of Mexico occurs primarily (85 percent) through the Main Ship Channel, although its location is determined by the magnitude of freshwater discharge and tidal phase. Third, a bay-wide vertical salinity gradient is usually apparent throughout the year but may vary significantly depending on the phase of the tide and wind conditions.

Salinity Characteristics. In Mobile Bay the dominant time scale over which salinity varies is seasonal. Freshwater inflow is the principal mechanism that decreases average system salinities, and it tends to stratify the water column during the high-flow period of February to April. Average winds at this time are from the north at 4-5 m/second (13-16 ft/second) and tend to enhance stratification further. During the low flow period of August through October, average system salinities increase and destratification occurs as wind and tide more effectively induce mixing.

To a lesser degree salinity variability is experienced on a time scale of days to weeks. Wind associated with frontal passages, typically occurring from October through March, is an important mechanism. Changes in salinities occur as winds rotate, mixing the water column and affecting system exchanges with adjacent shelf waters. In addition, bimonthly spring tides induce greater pulses of Gulf of Mexico waters which increase salinities and mixing. Low to slight variability is observed at time scales of hours to days. Tides have only a localized influence that is mainly confined to the mouth of Mobile Bay. Overall Mobile Bay is classified as a seasonal estuary due to a strong seasonal freshwater inflow signal, but it is susceptible to shorter term fluctuations as determined principally by wind.

Agriculture and Commercial Trade. The Mobile metropolitan area has abundant natural resources that support a wide range of business and industry. Major industries include paper and paper products, shipbuilding, chemicals, lumber products, computer hardware and software, and textiles. The Port of Mobile supports a major shipping industry.

Baldwin County and Mobile County outside the Mobile metropolitan area are largely agrarian, with potatoes, soybeans, corn, vegetables, pecans, and pulpwood being major sources of income. The seafood industry is an important means of livelihood for the residents of the communities along the bayous and bays in lower Mobile and Baldwin Counties. Also the beaches on Dauphin Island and along the Gulf shore of Baldwin County have fostered an appreciable tourist and vacation trade.

Florida

The Florida coastal zone extends northwest to southeast along 1000 km (620 mi) of coastline, from the tip of the Florida Panhandle down to the Florida Keys. A spectacular diversity of rivers, estuaries, and coastal landscapes occurs along the length of the Florida Gulf Coast. Patterns of freshwater inflow, salinity variation, and human impacts to inflows and salinity can be described in terms of the four latitudinal zones from the Florida Panhandle to the tropical waters of the Florida Keys. Each is under the jurisdiction of a distinct water management district.

The "Panhandle." Florida's continental lands west of the peninsula comprise the panhandle, a region rich in terms of water resources throughout the state. Eight of the state's 15 largest rivers flow through northwest Florida; seven of these have their headwaters in Alabama and Georgia. The combined average daily discharge of all Panhandle rivers is approximately 1,218 m^3/second (43,000 ft^3/second). Estuaries at the mouths of these alluvial streams are rich nursery grounds for a number of species upon which traditional fishery economies depend. Apalachicola Bay, for example, produces 90 percent of Florida's oyster harvest (equal to ten percent of the nation's harvest), and the Bay is a major producer of shrimp and blue crab.

The major threat to Florida's rivers and estuaries is the impact of upstream users on the quantity and quality of water flowing to the Gulf of Mexico. Most of the watersheds of Panhandle rivers have substantial portions (80 to 90 percent) outside of Florida. Because other states control the majority of such watersheds, Florida has little authority regarding the management, allocation, or protection of waters entering the state. The needs of estuaries are not presently considered in any management decisions being made in upper basin areas.

However, this situation is slowly changing. The state and federally funded Apalachicola-Chatahoochee-Flint and Alabama-Coosa-Talapoosa Rivers Comprehensive Studies are attempts to examine all water uses on each river system, including the needs of estuaries for freshwater inflow. These studies bring hope that basinwide management programs can be developed which would protect water needs of natural resources and balance human needs within watersheds.

Unfortunately, there are competing demands for the water resources of the rivers. For example, dams have been proposed on the main stem of some smaller northwest rivers for flood control, hydropower, and recreation. If built, these structures will alter the natural inflows of freshwater to estuaries and thereby alter estuarine productivity and usefulness.

"Big Bend." Florida's curving Gulf shoreline along the northern peninsula is the state's Big Bend region. The coastline, extending from Apalachee Bay on the north to Waccasassa Bay on the south, has been described as a single, vast estuarine area. Eight major streams discharge into the region--the St. Marks, Aucilla, Econfina and

Fenholloway Rivers, Spring Warrior Creek, and the Steinhatchee, Suwannee and Waccasassa Rivers. The eight streams have a combined average daily discharge of approximately 368 m^3/second (13,000 ft^3/second) to this region of the Gulf. About 81 percent of this volume is accounted for by the Suwannee, the second largest river in Florida (after the Apalachicola) in terms of discharge.

Freshwater also reaches the coast via smaller creeks and groundwater seepage as this region is hydrogeologically a groundwater discharge zone. In fact, a distinguishing feature of all streams draining to this part of the coast is that each receives substantial amounts of ground water from the Floridian Aquifer (Florida's major groundwater source). Because ground waters contribute to each estuary's salinity regime, but also supply potable, agricultural, and industrial users, the potential exists for competition between the water needs of rivers and estuaries and human water needs. Several major industrial and agricultural groundwater withdrawals currently exist in the area, but relationships between withdrawals and stream flows have not been determined.

Evidence does exist that land uses affect stream flows in the region. Forestry is the dominant land use in the watershed of the Steinhatchee River, for example. Compared to basin conditions prior to timber farming, flows of the Steinhatchee River are estimated to be five percent greater than normal on an average annual basis. Peak flows are estimated to be as much as 35 percent greater because of wetland conversion to pine forests and channelization. To date, few data have been collected relating freshwater inflow to the biological characteristics of the region (such as marsh or fisheries production). Quantitative description and analysis of these relationships is a crucial need for proper management of Big Bend estuaries.

The Middle Peninsula. The fifteen rivers and numerous coastal creeks that drain west-central Florida flow to one of three major embayments (Charlotte Harbor, Sarasota Bay, Tampa Bay) or directly to the Gulf of Mexico. Their combined average daily flow is approximately 198 m^3/second (7,000 ft^3/second). Six streams flowing to either Charlotte Harbor or Tampa Bay have been impounded for use as public water supplies. With one exception, dams were built within the natural extent of brackish waters in these streams, creating salinity barriers that truncated estuarine and tidal freshwater reaches. For three of these streams, these barriers probably represent the most significant ecological impact because withdrawals have been relatively small.

Withdrawals, however, have resulted in significant flow reductions in three major tributaries to Tampa Bay. Prolonged and substantial flow reductions occur in these rivers during the dry season, especially the spring, which is a peak utilization time for many estuarine-dependent species. Required flow releases for these reservoirs are minimal or non-existent and prolonged flow reductions are often followed by sudden releases in the wet season that cause dramatic salinity fluctuations in the receiving estuaries. Similar effects of salinity are probably associated with two major flood control channels (Tampa Bypass Canal and Cross Florida Barge Canal) that periodically divert large quantities of freshwater to coastal habitats.

Two other major withdrawals for public or industrial supplies in the region are more ecologically sound, as off-stream reservoirs are used for water storage. Municipal supply withdrawals from the Peace River, the largest tributary to Charlotte Harbor, have been the subject of much ecological review and this facility serves as a prototype for future water use in the region. Withdrawals from the Peace River cannot reduce streamflow by more than ten percent on any given day and off-stream storage has been supplemented by pumping treated river waters into underground aquifers for later retrieval.

The effects of lowered groundwater levels on freshwater flows are a growing concern. As in the Big Bend region, this is particularly true for rivers where there is a good hydrologic connection with underlying groundwater aquifers. Long-term analysis of rainfall relationships for the Peace River indicates that groundwater pumping has reduced flows in the upper basin. Such effects depend on regional hydrogeology, however, and in at least one other river (Little Manatee), excess irrigation waters taken from groundwater sources actually supplement dry season flows. Urbanization and channelization have probably also affected runoff rates in highly developed areas around Tampa and Sarasota Bays. Although much of this runoff is not measured, it is expected that urbanization has increased wet season flows and, less conclusively, reduced dry season flows to estuaries.

Florida Bay. Florida Bay is located at the southern tip of Florida. Its eastern and southern boundaries are defined by the arc of the Florida Keys and its northern boundary is the coast of the Florida mainland. The many small embayments that fringe the mainland from the southeastern Everglades to Cape Sable and open onto Florida Bay are considered part of the Florida Bay system. The main body of Florida Bay is made up of a number of shallow basins that are partially separated from one another by a labyrinth of banks. Parts of this system become hypersaline during the long South Florida dry season, whereas brackish water prevails in the extreme northeastern part of the system during the wet season. Much of the Florida Bay system lies within the Everglades National Park. The biota of the Florida Bay system contains many tropical species, and coral reefs parallel the Florida Keys.

Historically, the Florida Bay system has been the nursery ground for the multi-million dollar Tortugas pink shrimp fishery and the Florida Keys lobster fishery, as well as an important recreational fishing area supporting spotted sea trout, red drum, mangrove snapper, snook, and other desirable species. The past few years have seen a number of dramatic changes, beginning in the mid-1980s. These include the following: 1) a decline in both catches and catch per unit effort in the Tortugas shrimp fishery; 2) a spreading die-off of seagrass that already covers a large portion of central and western Florida Bay; 3) an enormous algal bloom; 4) a die-off of sponges; and 5) localized fish kills. Seagrasses are a major habitat for early juvenile pink shrimp, and sponges are a major habitat for young spiny lobster.

The Florida Bay system is at the receiving end of the Everglades "river of grass" and has likely been affected by the many changes that have been made to the natural flow of water through the Everglades. The most recent major change was the completion of the South Dade Conveyance System in the early 1980s. This conveyance system, as currently operated, lowers the water table in the southeastern Everglades and adjacent east coast ridge. This has affected the flow of water into Florida Bay.

Many knowledgeable South Florida scientists have concluded that changes in freshwater discharges to the coast that influence the Florida Bay system are responsible for the catastrophic changes in Florida Bay. However, there is some disagreement among scientists. Some contend nutrient inputs to the Bay have increased and that this might be responsible for the ecological disaster. The premise that nutrient inputs to the Bay are higher than they have been historically has been challenged. Thus far, the Florida Bay system has been neglected in previous multi-agency efforts to determine relationships between water management practices and ecosystem health and productivity in South Florida. Hopefully, the current crisis will focus attention and resources to properly address and resolve the ecological problems in this important estuarine system.

Summary & Conclusions. Imprinted upon the remarkable diversity of riverine and coastal landscapes of Florida are several important latitudinal gradients related to freshwater inflow and water management. Total flows are greatest in the Panhandle and decrease with latitude, as does the relative contribution of ground waters to surface water resources. The extent of inflow alterations and associated ecological impacts also follow the same latitudinal gradient. The extent of river flow alterations and existing ecological problems is least in the Panhandle, although resource managers are greatly concerned over the potential for future problems. The extent of inflow alterations and ecological problems in west central Florida is moderate, and a crisis of national significance is unfolding in the Everglades and Florida Bay.

Case Studies. Charlotte Harbor. (excerpted from Hammett, 1987) Charlotte Harbor is a 699 km^2 (270 mi^2) estuarine system in west-central Florida. It is being subjected to increasing environmental stress by rapid population growth and development. By 2020, population in the inflow area may double, which will result in increased demands for freshwater and increased waste loads. The Charlotte Harbor inflow area includes about 12,134 km^2 (4,685 mi^2). The Myakka, the Peace, and the Caloosahatchee are the major rivers emptying into the harbor. About 70 percent of the land in these three river basins is used for agriculture and range. In the coastal basin around Charlotte Harbor, about 50 percent of the total land area is devoted to commercial or residential uses. Water use in the inflow area is about 565 million gallons per day, of which 59 percent is used for irrigation, 26 percent for industry, 11 percent for public supply, and four percent for rural supply.

Total freshwater inflow from the three major rivers, the coastal area, and rainfall directly into Charlotte Harbor averages between 161 and 173 m^3/second (5,700-6,100 ft^3/second), which is more than 13 billion litres (3,500 million gallons/day). A trend analysis of about 50 years of streamflow data shows a statistically significant decreasing trend for the Peace River stations at Bartow, Zolfo Springs, and Arcadia. No significant trend has been observed in the Myakka or the Caloosahatchee River data. In the Peace River, the decrease in flow may be related to a long-term decline in the potentiometric surface of the underlying Floridian aquifer system, which resulted from groundwater withdrawals. It is not possible to determine whether the trend will continue. However, if it does continue at the same rate, then, except for brief periods of storm runoff, the Peace River at Zolfo Springs could be dry year-round in about 100 years.

By 2020, the population in the inflow area is expected to increase by more than 500,000 people. They will require an additional 288 million litres (76 million gallons/day) for water supply.

Apalachicola River. (excerpted from Leitman *et al.*) The Flint river joins with the Chattahoochee River at the Florida border to form the Apalachicola River. Maintenance of the base-flow of the Apalachicola River is important to the ecological functioning of its floodplain and estuary and for the provision of a federally authorized navigation project. Throughout the early 1980s, the Apalachicola River's estuary provided about 90 percent of the state's and ten percent of the U.S.'s oyster harvest and sizable shrimp, blue crab, and finfish yields. Annual seafood landings are valued in the tens of millions of dollars, but the real value of the estuary, however, is in its role as a nursery. The Apalachicola estuary's productivity is the result of good water quality, physical form, salinity regime, and energy subsidies in the form of nutrient/detrital transport from the river's floodplain. It is keyed to a diurnal tidal cycle and a salinity regime defined by an annual cycle of spring floods and winter low-flows and cyclical long-term fluctuations in river flow (Livingston, 1984).

Based on recent analyses, it can be concluded that the base-flow of the Flint River has been reduced since the early 1970s. As irrigation withdrawals accounted for the majority of the increases in water use in the Flint basin, irrigation is the prime suspect for causing this reduction. This reduction of base-flow would translate into a parallel reduction of base-flow in the Apalachicola River. Because of the ramifications of reduced freshwater inflow to Apalachicola Bay and to the availability of the federal navigation channel, the issue of irrigation withdrawal impacts on base-flow in the Flint and Apalachicola Rivers warrants closer inspection. If the base-flow of the Flint has been lowered as the result of irrigation activity, future withdrawals need to be controlled either through regulations or market mechanisms.

Louisiana

The Louisiana coastal zone is unique among all Gulf of Mexico states in that it includes and is dominated by the single largest freshwater and sediment source of the entire Gulf system--the Mississippi-Atchafalaya Rivers (Turner and Gosselink, 1975). The Mississippi and Atchafalaya Rivers, which drain about 40 percent of the U.S. and parts of Canada, provide approximately 79 percent of Gulf of Mexico freshwater inflow.

The Louisiana coastal zone consists of an extensive wetland system, which comprises approximately 25-41 percent of all U.S. coastal wetlands, depending on the classification system used (Turner and Gosselink, 1975; Alexander, 1985). These marsh systems are characterized hydrologically by numerous interconnecting lakes, channels, and bayous. The flows through these channels are coupled with extensive overland flooding, thus exchanging water between the marsh surface and the surrounding waterbodies.

Whereas many Gulf estuaries suffer from upstream diversions of freshwater, Louisiana's estuaries suffer from a different problem--entrainment of freshwater and sediments to the main channels of the principal rivers. During the past sixty or more years, the Mississippi and Atchafalaya rivers have been largely impounded by levees and control structures, preventing the natural annual cycles of overbank flooding that have nourished and maintained the most extensive wetland system in the entire Gulf coast. (Overbank flooding of river water is a natural function that is critical to estuaries.) A net sediment deficit in these wetlands is a principal cause of the conversion of emergent wetland habitat to open water habitat [approximately 66 km^2/year (25 mi^2/year) at present].

The Louisiana coastal wetland system has been eroding at a catastrophic rate during the last 100 years, largely as a result of cultural modifications including: direct development for residential, agricultural, or industrial uses; control of the natural cycle of Mississippi River switching, preventing new delta lobe formation; river leveeing for flood control, preventing overbank flooding and marsh nourishment; construction of artificial channels with dredged spoil typically disposed offshore; and canals, spoil banks, and other hydrological modifications, resulting in direct marsh destruction and salt water intrusion. All the above hydrological modifications have produced a net sediment deficit in a subsiding coastal zone which is also experiencing sea level rise.

In recognition of the projected loss of most of its remaining coastal wetlands within 150 years, the state of Louisiana embarked on a coastal wetlands restoration effort in 1989, funded by dedicated state monies (Act 6). In 1990, a federal bill was signed that established a federal-state effort to address the same problem. This bill, the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA) (see **Appendix A**), dedicated approximately $33 million/year until 1999 to support a larger restoration effort, that includes artificial diversion of freshwater and sediment into wetlands on a large scale from the Mississippi-Atchafalaya Rivers. At this time, the federal-state task force under CWPPRA recognizes that the restoration of Louisiana's coastal zone will be a very expensive undertaking, beyond the scope of presently authorized funding.

Additional authorities will be sought in the future to tackle other aspects of the restoration effort, such as constructing locks on navigation channels to block saltwater intrusions. The restoration of Louisiana's barrier islands has been identified as a key to maintaining much of the interior marsh system, but the island restoration alone will probably cost $1 billion.

Mississippi

The Mississippi Gulf Coast is a terraced deltaic plain with a fairly steep slope that reaches eight feet per mile in some areas. The Pascagoula and Pearl Rivers, with drainage areas of 24,346 km^2 and 22,533 km^2 (9,400 and 8,700 mi^2) respectively, have an average discharge into Mississippi Sound of 430 m^3/second and 365 m^3/second (15,200 and 12,900 ft^3/second), respectively. The Biloxi, Jourdan, and Wolf Rivers, Bayou Bernard, and numerous other smaller streams contribute to a total estimate of 50,764 km^2 (19,600 mi^2) of drainage area and an average discharge of 884 m^3/second (31,220 ft^3/second). Additional freshwater enters the Sound from the Pontchartrain-Lake Borgne drainage to the West and Mobile Bay to the East.

Mississippi Sound itself is an elongated, relatively shallow body of water separated from the Gulf of Mexico by a series of barrier islands. Four estuarine areas adjoin the Sound, creating a complex area that defies any clear-cut hydrological classification. The salinity gradient across Mississippi Sound and through the estuaries decreases from averages above 33 ppt at the islands to freshwater in the nearshore zone. A salinity decrease is also evident as one proceeds from east to west, most likely the result of increased freshwater inflows in the western Sound. A variety of vertical salinity gradients are evident in the Sound as well. Most typically, bottom salinity is higher than that of the surface; relatively sharp salinity interfaces may occur in some channels with rises in excess of 10 ppt occurring within a five foot increase in depth.

The marshes that surround each of the major estuarine areas possess a very similar flora. Most of the nearly 26,306 hectares (65,000 acres) of coastal mainland marsh is dominated by *Juncus roemerianus*. *Spartina alterniflora*, *Spartina patens*, and *Scirpus oleyi* are the major components of the saline marsh. Organic production in these marshes, by higher vascular plants alone, is estimated at 2.7 billion kg (3 million tons) annually, with a standing crop of approximately 2.7 billion kg (3 million tons). In addition to emergent coastal marshes, Mississippi Sound also harbors patchy areas of submergent seagrass beds, particularly along the northern shores of the barrier islands.

Freshwater inflows from the major river systems and their associated sediments maintain deposits of organic materials that extend from the mainland well into the Sound, especially near the entrances to the major river systems. These organic deposits are over sand which is exposed near the barrier islands and, in some cases, includes shell fragments. As a result, Mississippi Sound and the adjacent inland waters provide a diversity of plant and animal habitat.

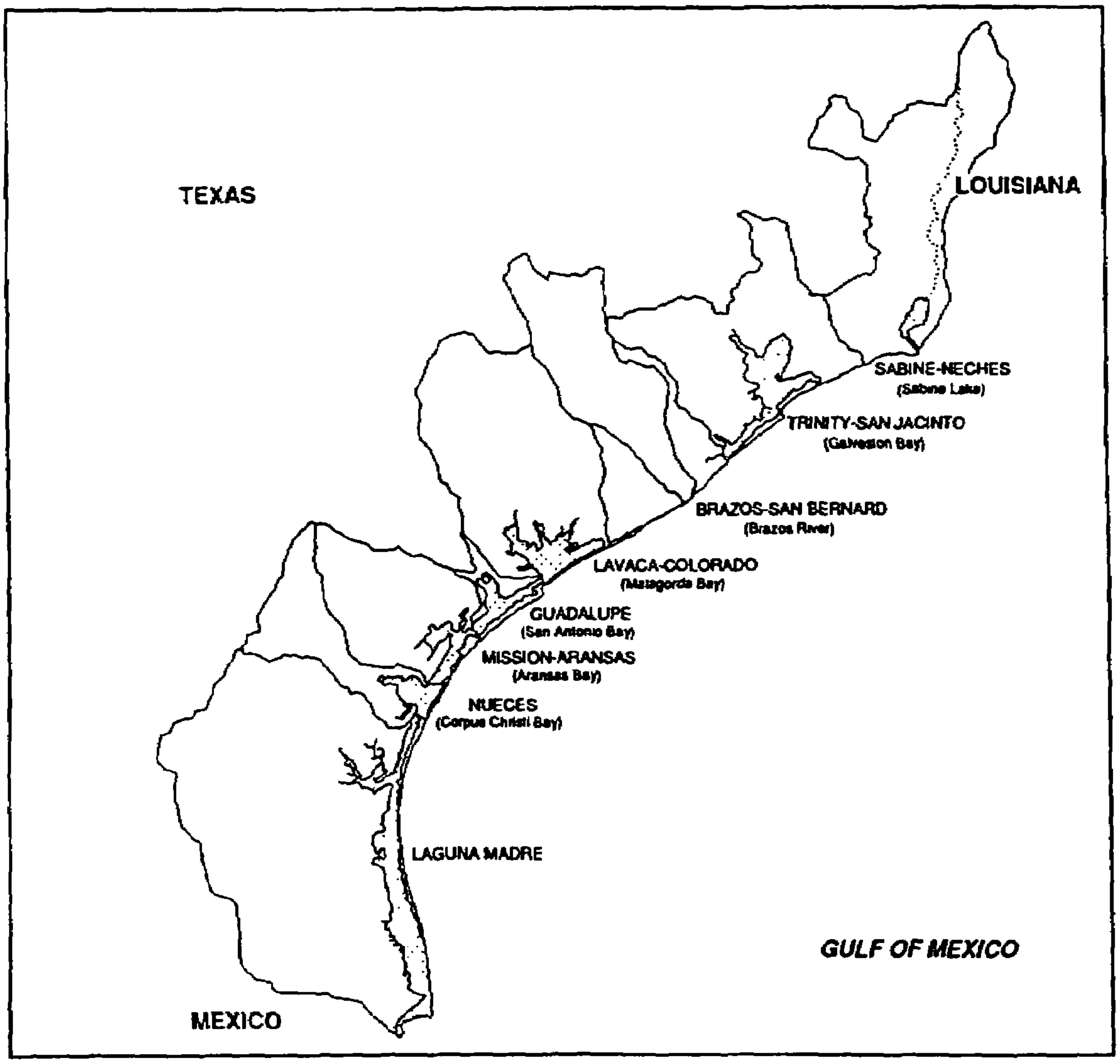
This habitat supports a sport and commercial fishery that has played an important role in the development of the Mississippi Gulf Coast. It has been estimated that some 98 percent of the species that comprise the state's commercial landings are estuarine-dependent in nature (Cooperative Gulf of Mexico Estuarine Inventory and Study, Mississippi). The long-term viability of these fisheries is inextricably linked to the overall health of the estuarine system and the maintenance of the freshwater inflows on which it depends.

Significant changes in freshwater inflows and fisheries production beyond a period of four or five decades are difficult to determine. However, tarpon, once widely caught in state waters according to historical accounts, have virtually disappeared; a native strain of striped bass ceased to exist in the late 1940s. Prudent management of Mississippi's freshwater resources may prevent additional losses in the future.

Texas

The Texas coastal zone is oriented on a northeast-to-southwest arc of coastline on the northwestern Gulf of Mexico. It extends almost 600 km (372 mi) along a nearly continuous chain of barrier islands from Louisiana to the Mexico border, behind which lies one of the most extensive estuarine systems in the U.S. Its watershed encompasses approximately 500,000 km^2 (193,000 mi^2) of Texas, Louisiana, and New Mexico, as well as northern Mexico (Orlando, *et al.*, 1993). These systems comprise more than 5,500 km^2 (2,123 mi^2) of open water and are bordered by tidal marshes and mud-sand flats (Orlando, *et al.*, 1993). While all of the estuaries are hydrodynamically coupled in varying degrees, it is useful to separate them into individual systems for detailed study and characterization (see **Figure 2.5**).

Figure 2.5 ***Coastal Zone of Texas Showing Major Estuarine Systems***



(Source: USDOC, 1991a)

Texas coastal plains estuaries typically include wetlands and open waters in which nutrients from river inflows, adjacent land runoff, and the sea support a productive community of plants and animals. Texas bays and estuaries cover over 1.05 million hectares (2.6 million acres) of land and provide over 2.4 million kg (10 million pounds) of sport fish and approximately 36.3 million kg (80 million pounds) of shrimp each year (Powell, 1991).

Freshwater Inflow. Year-to-year variability in freshwater input to Texas estuaries is great, responding to the large-scale climate fluctuations which produce periods of flooding and drought (USDOC, 1991a). The seasonal pattern of runoff tracks the pattern for precipitation. For most of the coast, the spring is the high-flow season and the summer is the low-flow season. In some years, the high-flow period is pronounced and lengthy; but in other years, it may be completely absent. Although river discharges in the low-flow period are less variable than those in the high-flow period, annual variability does occur. In some years, the low-flow period is shortened or eliminated by unusual runoff; in other years, it is prolonged.

Because river flow in Texas is governed by storm generated surface runoff, it is highly variable and rivers exhibit large, sudden excursions in flow. The greater frequency and intensity of precipitation-producing events in the watersheds of the upper coast, along with the detention created by reservoirs, lead to considerable overlap in the individual storm pulses (USDOC, 1991a). Hence, the freshwater inflow hydrography in the upper coast estuaries is typically manifested as a seasonal surge in runoff of several weeks to a few months in duration (USDOC, 1991a). Further south, the runoff pulses become more isolated in time and the spring inflow appears as a series of nearly discrete flood pulses. The monthly and seasonal cumulative variation in freshwater inflow produces the most dramatic changes in bay-wide salinity patterns in most Texas estuaries.

On the average, 29 million acre-feet of water per year flow into the bay and estuarine systems in Texas (Powell, 1991). However, almost 75 percent of that amount occurs in the two most eastern systems, the Sabine-Neches and the Trinity-San Jacinto. The rainfall in Texas ranges from over 55 inches in eastern areas to less than ten inches in western extremes. In addition, the Laguna Madre system in Texas is one of only four hypersaline systems in the world (Powell, 1991).

Salinity Characteristics of Texas Estuaries. (USDOC, 1991a) The salinity structure in Texas estuaries is determined primarily by hydrodynamic mechanisms which are governed by the interaction of marine and terrestrial influences. Freshwater plumes from the rivers that discharge into the northwestern Gulf of Mexico reduce salinities of nearshore Gulf waters, especially in May and October (Cochrane and Kelly, 1986). The degree to which salinities in Texas estuaries are affected by these low salinity waters depends on their proximity to major river plumes and to the year-to-year variability in river discharges, especially those of the Atchafalaya and Mississippi Rivers.

Except for the Brazos-San Bernard which is essentially riverine, the eight estuaries that were studied exhibit a similar geomorphology. These estuaries are lagoonal embayments which are broad and shallow and are largely isolated from the Gulf of Mexico, exchanging only through narrow inlets. Their large surface areas and shallow depths make the estuaries extremely responsive to winds. Tidal influences are negligible and are further attenuated by the narrow inlets that characterize this region.

Despite these gross similarities, Texas estuaries exhibit a wide range in hydrographic structure which, in turn, solicits a range of salinity response. However, the principal controls on salinity were found to be similar for certain systems.

In general, the seasonally-dominated salinity structure of the north coast estuaries is replaced by the event-driven structure of the mid-coast and lower coast systems. Variability is related to the volume and timing of freshwater to the system. A more variable salinity regime exists within the northern systems due to the presence of a significant and continuous freshwater source. In contrast, freshwater input to the lower coast estuaries is sporadic so that variability is generally associated with the occurrence of a significant (low frequency) hydrologic event. The Matagorda and Aransas systems are transitional, exhibiting the characteristics of two groups.

Upper Coast Estuaries (Sabine, Galveston, Brazos-San Bernard, and Matagorda). The salinity structure within these estuaries is dominated by a strong seasonal freshwater signal. On average, the volume of freshwater that enters these systems during the high-flow period is three times greater than during the low-flow period. This produces a seasonal difference in average salinities of 5 ppt. Within these estuaries, the interaction zone between freshwater and Gulf water (*i.e.*, the area exhibiting the strongest salinity gradient and, therefore, greatest variability) shifts due to changes in river discharge. As freshwater inflow decreases, Gulf waters intrude further landward providing greater stability of lower estuarine salinities (*i.e.*, dominated by the Gulf). At the same time, upper bay areas begin to experience instabilities as the zone of interaction is shifted landward.

Superimposed on this seasonal signal is the influence of meteorologically-induced transport and mixing. The frequent occurrence of cold frontal passages during the winter can account for as much as 50 percent removal of bay waters within a period of a few days. These frontal movements are a principal source of flushing and salinity variability as Gulf and estuarine waters exchange. Prevailing southeasterly winds are, to a lesser degree, a contributing factor to salinity variability and act to internally mix waters by the formation of large circulation gyres, wind waves, and shear dispersion between adjacent water masses of varying depth.

Finally, the relatively free connection between these estuaries and the Gulf (enhanced by the existence of ship channels) provides increased access to Gulf waters as density-induced currents act to convey and entrain more saline coastal waters. These coastal waters exhibit their own salinity variability due to the advection of river plumes along the shelf from Louisiana.

Mid-Coast Estuaries (Matagorca, San Antonio, and Aransas). The salinity structure within these estuaries is not dominated by a seasonal freshwater inflow signal. The principal time scale over which salinity varies ranges from weeks to months and is associated with isolated freshwater inflow events which can occur throughout the year. The effect on salinity is limited to the upper bay regions (*e.g.*, Lavaca Bay, San Antonio Bay, and Copano Bay) which are somewhat geographically confined and distinguishable from the lower lagoonal reaches adjacent to the chain of barrier islands.

This part of the Texas coast is prone to prolonged periods of drought which, in turn, contribute to the year-to-year variability of salinity. This, in conjunction with limited Gulf access, tends to dampen salinity variability when compared to upper coast systems. These bays tend to have a longer "memory" (*i.e.*, less intense flushing) of the freshwater event. In Copano Bay, for instance, short-duration freshets can depress salinities for several months. In contrast, the lower lagoonal reaches of these systems tend to be responsive to meteorological mixing and inter-estuarine exchanges which are dictated by the behavior of prevailing winds.

Lower Coast Estuaries (Aransas, Corpus Christi, and Laguna Madre). The salinity structure of these estuaries is determined by isolated freshwater pulses rather than seasonal discharge. When compared to the upper and mid-coast estuaries, these watersheds are more arid, frontal passages are less frequent, and inflows are lower. As a result, the salinity structure of these systems tends to be more stable. The reduced influence of freshwater allows other forcing mechanisms to become relatively more important. Evaporation is a significant factor that affects seasonal changes in salinity. Tides are important as a means of internal mixing and may actually reduce salinities when estuaries become hypersaline. Wind dictates inter-estuarine exchanges.

However, the internal gradients of salinity are generally small and exhibit a persistent stability. This behavior is only interrupted by the occasional freshet which may dramatically impact salinity for several weeks. Only under this condition are density currents an important mechanism for salinity intrusion.

Impacts of Alterations in Freshwater Inflows. There is concern that modifications of Texas estuaries, including creation of navigational channels and alteration of inflows, have caused, or could cause, a reduction in estuarine populations of fish and wildlife. Construction of the Intracoastal Waterway may have caused the Laguna Madre to become less saline and the Chenier Plains Marshes near Sabine Lake to become more saline. Alteration of seasonal inflows in the Sabine River due to Toledo Bend Reservoir may have sharply reduced shrimp production in the Sabine Lake area. Striped Bass (*Morone saxatilis*) no longer exist in Texas estuaries in harvestable quantities (Texas Water Development Board). Snook (*Centropomis undecimalis*) have also dramatically declined in abundance. Oyster (*Crassostrea virginica*) landings from Nueces Bay have essentially disappeared, and extensive dredging of oyster beds for shell during the period 1941 through 1967 reduced available substrate for oyster populations in many Texas estuaries (Texas Water Development Board). In addition, numbers of brown pelicans (*Pelecanus occidentalis*), Eskimo curlews (*Numenius borealis*), piping plovers (*Charadrius melodus*), and American alligators (*Alligator mississippiensis*) also have declined over the long-term. Recently, however, there have been significant increases in the numbers of brown pelicans, whooping cranes (*Grus americana*), and American alligators (Texas Water Development Board).

The reasons for the reductions in these populations are not always clear. Overfishing, habitat destruction or alteration, and pollution have occurred and are undoubtedly contributing factors. Alteration of seasonal freshwater inflows also has had some influence, and there is concern about the quantity of inflows reaching the estuaries. Even though there have been changes in the abundance of some species, the available data suggest that Texas estuaries still retain much of their historical composition and productivity (Texas Water Development Board).

C se Studies on Trends in Streamflow, Precipitation & Surface Water Withdrawals & Effects of Reservoirs (Green and Slade, 1992)

The four basins that were chosen for study are the Apalachicola River basin in Georgia, Alabama, and Florida; the Pearl River basin in Mississippi and Louisiana; and the Trinity River and Nueces River basins in Texas (see **Figure 2.6**). These basins were chosen because of their geographic distribution and diversity in hydrology, climate, land use, and extent of development. A variety of factors affect streamflow in these four basins.

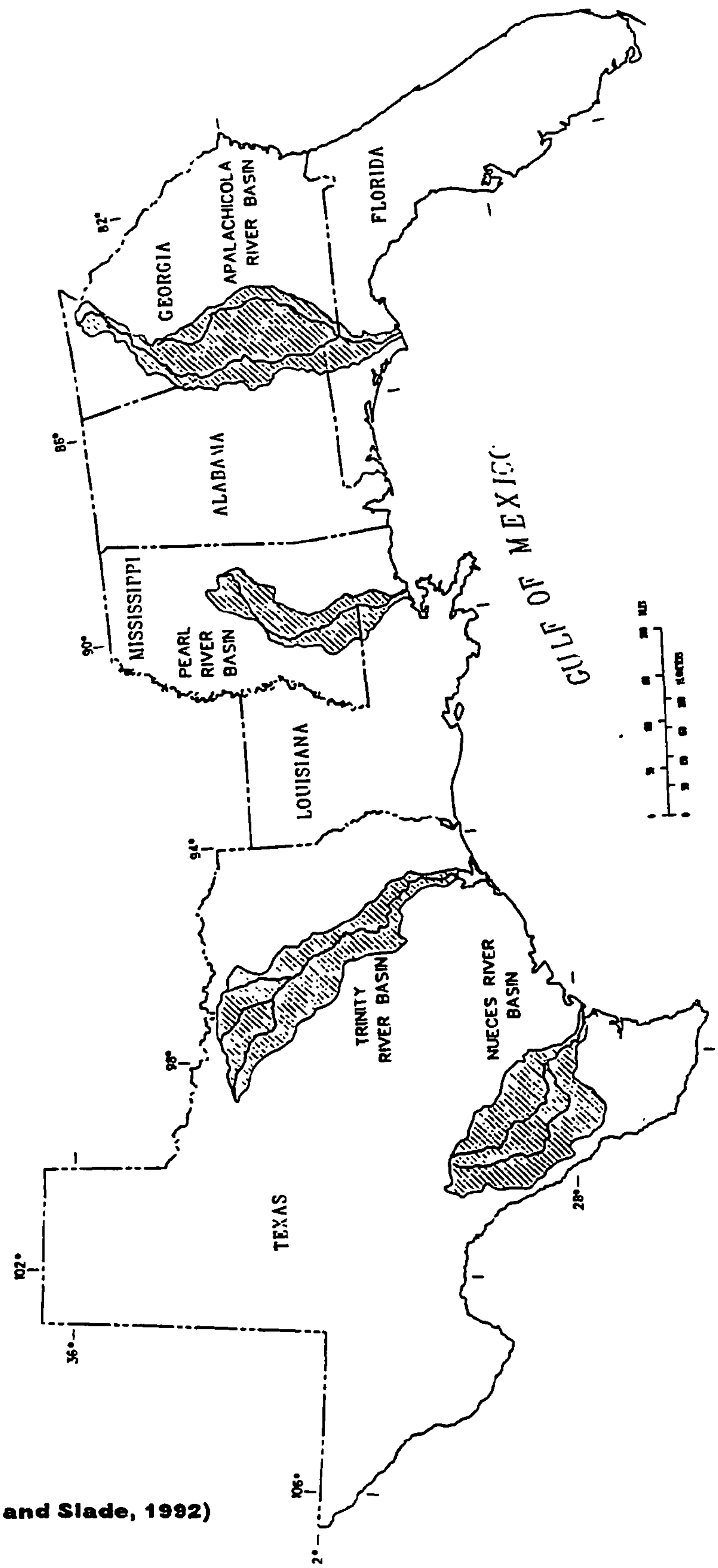
Temporal trends in streamflow were compared with trends in associated precipitation for the main channels and tributaries of four major rivers (Apalachicola, Pearl, Trinity, Nueces). Both long-term and short-term trends were identified for selected streamflow gages with at least forty years of record. Trends were determined for annual mean discharges, annual minimum and maximum daily mean discharges, and associated annual mean precipitation.

Case Study Trends. Long-term trends indicate no temporal change in annual mean and annual maximum discharges to the Gulf of Mexico from the Apalachicola River basin. Annual mean and annual maximum discharges to the Gulf increased temporally from the Pearl River basin and decreased from the Trinity River and Nueces River basins. Annual minimum discharges to the Gulf increased in all four of the basins studied. The annual mean precipitation associated with the most downstream gage also increased temporally during the periods of record studied in all four of the basins. The short-term trends in streamflow generally corresponded to the trends in associated precipitation for each gage. For some gages in the Trinity River basin, short-term trends in annual minimum discharge increased, and short-term trends in annual maximum discharge decreased.

Total reported surface water withdrawals increased more than fourfold in the Trinity River basin since 1940. Present surface water withdrawals from the Trinity River basin represent about one-fourth of the mean streamflow near the mouth. Total withdrawals increased more than eightfold in the Nueces River basin since 1940. Present surface water withdrawals from the Nueces River basin represent about one-third of the mean streamflow near the mouth.

Effects of selected reservoirs on streamflow in the four basins also were studied. Predicted peak discharges downstream from reservoirs on the upper reaches of the Apalachicola and Trinity Rivers were as much as 75 percent less for the fifty year flood after the reservoirs were constructed. Predicted peak discharges into the Gulf from the Apalachicola River were about 23 percent less for the fifty year flood after reservoir construction. Although one large reservoir was built on the Pearl River and many reservoirs have been built on the Trinity River and its tributaries, the findings indicated that peak discharges into the Gulf of Mexico from the Pearl and

Figure 2.6 ***Location of the Apalachicola River, Pearl River, Trinity River & Nueces River Basins***



(Source: Greene and Slade, 1992)

Trinity Rivers were not affected during the past fifty years. However, statistical analyses of the precipitation streamflow relations indicated that annual mean discharges were reduced following construction of the most downstream reservoirs on the Apalachicola and Trinity Rivers. A water budget analysis estimated that the mean discharge to the Gulf from the Nueces River was reduced by about 41 percent as a result of filling and evaporation at Choke Canyon Reservoir.

The trends identified in this study have important implications for the estuarine ecosystems that receive freshwater inflows from each of these basins. Sediment and nutrient inflows to bays and estuaries depend on streamflow. The findings of this study suggest that the pattern and quantity of streamflow from the Apalachicola, Pearl, Trinity, and Nueces River basins have changed during the period of record studied. Many of these temporal changes can be attributed to human activities in the basins.

Conclusion

Estuaries are by definition dependent upon certain levels of freshwater inflow. Water must be provided in the proper amount, location, and timing for estuaries to be productive. All other things being equal, estuaries with large inflows of freshwater are more productive than estuaries with less flow. A given estuary is more productive in and after wet years than dry ones.

Detrimental changes have been occurring in the amount, timing, and location of freshwater inflow to estuaries. Such changes are caused by impoundments, diversions of water for consumptive use, flood control, hydropower, navigation projects, and other public works projects in rivers and watersheds. Inflow alterations affect the delivery of sediment and nutrients and cause significant changes in estuarine circulation and salinity.

3 FEDERAL & STATE FRAMEWORK FOR ADDRESSING FRESHWATER INFLOWS

While no single agency or program has responsibility for freshwater inflows or is addressing this issue specifically, there is a broader legal and institutional framework currently in place in the Gulf of Mexico that can address freshwater inflow issues. For a description of this framework, see **Appendix A**. Action Items 9 and 10 in Chapter 4 of this document address the need for additional policies and programs to address freshwater inflow issues.

4 THE UNFINISHED AGENDA --
Both Current Commitments & Uncommitted Activities

Goal

This Freshwater Inflow Action Agenda for the Gulf of Mexico sets forth a framework for conserving, protecting, and restoring Gulf waters that will minimize freshwater inflow concerns. The Gulf of Mexico Program has established the following long-term goal for addressing freshwater inflow concerns:

- ❑ Protect, preserve, restore, and, where feasible, enhance the freshwater inflow to the Gulf of Mexico and the associated bays and estuaries for the purpose of maintaining the ecological health and integrity of those systems.

For the purposes of this Action Agenda, "freshwater" includes surface water, ground water, springs, and precipitation. Also, where the term "sediment" is used, it refers to the "sediment regime" (erosion, deposition, transport).

Objectives & Action Items

Four types of activity have been designed to meet the goal: 1) Policy, Planning & Implementation, 2) Research, 3) Monitoring & Assessment, and 4) Public Education & Outreach. Specific objectives and action items are grouped according to these areas (see **Index of Freshwater Inflow Objectives & Action Items**).

Objectives are the specific, short-term targets for attaining the goals. Each objective is followed by action items that describe specific tasks to meet the goals and objectives for the Freshwater Inflow Action Agenda. Each action item is presented under an appropriate objective. Some action items are cross referenced to other action items by a "→" sign in the left hand column. This signals a close relationship among those actions and a need for coordination.

Lead. The Freshwater Inflow Committee has identified a lead agency for each action item. A proposed action item may involve the execution of legislative or regulatory authorities or programmatic initiatives which derive from these authorities. In other cases, a proposed action item may involve the facilitation or coordination of activities among several agencies or organizations. In these cases, and where there is no clear legislative authority involved, the "lead" could be the agency or organization which expresses an interest in taking on the task during Gulf of Mexico Program Issue Committee deliberations, the action planning workshop or public comment period, or, in the Issue Committee's judgment, is best able to guide multiple parties in carrying out the activity. *This does not necessarily mean that the agency has agreed to carry out the activity or* *that the agency has the necessary funding. The Freshwater Inflow Committee understands these action items will require commitments by agencies and organizations that are dependent on budget decisions.* However, the Issue Committee members hope this document provides the rationale and support for such commitments and that future iterations of this document will include additional specific commitments.

Initiation Date. The date indicated represents a determination by the Issue Committee of the most realistic *initiation date* for the action item. As lead agencies begin implementation planning for specific action items, these initiation dates may change due to resource availability and prioritization within the individual agencies.

The Gulf of Mexico Program recognizes the need to identify indicators of environmental progress relative to this Action Agenda for freshwater inflow. Many of the action items specified in Chapter 4 of this document will aid the Program in developing a baseline for measuring success in the future. For the time being, however, acceptance and completion of action items specified in this Action Agenda will be considered a measure of success. As future Action Agendas are written and current action items are completed, new action items will be developed to better measure environmental progress. The Gulf of Mexico Program will coordinate among the eight Gulf of Mexico Program Issue Committees to eliminate overlap and duplication of efforts, as well as to integrate goals and activities across environmental issue areas.

Index of Freshwater Inflow Objectives & Action Items

Policy, Planning & Implementation

Objective: Develop a process for assessing the range of freshwater needs for estuarine and coastal waters of the Gulf of Mexico and identify the quantity and quality of freshwater necessary to meet those needs.

Action Item 1: Freshwater Predictive Tools for the Gulf of Mexico

Action Item 2: Use of International Literature to Increase Understanding of Freshwater Inflows to Gulf of Mexico Coastal Systems

Action Item 3: Gulfwide Forum for Assessment of Freshwater Needs

Objective: Identify and evaluate Gulf of Mexico estuaries with freshwater inflow issues and select appropriate estuaries for management attention.

Action Item 4: Identification of Gulf of Mexico Estuaries & Coastal Waters of Concern

Action Item 5: Comprehensive Plans for Selected Gulf of Mexico Estuaries

Action Item 6: Freshwater Inflow Demonstration Program for the Gulf of Mexico

Action Item 7: Freshwater Inflow Sediment Management in the Gulf of Mexico

Objective: Develop a coordinated Gulfwide strategy to provide adequate freshwater inflows to the estuarine and coastal waters of the Gulf of Mexico.

Action Item 8: Integrated Mississippi River Management Plan

Action Item 9: Freshwater Program & Policy Inventory

Action Item 10: Freshwater Program & Policy Recommendations & Case Studies

Action Item 11: "Partnership for Action" Among the U.S., Mexico & Caribbean

Objective: Develop policy alternatives on the allocation of water among Gulf of Mexico estuaries.

Action Item 12: Integrative Decision Methodology for Water Allocations

Action Item 13: Gulf of Mexico Management Options for Water Flows

Objective: Promote the watershed approach in national policy.

Action Item 14: Integration of Gulf of Mexico Program Committee Activities & Consistent Mapping

Action Item 15: Accounting for Freshwater Needs in Gulf of Mexico Development Plans & BMPs

Action Item 16: National Watershed Initiative Support

Index of Freshwater Inflow Objectives & Action Items (continued)

Research

Objective: Conduct research to improve the understanding of relationships among freshwater inflows, salinity patterns, nutrient delivery and uptake, sediment regimes, circulation and flushing times, estuarine productivity, and habitat (with an emphasis on major representative river systems) in the Gulf of Mexico.

Objective: Conduct research on the cumulative impacts of alterations on freshwater inflows to the Gulf of Mexico.

Objective: Conduct research on population and economic projections in the Gulf of Mexico related to freshwater needs and flows and related socio-political issues.

Index of Freshwater Inflow Objectives & Action Items (continued)

Monitoring & Assessment

Objective: Inventory all available data and identify data gaps relating to water quality and quantity, water use factors, and effects of freshwater inflow on Gulf of Mexico estuarine productivity–including salinity patterns, nutrient delivery and uptake, sediment regimes, land use and land use changes, biological parameters, geomorphology, and types of freshwater inflow (*e.g.*, surface water, ground water, and other sources).

Action Item 34: Gulfwide Priorities for Data Acquisition & Collection

Action Item 35: Inventory of Available Data & Information Sources Relevant to Gulf of Mexico Freshwater Inflows

Action Item 36: Acquisition, Quality Assurance & Synthesis of Gulf of Mexico Freshwater Inflow Data

Action Item 37: Minimum Data Set for Gulf of Mexico Estuaries or Basins

Action Item 38: Feedback Loop for Gulf of Mexico Freshwater Data Collection

Objective: Assess trends in freshwater inflows to the Gulf of Mexico.

Action Item 39: Identification of Data Needed for Freshwater Inflow Trend Assessment in the Gulf of Mexico

Action Item 40: Inventory of Major Gulf of Mexico Watershed Modifications

Action Item 41: Estimation of Naturalized Flows & Variability in the Gulf of Mexico

Action Item 42: Climatological Trends in the Gulf of Mexico

Action Item 43: Meteorological Trends in the Gulf of Mexico

Objective: Identify and evaluate causes of change in freshwater inflow quantity and quality relative to location, volume, and timing of change within an estuary or segment in the Gulf of Mexico.

Action Item 44: Identification & Ranking of Contributions to Causes of Freshwater Inflow Change in the Gulf of Mexico

Action Item 45: Future Agricultural/Industrial Management Practices Affecting Runoff & Hydrogeologic Patterns in the Gulf of Mexico

Action Item 46: Anthropogenic Activities Affecting Seasonal Runoff Patterns in the Gulf of Mexico

Action Item 47: Groundwater Inputs to Freshwater in Gulf of Mexico Estuaries

Action Item 48: Long-Term Climatic Effects on Surface Waters & Freshwater Inflows to the Gulf of Mexico

Objective: Determine Gulf of Mexico estuarine resource-based salinity requirements based on existing knowledge and working hypotheses (inventory what has been done and identify what needs to be done for major representative ecosystems).

Action Item 49: Salinity Requirements for Seagrasses in the Gulf of Mexico

Action Item 50: Salinity Requirements for Fish & Invertebrates in the Gulf of Mexico

Action Item 51: Natural Rate of Change in Gulfwide Salinity Based on Tidal Scale

Action Item 52: Gulf of Mexico Estuarine Flushing Times

Index of Freshwater Inflow Objectives & Action Items (continued)

Monitoring & Assessment (continued)

Objective: Identify linkages and assess relationships among freshwater inflows, salinity patterns, nutrient delivery and uptake, sediment regimes, estuarine productivity, other water quality parameters, and the adjacent Gulf of Mexico.

Action Item 53: Criteria & Process for Prioritizing Gulf of Mexico Freshwater Inflow Linkages & Relationships for Evaluation

Action Item 54: Methodology to Identify Freshwater Inflow Relationships & Linkages Within a Typical Estuary for Each Gulf State

Action Item 55: Expansion of State Freshwater Inflow Methodologies to Other Basins/Estuaries Throughout the Gulf of Mexico

Action Item 56: Gulfwide Characterization Workshops for Freshwater Inflow Concerns

Objective: Develop a Gulfwide monitoring program to assess the effectiveness of freshwater management actions on an estuary specific (or estuary class) basis.

Action Item 57: Management Objectives for Freshwater Monitoring Program Design for Gulf of Mexico Estuaries

Action Item 58: Assessment of NAS Monitoring Approach for Gulf of Mexico Use

Action Item 59: Development of Gulf of Mexico Monitoring Standards & Modification of Monitoring Plan Based on Planned Hydrologic Changes

Action Item 60: Gulf of Mexico Protocols for Biological Parameters & Basin Relationships

Action Item 61: Freshwater Monitoring Cost/Benefit Study for the Gulf of Mexico

Action Item 62: Gulf of Mexico Monitoring Coordination & Facilitation

Action Item 63: Gulfwide GIS & Data Management System

Index of Freshwater Inflow Objectives & Action Items (continued)

Public Education & Outreach

Objective: Promote the basin-wide public awareness of ecological, economic, and health impacts associated with alterations of freshwater inflows to estuarine systems and the cumulative role of those estuaries for sustaining the health of the Gulf of Mexico.

Objective: Promote the basin-wide awareness of federal, state, and local government officials and decision-makers of the ecological, economic, and health impacts associated with alterations of freshwater inflows to estuarine systems and the cumulative role of those estuaries for sustaining the health of the Gulf of Mexico.

Objective: Promote basin-wide public involvement to address the ecological, economic, and health impacts associated with alterations of freshwater inflows to estuarine systems and the cumulative role of those estuaries for sustaining the health of the Gulf of Mexico.

Policy, Planning & Implementation

No single agency or program has responsibility for freshwater inflows. This fact heightens the need for an integrated, coordinated Gulfwide approach to freshwater inflow concerns. The development of compatible policies or processes among federal agencies and Gulf Coast States is crucial in order to reduce freshwater inflow concerns in the Gulf of Mexico.

Specific objectives and action items follow:

Objective: Develop a process for assessing the range of freshwater needs for estuarine and coastal waters of the Gulf of Mexico and identify the quantity and quality of freshwater necessary to meet those needs.

Action Item 1 - Freshwater Predictive Tools for the Gulf of Mexico

Develop appropriate "predictive tools" to support the Gulf of Mexico freshwater assessment process for both present conditions and future time periods.
Lead Agency: National Oceanic & Atmospheric Administration, U.S. Environmental Protection Agency, and Gulf State resource agencies.
Initiation Date: 1996
→ 2, 53, 56, 63

Action Item 2 - Use of International Literature to Increase Understanding of Freshwater Inflows to Gulf of Mexico Coastal Systems

Review and analyze information from the international literature to increase understanding of Gulf of Mexico coastal systems regarding freshwater inflows and the potential to protect these systems from losses.
Lead: National Oceanic & Atmospheric Administration, U.S. Environmental Protection Agency, and Gulf State resource agencies, in coordination with Gulf of Mexico Program.
Initiation Date: 1994
→ 1, 10

Action Item 3 - Gulfwide Forum for Assessment of Freshwater Needs

Conduct a forum to share assessment ideas and approaches among the five Gulf States. This should include a review of the various salinity, nutrient, and sediment loading regimes needed to maintain an ecologically and economically sound environment in the receiving estuary systems, as well as biological indicators, societal values, and a framework for decision making.
Lead: Gulf of Mexico Program--Freshwater Inflow Committee, in coordination with appropriate Gulf State agencies.
Initiation Date: 1995
→ 56

Objective: **Identify and evaluate Gulf of Mexico estuaries with freshwater inflow issues and select appropriate estuaries for management attention.**

Action Item 4 - Identification of Gulf of Mexico Estuaries & Coastal Waters of Concern

Develop a consensus approach across the five Gulf States for defining "threatened" estuaries which will be used to drive the prioritization, and corresponding selection, of estuaries for future planning efforts. Criteria could include such factors as the severity of existing problems, cultural factors, expected near term anthropogenic changes, as well as infrastructure available to solve problems and the ability to achieve success. In addition, the significance and impact of smaller coastal basin estuaries should be addressed.
Lead: Gulf of Mexico Program--Freshwater Inflow Committee, in coordination with appropriate Gulf State agencies.
Initiation Date: 1995
→ 40, 56

Action Item 5 - Comprehensive Plans for Selected Gulf of Mexico Estuaries

Develop "comprehensive plans" for selected estuaries in the Gulf of Mexico starting with one in each of the five Gulf States and continuing using the priority listing generated in Action Item 4. Planning goals and components of the comprehensive plan will be developed by a five state working group. It is anticipated that the plans will include a documentation of needs, the development of resource-based water quality criteria, appropriate regulatory structures, and other requirements for meeting freshwater needs, as well as identification of restoration opportunities. Where appropriate, these plans will build on work completed (or underway) by the National Estuary Programs and Coastal Wetlands Planning, Protection & Restoration Act projects.
Lead: Appropriate Gulf State agencies.
Initiation Date: 1996
→ 4

Action Item 6 - Freshwater Inflow Demonstration Program for the Gulf of Mexico

Develop and implement one or more demonstration programs that focus on the "how to's" for ensuring the adequacy of freshwater to estuaries within the Gulf of Mexico. Provide technology transfer across the five Gulf States on a menu of successful approaches that could be adopted incrementally. Where appropriate, these plans will build on work completed (or underway) by the National Estuary Programs and Coastal Wetlands Planning, Protection & Restoration Act projects.
Lead: Gulf of Mexico Program--Freshwater Inflow Committee, in coordination with appropriate Gulf State agencies.
Initiation Date: 1997

Action Item 7 - Freshwater Inflow Sediment Management in the Gulf of Mexico

Identify areas within the Gulf of Mexico that need sediment enrichment, for the maintenance and creation of wetlands, and promote the management of sediments to increase loadings in these areas.
Lead: Appropriate Gulf State agencies, in coordination with Gulf of Mexico Program--Freshwater Inflow Committee and Habitat Degradation Committee.
Initiation Date: 1997
→ 6

Objective: **Develop a coordinated Gulfwide strategy to provide adequate freshwater inflows to the estuarine and coastal waters of the Gulf of Mexico.**

Action Item 8 - Integrated Mississippi River Management Plan

Develop an integrated management plan for the Mississippi River which focuses on the Delta. All appropriate Gulf of Mexico Program Issue Committees, including Habitat Degradation, Nutrient Enrichment, and Coastal & Shoreline Erosion, will participate in scoping the components of the plan. The freshwater focus will be on sediment transport.
Lead: Gulf of Mexico Program.
Initiation Date: 1998

Action Item 9 - Freshwater Program & Policy Inventory

Develop a comprehensive inventory of national, Gulf State, and local programs and policies that address the sufficiency of freshwater for estuaries. National programs should include the U.S. Environmental Protection Agency nonpoint source and NPDES storm water programs.
Lead: U.S. Environmental Protection Agency, in coordination with Gulf State agencies.
Initiation Date: 1994

Action Item 10 - Freshwater Program & Policy Recommendations & Case Studies

Using the inventory developed in Action Item 9, conduct an analysis of the strengths and weaknesses of current policies and approaches addressing freshwater needs and make recommendations to appropriate regulatory agencies to promote consistency and coordination within the Gulf of Mexico. Produce and distribute case studies of successful approaches for addressing freshwater needs.
Lead: Gulf of Mexico Program.
Initiation Date: 1995
→ 9

Action Item 11 - "Partnership for Action" Among the U.S., Mexico & Caribbean

Develop a "Partnership for Action" document, similar to the December 1992 Gulf of Mexico Program Partnership for Action, to be signed by Presidents and senior policy officials. This document should identify goals, challenges, and initiatives (including technology transfer) related to freshwater inflow for the Gulf of Mexico among the U.S., Mexico, and the Caribbean.
Lead: Gulf of Mexico Program.
Initiation Date: 1996

Objective: Develop policy alternatives on the allocation of water among Gulf of Mexico estuaries.

Action Item 12 - Integrative Decision Methodology for Water Allocations

Develop and/or identify an existing decision support methodology which integrates all available and appropriate information to support the allocation of water on a watershed basis.
Lead: Gulf of Mexico Program, in coordination with Gulf State resources agencies.
Initiation Date: 1995

Action Item 13 - Gulf of Mexico Management Options for Water Flows

Develop and make recommendations to the five Gulf States on management options for water flow to the estuaries. This could incorporate recommendations for interstate compacts.
Lead: Gulf of Mexico Program.
Initiation Date: 1996
→ 12

Objective: Promote the watershed approach in national policy.

Action Item 14 - Integration of Gulf of Mexico Program Committee Activities & Consistent Mapping

Work with all appropriate Gulf of Mexico Program Committees to use consistent digitized basin maps for planning and implementation activities and to integrate other activities as appropriate.
Lead: Gulf of Mexico Program--Data & Information Transfer Operations.
Initiation Date: 1994

Action Item 15 - Accounting for Freshwater Needs in Gulf of Mexico Development Plans & BMPs

Ensure that the freshwater needs of Gulf of Mexico estuaries for ecological and economic purposes are accounted for in water development plans, land development plans, BMPs for agriculture, and other factors that impact runoff.
Lead: Appropriate Gulf State agencies.
Initiation Date: 1996
→ **5, 10**

Action Item 16 - National Watershed Initiative Support

Support national initiatives that advocate appropriate watershed approaches.
Lead: Gulf of Mexico Program.
Initiation Date: Ongoing

Research

To adequately address Gulf of Mexico freshwater inflow concerns, more complete knowledge is needed. Most research funds are administered by federal agencies or state program offices in support of specific missions, with only limited funding going to research that examines the cumulative effects of decisions on the ecosystem as a whole. This action planning process provides the necessary mechanism to enable the producers, consumers, and funders of research to agree on priorities. A closer connection should be established between the research agenda of the scientific community and the information needs of managers, regulators, and those involved in decisions for the management of the Gulf of Mexico. Once a research agenda is developed and implemented, the research results should be used to understand the underlying processes and relationships and to support appropriate decisions regarding management of Gulf waters.

Specific objectives and action items follow:

Objective: **Conduct research to improve the understanding of relationships among freshwater inflows, salinity patterns, nutrient delivery and uptake, sediment regimes, circulation and flushing times, estuarine productivity, and habitat (with an emphasis on major representative river systems) in the Gulf of Mexico.**

Action Item 17 - Science Inventory Related to Freshwater Inflows

Inventory applicable scientific documentation to determine information needs and data gaps related to freshwater inflows in the Gulf of Mexico.
Lead: U.S. Geological Survey.
Initiation Date: 1995

Action Item 18 - Methodologies for Mapping Structural Habitats of Coastal Systems

Research and evaluate the methods for mapping the structural habitat of coastal systems. The objective is to be able to determine the probability that a habitat is a valuable nursery. Examine the present and past salinity and water quality patterns at high quality locations in the Gulf of Mexico. Emphasis should be placed on determining the most cost-effective methods.
Lead: U.S. Fish & Wildlife Service, in coordination with National Marine Fisheries Service and Gulf of Mexico Program--Habitat Degradation Committee.
Initiation Date: 1995

Action Item 19 - Relationship Between Freshwater Inflows & Productive Habitat in the Gulf of Mexico

Determine the relationships between freshwater inflows and productive habitat on an estuary by estuary basis throughout the Gulf of Mexico.
Lead: Gulf State resource agencies, in coordination with Gulf of Mexico Program--Freshwater Inflow Committee and Habitat Degradation Committee.
Initiation Date: 1996
→ **18**

Action Item 20 - Inflow Effects on Salinity Gradients & Organisms within the Gulf of Mexico

Determine the effects of changes in the amounts and locations of inflow on Gulf of Mexico estuarine salinity gradients and the estuarine organisms that depend on these gradients.
Lead: U.S. Fish & Wildlife Service and National Marine Fisheries Service.
Initiation Date: 1996

Action Item 21 - Surface Water System Augmentation & Salt Water Intrusion Model

Develop a model to investigate: 1) the ecological benefits of augmentation of surface water systems; and 2) the impacts of associated changes in salinity patterns.
Lead: National Oceanic & Atmospheric Administration.
Initiation Date: 1997
→ **20**

Action Item 22 - Quantification of Freshwater Linkages & Relationships in the Gulf of Mexico

Conduct research and studies needed to quantify linkages and relationships among Gulf of Mexico freshwater inflows, salinity patterns, nutrient delivery and uptake, sediment regimes, circulation and flushing times, estuarine productivity, and habitat for estuarine resources, such as fish and shellfish (with an emphasis on major representative river systems). Also, quantify the relationship between seasonal freshwater discharges to coastal systems and the life histories (abundance and distribution) of estuarine living resources.
Lead: U.S. Fish & Wildlife Service, in coordination with Gulf State resource agencies.
Initiation Date: 1995
→ **30**

Action Item 23 - Relationship Between Precipitation/Runoff & Input to Ground Water in the Gulf of Mexico

Determine the relationship between precipitation/runoff and input to ground water (base flow). Utilize both historic data and other qualitative records to construct long-term records of precipitation and runoff in the Gulf of Mexico.
Lead: U.S. Geological Survey.
Initiation Date: 1994
→ **42**

Action Item 24 · Gulf of Mexico Interagency/Interstate Freshwater Research Program

Develop an integrated, interdisciplinary, and interagency research program focusing on freshwater inflows, salinity, and estuarine productivity. Utilize working hypotheses to frame research programs and a multi-year agenda for the Gulf of Mexico.
Lead: Gulf State resource agencies and Gulf of Mexico Program--Freshwater Inflow Committee.
Initiation Date: 1994
→ 49, 50, 51, 52

Action Item 25 · Tools for Gulf of Mexico Managers to Utilize Freshwater Inflow Research

Develop tools to allow water, land, and living resource managers within the Gulf of Mexico region to utilize information developed from freshwater inflow research.
Lead: Gulf of Mexico Program--Data & Information Transfer Operations.
Initiation Date: 1996
→ 1, 3, 6, 36, 63

Objective: Conduct research on the cumulative impacts of alterations on freshwater inflows to the Gulf of Mexico.

Action Item 26 · Relationship Between Gulf of Mexico Anoxic Events Near River Outlets & Upstream Flow Alterations

Investigate the possible relationship between anoxic events in the area of river outlets in the Gulf of Mexico and the manmade changes that have occurred in the water pathways of the river. Initial investigations should concentrate on the Mississippi River outlet and the anoxic events off the coast of western Louisiana.
Lead: Louisiana Department of Natural Resources, in coordination with Gulf of Mexico Program--Freshwater Inflow Committee.
Initiation Date: 1995
→ 36, 63

Action Item 27 - Relationship Between Gaged Flow & Actual Flow to Gulf of Mexico Coastal Systems

Determine the relationship between gaged flows and the flow actually reaching Gulf of Mexico coastal systems.
Lead: U.S. Geological Survey.
Initiation Date: 1994

Action Item 28 - Precipitation Gauges in Gulf of Mexico Coastal Wetlands

Establish precipitation gauges in selected Gulf of Mexico coastal wetlands to monitor contributing runoff to estuaries and other parameters, such as atmospheric deposition.
Lead: National Oceanic & Atmospheric Administration--National Weather Service.
Initiation Date: 1995

Action Item 29 - Impacts of Sediment Delivered to Gulf of Mexico Coastal Systems

Research the impacts of the changing regime of sediment delivery to Gulf of Mexico coastal systems.
Lead: Gulf State resource agencies (Bureau of Economic Geology in Texas).
Initiation Date: 1994
→ 7

Action Item 30 - Review of Models & Technology to Compare Patterns of Freshwater Inflow, Salinity, Nutrients & Sediment Regimes in the Gulf of Mexico

Research existing watershed river and estuary models and modeling technology to compare historic (pre-development) and modern patterns of freshwater inflow, salinity, nutrients, and sediment. Compare the application and results of each methodology/model and evaluate the potential to combine existing models and technology into one working system to produce predictions of changing salinity, nutrients, and sediment regimes resulting from specific proposed or planned upstream activities.
Lead: Gulf State resource agencies and Mote Marine Laboratory.
Initiation Date: 1996
→ 21, 22

Objective: **Conduct research on population and economic projections in the Gulf of Mexico related to freshwater needs and flows and related socio-political issues.**

Action Item 31 - Effects of Economic Growth on Freshwater Inflows to Gulf of Mexico Coastal Systems

Determine how economic and population projections and future demands for freshwater will affect freshwater inflows to Gulf of Mexico coastal systems. Emphasis should be on addressing areas with significant projected growth/loss and the potential effects on the receiving waters of the Gulf of Mexico.
Lead: U.S. Department of Commerce.
Initiation Date: 1994

Action Item 32 - Use of Reclaimed Water to Replace Flow Losses to Gulf of Mexico Coastal Systems

Conduct research on the use and optimal location of highly treated reclaimed water (Clean Water Act advanced treatment standards or better), including wetland treatment, to replace flow losses to Gulf of Mexico coastal systems. Research should utilize international examples.
Lead: U.S. Environmental Protection Agency, National Aeronautics & Space Administration, and Gulf of Mexico Program--Freshwater Inflow Committee.
Initiation Date: 1994

Action Item 33 - Gulf of Mexico Water Conservation Alternatives Research

Conduct research on potential Gulf of Mexico water conservation alternatives on an ecological, economic, and socio-political basis.
Lead: Gulf State resource agencies and U.S. Environmental Protection Agency.
Initiation Date: 1995

Monitoring & Assessment

Establishing an adequate information base is very important for monitoring freshwater inflow conditions and for measuring the success of this action agenda. Current information should be used to develop a statistically valid baseline from which to monitor changing conditions in the rates and distribution of freshwater inflows to the Gulf of Mexico. Future activities and information collection can then be incorporated into the data base. Gulfwide priorities need to be set and procedures established to improve the inventorying and monitoring of this information among agencies and programs.

Specific objectives and action items follow:

Objective: Inventory all available data and identify data gaps relating to water quality and quantity, water use factors, and effects of freshwater inflow on Gulf of Mexico estuarine productivity--including salinity patterns, nutrient delivery and uptake, sediment regimes, land use and land use changes, biological parameters, geomorphology, and types of freshwater inflow (*e.g.*, surface water, ground water, and other sources).

Action Item 34 - Gulfwide Priorities for Data Acquisition & Collection

Establish priorities for data acquisition and collection based on Gulf of Mexico Program management objectives for monitoring and other needs of the program.
Lead: Gulf of Mexico Program--Freshwater Inflow Committee, in coordination with Data & Information Transfer Operations, Southeast Regional Climate Center, and state and regional water management agencies.
Initiation Date: 1994
→ 38

NOTE: Action Items 35 and 36 are a generic set of actions for each group of variables or parameters identified as important under Action Item 34.

Action Item 35 - Inventory of Available Data & Information Sources Relevant to Gulf of Mexico Freshwater Inflows

Identify and inventory all federal, state, and private programs relevant to Gulf of Mexico freshwater inflows. Emphasis should be placed on early review of regional, comparable sources such as the U.S. Environmental Protection Agency--Environmental Monitoring & Assessment Program and STORET.
Lead: Gulf of Mexico Program--Freshwater Inflow Committee, in coordination with Data & Information Transfer Operations.
Initiation Date: 1994

Action Item 36 - Acquisition, Quality Assurance & Synthesis of Gulf of Mexico Freshwater Inflow Data

Acquire, quality assure, and synthesize appropriate freshwater inflow data for the Gulf of Mexico. Summarize data based on quality and quantity available. Organize data using a Geographic Information System (GIS) format.
Lead: Gulf of Mexico Program--Freshwater Inflow Committee, in coordination with Data & Information Transfer Operations.
Initiation Date: 1995
→ 25, 63

Action Item 37 - Minimum Data Set for Gulf of Mexico Estuaries or Basins

Specify the minimum data set for each estuary or basin within the Gulf of Mexico. The set specification should identify variables, as well as geographic and temporal parameters. Consideration should be given to data availability, critical information needs for decision making, and cost factors.
Lead: Gulf of Mexico Program--Freshwater Inflow Committee, in coordination with Data & Information Transfer Operations.
Initiation Date: 1995
→ 3

Action Item 38 - Feedback Loop for Gulf of Mexico Freshwater Data Collection

Based on results of data evaluation, evolving needs of other action items, and any changes to Gulf of Mexico monitoring objectives, reevaluate what freshwater related data need to be collected (either primary or secondary collection).
Lead: Gulf of Mexico Program.
Initiation Date: 1996
→ 34

Objective: **Assess trends in freshwater inflows to the Gulf of Mexico.**

Action Item 39 - Identification of Data Needed for Freshwater Inflow Trend Assessment in the Gulf of Mexico

Identify the temporal (including seasonality) and spatial specificity needed to assess trends in freshwater inflow within the Gulf of Mexico region.
Lead: Gulf of Mexico Program--Freshwater Inflow Committee, in coordination with Data & Information Transfer Operations.
Initiation Date: 1995
→ 3

Action Item 40 - Inventory of Major Gulf of Mexico Watershed Modifications

Inventory past and identify projected future major watershed modifications on a state by state basis in the Gulf of Mexico, including land use, hydrologic modifications, dam projects, and other structural alterations. This will serve as a baseline planning tool, as well as provide valuable information for public education.
Lead: Appropriate Gulf State agencies, in coordination with Gulf of Mexico Program--Freshwater Inflow Committee.
Initiation Date: 1995

Action Item 41 - Estimation of Naturalized Flows & Variability in the Gulf of Mexico

Develop estimates of naturalized (pre-development) flows and variability for comparison with present flows on an estuary by estuary basis in the Gulf of Mexico.
Lead: Mote Marine Laboratory.
Initiation Date: 1995

Action Item 42 - Climatological Trends in the Gulf of Mexico

Integrate precipitation data for the Gulf of Mexico watershed using accepted hydrological techniques to produce an historic basin-scale precipitation record to use in analyses to determine changes in runoff to each estuary relative to precipitation within its watershed.
Lead: U.S. Geological Survey, in coordination with Texas Water Commission, Florida's regional water management districts, and Southeast Regional Climate Center.
Initiation Date: 1994
→ 2 3

Action Item 43 - Meteorological Trends in the Gulf of Mexico

Evaluate the contribution of tropical storms, hurricanes, and thunderstorms to seasonal water budgets in the Gulf of Mexico.
Lead: National Oceanic & Atmospheric Administration--National Weather Service.
Initiation Date: 1995

Objective: **Identify and evaluate causes of change in freshwater inflow quantity and quality relative to location, volume, and timing of change within an estuary or segment in the Gulf of Mexico.**

Action Item 44 - Identification & Ranking of Contributions to Causes of Freshwater Inflow Change in the Gulf of Mexico

Identify and prioritize the causes of freshwater inflow change within an estuary or estuary segment in the Gulf of Mexico.
Lead: Gulf State water resource agencies.
Initiation Date: 1996
→ 5, 46

Action Item 45 - Future Agricultural/Industrial Management Practices Affecting Runoff & Hydrogeologic Patterns in the Gulf of Mexico

Identify future agricultural and industrial management practices and regulations likely to dramatically change basin wide runoff patterns in the Gulf of Mexico.
Lead: U.S. Environmental Protection Agency, Soil Conservation Service, and Gulf State agencies.
Initiation Date: 1996

Action Item 46 - Anthropogenic Activities Affecting Seasonal Runoff Patterns in the Gulf of Mexico

Identify and prioritize the causes of freshwater inflow change within an estuary or estuary segment in the Gulf of Mexico.
Lead: Gulf State water resource agencies.
Initiation Date: 1996
→ 5, 44

Action Item 47 - Groundwater Inputs to Freshwater in Gulf of Mexico Estuaries

Estimate groundwater inputs, as a function of precipitation, to each estuary in the Gulf of Mexico.
Lead: U.S. Geological Survey, in coordination with Gulf State water resource agencies.
Initiation Date: 1996

Action Item 48 - Long-Term Climatic Effects on Surface Waters & Freshwater Inflows to the Gulf of Mexico

Determine long-term climatic (sea level, rainfall) effects on surface waters of the Gulf of Mexico and the impacts of changes on freshwater inflows.
Lead: Southeast Regional Climate Center, in coordination with state water management agencies.
Initiation Date: 1996

Objective: **Determine Gulf of Mexico estuarine resource-based salinity requirements based on existing knowledge and working hypotheses (inventory what has been done and identify what needs to be done for major representative ecosystems).**

Action Item 49 - Salinity Requirements for Seagrasses in the Gulf of Mexico

Determine salinity requirements and physical parameters for Gulf of Mexico seagrasses based on existing knowledge and working hypotheses and determine future research needs.
Lead: National Marine Fisheries Service, in coordination with Gulf State resource agencies and Gulf of Mexico Program--Habitat Degradation Committee.
Initiation Date: 1995
→ 24

Action Item 50 - Salinity Requirements for Fish & Invertebrates in the Gulf of Mexico

Determine salinity requirements and physical parameters for fish and invertebrates of economic and ecological importance in the Gulf of Mexico based on existing knowledge and working hypotheses. Determine future research needs.
Lead: National Marine Fisheries Service, in coordination with U.S. Fish & Wildlife Service, Gulf State resource agencies, Sea Grant Universities, and Gulf of Mexico Program--Living Aquatic Resources Committee.
Initiation Date: 1995
→ 24

Action Item 51 - Natural Rate of Change in Gulfwide Salinity Based on Tidal Scale

Determine the natural rate of change in Gulfwide salinity (or any other factor) on a tidal (daily) scale based on existing knowledge and working hypotheses. Determine future research needs.
Lead: National Oceanic & Atmospheric Administration--Strategic Assessments Branch, in coordination with state and regional water management agencies.
Initiation Date: 1995
→ **2 4**

Action Item 52 - Gulf of Mexico Estuarine Flushing Times

Determine Gulf of Mexico estuarine flushing times based on existing knowledge and working hypotheses and determine future research needs.
Lead: National Oceanic & Atmospheric Administration--Strategic Assessments Branch, in coordination with state and regional water management agencies.
Initiation Date: 1995
→ **2 4**

Objective: **Identify linkages and assess relationships among freshwater inflows, salinity patterns, nutrient delivery and uptake, sediment regimes, estuarine productivity, other water quality parameters, and the adjacent Gulf of Mexico.**

Action Item 53 - Criteria & Process for Prioritizing Gulf of Mexico Freshwater Inflow Linkages & Relationships for Evaluation

Develop criteria and a process to prioritize a limited list of Gulf of Mexico freshwater inflow linkages and relationships for evaluation, including the appropriate temporal scale.
Lead: Gulf of Mexico Program--Freshwater Inflow Committee, in coordination with appropriate Gulf State agencies.
Initiation Date: 1995
→ 1, 3, 54, 55

Action Item 54 - Methodology to Identify Freshwater Inflow Relationships & Linkages Within a Typical Estuary for Each Gulf State

Develop a methodology to completely identify freshwater inflow relationships and linkages in a single or typical Gulf of Mexico estuary or basin. Each state should develop this model for the estuary or basin that best typifies state conditions.
Lead: Gulf of Mexico Program--Freshwater Inflow Committee, in coordination with appropriate Gulf State agencies.
Initiation Date: 1996
→ 3, 6, 53, 55

Action Item 55 - Expansion of State Freshwater Inflow Methodologies to Other Basins/Estuaries Throughout the Gulf of Mexico

Modify or expand the state model to explain relationships or linkages in other basins or estuaries throughout the Gulf of Mexico. The order in which other watersheds are addressed depend on management priorities.
Lead: Gulf of Mexico Program--Freshwater Inflow Committee, in coordination with appropriate Gulf State agencies.
Initiation Date: 1997
→ 4, 5, 53, 54

Action Item 56 - Gulfwide Characterization Workshops for Freshwater Inflow Concerns

Convene a series of freshwater inflow characterization workshops, beginning with workshops in each state and culminating with a Gulfwide workshop. Experts on each estuary or basin and subject matter experts will characterize problems. The result will be a matrix that arrays problems against basins.
Lead: Gulf of Mexico Program--Freshwater Inflow Committee, in coordination with appropriate Gulf State agencies.
Initiation Date: 1994
→ 1, 3, 4, 44, 54, 65

Objective: Develop a Gulfwide monitoring program to assess the effectiveness of freshwater management actions on an estuary specific (or estuary class) basis.

Action Item 57 - Management Objectives for Freshwater Monitoring Program Design for Gulf of Mexico Estuaries

Identify or specify Gulf of Mexico management objectives to provide the basis for a freshwater-related monitoring program design for each Gulf estuary. Objectives stated should support establishment of monitoring criteria such as data completeness, extremes and rates of change, seasonality, and temporal scale. *Note - This Action Item should be part of the broad activities of the Gulf of Mexico Program.*
Lead: Gulf of Mexico Program.
Initiation Date: 1996
→ 58, 59

Action Item 58 - Assessment of NAS Monitoring Approach for Gulf of Mexico Use

Determine the feasibility of using the National Academy of Science approach (*Managing Troubled Waters*) to monitoring program design and evaluation. Each state and the Gulf of Mexico Program should conduct individual evaluations and consider the feasibility of a Gulfwide approach.
Lead: Gulf of Mexico Program--Freshwater Inflow Committee and Data & Information Transfer Operations, in coordination with appropriate Gulf State agencies.
Initiation Date: 1995
→ 57, 59

Action Item 59 - Development of Gulf of Mexico Monitoring Standards & Modification of Monitoring Plan Based on Planned Hydrologic Changes

Develop Gulf of Mexico monitoring program standards for use with continuous monitoring and recording equipment for appropriate parameters, *e.g.*, freshwater flows, tidal flows, salinity patterns, and ambient water quality parameters. Prepare changes to the monitoring plan when the states identify planned major hydrologic changes such as dam construction and channel changes. Modifications should be designed to capture freshwater flows before the hydrologic change and impacts after the change.
Lead: Gulf of Mexico Program--Freshwater Inflow Committee and Data & Information Transfer Operations, in coordination with appropriate Gulf State agencies.
Initiation Date: 1996
→ 57, 58

Action Item 60 - Gulf of Mexico Protocols for Biological Parameters & Basin Relationships

Develop Gulf of Mexico sampling protocols for biological parameters (*e.g.*, biomass, specific species) and basin system relationships for which direct biological monitoring can be used in place of physio-chemical monitoring.
Lead: Gulf State resource agencies and U.S. Environmental Protection Agency.
Initiation Date: 1996

Action Item 61 - Freshwater Monitoring Cost/Benefit Study for the Gulf of Mexico

Conduct a study of monitoring costs and benefits for the Gulf of Mexico to identify appropriate public and private parties for covering the costs of monitoring programs related to freshwater.
Lead: Gulf State resource agencies and Gulf of Mexico Program--Data & Information Transfer Operations..
Initiation Date: 1997

Action Item 62 - Gulf of Mexico Monitoring Coordination & Facilitation

Coordinate and facilitate communication, data management, and related monitoring activities among all Gulf area public and private institutions that are routinely conducting monitoring programs.
Lead: Gulf of Mexico Program--Data & Information Transfer Operations.
Initiation Date: 1995

Action Item 63 - Gulfwide GIS & Data Management System

Develop a Gulfwide, basin-based "super" Geographic Information and Data Management System to support monitoring and assessment. The system would include all freshwater flow quantity data, related variables, structures, and meteorological data. *Note: Need to develop a cross issue Gulfwide monitoring strategy, including appropriate modeling activities.*
Lead: Gulf of Mexico Program--Data & Information Transfer Operations.
Initiation Date: 1997
→ 1, 25, 36, 57, 60

Public Education & Outreach

People living in two-thirds of the U.S. ultimately affect the environmental quality of the Gulf of Mexico. Alternatively, the entire population of the U.S. can potentially be affected by the environmental quality of the Gulf. Therefore, effective environmental policy requires an ongoing commitment from an informed citizenry. Public outreach nurtures such a commitment. Public information, education, and involvement are three components of an effective outreach strategy, which can reap significant benefits both for the Gulf of Mexico and for citizens utilizing its resources. More and more, public outreach is recognized as an effective resource management tool to address problems resulting from individual actions and to create a sense of stewardship within the community.

Public outreach can foster recognition of the Gulf as a regional and national resource; stimulate civic, governmental, and private sector support for changing lifestyles; and develop the financial commitments necessary to preserve the resource.

The overall public education strategy for freshwater inflows is to use existing resources as much as possible to get the message out to target audiences, which will include the use of bilingual materials. New workshops and curricula should be sponsored only when existing ones are not sufficient. Corporate sponsorships should be considered for all education and involvement materials, activities, and events wherever possible. Key topics for freshwater inflow include:

- Relationships/interactions among freshwater and estuarine systems;
- Freshwater inflow and its impacts on water quality;
- Basic discussion of pollution, its sources, and impacts; and
- A watershed approach to freshwater inflow problems.

Specific objectives and action items follow:

Objective: **Promote the basin-wide public awareness of ecological, economic, and health impacts associated with alterations of freshwater inflows to estuarine systems and the cumulative role of those estuaries for sustaining the health of the Gulf of Mexico.**

Action Item 64 - Process to Identify Education & Outreach Needs for Gulf of Mexico Freshwater Inflows

Institute a standard process for the Gulf of Mexico Program Office to identify the public education and outreach needs for freshwater inflow and other issue areas. The process should help the Office obtain a comprehensive list of those needs by constituency. These needs would be summarized and specific actions developed to address the most significant needs. *Note - This Action Item should be part of the broad activities of the Gulf of Mexico Program.*
Lead: Gulf of Mexico Program--Public Education & Outreach Operations, in coordination with Freshwater Inflow Committee and other Issue Committees.
Initiation Date: 1994

Action Item 65 - Technical Overview Document to Describe Gulf of Mexico Freshwater Inflow Issues

Develop a scientifically rigorous overview and synthesis document, characterizing the problems associated with Gulf of Mexico estuaries' freshwater inflow. This document would describe the freshwater flow and salinity patterns in Gulf of Mexico estuaries as this information becomes available. It would also include the historic and projected future changes in the estuaries' freshwater inflow. The document would become the primary source of technical information for articles and publications.
Lead: Gulf of Mexico Program--Freshwater Inflow Committee.
Initiation Date: 1996
→ 40, 44, 56

Action Item 66 - Existing Publications That Reach the Gulf of Mexico Public on Freshwater Inflow Issues

Survey existing newsletters and other publications to identify those that can inform the general public about problems associated with freshwater inflow in the Gulf of Mexico. After identifying these newsletters, prepare articles that address specific topics, audiences, and geographic areas. Use existing mechanisms to write, incorporate, and distribute these articles to the newsletters.
Lead: Gulf of Mexico Program–Public Education & Outreach Operations, in coordination with Freshwater Inflow Committee.
Initiation Date: 1995
→ 79

Action Item 67 - Freshwater Inflow Curriculum

Identify lesson plans, outlines, etc. that describe problems associated with freshwater inflow. If necessary develop such materials. Modify a prototype watershed approach for water resources, such as Mote Marine Laboratory's "Drop of Water," to incorporate a freshwater inflow curriculum unit. Then, incorporate the modified prototype into existing environmental curricula. Conduct specific initiatives to increase teacher awareness of environmental issues, including announcements of the freshwater inflow unit in existing newsletters designed to reach teachers and science coordinators. Use the Elder Hostel Program to provide volunteers to teach this unit where feasible.
Lead: Gulf of Mexico Program–Public Education & Outreach Operations, in coordination with Freshwater Inflow Committee and Mote Marine Laboratory.
Initiation Date: 1996

Action Item 68 · Freshwater Inflow Workshops for Educators in the Gulf of Mexico Region

Modify existing or institute new annual workshops to increase teacher awareness of freshwater inflow issues in the Gulf of Mexico. The workshops should include a summary of the latest data, research, and information and should help identify the need for related educational materials on freshwater inflow and other environmental issues. The state and national forums should be supported by state governments as well as school administrators.
Lead: Gulf of Mexico Program–Public Education & Outreach Operations, in coordination with Freshwater Inflow Committee and state departments of education.
Initiation Date: 1997

Action Item 69 · Gulf of Mexico Freshwater Inflow Media Kits

Develop media kits that include public service announcements (PSAs), news releases, photographs, and brochures describing problems associated with freshwater inflow in the Gulf of Mexico. Media kits should be professionally done, timely, and always up-to-date, and should include a local technical contact. Specific topics might include use and reuse (*e.g.*, water conservation). Existing organizations/associations, such as the American Waterworks Association, should be surveyed for material that might be included.
Lead: Gulf of Mexico Program–Public Education & Outreach Operations, in coordination with Freshwater Inflow Committee.
Initiation Date: 1997

Action Item 70 · Gulf of Mexico Freshwater Inflow Public Broadcasting Program

Develop a thirty-minute freshwater inflow program to broadcast on public radio and television. The program should inform the general public about problems associated with freshwater inflow in the Gulf of Mexico, including specific technical issues about the quantity and quality of freshwater inflow.
Lead: Gulf of Mexico Program–Public Education & Outreach Operations, in coordination with Freshwater Inflow Committee.
Initiation Date: 1997

Action Item 71 - Gulf of Mexico Freshwater Inflow Information Portfolio

Develop a portfolio of basic information about freshwater inflow in the Gulf of Mexico that addresses the following issues: 1) implications for bay, estuary, and human health; 2) selected technical issues; and 3) other related problems. Make the portfolio available to individuals who request information for news stories, newsletters, and environmental curricula.
Lead: Gulf of Mexico Program--Freshwater Inflow Committee, in coordination with Public Education & Outreach Operations.
Initiation Date: 1997
→ 65, 67

Action Item 72 - Gulf of Mexico Freshwater Inflow Clearinghouse

Sponsor a clearinghouse/repository for freshwater inflow-related public education activities, events, and materials. Coastal managers and educators across the Gulf could access the clearinghouse/repository through an "800" number or the Gulf program's existing bulletin board system.
Lead: Gulf of Mexico Program--Public Education & Outreach Operations, in coordination with Freshwater Inflow Committee.
Initiation Date: 1995

Action Item 73 - Articles on Freshwater Inflow Issues in the Gulf of Mexico

Interact with local media organizations, especially newspapers, to encourage the publication of feature articles on freshwater inflow issues in the Gulf of Mexico. These articles should address the unique freshwater inflow problems associated with the readership's geographic area.
Lead: Gulf of Mexico Program--Public Education & Outreach Operations, in coordination with Freshwater Inflow Committee.
Initiation Date: 1995
→ 69

Action Item 74 - Gulfwide Water Resources & Fisheries Management Integration

Integrate the local and regional management of water resources and fisheries through state water resources boards in the Gulf of Mexico. This should help coordinate policies and research associated with water resources and fisheries management.
Lead: Appropriate Gulf State agencies.
Initiation Date: 1996

Action Item 75 - Establishment of Land Owners Associations in the Gulf of Mexico Region

Foster the formation of associations of waterfront/shoreline property owners who can educate themselves about the effects of specific behavior on the quality of freshwater entering bays and estuaries in the Gulf of Mexico. In addition, form specific action programs for property owners addressing freshwater inflow and other Gulf of Mexico Program action areas (*e.g.*, toxic substances & pesticides, nutrient enrichment, marine debris, and habitat degradation).
Lead: Gulf of Mexico Program Citizens Advisory Committee, in coordination with appropriate Gulf of Mexico Program Issue Committees.
Initiation Date: 1997

Action Item 76 - Awards Program for Gulf of Mexico Freshwater Inflow Issues

Institute an award program for citizens and non-profit/other organizations who successfully address freshwater inflow problems in the Gulf of Mexico. The award should provide additional incentives to sponsor freshwater inflow projects.
Lead: Gulf of Mexico Program--Public Education & Outreach Operations, in coordination with Freshwater Inflow Committee.
Initiation Date: 1996

Action Item 77 - Gulf of Mexico Urban Outreach Programs

Develop and/or sponsor public education materials and events on freshwater inflow targeted specifically to youth in urban areas and other groups that may be culturally and/or geographically distanced.
Lead: Gulf of Mexico Program–Public Education & Outreach Operations, in coordination with Freshwater Inflow Committee and other Issue Committees.
Initiation Date: 1996

Action Item 78 - Gulf of Mexico Model Landscape Program

Develop and institute a model program designed to encourage environmentally-sound landscape practices in neighborhoods, public sites, business centers, and school yards.
Lead: Gulf of Mexico Program–Public Education & Outreach Operations, in coordination with appropriate Gulf of Mexico Program Issue Committees.
Initiation Date: 1997

Objective: **Promote the basin-wide awareness of federal, state, and local government officials and decision-makers of the ecological, economic, and health impacts associated with alterations of freshwater inflows to estuarine systems and the cumulative role of those estuaries for sustaining the health of the Gulf of Mexico.**

Action Item 79 - Existing Publications That Reach Gulf of Mexico Officials on Freshwater Inflow Issues

Conduct a survey to identify existing newsletters that can inform Gulf of Mexico region elected officials about the problems associated with freshwater inflow. Once these newsletters are identified, write articles designed to address specific topics, audiences, and geographic areas. Place these articles in the selected newsletters through existing mechanisms.
Lead: Gulf of Mexico Program--Public Education & Outreach Operations, in coordination with Freshwater Inflow Committee.
Initiation Date: 1995
→ 66

Action Item 80 - Technical Papers on Gulf of Mexico Freshwater Inflow

Prepare and present "short" technical papers to key senior federal decision-makers. These papers will set a general context for understanding issues associated with freshwater inflow in the Gulf of Mexico, as well as address specific technical issues.
Lead: Gulf of Mexico Program--Freshwater Inflow Committee, in coordination with Public Education & Outreach Operations.
Initiation Date: 1996
→ 65, 81

Action Item 81 - Gulfwide Seminars on Freshwater Inflow Issues

Identify local and regional seminars where the Gulf of Mexico Program can disseminate information regarding freshwater inflow issues to elected officials and their staff people. If necessary, sponsor such seminars. These seminars should be held in something less than a public setting. They will help elected officials understand the general policy and specific technical issues associated with freshwater inflow.
Lead: Gulf of Mexico Program–Public Education & Outreach Operations, in coordination with Freshwater Inflow Committee and other Issues Committees.
Initiation Date: 1997
→ **8 0**

Action Item 82 - Gulfwide Road Shows on Freshwater Inflow Issues

Sponsor educational road shows for appropriate teams of coastal managers to brief elected officials in the Gulf of Mexico region and their staff on issues pertaining to freshwater inflow. Each road show should result in a series of specific actions for the elected official.
Lead: Gulf of Mexico Program–Public Education & Outreach Operations, in coordination with Freshwater Inflow Committee and other Issues Committees.
Initiation Date: 1997

Action Item 83 - Videos on Freshwater Inflow Issues in the Gulf of Mexico

Identify and/or develop short (ten minute) videos that detail the issues associated with freshwater inflow in the Gulf of Mexico region, as well as profile the related technical issues.
Lead: Gulf of Mexico Program–Public Education & Outreach Operations, in coordination with Freshwater Inflow Committee.
Initiation Date: 1997
→ **70, 82**

Action Item 84 - Information to Gulf of Mexico Legal Professions About Freshwater Inflow Issues

Identify bar associations, judges, and law enforcement officials throughout the Gulf of Mexico who should be informed about the legal issues associated with freshwater inflow. Develop and distribute specialized outreach materials for this audience.
Lead: Gulf of Mexico Program--Public Education & Outreach Operations, in coordination with Freshwater Inflow Committee and other Issues Committees.
Initiation Date: 1997

Objective: **Promote basin-wide public involvement to address the ecological, economic, and health impacts associated with alterations of freshwater inflows to estuarine systems and the cumulative role of those estuaries for sustaining the health of the Gulf of Mexico.**

Action Item 85 - Endorsement of Gulfwide Public Involvement Activities Related to Freshwater Inflow Issues

Endorse or sponsor specific Gulfwide public involvement activities and events designed to address problems associated with freshwater inflow. Many of the National Estuary Programs already sponsor these types of public events. This could include storm water stenciling packets and activities, volunteer monitoring/sampling (one time and regular sampling), festivals such as Galveston Bay Days, programs such as Florida Neighborhoods, and Galveston Bay's Pollution Reporting Hotline. Consider the use of corporate sponsorships to cover printing and other expenses. For example, Clorox is sponsoring a one day volunteer monitoring of the Mississippi River.
Lead: Gulf of Mexico Program--Public Education & Outreach Operations, in coordination with Freshwater Inflow Committee and other Issues Committees.
Initiation Date: 1995

Action Item 86 • Development of "What I Can Do" Lists to Address Freshwater Inflow Issues

Develop action-oriented citizen "to do" lists, which outline activities and behaviors that address freshwater inflow issues in the Gulf of Mexico. Where possible, influence existing state and local lists, such as Tampa and Sarasota Bays' "Bay Repair Kit" and Galveston Bay's "Resident Handbook."
Lead: Gulf of Mexico Program–Public Education & Outreach Operations, in coordination with Freshwater Inflow Committee.
Initiation Date: 1995

In Closing...

We intend this document to be a beginning, not an end. Our hope is that this Action Agenda will serve as an inspiration and a call to action for the millions who live and work in the Gulf of Mexico region. Together, our coordinated actions can make a difference and eliminate freshwater inflow concerns in the Gulf of Mexico system.

The Gulf of Mexico Program
Freshwater Inflow Committee

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FEDERAL LEVEL

International Boundary and Water Commission (IBWC).

The International Boundary and Water Commission was established by treaty on March 1, 1889, between the U.S. and Mexico. The Water Treaty of February 3, 1944, expanded the jurisdiction, responsibilities, and powers of the Commission and changed the name to the International Boundary and Water Commission, U.S. and Mexico. Prior to 1889, temporary commissions had performed the first joint projects between the two countries in surveying and demarcating the international boundary in accordance with the treaties of 1848 and 1853.

The Commission is an international body consisting of a U.S. and a Mexican Section, each funded by its government, and headed by an Engineer-Commissioner appointed by the respective President. The U.S. Commissioner reports to the Department of State for policy guidance, and the Mexican Commissioner reports to Mexico's Secretariat of Foreign Relations. The two sections maintain their respective headquarters in the adjoining cities of El Paso, TX, and Ciudad Juarez, Chihuahua, at the mid-point along the boundary. In addition, each section maintains appropriate field offices as necessary to operate, maintain, and monitor joint projects, and effect close coordination.

The mission of IBWC is to apply the provisions of the numerous boundary and water treaties and related agreements between the two countries and basically includes the following six major responsibilities: 1) demarcation of the land boundary; 2) maintenance of the river boundary; 3) control of floods from the international rivers; 4) distribution of the waters of the Rio Grande and Colorado Rivers; 5) operation and maintenance of the international dams, reservoirs, and hydroelectric plants on the Rio Grande; and 6) solution of border water quality problems, including adverse salinity, sanitation, and groundwater impacts. The Commission, through negotiation and approved cooperative projects, facilitates the solution of international boundary and water problems to improve the quality of life for the people on both sides of the border and contributes to better relations between the two countries.

Tennessee Valley Authority (TVA)

Since 1933, the Tennessee Valley Authority (TVA) has been charged with developing and managing the natural resources of the Tennessee Valley. TVA built the dams that created the Valley's reservoirs; with that came the responsibility to operate and maintain the waterways for the maximum benefit of all Valley residents. As stewards of Valley water resources, a major part of TVA's mission is to ensure that enough water of sufficiently high quality is available to meet the needs of the population. The 1933 TVA Act specifically defines TVA's priorities for managing the Valley's waterways. In order of priority, TVA is obligated to: 1) protect against flooding; 2) maintain an 11 foot navigation channel in the mainstream of the Tennessee River; 3) produce inexpensive electricity using hydropower; and 4) operate the reservoirs in a manner that preserves the environment and protects water quality. Maintaining pool levels suitable for recreation and aesthetics, fluctuating the water levels to reduce mosquito population, providing flows to help assimilate municipal wastewaters, providing enough water for industrial users, and adjusting levels to enhance wildlife and waterfowl habitat are a few of the many ways TVA reservoirs are managed for multiple uses. TVA sets limits on how fast water can be released from the reservoirs so that fish and wildlife populations will not be affected.

U.S. Environmental Protection Agency (USEPA)

USEPA has responsibility for several environmental protection laws that have the potential to influence freshwater inflows to the Gulf of Mexico. These statutes and related programs are discussed below.

Federal Water Pollution Control Act of 1972 (FWPCA). The U.S. Congress in 1972 significantly amended the Federal Water Pollution Control Act of 1948 and produced further amendments in 1977, 1981, and 1987. These amendments are also commonly known as the Clean Water Act (CWA). The objective of the Act is to restore and maintain the quality of our water resources to protect the health of humans, fish, shellfish, and wildlife from harmful pollutants. CWA establishes national water quality goals and creates a national permit system with minimum standards for the quality of the discharged waters (effluent). CWA does not set specific standards for water bodies, but does provide guidance to the states. States, however, are required to establish standards based on the designated uses of these waters.

Waters of the U.S. protected by the CWA include rivers, streams, estuaries, the territorial seas, and most ponds, lakes, and wetlands. In determining waters that are within the scope of the CWA, Congress intended to assert federal jurisdiction to the broadest extent permissible under the commerce clause of the Constitution. One factor that establishes a commerce connection is the use or potential use of waters for navigation. Other factors include (but are not limited to) use of a wetland (or other water) as habitat by migratory birds, including waterfowl; use by a federally listed endangered species; or use for recreation by interstate visitors.

CWA Section 404 regulates the discharge of dredged and fill material into waters of the U.S to ensure that such discharges comply with environmental requirements. Activities regulated by Section 404 include discharges of dredged and fill material commonly associated with activities such as port development, channel construction and maintenance, fills to create development sites, transportation improvements, and water resource projects (such as dams, jetties, and levees). Other kinds of activities, such as land clearing, are regulated as Section 404 discharges if they involve discharges of dredged or fill material (*e.g.*, soil) into waters of the U.S. CWA also includes specific exemptions from permitting requirements for certain activities under Section 404(f)(1), such as maintenance of currently serviceable structures (*e.g.*, dikes, dams, levees, ditches); normal farming, silviculture, and ranching practices; and construction or maintenance of farm or forest roads.

USEPA has primary roles in several aspects of the CWA Section 404 program including development of the environmental guidelines by which permit applications must be evaluated, review of proposed permits, prohibition of discharges with unacceptable adverse impacts, approval and oversight of state assumption of the program, establishment of the jurisdictional scope of waters of the U.S., and interpretation of Section 404 exemptions. As a jointly administered program, USACE and USEPA share responsibility for enforcing the Section 404 Program. USEPA can also enforce against non-compliance with permit conditions; however, USEPA generally focuses its resources towards discovering and enforcing against unpermitted (unauthorized) discharges.

National Estuary Program (NEP). In 1987, the National Estuary Program was established by an amendment to the Clean Water Act. The purpose of the Program is to identify nationally significant estuaries, to protect and improve their water quality, and to enhance their living resources. Under the Program, which is administered by USEPA, comprehensive management plans are developed to protect and enhance environmental resources. The governor of a state may nominate an estuary for the Program and request that a Comprehensive Conservation and Management Plan (CCMP) be developed for that estuary. Representatives from federal, state, and interstate agencies, academic and scientific institutions, industry, and citizen groups work during a five year period to define objectives for protecting the estuary, to select the chief problems to be addressed in the Plan, and to ratify a pollution control and resource management strategy to meet each objective. At present, there are twenty-one estuaries in the Program; five of these estuaries are in the Gulf of Mexico (Galveston Bay, Tampa Bay, Sarasota Bay, Corpus Christi Bay, and the Barataria-Terrebonne Estuarine Complex).

Safe Drinking Water Act of 1974, as amended. Under the Safe Drinking Water Act, grants are available to states from USEPA to develop wellhead area protection plans for public groundwater drinking supply recharge areas. The grants can cover from 50 to 90 percent of the costs of establishing and running a protection program. If a wetland is hydrologically located such that any contaminants entering it are reasonably likely to reach a public water supply, the protection program may apply to activities in the wetland. Decreasing freshwater inflow to and consequent increasing salinities of Gulf of Mexico estuaries could have potential impact on wellhead protection in low-lying areas.

National Environmental Policy Act of 1970 (NEPA). NEPA requires that all federal agencies recognize and give appropriate consideration to environmental amenities and values in the course of their decision-making. In an effort to create and maintain conditions under which humans and nature can exist in productive harmony, NEPA requires that federal agencies prepare an environmental impact statement (EIS) prior to undertaking major federal actions that significantly affect the quality of the human environment. Within these statements, alternatives to the proposed action that may better safeguard environmental values are to be carefully assessed.

U.S. Department of Defense

Army Corps of Engineers (USACE)

USACE has responsibility in its water resources projects for flood control, hydropower production, navigation, water supply storage, recreation, and fish and wildlife resources.

Rivers and Harbor Act of 1899. The Rivers and Harbors Act regulates all construction in or modification of traditionally navigable waters. The Act provides that the construction of dams and dikes, the dumping of refuse materials, or "any obstruction or alteration" in navigable waters or their tributaries, not affirmatively authorized by Congress, are expressly prohibited unless an authorized official of the USACE has issued a permit for such activity. The Act gives USACE discretion to deny a permit for the above activities in the interests of navigability or anchorage. USACE has promulgated regulations from time to time to reflect its evolving policies regarding these interests. However, in recent years, Congress has enacted legislation dealing with water-related interests other than navigation, and has required USACE to coordinate with or defer to the judgment of other state and federal agencies vis-a-vis the issuance of permits. These statutes include the Fish and Wildlife Coordination Act (see USFWS), the Federal Water Pollution Control Act, and the Marine Protection, Research, and Sanctuaries Act. USEPA, USFWS, and NMFS are the federal agencies most frequently involved in the coordinating effort.

- **National Flood Control Act of 1928 (as amended).** The National Flood Control Act regulates streamflow of the Mississippi and Atchafalaya Rivers. Since 1977, the USACE has regulated the streamflow in the lower reaches of these rivers so that 70 percent of the total flow for both rivers is in the Mississippi River and 30 percent is in the Atchafalaya River.

- **Water Resources Development Act of 1986.** This act provides for modification in the structure and operation of existing water resources projects for the purpose of improving the quality of the environment in the public interest. USACE districts perform coastal habitat restoration projects under the authority of Section 1135 of this act, in cooperation with other federal agencies under the Coastal America Program, National Estuary Program, and Cooperative Agreement with NMFS for Coastal Habitat Restoration.

- **Coastal Wetlands Planning, Protection & Restoration Act (CWPPRA).** CWPPRA establishes a mechanism to plan and fund implementation of wetland protection and restoration projects in coastal Louisiana. Freshwater inflow and sediment enrichment are important aspects of these plans. Planning and implementation activities are managed by a six-person/federal-state task force. In addition, CWPPRA calls for development of a Conservation Plan for the State of Louisiana, and provides funds for matching grants to assist other coastal states in implementing wetland conservation projects (*i.e.*, projects to acquire, restore, manage, and enhance real property interest in coastal lands and waters). Five years of recurring funding is established up to $50 million/year, 70 percent for Louisiana with 75 percent-25 percent federal/state cost sharing. Extension of authority and funding is possible, but is contingent on progress.

- **Clean Water Act Section 404** (see also: USEPA). USACE is authorized, after notice and opportunity for a public hearing, to issue permits for the discharge of dredged or fill material. USACE also has primary responsibility for monitoring and enforcement of compliance with Section 404 permit conditions. States can assume a portion of the permitting program from the federal government (for some waters only), but there has been limited interest by the states. USEPA works with USACE during the permit decision process, whenever possible, to ensure unacceptable adverse impacts are avoided, and most concerns are resolved through this interagency consultation. USACE and USEPA have developed a process through a Memorandum of Agreement (MOA) to quickly resolve any differences over permit decisions. FWS and NMFS have similar agreements with USACE.

U.S. Department of Agriculture (USDA)

Soil Conservation Service (SCS)

SCS is the U.S. Department of Agriculture's primary technical agency in the areas of soil and water conservation and water quality. SCS focuses its assistance on non-federal land. It works primarily with private landowners in planning and applying measures to reduce soil erosion, conserve water, protect and improve water quality, and protect other renewable natural resources such as plants, animals, and air. The guiding principle is the use and conservation treatment of the land and water in harmony with its capabilities and needs.

SCS has an office in almost every county in the U.S., where it works closely with local subdivisions of state government called Soil and Water Conservation Districts. The conservation districts are governed by local people and typically have legislative mandates to plan and implement comprehensive soil and water programs within their boundaries. These boundaries usually coincide with county lines.

SCS's basic authorities were created by P.L. (74) - 46, P.L. (83) - 566, and P.L. (78) - 534. Program authorities were added under various Farm Bills including those enacted in 1961 (Resource Conservation & Development), 1988 (Swampbuster, Sodbuster, Conservation Compliance, and Conservation Reserve Program) and 1990 (Wetlands Reserve Program and others). Under the Swampbuster provisions, SCS assists landowners to identify and protect wetlands. Loss of U.S. Department of Agriculture benefits and severe economic consequences can result for agricultural producers who convert wetlands to make possible the production of agricultural commodities.

SCS also conducts soil surveys and operates a system of twenty-seven Plant Materials Centers for selecting, developing, testing, and releasing plants for use in conservation programs. SCS also works with private landowners and others to preserve, protect, and restore wetlands and to develop wildlife and fisheries habitat.

U.S. Department of Commerce (USDOC)

National Oceanic & Atmospheric Administration (NOAA)

NOAA is a lead federal agency in the development and dissemination of scientific information and products for the nation's estuarine and coastal ocean waters. NOAA provides a wide range of observational, assessment, research, and predictive services for estuarine and coastal ocean regions. In the Gulf of Mexico, NOAA maintains coastal and marine research facilities, National Estuarine Research Reserves, and National Marine Sanctuaries, oversees approved Coastal Zone Management Plans in three coastal states, and has direct ties to universities and colleges through the National Sea Grant College Program. NOAA has developed an array of programs to address not only national-scale estuarine issues, but also specific problems affecting individual estuarine and coastal ocean systems.

- **National Estuarine Inventory (NEI).** NEI is a series of activities, within the Office of Ocean Resources Conservation and Assessment (ORCA), that define and characterize the nation's estuarine resource base and develop a national estuarine assessment capability. NOAA began NEI in 1983 because no comprehensive inventory of the nation's estuaries or their resources existed, despite increased conflicting demands for the goods and services they provide: habitat for fish and wildlife; food; areas for recreation; water disposal; energy; and transportation. Four major NEI atlases, six national data bases, and numerous technical reports containing thematic information about the nation's estuaries have been produced. NOAA continues to evaluate the scale and scope of information in NEI and make the necessary additions and refinements to improve its capability to assess the nation's estuaries.

- **Coastal Zone Reauthorization Act of 1990.** The purpose of this act is to effectively manage the nation's rich coastal zone, recognizing it as a resource of many values: *i.e.*, natural, commercial, recreational, industrial, and aesthetic. Management power and authority is placed at the state level, with the federal government establishing standards and playing a coordinating role. All federal activities, including permitting, licensing, and financial assistance, must be consistent with approved state coastal zone management plans. The Act specifically recognizes that fish shellfish, and other living marine resources are ecologically fragile and therefore vulnerable to the activities of humans.

National Marine Fisheries Service (NMFS)

The specific mission of NMFS is stewardship of the nation's living marine resources, including fishery species and protected species (*e.g.*, marine mammals and sea turtles). The primary activities of NMFS are the routine assessment of the status of stocks and the management of stocks through regulation of fisheries. Preservation of habitat is recognized by NMFS as essential to the long-term sustainability of marine resources and protected species. Although NMFS has no direct regulatory control over habitat, NMFS has a Habitat Conservation Program and actively works to conserve the habitat necessary to living marine resources and protected species by reviewing and commenting on licensing, permitting, legislative, and administrative activities potentially affecting such habitat. The authority for this involvement by NMFS in habitat conservation is provided by the Magnuson Fishery Management Act, U.S. Fish and Wildlife Coordination Act (see USFWS), NEPA (see USEPA), and CWA (see USEPA). The Habitat Conservation Program in NMFS is supported by habitat research, which develops information on the ecological relationship between living marine resources and their habitat.

The Southeast Regional Office (SERO), headquartered in St. Petersburg, Florida, handles NMFS responsibilities in the Gulf of Mexico and has a Habitat Conservation staff. In addition to performing stock assessments, the Southeast Fisheries Science Center (SEFSC), with laboratories in several Gulf Coast States, conducts research to support the NMFS Habitat Conservation Program in the Southeast. Estuarine-related habitat research in the Gulf of Mexico currently is conducted primarily at the Galveston, Texas, and Beaufort, North Carolina, laboratories. A new SEFSC laboratory, to be devoted to habitat research, will soon be opening in Lafayette, Louisiana. SERO has influenced several projects involving freshwater inflow. The SEFSC has conducted some research concerning the effect of freshwater inflow changes.

- **Magnuson Fishery Conservation and Management Act of 1976 (as amended).** The major purposes of this Act are: 1) to take immediate action to conserve and manage the fishery resources found off the coasts of the U.S. and the anadromous species and Continental Shelf fishery resources of the U.S.; 2) to establish Regional Fishery Management Councils; and 3) to prepare, monitor, and revise fishery management plans (FMPs) which will achieve and maintain, on a continuing basis, the optimum yield from each fishery. Each FMP includes readily available information regarding the significance of habitat to the fishery and an assessment of the effects of habitat changes on the fishery. Each Council may comment on, or make recommendations concerning, any activity undertaken, or proposed to be undertaken, by any state or federal agency, including dams and river diversion, that, in the view of the Council, may affect the habitat of a fishery resource under its jurisdiction. By special agreement between NMFS and the Gulf of Mexico Fishery Management Council, NMFS reports to regulatory agencies may also represent or convey the views and recommendations of the Council.

National Weather Service (NWS)

NWS has three programs directed toward coastal and estuarine waters. The Hurricane Guidance Program, the Tsunami Warning Program, and the Marine Weather Warning Forecast Program provide timely forecasts and warnings for coastal and estuarine waters. Other activities related to coastal and estuarine waters are the marine forecasts and advisories routinely issued by NWS forecast offices. In addition, the National Meteorological Center carries out operational storm surge modeling to announce warnings during the passage of hurricanes. These models have also been used to determine hurricane vulnerability in estuarine areas.

National Environmental Satellite, Data, and Information Service (NESDIS)

NESDIS conducts several coastal and estuarine related activities. The Assessment and Information Services Center (AISC) conducts studies on satellite remote-sensing application and use of numerical model data for circulation and bathymetry application and for simulation of sediment transport. The National Environmental Data Referral Service (NEDRES) is a computerized, online data base inventory that facilitates environmental data identification for ocean and coastal regions.

National Flood Insurance Program (NFIP)

For property owners to be eligible for federally subsidized flood insurance, their communities must adopt floodplain management regulations that will minimize future flood damage. Adoption is typically accomplished by incorporating the regulations into the local zoning ordinances and building codes. The Program's restrictions on floodplain development may, in effect, protect wetlands adjacent to the flood-prone waterway. Communities joining NFIP are rewarded with the incentive of substantial flood insurance coverage, whereas communities that do not participate are indirectly penalized by decreased funding for acquisition and construction purposes.

U.S. Department of the Interior (USDOI)

USDOI has responsibility for most nationally-owned public lands and natural and cultural resources. This includes fostering the wise use of land and water resources, protecting fish and wildlife, preserving the environmental and cultural values of national parks and historical places, and providing for the enjoyment of life through outdoor recreation. USDOI assesses energy and mineral resources and works to assure that their development is in the best interests of the citizens of the U.S. USDOI also promotes the goals of the Take Pride in America campaign by encouraging stewardship and citizen responsibility for public lands and promoting citizen participation in their care.

Bureau of Reclamation

The mission of the Bureau of Reclamation is to assist states, local governments, and other federal agencies in stabilizing and stimulating local and regional economies, enhancing and protecting the environment, and improving the quality of life through management, conservation, and development of water and related land resources. The Bureau has 17 resource programs nationwide. Reclamation projects provide for some or all of the following concurrent purposes: irrigation water service, municipal and industrial water supply, hydroelectric power generation, water quality improvement, groundwater management, fish and wildlife enhancement, outdoor recreation, flood control, navigation, river regulation and control, and system project beneficiaries. The Bureau also arranges for repayment to the government of reimbursable costs incurred in the construction and operation of water resource projects.

U.S. Fish & Wildlife Service (USFWS)

USFWS works under several authorities to protect fish and wildlife species and to protect, restore, and enhance their habitats. Amendments to the Federal Power Act in 1935, and in 1986 (see FERC), added requirements to incorporate fish and wildlife concerns in licensing, relicensing, and exemption procedures for hydropower facilities. Sections of the Water Resources Development Act (see USACE) provide for modification in the structure and operation of existing water resources projects for the purpose of improving the quality of the environment in the public interest.

- **Fish and Wildlife Coordination Act of 1958 (as amended).** The purpose of the Act is to ensure that fish and wildlife concerns are considered equally with navigation, landfill, hydroelectric power generation, flood control, and other water resource interests whenever a federal agency plans, licenses, or permits a watercourse modification for any purpose. The Act, as amended, and as modified by Reorganization Plan No. 4 of 1970, which transferred certain Department of Interior functions to the Department of Commerce, mandates that the public agency performing or permitting any water diversion, impoundment, dredging, filling, or other watercourse control or alteration shall consult with the federal and state fish and wildlife agencies to determine the impacts of the project on fish and wildlife. That agency may incorporate suggestions for protecting, conserving, and enhancing wildlife resources into the project plan.

- **Endangered Species Act of 1972 (as amended).** The major purposes of this Act are to provide a means whereby the ecosystems upon which endangered and threatened species depend may be conserved and to provide a program for the conservation of such endangered and threatened species. The Act also provides for the designation of critical habitats for those species, as needed. Such designated habitats should not be available for installation of dams, reservoirs, and water diversion structures if the structures would eliminate, degrade, or make less accessible any of the physical or biological features found essential to the conservation of the species.

National Park Service (NPS)

NPS administers an extensive system of public lands, including lakeshores and seashores, set aside for the protection of natural environments, the preservation of historic properties, and the education and enjoyment of all citizens. NPS is responsible for four separate areas in southern Florida that total in excess of two million acres--Biscayne, Everglades, and Dry Tortugas National Parks and Big Cypress National Preserve. Both the South Florida Water Management District and the USACE have responsibility for the management of the water supply.

An important part of the Gulf of Mexico watershed is the Everglades National Park, which is considered the most threatened national park in the National Park System. The river component is now designated the third most threatened river in the U.S. The park includes 607,050 hectares (1.5 million acres) of water and land, positioned at the southern tip of the Florida peninsula, at the bottom of the most extensive and complex water management system in the world. The Everglades ecosystem is generally described as the Kissimmee/Okeechobee/Everglades basin covering the southern half of the State of Florida. Since the early 1900s, water levels are estimated to have been lowered as a result of drainage throughout the Everglades by as much as four to six feet. Since the 1950s, these changes have accelerated with urban development and agribusiness expansion. As a result of these hydrological changes, aquatic food chains in many parts of the Everglades have collapsed resulting in serious declines in the number of wading birds, imperiling many threatened and endangered species, and contributing to the decline of the Florida Bay, the Florida Keys National Marine Sanctuary, and coastal estuaries.

- **National Park Service Organic Act of 1916.** The purpose of this Act, which created NPS, is to "conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations..."

- **Wild and Scenic Rivers Act of 1968.** The goal of the Wild and Scenic Rivers Act is to protect outstanding natural free-flowing rivers from damming and other forms of development. NPS is responsible for managing all designated river segments, except those managed by states, the Forest Service, or the Bureau of Land Management. The Act also encourages river protection by authorizing the Secretary of the Interior to provide technical assistance to state and local governments and to private interests in support of the law's objectives. Many state programs have benefited from this assistance.

Minerals Management Service (MMS)

MMS studies the potential impact of offshore activities, including the placement and construction of petroleum pipelines, on coastal wetlands and resources. MMS also funds research through state geoscience agencies for identifying mineral resources in the coastal zone.

U.S. Geological Survey (USGS)

The mission of the USGS, Water Resources Division, is to provide the hydrologic information and understanding needed for the optimum utilization and management of the nation's water resources for the overall benefit of the people of the U.S. USGS conducts research on the geologic framework of coasts and on sediment-transport processes; collects and analyzes hydrologic data; makes topographic, geologic, and hydrologic maps of coastal areas; and investigates ancient and modern coastal environments. Scientific studies of sedimentary processes and seismicity traditionally have been part of the USGS mandate, and recently, Congress directed USGS to take the lead in geologic studies of the coastal zone and wetlands by creating a National Coastal Geology Program. Areas of study include erosion, polluted sediments, and wetlands deterioration.

- **The Water Resource Research Act of 1984.** This Act established a Water Resource Institutes or Center in each of the 50 states. These are mandated by federal law to: 1) provide centers of expertise in water and associated land-use problems and serve as a repository of knowledge for use in education, research, planning, and community service, 2) serve public and private interests in the conservation, development, and use of water resources, 3) provide training opportunities in higher education, whereby skilled professionals become available to serve government and the private sector, 4) assist planning and regulatory bodies at the local, state, regional, and federal levels, and 5) communicate research findings to potential users in a form that encourages quick comprehension and direct application to a water-related problem.

  Many of the centers and institutes also have mandates in state law to assist state agencies in state water management and to facilitate and stimulate planning and management that deals with water policy issues. These are funded by grants from USGS, but guided by a set of state level priorities. The following institutes are located in the Gulf States: Alabama Water Resources Research Institute, Florida Wetlands and Water Resources Research Center, Louisiana Water Resources Research Institute, Mississippi Water Resources Research Institute, and the Texas Water Resources Institute.

Federal Energy Regulatory Commission (FERC)

- **Federal Power Act of 1986 (as amended).** This Act provides for FERC to license hydropower facilities. The amendments require FERC to incorporate fish and wildlife concerns in licenses and exemptions for hydropower facilities.

STATE LEVEL

Alabama

Coastal Zone Management. The Alabama Coastal Zone Management (CZM) Program was established in 1979 as a result of the need to implement the Coastal Zone Management Act, P.L. 92-583, passed by Congress in 1972. This legislation was initiated to improve the management of the nation's coastal area. The Alabama Coastal Program has been revised throughout its existence since 1979 to accommodate changes in coastal zone management policy.

A major function of the CZM program is resource protection. This encompasses a multitude of coastal resource issues such as recreation, shoreline erosion, commercial and recreational fishing, water quality, air quality, wetland protection, wildlife protection, industrial and urban development, hazard management, etc.

The responsibilities of the Alabama Coastal Zone Management Program are divided between two state agencies: the Alabama Department of Economic & Community Affairs (ADECA) and the Alabama Department of Environmental Management (ADEM).

Alabama Department of Economic & Community Affairs (ADECA). ADECA's role is to act as the lead agency responsible for overall management of the program including administration and planning, fiscal management, grants management, and public education and information.

The Alabama Department of Environmental Management (ADEM). ADEM has the authority to develop and enforce regulations affecting streamflow to the Gulf of Mexico. Water quality certification is the basic regulatory tool of ADEM and is required for certain projects in the Alabama coastal zone including dredging and filling work, bulkhead construction, jetty construction, shoreline maintenance, and other development projects. ADEM coordinates with the USACE on approval of Section 404 permits which are required for dredging activities and filling in wetlands. ADEM also makes determinations for consistency with the Alabama Coastal Zone Management Program.

In addition, the agency tracks water quality trends and presently has twenty-seven water quality monitoring stations located in Mobile and Baldwin counties, primarily on tributaries to Mobile Bay.

Current & Future Alabama Coastal Zone Management Planning Activities.
Public Education. ADECA, acting as the lead agency and in conjunction with ADEM, USACE, and several other agencies comprised the Alabama Steering Committee for "Year of the Gulf" Activities. A new event was created called "Mobile Bay Day, What a Difference a Bay Makes!" The event was held in April of 1993 and attracted

many participants and interested individuals and received much attention by the media.

These public education activities also served as the catalyst for the creation of the Alabama Coastal Foundation (ACF). This organization is dedicated to the conservation of the natural and economic resources of the Alabama coastal area. ACF serves as a proponent for many coastal activities including the Alabama Coastal Clean-up, Boater's Pledge, and Amnesty Day. The foundation also has future plans to publish a Coastal Newsletter.

During the past few years both Baldwin and Mobile Counties have experienced severe erosion in a few isolated areas such as Little Lagoon Pass and Dauphin Island's main beach. The CZM Program is presently formulating a comprehensive Shoreline Management Plan which will include: 1) a technical evaluation of past and projected erosion; 2) an economic evaluation of the value of Alabama's Gulf beaches, and 3) an identification of goals and objectives for shoreline management, management procedures, and funding sources.

Florida

Water Quantity & Quality. In Florida, several state, regional, and local regulatory and planning programs have effects on the quantity, quality, and timing of freshwater inflow to estuaries. The Department of Environmental Protection (DEP), recently formed by the consolidation of two agencies, regulates sources of potential water pollution under the general requirements of FLA. STAT. § 403.087. The wetlands permitting program is jointly administered by DEP and the state's five water management districts. It applies to dredge and fill activities occurring in surface waters to their landward extent, as defined by hydric soils and vegetation [FLA. STAT. § 373.414 (1993)]. The state program requires the project applicant to provide reasonable assurance that water quality standards will be met and that the project is not contrary to the public interest or, if it is in or significantly degrades an Outstanding Florida Water, that it is clearly in the public interest (Ibid).

The permitting agency is required to "consider and balance" a number of criteria in making the public interest determination, including, among others: adverse effects on the conservation of fish and wildlife, including endangered or threatened species, or their habitats; adverse effects on navigation or the flow of water or harmful erosion or shoaling; and adverse effects on fishing or recreational values or marine productivity in the vicinity [FLA. STAT. §373.414 (1993)]. Cumulative impacts must be considered, and if a proposed project is otherwise unable to meet the public interest test, DEP is required to consider mitigative measures that are "proposed by or acceptable to" the applicant (Ibid). The legislation also requires that estuaries be protected from inappropriate shoreline armoring. Activities such as drainage, harvesting, changing or obstructing water flow, and polluting are not specifically subject to wetland regulation.

The wetlands permitting program will be altered under recently adopted state legislation. By July 1, 1994, the new DEP is required to adopt rules for the consolidation of dredge and fill, management and storage of surface waters, storm water, and mangrove alteration regulations into a single permit to be known as the "environmental resource permit." Additionally, after legislative ratification in 1994, a statewide wetland delineation methodology, including regional variations, will supersede all existing approaches at the state, regional, and local level [FLA. STAT. § 373.421 (1993)]. By December 1, 1994, DEP must adopt rules for the delegation of the permitting program to local governments and pollution control authorities [FLA. STAT. § 373.441 (1993)].

Florida's five regional water management districts are responsible for the regulation of agricultural water management under the management and storage of surface water (MSSW) section of Chapter 373, Florida Statutes [FLA. STAT. § 373.403 *et. seq.*] Generally, district rules require that MSSW systems not adversely affect surface and groundwater levels; however, many agricultural activities and impacts are exempt from water management district regulation unless the activity is for the sole or predominant purpose of impounding or obstructing surface waters. The section also exempts an agricultural "closed system," located entirely within agricultural lands owned or controlled by the user and which require only filling, replenishing, and maintaining the water level [FLA. STAT. § 373.403(6)]. The districts are authorized to regulate activities in isolated wetlands, but only if the wetland is larger than 0.2 hectares (0.5 acres).

The permitting of consumptive use of surface and ground water is carried out by the water management districts and includes conditions on permits to ensure the use is "consistent with the overall objectives of the district" and "not harmful to the water resources of the area." FLA. STAT. § 373.219(1) (1991). The applicant must establish that the proposed use is "reasonable-beneficial," will not interfere with any presently existing legal use of water, and is consistent with the public interest. ["Reasonable-beneficial" means the use of water in such quantity as is necessary for economic and efficient utilization for a purpose and in a manner which is both reasonable ad consistent with the public interest. FLA. STAT. § 373.019(4) (1991).] The general permit criteria requiring reasonable-beneficial use and consistency with the public interest incorporate consideration of ecosystem needs.

The districts are also authorized to reserve water from use by permit applicants for the protection of fish and wildlife [FLA. STAT. § 373.223(3) (1991)]. The districts are required to establish minimum flows for watercourses and minimum levels for surface waters and aquifers [FLA. STAT. § 373.042 (1991)]. Minimum flows are limits at which further withdrawals would be "significantly harmful to the water resources or ecology of the area." Minimum levels are limits at which further withdrawals would be "significantly harmful to the water resources of the area" (Ibid). Generally, these requirements have not been met. In addition, district water shortage rules control when water shortages will be declared and what restrictions may be imposed on water use [FLA. STAT. § 373.175 (1991)].

Some of the most important planning responsibilities of the water management districts are those required by the district water management planning (DWMP) process [FLA. ADMIN. CODE r. 17-40.501 (1991)], and the Surface Water Improvement and Management (SWIM) Act [FLA. STAT. §§ 373.451-373.4595 (1991)]. Draft DWMPs were recently completed, with final DWMPs due in late 1994. Areas of planning responsibility are water supply, including analyses of needs and sources and source protection; flood protection, including analyses of facilities and flood prone areas; water quality management for both surface and ground water; and natural systems management, including analyses of ecosystem needs and minimum flows and levels.

The state's SWIM Act requires the districts to establish a list of prioritized surface waters and to develop plans for the restoration and maintenance of water quality in those waters. Many of Florida's estuaries bordering the Gulf of Mexico have been included in the planning process. Though consideration of the quantity and timing of freshwater inflow is not specifically required by the Act, most districts recognize the importance of the issue and have addressed it to varying degrees in the relevant SWIM plans.

The districts are also required to provide technical assistance to local governments on planning issues for water resources. Under the state's Growth Management Act [FLA. STAT. §§ 163.3161-163.3215 (1991)], local governments must prepare comprehensive plans addressing many aspects of growth, development, and resource protection. Local regulations must be consistent with the relevant plan elements. The coastal management element requires analysis of existing and proposed development of coastal resources and an analysis of the impact of drainage systems and point and nonpoint source pollution on estuarine water quality.

Coastal Zone Management. The Florida Coastal Management Program (FCMP) was approved by NOAA in 1981. The program revolves around the authorities of twelve agencies and is guided by the Coastal Resources Interagency Management Committee (IMC) composed of the Secretaries of these agencies. The agencies include the following:

- Department of Community Affairs
- Department of Environmental Regulation
- Department of Natural Resources
- Department of Commerce
- Department of Labor & Employment Security
- Department of Transportation
- Department of Health & Rehabilitative Services (Division of Environmental Health)
- Department of Agriculture & Consumer Services (Division of Forestry)

- Marine Fisheries Commission
- Game & Fresh Water Fish Commission
- Department of State (Division of Historical Resources)
- Governor's Office of Planning & Budgeting

The Chair of the Citizens Advisory Committee on Coastal Resources (CAC) also sits on the IMC. The members of CAC are appointed by the Governor to represent various interests in the coastal area, including local government, commercial fishing, recreational fishing, citizens at large, coastal development, conservation, energy, and environmental education.

IMC, with the assistance of CAC, identifies pressing coastal issues, conducts studies of the issues, and proposes policy changes to address them. They advise the Legislature, Governor, and Cabinet of their recommendations for action.

Since 1992, the lead agency for the FCMP has been the Department of Community Affairs. The lead agency coordinates a network of state agencies, regional groups, such as the water management districts and regional planning councils, and local governments to implement the program. One of the key functions of the lead agency is to help identify the appropriate parties for implementation of the goals of IMC.

Under an annual work plan, the program distributes funding to the participating groups for projects that implement the IMC's coastal action plan. The program also reviews federal projects and permits for consistency with the enforceable policies of the participating state agencies.

Louisiana

Coastal Zone Management. The State & Local Coastal Resources Management Act (SLCRMA) La. R.S. 49:21, was passed by the Louisiana Legislature in 1978 and received federal approval in October 1980. Presently the program is being administered by the Coastal Management Division (CMD) within the Office of Coastal Restoration and Management, Department of Natural Resources (DNR).

The Coastal Management Division of the Department of Natural Resources is charged with implementing the Louisiana Coastal Resources Program (LCRP). LCRP attempts to protect, develop, and restore or enhance the resources of the state's coastal zone. Its broad intent is to encourage multiple uses of resources and adequate economic growth while minimizing adverse effects of one resource upon another without imposing undue restrictions on any user.

CMD's regulatory responsibilities include administering the Coastal Use Permit (CUP) Program, the Consistency Program, and the Enforcement Program. The Coastal Use Permit is the basic regulatory tool of CMD and is required for certain projects in the coastal zone, including, but not limited to, dredge and fill work, bulkhead construction, shoreline maintenance, and other development projects. CMD has processed about 15,500 CUP applications since the inception of the program.

The Consistency Program requires activities of all federal and some state governmental agencies to be consistent with LCRP. Particular attention is given to environmental, economic, and cultural concerns. Most federal agencies conduct their own consistency determination and, if projects are found to be inconsistent with state regulations, they are not pursued. Examples of projects requiring a consistency determination are hurricane protection levees; USACE maintenance, dredging, locks, and drainage structures; navigation projects; freshwater diversions; and beach restoration projects.

The Enforcement & Monitoring Program ensures that any unauthorized projects in the coastal zone are investigated and action is taken. The program also monitors activities permitted by the CUP Program for compliance with permit conditions. The program gives the secretary of DNR the authority to enforce either legal or administrative procedures including fines, cease and desist orders, and restorative or mitigation work. The field investigative staff regularly monitors the entire coastal area for unauthorized activities and for non-compliance with permit conditions.

During the Second Special Session of 1989, the Louisiana Legislature passed Act 6, which requires the State of Louisiana to annually develop a Coastal Wetlands Conservation and Restoration Plan from both a short and long range perspective. The initiative for passing Act 6 was provided when it passed a voter referendum by approximately 75 percent.

The Coastal Restoration Division has the responsibility for implementing the Plan, which is designed to restore, preserve, and enhance Louisiana's coastal wetlands. The plan is the result of over 25 years of research and involves many innovative techniques designed to work with nature. The plan is an evolving one and includes a large number of individual projects which are designed to meet specific needs. Current restoration techniques include freshwater diversion, sediment diversion, marsh management, sediment capturing, shallow bay terracing, and structural shoreline erosion abatement devices.

Mississippi

Water Quantity and Quality. The Mississippi Department of Environmental Quality (MDEQ) has the authority to regulate the use of surface and ground waters in Mississippi. The statutes providing MDEQ with this authority are codified in Title 51, Chapter 3, of the Mississippi Code of 1972. MDEQ is also charged with regulating the quality of marine and fresh waters in Mississippi. This authority is located in Title 49, Chapter 17, of the Mississippi Code of 1972.

Projects Affecting Freshwater Inflows. The Mississippi Commission of Wildlife, Fisheries, and Parks is authorized in Title 49, Chapter 15, Section 15(6), of the Mississippi Code of 1972 to "support projects in the nature of digging or constructing canals or ditches in order to bring additional water to existing oyster reefs" or to establish new oyster reefs. The Commission is authorized to spend monies and enter into interstate agreements as it deems appropriate and necessary for freshwater diversion projects. Up to three million dollars was authorized for expenditure on the Mississippi and Louisiana Estuarine Areas Project in 1989 by the Mississippi Legislature for the purposes of constructing a freshwater diversion canal with Louisiana and the USACE (Title 57, Chapter 61, Section 32, in the Mississippi Code of 1972).

Coastal Zone Management. The Mississippi Coastal Program was approved by the Commission on Wildlife Conservation on August 22, 1980, and has been updated throughout its implementation. This program is built around ten goals for guiding decisions affecting the development of Mississippi's coastal resources. These goals include, but are not limited to the following:

- Providing for reasonable industrial expansion in the coastal area and insuring the efficient utilization of waterfront industrial sites so that suitable sites are conserved for water dependent industry.

- Favoring the preservation of the coastal wetlands and ecosystems, except where a specific alteration of a specific coastal wetlands would serve a higher public interest in compliance with the public purposes of the public trust in which the coastal wetlands are held.

- Encouraging the preservation of natural scenic qualities in the coastal area.

- Considering the national interest involved in planning for and in the siting of facilities in the coastal area.

The agencies responsible for the Coastal Program are the Bureau of Marine Resources, the Bureau of Pollution Control, the Bureau of Land and Water Resources, and the Department of Archives and History. These four agencies are responsible for monitoring state and federal decisions that affect the coastal area and for ensuring that such decisions are made in accordance with program councils.

The Bureau of Marine Resources (BMR) is the lead agency responsible for the overall administration of the coastal program. This agency regulates projects and activities under the Wetlands Protection Law and saltwater fisheries statutes. There are three types of activities regulated under BMR's jurisdiction. These are activities physically located in coastal wetlands (*i.e.*, piers, bulkheads), those not located in the coastal wetlands but affecting them by indirect means (*i.e.*, construction), and the erection of structures on sites suitable for water dependent industry.

Development is directly regulated to minimize adverse impacts. This is done by addressing special management areas (SMA). SMAs detail all regulations affecting an area and specifically state what will and will not happen in an area, thus ensuring that development will occur in a predictable manner.

Texas

Texas Natural Resource Conservation Commission (TNRCC). The Texas Natural Resource Conservation Commission (TNRCC) has the responsibility of protecting surface and groundwater quality. In addition to this responsibility, the Commission oversees surface water rights administration, dam safety management, the National Flood Insurance Program and flood control improvement project administration, injection well program administration, waste minimization initiatives, and water district supervision. (Effective September 1, 1993, the Texas Water Commission was combined with the Texas Air Control Board to form the Texas Natural Resource Conservation Commission.)

TNRCC has the authority to develop/enforce regulations affecting streamflow to the Gulf. These regulations are contained in Chapters 11.147 and 11.152 of the Texas Water Code. The 69th Texas Legislature assigned the responsibility for water rights permitting to TNRCC and gave the Texas Parks and Wildlife Department (TPWD) authority to be a party in hearings on applications for permits to store, take, or divert water--actions that can change the pattern or quantity of freshwater inflow. The Legislature directed TNRCC to consider effects on bays and estuaries for all water rights permits, with a specific directive to include protective provisions in certain permits by applying a performance standard when making decisions concerning water rights on rivers and streams leading to bays and estuaries.

Texas Water Development Board (TWDB). The Texas Water Development Board (TWDB) is the state agency responsible for planning, financing, and developing water and wastewater projects. TWDB was created in 1957 by acts of the 55th Texas Legislature, and its duties and responsibilities have been increased by subsequent legislative sessions and constitutional amendments. Statutory authority, specifically for the freshwater inflow needs assessment of Texas bays and estuaries, was expanded by acts of the 69th Legislature in 1985. TWDB's authority under state statutes is found in Chapters 6 and 15-20 of the Texas Water Code.

TWDB's mission is to provide state leadership in the conservation and responsible development of water resources for current and future generations of Texans, their economic well-being, and their quality of life. One of TWDB's primary goals is to plan and provide financial assistance for water supplies of sufficient high quality for human use and for maintenance and enhancement of the natural environment. The reservation and optimization of freshwater inflows, as well as the beneficial use of wastewater return flows, are important features of watershed protection and the ecological enhancement of wetlands associated with bays and estuaries which will further TWDB's ability to meet its goals for Texas. The 69th Legislature also directed TWDB and TPWD to establish and maintain a continuous data collection and evaluation program and conduct studies and analyses aimed at determining bay conditions that provide a sound ecological environment.

Funding for TWDB activities comes primarily from state general revenues, federal programs, and capitalization grants which finance the State Revolving Fund for construction of wastewater treatment plants. TWDB's financing of public water projects and the freshwater inflow studies also involve the Texas Water Assistance Fund, the Texas Water Development Bond Program, and the Texas Water Resources Finance Authority.

Texas Parks & Wildlife Department (TPWD). The Texas Parks & Wildlife Department (TPWD) operates the state parks system and wildlife refuges. A permit must be obtained from TPWD for the disturbance or dredging of sand, shell, or marl in public waters not authorized by other state or federal agencies. Public waters are defined as all the salt and fresh waters underlying the beds of navigable streams under the jurisdiction of the Parks & Wildlife Commission. TPWD is responsible for reviewing and commenting on state and federal permits affecting Texas wildlife resources and protecting endangered or threatened species.

Texas General Land Office (GLO). The Texas General Land Office (GLO), in conjunction with the School Land Board, manages the state's coastal public lands. GLO has developed a coastal management plan for Texas beaches and the state-owned submerged land underlying the Gulf of Mexico. On June 7, 1991, the Texas State Legislature passed two bills creating a State-Owned Wetlands Conservation Plan and a Coastal Management Plan addressing coastal erosion, beach access, dune protection, and planning and coordination of these activities. Texas recently submitted a coastal management plan for approval under the federal Coastal Zone Reauthorization Act.

The Commissioner of GLO may issue permits for geological, geophysical, and other investigations within the tidewater limits of the state. The Commissioner may also grant easements or leases for rights-of-way across state lands for pipelines and other transmission lines.

School Land Board. The School Land Board, in conjunction with GLO, manages the state's coastal public lands. The Board may grant leases to certain governmental bodies for public purposes; leases for mineral exploration and development; easements to littoral landowners; channel easements to surface or mineral interest holders; leases to educational, scientific, or conservation interests; and permits for limited use of previously unauthorized structures.

Soil & Water Conservation Board. The Texas State Soil & Water Conservation Board has the responsibility to plan, implement, and manage programs and practices for abating agricultural and silvicultural nonpoint pollution. The State Board also administers a voluntary conservation program with and through 212 local soil and water conservation districts which encompass over 99 percent of the surface acres of Texas. With a voluntary program, conservation practices are being applied by over 215,000 cooperating landowners on more than 48.6 million hectares (120 million acres).

Bay & Estuary Inflow Studies. In the 69th Legislative Session, and amended in the 70th Session, the Texas Legislature directed TWDB and TPWD to jointly establish and maintain a continuous bay and estuary data collection and evaluation program and to conduct studies and analyses for determining the bay conditions necessary to support a sound ecological environment [Texas Water Code 16.058(1)]. The final report will document the results of these studies on the effects of freshwater inflows on the biological productivity of bays and estuaries, the distribution and abundance of economically important and ecologically characteristic fish and shellfish species, and the estuarine life upon which they depend.

In addition to documenting the importance of freshwater inflows, this report will present an analytical method for determining freshwater inflow needs for Texas estuaries [Texas Estuarine Mathematical Programming (TXEMP) Model]. The procedure was designed to assist TNRCC in quantifying beneficial inflows that are necessary for maintaining an ecologically sound environment.

REGIONAL LEVEL

Water Districts. Within the State of Texas, the Constitution provides for the creation of water districts to address both local and regional issues associated with the use, preservation, and protection of the state's water resources. The various types of districts are created by either special law or general law and must comply with the laws contained in the Texas Water Code and other applicable statutes. For example, river authorities are special law districts that often encompass entire river basins and reach into many counties. Most river authorities operate major reservoirs and sell untreated water on a wholesale basis. They also may have responsibility for flood control, hydropower, soil conservation, and water quality. Many of the responsibilities delegated to river authorities and other types of water districts may influence the amount and timing of freshwater inflows to coastal waters.

River Authorities. There are 17 river authorities in Texas and their general functions are to regulate streamflow in rivers and enforce regulations that have effects on streamflow to the Gulf. The regulations generally involve River Management Plans, Reservoir Operation Plans, and sewage treatment facilities. The authorities for these regulations are included in Certificates of Adjudication, Water Appropriations Permits, Orders, and Resolutions of the Texas Natural Resource Conservation Commission.

Interstate Compacts. The State of Texas is party to five interstate compacts involving the Rio Grande, Pecos, Red, Sabine, and Canadian Rivers. The compacts are interstate agreements which equitably apportion the waters of each stream between the compacting states. The compacts are administered by interstate commissions which oversee the deliveries and use of water by the compacting states. As an example, the Sabine River Compact Administration is composed of Texas and Louisiana and administers water deliveries and diversions pursuant to the terms of the Sabine River Compact.

ACAMP	Alabama Coastal Area Management Program
ACF	Alabama Coastal Foundation
ADECA	Alabama Department of Economic & Community Affairs
ADEM	Alabama Department of Environmental Management
AL	Alabama
ATSDR	Agency for Toxic Substances & Disease Registry
BMP	Best Management Practice
BMR	Bureau of Marine Resources--Mississippi
CAC	Citizens Advisory Committee--Gulf of Mexico Program
CCMP	Comprehensive Conservation & Management Plan
CMD	Coastal Management Division--Louisiana
CUP	Coastal Use Permit--Louisiana
CWA	Clean Water Act
CWPPRA	Coastal Wetland Planning, Protection & Restoration Act
CZM	Coastal Zone Management
CZARA	Coastal Zone Act Reauthorization Amendments
DEP	Department of Environmental Protection--Florida
DNR	Department of Natural Resources--Louisiana
DWMP	District Water Management Planning--Florida
EIS	Environmental Impact Statement
ESA	Endangered Species Act
FCMP	Florida Coastal Management Program
FERC	Federal Energy Regulatory Commission
FL	Florida
FWPCA	Federal Water Pollution Control Act
GIS	Geographic Information Systems
GLO	General Land Office
GMP	Gulf of Mexico Program
GMPO	Gulf of Mexico Program Office
IBWC	International Boundary & Water Commission
IC	Issue Committee--Gulf of Mexico Program
IMC	Interagency Management Committee--Florida
LA	Louisiana
LADEQ	Louisiana Department of Environmental Quality
LCRA	Lower Colorado River Authority
LCRP	Louisiana Coastal Resources Program
MC	Management Committee--Gulf of Mexico Program
MDEQ	Mississippi Department of Environmental Quality
MMS	Minerals Management Service
MS	Mississippi
MSSW	Management & Storage of Surface Water--Florida Statutes
NAS	National Academy of Science
NASA	National Aeronautics & Space Administration
NEI	National Estuarine Inventory
NEP	National Estuary Program

NEPA	National Environmental Policy Act
NESDIS	National Environmental Data & Information Service
NFIP	National Flood Insurance Program
NMFS	National Marine Fisheries Service
NOAA	National Oceanic & Atmospheric Administration
NPS	National Park Service
NRC	National Research Council
NS&T	National Status & Trends
NWS	National Weather Service
OCS	Outer Continental Shelf
ORCA	Office of Ocean Resources Conservation & Assessment
PRB	Policy Review Board--Gulf of Mexico Program
PSA	Public Service Announcement
SAB	Strategic Assessment Branch
SCS	Soil Conservation Service
SEFSC	Southeast Fisheries Science Center
SERO	Southeast Regional Office--National Marine Fisheries Service
SLCRMA	State & Local Coastal Resources Management Act--Louisiana
SMA	Special Management Area
SWIM	Surface Water Improvement & Management Act--Florida
TAC	Technical Advisory Committee--Gulf of Mexico Program
TNRCC	Texas Natural Resource Conservation Commission
TPWD	Texas Parks & Wildlife Department
TVA	Tennessee Valley Authority
TWDB	Texas Water Development Board
TX	Texas
TXEMP	Texas Estuarine Mathematical Programming Model
USACE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard
USDA	U.S. Department of Agriculture
USDOC	U.S. Department of Commerce
USDOD	U.S. Department of Defense
USDOE	U.S. Department of Energy
USDOI	U.S. Department of the Interior
USDOT	U.S. Department of Transportation
USEPA	U. S. Environmental Protection Agency
USFDA	U.S. Food & Drug Administration
USFWS	U.S. Fish & Wildlife Service
USGS	U.S. Geological Survey

aerobic	Presence of free oxygen (oxygen gas).
algae	Any of a group of aquatic plants, including phytoplankton and seaweeds, ranging from microscopic to several meters in size.
algal blooms	Sudden spurs of algal growth, which can affect water quality adversely. Often, excessive blooms indicate nutrient enrichment. Some species cause potentially hazardous changes in local water chemistry.
ambient	Referring to average concentrations of substances in the surrounding media (water, air, or sediment).
anaerobic	Absence of free oxygen (oxygen gas).
anoxia	Absence of dissolved oxygen in water (<0.1 mg oxygen/L).
anthropogenic	Relating to, or resulting from, the influence of human beings on nature.
aquifer	An underground geological formation, or group of formations, containing usable amounts of ground water that can supply wells and springs.
benthic	Of or pertaining to the bottom or near bottom of a stream, lake, or ocean.
benthos	All marine organisms (plant and animal) living on or near the bottom of the sea.
biochemical oxygen demand (BOD)	A measure of the quantity of dissolved oxygen removed from water by the metabolism of microorganisms. Excessive BOD results in oxygen-poor water.
biota	Plants and animals inhabiting a given region.
biotic community	A naturally-occurring assemblage of plants and animals that live in the same environment and are mutually sustaining and interdependent.
bloom	Excessive growth of plankton in concentrations sufficiently dense to cause discoloration of water and reduced light penetration.
brackish	Salty, but not as salty as sea water. Brackish water occurs in estuaries, creeks, and deep wells.
characterization	The process of bringing together a number of information sources to synthesize overall patterns or make a statement of current conditions.
coastal runoff	Storm water and the materials it carries from land surrounding a coastal area.
coastal zone	Lands and waters adjacent to the coast that exert an influence on the uses of the sea and its ecology, or inversely, whose uses and ecology are affected by the sea. Legally, the definition varies from state to state.
compliance	Conformance to the rules and regulations regarding wastewater discharges.

control program	The methods used to reduce nutrient releases from both point sources and nonpoint sources.
controllable	Those sources of nutrients that arise or result from the impact of human activities and are not attributable to background loads. "Controllable" does not imply that these loads are scheduled for control or that they can all be managed, only that they can be controlled given the technologies available.
criteria	Acceptable limits in various media (*e.g.*, water, sediments) for pollutants derived by USEPA. When issued by USEPA, the criteria provide guidance to the states on how to establish their standards.
cumulative impacts	Combined effects resulting from more than one action.
decomposition	The breakdown of matter by bacteria and fungi. It changes the chemical make-up and physical appearance of materials being broken down and may cause changes in the environment as well.
dissolved oxygen (DO)	Concentration of oxygen in water, commonly employed as a measure of water quality. Low levels adversely affect aquatic life. Most finfish cannot survive when DO falls below 3 mg/L for a sustained period of time. SEE ANOXIA AND HYPOXIA
drainage basin	The land area drained by a river or stream and its tributaries.
dry weather overflows	Illegal discharges of untreated wastewater from combined sewer overflows and storm drains unrelated to rainfall events. During rainstorms such discharges are referred to as "wet weather overflows."
ecological impact	The effect that a human or natural activity has on living organisms and their non-living (abiotic) environment.
ecosystem	An ecological community consisting of living organisms and their physical and chemical environment.
effluent	Discharge or emission of a liquid or gas, usually from a point source (*e.g.*, pipe or stack), into the environment.
enrichment	The addition of nutrients (*e.g.*, nitrogen, phosphorus, carbon compounds) from sewage effluent, runoff, or atmospheric deposition to surface water. This process greatly increases the growth potential for algae and aquatic plants.
estuary	A semi-enclosed body of water, connected to the open sea, in which sea water is measurably diluted with freshwater from inland sources.
freshwater	Water that generally contains less than 1,000 milligrams-per-liter of dissolved solids.
Geographic Information System (GIS)	A computerized database of land use, land cover, and many other types of information that can be statistically analyzed and graphically displayed using maps.

ground water	Subsurface water saturating soil or porous rock which often returns, with its nitrogen loads, to surface streams during dry periods.
habitat	The place where a population (*e.g.*, human, animal, plant, microorganism) lives and its surroundings, both living and non-living.
hydrodynamic	Concerning the forces, energy, and pressure of water in motion.
hypoxia	Low levels of dissolved oxygen in water, defined as less than 2 mg/L.
land use	Refers to the ways in which a community or area makes use of its natural resources.
living resources	Plant and animal life.
loading	Quantity of contaminants, nutrients, or other substances introduced into a waterbody.
marine	Pertaining to the ocean or sea.
meteorological conditions	Atmospheric phenomena, such as precipitation, wind, and temperature, which ultimately drive the surface and groundwater flow of water and nutrients.
mitigate	To make less serious or severe.
model	A simplified mathematical representation of reality. Water quality modeling is used to study Gulf of Mexico processes and project effects of varying environmental conditions or management actions.
modeling	An investigative technique using a mathematical or physical representation of a system or theory, usually on a computer, which accounts for all or some of its known properties. Models are often used to test the effect of changes of system components on the overall performance of the system.
monitoring	Observing, tracking or measuring some aspect of the environment to establish base line conditions and short or long-term trends.
National Pollutant Discharge Elimination System (NPDES)	A provision of the Clean Water Act that prohibits discharge of pollutants into waters of the U.S. unless a special permit is issued by USEPA, state, or (where delegated) a tribal government on an Indian reservation.
nitrogen	A nutrient essential for life. May be organic or inorganic (ammonia, nitrate, nitrite). Elemental nitrogen constitutes 78 percent of the atmosphere by volume.
nonpoint source pollution	Toxicants, other contaminants, nutrients, or soil entering a waterbody from sources other than discrete discharges, such as pipes. Includes pollution on the land which originates as atmospheric deposition, as well as farm and urban runoff.
NPDES permits	National Pollutant Discharge Elimination System Permits to discharge treated wastewaters to the waters of the U.S. issued by either USEPA or the state.

nutrients	Chemicals required for growth and reproduction of plants. Excessive levels of the nutrients nitrogen and phosphorus can lead to excessive algae growth.
nutrient enrichment	Nutrient enrichment increases primary productivity in a waterbody, eventually resulting in depletion of dissolved oxygen essential to aquatic life (also called eutrophication).
organic	(1) Referring to or derived from living organisms. (2) In chemistry, any compound containing carbon.
organic matter	Carbonaceous waste contained in plant or animal matter and originating from domestic or industrial sources.
organism	Any living thing.
oxygen demand	Consumption of oxygen by bacteria to oxidize organic matter.
permit	An authorization, license, or equivalent control document issued by USEPA or an approved state agency to implement the requirements of an environmental regulation, *e.g.*, permit to discharge from a wastewater treatment plant or to operate a facility that may generate harmful emissions.
phosphorus	A nutrient essential for life found in both organic and inorganic forms.
phytoplankton	Microscopic plants that live in water such as algae.
point source pollution	Contamination from waste effluent discharged into a waterbody through pipes or conduits.
pollutant	Generally, any substance introduced into the environment that adversely affects the health of plants and animals, or the usefulness of a resource.
pollution	Generally, the presence of matter or energy whose nature, location, or quantity produces undesired environmental effects. Under the Clean Water Act, for example, the term is defined as the man-made or man-induced alteration of the physical, biological, and radiological integrity of the water.
productivity	Process by which plants remove dissolved carbon dioxide and micro-nutrients from the water and, using solar energy, convert them to complex organic compounds of high potential energy.
qualitative	Pertaining to the non-numerical assessment of a parameter.
quality assurance/ quality control (QA/QC)	A system of procedures, checks, audits, and corrective actions to ensure that research design and performance, environmental monitoring and sampling, and other technical and reporting activities are of the highest achievable quality.
quantitative	Pertaining to the numerical assessment of a parameter.
receiving waters	A river, lake, ocean, stream, or other watercourse into which wastewater or treated effluent is discharged.

residual	Amount of a pollutant remaining in the environment after a natural or technological process has taken place, *e.g.*, the sludge remaining after initial wastewater treatment, or particulates remaining in air after the air passes through a scrubbing or other pollutant removal process.
restoration	The act of returning something such as habitat or water quality to its condition prior to human disturbance. Measure taken to return a site to natural conditions.
runoff	Drainage of precipitation over the soil or a non-porous surface (*e.g.*, asphalt) to a stream, river, or other receiving body of water.
salinity	Amount, by weight, of dissolved salts in 1,000 units of water (reported as parts/thousand).
sediments	The loose solids, (*e.g.*, soil from erosion or runoff) that settle to the bottom of a waterbody or its tributaries which can be sources of nitrogen and phosphorus.
standards	Prescriptive norms that govern action and actual limits on the amount of pollutants or emissions produced. USEPA, under most of its responsibilities, establishes minimum standards. States can issue stricter standards if they choose.
storm water	Runoff caused by precipitation.
stratification	The layering of fresh water over salt water due to differences in relative density and temperature.
stream	A body of water, including brooks and creeks, that moves in a definite channel in the ground driven by a hydraulic gradient.
surface water	All water naturally open to the atmosphere (rivers, lakes, reservoirs, streams, impoundments, seas, estuaries, etc.); also refers to springs, wells, or other collectors that are directly influenced by surface water.
toxic	Harmful to living organisms.
tributary	A stream, creek, or river that flows into a larger stream, creek or river.
turbidity	Reduction of water clarity caused by suspended sediments and organics in the water.
wastewater	The spent or used water that contains dissolved or suspended matter from individual homes, a community, a farm, or an industry.
water clarity	A general term which describes the transparency of water in an aquatic system. Water clarity is reduced with increased amounts of particulate materials (*e.g.*, suspended sediments) in the water column. SEE LIGHT ATTENUATION
water column	A vertical extent of water reaching from the surface to the bottom substrate of a waterbody.
water quality	Status or condition of a waterbody in terms of defined variables characterizing the "health" of the water.

water quality standards	State-adopted and USEPA-approved ambient standards for waterbodies. The standards cover the use of the water body and the water quality criteria that must be met to protect the designated use or uses (*e.g.*, drinking, swimming, fishing).
watershed	Land area from which precipitation drains into a given body of water.
wetlands	An area that is regularly saturated by surface or ground water and subsequently is characterized by a prevalence of vegetation that is adapted for life in soil conditions. Examples include: swamps, bogs, fens, and marshes. Often defined based on soil characteristics.
zooplankton	Animal plankton of widely varying size that drift or swim weakly in the water. They consume the primary producers and are a second link in the food chain or food web.

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Florida Defenders of the Environment

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