Planning Activities
Associated with

South Florida Ecosystem Restoration

A compilation of existing plans

Reconnaissance Report:
Simulation Model of South Central Florida Hydrologic System
U.S. Army Corps of Engineers

Florida Bay Science Plan
National Park Service

Towards Ecosystem Management in Florida
Florida Department of Environmental Protection

Implementation Plan for Florida Bay
NOAA/Coastal Ocean Program

1994 Annual Report
South Florida Ecosystem Restoration Task Force - Working Group

Scientific Information Needs
South Florida Ecosystem Restoration Task Force - Science Subgroup

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March 1995

Six documents describing planning activities associated with South Florida ecosystem restoration, including Florida Bay, are included in this volume. This material has been compiled as background information for NOS's Florida Keys Integration Project.

1. Reconnaissance Report - Simulation Model of South Central Florida Hydrologic Ecosystem

U.S. Army Corps of Engineers - November 1991

The purpose of the reconnaissance study was to determine the technical feasibility and Federal non-Federal interest in developing a simulation modeling system of the south and central Florida hydrologic ecosystem. The report presents the general background and history of the project, objectives, and a description of the study area. The detailed appendices attached to the original report are not included here.

2. Florida Bay Science Plan

National Park Service - April 1994

This was the first "plan" put together addressing the environmental problems of Florida Bay. It was developed by an interagency working group at the request of Everglades National Park and the Department of Interior's National Park Service. The Executive Summary on page 5 describes its purpose. Please not that pages 9-10 were an oversized map of Florida Bay that could not be included in this volume.

3. Towards Ecosystem Management in Florida

Florida Department of Environmental Protection - March 1994

The publication of this report coincided with the opening of Florida's new Department of Environmental Protection. It was developed to demonstrate how ecosystem management strategies are being applied to six threatened ecosystems throughout the state, including Florida Bay (sections on the other ecosystems are not included here).

4. Implementation Plan for Florida Bay

NOAA/Coastal Ocean Program - July 1994

Following the publication of Park Service's Science Plan, NOAA's leadership (i.e. Doug Hall) directed the development of a plan outlining how NOAA would contribute to the restoration of Florida Bay in the areas of research, assessment, and analysis. This report was developed at the direction of Peter Ortner (NOAA/OAR/AOML) and Nancy Thompson (NOAA/NMFS/SEFSC), both of whom participated in the development of the Park Service's Science Plan. The projects described are funded by NOAA's Coastal Ocean Program. Selected FY94 projects were funded. FY95 funding is still pending.

5. Annual Report from Interagency Working Group

South Florida Ecosystem Restoration Task Force - August 1994

This report is an overview of all the issues and activities associated with the South Florida Ecosystem Restoration Task Force, a Federal inter-agency task force established in 1993.

6. South Florida Ecosystem Restoration - Scientific Information Needs

South Florida Ecosystem Restoration Task Force/Science Sub-Group - September 1994

This plan, which is not so much a plan as it is a plan of a plan, was developed by the Science Subgroup of the Federal task force established in 1993. It is one component of the activities described in the Task Force's Working Group Annual Report (4). This document reflects the Florida Bay restoration issues addressed in the NOAA Plan (2) and the Science Plan (1). It also addresses other issues associated with areas north of Florida Bay that are part of the larger South Florida ecosystem (see map on page 2). As described on page 1, this document is a summary of a much more extensive report on scientific information needs.

RECONNAISSANCE REPORT

SIMULATION MODEL OF SOUTH CENTRAL FLORIDA HYDROLOGIC ECOSYSTEM

U. S. ARMY CORPS OF ENGINEERS
JACKSONVILLE DISTRICT
SOUTH ATLANTIC DIVISION

NOVEMBER 1991

NOTICE

This reconnaissance report was submitted for review to the U.S. Army Corps of Engineers' headquarters and the office of the Secretary of the Army. As a result of that review, it was determined that due to the high cost of model development this study is not a priority activity and the Corps of Engineers will not proceed with development of the model.

RECONNAISSANCE REPORT

SIMULATION MODEL OF SOUTH CENTRAL FLORIDA HYDROLOGIC ECOSYSTEM

SYLLABUS

The Central and Southern Florida (C&SF) Project, authorized in 1948, involves an area of about 16,000 square miles, which includes all or part of 18 counties in central and southern Florida. It embraces Lake Okeechobee, its regulatory outlets, a large portion of the Everglades, the upper Kissimmee River Basin, and the lower east coast of Florida. The project primarily serves flood control and water conservation purposes.

The C&SF project is a complex system which manages the surface and ground water resources of the area to serve a variety of interests. The area's natural ecosystem has been substantially altered by human activities. There has been increasing concern over continued rapid growth in central and southern Florida and subsequent water use and management efforts on the ecosystem. There is particular concern about the Lake Okeechobee and Everglades National Park ecosystems, which have been overly stressed in recent years. The complex nature of both the hydrologic system and the ecosystem has made evaluation of changes to the C&SF Project or its operation or of other human activities in the vicinity difficult. A simulation modeling system is needed to adequately evaluate the impacts that changes could make on the ecosystem.

The purpose of this document is to present the findings of this reconnaissance study on South Central Florida Hydrologic Ecosystem Simulation Model. This study was authorized by *Section 11 of the Water Resources Development Act of 1988 (Public Law 100-676).*

For the purposes of this study, the Upper St. Johns River basin, while it is part of the C&SF Project area, was omitted since it is in another drainage basin. In addition, adjacent areas to the C&SF Project were added in order to assess impacts of human activities to areas receiving discharge from the C&SF Project.

A technical study plan was developed which addresses modeling purpose, scope, model development priorities, model linkages, data collection and research requirements, modeling methods, phases of model development, costs, management tasks during development and for operation of the modeling system. Several options to performing all of the tasks in the technical study plan were evaluated. Option B which involves performing the "high priority" tasks from each Task area - Water Quantity, Water Quality, Vegetation and Animal is recommended. This option was considered to be the most economically and technically feasible alternative. The cost of this option is $53,325,000. The authorization directs that the Federal share of developing and operating the simulation model shall be 75 percent. Therefore, the Federal share of this option would be $39,993,750. Due to the need for extensive interagency cooperation and coordination, which would be needed to successfully develop and operate the modeling system as well as the interagency benefits of such a system, funding for the development and operation of the modeling system could be provided by the Corps of Engineers and other Federal, State, and local agencies

This simulation modeling system will provide a means to establish an interagency exchange of ideas, data, and modeling efforts. The assembly of improved knowledge and the interchange of objective analytical concepts and techniques among hydrologic ecosystem researchers, resource managers, and development regulators can be expected to significantly improve system management procedures and technical coordination among agencies with management and regulatory responsibilities in the C&SF Project area.

This modeling system will be used by Federal and State water and land management agencies evaluating the status and goals of watersheds or regions. It will be used by the Corps of Engineers and other Federal agencies to evaluate projects based on a combination of economic and environmental benefits. This project will establish a Geographic Information System (GIS) which will be compatible between state water management agencies, the Corps of Engineers, the Environmental Protection Agency, U.S. Fish and Wildlife Service, Everglades National Park, and others. By establishing one compatible system, Federal, state and local agencies will have the use of the system at a total cost that will be less than if each agency develops their own system.

The results of this study have been coordinated with the study participants, the South Florida Water Management District (SFWMD) and the Everglades National Park (ENP). The SFWMD is the potential local sponsor and the ENP has expressed interest in participating as a Federal sponsor. In view of the favorable results of the analyses conducted for this study, the District Engineer recommends that development and operation of the Simulation Model of South Central Florida Hydrologic Ecosystem proceed.

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PLATES

1 CENTRAL AND SOUTHERN FLORIDA PROJECT MAP
2 STUDY AREA

INTRODUCTION

AUTHORITY

This study was authorized by *Section 11 of the Water Resources Development Act of 1988 (Public Law 100-676)* which states:

> "*(a) In General. – The Secretary, in cooperation with affected Federal, State, and local agencies and other interested persons, may develop and operate a simulation model of the central and southern Florida hydrologic ecosystem for use in predicting the effects –*
>
> > *(1) of modifications to the flood control project for central and southern Florida, authorized by the Flood Control Act of 1948,*
> >
> > *(2) of changes in the operation of such project, and*
> >
> > *(3) of other human activities conducted in the vicinity of such ecosystem which individually or in the aggregate will significantly affect the ecology of such ecosystem,*
>
> *on the flow, characteristics, quality, and quantity of surface and ground water in such ecosystem and on plants and wildlife within such ecosystem. Such model shall be capable of producing information which is applicable for use in evaluating the impact of issuance of proposed permits under section 10 of the Act of March 3, 1899 (30 Stat. 1151; 33 U.S.C. 403), commonly known as the River and Harbors Appropriation Act of 1899, and under section 404 of the Federal Water Pollution Control Act.*
>
> *(b) Availability to State and Local Agencies. – The Secretary shall allow Federal, State, and local agencies to use, on a reimbursable basis, the simulation model developed under this section.*
>
> *(c) Cost Sharing. – The Federal share of the cost of developing and operating the simulation model under this section shall be 75 percent.*"

PURPOSE AND SCOPE

The purpose of this reconnaissance study is to determine the technical feasibility and Federal and non-Federal interest in developing and operating a simulation modeling system of the south and central Florida hydrologic ecosystem. This reconnaissance report presents the general background and history of the project, objectives, and a description of the study area.

The report discusses the technical feasibility of developing and operating a simulation modeling system of the south and central Florida hydrologic ecosystem, the usefulness, costs and benefits of such a modeling system. Also discussed are the identification of a local sponsor; cost sharing requirements; model use reimbursement; and, finally, a recommendation on whether the next phase, model development, should be pursued.

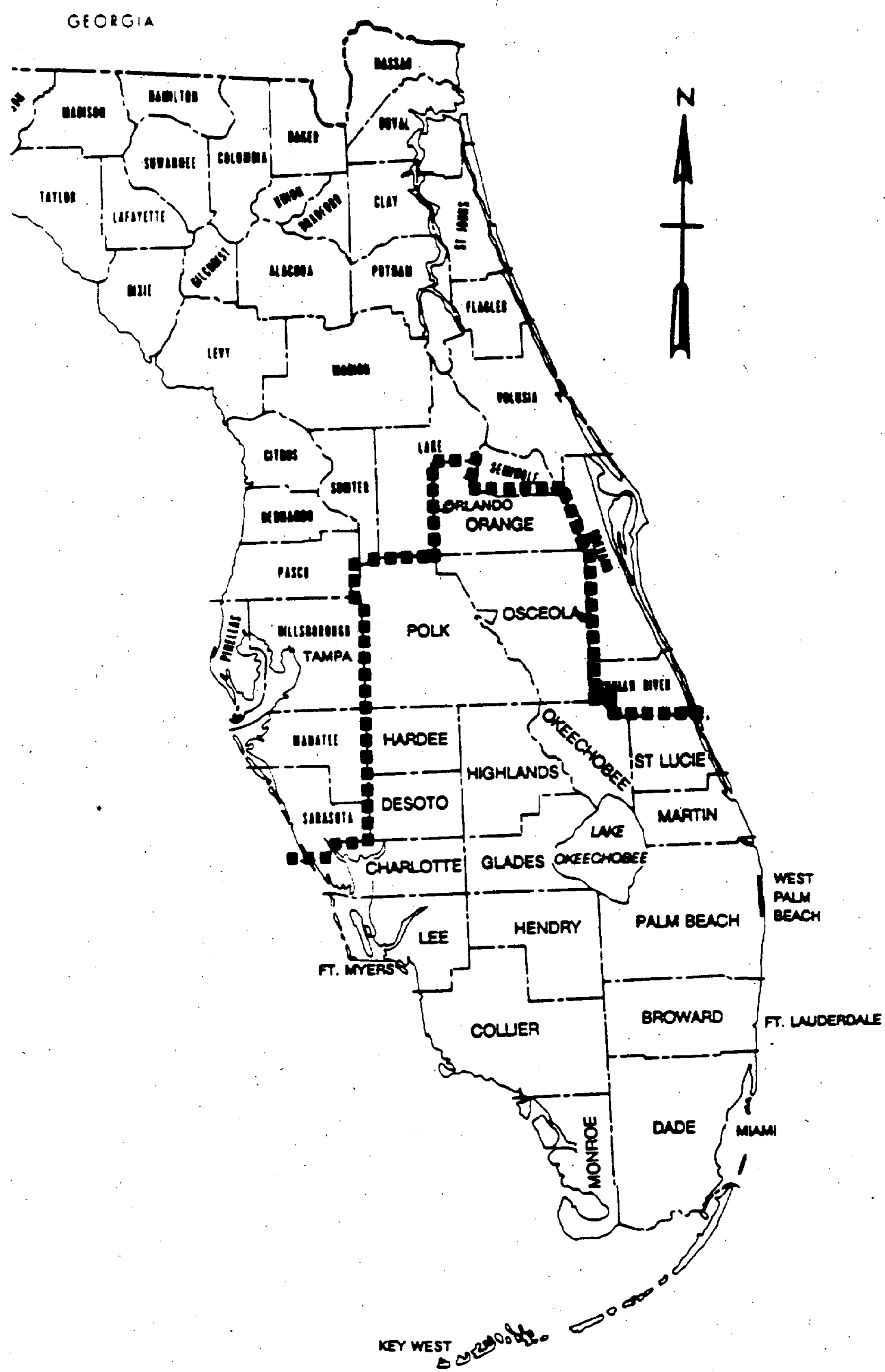
STUDY AREA

The study area covered by this investigation, shown on Figure 1, includes the entire area of the Central & Southern Florida (C&SF) Project, exclusive of the Upper St. Johns River Basin. The C&SF Project involves an area of about 16,000 square miles including all or part of 18 counties in central and southern Florida. The counties are Broward, Charlotte, Collier, Dade, DeSoto, Glades, Hardee, Hendry, Highlands, Lee, Martin, Monroe, Okeechobee, Orange, Osceola, Palm Beach, Polk, and St. Lucie. Additionally, portions of the southwest coast and the coastal areas of southern Florida not within the C&SF Project area have been included in this study.

For the purpose of developing this simulation modeling system, the Upper St. Johns River basin has been eliminated from the study area. While it is part of the C&SF Project, the basin drains north with a separate drainage basin and ecosystem. Areas adjacent to the C&SF Project were added to the study area in order to fulfill the purpose of the authorization, which is to predict impacts of the C&SF Project and other human activities on the ecosystem. Inclusion of these areas is necessary to understand how these activities will impact estuaries and bays which receive water from the C&SF Project.

REPORT AND STUDY PROCESS

Planning by the Corps of Engineers (Corps) for any Federal water resources project normally is accomplished in two phases: reconnaissance and feasibility. The reconnaissance phase is conducted at full Federal expense, while the feasibility phase is shared equally between the Federal government and a non-Federal sponsor. For this particular project; however, there will not be a feasibility phase. Instead, following the reconnaissance phase will be the model development phase. The reconnaissance phase has been accomplished at full Federal expense and the model development phase is to be cost shared 75 percent Federal and 25 percent non-Federal in accordance with the study authorization.



STUDY AREA

FIGURE 1

For the reconnaissance phase of this study, the objectives were to determine the technical feasibility of developing and operating a simulation modeling system and to ascertain the Federal and non-Federal interest in proceeding to the model development phase.

The model development phase will undertake a much more intensive examination of the problems of the study area while evaluating and adapting previous studies and models to the extent possible. The model development itself will be divided into phases which will include the development of a set of models and other tools. At the end of each phase, there will be an opportunity to evaluate progress and re-evaluate modeling efforts and objectives.

STUDY PARTICIPANTS

The Corps' Jacksonville District has the primary responsibility to conduct this study. The Corps' Waterways Experiment Station in Vicksburg, Mississippi was enlisted to provide technical assistance and to develop the technical study plan. The South Florida Water Management District and the Everglades National Park staff of the National Park Service have also been involved as partners. Other agencies, organizations, and individuals participated in the study.

HISTORY OF THE STUDY AREA

The following quote and much of the following history is from the *Central and Southern Florida Flood Control Project, Eight Years of Progress, 1948-57 Report,* published by the Central and Southern Florida Flood Control District (now the South Florida Water Management District) in 1957:

> *"Many centuries before the arrival of Ponce de Leon, prehistoric redmen lived along the shores of this immense natural water system. And various works still existing among the remains of their cultures show that they, too, had their water problems. Their difficulties with floods and droughts are not known, but they did dig canals for navigational and ceremonial purposes. Today these works can be seen easily from the air in the form of straight lines cutting through piney woods or in strange circles near mounds and other ancient earthworks."*

In 1847, two years after Florida was granted statehood, one of the State's original United States Senators, J.D. Westcott, made the first known proposal to drain the overflowed lands of the lower peninsula. The Senator's plan was based on reports of General William S. Harney, who had explored the Everglades area, and General Thomas S. Jessup, who had directed operations in the Kissimmee Valley and the area west and to the south of Peace Creek.

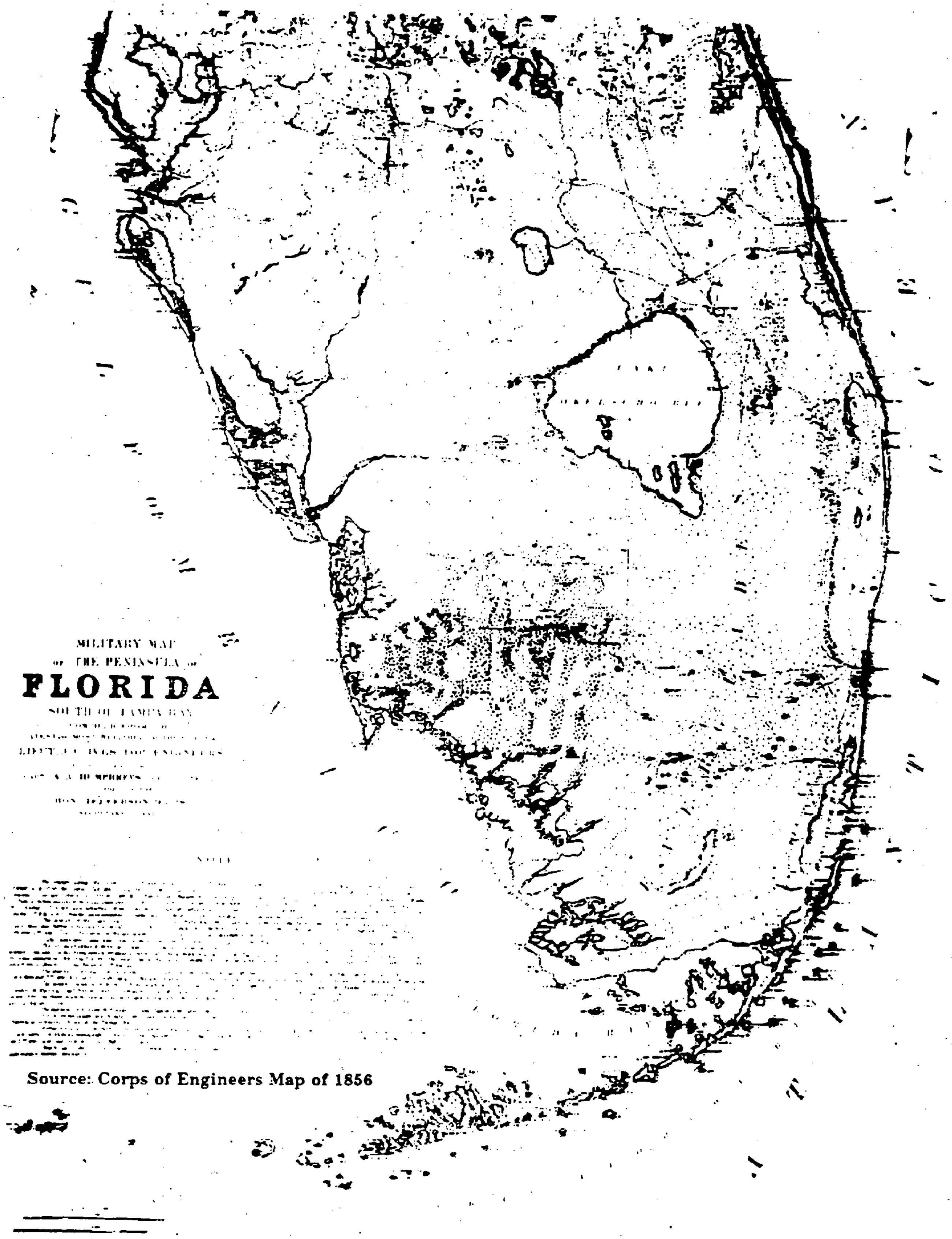
The Secretary of the Treasury, in 1848, appointed Buckingham Smith of St. Augustine to make a general inspection of the area and to report his findings. Smith reported to the United States Senate in June 1848 that he believed the Everglades could be reclaimed by a sensible system of canaling and by deepening the various streams that flowed both east and west to the coasts. He believed that drainage would insure the growth of a new agricultural empire in south Florida.

The United States Congress passed the *"Swamp Lands Act of 1850"*, which conveyed the whole of Florida's swamp and overflowed lands to State ownership. A stipulation in the act was that the sale of the lands to private interests should finance the necessary work of reclamation. To plan for the development of this huge area, a Board of Internal Improvements was created in 1851 by the State Legislature. Figure 2 shows the central and southern Florida region in the mid-19th century.

Little progress was made in the way of internal improvements for the next thirty years. Transportation was in poor shape in the state. During the Civil War, several extensions of the railroads were completed, when Florida became one of the main sources of supply for the South. But more railroads were destroyed by both sides as the material was needed and by the end of the war, rail transportation was set back again. During reconstruction by the carpetbag governments, the Internal Improvement Fund became so entangled in debt and politics that it was unable to accomplish anything constructive. The Trustees tried to get the Fund out of debt by increasing land sales. Before many deals could be made, creditors forced the District Court of North Florida to put the Fund in the hands of a receiver.

Thus by 1877, when actual home rule returned to the State, Florida possessed an Internal Improvement Fund in receivership, several millions in worthless bonds, and high taxation. Trustees continued to sell parcels of land through the receivership and the monies were used to settle claims and judgments against the Fund. But the ordinary sales of land were not enough to keep the debt from increasing and the Fund was being depleted by compound interest and the expense of litigation.

Samuel A. Swann, an agent of the Trustees, was authorized to negotiate the sale of three million acres at not less than thirty cents an acre. He spent from 1877 to 1881 with northern capitalists and English financiers looking for an immediate buyer of a large tract to save the Fund from disaster. Then in 1881, the Trustees found Hamilton Disston, a Philadelphian who had inherited his father's saw works a few years earlier.



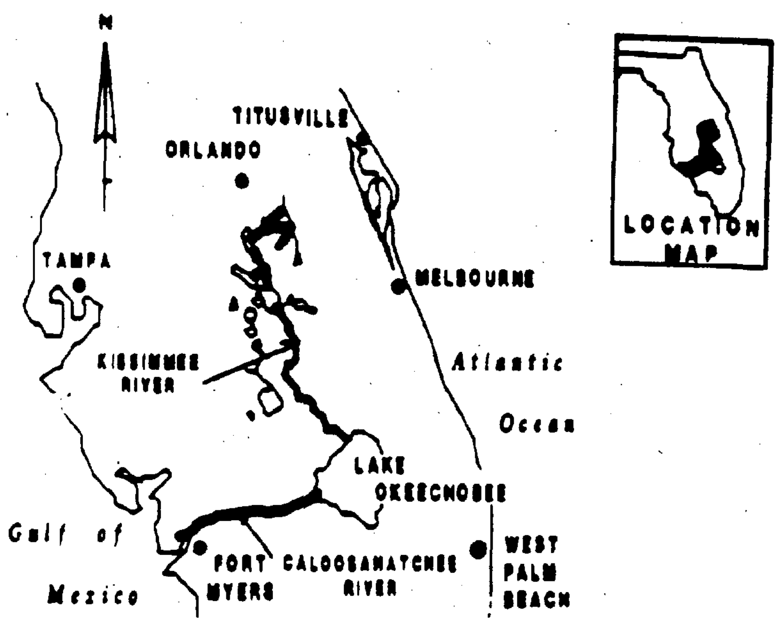
Source: Corps of Engineers Map of 1856

1856 MAP OF SOUTH FLORIDA

FIGURE 2

On February 26, 1881, Hamilton Disston signed the first contract, which would drain overflowed lands south of Township 23 East and east of Peace Creek in return for half the area reclaimed in the form of the odd sections in each township. Disston's first project was to give Lake Okeechobee an outlet to the Gulf through the Caloosahatchee River (see Figure 3). Work began at Lake Flirt in January 1882 and within a year the lake's waters began to flow to the Gulf through the cut and Okeechobee's level dropped considerably.

In July 1882, a second operation began in the upper Kissimmee valley with the cutting of the Southport Canal between Lake Tohopekaliga and Lake Cypress. Finishing the cut, the dredge turned to connecting Lake Tohopekaliga with East Lake Tohopekaliga. This canal, called the St. Cloud Canal, was begun in January 1883, and completed in September 1884. By the fall of 1883, the company had opened navigation from the Gulf to the town of Kissimmee.



DISSTON'S PROJECT WORKS

FIGURE 3

A tract of land on the Southport Canal, previously under three feet of water, was used for sugar cane in February 1884, and harvested later with much success. Disston opened a sugar plantation in January 1886, just east of the St. Cloud Canal on East Lake Tohopekaliga.

After Disston's death in 1896, his empire in Florida quickly crumbled. Disston's drainage project did not accomplish all that was expected and, in some cases, led to overdrainage. But it was the first large scale project in the central and southern Florida area and a major part of it is still functioning today.

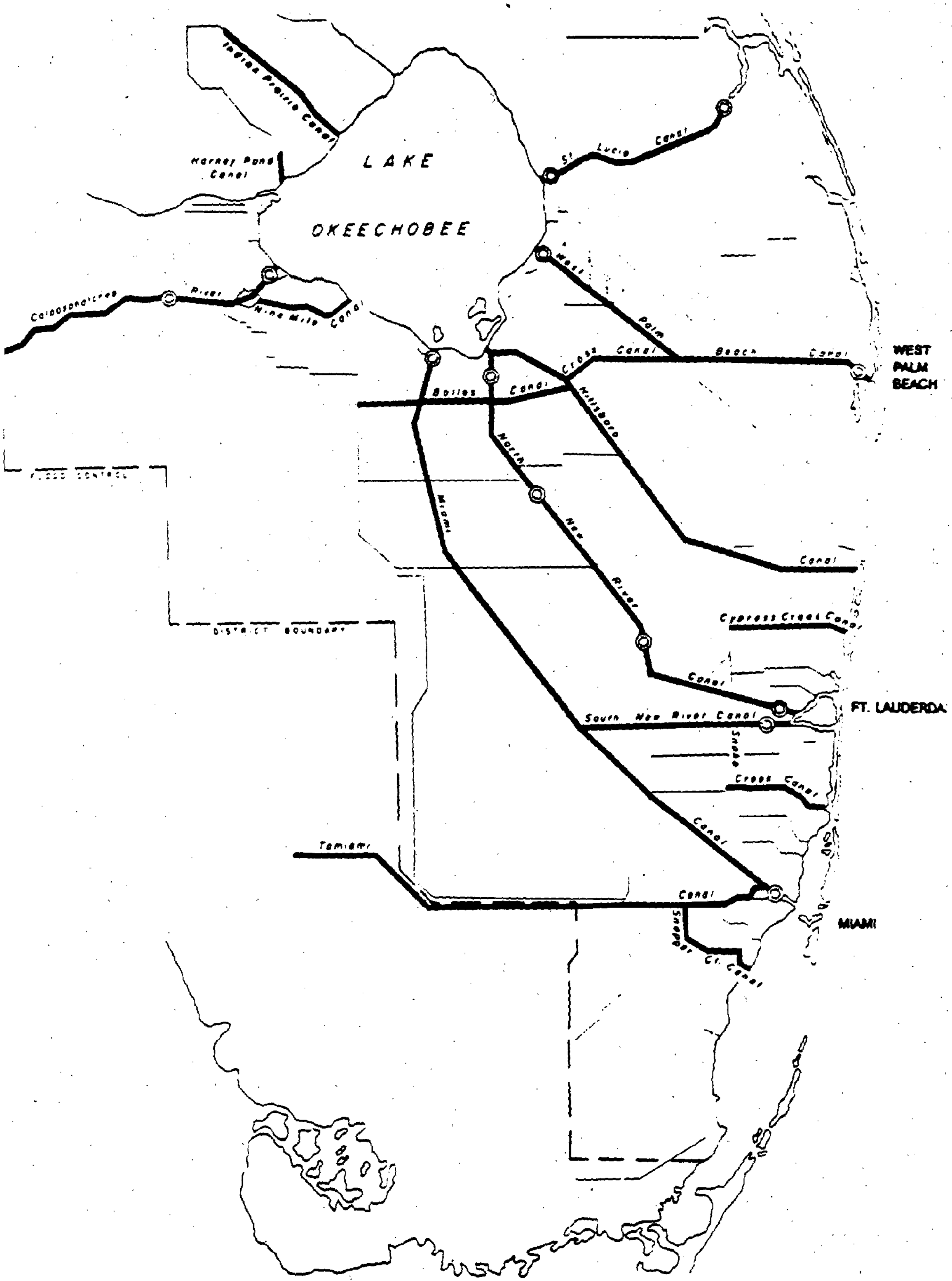
The State Legislature created a Board of Drainage Commissioners in 1905 and turned over to them lands acquired in 1850 by the *Swamp Lands Act.* This board was vested with the authority:

> *"to establish drainage districts and to fix the boundaries thereof in the State of Florida". They were ... "to establish a system of canals, levees, drains, dikes, and reservoirs...to drain and reclaim the swamp and overflowed lands within the State of Florida."*

In 1906, the Trustees of the Internal Improvement Fund and the Drainage Commissioners purchased and operated dredges. Between 1906 and 1913, 225.4 miles of drainage canals were dug, including the Miami, North New River, and South New River Canals. During the period 1913 to 1927, six major drainage canals and numerous minor canals, totaling 440 miles; 47 miles of levees; and 16 locks and dams were constructed (see Figure 4). The system of canals and locks constructed during this period provided the groundwork for draining the northern and eastern parts of the Everglades region. The five major canals originated at Lake Okeechobee and flowed easterly toward the Atlantic.

The partial drainage of the Everglades opened the area to farm settlement. The first wave of settlers came between 1910 and 1915, followed by another from 1920 to 1926. By 1921, the population in the lake region was estimated to be around 2,000 people. Most of the cultivated land in the glades was developed after 1920. The first crops grown commercially were sugarcane, tomatoes, beans, peas, peppers, and potatoes.

Although some 440 miles of canals had been completed and $18,000,000 expended, only the Caloosahatchee and St. Lucie Canals provided satisfactory outlets from Lake Okeechobee to the sea. The other canals lacked the slope necessary to reduce the lake level appreciably. In addition, efforts were so widely scattered that, on the whole, there was little return for the money spent. It also became apparent that canals alone did not afford sufficient protection from overflow during unusual weather. The hurricanes of 1926 and 1928, created wind tides on Lake Okeechobee which overflowed the surrounding areas with disastrous results. The hurricanes of 1926 and 1928 essentially marked the end of the construction period under the Everglades Drainage District; they also marked the start of the Federal interest in water control through the Corps.



EVERGLADES DRAINAGE DISTRICT WORKS 1905-1948

FIGURE 4

The hurricane which struck Miami and the Lake Okeechobee region in 1926 caused over 200 deaths and great financial loss. The Federal government was pressured to take action. Then the hurricane of 1928 swept in through the Palm Beach area toward the Lake. Wind-driven water of Lake Okeechobee, augmented by the torrential rains, overflowed the lake shore and drowned approximately 2,400 people near Moore Haven, in addition to destroying a vast amount of property.

To prevent a recurrence of these disasters, the State Legislature in 1929 created the Okeechobee Flood Control District, which was authorized to cooperate with the Corps in flood control undertakings. Prior to this time, the Corps had engaged only in the improvement of navigation in the rivers and harbors in the Lake Okeechobee area. After a personal inspection of the area by President Hoover, the Corps drafted a new plan which provided for the construction of floodway channels, control gates and major levees along Okeechobee's shores. Construction began in 1930.

In June 1936, a national flood control policy was adopted by Congress. *The Flood Control Act of 1936* established the policy that the Federal Government should:

"improve or participate in the improvement of navigable waters or their tributaries for flood control purposes, if the benefits to whomsoever they may accrue, are in excess of the estimated cost, and if the lives and social security of the people are otherwise adversely affected."

Successive extreme dry spells of 1931 through 1945 resulted in lowered groundwater levels and the threat of serious saltwater intrusion into the municipal wells of Miami and other coastal cities. When the water level fell in the Everglades area, salt water from the ocean rose in the wells upon which the cities depended. There was an important relationship between the areas around Lake Okeechobee and the other water resources of the region which had been overlooked in earlier efforts to drain the interior. Furthermore, land which in the past had regularly flooded, was now actually vanishing. The peaty, organic soils of the Everglades were drying out and shrinking at a clearly visible rate. Thousands of acres caught fire and the muck itself was consumed and lost forever.

During the dry years, with the resulting dehydration of the glades and the intrusion of salt water into the coastal area, it became apparent that water conservation was a necessary function of any drainage plan. Structures designed to drain certain areas while protecting them in time of flood, were also depriving them of necessary moisture during other periods.

In 1947, 100 inches of rain fell on south Florida, more than tripling the region's total rainfall for 1945 and ending one of the worst droughts in Florida history. In a few weeks, the rain had drenched farmland and filled lakes and canals. Then in the space of just 25 days, two hurricanes and a tropical disturbance dumped more water on an already saturated area. When the rains finally ceased, 90 percent of southeastern Florida, from Orlando to the Keys, was under water. The total damage of this disaster was estimated by the Corps at more than $59,000,000.

Following the disastrous flood in 1947, the problems of the area came to a climax. This flood, coupled with the experiences of the drought in 1945 and the intrusion of saltwater made it imperative that immediate corrective action be started. These actions were needed to prevent further loss of life and damage to property because of floods, and to conserve water for beneficial uses during periods of drought.

Acting upon the requests of many local agencies concerned with flood control and water conservation, and under the authority of various flood control acts, river and harbor acts of Congress, and resolutions of appropriate congressional committees, the Corps' Jacksonville District conducted public hearings throughout the area to determine the desires of the many local interests and to collect data from which to formulate a plan.

Views expressed during the public hearings stated that the problems were too large and complex for the capabilities of either the State or local agencies acting alone, therefore making it practically impossible for either to draft a plan that would be satisfactory to all.

A comprehensive plan for flood control and water conservation, which would encompass the entire area, while satisfying the major needs expressed by the various agencies, be beneficial to the greatest number and to the largest portion of the area, and be performed by the Federal government; with local cooperation, seemed to offer the best solution.

A comprehensive report was prepared by the Corps and submitted to higher authority on December 19, 1947. This report stated that the problems of flood protection, drainage, and water control were considered to be physically inter-related, and that the St. Johns, Kissimmee, Lake Okeechobee, Caloosahatchee, and Everglades drainage areas all formed a single economic unit. Accordingly, it recommended a comprehensive program in the interest of *"flood control, drainage and related purposes."*

Congress approved the plan as part of the *Flood Control Act of June 30, 1948,* and the report was published in *House Document No. 643, 80th Congress, Second Session.* The basic purpose of the overall Central and Southern Florida Flood Control Project, quoted from *House Document No. 643,* reads:

"In its natural state the part of central and southern Florida considered in this report was a vast wilderness of water, forest, prairie, and marshland. The forces of nature had combined to establish a fine balance which supported the vegetable, animal and human life that prevailed and resulted in building up the land to the condition in which white man first found it. A large part of this land, the Everglades, was still in a formative stage when its development began. The inherent fertility of the area and its resources made its development and use inevitable. This development, however, resulted in physical changes which altered the natural balance between water and soil, and much of the development was undertaken without any real knowledge of the area or of the hazards involved. The parched prairies and burning mucklands of the Everglades in 1945, the flooding of thousands of acres of farms and communities in 1947, and the intrusion of salt water into land water supplies of the east coast are basically the results of altering the balance of natural forces. The basic problem of this area is, therefore, to restore the natural balance between soil and water in this area insofar as possible by establishing protective works, controls, and procedures for conservation and use of water and land."

The Governor of Florida approved the plan for the State in February 1948. The following year, the State Legislature formed the Central and Southern Florida Flood Control District, later renamed the South Florida Water Management District (SFWMD), to act as a single local agency with which the Federal government could deal on all matters of local cooperation.

CENTRAL AND SOUTHERN FLORIDA PROJECT

The C&SF Project, first phase, (see Plate 1) was authorized by the *Flood Control Act of June 30, 1948* for the purposes of flood control, water level control, water conservation, prevention of salt water intrusion, and preservation of fish and wildlife.

The first phase consisted of most of the works necessary to afford flood protection to the agricultural development south of Lake Okeechobee and to the highly developed urban area along the lower east coast of the State. The second phase, consisting of all remaining works of the original *Comprehensive Plan*, was authorized by the *Flood Control Act of September 3, 1954.*

Improvements in Hendry County and Nicodemus Slough (just west of Lake Okeechobee) were added to the project by the *Flood Control Acts of July 3, 1958, and July 14, 1960,* respectively. Improvements in Boggy Creek, Cutler Drain Area, Shingle Creek, South Dade County, and West Palm Beach Canal were added to the project by the *Flood Control Act of October 23, 1962.* Improvements in Southwest Dade County were added to the project by the

Flood Control Act of October 27, 1965; the same act also modified the 1958 authorization for the Hendry County improvements.

The Flood Control Act of 1968 expanded the project to provide for increased storage and conservation of water and for improved distribution of water throughout much of the project area and added recreation as a project purpose. Flood control measures for Martin County were added. The 1968 modifications would also facilitate increased delivery of water to the Everglades National Park (ENP).

Section 2 of Public Law 91-282 enacted June 19, 1970, authorized appropriations for the Corps to accelerate:

> *"construction of borrow canal L-70, canal C-308, canal C-119W, and pumping station S-326, together with such other works in the plan of improvement as the Director of the National Park Service and the Chief of Engineers agree are necessary to meet the water requirements of the Everglades National Park: Provided further, That as soon as practicable and in any event upon completion of the works specified in the preceding proviso, delivery of water from the central and southern Florida project to the Everglades National Park shall be not less than 315,000 acre-feet annually, prorated according to the monthly schedule set forth in the National Park Service letter of October 20, 1967, to the Office of the Chief of Engineers, or 16.5 per centum of total deliveries from the project for all purposes including the park, whichever is less."*

Section 104 of the Everglades National Park Protection and Expansion Act of 1989 (Public Law 101-229) directed the Corps:

> *"to construct modifications to the Central and Southern Florida Project to improve water deliveries into the park and shall, to the extent practicable, take steps to restore the natural hydrological conditions within the park."*

The authorizing acts require that local interests shall provide all lands, easements, and rights-of-way; pay for relocations of highways (with certain exceptions), highway bridges, and public utilities which may be required for construction of project works; hold and save the United States free from damages resulting from construction and operation of the works; maintain and operate all works (except certain major regulating structures) after completion and make a cash contribution for each part of the work prior to its initiation.

Authorized project facilities include 30 pumping stations, 212 control and diversion structures, 990 miles of levees, 978 miles of canals, 25 navigation locks, and 56 railroad relocations (bridges). Construction was begun in January 1950. The project as a whole is about 81 percent completed.

The project provides for an east coast protective levee extending from the Homestead area north to the eastern shore of Lake Okeechobee near St. Lucie Canal. There are three conservation areas for water impoundment in the Everglades area, west of the east coast protective levee, with control structures to transfer water as necessary. There are also local protective works along the lower east coast with an encirclement of the Lake Okeechobee agricultural area by levees and canals. Enlargement of portions of the Miami, North New River, Hillsboro, and West Palm Beach Canals and existing Lake Okeechobee levees are part of the project. Also included are construction of new levees on the northeast and northwest shores of the Lake; increased outlet capacity for improved control of Lake Okeechobee; floodway channels in the Kissimmee River Basin, with suitable control structures to prevent overdrainage; and facilities for regulation of floods in the Upper St. Johns River Basin.

The project provides water control and protection from the recurrence of flood waters for the highly developed urban area along the lower east coast of Florida and for the agricultural areas around Lake Okeechobee (including the towns around the lake), in the Upper St. Johns and Kissimmee River Basin, and in south Dade County. Another project function is the conservation of flood waters for beneficial uses during dry seasons. In accordance with *Public Laws 91-282 and 101-229*, the project also delivers water to the ENP according to a set schedule.

The Corps operates and maintains project works on the St. Lucie Canal; Caloosahatchee River; Lake Okeechobee levees, channels, locks, and major spillways; and the main outlets for WCAs 1, 2A, and 3A. The SFWMD operates the remainder of the project in accordance with regulations prescribed by the Corps. The local sponsor has an essential role with the Corps in developing water management criteria for the C&SF Project. The local sponsor is responsible for allocation of water from project storage, except where mandated by Federal law.

DESCRIPTION OF STUDY AREA

The study area covered by this investigation involves over 16,000 square miles. The following chapter provides details on each of the regions that comprise this large study area. Plate 2 shows the location of each of these regions.

UPPER EAST COAST

The Upper East Coast area consists of approximately 1,139 square miles and includes Martin and St. Lucie counties as well as a portion of eastern Okeechobee County. The east coasts of Martin and St. Lucie counties are on the Atlantic Ocean, and a substantial portion of Martin County's western landmass borders Lake Okeechobee.

The land is generally flat, ranging in elevation from 15 to 60 feet NGVD[1] in the western portion with an average of 28 feet. The coastal area ranges from sea level to 25 feet. The coastal sand hills adjacent to the Atlantic Intracoastal Waterway (IWW) are higher than most parts of the county and reach a maximum of 60 feet.

The natural drainage has been altered by the construction of canals and drainage ditches with most of the drainage going to the east coast. Urban development is expanding along the coastal areas while the central and western portions are used primarily for agriculture where the main products are citrus, truck crops, sugarcane, and beef and dairy products. The area contains the Canal 23 (C-23)[2], C-24, and C-25 drainage basins and the drainage area served by the St. Lucie Canal. The St. Lucie Canal is Lake Okeechobee's eastern outlet, extending 25.5 miles from Port Mayaca to tidewater at the St. Lucie Estuary.

The geological characteristics of the area reflect the origin of the Florida peninsula and those significant climatological events that have resulted in significant changes in the mean sea level over time. The coastal areas are characterized by sand hills which contain much shell fragment. These overlie varying limestone formations of great depth. Inland areas have a notably higher organic content of near surface soil, which results in a muck in low lying

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[1] All elevations in this report refer to the National Geodetic Vertical Datum of 1929 (NGVD) unless otherwise noted.

[2] Canal designation

areas. In those more readily drained areas, soils tend to be sandier in nature. Here also much of the area is underlain by significant limestone formations. Common geologic groups found in this area include: the Pleistocene/Holocene Series comprised of the Anastasia Formation and undifferentiated terrace deposits of unconsolidated sand, shell, and clay interspersed with limestone, sandstone, and shell beds; the Miocene/Pliocene Series which includes the Tamiami Formation of fossiliferous sandy limestone; the Miocene Series which includes the Hawthorne Formation of a heterogeneous sequence of phosphatic, sandy, clayey, calcareous, and dolomitic sediments; and, the Eocene Series which includes the Avon Park Limestone and the Ocala Group limestone.

The occurrence of surface water in the area is highly dependent upon the terrain and location within the area. There are no significant natural surface water drainage ways within the interior areas. Along the coast, the St. Lucie and Loxahatchee Rivers provide drainage for the coastal ridges. Natural drainage of rainfall runoff in the large interior areas has until recent times depended upon the interaction between surface and groundwater of the area. Rainfall has in times past ponded on the flat interior areas until it was either evaporated back into the atmosphere or infiltrated into the groundwater system. The more recent construction of three major canals in this region has allowed some drainage of the interior areas to the east. More notably, except for Lake Okeechobee to the west, there are no significant freshwater surface lakes in the area.

As in all of south Florida, flora and fauna in this area are defined by land use practices and associated shifts in hydroperiods. In the Upper East Coast, natural resources are limited by the pasture and agricultural usage of the majority of inland areas, the increasing development of the coastal region, and the accompanying drainage of wetlands.

In inland areas where natural vegetation remains, eastern pineland flat woods predominate, with naturalized guava, slash pine, and saw palmetto as understory. There are some cabbage palms and scattered oak hammocks. Various glades and freshwater marshes continue to thrive in lower areas that have not been drained.

Downstream of the St. Lucie Lock and Dam, mangrove forests with associated buttonwood are present, and the coast is populated with sand pines, woody shrubs, palmettos, and sea grasses. Aquatic based vegetation further inland includes hyacinths, water lilies, and other freshwater species.

Due to extensive development, wildlife is largely confined to the remaining forested sections of unimproved pastures, and consists mostly of common upland species of mammals, including armadillos, raccoons, deer, cottontail rabbits, and gray foxes. Wading birds and water fowl inhabit the marshes, and songbirds and reptiles are found along the coast. Reptiles in the area are represented by alligators, ornate diamond back terrapins, and gopher tortoises.

The U.S. Fish and Wildlife Service (USFWS) has identified four endangered species in this area -- the bald eagle (*Haliaeetus leucocephalus*), red-cockaded woodpecker (*Dendrocopus borealis*), West Indian manatee (*Trichechus manatus*), and Everglade Kite (*Rostrhamus sociabilis plumbeus*) and two threatened species, the American alligator (*Alligator mississippiensis*) and eastern indigo snake (*Drymarchon corais*). Other endangered species, such as the peregrine falcon and woodstork, may also be present. There are designated areas of critical habitat only for manatees.

ST. LUCIE CANAL AND ESTUARY

The St. Lucie River basin is part of a much larger southeastern Florida basin which drains over 8,000 square miles. The St. Lucie River, which is composed of North and South Forks, lies in Martin and St. Lucie counties in the northeastern portion of the basin. The South Fork is a relatively short stretch of river. The North Fork, also known as an Aquatic Preserve, begins south of Fort Pierce and flows past the city of Port St. Lucie to an estuary.

Much of the St. Lucie River has been channelized and many drainage canals empty into the river, particularly the St. Lucie Canal, C-23 and C-24. The St. Lucie Canal, which is the largest overflow canal for Lake Okeechobee, is a navigation channel 8 feet deep and 100 feet wide connecting the IWW at Stuart with Lake Okeechobee at Port Mayaca. The surrounding uplands have also been modified by the extensive development associated with the cities of Port St. Lucie, Stuart, Palm City, North River Shores and other residential areas.

Beginning at the east central shore of the Lake, the St. Lucie Canal extends across a relatively high sandy ridge in a generally northeast direction to join the South Fork, an improved natural watercourse which drains northerly into St. Lucie River. The canal discharge is controlled at the Port Mayaka Lock and spillway located 25 miles downstream from Lake Okeechobee and the St. Lucie Lock and Dam at the eastern end of the canal.

The main vegetative communities along the North Fork are mangrove, freshwater swamp, and tidal flats. The river is a breeding and nursery area for crab, shrimp, and various fisheries. The corridor is also a nesting area for the Bald Eagle, American Oystercatcher, raptors, Red-cockaded Woodpeckers, alligators, and a variety of wading birds.

The St. Lucie River claims 83 species of fish, 17 of which are freshwater varieties. Among the most common are striped mullet, yellowfin, menhaden, sea catfish, and black crappies.

KISSIMMEE RIVER BASIN

The Kissimmee River Basin (see Figure 5) is comprised of 3,013 square miles, and extends from Orlando southward to Lake Okeechobee. The watershed, which is the largest providing surface water to the Lake, is about 105 miles long and has a maximum width of 35 miles.

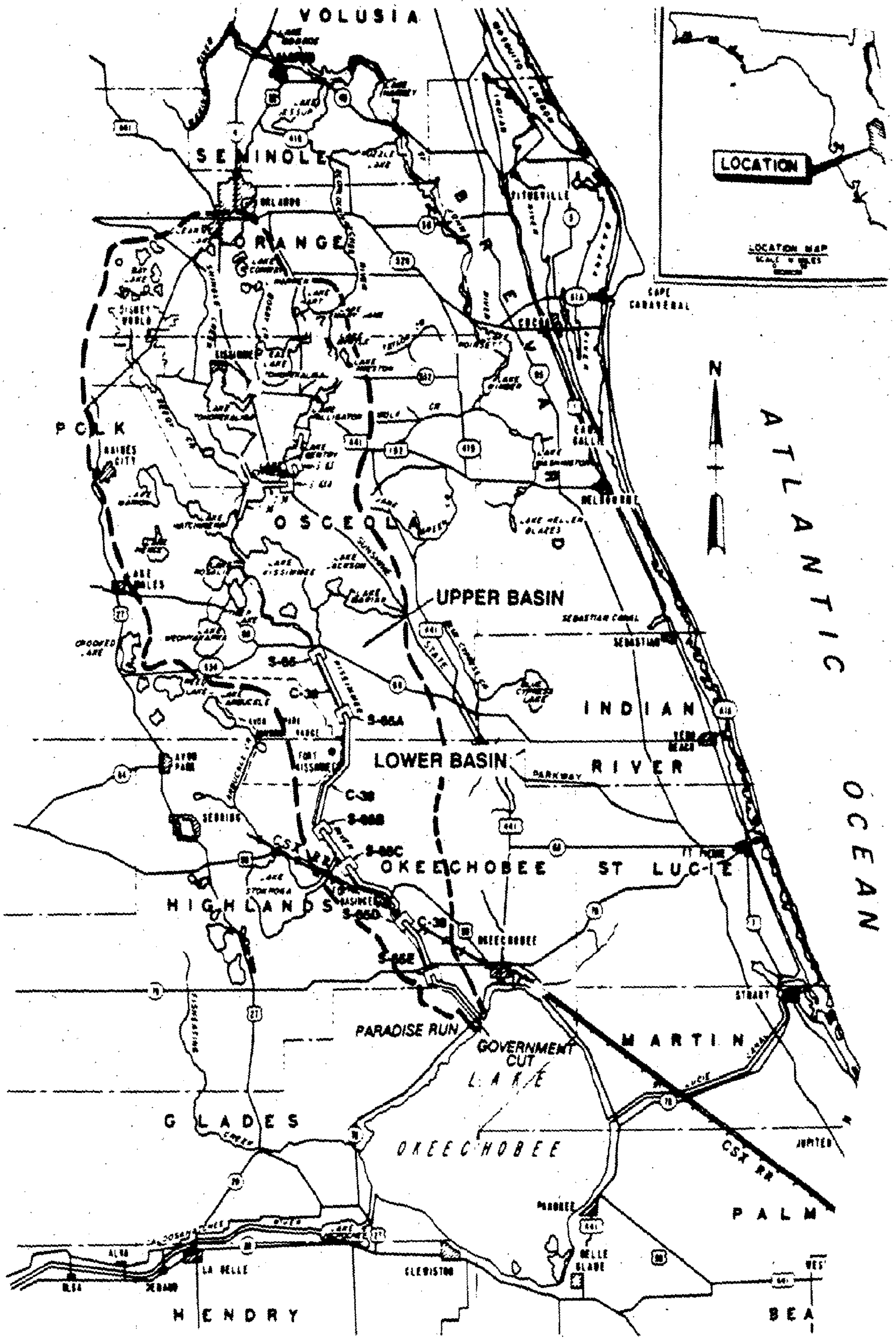
Project works in the basin for flood control and navigation were constructed by the Corps, as part of the C&SF Project. Upper Basin works consist of channels and structures that control water flows through 18 natural lakes into Lake Kissimmee. The Lower Basin includes the channelized Kissimmee River (C-38) as a 56-mile earthen canal extending from Lake Kissimmee to Lake Okeechobee.

The northern portion of the basin is comprised of many lakes, some of which have been interconnected by canals. This large sub-basin often termed the "Upper Basin" or "Chain of Lakes", is bounded on the southern end by State Road 60, where the largest of the lakes, Lake Kissimmee, empties into the Kissimmee River.

The Upper Basin is 1,633 square miles which includes Lake Kissimmee and the east and west chain of lakes area in Orange and Osceola Counties. A 758-square-mile Lower Basin, includes the tributary watersheds of the Kissimmee River between the outlet in Lake Kissimmee and Lake Okeechobee. The 622-square-mile Lake Istokpoga area provides tributary inflow to the Lower Basin.

The Upper Basin is the most heavily populated and intensively developed part of the watershed. The main municipalities are the southern half of Orlando; Kissimmee, which is the center of the cattle industry in central Florida; St. Cloud and Haines City. Walt Disney World is located in the Reedy Creek Improvement District in the upper portion of the basin.

The Lower Basin contains large areas devoted to improved and unimproved pasture for dairy and beef cattle. The Avon Park Air Force Bombing Range is located on the west side of the Kissimmee River. This



KISSIMMEE RIVER BASIN

FIGURE 5

military facility maintains an active resource management program for its large areas of natural grazing lands and wetlands.

Historically, the Kissimmee River meandered approximately 103 miles within a one to two mile wide flood plain. The flood plain was 49,000 acres (USFWS, 1991), sloping gradually to the south from an elevation of about 51 feet at Lake Kissimmee to about 15 feet at Lake Okeechobee; falling an average of about one-third of a foot in elevation over each mile of the river. Under historic conditions, river flows generally exceeded 250 cubic feet per second (cfs) 95 percent of the time, while overbank flooding occurred when flows exceeded 1,400 cfs in the upper reaches to 2,000 cfs in the lower reaches. The river moved very slowly, with normal river velocities averaging less than two feet per second.

Major plant communities found within these wetlands included maidencane and beakrush wet prairies, broadleaf marsh, and woody shrub. Other plant communities common in the wetlands, but not distributed extensively, included wetland hardwoods, cypress stands, oak-cabbage hammocks, switchgrass, sawgrass, and floating mats or tussocks (Pierce et al., 1982).

Distribution and maintenance of plant communities within the river wetlands depended on prolonged inundation and seasonally fluctuating water levels (Dineen et al., 1974; Toth, 1991). A fluctuating hydroperiod; coupled with the undulating topography of the flood plain, a meandering river channel, oxbows, and natural discontinuous levees, enhanced and maintained habitat diversity, including a mosaic of intermixed vegetation types (Perrin et al., 1982).

In the mid-1950's, the river fishery supported an estimated 35,000 fishing days annually in the 90-mile reach between the center of the current Pool A and the Government Cut at the lower end of the river. The rough fish (gar and bowfin) to game fish ratio is believed to have been about two-to-one. The Kissimmee River was especially renowned for its largemouth bass fishery. During normal water conditions, it was estimated that greater that 75% of the total fishing effort on the river would be directed toward black bass.

In the 1950's, the Kissimmee River flood plain harbored a large and diverse wintering waterfowl population, including ring-necked ducks, American widgeon, northern pintail, and blue-winged teal (USFWS 1958). The winter duck population was estimated at about 12,500 birds. White and glossy ibis also were found in the grassy wet prairies and flooded pastures of the Lower Kissimmee Basin. Wet prairies were the most valuable of the wetland communities to waterfowl. Under hydrologic conditions during this time, wet prairies were dry from spring through early summer, allowing annual plants such as wild millet to germinate and produce seed. Fall and early winter flooding made wet prairies attractive feeding sites.

In the past, south Florida's wetland habitats have supported a great diversity and abundance of wading birds - one of the largest centers of abundance in the world (Kushlan and White, 1977). Despite the 95% reduction in wading bird population in the state reported since the 1800's, all fourteen species of wading birds found in the eastern United States were reported nesting in Florida in 1977 (Custer and Osborn). The number of wading birds on the Kissimmee River flood plain prior to channelization was estimated at 18,000 birds (USFWS).

The river and flood plain were not discreet and independent ecosystems, and the ebb and flow of their life was closely interrelated. In November, ducks and probers, such as snipe and ibis, fed in the sloughs, potholes and wet prairies in upland areas near the tree line. Many of the same populations used the potholes, oxbows, backwaters, and marshes of the flood plain in February, and the river and the deepest marshes and cypress swamps near the river in May. In the 1950's, peak populations of ducks and wading birds centered in and around Lake Okeechobee ranged out to the Kissimmee, the Upper St. Johns River basin, areas known as the Water Conservation Areas (WCAs) south of Lake Okeechobee, and the northern reaches of ENP when and where water and feeding conditions were most favorable.

LAKE OKEECHOBEE

Lake Okeechobee lies 30 miles west from the Atlantic coast and 60 miles east from the Gulf of Mexico in the central part of the peninsula. Lake Okeechobee is a broad shallow lake which occurs as a bedrock depression. The large, roughly circular lake, with a surface area of approximately 730 square miles, is the principal natural reservoir in southern Florida. Historically, its depth has ranged from about 10 to 20 feet, and its bottom is near sea level. Lake Okeechobee is the second largest freshwater lake wholly within the United States. The drainage area, including the lake area, is about 5,600 square miles. The drainage is derived from the Kissimmee River basin, Taylor Creek, Nubbin Slough, Nicodemus Slough, Fisheating Creek, Indian Prairie Canal, Harney Pond Canal, the Everglades Agricultural Area (EAA), Lake Istokpoga, and contiguous areas.

The lake's largest outlets include the St. Lucie Canal eastward to the Atlantic Ocean and the Caloosahatchee Canal and River to the Gulf of Mexico. The four major agricultural canals, West Palm Beach, Hillsboro, North New River, and Miami Canals, have a smaller capacity, but are used whenever possible to release excess water to the WCAs, south of the lake, when storage and discharge capacity are available. When regulatory releases from the lake are required, excess water can be passed to the three WCAs up to the capacity of the pumping stations and agricultural canals, with the remainder going to the Atlantic Ocean and Gulf of Mexico.

The waters of the lake are impounded by a system of encircling levees, which form a multi-purpose reservoir for navigation, water supply, flood control, and recreation. Pumping stations and control structures in the levee along Lake Okeechobee are designed to move water either into or out of the lake as needed.

The geologic characteristics of the Lake area are similar to those found in the Upper East Coast area although near surface conditions reflect the effect of the flatter nature of the terrain. This has led to the formation of a more organic layer of topsoil in the northern and southern areas of the Lake.

Other surface water bodies include the Kissimmee River, Fisheating Creek, and Taylor Creek which flow into the Lake from the north; the Caloosahatchee River which flows out of the Lake to the west; the St. Lucie and West Palm Beach Canals that flow out of the Lake to the east; and the Hillsboro, North New River, and Miami Canals that flow out of the Lake to the south. The hydroperiod of the Lake is controlled, permitting water levels to fluctuate with flood and drought conditions and the demand for water supply.

The environmental setting of the Lake has been altered significantly by the construction and operation of works designed to reduce nearby flooding and enhance water supply capabilities by regulating lake levels. The levee system that surrounds the lake and the manipulation of water levels have resulted in increased development in contiguous areas.

The effects of water control and the associated changes in the water quality of Lake Okeechobee are being studied by local, State, and Federal agencies. There are concerns about the large inflows of water containing nutrients, phosphates, and pesticides which could have serious and detrimental effects on water quality of the Lake. The SFWMD recently reported that phosphorous concentrations in Lake Okeechobee have reached an all time high of 0.12 parts per million, which well exceeds the SFWMD's targeted level of 0.04 ppm (*Everglades Status: A Report,* October 25, 1988, Prepared by the Office of Planning and Budgeting, Governor Bob Martinez, p. 3).

The water control system surrounding the lake and the associated drainage and settlement have also extensively altered the original plant communities. The resulting distinctive vegetation within the dikes can be classified into four types - dike/berm areas, berm areas/disposal islands, natural islands, and the littoral zone.

The dike/berm areas are covered with herbaceous species maintained by mowing, including Bermuda and Argentine bahia grasses and brown mullet, with invasion by Spanish needles, periwinkles, and pepper and panic grasses.

The berm areas/disposal islands are invaded with exotic tree species such as *Melaleuca*, Brazilian pepper, and Australian pine. The natural islands in Lake Okeechobee contain upland and wetland species.

The limited upland areas are reserved for wild grasses, *Melaleuca*, shrub forests, and citrus, with some fig trees, guava, castor beans, and royal palm. There is a dense cover of torpedo and napier grass, along with Bermuda reed, and water penny wort. Small willows and custard apple trees are scattered, and water hemp can be found in exposed areas.

The littoral zone includes marshes extending from the upland-exotic plant communities at the levees to bullrush, cattail, and spikerush at 10 to 12 feet. The marsh encompasses a band from one-half to nine miles wide on the western side of the lake. The 95,000 acres of marsh support spikerush, beak rush, cattail, willow, bullrush, and wire cordgrass. There is some preserved cypress swamp, most notably near the northeastern shore. Land outside of the levees is devoted primarily to agriculture, with cattle ranchers and dairy farmers to the north, and sugarcane and vegetable growers to the south in the EAA.

Lake Okeechobee is known to support 43 species of fish. It is frequented by both sportsmen seeking mostly crappie, largemouth bass, warmouth, bluegill, and redear sunfish; and by commercial fishermen harvesting catfish and black crappie.

Waterfowl are prevalent at Lake Okeechobee. In addition to the predominant diving ducks, there are a variety of dabblers (including widgeon, pintail, teals, Florida duck, and mallard) which utilize the food and shelter offered by the marshes. Wading birds, such as the great egret, cattle egret, snowy egret, white ibis, glossy ibis, and woodstork also inhabit the marshes.

The Lake Okeechobee area contains several reptiles, including the American alligator, ornate diamondback terrapin, soft-shelled turtle, brown snake, indigo snake, and common mammals such as the raccoon and Florida water rat. Four endangered/threatened species: the endangered manatee (*Trichechus manatus*), woodstork (*Mycteria americana*), Florida Everglade kite (*Rostrahmus sociabilis plumbeus*), and Florida panther (*Felis concolor coryi*) have been identified in this area. The western side of Lake Okeechobee is designated critical habitat for the Everglade kite. One bald eagle (*Haliaeetus leucocephalus*) nest site has been located near the lake.

EVERGLADES AGRICULTURAL AREA

The lands located immediately south and southeast of the lake are known as the Everglades Agricultural Area (EAA). This area of about 700,000 acres is rich, fertile agricultural land. The average ground elevation is about 12 feet. Prior to the mid 1930's, the EAA was largely either undeveloped or devoted to the production of sugar cane crops. However, with the construction of the C&SF Project, the containment of Lake Okeechobee, and the improved runoff handling capabilities south of the Lake, agricultural use has intensified.

The flat nature of the area has permitted the gradual formation of a highly productive soil well-suited for farming. Today, the land is used primarily for sugarcane; along with some truck crops, including beans, celery, cabbage, tomatoes, and peppers. A large portion of the area is devoted to beef-cattle production on improved pasture.

The general soil types near the southeastern shore of Lake Okeechobee are Okeechobee muck and Okeelanta peaty muck; Everglades peat and peaty muck are found farther south. The area is encircled by levees to protect against floodwaters. A network of canals, structures, and levees divides the area to provide for removal of excess water to Lake Okeechobee and the WCAs and for delivery of water from Lake Okeechobee for dry season use.

Included in this area are two non-agricultural areas, the Holey Land and the Rotenberger Tract. The Holey Land encompasses 49.6 square miles of state-owned land. It is mainly wet prairie and marsh, but due to water management practices it receives less water than it did historically under natural conditions.

Four major habitat types exist in the Holey Land, including tree islands, sawgrass marshes, shrub communities, and a mixture of shrubs and sawgrass. The area represents an Everglades environment in transition to a terrestrial plant community of willow, elderberry, salt bush, dog fennel, and wax myrtle.

While fish are limited, 71 species of birds have been identified, predominantly in and around the tree islands. The most common are the yellow throat, yellow-rumped warbler, and red wing blackbird. Wading birds, such as ibis and the great egret, are less apparent due to the dryer conditions. Similarly, mammals are mostly of the small variety - e.g., cotton rat and cotton mouse -although there are some white-tailed deer. There are approximately 10 species of snakes. The endangered woodstork (*Mycteria americana*) is present in this area, and the Holey Land is a possible site for the endangered Florida panther (*Felis concolor coryi*). The SFWMD, in cooperation with the Florida Game and Fresh Water Fish Commission (FGFWFC), (Memorandum of Agreement dated October 7, 1983) is developing a plan to restore the Holey Land by controlling the water level and to monitor changes in water quality and vegetation.

The Rotenberger Tract is 35.5 square miles located west of the Holey Land, and is partially privately-owned. The area is at a slightly higher elevation and contains numerous tree islands which can support more deer.

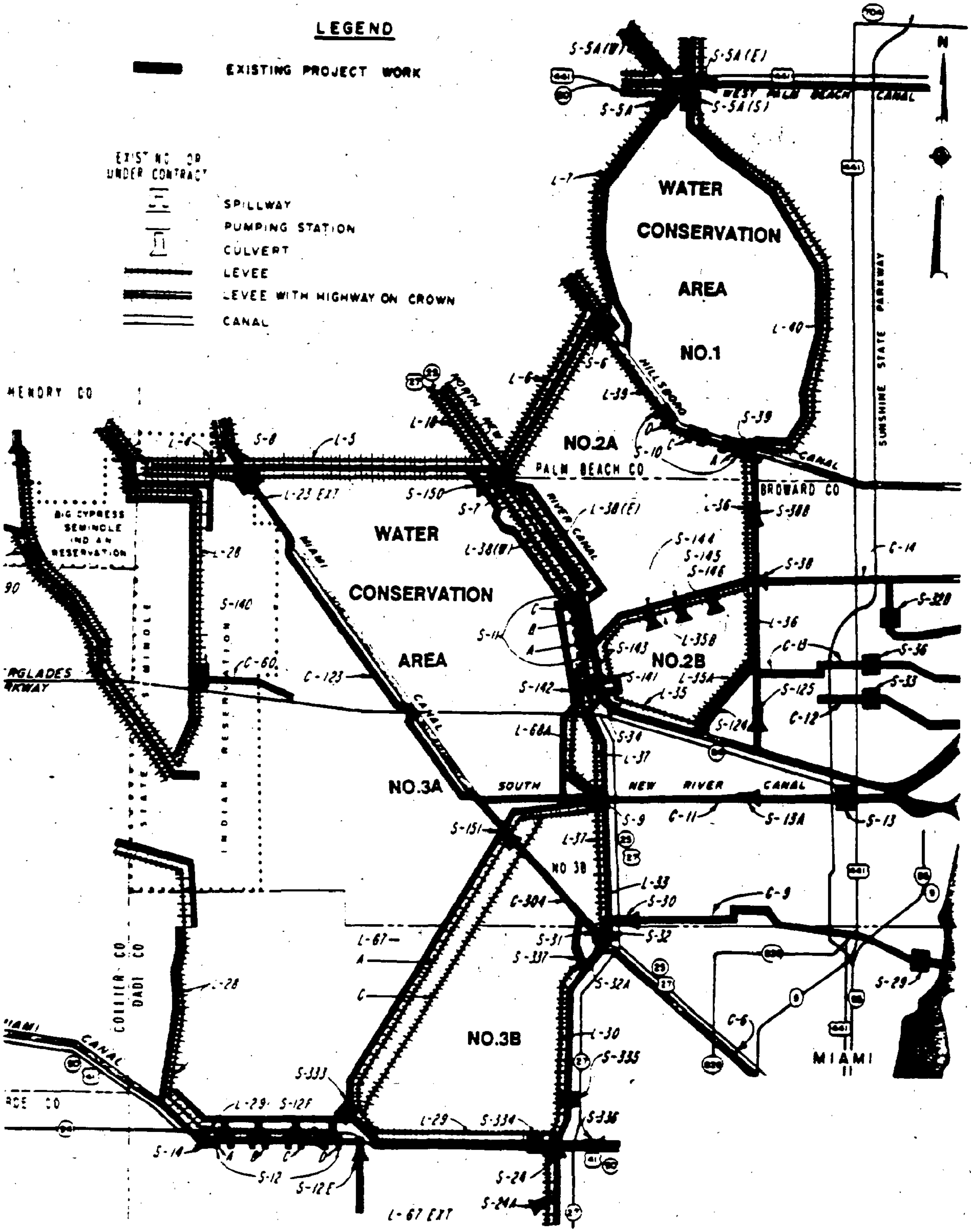
The geological characteristics of this area are similar to other areas except for the near surface soils. These are the result of the prolonged coverage of vegetation on the flat, poorly drained soils. Under this condition, the decaying vegetation developed a layer of organic muck above the normally sandy soil. This layer of muck was originally some 14 to 17 feet thick when cultivation was initiated. However, the highly organic nature of the muck causes an extremely accelerated rate of oxidation when the soil is dried and exposed to open air. Thus, the depth of this layer has been decreasing. Below this topsoil lies a more sandy, limestone formation which is similar to that found in the East Coast area.

The occurrence of surface water in the area is now a direct result of the construction of the numerous conveyance and drainage canals. The Miami, the North New River, and the Hillsboro Canals traverse the area north-south, and the Bolles and the Cross Canals extend east-west. Water levels and flows are stringently manipulated in the canals to achieve optimum crop growth and minimal soil oxidation. Major surface impoundments in the area are non-existent.

WATER CONSERVATION AREAS

General

The Water Conservation Areas (WCAs), Figure 6, are an integral component of the Everglades and freshwater supplies for south Florida. The WCAs, located south and east of the EAA, comprise an area of about 1,350 square miles, including 1,337 square miles of the original Everglades, which averaged some 40 miles in width and extended approximately 100 miles southward from Lake Okeechobee to the sea.



WATER CONSERVATION AREAS

FIGURE 6

The WCAs provide a detention reservoir for excess water from the agricultural area and parts of the east coast region, and for flood discharge from Lake Okeechobee. The WCAs also provide levees needed to prevent Everglades floodwaters from inundating the east coast, while providing a water supply for east coast agricultural lands and the ENP; improving water supply for east coast communities by recharging the Biscayne Aquifer (the sole source of drinking water for southern Palm Beach, Broward, Dade, and Monroe counties); retard salt water intrusion in coastal well fields; and benefit fish and wildlife in the Everglades.

Soils throughout the area are generally Loxahatchee peats. These peats vary greatly in depth and are soft and subject to large volumetric changes when drained. The area is underlain by either a sandy limestone or a highly porous marl. The depth of the surface layer may vary. Throughout the area the deeper substrates are Pleistocene marine and freshwater limestone as well as some shelly sands.

The characteristics and occurrence of surface water in this area have been greatly altered by the construction of the levees and control structures for each WCA. Historically, surface water moved through this area in a more random sheet flow nature with no major well-defined drainage ways. Overland flow generally began in Lake Okeechobee to the north moving southeast across the glades. However, the coastal ridge to the east prevented this water from reaching the Atlantic. Instead, it gradually turned the water westward to eventually empty into the Gulf of Mexico and Florida Bay areas via the ENP area. During floods, much water flowed out of the Everglades through the transverse glades in the coastal ridge to the Atlantic Ocean.

However, with the construction of the major drainage canals in the 1920's and the later construction of the WCAs in the 1950-60's, surface flow patterns were greatly altered. The major canals provided the means to drain surface water directly to the Atlantic Ocean. The WCAs provided the means to intercept and retain surface flow until such time as it could be released as desired. This has led to almost a complete regulation and control of the surface flow through this area. Water levels are now a direct result of the superimposed regulation schedules by which the overall system is operated. The net result is an increased hydroperiod (or the time over which an area is inundated) for most areas within the WCAs and a decreased hydroperiod for certain areas immediately adjacent to and/or downstream of the WCAs. Not only has the duration of inundation been altered but so has the depth. This has been most noticeable along the leveed borders of the WCAs where permanent surface water is now found.

Vegetation in the area consists chiefly of mixed varieties of grasses and semitropical water plants and sawgrass. This vegetation, when undisturbed by fire or prolonged flooding, effectively covers the ground to heights of 3 to 6 feet. There are also many hammocks of myrtle and bay which grow to a height of 10 feet.

Three major habitat types exist in these WCAs: tree islands, sawgrass marshes, and wet prairies (including sloughs). The tree islands are inhabited by wax myrtle, red bay, and swamp and royal fern. Sawgrass marshes support mostly wetland species of button bush, willow, and wax myrtle. The wet prairies contain typical wetland vegetation, including maidencane, spikerush, and beakrush. Sloughs in these areas are more reminiscent of the ideal Everglades pattern and support aquatic species such as water lotus, water hyssop, and bladderwort.

While parts of the southern WCAs are more typical of the Everglades, the more northern regions (WCA 3A, e.g.) display some transitional terrestrial understory vegetation. WCA 2 also varies from the Everglades environment, in this case due to the effects of the extended hydroperiod and increased water depths caused by impoundment. As a result, in WCA 2, the original plant communities - wet prairies, sloughs, tree islands, and open marsh - have been altered. Major plant communities include remnants of tree islands, with dahoon holly, wax myrtle, and red bay; open water sloughs, supporting such plants as water lotus and bladderwort; and large areas of sawgrass mixed with cattail.

The wet prairie vegetation has been virtually destroyed. Recent draw-down efforts designed to restore the natural alternation between wet and dry seasons have meant an increase in slough and wet prairie species, and some new herbaceous growth on the tree islands. Because of the slow movement of water in those densely vegetated areas, rapid removal of flood storage from the interior of those areas via the canals is limited.

WCA 1 is designated as the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge) managed by the USFWS. WCAs 2 and 3 are public hunting and fishing areas comprising the Everglades Wildlife Management Area maintained by the FGFWFC.

The WCAs are rich in fish and wildlife resources. The Florida Panther, Everglades Kite, Wood Stork, the American Alligator, and White-tailed Deer are only a few of the species that inhabit the WCAs.

The WCAs are frequented by wading birds. Prawns, crayfish, and fish, including the Florida gar and flagfish, are well adapted to the wet conditions and white-tailed deer tolerate wet conditions in some of the areas.

The endangered woodstork (*Mycteria americana*) and Everglade kite (*Rostrhamus sociabilis plumbeus*) inhabit parts of the WCAs. Much of the area has been designated as critical habitat for the Everglade kite. In fact, the USFWS manages the Refuge (WCA 1) to protect the Everglade snail kite and maintain the marsh habitat and apple snails critical to the kite's survival.

Water Conservation Area 1

WCA 1 is about 21 miles long from north to south and comprises an area of 221 square miles. The West Palm Beach Canal lies at the extreme northern boundary,and on the south the Hillsboro Canal separates WCA 1 from WCA 2. Ground elevations slope about 5 feet in 10 miles, both to the north and to the south from the west center of the area, varying from over 16 feet in the northwest to less than 12 feet in the south. The area, which is enclosed by about 58 miles of levee (approximately 13 miles of which are common to WCA 2), provides storage for excess rainfall, excess runoff from agricultural drainage areas of the West Palm Beach Canal (230 square miles) and the Hillsboro Canal (146 square miles), and excess water from Lake Okeechobee. Inflow comes from rainfall and runoff from the EAA through canals at the northern end. Release of water for dry-season use is controlled by structures in the West Palm Beach Canal, the Hillsboro Canal, and in the north-south levee which forms the eastern boundary of the area. When stages exceed the regulation schedule, excess water in WCA 1 is discharged to WCA 2.

The Refuge was established in 1951 by an agreement with the SFWMD and the USFWS. It is made up of sawgrass marshes, wet prairies, sloughs, and tree islands. Endangered and threatened species such as the snail kite and the American alligator live in this wetland habitat. The USFWS has the responsibility of managing and protecting the wildlife resources of the Refuge. Over 250 species of birds live at the Refuge, including ibises, egrets, herons, and snail kites. Migratory ducks such as blue-winged teal and ring-necked ducks are plentiful during the winter months along with the resident mottled ducks and wood ducks. Raccoons, river otters, bobcats, and white-tailed deer also live on the Refuge, as well as rabbits, coveys of bobwhite, and small reptiles.

Water Conservation Area 2

WCA 2 is comprised of two areas, 2A and 2B, and measures about 25 miles from north to south and covers an area of 210 square miles. It is separated from the other WCAs by the Hillsboro Canal on the north and the North New River Canal on the south. Ground elevations slope southward at 2 to 3 feet in 10 miles, ranging from over 13 feet in the northwest to less than 7 feet in the south. The area is enclosed by about 61 miles of levee, of which approximately 13 miles are common to WCA 1 and 15 miles to WCA 3. An interior levee across the southern portion of the area reduces water losses due to seepage into an extremely pervious aquifer at the southern end of the pool and prevents overtopping of the southern exterior levee by hurricane waves.

The upper pool, WCA 2A, provides a 173-square-mile reservoir for storage of excess water from WCA 1 and a 125-square-mile agricultural drainage area of the North New River Canal. Storage in WCA 2A provides water supply to the east coast urban areas of Deerfield Beach and Fort Lauderdale and irrigation water to approximately 75,000 acres of east coast agricultural area bordering the Pompano Canal (C-14) and Middle River Canal (C-13) areas. Water enters the area from WCA 1 and the Hillsboro Canal on the northeast side, and from the North New River Canal on the northwest side. Water in excess of that required for efficient operation of WCA 2A is discharged to WCA 3 via structures into C-14, the North New River Canal, and WCA 2B.

WCA 2B has ground elevations ranging from 9.5 feet in the northern portions down to 7.0 feet in the southern portions of the area. The area experiences a high seepage rate which does not allow for long term storage of water, and as a result, water is not normally released from the area.

Water Conservation Area 3

WCA 3 is also divided into two parts, 3A and 3B. It is about 40 miles long from north to south and comprises about 915 square miles, making it the largest of the conservation areas. Ground elevations, which slope southeasterly one to three feet in ten miles, range from over 13 feet in the northwest to six feet in the southeast. The Miami Canal traverses the area from northwest to southeast, and the North New River Canal separates it from WCA 2. The area is enclosed by about 111 miles of levee, of which 15 miles are common to WCA 2. An interior levee system across the southeastern corner of the area reduces seepage into an extremely pervious aquifer.

The upper pool, WCA 3A, provides a 752-square-mile area for storage of excess water from WCA 2A, rainfall excess from approximately 750 square miles in Collier and Hendry Counties and from 71 square miles of the Davie agricultural area lying east of Pumping Station 9, and excess water from a 208-square-mile agricultural drainage area of the Miami Canal and other adjacent areas to the north. Water enters WCA 3A from various sources on the northern and eastern sides. The storage is used to meet the principal water supply needs of adjacent areas, including urban water supply and salinity control requirements for Dade County, irrigation requirements, and water supply for the ENP.

LOWER EAST COAST AREA

The Lower East Coast area, which consists of the coastal ridge section in Palm Beach, Broward, and Dade Counties, is a strip of sandy land which forms the eastern border of the WCAs. The ground surface of the flatlands in the west ranges from about 25 feet in the upper part of the region to about 5 feet in lower Dade County. The coastal ridge is comprised of broad, low dunes and ridges with elevations ranging from 10 to 25 feet. This ridge area ranges from 2 to 4 miles in width from the northern part of the area down to northern Miami. South of Miami the ridge becomes less pronounced but significantly wider.

The Lower East Coast area is the most densely populated part of the State. The largest population centers are near the coast and include the cities of Miami, West Palm Beach, Fort Lauderdale, and Hollywood. The coastal canals are controlled near the coastal shoreline to prevent overdrainage and to resist salt water intrusion through these canals into the ground water and well fields upon which the urban areas depend for a potable water supply.

This area is characterized by sandy flatlands to the west, the sandy coastal ridge, and the coastal marsh and mangrove swamp areas along the Atlantic seaboard. The northern portion, generally that part north of Dade County, marks the shore of a higher Pleistocene Sea and occurs as one or more relict beach ridges. The southern portion appears to be marine deposited sands or marine limestones.

Extensive development has resulted in nearly complete urbanization of the coastal region from West Palm Beach southward through Miami, and these physiographical characteristics have been greatly overshadowed. South of Miami, in Dade County, this coastal area widens as the Everglades bends to the west to include urban areas and agricultural areas that extend almost to the southern coast. Dade County's agricultural industry covers more than 83,000 acres in the southwest of the coastal metropolitan. Vegetables, tropical fruits, and nursery plants are grown in this area.

The Atlantic Coastal Ridge supported pine or mixed forests and contained natural drainage ways through which water flowed from the Everglades to the Atlantic Ocean during high water periods. Coastal marshes and swamps generally surround the bays and inlets.

Southeast of the Everglades and Atlantic Coastal Ridge is the Southern Slope. This area is composed of mangrove swamps and coastal glades. The mangrove swamps formed a belt just inland from the barrier beaches on the northeast part of the Southern Slope, and only relics of these mangroves exist today. To the south, they broaden into a band eight to ten miles wide and range in elevation from slightly below sea level to approximately two feet.

Behind the mangrove swamps lie the coastal glades or freshwater marshes composed of layers of calcite mud soils, called Perrine Marl, and peat. These soils vary in depth from less than one foot to over six feet and cover limestone. The soils thin gradually inland until the bedrock of Miami Oolite outcrops and provides the separation between the Southern Slope and the Everglades. The predominate vegetations of the middle portion of the Southern Slope are sawgrass, spike rush, willow marshes, and dwarf cypress.

The environment of the Lower East Coast has been seriously altered by both urban and agricultural development. Much of what was once wetland or marsh, for example, is now utilized for agriculture - including vegetables, citrus, sugarcane, and grazing - or residential and related urban growth. Similarly, the natural surface water regime and sheet flow has been converted into a system of canals, levees, and control structures. There are no significant areas of surface storage east of the WCAs.

The climate resembles that of most of south Florida and is characterized by long hot summers and short mild winters. Temperatures range from a mean low of around 67° in February to a mean high of 83° in August. Most of the average 60 inches of rainfall per year occurs between May and October. The area is subject to hurricanes and tropical storms, on the one hand, and droughts, on the other.

The geology in this area is characterized by sandy topsoil overlying a very porous marl and limestone formation. Much of the Lower East Coast is comprised of the coastal ridge which historically formed the shoreline of the lower coast. The ridge itself is the remnant of the sea and wind-swept dune system common to seaside areas. The occurrence of large scale marl deposits reflects the historical inundation of the area during periods of higher sea levels. The extremely flat nature of areas surrounding the ridge was very conducive to the deposition of marine sediments and the subsequent formation of the marl. Deeper in the area, the limestone common to the western areas becomes predominant, exhibiting many of the same characteristics found elsewhere in the study area.

Vegetation and the wildlife supported by it is varied. Those areas not devoted to agriculture or urban development range from pine flatwoods, saw palmetto prairies, and prairie grasslands in the northern section, to cypress swamps, prairies and marshes, and mangrove swamps farther south.

The Loxahatchee Slough, located in Palm Beach County, is typical of the Lower East Coast area due to its natural sheet flow now being regulated by a control structure (S-46). The original wet prairie and marsh vegetation has been replaced by increased drainage and the resultant changes in hydroperiods, development, timbering practices, and the invasion of exotics. The cypress swamps have suffered the effects of logging and have been invaded by *melaleuca*. Because of dryer conditions, wetlands and prairie areas are now inhabited by slash pine, and marsh areas now support wax myrtle, saltbush, and Brazilian pepper.

Despite these changes, in addition to the deer, foxes, raccoons, and armadillos which can be found in this area, there are five endangered and two threatened species. These include the endangered red-cockaded woodpecker (*Dendrocopos borealis*), Florida Everglade kite (*Rostrhamus sociabilis plumbeus*), Kirtland's warbler (*Dendroica kirtlandii*), peregrine falcon (*Falco peregrinus tundrius*), and bald eagle (*Haliaeetus leucocephalus*), and the threatened eastern indigo snake (*Drymarchon corais couperi*) and American alligator (*Alligator mississippiensis*).

Located south of the Loxahatchee Slough, the area around the West Palm Beach Canal displays similar shifts from original sawgrass, marsh, cypress forest, and wet prairie to slash pine forests with scattered cabbage palm, saw palmetto, and some cypress. The exotic Australian pine was planted to reduce erosion along the canal. The same endangered and threatened species identified in the Loxahatchee Slough can be found in this region as well.

Sections of Palm Beach and neighboring Broward Counties support prairie grasslands and cypress swamps. The prairie grasslands are characterized by wire cordgrass, sawgrass, beakrush, and needlegrass. This vegetation provides habitat for the sandhill crane and burrowing owl, as well as numerous reptiles and mammals. It is subject to flooding and often utilized for cattle grazing. The flora and fauna of the swamp forests are adapted to the fluctuating water levels common in these areas. Vegetation (including sawgrass, cypress, cocoa plum, air plants, and invading *melaleuca)* and fish and wildlife (reptiles, birds, deer, bears, and panthers) are well-suited to this environment.

While agriculture and urbanization have claimed much of Dade County, this most southern area of the Lower East Coast does retain some of its natural environment. There is land around C-111, for example, which continues to be occupied by freshwater prairies, wetlands, and mangroves. Cypress domes and bayheads (containing red bay, cocoa plum, myrsine, poisonwood, and ferns) are scattered within the broad plain. The graminoid plain boasts a mixed community of muhly grass, beardgrass, maidencane, sawgrass, and spikerush. Farther south, spike rush, sawgrass, and red mangrove predominate.

This southern area provides rich and varied habitat for numerous species of birds, mammals, reptiles, amphibians, and fish. The Upper Florida Bay serves as a nursery area for pink shrimp, red drum, croaker, and sea trout, in part due to its lower salinity. The coastal marshes are more suited for snook, tarpon, ladyfish, and mullet. In addition, five endangered species have been located in this area. These are the Cape Sable seaside sparrow (*Ammospiza maritima mirabilis*), American crocodile (*Crocodylus actutus*), Florida panther (*Felis concolor coryi*), West Indian manatee (*Trichechus manatus*), and bald eagle (*Haliaeetus leucocephalus*). Designated critical habitat exists for the Cape Sable seaside sparrow, the manatee, and the Florida crocodile. In fact, an 18,000-acre sanctuary has been created for the crocodiles in the northeastern portion of Florida Bay.

BISCAYNE BAY

Biscayne Bay is a shallow, tidal sound located near the extreme southeastern part of Florida. Its original areal extent approximated 216 square miles, but it has since undergone major areal modifications as a result of development. Most shorelines and the northernmost extent of the bay have been greatly modified by dredging and filling such that the original headwaters no longer exist. The head is now considered to include dredged areas known as Maule Lake and Dumfoundling Bay, near the northern boundary of Dade County. The bay extends about 38 miles in a south-southwesterly direction from Dumfoundling Bay on the north to Card Sound on the south. It varies in width from less than 1 mile in the vicinity of the IWW passage to Dumfoundling Bay, to about 9 miles between the mainland and the reefline extending southward from Key Biscayne Island.

Depending upon the flood stages reached, all C&SF Project canals in adjacent Dade County can carry floodwaters to Biscayne Bay. However, much of the time, discharges from project canals represent primarily runoff or seepage from within the protected area of the county. These flows originate in the extensive networks of secondary drainage canals and storm sewers that discharge into the project canals. Supplementing the complex system of project canals and secondary drainage systems are many hundreds of other stormwater drainage canals and storm sewer outfalls within Dade County that discharge freshwater directly into Biscayne Bay.

Biscayne Bay is essentially a semi-closed system with restricted tidal flushing. It has a variable freshwater input from drainage canals and experiences extremes in temperature and salinity. The bay bottom is covered with silt and sand layers of varying depths that greatly influence the occurrence of community types.

The marine communities within the bay are extremely rich and varied. The most extensive bay-bottom community is turtle grass with sub-components of manatee grass, whose productivity is one of the highest of any marine type. It is the nursery ground for commercial shrimps and lobsters, as well as for many species of bay fishes. The principal organisms grazing on these grass beds are sea urchins and certain parrot fishes in the vicinity of patch reefs, but a great variety of other species depend indirectly on the shelter of substrate niches.

EVERGLADES NATIONAL PARK

Everglades National Park (ENP) encompasses 2,150 square miles of wetlands and submerged lands at the southern end of the Florida peninsula. The topography is extremely low and flat. Most of the area is below four feet, with the highest elevation (six to seven feet) found in the northeastern section. The coastal areas of the Park are highly susceptible to the influence of salinity from tidal action.

ENP was formally established by Congress in 1947 to preserve the unique ecology of the Everglades and is the second largest national park in the continental United States. It has been designated by the United Nations as a World Heritage Site. It has also been named as a Federal Wilderness Area, an International Biosphere Reserve, and a Wetland of International Significance. It is also one the nation's 10 most endangered parks. Since the 1930's, the Park's population of wading birds has dropped by 90 percent, its nesting bald eagle population is down and wood stork breeding has been halved since 1970. ENP is an aquatic environment and is dependent on seasonal rainfall and overland flow from the north. Historically, approximately half of the Park's water flowed in from the Everglades and Big Cypress Swamp.

The preservation of the Park is largely dependent on the continuance of water conditions which were instrumental in its formation. Prior to the settlement and development of central and southern Florida, overflow from the lower Everglades and during large floods from Lake Okeechobee and its tributary areas, flowed slowly through heavily vegetated areas west of the coastal ridge; much of it discharged into the area which now constitutes the ENP. However, drainage and flood control measures which were necessitated by urban and agricultural development and expansion have modified the original drainage pattern and the natural balance of fresh water and salt water volume and seasonal distribution of flow.

Adjacent to the Park and integrally linked to its ecological balance is an area designated as the East Everglades, which includes the Northeast Shark River Slough. Bordering the Park on the east, it is privately-owned and is inhabited and utilized by individual homeowners and agriculturalists. Over 90 percent of this area is undeveloped, and it serves as a buffer protecting the Park from encroaching growth and development.

SHARK RIVER SLOUGH

While not part of the ENP boundary, the Northeast portion of the Shark River Slough is included in this study as part of the ENP. The historic Slough was the principal pathway of water draining slowly southward from Lake Okeechobee to tidewater. Water flowed from Lake Okeechobee, and then:

- through what is now WCA 3A;

- through what is now WCA 3B;

- through the area now called Northeast Shark River Slough (NESRS), which is bordered by Levee 67 (L-67) Extension on the west; L-29, which is the southern component of WCA 3, and is adjacent and parallel to U.S. Route 41 (the Tamiami Trail) on the north; and L-31N on the east;

- and through the portion of ENP immediately south of L-29, the southern boundary of WCA 3A (sometimes called the "Chimney" of ENP).

Under natural conditions, the eastern boundary of the Everglades extended eastward to the coastal ridge. However, these areas have been developed and extensive urban and agricultural development which now exist in the historic peripheral Everglades. The Shark River Slough is a very broad (as much as 40 miles, depending upon season), shallow, natural drainage way at a slightly lower elevation than the surrounding Everglades.

The area known as East Everglades includes the NESRS and a developed area along the slough's eastern boundary. It is bounded on the north by L-29, on the east by L-31N, on the south by ENP, and on the west by ENP and L-67 extension.

Eight different vegetative associations are located in the area: sawgrass Everglades, mangrove forest, salt marsh, cypress forest, pine forest, mixed West Indian hardwood hammock forest, bayhead, and Cape Sable saw palmetto salt prairie. The vegetative communities most strongly affected by hydroperiod change are wetlands, particularly sawgrass marshes, spike rush flats, and prairies and the more hydric forest communities, such as bayheads, bayhead-hammocks and cypress formation.

About 300 species of birds have been identified in the ENP. Southern Florida's location makes it a migratory crossroads for West Indian and Central and South American birds. Numerous North American species are residents. Many of this continent's species of wading birds, shorebirds, and water fowl are represented here at some time of the year. Many of them are nesting residents, including some which seldom range farther north and others which have disappeared from areas where they once occurred.

The current alligator population has recovered from an estimated 80 to 90 percent reduction in numbers since the late 1800's. However, the current population is recovering in very changed conditions in Shark River Slough. NESRS, which historically received more water, now receives less, and the western slough inside the ENP where alligators are concentrated now receives more water than it did before minimum delivery schedules were imposed in 1971.

ENP's waters support a large variety of fish in both freshwater and salt water habitats. Fish populations in ENP's portion of Shark River Slough are seasonally and annually variable, being affected by both ambient and antecedent water conditions.

The ENP is classified as a subtropical wetland. Ninety-eight percent of the area is either permanently or seasonally under water. Its subtropical climate means warm temperatures - varying from a mean high of about 81° to a mean low of 66° - light winds, and alternating wet and dry seasons. The average annual rainfall of 57 inches represents the effects of tropical storms and hurricanes, and 85 percent occurs between May and October.

Water is introduced to the Park not only through precipitation, but by overflow and discharge through control structures from WCA 3A. Although the ENP receives water originating from areas affected by urban development and agricultural activities, Congress has enacted legislation to guarantee the quality of water entering the Park. The ENP depends upon regulated surface water flow, which is delivered from the Shark Slough through S-12, Taylor Slough (L-31W Canal), and C-111 cutouts.

The constant inundation of the area maintains the organic nature of much of the soil. This peat is intermixed with marl soils, particularly in the areas of rocky limestone outcrops.

Eight vegetation communities exist in the ENP, including sawgrass, mangrove forest, saltmarsh, cypress forest, pine forest, mixed West Indian hardwood hammock forest, bayhead, and Cape Sable saw palmetto salt prairie. Sawgrass and mangrove forests occur in areas which are inundated for part of the year. The sawgrass prairies are located inland in higher elevations on marl or muck soils, which are wet when flooded and subject to fires during the dry winter and spring.

The sedges, grasses, and marsh plants are replaced by mangrove forests near the coast which display red mangroves closest to the coast, black mangroves farther inland where there is greater salt content, and white mangroves in areas following floods. Dispersed in these forests are areas of salt marsh with cord grasses and rushes.

Farther inland, the cypress belt extends southeast to northwest across the Park and supports airplants, orchids, and cypress trees dwarfed by the lack of humus accumulation. The pine forests are intertwined with Indian hardwood hammocks which occur in areas with humus, marl, or rock and of great enough elevation to avoid saltwater intrusion, flooding, and fires. Tree islands with bayheads occur in elevated areas with peat soil, while cypress heads occupy shallow ponds.

The bayheads support red bay, magnolia, myrtle, willow, and holly, and are extremely susceptible to the damaging effects of fires. The Cape Sable salt prairies develop on marl flats and give rise to grass and shrubby vegetation - including cabbage palm, prickly pear, agave, and seaside lavender - and scattered buttonwood hammocks.

The ENP provides habitat for 27 species of mammals, over 300 species of birds, 3 to 4 species of salamanders, 6 species of lizards, 10 species of land and sea turtles, 12 frogs, and 23 snakes. Fifteen of these species are designated as endangered or threatened.

Mammals include the white-tailed deer, black bear, panther, opossum, raccoon, wildcat, otter, porpoise, and manatee. Most species of wading birds, shorebirds, and waterfowl frequent the Park, such as the sandhill crane, lumpkin, anhinga, cormorant, brown and white pelicans, and frigate.

Many others use it for feeding and nesting, including the roseate spoonbill, great white heron, reddish, great and snowy egrets, littleblue heron, woodstork, white and glossy ibis, bald eagle, and Everglade kite. There are crocodiles and alligators and large populations of sunfish, mullet, and saltwater catfish.

Included in the impressive list of fauna in the Park are the following endangered (E) and threatened (T) species: Florida panther (*Felis concolor coryi* - E), West Indian manatee (*Trichecus manatus* - E), Florida Everglade kite (*Rostrhamus sociabilis plumbeus* - E), bald eagle (*Haliaeetus leucocephalus* - E), Cape Sable seaside sparrow (*Ammospiza maritima mirabilis* -E), American alligator (*Alligator mississippiensis* - T), green turtle (*Chelonia mydas* - E), American crocodile (*Crocodylus acutus* - E), Atlantic ridley turtle (*Lepidochelys kempii* - E), loggerhead turtle (*Caretta caretta* - T), hawksbill turtle (*Eretmochelys imbricata* - E), leatherback turtle (*Dermocheloys coriacea* - E), Eastern indigo snake (*Drymarchon corais couperi* - T), Arctic peregrine falcon (*Falco peregrinus tundrius* - T), and the woodstork (*Mycteria americana* - E). The Park provides critical habitat for the manatee, Cape Sable sparrow, Everglade kite, and crocodile.

The East Everglades, including the Northeast Shark River Slough, borders the Park and is a significant part of the water recharge area for the Biscayne Aquifer. It is also an area of surface water runoff for the eastern section of the Park. The environment in the East Everglades is similar to that of the ENP, and the two areas are integrally related.

While only 3,000 acres of land are under cultivation in the East Everglades, 65 percent of the area retains its wetland characteristics. In addition to the rainfall, surface water is introduced from WCA 3A and seepage under L-29 from WCA 3B into the Tamiami Canal and ultimately into the Northeast Shark River Slough. Soils consist mainly of Everglades, Gandy, and Loxahatchee peats, which are poorly drained. Other areas are primarily rockland of Miami Oolite or porous, solution-ridden Tamiami Limestone with a very thin covering of unconsolidated soil material. The central portion of the rockland contains pinnacle rock, which is considered rare.

The marsh habitats in the East Everglades support sawgrass, spike rush, beakrush, maidencane, and cattail. Also prevalent are combined mesoic graminoid communities with muhly and beard grass. Like the adjacent Park, there are cypress trees, hardwood hammocks, prairie, willows, and mangroves. The original vegetation has been altered by reduced hydroperiods, causing increased growth of broadleaved trees and greater invasion by exotics, such as Australian pine, Brazilian pepper, and *melaleuca*. Fires have resulted in the spread of willow heads and cattail marshes.

This Everglades environment in the East Everglades supports over 350 species of animals. Most dominant are the 34 species of fish - including mosquitofish, golden topminnow, and killifish - 18 species of amphibians, and 44 species of reptiles - including pig and leopard frogs, water snakes, and alligators. The 28 species of mammals include white-tailed deer, otters, raccoons, and rabbits. More than 230 species of birds feed, nest, and/or migrate in the East Everglades.

Not only do the wildlife populations of the East Everglades resemble those of the ENP, but they move freely between the two areas. Seven of the endangered and two of the threatened species present in the Park are also found in the East Everglades. These are the endangered Florida panther, Florida Everglade kite, bald eagle, Cape Sable seaside sparrow, American crocodile, Arctic peregrine falcon, and woodstork, and the threatened American alligator and eastern indigo snake. The East Everglades also provides critical habitat for the Cape Sable seaside sparrow and the American crocodile.

The hydrology of the southern Everglades was altered by the construction of L-67A, L-67C, and L-29 flood control levees. Unseasonably high water conditions in the ENP in 1983 prompted Park officials to request emergency measures to be taken to correct the hydrologic imbalance and restore sheet flow to the northeast Shark River Slough. Congress authorized and the Corps conducted a program of experimental water deliveries to the Park.

In December 1989, President Bush signed the *Everglades National Park Protection and Expansion Act*. This act authorizes expansion of the ENP to include an additional 107,600 acres and authorized the construction of modifications to the C&SF Project to the benefit of the ENP in Dade County. The primary objective of this project is to enhance the natural resources of ENP in Shark River Slough through structural and operational water management alterations to the C&SF Project. A secondary objective is to develop an initial operating plan based on restoring, to the extent possible, the natural hydrologic conditions with the ENP and other contiguous Everglades habitat that may be necessary to achieve the primary objective. A flood mitigation system is proposed for a residential area in the east Everglades.

FLORIDA BAY, WHITEWATER BAY, AND THE TEN THOUSAND ISLANDS

Florida Bay and the Ten Thousand Islands comprise 1,500 square miles of ENP. The mangrove estuaries, where fresh water from the sawgrass marsh merges with salt water from the Gulf of Mexico, provide a nursery for the species that feed Florida's commercial fishing industry. The brackish fringes are breeding grounds for shrimp, stone crab and lobster, which alone mean $60 million annually to the state. Blue crabs, mullet and other fish also begin their lives here. In the Ten Thousand Islands and Florida Bay, tarpon, snook and redfish fishing are a $9 million industry. ENP's water supply is crucial to the health of Florida Bay. If there is not enough water flowing through the Everglades, then the bay gets too salty. Studies indicate Florida Bay is saltier than it should be. Southwest of the Southwestern Slope and the Everglades are the Reticulate Coastal Swamps composed primarily of mangroves and salt marshes, and includes the area known as the Ten Thousand Islands.

BIG CYPRESS BASIN

Much of the Big Cypress Basin watershed consists of variegated areas of swamps, marshes and sloughs that regenerate aquifers on which both urban and rural populations rely for water supply. Elevations in the Big Cypress Swamp are slightly higher than the Everglades to the east. Big Cypress Swamp spans approximately 1,205 square miles (771,000 acres) from southwest of Lake Okeechobee to the Ten Thousand Islands in the Gulf of Mexico. Because of its relative flatness, the Big Cypress Swamp is covered with water for several months each year. It is considered to have the best quality surface water in south Florida.

The Big Cypress Swamp is the primary home of the highly endangered Florida Panther and it contains numerous species of other endangered plants and wildlife. The 570,000-acre Big Cypress National Preserve (BCNP) was established by *Public Law 93-440* in 1974 to protect natural and recreational values of the Big Cypress watershed and to allow for continued traditional uses such as hunting, fishing, and oil and gas production. It was also established to provide an ecological buffer zone and protect the ENP's water supply. In 1988, Congress passed the *Big Cypress National Preserve Addition Act* which will add 146,000 acres to the BCNP.

The preserve consists of primarily undeveloped land containing cypress, pineland, and marsh communities, and is located in southwest Florida adjacent to the northwest side of ENP. Elevations range from 14 feet to sea level at the coast. There are more than 120 miles of canals and 39 structures which serve to provide drainage and storage of surface water within the Big Cypress Basin. This area contains almost 40 percent of the Big Cypress Swamp and, like the ENP, the BCNP is characterized by a water-dominated ecology. During the wet season, as much as 90 percent of the area is inundated while during the dry season, as little as 10 percent remains inundated, mostly in shallow ponds and sloughs. Plants and animals are basically aquatic and have adapted to fluctuating seasonal water levels. Wildlife within the BCNP, consists of numerous species of amphibians, reptiles, birds, and mammals. Several of these are classified as threatened or endangered by the USFWS.

Since the Preserve is generally flat, there are no well-defined streams. The slight gradient, combined with a dense vegetation cover, slows the movement of water. As the water level rises with the progression of the wet season, the natural sheet flow begins in the strands and sloughs and overflows into adjacent marshes. The water from the BCNP flows to the ENP. The water quality in this area has been designated as "Outstanding Florida Water".

Geologically, the Preserve occupies a bedrock of marine sands and limestone deposited during the Miocene - Pleistocene era. Soils consist of a thin layer of marl, sometimes mixed with sand, covering deeper strata of peat at the center of cypress domes.

Not surprisingly, the environment in the BCNP is dictated by the hydroperiods, and plants and animals well-suited to water fluctuations are found here. The vegetation communities include pine-palm-palmetto forest, wet prairie and marsh, freshwater swamp, and cypress forest. The pine-palm-palmetto forests occur in the dryer areas with the greatest elevation, and are inhabited by fire-adapted trees and shrubs, such as the slash pine, cabbage palm, saw palmetto, wax myrtle, and red bay.

Wet prairie and marsh appear at the ground elevation and are characterized by alternating wet and dry seasons. Although the marsh areas are wetter, they do experience dry periods as well. These areas are largely treeless with emergent vegetation such as scrub grasses, spikerush, and maidencane. The freshwater swamps are inundated most of the year and support hardwood, palms, airplants, orchids, and epiphytic ferns.

The cypress forests occupy the lowest elevation. Like the freshwater swamps, they are inundated for most of the year, and also foster growth of ferns, orchids, and bromeliads. They are distinguished, however, by cypress, not present in the swamps. The BCNP is also subject to exotic invasion by *Melaleuca* and Brazilian pepper.

Aquatic life adapted to the Big Cypress environment - prawns, mosquitofish, killifish, bass, and gar - as well as reptiles and amphibians inhabit the area. Also present, and sought after by hunters, are white-tailed deer, turkey, bobwhite quail, feral hog, gray squirrel, snipe, morning dove, marsh rabbit, raccoon, armadillo, and opossum.

The unique environment of the BCNP is ideal for numerous endangered and threatened species. The endangered Florida panther (*Felis concolor coryi*), woodstork (*Mycteria americana*), Cape Sable sparrow (*Ammospize maritima mirabilis*), red-cockaded woodpecker (*Demdrocopus borealis*), bald eagle (*Haliaeetus leucocephalus*), and Everglade kite (*Rostrhamus sociabilis plumbeus*), and threatened eastern indigo snake (*Dry marchon corais couperi*), have all been located in this region. Other species of concern to the State, such as the Florida tree snail, mangrove fox squirrel, and black bear, also inhabit the Preserve. The habitats of these species are subject to modification by logging activities, shortened hydroperiods, increased wildfires, and the invasion of exotic plants.

The National Park Service's (NPS) task of managing the environment in the BCNP is complicated by permissible usages by hunters, farmers grazing cattle, and the Seminole and Miccosukee Indians who have been granted the right to hunt and continue traditional ceremonial practices.

LOWER WEST COAST

The Lower West Coast region covers approximately 4,000 square miles in Lee, Hendry, and Collier Counties and a portion of Charlotte County. This area is generally bounded by Charlotte County to the north, Lake Okeechobee and the EAA to the east, the BCNP to the south, and the Gulf to the west. The area is characterized by the sandy flatlands region of Lee County, which give way to sandy though more rolling terrain in Hendry County; and the coastal marshes and mangrove swamps of Collier County. Most of the region is less than 15 feet above mean sea level.

Tourism is important to the economy of the area, particularly in coastal towns such as Naples and Fort Myers. The principal occupation in the remainder of the region, is truck farming, based predominantly on tomatoes, cucumbers, peppers, and watermelons, although cattle raising is also prevalent. Oil production adds to the economy, with an oil field located at Sunniland in central Collier County.

The West Coastal Watershed covers 2,197,000 acres along the Gulf coast from Charlotte County on the north to mainland Monroe County on the south. It is divided into two sub-watersheds: Coastal and Big Cypress sub-watersheds. The Coastal sub-watershed drains westerly to the Gulf of Mexico via the Caloosahatchee River and many small coastal streams. The Big Cypress sub-watershed includes all of the Big Cypress Swamp drainage area except the northeast corner, which drains into the WCAs (the Hendry-Collier sub-watershed).

The 1,278,200 acres of the Big Cypress sub-watershed is characterized by a swampy area which emerges into a coastal marsh on the southwest area of the peninsular. Because of poor drainage, as much as 90 percent of the undeveloped area is inundated for as long as 4 months during the rainy season, and reduces to about 10 percent inundation in the dry season. This results in a variety of plant communities, such as pine-palm-palmetto forest, wet prairie and marsh, freshwater swamp, and hammock forest in the area. Areal distribution of these communities depends mainly on land elevations.

In the western portion, the drainage is southward and westward through as extensive canal system of the Golden Gate development area. Drainage in the central and relatively undeveloped portion of the Big Cypress area is generally southward and tends to concentrate in the Okalachoochee Slough, the Baron River and Turner River Canals, and the Fakahatchee Strand.

Much of the natural environment included in the lower west coast has been disturbed by either urban development or agricultural use. The remaining areas support diverse vegetation communities, ranging from sawgrass marsh and wet prairie to pine flatwood and cypress and hardwood swamp, much of which has been subjected to invasion by exotic species. These varied areas provide habitat for mammals, fish, reptiles, amphibians, and birds.

The nearby Nicodemus Slough is located in a largely developed area. While ninety-five percent of Glades County is in agricultural use; most of which is devoted to grazing. The Slough supports scrub palmetto, maidencane marsh, broadleaf marsh, wax myrtle, and oak-cabbage palm hammocks. The greatest vegetation cover is for truck crops, sugarcane, and pasture. Nonetheless, the area is still inhabited by song and wading birds, wild turkeys, frogs and toads, snakes and lizards, deer, wild hogs, and rabbits. The endangered bald eagle (*Haliaeetus leucocephalus*) and Everglade kite (*Rostrhamus sociabilis plumbeus*) are also located here.

The Slough occupies an area with sandy soil composed of sand mixed with muck. Drainage is provided by two natural channels and a series of short tributaries. S-47B controls the water level in the slough and prevents overdrainage.

The Six-Mile Cypress Slough in Lee County, near Ft. Myers, is predominantly bald cypress, although *melaleuca* and Brazilian pepper have been making serious inroads. Associated wax myrtle and mid-sorous fern are prevalent. Some hardwood areas still exist with live oak, red maple, and cabbage palmetto.

The slough is inhabited by 20 species of mammals; 67 species of birds, including the endangered woodstork (*Mycteria americana*); 44 species of reptiles, including the threatened eastern indigo snake (*Drymarchon corais couperi*); 19 species of amphibians, 11 species of fish, and 8 species of invertebrates.

The Six-Mile Cypress Slough serves as a tributary drainage way to Ten Mile Canal and drains from the east towards the Ft. Myers area. The water is then transported to Mullock Creek and finally into Estero Bay, which is a State Aquatic Preserve.

The geological composition here consists of Holocene Series overlying Pleistocene sediment. The topsoil is fine to medium-grained quartz sand with some shell and clay covering shell beds and limestone. The underlying bedrock material includes the Tamiami and Hawthorne Formations.

Farther south in Collier County is the Big Cypress Swamp, which includes numerous cypress-dominated sloughs and strands (e.g., Fahkahatchee Strand), extending southwest from the Tamiami Trail. The surface water of this area discharges into the Gulf of Mexico through the Ten Thousand Islands. The environment and the geological characteristics here are similar to those in the BCNP. Vegetation is characterized by cypress forest within the Fahka Union Basin, mixed swamp forest, pine forest, pine-cypress forest, and areas of pine-dwarf cypress, pine-cypress-palmetto mosaic, pineland-grassland understory, pineland-saw palmetto understory, and dry and wet prairies. These diverse communities have been invaded by *melaleuca* and Brazilian pepper.

They also support large varieties of freshwater fish, including gar, bowfin, catfish, and perch; estuarine yellowfin menhaden, silver perch, and ladyfin; amphibians and reptiles; forest-dwelling, wading, diving, and shore birds as well as birds of prey; and 34 species of mammals, including skunk, opossum, black bear, white-tailed deer, and wild hog. Six endangered and one threatened species have been identified. These are the endangered red-cockaded woodpecker (*Dendrocopos borealis*), woodstork (*Mycteria americana*), peregrine falcon (*Falco peregrinus tundrius*), bald eagle (*Haliaeetus leucocephalus*), West Indian manatee (*Trichechus manatus*), Florida panther (*Felis concolor coryi*), and the threatened eastern indigo snake (*Drymarchon corais couperi*).

South of the Big Cypress Swamp are prairie and marsh areas that remain under surface water for more than 2 months per year. Marl soils (holocene marls overly Miocene to Pleistocene marine limestones) predominate with some intermixture of peat. Dominant vegetation in these areas is spike, beakrush, and sawgrass, with scattered tree islands. The endangered Everglade kite (*Rostrhamus sociabilis plumbeus*) and woodstork (*Mycteria americana*) depend on such locales.

Some coastal areas represent typical beach dunes with quartz and calcareous sands. These areas are vegetated by sand pines, palmettos, sea oats, and xerophytic woody shrubs. Scrub jays, gopher tortoises, and songbirds find these areas attractive.

Collier County - including the Big Cypress Swamp, prairie and marsh regions, and coastal areas - contains seven major drainage basins:

1. The Big Cypress Basin, which is located in northeast Collier County and transports water from north towards the southeast to WCA 3;

2. The Okalachoochee Basin, the largest in the county, which contains the Fahkahatchee Strand, much of Big Cypress Swamp, and the Okalachoochee Slough, and carries water south to ENP and ultimately the Gulf of Mexico;

3. Henderson Creek Basin, which flows southwest towards Marco Island and is drained by the Henderson Creek Canal;

4. Golden Gate Basin, comprised of 102 miles of drainage canals;

5. Cocohatchee Basin, involving the River Canal;

6. Corkskrew Basin, encompassing Corkskrew Swamp Sanctuary and Lake Tefford;

7. Fahka Union Basin, which is part of the canals for Golden Gate Estates.

In addition to supporting numerous endangered and threatened species, the Lower West Coast contains designated critical habitat for the manatee. Charlotte Harbor and the Caloosahatchee River in Lee County and the Ten Thousand Island area in southwest Collier County provide this critical habitat.

CALOOSAHATCHEE RIVER

The Caloosahatchee River Valley is the dominant physiographic feature of the Caloosahatchee River watershed. The valley's axis follows the Caloosahatchee from Lake Okeechobee to the Gulf of Mexico. The Caloosahatchee Incline slopes gradually upward on the north side of the valley and joins the Desoto Plain which is a very flat terrace extending to the Central Florida Highlands and is generally regarded as a submarine terrace formed below the Wicomics Shoreline. To the south of the Caloosahatchee Valley is the Immokalee Rise, an area which is predominantly sandy soils. Both the

Caloosahatchee Incline and the Immokalee Rise were formed as submarine terraces of the Pamlico Shoreline.

Southeast of the Immokalee Rise is the Big Cypress Spur, a sloping transition area between the Rise, the Everglades to the east, and the Southwestern Slope to the west. The spur is best characterized by its abundant dwarf cypress on marl soils to the west and its sandgrass/Everglades slough vegetation to the east. The Southwestern Slope lies southwest of the Immokalee Rise and the Big Cypress Spur and extends from the Caloosahatchee Valley to the Everglades. Its southern portion substrata are thin sands overlying Tamiami limestone with distinct slough and strand vegetation running perpendicular to the coastline. Toward the north, sands are often deeper and more prevalent as evidenced by increasing pineland vegetation and less distinct coast-perpendicular drainage.

The Coastal sub-watershed occupies an area of 909,800 acres, most of which is in Lee County. The Caloosahatchee River is the largest river in the watershed. Its major tributary, the Orange River, joins at a point 8 miles upstream from Fort Myers. With a drainage area of 83.4 square miles, the Orange River contributed an average annual flow of 7.83 inches during its only 10 year period (1935-45) of stream flow measurement, about 15 percent of the mean annual rainfall over its drainage area.

The Imperial River drains westerly along the southern edge of Lee County into the south end of Estero Bay. Its stream gaging station near Bonita Springs experienced a mean annual flow of 62,260 acre-feet during its only period of operation from 1940 to 1954. Line-A Canal originates in Fort Myers and intercepts flow from the Six Mile Cypress Slough on its 10 mile course to Mullock Creek.

The Caloosahatchee River sub-watershed includes an area of 550,900 acres in parts of Lee, Glades, Charlotte and Hendry counties. From a hurricane gate on the southwest shore of Lake Okeechobee at Moore Haven, the Caloosahatchee Canal drains westerly for about five miles through a very flat terrain into Lake Hicpochee. From there the canal joins the upper reach of the Caloosahatchee River. On its way to the Gulf of Mexico the river is controlled by navigation locks at Ortona (15 miles downstream from Moore Haven) and at Ogla near Fort Myers. Downstream from Ortona Lock, many tributaries join the river along its course to the Gulf. The Caloosahatchee River serves as a portion of the cross-state Okeechobee Waterway, which extends from Stuart on the east coast via the St. Lucie Canal, through Lake Okeechobee and the Caloosahatchee River to Fort Myers on the Gulf of Mexico. The river has been straightened by channelization through most of its 65 mile course from the Moore Haven Lock to Fort Myers.

The Caloosahatchee River region was once dominated by sawgrass marsh and wet prairie but has been ditched for agricultural and residential development. The river corridor does still display some cabbage palm-oak hammocks with cypress, maple, and hickory; and larger areas of pine flatwood.

Shorelines with mangrove vegetation have been invaded by Brazilian pepper. Submerged vegetation, including turtle and manatee grasses, as well as freshwater alligator weed, floating maidencane, water lettuce, and water hyacinths, do continue to thrive.

The river itself boasts 246 species of fish as well as crocodiles, turtles, lizards, and snakes. The threatened American alligator (*Alligator mississippiensis*) and endangered West Indian manatee (*Trichechus manatus*) have been identified in this area as has one bald eagle nest.

The Caloosahatchee River receives water from Lake Okeechobee and acts as a natural drainage way for stormwater runoff from adjacent lands. Canals now divert some runoff that once entered the River. The soils are mainly organic and marl, overlying limestone.

EXISTING CONDITIONS

The following chapter provides an overview of the population and economy of the study area. It also provides a general discussion of the climate and hydrology of the south and central Florida area and the operation of the C&SF Project.

POPULATION

Over the last several decades, Florida has consistently experienced population growth far above the national average. Between 1950 and 1960, the State's population grew 78.7 percent. Although growth slowed from this pace during the sixties and seventies, Florida still grew 43.6 percent between 1970 and 1980. The comparable rate for the nation during this latter period was 11.4 percent.

The resident population of the 18 counties, which make up the study area, before the C&SF Project was authorized in 1945, was 727,097. The population of those same counties in 1990 was 6,348,770. This does not include winter residents and tourists who double the population of the east and west coast centers during the winter season, or migratory workers who greatly increase the population of the Lake Okeechobee area during the period of heaviest crop production, which is also in the winter.

The population estimates to the year 2035, for Florida and the study area, are presented in Table 1. The population of the study area is estimated to increase to 7.0 million residents by 2000.

Since the early 1980's, Florida has outdistanced the Southeast and the nation in employment, income, and population growth. Above-average growth during the decade demonstrates Florida's resiliency during the most recent recession. The 1980-1982 recession affected Florida much less than it did the nation as a whole, and the State experienced a very strong recovery. The economy's momentum carried through 1985, although the pace of growth eased to more sustainable levels. The State's level of business activity remained high and expanded at a healthy pace during 1986, resulting in a very prosperous economy for the year.

Florida's economy has undergone extensive change and experienced strong growth during the last several decades. These changes have led to the

TABLE 1, POPULATION

COUNTY	1980	1985	1990	1995	2000	2005	2015	2035
			(ACTUAL)		(PROJECTED)			
Broward	1,081,257	1,101,000	1,255,488	1,342,905	1,432,064	1,504,441	1,652,033	1,867,365
Charlotte	58,460	79,500	110,975	96,533	104,628	110,984	121,693	137,302
Collier	85,971	117,100	152,099	164,226	182,002	195,861	218,855	252,891
Dade	1,625,509	1,744,500	1,937,094	1,818,028	1,876,698	1,935,714	2,067,347	2,249,365
Desota	19,039	21,400	23,865	26,999	28,922	30,537	33,025	36,850
Glades	5,992	6,800	7,591	7,646	7,986	8,288	8,787	9,598
Hardee	20,357	21,200	19,499	26,017	27,413	28,560	30,296	33,109
Hendry	18,599	22,600	25,773	29,733	32,044	33,933	36,699	40,873
Highlands	47,526	56,900	68,432	70,937	76,097	80,286	87,303	97,722
Lee	205,266	266,800	335,113	381,877	426,560	462,960	525,771	620,578
Martin	64,014	82,900	100,900	125,073	139,890	151,746	170,559	198,930
Monroe	63,188	71,100	78,024	91,693	98,789	104,457	116,769	127,492
Okeechobee	20,264	26,000	29,627	31,526	33,836	35,722	39,064	44,164
Orange	470,865	555,000	677,491	678,401	726,581	764,895	838,109	945,069
Osceola	49,287	76,700	107,728	106,038	118,970	129,101	146,744	173,365
Palm Beach	576,758	724,300	863,518	971,488	1,062,614	1,134,466	1,256,979	1,439,369
Polk	321,652	368,400	405,382	433,988	461,073	483,872	524,377	584,801
St. Lucie	87,182	115,700	150,171	165,078	183,521	198,399	221,970	257,187
TOTAL	4,821,186	5,457,900	6,348,770	6,568,186	7,019,688	7,394,222	8,096,380	9,116,030

SOURCE: US DEPARTMENT OF COMMERCE, BUREAU OF THE CENSUS, CENSUS OF POPULATION, 1980 & 1990

U.S. DEPARTMENT OF COMMERCE, BUREAU OF ECONOMIC ANALYSIS, REGIONAL ECONOMIC ANALYSIS DIVISION, COUNTY-LEVEL PROJECTIONS OF ECONOMIC ACTIVITY AND POPULATION, FLORIDA, 1990-2035.

State's evolution from an economy based primarily upon agriculture, tourism, and retirement living to an urban economy which also includes a sophisticated mix of industrial and commercial activities.

Until the 1960's, Florida's economy was dependent primarily upon the State's natural resources. Agriculture, forestry, citrus, commercial fishing, mining, resource-related manufacturing, and tourism composed the bulk of economic activity in the State. These activities were based on the moderate climate, the ocean and beaches, forests, vast tracts of undeveloped land, and mineral deposits.

However, industries which are based on natural resources are dependent upon finite supplies of some resources, weather conditions, and other natural phenomena over which man has no control. Too great a reliance on resource-based industries heightened the susceptibility of Florida's economy to severe problems resulting from a natural disaster. The development of other industrial sectors has led to a reduced dependence on the State's resource-based industries. Nevertheless, the State's natural resources have continued to play a major part in the growth and health of Florida's economy.

Agriculture has traditionally been a mainstay of the Florida economy. In 1985, Florida producers received $4.7 billion from marketing of agricultural products, ranking it ninth among the 50 States and accounting for 33 percent of the nations total.

Nearly 45 percent of all land in Florida is commercial forest land. The wholesale manufactured value of forest products in 1984 was $2.1 billion. Counting the value added by additional manufacturing, transportation, and marketing, forest products generated some $8.3 billion in income for the State.

In 1984, the State ranked fourth in the nation with nonfuel mineral production of $1.5 billion. Florida ranked first in the production of phosphate rock, peat, and masonry cement.

Florida had nearly one-tenth of the nations fishery products plants in 1984 with a total of 46. In 1982, commercial landings of fish and shellfish amounted to more than 193 million pounds valued at $171.3 million, dockside.

ECONOMY

During the period 1970 to 1985, private sector employment grew by 102.1 percent in Florida while advancing only 37.7 percent nationally. The State made strong gains in all private industry employment.

While the U.S. has shown no growth in manufacturing, the State showed a 60.2 percent increase. The State is becoming less dependent on manufacturing groups which are tied to agricultural and mining and moving more towards those industries which are keyed to advancing technology.

The State has been very successful in attracting high technology industry in recent years. Currently ranked sixth in the nation and first in the Southeast, the State has more than doubled in high technology employment since 1975. The southern region of Florida, including Dade, Broward, and Palm Beach counties features computers, aviation, telecommunications, and biomedical concentrations.

CLIMATE

The climate of the area is categorized as subtropical since occasional frosts do occur. The climate is influenced by several factors, the most important of these being: (1) low latitude; (2) proximity to the Atlantic Ocean and Gulf of Mexico; and (3) the inland lakes that are so prevalent over the area.

Area summers are long, warm and generally humid, while the winters are mild with occasional short, cool or cold periods. Coastal areas generally have slightly warmer winters and cooler summers than the inland areas at the same latitude. Annual temperatures average in the middle 70's on the mainland and may average as high as 77 to 78 degrees at Key West. Summer temperatures average 81 to 82 degrees throughout the area. During the coolest months, temperatures in the area average about 13 degrees higher than in the northern part of the state. July and August are generally the warmest in southern Florida, with January and February the coolest months.

The summer heat is tempered by sea breezes along the coast and by frequent afternoon and early evening thunderstorms in all areas. During the warm season, sea breezes are felt almost daily within several miles of the coast and occasionally 20 to 30 miles inland. Thundershowers, which on the average occur on about half of the summer days, frequently are accompanied by a 10 to 20 degree drop in temperature, resulting in comfortable weather for the remainder of the day. Since most of the large scale wind patterns affecting Florida have passed over water surfaces, hot drying winds seldom occur.

Average rainfall over the study area averages about 53.1 inches per year but it varies greatly, ranging from about 37.8 inches in 1961 to 117.0 inches in 1947. Rainfall distribution over the area is also quite variable at times.

Wet and dry seasons are well defined. Considering the entire area, about 55 percent of the rains occur during June through September and about 10 percent during December through February. However, seasonal distribution varies from one part of the area to another. Frontal movements result in widespread light to moderate rains that may last two or three days.

Thunderstorms rarely occur in any great number during the winter, but can occur as often as two days out of three during the summer. An average of about 70 thunderstorms a year occur over the extreme southwest part of the area, increasing to about 100 a year over the ridge along the western side of the Kissimmee River area. Hurricanes and less severe tropical storms are at times major sources of precipitation. They are often accompanied by two to five inches or more of rainfall over an area of several thousand square miles. On the average, two or three tropical storms a year may be expected to affect some part of the area.

HYDROLOGY

The major characteristics of south Florida hydrology are:

1. local rainfall,
2. evapotranspiration (ET),
3. canals and water control structures,
4. flat topography, and
5. the highly permeable Biscayne Aquifer near the land surface along a 30-to 40-mile wide coastal strip.

Water that is introduced from either direct rainfall or canals is rapidly removed by ET, seepage into the aquifer, or canal and overland surface drainage to the Atlantic Ocean, Florida Bay, or the Gulf of Mexico. Water that is introduced at a rate that exceeds that of removal tends to inundate a large area to relatively shallow depths.

The straight line distance from Lake Okeechobee southward to Florida Bay is approximately 125 miles. The natural flowage way of the Everglades from Lake Okeechobee southward is nearly flat with innumerable tree and brush vegetated hammocks and other grass and sedge vegetated areas grading into shallow depressions that contain surface water most or part of each year. Much of the Everglades is underlain by highly porous surficial aquifers. When rains are sufficient, surficial aquifers are recharged and surface water flows from points receiving rainfall into adjacent depressions. When enough rainfall occurs, surface water naturally moves slowly in a general southward direction. As water evapotranspires, surface water movement can cease, but a very slow movement of ground water can continue from surficial aquifer areas with higher water levels to areas with lower water levels. As seasonal and prolonged droughts occur and ET continues, normal surface water areas can become dry and water levels within the surficial aquifers may decline to levels several feet below average land surfaces.

In its natural state, the Kissimmee River basin drained into Lake Okeechobee, which in turn, spilled its surplus water into the Everglades. From the Everglades the water ran slowly in a south-southwesterly direction to the lower end of the peninsula. All of the area around the rim of Lake Okeechobee, except the sandy ridge above its northeastern shore, was subject to infrequent flooding when high lake stages occurred during major floods, or when hurricane tides on the lake overflowed its shallow rim. The latter occurred from the hurricanes of 1926 and 1928 and heavy loss of life and property damage resulted.

This natural interconnected ground water and surface water system has been substantially modified by the water control works incorporated into and constructed as part of the C&SF Project. The drainage project eliminated the natural flow of water and all the normal flowage from the Kissimmee basin was discharged into the ocean and Gulf by way of the St. Lucie Canal and the Caloosahatchee River.

The major canals south of Lake Okeechobee through the EAA serve a multiple purpose, that of assisting in regulatory discharges from the Lake southward, providing irrigation water to the agricultural area from lake releases, and as collecting sumps for agricultural area runoff to be pumped to the lake and WCAs. The interior canals in WCA 3A (Miami Canal, L-68A, and L-67A canals and L-67A Extension Canal) also serve as distribution channels for delivery of water to the ENP. C&SF Project canals also serve as small-boat navigation channels.

GROUND WATER HYDROLOGY

Shallow Aquifers

Shallow aquifers are present over most of the area, but are generally used only when supplies from the Florida or Biscayne aquifers are not available or of poor quality. They contain water under both non-artesian and artesian conditions and are located above the Floridan aquifer.

The thickness of the shallow aquifers varies throughout the area, ranging up to 40 feet in Orange County, 90 feet along the Gulf of Mexico

(Collier County) and considerably thicker in some portions of Polk County. Recharge is from local rainfall and percolation from surface water bodies. The water table generally follows local topography, but is more subdued, appearing at or near land surface in low areas and deeper in high areas. Water-level fluctuation is more pronounced in the topographically high areas than in the lowlands.

Discharge from shallow aquifers is by seepage into lakes, streams, marine waters, and canals; by ET; by pumping and by downward leakage to the Floridan aquifer.

Small-capacity wells are developed in the shallow aquifers for domestic and irrigation purposes. The wells are generally less than 12 inches in diameter and as much as 80 feet deep.

Water from the shallow aquifers is generally of good quality, though it ranges from soft to very hard, and is often high in color and iron content. Freshwater occurs in the shallow aquifers in all portions of the area except in coastal areas affected by recent sea-water encroachment, and in some inland areas where the aquifers contain residual saline water. The largest areas of residual saline water are under large agricultural developments in the Everglades southeast of Lake Okeechobee, and an inland area near Naples on the west coast.

Shallow aquifers are an important source of water in the Atlantic and Gulf coastal areas where deep artesian water is highly mineralized. They are the main source of good quality groundwater in Charlotte, Collier, Glades, Hendry, Lee, Martin, Palm Beach and St. Lucie Counties.

Major Aquifers

Groundwater is one of the most abundant and valuable natural resources in the Kissimmee-Everglades Area. The area is underlain by both artesian and non-artesian groundwater aquifers which consist of many water-bearing formations.

The principal source of groundwater in the northern portion of the area is the artesian Floridan aquifer; the non-artesian Biscayne aquifer supplies most of the water to the lower east coast. Throughout most of the area, small water supplies are obtained from shallow aquifers.

Floridan Aquifer

The Floridan aquifer underlies the entire area and is the principle source of artesian water. However, the aquifer becomes highly mineralized to the south of Lake Okeechobee, which greatly restricts its use in this area.

Most recharge to the Floridan aquifer occurs in the highlands area immediately northwest of the Kissimmee-Everglades Area, where the confining layer is absent or breached by sinkholes and the aquifer is overlain by permeable sediments. Recharge areas for the Floridan aquifer which lie within the area are mainly confined to the vicinity of the Highlands Ridge and the extreme northern portion of the area.

Water flows through the aquifer along faults, joint systems, fractures, intragranular spaces, along bedding planes and through cavities of various sizes, created by solution of the limestone. The magnitude and number of cavities is greater where the aquifer is near the surface and breached by sinkholes, such as in the highlands counties of Orange, Polk, and Highlands counties. Variations in these solution features throughout the aquifer cause extreme ranges in transmissivity, both regionally and locally.

In the northern portion of the area, except for Orange county, the Florida aquifer functions as a single hydrologic unit. South of Highlands County the aquifer consists of several water-bearing formations separated by relatively impermeable material.

The potentiometric surface of the aquifer generally slopes toward the coastal areas. The potentiometric surface in Polk and Highlands counties forms part of an elongate dome which reaches an elevation of more than 80 feet. The dome extends southward and flattens in the area south of Lake Okeechobee, where the potentiometric surface ranges in elevation from less than 60 feet in Hendry County and western Palm Beach counties, to less than 40 feet in the Miami area, to about 20 feet in southernmost Dade County. It is approximately at sea level in the Florida Keys.

Discharge of the Florida aquifer is by submarine springs, pumping, and artesian flow. Submarine discharge occurs through outcrops on the Atlantic Coast. The aquifer is not known to outcrop in the Gulf of Mexico west of southern Florida, but upward leakage probably occurs.

Thick, relatively impermeable beds of the Hawthorn Formation overlie the Floridan aquifer over most of the area and restrict the upward movement of water, thus causing artesian pressure. Artesian flow occurs in wells penetrating the aquifer in coastal areas, stream valleys, and in many other areas where the potentiometric surface is above land surface. Parts of the Kissimmee River watershed are the only major portions of the area where artesian flow does not occur. The artesian heads in the area differ with permeability differences in the aquifer and fluctuate in response to changes in recharge and discharge.

Generally, freshwater can be produced from the Floridan aquifer in and near the recharge areas on the north and west border of the Kissimmee River watershed, where the aquifer is near the surface and replenished by rainfall. South of the Kissimmee River watershed the aquifer is deeper, development of wells is more costly, and contamination by mineralized water is more probable.

In the Kissimmee River watershed, from the northern end of the area to southern Highlands and Okeechobee counties, the chloride content of ground water from the upper part of the Floridan aquifer is less than 250 parts per million (ppm), which is within the limits for chloride recommended by the U.S. Public Health Service. In the remainder of south Florida, the aquifer is highly productive, but contains water with chloride as high as 4000 ppm in coastal areas.

Biscayne Aquifer

The Biscayne aquifer is the chief source of groundwater in southeastern Florida. The fresh water portion of the aquifer underlies an area of about 3,000 square miles, and is the only major source of fresh groundwater in Dade and Broward counties. Water in the aquifer is generally under water table conditions, although artesian pressure exists locally.

The aquifer has an average fresh water saturated thickness of about 70 feet. It ranges in total thickness from 125 feet near Miami and 200 feet near Ft. Lauderdale to about 60 feet at the eastern edge of the WCAs west of Miami, to less than 60 feet in southern Dade County, to virtually 0 feet in eastern Collier and Monroe counties.

Recharge of the aquifer is mainly by rainfall, however, the numerous fresh water canals add to recharge when the water table is low. Percolation of water into the aquifer is aided by the permeable nature of the Miami Oolite at the surface. Generally, the water table is close to the surface.

Discharge of the aquifer is by ET, seepage into canals and coastal waters, and by pumping. Fresh water in the Biscayne aquifer generally has hardness ranging from 200 to 300 ppm and chloride ranging from 20 to 30 ppm. Most of the water in the upper part of the aquifer is highly colored, due to organic staining and/or iron, however, this condition decreases with depth. Underlying the Everglades, the water from the Biscayne is generally harder with higher chloride content due to saline residues.

Salt water has migrated into the Biscayne aquifer in many coastal areas due primarily to uncontrolled drainage by canals before 1946. Sea water encroachment responds to the fluctuation of fresh water levels in the aquifer. The greatest inland advance of salt water occurs in areas around tidal canals during low water table conditions.

SALT WATER ENCROACHMENT

Salt water encroachment has effected southern portions of the Southeast Coastal Watershed to a greater extent than northern portions of the area. Encroachment into the shallow aquifers in St. Lucie, Martin and Palm Beach counties has not been extensive, largely due to the relatively few canals that cut across the coastal ridge, and to adequate controls on existing canals that maintain sufficiently high groundwater levels near the coast. However, problems have occurred in local areas bordering salt water, such as Sewell Point and Hutchinson and Jupiter islands in Martin County. Most large municipal ground water supplies in coastal Palm Beach County are obtained from wells located approximately one mile inland, in order to avoid possible encroachment.

EVAPORATION AND TRANSPIRATION

Of all rainfall supplied to the area, the major portion is returned to the atmosphere by evaporation from water and soil surface, and also by vegetation uses. Abundant rainfall, numerous surface storages, relatively high temperature and solar radiation give rise to high ET losses (evaporations from water and land surface and transpirations by vegetation). In 1988, the Corps estimated these losses to be 88 percent of the total rainfall.

Evaporation from the soil surface and ET are investigated only at experiment stations, mostly located around Lake Okeechobee. Evaporation pan and evapotranspirometer data, which are only indexes of the basin ET, are only sparsely located in this area.

OPERATION OF THE C&SF PROJECT

The Central and Southern Florida Flood Control District was initially created by the state to comply with the conditions of local cooperation relating to the C&SF Project. The successor organization, the SFWMD, in addition to its other missions, is responsible for the operation and maintenance of the C&SF Project. The general operational strategy for the system is to provide adequate flood protection during the wet season (June through October) by placing water into storage and discharging excesses to the ocean; and to draw from the storage areas during the dry season (November through May). This strategy must also incorporate protection of the environmental and water quality values of the lakes, wetlands, and estuaries in south Florida.

Flood waters are placed either by gravity flow or by pumping into four large water storage areas, Lake Okeechobee, and the three WCAs. These storage areas also serve as a source of water supply during dry periods. A network of primary arterial canals covers most of the area and permits flood or water supply flows to be discharged either into or out of the storage areas or into the ocean. Innumerable secondary canals, managed by local entities, are connected to the primary system.

Management of the system is based on criteria designed to ensure that the congressionally authorized purposes are satisfied. Operation of each of the project's lakes and WCAs is based on a specific regulation schedule. The regulation schedule specifies a maximum desirable water level for any given time of the year. Generally, the schedules allow for the highest water levels at the beginning of the dry season to provide maximum water supply. By June 1, the beginning of the wet season, water levels have been lowered to provide the capacity for storage of the wet season's anticipated rainfall. In this way, both water supply and flood protection objectives can be satisfied.

Because of south Florida's flat terrain, some freshwater discharges through coastal structures are required even during water shortage conditions. Since storage availability in primary canals is very limited, a significant rainfall event could cause flooding in some low-lying areas unless adequate releases are made.

To operate the system, up-to-the-minute data are required, including the current status of all control structures, the existing water and weather conditions throughout the system, and a prediction of weather conditions in the immediate future. Observers are sent into the field to report on existing conditions. Other data are collected by SFWMD's staff meteorologist and from the Corps, the National Weather Service, various local water related agencies and cooperating private interests. Information is received at SFWMD headquarters by radio, telephone and teletype or through the communications and control system. This sophisticated electronic system is capable of gathering hydrologic data, as well as operating and monitoring water control structures through a centralized computer.

Vital water and weather data are transmitted via a telemetry system to SFWMD's Operations Control Center in West Palm Beach. Operational directives are then transmitted over the system to control facilities and are executed remotely. These actions are monitored around-the-clock at the control center.

Remote acquisition and control units contain environmental sensors and control elements which operate water control facilities. Aside from being used to open and close flood gates on canals, the system is capable of measuring and recording variables like rainfall, water levels, and salinity as well as temperature, wind speed and direction. While the communications and control system coverage is currently limited to locations south of Lake Okeechobee, an on-going expansion program is targeting other areas for inclusion in the system.

IDENTIFICATION OF ISSUES, PROBLEMS, AND NEEDS:

INTRODUCTION

This chapter and the following three chapters present an overview of the issues and needs of the study area as they pertain to the hydrologic ecosystem. These issues and needs have been categorized into Water Quantity, Water Quality, and Biotics. Although each issue or need has been categorized out of necessity for this report, it is recognized that many of these issues and needs fit into more than one category.

SCOPING WORKSHOPS

Two scoping workshops were held: the first at the University of Florida (UF), Gainesville, Florida on July 9-11, 1991, and the other at the SFWMD Auditorium in West Palm Beach on October 18, 1991. Concerns were identified by the participants of the workshops and further expanded by a team consisting of the SFWMD, ENP, and the Corps. The details of the workshop results can be found in Appendices B and C.

A background information package was mailed to all of the participants invited to the workshops. The information package included the identification of the objectives; study background; preliminary list of issues; and a review of past and present Everglades environmental restoration efforts, including an overview of major hydrologic and water quality modeling capabilities for central and south Florida. Participants of the October workshop also received the results of the July workshop to review.

July Workshop

The July workshop (Appendix B) was co-sponsored by the ENP and facilitated by Lance Gunderson and Dr. C. S. Holling of UF. The ENP has modeling efforts underway to aid in achieving restoration and management goals for the Park and have been of great assistance during the formulation of this reconnaissance study. UF had previously conducted a series of Adaptive Environmental Assessment (AEA) workshops that consisted of an informal consortium of scientists and managers attempting to model and screen policies for restoration of the Everglades ecosystem. The AEA workshops were initially sponsored by the ENP and SFWMD. The July workshop was designed to build upon the understandings learned from the series of AEA workshops. Many of the same participants were involved, but many new agencies/groups also attended the Simulation Modeling System workshops.

The goal of this workshop was to develop a collection of the most productive activities to be pursued in future modeling endeavors. To reach this goal, the participants were asked to:

1) review current and possible future issues
2) assess existing modeling activities
3) identify gaps in models, methods and understanding
4) propose approaches for meeting the needs identified in the earlier sessions
5) prioritize the activities.

All of the groups at the July workshop had a history of modeling activities, and therefore, a fair assessment of the status of existing modeling actions. The participants included 43 scientists and engineers from Federal, State, and local agencies, as well as universities and other research organizations. A list of the participants is included in Appendix B.

October Workshop

This workshop (Appendix C) was designed to identify critical issues and possible solutions while determining the needs of policy makers, resource managers, and other decision makers who affect or are affected by the hydrologic ecosystem. The attendees of the workshop consisted of Federal, State and local agencies, universities, research organizations, and representatives of environmental groups, agricultural interests, the Seminole and Miccosukee Indian tribes, and private engineering firms.

The workshops provided an environment for technical specialists of varied disciplines to discuss the issues of south and central Florida while proposing methods to address those issues. The workshops provided valuable information for completion of the technical study plan for model development including an understanding of the issues and priorities of agencies and interest groups in south and central Florida.

SYSTEM COMPLEXITY

The C&SF Project hydrologic ecosystem is very complex. The project area encompasses more than 16,000 square miles. The C&SF Project was developed to manage the surface and ground water resources of the project area and to serve a variety of interests for multiple purposes. Those purposes include flood control, water level control, prevention of salinity intrusion, water deliveries to the ENP, water supply, and fish and wildlife conservation. In addition, there are complex ground and surface water interactions, as well as complex groundwater and canal interactions that complicate the understanding of the hydrology of the area.

The ecosystem in central and southern Florida is also very complex and fragile. In the study area (see chapter entitled: Description of Study Area) there are a wide variety of ecosystems: mangrove swamps, estuarine systems, isolated freshwater wetlands, sawgrass stands, cypress swamps, lakes, marshes, tidal flats, hammocks, sloughs, bays, uplands and many others.

Due to the complexity of the hydrologic ecosystem, it has been very difficult to predict the impacts that proposed projects would have on the ecosystem. Many models have been developed over the years to study specific processes within limited subregions, but no previous attempt has been made to model water quantity, water quality, and biotic processes for the entire system. A consensus reached at both workshops was that there is a definite need to model the system as a whole. It was also recognized that meso-scale and micro-scale models would be developed for certain sub-regions and/or for specific processes, but the desired end product would be a simulation modeling system that encompasses the entire study area.

IDENTIFICATION OF ISSUES, PROBLEMS, AND NEEDS:

WATER QUANTITY

This chapter discusses issues, problems, and needs, categorized as water quantity issues. These issues, while they may differ slightly from region to region, have been identified as system-wide concerns.

WATER SUPPLY

The range and variety of competition for the limited water resources within the region is discussed in the following paragraphs.

Urban

Central and southern Florida has experienced unprecedented economic growth in recent decades with subsequent development and alterations of natural systems. Several million people now inhabit the Atlantic Coastal ridge lands to the east of Lake Okeechobee and the Everglades. Roughly 365,000 newcomers, 1,000 per day, move to south Florida each year. Each of these new residents uses 200 gallons of fresh water a day. This means 200,000 more gallons must be found daily to meet their needs (Duplaix, 1990). This rapidly growing population and associated economic activities are placing progressively increased demands upon the limited water resources of the surficial aquifers underlying the Everglades. The Biscayne aquifer still adequately supplies the east coast, but the west coast is increasingly forced to use desalinated water.

Agriculture

There is no consensus on how much water the agricultural industry uses. Many claim that agriculture uses much more water than natural systems or urban residents, while farmers claim that their croplands actually use less water than the natural vegetation. The farmers also claim that by retaining water within the canals in the EAA, less water is being lost to ET than the other Everglades lands which have a larger surface area. The farmers believe that there could be a further reduction in rainfall if land is taken out of production. Citrus and vegetable farmers further claim that much of the water used is taken from aquifers underneath their land, irrigates their land and runoff is captured and pumped into wetland areas where it returns to the aquifers. By contrast, they claim urban users pump water from the same aquifers but return relatively little of it. Much of the water winds up in sewer systems or canals and carried to the ocean.

There is increasing concern over the rapid expansion of citrus groves in Collier County. Since 1986, the number of producing citrus acres has increased from 10,100 acres to 23,600 in 1990. The increase is attributable to severe freezes driving growers from the central part of the state to the southwest. It has been forecasted that by 2010, there will be 59,800 acres of citrus, increasing their water usage from 24.1 billion gallons in 1990 to 55.7 billion gallons.

Natural systems

Natural resource managers in the study area claim that the water needs of natural systems are considered only after urban and agricultural needs are met.

The ENP is last in line in the 250-mile-long Everglades watershed and for many years had little to say about how much water it received and when. When a summer downpour filled the WCAs or flooded adjacent agricultural areas, the excess was released into the ENP. During droughts, urban and agricultural areas received water first and the ENP received what water was left, if any. A computer model was designed to mimic seasonal rainfall conditions and annual water deliveries along the ENP's northern boundary. This new model has significantly improved the timing and distribution of water allotments, but problems still exist. When the recent drought imposed restrictions on Miami residents in 1989, no water was released to the ENP for 37 weeks (Duplaix, 1990).

During the drought of 1989-91, the WCAs were expanses of cracked earth. The number of alligators in the Refuge fell 40 percent in just two years. In the Everglades, the number decreased by more than two-thirds. Alligators will not build nests if the marsh is too dry in April and May. In 1990, it was predicted that 90 percent of the alligators would probably not produce. In both the Refuge and the ENP, alligators that survive are generally the larger, older ones that have eaten many of the smaller offspring during the drought. The officials had to close the Refuge during the drought for six weeks, due to the extreme low water levels. The concerns included the belief that alligators driven into the canals for water would harass park visitors or that people would get in the way of wildlife attempting to reach water.

Woodstorks and great egrets and other wading birds found so little food, during the drought, that they were not nesting. In the late 1930's and early 1940's there were 8,000 to 10,000 adult storks nesting in the ENP. In the last few years, that number has dropped to 250. There were four traditional nesting spots in the Park; now there is one.

Resource managers claim that without the Everglades, much of South Florida would simply dry up. Evaporation from the wetlands in the summer and fall begin an atmospheric chain reaction that brings most of South Florida's rainfall and replenishes ground water supplies. They advocate that a water allocation system that shares adversity is absolutely necessary if the natural resources are to survive in the future.

Other Losses of Water

Beside the consumptive uses of water by the urban, agricultural, and natural system sectors, there are other losses of water in the system. These include:

1) Water is lost at the salinity control structures due to seepage losses from project storage areas along the more than 170 miles of coast. It has been estimated that the seepage loss rates range from 2 cfs/ft head/mile in the northern areas to 5 cfs/ft head/mile in the southern areas.

2) ET accounts for the major portion of rainfall loss and its evaluation is necessary in order to determine the amount of rainfall excess available for other purposes.

3) Seepage losses through and under the C&SF project levees have been found to range from 4 to over 100 cfs/ft head/mile of levee. The higher seepage losses occur along the exterior levees bordering WCA 3B. Estimated annual seepage losses from the three WCAs total about one-half million acre-feet during normal years. Some benefits accrue from this seepage, especially to the east coast agricultural and urban interests and to the ENP, in making up part of the supply to those areas. However, if losses to the aquifer and to the coastal canals that are excess to the needs of the area, and are discharged to tidewater, could be reduced, this would result in a considerable potential supply.

Sustainability

Another concern categorized as a water supply issue is that of sustainability. There is great uncertainty in just how much water is needed by all of the consumers in the project area. It is not known exactly how much water is needed by the present urban areas and how much might be needed for future residents. There is also limited accounting of all the water used for agricultural purposes. It is unknown how much water and what hydroperiod is needed to sustain the native fauna and flora or what water level is needed to sustain the remaining soil in the Everglades.

Historic Conditions

There is limited knowledge of historic regimes and the conditions that produced and sustained the system in the past. This information would be beneficial to a better understanding of the type of practices needed to sustain the current system or to attempt to restore the ecosystem.

Projected Water Use

Studies need to be undertaken to predict water needs in the future. Projections of agriculture, industry, and urban consumers should be undertaken to evaluate the existing hydrologic system structural and operational capabilities to accommodate future growth while maintaining supplies for the natural resources. The SFWMD has initiated preparation of a Water Supply Plan for the lower west coast. This area includes all of Lee County, most of Collier and Hendry counties and a portion of Charlotte, Glades and Monroe counties. The purpose of the plan is to project water demand and identify water sources and methods to meet this demand on a regional scale.

Global Warming

Global warming, also known as "the greenhouse effect, is still a hotly debated topic. Most scientists now agree that man-made increases in the amount of carbon dioxide and other atmospheric gases are making the world's climate hotter. The gases come from car exhausts, power plants, industrial smokestacks and the burning and clearing of the world's forests. The gases form a giant blanket holding in Earth's heat. The debates now focus more on how large the increase will be. With its long coastline, Florida is probably the most vulnerable state in the U.S. As temperatures heat up and seas rise, we can expect hotter summers, deeper floods, thicker air pollution, and vanishing beaches. In projecting needs for water supply, it is felt that this sea level rise will need to be taken into account.

Water Budget

A water budget is needed to understand more accurately how much water is available in the entire system. An accounting is needed to know how much water each sector uses, loss due to seepage, ET, floodwater releases to the oceans, and other losses. SFWMD has begun a 2-year effort on a water budget for the Lower East Coast.

Water Levels and Delivery

Not only is it necessary to understand the total volume of water needed by the consumers, but it is important to understand the optimum timing of the water deliveries. The manipulation of the water schedule has not simulated natural conditions. As discussed in the Natural Systems section above, the ENP has had problems with receiving too little water much of the time, but also with receiving too much water in a short period. The Refuge has also complained that water levels are not maintained for the best conditions for the vegetation and wildlife, but only the schedule needed for water storage for urban areas.

Problems also occur in other areas. The estuaries often receive large amounts of freshwater, when flood waters are routed through the canals. One example is the 12 inches of rain that fell in south Florida one day in August 1988. The flooded farmlands were relieved by releasing a plume of fresh water from C-111 into Barnes Sound, adjacent to the ENP. The fish, shrimp, sponges, crabs and lobsters that were not killed by the change in salinity, died in silt that spread over 25 square miles. This action temporarily wiped out this marine breeding ground for shrimp and fish, a source of food to humans and to thousands of wading birds. Two years later, the areas still had not recovered. In Barnes Sound and adjacent Florida Bay, a fairly precise mix of brackish water is required to produce the small fish and shrimp, that the birds need to survive. The St. Lucie and Caloosahatchee Estuaries experience similar problems with water delivery.

In 1983 tons of fresh water released from Lake Okeechobee into the St. Lucie Estuary chased away fish, wiped out oyster beds and caused the deaths of dozens of endangered brown pelicans. For 46 consecutive days, lake water from heavy rains poured into the salty estuary. One proposal to alleviate the excessive floodwaters released to the estuary involves a plan to discharge water into the estuary more frequently but in smaller quantities. This "pulse" method is largely theoretical and only one of several recommended plans. Others propose a plan to release water when Lake Okeechobee's water level reaches 14.5 feet. They say that this would be more environmentally sound. Another plan is to release fresh water when the Lake rises to 16 feet. This latest plan is favored by agricultural interests because the added storage capacity in the Lake would be a reserve against drought. There has been debate for several years about what water level is best to maintain for the Lake; in order to sustain marsh vegetation and fish and wildlife. Another question that needs to be answered is what effect those lake levels would have on nutrient dynamics. State and Federal regulatory agencies would have to approve any plan.

On the west coast, millions of gallons of fresh water flow into the relatively brackish estuaries daily from the State Road 29 canal and the Faka Union canal into the Ten Thousand Islands, from the County Road 951 canal and Henderson Creek into Rookery Bay from the Golden Gate canal into the Gordon River and Naples Bay and from the Immokalee Road canal into Wiggins Bay. The result can be a catastrophic modification of the saline balance and that can dramatically alter the ability of the estuary to function properly. The only estuary on the southwest coast that is regularly monitored for freshwater intrusion is Rookery Bay, halfway between Naples and Marco Island. The Rookery Bay system is managed and protected by the Rookery Bay National Estuarine Research Reserve. More freshwater species like bass and alligators have been seen in the bay lately.

There is also a problem with insufficient freshwater being delivered to the bays. Salt concentrations of twice the level of sea water have been found in parts of Florida Bay. Hypersalinity has also been a problem in St. Lucie Estuary. Before roads were built and canals dug to drain the wetlands, water flowed evenly into the estuaries like a sheet over the land. Nature maintained the salinity balance in the estuaries. But canals built for irrigation and water consumption hold back fresh water that used to feed the estuaries for increased municipal and agricultural use of water supplies.

Salt Water Intrusion

In coastal areas, particularly along the lower southeastern coast, the fresh and saline interface is primarily governed by the groundwater table and the ease of water movement. In these areas, significant problems have been encountered with salinity intrusion, or the gradual shift of the fresh/salt interface inland. This has resulted from two major events.

The first is the lowering of the groundwater table in the area due to the overdrainage and reduced recharge as well as the increased withdrawal of water by pumping. The second reason, which had a more direct impact, is the construction of numerous drainage and navigation canals from inland areas to the coastal waters. This provided an unobstructed route for salt water to migrate inland. The inland migration was halted by actions taken in the 1960's to contain the movement of salt water up the drainage canals. Now when coastal monitoring wells detect saltwater contamination, freshwater pumping is shifted inland or more water is sent through canals to block the advance of saltwater. However, continued and increased withdrawals from the aquifer continues to aggravate the intrusion problem. As a result, several of the municipal water supply wells located along the coast have been abandoned and many others are threatened by salt water contamination. A prolonged drought would aggravate the situation to a much greater degree.

Salinity related issues occur in the estuaries around the southern part of the state, and at the interface of fresh/saline groundwater. Riverine freshwater flow influences the salinity in estuaries of the Indian River Lagoon, and the Caloosahatchee River. Overland sheet flow and groundwater influences the salinities through the Whitewater Bay/Ten Thousand Island Area and into Florida Bay. Saltwater intrusion into wells continues to plague coastal areas along the east and west coasts of south Florida.

Wellfield Impacts

Another concern is the impact that wellfields are making on the water supply. Especially in the lower east coast areas, more and more wellfields are being constructed to the detriment, many believe, of the aquifer and the ecosystem in the region. A regional wellfield was just approved for North Broward County in August. The wellfield, which will pump 10 million gallons a day, is expected to take care of that area's growing demand for water through the end of the century. Broward County had already been given permission last December to begin work on a wellfield to serve cities in the southern part of the county.

A wellfield is proposed by Dade County officials to help provide water to a growing Miami population. The proposed wellfield would pump 140 million gallons of water daily. The wellfield would be located just east of the ENP. Park officials are extremely concerned of potential impacts to the Park's already troubled water supply and will likely demand that consumption be cut by more than two-thirds, to about 40 million gallons a day.

Drought

Dry seasons are normal in south Florida, they are part of the natural cycle of wet and dry that characterizes the climate. Each year water levels drop naturally from January until June in advance of the rainy season. All storage areas are scheduled to be their lowest on June 1 to absorb the rain which falls during the summer. Eighty percent of south Florida's rainfall comes during the summer months. However, there have been several record droughts in the past decade.

The dry season of 1980-81 was not especially noteworthy, but when the dry season should have ended in June, the rain did not begin. The trend continued throughout that rainy season. By the spring of 1981, Lake Okeechobee had fallen below 12 feet. The Lake continued to drop, and more and more concern was expressed for the safety of coastal wellfields, which are always susceptible to saltwater intrusion. In April 1981, the SFWMD requested all south Floridians to conserve water. In May the request became mandatory, with the SFWMD taking official action to declare a water shortage emergency throughout the District.

Conservation measures helped relieve the pressures to draw water from the aquifers faster than it could be replenished. The threat of saltwater intrusion still existed, but did not actually occur in any wellfields. However, June came and went, again without the beginning of a rainy season. Lake Okeechobee continued to drop, and reserves in the WCAs dwindled. Sinkholes began occurring in central Florida. By July, Governor Bob Graham declared the entire southern end of the state in a drought disaster. All of the lakes in the Upper Kissimmee chain experienced extreme low stages; Lake Istokpoga and the Kissimmee River were far below normal. A statistical analysis showed that the severity of the drought in this area was on the order of a one-in-400 year event.

Lake Okeechobee reached its all-time low of 9.75 feet on July 29, 1981. The WCAs were depleted of water and the soil dried and cracked. The actual severity of the drought in the southern end of Florida was not as extreme as in the north, but the number of people relying on the limited amount of water exaggerated the condition to make it a drought of major proportions. A cloud-seeding project brought some rain to the parched Kissimmee Valley. A respite was felt in August and September when rain fell throughout south Florida, but water levels in the ground and all storage areas were precariously low as the 1981-82 dry season approached.

Less than a month after Lake Okeechobee hit its record low level on July 29, 1981, Tropical Storm Dennis, blowing in from the southwest, emptied nearly 20 inches of rain on southern Dade County, while missing the drought-stricken Lake Okeechobee drainage basin almost entirely. The same area received another 24 inches of rainfall in September. Two extremes of nature occurred at the same time; a record drought in the northern and central regions of the study area and a record flood in the southern reaches. While agriculturalists and homeowners in Palm Beach and Broward counties were practicing water conservation, their neighbors in southern Date County were bailing out their homes and watching avocado groves suffocate under a foot or more of floodwaters caused by extremely high water tables.

However, as the 1981-82 dry season continued, the level of Lake Okeechobee, a prime indicator of water conditions throughout much of the study area, continued to remain low. Sporadic rain fell through the winter months, but provided little relief. By November 1981, farmers were seeking reassurance that their harvest would be able to take place in the spring. Harvesting, especially for sugarcane, requires a high water table - a requirement no one could guarantee could be met as the dry season progressed.

Then from late May through June much of the study area received abnormally high rainfall. The lake level rose from 10.5 feet to 13.5 feet in about a month. This drought lasted 18 months, but then the floods began. Those floods are discussed in the following section.

Another drought struck in 1989 which lasted two and one-half years. This drought broke the record from 1980-82 and the Everglades were at their driest since 1957. The snail kite and wading birds that live off small fish, sought other feeding areas. Some of the animals showed up hundreds of miles to the north, in western Indian River County in central Florida, an area filled with a broad band of freshwater marshes, wetlands and Blue Cypress Lake.

The water level in the Refuge fell below 11 feet. Once water levels fall below 13 feet in its rim canals, interior marshes drain into them and dry out. Thousands of acres in the Refuge were dry, including 10,000 acres at the north end that had been dry for nearly two years. Nearly all life in the dry areas died or moved away. The managers estimated that when the water returned, recovery could take up to three years.

Water restrictions had to be imposed on both coasts. Water restrictions were in effect on the West Coast from November 1988 until July of 1989. On the East Coast, restrictions were imposed on areas in northern Broward County in April 1989, and in northern Palm Beach County and around Lake Okeechobee as they were lifted on the West Coast in July 1989. Lake Okeechobee dropped to 11.18 feet, close to three feet below normal by August 1989. The SFWMD was forced to briefly resume backpumping into Lake Okeechobee in September 1989.

Throughout the District, rainfall was 13 inches below normal - a one-in-50 year drought. In the EAA, the rainfall deficit was over 20 inches. When rain did occur, it seldom fell over areas like Lake Okeechobee or the WCAs, where it could be held for later use. The surface water supply system lost a record 3.1 million acre feet from September 1988 to August 1989.

Groundwater levels at Cape Coral and southern Fort Myers on the west coast hit record lows. The aquifer in that area dropped to 40 feet below sea level. In 1989, groundwater levels in South Palm Beach and North Broward counties dropped between one and three feet to just above sea level. Levels continued to drop as the drought lasted.

The fourteen inches in October that flooded parts of south Florida still left the region critically short of water since most of the deluge washed out to sea. In October, the SFWMD designated a 13-county area as "a critical water supply problem area". This allows the SFWMD to force communities to take conservation measures such as using recycled, treated sewer water for lawn-watering. This designation means that all communities in this area meet certain conditions and are likely to experience water shortages in the next 20 years. In December, the SFWMD is to decide whether to require all water extracted during the sewage treatment process to be reused. If that plan is approved, utilities in the critical zone will be required to begin reusing treated waste water within five years.

Counties throughout the west coast are developing conservation programs. Some of the measures under consideration include: low-flow toilets, shower heads and sprinkler systems, low pressure water delivery systems that would reduce water pressure in pipes, re-use of treated waste water for irrigation, and mandatory xeriscaping. Xeriscaping uses drought-resistent plants for landscaping.

Flood Protection

Flood protection was the primary purpose for the construction of the C&SF Project. It is still a very critical function of the project today. During recent flooding in the EAA, farmers complained that tens of millions of dollars worth of crops were lost. They claimed that the SFWMD waited too long to start pumps that move storm water into Lake Okeechobee and prevent fields from flooding. According to SFWMD, the pumps were started as soon as criteria permitting pumping had been met. There is concern that the criteria set by the State and the Corps is outdated. It is felt that the subsidence of muck in the region needs to be taken into account (Shuchman, 1991). Urban flooding in October caused damage to 900 homes in Dade County. Once again the SFWMD was blamed for not opening flood gates to drain nearby canals soon enough. SFWMD staff however said that the system could not handle the excessive rain that fell in the short period of time.

Tropical Storm Dennis, discussed in the Drought section above, emptied nearly 20 inches of rain on southern Dade County in August 1981. The SFWMD responded to this major flooding episode by opening all water control structures in the South Miami-Homestead area to full discharge capacity. The earthen plug at the southern end of C-111 was removed for the second time since its construction in 1968, allowing maximum releases to be made from the area.

After 18 months of drought, the 1982 rainy season began with a bang. From May 23 to June 26, 1982, a total of 22.37 inches of rain was recorded at a rain gauge station in LaBelle. The same pattern occurred throughout the 900 square mile WCA 3A, amounting to twice the amount of rain normally received in these areas during May and June. Due to the unusually heavy rains, and in some cases compounded by inadequate drainage systems, severe flooding occurred in several areas of the study area. One county especially hard hit was Hendry County. A federal emergency task force declared a state of emergency for the area on June 18, 1982, and requested President Reagan on June 30 to declare a major disaster in the area. On that same day, Governor Bob Graham declared Hendry County, and several other counties outside of the study area, a flood disaster area.

While work was progressing to relieve flooding in Hendry County, WCA 3A also began to have problems. On May 1, 1982, the level of WCA 3A was two feet below regulation schedule. When the rains came later that month, the level began to rise. This direct rainfall was supplemented by water flowing into the area from flood water releases out of the north. The level increased from 7.7 feet on May 1 to 11.04 feet on July 19. While the recharge of south Florida's water supply was welcome, the high levels caused problems for wildlife.

The wildlife in WCA 3A is managed by the FGFWFC. Aware that the rising water would lead to increased competition by the deer and other upland animals for food and dry habitat, the FGFWFC announced plans for a special deer hunt. Anti-hunting groups, claiming that the animals should be rescued from the area or left to die a "natural" death, challenged the hunt in court. In response to this controversy, which received much local and national publicity, Governor Graham appointed an Everglades Wildlife Management Committee. The committee was charged with considering ways to better manage Everglades wildlife in concert with basic water management goals in south Florida. The committee made several recommendations for improving both wildlife management and water management in the Everglades.

Overdrainage

The original need to provide flood control and drainage improvements to the developed areas, combined with the haste to drain additional areas for development opportunities, has resulted in area-wide problems related to overdrainage of soil and shallow aquifers. The increased rates of water removal from developed areas by improved drainage systems has also reduced aquifer recharge. This, combined with the ever increasing pumpage of water from the aquifer, has reduced the natural storage and availability of water from the major surficial aquifers, such as the Biscayne Aquifer. In the lower southeast coast, the Biscayne Aquifer serves as the major supplier of water. Anything adversely affecting this aquifer has far-reaching effects on both the population and economy of the entire area.

Largely as a result of the agricultural and urban growth along the Orlando upland on the north and the Lake Wales ridge to the west of the Kissimmee River, the potentiometric surface of the Floridan aquifer beneath these uplands has declined almost 35 feet since the 1930's. This potentiometric level decline has resulted in reduced ground water seepage that previously reemerged as surface water contributions to the upper Kissimmee River basin chain of lakes, to the Kissimmee River, and to Lake Okeechobee.

WATER MANAGEMENT POLICIES

Another problem identified was that the policies governing the system are not flexible enough to investigate feasible operational alternatives that would cover a wide range in conditions. It is felt that studies are required to attain optimum or maximum benefits for the entire area as a whole.

As discussed in the previous chapter, the hydrologic ecosystem is very complex. Many people question that the water supply problem is real in an area where an average of 60 inches of rain falls each year. However water shortages can, and do, occur here; because most of those rains fall during a period of time, from June through October, when people's demands are lowest, and flooding is the greatest threat to the works of man. It is also not always well understood that water withdrawn anywhere in the region can affect levels elsewhere in the system. Reserves of groundwater or surface water pay little attention to boundaries. A Dade County farmer's underground well drilled into the Biscayne Aquifer depends on surface water conveyed from canals or reservoirs as far away as Lake Okeechobee.

The attempt to model this system in the past has been limited in scope. The South Florida Water Management Model (SFWMM) developed by the SFWMD is the most heavily used modeling tool within the region.

The code used in that model integrates surface water and groundwater flows to address water management issues (such as water supply, flood control, and environmental quality). The model simulates flow for an area that includes the WCAs, EAA, much of the BCNP, ENP, and the lower east coast. The model provides differing levels of simulation sophistication for all of the important processes affecting water management in this area: rainfall, runoff, ET, interconnections between surface systems (particularly the canal system) and aquifers (particularly the Biscayne Aquifer), and overland, canal, and groundwater flows.

While the model is highly advanced, it still has a number of opportunities for improvement. This is discussed in more detail in later chapters, but one of its major criticisms is the very complex nature of the model. The model requires a computer programmer to operate it and to interpret the large file of numbers that is produced as output. It is not possible to efficiently run a number of alternative water management scenarios as the computer code must be rewritten to incorporate changes.

IDENTIFICATION OF ISSUES, PROBLEMS, AND NEEDS:

WATER QUALITY

Water quality issues in the study area basically fit within three categories: eutrophication, salinity/dissolved solids and contaminants. The topics were primarily defined at the sub-region level, however, the same or related problems appear throughout the entire system.

EUTROPHICATION

The eutrophication issue has a long history in some areas, while other areas are potential sites for problems. A major eutrophication issue for at least the past 20 years, has been the effect of nutrient enrichment (primarily nitrogen and phosphorus) on Lake Okeechobee. The other major eutrophication issue involves the freshwater marshes of the Everglades system (WCAs and the ENP). The freshwater marshes of the natural systems are extremely oligotrophic; seemingly minor changes in the nutrient status can result in dramatic changes in the microflora and macrophytes. Eutrophication is also currently an issue in the upper watershed, or Kissimmee River Basin. The infestation of aquatic plants in the canals of the system is related to nutrient enrichment. Potential areas of eutrophication include the Big Cypress area, mangrove zones, estuarine bays, and Florida Bay. In the foreseeable future, impacts from agriculture will become apparent in southwest Florida, as cultivation of citrus groves and other crops becomes established.

Kissimmee River Basin

The Kissimmee River Basin has been identified as one possible source for excess nutrients (ie: phosphorus, nitrogen) that can been blamed for the eutrophication of Lake Okeechobee and systems downstream. The dairy industry is located in this area. The dairy farms' 45,000 cows each produce raw waste equivalent to that of 22 human beings. The 2,295 tons of waste contribute to the 1.5 tons of phosphorus that flow into the lake each day (Duplaix, 1990). These huge inflows of phosphorus and nitrogen, accumulating in the silty bottom of Lake Okeechobee, hasten the natural aging process of eutrophication. There is a need for scientific study to understand the sources, means of transport and fate of the excess nutrients. It would then be possible to establish Best Management Practices (BMPs) for the farms in the basin.

Some measures have already being undertaken or considered to enhance the quality of the water discharged into Lake Okeechobee. As discussed in the following section on Lake Okeechobee, a dairy buy-out program has been instituted by SFWMD, along with other phosphorus reduction measures.

Another project currently being studied by the Corps and SFWMD is the restoration of the Kissimmee River. The proposed modification includes completely backfilling about 29 miles of the canal, partially backfilling another 16 miles, primarily in Okeechobee County, excavating 12 miles of new river channel, and construction of a by-pass weir at Structure 65 on S.R. 60 in Polk/Osceola counties. The Kissimmee River provides 30 percent of the water flowing into the north end of Lake Okeechobee. Restoration of the river and surrounding wetlands and implementation of BMPs are expected to halt the contamination of the Lake and replenish the depleted water flow to the Everglades. It is estimated that the water quality would improve by 15 to 20 percent.

Lake Okeechobee

Lake Okeechobee is the largest freshwater lake in the U.S., south of the Great Lakes. It is a primary source of drinking water for South Florida and supplies water directly to several cities around the Lake. In times of drought, water from the lake is used to recharge the Biscayne Aquifer, primary water supply for the 4.5 million people in southern Palm Beach, Broward, Dade, and Monroe Counties.

During the 1971 drought, the USGS released a report stating that Lake Okeechobee was in danger, by being overburdened with nutrients, and aging too rapidly. Lakes, like every other living organism, have a natural life cycle. Lake Okeechobee could suffer a decline unless this early eutrophic state was reversed. In 1972, Governor Reubin Askew convened a conference on water management which clarified the necessity of balancing man's and the environment's needs and managing water resources on a regional basis. Later that year, the State legislature enacted the *Water Resources Act, the Florida Comprehensive Planning Act and the Environmental Land and Water Management Act.*

This legislation created five regional water management districts responsible for all surface and ground waters within their boundaries, rather than just flood control works. This changed SFWMD's mission and mode of operation, shifting the emphasis from flood control to water management.

In the summer of 1986, national attention was focused on Lake Okeechobee after a record 120 square miles of the lake was covered with an algae bloom. This particular outbreak was identified as *"anabaena circinalis,"* a blue-green algae considered to be deadly to aquatic life, since it robs the water's oxygen during its decomposition. Scientists from the Lake Okeechobee Technical Advisory Committee (LOTAC) concluded that the increased algae blooms on Lake Okeechobee were a result of the increases of phosphorus and nitrogen. They recommended the physical removal of phosphorus via aquatic weed removal; expansion of BMPs to the Lower Kissimmee; improved conservation from agriculture via SFWMD permit renewals; and the diversion and aquifer storage and recovery of nutrient-rich water.

Scientists say that Lake Okeechobee is overloaded with phosphorus, primarily from the dairy farms at the north end of the lake and from the agricultural farms which rim the southern end, and is quickly becoming stagnant. The canal water also carries nitrogen compounds leached from the Everglades muck. Back-pumping farm drainage into the lake to raise water levels was routine until 1979, when the SFWMD decided that the quantities of nitrogen and phosphorus had begun to threaten the viability of the Lake. The water was then sent south through the WCAs. Back-pumping still occurs, but only as a last measure. Stormwater runoff carrying fertilizer into the lake has also been cited as a problem.

Between 1974 and 1984, concentrations of total phosphorus in Lake Okeechobee almost doubled. Preliminary evidence suggests that excessive nutrient loading has reduced the Lake's capacity to assimilate phosphorus. In addition, the ratio of total nitrogen to total phosphorus has shown a significant downward trend, which may indicate a shift in species composition from the Lake's normal algal flora to less desirable nitrogen-fixing blue-green algae, such as *Anabaena.* If these trends continue, it is possible that eutrophication will accelerate and that the Lake will suffer an ecological collapse of its food chain and fishery resource (Swift, Anclade, and Kantrowitz, 1987).

The Surface Water Improvement and Management (SWIM) Act was passed in 1987 which required each water management district to develop a priority list of water bodies in need of restoration and protection, and then identify strategies to protect or restore them. Water bodies identified by the *SWIM Act* for priority improvement in South Florida included Lake Okeechobee, Biscayne Bay, and the Indian River Lagoon. Others would be added: the Everglades, including the three WCAs and ENP. During 1987, Interim Management Plans for the Indian River Lagoon and Biscayne Bay were completed. New studies of Lake Okeechobee water levels and the importance of the Lake's littoral zone were begun, as was an interim *SWIM Plan* for the Lake.

Because ambient levels of phosphorus in the Lake reached a record high in 1987-88, the Lake Okeechobee *SWIM Plan* adopted in 1989, calls for immediate implementation of some very aggressive phosphorus reduction strategies. The *SWIM Plan* set phosphorus limits of 0.18 part per million of water entering all points around the Lake to achieve a maximum annual loading of 397 tons. The total phosphorus loading to Lake Okeechobee from October 1990 to June 1991 is estimated to be 252 tons. The current projection for the year ending September 30, 1991 is 574 tons. Therefore, phosphorus loading for 1991 is expected to exceed the target of 397 tons, or forty-five percent. The increased phosphorus loading is primarily due to excess stormwater runoff caused by higher than normal rainfall. There were several algae blooms in Lake Okeechobee in June, in July there were no algae blooms, but in August there was a bloom of 4-5 square miles at the south end of the Lake (Office of the Governor, 1991). Another algae bloom covering 20 square miles appeared in late August.

The *Lake Okeechobee SWIM Plan* goal is to reduce phosphorus loadings to 397 tons per year. To accomplish this goal, the SFWMD is implementing a regulatory program to control the sources of nutrient-laden runoff. A dairy buy-out program has been instituted by SFWMD. The dairy buy-out program, involving the SFWMD and DER, pay the dairies a fee per cow for closing their farms in exchange for a guarantee that dairy farming operations will never occur on that property again. Other dairies are required to apply for permits for the construction of BMPs. BMPs include aquifer storage and recovery, on-site surface storage, crop rotation, letting certain lands periodically lie fallow, and others described in a *Draft SWIM Plan*. The SFWMD will submit a final *Lake Okeechobee SWIM Plan* to the Florida Department of Environmental Regulation (DER) by June 1992.

Water Conservation Areas and Everglades National Park

Pollutants entering the WCAs have damaged the ecosystem. The contaminated water contains 10 to 20 times the normal concentrations of phosphorus and nitrogen. Where the pollutants have penetrated the Refuge and other areas in the WCAs, the original sawgrass swamp is being overtaken by cattails. The cattails thrive on the excess phosphorus and soon crowd out the sawgrass with their roots and leaves. The exotic cattails also shade out the oxygen-producing periphytic algae, which is the base of the Everglades food web. Thousands of acres of native sawgrass have been displaced in the WCAs alone in the past 10 years. Phosphorus also eats away algae critical to the Everglades food chain and keeps oxygen from dissolving properly in water.

It is believed that the unnatural phosphorus loads from the north would be better dispersed if water were delivered more slowly and naturally. The phosphorus is blamed for disrupting biological processes that support a diverse community of plants and animals. The goal of the cleanup plan is for the WCAs to receive no more than 41 tons of phosphorus by the year 2002.

MARJORIE STONEMAN DOUGLAS ACT

The Marjorie Stoneman Douglas Everglades Protection Act, Section 373.4592, Florida Statue, went into effect July 1, 1991 with the purpose of facilitating the surface water improvement and management (SWIM) process by providing a funding mechanism to implement Everglades SWIM plan strategies and other projects necessary to meet Everglades water quality requirements. Specifically, the act authorizes SFWMD to acquire lands and create stormwater utilities for the construction and operation of stormwater management systems and programs.

The act requires SFWMD to apply for 5-year interim permits for its structures in the C&SF Project, which should include recommended ambient concentration levels and discharge limitations for phosphorus necessary to meet state water quality standards, proposed interim concentration levels, and strategies to achieve compliance-including the development of a regulatory program to improve water quality before it enters the stormwater management systems. SFWMD must also publish rules by April 1992 for permits authorizing discharges from the EAA and set nutrient limitations for such discharges.

EVERGLADES LAWSUIT

The U.S. Attorney's office in Miami sued the SFWMD and DER in 1988, charging SFWMD and DER with: 1) violating state law by failing to enforce state water quality standards against EAA farmers, 2) operating SFWMD water management structures within the project without state permits, and 3) allowing EAA nutrient enriched waters to enter the Refuge and ENP causing an *"imbalance in natural fauna and flora"* in violation of Class III water quality standards.

In full recognition that the Park and Refuge are unique and irreplaceable natural resources and, in order to settle the lawsuit, in July 1991 the Federal and State parties agreed to cooperate in a commitment to restore and maintain the quality of water delivered to the Park and Refuge.

Under the Agreement, the Federal and State parties committed to cooperate to protect and enhance the water-dependent ecosystems of the Park and Refuge, subject to events beyond their control, such as natural disasters or unavoidable legal barriers or restraints, including those arising from the actions of third parties. Section 4 of the Agreement provides, "In recognition of the serious and potentially devastating degradation threatening the Park and Refuge as a result of nutrient-laden waters, . . . [the United States, DER, and SFWMD] commit themselves to guarantee water quality and water quantity needed to preserve and restore the unique flora and fauna of the Park and the Refuge."

The Corps is cooperating with the SFWMD in the operation of the its structures to assist the District in achieving its water quality goals. In addition, the Corps agreed to assist in research and monitoring and to defend the agreement against third parties.

On July 11, 1991, Governor Chiles and U.S. Attorney General Thornburg announced agreement on the terms of settlement of the Everglades Lawsuit. Major points of the agreement include:

<u>Restoring and Maintaining Water Quality</u>: The settlement provides that such actions as necessary shall be taken so that waters entering the Everglades systems will achieve water quality standards by July 1, 2002. Phosphorus load-reduction required by the settlement is quantified with interim levels to be achieved by 1997, and long-term goals to be reached by 2002.

<u>Water Quantity Requirement</u>: Quantity, distribution and timing of water flow must be sufficient to maintain and restore abundance and diversity of natural flora and fauna in ENP and the Refuge.

<u>Stormwater Treatment Areas (STAs)</u>: Under the settlement agreement, SFWMD commits to purchase, design and construct stormwater treatment areas to reduce phosphorus concentrations. These areas will include approximately 35,000 acres within the EAA at key inflow points to the system.

<u>Research and Monitoring</u>: The parties of the settlement agree to on-going research and monitoring programs necessary for implementation and compliance of the agreement.

<u>Regulatory Program</u>: A regulatory program for the EAA will be designed to achieve a ten percent reduction of phosphorus in the water leaving the EAA by 1994, and a 25 percent reduction by 1996. The regulatory program shall require permits for internal drainage systems in the EAA, BMPs designed to meet phosphorus allocations, monitoring and reporting.

Implementation: Under the settlement, the SFWMD shall apply to DER for five-year interim permits by October 1, 1991, and DER shall take final agency action on permit applications before July 1, 1992. The permits are to be designed to ensure meeting phosphorus concentration limits. Additionally, the SFWMD shall develop a SWIM plan by October 1, 1991, and shall take final agency action on the SWIM plan by March, 31, 1992.

Technical Oversight Committee (TOC): A TOC, composed of scientific representatives from the Corps, the ENP, the Refuge, DER and SFWMD will oversee research, monitoring and compliance.

Settlement of Disputes: The parties agree to settle disputes through good faith negotiation. A mediation framework is established, and the court retains jurisdiction.

The Corps was involved as a plaintiff in the lawsuit. Under the terms of the agreement the Corps agreed to apply for stormwater management permits for the operation of the S-10s, S-11s, and S-12s by 1 October 1991. The Corps has submitted the application for a stormwater permit for the Corps structures, which are the main outlets from the WCAs.

EVERGLADES SWIM PLAN

The SFWMD has been tasked to develop the *Everglades Surface Water Improvement and Management (SWIM) Plan under Sections 373.451-373.4595, F.S., and the Marjorie Stoneman Douglas Act*. The Everglades SWIM Plan describes the area's development and management history, summarizes the present knowledge of the system, and provides an overview of the ecosystem's current conditions. The plan then attempts to integrate proposed and existing programs to address various aspects of water resource management within the Everglades such as, water quality, water quantity, water supply, flood control, and environmental enhancement.

The overall goals of the plan are to: 1) make structural and operational changes as needed to correct certain known hydroperiod problems in the Holey Land, north ends of water conservation areas, the Park, the C-111 Basin and coastal estuaries; 2) reduce phosphorus loadings into the Everglades marshes by 75 percent; and 3) expand continuing efforts to control the spread of the exotic tree, *Melaleuca,* which is invading Everglades wetlands. The plan provides a regulatory framework for achieving these goals in the Everglades system. This requires the use of individual best management plans by agricultural interests in the region in order to achieve the goals set by the plan.

The plan represents an overall approach and guidelines for integrating Everglades water resource management activities and is subject to public review and State approval. All implementation programs and projects are authorized by separate public processes such as SFWMD Governing Board Approval, permits and rule making. The document is currently in draft form, having not yet been approved by the DER. The Corps has been an active participant in the development of the plan and is firmly committed to the goal of maintaining and restoring the full abundance and diversity of the native flora and fauna in the Park and Refuge.

EVERGLADES MEMORANDUM OF AGREEMENT

There is currently in force a Memorandum of Agreement (MOA) between the SFWMD, the Park, and the Corps, signed December 4, 1979 and updated in 1984, on the quality of water entering the Park. This agreement provides specific numerical water quality criteria for the Park. The original numerical criteria were developed by Park staff at levels above existing water quality measurements to serve as an indicator of potential problems rather than daily safeguards. The criteria were calculated from baseline water quality data from two inflow points that discharged water to the Park from WCA 3A over a period of record from 1970 to 1978. Under the terms of the MOA, the Corps monitors four inflow stations to the Park. A specific paragraph in the MOA says that should a clear and present danger to the Park be present the parties shall take such measures as may be necessary to improve the water being delivered to the Park. As part of this agreement an additional ten (10) water quality stations are monitored by SFWMD at areas around the Park.

The obligations of the parties to the MOA are not altered or affected by the Settlement Agreement.

The settlement would enforce an Everglades cleanup plan requiring 35,000 acres of farmland be converted to pollution-filtering marshes at an estimated cost of $300 to $600 million. At the present time, farmers in the area are fighting the settlement in State and Federal courts. They claim to have been unfairly burdened with pollution cleanup costs. They question the scientific basis of the cleanup and point out that the settlement agreement acknowledges that there is considerable uncertainty regarding how well the planned corrective measures, including STAs and the regulatory program in the EAA, will work and that there may be a need for additional remedies.

In addition, farmers have never conceded that agriculture is detrimental to the Everglades. They argue that phosphorus is only a small contributor to the Everglades' ills, and that most of it occurs naturally in the south Florida soil. They blame the State's mismanagement of water supplies throughout southern and central Florida.

Since it is just as important that the Everglades receives enough water and at the right time of year, one of the specifications of the settlement is that farmers may retain on their land no more than 20 percent of the water which otherwise would flow south. Farmers say that they cannot obey those limits and still remove 25 percent of the phosphorus from their runoff, another provision of the settlement. They can either put the water into surface impoundment areas, where grasses would absorb phosphorus, or pump it deep into the ground, where the phosphorus would bind to limestone. In either case, however, they claim that more than 20 percent of the water would be lost.

NUTRIENT REMOVAL SYSTEMS

Proposed Stormwater Treatment Areas

The lawsuit settlement requires setting aside approximately 35,000 acres of farmland for marshes to filter pollution from water bound for the WCAs and ENP. The primary strategy of the STAs is to remove nutrients from agricultural runoff. Through management of the growth of specific plant species in the STAs, SFWMD plans to produce a significant reduction in the total nutrients. The reduction in nutrients is due to the scavenging actions of the plant species and the reduction in total suspended nutrients by settling due to reduction in velocity.

The STAs will mainly receive stormwater from the primary agricultural drainage canals and hold and process it for the removal of nutrients through intensive management. Deliveries may be made to the STAs from Lake Okeechobee or other sources. These areas will be designed, operated and managed primarily to purify the waters entering the WCAs, the ENP, and the Refuge. The water from these treatment areas is expected to eventually be passed through the S-10, S-11, and S-12 water control structures. The plan requires that phosphorus overloads be reduced by 80 percent within ten years.

Before the lawsuit, the SFWMD, as part of its overall Everglades cleanup efforts, worked for nearly three years on such a filtration marsh project in the EAA adjacent to the Refuge. The 3,742-acre Everglades Nutrient Removal (ENR) project system is on the site of state-owned land in the EAA which had been farmed for 20 years. This ENR was to act as an experimental project to provide information for larger filtration projects being planned.

In August 1989, Phase I of the ENR project was completed. Phase I consisted of flooding 1,200 acres to allow growth of marsh vegetation. An on-site nursery containing bulrushes and other flora has been developed to provide the plants needed for the project. The flooded land will be used to monitor vegetation growth during construction of the whole project as well as nutrient uptake.

Phase II consists of design and construction of the primary structural components of the project. This phase includes the 7.4-mile perimeter levee around the triangular-shaped tract, the initial construction project will include culverts, canals and levees, and pump stations to move water in and out of the entire area.

Phase III encompasses the design and construction of the interior water distribution system and components required to build and regulate the internal nutrient retention system. The interior of the ENR project will be made up of four cells of wetlands that will allow water to be treated in a north-to-south sequence. Cell One, on the northern end, will be the deepest and will serve as the initial nutrient removal component of the system. Cells Two and Three, in the center, will be the primary nutrient removal cells, while Cell Four will be the shallow "polishing" cell, from which water will be discharged directly into the refuge. Predictions are that the system eventually will treat 125,000 acre-feet (nearly 41 billion gallons) of stormwater per year.

Completion of the total ENR project is set for 1993. This will be the first scientifically-based and monitored large-scale conversion of agricultural land into a marsh system for the purpose of removing nutrients. However, the lawsuit settlement requires the construction of 35,000 acres of STAs. The ENR project will be incorporated into a larger project, STA 1. STA 2 will be constructed along Hillsboro Canal adjacent to WCA 2A. STA 3 will be constructed adjacent to North New River Canal along WCA 3A and STA 4 will be constructed along the Miami Canal north of the Holey Land tract.

Another project that the SFWMD was working on before the lawsuit is the restoration of the Holey Land and Rotenberger Tracts. These 95-square-mile area tracts are adjacent to the northern boundary of WCA 3. This former Everglades area has been degraded by overdrainage, muck fires, and invasion by upland weeds and other plants. Construction to restore the wetlands of the Holey Land, a 35,000-acre-tract of land located in southwest Palm Beach County, began in 1985, and was completed by September 1989. Some of the water from the EAA can now be passed through this marsh, and distributed across a broad front as it enters WCA 3.

These STAs have been controversial. No one knows the correct levels of nutrients required by the Everglades. Sound, scientific research must be performed to determine what the goal should be. It is still unknown how large these marshes need to be, how efficiently they will remove nutrients, and how long they will remain effective. A nutrient budget for the entire system is needed to quantify present and past nutrient fluxes and storage. Then models should be developed to predict allowable nutrient loads and timing required to achieve desirable concentrations. Research is also needed to understand the impacts that contaminants or excessive nutrients have on a particular system. There is limited knowledge of plant uptake rates and the biotic thresholds for various substances.

In September, consultants for SFWMD stated that a 35,000-acre marsh system would need 10-foot-deep ponds surrounded by 20-foot-high dikes, two-thirds the height of the Herbert Hoover Dike around Lake Okeechobee; canals larger than any of the existing canals; and pumping stations 20 percent larger than the S-5A, which is one of the largest in the world. Marsh vegetation can not survive in water more than 2 or 3 feet deep, and this vegetation is a key factor in removing pollutants. If 10-foot ponds are needed on 10,000 of the 35,000 acres, it would take another 20,000 acres to lower the water to acceptable levels. The consultants are still studying the plans.

An experimental water-filtering project at Lake Apopka is being closely watched for possible use in cleaning up Everglades pollution. Some say that Lake Apopka, located in Lake and Orange counties in central Florida, is a dead lake because generations of diking and drainage encouraged massive algae blooms that chocked off almost all marine life. The only fish left is gizzard shad. The 950-acre project is in its early stages, the work underway since November is only a pilot project intended to eventually cover 5,000 acres. The water flows by gravity from the 31,000-acre lake into a marsh created by flooding vegetable farms. The only artificial action is pumping the water from a reservoir into a canal connecting Lakes Apopka and Beauclair. Scientists say the wetlands filters out 90 percent of the sediments and 45 percent of the phosphorus.

St. Lucie River

One hundred years ago, there were areas of the upper estuary where the water ran as deep as 16 feet. Today, in some of those same areas, the water is only a foot deep. Sediment carried by large discharges from Lake Okeechobee and storm runoff from canals is filling in and polluting the river. Development along the banks, flood control efforts and agricultural runoff have had a major impact on the biology of the river. Sediment, water color, and other physical aspects of the river need to be addressed. Clay combined with organics and metallics is flowing into the North Fork of the river and heavy metals can be found on the river bottom. A normal estuary contains ten percent or less of flocculent ooze, but several areas in the St. Lucie contain as much as 30 percent. In several large pockets, more than 40 percent of the bottom sediment is muck. That much sediment can kill all of the fish and vegetation in that area of the river. The bottom sediment steals all of the oxygen out of the water, creating an anaerobic environment. The 3-foot-deep ooze blocks sunlight, harming aquatic plants. Freshwater entering the estuary is carrying pollutants, sea grasses and mangroves are declining.

Big Cypress Basin

Big Cypress Basin was identified as an area of potential concern for eutrophication. Impacts from drainage, agriculture, and discharge of mineralized water need to monitored in the future.

SALINITY AND DISSOLVED SOLIDS

Salinity problems were discussed in the previous chapter on Water Quantity. Dissolved organics in the groundwaters of the lower east coast pose treatment problems. Waters from the Everglades that are transferred via canals or surficial aquifers to wells have high concentrations of dissolved organic compounds, which may lead to problems in treatment for human consumption.

CONTAMINANTS

In August, the nonprofit Institute for Southern Studies released its *Green Index*, a book that ranks the 50 states in various environmental and public health categories. Overall, Florida was ranked among the healthier places to live, except for having the most polluted water in the United States. Among the factors were the volume of toxic chemicals released to surface waters and sewers or injected into deep underground wells, sewage treatment problems, polluted lakes and streams and pesticide contamination of groundwater (Olinger, 1991). Contaminants in the waters of the system include heavy metals, especially mercury and residues from agricultural practices, including herbicides and pesticides.

Ethylene dibromide (EDB), a pesticide banned in the 1980s because of its cancer-causing potential, has seeped into drinking water supplies in 22 Florida counties. The contamination ranges from northern counties; where EDB has been detected in the Floridan aquifer, a large underground reservoir that supplies much of the state's drinking water; to central Florida; where filters have been installed to remove EDB from school water fountains in the town of Alturas. State workers have detected EDB in drinking water in about 2,500 wells, mostly in citrus and peanut-growing areas of central and north Florida. Because EDB is a durable compound and was widely applied, the State program to monitor a pesticide no longer in use could last a century (Olinger, 1991).

The water systems for the towns of Belle Glade, South Bay and Pahokee have shown an increase in trihalomethanes (THMs), compounds that are known carcinogens and which are produced by treating nutrient-rich water with chlorine. Fort Myers has also been plagued by THMs. EPA allows levels up to 100 micrograms of THMs per liter. Fort Myers' city water currently averages 400 micrograms per liter (Hersch, 1990).

A $2 million study is currently researching the source of pollution apparently killing off coral reefs in Palm Beach County and slowly spreading south. Scientists suspect that either farm runoff or city sewage is to blame for the spread of codium, a once-rare algae that sails from reef to reef on parachute-shaped spores. Over the past three years, the algae has killed off several square kilometers of America's northernmost coral reef. It is believed that too many nutrients, in the form of phosphate and nitrate from sewage or fertilizer, are probably to blame for the algae's bloom. The research is attempting to determine if sewage is thoroughly diluted by sea water, or whether it creates pockets of pollution that could cause the algae bloom. The reefs off Palm Beach County are the only ones affected so far.

Historically, the Miami River served as a vital link between the Everglades system and Biscayne Bay. The Everglades spilled over its eastern rim and freshwater flowed from the Everglades and natural springs down the river providing nourishment to Biscayne Bay's brackish estuarine system. The very form and uses of the river changed in the early 1900s when the Everglades drainage project began and Henry Flagler laid the first sanitary sewer pipe along Miami Avenue, discharging raw sewerage into the Miami River. Large volumes of raw sewage were discharged into these waters from 1920 to 1955. Today, the river receives stormwater runoff from urban Miami and provides flood protection and drainage to over 132 square miles in Dade County. The Miami River is Biscayne Bay's most polluted tributary and is considered one of the most polluted waterways in Florida.

Biscayne Bay, historically, was a clear shallow coastal estuary. Today, turbidity is a major problem and has been a continuing cause of water quality degradation since extensive dredging and filling of North Bay began in the early 1900's. Major sources for continued turbidity are sedimentary input associated with the erosion of non-stabilized spoil, resuspension of fine and flocculent materials from dredged materials from dredged areas and deep holes, stormwater runoff, and phytoplankton blooms associated with abnormally high nutrient content. Wastes from residential communities also pollute the Biscayne Bay National Park, adding to the agricultural runoff of pesticides and herbicides.

Biscayne Bay is a highly visible and vital part of the region's identity, economy, and recreational life. However, the direct relationship between water quality in the Bay's tributaries, specifically the Miami River, and the Bay itself is not always understood.

There is growing concern that disturbing levels of toxic chemicals are being found in hard and soft corals in the reefs that border Biscayne and Florida Bays. In 1989, the University of Miami reported toxins including heavy metals and such organochlorine pesticides as lindane, heptachlor, and DDT have been found in the reefs. These are also found in fish and shellfish that people eat. No one is sure where these chemicals are coming from. Additional laboratory tests are under way to verify the levels of contamination (Laycock, 1991).

Mercury

Recently, in Florida, mercury in the environment has come under intensive investigation after widespread amounts of mercury were discovered in freshwater bass. The discovery led to the appointment of a mercury task force in December 1989. The national safety standard for human consumption of mercury is one part per million (ppm), but tests have found up to seven ppm in fish, 3 ppm in alligators. Tests on liver tissue taken from a Florida panther that died of unknown causes registered 110 ppm (Seminole Tribune, 1989). Mercury levels of up to 1.5 parts per million have been found in fish all over the state, but the highest levels - 3 parts per million - have mystifyingly turned up in the Everglades (Santaniello, Neil, 1989). Since November 1988, toxic levels of mercury have been detected in largemouth bass in about half of 120 major rivers and lakes that have been tested in the State. The State has issued health advisories calling for limited consumption of certain fish taken from the Everglades, a state preserve in St. Lucie County, eight rivers and nine lakes.

The mercury's origin is a mystery; no point source of contamination has been identified. Mercury is an element that occurs naturally in the environment, particularly in salt water. Mercury is believed to be accumulated in fish in two ways - by direct absorption from the water through the gills and through the food chain. The source of the mercury needs to be determined.

The theories are that it could be coming from atmospheric fallout (from smokestacks and incinerators), from old pesticide residue, or that man could be doing something that is creating organic mercury from naturally occurring elemental mercury. Batteries and florescent tubes placed in landfills are being blamed. According to scientists, high amounts of mercury in the soil can be immobilized by the organic compounds that bind them in such a way that only negligible amounts escape, thus preventing a contamination problem. But it is thought that certain processes mobilize the mercury, allowing it to be ingested by fish and other aquatic wildlife and move up the aquatic food chain, where higher concentrations can be detected in large predatory animals, such as large-mouth bass.

Environmental groups claim that the practice of burning sugar cane fields before harvest spreads mercury and the pesticide paraquate. Scientists know that for some reason, mercury builds up in the rich, black muck soils like those where sugar cane is grown near Lake Okeechobee. Some of this mercury is apparently taken up by the sugar cane through roots. They say that up to 11 tons of mercury are released each year by burning the mercury. Another theory is that the current suspected high levels of mercury are merely a previously unknown but naturally occurring phenomenon.

Warnings were issued two years ago, after dangerous levels of mercury were found in the organs of Everglades fish. Today, health advisories warning of mercury poisoning have been issued for one-third of Florida's rivers, lakes, and streams. No person has been diagnosed with mercury poisoning, but high levels of mercury have been found in the livers of Florida panthers. One panther that died in the ENP in July 1989, had a mercury level of 110 parts per million (ppm). After this discovery, USFWS conducted additional tests on various tissues of other dead panthers. Test results from the livers of 11 dead panthers ranged from 0.049 ppm to 20 ppm. The death this summer of the last two breeding female panthers in the ENP has been blamed on mercury. One showed a fivefold increase in the level of mercury since being tested in November. ENP officials are considering moving the last two panthers, a pair of males, from the Park to BCNP to protect them from further exposure to mercury. There are only 30 to 50 of the endangered species left. Wildlife biologists are beginning to question whether mercury poisoning might also account for the decline of wading birds and other species.

DER has developed a multi-year plan to study the source of the mercury contamination, and how the toxic heavy metal travels in air, water, sediment and aquatic life. Scientists will submit study plans for $200,000 in research money allocated by the State Legislature last spring. The research could begin by May 1992. The study could take three to five years and the $200,000 is only a fraction of the study's cost. Up to $5 million eventually may be needed. The agency likely will seek additional money from the Legislature and possibly the electric utility industry.

IDENTIFICATION OF ISSUES, PROBLEMS, AND NEEDS:

BIOTA

This chapter discusses issues, problems, and needs, categorized in the area of vegetation and animal life. Most of the vegetation issues appear to occur at the meso-scale, although there are some micro-scale issues such as the massive seagrass degradation in Florida Bay. The animal issues are similar to the vegetation in that they are related to both the effects of water management actions, both directly and indirectly, and have legislative mandates for protection, preservation and restoration.

LOSS OF HABITAT

The following chapters describe examples of the loss of habitat that have occurred in the study area.

Kissimmee River Basin

One of the largest projects of the 1960s was the channelization of the Kissimmee River, a response to devastating floods which swept through central Florida in the 1940s and 50s. Over almost ten years, the meandering 103-mile river was deepened and straightened by the Corps. The channel was designed to remove flood waters from central Florida, and more quickly convey them to Lake Okeechobee. Flooding was successfully alleviated, but when as much as 45,000 acres of floodplain were drained by the deepened, widened channel, natural habitat was lost. Water fowl populations are estimated to have declined by as much as 90 percent. The river ecosystem was altered. It became more like a man-made lake than a river. Extensive studies have been and are currently being done to attempt to restore the river, while continuing to provide flood protection to those living in the basin.

It is believed that restoration efforts would provide favorable conditions for endangered plant species; re-establish waterfowl usage of the floodplain; restore wading bird utilization of the flood plain, particularly for the endangered wood stork and the threatened sandhill crane; restore the food base for bald eagles and the wading bird and fish food chains; and increase the spawning, nursery, and feeding habitat for fish species. The restoration would also decrease the need for control of in-stream vegetation and the chemical pollution associated with that activity. If the flood plains are restored, the sponge effect for filtering waters would be re-instated, aerating and cleansing the water before they flow into the lake.

Everglades

At the turn of the century, the Everglades covered about 4 million acres, extending as far west as Fort Myers and as far east as what is now SW 27th Avenue in Dade County. It stretched north to Lake Okeechobee and south to Florida Bay. It has now shrunk to less than half of its original size.

Loss due to Pollutants

Loss of habitat is also caused by the pollutants entering the ecosystems. As discussed in the previous chapter, contaminated water entering the WCAs carry ten to twenty times normal concentrations of phosphorus and nitrogen. This threatens to change the entire vegetative pattern of the Everglades. Where the pollutants have penetrated the Refuge and other WCAs, the original saw grass swamp is being displaced by cattails. In the past decade cattails have taken thousands of acres in the WCAs alone. A report by SFWMD in August of 1990 said cattails have nearly taken over 6,000 acres of Everglades and are present in another 14,000 acres. For this reason, the Refuge is listed among the nation's ten most endangered.

Loss of Wetlands

"Wetlands" is a broad term applied to ecosystems ranging from prairie potholes to vast tidal marshes. They filter pollutants, replenish water supplies, nourish organisms essential to the food chain and provide an important habitat and breeding ground for wildlife. They act as sponges, retaining water and slowly releasing it, decreasing the severity of flooding. Their plants also protect shorelines from erosion. *The Clean Water Act of 1972* required anyone seeking to fill a wetland to obtain a permit from the Corps and submit to be reviewed by EPA. The Government estimates that more than half of the 215 million acres of wetlands originally found in the 48 contiguous states have been destroyed. About 200,000 acres of wetlands were lost in 1990 alone (Valbrun, 1991). More than half of the wetlands, about 9.3 million acres, that existed when Florida became a state have been destroyed. The losses are insidious and incremental. Wetlands are slowly piece-mealed out of existence. It often takes years to understand the cumulative effect of the losses. Some scientists theorize that massive destruction of wetlands has caused south Florida's climate to be drier. Sea breezes, so the theory goes, are more likely to become saturated and lead to rain if they travel over humid wetlands than over hot, dry ground (Reilly, 1991).

Seagrass Die-off in Florida Bay

More than 400,000 acres of sea grass, primarily turtle grass, covered Florida Bay in 1984. In the summer of 1987, biologists first noticed the grass was dying. Fifteen thousand acres of the seagrass are dead, while another 50,000 acres have been damaged. The cause of this is still unknown, although hypersalinity and abnormally high levels of nutrients are suspected. In addition, seagrasses respond to variations in temperature, insolation, salinity and other factors. The decline is allowing other sea grasses to colonize the estuary, increasing animal and plant diversity.

DECLINE OF ANIMAL SPECIES

Wading birds, Alligators, Fish, Shrimp, and Deer Populations

The Everglades is home to more than 40 animal species, 300 bird species, 50 reptile species, 18 amphibian species, 120 tree species and 1,000 plant species. About 95 percent of the wading birds that once dwelt in the Everglades are gone, biologists say, victims of not enough water. Wood storks, white ibis, roseate spoonbill, and a variety of herons have a smaller food supply when water disappears. In 1988, the entire Everglades system was dried out. Only 7,600 pairs tried to raise young throughout the WCAs and the ENP, and at least half abandoned their nests or were unable to feed their young. Bird populations are at an all-time low in the southern Everglades and the Big Cypress Swamp. Overall, the number of wading birds attempting to nest in the Everglades each year is believed to have dropped from a high of about 300,000 in the 1930s to the current level between 15,000 and 30,000.

The droughts also affect fish resources and alligators. Millions of small fish that live in the marshes die without freshwater supplies. It is estimated that the alligator population has declined from an estimated 50,000 two years ago to approximately 10,000 now.

Nesting wading birds, 300,000 strong 60 years ago, today number 15,000 in the Everglades. ENP biologists believe that with improved water deliveries some bird populations can recover, although there is no longer enough natural freshwater marshland left for huge flocks of waders. Saltwater wading birds pose a different problem. The mix of brackish water needs to be just right to produce the small fish and shrimp that the birds need to survive (Duplaix, 1990).

In the summer of 1982, the Everglades deer herd suffered large losses as a result of high water in the WCAs. Wildlife officials estimated that up to

5,000 deer were struggling for food and dry land when the water rose in 1982. The wholesale drowning and starvation caused nationwide controversy (see chapter entitled: Identification of Issues and Needs - Water Quantity). To avoid similar future problems, the Governor and other State officials directed FGFWFC to control the size of the herd so it would have enough food and shelter even during wet years. Biologists figured the areas could sustain approximately 3,250 deer, but the herd has never gotten above 2,000 since the die-off. The lowest count was in 1988 when most of the fawns were lost to high water and only about 600 animals were left. A 1991 count estimates there are 1,640 in the WCAs (McLachlin, 1991).

South Florida's shrimp catch in 1990 was at a historic low. In 1990 the shrimp catch was measured at 2.4 million pounds in Monroe County, down from an annual average of 6.4 million pounds for the years 1968 to 1988. Imports of pond-grown shrimp are considered a major factor in the decline of the Florida shrimp industry. But marine biologists also suspect that habitat degradation has caused shrimp populations to decrease over the last couple of years.

Marine biologists are also concerned about the dwindling fish populations in Florida Bay. A series of massive fish kills have occurred in the 1990's. The largest fish kill in the ENP's history occurred in 1990. Hundreds of thousands of fish from almost a dozen species, including redfish, spotted seatrout, and jack crevalle, died in Garfield, Rankin and Snake bights. Park officials blamed high salinity levels, warmer than normal water temperature and oxygen depletion for the kill. The officials reported that fish kills routinely occur in Rankin Bight during summer because the water has poor circulation and is prone to extreme temperature shifts. The oxygen level decreases because of decaying seagrass and other organic matter on the bottom. Large areas of dead seagrass have been found in Rankin, Garfield and Santini bights. Some scientists believe that a kill of this size could indicate that a pollutant was involved (Klinkenberg, 1990).

Endangered species (kite, wood stork, and panther)

South Florida's wilderness is home to many endangered species, including Florida panthers, red-cockaded woodpeckers, American crocodiles, wood storks, Southern bald eagles, West Indian manatees, snail kites, and Atlantic Ridley turtles. Altogether, nearly 250 species of birds and mammals live in the region, from falcons and swallows to otters and black bears.

Fourteen endangered or threatened species live in the ENP including the Florida panther, wood stork, snail kite, apple snail, American crocodile, West Indian manatee, green turtle, and Schaus' swallowtail butterfly. Their numbers are thinned each year by the pressures of living in the nation's fastest growing state.

A 1990 mid-winter count estimates are that 418 Everglades Kites remain (the Florida Game and Freshwater Fish Commission estimated a population of 668 birds in 1984). Only the California condor and the whooping crane are more rare. Declines in the kite population have been attributed to widespread drainage and drought conditions. The Everglades Kite (also known as the snail kite) is influenced significantly by the timing, volume and distribution of water flow, and the existence of open marsh habitat and specialized vegetation which allows the kites to obtain their primary food source - apple snails (Office of Governor Chiles, 1991). Only 100 snail kites hatched in 1989.

Drought has driven the snail kites in the Everglades into an area where citrus groves and farms pushed the birds out decades ago, Indian River County. A $100-million project designed to hold water for flood control and agribusiness has attracted the birds to the area, about 100 miles north of the Everglades. The St. Johns River Water Management District, using Federal and State funding, has constructed this intricate system of holding ponds, dikes and levees to store water, but never anticipated the arrival of about 90 snail kites. The problem is that the project was not designed for them. Draining or even raising the water in a wetlands area quickly disrupts the kites' access to the apple snails. The half-dollar-sized snails require little care and feeding, but they do not react well to changes in their watery habitat. If there is too much water then the plant stems that the snails live on will be covered with water. Too little water and the snails' environment dries up. When the apple snails do not survive, the snail kites often do not survive either.

Abundant rainfalls this spring, back-pumping by growers getting rid of excess water and the flood control project have combined to leave water much deeper this year. Though years of drought or heavy rainfall are part of the natural order of things, dikes, ditches and the like have two profound effects. First, the structures artificially quicken the drought cycles, which in turn harms wildlife. Secondly, the droughts tend to be more severe, harming wildlife. Steve Beissinger, associate professor of wildlife ecology at Yale University and an expert on snail kites, studies weather records kept since before the turn of the century. He noted that the natural period between serious droughts was seven to ten years before the Everglades were cut off from Lake Okeechobee by the network of levees, canals and drainage ditches. Since the flood control construction, however, the drought cycle has speeded to every four to five years (Rogers, 1991).

The numbers of pairs of breeding wood storks have dropped 80 percent in the last 25 years. Approximately 500 wood storks remain in the Everglades.

Man-made changes in water delivery have caused the wood storks to postpone winter nesting until spring, when rains disperse the fish needed to feed chicks. In 1989 and 1990, the wood stork failed to increase their population.

It is estimated that thirty to fifty adult Florida Panthers now survive in south Florida, making it one of the most endangered animals on earth. Habitat loss, mercury poisoning, illegal hunting, poor food supplies, inbreeding and highway mortalities are the greatest threats to the panther. In 1990 there were 10 panthers in the ENP; at the close of 1991 there are two males left and Park officials are considering removing them to BCNP for their protection. Protection of the Florida Panther has become a national priority and a number of State and Federal agencies have contributed significant resources to panther recovery.

The endangered Florida panther roams in the BCNP now, which also boasts three bald eagle nests and the largest concentration of the rare red-cockaded woodpecker nests in south Florida. Black bears have been sighted there. Alligators, river-otters, raccoons and opossums are numerous. So are deer and wild hogs. The water flowing through is clean, unlike south Florida's other wilderness areas. Most of the preserve is self contained; its water mostly comes from rainfall. Big Cypress drains in the ENP. When Congress establish BCNP in 1974, it told the National Park Service to preserve, conserve and protect the land, water trees and animals. But Congress also told the park service to allow hunting, fishing, trapping, oil exploration and farming. That is where the most of the problems lie for the BCNP. The Preserve officials have to ensure that hunters don't shoot all the panthers' food, that the all-terrain vehicle drivers don't destroy the ground, the Indians don't cut down too many cypress trees for their chickens, and carefully monitor the oil well sites.

Nearby Fakahatchee Strand State Preserve has suffered due to surrounding development and drainage canals along its western border. The canals and the 117-square-mile preserve belongs are a legacy of the now-defunct Gulf American land Corporation, which turned the Fakahatchee Strand over to Florida as mitigation for the company's illegal development practices. Gulf American built the canals to drain water from its Golden Gate Estates development site. But the canals also pull water from the preserve, radically altering the plant life. That has affected the deer there. Much of their lush forage has been replaced by sense, woody underbrush. In 1987, FGFWFC outlawed all deer hunting with the preserve in an attempt to save the few whitetail deer left for the endangered Florida panthers that live there.

The canal that carries water away from the Fakahatchee dumps it into Faka Union Bay, part of the Ten Thousand Islands. A recent National Marine Fisheries Service study showed that by upsetting the natural balance of fresh and salt water in the bay, the canal has drastically reduced the numbers of small fish and shellfish in the estuarine nursery. Also the diversion of fresh water has allowed salt water to move into wells north of U.S. 41, toward Golden Gates Estates.

LOSS OR CHANGES IN SOIL

The EAA, lying south of and adjacent to Lake Okeechobee, is composed of muck-land farms on what was originally part of the "Everglades"-- a densely vegetated marsh area. It is one of the richest agricultural areas in the world. Farming in the EAA just south of Lake Okeechobee is a $2.4 billion industry with 20,000 full-time jobs and other 10,000 foreign workers who come to Florida to cut sugar cane (Sewell, 1991).

Originally, the ground elevation in the EAA was at about elevation 17-18 feet. Farming operations and natural fires during droughts have lowered ground levels through oxidation and burning of the peat soil. A concrete marker at the University of Florida's agricultural research station in Belle Glade show that more than 5 feet of soil have been lost in the past 68 years. The soil is disappearing at the rate of an inch every year and by the year 2000, half of the EAA will have less than a foot of soil left on top of the bedrock, and 87 percent of it will have less than 3 feet (McLachlin, 1989).

MESO-SCALE DISTURBANCES

Vegetation changes are not only due to changes in water quantity or quality, but also linked to and interact with other meso-scale phenomena (especially fire) in altering composition and structure. There is a need to assess impacts of variations in nutrients, hydrological changes, altered fire regimes, alien species, air pollutants and other factors on biota.

Fires

Historically, surface and groundwater levels in the Everglades were considerably higher than at present, and in wet years water levels were probably higher than they have been since reliable recording began. Even then, at least part of the Everglades dried in most winters and droughts occurred periodically with a general drying of large areas. During these dry periods there were natural fires. However, because the water table generally remained high in the rich, organic muck-soil, these fires rarely damaged much of the soil itself, but acted instead as an ecological control mechanism which prevented the fire-adapted sawgrass from being outnumbered by other types of vegetation. However, due to overdrainage, fires have consumed the organic soil down to the limestone bedrock in many areas. While it takes thousands of years to produce peat, it can be burned in a matter of days.

Fires used to come naturally in May or June, at the beginning of the wet season, sparked by lightning from springtime thunderstorms. Now they usually are started by people, either controlled burns set by foresters or accidental blazes set by sparks from boat motors or automobile exhaust systems, while some are set by arsonists. The controlled burns serve the same functions as the natural fires that are part of the age-old cycle of the Everglades; clearing older plants and fertilizing the soil. But early, uncontrolled blazes are harmful. If a fire goes through too early, the leaves will be killed, the plant will not have the reserves to produce new leaves, and the plant will subsequently die. In 1989, fires from March to June attacked nearly 500,000 acres - including more than 140,000 acres in the ENP and 43,000 acres in the Refuge.

Invasion of exotic plant species

Water hyacinths were unsuspectingly imported as flowers in about 1888, and have become an expensive nuisance in the waterways. During flood periods, great masses of hyacinths tear loose and float down the canals, clogging culverts and bridges along the way. The system then overflows with serious damage to crops, dikes and drainage facilities. Even in normal stages, they can so completely clog canals and ditches as to make water movement very difficult. Their growth are escalated by excess nutrients from fertilizer runoff. Hyacinth, hydrilla and cattails deprive native fish and plants of light and oxygen. When deprived of enough oxygen, plants may die off, but then algae feed off the dying vegetation and use up any remaining oxygen in the process - causing massive fish kills.

Hydrilla was brought into Florida in 1960 from central Africa and sold for use in aquariums. One theory as to how the plant arrived in U.S. waters is that when people moved or grew tired of their aquariums they dumped them into streams. It quickly covered canals in south Florida and began to spread from canal to river to lake. In 1984 more than 45,000 acres of the plant was present in 214 water bodies.

More than 400 foreign plant species have taken root in the State, including *Melaleuca,* Australian pines, Brazilian pepper. It is estimated that *Melaleuca*, imported early this century from Australia to drain swamps, are taking over 10,000 to 20,000 acres a year. They have no natural enemy in Florida. A typical 25-foot tree can contain 20 million seeds, but they tend to fall close by. *Melaleucas* are incredibly resilient. They are tolerant of salt, wind and fire, and consume up to five times as much water as native plants.

They release all their seeds 24 to 48 hours after they have been cut or even burned. Fire dries out the seed pods, causing them to burst. So unless the debris is immediately trucked away, cutting down one tree can create a forest of seedlings. The tree's layers of spongy bark also insulate its living core from flames. Once the plant moves in, it chokes out other species and native animals. Pure *Melaleuca* stands can cover an estimated 40,000 acres.

Biologists estimate 25 percent of south Florida's wetlands are now infested. In 1980, the figure was about 15 percent. In 1988, *Melaleucas* were scattered on about 6,000 acres of the 145,000-acre Refuge. During the 1989-91 drought, the trees spread to an additional 1,250 acres. If the seeds land in standing water deeper than six inches, they usually cannot germinate and will eventually die. But the sheet of water that feeds the marshes and wet prairies of the Refuge disappeared during the drought. When the water returned this year, *Melaleucas* had taken root where years before there had been thick sawgrass. Scientists estimate 6 billion trees, covering one-fourth of the Everglades, are growing in south Florida. They fear the trees will cover the Everglades by the end of the decade. DNR reports that more wetlands are lost in Florida each year to exotic plants than to development.

Brazilian pepper, marked by red berries and imported as a pretty bush, turns out to grow unabated in Florida's hospitable soil and climate. It spreads seeds everywhere and has covered thousands of acres of south Florida, growing as high as 40 feet with a trunk three feet in diameter. The tree's toxic berries have been blamed for massive bird kills, and it sickens domestic animals and children. The bark causes a serious allergic rash and its pollen can be disastrous for hay fever sufferers.

The rapidly spreading Australian pine thrives in salty coastal areas, can grow ten feet in a years, and usurps the nesting places of endangered loggerhead and green sea turtles, and the rare American crocodile. Its branches break off easily, and its shallow root system means a hurricane can easily topple it.

There is a new exotic plant species, the cat-claw mimosa or *mimosa pigra*, that many say could be as destructive to Florida wetlands as the *Melaleuca* tree. The cat-claw is a hardy, bush-like tree which was brought in to Florida from Latin America 50 years ago. It grows in dense, impenetrable thickets that crowd out native plant species. The cat-claw can grow from a seedling to a mature plant in three months in ideal conditions. One plant can produce 90,000 seeds in a year, and those seeds remain viable for as long as 10 years.

DATA AND/OR KNOWLEDGE GAPS

The following are some of the gaps in understanding that members of the workshops identified:

1. Better topographical information,

2. A better understanding of changes in aquatic organism dynamics and vegetation dynamics,

3. Relationships between water quality and species response,

4. Influence of flow, circulation and salinity on distribution and abundance of organisms,

5. Subsistence levels for biotic species,

6. A better understanding of historic regimes.

More detail is presented in Appendices B and C.

NEED FOR SYSTEM-LEVEL RESTORATION

Everglades vegetation and the fish and wildlife that depend upon it require water levels to rise and fall in accord with natural, seasonal and annual rainfall. Historical patterns have been much distorted by water management intended to drain land for agricultural and urban development and to supply water for agricultural irrigation. When water is plentiful, canals cause water to flow faster than natural through the Everglades. Water piles up abnormally high on the downstream levees of the WCAs and falls prematurely in the upstream area. When water is in short supply, it first drained from the WCAs to supply agriculture and urban areas. The WCAs and ENP then become abnormally dry.

Human manipulation of water flow has meant too little water in the Shark River Slough at the top of the Park and often too much water at the southern end. Canals divert water past the northern area and allow it to gush into the sensitive ecosystem below.

No one disputes that the drainage system has disturbed the Everglades' vital water supply. More recently, water problems have been compounded by pollution from phosphorus, a naturally occurring fertilizer that is leaching into the Everglades.

John Ogden, an ornithologist at the ENP, wrote an article in the Everglades Update in 1990 stating that while some features of the Everglades ecosystem are irreversibly gone, others are not. Accumulated research and understanding of the hydrological patterns, population dynamics, and habitat requirements would now enable resource managers to recommend a course for restoration of the ecosystem. The critical element is a return to natural hydrological conditions in the remaining wetlands with ENP and adjacent upstream marshes. The volume of water, timing of surface water flows, distribution patters of flooding, and extent of flooding will result in a substantial increase in levels and extent of biologically productive wetlands. In addition, the program will produce long-term stabilization and, at the very least, partial recovery for many characteristic and endangered Everglades animals. The current water management system has compartmentalized the system, especially in distribution and timing of surface water flooding and flows.

Ogden named these key steps for restoration:

1) Publish papers from the October 1989 Everglades Symposium to provide biological and hydrological guidelines for restoration.

2) Acquire the 107,000-acre addition to ENP.

3) Develop an improved hydrological model for the entire southern Everglades system, including downstream mangrove estuaries.

4) Develop a single regional restoration plan - outlining overall goals and management guidelines for all State and Federal agencies responsible for the Everglades.

5) Modify structural components of the water delivery system for the Shark and Taylor slough's drainage basins in order to provide greater flexibility in future water deliveries; and re-establish natural hydrological conditions.

6) Evaluate and revise current water delivery schedules to Shark and Taylor Slough's basins so that when structural changes occur more natural hydrological patterns are achieved.

7) Monitoring must continue and expand during restoration. Especially important are wading bird nesting colonies, total wading bird distribution patterns, alligator nesting efforts and success, and distribution and population trends for key indicator species - Florida panther, wood stork, snail kite, Cape Sable sparrow and American crocodile.

Ogden further stressed that *"restoration management is still new and Everglades restoration must be undertaken as an experiment. The results of each step are difficult to predict with certainty, and the outcome of each step determines the next. All agencies must work together and must maintain trust and flexibility."*

The authorization directs the Corps to develop a modeling system to predict the effects of modifications to the C&SF Project and other human activities on the flow, characteristics, quality, and quantity of surface and ground water and on the plants and wildlife within the ecosystem. As shown in these last three chapters and in the workshop discussions in Appendix B and C, the problems and needs of the water quantity, water quality, and biotics are complex and varied. In addition to the complexity of the system itself and the complicated and varied problems, the system must be managed to fulfill the needs of a variety of competing users. More knowledge is needed about the existing and historic systems to help predict the needs of the future.

In planning for the future, many changes are foreseeable, but other changes are inherently unpredictable and it is necessary to develop adaptive strategies. There are many existing models and other tools to describe subregions of the study area and individual processes; but no attempt has been made to incorporate all of these tools and construct new models, collect data, and perform research to extend the tools to the entire study area and to provide linkages between the tools. As stated in the introduction of these chapters on issues (see chapter entitled: Identification of Issues and Needs: Introduction), the participants of the workshops emphasized that the most critical need was for a cooperative effort to construct a "system-wide" modeling system.

FORMULATION OF MODEL DEVELOPMENT APPROACH

During the reconnaissance phase, planning efforts were primarily directed toward formulating feasible modeling approaches. Emphasis was placed on utilizing experts in the various disciplines and assessing existing data and models for possible use in the development of a hydrologic ecosystem modeling system. The technical study plan, which was prepared by WES and is summarized in this chapter, addresses, in general, the types of research efforts, data collection, and models needed to develop an interdisciplinary modeling system. Estimated time and costs necessary to complete these tasks are also included in the technical study plan. However, it must be recognized that due to the complexity of this modeling task, refinements and modifications to the model development scope will occur during the model development phase. Also presented are various options or levels of scope for performing all of the work proposed in the technical study plan.

MODEL OBJECTIVES

The basic objective of a simulation modeling system of south central Florida hydrologic ecosystem is to address three major water resource issues of the study area: (1) the ability of the C&SF Project to sustain the three major water use sectors (urban, agriculture, and natural areas); (2) impacts of land use (agricultural and urban) on the natural system; and (3) preservation and restoration of natural portions of the ecosystem. The models will be capable of producing information useful in assessing environmental impacts and evaluating regulatory applications.

Simulation modeling requires some form of fundamental understanding of the variables to be modeled. Basic to the modeling process is the quantification of values for each variable included in the model. Quantification requires either empirical data or sets of assumptions based upon fundamental knowledge of each variable's functions. This information in ecological studies is typically drawn from comparable ecosystem structures or theoretical assumptions. Typical investigations begin with the development of prototype simulations. These preliminary efforts provide means for identifying and organizing essential data. As understanding of variable functions and interactions improve, the simulation modeling process permits the development of improved knowledge on the hierarchical, temporal, and spatial functions of each modeled variable.

Regardless of the basis used to establish values for variables, a simulation model of the C&SF Project area will represent a simplification of the complex abiotic and biotic interactions, materials cycling, and other factors occurring within the hydrological framework of the modeled ecosystem. Modeled findings can never provide accurate descriptions of the real ecosystem. Simulation models fundamentally provide mechanisms for comprehending sets of complex interactions through forced quantification and simplification of selected system processes. The modeling process forces the analyst to move from subjective assumptions and opinions into an analytical process predicated upon quantifications of assembled knowledge.

When used in an analytical mode to develop improved objective knowledge, the simulation modeling process permits the analyst to establish and test probable value ranges for variables that are expected to be representative of selected conditions within an ecosystem of concern. Repeated simulations lead to patterns of modeled responses that, when understood and replicated or otherwise verified, can result in improved confidence in modeled assumptions. As confidence in the products of subsystem components or submodels increases, the model findings can provide improved guidance on the probable impacts of management actions on aspects of the ecosystem's functions. The general acceptability of simulation modeling results for management purposes will be dependent upon the consensus developed between the discipline specialists and resource managers participating in the model development and use process.

In ecological analyses, simulation models have been used for several decades to predict probable cause and effect relationships of proposed resource management actions impacting populations of species within localized ecosystems. Sequences of calculations, often based upon available general knowledge of a subject species' population characteristics, production rates, survival rates, etc., and with very limited empirical data, are typically used to simulate a species' survival rates and maintenance potentials.

The sets of calculations used for these purposes are called models. The calculations typically are organized into hierarchies of complexity. More detailed models require more assumptions and information. As the process becomes more complex, the likelihood of omitting or misinterpreting critical calculations increases, and chances of predictive errors also increase. Similarly as a model's complexity increases, the intuitive consequences of the modeled conditions becomes less apparent, and the model's resource management utility tends to decrease.

As a result of the above tendencies, the ecological simulation model development process requires extreme care in the definition of variables and careful attention to logic and consistency in formulation of the sequence of calculations that become the model structure. The process requires a very close partnership among the discipline specialists, resource managers, and the model designers and programmers. Finally, all participants must have a common understanding of the model development purposes.

FORMULATION OF MODELING SCOPE

During this reconnaissance study, the technical expertise of WES, the SFWMD, ENP, and many other agencies and groups was used. Due to the complexity and vast scope of this endeavor, inter-agency cooperation was the best approach to gain knowledge from modeling experts, as well as experts familiar with the study area. Part of this cooperation was accomplished during the interagency/interest group workshops previously discussed. These experts provided knowledge of past and on-going data collection, research and modeling efforts. They discussed problems in the study area, identified gaps in knowledge and technology, and recommended approaches to address those needs.

A meeting was held with personnel from the Corps' Baltimore District in March 1991, regarding a similar project; the Chesapeake Bay 3-D Time Varying Hydrodynamic and Water Quality Model. The Chesapeake Bay study was accomplished under a Memorandum of Understanding (MOU) between EPA and the Secretary of the Army. The Baltimore District was responsible for model production and delivery; this involved using the expertise of WES, as well as other agencies, research institutions, private contractors, and consultants. The Baltimore District provided helpful insight on the structure, management, and sponsor participation in Chesapeake Bay's complex modeling effort. While that effort is not identical to this model development effort, there are parallels which were useful in developing an approach.

ASSESSMENT OF EXISTING MODELS

In order to assure that existing knowledge would be utilized as much as possible, a number of activities were performed to assess existing models, data, and research in the study area. Meetings were held with various sources and a literature search was conducted by WES. The automated literature search to identify appropriate models and related studies identified approximately 400 citations. WES reviewed the abstracts and selected publications. A few of the existing models that should prove to be beneficial to this modeling effort are discussed below. Others are discussed in the background and results of the workshops presented in Appendices B and C, and in the technical study plan in Appendix D.

Technical discussions were held at the SFWMD in March 1991, concerning past and present data collection programs, modeling studies, and database management activities. SFWMD has been active for many years collecting water quality data throughout the study area. These data are currently being loaded into a database management system that also includes information on surface water and groundwater. Work in the area of modeling has concentrated on hydrologic/hydraulic models, although in the last few years they have initiated studies at UF to develop watershed loading models and a three-dimensional sediment/water interaction model of Lake Okeechobee with an emphasis on phosphorus dynamics. Future water quality and ecological modeling is currently being planned.

Other related efforts by the SFWMD include the following. A project is planned to begin in Fiscal Year (FY) 1992 to re-evaluate and redesign the SFWMM. This project is anticipated to take three years and will produce a more scaleable, easier to use model. Part of this effort will be contracted to research institutions. SFWMD has modified the SFWMM to produce the Natural System Model (NSM). The NSM predicts the hydrology of the Everglades prior to influence by man. The NSM is considered to have a high potential for determining restoration objectives. Additional work toward improving the model is necessary before it can be used to develop restoration objectives. A project planned for FY 1992 is to develop a model that links rudimentary water quality and ecological dynamics to water quantity models. It is anticipated to take three years. A contract with the University of Maryland is proposed in FY 1992 to produce a landscape dynamics model of the Everglades Basin, including coupled hydrologic, sediment, nutrient, and vegetation dynamics. This model would be built on the SFWMM hydrologic routines with some modifications. It is expected to take two years.

The SFWMM is, and will continue to be, the cornerstone modeling technology for water quantity decision support relative to the south and central Florida hydrologic system. The model integrates surface water and groundwater flows in order to address water management issues, including water supply, flood control, and environmental quality. The model simulates flow for an area that includes the WCAs, EAA, much of the BCNP, ENP, and the Lower East Coast areas (i.e., Broward and Dade counties). The model provides differing levels of simulation sophistication for many of the important processes affecting water management in this area. The model has been used on numerous occasions as a primary aid for water management decision-making.

Technical meetings were held at UF in March and May 1991, to discuss their work within the study area pertaining to hydrodynamic and phosphorus modeling and associated field efforts. Process oriented studies are being conducted in Lake Okeechobee to better understand phosphorous dynamics, sediment geochemistry, littoral/pelagic exchanges, and vegetation dynamics. Sub-watershed studies are emphasizing nutrient loadings to Lake Okeechobee from sugar cane and dairy activities.

Another study that UF, in conjunction with SFWMD and ENP, has been working on is the development of a dynamic simulation modeling effort for the Everglades. From October 1989 through April 1991, a series of workshops were held at ENP and UF, addressing Everglades environmental research and management. The initial workshops focused on the development of simplified hydrogeologic and ecologic models of the Everglades watershed, to be used as conceptual tools for synthesis during the Everglades symposium. The later workshops used these models (referred to as the AEA models) to design a series of ecological restoration options, and examine the impacts and tradeoffs of the different alternatives. Additional funding has been provided to review the management history in a set of complex, regional systems around the world, in order to examine the dynamics of ecological change and institutional response. This work has been developed in conjunction with the AEA workshops discussed in the chapter entitled Identification of Issues, Problems, and Needs: Introduction.

A site visit was conducted in April 1991, to acquaint the team from WES with the C&SF Project and the study area. Meetings were also held with the Corps' area office in Clewiston, and ENP and USFWS personnel at the Refuge. Detailed discussions of the meetings are included in Appendix A.

A technical meeting was held at the U.S. Geological Survey (USGS), Miami office, in May 1991, to discuss their surface water and groundwater studies being conducted in the study area. For more detailed evaluations of groundwater resources and their interactions with wetland and riverine systems, the USGS has coupled their three-dimensional saturated-zone groundwater model, MODFLOW, with in-house surface water flow routing models. This modified model, named MODBRANCH, has been used successfully to evaluate various groundwater pumping schemes in Dade and Broward counties. Appendix A discusses other work that USGS is doing, as well as their recommendations for this modeling study.

PARAMETERS FOR MODEL DEVELOPMENT

The following section discusses the basic parameters followed in the development of the technical study plan. These parameters are proposed to ensure that the most efficient methods are used during the model development phase. The main technical concerns of this undertaking include the extremely large geographic area under consideration, the massive amount of data that will be collected, and the effort needed to organize the data in an efficient manner.

Components

It became apparent very early on, that one model could not be developed efficiently to simulate over 16,000 square miles as well as performing hydrology, water quality functions, and vegetation and animal processes. Therefore, the technical study plan divides the model development tasks into five major components - water quantity, water quality, vegetation, animal, and technology integration. Tasks were developed for each of these components. Each of these tasks was then broken down into sub-tasks.

Geographic Information Systems (GIS)

It is important to understand the interconnection between these components of the hydrologic ecosystem, so an important task will be to develop linkages between the different kinds of models. It is also critical to design this modeling system to be as "user-friendly" as possible. In order to accomplish that, it was decided that the modeling system would use a GIS input and output shell. Linkages between the databases, models, and the GIS shell will also be required.

GIS technology allows for the generation of new spatial data through the comparison and analysis of multiple spatial themes. To accomplish this creation of new data, most GIS systems share a conceptual model that differentiates spatial elements into layers or themes, such as vegetative cover, soil types, land use zones, slope types, etc. These themes are represented in various formats, such as arcs/nodes, polygons, grid cells and triangulated networks. GIS organizes information about both the spatial location and the value of each unit in a data layer, so that new data can easily be derived when two or more layers are compared.

GIS allows the user to store, manipulate, and analyze large volumes of cartographic data that would be cumbersome using conventional methods and helps in developing an easily updated resource database. GIS can be used to develop land-use, soil-group and sub-basin boundary maps.

GIS, used in conjunction with image processing, computer-aided design and drafting, automated mapping and facility management, and related tools that use digital spatial data, are already proving essential resources for helping to manage resources. GIS users include public agencies that have land management missions, such as the Bureau of Land Management, the National Park Service, and U.S. Forest Service; state and local governments that evaluate transportation, land use, taxation, and facility siting issues; and public, educational and private organizations that attempt to model complex landscape (or seascape) phenomena - such as wildfire dynamics, groundwater movement, soil and sediment transport, optimal land use schedules, and best path routing/corridor analysis.

The Corps uses GIS technology to plan recreation, water storage and flood control projects, to monitor and manage Corps operated lands and waterways, to evaluate applications for activities on wetlands, to site dredge materials, to model hydrologic phenomena, and to assist the Army in managing training lands. Not only is the Corps using GIS technology, but several Corps labs have developed GIS software - including the Geographic Resources Analysis Support System (GRASS) which was developed by the Construction Engineering Research Lab and is now a standard for numerous Federal agencies.

GIS technology links geographical and infrastructural features to tabular data related to those features. Once spatial features and data are digitized, they can be used immediately to produce maps of natural or manmade features. Understanding local and regional geography is a critical part of managing water resources. Determining the relationships between spatial features on a map is the basis of a geographic information system. GIS allows for the utilization of data collected or created by other agencies such as the U.S. Census Bureau and USGS.

The models must be integrated in a manner that minimizes the effort required for application and interpretation. GIS provides a means to accomplish some of the interfacing. A GIS could be used to import and couple input data to the models and provide graphical display. Most GIS software can reside on current and anticipated new generation microprocessor workstations. Unix based workstations with powerful graphics capabilities facilitate linkage of models, development of user-model interfaces, and development of highly versatile graphical output options. For these reasons, the modeling system will be GIS based.

Hardware and Software

In order to ensure that this modeling system is available to as many agencies, groups and individuals as possible, the hardware and software systems will be designed to be as compatible as possible with existing systems. Therefore, the modeling system will be designed to run on microcomputers or workstations and every attempt will be made to design software to be compatible with systems currently being used by the SFWMD, ENP, USGS, and other agencies and interest groups working in the study area.

Use of Existing Data/Models

Existing data and models will be utilized whenever possible and a coordinated system for data transfer will be established. The assessment of models that have been developed for the study area or that could be adapted for use in the study area have been discussed previously. During the model development phase, a continuous effort will be made to utilize existing data and models whenever possible.

Two-Way Usage

To allow maximum flexibility in the use of the modeling system, the modeling system will be designed to function in a two-way manner. For example, a resource manager will be able to determine the effects on the vegetation or wildlife process, if modifications are made in the quantity or quality of water; as well as address the possible effects on the quantity or quality water if land use changes are made.

Phasing

Developing a complex modeling system for the study area will take an extended period of time and effort. It will need to be "phased" in order to efficiently manage all the efforts that will be undertaken. Phasing will also provide a way for usable products to be available throughout the model development period. Various databases and models will be available for use before the entire modeling system is completed.

TECHNICAL STUDY PLAN

The technical study plan was developed using the parameters discussed in the previous section. The complete technical study plan is included in Appendix D. The technical study plan addresses modeling purpose, scope, model development priorities, model linkages, data collection and research requirements, modeling methods, phases of model development, costs, management tasks during development and also for operation of the modeling system. The work proposed in the plan deals with model development, calibration, verification, and application. The model package includes both system-wide and regional models, as well as models of selected vegetative communities and animal populations. The technical study plan presents a generalized approach and is the basis for future development of detailed technical scopes of work.

The summaries of problems and issues discussed in previous chapters allow the identification of the following targets for technology development:

Water Quantity

1. South and central Florida hydrology and water quantity management
2. South and central Florida system optimization for improved water management strategies

Water Quality

3. Nutrients and other eutrophication related variables
4. Toxins sources, exposure, transport, fate and risk assessment
5. Total Dissolved Solids (TDS)
6. Groundwater salinity intrusion
7. Salinity for Florida Bay, coastal estuaries, and the St. Lucie and Caloosahatchee River Estuaries

Biota (Vegetation and Animal)

8. Vegetation community structure and landscape changes
9. Fish and wildlife habitat loss
10. Impacts of salinity levels on flora and fauna
11. Decline in productivity of higher trophic levels, such as wading birds.

The following sections present a summary of the tasks which comprise the technical study plan.

WATER QUANTITY TASKS (Task Area I)

Five major research and development tasks will be required to produce the technology needed to answer the water quantity concerns in south and central Florida.

Task I.1: Modify, Enhance, and Apply the South Florida Water Management Model (SFWMM)

As discussed previously, there are several modifications and enhancements which should be made to the SFWMM to improve and extend its performance and utility. A two-step approach is recommended for the proposed changes to the SFWMM. First, the existing SFWMM will be improved in several ways over a two-year period to allow for its relatively immediate use in water quantity decision-making. Secondly, and concurrent with, the modification of the existing SFWMM, major enhancements to the SFWMM are proposed. These efforts will take approximately four years to complete. Once completed, most of the water quantity issues for the freshwater system could be answered within a single modeling framework.

Task I.2: Develop and Apply Groundwater-Wetland Models

Site-specific questions in several sub-system components whose hydrologic regimes are dominated by wetland/groundwater interchanges (such as the WCAs, the EAA, or the Lower East Coast well fields) will require development of localized groundwater/wetland models. These models will answer localized questions, such as the effects of large-scale groundwater pumping within Dade county on the hydrology of the C-111 basin, detailed distribution of flows delivered to the Refuge and ENP, as well as the distribution of flows within the EAA or EPA. Finally, the need to evaluate salinity intrusion within the Biscayne Aquifer will also require more detailed groundwater modeling capabilities than those proposed for the SFWMM.

The groundwater model development proposed in this task will require extensive field data collection related primarily to the establishment of a more definitive database on subsurface stratigraphy and transmissivities, particularly in the vicinities of canal reaches. Applications of the models developed in this task will center on evaluation of the effects of operational water delivery changes on coastal salinity intrusion, the effects of the large well fields being implemented in Dade county, and the inter-connections of major wetland and groundwater connections within the system.

Task I.3: Develop and Apply a System-wide Water Budget

A complementary and insight-providing component of any numerical modeling study is to evaluate the sources and sinks of the quantity being simulated. In the case of south and central Florida, this is particularly true relative to the sources and sinks of water within the system. Although water budgets have been constructed for certain system components, an exhaustive budget has not been completed for the system as a whole.

The worth of a water budget for the south and central Florida hydrologic system would be a valuable investigation in that: the major sources and sinks of water would be specifically identified; the locations where inadequate data exist would be determined; and, a fairly concise estimate of the actual magnitude of water available in the system would be known. This information would, in turn, support the activities proposed under other Water Quantity tasks, and would provide additional insight into system performance under anthropogenic influences.

The activities proposed to complete this task would commence in the first year of the proposed overall study and conclude in the middle of the study's third year.

Task I.4: Develop and Apply Multi-dimensional Hydrodynamic Models

The need to address major environmental questions for several of the south Florida estuaries and Lake Okeechobee will require development of two and three-dimensional hydrodynamic models. These models must be able to accurately and efficiently simulate the effects of numerous forcing functions, such as time-dependent boundary conditions (i.e., meteorology, tidal influences, fresh water delivery schemes, etc.) and the impacts of density stratification, over multiple study years and operating plans. These models must include temperature and salinity transport that are coupled through state equations to water density, which is included in the hydrodynamic equations. The models must also produce velocity fields that conserve mass and "map" to water quality models for additional analyses.

Task I.5: Develop and Apply Dynamic Routing and Watershed Runoff Models for the Kissimmee River System

Dynamic river routing and field-level watershed runoff modeling capabilities are needed within and along the Kissimmee River System (KRS). The KRS is of general concern relative to the south and central Florida ecosystem for two reasons: (a) the river often carries high nutrient loads from dairy farm runoff in the Kissimmee watershed; (b) the potential restoration of the KRS (i.e., the removal of certain Corps-constructed structural features within the system as means of returning the system to a more natural environment).

WATER QUALITY TASKS (Task Area II)

Four tasks are proposed for the Water Quality task area and are discussed in the following paragraphs.

Task II.1: Develop and Apply a System-Wide Nutrient Budget

The first step to gaining a better understanding of nutrient fate is to develop a nutrient budget, or accounting of nutrient fluxes at various control points throughout the system. The system for Task II.1 includes all the freshwater areas of the SFWMD, such as the Kissimmee River basin, Lake Okeechobee, C&SF Project, EAA, WCAs, ENP, etc.

Observed nutrient concentrations and water discharge would be used to compute mass flux (i.e., loads) for the nutrient budgets. Any use of simulated water discharges would require interfacing the nutrient budget software with hydrologic models developed under Task Area I. By comparing loads at points of interest, such as influent and effluent points of a WCA, general conclusions can be drawn regarding nutrient import, export, and trapping. Additionally, it would be advantageous to be able to use the nutrient budgets for more accurately prescribing boundary conditions for various nutrient/water quality simulation models. This would require interfacing the nutrient budget software with the water quality models.

Task II.2: Develop and Apply Models of Nutrient Dynamics and Water Quality for Landscape Regions

The landscape regions are major components pertaining to nutrient enrichment issues. The term "landscape regions" as used here refers to freshwater areas that are not lacustrine, such as wetlands of the ENP and WCAs, canals of the C&SF, and overland flow areas of the EAA. A nutrient dynamics and water quality model for these regions is required to predict the impacts of various water management decisions. For this task, the system is defined as the freshwater, non-lacustrine areas extending from the outflows of Lake Okeechobee to inflows of Florida Bay, including the EAA, C&SF Project, WCAs, Big Cypress National Preserve, and the ENP. A generic nutrient dynamics and water quality model is needed to evaluate water quality of various subregions within the system or the system as a whole. Therefore, it is proposed that a general water quality model (i.e., SFWQM) be developed for nutrients and other water quality variables. This general model would be the basis for developing and applying a system-wide model or sub-regional models, such as for WCA 1 or the ENP.

It is envisioned that this model would satisfy the need for a phosphorus dynamics models as described in the Federal-State settlement agreement. The model would be used for simulating all forms of major nutrients and carbon, phytoplankton, periphyton, macrophytes, Ph, and dissolved oxygen. The model could also be used for studying other water quality variables of interest, such as TDS, and could serve as a framework for future contaminant modeling.

The SFWQM would be a companion to the SFWMM and would use the same grid as this model or versions of this model applied to subregions. Output from the SFWMM would be indirectly linked to the SFWQM, i.e., information from the hydrologic model would be saved and used subsequently by the SFWQM for transport computations. A substantial amount of research and development will be required to build and validate the appropriate sub-models and algorithms, which would be of a mechanistic nature.

Output from the SFWQM would be indirectly linked to plant succession models (i.e., landscape change model). Likewise, information from the landscape change model could be used to modify input conditions for the SFWQM, and the SFWQM could be run for vegetation changes.

Task II.3: Develop and Apply Models of Field-Scale Agricultural Runoff of Nutrients and Water Quality

A model is needed to assess nutrient, TDS, and pesticide runoff characteristics from agricultural areas. The term *field-scale* refers to the fact that this model is intended for application to agricultural fields and orchards and not to large watershed regions. This field runoff model would be used to assess various existing and proposed land use and agricultural practices. Output from this model would be coupled to the SFWQM of Task II.2 to evaluate large-scale impacts.

Task II.4: Modify and Apply Nutrient Dynamics and Water Quality Model for Lake Okeechobee

Much work has been completed or is ongoing regarding eutrophication of Lake Okeechobee. The UF, through funding from SFWMD, has developed a hydrodynamic and water quality model of the lake. Modeling work is scheduled for completion in 1992. There are a number of improvements to the water quality model that have been identified and would be completed as part of this task.

It should be noted that five water quality targets were outlined above. It is recommended that Target 4, which deals with toxic substances, be addressed in a separate study. The problems and issues surrounding Target 4 have already caused significant attention, which is evident by the Mercury Technical Committee (1991) study and recommendations. This committee recommended a six year effort with about 10 million dollars to exclusively study mercury problems.

The mercury issues are different from the other water quality issues and can be treated as a separate component through other funding sources. it is also recommended that activities pertaining to development of eutrophication models for estuarine and coastal environments, not be addressed within this study. This decision is based on the lower priority this task received, relative to the other water quality tasks, during the scoping workshops.

VEGETATION TASKS (Task Area III)

Two tasks are proposed for the vegetation task area and are discussed as follows.

Task III.1. Develop and Apply a System Level Landscape Vegetation Model for Freshwater Wetlands

The objective of this task will be to construct a landscape ecosystem model for the Everglades Protection Area (EPA); which consists of the WCAs, the Refuge, and ENP; that will be used to evaluate the effects of water management actions on the vegetative landscape, habitat loss and the associated loss of native flora, the impacts of exotics on the native landscape, and assessments of the current and future status of native plant assemblages.

This task will involve a first year literature and information search for available data on the current and historical vegetative state of the EPA system. An information collection and monitoring network will be established in the study region to provide data on the distribution and abundance of vegetation types and relevant edaphic factors. This task will additionally require updated topographic maps of the region. A research effort will be established to provide data for a more thorough understanding of the seasonal and long-term successional patterns of the dominant plant species.

A conceptual landscape model based on the CELSS technology will be developed in year two. The conceptual model will be used to determine linkages between the vegetative landscape and the SFWMM. Data collection efforts will provide data input into and calibration of the conceptual model. The working landscape model will be designed to provide output for scientific animation programs and the common GIS.

Task III.2. Develop and Apply Habitat-Specific Landscape Vegetation Models in Conjunction with Individual Based Models

The objective of this task is to develop and apply landscape vegetation models with fine-scale spatial resolutions (10 - 100 meter) for freshwater wetland habitats to be completed with an individual based wading bird model and alligator model. Linkages will be developed among the vegetative dynamics, SFWMM, and the SFWQM such that these models can be used as input to drive forcing functions in the landscape model.

ANIMAL TASKS (Task Area IV)

Four major research and development tasks will be required to provide the technology necessary to address the animal issues in south and central Florida.

Task IV.1: Develop and apply individual oriented/species level models

The primary goals of any animal modeling effort in the south and central Florida region is the protection, preservation, and restoration of native and endemic species. In order to address these problems a considerable amount of information is needed on the population dynamics, behavior, and ecological energetics of the target species. These data can be used to create models which examine the impacts of alterations to the hydraulic regime on species assemblages. The Oak Ridge National Laboratory has developed an individual-based modeling (IBM) approach which utilize daily time budgets for numerous organisms in a population to construct fine-scale simulations of animal/vegetation patch dynamics. One such IBM has been constructed for wood storks in the ENP.

Task IV.2: Develop process oriented and structured population models and develop network flow characterization for freshwater wetlands in the EPA.

The objective of this task will be to develop a descriptive and predictive modeling system of the trophic community within the wetland region based on the biomass flow through the trophic structure of the system. This modeling system will be used to evaluate restoration efforts and proposed changes in operational and structural water management decisions on the trophic structure and dynamics of the wetland region. The modeling system will also be used to determine the effect of habitat loss or alteration, loss of keystone species, changes in soil/water column/organism assemblage interactions, and changes in food web connectivity and linkages due to wetland system perturbations. The modeling system will be designed to accept input from the system hydrologic and water quality models. This modeling system will also provide output to the standardized GIS and scientific visualization programs.

Task IV.3. Develop and apply process oriented and structured population models and network flow characterization for the Florida Bay ecosystem

The objective of this task will be to develop a descriptive and predictive modeling system of the trophic community for the Florida Bay ecosystem based on the biomass flow through the trophic structure of the system. This modeling system will be used to evaluate restoration efforts and proposed changes in operational and structural water management decisions on the trophic structure and dynamics of Florida Bay. The modeling system will also be used to determine the effect of habitat loss or alteration, loss of keystone species, changes in soil/water column/organism assemblage interactions, and changes in food web connectivity and linkages due to wetland system perturbations. The modeling system will be designed to accept input from the system hydrologic and water quality models. This modeling system will also provide output to the standardized GIS and scientific visualization programs.

Task IV.4. Develop and apply process oriented and structural population and network flow characterization for Lake Okeechobee

The objective of this task will be to develop a descriptive and predictive modeling system of the trophic community for the Lake Okeechobee ecosystem based on the biomass flow through the trophic structure of the system. This modeling system will be used to evaluate restoration efforts and proposed changes in operational and structural water management decisions on the trophic structure and dynamics of Lake Okeechobee. The modeling system will also be used to determine the effect of habitat loss or alteration, loss of keystone species, changes in soil/water column/organism assemblage interactions, and changes in food web connectivity and linkages due to wetland system perturbations. The modeling system will be designed to accept input from the system hydrologic and water quality models. This modeling system will also provide output to the standardized GIS and scientific visualization programs.

TECHNOLOGY INTEGRATION, MAINTENANCE, APPLICATION, AND DISTRIBUTION TASKS (Task Area V)

The models discussed in the above sections must be integrated in a manner that minimizes the effort required for application and interpretation. This integration requires the development and coupling of basically four types of interfaces: 1) model-user interface; 2) model-model interface; 3) input data-model interface; and 4) output data-graphical/visualization interface. The model-user interface is a convenient means of accessing the model to make scenario changes and execute simulations. This interface would be graphics based with windows and pull down menus. The model-model interfaces are essential for linking the various models, such as providing flows/hydrodynamics to the water quality models, and would be transparent to the user. Input data-model interfaces are necessary to couple large data bases for changing model input conditions. Output data-graphical interfaces are required to allow easy manipulation and graphical display of model output.

The technology proposed for development in Task Areas I through IV represents, in and of itself, a very important cog in the creation of appropriate management strategies for the south and central Florida ecosystem. The most effective use of this technology, however, must involve the integration of developed system components within a framework easily used by scientists, engineers, and decision-makers. Additionally, given the investment to be made in this technology and the long range nature of ecosystem management decisions, it is imperative that the maintenance, application, coordination, and distribution of said technology be well planned. The following section presents a series of tasks to address these concerns. It should be noted that these tasks are proposed to be completed throughout the development of the modeling system. Maintenance, coordination, and distribution will also need to be performed after the model development phase is completed, but that issue will be discussed later in this report and is not included in the tasks, products, and costs discussed below.

To accomplish the tasks in Task Area V, it is absolutely essential that a single group or organization be responsible for their planning and execution. This group or organization will have as its primary mission the execution of the tasks presented in this section below. The office should be located in Florida, and act as a technology center in support of the consortium of agencies involved with the management of the south and central Florida hydrologic ecosystem. Additional details of the office, such as its staffing, management, and reporting chain, require agreements among participating parties, and are beyond the scope of this reconnaissance report.

Four tasks are envisioned for this group or organization which involve both research and development and technology transfer. These tasks which are detailed below are:

Task V.1. Integrate Modeling Components

Most of the products being developed within Tasks I-IV will be developed as somewhat discrete pieces of technology. To have their greatest management utility, these items must be appropriately linked/coupled. For example, the SFWMM output, while of interest separately, is also the needed input to the SFWQM. This model's output, in turn, along with that of the former, is input to various biotic models. From this information, the impacts of various water management decisions upon the ecosystem's components can be evaluated. The linkage of these models, however, is not a trivial set of tasks.

The integration of the models and tools discussed in previous sections will require the development of four basic types of interfaces: (1) model-user interface; (2) model-model interface; (3) input data-model interface; and, (4) output data-graphical/visualization interface. The model-user interface is the actual environment through which the user accesses various programs, selects program attributes, inputs data, simulates various conditions, and evaluates model output. The model-model interface, which is transparent to the user, includes the essential linkages between various models and their outputs. The input data-model interface is necessary to couple large databases with models, and to allow efficient retrieval of data based on user-selected conditions. Finally, the output data-graphical/visualization interface is critical to the presentation of voluminous and sophisticated model results in a fashion amenable to interpretation by decision makers, as well as scientists and engineers.

Beyond this interface development, large, but separate, databases must be compiled, integrated, and placed in a single repository for common use. Analogously, the models being developed or adapted within this proposed plan must be compiled and integrated through the above interfaces.

Task V.2. Maintain System Components

The investment represented by the models, tools, and databases proposed for development within this plan of study will be large. For their effective use over the length of the study and the long term, the technology must be appropriately maintained. Maintenance, in this context, is much more than providing for locations for data and models to reside. The term includes modification of these technologies due to error identification, improved technology, or additional requirements not within this plan of study. In addition, hardware and communications systems must be maintained to allow users to access models and data from remote entry locations.

Task V.3. Distribute Technological Products

As the central repository for databases and models, it would be appropriate for the group or organization to also be the primary distributor for reports, users manuals, model user support, etc. Additionally, the office would publish periodic newsletters or information bulletins delineating new available technologies, updates to existing models, errors found in existing models, etc., and respond to requests for various models and data bases.

Task V.4. Apply Models

In its efforts to support users and to maintain technology, the group or organization should become proficient appliers of the models developed within this plan of study. Agencies and groups having either in-house or contractor expertise will also be proficient in model application. A hardware and software base must be nurtured to allow the office to apply these codes. These applications will be on a cost-reimbursable basis, with reimbursement coming from the agency requesting the application. Only a single subtask, that of applying the models, is presented due to the highly site and case-specific nature of the requests that the office will receive.

TIME, COSTS, AND PRODUCTS

This section provides estimates of time and cost required to accomplish the tasks outlined above. Anticipated products and task/product schedules are also included here. All costs are in constant 1991 dollars without adjustment for inflation.

Schedule of Time and Costs

The estimated time and costs required to accomplish each of the tasks/sub-tasks are outlined in the technical study plan. It should be recognized that these times and costs are estimates, and adjustments may be required during the study. Thus, periodic reporting and review are extremely important during the study.

Discussion with ENP personnel showed that numerous tasks proposed herein are planned or underway within their work program. These tasks are related to modification of the current SFWMM, topographic and biotic data collection and analysis within ENP, and the development of component biotic models. The ENP staff has estimated that approximately $2,000,000[3] of current or proposed Federal funding that they are to receive annually could be earmarked for investigations proposed (or subsets thereof) in this scope. Given that this is Federal funding, and it is expected to continue over the life of the investigation proposed herein, this funding was used to reduce the funding requirements of the studies proposed herein as shown in the table below. The amount was adjusted to $500,000 for the first and last years of study to reflect ramp-up and ramp-down portions of the overall study.

This report serves as general technical plan of study. Following initiation of this project, specific technical workshops will be held and additional planning will be conducted to develop detailed scopes of work for each task.

It is recognized that the size and scope of this study will require the involvement of many technical institutions/agencies. There is not a single

[3] This figure was based on coordination with ENP staff. ENP's letter (Appendix A) indicates that current funding is $275-300K now; but additional funding may be available in FY 93 from new programs.

agency, university, or consulting firm that is capable of conducting all of this large, diverse effort. It is envisioned that multiple Federal and State agencies, universities, and consulting firms will be required to successfully accomplish this work in a team atmosphere.

The total cost (in 1991 dollars) for all five task areas by year and the total of the entire study are shown in Table 2.

TABLE 2

TOTAL COSTS OF MODEL DEVELOPMENT

FUNDING $M, BY YEAR

TASK	1	2	3	4	5	6	7	8	9	TOTAL
Area I	1200	2750	3300	2175	1875	1800	1800	1850	850	17600
Area II	810	3325	3925	5750	6375	5575	3725	2075	400	31960
Area III	500	1700	1750	1600	200	0	0	0	0	5750
Area IV	875	1475	1275	1425	1825	925	1725	1675	1175	12375
Area V	250	700	950	850	850	800	800	750	650	6600
TOTAL	3635	9950	11200	11800	11125	9100	8050	6350	3075	74285
						NON-FEDERAL SHARE (25%)				18571
						FEDERAL SHARE (75%)				55714
						ENP EFFORTS				15000[4]
						REMAINING FEDERAL				40714

As shown in Table 2, the estimated total time and cost of conducting this study is nine years and about $74.3 million (1991 dollars). The tasks were scoped to include all components of study, i.e., research, data collection, monitoring, and modeling.

[4] The technical study plan developed by WES shows $15 million in effort by ENP towards model development. This figure was based on coordination with ENP staff. ENP's letter indicates that current funding is $275-300K now; but additional funding may be available in FY 93 from new programs.

OPTIONS FOR MODEL DEVELOPMENT

The previous discussions in this chapter outlined the tasks proposed to develop a hydrologic ecosystem modeling system that would fulfill the study authorization. The technical study plan incorporated the most feasible tasks of those determined necessary by the participants of this reconnaissance study; workshop attendees and study partners. Unfortunately; not all of the research, data collection and modeling efforts desired by the participants are feasible, due to limited knowledge, technology, or funding.

In addition to narrowing the scope of the modeling system during the development of the technical study plan, levels of scope of the completed technical study plan were also considered. These levels of scope, or options, were considered in order to ensure that the most technically sound and economical model development proposal was recommended. The following section describes four options that were considered, evaluations of each option, and the recommended option.

Option A

This option proposes that all of the tasks enumerated in the technical study plan be performed, but in a phased approach. The tasks would be divided into three phases. The first phase would include Years 1 through 2 and is estimated to cost a total of $13,585,000 (refer to Table 2). The primary products that would be developed during Phase I include: the modified SFWMM, a water budget database, nutrient database and analysis software, initial framework for the SFWQM, landscape vegetation models, and databases on selected species and freshwater wetland organisms.

Phase II include Years 3 through 5 and costs $34,125,000. The major products to be accomplished during this phase would include: the enhanced SFWMM, water budget software, landscape vegetation models, groundwater models, estuarine hydrodynamic/salinity models, the SFWQM and databases on selected species and Florida Bay organisms.

Phase III would last from Year 6 through 9 to complete the model development phase and is estimated to cost $26,575,000. This phase would include: an agricultural runoff water quality model, population/community dynamics and food web models, estuarine databases and models, a Lake Okeechobee water quality model, adapted Kissimmee riverine and watershed models, nutrient budget analyses, and individual based models for selected species. The total cost of this option is $74,285,000. The Federal share of this option, 75 percent, would be $55,714,000. The non-Federal share, 25 percent, would be $18,571,000.

As discussed in a previous section, Schedule of Time and Costs, discussion with ENP personnel showed that numerous tasks proposed herein are planned or underway within their work program. As previously discussed, the ENP staff has estimated that approximately $2,000,000 of current or proposed Federal funding that they are to receive annually could be earmarked for investigations proposed (or parts thereof) in this scope.

The 9-year effort is the shortest possible time frame to conduct the described technical study plan, and the identified funding to be the minimum required to adequately address the effort.

This option meets the full intent of the authorization, is technically sound as a "road map", addresses the important concerns and issues of the region, and is consistent with information and priorities obtained at the July and October 1991 workshops.

Option B

This option, refer to Table 3, is based upon conducting only those tasks in the technical study plan that were considered high priority by the October 1991 workshop participants. The major Water Quantity Tasks would include: modification of the SFWMM; development of groundwater/wetland models; and development of a system-wide water budget. The Water Quantity Tasks that would be omitted under Option B would include the development of multi-dimensional hydrodynamic models and dynamic routing and watershed runoff models for the Kissimmee River System.

The major Water Quality Tasks would include the development of a system-wide nutrient budget and models of nutrient dynamics and water quality for landscape regions. The Water Quality Tasks omitted would include the development of models of field-scale agricultural runoff of nutrients and water quality and the modification of nutrient dynamics and water quality models for Lake Okeechobee.

The major Vegetation Tasks would include the development of a system-level landscape vegetation model for freshwater wetlands and habitat landscape vegetation models in conjunction with Individual Based Models. No Vegetation Tasks would be omitted with this option.

The major Animal Tasks would include the development of individual oriented/species level models and process oriented and structured population models and network flow characterization for freshwater wetlands in the Everglades Protection Area. The Animal Tasks that would be omitted would include process oriented and structured population models and network flow characterization for Florida Bay and for Lake Okeechobee. It is estimated that approximately 90 percent of Task V would still need to be performed.

TABLE 3

OPTION B

HIGH PRIORITY TASKS

FUNDING $M, BY YEAR

TASK	1	2	3	4	5	6	7	8	9	TOTAL
I.1	1050	2100	2000	1450	1000	400	200	0	0	8200
I.2	50	350	900	725	575	0	0	0	0	2600
I.3	100	300	400	0	0	0	0	0	0	800
II.1	365	1175	1325	1525	1525	1525	1525	1225	0	10190
II.2	445	2150	2450	2675	2350	950	850	450	250	12570
III.1	250	1100	1300	1150	200	0	0	0	0	4000
III.2	250	600	450	450	0	0	0	0	0	1750
IV.1	625	625	525	625	625	125	125	125	125	3525
IV.2	250	850	750	800	800	300	0	0	0	3750
V	225	630	855	765	765	720	720	675	585	5940
TOTAL	3610	9880	10955	10165	7840	4020	3420	2475	960	53325
						NON-FEDERAL SHARE (25%)				13331
						FEDERAL SHARE (75%)				39994
						ENP EFFORTS				11250[5]
						REMAINING FEDERAL				28744

OPTION C

It is proposed that this option also be phased as described in Option A. Phase I would cost $13,490,000. The major products would include: the modified SFWMM, water budget database, nutrient database and analysis software, initial framework for the SFWQM, landscape vegetation model for EPA, and databases for selected species. Phase II would cost $28,960,000. The major products would include: water budget software, landscape vegetation models, enhanced SFWMM, groundwater models, SFWQM, and databases on selected species and freshwater organisms. Phase III would cost $10,875,000. The major products would include: population/community dynamics and food web models, nutrient budget analyses, and individual based models for selected species. This option would cost $53,325,000 (refer to table 3). The Federal share of this option would be $39,994,000. The non-Federal share would be $13,331,000.

[5] The technical study plan developed by WES shows $15 million in effort by ENP towards model development. This figure was based on coordination with ENP staff. For Option B this amount was reduced to $11.25 million to account for the elimination of some tasks. ENP's letter indicates that current funding is $275-300K now; but additional funding may be available in FY93 from new programs.

These tasks from the technical study plan are shown below along with that portion of Task V required to support the overall study. Although a detailed analysis of the phasing of products under this option was not performed, it is reasonable to assume the general phasing would be consistent with that shown in the technical study plan for the identified tasks. The cost reduction shown for the ENP were assumed to be $11,250,000; 75 percent of that assumed for the technical study plan, due to the reduced scope.

The advantage of this option is that it does address the "perceived" high priority items based upon a "show of hands vote" taken at the October 1991 workshop. However, the information available to workshop participants did not include the technical study plan, wherein details of various tasks were described. Some important areas would not be studied. For example, the agricultural areas, selected landscape subregions, Lake Okeechobee, Kissimmee River System, and the bays and estuaries are omitted in this option. This option, while it does narrow the scope of the technical study plan, still would fulfill the intent of the study authorization.

Option C

This option includes only Tasks I and II of the technical study plan and appropriate level of Task V to support the overall effort. It is assumed that the phasing of products would generally be the same as presented in the technical study plan. Funding for this option is shown in Table 4. The cost reduction shown for the ENP are assumed to be $3,800,000; 25 percent of that assumed in the technical study plan. Note that Task V below is 85 percent of that shown in the technical study plan. Phase I would cost $8,895,000. The major products would include: the modified SFWMM, water budget database, nutrient database and analysis software, and initial framework for the SFWQM. Phase II would cost $25,650,000. The major products would include: water budget software, groundwater models, enhanced SFWMM, estuarine hydrodynamic/salinity models, nutrient budget database and analyses, and SFWQM. Phase III would cost $20,625,000. The major products would include: agricultural runoff water quality model, estuarine databases and models, Lake Okeechobee water quality model, adapted Kissimmee riverine and watershed models, and nutrient budget database and analyses. The total cost of this option is $55,170,000. The Federal share would be $41,3780500 and the non-Federal share would cost a total of $13,792,000.

By deleting the work pertaining to vegetation and animals (i.e., Tasks III and IV), this option would produce a very restricted hydrologic ecoystem modeling system. Significant savings are not obtained over Option A. The major problem with this option is that it does not address very important issues and concerns of the region. Preliminary discussions with the SFWMD and ENP indicated that they would not support this option.

TABLE 4

OPTION C

TASKS I AND II ONLY

FUNDING $M, BY YEAR

TASK	1	2	3	4	5	6	7	8	9	TOTAL
I	1200	2750	3300	2175	1875	1800	1800	1850	850	17600
II	810	3325	3925	5750	6375	5575	3725	2075	400	31960
V	215	595	810	720	720	680	680	640	550	5610
TOTAL	2225	6670	8036	8645	8970	8055	6205	4565	1800	55170
							NON-FEDERAL SHARE (25%)			13792
							FEDERAL SHARE (75%)			41378
							ENP EFFORTS			3750[6]
							REMAINING FEDERAL			37628

Option D

This option, refer to Table 5, includes only the high priority tasks in the Water Quantity and Water Quality areas, which includes Tasks I.1, I.2, I.3, II.1, and II.2. The major Water Quantity Tasks would include: modification of the SFWMM; development of groundwater/wetland models; and development of a system-wide water budget. The Water Quantity Tasks that would be omitted under Option B would include the development of multi-dimensional hydrodynamic models and dynamic routing and watershed runoff models for the Kissimmee River System. The major Water Quality Tasks would include the development of a system-wide nutrient budget and models of nutrient dynamics and water quality for landscape regions. The Water Quality Tasks omitted would include the development of models of field-scale agricultural runoff of nutrients and water quality and the modification of nutrient dynamics and water quality models for Lake Okeechobee. The cost reduction shown for the ENP are assumed to be $3,800,000; 25 percent of that assumed in the technical study plan. It is estimated that 85 percent of Task V would still need to be performed.

It is assumed that the phasing approach proposed in the previous options would be used for this option. Phase I would cost $8,895,000. The major tasks

[6] The technical study plan developed by WES shows $15 million in effort by ENP towards model development. This figure was based on coordination with ENP staff. For Option C this amount was reduced to $3.75 million to account for the elimination of tasks. ENP's letter indicates that current funding is $275-300K now; but additional funding may be available in FY 93 from new programs.

would include: the modified SFWMM, water budget database, nutrient budget database and analysis software, and initial framework for the SFWQM. Phase II would cost $21,150,000. The major products would include: water budget software, groundwater models, the enhanced SFWMM, and the SFWQM. Phase III would cost $9,925,000. The major products would include: the nutrient database and budget analyses. The total cost of this option is $39,970,000 (refer to Table 5). The Federal share would be $29,978,000; the non-Federal share $9,992,000.

By deleting the work pertaining to vegetation and animals (i.e., Tasks III and IV), this option, like Option C, would produce a very restricted hydrologic ecosystem modeling system. Preliminary discussions with the SFWMD and ENP indicated that they would not support this option. The SFWMD is required by law to perform modeling tasks that will ensure that the ecosystem of the Everglades Protection Area (EPA) is not jeopardized by any management actions. To meet this requirement by the deadlines imposed in the lawsuit settlement, the SFWMD must perform ecosystem modeling. The SFWMD has emphasized that this modeling effort must not interfere with the efforts that they must undertake to meet their legal obligations. ENP staff has also preliminarily stated that they would not be interested in any option that would not fulfill ecosystem modeling.

TABLE 5

OPTION D
TASK I AND II
HIGH PRIORITY ONLY
FUNDING $M, BY YEAR

TASK	1	2	3	4	5	6	7	8	9	TOTAL
I.1	1050	2100	2000	1450	1000	400	200	0	0	8200
I.2	50	350	900	725	575	0	0	0	0	2600
I.3	100	300	400	0	0	0	0	0	0	800
II.1	365	1175	1325	1525	1525	1525	1525	1225	0	10190
II.2	445	2150	2450	2675	2350	950	850	450	250	12570
V	215	595	810	720	720	680	680	640	550	5610
TOTAL	2225	6670	7885	7095	6170	3555	3255	2315	800	39970
							NON-FEDERAL SHARE (25%)			9992
							FEDERAL SHARE (75%)			29978
							ENP EFFORTS			3750[7]
							REMAINING FEDERAL			26228

[7] The technical study plan developed by WES shows $15 million in effort by ENP towards model development. This figure was based on coordination with ENP staff. For Option D this amount was reduced to $3.75 million to account for the elimination of tasks. ENP's letter indicates that current funding is $275-300K now, but additional funding may be available in FY93 from new programs.

Recommended Option

An evaluation of these options showed that all options would fulfill the intent of the study authorization. Options C and D, however perform very limited work pertaining to vegetation and animals; only the minimum necessary to complete the water quantity and water quality tasks. Therefore, those options would produce a very restricted hydrologic ecosystem modeling system. Because of the importance of evaluating the vegetation and animals to understand the overall ecosystem, Options C and D were eliminated. Preliminary discussions held with the SFWMD indicated that the agency would not support Options C or D. Furthermore, the ENP has stated that they would not support those options.

Option B, while it does not include all areas of the ecosystem, would perform those tasks that were considered the highest priority. Option A would provide a more complete ecosystem modeling system, but at a substantially greater cost. Option B would produce a simulation modeling system of the south and central Florida hydrologic ecosystem. Option B is the recommended approach for model development.

BENEFITS OF MODEL DEVELOPMENT

The general acceptability and broad use of this modeling system as an analytical device for improving resource management procedures can be accomplished through continued and progressive participation from the majority of local interests concerned with the project area's ecosystem. The modeling system development process will require extended cooperative efforts among all Federal, State, and local institutions with technical capabilities and management concerns for the C&SF project area. The assembly of improved knowledge and the interchange of objective analytical concepts and techniques among hydrologic ecosystem researchers, resource managers, and regulatory agencies can be expected to significantly improve system management procedures and technical coordination among agencies with management and regulatory responsibilities in the study area.

Specific benefits of developing this modeling system include gaining a common database of south and central Florida, developing a coordinated system of sharing that data, learning more about the hydrology and various ecosystem processes, improving management practices, securing a better understanding of cumulative and secondary impacts of decisions, and more accurately predicting the effects of project.

C&SF Project Modifications

One of the purposes of developing this modeling system is to predict the impacts of modifications to the C&SF Project. There are a number of proposed modifications currently being considered by the Corps which are discussed in the next few paragraphs. While these modifications may not benefit by the proposed modeling system, once developed, similar projects could be evaluated to predict the impacts they might have on the south and central Florida ecosystem.

Bolles and Cross Canals

The canals are located in the EAA between the Miami, New River and Hillsboro Canals. The Bolles and Cross canals have a limited capacity which is insufficient to convey the stormwater discharge from adjoining farms after a significant storm event. The proposed project is to provide flood control benefits and permit the inter-basin transfer of storm waters which in conjunction with the Everglades SWIM plan may ultimately result in improvements to water quality.

C-51 West Project

C-51 is located in central Palm Beach County, between WCA 1 and the IWW. The area has experienced periods of heavy rainfall which have resulted in localized flooding. Proposed plans include canal improvements, construction of a divide structure and a pumping facility, and a detention area.

C-111/South Dade Flood Control Project

C-111 is located in southeastern Dade County. The canal was constructed to provide flood control. The basin is developed primarily by agriculture which has exceeded projected growth trends. Extended durations of flooding due to periodic major storm events, has an impact on agricultural productivity in portions of the basin. Environmental problems have persisted due to the alteration of wetlands in the basin which has affected wildlife productivity and habitat values. Surface water overflow to the ENP and northeast Florida Bay is poorly distributed. Operational releases of large volumes of freshwater and the loss of overland sheet flow has contributed to a reduction of marine and estuarine productivity. The objectives of this project area are to provide flood control benefits to agricultural interests, restore sheet flow to the marsh adjacent to C-111 and northeast Florida Bay via the ENP, reduce large freshwater flows to Barnes Sound and protect, preserve, and minimize impacts on significant archaeological and historical resources.

Hillsboro Canal

The Hillsboro Canal is located in southeastern Palm Beach and northeastern Broward Counties. Periodic flooding has occurred in the service area as a result of increased drainage problems due to highly developed urban areas and prolonged heavy seasonal rainfall combined with an inadequate primary drainage system. Concern has also been expressed over the lack of adequate protection from rising waters within WCA 1 that may adversely affect wildlife habitat and nesting behavior. Increased capacity in the Hillsboro Canal would also aid the restoration efforts in WCA 2.

Kissimmee River Restoration

This project, located in Highlands, Okeechobee, Osceola, and Polk Counties, involves revitalizing headwaters by modifying upper basin features and backfilling three to five miles of the canal in the central reach of the river. This is the first step towards backfilling a continuous 25 to 30 mile section of the canal and will restore approximately 8500 acres of floodplain wetlands.

Modified Water Deliveries to Everglades National Park

The hydrology of the southern Everglades was altered by the construction of L-67A, L-67C, and L-29 flood control levees. Unseasonably high water conditions in the ENP in 1983 prompted Park officials to request emergency measures to be taken to correct the hydrologic imbalance and restore sheet flow to the northeast Shark River Slough. Congress authorized and the Corps conducted a program of experimental water deliveries to the Park. In December 1989, President Bush signed the *Everglades National Park Protection and Expansion Act*. This act authorizes expansion of the ENP to include an additional 107,600 acres and authorized the construction of modifications to the C&SF Project to the benefit of the ENP in Dade County. The primary objective of this project is to enhance the natural resources of ENP in Shark River Slough through structural and operational water management alterations to the C&SF Project. A secondary objective is to develop an initial operating plan based on restoring, to the extent possible, the natural hydrologic conditions with the ENP and other contiguous Everglades habitat that may be necessary to achieve the primary objective. A flood mitigation system is proposed for a residential area in the East Everglades.

Shingle Creek Basin Project

This project involves correction of flooding problems and enhancement of water quality for portions of Orange and Osceola Counties. Proposed plans will provide flood protection for the upper and extreme lower basins. The project will include the enlargement of the existing Shingle Creek Canal in the upper basin; construction of a water control structure in the south end of the upper basin; and clearing/reshaping of a local drainage canal. The structure will eliminate potential erosion problems downstream and prevent overdrainage of the upper basin. *The General Design Memorandum* has been completed and the Corps is proceeding with the engineering details to prepare a *Detailed Design Memorandum.*

The benefits that are expected to result from the proposed works listed above include: flood protection, increased water conservation and improved distribution of water throughout the project area. In 1968, the project was expanded to include provisions for storage and conservation of water and improved distribution of water throughout the project area. In recent years greater emphasis is being given to the maintenance and enhancement of water quality throughout the project. In addition, benefits from the restoration and enhancement hydrological and water quality conditions in ENP, the Everglades area and the Kissimmee River.

Along with structural changes such as those mentioned above, resource managers need to be able to predict impacts on the ecosystem from changes in the operation of water schedules, reduction of nutrients, and other non-structural alternatives. As an example, alternative water delivery scenarios could be run to predict the impacts on the water levels and resultant changes in vegetation throughout the entire study area, in order to study the optimum water delivery schedule.

Regulatory Activities

The authorization directs that the modeling system be capable of producing information useful in evaluating Section 10 and 404 permit applications.

The management decision model based on a GIS database could be used by regulatory agencies to test the compatibility of site specific permit requests. GIS can be used to compile a database on environmentally sensitive areas; denoting areas of special concern for species, sensitivity, landforms, functions and aesthetics. The model will be programmed by Federal and State water and land resource management agencies in defining the status and goals of watersheds or regions. And it could be used by the Federal government to evaluate projects based on environmental benefits. This project will establish a GIS which will be compatible between State water and land resource management agencies, EPA, USFWS, the Corps, and others.

The Corps has been looking for ways to enhance enforcement capabilities with image processing, remote sensing and GIS. Currently, a limited number of workers or "enforcement scientists" with heavy caseloads try to investigate and evaluate filling and dredging activities. In 1989, the Corps' Army Engineer Topographic Laboratory (USAETL) helped the Corps' Norfolk District's

Northern Virginia field office with image processing and GIS support for two suspected illegal fillings. Landsat Thematic Mapping imagery and scanned aerial photography were used to study the extent of the suspected fill in a street extension project in Virginia. Comparison of the Landsat images from two different years, processed against each other, showed changes in patterns of vegetation and surface hydrology.

Also in Virginia, an in-house image processor and GIS determined the extent of an illegal fill, and measured the drainage basin above the site. A spring 1987 Landsat Thematic Mapper scene and an aerial photo of the area were geographically referenced to a 1:24000 scale USGS topographic quadrangle. In addition, a portion of the corresponding national wetlands inventory map was digitized and fed into the GIS. From this comparison the Corps and EPA determined the illegal filling and draining and issued a stop-work order. The time and effort saved from the personal evaluation of filling and dredging activities will offset the cost of remote sensing and GIS. This type of desk top evaluation will also support litigation (Austin, 1990).

This research, data collection, and modeling activities would allow agencies to learn more about how wetlands function and how to design and engineer wetland restoration and construction.

While it would not be practical to use the modeling system for each permit application that is submitted, the modeling system could be used for proposed large developments or evaluating a Regional Impact Assessment. One means for this modeling tool to assist regulatory agencies would be to assist in the preparation of *Advanced Identification of Wetlands (ADID) Studies*. An ADID is a planning tool for use by potential developers, the general public, and the federal regulatory agencies to identify, in advance of any permit application, those sites (wetlands) for which the discharge of dredged or fill material would likely comply with the *Section 404(b)(1) Guidelines in the Clean Water Act.*

One example of an ADID is described in the following paragraphs. The Corps and EPA recently completed a draft two-year study of wetlands in Broward County. EPA, Region IV, Atlanta, Georgia, with the cooperation of the Corps, Jacksonville District, made a determination of possible future disposal sites and areas general unsuitable for the disposal of dredged or fill material with West Broward County. The ADID study area encompasses approximately 52 square miles of historic Everglades wetlands in western Broward County. The final draft of the Technical Summary Document for the ADID was completed by EPA and a public meeting to solicit comments was held in September 1991. The comments are currently under review and the results of the analyses by both agencies will be completed soon.

In their study of the area, the EPA and the Corps determined that wide swaths of southwest Broward's wetlands are vital to preserving underground water supplies, maintaining wildlife habitat and controlling floods. The study had two purposes: to identify wetlands vital to protect and to act as a guideline where development generally would be allowed or prohibited.

The draft ADID proposes designating 24 square miles of southwest Broward County as unsuitable for development. The study recommends that no development be allowed on all land west of U.S. 27 but outside Everglades conservation areas, known as the Everglades Buffer Strip, plus a half-mile wide sliver of land north of Griffin Road and east of U.S. 27. No development, except in limited circumstances, would be allowed in an area southwest of Weston and north of Griffin Road and a tract bounded by Pines Boulevard, U.S. 27, Dade County and Southwest 172nd Avenue. Development would be allowed with requirements for environmental compensation in other lower quality wetlands in southwest Broward west of Interstate 75.

Resource Management

One of the difficulties of managing the C&SF Project has been that while certain actions that may benefit one segment, they may be disastrous to other areas. For example, efforts to regulate Lake Okeechobee's lake level for flood control have often had a negative effect on wildlife. Decisions to enhance the fishing industry may conflict with the agriculture industry. Most often the reasons for these conflicts have been the lack of scientific data, the lack of understanding of the long-range impact of various decisions and the absence of a coordinated system of coordination. This authorization provides an opportunity to develop a management system tool which will address these problems and permit decisions to be made based on common and scientific information and allow for logical prediction of the impact of those decisions on all segments of the ecosystem.

The ecosystem modeling system has tremendous potential for increasing the knowledge and understanding of the south and central Florida ecosystem and for improving current predictive abilities necessary for water resources planning, management and decision-making.

One of the major benefits of this project would be to establish and maintain the needed mechanism for the scientists and engineers to communicate and coordinate their research and planning efforts associated with the south and central Florida ecosystem. Another benefit derived from this project would be that the modeling system, if developed by a cooperative effort, would be acceptable to the scientific community. The data collected and the models developed would be accessible to the resource agencies and the scientific community.

MODEL IMPLEMENTATION AND OPERATION

The technical feasibility, utility, and benefits of developing the simulation modeling system were discussed in the previous chapter. The technical study plan describes the tasks, with associated time and costs, to accomplish a hydrologic ecosystem modeling system for the entire study area. Alternatives were discussed and a recommended approach was proposed. This chapter presents an outline of the management organization necessary for model development to succeed. Also presented are the requirements for cost sharing and the views of the potential local sponsor.

MANAGEMENT ORGANIZATION

Model development will require a system management structure to provide direction and oversight for the effort. Model operation will, likewise, require a management structure to insure that the models which are developed are utilized effectively and are updated and maintained as needed, not only during the model development phase, but also once the actual model development is over. Procedures delineating Federal and local sponsor model management responsibilities and contingencies will be developed in detail as part of the negotiations for a cost sharing agreement for model development and operation, but the following paragraphs provide a preliminary approach.

Model Development

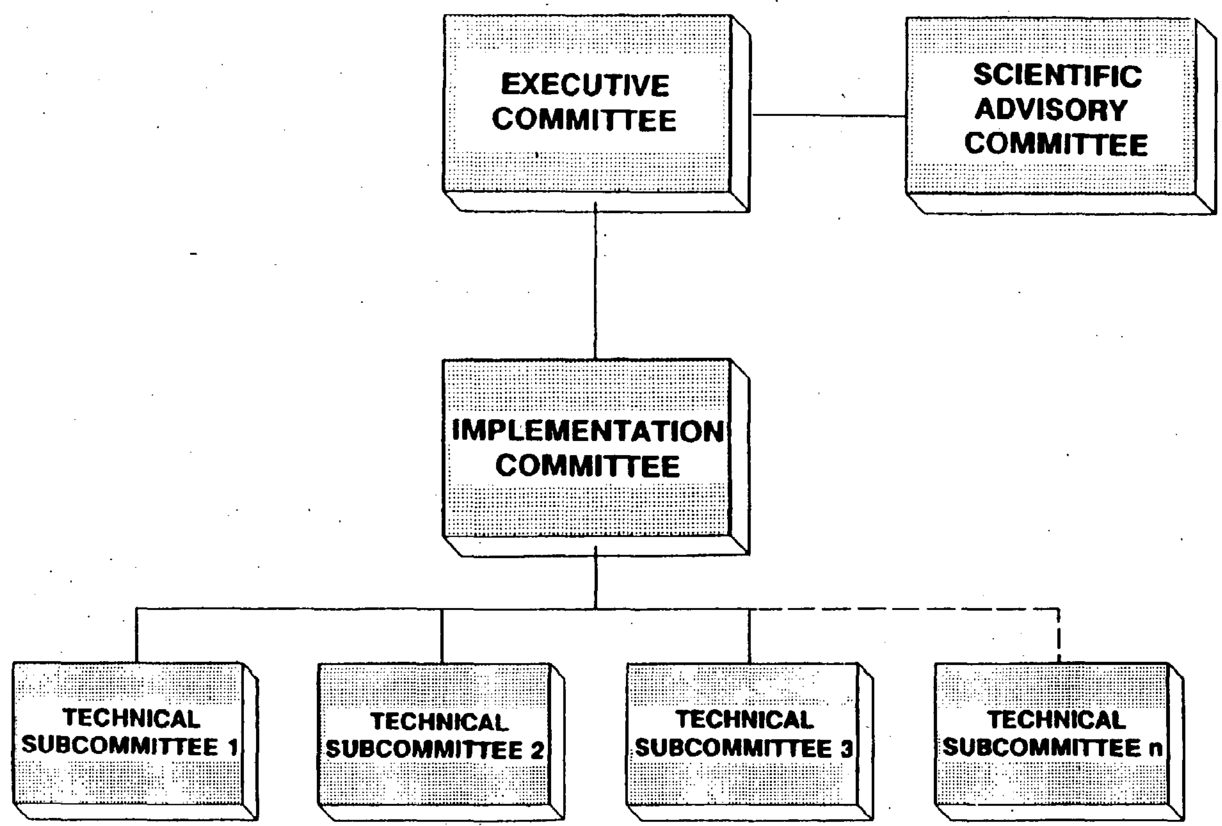
The final management structure for the model development phase will be developed during negotiation of the cost sharing agreement. However, the final management structure that is developed should be based on consideration of the expertise, responsibilities, and interests of the Federal, State, and local agencies, resource managers, and others that manage the hydrologic ecosystem in south and central Florida. For this reconnaissance report, a preliminary management organization structure was developed. This preliminary organization chart for the management structure is shown on Figure 7.

The top level of the management organization is the Executive Committee that would consist of decision makers from each of the agencies which comprise the study partners. This committee would have the final decision-making authority on all model development matters.

To assist the Executive Committee, a Scientific Advisory Committee should be formed to provide an impartial oversight of the modeling efforts. This group would be comprised of senior members of the scientific and

FIGURE 7

Model Development Management Structure



engineering community that would not be involved in any of the actual research, data collection, or modeling efforts. Some of the members of the Scientific Advisory Committee could be Deans and Department Chairs from major universities.

The mid-level of the management organization is an Implementation Committee. This committee would coordinate efforts that the Technical Subcommittees, discussed in the following paragraph, are pursuing and maintain communication with other agencies or research organizations. The Implementation Committee would report on all aspects of model development activities to the Executive Committee. They would also be responsible for setting all the parameters for modeling activities and ensuring that all Technical Subcommittees work within those parameters. This will ensure that all model development activities are performed with an interdisciplinary approach. This committee would, at a minimum, include the chairpersons from each of the Technical Subcommittees. Other members of the Subcommittee could include the chairpersons of each of the working group that will be set up within each Technical Subcommittee.

The final level of the management organization would be the Technical Subcommittees. It is anticipated that three to six of these committees would be formed to coordinate efforts for: Hydrologic and Water Quality Modeling, Hydrologic and Water Quality Monitoring, Ecosystem Modeling, Ecosystem Monitoring, and GIS and Database Management and Integration. Each Technical Subcommittee would be responsible for a particular area of the model development effort and would be composed of technical staff involved in the modeling effort. Membership would also include technical staff from agencies or organizations that are not parties to the cost sharing agreement. Numerous working groups would be formed under these Technical Subcommittees to handle specific tasks. It is anticipated that each Technical Subcommittee would have an external technical peer review panel, whose expertise is specific to the work of the particular Technical Subcommittee.

Initial items which the management organization should address include: detailed scopes of works, sub-model development priorities, and requisite sub-model to general model evolvement; software development; model implementation concepts and procedures; knowledge base management and library requirements; data and information forms and transfer procedures; system hardware requirements; funding and funds management needs; and the form of organization necessary for general management and accountability.

The proposed settlement of the Everglades lawsuit filed by the Department of Justice requires the formation of a Technical Oversight Committee (TOC) to oversee all activities related to the settlement. Since it is anticipated that the modeling system which is developed would be used to assist in activities required by the proposed settlement, there should be some linkage of the model development management organization and the TOC. The nature of this would need to be determined as the final management organization is developed and responsibilities at each level are delineated.

Model Operation

In order to ensure that there would continue to be adequately trained personnel to operate the program, continuously refine the model, and also to use the model for system-wide (hydrologic and ecologic) evaluation of proposed changes to the water management system, it is vital that the databases and models developed during this modeling effort continue to be maintained and operated after the model development phase is completed.

The technology proposed for development in Task Areas I through IV represents, in and of itself, a very important cog in the creation of appropriate management strategies for the south and central Florida ecosystem. The most effective use of this technology, however, must involve the integration of developed system components within a framework easily used by scientists, engineers, and decision-makers. Additionally, given the investment to be made in this technology and the long range nature of ecosystem management decisions, it is imperative that the maintenance, application, coordination, and distribution of said technology be well planned.

To accomplish the tasks in Task Area V, it is absolutely essential that a single group or organization be responsible for their planning and execution. This group or organization will have as its primary mission the execution of those tasks. The office should be located in Florida, and act as a technology center in support of the consortium of agencies involved with the management of the south and central Florida hydrologic ecosystem.

It is envisioned that the technology center that is proposed to complete the activities for Task V - Technology Integration, Maintenance, Application, and Distribution, would continue after completion of model development to perform model operation tasks. This would involve a commitment for continued funding and personnel from the study partners and other participants. No costs for this continued operation has been included in the technical study plan.

Model Availability

The authorization directs that the model shall be available for Federal, State, and local agencies to use on a reimbursable basis. Procedures regarding this process will developed in the context of the model management structure.

COST SHARING REQUIREMENTS

Model Development

Section 11 of the Water Resources Development Act of 1988 directs that the Federal share of model development and operation shall be 75 percent. However, the authorization does not specify whether the 25 percent non-Federal share of the cost must be in cash or whether in-kind services may make up all or a portion of the non-Federal share.

The potential local sponsor for this project is the South Florida Water Management District (SFWMD). Over the past twenty years or more, the staff at the SFWMD has developed a number of numerical models in the subject area to assist in the evaluation of surface water resources conditions; such as flow rates, peak elevations, drought situations, and management alternative evaluations. One of these models, the South Florida Water Management Model (SFWMM), simulates water surface elevations for the entire Lower East Coast, the Everglades Agricultural Area, Lake Okeechobee, the Water Conservation Areas, Big Cypress National Preserve, and the Everglades National Park. The SFWMM also contains a system management routing which can estimate discharge at major structures. Although it is generally agreed that this model could benefit from refinements, it has become apparent that the SFWMM could provide the cornerstone of the simulation modeling system for the South Central Florida Hydrologic Ecosystem. In addition, the SFWMD has the capability to provide a great deal of assistance towards model development.

The SFWMD has indicated a desire to utilize in-kind services for the non-Federal share. The extent of in-kind services which are allowed to be furnished by the SFWMD must be determined prior to negotiating the cost sharing agreement.

There has been interest expressed by the ENP of the possibility of their participation in the model development phase and the use of ENP funds for model development. Preliminary discussions have been held regarding the possibility of negotiating a Memorandum of Understanding (MOU) between the Corps and the National Park Service or the Department of the Interior. Further discussions with these agencies, as well as other Federal, State, and local agencies, will be held during the negotiation of the cost sharing agreement with the local sponsor and the development of the model management organization structure.

COORDINATION AND SPONSOR VIEWS

Throughout this reconnaissance study, close and extensive coordination was maintained with many agencies, organizations and individuals. Numerous meetings were held and two workshops conducted. A more detailed discussion of this coordination may be found in Appendix A - Coordination and Public Views. Close coordination was maintained with the potential local sponsor, the South Florida Water Management District and the Everglades National Park. Both agencies were provided a draft of the technical study plan for review and comment. The SFWMD has expressed their desire to continue participation in this study. The ENP has also expressed their support of the continuation of this study.

CONCLUSIONS

The development and operation of a simulation modeling system for the central and southern Florida hydrologic ecosystem is being conducted in two phases - a reconnaissance phase and a model development phase. The reconnaissance phase is the subject of this report. The main purposes of the reconnaissance phase were to determine the technical feasibility of developing such a simulation modeling system, to determine if there is a Federal and non-Federal interest in developing such a modeling system, and to prepare a work plan and cost estimate for the proposed model development phase. The main purpose of the model development phase will be to conduct research, collect data, and develop models and other tools for use in predicting the effects of modifications or changes in the operation of the C&SF Project and other human activities on the flow, characteristics, quality, and quantity of surface and groundwater and on the plants and wildlife within the ecosystem.

During the reconnaissance phase, extensive efforts were made to define the issues, problems, and needs of the study area. These efforts included field reconnaissance; meetings with Federal and State agencies and universities; and workshops conducted to communicate with Federal, State, and local agencies, as well as research organizations, environmental groups, agricultural interests, and private engineering firms.

The problems of the study area are numerous and varied. The C&SF Project hydrologic ecosystem is very complex. The project area encompasses more than 16,000 square miles. The C&SF Project was developed to manage the surface and groundwater resources of the project area and to serve a variety of interests for multiple purposes. Those purposes include flood control, water level control, prevention of salinity intrusion, water deliveries to the ENP, water supply, and fish and wildlife conservation. The ecosystem in central and southern Florida is also very complex and fragile.

The issues, problems, and needs of the study area were categorized into Water Quantity, Water Quality, and Biota - Vegetation and Animal, for the purpose of this report. Water Quantity problems included: competition for water resources; limited knowledge of historic, current, and future needs of the system; optimum water levels and delivery, and the need for more flexible management policies. Water Quality problems mainly pertained to eutrophication, dissolved solids, and contaminants. Biotic problems focussed on loss of habitat; decline of species; loss or change in soil; meso-scale disturbances such as fires, and invasion of exotic plant species; limited knowledge of vegetation and animal dynamics; and the need for system-level restoration.

The purpose of the modeling system is to address the three major resource issues of the area: (1) the ability of the C&SF Project to sustain the three major water use sectors (urban, agriculture, and natural areas), (2) impacts of land use on the natural system, and (3) preservation and restoration of natural portions of the ecosystem. The modeling system will be capable of producing information useful in assessing environmental impacts and evaluating regulatory applications.

Due to the complexity of the hydrologic ecosystem, it has been very difficult to predict the impacts that proposed projects would have on the water levels or water quality in other areas of the system and what the ecosystem response to those changes would be. Some of the changes can be anticipated, but others are unpredictable and require adaptive strategies.

There are numerous existing models and other tools that have been developed to describe subregions of the system and individual processes; but no attempt has been made to consolidate these tools, perform research, collect data and construct additional models to extend the tools for the entire study area and provide linkages across scales and disciplines. The consensus reached by the study participants was that the most critical need in understanding the hydrologic ecosystem of south and central Florida, is to develop a system-wide, interdisciplinary modeling system.

The best approach to construct this simulation modeling system is to continue extensive collaboration with the many agencies and interest groups involved throughout the study area. A model management structure is proposed within this report to form interagency management and technical committees. This management structure will provide a means to utilize the expertise of the many Federal, State, local agencies and others and provide a forum for exchanging information and ideas.

A generalized work plan in the form of a technical study plan was developed for this reconnaissance report. This plan was developed with cooperation from the study participants. The proposed plan outlines the development of a series of simulation models for the management of the south and central Florida hydrologic ecosystem. The technical study plan addresses scope, model development priorities, model linkages, data collection and research requirements, modeling methods, phases of model development, costs, and management tasks during development and also for operation of the modeling system. The model package includes both system-wide and regional models, as well as models of selected vegetative communities and animal populations.

The technical study plan presents a generalized approach and is the basis for future development of detailed scopes of work. It is to be recognized that changes in scope or direction may need to be made during the model development phase to take advantage of technological breakthroughs or a change of priorities.

The parameters followed in this technical study plan included:

A) Dividing the model development tasks into five major components - Water Quantity, Water Quality, Vegetation, Animal, and Technology Integration;

B) Designing this modeling system to be as "user-friendly" and accessible as possible;

C) Utilizing existing data and models whenever possible;

D) Designing the modeling system to exchange information between disciplines and in a two-way manner; and

E) Phasing the model development, such that usable products will be available throughout the effort and allow an efficient way to manage and review efforts undertaken in this model development phase.

Water Quantity Tasks include: 1) modification, enhancement, and application of the South Florida Water Management Model (SFWMM); development and application of 2) groundwater/wetland models, 3) a system-wide water budget, 4) multi-dimensional hydrodynamic models, and 5) dynamic routing and watershed runoff models for the Kissimmee River system.

Water Quality Tasks include the development and application of 1) a system-wide nutrient budget, 2) models of nutrient dynamics and water quality for landscape regions, 3) models of field-scale agricultural runoff of nutrients and water quality, and 4) modification and application of nutrient dynamics and water quality model for Lake Okeechobee.

Vegetation Tasks include the development and application of 1) a system-level landscape vegetation model for freshwater wetlands, and 2) habitat-specific landscape vegetation models in conjunction with Individual Based Models.

Animal Tasks include the development and application of: 1) individual oriented/species level models, 2) process oriented and structured population models and network flow characterization for freshwater wetlands in the Environmental Protection Area, 3) process oriented and structured population models and network flow characterization for the Florida Bay ecosystem, and 4) process oriented and structured population and network flow characterization for Lake Okeechobee.

Technology Integration Tasks include 1) integration of modeling components, 2) maintenance of system components, 3) distribution of technological products, and 4) application of models.

The performance of all of the tasks in the technical study plan as outlined above, has been estimated to require nine years and a total cost of $74,285,000. The Federal share of this cost would be $55,713,750; the non-Federal share $18,571,250. Due to the extensive time and costs required, four options were considered.

Option A would consist of performing all of the tasks in the technical study plan, but in a phased approach. The total cost is the same discussed in the paragraph above. Phase I, Years 1 and 2, would cost a total of $13,585,000. Phase II, Years 3 through 5, would cost $34,125,000. Phase III, Years 6 through 9, would complete the model development phase at a cost of $26,575,000.

Option B involves conducting "high priority" tasks, also in a phased approach taking nine years. The major Water Quantity Tasks would include: modification of the SFWMM; development of groundwater/wetland models; and development of a system-wide water budget.

The major Water Quality Tasks would include the development of a system-wide nutrient budget and models of nutrient dynamics and water quality for landscape regions.

The major Vegetation Tasks would include the development of a system level landscape vegetation model for freshwater wetlands and habitat landscape vegetation models in conjunction with Individual Based Models.

The major Animal Tasks would include the development of individual oriented/species level models and process oriented and structured population models and network flow characterization for freshwater wetlands in the Everglades Protection Area. The total cost of Option B would be $53,325,000. The Federal share would be $39,993,750; the non-Federal share $13,331,250. Phase I would cost $13,490,000. Phase II would cost $28,960,000. Phase III would cost $10,875,000.

Option C would involve performing only Water Quantity and Water Quality Tasks, with appropriate Technology Integration Tasks. It was assumed that phasing of this option over nine years would generally correspond to that proposed for Options A and B. The total cost of this option would be $55,170,000. The Federal share would be $41,377,500; the non-Federal share $13,792,500. Phase I would cost a total of $8,895,000. Phase II would cost $25,650,000. Phase III would cost $20,625,000.

Option D proposes performing only the "high priority" tasks in Water Quantity and Water Quality areas, with appropriate Technology Integration Tasks. The major Water Quantity Tasks would include: modification of the SFWMM; development of groundwater/wetland models; and development of a system-wide water budget.

The major Water Quality Tasks would include the development of a system-wide nutrient budget and models of nutrient dynamics and water quality for landscape regions. The total cost of Option D is $39,970,000. The Federal share would be $29,977,500; the non-Federal share $9,992,500. Phase I would cost $8,895,000. Phase II would cost $21,150,000. Phase III would cost $9,925,000.

An evaluation of these options showed that all options would fulfill the intent of the study authorization. Options C and D, however perform very limited work pertaining to vegetation and animals; only the minimum necessary to complete the water quantity and water quality tasks. Therefore, those options would produce a very restricted hydrologic ecosystem modeling system. Because of the importance of evaluating the vegetation and animals to understand the overall ecosystem, Options C and D were eliminated. Preliminary discussions held with the SFWMD indicated that the agency would not support Options C or D. Furthermore, the ENP has stated that they would not support those options.

Option B, while it does not include all areas of the ecosystem, would perform those tasks that were considered the highest priority. Option A would provide a more complete ecosystem modeling system, but at a substantially greater cost. Option B would produce a simulation modeling system of the south and central Florida hydrologic ecosystem. Option B is the recommended approach for model development.

Given that model development of the south central Florida hydrologic ecosystem is feasible and it has been shown that there is a Federal and non-Federal interest in pursuing model development, proceeding to the model development phase is warranted. Due to the need for extensive interagency cooperation and coordination which would be needed to successfully develop and operate the modeling system as well as the interagency benefits of such a system, funding for the development and operation of the modeling system could be provided by the Corps of Engineers and other Federal, state and local agencies.

RECOMMENDATION

I recommend that development and operation of the Simulation Model of South Central Florida Hydrologic Ecosystem proceed generally in accordance with Option B as outlined in this reconnaissance report, dependent upon development of funding agreements between the Corps of Engineers and other Federal, State, and local agencies to share the costs of model development and operation.

TERRENCE C. SALT
Colonel, Corps of Engineers
Commanding

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FLORIDA BAY SCIENCE PLAN

A science planning document provided to the Interagency Working Group on Florida Bay

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I. EXECUTIVE SUMMARY

The following science plan was developed by the Florida Bay Interagency Working Group, which was initiated by Everglades National Park in January 1993. The plan focuses upon the research, monitoring, and modeling objectives that must be addressed to guide the restoration of Florida Bay and represents a synthesis of research plans prepared over the past year by several federal and state agencies. With additional plans focused on the coastal mangrove estuaries of southwest Florida, the Florida Reef Tract, and, the Florida Keys and Dry Tortugas, this science plan will serve as the basis for restoration of Sub-region 8 under the aegis of the South Florida Ecosystem Task Force.

Administratively, an interagency research plan for Florida Bay is especially needed because of the number of agencies that have jurisdiction over areas affected by Florida Bay research and restoration. Representatives of the major agencies (Department of Commerce, Department of Interior, Florida Department of Environmental Protection, and the South Florida Water Management District) have participated in drafting an interagency plan consistent with their respective responsibilities. As recommended by a disinterested advisory panel convened in September 1993 at the behest of the Assistant Secretary of the Interior for Fish and Wildlife and Parks, a management framework has been explicitly set forth to ensure continuing integration of the activities of the different agencies. This framework includes an Interagency Program Management Committee, a Review Panel, and a Technical Advisory Group. It was agreed that individual implementation plans prepared by each agency should not only be consistent with the scientific approach and priorities of the interagency science plan but each should also include the following:

1) Cross-references to and discussions of the implementation plans developed by other agencies,

2) A funding source for participation in annual interagency principal investigator meetings at which data and results can be exchanged, and

3) Compatible data-management plans and procedures.

The management objective for Florida Bay is to restore it to a naturally functioning ecosystem. Elements of the restoration process and the degree to which management can effect change, in large part, define the focus, approach, and priorities of this science plan. To support restoration, the science program must be long-term and goal-oriented in perspective. The program must be committed to the process of integrating scientific understanding of Florida Bay into the management decision-making process and must focus on interdisciplinary ecosystem-based research. The specific objectives of the science program should include the following:

1) Developing an understanding of the condition of Florida Bay prior to significant alteration by man;

2) Separating anthropogenically induced changes in Florida Bay from natural system variation;

3) Developing a basic understanding of the ecology of Florida Bay by evaluating alternative hypotheses;

4) Developing the capability to predict how the ecosystem as a whole and how a suite of species that collectively may be considered indicators of Florida Bay ecosystem health respond to perturbation.

The approach recommended embraces a closely linked program of monitoring, research, and modeling. By monitoring, we can track critical ecosystem parameters and provide baseline data and model parameterization. By conducting research, we can develop an understanding of the physical and biological processes regulating Bay ecosystem status, test model predictions, and evaluate cause and effect relationships. Computer simulation models, in which our best understanding of the Bay's ecology within the regional landscape is expressed, will be used in a predictive mode to assess system response to change, to hindcast historical conditions, and to develop and select management alternatives.

Four general topic areas were considered: 1) water budgets, circulation dynamics, and salinity; 2) water quality and nutrient cycling; 3) seagrass, mangrove, and hardbottom habitats; and 4) living resources. Following the recommendation of the advisory panel, priorities were then established within each of the general topic areas by formulating questions that must be answered in order to understand the ecosystem of Florida Bay, the changes it has undergone, and the possible effects of alternative restoration scenarios. These are some of the questions posed:

1. What is the relationship of surface water and groundwater flows through the Everglades to the salinity of Florida Bay?

2. What has been the effect of the relative lack of storms over the past three decades on the buildup of sediments, nutrients, and organic material in the Bay?

3. What have been the effects in Florida Bay of increased residence time of water caused by restricted water flow through channels between the Keys, shoaling, and reduced freshwater inflows?

4. What are the sources, quantities, and ecological effects of "external" nutrients introduced into Florida Bay?

5. What are the rates of nutrient exchange between the sediment and water column within Florida Bay, and what controls the magnitude and direction of these fluxes?

6. What are the rates of nutrient assimilation by phytoplankton in the Bay, and what limits the growth of the phytoplankton assemblage?

7. What are the sources, quantities, and effects of toxic pollutants introduced into the Florida Bay ecosystem?

8. What is the cause of turbidity in the Bay, and what is its effect on Bay water quality?

9. What environmental and biological factors explain the observed distribution of seagrasses within the Bay and the recent die-off?

10. What environmental factors explain the pattern of mangrove die-back within the Florida Bay ecosystem?

11. What has been the cause and consequence of sponge die-off and the subsequent alteration of hardbottom communities?

12. Has recruitment into Florida Bay been affected by habitat changes in Florida Bay, and have altered environmental conditions affected growth and survival of animals in Florida Bay?

13. Has habitat degradation or loss caused a reduction in fishery productivity in the Bay?

14. Have environmental and habitat changes in the Bay affected the distribution and reproductive success of higher-trophic-level consumers?

II. INTRODUCTION AND FRAMEWORK

A. Context

Since 1987, a series of changes in Florida Bay (Fig.1) have become evident to even the most casual observer. To date, these have included extensive losses of seagrass habitat, diminished water clarity, micro-algal blooms of increasing intensity and duration, and population reductions in economically significant species such as pink shrimp, sponges, lobster, and recreational gamefish. In response to heightened local concern, the representatives of a number of state and federal agencies began meeting in January 1993 as an informal Working Group for Florida Bay. In fact, however, not only Florida Bay but the entire South Florida ecosystem, a unique, interdependent landscape-seascape, may be threatened. With national attention to this crisis, the relevant federal agencies (see below) entered into an historic Agreement[1] to cooperate and work with the State of Florida "to address and solve the myriad issues involved in restoring and maintaining the unique world resources embodied in the South Florida ecosystem."

The Agreement established an interagency Task Force consisting of Departmental Assistant Secretaries (or their equivalents) from the Dept. of the Interior (DOI), the Dept. of Commerce (DOC), Dept. of the Army (Civil Works), Dept. of Justice, Dept. of Agriculture, and the Environmental Protection Agency. It is intended that, as soon as possible, the appropriate State of Florida (Department of Environmental Protection/DEP) and regional (South Florida Water Management District/SFWMD) agencies will be invited to become members of the Task Force and its subsidiary bodies. The Task Force has already established a South Florida Management and Coordination Working Group consisting of local administrators, which has in turn established, among other advisory subgroups, a Scientific Working Sub-Group to provide necessary technical advice. This last body began to meet in October 1993, and, at the request of the Army Corps, has provided the South Florida Management and Coordination Working Group (and Task Force) with a set of objectives and success criteria for the hydrological and ecological restoration of the South Florida Ecosystem. Objectives and criteria were separately provided for ten subregions, which were viewed not as a set of isolated geographic areas but rather as an integrated whole[2].

For each subregion (or combinations thereof), detailed science plan have been developed that will be integrated into a regional, ecosystem-based science program. The Agreement not only envisions such integration, but also explicitly sanctions line agency cooperation and facilitates mechanisms (e.g., interagency transfers of funds) needed to accomplish efficient integration.

The document to follow was developed at the request of the chairman of the South Florida Management and Coordination Working Group for Florida Bay, the Superintendent of Everglades Park. It represents the first interagency science plan for any South Florida subregion since the Agreement was executed.

The following plan focuses upon the research, monitoring, and modeling objectives that must be addressed in the restoration of Florida Bay. The substance of this plan is a synthesis of the following: a draft research program for Florida Bay developed by the National Park Service's South Florida Research Center (now the South Florida Natural Resources Center)[3]; a draft report from a NOAA workshop held to define Florida Bay research priorities[4]; and the internal draft research plans recently prepared by the South Florida Water Management District, the Florida Department of Environmental Protection, and the United States Geological Survey. The synthesis effort was preceded by a scientific review of Florida Bay problems conducted by a panel of nationally recognized scientists, as requested by Assistant Secretary Frampton (DOI)[5].

B. Management Responsibilities and Research Activities

Administratively, an interagency research plan for Florida Bay is essential because of the number of agencies that have jurisdiction in Florida Bay or in ecologically connected areas. The principal federal "research" agencies are in the DOI and the DOC. Approximately 85% of Florida Bay lies within the Everglades National Park, and the National Park Service (DOI) also manages the adjacent Dry Tortugas and Biscayne National Parks. Under the Organic Act of 1916, the NPS is responsible for both protecting and preserving these unique environments. For the past several decades, the ENP has both conducted its own research in Florida Bay and funded academic researchers. Moreover, the Fish and Wildlife Service (DOI) has twelve national wildlife refuges in the South Florida regional ecosystem as well as significant responsibility under the Endangered Species Act (ESA) for endangered terrestrial species utilizing the Bay and adjacent coastal wetlands.

The remainder of the Bay lies with the Florida Keys National Marine Sanctuary, which is managed by the National Oceanic and Atmospheric Administration (NOAA/DOC) under the National Marine Sanctuaries Act. Sanctuary managers now have an explicit mandate to look upstream outside its boundaries, if necessary, to protect the FKNMS's unique coral habitats. In 1990, Congress directed EPA and the State of Florida, in conjunction with NOAA, to develop a comprehensive water-quality protection program for the Sanctuary.

The Bay is a critical nursery habitat for recreationally and commercially fished species and is the habitat of protected marine mammals and a number of threatened and endangered marine species. The National Marine Fisheries Service (NMFS/NOAA/DOC) is responsible for research on and conservation of living marine resources and their habitats under the Magnuson Fishery Conservation and Management Act of 1976, for marine mammals under the Marine Mammal Protection Act, and for endangered marine species under the Endangered Species Act. Moreover, under the Fish and Wildlife Coordination Act, NMFS is charged with representing the interests of living marine resources in government decisions regarding land and resource management or development. NOAA/NMFS has been conducting research in the Bay since the early 1980's.

The USGS, which has no management responsibilities for Florida Bay, maintains long-term ground-water and surface-water monitoring programs in South Florida that are expanding this year through the USGS's National Water Quality Assessment (NAWQA) Program. This monitoring provides baseline data on water flow into the coastal areas. Coastal processes including erosion, deposition, and sediment transport and certain associated pollutants are evaluated by the Marine and Coastal Program of the USGS.

The principal state management agency is the Florida DEP. The state manages fisheries within its territorial waters and since 1983 has been conducting research aimed at assessing the pre-fishery recruitment of resource species which utilize estuarine and near-coastal areas. The Florida Marine Research Institute (DEP) has recently implemented a substantial monitoring program in Florida Bay and has proposed that it be significantly expanded in the next legislative session.

Last, and perhaps most critically, neither the National Park Service (DOI), NOAA (DOC), nor DEP controls the fresh water delivered to Everglades National Park and in turn to the Bay. Water delivery is regulated by the South Florida Water Management District (SFWMD) in conjunction with the Army Corps of Engineers (DOD). The SFWMD conducts its own research in the Bay and sponsors academic research through the ENP.

No one agency has sufficient management control, scientific expertise, and financial resources to independently solve the problems of Florida Bay. As concluded by Boesch *et al.*, "surely, the problems of Florida Bay are so severe and the difficulties in understanding them so challenging that Interior, NOAA, EPA, the Corps, Florida DEP, the South Florida Water Management District and Florida universities can find a way to make complementary contributions and encourage synergy in the scientific enterprise."[5] It is our hope that this plan is a major step in that direction.

C. Management Framework for Florida Bay Research

1. Interagency Florida Bay Program Management

To assure that the broad range of scientific activities planned for Florida Bay are integrated, an interagency Program Management Committee (PMC) will be established consisting of representatives from each federal agency, the Florida DEP, and the SFWMD. Each participating agency will be responsible for drafting its own detailed Florida Bay Implementation Plan. The primary role of the interagency PMC will be to review each of these implementation plans as they are completed to assure that they are consistent with this Interagency Florida Bay Science Plan. The PMC also will attempt to take advantage of the particular scientific and institutional strengths of the participating agencies. Thus the PMC will assure that each of the critical science priorities defined by the cooperating agencies is addressed by the agency or agencies best suited to do so. The science priorities will be based on research needs, which will form the basis for the scientific requirements of restoration and support any restoration plan developed by responsible agencies.

The NPS, through Everglades National Park, accepts responsibility for leading deliberations on Florida Bay restoration planning, for setting scientific priorities, and for coordinating the science programs conducted in Florida Bay. The Park's responsibility includes convening management groups and regularly communicating relevant information to agencies and institutions. The Park will use its permitting process to track the initiation of new projects and to track the reporting of results from these projects as required by the permits.

Given differences in practice and institutional experience, implementation plans may differ markedly-- e.g., some agencies award contracts, whereas others issue grants; some use panel review, and others use mail review; some conduct their own research, others primarily fund academic scientists, and still others rely upon formal government-academic cooperative units. This plan endorses no particular approach. However, the overall program must be as integrated as possible so that each implementation plan is complementary. <u>Explicit cross-references and discussions of implementation plans developed by the various participant agencies will, therefore, be required in all agency implementation plans.</u> A second important role of the PMC will be to provide additional discussion about and review of decisions made within individual research agencies. It is assumed that PMC agency representatives will communicate recommendations made at PMC meetings to their administrative superiors. It is further assumed that, if recommended by the PMC, administrators authorized to develop Florida Bay science plans and programs for their agencies will modify current plans and introduce new elements into future plans.

Experience in multi-institutional interdisciplinary scientific programs shows that improving communication between the principal investigators is instrumental to the program's success. This is even more critical when the scientists work for different agencies and those agencies have different funding mechanisms. <u>All agency implementation plans will at least have to provide for their scientists' participation in annual meetings of principal investigators. Funding for requisite electronic interconnection, InterNet, and/or OMNET is also highly desirable.</u> All agency implementation plans should also provide for their scientists' participation in annual agency (or multi-agency) program reviews.

<u>Agencies will be expected to specifically address data management in their implementation plans.</u> Too often this is added as an afterthought, but given the multi-institutional, interdisciplinary nature of the science proposed herein, efficient integration of all the information generated is critical to the program's success. The data policy for the overall federal interagency program should be consistent with that already agreed upon for the interagency U.S. Global Change Research Program.[6] In brief, this requires early and continuing commitment to maintaining and distributing data, full and open sharing of data, archiving of data, assuring data accessibility, limiting periods of exclusive principal investigator access to an as-needed basis only, and using nationally and internationally approved standards wherever appropriate. Individual implementation plans should include a data management function and centralized databases that can be readily linked to and integrated with those implemented by other agencies.

To assure scientific quality, an interagency Technical Advisory Group (TAG) consisting of scientists representing a broad range of disciplines will be appointed to advise the PMC on the complex technical issues certain to arise in setting research priorities and planning programs. Membership will consist predominantly of principal investigators funded by the different agencies but will not be restricted to that group. Members could be added to the TAG as needed to address particular short-term needs and the TAG could also establish semi-permanent subgroups to address recurrent issues such as interdisciplinary modeling, reviewing proposals for new work and evaluating scientific priorities.

2. Florida Bay Scientific Review Panel

An interdisciplinary panel of nationally recognized scientists will be invited to become members of an interagency Florida Bay Scientific Review Panel. Its role will be to provide periodic, broad, technical review of agency plans, PMC recommendations, and research results. The group will be asked to attend annual agency (or interagency) program reviews and to provide written comments and specific suggestions as to how programs can be improved. The panel will assist the agencies in setting science priorities for the Bay. Membership would be for at least four years and terms would be staggered. Membership continuity is essential to assure institutional memory--i.e., to ascertain whether programs have been responsive to the panel's review and what suggestions have proven helpful. Members of the panel will have to forego subsequent research as investigators funded under the interagency Florida Bay Science Plan.

3. General Policy Oversight

Assuming that state and regional agencies are officially incorporated into the South Florida Task Force, and the South Florida Management and Coordination Working Group, policy oversight will be provided by the Task Force through the Working Group. The Task Force has been specifically charged with coordinating the development of consistent policies, strategies, and plans and with monitoring all restoration-related research programs and activities to assure that they further the overall objective of ecosystem restoration. The Task Force was also established to facilitate the implementation of projects and programs included in the overall interagency coordinated plan for the restoration of the South Florida ecosystem.

4. The Role of the Florida Bay Working Group

As mentioned above, this document is intended to provide guidance and facilitate integration of the research to be conducted by the agencies represented in the Florida Bay Working Group and their cooperators. The PMC will communicate with the Florida Bay Working Group by reporting at Working Group meetings on the progress being made in science program implementation. The Working Group, in turn, can provide the PMC essential feedback from its primary constituents: restoration managers, environmental and economic interest groups, and the general public.

III. GENERAL BACKGROUND

Florida Bay is a triangularly shaped body of water about 2200 km^2 in area. Over 80% of the Bay lies within Everglades National Park. The Bay is bounded by the Florida mainland on the north, U. S. Highway 1 on the northeast, the Florida Keys on the southeast, and the Intracoastal Waterway between Long Key and East Cape Sable. The region west of the Park's western boundary across to the Middle Keys is also commonly considered to be part of Florida Bay. The Bay is shallow, often hypersaline and until recently, was characterized by clear waters and lush seagrass meadows covering a mosaic of shallow-water banks and relatively deeper water basins or "lakes." Deep-water channels (1 to 5 m deep) connect neighboring basins. Hardbottom habitats in southwestern Florida Bay support sponge and hard and soft coral communities. Florida Bay is known as the principal inshore nursery for the offshore Tortugas pink shrimp, Penaeus duorarum, fishery and for providing critical habitat for juvenile spiny lobster, Panulirus argus, and stone crab, Menippe mercenaria. The Bay is the site of an extensive sport fishery and supports populations of the American crocodile, bald eagle, osprey, numerous wading bird species, the bottlenosed porpoise, manatee, several species of sea turtle, and other noteworthy species. Over 200 small islands or "keys" occur in the Bay, all of which are rimmed with mangroves. Most islands have interior, irregularly flooded "flats" with calcareous blue-green algal mats that serve as foraging and resting sites for migratory birds.

Florida Bay exchanges waters with the Straits of Florida through numerous channels between islands and with the Gulf through tidal flux and long-shore currents. In addition, some seepage must occur through the porous Key Largo Limestone. Surface fresh water flows into Florida Bay mainly from Taylor Slough and numerous small streams to the east. Groundwater seepage from the peninsula is believed to be a major but poorly quantified freshwater input. Large flows of fresh water from the Shark River Slough reach Florida Bay only after mixing with Gulf of Mexico water and flowing eastward around Cape Sable. For most of the western half of the Bay, currents are presumed to move in a southerly direction, although few direct measurements support this pattern. Currents on the Bay side of the Upper and Middle Keys presumably flow to the southwest, resulting in a net flow from the Bay toward the Atlantic side through the channels between the Keys. Thus, constriction of the channels between the Keys could reduce net flow of water through the Bay.

The complex bottom topography of the Bay divides it into various subenvironments that have different physical and chemical conditions. The uppermost part of the Bay consists of a number of semi-enclosed sounds that are partly isolated from one another. Southwest of Blackwater and Little Blackwater sounds (northeastern Florida Bay proper), the mud shoals and islands become less numerous, and the area is shallow. Toward the Gulf of Mexico on the mainland side, mud banks increase in width and depth. On the Keys side (toward the Atlantic), the mud banks are narrower and encircle deep, hardbottom "lake" areas.

Northeastern Florida Bay is strongly influenced by seasonal freshwater runoff. Salinities range widely, from brackish to salinities greater than seawater. The interior of Florida Bay is characterized by extremely restricted circulation and widely fluctuating salinities and temperatures; evaporation exceeds freshwater inflow and direct rainfall. Flushing is slow except for occasional wind-driven transport across shallow boundary sills. In contrast, along the western margin of the Bay, temperatures are relatively moderate and salinities fluctuate near oceanic levels.

The rainy season, May through October, coincides with a seasonal rise in sea level. As the sea level falls (about 15 cm), water of lower salinity reaches well out into the Bay. In addition to this seasonal salinity variation, drought/flood cycles also affect annual salinity ranges. The effects of such cycles can be pronounced. For example, August salinities in northeastern Florida Bay may range from 15 ppt to 50 ppt in successive years, depending on rainfall/runoff conditions. Salinities approaching 70 ppt are reported to have occurred in the central Bay during the droughts of the early 1950s when freshwater supply to the northern Bay was reduced to meet agricultural and municipal requirements.

The Bay is underlain by a floor of extremely flat and permeable Pleistocene limestone that was formed between 125,000 and 145,000 years ago during the last interglacial. This floor gently slopes to the southwest, so that during the last glacial melting, the Bay was flooded from southwest to northeast as sea level approached its present position. During the past 4500 years, peat and carbonate mud have accumulated to form a series of Holocene intertidal mud banks and mangrove islands that now dissect the Bay into shallow basins locally termed "lakes." The present configuration of mud banks is the result of complex deposition and erosion processes that form coastal levees, ponds, storm ridges, migrating islands, and mud banks at various locations throughout the Bay. These sediments are formed from organisms living in the Bay at rates that have easily kept up with sea-level rise during the past few thousand years. Rapid sedimentation may be further restricting the Bay; however, large volumes of sediment are also exported from the Bay, and it is unclear if sedimentation is keeping up with the relatively rapid sea-level rise that has occurred during the last century.

Over the past decade, a number of biological, chemical, and physical changes in Florida Bay have been observed by scientists, tourists, and fisherman who frequent the Bay. Seagrasses in western Florida Bay, principally turtlegrass (Thalassia testudinum) have been dying since the summer of 1987 and continue to as of March 1994. Mass mortality of this magnitude has not been observed previously in Florida Bay nor has it been reported in the scientific literature on tropical seagrasses. Initially, three causes of seagrass die-off were proposed.[5] First, the synergistic effects of several long- and short-term factors appear to have caused a production/respiration imbalance. Second, the observed contagious distribution of die-off patches and the rapidity of the die-off process suggest that a pathogen was the proximate cause of seagrass die-off. Third, eutrophication was considered a possible cause of die-off, although evidence of eutrophication was observed prior to seagrass die-off in Florida Bay.

Several adverse trends have accompanied the die-off, most notably declining water quality as algal blooms have increased in intensity and duration. Declines in the pink shrimp and sport fisheries and the die-back of sponges threatening the lobster fishery have also coincided with seagrass die-off in the Bay.

Conditions that have been present in the Bay since 1988 appear to be associated with, and may result in some way from, seagrass die-off. For example, Florida Bay has had plankton blooms since the seagrass die-off in 1987, but not before. The blooms have reoccurred each year and have become steadily bigger and more persistent as the seagrass die-off has spread to relatively higher-energy areas of the Bay such as Sandy Key Basin. The exposed sediments are resuspended daily by the tides and frequently by winds, increasing turbidity and probably releasing nutrients into the water column.

The most compelling hypothesis for the cause of seagrass die-off involves long- and short-term processes, both involving alteration of freshwater supply to the Bay. Over the long-term period of a half century or more, the diversion of fresh water by upland water management has contributed to increasingly marine-like conditions in Florida Bay. Knowledge of the comparative biology of the seagrasses suggests that this trend has favored the dominance and growth of turtlegrass over other species.

Over the past three decades. Florida Bay has experienced fewer hurricanes compared to the long-term record in South Florida, and water management has diverted peak storm flows that otherwise would have reached Florida Bay. Both trends have had the effect of reducing disturbance of the Bay benthos and sediments. The absence of these high-volume inflows has led to stabilization and deepening of bottom sediments and heavy accumulation of seagrass detritus.

On the time scale of several years, high salinities and elevated water temperatures have been measured in Florida Bay at levels that are understood to cause physiological stress in seagrasses. Both stresses may have contributed to seagrass die-off. In addition, since August 1992, Florida Bay has experienced Hurricane Andrew, the "storm of the century" (in March 1993), and the wettest January (1993) on record. Each of these events, as well as the severe 1989 freeze, may have contributed to the present status of Florida Bay.

IV. ORGANIZING STRATEGY

A. Restoration Perspective

The management objective for Florida Bay is to restore it to a naturally functioning ecosystem. The restoration process and the degree to which management can effect change define, in large part, the focus and priorities of the scientific activities supporting Florida Bay restoration.

Restoration as a goal assumes, *a priori*, that the Bay has been impacted by man. The current perception of Florida Bay is that the Bay is a system in decline. Seagrass die-off, persistent plankton blooms, extensive turbidity, and declining commercial and recreational fisheries are thought to be the consequence of accelerating human population growth, land use changes, the expansion of agriculture, and the development of increasingly invasive and environmentally destructive water-management practices in the headwaters of Florida Bay. Although it is probable that the Bay is, and has been, strongly impacted by man's activities in

South Florida, cause-and-effect relationships have not been rigorously determined. Long-term natural changes have not been clearly separated from those that result from human intervention. Various hypotheses have been put forth to explain current problems in the Bay. These are not mutually exclusive. However, limitations of the means available to direct change in Florida Bay strongly argue for a research program that emphasizes hypotheses linked to manipulation of the quality, quantity, timing and distribution of freshwater inflow to the Bay.

Defining a realistic restoration endpoint is an important step. To what condition, to what status, do we seek to return the Bay? In one sense, restoration implies that the natural ecological condition for the Bay is known or can be known. Since 1988, Florida Bay has definitely differed from the clear-water, turtlegrass-dominated system well documented to be characteristic of the Bay over recent decades. But a reliable historical picture of what Florida Bay was like in its natural, unregulated condition is unavailable. The era of water management began more than 100 years ago, when few scientific data were collected. A major challenge, therefore, is to determine to what extent any reconstruction of Florida Bay to conditions that existed prior to human intervention constitutes an achievable restoration target. The present and future regional environment of which Florida Bay is a part may further constrain an historically-based definition of successful restoration.

Management options and capabilities with regard to restoration are regional in context, and the principal available options relate to the controlling of physical or chemical factors (e.g., manipulation of water deliveries, improved agricultural practices, nutrient removal). In contrast, the success of restoration will be measured in biological terms. For example, the Bay functions as a nursery ground for pink shrimp, as critical habitat for numerous endangered species and as the foundation of the recreational fishing industry throughout South Florida, including the Keys. These and other ecological functions must serve as criteria for evaluating the success of Florida Bay restoration. Thus, interdisciplinary research must link physical and chemical factors to biological processes.

Implicit in the restoration goal is the intention to modify or eliminate anthropogenic processes harmful to the Bay and thus regain the natural ecosystem. Absent from this goal is any intent to modify the Bay's natural function to enhance the prospects of a single species or to maximize economic return. This perspective has guided us in developing the scientific goals and objectives described below.

B. Scientific Goals and Objectives

The science program needed to accomplish successful restoration must be long term and goal oriented and be committed to the integration of emerging results into the management decision-making process. The research program, discussed in detail below, addresses several broadly complementary research objectives. It will provide the basic understanding of the Florida Bay ecosystem so that appropriate plans for restoration can be determined. Specific objectives include the following:

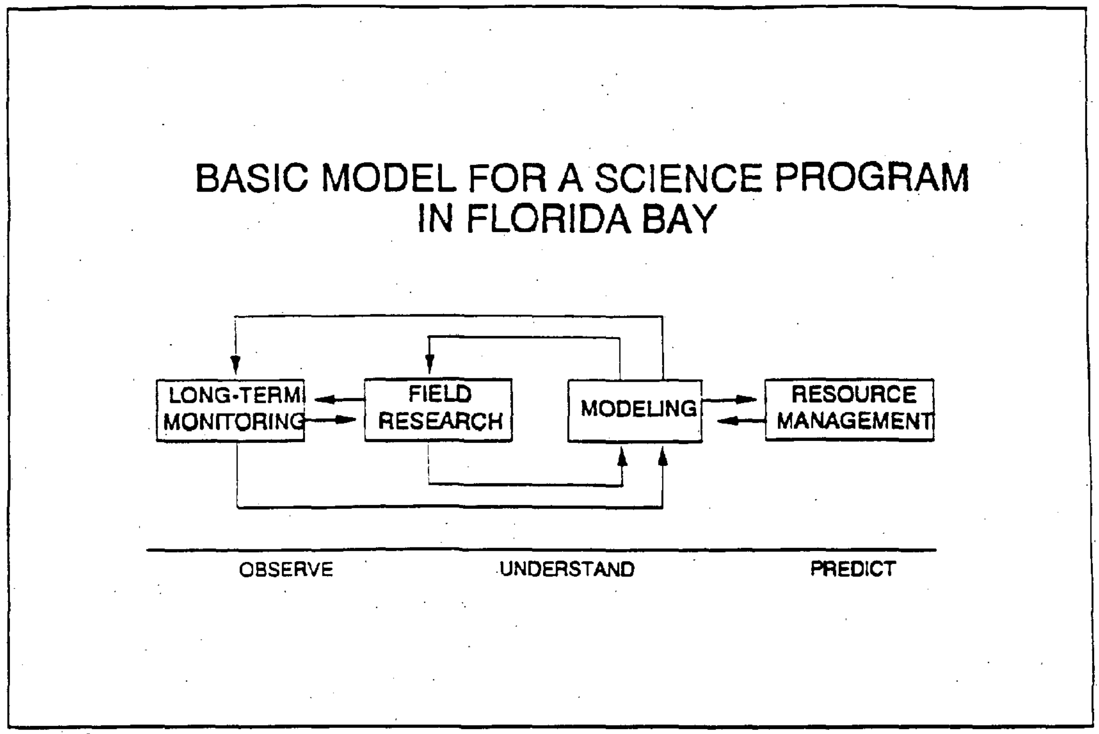

Figure 2

1) Developing an understanding of the condition of Florida Bay prior to man's significantly altering it. This information will help provide an "idealized" target for restoring Florida Bay. Although full restoration may prove impossible, an historical understanding provides a perspective on the extent and effectiveness of management restoration actions.

2) Separating anthropogenically induced changes in Florida Bay from natural system variation. Both natural disturbances (e.g., hurricanes, freezes) and long-term climate processes (drought cycle, sea-level rise) have strongly influenced the structure and function of the Bay. These same processes may mask or exacerbate the effects of anthropogenic forces on the Bay. Therefore, it is essential to understand anthropogenic effects within the context of natural system function and variation.

3) Developing a basic understanding of the ecology of Florida Bay by evaluating alternative hypotheses.

4) Developing the capability to predict the response to perturbation of a subset of species or ecological processes that collectively may be considered indicators of key processes or functions of Florida Bay. Restoration of Florida Bay will require choosing among alternative management actions based on ecosystem responses. Relating the responses of these indicators to potential management alternatives is one way in which an ecological understanding of the Bay becomes a key ingredient in the decision-making processes of agency managers.

C. Research Approach

If a science program is truly to support restoration efforts in Florida Bay, monitoring, research, and modeling elements must be tightly linked, as illustrated in Figure 2. By monitoring, we can track critical ecosystem parameters and support long-term research and modeling efforts by providing baseline data and the means to calibrate and validate models. Further, after management decisions have been made, monitoring data will be used to evaluate the effectiveness of these decisions. Through research, we will develop an understanding of the physical and biological processes regulating Bay ecosystem status by establishing statistical associations, defining and testing conceptual and research models, evaluating cause-and-effect relationships through experimentation, and synthesizing available information. Computer simulations that synthesize our best understanding of the Bay's ecology will be developed to a stage that allows for predictions of system responses to change, hindcasting of historical conditions, and selection of management alternatives. Regular feedback between program elements is needed to yield increasingly reliable computer simulations of the Florida Bay ecosystem for use by management.

D. Linking Research and Resource Management

Modeling is central to the process of linking research findings with resource management decisions that will implement restoration actions. Hydrology models and biological models will be used to develop and select appropriate management alternatives for restoring the Bay. The feasibility of a modeling approach already has been demonstrated. For example, the hydrology of Taylor Slough, at the headwaters of Florida Bay, has been modeled. These models are being used to predict the hydrologic effects of structural or water-delivery modifications of the existing canal system or to predict water conditions in the absence of canals. Biological models should be further developed so that they can predict the response of "representative" species to hydrologic conditions established by water-management alternatives. The current Army Corps of Engineers General Reevaluation Report and Environmental Impact Statement for Canal 111 (C-111 GRR) is one element in a process whereby preferred structural and operational water-management alternatives would be selected and implemented. Analyses of hydrologic and biological monitoring data would allow researchers to evaluate the system's actual response to the resultant hydrologic conditions and would provide the basis for evaluating alternatives and refining models.

Conceptually, this process is iterative. However, the relatively high level of natural variation in the Florida Bay ecosystem; the expected relatively slow response of the flora and fauna of the Bay to changed hydrologic conditions; and the time required to plan, fund, and construct canal structures for water deliveries, argue that restoration of Florida Bay will be a long-term process and that the first iteration must achieve significant restoration benefits. The system's inherent complexity also supports the emphasis in this strategy placed on predictive modeling as the best tactic for testing and evaluating alternatives.

V. MAJOR RESEARCH TOPIC AREAS

Management decisions on restoration must be based on scientific understanding of the Bay, of the changes the Bay has undergone, and of the various natural and anthropogenic processes determining the Bay's present and future status. The following four comprehensive topics describe the major gaps in our present understanding of the Florida Bay ecosystem, our continuing data needs, and the necessity of improving our predictive capacity. Carrying out these specified tasks will provide answers to the questions that need to be answered if restoration is to proceed on a scientifically sound basis. In order to focus in this document on programmatic needs rather than on technical procedures, no attempt was made to provide technical references. Rather, the reader is directed toward the following compilations for further information: the special issue of the Bulletin of Marine Sciences[7] published in 1989, the SWIM Plan for the Everglades[8], and the bibliography of the Science Sub-group report to the Federal Restoration Working Group[9].

A. Water Budgets, Circulation Dynamics, and Salinity

Three interrelated aspects of Florida Bay water budgets and circulation dynamics are considered here, particularly as they relate to salinity patterns and trends in the sub-environments of the Bay. Quantitative knowledge of the mass balance and circulation dynamics of Bay waters is essential to understand the causes of observed biological and chemical patterns within the Bay and their relation to processes outside the Bay.

1. What has been the relationship of surface water and groundwater flows through the Everglades to the salinity of Florida Bay? How has this relationship changed in the past, and how is it expected to change with future management plans?

Under present conditions, the natural flows of fresh water into Florida Bay are much reduced. The Natural System Model indicates that for the 1965-1989 period, as the system is currently managed, less than one half of the "natural" surface-water flow through Taylor Slough was discharged into Florida Bay (32,500 ac-ft/yr versus 82,000 ac-ft/yr). The flow of Shark River also seems to have been significantly reduced from "natural" conditions, although flows during 1991 and 1992 were nearly three times the annual average for the 1980s. How changes in freshwater delivery through the Shark River Slough (whose flow is an order of magnitude greater in volume than the natural flow through Taylor Slough) have affected Florida Bay is not well known.

Salinity records, anecdotal evidence, and predictive models linking groundwater levels in northern Taylor Slough to salinity in Little Madeira and Joe bays provide evidence that salinities in northeastern Florida Bay have increased as a result of reductions in freshwater inflow. Salinities have been elevated since at least the mid-1950s and on occasion have been markedly hypersaline (to 70 ppt). The relationship between salinity levels in the open central Bay and reductions in freshwater discharge is unclear. Discontinuous salinity measurements made in the more open central and western Florida Bay from 1955 through 1990 show no obvious changes in salinity, although hypersaline conditions have characterized the northcentral and northwestern Bay at least since the mid-1950s. The historical record, however, indicates that large increases in freshwater inflow during extended periods of heavy rainfall (e.g., during 1983) can eliminate hypersaline conditions in the eastern and central Bay, whereas hypersaline conditions developed during dry years, even before most of the flow through Taylor Slough was diverted down the C-111 canal.

Key Research Needs

The goal of the physical oceanographic research and modeling effort will be to collect data and to develop models sufficient to predict, both for the Bay as a whole and for its major subbasins, the influence of varying freshwater inflow and precipitation on circulation dynamics and salinity patterns.

Specific Tasks

i. Determine the rates and effects on water quality of freshwater flows through the Taylor Slough rivers and channels, canals and adjacent panhandle area into Florida Bay. The spatial and temporal variation across this transition zone must be quantified for a range of wet and dry hydrologic regimes. A sampling system is needed so that episodic events and low flow conditions are accurately characterized. Salinity/runoff relationships must be developed so that effects on inflow rates of differing water-delivery policies can be quantitatively predicted.

ii. Quantify the importance of groundwater as part of freshwater input and as a factor influencing water quality in Florida Bay. Groundwater contributions to Florida Bay are one of the most poorly known components of the water budget. Because of the difficulty of measuring it, groundwater is often estimated fromhydrolo gic models. Some field measurements are essential to calibrate and verify models. Estimates of flows through he Buttonwood Ridge and other components of the mangrove fringe and associated boundary areas in the southernmost mainland are particularly critical.

iii. Determine the linkage between Shark River Slough discharges and Florida Bay. Temperature, salinity, and current measurements in the tributaries of the Slough and perhaps tracer studies of nearshore currents between the main Shark River estuaries, Cape Sable, Sandy Key Basin, and the Flamingo area are needed to permit quantification of the net flux of water and salinity into the Florida Bay. Data are needed over several annual hydrologic cycles in order to understand seasonal and interannual effects.

iv. Determine the spatial pattern of salinity in Florida Bay and its relationship to freshwater inflow and climatic variation. Consideration should be given to supplementing the existing salinity-sensor network with automated salinity sensors and/or augmenting these measurements with micro-radiometry-based remote sensing of surface salinity when operational systems become available. Efforts should also be made to determine historical salinity patterns in Florida Bay.

v. Determine evaporation rates from the Bay and the canals and characterize their temporal and spatial variations.

vi. Improve monitoring of rainfall. The precision of traditional rain gauges is poor, but their performance could be improved by judicious use of radar- and acoustic-based measurement methods.

vii. Develop a circulation dynamics model for Florida Bay. The model should incorporate existing model structures from other water bodies as much as possible and be capable of simulating circulation and transport across the Bay as a whole, both within the major sub-environments and within local basins. Development of the model should proceed cooperatively with ecological modeling efforts so that model structure and outputs are accessible for addressing questions on the movement, recruitment, and distribution of marine organisms and on the transport, accumulation, and cycling of nutrients and contaminants. Adequate answers to these questions may eventually require a three-dimensional model, but until that is demonstrated, a two-dimensional model will suffice.

viii. Integrate circulation models of Florida Bay with larger-scale physical oceanographic, hydrological, and meteorological models that provide the Bay model with its boundary conditions and forcing functions. Erosion and sea level rise are two important continuing processes that must be explicitly tested in a complete model. A mesoscale meteorological model that could improve prediction of precipitation intensity and distribution would be invaluable to both circulation and hydrological modeling.

2. What is the effect of the relative lack of storms over the past three decades on the buildup of sediments, nutrients, and organic material in the Bay?

Hurricanes are believed to resuspend and transport sediments and organic detritus out of bays. Few, if any, hurricanes have significantly affected Florida Bay since 1965. In the absence of these erosional events, production of sediments and their trapping by seagrasses and mangroves could reduce water circulation, thereby affecting salinity distribution, water temperature, nutrient supply, habitat, and movement of marine organisms.

Quantitative evidence on the effects of storms is lacking, but qualitative observations suggest that the reduced occurrence of major storms has resulted in significant accumulation of calcareous muds and entrained nutrients.

Key Research Needs

Because Florida Bay is a shallow-water system, sediment dynamics are particularly important. Much of the primary production in the Bay is benthic, and resuspended sediments can markedly reduce photosynthetic potential. The fine-grained, shallow sediments are susceptible to physical and chemical alteration by the forces of weather and biological and human activity. Despite the importance of sediments, however, information on their dynamics, composition, and spatial patterning is insufficient for reaching a quantitative understanding of their role in the changing conditions of Florida Bay.

Specific Tasks

i. The bottom topography of the Bay has not been systematically examined in three decades. Plotting the bottom contours on a grid fine enough to delineate the basins and their interconnections is essential both to document changes in water depth and to supply information for circulation modeling. Whether this can be done by compiling existing data or whether extensive new measurements are required cannot be determined in advance. The answer may depend on the degree of sensitivity of various models to water depth. The scale of the bathymetry data should be appropriate to circulation modeling requirements.

ii. Determine the main components of the sediment budget for Florida Bay, including exchanges with connected waterbodies, inputs from the mainland, and accumulation within selected subbasins.

iii. Determine the physical and chemical composition of the sediments, the pattern of composition throughout the Bay, and the variability in composition over hydrologic cycles and in relation to storm events.

iv. Determine the historical pattern of sediment accumulation and composition. Bay sediments should be cored following standard procedures. Cores should be subjected to radioisotope dating, stable isotopic analysis, and any other physical or chemical analyses deemed to be helpful in reconstructing historical Bay conditions.

3. What have been the effects in Florida Bay of increased residence time of water caused by restricted water flow through channels between the Keys, shoaling, and reduced freshwater inflows?

Little is known about the residence time of water within Florida Bay, although a decrease in the flushing rate could have widespread consequences to this ecosystem. As a result of land-filling along the Keys, an increase in residence time is likely to have occurred. Mudbank shoaling may also have further decreased flushing of isolated basins in the Bay. But the extent to which flushing may have been decreased by channel constriction or shoaling is unknown. Except for the regions of the northeastern Bay directly affected by the Taylor Slough discharge, reductions of freshwater flows may have had little impact on the flushing rate of the Bay. Salinity could have increased through more evaporative concentration of Bay water, especially because freshwater inputs have decreased. Greater stagnation could also increase temperature extremes, increase concentrations of plant nutrients, and disrupt recruitment of planktonic fish and invertebrate larvae.

If one assumes that flow through Taylor Slough has been reduced by 50,000 ac-ft/yr and that the average depth of the Bay is about 1 m, the total diverted flow during a full year would, on the average, be sufficient to replace only about 10% of the volume of the Bay. Tidal and wind-driven flows surely exchange far more of the Bay's volume, probably on the scale of days. Also, because the Bay is shallow and vertically well mixed, there should be no appreciable gravity flows of the type found in deeper, stratified estuaries by which the flushing effect of freshwater inputs is greatly magnified.

Specific Tasks

i. Determine the effect on circulation of shoaling caused by sediment accretion on the mudbanks. This could have a very great effect on the flushing rates for basins in the central and eastern Bay, but this effect has not been measured or estimated. A program of field-data collection in selected subbasins is needed. This program should quantify both incremental processes and mass movements that may accompany episodic climatic events. Since the data are valuable for circulation modeling, compatibility with models is important.

ii. Determine the relative importance of tides, winds, and altered freshwater inflows on flushing rates and exchanges with adjacent waterbodies. Data are needed on time scales of days, months, and years across a range of wet and dry cycles to adequately parameterize circulation models.

B. Water quality and nutrient cycling

1. What are the sources, quantities, and ecological effects of "external" nutrients introduced into Florida Bay?

The exchange of nutrients between Florida Bay and adjacent regions ("external" dynamics) and the cycling of nutrients within Florida Bay ("internal" dynamics) underpin the entire Bay's ecological structure and function, the occurrence of algal blooms, seagrass mass mortality, and the sustenance of critical species. We currently have little understanding of the rates of these processes or the mechanisms that control the rates. Furthermore, we have little understanding of how these dynamics have naturally varied in the past or how human activities have affected them.

Algal blooms in the Bay appear to be similar to blooms caused by anthropogenic nutrient loading, which has been observed in estuaries throughout the world. However, the sources of the nutrients that sustain Florida Bay's blooms are unknown. Although it is likely that the blooms are in part sustained by nutrients derived from decomposing seagrass detritus resulting from seagrass die-back events, the blooms may also depend upon the supply of external nutrients from agriculture, fertilizer mining, or sewage in the Keys. Changes in the input of nutrients to the Bay may also result indirectly from altered hydrology; changes in freshwater flow and salinity intrusion may have reduced the retention of nutrients within the Everglades and mangrove ecosystems. Finally, the Bay may appear eutrophic not because the total inflow of nutrients has increased, but because the residence time of source waters with high concentrations of nutrients has increased with diminished flushing rates (see above), or because internal sinks of nutrients have decreased.

Understanding the exchange of nutrients between Florida Bay and adjacent regions requires an integrated effort to 1) measure the flux of nutrients across the Bay's boundaries; 2) characterize the physical, chemical, and ecological mechanisms that regulate these fluxes; and 3) integrate this information into a regional landscape model of nutrient transport and transformation. The major boundaries that must be considered are between Florida Bay and the atmosphere, the northern coast, the Gulf of Mexico, and the Florida Keys. Thus, an effort to understand the nutrient dynamics of the Bay must be integrated with efforts to accurately describe surface and groundwater inflows from the Florida mainland, the exchange of Bay water with the Gulf of Mexico and through passes in the Florida Keys, and atmospheric deposition rates.

Key research needs

Atmospheric deposition of nutrients is known to be a significant nutrient source in many coastal ecosystems and may be particularly important in Florida Bay because the Bay appears to have been oligotrophic throughout much of its history and is surrounded by relatively low-nutrient wetlands and water bodies. A key research need is to determine deposition rates and atmospheric nutrient sources.

Specific Tasks

i. Measure the deposition of wet and dry nutrients into the Bay.

ii. If these inputs are important, relative to other inputs, determine the sources of these nutrients and estimate their historical variability.

Additional research is needed to determine the exchanges of nutrients between the Bay and the Gulf of Mexico and the degree to which these exchanges have been altered by human activity. The Gulf of Mexico may be an important nutrient source for the Bay for several reasons. First, there appears to be a net advection of water from the Gulf into the northwestern Bay. Second, the Gulf ecosystem, like most marine ecosystems, is probably N limited, and thus has a small "excess" of P, relative to N. Third, the Florida fertilizer industry may enrich Gulf waters. Fourth, organic P flows into the Gulf from the western Everglades and the dense mangroves along the southwest Florida coast. Although this water has a high N:P ratio, the absolute quantity of organic P delivered to the Bay may nevertheless be significant. This N source may, furthermore, stimulate algal blooms and benthic macrophytes west of the Bay, where N limitation may be more prevalent than in the Bay.

Specific Tasks

i. Continue and extend water-quality monitoring in the western Bay and southwestern Florida coastal waters on both a regular schedule and on an event basis, so that exchanges during storm events can be determined.

ii. Monitor the distribution, transport, and nutrient demands of algae along the western Bay boundary.

iii. If budgets suggest that Gulf waters are an important nutrient source, investigate the import and export of nutrients through mangrove ecosystems in representative sectors of the southwest Florida coast and estimate their historical variability (see mangrove subsection below).

Determining the exchange of nutrients between the northern Bay and the South Florida wetlands and the degree to which these exchanges have been altered by human activity is also needed. No measurements have been made of the flux of organic or inorganic nutrients across the salinity transition zone of the coastline. The rapid appearance and disappearance of dense macroalgal clumps in streams that feed into the northeastern Bay suggest that the export of nutrients from this zone may at least be locally important. The N:P ratio of this source is probably high, and the mechanisms altering this ratio have not been studied in the transition zone.

Specific Tasks

i. Estimate nutrient flux by measuring surface and groundwater flows into the Bay and their nutrient concentrations across the entire northern coast.

ii. Continue water-quality monitoring in the northern Bay.

Another key to understanding the inflow of nutrients to the Bay from both the southwest and south Florida coasts is understanding the ecology and biogeochemistry of mangrove ecosystems. Along with the Everglades marshes, mangroves are a biological filter through which much of the freshwater inflow passes before reaching the Bay. Despite low P inputs from the Everglades to the mangrove forests, the mangrove forests are highly productive, and their standing stock and litter represent a potential nutrient source. A large export of nutrients from these systems either on a regular (e.g., seasonal) or episodic basis (e.g., freezes and hurricanes) is possible. Furthermore, the extent to which the retention or release of nutrients by coastal wetlands and mangroves has changed in response to human activities and climate change (e.g., increased intrusion of seawater resulting from sea-level rise and freshwater diversion) is unknown.

Specific Tasks

i. Measure water flow and the import and export of dissolved and particulate nutrients at selected sites, especially after episodic disturbances.

ii. Investigate the sources of nutrients for mangrove trees (marine, inland, sediments).

iii. Investigate the effects of altered salinity regimes upon nutrient dynamics within mangrove and marsh systems, including effects on decomposition, mobilization from, and immobilization in sediments.

iv. Assess recent changes in the distribution and biomass of mangroves along South Florida coasts (see section C below).

v. From Bay sediment cores, assess changes in the historical accumulation of organic matter derived from mangroves and other terrestrial sources.

Research is needed to determine nutrient fluxes through passes in the Keys and the input of nutrients to the Bay from sewage in the Keys. Sewage effluent from the Keys is known to have caused localized eutrophication. The regional importance of this nutrient source is not known. This may be of more direct significance to the Florida Keys National Marine Sanctuary. Researchers sponsored by the Sanctuary should be directed to undertake the following in collaboration with the Florida Bay program.

Specific Tasks

i. Monitor the flow of water and organic and inorganic nutrients through the Keys' passes.

ii. Estimate the input of anthropogenic nutrients from the Keys.

2. What are the rates of nutrient exchange between the sediment and water column within Florida Bay, and what controls the magnitude and direction of these fluxes?

Because of Florida Bay's shallow depth and the carbonate composition of its sediments, the internal dynamics of nutrients within the Bay are regulated by sedimentary processes. Given the Bay's shallow depth and historical clarity, seagrass primary production has been considered the basis of overall Bay productivity. However, the shallow depth of the Bay also results in high resuspension rates for unconsolidated sediments (see section C). Suspended sediments not only decrease light penetration through the water, but also scavenge particle-reactive solutes such as inorganic phosphates from the water. The carbonate composition of these sedimentary particles is important because the particles have the potential to bind inorganic P under both oxic and anoxic conditions. Thus, apparent P limitation in the Bay may be due not to biological utilization but to loss to the sediments. We need to know if mechanisms exist whereby this P can be released.

One such mechanism may involve the normal physiological activities in the seagrass rhizosphere. It is possible that seagrasses exude organic acids or sustain a microbial consortium that mobilizes phosphorous. Thalassia may be particularly important in this regard because this species has a deep and extensive root system. It has thrived in recent decades in waters with salinities that were higher than those found before the water diversion from the Everglades (see above); as a result P mobilization from the sediment may have also been accelerated.

Other mechanisms that may alter the extent to which P is bound to or released from carbonate particles may involve the surface chemistry of carbonate particles, in particular their organic coatings. Seagrass and mangrove die-offs and wetland perturbation may have altered organic inputs into the Bay. Salinity itself may play a direct role because ionic strength is an important variable affecting surface reactions.

Key Research Needs

Key research needs include estimating rates of benthic nutrient fluxes at various sites in order to accurately estimate flux for the Bay as a whole, assessing the importance of different mechanisms upon the mobility of nutrients bound in sediments, and assessing how the internal nutrient cycles of Florida Bay may have changed during past decades and centuries.

Specific Tasks

i. Measure net fluxes in benthic chambers and from sediment cores.

ii. Measure rates of detrital decomposition in healthy and declining seagrass stands.

iii. Investigate the processes by which seagrasses, particularly Thalassia, assimilate nutrients from sediments and assess the effect of environmental (e.g., light, temperature, and salinity) conditions upon observed rates.

iv. Investigate the chemical and microbial processes that mobilize or immobilize nutrients in the sediments.

v. Develop a model of the benthic subsystem that includes seagrass populations and all the nutrient pools and pathways potentially significant to the overall nutrient cycle.

vi. Determine the contribution of nutrients from tidal pumping nutrient-rich subsurface water from the permeable limestone floor to the water column.

vii. Obtain and date sediment cores; estimate rates of sediment and nutrient accumulation and their temporal variation.

3. What are the rates of nutrient assimilation by phytoplankton in the Bay, and what limits the growth of the phytoplankton assemblage?

Pelagic primary production has increased in relative importance in much of the Bay. With continued seagrass die-off, sediment resuspension has increased, thus increasing light extinction by inorganic particles. The situation may be perpetuated by a feedback loop whereby dense microalgal blooms inhibit seagrass recovery by absorbing light and thereby increase sediment resuspension, furthering their own competitive advantage. Pelagic dynamics that have been heretofore ignored now need to be studied.

Key Research Needs

Key research needs include developing basic information on the phytoplankton ecology of the Bay and assessing the importance of factors other than nutrients upon the development and maintenance of algal blooms.

Specific Tasks

i. Measure the distribution, biomass, productivity, and composition of the phytoplankton community.

ii. Monitor light distributions in the water column.

iii. Determine photosynthesis versus light extinction curves for the dominant phytoplankton species.

iv. Measure nutrient uptake kinetics of the dominant phytoplankton species and conduct experiments to study phytoplankton nutrient limitations.

v. Measure zooplankton biomass and grazing rate.

vi. Measure benthic filter feeder biomass and grazing rate.

vii. Estimate the effect of sediment resuspension upon light and nutrient availability in the water column.

viii. Use the sedimentary record to determine whether extensive phytoplankton blooms occurred in the past and if so under what conditions.

ix. Develop a model of water column processes that is coupled to the benthic model (and sediments) and that incorporates both pelagic nutrient dynamics and grazing losses.

4. What are the sources, quantities, and effects of toxic pollutants introduced into the Florida Bay ecosystem?

Pollutants are a common problem in coastal ecosystems, but given the relative isolation of Florida Bay from extensive municipal and industrial development, toxic pollutant inputs from sources other than local agriculture should be minimal. However, we currently have little information on inputs, pathways, or effects of toxic pollutants in the Bay. Because it is likely that management actions taken to restore freshwater inputs to the Bay will also affect pollutant dynamics, we need to establish a monitoring program before these changes are made.

Mercury is a pollutant of special concern. It is a human health hazard because of its toxicity, persistence, and the extent to which it bioaccumulates in tissues and biomagnifies through the food chain. It has also been found at high levels in the Everglades biota, including fish in northeastern Florida Bay. Thus, mercury contamination in the Bay may be increasing.

The other major group of toxic pollutants of particular concern are synthetic organic compounds that are used as pesticides both in mosquito control and in South Florida agriculture.

Key Research Needs

Key research needs include determining the extent, pathways, and history of mercury contamination in the Bay; determining the flux of dissolved and absorbed toxic organics into the Bay; and determining the atmospheric flux of pesticides into the Bay. Monitoring mercury concentrations in selected Florida Bay biota is a prudent first step given the problems already evident in the Everglades. Monitoring all or most of the toxic organics used in Florida agriculture is unnecessary. Rather, attention should be paid to pesticides that are used in large quantities, are mobile in surface water or groundwater, are relatively persistent, and are known to have significant ecological effects. A Contaminants Advisory Committee should be established to determine which compounds warrant study.

The main concern in determining atmospheric flux is direct aerial input because pesticides are extensively used for mosquito control in Dade and Monroe counties. This may have a local effect at the time of application. Larval crustaceans are particularly sensitive to such chemicals, and thus, the timing of these doses and their distribution in the Bay warrant further study.

Specific Tasks

i. Monitor tissue concentrations in fish and organisms from upper trophic levels, e.g., crocodile eggs.

ii. Monitor water column mercury concentrations and chemical forms in water entering the Bay and at selected stations within the Bay.

iii. Measure atmospheric mercury inputs.

iv. Measure the historical record of mercury accumulation in the Bay from sediments, peat, or corals.

v. Monitor mercury concentrations in canals and other surface water and groundwater.

vi. Monitor water and sediment mercury concentrations at a set of Bay stations.

vii. Monitor mercury concentrations in those fauna that may integrate the variability of exposure in the Bay (e.g., filter-feeding bivalves), those species that may have high body burdens (e.g., from upper trophic levels or those with an especially high fat content), and those species that may be particularly sensitive to pesticides (e.g., the osprey).

viii. Monitor the time, amount, and extent of pesticide application (including information on not only the "active" compounds but the associated solvents) and establish a centrally accessible data base.

ix. Relate actual pesticide application to potentially critical areas and periods within the Bay, considering the life history and recruitment of key species.

x. Monitor the body burden of the pesticide compounds applied to the larvae, juveniles and adults of key species (e.g., pink shrimp).

xi. Perform special studies to assess specific pesticide application events.

5. What is the cause of turbidity in the Bay, and what is its effect on Bay water quality?

Increased turbidity is the most conspicuous change in the Bay since 1987. Declining water clarity has the potential to shift Florida Bay away from a system dominated by benthic primary production towards one dominated by water-column productivity. This critical area needs to be researched further.

Specific Tasks

i. Determine biological components of turbidity.

ii. Determine contribution of resuspended sediments to turbidity and determine how suspended sediments relate to sediment transport, erosion, and deposition.

C. Seagrass, Mangrove, and Hardbottom Habitats

The three major habitat types in Florida Bay are discussed here. Each has undergone significant change, particularly seagrass meadows. Historically, seagrasses have been the dominant primary producers in Florida Bay. In addition they structure the benthic habitats by providing refuge to important consumer species in their vulnerable early stages and by consolidating otherwise readily resuspended carbonate sediments. Recent changes in seagrass distribution and abundance throughout Florida Bay constitute a major shift in the functional dynamics of the ecosystem. The resultant effects on organisms, food chains, processes, and the Bay as a whole are of major concern for all three habitat types.

1. What environmental factors explain the observed distribution of seagrasses within the Bay and caused the recent die-off?

Reduced freshwater flow into Florida Bay resulting from drought and diversion of upland runoff is thought to have caused significant increases in average salinities in the interior basins of Florida Bay. The higher salinities have allowed Thalassia testudinum beds in the north-central and western Bay to develop very high densities and biomass in basins that historically supported a more diverse, more typically estuarine seagrass assemblage (e.g., Halodule, Ruppia, and Thalassia).

Nonetheless, seagrass populations of Florida Bay appeared to be thriving as late as 1984. Leaf defoliation of bank-top seagrasses and seagrass die-off was observed during the summer of 1987. Seagrass die-off spread rapidly, affecting primarily but not exclusively the dense beds of north-central and western Florida Bay. It is speculated that the shallow waters and restricted circulation of Florida Bay, coupled with diminished freshwater flow from the Everglades and the exaggerated near monospecificity attained under these conditions, amplified the effects of natural temperature and salinity variations and thus caused large-scale die-offs.

Key Research Needs

The first step is to fully understand the causes (both natural and anthropogenic) of the observed changes and the relationships between these factors. Detailed physiological, ecological, and demographic information is essential if we are to develop a predictive capability. Estimating future changes in seagrass distribution, abundance, and dynamics is an essential component of the scientific basis for restoration management.

Specific Tasks

i. Determine current seagrass species distributions, abundances, and biomasses to assess possible large-scale spatial changes that have taken place since the 1983-84 survey. Incorporate these data into a GIS database.

ii. Determine the effects of salinity, light, temperature, and nutrient concentration upon seagrass species distribution and productivity, population growth, and succession by conducting controlled factorial laboratory and field/mesocosm experiments. Light compensation points and limiting nutrient dynamics need to be determined for growth in the carbonaceous (and high-sulfide) sediments of Florida Bay. The effects of persistently reduced light on seagrass species distribution need to be assessed.

iii. Conduct surveys of benthic and epiphytic macroalgae to assess relative eutrophication of the system and possible competitive effects upon the seagrasses.

iv. Determine the age structure and mortality and reproduction patterns in Thalassia, Halodule, and Ruppia subpopulations. The distribution of Thalassia rhizomes in areas currently unvegetated or vegetated by other seagrasses should be used to map past mortality events.

v. Monitor productivity, plastochrone interval, and shoot-specific leaf area in Thalassia; these characteristics provide indications of physiological status of Thalassia and are indicative of environmental stress. Determine whether these characteristics are useful indicators in the other seagrass species.

vi. Determine the etiology of seagrass die-off in situ in Florida Bay. The patchy distribution patterns, density dependence, spread rates, and leaf necroses associated with die-off of Thalassia suggest the involvement of a pathogenic organism. Given the high concentrations of dissolved sulfide in sediment porewater, hypoxic stress of subterranean Thalassia tissue also may play a role. Although it may be impossible to determine with any certainty what precipitated the original die-off event, it is still important to determine the proximal causes of die-off if we are to anticipate future events.

vii. Determine the influence that increased epiphytism, decreased water clarity due to resuspension of unvegetated sediments, and increased phytoplankton concentrations have upon seagrass recolonization and population recovery rates.

viii. Develop spatially coupled physical-biological models linking experimentally verified causes of die-off to the distribution of seagrasses throughout Florida Bay in order to evaluate recovery potential and predict the effects of restoration efforts. Verify these models through a continuing monitoring program.

2. What environmental factors explain the pattern of mangrove die-back within the Florida Bay ecosystem?

Mangrove communities in South Florida are potentially affected by a number of anthropogenic and natural factors whose relative significances are not well known. These may act synergistically to significantly change the mangrove community. The importance of the transition zone and island mangrove communities to the Bay ecosystem dictates that greater attention be paid to their physiological ecology, growth, and reproductive biology.

Hurricane Andrew severely damaged more than 70,000 acres of mature mangrove forest on the west coast of Everglades National Park. Winter freezes in 1983 and 1989 also damaged large areas of mainland mangrove communities, but no quantitative damage assessment has been made. Reduction in freshwater delivery to the southern margin of the mainland and Florida Bay also has been suggested as a factor in mangrove mortality. An increasing problem is associated with the exotic tree Schinus terebinthifolius, which has displaced mangroves in some areas of the Gulf coast mangrove forest.

The impact of the 1989 freeze may have been exacerbated by low water levels in the Everglades, which in turn resulted from drought and hydroperiod manipulations. Although hurricanes have been an historical factor in the evolution of South Florida mangrove ecosystems. dispersal and establishment of alien plant species in mangrove communities is facilitated by hurricanes. Mangrove communities, possibly more than any other community, will be vulnerable to changes in tidal inundation patterns associated with eustatic sea-level rise and the accelerated sea-level rise forecast in global-climate-change scenarios.

Key Research Needs

A combination of monitoring and experimentation will be required to elucidate the key mechanisms that could change the mangrove communities of Florida Bay, the extent of present mortality, and the impact of this upon the Bay ecosystem.

Specific Tasks

i. Monitor mangrove community composition and coverage on the South Florida mainland and islands in Florida Bay. Quantify changes for the entire area on a multi-year schedule, and sample smaller areas more frequently. Analyze available aerial photographs to determine past changes. Incorporate all data into a GIS-database.

ii. Determine the effects of tidal inundation patterns, freshwater-flow alteration, and nutrient availability upon mangrove growth, physiology, and reproduction.

iii. Determine the relationship of past, present, and future freshwater-flow patterns to the extent, vigor, and functional integrity of mangrove communities within the mainland region of Everglades National Park and on the Florida Bay keys.

iv. Continue assessment of Hurricane Andrew's impacts on mangroves, with particular emphasis on recovery patterns and invasion by exotic plant species.

v. Model mangrove population dynamics in Florida Bay and adjacent mainland areas based upon the above data [i-iv].

vi. Determine the significance of mangrove habitats, production, and nutrient cycling to the Florida Bay ecosystem by studying food-web and habitat utilization, and incorporate the mangrove community into an overall ecosystem model (see section B).

vii. Monitor salinity of hypersaline groundwater on islands in relation to mangrove die-off.

3. What has been the cause and consequence of sponge die-off and the subsequent alteration of hardbottom communities?

Mass mortality of sponges has occurred throughout large areas of the south-central and southwestern portions of Florida Bay. Circumstantial evidence links sponge mortality to the presence of the algal bloom that has persisted in that region; however, no experimental confirmation of that linkage exists. Sponges are a major structural component of Florida Bay hardbottom communities and may contribute to water clarity through filtration. Little is known about the ecological implications of their loss.

Specific Tasks

i. Determine the mechanism for sponge mortality. Experimentally verify the linkage between phytoplankton blooms and sponge mortality using cultures of dominant bloom species in controlled laboratory experiments. Transplant sponges to bloom areas to evaluate susceptibility of individual species. Include cellular analysis of sponges.

ii. Incorporate hardbottom communities into a biological monitoring program. The initial goals of such a program will be to evaluate variations in abundance of the structural components of hardbottom habitat across Florida Bay and use these data to experimentally test the effects of change in this community and the community's relationship to living resources.

D. Living Resources

The living resources of the Bay include, as a general category, those organisms specially recognized because of the species' ecological, regulatory, conservation, and/or economic value. To varying degrees, many of these have exhibited population trends suggesting that Florida Bay's capacity to support them is declining. Other species, however, have not been studied enough to evaluate trends.

1. Has recruitment into Florida Bay been affected by habitat changes in Florida Bay, and have altered environmental conditions affected growth and survival of animals in Florida Bay?

The interactions of known and suspected environmental changes such as salinity variations, current modifications, nutrient or pollution inputs, freshwater input, algal blooms, grass die-offs, and sponge die-offs are suspected to affect the distribution and abundance of living resources. A given taxon's sensitivity to any of these factors may differ with life history, trophic position, and length of exposure to Florida Bay water (e.g., whether the entire life cycle or just a part is spent within Florida Bay). Often the most sensitive stages are the recruit and the juvenile stages. Therefore, the study of recruits and juveniles can provide valuable predictive information about subsequent overall population changes. Along with community-level studies, a suite of critical or indicator species will be selected as the focus of these population level and physiological studies.

Key research needs

A combination of monitoring, research, and modeling is required to link habitat change to shifts in living resources. The key elements of each are defined below.

Specific Tasks

i. Develop a baywide faunal monitoring program in the major sub-environments of the Bay. Design surveys to establish correlations with other measured factors that then will be tested experimentally for causal relationships. Compare results with past studies in retrospective analyses. Critical observations should include but not be limited to the following:

- the age and/or size of animals - e.g., detection of shifts in abundance from one size- or age-class to another will lead to the testing of hypotheses relating population changes to ecosystem changes.

- health and condition of organisms.

- reproductive condition or stage.

Additional actions needed to test specific hypotheses may include sampling algal blooms within and beyond Florida Bay and sampling across gradients of salinity, latitude, and distance from channels between the keys.

The monitoring program must be of sufficient duration to permit meaningful time-series analyses of trends and restoration efforts. Special attention is needed on the following taxa:

- Pink and Caridean Shrimp - because of their utilization of grassbeds as a nursery area.

- Spiny Lobster - because algal blooms depleted the number of sponge shelters for juvenile lobster.

- Fishes - because they may be quantitatively censused with nets in bloom waters. Community-level analyses of fish assemblages may provide a means to measure changes in habitat.

- Mollusks - because many are indicative of salinity and because shell accumulations permit comparisons of compositional change over time.

ii. Conduct comprehensive life-history studies of selected species for basic information such as levels of recruitment and transport of recruits, critical shelter and forage habitats, and how habitat use changes with environmental modification.

iii. Conduct manipulative field experiments testing the impacts of change in critical habitats on distribution, abundance, and survival of critical life stages.

iv. Couple the above field work with laboratory-based physiological and behavioral experiments investigating the tolerances and preferences of fishes to conditions that exist in Florida Bay or might exist under proposed management strategies.

v. Develop models linking experimental data to information on life histories, habitat change, and changes in the physical environment that will emerge from research described in other areas of this plan. These models should be sufficiently detailed to evaluate causes of changing abundance patterns, if any, and sufficiently broad to evaluate any changes that occur on a regional scale. Model outputs need to be regularly verified by the monitoring and experimental approaches described above.

2. Has habitat degradation or loss caused a reduction in fishery productivity in the Bay?

Degradation of Bay habitats has been blamed for causing declines in fishery resources as reflected in fishery-dependent data. However, these data encompass only adult life-history stages. Although these data are sufficient indicators of fisheries productivity at a given time, they are subject to biases due to gear type, angler behavior, and fishing regulations. Furthermore, the fact that commercial fishing has been prohibited in the NPS portion of the Bay since 1985 further confounds data interpretation. In short, the causes of observed declines have not been identified with any certainty. Some fishery-independent sampling has been conducted in the Bay and adjacent waters but only to a limited areal and temporal extent. Collectively these data may provide some basis for comparison with results from future surveys.

Kev Research Needs

Detailed information is needed on the quality and quantity of available habitat and species' habitat preferences. Much of this information will be obtained from research and monitoring efforts described earlier. Fisheries landings data, collected since the 1960's, will provide an initial basis for research on impacts upon fisheries productivity and can guide additional data collection allowing more rigorous determination of cause and effect relationships. The direct impact of habitat change or degradation can be ascertained by analyzing specific tissues and forage items that accumulate toxins and pollutants. Elucidating the physiological impact on selected species of such toxins will require laboratory studies.

Specific Tasks

i. Collect unbiased information on all the life-history stages of selected indicator species. This information is best derived by supplementing fishery- dependent sampling with fishery-independent sampling. Fishery-independent sampling should be directed at specific life-history stages and should be habitat based.

ii. Focus on habitat-based research, particularly the structure and function of each habitat type. Research that defines the linkage between seagrass and mangrove habitats and the effects on fisheries of changing benthic vegetation is critical. Specifically, pre- and post-die-off seagrass and mangrove faunal community composition must be quantified.

iii. To address the decline in the pink shrimp fishery, develop a model that relates cohorts on nursery grounds to cohorts in the Tortugas fishery landings.

iv. Attempt to measure the impacts of habitat change via tissue analysis and stomach contents analyses. For some species, tissues will need to be examined to define the overall health of a particular species within the Bay.

v. Conduct complementary laboratory physiological research on early life- history stages of key species to evaluate changes in habitat on coastal resources.

3. Have environmental and habitat changes in the Bay affected the distribution and reproductive success of upper- trophic-level consumers?

Everglades National Park and Florida Bay are important foraging and rookery habitats for many species of wading birds, shore birds, and top-level predatory birds such as eagles, ospreys, and brown pelicans. In addition, the entire U.S. population of the Great White Heron resides in southern Florida, and about 65% of the population nests on fringing mangroves and mangrove islands in Florida Bay. Declines in many species, particularly wading birds and ospreys, have been measured over the past several years. One possible explanation for these population declines is that they are the direct result of declines in the quality of resources available.

Four species of marine turtles have been reported to occur in Florida Bay; loggerhead and green turtles are regular residents. Kemp's ridley and the hawksbill turtle are present but less common. Adult male loggerheads are particularly common, and the Bay may serve as adult resident habitat or an important migratory route for the western Atlantic loggerhead reproductive contingent. Seagrass communities provide forage for turtles, and seagrass community diversity has been shown to be significant in providing sufficient nutrition for the herbivorous green turtle. Fibropapilloma disease affects 70% of all captured green turtles and has been documented in more loggerheads within South Florida than ever reported from any other geographic location. Although the etiology of the fibropapilloma disease is unknown, one hypothesis is that environmental contaminants may weaken the turtle's immune system.

Bottlenosed dolphin are regular residents and users of Florida Bay. Although dolphins consume Bay finfish, the relative importance of this habitat to dolphins in the southeastern U.S. is unknown.

Manatees utilize the Bay and adjacent waters on a seasonal basis and their numbers within the Bay have been well documented. Changes in the distribution of manatees in the Bay over time suggest a decline in use of the northern Bay, although historically, the northeastern portion was the most important area of the Bay for manatees. Proposed changes in freshwater inflow may have direct impacts on the benthic vegetation, which is critical forage for manatees. How these changes in vegetation have affected the distribution and abundance of manatees in the Bay is poorly understood.

The endangered American crocodile is found exclusively in South Florida from the southern portion of Biscayne Bay to Florida Bay. The distribution and growth of crocodiles are related to seasonal fluctuations in salinity. In addition, the survival of hatchlings has been linked to periodic access to freshwater. How changes in freshwater inflow affect the distribution, abundance, and survivorship of hatchlings is unknown.

Clearly, changes in freshwater inflow into the Bay will influence the quality and quantity of habitat available to all life-history stages of manatees, turtles, dolphins, and crocodiles. The scientific basis for predicting the extent of the habitat change is currently weak. However, as coastal habitat outside the Bay diminishes in quality and quantity, the relative importance of the Bay to the protection and recovery of these species will likely increase. Therefore, investigation of the impacts of habitat change in the Bay upon all protected species groups is imperative.

Key Research Needs

Protected areas such as the Bay will likely become increasingly important as refuges for protected species as coastal development continues. To develop predictive models, information on the abundance and distribution of animals in the Bay is critical. These results will be used to evaluate the carrying capacity of the Bay for these species, an essential element of restoration management. Information on the movements and use of the Bay as nursery or developmental habitat is essential. Information needs to be collected over many years to delineate population trends in the species that have long generation times. Information on the impact of toxins and pollutants on protected species is critical if recovery is to be achieved.

For some species, such as osprey and bald eagle, available monitoring records are sufficient to determine the current status of populations in the Bay; for others, however, regular population monitoring should be initiated and continued. For all species, consistent censusing must be either continued or initiated to determine the impacts of habitat change on these populations. Monitoring of both the nesting and foraging components of all populations are needed. As such, all species can be used as indicators of ecosystem health. The accumulation of toxins has been documented for some species. The impact of this on individuals and on reproductive and hatchling success must be quantified.

Specific Tasks

For predatory birds:

i. Monitor the abundance and distribution of key species. The most commonly used method is via aerial survey counts. To evaluate hatching and fledging rates, nests must be routinely sampled.

ii. Determine the relative importance of specific areas for nesting, feeding and roosting within the Park and the Bay, using radio- and satellite-tracking tags.

iii. Analyze stomach contents to provide needed information on feeding and habitat preferences.

iv. Sample nests for egg and hatchling productivity.

v. Population changes can only be determined by monitoring these species in the Bay and adjacent coastal waters. On the larger scale, aerial surveys are an appropriate method to census animals and evaluate distributional changes.

For crocodiles:

vi. Nest censuses need to be used to determine population status.

For sea turtles:

vii. Netting studies are appropriate when accompanied by tagging as currently practiced. The use of point-transect sampling may also provide abundance estimates.

viii. Distribution and abundance data on legally protected species, Florida Bay habitat characterization and environmental parameter data need to be integrated in order to evaluate the effects of environmental changes on turtles.

ix. Radio-tagging studies should be undertaken to provide information on the movements of animals within and outside the Bay, including their migratory movements.

x. The examination of stranded animals should be used to provide additional information on habitat use and preference via stomach-contents analyses. Stomach contents should be examined via gastric lavage of living animals.

xi. Specific study of the fibropapilloma disease is needed to provide for mitigation and recovery.

For all species:

xii. Analyses of toxins in forage items and tissues must be completed and tissues from all life-history stages should be analyzed for contaminants.

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7/25/94

NOAA Florida Bay Implementation Plan FY94

I. PROJECT BACKGROUND

A. Background

Florida Bay is a triangularly shaped body of water about 2200 km2 in area. Over 80% of the Bay lies within Everglades National Park. The Bay is bounded by the Florida mainland on the north, U. S. Highway 1 on the northeast, the Florida Keys on the southeast, and the Intracoastal Waterway between Long Key and East Cape Sable. Commonly the region west of the Park's western boundary across to the Middle Keys is included in Florida Bay. In the Park over 200 small islands or "keys" occur in the Bay all of which are rimmed with mangroves and have interior, irregularly flooded, "flats" with calcareous blue-green algal mats. The Bay is shallow, often hypersaline, and, until recently, was characterized by clear waters, and lush seagrass meadows covering a mosaic of shallow water banks and numerous relatively deeper water basins or "lakes". Deep narrow channels (1 to 5 m deep) connect neighboring basins. Hardbottom habitats in southwestern Florida Bay support sponge and hard and soft coral communities.

Florida Bay is known as the principal inshore nursery for the offshore Tortugas pink shrimp fishery, Penaeus duorarum, for providing critical habitat for juvenile spiny lobster, Panulirus argus, stone crab, Menippe mercenaria and many important finfish species. The Bay is the site of an extensive sportfishery and supports populations of the bottlenosed porpoise, and several species of sea turtles as well as other noteworthy species.

Seagrasses in western Florida Bay, primarily turtlegrass, (Thalassia testudinum), have been dying since the summer of 1987. This seagrass die-off continues today. A phenomenon such as this has not been observed previously in Florida Bay nor has a mass mortality of any tropical seagrass been reported in the scientific literature. In some areas, vegetative cover has been partially reestablished, by either the original species or another species. In other areas, however, recolonization has been slow, and large areas of the bottom are devoid of vegetation.

There are many other indications that the environmental health of Florida Bay has deteriorated. Fishing success has declined for many of the commercial and recreational species that depend upon the Bay as a juvenile nursery habitat, suggesting a decline in recruitment. Changes in resident fishery populations associated with these habitat changes are occurring. Atypical phytoplankton blooms have been reported in the last few years across much of the western Bay and have extended into the Florida Keys. Loggerhead sponge dieoffs have been attributed to such blooms. Most recently, mangroves, interior and along the edge of mangrove islands within the Bay, are reported to be in decline. While the causes of the various problems and the relationships between them are not well understood, there is no question that, like the sawgrass habitat of the Everglades, the Florida Bay coastal marine ecosystem as we know it is in jeopardy.

Florida Bay and its seagrass, mangrove, and coralline habitats are closely coupled with the freshwater Everglades, the Florida Keys reef tract, and the West Florida shelf. The freshwater that flows through the sawgrass habitat of the Everglades eventually meets saltwater to create an estuarine environment dominated by mangroves and seagrasses. Bay waters are a mixture of the freshwater runoff from the Everglades and coastal shelf waters that enter around Cape Sable from the west Florida shelf. There are infrequent local intrusions of near oceanic water through inlets between the Keys along the eastern edge of the Bay. More regularly, the coral reef tract is itself inundated by Bay water that escapes seaward through these same inlets. These environments constitute a closely coupled coastal landscape and cannot be considered in isolation.

More freshwater alone may not return Florida Bay to its pristine condition. Timing, location, and quality of the inflowing waters is important. Water quality is particularly important, and measures to address pollution specific to the Everglades may not have been adequate to protect Florida Bay. Increasing freshwater flow to the Bay, all else being equal could increase nutrient loading, which might induce more frequent, more extensive phytoplankton blooms. These could in turn result in further losses of bottom vegetation in the Bay by light limitation. Nutrient loads in Bay waters that exit between the Keys could be injurious to the coral reefs of the Florida Keys Marine Sanctuary. Lastly, increasing water flow may also increase trace contaminant loading. In short, quantity, timing, location and quality of fresh water released to Florida Bay must be considered.

At present there is not sufficient scientific knowledge to with confidence, predict the consequences of anticipated alterations in freshwater input to Florida Bay. Although increased flow can certainly reduce the frequency and severity of hypersalinity, fine-tuning of water flow, reduction in plant nutrient concentrations in inflowing water, and other corrective measures may be necessary to restore the health and productivity of the Bay.

Since no one can turn back the clock and South Florida's rapid development will almost certainly continue, a series of compromises and tradeoffs will have to be made in restoring and maintaining a healthy South Florida coastal ecosystem. It is essential that decisions be made based on reliable scientific information. As concluded by a workshop convened last summer, given its individual responsibilities with the Bay (see below) and the pivotal role of Florida Bay within the larger South Florida coastal ecosystem, NOAA must become an active participant in the scientific effort that will inform Bay Restoration1.

B. NOAA Mandates

The NOAA assigns responsibility for research on Living Marine Resources (LMRs), their habitats, and their conservation to its National Marine Fisheries Service (NMFS). NMFS carries out these responsibilities under many laws and mandates from Congress, but those that have most relevance to Florida Bay are the Magnuson Fishery Conservation and Management Act of 1976, which regulates fisheries within the U.S. Exclusive Economic Zone (EEZ); the Endangered Species Act, which protects species determined to be threatened or endangered; the Marine Mammal Protection Act, which regulates taking of marine mammals and requires that populations be maintained at or restored to optimum levels; the Lacey Act, which prohibits fishery transactions that violate state, Federal, American Indian or foreign laws; and the Fish and Wildlife Coordination Act, which authorizes NMFS to represent the interests of living marine resources in government decisions regarding land and water resource management or development.

The living marine resources harvested along the South Florida coast depend upon a healthy, productive Florida Bay. For many species, Florida Bay is the principal nursery area (e.g., spotted seatrout, gray snapper, grunt, spiny lobster, pink shrimp).

For this reason NOAA has the mandate to protect and, where degraded, restore the Bay habitat. The NMFS/SEFSC has ongoing efforts to assess the relation between juveniles of fishery species and changing habitats within the Bay. NMFS/SEFSC has developed a predictive model on the Tortugas pink shrimp fishery relative to an index of freshwater inflow to the Bay. Both efforts require expansion and augmentation from the point of view of Bay restoration.

NOAA is responsible for the designation and protection of endangered marine species. Florida Bay serves as important habitat for three endangered species of sea turtles and for the jewfish, which soon may also be listed as endangered. Given the presence of these species in this threatened environment, the Bay could be designated a Critical Habitat under the Endangered Species Act. NMFS also is charged with protecting marine mammals, and substantial local bottlenose dolphin populations utilize the Florida Bay habitat.

NOAA's National Ocean Service (NOS) has responsibility, under the National Marine Sanctuaries Act, for the Florida Keys Marine Sanctuary (FKNMS). The FKNMS preserve includes the coral reef tract and the 10% of the Bay not in Everglades National Park. FKNMS regulations are now being finalized after extensive public comment and discussion. Under the Oceans Act of 1992 the FKNMS has the mandate to look upstream outside its boundaries - i.e., to the remainder of Florida Bay, if necessary, to protect the FKNMS's unique coral habitats.

..ven in the absence of all these specific obligations, NOAA would have a general responsibility under the Coastal Zone Management Act to work with the State of Florida and other Federal agencies to protect the coastal marine ecosystem, including Florida Bay and its adjacent waters.

C. NOAA Context - The NOAA STRATEGIC PLAN

It is the intention of our Administrator that the priorities and directions within NOAA be guided in large part by NOAA's Strategic Plan. The Portfolio within that Plan particularly concerned with coastal regions is entitled Environmental Stewardship. A Florida Bay project would directly address three of its critical program elements: Rebuild U.S. Fisheries; Recovering Protected Species; and, Coastal Ecosystems Health.

1. Rebuild U.S. Fisheries

The living marine resources harvested along the South Florida coast depend upon a healthy, productive Florida Bay. For many species, Florida Bay is the principal nursery area (e.g., spotted seatrout, gray snapper, grunt, spiny lobster, pink shrimp). In 1990 almost 20 million pounds of fish and shellfish were landed in Monroe County. Their dockside value was almost $50 million. This county alone represents over 20% of the total commercial landings for Florida. The wholesale value for these products was estimated at $64 million. The net result to the economy of this area includes $90 million in economic activity, $32 million in earnings, and 2,230 jobs. Recreational activities and tourism account for an estimated 50% of the total employment in Monroe County. Recreational fishing contributes about $77 million to the local economy, while diving contributes $354 million. The progressive degradation of the Bay is evident. A continuing decline in resource productivity and the quality of the marine environment would result in significant job loss in South Florida tourism and fisheries-related industries. In contrast, restoration of the pink shrimp fishery alone would be worth almost $20 million dollars at dockside and many times that to the regional economy.

2. Recovering Protected Species

Florida Bay serves as important habitat for three endangered species of sea turtles and for the jewfish, which soon may also be listed as endangered. Given the threat to these species posed by progressive degradation, the Bay could conceivably be designated a Critical Habitat under the Endangered Species Act. Substantial local bottlenose dolphin populations utilize the Florida Bay habitat and data is insufficient to determine if their health or abundance has been adversely affected.

Restoration efforts will almost certainly alter their habitat and effect their feeding and possibly reproduction. The populations will have to be monitored far more closely than in previous decades.

3. Coastal Ecosystems Health

The emphasis of NOAA's Coastal Ecosystem Health strategy is federal/state/private collaboration implementing integrated coastal zone management. Consistent with this the NOAA Florida Bay Project will contribute to the Interagency coordinated scientific program necessary to develop an understanding of the structure and function of the Florida Bay coastal ecosystem in the context of the entire south Florida landscape. The present Bay ecosystem is the result of decades of increasing development and environmental alteration throughout south Florida. Our management goal is to re-establish and sustain the natural diversity, abundance and behavior of the marine and estuarine flora and fauna. With a coordinated systematic federal mitigation strategy and direct state and local participation substantial progress can be made in that direction. Nonetheless, we must remain realistic. Additional flow to the Everglades is not enough. Timing, location, type and quality of input are all critical to the Bay. Integrated, scientifically sound management of the entire coastal ecosystem of which Florida Bay is a part is absolutely essential. Coastal Ecosystem Health seeks sustained economic growth. In fact scientifically well-informed integrated management is necessary to maintain the quality of life in south Florida much less to accommodate any future development. Bay restoration should be an iterative process through which management alternatives are developed and selected, the preferred alternative implemented, the physical and biological responses assessed and the process repeated as restoration proceeds.

D. INTERAGENCY CONTEXT -

The alarming changes in Florida Bay have become evident to even the most casual observer. In response to heightened local concern the representatives of a number of state and federal agencies began meeting more than a year ago as an informal Working Group for Florida Bay. In fact, not only Florida Bay but the entire South Florida ecosystem, a unique interdependent landscape-seascape, may be threatened. With national attention to this crisis, the relevant federal agencies (see below) entered into an historic Agreement[2] to cooperate and work with the state of Florida in order "to address and solve the myriad issues involved in restoring and maintaining the unique world resources embodied in the South Florida ecosystem[3]".

The Agreement established an interagency Task Force consisting of Departmental Assistant Secretaries (or their equivalents) from the Dept. of the Interior (DOI), the Dept. of Commerce (DOC), Dept. of the Army (Civil Works), Dept. of Justice, Dept. of Agriculture and the Environmental Protection Agency. As soon as possible the appropriate state of Florida (Department of Environmental Protection/DEP) and regional (South Florida Water Management District/SFWMD) agencies will become members of the Task Force and its subsidiary bodies. The Task Force has already established an Interagency Working Group consisting of local administrators which has in turn established, among other advisory subgroups, a Scientific Working Sub-Group to provide necessary technical advice. This last body began to meet only in October. At the request of the Army Corps it provided the Working Group (and Task Force) with a set of objectives and success criteria for the hydrological and ecological restoration of the South Florida Ecosystem. Although objectives and criteria were separately provided for ten subregions, these were viewed not as a set of isolated geographic areas but rather as an integrated whole[4]. Each subregion (or combinations thereof) will eventually develop detailed science plans for eventual incorporation into a regional ecosystem-based integrated science program. The Agreement not only envisions such integration, but also explicitly sanctions line agency cooperation and facilitates mechanisms (e.g. interagency transfers of funds) needed to accomplish efficient integration. The first such interagency South Florida subregional science plan that has been developed was the Florida Bay Interagency Science Plan[5].

Administratively there is a special need for an interagency science plan for Florida Bay because of the number of agencies whose jurisdiction is implicated by Florida Bay research and restoration. Representatives of the major agencies (DOC, DOI, Florida DEP and the SFWMD) participated in drafting an interagency plan compatible with their respective responsibilities. As recommended by a disinterested advisory panel convened last September at the behest of the Assistant Secretary of the Interior, a management framework was explicitly set forth to ensure continuing integration of the activities of the different agencies.

This framework includes an Interagency Program Management Committee, Review Panel and Technical Advisory Group. The individual implementation plans prepared by each agency will have to be consistent with the scientific approach and priorities of the interagency science plan. The intention is that individual agency Implementation plans be complementary rather than comprehensive.

The substance of the Interagency Plan relied upon a draft Research Program for Florida Bay developed by the National Park Service's South Florida Research Center6, a NOAA workshop held to define Florida Bay research priorities7, and the internal draft research plans more recently prepared by the South Florida Water Management District, the Florida Department of Environmental Protection and the United States Geological Survey. The synthesis effort was guided by a thorough review of Florida Bay problems that was conducted at the behest of Assistant Secretary Frampton (DOI) by a panel of nationally recognized scientists working in other estuarine systems8.

NOAA's institutional expertise and its specific environmental mandates delimit NOAA's participation in the Florida Bay Interagency effort and guide the substantive content of this Implementation Plan. On the one hand, NOAA will focus upon the larger oceanographic, atmospheric and fisheries context within which Bay restoration will proceed. This implies attention to the Bay's linkages with the adjacent Atlantic and Gulf of Mexico ecosystems and its regulation by large scale atmospheric and meteorological processes. On the other hand, NOAA will collaborate in conducting biological studies within the Bay particularly in regard to fisheries habitat assessment and protected species. Last, being an interagency "partner" implies an obligation to additionally contribute where NOAA's technical capabilities and experience may be unique: e.g., in regard to the problems of accurately estimating evaporation and precipitation or of understanding nutrient dynamics.

E. RELATIONSHIP TO THE FKNMS

The Florida Keys National Marine sanctuary (FKNMS) was created with signing of HR5909 (Public Law 101-605, Florida Keys National Marine Sanctuary and Protection Act) on 16 November 1990. Included in the Sanctuary are 2800 square nautical miles of nearshore waters extending from just south of Miami to the Dry Tortugas which includes the eastern portion of Florida Bay adjacent to Everglades National Park.

The act directs the Federal Government and the State of Florida to jointly develop and implement a comprehensive program to reduce pollution in the waters offshore the Florida Keys to protect and restore the water quality, coral reefs, and other living marine resources of the Florida Keys environment. In addition, the extent to which problems within the FKNMS are affected by conditions beyond its jurisdictional boundaries, the plan is to reflect measures necessary to address these problems.

As part of this program EPA in conjunction with the State of Florida and in cooperation with NOAA has developed a Water Quality Protection Program which consists of four interrelated components: corrective actions, monitoring, research, and public education/outreach. For each component a list of strategies (see Attachment) has been developed to address critical needs. Of these several have direct implications as they relate to Florida Bay and its influence on the FKNMS as discussed below.

Specific recommendations have been reflected in the plan to examine the influence of Florida Bay on water quality in the sanctuary and its possible effects on resources (Strategies W.19: Florida Bay Freshwater Flow; and W.24: Florida Bay Influence). To the degree possible it is hoped that activities funded by this Water Quality Protection Program be consistent with and contributory to NOAA and other Interagency Florida Bay research projects. In addition, other research/monitoring strategies (W.20: WQ Monitoring Program, W.21: Predictive Models, W.22: Pollutant Assessment, W.23: Leachate Transport, W.25: WQ Impact Research, W.26: Indicators, W.27: Other Monitoring Tools, W.28: Regional Database, W.29: Dissemination of Research Findings, W.31: Global Change, and W.32: Technical Advisory Committee) will establish operational Protocols and procedures which need to considered and in the development of a research plan for Florida Bay.

II. PROJECT OBJECTIVES

A. Research Hypotheses

Following the recommendations of an advisory panel, the Interagency Florida Bay Science Plan drafting committee formulated the following questions the answers to which were deemed critical to understanding the ecosystem of Florida Bay, the changes it has undergone and the possible effects of alternative restoration scenarios:

1. What is the relationship of surface and groundwater flows through the Everglades to the salinity of Florida Bay?

2. What is the effect of the relative lack of storms over the past three decades on the buildup of sediments, nutrients and organic material in the Bay?

3. What have been the effects of increased residence time of

water due to restrictions to flow through channels between the Keys, shoaling and reduced freshwater inflows?

4. What are the sources, quantities, and ecological effects of "external" nutrients introduced into Florida Bay?

5. What are the rates of nutrient exchange between the sediment and water column within Florida Bay and what controls the magnitude and direction of these fluxes?

6. What are the rates of nutrient assimilation by phytoplankton in the Bay and what limits the growth of the phytoplankton assemblage?

7. What are the sources, quantities, and effects of toxic pollutants introduced into the Florida Bay ecosystem?

8. What environmental factors are significant to seagrass physiology, growth and reproduction and to what degree has a synergy between these resulted in the observed distribution of seagrasses within the Bay and caused the recent dieoff?

9. What environmental factors are significant to physiology, growth and reproduction and how have they affected mangrove distribution within the Florida Bay ecosystem?

10. What has been the cause and consequence of sponge dieoff and the subsequent alteration of hardbottom communities?

11. What are the changes in the distribution and abundance of living resources that have occurred as a result of habitat changes in Florida Bay?

12. Is habitat degradation causing reduced fisheries productivity as reflected in declining recreational and commercial landings since the 1960's?

13. Has reduced availability of resources resulted in declines in populations of protected resources in the Bay and adjacent coastal waters?

14. Is the quality of the water flowing from the Bay contributing to the degradation of corals along the reef tract of the Florida Keys in the Atlantic Ocean?

15. Have changes in Bay habitat caused declines in bird abundance and diversity?

As a participant in the Interagency effort these same questions necessarily guide the NOAA Florida Bay Implementation Plan.

B. Research Approach

NOAA's efforts will include retrospective analyses, monitoring, modeling, and the acquisition of critical new information through both field studies and laboratory experiments. Monitoring, modeling, and research are necessary and complementary components of scientific investigation in support of restoration. The understanding derived from basic research into system processes and function will be incorporated into models to make predictions useful in guiding management decisions. Monitoring will not only provide data for model input and model validation but will also allow the effect of restoration efforts to be evaluated. Analyses and models make monitoring meaningful, help guide further research, and lead to recommendations on how to improve the restoration actions.

Retrospective analyses are essential to document the timing and extent of change already experienced in Florida Bay as well as the degree of natural variability in system parameters. This includes both synthesis and assimilation of data or samples that have already been collected as well as analysis of samples to be collected for the specific purpose of documenting historical change.

Monitoring design must reflect the spatial heterogeneity of the Bay. Moreover it must be closely integrated with present and planned monitoring efforts either in the Bay (ENP) or in adjacent waters (e.g., the FKNMS and SFWMD). NOAA monitoring could markedly augment the station coverage planned or already ongoing by ENP or expand its geographic scope to include the adjacent waters that influence and interact with Florida Bay. It must also supplement the parameters being monitored within the Bay by other agencies and their contractors. In general Bay monitoring by the set of participating agencies and academics must address the full set of biological and physical process measurements that need to be done to document system changes and to understand the relationship between the various parameters. Water quality parameters, physical processes (e.g., wind, rainfall, and evaporation), fish stocks, benthos (including plant and animal community structure and ecological associations) and plankton all need to be monitored. Some must begin as soon as possible in order to document any changes that occur with the onset of increased freshwater flow and must be continued sufficiently long to follow changes in the ecosystem as it responds to new conditions. This charge exceeds the resources and capabilities of any one contributing agency.

Modeling is an essential component of the NOAA Florida Bay Implementation Plan. To be useful to managers, any understanding of the ecosystem gained by scientific investigation has to be incorporated into models yielding "what if" predictions of water quality and ecological effects. Models are invaluable in testing hypotheses to determine if they are consistent with fundamental physical laws and are realistic. Models also can generate hypotheses that can be tested by targeted experimental and field research. Results from these activities can then be used to refine the models. Model simulations can provide valuable insight for designing restoration approaches and finetuning restoration efforts.

Considering the intense public interest in Florida Bay, there is little basic information about the ecosystem. While it is obvious that the Bay has undergone changes, available information is simply insufficient to support rigorous prediction. Research is essential to address this deficiency. An adequate program to obtain this Critical New Information includes both field studies and experimentation.

III. PROJECT COMPONENTS

A. Year One (FY94) Activities:

Some FY94 activities build upon collaborative efforts already underway while others represent new starts. Not all activities required Coastal Ocean Program FY94 funds. Some are being entirely funded by NOAA line organizations. Some of these are very closely integrated with the Coastal Ocean Program funded activities. Scientific merit, principal investigator competence, overall scientific priority, LO responsibilities, other agency plans and general feasibility determined which of a large number of proposed activities were inititiated in FY94. The basic procedures of selection are discussed below under Program Management. A few of the listed FY94 activities have not yet been funded. When and if additional funds are made available to the program a competitive process will be initiated to determine which of these merit funding.

1. Retrospective Analyses

a.) Compile available historical information on impacts to the Bay: (NOS, NESDIS and RSMAS)

To assist in determining the Bay's former condition and to catalogue changes, events that may have affected or have occurred in the Bay are being described, listed and graphically displayed in a common time scale. The time coverage begins in 1910 with construction activities along the Florida Keys and in what later became the Everglades National Park. Included are global scale atmospheric, geological and astronomical phenomena such as El Nino events, volcanic eruptions and solar activity that may affect local weather. On local scales, observations of the dieoffs of species such as sea grasses, sponges and fishes; occurrences of algal blooms, coral reef degradation, fishery catches and soil subsidence; and human activities such as population increases, and construction are catalogued.

b.) Collection and assemblage of AVHRR coastal sat llite imagery: (NMFS, RSMAS)

4-km spatial sea surface temperature (SST) fields are being acquired from RSMAS by SEFSC and are being used to construct 5-day composites of the waters of the western North Atlantic along the eastern U.S. seaboard. The data set will consist of May-October 1983-1984, all months from 1985 through 1990, May-October from 1991-1992, May-August 1993 and September 1993 SST. The data will be used

by SEFSC, Miami, to prepare time series of mean, median, and maximum sea surface temperatures for Florida Bay from 1983 to the present.

c.) The Sediment Record as a Monitor of Natural and Anthropogenic Changes: (OAR/AOML, RSMAS, UM, FIT)

We need to understand how the environment may have changed since the building of the water-diversion canals. The sediments potentially contain a continuous record of such changes and may provide the data that can be evaluated in a manner analogous to a long-term monitoring study through a multiparameter investigation of the sediment record. Planned USCGS/SFWMD Florida Bay coring program would be supplemented and complemented by coring in brackish marginal lakes and at the southern terminus of the Florida peninsula, and obtaining surficial grab samples on a grid across Florida Bay. The brackish marginal lakes contain potentially continuous records of both terrestrial and marine variability and define the northern boundary conditions for Florida Bay.

d) Refinement of Florida Bay Bottom topography: (NOS, NBS)

The objective is to define the significant topographic features of Florida Bay (i.e., mud banks, mud bank cuts, shoaling areas, basins, and islands). The purpose is to refine the existing bathymetry maps to support circulation model and resource assessments needs. The approach will be to update the current navigation charts using available T-sheets, aerial photography, and satellite imagery. An analysis will be conducted to determine areas of change and areas for which additional aerial photography and hydrographic surveys will be required. For areas determined as topographically stable, and examination will be made of the extent to which archival hydrographic surveys can be used to resolve bathymetry. Based upon the above, a field survey will be designed and conducted using the most effective combination of alternative surveying techniques for selected areas in Florida Bay. This work will be coordinated with USGS bathymetric surveying efforts. [THIS HIGH PRIORITY ACTIVITY HAS YET TO BE FUNDED]

2. Monitoring

a) Focus sampling of commercially and recreational important fisheries resources include additional biological information needed for predictive stock assessment: (NMFS)

Currently, NMFS is collecting commercial fisheries statistics for the EEZ including the FKNMS but has not focused specifically on Florida Bay. Data collection is ongoing as part of a regional or national data collection effort. To complete stock assessments, age and growth, and fecundity estimates are required. This information is provided by the NMFS/SEFSC regional data collection program under its Trip Interview Program (TIP). The intensity of TIP sampling will be changed to permit better prediction of fisheries productivity associated with progressive changes in Bay habitat as restoration proceeds.

b) Expand Mussel Watch stations into Florida Bay: (NOS/NS&T)

Five NS&T Mussel Watch sites are located in South Florida and one in the Florida Keys. In order to improve our ability to evaluate the impact of the restoration project in the Everglades on levels of toxic contaminants in Florida Bay, two new Mussel Watch sites have been added in 1994. These are located at Flamingo and in Blackwater Sound.

c) Initiate an Ecosystem Health Survey: (NOS/NS&T, EPA)

In the summer of 1994, The NS&T Program will conduct a survey of the benthic community of Florida Bay and adjacent waters. Samples of macrobenthos will be collected at about 50 sites in Florida Bay and adjacent waters out to a line between Naples and Key West. The numbers of species and of the individuals of each species will be determined to obtain baseline information on the composition and biodiversity of the macrobenthic community of this region. This project is being conducted in cooperation with the Estuarine component of the Environmental Protection Agency's Environmental Monitoring and Assessment Program

(EMAP-E). The data will be used to calculate a Benthic Index of the health of the benthic community following the procedures already established by the EMAP-E program for estuarine monitoring.

d) Initiate a Bioeffects Survey: (NOS/NS&T, NMFS and Dade County/DERM)

A Bioeffects Survey of Biscayne Bay will be conducted during the summers of 1994 and 1995. The survey is designed to assist the magnitude and extent of biological effects due to toxic chemical contamination in this area. The survey will include investigations concerning sediment toxicity, impairment of fish reproduction, genetic damage in fish, and indicators of toxic chemical effects in bivalve molluscs.

e) Continue monitoring water temperature in the Keys Reef Tract and along the Bay side of the Keys: (NOS/FKNMS)

A total of thirty stations have or will be established to monitor water temperature both along the reef tract and along the Bay side of the Keys. Most of these stations were established in 1990 and include a thermograph deployed

within 30 cm of the seabed as each location. Instruments are PC programmed to record at 2 hour intervals in degrees Celsius and will operate for 530 days. Accuracy of these are plus or minus .3 o C. All units are retrieved annually

and downloaded on diskette.

f) Data Management: (NOS/NESDIS, NMFS)

The National Environmental Data and Information Service, NESDIS of NOAA, is responsible for collecting, quality checking, and archiving all oceanographic and meteorological (including satellite) data collected by U.S. investigators. It has provided the NOAA Florida Bay Program a local data coordinator who is contacting the other agency data coordinators, has arranged a joint meeting, resolved issues of selecting a common database structure and has established an InterNet mailing list of various agency and academic participants. Eventually specific hardware and software will be acquired (and discussions have already proceeded with NMFS ADP personnel in Miami) for a local bulletin board and data retrieval network. In addition preliminary work has begun on specifying data reporting and collection requirements for the NOAA funded PI's.

g) NOAA South Florida Contaminants Committee: (NMFS,OAR/AOML, Florida/DEP)

A NOAA Contaminants Committee has been formed to obtain available inforn ation on the contaminants entering the South Florida environment, identify sources and potential problems, and explore possible means of reducing contaminant inputs to South Florida waters. It consists of four NMFS representatives and one representative each from The Nature Conservancy and the Florida Department of Environmental Protection.

h) Monitor responses of fish and shellfish to habitat changes: (NMFS/Beaufort, NMFS/Galveston, NBS/Miami)

Quantify and compare densities of fishes and decapods in central Florida Bay basins (subject to hypersalinity) and western Florida Bay (not subject to hypersalinity) as freshwater flow to central basins is increased. This will continue our sampling and analysis of fisheries and habitats in low salinity, transitional salinity and high salinity zones of Florida Bay that were initiated during 1993 and 1994 under funding from the SEFSC. It will allow comparison of pink shrimp and other resident fish and shellfish in the area of the Corps of Engineers inflow experiment with those from other regions that will not be directly influenced. Comparative sampling will be conducted with drop frames (Galveston), trawls and possibly pop nets (Beaufort) twice during the rainy season and twice during the dry season. These data will be complemented with benthic habitat information (e.g., seagrass species composition and abundance, sediment depth) as well as temperature and salinity.

i) Mercury assessment and bioaccumulation in Florida Bay biota (NMFS)

A program of mercury monitoring in target species will be initiated and conceptual models developed to better understand the transfer of mercury up the food chain to species most at risk from methylmercury accumulation. These results will be used to anticipate and predict changes in mercury bioaccumulation in response to changes in water management via restoration. Mercury concentrations will be monitored in critical target species. [THIS HIGH PRIORITY ACTIVITY HAS YET TO BE FUNDED]

3. Modeling

a) Publish and distribute Circulation Modelling Workshop Report: (NOS/ORCA)

This workshop was jointly sponsored by the NPS and NOAA/NOS and was held early this Fall. NOS has taken the responsibility of completing the workshop report this fiscal year. It will be used to guide NPS and SFWMD funding decisions regarding circulation modeling. Those agencies will soon be issuing an RFP in this regard. The NOAA circulation work will have to be complementary to and integrated with whatever efforts are funded by these other participant agencies.

b) Mesoscale Atmospheric Modeling Applied to the South Florida Ecosystem: (OAR/AOML, NWS, SFWMD)

A high resolution, non-hydrostatic mesoscale atmospheric model will be employed for prediction of the initiation, evolution and distribution of rainfall in the Everglades and Florida Bay and for predicting surface wind fields relevant to circulation patterns in Florida Bay. A high resolution (1-10 km grid), non-hydrostatic model is well suited to simulating thunderstorm complexes that form due to sea breeze convergence forcing from the east and west Florida coasts. With proper boundary conditions, this model is also suitable for prediction of heavy rain episodes associated with tropical disturbances and fronts. The model selected for this study is the Advanced Regional Prediction System (ARPS) developed with NSF support at the University of Oklahoma's Center for Analysis and Prediction. It will be adaped to South Florida. Moreover NEXRAD and WSR-88D radar data will be incorporated to determine thunderstorm complex interactions.

c) Regional Numerical Ocean Circulation Modeling System: (RSMAS, FIT)

The circulation of the Intra-Americas Sea (the Gulf of Mexico, the Caribbean Sea and the adjacent waters from the Guianas to the Bahamas), is central to understanding the external forcing of Florida Bay. As in so many other areas

of the ocean, there is both intense mesoscale variability and a paucity of observations. Thus, a modeling system is needed that can resolve the mesoscale variability, utilize effectively whatever data are available, and provide guidance for enhancing the observing system with critical observations. In such a modeling system, we envision a hierarchy of numerical circulation diagnostic and prediction models whereby a Florida Bay model is nested into a Straits of Florida model, which in turn is nested into a regional-scale (Gulf/Caribbean/Bahamas/Guianas) model, which is nested in an (existing) operational Atlantic basin model. An initial evaluation process would be conducted by NOS as a first step in developing this modeling effort.

It is necessary to establish (and evolve) a continually operating circulation model for the region from the offing of the Guianas to Cape Canaveral, with regional participation in the observing system and interpretation of the model output. A progressive development is envisioned which will eventually involve the Group of Experts on Ocean Processes and Climate of the Subcommission for the Caribbean and Adjacent Regions of the Intergovernmental Oceanographic Commission of UNESCO, the World Meteorological Organization's regional body in the development and evaluation process; undertake feasibility studies for 4-dimensional data assimilation; explore the use of alternative methods for 4-dimensional data assimilation; conduct simulations of alternative observing systems; and analyze the model output for evidence of climate variability. Thus a direct and active link is established between university and government researchers, international organizations, and users, with continual feedback to assure the quality, utility, and availability of nowcasts and forecasts for operational and research objectives.

4. Critical New Information

a) Evaluate seagrass habitat health and community diversity and compare with historical information: (NMFS)

The NMFS Beaufort and Galveston Laboratories have been conducting fishery-habitat sampling along salinity gradients in northwestern Florida Bay. To date three sampling trips have been conducted to evaluate fisheries populations in low salinity (9-17 o/oo) and salinity transition (> 20 o/oo) areas in the vicinity of Little Madeira and Madeira Bays. At each station bottom samples are taken for vegetation type and abundance, and salinity and temperature are taken as well. Fish and shellfish are identified from each collection and data are to be compared with similar samples taken during 1990-1993 in the high salinity Gulf portion of the Bay for comparison of community structure. Additionally, Beaufort has established GPS coordinates for these sites as well as for all published sites sampled during the 1984-1985 pre-seagrass die-off studies.

b) Prop-Scar restoration in the Florida Keys National Marine Sanctuary: (NOS, NMFS)

Motor boat propeller scarring of seagrass meadows in the Florida Keys National Marine Sanctuary has had a major impact on these habitats that is increasing in both incidence and acreage impacted. This is resulting in a concomitant loss of fishery habitat. Thousands of acres of habitat have been impacted over the past, and these areas actually expand over time due to modifications in current patterns that result. A research study has been initiated to develop and evaluate techniques for restoring these habitat impacts in the Sanctuary. Seagrass transplanting techniques using bare root and peat pot (plus nutrients) will be evaluated under several experimental designs. Experimental sites and control sites have been selected, and activities will be initiated in May 1994. Transplant population dynamics and growth and coverage rates will be assessed and used to develop or modify an existing model of seagrass population dynamics.

c) Zooplankton Abundance and Grazing Potential in Florida Bay: (LUMCON, OAR/AOML)

There is not a single published report quantitatively characterizing the resident population nor estimating their contribution to secondary production in the Bay. With a decline in seagrass coverage and an increase in the areal extent and duration of phytoplankton blooms the relative importance of zooplankton grazing may have increased. In fact, the fact that the Bay historically supported large populations of teleost larvae whose primary food is copepod nauplii (e.g., spot and croaker) suggests that zooplankton played a significant role even when the Bay was clear and phytoplankton blooms were rare. It is important to recognize that adjacent environments like Biscayne Bay support large populations of estuarine copepods like Acartia tonsa by supplementing their phytoplankton diet with macrophytic plant detritus. Many macroinvertebrates have meroplanktonic stages that can serve as important food resources to larval fish. Net sampling will be used to quantify the abundance of various holo and mero-planktonic animals in the Bay in relation to concomitantly measured hydrographic information in conjunction with a recently initiated Florida DEP fisheries independent survey of Florida Bay. In addition the "gut fluorescence" method will be used to determine the grazing rate of the dominant copepod species encountered. Data collection will continue as Bay conditions change with Restoration

d) Rates of bioerosion of the Florida Keys reef tract: (NOS/FKNMS)

Bioerosion refers to the natural breakdown and reduction of reef mass by the activities of various organisms such as boring sponges and mulluscs, certain sea urchins and parrotfish which continually work to wear down the structure of the reed in their search for food and shelter.

The Hens and Chickens reef was selected for study because the primary reef building coral species there, mountainous star coral, displays both normal annual growth bands and stress bands, which chronicle severe cold weather events, much like the records of draught found within the growth rings of trees. During the winter of 1969-70, record low temperatures resulted in the death of the majority of mountainous star coral heads at Hens and Chickens. Those that did survive now contain a permanent time marker from which subsequent growth or erosion of the coral surface can be measured. Core samples will be taken from living and dead corals and the rates of loss or accretion of material since the 1969/70 event will be measured.

e) Complete photointerpretation of bottom habitats in the Bay with groundtruthing via C-CAP: (NMFS, NOS, Florida/DEP)

Precipitous declines in fisheries of Florida Bay have been associated with reported die-offs of marine and estuarine aquatic beds and reefs. Losses of submerged rooted vascular (SQV) aquatic beds, persistent phyutoplankton blooms, and elevated turbidity are symptoms of a major ecological change for the system. Quantification of the status and recent change in the spatial distribution and extent of SRV is central to understanding the nature and extent of these declines and to guide research and management efforts. This effort if a joint effort of C-CAP and the Florida DEP and augments and extends ongoing studies. Completion of the inventory and change detection will require a combination of new photography and historical photography.

g) Environmental controls upon algal blooms, food web structure and carbon flow: (OAR/GLERL, U Mich.)

Multifactorial field microcosm and mesocosm experiments will be used to determine the importance of various micronutrients, light, salinity and turbulence in initiating bloom formation. Autoecological laboratory experiments would also be conducted. Translocation mesocosm experiments would be used where distinct food webs could be subjected to simulated bloom conditions. Field experiments would be used to investigate remineralization and nutrient regeneration pathways particularly in regard to sediment/water column flux.

h) Relationship of pink shrimp cohorts on nursery grounds to fishery productivity: NMFS/ Miami, Galveston, and Charleston, NBS and RSMAS)

The pink shrimp is viewed as an ideal indicator of ecological health of Florida Bay. Pink shrimp support a valuable commercial fishery for which a relatively long time series of consistent records of catch and effort are available. Statistical analyses of the commercial catches suggest that pink shrimp are sensitive to freshwater inflow. Furthermore, pink shrimp are a principal prey item of many important game fish species in Florida Bay.

This comprehensive study involves statistical analysis, biological modeling, physiological trials, caging experiments, resource surveys, and genetic analysis of the pink shrimp stock supporting the multimillion dollar Tortugas fishing grounds. The study will characterize the within-year cohorts in the fishery and link them to specific nursery grounds in Florida Bay and nearby estuaries. Pink shrimp catch rates suggest a longterm stock decline, with an increasing rate of decline in the past decade. The study is designed to gain understanding on how environmental conditions and anthropogenic manipulations of the environment affect pink shrimp recruitment. Researchers will study the environmental requirements of pink shrimp growing on nursery grounds in or near Florida Bay where they are exposed to markedly environmental conditions. The improved understanding of pink shrimp ecology gained from this study will be used in models to evaluate proposed management alternatives in the restoration process and to develop a monitoring program based on pink shrimp that will help assess the effect of management actions.

j) Pesticide Analysis of Agricultural Nonpoint Source Waters: (NMFS)

In south Florida there are significant agricultural activates in the upland areas adjacent to Florida Bay. In the Homestead, Florida area there are numerous truck farming operations which utilize a plastic row cover in the cultivation of crops such as tomatoes and other vegetables. For example it has been found that these plastic row covers enhanced the runoff potential by 70% of pesticides in plot studies in coastal areas of South Carolina. Additionally these vegetable crops use large quantities of pesticides to control insect, fungal and plant pests.

To address the potential inputs of agricultural pesticides from vegetable farming operations in South Florida on estuarine water quality in Florida Bay, a baseline study was conducted. Results to date indicate significant levels of the insecticide endosulfan in the C-111 canal at concentrations ranging from 0.002-0.170 ug/L. Levels of 0.002 ug/L were also found just southwest of Man of War Key in western Florida Bay. As more freshwater runoff is diverted into Florida Bay as a result of the recent agreement on the Everglades reflooding, there is an increased possibility of agricultural nonpoint source runoff entering Florida Bay.

Research activities will include: 1) expanded monitoring of pesticide runoff and toxicological (i.e. Mysid IQ Test and grass shrimp) assessment of runoff effects on crustaceans; 2) Ecotoxicological assessment of fish and crustacean populations in Florida Bay using Beaufort Laboratory's historical data base and additional sampling to augment runoff studies conducted in 1994; 3) Establishment of first kinetic loading models for pesticide runoff into Florida Bay; and 4) Comparisons of findings for 1993-94 with historical contaminant information for Florida Bay.

k) Monitoring and evaluation of radar measured rainfall estimates over Florida Bay and the Everglades: (OAR/AOML, NWS, NASA-Goddard, SFWMD and NPS)

The new next-generation Doppler weather radars (NEXRAD) will be capable of producing rainfall estimates over the entire Florida Bay area at a resolution never before possible. Because of the small size scale of convective rainfall events and a dearth of rain gages over Florida Bay and portions of the Everglades, NEXRAD will provide the only large scale estimate of the fresh water contribution from direct rainfall. While estimates of the contribution of rainwater runoff to Florida Bay from the Everglades may be made from hydrological models, these models rely on input data from rain gage measurements and, in the near future, from the new Doppler radars. In order for the new radars to be valuable for hydrological purposes over Florida Bay and th Everglades, their rainfall estimation algorithms must be evaluated against existing rain gages and disdrometer measurements including drop distribution measurements made during P-3 overflights.

[THIS HIGH PRIORITY ACTIVITY HAS YET TO BE FUNDED]

1) High resolution synoptic salinity mapping of Florida Bay with airborne remote sensor: (NOS/NESDIS, NMFS, OAR/AOML, RSMAS, NPS)

Determining the relationship between freshwater discharge and salinity patterns is critical to the overall Florida Bay restoration effort. Salinity patterns in Florida Bay are complex because of the Bay's basin-bank topography, wind effects on water movement, and the number of locations of freshwater input. Given the size and complexity of Florida Bay, the most practical way to map salinities is with an airborne sensor. The first year would

be a pilot test, or prototype study, to work out the logistics of preparing synoptic salinity maps of Florida Bay using a light-weight, GPS-logged, airborne salinity sensor based on a microwave radiometer carried beneath a small plane. A multispectral video camera will also be on board and will be used to map algal blooms and other color features of the Bay, such as the yellow-brown color ("gebstoff") often associated with freshwater discharge. The intent is to prepare salinity maps of the entire Bay, while water color maps may be prepared for only the northern part of the Bay since Florida DEP is mapping the algal blooms in the western part of the Bay. Groundtruthing

would calibrate the color data and insure the accuracy of the salinity instrument in Bay waters. Eventually routine salinity maps (weekly, bi-weekly, or monthly) could be overlain on habitat maps of the Bay to determine effective habitat area (i.e. habitat area that is within the appropriate salinity range). In follow up years, we plan to

collaborate with C-CAP, Florida DEP, and other groups who are preparing habitat maps of Florida Bay. Approaches developed in Year 1, as well as economies of scale, are expected to enable cost cutting procedures that will reduce

unit mapping costs in subsequent years.
[THIS HIGH PRIORITY ACTIVITY HAS YET TO BE FUNDED]

IV. PROJECT PRODUCTS

A. First Year Products:

1. A NOAA technical memorandum entitled: Natural and Anthropogenic Events Impacting Florida Bay: 1910-1993 Timeline.

2. An AVHRR coastline database

3. A collection of sediments from brackish marginal lakes

4. Fisheries statistics database for Florida Bay

5. Marine Mammal census data and tissue sample collection

6. Establishment of Florida Bay Musselwatch stations

7. An NS&T benthic database reflecting overall ecosystem health

8. Comparison data on benthic organisms in neighboring Biscayne Bay

9. Continuation of the long-term temperature database for the FKNMS

10. Establishment of NOAA South Florida Contaminants Committee

11. Publication of NPS, NOAA Circulation Modeling Workshop Report

12. Adaptation of Mesoscale Atmospheric Model to the South Florida Ecosystem

13. Initial integration of Florida Bay circulation model with numerical ocean circulation model for the region

14. Estimates of biodiversity in changing seagrass habitats within the Bay

15. Prop-scar mitigation through seagrass replanting trials in the FKNMS

16. Estimates of zooplankton abundance and grazing potential

17. Estimates of bioerosion in FKNMS corals

18. Delimitation of bottom habitat types by aerial photography and groundtruth estimation

19. Assessment of the relative importance of different

plant nutrients and physical changes in stimulating algal blooms

20. Estimation of the relationship between pink shrimp productivity and nursery habitat condition

21. Initial assessment of non-point source pesticide introduction into Florida Bay

V. PROJECT MANAGEMENT

The NOAA Florida Bay Project exactly complies with the distributed project management approach characteristic of the NOAA Coastal Ocean Program (COP). This mechanism has proven highly effective in multiple line organization interdisciplinary federal/academic collaborative programs like NECOP and SABRE. Designated representatives of two different participating NOAA line organizations as well as one academic serve on a three person Project Management Committee (PMC) - See Appendix One. The PMC is responsible both for continuing project management and for making specific funding decisions; their first task was to appoint a small Technical Advisory Group (TAG) consisting of federal, state or academic scientist with the expertise necessary to advise the PMC (See Appendix One). The NOAA Florida Bay PMC reports directly to the Coastal Ocean Program. One of its members (NT with PBO as alternate) serves on the Interagency Florida Bay Program Management Committee responsible for coordinating individual agency activities and implementation Plans. Another member (PBO) serves on the Science Subgroup of the Interagency South Florida Ecosystem Restoration taskforce.

Membership in the TAG will be for at least four years with staggered terms. The TAG will attend formal annual program reviews and assist the PMC in the funding decision process. Membership continuity is essential to assure institutional memory-i.e., to ascertain whether programs have been responsive to the panel's review and what suggestions have proven helpful. The first job of the TAG was to provide reviews of proposed Year One activities so that the PMC could allocate the available COP funds (see Appendix Two).

Many of the Year One activities consist of supplementing funding to projects already underway. Given the extensive planning process that has gone on with regard to Florida Bay over the past year (and the fact that we needed to begin work without further delay) the PMC in consultation with its COP and LO funding sources based project selection upon 5 page workplan/planning letters accompanied by curriculum vitae and budgets rather than full proposals. To help the PMC chose among these, the TAG provided detailed reviews of each short proposal. Every effort was made to assure minimal overlap and maximally efficient resource utilization across all state and federal agencies collaborating in Florida Bay. The COP funded projects were given only nine months funding after which they will have to compete with all new submissions. In subsequent years the more deliberate process described below will be followed.

In addition all funded principals were required to modify their workplans to accomodate the significant criticisms of the TAC. Copies of all reviews were retained by the PMC and were promptly provided (albeit as anonymous "abstracts") to applicants upon request. Appendix Three includes all responses sent to principal investigators seeking COP funds in FY94.

In FY95 and beyond years a more exhaustive process similar to that followed in SABRE and NECOP will be followed. It will be initiated in November of 1995. First, potential NOAA participants will be asked to submit brief planning letters describing their prospective research and accompany these with required supporting documentation (curriculum vitae, budgets indicating organizational funds to be contributed, etc.) to corroborate their capabilities and their institutional commitment. The PMC with the assistance of its TAG will then decide what aspects of the Project can and should be done within NOAA. The technical criteria used to evaluate planning letters will be individual scientific promise, the degree to which research proposed is essential to long-term and short-term objectives, the documented competence of the principal investigators, the extent of institutional commitment and the total funds made available within NOAA. It goes with out saying that a significant programmatic consideration criterion will be the source of the funds made available and the specific mandates and responsibilities of the contributing line organizations.

Second, the PMC will send out a request for planning letters to the academic community. Those who inquire will be supplied the NOAA FY95 Florida Bay Implementation Plan, a document describing FY94 activities and a rough target figure for individual academic project budgets. As in NECOP and SABRE, academic research plans explicitly collaborative with NOAA scientists are anticipated but that would not be an absolute requirement. What is expected, however, is fundamentally collaborative academic-NOAA research and not simply the subcontracting or farming out of routine work tasks.

All planning letters submitted would have to include not only research plans anda budget but also curricula vitae. The PMC, assisted by its TAG will then evaluate academic planning letters using the very same criteria listed above excepting "institutional commitment".

Only when evaluation of planning letters has been completed and decisions as to overall project priorities have been made, will requests for more detailed multiyear proposals be sent to the selected principal investigators. Requests for preparation of full proposals (to both NOAA and academic participants) will include specific technical and budgetary guidance. Explicit suggestions will be made concerning collaboration with other investigators where appropriate. Submissions will then be directed at specifying research plans and technical approaches rather than rejustifying the significance of the proposed research. Clearly, the PMC will have to work closely with PI's asked to prepare proposals. This will almost certainly require an iterative process of proposal modification, in order to assure coherence and integration with the overall Interagency Florida Bay effort. Both NOAA and academic proposals will then be reviewed by the TAG who will also be provided with the guidance letters sent out by the PMC. Where the PMC and/or TAG deems it necessary, mail reviewers will also be employed to review proposals.

The mechanics of data management are entirely consistent with the policies agreed upon in the Interagency Florida Bay Science Plan. These in turn rely upon the accepted policies for the national Global Change Program9. Plans have been made to establish a remotely accessible database at either the NMFS or OAR laboratory in Miami. We anticipate that the same computer system will function as an electronic bulletin board linking various NOAA and NOAA-funded investigators with each other and with other components of the Interagency effort.

Day to day project management within NMFS, ERL and NOS will be coordinated with and implemented through separate institutional management structures just as has been the case in most Coastal Ocean Program and Global Climate Change programs. Funding for some academic participants has been distributed through cooperatative arrangements like the Cooperative Institute for Marine and Atmospheric Science (CIMAS/UM) while funds for other academic participants were distributed as subcontracts or under other existing NOAA/academic agreements. In subsequent years we expect this function to be performed predominately by state Sea Grant Offices as with other COP programs.

VI. PROJECT FUNDING (as of 7/94)

The following table lists NOAA organization contributions to the respective projects. Line organization contributions entirely funds some projects and are also a requirement to match COP funds going to NOAA investigators. COP contributions total $545K in FY94. Of this $254K was allocated to non-NOAA (90% university) investigators and $291K to NOAA principal investigators based on the process described above.

I. RETROSPECTIVE ANALYSIS

a) Compile available historical information on impacts to the Bay:

NESDIS	15
NOS/S&T	50
SubTotal:	65

b) Collection and assemblage of AVHRR coastal satellite imagery:

NMFS	35
SubTotal:	35

c) The Sediment Record as a Monitor of Natural and Anthropogenic Changes:

COP	65
OAR	21
SubTotal:	86
Retrospective Total:	186K

d) Refinement of Florida Bay Bottom topography:
[THIS HIGH PRIORITY ACTIVITY HAS YET TO BE FUNDED]

II. MONITORING

a) Focus sampling of commercially and recreational important fisheries resources include additional biological information needed for predictive stock assessment:

NMFS	75
SubTotal:	75

b) Expand Mussel Watch stations into Florida Bay:

NOS/S&T	30
SubTotal:	30

c) Initiate an Ecosystem Health Survey:

NOS/S&T	30
SubTotal:	30

d) Initiate a Bioeffects Survey:

NOS/S&T	50
NMFS	15
SubTotal:	65

e) Continue monitoring water temperature in the Keys Reef Tract and along the Bay side of the Keys:

NOS/FKNMS	10 [estimated contribution]
SubTotal:	10

f) Data Management:

NESDIS/NODC	
SubTotal:	50

g) NOAA South Florida Contaminants Committee:

NMFS	15
OAR	10
SubTotal:	25

h) Monitor responses of fish and shellfish to habitat changes:

COP	70
NMFS	75
SubTotal:	145
Monitoring Total:	430K

i) Mercury assessment and bioaccumulation in Florida Bay biota (NMFS)
[THIS HIGH PRIORITY ACTIVITY HAS YET TO BE FUNDED]

3. MODELING

a) Publish and distribute Circulation Modelling Workshop Report:

NOS/ORCA	15

SubTotal: 15

b) Mesoscale Atmospheric Modeling Applied to the South Florida Ecosystem:

COP	65
OAR	70
SubTotal:	135

c) Regional Numerical Ocean Circulation Modeling System:

COP	70
SubTotal:	70
Modeling Total:	220K

4. CRITICAL NEW INFORMATION

a) Evaluate seagrass habitat health and community diversity and compare with historical information:

NMFS	75
SubTotal:	75

b) Prop-Scar restoration in the Florida Keys National Marine Sanctuary:

NOS/FKNMS	20 (estimated contribution)
NMFS	20
SubTotal:	40

c) Zooplankton Abundance and Grazing Potential in Florida Bay:

COP	25
OAR	9
SubTotal:	34

d) Rates of bioerosion of the Florida Keys reef tract:

NOS/FKNMS	30 [estimated contribution]
SubTotal:	30

e) Complete photointerpretation of bottom habitats in the Bay with groundtruthing via C-CAP:

COP	30
NMFS	10
SubTotal:	40

f) Environmental controls upon algal blooms, food web structure and carbon flow:

COP	55
OAR	56
SubTotal:	111

g) Relationship of pink shrimp cohorts on nursery grounds to fishery productivity:

COP	135
NMFS	85
SubTotal:	220

j) Pesticide Analysis of Agricultural Nonpoint Source Waters:

COP	36
NMFS	36
SubTotal:	72
New Information Total:	622

k) Monitoring and evaluation of radar measured rainfall estimates over Florida Bay and the Everglades:
[THIS HIGH PRIORITY ACTIVITY HAS YET TO BE FUNDED]

1) High resolution synoptic salinity mapping of Florida Bay with airborne remote sensor:
[THIS HIGH PRIORITY ACTIVITY HAS YET TO BE FUNDED]

Overall Project FY94 Total: $1.458M

VII. REFERENCES

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Toward Ecosystem Management In Florida

Florida Department of Environmental Protection

Lawton Chiles, Governor

Virginia B. Wetherell, Secretary

March, 1994

Florida Department of
Environmental Protection

Lawton Chiles
Governor

Marjory Stoneman Douglas Building
3900 Commonwealth Boulevard
Tallahassee, Florida 32399-3000

Virginia B. Wetherell
Secretary

February 25, 1994

Dear Reader:

The legislation that created the Department of Environmental Protection also empowered this new department to focus more of its resources on the protection of entire ecological systems.

We take that charge seriously, and in the pages that follow you will find descriptions of the kinds of activities we at the Department feel are part of ecosystem management. After reading them, I think you will discover that in some areas we in Florida have been doing ecosystem management all along. What is new is the Department's commitment to the process in the future.

Governor Chiles' merger of the two premier state environmental and natural resource agencies gives us the chance to do it better. Now, with almost all of the tools needed for ecosystem management under the same roof--tools such as planning, land acquisition, environmental education, regulation, and pollution prevention--we have new opportunities for cooperation. Working with the five water management districts, we can use these tools to improve our ties with local governments and other agencies which have key roles to play in ecosystem management, and with landowners and other members of the public. We can begin to develop a public ethic of shared responsibility for the world around us. We can become more efficient; more effective. Our combined resources will let us reduce duplication and overlap--resulting in better use of both state and local tax dollars. Most importantly, we can do a better job.

To illustrate how we have moved toward ecosystem management over the years, and to show how it can be done in the future, we chose six of Florida's threatened ecosystems as examples. We easily could have chosen others. In the pages that follow, you will see that for one or two of these areas our ecosystem activities are well advanced. In others, we have scarcely begun. You also will see how ecosystem management will work for Florida--and that it works best when public and private interests in an area work in partnership. The following are the six areas we chose:

Apalachicola River and Bay. Of the six areas, the Apalachicola-Chattahoochee-Flint (ACF) Rivers basin in Florida, Georgia and Alabama is perhaps the most advanced example of ecosystem management in action. Interstate activities in the ACF basin have been going on since the late '70s. The three states and the Army Corps of Engineers are in the midst of an extensive study that will result in a blueprint for managing this resource which is so critical to the health of the Apalachicola Bay and the economy it supports. Much, however, remains to be done to assure that the needs of residents around the Apalachicola River and Bay are considered when land and water use decisions are made by upstream jurisdictions.

Lower St. Johns River. The Lower St. Johns (the river reach between the north end of Lake George and the Atlantic Ocean), is a less-studied river basin than the Apalachicola. State agencies and the water management district each have worked in the river, but while there have been successful attempts at project-by-project coordination, most of the work was to meet an agency's specific need--water quality or water quantity--and associated land uses often were considered in only a cursory fashion. With the merger, ecosystem management for the lower St. Johns River offers the chance to bring the agencies, local governments, land owners, and others together for the good of the river basin and themselves.

Florida Bay. Although a flurry of activity over the last several months might make it seem otherwise, Florida Bay is one of the least-studied ecosystems in Florida. Management of the bay is a challenge because of the huge number of complicating issues that must be dealt with. Ecosystem management for the bay and its immediate tributary watersheds focuses upon three key areas: intergovernmental coordination; restoration-oriented research and monitoring, and reestablishing the water quality and hydroperiod of Taylor Slough.

Wekiva River. The Wekiva River basin is another in which much has been done but more needs doing. The river flows through a rapidly growing and urbanizing area, and interagency and community groups--such as the Friends of the Wekiva, the Governor's Wekiva River Task Force and the Wekiva River Basin Working Group--have been working on the basin for several years now. Ecosystem management for the Wekiva will concentrate on urban problems such as stormwater, interagency cooperation and continued protection for the natural systems that surround and buffer the river.

Hillsborough River. The Hillsborough River basin is another in which some work has begun, but where most of it still lies ahead. Located in another growing population center, the basin faces issues that run the gamut from land use through water quality (both fresh and salt water), water supply, air quality, and natural habitat. The effectiveness of an ecosystem management program for the Hillsborough River basin will depend upon continued commitment not only from the Department and the water management district, but from all public and private interests in the basin.

Suwannee River. Water quality issues in the Florida portion of the Suwannee River have a relatively long history of intergovernmental coordination and cooperation. As a result, water quality in the Suwannee is quite good--with local exceptions. However, like the ACF, the Suwannee is an interstate river, and while the part of the river within Florida has been extensively studied, we know much less about the interstate issues that affect the basin. Ecosystem management for the Suwannee will focus upon these; and upon bringing together the public and the 57 governmental units with some kind of jurisdiction within the basin.

One common thread among all of the ecosystem management programs we have highlighted is the need for better intergovernmental coordination. But, important as that may be, ecosystem management is much more than just coordination between governments. It is coordination of the interests of all the stakeholders within an ecosystem. After you have read these pages, I hope you will support and join with us at the Department of Environmental Protection and the five water management districts as we begin to move toward ecosystem management in Florida.

Virginia Wetherell

Virginia B. Wetherell
Secretary,
Department of Environmental Protection

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Ecosystem Management

"An integrated approach to management of Florida's biological and physical environments--conducted through the use of tools such as planning, land acquisition, environmental education, regulation, and pollution prevention--designed to maintain, protect and improve the State's natural, managed, and human communities."

Florida Bay Ecosystem Management Area

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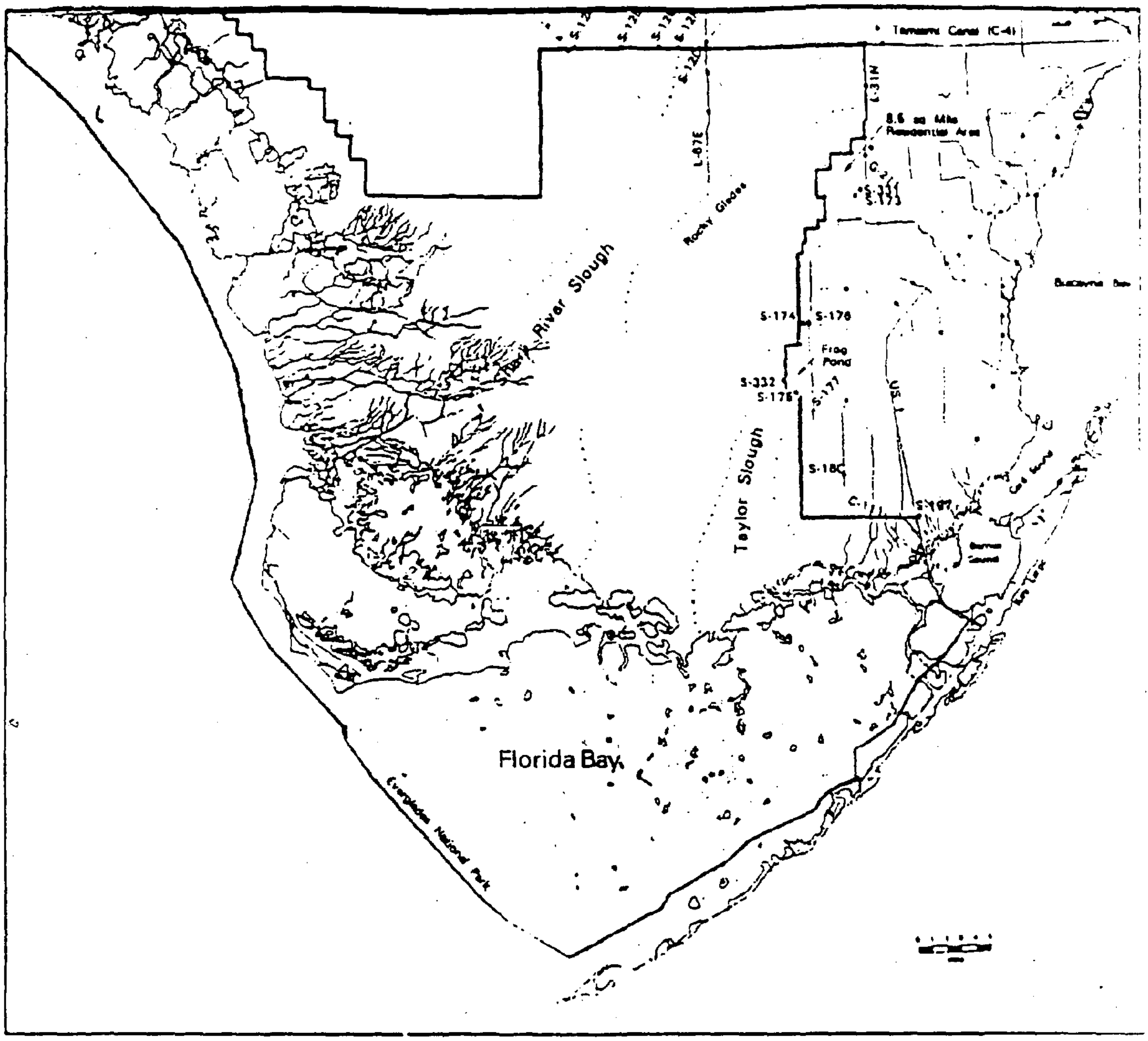

Florida Bay Ecosystem

Introduction

In contrast to most of the other Ecosystem Management Areas, Florida Bay and its immediate tributary areas have only recently become the subject of intensive research, concentrated interagency attention, and the funding necessary to resolve difficult environmental resource problems. Restoration and management of Florida Bay is an urgent and challenging issue from a variety of viewpoints--including research, implementation, interagency coordination, funding and litigation. To date, governmental efforts have not demonstrated the speed and responsiveness commensurate with the problems of Florida Bay. One purpose of this document is to improve the response of state government to the Florida Bay crisis.

The Florida Bay ecosystem is changing in a drastic and catastrophic manner. Visual observations of widespread mortality of seagrass, turbid water associated with a die back, and the occurrence of large and sustained phytoplankton blooms support this perception. Moreover, there is a coincident decline in the yield of commercial and sport fisheries. These observations have prompted many concerned citizens to conclude that Florida Bay is dying (Everglades Coalition, 1993). A recent report (Boesch et al, 1993), examined eleven hypotheses and identified a variety of causal factors in which more information is needed to determine causes and effectively guide restoration.

Significant hydrologic changes have occurred within the tributary watersheds of Florida Bay, primarily as a result of public flood control efforts. The Taylor Slough basin, (ref. map) has experienced a significant decrease in water levels and in the duration of inundation (hydroperiod). Restoration of water levels and hydroperiods in Taylor Slough and the Eastern Panhandle C-111 basin will benefit the ecosystem of Northeast Florida Bay (Boesch et al, 1993).

As a result of the high level of public concern, several governmental agencies are focusing attention on Florida Bay. The Federal Task Force, headed by an Assistant Secretary of the Interior, and with comparable appointees from other federal agencies and departments, was formed in 1993 to coordinate federal activities. A Management Working Group, Sub Groups and area-specific committees were created to implement the charge. In addition, an Interagency Work Group was formed by Everglades National Park (ENP) that includes federal and state and local scientists to define research needs for Florida Bay. The Florida Keys National Marine Sanctuary (sponsored by NOAA) includes portions of Florida Bay, and its Steering Committee also is active in guiding management of the sanctuary, with accompanying adverse effects on Florida Bay.

At the State level, the involved agencies are coordinated through the Interagency Management Committee (DCA, DEP, Governor's Office, Department of Commerce, FGFFC, Marine Fisheries Commission, and others). The Coastal Management Citizens Advisory Committee is focusing on Florida Bay. The South Florida Water Management District operates and maintains the Central and Southern Florida Flood Control Project as local sponsor for the Corps of Engineers, in addition to carrying out a variety of other water management tasks, such as administering the Bay Watch contract. The Department of Environmental Protection is currently developing a state Council composed of state agencies and others to recommend improvements regarding Florida Bay.

Locally, the South Florida Regional Planning Council has formed a Florida Bay Committee to address Florida Bay issues. In addition, a coalition of Florida Keys interest groups have joined to form the Water Quality Joint Action Group to focus on Florida Bay and the Marine Sanctuary.

The role of such groups as the Everglades Coalition, the Nature Conservancy, other groups and various individuals are a significant influence on the course of events within the Florida Bay Area. Indeed, these organizations and individuals have been a key forcing function in galvanizing government into action.

Ecosystem Management in Florida Bay and its immediate tributary watersheds is focusing on three key areas: intergovernmental coordination, restoration research and monitoring, and hydroperiod and water quality restoration. In addition to the information deficiencies identified by the Boesch panel and the various groups addressing research, restoration of the hydroperiod and the water quality of Taylor Slough is a critical issue. Of perhaps greatest importance, however, is the need to coordinate the efforts of the various interagency groups working towards the restoration of Florida Bay. These issues and implementation steps are identified in subsequent sections.

Management Area

To accomplish a fully implemented ecosystem management approach to Florida Bay and the Southern Everglades, the entire Everglades Ecosystem from Lake Okeechobee to Florida Bay and the Florida Keys must be considered. However, to initiate and demonstrate the process of ecosystem management two drainage basins--Taylor Slough and the C-111 canal sub-basin--have been selected for focus along with Florida Bay (see Map). Ultimately, the entire Everglades system must be considered if Florida Bay is to be protected.

The Taylor Slough drainage basin is formed by an extension of the Miami Coastal Ridge southeast and a southeast/northeast ridge known as Long Pine Key (Schomer and Drew, 1982). The Taylor Slough headwaters are partially located within the Everglades National Park, but most of the headwaters are within private ownership known as the East Everglades. To the east and south of the main stem of Taylor Slough is the C-111 canal sub-basin. The natural resources of C-111 and Taylor Slough drainage basins reflect a system of modified hydrologic regimes and land-use alterations.

Natural Systems

The natural system includes hardwood hammock forest, thicket and shrubs, sawgrass prairie and tree islands, pine woods, and sawgrass and mulhy marsh. The upper basin of Taylor Slough has been significantly modified and is dominated by agricultural land and urban sprawl. The C-111 canal system is a major water conveyance system that bifurcates the Taylor Slough and C-111 basin and terminates in the eastern Florida Bay, Barnes Sound. The C-111 canal system is part of the greater Everglades canal system but is locally effective in maintaining lowered water tables to prevent urban and agricultural flooding. The conveyance system has significantly reduced the volume and timing of water in Taylor Slough and the C-111 drainage area and has allowed large discharges through the C-111 canal to Barnes Sound. Altered hydroperiods have initiated, in some cases, changes in the conditions of the natural landscape and in animal populations such as wading birds and amphibians.

Florida Bay is a key link in the Everglades/Florida Bay/Florida Keys ecosystem and lies between Cape Sable, the southernmost point of Florida's mainland, and the Florida Keys, encompassing some 1000 square miles of shallow marine and estuarine waters. The Bay supports the second largest area of critical seagrass habitat in the U.S, has abundant mangrove and salt marsh habitat, and has a complex of hardbottom and sponge communities. These habitats are critical juvenile nursery habitat for many species both economically and ecologically important to south Florida including pink shrimp and spiny lobster.

Issues

1) Intergovernmental Coordination

Discussion

There are more than a dozen interagency groups on the local, state, and federal levels devoting time and energy to restoration of Florida Bay. A major part of their effort is restoration of this water body to some semblance of a "natural" condition. Although their implementation plans have several key points in common, none of these groups has attempted a broad-based, process-driven, coordination process.

Both the Department and the SFWMD have independently concluded that facilitation of interagency research and management is an important part of their charge with respect to Florida Bay. Thus far, the responsibility has been taken by the federal government, but several legal bottlenecks have kept state agencies from being full partners in some of the federal efforts. The two primary agencies must take on this important responsibility for Florida Bay.

This proposal puts forth a multi-step effort to achieve the following goals:

- broad-based education and communication regarding the current state of understanding of the science of Florida Bay;
- completion of a vision/mission/strategy effort, designed to clarify objectives, and ensure consistency between agencies, environmental groups and "concerned citizens"
- assessment of each agency's role and objectives in the management plan for Florida Bay; and
- a carefully crafted implementation plan, based on the work defined above.

Implementation

Proposed Actions:

DEP and the South Florida Water Management District staff will:

- assess current activities by agency and discipline; by 3/94

- determine strengths and deficiencies of current processes; by 4/94

- develop a working plan to build on strengths/resolve deficiencies by 5/94
- bring plan forward for approval by DEP hierarchy and District Governing. Board by 6/94

The next action steps will begin the actual vision/mission/strategy work to build a coalition of agencies, environmental groups and concerned citizens.

Proposed Actions:
DEP and SFWMD staff will:

- utilize a working plan to outline the process for the vision/mission/strategy work; by 8/94
- identify facilitators and share working plan with them; by 8/94
- develop v/m/s process and schedule; by 9/94
- implement process and develop feedback mechanisms to ensure success; by 11/94

Upon completion of these tasks, and approval of the implementation plan, the next step will be to secure funding from appropriate sources (ie. Legislature, Governing Board, etc). When the funding is secured, DEP and SFWMD technical staff will begin preparation of the technical implementation plan. It will be the responsibility of this group to accomplish the following:

- define appropriate methods to achieve the various projects (ie. RFP, contract, grants, other mechanisms) and develop a time line for implementation; by 1/95
- implement funding of various projects; by 5/95
- recommend strategies to ensure effective coordination and communication of results obtained from the work, including a newsletter, electronic bulletin board, or similar vehicle for communication (ongoing)
- ensure the various agencies carry through in their commitments for implementation (ongoing)

Future Actions or Needs

- The most important outcome of these actions will be coordination of the various agencies' efforts to avoid redundancy or significant misses in research, management and other related actions. The best way to accomplish this is a central database for ALL Florida Bay information. A key discussion item in the near term will be creation of such a data base, input and output accessible by all participating agencies and individuals. A secondary, but no less crucial item will be a public education plan that ensures that research findings and subsequent management plans receive broad-based dissemination to all appropriate parties.

- Create a working group to develop a program that will tie the entire Everglades system into the effort to protect Florida Bay.

2) Restoration Research and Monitoring
Discussion

Although the Everglades Ecosystem has received considerable attention over the last several decades, Florida Bay still is poorly understood. It did not receive adequate consideration when the South Florida water delivery system was designed. A series of catastrophic events have occurred in the Bay that have ecological and economic consequences and reflect the need for an ecosystem approach to management.

Habitat and associated wildlife have been experiencing unprecedented change in Florida Bay. A seagrass die-off was first observed in 1987. By 1990, nearly 63,000 acres of turtle grass (Thalassia) had been lost. Although die-off events have been poorly monitored and documented since 1990, an estimated 100,000 acres of total seagrass have been lost. Blooms of microalgae are occurring with increasing frequency and intensity. These blooms have become a more widespread and persistent feature of the Bay and may be having devastating effects on many benthic communities. Associated with the algal blooms, sponge mortality has occurred from Everglades National Park to Marathon; many areas have experienced a 100% mortality of all sponge species. Mangroves on islands and the mainland in the central region of Florida Bay have been dying since 1991. These and other fundamental changes in the Florida Bay landscape are linked to reduced abundance of pink shrimp and juvenile spiny lobsters and may be affecting a range of dependent species.

The Florida Bay and Everglades Ecosystem is complex. Considering the importance of Florida Bay, we have comparatively little scientific information about its problems and the exact causes (Boesch, et al, 1993). Many compounding factors related to natural cycles and man's intervention are not fully documented. However, there is unanimous agreement that the historical flow, timing of flow, or distribution of freshwater to Florida Bay has been altered, and that these changes are damaging the Bay.

Water delivery to Taylor Slough and the C-111 sub-basin upstream of the Bay are of special concern. Everglades water management has created a long-term reduction in freshwater entering Taylor Slough and the C-111 basin, altering the seasonal timing of flow and the location of water delivery. This has contributed to marine and hypersaline conditions. These changes are thought to be contributing to the biological changes in the northeastern Bay.

A number of factors may be involved in the various ecosystem perturbations being observed. (Boesch et al, 1993) To effectively describe the events, elucidate cause and effect, and ensure long-term corrective measures a multi-government-agency, private-science-based effort must be maintained and coordinated. A multi-agency science group has drafted a research and monitoring program that recommends specific objectives leading to ecosystem restoration:

- developing an understanding of the condition of Florida Bay prior to significant alteration by man;
- separating anthropogenic induced changes in Florida Bay from natural system variation,
- developing a basic understanding of the ecology of Florida Bay and,
- developing the capability to predict the response to perturbation of a suite of species which collectively may be considered "representative" of Florida Bay.

Implementation

The DEP and the SFWMD are dedicated to making significant contributions to building the scientific knowledge necessary for science-based understanding, management, and restoration of the ecosystem. The Interagency Working Group on Florida Bay has identified four priority research and monitoring topics for implementation. The DEP and WMD are contributing to these four priority topics as follows:

Topic 1. Assess water budgets, circulation dynamics, and salinity to determine 1) the relationship of surface and ground water flows through the Everglades to the salinity of Florida Bay, 2) the effect of the relative lack of storms over the past three decades on the build-up of sediments, nutrients, and organic material in the Bay, and 3) the effects of increased residence time of water due to restrictions to flow through channels between the Florida Keys, shoaling, and reduced freshwater inflows.

Proposed Actions:

● Determine the long-term net water transport patterns linking Florida Bay with the Gulf of Mexico and link these patterns to external wind, tidal and oceanic forcing. Results from this research will be incorporated into a broader circulation model of Florida Bay. Sponsored by DEP. Start: February 1994.

● Determine sediment history in Florida Bay and conduct coral dating for historical salinity analyses using isotope dating. Sponsored by SFWMD. Start Date: mid-1994

● Analyze historical salinity, nutrients, food web variations by stable isotopes, pigments, etc., in sediment. Sponsored by SFWMD. Start Date: 1996.

● Salinity in Everglades National Parks. Sponsored by SFWMD. Start Date: On-going.

● Conduct circulation modeling of Florida Bay and conduct elevation surveys of ENP platforms for circulation studies. Sponsored by SFWMD. Start Date: requests for proposals in preparation.

Topic 2. Assess water quality and nutrient cycling to determine 1) the sources, quantities, and ecological effects of "external nutrients" introduced into Florida Bay, 2) the rates of nutrient exchange between the sediments and water column within Florida Bay and what controls the magnitude and direction of these fluxes, 3) the rates of nutrient assimilation by phytoplankton and what limits the growth of the phytoplankton assemblage and, 4) the sources, quantities, and effects of toxic pollutants introduced into the Florida Bay ecosystem.

Proposed Actions:

● Map and correlate microalgal bloom event in relation to basic physical and chemical variables and identify nutrient sources and fluxes that may regulate blooms. DEP is conducting or sponsoring the phytoplankton studies and cooperating with BAYWATCH and existing nutrient sampling efforts funded by the SFWMD. Ongoing.

● Determine the ambient water quality and nutrient levels in the western portion of Florida Bay. DEP and SFWMD are sponsoring this study. Start Date: February 1994.

● Determine ambient water quality and nutrient levels in Florida Bay ENP boundaries. Sponsored by SFWMD. Start Date: on-going.

● Develop a citizen based algal bloom monitoring program for Florida Bay called BAYWATCH. Sponsored by SFWMD. Start Date: February 1994

Topic 3. Assess seagrass, mangrove, and hardbottom habitats to determine 1) environmental factors significant to seagrass physiology, growth and reproduction and determine to what degree a synergy between these has resulted in their distribution and caused the recent die-off, 2) environmental factors significant to mangrove physiology, growth and reproduction and how they have affected distribution within the Florida Bay ecosystem and 3) the cause and consequence of sponge die-off and subsequent alteration of hardbottom communities.

Proposed Actions:

● Determine the present distribution and abundance of benthic macrophytes and compare the present conditions with conditions ten years before, assess the vigor of turtle grass, and determine the severity and recovery potential of mangrove die-off. DEP is conducting or sponsoring these studies. Ongoing.

● Evaluate the effects of changing lobster nursery habitat (sponge die-off) on recruitment to the fishery and develop a predictive capability regarding habitat change and lobster populations. DEP is conducting and sponsoring this study. Ongoing.

● Determine seagrass response to salinity and nutrients. Conducted by SFWMD and cooperative agreement. Start Date: Mid-1994.

● Biology in Joe Bay and Long Sound. Sponsored by SFWMD. Ongoing.

Topic 4. Assess living resources to determine 1) changes in the distribution and abundance of living resources as a result of habitat change, 2) whether habitat degradation is causing reduced fisheries productivity reflected in recreational and commercial landings since the 1960's, 3) if reduced availability of resources has resulted in declines in populations of protected species in the Bay and adjacent coastal waters, 4) whether the quality of water from Florida Bay is contributing to degradation of the coral reef tract and, 5) whether changes in Bay habitat have caused declines in bird abundance and diversity.

Proposed Actions:

● Establish baseline data on distribution patterns of fauna prior to restoration efforts and continue sampling to evaluate change in faunal communities as restoration proceeds. Conducted by DEP. Ongoing.

● Identify, collate and synthesize information on temperature and salinity tolerances of recreationally important species in Florida Bay and evaluate the potential effects of restoration on these species. Conducted and sponsored by DEP. Ongoing.

Future Actions or Needs

- Increase research and monitoring efforts in Florida Bay through a DEP legislative budget request in the 1994 legislature and by DEP and SFWMD using collective resources to leverage additional federal contributions to the science programs of the south Florida ecosystem. Sponsored by DEP and SFWMD
- Establish a GIS oriented data management system that fosters data exchange and cooperative analysis for science based resource management of the region. Sponsored by DEP and SFWMD.
- Initiate a re-mapping of the benthic communities of Florida Bay.
- Establish a monitoring program in Taylor Slough and the C-111 sub-basin to adequately define hydrologic regimes and change in those regimes.

3) Hydroperiod and Water Quality Restoration Through Land Acquisition

Discussion

Historic water management practices are contributing to the alteration of the hydroperiod of the Taylor Slough. The reduced freshwater flows and alteration of the pre-development quality, quantity and timing of freshwater into the system are thought to be a major contributing factor to the hypersaline conditions and abrupt salinity changes in Florida Bay.

Hydroperiod restoration will require an integrated approach combining engineering and land acquisition. However, a consensus approach to the engineering design has not been reached. The U.S. Army Corps of Engineers preliminary draft of the C-111 General Re-evaluation Report (GRR) proposed a series of alternatives designed to enhance hydroperiod restoration to Taylor Slough and the C-111 canal. The proposed alternatives involve a land acquisition component. A flexible process to purchase the lands required for implementation of the approved Army Corps of Engineers alternative when finalized is lacking

Two state land acquisition programs acquire lands necessary for restoration, the Conservation and Recreation Lands program administered by the Department of Environmental Protection, and the Save Our Rivers Program administered by the South Florida Water Management District. Innovative, flexible acquisition strategies must be developed for both of these programs

For either program to purchase lands, the land must be part of an approved project. Fortunately, the East Everglades CARL project and the Frog Pond/L-31N SOR project, both considered critical to restoration of Taylor Slough and Florida Bay, are existing approved projects.

The East Everglades CARL acquisition project comprises 100,563 acres in western Dade County. The project borders Everglades National Park and is considered critical to the park's ecosystems. East Everglades serves as a water storage area that will prevent flooding and serves as a recharge area for well fields in south Dade County. The East Everglades CARL project has a pending addition which overlaps the Frog Pond/L-31N Transition Lands Save-Our-Rivers (SOR) project. The East Everglades addition is a 15,435 acre study area consisting of three separately named but spatially continuous parcels: the Eight-and-a-half Square Mile Area, the L-31N Buffer Strip (also called the Rocky Glades), and the Frog Pond. Over 95% of the area is disturbed to the extent that the Florida Natural Areas Inventory (FNAI) does not classify the area as a natural community. The natural communities remaining on each of the three parcels have been subject to a variety of differing land uses ranging from very limited disturbance to complete removal of natural communities as a consequence of extensive and ongoing agricultural enterprises. Associated with this variation in land uses are changes to the natural topography of each area.

The Frog Pond/L-31N SOR project is located within the boundaries of the larger East Everglades CARL project. These lands have been identified in one or more of the Army Corps of Engineers GRR alternatives as having crucial importance to the restoration of more normal hydrologic conditions in the eastern part of Everglades National Park and to the principle freshwater feature of the park, Taylor Slough. It is widely held by local, state, and national scientists that an increase in surface water levels and flows from and through the historic headwaters of Taylor Slough is necessary to reestablish natural conditions in northeast Florida Bay.

There is no consensus on which, if any, additional parcels of land not included in a CARL or SOR project are needed to restore the hydroperiod and water quality of the area. Identification of these lands needs to be coordinated with on-going restoration planning activities.

Implementation

Proposed Actions:

- Support the SFWMD initiative to add the Frog Pond and L-31 N Transition Lands to the East Everglades CARL Project. (DEP; February 1994).
- Support legislative initiatives to use CARL trust fund dollars to be used on a dollar-for-dollar matching basis with the SFWMD funds to purchase lands in the Frog Pond, the L-31N Transition Lands, and any additional lands needed for the primary purpose of Taylor Slough/Florida Bay restoration. (DEP & SFWMD; June 1994)
- Coordinate land acquisition efforts between DEP and SFWMD. Formalize with agreement. (June 1994)
- Identify, jointly with Army Corps of Engineers and the National Parks Service, additional parcels of lands which may be needed for implementation of restoration activities. (DEP & SFWMD; September 1994)
- Pursue adding identified projects to the CARL and SOR lists or amend existing project boundaries. (DEP & SFWMD February, 1995)
- Establish flexible strategy for land acquisition to purchase lands required for implementation of the approved C-111 GRR alternative, when finalized and future Taylor Slough/Florida Bay restoration plans. (DEP & SFWMD; June 1995)
- Cooperatively develop and implement Taylor Slough and Florida Bay restoration plans with SFWMD, Corps of Engineers, Everglades National Park, and Department of Environmental Protection. (DEP & SFWMD; June 1998)

Future Actions or Needs

- Investigate and develop innovative permitting processes that facilitate restoration projects that have a net environmental benefit.

1994 REPORT
INTERAGENCY WORKING GROUP
ECOSYSTEM RESTORATION AND MAINTENANCE

DRAFT: AUGUST 19, 1994

On September 23, 1993, a five-year Interagency Agreement on South Florida Ecosystem Restoration was signed by the Departments of Interior, Commerce, Army, Justice, and Agriculture, and the Environmental Protection Agency. The task force resulting from this agreement coordinates "the development of consistent policies, strategies, plans, programs and priorities for addressing the concerns of the South Florida ecosystem." It has tasked an 11-member working group with responsibility annually to formulate and recommend to the task force management policies, strategies, plans, programs, and priorities for ecosystem restoration and maintenance. A draft of this first annual report follows. The working group recognizes that significant improvements may need to be made prior to the final transmission of this report, ranging from addition of suitable graphics and maps to substantive changes in content.

DRAFT 1994 REPORT
INTERAGENCY WORKING GROUP
ECOSYSTEM RESTORATION AND MAINTENANCE

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LIST OF ACRONYMS

ADID	Advances Identification
AF	acre-feet
APHIS	Animal and Plant Health Inspection Service
ARS	Agricultural Research Service
ATLSS	Across Tropic Levels System Simulation
BIA	Bureau of Indian Affairs
BMP	Best Management Practice
CARL	Conservation and Recreational Lands Program
cfs	cubic feet per second
COE	Corps of Engineers
DEIS	Draft Environmental Impact Statement
DEP	Florida Department of Environmental Protection
DOA	Department of Army
DOC	Department of Commerce
DOI	Department of Interior
DOT	Department of Transportation
EA	Environmental Assessment
EAA	Everglades Agricultural Area
EIS	Environmental Impact Statement
ENP	Everglades National Park
EPA	Environmental Protection Agency
ET	evapotranspiration
FACA	Federal Advisory Committee Act
FEMA	Federal Emergency Management Agency
FWS	U.S. Fish and Wildlife Service
FY	fiscal year
GEIS	Generic Environmental Impact Statement
GFC	Game and Fish Commission
GIS	geographic information system
IFAS	Institute of Food and Agricultural Sciences
LOTAC	Lake Okeechobee Technical Advisory Committee
MDWASA	Metropolitan Dade Water and Sewer Authority
mg	milligram
mgd	million gallons per day
mg/L	milligram per liter
NBS	National Biological Survey
NGO	non-governmental organization
NGVD	National Geodetic Vertical Datum
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollution Discharge Elimination System
NPS	National Park Service
OMB	Office of Management and Budget
ppb	parts per billion
ppm	parts per million
SCS	Soil Conservation Service
SFWMD	South Florida Water Management District

SJRWMD	St Johns River Water Management District
SOR	Save Our Rivers
SRF	Systematic Reconnaissance Flights
STA	stormwater treatment area
SWIM	Surface Water Improvement and Management Plan
TMP	Technical Mediated Plan
TOC	Technical Oversight Committee
TMDF	total maximum daily flow
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
WCA	Water Conservation Area
WES	Waterways Experiment Station, COE

NOTE TO REVIEWERS

On September 23, 1993, a five-year Interagency Agreement on South Florida Ecosystem Restoration was signed by the Departments of Interior, Commerce, Army, Justice, and Agriculture, as well as the Environmental Protection Agency. This agreement was a first--a federal effort formally establishing the South Florida Ecosystem Restoration Task Force made up of assistant secretaries and taking on responsibility for coordinating the development of "consistent policies, strategies, plans, programs and priorities for addressing the concerns of the south Florida ecosystem."

To help accomplish this, the Task Force established a management and coordination team, known as the Interagency Working Group, comprised of 11 agency managers with management and/or regulatory responsibilities in south Florida. This group was charged with developing and submitting a south Florida ecosystem restoration report to the Task Force within a year.

To accomplish this task, the Interagency Working Group appointed three sub-groups: on science, on infrastructure, and on management. These groups were responsible for reporting back to the Working Group, as well as contributing to the development of federal ecosystem strategies and coordination in south Florida. The Working Group also met regularly as its members began the complex and intensive process required to produce the following report.

As you read, keep in mind the nature of this report. Requirements of the Federal Advisory Committees Act have made it difficult for the Interagency Working Group to quickly and comprehensively incorporate the resources and experience of all levels of government currently involved in south Florida land and natural resource management issues. Numerous state and local groups have been working for years on land and water issues linked to Florida's agricultural, ecological and recreational interests. For years individual federal agencies have been involved with them on various projects. However, these projects have not been carried out within the framework of an ecosystem management strategy. Such a framework is only now beginning to evolve. The federal Task Force is one avenue through which ecosystem restoration is being approached. The Governor's Commission for a Sustainable South Florida, the Man and the Biosphere program, the ecosystem management by the Florida Department of Environmental Protection, and the work of the South Florida Water Management District are other prominent efforts.

Think of these groups as operating on parallel tracks, connected by their efforts on behalf of sustainability and ecosystem restoration rather than by a single mandate or mechanism tasking them to carry out a mutual set of goals. If you can picture this, you will have a better sense of the complex level of activity in south Florida today as parallel interests attempt to converge.

Contributing to this convergence, the Interagency Working Group has begun to hold its public meetings in conjunction with the Governor's Commission on Sustainable Development to encourage close coordination and wide attendance, while avoiding as much duplication as possible. The goal is to generate an atmosphere in which information is shared freely and communication takes place effectively. Certainly, much remains to be done before all the ecosystem-related efforts and the groups responsible for carrying them out coalesce behind a unified vision and a coordinated effort. However, coincidentally scheduling public Working Group meetings is an important step in that direction.

In the meantime, this draft report is intended as a starting point for comment. The Working Group intends to reach out to south Florida groups through the public comment process, drawing on a full range of expertise that, to date, has been unavailable. Comments received will be considered in the report finally adopted and transmitted to the Task Force, the first of five annual reports by the Interagency Working Group.

The purpose of this draft is to indicate how far the work of the participating federal agencies has gone and where those agencies stand in developing a strategy and in carrying out their responsibilities to the south Florida ecosystem. Undoubtedly, there are gaps in information, recommendations and issues being worked on by other entities that may be more fully addressed this year as a result of public comment, or developed in next year's report or the ones that follow.

The Interagency Task Force, through its Interagency Working Group, is not yet in a position to propose a comprehensive, fully integrated restoration plan for the south Florida ecosystem. That will come as the result of ever-closer relationships and consensus with non-federal groups also carrying out ecosystem restoration. However the Working Group is making a series of recommendations that should lead toward the development of that plan as well as continue coordinated steps toward ecosystem protection. In addition to this report, the Interagency Working Group has completed the first Task Force initiative—to assist the Corps of Engineers with their reconnaissance study of the Central and Southern Florida Flood Control Project (Appendix A).

As you read, be aware that a multiplicity of activity is occurring throughout south Florida--that the energy and necessity motivating ecosystem restoration is occurring at the state and local levels as well as throughout the scientific community. Since this report is strictly a federal effort, it does not reflect the important contributions of these other groups. Please be aware that these other efforts exist as you consider the following report and its recommendations. Make your voice heard by providing ideas on how to improve the federal effort, as well as how better to integrate it with state and local government. Those involved in the federal effort recognize that full restoration of the south Florida ecosystem cannot be accomplished until local, state, scientific, and federal efforts are combined.

We look forward to hearing from you between now and mid-September regarding this year's report. We hope to continue hearing from you as matters arise that you feel require our attention.

Management and Coordination Working Group

I. FROM KISSIMMEE THROUGH THE KEYS: INTRODUCTION TO THE PROBLEM

A. *Introduction*

Water is life in south Florida--from the head waters of the Kissimmee to the end of the Florida Keys, which define the ecosystem. For the area's animal and plant populations, as well as its human community, clean, abundant water has been fundamental to prosperity and growth. Yet urban development of south Florida during the past 100 years has altered natural processes, and shifted the centuries-old relationship between land and water.

Channelization of water flow and drainage, as well as the filling of wetlands--long accepted means for land development--have gradually altered natural communities and the hydrologic regime. Over the past years, the south Florida ecosystem has shown increasing signs of stress, with a severe loss of its wading birds, and 56 plant and animal species either threatened with, or endangered by, extinction. Wetlands loss, organic soils subsidence, exotic plant and animal invasions, and such catastrophic events as algal blooms, seagrass and mangrove die-offs, and coral diseases manifest ecosystem stress in south Florida at a time when protection of the area's drinking water supply, as well as its diverse plant and animal communities, depends on a stable, healthy system.

Many regard the catastrophic changes in Florida Bay as harbingers of south Florida's future, failing corrective action. From estuary to marine lagoon, the Bay now contains areas in which salinities exceed sea water strength, a condition that many feel has led to the loss of of thousands of acres of seagrass, continuing algal blooms, and fish kills.

Before human intervention in the south Florida area, a stable, predictable hydrologic system sustained fish and wildlife populations and their habitat. Changes occurred when human populations required increased acreage of dependable dry land. Few realized the impact that lowering the water table could have on the overall system, only one of which was allowing sea water to flow into the estuaries and infiltrate parts of the fresh-water aquifer.

Although resource managers now better understand the interconnectedness of the south Florida ecosystem, this understanding comes at a time when the area's human population has grown to slightly more than six million--about half Florida's total population. Attracted by the area's mild climate, they have contributed to the state's two most significant industries, agriculture and tourism.

South Florida's mild temperatures provide an extended growing season which, in conjunction with effective water drainage, has made agriculture a year-round endeavor. Citrus, cattle, sugarcane and vegetable farming dominate, while commercial fishing for fin fish, shrimp, lobster and crab lead the marine industries.

Tourism, the largest industry in south Florida, attracts international travelers to the eastern and western seaboards, as well as to the Florida Keys. They come for diving, snorkeling, and recreational fishing, to relax in the sun and enjoy the climate. They contribute approximately $77 million to the economy from recreational fishing. (need reference) The resulting economic growth, which has impacted population growth, has focused attention on infrastructure flood control and drinking water supply issues.

Tourism and agriculture, as well as the quality of human life depend on environmental quality. But if human populations have altered the natural system, how can commerce and environmental quality coexist? Some have translated this dilemma into a debate between the economy and the environment. In reality, the two are so closely linked that the economy may not be sustainable if the ecosystem supporting it fails.

The challenge of the Task Force on South Florida Ecosystem Restoration is to help propel the community of south Florida with its varied array of stake holders to a state of balance where human activities and a healthy environment coexist.

B. Partners In The Solution

The September 1993 signing of the Interagency Agreement on the South Florida Ecosystem led to the creation of the Task Force, as well as its Working Group, whose membership comprises various federal agencies. As a federal entity, the Interagency Working Group (IWG) conducts itself in accordance with the Federal Advisory Committees Act, which makes it difficult for the group to comprehensively incorporate the resources and experience of non-federal organizations currently involved in south Florida land management issues. Given the legislative limits within which it has been necessary to operate, the IWG still has attempted to encourage communication by keeping its meetings public. Formal partnership with the state of Florida, the South Florida Water Management District, the Florida Department of Environmental Protection, other state agencies, and local and tribal governments, as well as the public does not exist at the present time. However, federal IWG members recognize that full restoration of the south Florida ecosystem cannot be accomplished until local, state, scientific, and federal efforts are combined, and they are working toward that end. Indeed, public involvement in this restoration effort is critical, if change is to occur successfully at the grassroots level.

In a very broad sense each resident of south Florida holds a stake in the process. The area's two dominant industries, agriculture and tourism, depend on ecosystem health. So does the quality of urban life. Adequate drinking water not only impacts the way Floridians live but also affects other components of the ecosystem. Certainly local, state and federal agencies with trustee responsibilities for south Florida's natural resources are vested in this effort. Working with the public for productive change, the following federal agencies play important roles as Working Group members:

U. S. Department of Interior

The National Park Service administers three national parks (Everglades, Biscayne and Dry Tortugas), and one national preserve (Big Cypress) in south Florida. It assists with state and local conservation and recreation planning.

The Fish and Wildlife Service administers 10 national wildlife refuges, manages all actions under the Endangered Species Act, provides comments on comprehensive wetland programs including permitting, carries out authorities of the Fish and Wildlife Coordination Act and enforces federal wildlife laws.

National Biological Survey, a newly formed agency, is responsible for inventorying, monitoring, and conducting research on biological resources.

United States Geological Survey provides geologic, topographic, and hydrologic information.

Bureau of Indian Affairs has trust responsibility for south Florida's federally recognized Miccosukee and Seminole Indian Tribes.

U. S. Department of Commerce

National Oceanic and Atmospheric Administration (NOAA) has the trusteeship responsibilities for U. S. marine resources, and extensive research capabilities in marine and atmospheric research, some of which address south Florida issues. The agency has the following main line components:

- *National Marine Fisheries Service (NMFS)* reconciles conflicts between water resource projects and marine resources; handles review and permit processes pertaining to marine resources; consults, evaluates, and reports on marine species; protects cetaceans; and manages marine fishery resources.
- *National Ocean Service (NOS)* administers the Florida Keys National Marine Sanctuary and administers the Coastal Zone Management Program which provides assistance to states for planning.

OOAR has no information available.

COP has no information available.

U. S. Department of Agriculture

Soil Conservation Service provides technical assistance to farmers and ranchers; maps the nation's soils, and develops erosion-resistant plants; provides flood prevention and water conservation assistance for irrigation, recreation, wildlife habitat and other uses; and through local water resources research, enabling local governments and citizen groups to plan water-related needs.

Agricultural Research Service (ARS) is the primary in-house research arm of the Department of Agriculture, carrying out research in categories ranging from soil, water and air to systems integration.

U. S. Department of the Army

U. S. Army Corps of Engineers (Corps) has flood control authority in central and south Florida; and is responsible for water deliveries to Everglades National Park; for restoration of the Kissimmee River; and for studying the effects of modifying the Central and Southern Florida Flood Control Project on environmental quality, aquifer protection, and urban water conservation. Under the Clean Water Act the Corps issues all federal permits for dredge or fill of wetlands.

U. S. Department of Justice

U. S. Attorney's Office for the Southern District of Florida represents federal agencies in judicial actions involving the United States in south Florida.

U. S. Environmental Protection Agency

The Environmental Protection Agency is charged with restoring and maintaining the chemical, physical and biological integrity of the nation's water, as well as permitting discharges. In addition, it is required to develop a water quality protection program for the Florida Keys National Marine Sanctuary, and to recommend priority corrective actions and compliance schedules addressing point and nonpoint pollution.

II. MOSAIC OF WATER, LAND AND PEOPLE: UNDERSTANDING THE PROBLEM

A. *The Natural System*

The south Florida ecosystem encompasses approximately 28,000 square kilometers with at least 11 major physiographic provinces: Everglades, Big Cypress, Lake Okeechobee, Florida Bay, Biscayne Bay, Florida Reef Tract, nearshore coastal waters, Atlantic coastal ridge, Florida Keys, Immokalee Rise, and Kissimmee River Valley. Kissimmee River, Lake Okeechobee, and the Everglades form the watershed that connect a mosaic of wetlands, uplands, coastal areas, and marine areas.

Prior to drainage, which began in the late 1800s, wetlands covered most of central and southern Florida (Fig. 1). The Everglades region, nearly flat and sloping slightly from east to west, was nevertheless heterogenous in landscape, sculpted by 5,000 years of hydrologic and biological evolution on a Pleistocene limestone platform. A circa 1850 military map (Ives 1856) provides the best template for determining pre-drainage conditions.

The pre-drainage landscape was characterized by swamp forest; sawgrass plains; mosaics of sawgrass, tree islands, and ponds; marl-forming prairies dominated by periphyton; wet prairies dominated by Eleocharis and Nymphaea, cypress strands, pine flatwoods, pine rocklands, tropical hardwood hammocks, and xeric hammocks chiefly of oak. The estuarine-coastal system had its own identity: shallow seagrass beds, riverine and fringe mangrove forests, intertidal flats, coral reefs, hard bottom communities, mud banks, and shallow, open inshore waters. Land and water interconnected on a topographic gradient ranging from about 20 feet above mean sea level at Lake Okeechobee to below sea level at Florida Bay. Sustaining these communities was a hydrologic system that stored and released water on a large scale over a vast territory of diverse habitats, home to innumerable plants and animals.

B. History of Change

The first haphazard efforts in the late 1800s to drain portions of south Florida were followed in the early 1900s by the creation of the Everglades Drainage District, established to encourage Everglades drainage for agricultural and urban use, especially south of Lake Okeechobee in what is now the Everglades Agricultural Area (EAA). By 1929, 440 miles of canals and levees had been constructed, including four major canals draining southeastward from Lake Okeechobee to the Atlantic Ocean.

In 1926 a hurricane swept water from Lake Okeechobee southward killing 400 to 500 people. In 1928 another hurricane killed 2,400 people living in farming communities within the EAA and the city of Okeechobee. Consequently, the federal government built Hoover Dike around a portion of Lake Okeechobee in the 1930s. Drought and subsequent fires prevailed until 1947, when two hurricanes inundated the region, causing about $60 million of property damage.

Congress declared the need for a regional master plan balancing flood control and water supply protection. In 1948, the Army Corps of Engineers assumed responsibility for a comprehensive state-federal water control program known as the Central and Southern Florida Flood Control Project (C&SF) that would cover 15,000 square miles. Congress authorized $208 million.

Designed and built by the Corps, the C&SF is maintained and operated both by the Corps and by the South Florida Water Management District, the local sponsor. It includes:

- 990 miles of levees
- 978 miles of canals
- 30 pumping stations
- 212 flood control or water diversion structures
- secondary water management systems constructed by local interests.

Costing approximately $1 billion, with much of the work completed during the 1950s and 1960s, C&SF work includes:

- channelization of the Kissimmee River into a 56-mile canal with control structures
- a levee surrounding Lake Okeechobee (730 square miles) with control structures, hurricane gates and pumping stations
- encirclement of the 1000 square mile Everglades Agricultural Area by canals and levees, with 7 pumping stations to provide forced drainage
- an east coast protective levee for urban flood control extending from the eastern shore of Lake Okeechobee 130 miles southward to Homestead
- local protective works along the developed lower east coast
- three multi-purpose Water Conservation Areas—one the Loxahatchee National Wildlife Refuge—(totaling 1137 square miles) in the Everglades west of the east coast levee with control structures to effect water transfer, including transfer to Everglades National Park

Authorized project purposes include flood control, water supply, drainage, fish and wildlife preservation, Everglades NP water supply, recreation, navigation, and saltwater intrusion prevention. The C&SF Project was designed to accommodate the area's high evapotranspiration rates, significant overland flow, subsurface flow in highly transmissive aquifers, pronounced wet and dry seasons, drought, intense rainfall, tropical storms, low coastal elevations and other hydrologic characteristics. Complex water quality demands and growing environmental awareness made resolving conflicting priorities within the multi-purpose C&SF Project more and more difficult.

C. Other Forces That Changed The System

1. Population Growth: In the 1800s Seminoles and Miccosukees chiefly populated south Florida because floods and hurricanes discouraged the region's urban and agricultural development. Growth occurred only in such naturally well-drained areas as the Atlantic Coastal Ridge.

In 1890 the population of the area presently encompassed by Dade, Broward and Palm Beach Counties was 861, while nearly all of the lower west coast population of 20,200 was located in Key West—in contrast to the current population of south Florida that numbers more than 6 million. The population of what became the South Florida Water Management District (SFWMD) was 32,000.

Comprehensive flood control has helped to transform the area, expanding developable acreage, which resulted in increased population and appraised property value:

- The lower east coast population was about 215,000 in 1930, 694,000 in 1950, 2.2 million in 1970 and 4.0 million in 1990.
- The population of the 18 counties within SFWMD boundaries was 727,097 in 1945, and 6.3 million in 1990.
- Population projections show south Florida tripling within 50 years.
- The appraised property value was $1.2 billion in 1950, $240 billion in 1991.

2. *Land Use Conversions:* Highly fragmented, the south Florida ecosystem contains four wetland landscapes now reduced to remnants: the cypress strands fringing the western side of the Atlantic coastal ridge, the pond apple forest/swamp on the southern shore of Lake Okeechobee, the tall sawgrass plain of what is now the Everglades Agricultural Area (EAA), and the biologically important peripheral wet prairies (Davis et al. 1994).

- On the east coast ridge, only 10% of the former rockland pinelands and 10% of the tropical hardwood hammocks persist; stressed by a lowered water table and introduced exotics, they are more vulnerable to natural disasters.
- Compartmentalizing the Everglades further fragmented the system by creating a series of poorly connected wetlands.
- Urbanization fragmented the upland systems and placed stress on the ecosystem's water supply and water storage capacity.
- Roughly 50% of the pre-drainage wetlands have been lost to agricultural, industrial, and residential development (Fig.), especially the peripheral (short hydroperiod) wetlands on the eastern side of the Everglades, and continue to be incrementally diminished by wetland permitting programs.
- Wetland loss has reduced landscape heterogeneity and long-term population survival for vertebrate species requiring extensive territory, among them wading birds, snail kites, and panthers.
- Decreasing the extent of south Florida's wetlands has reduced the solar collector area feeding aquatic productivity.

By any measure of species richness, there has been a drastic erosion of south Florida's biodiversity.

In their natural condition, the Everglades and other wetlands were naturally flowing systems that not only covered a greater area but also exhibited longer inundations and more sustained outflows to estuaries than exist in their current managed state. With decreased wetlands has come a decrease in the function, sheet flow, and base flow of wetlands. Water management significantly changed the volume and timing of water flow, as well as overland flow patterns across wetlands and into estuaries.

3. *C&SF Project:* The 1948 cost-benefit analysis that justified the C&SF Project projected the greatest benefit to be the increased land use. Since the project's initiation in the late 1940s, rapid growth has increased the demand for flood control and water supply to meet municipal, industrial, agricultural, and environmental needs. Although millions of acres of south Florida have been placed in public ownership, the ecological condition of the Everglades watershed ecosystem continues to deteriorate. Increased concern and often conflicting expectations regarding flood control, environmental restoration, and competition for water resources have led to the need for an in-depth comprehensive study of the multi-purpose C&SF Project.

D. The Ecosystem Today

Though altered considerably from its pre-drainage condition, the south Florida ecosystem is vitally important to both the economy and the ecology of the nation. It is:

- the predominant source of fresh water for Florida's most populous region
- home to 56 federally-listed threatened or endangered species and 29 candidate species
- the principal nursery area (Florida Bay and adjacent estuaries) for the largest commercial and sport fisheries in Florida: This area is important to bottlenosed dolphin and is an important developmental and nesting habitat for nesting sea turtles.
- home of the largest wilderness east of the Mississippi River
- location of the only living continuous coral reef system adjacent to the continental United States (the third largest barrier reef community in the world)
- site of the two federally-recognized nations of the Seminole Tribe of Indians and the Miccosukee Tribe of Indians of Florida
- an international commercial and tourist center
- primary domestic producer of the nation's sugar and

winter vegetables

- home of an expanding population exceeding 6 million people
- the location of Lake Okeechobee and other world class sport fishing areas
- the most significant breeding ground for wading birds in North America; wintering grounds for more than half the nation's wood stork population and more than 100,000 white ibises; staging area for glossy ibises, peregrine falcons, and swallow-tailed kites migrating between breeding and wintering grounds
- home of 3 national parks, 1 national preserve, 10 national wildlife refuges, 1 national marine sanctuary, and numerous areas protected under state or local ownership
- home of the Everglades, designated by the United Nations as a World Heritage Site and a World Biosphere Reserve, and by the International Union for the Conservation of Nature as a Wetland of International Significance
- the world's largest organic soil deposit

E. Restoration Issues

Although vast areas of south Florida have been set aside as protected public areas, symptoms of ecological decline continue to increase. The region faces major environmental issues:

- planning for regional population growth (expected to triple within 50 years)
- competition for a finite water supply among an expanding urban population and agricultural interests and remnant natural resources
- identification and implementation of the structural and operational modifications to the C&SF Project needed to restore the ecosystem
- nutrient enrichment of the Everglades and coastal marine ecosystem by agricultural drainage or urban waste water
- declining health of the coral reef system
- permitting and mitigation programs ineffective in preventing loss of remaining natural uplands and wetlands
- purchase and public ownership of critical unprotected lands in south Florida's watershed
- extensive mercury contamination of freshwater fish and other biota
- increase in introduced (exotic) plants and animals and decline in native species
- incomplete understanding of what constitutes a functioning system for the area, as well as conflicting views on restoring the water system

- lack of public understanding of ecosystem values and the human environment
- natural resource compatible recreational access
- lack of consensus on the causes of and solutions for ecosystem degradation
- adequate financial commitment to ecosystem restoration
- organic soil subsidence
- minimization of water quality degradation and maximization of water conservation through structural and agronomic management practices in urban and agricultural areas
- sustainable economic development
- ecological degradation of Florida Bay including extensive algal blooms and seagrass die-off

F. Sustainability: Balancing Environment And Use

Growth in south Florida has followed a cyclical pattern: increasing population has required increasing commercial development, which in turn has paved the way for new population growth. This cycle of change has placed intense demands on the area's water supply, flood control, shelter and service as public systems continually have adjusted to meet demand.

This is south Florida today, possessed of a wealth of resources diminishing in the face of increased demand. The challenge is to balance environmental and urban landscapes, preserving the one and satisfying the resource needs of the other. One potential answer to this dilemma is the emerging concept of sustainable development, which seeks to achieve balance between environment and use. Defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs," (needs citation) it has four dimensions: economic, human, environmental and technological. Integrating these components into policy, planning and design should allow industry and a healthy ecosystem to coexist.

For the purposes of the present federal planning effort, sustainability is being defined as "the wise, appropriate and efficient use of resources, so that population and demand do not outrun or damage the environment's long-term life-supporting ability" (Frank and Brownstone, The Green Encyclopedia, 1992 Prentice Hall). In south Florida, this means that ecosystem restoration and maintenance must be accomplished within the context of a healthy economy.

How does one accommodate continued growth in south Florida while simultaneously halting or at least reducing symptoms of ecosystem decline? While the need to grow in order to maintain economic health is apparent, managers are recognizing the need for potential trade-offs to maintain environmental integrity. Industrial growth that once transformed "useless" swamps and flatwoods into developed land is being reevaluated as beneficial wetlands functions become better understood. In south Florida now, the public places increased importance on preserving undeveloped lands and regaining lost wetland benefits by restoring high-value natural areas such as the Kissimmee River.

However, the current philosophy of sustainability cautions managers against halting management practices until scientific consensus can be reached, and encourages them to recognize the impossibility of managing for the sustained use of non-renewable resources. The challenge, of course, is to find a way to apply sustainable development theory to the specific problems in south Florida. Ludwig et. al (1993) recommend five principles relevant to this restoration effort.

- Include human motivation and responses as part of the system to be studied and managed.
- Act before scientific consensus is achieved.
- Rely on scientists to recognize problems, but not to remedy them.
- Distrust claims of sustainability.
- Confront uncertainty and allow for decision making in the face of uncertainty, building flexibility into a long-range process so as to respond to changing conditions.

The Interagency Working Group has adapted these principles to guide its interagency efforts and establish its strategies for Everglades restoration.

G. *Ecosystem Management Objectives*

The Interagency Working Group recommends that all Task Force management coordination and restoration activities be conducted consistent with the following broad objectives:

1. *Florida Bay, Estuaries, and Near Coastal Waters*
   - Restore and sustain healthy ecosystem conditions in these waters, which allow natural processes, functions, and cycles to continue or be re-established.
   - Manage use of natural resources (commercial, sport fisheries, and others) to maintain sustainable populations.
   - Maintain the health and biodiversity of the coral reef ecosystem component.

2. *Fresh Water*
   - Manage the hydrological conditions in the remaining undeveloped and potentially restorable lands in a way that maximizes natural processes characteristic of the historic south Florida ecosystem (including water quality, quantity, distribution, timing, and

biological integrity). Restoration of the natural system will be evaluated and implemented to maximize benefits to the overall ecosystem.

- o Develop and manage the total hydrologic system to maximize ecosystem restoration while providing appropriate consideration to meet the needs of urban, agricultural, and man-made components. The Working Group recognizes that future management of the system will require shared adversity where the full range of hydrologic needs cannot be fully met.

3. *Development*

- o Ensure that any development plans or permits for development are fully coordinated among affected governmental agencies and are compatible with restoration of the south Florida ecosystem.
- o Ensure that existing development that has an adverse impact reduces or eliminates degradation and that new development does not contribute to degradation.
- o Develop and use a system-wide integrated mitigation plan, coordinating all levels of government, which contributes to overall restoration.
- o Ensure that regardless of any future development there is a sufficient land, water, and resource base to conduct the required natural resource restoration efforts.

4. *Research*

- o Implement a coordinated research program to develop an understanding of the physical, chemical, and biological processes essential to achieving restoration of the south Florida ecosystem.

5. *Plants and Animals*

- o Restore and maintain the biodiversity of native plants and animals in the upland, wetland, marine, and estuarine communities of the south Florida ecosystem.
- o Eradicate or control invasive exotic plants and animals.
- o Provide for adequate natural habitats for native plants and animals.
- o Recover species that are threatened or endangered.

6. *Education*

- o Coordinate a multi-cultural information and education program to ensure that the public is informed of the unique values of the south Florida ecosystem and that they are regularly apprised of the environmental, social, and economic benefits of restoration.

7. *Indian Nations*

- Provide for the implementation of Tribal resource development consistent with sound water management and environmental principles, and as compatible as possible with restoration.
- Provide protection of the reservations from adverse water quality and quantity impacts, either through upstream controls for other use impacts or funded on reservation mitigation for impacts.
- Provide for timely restoration of the ecosystem in WCA-3A to protect tribal rights.

III. BUILDING BLOCKS OF RESTORATION: DEFINING ECOSYSTEM RESTORATION, PROTECTION AND MAINTENANCE

Water created the south Florida ecosystem, and water management practices have critically altered it. This makes hydrologic restoration--the natural distribution of quality water in space and time--a necessary starting point for ecological restoration. How the hydrologic system is managed affects land use, a critical factor in planning for restoration. In recognition of the role supportive land use planning and permitting can play in restoration success, the Interagency Task Force follows three objectives:

- Support development of a comprehensive wetland permit mitigation strategy for south Florida that furthers ecosystem restoration.
- Reduce constraints on economic expansion by increasing the overall water supply and improving quality of life.
- Address south Florida's water quality and supply, as well as subsidence of organic soils so as to provide for more sustainable economic opportunities while improving natural ecosystem sustainability, recognizing that current urban, economic, and agricultural growth rates are not sustainable.

A. The Altered System

Changes in the hydrologic structure of south Florida, which began before the turn of the century when Hamilton Disston connected the Caloosahatchee River with Lake Okeechobee in 1883 and culminated with the 1948 implementation of the Central and Southern Florida Project, created an intricate network of levees, canals, and pumping stations for flood control, drainage, and water supply. Flood control made possible massive land-use changes that decreased the availability of land for water storage and recharge. The current hydrology of south Florida functions not at all as it did prior to the 1800s.

1. Soil Subsidence: Extensive drainage for agricultural purposes south of Lake Okeechobee caused tremendous organic soil losses. Without water, the soil became denser and drier--one of the first environmentally destructive effects of drainage--resulting in losses of 5 or more feet of soil by 1984 (Stephens 1984) and now calculated at 3 cm per year, a substantial loss when the maximum thickness was only 12 to 14 feet initially. Although soil loss still continues, the process has been slowed by reflooding fallow fields and maintaining a high water table.

Soil loss of such magnitude has heavily impacted Everglades hydrology and ecology, especially the elevation gradient from the upper to the central Everglades. Soil loss has meant elevation loss, which has meant loss of the hydraulic head that once naturally drove water south. Moving water from north to south now requires pumping, an effort that grows more extensive as soils continue to subside. In addition to impacting elevation, soil loss has also meant reduction in water storage capacity--the area's ability to absorb water, thus balancing seasonal and long-term variations in rainfall.

Add to the problems associated with soil loss the enormous spatial extent over which the loss has occurred and the restoration issues are magnified. In fact, the loss extends beyond the Everglades Agricultural Area (EAA) into the Everglades.

2. *Water Quality Implications of Soil Loss:* The combination of 1) soil loss in EAA, 2) routing water around EAA, 3) EAA's water demands, and 4) materials leaching out of the area have caused significant downstream impacts. Soil loss may have concentrated compounds and minerals such as phosphorus in the remaining soil. As soil loss continues, the binding capacity of remaining soil is likely to become so saturated it will be unable to retain minerals, which will be released into downstream waters. The problem also is magnified by pesticides and other chemical applications accumulating in the environment for at least 50 years:

- High mercury concentrations found in large-mouth bass, alligators, panthers, and other top predators demonstrate the existence of contaminants in aquatic food chains, even though the sources and movement through the ecosystem remain uncertain.
- Water discoloration indicates dissolved organic carbons, precursors to trihalomethanes (a known cancer causing agent) formed as a result of the chlorination treatment process for drinking water; drinking water supplied by Lake Okeechobee and the Everglades to east coast cities first passes through major canals traversing the EAA; an EPA study found the Miami Preston-Hialeah well field to contain one of the highest concentrations of trihalomethanes in drinking water supplies; Dade County water treatment plants have switched to a chloramine-based purifying process, though public health concerns may exist

with this product also.

- Organic soils oxidizing due to drainage in the EAA and elsewhere appear to be the source of the dissolved compounds, which decrease in canal water with distance south from the EAA (EPA, provisional data).

3. *Nutrient Enrichment and Contamination:* Eutrophication and water quality degradation are growing concerns in south Florida. Nutrient-laden agricultural runoff has altered marsh macrophyte and algal communities, diminishing their supporting role as food chain bases and habitats. Extensive eutrophic zones have been found in the public Everglades marshes. Elevated concentrations of chlorinated hydrocarbon pesticides or their derivatives have been found in great egrets and other wading birds from Water Conservation Area 1 (Winger 1987).

4. *Mercury Contamination:* A human health fish consumption advisory due to mercury contamination either bans or restricts the consumption of freshwater fish from two million acres encompassing the Everglades and Big Cypress National Preserve, and there is extensive mercury contamination of other biota associated with aquatic food webs. Since 1989 mercury has been found at elevated concentration in varied Everglades biota, including freshwater fish, raccoons, wading birds, and alligators. A Florida panther (an endangered species) found dead in Everglades NP in 1989 had a liver mercury concentration of 110 ppm. The maximum concentrations found in bass (4.4 ppm) and bowfin (over 7 ppm) collected from a WCA-3A canal are the highest concentrations found in the state of Florida, and are higher than concentrations found at Superfund sites in the Southeast that are contaminated with mercury. The source(s) of mercury, and the mechanism(s) and environmental conditions resulting in the bioaccumulation of toxic methyl mercury in the Everglades remain unknown.

5. *Uncoupling Wetlands/Estuaries From Rainfall:* Water impoundment in the Water Conservation Areas and surface water diversion to the Atlantic coast, as well as ground water and levee seepage losses eastward in the modified system have reduced flows to the southern Everglades, shortening hydroperiods. Not only have these changes meant larger intra-annual flow variations but also large volumes of rainwater drained to sea annually that did not occur historically. This eastward water diversion occasions a several hundred-thousand-acre-foot loss per year to the sea.

Reduction in flow from upstream also has reduced flood duration as well as the maximum area annually inundated. Peak flows are higher after major rains and flow rates drop off more abruptly at the end of the wet season than they would have in pre-drainage days. Channelization and impoundment also have disrupted the annual pattern of rising and falling water depths in remnant wetlands.

6. Altered Hydroperiods: The accelerated runoff rates that have accompanied increased development have meant increased wetland drying over vaster areas. Land is saturated with water for shorter periods of time, resulting in lower aquatic production at all levels of the food chain. Surface water refugia supporting aquatic fauna and their predators during drought are smaller and fewer in number, having been relocated and subdivided as part of the currently-managed system.

In a few areas, such as the southern parts of the Water Conservation Areas, channelization, coupled with impoundment, have increased depth and hydroperiods. Resulting regulation water releases have caused unseasonable flooding of alligator nesting sites in Everglades National Park and disrupted wading bird nesting, which depends on concentrated food supplies.

7. Invasive Introduced Species: The canal networks have provided a kind of deep-water refugia for introduced (exotic) plants and animals, encouraging communities substantially different than the natural ones, particularly where predatory fish are concerned. Furthermore, the water conveyance system may be a conduit for the dispersal of invasive species. It also may foster introduced species by creating conditions favoring exotics above natives.

8. Loss of Hydraulic Head and Recharge: Artificial drainage drastically lowered the water table and increased water table recession rates on the east coast ridge. This impacted water flow to both interior wetlands and estuaries. It also affected ridge plant communities, the salt/fresh interface, and water supply.

9. Fire Regime Changes: Fragmentation has interfered with the ability of fire to maintain natural mosaics. In the natural system, fire increased habitat diversity; in the current managed system, it reduces diversity due to altered seasonal burning accompanied by over drying of wetlands. Human tendency to replace natural variations and extremes in disturbances like fire with regular schedules can lead to the loss of biological diversity because species tend to adapt to natural variations in environmental conditions. Regularizing physical driving forces may favor some species over others and affect species composition.

10. Lost Wetland Function Greater Than Lost Wetland Area: South Florida wetlands have been reduced by half, but breeding wading bird populations have been reduced to less than 10% of their former number. This suggests either: (1) that the particular wetlands that were lost played an especially critical role in wading bird feeding and nesting success, and/or (2) that the remaining wetlands are so degraded that their carrying capacity for wading birds is only 20% of the former capacity. The estuarine system serves as a foraging ground for wading birds, and loss of estuarine feeding opportunities may also have decreased the wading bird carrying capacity of the ecosystem.

11. Estuarine Impacts: Water management has resulted in:

- more short duration, high volume water flow to estuaries and less base flow;
- regulatory releases to control lake and ground water levels according to prescribed flood-preventive formulae, which have produced pulses of fresh water entering estuaries, causing rapid, drastic decreases in salinity that stress estuarine organisms;
- water flows diverted from one receiving basin to another, changing long-term salinity regimes;
- water diversion and increased runoff rate, providing Florida Bay with less water flow than it received historically and creating salinities exceeding oceanic concentrations (Florida Bay salinities have reached 70 ppt during severe drought; Biscayne Bay may exhibit abnormal negative or reverse salinity gradients, with hypersaline conditions inshore; and salinities in Manatee Bay have dropped from 36 ppt to 0 ppt in a matter of hours due to abrupt regulatory releases from the South Dade Conveyance System—especially disruptive to Manatee Bay, which ordinarily experiences extremely high salinities due to natural freshwater inflow loss);
- long-term changes in freshwater inflow rates to estuaries, which have shifted salinity zones upstream or downstream, resulting in areas within species' optimum salinity ranges that no longer coincide with the estuary features supporting species' growth and survival;
- spatially compressed (steeper) salinity gradients providing less overall area within some salinity zones and less opportunity to overlap with favorable structural habitat--estuary salinity zone shifts and area changes within various salinity ranges may have reduced species' optimum habitat and even eliminated some species' habitat all together.

12. Estuarine and Reef Resources Declines: Fisheries productivity depends on habitat quality and quantity. One measure of habitat carrying capacity is the abundance of fish age 0 to 1 (known as recruitment). Decreased fisheries productivity may be reflected in catch rate declines. (deletion) Landings in the valuable Tortugas pink shrimp fishery, dependent upon Florida Bay nursery grounds, have declined sharply since the mid 1980s. Long-term catch rates, standardized for vessel power increases, declined from the 1960s through the 1970s. Unstandardized catch rates declined precipitously beginning in the mid 1980s (Browder 1985).

In addition to declining catches, fish displaying abnormal dorsal fins and misaligned scales are common in North Biscayne Bay (Browder et al. 1993), and present in the St. Lucie Inlet and the lower Indian River (Kandrashoff pers. comm.). The same abnormalities have been seen in at least 10 species, suggesting a cause common to the environment of these species. On the reef tract, a declining community is also evident, exemplified by coral bleaching, coral diseases (including black band disease), and a decline in coral cover and recruitment. Recently, DDE and other chlorinated hydrocarbons have been found in coral reef tissue (Skinner and Japp 1986). Extensive seagrass loss has occurred due to poor water quality (increased nutrients and turbidity, decreased light penetration), alteration of the natural freshwater inflow pattern, dredge and fill activities, and boating activities (Kenworthy and Haunert 1990).

B. The Process of Restoration

1. What Restoration Means: In the context of south Florida, restoration means a return to pre-existing ecological conditions. The conceptual target for south Florida's wetlands and estuaries is pre-drainage topography and hydrology evidenced by the 1858 military map, and for vegetative cover the 1943 natural vegetation map prepared by Davis, expanded to include southwest Florida and the Kissimmee River Valley (Fig 1). In reality, the irreversible loss of significant wetland areas (the large spatial scale was key to long-term ecosystem maintenance), as well as the almost complete urbanization of the east coast ridge (a major ground water recharge area) and the need to accommodate agriculture make the restoration target only approachable. What we can hope to recapture are the essential hydrologic and landscape characteristics critical to a sustained, healthy south Florida ecosystem.

2. Rationale For Hydrologic Restoration: Hydrologic restoration is a necessary beginning to ecological restoration. However, encouraging habitat heterogeneity may require additional restoration efforts, among them:

- reduction in water and airborne nutrients and contaminants
- ending soil subsidence
- control of invasive exotics
- re-establishment of natural corridors in uplands and wetlands for native biotic dispersal and diversity

The restoration approach has three overlapping components, discussed in terms of alternative minimum, incremental, and maximum (unconstrained) restoration areas:

- o Restore the areal extent of the system, as well as its hydrological integrity to recover sustainable biotic populations.
- o Adjust hydrological restoration plans to maximize ecological restoration.
- o Establish a comprehensive, regional monitoring program to measure hydrological and ecological responses (referred to as success criteria) to the hydrologic restoration programs.

Certainly, the identity of the resulting landscape will emerge from the identity of the re-established system. Management's challenge is understanding these new system trajectories and guiding them toward ecosystem health and sustainability, possibly supporting the design of enhancement projects.

3. Models, Rain-driven Formulae, and Adaptive Management: Linking current hydrologic models and future models of water quality, ecology, and plant and animal populations should help determine differences between pre-drainage and present-day conditions. Developed at scales ranging from regional landscapes to constituent communities (Appendix M), these models must have scientific credibility to guide restoration.

Since quantitative measures of hydrological and ecological changes from pre-drainage times to the present are lacking, the best guide is the family of natural system models (NSMs), coupled with spatially explicit simulation models of species at the landscape level. Existent models of natural system hydrology have been calibrated based on present system hydrologic models, but with canals, levees, and control structures removed.

Assuming identical rainfall, comparisons of NSM with present model results allow changes in flood stages, duration of flooding, spatial extent of flooding, and other related information to be assessed. For instance, they show the spatial distribution of hydroperiods under pre-drainage and present conditions (Fig. 4), indicating that hydroperiods in pre-drainage times were longer. How to translate NSM output into a water delivery schedule adjusted for rainfall at various landscape locations has yet to be determined. However, a rain-driven formula (based on a regression of water flow rates on rainfall, paced to reflect natural system delays from storage) currently is being used by SFWMD to schedule more natural volume and timing for Everglades water deliveries from the upstream Water Conservation Area. Similar formulas based on NSM (Fennema et al. 1994) output could provide improved water deliveries system wide. Also the NSMs can provide perspective on how to restore more natural water flow volume and timing to estuaries.

To understand the role of water among biotic communities, ecosystem-level modeling needs to be coupled with NSMs and the various hydrological alternatives. Currently, several ecological models are being developed, among them an innovative approach to be used by the Park Service, Biological Survey and the University of Tennessee/Oak Ridge National Laboratory. Designed to accept calibrated input, suggest monitoring strategies, and evaluate management alternatives, this approach uses integrated simulation models of major trophic groups along with monitoring programs that include broad-scale landscape characterization, water quality and quantity measures, and natural resources (e.g., wading bird populations, fisheries, snail kites, vegetation communities, and contaminants in air, water, sediments, and biota).

Modeling and monitoring, along with research, are part of the adaptive management process--the repeated use of models, research, and monitoring to revise, improve, and fine tune management procedures.

4. *Structures V. No Structures:* Potential hydrologic solutions to south Florida's ecosystem dilemma lie within two restoration extremes: 1) remove all water control structures, including canals and levees, or 2) add more structures/modify existing structures to approximate natural hydrologic conditions despite constraints imposed by wetland and upland losses.

Removing structures would reestablish natural patterns of wetland continuity, sheet flow, and animal movements, as well as reduce conduits for introduced species and pollutants. However, current reduced water storage capacity and recharge may make restoration to pre-drainage flow rates, timing, and spatial patterns impossible.

Option 2—modifying and/or adding to existing water control structures—provides the flexibility with which to adjust water management operations in response to system needs (adaptive management). However, adding structures also may have undesirable effects, unless innovative designs reduce negative long-term impacts on the restoration process. Determining the most appropriate approach will have to be on a case-by-case basis, taking into account ecological costs and benefits.

C. Establishing A Restoration Direction

As previously stated, the over-arching intent is restoration of pre-drainage, landscape-scale hydrology and ecology re-establishing ecosystem integrity and sustainable biodiversity: a healthy, sustainable ecosystem that has room for human activities.

D. Achieving Restoration

- Maximize the system's spatial extent and landscape heterogeneity to recover ecological structure and function. Prevent further wetland loss, recover undeveloped degraded wetlands, and restore landscape elements lost to development.
- Re-establish natural hydrologic structure and function through the restoration of: 1) sheet flow; 2) strong hydrologic linkages between areas; 3) natural dynamic water storage capacity; 4) natural relationship of ground and surface water levels, as well as water flow with rainfall; 5) natural quantity, timing, location, and quality of freshwater flow throughout the system and into estuaries.
- Gradually decompartmentalize the Water Conservation Areas (WCA) to reinstate sheet flow from WCA1 through WCA3, perhaps making water movement from Lake Okeechobee to the WCAs easier.
- Recover threatened and endangered species.
- Restore natural biological diversity.
- Re-establish natural vegetation and periphyton communities spatially and compositionally.
- Strive to evolve an EAA agriculture allowing EAA to function hydrologically as the area did in the pre-drainage system, providing delayed release of wet season rainfall from Lake Okeechobee to downstream natural areas.
- Promote water conservation and water reuse in urban and agricultural areas.
- Restore natural rates of ecosystem productivity.
- Re-establish sustainable breeding wading bird populations and colonies.
- Halt and reverse the invasion of exotic plants and animals.
- Prevent point and non-point airborne or waterborne pollution (contaminants, excessive nutrients, and thermal pollutants).
- Re-establish the corridors for movement, dispersion, and interactions among vegetation and animals.
- Increase the hard coral cover on Florida Keys reefs.
- Restore natural estuarine and coastal productivity and fisheries, and natural seagrass communities.
- Link agricultural and urban growth management with ecosystem management.
- Restore a natural system that is self-maintaining with little human intervention.
- Implement best urban and agricultural management to improve water quality and reduce water consumption.
- Restore the sustainability of human and natural systems supporting cities, farms, and industries in an environment characterized by clean air, clean water and abundant natural resources.

E. Conceptual Foundation of Restoration

Drawing on a variety of information and views, many represented in the recently published book, *Everglades: The Ecosystem and Its Restoration* (Jan. 1994, Davis & Ogden, ed.), the conceptual foundation of the restoration effort should be as follows:

- The fact that spatial extent is a critical aspect of the south Florida ecosystem indicates the need to reverse the trend toward incremental loss of natural areas and compartmentalization of the remaining systems. Fragmentation results in erosion of biodiversity and must be corrected by restoring connections between biotic communities.
- Water is life. Without it, the ecosystem fails to function. The importance of hydrology to the annual pulse of wet and dry cycles as well as to random disturbances of those cycles mandates the development of rainfall-based water delivery plans with built-in dynamic storage and delays. The plans should provide formulas derived from present and future NSMs that will: 1) restore pre-drainage sheet flow volumes and distributions in time and space; 2) restore pre-drainage depth patterns, and 3) mimic pre-drainage hydroperiods, including extended periods of flooding.
- The role of drought and fire in maintaining ecosystem heterogeneity suggests the importance of allowing environmental fluctuations and extremes to occur as they would have naturally.
- Recognition of the damage caused by nutrients, contaminants, and other materials introduced into this fragile ecosystem demands their significant reduction or elimination from the airsheds and watersheds of the ecosystem to below-detrimental levels.
- The role of spatial salinity gradients in sustaining nursery and other supportive habitat in coastal wetlands and estuaries requires creation of more natural volume, timing, and locations of freshwater inflows to restore the historic salinity structure.
- Altered water depths and hydroperiods have given the edge to introduced species; natural hydroperiods and water depths need to be reestablished to control such species.
- The relationship between ground and surface water necessitates that water table levels be raised to restore more natural flows to wetlands and estuaries.

- The pre-drainage role of sheet flows in structuring and integrating the physical and biotic landscape makes it imperative to reestablish sheet flow conveyance on the system's historic north-south gradient. This must emanate from the top down and be massive enough to restore historic water volume transport in time and space.
- Soil subsidence has diminished the natural hydrologic system, including the dynamic storage and hydraulic head provided by the former soils and their associated marshes. This function needs to be engineered in the short term, but in the long term may be reinstated as conditions are created to promote the accretion of organic soils.
- Agriculture in the Everglades Agriculture Area (EAA) is not sustainable as currently practiced due to organic soil oxidation (Snyder and Davidson 1994). However, urban development would be a poor alternative land use, as well as a poor use of resources required to maintain drainage in what is, in effect, the middle of the basin. Restoration efforts must strive to develop a productive EAA agriculture that halts soil subsidence and contributes to ecological restoration.
- Agricultural practices decreasing airborne and waterborne export of nutrients and contaminants need to be encouraged (e.g., use of native rangeland instead of improved pasture, water tolerant strains of sugar cane, organic farming, and sterile cultivars of ornamental non-native species).
- Urban water consumption and contamination of ground and surface waters diminishes available clean water. Water conservation and improved techniques for treating and reusing urban waste water and storm water runoff need to be encouraged.
- Areas serving the ecosystem need to be retained in setting boundaries influencing restoration. Rather than degrade functioning systems, degraded ones need to be improved.

F. Regional Restoration Success Criteria

The challenge of restoration is the reestablishment of a healthy, functioning ecosystem, rather than increasing production of any one species. However, certain species, such as fishery species and wading birds, are used as success criteria because holistic indices are more difficult to acquire.

- Reinstatement of natural hydroperiods and sheet flow, as approximated by natural system models
- Re-establishment of pre-drainage wading bird nesting colony locations and timing of nesting
- No further wetland losses
- Restoration of degraded wetlands
- Wetland use permits require enhanced hydrologic connectivity, water quality, and water storage
- Improved recruitment of fishery and non-fishery species in estuaries
- Increased fish abundance and species recovery in pre-disturbance locations
- Reduction in body burdens of mercury large-mouth bass, alligators, panthers, and other top carnivores
- Elimination of organic soils subsidence
- Contaminant reduction in canal surface sediments at locations monitored by SFWMD
- Increased native landscape diversity and faunal diversity
- Reestablisment of lost vegetative landscapes
- Reduced numbers of deformed fish in estuaries
- Nutrient-tolerant plants reduced or eliminated
- Exotic plants or animals reduced or eliminated
- Periphyton community taxonomic composition characteristic of oligotrophic, natural hydroperiods
- Increased populations of threatened and endangered species
- Increased seagrass cover

G. *Goals of Evaluation Process for Successful Restoration*

Restoring south Florida's ecosystem depends on agencies' ability to sustain long-term, effective, coordinated actions. Success needs to be evaluated in terms of the entire ecosystem. The evaluation process needs to:

- Assess Task Force effectiveness and individual agency actions in restoring the south Florida ecosystem.
- Provide information that is suitable and sufficient for making management decisions about future actions.
- Provide information that enables the public to judge ecosystem restoration success.

H. *Requirements For Annual Evaluation Process*

To meet these objectives, the Task Force will establish an annual evaluation process:

- providing a reliable basis for federal managers to assess accomplishments and prepare, revise, and execute management plans;
- having consistent format and standards;
- addressing the Regional Restoration Success Criteria in the November 15, 1993, Science Subgroup Report;
- addressing agency-appropriate Sub-Region Success

Criteria identified in the Science Subgroup Report;
- o coinciding with annual agency budget preparation;
- o resulting in agency reports to the Task Force that precisely identify the extent of success and describe planned corrective actions coordinated among Task Force agencies;
- o resulting in an annual report, with executive summary, at the Task Force level, describing agency efforts, accomplishments, and adjustments in management actions necessary to restore and maintain the south Florida ecosystem.

IV. WORKING GROUP ACTIVITIES

During the past year, the Interagency Working Group has been actively engaged in identifying, coordinating, and accelerating implementation of south Florida ecosystem-related projects that were already in progress at the inception of the group. It has accomplished this through numerous public meetings bringing people together both formally and informally. Working Group members have been tasked with and accomplished activities ranging from research to report writing. Among the projects the group has helped expedite are:

- o the Army Corps of Engineers Central and South Florida Restudy, which defines problems and opportunities connected with south Florida's interconnected water system
- o the C-111 Project, which addresses modifications of the South Dade County Conveyance Canal System intended to restore more natural hydrologic conditions in Taylor Slough
- o the Kissimmee ground breaking that should lead to restoration of natural wetland habitat in a large part of the floodplain
- o L-67 degrading, intended to restore more natural hydrologic conditions in Shark River Slough
- o the Florida Bay Science Plan, a comprehensive state-federal research and monitoring strategy for Florida Bay.

V. WORKING GROUP RECOMMENDATIONS

The Working Group also has completed this draft of the report it was tasked to provide to the Task Force. Expanding of the priorities approved by the Task Force at its inception in September 1993, the Working Group makes the following individual recommendations that it strongly feels must be addressed in order to approach ecosystem restoration for south Florida. We intend to proceed with those the working group has tasked itself to carry out. We are recommending the Interagency Task Force follow through with those it is tasked with and establish priorities among them.

Also, we are recommending similar action with those recommendations tasked to specific agencies. (Note: The letters [A. etc.] do not correlate to the lettering of the appendices since many recommendations are referenced in more than one appendix, as noted in each recommendation.)

A. Sustainable Development

The following recommendations focus on the goal of sustainable development, which is the primary aim of ecosystem restoration—the establishment of a sustainable system that balances biodiversity and human activities. To accomplish sustainability, the Working Group recommends actions that will draw together the major participants in united action. For additional background on these issues, see Appendices B and M.

1. Establish 1) a multi-agency federal initiative to assist and complement state or regional sustainable development studies; and 2) an IWG federal advisory group composed of industry, municipalities, agencies, environmental organizations, and others. (Lead--Office of Coastal Zone Management, NOAA; ITF Executive Director)

To encourage a basis for common understanding among federal, state and local policy makers, the initiative would include:

- projections of future land, water and resource bases, as well as land uses (urban, residential, and agricultural) as these pertain to population growth projected for 2010, 2030, and 2050;
- a comprehensive inventory of economic development (residential and industrial) in south Florida, resulting in a list of industries, with their financial contribution, their environmental impacts, and their societal importance;
- a method whereby federal, state and local agencies may assess the economic, social, and environmental consequences of proposals to restore the Everglades, as well as the consequences of not adopting them.
- identification of possible policy or legislative options (e.g., tax incentives, regulatory program changes) encouraging sustainable development.

To carry out the second part of this recommendation, the establishment of the IWG advisory group, the Interagency Task Force executive director would need to acquire the necessary approvals pursuant to the Federal Advisory Committee Act (FACA).

2. Engage state agencies (FG&FWFC, SFWMD, FDEP) in restoration efforts. (Lead--ITF)

An enormous base of expertise exists within institutions engaged in south Florida research modeling and monitoring, expertise that needs to be recognized, coordinated, and integrated into federal efforts. The Task Force should embark immediately upon engaging these agencies as partners in south Florida's ecosystem restoration.

B. Agency Coordination

To implement ecosystem restoration, federal agencies not only have to work together with partners but also to direct their united efforts beyond their own boundaries to keep the public fully informed of developments as they occur. This group of recommendations aims to increase communication among federal and non-federal groups as well as the public. For additional background on these issues see Appendices C, E and L.

1. Assign responsibility for interagency coordination to several groups, including Management, Science, and Projects sub-groups, also adding an information/education sub-group. (Lead--IWG)

IWG members will work together to resolve communication, coordination, or differing agency positions at their level, bringing issues that require higher level policy review to the attention of agency superiors.

2. Actively participate in Florida Commission on Sustainable Development to ensure compatibility of water supply issues with development and growth management; and coordinate with the South Florida Water Management District (SFWMD) to ensure compatibility of Lower East Coast Water Supply Plan with restoration efforts, as well as to adopt more efficient municipal and industrial water use. (Lead--IWG, Corps)

3. Establish a public involvement sub-group, which would: 1) establish a mechanism to provide timely information via media and others to south Florida cultural groups; 2) inventory and coordinate existing educational activities and sponsor new outreach efforts; and 3) adopt standard operating procedures for public meetings. (Lead--IWG, Public Involvement Sub-group)

The Public Involvement Sub-group, comprised of member agencies' public involvement specialists, would meet periodically with their counterparts in other agencies to coordinate activities on specific restoration endeavors. The mechanism they develop to provide the public with information would include:

- a list of interested parties and media through which to communicate, such as public notices, special mailings, newsletters, and electronic bulletin boards with access to documents under consideration by IWG
- information presented in various languages and

disseminated in various ways (speeches, exhibits, brochures)

- research on public perceptions of restoration, environmental activities, and possible support of these activities

Public education with an ecosystem focus includes information on ecosystem structure, wetlands, water quality, water supply conservation measures, and ground water protection. The IWG, through the Public Involvement Sub-group, would 1) conduct and maintain an inventory of on-going federal, state and local educational activities; 2) help increase coordination in the content, presentation and distribution of educational efforts; 3) suggest modification of existing efforts to include restoration-related information; 4) identify and sponsor new educational efforts; and 5) help incorporate the education program into local efforts, which might require establishing a speakers bureau within the IWG.

Adopting standard operating procedures for public meetings and document publication would provide the public with a reliable process for their involvement. Such considerations might include: minimum amount of notice time prior to meetings; method of notice distribution; meeting agenda/format; publication of results; and provisions for reaching various cultural groups. The procedures would be drafted by representatives from federal, state and local agencies, various interest groups and the general public.

C. Expediting Restoration

This category includes research and data collection approaches to expediting restoration. For additional background on these issues see Appendices D and M.

1. Implement a research program defining the correlation between water management and ecosystem health, and including a detailed description of the science required to support restoration. Workshops would be conducted to assess monitoring needs and capabilities; adopt quality control procedures; and coordinate efforts. (Lead--Science Sub-Group)

The South Florida Task Force, through its Science Sub-group, in conjunction with state and regional agencies, will oversee and coordinate the south Florida ecosystem's restoration research, avoiding duplication and identifying areas needing additional investigation.

2. Identify ongoing data collection efforts and gaps, and recommend data format and exchange methods. (Lead--Science Sub-group)

3. Establish interagency project teams for each of the major Corps environmental restoration projects. (Lead--Corps

of Engineers)
Interagency project teams will provide the Corps with input regarding project objectives, alternative plan formulation and evaluation, and project design and construction. Periodic team meetings and updates should be held throughout project planning, design, and construction, with participation, when appropriate, of Department of Agriculture and Department of Transportation agencies.

D. Water Quality and Supply

One of the keys to ecosystem restoration is water quality and supply. These recommendations focus on water management from this perspective, emphasizing new ways to re-use water, encourage its conservation, and move it effectively from one part of the system to another. For additional background on these issues, see Appendices E, F, and M.

1. Restore more historic volume, timing, and location of freshwater flow to Everglades, Florida Bay, Biscayne Bay, and other bodies. (Lead--Corps, with coordination and cooperation of all federal agencies and SFWMD)

2. Encourage water conservation and re-use. (Lead--SFWMD)
SFWMD, with the cooperation of all federal agencies, will encourage such approaches as use of nutrient-enriched waters for golf courses and agricultural lands; bricks or other devices in toilets; and more efficient, water-saving shower heads; plus establishment of water supply reserves.

3. Perform studies to reclaim waste water, and to redirect stormwater from western Dade, Broward, and Palm Beach Counties inland rather than toward the coast. (Lead--USGS)
Using GIS and other tools, prepare countywide comprehensive plans for the reuse of treated wastewater in such areas as golf courses, county parks and the lands around public buildings. Conduct waste water reuse pilot studies on different substrate, including rockland of south Dade County, and examine the effects of waste water reuse on water quality in associated ground and surface waters. Also determine the economic and ecological impacts/costs of redirecting some stormwater runoff inland to proposed catchment areas.

4. Use hydrologic models to test various landscape scenarios on undeveloped lands for their effect on supply and management flexibility. (Lead--USGS)

5. Study feasibility of reducing trihalomethane formation in drinking water through water management to reduce organic carbon content of surface and seepage water recharging the Biscayne aquifer. (Lead--?)

6. Develop a water budget for south Florida. (Lead--Corps, with USGS and SFWMD)

Accomplish this through authorization for a feasibility study.

7. Determine water quality status throughout the system and use a monitoring program to determine constituent loads. (Lead--USGS, NBS, NPS, Corps, NOAA, EPA)

8. Seek authority under Clean Water Act to regulate all nonpoint sources of pollution in south Florida, and to provide up-front matching funds to local governments for nonpoint pollution abatement, including authority to recover costs from polluters. (Lead--EPA)

9. Determine critical pollutant numeric threshold levels adequate for native flora and fauna preservation. (Lead--NPS, NBS, FWS, EPA)

10. Determine sources, mechanisms, and environmental conditions resulting in biological accumulation of mercury and take appropriate remedial action. (Lead--EPA, NPS, USGS, NBS, FWS, NOOA, State of Florida)

11. Investigate the biological hazards posed by other contaninants routinely applied in south Florida and take remedial actions as warranted. (Lead--EPA)

Florida's sandy soils and highly permeable substrate make pesticide contamination a particular concern with regard to protection of aquatic life and drinking water quality. Several massive mortalities of fish and other aquatic life have been reported in association with heavy rains shortly after the application of Nemacur (active ingredient fenamiphos) to golf courses.

12. Identify and ensure numeric standards are in place for key pollutants in ecosystem waterbodies. (Lead--EPA)

E. Wetland Permitting and Mitigation Strategy

The way wetland permitting and mitigation are carried out will have a significant impact on ecosystem restoration in south Florida. The following recommendations should help ensure wetland protection as part of the restoration effort. For additional background on this issue, see Appendix G.

1. Develop a South Florida Ecosystem Wetland Conservation Plan by September 1996, including completion of the 5 tasks identified under section G.IV.3. (Lead--Corps, EPA, FWS)

2. Require an annual report to be submitted by the Interagency Working Group to the Task Force that summarizes the effect of the federal 404 wetland fill permitting *program on the south Florida environment. This report will contain information by county for the number of permit applications received (for individual and general permits, including nationwide permits), number of permits modified prior to approval, number of permits approved, number of permits denied, number of veto actions, wetland acreage filled in original application and in approved permit, and mitigation required. (Lead--Corps, FWS, EPA)*

3. Develop and maintain a wetland permitting information database that facilitates completion of these reports as well as ongoing efforts to assess the cumulative effects of the wetland permitting program on the goal of south Florida ecosystem restoration and the region's remaining natural resource base. (Lead--Corps, EPA, FWS)

4. Integrate the federal wetland permitting program with ongoing federal planning activities and ongoing county comprehensive planning programs. (Lead--Corps, EPA, FWS)

5. Form a Wetland Interagency Coordination Group (WICG) that meets regularly to ensure that wetland regulatory, permitting and planning activities are proceeding on a timely basis; discuss and resolve emerging permitting and ecosystem restoration issues; and discuss pending permit applications. This would cut review time, reduce correspondence, and lead to increased uniformity and consensus. (Lead--Corps, EPA, FWS, NMFS)

6. Identify wetlands of particular ecological significance (critical areas). Their functionality should be assessed in a manner that incorporates a holistic consideration of the functions that the particular wetland (and upland) provides to the greater ecosystem. These assessments and identification of critical areas must be performed in a coordinated manner by the federal agencies involved in permitting processes. (Lead--Corps, EPA, FWS)

7. Increase emphasis on wetland enforcement and on permit compliance to ensure that the wetland regulatory program and mitigation requirements are providing projected benefits. Expand funding of contracts for monitoring and compliance to ensure that mitigation is providing projected benefits. (Lead--Corps, EPA, FWS)

8. If appropriate, Corps may deny a permit or EPA initiate a 404(c) action to avoid wetland loss or irrevocable changes to a particular area so that restoration initiatives are not precluded. (Lead--Corps, EPA)

9. Invite local governments to evaluate any programs they have that match the current federal ones and invite them to submit delegation ideas. (Lead--Corps)

10. Increase the south Florida presence of agencies with limited or no local satellite offices by increasing travel funds, co-location of offices, or relocating personnel to south Florida. (Lead--IWG)

11. Develop a uniform wetland assessment approach that produces consistent assessments of wetland functions and filling impacts. (Lead--WICG)

12. Identify specific critical areas that require watershed management plans and recommend priorities. (Lead--WICG)

13. Prepare and update master map of activity along urban-natural edge, including permits, restoration projects, and planning efforts. (Lead--FWS)

14. Evaluate potential conflicts between proposed development projects and the recommended restoration projects contained within this plan. If appropriate, initiate an EIS if there is a conflict in an identified critical area. (Lead--WICG)

15. Expedite completion of Advanced Identification of Disposal Area projects (ADIDs). (Lead--EPA)

16. Invite state and local agencies to present their comprehensive plans to the group and provide a formal opportunity to comment (or provide information on federal efforts) on the plans. These comments would be coordinated with the other entities of the Interagency Working Group. (Lead--WICG)

17. Encourage establishment of mitigation banks through new legislative authority to provide seed money or loan guarantees and through expedited review of bank applications. (Lead--ITF)

18. Seek legislative authority to return fines and fees collected during the regulatory process back to the restoration effort. Ensure that these funds are used to achieve wetland conservation or preservation goals. (Lead--ITF, Corps)

F. Habitat Restoration--Exotic Plants and Animals

The introduction of exotic flora and fauna have contributed to the decrease of native communities. The following recommendations are aimed at controlling exotics in the south Florida ecosystem. For additional background on this issue, see Appendices H and M.

1. Assign a representative(s) of the Working Group or Science sub-Group to the Federal Interdepartmental Committee *for the Management of Noxious Exotic Weeds; help organize a similar interagency group to coordinate and integrate research and management of non-indigenous animals. Integrate efforts with state, local and non-government entities.*

2. *Establish separate working groups for plants and animals to develop comprehensive multi-species management plans for control of invasive or otherwise harmful nonindigenous species. (Lead--Departments of Interior and Agriculture)*

Include state and county entities and assign responsibilities to specific agencies and individuals at all government levels. Adopt the Exotic Pest Plant Council's current list to identify invasive plant species recognized as problems. Determine the magnitude of infestation and the relative threat to natural areas to help prioritize critical target areas and species for eradication efforts. Encourage and assist the coordination of programs and management efforts, as well as the sharing of information on eradication techniques. Provide regionwide perspective for addressing issues. Assist with funding and incentive programs.

3. *Provide funding for increased research to prevent, halt, or reverse invasions by nonnative species. (Corps, NBS, NPS)*

With respect to plants, more work is needed on (1) biological control agents, (2) factors that affect the invasibility of natural areas, (3) environmental requirements and phenology of particular problem species as these relate to their vulnerability to specific controlled burning or water management regimes, and (4) habitat restoration strategies to control reinvasion by non-indigenous species after their removal, With respect to animals, research is needed on how non-indigenous species reproducing in the wild have impacted food webs, community structure, and populations of species in natural areas in which they have become established.

For both animals and plants, research is needed to develop methods of screening and risk assessment to prioritize efforts at all stages of control (importation, distribution, eradication). Developing effective criteria for identifying and screening potentially invasive exotics before they become well established will help to focus preventive efforts.

Coordinate through the Science Sub-group to use research findings to support management and operational procedures.

4. *Fully fund the Melaleuca Biological Control Quarantine Facility and biological control investigations and continued eradication efforts by federal, state, and local agencies for melaleuca, brazilian pepper, and other high priority*

problem species. (Lead--Corps, DOA/ARS)
Funds could be raised through user and recreational fees.

5. *Promote development of organized, holistic control strategies to protect natural areas that emphasize prevention of invasions by non-indigenous species. (Lead--FWS, ARS)*
Target the three stages of introduction: importation, propagation, and distribution. Preventive efforts might include import restrictions, local planting ordinances, and public education. Implement the recommendations in OTA (1993) that address the problem of potentially invasive new imports of both plants and animals. Consider proposing new legislation and/or lengthening the list of species prohibited from importation under the Lacey Act (Lead--FWS).

6. *Require the use of native species for all landscaping of federal property, including federal buildings, prohibit the planting of invasive non-indigenous species on public lands, and institute vigorous control actions against existing stands. (Lead--ITF)*
Adopt the Exotic Pest Plant Council's list for prohibition and eradication. Develop policy requirements prohibiting the use of invasive non-indigenous species for landscaping federally funded projects such as highways and greenbelts. Urge that state and local governments act similarly. Urge state, local, and non-government groups to use native vegetation, rather than drought- tolerant non-native species, in xeriscape programs.

7. *Identify existing monitoring programs and ensure they are complementary, not duplicative. (Lead--FWS, NBS, NPS)*
Ensure that basic variables are defined and measured the same way so that data can be analyzed across areas, not just locally. Support the activities of the COVER Group (Colloqui of Vegetation Everglades Research). Develop a computerized atlas of ongoing monitoring programs.

8. *Reallocate existing funding or testify for appropriation of additional funding to support a multi-pronged approach to controlling harmful non-indigenous species. (Lead--FWS)*
Emphasize non-aquatic species to close the gap in control efforts between aquatic and non-aquatic species.

9. *Document the present nature and extent of invasion of south Florida's natural areas by non-native plant species and prepare a summary report. (Lead--NBS)*
Quantify and map invasions of selected areas, prioritized according to representativeness, sensitivity, or special concerns. Use the resulting report to prepare brochures and

to prioritize critical target areas. Coordinate with the Florida DEP effort and the COVER group.

10. Design and implement public education and training programs. (Lead--FWS)
Raising public awareness of the role of invasive non-indigenous species in south Florida's ecosystem degradation is integral to effective solutions. Certification training classes should be developed for workers involved with screening imports or enforcing ordinances. Landowners should be encouraged to remove exotic pest plants and replant with natives.

11. Establish a horticultural program to develop sterile cultivars of popular and widely used but invasive non-native ornamental plants, such as certain flowering trees and Ficus species. (Lead--Department of Agriculture)

12. Encourage and support the inclusion of non-indigenous species eradication efforts in mitigation and compensation plans. (Lead--FWS)

G. Habitat Restoration and Recovery Plan--
Native Flora and Fauna

Controlling or eradicating exotic plants and animals are not enough. Protection of native flora and fauna also requires strong directive actions. Many species within the region are declining in abundance: 54 plant and 51 animal species are listed, or candidates for listing, under the Endangered Species Act. Because of the importance of habitat to survival, a major focus should be protection and enhancement. Emphasis on habitat dictates a multi-species approach, that will not only be more effective, but will provide better orientation toward whole ecosystem restoration than single-species management. For additional background on these issues, see Appendices I, J, and M.

1. Identify all federally listed threatened and endangered species; then refine the list to exclude those with limited distribution in south Florida. (Lead--FWS)
Review the project boundaries established by the Task Force and list threatened and endangered species within those boundaries.

2. Map species distribution and key habitat associations, as well as land use classification, master plan designations, and land ownerships. (Lead--USFWS, NBS)
Compare species' spatial distribution with public land use maps, integrating species information with land use classification, master plan designations, and ownership. Identify gaps in habitat protected under public ownership or

restricted land use categories. Develop strategies to protect poorly covered species.

3. *Develop a team of individuals representing involved agencies and land managers to help develop a multi-species recovery report. (Lead--FWS)*

4. *Establish a south Florida ecosystem endangered species coordinator. (Lead--FWS)*
The coordinator will serve as the central contact for endangered species recovery issues of the ecosystem.

5. *Develop multi-species strategies and long-term goals, including analysis of ongoing recovery efforts. (Lead--FWS)*
Review on-going actions to determine if they can be combined to benefit multiple species (e.g. combining snail kite and wood stork surveys with annual surveys for wading birds). Develop recovery goals that identify essential research and management actions, focusing on improving coordination among managers. Identify specific lands important to recovery efforts and take actions toward land protection and/or land management (e.g., prescribed burning or water management for improved hydroperiods or improved water quality).

6. *Conduct research aimed at restoring the structure of native floral and faunal communities. (Lead--FWS, NBS)*
Research must: 1) assess status and trends of wildlife populations and habitat resources such as vegetative communities, periphyton, and coral reefs, and 2) identify and understand effects on natural community structure and productivity of major influencing factors (e.g., nutrients, mercury, pesticides, habitat alteration, hydrologic alterations, and global change). Research on threatened and endangered species must: 1) identify species "on the brink" of listed species status; 2) determine the ecological requirements for species recovery, especially considering interaction with other native flora and fauna (using GIS-based, integrated, multi-species approach); 3) assess status and trends of all threatened and endangered species, and ongoing interactions with other native flora and fauna (also using GIS-based, integrated, multi-species approach).

7. *Initiate projects to improve habitat. (Lead--FWS)*
These may include: 1) adding or removing water control structures; 2) changing hydrologic operational criteria; or 3) implementing management actions involving control of exotic plants, fire, or grazing, as well as establishment of sanctuary areas. Highest priority should be given to increasing spatial extent of wetlands or sheet flow, or returning the natural habitat heterogeneity of wetlands.

8. *Predict and assess various water management alternatives*

using adaptive management processes. Develop models to assess restoration alternatives. (Lead--NBS)

9. Research and identify spatial thresholds that relate wildlife population dynamics to conditions of water and vegetation patterns. Determine the response of vegetative habitats to improved spatial and temporal water conditions. (Lead--NBS)

Support research: 1) relating forage fish and invertebrate population dynamics to conditions of water depth, timing, and duration over the habitat mosaics of south Florida's ecosystem; 2) relating habitat conditions (hydroperiods, hydropatterns, water depth, forage base dynamics, and vegetation patterns) to wading bird abundance, distribution, and reproductive success; and 3) relating spatial extent of the ecosystem to the sustainability of viable populations of wading birds and their forage base (including relationship of spatial thresholds and water condition constraints to sustained reproductive success of the wading birds and their associated prey).

10. Determine recovery potential of habitats impacted by excessive nutrients, and determine thresholds for undesirable conversions. (Lead--NBS)

11. Initiate and sustain routine system-wide monitoring of wading bird populations, as well as incorporate critical needs criteria for wading birds into permitting process. (Lead--FWS, NBS)

Integrate systematic reconnaissance flights (SRF) and SFWMD efforts and expand to cover entire ecosystem. (Lead--NBS)

12. Establish ecosystem-wide databases of contacts, jurisdiction and authorities, and GIS-based spatial data. (Lead--USGS)

These data bases will include: 1) a list of contact points, agencies, and organizations involved in habitat management throughout the ecosystem; 2) a summary of agency jurisdiction and authorities over large tracts of natural areas; and 3) a GIS-based system for compiling, organizing, and managing spatial data.

13. Restore the Richmond federal pineland and adjacent properties. (Lead--FWS)

Support the Dade County Park and Recreation Department in their FEMA funding request to restore the Richmond federal pineland properties, as well as adjacent county- and University of Miami-owned pineland and Navy Wells properties.

14. Restore natural fire regimes (including prescribed burns) and develop educational material on the role of fire.

(Lead--NBS)

15. Use disturbed sites (levees, abandoned railroad right-of-ways, and power line right-of-ways) to develop wildlife corridors; and require use of native plant species in greenways. (Lead--?)

Encourage, plant, and maintain native vegetation appropriate to the soil, microclimate, hydrologic conditions, and nearby native plant communities. Also, require that projects qualify for federal funding only if landscaped with native plant species and/or if existing native vegetation is not destroyed.

16. Enforce laws and develop educational materials to prevent human disturbance of rookeries, nesting areas, and den sites. (Lead--FWS)

H. Habitat Restoration--Near Coastal Waters

To be successful, habitat restoration and recovery must include provisions to restore the effectiveness of near coastal waters. These suggested provisions follow. For additional background on these issues, see Appendix K.

1. Identify gaps in existing programs consistent with objectives identified for ecosystem restoration. (Lead--?) *The first step to habitat restoration and recovery is identifying federal, state and local programs consistent with south Florida's ecosystem restoration strategy. The next step is identifying the gaps as they apply to the following areas:*

Habitat Restoration: The following projects will help restore and sustain healthy ecosystem conditions encouraging natural processes, functions, and cycles to continue or be re-established:

- Initiate the Central and Southern Florida (C&SF) Project Restudy feasibility phase to aid in long-term strategic identification of portions of the ecosystem where hydrological restoration can occur, taking into consideration potential adverse impacts to all coastal ecosystems from manipulating the flood control system.
- Initiate construction on the C-111 environmental restoration project to provide more freshwater into Taylor Slough.
- Purchase lands identified in the Everglades Forever Bill and expedite restoration necessary to prepare the land for hydrological use.
- Implement the Lower East Coast Water Supply Plan.
- Maximize restoration of water flow under US 1 along the 18 mile stretch proposed for widening, including mitigation projects proposed by the Florida

Department of Transportation (e.g. filling in canals, restoring habitats, and installing culverts).
- Remove the old US 1 bridges in the Keys that impede water circulation between Florida Bay, the Gulf, and the Atlantic Ocean (the new replacement bridges, built after DOT widened US 1, are supported by smaller pilings that don't impede ebb and flood tidal cycles like the older bridges).
- Continue Coastal America projects such as those used to install mooring buoys to protect critical habitats.
- Implement NOAA's damage restoration plan for coral reefs impacted by ship and small vessel groundings.
- Expand NOAA's seagrass restoration project at a site damaged by prop-wash deflectors.
- Remove old fill areas that impede water circulation along shorelines and between embayments.

Water Quality Management: At a minimum, several Keys projects addressing water quality must be implemented:

- the Water Quality Protection Program (WQPP) for the FKNMS, with implementation to address deterioration of water quality in Florida Bay; eutrophication of near-shore waters; sources of nutrients entering the near-shore waters of the Keys; and stormwater run-off
- point source discharge permit programs
- identification of non-point discharge sources, along with implementation of management/grant programs
- stormwater treatment programs
- enforcement of septic tank regulations
- identification and removal of illegal cess pits
- installation of marina pump-out facilities
- on-site Sewage Disposal System Demonstration projects
- Alternative Waste Water Treatment demonstration projects
- study of the Key West Sewage outfall plume
- local existing water quality management plans for specific water bodies

Species/Habitat Management: Managing use of natural resources (commercial, sport fisheries, and others) to maintain sustainable populations depends on coordination among involved state and federal agencies, as well as increased focus on such permit programs as point source discharge and dredge/fill. What follows is a partial list of habitat management plans and actions for the Florida Keys and the coral reef community that must be implemented to ensure management of natural resources for sustainable populations:

- Monroe County's land use plan

- o proposed marine zoning plan (FKNMS)
- o protection of significant habitats (e.g., seagrasses, hard bottoms, coral reefs) from direct impacts (FKNMS DEIS/MP)
- o management action plans contained in the DEIS/MP for the FKNMS (e.g., channel marking plan, mooring buoy plan, regulatory plan, etc.)
- o USFWS Backcountry Management Plan and other refuge management plans
- o dredge and fill permitting program(s)
- o endangered species recovery plans in Keys
- o agencies' management plans

Public Education: The education staff of the FKNMS has prepared a directory of the Florida Keys' environmental education programs. The programs that need support are:

- o Florida Bay Watch Program, using citizens and various user-groups to monitor water quality in and around the Florida Bay
- o Coral Watch Program, using interested individuals to monitor Florida Keys corals
- o FKNMS' Education Action Plan
- o on-going NPS educational programs
- o on-going USFWS education program used on refuges
- o environmental education plans developed by grass roots, local, state, and federal organizations, using FKNMS' Education Action Plan as a mechanism for coordination
- o NGOs capable of getting information to the public

2. Develop programs to expand existing programs and fill in the gaps. (Lead--?)

After existing programs have been integrated and research ascertains specific impacts to the coastal areas, additional management measures will likely be necessary, among them:

- o Use acquired land in the proposed buffer zone for treating upland runoff.
- o Expand legislative authority to include non-point source discharges and require specified treatment.
- o Identify and prioritize sites suitable for habitat restoration/improvement activities and pursue this under existing programs such as Coastal America or the dredge and fill permitting program (mitigation).
- o Enhance enforcement of existing regulations (e.g. septic tank operation, dredge and fill, NPDES, bilge dumping, prop dredging).
- o Implement public education efforts through radio/tv public service announcements, brochures, school curriculum supplements, and speaker's bureau.

3. Identify sources of coastal system degradation through research efforts coordinated with the Science sub-group. (Lead--?)

I. Land-Based Protection

Restoring the mosaic of land and water also requires land acquisition. The importance of land-based protection is reflected in the following recommendations. For additional background on these issues, see Appendix L.

1. Establish an ad hoc interagency team. (Lead--?)
A land acquisition strategy would be developed by an ad hoc interagency team made up of agencies with land purchasing authority and those interested in preserving natural resources impacted by land use (e.g. Corps, NPS, USFWS, SFWMD, NOAA, EPA, local county agencies).

2. Develop a land acquisition strategy (including the feasibility of a Restoration Land Trust) and prioritization criteria. (Lead--ad hoc interagency team)
Tentative elements of the land acquisition strategy include: 1) addressing relevant issues identified above; 2) exploring establishment of a South Florida Restoration Land Trust with the following capabilities and benefits:

- obtaining and holding land acquisition funds
- anticipating opportunities and needs for specific land parcels
- streamlining the land acquisition process using avenues available to private developers

3) developing criteria with which to establish priorities:

- natural resource value of the land
- regional water table sensitivity to land development (based on elevation, permeability, etc.)
- potential usefulness of land to south Florida's overall restoration
- as a buffer between areas of differently managed water levels
- as a flowway for water conveyance
- along canals to create littoral zones (on gradual inclined banks)
- predict relevant land use changes
- map organic soil thickness
- analyze master plan alterations/zoning changes
- analyze permit applications.

J. Science Program

A strong science program is integral to ecosystem restoration. Without it effective decisions could not be made on hydrology, flora and fauna, and all the other aspects critical to restoration that have been expressed in the previous recommendations. A strong science program is recommended here as a critical tool for carrying out all aspects of ecosystem restoration. For additional background on these issues, see Appendix M, as well as other related appendices indicated above.

1. *Develop an assessment protocol that helps focus modeling and monitoring activities on predicting and measuring restoration success indicators. In workshop settings in interaction with model and monitoring planning, define practical and sensitive indicators, starting with the restoration success criteria recommended in the Science Sub-group Report. (Lead--Science Sub-group)*

First, select a set of indicators for which sufficient baseline information and understanding is available to support their immediate use. Then propose a second set of potential indicators for which baseline information should be developed to allow their eventual use.

2. *Develop a monitoring plan, bringing together in workshop settings the major participants in present and proposed monitoring efforts. (Lead--Science Sub-group)*

Conduct special topic workshops, as for instance, the geospatial workshop of September, 1994.

3. *Establish groups to model the hydrologic, hydrodynamic, landscape, meteorologic, and ecologic processes of the south Florida restoration area, taking into account existing models. (Lead--Science Sub-group)*

The first step will be development of a hydrologic model for the south Florida land base. Existing models will be upgraded and new ones developed for areas not yet covered by hydrologic models. Hydrologic models will provide input for hydro-dynamic models being developed to predict circulation, mixing, and salinity patterns in Florida Bay as a function of freshwater inflow and other variable factors. The set of models will consist of a 3-dimensional model for Florida Bay, quantified for operating in 2 dimensions until sufficient data to support 3-D runs can be obtained, and 2) a regional numerical ocean circulation modeling system that can provide boundary conditions for the Florida Bay model. Ecological models that relate species, populations, communities, and landscapes to the simulation outputs of hydrologic or hydrodynamic models will provide an objective aprior way to evaluate alternative water management strategies for their influence on the ecosystem.

4. *Provide an institutional framework, including a home and consistent funding, for each of the major types of modeling. (Lead--ITF, with advice from Science Sub-group)* Support model development, maintenance, upgrading, and application to assessment and other restoration needs.

5. Upgrade the hydrologic monitoring network to improve present flow estimates and to cover areas presently not covered. (Lead--Science Sub-group, USGS, NPS)

An expansion of the hydrologic monitoring network is needed to provide more complete and accurate data on surface and groundwater flows to estuaries. This information is critical to hydrologic model testing and refinement and to restoration planning and assessment. It will enable more accurate water budgets to be constructed and will provide baseline data from which to evaluate operational changes that affect surface and groundwater flows to Biscayne Bay, Florida Bay, and west coast estuaries.

6. Develop the information base for application of the adaptive management approach, emphasizing the building of understanding and assessment capability. (Lead--Science Sub-group)

Promote research integrated with modeling and monitoring. Emphasize the acquisition of information that can be used in assessment to support the adaptive management strategy.

7. Encourage the developing landscape studies program consisting of modeling, retrospective paleontological studies, trend and gradient analyses, and monitoring. (Science Sub-group, NBS)

Landscape models are needed that simulate vegetation succession as a function of the hydrologic regime and aperiodic events, incorporate land shaping processes such as soil accretion and soil subsidence, can interact with hydrologic models to affect hydrologic processes, and can provide the explicit spatial framework necessary for models of species and communities that are influenced by landscape patterns.

A landscape studies program that includes landscape modeling is underway and needs further support and some reorientation to meet the modeling needs described above. Complementary projects are being carried out at the South Florida Water Management District (ELM) and in a cooperative project by ENP/NBS/ORNL (ATLSS).

Paleontological studies provide retrospective perspectives and complement models that hindcast previously existing conditions.

8. Perform research to develop technology for maintaining current agricultural harvest levels with zero soil subsidence in the Everglades Agricultural Area (EAA). (Lead--Department of Agriculture/ARS)

Such research would help determine: 1) required annual period for maintaining saturated soils; 2) required maximum water table depth during other times; and 3) most water tolerant cultivars of existing crops. Plant breeding and biotechnology would be used to encourage this trait.

Supporting work should evaluate the present C&SF Project for its capability to support on-farm water management for zero-subsidence agriculture, and design modifications to provide this support. Hydrologic models should be used to evaluate the effect of a summer-flooding-based, zero-subsidence agriculture in the EAA and a supportive redesigned C&SF Project on 1) the timing and volume of water released from the EAA to the Water Conservation Areas and 2) seasonal conveyance capacity from Lake Okeechobee through the EAA.

9. Use hydrologic models to test, for their effect on water supply and water management flexibility, various land use scenarios for the undeveloped lands in western Dade, Broward, and Palm Beach Counties east of the Water Conservation Area levees. (Corps, USGS)

Both local governments and permitting agencies have little perspective on the cumulative effects of land use decisions, particularly as they relate to water. Evaluations of cumulative effects of potential land use changes on water supplies and water management flexibility is needed.

10. Ensure agencies have the authority to address ecosystem-wide issues. (Lead--ITF)

11. Provide continuous funding as an integral part of restoration operations budgets for this multi-year adaptive management effort. (Lead--?)

Adaptive management for ecosystem restoration requires continual predictions and feedback from the interactive modeling, monitoring, and research efforts--and thus, continuous funding.

12. Ensure resources to support the planning, coordination, and oversight activities of the Science Sub-group. (Lead--ITF)

APPENDIX A
PROGRESS IN TASK FORCE INITIATIVES

I. BACKGROUND

The Interagency Agreement on South Florida Ecosystem Restoration instructs the Interagency Working Group to "implement Task Force initiatives concerning South Florida Ecosystem restoration and maintenance." One task was to assist the Corps of Engineers in their reconnaissance study of the Central and Southern Florida Project.

II. PLANNING OBJECTIVES FOR THE CORPS OF ENGINEERS RESTUDY OF THE C&SF PROJECT

The Interagency Working Group was asked by the Corps to provide consolidated federal objectives of ecosystem restoration to the Corps' restudy team. Objectives were provided to the Corps and were presented at public workshops conducted by the Corps. Based on additional scientific information and public comments, they were refined by the Corps' Study Team into a set of planning objectives. An abbreviated version of the Study Team's presentation of the planning objectives follows.

Each objective is discussed below in the context of public comments, as well as supporting information provided by the Working Group and scientific publications. Three publications in particular supplied scientific support to the first four planning objectives. These publications were *The Science Sub-Group Report: Federal Objectives for the South Florida Restoration* (Science Sub-Group, 1993), *Everglades, The Ecosystem and Its Restoration* (Davis and Ogden, 1994), and *Ecosystems of Florida* (Myers and Ewel, 1990). Direct quotations are from those documents unless otherwise noted. The first objective deals with spatial extent.
The Corps' Study Team said that, although acquisition of some type of real estate interest is an obvious response to this objective, it is not necessarily the only way to increase spatial extent of wetlands. The study team does not consider this to be a mandate for purchase of additional public lands for ecosystem restoration, but rather intends that a full range of alternative methods will be considered. The second objective deals with habitat heterogeneity.

The Interagency Working Group suggests that every regulatory and planning project developing actions should incorporate the noted views of the Science Sub-Group (1993), Davis and Ogden (1994), and Myers and Ewel (1990) concerning the importance of habitat heterogeneity in achieving habitat restoration.

Reconnaissance Study Planning Objectives

Objective #1 - Increase the total spatial extent of wetlands.

Wetland area has been reduced to roughly 50 percent of its former size.

What scientists have said:

> Extensive areas "provide enough space to support genetically viable numbers of individuals and sub-populations for those species with large home ranges. . .or with narrow habitat requirements."
>
> "Protection of representative examples of each of Florida's ecosystems does not ensure sufficient habitat for all of their characteristic species. Wide-ranging species. . .have little future in Florida unless large blocks of their habitats are set aside."
>
> Extensive areas "increase the solar collector area that becomes transformed into aquatic productivity" and thus enable "the system-wide aquatic production in a nutrient-poor system necessary to support large populations of wading birds, snail kites, and other consumers dependent upon aquatic food webs."
>
> Extensive areas allow "for the perpetuation of habitat diversity through the processes of natural disturbances."
>
> Extensive areas serve "as a buffer to prevent patchwise population changes from creating species or population extinctions in the area as a whole" since "population resiliency is proportion to the area of these wetlands because habitat diversity, the amount of seasonal refugia, and the number of dispersal options are proportional to wetland area."

What the public said:

> South Florida's ecosystem, particularly changes in the Everglades, was one of the most important concerns expressed by the public. While there were only a few comments from the public that explicitly addressed spatial extent, many people observed that the size of the ecosystem had been reduced as part of human development. Many also stated they did not believe the natural area of the ecosystem should be enlarged at the expense of communities, jobs, and businesses.

Objective #2 - Increase habitat heterogeneity: (a) reestablish at least the minimum threshold size of historic community *types, (b) reestablish relative balance among historic community types, (c) reduce fragmentation within and among community types, (d) and reduce the extent of non-native plants and animals.*

Natural habitats are now fragmented and several landscapes have been reduced to remnants.

What scientists have said:

> "Functional losses of the ecosystem that have accompanied landscape and plant community change. . .include reduction in spatial extent of system aquatic productivity, reduction in aquatic productivity of the southern Everglades due to shortened hydro-periods and interrupted flows as a result of development of marshes upstream, reduction in cover of wet prairie and slough and related aquatic productivity in the remaining system, loss of habitat diversity at the landscape and community level, and reduction in early dry season feeding habitat of wading birds."

> "The Everglades and Florida Bay are unique in the northern hemisphere. The mangrove forests of south Florida, together with the wetlands systems of Florida's northern river estuaries, represent important habitats in terms of biological activity and diversity" for both commercially and non-commercially important species (Livingston in Myers and Ewel, 1990).

> "Historically, most of the large, traditional wading bird colonies were located close to the lower Shark River Slough/mangrove ecotone because of the more dependable foraging conditions created by the juxtaposition of a long hydro-period freshwater pool next to a highly productive estuarine region."

> "The size of the area is not the only important consideration. A small fragment, if connected by a corridor of habitat to a larger one, will typically support more interior species [although possibly at lower densities] than will a similar-sized fragment without a corridor. The value of such corridors has been clearly demonstrated. . ." (Shaw, 1985).

> "Fragmentation results in erosion of biodiversity and must be corrected by restoring connections between biotic communities."

> ". . .invasion of melaleuca. . .drastically changes ecosystem structure and dynamics: Melaleuca forest replaces marsh, thus changing animal use; leaf litter and woody debris change relative soil elevation and hence

hydrology; tree weight can compress underlying peat depots; organic matter results in heavy fuel loads of very combustible materials, leading to very hot fires. . ." (White 1994).

What the public said:

The public noted adverse changes in habitats, such as the sawgrass, mangroves, seagrass beds, and other native wetland habitats. They also commented on adverse changes in fish and wildlife species, such as wading birds, alligators, shrimp, and lobsters, that depend on the native habitats for survival. The adverse effects of invasive non-native species, such as melaleuca, Brazilian pepper, and Australian pine, concerned many.

Objective #3 - Restore hydrologic structure and function: (a) restore sheet flow, (b) increase dynamic storage capacity, (c) restore hydrologic linkages, (d) restore more natural hydroperiods, and (3) restore more natural water delivery characteristics to estuaries and bays.

What scientists have said:

"An essential defining characteristic of the pre-drainage Everglades was its regionally dynamic patterns of water storage and sheet flow." Although 80 percent of annual rainfall fell between June and October (Gunderson and Loftus, 1993; Duever et al., 1994), the system's large spatial extent and broad sawgrass plains stored wet season rainfall and released it with a delay that maintained flows throughout much of the dry season. This produced a much wetter system that exists under managed conditions (Fennema et al., 1994) and was essential to the production and survival of aquatic animals (Loftus et al., 1986; Davis and Ogden, 1994) and the higher trophic-level organisms dependent on the small aquatic animals for food.

"Past water management practices and the construction of related works have resulted in: (1) loss of transitional wetlands, which provided an early-season feeding habitat for wading birds; (2) modification of flow pattern (from attenuated to pulsed), which reduced hydro-periods; (3) unnatural pooling and over-drainage as a result of canals and levees; (4) reversal from muck building to rapid oxidation of soils; and (5) abandonment of wading bird nesting areas in Everglades National Park due to change in hydro-period."

Longer hydroperiods characteristic of the pre-drainage Everglades were necessary to the reestablishment of macro-invertebrate and fish populations after the dry season (Loftus et al., 1986 and Loftus and Eklund, 1994). Higher groundwater levels may have allowed solution and alligator holes to maintain remnant populations (Loftus et al., 1992).

Ogden (1994) hypothesized that abandonment of traditional colonial wading bird nesting sites and reductions in regional breeding populations was caused in part by greater dry-down frequency and extent in deeper areas of southern Shark Slough and by reduced flows into mainland estuaries and flanking freshwater prairies.

What the public said:

Speakers and writers noted many changes in the historic hydrologic regime and other physical characteristics of south Florida. Many people believe that changes in sheet flow and hydro-patterns brought about by man's water management activities, including the C&SF Project, are important causes of ecosystem decline.

Objective #4 - Restore water quality conditions: (a) restore more natural salinity characteristics in estuaries and bays, (b) restore more natural quality characteristics.

Water quality problems in south Florida are complex and varied and fall into three categories: eutrophication, contaminants, and salinity changes.

What scientists have said:

Eutrophication, caused by watershed activities that have increased nutrient loads, is represented by dramatic increases in algal growth within Lake Okeechobee and shifts from sawgrass to cattails within the Everglades. These changes affect ecosystem functioning.

Contamination problems are characterized by pesticide and herbicide residues and bio-accumulation of mercury within the system. The cause of mercury contamination remains uncertain because little is known about the mercury sources or factors influencing transformation and mobilization.

Changes in salinity characteristics of estuaries throughout south Florida have resulted from the alteration of freshwater inflow. Estuarine ecosystems have been disrupted by both too much and too little fresh water. St. Lucie and Caloosahatchee estuaries and Manatee Bay-Barnes Sound have been damaged by sporadic high volume freshwater releases. Florida Bay has been affected by diminished freshwater inflow. Salinities greater than seawater strength are thought to have become more persistent and widespread over Florida Bay and may have contributed to the observed reduced recruitment of pink shrimp, snook, and redfish; lowered reproductive success of ospreys and great white herons; distribution shifts in manatees, crocodiles, and many wading birds; and mass mortality of seagrasses.

What the public said:

Concerns focused on six major topics: pollution of Lake Okeechobee, regulatory releases from the lake, outflow from the Everglades Agricultural Area, salinities in Florida Bay, urban water quality, and system-wide mercury pollution.

Objective #5 - Improve the availability of water: (a) improve efficiency in water use, (b) improve water supply.

What scientists have said:

The 1990 base case developed by the South Florida Water Management District (SFWMD) indicates numerous water supply shortfalls. Modeling suggests that, by 2010, the supply shortages will be severe and unacceptable to the public. The modeling for the 2010 planning horizon did not include environmental demands that may be identified by SFWMD and the interagency restoration effort.

What the public said:

The public recognized three main water users: the environment, the urban areas, and agriculture. Problems identified included conflicting demands among users, water waste, an inadequate water management system, the need to increase the supply of water, and the need for water conservation to reduce demand.

Objective #6 - Reduce flood damages on Seminole and Miccosukee tribal lands.

The Seminole Tribe of Florida and the Miccosukee Tribe of Indians of Florida have reservations in south Florida that are affected by the structures and operations of the C&SF Project.

The Seminole Tribe's Brighton Reservation is in Glades County southeast of Lake Istopoga and northwest of Lake Okeechobee and is protected by the Herbert Hoover Dike. Their Big Cypress Reservation is in Hendry County in the L-28 basin adjacent to WCA 3A. The Miccosukee Tribe of Indians of Florida Reservation is adjacent to the Big Cypress Reservation. The latter two reservations have surface water management systems that discharge into the L-28 canal. The S-140 pump station, which discharges from the L-28 canal into Water Conservation Area 3A, is designed to discharge 7/16

inches of water per day from the L-28 basin.
Both Tribes expressed a need for improved flood protection in their Reservations near the L-28 canal.

What Tribe representatives said:

> The Tribes and other land owners in the L-28 basin have improved their lands since completion of the L-28 basin works, and they continue to intensify these uses. The capacity of the L-140 pump station may be inadequate, particularly in the triangle area formed by the L-28 canal on the east, the L-28 interceptor canal on the west, and I-75 on the north. A significant portion of flood waters from the C-139 and L-28 basins are routed through the L-28 borrow canal across the Big Cypress Reservation. Current project works are inadequate to handle this volume of water; flooding on the reservation often occurs during heavy storms. In addition, there is no protective levee in the Big Cypress Reservation to prevent the L-28 borrow canal from overflowing onto the Reservation. An existing protective levee within the Miccosukee Reservation ends at the Miccosukee Reservation boundary. Water ponds in the eastern portion of the Big Cypress Reservation.

APPENDIX B
SUSTAINABLE DEVELOPMENT

I. MAJOR ISSUE

Fundamental to ecosystem restoration and management is the concept of sustainable development. It must be the foundation of any successful restoration effort. The concept recognizes that lasting solutions require a balance between resolving urgent environmental concerns while providing for the essential needs of development and industry—meeting the needs of the present without compromising the ability of future generations to meet their own needs. More specifically, development and economic activity in south Florida must be compatible with attainment of the over-arching goal of south Florida ecosystem restoration and maintenance and the ecosystem must support a healthy south Florida economy. Restoration must proceed within the context of a healthy economic setting.

II. BACKGROUND

People are attracted to south Florida for many reasons. Some are very conscious of the vast natural, undeveloped areas and routinely enjoy the recreational opportunities they afford. Others choose to live in south Florida because of the mild climate or for family or business interests. Many own undeveloped land which they plan to develop in the future as retirement homes. All are part of a regional economy that is fundamentally based on how the land is used or preserved. In general, economic growth in Florida is synonymous with conversion of undeveloped "useless" land to another use. There is a growing recognition that this "useless" land provides essential benefits to the general public. The challenge is to describe these benefits in relevant terms and then determine the value of those benefits to the general public.

In the past 90 years, the population of Florida has grown dramatically. The advent of the railroad, modern conveniences such as air conditioning, channelization of water flow, and subsequent drainage of wetlands have rendered once uninhabitable areas not only inhabitable but, in concert with the mild climate of south Florida, most desirable.

The setting established by modernization created the nearly ideal conditions for the state's two most significant industries, agriculture and tourism. A third key group of regional industries is residential and light commercial development. Many commercial enterprises and retirees are moving to Florida for its quality of life. Florida, particularly in the south, continues to experience rapid growth. In 1945 the population of the 18 counties that encompass the south Florida watershed was about 730,000. In 1990 the population in these same counties was 6.3 million. Concurrent with this population growth has been the conversion of natural lands (uplands and wetlands) within the region to urban, residential, and agricultural land uses. Present estimates of population growth indicate an additional tripling of the human population in south Florida within the next 50 years. The cycle of increasing population requiring increasing commercial development paving the way for new population increases will repeat and will result in increased demands within the region for water supply, flood control, shelter, transportation, and service needs.

The pressures of this growth on the ecosystem is producing clear signs of severe stress. Loss of wetlands, invasions of non-native species, declines in water quality, increases in the occurrence of ecological events such as marine-based algal blooms, seagrass die-offs, mangrove decline, and coral diseases are a few of the manifestations of ecosystem stress and if not corrected, threaten the economic vitality of key regional economies. The ecosystem cannot sustain current pressures.

Recognition that humans are a part of the south Florida ecosystem is necessary to ecosystem restoration planning. The restored south Florida ecosystem cannot and should not be exactly the same as the system that existed prior to human intervention, because the basic needs of human communities for flood control and water supply must be accommodated.

Managers should not wait until scientific consensus is reached before taking action. Ludwig et al. (1993) cite the California sardine fishery as an example of this danger. The Pacific anchovy harvest plunged from 10 million metric tons per year to near zero following a decision allowing liberal fishing limits and a series of El Nino events. There is still scientific debate over the influence of exploitation versus El Nino events. Throughout south Florida, and particularly in Florida Bay, this same dilemma appears. There are conflicting opinions on the causes of the problems. Managers cannot wait for a complete scientific understanding before taking prudent action. They must instead use the best available information and be willing to accept reasonable risk in their actions.

In south Florida, the challenge is to restore the health and defining characteristics of the regional ecosystem within the context of a vibrant economy. A healthy ecosystem is an essential prerequisite to long-term sustainability of human communities and economic endeavors. Water purification, clean air, and safe edible natural resources such as fish and shellfish are provided by healthy ecosystems. We must develop and apply ecologically friendly methods in agriculture, industry, and other human pursuits so that the health and defining characteristics of the ecosystem are restored and its support functions for human communities are operational. The future growth in south Florida must facilitate the halting and eventual reversal of the varied and widespread symptoms of ecosystem decline. Public and industry officials must embrace a sustainable development approach if the economy and natural resources of south Florida are to thrive over the long term.

III. OBJECTIVES

The Interagency Working Group proposes four management objectives for sustainable development:

- Ensure that any development plans or permits for development are fully coordinated among affected governmental agencies and are compatible with restoration of the south Florida ecosystem.

- Ensure that existing development which has an adverse impact reduces or eliminates degradation and that new development does not contribute to degradation.

- Develop and utilize a system-wide integrated mitigation plan, coordinating all levels of government, which contributes to overall restoration.

- Ensure that regardless of any future development there is a sufficient land, water and resource base to conduct the required natural resource restoration efforts.

Attaining the goal of sustainable development in south Florida will require an adaptive, multi-faceted approach which focuses on assessments, creative business alternatives, incentives and education. Enduring solutions to economic and environmental problems are only as effective as the commitment of the citizens who are part of that economy and environment. Therefore, public officials should have a long-range view which provides the basis for the pragmatic, sequential actions necessary for success.

APPENDIX C
COORDINATING AGENCY POSITIONS AND ACTIONS

I. MAJOR ISSUES

Ecosystem restoration activities are being undertaken by eleven agencies within six federal departments. Numerous other federal agencies are engaged in significant programs or projects in south Florida that have major effects on the success of restoration efforts including: the widening of U.S. Rte. #1 to the Florida Keys, funded by the Federal Highway Administration, and oil and gas permitting on federal lands and offshore waters by the Bureau of Land Management. In addition, a wide variety of state and local government agencies are actively involved in planning, regulatory activities, and projects that target restoration goals or significantly affect ecosystem conditions. There is a continuous need for the communication and coordination of strategies, plans, funding proposals, project schedules, permit requirements, and program/project evaluations among this array of agencies' activities to assure a comprehensive effort, avoid duplication, maintain linkage of funding and schedules, resolve differing agency positions, and compare results against overall objectives.

II. BACKGROUND

There are currently more than 14 different working groups, committees, advisory councils and commissions at work in south Florida trying to address or coordinate some aspect of agency restoration effort. Agencies' personnel regularly coordinate, consult, and resolve differences on specific projects and programs.

While these extensive advisory and agency efforts accomplish a great deal, the total number and compartmented nature of the efforts have substantial drawbacks. Typically, these individual efforts can overlook some interested or affected party. Often they leave agency differences unresolved, or without necessary approvals or realistic commitments. This contributes to delays and misunderstandings until agency managers or higher authorities are consulted.

The public and agency officials are often confused over which agency or advisory/coordinating group is charged with, or can impact, a given restoration activity. Frustration resulting from these circumstances often lead to misunderstanding, confrontation, and/or unilateral action to obtain decisions or move a project forward. The Interagency Working Group (IWG) has the charge and the opportunity to integrate the federal side of the restoration effort and to create a strong link with state and local activities.

III. OBJECTIVE

Develop and implement a clear, unified process to: communicate status of restoration plans and activities; coordinate priorities, funding, and implementation schedules among all agencies; and quickly identify, confront, and resolve agency differences.

IV. APPROACH

The Interagency Working Group will assign areas of coordination responsibility to several sub-groups, including the existing Management, Science, and Projects Sub-groups and add at least an information/education sub-group. Each will be required to routinely meet and review all federal agency activity in the assigned area. The IWG will identify, discuss, and work to informally coordinate and resolve matters of concern. It will provide periodic opportunities for state and local agency presentations and public comment to identify the full range of coordination issues and opportunities appropriate for consideration. (Sub-group membership would be altered as appropriate to include state and local government representatives and citizen advisors upon implementation of the recommendations in Appendix M.) Each Sub-group will immediately bring items to the attention of individual affected members, or to the full IWG if management action is needed to expedite an effort or resolve an issue.

Each participating agency manager will dedicate the necessary personal time and staff support to support this process on a continuing basis.

APPENDIX D
EXPEDITING CORPS RESTORATION PROJECTS

I. BACKGROUND

The Central and Southern Florida (C&SF) Project was designed and constructed by the Corps of Engineers with the South Florida Water Management District (SFWMD) and the St. Johns River Water Management District (SJRWMD) acting as the local sponsors. The project serves the congressionally authorized purposes of flood control, urban and agricultural water supply, prevention of salt water intrusion, recreation, navigation, protection of fish and wildlife resources, water supply for Everglades National Park (ENP), and environmental restoration. The project area includes the Upper St. Johns River Basin, the Kissimmee River, Lake Okeechobee, the Everglades Agricultural Area, the Water Conservation Areas (WCA), and the lower east coast. In recent years, the dominant theme of Corps studies and projects has been to develop and implement modifications to the water management system that restore and enhance the region's natural resources while still maintaining other authorized project purposes.

II. ISSUES/PROBLEMS

Congressional appropriations to the Corps for these projects have been adequate. Yet, the rate of actual progress has often been disappointing, creating important problems in expediting Corps restoration projects.

a. Environmental Evaluations The single most difficult task in the design of any environmental restoration project is predicting the potential benefits. Environmental benefits must be described in a way that supports optimization of the project design and justification of federal expenditures. This requires prediction of environmental impacts in quantifiable terms. Unfortunately, in most cases, it is not possible to make quantifiable predictions that are scientifically valid. This has necessitated the use of expert opinion and has made documentation of project justification particularly difficult.

The lack of predictive ability has hampered design of restoration projects. For example, both the Modified Water Deliveries to ENP and the C-111 projects were designed without the benefit of a final operating plan. Necessary environmental data collection, evaluation, and model development for use in developing an operating plan have not been completed. This work will continue through construction of the project features. The structural systems were designed to provide maximum operational flexibility.

b. Plan Formulation The development of environmental restoration objectives and the formulation of alternative plans to address those objectives have caused project delays. Criticism of the Corps' plan formulation by other federal agencies has typically occurred as a part of the final coordination of a plan formulation report and/or NEPA document. It is very inefficient to attempt to modify project objectives or reformulate alternatives at this stage of the process.

c. Environmental Monitoring A lack of adequate environmental data has been a consistent problem in environmental restoration projects. There is a lack of data that relates ecologic and hydrologic parameters. Hydrologic data collection is generally adequate; however, the available processes for sharing and transferring data need improvement. There is generally a shortage of associated environmental data and a comprehensive program to coordinate environmental monitoring studies is needed.

III. SCOPE

The Corps of Engineers is implementing a number of environmental restoration projects in south Florida within the boundaries of the South Florida Water Management District. The projects can be separated into four categories: operational modifications, projects in the design and construction phase, plan formulation for authorized projects, and plan formulation for projects to be recommended for authorization. These categories encompass the full range of action from immediate improvements through operational changes limited by the capability of the existing water management system to long-term planning efforts addressing fundamental changes to the structural and operational system.

a. Operational modifications Operational modifications are changes to the operating criteria of various features of the C&SF Project to restore more natural water conditions. Operational modifications are constrained by the capabilities of the physical project features and the need to protect the authorized project purposes.

(1) Lake Okeechobee Regulation Schedule Review: At the request of the SFWMD, the regulation schedule is being reviewed to consider possible operational modifications. High water levels associated with the current Lake Okeechobee Regulation Schedule have altered the vegetative

communities within the lake that developed during years of lower lake schedules. A review of the regulation schedule is being conducted to determine whether alterations should be made to correct this problem. All associated impacts are being evaluated including water supply, discharges to the estuaries, water quality, etc. Recommendations will be made in the summer of 1994.

(2) WCA No. 1 Regulation Schedule Review: At the request of the U.S. Fish and Wildlife Service (FWS), the regulation schedule for WCA No. 1 is being modified to restore more natural water conditions for the benefit of nesting wading birds and snail kites. The revised schedule will be implemented in the summer of 1994.

b. <u>Design/Construction of Approved Projects</u> The basic designs of these projects have been approved and detailed design and construction are proceeding, although some modification of the design details may be appropriate as detailed design proceeds. NEPA documentation for these projects is complete.

(1) Kissimmee River Restoration: The project consists of the revitalization of the headwaters and restoration of the historic floodplain wetlands in the lower basin. In the upper basin, Lakes Kissimmee, Cypress, and Hatchineha will be operated to achieve more natural water level fluctuations with respect to historic elevations and seasonality. This will revitalize the peripheral marshes around the three lakes and will reestablish historic flows to the lower basin. In the lower basin, about 25 miles of the existing flood control canal will be filled and flow will be restored to about 50 miles of the natural river channel. In so doing, about 29,000 acres of the historic wetland habitat will be restored. Land acquisition is required in both basins for areas that will be subjected to more flooding. The test fill construction contract has been awarded and a ground-breaking ceremony was held in April 1994. Construction is scheduled to take approximately 15 years.

(2) Modified Water Deliveries to ENP: The purpose of this project is to modify the C&SF Project to restore more natural hydrologic conditions in Shark River Slough, ENP's largest slough system. The project is being implemented in conjunction with Department of Interior's acquisition of about 107,600 acres in the East Everglades for incorporation into ENP. It includes the construction of water control structures, canals, and levees in WCA No. 3 and the removal of a 10-mile-long canal and levee to restore water flows through the historic flow-way. It also includes the construction of two pump stations, a seepage levee, and a seepage collection canal to avoid adverse impacts to adjacent developed areas. The first of five Feature Design Memorandums for the project was approved in December 1993.

Construction is scheduled to be initiated in FY 1994.

(3) C-111: The purpose of the C-111 project is to modify the water management system to restore more natural hydrologic conditions in Taylor Slough in ENP while maintaining flood protection for the adjacent agricultural areas. The draft General Reevaluation Report (GRR) recommends the acquisition of agricultural lands that lie between the ENP boundary and L-31N and C-111. A system of canals, levees, and pumps will create a buffer zone and a floodwater detention/retention area between the park and agricultural lands. This will enable the restoration of large areas of short hydroperiod wetlands in the upper zone and headwaters of Taylor Slough. The recommended plan also includes a pump and spreader canal to restore overland sheet flow over an existing wetland north of the lower section of C-111. This project will produce more natural flows to Florida Bay and a reduction in damaging freshwater discharges to Manatee Bay/Barnes Sound. The GRR is undergoing final public and agency review. If approved in June 1994, as scheduled, detailed design will be initiated. Construction is scheduled to be initiated in FY 1996.

c. <u>Plan Formulation of Authorized Projects</u> Only about 70 percent of the authorized C&SF Project features have been constructed. For some of the authorized but unconstructed projects, studies have been requested by SFWMD to determine whether construction is still justified. Plan formulation and NEPA documentation for projects in this category is under way.

(1) C-51 West: The original design for the C-51 project provided flood control benefits to the eastern and western C-51 basins. Project features for the eastern basin were completed in 1991. A Detailed Design Memorandum for the C-51 West project features was under review in 1991. The report was withdrawn when negotiations related to the resolution of the Everglades litigation led to recommendations for implementation of a modified C-51 plan. It was included in the Technical Mediated Plan (TMP) that resulted from mediation discussions. Even though the mediation reached an impasse, the federal government is still committed to implementing the TMP, including the modified C-51 plan. The new plan would provide flood control benefits, but it would also provide water quality enhancement and water supply benefits. The physical features of the plan would be substantially altered. The original 1,600 acre flood detention area would be expanded to form a larger shallower Stormwater Treatment Area 1 East.

(2) Operational Studies for Shark Slough and Taylor Slough Water Deliveries: Preliminary operating plans were developed for Modified Water Deliveries to ENP and the C-111

Projects as a part of the general design phase. However, reports for both projects recognized the need for additional data collection and analysis and recommended additional studies to develop operational strategies to optimize environmental benefits. The Experimental Program of Modified Water Deliveries to ENP has been underway since 1985. The testing program allows restoration of more natural hydrologic conditions to the extent possible within the constraints of the existing structural system. It is also enabling the collection of hydrologic and ecologic data that can be used to develop an optimum operating plan. Although the testing program initially only addressed Shark River Slough, it was expanded in July 1993 to include Taylor Slough. The testing program will continue through completion of construction of the Modified Water Deliveries to ENP and C-111 Projects. An adaptive management strategy is being used to enable the evolution of the operational strategy as data is collected and analyzed, as the required hydrologic and ecologic models are improved, and as other modifications are made to the water management system (i.e., construction of Stormwater Treatment Areas, implementation of the Lower East Coast Regional Planning Project recommendations, construction of the West Dade well field, etc).

(3) Melaleuca Quarantine Facility: Federal and state agency efforts have been underway to identify a biological control of Melaleuca infestation. To date, the research has been performed in Australia, the native home of the trees. Congress has authorized the Corps, in consultation with the U.S. Department of Agriculture, to design and construct a quarantine facility required to complete the process of safely identifying and introducing insects to south Florida. Once constructed, the facility will be operated by the USDA.

(4) Manatee Protection: Manatees are a federally listed endangered species native to Florida. The operation of certain C&SF Project water control structures and locks has resulted in the death of manatees through crushing or drowning. A study is underway to design modifications to the structures to prevent injury to manatees.

(5) Homestead and Cape Sable Canals: These canals are located at the southern end of mainland Florida and are within ENP. They were constructed in the early 1900s by local interests to drain wetlands. When ENP was established, the canals were plugged with earthen dams. Extreme wind tides, waves, and water velocities that occurred as a result of Hurricane Andrew substantially damaged these plugs. Both plugs leak badly and are in danger of total failure. If the plugs failed, fresh water would drain from upstream shallow lakes and salt water would be allowed to intrude freshwater areas. The Corps is

designing a plan for permanent repair of these plugs.

d. <u>Plan Formulation for projects to be recommended for authorization</u> Congress authorizes the Corps to study water resources problems to determine whether there is a federal interest in implementing a solution. Currently, there are two pre-authorization studies under way addressing environmental restoration in south Florida.

(1) C&SF Comprehensive Restudy: This study is reviewing the existing C&SF Project with a view towards determining whether it should be modified to benefit the environment. Flood control and water supply will also be evaluated. A reconnaissance study will be submitted in November 1994. It is anticipated that SFWMD will be the local sponsor. The Federal Interagency Task Force has played a major role throughout the study process.

(2) Coast of Florida Erosion and Storm Effects Study: This study is a multi-year, phased regional feasibility study examining the entire developed east coast ocean shoreline and west coast gulf shoreline. The objective is to develop a comprehensive understanding of the coastal processes and associated environmental resources to help in the development of enhanced shore protection projects while reducing negative project impacts. Geographic information system technology is being used in developing the associated databases which will provide comprehensive information on all associated natural and physical resources and processes in the region.

To help efficiently manage this study, the coastline has been sub-divided into five separate regions, based on distinctive characteristics. The first region of study, presently nearing completion, includes the Dade, Broward and Palm Beach County coastlines (Region III). Two of the primary environmental databases include identification and quantification of offshore hard grounds and sea turtle nesting information. Close to 1,000 new line miles of side scan sonargrams were used to complete the hard ground database. Sand bypassing and nearshore disposal/berm placement are two key alternatives under development in this region. Over 20 such potential projects are being assessed in Region III. Field investigation of the four central east county coastlines will be initiated during FY 95. The southwest coastline investigation is scheduled for initiation during FY 96.

IV. OBJECTIVES

The Florida Working Group is expediting Corps projects that benefit the region's natural resources by insuring that necessary information has been developed, creating interagency project teams, and by installing and maintaining a hydrologic and ecologic monitoring system.

No changes in the respective interagency roles are necessary in expediting Corps restoration projects. The Corps of Engineers should continue to have the lead on these projects with support provided from other agencies as appropriate. There should be a greater emphasis on interagency partnering continuously throughout the process. Of particular note is the need for greater involvement of U.S. Department of Highway Transportation in the execution of several restoration projects.

APPENDIX E
WATER SUPPLY ISSUES:
AGRICULTURAL, URBAN AND ECOSYSTEM NEEDS

I. BACKGROUND

Historically, the Kissimmee-Lake Okeechobee-Everglades watershed was part of one large, hydrological and ecologically connected system. The watershed was a subtropical landscape featuring shallow lakes, meandering river channels, sloughs, floodplains, wetlands, and a gradual hydrologic gradient that moved water slowly from central Florida to Lake Okeechobee through the Everglades, and ultimately discharging to Florida Bay, Whitewater Bay, and the Gulf of Mexico.

The late 1800s brought the manipulation of the system to provide drainage, flood protection, and water supply needs. The most extensive changes to the system are the result of construction of the Central & South Florida (C&SF) Project authorized by Congress in 1948, designed and largely constructed by the Corps of Engineers. As a result of the project, the existing hydrologic unit is a highly managed system of canals and levees, and six major impoundment areas including Lake Okeechobee, a large (about 740 square miles), shallow, subtropical lake with a marsh area of about 25 percent of the lake's surface. At the southern end of the watershed lie the components of the historic Everglades including the Everglades Agricultural Area (EAA), the Water Conservation Areas (WCAs) and Everglades National Park (ENP). This highly managed hydrologic system has been referred to as the lifeblood of south Florida.

Prior to drainage, the Everglades was up to 60 miles wide and stretched from Lake Okeechobee southward to the southern tip of the state between Florida Bay and the Ten Thousand Islands area. The EAA is a large (about 1100 square miles), highly productive agricultural area of organic peat or muck soils south of Lake Okeechobee. The three WCAs (located south and east of the EAA and west of the urbanized East Coast) make up an area of about 1350 square miles: a large segment of the original Everglades. The Everglades is an ecosystem that evolved under very limited nutrient supplies where minor increases in nutrient supply have been attributed to have major ecosystem impacts.

Immediately west of the Everglades is the 2,400-square-mile Big Cypress Swamp region. The Big Cypress National Preserve was established in 1974 and encompasses 574,000 acres (with an additional 146,000 acres authorized for acquisition).

The Florida Keys is a unique system composed of a string of islands 100 miles long that extends from Key Largo in Biscayne Bay southwesterly to Key West. The Keys are situated on the edge of an ocean shelf that separates the deep water of the Atlantic

Ocean from the shallow waters of the Gulf of Mexico. Biscayne Bay, a shallow, subtropical ecosystem provides beauty, recreation, economic, and environmental benefits for south Florida.

II. ISSUES/PROBLEMS

The increasing consumption of water by urban and agricultural areas and the resulting competition for available water resources with the natural system may be the most serious issue facing the south Florida ecosystem. The tremendous population growth in south Florida during the last century and the urban growth and agricultural activities have placed increasing demands on the region's water supply during the dry season. Dade County has historically had the most rapid population growth; other counties within the region are expected to experience greater future growth than Dade County, increasing fresh water demands.

A critical issue is providing an adequate fresh water resource base for restoration of wetlands and freshwater flow to Florida Bay and other estuarine areas, while accommodating water needs of agriculture and urban interests. Compounding the problem is the fact that pumps in agricultural areas are not metered. Therefore, valid data regarding actual volumes of water moving into and out of agricultural fields does not exist.

Ground water is the predominant source for public water supply in south Florida. Ground water resources are utilized for potable, municipal, industrial, and agricultural supplies virtually throughout the area. Surface waters are used for agricultural supply in the EAA and for potable supply in a few communities bordering Lake Okeechobee. The aquifers used for water supply are the Biscayne Aquifer in the southeast and surficial and/or intermediate aquifers elsewhere.

Freshwater resources have been viewed as being abundant within south Florida. Competition for the fresh water resources is of particular concern in those areas served by the Biscayne Aquifer and the C&SF Project. The primary competitive demand is the need for sufficient flow of water into the Everglades to support the unique wetland and aquatic habitats that exist in the WCAs, ENP, Big Cypress National Preserve and other natural resource assets. In the past, water supply was made a higher priority in decisions regarding allocation of fresh water resources in the study area. Rainfall, the primary source of all fresh water in the south Florida hydrologic system, is concentrated in May-October and November-April is relatively dry.

Intensified withdrawals have stressed the aquifers used for water supply. One result of these increased demands was an increase in salt water intrusion into fresh water aquifers. In the Biscayne aquifer, the C&SF system of canals and control structures was effectively used to minimize salt water intrusion from the ocean. Upward migration of mineralized waters from deeper formations has not had a significant impact on water quality in the Biscayne. In other areas, the surficial and intermediate aquifers have been affected both by landward migration of seawater in coastal areas and the upward migration of mineralized waters from deeper formations in the interior. This trend will continue as these aquifers are more intensively used as a result of growth.

A major issue regarding water resource management practices in south Florida is conservation of the fresh water resource. Once conservation measures are in place, more effective management practices, especially for the purpose of environmental protection and/or enhancement, will be more easily implemented.

Water resources management activities have largely concentrated in the past on flood control and water supply. Management activities are much more intense and well-developed in the highly urbanized southeast coastline, the EAA, the WCAs, and the agricultural areas in the vicinity of Homestead and Florida City, including the lands managed by federal and state governments for their natural resource value, such as ENP.

Water supply practices in south Florida have the overall effect of diverting large volumes of fresh water from natural system demands. Historically, this diversion has been primarily from resources that might otherwise support hydrologic maintenance of wetland and aquatic habitats in the Everglades. The periods of the greatest diversion occur in the dry season when water resources are generally scarce and, therefore, when the potential for adverse impacts to wetlands and aquatic habitats are greatest. This trend is likely to increase in the foreseeable future, as major withdrawal points for water supply are moved farther inland, closer to the recharge areas in the Everglades, and farther away from the effects of salt water intrusion at the coastline, as in the Northwest well field, operational since 1984, and the proposed West Dade well field, both owned and operated by the Metro-Dade Water and Sewer Authority (MDWASA). These well fields are located immediately adjacent to the WCAs in the western part of Dade County. Increased agricultural pumpage in the East Everglades area will have a similar effect on the overall availability of water for maintenance of natural resources in the overall Everglades system. The Everglades Forever Act requires a 28 percent increase in the volume of water delivered to the Everglades as compared to the annual volume delivered from 1979 to 1988. In addition, Florida law requires the establishment of minimum flows and levels for the Everglades.

Flood control practices in the study area have had the effect of reducing the volume of fresh water storage in the overall system and of accelerating the movement and discharge of excess wet season flows. In some areas, storage has been reduced through lowering of the water table due to pumpage. In the EAA, subsidence of the land surface has occurred due to oxidation of organic soils when exposed to unsaturated conditions. Greater volumes of excess flow must therefore be routed to other storage points (the WCAs) or to discharge points into estuarine or marine environments. This effect, coupled with expanding urban and agricultural areas for which flood control must be provided, may necessitate the movement of increasing volumes (estimated to be up to 25 percent) into storage or discharge. This could accelerate the loss of fresh water resources from the system. Loss also occurs from evapotranspiration in the open WCAs and from the large volumes discharged to the marine environments.

South Florida's rich deposits of organic soils are subsiding at a rate that suggests that agriculture, as currently practiced in the EAA, is not sustainable. Maintenance of a low water table as part of farming operations results in oxidation of the soil, which is underlain by dense limestone rock. A review of research already conducted suggests it may be feasible to grow conventional crops profitably practicing a zero subsidence agriculture. A water management regime in phase with the seasonality of rainfall and more water-tolerant cultivars could be the key. Such a management regime, while extending the lifetime of agriculture in the area, could also be more hydrologically compatible with natural systems downstream and could improve water quality.

The effects of the C&SF Project are in essence no different from those associated with other flood control projects, and for that purpose the C&SF Project has functioned effectively. Additional purposes to which the C&SF system have been put, such as enhancing water supply and prevention of salt water intrusion, demonstrate the flexibility of the system in responding to emerging water resource issues within the southeast portion of the study area. The Modified Water Delivery Plan (MWDP), a proposed alteration of the C&SF system of canals and control structures, has environmental enhancement as the main purpose. This will be achieved by facilitating the delivery of fresh-water flow into Shark River Slough, the major drainage feature of ENP. This is also a demonstration of the inherent flexibility of the C&SF project, in that system modifications are proposed for a purpose other than water supply or flood control.

Estuarine areas are impacted by freshwater releases from the C&SF Project. Large regulatory releases adversely affect the salinity regime in the St. Lucie and Caloosahatchee Estuaries. Estuarine areas, such as Florida Bay, have also been impacted by reductions of freshwater flow. The Modified Water Deliveries to Everglades National Park Project, Canal 111 General Revaluation Report, and Taylor Slough Demonstration Project are examples of projects that could help improve freshwater flows.

Big Cypress Basin obtains ground water from unnamed surficial and intermediate depth aquifers. The surficial aquifers are unconfined and the intermediate aquifers are semi-confined to well-confined and all are vulnerable to contamination from surface sources. These aquifers are generally more susceptible to saltwater intrusion both from a landward migration of seawater and from up-welling of more mineralized waters from underlying geologic formations.

III. OBJECTIVES

Manage the hydrological conditions in the remaining undeveloped and potentially restorable lands in a way that maximizes natural processes characteristic of the historic south Florida ecosystem (including water quality, quantity, distribution, timing, and biological integrity). Restoration of the natural system will be evaluated and implemented to maximize the benefits to the overall ecosystem.

Develop and manage the total hydrologic system to maximize ecosystem restoration while providing appropriate consideration to meeting the needs of urban, agricultural, and man-made components. It is recognized that future management of the system will require shared adversity where the full range of hydrologic needs cannot be fully met.

The Task Force, through the Interagency Working Group, needs to be an active participant with the Florida Commission on Sustainable Development to assure that water supply issues are compatible with development and growth management in south Florida.

APPENDIX F
WATER QUALITY MANAGEMENT STRATEGIES

I. MAJOR ISSUES

Water quality throughout the south Florida ecosystem has been a major issue for many years. Nutrient enrichment has been identified as a concern for Lake Okeechobee, the Everglades, the Indian River Estuary, and the Caloosahatchee River. Anthropogenic nutrients or perturbations to nutrient cycling processes have been suggested by some as a possible cause for symptoms of ecological degradation observed in Florida Bay (seagrass die-off, algal blooms), the Florida Keys National Marine Sanctuary, and the coral reef system. Other water quality related issues include the widespread contamination of biota throughout the Everglades region with mercury of unknown source(s), the contamination of public drinking water supplies along the lower east coast with synthetic organic chemicals, contamination of the Miami River, concern about the integrity of the Dade County Water and Sewer Authority's Cross Biscayne Bay municipal sewer line, and seagrass loss due to poor water quality. Toxicological contaminants of concern in the system have included metals, organic compounds and pesticides.

II. BACKGROUND

The south Florida ecosystem contains varied aquatic natural resources, habitats, and biological communities. Each of these aquatic systems developed under specific water quality and hydrologic conditions. As such, the quality of the water in these aquatic systems is an important driving force in defining habitats and determining the suitability of a water for specific organisms.

The rapid and extensive urban and agricultural development in south Florida has had negative impacts on system water quality. Urban and agricultural activities in the watershed have affected the quality of water delivered to the natural resources of the downstream water receivers. Some of the potential contaminant sources include marinas, marine sewage, sanitary sewers, stormwater sewers, industrial effluents, and agricultural runoff. The Central and Southern Florida Flood Control Project (C&FS) has affected water movement and hydroperiod throughout much of the system. This in turn has affected water quality. The canal system also has the potential to serve as a conduit for the conveyance of pollutants to other portions of the system.

Any successful program to restore the south Florida ecosystem must view the system holistically. Water quality conditions and processes throughout the system have been greatly affected by modifications to the natural system over the past century resulting in loss of wetlands, loss of mangroves, loss of grass beds, loss of coastal upland communities, altered hydrology, and altered circulation in bays. Water quality conditions influence ecological integrity and have a direct bearing on the ability to achieve various objectives identified in the ecosystem restoration: habitat restoration strategy to address the ecological degradation of Florida Bay and the coral reef system, and strategies intended to provide adequate habitat for native species of fauna such as wading birds. In addition, actions undertaken to address water supply concerns and structural or operational modifications to the C&SF Project may influence water quality.

Ground water contamination has impacted water supply activities in south Florida urban areas. Plumes of ground water contamination from old landfills, Superfund sites, leaking underground storage tanks and industrial activities have caused localized degradation in the Biscayne Aquifer (a federally designated Sole Source Aquifer under the Safe Drinking Water Act). Two major water supply well fields operated by the Metropolitan Dade Water and Sewer Authority were contaminated with volatile organic chemicals, presumably originating at nearby superfund sites. Numerous private wells were contaminated by a plume emanating from the old 58th Street Landfill in Dade County. Regional aquifers are highly vulnerable to contamination because of the lack of soil, high transmissivities, and the nearness of the water table to the ground surface. Because of widespread and increasing urbanization of the area, the incidence of ground water contamination is likely to increase.

III. OBJECTIVE

The objective is to assure that the quality of water found throughout the south Florida ecosystem is adequate for attaining ecosystem restoration, protection and maintenance.

IV. APPROACH

A complex set of laws and institutions are in place to protect or restore the chemical integrity of surface water and ground water. The federal strategy relies heavily on state implementation and leadership. A suite of federal, state and local laws and regulations disperse implementation responsibility among various federal, state, and local agencies. Two concepts fundamental to any successful strategy are contaminant cleanup and pollution prevention. A number of significant state or federal efforts are underway to address water quality concerns throughout the south Florida ecosystem.

In general terms, components of an effective water quality management strategy must include:

- appropriate water body classification
- development and adoption of water quality standards and criteria that are adequate for resource protection
- adequate regulatory and permitting programs including compliance determination and enforcement
- monitoring and research to define appropriate standards, identify status and trends, and determine compliance
- public education and awareness

Federal Activities Federal agencies have various programs in place to address water quality issues. The objective of the Clean Water Act is "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters." Among federal agencies EPA has assumed the dominant role in directing and defining water pollution control programs.

The Florida Keys National Marine Sanctuary requires EPA and Florida, in consultation with NOAA, to develop a Water Quality Protection Program for the Sanctuary that addresses point and nonpoint sources of pollution to restore and maintain the chemical, physical, and biological integrity of the sanctuary, including restoration and maintenance of corals, shellfish, and fish and wildlife.

Monitoring and Research Programs Federal agencies have invested much in water quality monitoring and research efforts throughout the ecosystem. Ongoing efforts include those of the USGS, NOAA, NBS, NPS and EPA. In addition Florida agencies such as SFWMD have significant monitoring efforts in place throughout the Ecosystem.

State Activities The state of Florida plays a critical role in water quality issues in south Florida. The Clean Water Act authorizes the states to establish ambient water quality standards and water quality management plans. Two Florida agencies that have a major influence on water quality in the south Florida ecosystem are the South Florida Water Management District and Florida Department of Environmental Protection.

Out of concern for the declining quality of Florida's surface waters, the Florida Legislature passed the Surface Water Improvement and Management (SWIM) Act of 1987. This act required SFWMD to prepare SWIM Plans for Lake Okeechobee, Biscayne Bay, and the Indian River Lagoon. Plans for these water bodies have been adopted. Nutrient enrichment problems in the Kissimmee River, Lake Okeechobee, and the Everglades have been difficult to resolve. For example, the issue of nutrient levels in the Everglades Agricultural Area and the eutrophication of the Everglades has been a focus of many state activities, including the Lake Okeechobee Technical Advisory Council (LOTAC) I (1985-1986), LOTAC II (1987-1990), The SWIM Act of 1987, the Marjory Stoneman Douglas Everglades Protection Act of 1991, and the SWIM planning process (1988-present). A SWIM Plan for the Everglades adopted by the SFWMD Governing Board in 1992 has been superseded by the Everglades Forever Act enacted in April 1994. The act requires BMP based reductions in phosphorus released from the EAA, wetlands constructed for phosphorus removal, and attempts to establish a method of payment.

A variety of water quality issues must be addressed by managers involved with south Florida ecosystem restoration. Some of these issues and approaches for addressing them include:

- the need to control urban stormwater runoff
- the adequacy or inadequacy of voluntary BMPs in meeting water quality standards throughout the south Florida region (Should voluntary BMPs not result in attainment of water quality standards then appropriate regulation will be required.)
- the lack of authority to regulate nonpoint sources of pollution (The authority to regulate these sources must be sought.)
- the application of Total Maximum Daily Loads (TMDLs, section 303d of the Clean Water Act) for water bodies that are not in compliance with water quality standards
- numeric interpretation of the Class III narrative water quality standard for nutrients and the need for appropriate research to determine a numeric standard that is adequate for preservation intact of native flora and fauna
- determining sources of and appropriate and effective remediation strategies for the contamination of biota throughout the Everglades region with mercury
- addressing the pumping of untreated urban water pumped directly into the Everglades through S-9 and untreated urban/agricultural drainage water pumped through S-332 and the C-111 basin
- the rapid growth along the west coast of south Florida and water quality impacts on wetlands or coastal resources in this region
- agricultural expansion in the Big Cypress Watershed and potential water quality impacts on downstream water receivers
- effectively dealing with nutrient problems in the S-4 basin and the region immediately west of the EAA
- effective remediation of Superfund sites throughout the south Florida region
- the potential problem of wading birds being adversely affected by parasites and the role nutrient enrichment may play
- the cause of deformities found in fish in Biscayne Bay and other estuaries
- estrogen mimicking compounds and the effect that they may be having South Florida faunal populations
- the cumulative effects of pesticides on the environment, given the heavy use of a large number of pesticides for a variety of purposes, including agriculture, golf courses, mosquito control, aquatic plant control, right of ways and lawns
- the contamination of drinking water supplies with trihalomethanes

APPENDIX G
COMPREHENSIVE WETLAND PERMITTING AND MITIGATION STRATEGY

I. ISSUES

During the last century, about 50 percent of the wetland area within the south Florida ecosystem has been drained or filled and converted to agricultural, residential or industrial development. Critical peripheral short hydroperiod wetlands have been and continue to be diminished in spatial extent by development. This overall loss of wetland area has reduced the habitat options for the region's fauna and incrementally removed or diminished the functions that these natural areas performed, such as water quality filtration, flood control, aquifer recharge, and habitat.

The Clean Water Act requires a specific permit to dispose of dredge or fill material in the nation's waters, including wetlands. This permit program is administered by the Corps of Engineers (Corps), subject to and using the Environmental Protection Agency's (EPA) Section 404(b) environmental guidelines. The Clean Water Act Section 404 wetland fill permitting is an ongoing federal program that has a major impact on the south Florida environment, and probably has as much of a cumulative impact as any ongoing federal program. It affects the ability to attain many ecosystem restoration objectives—maximize spatial extent to recover ecological function and structure, prevent further wetland loss, recover undeveloped degraded wetlands, restore linkages, restore sheet flow, reestablish biological corridors, halt exotic species spread, etc. It affects the ability to attain restoration success criteria (no further wetland losses, degraded wetlands restored, reinstatement of natural hydroperiods, wetland use permits stipulate requirements for enhanced hydrologic connectivity, water quality, and water storage, etc. Wetland permitting and subsequent filling incrementally, and often irrevocably, reduces the land and natural resource bases available for ecological restoration. Viewing a 1970-era and a 1990-era satellite image of south Florida is illustrative. Resulting development often requires further infrastructure demands, results in increased water supply and flood control demands, and complicates water management decisions and ecological restoration alternatives.

1. <u>Development</u> Development is proceeding faster than restoration planning and faster than the current ability of the federal agencies to assess the cumulative impact. The regulatory response has been to look at individual permit requests without a broader watershed or ecosystem view. The regulatory process is also reactive in that it comes after land-use plans are written and landowners make development decisions guided, in part, by those plans. There is pressure for continued development caused by the climate, natural and cultural amenities, and quality of

life offered by south Florida. Development started on the coasts and has moved inland into wilderness areas, remnant natural habitats and wetlands. A significant and growing portion of the natural south Florida landscape has been developed. Development is not the concentric expansion of cities with the creation of urban metropolitan areas, but the march of large planned communities into undeveloped or agricultural tracts remaining under single ownership. There is a unique clash of urbanization and relict wildlife populations.

2. <u>Mitigation</u> The regulatory program currently requires mitigation to offset unavoidable functional loss, but that requirement is largely dependent on the circumstances of the individual permit. In the past, the ratios of impact area to mitigation area have varied widely over time and throughout the region, especially when compared with other parts of Florida. In a number of cases, past mitigation did not compensate for the loss of wetland functions. Often, there is an ongoing lack of a large strategic view for appropriate mitigation. There continues to be fragmentation of the ecosystem by the way the mitigation is established and by development patterns. Disagreement among agencies on the amount of mitigation necessary for a project, the value of on-site versus off-site mitigation and the appropriate type of mitigation (preservation, restoration, enhancement, and/or creation) continues. Fragmentation occurs when a wetland on a particular site is preserved or enhanced, but then is later disconnected from the overall fabric of the ecosystem by subsequent permit decisions.

3. <u>Coordination</u> Federal level coordination has improved but needs further coordination, especially with Water Management Districts and counties. Coordination involves not only sharing of knowledge of the ecological resource, but also of knowledge of transportation and other social or economic needs. Building a consensus at the local or staff level on approaches to regulatory decisions is difficult due to different and, at times, conflicting regulations, policies, and implementation strategies. Wetland regulatory programs are fragmented, overlapping, and have duplicate authorities and responsibilities.

II. BACKGROUND

1. <u>Regulatory Program</u> Section 404 of the Clean Water Act regulates the discharge of dredge and fill material into waters of the United States that include wetlands, lakes, estuaries, rivers, canals and borrow pits. The Jacksonville District of the Corps through its regulatory offices in Jacksonville and satellite offices in Miami, Fort Myers, Vero Beach, and the Keys, reviews and issues permits authorizing the fill. The EPA provides guidelines for discharge of fill and, through its Region IV office in Atlanta comments on the application of these guidelines for pending applications. The National Marine

Fisheries Service (NMFS) Panama City office and.satellite office in Miami, and the U.S. Fish and Wildlife Service (USFWS) Vero Beach office, and their satellite office in Naples, comment on pending applications under the Fish and Wildlife Coordination Act and the Endangered Species Act. These agencies also have separate responsibilities under these acts. The EPA and the Corps cooperate in monitoring compliance with issued permits and enforcement of unauthorized discharges. The Corps also regulates any activity (fill, excavation, and structures) in navigable waters, including ocean areas to the limits of the territorial sea, Florida Bay, rivers, and canals to the limit of navigation. The scope of jurisdiction over the south Florida ecosystem has been refined over the years to now include land clearing, rock mining, rock plowing, isolated waters, and drainage projects.

For the purpose of this plan, permit is defined to include Individual Permits and General Permits (including Nationwide Permits).

The federal agencies involved in the wetland permitting program have yet to provide detailed summaries of the cumulative effect of the ongoing permitting activities on the south Florida environment. It is imperative that a database is developed that will allow these summaries to be prepared.

Permitting program decisions often are relevant to ongoing planning activities. South Florida wetland regulatory programs should be integrated with pertinent planning activities, such as the Corps ongoing C&SF Project reformulation study. Specific permitting actions may have direct bearing on reformulation study considerations, such as the buffer concept or water supply preserves.

2. Projects Major types of projects include large residential developments that can encompass several thousand homes and often incorporate light commercial areas in a planned community concept, rock mining, and recreational complexes. Some areas where the land ownership was subdivided in the past are now experiencing the cumulative impacts of many small projects.

3. Ecosystem impacts. The regulatory program has not entirely addressed or documented the loss of ecosystem wetland habitat caused by development or alleviated the pressure on the ecosystem. But in recent years the program has slowed the rate of habitat destruction and has increased mitigation requirements, an improvement based on the refinement of the regulatory jurisdiction. However, documenting these improvements is currently difficult. One of the greatest difficulties in determining the effectiveness of the south Florida wetland regulatory program is the lack of a comprehensive understanding of the system and the inability to assess the impacts from individual decisions. Geographic Information System (GIS)

technology and data must be developed to accomplish this.

4. Data Management One of the difficulties associated with coordinating and evaluating the various wetland regulatory programs, is that data, maps and other wetland information are fragmented, duplicative and inaccessible to the various regulatory agency personnel. This leads to case-by-case decisions with limited ability to address issues such as cumulative effects, loss of important corridors, and other ecosystem-level impacts. A tremendous amount of information, including GIS data, is available on the south Florida wetland communities. However, this information is located in a variety of federal, state, and local agencies with limited coordination and no overall plan for assessing and managing the ecosystem or improving information exchange. The goal must be to ultimately put a system in place where the best available information (i.e. via GIS and improved wetland assessment methods) would be at the fingertips of those reviewing and deciding on individual permit applications.

5. Trends There are several important trends that need to be recognized. In some areas, almost all the uplands are in some sort of use or developed condition. Development is encroaching inland from both coasts and south from Orlando. The rate of wetland loss related to individual permits has been reduced but there is increasingly more fragmentation of remaining wetlands. Because of the regulatory authority on wetlands, the regulatory program has pushed development into uplands. Some of these uplands are of very high quality and are a limited resource in some areas, such as the Florida Keys. The only time the regulatory program has been able to recognize and preserve uplands is when they are an exceptional habitat (such as for endangered species) and where the wetland loss was of lesser environmental impact than the loss of the uplands. There continues to be a time lag, or at least a difficulty in assessing the impact of the time lag, between the occurrence of impact and the point when mitigation reaches full functionality. There are also problems with some mitigation actions-reaching full success or, in some cases, even being implemented as required by permit. Up-front mitigation by developers has not been regularly required by the permitting agencies.

III. OBJECTIVES

The overall objective is to develop a system-wide integrated wetland permitting, preservation and mitigation strategy, including coordination among all levels of government which furthers south Florida ecosystem restoration. The following elements have been identified as necessary:

1. Develop a pro-active regulatory approach.

2. Develop a South Florida Wetland Conservation Plan that coordinates and prioritizes all regulatory and non-regulatory programs affecting wetlands at all levels of government, the private sector, conservation groups and the general public.

3. Increase the speed of the planning process (shorten the time between recognition of a critical concern and implementation of a regulatory reaction).

4. Promote greater involvement in the development and implementation of plans by agencies, the public, and by the regulated community.

5. Conduct planning that spans all government levels that have an interest in, the resource to address, or the authority to act on a concern (horizontal coordination with federal and vertical coordination with state and local agencies).

6. Promote mitigation strategies that work toward the overall goal of ecosystem restoration.

7. Develop uniform functional assessment methodologies.

8. Recognize when regulatory actions make an irreversible commitment that would preclude future options for ecosystem restoration.

9. Eliminate fragmented or duplicative authorities and processes.

10. Engender feedback that brings all viewpoints into the regulatory decision processes.

11. Reduce the confrontational aspects of the program by emphasizing team building based on a uniform view of what south Florida should look like now and in the future.

12. Identify research and monitoring needs.

IV. APPROACHES

Development and implementation of a South Florida Comprehensive Wetland Permitting and Mitigation Strategy (SFCWPM Strategy) will require improved coordination between federal resource agencies involved in the Section 404 program and increased interaction between the federal agencies and state/local planning and regulatory agencies involved with wetlands. Reliable and scientifically valid wetland quality data bases must be developed to guide the wetland permitting and planning process. Ecosystem-level wetland quality/restoration needs information within given watersheds is currently not available to enable analysis of cumulative impact assessments of individual wetland permit decisions. Currently individual wetland permit decisions are made with little or no data available to assess ecosystem impacts or the short- or long-term impacts of permit decisions on the larger south Florida ecosystem restoration goals.

It is imperative to develop the SFCWPM Strategy expeditiously. The administration's initiative on permitting is that decisions must be made in a timely manner upon receipt of an application. The best decision must be made using available information. Increased staffing and funding resources must be directed at the south Florida ecosystem area by the involved federal wetland regulatory agencies in order to accomplish SFCWPM Strategy objectives. Agencies must target resources based on the assumption that there are limits to the resources that can be devoted to south Florida. These resources need to be applied where the greatest need or benefit to the overall restoration plan will be realized. This means that (1) resources must be targeted where needed to provide intensive review on critical projects, (2) consensus must be reached quickly to free and direct some of the attention to (3) increase pro-active planning. The plan for permitting and mitigation must and will adapt as information and experience is gained.

The following approaches would facilitate development and implementation of a SFCWPM Strategy that furthers ecosystem restoration. Much of the following will require additional resources or significant reprogramming of existing resources.

1. Wetland permitting program summaries. Beginning in 1994, the Interagency Working Group will submit to the Task Force an annual summary of the federal wetland permitting program in south Florida. This summary will include information by county for the number of permit applications received (includes individual, general and nationwide permits), number of permits denied, number of permits vetoed, number of permits approved, number of permits modified prior to approval, acreage of wetland to be filled in permit application, acreage of wetland filled in approved permit, and mitigation required. The development of these annual reports should be a high priority of the permitting program. The Corps, EPA and FWS will develop and maintain the wetland permitting information database that makes this possible. This will require additional resources or reprogramming existing resources.

2. Interagency Coordination A Wetland Interagency Coordination Group (WICG) will be formed.

3. South Florida Wetland Conservation Plan This is a major element of the wetland permitting and mitigation strategy. A South Florida Wetland Conservation Plan (SFWCP) should be developed that coordinates and prioritizes all regulatory and non-regulatory activities affecting wetlands at all levels of

government, private interests, conservation groups and the general public. Initial SFWCP tasks to be completed by September 1996 include:

a. Identify and map all wetlands within the SFWMD on public and private lands.

b. Designate the relative ecological functional value of all identified wetlands in high/medium/low functional quality categories. Landscape ecology concepts and GIS analysis will be used to perform the wetland functional assessments.

c. Identify and prioritize wetland restoration/enhancement sites SFWMD-wide.

d. Identify and prioritize wetland acquisition or preservation lands based on an ecological needs basis, independent of present Florida CARL and Save Our Rivers program lists. Acquisition or preservation could be through public or private means.

e. Identify critical areas, wetlands where intense development pressures require further detailed wetland assessments to be performed as quickly as possible in order to assist the wetland regulatory program decision making process.

(Resources: The Corps and EPA intend to equally dedicate resources to accomplish this, however, additional resources will be required.)

4. <u>Identify critical areas</u>. These are wetlands of particular ecological significance. Their function should be assessed by the federal agencies involved in permitting processes.

a. FWS contract for reports on changes in natural cover types over the years.

b. FWS assess whether the total area any one or more cover type that is at the point where any further reduction would impact the species mix now found in the area.

c. FWS identify cover types or topographic features that are remnant. That is, no longer provide full function and not part of the restoration plan.

d. FWS prepare a document mapping these critical areas with an assessment that will be used in permitting decisions, including denial or determining mitigation requirements.

5. <u>Increase emphasis on wetland enforcement and permit compliance by EPA and Corps.</u> EPA should increase emphasis on wetland enforcement and the Corps should increase emphasis on permit compliance to ensure that the wetland regulatory program and mitigation requirements are providing projected benefits.

a. Corps expand funding of contracts now in use for monitoring compliance with issued permits and for surveillance for unauthorized activities.

b. Corps distribute a synopsis document to the IWG describing techniques that have worked or failed.

6. Wetlands to be protected. The Clean Water Act Section 404(c) can be used to stop projects with unacceptable impacts or to protect areas in advance of development. Projects that have unacceptable impacts can also be denied a permit. Both denial and 404(c) actions can be very labor intensive, are very project specific, and in the case of 404(c), is limited to the five factors in the law. Some permit denials could result in takings claims by applicants.

a. Corps and EPA prioritize the importance that various geographical areas remain available and unchanged in order that restoration initiatives are not precluded. Priority may be based on their potential as a critical link in the ecosystem or their critical role or location as defined by planning activities. If appropriate, Corps deny a permit or EPA initiate a 404(c) to prevent irrevocable changes.

7. Watershed Management Plans and Advanced Identification. Watershed management plans and advanced identification of wetlands will encourage local government sponsorship and/or implementation through grants or contracts from EPA or Corps. Local governments will be involved with project planning, data gathering and analysis, and public outreach.

Prepare Watershed Management Plans (WMPs). WMPs would have the advantage of addressing cumulative impacts to wetland ecosystems, having a unified ecosystem approach that can across watersheds, can be used to locate mitigation banks, and can result in a high level of predictability for the regulated community. However, they can be time and resource intensive, need to have the buy-in to avoid controversy, could cause the focus on some critical issues or portion of the watershed to be diffused, and is a relatively new approach so regulatory programs do not have experience in conducting them.

Expedite completion of Advanced Identification of Disposal Area projects (ADIDs). An ADID produce good resource information and simple, easily understood maps for public use. An ADID is flexible in the level of detail that is used to make the identifications, ranging from heavy reliance on aerial geographic information system (GIS) data for a large geographic area to a more site specific studies. While this flexibility is an advantage, the result is that there is no overall clear statement of purpose for ADIDs in general, and therefore the purpose or goal must be defined individually at the start of each ADID. However, performing ADIDs can be a slow process due to the need for consensus building, the need to ground truth information, and ADIDs have been perceived by some as only a planning tool with little or no regulatory teeth. The time required for completion of some ADIDs is a concern. It is crucial that the completion of an ADID be expedited in order to increase its usefulness and timely application to the permitting process.

a. EPA send representatives to expedite the interagency team to finish the ground truthing for the Florida Keys ADID.

b. EPA expedite the preparation of the functional assessment for the Rookery Bay ADID.

c. The Wetland Interagency Coordination Group will identify specific critical areas that require watershed management plans and recommend priorities. This will include identification of local players or sponsors.

d. EPA provide grant money for gathering and interpretation of data.

e. FWS and NMFS support habitat evaluations.

8. Delegation of administration of General Permits. Delegation of some role in the regulatory process to non-federal agencies offers ways to increase efficiency of the program, has more local site specific input, reduces duplicative efforts, and generates cooperation among federal and other agencies. The potential exists for delegation of the administration of any General Permit. Federal oversight is important to ensure the achievement of preservation or restoration goals. Delegation will only be to entities that have demonstrated an interest in and commitment to ecosystem restoration.

9. Increase local presence in South Florida. Increasing the federal agencies presence in South Florida would facilitate development of the wetland permitting and mitigation strategy, expedite permitting decisions, and facilitate coordination.

10. Wetland assessment methods. Wetland assessment approaches must be developed at two scales: landscape level and site-specific level. The landscape level wetland assessment method will be developed for all wetlands within the SFWMD boundary during the development of the South Florida Wetland Conservation Plan, which is to be completed by September 1996. This landscape level wetland assessment method will employ GIS analysis and landscape ecology concepts to evaluate the functionality of wetland areas into general high/medium/low functional categories. This information will be used in all future 404 wetland permitting decisions in the south Florida ecosystem.

With the site specific wetland functional assessment methodology, presently there are a number of different approaches to assessing development impacts and determining required mitigation. These include analyses based on ratios, by relative scoring values, or by an integrated matrix. There frequently is no continuity of assessment techniques among projects and difficulty in comparing results. There can be a wide disparity in the how a particular method is applied for the same project by different participants in the process, as well as among projects in the same area. There is a need to come up with a consensus on a scientifically based approach and uniform set of assumptions for one or more assessment methodologies. The methodology should be relatively easy and rapid to employ by professionals in the geographic area of application and must produce consistent assessments of wetland impacts as well as uniform determinations of mitigation requirements.

a. WICG decide the scope of the assessment methodology. This could be (1) uniform approach for the entire ecosystem, (2) develop sub-regional methodologies, or (3) continue to create tailored made protocols for each project.

b. Corps prepare a report to summarize current practices of assessment.

c. EPA in cooperation with the WICG will assist in the development of the chosen assessment model to adapt it to the scope decided on.

11. <u>National Environmental Policy Act compliance.</u> A Generic Environmental Impact Statement (GEIS) or other types of EIS, environmental assessments, or other National Environmental Policy Act (NEPA) documents that encompass a geographic or industry scope is a proven process that has the benefit of being proactive, very broad in scope, very flexible in the issues addressed, and encompass the participation of a wide variety.of concerns including the regulated community, resource agencies, conservation groups, and the general public. However, the scope of a GEIS can be hard to define or limit and can be perceived as potentially slowing development in an area. It may be possible under NEPA to delay the processing of permit applications that are pertinent to a specific EIS.

12. <u>State and local comprehensive planning.</u> Increased involvement in state and local comprehensive planning can lead to good information exchange, avoid conflicts between state plans and federal regulation, engender federal support for local plans, and lends support to the Local planning process. The FWS has already been involved in local planning efforts related to endangered species at the invitation of the local governments. However, there is some concern regarding the appropriate level of federal involvement in local planning.

13. <u>Establishing mitigation banks</u>. Mitigation banking has the advantage of a high level of predictability and quicker permit

issuance and review, can set aside large blocks of land in advance of ecosystem impacts that include both wetlands and uplands, and can incorporate connectivity needs. Mitigation banks have a greater probability of success due to management expertise (can be placed in the hands of an ecosystem manager rather than a developer), but there have not been many banks in existence for an extended period of time so there is a concern about the long term success of biological maintenance and protection from development or development encroachment. mitigation banking is a new industry ripe for entrepreneurial efforts. The potential for establishing a bank can add value to a property by providing another economic use for the land. However, mitigation banking can result in off-site or out-of kind mitigation, but this can be used to restore the balance of vegetative communities or habitat lost in the ecosystem by previous development. Mitigation banking can give the perception that the regulated community is buying a permit but also could be viewed as a mechanism to better use the dollars committed to mitigation.

a. The ITF could seek legislative authority to provide seed money or loan guaranty for the establishment of mitigation banks through a revolving fund or outright grants. This would be available to the private entrepreneur as well as to conservation organizations, such as The Nature Conservancy, who have considerable volunteer and other expertise to implement a Bank but not the capital. The Department of Agriculture may be an appropriate entity to administer this new program since it already administers banking type programs for wetlands and soil conservation.

14. <u>Return user regulatory fees and fines</u> to the regulatory program or the restoration effort.

APPENDIX H
HARMFUL NONINDIGENOUS PLANTS AND ANIMALS

I. BACKGROUND

Nonindigenous species are those not native to a specific area but introduced anthropogenically. They are sometimes referred to as nonnative species or exotic species. Some of these species are also referred to as pest, nuisance, harmful, or invasive species.

Many such plant and animal species have escaped cultivation and become established in south Florida. Some have not only colonized disturbed sites, but also invaded natural lands that have been set aside for preservation of natural communities and landscapes. South Florida probably has more problems with aggressive nonindigenous species than any other state. The state as a whole has approximately 925 established nonindigenous plant species growing outside of cultivation (OTA 1993). Over 100 of these are listed as invasive in Florida by the Exotic Pest Plant Council (1993). At least 23 nonindigenous plants now are found in Florida's waters (McCann et al. 1994). Nonindigenous plants and land animals constitute about 25 percent of all species in the state (OTA 1993).

Many noninidigenous animal species have become established in Florida's aquatic systems: 83 fish, at least 26 insects since 1970, 2 amphibians, 3 birds, 1 mammal, 1 reptile, 5 mollusks, 1 crustacea and an unknown number of pathogens (McCann et al. 1994). Many nonindigenous terrestrial animals, particularly birds, reptiles, and amphibians, have escaped captivity and are reproducing in south Florida; 63 percent of the introduced nonindigenous bird species in the continental U.S. are found in Florida, which also has the largest number of established nonindigenous amphibians and reptile species in the U.S. (OTA 1993).

Not all nonindigenous species are harmful. Many exotic plant species never escape cultivation. Nor are all those that spread beyond their planting site are invasive. In south Florida, however, the potential for harm to natural areas from even one invasive plant species is enormous. The magnitude of the present and potential damage to south Florida's remaining natural areas from invasive nonindigenous species and the urgency for resolution are greatly under-recognized.

Problems Caused by Invasive Nonindigenous Species

Nonindigenous plant species cause severe ecologic, economic, and resource management problems in the state. Aquatic plants such as hydrilla, water lettuce and water hyacinth clog streams, canals, rivers and lakes. Aquatic weeds create a continual problem by obstructing navigable waterways throughout the Kissimmee-Okeechobee-Everglades system. Nonindigenous aquatic plants also interfere with recreation, natural vegetation, water flow, water quality and natural wildlife. By requiring control, they have been responsible for the release of tons of herbicides into south Florida canals and estuaries.

Invasive nonindigenous plants negatively impact natural areas by out-competing and replacing native species, decreasing natural diversity, decreasing local species richness, and altering topography and soils. *Melaleuca quinquenervia* is one of the key problems for the natural environment. Introduced in the early 1900s, melaleuca trees have rapidly expanded, in recent times showing a 50-fold increase; some 450,000 acres of south Florida are now infested to some degree (OTA 1993). Fire and water management have enhanced its spread. Melaleuca monocultures have replaced sawgrass marshes, sloughs, cypress stands, and other natural plant communities. By replacing native vegetation, dense melaleuca monocultures can decrease the availability of nesting and foraging habitat for endangered species such as the Snail Kite and Cape Sable Seaside Sparrow (OTA 1993).

Disturbed sites such as canal banks and fallow fields may be the first sites colonized by nonindigenous plant species escaping cultivation because the typical cover of such sites is nonnative species. The urban and agricultural development of south Florida has created many such sites where these species can become established. Water management practices that alter hydroperiods and water tables have created disturbed conditions that make natural areas vulnerable to invasions by nonindigenous plants. Catastrophic events such as hurricanes and fires increase the vulnerability of natural areas. Colonization of disturbed sites allows the nonindigenous species to develop the reproductive power with which to invade natural areas when disturbances make these areas more vulnerable. Nonindigenous species that escape cultivation can spread rapidly because the predators, parasites, or diseases that naturally control their growth and reproduction were left behind in their country of origin. Consequently, a virtually uncontrolled expansion of harmful nonindigenous plants is altering the south Florida landscape and natural biological integrity.

The potential threat of nonindigenous plant species to Florida's remaining natural areas has increased in the decades since melaleuca, Australian pine, and Brazilian pepper trees were introduced. Ornamental plants from around the world are distributed in the nursery trade and used intensively in landscaping. Development has caused the acreage planted in nonindigenous species to greatly expand, while at the same time decreasing the acreage of native vegetation. Because of relative seed supply alone, the potential for nonindigenous species to colonize newly available sites in both disturbed and natural areas is much greater now than it was 40 or 50 years ago.

Some non-native plant species with invasive tendencies currently have larger populations in south Florida than many native plant species. For instance, while there now remains only about 8,000 to 10,000 acres of rock-ridge pine savanna community in south Florida (Doren et al. 1993), there currently exists over 700,000 acres of Brazilian pepper in nondeveloped areas and at least 50,000 to 60,000 acres of melaleuca growing as a monoculture (R. Doren, pers. comm.).

Several hundred species of nonnative animals are established in developed areas of south Florida (Robertson and Frederick 1994). Birds, herpitifauna, and fish are the most noticeable of these. The aquatic species appear to pose the most serious threat to natural areas. Many aquatic nonindigenous fish and invertebrate species are imported for sport, aquarium, or aquaculture purposes. Most are imported from tropical climates and are well adapted to the South Florida region. Accidental or intentional releases into canals, lakes, and other water bodies have resulted in the establishment of reproducing populations of a number of these species. The blue tilapia, walking catfish, black acara, oscar, Mayan cichlid, and the blackchin tilapia are the most problematic and widespread of nonindigenous tropical fishes. Almost nothing is known about the ecological effects of these nonindigenous fish and invertebrates on native populations. Prolific nonindigenous aquatic species may degrade the quality of habitat for native species, introduce diseases or pathogens, or out-compete or prey on native species. Nonnative herpetifauna such as *Anoles segrii* have displaced native congenitors such as *Anoles carolinensis*. Wild hogs are problems in some natural areas, causing extensive damage and disturbance in pinelands and hammocks, creating sites that are vulnerable to colonization by invasive nonnative plants.

Economic Consequences of Exotics

The economic costs of control of nonindigenous plants, once established in the ecosystem, are enormous. In 1992, almost $1 million was spent by three agencies to control melaleuca (OTA 1993). The cost to eradicate melaleuca from Water Conservation Area A alone is estimated at $12.9 million over 5 years, based on current rates of expansion (OTA 1993). Roughly $14 million and extensive labor are spent in Florida each year to reduce the impediment caused by aquatic weeds; $11 million alone is spent on hydrilla, water hyacinth, and water lettuce control (McCann et al. 1994).

On the other hand, the economic costs of NOT controlling the harmful nonindigenous plants in south Florida are substantial. The estimated benefits of melaleuca removal, $168.6 million (OTA 1993), provide one estimate of the cost associated with melaleuca dominated landscapes. A study of Orange Lake in north central Florida indicated that tourism and recreational fishing amounting to $11 million annually is all but lost in years when hydrilla covers the lake (OTA 1993). Brazilian pepper growing in proximity to croplands is believed to support large populations of vegetable damaging insects (OTA 1993).

Existing Control Efforts and Their Limitations

The extensive effort to control harmful nonindigenous species extends far beyond the federal realm to encompass state, local, private, and university initiatives.

The Exotic Pest Plant Council (EPPC) is a nongovernmental group formed in 1982 to address the dilemma of invasive nonindigenous plants in Florida. One major activity of this group has been to develop an extensive, prioritized list of harmful non-indigenous plants. The list is updated every other year. Four nonindigenous plant species were suggested as the most significant concerns when the group was first formed: Melaleuca (*Melaleuca quinquenervia*), Giant Sensitive Catsclaw (*Mimosa pigra*), Australian Pine (*Casurina equisetifolia*) and Brazilian Pepper (*Schinus terebinthifolius*). The present list includes 126 problematic nonindigenous species.

The Melaleuca Task Force is composed of several concerned entities that have joined together to systematically eradicate melaleuca. Several control operations and methods are currently being researched and implemented. A complete explanation of these management programs and techniques is found in Melaleuca Task Force (1994).

The Florida Department of Environmental Protection and the Corps of Engineers contribute to and support numerous exotic removal programs. The South Florida Water Management District leads several exotic eradication efforts. The Florida Department of Transportation continually reduces and maintains invasive nonindigenous plants on right-of-ways. National Wildlife Refuges, such as Ding Darling NWR, Florida Panther NWR, and Loxahatachee NWR and National Parks and Preserves, such as Big Cypress Preserve, Everglades and Biscayne National Parks, have implemented ongoing exotic elimination projects within their boundaries. On the local level, a persistent concern for the spread of the exotic Cogongrass (*Imperata cylindrica*), led to a campaign that it as a Noxious Weed in July 1993. Local county park and recreation departments' efforts have concentrated on removing invasive nonnative plants from natural areas throughout the south Florida region. The Dade County Park and Recreation Department has a multi-million dollar exotic control program under way in tropical hammock areas to help the park natural areas recover from invasions of nonindigenous plants and some prolific native vines after Hurricane Andrew.

The U.S. Department of Agriculture and the University of

Florida are investigating various biological control organisms on several nonindigenous plants. Host-specific organisms are tested for their effectiveness as control agents and evidence for general safety. The introduction of host-specific insects, such as seed and sapling eaters, can safely and economically decrease the spreading of pest plants. Considerable progress has been made on the identification and testing of a biological control agent for melaleuca. At a proposed quarantine facility in Ft. Lauderdale, USDA plans to investigate the possibilities of using insects or plant pathogens to control or reverse the expansion of invasive nonindigenous plants such as melaleuca, but the quarantine facility is not fully funded.

Several federal laws deal with the importation of nonindigenous species. The Non-indigenous Aquatic Nuisance Prevention and Control Act of 1990 and the Lacey Act authorize the U. S. Fish and Wildlife Service to issue regulations on aquatic and other nuisance species and restrict importations of exotic species. The U.S. Department of Agriculture (APHIS) also has responsibilities under the Lacey Act and administers the Federal Noxious Weed Act of 1974 and the Federal Plant Pest Act. U.S.D.A. responsibility includes the identification of actual or potential noxious weeds and preventing their entry into the United States (OTA 1993). Neither the U.S. Fish and Wildlife Service nor the Department of Agriculture have been effective in preventing the importation of nonindigenous species potentially harmful to natural ecosystems. Under the Lacey Act, only a small number of organisms are considered nuisances: 2 families, 13 genera, and 6 species. The USDA/APHIS only inspects imported species that are risks to agricultural activities and does not screen for nonindigenous species that may be detrimental to natural communities (OTA 1993).

Recently a federal interagency group was formed entitled the Federal Interdepartmental Committee for Management of Noxious Weeds. Seventeen or 18 agencies within The Departments of Interior, Transportation, Energy, and Agriculture are involved. They are responsible for coordinating noxious weed management. They are attempting to reorient the emphasis of control efforts toward protecting natural lands and rangelands, not just croplands.

The Office of Technology Assessment report on harmful nonindigenous species (OTA 1993) is a major step forward because it provides an overview of the problem and the present institutional framework for addressing the problem and an evaluation of the current way the problem is--or is not-- being addressed. The Florida Department of Environmental Protection is planning to write a similar document specific to the state. The National Park Service is planning a similar report for the Park Service.

II. MAJOR ISSUES/PROBLEMS

Invasive plants and animals from other parts of the world are becoming established in south Florida's natural areas, altering landscapes, community structure, and food webs; and too little is being done in defense of the south Florida ecosystem, considering the magnitude and seriousness of the threat. Although a concerted effort is being made at manual, mechanical, and chemical control of melaleuca, biological control, an essential element in control of widespread, prolific pest plants such as melaleuca, is seriously under-funded. As a result, although promising control organisms have been found, implementation of biological controls for melaleuca and Brazilian pepper has been delayed. Although much attention is being given to the control of well established pests such as melaleuca, many other plants are invading natural areas with little or no human resistance.

Of possibly even greater concern is the lack of attention given to prevention. Virtually nothing is being done by any federal, state, or local agency to prevent the propagation and distribution of the 126 plant species listed as invasive, problematic species in Florida by the Exotic Pest Plant Council (1993). It is possible to appraise the potential invasiveness of new species being imported (EPPC 1993, OTA 1993) and to use this information to establish appropriate regulations, however neither the screening nor the regulation are presently being performed (OTA 1993). Meanwhile, new species with invasive potential continue to be imported, propagated, and distributed.

Within the state of Florida, some local, state, and federal agencies are actually encouraging the use of EPPC-listed species for landscaping. Agencies sometimes distribute, at no cost to homeowners, nonindigenous plants listed by EPPC as invasive (e.g., carrotwood). This practice is quite widespread and occurs in the face of the tremendous economic costs some of these same agencies are incurring in controlling species such as melaleuca.

In the name of water conservation, some agencies currently are promoting xeriscape programs in which many of the recommended species are nonindigenous and may compound the problem. Xeriscape species, because they tolerate extended periods of drought, may be more likely to escape cultivation in south Florida than landscape plants that require irrigation, so xeriscape programs should emphasize the planting of native species, many of which are adapted to periods of sustained drought and are not a threat to the ecosystem.

Some of the listed species are used in landscaping on government lands, including highway rights of way. In addition, there are few control programs for removal of invasive nonindigenous plants from government lands, except parks.

Laws controlling imports of harmful nonindigenous species, as administered, are ineffective in preventing the entry to this country of plants and animals potentially damaging to natural ecosystems. No screening mechanism and protocol exists for identifying imports not already present in this country that are potential threats to natural areas.

At the heart of the issue is the lack of awareness and knowledge of the potential damage that these species can cause. Education can be a means of reducing the threat from invasive nonindigenous species. People who are concerned about environmental degradation often will change their habits if they realize that what they are doing is having a negative environmental impact. But educational programs are not well organized and are poorly funded. An intensive effort is needed to reach the influx of newcomers to the state, including people from many different cultures.

The poor defense on all fronts against invasive nonindigenous species is partly a reflection of the lack of recognition by the public and government policy makers of the magnitude and seriousness of this problem. The insufficient education effort is part of the reason why the public is not more concerned.

One might say that the greatest obstacle in combating nonindigenous species is lack of funding and human resources to stay ahead of problems. But solutions are made more costly by failure to act promptly and effectively, once problems are recognized, and the lack of emphasis on preventive programs.

OBJECTIVES

The objectives of the South Florida Restoration effort, with respect to harmful nonindigenous species are to:

- Halt or reverse the spread of invasive species already widespread in the environment.
- Eradicate invasive species that are still locally contained.
- Prevent the introduction of new invasive species to the south Florida environment, including both those now present in cultivation in south Florida and those that would be imported.

APPENDIX I
HABITAT RESTORATION AND MANAGEMENT STRATEGY THAT ADDRESSES THE DECLINE OF NATIVE FLORA AND FAUNA SUCH AS WADING BIRDS

I. BACKGROUND

The vast and heterogeneous wetland landscape that characterized the pre-drainage south Florida ecosystem supported enormous numbers of water birds, particularly wading birds. The whole system was a complex heterogenous mix of various extents of water depths and vegetative types. It was this vast heterogenous mix, maintained be fire, freezes, and rainfall extremes, that provided the habitat support for the production and survival of the diverse, yet immense populations of wading birds. The productivity, dispersal, and survival of these wildlife—the birds and their forage fish base—were regulated by the annual periodicity of the wet-dry cycles and rates of drying and flooding that concentrated the dispersed nutrient base of the system.

These wading birds represent a critical component in the trophic structure of the wetland landscapes that comprise the south Florida ecosystem. Because of their wide foraging range and their narrow foraging requirements in terms of water depth and concentrated prey, they reflect the health of the ecosystem, particularly in their ability to reproduce successfully.

Wading birds numbers have seriously declined concurrent with the drainage and development associated with the C&SF Project. The number of successful wading birds nesting throughout the system has declined more than 90 percent according to historical records. The wood stork, on the Federal Endangered Species list, is closely identified with the Everglades and its current status indicates the serious problems inherent in the entire Everglades system.

II. ISSUES

The problems for wading birds and other natural flora and fauna are related to the diminishing size of the ecosystem itself. Much of the area eliminated was prime short hydroperiod habitat critically important to wading birds. The remaining wetlands are seriously degraded. The hydrologic character of the entire Everglades has been altered, consequently reducing habitat capacity and refugia. The distribution, timing, and quantity of water throughout the system have been disrupted, seriously constraining wading bird reproduction to narrow time frames subject to numerous drastic and catastrophic disruptive conditions.

In addition, excessive nutrient loading from agriculture has resulted in major vegetative conversions to both the macrophyte and periphyton communities in vast areas of the remaining Everglades: enormous areas in the Water Conservation Areas and the littoral system of Lake Okeechobee have been converted to monotypic stands of cattail and periphyton communities.

Although declining wading birds are indicators of system function, there is at present no dependable funding source for monitoring of animal groups including wading birds. A coordinated aerial wading bird census (systematic reconnaissance flights) has been underway in portions of south Florida for several years. Rookery counts and some nesting success information are collected in some areas by some agencies. Except for current small scale projects underway in the Everglades National Park and Loxahatchee National Wildlife Refuge, there has been only minimal effort to study the distribution, abundance, and trophic relations of forage fish and invertebrates that are important prey for wading birds and other vertebrate predators. Virtually nothing is known of the life history and requisite requirements of the apple snail that could be considered a keystone species to the system.

Upland habitats have been reduced to remnant areas, but still support a high diversity of native plants and animals, including several listed threatened or endangered species. Rockland pinelands in southern Dade County were heavily damaged by Hurricane Andrew and recovery has been impeded by invasion by non-native plants and a post hurricane invasion by pine bark beetles, which killed many pines. Only Longpine Key within Everglades National Park survived relatively intact. The next largest stands are on publicly owned land (including federal property) for which the Dade County Park and Recreation Department has unsuccessfully sought funding from FEMA and the state. FEMA's unwritten policy is not to fund restoration of natural areas. The state did not appropriate requested funds in the recently passed budget. The opportunity to recover these pinelands may be lost. Loss of these pinelands could affect pineland dependent species in Everglades National Park.

III. OBJECTIVE

In 1993 the federal interagency Task Force on the South Florida Ecosystem adopted several management objectives. These included:

- Restore and maintain the biodiversity of native plants and animals in the upland, wetland, estuarine and marine communities of the South Florida ecosystem.

- Provide for adequate natural habitats for native plants and animals.

- Recover species that are threatened or endangered.

APPENDIX J
MULTI-SPECIES RECOVERY PLAN

I. BACKGROUND

A large number of federally listed threatened or endangered species occur within the south Florida ecosystem. One of the purposes of the Endangered Species Act of 1973 is to provide a mechanism to protect threatened and endangered species and provide a program for their conservation. Conservation is defined as bringing a species to the point where the measures outlined in the law are no longer necessary. The process of taking the species from its listed status to full conservation, that is reversing the decline and neutralizing the threats, is called recovery. A species restored to a healthy condition no longer needing the protection of the act is considered recovered. Our goal will be to recover all listed species in the south Florida ecosystem.

Section 4 of the Endangered Species Act requires that the Fish and Wildlife Service and the National Marine Fisheries Service develop recovery plans for all listed species. These plans are an integral part of the overall recovery program whose primary goals are:

1. Identification of those ecosystems and organisms that face the highest degree of threat.

2. Determination of the tasks necessary to reduce or eliminate the threats.

3. Application of the resources available to the highest priority recovery tasks.

The first step in the recovery process is the development of a recovery plan that delineates, justifies, and schedules the research and management actions necessary to recover a species. The plans are comprehensive documents that identify all known recovery actions and anticipated costs. These plans serve as blueprints for private, federal and state interagency cooperation because they identify specific actions and the appropriate responsible agency.

Recovery plans serve as a catalyst to encourage all participants to work toward species recovery. They have been very effectively used as an impetus for budget formulation, agency policy review and development of agency management plans.

II. ISSUES

The south Florida ecosystem contains numerous listed species, many of which already have approved recovery plans. Each plan addresses only one species. A review of the plans indicates that depending on the ecological status of the species and the type of habitat they occupy, some plans are complementary and some may be at odds with one another. Thus, it may be possible to conduct an action that benefits one species while creating problems for another. The development of a comprehensive plan that looks at the ecosystem as a whole, rather than it's parts, is needed. The importance of each part must be considered, but efforts need to be made to put all the parts together as a whole. Furthermore, there needs to be close coordination between the National Marine Fisheries Service and the Fish and Wildlife Service to ensure that the federal agencies assigned the responsibilities are working together.

Recovery plan development and implementation is further compounded because of the wide variety of land ownership and land uses. The variety of uses, management and owner expectations is even evident on public land. With a host of agencies charged with a multitude of purposes, it is difficult to arrive at mutually acceptable goals.

The problem is further compounded because of the degraded nature of many of the habitats. Large and expanding human populations, intensive agriculture, complex water control structures and invasion by a host of exotic species have made management of remnant natural systems extremely difficult.

Recovery can be a slow and difficult process where results are costly and sometimes not immediately obvious. Some of the problems associated with recovery are:

1. The lack of funds available to conduct the most critical recovery actions.

2. Lack of information on a species makes it difficult to design an effective recovery plan. Research is necessary to answer some of the questions.

3. Often, research will produce unanticipated results and a new approach must be developed.

4. Recovery is a very gradual process. Several generations of success may be needed before the Service is confident that a species can be de-listed.

5. Just as it took many years for a particular species to decline, it may take many years to reverse the decline.

III. OBJECTIVE

The management objective is to recover species that are threatened or endangered. This recovery will involve restoring health to the entire ecosystem. Such an approach will prove beneficial to many other organisms in the ecosystem. Efforts will be focused on ensuring the protection of biodiversity emphasizing the importance of community associations and habitat protection and enhancement.

IV. CURRENT ACTIVITIES AND APPROACH

The Fish and Wildlife Service and the National Marine Fisheries Service have developed individual recovery plans for most of the species in the south Florida ecosystem. These plans vary greatly in quality and some are in need of revision. Some species are receiving funding attention and some are not. There are active recovery programs under way for a number of the more visible species.

The state of Florida is also actively involved in recovery efforts for many listed species. Through Section 6 of the Endangered Species Act (ESA), the Fish and Wildlife Service can provide funding on a three-to-one ratio to states that have a cooperative agreement. In Florida, the Florida Game and Fresh Water Fish Commission, the Florida Department of Environmental Protection (for marine species) and the Division of Forestry (part of the Florida Department of Agriculture and Consumer Services) have agreements with the Fish and Wildlife Service. These three agencies cover all listed species from marine mammals to plants. All three agencies are actively involved in recovery of listed species in south Florida and work closely with the services in accomplishing actions identified in approved recovery plans.

The services also use recovery plans and the actions they contain to make specific recommendations to federal agencies and applicants who are required to enter into consultation under Section 7 of the ESA. Through the Section 7 program federal agencies are required to consult with the Fish and Wildlife Service (and the National Marine Fisheries Service) on actions they authorize, fund, or carry out that "may affect" listed species or "destroy or adversely modify" critical habitat. The services conduct hundreds of consultations each year on federal agency actions which range from permits for wetland fill authorized by the Corps of Engineers to road and runway projects funded by the Federal Highway Administration and the Federal Aviation Administration. During these consultations the services make recommendations on how project impacts can be reduced or encourages actions to be taken to improve the status of listed species. The basis for most of these recommendations is approved recovery plans.

The vast array of recovery efforts and the development and implementation of recovery plans need to be coordinated in a cohesive manner. The goal is to develop a comprehensive, ecosystem wide-recovery/management plan that recognizes the needs of each species and is responsive to the varying objectives of the agencies charged with managing the land. It is hoped that we can develop a consolidated and unified strategy that, within the objectives of the Endangered Species Act, would look at all endangered species and their habitats in the system and deal with them holistically rather than focusing on individuals. Only a system-wide approach will ensure that all species are protected and none are protected at the expense of others. It must be recognized that actions to protect listed species associations will benefit many other life forms that occur in the same area. Threatened and endangered species do not exist as independent species, they are active components of the larger system. Responsible management actions that benefit listed species will in most cases benefit the overall ecosystem.

V. FUNDING AND LEAD AGENCY

The Fish and Wildlife Service, in close coordination with the National Marine Fisheries Service, will lead this effort. Staff of each agency will work together in a complimentary fashion. Funding may be supplied to the State agencies, universities or private consulting firms to carry out individual tasks. The goal is to have a comprehensive plan that embraces all agencies and interest groups and solicits support from agriculture and business to federal, state, regional, county and city government.

It is estimated that the development and approval of a Multi-species Recovery Plan will take two years; one year to prepare a draft and one year of review and refinement. In order to meet the two year date it will require three full-time staff biologists with appropriate clerical support. These individuals will need to be experienced in the Recovery Program of the Fish and Wildlife Service and will be assigned this responsibility as their full-time job.

There will be additional costs associated with reproduction of plans, public meetings, etc. A comprehensive plan will be of great value to land owners and managers alike.

APPENDIX K
HABITAT RESTORATION AND MANAGEMENT PLAN STRATEGY FOR NEAR COASTAL WATERS INCLUDING FLORIDA BAY, THE FLORIDA KEYS AND THE CORAL REEF SYSTEM

I. MAJOR ISSUES

Much of the interest in south Florida ecosystem restoration has focused on the Everglades National Park and the historic Everglades terrestrial and freshwater ecosystems. While restoration efforts directed at the Everglades ecosystem may benefit the coastal, nearshore and offshore systems of south Florida, additional efforts will be necessary to restore these areas. Chronic losses in near-coastal waters have been amplified by recent dramatic events such as massive seagrass, mangrove, and faunal die-offs as well as other symptoms such as increased algal blooms, reduced fish landings, overall deterioration of fringe reef systems, and decreased species diversity in flora and fauna (aquatic and terrestrial).

A. Alteration of Freshwater Flow to Estuaries The C&SF Project altered the quantity, timing and distribution of freshwater entering the estuaries. Hypersalinity in the bays, presumably resulting from the freshwater flow alterations, has been suggested as one causative factor in the seagrass and mangrove die-offs. Channelized freshwater flow, chronic, and episodic voluminous releases from control structures have caused marine faunal and floral mass mortalities and habitat loss.

B. Water Quality Degradation Pollutant input, particularly excess nutrients, has contributed to the observed loss and degradation of nearshore and offshore habitats such as seagrass and coral reefs. Likely primary sources of pollutants include urban runoff within the Florida Keys and upstream, agricultural runoff and industrial runoff. Other possible sources include recreational and commercial boating activity and point/nonpoint source discharges from other countries which end up in ocean currents moving along the south Florida coastline.

C. Loss of Habitats to Development Aquatic and terrestrial habitats have been affected directly and indirectly by the development boom. The resulting methods of sewage disposal (e.g. septic systems, shallow well injection, cess pits), lawn care, traffic, etc., also contribute as nonpoint sources of pollution, resulting in the degradation of local water quality and loss of habitat (seagrass, mangrove, "live" hard bottom) from dredge and fill activities.

D. Impacts to Habitats From Recreation & Commercial Activities Boating impacts have caused significant damage to both seagrass and coral reefs. Over 10,000 acres of seagrasses have been destroyed by propeller scarring in the Florida Keys. An average of over 40 small vessel groundings occur each month in the FKNMS; many result in direct impact to coral reefs. Additional impacts occur from boats anchoring on corals, or improperly moored live-aboards that directly impact seagrasses and other important marine habitats. Hard bottom habitats, coral rubble, and coral reef substrate that support a wide diversity of reef organisms are under increasing pressure from harvest as the demand for live rock in the aquarium industry increases. An increase in commercial sponging in the Keys has added additional pressure on the sponge community, another important component of the ecosystem. The cumulative impact of a wide range of commercial and recreational activities contributes to habitat and water quality degradation.

II. BACKGROUND

Coastal and nearshore communities are highly productive ecosystems that support a wide variety of species and provide economic and social benefits. Commercial and recreational fisheries, diving and snorkeling, wildlife observation, boating and swimming are just a few of the activities that contribute to the economic and social well being of south Florida. The continued health and productivity of these natural systems depend on maintaining a viable balance among their various components and the pressure of the human activities.

Local fishers and divers have noted subtle changes in south Florida's nearshore and offshore habitats for the past decade: changes in water color and transparency, reduced fisheries landings, and a general decline in the coral reef habitats. Symptoms of these ecological changes began in the early 1980s with fish die-offs, coral disease outbreaks, coral bleaching, and other changes in the health of the natural resources. This general degradation was dramatically illustrated in 1987 when Florida Bay began experiencing a sudden, massive die-off of seagrass. Around the same time, and in many of the same general areas, mangroves on wash-over islands also experienced die-offs. In addition, a coral bleaching event occurred along the length of the coral reef tract that parallels the Florida Keys. Some of the causes of degradation are obvious: increased development, boating activities, a proliferation of septic tanks and artificial canals, etc. However, there are disparate theories within the scientific community regarding the specific causes of many of these occurrences. Theories include reduced freshwater inflow to the estuaries due to the C&SF Project, excess nutrients from upland runoff and contaminants from upland runoff. Until specific causes of the degradation are identified, management of these habitats must depend on existing knowledge and best professional judgment.

III. OBJECTIVES

a. Restore natural or near natural freshwater distribution to south Florida bays and estuaries, including Florida Bay.
b. Provide adequate treatment of runoff from urban, agricultural and industrial areas to remove contaminants and excess nutrients (primarily nitrogen and phosphorus). Treatment activities should include Florida Keys upland areas as well as upstream areas on the mainland.

c. Identify, reduce and eliminate pollution from septic systems, bilge pumps, "heads", foreign sources, etc.

d. Achieve a no-net habitat loss due to development.

e. Produce a net increase in value and function of existing habitats through restoration, enhancement and management.

f. Restore historic fisheries productivity.

g. Eliminate adverse impacts of recreational and commercial activities on existing habitats.

h. Identify additional causes of ecosystem degradation.

IV. GEOGRAPHIC SCOPE

For consistency, the geographic scope of this habitat restoration and management plan is the same as Subregion 8 for the Science Subgroup. It encompasses the coastal, nearshore and offshore areas from Biscayne Bay on the Atlantic Ocean, around the Florida Keys, and up to Rookery Bay on the Gulf of Mexico. Consideration may be given to expanding the scope at a later date to include all of the three focus areas identified in the U.S. Fish and Wildlife Service's South Florida Coastal Ecosystem Restoration Initiative (FWS Coastal Initiative). The three focus areas include Florida Bay/Florida Keys, Indian River Lagoon/Lake Worth and Charlotte Harbor.

APPENDIX L
SUPPORT LAND BASED PROTECTION STRATEGY

I. BACKGROUND

The general trend of water resource development in south Florida during the 100 years before the Central and Southern Florida Project had been more or less defined before Florida became a state. Leaders of the day had grand visions of extensive agricultural development of the muck lands around the Kissimmee Valley lakes and Lake Okeechobee. On admission into the Union in 1845, the Florida Legislature instructed the senators and representative from the state to press upon the Congress the importance of reclaiming the Everglades.

In connection with all the activities revolving around the Everglades, one of the state's first two U. S. Senators, J. D. Westcott, proposed to the Congress that the United States grant to the state those lands lying south of a line from Sarasota on the west coast to Walton on the east coast (with certain exceptions) provided the state would undertake the reclamation of the lands. Senator Westcott introduced a bill making specific provision for the grant. The bill was referred to the Committee on Public Lands, which considered it in connection with other available information.

Largely as a result of Senator Westcott's activities, and that of other states, Congress, in 1850, passed what is generally referred to as the Swamp and Overflowed Lands Grant Act. The act granted to Florida those swamp and overflowed lands which remained unsold at the time of the passage of the act, with the stated purpose to enable the state to reclaim the swamp and overflowed lands. This donation included the major part of the peninsula, large areas of which were not wetlands or identified swamp and overflowed lands. At the time it was thought to be about 12 million acres, but was later discovered to be over 20 million acres, including the Everglades. An important stipulation in the act was that the sale of the lands to private interests should finance the necessary work of reclamation. The fate of the lands in the Everglades then went through a series of events punctuated by the state's creation of the Trustees of the Internal Improvement Fund to sell the donated land; the Civil War; the era of Hamilton Disston, hired by the state to drain the Everglades; the Everglades Drainage District, created to take up where Disston left off; the opening of the area south of Lake Okeechobee to farming; the Florida land boom; the major hurricanes of 1926 and 1928 which led to the levees around Lake Okeechobee; the Great Depression; the creation of the Everglades National Park; and the Central and Southern Florida Flood Control Project in 1948.

The cumulative effect of these actions including the features of the Central & South Florida Project has succeeded in accommodating and supporting a 5.5 million population along with a large and diverse economy.

The state and the federal governments now find themselves in the position of having to repurchase or provide regulatory protection to large tracts of land included in the original land grant to preserve and restore critical hydrological and biological functions of the same Everglades considered 150 years ago to be "utterly worthless to the United States for any purpose whatever."

Other lands are being identified by state, county, and local governments for repurchase or zoning protection to ensure a clean and sufficient supply of water for a growing population and economy.

Significant contributions to these purposes are also being made voluntarily by some private landowners and non-governmental organizations.

The result is a mosaic of land uses, protection activities, and strategies across the south Florida ecosystem.

II. ISSUES

Public protection of land values critical to sustainable environment and development in south Florida, is based in local, county, and regional land use plans and zoning. Compliance is achieved through information and education or through regulatory enforcement. While these plans usually reflect a good sense of community needs and interests, they often do not reflect clearly how to integrate into broader ecosystem based strategies of environmental restoration and sustainable economic development. Significant efforts must be undertaken by federal agencies, coordinated through the ITF and its Florida-based IWG to offer and provide scientific and technical planning assistance to state, regional, county, and local comprehensive land-use planning efforts to fully integrate ecosystem-based sustainability objectives and conforming solutions. Successfully conforming a plan with provisions to assure its implementation should be met with authority for expedited clearance of required federal permits and approval necessary for implementation.

As effective as these efforts can be to accomplishing environmental protection and sustainable development strategies, public acquisition and direct management of critical land remains an important component of restoring environmental values and sustaining development and the population of the south Florida ecosystem. It is not the purpose of this appendix to propose specific lands for acquisition. This is being accomplished by several ongoing activities interwoven into the restoration effort. We have included a list identifying existing approved public acquisition activities pertinent to sustainable ecosystem goals. We endorse the completion of these actions. Further, there are several strategies that pertain to land acquisition that need to be more fully developed. Among these are:

a. A methodology or evaluation criteria for identifying and prioritizing specific types of lands that must be publicly acquired and directly managed to accomplish and sustain ecosystem restoration; some are critical, some important, others marginal.

b. Responsibilities (who), scheduling and funding for land acquisition will need to be clarified.

c. Strategies for land acquisition.

III. OBJECTIVES

Probably the best vehicle to tackle these issues would be the development of a multi-agency land protection strategy. It would outline the land protection process from identification through management of acquired land. An outline for the multi-agency land acquisition strategy would be:

a. Development of evaluation criteria for the specific types of lands required for ecosystem restoration.

b. Identification and inventory of all lands currently in public ownership, lands being and to be acquired by public entities, and lands identified in current reports which may be acquired by public entities. This would include lands owned by, to be acquired by, or identified by various federal, state, or local government agencies; including any lands identified by the Interagency Task Force and Working Group and sub-groups; by the Corps restudy; and any other source interested in Everglades restoration. This would be an iterative process, and would be included in the land protection strategy.

c. Prioritization of identified lands. Determine which are the most important lands and types of lands with respect to restoration/availability; which are the least important.

d. Determination of levels of title needed for various lands or types of lands identified for acquisition. Where would fee acquisition be needed, where would easements be adequate, where would zoning be appropriate, etc.

e. Availability of land use mapping Using on-line GIS systems, county master plans, wetland mapping, etc.

f. Existing mechanisms for land protection by responsible agencies, i.e.,:

- negotiated free market acquisition
- eminent domain and/or necessary legislative authority
- funding sources (input from another sub-sub-group)
- land swap potential
- zoning ordinances
- tax incentives in return for land donations
- mitigation banking
- private initiatives, such as the Trust for Public Lands
- establishment of real estate arrangements to facilitate donation of private lands or private funds

for restoration
- any other initiatives available to acquire interest in land

g. Development of a land management strategy for all lands acquired by federal, state, and local government agencies for ecosystem restoration to provide for consistency.

h. Obstacles to land protection initiatives including mineral rights, tax losses, infrastructure changes, community acceptance, relocation services, ad infinitum.

The charge for the group would be to deliver a report that addresses all the issues identified herein, and all others that are determined at a later date. The end product would be a stand alone document that could be used by the task force, the Corps study team, and all other interested parties to understand the land acquisition ramifications of the restoration efforts.

APPENDIX M
COORDINATED ECOSYSTEM BASED SCIENCE PROGRAM

I. INTRODUCTION

This Science Plan and its extended version is designed to provide scientific information to help guide the restoration. The Science Plan outlined here is directed at the following themes:

characterizing the pre-drainage system

determining the key characteristics of the natural hydrologic system that supported the rich diversity and abundance of wildlife that has been lost

predicting effects of alternative structural modifications and operational changes

assessing the hydrologic and ecological results of these changes

evaluating the impact of present and alternative urban and agricultural practices

recommending modifications of design and urban and agricultural practices

II. PROJECT MANAGEMENT

The Science Sub-group is developing a detailed description of the scientific support required for the south Florida ecosystem restoration effort. The objective is to formulate an overall research plan, describe relevant ongoing efforts that will be integrated into the overall plan, and identify gaps. Interagency planning efforts are being initiated to ensure efficiency and integration of efforts. This approach involves broad involvement of the scientific community and appropriate peer review. Regular communication of progress will be scheduled to obtain essential feedback from primary constituents: restoration managers, environmental and economic interest groups, and the general public. Data management requirements for all projects follow the policies agreed to by the interagency U.S. Global Climate Change program to ensure data compatibility. A difficulty in achieving these goals is that management responsibilities for south Florida ecosystem restoration are currently fragmented. Ludwig et al. (1993) in the third principle of effective management states that scientists should be relied on to recognize problems, but not to remedy them, noting that individual scientists are heavily influenced by their discipline training and that interactions involving many disciplines are critical to solving ecosystem management problems. Ludwig also notes that individual scientists in management situations have often been subject to intense political pressure that influences their decisions, but without a broader community aware of the impact of such pressures. The Science Subgroup has attempted to deal with these issues by being a collective body with a significant mix of disciplines and interacting directly through the Interagency Working Group made up of agency managers with responsibilities for decision making.

The Florida Bay Science Plan has already been developed. Its management structure involves an interagency program management committee, an interagency technical advisory group, and a scientific panel of nationally recognized scientists.

III. COOPERATION

Research currently underway or planned at the South Florida Water Management District(SFWMD), Florida Department of Environmental Protection, the University of Florida, and the Florida Game and Fish Commission is a vital component of this Science Plan. For example, the existing hydrologic models (the South Florida Water Management Model [SFWMM] and its natural system corollary [NSM]) that will be the core of the proposed hydrologic modeling system were developed by SFWMD and already are undergoing considerable upgrading that will make them even more useful in restoration modeling. SFWMD also is developing a landscape model (Everglades Landscape Model [ELM]) that could be expanded in scope to be extremely useful to the restoration effort. SFWMD is engaged in other modeling, monitoring, and process-oriented studies in support of the Surface Water Improvement Act, the Everglades Forever Act, and the Settlement Agreement. These efforts are focused primarily on resolution of water quality problems, particularly phosphorus. Integration of all public and private activities with federal efforts into a South Florida Ecosystem Restoration Science Plan is essential to a successful restoration.

IV. MONITORING

Monitoring is essential to the restoration process. It will provide necessary information for fine tuning the predictive models and ultimately evaluating the degree to which the restoration is successfully meeting its stated goals and objectives. Therefore, development and implementation of a comprehensive system-wide monitoring plan is a critical first step in the restoration process. Numerous on-going and planned monitoring programs exist throughout the region. The need to assess, coordinate, and integrate these programs into the South Florida Ecosystem Restoration Science Plan is absolutely imperative.

As a first step at integration and coordination of monitoring activities among the various interested agencies, representatives from the Science Sub-group, the Federal Geographic Data Committee (FGDC), the Florida Department of Environmental Protection, and the SFWMD have jointly arranged workshops to encourage the coordination, sharing, and mutual archival of all geo-spatial information regarding the Kissimmee-Okeechobee-Everglades watershed. The workshops are preliminary to establishing a joint federal, state, and local geo-spatial data agreement that insures format QA/QCs, metadata protocols, and electronic retrieval-archival capabilities for coordination and data sharing. The workshops will be useful in identifying data gaps in terms of geographic areas and types of information not covered. They will highlight opportunities for further coordination and resource sharing (e.g., NBS GAP, NOAA C-CAP, USGS NAWQA, NWI Wetlands, and GFC Integrated Habitat Plan).

V. MODELING

Modeling activities include the design or adaptation of several categories of models: models of physical processes (hydrologic, hydrodynamic, transport, and meteorological models), ecosystem models (landscape and ecological models), and water quality models (models of nutrient uptake and cycling in waters, soils, and the biota—and models of the movements, chemical transformations, and bioaccumulation of contaminants such as mercury). One important task will be to integrate the models into an interactive capability.

An integrated hydrologic modeling system covering the entire south Florida ecosystem, developed from existing sub-regional models, is the critical first need of the restoration effort. The output of hydrologic models will drive all the other types of models. The hydrologic models will support model-based research related to natural resource rehabilitation, as well as agricultural and urban sustainability. Critical components of the hydrologic modeling system will be natural systems model versions in which all canals and other control structures have been removed and the pre-drainage topography has been reconstituted. Their output will provide the most objective view of the structure and function of the pre-drainage hydrologic system.

A present impediment to the development of system-wide modeling capability is that there is no mandate for any state or federal entity to model the entire south Florida restoration region. It is imperative that a group dedicated to this task be established.

Landscape and ecological models involving populations and communities will enable hydrologic information to be evaluated in terms of ecological effects. Since the landscape influences water flow and is subsequently shaped by it, hydrologic and landscape models eventually will be linked to allow two-way interactions so that the effect on water flow of long-term processes such as soil building and landscape pattern formation can be followed. Individual-based species models will assess the effect of changes in hydroperiods and hydro-patterns on the reproduction responses of populations such as colonial nesting wading birds. Because the foraging area of such species is so broad and foraging success is closely coupled with hydrologic patterns, modeled trends in abundance and recruitment in these populations will reflect trends in ecosystem function. In a parallel effort, statistically based habitat association models will be used to evaluate potential species responses to various conditions of changing hydropatterns, hydroperiods, and vegetation types.

Ecological model development will start at the beginning of the restoration effort. Only the development and application of ecological models, even with cursory data, can reveal the type of information that is necessary from hydrologic and hydrodynamic models and demonstrate why it is needed. Research and monitoring will be fully integrated with the modeling.

Estuarine hydrodynamic models will allow the output of hydrologic models to be translated into salinity and circulation patterns in estuaries. This information will help determine how proposed modifications in the C&SF Project will affect the estuarine resources in Florida Bay and, eventually, other estuaries. Fine-scale hydrodynamic and transport models will enable the movement of nutrients and contaminants such as mercury in freshwater wetlands to be followed.

Meteorological modeling will be used to improve the grid of rainfall estimates needed as input to hydrologic models. South Florida's rainfall is so spatially variable that the current monitoring network may not adequately reflect the spatial pattern. Surface water and soil moisture influence rainfall and are required inputs to the meteorological model. Therefore, the meteorological model will eventually be used to determine the extent to which the C&SF Project and its predecessors may have affected south Florida's rainfall and evaluate restoration alternatives for their potential effect on rainfall. This will require linking the meteorological and hydrologic models so that two-way interactions can occur.

VI. MODELING, MONITORING, AND RESEARCH

Hypothesis testing research must be closely linked to the modeling and monitoring effort (Fig. 1). By conducting research, we can develop an understanding of the physical and ecological processes regulating the south Florida ecosystem status, test model predictions, and evaluate cause and effect relationships.

VII. HYDROLOGIC PROCESSES

The hydrologic modeling effort has three parallel tracks:

model improvement, model development, and model application. Models are used in conjunction with process studies and monitoring. Both water quantity and water quality issues can be addressed with hydrologic research because water movement influences water quality.

The first step in the hydrologic modeling effort will be to develop a hydrologic modeling system that covers the entire south Florida ecosystem land base. In the immediate term, existing models will be upgraded, models will be developed for areas not yet covered by appropriate hydrologic models, and the models will be integrated with one another.

Several areas of south Florida have no adequate existing models to assist restoration efforts. Spatially explicit models that include both surface and ground water do not presently exist for southwest Florida. Existing models do not have the topographic detail needed to adequately model freshwater flows to estuaries. Therefore, more detailed models for the coastal areas are needed. Such a model is particularly important to determining how to establish a more natural timing and volume of freshwater inflow to Florida Bay.

At the same time existing models are being improved, a more advanced and comprehensive modeling system will be developed. New models will take advantage of more powerful programming languages and support systems.

These are the fundamental steps of the hydrologic research plan for the entire south Florida ecosystem:

- Characterize natural hydrologic structure and function.
- Assess present-day conditions.
- Formulate specific restoration objectives that consider natural system requirements and societal demands.
- Develop and evaluate alternative strategies for achieving the objectives.
- Define success criteria.
- Implement the above through the structure and operation of the C&SF Project system.
- Evaluate implementation consequences using success criteria.

Process studies and measurements are needed to improve algorithms and parameters such as evapotranspiration, flow resistance, levee leakage, and seepage in the hydrologic models. With respect to associated water quality modeling, process studies will examine geochemical processes, nutrient cycling, and biological activity in the water column and sediments.

Hydrodynamic and transport models for wetlands may be needed to provide input to water quality models concerning nutrients and contaminants. These have not yet been defined. A meteorological model to provide improved rainfall estimates and interact with the hydrologic models is another model of physical processes to be used in the restoration effort.

VIII. HYDRODYNAMIC PROCESSES

Many of the major issues concerning Florida Bay could be better addressed by the use of a hydrodynamic model that simulates salinity patterns and circulation processes with the bay as a function of freshwater inflow, local precipitation, wind, and regional circulation processes. These regional processes need to be defined by regional circulation models of the eastern Gulf of Mexico and the Florida Straits. Therefore, the scope of the hydrodynamic modeling program must of necessity extend beyond the boundaries of Florida Bay to the processes influencing conditions along the boundaries of the bay.

A workshop sponsored by Everglades National Park and organized by the Florida Institute of Oceanography, in cooperation with NOAA, was held October 13-14, 1993.

and what was the outcome?

IX. LANDSCAPE PROCESSES

The tools to address landscape issues are landscape models, trend and gradient analyses, and paleo-ecological investigations. Some major questions of restoration can only be answered with landscape models. For instance, what processes shape landscape structure? How are these processes and landscape structure affected by barriers such as roads, levees, and canals? What are the landscape-scale ecosystem functions in this system? How are landscape-scale ecosystem functions affected by barriers? How are these functions affected by water management?

Landscape modeling is dependent upon hydrologic modeling and needs to be fully integrated with hydrologic modeling studies. Landscape models, in combination with hydrologic models, are needed to address ecosystem-level questions concerning wildlife. Models and paleo-ecological results can be mutually supportive.

The landscape model can be verified by imposing the C&SF Project on the pre-drainage landscape and simulating the landscape change over time; the resulting landscape can then be compared to the present landscape.

A seascape model—for example, Florida Bay estuarine and Keys models that includes bottom topography and the overseas highway—is required to adequately model salinity and circulation patterns and nutrient/biota dynamics in Florida Bay and the Florida Reef Tract.

In addition to models, trend and gradient analyses in both a monitoring and research mode and retrospective paleo-ecological studies are required to support the modeling and to generate additional information.

X. ECOLOGICAL PROCESSES

Ecological models are an essential component of the South Florida Ecosystem Restoration Program. Ecological models that relate species, communities, and landscapes to the simulation outputs of hydrologic models are the only objective way to evaluate alternative water management strategies for their influence on landscapes, plant communities, and wildlife. These models must demonstrate how certain key features of the pre-drainage Everglades—large spatial extent, spatial heterogeneity, sheet flow, and dynamic storage—supported a healthy ecosystem. A quantitative explanation of the connections is needed to strengthen understanding about why these system attributes must be reinstated and to communicate this understanding to others.

Comparison of population trends, plant community succession, and various ecological processes simulated under present and pre-drainage conditions, given the same time series of rainfall, can be used to gain perspective on how the system has been changed, an understanding of the natural relationship of spatial and temporal patterns of hydrologic conditions with species, communities, and landscapes characteristic of South Florida, and an ecologically supportable, objectively determined, and relatively unbiased target for restoration efforts.

Models are needed for key categories of species. For example, Wood Storks and snail kites, which, because of their wide foraging area and specific foraging requirements, reflect ecosystem functioning at the landscape level in their recruitment. Pink shrimp, which, because of their position at the lower end of the food chain, represent the overall productivity of the ecosystem with their recruitment.

The capability to predict community-level responses to water management changes is needed. Important communities to examine include periphyton communities in the freshwater Everglades, nuisance algal blooms in Florida Bay, freshwater macrophyte communities experiencing a change in species dominance, wading bird communities, and the fish communities supporting the birds. The need to control the spread of invasive non-native species into native plant communities is another community-level concern that will be addressed by modeling.

Understanding the entry of mercury into the ecosystem, its transport, transformations, and accumulation in food chains requires models capable of integrating across several scales.

XI. URBAN AND AGRICULTURE

The management goal is to recreate the overall hydrologic support functions for our remaining natural areas that, prior to drainage, were provided by the lands now occupied by urban and agricultural areas—while, at the same time, improving quality of life for human populations. Working to achieve this and related goals is a major scientific challenge.

The increased human population and human activity in south Florida have brought with them not only an increased need for water but also a decrease in water supply and deterioration in water quality. Issues of land use, routing of stormwater runoff, and disposition of treated waste water all relate to concerns for human water supply. Loads of nutrients, various contaminants, and total organic carbons associated with human alterations of the systems affect the quality of water vital to both human and natural systems. Several proposed science plan topics address these problems.

South Florida has productive agricultural systems that could contribute to—and benefit from—ecosystem restoration. The EAA now contains a productive agriculture of major economic importance to the region. However, this agriculture is on organic soils that are losing depth, primarily due to microbial oxidation resulting from drainage. This continued loss of soil depth is a severe concern. The release of phosphorus and dissolved organic carbons into drainage waters are environmental concerns associated with soil subsidence. Previous studies suggest that a zero subsidence agriculture producing present crops and maintaining current harvest levels is an achievable goal through research. A research program is proposed with the objective of developing the technology for this zero subsidence system. It is possible that successful research would help modify the hydrologic function of the EAA, with respect to downstream natural ecosystems, to more closely resemble the hydrologic function of the area prior to drainage (i.e., providing dynamic storage and allowing conveyance of water from Lake Okeechobee). One of the following science plan initiatives relates to this topic.

In general, studies must address these questions: What are the critical feedbacks of the natural system to urban and agricultural systems and vice versa? How will the natural system and its support functions for humans be affected by different population levels and land-use configurations? What landscape combination will allow healthy natural systems and urban and agricultural systems to coexist?

APPENDIX N
PUBLIC INFORMATION/EDUCATION/INVOLVEMENT

I. BACKGROUND

There are numerous stakeholders in restoration efforts in south Florida. These stakeholders have competing goals and expectations. Federal agencies' ongoing activities include the Central and Southern Florida (C&SF) Project restudy, the restoration of the Kissimmee River, and the Everglades Expansion Act land purchases. State agencies' plans and activities include the South Florida Water Management District's Save Our Rivers program which has acquired over 150,000 acres of land for public ownership, the Save Our Everglades plan which has acquired over 326,000 acres of land, and the South Florida Water Management District Lower East Coast Water Supply Study. The Everglades Construction Project under the state's Everglades Forever Act, will involve a massive construction effort. Special interest groups have also joined in the restoration efforts: the Everglades Coalition has published a Greater Everglades Ecosystem Restoration Plan. While restoration proceeds, development and water supply must keep pace for the rapidly expanding population of south Florida. The state provides 25 percent of the sugar grown in the United States (all from the south Florida ecosystem) and its citrus crops and winter vegetables contribute jobs and millions of dollars to the economy. The tourism industry which is in part dependent on fishing, beaches, and diving contributes enormously to the economy and creates a wide variety of employment. The Miccosukee and Seminole Indian Tribes make their home in South Florida and have an historical and legal interest in restoration.

Many Federal agencies have ongoing public information, education, and involvement activities that vary from minimal to very extensive. In many instances, they are project or issue specific, but are not usually multi-agency in their approach. Recently, there have been some efforts to develop more comprehensive public involvement strategies: The Corps of Engineers C&SF Project Comprehensive Review Study has attempted to involve a large segment of the public through the use of workshops.

II. ISSUES/PROBLEMS

While the public often recognizes the importance of the ecosystem and, according to a recent study, supports the clean-up of the Everglades, there are "strong doubts over government's ability to use the money for its intended purpose." The survey also reported that the public did not differentiate clean-up of the Everglades from restoration. During December 1993 public workshops for the C&SF restudy, opposition was expressed by many to restoration which meant loss of homes and businesses while others expressed opposition to a continuing degradation of the ecosystem to support the economy. This points out the need to present information and educate the public about restoration and sustainable development.

Litigation further complicates the scenario with parties filing suit over enforcement of water quality standards, payment for damages and clean-up, and to stop proposed restoration projects. Ongoing litigation and the threat of further litigation has fostered polarization of the stakeholders as well as a climate of distrust in south Florida.

The objective of the restoration effort is to develop and foster a coordinated, well-supported, balance among the federal agencies, state agencies, interest groups, and the public. This plan will be doomed to failure if the state agencies are not seated as full partners on the Interagency Working Group or the Task Force. Therefore, fulfilling the requirements of the Federal Advisory Committee Act (FACA) is necessary.

III. SCOPE

Restoration activities of the Interagency Task Force and the Interagency Working Group will take place in the south Florida area and possibly impact natural resources and activities of local residents. Because the Everglades ecosystem is a resource that can positively impact the entire state, there is a need for the activities to be understood not only in south Florida, but in the entire state. Additionally, agencies will propose activities whose benefits will need to be communicated to Congress and national interest groups.

IV. OBJECTIVES

The ultimate objective of public information, education, and involvement is to develop and foster a coordinated, well-supported, balanced restoration effort among the federal, state and local agencies; interest groups; and the public. The activities proposed will:

a. Provide stakeholders and the public facts on the purposes, costs, and benefits of the activities of the Interagency Task Force and the Interagency Working Group so that informed decisions can be made.

b. Increase public awareness of the importance of ecosystem restoration and actions that can possibly contribute to the restoration.

c. Provide a mechanism for input from stakeholders to the

Interagency Task Force and the Interagency Working Group on proposed activities.

These activities should be coordinated by a Public Involvement Working Sub-Group, made up of public involvement specialists at the member agencies.

The Public Involvement Sub-group would be responsible for implementing the activities outlined in this public information, education, and involvement plan. In addition, each agency should ensure that its public involvement specialists coordinate activities with the Interagency Working Sub-group. The lead agency should be the Everglades National Park. As such, it should ensure that all provisions of FACA and NEPA are met insofar as public coordination of Working Group activities and reports are concerned.

APPENDIX O
STATE, LOCAL, AND TRIBAL PARTNERSHIPS

I. BACKGROUND

There are myriad public agencies and private organizations working on various aspects of the restoration of the south Florida ecosystem. In the past year this altogether confusing array has distilled into major groups. The federal effort, made up of the Interagency Task Force and the Interagency Working Group and sub-groups, is only one focal point; others include:

- on the state level, the Florida Department of Environmental Protection Ecosystem Initiative

- on a regional level, the South Florida Water Management District

- the academic effort chartered as a case study through the Man and the Biosphere program

- the Governor's Commission for a Sustainable South Florida that pulls together, in an advisory capacity, people representing all levels of the private sector—from agribusiness to the conservation community

- other organizations of government including the Seminole and Miccosukee Tribes as sovereign governments and the county land-use planning departments

- a wide range of private interests and concerns such as the Everglades Coalition

All of these entities have significant interests and responsibilities that can feed into one of the processes discussed in the report of the Interagency Working Group.

We feel that the myriad efforts and integrated systems associated with ecosystem management and sustainability need to work together toward unifying their visions for restoration in south Florida. The best mechanism for accomplishing ecosystem restoration seems to be a synthesis of all of these efforts. The federal Interagency Task Force is only one of a number of essential participants. Our mutual vision cannot be fully articulated or accomplished until all the participants are fully integrated.

II. PROPOSED ACTIONS

To date, while there has been communication and some effort at coordination among these groups, this in no way represents the development of an integrated process that must be the objective for the coming year. Further steps must be taken to:

- Schedule coordinated public meetings by the Interagency Working Group that provide regular opportunities for the major groups involved at the federal, state, and regional level in ecosystem management to communicate and coordinate with the Interagency Working Group. (This has been started with the Governor's Commission on a Sustainable South Florida.)

- Seek an amendment to the Federal Advisory Committees Act (F.A.C.A.) to categorically exempt employees of other government agencies with responsibilities so they can work together on ecosystem strategies.

* Recommend the establishment of a federal advisory committee under F.A.C.A. to provide a forum for other knowledgeable and interested individuals and organizations to provide expert opinion and recommendations to the Task Force and Working Group.

- Support efforts to establish and maintain a publicly accessible electronic directory of all projects, organizations, and meetings related to ecosystem management and restoration.

APPENDIX P
BUREAU OF INDIAN AFFAIRS PERSPECTIVE
on
1994 INTERAGENCY WORKING GROUP REPORT

Areas Having the Potential to Impact Both the Trust Resources and the Rights of the Seminole and Miccosukee Tribes

WATER QUALITY MANAGEMENT

Major Issues

o Surface water quality entering and leaving the Indian lands

o Heavy metals (especially methylated mercury) in the surface water

o Establishment of tribal water quality standards - impacts on the restoration efforts

o Sludge disposal on nearby lands

o Enforcement of current State and Federal Water Quality Standards

o Pollution from the West Basin

o Full tribal participation in all federal water quality management planning activities

o Federal government's trust responsibility to protect tribal trust resources i.e., water and tribal rights to clean water

o Protection needed for WCA-3A water quality at the same level as Everglades National Park and the Loxahatchee NWR

o Establishment and enforcement of final numerical water quality standards necessary to save and restore the Everglades

o Protection from sediment nutrient loading

o Coordinated research and real time monitoring

o Protection from eutrophication and resulting imbalance in flora and fauna

Background

The Seminole and Miccosukee Indian Tribes are federally recognized tribes and the federal government is the trustee of their lands and resources and the protector of their rights. Indian lands of the Seminole and Miccosukee Tribes are subjected to run-on of water from upstream sources of surface water contaminated with high levels of nitrogen, phosphorous, heavy metals and other pollutants.

These pollutants are generally attributed to intensive upstream agricultural development and recently, possibly to the spreading of sludge from municipal waste treatment plants. This pollution has, over the years, resulted ln contaminated fish and wildlife which tribal members consume as part of their traditional subsistence hunting and fishing lifestyle. Additionally, tribal lands have not been offered the trust resource protection that is required of the federal government, resulting in the lands being used as filters and treatment areas for polluted waters. This has resulted ln the conversion of a large part of the wetlands to areas lacking natural floral and faunal diversity of the past.

Indian lands which are adversely impacted total approximately 462,000 acres including much of WCA-3A which is perpetually leased by the state of Florida to the Miccosukee Tribe. The traditional and modern lifestyles of approximately 2,500 tribal members are also adversely impacted.

Objectives

o Restoration of floral and faunal diversity in WCA-3A

o Establishment and protection of the tribal rights to clean water

o Elimination of heavy metal pollution.

o Reduction of phosphorous pollution to natural background levels

o Restoration of dissolved oxygen levels (approx. 5mq/1)

Approach

o Development, implementation and enforcement of tribal water quality standards

o Full tribal participation tn all federal water quality management planning activities

o Conducting of essential research (coordinated) and development of real-time systems for the reservations which will be capable of monitoring both water quality and quantity

COMPREHENSIVE WETLAND PERMITTING AND MITIGATION STRATEGY

Major Issues

o NPDES permitting of STAs with nondegradation standards

o Moratorium on permitting within the Everglades buffer strip pending analysis of cumulative impacts on restoration efforts
o Establishment of minimum flows and levels

Background

The Seminole and Miccosukee tribal lands have been adversely impacted by both reduced quantity and quality of available surface water. The degradation of these trust resources is principally due to non-tribal agricultural/commercial/ residential and infrastructure development within the historic boundaries of tho Everglades Ecosystem. No one knows how much more development can be sustained without (if it already has not happened) rendering the Everglades completely dysfunctional and beyond feasible restoration.

Objectives

Protection of the Everglades and tribal lands from further and possibly irrevocable degradation caused by further development of wetlands in the buffer zone.

Approach

o Require that significant development be permitted in areas on the eastern coast buffer strip to the Everglades ecosystem, only after an Environmental Impact Statement is prepared in accordance with the National Environmental Policy Act.

o Provide Bureau support for maintaining the requirement that STAs must have NSDES permits that contain non-degradation standards and feasible compliance schedules.

SUSTAINABLE DEVELOPMENT

Major Issues

o Continued development, without enforcement of numerical non-degradation water quality standards, will continue to further degrade tribal trust water resources.

o Tribal economic and social needs (especially the Miccosukee Tribe) are tied directly to and are dependent upon the quality of the Everglades environment much more so than the average citizen of Florida.

o The federal government is obligated to support the development of tribal lands as long as there are no significant adverse environmental impacts. There is concern that as more development occurs outside of Indian lands, the probability of significant impacts is increased i. e., the tribes will nct be able to rightfully develop their land because it is needed for resource protection .

o No one knows how much development can be sustained without a complete and irreparable breakdown of the Everglades ecosystem,

Background

There will be continued pressure to develop the remaining areas of tho Everglades buffer zone etc. Without proper assessment, the cumulative impact of development and the breaking point of the system are not known. Current trends ln the Everglades ecosystem indicate that environmental quality continues to decline. Additional development around the fringes will further restrict the opportunities for system restoration and make it more difficult to reverse the negative trend. Serious restoration efforts to reverse the trend may not work with the limited area currently available - the trend should become positive before more Everglades area is lost to development.

Additionally, the long term problem of restricting tribal development rights because of the cumulative impacts of surrounding development, must be addressed. The federal government, unlike the State of Florida, has an obligation to protect these rights.

Tribal populations can be expected to increase with time as will the need for housing, infrastructure, and economic development. Tribal population growth is slow and from within. Tribal members live on the reservation because it is their traditional homeland and their sovereign nation as established by Congress. There are no options for them to move elsewhere. Their right to grow and prosper and utilize their resources for the benefit of their people must be protected and be a high priority when limitations on sustainable development are addressed.

Objectives

o Protection of the Everglades ecosystem from the negative impacts of excessive further development

o Protection of tribal development rights

Approach

Assure that tribal development rights are a key component of any federally approved sustainable development plans or recommendations .

HABITAT RESTORATION AND MANAGEMENT PLAN ADDRESSING THE DECLINE OF NATIVE FLORA AND FAUNA

Major Issues

o Polluted surface water entering Indian lands has caused areas to become cattail monocultures.

o Indian lands which are subject to a flowage easement in the Everglades and WCA-3A should receive the same consideration for protection and restoration as parks and preserves.

o Protection of tribal hunting and fishing rights ln WCA-3A.

Background
As stated in Water Quality Management and additionally that approximately 353,000 acres of tribal land, including all of WCA-3A, should receive environmental equity with the parks and preserves. Existing cattail monoculture occupies portions of Indian lands.

Approach

o Restoration of cattail areas to traditional floral and faunal diversity after phosphorous levels are reduced to normal

o Environmental equity for Indian lands and WCA-3A

Strategy

o Full tribal participation in the planning and restoration process

o Assertion of federal trust responsibility by all federal agencies to protect tribal trust resources from degradation

COORDINATING AGENCY POSITIONS AND ACTIONS

Major Issues

o Are any of the currently implemented activities designed to improve the ecosystem showing success as measured by success criteria?

o The Indian tribes are only seeing continued system degradation with resultant adverse impacts to trust resources.

o Individual uncoordinated agendas are the rule for restoration efforts without conducting a complete cumulative impact analysis.

o How are we going to know when the feasible restoration efforts have been completed?

Background

As stated by the Miccosukee Tribal Elders "The snakes are dead; the turtles are dying; we cannot eat the frogs and the fish. Are we Indians next to perish in the Everglades? You (BIA) do something about i$t." From the Native American perspective the visible degradation of the Everglades and its wildlife resources is adequate measure that nothing is yet working. A statement by a tribal elder fifty, one-hundred or two-hundred years from now reflecting worse or hopefully better conditions will still be an accurate reflection of the condition of the Everglades. To go beyond a personal reflection will require a coordinated effort by federal, tribal state and local agencies; industry; agricultural interests; and environmental groups to monitor the health of the entire Everglades ecosystem. The problem is less one of determining indicators than it is of coordination.

Objectives

o To establish, on a real-time basis, changes in the health of the Everglades ecosystem.

o To know, from a management standpoint, when enough is enough be it restorative action or development that degrades the ecosystem.

Approach

o To develop a real-time remote sensing system for the tribal lands which will monitor environmental conditions as restoration efforts progress.

o To be part of a coordinated effort to determine the overall health of the ecosystem.

o To be a full partner ln the ongoing restoration planning and implementation process.

APPENDIX Q
INTEGRATED FINANCIAL PLAN

I. BACKGROUND

Agencies signatory to the Interagency Agreement on South Florida Ecosystem Restoration are funded through five separate federal appropriations bills. In addition, funds, lands, work-in-kind, etc., may be received/required by the state of Florida, the South Florida Water Management District, and numerous private corporations, trusts, and concerns. Signatory agencies and their respective appropriation bills are shown in the following table along with other possible non-federal sources of funding:

AGENCY	APPROPRIATION BILL
U.S. Department of Agriculture	Agriculture
U.S. Department of the Army	Energy - Water Development
U.S Department of Commerce	Commerce-Justice-State
U.S. Department of the Interior	Interior
U.S. Department of Justice	Commerce-Justice-State
Environmental Protection Agency	VA-HUD-Independent Agencies
State	State of Florida
Local	South Florida Water Management District
Private	Private Corporations, Trusts, Concerns

At present, each agency requests its own funding through its own standard procedures.

II. ISSUES/PROBLEMS

a. Multiple Possible Funding Source   It is possible that, upon an individual agency's budget request reaching the Office of Management and Budget (OMB), the level of priority for funding of that individual agency's efforts towards the restoration initiative may or may not be the same priority accorded other involved agencies. If all the involved OMB examiners consider the restoration initiative efforts of the agency under their review to be a high priority for that agency it would reduce the possibility of individual agency funding gaps that could delay the project. Obviously, if one or more agencies having responsibility for work products that are on the overall critical path should not receive sufficient funding for their required effort, the entire restoration initiative could be delayed.

In preparing individual agency budget requests for the initiative, a high degree of coordination and cooperation from all involved agencies will be necessary. This will be required not only to ensure that there is not an overlap in work to be performed, thereby increasing costs, but to be sure that funds will be available for a particular agency's individual efforts at the time they are required. Proper coordination may result in the individual agency requests being adequate for the proposed future work, however this is by far no solid indication that the budget request will be approved, either in its entirety or partially. Once an individual agency's budget come before its appropriation subcommittees and/or committees, funding for the South Florida Ecosystem Restoration may not be viewed with the same priority. For this reason, it would be beneficial to have each agency's budget request for the South Florida Ecosystem Restoration initiative be reviewed by a single examiner at OMB.

III. OBJECTIVES/APPROACH

a. Budgeting Options There are three budgeting alternatives that could be used to obtain necessary federal funding for the south Florida ecosystem restoration initiative. The first is to maintain the status quo and let each department/agency compete for funding independently. The second alternative would be to proceed with a cross-cut approach whereby each agency attempts to receive its own funding through their respective appropriation process after coordinating requirements within the Task Force. The third alternative would be to have all required funding requested by a single lead agency.

b. Status Quo Each agency would be responsible for requesting and obtaining the funds required for its particular items of work. This option does not allow for any synergistic savings and runs the risk of dealing with various OMB examiners.

c. Cross-Cut A high level of cooperation and coordination would be needed to ensure that agencies know what work items would be required of their agency, when the particular work would be taking place, and an accurate estimate of the cost of the work to be performed. Lead time for a budget request would normally be about 18 months prior to actually receiving funding.

Intense coordination at the working group level would be required to the maximum extent practicable in order to ensure adequate funding requests without duplication of work by two or more involved agencies. The agencies would then submit their budgets through normal channels. Once budgets had reached the departmental level, a meeting of Task Force members would be held to review the requests of the separate agencies portion related to the South Florida Ecosystem Restoration efforts. After any changes, the budget would then be submitted individually to OMB.

With numerous federal agencies involved, the South Florida Ecosystem Restoration initiative should be reviewed by a single examiner at OMB. In this way, it may be possible to prevent funding delays by any particular agency whose work efforts may be on the critical path for the restoration effort. With all the various agency requirements looked at by the same examiner, the funding stream could be more fluid and prevent delays in desired efforts.

Each participating agency should use a common accounting system for the funds provided for and used on the South Florida Ecosystem Restoration initiative. A standard system that all agencies could readily understand should be used to provide an accurate accounting of all initiative expenditures. A single agency should be appointed as the lead for financial reporting of ecosystem efforts. All involved agencies would submit monthly financial information to the lead financial agency for consolidation and compilation of data and statistics.

d. Lead Agency Budgeting A possible benefit of having one agency budget for necessary funding would be to help reduce the possibility of any particular agency not receiving necessary funding for the initiative, thereby possibly delaying the entire effort.

Additionally, If one agency, as the lead, were to request funding for all the major agencies involved in the initiative, it would be necessary that the budget ceilings for the affected agencies be adjusted downward accordingly. It should be obvious that the other programs of the budgeting lead agency should not be penalized by the fact that the agency is requesting funding that will be sent to other agencies, thereby effectively reducing the lead agency's other programs' ability to receive adequate funding because part of its budget authority was used for funding that is for the other agencies. It also stands to reason that the agencies receiving the funding from the lead agency should have their budget ceiling reduced by the amount of funding they receive from the lead agency.

In most agencies, the lead time for submitting an initial budget request and receiving actual funding is between 16 and 18 months. During this time many unforeseen problems and/or circumstances can arise which provides either a surplus of required funds or a need for additional funds in the budgeted fiscal year. It is possible that this scenario could happen for the South Florida Ecosystem Restoration Initiative. A particular agency may experience a delay creating a funding surplus or encounter some unforeseen circumstances that would require funding beyond the level available to them. Some agencies may have authorities which permits the reprogramming of funds from one project or study to another, thereby offsetting or even reducing the shortfall. These authorities in and of themselves may not prevent a shortfall from delaying work as there can be no assurance that surplus funds would be found from another project. In more likelihood, in this ever competitive environment for federal funding, it will be more and more difficult to make up for funding shortfalls in this manner. Another possible solution may be a cooperative effort among participating agencies. Coordination among these agencies may help to alleviate such a funding problem by having agencies experiencing a funding surplus do additional work that would have been done by an agency experiencing a funding shortfall.

IV. TRANSFERS

Currently, the Jacksonville District requests additional Department of the Interior funds for the Modified Water Deliveries Project from their Washington headquarters. Additional approval is required through the Department of the Interior chain of command beginning in Atlanta. The ability to transfer the required funding from the one agency to another should reside at the lowest level possible. This would help to ensure that there would be no unnecessary delays in an agency receiving necessary funds.

V. DISCRETIONARY FUNDING

Authority and appropriation for the expenditure of $5 million per annum by the South Florida Ecosystem Restoration Task Force would be requested. These funds would only be used on the initiative and could help fill funding gaps for unseen work or unexpected situations that might develop. Monies could be appropriated piecemeal to each agency or in a lump sum to a lead agency and distributed as needed.

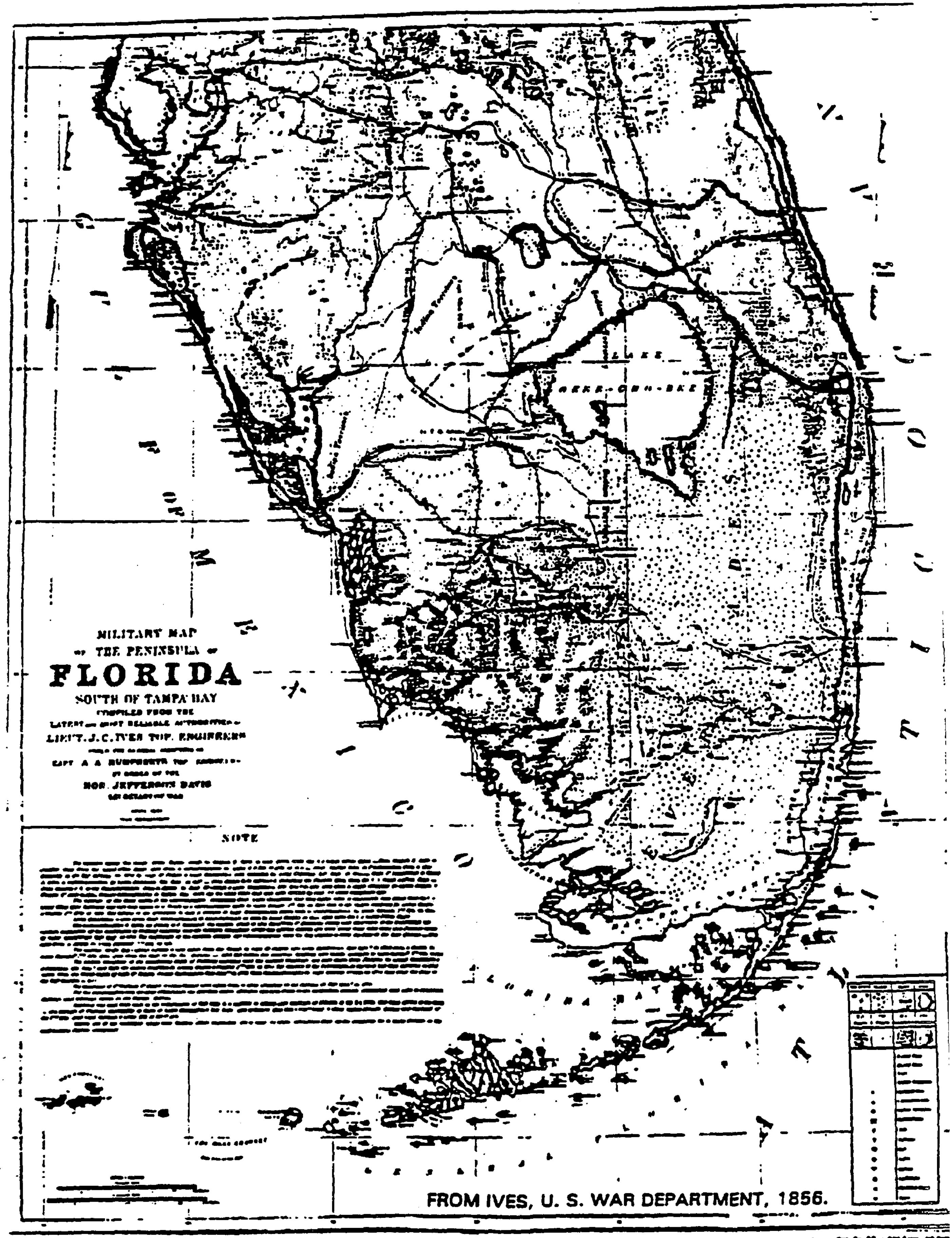
VI. FUNDING LEVELS

It is our intention to list an integrated system of financial requirements characterizing the level of activities occurring and the efforts to undertake the recommendations in this report. From the statement of needs, individual agencies can make decisions for the future funding on an agency-by-agency basis along programmatic categories. Attached is a sample matrix.

VII. RECOMMENDATION

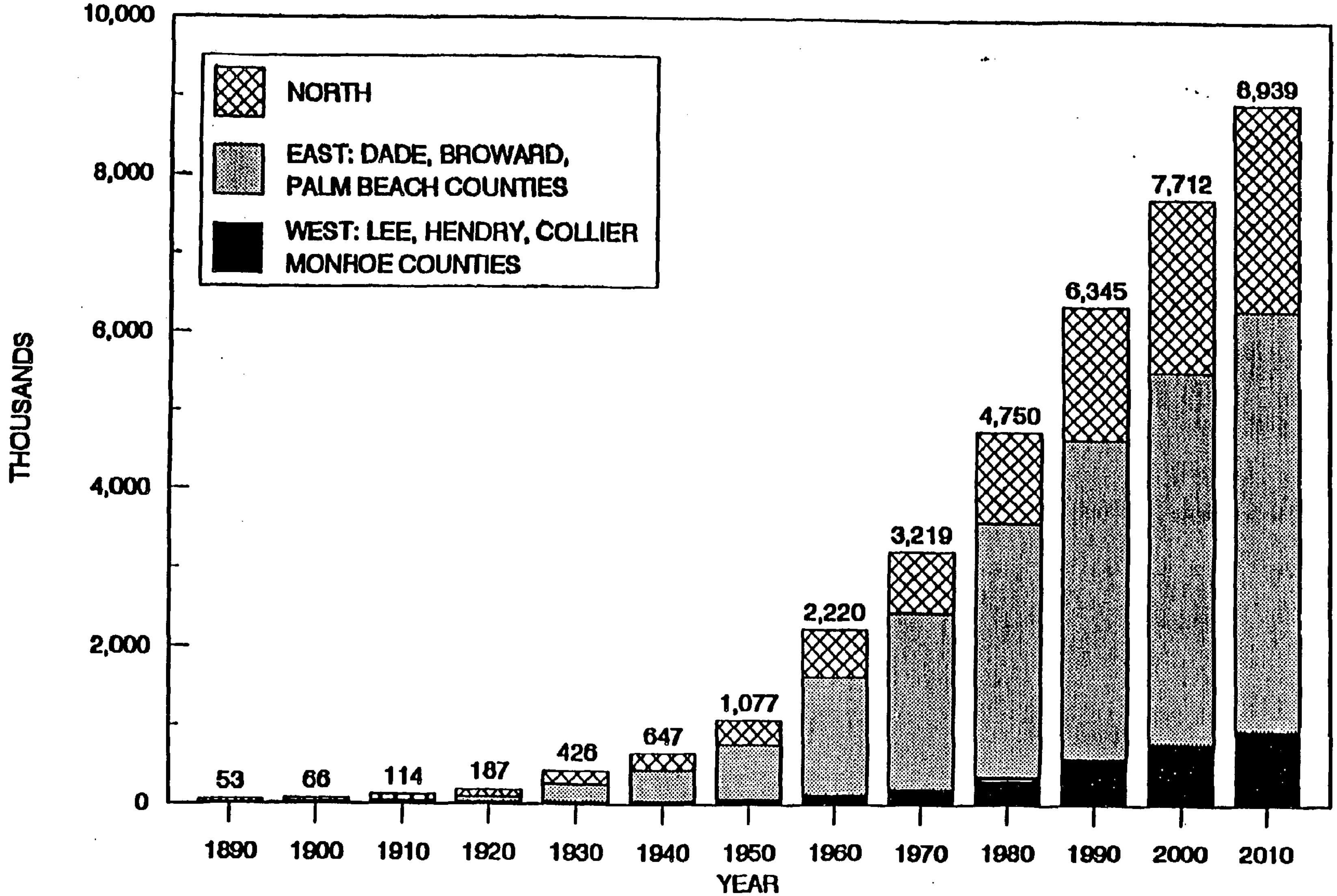
It is recommended that individual agencies continue to budget for the ecosystem restoration effort through their normal budgeting procedures using the cross-cut approach. Coordination, as discussed above, would be required at the Working Group and Task Force level to ensure adequate funding for individual agencies needs.

AGENCY	FEDERAL COST	NON-FEDERAL COST	THROUGH FY 1994	FY 1995	BALANCE
DEPARTMENT OF INTERIOR	0	0	0	0	0
DEPARTMENT OF COMMERCE	0	0	0	0	0
DEPARTMENT OF AGRICULTURE	0	0	0	0	0
U.S. ARMY CORPS OF ENGINEERS	1,218,000	665,000	404,468	24,747	787,900
DEPARTMENT OF JUSTICE	0	0	0	0	0
E.P.A.	0	0	0	0	0
TOTAL	1,218,000	665,000	404,468	24,747	787,900



FROM IVES, U. S. WAR DEPARTMENT, 1856.

SOUTH FLORIDA POPULATION 1890-2010



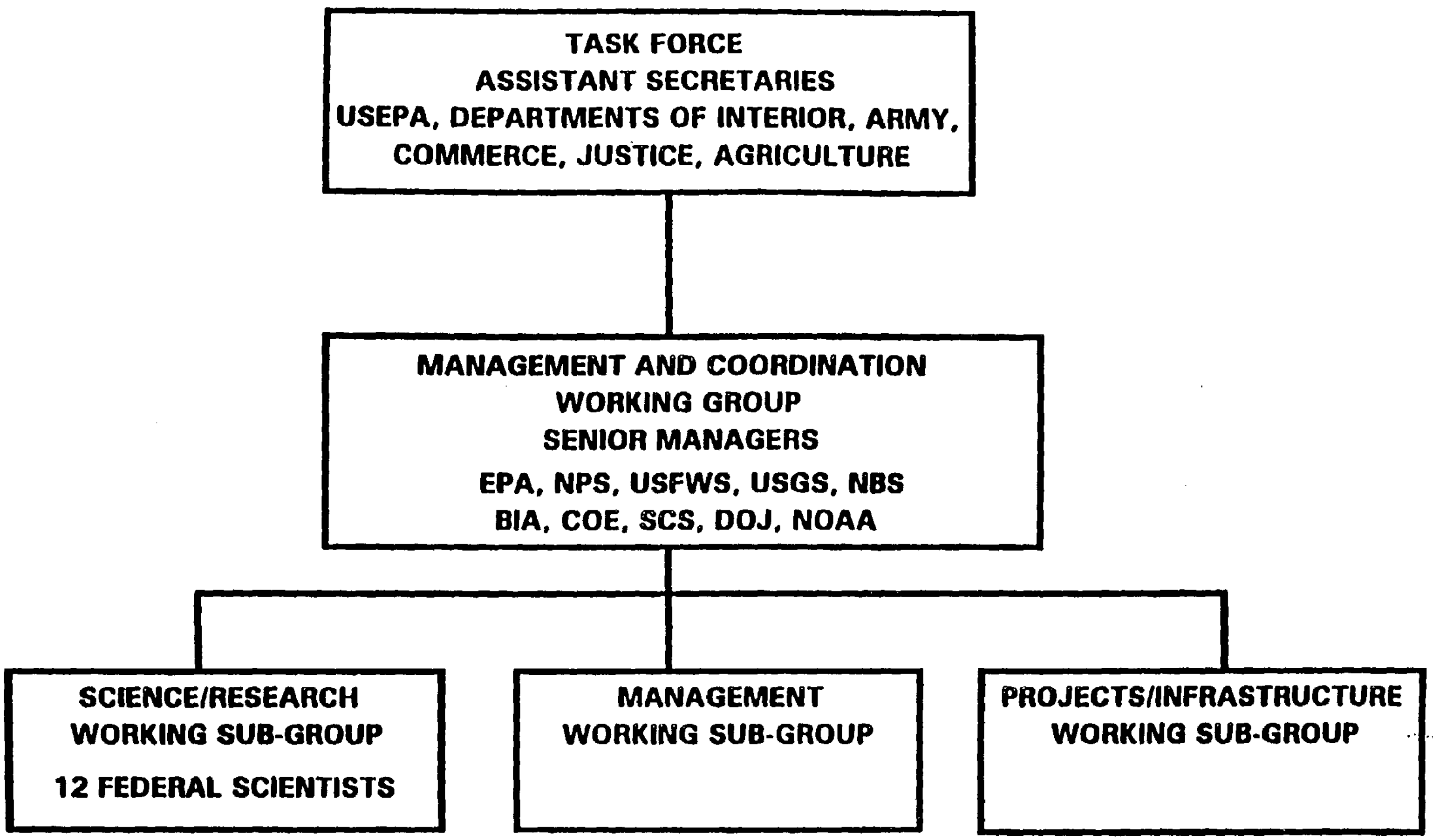
(U.S. CENSUS; STATE OF FLORIDA)

SOUTH FLORIDA POPULATION 1890-2010.

COUNTY	1890	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000 (EST)	2010 (EST)
DADE	861	4,955	11,933	42,753	142,955	267,739	495,084	935,047	1,267,792	1,625,979	1,937,094	2,170,410	2,383,217
BROWARD	X	X	X	5,135	20,094	39,794	83,933	333,946	620,100	1,014,043	1,255,488	1,467,987	1,656,463
PALM BEACH	X	X	5,577	18,654	51,781	79,989	114,688	228,106	348,753	573,125	863,518	1,089,716	1,298,620
EAST TOTAL	861	4,955	17,510	66,542	214,830	387,522	693,705	1,497,099	2,236,645	3,213,147	4,056,100	4,728,113	5,338,300
MONROE	18,786	18,006	21,563	19,550	13,624	14,078	29,957	47,921	52,586	63,098	78,024	90,166	100,930
COLLIER	X	X	X	X	2,883	5,102	6,488	15,753	38,040	85,791	152,099	218,937	277,879
HENDRY	X	X	X	X	3,492	5,237	6,051	8,119	11,859	18,599	25,773	32,837	38,364
LEE	1,414	3,071	6,294	9,540	14,990	17,488	23,404	54,539	105,216	205,266	335,113	442,007	542,275
WEST TOTAL	20,200	21,077	27,857	29,090	34,989	41,905	65,900	126,332	207,701	372,754	591,009	784,147	959,388
GRAND TOTAL	21,061	26,032	45,367	95,632	249,819	429,427	759,605	1,623,431	2,444,346	3,585,901	4,647,109	5,512,260	6,297,688

X = County did not exist. Population for that area is included in another reported county

Source: U. S. Census, 1890 - 1990;
University of Florida Bureau of Economic and Business Research, 2000 - 2010.



SOUTH FLORIDA ECOSYSTEM RESTORATION FEDERAL TASK FORCE ORGANIZATION

1/5/94

Past Land Use - 1940
South Florida Water Management District

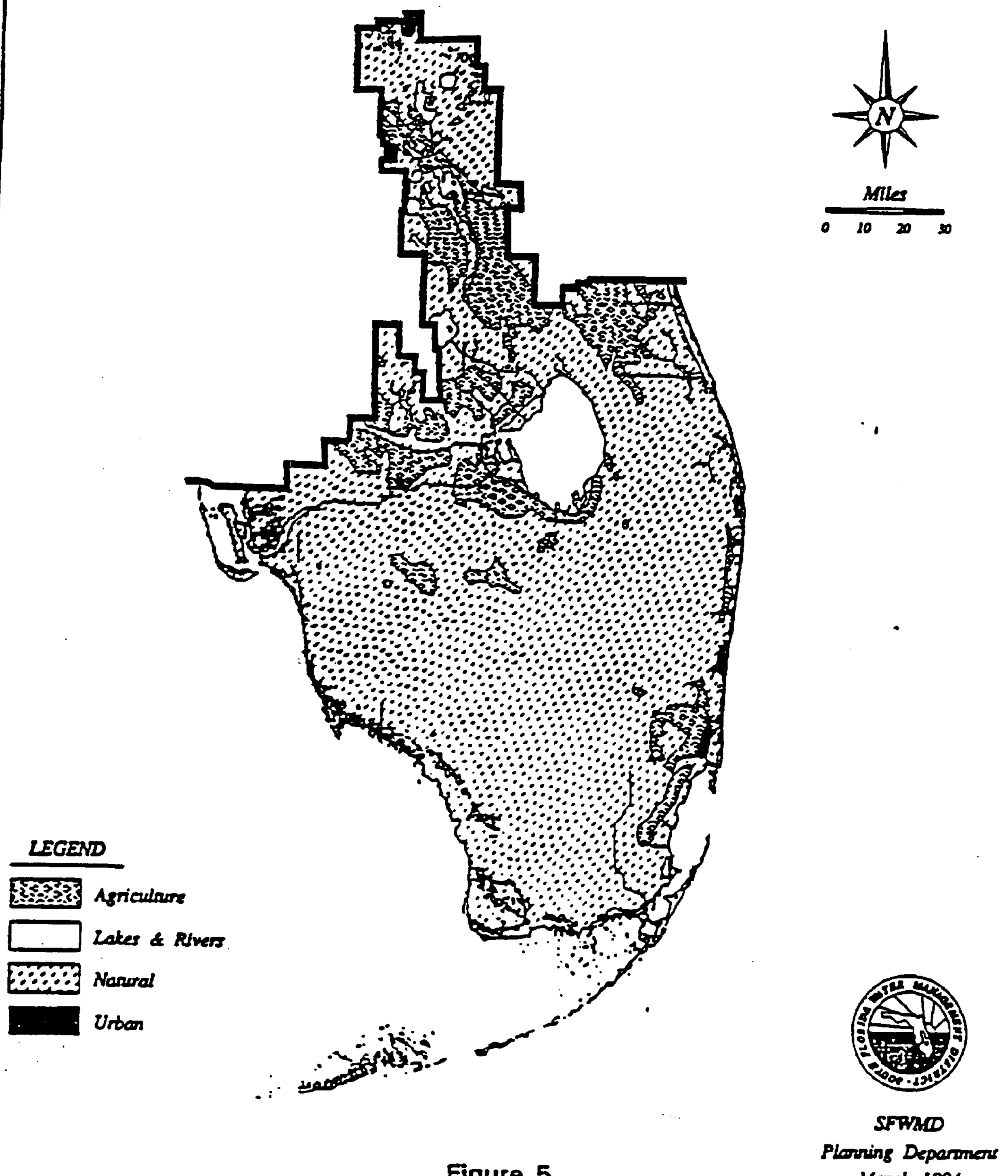


Figure 5

Existing Land Use
South Florida Water Management District

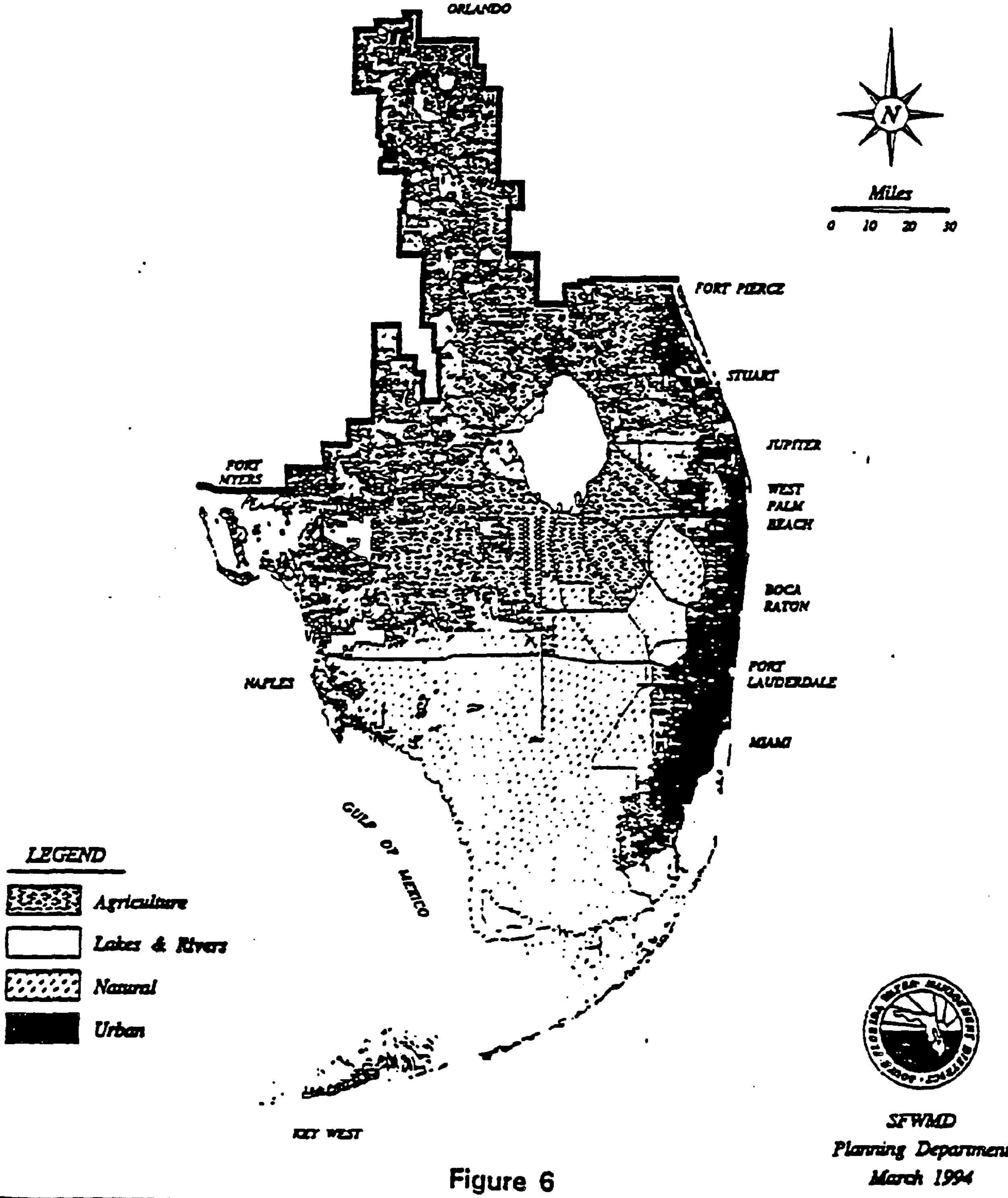


Figure 6

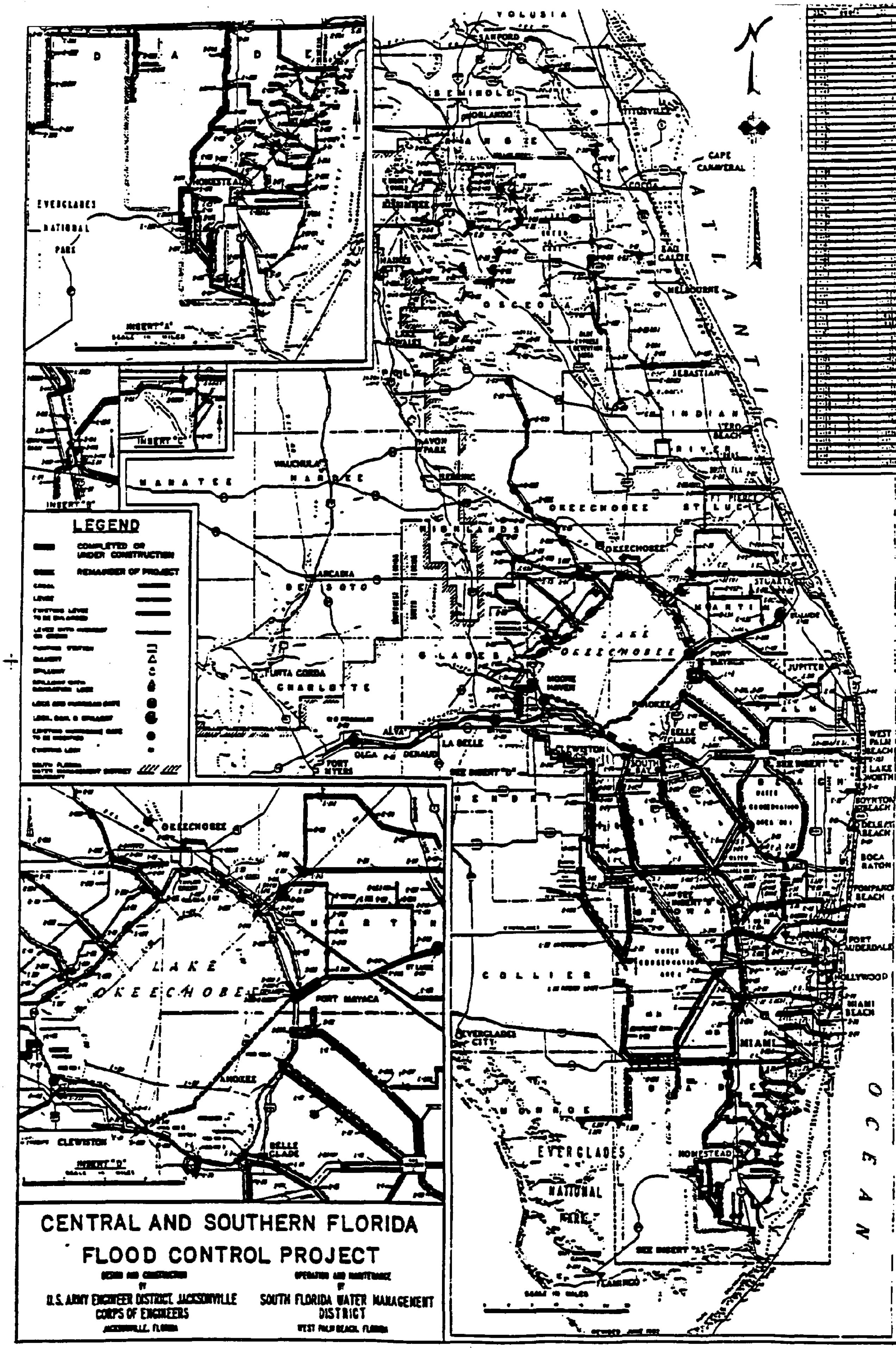
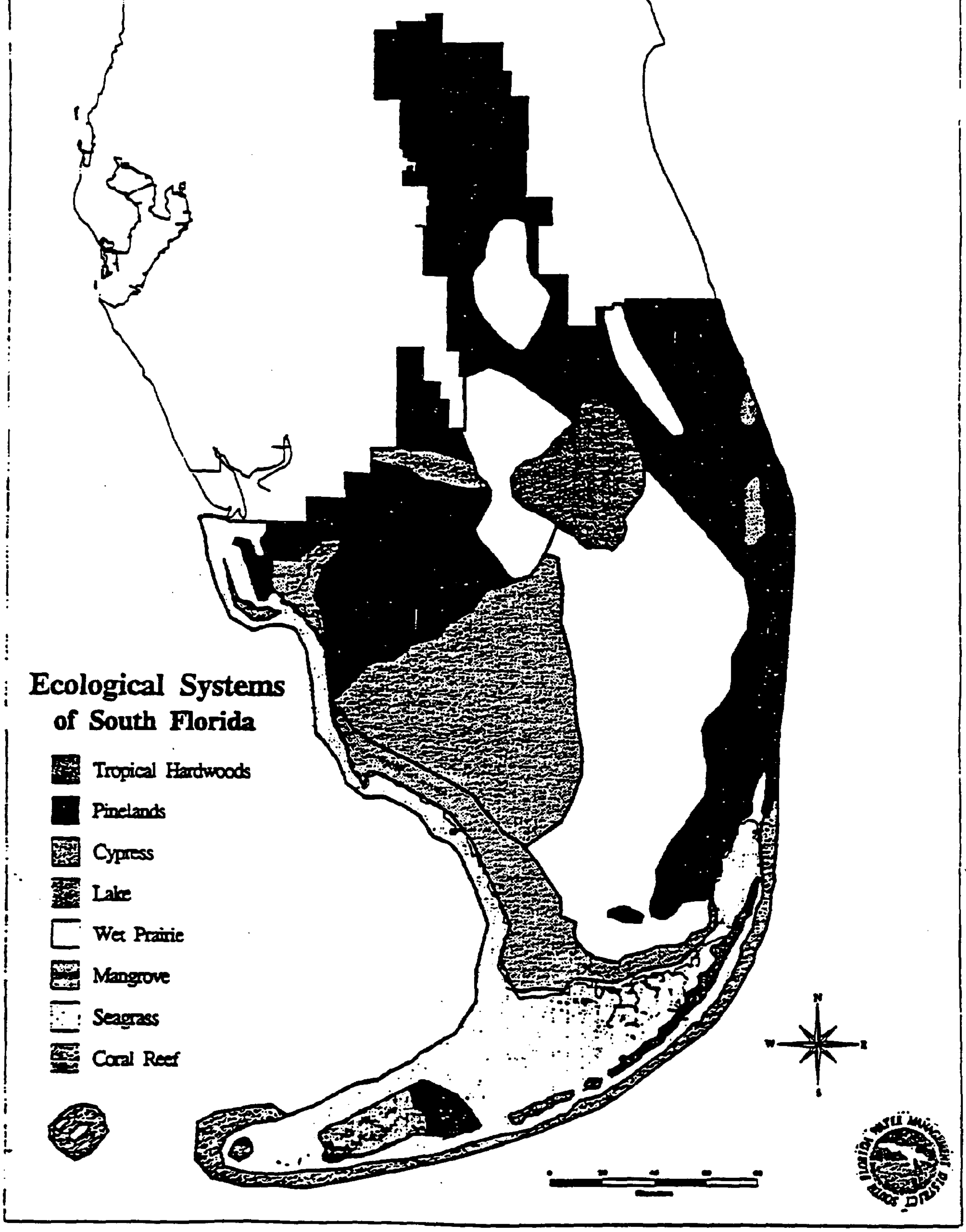

CENTRAL AND SOUTHERN FLORIDA
FLOOD CONTROL PROJECT
U.S. ARMY ENGINEER DISTRICT, JACKSONVILLE
CORPS OF ENGINEERS
SOUTH FLORIDA WATER MANAGEMENT
DISTRICT
WEST PALM BEACH, FLORIDA
LEGEND
COMPLETED OR
UNDER CONSTRUCTION
REMAINDER OF PROJECT
INSERT "A"
INSERT "B"
INSERT "C"
INSERT "D"
EVERGLADES
NATIONAL
PARK
HOMESTEAD
VOLUSIA
SANFORD
SEMINOLE
ORLANDO
TITUSVILLE
CAPE
CANAVERAL
COCOA
MELBOURNE
OSCEOLA
SEBASTIAN
INDIAN
RIVER
VERO
BEACH
MANATEE
WAUCHULA
HARDEE
AVON
PARK
SEBRING
HIGHLANDS
OKEECHOBEE
ST. LUCIE
FT. PIERCE
STUART
MARTIN
ARCADIA
DE SOTO
GLADES
LAKE
OKEECHOBEE
MOORE
HAVEN
PUNTA GORDA
CHARLOTTE
PORT MAYACA
JUPITER
ALVA
LA BELLE
OLGA
DENAUD
FORT
MYERS
CLEWISTON
BELLE
GLADE
HENDRY
WEST
PALM
BEACH
LAKE
WORTH
BOYNTON
BEACH
DELRAY
BEACH
BOCA
RATON
POMPANO
BEACH
BROWARD
FORT
LAUDERDALE
HOLLYWOOD
COLLIER
MIAMI
BEACH
MIAMI
EVERGLADES
CITY
DADE
MONROE
FLAMINGO
ATLANTIC
OCEAN

Figure 1. Distribution of predrainage wetlands (adapted from Davis (1943).



SOUTH FLORIDA ECOSYSTEM RESTORATION: SCIENTIFIC INFORMATION NEEDS

DRAFT SUMMARY

September 9, 1994

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INTRODUCTION

This document is a summary of a much more extensive report on scientific information needs. That document is a beginning toward developing an organizing framework for collecting the information required for the ecosystem approach to a South Florida Comprehensive Science Plan mandated by the Interagency Task Force in its September 23, 1993, agreement concerning the South Florida Ecosystem Restoration effort. The document is multiauthored and multidisciplined and has already been reviewed by many experts. Monitoring is to be a major component of the Science Plan. The Science Sub-Group decided that organizing the information needs to support regionwide restoration into a document that could be reviewed and circulated was a necessary preamble to the development of a coordinated, comprehensive monitoring plan. This is yet to come, although this draft contains many elements of monitoring.

This statement of scientific information needs is a precursor to a Science Plan to develop the knowledge to support planning and implementation of restoration strategies and the tools for incorporating the knowledge into the decision making process. The modeling, monitoring, and special studies called for in this plan will provide the information basis for ecosystem management.

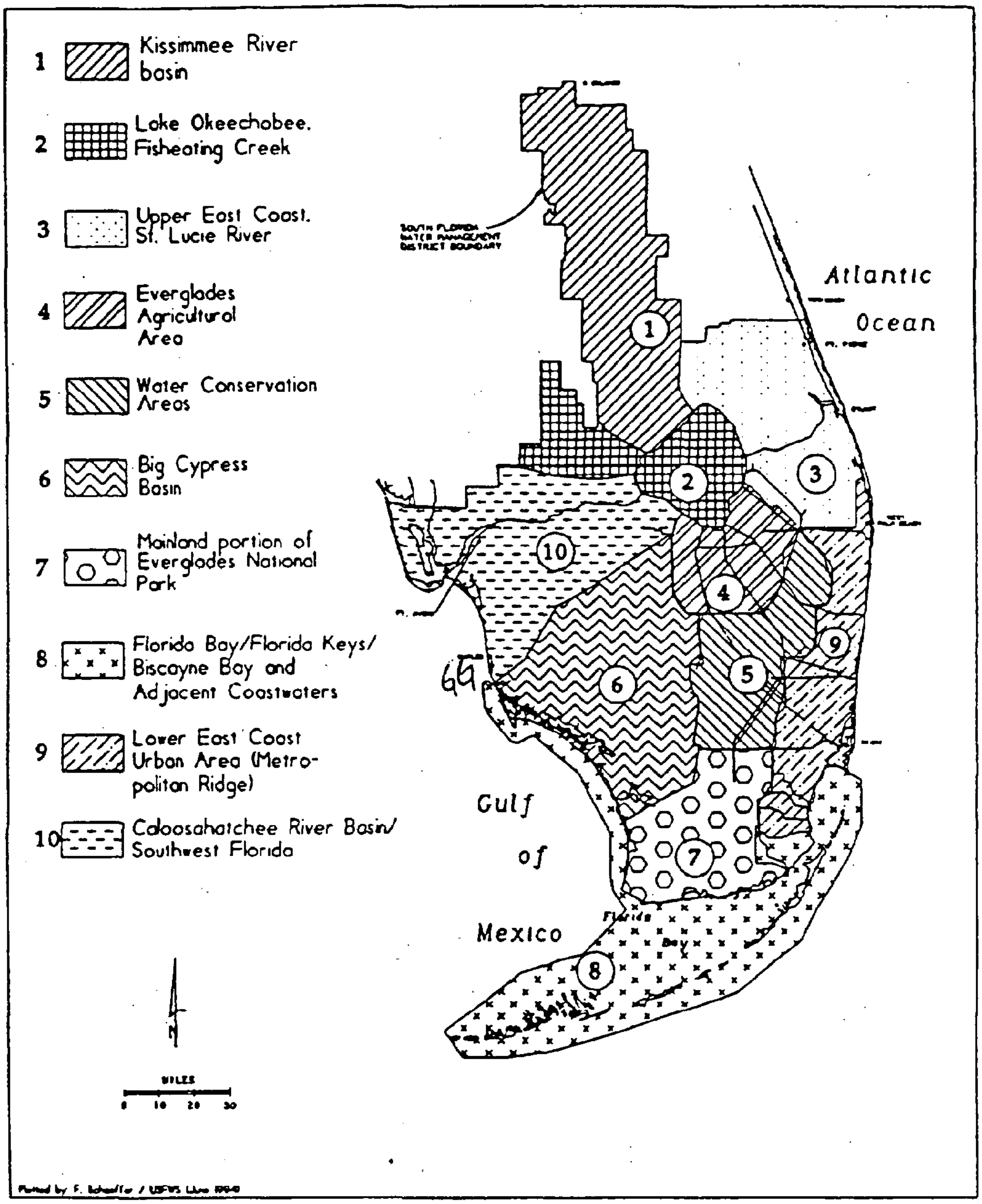
The report that follows is subdivided into sections that detail the research needs of each of the subregions identified in the Science Sub-Group Report, as modified to include a Subregion 10 (Fig. 1). Subsections also were developed for the following special topics: mercury, endangered species, exotic species, and modeling (hydrologic, hydrodynamic, meteorologic, and ecologic). These are preceded by 1) a description of South Florida that addresses issues of sustainability and 2) a description of the approach to obtaining the scientific basis for restoration, as well as the issues involved in applying this approach.

Development of many of the sections involved bringing teams of experts together and gaining consensus regarding information needs. Other sections were developed through interviews with knowledgeable experts on the area or the topic. Since Subregions 3, 9, and 10 involved lands and waters controlled by local governments, local government representatives contributed substantially to the development of these sections. Background or initial organizing issues were those provided by the Science Sub-Group Report.

The subregion sections are uneven in format and detail, although all started with the same basic format: a) Major Issues, b) Background, c) Scope, d) Objectives, and e) Approach. Each group worked independently, and the format was more applicable to some topics than others. Therefore, the outline was modified to accommodate the separate needs. Science Plans were already in place for Sub-regions 1 and 8 at the time the Interagency Task Force Science Plan Draft was prepared. These two sections of this plan simply expand upon or integrate the existing plans into the region-wide restoration initiative.

The sections of this report are as follows:

- Overview
- Modeling
    - Modeling hydrologic processes
    - Modeling hydrodynamic processes
    - Modeling meteorologic processes
    - Modeling ecological processes
- Mercury
- Protected species
- Harmful non-indigenous species



SUB-REGIONS FOR REVIEW OF

ACTIONS TO RESTORE ECOSYSTEMS IN SOUTH FLORIDA

Figure 1.

- Subregions

1	Kissimmee River Basin
2	Lake Okeechobee
3	Upper East Coast-St. Lucie River Area
4	Everglades Agricultural Area
5	Water Conservation Areas 1, 2, and 3
6	Big Cypress Basin
7	Everglades National Park (mainland portion)
8	Florida Bay/Florida Keys/Biscayne Bay/Florida Keys Reef Tract
9	Lower East Coast Area
10	Caloosahatchee River Basin/Southwest Florida

THE REGIONAL ECOSYSTEM

The South Florida Ecosystem encompasses an area of approximately 28,000 km^2 comprising at least 11 major physiographic provinces, including the Kissimmee River Valley, Lake Okeechobee, the Immokalee Rise, the Big Cypress, the Everglades, Florida Bay, the Atlantic Coastal Ridge, Biscayne Bay, the Florida Keys, the Florida Reef Tract, and nearshore coastal waters, arranged along a topographic gradient of 2.8 centimeters per kilometer, with elevations ranging from about 6 m at Lake Okeechobee to below sea level at Florida Bay.

South Florida is a heterogeneous system of wetlands, uplands, coastal areas, and marine areas, dominated by the watersheds of the Kissimmee River, Lake Okeechobee, and the Everglades. Prior to drainage, wetlands dominated the ecosystem, covering most of central and southern Florida.

The wildlife abundance of predrainage South Florida was maintained by the complex annual and long-term hydrologic patterns of the natural system, as expressed in wet-dry cycles, drying and flooding rates, surface water and water depth patterns, annual hydroperiods, flow volumes, and, at the coast, salinity and mixing patterns. Superimposed over the periodic changes were sporadic events such as storms, fires, and freezes, which helped to establish and maintain habitat heterogeneity. Wetland productivity was dependent on dynamic storage and sheetflow, large spatial scale, and habitat heterogeneity.

Human alterations in the hydrologic system beginning in the late 1800s have created water quality and water quantity problems for South Florida's natural systems, including the Everglades and the estuaries. Hydroperiods and hydropatterns, which relate to the duration, timing, and extent that wetlands are wet, have been greatly distorted. The quantity, timing, and location of freshwater flow to estuaries have been greatly modified. Excess nutrients and contaminants add to the problems experienced by living organisms in both the wetlands and estuaries. The pace of deterioration seems to be increasing. Known wildlife populations are now a fraction of their size of even 30 ago. Florida Bay is experiencing obvious catastrophic change manifested in massive seagrass dieoffs and noxious algal blooms. Even the reef tract is not immune to probable landbased detrimental influences.

The regional human population currently exceeds 5 million and is expanding rapidly. Tourism is a major industry, much of the area's attraction being due to remaining natural areas and their living resources. Agriculture, consisting primarily of sugarcane, winter vegetables, and citrus, forms another significant industry, which also is growing. Most of the population of South Florida is concentrated along the Lower East Coast in Palm Beach, Broward, and Dade counties. This is the most heavily urbanized area of not only South Florida, but the entire state. The west coast, on the other hand, is the fastest growing urban area.

This expanding human presence has dramatically changed the South Florida Ecosystem. In addition to hydrologic alterations, the changes include an increasing water demand by agricultural and urban uses, while, at the same time, the water supply has actually been decreased by the conversion of land to agricultural and urban uses and by the shunting to the coast of freshwater that previously was stored in the wetlands, the soils, and the aquifers.

Other changes are water quality and treatment problems, soil subsidence in the Everglades Agricultural Area, nutrient enrichment, pollution by contaminants, introduction of invasive non-native plants and animals, fragmentation of habitats and landscapes, loss of wetland areas and functions, altered fire regimes, and declines in reef and estuarine resources. By addressing these problems, the restoration of the South Florida Ecosystem will provide for more sustainable economic opportunities while at the same time improving the sustainability of natural ecosystems.

SYSTEM-WIDE SCIENTIFIC APPROACH

This section of the Information Needs report addresses the entire ecosystem, cutting across the artificial boundaries of designated subregions, as well as geopolitical and geomorphological boundaries, to present the broader issues of developing an interagency and interdisciplinary ecosystem-based science program to support South Florida restoration. Here we discuss the general premise and the general approach, with brief discussions on monitoring, modeling, and special studies. The latter two topics are covered in greater detail in other sections.

Quality of life in South Florida is strongly affected by the condition of its natural systems, which provide many benefits to agriculture and urban communities. These benefits include adequate supplies of clean water, clean air, aesthetically pleasing natural landscapes, and an interesting diversity of wildlife and fishery resources. If the natural systems are destroyed or reduced, the free services they contributed are then attainable only at much higher cost, if at all.

Scientific investigations to support the restoration, as described throughout the Science Plan, are directed at (1) characterizing the predrainage system and comparing it to the present system, particularly hydrologically, (2) determining the key characteristics of the former, natural hydrologic system that supported the rich diversity and abundance of wildlife that have been lost, (3) designing structural and operational modifications of the Central and Southern Florida (C&SF) Project that would recreate the key characteristics of the natural hydrologic system, (4) assessing the hydrologic and ecological results of these modifications, through pre- and post-modification monitoring, and (5) modifying the design to make improvements.

Adaptive management is a structured, iterative approach that faces the fact that the information used in making decisions is imperfect and that, as decisions are implemented, a structure must be in place to gain better information and adjust the implemented action accordingly. This structure consists of models, special studies, and monitoring, used as coordinated, supportive tools. Models provide a framework for special studies that lead to the development of better information, which then used to propose alternative actions. Once an alternative is selected and implemented, monitoring is used to evaluate the consequences. Models help interpret monitoring data, and this information can be used to design better management strategies, as well as better models. Feedback to both scientists and managers will be a key component of the adaptive management strategy, as applied in South Florida. All three elements--monitoring, modeling, and special studies--are critical to successful restoration.

Periodic assessment is the operational foundation of the adaptive management strategy. In adaptive management, models and monitoring are applied within the framework of an assessment protocol. The protocol helps focus monitoring efforts and define how models will be applied at various stages in management. Development of an assessment protocol for the South Florida Ecosystem restoration effort will be an evolving process.

In adaptive management, ecological indicators simulated by models are used to evaluate and help select among management alternatives. A baseline condition is determined for the same indicators, using monitoring before restorative changes are made. Then the same indicators, which continue to be measured with monitoring after the changes are in place, are used to assess the effect of a management action. Ecological indicators, to be effective, must be practical and sensitive and capable of being both monitored and modeled.

MAJOR ISSUES

- Existing or planned monitoring activities are not completely coordinated and integrated into the South Florida Ecosystem restoration effort. Gaps in coverage exist.
- The piecemeal approach to solving environmental problems associated with the Central and Southern

Florida Project has led to seriously deteriorating state of the ecosystem. A holistic, regionwide ecosystem approach is needed by requires special effort, personnel, and supporting resources to achieve.

- Models currently existing or under development are not broad enough in geographic scope to meet regionwide ecosystem management needs. This is true of the water management model, the natural systems model, the landscape model, and the wading bird models, all of which need to be expanded to provide regionwide perspective.

- Restoration management using the adaptive management approach will be heavily dependent upon simulations from models, particularly hydrologic models; yet no one experienced with the most suitable current hydrologic models (SFWMM and NSM) has been assigned to make simulations specifically for the interagency restoration effort.

- Systems of nested models are needed in which finer resolution can be provided to address some questions and coarser resolutions can be provided to address others.

- Modeling and special studies are most effective when used complementarily, but modeling is not well integrated with present research, and funds for modeling do not usually include sufficient funds for special supporting studies, including verifications.

- Use of models as technical tools in the restoration effort requires buy-in by all the parties. An objective process is needed for evaluating existing models and ensuring that necessary improvements are made, while at the same time protecting useful models against possibly one-sided attacks on their credibility. The fact that useful, credible models are available should not preclude the development of new models that can address problems of resolution, scope, and flexibility.

- Certain key species or communities that might be suitable ecological indicators because of their important roles in the ecosystem or their sensitivity to anthropogenic changes are so poorly studied that they cannot be used as indicators. Furthermore, lack of knowledge about the response of these species or communities to hydrologic variables may seriously handicap the restoration effort.

- Flexible and sustained resources are essential to an effective, comprehensive restoration effort. The various involved agencies have unique and complex funding strategies. There is no South Florida Ecosystem Restoration funding source. Critical activities needed at early stages in the restoration process are being neglected for lack of directed resources.

- Issues of agency authority are at times a barrier to focusing efforts at problem sources. Control of harmful non-indigenous plant species is an arena where there are jurisdictional gaps. The many aggressive upland species invading publicly owned natural areas are not included in major control and research initiatives, which appear confined primarily to control of aquatic weeds, Melaleuca, and agricultural pests. Soil subsidence is another arena where there may be jurisdictional gaps.

- Critical linkages between subregions are not being adequately addressed within agencies. For instance, Florida Bay is perceived as being in a crisis state, demanding immediate attention, and alteration in freshwater flow is thought to be a major contributor to the decline in this system. Yet the models and supporting measurements and special studies to estimate freshwater inflow to Florida Bay are not being given high priority relative to other issues.

- Information exchange is a problem, because there is so much information in the hands of myriad sources, including local governments.

- Many who live in South Florida do not realize the benefits they receive continuously from a functioning natural ecosystem and what ecosystem collapse would mean to them. Both tangible and intangible connections between natural and human systems need to be quantified and widely communicated while reinstatement of a sustainable system is still possible.

- Potential opportunities need to be explored for configurations of land and water that lead to ecosystem restoration and enhanced quality of life and economic sustainability in human communities.

- Decision makers and the general public appear not to understand the potential consequences of developing in wetlands. A scientifically based analysis is needed to demonstrate alternative futures under various land and water configurations.

RECOMMENDED APPROACH

- **Projects specifically organized around modeling should be funded sufficiently to allow these projects to finance related special studies involving field and/or laboratory work.**

The best results are achieved if the modeling is initiated at the beginning of the project rather than at the end and if special studies are included with modeling.

- **Establish groups to model the hydrologic, hydrodynamic, landscape, meteorologic, and ecologic processes of the South Florida restoration area, taking into account existing models. (Lead--Science Sub-group)**

The first step will be development of a hydrologic model for the South Florida land base. Existing models will be upgraded and new ones developed for areas not yet covered by hydrologic models. Hydrologic models will provide input for hydrodynamic models being developed to predict circulation, mixing, and salinity patterns in Florida Bay as a function of freshwater inflow and other variable factors. A hydrodynamic model for Florida Bay (with 3-D capability, but initially run in 2-D mode because of data limitations) will be supported by a regional numerical ocean circulation model to provide boundary conditions. Ecological models that relate species, populations, communities, and landscapes to the simulation outputs of hydrologic or hydrodynamic models will provide an objective way to evaluate alternative water management strategies for their potential effects on the ecosystem.

- **Establish a set of ecological indicators, starting with the assessment criteria recommended by Science Sub-Group. (Lead--Science Sub-group)**

Refine the original list of assessment criteria into a set of practical and sensitive indicators in coordination with the planning of modeling and monitoring activities. Select species and communities that play major roles in ecosystem function. Give priority to species or communities that are indicators of regionwide ecosystem function and those species and communities for which information and time series of data are available.

- **Propose potential ecological indicators for which little information is available and target these species or communities for special research attention.**

Several key species and communities in the environment would be appropriate ecological indicators, except that little is known about them. For instance, the apple snail is the critical prey of several species, including the endangered snail kite, yet little is known about its population biology and ecology.

- **Develop an assessment protocol that helps focus modeling and monitoring activities on predicting and measuring restoration success indicators. Identify core modeling and monitoring needs. (Lead--Science Sub-Group)**

An assessment protocol is needed to help focus monitoring efforts and define how models will be applied at various stages of the restoration effort. The assessment protocol must be developed concurrently with model development and the preparation of a monitoring plan, and modelers and those involved in developing the monitoring plan should take part in preparing the assessment protocol.

- **Ensure the continued development and upgrading of natural system models as part of the hydrologic modeling effort in order to provide input data for ecological models. (Lead--Science Sub-Group)**

  Comparison of the present system with the predrainage system is important to developing restoration targets. The best guide for understanding the ecological ramifications of the changes in spatial extent and hydrologic conditions that have occurred from predrainage days to present is the simulated output of spatially explicit "natural system" hydrologic models supporting a system of ecological simulation models that operate at several scales. Natural system hydrologic models are versions of water management models in which the control structures have been removed and the topography restored to approximate the predrainage system.

- **Initiate ecological model development at the beginning of the restoration effort and integrate it with the development of hydrologic and hydrodynamic models.**

  By developing ecological models concurrently with the hydrologic and hydrodynamic models to support them, scientists can ensure that the hydrologic and hydrodynamic models will provide suitable support for addressing ecological questions.

- **Integrate modeling with monitoring and research planning and use models to help organize information, communicate concepts and ideas, design research, and identify critical information needs.**

  Initiate modeling at the beginning of scientific studies rather than at the end to help insure that the studies are complementary and gaps in information are minimized. Models should be an essential component of investigations that include field studies, experiments, laboratory analyses, and other means of obtaining information. Models can be used to integrate results from several studies into a higher order of information.

- **Develop a monitoring plan, bringing together in workshop settings the major participants in present and proposed monitoring efforts. (Lead--Science Sub-group)**

  Conduct special monitoring-related topic workshops, such as the geospatial workshop of September, 1994, to (1) consider restoration assessment needs from monitoring, (2) explore current capabilities, (3) discuss existing monitoring activities and monitoring plans, (4) adopt common quality control procedures, (5) coordinate efforts, and (6) share resources and information. Prepare a comprehensive, integrated monitoring plan from results of these workshops.

- **Provide continuous support as an integral part of restoration operations budgets for this multi-year adaptive management effort.**

  Adaptive management for ecosystem restoration requires continual predictions and feedback from the interactive modeling, monitoring, and research efforts--and thus, continuous funding.

- **Ensure resources to support the planning, coordination, and oversight activities of the Science Sub-Group. (Lead--ITF)**

  A special annually replenished fund should be made available for Science Sub-Group activities relating to planning, coordination, peer review, and other oversight activities needed to expand and strengthen the scientific basis for ecosystem restoration.

- **Conduct special studies, integrated with modeling and monitoring, to develop the information base for application of the adaptive management approach, emphasizing the building of understanding and assessment capability. (Lead--Science Sub-group)**

  Promote research integrated with modeling and monitoring and acquire information that can be used in assessment to support the adaptive management strategy. Strengthen the scientific understanding that will enable effective management actions to be proposed and implemented. Emphasize improved understanding of how vegetation communities and wildlife are affected by hydrologic regime, anthropogenic nutrients, and contaminants. Focus on ecological indicators to be used in making assessments.

- **Support scientific studies that will lead to productive, supportive interactions between natural and** human systems.

In general, studies must address these questions: What are the critical feedbacks of the natural system to urban and agricultural systems and vice versa? How will the natural system and its support functions for humans be affected by different population levels and landuse configurations? What landscape combination will allow healthy natural systems and urban and agricultural systems to coexist?

- **Prepare flow charts showing critical nodes and pathways in the development of information for ecological restoration, including building knowledge and providing assessment tools.** (Science Sub-Group)

Such a diagram can help prioritize restoration activities for initial emphasis to ensure that the restoration is not delayed. For instance, a hydrodynamic model for Florida Bay will require input from a hydrologic model; therefore, considerable attention should be given to ensuring that a hydrologic model capable of providing the information is available when it is needed.

MODELING

Models are critical component of the South Florida Ecosystem restoration process. Models must be used to establish targets, select among alternatives, and interpret monitoring information to assess progress toward the targets. Modeling activities will involve the design of new models or adaptation of existing models in the following categories: 1) models of physical processes (hydrologic, hydrodynamic, transport, and meteorological models), 2) ecosystem models (landscape and ecological models), 3) nutrient models, and 4) models of the movements, chemical transformations, and bioaccumulation of contaminants such as mercury. One important task will be to integrate the models into an interactive modeling capability.

MODELING HYDROLOGIC PROCESSES

Issues:

South Florida has experienced unprecedented economic growth in recent decades with subsequent development and alterations of natural systems. This rapidly growing population and associated economic activities are placing progressively increased demands upon the limited water resources of the Everglades.

Land use changes being allowed by governments are causing development to encroach into wetlands, diminishing both ground and surface water storage, thereby reducing the water supply. Shallow aquifer systems provide major water supplies. Anything adversely affecting these aquifers has far-reaching effects.

Management to control flooding of low-lying areas in wet years has had a devastating effect on water supplies, wetland systems, and estuaries during dry years.

Saltwater intrusion, the inland shift of the fresh/salt interface, has been caused by a general lowering of the water table. Several of the municipal water supply wells located along the coast have been abandoned and many others are threatened by salt water contamination. Saltwater intrusion is not only an urban problem, but also a problem for natural ecosystems. The landward spread of mangroves at the northern end of Florida Bay was caused by saltwater intrusion and has been accompanied by a loss of freshwater marsh.

Because the location of the fresh/salt boundary is a function of the difference between the water table and sea level, sea level rise, a continuing phenomena that has been proceeding at a rate of about 3 cm every 10 years in South Florida, exacerbates the problem of salt water intrusion and may someday threaten freshwater wetlands as well as aquifer water supplies.

Wellfields to supply increasing urban demand are drawing down the aquifer, affecting water supply and decreasing the hydroperiods in nearby wetlands. New wellfields continue to be constructed, especially in the lower east coast areas.

Declines of as much as 35 ft since the 1930's have occurred in the potentiometric surface of the Florida aquifer between Orlando and Lake Okeechobee. The lowering of the potentiometric surface has reduced the groundwater seepage that previously reemerged as surface water contributions to the upper Kissimmee River basin chain of lakes, the Kissimmee River, and Lake Okeechobee.

Drainage, impoundment, and diversion of water has changed the quantity, timing, and distribution of freshwater flow to estuaries. As a result, some estuaries often receive too much fresh water too quickly during the wet season and too little fresh water for too long during the dry season. Others, such as Florida Bay, probably receive considerably less freshwater throughout the year than they did under predrainage conditions and now experience severe hypersaline conditions.

Questions:

How will restoration changes made in the Kissimmee River affect water levels in Lake Okeechobee and the need for regulatory releases to the St. Lucie and Caloosahatchee Rivers?

How will proposed changes in the regulation schedule of Lake Okeechobee affect Lower East Coast water supplies and water flow to Florida Bay?

How has the C&SF Project changed the spatial and temporal pattern of surface water coverage, water depth, and water movement in wetlands?

How would hydroperiods and hydropatterns in natural areas be affected by various proposed changes in structures or operating procedures?

How has the C&SF Project changed the volume, timing, and location of freshwater inflow to estuaries?

How would the quantity and timing of freshwater flow to estuaries be affected by various proposed changes in structures or operating procedures?

How might planned or anticipated land use changes impact water supply and the ability to manage water for ecosystem restoration?

How might changes in on-farm water management practices and changes in the structure and operation of the C&SF system to control subsidence in the Everglades Agricultural Area affect the volume and timing of water flow to downstream areas from Lake Okeechobee and the Everglades Agricultural Area?

How does undeveloped wetland modulate hydrologic exchanges between protected wetlands in the Everglades and the developed east coast?

How do undeveloped interior wetlands modulate hydrologic exchanges between estuaries and the developed east coast?

Recommendations:

- **Modify, enhance, and apply the South Florida Water Management Model (SFWMMM) and the corollary Natural Systems Model (NSM).**

Several modifications and enhancements should be made to the SFWMM to improve and extend its performance and utility. A 2-step approach is recommended. The existing SFWMM should be improved to allow for its relatively immediate use in water quantity decision-making. Concurrently, major enhancements to the SFWMM are proposed. Once completed, most of the water quantity issues for the freshwater system could be answered within a single modeling framework.

- **Improve the information used in SFWMM and NSM.**

Some of the more important information needs are 1) seepage losses from the salinity control structures from project storage areas along the coast, 2) evaporation as a function of vegetation and microclimate, 3) groundwater flow and levee seepage losses, 4) surface freshwater discharge to the East Coast via canals is poorly estimated for 19 of the 25 canals discharging to the East Coast, 5) estimates of both surface and groundwater flows to Florida Bay are needed, and 6) many of the canals discharging fresh water to the lower southwest coast are not calibrated or monitored.

- **Develop and apply groundwater-wetland models.**

Development of fine resolution groundwater/wetland models is needed to address site-specific questions in several sub-regions whose hydrologic regimes are dominated by wetland/groundwater interchanges (such as the WCA's, the EAA, or the Lower East Coast well fields). These models will answer local questions, such as the effects of large-scale groundwater pumping or lowered within Dade County on the hydrology of the C-111 basin, detailed distribution of flows delivered to the Loxahatchee Wildlife Refuge and ENP, as well as the distribution of flows within the EAA. The need to evaluate salinity intrusion within the Biscayne Aquifer will also require more detailed groundwater modeling capabilities than those proposed for the SFWMM.

- **Groundwater model development will require extensive field data collection to establish a more definitive database on subsurface stratigraphy and transmissivities, particularly in the vicinity of canals.**

Applications of the models developed will center on evaluation of the effects of operational water delivery changes on coastal salinity intrusion, the effects of the large well fields being implemented in Dade county, and connections between ground water and major wetlands.

- **Develop software for routine calculation of water budgets from model input and output.**

A water budget for the South Florida hydrologic system is essential to identify the major sources and sinks of water, determine locations where inadequate data exist, and provide a fairly concise estimate of the actual magnitude of water available in the system. The modeling system should be capable of generating a water budget that quantifies inflows and outflows for the region as a whole as well as subregions.

- **Develop interfaces to link hydrologic models to other models.**

Hydrologic models must support other types of models to support ecosystem restoration. These include hydrodynamic, meteorological, landscape, ecological, and water quality models. One of the most important needs from a hydrologic modeling system is simulated freshwater flows to estuaries for use as input to hydrodynamic models. The hydrodynamic models can then demonstrate how various water management scenarios would be expected to affect estuarine salinity and circulation patterns. Since both the landscape and rainfall patterns affect the hydrologic regime and are affected by it, two-way linkages should be developed between hydrologic models and the landscape and meteorological models.

- **Develop and apply dynamic routing and watershed runoff models for inflows to Lake Okeechobee.**

Dynamic river routing and field-level watershed runoff modeling capabilities are needed within and along the Kissimmee River System (KRS), Fisheating Creek, Taylor Creek, and Nubbins Slough. A Kissimmee River model is particularly needed because the restoration project in progress in the Kissimmee basin may affect water levels in Lake Okeechobee.

- **Develop interfaces for technology integration, maintenance, application, and distribution.**

The hydrologic models must be integrated in a manner that minimizes the effort required for application and interpretation. This integration requires the development and coupling of four types of interfaces: 1) model-user interface; 2) model-model interface; 3) input data-model interface; and 4) output data-graphical/visualization interface.

- **Designate a group or organization, located in Florida, to act as a support center for hydrologic modeling in support of the South Florida Ecosystem restoration effort.**

A single group or organization should be responsible for the Federal role in planning and execution of the four tasks described below, which should be the primary mission of this group or organization. This group should be responsive to the Federal Task Force through the Science Sub-group and its technical designees.

- Integrate Modeling Components.

Integration of models and tools will require the development of four basic types of interfaces: (a) model-user interface; (b) model-model interface; (c) input data-model interface; and, (d) output data-graphical/visualization interface. The model-user interface is the actual environment through which the user accesses various programs, selects program attributes, inputs data, simulates various conditions, and evaluates model output. The model-model interface includes the essential linkages between various models and their outputs. The input data-model interface couples large databases with models and allows efficient retrieval of data based on user-selected conditions. Finally, the output interface is critical to presentation of simulations results in a form interpretable by decision makers, scientists, and engineers.

- **Compile and integrate databases relevant to hydrologic modeling and place them in a single repository for common use.**

Compile and integrate through the above system the models developed or adapted as part of the restoration effort.

- **Maintain system components.**

Maintenance is much more than providing for locations for data and models to reside. The term includes modification in the event of error identification, the opportunity to benefit from improved technology, or to fulfill additional requirements as they arise, including adaptations to address management questions. Furthermore, hardware and communications systems must be maintained to allow users to access models and data from remote entry locations.

- **Transfer technological products.**

Distribute reports, users manuals, model user support, etc. Publish periodic newsletters or information bulletins delineating available new technologies, updates to existing models, errors found in existing models, etc., and respond to requests for various models and data bases.

- **Apply models.**

Support the South Florida Ecosystem restoration effort by applying the models to address management questions, test alternatives, or provide input to other models, as required. Provide access to other agencies and groups having either in-house or contractor expertise with model application. A hardware and software base must be nurtured for this purpose.

- **Reorient the Corps of Engineers toward addressing hydrologic issues from a system-wide approach, rather than on a project by project basis.**

Traditionally the Corps of Engineers has studied and built projects to solve specific problems. In large basins with several watersheds, changing one of the sub-watersheds for flood control can impact functions in other sub-watersheds; i.e. groundwater flow, water supply or even the timing of natural runoff. A Hydrologic Modeling Section in the Hydrology and Hydraulics Branch is needed, independent of project oriented operations, that would build and/or maintain large basin hydrologic models.

- **Apply U.S. Geological Survey knowledge and expertise to improving algorithms and parameters for major flow pathways in hydrologic models, making measurements to supply gaps in needed data for model calibration and validation, and developing spatial data bases and digital maps to support modeling.**

USGS hydrologic modeling objectives are to (1) review and evaluate the algorithms that comprise the existing regional model and perform error and sensitivity analyses, (2) improve parameters concerning aquifer characterization, evapotranspiration, vegetative resistance to flow, and land elevation, and (3) construct and test a framework of computer codes for integrating numerical models of hydrologic and hydrodynamic processes such as overland, channel, and groundwater flows and transport (also improve methods for simulating the nonlinear dynamics of fluid-driven mass and constituents in connected canal/wetland systems [develop a coupled mathematical/numerical model]), and (4) measure and model the groundwater flow from Water Conservation Area 3B under the protective levee. Measurement efforts will cover surface freshwater discharge to the East Coast, surface and groundwater discharge to Florida Bay, and surface freshwater discharge to the southwest coast.

- **Provide increased support for Everglades National Park's numerical modeling program, which applies the South Florida Water Management Model (SFWMM) and Natural System Model (NSM) to help evaluate proposed structural and operational changes in the C&SF system.**

Model output produced by simulating proposed alternative strategies are processed, evaluated, and documented with regard to their effects on hydroperiods and hydropatterns in the natural areas of Everglades National Park. Ecologists use these interpretations to evaluate impacts on the ecosystem. Improved rainfall/runoff formulas to return the wetlands to a more natural condition and revised operational schemes to improve freshwater deliveries to Florida Bay have been prepared by the Park's cooperators and will require extensive evaluation before implementation. In order to enhance the reliability of the current models, particularly in the wetlands, the Park's hydrologist and modeler are evaluating the models' algorithms and data sets. A higher level of effort by the Park hydrology staff will be needed to evaluate impacts of alternative strategies on wetlands for the restoration effort and to analyze wetland-related algorithms and data sets.

- **Support improved capability for evaluating the effect of structural and operational modifications in the C&SF System on Florida Bay in NOAA and other agencies**

Analyze outputs from the existing SFWMM and NSM. NOAA/NMFS proposes to work with other Federal agencies and the South Florida Water Management District to develop and implement analyses and environmental assessment procedures for simulation data that can be used as an index of freshwater flow to Florida Bay and Biscayne Bay. Results can be used develop operational guidelines and to evaluate alternative strategies proposed to improve estuarine conditions.

- **Encourage SFWMD's current activities related to developing a new South Florida Regional Simulation Model.**

The South Florida Regional Simulation Model (SFRSM) will be a completely redesigned version of the existing South Florida Water Management Model with extensions to simulate the natural system (without water management facilities). It will not be a modified or enhanced version of the existing codes of the SFWMM and NSM, but a completely new model designed to analyze future regional water management alternatives efficiently using the best available techniques, computer technology, and data. This new SFRSM will take advantage of recent advances in computer technology, in particular, GIS, Databases, and Object Oriented Model Development. It will use the more realistic, accurate, and efficient numerical algorithms that were not implemented during the original development of the SFWMM due to resource limitations and lack of data.

MODELING HYDRODYNAMIC PROCESSES

Major issues:

- Lack of a hydrodynamic model that can relate circulation and salinity in the bay to freshwater inflow.
- Lack of hydrographic data with which to create boundary conditions and obtain other parameters for a hydrodynamic model.
- Unknown influence of circulation patterns in adjacent waters.
- Lack of measurements of freshwater inflows to Florida Bay.
- Lack of models to adequately model freshwater inflows to Florida Bay as a function of rainfall.

Questions:

What are the patterns of salinity and circulation in Florida Bay in relation to freshwater inflow?

How does water from Shark Slough affect salinity patterns, circulation, and nutrient dynamics in Florida Bay?

What are the major factors influencing circulation in Florida Bay?

What are the oceanic contributions of nutrients to Florida Bay relative to the terrestrial contributions?

How are algal blooms in Florida Bay influenced by circulation?

What is the turnover time of water in Florida Bay and how does it differ by region of the bay?

How has the Overseas Highway affected the circulation of Florida Bay?

Planned approach:

- Develop a three-dimensional hydrodynamic model capable of resolving the tidal, density driven, and wind driven components of the Florida Bay circulation.
- To initiate studies before adequate data for 3-D are available, quantify the model for 2-D execution.
- Through modeling activities, address first order questions of mass balance and help determine the most critical data needs for higher resolution and higher dimension modeling.
- Collect data.
  - Boundary conditions (i.e., current velocities and directions, salinities) along the western margin of the Bay and in the Keys channels.
  - Elevation data for existing ENP continuous monitoring stations.
  - Ground and surface water flows into the northern part of the Bay (both measured and provided by hydrologic models).
  - Direct precipitation on the Bay (from Radar estimates).
  - Salinity patterns over the entire bay under a range of conditions of freshwater inflow, winds, and influencing factors.
  - Updated topography of Florida Bay.
- Use existing models of the offshore circulation to provide the external forcing for the Florida Bay models (adapt regional circulation models for this use).

MODELING METEOROLOGIC PROCESSES

Major issues:

- Rainfall over south Florida is highly variable in both space and time, causing errors in estimates of total rainfall from spot measurements. These errors can affect the accuracy of hydrologic models and their ability to predict stream flows. High resolution quantitative precipitation predictions for south Florida are not currently available.

- Changes in land surface influence rainfall. The area of moist surface or surface water influences evapotranspiration, which feeds convective rainfall. The replacement of forested surfaces with paved surfaces affects albedo and the vertical temperature gradient. There have been many changes of this type in South Florida in the past century, suggesting that rainfall could have changed as a result.

- Surface wind stress is a dominant force determining circulation in Florida Bay, and surface wind predictions are needed for input to hydrodynamic models of Florida Bay.

- Direct precipitation is a major source of freshwater to Florida Bay, and is poorly measured. High resolution spatial rainfall predictions for Florida Bay are not currently available.

- Improved accuracy and resolution of hydrologic models is important to the restoration effort and is also important to water managers in handling stormwater runoff following major rainfall events.

- Evaporation is another important influence on salinity patterns and circulation in Florida Bay, but information on evaporation is lacking.

- A regional meteorological model would be useful in improving rainfall, runoff, wind stress, and evaporation estimates, but does not currently exist for South Florida.

Recommendations (Currently funded for FY-94 by NOAA):

ARPS (Advanced Regional Predictor System) is a high resolution (1-10 km grid), non-hydrostatic model suited to simulating thunderstorm complexes that form due to the convergence of sea breezes from the east and west Florida coasts. With proper boundary conditions, this model should be suitable for prediction of heavy rain episodes associated with tropical disturbances and fronts. The model should be capable of supplying boundary conditions to ocean and bay circulation models and hydrologic models. Other advantages of this model are explicit cloud microphysics (critical for resolving individual thunderstorm complexes), an adaptive grid in which grid points are dynamically redistributed for increased resolution in high gradient regions, and ease of portability among different computer architectures.

The model should be useful for evaluating the possible effect of drainage and land use changes in South Florida on rainfall. The surface evaporation and radiation budgets of the model are highly dependent on landuse, vegetation, and soil specifications which help determine the soil moisture, surface albedo, roughness length, surface heat capacity, the fraction of a grid cell covered by vegetation, the evapotranspiration, and the surface temperature. The model should be able to accept initial input boundary conditions concerning soil moisture, vegetation, and surface water area from the South Florida Water Management Model and the Natural System Model.

The adaptation of the ARPS model to the South Florida environment is a multi-year project that already has been initiated by the Hurricane Research Division of NOAA's Atlantic Oceanographic and Meteorological Laboratory in cooperation with the Miami National Weather Service Forecast Office and the South Florida Water Management District. The first year's work will proceed in the following steps:

- Download the version 4.1 of the ARPS model code and begin to set up model parameters appropriate for the South Florida simulations.

- Make arrangements for obtaining 300 h of CPU time and remote supercomputer access on the University of Alaska Cray-2 for testing the model with high resolution.

- Make necessary software adaptions for running the model on existing HP-755 workstations, supplementing storage and memory capabilities as required.

- Perform an inventory of available surface observations (including anemometers and rain gages) to determine the optimal method of constructing fields for model evaluation.

- Investigate options available for high resolution local databases of terrain, coastline bitmask, land use, soil type, and vegetative index required to adapt the model to south Florida.

- Organize an informal workshop with local circulation and hydrology modelers and operational meteorologists from the National Weather Service and SFWMD to encourage cooperation and interaction, discuss overlapping boundary condition interests, grid geometries, simulation experiments and verification data and address potential cross-discipline use of the ARPS model.

- Obtain and develop software for presenting and evaluating model results. Perform model tests using idealized homogeneous sounding background state initial conditions. Arrange for acquisition of larger-scale three-dimensional initial conditions from the operational National Meteorological Center Eta model for later real data simulations.

Continuation into subsequent years, if support allows, will proceed as follows:

- Obtain data for model test cases, including WSR-57 or WSR-88D radar data for verification. Initialize the model with observed data and evaluate the ability to predict the organization of precipitation by comparison with radar data and rain gage data where available. NEXRAD WSR-88D radars will be operational near the four corners of the model domain at Miami, Tampa, Melbourne and eventually Key West.

- Perform a natural system sensitivity test to estimate the impact of changing land use and soil conditions on the typical summer-time sea breeze thunderstorm development cycle and subsequent rainfall distribution.

- If appropriate, conduct a field experiment using the sophisticated suite of atmospheric and oceanographic sensing equipment aboard the NOAA P3 aircraft to better define initial conditions for a real time model test and document thunderstorm evolution.

- Evaluate the prediction of surface wind fields by comparison with all available wind observations. Develop and apply techniques for generating detailed surface wind analyses for input into ocean and bay circulation models. Investigate the possibility of using WSR-88D wind and reflectivity data to initialize and verify the model.

- The eventual goal of this work is to provide the atmospheric component of a comprehensive coupled hydrologic-hydrodynamic-meteorologic model containing the Everglades, Florida Keys, Florida Bay, Biscayne Bay and portions of the Atlantic and Gulf of Mexico basins.

MODELING ECOLOGICAL PROCESSES

Major issues:

- Ecological models are critical to application of the adaptive management methodology adopted by The Working Group, and an adequately and continuously funded, concerted model development program is needed.

- Landscape models are needed that simulate vegetation succession as a function of the hydrologic regime and aperiodic events, incorporate land shaping processes such as soil accretion and soil subsidence, can interact with hydrologic models to affect hydrologic processes, and can provide the explicit spatial framework necessary for models of species and communities that are influenced by landscape patterns. Landscape models in progress need to be reoriented to meet these needs.

- Model development activities should involve South Florida experts concerning the species or community being modeled and should involve scientific oversight that helps focus the modeling effort on implementation for ecological assessment.

- The success criteria recommended by the Science Sub-Group need to be refined into a set of appropriate and workable ecological assessment indicators for both immediate and longterm applications.

- An ecological assessment protocol is needed to ensure that monitoring and modeling efforts are focused on providing the ecological assessment indicators.

- Model development should be supported by--and incorporated with--research to supply critical information needs.

- Information is limited for certain species and communities (i.e., apple snail, periphyton community, mangrove fish community) that, otherwise, would make valuable indicators because they are so important in the system. The ecology of important potential indicators should be major research topics.

Questions:

What were the essential processes that created, shaped, and maintained the predrainage South Florida landscape and how did that landscape support the rich wildlife once present?

What was the predrainage landscape mosaic and how did it influence hydrologic regime and ecosystem function?

What were the plant community and wildlife responses to that mosaic and what are the minimum needs, in terms of spatial extent, habitat heterogeneity, and sheet flow, in order to support healthy, viable plant and animal populations?

How should the hydrologic regime be restored to best restore characteristic species and landscapes? What other actions should be taken in concert with hydrologic restoration?

Given the reduced spatial extent of the central Everglades, can adequate throughflows be restored to support the freshwater inflow needs of Everglades National Park and Florida Bay without disruption to structure and function in the central Everglades?

How has the general lowering of land elevations in the upper and central Everglades due to soil subsidence affected the ability to move water south to Everglades National Park and Florida Bay?

Can soil rebuilding within the natural Everglades be accomplished by ecosystem restoration? What is the maximum rate of elevation gain that can be expected?

How do timing, frequency, intensity, spatial coverage, and duration of aperiodic events such as fire, freezes, wind storms, and weather extremes (droughts and floods) affect landscape structure? What were the characteristics of these events in the predrainage system?

How is landscape structure affected by barriers such as roads, levees, and canals, which affect the movement of water and the spread of fire?

What are the landscape-scale ecosystem functions in this system, and how are these functions affected by barriers and by water management?

How are populations of animals of various sizes and types affected by fragmentation and decreased size of habitat? How might the establishment of wildlife corridors affect their populations? Needed is the determination of minimum size of available habitat required to support populations, as affected by its spatial distribution.

How much of each ecosystem type will result from a given restoration alternative (e.g., pocket wetlands, hydric pine lands, tree islands), and how will each type be distributed across the South Florida landscape?

What were the wildlife patterns of the predrainage system and how did they conform to the hydrologic and landscape patterns?

What factors determine nesting site establishment and how are they related to the factors that determine nesting success in various wading bird species, alligators, crocodiles, etc.?

For a given long-lived species, what are the hydrologic requirements for feeding and reproduction? How frequently do conditions for successful nesting occur today and how frequently would they have occurred in an undrained system? How frequently would favorable conditions have to occur for long-term population stability (i.e., 2 out of 5 years?, 3 out of 5 years?)

What are the species' habitat requirements and the hydrologic requirements of the habitat, and how has water management affected habitat quality?

What are the relative effects of hydrologic regime, nutrients, mercury contamination, and hydrologic regime on species abundance and community structure, both taxonomic and trophic?

How will plant and animal communities respond to landscape mosaics, reestablishment of natural hydrology in various restoration scenarios? What is the natural species richness of bird communities, fish communities for this area? How will restoration options affect species richness of selected taxa?

What were the predrainage spatial and temporal distributions of vegetation communities and periphyton communities? What factors determined those distributions?

What is the relative importance of hydrology and nutrients in determining community structure, macrophytes and periphyton?

What are the fundamental food webs and major energy and material flows in Everglades wetlands, the Big Cypress, and Florida Bay, and how are they affected by changes in hydrologic regime?

Why did South Florida lose 90% of its wading birds when only 50% of wetlands were lost? Can changed hydroperiods and hydropatterns explain the loss?

Why are wading birds no longer occupying the large nesting colonies in the coastal mangrove area of Everglades National Park east of the Shark River?

What factors control the rate of invasion by exotics and what makes a given habitat or site more invasible than others? What are the conditions that enhance invasibility?

Why are the spatial patterns of mercury in large mouth bass not correlated with the spatial patterns of mercury concentrations in soils?

What is the long term effect on coral cover of changes in water quality affecting photosynthesis?

Does the dependency of reef tract biota on seagrasses and mangroves result in feedbacks that cause declines in seagrasses and mangroves to affect coral reproduction, growth, and survival?

Can spatial patterns of existing coral cover on the Florida reef tract be explained by differential influences of Florida Bay water in different areas?

How much of an increase in estuarine production overall can be expected from a given increase in freshwater flow to Florida Bay?

How much of an increase in seagrass coverage can be expected from a given increase in freshwater flow or a given decrease in concentration of nutrients?

Could nutrients released from the death and decay of seagrasses alone be responsible for the observed bluegreen algal blooms in Florida Bay?

What are the critical feedbacks of the natural system to urban and agricultural systems and vice versa? How will the natural system and its support functions for humans be affected by different population levels and landuse configurations?

What is the landscape configuration and water regime that will provide a high degree of restoration with the lowest maintenance requirements?

Recommendations:

- **Design integrated modeling systems in which ecosystem models must accept the output of hydrologic and landscape models and interpret these outputs in an ecosystem context.**

The promising ecological modeling systems already underway for use in South Florida should be fully supported and expanded in their application.

- **Encourage and nurture the promising modeling concepts of ATLSS by providing continuous funding at an increased level, guidance to ensure the models will simulate ecological assessment measures, or indicators, and access of modelers to a wider group of authorities on South Florida ecology.**

ATLSS is a set of linkable landscape, aquatic primary production, fish community, and individual-based higher trophic level models being developed in a cooperative ENP/NBS/University of Tennessee project. Because of their ability to respond to hydropatterns and a heterogeneous landscape, these models are particularly suited for use in the South Florida Ecosystem restoration effort. Properly directed and given adequate development funding, models developed within ATLSS can be extremely useful for evaluating alternative management options and measuring restoration progress.

- **Support the Florida GAP initiative to help it meet objectives of the South Florida restoration effort. Fill the "gaps" in GAP funding.**

The NBS-GAP initiative is another approach that has many values to the Restoration Effort. GAP looks at biodiversity, protected species, and exotic invasions from a habitat perspective and provides a multispecies approach to optimizing native biodiversity, recovering threatened and endangered species, and controlling invasive non-indigenous species. GAP addresses many needs implied by sub-region presentations. GAP is a cost-effective means of region-wide analysis because it is based on remote sensing and computerized habitat classification and mapping.

- **Support the independent landscape modeling initiatives started by the SFWMD and NBS/ENP/ORNL and give the modelers more direction to enhance the usefulness of the models for ecosystem restoration.**

A vegetative landscape modeling capability is needed that will be responsive to the dynamics of hydropattern and water quality over time and space. Model responsiveness is needed to conditions that vary on seasonal, annual, and decadinal time frames and involve changes in water management, climatic change, and events including fire, rainfall extremes, freezes, and hurricanes. Models should simulate landscape development, including vegetation succession, soil formation and dissolution, and change in elevations. This capability will fill many needs. Landscape models will be most effective if used interactively with spatially explicit hydrologic models, providing a dynamic landscape that influences water flow and surface water patterns.

- **Integrate landscape model development with development of a restoration assessment protocol. Some guidance, as well as communication between modelers, should insure that the models serve complementary needs.**

ELM, because it is spatially explicit, could be useful for simulating soil building processes, land recontouring, the formation of tree islands, sloughs, sawgrass stands, batteries, etc., and the effect of vegetation patterns on water flow, hydroperiods, and hydropatterns. The ATLSS landscape model will be most useful for understanding animal responses to the current landscape and landscapes arising from alternative water management strategies proposed to support ecosystem restoration.

- **Support trend and gradient analyses and retrospective paleoecological studies as part of a landscape studies program that includes landscape models.**

These techniques are required to generate essential information that can be used most advantageously through incorporation into landscape models.

- **Develop models that provide spatially explicit views of estuaries to determine now salinity patterns, as established by freshwater inflow, overlap with habitat features important to estuarine dependent species.**

Initially, attention should be focused on Florida Bay. The model should include bottom topography and the overseas highway. It should be capable of accepting spatial information on salinity, circulation patterns, and nutrients from monitoring or other models.

- **Use conceptual models appropriately in the restoration effort.**

Conceptual models, composed simply of diagrams and descriptions, are a good way to integrate information, communicate ideas, and share understanding on a topic. They are effective organizing tools at the beginning of a study and can provide the initial design basis for simulation models. They might be particularly useful in the assessment protocol development process.

- **Encourage several ecological modeling approaches. Consider, in the context of the suite of capabilities that will be needed, the full range of potentially useful models that may be offered. (Lead--Science Sub-Group)**

Models that can integrate the ecological system across scales appear the most useful, but the door should not be closed to other modeling approaches because modeling science, like the biological world, is evolving, and diversity is the basis for success.

- **Provide an institutional framework, including a home and continuous funding at an increased level, for ecological modeling. (Lead--ITF, with advice from Science Sub-group)**

Models are critical to the application of adaptive management methodology. The Science Sub-Group should propose an institutional framework to support ecological modeling in order to ensure the model development, maintenance, upgrading, and application of models to support assessment and other restoration needs.

- **Ask the right questions.**

The right questions must be asked in order that models are developed that will provide meaningful information for decision making. How the question is framed may make a difference in whether it can be answered and, if answered, translated into effective management.

MERCURY IN SOUTH FLORIDA

Many federal, state, and local organizations are engaged in an effort to assess mercury problems in South Florida. Upon completion of this work, a much improved understanding of environmental mercury cycling in South Florida will be available. Because many of the abiotic processes regulating mercury bioavailability are poorly understood one component of these efforts is to better characterize those key, abiotic processes significant to the overall issue of mercury bioavailability. The remainder of this section will discuss selected aspects of the abiotic chemistry of mercury in South Florida for the purpose of providing background documentation on current research needs.

RECOMMENDED RESEARCH

- Develop quantitative methods to assess divalent and monomethylmercury binding with natural organic carbon

- Assess South Florida sediment porewater chemistry within the context of potential mercury migration

- Develop analytical methods/protocols to assess potential multimedia mercury migration.

- Investigate the environmental factors that influence the rates of microbial methylation and demethylation, test hypotheses for sources and transport of mercury that are consistent with conditions and historical changes associated with the Everglades, and evaluate ameliorative strategies.
- Identify the role of microbial activities in the fate, transport and biological uptake of mercury, and the environmental constraints on those processes, in light of the unique attributes of the Everglades ecosystem and the anthropogenic stresses to which it has been subjected. Investigation such factors as the influence of nutrients, pH, oxygen, and organic carbon on the rates of microbial methylation/demethylation (M/D) are critical to the development of mathematical expressions for microbial M/D that can be applied to fate and transport modeling for mercury.

- Characterize ecological zones and land uses, present and historical, within the Everglades with respect to conditions that influence the rates of M/D, in order to integrate and analyze data on the forms and concentrations of mercury.

- Determine the nature of the organic matter (e.g. periphyton vs. detritus of emergent plants) that serves as microbial substrate for methylation, as it is impacted by altered nutrient and aeration conditions,

- Determine the effects of periodic inundation of agricultural lands

- Determine the importance of organomercury species other than methylmercury.

- Determine the importance of demethylation pathways under altered aeration regimes.

- Elaborate on linkages among the carbon, nitrogen, phosphorus, and sulfur cycles as they impact the methylation of mercury.

- Determine the relative rates of transport and decomposition/transformation of particulate-associated mercury.

- Determine the ecological effects of mercury in the South Florida Ecosystem by developing a suite of process-based models (with user oriented interfaces) that describe

- the nominal trophic dynamics and habitat utilization of vertebrate and invertebrate wildlife in wetland and estuarine ecosystems,
- the effects of hydrology, water quality, and vegetative habitat structure alterations on these ecological processes,
- the bioaccumulation of mercury and other persistent organic chemicals and metals in wetland and estuarine biota, and
- the direct and indirect effects of chemical contamination on the structure and function of wetland and estuarine ecosystems

- Develop conceptual models describing the foodwebs and habitat utilization of South Florida ecosystems to delineate the principal ecological interactions and forcing functions needed to sustain viable populations of the major vertebrate and macroinvertebrate wildlife.

- Develop and quantify algorithms describing the effects of mercury and water quality (*i.e.*, temperature, dissolved oxygen, and mineral salts) on the bioenergetics and habitat selection of aquatic organisms.

Quantitative relationships between these variables and the mortality, feeding, assimilation, photosynthesis, respiration, and growth of South Florida Ecosystem biota must be identified and incorporated into the wetland and estuarine foodweb models.

- Existing habitat based models for vertebrate wildlife species should be reviewed and used as an integral part of this research. These models should be used was the initial, but not necessarily final, frameworks to address the foraging, nesting/reproductive, and roosting habitat requirements of vertebrate wildlife species of concern.

A realistic forest stand model (*e.g.*, FORET, FOREST, JABOWA, KIAMBRAM, SILVA, SWAMP) should be an integral part of the wetland foodweb model to simulate the structural characteristics of wetland vegetation required by wetland vertebrates for food, shelter, and reproduction. This stand model should be responsive to hydrologic alterations, fire, local and regional climatic factors, and episodic disturbances such was hurricanes. This model should also facilitate direct calculation of evapotranspiration and impedance to hydrologic flow to improve and be input to the suit hydrologic models being developed for the South Florida Ecosystem.

- Wetland and estuarine community models should be validated piece-wise using literature data and field and laboratory studies planned as part of the Everglades Restoration Project.

As various submodels are validated, databases of ecological, morphological, and physiological parameters required by the submodels must be compiled to facilitate rapid and effective model parameterization. User interfaces must be developed.

- Conduct model sensitivity tests that address:
  - How does different assumed community structures affect model results? For example, how does including or excluding community components of minimal interest affect predications for components of immediate regulatory or decision-making concern?
  - How does aggregation of model components affect model predictions? For example, are model results significantly different when all salmonids are treated as a single component versus when they are treated as individual species?
  - How does different parameterization of components of interest affect model results? That is, how does parameterizing component of interest with specific or generic data affect model results?
  - How should model results that are simulated for a specific location or set of locations be combined and analyzed to assess watershed or regional effects?

- Select and adapt environmental fate models to link with a food web model.

- Examine the sensitivity of the model to information uncertainty.

- Acquire critical data for aquatic fate models. Likely to be important are hydrogeometry, advective flows, dispersive transport, external loadings and boundary concentrations, and various chemical constants and environmental parameters.

The chemical constants and environmental parameters required for mercury modeling will depend upon how the speciation and transformation processes in the model are formulated. Some environmental parameters that are expected to be important include pH, dissolved oxygen, dissolved organic carbon, sulfide, sulfate, and TDS.

- Describe and test the form of the kinetic equations, the dependencies on environmental parameters, and the rate constants in a variety of aquatic environments.

The methyl forms of mercury are known to bioaccumulate strongly and provide the most risk to humans and other predators. Most of the mercury delivered to the aquatic environment is inorganic. The internal production of methyl mercury, then, is a crucial process in any mechanistic mercury fate model.

- Describe the biogeochemistry of DOC and fine organics in canals and wetlands. Quantify formation and loss processes.

Those species of mercury that are complexed with dissolved or fine organic material are mobilized for transport, but may be shielded from some loss processes. Good process models should be able to describe the binding capacity and strength of this material for various species of mercury.

- Develop or adapt process models that can describe the sorption process for the important species of mercury. Collect data to characterize the sediments in South Florida so that their sorption capacity can be modeled. Describe sediment transport processes through canals and wetlands, especially for silt and clay fractions.

Those species of mercury that sorb onto suspended sediments can be deposited into the benthic environment and transformed or buried.

- Conduct research to examine uptake by aquatic plants and microalgae, particularly periphyton.

The amount of partitioning or uptake of mercury into the base of the aquatic food web drives the subsequent bioaccumulation. Research is needed into how this can best be represented, the coefficients or rates for mercury species onto various phytoplankton and plants, and what environmental parameters might affect the kinetics.

- Develop a spatially distributed food web model to examine aquatic systems with gradients of exposure concentrations, rather than concentrations in just one place. Conduct site descriptions to support the model.

Such a model would allow the user to specify a range for each fish species and age class. Plankton would be carried through the spatial network by advective currents. Overlapping ranges would be taken care of properly. Modeling technology must be developed to facilitate the representation of the biology and to perform the bookkeeping properly.

- Link aquatic fate and food web models to adequately represent bioaccumulation.

Aquatic fate and bioaccumulation cannot be treated separately for methylmercury. Traditional aquatic chemical fate models do not include a food web internally. Bioaccumulation calculations are traditionally performed following the aquatic fate calculations, as the aquatic concentrations are not usually affected significantly by the food web.

- Develop information on atmospheric emissions and depositions to support atmospheric environmental fate models.

- Develop methods to analyze species of mercury in emissions.

Loadings of mercury introduced to the atmosphere from various sources, including coal-fired utilities, municipal waste incinerators, and medical waste incinerators must be quantified and characterized. Knowledge of the oxidative state and physical form of the emitted mercury is important because these properties can influence the pattern of atmospheric dispersion and deposition. Loadings of elemental, mercuric, and methyl mercury are desired. Current stack sampling methods do not adequately characterize the chemical and physical form of mercury emissions as they manifest themselves on the regional scale. Chemical and physical transformations that appear to be occurring in the exhaust flue and/or the local plume create a discrepancy between the mercury constituents measured in the stack and those measured in the atmosphere.

- Describe, spatially and temporally, the depositional loadings of elemental, mercuric, and methyl mercury is needed to drive the aquatic fate models.

While wet and dry fluxes may be measured at selected locations, a regional airshed model with local sources should be used with the observed data to more precisely understand the loading patterns and to distinguish between various local sources and regional and global background sources.

- Measure mercury vapor concentrations and exchange rates at selected sites. Include mercury vapor transport and reactions in a regional airshed model. Undertake experiments to quantify volatile exchange rates.

Elemental mercury in the air may undergo volatile exchange with concentrations in soil and water. This may provide a net source or sink to the watershed.

- Describe physical and chemical reactions affecting mercury speciation in the plume.

These reactions are expected to affect the amount of mercury that is deposited locally in wetfall, and the concentration of elemental mercury vapor that may exchange with the watershed. They may also help to explain the discrepancies in the chemical and physical form of mercury that often appear between stack gas measurements and ambient atmospheric measurements.

- Modify existing atmospheric mercury fate models to handle the special transfer and transformation reactions that affect major mercury components.

Present atmospheric mercury fate models are built upon the framework of existing chemical transport and fate models. Several existing chemical models handle environmental transport processes and chemical transformation processes in a general manner that can be used for many organic and inorganic chemicals.

- Link terrestrial and aquatic fate models to atmospheric models.

Atmospheric models are generally used to estimate direct human exposure and to provide loadings to surface water and soil. Volatile exchanges, however, could provide significant loadings from watersheds to the air. The nature of mercury dynamics requires an interconnection between these models that is achieved only crudely at present.

ENDANGERED AND THREATENED SPECIES FOR SUBREGIONS 4-9

The large number of endangered and threatened species within the south Florida ecosystem reflects the substantial direct loss of habitat and the alteration of ecological processes of the remaining system. Patterns and quality of water flow through wetlands have been altered and water tables have been lowered under remaining upland habitat. Fifty-four plant and 51 animal species within the region are listed or candidates for listing under the federal endangered species act. Additional species are listed by the Florida Game and Freshwater Fish Commission, Florida Natural Areas Inventory, and Florida Committee on Rare and Endangered Biota, as rare, threatened or endangered.

For wetland dependent endangered species, hydrologic restoration may be the best option for achieving recovery of these species. Endangered and threatened species within the south Florida ecosystem can be classified into two broad groups. The first are those wetland dependent species for which restoration of natural hydropatterns and the quality of water within the system should improve the habitat for these species. The other group includes terrestrial species which may or may not benefit from restoration of freshwater conditions. These include species found in the uplands of the Florida Keys, pinelands and hardwood hammocks throughout the region, and the coastal ridges. The status of these species is determined by the amount, fragmentation and isolation of the remaining habitat.

The federal list of endangered and threatened reptiles, which are known to occur in one or more of the central and southern subregions of the Everglades basin, consists of five species of sea turtles (green, leatherback, loggerhead, hawksbill & Kemp's ridley), the American crocodile, and the Eastern indigo snake. Sea turtles once were much more common in southern Florida estuaries, as is indicated by the prevalence of a commercial sea turtle fishery in these waters between the 1850s and 1973. The impacts that degradation in sea grass beds and coral reef communities have had on these turtles remains unknown, in large part because of difficulties in estimating current populations and seasonal patterns from existing data. The continuing importance of these habitats, however, is suggested by a sample of sea turtles captured for tagging on banks in western Florida Bay in 1990 and 1991, which consisted of 51 loggerheads, 23 greens and one hawksbill (mostly subadults). Hawksbills are more common around reefs and ocean creeks in Biscayne and Fort Jefferson National Parks.

The American crocodile has disappeared from most of its former range in Biscayne Bay and the Florida Keys, and has retained viable nesting sub-populations only in eastern and northern Florida Bay as far west as the Cape Sable peninsula, on northern Key Largo, and in the Turkey Point cooling canals. Although the number of nesting female crocodiles in Everglades National Park has been stable or slowing increasing during the past decade, the number nesting in traditional creek habitats in northeastern Florida Bay has declined. The fact that a major segment of the nesting population occurs downstream from the degraded Taylor Slough/C-111 basins and relationships between crocodile distribution and salinity remain poorly known demands that close attention be given to this species during the restoration process.

Except for sea turtle nest monitoring projects on several public beaches in south Florida, conducted largely by volunteers, no organized research or monitoring for sea turtles is presently in place. Most known crocodile nests at Turkey Point, northern Key Largo, and in Everglades National Park, are monitored annually for measures of activity and success. Although the indigo snake remains widespread in pinelands and hammocks throughout southern Floridâ, little is known of population trends. Subpopulations are expected to remain secure on well protected, public lands, but may decline where habitat alteration and collecting can occur.

Roughly 55 percent of the combined state- and federal-listed plant species occur or once occurred within the South Florida Ecosystem. Nine plant species, 7 endangered and 2 threatened, have been listed or proposed for listing by the USFWS within the restoration area. The endangered Okeechobee gourd (Cucurbita okeechobeensis) and the threatened climbing dayflower (Commelina gigas) are plants of wetlands of Lake Okeechobee and the northern Everglades. The remaining federally-listed plants are upland species, mainly from pine rocklands and beaches: Miami lead plant, Amorpha crenulata; Small's milkpea, Galactia smallii; tiny milkwort, Polygala smallii; the threatened Garber's spurge, Chamaesyce garberi; tree cactus, Cereus robinii; pineland clustervine, Jacquemontia curtisii; and, beach clustervine, Jacquemontia reclinata. The major enclave of rare wetland plants (but no current federally-listed species) within the restoration area is the Fakahatchee Strand in southern Collier County. Ponds and swamp forests in this area harbor about 25 species of epiphytic ferns, orchids, and bromeliads not found elsewhere in the U.S.

The federal list of birds includes seven endangered species, two threatened and five candidate species. Restoration of pre-drainage patterns of freshwater flow from Lake Okeechobee south through the Everglades to the estuaries should benefit two endangered species (wood stork, snail kite), but will have uncertain affects on two other endangered species (Cape Sable sparrow, and bald eagle), and on two candidate species (mangrove clapper rail, reddish egret). Proper management of old growth pine forests within the region probably will have the greatest benefit for the red-cockaded woodpecker (Endangered) and Southeastern kestrel (candidate). Conversion of wetlands into citrus groves represent a serious threat to all freshwater, endangered species. Southeastern snowy plovers (candidate) winter along sandy beaches within the region, and peregrine falcon (Endangered) migrate through the entire region and winter in coastal areas. Protection of tropical upland forests on the mainland and in the Florida Keys is the largest factor influencing the status of white-crowned pigeon (candidate).

Seven species of mammals that are federally listed as endangered or threatened occur in the central/southern subregions of the Everglades basin (Florida panther, key deer, Key Largo cotton mouse, Key Largo woodrat, lower keys marsh rabbit, silver rice rat, and West Indian manatee).

RECOMMENDATIONS

- Conduct censuses of breeding and wintering populations of all endangered and threatened species at regular intervals throughout the Everglades basin. Censusing protocols must be repeatable, statistically sound, and standardized across the region. New census protocols must be developed for some species.

- Develop ecological studies that address critical management questions for each of the species. These data will be essential for the development of restoration plans in a manner that insures the improvement of the status of the species within the system.

- Undertake a population viability analysis for each species to help identify bottlenecks in the life cycle of each species which must be addressed during restoration planning.

- Evaluate the status of state-listed species, and other species or populations not currently federally listed, but which may be threatened with extirpation in the Everglades basin. Develop priorities for research and monitoring from this expanded list of species of regional concern.

- Append to restoration plans a multi-species recovery plan, which identifies potential conflicts between species recovery plans and restoration plans, and describes protocols for addressing these conflicts.

- Monitor the status of endangered and threatened species throughout the entire restoration effort and, in certain cases where concerns are raised, conduct special studies or reviews to estimate potential impacts of specific actions on these species.

- Approach restoration objectives with incremental actions and follow the adaptive management process to insure the protection of certain species as the system moves through changed states in response to restoration actions.

- Determine relationships between crocodile distribution, nesting patterns and success, survival of age classes, and salinity.

- Continue and expand long-term monitoring program for crocodile nesting in South Florida.

- Implement nesting censuses for sea turtles using standard sea turtle nest census protocols, on beaches in Everglades and Ft. Jefferson National Parks and elsewhere as required, to compare with earlier nesting studies.

- Determine condition and relative importance of sea turtle feeding habitats in Florida Bay and in waters adjacent to the upper Florida Keys, and develop a GIS model of juvenile habitats.

- A better definition of the habitat requirements of Cape Sable Seaside Sparrows in terms of fire frequency and hydrology needs to be developed for this species in both the Taylor Slough and southern Big Cypress basin. Annual censuses of the distribution and density of the sparrows, relative to fire and water conditions, are required.

- It is critical that the dispersal and colonization ability of both adult and young sparrows be well understood. Radio-telemetry studies of adults and young should be undertaken to determine movement patterns of individual birds.

- Improvement in the understanding of habitat requirements and the reasons for patchy distribution is necessary for the development of restoration plans that will maintain the Cape Sable Seaside Sparrow as hydrological conditions are changing during the restoration process.

- Detailed color-marking study of one Cape Sable Seaside Sparrow colony needs to be undertaken to determine aspects of demography such as dispersal patterns relative to age and sex, survivorship, and effects of fire on distribution.

- Continue detailed ecological studies of the response of kites to changing water conditions within south Florida, to take advantage of the large number of birds currently carrying functional radio transmitters. Maintain monitoring and reproductive studies of breeding populations of snail kites throughout their Florida range.

- Develop an study of the ecology of apple snails and what conditions make them available to snail kites. Although snail kites feed almost exclusively on apple snails, the environmental dynamics of snail populations are only poorly understood, in large part because of difficulties in measuring snail numbers, densities, and survival patterns.

- Implement an improved kite censusing program that more accurately estimates kite populations.

- A detailed demographic study of storks nesting in the Everglades basin needs to be undertaken with the aim of better quantifying aspects of recruitment, and adult and juvenile survivorship related to late nesting.

- A detailed study of the effects of mercury, other toxins, and parasites on the survivorship and reproductive success of wood storks.

- Analyze the factors that determine when and where Wood Storks forage and nest. The Systematic Reconnaissance Study data set in combination with colony and historical survey data should be used to look at the relationships between timing and location of colonies and regional hydrological patterns. Document what appear to be changing relationships between stork nesting patterns and regional hydropatterns which presumably reflect fundamental changes in the way the Everglades system operates at primary and secondary production levels.

- A detailed monitoring and research program is required to look at the distribution and possible impacts of mercury on bald eagles.

- Radio-tracking and/or satellite tracking of juvenile and adult eagles nesting in Everglades National Park and the Florida Keys needs to be undertaken to determine annual movement patterns related to habitat requirements, especially during non-breeding periods.

- Continue, and expand as needed, monitoring of nesting bald eagles throughout Everglades National Park, the Big Cypress region and the Florida Keys.

- An expanded ecological and distributional survey of the Big Cypress red cockaded population is required. Distributional surveys of clans within Big Cypress Preserve and the addition area needs to be completed and maintained. Survey area should be expanded to include surrounding pinelands not in federal ownership that may contain woodpeckers or could have them reintroduced.

- Ecological studies of the Big Cypress population to better measure habitat requirements, survivorship, dispersal capabilities, movement patterns and population viability.

- Survey areas where red-cockaded woodpeckers may be able to be reintroduced, including Long Pine Key, Everglades National Park.

- Purchase and protect all remaining tropical forest parcels larger than 5 ha from Key Largo south to Key West. Complete North Key Largo, Tropical Flyways, Big Pine/Coupon Bight, and Lower Keys Hammocks project on the Conservation and Recreational Lands Program. Finish federal acquisition of lands in Crocodile Lakes and Key Deer National Wildlife Refuges.

- Conduct comprehensive censuses of pigeon nesting and feeding habitats in the lower Florida keys.

- Continue long-term censuses of manatee, to measure distribution and abundance.

- Develop benthic vegetation maps for Everglades National Park, for the interpretation of manatee movement/distribution patterns.

- Determine the ecological and physiological freshwater requirements of the manatee. Use telemetry to address movement patterns related to hydrological parameters.

- Analyze existing food habits data for the panther, relative to the effects that hydrological patterns have on the distribution and abundance of prey species.

HARMFUL NON-INDIGENOUS SPECIES

Invasion by non-indigenous plant species originating from throughout the tropical-subtropical world is a major factor threatening south Florida natural areas. Many nonindigenous plant and animal species have escaped cultivation and become established in south Florida. Some have not only colonized disturbed sites, but also invaded natural lands that have been set aside for preservation of natural communities and landscapes. South Florida probably has more problems with aggressive non-indigenous species than any other state. The state as a whole has approximately 925 established non-indigenous plant species growing outside of cultivation. Over 100 of these are listed as invasive in Florida by the Exotic Pest Plant Council. Melaleuca and Brazilian pepper are better known examples of harmful non-indigenous trees that are widespread and increasing in South Florida. At least 23 non-indigenous plants now are found in Florida's waters. Non-indigenous plants and land animals constitute about 25 percent of all species in the state.

Many non-indigenous animal species have become established in Florida's aquatic systems: 83 fish, at least 26 insects since 1970, 2 amphibians, 3 birds, 1 mammal, 1 reptile, 5 mollusks, 1 crustacea and an unknown number of pathogens. Many non-indigenous terrestrial animals, particularly birds, reptiles, and amphibians, have escaped captivity and are reproducing in south Florida. Sixty-three percent of the introduced non-indigenous bird species in the continental U.S. are found in Florida, which also has the largest number of established non-indigenous amphibians and reptile species in the U.S.

ISSUES

- Scientific research on exotic species in Florida has been underfunded, considering the magnitude of the problem and the potential for further damage to the ecosystem. Most resources have been focused on agricultural pests and aquatic weeds. Little has been spent on research concerning exotic species that are a threat to natural areas. Two types of research are needed: (1) research to develop technology and (2) basic biological and ecological research to improve understanding of invasive exotic species.

- Biological control research, although it has made promising progress, is inadequately funded, and other eradication methods alone cannot control regionwide invasions.

- Scientifically based screening and risk assessment methods are lacking, but are needed to prioritize species so that the greatest threats receive the most attention.

- Habitat restoration strategies are needed to prevent invasive non-indigenous plants from returning, once they are removed from heavily infested areas. One general strategy is to replant native vegetation, but scientifically supported guidelines on how to reestablish native plant communities most effectively are limited for south Florida.

- The limited amount of biological and ecological information concerning invasive species affects the ability to generate public understanding and support of the public and decision makers. This lack of information also limits the ability to devise effective control strategies.

What affects will water management alterations for purposes of ecologic restoration have on non-indigenous plants and animals?

What are the impacts on native species and natural areas of infestation with non-native species?

What ecological roles do non-native animals play in the natural habitats in which they are found?

What are the major factors influencing expansion rates of specific problem species in south Florida?

What factors make a natural area site susceptible to invasion by non-natives?

What are autecological aspects of various problem species, including phenology and response to environmental variables, that might allow them to be controlled by management measures such as adoption of new water management or control burning practices?

How do non-indigenous plant species that establish monocultures affect the water budget? For instance, does melaleuca consume more water, particularly during the dry season, than the native species it replaces?

RECOMMENDATIONS

- **Prepare coordinated research programs on invasive or otherwise harmful non-indigenous species for inclusion in separate multi-species management plans for plants and animals.**

- **Provide a comprehensive review of recent and ongoing research, utilizing the planning and coordinating work of the Exotic Pest Plant Council.**

Research should not be restricted to only studies of individual species, but rather should attempt to build a set of principles that helps support a holistic, ecosystem approach to exotics control. The questions listed in the major issues section above should be addressed.

- **Continue and expand biological control research. (Suggested lead--USDA/ARS, ACE)**

This research must include:

a. foreign exploration - searching for most effective control species in the species' native land
b. overseas screening process - determine most effective and safest species before importing tho the U.S.
c. quarantine follow-up - clearance for field release
d. on-site field sites - colonization in areas affected
e. assess the success and performance of introduced species
f. technology transfer - distribute organism throughout range of species

- **Provide support for the quarantine facility at Ft. Lauderdale and necessary personnel; this is a critical component of the biological control research program.**

- **Conduct research to develop an ecological understanding of invasive non-indigenous species. (Suggested lead NBS)**

With respect to plants, more work is needed on determining (1) factors that affect the invasibility of natural areas, (2) environmental requirements and phenology of particular problem species as these relate to their vulnerability to specific controlled burning or water management regimes, (3) common characteristics of invasive non-native species in Florida, (4) effects of non-indigenous plant infestations on native species and the environment, and (5) effective habitat restoration strategies to prevent reinvasion by non-indigenous species after their removal.

With respect to animals, research is needed on how non-indigenous species reproducing in the wild have impacted food webs, community structure, and populations of species in natural areas in which they have become established.

- **Develop scientifically based methods for screening and risk assessment to prioritize efforts for controlling invasions at relatively early in the process (importation, distribution, colonization). (Suggested leads--USDA/ARS, NBS)**

Effective criteria for identifying and screening potentially invasive or otherwise harmful non-indigenous plants and animals before they enter the country or before they become well established will help to focus preventive efforts.

- **Develop a multi-species monitoring plan.** (Suggested Leads--NBS, FWS, NPS)

As part of plan development, existing monitoring programs should be inventoried, and an analysis should be made to determine overlaps and gaps in coverage. The plan should ensure that basic variables are defined and measured the same way so that data can be analyzed across areas, not just locally. Prepare a computerized atlas of ongoing monitoring programs should be prepared.

- **Document the present nature and extent of invasion of south Florida's natural areas by non-native plant species and prepare a summary report. (Suggested Lead--NBS)**

The survey might be approached through interviews with land managers, field biologists, and naturalists. In addition, limited areas should be selected, based on representativeness, sensitivity, or special concerns, for a quantitative analysis of plant invasions, including mapping. This activity should be coordinated with Florida DEPs current activities and with the COVER group.

- **Prepare a prioritized list of non-indigenous plant species that are currently and potentially the greatest threat to natural areas. Suggest target areas and species for expanded control efforts.**

Start with the list prepared by the Exotic Pest Plant Council. Use information from the recommended survey and available monitoring results. Develop information on a plant community basis.

- **Based on information from the above studies, generate brochures and news releases that describe the problem with non-indigenous species in South Florida to land managers, decision makers, and the public.**

A public information effort based on scientific information will help develop a greater awareness of the problem and its present and potential impacts on natural areas. Once informed of their contributions to such problems, a concerned public often will change its habits.

- **Conduct horticultural research to develop sterile cultivars of popular and widely used but invasive non-native ornamental plants, such as certain flowering trees and Ficus species. (Suggested Lead--Department of Agriculture)**

This technology is being used elsewhere for esthetic reasons. Fruitless mulberry trees and podless locust trees are very popular nursery items in the southwestern United States. Developing sterile cultivars of non-natives with invasive tendencies should be an intensive activity that leads to quick results. Species such as royal poinciana, the orchid tree, surinam cherry, the exotic *Scaevola*, and the many ornamental ficus trees would be good candidates for this treatment. Use the EPPC list to select non-native trees and shrubs whose propagation outside of cultivation should be controlled.

SUBREGION 1: KISSIMMEE RIVER BASIN

Restoration of the Kissimmee River Basin is several years ahead of the restoration of the rest of the South Florida Ecosystem. A plan was developed out of state and federal effort to evaluate the effectiveness of the restoration program already in progress. The program involves structural modifications to backfill parts of the canal and reestablish flows through the natural channel. The assessment plan in its entirety forms the Sub-region 1 section of this report. The four goals of the assessment plan are as follows:

- Provide thorough understanding of ecosystem structure and function before and after restoration,
- Show direct cause-effect relationships between restoration efforts and ecological responses,
- Include quantifiable biological responses and hypothesis-driven experimental approaches,
- Document changes of social and scientific importance.

The plan calls for establishing a set of pre-restoration reference conditions and designing a suite of conceptual models that describe ecological relationships and influences of hydrologic factors on selected ecologic communities and functions. the models will facilitate understanding effects of restoration on the ecosystem and provide a conceptual framework for the evaluation program. The models will help set expectations concerning responses to hydrologic modification of wading birds, water fowl, fish, invertebrates, floodplain vegetation communities, littoral vegetation communities, hydrologic conditions, and water quality.

Expectations will be compared to reference conditions, which are based on historic reports and published literature. Assessment will be made on population densities of selected species or guilds, establishment of rookeries, and habitat-based projections. Quantitative historical data on wintering water fowl are available for 1949 through 1957 from the U.S. Fish and Wildlife Service and Florida Game and Freshwater Fish Commission. Targets are increased usage of reestablished wet prairie habitat on the floodplain by resident mottled ducks and migratory dabbling ducks, with full recognition that extraneous factors have had on both regional and migratory waterfowl populations. Through a combination of historical data, published literature, and samples collected from relatively pristine sites both within and outside the basin, a set of expectation metrics for fish and invertebrate communities will be obtained. Macrophytic and littoral vegetation will be compared to interpreted prechannelization historic photography, which will set the reference conditions against which the restoration expectations will be measured. A historic data base on stages and discharges will provide expectations concerning hydrologic conditions after modifications are made. No prechannelization water quality data are available. A model for dissolved oxygen regimes is being developed that will provide expectations for this parameter. Other parameters--nutrients and carbon--will be compared against published data for similar river systems.

SUBREGION 2: LAKE OKEECHOBEE

The Lake Okeechobee section represents the consensus of a convened panel of experts. A workshop format was used to develop the strategic questions, approach, and research tasks that comprised the report. It focused on the hydrologic and ecologic issues stated in the Science Sub-Group Report. The report details the major issues impinging on Lake Okeechobee as they relate to the restoration of the South Florida Ecosystem. Primary among these were the use of the Lake as a regional water storage and supply system, excessive nutrient loading from agricultural activities in the basin, concern for exotic invasion of the wetland systems, and concern for the ecological integrity of the littoral system of the Lake. The report summarizes plans by the South Florida Water Management District to deal with the above issues. These include the Lake Okeechobee Technical Advisory Council reports, the Lake Okeechobee Surface Water Improvement and Management Plan (SWIM), and the Lake Okeechobee Research Plan. Next, the report details the restoration objectives in the Science Sub-Group Report, followed by research questions formulated to address information needs relative to the objectives.

Following are the questions that were raised and associated tasks that are recommended. Moving a portion of the northwest part of the Hoover Dike around Lake Okeechobee is under consideration as a means of restoring Lake littoral zone if Lake regulation stages are raised to accommodate possible water supply needs for South Florida Ecosystem restoration and expected urban expansion. The first question was formulated to explore the potential value of moving the dike in terms of replacing existing littoral zone that probably would be lost at higher Lake stages.

Research question: What will be the spatial extent and hydrologic character of the expanded littoral zone along the northwest shoreline?

- Conduct a grid based topographic survey of NW area behind the Herbert Hoover Dike.
- Incorporate this area into grid based spatial hydrologic models.
- Integrate output from the hydrologic models into GIS databases.

Research question: What are the water quality impacts associated with changes lake stage and littoral zone configurations?

- Develop models of phosphorus transport from sediments in the open water to the littoral zone.
- Develop hydrologic models to investigate the potential for nutrient input via lake water to areas in the existing littoral zone that are isolated from eutrophic water.

Research question: How will vegetative and animal communities respond in the expanded littoral zone?

- Develop models of vegetative community response to hydrologic conditions in littoral zone.
- Develop models of the responses of fish, wading birds, and snail kites to predicted hydrologic and vegetative conditions in the littoral zone.
- Develop and implement long-term monitoring programs at the appropriate spatial and temporal scales for vegetation, fish, wading birds, and snail kites in the littoral zone.

Research question: What will be the impacts to the southern islands under different regulation schedules?

- Conduct a grid based topographic survey of islands in SW.

- Incorporate these islands into based spatial hydrologic and nutrient transport models.

- Integrate output from the hydrologic models into GIS databases.

Research question: What are the impacts of exotic plants on the Lake Okeechobee system and how can these impacts be mitigated.

- Map the distribution of exotic plant species.

- Perform gradient analysis to determine controlling factors in the distribution and spread of exotics.

- Develop a priority list of exotics to control.

- Develop biologic control mechanisms for all exotic species.

Research question: Are exotic and native fish competing for resources?

- Conduct census surveys and feeding studies as necessary to assess resource partitioning between native and exotic fish.

Research question: What is the relative role of internal recycling vs. external loading in the development of phytoplankton blooms?

- Collect data and analyze trends (spatial and temporal) in nutrient concentration, nutrient loading, and bloom development, composition, and magnitude. (This question is being addressed comprehensively in the SFWMD Lake Okeechobee Research Plan. This task is intended to reaffirm the need for this information.

Research question: What is the response of the aquatic invertebrate community to the changes in water/sediment quality?

- Collect data and perform gradient analysis on benthic invertebrate communities over the range of sediment type/quality.

Research question: What contaminants are likely to be impacting fish and wildlife communities?

- Acquire data on local, regional, and global sources, transport mechanisms, fate, and effects and develop list of contaminants that warrant investigation.

- Design appropriate monitoring programs to assess the extent and magnitude of impacts due to the contaminants of concern.

Research question: What is the system wide water budget on a yearly basis since levee construction?

- Acquire the necessary data to develop a system wide water budget.

Research question: What dynamic regulation schedule will better mimic natural hydrologic variability?

- Develop a "base" hydrologic model of lake stage that is coupled with inputs from the Kissimmee basin and rainfall.

- Use the "base" model to investigate changes in lake stage associated with various restoration alternatives, including but not limited to: reduced east-west discharges, changes in agricultural /urban water demands, interbasin transfer of water from the Caloosahatchee urban areas into the lake, and changes levee configuration.

Research question: What are the potential impacts to the levee (structure, integrity, leakage) as a result of changes in regulation schedule.

- Perform engineering studies as required.

Research question: What will be the "ecological" consequences associated with changes in regulation schedule?

- Prepare a family of models to assess potential impacts to vegetation, fish, wading birds, and snail kites resulting from changes in lake stage.

Research question: What are alternative water delivery mechanisms to create littoral zone on the NW end of Lake Okeechobee? (e.g, reconfigure Paradise Run)

- Develop models of various water delivery scenarios.

Research question: What is the feasibility of restoring predrainage flows from Lake Okeechobee south to the Everglades?

- Investigate the use of both operational methods and structural modifications (i.e., enlargement of maximum conveyance capacity in channels and pumps) to eliminate regulatory releases from Lake Okeechobee to the St. Lucie and Caloosahatchee canals and substantially increase the delivery of water from Lake Okeechobee to the Water Conservation Areas.

SUBREGION 3: UPPER EAST COAST-ST. LUCIE RIVER AREA

Circulation and freshwater inflow patterns to the St. Lucie and Indian River estuaries have been greatly modified through a combination of inlet construction and channelization of the watershed, including the interbasin connection of Lake Okeechobee to the St. Lucie system. The North and South Forks of the St. Lucie River and the St. Lucie Estuary are particularly stressed. The North Fork receives sporadic stormwater runoff through Canals C-23, C-24, and C-25. The South Fork receives sometimes massive regulatory releases from Lake Okeechobee through the St. Lucie Canal (C-44). The estuaries are showing many signs of stress, including accumulation of organic rich flocculant sediments, loss of seagrass beds, and declines in fish densities. Although restoration of predrainage conditions in these estuaries is out of the question, recovery of healthy conditions in the estuaries through mitigative measures, including landscape and water management redesign, is a reachable goal. Innovative uses of regional and on-site detention areas is the best hope for recovery of the estuaries and also could provide water supply and flood control benefits to agriculture in the area. The ecological future envisioned is one of more stable estuarine systems rather than the historical pattern of alternating freshwater aquatic and maritime regimes. Regional landscape and water management redesign is proposed based on a set of hydrologic, three-dimensional hydrodynamic, landscape, and ecological models. Data needs associated with the modeling include particularly:

- Complete, and accurate, regional water budgeting.
- Accurate flood and discharge profiles for canals and structures in the region, including a capability to evaluate the consequences of structure modifications.
- Capability to evaluate impact of current and proposed secondary structures (e.g., weirs in feeder canals).
- Ground water recharge and withdrawal scheduling.
- Ability to accept weather service forecast and stage monitoring data, and respond with appropriate infrastructure operations schedules.
- Ability to track actual response (stage, discharge, water quality data) to continually recalibrate empirical and process-based response functions--for both quantity and quality parameters, including turbidity, dissolved oxygen, nutrient loads, and industrial, domestic, and agricultural toxic substances loadings.
- Salinity and circulation patterns in relation to freshwater inflow.
- Salinity requirements of major benthic organisms and fishes.

SUBREGION 4: EVERGLADES AGRICULTURAL AREA

The report summarizes scientific progress related to ecosystem restoration in the Everglades Agricultural Area (EAA). The report discusses completed and ongoing work and identifies future scientific priorities for the EAA. The report emphasizes approaches that could benefit both the natural ecosystem and agriculture of the EAA.

Several classes of organic, or muck soils exist in the EAA. However, about 87% of these soils are composed largely of decomposed sawgrass (*Cladium jamaicense* Crantz) and may contain more than 85% organic matter. Soon after draining, scientists noted that these organic soils were subsiding, or decreasing in depth. This report identifies soil subsidence as the major ecological issue within the EAA, and as the major obstacle for achieving a sustainable agriculture in the EAA.

Soil subsidence is caused by physical, chemical, and microbiological processes. Although research is needed to further clarify its contribution to subsidence, oxidation of soil organic matter probably causes most of the subsidence now occurring in the EAA. This oxidation is caused primarily by microorganisms that thrive under aerobic conditions. As a result of the oxidation process, insoluble carbon portions of the organic matter convert to gaseous and water-soluble products. With this conversion of carbon comes the resulting loss of soil mass.

Scientists have advised EAA growers since at least the 1940's that to increase the longevity of their agriculture, they must reduce the rate of subsidence. The most practical means of reducing subsidence is to maintain water tables as close to the soil surface as possible; the more soil within the profile that is inundated, the less oxidation occurs. Historically, this water-table management strategy has not professed to control subsidence completely with conventional agriculture of the EAA, only to reduce the rate of subsidence. Subsidence rates in the EAA have averaged about 3 cm per year. However, due to changes in water-table management, the annual subsidence rate in the EAA now is probably less than 3 cm.

Scientists have experimented with alternate crops that could be grown under conditions that would completely control subsidence. Although they present a biological solution, these crops would not be practical because they do not have sufficient markets to warrant their commercial cultivation. Research attempting to improve yields and expand markets of these crops should be encouraged.

Sugarcane (a complex hybrid of *Saccharum* spp.) is the predominant crop in the EAA. A successful sugarcane industry depends upon a large infrastructure. Factories to convert the juice of sugarcane to raw and refined sugar; trucks, trains, railroad tracks, tractors, and wagons to transport the sugarcane from the fields to the factories; and in uses of sugarcane by-products, such as to generate electricity for public utilities, form a portion of this infrastructure. South Florida faces severe economic consequences if ecological restoration means fragmenting EAA agriculture or changing it from a predominantly sugarcane agriculture.

Much of this document describes approaches in agricultural management and research whose ultimate goal is to have no subsidence in the EAA. Improvements or changes in the hydrological system with changes in priorities for its management may be necessary to reach this goal. Past strategies to control subsidence proposed only partial control measures or use of crops not yet profitable. The research to control subsidence presented here proposes to completely control subsidence while cultivating sugarcane and other crops now grown profitably in the EAA.

Growers have already made important changes by including rice (*Oryza sativa* L.) in their sugarcane rotations, increased use of summer floods, and growing all their crops at higher water tables. A scenario is illustrated that in the short term would reduce subsidence rates from a theoretical 3.66 cm per year to 1.04 cm per year. This major improvement could be achieved by summer flooding about 77,000 ha, 37% of the cropped EAA, and growing sugarcane with water tables at 30 cm from the soil surface. Research is needed to identify sugarcane cultivars adapted to a 30 cm water table. Past research presents an optimistic outlook for quickly identifying such cultivars.

Further improvements would be more long term and gradual, but previous research suggests that chances for success are good. The major needs for long-term research are to breed and select sugarcane cultivars adapted to water tables closer to the soil surface, determine stages of growth and height of water above ground at which flooding does not harm sugarcane, determine duration of flood sugarcane can withstand without yield loss, and determine proper management of alternate flooding and moderate draining that would not harm sugarcane while not permitting oxidation. Research on rice should aim to extend flood duration by planting and harvesting it under flooded conditions. A standard condition of publicly supported genetic research on all EAA crops should be to identify cultivars adapted to higher water tables and less phosphorous fertilizer.

Since the South Florida Ecosystem is massive and contains diverse regions, it is generally agreed that the restoration process must be holistic and adaptive. The approach identified here for the EAA meets both requirements. It is holistic because it would benefit both the EAA subregion and the ecosystem. It does so by proposing an agriculture that is managed to take advantage of natural weather patterns and hydrology. Doing so would help control subsidence and permit more water storage in the EAA. Potential benefit to the natural system would be the increased ability for water to flow south according to more natural hydroperiods, and decreased need to release water in east or west outlets from Lake Okeechobee. The approach is more adaptive than other solutions proposed for the EAA, such as publicly acquiring the EAA or constructing flowways within the EAA.

Phosphorous runoff from the EAA has received more attention than other EAA-related issues. Reviewing published and ongoing projects on phosphorous runoff shows that much excellent and complex work has been accomplished and major gains have been made. A workshop was held on April 14, 1994 in Belle Glade, FL at which participants identified key concerns related to the phosphorous issue.

The workshop summary in this report shows that the issue is complex and multidisciplinary. The workshop summary does not prioritize research strategies. Further attempts at summarizing progress related to phosphorous should include teams of multidisciplinary scientists.

The final section of the report summarizes sources of scientists and funding to continue the South Florida restoration process in the EAA. Three public sources with research scientists in place in or near the EAA are the South Florida Water Management District, the University of Florida's Everglades Research and Education Center, and the USDA-Agricultural Research Service's Sugarcane Field Station. Private agricultural enterprises already have full-time scientists working on ecosystem-related issues and several scientists have worked as consultants on these issues. In addition to these sources for scientists and funding, the Environmental Protection District and the Florida Sugar Cane League, Inc. are possible sources of funding. Other important public sources of technical support include the Cooperative Extension Service, the USDA-Soil Conservation Service, and the Palm Beach Soil and Water Conservation District.

SUBREGION 5: EVERGLADES WATER CONSERVATION AREAS

The Water Conservation Areas represent a large portion of the Everglades that has been protected from development, but greatly modified by channelization and diking. These impoundments were constructed in phased steps over a number of years, culminating in the current configuration in the early 1960's. The principal function of the units is water control for economic development. The system provides a compartmentalized detention reservoir for excess water from the EAA and parts of the east coast region as well as accommodating flood discharges form Lake Okeechobee. The levee system on the east prevents flood waters from inundating the principally urban east coast while providing water supply for the east coast agricultural lands and the Everglades National Park. The areas enhance the supply to the east coast by recharging the Biscayne Aquifer, the primary drinking water source for the southern urban east coast, and retarding salt water intrusion. All these functions are to be accomplished in a manner benefitting the considerable wildlife resources dependant on the system.

The WCA's are precariously juxtaposed to the urban development on the east and agricultural development to the north and west, concomitant with their ever increasing demands for flood protection and consumptive needs for water supply. By virtue of their spatial placement in the center of the hydrologic gradient; the highly managed nature of their input and output regimens; and the documented consequence of receiving the nutrient enriched drainage of the surrounding agricultural and urban areas (SFWMD Everglades SWIM Plan), these areas are severely impacted by the current water management operations of the Central and South Florida Project and are integral to the restoration effort. These areas contain the last remnants of the tall-sawgrass landscape, as well as, the bulk of deep marshes, wet prairies, and tree island hammocks outside the ENP. Additionally the WCA's provide habitat for a diverse array of flora and faunae, including endangered species, particularly snail kites and wood storks. Since a major portion of the Kissimmee/Okeechobee and East Coast Ridge drainage are diverted to sea for regulatory flood control, the historic hydrologic throughput or volume through these units is severely reduced. The areas have been virtually isolated from the Kissimmee/Okeechobee watershed and the resultant sheet flow with all its natural variation that was a critical element in the formation and the ecological structure and function of the Everglades landscape.

The WCA's are critically important to the wildlife resources of the Everglades. The areas are rich in fish and wildlife, particularly wading birds (including the Endangered wood stork), the American alligator, and the Endangered snail kite. Grass shrimp, crayfish, and select fish species are well adapted to the periodic wet/dry regimens that characterize the Everglades.

In its natural state the Everglades ecosystem was essentially an oligotrophic system, deriving most of its nutrient input through atmospheric deposition. Concomitant with the drainage and development of the EAA, the WCA's have become retention/detention systems for storage and elimination of agricultural drainage. The chronic introduction drainage waters with elevated concentrations of nutrients (10 to 20 times background concentrations) has resulted in massive conversions of sawgrass and wet prairie communities to stands of robust Typha and Typha/saw grass mixes along with a replacement of the typical periphyton mat communities to species mixes more reflective of deteriorated water quality.

The impoundments replace the historic inclined hydrologic gradient, formerly subject to sheetflow, with a series of stepped basins connected through control structures that localize and minimize the forces of the flow that historically shaped and maintained the landscape structure of the system. In addition, by hydrologic regulation schedules, these systems are practically decoupled from rainfall, becoming over inundated in response to flood protection and overly de-watered in response to consumptive water supply demands in dry years. In addition there have been major altered hydroperiod impacts resulting from the impoundment of these systems. Channelization coupled with impoundment has increased depth and hydroperiods at the southern end of the systems, while over de-watering and shortening hydroperiods in the northern ends. One result is extensive invasion by the exotic Melaleuca as well as numerous exotic fish. Another is the shortening of hydroperiods and reduction in water coverage, vital to successful wading bird reproduction. This is particularly critical since these units provide major rookery and foraging habitat for wading birds in normal and dry years.

The following list of research questions identifying information needs resulted from a process employing the Adaptive Environmental Assessment Approach for identifying major issues and information needs. The process began with stating the intended objectives of the restoration project (both hydrological and ecological) followed by the development of frame strategic questions that address the information needs required to meet the objectives. This assessment was conducted in a two day workshop format with invited participants with the necessary expertise to address the multidisciplinary issues and scientific/technological approaches to resolving the issues.

Research Question 1. What were the predrainage sheet flow and hydro-patterns over the range of rainfall/evapotranspiration conditions that occurred within annual to century time scales?

Approach:

- Develop a series of spatially explicit grid-based hydrologic models (natural systems type) at various spatial/temporal scales to hindcast predrainage hydro-patterns at scales that match critical system features (topographic gradients, waterway networks, flow ways, etc.) and processes (rainfall extremes, overflow events, stage fluctuations, etc.).
- Synthesize existing information on basement topography, historic topographic elevations, rainfall/climatic cycles, vegetation, lake stage and overflow, soil types, and basement geology
- Perform paleogeologic studies to fill information gaps for model input.

Research Question 2: What hydrologic and associated forcing functions (fire, etc.) maintain the structure, function, and sustainability across spatial scales of km to 100's km of the South Florida ecosystem.

Approach:

- Design a paleoecologic study based on stratigraphic analysis of cores strategically located throughout the Everglades.
- Through analysis of peat/marl structure and charcoal remnants determine extent, frequency, of drought, fire, floods, hurricanes, etc.
- Given the connection between basement topography and physiographic landscapes, determine relationship(s) between finer scale landscape features (tree islands, sloughs etc.), hydrologic (and hydrologically controlled) forcing functions, and basement topography.

Research Question 3: What is the nature and degree of the flow / hydropatterns alterations due to compartmentalization?

Approach:

- Analyze existing hydrologic conditions utilizing the SFWMD's SWMM model to characterize the current patterns in hydroperiod, flow, storage, and gradients in the WCA's.
- Utilize the natural systems models (See Research Question 1) to characterize historic patterns of flow and hydropatterns prior to compartmentalization.
- Existing models (both SWMM and current version of natural systems model, Fennema et al., 1994): require considerable enhancement to address restoration questions at the scale required by the above question.
    - conduct extensive and comprehensive topographic surveys in the WCA's.
    - determine specific manning's coefficients for various vegetative types (particularly vegetative types that dominate landscape features).
    - determine percolation within the various reaches of the WCA's.
    - improve the resolution rainfall data and water delivery patterns
    - validate model(s) with field measurements of water levels and flow.
- Compare output from current and historic models.
- Collect hydrologic data (flow, water level etc.) to supplement existing data and model output to document the nature and extent of hydrologic alterations.

Research Question 4: How are these alterations expressed in the existing landscape?

Approach:

- Conduct an extensive survey of peat bed depths across the WCA's and ENP. Determine the relationship between peat depths and current hydrologic conditions on the affected areas.
- Determine at various scales which patterns (elevation, vegetation etc.) in the contemporary landscape are the result changes in hydrologically controlled forcing functions as reflected in trend analysis and modelling.
- Perform gradient analysis to determine the relationships between hydrologic parameters and composition, abundance and distribution of periphyton and macrophytes.
- Utilizing the above information and the SWMM model determine relationships between recent vegetative patterns and dynamics with hydrologic (and associated) forcing functions spatially across the WCA's.
- Integrate information obtained above with the output of SWMM and natural systems models into a spatially explicit landscape modelling capability as per the Everglades Landscape Model of the SFWMD and compare the results for resolving the impacts of compartmentalization.

Research Question 5: Is there adequate water available to support the desired system structure and functions? Is removal of the inter-unit dike and canal works of the WCA's feasible in terms of the current or projected demands for water in the South Florida Ecosystem?

Approach:

- Develop system wide (Kissimmee/Okeechobee/Everglades Watershed) water budget and projections of future water demands by consumptive users in the landscape (urban, agriculture etc).
- Develop a range of water requirements (volume, timing, placement, and conveyance requirements) to support critical natural system structure and functions.
- Determine the capacity of a restored system (an Everglades minus the water control structures that currently comprise the WCA's) to accommodate rainfall extremes while providing a significant capacity to absorb storm water run-off from the developed adjacent areas.

Research Question 6: Given the reduced spatial extent of the system, can adequate gradients and throughput be restored to support the freshwater inflow requirements of the downslope systems (i.e. estuarine and ENP) without sacrificing critical system structure and functions.

Approach:

- Based on critical water needs (amount, timing etc.) of South Florida system components (estuary, urban, ag, northern Everglades, southern Everglades) investigate (feasibility, impacts etc.) various means for moving water from Lake Okeechobee to estuaries and southern Everglades.
- Enhance the landscape level modelling capability (ELM, as per SFWMD) to interact with both SWMM and "natural systems" hydrologic models.

Research Question 7: What water quality is necessary to remove inorganic stressors on the system? What level of nutrients/contaminants trigger ecological impairment?

Approach:

- Conduct threshold studies for critical system components (periphyton, macrophytes, etc.).
- Perform gradient analysis of relationships between nutrients in water/soil and composition, abundance and distribution of periphyton and macrophytes.
- Determine peat accumulation and nutrient sequestering capacity of vegetative communities along gradients of nutrient inputs.

Research Question 8: What is the relative importance of hydrology and nutrients in modifying critical system components?

Approach:

- Perform multivariate analyses on the combined data sets of hydrology, nutrients, and composition, abundance and distribution of vegetation/periphyton generated in the gradient analysis described above.

Research Question 9: What forcing functions, operating on scales from patches to landscape, control the distribution, abundance, and dynamics of the following: periphyton, plant communities (emergent-cypress), aquatic inverts, fish, amphibians, reptiles, wading birds, snail kites, small mammals, and large mammals (deer, panthers).

Approach:

- Synthesize existing information, identify gaps, and design status and trend studies to determine the distribution, abundance, and population dynamics of the above groups.
- Determine the relationships (gradient analysis) between environmental factors (nutrients, contaminants, hydrology) and the distribution, abundance, and population dynamics of the above groups (gradient studies, impacted vs. unimpacted areas).
- Develop trophic relationships in the system. (stable isotope ratios?, prey base studies etc).
- Develop a family of models to investigate relationships between controlling variables and flora and fauna components.
- Conduct studies to determine if fauna movements are altered due to compartmentalization (fish, amphibians herps)

Research question 10: How can the predrainage vegetative landscape patterns be recreated within the context of existing spatial and hydrologic limitations?

Approach:

- Develop a set (hierarchical) of landscape succession models to examine restoration scenarios. (Based on analysis of water requirements for system components - see hydrology objectives).
- Develop indices of "ecological integrity" at scales appropriate to the individual target groups (periphyton - landscape)
- Conduct status and trend analyses of biodiversity as measured by vertebrate species richness (minimum).
- Combine information from natural system models with paleoecological data to determine correlations between hydrologic forcing functions and vegetative patterns and dynamics.
- Conduct time series analyses on from hydrologic models and relate to patterns in vegetation data.

Research Question 11: What constitutes impairment of ecological integrity?

Approach:

- Develop a suite of indices to evaluate ecological integrity.
- Conduct studies to compare faunal differences along gradients and extremes of water/sediment quality.

Research Question 12: What nutrients and contaminants are of concern?

Approach:

- Using information on local, regional, global sources and transport mechanisms develop a list of nutrients and contaminants that warrant investigation.

Research Question 13: What levels of nutrients and contaminants trigger impairment of ecological integrity?

Approach:

- Based on existing information on sources, transport, fate, and effect determine measurement endpoints for the nutrients and contaminants of concern.
- Conduct a system wide survey of nutrient and contaminant presence and/or effect using the appropriate endpoints.
- Develop threshold values for selected nutrients and contaminants via existing information, gradient analysis, or dosing studies.

Research question 14: What are the effects of exotics on system components and processes?

Approach:

- Map distribution and abundance of exotic species.
- Determine the linkages between the spread of exotics and alterations in critical ecosystem components and processes.

- Develop a procedure for prioritizing exotics for control.

Research question 15: What are the best methods to control exotics?

Approach:

- Investigate the use of biological controls for exotics.
- Determine which exotics may be controlled (or spread) by disturbances and changes in the forcing functions as a result of compartmentalization or restoration.

Research Question 16: What was predrainage fire frequency and aerial extent of fire?

Approach:

- Conduct coring studies to determine the extent and frequency of fire.

Research Question 17: Given the reduced spatial extent of the system, can patterns of fire frequency and extent be restored?

Approach:

- Integrate fire ecology into hydrologic models.

SUBREGION 6: EVERGLADES NATIONAL PARK AND THE BIG CYPRESS PRESERVE

Subregion 6 comprises the Big Cypress watershed north to the Caloosahatchee River watershed including the Panther National Wildlife Refuge and the Fakahatchee Strand. Subregion 7 consists of the non-marine southern Everglades region and is coincident with the freshwater and terrestrial portions of Everglades National Park and the adjacent authorized East Everglades acquisition lands. The writing team addressed research needs in the context of major ecological issues. The most fundamental concerns in these subregions, particularly as they relate to the concept of restoration of the regional ecosystem can be articulated as the need to understand the nature and implications of *ecological change within subregions 6 and 7.* The changes include all those known or suspected to have occurred in the subregions since the period prior to the earliest organized drainage enterprises of the late 19th century.

MAJOR ISSUE: Ground and surface water patterns have been changed.

Background

Current flow patterns in the Everglades National Park are strongly influenced by management of the impoundments to the north, extensive agricultural and urban pumping, and the drainage canals to the north and east. Water level declines have occurred throughout the Park, the major declines occurring along the eastern Park boundary in Northeast Shark Slough, Rocky Glades and northern Taylor Slough. At times, western Shark Slough receives large regulatory releases, substantially altering natural water patterns, transforming what were originally peripheral wetlands into a main flow way. Abnormally steep seasonal recessions of water levels and large discharges for flood control purposes result in unnatural hydroperiods and hydropatterns.

Recent urban and agricultural expansion have caused the lowering of the water tables north of the Big Cypress Preserve. Water level declines in Big Cypress originate along the northern boundary and extend southward.

Hydrological restoration efforts in the remaining wetlands are based on the reestablishment of natural hydroperiods and hydropatterns. In order to define what the natural water levels should be, information is needed concerning pre-drainage and historical hydrology. Development of this fundamental knowledge depends upon research on many hydrologic processes.

Current Research

Several aspects of the hydrology of subregions 6 and 7 are under current investigation by the Park and Preserve research staff. In addition, extensive monitoring of stage levels is ongoing. Fifty stations are active throughout the freshwater Everglades and 12 in the Big Cypress National Preserve. The investigations include: Shark Slough Experimental Water Delivery Evaluation, An Assessment of Changes in Discharges and Resulting Marsh Water Levels in the Lower C-111 Basin in response to the C-111 Interim Project, Management of Water Levels in the C-111 Basin, and Urban Runoff Retention, Taylor Slough Demonstration Project Assessment, Taylor Slough Delivery Formula Testing, Shark Slough Delivery Formula Development/Testing, Shark Slough Modified Water Deliveries FDM Assessments, Natural System Model Improvements, Regional Hydrologic Assessments/Restoration Modeling in the Everglades, Operational Studies - Modified Water Deliveries and Canal 111 GRR, and C&SF Restudy/South Florida Ecosystem Restoration Support.

Critical Questions and Research Approach

1. How does evapotranspiration rate vary across vegetation type and soil type and depths?
   Approach:

Evaporation is a large, but little known, component of the water budget that must be better defined for calibration and verification of models and water budgets. Set up field measurement stations at six different communities within the freshwater Everglades and Big Cypress basin for long-term monitoring.

2. What are the spatial characteristics of the shallow aquifer below the freshwater Everglades and Big Cypress basin?

Approach:

Very little subsurface information exists on the shallow aquifer's depths, transmissivities and storage coefficients. A field program is needed to better define these parameters. Test wells and core analysis coupled with surface geophysics will be included for a comprehensive analysis of the subsurface.

3. What are the land elevations in the western sections of the freshwater Everglades and the entire Big Cypress basin?

Approach:

Approximately 50 percent of the freshwater Everglades has not been surveyed and none exists in the Big Cypress basin. This is a fundamental data set and is needed for all hydrological and ecological modeling and analysis. Conventional surveying coupled with testing of remote techniques will be used.

4. What are the overland flow characteristics in the wetlands of the freshwater Everglades and the Big Cypress basin?

Approach:

In order to quantify wetland flows and freshwater releases to the estuaries the basic parameters relating to flow resistance are needed. Parameter determination using both laboratory and field experiments will be conducted.

5. What are the infiltration rates in different soil and vegetation communities of the freshwater Everglades and Big Cypress basin?

Approach:

This parameter is used in water budget calculations and hydrologic modeling and quantifies seepage between the surface water and ground water. Field studies will be conducted in areas with different soil characteristics.

6. What are the ground water seepage rates to the canals and estuaries?

Approach:

Large seepage flows are known to occur from the natural areas to the canals along ENP's eastern boundary and from the canal to the natural areas along the northern boundaries of BC and ENP. Also, both surface and ground water flows to the lower estuaries have not been quantified. Using both test wells and flow meters these flows will be better defined during a long term field study.

7. What are the rainfall/runoff relationships and the natural variability of water levels within the freshwater Everglades and Big Cypress basin?

Approach:

To determine the operational schemes that promote BC and ENP restoration, relationships between stages, flows and rainfall need to be established to guide water managers. Using physically based and statistical models, formulas will be refined, developed and evaluated to guide water deliveries to the natural areas.

8. What are the pre-drainage hydroperiods and hydropatterns within the freshwater Everglades and Big Cypress basin?

Approach:

This information is needed to guide the restoration effort. Comparisons can be made between the pre-drainage and drainage periods to evaluate natural spatial and temporal water distributions within a reduced Everglades. Using historical information and models these relationships will be developed and analyzed.

MAJOR ISSUE: Significance of Soil Changes in Sub-regio.ıs 6 & 7 for Hydrological and Biological Restoration of the Everglades

Background

Drainage has caused a loss of surficial organic soils throughout much of the Everglades as a result of accelerated oxidation and wildfires, which have been enhanced by drainage.

Soil formation rates are little known for the marl and peat types in the region, but are relatively high for the latter and low for the former. The qualitative role of vegetation in the form of arboreal, macrophyte or periphyton in forming the broad soil types is generally known, but how and why the rates differ is not. In coastal areas, strong hurricanes move large quantities of sediments around, reshaping ground elevations, creating or destroying natural levees and otherwise modifying topography. Such episodic processes influence vegetation development and local hydrology and therefore animal habitat over extensive coastal areas that extend into the freshwater Everglades.

The overall soil mass influences the hydrologic dynamics of the Everglades in several ways. By mantling the limestone substrate with varying depths of sediment accumulation, local topography is modified. This influences sheet flow dynamics, ground water recharge, and seasonality of flows and hydroperiods thus helping to define wetland hydrological characteristics. Soils also contribute to the timing and storage components of the water budget by influencing such properties as hydraulic conductivity rate and water retention capacity. Deep peat deposits, for example, store water long after precipitation events, thus mediating a gradual, lagged release of water long after the cessation of the wet season.

The distribution and depth of peat and marl soils and associated characteristic vegetation types (including periphyton) structure habitat for terrestrial and aquatic animals. Changes in soils, whether natural or man-caused, alter this function, creating new vegetation types and related animal communities.

Most of the known or suspected soil changes have occurred within Subregion 7, particularly in the Northeast Shark Slough area, Rocky Glades and adjacent Taylor Slough. Reduction in peat depths also seems likely in Shark Slough proper, but little evidence is available for drawing conclusions. Alteration of deposits related to hurricanes are to be expected in the southwest area, on the mainland north of Florida Bay, Cape Sable and along the Gulf Coast. Changes in soils that have occurred in the adjacent Water Conservation Areas have affected the hydrologic regime and habitat in Subregions 6 and 7.

Current Research

Little research on soils is being conducted in the sub-regions, except that incidental to other topics such as mercury accumulation in sediments. The Center for Climate Research of the University of Wisconsin is, however, engaged in an analysis of sediment cores taken from a wide area including Water Conservation Area 3, the Everglades and the Florida Keys. The study's purpose is to reconstruct historic vegetation patterns and infer hydrologic conditions from paleoecological materials. Results are expected in late 1995.

Critical Questions and Research Approaches

1. What are the formation rates of the major soil types and what are the critical hydrologic and vegetation factors determining the rates?

Approach:

Estimate past formation rates from isotope activity profiles. Estimate present and future rates by creating marker horizons or other procedures for measuring accretion of soil materials in major ecosystem types in sub-regions 6 and 7.

2. Over what area have soils been altered as a direct and indirect result of overdrainage?

Approach:

Complete modern soil survey across sub-regions 6 and 7. Compare results with past surveys. Combine with survey data from adjacent areas. Include estimates of hydraulic properties, total mass and volume, state of decomposition and related characteristics in relation to spatial pattern.

3. Within the major basins that have experienced alterations, what are the estimated volumes (area and depth) of soil losses and how has the local topography been affected?

Approach:

Use historical dating of sediments in areas to reconstruct soil depth profiles and determine age of surficial layers. Compare present soil composition and depth to predicted soil composition as inferred from vegetation pattern.

4. How have the relationships between vegetation and soil types changed since pre-drainage times?

Approach:

Develop a model of landscape vegetation-soil dynamics that allows for hindcasting of soil formation dynamics from historic vegetation data. Include treatment of periphyton calcite formation and marl soil formation and how these processes vary with changes in periphyton composition and mass.

5. What is the significance of the soil changes for sheet flow and ground water recharge?

Approach:

Simulate hydrol^gy of selected sub-basins within the region incorporating explicit simulation of soils based on measurements of soil physical and chemical properties.

6. What is the role of the major organic soil and marl soil types for aquatic food chain support?

Approach:

Conduct field, laboratory and mesocosm studies of mineralization and uptake of nutrients from common organic and marl soil types in natural systems. Note that some of this work is proposed below under aquatic invertebrates.

In related work, investigate transfer of soil generated nutrients into aquatic food chains. Determine, through field and mesocosm studies how uptake and food chain transfers vary with habitat, soil type and hydrology. Note that some of this work is proposed below in the water quality section.

MAJOR ISSUE: Changes in water quality in the Everglades.

Background

The historic Everglades was a hardwater, oligotrophic system depending primarily upon rainfall for nutrients. Flows from Lake Okeechobee periodically augmented the northern Everglades's supply of nutrients, suspended organic particles, dissolved organic, and other materials. Now the Everglades is subject to intense disruptions of geochemical processes due to human activities. along its margins, and to some extent from atmospheric transport processes. With the advent of many intense land use changes, notably the drainage and cultivation within the Everglades Agricultural Area, development of the eastern coastal ridge, phosphorus and other materials are delivered to the Everglades in quantities significantly above historic levels. The consequences of such enrichment can be understood from the extensive development of cattail stands in phosphorus enriched areas formally dominated by sawgrass.

The Everglades is protected by, among other standards (including nondegradation standards), Florida's Class III narrative nutrient standard. This standard requires that nutrient additions shall not be permitted at levels which cause an imbalance in fauna or flora.

Present technology to treat agricultural runoff, the primary source of excess phosphorus currently reaching the Everglades in large amounts, is expensive and untried in the oligotrophic range for phosphorus. Thus there is great interest in determining the "threshold" number which when adopted will represent a maximum concentration which can be delivered without harm to natural communities of the Everglades.

The agricultural industry has spent several million dollars in determining that level by field dosing studies in WCA-2B. The state is embarking upon a $6.6 million effort, based upon transect and field mesocosm research, but believes controlled dosing in channels is not feasible or necessary. However many scientists feel that direct application of nutrients under controlled hydroperiod will be necessary to determine a protective phosphorus standard, as outlined in the TOC's 1992 report. The federal members of the TOC have recommended that such studies be implemented immediately.

The Department of Environmental Protection will make the final determination of the standard through their administrative procedures to report a number by 2001.

Current Research

The sole research activity in the two sub-regions at present is an field-intensive, multi-channel dosing study being planned for the freshwater Everglades in Shark Slough within ENP. The project is presently undergoing research design refinement and peer review and will begin in next fiscal year. Results are expected to satisfy administrative needs to determine a field threshold for phosphorus effects in the freshwater Everglades and provide much basic data on nutrient dynamics and ecological effects.

Critical Questions and Research Approaches

1. What levels of biogeochemical disturbance are compatible with the restoration and preservation of a viable Everglades system?

Approach:

a) Estimates of rates of influx, storage, recycling, and loss to the Everglades system are fundamentally important. Mass balance models are a first step and can be constructed from available information. More refined models requiring new data gathering efforts can then be prescribed and assembled.

b) Finer scale models of process dynamics for phosphorus, nitrogen, selected ions (including mercury) should simultaneously be initiated to refine internal cycling relationships, including the dynamics of movement and accumulation in the food web.

c) Special emphasis in both large scale mass-balance models and fine internal process investigations should be dedicated to the role of organics, both dissolved and particulate, in the evaluation of the natural and culturally impacted biogeochemicals of the modern Everglades.

2. What threshold value for total phosphorus can be released to the Everglades system from the Everglades Agricultural Area, eastern ridge urban development, and the southeastern catchment basin?

Approach:

Develop an experimental design with adequate statistical power and reliable technology to provide accurate concentrations and flow measurements under rigorous field conditions. Implement the design in appropriate areas of the Everglades system; collect a minimum of 3 years of field data.

3. What sources, modes of transport, interaction with organic matter, and sinks exist for pesticides used on the periphery of the Everglades? What are the pathways for bioaccumulation into the food web of the Everglades? What additional monitoring of these phenomena is necessary?

Approach:

Much of the current monitoring for pesticides may detect some of the compounds because they are bound to the high organic content of the inflows to the Everglades. Additional research to determine the compounds currently in use, the timing of usage, the interactions likely to occur within the water column and within sediments is necessary. Small scale field and laboratory projects are required.

4. What are the full effects of water quality decline on the plant and animal communities of the Everglades?

Approach:

A great deal of new research and monitoring has been initiated by the recent litigation. Follow-up studies which replicate sampling of water quality and plant responses along transects in the WCA's and Everglades National Park are needed to document future trends. Particularly needed are replicated field studies of community and species functions and properties from sites located along transects that are accurately characterized as to sediment, water column, detritus and biomass content of N and P. Related work should include mesocosm and laboratory studies of the effects of nutrient additions and changing ratios upon periphyton, macrophytes, decomposers and short-lived consumers.

MAJOR ISSUE: Vegetation Changes

Background

The vegetation of the two sub-regions is controlled to a large degree by a few interrelated factors, including elevation, substrate characteristics, hydroperiod, water depths, and several aspects of fire. Disturbances such as freezes, hurricanes, droughts, and nutrient enrichment also play a role in determining vegetation structure and function. Human-induced changes such as modification of hydrology, altered fire regime, loss of organic soils and the introduction of exotic pest plants have caused both obvious and subtle changes in vegetation. Distinguishing natural from anthropogenic sources of vegetation change is important for evaluating restoration success. Although vegetation in sub-regions 6 and 7 for the most part is relatively little altered compared to other sub-regions, evidence suggests that important components of the freshwater and terrestrial vegetation of the region (especially sub-region 7 but also to some extent sub-region 6) are in disequilibrium with respect to present hydrology, soils and fire regime.

Numerous general descriptions of vegetation in ENP and BC exist. Currently the University of Georgia is developing a before- and after-Hurricane Andrew vegetation map of ENP, BC, and Biscayne National Park that would represent the first detailed map of the combined area. Several relatively small scale vegetation maps have already been completed for selected areas of ENP and BC. Unfortunately, there is no systematic program to monitor vegetation in ENP and BC. Those permanent plots that exist are neither well documented nor routinely sampled. However a series of aerial photographs exists for most of the area dating back 30 years or more. Changes in physiognomy over the last few decades can be detected by comparing remote imagery, but more subtle changes in species composition cannot.

Current Research

Most of the previous vegetation research in subunits 6 and 7 is related to exotic plants or fire. Current studies concentrate on the impacts of Hurricane Andrew on the structure of forested communities: mangroves, hammocks and pinelands.

Critical Questions and Research Approaches

1. What changes have occurred in the south Florida vegetation pattern since the pre-drainage era? How can we detect future changes?

Approach:

a. Conduct paleolimnological studies of Deep Lake and other similar features to document changes over the last few thousand years.

b. Using available imagery and field data, document changes that have occurred over the last several decades.

c. Develop a comprehensive vegetation monitoring program using a combination of remotely sensed imagery and permanent plots.

2. What environmental factors have been responsible for the observed changes in vegetation structure? What is their relative importance?

Approach:

a. Conduct field experiments which include manipulation of suspected factors, including hydroperiod, water depth, water quality, substrate, and fire.

b. Develop a process model of vegetation development for selected major vegetation types based on results of field experiments and on relationships of vegetation pattern to site characteristics at a large number of sites.

3. Where a given vegetation cover type has persisted since the pre-drainage era, what changes have occurred in composition and productivity?

Approach:

Within major vegetation types, measure accumulated standing crops and estimate present rates of primary production using standard harvest methods and repeated sampling appropriate to habitat and vegetation type. Compare areas differing in present condition and recent history. Develop a stand development or growth model that takes into account influences of hydrologic regime and sporadic events such as fires and freezes.

4. To what extent is plant succession a factor in determining vegetation composition and development?

Approach:

Reconstruct historical patterns based on archival information. Determine fire, hurricane and freeze chronologies for documented sites. Review botanical literature from other hurricane-prone regions. Establish temporal trends for selected sites using earlier studies (including Hurricane Andrew plots) and archived information. Continue plot analysis where plot locations from past studies can be determined. Establish a permanent plot network with standardized sampling to evaluate future trends.

5. What is the status of special (rare or listed) plant populations? How can the long-term survival of these populations be assured?

Approach:

a. Design and implement a monitoring program for populations of special plant species.

b. For species suspected to be in decline, conduct detailed studies of population dynamics, including manipulative experiments, if necessary.

6. To what extent have exotic species disrupted natural community function and what needs to be done to minimize these effects? What exotic species may pose problems in the future?

Approach:

a. For the area as a whole and for sites differing in extent of invasion, determine through field studies how community characteristics have been altered.

b. Improve control strategies for known problem species through integrated use of herbicides, biological control, and mechanical control including fire.

c. Develop autecological profiles for anticipated problem species. e.g., *Neyraudia* and *Rhodomyrtus*.

MAJOR ISSUE: Declines in freshwater fish, aquatic invertebrates, and aquatic herpetofauna.

Background

Natural environmental conditions in the Everglades and Big Cypress vary seasonally, annually, and from year to year. The effects of periodic environmental variability on aquatic animals are compounded by sporadic events like hurricanes and severe fires. The aquatic animals have a variety of means to cope with environmental variability: movements among habitats to find breeding sites or refuge from drying, resting stages to survive drought, reproductive adaptations, etc. Human-induced changes have affected natural variability by altering the seasonality and areal extent of flooding in the wetlands, drainage or impoundment of neighboring marsh systems, and addition of excess chemicals from urban and agricultural areas. Aquatic communities respond to human-induced changes through loss of diversity, changes in composition and abundance, and probably through alterations in energy-flow pathways. Some changes are subtle and difficult to detect until they are manifested in obvious collapses of native communities and natural processes. As human population pressures increase on the wetland systems, it is crucial to have adequate information to distinguish natural variations in environmental factors and community responses from those produced by human interference. Changes that reduce the population sizes, community composition, or availability of aquatic animals will affect all facets of the ecology of these wetlands.

To insure healthy aquatic ecosystems and to be able to detect natural or human-induced changes in those systems, baseline data on the constituent aquatic communities and their ecology are needed. Because the Everglades/Big Cypress system is composed mainly of aquatic habitats, knowledge about fishes is especially important, but fish populations of the area have been understudied.
Because of the hydrological changes wrought by drainage and impoundment and the loss of spatial extent and functioning of former wetlands to development, there can be little doubt that fish standing crops and overall numbers have declined. Those changes to the original system have also altered the timing and the areas of fish availability to predators. Fish are an important food source for wading birds, alligators, otter, and other higher organisms of the area, some of which are known to have seriously declined.

Freshwater invertebrates are abundant throughout the Everglades/Big Cypress system and important in the transfer of energy through the system, but particularly in the shorter hydroperiod wetlands. These animals operate at several trophic levels: as primary consumers of plant material and detritus to carnivores and scavengers. Some species, such as the crayfish and the apple snail, are major prey for fishes and other predatory species, including characteristic or endangered animals like the Snail Kite, White Ibis, and American Alligator. Factors that influence invertebrate numbers, biomass, and composition therefore affect energy flow through the wetlands. The ecology and life histories of the invertebrates are intimately tied to the hydrology of the marsh, which is determined mainly by rainfall, but increasingly by water-management practices.

Aquatic herpetofauna such as frogs, toads, salamanders, snakes, and freshwater turtles are often abundant components of the ecosystems in this subregion, serving as both predators and prey. In particular, the amphibians may be found over the widest range of habitats, from temporary pools formed in the wet season to the deepest, most permanent sloughs and strands. Frogs and toads appear to be particularly abundant in short-hydroperiod wetlands. Several species, especially the pig frog, alligator, and Florida softshell turtle, are harvested for food by humans. Those species and others collected for the pet trade provide some economic return in the ecosystem.

Anecdotal information from Native Americans and others suggests serious declines in some of the herpetofauna. Despite their importance in the system and concern about their suspected declines, basic biological/ecological data on size-frequency, food habits, and reproduction for the marsh herpetofauna have not been produced.

Current Research

Recent investigations include a study of the effects of hydroperiod alteration on marsh food webs, and the study of the effects of Hurricane Andrew on the fish community. A long-term study of the effects of natural and altered hydropattern on aquatic animal community structure and standing stocks in several Everglades marshes is continuing and has been expanded. Since 1990, the Florida Game and Fresh Water Fish Commission has sampled game fishes in this sub-region for mercury concentrations.

Freshwater fish and aquatic invertebrates are sampled regularly in Shark River Slough. continuing a data base begun in 1977. Electrofishing in five alligator ponds is done twice a year and, for qualitative purposes, pull traps continue to be employed to sample aquatic animals in the slough.

Critical Data Needs and Approaches

1. Within the subregion, collect data on fish, invertebrate, and herpetofauna community composition and dynamics on a multi-year basis to understand the functioning and the organization of communities. Undersampled habitats and landscape areas such as the Big Cypress Swamp, the freshwater-mangrove interface, and short-hydroperiod peripheral wetlands should receive emphasis. The current sampling program in Shark Slough should be expanded to include aquatic herpetofauna. The data should be related to seasonal and annual environmental variation in subregion habitats through collections across several years. Methods and sampling frequency should conform to the current fish and invertebrate sampling program in Everglades National Park and should be coordinated with a regionwide sampling program, if one is developed, so that comparisons can be made among parts of the Everglades subjected to different hydrologic management.

2. Life-history parameters and construction of life tables of important fish and invertebrate species remain to be studied at sites that represent a range of sub-region environments. Little work of this kind have been done on the regional aquatic herpetofauna. Methods for accomplishing this work on fish include a study of fish otoliths for daily growth increments to calculate age at size as well as to estimate growth rates under different seasons and habitats. Studies of fecundity and related parameters are needed to estimate reproductive potential. These studies, in combination with the data from #1 above, would provide the information needed to construct life tables for the major species of aquatic communities living under different conditions within the Everglades.

3. Food webs involving the fishes, invertebrates, and aquatic herpetofauna of the subregion are poorly understood, but determining the connections and calculating the flow networks will be valuable. These data are obtained by direct observations of fish gut contents and feeding behaviors, and by stable isotope analysis of fish tissues to determine which plant groups are the primary carbon sources for fishes in different habitats. The data are also useful in predicting the passage of biocontaminants through the system.

4. Sampling of aquatic habitats in the subregion is needed to assess ranges, composition, and abundance of non-native fishes, invertebrates, and aquatic herpetofauna. Periodic and well-planned monitoring of habitats not covered by the fish sampling study, in addition to interaction studies discussed under Mesocosm Studies, will be required to fully understand the non-native problem. Possible control strategies will be explored in view of life-history research to identify vulnerable life stages or behaviors that can be targeted.

5. Biocontaminant studies have not been done in a systematic manner for fishes and are even more limited for aquatic invertebrates and herpetofauna. Screening for contaminants should be funded on a periodic basis to detect potential problems. Fishes and snakes, in particular, are integrators of contaminants in their environment, so are effective, early-warning animals for contaminant detection. Studies of mercury mobilization, transfer, and direct effects on fish health and behavior are needed.

6. Attempts to build credible and useful simulation models for the fishes and invertebrates in this subregion are underway, but are limited by the lack of important data. The studies needed to provide those data include those mentioned above (reproduction, recruitment, age, growth, and mortality). There are several landscape-based studies also required to build these models. One would involve the dynamics of fish movements related to the seasonal fluctuations in water level, including composition and numbers in refugia during the dry season, the distances and rates of seasonal dispersal movements, etc. An effective indirect way to investigate these questions is by using genetic markers to identify population structure in the fish populations, which may provide a gauge of the degree of mixing of populations via dispersal movements.

7. Trophic-network modeling of the aquatic community provides a "circuit diagram" of the pathways and amounts of energy flow and compartmentalization. This modeling approach is a useful diagnostic tool in systems studies. It also has value in tracking the movement of contaminants through the food web. There is a possibility of integrating this kind of model with the simulation models to have a dynamic picture of how changes in the environment translate into community changes and thence into food web shifts. Construction of a trophic network requires better data for the fish-prey population biomass and cycling.

8. An experimental mesocosm has been proposed for construction in Everglades National Park to meet the needs of certain kinds of investigations. If funded, this facility will be useful in answering questions about predator-prey, competitive, and indirect interactions in fish, invertebrate, and herpetofaunal communities. The mesocosm is suited to address questions about the influence of nutrient inputs on marsh food webs. The mesocosm will provide the opportunity to examine introduced/native fish interactions, and to test potential control methods.

MAJOR ISSUE: Declines in mammals dependent on freshwater marsh habitat.

Background

Although no empirical data exist that would document population trends by most species of mammals occurring in the Everglades/Big Cypress basins, and which are not listed as endangered or threatened, it is widely speculated that several species which are dependent on freshwater marsh habitats have substantially declined due to water management practices. Two species of principal concern are the round-tailed muskrat and the river otter. Other, more upland species such as the three native squirrels (Gray, Fox, and Southern flying) and the Black Bear have become greatly reduced in numbers and range. In addition, the ecological consequences of an expanding population of introduced feral pigs have not been measured.

With the exception of the well-studied panther and deer, we have only limited information on population trends, regional distribution patterns, or on the biology or population ecology of most Everglades/Big Cypress mammals. The basic need is for the development of census protocols for a number of these species, the initiation of censuses based on these protocols, and for a series of field ecology studies for species suspected of having declined and/or been adversely affected by management practices. Recently initiated efforts to design models for predicting population responses by panther and deer to management alternatives must receive a high priority.

Current Research

Florida Panther and White-tailed Deer continue to be studied and monitored in the Big Cypress region, through projects coordinated by the Game and Fresh Water Fish Commission and Fish and Wildlife Service for the panther, and Dr. Ron Labisky (University of Florida) and the National Park Service for the deer. The Systematic Reconnaissance Flights at Everglades National Park include a dry season and wet season census of deer in Shark Slough. A very small study of food habits by feral pigs is being coordinated through Everglades National Park. Development of ATLSS models for panther and deer is continuing, under the direction of Dr. Lou Gross, University of Tennessee, and Dr. Michael Huston, Oak Ridge National Laboratory, respectively. No other mammal projects are currently active for these sub-regions.

Critical Questions and Research Approaches

1. Develop and implement long-term census program for Marsh Rabbit, Round-tailed muskrat, River Otter (and others?).

2. Conduct base-line censuses for other species suspected of having declined in numbers or had a reduction in range (squirrel species, etc.).

3. Establish a study to determine the impacts of the increase and range expansion by feral pigs.

4. Continue the development and evaluation of panther and deer models for the freshwater basins of the southern Everglades/Big Cypress.

MAJOR ISSUE: Massive declines in wading birds throughout the region.

Background

The total number of wading birds nesting in these two sub-regions, for the five species that numerically dominated the traditional, Everglades colonies (Great Egret, Snowy Egret, Tricolored Heron, White Ibis, Wood Stork), has declined by more than 95% from the peak estimates of nesting birds during the 1930s. Peak annual estimates of nesting waders in the region of these traditional colonies was 180,000-245,000 birds during the 1930s compared to peak numbers of 5,700-7,500 nesting birds in the decade between 1984-1993.

Wading birds are among the most important vertebrate indicators of ecological trends in the Everglades basin. The current wading bird database for the southern Everglades contains considerable information on colony locations, numbers and species of nesting birds, timing and success of colonies, basic reproductive biology and food habits for the principal species, foraging patterns around colonies, regional foraging patterns of total wader populations (Systematic Reconnaissance Flights), long-term population trends. Wading birds have responded to unnatural alterations in hydropatterns by (1) reducing the number of birds attempting to nest, (2) relocating colonies, (3) changing the timing of nesting, and (4) having fewer years of successful nesting. Relocation of nesting has occurred primarily by birds moving away from the traditional colony sites to the Water Conservation Areas. Changes in location and timing of nesting may be the major causes for the great reductions in nesting effort and colony success rates among all species.

Substantial improvement in our understanding of the relationships between the decline in wading birds and the changes in hydropatterns in the southern Everglades that have resulted from water management practices will require increased research efforts into (1) the dynamics of the birds' prey populations, and (2) the specific foraging strategies and patterns of the birds that are associated with successful nesting. Wading birds feed primarily on small fishes and the larger aquatic invertebrates, whose production and survival in each of the major habitats/communities of the Everglades, as affected by water quantity and quality parameters, are poorly measured on a regional basis. The water management strategies that will recover these prey populations, and the ecological processes that must be understood as a framework for designing these management strategies, are yet to be determined.

Current Research

Wading bird nesting colonies continue to be minimally censused in subregion 6, but not in 7. Total wading bird numbers are measured annually, primarily during 6 dry season months and a single wet season month, by the Systematic Reconnaissance Flights. Dr. Peter Frederick is continuing a study of wading bird foraging behavior related to colony dynamics, in the Water Conservation Areas and in the Shark Slough of subregion 6. Development of the ATLSS wading bird models is being coordinated by Dr. W. F. Wolff, Oak Ridge National Laboratory and University of Tennessee.

Critical Questions and Research Approaches

1. Determine the relationships between the characteristics of small fish/aquatic macroinvertebrate populations and water quantity and quality patterns (including salinity), for major wading bird foraging habitats. Priority study sites should include most mainland, estuarine habitats (tidal and non-tidal creeks, brackish marshes, marl flats, etc.), shorter hydroperiod, freshwater marl prairies, and pond cypress/bald cypress mosaics. Specific questions that should be answered include: Are mainland estuarine habitats potentially more productive of these prey species, and capable of creating higher concentrations, than freshwater habitats, and if so, how and by what processes? Has substantial reductions of freshwater flow into the mainland estuaries resulted in a degraded prey base for wading birds?

2. Expand and standardize wading bird colony censuses, to include all of subregions 6 and 7 and integrate with a

regionwide censusing effort. Regional response patterns by wading birds to hydrological conditions will not be fully known until a comprehensive wading bird colony census is employed. The wading bird colony record is the strongest vertebrate database from the Everglades basin, and its value for showing temporal and spatial responses to management practices is increasingly appreciated.

3. Examine the Systematic Reconnaissance Flight database (1985-1994) to determine whether regional foraging patterns by wading birds provide insights into the dynamics of colony patterns, specifically the species composition, number of nesting birds, and the location and timing of nesting. If linkages can be shown between regional hydropatterns, wading bird foraging patterns and colony patterns, these relationships can have strong management applications during the implementation and refinement of experimental programs for Everglades restoration.

4. Determine the ecology of the avian nematode parasite, Eustrongylides ignotus. Key questions pertain to possible relationships between this nematode and waters with high nutrient loads, and to the potential for this nematode to cause high rates of mortality among nestling wading birds. One colony in Everglades National Park in 1988 (Rodgers River Bay) had an 80% infestation rate among nestling herons and egrets.

5. Continue on-the-ground studies of colony nesting success patterns, particularly to measure relationships between hydrological/climatological parameters and reproductive performance.

6. Determine relationships between mercury contamination in the freshwater Everglades/Big Cypress and wading bird reproductive dynamics.

7. Continue development and refinement of regional, inter-active wading bird models; evaluate our needs for an array of wading bird models, for dealing with future restoration projects which are expected to occur at a range of spatial scales.

MAJOR ISSUE: Declines in water birds (all species other than wading birds)

Background

Long-term, qualitative observations in the southern Everglades suggests that most of the formerly common water birds (Pied-billed Grebe, Anhinga, Mottled Duck and wintering waterfowl in general, Coot, Limpkin, etc.) have substantially declined in numbers in the southern Everglades during the past several decades. Relatively little quantitative information exists for these species.

The common perception is that all species of waterbirds that were once commonly associated with the freshwater Everglades communities have become numerically much less common and less widely distributed in the system. A limited amount of quantitative data exists that supports the perceptions for a few species. The declines are likely due to (1) loss of wetlands, (2) reductions in food availability in remaining wetlands having altered hydropatterns, (3) reductions in food caused by increases in salinity in mainland estuarine lakes, and (4) problems for migratory species occurring outside of the Everglades.

The population trends and baseline population measures need to be determined for these species by means of systematic reviews of historical data and the implementation of censuses for select species and habitats.

Current Research

Except for a single, mid-winter census of waterfowl in sub-region 6, and on-going research on the endangered Snail Kite (see Endangered species), no studies of these species are currently active.

Critical Questions and Research Approaches

The priority is to develop and implement census protocols for those species not previously censused (grebe, anhinga, limpkin), and to review established census protocols for other species (waterfowl, coot). Censusing of several of these species should become a part of a much more comprehensive, regional census program for the Everglades/Big Cypress basins, designed to measure species responses across a wide range of habitats and for representative species from the full spectrum of food habits guilds.

MAJOR ISSUE: Decline in numbers and shift in center of distribution of the American alligator

Background

The American Alligator is one of the most ecologically significant of the larger vertebrates in the Everglades and Big Cypress basins. A properly designed monitoring program for this animal can serve both to define the nature of ecological problems in these systems, and as a measure of progress towards achievement of restoration goals. Ecological studies of the alligator in Everglades National Park have shown that recent water management strategies have caused reduced reproductive effort, increased frequencies of nest flooding, and increased rates of juvenile mortality. While these recent studies have produced valuable information on southern Everglades alligators, considerable additional data is required for improving alligator population models and for strengthening the utility of this species as an indicator of ecosystem conditions.

American Alligators in the southern Everglades have shown large changes in numbers and distribution in response to the shifting influences of over-harvesting, protection and habitat alterations. Perhaps the most important ecological change has been the substantial reduction of the population in the higher elevation, freshwater marshes flanking the deeper sloughs, and in the inner, more freshwater portions of the mainland mangrove regions. Conversely, numbers of alligators have increased in the deeper, central sloughs, in areas that apparently were too deeply flooded in the pre-drainage Everglades to support a large nesting population.

The number of adult female alligators that initiated nesting in Shark Slough has been shown to be inversely related to the areal extent of surface water remaining in the study area at the end of each dry season. Thus, the increased frequency of major drydown events in Shark Slough, as a consequence of recent water management practices, has become the single most important factor responsible for reduced production by alligators in the primary habitat for this population.

The importance of the alligator as an indicator of ecosystem conditions requires that additional research and monitoring be conducted, and that one or more models of alligator population dynamics related to hydrological patterns be developed and evaluated. An improved monitoring capability will require the development of refined census protocols, most importantly for cypress and mangrove communities.

Current Research

The program of Systematic Reconnaissance Flights to measure alligator nesting effort and success was expanded in 1994 to cover both Shark and Taylor sloughs in sub-region 6. Development of an ATLSS model for the alligator is being coordinated by Dr. W.F. Wolff, Oak Ridge National Laboratory and University of Tennessee.

Critical Questions and Research Approaches

1. Develop protocols and implement long-term monitoring for measuring alligator nesting patterns related to hydrological conditions, for cypress, mangrove, and marl soil Everglades communities.

2. Develop protocol and implement monitoring of seasonal and annual alligator population structure (age and sex classes) related to community types.

3. Determine daily and seasonal activity patterns, movements, activity ranges, and habitat preferences by sex and

age classes; seasonal food habits by sex and age classes; and sex and age specific growth and survival rates.

4. Continue the development, evaluation and refinement of alligator population model(s).

MAJOR ISSUE: The continuing, possibly accelerating, loss of species from the upland communities of sub-regions 6/7 and the Florida Keys.

Background

The initial thinking and planning about restoration of the Everglades focused on the expansive wetlands. The fact that upland biotic communities are an integral part of the Southern Everglades ecosystem has often been entirely overlooked or dismissed with token comment. It is not well recognized that: 1) The fragmented uplands at the southern extremities of the coast ridges in sub-regions 6/7 and the Florida Keys harbor most of the biological endemism that exists in the region's terrestrial communities as well as a large proportion of regional biotic diversity; 2) Within sub-regions 6/7, economic development has eliminated 65 to 80 percent of the original upland habitats (pine forest, tropical/subtropical hardwood forest, short-hypdroperiod prairie); 3) Reduced habitat area and deteriorated habitat quality have apparently resulted in an on-going loss of plant and animal species, including endemics, from the upland communities of sub-regions 6/7; 4) Although issues of bio-diversity are frequently discussed in relation to Everglades wetlands, all of the known and imminently threatened losses of species in the present sub .egions appear to be associated with uplands.

Current Research

Surveys of upland bird communities of Long Pine Key are being conducted. Results are being interpreted in relation to hurricane damage and potential for restoration. The work is funded out of the Hurricane Andrew research program. Similar work is focused on red-cockaded woodpeckers. Breeding colonies are under intensive observation over several or more years. Both projects are noted in the Hurricane Research Program table.

Critical Questions and Research Approaches:

The objective of this study is to understand the widespread loss of bio-diversity from upland communities in southern Florida and determine whether feasible corrective measures exist.

The principal research tasks are: 1) Characterize the temporal and spatial patterns of all documentable loss or decline of species in the uplands of sub-regions 6/7 and the Florida Keys; 2) Determine in detail how these patterns relate to the direct and indirect effects of upland development and to possible non-anthropogenic forces; and 3) Investigate the feasibility of available means to correct, mitigate, or restore biotic losses in upland communities.

The study would look intensively at past and present biotas and land-use history of upland communities in the Big Cypress are, southeastern mainland Florida, and the Florida Keys. This work probably would involve travel to major museums in the eastern and central U.S. where biological collections from relevant areas are deposited. As the research develops, it may be advisable to examine specific aspects of upland communities farther north in the Everglades system or comparable habitats south of Florida (northern Bahamas, Cuba).

SUBREGION 8: FLORIDA BAY-FLORIDA KEYS-FLORIDA REEF TRACT-SOUTH BISCAYNE BAY-AND ADJACENT COASTAL AREAS

Subregion 8 includes a diversity of marine, estuarine, fringing, and terrestrial habitats. It consists of the Atlantic coast estuaries from Biscayne Bay to Barnes Sound, the Florida Keys, the Florida reef tract, Florida Bay, and west coast estuaries from Ponce de Leon Sound to Charlotte Harbor. This area is characterized as shallow water of natural salinities with extensive seagrass habitat which is important nursery areas for reef species. Florida Bay proper is included with the fringing mangrove habitat. The Florida Keys include hardwood hammocks, coastal strand communities, and fringing mangrove, beach or rocky habitat. The reef tract is characterized by a rich biodiversity which requires clear, naturally oligotrophic ocean water. This report presents a plan for research for this subregion with the purpose of promoting recovery as defined by the Science Sub Group Report on the Federal Objectives for the Restoration of South Florida. The major issue for this area is the alteration in quantity, timing, location, and quality of freshwater inflow to estuaries that is associated with drainage and flood control practices.

The diversity of this subregion is such that while there is much information available on each area there is no information on how these areas are linked either physically or biologically. In particular, the impact of waters adjacent to the subregion including, fresh, estuarine, and oceanic on the hydrography is not well described nor are the impact of these processes on the ecology of the area. Specifically the following questions have been developed which need to be addressed: 1) how will hydrological changes, both in the quality and quantity of fresh, estuarine, and oceanic waters from all boundaries impact the coastal waters and associated habitats from Barnes Sound to Charlotte Harbor; 2) how will sealevel rise impact the area and interact with anthropogenic changes; 3) how does water quality impact subregions upstream from subregion 8; 4) how will the hydrolgic regime be further altered by continued development in Monroe, Dade and Collier counties; 5) what are the main land-sea-human interactions within the area?

Many plans have been developed or are already in place that address the management of specific areas within the subregion. To determine the extent to which these plans address the above critical questions, all these plans were reviewed. These plans also were reviewed to determine the extent to which they covered the sub-region. Research recommendations are designed to fill information gaps that were identified. The plans that were reviewed include the Interagency Science Plan for Florida Bay, Water quality Protection Plan for the Florida Keys National Marine Sanctuary, Surface Water Improvement and Management (SWIM) Plan for Biscayne Bay, the FKNMS Draft Environmental Impact Statement and Management Plan, the West Florida Shelf: Past, Present, and Future, Surface Water Improvement and Management Plan for the Everglades (which includes consideration of freshwater flow to Barnes Sound, Manatee Bay, and Florida Bay and its associated estuaries, through Whitewater Bay), An Environmental Characterization of the Rookery Bay National Estuarine Research Reserve: Phase I, NOAA's Florida Bay Implementation Plan, Management Agreement for Backcountry Portions of Key West National Wildlife Refuge, Great White Heron National Wildlife Refuge, and National Key Deer Refuge. Two plans which are in the process of implementation are included with this report because they represent most of the total area within the subregion. These two plans are the Science Plan for Florida Bay; and the Water Quality Plan for the Florida Keys National Marine Sanctuary.

RECOMMENDATIONS

- A comprehensive strategic plan that includes all the wildlife refuges within the subregion and perhaps the state should be developed by the Fish and Wildlife Service. A research implementation plan must be developed which includes impacts of continued development on habitat, especially as related to endangered species. Research priorities include: a) determining the ecology and status of the Key deer and impacts of habitat loss or change on population status and condition; b) impact of prescribed burning on habitat and guidelines concerning frequency, timing, usefulness; c) a species inventory emphasizing endangered species and determination of candidate species for listing under the ESA.

- The only coastal areas not included under an existing plan, are a) a small area of the bay adjacent to both the Florida Keys National Marine Sanctuary and the Everglades National Park and b) the northern and southeastern parts of Biscayne Bay. This area needs to be included within under an existing plan. Both DOI/NPS (including the Everglades National Park and Biscayne National Park), the DOC/NOAA and the state of Florida/DEP need to determine how to best include these waters in their areas to insure proper management and protection.

- Each agency needs to develop an implementation plan relative to their jurisdictional responsibilities. Plans need to be complementary and supplementary in scope and all attempts to minimize overlap must be made.

- A complete biological inventory of the sub-region must be completed by the agency with primary jurisdictional responsibility for each area within the subregion. Monitoring of all endangered and threatened species must be continued to insure recovery.

- Linkages between upland influences relative to coastal habitat need to be better defined and identified in all existing plans.

SUBREGION 9: LOWER EAST COAST URBAN AREA

Subregion 9, the Lower East Coast, extends just over 100 miles from West Palm Beach to Florida City. It encompasses those portions of Dade, Broward, and south-central Palm Beach County that lie east of Everglades National Park and the Water Conservation Areas. The area is primarily urban, forming a megalopolis that stretches almost the entire extent of the Subιegion, but it also contains substantial agricultural acreage, particularly in the southwestern part of Dade County.

The Lower East Coast's demands for water, energy, recreation, housing, and other services have considerable impact on the other subregions of South Florida. The Lower East Coast is tied to these other subregions principally by water. Groundwater, dependent partly on recharge by the canals extending from Lake Okeechobee, is the major water source for the urban areas. Releases from the regional system help prevent saltwater intrusion along the coast. These demands affect the water needs of the lake and those areas connected to the lake by the St. Lucie Canal and the Caloosahatchee River. Water needs and drainage demands of the agricultural area in extreme western Dade Co. impact the water supply to Everglades National Park and Florida Bay. Dade County groundwater is the primary source of drinking water for the Florida Keys. Subregion 9 is on the downstream receiving end of many surface water discharges from other subregions. Florida Bay, Biscayne Bay, and the north Florida Keys receive discharges from the Lower East Coast. Residents of Subregion 9 and tourists benefit from the wildlife resources and recreational values of surrounding subregions, especially those near the metropolitan area, such as Biscayne National Park, Everglades National Park, Florida Bay and the Florida Keys, and the Water Conservation Areas. The recognized tourism values of these nearby areas enhance the image and economy of the Lower East Coast and are a primary reason many people travel to or through Subregion 9. In addition, the fishery resources of these areas and the products of the agricultural areas provide food for the Lower East Coast.

OBJECTIVES

The primary goal of proposed research in Subregion 9 is to determine ways to reduce or reverse the impacts of the area's population growth and continuing land development on the natural systems of South Florida and to enhance the expected benefits of the South Florida Ecosystem Restoration to the quality of life in the metropolitan and rural areas.

BACKGROUND

The Lower East Coast has many types of topographic features that provide many habitats. natural tributary drainage. The outstanding topographic feature region is the Atlantic Coastal Ridge, a narrow limestone ridge (2-10 miles wide) that borders the Atlantic Ocean and forms a barrier between it and the Everglades basin. The cities of the Lower East Coast initially developed along the ridge; now they extend far beyond it.

The Coastal Ridge was historically covered with pines and palmetto, interspersed with hardwood hammocks. Even with intensive urban development, the Lower East Coast still contains many representatives of most natural plant communities characteristic of South Florida, although these are now reduced, fragmented and stressed. These include beach and dune; mangrove swamp; coastal saltwater marsh; freshwater marsh; maritime hammock; coastal strand; rockland hammock; pine rocklands; scrub; sandy pine flatwoods; and short-hydroperiod wet prairie. Some of these vegetation communities, as well as many individual plant species within them, are endemic only to South Florida and are protected in parks in the three counties.

The Lower East Coast is the most heavily urbanized part of Florida. With a combined population of more than 4 million people, the three counties of Subregion 9 are home to more than 30% of the residents of the state of Florida. Dade, Broward, and Palm Beach counties are 1, 2, and 3 respectively in the state's population rankings. Dade County contains almost 15% of the state's population.

Water availability in the region depends on rainfall and storage capacity in the surface and groundwater systems. The Lower East Coast is a producer, as well as South Florida's largest consumer, of fresh water. The state's heaviest rainfall occurs along the East Coast ridge between West Palm Beach and Miami, where the annual average is as high as 64 inches (1975 data), compared to only 52 inches over Lake Okeechobee.

The Lower East Coast is dependent on shallow, unconfined aquifers for its potable water. The Biscayne Aquifer is the largest and most productive unit of the surficial system. It extends northward from Dade County, where its permeability is highest, into Broward and the southern and central parts of Palm Beach County. The USGS considers the Biscayne Aquifer one of the most permeable aquifers ever investigated, and it is probably the most permeable water-table aquifer in the world. Aquifer recharge is mainly by direct infiltration from rainfall. This is supplemented by water carried into the area by canals to supply well fields and prevent coastal saltwater intrusion during the dry season.

Drainage of interior wetlands has lowered the water table, altered the natural groundwater flow, eliminated coastal springs and artesian wells, and increased the amplitude of seasonal hydrological fluctuation along the Lower East Coast. Saltwater intrusion has been a concern since coastal well fields showed evidence of increasing salinity more than 40 years ago. Because of the threat of saltwater intrusion, levels of fresh water near the saltwater interface must be maintained higher than the sea level.

The Lower East Coast's natural drainage pattern of streams and transverse glades has been almost totally altered and replaced by a manmade system of canals. Roughly 3.2 million acre ft per year of freshwater empty to coastal estuaries in Subregion 9 through 28 main canals of the Central and Southern Florida Project. Half of these are in Dade County and discharge into Biscayne Bay. The discharges include stormwater, drainage water from agricultural and urban land, excess water from the water conservation areas, and water released to the Lower East Coast to recharge the groundwater and prevent saltwater intrusion.

The Lower East Coast is the center of distribution of non-native plant and animal species introduced into the South Florida environment. Over 300 species of exotic plants are known to be naturalized in natural community fragments in Dade County south of the Miami River. The Dade County Park and Recreation Department is involved in intensive exotic removal and maintenance of its natural areas to prevent permanent damage to these areas from invasive non-native plants following Hurricane Andrew. A draft U.S. Fish and Wildlife Service report identifies 82 nonindigenous fish species, many of which occur in South Florida. Cichlids, such as the oscar and the spotted tilapia, have been extremely successful in establishing populations throughout the Lower East Coast. South Florida has more introduced and established reptiles and amphibians than any other area in the U.S.; many of these species were first observed in the urban areas of Dade County and were introduced as stowaways or as releases by animal dealers or pet owners.

In Subregion 9, 19 animal species and 8 plant species might be found that are federally listed as threatened or endangered.

MAJOR ISSUES

Human Population Growth: Between 1970 and 1990, the population of the three counties of Subregion 9 increased by 81% overall.

Land Development: The westward expansion of development in Subregion 9 continues to convert wetlands and agricultural fields to housing subdivisions, shopping centers, roads, office complexes, and, potentially, commercial theme parks. Both urban and agricultural developments are expanding westward into the buffer wetlands just east of the Water Conservation Areas and Everglades National Park. Some of the most rapid development, or proposed development, is now occurring in southwest Broward County, much of which is flood-prone wetlands.

Land development in wetlands impacts water supply because it reduces areas of standing water and often leads to a lowering of the water table, which means that less water is stored in the aquifer. Because of the highly permeable surficial aquifer in south Florida, a lowering of the water table in one area affects the water table for miles around. Stormwater discharge increases after land is developed, not only because of additional drainage works to provide flood control, but also because creation of impervious surfaces such as parking lots, roads, foundations, and patios. This loss of open space results in reduced infiltration into soils and groundwater and reduced aquifer recharge potential.

Land development also affects water quality through chemical contamination and saltwater intrusion. Contributing to contaminant loads, principally by stormwater runoff, are lawn fertilizers, pesticides, and pet wastes from residential areas; metals and solvents from industry; fuel, grease, and oils from highways, parking lots, and airports; leachates from landfills, and pesticides from golf courses.

Water Conservation for Wildlife and Human Populations: Demand for water by the Lower East Coast is out-of-phase with the natural seasonal hydrologic cycle; it is highest during the dry season (November through May) when only 35% of the rainfall occurs Demand is expected to increase enormously. The projected demand on the public water supply for the year 2010 is estimated to be an increase over 1990 demand of 43% in Dade County, 68% in Broward County, and 115% in Palm Beach County. Excessive withdrawals from the surficial aquifer can cause environmental problems such as shortening of the hydroperiod in nearby wetlands.

Quantity and Quality of Freshwater Flow to Estuaries: Estuaries, particularly Biscayne Bay, are being detrimentally affected by the impact of sporadic, short-term, extraordinarily high-volume canal discharges. The occasional releases from the C-111 canal into Manatee Bay, which opens into Barnes Sound in the southern part of the Biscayne Bay system, are an extreme example. Lake Worth is also subject to extremes of freshwater discharge. Other receiving areas for canal discharges are detrimentally impacted repeatedly, though not so severely, each year. The estuaries are also stressed by long periods with little or no freshwater inflow. Lack of flow during dry periods is caused by draining rainwater to the coast as soon as it falls. The naturally occurring slow seepage of groundwater into estuaries from the coastal ridge during the dry season has been eliminated by the lowering of the water table.

Most surface runoff of nutrients and contaminants from agriculture and urban land uses is discharged to the estuaries. These contaminant loads are not being adequately regulated to prevent damage to coastal ecosystems. Existing laws, standards, regulations, and enforcement may all be insufficient.

Quality of Groundwater and Inland Surface Water: Because of the shallow depth of the aquifer, groundwater contamination is a constant threat. Numerous contamination sites have been identified in Dade, Broward, and Palm Beach counties; some of these are close to active public water supply wellfields. Over the last 2 years, levels of lead that exceed federal standards have been found in nine Broward County communities and seven Dade County communities.

Trihalomethane formation, caused by an interaction of dissolved organic carbons in raw water supplies with the chlorine used in water treatment, is a problem in some southeast Florida water treatment plants. Trihalomethanes have been associated with human cancer and genetic defects. Dade County recently installed air strippers, spending \$30-\$40 million in funds provided by EPA, to solve the problem. The Biscayne Aquifer is recharged not only by rainfall but also by canal flow from Lake Okeechobee and the Everglades. Without disturbance, Everglades waters are naturally clear. The main source of the trihalomethane problem may be the drainage of organic soils, which is causing subsidence and the release of dissolved organic carbons.

Preservation and Restoration of Natural Areas: The natural habitats of the Lower East Coast, now scattered in fragments within the urban/agricultural landscape, are so reduced in extent that examples of any natural community in good condition are considered environmentally sensitive areas. All three counties and the state have recognized the loss of natural areas as a critical issue and have programs to purchase sensitive lands for preservation. Many of these lands protect populations of endangered plants; other lands, such as those in mitigation land banks, are restored to native vegetation.

Hurricane Andrew devastated areas of native plant communities in southern Dade County, exposing them to unprecedented invasion by non-native plants and disease. Several county, state, and cooperative efforts have been initiated in hurricane-damaged areas of Dade County and also in areas that serve as mitigation banks. State and county governments have undertaken a number of natural community restoration projects, many of which were drastically altered or accelerated in Dade County by Hurricane Andrew. These efforts include intensive removal of invasive non-native species; fostering remnant mangrove, coastal strand, wetland, and hammock communities; and extensive planting of native vegetation. However, well documented restoration methodologies are lacking for South Florida vegetation communities. Planting experiments and adequate monitoring and documentation from which to develop better methodologies for future projects may not be conducted for lack of funds and in some cases lack of understanding of the need by decision makers in the agencies involved.

Remnants of natural communities, even though preserved or restored, are subject to continued stress because of fire suppression, alteration of natural hydrology, invasion by aggressive non-native plants, and other factors. For instance, eradication of exotics will be a constant task because of persistent invasion from surrounding areas. Natural areas require management in perpetuity.

Invasive Nonindigenous Species: Aggressive non-native plant species such as melaleuca, Brazilian pepper, and Australian pine have spread beyond any possibility of mechanical control. Invasive non-native plants are of much ecological concern because they have undergone large population explosions and formed monocultures that out-compete native species. Loxahatchee National Wildlife Refuge has one of the most severe infestations of melaleuca because of its proximity to numerous urban plantings made in the Palm Beaches. Biological controls under development are the only real hope of halting the destruction of native landscapes and plant communities by melaleuca encroachment. Meanwhile, other species have escaped into the environment and already are posing threats to natural areas. Additional species continue to be introduced into the environment of the Lower East Coast by the nursery, pet, and aquarium trades.

Loss of Habitat for Protected and Other Native Species: The protected habitat for threatened and endangered species is so small that their future is not guaranteed. Losses of coastal scrub, pineland, and hammock are of particular concern. Both scrub and pineland contain a high proportion of endemic plants. Hammocks contain tropical hardwood trees that are found nowhere else in the continental United States. Coastal regions are especially important habitat for reptiles, birds, and mammals. Coastal uplands (beach strands and maritime hammocks), habitats now almost totally lost in Subregion 9, are important habitat for large numbers of vulnerable taxa.

Limited Federal Responsibility: The federal government has limited jurisdiction over factors relevant to South Florida Ecosystem Restoration in the urban and agricultural areas of the Lower East Coast. A serious obstacle to solving growth problems is the absence of formal political institutions or a coordinated approach to address the entire range of issues and their cumulative impacts. The federal government does not always know what state and local governments are planning that could affect the restoration effort. Perhaps even more importantly, there is no central knowledge of ways that the federal government, itself, through laws and policies in many agencies, may be affecting the restoration of South Florida Ecosystems, either positively or negatively.

Lack of Understanding About the Environment by Urban Residents: The great diversity of the Subregion 9 population (e.g., many different races and income levels, large number of non-native residents, many different tourist groups) makes it difficult for scientists or managers to use only one message to promote environmental protection, wildlife preservation, or water conservation. Many residents have lived in South Florida for such a short time that they do not understand its environment or its problems.

RECOMMENDED APPROACH

Municipal and county governments carry out many activities related to these issues and to the restoration interests of the Federal Task Force, and there is an outstanding base of expertise in the these agencies that is crucial to the implementation of federal restoration plans. Because of the strong local efforts, federal plans concerning research to support the above objectives must be coordinated with local governments, as well as environmental groups, to ensure that: (1) the South Florida Ecosystem restoration effort contributes to planned or ongoing restoration efforts by these groups, (2) the South Florida Ecosystem restoration effort results in direct environmental benefits to the Lower East Coast, and (3) planned or ongoing activities by these groups contribute to and enhance the South Florida Ecosystem restoration effort. Following are research recommendations for Subregion 9:

Comprehensive Program Planning Evaluations. (These could be initiated by conducting workshops.)

- Determine and catalogue research being done or planned that relates to and supports the South Florida Ecosystem Restoration effort.
    - Identify lead agencies and individuals.
    - Identify research needed to support the efforts or to make the efforts more beneficial to the overall South Florida Ecosystem Restoration effort.

- Conduct a "Federal Consistency Study" to determine present or potential influences of federal government activities on the South Florida Ecosystem Restoration.
    - Compile an annotated list of the federal government agencies, programs, and laws that, through regulations, grants, tax incentives, or otherwise, undermine federal efforts to restore the South Florida Ecosystem.
    - Identify federal programs that might potentially be used to enhance the South Florida Ecosystem Restoration effort.
    - Give particular emphasis to factors that influence land use planning, zoning, and development decisions that result in encroachment of urban or agricultural development into wetlands and urban development into agricultural lands.

- Develop the same information as above for regional, state, and local agencies, programs, and laws.

Critical Lands.

- Conduct a short interagency study, the U.S. Fish and Wildlife Service having the lead, to identify critical lands that should be preserved to support Ecosystem Restoration.
    - Develop a digitized map with information layers in a GIS framework for use in establishing mitigation banks and investigating the feasibility of land acquisition or other habitat protection measures. Criteria that should be used include: habitat value for federally listed threatened and endangered species and state species of special concern (particularly replacement of short-hydroperiod wetlands needed by wading birds), present value of the land for aquifer recharge, and potential usefulness of the land for water reserves.
    - Consider the potential effect on water supplies if the land were developed and development resulted in a general lowering of the water table.

- To aid the above study, conduct a short term, quantitative analysis to determine, from a water supply and South Florida Ecosystem Restoration perspective, how various alternative scenarios of future land use and associated local water management in the presently undeveloped wetlands between the urban east coast and the Water Conservation Areas and Everglades National Park (hereafter referred to as "The Buffer Lands") would affect water supply and water management in support of ecosystem restoration.
  - Determine the impacts of full or partial development of these lands. Include testing of the "worst case" scenario of full residential and/or commercial development.
  - Evaluate the potential use of the subject lands for stormwater treatment, aquifer recharge, wildlife support, and compatible outdoor, nonstructured, low-impact recreational activities.
  - Use the latest version of the South Florida Water Management Model, the Natural System corollary of that model, and other quantitative analytical tools.

- Using the above information, evaluate the interaction between natural, urban, and agricultural systems.
  - Determine the critical feedback linkages of the natural system to urban and agricultural systems and vice versa.
  - Determine the landscape configuration that will allow healthy natural systems and urban and agricultural systems to coexist.
  - Determine how the natural system and its benefits to humans will be impacted by different population levels and landuse configurations.

- To further aid the selection of critical lands, conduct a GAP study for the Lower East Coast.
  - In a GIS framework, overlay spatial data on coverage of various plant communities, habitat of endangered and threatened species and other species of special interest, public lands, and lands covered by covenants.
  - Determine the gaps in species protection.

Quantity and Timing of Freshwater Flow to Estuaries.

- Model the effect of various proposed Canal C-111 redesign alternatives (in the GRR) on water flow to Manatee Bay and Barnes Sound.

- Model the effect of various proposed Canal C-111 redesign alternatives (in the GRR) on water flow to northeastern Florida Bay across Canal C-111.

- Estimate the predrainage salinity patterns in Biscayne Bay by retrospective analyses of bottom sediments (i.e. foraminifera shells or diatom tests) and application of a natural system hydrologic model, refined and specially adapted to this use.

- Collect the required field data to calibrate the relationship between stage and discharge in canals discharging to Biscayne Bay and other coastal waters of the Lower East Coast.
  - Recalculate historic flows based on the new calibration and existing time series of stage data.
  - Install continuous stage recording instruments in canals lacking this instrumentation.

- Map the salinity patterns in Biscayne Bay under a range of freshwater inflow rates, and use this information to develop and calibrate a hydrodynamic model to relate freshwater discharges to salinity patterns in Biscayne Bay.

- Develop and apply a methodology to test various scenarios of use of the Buffer Lands discussed above and associated canal operations for their effect on the quantity, timing, and quality of freshwater discharges to Biscayne Bay (adapt the South Florida Water Management Model to this use).
  - Use this information to design a structural configuration and operational strategy that would reestablish a more natural seasonal pattern of freshwater flow to Biscayne Bay.

- Use output from the Natural System Model and any available information relating freshwater flows to salinities for general guidelines concerning the natural seasonal pattern in relation to rainfall.

- Determine the ecological, hydrologic, and economic impacts of redirecting a portion of stormwater runoff to proposed catchment areas of western Subregion 9 rather than to the coast.

Surface Water and Sediment Quality.

- Compile and synthesize the information necessary to reevaluate, update, and customize existing water quality standards and monitoring activities from the standpoint of the unique chemistry of South Florida soils and waters and from the standpoint of current local practices associated with agricultural activities, lawn care and maintenance, aquatic weed control, golf course maintenance, local manufacturing, etc. Determine the answers to such questions as:
  - Are the right contaminants being measured, given current South Florida application practices?
  - For some pollutants, such as nitrogen and phosphorus, are the thresholds for environmental damage appropriate, given the natural concentrations of these constituents in South Florida's fresh waters and coastal waters?
  - For contaminants such as heavy metals, PAHs, and synthetic organic chemicals, are the thresholds for environmental damage appropriate, given the relative low adsorbance characteristics of constituents of South Florida fresh and coastal waters (i.e., low concentrations of clay particles and organics that bind heavy metals and organic chemicals and make them less available)?
  - Finally, should water quality monitoring include biological indicators, since living organisms integrate the biological effects of all stressors? Could a suite of biological indicators be developed for routine use? How can biomonitoring be best integrated with chemical analyses to determine ecological health?

- Quantify the applications of pesticides, herbicides, and other xenobiotic materials on residential and agricultural areas, golf courses, and public lands.

- Investigate methods of reducing pesticide and herbicide applications to golf courses and other urban landscapes, including use of alternative landscape materials and designs.

- Determine the concentration and loading of various pollutants, including nutrients and contaminants, in canal discharges and direct (pipe) discharges to Biscayne Bay and other coastal water bodies.
  - Identify hot spots, in terms of point source or nonpoint discharges of pollutants, including sewage.
  - Compare the quality (pollutant concentrations) of water entering the developed part of each county at the boundary of the Water Conservation Areas and water exiting the county into coastal waters through the major canals (Miami; North New River; Hillsboro; West Palm Beach; and L-31N, which exits through C-111).
  - Use the above information to help determine total maximum daily loads (TMDLs) and establish pollution load reduction goals (PLRGs) in compliance with federal (EPA) and state (FDEP) water quality standards.
  - Recommend that the State design its non-point source program toward staying within the established TMDLs. (See Section 303D of the Clean Water Act.)
  - Determine the significance of seasonal runoff and storms in controlling rates of production in coastal waters.

- Determine the ecological impacts on surface water and biota of pesticides and fertilizers used on golf courses.

- Conduct research on biological effects of pollutants in subtropical estuaries (e.g., examine the increase in occurrence of cellular micronuclei observed with pollutant exposure).

- Support continued research to support development of a water quality criterion for transparency to protect benthic communities, such as seagrass.

- Support cooperative surveys of sediment toxicity in Biscayne Bay.

- Support continued development of toxicity and mutagenicity screening techniques to reduce expenses of sampling and chemical analyses.

- Investigate use of an alternative (e.g., coliphage) to fecal coliform bacteria as an indicator of sewage-associated pathogens, given the rapid destruction of fecal coliforms in subtropical marine waters, and evaluate the appropriateness of sewage contamination standards for the coastal waters of Subregion 9.

- Organize a contaminants committee that would work to help focus research and monitoring relative to contaminants, reduce redundancy in monitoring programs, achieve consistency in data collection protocols, and reduce pollutant loads at the local community level.

- Determine the water quality impacts of redirecting urban stormwater runoff into natural areas.

- Evaluate the use of the Buffer Lands in Palm Beach, Broward, and Dade County for the treatment of storm water runoff to improve water quality of future discharges to the Everglades, Florida Bay, and Biscayne Bay.
    - Evaluate the effect of this usage on the Biscayne Aquifer from the standpoint of both water quantity and quality.
    - View the concept in terms of water supply, wetlands, wildlife, and human health.

Drinking Water Quality.

- Determine the feasibility of using a water management approach compatible with the South Florida Ecosystem Restoration Program to reduce trihalomethane formation in treatment of drinking water supplies by lowering the concentration of precursors in raw water supplies.
    - Estimate the potential cost savings of implementing such an approach.
    - Conduct additional investigations, possibly including field studies and experiments, to better quantify the potential improvements and savings.

Water Consumption.

- Investigate the attitudes of homeowners, professional landscapers, and nurserymen to determine the most effective methods of promoting use of xeriscape landscaping with native plants. Non-native species suitable for xeriscape landscaping are the same species that are most likely to become invasive in South Florida disturbed sites and natural areas. The promotion of xeriscape landscaping with these plants will exacerbate the problem of invasive non-natives.

- Investigate how local government ordinances influence (promote/hinder) use of native xeriscaping.

- Prepare countywide comprehensive plans for reuse of treated wastewater.
    - Develop pilot programs to investigate and demonstrate wastewater reuse on different substrates, including rockland sites, and particularly on golf courses, parks, and public facility grounds.
    - Quantify the potential benefits of water reuse to the future water supply of Subregion 9.
    - Using GIS techniques, locate and quantify suitable lands and wastewater treatment facilities.
    - Determine the influence of environmental and health regulations on water reuse.
    - Examine the effects of wastewater reuse on groundwater and surface water quality.

- Investigate less intensive water use for golf course grass and other landscaping.

Preservation and Restoration of Natural Areas, Wildlife Corridors, and Other Areas of Connectivity.

- Support research to guide state and local efforts to identify and purchase or otherwise preserve ecologically endangered lands.

- Support easements for private lands by providing funds and incentives to counties for acquisition of titles or permanent development rights to preserve natural areas presently in private ownership. Emphasize acquisition of pineland, with or without pine stands, as well as wetlands.

- Compile a comprehensive list of public lands in Subregion 9 in need of restoration, including what is required to restore and maintain each tract.

- Support research needed to develop standard procedures for successful restoration of natural areas.
    - Methods to determine appropriate siting conditions (e.g., soil contours, depth of salt/freshwater lens interface) for restoration/creation of wetlands.
    - Efficient propagation techniques for native plants; e.g., seed germination.
    - Establishment/maintenance nurseries to provide plants for restoration.
    - Optimum reforestation/revegetation strategies (e.g., to achieve uneven age structure in pinelands).
    - Urban fire techniques appropriate for use in Subregion 9.

- Support monitoring and research in conjunction with the restoration of parks and private lands (hammocks, pineland, mangroves).
    - Life history and reproduction of endemic plants of pine rocklands and scrub habitat.
    - Comparative, quantitative vegetation analyses of remaining hammocks to characterize and catalogue them by species composition, species dominants, and spatial patterns of species distributions to provide information needed to guide management activities (e.g., to prevent degradation from nearby inappropriate landscape plantings).
    - Restoration of the hydric components of pine rocklands and hammocks (e.g., pineland/prairie ecotones).
    - Impact of fragmentation on restored areas and of potential benefits of connectivity among restored areas and between them and proposed Buffer Lands.

- Conduct a GIS analysis of the urban Lower East Coast in the context of surrounding natural areas and endangered species populations.
    - Identify potential pathways for connecting all or many of the remaining natural areas into a greenbelt/wildlife corridor and linking these to the proposed buffer areas, using opportunities such as existing canal banks and railroad rights of way or undeveloped property in critical locations, even if disturbed.
    - Identify wetland sites and their soils and history of land use (i.e., whether farmed or not).

- Support the development of comprehensive greenway plans and demonstration projects currently being organized in all three counties.
    - Provide federal funding for broad-scope greenbelt projects in each county.
    - Require that native species appropriate to the local natural areas are used for all plantings along federally financed trails.
    - Emphasize use of the trails as wildlife corridors.

- Support research on wildlife and human ecology effects of existing and future wildlife corridors; e.g., effect of corridor size on wildlife movements.

- Conduct an urban wildlife survey to compare the wildlife support values of various existing landscapes within the urban setting, including resident, migrant, and wintering birds; herpetofauna such as lizards; and insects such as butterflies.

Protected Species.

- Support research to collect the information needed on species that are candidates for federal listing as threatened or endangered, especially those threatened by imminent habitat loss in rapidly developing areas.

- Assist Dade County with the development and implementation of a restoration plan for the Richmond Pineland Preserve, which includes federally owned land (U.S. Coast Guard, U.S. Customs, and U.S. Navy) in addition to land owned by the Dade County Park and Recreation Department and the University of Miami.

- Assist Dade County with development and implementation of restoration plans for other natural areas.

- Support continued study of manatee behavior and migration patterns in the Biscayne Bay system.

- Support quantitative studies of wildlife use in the remaining wetlands of southeast Dade County and the interior western portions of all three counties.

- Develop a curriculum for training courses for certification of contractors bidding on Army Corps of Engineers construction projects that could affect species of environmental concern, such as plants and animals on federal and state listings of endangered and threatened species.

Invasive Non-native Species.

- Conduct horticultural research to develop sterile cultivars of the more popular landscape plants, such as poinciana and the many ornamental *Ficus* species, that are showing tendencies of becoming invasive as landscape plantings increase and the acreage--and resultant seed bank--of native species decreases.

- Starting with the EPPC list, develop a consistent, effective methodology for ranking non-native plant species for their invasive tendencies in the South Florida environment.
    - Identify the greatest immediate threats as candidates for (1) major short-term, intensive, localized mechanical control efforts and (2) longer term biological control efforts. This will provide more lead time for developing environmentally safe, effective biological controls before each invasive species, by its spread, causes major damage to natural areas and wildlife habitat.

- Develop an effective, scientifically based approach to screening, for potential invasive tendencies in South Florida, (1) plant materials entering the country and (2) plant materials already in the landscape trade, but not yet observed outside of cultivation.

- Design an approach to preventing future invasions by the above species, considering a mix of regulatory, incentive, and public education options.

Education and Sociology.

- Conduct and/or support outreach programs to educate urban residents and tourists about methods to reduce their impact on the South Florida ecosystem. An example is SFWMD's program on water use for the Hispanic community.

- Conduct and/or support research on the attitudes of the region's diverse groups of urban residents, private landowners, and tourists about wildlife, habitat, environmental protection, and water conservation and methods to influence those attitudes.

- Conduct and/or support programs to teach citizens how they can influence government actions on land use and environmental issues related to South Florida.

SUBREGION 10: CALOOSAHATCHEE RIVER BASIN AND SOUTHWEST FLORIDA

This subregion encompasses the Caloosahatchee River watershed; lower Charlotte Harbor estuarine ecosystem, and the coastal system south to Naples Bay; and the Corkscrew regional ecosystem watershed, including the Immokalee agricultural area. The subregion includes Lee County, western Collier and Hendry Counties, southern Glades County, and southeastern Charlotte County.

The human population is concentrated along the coast, which is rapidly becoming highly urbanized. This coastal zone has the highest growth rate in Florida in the last ten years and the highest projected growth rate from now to 2010. The Cape Coral - Ft. Myers and Naples metropolitan areas are among the seven fastest growing in the United States.

This subregion has many large scale "planned" residential development projects, which were initiated in the late 1950s to the early 1970s. Cape Coral, Leigh Acres, and Golden Gates are the largest of these. Massive land clearing, road construction, canalization, and filling were characteristic of these large developments, which destroyed vast areas of natural habitat (over 90% destroyed by Cape Coral alone).

Agriculture is a major land use in the interior, which is rapidly converting to agriculture, primarily citrus. From 1985 to 1990, citrus acreage in Collier, Hendry and Lee Counties increased 134%, 83% and 46%, respectively. This boom is the result of movement of citrus from central to southwest Florida following several severe freezes in the mid-1980's. The movement is expected to continue.

MAJOR ISSUES

As elsewhere in South Florida, the natural pattern (quantity and timing) of freshwater inflow to estuarine ecosystems in this subregion has been altered by anthropogenic activities. These activities include channelization, dredging, and filling for flood control, navigation, wetland drainage, and urban and agricultural land development.

Periodic regulatory releases from Lake Okeechobee are made to the estuary via the Caloosahatchee River, which was connected to the Lake by dredging in the late 1800s. During such releases the volume of freshwater entering the estuary can be >10,000 cfs. Conversely, when regulatory discharges are not occurring, unnaturally low freshwater inflow can occur during the dry season due to high water demand for agricultural and urban uses.

Discharges >6000 cfs from Franklin Lock cause the entire estuary to become oligohaline and can decrease salinity in the outer embayments, San Carlos Bay and Matlacha Pass. Submerged vegetation in the estuary has decreased significantly since the installation of the Franklin Lock. Impacts on water quality, benthic fauna, and fisheries are suggested.

The concept of "spreader waterway" was a mitigation technique developed to reestablish sheet flow of water in wetlands that are anthropogenically altered. Spreader systems are common in southwest Florida. A spreader waterway was added when construction of the 650 km Cape Coral residential canal system altered the natural freshwater sheet flow pattern into Matlacha Pass (Charlotte Harbor), but it is not functioning properly. Many breaches result in channelized freshwater flow into Matlacha, which has eliminated or degraded seagrass and mangrove habitat and reduced seagrass productivity.

The Faka Union and Golden Gates Estates canal systems altered the natural freshwater sheet flow into Faka Union Bay and adjacent estuarine areas. The canal systems increased the rate of surface water runoff, resulting in substantial point loads of freshwater into the estuaries. This has altered salinity patterns, caused sporadic freshwater shocks, decreased the nursery value for fish and shellfish by reducing area with salinity ranges favorable for planktonic and juvenile forms, reduced abundances of subadult and adult fish, increased nutrient loading, and had long term negative effects on habitat quantity and quality, including a likely decline in seagrass coverage.

RESEARCH NEEDS

Alteration of Freshwater Inflow to Estuaries

- o Freshwater flow pattern into the tidal Caloosahatchee: The indicator species approach proposed by SFWMD should be independently evaluated. SFWMD should immediately establish a comprehensive water quality monitoring program in the Caloosahatchee estuary.

- o Research is needed on spreader waterways to determine best design to perform intended ecological and hydrological functions.

Charlotte Harbor Estuarine Ecosystem

- o A comprehensive, integrated SWIM plan must be developed for the entire system. Major research and monitoring projects should also be system-wide. Two water management districts share jurisdiction for the Charlotte Harbor system (like Indian River Lagoon), but, unlike Indian River, there is no joint system-wide SWIM plan.

- o GIS based habitat and land use trend analyses for the entire system should be conducted every 3 to 4 years.

- o Water quality monitoring program for the SFWMD portion, including tidal Caloosahatchee, to compliment SWFWMD part.

- o System-wide nutrient and other pollutant loading study (including septic tanks).

- o System-wide hydrologic and circulation model (current USGS study may meet this need).

- o Diagnostic watershed assessment for SFWMD part to compliment that being done in SWFWMD portion.

- o Nutrient limitation and dosing experiments on seagrass - seagrass epiphyte - fleshy macroalgae - phytoplankton complex. Ideally in several areas of estuary.

- o Irradiance limitation and sedimentation experiments on seagrass. Closely coupled with nutrient limitation study.

- o Develop predictive model of benthic vegetation change related to pollutant loading.

- o Freshwater inflow studies: see that section.

- o Field and laboratory studies of chronic and sublethal effects of mosquito pesticides to non-targets species (various life stages), especially repeated applications and extended exposure.

- o Mosquito adulticide drift studies and ecological effects.

- o Continued research into alternative (non-pesticide) mosquito control methods.

Freshwater Caloosahatchee River

- o Basin wide nutrient and other pollutant loading study.

- o Basin wide GIS-based habitat trend analysis every 3-4 years.

- o Assessment of biological resources in river.

Estero Bay Estuary and Watershed

There is little information on the ecology and hydrology of Estero Bay. The following studies are recommended:

- o Assessment of biological resources in bay, especially seagrass beds.

- o Basin wide nutrient and other pollutant loading study.

- o System wide water quality monitoring.

- o Bay circulation and flushing model.

- o Watershed hydrologic study, particularly addressing altered freshwater flow into Estero Bay.

- o Nutrient limitation and dosing experiments on seagrass - seagrass epiphyte - fleshy macroalgae - phytoplankton complex.
- o Irradiance limitation and sedimentation experiments on seagrass. Closely coupled with nutrient limitation study.

- o Develop predictive model of benthic vegetation change related to pollutant loading.

Citrus Development and Other Agricultural Issues

- o Develop techniques to improve irrigation efficiency and water conservation (surface and groundwater). Agriculture so dominates water use in the interior that even small improvements in efficiency would result in considerable water conservation.

- o Investigate potential ecological effects of agriculture on surface and groundwater quality; ecological effects of surface water runoff from agricultural lands.

- o Investigate potential ecological and hydrological effects of lowered water table, particularly in wetlands, from agricultural activities.

- o More information is needed on the potential effects of environmental contaminants (pesticides, nutrients, metals) on wildlife in citrus groves.

- o Develop a system for evaluating ecological and hydrological functions that can be used to better assess predevelopment environmental conditions and the success of mitigation.

Corkscrew Regional Ecosystem Watershed

- o System wide habitat trend analysis every 3 or 4 years (GIS based).

- System wide surface and groundwater quality assessment (GIS based).
- Investigate ecological and hydrological effects of agriculture adjacent to CREW, especially potential nutrient and other contaminant loading from agriculture runoff.
- Examine possible hydrological and ecological impacts of oil exploration.
- Investigate ecological and hydrological effects of residential development adjacent to CREW.
- Investigate ecological and hydrological effects of municipal wellfields adjacent to CREW.
- Flintpen Strand subbasin hydrologic and hydraulic study to assess the impact of new and proposed controlling structures in Kehl canal system.

Hydric Pine Flatwoods

- Recognition of hydric pine flatwoods as a separate biological community type. Landscape scale inventory and monitoring, including historical distribution and aerial coverage, temporal changes.
- Floral and faunal inventory and monitoring, including protected species. Examine wildlife habitat value of hydric pine flatwoods.
- Ecological and hydrological effects of invasive exotics.
- Hydrologic studies including surface water hydrologic conditions need to maintain system and groundwater recharge potential.
- Influence of fire regimes in maintaining natural plant species composition and diversity.

Naples Bay Ecosystem

- Assessment of biological resources in bay.
- Basin wide nutrient and other pollutant loading study.
- System wide water quality monitoring.