I. INTRODUCTION

A. OVERVIEW

The South Florida Water Management District (SFWMD) has undertaken the development of regional and county level water supply plans to provide for better management of South Florida's water resources.

The Lower East Coast Regional Water Supply Plan will address water-related needs and concerns of southeastern Florida through the year 2010. The planning boundaries include Palm Beach, Broward, Dade and Monroe counties, and portions of northeastern Collier and eastern Hendry counties. This area includes a number of natural areas, including Lake Okeechobee, the Water Conservation Areas (WCAs), Everglades National Park (ENP), Biscayne Bay, Biscayne National Park, Florida Bay and other estuaries (**Figure I-1**). The plan is being developed in accordance with the SFWMD's Water Supply Policy Document. It will address issues and concerns related to water supply demands of urban and agricultural users and water needs of the environment, including the role of the regional water storage and delivery system.

This Draft Working Document provides background and other introductory information for review by the Lower East Coast Regional Water Supply Plan Advisory Committee, as well as local and state governments, individual utilities and other agencies and interested parties who may wish to provide input to the SFWMD's planning process. The final plan will provide a set of data, assumptions, and solutions to support related SFWMD functions such as Regulation, Operations, Land Management and other departments; it will also provide guidance for local government programs such as comprehensive and utility planning processes and land use decisions. Within the Lower East Coast region, three more detailed water supply plans are being developed by the SFWMD with the assistance of separate local water supply advisory committees. These three subregional plans will cover the Dade County-Florida Keys area, Broward County and Palm Beach County and must be consistent with the regional plan. While these water supply plans will support the SFWMD's regulatory programs, they will not replace the agency's permitting program. Counties, municipalities, utilities will find it necessary to conduct additional, site-specific studies to meet local comprehensive planning requirements and to support permit applications for utility development or expansion programs.

1. Draft Working Document Description

This working document is a compilation of background material for the Lower East Coast Regional Water Supply Plan. Included in this document are preliminary evaluations of available information that is related to the supply and use of regional water resources and the relationship of the regional resource to localized water supply systems in Monroe, Dade, Broward, Palm Beach, Collier and Hendry counties. This initial working document includes seven sections:

- **I. Introduction.** This section includes a description of water supply goals, objectives, and policies as they apply to regional water supply issues. It also identifies the study area, past water supply studies and related information.
- **II. Regional Water Resources.** This section provides a description of the water resources in the study area.

- **III. Environmental Resources.** This section discusses the environmental resources of the study area.
- **IV. Population and Demand Projections.** This section documents the SFWMD's projections of water demands for urban and agricultural uses through the year 2010 for Dade, Monroe, Broward and Palm Beach and eastern Hendry counties.
- **V. Overview of Methodology and Models.** This section presents the methodology for developing and analyzing alternatives. It also gives a suggested methodology for estimating environmental water needs and includes a description of primary computer models available to support these analyses.
- **VI. Overview of Alternatives, Components, and Potential Options.** This section offers a preliminary list of demand management and water supply options for implementation at regional and local levels, and discusses how these potential options can be packaged to form alternatives.
- **VII. Overview of Preliminary Water Resource Analyses.** This section summarizes preliminary analyses which have been developed to support the water supply planning process.
- **VIII. Literature Cited.** This section provides a list of literature cited in the draft Working Document.

In addition, the SFWMD has prepared a volume of Draft Appendices and Technical Information in support of this Draft Working Document.

The materials contained in the Draft Working Document will form the base on which the final plan will be developed. Some of the background material may be expanded, deleted or otherwise modified for inclusion in the final plan. The Draft Working Document will be useful in the planning process for selecting options and developing alternatives. Sections describing the selection of potential options, the development of water supply alternatives, the analysis of alternatives, including graphic display of the selected performance measures, will be added to the Draft Working Document at appropriate times. Ultimately, a regional water supply plan, including identification of the preferred alternative(s) and other recommendations, will be developed for consideration by the SFWMD Governing Board.

The analyses for this plan will be based on water supply and use, estimated demands, estimated environmental needs and system constraints that are described in this initial working document, and other information developed as part of the county-level water supply plans for Palm Beach and Broward counties, and the Dade County-Florida Keys area. The analyses will include conventional water supply and treatment alternatives, consideration of innovative treatment and supply methods, and cost estimates of regional options. A regional-scale, two-dimensional, integrated surface water-ground water model, the South Florida Water Management Model (SFWMM), will be used as the primary tool for assessing the effects of various regional management options. Information from the SFWMM will be entered into the more detailed computer models of the surficial aquifer systems in Dade, Broward and Palm Beach counties. The modeling results will be used by the county committees to analyze the effects of various subregional management options for the county-level plans. The regional study area is depicted on a satellite image (**Figure I-1**) and a map of the region, including areas covered by the model, is provided in **Figure I-2**.

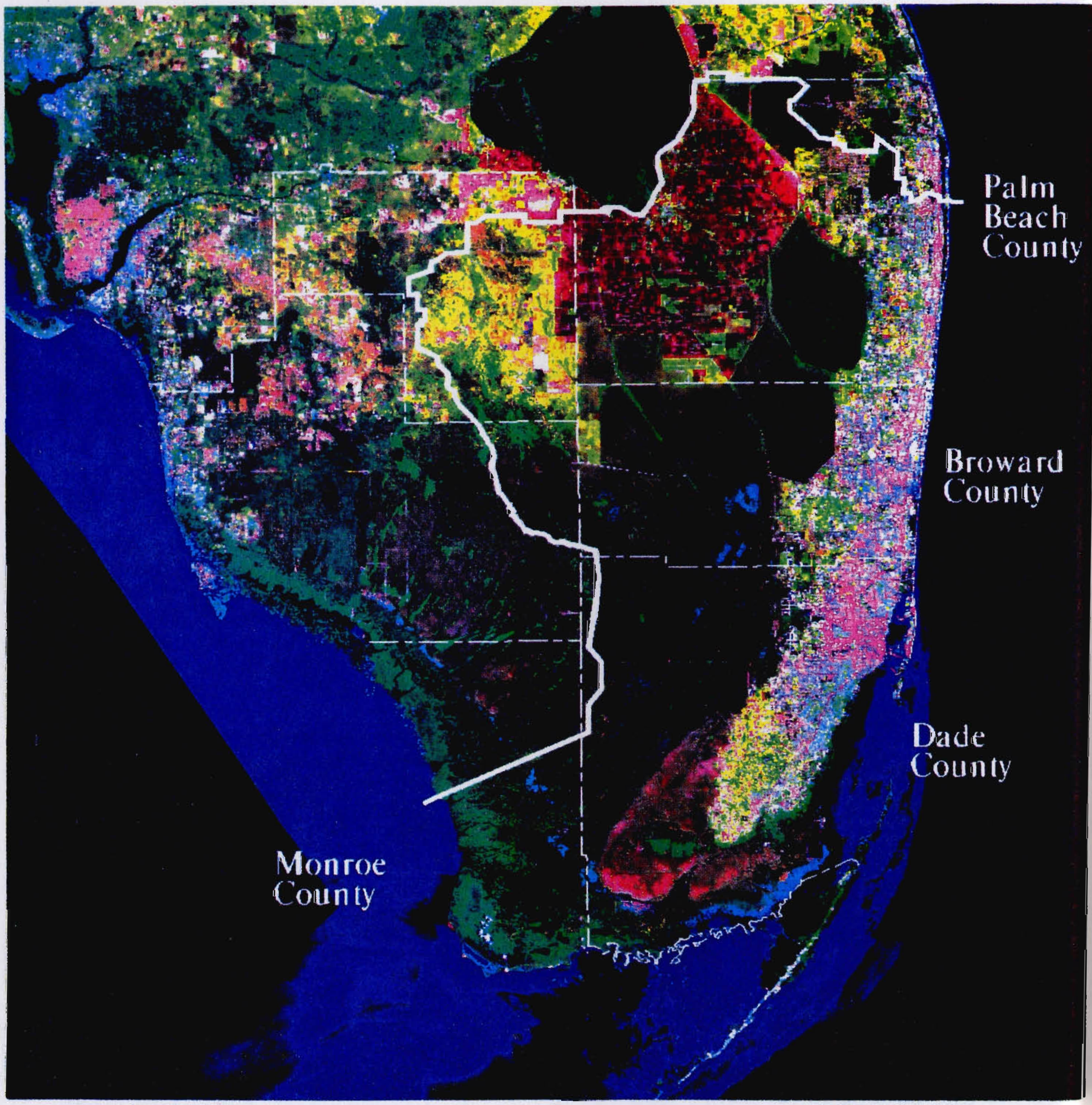

Figure I-1. Satellite Image of Lower East Coast Regional Water Supply Plan Study Area.

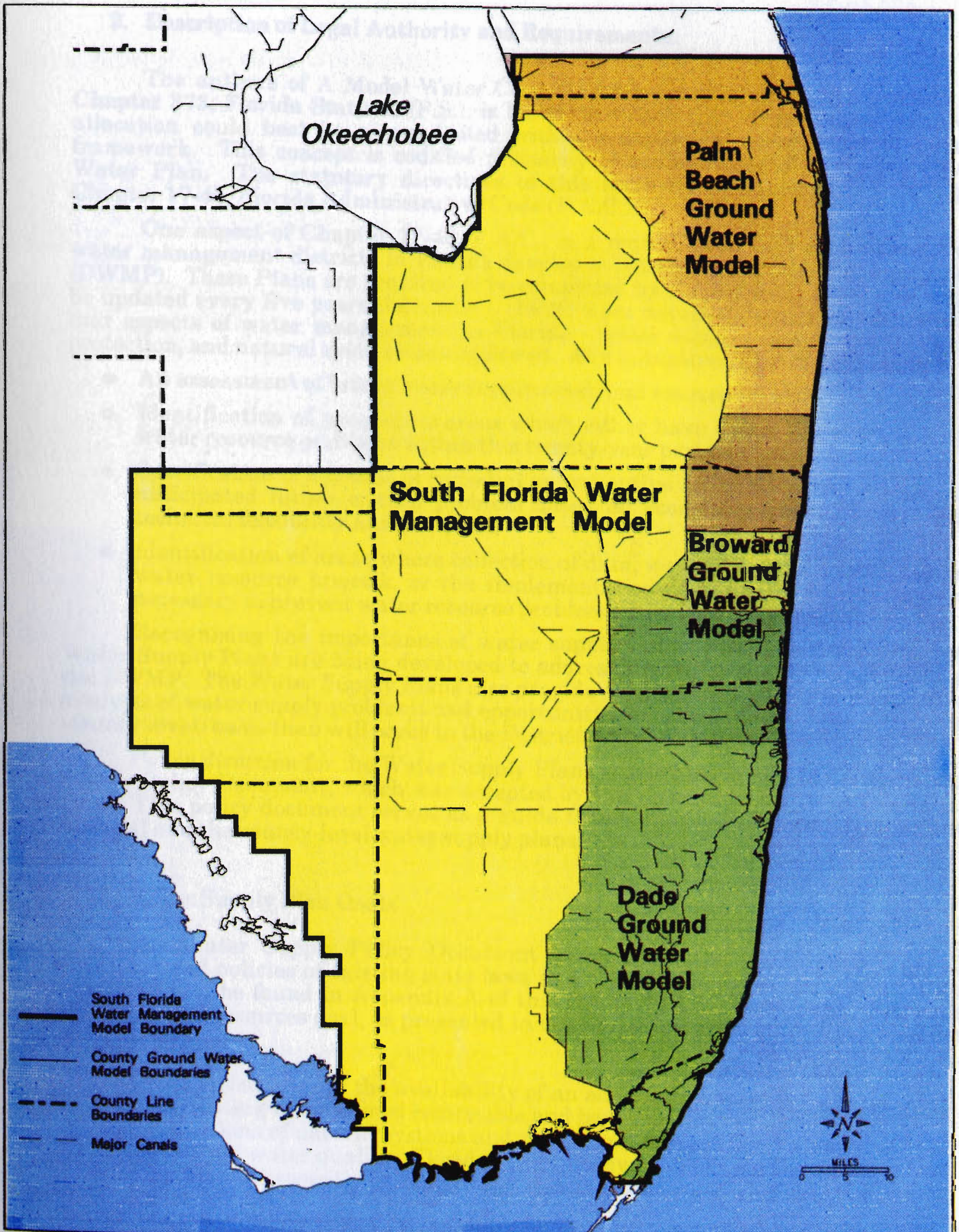

Figure I-2. Map Indicating Areas Covered by Various Models.

2. Description of Legal Authority and Requirements.

The authors of A Model Water Code (Mahoney, 1972), upon which much of Chapter 373, Florida Statutes (F.S.), is based, theorized that proper water resource allocation could best be accomplished within a statewide, coordinated planning framework. This concept is codified primarily in section 373.036, F.S., the State Water Plan. The statutory directives of this section are implemented through Chapter 17-40, Florida Administrative Code (F.A.C.).

One aspect of Chapter 17-40, F.A.C., is a requirement that each of the five water management districts in Florida develop a District Water Management Plan (DWMP). These Plans are required to be completed by November 1, 1994, and must be updated every five years thereafter. DWMPs are required to address each of the four aspects of water management in Florida - water supply, water quality, flood protection, and natural systems management. At a minimum, they must include:

- An assessment of future water supply needs and sources for a 20-year period;
- Identification of geographic areas which either have or are projected to have water resource problems within this twenty-year period;
- Specification of a course of remedial or preventive action for each current and anticipated future critical problem based on economic, environmental and technical feasibility analyses; and
- Identification of areas where collection of data, water resource investigations, water resource projects, or the implementation of regulatory programs are necessary to prevent water resource problems from becoming critical.

Recognizing the importance of water supply issues throughout the District, Water Supply Plans are being developed to address the water supply components of the DWMP. The Water Supply Plans also provide an opportunity for a more detailed analysis of water supply problems and opportunities on a regional and a subregional (county level) basis than will occur in the District-wide DWMP.

Policy direction for the Water Supply Plans is provided by the District's Water Supply Policy Document, which was accepted by the Governing Board in December 1991. This policy document serves as a guide to ensure consistent direction for the regional and the county-level water supply plans.

3. Water Supply Plan Goals

The Water Supply Policy Document summarizes the water supply goals, directives and policies of existing state laws and rules. Selected excerpts from state water law can be found in Appendix A of this Draft Working Document. Florida's overall water resources goal, as presented in the State Comprehensive Plan (Section 187.201, F.S.), is:

> "Florida shall assure the availability of an adequate supply of water for all competing uses deemed reasonable and beneficial and shall maintain the functions of natural systems and the overall present level of surface and ground water quality. Florida shall improve and restore the quality of waters not presently meeting water quality standards."

The goal of the SFWMD's Water Supply Planning effort, as stated in the Water Supply Policy Document, is to attain maximum reasonable-beneficial use of water.

Six major water supply planning directives are identified in the law, as indicated in Figure I-3.

1. Prevent wasteful, uneconomical, impractical, or unreasonable uses of the water resources.
2. Promote economic development of the water resources consistent with other directives and uses.
3. Protect and enhance environmental resources while providing appropriate levels of service for drainage, flood control, water storage, and water supply.
4. Maximize levels of service for legal users, consistent with other directives.
5. Preserve and enhance the quality of the state's ground and surface waters.
6. Develop and maintain resource monitoring networks and applied research programs (such as forecasting models) required to predict the quantity and quality of water available for reasonable- beneficial uses.

Source: SFWMD Water Supply Policy Document, 1991

Figure I-3. Six Water Use Directives Derived from State Law.

4. Lower East Coast Regional Plan Objectives

The Lower East Coast Regional Water Supply Plan Advisory Committee has developed a list of objectives which attempt to further define the directives listed in the SFWMD's Water Supply Policy Document. Advisory committees for each of the county-level plans also have engaged in the development of objectives which reflect localized issues and concerns. SFWMD staff intends to develop a comparison of the combined objectives of the four committees to ensure consistency with the Water Supply Policy Document and to address any potential conflicts between committees. The Regional Advisory Committee recommended that the water resources of South Florida are managed to achieve the following objectives:

1. Protect and enhance the environment including federal, state and locally identified natural resource areas.
2. Protect and conserve the water resources of South Florida to ensure their availability for future generations.
3. Provide for the equitable, orderly, cost effective and economical development of water supplies to meet South Florida's agricultural, urban, and industrial needs, without harming the environment.
4. Respect local control over land use planning and local water supply options, consistent with regional water supply, flood control, and environmental protection objectives.
5. Improve local and regional resource management through the integration of water supply and land use planning.
6. Develop a long range program for improving the SFWMD's ability to predict the impacts of development and management decisions, to evaluate water resource management strategies, and to enforce compliance with the chosen strategies.

5. Role of Advisory Committee

The primary role of the Lower East Coast Regional Water Supply Plan Advisory Committee is to represent the public in the development of the Lower East Coast Regional Plan and to make recommendations to the SFWMD concerning the content of the plan. The committee's first task was to review and critique a document describing the technical approach SFWMD staff has proposed for the development of the plan. The committee was asked to determine whether the suggested objectives, components, performance measures and methods of display are relevant and adequate. The committee also will review and suggest modifications to this working document. An Environmental Subcommittee was formed to review a SFWMD staff position paper titled "Estimating the Environmental Water Needs of the Remaining Everglades." The staff position paper and the subcommittee's recommended changes are presented in Appendix D.

The SFWMD staff is in the process of developing computer simulations of historical and base case conditions which can be used as a reference point in the analysis of simulated alternatives. An Alternatives Subcommittee was established to review and comment on these proposed simulations. Additionally, the SFWMD is preparing several initial water supply alternatives for the committee's review. After reviewing the suggested alternatives, the committee will play a key role in developing and evaluating additional alternatives. Finally, the committee will review and comment on all major technical and policy-related documents produced as a part of this planning effort.

6. Related SFWMD Activities

The water resource management system of Central and Southern Florida is a complex interrelated system in which any component can be impacted by the changes in water management practices in other basins. The Lower East Coast Regional Water Supply Plan may impact water management activities in the adjacent basins and likewise could be impacted by proposed changes in the neighboring basins.

In addition to the Water Supply Policy Document and the regional and subregional water supply plans, other key activities are needed to meet the directives of Chapter 373, F.S., as amended over the past twenty years. These include completing the District Water Management Plan, preparing water supply elements for Surface Water Improvement and Management (SWIM) plans and updating the SFWMD's Basis of Review for consumptive use permitting. Discussions of several of these important water resource programs are provided below.

District Water Management Plan. Section 17-40.501, F.A.C., mandates that each of the five water management districts complete a District Water Management Plan (DWMP). The DWMPs are required to be completed by November 1, 1994, and must be updated every five-years thereafter. They must discuss the problems and activities being undertaken by the respective Districts with regard to each aspect of water resource management - water supply, water quality, flood protection, and natural systems management.

As discussed previously in this section, specific water supply issues must be addressed in the DWMP, including a discussion of water supply needs and sources for a 20-year planning period; identification of areas with current or future water supply problems; development of remedial or preventive actions to address specific problems and a determination of areas where studies, projects, or regulatory actions that could keep water supply problems from becoming critical.

The water supply component of the DWMP for South Florida will be based upon the regional and subregional water supply plans. These plans will provide a more detailed discussion and analysis of water supply issues than is possible in the DWMP, with its District-wide focus.

Water Supply Elements of SWIM Plans. Integration of water supply planning and SWIM planning will be a critical link between efforts to meet the water quantity and water quality requirements of wetlands, estuaries and other ecosystems, and to further integrate these with the maximum reasonable-beneficial use of the resource. Policies established by the SFWMD must be coordinated with the goals, objectives and strategies of appropriate SWIM plans, including upstream supply sources and downstream receiving bodies. Because water supply elements are key components of SWIM plans, the water supply planning process takes into consideration the water quantity, environmental, and other related goals of these plans. This will allow the water supply plans for specific regions to be incorporated into SWIM plans with minimal conflict.

The SWIM program for Lake Okeechobee is designed to reduce the nutrients in the inflows to the lake from the dairies and other land uses to the north and from the EAA farms to the south. The implementation of these and future SWIM programs may result in a reduction of carryover storage in the lake, which is an important source of the water during drought periods.

The restoration of the Everglades with the construction of proposed Stormwater Treatment Areas (STAs) outlined in the Everglades SWIM plan, will impact the volume and timing of the tributary inflows from the EAA to the WCAs. Proposed Best Management Practices (BMPs), increased evapotranspiration in the STAs and water detention will reduce flows to the WCAs and change the timing of those flows. A discussion of the configuration and potential impacts of the STAs is presented in Section VI and Appendix C.

The SWIM plan for Biscayne Bay, the Florida Bay component of the Everglades SWIM plan and any future plans for other estuarine systems in the Lower East Coast, Lower West Coast or Upper East Coast could affect water requirements from the regional system. Changes in operations of canals, structures and regulation schedules in the system can also impact the storage in the lake, the WCAs and the water distribution system.

Basis of Review (BOR) for Consumptive Water Use Applications. The SFWMD's existing water use permitting program is governed by the Basis of Review. The BOR contains rules and procedures for the issuance of consumptive water use permits. As such, the regulatory program as represented by the BOR will be an important tool to implement the water supply planning initiative. As a result of the Water Supply Policy Document and other on-going programs, a number of areas in the BOR have been identified for possible amendment and revision. Others will be considered later in the process. The plan itself may result in specific recommendations to modify the BOR. Areas that recently (1992) have been revised :

- Mandatory urban demand management, including irrigation hours, plumbing standards, conservation rate structures and Xeriscape criteria.
- Agricultural demand management, including water use accounting, conservation, allocation criteria, and other limiting conditions.
- Regionalization / utility interconnects.
- Wastewater reuse requirements.

As a result of its regulatory and planning activities, the SFWMD has identified other areas that may be addressed in future revisions. These include:

- Water quality limitations for consumptive use permits.
- Environmental allocations, including protection and enhancement of natural systems such as wetlands and estuaries.
- Evaluation of cumulative impacts.
- Modifications to supplement crop requirements.
- An EAA water management program.
- Further directions for the reuse of reclaimed water.
- Water use zoning (aquifer zoning).
- Defining allowable impacts to aesthetic lakes and canals.
- Restricted allocation areas.
- Updated saltwater intrusion criteria and contamination movement restrictions.
- Special criteria for sinkhole-prone areas.
- Wetland protection criteria and wetland mitigation.

Other Projects. The SFWMD also has implemented other water supply-related projects that affect the Lower East Coast Regional planning effort, including:

- Development of a Needs and Sources Document. This document, accepted by the SFWMD Governing Board in July 1992, identifies the projected demands and supply potential for specific regions over the next 20 years.
- Critical Water Supply Problem Area Rule. This regulation, Chapter 40E-23, F.A.C., designates areas that presently have critical water supply problems or are expected to have critical problems during the next 20 years. It was adopted by the Governing Board in October 1991. The designations will be updated every five years.
- Land Acquisition and Management. The SFWMD has been very actively involved in acquiring a wide variety of properties in the study area under the Save Our Rivers program.

B. REGIONAL PLANNING BOUNDARIES

1. Lower East Coast Region

The SFWMD is divided into four planning regions. The Lower East Coast region includes all of Dade and Broward counties, most of Palm Beach and Monroe counties, and small portions of Collier and Hendry counties. Regional planning boundaries are indicated in **Figure I-4.** The Lower East Coast region's northeast boundary is the upper limit of the West Palm Beach Canal (C-51) basin, while the northwest boundary is Lake Okeechobee. The region is also bounded on the east by the coastline of Palm Beach, Broward, Dade and Monroe counties, on the south by the Florida Keys and Florida Bay, and on the west by the Lower West Coast planning area, including the Big Cypress Basin and the Caloosahatchee River Basin. Lake Okeechobee is considered an important resource of all four planning regions. Selected portions of the other regions will be considered in the Lower East Coast plan development and are discussed below.

2. Other Related Planning Areas

Several areas which are not included in the boundaries of the Lower East Coast planning area will directly or indirectly affect, or be affected by, the regional options considered in the plan. Of these related areas, three are especially important and must be considered during the Lower East Coast regional planning efforts. The three key related areas are depicted in **Figure I-5** and include:

- Portions of the Lake Okeechobee service area outside of the Lower East Coast boundary;
- The northeast corner of Palm Beach County;
- The Big Cypress National Preserve.

The Lower East Coast Plan will consider the water supply needs of Lake Okeechobee and the projected demands of its service area, including those outside of the actual Lower East Coast planning area. These external areas include communities adjacent to the lake and areas connected to the lake by the Caloosahatchee River and the St. Lucie Canal.

Likewise the LEC Regional Planning Process must consider issues related to Northeastern Palm Beach County. Although this area is located in the Upper East Coast Region, it will be analyzed in greater detail during the development of the Palm Beach County Water Supply Plan.

Water flows between Big Cypress and the Everglades system must also be considered in the development of the LEC Regional Plan.

3. Planning Region Descriptions

The DWMP will provide a vehicle to consider any issues or conflicts that arise between the regional plans. Brief descriptions of the other planning regions follows.

Kissimmee Planning Region. This region includes the northernmost reaches of the SFWMD boundaries and includes two major basins.

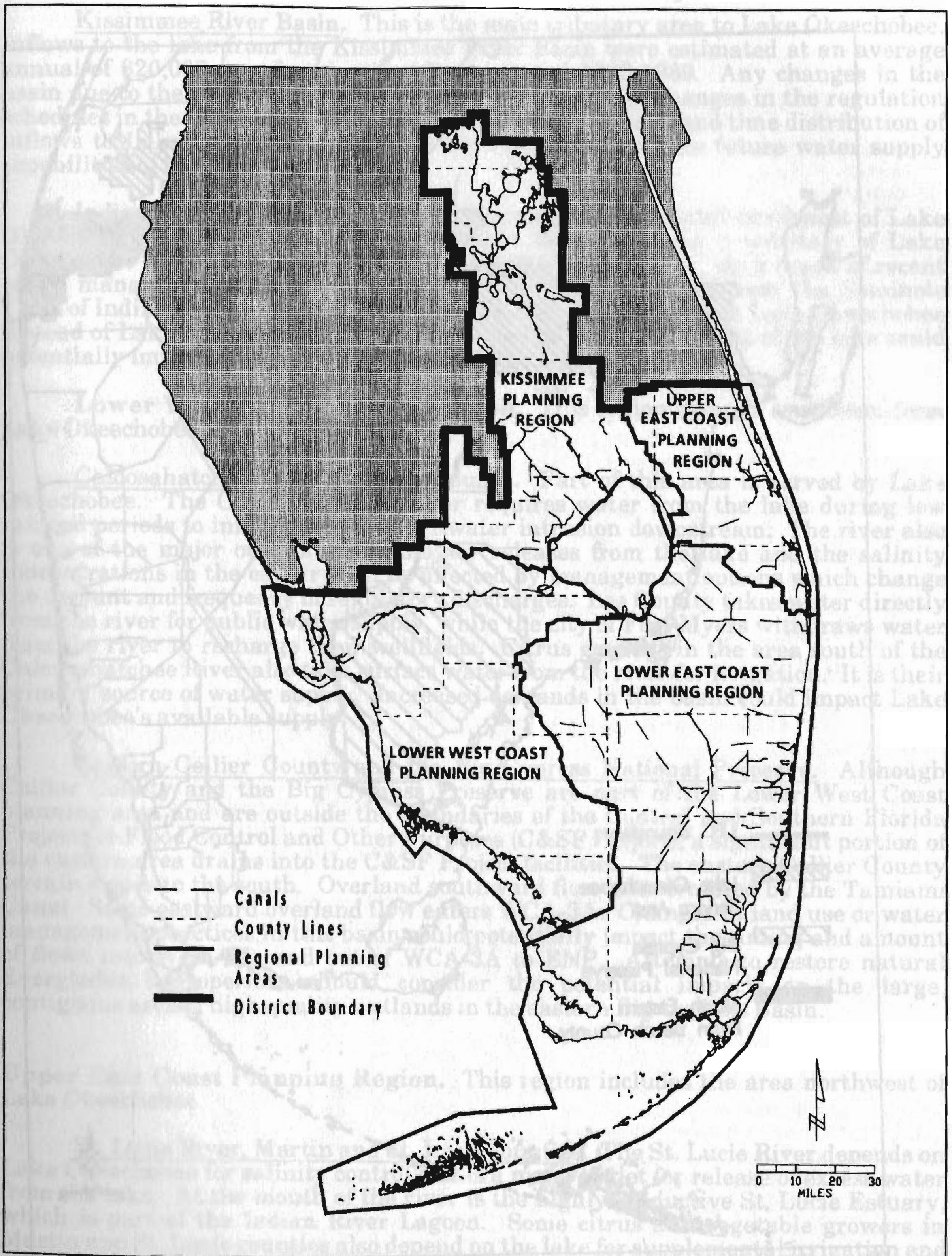

Figure I-4. Regional Planning Boundaries.

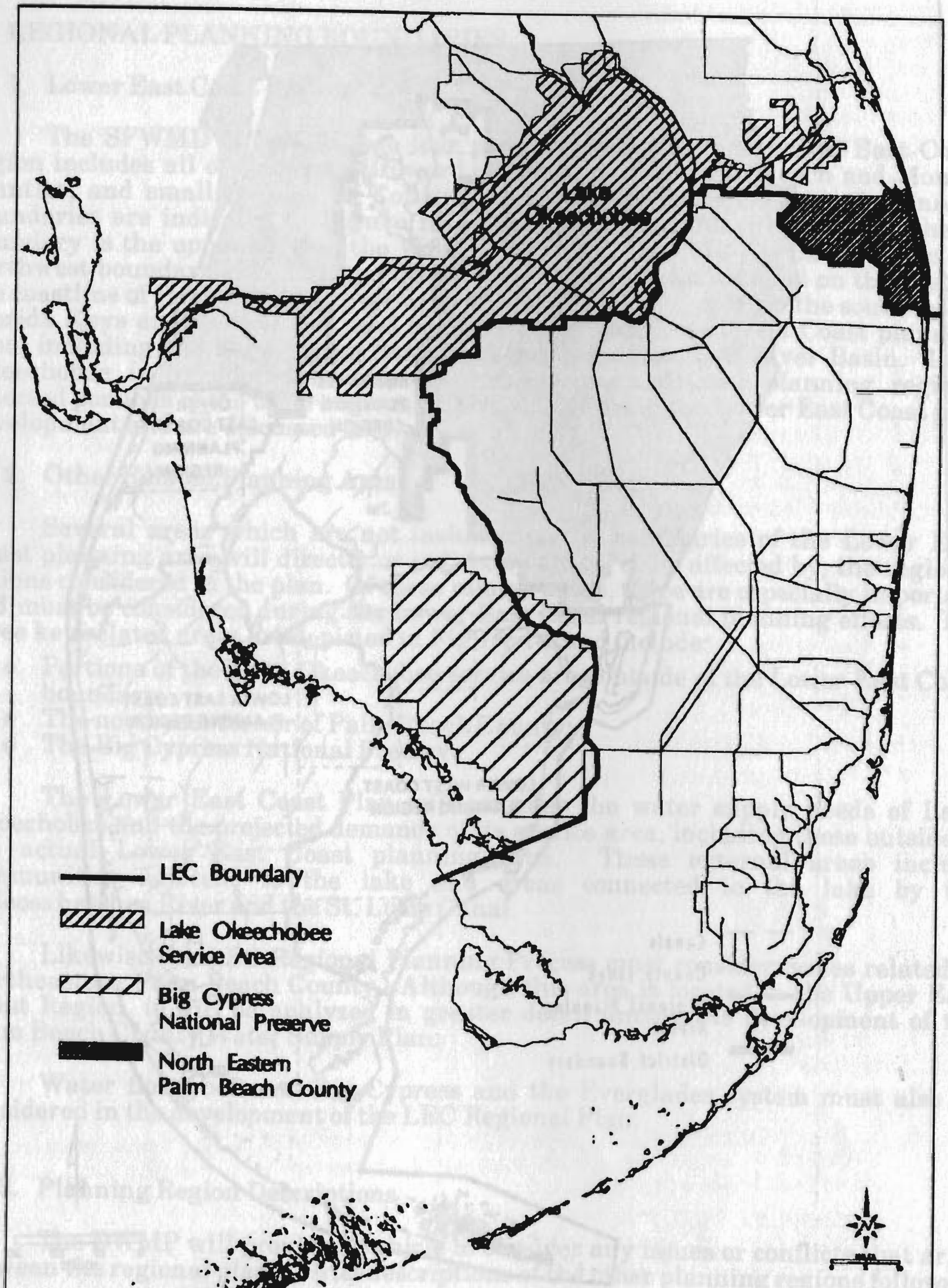

Figure I-5. Areas Outside the Plan Boundary with Significant Relationships to the Lower East Coast Planning Process.

Kissimmee River Basin. This is the main tributary area to Lake Okeechobee. Inflows to the lake from the Kissimmee River Basin were estimated at an average annual of 820,000 acre-feet for the 10-year period 1980-1989. Any changes in the basin due to the proposed Kissimmee River restoration or changes in the regulation schedules in the upper chain of lakes may change the volume and time distribution of inflows to Lake Okeechobee and may have an impact on the future water supply capabilities of the lake.

Indian Prairie Basin. The Indian Prairie Basin is located northwest of Lake Okeechobee. Historically the Indian Prairie Basin has been a tributary of Lake Okeechobee with a small water supply demand from the Lake. As a result of recent water management changes in the basin, the water demands from the Seminole Tribe of Indian's Brighton Reservation are now met primarily from Lake Okeechobee instead of Lake Istokpoga. Significant changes in the management of the lake could potentially impact the water supply needs of the reservation.

Lower West Coast Planning Region. This region extends southwest from Lake Okeechobee to the Gulf of Mexico.

Caloosahatchee River and Lee County. Part of this area is served by Lake Okeechobee. The Caloosahatchee River requires water from the lake during low rainfall periods to inhibit excessive saltwater intrusion downstream. The river also is one of the major outlets for regulatory releases from the lake and the salinity concentrations in the estuary can be affected by management options which change the amount and frequency of regulatory discharges. Lee County takes water directly from the river for public water supply, while the city of Fort Myers withdraws water from the river to recharge their wellfields. Citrus growers in the area south of the Caloosahatchee River also take surface water from the river for irrigation. It is their primary source of water supply. Increased demands in the basin could impact Lake Okeechobee's available supply.

Eastern Collier County and the Big Cypress National Preserve. Although Collier County and the Big Cypress Preserve are part of the Lower West Coast planning area and are outside the boundaries of the Central and Southern Florida Project for Flood Control and Other Purposes (C&SF Project), a significant portion of the eastern area drains into the C&SF Project facilities. The eastern Collier County terrain slopes to the south. Overland southward flow is intercepted by the Tamiami Canal. Some eastward overland flow enters WCA-3A. Changes in land use or water management practices in this basin could potentially impact the timing and amount of flows into WCA-3A, and out of WCA-3A to ENP. Attempts to restore natural Everglades hydroperiods should consider the potential impacts on the large, contiguous area of high quality wetlands in the eastern Big Cypress Basin.

Upper East Coast Planning Region. This region includes the area northwest of Lake Okeechobee.

St. Lucie River, Martin and St. Lucie counties. The St. Lucie River depends on Lake Okeechobee for salinity control and is a major outlet for release of excess water from the lake. At the mouth of the river is the highly productive St. Lucie Estuary, which is part of the Indian River Lagoon. Some citrus and vegetable growers in Martin and St. Lucie counties also depend on the lake for supplemental irrigation and might be affected if the management of the lake reduces the water availability for water supply. Also, increased basin demands and potential minimum flow requirements of the estuary may impact Lake Okeechobee.

<u>Northeastern Palm Beach County</u>. As mentioned above, a portion of Palm Beach County is included in the Upper East Coast Planning Region for hydrological reasons. This northeastern areas is drained by the C-18 Canal and the Loxahatchee River. However, for the purposes of this plan, the northeastern area's future demands and other related information are incorporated into the countywide totals. This approach will keep the information reported in the regional plan consistent with the data which will be presented in the draft Palm Beach County and Upper East Coast water supply plans later in the process.

C. REGIONAL ISSUES, OPPORTUNITIES AND CHALLENGES

This planning effort and previous studies by other agencies and local governments have identified key issues concerning Lower East Coast Regional water supplies. Each of these topics presents opportunities, challenges and requirements that need to be considered in the development and selection of the alternatives. Some of those issues will require input from the advisory committee or technical management decisions on the part of the the SFWMD, local government or other agencies. In addition, the decisions concerning these issues are related to assumptions that may be used in the computer simulations of ground water and surface water resources. Some of those issues are constraints that need to be considered in the evaluation of alternatives. This section includes a brief description of each topic.

1. Water Supply Augmentation.

The existing water supply storage and delivery system can be modified to increase the storage capabilities and or the efficiency of it deliveries. Options such as additional reservoirs and water supply backpumping can provide additional surface water storage. In addition, the construction of additional or improved conveyance facilities that could transport water at low stages and with minimal transmission losses could increase the efficiency of water distribution.

There are other technologically feasible water supply options which allow the use of surface and ground waters, previously considered unusable, such as brackish and sea water. Options such as wastewater reuse, aquifer storage and recovery (ASR), reverse osmosis (RO), and desalination techniques can provide additional sources of water for irrigation, industrial or other uses.

2. Water Conservation Opportunities

More efficient demand management will indirectly increase the water supply capabilities of the system and minimize the need for additional water supply augmentation options. Short and long term conservation practices will reduce the demand and stretch the supply. The challenge to implement and accept water conservation measures as a necessary water saving scheme will enhance the feasibility of the plan. Water conservation is a high priority of SFWMD policy. State and SFWMD policy require that steps be taken to prohibit wasteful and unreasonable uses of water.

3. Surface Water Availability

Water availability depends on rainfall conditions and storage capacity in the regional surface and ground water system. Approximately 65 percent of the annual rainfall amount occurs during the wet season months (June through October), when the demands are moderate. Only 35 percent occurs during the dry season months (November through May), when the demands are largest. Because of the time variability of rainfall, there is a great need for water storage. Moreover, the multi-year rainfall cycles of wet periods and dry periods make the carry over storage of rainfall a necessity in order to meet the increasing demands during droughts. **Figure I-6** illustrates the annual variability of rainfall within the SFWMD's boundaries.

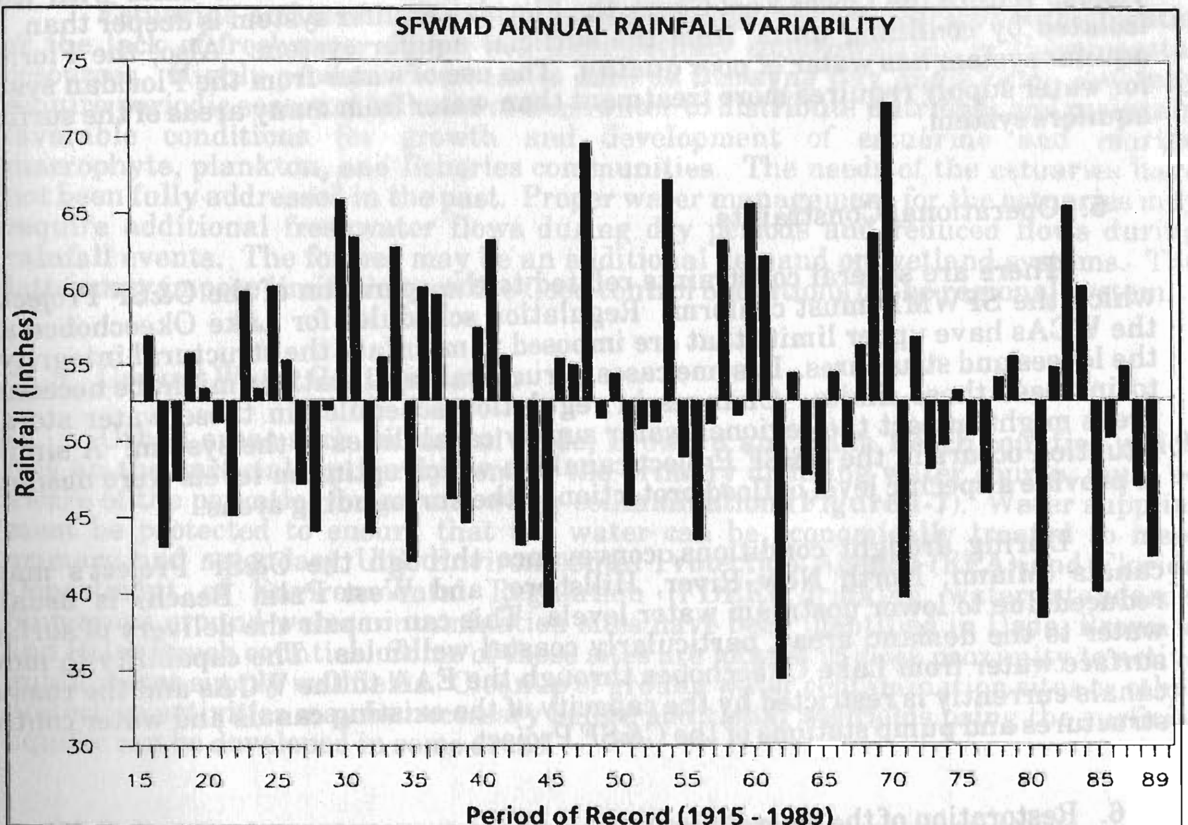

Figure I-6. Variation from Annual Average Rainfall Within the South Florida Water Management District. (Source: SFWMD, 1991)

Historically, the C&SF Project has served as the primary supplemental water supply source to recharge coastal aquifers in Broward, Dade and southern Palm Beach counties during periods of low rainfall and drought. Water has been released from the regional system on demand to maintain coastal canal water stages. During recent droughts, the regional system has not been able to meet existing demand, resulting in water restrictions. Operational changes to the system in the future could potentially vary the amount of water available from the regional system as a supply source for other uses. These potential changes must be considered when evaluating the feasibility of, and need for, various demand management and supply augmentation options.

4. Ground Water Availability

The surficial aquifer systems within the Lower East Coast region primarily consists of the Biscayne Aquifer in the coastal areas east of the WCAs and a surficial aquifer in the northern and western parts of the study area. The Biscayne Aquifer, which is located under the urbanized areas of Dade, Broward and southern Palm Beach counties, is a very prolific portion of the surficial aquifer with high storage capabilities. The rest of the surficial aquifer system consists of units with lesser yields. Within the Lower East Coast, the Floridan aquifer system is deeper than, and isolated by confining units, from the surficial aquifer system. Also, the Floridan aquifer system has water of poor quality. The use of water from the Floridan system for water supply requires more treatment than water from many areas of the surficial aquifers system.

5. Operational Constraints

There are several constraints related to the operation of the C&SF Project to which the SFWMD must conform. Regulation schedules for Lake Okeechobee and the WCAs have upper limits that are imposed to maintain the structural integrity of the levees and structures. In some cases, structural modifications might be necessary to increase those limits. Changes in regulation schedules in those water storage areas might impact the regional water supply capabilities of the system. A similar situation occurs in the C&SF Project canals in which optimum levels were designed to provide a specific level of flood protection to the surrounding areas.

During drought conditions, conveyance through the C&SF Project's major canals (Miami, North New River, Hillsboro, and West Palm Beach) is usually reduced due to lower upstream water levels. This can impair the delivery of surface water to the demand areas, particularly coastal wellfields. The capability to move surface water from Lake Okeechobee through the EAA to the WCAs and the coastal canals currently is restricted by the capacity of the existing canals and water control structures and pump stations of the C&SF Project.

6. Restoration of the Everglades

Water supply to meet environmental needs must conform with the water quality standards outlined in the Everglades SWIM plan, which was adopted in March 1992. The plan recommends the development of approximately 36,000 acres of artificial marshes known as stormwater treatment areas (STAs) which will be designed to improve the water quality entering the WCAs and ENP. Another important component in the restoration process will be the development of strategies to restore the hydroperiod of the Everglades. Hydroperiod restoration should be designed to meet the water requirements of the vegetative communities in the Everglades.

7. Wetlands outside of the Everglades

Wetlands in the vicinity of surficial aquifer withdrawal sites are more likely to be impacted by induced seepage and drawdowns. The disruption of the normal hydrologic function of a wetland leads to changes in vegetation composition, decreased size, degradation of fish and wildlife habitat, loss of organic soils, loss of aquifer recharge and other undesirable effects. These impacts must be considered when evaluating additional withdrawals from the surficial aquifer. Identifying wetlands which have been or may be impacted by withdrawals is essential.

8. Protection and Management of Coastal Resources

Estuarine and marine habitats can be impacted by large inflows of freshwater or the lack of freshwater which will alter salinity concentrations in these coastal resources. Highly productive estuaries such as Biscayne Bay and Florida Bay may require periodic seasonal influxes of freshwater to distribute nutrients and maintain favorable conditions for growth and development of estuarine and marine macrophyte, plankton, and fisheries communities. The needs of the estuaries have not been fully addressed in the past. Proper water management for the estuaries may require additional freshwater flows during dry periods and reduced flows during rainfall events. The former may be an additional demand on wetland systems. The latter may impose limitations on the flood control operations of the regional system.

9. Ground Water Contamination

Urban areas such as coastal Dade, Broward and Palm Beach counties which rely on the surficial aquifer system as the primary drinking water source, must be aware of the potential for ground water contamination (**Figure I-7**). Water supplies must be protected to ensure that the water can be economically treated to meet primary and secondary U.S. Environmental Protection Agency (EPA) and Florida Department of Environmental Regulation (FDER) drinking water standards. Numerous ground water contamination sites have been identified in Dade, Broward and Palm Beach counties. Some of these sites are located in close proximity to active public water supply wellfields. Cleanup of ground water contamination sites or other protective activities may be necessary before additional wellfields using the surficial aquifer can be developed in some areas.

10. Saltwater Intrusion

The inland migration of saltwater intrusion has been, and continues to be, a primary threat to public drinking water supplies in some coastal locations of the Lower East Coast. Increasing pumpage of the surficial aquifer and recent drought conditions have accentuated this problem.

The saltwater intrusion problem is compounded by the coastal locations of existing wellfields and the lack of a comprehensive standardized monitoring program. Existing criteria to protect against saltwater intrusion requires maintenance of a one-foot mound of fresh water between the withdrawal point and the saline interface. There is insufficient data to determine whether this level of protection is adequate or appropriate for all areas of the region. Future wellfield development proposals should consider the impact of existing and future saltwater

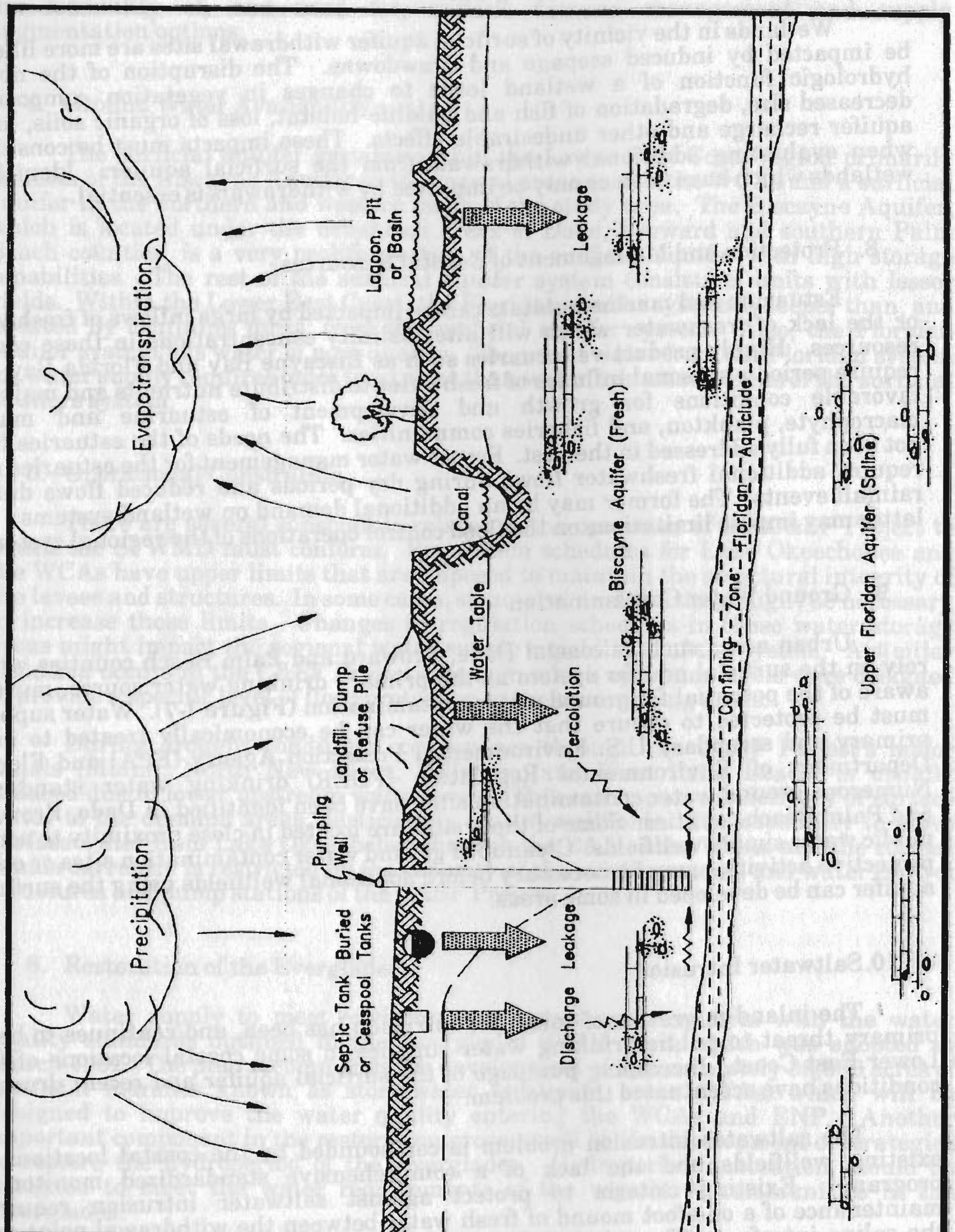

Figure I-7. Examples of Potential Ground Water Contamination Sources.

intrusion threats. The possibility of sea level rise may pose additional saltwater intrusion issues in the future.

11. Future Land Use Planning

Land use planning and regulation is a fundamental responsibility of local governments. By Florida law, this responsibility translates to the development and implementation of local comprehensive plans, including Future Land Use elements. The Local Government Comprehensive Planning and Land Development Regulation Act of 1985, Chapter 163, F.S., requires local governments to prepare and adopt plans which comply with specific requirements related to analyses of key subject areas, including water supply. Water resource considerations - water supply, flood protection, water quality management and natural systems management - are a vital group of components of the local plans.

As part of the evaluation of water resource planning and management issues, the local plans must address the availability of water supply sources to serve the demands of the projected land uses and future population. These local projections of future population are the basis for the water use projections in this plan. The local comprehensive plans are thereby linked directly with the SFWMD's water supply planning effort. The SFWMD reviews all proposed amendments to the local comprehensive plans, thereby maintaining a continuing link to local planning.

D. OTHER WATER SUPPLY STUDIES

Several reports and studies have been conducted to address the water supply of central and southern Florida.

1. 1968 USCOE Survey Review

The USCOE published a survey review report in 1968 on the C&SF Project. The report was published as House Document 369, 90th Congress, 2nd session. That study recommended several modifications to the C& SF project in order to improve flood control, water supply and other water management functions in the area. Among those recommended modifications were:

- Construction of facilities for pumping excess water from the east coast areas into storage in Lake Okeechobee and the Water Conservation Areas.
- Development of a system of interrelated canals, levees, pumping stations and control structures for conveyance and distribution of water to demand areas.
- Raising of the levees surrounding Lake Okeechobee to provide for an increase of about 4 feet in the authorized regulation stages (from 17.5 to 21.5 feet)

None of the recommended projects by the survey review report have been implemented.

2. SFWMD 1977 Water Supply Plan

The SFWMD prepared a water supply and development plan for the Lower East Coast of South Florida. In this 1977 plan, the SFWMD recommended the following water supply alternatives.

- Conservation -- The SFWMD encouraged public information and education to promote the need for water conservation. It also suggested the development of water shortage plans to be used during drought periods.
- Wellfield Development -- The SFWMD proposed regionalization of wellfields where applicable and encourage development within the limits of safe aquifer yields.
- Backpumping -- The SFWMD supported the concept of environmentally compatible backpumping schemes. It suggested the basins served by C-51, Western Tamiami and Hillsboro canals as possible backpumping areas.
- Desalination -- The SFWMD suggested the use of desalination techniques on a local or individual user basis where cost effective.
- Deep Aquifer Storage and Recovery -- The SFWMD recommended additional research and experimentation in this area.
- Increased Lake Okeechobee Storage -- The SFWMD recommended to raise the Lake Okeechobee regulation schedule from 14.5 - 16 ft. msl to 15.5 - 17.5 ft. msl. which can be attained with the existing facilities.
- Wastewater Reuse -- The SFWMD will support local governments that desire to investigate this alternative for specific areas.

Some of those recommended alternatives have been implemented such as the increase in the Lake Okeechobee regulation schedule which was adopted in 1978 and the development of water shortage plans in 1980. The SFWMD has also supported the use of reverse osmosis for treatment of brackish water and some municipalities are already using this technology. Some ASR pilot projects have been conducted and this technology has been found to be practical in certain areas. The SFWMD also has promoted water conservation throughout the region through public education and other programs.

3. USCOE 1979 Water Supply Report

The USCOE published a reconnaissance study report on water supply for central and southern Florida. In that 1979 report the USCOE suggested that the planning objectives would be to determine:

- How much water would be available from Lake Okeechobee at regulation schedules of 15.5 to 17.5 feet, 16.5 to 18.5 feet, 17.5 to 19.5 feet, 18.5 to 20.5 feet, and 19.5 to 21.5 feet.
- The water needs of the entire central and southern Florida area for the period of 1985 to 2035.
- The safe yield of wellfields along the Lower East Coast and Lower West Coast.
- The water demands of municipal, industrial and agricultural users; and the water required for salinity control and to meet the needs of ENP.
- The potential impact of water conservation on total water demand.

The reconnaissance study report recommended a detailed study on the following alternatives:

- Raising the regulation schedule of Lake Okeechobee.
- Backpumping of east coast canals.
- Wellfield development.
- Water conservation.
- Wastewater recycling.
- Desalination.
- Deep aquifer storage and recovery.
- New conservation areas.

4. USCOE 1989 Water Supply Report

The final report of the USCOE's Central and Southern Florida Water Supply Study was published in 1989 and recognized the conflicts between environmental needs and the capabilities of the C&SF Project to continue meeting existing and increased water supply. As a result of this study, the South Florida Water Management Model was developed. The study recommended alternatives previously suggested in the 1968 USCOE report and in the 1977 SFWMD report, particularly water conservation, desalination, wastewater reuse and aquifer storage and recovery. It also recommended no federal action to modify the existing C&SF Project to provide alternative sources of water supply.

5. C&SF Project Reviews

In 1992, Congress authorized the USCOE to conduct a review of the C&SF Project. However, no funds were allocated for the study. Additionally, the House Committee on Public Works and Transportation authorized the USCOE to review a past report on the C&SF Project for the purpose of providing a coordinated ecosystem study of Florida Bay.

II. REGIONAL WATER RESOURCES

A. BACKGROUND

This section describes the unique hydrologic features of South Florida, including a brief discussion of one of the most complex water management systems in the world, the Central and Southern Florida Project for Flood Control and Other Purposes (C&SF Project).

Because of its low, flat land surface, South Florida has a unique hydrologic system. The system includes natural and manmade features which do not exist in the other parts of the United States. These features include the Water Conservation Area impoundments; vast, flat open Everglades wetlands; and numerous small and large, natural and artificial, lakes and waterways. This hydrologic system allows retention or detention of huge volumes of water.

Even though the South Florida hydrologic system is highly managed, it is primarily rainfall driven and is highly influenced by the other natural processes such as evapotranspiration (ET).

1. The Hydrologic Cycle

A diagrammatic representation of the hydrologic cycle is shown in **Figure II-1**. The hydrologic cycle is a closed system. The power source for the hydrologic cycle is solar energy, which induces evaporation. Once evaporated, water vapor condenses and falls as precipitation. Part of the precipitated water may be retained in the form of surface detention or surface storage, while part of it becomes overland flow or runoff, which eventually makes its way to the ocean. A portion of the surface water seeps into the ground. As this water infiltrates through the soil, a portion may be consumed by plants and recycled back into the atmosphere in the form of transpiration. Some moisture will remain in the soil during unsaturated conditions while some seeps downward by gravity until it reaches the ground water table. Some ground water flows back to the surface water system. However, portions of the ground water may stay beneath the land surface for long periods of time. During the above processes, surface water evaporates, continuing the cycle back to the atmosphere.

2. Regional Hydrologic System

Key characteristics of the South Florida hydrologic system include rainfall patterns which are highly seasonal and generate large volumes of water; evapotranspiration (ET), which causes much of the rainfall to be recycled back into the atmosphere; and surface water storage, inflows and outflows, which are impacted by the climatic variations and the limitations of the regional storage and distribution system. Ground water storage and flows, while less susceptible to climatic change, are impacted by regional water management operations.

Rainfall and ET. The average annual rainfall for the overall Lower East Coast region is approximately 52.2 inches however it ranges from a maximum of 58.3 inches in the Lower East Coast developed area along the coast to a minimum of 44.8 inches in Lake Okeechobee, based on a period of record from 1915 to 1985 (Sculley, 1986). Although the average is an indication of what can be expected most of the

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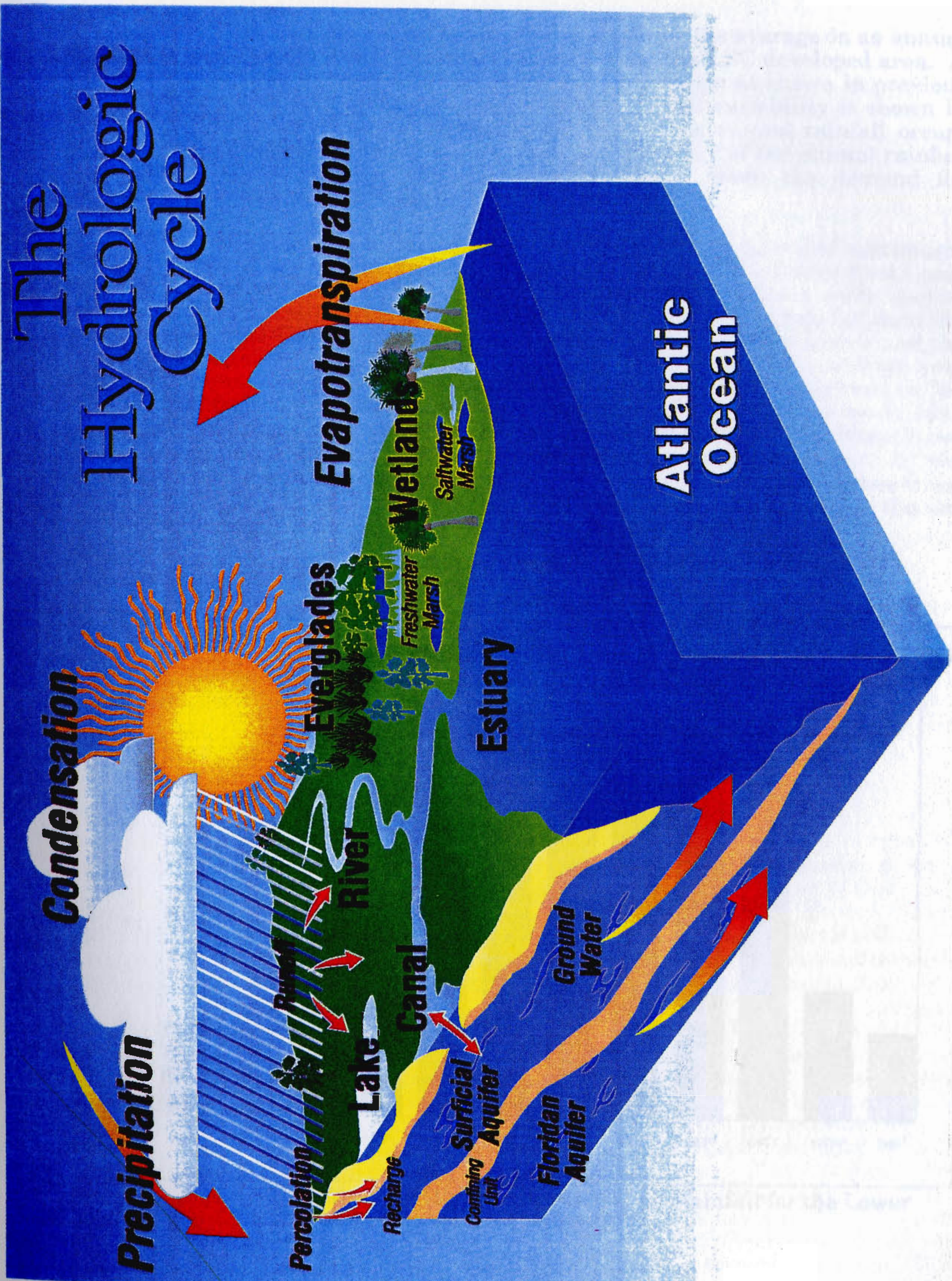

Figure II-1. The Hydrologic Cycle

time, in actuality most of the region's rainfall deviates from the average on an annual basis. **Figure I-6** illustrates the rainfall variability for the LEC developed area. A similar pattern exists in most of the basins of the LEC region as shown in previous District studies, (Sculley, 1986). Average monthly rainfall variability is shown in **Figure II-2**. In general, approximately two-thirds of the annual rainfall occurs during the wet season months (June - October) and one-third of the annual rainfall occurs during the dry season months (November-May) when the demand for supplemental surface water are the highest (Sculley, 1986)

Table II-1 shows the historical averages (mean), maximums and minimums for annual, wet and dry seasons rainfall for the major basins of the Lower East Coast region for the period from 1915 to 1985. These numbers indicate some spatial variability of rainfall i.e. the inland areas receive significantly less rainfall than the coastal areas. Lake Okeechobee receives an annual average of 44.8 inches and the Water Conservation Areas 45.2 inches, while the Lower East Coast coastal area receives an annual average of 58.3 inches. The same pattern can be observed on the extremes in which the LEC developed area received a maximum of 103 inches in 1947 and had received more than 70 inches 15 times since 1915 while Lake Okeechobee received a maximum of 58 inches. On the low side, the annual minimum for the Lower East Coast developed area has been 40 inches while in Lake Okeechobee it has been 29 inches. The rainfall patterns show more spatial variability during the wet season than in the dry season.

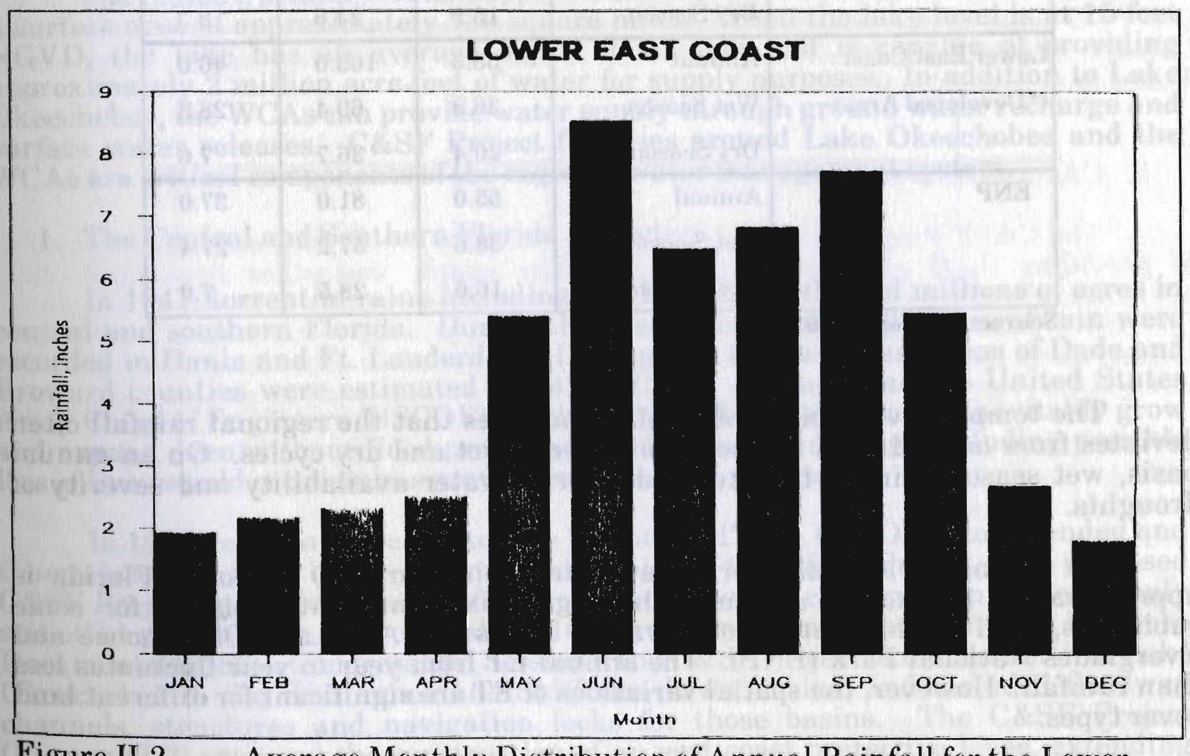

Figure II-2. Average Monthly Distribution of Annual Rainfall for the Lower East Coast Developed Area, 1915-1985. (Source: Sculley, 1986.)

Table II-1. Average Annual and Seasonal Rainfall Maximums and Minimums, 1915-1985 (inches).

Mean	Rainfall Period	Mean	Max.	Min.
Lower East Coast	Annual	51.9	77.5	36.7
(Total Region)	Wet Season	34.5	53.5	23.4
	Dry Season	17.4	30.9	7.3
Lake Okeechobee	Annual	44.8	58.0	29.0
	Wet Season	28.4	45.3	17.1
	Dry Season	16.4	28.5	7.1
EAA	Annual	52.9	79.0	37.0
	Wet Season	35.2	53.1	22.6
	Dry Season	17.7	37.1	6.6
WCAs	Annual	45.2	61.7	37.0
	Wet Season	30.1	39.1	18.2
	Dry Season	15.9	24.6	8.3
Lower East Coast	Annual	58.3	103.0	40.0
(*Developed Area)	Wet Season	36.9	69.4	28.3
	Dry Season	20.4	36.7	7.6
ENP	Annual	55.0	81.0	37.0
	Wet Season	38.6	57.2	27.4
	Dry Season	16.6	28.5	7.0

Source: Sculley, 1986.

The temporal variability of rainfall indicates that the regional rainfall often deviates from normal with frequent, multi-year wet and dry cycles. On an annual basis, wet season rainfall is a key indicator of water availability and severity of droughts.

An estimated annual average evapotranspiration (ET) in South Florida is approximately 34 inches, although this figure is significantly higher for some subbasins, such as the Water Conservation Areas (WCAs), Lake Okeechobee and Everglades National Park (ENP). The annual ET from year to year fluctuates less than rainfall. However, the spatial variations of ET are significant for different land cover types.

B. SURFACE WATER RESOURCES

Prior to development, the majority of the study area was characterized by low-lying, flooded lands that were not suitable for agricultural, industrial, or residential use. Water management activities in this region were necessary to provide drainage, flood protection, and water supply. The Central and Southern Florida Project for Flood Control and Other Purposes (C&SF Project) (**Figure II-3**) was designed, built and operated to meet these objectives.

Surface water inflows, outflows and storage are directly dependent upon regional rainfall. Therefore, surface flows and storage in this region are regulated to increase the beneficial use of the water resources. The major storage areas in the region are the WCAs and Lake Okeechobee, the second largest freshwater lake within the coterminous United States. Storage in these areas is replenished by direct rainfall and runoff generated in adjacent basins that discharge to storage areas through a network of canals, water control structures and pump stations. The amount of stored water is of critical importance to both the natural ecosystems and the developed areas in this region. Management of regional storage capacity involves recognizing and resolving the sometimes conflicting objectives of flood control, water supply and environmental enhancement. For example, the volume of water in storage may be reduced for flood protection or environmental enhancement. If this reduction is followed by a period of deficient rainfall, a water shortage condition may result.

The region's primary water supply reservoir is Lake Okeechobee. The lake has a surface area of approximately 730 square miles. When the lake level is at 15 feet NGVD, the lake has an average depth of ten feet and is capable of providing approximately 2 million acre-feet of water for supply purposes. In addition to Lake Okeechobee, the WCAs can provide water supply through ground water recharge and surface water releases. C&SF Project facilities around Lake Okeechobee and the WCAs are critical components of the regional water management system.

1. The Central and Southern Florida Project

In 1947, torrential rains including two hurricanes flooded millions of acres in central and southern Florida. During that year more than 100 inches of rain were recorded in Dania and Ft. Lauderdale. Damages to the east coast areas of Dade and Broward counties were estimated at $42 million. At that time the United States Army Corps of Engineers (USCOE) concluded that those areas would inevitably grow and expand even without flood protection, and extensive damage including possible loss of lives would occur unless preventive measures were taken.

In 1948, less than a year after the "great flood", the USCOE recommended and Congress authorized the design and construction of the C&SF Project. The proposed C&SF Project included elements for flood control, water conservation, water supply and other purposes for an area of about 16,000 square miles. It was outlined in House Document 643, 80th Congress 2nd Session. The C&SF Project extended north of Lake Okeechobee to the Kissimmee and St. Johns River basins, and included floodway channels, structures and navigation locks for those basins. The C&SF Project (**Figure II-3**) proposed the construction of an east coast protective levee, extending more than 100 miles from southwest Miami to Lake Okeechobee near the St. Lucie Canal. The C&SF Project also included the construction of three WCAs in Palm Beach, Broward and Dade counties to be used for water impoundment and other purposes in the Everglades west of the east coast protective levee, with water control structures to allow transfer of water as necessary.

Also included in the C&SF Project were additional levees, canals, spillways, pump stations and dams; the enlargement of portions of the Miami, North New River, Hillsboro and West Palm Beach canals; the construction of new levees and canals on the northeast and northwest shores of Lake Okeechobee and enlargement and rebuilding of existing levees. The C&SF Project provided increased outlet capacity for Lake Okeechobee by widening and deepening the Caloosahatchee River and making improvements to the St. Lucie Canal.

In order to build the C&SF Project, a local sponsor was required. In 1949 the Florida Legislature created the Central and Southern Florida Flood Control District (FCD) to act as the local sponsor of the C&SF Project and was charged with the responsibility of operating and maintaining those C&SF Project facilities not retained by the USCOE. The FCD was set up as a Special Taxing District to represent the state and all local interests in the building, local financing and operating of the C&SF Project. The cost of the C&SF Project was estimated at $208 million with the local financing of the C&SF Project to be 15 percent of the construction cost plus land easements and rights of way. The majority of the existing C&SF Project was constructed between 1950 and 1975. Certain portions of the originally authorized project were never built because the Corps and the District did not find reasonable benefits to justify the additional expenses. Those portions are designated in green in **Figure II-3**. As a result of the Water Resources Act of 1972, the FCD became the South Florida Water Management District (SFWMD) with broader responsibilities, slightly different boundaries and an increase in Governing Board members from five to nine.

2. C&SF Project Objectives

The C&SF Project was originally designed as a multi-purpose project capable of providing flood protection, drainage, water supply and other benefits to the agricultural area adjacent to Lake Okeechobee and the rapidly urbanizing basins of the Lower East Coast of Florida. It was designed to provide water control and water conservation in the WCAs. In addition, it was intended to provide salinity control, navigation improvements, preservation of fish and wildlife and recreational benefits.

Flood Protection. One major design feature of the C&SF Project was to provide flood control and drainage to agricultural and urban areas in central and southern Florida. The design level of flood protection varies with land use and location. In the Everglades Agricultural Area (EAA) and other agricultural areas the criterion was to remove 3/4 inch of stormwater runoff per day. This was equivalent to a flood protection frequency of once-in-5 to once-in-10 years. Most of the urban areas were designed for the removal of a once-in-10 years frequency peak discharge, although in some areas the flood protection design was significantly higher, ranging from once-in-25 to once-in-100 years flood frequencies. Recent increases in urbanization particularly in the coastal areas have reduced some of the C&SF Project capabilities to meet the flood protection design frequencies.

Water Supply. The water supply capabilities of the C&SF Project are vitally important to the region's agricultural enterprises and the urban population centers. **Figure II-4** shows the water supply flow distribution of the C&SF Project. Lake Okeechobee has a capability of providing an average of 350,000 to 450,000 acre feet of

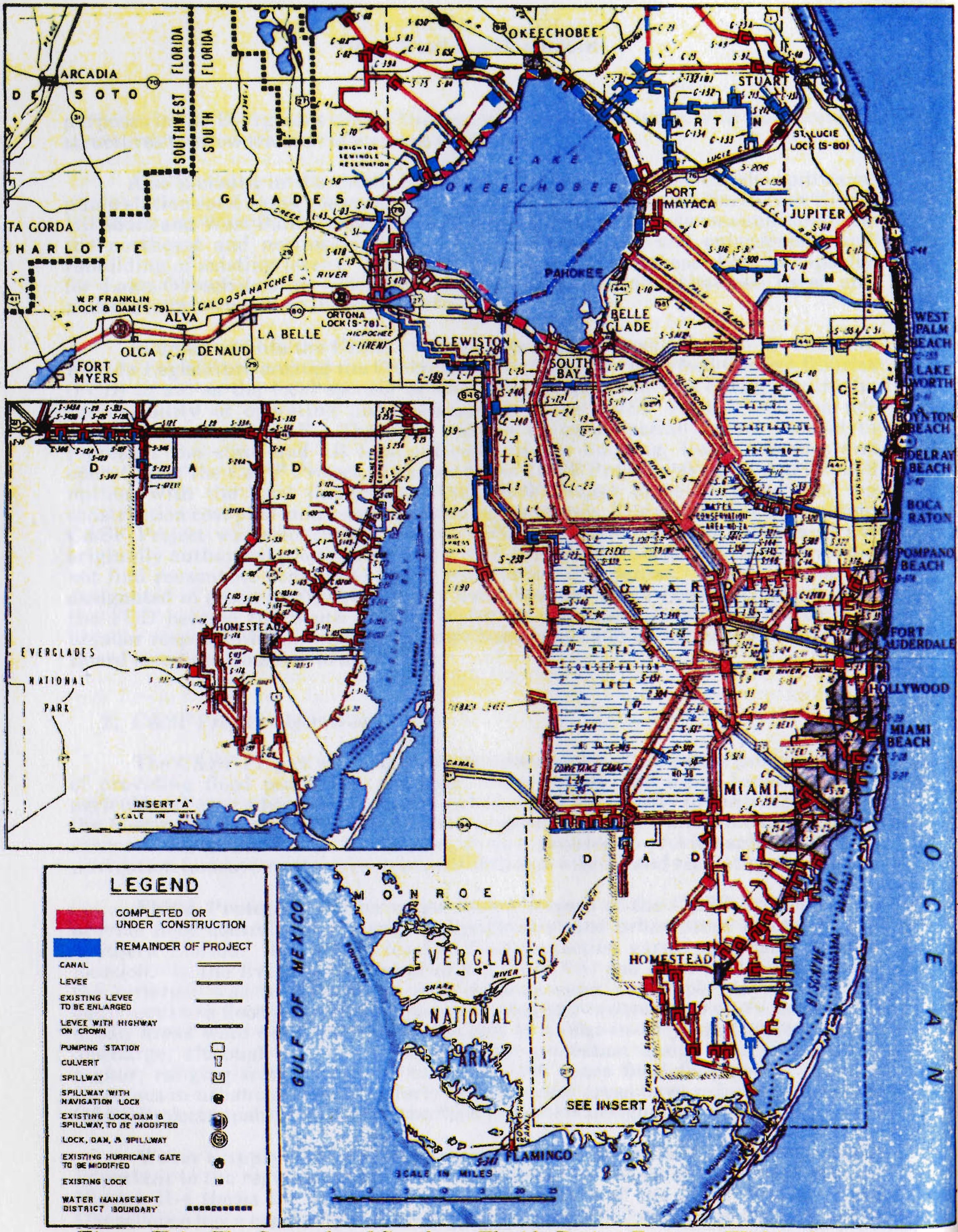

Figure II-3. The Central and Southern Florida Project Features Within the Planning Area.
(Source: Modified from U.S. Army Corps of Engineers.)

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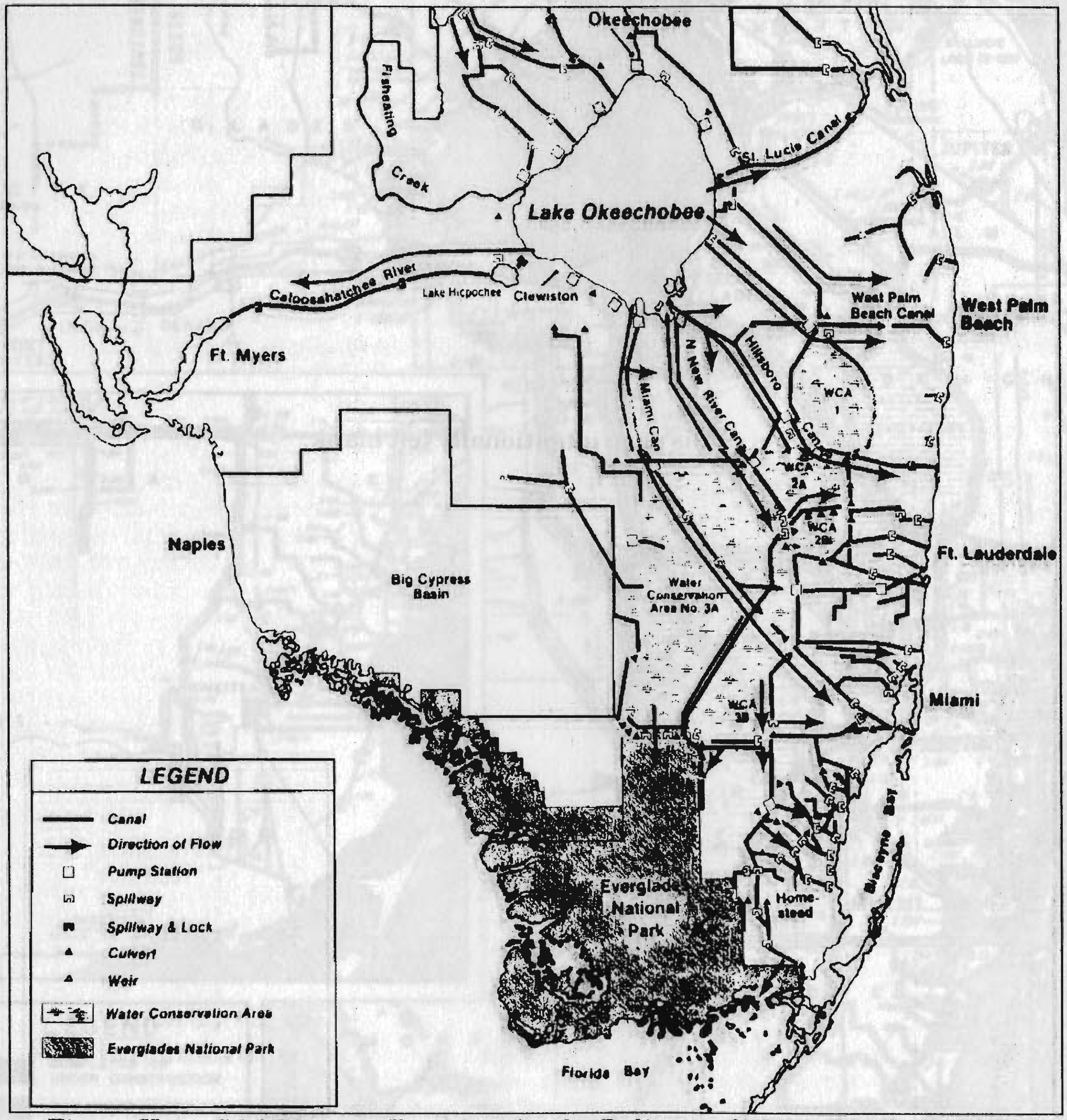


Figure II-4. C&SF Project Facilities for the Delivery of Water Supply.
Source: SFWMD.

water per foot of storage. It provides the majority of the supplemental water supply of the EAA and serves as a backup water supply for the Lower East Coast basins and ENP, particularly late in the dry season and in times of drought. The WCAs provide surface water supply for the coastal basins and for ENP and contribute to recharging the surficial aquifer through ground water seepage. Although the coastal basins use primarily ground water for supply, the surface water system makes critical contributions to protect and recharge some of the coastal wellfield facilities.

Salinity Control. Mitigating the inland migration of saline water was a purpose cited in the design of the C&SF Project. Eastern sections of the surficial aquifer are threatened by salt water contamination, including areas served by coastal canals. In spite of the coastal structures that serve as barriers to the inland seawater movement, leakages and underground flow contributes to the movement of saline water upstream of the structures. Likewise, upward movement of the salt water interface can contaminate coastal wellfield facilities. Keeping fresh water canals at their design levels reduces the threat of salt water contamination.

Navigation Improvements. The C&SF Project made improvements to the Okeechobee Waterway by dredging the Caloosahatchee River and St. Lucie Canal to a minimum depth of eight feet. This work allowed navigation from the Atlantic Ocean to the Gulf of Mexico through Lake Okeechobee. Navigation locks were installed in both the Caloosahatchee River and the St. Lucie Canal. Many of the C&SF Project canals can serve as useful waterways for small craft.

Preservation of Fish and Wildlife and Recreation. Even though the C&SF Project was primarily a flood control and water supply project, it took into consideration the recommendations of the U.S. Fish and Wildlife Service to leave large areas of the original Everglades in their natural state for preservation of fish and wildlife. Recreational boating, fishing and hunting are important factors in the economic benefits of the region. The C&SF Project anticipated the enhancement of the recreational activities in the area.

3. Operation of Regional C&SF Project Features.

The C&SF Project facilities includes six major water storage areas, 1,500 miles of canals and levees, 125 major water control structures, 18 major pumping stations, and several hundred minor structures. The system is generally operated to provide flood protection during the wet season by placing water into storage and discharging excess water to the ocean, and to supply water from storage in the dry season for agricultural irrigation, plus urban and environmental purposes. Regulation schedules for the WCAs and Lake Okeechobee allow for the highest water levels at the beginning of the dry season to provide maximum water supply. By the beginning of the wet season, water levels are at their minimum to make storage available for wet season rainfall.

Water Conservation Areas. The WCAs are water storage areas created as part of the C&SF Project by the construction of levees in the upper region of the Everglades. These areas were intended to serve as flood and water supply storage areas while preserving some of the environmental characteristics of the Everglades. The high transmissivity rates of areas east of the WCAs produce large volumes of seepage out of the WCAs, allowing for ground water recharge, but limiting the water storage capabilities. There are three major water conservation areas, of which two have been subdivided in to "A" and "B" units for water management purposes.

Water Conservation Area 1 (WCA-1) has been designated the Arthur R. Marshall Loxahatchee National Wildlife Refuge. It has a surface area of 221 square miles. The state leases WCA-1 to the U.S. Fish and Wildlife Service for environmental management. The area receives surface water from Lake Okeechobee and the EAA through the S-5A pump station in the north and the S-6 pump station in the southwest. It has the capability to release water downstream to WCA-2A through a set of water control facilities known as the S-10 structures and to the east through the S-39 structure in the Hillsboro Canal.

Water Conservation Area 2 (WCA-2) has been subdivided into two units, WCA-2A and WCA-2B. WCA-2A has a surface area of 173 square miles and WCA-2B has a surface area of 37 square miles. Both WCA-2A and WCA-2B hold relatively small amounts of surface water storage, although seepage from these areas recharges the Broward County portion of the Biscayne Aquifer. These areas also can discharge water to WCA-3A through a set of water control facilities known as the S-11 structures. WCA-2 is linked to Lake Okeechobee via the North New River Canal. It receives stormwater from the EAA via the North New River Canal and the S-7 pump station. It has been leased for environmental management to the Florida Game and Fresh Water Fish Commission (FGFWFC). WCA-2A can discharge water to the coast through the S-38 in the North New River Canal.

The largest of the WCAs is Water Conservation Area 3 (WCA-3) which also has been subdivided into two units, WCA-3A and WCA-3B. WCA-3A has a surface area of 787 square miles and is located immediately north of ENP. Adjacent to WCA-3A is WCA-3B with a surface area of 128 square miles. These are leased for environmental management to the FGFWFC. WCA-3A provides water to the ENP through the S-12 and S-333 structures. WCA-3A provides surface water supply during the dry season and during drought periods to the coastal communities in Dade County, and also contributes water to maintain proper canal levels in the South Dade Conveyance System. WCA-3B recharges the Biscayne Aquifer in Dade County through seepage.

Within WCA-3A the Miccosukee Indian Tribe has a perpetual lease on 189,000 acres. The Tribe has rights to hunt, fish, frog, farm and build traditional residences. Nearly all of the Tribe's 500 members live along Tamiami Trail adjacent to the southern boundary of WCA-3A on a 333-acre strip of land leased from the National Park Service.

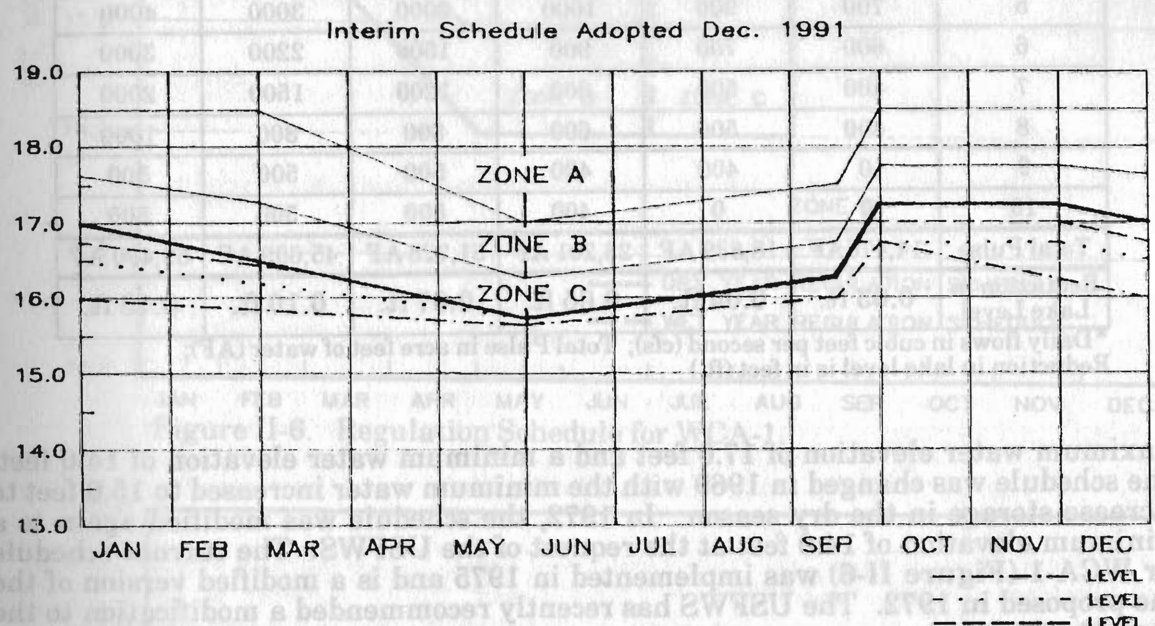
WCA-3A receives surface water inflows from Lake Okeechobee through the Miami Canal. Pump station S-8 discharges drainage water from the EAA into WCA-3A, which also receives surface water from the S-140 and S-9 pump stations.

Regulation Schedules. The water bodies in the C&SF Project are managed using regulation schedules. These schedules, referenced to NGVD, have been developed according to the management objectives for each area. These schedules have been modified from time to time to better manage the resources of these areas. However, there are flood control constraints which establish the maximum water levels that can be held in a given area at certain times. These flood control constraints cannot be violated without risking the integrity of the levees surrounding the areas and the water control structures that discharge water out of those areas. The established maximum water levels cannot be increased without additional structural modifications

The regulation schedules for Lake Okeechobee and the WCAs have changed several times since the construction of the project. The lake has been regulated from a relatively low schedule (12.5 to 14.5 feet) in the late 1940s to a relatively high schedule (15.5 to 17.5 feet) from 1978 to 1992. In 1991, the SFWMD proposed modification to the schedule to allow for multiple zones to better manage the releases to the St. Lucie and Caloosahatchee estuaries. This schedule (15.75 to 17.25 feet, also known as Run 25) was adopted by the USCOE in 1992 and is shown in **Figure II-5**.

Included in this schedule is a zone to reduce long duration, high volume discharges to the estuaries. In this zone, pulse releases are made while the lake level is rising, but before the level reaches the high discharge zone. This action is designed to emulate a natural rainfall event and minimize the chance of the lake reaching the high discharge zone. Table II-2 gives the current schedule of pulse releases from Lake Okeechobee for the Caloosahatchee and St. Lucie estuaries. A more detailed description of the history of Lake Okeechobee regulation schedules can be found in Trimble and Marban (1988).

The WCAs regulation schedules have been modified to better manage the natural resources of the remaining Everglades. The current schedule for WCA-1 is the third schedule used since its completion in 1960. The original schedule had a



Releases Through Outlets

Zone	Agricultural Canals	Caloosahatchee River	St. Lucie Canal
A	Pump maximum practicable to WCAs	Up to maximum capacity at S−77	Up to maximum capacity at S−80
B	Maximum practicable to WCAs	6500 cfs	3500 cfs
C	Maximum practicable to WCAs	4500 cfs	2500 cfs
LEVELS I,II & III	Maximum practicable to WCAs	See Table II-2	See Table II-2

Figure II-5. Regulation Schedule for Lake Okeechobee.

Table II-2. Pulse Release Program for the St. Lucie and Caloosahatchee Estuaries and Its Impact on Lake Okeechobee Water Levels.*

Day	St. Lucie Level I	St. Lucie Level II	St. Lucie Level III	Caloosa Level I	Caloosa Level II	Caloosa Level III
1	1200	1500	1800	1000	1500	2000
2	1600	2000	2400	2800	4200	5500
3	1400	1800	2100	3300	5000	6500
4	1000	1200	1500	2400	3800	5000
5	700	900	1000	2000	3000	4000
6	600	700	900	1500	2200	3000
7	400	500	600	1200	1500	2000
8	400	500	600	800	800	1000
9	0	400	400	500	500	500
10	0	0	400	500	500	500
Total Pulse	14,476AF	18,839 AF	23,201 AF	31,728 AF	45,609 AF	59,490 AF
Reduction in Lake Level	0.03 ft.	0.04 ft.	0.05 ft.	0.07 ft.	0.10 ft.	0.13 ft.

*Daily flows in cubic feet per second (cfs); Total Pulse in acre feet of water (AF); Reduction in lake level is in feet (ft.)

maximum water elevation of 17.0 feet and a minimum water elevation of 14.0 feet. The schedule was changed in 1969 with the minimum water increased to 15.0 feet to increase storage in the dry season. In 1972, the schedule was modified again to a minimum elevation of 14.0 feet at the request of the USFWS. The current schedule for WCA-1 (**Figure II-6**) was implemented in 1975 and is a modified version of the one proposed in 1972. The USFWS has recently recommended a modification to the current schedule.

The regulation schedule in WCA-2A has been modified once, although two controlled, experimental drawdowns were conducted prior to the schedule change. The original schedule proposed by the USCOE when the area was built had a maximum water level of 14.5 feet and a minimum of 13.0 feet. The existing schedule, which ranges from a maximum of 13.0 feet and a minimum of 11.0 feet, was adopted by the USCOE in 1987. This schedule, shown in **Figure II-7**, seems to resemble the water levels that existed in the area prior to the construction of the project and provides significant environmental benefits (Worth, 1988).

The WCA-3A regulation schedule was recently modified from the original schedule which ranged from a minimum level water of 9.5 ft. NGVD to a maximum level water of 10.5 ft NGVD. The present schedule shown in **Figure II-8** has multiple zones in order to facilitate the implementation of the rainfall delivery formula for the ENP. This schedule was adopted by the USCOE in 1985.

WCA-2B and WCA-3B have regulation schedules with upper limits beyond which regulatory releases must be made. Those levels are 11.0 feet for WCA-2B and 9.0 feet for WCA-3B.

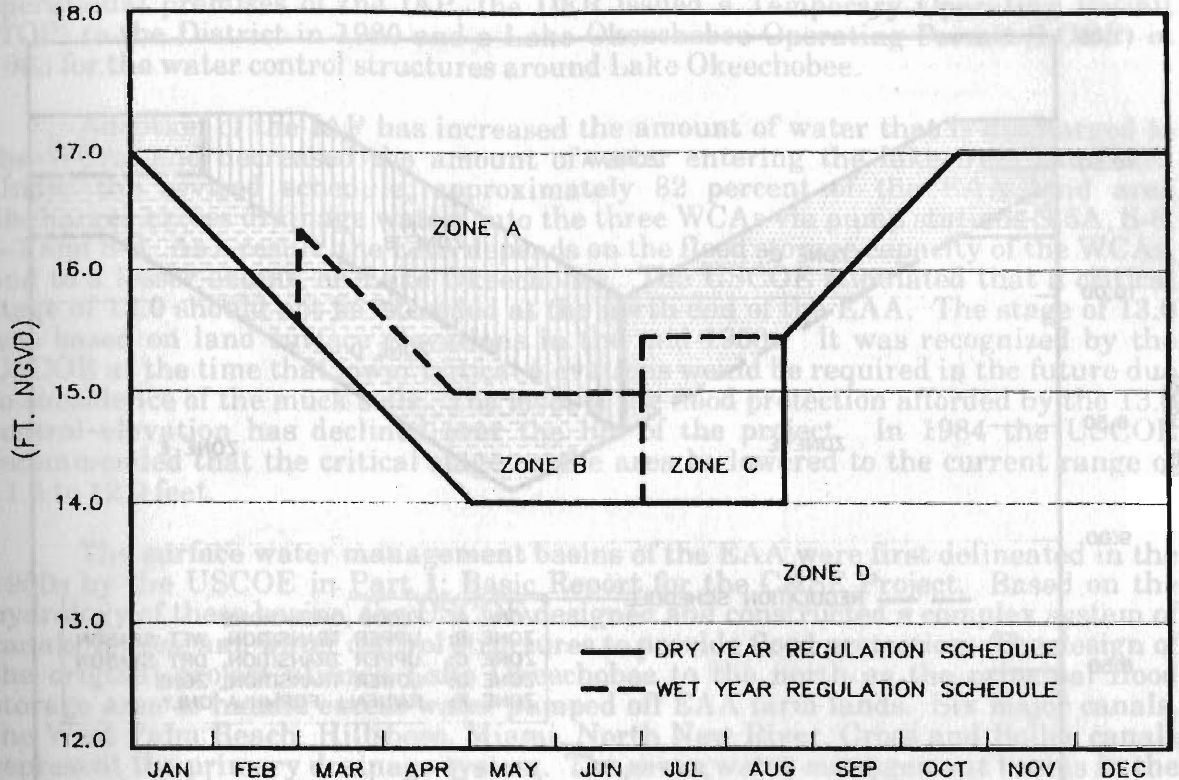


Figure II-6. Regulation Schedule for WCA-1.

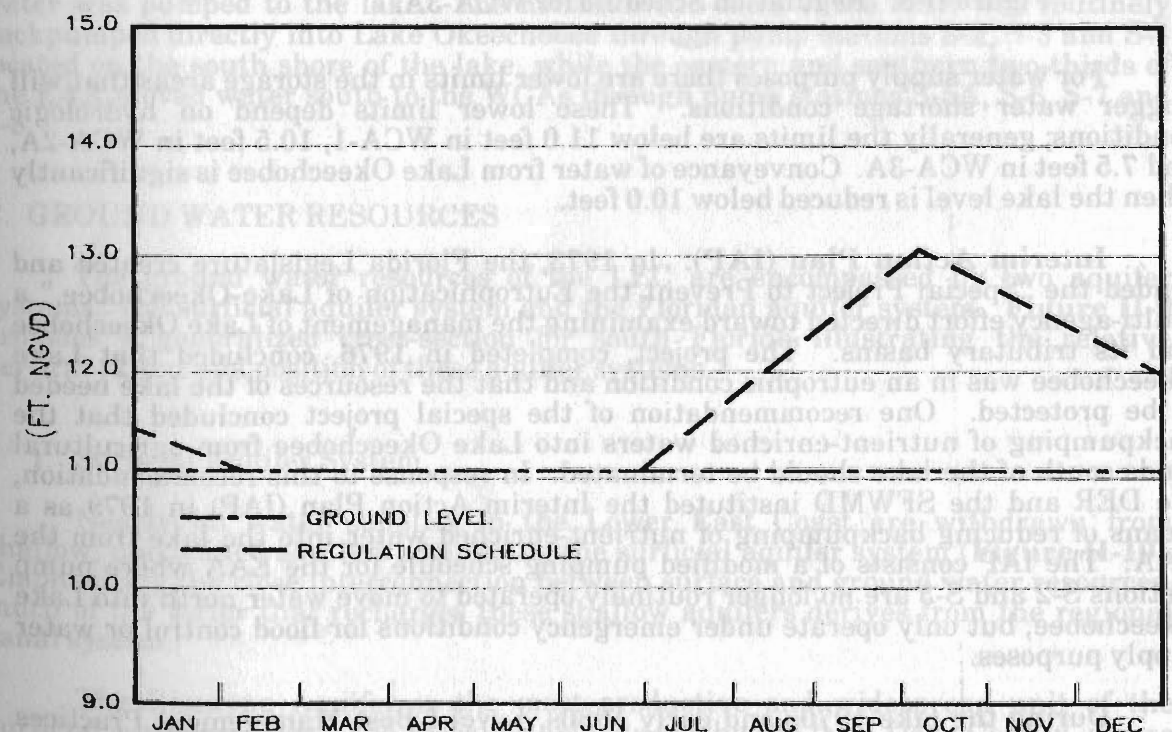


Figure II-7. Regulation Schedule for WCA-2A.

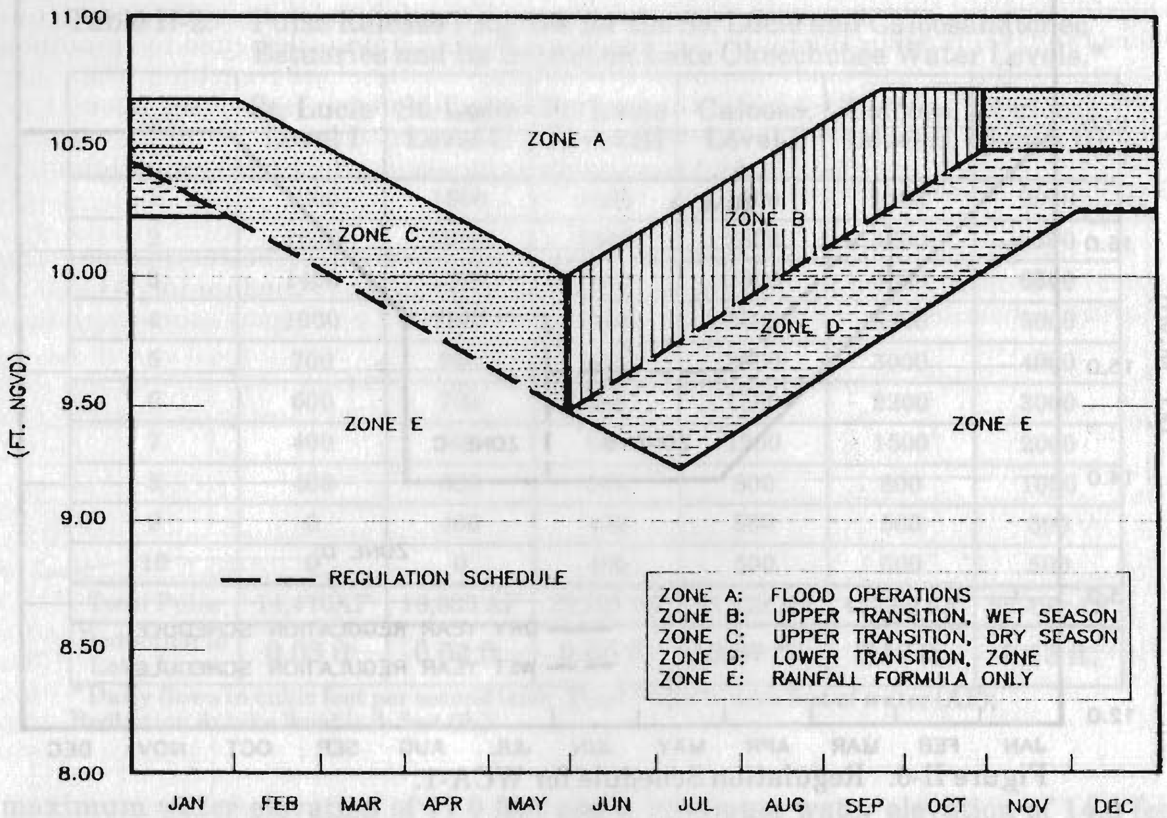


Figure II-8. Regulation Schedule for WCA-3A.

For water supply purposes there are lower limits in the storage areas that will trigger water shortage conditions. These lower limits depend on hydrologic conditions; generally the limits are below 11.0 feet in WCA-1, 10.5 feet in WCA-2A, and 7.5 feet in WCA-3A. Conveyance of water from Lake Okeechobee is significantly when the lake level is reduced below 10.0 feet.

Interim Action Plan (IAP). In 1973, the Florida Legislature created and funded the "Special Project to Prevent the Eutrophication of Lake Okeechobee," a multi-agency effort directed toward examining the management of Lake Okeechobee and its tributary basins. The project, completed in 1976, concluded that Lake Okeechobee was in an eutrophic condition and that the resources of the lake needed to be protected. One recommendation of the special project concluded that the backpumping of nutrient-enriched waters into Lake Okeechobee from agricultural lands south of the lake should be terminated. In response to this recommendation, the DER and the SFWMD instituted the Interim Action Plan (IAP) in 1979 as a means of reducing backpumping of nutrient-enriched water into the lake from the EAA. The IAP consists of a modified pumping schedule for the EAA where pump stations S-2 and S-3 are no longer routinely operated to move water north into Lake Okeechobee, but only operate under emergency conditions for flood control or water supply purposes.

During the lake 1970s and early 1980s, Level I Best Management Practices (BMPs) in the Taylor Creek/Nubbin Slough basins and nutrient loading criteria for the lake and its tributaries were developed and implemented. Based on the operational premises of the IAP, the DER issued a Temporary Operating Permit (TOP) to the District in 1980 and a Lake Okeechobee Operating Permit (LOOP) in 1983 for the water control structures around Lake Okeechobee.

Adoption of the IAP has increased the amount of water that is discharged to the WCAs and decreased the amount of water entering the lake from the EAA. Under the revised schedule, approximately 82 percent of the EAA land area discharges excess drainage waters into the three WCAs via pump stations S-5A, S-6, S-7 and S-8. As a result, the EAA depends on the flood storage capacity of the WCAs, and to a lesser extent, on Lake Okeechobee. The USCOE stipulated that a critical stage of 13.0 should not be exceeded at the north end of the EAA. The stage of 13.0 was based on land surface elevations in the mid-1950s. It was recognized by the USCOE at the time that lower critical elevations would be required in the future due to subsidence of the muck soils. The level of the flood protection afforded by the 13.0 control elevation has declined over the life of the project. In 1984 the USCOE recommended that the critical stage on the area be lowered to the current range of 11.5 to 12.0 feet.

The surface water management basins of the EAA were first delineated in the 1950s by the USCOE in Part 1: Basic Report for the C&SF Project. Based on the hydrology of these basins, the USCOE designed and constructed a complex system of canals, levees, and water control structures to provide flood protection. The design of the original project utilized Lake Okeechobee to the north as the principal flood storage area to handle excess water pumped off EAA farm lands. Six major canals, the West Palm Beach, Hillsboro, Miami, North New River, Cross and Bolles canals represent the primary drainage system. The seven water management basins in the EAA are named after the major pump station which drains each basin. Prior to adoption of the IAP, under normal operational procedures, significant EAA excess water was pumped to the lake. The northern one-third of the EAA was routinely backpumped directly into Lake Okeechobee through pump stations S-2, S-3 and S-4 located on the south shore of the lake, while the eastern and southern two-thirds of the EAA moved water south to the WCAs through pump stations S-5A, S-6, S-7 and S-8.

C. GROUND WATER RESOURCES

The ground water resources of the LEC are encompassed by two aquifer systems: the surficial aquifer system and the Floridan aquifer system. **Figure II-9** provides a generalized cross-section for south Florida illustrating the relative vertical extent and position of these aquifer systems.

1. Surficial Aquifer System

Nearly all water supplies in the Lower East Coast are withdrawn from shallow, unconfined aquifers comprising the surficial aquifer system (**Figure II-10**). Emphasizing the close interconnection between surface and ground water resources, much of the water that recharges these shallow aquifers derives from the regional canal system.

The Biscayne Aquifer is the most productive and widespread unit of the surficial aquifer system. The Biscayne extends northward from Dade County, where its permeability is highest, into Broward and the southern and central parts of Palm

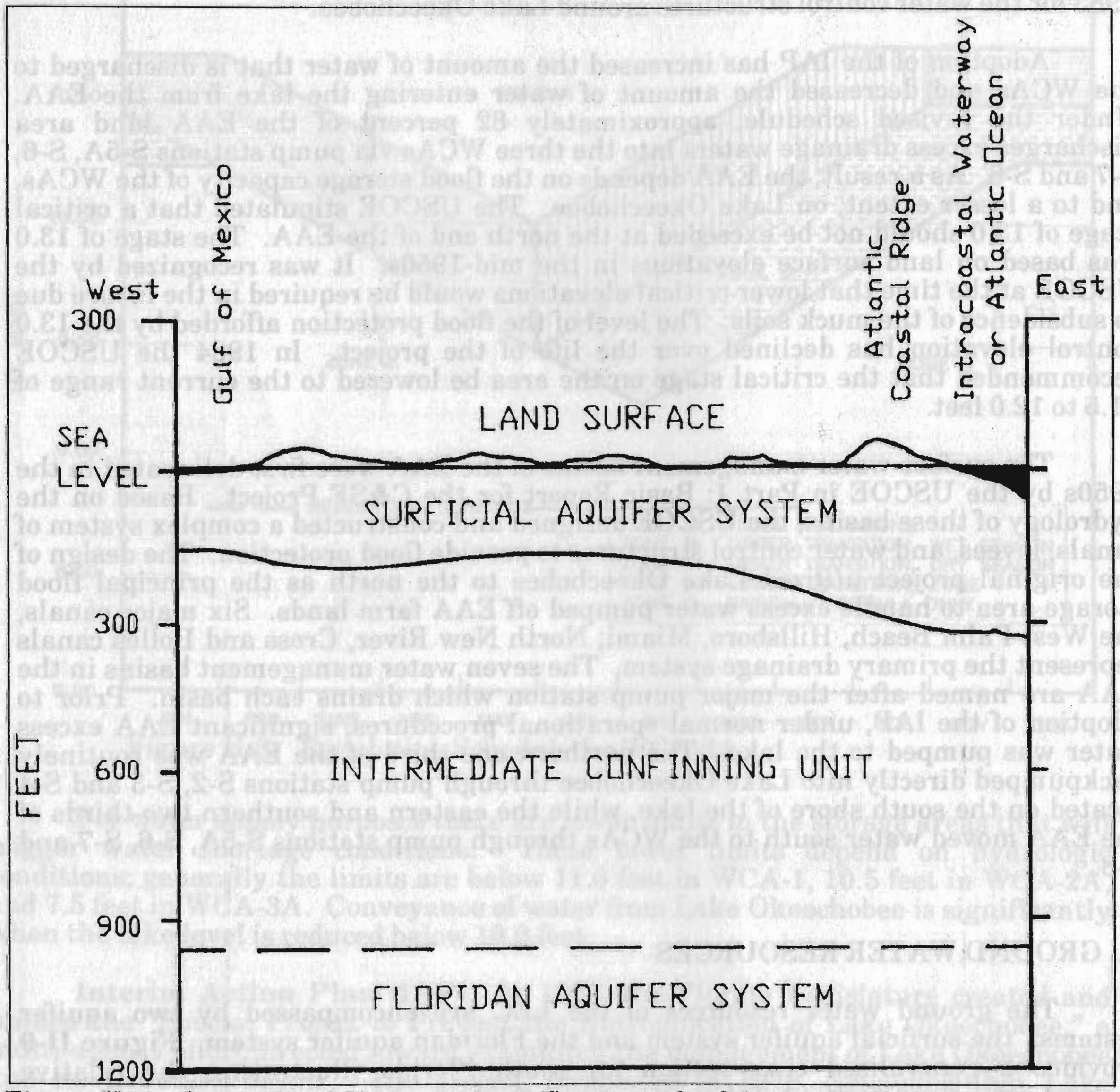


Figure II-9. Generalized Hydrogeologic Framework of the Lower East Coast.

Beach County. Solution-riddled limestones constitute the principal water-yielding zones within the Biscayne.

In areas where the Biscayne is absent, ground water is derived from variable water-yielding units of the surficial aquifer system. These units are composed predominantly of sand and their permeability is less than that of the Biscayne aquifer. The most productive of these units occur in the central and northern parts of eastern Palm Beach County.

The ground water within the more permeable units of the surficial aquifer is generally low in mineral content and salinity. By contrast, ground water from the lower permeability units in the northwestern part of the LEC region is generally very

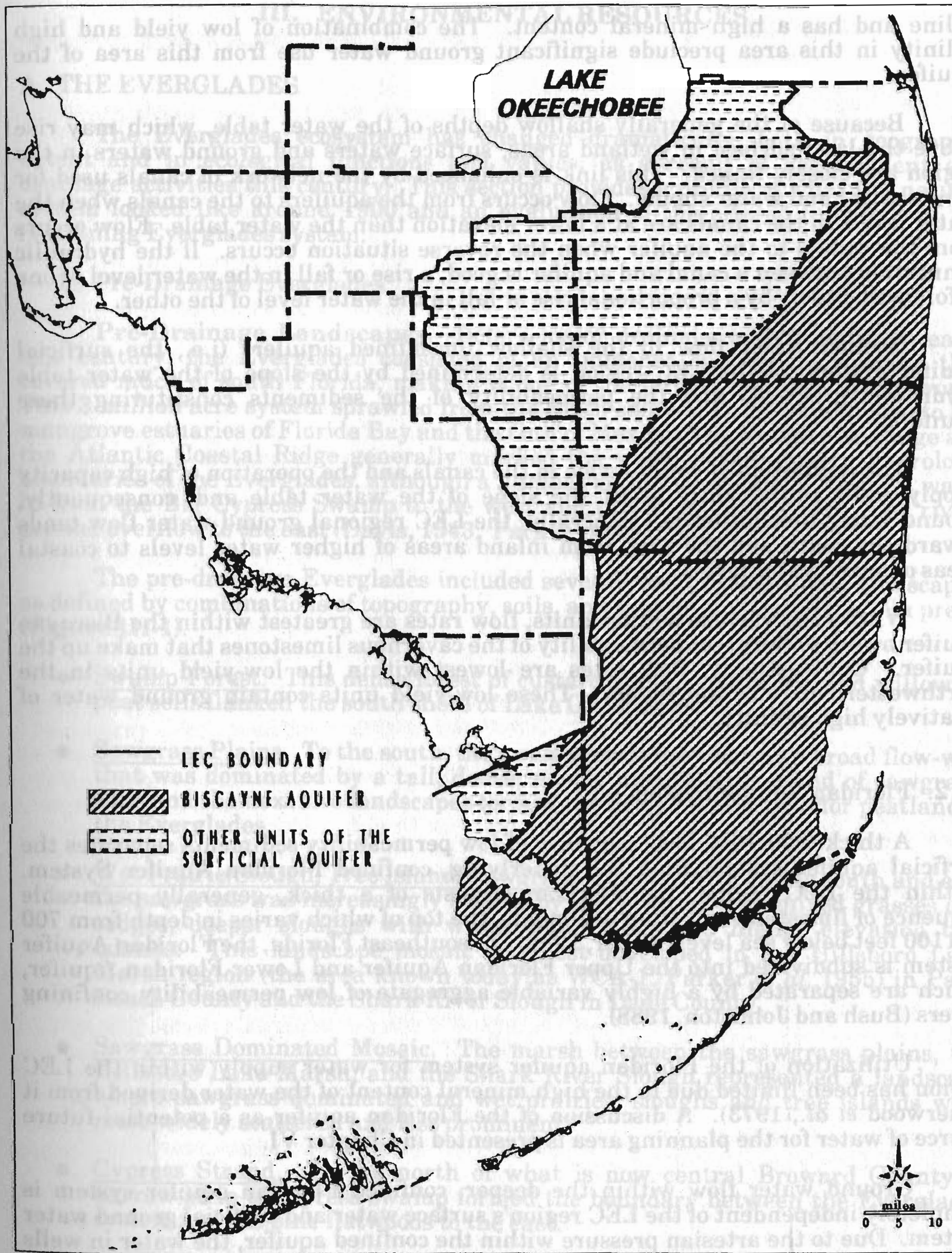


Figure II-10. Units of the Surficial Aquifer System within the Lower East Coast Study Area.

saline and has a high mineral content. The combination of low yield and high salinity in this area preclude significant ground water use from this area of the aquifer.

Because of the generally shallow depths of the water table, which may rise above the land surface in wetland areas, surface waters and ground waters in the region are closely linked. This link is enhanced by the network of canals used for flood control and water supply. Flow occurs from the aquifers to the canals when the water levels in the canals are at a lower elevation than the water table. Flow occurs from the canals to the aquifer when the reverse situation occurs. If the hydraulic connection between a canal and aquifer is good, a rise or fall in the water level of one is followed closely by a proportional rise or fall in the water level of the other.

Ground water flow in the shallow unconfined aquifers (i.e., the surficial aquifer system) of the LEC region is determined by the slope of the water table (hydraulic gradient) and the permeability of the sediments constituting these aquifers.

The regulation of water levels in the canals and the operation of high capacity supply wells significantly affect the slope of the water table and, consequently, ground water flow patterns. Generally, the LEC regional ground water flow tends toward the south and the east, from inland areas of higher water levels to coastal areas of lower water levels.

Within the various aquifer units, flow rates are greatest within the Biscayne aquifer owing to the great permeability of the cavernous limestones that make up the aquifer. Contrastingly, flow rates are lowest within the low-yield units in the northwestern part of the region. These low-yield units contain ground water of relatively high salinity.

2. Floridan Aquifer System

A thick (800-1000 foot) sequence of low permeability sediments separates the surficial aquifer system from the underlying, confined Floridan Aquifer System. Within the LEC region, the Floridan consists of a thick, generally permeable sequence of limestone and other sediments, the top of which varies in depth from 700 to 1100 feet below sea level (Miller, 1986). In southeast Florida, the Floridan Aquifer System is subdivided into the Upper Floridan Aquifer and Lower Floridan Aquifer, which are separated by a highly variable aggregate of low permeability confining layers (Bush and Johnston, 1988).

Utilization of the Floridan aquifer system for water supply within the LEC region has been limited due to the high mineral content of the water derived from it (Sherwood *et al.*, 1973). A discussion of the Floridan aquifer as a potential future source of water for the planning area is presented in Chapter VI.

Ground water flow within the deeper, confined Floridan aquifer system is completely independent of the LEC region's surface water and surficial ground water system. Due to the artesian pressure within the confined aquifer, the water in wells drilled into the Floridan in the LEC region will flow naturally. However, the salinity of the water naturally occurring in this aquifer is too high for most uses.

III. ENVIRONMENTAL RESOURCES

A. THE EVERGLADES

The Everglades ecosystem has changed dramatically, both in geographic extent and in ecological functions and values, as a result of development and drainage activities this century. This section provides a profile of what the natural system looked like around 1900 and an evaluation of the altered functions of the remaining Everglades system.

1. Pre-Drainage Everglades

Pre-Drainage Landscapes. Before major drainage activities began early this century, the Everglades consisted of an immense subtropical wetland that covered much of south Florida, making it one of the largest marshes in the world. This 3 million acre system sprawled from the south shore of Lake Okeechobee to the mangrove estuaries of Florida Bay and the Gulf of Mexico. The Immokalee Ridge and the Atlantic Coastal Ridge generally marked the western and eastern hydrologic boundaries of the Everglades, although a number of flow connections brought water in from the Big Cypress Swamp to the west and the Miami and North New rivers carried overflow to the east (Davis, 1943; Parker *et al.*, 1955).

The pre-drainage Everglades included seven broad physiographic landscapes, as defined by combinations of topography, soils, and vegetation (Davis *et al.*, in press) **(Figure III-1)**.

- Swamp Forest. This dense forest of custard apple, elderberry, and willow on peat soils flanked the south shore of Lake Okeechobee.
- Sawgrass Plains. To the south, the swamp forest opened into a broad flow-way that was dominated by a tall, dense, nearly monospecific stand of sawgrass. This and the next two landscapes formed the deeper-water interior peatland of the Everglades.
- Wet Prairie/Slough, Tree Island, Sawgrass Mosaic. Progressing south and east the sawgrass was increasingly broken by wet prairies with mixed grasses and sedges, deeper sloughs with white water lilies and higher elevation tree islands. This landscape mosaic was best developed in the Hillsboro Lake Marsh region (the area known today as WCA-1, Parker *et al.*,1955) in Palm Beach County and the Shark River Slough in Dade County.
- Sawgrass Dominated Mosaic. The marsh between the sawgrass plains, the Hillsboro Lake Marsh, and the Shark River Slough represented a landscape where sawgrass dominated and wet prairies, sloughs and tree islands were more widely scattered and less prominent.
- Cypress Strand. To the north of what is now central Broward County, a narrow strip of cypress swamp formed the boundary between the Everglades system and the pine flatwoods to the east.
- Peripheral Wet Prairies. These occurred on primarily sandy soils. The prairie community was interspersed with pine islands and cypress heads, forming a

diverse landscape that bordered both sides of the northern and central Everglades.

- Southern Marl-Forming Marsh. This was a highly diverse, low-stature marsh dotted with tree islands and tropical hammocks growing on marl and rocky soils to form a landscape that characterized the shallower and shorter-hydroperiod wetlands on either side of Shark River Slough and included the Taylor Slough basin. Places where limestone was exposed in the marsh were known as rocky glades.

Proceeding downstream into the transition zone between the freshwater Everglades and the marine environments of Florida Bay and the Gulf of Mexico, mangroves and other emergent salt-tolerant plants became increasingly abundant forming transitional estuarine forests and marshes through which tidal creeks and rivers flowed in branching patterns toward the bay and the gulf.

Ecosystem Size and Hydrology and Productivity. The Everglades landscapes have worked in concert to provide habitats and food chains that supported the lush diversity of plants and spectacular populations of animals, particularly wading birds, for which the system was known. The Everglades may have had relatively low densities of small food animals compared to other wetlands in southeastern North America (Loftus and Eklin, in press). It was, however, able to support vast populations of birds and other wildlife because of its immense size.

Flooding is essential to the productivity of the Everglades. Recent models of the hydrology of the pre-drainage Everglades support historical accounts of a much wetter system than is observed today (Johnson *et al.*, in press). The dense sawgrass of the northern Everglades apparently slowed the southward flow of water from rainfall and Lake Okeechobee overflow. The result appears to have been prolonged or continuous flooding in the peatlands currently in the Water Conservation Areas (WCAs) and Everglades National Park (ENP). Persistent pools of water remained during the dry seasons fed by gradual southerly flow of water accumulated during the wet season. Historical accounts also suggest that the Everglades may have only dried out during drought years (Johnson *et al.*, in press). Small fishes are an important food for wading birds and recent information shows that densities of small fish increase with the number of months of flooding, and highest densities are attained only after several years of continuous flooding (Loftus and Eklin, in press).

The peripheral wet prairies and the southern marl-forming marsh landscapes have always had relatively short periods of flooding and shallow water. The pre-drainage hydrology models suggest that annual hydroperiods were six to eight months during normal years, when the lower-elevation interior peatland remained continually flooded. While temporarily flooded marshes could not have maintained permanent fish populations, they would have been valuable wet-season habitat for fish. Data from ENP confirms that small fishes extensively and rapidly recolonize into reflooded marshes from adjacent pools or sloughs which they use as dry season refuges (Loftus and Eklin, in press).

The marl and rocky glades appear to have provided a critical support function for woodstorks and probably other wading birds because they were the first areas where the water levels receded to depths which concentrated fish. This enabled woodstorks and other wading birds to forage effectively at the beginning of the dry season, which in turn allowed the parent birds to begin nesting early, giving them adequate time to raise nestlings before the onset of summer rains, rising water levels, and dispersing food organisms. There is a direct correlation between nesting success and the early initiation of nesting (Ogden, in press).

Freshwater Flows to Estuaries. Mangrove estuaries are recognized as highly productive and critical environments that support coastal food chains and serve as marine nursery grounds (Heald, 1971; Odum,1971). Pre-drainage hydrology models suggest that annual freshwater flows to Florida Bay and Gulf of Mexico estuaries may have been much greater than they are today (Walters *et al.*, 1992). Studies of growth rings in coral in Florida Bay have been interpreted as supporting this idea (Smith *et al.*,1989). If such indirect evidence is correct, then the estuaries could originally have been more productive since fresh water inflows tend to prevent destructive high salinities and may have other beneficial effects.

Three wading bird nesting colonies in the Gulf mangrove zone near the mouth of the Shark River supported eighty percent of the total breeding population of wading birds in the Everglades in the 1930s. The majority of these birds nested in the Rookery Branch colony located directly at the mouth of the Shark River. The success and importance of these colonies are hypothesized to have been the result of the availability of two nearby feeding grounds - the highly productive estuary and a persistent freshwater pool a short distance upstream in lower Shark River Slough. Both the productivity of the estuary and the persistence of the freshwater pool were enhanced by overflow from the Everglades (Ogden, in press).

2. The Everglades of Today

Present Landscapes. Drainage and development in this century have reduced the Everglades by half. Three of the seven physiographic landscapes have been nearly eliminated. **(Figure III-1)** The swamp forest along the southern shore of Lake Okeechobee was cleared for agriculture. The peripheral wet prairies and the eastern cypress strand have undergone agricultural and urban development to the point that only isolated patches remain. The deep Everglades peat of the sawgrass plain was converted to the productive crop lands of the Everglades Agricultural Area (EAA). Undeveloped remnants of the sawgrass plain lie mostly within the Holey Land and Rotenberger tracts and northeastern WCA-3A. Urban encroachment has replaced almost half of the sawgrass dominated mosaic; what remains is primarily in WCA-2A, WCA-2B, WCA-3A and WCA-3B. The deeper water mosaic of wet prairie/slough, tree island and sawgrass remains mostly undeveloped, protected within WCA-1 and WCA-2A, although some loss has occurred along the eastern edge. Shark River Slough, which is the largest expanse of this mosaic, remains undeveloped but is dissected by levees and canals into WCA-3A, WCA-3B, the East Everglades and the Everglades National Park. Urban and agricultural encroachment on the southern marl-forming marsh has occurred along the eastern side of ENP, however much of this landscape remains undeveloped within ENP and south of Miami in the C-111 area.

Environmental Changes in the Everglades. Best available information indicates that historical populations of wading birds have been significantly reduced in South Florida and the Everglades (Kushlan, 1976; Runde, 1991; Ogden, in press). Reduction of the original Everglades ecosystem by half has placed a fundamental limitation on its capacity to support populations of wading birds, alligators, and panthers that once utilized this area in much greater numbers.

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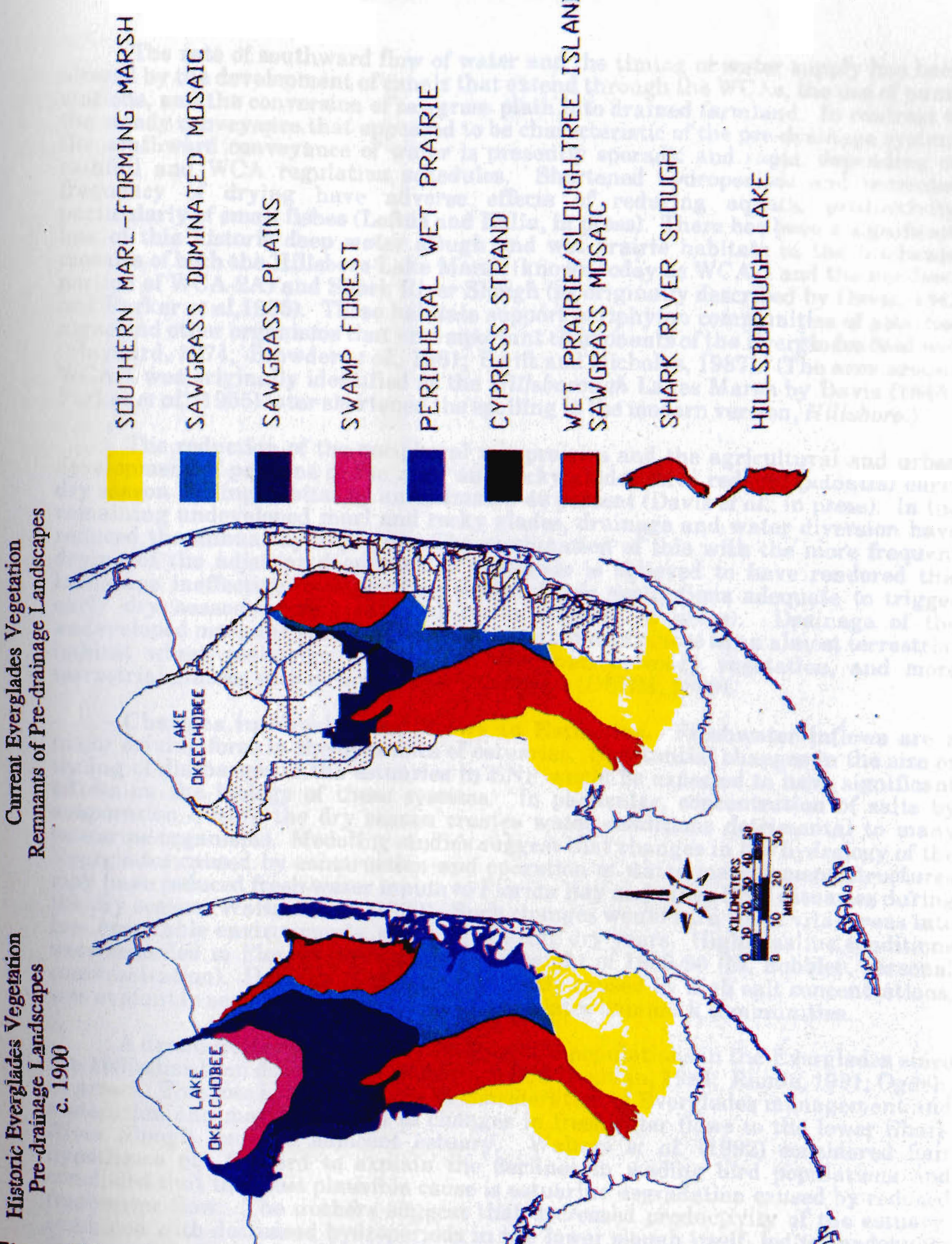


Figure III-1. Comparison of Historical and Current Everglades Vegetation Patterns.

The rate of southward flow of water and the timing of water supply has been altered by the development of canals that extend through the WCAs, the use of pump stations, and the conversion of sawgrass plain into drained farmland. In contrast to the steady conveyance that appeared to be characteristic of the pre-drainage system, the southward conveyance of water is presently sporadic and rapid, depending on rainfall and WCA regulation schedules. Shortened hydroperiods and increased frequency of drying have adverse effects of reducing aquatic productivity, particularly of small fishes (Loftus and Eklin, in press). There has been a significant loss of this historic deep water slough and wet prairie habitats in the landscape mosaics of both the Hillsboro Lake Marsh (known today as WCA-1 and the northern portion of WCA-2A) and Shark River Slough (as originally described by Davis, 1943 and Parker *et* al,1955). These habitats support periphyton communities of attached algae and other organisms that are important components of the Everglades food web (Maynard, 1974; Browder *et al.*, 1981; Swift and Nicholas, 1987). (The area around WCA-1 was originally identified as the *Hillsborough* Lakes Marsh by Davis (1943); Parker *et al.* (1955) later shortened the spelling to the modern version, *Hillsboro.*)

The reduction of the peripheral wet prairies and the agricultural and urban development of portions of the marl and rocky glades have reduced potential early dry season feeding habitat by an estimated 40 percent (Davis *et al.*, in press). In the remaining undeveloped marl and rocky glades, drainage and water diversion have reduced the annual hydroperiod. The combination of this with the more frequent drying of the adjacent deeper-water peatlands is believed to have rendered this landscape ineffective in supporting seasonal fish populations adequate to trigger early dry season nesting of wood storks (Ogden, in press). Drainage of the undeveloped marl and rocky glades has converted it in places to an almost terrestrial habitat where melaleuca, Australian pine, native woody vegetation, and more terrestrial grasses such as muhly now proliferate (DERM, 1989).

Changes in Freshwater Flows to Estuaries. Freshwater inflows are a major driving force in the dynamics of estuaries. Substantial changes in the size or timing of discharges to the estuaries in ENP would be expected to have significant effects on the biology of these systems. In particular, concentration of salts by evaporation during the dry season creates water conditions detrimental to many estuarine organisms. Modeling studies suggest that changes in the hydrology of the Everglades caused by construction and operation of water management structures may have reduced fresh water inputs to Florida Bay and other ENP estuaries during the dry season (Walters *et al.,* 1992). Such changes would turn these vital areas into less hospitable environments, especially during dry years. Highly saline conditions were recorded in Florida Bay during the drought of 1989-90 (M. Robblee, personal communication). Damage to plants, apparently caused by high salt concentrations, was evident in sea grass, mangrove and fresh water hammock communities.

A dramatic decline in native wading bird populations in the Everglades since the 1930s has been documented (Robertson and Kushlan, 1984; Runde, 1991; Ogden, in press). This loss is a major focus in consideration of Everglades management and restoration and may be related to changes in freshwater flows to the lower Shark River Slough and the adjacent estuary. Walters *et al.* (1992) considered four hypotheses put forward to explain the declines in wading bird populations and concluded that the most plausible cause is estuarine degradation caused by reduced freshwater flow. The authors suggest that decreased productivity of the estuary, combined with decreased hydroperiods in the lower slough itself, led to inadequate food supplies for the large nesting colonies at the south end of Shark River Slough. The birds responded by moving north into the WCAs. The new locations, however, were not as reliable as the old location had once been. Decreased success in rearing young led to the observed population losses. Walters *et al.* (1992) recommended experimentation with increased flows through the Everglades to the lower Shark River Slough and estuary with the goal of attracting wading birds back to their original breeding grounds.

Biologists currently do not understand the dynamics of wading bird populations well enough to predict with any certainty how they will respond to environmental changes. Even if the hypothesis favored by Walters *et al.* (1992) is correct, it is not possible to predict how long the birds might take to move nesting colonies. Although this hypothesis has credence among many Everglades researchers, alternative hypotheses can not be eliminated. An additional consideration is that two major hurricanes have dramatically altered the coastal areas of ENP (Craighead, 1971). The Labor Day Hurricane of 1935 destroyed the mangrove forests east of Cape Sable and Hurricane Donna, in 1960, devastated remaining mangroves, including those in the Shark River area. Mature mangrove forests that had taken centuries to develop were almost totally eliminated from the southern tip of Florida. This loss might be expected to affect the attractiveness of the area to wading birds.

The reduced freshwater flows noted for Shark River Slough estuaries also apply to Taylor Slough and the C-111 area to the east. Water has been diverted from the now-agricultural headwaters of Taylor Slough and is conveyed southward by the L-31N canal with normal discharge occurring through the gaps in C-111. Large, releases of fresh water to Manatee Bay and Barnes Sound during major storm events have had severe effects on these marine systems, temporarily depressing salinity concentration by an order of magnitude killing many forms of marine life (SFWMD, 1990). The South Florida Water Management District (SFWMD) has installed a spillway (G-211) in L-31N and additional culverts at S-197 in C-111 as temporary measures to attenuate flood control discharges into Manatee Bay. The U.S. Army Corps of Engineers (USCOE) is preparing a General Reevaluation Report to provide broader scale solutions to the South Dade, Taylor Slough and C-111 problems.

Nutrient Impacts. Studies conducted by the SFWMD and other agencies show that Everglades aquatic plant and animal communities are adversely impacted by pumped inflows of high phosphorus runoff water from the EAA and urban areas. Nutrient impact assessments have often emphasized the spread of cattail, which derives competitive advantage over sawgrass when nutrient supply increases. Sawgrass is adapted to survival under the low nutrient conditions under which the Everglades developed (Davis, 1991). Accompanying impacts that reduce aquatic productivity include accelerated accumulation of flocculent detritus, reduced dissolved oxygen concentrations (Belanger *et al.*, 1989), change in detritus microbial (Reeder and Davis, 1983) and macroinvertebrate communities (Urban and Kobel, in review), and change in periphyton communities toward reduced diversity and dominance by pollution-tolerant algal species (Swift and Nicholas, 1987).

B. WETLANDS OUTSIDE THE EVERGLADES

For convenience in discussing different subregions in this water supply plan, the boundary of the Everglades is considered to be the levees that enclose the Water Conservation Areas and Everglades National Park. In reality, parts of the Everglades were excluded from the WCAs. Inside the levees the land is largely controlled by public entities. Major environmental issues center around management decisions and controlling the quantity and quality of water entering the wetlands. Outside the levees the land is mostly in private ownership. Major issues here are regulatory restrictions on use of the land in order to preserve environmental values and the priority of public acquisition of the most environmentally sensitive areas. This section will provide a pre-drainage profile of freshwater wetlands outside of the Everglades, an evaluation of the altered functions of the remnant freshwater wetlands and how the needs of these areas can be addressed.

1. Pre-Drainage

The region to the east of today's Everglades consists of about 1,800 square miles that, in its natural condition, was an intricate association of upland and wetland vegetation communities. District staff have provided an estimate of the dominant pre-drainage upland and wetland habitats that historically existed within this area (c. 1900) by reconstructing a map originally developed by Costanza and Brown, 1972 (Table III-1). **Table III-1** summarizes the dominant habitats, along with their approximate original percentages for the subregion.

Table III-1. Dominant Pre-Drainage (c. 1900) Habitats for the Area East of the Everglades.

Dominant Habitat	Original Cover
Pineland (including scattered wetlands)	50%
Wet prairie	23%
Sawgrass	13%
Marshes and sloughs	5%
Cypress strand	4%
Saltwater marsh and mangrove	3%
Beach and dune including scrub	1%
Hardwoods	1%

The pineland of the coastal ridge was dominated by flood tolerant slash pine. Occasional elevated areas of alkaline soil supported dense islands of hardwood hammock containing a diverse collection of tropical trees. Sterile, white, acid sand hills supported scrub communities dominated by sand pine and scrub oaks. Even the highest and driest of the original upland communities, however, existed in close association with wetlands. Lagoons and bays with fringing mangrove swamps and saltwater marshes bordered the narrow coastal ridge on the east and the Everglades system stretched off to the west. South of Fort Lauderdale, the transition between the Everglades and the coastal ridge was a system of shallow wet prairies with innumerable fingers extending into the pineland. A strip of cypress swamp formed the border farther north.

In Dade County, the main feature east of the Everglades is a ridge of exposed limestone about five miles wide that runs along the coast, turning inland south of Miami and ending as a series of low islands in ENP referred to as "Everglades keys."

The limestone ridge is covered with sand where it continues north through Broward and into Palm Beach County. At about Boynton Beach, the original edge of the Everglades turned northwest and extended to the vicinity of Canal Point on Lake Okeechobee. The large triangle of flat land in Palm Beach County east and north of the boundary of the Everglades was covered by wet sandy pine woods essentially similar to the northern part of the coastal ridge.

To the south, the rock ridge was split by "transverse glades" that were drainage channels that allowed water to overflow from the Everglades across the ridge to coastal areas. These valleys cutting through the limestone averaged about 0.5 miles in width, were lined with marl soil, and supported marsh vegetation. Another wetland feature of the Miami rock land that impressed early naturalists was the sinkholes. These are deep holes dissolved in the limestone by percolating rainwater at a time when the sea level was much lower than today. Before drainage, sinkholes in Dade County commonly contained permanent water and supported wetland plants. Early accounts suggest that much of the pine woods on the rock ridge in Dade County were regularly flooded and might have been classified as wetland by present day criteria (Simpson, 1920).

To the north, the coastal ridge was marked by elongate wetland sloughs paralleling the coast separated by shallow sandy ridges, representing the worn down remains of swales and coastal dunes from times of higher sea level. In addition, the flat, sandy pine lands are peppered with small, round, marshy depressions. The depressions are often connected in chains by low areas forming flow-ways. Thus, the pine lands of the northern coastal ridge and associated flatlands are themselves a complex mix of habitats that were approximately 50 percent wetland in the undrained condition.

2. Remaining Wetlands Outside of the Everglades

The higher ground of the Atlantic coastal ridge, combined with its almost tropical climate and broad, sandy beaches, attracted development that created the urban strip that most people associate with "Southeast Florida." Early development replaced pineland, tropical hammock, and scrub vegetation on high ground. Lowered water tables from drainage canals greatly decreased the extent and hydroperiods of wetlands associated with the ridge. The marl soil in the transverse glades was found to be productive for farming potatoes. Bulkheading and filling of coastal wetlands allowed development of the desirable land on the edge of the water. Farming, and eventually residential development, spread from the uplands into the wetlands on the edge of the Everglades. Development eventually extended several miles west in some places that had been deep sawgrass marsh.

The flood-prone pine flatwoods in northern Palm Beach County have been the slowest area to develop in this subregion. The flatwoods were far north of the centers of development in Miami and Fort Lauderdale and extended 25 miles west from the coast along the northern Palm Beach County line. Furthermore, the flatwoods soils in northern Palm Beach County have impervious layers that make them remarkably resistant to drainage efforts (Parker *et al.*, 1955).

Today, all the natural habitats of the Atlantic coastal area have been so reduced in extent that examples of any natural community in good condition are considered environmentally sensitive areas by county governments. A comparison of the dominant pre-drainage habitats for the area east of the Everglades and existing land cover in the 1,800 square mile subregion east of the Everglades is provided in Table III-2.

Table III-2. Land Cover Comparison for the Area East of Today's Everglades.

Land Cover	Pre-Drainage (ca. 1900) [1]	1990 [2]
Natural Upland	52%	17%
Natural Wetland	48%	10%
Agriculture and other managed or disturbed vegetation	-	27%
Urban and Barren Land	-	46%

1 Costanza and Brown (1972)
2 Landsat Satellite Imagery, Florida Game and Fresh Water Fish Commission (1990)

The loss of so much upland and wetland habitat along the Atlantic coast has greatly diminished the abundance and diversity of native plants and animals in southeast Florida. Because important wildlife, particularly birds, move great distances across south Florida, losses in this area clearly affect the WCAs and ENP.

Many of the wetlands in the region have suffered decreases in water levels, changes in water quality, changes in frequency and seasonality of burning, physical damage from vehicles or wild pigs (introduced from Europe by man) or other kinds of disturbance. The most visible sign of stress in these wetlands is vegetation change with increases in the numbers of weedy native species, such as cattail and primrose willow, and exotic species, such as melaleuca and Brazilian pepper. At the same time, many native plants disappear, either directly because of the disturbed environment, or because they are crowded out by weeds.

3. Major Wetlands Outside the Everglades.

This section describes the wetland systems that occur outside the Everglades and that are considered to be regionally significant. These wetlands may be impacted by changes in regional operations, such as changes in seepage due to higher or lower stages within the WCAs. Some major wetland areas may be examined as potential detention areas for possible backpumping scenarios. The following wetland resources will be considered in either the regional or county model analysis:

- **Western Basins.** The Western basins of the Lower East Coast Water Supply Planning area refers to those lands located in eastern Hendry county that lie directly west of the western boundary of the EAA (L-1, L-2 and L-3 canals) and north of the Big Cypress National Preserve. The western basins are comprised of four primary basins: the C-139 basin, the L-28 Basin,the Feeder Canal basin and the L-28 Tieback Basin which drain into the northwest section of WCA-3A. Inflows from the western basins enter WCA-3A through S-140, S-190 and G-155. Land use within the C-139, Feeder Canal and L-28 Interceptor basins is largely agriculture. The remainder of the area is predominately wetlands and forested uplands, while the L-

29 Tieback Basin consists of almost entirely of wetlands (98%). Urban land use occupies from one to four percent of the land cover within these four basins.

The Western Basins lands also include land occupied by the Seminole Tribe of Florida and the Miccosukee Tribe of Indians of Florida. These Indian lands include extensive private holdings which traditionally have been used for cattle operations on native range land or improved pasture.

Attention has focused in recent years on the quality of water entering the Everglades from the Western Basins as a result of changing land uses and increased agricultural activity. This area has recently experienced rapid agricultural development. During the 1980s native range land and improved pasture have been undergoing conversion to citrus, sugar cane or other agricultural development.

- **Loxahatchee Slough.** The slough, located in northern Palm Beach County, is a diverse area of native wetland habitat interspersed with pineland, oak and subtropical hardwoods. Large portions of this area have been acquired through the Save Our Rivers Program. Extensive studies on the water supply and drainage requirements for the Loxahatchee River basin have been completed. Efforts to provide more water to the slough have been discussed. Restoration of the base flows into the Northwest Fork has been initiated. Although the slough is outside of the study area, the restoration efforts may require connections back to facilities within the Lower East Coast region.

- **Strazzula.** This tract is located east of, and adjacent to, the Arthur R. Marshall Loxahatchee National Wildlife Refuge, which is also known as Water Conservation Area 1 (WCA-1). The area is a combination of sawgrass marsh and cypress slough. Water supply to this area comes from rainfall and seepage from WCA-1.

- **Everglades Buffer Strip.** This land is located in Broward County along L-37 and between the North and South New River Canals. Approximately 2,044 acres of the buffer strip have been purchased by the SFWMD. The area has been impacted by invasion of exotic vegetation and rock mining. Water supply to the area is primarily by rainfall and seepage from WCA-3 under L-37 and L-33.

- **Dupuis Reserve / J.W. Corbett Wildlife Management Area / Pal-Mar.** These areas are contiguous. These are very large areas of natural habitat in Palm Beach and Martin counties. The Dupuis Reserve and the J.W. Corbett Wildlife Management Area are in public ownership. The Pal-Mar tract is under consideration for purchase by Save Our Rivers. Only those portions within Palm Beach County will be considered in this plan. Water supply to these areas is primarily from rainfall.

- **Bird Drive / Pennsuco / North Trail / Dade-Broward Levee.** These areas once were part of the Everglades and are located in the general area of north central Dade County. These areas are influenced by development, including extensive rockmining, and are in the cone of influence of the Dade County's Northwest Wellfield. Portions of these areas are overdrained by adjacent canals.

- **C-111.** A high percentage of the C-111 area wetlands, which are east of ENP, are undeveloped. Some of the other C-111 wetlands generally are areas that have a low to moderate level of disturbance. The C-111 wetlands provide habitat for several endangered species. Land cover includes pineland remnant, tropical hardwood hammocks and sawgrass glades. Restoration of sheetflow to Florida Bay through the C-111 area is in the planning stages.

4. Big Cypress National Preserve.

Historically the Big Cypress National Preserve has been regarded as a "peripheral area" to the Everglades and has been given less attention in terms of regional water management. Although the Big Cypress National Preserve (3,120 sq. kilometers) is considered part of the District's Lower West Coast Water Supply Planning area, the northeastern portion of the Big Cypress National Preserve (1,170 sq. kilometers) drains to the southeast into WCA-3A with some of this water eventually entering ENP through the Tamiami Canal to the south and through the L-28 interceptor canal and L-28 gaps to the north.

The Big Cypress National Preserve differs from the adjacent Everglades in topography, soils, water quality, and vegetation. Higher land elevations, thin soils comprised of marl or sand, the absence of large peat deposits, a swamp forest comprised of stunted cypress tress interspersed with pine and hammock forests, wet prairies and marshes distinguish this wetland area from the Everglades (McPherson, 1974).

Up to the early 1950s the Big Cypress was directly connected to the Everglades. One of the initial efforts of the C&SF Project was to enclose the three water conservation areas. By 1963, the western levee (L-28) of WCA-3A was built which essentially eliminated historical sheet flow from the Big Cypress National Preserve into the Everglades with the exception of small area known as the L-28 Gap (Duever *et al.*, 1979).

The Big Cypress is largely comprised of cypress forested wetlands, with isolated hardwood hammocks, scattered pinelands interspersed with freshwater marshes and sloughs. In the extreme southern portion of the preserve these habitats integrate into coastal prairie and mangrove forests. The primary land use is recreation which includes hunting, fishing, off-road vehicle use, environmental education, nature appreciation and eco-tourism. Oil exploration and extraction are active within the eastern one-third of the preserve.

5. Wetland Hydrology.

Maintaining appropriate wetland hydrology is the single most critical factor in maintaining a viable wetland ecosystem (Duever, 1988; Mitsh and Grosselink, 1986). Hydrology regulates a wetland's community structure and function. Activities that modify or alter wetland hydrology also significantly affect the species composition and ecology of wetland ecosystems. Lowered ground water tables in areas surrounding wetland communities have been shown to decrease hydroperiod. Hydroperiod refers to the length of time in duration and depth that surface water inundates a wetland. The most obvious impact of reducing water levels is a decrease in the size of the wetland. This is especially true of shallow low gradient wetlands, which may be entirely eliminated. Decreased wetland size reduces the available wildlife habitat and the area of vegetation capable of nutrient assimilation.

Decreasing the hydroperiod of an existing wetland also can disturb the system. The immediate response is likely to be invasion of the wetland by rapidly spreading weedy plants such as melaleuca or certain native species. Given sufficient time and absence of additional disturbance, the wetland might undergo a natural succession to a healthy short hydroperiod wetland. Unfortunately, there is not enough known about how much time this might take or how small the threat of invasion by melaleuca would be.

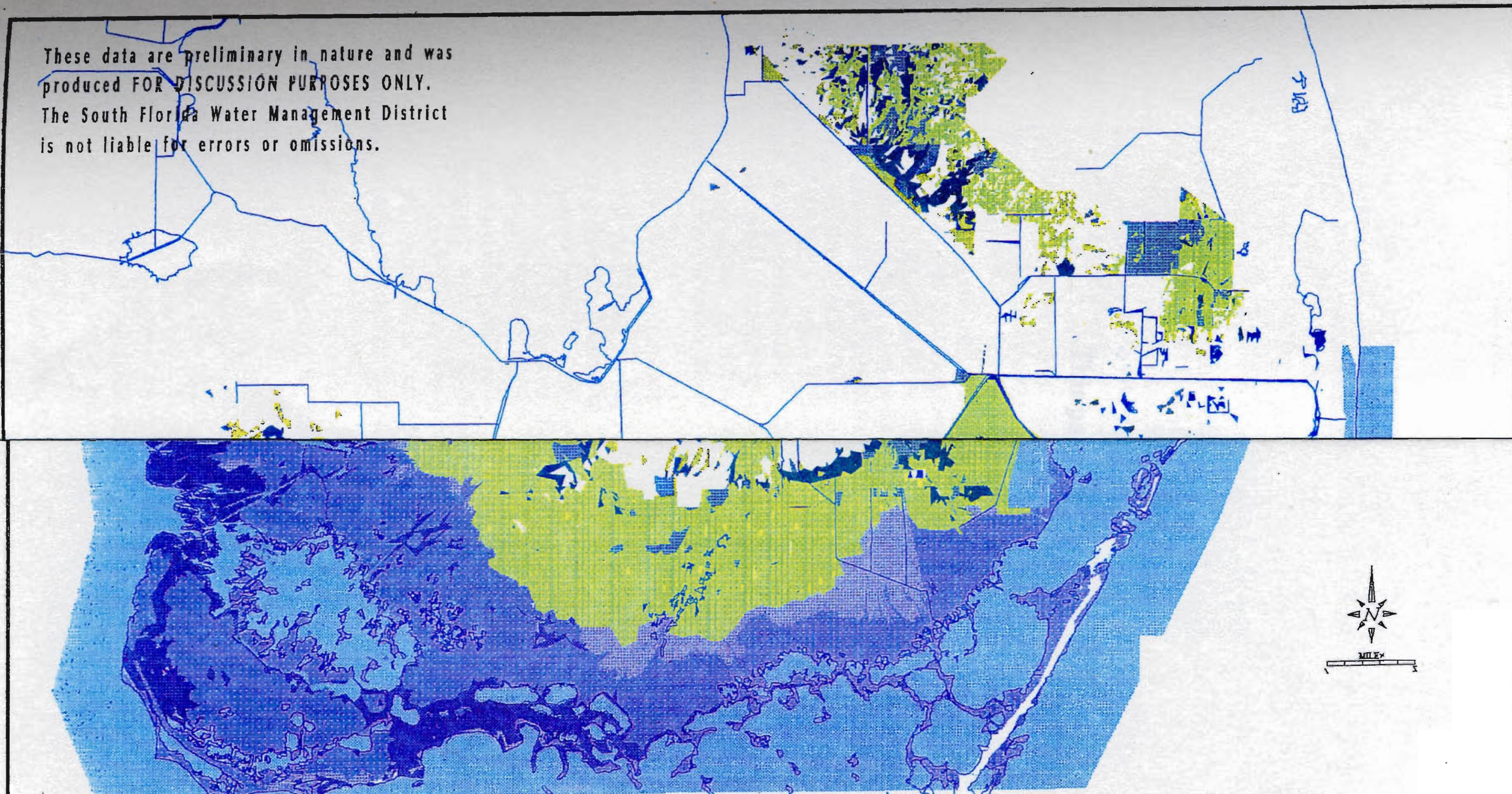
Unnatural fluctuations in the water table is another factor that may work against establishment of natural short hydroperiod wetland vegetation in partially dewatered wetlands. Since human water use tends to be greatest during the dry season, when levels in natural systems are low, the seasonal fluctuation in water level may be increased. This introduces a stress factor that tends to favor undesirable, weedy vegetation.

Outside the Everglades, wetlands in the Lower East Coast are scattered in partially developed basins (**Figure III-2,** fold out map). The water needs of these wetlands must be met, but the approach at this time should not be to define specific flows and levels for each of them, but rather to protect them against changes in existing water regimes. Although many of the wetlands in question have suffered decreases in water supply because of interruption of overland flow and lowering of ground water levels associated with human development, in most cases restoring ideal water levels is not feasible. Many of the wetlands are in private ownership and others adjoin private land that would be flooded if water levels were raised.

Wellfield Impacts on Wetland. In the region east of the Everglades the most common threat to wetlands from human water use is the drawdown of the water table in the vicinity of a wellfield. Partial drainage of wetlands can be caused by groundwater withdrawals in adjacent upland areas. These withdrawals effectively lower underlying water tables and "drain" the wetland. Drainage facilities such as canals and retention reservoirs constructed near wetlands also have a history of draining and reducing the hydroperiod of south Florida wetlands (Rochow, 1989; Hofstetter and Sonenshein, 1990; Irwin, 1991).

Many of the deleterious effects of removing water from wetlands are of the type that would not be expected to show thresholds. For example, even a small removal of water could cause a decrease in production of aquatic food organisms because of (a) shortened hydroperiod, (b) increased probability of soil-destroying fires during droughts because of lower soil moisture, and (c) release of nutrients from soil because of greater exposure to air. Although no studies have proven that shortening the hydroperiod by one day or decreasing the water table by half an inch affect a wetland, our understanding of wetlands points to the conclusion that such small changes would have ecological effects, although they may be correspondingly small and require long, expensive studies to detect.

Locating wellfields away from wetlands is an approach that can reduce local environmental effects but has become difficult to implement in the Lower East Coast. The Florida Keys Aqueduct Authority Wellfield in southern Dade County is an example, since it is located in a pineland. Although the pineland now has an unnaturally low water table that has probably affected the vegetation, it still supports a diverse flora, including rare species. Unfortunately, large, undeveloped tracts of upland are not readily available in the region. Locating a wellfield is reduced to a choice between undeveloped areas with environmentally sensitive wetlands and developed uplands where the potential for wellfield contamination is a serious concern.



WETLAND INVENTORY OF THE LOWER EAST COAST WATER SUPPLY PLANNING AREA

This map is an update of the National Wetlands Inventory. Produced by the South Florida Water Management District, Planning Department, Lower District Planning Division, West Palm Beach, Florida.

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C. COASTAL RESOURCES

Coastal resources within the planning area include both major estuarine systems and other important marine systems which are dependent on freshwater flows from upstream sources to provide favorable conditions for a variety of aquatic life forms.

1. Major Estuaries.

The major systems of coastal resources in the Lower East Coast region include Florida Bay and Whitewater Bay within Everglades National Park, and Biscayne Bay, part of which lies within Biscayne National Park. This section describes each of the major systems (**Figure III-3**) in context of their resources, impacts due to development and drainage and their environmental water needs. (This section does not describe major estuaries outside of the study area such as the St. Lucie, Caloosahatchee or Loxahatchee. Potential impacts to these areas will be considered during the analysis of alternatives as part of the environmental component.)

Estuaries provide habitats for a wide range of organisms throughout the year. The vegetation of the estuary, especially the phytoplankton, traps the nutrients that enter the system as runoff. In addition, the primary productivity of seagrasses, algae, coastal saltmarsh and mangroves, creates large amounts of detritus, leaf litter and dissolved organic material that are added to the nutrient cycles of estuaries. These nutrients form the basis of the food chain for zooplankton, benthic invertebrates, fishes, mammals and seabirds. Due to the variety of organisms involved, and the natural variability of this environment, estuarine communities are dynamic and respond in complex ways to seasonal changes in temperature, tides and water flow. Estuarine communities may also change dramatically in response to the sudden input of nutrients or pollutants that may occur from severe storms or manmade influences such as sewage discharges or oil spills.

In addition to the biological functions of estuaries, man has found that coastal embayments and river channels furnish unique opportunities for commercial fishing, boat dockage, transportation facilities and recreation. These areas are generally suited for development due to their natural beauty and utility. Man's activities during the past century in south Florida have substantially modified the coastal zones. In some cases, these changes have created additional estuarine areas due to construction and stabilization of inlets and modification of natural patterns of freshwater flow to the sea. In many cases, however, human actions have caused adverse changes in estuarine areas through shoreline development, dredging and filling, alteration of freshwater inflows, pollution, and commercial and recreational use.

The east coast of Florida is bordered by a band of islands that extend from the Tortugas northward. North of Biscayne Bay, the islands form a nearly continuous barrier against the sea. Periodic violent storms and the continual buffeting by counter currents of the Gulfstream have caused a migration of sediment along the shoreline from north to south and the periodic breaching of the barrier islands to form inlets. Historically, the area west of these islands and east of the coastal ridge consisted of freshwater lakes and marshes (Harlem, 1979). Eventually, man began to stabilize the intermittent inlets to provide access to the sea. Later the marshes and lakes were dredged to create a navigable north-south inland waterway, and the freshwater flows from the uplands were altered by drainage and flood control projects. The saline and brackish water characteristics of the coastal areas thus

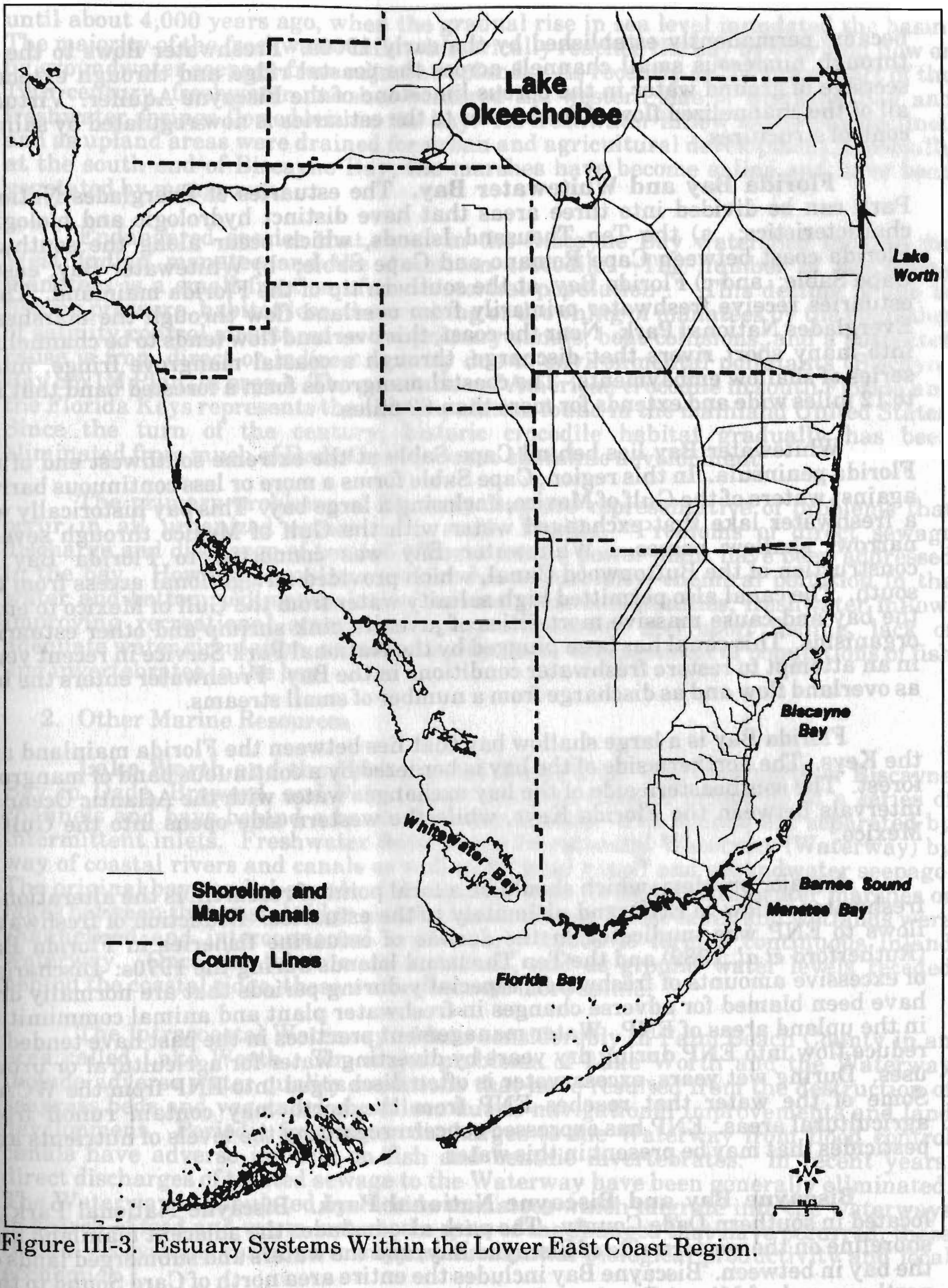


Figure III-3. Estuary Systems Within the Lower East Coast Region.

became permanently established by the early 1900s. Freshwater flows to the sea through numerous small channels across the coastal ridge and through extensive seepage of ground water in the porous limestone of the Biscayne Aquifer. Virtually all of the channelized flow of freshwater to the estuaries is now regulated by salinity control structures.

Florida Bay and Whitewater Bay. The estuaries of Everglades National Park can be divided into three areas that have distinct hydrologic and biological characteristics: a) the Ten Thousand Islands, which occur along the southwest Florida coast between Cape Romano and Cape Sable; b) Whitewater Bay, east of Cape Sable; and c) Florida Bay, at the southern tip of the Florida mainland. These estuaries receive freshwater primarily from overland flow through the marshes of Everglades National Park. Near the coast, this overland flow tends to be channelized into many short rivers that discharge, through a coastal mangrove fringe, into a series of shallow embayments. The coastal mangroves form a forested band that is 6 to 12 miles wide and extends for more than 60 miles.

Whitewater Bay lies behind Cape Sable at the extreme southwest end of the Florida peninsula. In this region, Cape Sable forms a more or less continuous barrier against waters of the Gulf of Mexico, enclosing a large bay. This bay historically was a freshwater lake that exchanged water with the Gulf of Mexico through several narrow, shallow passes. Whitewater Bay was connected to Florida Bay by construction of the Buttonwood Canal, which provided navigational access from the south. The canal also permitted high salinity water from the Gulf of Mexico to enter the bay and cause massive mortalities of juvenile pink shrimp and other estuarine organisms. This canal has been plugged by the National Park Service in recent years in an attempt to restore freshwater conditions in the Bay. Freshwater enters the bay as overland flow and as discharge from a number of small streams.

Florida Bay is a large shallow bay that lies between the Florida mainland and the Keys. The northern side of the bay is bordered by a continuous band of mangrove forest. The southeastern side of the bay exchanges water with the Atlantic Ocean at intervals between the Florida Keys, while the western side opens into the Gulf of Mexico.

A major problem, which should be a focal point of research, is the alteration of freshwater inflow to ENP, and ultimately to the estuaries. Reduction of freshwater flows to ENP was implicated in the decline of estuarine fisheries in Florida Bay (Rutherford *et al.*,1989) and the Ten Thousand Islands during the 1970s. Discharges of excessive amounts of freshwater, especially during periods that are normally dry, have been blamed for adverse changes in freshwater plant and animal communities in the upland areas of ENP. Water management practices in the past have tended to reduce flow into ENP during dry years by diverting water for agricultural or urban uses. During wet years, excess water is often discharged into ENP from the WCAs. Some of the water that reaches ENP from the north may contain runoff from agricultural areas. ENP has expressed concern regarding the levels of nutrients and pesticides that may be present in this water.

Biscayne Bay and Biscayne National Park. Biscayne National Park is located in southern Dade County. The park also includes the adjacent mainland and shoreline on the western side of Biscayne Bay, and the waters and submerged lands of the bay in between. Biscayne Bay includes the entire area north of Card Sound to the northern end of Miami Beach at Dumfoundling Bay, a distance of about 25 miles. This lagoon system was primarily a freshwater basin -- a shallow marsh or lake --

until about 4,000 years ago, when the gradual rise in sea level inundated the basin. The majority of the freshwater inflow historically reached the bay by overland flow or by groundwater seepage from adjacent uplands. As recently as the latter part of the 19th century, freshwater marshes bordered the western side of Biscayne Bay and freshwater springs flowed within the bay. As freshwater inflow to the bay declined and as upland areas were drained for urban and agricultural development, especially at the south end of Biscayne Bay, the marshes have become saline and have been vegetated by mangroves.

Endangered species that occur in the Biscayne Bay watershed include the West Indian manatee and the American crocodile. The number of remaining manatees is a small fraction of the historical population . This decline is due to fishing pressure, habitat loss, the crushing or drowning of manatees by the operation of salinity control structures in the primary canals, boat collisions, and a suspected cause is from direct or indirect toxicity due to environmental pollutants (Biscayne Bay SWIM Plan, in prep.). The population of American crocodile in south Florida and the Florida Keys represents the only population found in the mainland United States. Since the turn of the century, historic crocodile habitat gradually has been eliminated from much of Dade County due to shoreline development.

The primary problems of Biscayne Bay are representative of problems that occur in all urbanized estuaries in south Florida. Problems of direct sewage discharge and discharge of treated effluent from a power plant have been addressed in the bay. However, problems persist due to turbidity, chemical pollution in the water and bottom sediments, loss of marine grass communities, freshwater inflow, improving recreational access and uses, commercial and sport fishing, lack of adequate water circulation, as well as methods for management of populations of fish and invertebrates in the bay.

2. Other Marine Resources

Lake Worth and the Intracoastal Waterway. The area north of Biscayne Bay in Dade, Broward, and Palm Beach counties consists primarily of a series of channels and bays behind a band of barrier islands. The islands are separated by intermittent inlets. Freshwater flows to the Intracoastal Waterway (Waterway) by way of coastal rivers and canals as well as by local runoff and groundwater seepage. The original bays and channels of the system were formed as freshwater marshes or lakes between the coastal ridge and the beach dunes. These lakes and wetlands were channelized and interconnected in the early 1900s to form a continuous inland waterway. Once the inlets were stabilized, and as ground water levels receded behind the coastal ridge, these waters became more saline.

The Intracoastal Waterway widens considerably in Palm Beach County in an area called Lake Worth. The major problems of Lake Worth and the Waterway include adverse water quality conditions that have resulted from the destruction of seagrass beds and vegetated shorelines due to navigational improvements and land development. Periodic freshwater discharges to the Waterway from flood control canals have adverse impacts on fish and benthic invertebrates. In recent years, direct discharges of treated sewage to the Waterway have been generally eliminated. The Waterway is populated by Florida manatees which migrate into the waterways in search of food and warm waters. In spite of the changes that have occurred, these coastal ecosystems continue to support substantial biological productivity and local economies.

Florida Keys National Marine Sanctuary. In November 1990, the Florida Keys National Marine Sanctuary (FKNMS) was created and includes 2,600 square nautical miles of nearshore waters extending from Key Biscayne in Dade County to the Dry Tortugas in Monroe County. Broadly speaking, the FKNMS contains three marine biological communities: the mangrove forest lining its shoreline, the extensive seagrass meadows, and the Florida Reef Tract (EPA, 1992). Most of the fish and invertebrate species that contribute to Florida's sports and commercial fishing economy, as well as the majority of other mobile reef species, utilize all three of these habitats at various stages of their development. These communities form an integrated and unique ecosystem.

3. Impacts to Estuaries.

The sub-tropical estuarine or semi-estuarine systems existing along the entire fringe of the Lower East Coast of Florida have been severely altered and damaged in several ways. The nature of these alterations and remedies are discussed in related Surface Water Improvement and Management (SWIM) Plans for Biscayne Bay and the Everglades. Among the things that may have impacted the estuarine systems are:

- Lower Water Levels. Water levels have been substantially reduced on the uplands in the last several decades and, consequently, freshwater flows to the estuarine systems are a fraction of historical flows resulting in much higher salinities. This has caused a general shift from planktonic (floating organism) primary productivity to benthic (bottom- dwelling organism) primary productivity.

- Channelization. Channelization in coastal areas has cut off large expanses of coastal wetlands from overland flow, resulting in decreased productivity. The wetlands themselves have been largely filled for urban development. In addition, discharge of freshwater through control structures is often sporadic rather than continuous which causes stress in the system at the point of discharge, further reducing productivity at these locations.

- Breaching Barrier Islands. The permanent opening of a number of inlets into the once confined lagoonal system for purposes of vessel traffic has resulted in increased salinities and alteration of habitats as described under the first management concern.

- Degraded Water Quality. The estuarine resources are down gradient of urban and agricultural development that has introduced contaminants into the system compounding the degradation of the existing ecosystem.

Initiatives to reestablish sheet flow through remaining coastal wetlands, once it has been determined that such flows will benefit the estuaries of Biscayne and Everglades national parks, represents a highly beneficial use of water. Flows into these systems should be based upon a rainfall model that provides for distribution of flow over a large area and creates an appropriate time delay and spreading of the discharge over time following a rainfall event.

4. Environmental Water Needs of Estuaries

The coastal bays or lagoons are the transition zones between freshwater rivers or marshes and open marine waters. These protected bays may be freshwater, brackish or marine depending on river flow, size of inlets, tides and the degree of protection afforded by islands. Drainage, flood control and water supply development projects have altered the timing and quantity of freshwater flows to estuaries and resulted in major changes in biological conditions in these systems in recent years.

Florida has occasional periods of extreme weather, including floods, hurricanes and droughts. Excessive rainfall and flooding cause intermittent massive discharges of fresh water to estuaries and may have dramatic effects on salinity, sediments and water quality. Another condition results from the long-term effects of reduction of freshwater flow, such as has occurred in Biscayne Bay. Occasional reductions in freshwater flow occur naturally due to drought. However, land development activities often cause increased retention and use of water in upland systems, lowered groundwater tables and reduced discharges to tidewater, so that the brackish and freshwater characteristics of the estuary are lost. Freshwater and brackish water organisms are gradually replaced by marine organisms. While these short term and long term changes have been noted in the literature, there has been no thorough documentation of these events or trends in South Florida.

Defining and meeting the freshwater needs of South Florida's estuaries poses several significant challenges. Historically, much of the freshwater entered coastal waters as groundwater seepage or as sheet flow across marshlands. Construction of drainage canals along the southeast Florida coast has lowered groundwater stages, and reduced seepage, eliminated much of the natural overland flow and has largely channelized the flow of freshwater so that it enters the coastal waters as a "point source" discharge, generally from the water control structure of a canal. During the last century, many of the wetland systems have been altered from freshwater embayments and marshes to more saline systems. In this context, discharges of freshwater from canals may be considered more as a pollutant.

D. LAKE OKEECHOBEE ENVIRONMENTAL RESOURCES

Lake Okeechobee is a large, shallow eutrophic lake and is a major feature of the Kissimmee-Okeechobee-Everglades (KOE) system. With a surface area of 450,000 acres, it is the second largest lake within the contiguous United States. This water represents the heart of south Florida's water supply and flood control system. Lake Okeechobee provides drinking water for urban areas, irrigation water for agricultural land, recharge water for aquifers, and is a major source of inflow water for the Everglades. This section will describe the environmental resources of Lake Okeechobee, environmental water supply needs of the lake and the management of the lake.

1. Environmental Resources of Lake Okeechobee.

Littoral Zone. Lake Okeechobee in addition to serving as a water supply reservoir for various users in south Florida contains marshes which represent a valuable component of the KOE ecosystem (see **Figure III-4**). These vegetation communities, commonly known as the littoral zone, provide significant feeding and nesting habitat for thousands of wading birds and migratory waterfowl as documented by Zaffke in 1984. Birds from other areas such as woodstorks from

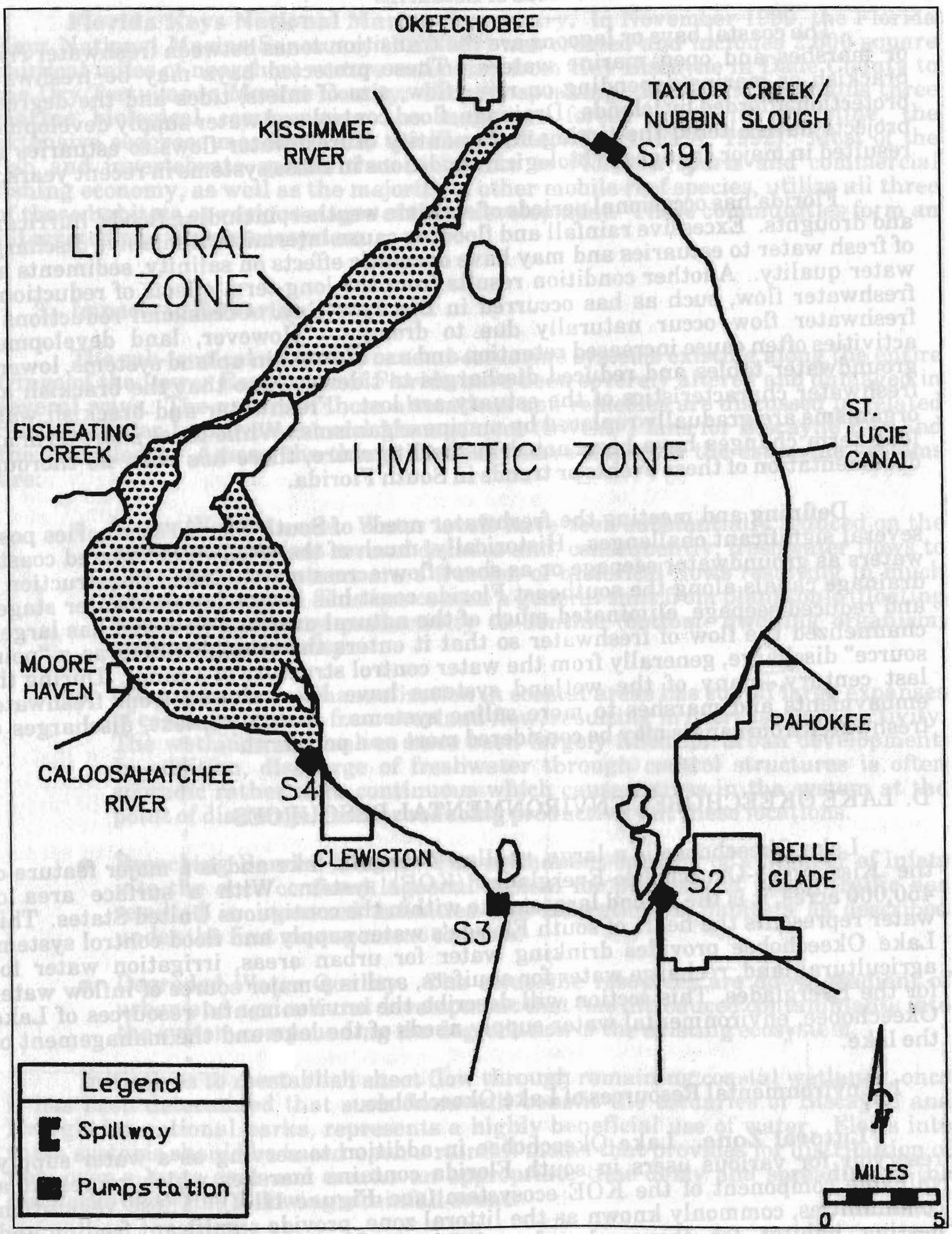


Figure III-4. Lake Okeechobee Littoral Zone

Corkscrew Sanctuary and white ibis from Lake Istokpoga quite often use Lake Okeechobee marshes in the latter part of their nesting period. These marshes form a band ranging from 0.5 to 9 miles in width which occupy lake bottom elevations between 10.0 and 15.5 feet NGVD. The landward extent of the marsh is limited by the Herbert Hoover dike that encircles the lake. The shallow sandy soils of the littoral zone are underlain by Fort Thompson limestone. There are also muck and peat deposits contained within three formerly farmed islands at the south end of the Lake.

Preliminary results reported in Shireman *et al.* (1991), indicate that lake stage and thus hydroperiod, is one of the most important factors controlling the patterns of littoral zone vegetation and wading bird foraging and nesting activity. Comparisons of the 1989 computer-generated satellite map of littoral zone vegetation with a field survey map done by district researchers in in 1974 (Pesnell and Brown, 1977) reveals substantial changes in the distribution and occurrence of important plant species. Substantial short-term changes in littoral vegetation are also indicated by a comparison of 1989 and 1990 images. The 1989 - 1990 drought, coupled with a severe freeze in 1989 and fires in 1990, resulted in dramatic changes in littoral vegetation over a relatively short time period from typical marsh vegetation to a community characterized by successional species (Lake Okeechobee SWIM Plan, 1993).

Birds. Lake Okeechobee supports a variety of resident and migratory bird species (Robertson and Kushlan, 1974). In south Florida, 379 bird species have been sighted and many of these birds utilize Lake Okeechobee at various times. Most notable resident birds include the double-breasted cormorant, anhinga, gallinules, coots, white ibis, limpkin, and the snail kite (Robertson and Kushlan, 1974). Dominant waterfowl species include the ringed-neck duck, scaup, fulvous whistling duck, blue-winged teal, and mottled duck (Johnson and Montalbano, 1984). Feeding activity on the lake coincided with lake stages below 15 feet NGVD which physically provided large areas of feeding habitat for wading bird populations (Zaffke, 1984; Milleson, 1987). Beakrush, spikerush, and mixed grass communities were preferred foraging habitats for these birds (Zaffke, 1984). Willows were heavily utilized for nesting.

Fisheries. Lake Okeechobee is an extremely fertile lake where plants and fish grow in great proportions. Under normal conditions, warm water fish such as bass and bream grow rapidly. While the lake has always been considered an important resource by Florida's vast fresh water sport fishing community, it is also the backbone of the state's commercial freshwater fishing industry. A total of 43 species of fish inhabit the lake including largemouth bass and black crappie (Ager, 1971). Each year, commercial fishermen catch an estimated two million pounds of catfish or about one third of the available harvest. A significant amount of the total fish population of the lake is rough fish such as gizzard shad, gar and mudfish which are not taken by the sport or commercial fishermen. In addition, the majority of the fish population stays in the open waters which are very seldom visited by sport fishermen.

Amphibians, Reptiles and Mammals. Lake Okeechobee supports a wide diversity and abundant populations of amphibians and reptiles. Based on the ranges provided by Whitaker (1968), approximately 22 amphibian and 40 reptile species temporarily or permanently inhabit the lake or the surrounding levee. Amphibians and reptiles commonly found in the lake include frogs, tree frogs, sirens, alligators, soft-shell turtle, cottonmouth moccasin snake, and water snakes. The majority of these species inhabit the extensive littoral zone.

According to Whitaker's range maps probably 24 species of mammals temporarily or permanently inhabit or utilize Lake Okeechobee and the surrounding levees. Most notable are raccoon, round-tailed muskrat, river otter, opossum, armadillo, rabbits, mice, and the cotton rat.

2. Lake Okeechobee Environmental Water Supply Needs.

Substantial changes in the composition and distribution of plant communities of the Lake Okeechobee littoral zone were observed during the period from 1972 to 1982, as documented by Milleson (1987). The most apparent changes were elimination of the spikerush community, expansion of the cattail zone and domination of the mixed grass zone by torpedo grass. These observed vegetation changes were attributed to higher water levels in Lake Okeechobee as a result of the change in regulation schedule from 13.5-15.5 feet NGVD in 1973 to a 15.5-17.5 feet NGVD in 1978 and the high rainfall period of 1978 through 1980.

Since the majority of Lake Okeechobee marsh lies below 15.0 feet NGVD, extended stages above that level will keep the marsh continuously inundated. When the marsh is kept inundated, germination and development of millet and other important food plants is minimal (Chamberlain, 1960; Ager and Kerce, 1970). Milleson concluded that continued adherence to the 15.5-17.5 feet NGVD regulation schedule will affect not only the marsh itself but the variety of waterfowl, wading birds, reptiles, fishes and other species that depend on the variety of habitats provided by the complex littoral zone ecosystem.

In 1988 the SFWMD organized a technical committee to advise on the conditions of the littoral zone and its relationship with the lake water levels. The committee was called Lake Okeechobee Littoral Zone Technical Group (LOLZTG).

The group after several months of consultation and examination of data concluded that:

1. Loss of wading bird feeding habitat constitutes an emergency situation and a lowering of the present lake schedule to 14-16 feet NGVD was recommended.
2. Melaleuca infestation of the western littoral zone is increasing and a lower lake stage may allow for further expansion.
3. Torpedo grass has formed dense monocultures in the western littoral zone and provides poor habitat for wildlife.
4. Dense monocultures of cattail (Typha spp.) are expanding. These monocultures produce poor fish and wildlife habitat. High lake stages and high nutrient content in the water may stimulate cattail expansion.
5. The willow community, which provides rooking sites for wading birds and snail kites has declined due to higher lake stages.
6. Annual plants, which serve as food for waterfowl, have declined.
7. Hydrilla expansion reduces fishing accessibility but provides food for waterfowl.

LOLZTG recommended lowering the present schedule to increase the frequency of low stages and reduce the frequency of inundation above 15 feet NGVD in order to improve fish and wildlife habitat in the littoral zone. The committee recommended a schedule which fluctuates between a high of 16 feet and a low of 14 feet.

Also affected by water level and vegetative changes are sport and commercial fish populations. High lake stage and an abundant food supply has increased the reproductive success of the lake's black crappie populations and therefore increased the number of fish since 1978.

Control of introduced exotic plants was identified as a major environmental concern for the lake in the Lake Okeechobee SWIM plan. The occurrences of low lake stages during 1989 and 1990 has allowed melaleuca to expand within the lakes western littoral zone. Current estimates indicate that over 3,000 acres of dense melaleuca stands now occupy this area of the lake with approximately another 3,500 acres being invaded by one or two year old trees.

3. Lake Okeechobee Management

Historically Lake Okeechobee's regulation schedule was developed primarily to meet flood control and water supply objectives--the primary purposes for construction of the C&SF Project. The environmental concerns for the lake's littoral zone and wildlife habitat and the downstream estuaries have generally been compromised in order to meet the water supply needs of south Florida. This section will describe the ongoing efforts to determine the regulation schedule that best meets the competing needs of south Florida.

Interim Lake Regulation Schedule. Trimble and Marban(1988) performed an analysis of the Lake Okeechobee regulation schedule which incorporated a trade off analysis framework and resulted in the recommendation of an improved schedule known as "Run 25." This recommended schedule reduced the water quality impacts associated with regulatory discharges to the St. Lucie and Caloosahatchee estuaries by reducing the need to discharge large volumes of freshwater from the lake, without significantly impacting existing flood control, water supply and environmental benefits provided by the previous (15.5-17.5 feet) schedule approved in 1978. This schedule was approved by the District's Governing Board in December 1991 and approved on a two year interim basis by the USCOE in May of 1992. The SFWMD has requested the USCOE develop the required environmental and economic impact statement in anticipation of a recommendation for a lower lake regulation schedule at the end of the two year period. Regulatory releases are to occur at lower lake stage and at lower and more environmentally sensitive rates of discharge than the previous schedule. The lower rates of discharge are made in a "pulse" fashion which simulates a natural rainstorm event within the St. Lucie (C-44) Basin **(see Figure II-5)**. Each pulse takes 10 days to complete. This method allows estuarine biota to tolerate changes in salinity and the discharges to remain within the natural range of freshwater flow to the estuary.

Preliminary meetings between the SFWMD and the USCOE have been held to determine what is required to develop and implement a revision of the lake regulation schedule operating strategy. As a result, the following problem statement was adopted for reviewing the lake regulation schedule: "In light of new and existing information, review the possibility of modifying the Lake Okeechobee regulation schedule to enhance the lake's environmental resources and downstream water bodies while minimizing impacts to other project purposes."

Lake Okeechobee SWIM Plan. The Lake Okeechobee SWIM Plan proposed the Lake Okeechobee Regulation Schedule Trade-Off Analysis. This project would develop and apply a suitable methodology capable of quantitatively examining a number of different lake regulation schedules or schemes that will result in more effective management of the environmental resources of the lake. The project is proposed for the SFWMD's 1994 Fiscal Year with a final product by May 1994.

Lake Okeechobee Ecosystem Study. In response to recommendations by the Lake Okeechobee Technical Advisory Committee (LOTAC, 1988) and other mandates the SFWMD initiated a five-year contract in April of 1988 to provide the primary basis for assessing the biologic impacts and measuring the ecosystem response to ongoing lake management. The study is investigating the following:

- Patterns of vegetation in the littoral zone and their controlling factors
- Water chemistry
- Plankton community dynamics
- Larval and juvenile fish ecology
- Distribution and ecology of wading birds
- Distribution and ecology of macroinvertebrates and adult fish

The final report is due in October of 1993.

IV. DEMAND ESTIMATES AND PROJECTIONS

A. OVERVIEW OF DEMAND ESTIMATES AND PROJECTIONS

This chapter presents the estimates and projections for the water demands of the Lower East Coast planning region (**Figure I-4**). For 1990, the South Florida Water Management District (SFWMD) estimated that total water demand for the Lower East Coast region was approximately 729,000 million gallons for the year (MGY). This equates to 2.2 million acre feet for the year. **Figure IV-1**, shows the relative water demand by each category of use. As used in this document, *public water supply* refers to all potable water supplied by state-licensed utility systems to all types of customers, not just residential. The other five categories of water use identified in this document are self-supplied. *Industrial* refers to water that is supplied by the respective industrial operations using over 100,000 gallons per day. The *golf course* category includes only those operations which obtain water from their own irrigation wells. The *landscape* grouping includes water used for parks, cemeteries and other irrigation applications greater than 100,000 gallons a day, excluding golf courses. *Residential self-supplied* is used to designate only those households whose primary source of water are private wells. *Agriculture* includes water used to irrigate all crops, including nurseries and improved pasture; it also includes cattle watering Each category is discussed in the following sections. Irrigation uses (golf, landscaping, and agriculture) are presented in millions of gallons per year (MGY) because there is relatively high seasonal variability of actual usage. The other categories are presented in millions of gallons per day (MGD).

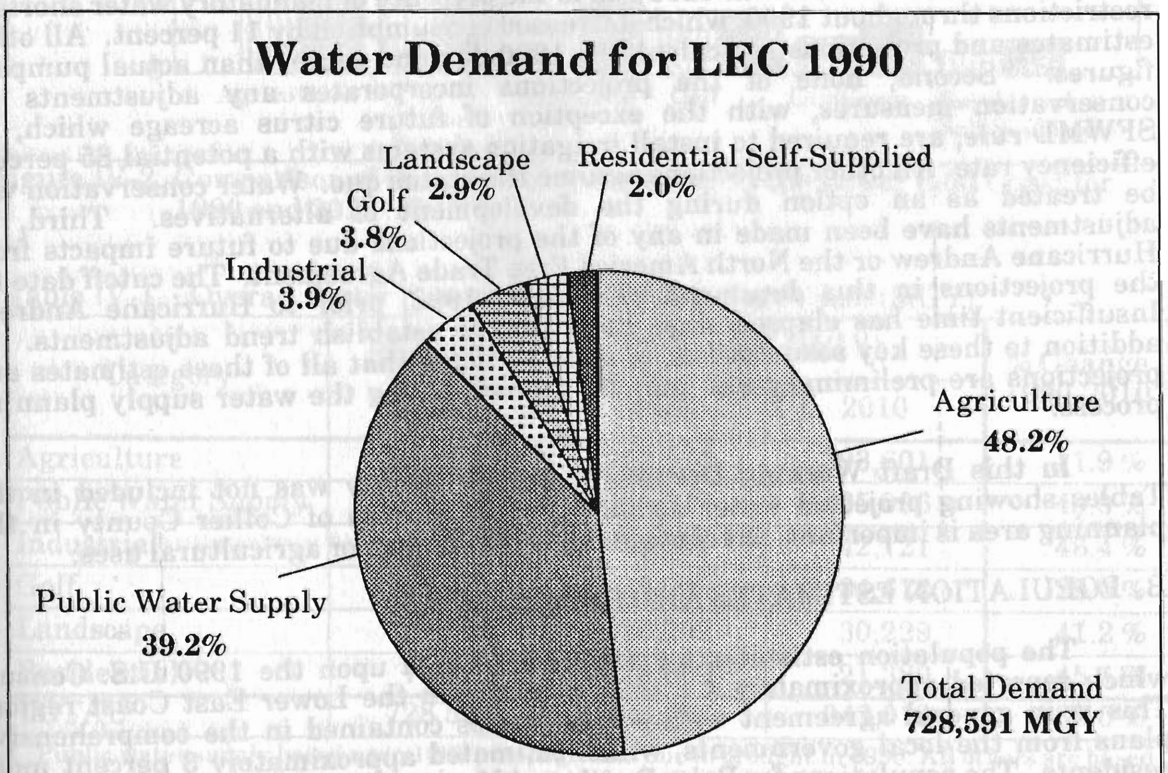


Figure IV-1. Lower East Coast Overall Water Demands for 1990.

Table IV-1 identifies the water demand estimates for 1990, by category, as well as the projected demands for 2000 and 2010. **Figure IV-2** illustrates the relative growth in demand projected for each category from 1990 to 2010. During the 20-year period, overall water demand is projected to increase by 30 percent to more than 947,000 MGY. Public water supplies account for 64 percent of the total increased demand. By the year 2000, public water supplies are projected to have replaced agriculture as the single largest category of user.

In 1990, "urban uses," that is all uses except agriculture, accounted for 52 percent of the total demand. By 2010, urban uses are projected to be more than 58 percent of the total demand. Agricultural demands are projected to increase by almost 12 percent by 2010, accounting for 42 percent of the total demand.

Dividing the total estimated water demand of the urban uses for 1990 and by the population of the Lower East Coast region is approximately 250 gallons per person per day. By comparison, the aggregate 1990 urban use for the St. Johns River Water Management District is 307 gallons per person per day. The comparable aggregate 1990 urban water use for the Southwest Florida Water Management District is 199 gallons per person per day.

In making the estimates and projections presented in this chapter, a number of assumptions have been made. These are identified in the following sections of this chapter that discuss the methodology used in computing the demands of each category of use. Three assumptions are sufficiently important that they bear discussion. First, projections for the public water supply demands utilize 1989 pumpages. The 1989 data was used due to the presence of mandatory water shortage restrictions throughout 1990, which decreased consumption by 11 percent. All other estimates and projections use calculated 1990 demand rather than actual pumpage figures. Second, none of the projections incorporates any adjustments for conservation measures, with the exception of future citrus acreage which, by SFWMD rule, are required to install irrigation systems with a potential 85 percent efficiency rate. All other projections assume the status quo. Water conservation will be treated as an option during the development of alternatives. Third, no adjustments have been made in any of the projections due to future impacts from Hurricane Andrew or the North America Free Trade Agreement. The cutoff date for the projections in this document were June 1992, prior to Hurricane Andrew. Insufficient time has elapsed since the storm to establish trend adjustments. In addition to these key assumptions, it must be noted that all of these estimates and projections are preliminary and may be refined during the water supply planning process.

In this Draft Working Document, Collier County was not included in the Tables showing projected water demands. This portion of Collier County in the planning area is important, but contains very little urban or agricultural uses.

B. POPULATION ESTIMATES AND PROJECTIONS

The population estimates for 1990 were based upon the 1990 U.S. Census, which reported approximately 4.1 million people in the Lower East Coast region. This is in general agreement with the estimates contained in the comprehensive plans from the local governments, which estimated approximately 3 percent more residents. The populations for Palm Beach and Monroe counties cover each county in its entirety, not just the portions within the Lower East Coast plan boundaries. The vast majority of the populations of these counties is within the plan boundaries.

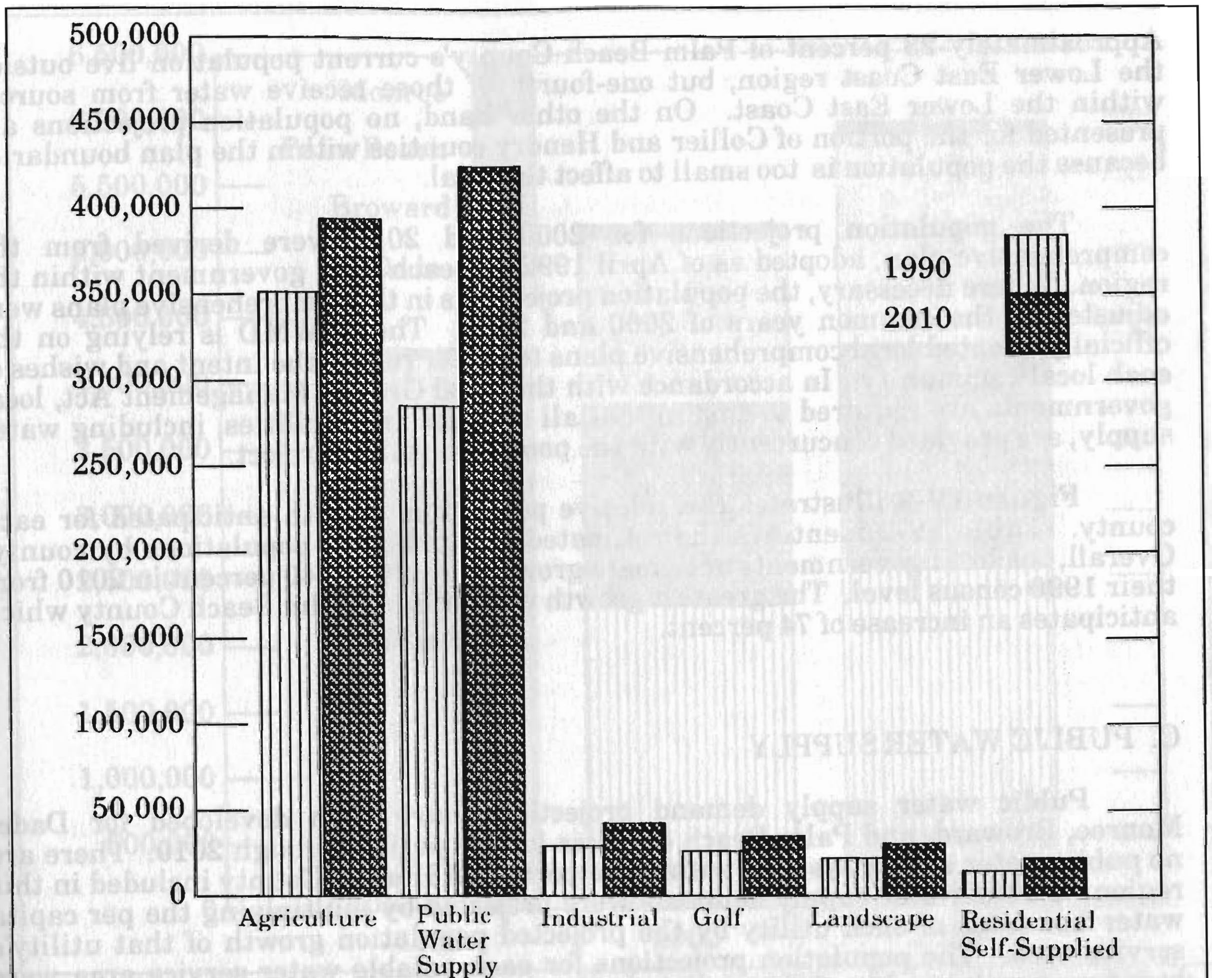


Figure IV-2. Comparison of Overall Water Demands in the Lower East Coast for 1990 and 2010 (MGY).

Table IV-1. Overall Water Demands in the Lower East Coast (MGY).

Category	Estimated (MGY) 1990*	Projected (MGY)		% Change 1990-2010
		2000	2010	
Agriculture	351,616	362,574	393,601	11.9 %
Public Water Supply	285,320	364,927	425,006	49.0 %
Industrial	28,762	35,661	42,121	46.4 %
Golf	26,783	30,729	34,672	29.4 %
Landscape	21,400	26,207	30,229	41.2 %
Residential	14,710	18,469	21,389	45.4 %
TOTAL	728,591	838,867	947,018	30.0 %

* Public water supply based upon 1989 pumpage data due to drought in 1990. All others are based upon calculated 1990 demands and represent self-supplied users.

Approximately 23 percent of Palm Beach County's current population live outside the Lower East Coast region, but one-fourth of those receive water from sources within the Lower East Coast. On the other hand, no population projections are presented for the portion of Collier and Hendry counties within the plan boundaries because the population is too small to affect the total.

The population projections for 2000 and 2010 were derived from the comprehensive plan, adopted as of April 1992, for each local government within the region. Where necessary, the population projections in the comprehensive plans were adjusted to the common years of 2000 and 2010. The SFWMD is relying on the officially adopted local comprehensive plans to better reflect the intent and wishes of each local community. In accordance with the 1986 Growth Management Act, local governments are required to ensure that all services and facilities, including water supply, are provided concurrently with the populations they project.

Figure IV-3 illustrates the relative population growth anticipated for each county. **Table IV-2** identifies the estimated and projected populations by county. Overall, the local governments anticipate growing by almost 40 percent in 2010 from their 1990 census level. The greatest growth will occur in Palm Beach County which anticipates an increase of 74 percent.

C. PUBLIC WATER SUPPLY

Public water supply demand projections have been developed for Dade, Monroe, Broward, and Palm Beach counties for the period through 2010. There are no public water supply systems within the portion of Hendry County included in this region. Public water supply demands were projected by multiplying the per capita water use rates of each utility by the projected population growth of that utility's service area. The population projections for each potable water service area were based primarily on data from the local comprehensive plans. Per capita water use rates were determined with 1990 population data for each service area and the reported 1989 pumpage. Pumpage data for 1989 was used instead of 1990 data because 1990 data reflects the impacts of mandatory water shortage measures due to the drought conditions that year (1990 pumpage was 11 percent less than 1989). An explanation of the methodology follows. A more detailed explanation and additional data will be found in **Appendix E**.

The population projections were derived from the comprehensive plan of each local government. The population estimates were then distributed by utility service areas for 1990, 2000, and 2010. The service areas used are those defined in the SFWMD water use permit files, which are based upon information submitted to the SFWMD by individual utilities. Data from the local comprehensive plans, U.S. Census, the Metropolitan Planning Organization Traffic Analysis Zones, and existing land use were evaluated to assess the geographic location of the existing population as well as that of the future population. The population estimates and projections from each local government's comprehensive plan were allocated to each of the utility service areas.

Average daily per capita water use rates were based on data from historical pumpage for 1989 as reported by the utilities. Average daily pumpage for each service area was divided by permanent population served by a utility, as identified in the local comprehensive plans within the service area in 1990, except for Palm Beach

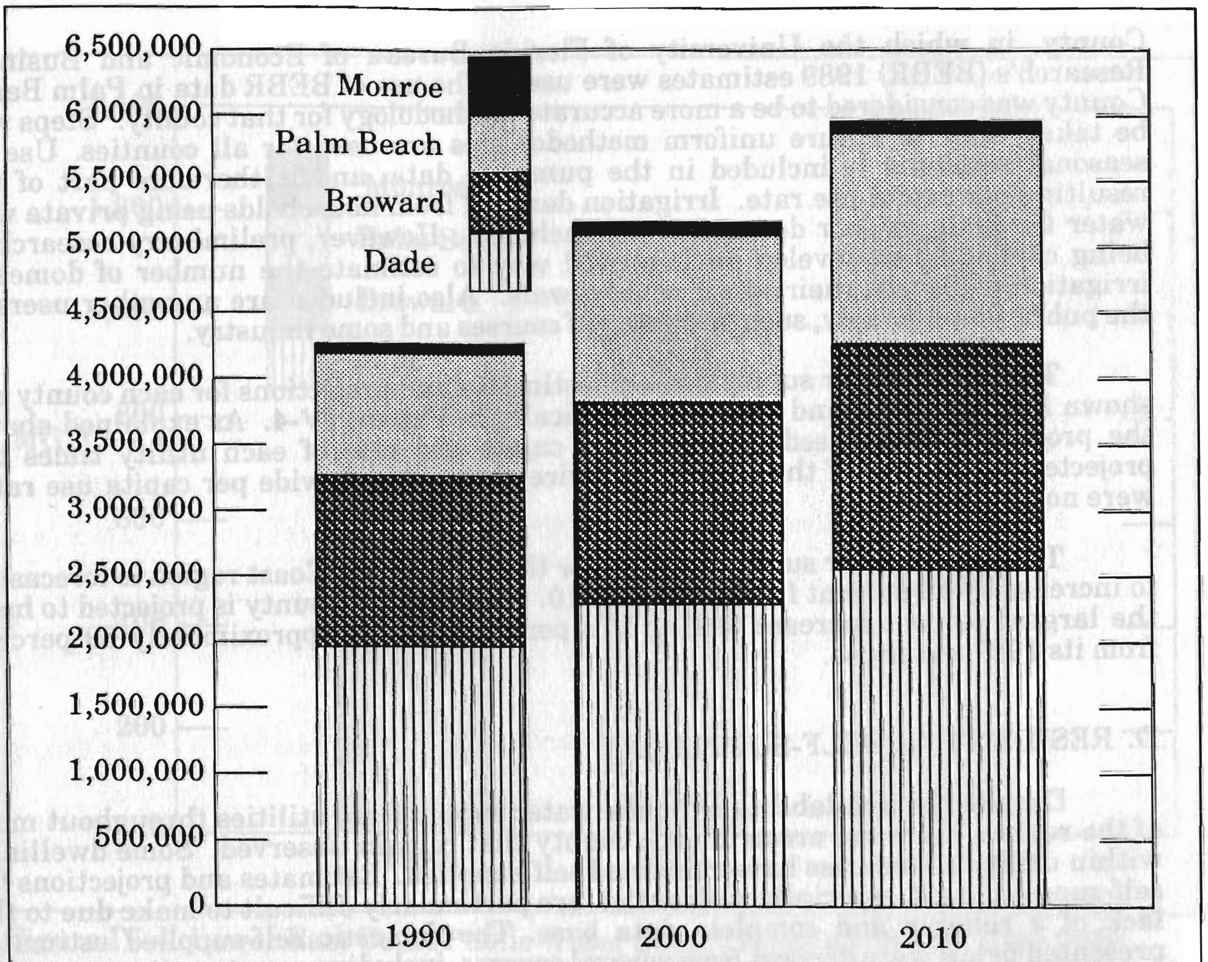


Figure IV-3. Comparison of Population Estimates and Projections in the Lower East Coast for 1990-2010.*

* Population of Hendry and Collier counties within the LEC boundaries does not affect totals.

Table IV-2. Population Estimates and Projections for the Lower East Coast.

County**	Census 1990	Comp. Plan 1990	% Diff. Comp. Plan/ Census	Comp. Plan 2000	Comp. Plan 2010	% Change* 1990-2010
Dade	1,937,094	1,954,845	0.9 %	2,280,718	2,556,377	32.0 %
Broward	1,255,488	1,314,918	4.7 %	1,554,672	1,718,849	36.9 %
Palm Beach	863,518	920,564	6.6 %	1,270,216	1,597,535	85.0 %
Monroe	78,024	80,746	3.5 %	93,038	97,433	24.9 %
TOTAL	4,134,124	4,271,073	3.2 %	5,198,644	5,970,194	44.4 %

* Based upon 1990 U.S. Census.

** Population of Hendry County within the LEC boundaries is not significant.

County, in which the University of Florida Bureau of Economic and Business Research's (BEBR) 1989 estimates were used. The use of BEBR data in Palm Beach County was considered to be a more accurate methodology for that county. Steps will be taken later to ensure uniform methodologies are used for all counties. Use by seasonal residents is included in the pumpage data, and is therefore part of the resulting per capita use rate. Irrigation demand from households using private well water for their outdoor demand is not included. However, preliminary research is being conducted to develop an improved way to estimate the number of domestic irrigation wells and their water withdrawals. Also included are any other users of the public water supply, such as a few golf courses and some industry.

The public water supply demand estimates and projections for each county are shown in **Table IV-3** and depicted graphically in **Figure IV-4.** As explained above, the projections are based upon the per capita use rate of each utility times the projected population of that utility's service area. Countywide per capita use rates were not developed.

The public water supply demand for the Lower East Coast region is forecasted to increase by 49 percent from 1989 to 2010. Palm Beach County is projected to have the largest percent increase during this period, growing approximately 89 percent from its 1989 water use.

D. RESIDENTIAL SELF-SUPPLIED

Despite the availability of public water supply from utilities throughout most of the region, there are areas in each county that remain unserved. Some dwellings within utility boundaries have remained self-supplied. Estimates and projections for self-supplied uses, especially residential, are particularly difficult to make due to the lack of a reliable and complete data base. The domestic self-supplied estimates presented below were derived from several sources, including county government and USGS estimates. The SFWMD currently is working to improve these estimates using 1990 U.S. Census data.

Table IV-4 shows the estimated domestic self-supplied water use in Dade, Palm Beach and Broward counties. Monroe County only has approximately 100 wells according to the U.S. Census because salt water underlies virtually all of the Keys. There are estimated to be even fewer residential wells within the Lower East Coast portion of Hendry County due to the sparse population.

E. INDUSTRIAL SELF-SUPPLIED WATER USE

Industrial self-supplied users include electric power plants, bottling plants, cement producers and other industries that use water from their own wells rather than a public water supply system. Industrial users need individual permits from the SFWMD if they are withdrawing over the permitting threshold for their county, which in the case of the Lower East Coast counties is 100,000 gallons per day (GPD). Unlike public water supply (PWS) permit holders, however, these users have not been required in the past to submit monthly pumpage reports. These wells were not previously required to have meters, and as a result there are no records to document how much water has been pumped. The permit allocations are based upon the system's capacity.

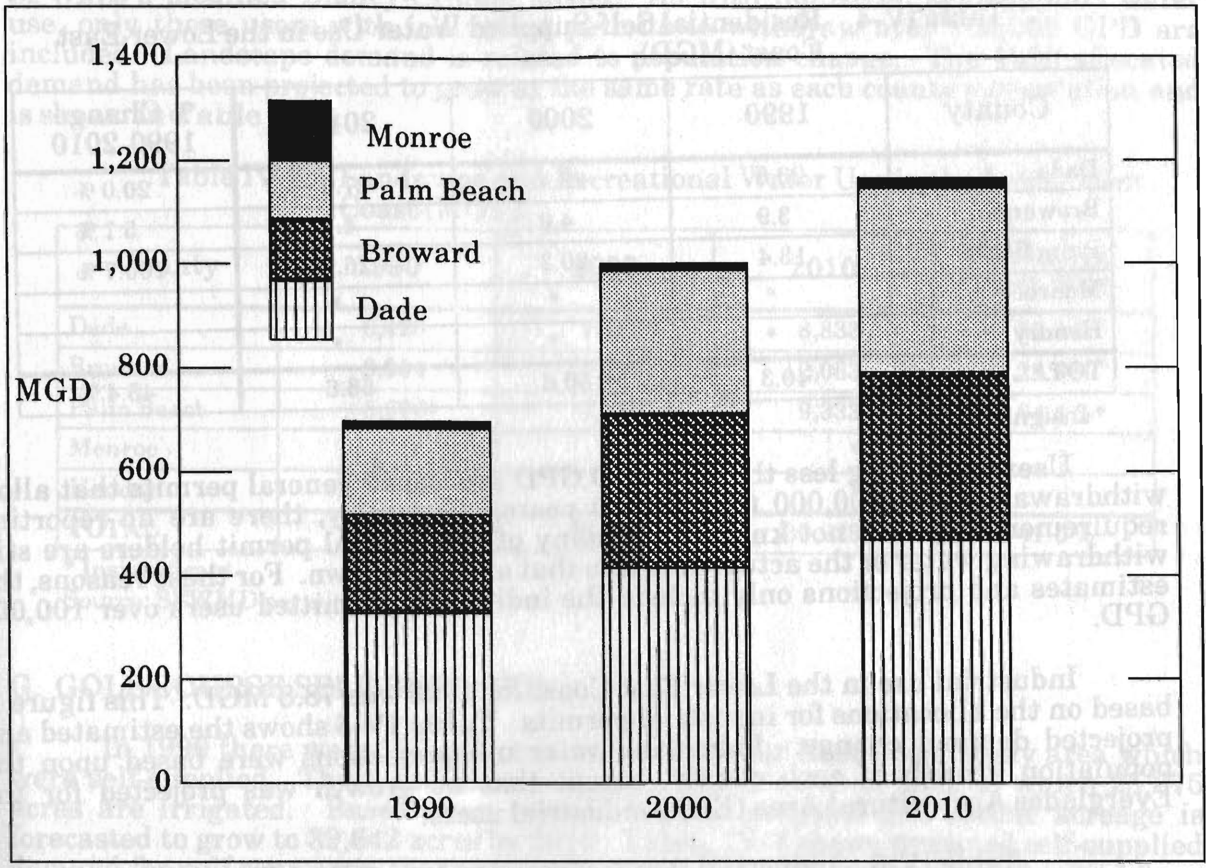


Figure IV-4. Lower East Coast Public Water Supply Demand (MGD), 1990-2010.
(No public water supply systems are within the LEC portion of Hendry County.)

Table IV-3. Public Water Supply Estimates and Projections for the Lower East Coast.

County	Estimated (MGD)		Projected (MGD)		% Change 1989-2010
	1989	1990	2000	2010	
Dade	352.9	325.0	414.0	466.0	32.0 %
Broward	226.0	194.2	297.2	325.3	43.9 %
Palm Beach	189.4	165.9	273.2 *	357.0	88.5 %
Monroe	13.4	11.2	15.4	16.1	20.2 %
TOTAL	781.7	696.3	999.8	1,164.4	49.0 %

* Extrapolated using 1989 and 2010 estimates.

Source: Draft Dade County - Florida Keys Water Supply Background Document, April 1992.
Phase 1 Broward County Water Supply Plan, October 1991.
SFWMD Planning Department estimates and projections for Palm Beach County, 1992.

Table IV-4. Residential Self-Supplied Water Use in the Lower East Coast (MGD).

County	1990	2000	2010	% Change 1990-2010
Dade	23.0	26.4	27.6	20.0 %
Broward	3.9	4.0	4.1	5.1 %
Palm Beach	13.4	20.2	26.9	100.7 %
Monroe	*	*	*	
Hendry	*	*	*	
TOTAL	40.3	50.6	58.6	45.4 %

* Insignificant

Users requiring less than 100,000 GPD are issued general permits that allow withdrawals up to 100,000 GPD for 20 years. Currently, there are no reporting requirements, so it is not known how many of the general permit holders are still withdrawing water or the actual amounts that are withdrawn. For these reasons, the estimates and projections only include the individual permitted users over 100,000 GPD.

Industrial use in the Lower East Coast for 1990 was 78.8 MGD. This figure is based on the allocations for industrial permits. **Table IV-5** shows the estimated and projected demand change. Industrial water use projections were based upon the population growth of each county, except that no growth was projected for the Everglades Agricultural Area (EAA) industrial users.

Table IV-5. Industrial Water Use in the Lower East Coast (MGD).

County	1990	2000	2010	% Change 1990-2010
Dade	49.7	58.3	68.4	37.6 %
Broward	2.6	3.1	3.4	30.8 %
Palm Beach	26.5	36.3	43.6	64.5 %
Monroe	*	*	*	
Hendry	*	*	*	
TOTAL	78.8	97.7	115.4	46.4 %

* Insignificant
Source: SFWMD permit files.

F. PERMITTED LANDSCAPE AND RECREATION SELF-SUPPLIED WATER USE

Landscape and recreation use estimated for 1990 refers to large-scale permitted water use. These SFWMD permit allocations are usually for the irrigation of large areas such as playing fields, condominium grounds, or the green space of business parks or shopping centers. Little or no data exists on the actual use of landscape and recreation permit holders. In the past, such systems usually were not metered and periodic pumpage data were not required. The permit allocations are based on the landscapes' supplemental water requirements as estimated by the SFWMD's modified Blaney-Criddle Model. As with industrial self-supplied water use, only those users with individual permits to withdraw over 100,000 GPD are included. Landscape demand is related to population change. The 1990 allocated demand has been projected to grow at the same rate as each county's population and is shown in **Table IV-6**.

Table IV-6. Landscape and Recreational Water Use in the Lower East Coast (MGY).

County	1990	2000	2010	% Change 1990-2010
Dade	6,420	7,530	8,833	37.6 %
Broward	9,304	10,899	12,063	29.6 %
Palm Beach	5,676	7,778	9,333	64.4 %
Monroe	*	*	*	
Hendry	*	*	*	
TOTAL	21,400	26,207	30,229	41.3 %

* Insignificant
Source: SFWMD permit files.

G. GOLF COURSE SELF-SUPPLIED

In 1990 there were 187 golf courses in the Lower East Coast study area which were self-supplied. These golf courses occupy 39,801 acres of land, of which 25,275 acres are irrigated. Based upon current trends, irrigated golf course acreage is forecasted to grow to 39,642 acres by 2010. Table IV-7 shows projected self-supplied demand for golf courses in the study area. Total average annual water demand from all sources for the region's golf courses is given in **Table IV-8**.

Table IV-7. Total Average Annual Self Supplied Water Demand by Golf Courses in the Lower East Coast (MGY).

County	1990	2000	2010	% Change 1990-2010
Dade	3,793	4,428	5,062	33.5 %
Broward	7,559	8,142	8,423	11.4 %
Palm Beach	14,927	17,655	20,683	38.6 %
Monroe	504	504	504	0 %
Hendry*	N/A	N/A	N/A	
TOTAL	26,783	30,729	34,672	29.5 %

*N/A: Not applicable. There are no golf courses in the LEC portion of Hendry County.

Table IV-8. 1990 Golf Course Water Demands for the LEC (MGY).

County	Public Water Supply	Reuse	Self Supply	Total
Dade	542	0	3,793	4,335
Broward	0	420	7,559	7,979
Palm Beach	277	1,195	14,927	16,399
Monroe*	59	81	504	644
Hendry**	N/A	N/A	N/A	N/A
Total	878	1,697	26,783	29,357

* Preliminary data.
**N/A: Not applicable. There are no golf courses in the LEC portion of Hendry or Collier counties.

H. AGRICULTURE

Agricultural water demand is defined here as the irrigation water requirement which consists of the water needed to irrigate the crop, as well as water losses incurred getting water to the crop's root zone, minus effective rainfall. "Effective rainfall" refers to the amount of rainfall that actually reaches and is stored in the crop's root zone. Six inches of rainfall in one week provides less effective rainfall than that same amount spread over several weeks. The demand projections were developed using the modified Blaney-Criddle method utilized by the SFWMD in issuing consumptive use permits. It takes into account crop type, local rainfall, soil type and estimated irrigation system efficiency. The details on these factors and the methods used in the projection of crop acreage are found in **Appendix E**.

The numbers presented for irrigation demand estimates and projections are equal to ET minus effective rainfall, plus the impact of the relative irrigation system's estimated efficiency. These demands are the sum of calculated withdrawals for irrigating the relevant crop / land parcel / acreage combinations. Return flow is not included in the demand numbers but rather is dealt with in the modeling process. This is consistent with the modeling runs carried out for the rest of the District.

In the EAA, due to the surface water supply source and the nonporous layer beneath the muck, return flow is often directly utilized for crop irrigation downstream, and therefore the sum of withdrawals is conceptually and numerically different from the values derived from a water balance of the region. This difference is rudimentary but often misconstrued. Also, in the EAA much of the noneffective rainfall is retained in the system. Therefore, the sum of the irrigation requirements for crop / land parcel / acreage combinations is not equal to the measured inflows minus the outflows from the system. Noneffective rainfall and return flow to supply sources are dealt with in the modeling process.

Lower East Coast acreage and demand projections represent agricultural acreage and demand data from all four counties. However, the EAA in Palm Beach County and the farming areas of South Dade County constitute the majority of the agriculture in the Lower East Coast region. Monroe County has virtually no agriculture (except a few plant nurseries) and Broward County's agriculture is confined generally to ornamental nurseries and some vegetable acreage.

Table IV-9 and **Table IV-10** show the net acreage devoted to agriculture by county and crop, respectively. **Table IV-11** shows the annual average agricultural water demand by county while **Table IV-12** shows the annual average agricultural water demand by crop. Shares of water demand of the various crops for 1990 and 2010 are presented in pie charts in **Figures IV-5** and **IV-6**. These charts show how the changes in the total water required by agriculture relate to the changes in crops being grown in the region. **Figure IV-7** presents a graphical comparison of agricultural demand by crop type for 1990 and 2010. For a complete description of agricultural water demand by crop in individual counties, see Table E-98 in **Appendix E**.

The information on annual average agricultural water demand is intended to provide a sense of the overall order of magnitude and amount of increase or decrease projected for future demand. It should be noted, however, that annual averages are not used in the computer models during the alternatives analysis process. The models will compute the water demands for specific climatic conditions that occurred historically. Thus, during droughts, the models will compute a greater demand than the averages shown here.

Table IV-9. LEC Agricultural Acreage by County.

County	1990	2000	2010	% Change 1990-2010
Dade	95,731	98,517	102,401	7.0 %
Broward	6,675	4,796	3,811	-42.9 %
Palm Beach	420,079	410,257	407,755	-2.9 %
Hendry*	163,633	215,347	254,918	55.8 %
Monroe	**	**	**	
TOTAL	686,118	728,917	768,885	12.1 %

* Includes only portions of Hendry County within the LEC region.
** Insignificant.

Table IV-10. LEC Agricultural Acreage by Crop.

Crop	1990	2000	2010	% Change 1990-2010
Sugar cane, LEC	399,900	380,587	379,296	-5.2 %
Citrus, LEC	96,193	130,101	164,832	71.4 %
Vegetables, LEC	119,168	113,826	113,157	-5.0 %
Nursery, LEC	12,549	18,662	23,996	91.2 %
Sod, LEC	20,581	26,475	28,215	37.1 %
Rice, EAA	17,150	40,000	40,000	133.2 %
Tropical fruit, Dade	14,964	16,132	17,300	15.6 %
Field crops, Dade	4,613	2,134	1,089	-76.4 %
Cut flowers, Hendry*	1,000	1,000	1,000	0.0 %
TOTAL	686,118	728,917	768,885	12.1 %

*Includes only portions of Hendry within the LEC region.

Table IV-11. Average Annual Water Demand for Agriculture by County (MGY).

County	1990	2000	2010	% Change 1990-2010
Dade	51,434	56,017	60,606	17.8 %
Broward	5,148	4,102	3,623	-29.6 %
Palm Beach	250,883	239,627	239,966	-4.4 %
Hendry*	44,150	62,834	89,406	102.5 %
Monroe	**	**	**	
TOTAL	351,616	362,574	393,601	11.9 %

*Includes only portion of Hendry within the LEC region.
**Agricultural water use in Monroe is insignificant.

Table IV-12. Total Agriculture Water Demand in the Lower East Coast (MGY).*

Year	1990	2000	2010	% Change 1990-2010
Sugar cane	212,129	193,642	192,662	-9.2 %
Citrus	28,698	44,954	69,607	142.6 %
Nurseries	17,544	26,692	34,644	97.5 %
Vegetables	58,791	53,384	51,123	-13.0 %
Rice	3,686	8,598	8,598	133.3 %
Sod	18,163	23,074	24,523	35.0 %
Tropical Fruit	8,626	9,299	9,972	15.6 %
IP/Cattle**	941	904	869	-7.6 %
Cut Flowers	1,160	1,160	1,160	0.0 %
Field Crops	1,877	868	443	-76.9 %
TOTAL	351,616	362,574	393,601	11.9 %

* Includes only portion of Hendry within the LEC region.
** IP: improved pasture.

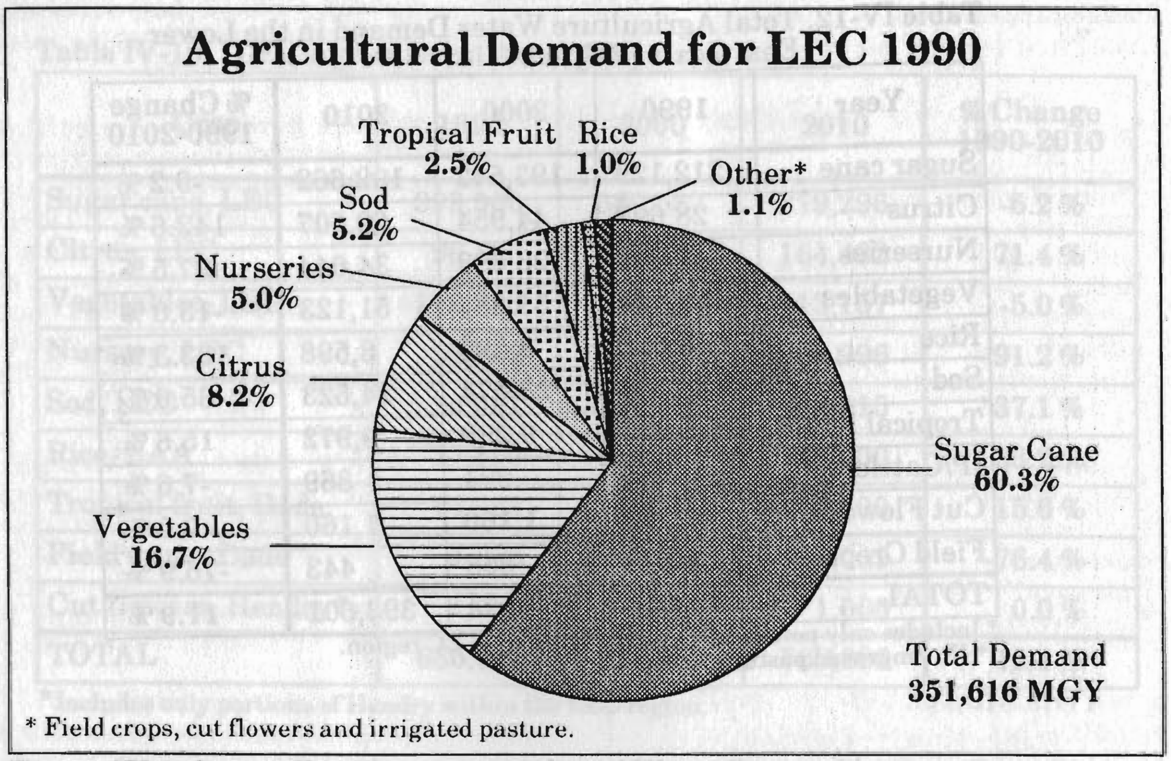


Figure IV-5. Lower East Coast Agricultural Water Demand by Crop Type for 1990.

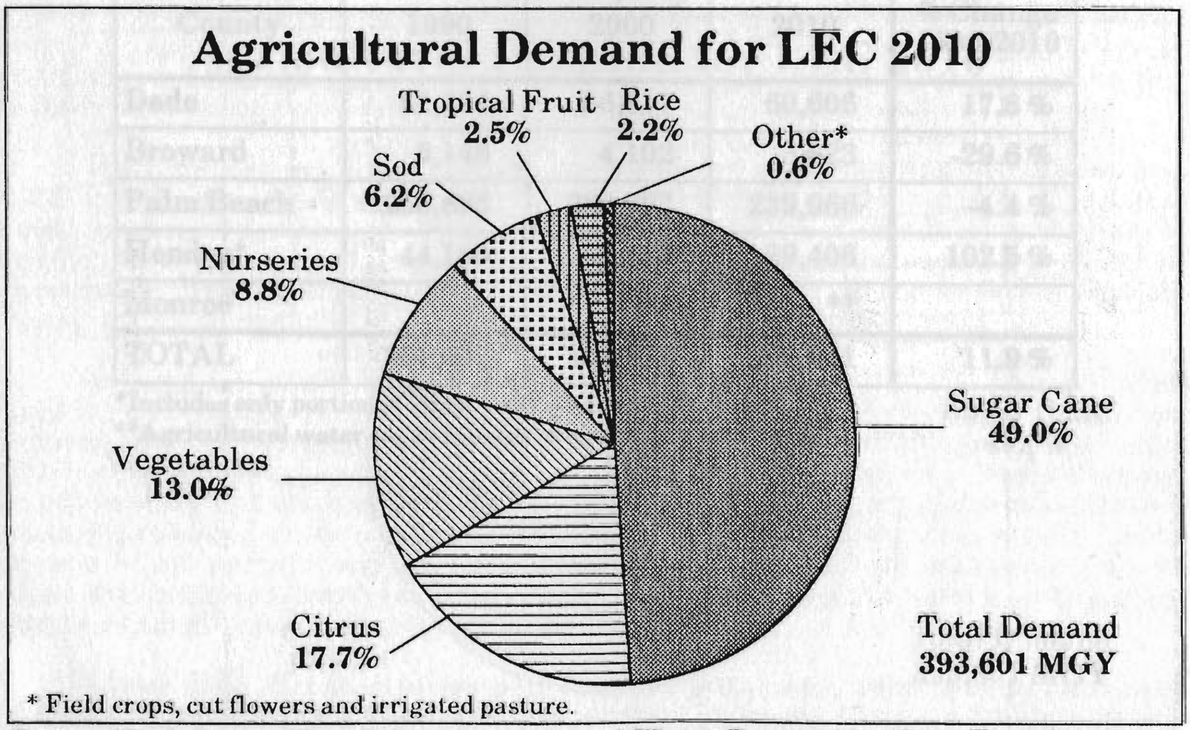


Figure IV-6. Lower East Coast Agricultural Water Demand by Crop Type for 2010.

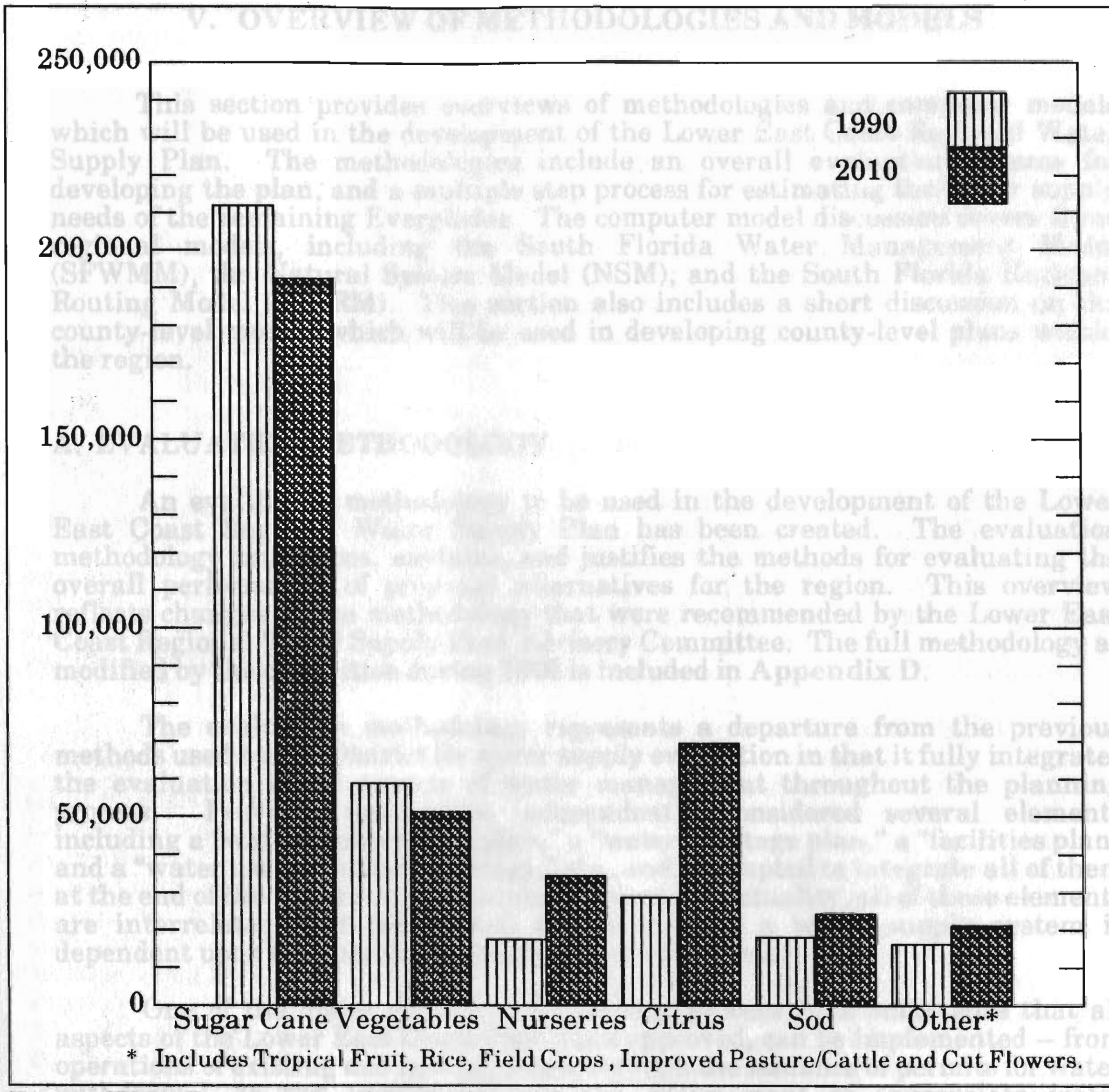


Figure IV-7. Comparison of Agricultural Demand in the Lower East Coast for 1990-2010 (MGY).

V. OVERVIEW OF METHODOLOGIES AND MODELS

This section provides overviews of methodologies and computer models which will be used in the development of the Lower East Coast Regional Water Supply Plan. The methodologies include an overall evaluation process for developing the plan, and a multiple step process for estimating the water supply needs of the remaining Everglades. The computer model discussion covers three regional models, including the South Florida Water Management Model (SFWMM), the Natural System Model (NSM), and the South Florida Regional Routing Model (SFRRM). This section also includes a short discussion on the county-level models which will be used in developing county-level plans within the region.

A. EVALUATION METHODOLOGY

An evaluation methodology to be used in the development of the Lower East Coast Regional Water Supply Plan has been created. The evaluation methodology introduces, explains, and justifies the methods for evaluating the overall performance of proposed alternatives for the region. This overview reflects changes to the methodology that were recommended by the Lower East Coast Regional Water Supply Plan Advisory Committee. The full methodology as modified by the committee during 1992 is included in **Appendix D**.

The evaluation methodology represents a departure from the previous methods used by the District for water supply evaluation in that it fully integrates the evaluation of all aspects of water management throughout the planning process. Previous approaches independently considered several elements including a "water conservation plan," a "water shortage plan," a "facilities plan" and a "water use permitting strategy," etc., and attempted to integrate all of them at the end of the water supply planning process. In actuality, all of these elements are interrelated, and the overall effectiveness of a water supply system is dependent upon the successful integration of all of them.

One of the major goals of the planning process is to make sure that all aspects of the Lower East Coast Plan, once approved, can be implemented -- from operations of existing and new facilities, through the issuance of permits for water withdrawal, to the implementation and enforcement of appropriate water shortage plans.

1. Definition of an Alternative.

For the purposes of this plan, an "alternative" is defined as essentially a complete strategy for current and future demand management, system operations, and expansion. In order to properly predict the impact of an alternative on the LEC water supply, it is necessary to reflect its characteristics in the computer models that will be used in the analysis. Therefore, seven functional components have been identified which together make up an alternative and reflect it's characteristics. Many aspects of these components can be independently represented in the computer models through various equations, input data adjustments and coding changes. Some aspects, such as water quality, can not be directly represented in the models; where possible, a hydrologic substitute will be used. Each alternative will be evaluated as a collection of the following seven related components:

- Environmental.
- Regulatory Strategy.
- Long-Term Conservation.
- Water Shortage Plan.
- Physical Facilities.
- Operations.
- Water Quality.

Each component is described in greater detail in Chapter VI and in Appendix D in the full text of the Evaluation Methodology.

2. Objectives and Performance Measures

In order to evaluate alternatives in a multi-objective framework, the ability of each alternative to meet all of the objectives of the LEC Plan must be compared. The ways in which success at meeting objectives can be quantified or otherwise displayed are called performance measures. Numerical standards for the performance measure will be defined during the development of the plan. The proposed measures of performance are listed here under the objectives that they are intended to quantify.

- **Objective 1**. Protect and enhance the environment.

Performance Measure 1. Environmental values will be assumed to be represented by maps showing the expected hydroperiod for sections of the Water Conservation Areas (WCAs) and Everglades National Park (ENP). These maps will be compared to output from the Natural System Model (NSM), which simulates the hydrologic response of the system prior to the Central and Southern Florida Project improvements. The District is currently working with the University of Maryland Center for Environmental and Estuarine Studies to develop an Everglades Landscape Model to provide better measures of health for the Everglades. However, this model will not be available in time to be incorporated into this water supply plan.

Performance Measure 2. Ground water stage duration curves beneath critical wetland areas outside the WCAs and ENP will be presented as a surrogate for environmental performance.

Performance Measure 3. Environmental impacts of LEC canal releases on selected estuaries will be illustrated using frequency and duration curves for extreme high and low discharges and, where possible, the estimated effects on salinity concentrations. Other estuarine impacts will be evaluated by the best available means.

Performance Measure 4. Frequency and duration curves of Lake Okeechobee water levels will be used as a surrogate for evaluating Lake Okeechobee littoral zone impacts. Lake levels may be combined with depth/phosphorus concentration relationships to estimate water quality impacts in the lake.

- **Objective 2.** Protect and conserve the water resources of South Florida to ensure their availability for future generations.

  Performance Measure 1. Surficial aquifer protection will be determined qualitatively for each alternative by examining the ground water heads and gradients at the saltwater boundary. This will be displayed for critical drought years.

- **Objective 3.** Provide for the equitable, orderly, cost effective and economically feasible development of water supplies to meet South Florida's agricultural, urban, municipal and industrial needs without harming the environment.

  Performance Measure 1. Water supply adequacy for major classes of users will be displayed using frequency and duration plots of the water shortage impacts of short-term conservation measures.

  Performance Measure 2. Costs and cost effectiveness for water, for additional facilities, and for long-term conservation measures will be estimated and displayed by geographic location by user class.

  Performance Measure 3. If possible, crop production (based on land and water availability, rainfall, and crop production functions) will be displayed for various geographic locations.

  Performance Measure 4. Sources of water (surface water, surficial aquifer, Floridan aquifer, reuse, etc.) will be displayed as a percent of supply by geographic location.

  Performance Measure 5. Economic benefits of each alternative will be estimated as the values of: 1) reductions in losses to crops, landscapes and other water uses and 2) the costs of avoiding losses that are incurred during water shortages.

- **Objective 4.** Respect local control over land use planning and local water supply options, consistent with regional water supply, flood control, and environmental protection.

  Evaluation of this objective, of necessity, will be subjective, and based on individual review of each alternative. However, the District will attempt to include alternatives that provide the potential for independent action by local authorities to ensure their own water supply.

- **Objective 5.** Improve the process of local and regional resource management through the integration of water supply and land use planning.

  No performance measures are specifically recommended for evaluating this objective. The District will however take into consideration the conclusions and recommendations of the LEC Plan regarding water supply during its future reviews of local government comprehensive plans.

- **Objective 6.** Develop a long range program for improving the District's ability to predict the impacts of development and management decisions and to evaluate water resource management strategies.

  No performance measures are specifically recommended for evaluating this objective, however, through the planning process, the Advisory Committee, public, and governmental agencies are encouraged to provide suggestions to the District regarding the long range program.

B. OVERVIEW OF METHODOLOGY TO DETERMINE ENVIRONMENTAL WATER NEEDS FOR THE REMAINING EVERGLADES.

In 1992, the South Florida Water Management District (SFWMD) staff presented to the Lower East Coast Advisory Committee a proposed methodology for determining the environmental water needs of the remaining Everglades. The advisory committee appointed an Environmental Subcommittee to review the staff proposal. The subcommittee made a number of significant changes to the document and presented the modified proposal to the full committee on January 27, 1993. Both the SFWMD staff's original proposal and the subcommittee's report are presented in **Appendix D**. The subcommittee's report is summarized below, although it is recognized that additional changes may occur as part of the continuing review by the full committee.

In its paper the subcommittee proposed a step-by-step procedure for identifying areas of the remaining Everglades which are in particular need of hydrologic restoration and designing strategies to achieve hydrologic restoration. It is also proposing criteria to be used in evaluating the ability of a particular strategy to meet the hydrologic restoration goals.

Florida law and SFWMD policy require that the SFWMD's water supply plans provide for protection or enhancement of the natural environment. The Lower East Coast Water Supply Plan has been designated as the plan which will deal with the environmental needs of the remaining Everglades. Because the remaining Everglades represents an ecosystem which is an important state, national, and international resource, the SFWMD considers it a critical responsibility to establish the timing, distribution, and volume of water needed to restore that ecosystem to a healthy state.

The remaining Everglades as defined in the subcommittee's report consists of the Holey Land, Brown's Farm, Rotenberger Tract, WCAs, Arthur R. Marshall Loxahatchee National Wildlife Refuge, Strazzulla tract, Pennsuco Wetlands, eastern Big Cypress Preserve, ENP and the coastal wetlands east of ENP and south of Biscayne National Park. A map of these areas is included with the subcommittee's report in **Appendix D**. The subcommittee recognized that achieving the biological goal of a healthy environment may require the protection, restoration, and creation of wetlands in southern Florida outside of these areas but the intent of the subcommittee's report was to deal with the remaining Everglades.

It is proposed to use a combination of NSM simulations, 1989 base case SFWMM simulations and existing biological and soils evidence to determine where there are areas which need restoration. The NSM simulation provides a guideline for hydrologic restoration, but cannot be exclusively relied upon.

Therefore, it is recommended that a process through which hydrologic objectives for various components of the remaining Everglades be established. Performance measures to be used in the evaluation methodology will be based on analysis of how closely a modeled alternative approaches the hydrologic objectives.

The operation of the C&SF Project has modified the natural flow regime both temporally and spatially. Returning surface water inflows to their natural condition within the remaining Everglades would not completely restore the natural hydrologic regimes because much of the presently delivered surface water leaves the system through structures and seepage to the urbanized coastal region. Thus, more surface water may be required to restore natural hydrologic conditions within the remaining Everglades than occurred naturally, unless seepage and structure discharges are reduced.

A review by SFWMD staff and the Advisory Committee of proposals to augment the current water delivery system, and/or reduce or recapture seepage and structure discharges, will be conducted to determine which proposals seem most likely to make significant contributions to the restoration effort. The key proposals selected by the SFWMD in conjunction with the Advisory Committee will then become part of the strategies to be modeled and evaluated following the evaluation methodology proposed by SFWMD planning staff. An important provision of that methodology is that for each alternative there will be components describing a regulatory strategy, conservation, water shortage plan, physical facilities, operations, and water quality.

The subcommittee proposed that the following 10 specific steps be undertaken during the water supply planning process to implement this approach:

1. SFWMD staff will present to the subcommittee the status of the verification process of the NSM. This will include a sensitivity analysis of Lake Okeechobee levels up to 22 feet NGVD, and a report on the sensitivity of the model to various evapotranspiration equations.

2. The NSM simulations will be compared to predictions of pre-drainage hydropatterns derived from existing species, community, and soils data to look for consistencies and inconsistencies with the NSM output. The objective of this step is to use this existing data as a form of verification of the NSM output.

3. Biologically significant hydrologic parameters (e.g., depth of soil drying, frequency of inundation, and many others) will be identified and NSM and SFWMM outputs compared to determine which parameters have been changed and where the greatest changes have occurred. Decisions will be made on which changes are significantly detrimental. On this basis, a list will be compiled of hydrologic parameters that should be restored closer to natural system values. This list will contain certain conflicts because of multiplicity of biological objectives. The subcommittee recommended, however, that such a comprehensive set of performance measures be used in evaluation of alternatives, because of the complex nature of environmental restoration.

4. The NSM in its currently accepted version will be used to estimate the stage and distribution of water, timing of flow, volume of flow, rates of

recession, and hydroperiods of the historic Everglades. These estimates should be made for key areas such as the Holey Land, Water Conservation Areas, Tamiami Trail section of ENP, central Shark Slough south of Tamiami Trail, a slough crossing the Loop Road in Big Cypress, Northeast Shark Slough, Taylor Slough, and C-111 Basin. This information represents an estimation of how the hydrologic regimes of the Everglades might have looked if the C&SF Project never existed under the rainfall conditions from 1965 through 1989. The specific variables used at a given site will depend upon the confidence in the output of the NSM at that location. This information may provide the basis for modifying the formula currently used to deliver flows to ENP. Iterative testing will be done to determine how well the revised formula can be expected to work.

5. NSM simulations will be compared with a base case (1989) run of the SFWMM. The SFWMM will be run using the current operational criteria in place during 1989. This base case run represents a model estimation of what the hydrologic regimes in the remaining Everglades would have been if the current facilities and operational policies had been in place over the 25 year period under 1965 through 1989 rainfall conditions. The comparison of the base case and NSM outputs can also be used as a preliminary technique for identifying areas where restoration may be needed.

6. In specific areas where confidence in the historical version of the SFWMM output is high, biological assessments will be made using aerial photos, field observations, and any written information on plant communities and animal populations. This will increase our understanding of the relationship between hydrology and biology and provide an opportunity to use biological data to modify the hydrologic objectives for restoration.

7. From the information gained in the above steps, a series of recommendations for restoring natural hydrologic regimes in the remaining Everglades will be developed.

8. The possibility of adjusting operational criteria for various areas in the Everglades to meet the hydrologic objectives developed in the previous steps will be the first strategy examined.

9. Develop a list of biological restoration objectives that can be used to design a monitoring program to judge the ultimate success of hydrologic restoration of the Everglades. Biological monitoring is vital because of uncertainties about modeling. The subcommittee can anticipate adjustments of Everglades management far into the future, as feedback from biological monitoring of restoration projects increases understanding of Everglades ecology.

10. Provide a report to the entire LEC committee on the results of this process. The entire LEC committee must recommend appropriate alternatives to be modeled as part of an overall strategy to meet water needs and reasonably satisfy the projected urban and agricultural demands.

In addition, the subcommittee recommended that the advisory committee determine what options might be used to deliver water through the current system to replicate the historic hydrologic regimes determined by the above process. Further, the advisory committee may need to develop and recommend changes in the structural system and its management to achieve the historic hydrologic regimes in areas where the current structural system is not capable of replicating the desired hydrologic regimes. The impacts of various options on water quality objectives or, conversely, the impacts of maintaining adequate water quality for the various options needs to be determined. Evaluations of these components will help determine the preferred alternative.

The Environmental Subcommittee recommends that the Advisory Committee establish an on going collaborative process to:

1. Establish intermediate and long term work plans and schedules;

2. Recommend future research and data collection needs;

3. Address water quality issues; and

4. Recommend improvements as the chosen strategy is being implemented. It is critical that the restoration process be considered an iterative process where continued monitoring, research and modeling can be used to adjust the initial recommendations of the Environmental Subcommittee so that the real goal of "biological restoration" be achieved.

C. COMPUTER SIMULATION MODELS

The interaction of southeastern Florida's hydrology with the Central and Southern Florida Project and its operation is complex. Changes in water management in the upstream parts of the region can potentially effect the hydrology of the entire system. To estimate the potential effects of structural and/or operational changes to the system, or changes in water demands and/or land cover, water resource systems simulation models are essential.

A simulation model is a tool developed to represent the performance of a real system. There are several types of simulation models used for water resources systems. Physical models are typically scale models of the real system that are tested in a laboratory. Analog models, although not common today, consist of a system of electrical components, resistors and capacitors, constructed to act as analogs of flow resistance and storage. Mathematical models consist of mathematical equations that describe the physics of the real system; they are typically operated using digital computers. Mathematical simulation models, also referred to as computer simulation models, are the most common type of model used today. The primary models that will be used in this plan are mathematical models.

Computer simulation models can play an important role in water resources planning. They are an increasingly important source of information for planning purposes and are very useful for understanding the behavior of the real system. However, information generated by simulation models is not always complete, and contains various levels of uncertainty. Therefore, models should never be a substitute for the judgment of experienced engineers, scientists, and planners.

Models can be thought of as providing necessary, but not completely sufficient, information that is required for making wise planning decisions.

The computer simulation models selected to be used for the analysis of alternatives are: (1) the South Florida Water Management Model (SFWMM); (2) the Natural System Model (NSM); (3) A Modular Three-Dimensional Finite-Difference Ground Water-Flow Model (MODFLOW); and (4) the South Florida Regional Routing Model (SFRRM). General overviews of each of these four models and a description of how they will interact are presented in the following sections.

1. South Florida Water Management Model

The South Florida Water Management Model (SFWMM) (MacVicar *et al.*, 1984) is a regional-scale integrated surface water - ground water model that simulates the hydrology and water management of most of the southeastern Florida region affected by the Central and Southern Florida Flood Control Project. This region is approximately 7,600 square miles including Lake Okeechobee, the Everglades Agricultural Area, the Water Conservation Area System, Everglades National Park, the Lower East Coast Developed Areas, and parts of the Big Cypress National Preserve.

The SFWMM was developed in the early 1980s by the SFWMD for the U.S. Army Corps of Engineers for their efforts with the Central and Southern Florida Water Supply Study (USCOE, 1989). The SFWMM performs, on a daily basis, a continuous simulation for 25 years of historic climatic data (rainfall and evaporation). The model also has the option to use either historical structure discharge data (where it is available) or to simulate the structure operation and compute the discharge. The structure operations will be simulated in the analysis of alternatives for this plan. The option to use historic structure flow data is useful for calibrating the model and for estimating historic water budgets.

Output from the model includes water levels and discharge for Lake Okeechobee and for any of the major canals and water control structures. Output at any of the more than 1,700 four-square-mile grid cells includes surface water and ground water levels, surface water flow, ground water flow, and evapotranspiration.

The model has been continually modified and improved by the SFWMD and the Corps of Engineers during the past eight years and has been used for several applications to evaluate water quantity impacts from proposed structural and/or operational changes to the system. Some of these applications include evaluations of:

- Water delivery alternatives for Everglades National Park;
- Proposed management alternatives for the Holey Land;
- Impacts of increased pumpages at existing Broward County wellfields (1983);
- The proposed west Dade wellfield;
- Preliminary water quantity and hydroperiod effects of the Stormwater Treatment Areas (STAs).

The model is currently undergoing significant modifications in order to be able to be reasonably consistent with the with the county level models, to simulate the current operational strategies and to provide the performance measure outputs that are required for evaluating alternatives.

The SFWMM will be the primary tool used to evaluate the alternatives for Lower East Coast Regional Water Supply Plan development and is described in more detail in Appendix C and in the documentation report (SFWMD Technical Publication 84-3).

2. County-Level Models

The county models are a smaller scale, finite-difference based ground water model with the integration of several surface water components of the South Florida Water Management Model (SFWMM). The county models are divided into three separate models covering eastern Palm Beach, Broward and Dade counties.

The Palm Beach County Model was originally developed by the South Florida Water Management SFWMD in 1989 as two separate models encompassing the northeastern and southeastern portion of the county (Shine *et al.*, 1989). The Broward County model was developed by the SFWMD in 1992 to evaluate ground water flow in that county (Restrepo *et al.*, 1992), while the Dade County model is under development by the SFWMD. The county models perform, on a monthly time step, a continuous yearly simulation using historical data including pumpage, rainfall, and evapotranspiration. The models can be run for consecutive years, however, the extensive data requirements for continuous multi-year simulations inhibit its use for this scenario. Therefore, multi-year simulations require a series of consecutive yearly runs.

Output from the county models include water levels, drawdowns and a complete water budget analysis for the study area. Output for any of the grid cells for these county models, includes ground water levels, ground water drawdowns, seepage into and out of the canals, evapotranspiration, storage, pumpage, recharge and ground water flow.

The county models were originally developed to analyze ground water flow. The Palm Beach County Model has been combined into a single model with the boundaries expanded to incorporate portions of Broward and Martin counties. The Broward County Model is in the process of being recalibrated. Since their development, the Palm Beach and Broward County models have been used to evaluate a number of proposals including: 1) determining the water demands of the Lake Worth Drainage District, 2) evaluating potential adverse impacts to adjacent users, the resource and regional storage as a result of the proposed Broward County North Regional Wellfield, and 3) evaluating potential impacts between the City of Deerfield Beach and Broward County 2A wellfields and their combined impact on the saline interface.

The county models in conjunction with the SFWMM will be used as the primary tools to evaluate the alternatives for the county water supply plan development. A more detailed description of the county models can be found in the documentation reports (Shine *et al.*, 1989; Restrepo *et al.*, 1992).

3. Interaction Between the South Florida Water Management Model and the County-Level Models

The principal aquifer in the Lower East Coast is the Biscayne aquifer which is one of the most transmissive aquifers in the country. Due to the direct connection between the aquifer and a large number of maintained canals, water levels within the Biscayne aquifer are directly controlled by the levels of the canals. During the dry season, water is brought to the coastal communities from Lake Okeechobee and the Water Conservation Areas to maintain ground water levels to off-set the potential for saline intrusion and to supplement wellfield withdrawals. Due to the complex interaction of surface water and ground water in the Lower East Coast, the need arises to simulate adequate canal inflows and localized stresses on the aquifer (Krupa *et al.*, 1992).

Due to the large grid space discretization of the SFWMM, the ability to analyze local stresses on the aquifer is limited. Therefore, the county models, with their significantly smaller cell size, will be used to evaluate alternatives on a local scale. Canal stages and equivalent recharge (boundary conditions) will be taken from the SFWMM, on a monthly basis, and used as input to the county models. This will insure that surface water flow and canal leakance, as predicted by the SFWMM, will be incorporated into the county models.

The county models will be evaluated against the SFWMM to assure consistency. Components similar to the models include ground water flow, ground water levels, evapotranspiration, changes in ground water storage, recharge and canal seepage. The models will be modified and recalibrated, as necessary, in order to achieve similar results. A more detailed discussion on the interaction and the consistency check between the models can be found in Krupa *et al.*, 1992.

4. Natural System Model

The "Natural" System Model (NSM) (Perkins and MacVicar, 1991) was created primarily to estimate "natural" flows and stages in existing Everglades areas, such as Everglades National Park and the WCA system, prior to significant human influence on the landscape. At this stage of the Lower East Coast Regional Water Supply Plan development, the output from the NSM will be used to provide an estimate of the "natural" hydrologic response of the predevelopment Everglades to be used as a potential guideline for identifying restoration needs.

The NSM (Version 3.6) was developed using the same calibrated algorithms and parameters used by the SFWMM for the hydrologic and hydrogeologic processes, but the components of the Central and Southern Florida Flood Control Project as well as all of the wellfields were removed. Estimates of pre-subsidence topography and a reasonable approximation of natural vegetation cover are used in lieu of the SFWMM data sets.

As with the SFWMM, the NSM performs, on a daily basis, a continuous simulation for 25 years of historic rainfall and pan evaporation data. The NSM covers the same area as the SFWMM but includes an additional 728 square mile portion of Hendry County that was considered a significant tributary to the Everglades. Output from the NSM includes surface water and ground water levels, overland flow, ground water flow, and evapotranspiration at any of the more than 1,900 four-square-mile grid cells.

There is more uncertainty in the NSM results than there is in the SFWMM results. This uncertainty is primarily due to the nonexistence of pre-drainage hydrologic data. Several weaknesses of the NSM have been identified by technical staff of the District, ENP, and the Corps of Engineers. One significant weakness is the way that the NSM simulates natural Lake Okeechobee stages and spills. Other areas of Version 3.6 of the NSM which need improvement have been identified and a joint effort between District and ENP staff has been initiated to perform the tasks associated with improving the model. Even with its current limitations, version 3.6 of the NSM is useful for making some general comparisons and inferences.

For more details on the NSM, refer to **Appendix G** or to the documentation report (Perkins and MacVicar, 1991).

5. South Florida Regional Routing Model

The South Florida Regional Routing Model (SFRRM) (Trimble,1986) is an additional regional scale model that simulates areal averaged water levels and structure discharges for Lake Okeechobee and the Water Conservation Areas. The principal benefits of this model are its computational speed and flexibility offered for modeling complex operational rules. Twenty five years of daily simulated water levels and discharges can be computed for Lake Okeechobee and the Water Conservation Areas in a matter of a few minutes. This speed is accomplished by using a mass balance, or water budget, approach on Lake Okeechobee and each Water Conservation Area and preprocessing the surface water needs of the Lake Okeechobee and Lower East Coast Service Areas.

Operational rules are incorporated into the model which determine the timing and magnitude of the discharges to be made through various structures for water supply, flood protection and environmental enhancement. Physical constraints on water movement between basins and surface water reservoirs are incorporated into the model.

The preprocessed Lower East Coast Service Areas surface water demands are defined as the water requirement necessary to maintain the canal water levels at the desirable levels to recharge the shallow aquifer and help prevent salt water intrusion. These demands are computed directly from the SFWMM to assure consistency between models. The Lake Okeechobee Service Area demands are also preprocessed, or computed prior to the SFRRM simulation, using similar crop coefficients and acreage as those included in the SFWMM.

This model has been used since the late 1970s as a tool to analyze the Lake Okeechobee-Lower East Coast regional hydrologic system. Most recently it has been used to evaluate the Lake Okeechobee regulation schedule (Technical Publication 88-5). Although this model does not compute the areal distribution of water levels within the Water Conservation Areas, its computational speed and flexibility for modifying operational rules makes it a useful screening tool for the current Lower East Coast Regional Water Supply Plan analysis.

VI. ALTERNATIVES, COMPONENTS AND POTENTIAL OPTIONS

The purpose of the planning process for the Lower East Coast region is the selection and implementation of a plan of action for the current and future regional system. This will be done after examining different viable alternatives. These alternatives must consist of more than simply specifying what additional supply facilities to build. They must deal with all aspects of the South Florida Water Management District's (SFWMD) responsibilities in water management, including operations, permitting and demand management, together with interfaces between SFWMD's responsibilities and those of the state and local governments.

Under this definition an "alternative" is essentially a complete strategy for demand management, system operations and expansion, now and in the future. In order to properly predict the impact of an alternative on the LEC water supply, it is necessary to reflect it's features in the computer models that will be used in the analysis. These features of an alternative will be defined for the purposes of this document, as "options". Options are the functional elements or pieces of the water supply strategy which will make up a given alternative. They are elements which can be specifically identified and analyzed to determine their effect on water supply. Some options may be coded into the computer models, but it is neither necessary or possible to incorporate all options into the computer simulations. Some aspects, such as water quality, can not be directly represented in the available models; where possible, a hydrologic surrogate will be substituted.

Examples of options could be a new water storage facility, such as a detention area or an aquifer storage and recovery (ASR) project. Options also would include a new or modified water control structure, a plan for improved delivery of water to an environmental system, or proposed water shortage indicators and other regulatory criteria. In order to simplify the process of option identification and evaluation, the SFWMD has identified seven functional components of an alternative, under which the options can be grouped or categorized. This section provides an initial list and description of some potential options that could be considered under each component. **Table VI-1** provides an example of how the options may be distributed or shared among the components.

Note, however, that one alternative may differ from another only slightly and need not be a completely new collection of options under the seven components. The number of possible "alternatives" is very large. However, physical, institutional and financial constraints will help limit the set of feasible alternatives to a reasonable number. The number of alternatives may also be reduced by defining what options will be considered in the regional plan. It may be useful to make a preliminary determination of those options which may have significant effects on regional water supply. Any options which are determined to have significant localized effects, but limited regional impacts should be considered in the county level water supply plans.

The seven components of an alternative can be summarized as follows:

- **Environmental Component.** This component will consist of several environmental options, which will include a set proposals to address the water needs of the Everglades, other regional wetlands and estuaries. Meeting the environmental water needs will be given highest priority for water allocation in every alternative. Other environmental needs to be addressed include water resource requirements related to the Lake Okeechobee littoral zone.

- **Regulatory Strategy Component.** The end result of the permitting process is to prescribe how much water may be withdrawn from each source and for what purposes. This component will consist of a set of criteria for withdrawal of water from specified sources, and for setting conditions (quantity and timing) on those-withdrawals. The "sources" include Lake Okeechobee, the SFWMD canals, the surficial aquifer, the Floridan Aquifer, and ocean water sources. Considering the interaction between these sources, the net result should be a scheme for surface water and aquifer management.

- **Long-term Conservation Component.** This component will consist of a set of measures for reducing long-term water demands through conservation measures such as water-conserving rate structures, retrofit of plumbing fixtures, Xeriscape landscape ordinances, efficient irrigation practices and other measures.

- **Water Shortage Plan Component.** This component will consist of a set of strategies for implementing short term reductions in water use (or water withdrawals from particular sources) when the potential for regional water shortages increases due to drought. This includes not only the actions (e.g. limitations on irrigation, source substitution, etc.) but also the means for determining when they should be implemented. This determination might be based on seasonally-adjusted trigger levels in Lake Okeechobee and other storage areas. Other indicators could be ground water levels in coastal (salinity) monitoring wells, selected environmental areas or public water supply wellfields.

- **Physical Facilities Component.** This component will consist of a set of existing and new water control, water storage and treatment facilities. These include all existing structures (although some alternatives may eliminate selected existing structures) as well as new structures. New structures or treatment facilities might include levees, pipelines, culverts, weirs, gated spillways, pump stations, reservoirs, regional aquifer storage and recovery (ASR) wells, wetlands, Stormwater Treatment Areas (STAs), well fields, or others.

- **Operations Component.** This component will consist of a set of guidelines for operating the facilities. These include not only target levels for Lake Okeechobee, but also rules for determining which sources to tap for what uses at what times, and what levels to maintain in canals, reservoirs and Water Conservation Areas (WCAs).

- **Water Quality Component.** Because this is a water supply plan, the water quality component will not vary substantially among alternatives. Rather, the necessary facilities and/or processes will be included in each alternative to ensure that all water quality standards and SWIM plan objectives will be met.

Table VI-I. Examples of Options to be Considered in the Development of Alternatives for the LEC Plan.

Options \ Component	Environ-mental	Regulatory Strategy	Long Term Conservation	Water Shortage	Physical Facilities	Opera-tions	Water Quality
Modify Regulation Schedule / Deliveries to WCAs	**X**				X	X	X
Improve flow to ENP, Shark River & Taylor sloughs	**X**				X	X	X
Modified Delivery to C-111	**X**				X	X	X
Modify Delivery to Regional wetlands outside of Everglades	**X**				X	X	X
Modified Deliveries to Estuaries	**X**					X	X
Geographic /User Group Basis for Withdrawals		**X**					
Geographic / source Basis for Withdrawals		**X**					
Wastewater Reuse		X	X		**X**		
Urban Conservation Elements			**X**				
Agricultural Water Conservation Elements			**X**				
Application of Short Term Cutbacks				**X**			
Water Shortage Indicators	X			**X**			
Surficial Aquifer Wellfield Expansion & Rehabilitation					**X**		
New Detention/ Storage Areas	X				**X**		X
Brackish & Saltwater Treatment					**X**		
Aquifer Storage & Recovery					**X**		
Regional Conveyance Mechanisms					**X**		
Lake Okeechobee Regulation Schedule	X					**X**	
Modified Operational Guidelines for the EAA						**X**	
Modified Operational Guidelines for Existing Structures & Canals	X					**X**	
Operational Guidelines for Proposed Structures & Canals	X				X	**X**	
Saltwater Intrusion Control					X		**X**
Stormwater Treatment Areas	X				X	X	**X**

X Option included as this Component

X Option may affect or be implemented through this Component

A. ENVIRONMENTAL COMPONENT

1. Introduction

The environmental component will consist of various hydrologic strategies which will be identified as options in the context of this study. These options will be formulated to meet the environmental water requirements of the sensitive wetland and estuarine habitats of the LEC.

Options considered to be part of the environmental component will be implemented through physical facilities modification or changes in the operation of the SFWMD's water management facilities. As a result, the environmental component will serve as a means to more clearly identify groups of physical facility or operational changes which will be proposed to implement the environmental strategy of a plan alternative. Nonetheless, it is important to maintain a separate environmental component to ensure that these important issues are adequately addressed in each alternative to be considered.

2. Potential Options

Options in water allocation and distribution for the environment will be analyzed to derive a preliminary plan which will, to a greater or lesser extent, replicate hydropatterns associated with the natural system hydrology. A number of environmental options have been identified for possible use in this component and will be grouped under the following categories:

Remaining Everglades

- Modify Delivery and Restore Hydroperiods to the Water Conservation Areas.
- Modify Delivery and Restore Hydroperiods to Everglades National Park, including Shark River Slough and Taylor Slough.
- Modify Delivery to C-111.

Regional Wetlands Outside of the Everglades

- Modify Delivery to the Northwest Fork of the Loxahatchee River
- Modify Delivery to the Strazzulla Tract
- Modify Delivery to the Everglades Buffer Strip
- Modify Delivery to the West Palm Beach Water Catchment Area.
- Modify Delivery to the Pennsuco Everglades.
- Modify Delivery to Big Cypress National Preserve
- Others

Coastal Resources

- Modify Delivery to Biscayne Bay
- Modify Delivery to Florida Bay
- Modify Delivery to Whitewater Bay
- Modify Delivery to Manatee Bay
- Modify Delivery to Lake Worth
- Others

Lake Okeechobee

- Modify Lake Management to Enhance Littoral Zone

A brief description of the options within each of these categories is given below.

3. Descriptions

Remaining Everglades

Modified Deliveries to the Water Conservation Areas. The problems currently threatening the Everglades region and the ENP are not new and have been recognized for years. Most of the surface flow entering the ENP occurs through the C&SF Project. Water control works that were constructed immediately adjacent to Shark River Slough, Taylor Slough, East Everglades and the panhandle of the ENP allow water managers to regulate flow across park boundaries. Special delivery scenarios were implemented from 1962 to 1982 to meet delivery goals for the ENP.

The potential options discussed below come from several sources including the C-111 General Design Memorandum (GDM), the GDM for Modified Water Deliveries to the ENP, ENP "Seven Point Plan" and the alternatives described by the Special Area Management Plan Committee for the Bird Drive Everglades.

An option for WCA-1 could be to modify the regulation schedule to prevent drying of the northern end. This would be an environmental option as well as a operational option. Enclosure of WCA-1, also known as the Arthur R. Marshall Loxahatchee National Wildlife Refuge, by canals and levees has eliminated historical sheetflow patterns in the refuge, altering the hydroperiod characteristics of certain areas of the marsh. Impoundment of the southern lower elevations of WCA-1 has left this area flooded for long periods of time while allowing more frequent drying of the extreme northern portion of the marsh (Pope, 1987). A narrow swath of disturbed vegetation extends around the perimeter of WCA-1.

An option for WCA-2A could be to modify the regulation schedule to better distribute water levels across the area while preserving the intent of the current drawdown of wet season water elevations to promote the re-growth of tree islands and wet prairie vegetation communities. In the 1960s and 1970s, WCA-2A was used as a regional water storage area which resulted in prolonged high water levels and eliminated the natural Everglades hydroperiod. Plant communities have changed from tree islands, sawgrass and wet prairie communities to remnant drowned tree islands, open water sloughs, large expanses of sawgrass and sawgrass intermixed with dense cattail. In recognition of these problems the SFWMD initiated several experimental drawdown studies of WCA-2A for the purpose of stimulating more natural drying conditions that would promote the regrowth of wet prairie vegetation and tree island communities. Experimental drawdowns were conducted in 1974 and in 1980. A modified version of the drawdown plan was incorporated into the WCA-2A regulation schedule in the 1980s.

An option for WCA-2B could be establishment of a regulation schedule to lengthen the hydroperiod. This option could include a physical facilities modification to deal with increased seepage. WCA-2B was impounded by L-35 in an effort to reduce water seepage losses to the south, provide flood control, and to increase the water storage capability of WCA-2A. The completion of the levee in 1972 resulted in a lowered water table and a shortened hydroperiod for WCA-2B. Invasion of exotic vegetation has occurred. Draw down efforts in WCA-2A during the 1980s resulted in increased volumes of water being diverted to WCA-2B. These efforts have helped somewhat to slow down the invasion of melaleuca. The highly permeable aquifer underlying WCA-2B has made it difficult to maintain historical water levels within this impoundment. As a result no regulation schedule is currently maintained for WCA-2B.

An option for WCA-3A would be to modify delivery of water to reduce the overdrainage of the northern end or to compartmentalize the northern end to better regulate the hydroperiod. Improvements made to the Miami Canal and the impoundment of WCA-3A by levees have over-drained the north end of WCA-3A and shortened its natural hydroperiod. The construction of the original Alligator Alley cut off sheet flow to the central and southern portions of WCA-3A. The road bed and related borrow canals resulted in excessive drainage of the marsh on both sides of the road. The redesign of this trans-Everglades highway into Interstate 75 was intended to reduce these impacts with an increased number of culverts and bridges. Prior to the I-75 project, two environmental enhancement structures S-339 and S-340 were constructed in the Miami Canal in 1980 to divert water across WCA-3A north and WCA-3A south in an effort to prolong the marsh hydroperiod, increase water table levels and to decrease flow rates to the south end of WCA-3A (Zaffke, 1983). The east central portion of WCA-3A south periodically experiences prolonged deep water conditions. Completion of L-29 across the southern end of WCA-3 in 1962 coupled with improvements to the Miami Canal, L-67A, L-29 and L-38W has accelerated historical flow of water southward causing a longer period of inundation and relatively deeper water levels at the extreme south end of WCA-3A.

An option for WCA-3B which could help reduce the threat of invasion by exotic vegetation would be to deliver more water by reconnecting the area to the rest of the Everglades System. This is an environmental option which can be implemented through the operational and physcial facility components. This area has changed little since the enclosing levees were completed in the early 1960s. Tree islands in this area however are threatened by the invasion of melaleuca, which have become firmly established as a seed source within the Bird Drive/Pennsuco wetlands located just east of WCA-3B in western Dade county.

Modify Delivery and Restore Hydroperiods to Everglades National Park, including Shark River Slough and Taylor Slough. Options for returning flow to the entire width of Shark River Slough include the construction of structures in L-67A to allow water to be passed from WCA-3A to WCA-3B, construction of structures in L-29 to allow water to be passed from WCA-3B to Northeast Shark River Slough, fill in L-67E canal and remove the levee, and distribute water deliveries along the the entire length of Tamiami Canal. These options will be implemented through a mixture of operational and physical facilities components but are all environmental options. Shark River Slough (SRS) provides the primary inflow of water to the ENP. Historically the SRS drainage originated in what is now WCA-3. Water flowed southwestwardly in an arc that swept through the heart of the ENP (Beard, 1938; Davis; 1943). SRS is now dissected into WCA-3A, WCA-3B, the East Everglades and the ENP. The slough is presently divided in the northern portion by levee L-67E. The L-67E levee was constructed to allow more water to move from WCA-3A to the ENP, but has resulted in the channeling of the once 25 mile wide sheet flow of the historic SRS system into less than 10 miles of the western portion of the area. Construction of the L-29 levee in WCA-3B coupled with the completion of the L-67E canal and levee in the ENP cut off sheet flow to the central portion of SRS. Efforts to restore more natural flows to SRS have been underway since 1985, starting with a field test of the Rainfall Plan in 1985. Additional refinements are needed to restore the historic structure and function of the SRS, which is critical for the restoration of the ENP.

Options for improving flows to Taylor Slough include: 1) the relocation of the L-31W and the borrow canal east; 2) the reconnection of the isolated portion of

Taylor Slough and wetlands; and 3) the installation of culverts in portions of the L-31W. Headwaters of Taylor Slough provide the main inflow to the eastern ENP. Taylor Slough headwaters include the area known as the Frog Pond and is the central component of the Florida Bay drainage area. Under natural conditions it is the major source of overland freshwater flow into northeast Florida Bay. The South Dade Conveyance System (SDCS) was designed and built to provide additional water to the ENP and to support agricultural production in south Dade County. However, this system has resulted in an increase in the amount of water discharged to the southern end of the C-111 canal system. The completion of the SDCS enlarged the capacity of the existing northern portion of the canal system above the C-111 Canal without adequate provisions to accommodate additional of water in the southern end of the system. Construction of the SDCS also facilitated agricultural and residential development of adjacent wetlands during dry years. This resulted in increased flooding of agricultural lands during wet years and subsequent requests for additional drainage and flood protection.

Modify Delivery to C-111. Options for C-111 basin include: 1) modifying deliveries to restore the 6-8 month hydroperiod during normal water years in the marl and rocky glades of the C-111 area, Taylor Slough and East Everglades; 2) increasing the hydroperiod in the northern C-111 wetlands through higher C-111 canal stages or removal of substrate; 3) installing culverts under U.S. 1 to direct water to historic flow channels to deliver water to Barnes Sound and Manatee Bay; 4) removing the westernmost spoil on the south side of the C-111 canal between S-18C and C-11; 5) removing C-109 and C-110 levees to prevent unnatural impoundment of surface waters north of the lower C-111. These environmental options will be implemented by a mixture of operational and physical facilities options. Prior to human activity the C-111 basin was a wetland that extended north to Florida City and west to Taylor Slough. C-111 is the southern most canal in the C&SF Project, bordering the ENP. The three main functions of the C-111 system are to 1) supply water to the eastern panhandle of the ENP, 2) prevent saltwater intrusion, and 3) provide flood protection for upstream agricultural interests. Operation of the system results in occasional large discharges of freshwater into Barnes Sound and Manatee Bay. The addition of the C-111 canal has drained surface water from adjacent marshes and reduced their hydroperiods. In other areas, ponding has occurred, e.g., where C-111 intersects U.S. Highway 1. There are few provisions in the U.S. 1 design to allow for sheet flow to the southeast (the natural drainage pattern) and so the roadbed serves as a levee and prevents overland flow of freshwater to Barnes Sound. Additionally there is poor distribution of flow over the marshlands in the eastern panhandle of the ENP to the northeast Florida Bay.

Regional Wetlands Outside of the Everglades. Options in water allocations and distribution for regional wetlands outside of the remnant Everglades will be analyzed to derive a preliminary plan which will to a greater or lesser extent, replicate hydropatterns associated with the natural system hydrology.

The areas described above can be impacted by changes in regional operations, such as changes in seepage due to higher or lower stages within the WCAs. Some major wetland areas, such as the Everglades Buffer Strip, may be examined as potential retention areas or reservoirs for possible backpumping schemes. The physical facilities section in this chapter will describe these types of options. County water supply plans will discuss these areas in more detail.

An option for Big Cypress may be the filling in of the L-28 canal and the removal of levee segments. Removal of the levee will provide some flood relief to ENP and restore high-water flow through several historical drainage channels. L-28 is overdraining the eastern Big Cypress during the dry season, and the levee prevents high water from moving into Big Cypress as it traditionally did.

These options would be implemented through a mixture of operational and physical facilities components but are considered environmental options.

Coastal Resources. The major estuaries and other important coastal areas in the Lower East Coast planning area are described in Section III.

Large volumes of freshwater can be a pollutant in some areas of the more saline coastal systems. If possible the release of water should be based upon a "rainfall model" of the watershed. Excess runoff that falls outside the threshold of the model would be appropriate for potential detention and storage. The physical facilities component section of this chapter describes options for potential new detention areas. Unless provisions are made for water quality treatment, backpumping of stormwater to surface storage areas may increase the potential for water contamination. The release of those waters could then increase the potential contaminant load to receiving water bodies. The use of this concept would need to be evaluated on a site-specific basis.

At the same time, significant decreases in freshwater flow have been identified as a factor in the decline of Florida Bay. Restoration of overland flows to Florida Bay may be accomplished in part by implementing the options discussed in the Taylor Slough and C-111 sections above.

In addition, this plan will consider the needs of other major coastal resource areas outside of the planning area which could be impacted by changes in water management practices. Two areas of special concern are the St. Lucie and Caloosahatchee estuaries, which are external to the study area but critical issues in Lake Okeechobee water level considerations.

Adverse environmental impacts from the operation of the regional system can be remedied through the manipulation of other components of this plan. Operating standards set for coastal structures and the resulting outflows will provide data for estimating freshwater flows and potential pollutant loading into the downstream receiving bodies. These discharges will be expressed in volume and duration. In the case of the St. Lucie and Caloosahatchee estuaries, pulse releases will be examined. Appropriate pulse release programs may be considered in conjunction with other storage areas. The physical facility component will factor in the possible effects of backpumping to surface storage, aquifer storage and recovery (ASR) and wastewater reuse on the estuaries of the planning area.

Lake Okeechobee. In 1988 the District organized a technical committee to give advice on the conditions of the littoral zone of Lake Okeechobee and its relationship with lake water levels. The committee was called the Lake Okeechobee Littoral Zone Technical Group (LOLZTG). This group concluded that higher stages are responsible for declines in quality and quantity of important waterfowl habitat in the emergent littoral zone. LOLZTG recommended significant changes to the management plan for the lake to allow for a regulation schedule with fluctuating water levels between a high of 16 feet and a low of 14 feet NGVD.

It is important to note that historically, Lake Okeechobee has been an important source of fresh water for the Lower East Coast planning area during periods of low rainfall. Still, the balance between effective use of water and the environmental consequences of that use must be properly evaluated. Therefore, any option to modify the present system of water supply deliveries from Lake Okeechobee must consider the potential impacts to the littoral zone.

B. REGULATORY STRATEGY COMPONENT

1. Introduction

The end result of the permitting process is to prescribe how much water may be withdrawn from each source and for what purposes. This component will consist of a set of criteria for the withdrawal of water from specified sources and for setting conditions (quantity and timing) on those withdrawals. The sources include Lake Okeechobee, the SFWMD canals, the surficial aquifer, the Floridan aquifer, ocean water sources and other surface water sources. Considering the interaction of these sources, the net result will be a scheme for surface water and aquifer management. These options may be used alone or in combination. They may be implemented District-wide, countywide, or by other geographic location. Guidelines may also be considered for granting exceptions to the criteria.

The District must follow water requirements of Florida State Law to allocate water and has the responsibility to develop water allocation policies. The District must assure that proposed operating rules, water allocations and physical facilities provide for sufficient water to maintain public health and safety, and provide for the reasonable beneficial use of water.

2. Potential Options

User Classification

- Agricultural withdrawals may be based on geographic location and/or crop type.
- Urban potable withdrawals may be based on geographic location

Source Classification

- Total withdrawals from the surficial aquifer in a geographic location may be considered.
- Total withdrawals from the Floridan aquifer in a geographic location may be considered.
- Total withdrawals from surface water sources in a geographic location may be considered.
- Others.

3. Descriptions

User Classification

Agricultural Withdrawals. Setting limits on agricultural withdrawals by geographic location or crop type may be necessary where surface water sources are inadequate to provide for present or future irrigation demands. Different crop types require different levels of irrigation to supplement evapotranspiration (ET), therefore the identification of soil types related to crop types and irrigation demands will be analyzed and a scheme for allocation developed as part of this option.

Source Classification

Surficial Aquifer Withdrawals. Allocating total withdrawals from the surficial aquifer by geographic location or land use will be evaluated by identifying those geographical areas or land uses most suitable for withdrawing water of the quality found in the surficial aquifer. Varying uses may or may not need additional treatment of the surficial source.

This will be recognized by model simulations by adjusting withdrawals by geographic location or land use from the surficial aquifer.

Floridan Aquifer Withdrawals. Allocating total withdrawals from the Floridan aquifer by geographic location or land use will be evaluated by identifying those geographical areas or land uses most suitable for withdrawing water of the quality found in the Floridan aquifer and having the ability of providing treatment of that water. Varying uses may or may not need additional treatment of the Floridan source.

This will be recognized by model simulations by adjusting withdrawals by geographic location or land use to the Floridan aquifer and by reducing the surficial aquifer demands from those areas and uses if applicable.

Surface Water Withdrawals. Allocating total withdrawals from surface water sources by geographic location or land use will be evaluated by identifying those geographical areas or land uses most suitable for withdrawing water of the quality found in surface water sources. Varying uses may or may not need additional treatment of the source.

This will be recognized by model simulations by adjusting withdrawals by geographic location or land use to surface water sources and by reducing the surficial aquifer demands from those areas and uses if applicable.

C. LONG-TERM CONSERVATION COMPONENT

1. Introduction

The long-term water conservation component in this plan consists of integrated and coordinated combinations of urban and agricultural water conservation options. These water conservation options reflect specific changes in water use practices and technology that can lead to permanent reductions in water use. Important considerations are the effect of conservation on total demand and the effect of demand reduction on evapotranspiration. Savings that are realized may reduce annual average and/or peak period water use. The options in this plan are water use practices and technologies which have been tested and proven reliable and capable of providing the services desired by the users while using less water. Recent revisions to the District's Basis of Review for water use permitting, effective as of January 1993, have made a number of conservation measures a mandatory part of the consumptive use permit process. The mandatory urban conservation measures include adoption of Xeriscape landscape codes, utility leak detection and repair programs, conservation rate structures, public education programs, ultra-low volume fixture ordinances, rain sensor switch ordinances for new automatic sprinkler systems, and 10:00 a.m. to 4:00 p.m. irrigation restriction ordinances. More efficient irrigation methodologies for agricultural operations which are now mandatory include the use of micro-irrigation systems for citrus and systems that are capable of achieving efficiency equivalent to micro-irrigation for container nurseries. Water demands for the 2010 base case will be adjusted to reflect the implementation of these mandatory conservation measures. More detailed descriptions of these measures can be found in **Appendix F**. Additional conservation options which are not mandatory at this time will be considered in this plan. Water demands will be adjusted to reflect the implementation of these options so that simulations and analyses can be conducted to determine how much their implementation could contribute to solving potential water resource problems, and what benefits and costs could be expected. For purposes of this plan, conservation options will be evaluated on a regional basis, while the individual county plans will deal with these various options in a more local manner.

A number of publications summarize the extensive data available on long term conservation (Brown and Caldwell, 1984a; Brown and Caldwell, 1984b; American Water Works Association, 1990). In addition, the IWR-MAIN model (Davis *et al.*, 1987) identifies a number of water conservation measures and provides coefficients for the water savings associated with each. The application of measures for conserving the use of water provided by utilities in South Florida is discussed in the "Water Utilities Conservation Study" (Brown and Caldwell, 1987).

As previously noted long-term water conservation options in this section achieve permanent changes in water use. This separates them from the water shortage component which provides for short-term reduction in water use when implemented. These measures are discussed in the Water Shortage Component of this chapter.

2. Potential Options

A large number of long-term conservation options have been identified for possible use in the long-term conservation component. These options can be described in two main categories:

Urban Water Conservation Options

- Indoor Audit
- Indoor Retrofit
- Landscape Audit
- Landscape Retrofit.
- Utility Filter Backwash Recycling
- Utility Pressure Control
- Wastewater Utility Infiltration Detection and Repair

Agricultural Water Conservation Options

- Micro-irrigation systems
- Linear move irrigation systems
- Water table management
- Tailwater recovery in seepage systems
- Ebb and flow systems

A brief description of options within each category are described below. More detailed discussions of a number of the options can be found in **Appendix F**.

3. Descriptions

Urban Water Conservation Options. As previously discussed a number of water conservation measures are now a mandatory part of the District consumptive use permit process for public water supply utilities. The conservation options discussed below are additional measures which may enable the water user and public water supply utilities to save water and be found to be cost effective.

Indoor Audit. This measure provides information and services directly to households and other water users to achieve efficiency in the use of interior water using appliances. This includes inspections to locate leaks and determine if plumbing devices are operating properly, repair of minor problems and information on indoor conservation measures and devices.

Indoor Retrofit. Indoor retrofit is the installation of ultra-low volume plumbing fixtures in existing structures or the installation of device modifications which improve the performance of existing fixtures. Water savings will in most cases be utility supplied water although it may also be self supplied. The costs of implementation will depend on the devices chosen for retrofit and the methods of installation.

Landscape Audit. This measure provides information and services directly to households and other water users to achieve efficiency in the use of water for landscaping. Services performed during a landscape audit include inspections to determine if the irrigation system is operating properly and adjustments to irrigation time clocks to assure that a water conserving schedule is being followed. Landscape audits also include adjustment of heads to assure that the irrigation system is providing adequate coverage and not wasting water by irrigating impervious surfaces. Information provided includes irrigation scheduling, calibration procedures as well as plant and irrigation system retrofit data. As an individually oriented information measure, there are usually significant costs to carrying out the visits and audits.

Landscape Retrofit. This measure provides information and incentives for users to implement Xeriscape measures. These include installing water control devices on irrigation systems to increase efficiency, rezoning irrigation systems, converting turf to drought tolerant plants, mulching, installing hardscape, etc. Devices suitable for this type of effort are those that prevent unnecessary irrigation by sensing soil moisture or detecting recent rainfall. These devices preclude the automatic activation of irrigation cycles through the time clock until the reason for delaying irrigation is no longer detected.

Utility Filter Backwash Recycling. This measure requires water utilities backwashing filter systems to allow settling of the water. A major portion of this backwash water is then reintroduced into the treatment train. Information supplied by utilities indicates that an overwhelming majority of treatment processes already incorporate this conservation measure.

Utility Pressure Control. Water conserving utility pressure control measures seek to maintain system pressure no higher than necessary to keep water using devices working properly so that uses based on time rather than volume do not waste water. Pressure reduction valves, interconnecting and looping of utility mains are some of the means used to equalize and, therefore, reduce overall operating pressure. Unlike the pressure reduction efforts during water shortages, which call for reductions in pressures to levels necessary to meet minimums for fire flow, these changes target reductions only at locations where pressures are high within the system. High pressures aggravate water loss due to leaks. Increased use is caused when the amount of water use is based on time rather than the volume of water discharged. Irrigation systems on timers and showers are examples of uses which are affected by changing pressure.

Wastewater Utility Infiltration Detection and Repair. A wastewater utility infiltration detection and repair measure includes estimation and detection efforts to quantify infiltration. It also identifies the locations of infiltration and repair efforts needed to reduce the infiltration when it is cost effective to repair. The problem of infiltration is particularly important in the Lower East Coast because many of the wastewater lines are located below the water table for most of the year. The major concern with infiltration into sewage systems is that virtually all water entering the wastewater system is lost from the water supply because the treated effluent is disposed of by deep well injection or ocean outfall. As reuse systems are implemented, reductions in infiltration of fresh water will reduce the amount available for reuse. On the other hand, reductions in infiltration of brackish water will improve quality of water reuse.

Agricultural Water Conservation Options. Efficient irrigation system design and operation is the key to conserving water in agricultural operations. Methods of cultivation and irrigation vary widely throughout the region depending on the type of crop grown, soil type, and the source of irrigation water. The efficiency with which crops are irrigated varies greatly from as high as 90% for micro-irrigation down to 50% for seepage and some overhead sprinkler irrigation systems. Irrigation efficiency is generally defined as the percentage of total water applied to a crop that is stored in the plant's root zone. The effects of different irrigation efficiencies will be expressed by a reduction in demands entered into the models. The following is a brief overview of current farming practices affecting agricultural water conservation, and possible options for improving irrigation efficiency for the Lower East Coast region. Additional cost information for installation and maintenance of a variety of irrigation systems is presented in **Appendix F**. An explanation of each method is presented below.

Micro-irrigation. These systems are low pressure (30 psi or less) irrigation methods employing a network of flexible plastic tubing of small diameter discharging through various sizes of emitters or small jets near the root zone. These systems apply water in small frequent applications. Micro-irrigation is a general term used to describe both drip irrigation and micro sprayer irrigation. Efficiency of water use for these systems ranges from 75 to 90%(Pitts and Smajstrla, 1989). Crops which can be grown using these types of systems include vegetables, field crops, citrus, tropical fruits, and ornamental nurseries.

Linear Move. These irrigation systems are large, self-propelled and highly mechanized. These are low volume and pressure (15 psi) systems which apply water uniformly to crops through spray heads at 3-4 feet above the ground. Efficiency of water use for these systems range from 65 to 80%(Pitts and Smajstrla, 1989). Vegetables and field crops are the predominant crops that can be grown using this method of irrigation.

Water Table Management. This is an important water management and soil conservation tool. The relationship between water table management and the rate of subsidence in the Everglades Agricultural Area has been documented. Soil subsidence is a result of oxidation of highly organic soils. Oxidation occurs more rapidly when the water table in organic soils is lowered. To minimize subsidence, organic soils should be kept saturated whenever not in use. When organic soils are used, the water table should be maintained as high as possible for that use. (Snyder *et al.*, 1978).

Tailwater Recovery. This water management technique collects irrigation runoff in a ditch or a reservoir, below the outlet of an irrigated field and is recycled back into the seepage irrigation system. This recycling generally requires adequate pumping capacity, so that water can be moved back into the field. Recycling of tailwater can substantially improve the efficiency of seepage irrigation systems used to irrigate vegetables, field crops, sugar cane, sod and rice as well as overhead irrigation systems used for nursery crops.

Ebb and Flow Systems. These irrigation systems involve subsurface seepage irrigation on an impermeable surface. Excess runoff is collected and recycled back into the system in order to maximize water use efficiency. This system is primarily used for small container grown nursery crops.

D. WATER SHORTAGE COMPONENT

1. Introduction

This component will consist of a plan or plans for implementing short term reductions in water use (or water withdrawals from particular sources) when the potential for large water shortages increases due to drought. A water shortage plan includes both the actions (e.g. limitations on irrigation, source substitution, etc.) and the means for determining when reductions should be implemented. Determining factors for initiation of water shortage include seasonally-adjusted trigger levels in Lake Okeechobee and other storage areas, the presence of salinity in monitoring wells, or reduced ground water levels in selected environmental areas or public water supply production areas. In this component, alternate water shortage strategies will be considered. The existing District Water Shortage Rule (Chapter 40E-21 F.A.C.) will be used as the initial starting point for this component.

2. Potential Options

Options for the water shortage component include:

Application of Short Term Cutbacks

- Allowable times for water use
- Locations of water use
- Operating practices
- Allowable technologies

Proposed Water Shortage Indicators

- Available storage in Lake Okeechobee
- Ground water gradients identifying salt water intrusion
- Ground water levels near wetlands
- Available storage within reservoirs

3. Descriptions

Application of Short Term Cutbacks. The current Water Shortage Rule establishes that the Governing Board may quantitatively restrict water withdrawals. This is particularly relevant in Phases III and IV for agricultural users. The current rule states that "Withdrawals by each user from each source class in each month shall be limited to an amount that represents each user's share of the total allocation for agricultural irrigation made by the District from that source for that month and in that basin." 40E-21.541(2)(a)5. and 40E21.551(2)(a)5. To date Phase III or Phase IV shortage restrictions have not been implemented in the coastal basins of the Lower East Coast. In the area directly served by Lake Okeechobee quantitative restrictions have been implemented by a management program the District has termed "Supply-Side Management." Under this program releases from Lake Okeechobee as a whole and to specific basins have been limited to quantities the District deemed to be a safe and equitable management plan for scarce supplies.

The current District Water Shortage Rule specifies four phases of cutback, related to the increasing severity of the shortage. These phase are termed "moderate" (Phase I), "severe" (Phase II), "extreme" (Phase III), and "critical" (Phase IV). For each phase, specific restrictions on water use activities and processes are imposed for virtually all types of users. These restrictions include limitations on:

Allowable times for water use. This option would include restrictions on the periods of time when watering of lawns, car washing, etc. would be allowed.

Locations of water use. This option could consist of a set of requirements which define specific locations for various types of water use. An example would be the restriction of car washing to pervious surfaces only.

Operating practices. This option would consist of utility oriented operating procedures which could be utilized as a short-term cutback strategy. This could include the practice of lowering operating pressures on public water distribution facilities to reduce consumption.

Allowable technologies. This option would allow continued operation of select facilities providing the operators have applied technologies which significantly reduce the consumption of water supplies. As an example, only those commercial car washes meeting certain water conservation standards, such as gallons of water used per wash, would be allowed to continue operation during selected severity of water shortage.

The phases have targeted overall reductions but do not have amounts or percents of reduction specified for any given user or use. The cutbacks focus on reductions in water withdrawals. To accomplish this, several evaluations are required. The first will determine what water resource characteristics will result in the declaration of water shortages and the implementation of the mandatory conservation measures. These indicator levels are discussed in some detail in the section below. The second will translate the behavioral changes mandated by the rule in each phase into adjustments to the "without water shortage declaration" water withdrawals and consumptive use which are included in the water resource models.

Water Shortage Indicators. A water shortage can be defined as a condition where available water supplies, represented by some hydrologic indicator or indicators, fall below a minimum "acceptable amount." The hydrologic parameters used for this purpose are often referred to as water shortage indicators. Water shortage indicators can be thought of as various threshold levels of a hydrologic parameter which reflect both the existence and severity of a water shortage. Examples of hydrologic parameters that can serve as water shortage indicators would include ground water levels, stream flow, reservoir levels and rainfall. The states of Pennsylvania, Colorado, Delaware, and New York currently have drought monitoring programs where indicators such as stream flow, ground water levels, rainfall and reservoir levels are compared on a regular basis to a threshold value in order to assess the onset, severity and duration of a drought. For example, a fixed ground water elevation can be used to detect the onset of a water shortage if drawdown of the water surface below that elevation would create a potential for salt water intrusion or environmental damage. A set of reservoir elevations within the limits designated for water supply storage could be used as indicators to signal the onset and severity of water shortages when available supplies within those limits are compared to expected inflows, losses and demands. These are the types of indicators that are proposed for monitoring water resources and managing water shortages for the Lower East Coast regional planning area.

Water shortage indicators may be proposed for use in the LEC Water Supply Plan to indicate conditions which require water use cutbacks. These indicators may include 1) water levels in lakes which indicate that the lake supply will fall or is falling short of demand; 2) water levels near the coast which indicate that salt water intrusion is imminent or occurring; 3) water levels under viable, significant wetlands which indicate that they will be or are being significantly impacted; and 4) storage volumes in reservoirs. Each indicator may have associated phased water shortage cutbacks which could vary according to use type and the indicated severity of the water shortage.

<u>Available Storage in Lake Okeechobee.</u> Lake Okeechobee is presently operated as a multipurpose reservoir to provide flood control, water supply, and environmental benefits. The quantity of supplemental water delivered from Lake Okeechobee to the Lower East Coast and the Lake Okeechobee Service Areas during periods of low water levels in the lake is based on the SFWMD's Supply Side Management Plan (Hall, 1991). This plan is put into effect to assure that during periods of limited supply that water will be kept in reserve for high demand periods that occur late in the dry season. The plan also assures that the available water will be distributed in an equitable manner. The Supply Side Management Plan is put into effect when it is projected that the Lake Okeechobee water level will fall below 11 feet before the end of the dry season (May 31), assuming normal rainfall and water use conditions will exist for the remainder of the dry season.

<u>Ground Water Gradients Identifying Salt Water Intrusion.</u> The proposed water shortage indicator for salt water intrusion prevention in the plan will be used to simulate water shortages. Water shortage indicator locations and associated cutback zones will be specified throughout the LEC area. Each indicator will have a set of four critical levels corresponding to different water shortage phases. When simulated water levels at an indicator location reach critical levels, the model will simulate water use cutbacks based on the associated water shortage phase. Cutbacks in water use for each phase will vary by water use type.

Current water shortage indicators that are used for salt water intrusion control are based on water levels and chloride concentrations in monitoring wells near the coast. When water levels in these wells fall to a level between 1 and 0 feet NGVD, indicating that the 1-foot freshwater mound near the coast is compromised, a water shortage warning is issued. When water levels in these wells are below 0 foot NGVD or show a water level gradient from the salt water interface to a wellfield, implying likely movement of the salt water interface, a Phase I water shortage is declared. A Phase II water shortage is declared when monitoring wells shows two or more chloride concentration readings that are 10 percent or more above background chloride concentrations.

At the present, water shortage indicators in the models based on water levels alone are proposed for the water supply plan. Critical water levels to trigger each water shortage phase will be based on analysis of available salt water intrusion data. If necessary, indicators based on water level gradients also may be used in the plan. It is not possible to include indicators based on chloride concentrations because the available planning models do not simulate chloride concentrations.

Ground Water Levels Near Wetlands. Although certain regulatory criteria exist in the water use permitting process for wetland protection, water shortage indicators based on wetland protection criteria may be considered. Water level indicators may be used to avoid unacceptable drawdowns to selected, viable wetlands. As in the case of saltwater intrusion, the increased frequency, severity and duration of cutbacks could be associated with increasing severity of drawdowns.

Available storage within detention areas. This option would use storage available to meet water supply demands in regional detention areas as a water shortage indicator.

E. PHYSICAL FACILITY COMPONENT

1. Introduction

The physical facilities component consists of a set of existing and new water control, water storage and treatment facilities which will operate in conjunction with the Central and Southern Florida Flood Control Project (C&SF Project). The various structural elements of the C&SF Project will be described as physical facilities options in the context of this discussion. These facility options will include all existing structures as well as new structures, although some plan alternatives may eliminate some existing structures. The physical facilities component will provide the system infrastructure necessary for the control, distribution and storage of potential water supplies.

2. Potential Options

This subsection summarizes the physical options which may be used to supplement the current sources of water in the Lower East Coast region. This discussion will outline various options which have been recently developed as well as those which have been proposed as the C&SF Project developed. Each option will be presented with a brief description of the facility, reasons for consideration of the option, and issues relating to the potential performance of the option as an element of the overall plan. The discussion will also include the manner in which the option will be incorporated in the computer modeling effort. Further discussion of this topic is provided in **Appendix G**. The facility options which will be considered are:

Ground Water Sources
- Surficial Aquifer Wellfield Expansion and Rehabilitation
- Brackish/Saltwater Treatment
- Aquifer Storage and Recovery

Surface Water Sources
- New Detention Areas
- Regional Conveyance Mechanisms
- Wastewater Reuse
- Ocean Water/Saltwater Treatment
- Others

3. Descriptions

Ground Water Sources

Surficial Aquifer Wellfield Expansion and Rehabilitation. Expansion of an existing public water supply wellfield or development of a new wellfield utilizing the surficial aquifer is commonly selected by a utility when additional raw water is required. Wells however, are limited in the amount of water they can produce by the characteristics of the aquifer in the area they are drilled. Other factors which can affect well or wellfield production include proximity to sources of contamination such as saltwater intrusion, poor quality ground water or chemical contamination. If contamination of an existing wellfield should occur, in some cases, rehabilitation is possible. Rehabilitation of an existing wellfield is accomplished by implementing the appropriate treatment at the well heads and/or at the water treatment facility.

Wellfield expansion utilizing the surficial aquifer will be applied as specific points of withdrawal in the models. Rehabilitating an existing wellfield which may have shut down due to contamination, would also be applied as a new point of withdrawal or an increased quantity to be withdrawn from an existing withdrawal point. Wellfield expansion and rehabilitation will be recognized in the model simulations by adding new, or increasing existing surficial ground water withdrawal points.

Brackish Water Treatment Facilities. The use of brackish water and saltwater could be used to supplement existing freshwater supply sources along the Lower East Coast. The Floridan Aquifer System underlies all of Florida. The Upper Floridan Aquifer is a primary source of potable ground water for most of the state. In southern Florida, however, the Upper Floridan is brackish and has not been extensively utilized, although the potential exists for increased usage of this resource in the future. The Upper Floridan is preferred as a potential source for water supply augmentation given the much higher salinity of water within the Lower Floridan and the higher drilling costs involved in reaching this deeper aquifer. The brackish water of the Upper Floridan can be effectively treated to drinking water standards by blending with freshwater from the surficial aquifer or by treatment methods such as reverse osmosis and electrodialysis reversal.

The utilization of the Upper Floridan Aquifer will be represented in the model simulations as a decrease in the demand on the surficial aquifer. More detailed information on the Floridan Aquifer and treatment technologies can be found in **Appendix F**.

Aquifer Storage and Recovery. Aquifer storage and recovery (ASR) is storage of injected water in an acceptable aquifer during times when water is available (**Figure VI-1**). The stored water is then recovered from the well, when needed, and distributed to meet demands. Simply stated, the aquifer acts as a reservoir for the injected water. Sources of injection water include treated, untreated surface and ground water. The utilization of treated surface water for ASR will be the focus of this plan. The primary aquifer to be utilized as a storage reservoir on the Lower East Coast is the Upper Floridan Aquifer.

The application of ASR in the regional system might include co-location of facilities with surface storage and water treatment areas. This type of coordination could be utilized to optimize long term storage in ASR aquifer zones coupled with short term storage in surface reservoirs to provide a more efficient supply augmentation option.

Public treatment facilities could utilize ASR to inject treated water during times of low demand such that increased deliveries to the distribution system could be made from the ASR wells coincident with peak treatment plant operation during times of high demand.

Although ASR has the potential to benefit water supply strategies, several key constraints presently exist which could limit the overall effectiveness of ASR in the context of regional water supply.

Rules governing the injection of water into the Floridan Aquifer are implemented by the Florida Department of Environmental Regulation and the U.S. Environmental Protection Agency. The potential option of capturing stormwater runoff for ASR injection poses specific problems when viewed in light of the existing regulatory criteria. These facilities would be required to either treat the runoff to drinking water quality standards or request an aquifer exemption for each facility from the state.

The other constraint in the application of ASR technology is the physical limitation on injection rates into the Floridan Aquifer. Injection rates are limited by the flow capacity of the well and associated pumping facilities as well as the receiving capacity of the aquifer. These constraints generally restrict the potential injection rates to levels below the amount of runoff available for capture. While these constraints could limit the application of ASR as a regional water supply option, local use of this technology may greatly improve water supply augmentation efforts.

The use of ASR will be recognized in model simulations as a reduction in dry season demands because of an increased utilization of excess surface or ground water during the wet season.

Surface Water Sources

New Detention Areas. The development of potential regional surface water detention areas in the Lower East Coast is limited by the availability of undeveloped land not currently reserved for environmental purposes. Potential sites in the Lower East Coast that currently meet this criteria could include parts of the Everglades

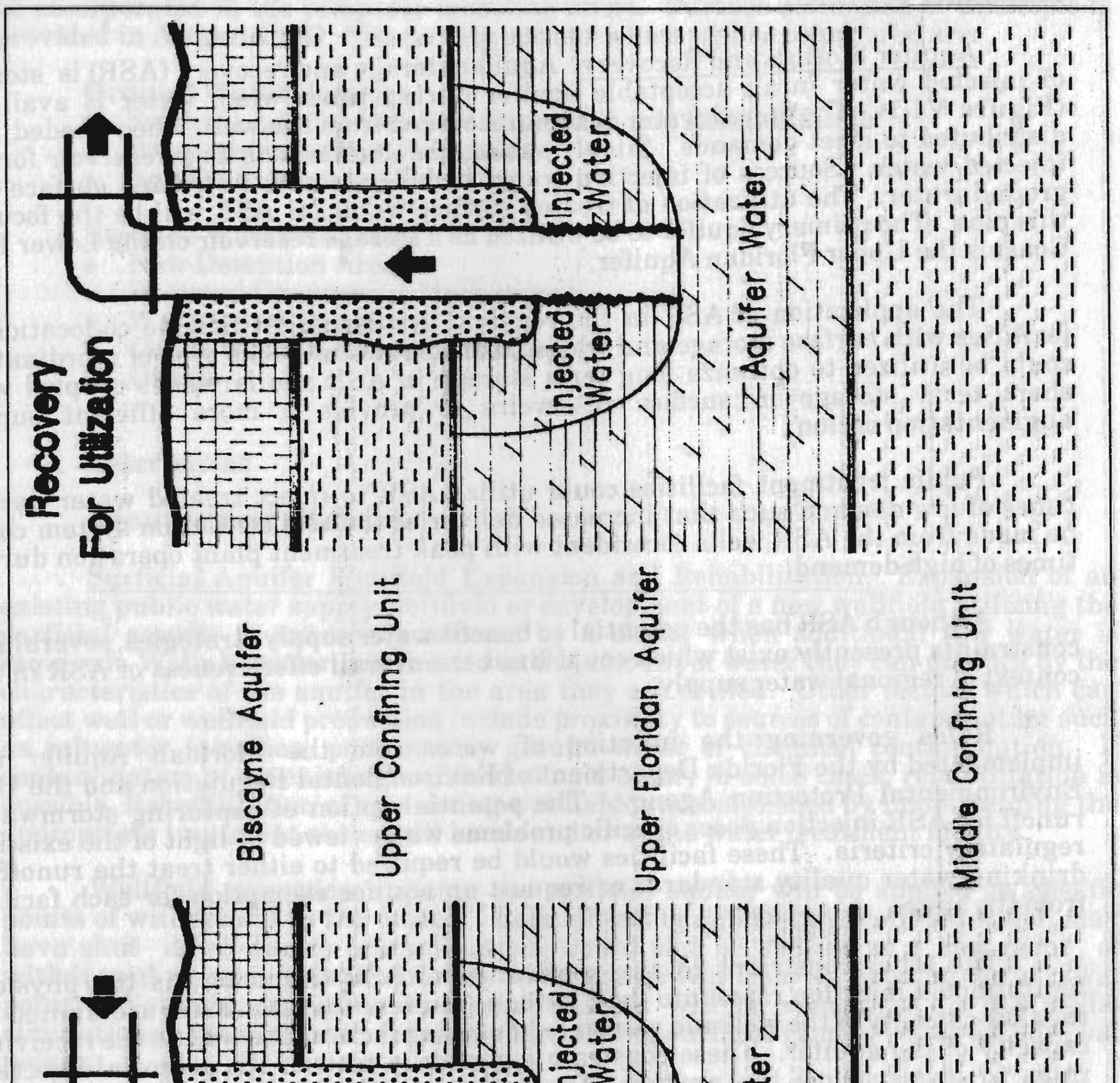


Figure VI-1. Conceptual illustration of Aquifer Storage and Recovery (ASR) Project Utilizing Treated Water.

Buffer Strip, and selected areas of the Western C-51, Hillsboro and Bird Drive basins (**Figure VI-2**). Each of these sites would have the potential to provide long-term water supply benefits through increased storage, the reduction of peak discharges, potential ground water recharge, and seepage reduction for those areas adjacent to existing water storage areas such as the WCAs.

The mechanism by which water supply could be augmented using detention area storage is via the capture of stormwater runoff and subsequent backpumping to treatment and surface storage areas. The concept of backpumping is based on pumping surface water runoff into regional storage systems during periods of excessive rainfall to provide additional water supply and flood protection. Multipurpose backpumping reservoirs could be operated to provide adequate storage for flood waters during water quality treatment and supplement flows to the environment through the Water Conservation Areas. Water could also be released from the reservoir impoundments to maintain canal levels which would in turn supplement deliveries to adjacent wellfields. The impacts of the detention areas may be analyzed using computer simulations.

Regional Conveyance Mechanisms. An important component of any regional storage facility is the ability to effectively transport water to meet regional demands with the smallest potential loss due to seepage, evaporation, etc. The C&SF Project presently serves as the central conveyance system for flood control as well as water supply purposes. However, losses due to soil transmissivity and evaporation reduce the quantity of available water during transmission. Canal conveyance systems are not as efficient as other transmission mechanisms. Several types of conveyance mechanisms exist which could be utilized to more efficiently convey water supplies from regional storage facilities to points of demand. These consist of pressure pipeline facilities and impervious lined channels. These facilities, used in conjunction with regional storage, improved discharge capacities for existing control structures and pumping systems, could potentially provide an effective conveyance mechanism to assist in satisfying water demands from regional supplies. Regional conveyance system modifications may be represented in the model simulations as a transfer of storage between locations.

Wastewater Reuse. Reclaimed water is wastewater that has received at least secondary treatment and is reused after flowing out of a wastewater treatment plant (Chapter 17-610, F.A.C.). Reuse includes uses such as landscape and agricultural irrigation, ground water recharge, industrial uses, environmental enhancement and fire protection. Using water that has been used before, recycles the use of the water resource.

A number of benefits result from using reclaimed water to replace a potable supply that is used for nonpotable needs. These benefits include postponement or elimination of future water treatment plant expansions, postponement or elimination of construction of additional water supply wells, reduction in the size of the potable water distribution lines and lower monthly water bills. For ground water users, use of reclaimed water provides a guaranteed source of water and exemption from water shortage/restriction requirements among other benefits.

Health risks associated with reclaimed water are relative to the adequacy and reliability of the treatment processes that produce the reclaimed water and the degree of human contact. Reclaimed water treatment, quality and use is regulated at the state level by the Florida Department of Environmental Regulation (FDER). The FDER has developed reuse regulations that require extensive treatment and

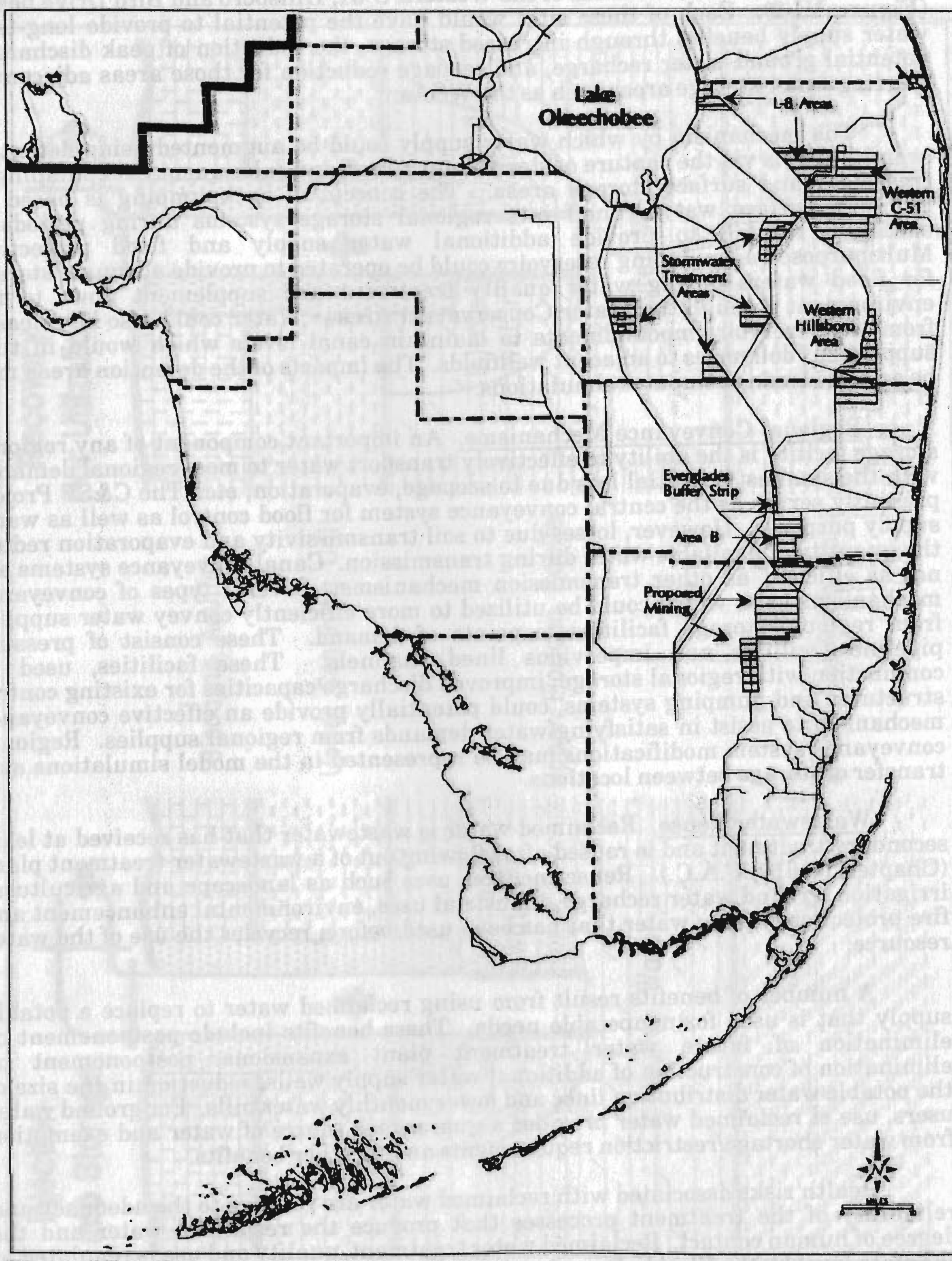


Figure VI-2. Potential Sites for New Detention Areas.

disinfection to assure that continuous and reliable supplies of high quality reclaimed water are produced to ensure that public health and environmental quality are protected.

The utilization of reclaimed water will be recognized in model simulations as a reduction in the surficial aquifer demand and in some cases as a source of additional recharge to the surficial aquifer. More detailed information regarding wastewater reuse can be found in Appendix F.

Ocean Water Treatment Facilities. The Atlantic Ocean, while saline, represents an essentially unlimited source of water. Ocean water treatment systems are in use successfully worldwide. Most distillation treatment facilities are located in areas which have very limited fresh or brackish raw water resources such as the Middle East area. Seawater averages about 3.5 % dissolved salts most of which is sodium chloride with total dissolved solids (TDS) concentrations in the range of about 35,000 to 45,000 mg/L. Reverse osmosis (RO) and distillation are the two treatment methods utilized for conversion of seawater to freshwater. As with all surface waters, the ocean is also vulnerable to discharges or spills of pollutants which could impact a water treatment system. Costs associated with the construction and operation of seawater RO and distillation systems are high when compared with the conventional fresh water treatment systems currently in use in the planning area.

The utilization of ocean sources will be represented in the model simulations as a decrease in the demand on the surficial aquifer.

F. OPERATIONS COMPONENT

1. Introduction.

The operations component will consist of a set of guidelines for operating the physical facilities. These will include not only target levels for Lake Okeechobee, canals, reservoirs and WCAs, but also rules for determining which sources to tap for what uses at what times.

2. Potential Options.

The proposed options for the operations component will include potential modifications of operational guidelines for areas such as:

Operation of Existing Facilities

- Modify the Lake Okeechobee Regulation Schedule
- Modify Canal Elevations in the Everglades Agricultural Area (EAA)
- Modify the Water Conservation Areas (WCAs) Regulation Schedules
- Modify Control Elevations of Existing Control Structures and Canals

Operation of New Facilities

- Operation Strategies for Proposed Control Structures and Canals
- Operation Strategies for Detention Areas
- Others

3. Descriptions.

Operation of Existing Facilities

Modify the Lake Okeechobee Regulation Schedule. A range of regulation schedules for Lake Okeechobee will be incorporated into the computer models to evaluate the effects of Lake Okeechobee water levels and releases on the lake littoral zone, St. Lucie and Caloosahatchee estuaries, Water Conservation Area hydroperiod and overall water supply. Careful consideration must be given to each regulation schedule evaluated to assess how they will affect, positively or negatively, each of the competing uses.

The regulation schedules will be coded into the SFWMM as a set of time-variant rule curves to trigger discharges or cutbacks based on simulated water levels in Lake Okeechobee.

Modify Operations in the EAA. Eight major pump stations serve the EAA for flood protection purposes. These pump stations were designed as part of the C&SF system to remove up to 0.75 inches of runoff per day from this agricultural production area.

The discharge characteristics of pump stations will be incorporated into the SFWMM to provide the same flood protection to the EAA as originally designed.

Modify the WCAs Regulation Schedules. Various operational schedules will be analyzed for the WCAs to estimate the potential for enhancing WCA hydroperiods and meeting the environmental water needs of the ecosystem. The targets for these deliveries will be developed under the Environmental Component Section. However once these target deliveries have been established, this option will analyze the proper regulation schedules to satisfy those deliveries.

The regulation schedules will be coded into the SFWMM as a set of time-variant rule curves for triggering discharges into, or from, each Water Conservation Area, based on simulated water levels.

Modify Control Elevations of Existing Control Structures and Canals. Existing water control structures regulate the water levels within, and dictate the allowable discharge from, the C&SF Project canals. Adjusting the control elevations for structures to provide additional canal storage and reduced coastal discharge may be evaluated as part of the plan. These water levels will be evaluated under various operational rules to determine which set of rules best meets the needs of the Lower East Coast Service Area while minimizing the impacts to the Lake Okeechobee and the Everglades ecosystem.

Discharge and elevation criteria of existing control structures are incorporated into the SFWMM as a set of operational rules for each structure.

Operation of New Facilities

Operation Strategies for Proposed Control Structures and Canals. The various physical facility options under investigation may result in the need for additional water control structures, canals or pump stations in order to provide for options of the Physical Facilities Component, such as backpumping or regional ASR, and for other components, such as environmental water needs. This option would then apply the resulting operational features of those proposed systems into the computer models.

The discharge and elevation criteria of each proposed control structure will be incorporated into the SFWMM as a set of operational rules for each structure.

Operation Strategies for Detention Areas. Various operational features of existing and proposed detention areas will be analyzed in the plan. This option will consist of wet and dry season target levels and discharges which will be defined in the Physical Facility Component Section and applied under this option.

The target levels and discharges will be incorporated into the SFWMM as a set of operational rules for each detention area.

G. WATER QUALITY COMPONENT

1. Introduction.

Water quality is a component of the water supply plan which does not necessarily involve the distribution of regional water supplies to meet water demands. As a result, the water quality component may not vary substantially among alternatives. Rather, the necessary facilities and processes will be included in each alternative to meet statutory requirements related to water quality as well as related SWIM plan objectives.

Options considered part of the water quality component will be implemented through physical facilities modification or changes in the operation of the SFWMD's water management facilities. As a result, the water quality component will serve as a means to more clearly identify groups of physical facility or operational changes which will be proposed to implement the water quality strategy of a plan alternative. Nonetheless, it is important to maintain a separate water quality component to ensure that their important issues are adequately addressed in each alternative to be considered.

2. Potential Options.

Several facilities options have been envisioned which are primarily focused on water quality improvement for both ground water and surface water improvement These options are discussed in this section. Many of the options contained in other components such as physical facilities, operations and environmental will have a water quality improvement element included as an aspect of their formulation. One example would be the potential surface water impoundments proposed to capture urban stormwater runoff for use in surficial aquifer recharge or supplemental supplies to the environment. The design of these facilities would include reservoir cells designed specifically for water quality improvement of the captured stormwater. In addition, the impoundment and subsequent diversion of coastal stormwater runoff is anticipated to have a beneficial water quality impact on the estuaries along the Lower East Coast through the reduction of freshwater flows into the marine environment. The water quality options presently under consideration are:

Saltwater Intrusion Control
- Structural Salinity Barriers
- Hydrodynamic Salinity Control Barriers

Regional Stormwater Treatment
- Stormwater Treatment Areas (STAs)
- Treatment Plants

3. Descriptions.

Saltwater Intrusion Control.

The control of saltwater intrusion into the surficial aquifer system has been a serious concern since the initial construction of drainage improvements in South Florida. Construction of drainage facilities for flood control purposes dating back as far as 1907 lowered the elevation of the surficial aquifer along the Lower East Coast. This reduction in the hydraulic gradient promoted the intrusion of saltwater inland, resulting in saltwater contamination of wells in the Miami area as early as 1935 (Parker *et al.*, 1955). The saltwater intrusion problem continued to intensify and reached a peak in 1945 as a result of a prolonged drought occurring at the end of a period of uncontrolled drainage in South Florida (Leach *et al.*, 1972). Significant changes to the hydrology of the Lower East Coast took place during the 15 year period from 1950 to 1965. Canals were extended inland and new canals were constructed through the coastal ridge. Each new major canal constructed was equipped with a gated control structure which served the dual purpose of improved drainage ability and water table elevation control to prevent lowering of water levels. This resulted in the stabilization of the salt front in most areas (Leach *et al.*, 1972). As the demand for water increases, the landward advance of the salt front is expected to continue, especially during periods of drought.

The control of saltwater intrusion can be accomplished by two methods: structural salinity barriers and hydrodynamic salinity barriers.

Structural Salinity Barriers. These devices provide an effective method for preventing upstream flow of salt water in coastal areas. These structures allow canal water surface elevations to be maintained at levels which would inhibit the landward flow of highly saline ground water originating from the ocean and coastal estuaries. Relocation of existing structures further east or construction of additional structures would be considered in order to increase the amount of fresh ground water available from the surficial aquifer in coastal areas. Although operationally more complex due to their proximity to highly populated urban areas, these structures would conserve and make better use of water within the Lower East Coast by allowing increased inland detention and retention of freshwater before discharging to tide. Site specific issues complicating the use of structural salinity barriers are navigation conflicts and increased coastal flooding potential. Adding or relocating control structures would be simulated in the models as a new or moved structure. Changes in water levels adjacent to the canal and a change in gradient of the freshwater aquifer would be simulated.

Hydrodynamic Salinity Control Barriers. These barriers are created through the use of surficial aquifer injection wells. These wells are used to inject supplemental water into the surficial aquifer to create a hydraulic "mound" of sufficient height to inhibit the landward migration of the salt front. Treated wastewater and excess surface water runoff could be principal sources for injection. Under existing regulations, both of these sources would require additional treatment before injection into the surficial aquifer. This option would be applied in the computer models as a specific point of recharge.

Regional Stormwater Treatment Facilities

Stormwater Treatment Areas (STAs). Four STAs are proposed in the Everglades Agricultural Area (EAA) for the purpose of enhancing the water quality of stormwater runoff prior to discharge to the Water Conservation Areas (WCAs). The STAs and associated pump stations and discharge structures will be incorporated into the models as an option to analyze their effect on the timing and distribution of the discharge, as well as determine the potential hydroperiod benefits of redistributing the discharge over portions of WCA-1, WCA-2A and WCA-3A. Any volume reduction associated with this option will also be analyzed.

The STA option is primarily water quality related, however, it will be implemented as a physical facilities option. The STAs, including associated pump stations and discharge structures, will be incorporated into the SFWMM using hydraulic equations and operating rules to simulate their characteristics. Additional information regarding this option can be found in Section VII and **Appendix C**.

Treatment Plants. In the evaluation of treatment alternatives for stormwater runoff from the Everglades Agricultural Area, several options were considered, including mechanical and chemical treatment facilities. Two of the most promising were Direct Filtration and Chemical Treatment. These potential options entail the construction of stormwater treatment plants constructed in lieu of the proposed STAs and would function much like the their urban counterparts which treat domestic wastewater. These water quality treatment facilities could also work in conjunction with wetland systems which would function as a final treatment mechanism.

VII. PRELIMINARY WATER RESOURCE EVALUATION

Preliminary analyses have been performed to provide some background information regarding the past, present-day, and possible future regional hydrology of the Lower East Coast. This chapter presents the results of three analyses: (A) Preliminary Estimated Historical Water Budgets - provides an overview of the historical quantity and distribution of water for the major physiographic areas of the Lower East Coast; (B) Estimated Effects of Historical Water Management on the Hydrology of Southeastern Florida - provides both qualitative and quantitative information through comparisons of the hydrology of the managed system with an estimate of the natural system hydrology; and (C) Preliminary Evaluation of Regional Water Quantity Impacts from the Stormwater Treatment Areas (STAs) provides an initial estimate of the hydrologic changes to Lake Okeechobee and the WCAs that may result from the STAs that are proposed in the Everglades Agricultural Area.

A. PRELIMINARY ESTIMATED HISTORICAL WATER BUDGETS

To provide an overview of the historical quantity and distribution of water, both spatially and temporally, preliminary estimates of historical water budgets have been prepared. These budgets consider all the major components of the hydrologic cycle and present a "big picture" of southeastern Florida's hydrology. The budgets were prepared for eleven separate subbasins including Lake Okeechobee, each of the Water Conservation Areas, the Everglades Agricultural Area, Eastern Everglades National Park, and the developed areas of Palm Beach, Broward, and Dade counties. To simplify the presentation of this information, annual average summaries of the preliminary estimated historical water budgets for the overall LEC basin and five major subbasins (Lake Okeechobee, the Everglades Agricultural Area, the Water Conservation Areas, the LEC developed areas, and eastern Everglades National Park) have been prepared for this draft working document. A map of the major subbasins is shown in **Figure VII-1**. Preliminary estimated water budgets for all 11 subbasins are presented in detail in Appendix C.

The major hydrologic components considered for the development of the historical water budgets include: rainfall, evapotranspiration, overland flow, ground water flow, levee seepage, structure/canal flows, and both surface and ground water storage changes. These components were either measured using available data or estimated using a computer model. There are degrees of uncertainty in both the measured and the estimated components that vary depending on the reliability of the data collected and the estimation methods. Nevertheless, water budgets can produce useful summary information in comparing the relative magnitudes of the different components which may provide some indications of the most feasible water supply alternatives or options.

To develop the regional water budgets, the South Florida Water Management Model (SFWMM) was used to help estimate the budget components that are not directly measured such as ground water flow, levee seepage, overland flow, evapotranspiration, and surface and ground water storage changes. Historical data input to the SFWMM consisted of rainfall, pan evaporation, wellfield pumpage, and structure/canal discharge (where available). By using historical well pumpage and structure/canal discharge data, the actual or historical operation of the water control system was considered. Thus, interpretation of the historical water budget results should be done with care, especially if the results are compared to simulated water budget results generated from the SFWMM where projected wellfield pumpages are

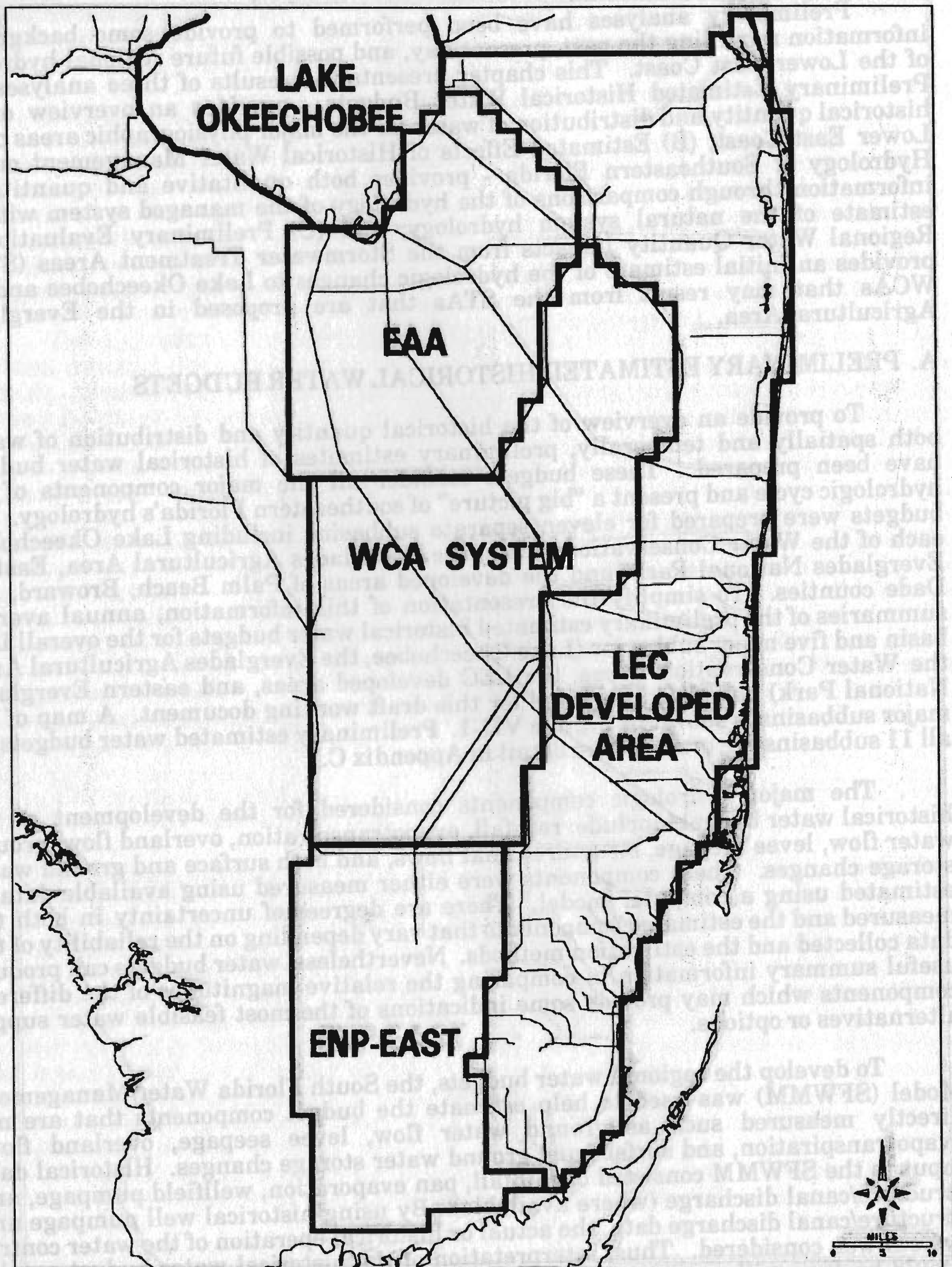


Figure VII-I. The Major Water Budget Subbasins of the Lower East Coast.

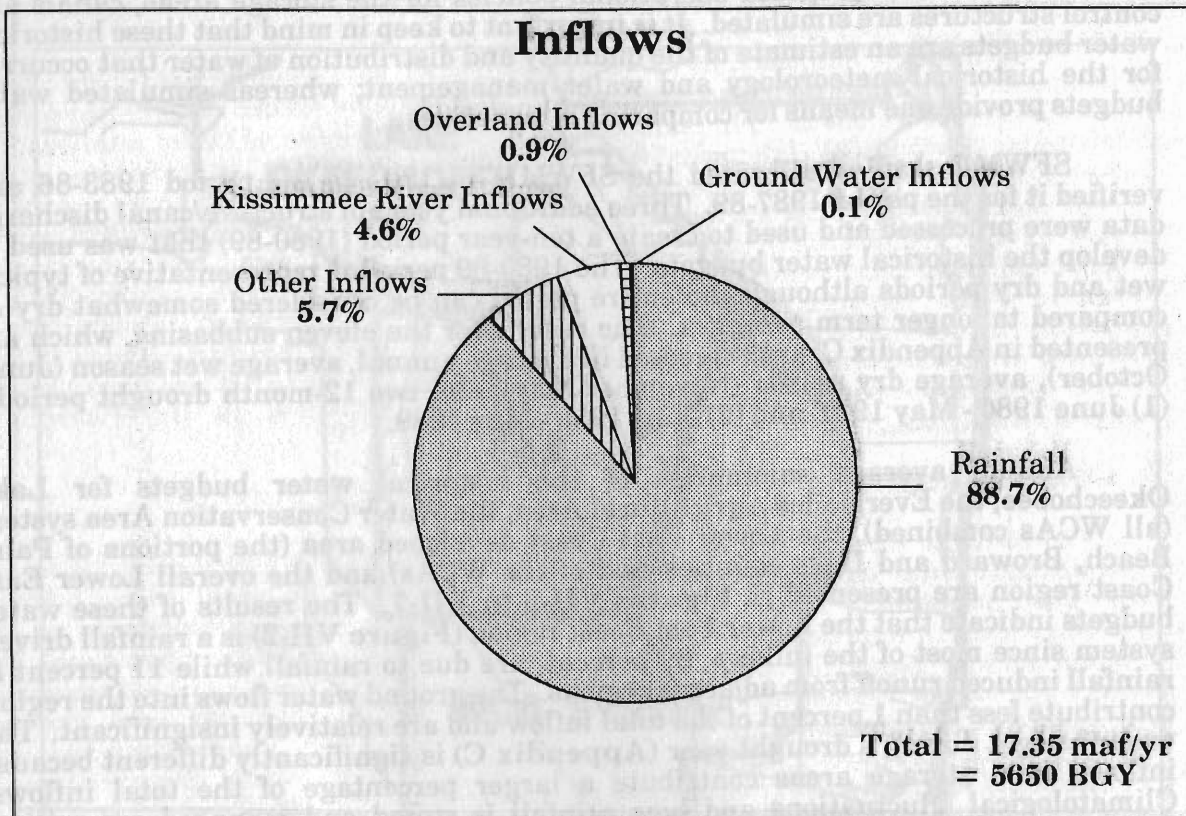
used and current or proposed operational policies for the storage areas, canals and control structures are simulated. It is important to keep in mind that these historical water budgets are an estimate of the quantity and distribution of water that occurred for the historical meteorology and water management; whereas simulated water budgets provide one means for comparing alternatives.

SFWMD staff recalibrated the SFWMM in 1991 to the period 1983-86 and verified it for the period 1987-89. Three additional years of structure/canal discharge data were processed and used to create a ten-year period (1980-89) that was used to develop the historical water budgets. The 1980-89 period is representative of typical wet and dry periods although the entire period can be considered somewhat dry as compared to longer term averages. The results for the eleven subbasins, which are presented in Appendix C, are expressed in average annual, average wet season (June-October), average dry season (November-May), and two 12-month drought periods: (1) June 1980 - May 1981, and (2) June 1988 - May 1989.

Annual average summaries of the historical water budgets for Lake Okeechobee, the Everglades Agricultural Area, the Water Conservation Area system (all WCAs combined), the Lower East Coast developed area (the portions of Palm Beach, Broward and Dade counties east of the WCAs) and the overall Lower East Coast region are presented in **Figures VII-2 to VII-7**. The results of these water budgets indicate that the Lower East Coast region (**Figure VII-2**) is a rainfall driven system since most of the inflows, 89 percent, are due to rainfall while 11 percent is rainfall induced runoff from adjacent regions. The ground water flows into the region contribute less than 1 percent of the total inflow and are relatively insignificant. The water budget during a drought year (**Appendix C**) is significantly different because inflows from storage areas contribute a larger percentage of the total inflows. Climatological fluctuations and how rainfall is stored and managed are critical factors affecting the water supply available to meet user needs.

The dominance of rainfall as the critical factor in the inflows is also prevalent among all the LEC subbasins, although to a lesser degree. For example, in Lake Okeechobee, rainfall contributes 49 percent of the inflows while surface water inflows from the Kissimmee River Basin contributes 25 percent, a significant percentage. In the Water Conservation Areas the rainfall contribution is 70 percent while flows from the EAA, Lake Okeechobee, and the LEC developed areas contributes 29 percent to the inflows. The contribution of rainfall to the LEC developed area and the EAA is 81 and 78 percent respectively. In the LEC developed area there is a substantial ground water inflow beneath the WCA levee system. On average, Lake Okeechobee contributed 16 percent of the total annual inflows to the EAA, 7 percent of the total wet season inflow, and 30 percent of the total dry season inflow. During droughts (Appendix C) the lake contribution to the EAA was much larger than average, 22 percent during the 1980-81 drought period and 31 percent during the 1988-89 drought period.

While rainfall is the dominant factor influencing the inflows, evapotranspiration (ET) is by far the dominant factor on the outflows. In the water budget for the overall LEC region, ET losses contribute to 66 percent of the outflow. The next largest outflow from the region is surface water released to tidewater, which contributes 22 percent. As expected ET losses are higher on areas dominated by open waters or wetlands systems such as Lake Okeechobee and the Water Conservation Areas than in the Lower East Coast developed region. In Lake Okeechobee, ET losses are 67 percent of the total losses while in the WCAs the ET losses are on the order of



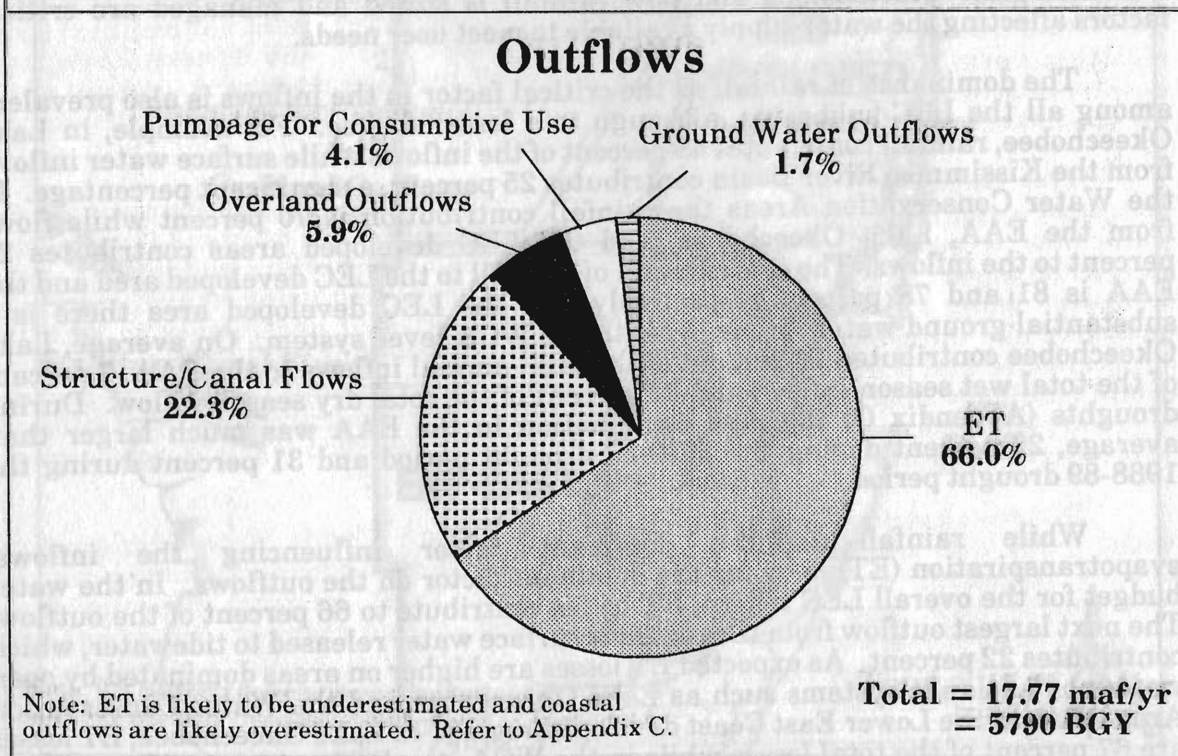


Figure VII-2. Comparison of Estimated Historical Annual Average (1980-89) Inflows and Outflows for the Overall LEC Region.

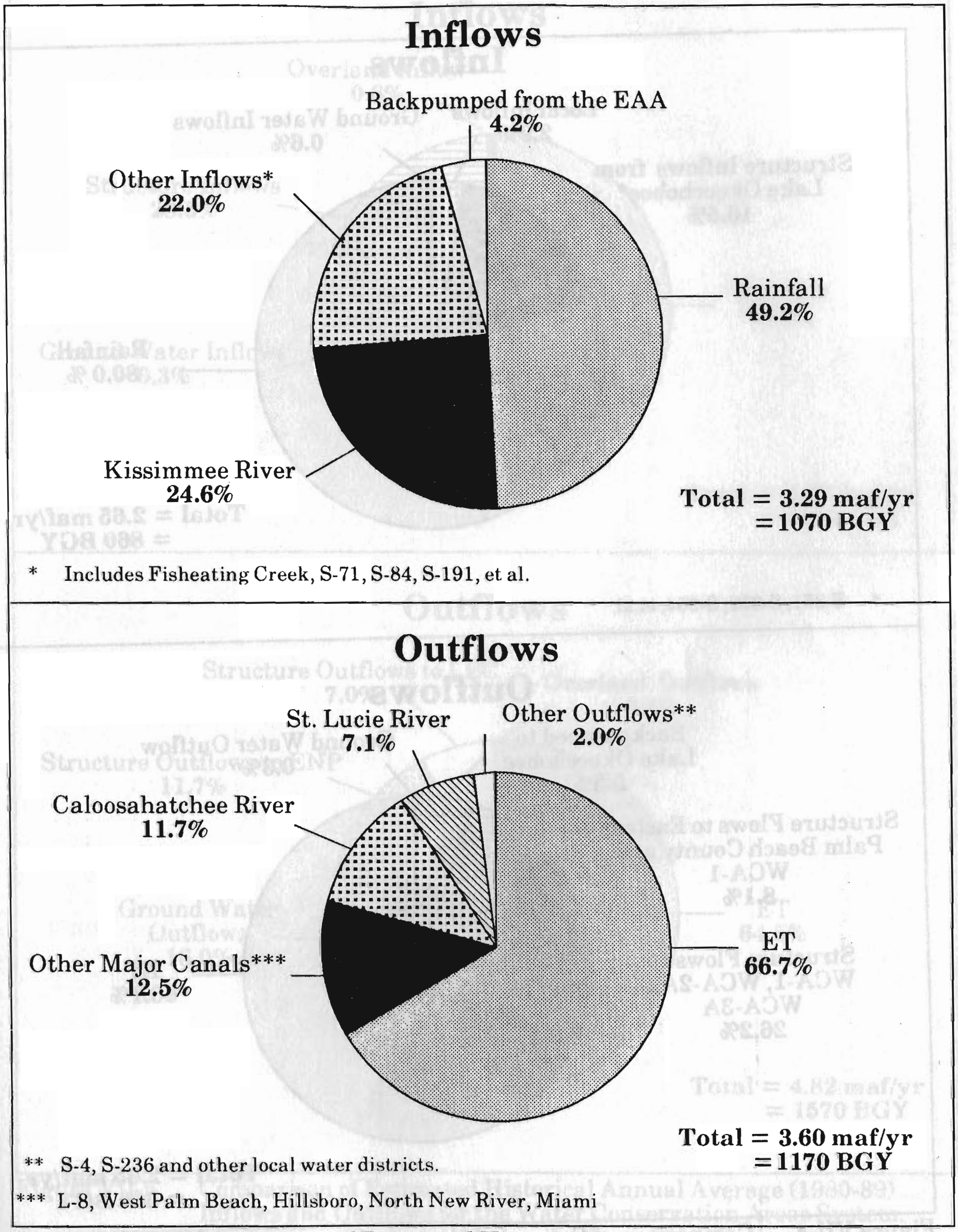


Figure VII-3. Comparison of Estimated Historical Annual Average (1980-89) Inflows and Outflows for Lake Okeechobee.

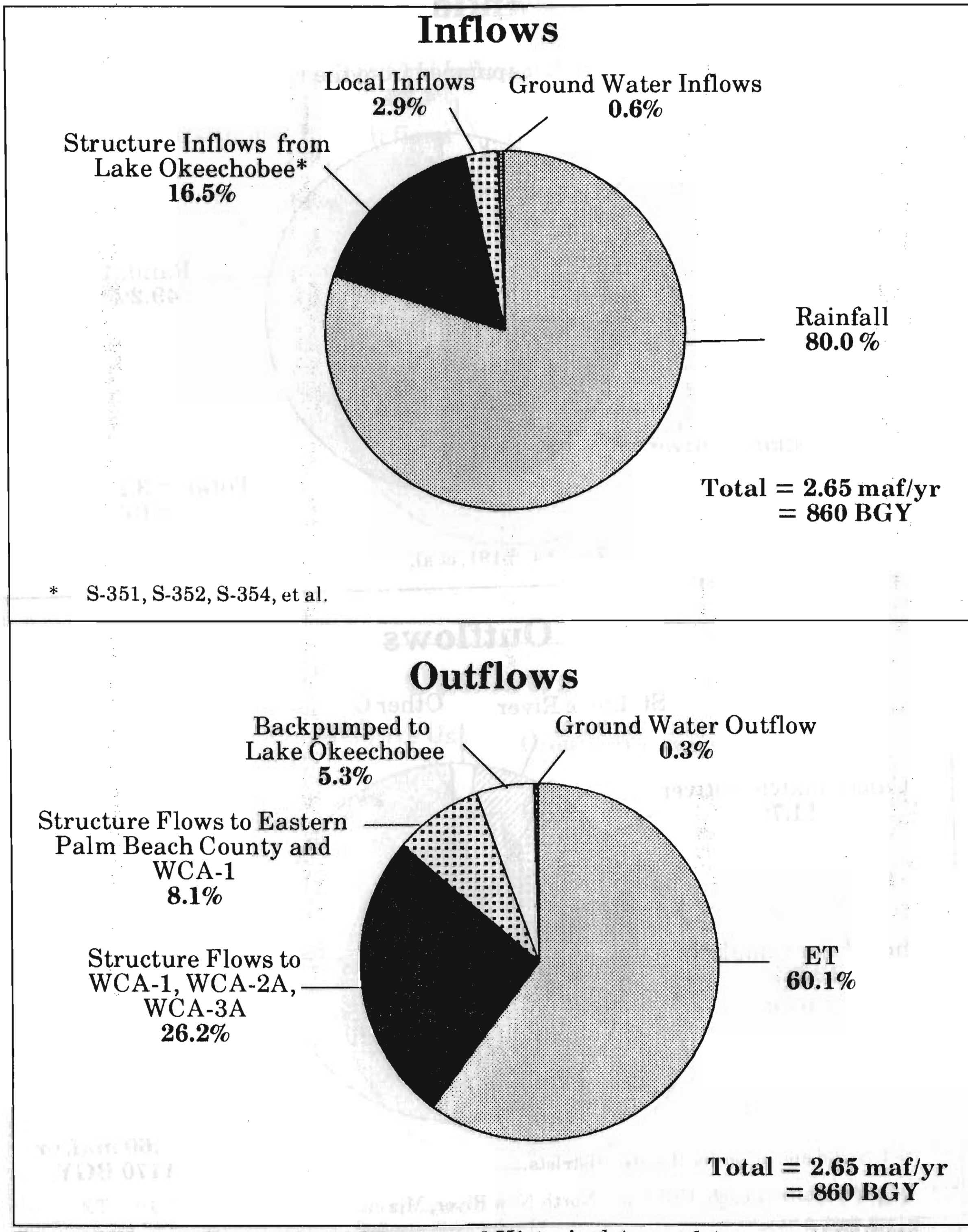


Figure VII-4. Comparison of Estimated Historical Annual Average (1980-89) Inflows and Outflows for the Everglades Agricultural Area.

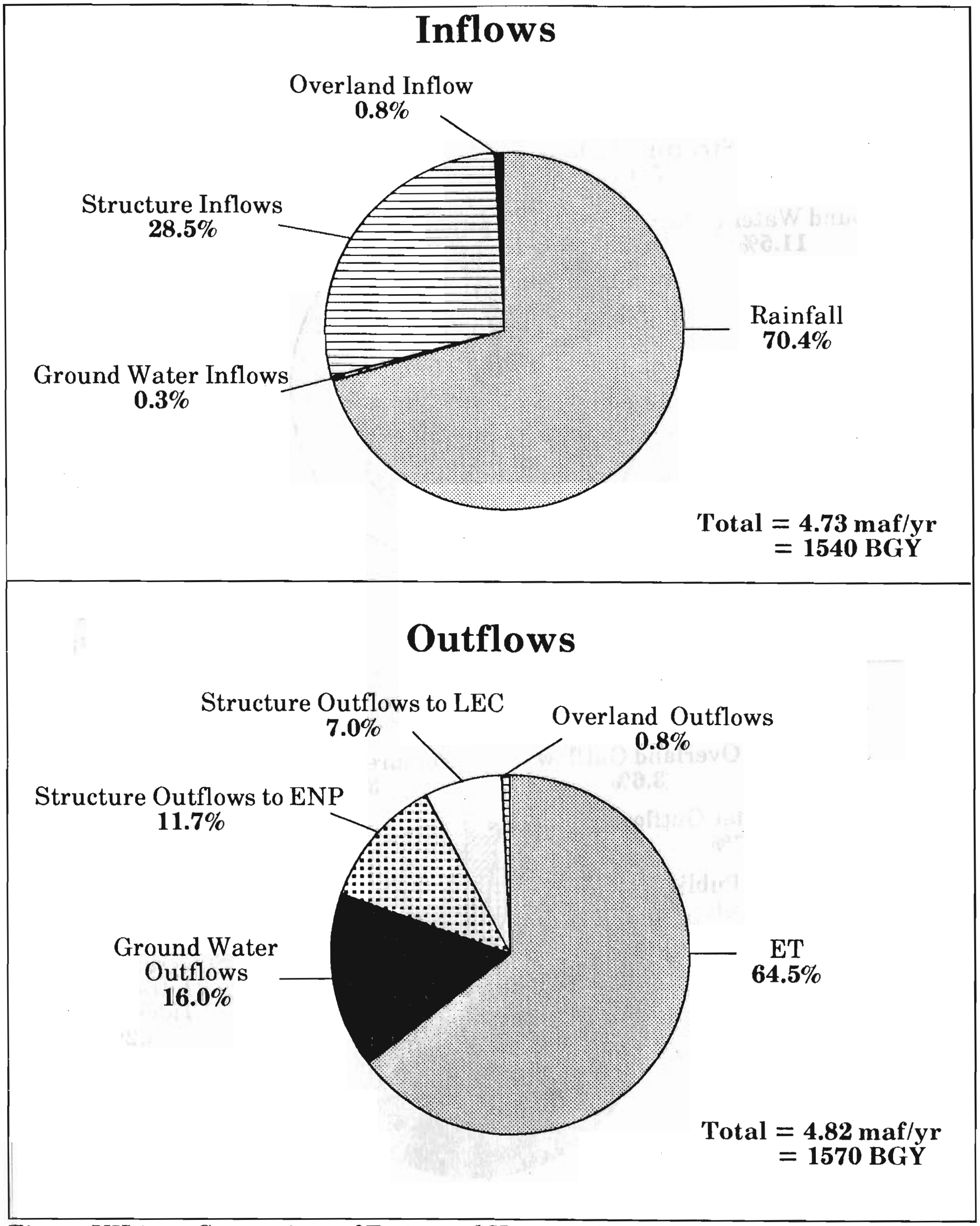


Figure VII-5. Comparison of Estimated Historical Annual Average (1980-89) Inflows and Outflows for the Water Conservation Areas System.

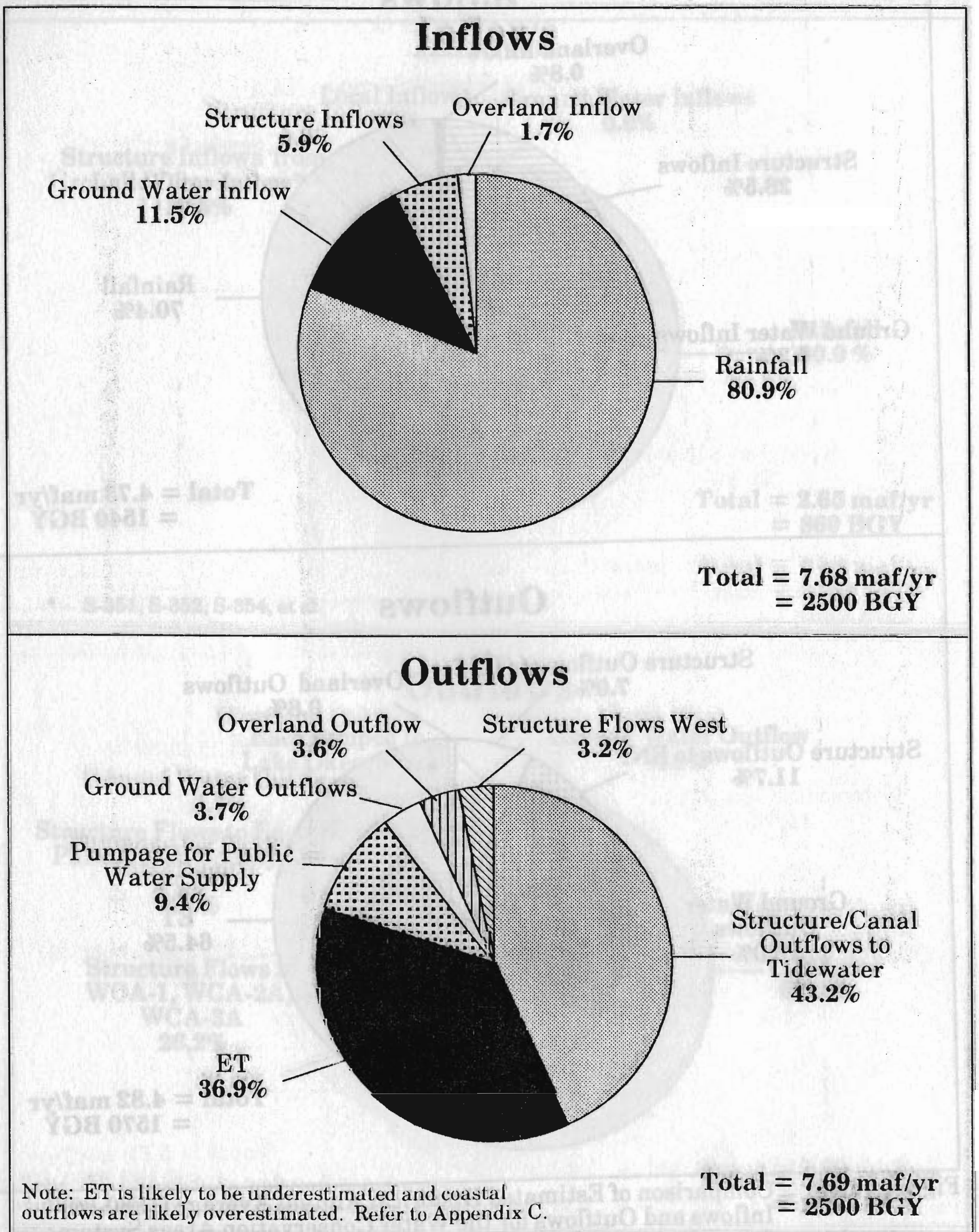


Figure VII-6. Comparison of Estimated Historical Annual Average (1980-89) Inflows and Outflows for the LEC Developed Area.

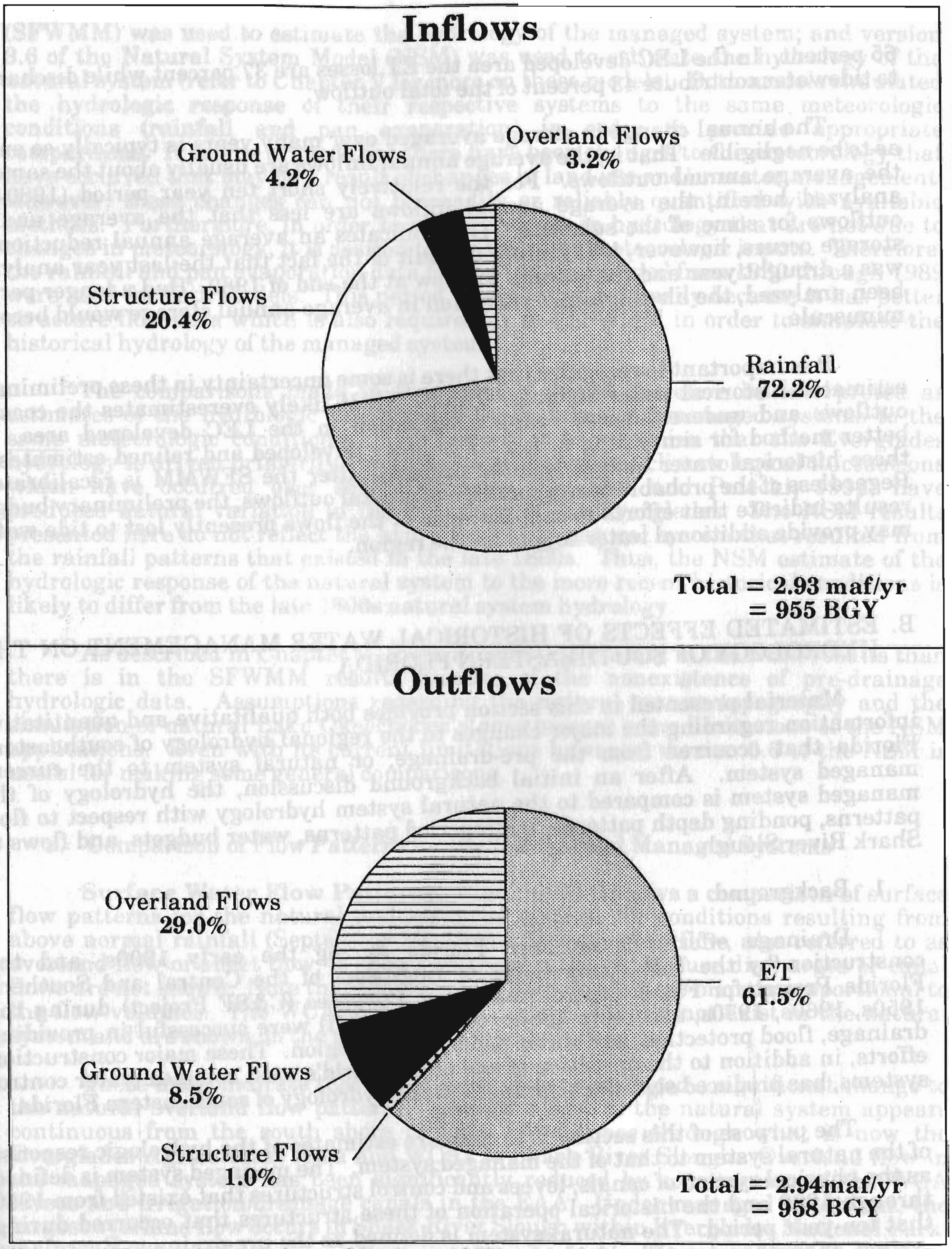


Figure VII-7. Comparison of Estimated Historical Annual Average (1980-89) Inflows and Outflows for Eastern Everglades National Park.

65 percent. In the LEC developed area the ET losses are 37 percent while discharges to tidewater contribute 43 percent of the total outflow.

The annual change in storage averaged over many years is typically so small as to be negligible. That is, the average annual inflows are usually about the same as the average annual outflows. For the relatively short ten year period (1980-89) analyzed herein, the average annual inflows are less that the average annual outflows for some of the subareas. This indicates an average annual reduction in storage occurs, however, it is merely a result of the fact that the last year analyzed was a drought year and the storage was low at the end of 1989. Had a longer period been analyzed, the already small reduction in average annual storage would become minuscule.

It is important to recognize that there is some uncertainty in these preliminary estimated historical water budgets. The SFWMM likely overestimates the coastal outflows and underestimates evapotranspiration in the LEC developed area. A better method for simulating urban ET is being developed and refined estimates of these historical water budgets will be prepared after the SFWMM is recalibrated. Regardless of the probable overestimation of coastal outflows, the preliminary budget results indicate that efforts to capture some of the flows presently lost to tide water may provide additional water supply for the region.

B. ESTIMATED EFFECTS OF HISTORICAL WATER MANAGEMENT ON THE HYDROLOGY OF SOUTHEASTERN FLORIDA

Material presented in this section provides both qualitative and quantitative information regarding the major changes to the regional hydrology of southeastern Florida that occurred from the pre-drainage, or natural system to the current managed system. After an initial background discussion, the hydrology of the managed system is compared to the natural system hydrology with respect to flow patterns, ponding depth patterns, hydroperiod patterns, water budgets, and flows to Shark River Slough.

1. Background

Drainage efforts in southern Florida during the early 1900s, and the construction by the U.S. Army Corps of Engineers of the Central and Southern Florida Project for Flood Control and Other Purposes (C&SF Project) during the 1950s, 1960s, 1970s, and early 1980s (see Chapter II) were successful in providing drainage, flood protection, and water supply to the region. These major construction efforts, in addition to the operation of one of the world's most complex water control systems, has produced significant changes in the hydrology of southeastern Florida.

The purpose of this section is to compare estimates of the hydrologic response of the natural system to that of the managed system. The managed system is defined as the physical system of canals, levees and control structures that existed from 1980 through 1989 and the historical operation of these structures that occurred during that ten-year period. The natural system is defined as the pre-drainage Everglades system, or southeastern Florida during the late 1800s.

In order to compare the hydrologic responses of these systems, two simulation models were used. Version 1.1 of the South Florida Water Management Model

(SFWMM) was used to estimate the hydrology of the managed system; and version 3.6 of the Natural System Model (NSM) was used to estimate the hydrology of the natural system (refer to Chapter V for more on these models). Both models simulated the hydrologic response of their respective systems to the same meteorologic conditions (rainfall and pan evaporation) in order to provide appropriate comparisons. It can be argued that there have been changes to the meteorology that have occurred that may be a result of changes in land use and/or water management. However, these changes can not be readily or reliably quantified with available methods. Furthermore, in order to assess changes in hydrology that are not due to changes in meteorology, it is desired to use the same meteorologic inputs. Therefore, the rainfall and pan evaporation data for the ten-year period from 1980 through 1989 were used for both models. This period was selected primarily because it has better structure flow data which is also required by the SFWMM in order to simulate the historical hydrology of the managed system.

The comparisons made in this section should therefore be interpreted as estimates of the hydrologic responses of the natural and managed systems to the same meteorologic conditions. It is important to recognize that the Everglades hydrology is driven primarily by rainfall and that global climatological fluctuations which have occurred over several decades (Leathers and Palecki, 1992) have produced natural variation in the hydrology of the Everglades. The NSM results presented here do not reflect the hydrology of the natural system that resulted from the rainfall patterns that existed in the late 1800s. Thus, the NSM estimate of the hydrologic response of the natural system to the more recent historical conditions is likely to differ from the late 1800s natural system hydrology.

As described in Chapter V, there is more uncertainty in the NSM results than there is in the SFWMM results because of the nonexistence of pre-drainage hydrologic data. Assumptions regarding the natural system topography and the simulation of natural Lake Okeechobee stages present some limitations of the NSM applications. Even with its current limitations however, version 3.6 of the NSM is useful for making some general comparisons.

2. Comparison of Flow Patterns for the Natural and Managed Systems

Surface Water Flow Patterns. **Figure VII-8** shows a comparison of surface flow patterns for the natural and managed systems for conditions resulting from above normal rainfall (September 30, 1988). Only surface flow, also referred to as overland flow or sheet flow, is shown on these maps. Structure discharges or canal flows are not shown. Note that the size of the vectors on these maps is proportional to the flow volumes. The WCA levees, L-31N, and C-111 did not exist in the natural system and are shown on the map for reference only.

These maps indicate that water management produced a significant change to the natural overland flow patterns. Overland flow in the natural system appears continuous from the south shore of Lake Okeechobee through what is now the Everglades Agricultural Area and WCAs to Shark River Slough. Overland flow in the managed system has been significantly reduced by construction of the WCA levees and irrigation/drainage canals in the EAA. Under managed conditions, the largest overland flow occurs in Shark River Slough within Everglades National Park.

Ground Water Flow Patterns. **Figure VII-9** provides a comparison of ground water flow patterns for the natural and managed systems for the same date

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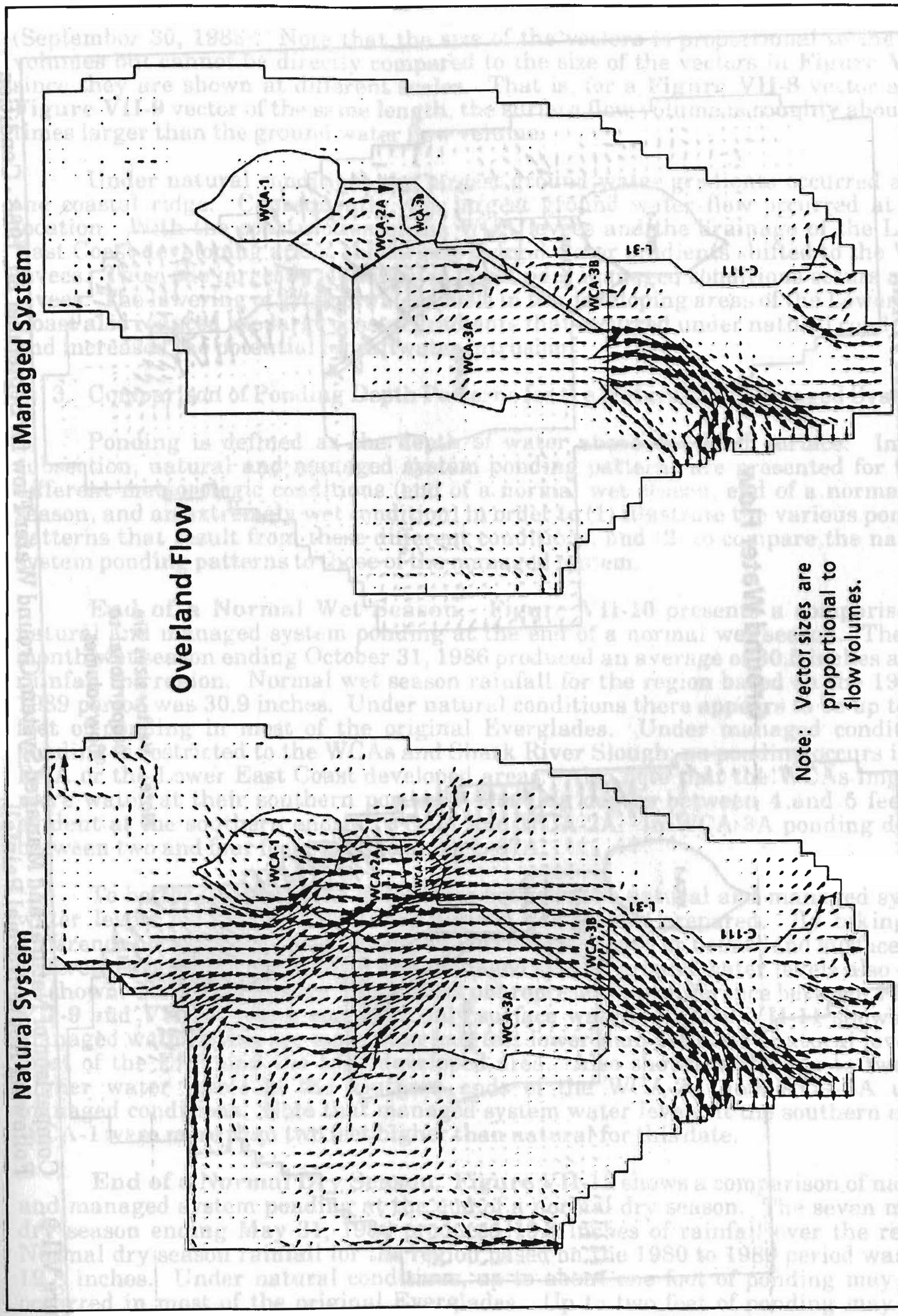

Figure VII-8. Comparison of Natural and Managed System Overland Flow for September 30, 1988 - Condition Following Above-Normal Rainfall.

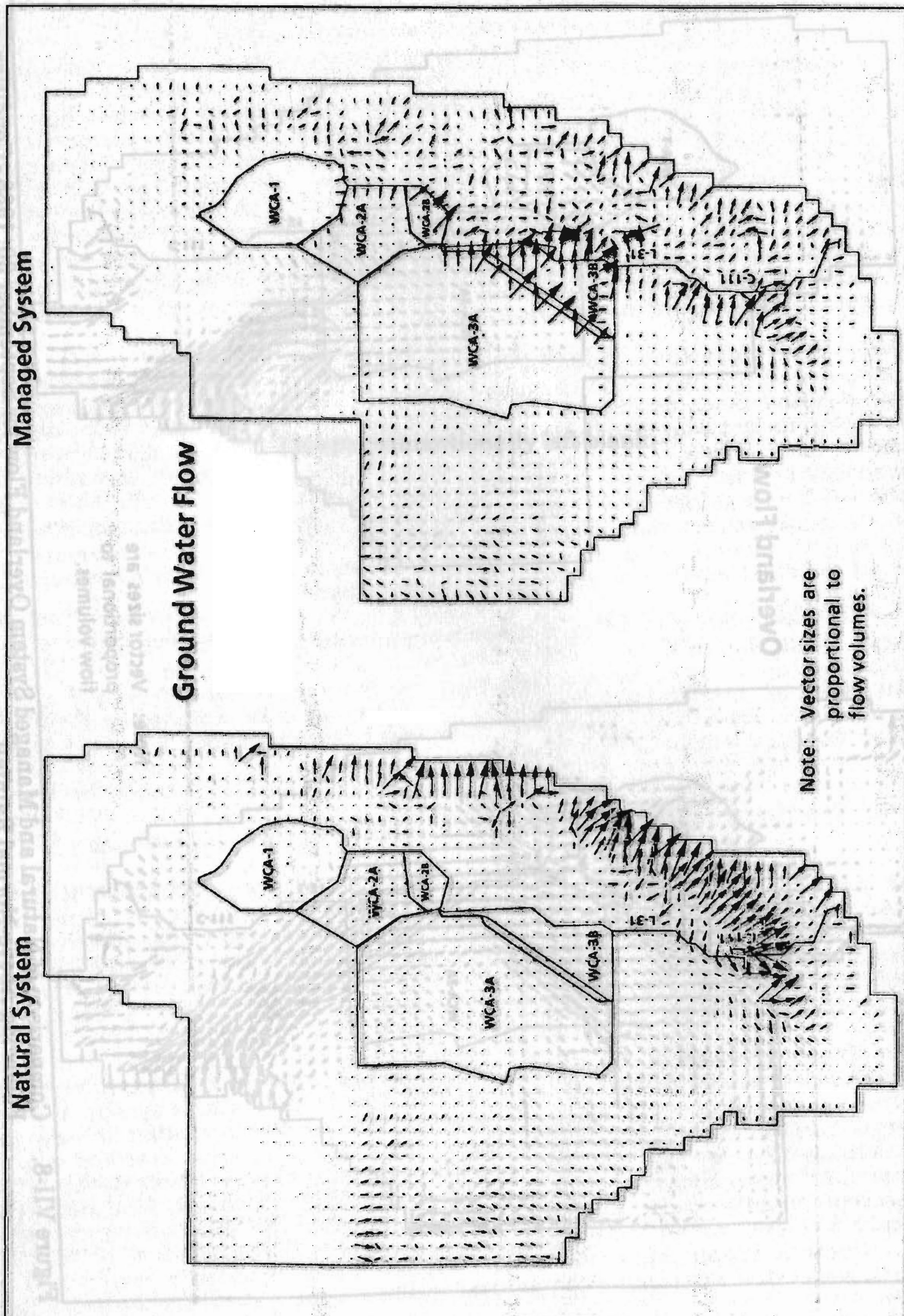

Figure VII-9. Comparison of Natural and Managed System Ground Water Flow for September 30, 1988 - Condition Following Above-Normal Rainfall.

(September 30, 1988). Note that the size of the vectors is proportional to the flow volumes but cannot be directly compared to the size of the vectors in **Figure VII-8** since they are shown at different scales. That is, for a **Figure VII-8** vector and a **Figure VII-9** vector of the same length, the surface flow volume is roughly about ten times larger than the ground water flow volume.

Under natural conditions the largest ground water gradients occurred along the coastal ridge. Consequently, the largest ground water flow occurred at that location. With the construction of the WCA levees and the drainage of the Lower East Coast developing areas, the largest ground water gradients shifted to the WCA levees. Thus, the largest ground water flow under managed conditions occurs at the levees. The lowering of ground water levels in the developing areas of the Lower East Coast also reduced the large coastal gradients that occurred under natural conditions and increased the potential for saltwater intrusion.

3. Comparison of Ponding Depth Patterns for the Natural and Managed Systems.

Ponding is defined as the depth of water above the land surface. In this subsection, natural and managed system ponding patterns are presented for three different meteorologic conditions (end of a normal wet season, end of a normal dry season, and an extremely wet condition) in order to (1) illustrate the various ponding patterns that result from these different conditions, and (2) to compare the natural system ponding patterns to those of the managed system.

End of a Normal Wet Season. **Figure VII-10** presents a comparison of natural and managed system ponding at the end of a normal wet season. The five month wet season ending October 31, 1986 produced an average of 30.5 inches across rainfall the region. Normal wet season rainfall for the region based on the 1980 to 1989 period was 30.9 inches. Under natural conditions there appears to be up to two feet of ponding in most of the original Everglades. Under managed conditions, ponding is restricted to the WCAs and Shark River Slough; no ponding occurs in the EAA or the Lower East Coast developed areas. Also note that the WCAs impound more water at their southern portions. Ponding depths between 4 and 5 feet are evident at the southern ends of WCA-1 and WCA-2A. In WCA-3A ponding depths between two and four feet occurred along L-67A.

To better illustrate the differences between the natural and managed system water levels for October 31, 1986, **Figure VII-11** was prepared. By taking the difference between the water levels, which could be above or below land surface, the differences between the natural and managed system ground water levels also could be shown. Note that **Figure VII-11** does not represent the difference between **Figure VII-9** and **VII-10,** which considers only surface water. **Figure VII-11** shows that managed water levels are more than four feet lower than estimated natural levels in most of the EAA and the LEC developed area. Also shown is the one to two feet higher water levels in the southern ends of the WCA-2A and WCA-3A under managed conditions. Note that managed system water levels at the southern end of WCA-1 were more than two feet higher than natural for this date.

End of a Normal Dry Season. **Figure VII-12** shows a comparison of natural and managed system ponding at the end of a normal dry season. The seven month dry season ending May 31, 1986 produced 19.8 inches of rainfall over the region. Normal dry season rainfall for the region based on the 1980 to 1989 period was also 19.8 inches. Under natural conditions, up to about one foot of ponding may have occurred in most of the original Everglades. Up to two feet of ponding may have

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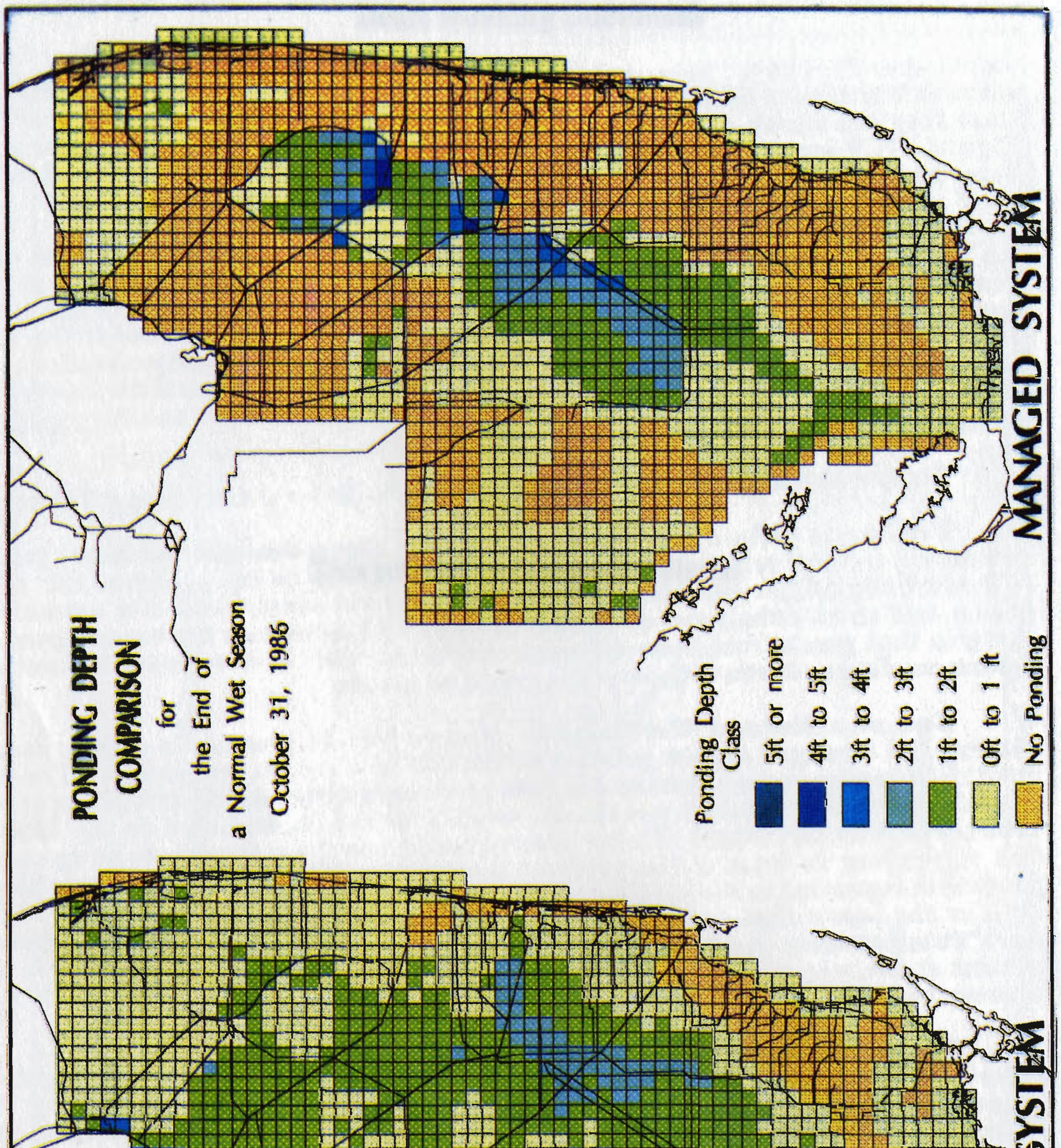

Figure VII-10. Comparison of Natural System and Managed System Ponding Depth Patterns at the End of a Normal Wet Season - October 31, 1986.

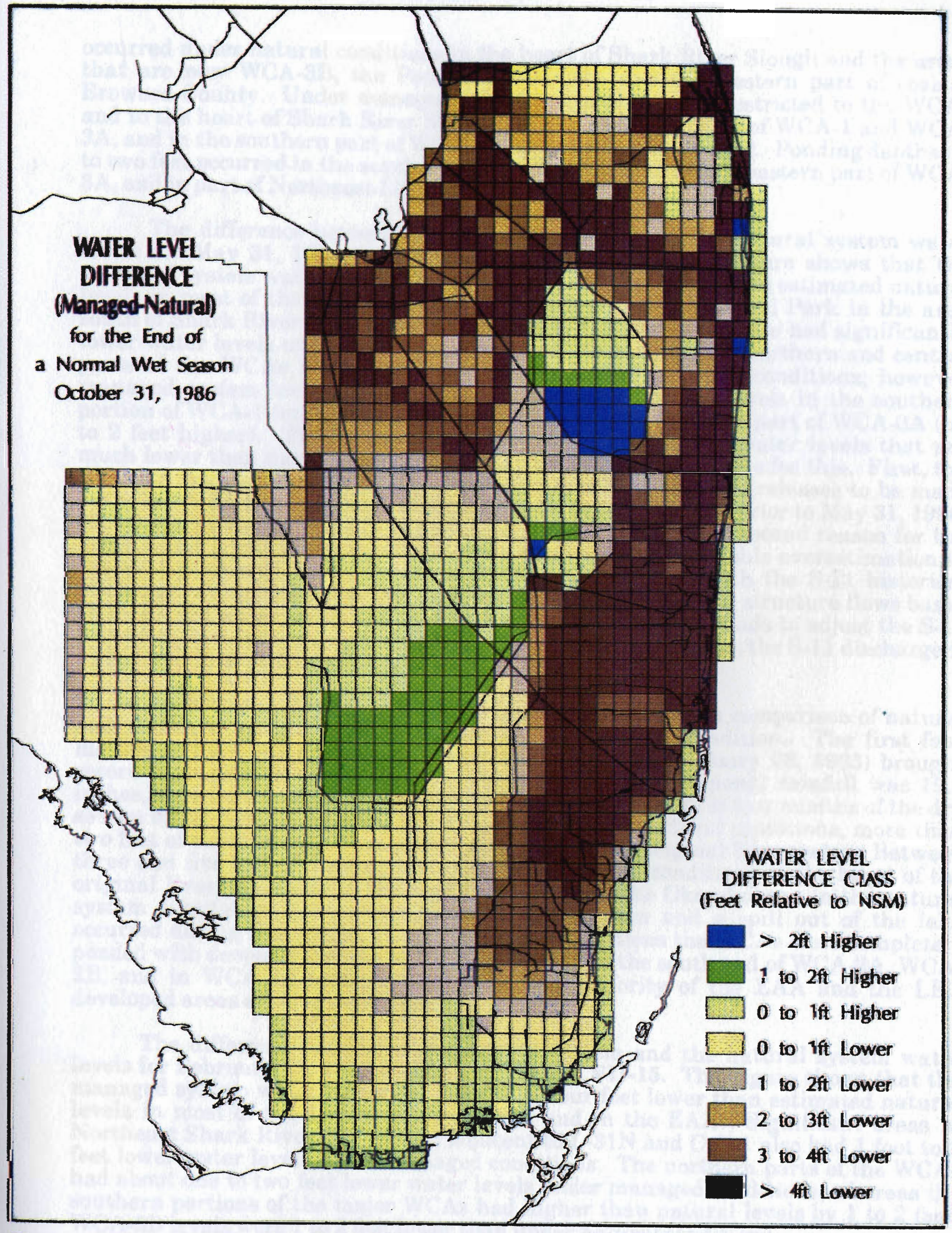

Figure VII-11. Difference Between Managed System and Natural System Water Levels at the End of a Normal Wet Season - October 31, 1986.

occurred under natural conditions in the heart of Shark River Slough and the areas that are now WCA-3B, the Pennsuco wetlands, and the western part of coastal Broward County. Under managed conditions, ponding was restricted to the WCAs and to the heart of Shark River Slough. In the northern parts of WCA-1 and WCA-3A, and in the southern part of WCA-2A, no ponding was evident. Ponding depths up to two feet occurred in the southern part of WCA-1, in the southeastern part of WCA-3A, and in part of Northeast Shark River Slough.

The difference between the managed system and the natural system water levels for May 31, 1986 is shown in **Figure VII-13**. This figure shows that the managed system water levels were more than four feet lower than estimated natural levels in most of the LEC developed areas. Everglades National Park in the area south of Shark River Slough and adjacent to L-31N and C-111 also had significantly lower water levels under managed conditions. In general, the northern and central parts of the WCAs have lower water levels under managed conditions; however managed system levels are higher than estimated natural levels in the southern portion of WCA-1 (more than 2 feet higher) and in the southern part of WCA-3A (up to 2 feet higher). The southwestern part of WCA-2A shows water levels that are much lower than natural (up to two feet). There are two reasons for this. First, the WCA-2A regulation schedule (or drawdown schedule) required releases to be made out of WCA-2A through the S-11 structures for several months prior to May 31, 1986. This lowered water levels in the south end of WCA-2A. The second reason for the lower water levels under managed conditions is due to a probable overestimation in the S-11 discharge data. Problems have been identified with the S-11 historical discharge rating curve that was used to calculate the historical structure flows based on measured water levels and gate operations. Efforts were made to adjust the S-11 historical flow data during the SFWMM recalibration, however, the S-11 discharge is considered to be still somewhat overestimated.

An Extreme Wet Condition. **Figure VII-14** shows a comparison of natural and managed system ponding during an extreme wet condition. The first four months of the 1983 dry season (November 1, 1982 to February 28, 1983) brought record high rainfall to the region. During this period regional rainfall was 19.9 inches,more than double the average that occurred for the first four months of the dry season based during the 1980 to 1989 period. Under natural conditions, more than two feet of ponding may have occurred in most of the original Everglades. Between three and five feet of ponding occurred under natural conditions in the heart of the original Everglades and in the area just south of Lake Okeechobee. In the natural system simulation, lake stages were at a maximum and a spill out of the lake occurred during this period. Under managed conditions the WCAs were completely ponded with deeper water (up to 5 feet) occurring in the south end of WCA-2A, WCA-2B, and in WCA-3A along L-67A. The vast majority of the EAA and the LEC developed areas experienced little or no ponding.

The difference between the managed system and the natural system water levels for February 28, 1983 is shown in **Figure VII-15**. This figure shows that the managed system water levels are more than four feet lower than estimated natural levels in most of the LEC developed areas and in the EAA. Significant areas in Northeast Shark River Slough and adjacent to L-31N and C-111 also had 1 foot to 2 feet lower water levels under managed conditions. The northern parts of the WCAs had about one to two feet lower water levels under managed conditions; whereas the southern portions of the major WCAs had higher than natural levels by 1 to 2 feet. WCA-3B levels were 1 to 2 feet lower than under natural conditions.

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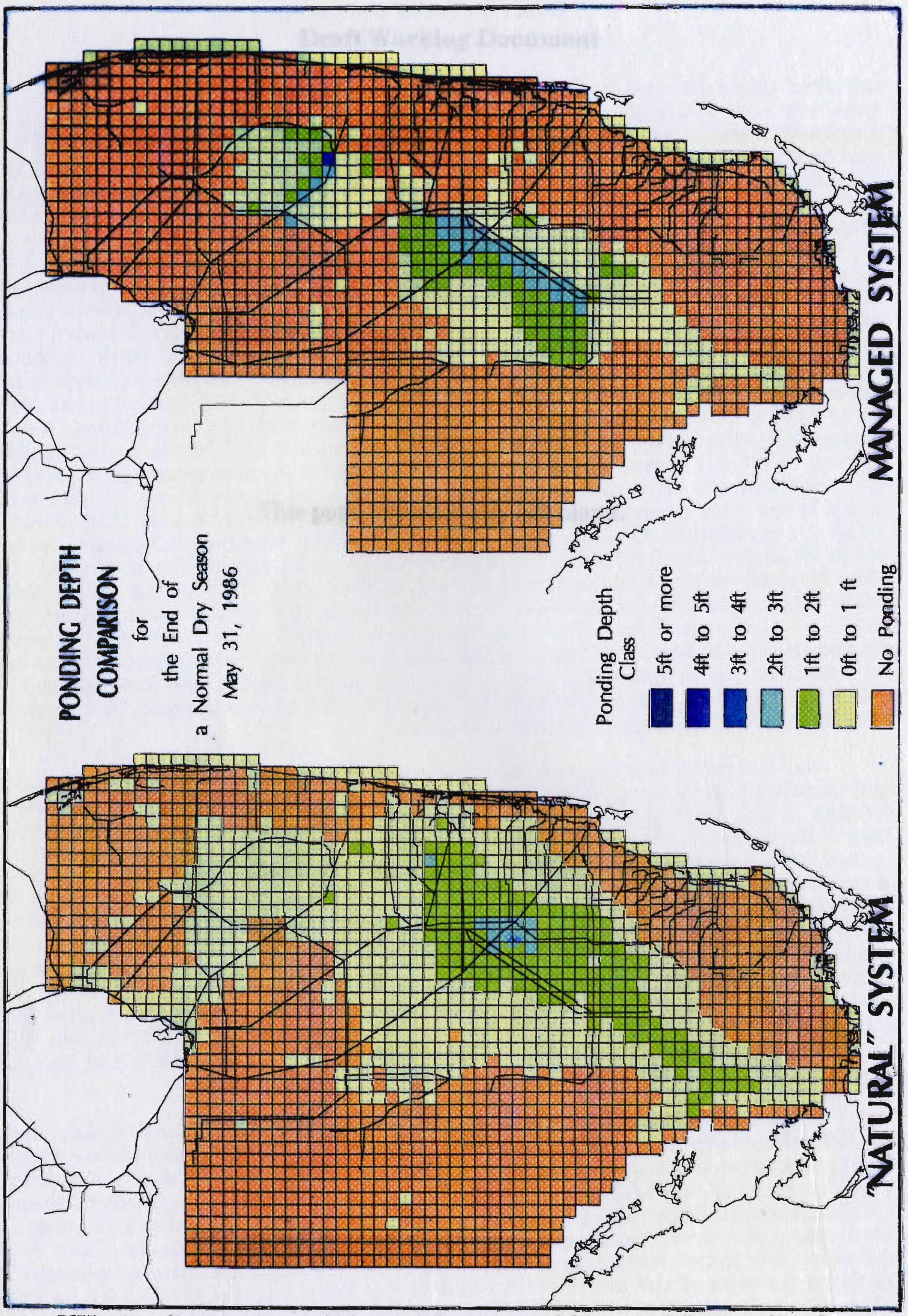

Figure VII-12. Comparison of Natural System and Managed System Ponding Depth Patterns at the End of a Normal Dry Season - May 31, 1986.

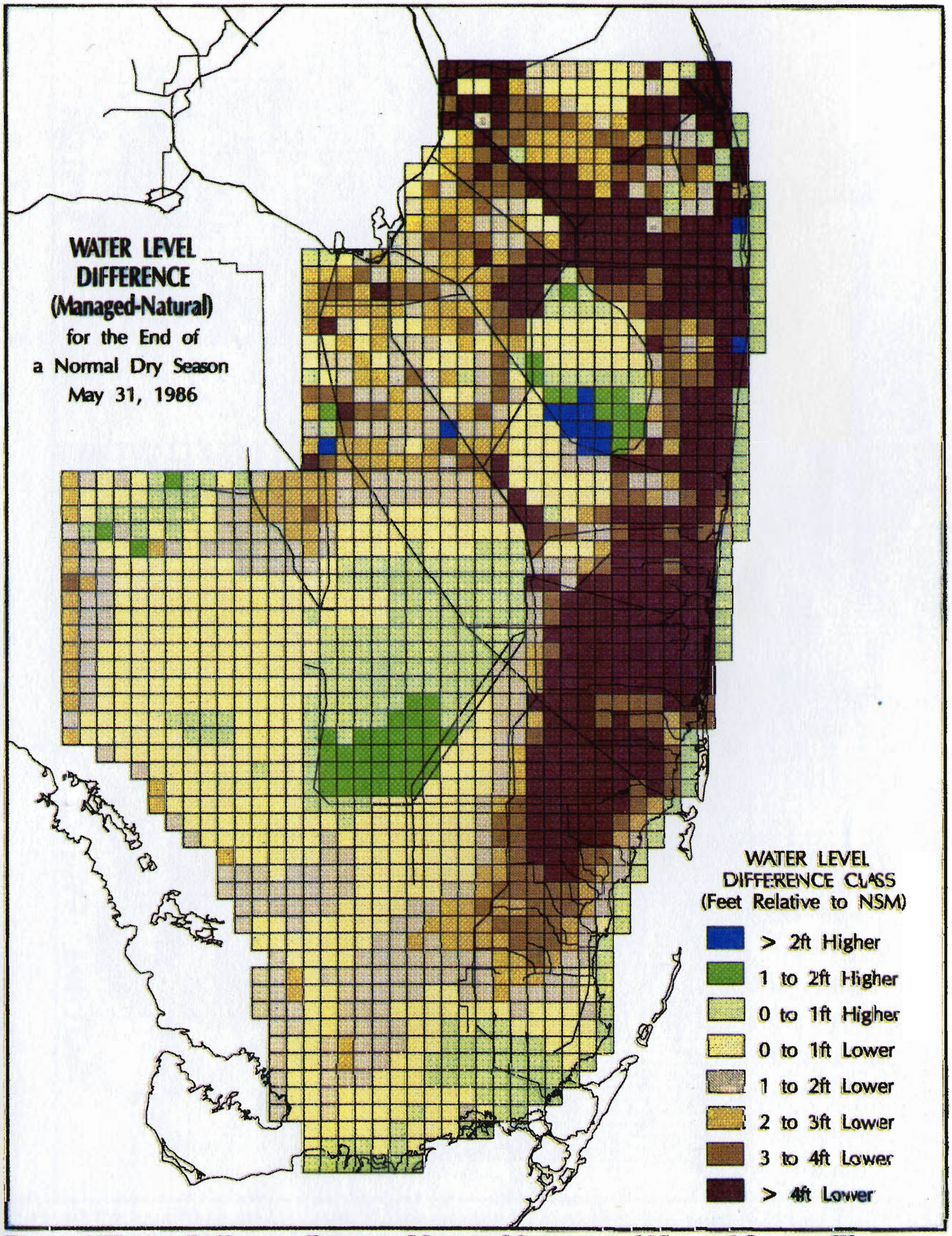

Figure VII-13. Difference Between Managed System and Natural System Water Levels at the End of a Normal Dry Season - May 31, 1986.

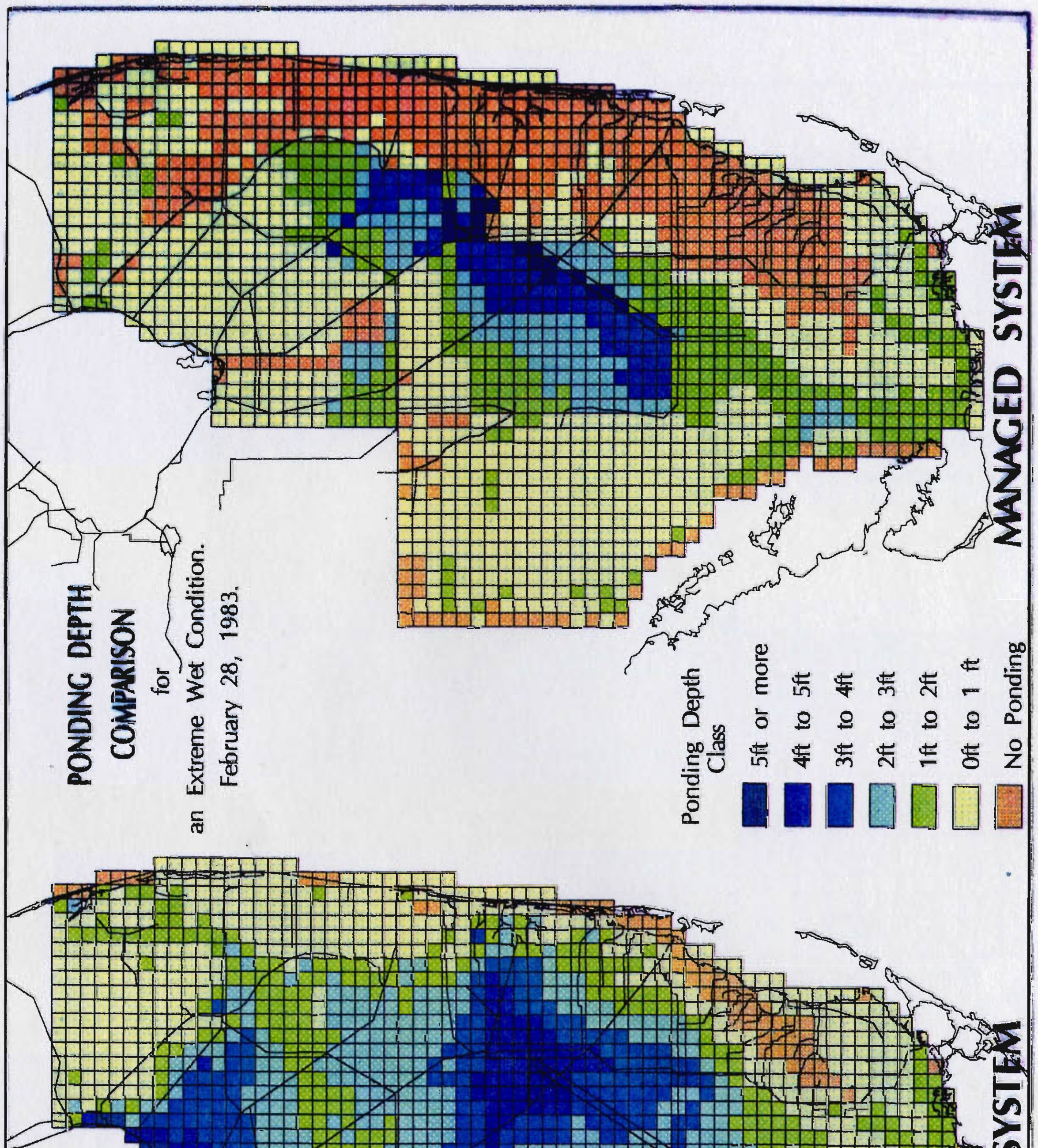

Figure VII-14. Comparison of Natural System and Managed System Ponding Depth Patterns for an Extreme Wet Condition - February 28, 1983.

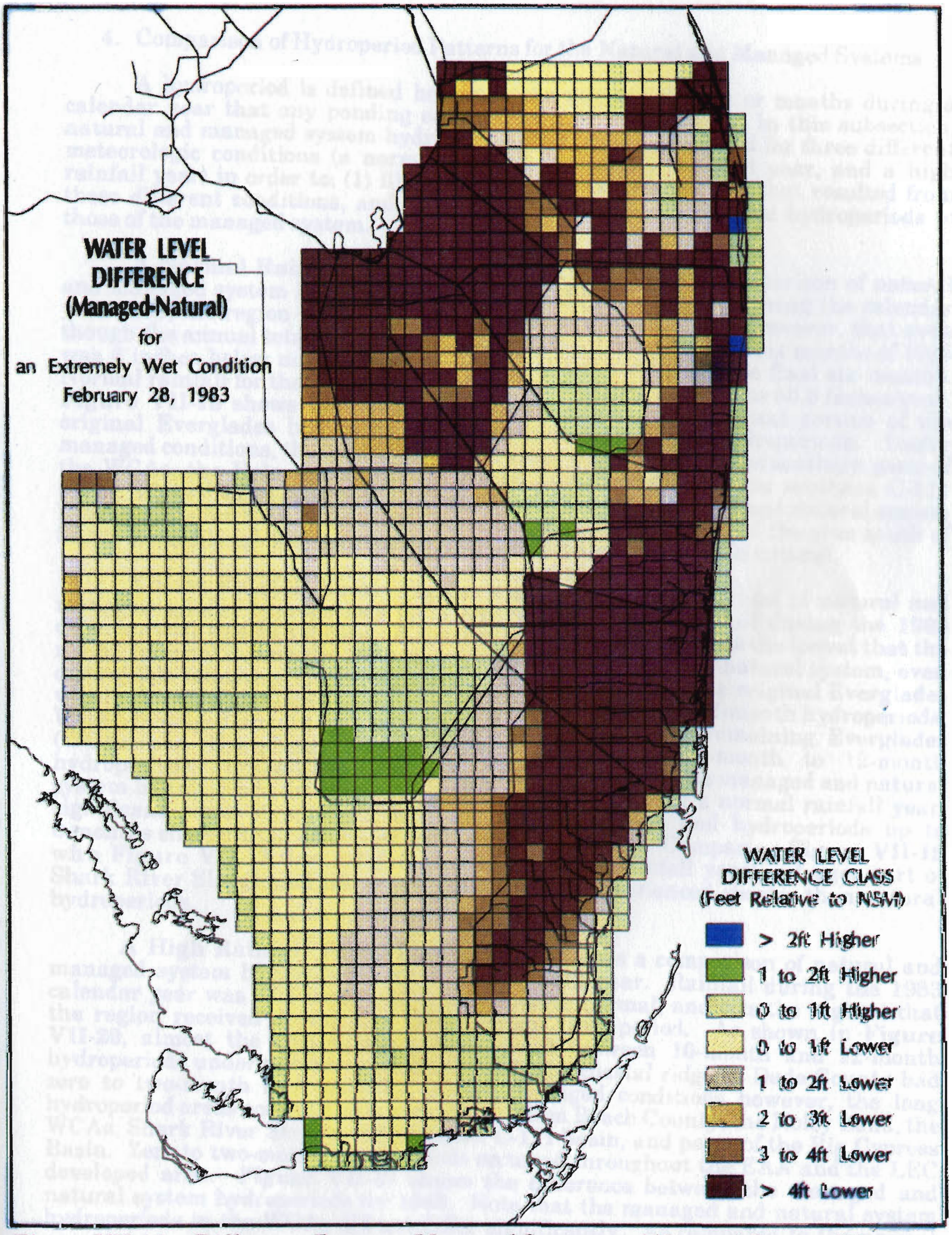

Figure VII-15. Difference Between Managed System and Natural System Water Levels for an Extreme Wet Condition - February 28, 1983.

4. Comparison of Hydroperiod Patterns for the Natural and Managed Systems

A hydroperiod is defined herein as the number of days or months during a calendar year that any ponding occurred in a given grid cell. In this subsection, natural and managed system hydroperiod patterns are presented for three different meteorologic conditions (a normal rainfall year, a low rainfall year, and a high rainfall year) in order to: (1) illustrate the various hydroperiods that resulted from these different conditions, and (2) to compare the natural system hydroperiods to those of the managed system.

A Normal Rainfall Year. **Figure VII-16** presents a comparison of natural and managed system hydroperiods for a normal rainfall year. During the calendar year 1985, the region experienced 49.9 inches of rainfall. Note, however, that even though the annual total was near normal, rainfall during the first six months of 1985 was 6 inches below normal and five inches above normal for the final six months. Normal rainfall for the region based on the 1980 to 1989 period was 50.8 inches/year. **Figure VII-16** shows that under natural conditions, a significant portion of the original Everglades had between 10-month and 12-month hydroperiods. Under managed conditions, the long hydroperiod areas were limited to the southern parts of the WCAs, the Holey Land, central Shark River Slough, and the southern C-111 basin. **Figure VII-17** shows the difference between the managed and natural system hydroperiods for 1985. Significant parts of northern WCA-3A and the area south of Shark River Slough had hydroperiods up to 6-months shorter than natural.

A Low Rainfall Year. **Figure VII-18** shows a comparison of natural and managed system hydroperiods for a low rainfall year. Rainfall during the 1989 calendar year was 40.4 inches, 10.4 inches below normal, and was the lowest that the region received during the 1980 through 1989 period. For the natural system, even during this relatively low rainfall year a significant part of the original Everglades within Broward and Dade Counties experienced 10-month to 12-month hydroperiods. Under managed conditions, only limited areas within the remaining Everglades (WCAs and Everglades National Park) experienced 10-month to 12-month hydroperiods. **Figure VII-19** shows the difference between the managed and natural system hydroperiods for 1989. As with the similar map for a normal rainfall year, significant parts of northern WCA-3A appear to have had hydroperiods up to 6-months shorter than estimated for the natural system. Comparing **Figure VII-19** with **Figure VII-17** (low rainfall year to a normal rainfall year), a larger part of Shark River Slough and the areas west of L-31N experienced shorter-than-natural hydroperiods.

A High Rainfall Year. **Figure VII-20** shows a comparison of natural and managed system hydroperiods for a high rainfall year. Rainfall during the 1983 calendar year was 64.1 inches, 13.3 inches above normal, and was the highest that the region received during the 1980 through 1989 period. As shown in **Figure VII-20**, almost the entire region experienced between 10-month and 12-month hydroperiods under natural conditions. Only the coastal ridge in Dade County had zero to two-month hydroperiods. Under managed conditions however, the long hydroperiod areas occurred only in northern Palm Beach County, the Holey Land, the WCAs, Shark River Slough, the southern C-111 basin, and parts of the Big Cypress Basin. Zero to two-month hydroperiods occurred throughout the EAA and the LEC developed area. **Figure VII-21** shows the difference between the managed and natural system hydroperiods for 1983. Note that the managed and natural system hydroperiods in the WCAs did not differ significantly. As compared to the normal

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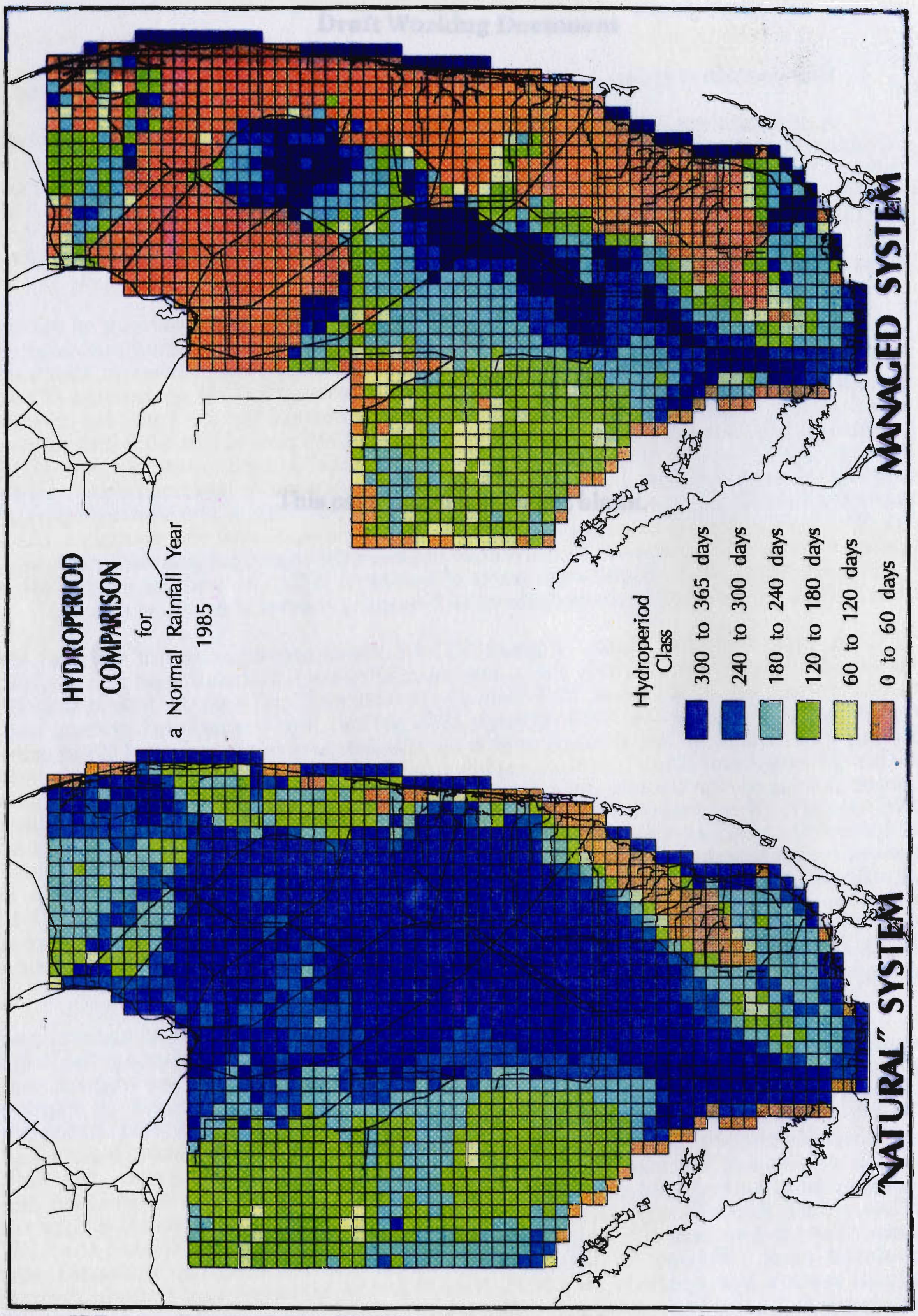

Figure VII-16. Comparison of Natural System and Managed System Hydroperiod Patterns for a Normal Rainfall Year - 1985.

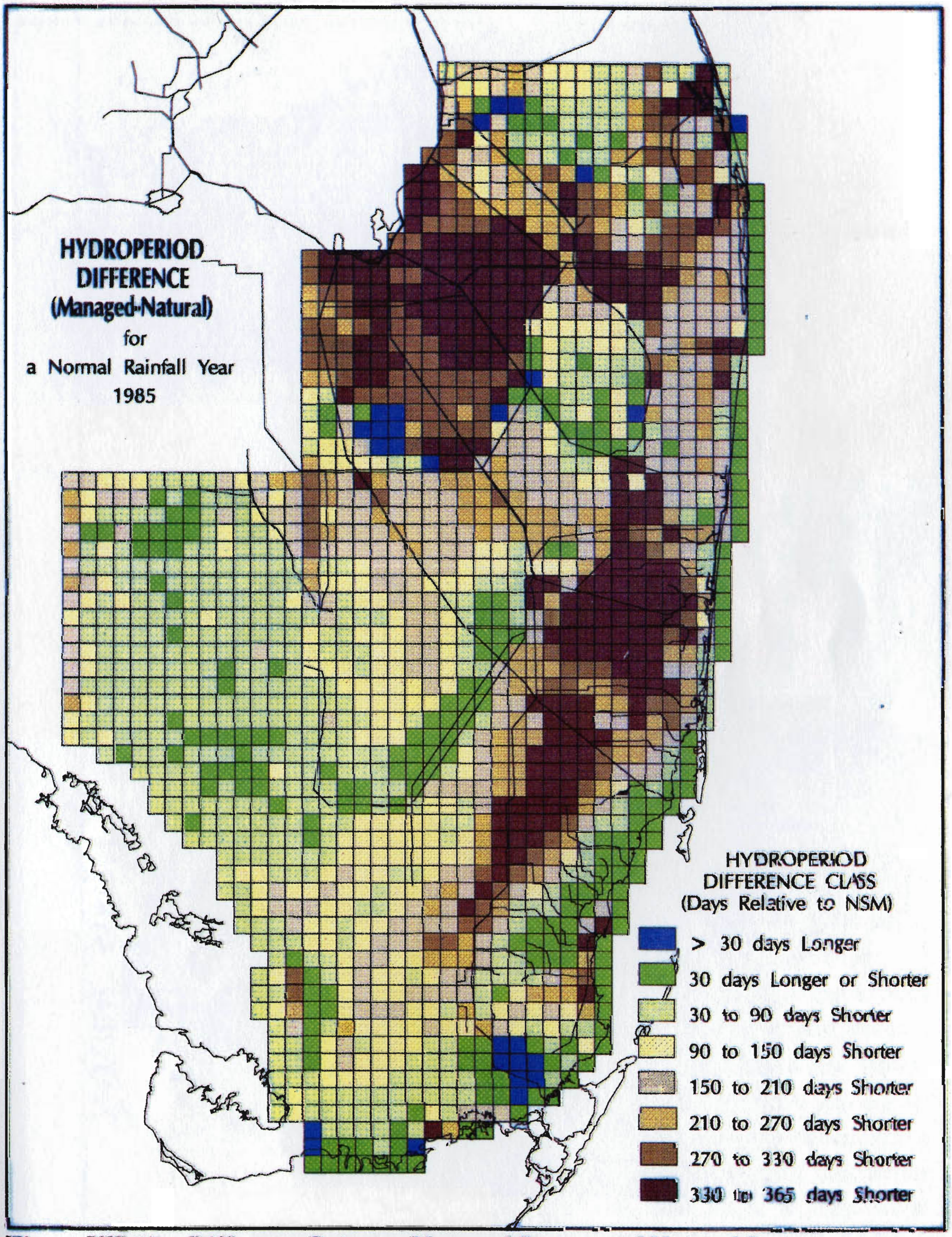

Figure VII-17. Difference Between Managed System and Natural System Hydroperiod Patterns for a Normal Rainfall Year - 1985.

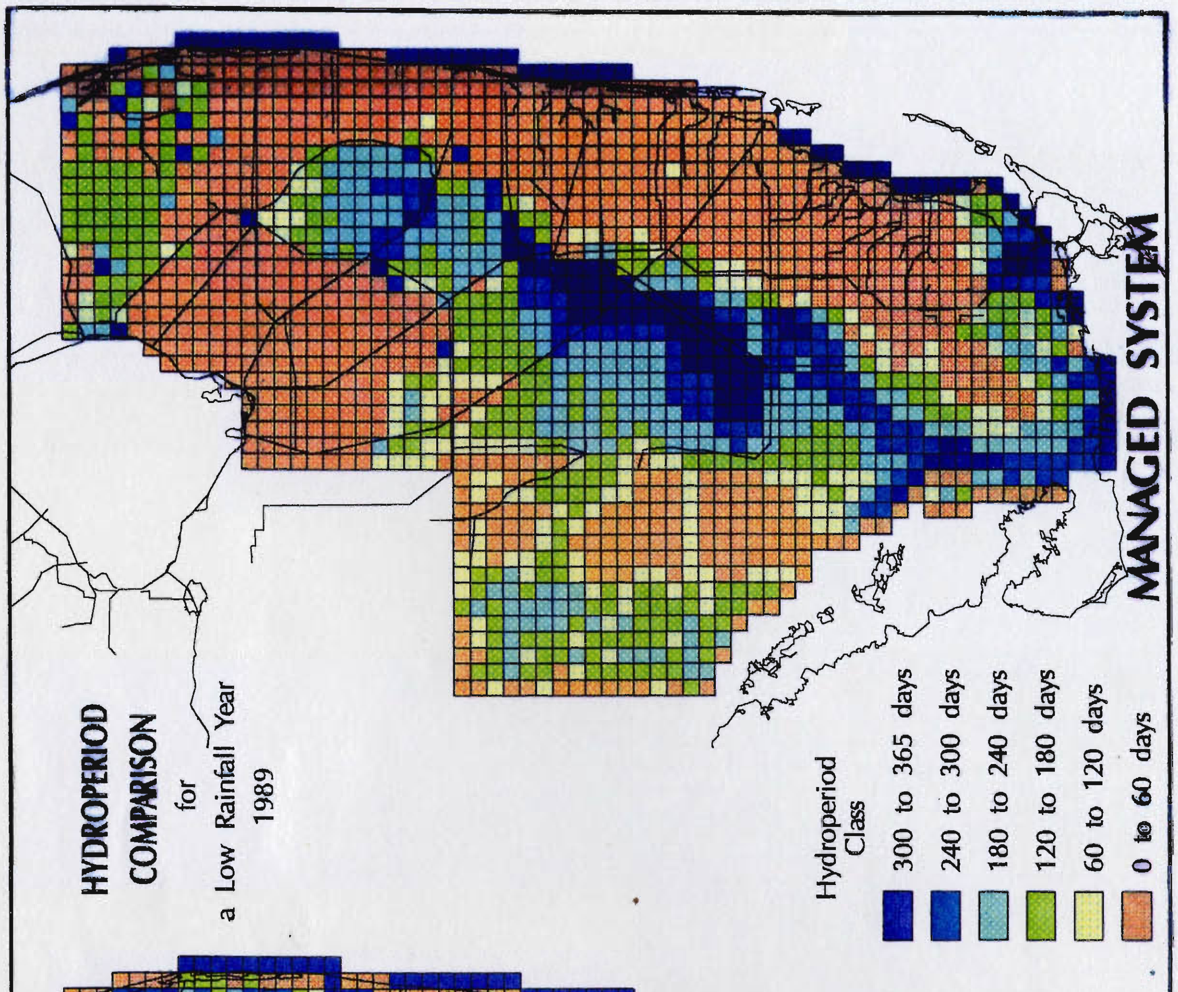

Figure VII-18. Comparison of Natural System and Managed System Hydroperiod Patterns for a Low Rainfall Year - 1989.

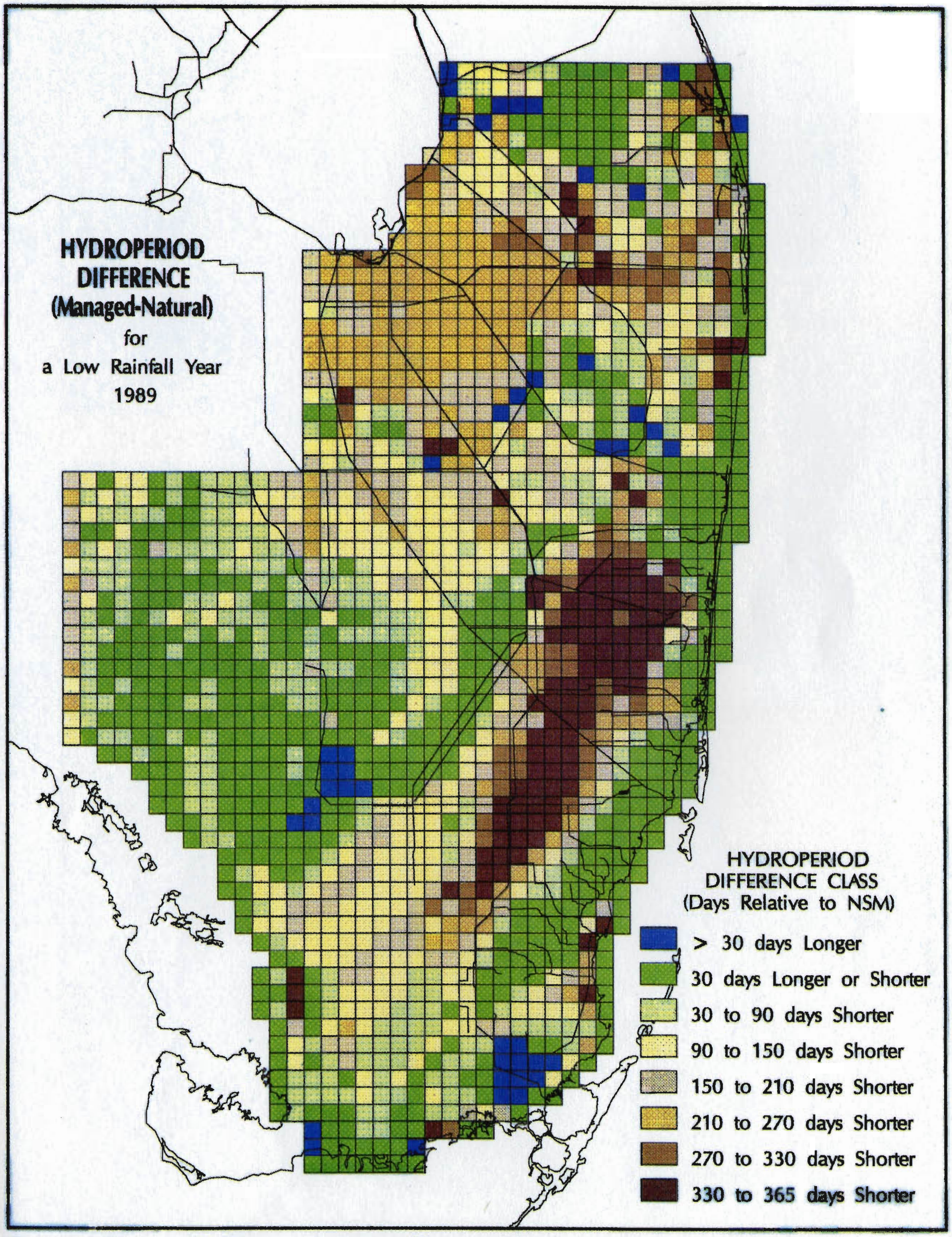

Figure VII-19. Difference between Managed System and Natural System Hydroperiod Patterns for a Low Rainfall Year - 1989.

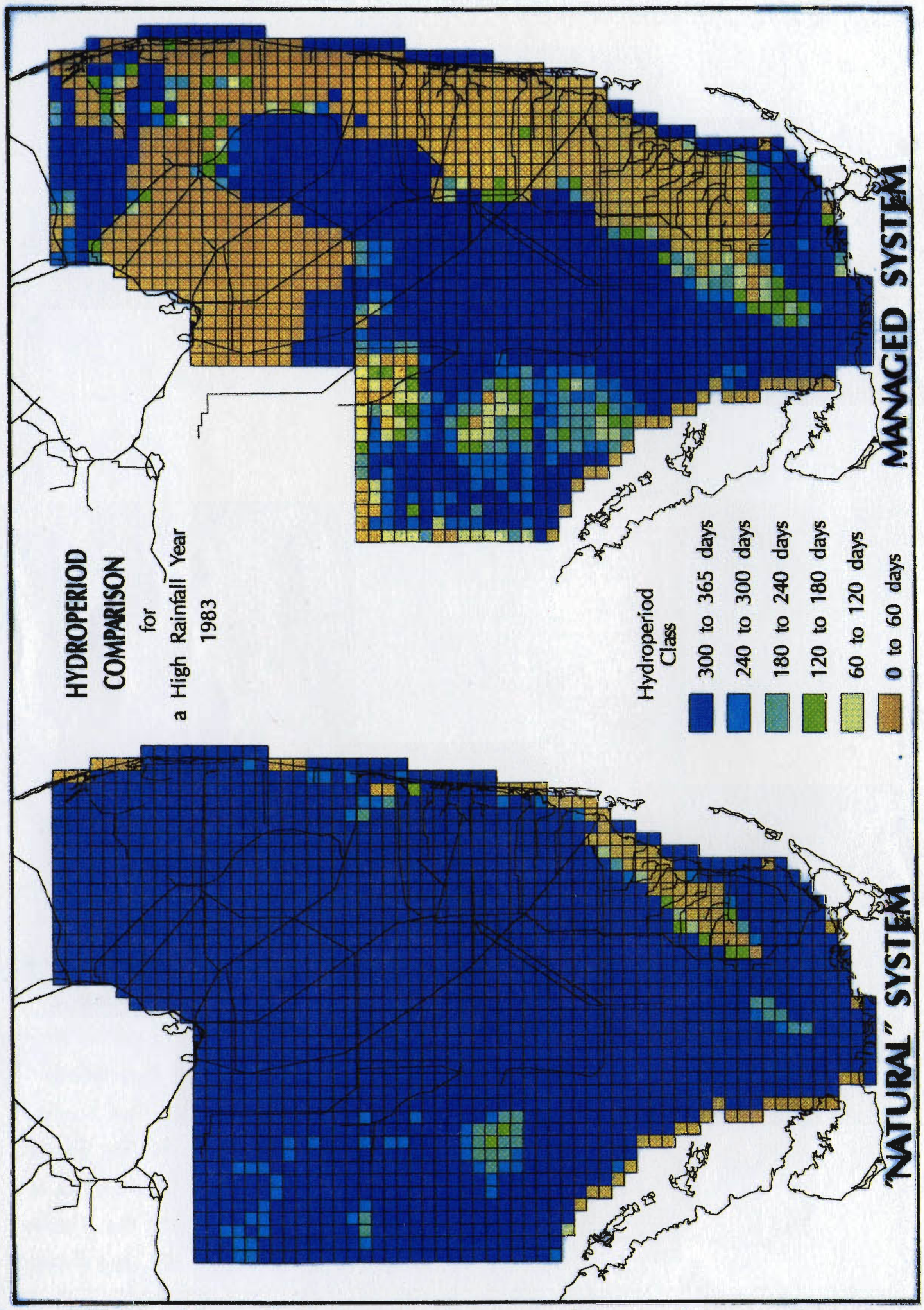

Figure VII-20. Comparison of Natural System and Managed System Hydroperiod Patterns for a High Rainfall Year - 1983.

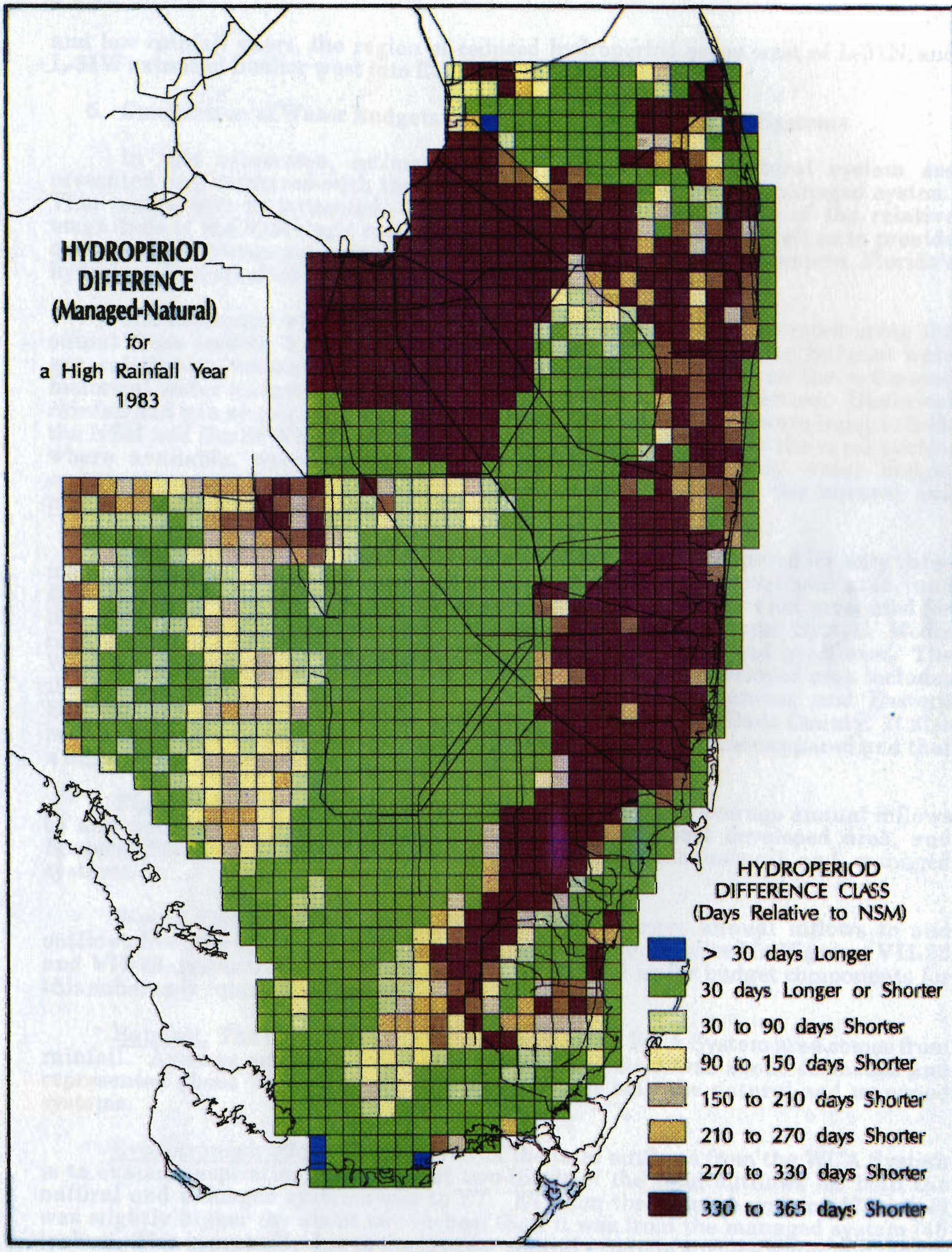

Figure VII-21. Difference between Managed System and Natural System Hydroperiod Patterns for a High Rainfall Year - 1983.

and low rainfall years, the region of reduced hydroperiod areas west of L-31N and L-31W extended further west into Everglades National Park.

5. Comparison of Water Budgets for the Natural and Managed Systems

In this subsection, estimated water budgets of the natural system are presented and compared with the estimated water budgets of the managed system. This comparison is presented in order to portray a big picture of the relative magnitude of the hydrologic components of the natural system as well as to provide quantitative information regarding the major changes in southeastern Florida's hydrology that resulted from water management.

The estimated water budgets of the natural system were generated using the output from version 3.6 of the NSM. The managed system water budgets were generated with version 1.1 of the SFWMM and are the same as the estimated historical water budgets that were previously described in this Section. Historical rainfall and pan evaporation data for the ten-year period (1980-89) were input to both the NSM and the SFWMM. Historical structure discharge data for the same period, where available, were input to the SFWMM. The remaining water budget components were estimated by the NSM and the SFWMM for the natural and managed systems, respectively.

The natural and managed system water budgets were compared for only three major subbasins, the WCA System, the Lower East Coast developed area, and Eastern Everglades National Park (**Figure VII-1**). Budgets were not presented for the EAA because of limitations in the accuracy of the Natural System Model regarding the simulation of natural Lake Okeechobee stages and overflows. The WCA System includes the five WCAs; the Lower East Coast developed area includes the eastern portions of Palm Beach, Broward and Dade counties; and Eastern Everglades National Park includes that portion of ENP within Dade County. It also is important to note that only average annual water budgets were compared and that a high degree of seasonal variability exists.

Figures VII-22 to **VII-27** illustrate summaries of the average annual inflows to and outflows from the WCA System, Lower East Coast developed area, and Eastern Everglades National Park subarea for both the natural and managed systems.

Water Conservation Area System. The average annual inflows to and outflows from the 1,312 square mile WCA System are summarized in **Figures VII-22** and **VII-23**, respectively. A comparison of each of the water budget components for this subarea is summarized below.

Rainfall. The majority of the total inflows to the WCA System area comes from rainfall. Average annual rainfall over the WCA System was about 48 inches and represented about 70 percent of the total inflow for both the natural and managed systems.

Evapotranspiration. The majority of the total outflows from the WCA System is to evapotranspiration (ET). About two-thirds of the total outflows for both the natural and managed systems was to ET. ET from the natural system (47 inches) was slightly higher (by about two inches) than it was from the managed system (45 inches). This is probably due to the broader spatial extent of surface water and longer

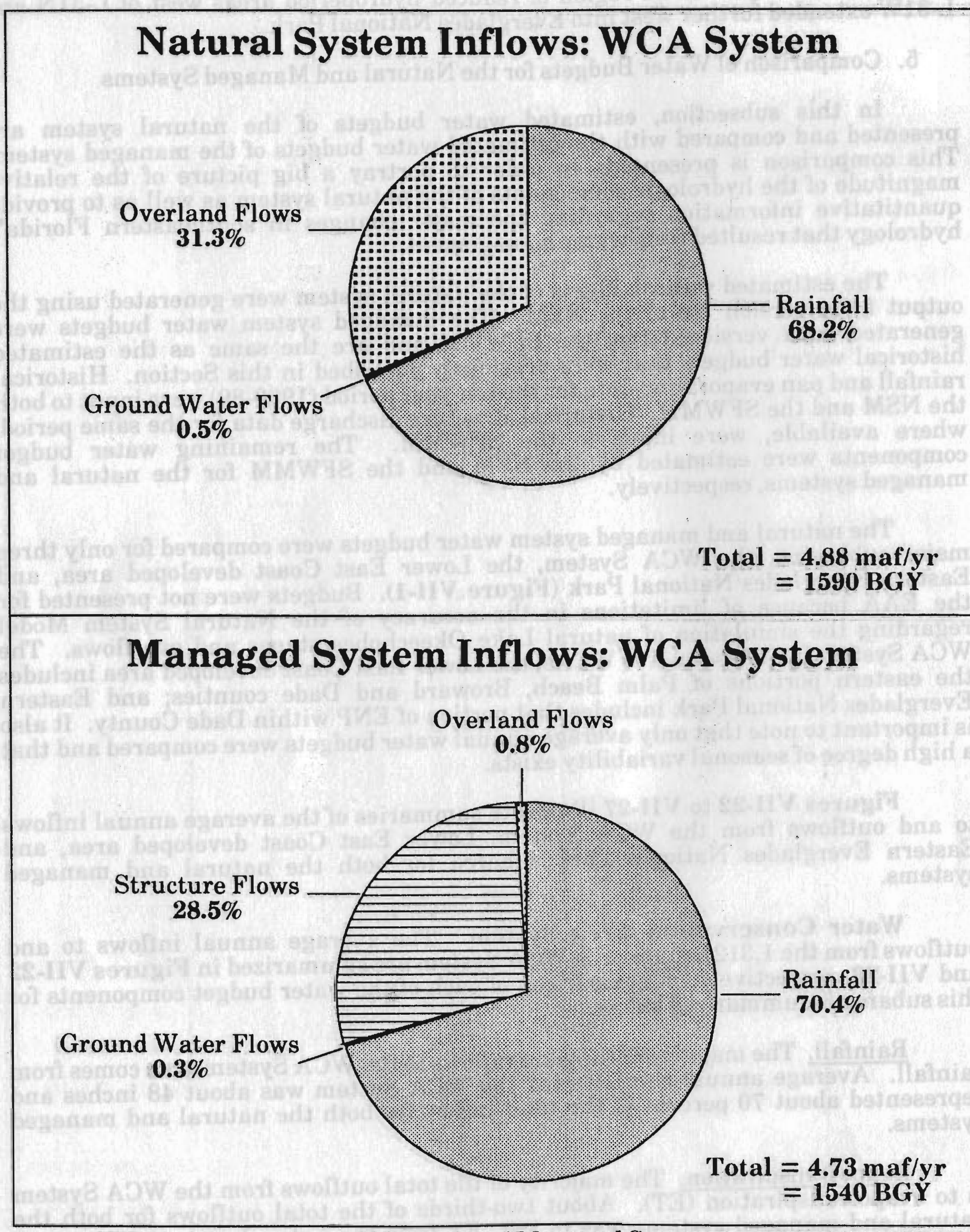

Figure VII-22. Comparison of Natural and Managed System Average Annual (1980-89) Inflows to the WCA System.

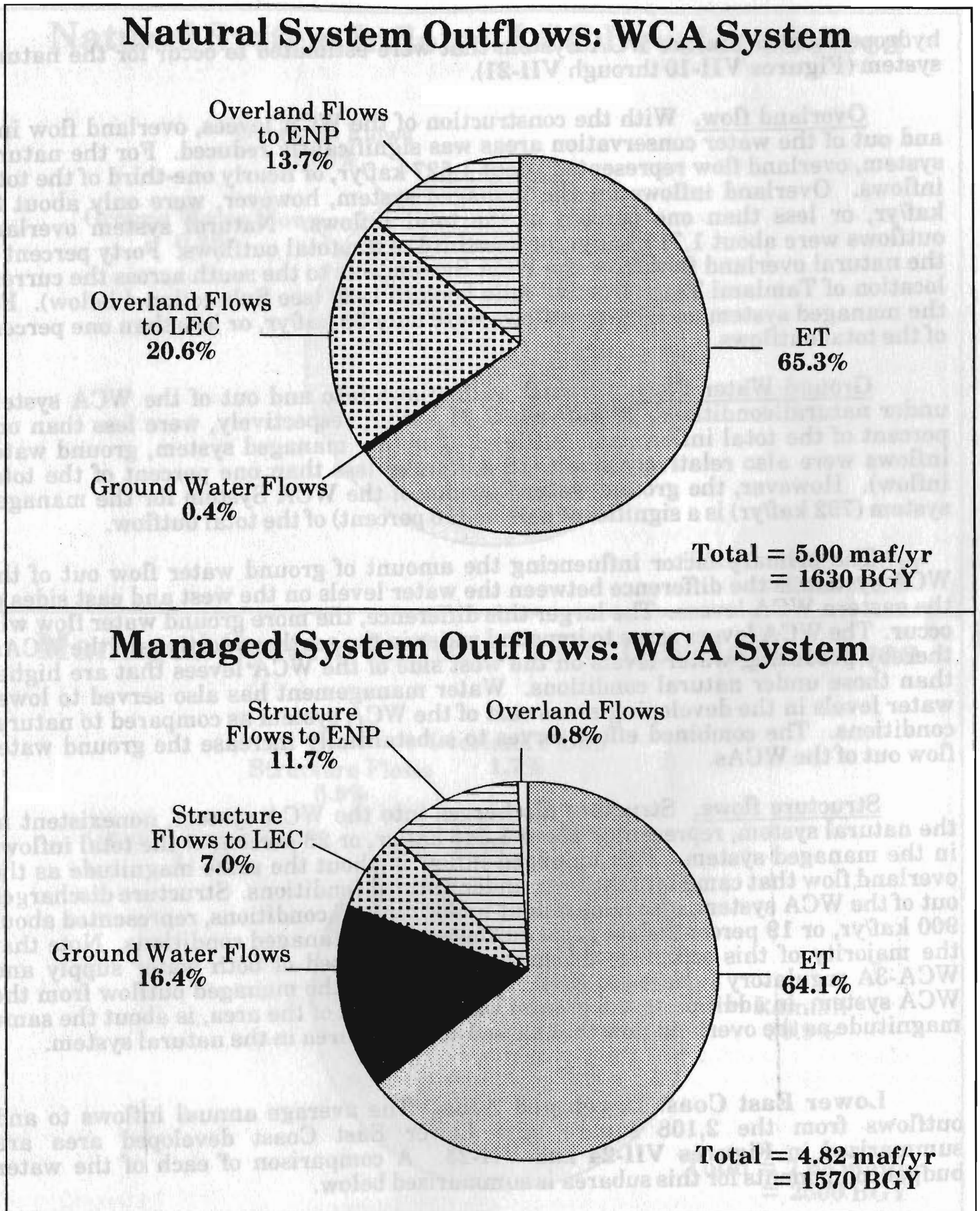

Figure VII-23. Comparison of Natural and Managed System Average Annual (1980-89) Outflows from the WCA System.

hydroperiods within the WCA System that were estimated to occur for the natural system (**Figures VII-10** through **VII-21**).

Overland flow. With the construction of the WCA levees, overland flow into and out of the water conservation areas was significantly reduced. For the natural system, overland flow represented about 1,527 kaf/yr, or nearly one-third of the total inflows. Overland inflows for the managed system, however, were only about 37 kaf/yr, or less than one percent of the total inflows. Natural system overland outflows were about 1,717 kaf/yr, or one-third of the total outflows. Forty percent of the natural overland flow from the WCA System was to the south across the current location of Tamiami Trail from 40-mile bend to L-30 (see Subsection 4 below). For the managed system, overland outflows were only 38 kaf/yr, or less than one percent of the total outflows.

Ground Water Flow. Ground water flows into and out of the WCA system under natural conditions, 26 kaf/yr and 21 kaf/yr, respectively, were less than one percent of the total inflows and outflows. For the managed system, ground water inflows were also relatively small (15 kaf/yr, or less than one percent of the total inflow). However, the ground water flow out of the WCA System for the managed system (792 kaf/yr) is a significant portion (16 percent) of the total outflow.

The primary factor influencing the amount of ground water flow out of the WCA system is the difference between the water levels on the west and east sides of the eastern WCA levees. The larger this difference, the more ground water flow will occur. The WCA levees serve to impound water in the southern sections of the WCAs, thereby producing water levels on the west side of the WCA levees that are higher than those under natural conditions. Water management has also served to lower water levels in the developing areas east of the WCA system as compared to natural conditions. The combined effect serves to substantially increase the ground water flow out of the WCAs.

Structure flows. Structure discharges into the WCA system, nonexistent in the natural system, represented about 1,346 kaf/yr, or 28 percent of the total inflows in the managed system. This managed inflow is about the same magnitude as the overland flow that came into the area under natural conditions. Structure discharges out of the WCA system, also nonexistent under natural conditions, represented about 900 kaf/yr, or 19 percent of the total outflows under managed conditions. Note that the majority of this structure discharge was comprised of both water supply and WCA-3A regulatory releases to ENP. Also note that the managed outflow from the WCA system, in addition to the ground water flow out of the area, is about the same magnitude as the overland flow that passed out of the area in the natural system.

Lower East Coast Developed Area. The average annual inflows to and outflows from the 2,108 square mile Lower East Coast developed area are summarized in **Figures VII-24** and **VII-25**. A comparison of each of the water budget components for this subarea is summarized below.

Rainfall. The majority of the total inflows to the Lower East Coast developed area comes from rainfall. Average annual rainfall over the Lower East Coast developed area was about 55 inches. Rainfall represented about 84 percent of the total natural system inflows and about 81 percent of the total managed system inflows.

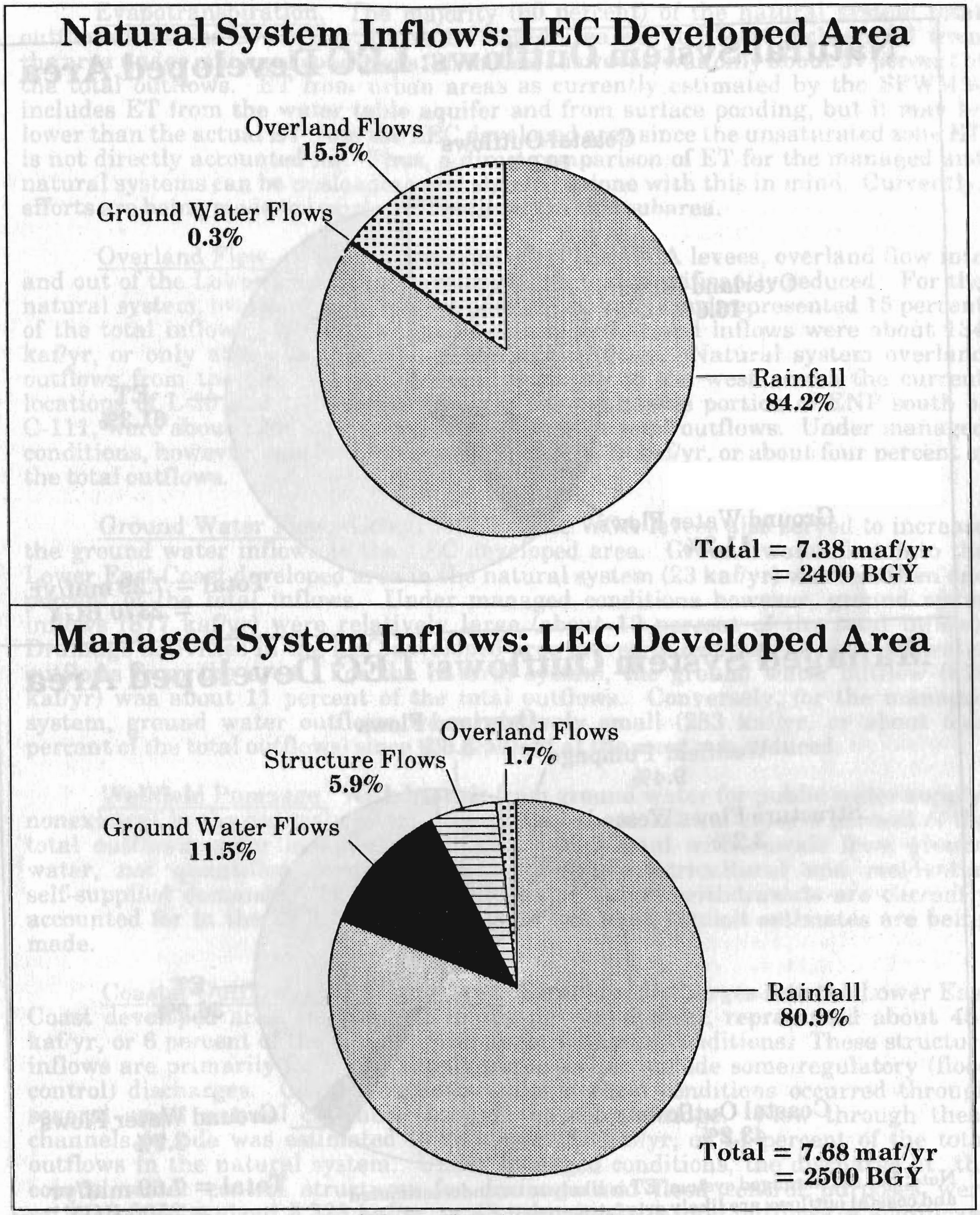

Figure VII-24. Comparison of Natural and Managed System Annual Average (1980-89) Inflows to the LEC Developed Area.

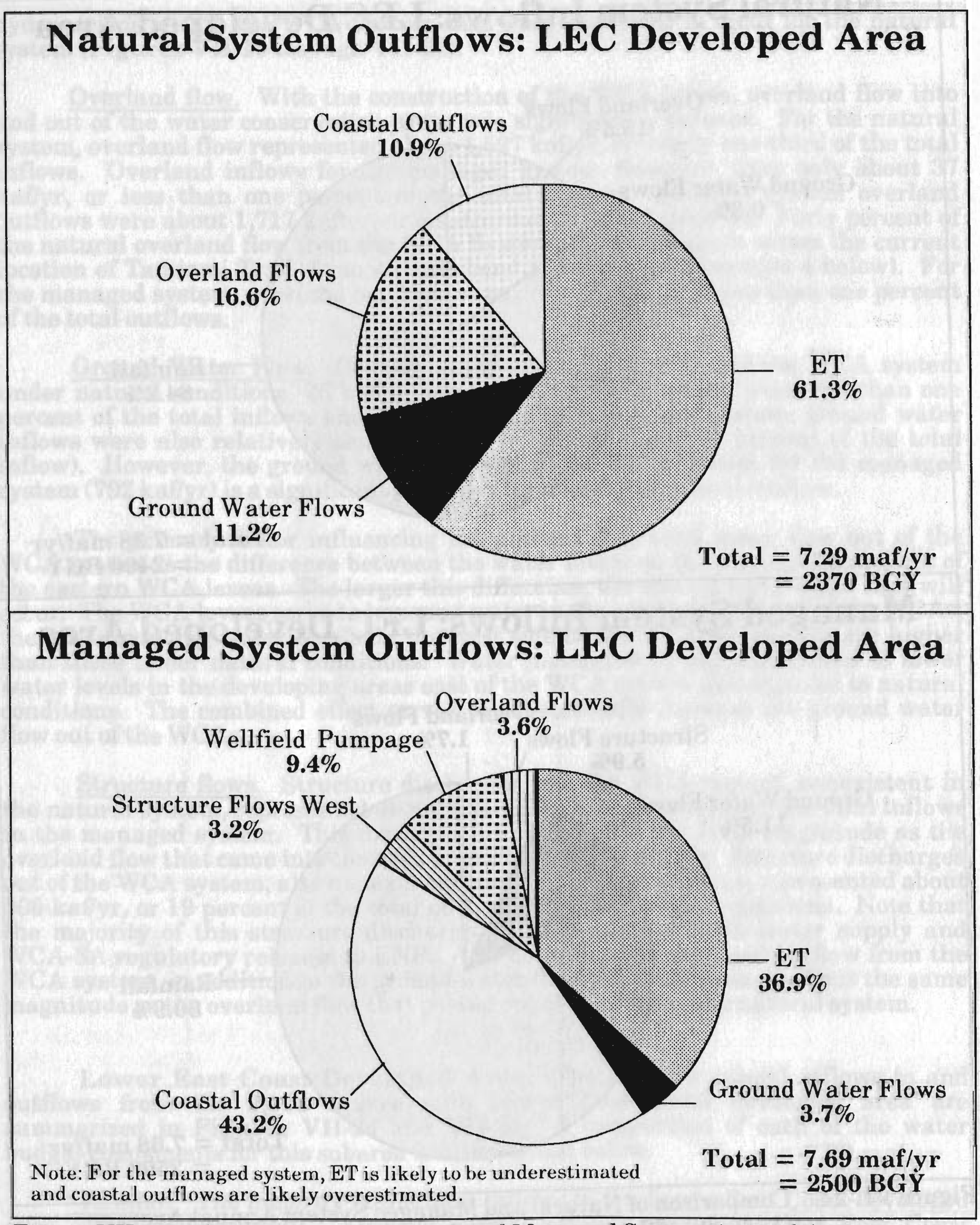

Figure VII-25. Comparison of Natural and Managed System Annual Average (1980-89) Outflows from the LEC Developed Area.

Evapotranspiration. The majority (60 percent) of the natural system total outflows from the Lower East Coast developed area was to ET (40 inches). ET from the area under managed conditions (25 inches), however, was only about 37 percent of the total outflows. ET from urban areas as currently estimated by the SFWMM includes ET from the water table aquifer and from surface ponding, but it may be lower than the actual ET from the LEC developed area since the unsaturated zone ET is not directly accounted for. Thus, a direct comparison of ET for the managed and natural systems can be misleading and should be done with this in mind. Currently, efforts are being made to improve ET estimate in this subarea.

Overland Flow. With the construction of the WCA levees, overland flow into and out of the Lower East Coast developed area was significantly reduced. For the natural system, overland inflows were about 1142 kaf/yr and represented 15 percent of the total inflows. Under managed conditions, overland inflows were about 134 kaf/yr, or only about two percent of the total inflows. Natural system overland outflows from the LEC developed area, primarily to the west across the current locations of L-30 and L-31N, and south to the panhandle portion of ENP south of C-111, were about 1208 kaf/yr, or 18 percent of the total outflows. Under managed conditions, however, overland outflows were only 279 kaf/yr, or about four percent of the total outflows.

Ground Water Flow. Construction of the WCA levees also served to increase the ground water inflows to the LEC developed area. Ground water flow into the Lower East Coast developed area in the natural system (23 kaf/yr) was less than one percent of the total inflows. Under managed conditions however, ground water inflows (877 kaf/yr) were relatively large (about 12 percent of the total inflow). Drainage activities in the LEC developed area served to decrease the ground water outflows from the area. For the natural system, the ground water outflow (818 kaf/yr) was about 11 percent of the total outflows. Conversely, for the managed system, ground water outflows were relatively small (283 kaf/yr, or about four percent of the total outflows) since the gradient at the coast was reduced.

Wellfield Pumpage. Withdrawals from ground water for public water supply, nonexistent in the natural system, represented about 723 kaf/yr, or 9 percent of the total outflows under managed conditions. Additional withdrawals from ground water, not quantified here, are made to satisfy agricultural and residential self-supplied demands. These nonpublic water supply withdrawals are currently accounted for in the SFWMM's ET estimate but more explicit estimates are being made.

Coastal Outflows / Structure Flows. Structure discharges into the Lower East Coast developed area, nonexistent in the natural system, represented about 455 kaf/yr, or 6 percent of the total inflows under managed conditions. These structure inflows are primarily for water supply purposes but include some regulatory (flood control) discharges. Coastal outflows under natural conditions occurred through several small natural channels through the coastal ridge. Flow through these channels to tide was estimated to be about 797 kaf/yr, or 11 percent of the total outflows in the natural system. Under managed conditions, the discharge at the coastal water control structures for drainage and flood control purposes were estimated to be about 3,323 kaf/yr, or 43 percent of the total outflows, a significant increase. Note that these coastal outflows are likely to be overestimated and efforts are underway to make better estimates. Although not all of these coastal outflows can be intercepted and used for water supply, some can be considered as a potential water supply source. About 205 kaf/yr, or 3 percent of the total outflow from the

Lower East Coast developed area was pumped into WCA-3A via S-9 and G-123. This backpumped water represents about 6 percent of the total structure outflows from the Lower East Coast developed area.

Eastern Everglades National Park. The average annual inflows to and outflows from the 800 square mile Eastern Everglades National Park (ENP) subarea are summarized in **Figures VII-26** and **VII-27**. A comparison of each of the water budget components for the subarea is summarized below.

Rainfall. The majority of the total inflows to the Eastern ENP subarea comes from rainfall. Average annual rainfall over the Eastern ENP subarea was about 50 inches. Rainfall represented about 64 percent of the total inflows for the natural system, but only about 72 percent for the managed system. The reason why rainfall is a more significant contribution to total inflow under managed conditions is due to the reduction in overland flow. This change in flow into the Eastern ENP area resulted from construction of L-29 and L-31N (see the overland flow discussion below). As shown in **Figure VII-26,** the resulting managed system total inflow to the Eastern ENP subarea was significantly lower than that of the natural system.

Evapotranspiration. The majority (59 percent) of the total outflows from the Eastern ENP subarea in the natural system was to ET (46 inches). ET from the area under managed conditions was four inches less (42 inches), or 62 percent of the total managed system outflows. As with the ET from the WCAs, the Eastern ENP subarea ET was higher for the natural system because of the broader spatial extent of surface water and longer hydroperiods that were estimated to occur (**Figures VII-10** through **VII-21**).

Overland Flow. For the natural system, overland flow represented about 34 percent (1140 kaf/yr) of the total inflows but only about three percent (94 kaf/yr) of the total inflow for the managed system. This significant reduction in overland flow into the Eastern ENP subarea was caused by the construction of L-29, L-31N and the drainage of eastern Dade County. Although the overland flow across the current location of L-29 was cutoff when it was constructed, water control structures were built to deliver water to Shark River Slough (please see discussions below on structure flows to ENP and on natural and managed flows to Shark River Slough).

Overland flow out of the Eastern ENP subarea, primarily through Shark River Slough at the Dade County - Collier County line was also significantly reduced from the natural system to the managed system. The natural system overland outflow was about 40 percent (1340 kaf/yr) of the total outflow; whereas the managed system overland outflow was only about 29 percent (850 kaf/yr) of the total. This reduction in overland outflows is likely a result of both the reduced overland inflows and the increased ground water outflows to the east (see discussion below).

Ground Water Flow. For the natural system ground water flow into the Eastern ENP subarea was about two percent (63 kaf/yr) of the total inflows as compared to four percent (123 kaf/yr) of the total inflows under managed conditions. The increase in ground water inflows under managed conditions is primarily from seepage under Tamiami Trail into Shark River Slough from WCAs 3A and 3B.

Ground water outflows from the Eastern ENP subarea increased significantly from the natural to managed systems. The natural system ground water outflow was about one percent (40 kaf/yr) of the total outflows; whereas the managed system

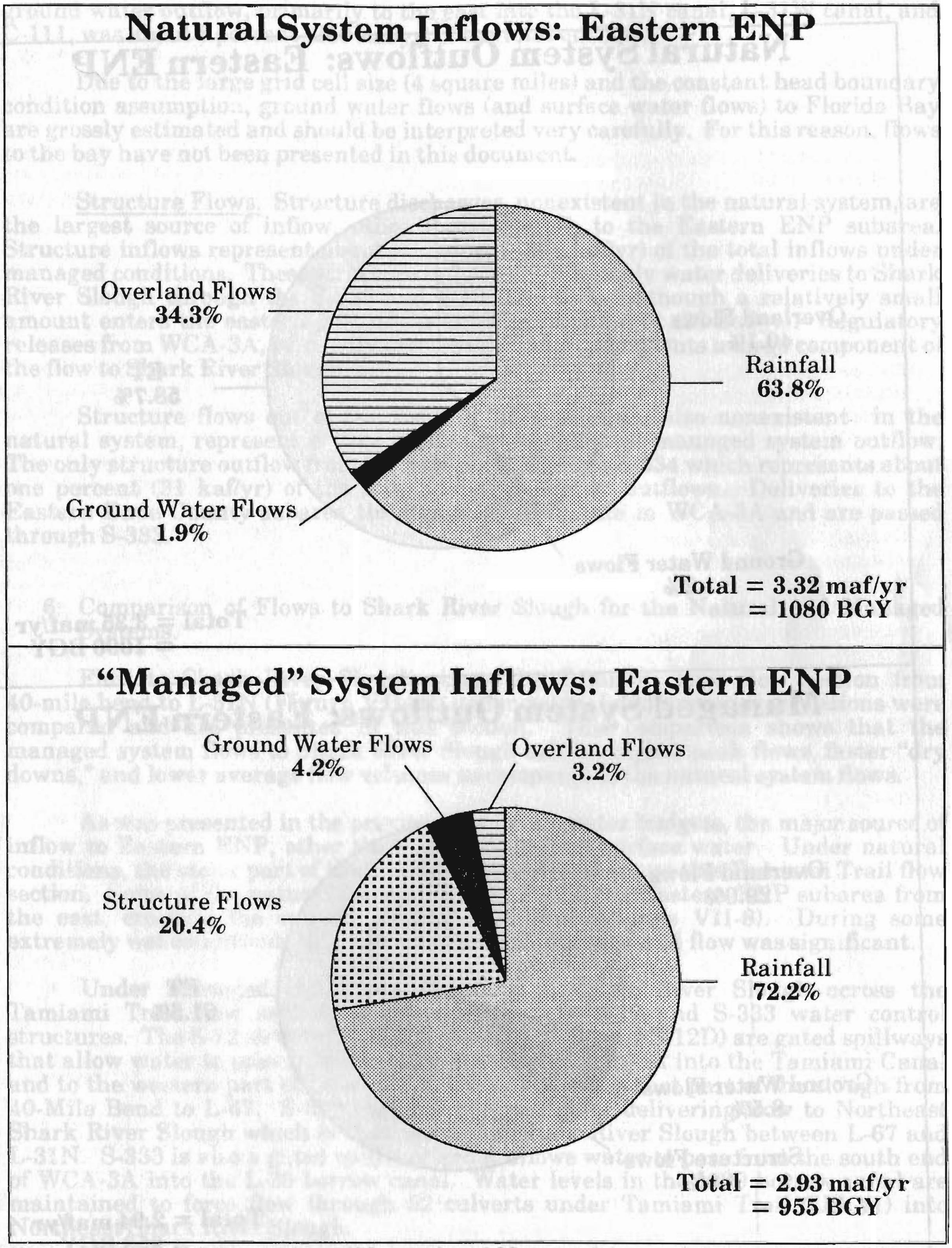

Figure VII-26. Comparison of Natural and Managed Annual Average (1980-89) Inflows for Eastern Everglades National Park.

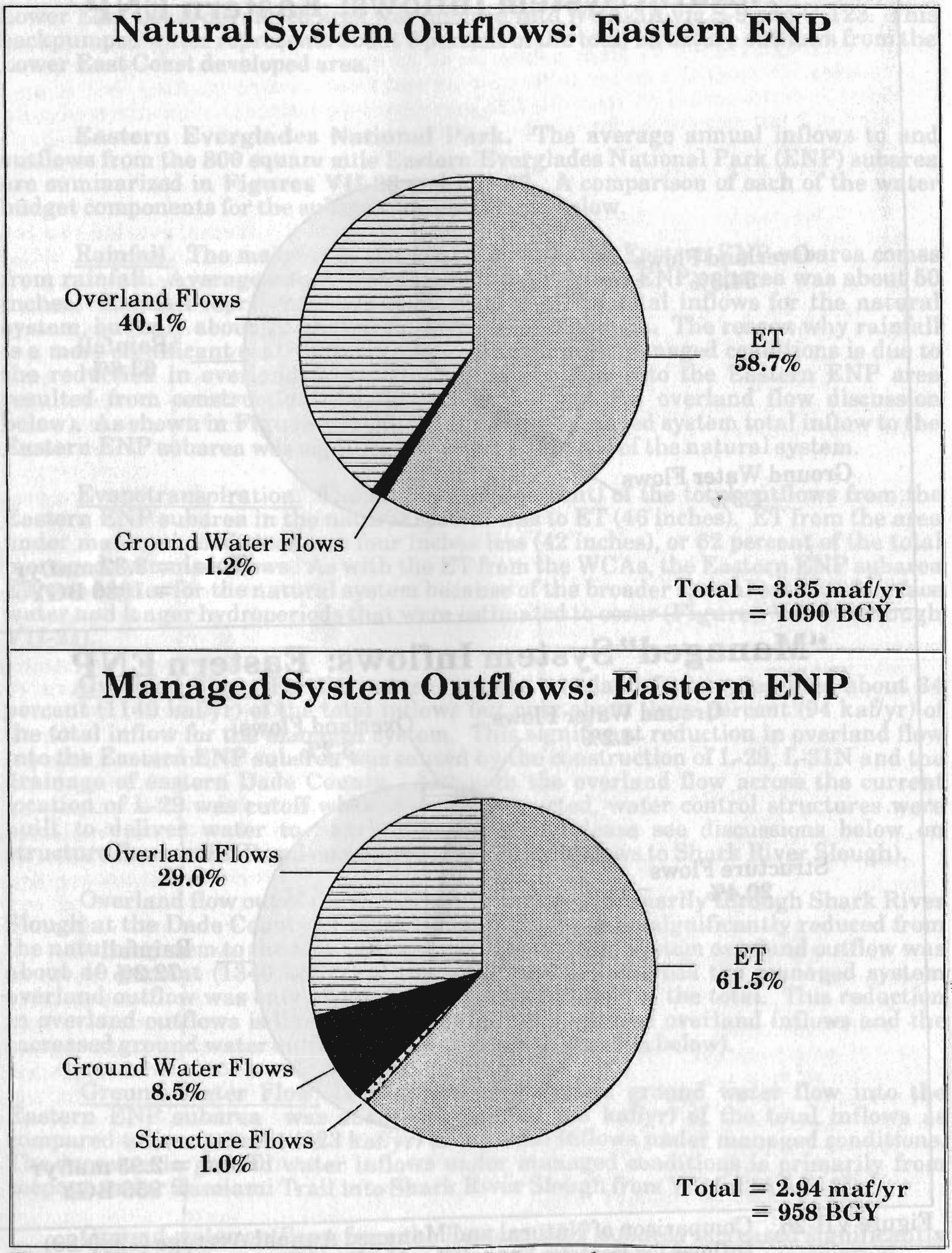

Figure VII-27. Comparison of Natural and Managed Annual Average (1980-89) Outflows for Eastern Everglades National Park.

ground water outflow, primarily to the east into the L-31N canal, L-31W canal, and C-111, was about 8 percent (250 kaf/yr) of the total outflow.

Due to the large grid cell size (4 square miles) and the constant head boundary condition assumption, ground water flows (and surface water flows) to Florida Bay are grossly estimated and should be interpreted very carefully. For this reason, flows to the bay have not been presented in this document.

Structure Flows. Structure discharges, nonexistent in the natural system, are the largest source of inflow, other than rainfall, to the Eastern ENP subarea. Structure inflows represent about 20 percent (598 kaf/yr) of the total inflows under managed conditions. These structure inflows are primarily water deliveries to Shark River Slough through the S-333 and S-12 structures, although a relatively small amount enters the eastern part of the subarea from S-174 (35 kaf/yr). Regulatory releases from WCA-3A, primarily through the S-12s, represents a large component of the flow to Shark River Slough.

Structure flows out of the Eastern ENP subarea, also nonexistent in the natural system, represent a very small part of the total managed system outflow. The only structure outflow from the subarea is through S-334 which represents about one percent (31 kaf/yr) of the total managed system outflows. Deliveries to the Eastern Dade County subarea through S-334 originate in WCA-3A and are passed through S-333.

6. Comparison of Flows to Shark River Slough for the Natural and Managed Systems.

Flow to Shark River Slough across the Tamiami Trail flow section from 40-mile bend to L-31N (**Figure VII-28**) under natural and managed conditions were compared and are presented in this section. This comparison shows that the managed system flows to Shark River Slough exhibit higher peak flows, faster "dry downs," and lower average flow volumes as compared to the natural system flows.

As was presented in the previous section on water budgets, the major source of inflow to Eastern ENP, other than rainfall, is from surface water. Under natural conditions, the major part of this surface water flowed across this Tamiami Trail flow section. Some of the natural surface inflow entered the Eastern ENP subarea from the east, crossing the current location of L-31N (**Figure VII-8**). During some extremely wet conditions, this portion of the natural overland flow was significant.

Under managed conditions, the flow to Shark River Slough across the Tamiami Trail flow section is delivered via the S-12 and S-333 water control structures. The S-12 structures (S-12A, S-12B, S-12C and S-12D) are gated spillways that allow water to pass from the southern end of WCA-3A into the Tamiami Canal and to the western part of Shark River Slough which is that part of the slough from 40-Mile Bend to L-67. S-333 provides the means for delivering flow to Northeast Shark River Slough which is that section of Shark River Slough between L-67 and L-31N. S-333 is also a gated spillway and it allows water to pass from the south end of WCA-3A into the L-29 borrow canal. Water levels in the L-29 borrow canal are maintained to force flow through 52 culverts under Tamiami Trail (US 41) into Northeast Shark River Slough.

With the construction of L-31N and the drainage of eastern Dade County, the natural surface flow from the east was eliminated. Thus, the only current source of surface inflow to Shark River Slough is from the S-333 and S-12 structures. ENP also receives flow from the South Dade Conveyance System to Taylor Slough via the S-332 pump station, and to the panhandle portion of the Park via the S-18C spillway and the gaps in the south spoil berm of C-111. However, these flows are relatively small as compared to the flows to Shark River Slough and will not be part of the comparison presented herein.

Figure VII-29 compares hydrographs of monthly flow to Shark River Slough across the Tamiami Trail flow section under natural and managed conditions for the ten-year period 1980 through 1989. The natural flow was estimated using the NSM and the managed flow was computed as the sum of the historical S-333 and S-12 discharge data. From **Figure VII-29**, note that the historical flows tend to have higher peaks than the natural flows. The higher peaks in the historical flow hydrograph are a direct consequence of the Central and Southern Florida Project and water management. Specifically, the levees that allow water to be impounded in WCA-3A, and the WCA-3A regulation schedule have created a situation where water is stored in the WCA until a maximum allowable stage is reached. When this maximum allowable stage is exceeded, flood control releases, also known as regulatory discharges, are made. These regulatory releases are made primarily through the S-12s, and through S-333 since 1985, to lower the WCA stage below the maximum allowable stage.

Also note from **Figure VII-29** that the natural hydrograph recessions are considerably longer than those of the historical delivery hydrograph. The longer natural recessions are a consequence of the tremendous amount of storage in the natural Everglades system; water slowly passed through the system, thereby providing a source of water to Shark River Slough well into the dry season months. A

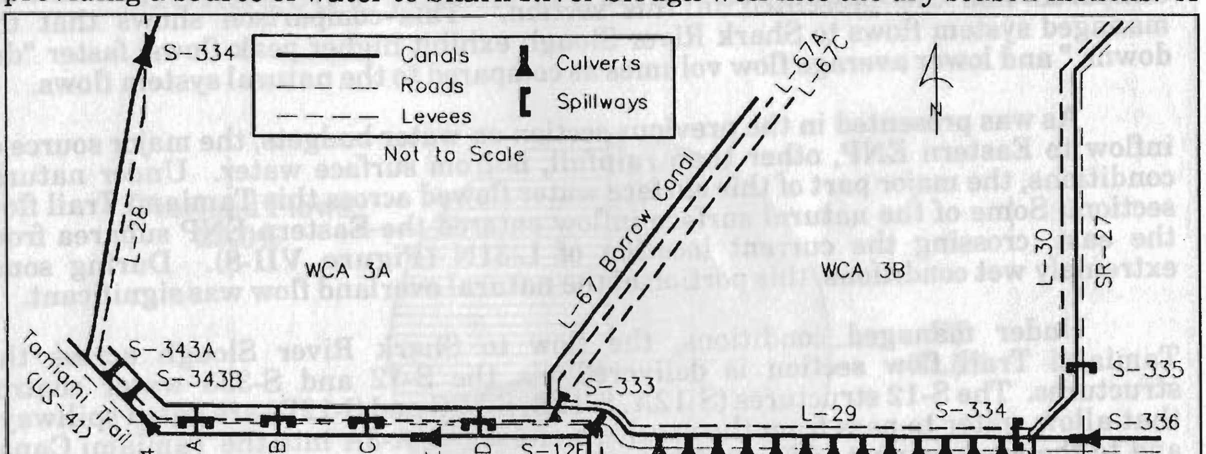

Figure VII-28. Major Features of Water Management System in General Area of Shark River Slough.

summary of the average monthly flows across the Tamiami Trail flow section under natural and managed conditions is shown in **Figure VII-30**. Note that the average wet season historical deliveries are higher than the natural flows, and that the average dry season historical deliveries are considerably lower than the natural flows. Also note that the historical average annual flows to Shark River Slough for the ten year period 1980 through 1989 (559 kaf) were 127 kaf lower than the average annual flows estimated by the NSM (686 kaf) for the same meteorologic conditions.

Finally, note from **Figure VII-29** that the hydrograph of the rain-driven component of the Rainfall Plan is shown for comparison with the NSM flow hydrograph. Testing of the Rainfall Plan began in July, 1985, and continues today (Neidrauer and Cooper, 1989). The Rainfall Plan provides flow to Shark River Slough via two flow components: (1) a rain-driven component that is computed from a statistical formula that relates natural flows across the Tamiami Trail flow section to rainfall and evaporation in WCA-3A (based on 1942-1953 data); and (2) a regulatory component that is based on the WCA-3A regulation schedule. The sum of these two components is computed weekly and delivered to Shark River Slough, subject to conveyance and flood control constraints.

This final comparison shows that the timing of the rain-driven component of the Rainfall Plan is similar to that of the NSM, but the magnitudes of the peak flows differ and the NSM recessions are longer. Also note that the NSM peak flow was considerably larger than that of the rain-driven component during the 1988 wet season; and the NSM recession extended well into the 1989 dry season as compared to the zero flow that was computed via the rainfall formula. As further enhancements

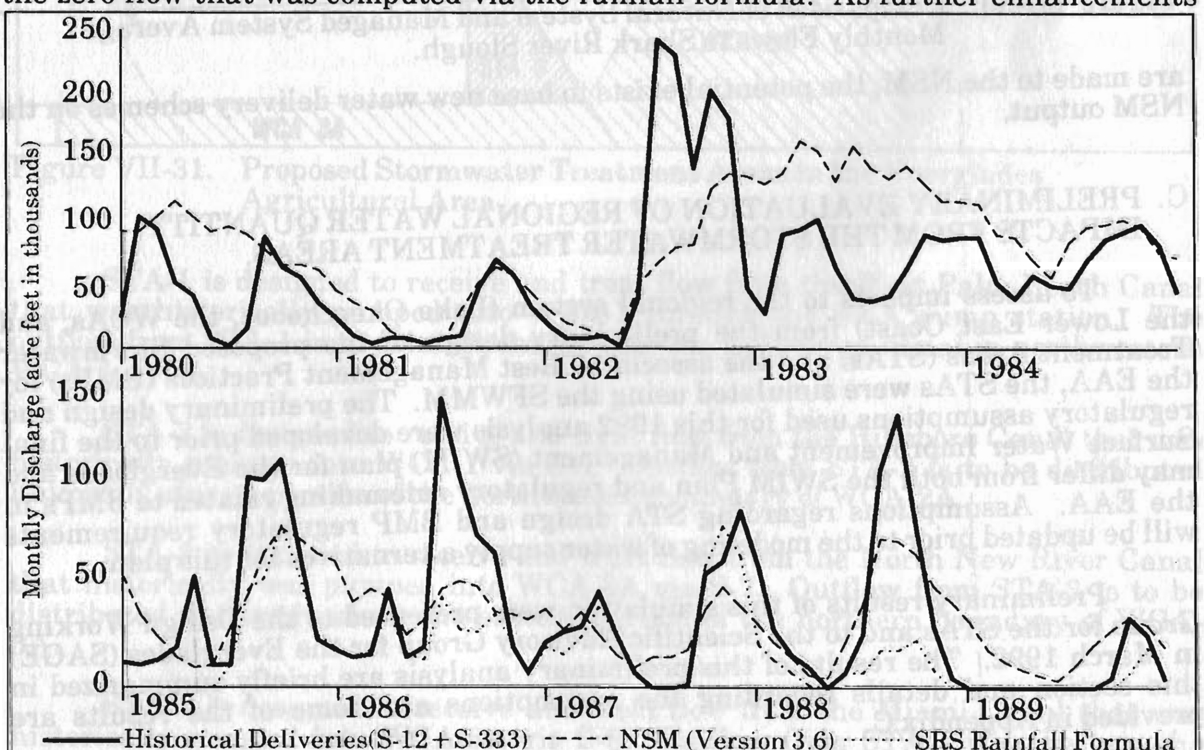

Figure VII-29. Comparison of Natural System and Managed System Monthly Flows Across the 20 Mile Tamiami Trail Section (40 Mile Bend to L-31N).

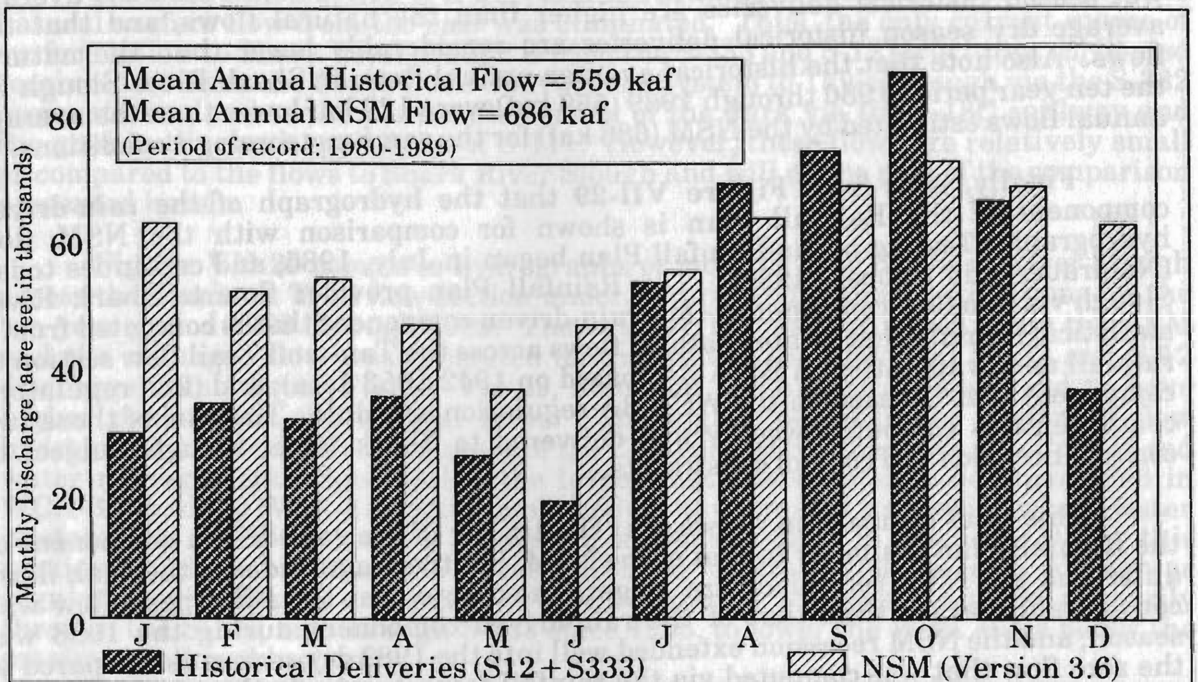

Figure VII-30. Comparison of Natural System and Managed System Average Monthly Flows to Shark River Slough.

are made to the NSM, the potential exists to base new water delivery schemes on the NSM output.

C. PRELIMINARY EVALUATION OF REGIONAL WATER QUANTITY IMPACTS FROM THE STORMWATER TREATMENT AREAS.

To assess impacts to the regional system (Lake Okeechobee, the WCAs, and the Lower East Coast) from the preliminary design of the proposed Stormwater Treatment Areas (STAs) and the associated Best Management Practices (BMPs) for the EAA, the STAs were simulated using the SFWMM. The preliminary design and regulatory assumptions used for this 1992 analysis were developed prior to the final Surface Water Improvement and Management (SWIM) plan for the Everglades and may differ from both the SWIM Plan and regulatory rulemaking related to BMPs in the EAA. Assumptions regarding STA design and BMP regulatory requirements will be updated prior to the modeling of water supply alternatives for this plan.

Preliminary results of this simulation were presented to the Design Working Group for the STAs and to the Scientific Advisory Group for the Everglades (SAGE) in March 1992. The results of this preliminary analysis are briefly summarized in this section and details regarding the assumptions and some of the results are provided in Appendix C.

1. Background

Four STAs are proposed to be constructed in the Everglades Agricultural Area (EAA) and serve to biologically filter phosphorous from EAA runoff before it enters the WCAs (**Figure VII-31**).

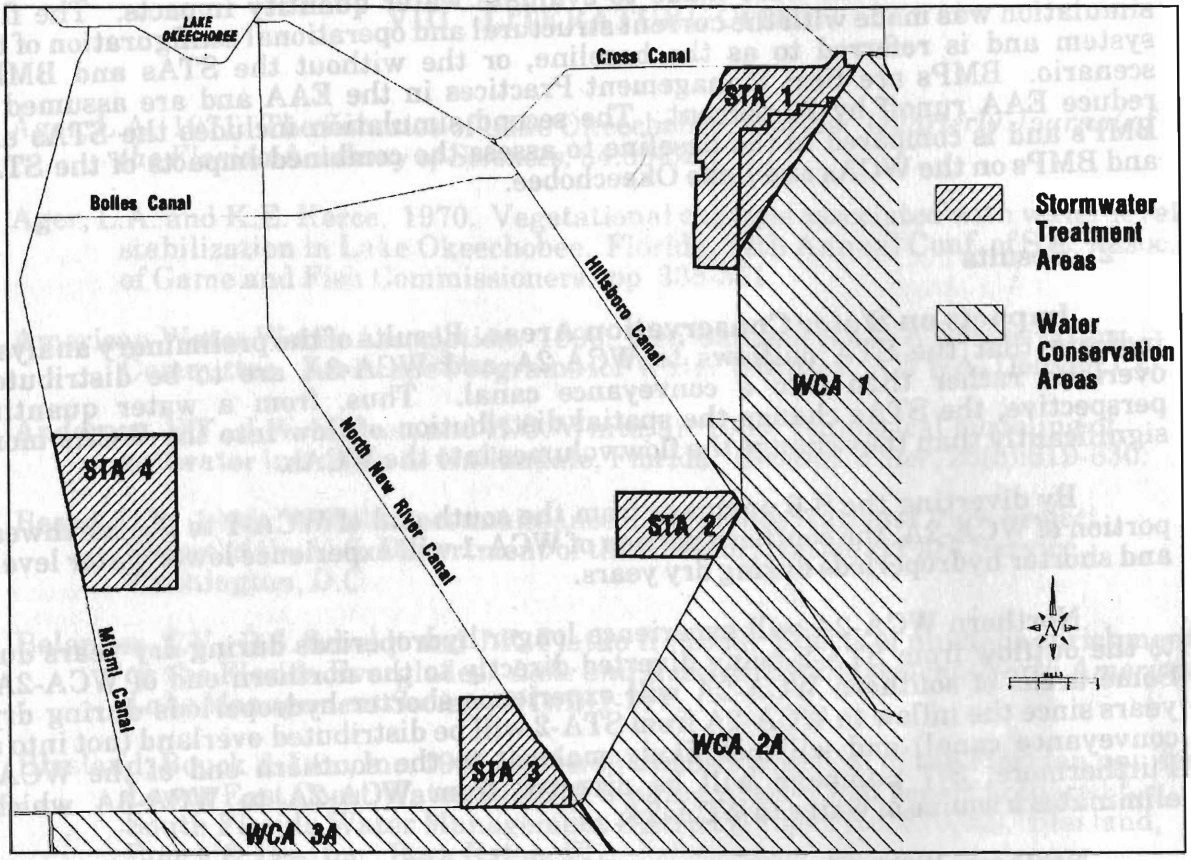

Figure VII-31. Proposed Stormwater Treatment Areas in the Everglades Agricultural Area.

STA-1 is designed to receive and treat flow from the West Palm Beach Canal that was historically pumped into WCA-1 through the S-5A pump station. The outflow from STA-1 is to point discharge into the L-7 borrow canal in northwestern WCA-1.

STA-2 is designed to receive and treat flow from the Hillsboro Canal that was historically pumped into WCA-1 via S-6. Outflow from STA-2 is to be distributed uniformly along a portion of the northwestern boundary of WCA-2A.

STA-3 is designed to receive and treat flow from the North New River Canal that historically was pumped into WCA-2A via S-7. Outflow from STA-3 is to be distributed uniformly along the eastern portion of the northern boundary of WCA-3A.

STA-4 is designed to receive and treat flow from the Miami Canal that was historically pumped into WCA-3A via S-8. Outflow from STA-4 is to be into the Miami Canal and then into the Holey land and/or distributed uniformly along the western portion of the northern boundary of WCA-3A.

Two simulations were made to evaluate water quantity impacts. The first simulation was made with the current structural and operational configuration of the system and is referred to as the baseline, or the without the STAs and BMPs, scenario. BMPs are Best Management Practices in the EAA and are assumed to reduce EAA runoff by 20 percent. The second simulation includes the STAs and BMPs and is compared to the baseline to assess the combined impacts of the STAs and BMPs on the WCAs and Lake Okeechobee.

2. Results

Impacts on Water Conservation Areas. Results of the preliminary analysis indicate that the STA outflows to WCA-2A and WCA-3A are to be distributed overland rather than into a conveyance canal. Thus, from a water quantity perspective, the STAs change the spatial distribution of flow into the WCAs more significantly than they change the flow volumes into the WCAs.

By diverting the S-6 pumpage from the south end of WCA-1 to the northwest portion of WCA-2A, the southern portion of WCA-1 will experience lower water levels and shorter hydroperiods during dry years.

Northern WCA-2A will experience longer hydroperiods during dry years due to the outflow from STA-2 being diverted directly to the northern end of WCA-2A. Some areas of southern WCA-2A will experience shorter hydroperiods during dry years since the inflow to WCA-2A from STA-2 will be distributed overland (not into a conveyance canal) and will not likely make it to the southern end of the WCA. Furthermore, S-7 pumpage will be diverted from WCA-2A to WCA-3A which eliminates a source of water to WCA-2A.

Northern WCA-3A will experience longer hydroperiods during both wet and dry years since the outflow from S-7 and S-8 will be diverted uniformly via STA-3 and STA-4, respectively, to the northern portion of WCA-3A. Slightly shorter hydroperiods and lower water levels will be experienced in the southern portion of WCA-3A during dry years. No differences should be experienced during wet years.

It must be reemphasized that the results of these simulations are preliminary and have not yet been evaluated from a biologic perspective to assess the significance of these hydroperiod changes.

Changes in Lake Okeechobee Flows and Levels. Results from the preliminary simulations indicate that no water supply deliveries are necessary from Lake Okeechobee to maintain the desired six inch depth of water in the STAs. Furthermore, projected water supply releases to the Lower East Coast are not significantly different from those under the scenario without STAs and BMPs.

Stages in Lake Okeechobee are, however, slightly lower with the STAs and BMPs in place. This is due to an assumed reduction of flood control backpumping to the lake. Since the BMPs are assumed to reduce EAA runoff by 20 percent, the frequency and magnitude of flood control backpumping is reduced, thereby resulting in less inflow to the lake from the EAA and slightly lower lake stages as compared to the without STAs and BMPs simulation. Further work is necessary to estimate the possible impacts that the BMPs may have on storage and runoff in the EAA.