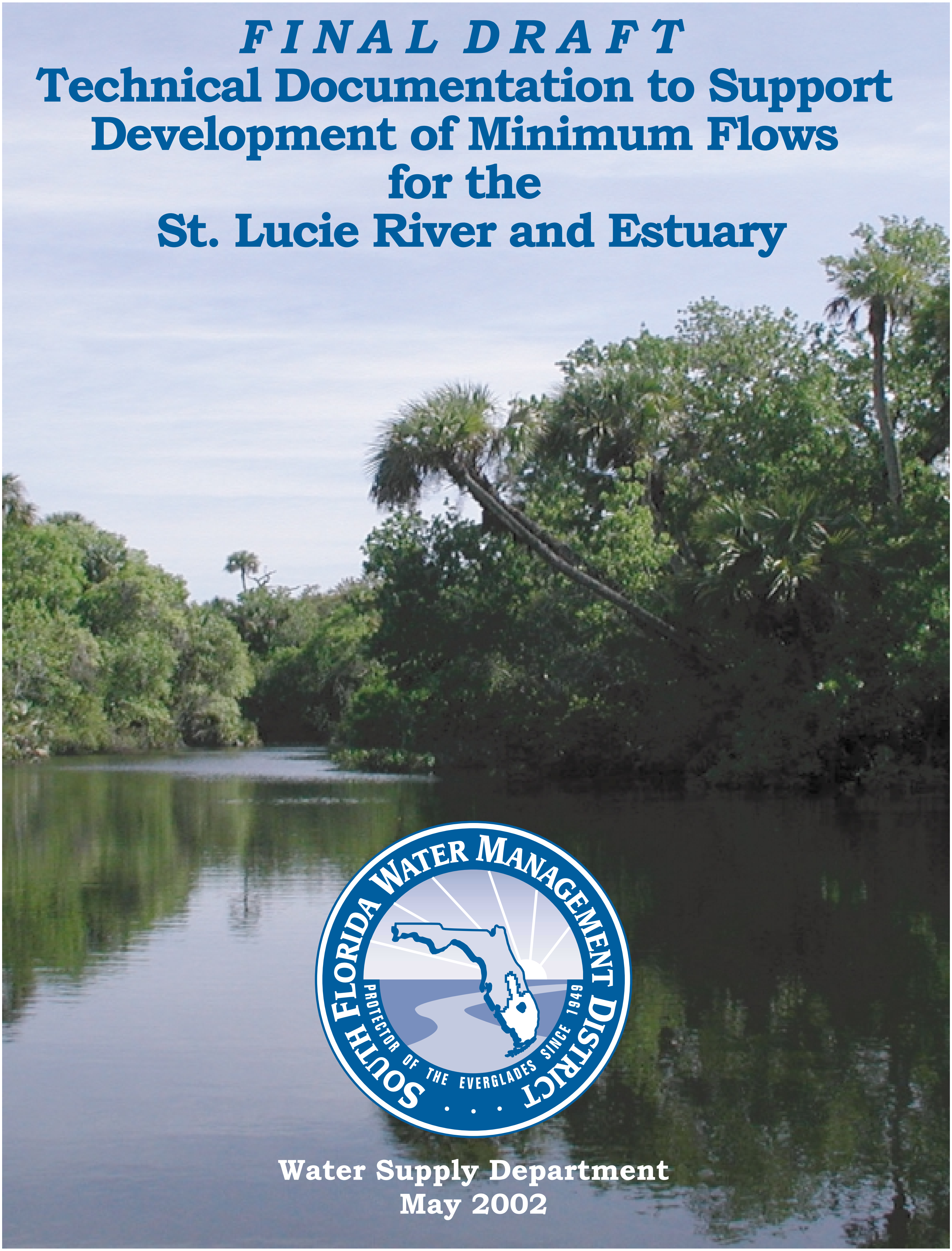
FINAL DRAFT

Technical Documentation to Support Development of Minimum Flows for the St. Lucie River and Estuary



Water Supply Department

May 2002

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Technical Documentation to Support Development of Minimum Flows for the St. Lucie River and Estuary

prepared by the

Water Supply Department
South Florida Water Management District

May 2002

EXECUTIVE SUMMARY

Florida law requires the water management districts to develop a priority list and schedule for the establishment of minimum flows and levels for surface waters and aquifers within their jurisdiction (Section 373.042(1), Florida Statutes). This list, included in the *District Water Management Plan* for the South Florida Water Management District (SFWMD, 2000a), requires that minimum flows and levels for the St. Lucie River and Estuary be established by 2001. A request for extension of this deadline to December 2002 has been approved.

Establishing *minimum* flows and levels alone will not be sufficient to maintain a sustainable resource during the broad range of water conditions occurring in the managed system. For the St. Lucie River and Estuary, extended periods of large volume freshwater flows also impact the resource. Setting a minimum flow is viewed as a starting point to define minimum water needs for protection against significant harm. While this report documents the full range of water resource issues associated with the St. Lucie River and Estuary watershed, technical criteria development focuses on minimum flows.

The minimum flow is defined as the "...limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area." For purposes of establishing minimum flows, significant harm is defined as a loss of water resource functions that takes more than two years to recover. Water resource functions protected under Chapter 373 include flood control, water quality, water supply and storage, fish and wildlife, navigation, and recreation. Water management districts must also consider any changes and structural alterations that have occurred, and develop a recovery and prevention strategy for water bodies that do not or are not expected to meet the proposed criteria during the planning horizon.

This report documents the methods and technical criteria used by staff of the South Florida Water Management District to develop minimum flows and levels for the St. Lucie River and Estuary. The St. Lucie River and Estuary watershed is located on the southeastern coast of Florida in Martin and St. Lucie Counties. It includes the North and South Forks of the St. Lucie River, several major drainage and irrigation canals, the surrounding watershed, and the estuary. This system is of particular importance because it lies at the confluence of two major transportation waterways. It is located adjacent to the Indian River Lagoon (part of the National Estuary Program), and provides an outlet for discharge of excess water from Lake Okeechobee.

Prior to development, most of the region was characterized by nearly level, poorly drained lands subject to frequent flooding. The current managed system includes numerous water control facilities that have been constructed to make this region suitable for agricultural, industrial, and residential use. Structural changes that were considered during criteria development included construction of major drainage canals; connection to Lake Okeechobee, withdrawals of water to provide agricultural irrigation; dredging, filling, and bulk heading the estuary; and improvements to the St. Lucie Inlet. Effects of such changes on regional hydrology and estuary hydrodynamics are documented. Over a century of water control has led to changes to the quality, quantity, timing, and distribution of flows to the estuary resulting in ecological changes to the system.

Pursuant to the requirements contained within Chapter 373 of the Florida Water Resources Act, water resource functions are identified and technical relationships of these functions to water flows and levels are described based on the best available information. This information includes results of a literature review; analysis and synthesis of present and historical flow data; incorporation of data, results, and conclusions from previous and ongoing investigations; and the development and application of mathematical models and empirical flow/salinity relationships.

Proposed minimum flow criteria for the St. Lucie River and Estuary are linked to the concept of protecting valued ecosystem components from significant harm. The specific valued ecosystem components identified for the St. Lucie River and Estuary are the assemblage of organisms inhabiting the low salinity, oligohaline zone.

The proposed minimum flows and levels criteria for the St. Lucie River and Estuary were based on the determination that significant harm occurs to the oligohaline zone when net freshwater flows (sum of surface and ground water inflows minus evaporation) to the estuary are at or below zero for a period of two consecutive months for two or more years in succession. Modeling results indicate that flows at or below 21 cubic feet per second in the North Fork of the St. Lucie River, in combination with mean monthly flows at or below 7 cubic feet per second (cfs) in the South Fork of the St. Lucie River, may result in significant harm to the St. Lucie Estuary.

Understanding the importance of maintaining the north-south flow distribution pattern, but acknowledging the fact that we neither currently monitor the South Fork nor have any conveyance options to supplement South Fork flows, the following minimum flow criteria for the St. Lucie River and Estuary are proposed:

> *Mean monthly flows to the St. Lucie Estuary of more than 28 cubic feet per second from the North Fork of the St. Lucie River represent the amount of water necessary to maintain sufficient salinities in the St. Lucie Estuary in order to protect the oligohaline organisms that are valued ecosystem components of this system. If flows fall below this minimum for two consecutive months, the minimum flow criteria will be exceeded and harm occurs to estuarine resources. If harm, as defined above, occurs during two consecutive years, significant harm and a violation of the minimum flows and levels criteria occur.*

Although the river and estuary presently receive an adequate supply of fresh water, and are expected to continue to do so as the Comprehensive Everglades Restoration Plan is implemented, a prevention strategy may be required to protect this resource. The ability to better manage water in the watershed may also make it possible to capture and retain water from the watershed for allocation to other (e.g., urban and agricultural water supply) users.

Prevention strategy components include management objectives for the North and South Forks that are based on protecting the system from significant harm. Also included in the prevention strategy is the recommendation for an adaptive assessment approach to research and monitoring of the watershed in order to fill data gaps in our knowledge of the hydrodynamics and ecology of the St. Lucie River and Estuary. The proposed criteria will be refined and incorporated into the next update of the Upper East Coast Water Supply Plan as new information is assimilated into the minimum flows and levels development process.

This document has been peer reviewed by an independent scientific peer review panel. Their report, in addition to the South Florida Water Management District staff response, is included in **Appendix I**. Also included in the appendices are technical reports to support criteria development.

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ACKNOWLEDGEMENTS

This document is the result of a cooperative effort between the Water Supply and Watershed Management Departments of the South Florida Water Management District. The managers supporting this effort at the time of publication are as follows:

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ACRONYMS AND ABBREVIATIONS

^{o}F	degrees Fahrenheit
AFSIRS	Agricultural Field-Scale Irrigation Requirements Simulation
BMP	best management practice
C&SF Project	Central and Southern Florida Project
CERP	Comprehensive Everglades Restoration Plan
CITES	Convention on International Trade in Endangered Species
cfs	cubic feet per second
cm	centimeters
District	South Florida Water Management District
DO	dissolved oxygen
DOC	dissolved organic carbon
DWSA	deep water storage area
F.A.C.	Florida Administrative Code
FDACS	Florida Department of Agriculture and Consumer Services
FDEP	Florida Department of Environmental Protection
FEQ	Full Equations Model
FORTRAN	Formula Translation Model
F.S.	Florida Statutes
FWC	Florida Fish and Wildlife Conservation Commission
GIS	geographic information system
GPD	gallons per day
HSPF	Hydrologic Simulation Program - FORTRAN
MFLs	minimum flows and levels
mg/l	milligrams per liter
MGY	million gallons per year
NGVD	National Geodetic Vertical Datum
NOAA	National Ocean and Atmospheric Administration
NRCS	Natural Resources Conservation Service
NSM	Natural Systems Model

PLRG	pollution load reduction goal
POC	particulate organic carbon
ppt	parts per thousand
RECOVER	restoration coordination and verification
Restudy	Central and Southern Florida Project Comprehensive Review Study
SFWMD	South Florida Water Management District
SWIM	Surface Water Improvement and Management
TMDL	total maximum daily load
topo quad map	topographical quadrant map
USACE	United States Army Corps of Engineers
FDA	Food and Drug Administration
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VEC	valued ecosystem component
WSE	Water Supply and Environmental

Chapter 1
INTRODUCTION

BACKGROUND

This report documents the methods and technical criteria used by staff of the South Florida Water Management District (SFWMD or District) to develop minimum flows and levels (MFLs) for the St. Lucie River and Estuary. These MFLs are being developed pursuant to the requirements contained within the Florida Water Resources Act, Sections 373.042 and 373.0421, Florida Statutes (F.S.), as part of comprehensive water resources management actions that are being taken to assure the sustainability of the water resources.

The *District Water Management Plan* for the SFWMD (SFWMD, 2000a) includes a schedule for establishing MFLs for priority water bodies within the District. This list requires that MFLs for the St. Lucie River and Estuary be established by 2001. A request for extension of this deadline to December 2002 has been approved.

The proposed MFLs are not a "stand alone" resource protection tool. They should be considered in conjunction with all other resource protection responsibility granted to the water management districts by law. This includes consumptive use permitting, water shortage management, and water reservations. A model framework identifying the relationships among these tools is discussed in this document and was used in developing the MFLs. In addition, the District has completed regional water supply plans, pursuant to Chapter 373.0361, F.S., that also include recommendations for establishment of minimum flows and recovery and prevention strategies (SFWMD 2000b, 2000c, and 2000d).

Establishing *minimum* flows and levels alone will not be sufficient to maintain a sustainable resource during the broad range of water conditions occurring in the managed system. For the St. Lucie River and Estuary, extended periods of large-volume freshwater flows also impact the resource. Setting a minimum flow is viewed as a starting point to define minimum water needs for protection against significant harm. The necessary hydrologic regime for restoration of the St. Lucie River and Estuary ecosystem will also be defined and implemented through the use of other water resource protection tools. Achieving the required water levels throughout this system is an overall, long-term restoration goal (USACE and SFWMD, 1999). *Maximum* flows for the St. Lucie River and Estuary are controlled in part by regulation schedules for Lake Okeechobee and the amounts of water discharged from the following structures: S-80 in the C-44 Canal, S-48 in the C-23 Canal, and S-49 in the C-24 Canal.

As a first formal step to establish MFLs for the St. Lucie River and Estuary, this report includes the following:

- Description of the framework for determining MFLs based on best available information (this approach may be applied to other surface and ground waters within the District)
- Development of a technical methodology and basis for establishing MFLs for the St. Lucie River and Estuary
- Results of an independent scientific peer review conducted pursuant to Section 373.042, F.S.

Rule development workshops will be held to discuss the concepts proposed and specific rule language. Persons who wish to receive notice of these workshops, as well as any public meetings should notify the District.

PROCESS AND BASIS FOR ESTABLISHMENT OF MINIMUM FLOWS AND LEVELS

Process Steps and Activities

The process for establishing minimum flows for the St. Lucie River and Estuary can be summarized as follows:

1. Through the development of the *Upper East Coast Regional Water Supply Plan* (SFWMD, 1998a), the Indian River Lagoon Feasibility Study (USACE and SFWMD, 2001) and concurrent staff research and analysis, a methodology and technical basis for establishment of the MFLs was developed.
2. An initial draft of the MFL technical criteria document was completed in April 2001.
3. A technical workshop was conducted to review the initial draft and the draft was revised to incorporate comments received from the public and various agencies. A revised draft was released in May 2001.
4. A scientific peer review of the technical documents was conducted during the summer of 2001 to verify the criteria pursuant to Section 373.0421, F.S.
5. Revisions to the MFL report recommended by the panel, as appropriate, were incorporated into the criteria, resulting in this draft.
6. Further public consideration of the technical basis and methodology for establishing the MFLs and review of the first draft of the rule will be conducted during rule development workshops.
7. A final rule draft will be presented to the Governing Board for establishment in 2002.

LEGAL AND POLICY BASIS FOR ESTABLISHMENT OF MINIMUM FLOWS AND LEVELS

Florida law requires the water management districts to establish MFLs for surface waters and aquifers within their jurisdiction (Section 373.042(1), F.S.). The minimum flow is defined as the "...limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area." The minimum level is defined as the "limit at which further withdrawals would be significantly harmful to the water resources of the area." The statute further directs water management districts to use the best available information in establishing MFLs. Each water management district must also consider, and at its discretion may provide for, the protection of nonconsumptive uses in the establishment of MFLs (Section 373.042, F.S.). In addition, a baseline condition for the protected resource functions must be identified through consideration of changes and structural alterations in the hydrologic system (Section 373.042(1), F.S).

The following sections outline the legal and policy factors relevant to establishing MFLs under the MFL law. In summary, the following questions are answered:

- What are the priority functions of each water resource and what is the baseline condition for the functions being protected?
- What level of protection for these functions is provided by the MFL standard of protection - significant harm?

Identify Relevant Water Resource Functions

Each surface water body or aquifer serves an array of water resource functions. These functions must be considered when establishing MFLs as a basis for defining significant harm.

The term "water resource" is used throughout Chapter 373. Water resource functions protected under Chapter 373 are broad, as illustrated in Section 373.016, F.S. These functions include flood control, water quality protection, water supply and storage, fish and wildlife protection, navigation, and recreation.

The State Water Resource Implementation Rule, Chapter 62-40.405, Florida Administrative Code (F.A.C.), outlines specific factors to consider, including protection of water resources, natural seasonal changes in water flows or levels, environmental values associated with aquatic and wetland ecology, and water levels in aquifer systems. Other specific considerations include the following:

- Fish and wildlife habitat and the passage of fish
- Maintenance of freshwater storage and supply
- Water quality
- Estuarine resources
- Transfer of detrital material

- Filtration and absorption of nutrients and pollutants
- Sediment loads
- Recreation in and on the water
- Navigation
- Aesthetic and scenic attributes

This policy determination as to which resource functions to consider in establishing MFLs is within the SFWMD Governing Board's purview. This analysis requires a comprehensive look at sustainability of the resource itself as well as its role in sustaining overall regional water resources. **Chapter 3** of the MFL document provides a detailed description of the relevant water resource functions of the St. Lucie River and Estuary.

Identify Considerations and Exclusions: Baseline Conditions to Protect Water Resource Functions

Once the water resource functions to be protected by a specific minimum flow or level have been identified, the baseline resource conditions for assessing significant harm must be identified. Considerations for making this determination are set forth in Section 373.0421(1)(a), F.S., which requires the water management districts, when setting a minimum flow or level, to consider changes and structural alterations that have occurred to a water resource. Likewise, Section 373.0421(1)(b), F.S., recognizes that certain water bodies no longer serve their historical function and that recovery of these water bodies to historical conditions may not be feasible. These provisions are discussed in **Chapter 3** and their applicability to the minimum levels that are proposed for the St. Lucie River and Estuary are examined.

Level of Protection for Water Resource Functions Provided by the MFL Standard of Significant Harm

The overall purpose of Chapter 373 is to ensure the sustainability of water resources of the state (Section 373.016, F.S.). To carry out this responsibility, Chapter 373 provides the District with several tools with varying levels of resource protection standards. MFLs are one part in this framework. Determination of the role of MFLs and the protection that they offer, versus the roles played by other water resource tools available to the District, is discussed below.

The scope and context of MFLs protection rests with the definition of significant harm. The following discussion provides some context to the MFLs statute, including the significant harm standard, in relation to other water resource protection statutes.

Sustainability is the umbrella of water resource protection standards (Section 373.016, F.S.). Each water resource protection standard must fit into a statutory niche to achieve this overall goal. Pursuant to Parts II and IV of Chapter 373, surface water management and consumptive use permitting regulatory programs must prevent **harm** to the water resource. Water shortage statutes dictate that permitted water supplies must be restricted from use to prevent **serious harm** to the water resources. Other resource protection tools include reservation of water for fish and wildlife, or health and safety (Section 373.223(3), F.S.), and aquifer zoning to prevent undesirable uses of the ground water (Section 373.036(4)–(5), F.S.). By contrast, MFLs are set at the point at which **significant harm** to the water resources or ecology would occur. The levels of harm cited above - harm, significant harm, and serious harm - are relative resource protection terms. Each plays a role in the ultimate goal of achieving a sustainable water resource.

The conceptual relationships among the terms harm, significant harm, and serious harm proposed by the District are shown in **Figure 1**. The general narrative definition of significant harm proposed by the District (SFWMD, 2000e) for the water resources of an area is as follows:

***Significant harm** is defined as a loss of specific water resource functions resulting from a change in surface water or ground water hydrology that take two or more years to recover.*

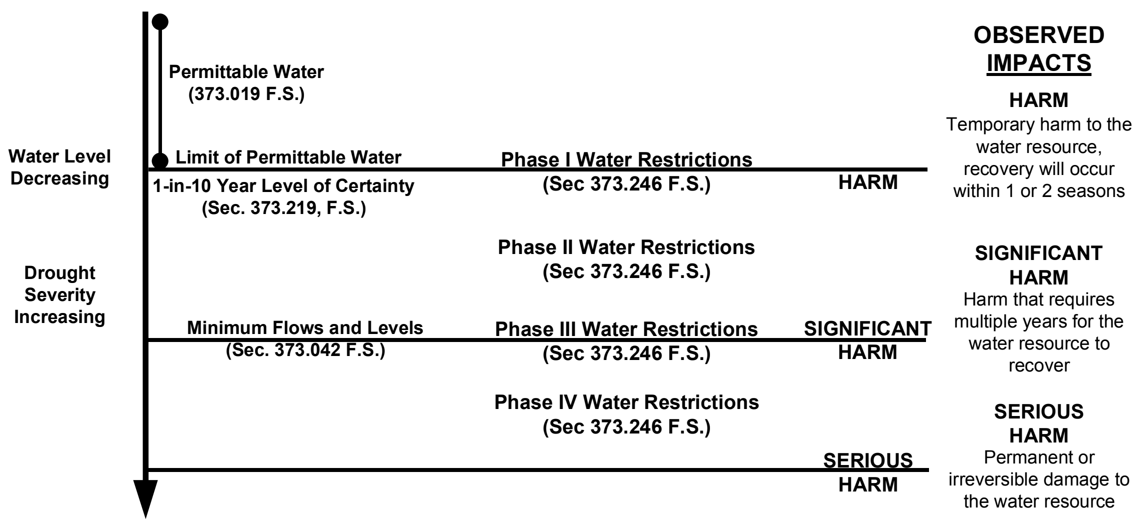


Figure 1. Conceptual Relationships among the Terms *Harm*, *Significant Harm*, and *Serious Harm*

OTHER LEVELS OF HARM CONSIDERED IN FLORIDA STATUTES

A discussion of the other levels of harm identified in the conceptual model for consumptive use permitting and water shortage is provided below to give context to the proposed significant harm standard.

Consumptive Use Permitting Role - No Harm Standard

The resource protection criteria used for consumptive use permitting are based on the level of impact that is considered harmful to the water resource. These criteria are applied to various resource functions to establish the range of hydrologic change that can occur with no harm to the water resources. The hydrological criteria include level, duration, and frequency components and are used to define the amount of water that can be allocated from the resource. Saltwater intrusion, wetland drawdown, aquifer mining, and pollution prevention criteria in Chapter 40E-2, F.A.C., define the **no harm** standard for purposes of consumptive use allocation. These **no harm** criteria are applied using climate conditions that represent an assumed level of certainty. The level of certainty used in the *Upper East Coast Water Supply Plan* (SFWMD, 1998a), *Lower East Coast Regional Water Supply Plan* (SFWMD, 2000b), and the *Lower West Coast Water Supply Plan* (SFWMD, 2000c) is a 1-in-10 year drought frequency, as defined in the District's permitting rules. The 1-in-10 year level of certainty is also the water supply planning goal that was established in Section 373.0361, F.S.

Water Shortage Role - Serious Harm Standard

Pursuant to Section 373.246, F.S., water shortage declarations are designed to prevent serious harm from occurring to water resources. Serious harm, the ultimate harm to the water resources contemplated under Chapter 373, F.S., can be interpreted as long-term, irreversible, or permanent impacts. Declaration of water shortages is the tool used by the Governing Board to prevent serious harm. These impacts associated with serious harm occur at drought events that are more severe than the 1-in-10 level of certainty used in the consumptive use permitting criteria.

When drought conditions exist, water users, typically for irrigation or outside use, increase withdrawals to supplement water not provided by rainfall. In general, the more severe the drought, the more supplemental water is needed. These increased withdrawals increase the potential for harm to the water resource.

The District has implemented its water shortage authority by restricting consumptive uses based on the concept of equitable distribution between users and the water resources (Chapter 40E-21, F.A.C.). Under this program, different levels or phases of water shortage restrictions are imposed relative to the severity of drought conditions. The four phases of the current water shortage restrictions are based on relative levels of risk posed to resource conditions leading up to serious harm impacts. Under the District's program, Phase I and II water shortages are primarily designed to prevent harm, such as localized, but recoverable, damage to wetlands or short-term inability to maintain water levels needed for restoration. Actions that may be taken include reducing water use through conservation techniques and minor use restrictions, such as car washing and lawn watering. Phases III and IV, however, require use cutbacks that are associated with some level of economic impact to the users, such as agricultural irrigation restrictions.

MFL RECOVERY AND PREVENTION STRATEGY

MFLs are implemented through a multifaceted recovery and prevention strategy, developed pursuant to Section 373.0421(2), F.S. If it is determined that water flows or levels are currently being met, but will fall below an established MFL within the next 20 years, then a prevention strategy must be developed. If water flows or levels are presently below the MFL, the water management district must develop and implement a recovery or prevention strategy. The twenty-year period should coincide with the regional water supply planning horizon for the subject area and the strategy is to be developed in concert with that planning process. A prevention strategy is recommended for the St. Lucie River and Estuary.

The general goal of a recovery and prevention strategy is to continue to provide sufficient water supplies for all existing and projected reasonable-beneficial demands, while taking actions to achieve the MFL criteria. If the existing flow or level is below the MFL, recovery to the MFL must be achieved "as soon as practicable." Many different factors will influence the water management district's capability to implement the proposed actions in a timely manner, including funding availability, detail design development, permittability of regulated actions, land acquisition, and implementation of updated permitting rules.

From a regulatory standpoint, depending on the existing and projected flows or levels, changes to either water shortage triggers, interim consumptive use permit criteria, or both, may be recommended in the recovery and prevention strategy. The approach varies depending on whether the MFL is currently exceeded or not and what is causing it to be exceeded. Causes could include consumptive use withdrawals, poor surface water conveyance facilities or operations, overdrainage, or a combination of these.

Incremental measures to achieve the MFLs must be included in the recovery and prevention strategy, as well as a timetable for the provision of water supplies necessary to meet reasonable-beneficial uses. Such measures include development of additional water supplies and conservation and other efficiency measures. These measures must make water available "concurrent with, to the extent practical, and to offset, reductions in permitted withdrawals, consistent with …[Chapter 373]." The determination of what is "practical" in identifying measures to concurrently replace water supplies will likely be made through the consideration of both the economic and the technical feasibility of potential options. Additional information about the prevention strategy recommended for the St. Lucie River and Estuary is provided in **Chapter 6**.

DOCUMENT STRUCTURE

Chapter 2 describes the geographic setting, the resources at risk, and the major issues concerning the use and conservation of resources within the St. Lucie River and Estuary. **Chapter 3** documents the resource functions and considerations for technical criteria development. **Chapter 4** presents the methods that were used to establish significant harm criteria and describes the specific hydrologic criteria that were developed to indicate the point at which significant harm occurs. **Chapter 5** includes an analysis of the specific relevant factors and implications of the proposed definition of significant harm. Conclusions and recommendations are presented in **Chapter 6**. The **References** and the glossary follow **Chapter 6**. Technical **Appendices A** through **L** are provided in a separate volume and include more detailed descriptions and analyses of available data, literature, and issues raised during the review process.

Chapter 2
DESCRIPTION OF THE WATER BODY

INTRODUCTION

The St. Lucie River and Estuary and its watershed are located on the southeastern coast of Florida in Martin and St. Lucie counties. The St. Lucie River and Estuary watershed encompasses about 781 square miles and is divided into five major basins and several small basins (**Figure 2**). The western basins are predominantly agricultural with about 70 percent of land in citrus and improved pasture. The two eastern basins (North St. Lucie and Tidal) are more urban with about 45 percent of the land devoted to agricultural activities. The St. Lucie Canal (C-44) is an important component of the Central and Southern Florida (C&SF) Project and is used, along with the Caloosahatchee River (C-43), primarily for water releases from Lake Okeechobee when lake levels exceed United States Army Corps of Engineers (USACE) regulation schedules (USACE, 2000). In addition to regulatory discharges for flood protection, the river and estuary also receive water deliveries from the lake to maintain water levels for navigation and water supply. The C-44 basin is particularly dependent on the lake for supplemental water supply and aquifer recharge (SFWMD, 1998a).

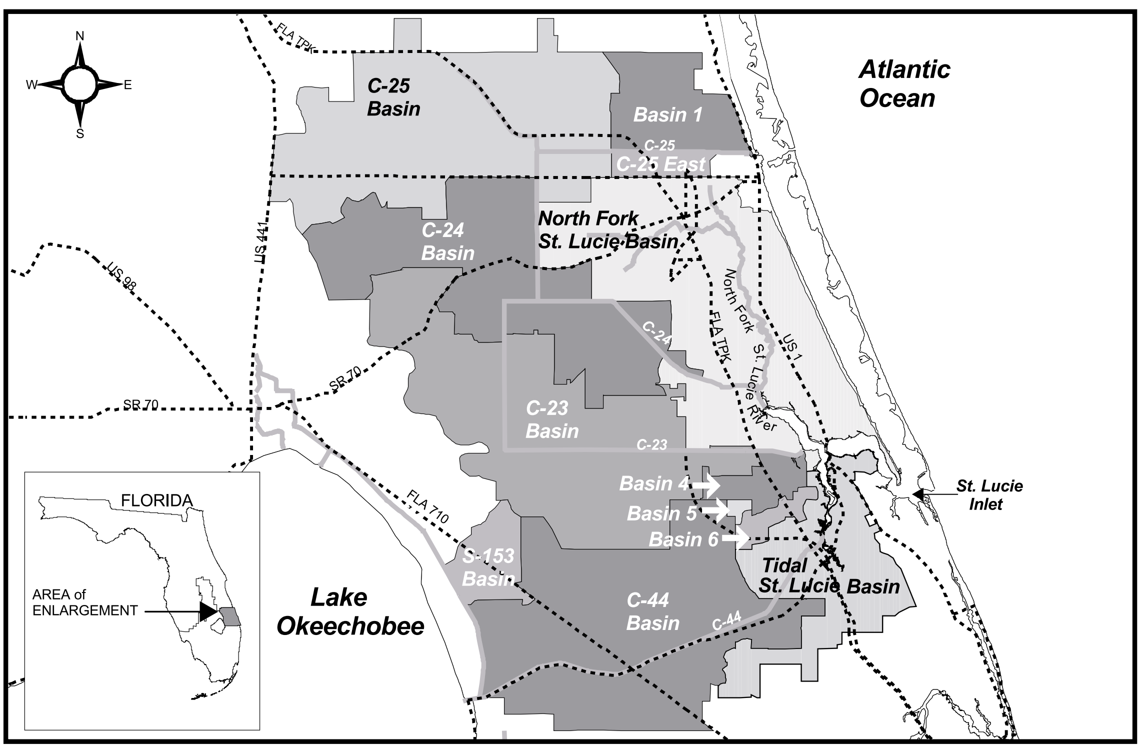


Figure 2. Major Drainage Basins, Rivers, and Canals in the St. Lucie Watershed

CLIMATE, RAINFALL, AND SEASONAL WEATHER PATTERNS

The main components of the hydrologic cycle in the St. Lucie watershed are precipitation, evapotranspiration, surface water flow, and ground water flow. The climate is classified as subtropical. The average seasonal temperatures range from 64 degrees Fahrenheit (^{O}F) during the winter to about 81 ^{O}F during the summer (University of Florida, 1993).

The 52-year average annual rainfall in the region is approximately 51 inches (Ali and Abtew, 1999), but varies considerably from year to year (**Figure 3**). Florida has a distinct wet season from May through October, and a dry season from November through April. About 72 percent of the annual rainfall occurs during the May through October wet season. The maximum monthly average rainfall is 7.52 inches in September (St. Lucie County) and the minimum monthly average rainfall is 1.93 inches in December (Martin County). Monthly rainfall displays a higher measure of relative variability during the dry period. Rainfall also varies spatially, with rainfall amounts generally decreasing from east to west.

Evapotranspiration is the sum of evaporation and transpiration, and is generally expressed in inches per year. In South Florida, approximately 45 inches of water per year is returned to the atmosphere through evapotranspiration. The excess of average precipitation over average evapotranspiration is equal to the combined amounts of average surface water runoff and average ground water recharge.

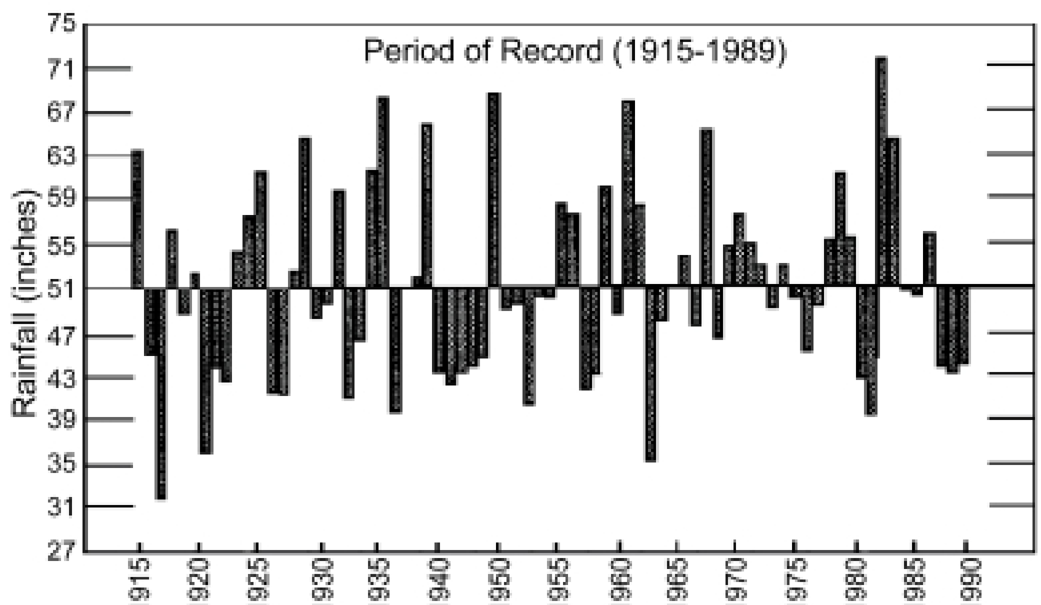


Figure 3. Variation from Annual Average Rainfall (Ali and Abtew, 1999)

PREDEVELOPMENT HYDROLOGY

Prior to development, most of the region was characterized by nearly level, poorly drained lands subject to frequent flooding. The natural surface drainage systems included large expanses of sloughs and marshes such as St. Johns Marsh, Allapattah Slough (also referred to as Allapattah Flats), Cane Slough, and the Savannas (**Figure 4**). Drainage systems with higher conveyance included the North and South Forks of the St. Lucie River, Ten Mile Creek, Five Mile Creek, and Bessey Creek. A characterization of the predevelopment St. Lucie watershed based on historical sources can be found in **Appendix E**.

Since the early 1900s, numerous water control facilities have been constructed to make this region suitable for agricultural, industrial, and residential use. The St. Lucie Canal (C-44) was constructed between 1916 and 1924 to provide an improved outlet for Lake Okeechobee floodwaters. From 1918 to 1919, the Fort Pierce Farms Drainage

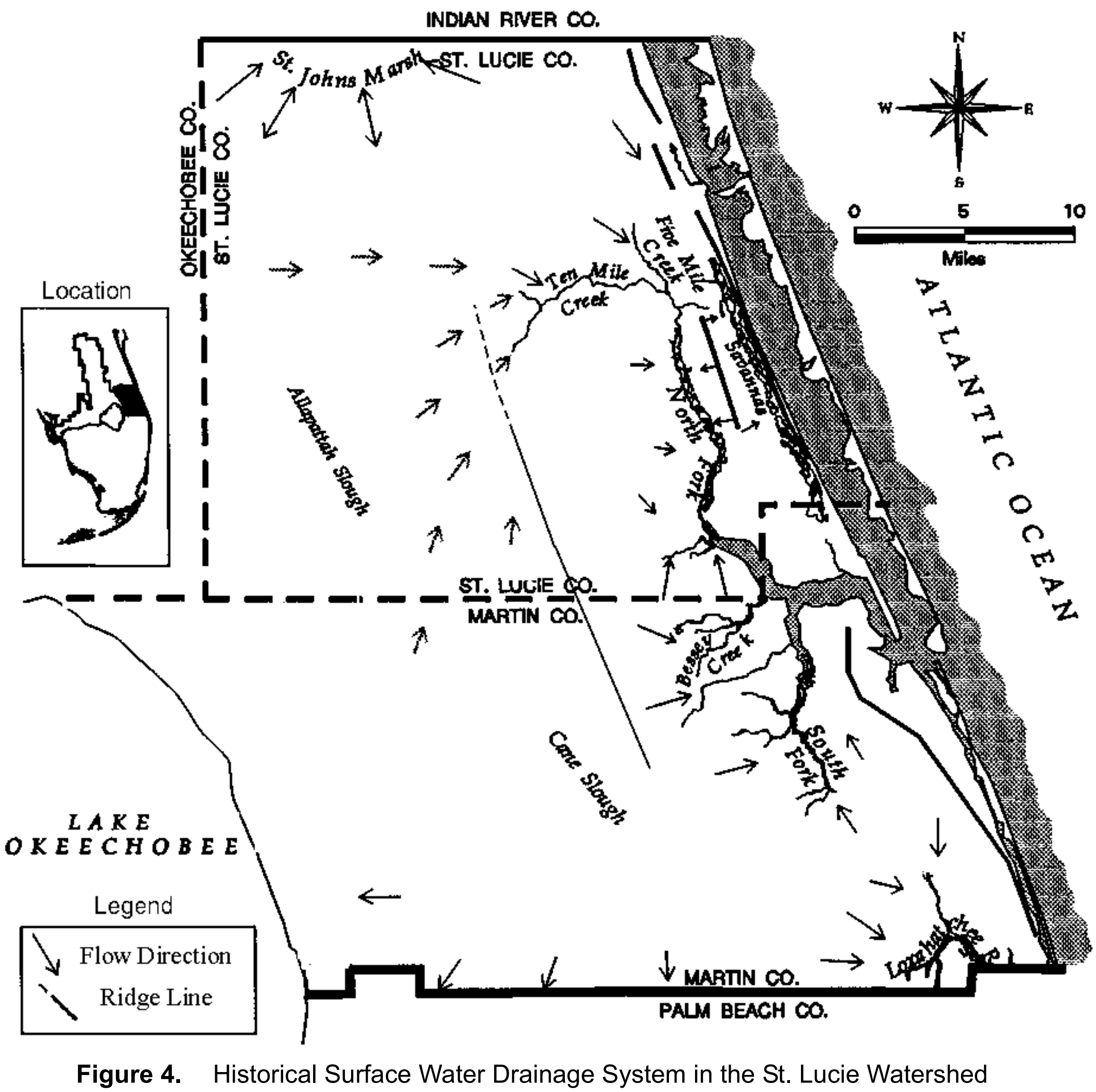


Figure 4. Historical Surface Water Drainage System in the St. Lucie Watershed

District and the North St. Lucie River Drainage District were formed to provide flood control and drainage for citrus production in east-central and northeastern St. Lucie County. The C-25 Canal (also known as Belcher Canal) provided a drainage outlet for the Fort Pierce Farms Drainage District, as well as a limited flood protection levee. The C-24 Canal (also known as the Diversion Canal) provided drainage and limited flood protection west of the North St. Lucie River Drainage District protection levee. The C-23 Canal provided water control in Allapattah Flats during the dry season. However, large areas continued to be under water for months at a time during the wet season.

Torrential rains and extensive flooding in South Florida in 1947 prompted the United States Congress to authorize the design and construction of the C&SF Project. The C&SF Project included construction of levees, canals, spillways, pump stations, and dams. The project incorporated the existing canals and provided increased outlet capacity for Lake Okeechobee by making improvements to the St. Lucie Canal.

MAJOR BASINS

St. Lucie Agricultural Area

The St. Lucie Agricultural Area is located in western St. Lucie County, eastern Okeechobee County, and northern Martin County. It includes all of the C-23, C-24, and C-25 basins, and part of the North Fork St. Lucie River basin (**Figure 5**).

The C-23, C-24, and C-25 Canals and control structures were improved under the C&SF Project. Their current functions are 1) to remove excess water from their respective basins, 2) to supply water during periods of low rainfall, and 3) to maintain ground water table elevations at the coastal structures to prevent saltwater intrusion.

The canals and control structures were designed to pass 30 percent of the Standard Project Flood and to meet irrigation delivery requirements for the basin. In this planning area, a Standard Project Flood is statistically equivalent to a 1-in-10 year, 72-hour storm event. Excess water may be discharged from C-25 to tidewater by way of the S-99 and S-50 structures, or to C-24 by way of the G-81 structure. Excess water in C-24 may be discharged to tidewater by way of S-49, to C-25 by way of G-81, or to C-23 by way of G-78. Excess water in C-23 may be discharged to tidewater by way of S-97 and S-48, or to C-24 by way of G-78 (SFWMD, 1993).

Flow in each of the C&SF Project canals is regulated by their respective control structures. For flood control and drainage, water elevations in the canal are set far enough below ground surface to provide slope in the secondary drainage systems. Water supply, on the other hand, requires that the water surface in the primary canal be maintained sufficiently high to prevent overdrainage. When flow in the canals is adequate, control structures are operated to maintain a headwater stage within a seasonally dependent range (**Table 1**).

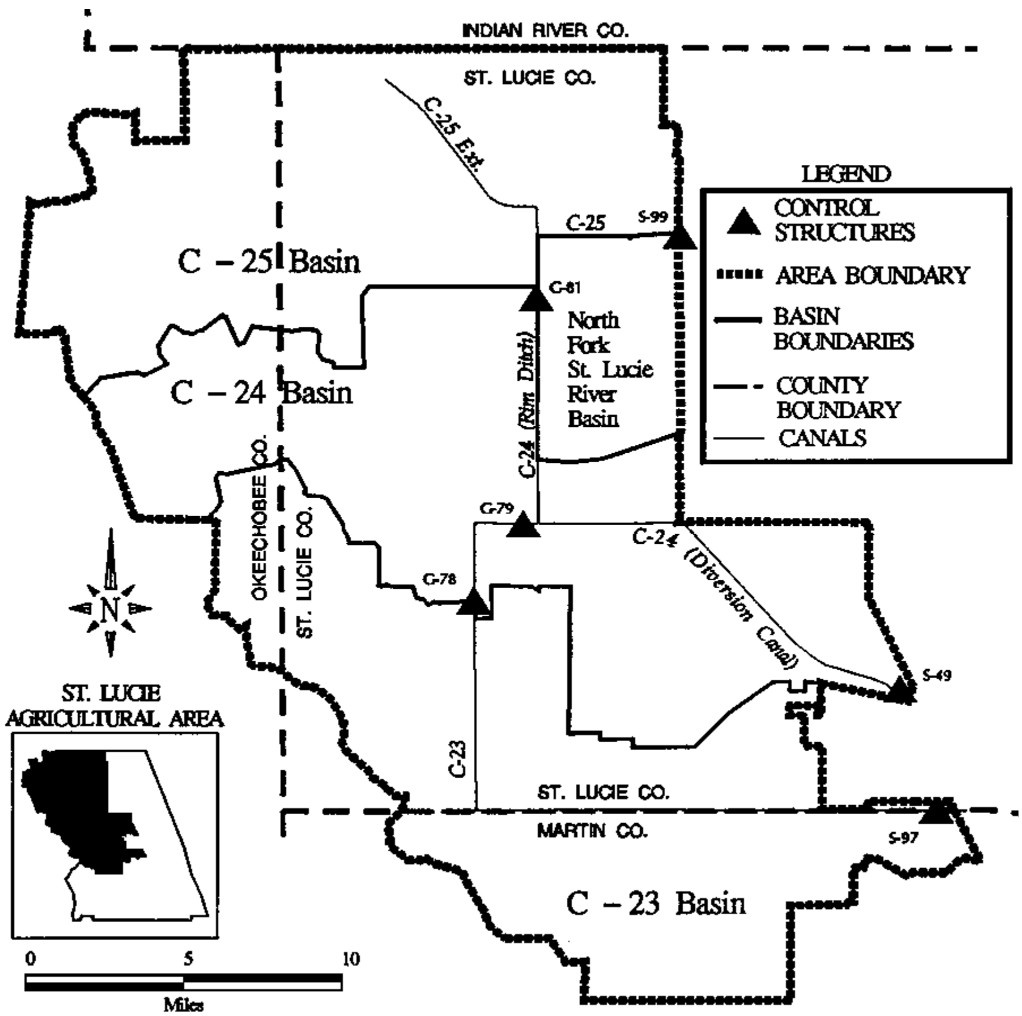


Figure 5. St. Lucie Agricultural Area Drainage Basins

Table 1. Optimal Headwater Stage for Project Canals

Canal	Structure	Headwater Stage (feet NGVD[a])	
		Wet Season[b]	Dry Season[c]
C-25	S-99	19.2 - 20.2	21.5 - 22.5
C-25	S-50	>12.0	>12.0
C-24	S-49	18.5 - 20.2	19.5 - 21.2
C-23	S-97	20.5 - 22.2	22.2 - 23.2
C-23	S-48	>8.0	>8.0

a. NGVD = National Geodetic Vertical Datum

b. Wet season is from May 15 to October 15 (Cooper and Ortel, 1988).

c. Dry season is from October 16 to May 14

Although the primary function of the C&SF Project was for flood control and drainage, the drainage network formed by the project canals and the secondary canals and ditches have become an important source of irrigation water and frost protection for agriculture. In general, rainfall, ground water inflow, and runoff replenish water stored in the canals.

Eastern St. Lucie Area

The Eastern St. Lucie Area includes most of the North Fork St. Lucie River basin and all of Basin 1. A map of the Eastern St. Lucie Area is presented in **Figure 6**.

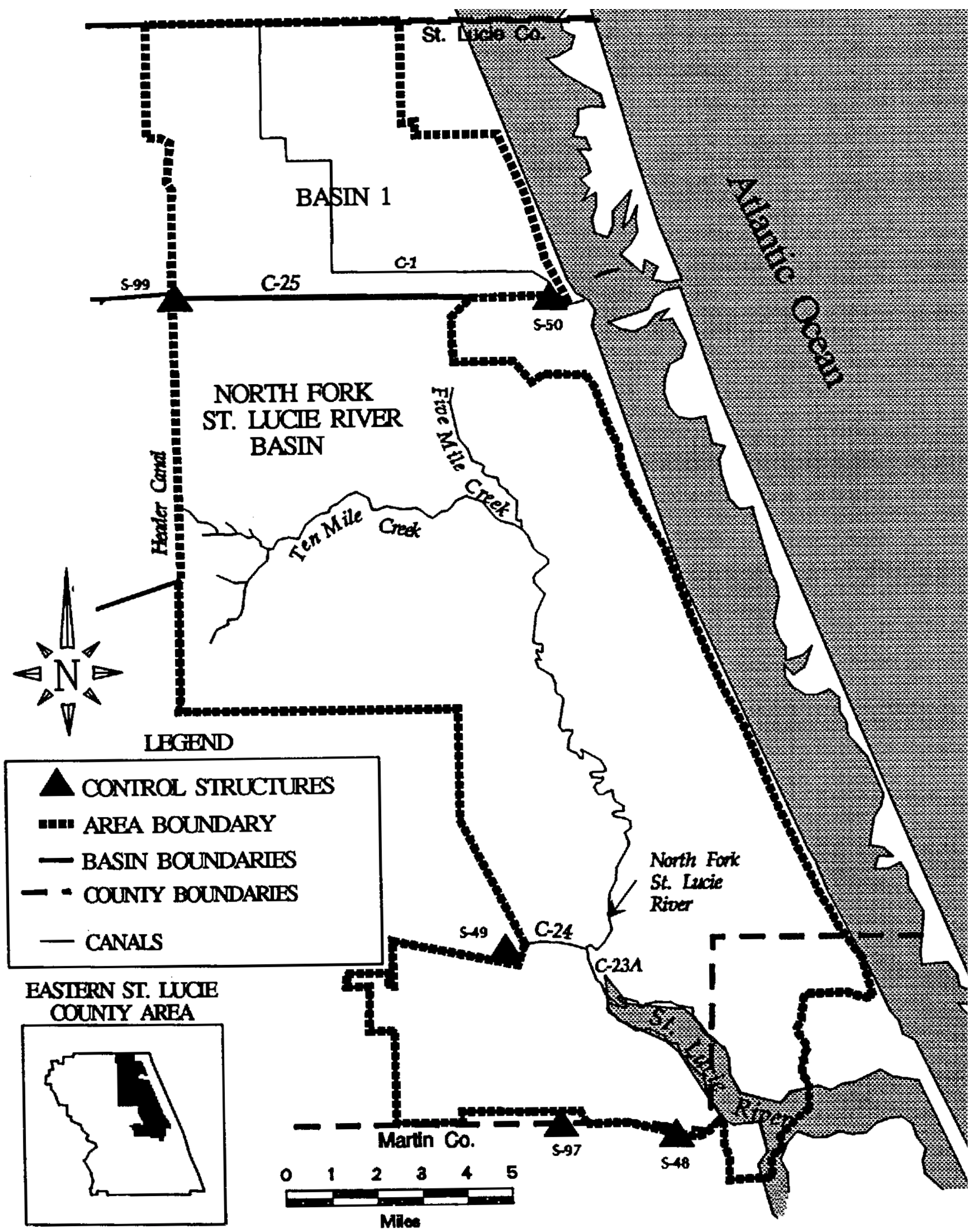


Figure 6. Eastern St. Lucie Area Drainage Basins

The North Fork of the St. Lucie River, is a natural watercourse although portions have been channelized. Ten Mile Creek and Five Mile Creek tributaries form its headwaters and, nineteen miles downstream, it joins the South Fork in discharging to the Atlantic Ocean via the St. Lucie Estuary and the Indian River Lagoon. Stages in the North Fork are tidally influenced throughout its length which varies from 100 feet wide upstream to over 4,000 feet wide downstream (Camp Dresser & Mckee, 1993). Portions of the North Fork are designated a state aquatic preserve flanked by a state buffer preserve on either side.

The North Fork of the St. Lucie River and the C-24 Canal serve as the primary drainage conveyances for southeastern and west-central St. Lucie County, and for small portions of eastern Okeechobee and northeastern Martin counties (Camp Dresser & McKee, 1993). Two C&SF Project canals, C-23A and C-24, are located in the North Fork St. Lucie River basin. C-23A is a short section of canal in the lower reach of the North Fork of the St. Lucie River. This canal passes discharges for both the North Fork and the C-24 Canal to the St. Lucie Estuary. A short reach of the C-24 Canal extends from the S-49 control structure to the North Fork, just north of C-23A. C-23A was designed to pass 30 percent of the Standard Project Flood from the North Fork St. Lucie River basin and from the C-24 basin.

Greater St. Lucie Canal Area

The Greater St. Lucie Canal Area covers most of Martin County (**Figure 6**). It can be subdivided in two categories: 1) the Canal Area which includes all of the C-44, S-153, and Tidal St. Lucie basins served by C&SF Project canals, and 2) Basins 4, 5, 6, and 8. Basin 8 drains out of the planning area and has little interaction with the rest of the Greater St. Lucie Canal Area. The Canal Area contains the only basin (C-44 basin) in the planning area that is hydrologically connected to Lake Okeechobee. Therefore, this section includes a discussion of the lake's regulation schedule.

Canal Area

The C&SF Project canal and control structures in the C-44 basin have five functions: 1) to provide drainage and flood protection for the C-44 basin; 2) to accept runoff from the S-153 basin and discharge this runoff to tidewater; 3) to discharge water from Lake Okeechobee to tidewater when the lake is over schedule; 4) to supply water to the C-44 basin during periods of low natural flow, and 5) to provide a navigable waterway from Lake Okeechobee to the Intracoastal Waterway. Excess water is discharged to tidewater by way of the S-80 structure and the C-44A Canal. Under certain conditions, excess water backflows to Lake Okeechobee by way of S-308. This happens about 50 percent of the time. Regulatory releases from Lake Okeechobee are made to the C-44 Canal by way of S-308. Water supply to the basin is made from Lake Okeechobee by way of S-308 and from local rainfall. Both S-80 and S-308 have navigation locks to pass boat traffic.

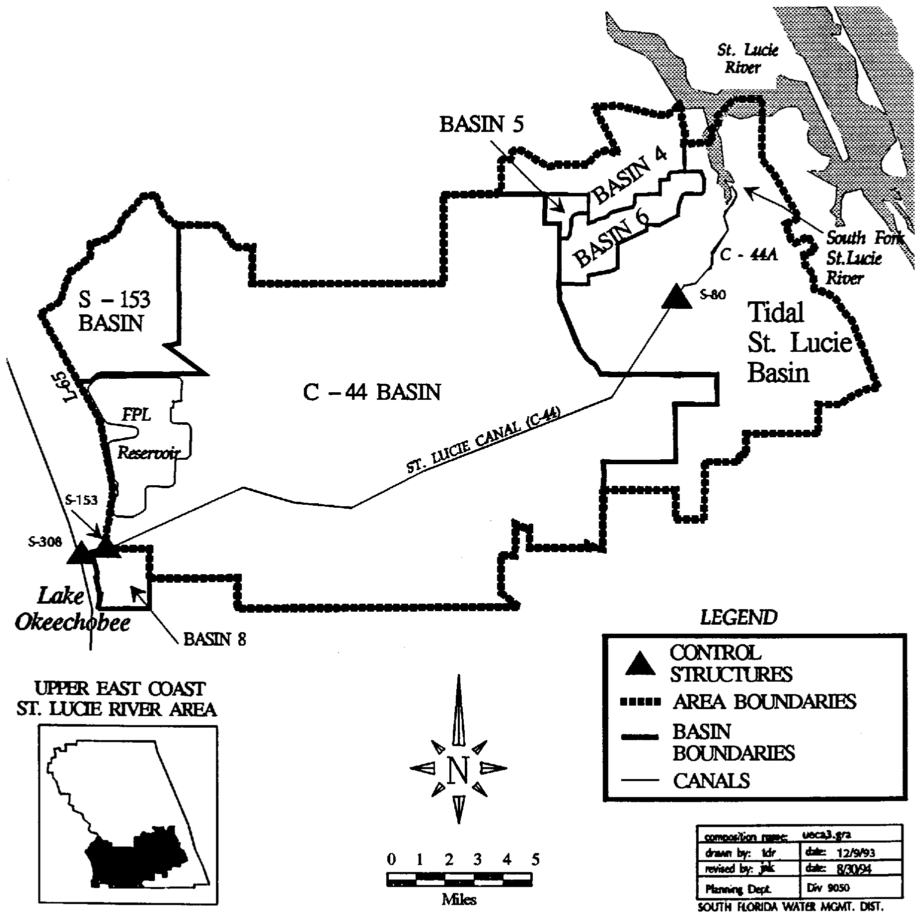


Figure 7. Greater St. Lucie Canal Area Drainage Basins

Lockages are performed "on demand" at S-80, except when water shortages have been declared or maintenance and repairs to the structure are taking place. Although, a water shortage plan has not been developed for S-80, the USACE will curtail lockages at the request of the District. Maintenance and repairs that result in stoppage of lockages are done on an as-needed basis, usually occurring every three to five years (SFWMD, 2000b). Each lockage at S-80 releases over 1.3 million gallons of water. The average number of lockages at S-80 varies monthly. Between 1987 and 1991, S-80 had an average of 15 lockages per day (SFWMD, 2000b).

The S-153 structure provides flood protection and drainage for the S-153 basin. Excess water in the basin is discharged to the C-44 Canal by way of the L-65 Borrow Canal. This 6,600-acre reservoir was originally part of the S-153 basin, but is now hydraulically connected to the C-44 Canal and is considered part of the C-44 basin. The S-153 control structure is operated to maintain an optimum stage of 18.8 feet National Geodetic Vertical Datum (NGVD).

The S-80 structure in the Tidal St. Lucie basin has three functions. These functions are 1) to accept flow from the C-44 Canal and to discharge those flows to tidewater in the St. Lucie River; 2) to provide a navigable waterway from the St. Lucie Canal to the Intracoastal Waterway; and 3) to provide drainage for portions of the Tidal St. Lucie basin.

The C-44 Canal and the S-80 Structure were designed to pass the Standard Project Flood from the C-44 basin and the S-153 basin and to pass regulatory discharges from Lake Okeechobee to tidewater. The S-308 and S-80 control structures are operated to maintain an optimum canal stage of 14.5 feet NGVD within the Tidal St. Lucie basin.

Contributing to surface drainage in the Tidal St. Lucie basin, the Old South Fork of the St. Lucie River is characterized by numerous oxbows winding through floodplain hammock and pine flatwoods for more than eight miles before connecting to the Okeechobee Waterway (C-44). It remains virtually unaltered from its historical watercourse although it has experienced hydrologic impacts due to surrounding land use classified as "predominantly well drained pasture/citrus groves connected to the river through a complex network of feeder canals" (Janicki et al., 1999).

Basins 4, 5, and 6

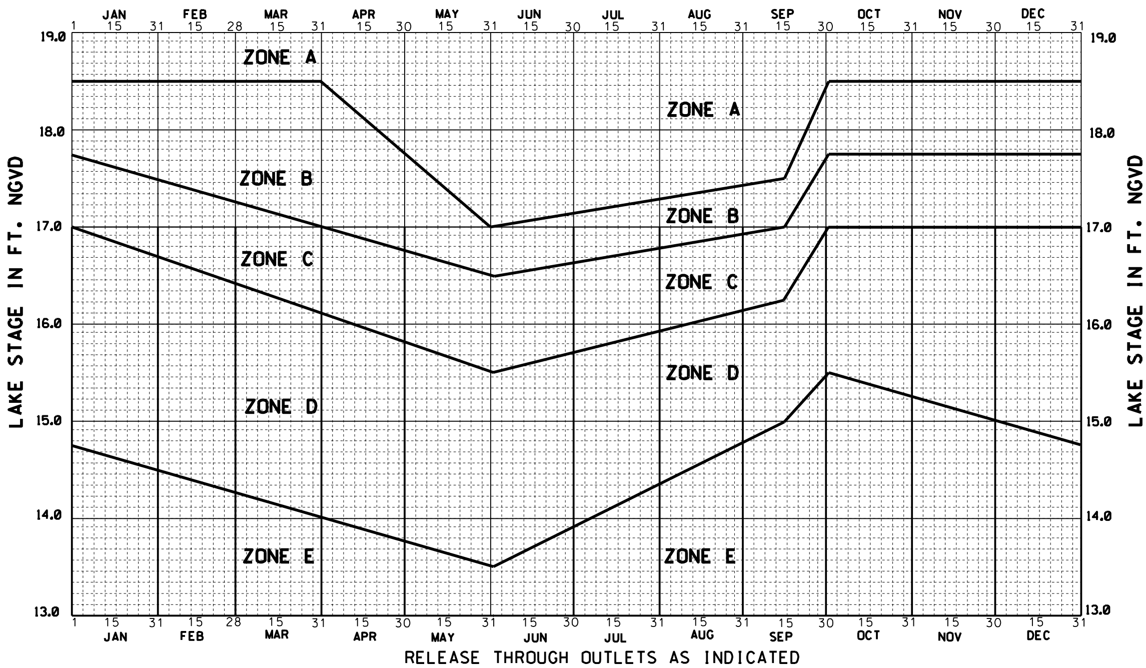
Basins 4 and 6 are drained by Bessey and Danforth Creeks, respectively. Bessey Creek discharges to the mouth of the C-23 Canal, which in turn empties into the St. Lucie River. Danforth Creek discharges to the South Fork of the St. Lucie River Estuary. Basin 5 is generally landlocked, with a poor hydraulic connection to Bessey Creek. Inadequate conveyance in the drainage systems in these basins has frequently resulted in areas of inundation in flood prone areas.

Lake Okeechobee

Lake Okeechobee is managed as a multipurpose freshwater resource in the C&SF Project. The primary tool for managing lake water levels is the regulation schedule. This schedule defines the ranges of water levels in which specific discharges are made to control excessive accumulation of water within the lake's levee system.

The schedule varies seasonally to best meet the objectives of the C&SF Project. A number of lake regulation schedules have been adopted since the construction of the C&SF Project (Trimble and Marban, 1988). In 1978, the USACE adopted the "15.5 – 17.5" schedule in which regulatory releases were made if stages in the lake exceeded 15.5 to 17.5 feet NGVD. A pulse release program was added in 1991 to reduce the likelihood of making large freshwater releases to the St. Lucie and Caloosahatchee River Estuaries. This schedule is commonly referred to as "Run 25".

Water releases from Lake Okeechobee to the estuaries currently depend on policies contained within the newly adopted Water Supply and Environmental (WSE) regulation schedule (**Figure 8**), which is structured to provide additional flexibility for discretionary releases of water from the lake for environmental benefits (USACE, 2000). An adaptive protocol process will be used to implement the operational flexibility of the WSE by providing additional guidance to operations for greater protection of Lake Okeechobee and downstream ecosystems while continuing to provide a reliable water supply for agricultural and urban areas that depend on the lake (SFWMD, 2002).



ZONE	AGRICULTURAL CANALS To WCAs (1,2)	CALOOSAHATCHEE RIVER AT S-77 (1,2,4)	ST. LUCIE CANAL AT S-80 (1,2,4)
A	PUMP MAXIMUM PRACTICABLE	UP TO MAXIMUM CAPACITY	UP TO MAXIMUM CAPACITY
B (3)	MAXIMUM PRACTICABLE RELEASES	NORMAL TO WET: UP TO 6500 CFS DRY: UP TO MAXIMUM PULSE RELEASE	NORMAL TO WET: UP TO 3500 CFS DRY: UP TO MAXIMUM PULSE RELEASE
C (3)	MAXIMUM PRACTICABLE RELEASES	WET: UP TO 4500 CFS NORMAL: UP TO MAXIMUM PULSE RELEASE DRY: NONE	WET: UP TO 2500 CFS NORMAL: UP TO MAXIMUM PULSE RELEASE DRY: NONE
D (3,5)	AS NEEDED TO MINIMIZE ADVERSE IMPACTS TO THE LITTORAL ZONE WHILE NOT ADVERSELY IMPACTING THE EVERGLADES. (SEE NOTE 5.)	VERY WET: UP TO MAXIMUM PULSE RELEASE OTHERWISE: NONE	VERY WET: UP TO MAXIMUM PULSE RELEASE OTHERWISE: NONE
E	NO REGULATORY DISCHARGE	NO REGULATORY DISCHARGE	NO REGULATORY DISCHARGE

NOTES: (1) SUBJECT TO FIRST REMOVAL OF RUNOFF FROM DOWNSTREAM BASINS
(2) GUIDELINES FOR WET, DRY AND NORMAL CONDITIONS ARE BASED ON: 1) SELECTED CLIMATIC INDICES AND TROPICAL FORECASTS AND 2) PROJECTED INFLOW CONDITIONS. RELEASES ARE SUBJECT TO THE GUIDELINES IN THE WSE OPERATIONAL DECISION TREE, PARTS 1 AND 2.
(3) RELEASES THROUGH VARIOUS OUTLETS MAY BE MODIFIED TO MINIMIZE DAMAGES OR OBTAIN ADDITIONAL BENEFITS. CONSULTATION WITH EVERGLADES AND ESTUARINE BIOLOGISTS IS ENCOURAGED TO MINIMIZE ADVERSE EFFECTS TO DOWNSTREAM ECOSYSTEMS.
(4) PULSE RELEASES ARE MADE TO MINIMIZE ADVERSE IMPACTS TO THE ESTUARIES
(5) ONLY WHEN THE WCAs ARE BELOW THEIR RESPECTIVE SCHEDULES

CENTRAL AND SOUTHERN FLORIDA
INTERIM REGULATION SCHEDULE
LAKE OKEECHOBEE

DEPARTMENT OF THE ARMY, JACKSONVILLE DISTRICT
CORPS OF ENGINEERS, JACKSONVILLE, FLORIDA
DATED: 5 NOVEMBER 1999

WSE (WITH CLIMATE OUTLOOK)

Figure 8. The Interim WSE Schedule for Lake Okeechobee

Pulse releases prescribed in Zone D of the WSE are designed to lower lake stage with minimal impact to the estuary. The pulse releases consist of 10-day pulses that follow the release patterns that were designed to reflect the natural hydrology of storm water runoff. The release rate begins low on the first day and is increased to the highest release rate on the third day, followed by reduced flow rates for days seven through ten. After day ten the pattern of discharge is repeated until the lake level is sufficiently lowered. The pulse releases increase from Level 1 to Level 3 as shown in **Table 2**. The level of release is determined by the water stage in Lake Okeechobee.

Table 2. Pulse Release Schedules for the St. Lucie and Caloosahatchee River Estuaries and Their Effect on Lake Okeechobee Water Levels[a]

Day	Daily Discharge Rate (cubic feet per second)					
	St. Lucie Level I	**St. Lucie Level II**	**St. Lucie Level III**	**Caloosa.[b] Level I**	**Caloosa. Level II**	**Caloosa. Level III**
1	1,200	1,500	1,800	1,000	1,500	2,000
2	1,600	2,000	2,400	2,800	4,200	5,500
3	1,400	1,800	2,100	3,300	5,000	6,500
4	1,000	1,200	1,500	2,400	3,800	5,000
5	700	900	1,000	2,000	3,000	4,000
6	600	700	900	1,500	2,200	3,000
7	400	500	600	1,200	1,500	2,000
8	400	500	600	800	800	1,000
9	0	400	400	500	500	500
10	0	0	400	500	500	500
Acre-Feet per Pulse and Correlating Lake Level Fluctuations						
Acre-Feet per Pulse	14,476	18,839	23,201	31,728	45,609	59,490
Impact on Lake (feet)	0.03	0.04	0.05	0.07	0.10	0.13

a. Source: SFWMD, 1997

b. Caloosa. = Caloosahatchee

Although Lake Okeechobee is a potentially large source of water, it must supply many users within the region and is subject to regional rainfall conditions. These factors contribute to lake levels occasionally falling within the supply-side management zone (**Figure 9**). At low lake stages, water supply allocations are determined through procedures described in the *Lake Okeechobee Supply-Side Management Plan* (Hall, 1991), as modified in the *Lower East Coast Regional Water Supply Plan* (SFWMD 2000b). This plan states that the amount of water available for use during any period is a function of the anticipated rainfall, lake evaporation, and water demands for the balance of the dry season in relation to the amount of water currently in storage. If the projected lake stage falls below 10.5 feet NGVD at the end of the dry season, or below 13.0 feet NGVD at the end of the wet season, the Lake Okeechobee Supply-Side Management Plan (Hall, 1991) is implemented in conjunction with the District's Water Shortage Plan (Chapter 40E-21, F.A.C).

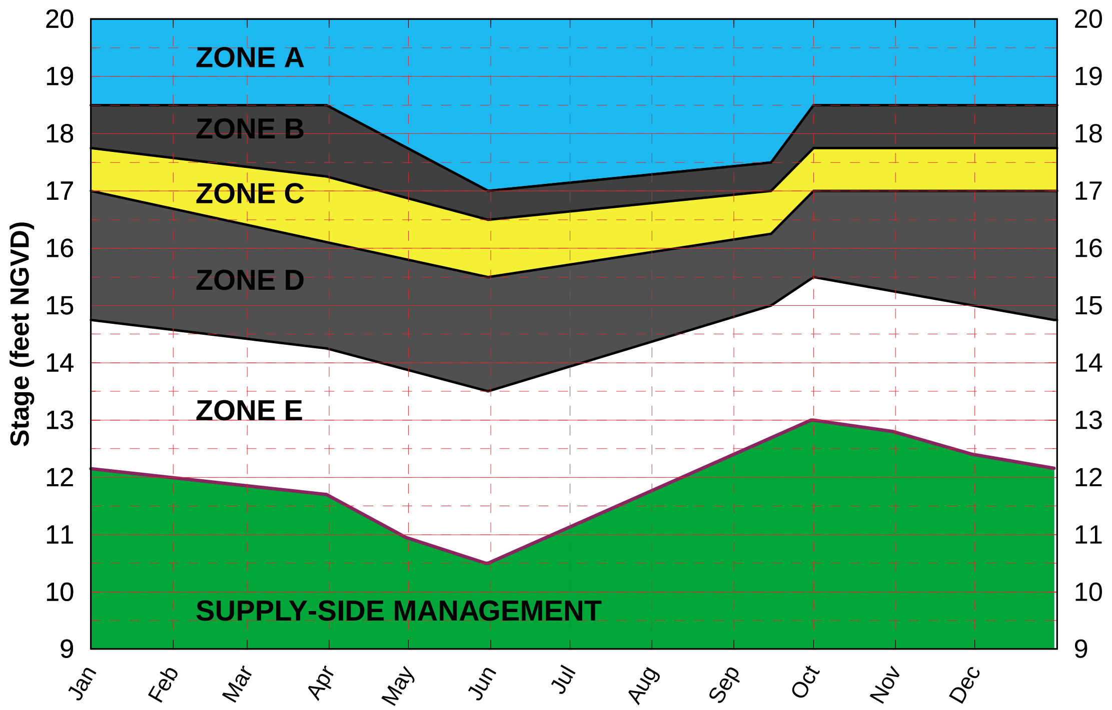


Figure 9. Management Zones for Lake Okeechobee, including Zones A through E Associated with the WSE Regulation Schedule and the Supply-Side Management Zone

St. Lucie Estuary

The estuary is divided into three major areas: the inner estuary, comprised of the North and South Forks; the midestuary, consisting of the area from the juncture of the North and South Forks to Hell Gate; and the outer estuary extending from Hell Gate to the St. Lucie Inlet (**Figure 10**). The main body of the North Fork is about four miles long, with a surface area of approximately 4.5 square miles and a volume of 468.7 by 106 cubic feet. The midestuary extends approximately 5 miles from the Roosevelt Bridge to Hell Gate and has an area and volume similar to the North Fork (4.7 square miles and 972.7 by 106 cubic feet) (Haunert and Startzman, 1985).

The bathymetry of the estuary has been mapped by the District (Morris, 1986). The center of the North Fork is approximately 10.0 feet deep; depth increases to 15.0 feet near its juncture with the South Fork. Depths within the South Fork also approach 10.0 feet within the channel, however, depths are generally much shallower near the Palm City Bridge. Maximum depths within the estuary are about 25.0 feet at sites near the Roosevelt Bridge and Hell Gate. Tidal influences in the North Fork reach 15 miles north of Stuart in Five-Mile Creek, and to a water control structure on Ten-Mile Creek just west of the Florida Turnpike at Gordy Road. Tidal influences in the South Fork extend about 8 miles south of Stuart to the St. Lucie Lock and Dam on the St. Lucie Canal. Tidal influence also extends into the extremes of the nearby Old South Fork tributary (Morris, 1987).

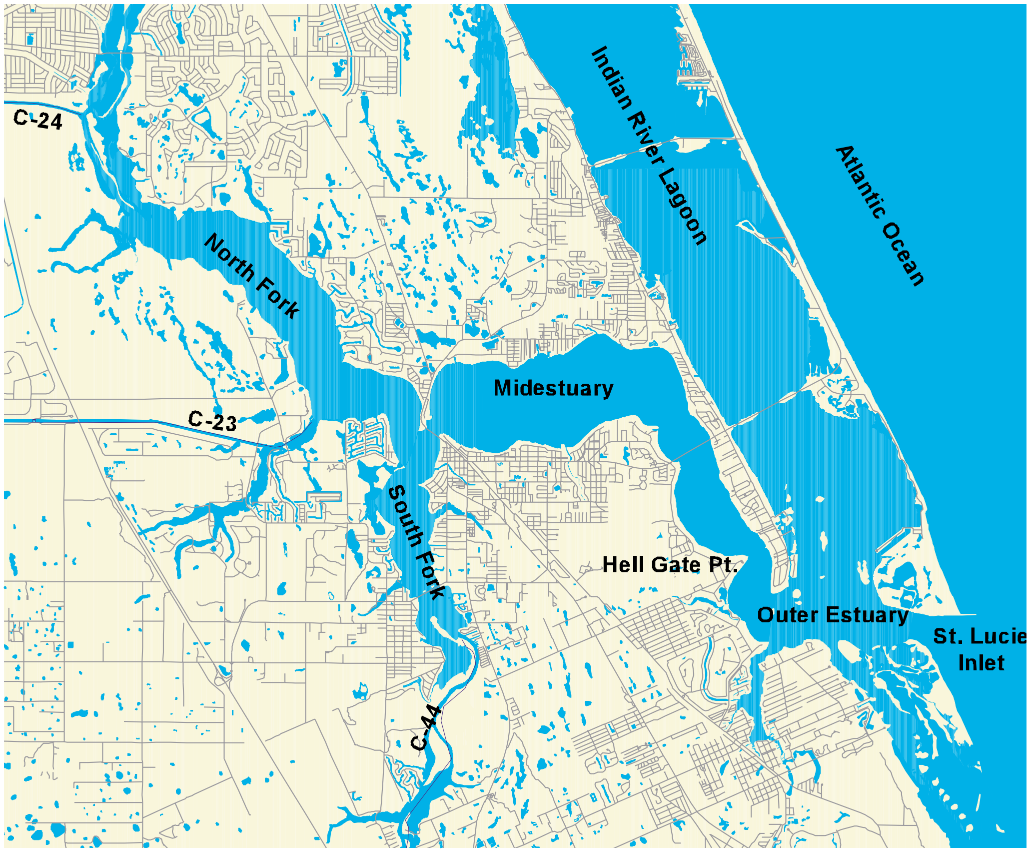


Figure 10. St. Lucie Estuary Hydrography

Surface sediment composition within the estuary has also been mapped by the District (Haunert, 1988). Sediment composition within the St. Lucie Estuary is influenced by hydrodynamics and is somewhat correlated to depth. Sand substrates, with little organic content, are found along the shallow shorelines of the estuary and in the St. Lucie Canal. This reflects the impacts of wave turbulence and rapid currents. Substrates comprised of mud and moderate quantities of sand are present in areas that are more typically low energy environments, but subjected to occasional high energy events. Mud substrates are found in low energy areas such as dredged areas and the deeper portions of the estuary. These mud sediments often contain high concentrations of organic materials.

The estuarine environment is sensitive to freshwater releases, and modification of the volume, distribution, circulation, or temporal patterns of freshwater discharges can place severe stress upon the entire ecosystem. Salinity patterns affect productivity, population distribution, community composition, predator-prey relationships, and food web structure in the inshore marine habitat. In many ways, salinity is the master ecological variable that controls important aspects of community structure and food web organization in coastal system (Myers and Ewel, 1990). Other aspects of water quality, such as turbidity, dissolved oxygen content, nutrient loads, and toxins, also affect functions of these systems (USFWS, 1990; Myers and Ewel, 1990).

Estuarine biota is well adapted to, and depends on, natural seasonal changes in salinity. The temporary storage and concurrent decrease in velocity of floodwaters within upstream wetlands aid in controlling the timing, duration, and quantity of freshwater flows into the estuary. Upstream wetlands and their associated ground water systems contribute to base flow discharges into the estuaries, providing favorable salinities for estuarine biota. Maintenance of these base flows supports the propagation of many commercially important fish species, such as snook, tarpon, sea trout, and redfish.

During the wet season, upstream wetlands provide pulses of organic detritus, that are exported downstream to the brackish water zone. These materials are an important link in the estuarine food chain.

LAND USE

The St. Lucie watershed is predominantly agricultural, especially in St. Lucie County. Urban land use is primarily located in the coastal portions of Martin and St. Lucie Counties. The highest percentage of wetlands is in Martin County (**Table 3**).

Based on local government comprehensive plans, urbanization is anticipated to increase in both Martin and St. Lucie Counties. Agriculture has been the predominant land use in both counties and is projected to remain so in the future. However, the percentage of agricultural land use is projected to decrease as a result of urban encroachment. The most significant change in land use is the doubling of urban acreage, which reflects population growth in these two counties.

Table 3. Acreages and Percentages of Land Use by County[a]

Land Use	Martin County		St. Lucie County	
	Acres	Percent[b]	Acres	Percent[b]
Agriculture	137,361	40	191,081	50
Urban and Transportation	50,416	15	72,500	19
Wetlands	54,116	16	33,374	9
Upland Forest	64,201	19	38,880	10
Rangeland	5,503	2	8,129	2
Barren	2,075	1	316	0
Water	26,706	8	40,612	10
Total	**340,378**	**100**	**384,892**	**100**

a. Source: SFWMD Florida Land Use/Land Cover geographical information system (GIS) database, 1995

b. Percentages rounded to the nearest tenth

WATER RESOURCES

Surface Water Inflow and Outflow

Essentially all surface water inflows and outflows in the planning area are derived from rainfall. The exception to this is the St. Lucie Canal (C-44), which also receives water from Lake Okeechobee. In addition, most of the flows and stages in the regions' canals are regulated for water use and flood protection. The amount of stored water is of critical importance to both the natural ecosystems and the developed areas in the region. Management of surface water storage capacity involves balancing two conflicting conditions. When little water is in storage, drought conditions may occur during periods of deficient rainfall. Conversely, when storage is at capacity, flooding may occur due to excessive rainfall, especially during the wet season.

Surface Water-Ground Water Relationships

Sections of two vast aquifer systems, the Surficial Aquifer System and the Floridan Aquifer System, underlie the St. Lucie watershed. Ground water inflows from outside the area form an insignificant portion of recharge to the Surficial Aquifer System. Rainfall is the main source of recharge to this system, and because of this, long-term utilization of this source must be governed by local and regional recharge rates. The Floridan Aquifer System, on the other hand, receives most of its recharge from outside of the St. Lucie watershed.

The construction and operation of surface water management systems affect the quantity and distribution of recharge to the Surficial Aquifer System. Although a major source of water supply, in terms of their interaction with ground water, surface water management systems within the planning area function primarily as aquifer drains. Adams (1992) estimated that 19 percent of ground water flow in Martin County is discharged into surface water bodies, while only one percent of aquifer recharge is derived from surface water sources. Surface water management systems also impact aquifer recharge by diverting rainfall from an area before it has time to percolate down to the water table. Once diverted, this water may contribute to aquifer recharge elsewhere in the system, supply a downstream consumptive use, or it may be lost to evapotranspiration or discharged to tide.

Water Supply

Water for urban and agricultural uses in the region comes from three main sources: the Floridan Aquifer System, the Surficial Aquifer System, and surface water. Surface water is used primarily for agricultural irrigation, with the Floridan Aquifer System used as a backup source during periods of low rainfall. Although the Floridan Aquifer System is not hydraulically connected to surface water within the planning area, Floridan Aquifer System water is usually diluted with surface water to achieve an acceptable quality for agricultural irrigation.

The Surficial Aquifer System is the principal source for public water supply and urban irrigation. However, as the population in the planning area increases, the urban areas are anticipated to increase their use of the Floridan Aquifer System as a source of drinking water (SFWMD, 1998a).

Nonenvironmental water use assessments for 1990 and projections for 2010 were made for five categories of water use. The category of *public water supply* refers to all potable water supplied by regional water treatment facilities with pumpage greater than 500,000 gallons per day (GPD) to all types of customers, not just residential. The other four categories of water use are self-supplied. *Commercial and industrial self-supplied* refers to operations using over 100,000 GPD. *Recreation self-supplied* includes landscape and golf course irrigation demand. The landscape subcategory includes water used for parks, cemeteries, and other irrigation applications greater than 100,000 GPD. The golf course subcategory includes those operations not supplied by a public water supply or regional reuse facility. *Residential self-supplied* is used to designate only those households whose primary source of water is private wells. *Agriculture self-supplied* includes water used to irrigate all crops, and for cattle watering (SFWMD, 1998a).

From 1990 to 2010, the total water demand is projected to increase by 34 percent (**Table 4**). Public water supply has the largest projected increase of 143 percent. However, agricultural water demand is projected to remain the single largest category of use. In 1990, agriculture accounted for 84 percent of the total demand.

Table 4. Overall Water Demands for 1990 and 2010[a]

Category	Estimated Demands 1990 (MGY[b])	Projected Demands 2010 (MGY)	Percent Change 1990-2010
Public Water Supply	9,607	23,371	143
Commercial and Industrial Self-Supplied	850	1,570	85
Recreation Self-Supplied	7,233	13,910	92
Residential Self Supplied	6,398	6,876	7
Agriculture Self-Supplied	130,191	160,528	23
Total	**154,279**	**206,255**	**34**

a. Source: SFWMD, 1998a
b. MGY = million gallons per year

Agricultural drainage and residential development have extensively modified the watershed of the entire St. Lucie Estuary. Major effects of these anthropogenic changes in the landscape and water management practices are increased drainage manifested by a lowered ground water table and dramatic changes in how storm water runoff is introduced to the estuary. Typically, when a watershed is highly drained like the St. Lucie Estuary watershed, all three runoff factors (quality, quantity, and timing) are negatively affected. From a yearly cycle perspective, the quantity of water drained to the estuary is increased, the water quality is degraded and the seasonal distribution of runoff is altered such that dry season flows are of lesser magnitude and less frequent and wet season flows are of greater magnitude and more frequent. From a short-term perspective, these three factors are all negatively affected due to the accelerated rate of runoff from the watershed. The vast majority of runoff occurs within the first three days instead of over an extended period of time.

Urban Water Supply Demands

Urban water demands include 1) public water supply provided by utilities, 2) residential self-supplied, 3) commercial and industrial self-supplied, and 4) recreation self-supplied. In the Upper East Coast Planning Area, public water supply was the largest component (40 percent) of urban water demand in 1990, followed by recreation self-supplied (30 percent), residential self-supplied (27 percent), and commercial and industrial self-supplied (4 percent). Urban water demand in 1990 was estimated to be about 24 billion gallons per year and is projected to increase to almost 46 billion gallons per year in 2010 (SFWMD, 1998a).

The driving force behind urban demand is population. Population numbers for 1990 were taken from the United States Census. Population projections for 2010 were obtained from the county and local government comprehensive plans, derived from the portions of the counties within the planning area (**Table 5**), and used to develop urban demand projections. The total population of the planning area for 1990 is projected to increase 77 percent in 2010 (SFWMD, 1998a).

Table 5. Estimated and Projected Population in the Upper East Coast Planning Area for 1990 and 2010, respectively[a]

	Estimated Population 1990			Projected Population 2010		
Region	**Total**	**Public Water Supply**	**Residential Self-Supplied**	**Total**	**Public Water Supply**	**Residential Self-Supplied**
St. Lucie Area	150,171	86,808	63,364	290,100	221,320	68,780
Martin Area	100,900	54,935	45,965	154,200	101,520	52,680
Okeechobee Area	1,015	0	1,015	1,625	0	1,625
Total Planning Area	252,086	141,743	110,344	445,925	322,840	123,085

a. Source: Local Government Comprehensive Plans and United States Bureau of the Census, 1992

Agricultural Water Supply Demand

Agricultural water demand was estimated for 1990 to be approximately 130 billion gallons. Citrus was by far the largest agricultural water demand (82 percent) and is followed by sugarcane (11 percent). Vegetables, sod, cut flowers, and ornamental nurseries combined account for about three percent of the total agricultural demand. The combined water demand for cattle watering and irrigation of improved pasture also account for about three percent (SFWMD, 1998a). Subsequent analyses prepared while updating the Upper East Coast Water Supply Plan (due in 2003) indicate that citrus production is projected to gradually decline and level off, resulting in a 116 million gallons per day reduction in water needs (SFWMD, 2001a).

Agricultural water demand is forecast to increase by 23 percent to 161 billion gallons per year in 2010. Approximately 95 percent of the agricultural water demand is anticipated to be for citrus (85 percent) and sugarcane (10 percent). Vegetables, sod, and ornamental nurseries are each projected to represent about one percent of the total 2010 agricultural water demand (SFWMD, 1998a).

WATER QUALITY

A critical relationship exists between water quality and human activity, including the use of land for urban, agricultural, and industrial purposes and withdrawal of water for supply. Drainage, runoff, and seepage from developed lands carry sediments, fertilizers, and pollutants into surface and ground waters. Increased withdrawals and the by-products of treatment may increase the concentrations of impurities in the remaining water. Other human activities such as waste disposal and chemical spillage have the potential of degrading ground and surface water systems.

Modifications to the watershed have caused increased inflows to the St. Lucie Estuary during the last 100 years. Construction of canals, land development, extreme salinity fluctuations, and corresponding increases in sediment and chemical loadings have contributed to major changes in the structure of plant and animal communities within the estuary, resulting in loss of important features such as shoreline vegetation, sea grasses, and oysters. Phillips (1961) described the marine plants in the St. Lucie Estuary. At the time, mangroves were abundant in the North and South Forks and sea grasses, although stressed, were still found in many areas of the estuary. Today, the presence of sea grasses is severely limited and ephemeral and mangroves are sparsely distributed. Oyster populations in the estuary are virtually nonexistent due to the continual exposure to low salinities and lack of suitable substrate (clean hard objects) for larval recolonization (Haunert and Startzman, 1980, 1985).

Lake Okeechobee and C-44 Canal Discharges

Major regulatory discharges from the C-44 Canal have been documented to adversely impact the St. Lucie Estuary by depressing the salinity range far below the normal range, and by transporting large quantities of suspended materials into the estuary. Sedimentation problems in relation to C-44 discharges were recognized as early as the 1950s (Gunter and Hall, 1963). While current monthly average flows from the watershed to the St. Lucie Estuary seldom exceed 2,500 cubic feet per second (cfs), regulatory releases from the C-44 alone have produced flows in excess of 7,000 cfs. The quantity of suspended solid material passing through the S-80 structure reached a peak of 8,000 tons a day when daily discharges neared 7,000 cfs in 1983. Much of this material passes through the estuary and into the Indian River Lagoon or the Atlantic Ocean (Haunert, 1988). It was recognized then that these discharges transported sand as well as very fine, organic-rich suspended material to the estuary. Recent studies (FDEP, 2001) indicate runoff from the basin and water from the lake may also periodically contain significant concentrations of nitrogen and phosphorus.

A regulatory discharge from Lake Okeechobee that occurred as part of the managed recession in April 2000 resulted in a rapid drop of salinity and high levels of turbidity. More than 16 tons of phosphorus were discharged during this event. Oysters that were placed in the South Fork Estuary to monitor biological effects of the discharge were killed, whereas similar oysters placed in the North Fork Estuary, Middle Estuary, and Indian River showed no mortality (FDEP, 2000).

Inflow Water Quality from Other Tributaries

Graves and Strom (1992) concluded that the major canals (C-23, C-24, and C-44) provide the majority of nitrogen, phosphorus, and suspended solids that are discharged into the estuary. Sediments and water in these canals also periodically contain sufficiently high levels of certain heavy metals and pesticides to be toxic to fishes and aquatic invertebrates. Remaining “natural” waterways that pass through urban or residential landscapes may have a wider range of nutrient and dissolved oxygen concentrations, but are less of a problem in the sense that they contribute much less flow and material to the estuary.

Algal blooms that occurred during 1999 in the St. Lucie Estuary were linked to runoff from local watersheds rather than discharge from Lake Okeechobee. Samples indicated that high levels of nitrogen and phosphorus, as well as copper and the pesticide simazine were present in runoff from tributary basins (FDEP, 1999a). Additional sampling indicated that arsenic and ethion were present in high concentrations in some areas associated with runoff from a golf course and farms. High levels of nitrogen and phosphorus occurred in runoff from residential areas in Fort Pierce and Port St. Lucie (FDEP, 1999b).

Sediment Quality

In 1969, the United States Geological Survey (USGS) characterized suspended sediments carried by the C-23 and C-24 Canals. It was estimated that, in 1969, these canals discharged 4,500 and 9,000 tons of sediment, respectively, to the St. Lucie Estuary. These have also been characterized as very fine organic sediments (Pitt, 1972). Land use in the watersheds of these tributaries is primarily agricultural. The C-23 basin also contains a substantial proportion of upland forest, wetlands, range, and open water. Occasional high levels of phosphorus and nitrogen occur. Ethion, copper, and lead are present in high concentrations in the sediments (FDEP, 2000b, 2000c).

In 1984, the SFWMD provided funding to the University of South Florida to study sedimentation within the St. Lucie Estuary. High sedimentation rates were estimated at 0.5

to 1.0 centimeters (cm) per year for the past 100 years based upon historical bathymetry, and 1.0 to 2.6 cm per year based upon a radioactive dating technique (Davis and Schrader, 1984; Schrader, 1984). Recently deposited sediments were characterized as a black, organic-rich muck covered by a flocculent layer. The flocculent layer varied in thickness, with an average depth of 1.6 feet (Schrader, 1984).

Findings from a comprehensive characterization of the St. Lucie Estuary surface sediments (Haunert, 1988) indicate that portions of the St. Lucie Estuary contain extremely high concentrations of organic material (muck) in sediments when compared to other similar estuarine systems. These organics, contributed from upland sources and biological die-off within the estuary, produce anaerobic conditions and toxic hydrogen sulfide within the estuary. Samples in the North Fork contain as much as 64 percent organics by dry weight. South Fork values are as high as 49 percent by dry weight. In the middle estuary, an area of enriched sediments (20 to 30 percent) is found near the former discharge site of the Stuart Wastewater Treatment Plant (Haunert, 1988). More recent studies have confirmed the presence of a large layer of flocculent ooze within deeper portions of the St. Lucie Estuary (Schropp et al., 1994).

Water Quality Impacts of MFLs

Studies of the St. Lucie Estuary by Chamberlain and Hayward (1996) concluded that water quality in the estuary is dramatically impacted by the high flow rates that occur during severe storm events and regulatory discharges and that more stable, lower flows will improve water quality. It is important to quantify the water quality characteristics of lower inflows to determine potential impacts of the proposed MFL criteria. Freshwater inflow to estuaries brings with it nutrients, dissolved and particulate organic matter, inorganic particles including silts, clays, and sand. The effects of altering these inputs should be considered. A water quality model is an appropriate tool to perform such an analysis. In particular, the water quality model can be designed to address the following questions related to MFLs:

- What are the nutrient loads under the minimum flows?
- How does the St. Lucie Estuary respond, in terms of algal growth and dissolved oxygen, to a prolonged period of minimum flows?
- Under low inflow conditions, salinity levels may be well mixed within the water column, yet further salinity intrusion will take place. On the other hand, the water column may become more stratified under high inflows. Do these changes intensify the dissolved oxygen stratification in the water column?
- What is the role of sediments in contributing to benthic oxygen demand and nutrient fluxes when the bottom layer of the water in the estuary becomes anaerobic?

It should be pointed out that several water segments in the St. Lucie River basin are listed in the 303(d) list for water quality impairment as defined under Section 99-223, F.S., and the FDEP Impaired Water Rule (Chapter 62-303, F.A.C.): St. Lucie Estuary, St.

Lucie Canal, and the South Fork of the St. Lucie River. Modeling studies in the St. Lucie Estuary were conducted to develop total maximum daily loads (TMDLs) should be consulted as a basis for refining the St. Lucie Estuary MFLs in the future. Further discussion of the effects of freshwater discharge on salinity, nutrients, organic materials, and sediments is provided in **Chapter 3**.

NATURAL SYSTEMS

Wetlands

Wetlands are present throughout the region as shown in **Figure 11**. Although numerous man-made impacts have altered the landscape, significant wetland systems remain in the region.

Martin County

The area now known as the Allapattah Flats (**Figure 4**) was historically a series of sloughs that, during wet years, flowed from St. Lucie County southeast into Martin County and into the St. Lucie River (**Appendix D**). During average and dry years, the western wetlands generated no runoff. Highways, railroads, and drainage projects (FPL, 1988) have modified this drainage pattern. Currently, a series of isolated creeks, ponds, hammocks, sloughs, and wet prairies exist within the footprint of the original Allapattah Slough (MCGMD, 1990).

Another large wetland system, Cane Slough (**Figure 4**), is located immediately west of Interstate 95. This slough flows from the northwest to the southeast and is a recharge area for the headwaters of the St. Lucie River. A channelized connection exists between Cane Slough and the St. Lucie Canal. As a result of channelization and dikes, Cane Slough now consists of isolated cypress areas, ponds, and wet prairies.

The DuPuis Reserve and the Pal Mar Tract (**Figure 11**) also contain significant wetland systems. The 21,875-acre DuPuis Reserve is located in southwestern Martin County and northwestern Palm Beach County. This site contains numerous ponds, wet prairies, cypress domes, and remnant Everglades marsh. Management efforts are being directed toward improving wildlife habitat by restoring the hydrology of marshes and wet prairies and implementing prescribed burning and melaleuca control programs. The 37,314-acre Pal Mar Tract is located in Martin and Palm Beach counties. This tract is in the process of being acquired through the Save Our Rivers Program, the Conservation and Recreation Lands Program, and Martin and Palm Beach County acquisition programs. Pal Mar wetlands are primarily wet prairie ponds interspersed within a pine flatwood community. Despite some ditching, these wetlands are generally in good condition. The Pal Mar Save Our Rivers acquisition boundary includes a wildlife corridor that would connect Jonathan Dickinson State Park, Pal Mar, Corbett Wildlife Management Area (in Palm Beach County), and the DuPuis Reserve.

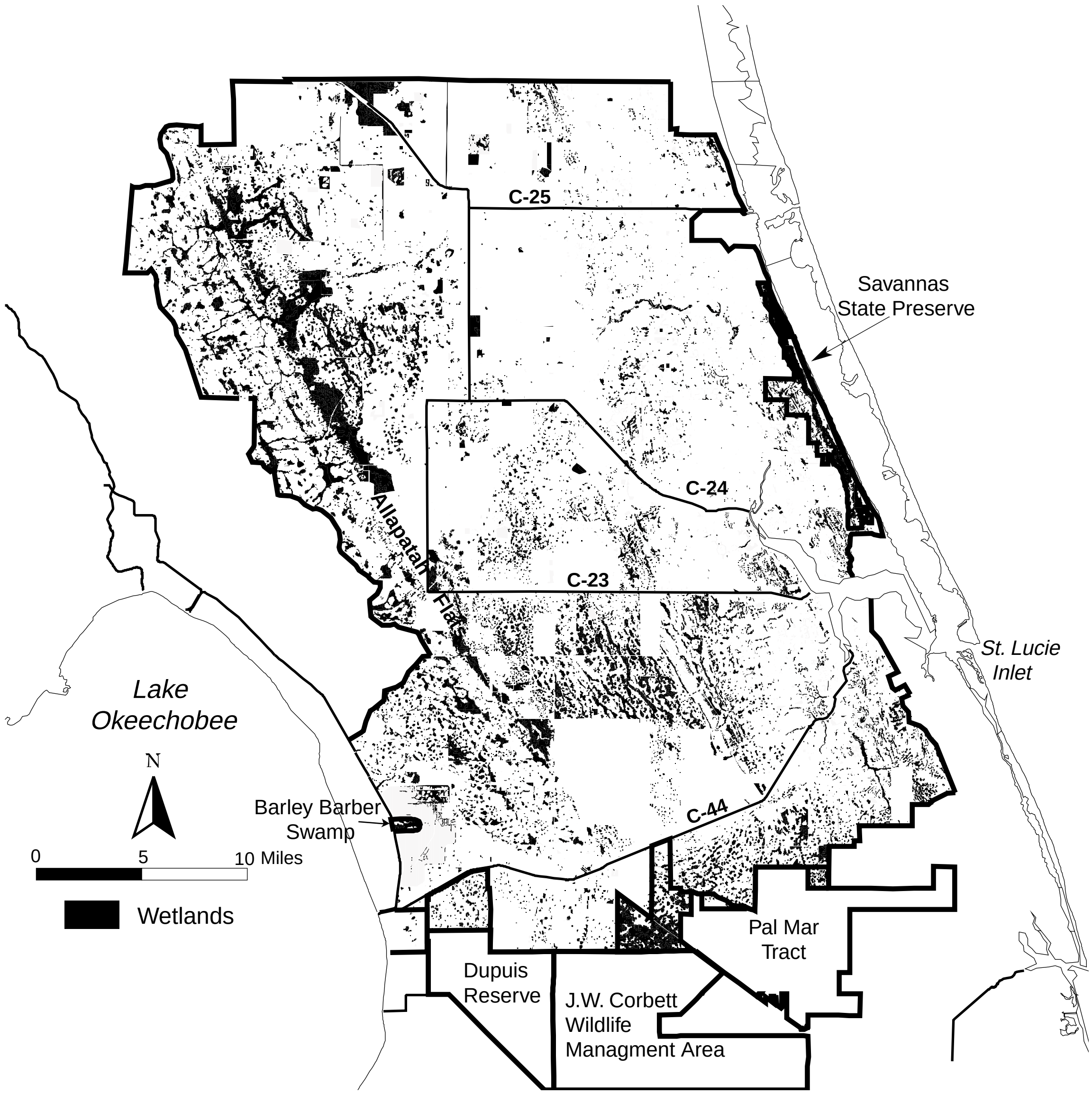


Figure 11. St. Lucie Watershed Wetlands and Natural Areas

St. Lucie County

Emergent shrub and forested wetlands once covered much of St. Lucie County. However, many of these wetlands have been extensively drained to support agricultural and urban development. The few large remaining inland wetland systems include the Savannas; wetlands associated with Five Mile, Ten Mile, Cow, Cypress, and Van Swearingen Creeks; remnant portions of St. Johns Marsh; and the floodplain of the North Fork of the St. Lucie River (**Figure 4**).

The Savannas is a freshwater wetland system located west of the Atlantic Coastal Ridge. It is one of the most endangered natural systems in the region. Historically, the

Savannas formed a continuous system that stretched the length of the county. It was later interrupted by the drainage and development of Fort Pierce. The State of Florida under the Conservation and Recreation Lands Program (**Figure 11**) has purchased much of the system south of Fort Pierce.

Uplands

Upland plant communities in the region include pine flatwoods, scrubby flatwoods, sand pine scrub, xeric oak, and hardwood hammocks. Uplands serve as recharge areas, absorbing rainfall into soils where it is used by plants or stored underground within the aquifer. Ground water storage in upland areas reduces runoff during extreme rainfall events, while plant cover reduces erosion and absorbs nutrients and other pollutants that might be generated during a storm. Upland communities, particularly pine flatwoods and sand pine scrub, are seriously threatened by development.

Pine flatwoods are the dominant upland habitat within the region. These plant associations are characterized by low, flat topography, and poorly drained, acidic, sandy soils. Under natural conditions, fire maintains flatwoods as a stable plant association. However, when drainage improvements and construction of roads and other fire barriers alter the natural frequency of fire, flatwoods can succeed to other community types. The nature of this succession depends on soil characteristics, hydrology, available seed sources, or other local conditions (Myers and Ewel, 1990).

Xeric sand pine scrub communities, although not as diverse as pine flatwood communities, contain more endangered and threatened plants and animals than any other South Florida habitat. Most of the sand pine scrub in the area is associated with the one to three-mile wide ancient dunes that line along the eastern edge of the coastal ridge in Martin and St. Lucie counties.

St. Lucie Estuary

Conceptual Model Approach

Participants in a series of interagency workshops held from August 1999 to November 2000 developed the framework for a conceptual model of the St. Lucie Estuary and Indian River Lagoon. This model was developed and structured to support the applied science strategy currently being implemented in the restoration, coordination, and verification (RECOVER) monitoring and assessment process that is a major component of the Comprehensive Everglades Restoration Plan (CERP). The St. Lucie Estuary/Indian River Lagoon Conceptual Model (**Appendix A**) identifies the major stressors in the St. Lucie River and Estuary watershed, the ecological and biological effects they have on the ecosystem, and the attributes in the natural systems that are the best indicators of the changes that have occurred as a result of the stressors (USACE and SFWMD, 1999). The basic features of this model are represented in **Figure 12**. The elements of this model that are related to development of MFLs are primarily linked to water management practices (as an external driver) as these result in altered hydrology and altered estuarine salinity

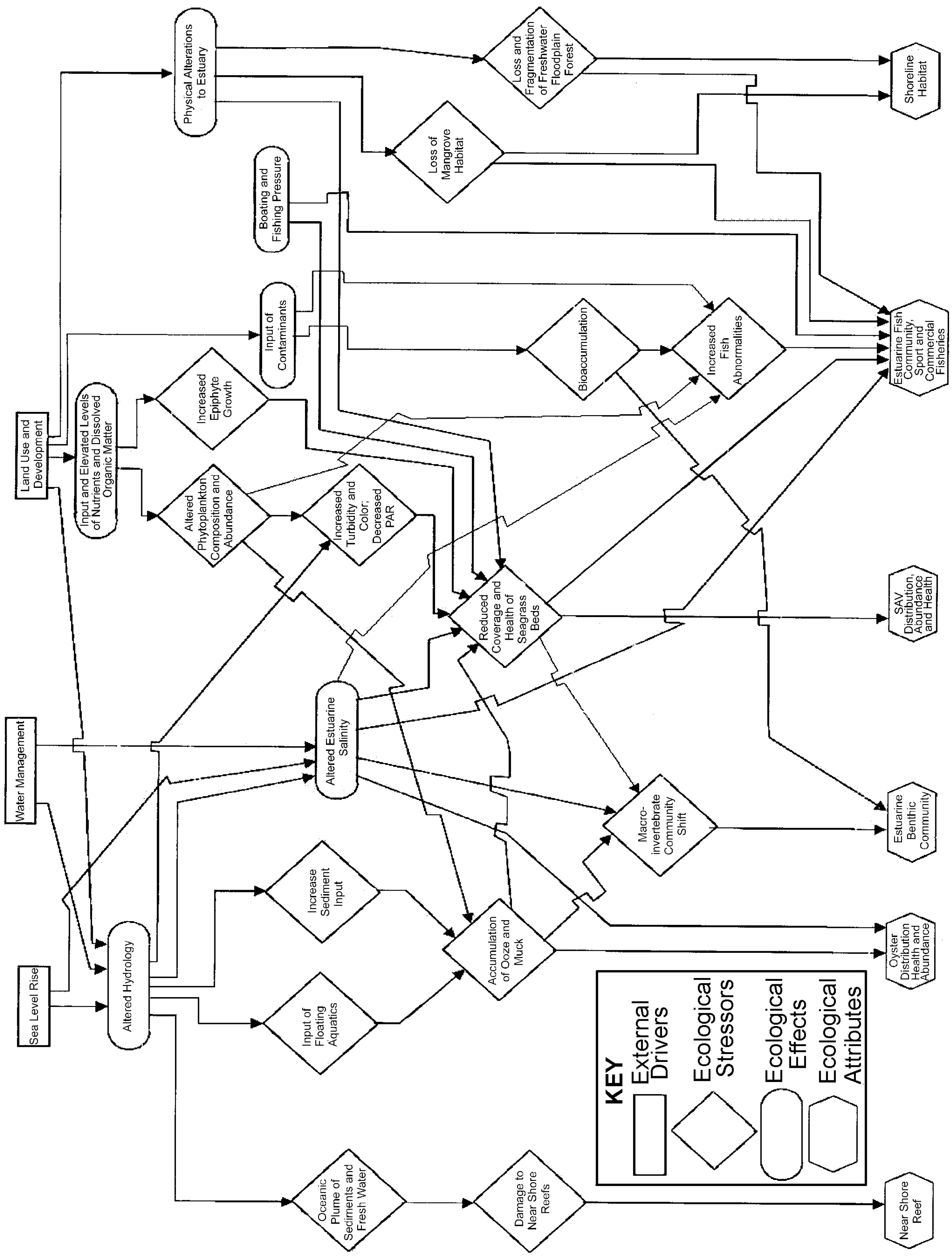


Figure 12. St. Lucie Estuary/Indian River Lagoon Conceptual Model

(ecological effects). According to the model, these effects, in turn, induce stress by causing increased turbidity, damage to sea grasses, shifts in macro invertebrate communities and accumulation of ooze and muck sediments. Changes in ecological attributes, such as oysters, benthic communities, aquatic vegetation, and fishes, reflect impacts to the estuary as noted in the following sections that are summarized from **Appendix A**.

Oyster Distribution Health and Abundance

Oysters and other bivalves, such as mussels and *Rangia,* are sensitive to salinity and siltation in the St. Lucie Estuary. Under natural conditions, oyster reefs can be very large and provide extensive attachment area for oyster spat and numerous associated species such as mussels, tunicates, bryozoans, and barnacles (Woodward-Clyde, 1998). Oysters have been documented in the past as abundant in the estuary and lagoon. Presently, their distribution is limited to approximately 200 acres from the estimated historic coverage of 1,400 acres (Woodward-Clyde, 1998). Generally adult oysters require salinity levels above 3 ppt, thrive at 12 to 20 ppt, and are adversely affected by diseases, predators, and algal blooms at seawater salinity conditions (Quick and Mackin, 1971; Mackin, 1962).

Estuarine Benthic Communities

Benthic macro invertebrate communities in the St. Lucie Estuary are sensitive to bottom type, water quality, and salinity fluctuations. A decline in diversity of benthic organisms and the spread of pollution-tolerant macro invertebrates is often an indicator of deteriorated water quality in an estuary. Haunert and Startzman (1985) found that fluctuations between periods of high and low discharge cause alternating shifts between estuarine and freshwater species. An overall reduction of 44 percent of the benthic macro invertebrates occurred during a three-week experimental freshwater release of 2,500 cfs. The greatest change in benthic species composition occurred in the newly created oligohaline zone (0.5 to 5 ppt). In this zone, the freshwater midge (*Chironomus crassicaudatus*) increased dramatically. Additionally, six freshwater species were introduced and at least four estuarine species were lost from the shifted oligohaline zone (Haunert and Startzman, 1985).

Submerged Aquatic Vegetation

Submerged sea grasses and freshwater macrophytes provide habitat and nursery grounds for many fish and invertebrate communities (Gilmore, 1977, 1988; Gilmore et al., 1981, 1983; Stoner, 1983) and they are food sources for trophically and commercially important organisms (Dawes et al., 1995; Virnstein and Cairns, 1986). Other important roles of submerged aquatic vegetation include benthic-based primary productivity and sediment stabilization (Stoner 1983; Virnstein et al., 1983; Gilmore, 1987; Woodward-Clyde, 1998). In a field study conducted by Woodward-Clyde in 1997, the only significant submerged aquatic vegetation beds in the St. Lucie Estuary occurred in the lower estuary near Hell Gate Point. Shoal grass *(Halodule wrightii)* was the dominant species throughout most of this area, with Johnson's sea grass (*Halophila johnsonii)* as the secondary species. The only other documented occurrences of submerged aquatic vegetation during that study was a very small amount of widgeon grass *(Ruppia maritima)*, wild celery (*Vallisneria americana)*, and common water nymph (*Najas guadalupensis*) in the South Fork of the estuary as well as a small area of widgeon grass in the North Fork.

All species of submerged aquatic vegetation respond negatively to rapidly changing salinity. Decreased light penetration that results from silt, turbidity, color, and phytoplankton blooms further stresses these plant communities. Sea grass loss negatively impacts fish and invertebrate communities. Also, it results in the destabilization of sediments and a shift in primary productivity from benthic macrophytes to phytoplankton, which provide negative feedback to further diminish sea grass beds (Woodward-Clyde, 1998).

Estuarine Fish Communities/Sport and Commercial Fisheries

The St. Lucie Estuary provides habitats and nursery grounds for a variety of estuarine fish communities (Gilmore, 1977; Gilmore et al., 1983). Species richness in many of the fish communities of the estuary has declined since the 1970s when baseline data were collected. In addition to the general decline in species richness, specific fish communities appear to be affected by salinity and habitat changes. Submerged aquatic vegetation communities provide nursery ground habitat for juvenile stages of reef and recreationally important fishes in the St. Lucie Estuary (Lewis, 1984; Virnstein et al., 1983). This community includes mutton, yellowtail and lane snappers, yellowtail parrot fish, gag grouper, sailor's choice grunt, tarpon, snook, jack crevalle, spotted sea trout, and redfish. Ichthyoplankton recruitment into the St. Lucie Estuary and the Indian River Lagoon is diminished due to flushing that results from regulatory discharges during key times of the year (Gaines and Bertness, 1992). Estuarine fish species that are negatively affected include spotted sea trout, snook, opossum pipefish, and lower trophic level fishes (Gilmore, 1999).

Woodward-Clyde (1994) noted that a shift in species composition of finfish appears to have taken place, with a higher proportion of lower priced species being taken more recently. The increased harvest of species such as menhaden and mullet may also have an effect on the overall ecology and productivity of the lagoon. One species, the spotted sea trout, showed significant decline (over 50 percent) in landings from 1962 to 1988.

Salinity Envelope

Results of this analysis indicated that the St. Lucie Estuary is very sensitive to freshwater input and that modifications to the volume, distribution, circulation, or temporal patterns of freshwater discharges can place severe stress upon the entire ecosystem (Steward et al., 1994). The SFWMD determined that an effort should be made to define the desired optimal salinity regime for the estuary for use as a management goal to guide long-term restoration efforts. Such restoration conditions are, however, distinctly different from the MFL criteria, which are intended to avoid significant harm.

Salinity patterns affect productivity, population distribution, community composition, predator-prey relationships, and food web structure in the inshore marine habitat. Salinity is the master ecological variable that controls important aspects of community structure and food web organization in coastal ecosystems (Myers and Ewel, 1990). In order to develop an environmentally sensitive plan for management of flows from the St. Lucie Estuary watershed, biological and physical information was needed to determine a desirable range of flows to the estuary. In 1975, the South Florida Water Management District (SFWMD) began baseline investigations to determine the seasonal presence of biota and to document the short-term reactions of estuarine organisms under various salinity conditions during controlled regulatory releases and watershed runoff events (Haunert and Startzman, 1980, 1985; Haunert, 1987). Based on these field investigations and subsequent modeling studies, a favorable range of flows, referred to as the "salinity envelope," was defined to occur in the St. Lucie Estuary when inflows were in the range from 350 to 2,000 cfs.

A more detailed understanding of flows is needed to develop a watershed management plan. The full range of natural intra- and interannual variation of salinity regimes, and associated characteristics of timing, duration, frequency, and rate of change, are critical in sustaining the full native biodiversity and integrity of estuarine ecosystems (Estevez, 2000). Better watershed flow distribution targets are needed to ensure the protection of the salinity-sensitive biota in the estuary. It is assumed that species diversity in the St. Lucie Estuary requires the hydrology to have characteristics of a natural system and that the monthly flow distribution is a critical hydrologic characteristic.

Protected Species

Southeastern Florida, in general, has a rich diversity of native flora and fauna. These include endemic and subtropical species that cannot be found anywhere else in the United States. The St. Lucie basin supports a diverse and abundant array of fish and wildlife species, including many endangered and threatened species (**Table 6**).

Table 6. Threatened, Endangered, and Species of Special Concern in Martin and St. Lucie Counties[a]

Common Name	Scientific Name	County[a]	Species Designation[cd]			
			FWC	FDACS	USFWS	CITES
Mammals						
Florida mouse	*Podomys floridanus*	M,S	SSC			
Florida panther	*Felis concolor coryi*	M	E		E	
Sherman's fox squirrel	*Scuirus niger shermani*	M,S	SSC			
Southeastern beach mouse	*Permyscus polionotus niveiventris*	S	T		T	
West Indian manatee	*Trichechus manatus*	M,S	E		E	
Birds						
American oystercatcher	*Haematopus palliatus*	M,S	SSC			
Arctic Peregrine falcon	*Falco peregrinus*	M,S	E		T	
Audubon's crested caracara	*Polyborus plancus audubonii*	M,S	T		T	
Bald eagle	*Haliaeetus leucocephalus*	M,S	T		E	
Black skimmer	*Rynchops niger*	M,S	SSC			
Brown pelican	*Pelecanus occidentalis*	M,S	SSC			
Burrowing owl	*Speotyto cunicularia*	M, S	SSC			
Crested caracara	*Caracara plancus*	M, S	T		T	
Florida sandhill crane	*Grus canadenses pratensis*	M,S	T			
Florida scrub jay	*Aphelocoma coerulescens coerulescens*	M,S	T		T	
Least tern	*Sterna antillarum*	M,S	T			
Limpkin	*Aramus quarauna*	M,S	SSC			
Little blue heron	*Egretta coerulea*	M,S	SSC			
Osprey	*Pandion haliaetus*	S	SSC			
Oystercatcher	*Haematopus palliatus*	S	SSC			
Peragrine falcon	*Falco peragrinus*	M, S	E		E	
Piping plover	*Charadrius melodus*	M,S	T		T	
Reddish egret	*Egretta rufescens*	S	SSC			
Rivulus	*Rivulus marmoratus*	S	SSC			
Red-cockaded woodpecker	*Picoides borealis*	M	T		E	
Roseate spoonbill	*Ajaia ajaia*	M,S	SSC			
Snail kite	*Rostrhamus sociabilis plumbeus*	S	E		E	
Snowy egret	*Egretta thula*	M,S	SSC			
Southeastern American kestrel	*Falco sparverius paulus*	M,S	T			
Tricolor heron	*Egretta tricolor*	M,S	SSC			
White ibis	*Eudocimus albus*	M, S	SSC			
Wood stork	*Mycteria americana*	M,S	E		E	
Reptiles and Amphibians						
American alligator	*Alligator mississippiensis*	M,S	SSC			
Atlantic green turtle	*Chelonia mydas mydas*	M,S	E		E	
Atlantic hawksbill turtle	*Eretmochelys imbricata imbricata*	M	E		E	
Atlantic loggerhead turtle	*Caretta caretta caretta*	M,S	T		T	
Eastern indigo snake	*Drymarchon corais couperi*	M,S	T		T	

a. Source: Nature Conservancy, 1990; FGFFC, 1993; FDEP, 1991; Florida Natural Areas Inventory, 1998; FWS, 2001.

b. County: M = Martin; S = St. Lucie

c. Species Designation: **T** = threatened; **E** = endangered; **SSC** = species of special concern; **C** = commercially exploited species; **R** = species potentially at risk due to restricted geographic range/habitat or sparse distribution

d. Agencies: **FWC** = Florida Fish and Wildlife Conservation Commission – jurisdictional over Florida's animals (vertebrates and invertebrates); **FDACS** = Florida Department of Agriculture and Consumer Services – jurisdictional over Florida's plants; **USFWS** = United States Fish and Wildlife Service – jurisdictional nationally over plants and animals; **CITES** = Convention on International Trade in Endangered Species

Table 6. Threatened, Endangered, and Species of Special Concern in Martin and St. Lucie Counties[a] (Continued)

Common Name	Scientific Name	County[a]	Species Designation[cd]			
			FWC	FDACS	USFWS	CITES
Florida pine snake	*Pituophis melandeucus mugitus*	S	SSC			
Gopher frog	*Rana capito*	M, S	SSC			
Gopher tortoise	*Gopherus polyphemus*	M,S	SSC			
Kemp's ridley	*Lepidochelys kempii*	S	E		E	
Leatherback turtle	*Dermochelys coriacea*	M,S	E		E	
Fish						
Atlantic sturgeon	*Acipenser oxyrinchus*	S	T			
Bigmouth sleeper	*Gobiomorus dormitor*	S	T			
Common snook	*Centropomus undecimalis*	M,S	SSC			
Lake Eustis pupfish	*Cyprinodon variegatus hubbsi*	S	SSC			
Mangrove rivulus	*Rivulus marmoratus*	S	SSC			
Mountain mullet	*Agonostomus monticola*	S	R			
Opossum pipefish	*Microphis brachyurus lineatus*	S	T			
River goby	*Awaous tajasica*	S	T			
Slashcheek goby	*Gobionellus pseudofasciatus*	S	T			
Spottail goby	*Gobionellus stigmaturus*	S	SSC			
Striped croaker	*Bairdiella sanctaeluciae*	S	SSC			
Plants						
Atlantic Coast Florida lantana	*Lantana depressa var Floridana*	M		E		
Banded wild-pine	*Tillandsia flexuosa*	M		E		
Bay cedar	*Suriana maritima*	S		E		
Beach jacquemontia	*Jacquemontia reclinata*	M		E	E	
Beach star	*Remirea maritima*	S		E		
Blunt-leaved peperomia	*Peperomia obtusifolia*	M,S		E		
Burrowing four-o'clock	*Okenia hypogaea*	M,S		E	E	
Butterfly orchid	*Encylia tampensis*	M,S		T		T
Cardinal Wild-pine	*Tillandsia fasciculata var. densispica*	S		E		
Carter's large-flowered flax	*Linum carteri var smallii*	M		E		
Catesby's lily	*Lilium catesbaei*	M,S		T		
Coastal hoary-pea	*Tephrosia angustissima var curtissii*	S		E		
Coastal vervain	*Glandularia maritima*	M,S		E		
Curtiss' milkweed	*Asciepias curtissii*	M,S		E		
Dollar orchid	*Encyclia boothiana var erythroniodes*	M		E		
Florida beargrass	*Nolina atopocarpa*	S		T		
Florida Keys ladies' tresses	*Spirantes polyantha*	M		E		
Florida tree fern	*Ctenitis sloanei*	M		E		
Four-petal pawpaw	*Asimina tetramera*	M		E	E	
Fragrant prickly apple	*Cereus eriophorus var fragrans*	S		E		

a. Source: Nature Conservancy, 1990; FGFFC, 1993; FDEP, 1991; Florida Natural Areas Inventory, 1998; FWS, 2001.

b. County: M = Martin; S = St. Lucie

c. Species Designation: **T** = threatened; **E** = endangered; **SSC** = species of special concern; **C** = commercially exploited species; **R** = species potentially at risk due to restricted geographic range/habitat or sparse distribution

d. Agencies: **FWC** = Florida Fish and Wildlife Conservation Commission – jurisdictional over Florida's animals (vertebrates and invertebrates); **FDACS** = Florida Department of Agriculture and Consumer Services – jurisdictional over Florida's plants; **USFWS** = United States Fish and Wildlife Service – jurisdictional nationally over plants and animals; **CITES** = Convention on International Trade in Endangered Species

Table 6. Threatened, Endangered, and Species of Special Concern in Martin and St. Lucie Counties[a] (Continued)

Common Name	Scientific Name	County[a]	Species Designation[cd]			
			FWC	FDACS	USFWS	CITES
Geiger tree	*Cordia sebestena*	S		E		
Giant leather fern	*Acrostichum danaeifolium*	M,S		T/C		
Giant wild-pine	*Tillandsia utriculata*	S		E		
Golden polypody	*Phlebodium aureum*	S		T		
Green ladies'-tresses	*Spiranthes polyantha*	M		E		
Hand adder's tongue fern	*Ophioglossum palmatum*	M,S		E		
Hand fern	*Cheiroglossa palmata*	M,S		E		
Inkberry	*Scaevola plumieri*	S		T		
Johnson' seagrass	*Halophila johnsonii*	S		T		
Lakela's mint	*Dicerandra immmaculata*	S		E	E	
Large flowered rosemary	*Conradina grandiflora*	M,S		E		
Low peperomia	*Peperomia humilis*	M		E		
Night scent orchid	*Epidendrum nocturnum*	M		T		
Nodding pinweed	*Lechea cernua*	M,S		E		
Non-crested coco	*Pteroglossaspis ecristata*	M		T		
Pepper	*Peperomia humilis*	M,S		E		
Pine pinweed	*Lechea divaricata*	M		E		
Rain lily	*Zephyranthes simpsonii*	M				
Redberry ironwood	*Eugenia confusa*	M		T		
Rigid epidendrum	*Epidendrum rigidum*	M		E		
Sand dune spurge	*Chamaesyce cumulicola*	M,S		E		
Sea lavender	*Argusia gnaphalodes*	M,S		E		
Shoestring fern	*Vittaria lineata*	S		T		
Simpson zephyr lily	*Sephyranthes simpsonii*	M		E		
Small's milwort	*Polygala smallii*	M		E		
Spotless - petaled baim	*Dicerandra immaculata*	S		E		
Tampa vervain	*Glandularia tampensis*	S		E		
Terrestrial peperomia	*Peperomia humilis*	M,S		E		
Tiny polygala	*Polygala smallii*	S		E	E	
Toothed habernaria	*Habenaria odontopetala*	S		T		T
Tropical ironwood	*Eugenia confusa*	M		E		
Twisted air plant	*Tillandsia flexuosa*	M		T		
Twistspine prickly pear	*Opuntia compressa*	S		T		T
Vanilla	*Vanilla mexicana*	M		T		
Venus hair fern	*Adiantum capillus-veneris*	M		T		
Wild coco	*Pterogiossaspis ecristata*	M		T		
Wild cocoa	*Eulophia alta*	M				
Wild pine	*Tillandsia balbisiana*	S		T		

a. Source: Nature Conservancy, 1990; FGFFC, 1993; FDEP, 1991; Florida Natural Areas Inventory, 1998; FWS, 2001.

b. County: M = Martin; S = St. Lucie

c. Species Designation: **T** = threatened; **E** = endangered; **SSC** = species of special concern; **C** = commercially exploited species; **R** = species potentially at risk due to restricted geographic range/habitat or sparse distribution

d. Agencies: **FWC** = Florida Fish and Wildlife Conservation Commission – jurisdictional over Florida's animals (vertebrates and invertebrates); **FDACS** = Florida Department of Agriculture and Consumer Services – jurisdictional over Florida's plants; **USFWS** = United States Fish and Wildlife Service – jurisdictional nationally over plants and animals; **CITES** = Convention on International Trade in Endangered Species

WATER RESOURCE ISSUES

This section summarizes the major water resource issues associated with management of the St. Lucie River and Estuary as identified in a conceptual model of the system.

Hydrologic Alteration of the Watershed

Due to Lake Okeechobee regulatory releases, basin flood releases, basin water withdrawals, and diversion of water from the natural river to the canals, freshwater flow distribution, volume, and timing in the St. Lucie River and Estuary watershed have been altered. Hydrologic alterations affect salinity and siltation patterns resulting in major ecological impacts to every component of the estuarine ecosystem.

Altered salinity patterns affect productivity, population distribution, community composition, predator-prey relationships, and the food web structure in the St. Lucie River and Estuary as evidenced by deteriorating oyster health and abundance, decline in benthic organisms, and the lack of significant submerged aquatic vegetation.

Extensive deposits of ooze and muck in the estuary are related to the transport of organic and inorganic sediments during regulatory and other high volume water releases from the canals. The ooze-covered bottom compromises oyster, fish, and benthic macro invertebrate habitat and has resulted in an increase in pollution-tolerant species. Submerged aquatic vegetation is also affected by the decreased light conditions resulting from siltation.

Input of Nutrients and Dissolved Organic Matter

Water quality within the St. Lucie River and Estuary is threatened by altered freshwater inputs, nutrient loss from agricultural activities, anthropogenic organic compounds, trace elements, and storm water runoff from developed areas. The system has experienced an 100 percent increase in phosphorus load and a 200 percent increase in nitrogen. The dramatic increase in nutrients and dissolved organics degrade water quality and may contribute to the buildup of muck. This results in changes in phytoplankton, macro algae, and submerged aquatic vegetation communities, and creates a generally favorable habitat for primarily pollution-tolerant organisms. The increased nutrients in the St. Lucie Estuary have increased primary productivity within the system to the point that unhealthy levels of dissolved oxygen occur on a regular basis in the inner estuary. The integrity of riverine and estuarine ecosystems is dependent on water quality. As water quality diminishes, so does the overall quality of the system.

Input of Toxins

The estuary has experienced increased input of toxins from agricultural runoff, urban development, and the boating industry. The presence of fish abnormalities and mortality has been noted in recent years. Bioaccumulation of toxins, including metals and pesticides, in the estuarine aquatic food chain may also have secondary effects on fisheating birds and dolphins. A decline in diversity of benthic organisms and the spread of pollution-tolerant macro invertebrates is an indicator of poor water quality in the estuary.

Recreational Use

Population increase in this region has fueled a rapid expansion of the boating and fishing industries resulting in ecological impacts to the St. Lucie River and Estuary. Increased pressure from recreational fisheries has contributed to the significant decline of species such as the spotted sea trout. The increased harvest of species such as menhaden and mullet has an impact on the ecology of the river and estuary.

Physical Alterations to the Estuary

Shorelines and intertidal areas of the estuary that were once populated by mangroves and other detritus producing vegetation now support very little vegetation. In many areas, sea walls and docks have replaced mangrove and sea grass habitats. The natural shoreline vegetation once helped stabilize the substrate, filter storm water runoff, and provide quality habitat. Further, unconsolidated sediments with high amounts of organic material have accumulated in the estuary and are frequently suspended by wave energy (Haunert, 1988). This sedimentation process has degraded habitat for bottom dwelling organisms and added to water quality problems. A significant portion of the floodplain of the North Fork of the St. Lucie River is completely or partially isolated from the river's main branch because of dredging conducted by the USACE during the 1920s through the 1940s. This isolation has compromised the system's nutrient filtering capability. Overall, these current conditions compromise the development of healthy biological communities and reduce the potential for sustaining these communities in the estuary.

Water Supply

Prior to large-scale citrus expansion in the 1960s, canal storage in St. Lucie County was adequate to meet irrigation demands. Subsequent drainage and development have depleted surface water storage while water management for flood protection has reduced ground water storage. The *Upper East Coast Water Supply Plan* (SFWMD, 1998a) analysis of surface water needs estimates that, by 2020, overall water demand is projected to increase by 34 percent. Annual surface water deficit estimates for a 1-in-10 year drought condition and projected demands are shown in **Table 7**. Unmet surface water needs were distributed to available ground water sources, primarily the Floridan Aquifer.

Development of water management and storage infrastructure to effectively capture and store the surface water flows in the St. Lucie basin were proposed in the *Upper East Coast Water Supply Plan* (SFWMD, 1998a) and the *Central and Southern Florida Project Comprehensive Review Study* (USACE and SFWMD 1999), also known as the Restudy. The facilities recommended in the Restudy are being refined and implemented through the CERP. With these facilities in place, the projected future (2020)

Table 7. Annual Surface Water Deficit Estimates for a 1-in-10 Year Drought Condition

Surface Water Basin	Acre-Feet	Millions of Gallons per Day
C-23 Canal	48,476	43.27
C-24 Canal	23,372	20.88
North Fork of the St. Lucie River	18,589	0
Tidal St. Lucie	0	0

surface water needs of the basin and the estuary can be met. The evaluated components, once constructed, would be adequate to meet the demands in the basin during a 1-in-10 year drought event.

Need for Maximum Flow Criteria

For both Lake Okeechobee and the St. Lucie River, floods or extended periods of high water result in the need to release large volumes of water to the St. Lucie Estuary for flood protection purposes. These high volume discharges have been shown to significantly impact the resource. Setting a minimum flow is viewed as a starting point to define the water needs of the estuary for sustainability. The necessary hydrologic regime for restoration of the regional ecosystem must also be defined and implemented through the use of water resource protection tools. Achieving the required water levels and flows through this system in an overall, long-term restoration goal of the CERP and the *Upper East Coast Water Supply Plan* (SFWMD, 1998a).

The maximum flow that should not be frequently exceeded for the estuary is 2,000 cfs. Rates above this amount often occur due to watershed flows alone. Even greater flows occur due to the Lake Okeechobee regulation schedule and pulse releases. The overall ability of the schedule to protect the resource is uncertain due to the limited water storage capacity of the regional system, especially during high rainfall years.

RESOURCE PROTECTION PROGRAMS

Indian River Lagoon SWIM Plan

The *Indian River Lagoon Surface Water Improvement and Management (SWIM) Plan* initially completed in 1989 (SFWMD, 1989) and updated in 1994 (SFWMD, 1994), addresses water quality concerns and environmental water supply needs by providing targets for freshwater inflows to the St. Lucie Estuary and the Indian River Lagoon. Planning and research conducted under the direction of the SWIM program have resulted in the development of a salinity range restoration target for the estuary. Related planning efforts are itemized in **Appendix G**.

Ten Mile Creek Project

The Ten Mile Creek Project is a Critical Restoration Project that was authorized by the United States Congress under Section 528 of the Water Resources Development Act of 1996. The intent of the Ten Mile Creek Project is to attenuate wet season storm water flows into the North Fork of the St. Lucie River from the Ten Mile Creek basin by capturing and storing storm water. The sedimentation of suspended solids will reduce sediment loads delivered to the estuary. The captured storm water will be passed through a polishing cell for additional water quality treatment before being released into the North Fork. Dry season discharge from the reservoir will serve the purpose of recharging local canals for irrigation, resulting in a reduced dependence on the Floridan Aquifer in this area. Construction is scheduled to begin in August 2002.

Indian River Lagoon Feasibility Study

To address the freshwater discharges to the St. Lucie Estuary and Indian River Lagoon, the SFWMD, in cooperation with the USACE, is conducting the Indian River Lagoon Restoration Feasibility Study (USACE and SFWMD, 2001) to investigate regional water resource opportunities in relation to the C&SF Project canal system. Regional attenuation facilities (surface water storage areas) and stormwater treatment areas designed to capture, store, and filter local runoff in the C-23, C-24, C-25, and C-44 basins were evaluated for their ability to attenuate flood flow to the estuary, provide water supply benefits, and provide water quality benefits to control salinity and reduce loading of nutrients, pesticides, and other pollutants contained in runoff presently discharged to the estuary. Contingent upon congressional authorization in 2002, project construction is scheduled to begin by September 2004.

The Indian River Lagoon Feasibility Study (USACE and SFWMD, 2001) refined the salinity targets established for the St. Lucie Estuary during Restudy alternative evaluations and identified an acceptable range of inflows to the estuary to meet targets of 350 cfs to 2,000 cfs (USACE and SFWMD, 1999). Research conducted to establish these inflow targets for the St. Lucie Estuary provided baseline assumptions for MFL technical criteria development, including the understanding that “native aquatic biodiversity depends on maintaining or creating 'some semblance' of natural flow variability, and that native species and natural communities will [may] perish if the environment is [consistently] pushed outside the range of natural variability” (Haunert and Konyha, 2001).

Chapter 3
RESOURCE FUNCTIONS AND CONSIDERATIONS

INTRODUCTION

Once the water resource functions to be protected by a specific minimum flow or level have been defined, the baseline resource conditions for assessing significant harm must be identified. Considerations for making this determination are set forth in Section 373.0421(1)(a), F.S., which requires the water management districts to consider changes and structural alterations that have occurred to a water resource when setting a minimum flow or level.

This chapter identifies the water resource functions of the St. Lucie River and Estuary; summarizes alterations to the resource; and establishes baseline considerations for MFL development. A detailed accounting of structural alterations and operational protocols is presented in **Chapter 2**.

WATER RESOURCE FUNCTIONS AND CONSIDERATIONS

Watershed

The primary resource functions provided by the St. Lucie River watershed that need to be considered in the development of MFLs include water supply, flood control, maintenance and improvement of water quality, the protection of fish and wildlife habitat, and recreation.

Water Supply and Flood Control

The C-23, C-24, and C-25 Canals and control structures were improved under the C&SF Project. Their current functions are 1) to remove excess water from their respective basins; 2) to supply water during periods of low rainfall; and 3) to maintain ground water table elevations at the coastal structures to prevent saltwater intrusion.

The establishment of MFL criteria for the St. Lucie River will aide in resisting saltwater intrusion into the freshwater ground water table along this coast. Increasing risk of saltwater intrusion into coastal wells is an issue in other areas on the southeastern coast of Florida. This problem will only increase through time as development increases, urban water demands increase, and sea levels continue to rise. MFLs for the St. Lucie River will provide a mechanism for protection of the coastal aquifer.

The C&SF Project canal and control structures in the C-44 basin have five functions: 1) to provide drainage and flood protection for the C-44 basin; 2) to accept runoff from the S-153 basin and discharge this runoff to tidewater; 3) to discharge water from Lake Okeechobee to tidewater when the lake is over schedule; 4) to supply water to the C-44 basin during periods of low natural flow; and 5) to provide a navigable waterway from Lake Okeechobee to the Intracoastal Waterway.

Wetland communities in the St. Lucie watershed offer storage, retention, and infiltration sites for surface water flows. Both surface water and ground water sources are used within this watershed to meet potable (urban) water supply needs, and for irrigation of landscape and agricultural crops.

As agricultural and urban development continues, the volume, duration, and frequency of floodwaters may increase. The existing infrastructure of drainage systems was never intended to totally eliminate flooding in developed areas. Natural and undeveloped area in the watershed, as well as the river itself, provide flood control by providing areas for storage and infiltration of runoff as well as a vehicle for moving floodwaters away from developed areas.

Water Quality

Undeveloped lands along the North and South Forks of the St. Lucie River provide an important source of clean fresh water to the estuary. These lands contribute to improved water quality downstream by providing soil stabilization, low pollution loading, reduction of pollutants from runoff, a buffer from urban land uses, maintenance of the oligohaline zone of the river, and reduced risk of hypersalinity to the estuary. Agricultural and urban lands provide sources of excess nutrients, pollutants, and contaminants that may adversely impact downstream resources.

Protection of Fish and Wildlife Habitat

Maintenance of sufficient water depth within the watershed is needed to protect plant and animal communities in wetlands and lakes. Freshwater lakes and wetlands in the watershed provide habitat for wildlife species that is important to both recreational fishing and hunting interests, as well as for predatory animals (e.g., wading birds). Freshwater fish species include largemouth bass, speckled perch, bluegill, shellcracker, redbreast, warmouth, bowfin, channel catfish, and many species of minnows. Game wildlife include deer, wild turkey, hogs, and ducks. The freshwater swamp community contains a number of species of trees and shrubs that provide important specialized habitats and food (e.g., fruits and seeds) to birds, especially migratory and endangered species, and other wildlife. According to Florida Fish and Wildlife Conservation Commission's *Closing the Gaps in Florida's Wildlife Habitat Conservation System* (Cox et al., 1994), the region was identified as an important area in terms of maintaining several wide ranging species that make up an important component of wildlife diversity in the state. Furthermore, the southeastern Florida region is a unique place for the concentration of migratory species. Many birds use the area for wintering, breeding, feeding, and nesting. In addition, several species of marine fish depend on the fresher water estuary as a spawning and nursery area.

River headwaters originating in this watershed flow to protected lands and water bodies. These include the North Fork St. Lucie River Aquatic Preserve, the North Fork St. Lucie River State Buffer Preserve, and the Indian River Aquatic Preserve. These preserves harbor several protected species (e.g., Johnson's sea grass) that rely on appropriate timing and distribution of freshwater inputs to preserve their habitats.

Recreation

Recreational activities that occur in the watershed include hiking, canoeing, camping, birding, fishing, and hunting. Identifying the MFLs required in the river watershed is necessary to provide for adequate access and enjoyable use of the resource. MFLs are also necessary to sustain the vegetation communities that provide the landscape and wildlife that support these recreational activities.

River

The primary resource functions provided by the North and South Fork riverine communities include water storage, maintenance and improvement of water quality, the protection of fish and wildlife habitat, recreation, and cultural values.

Water Storage

Riverine wetland communities offer storage, retention, and infiltration sites for surface water flows.

Water Quality

The North and South Forks of the St. Lucie River provide an important source of clean fresh water to the estuary. The undeveloped lands and riverine wetlands along the North and South Forks provide water that has little, if any, human-contributed sources of pollution. Riverine wetlands provide significant water quality improvements by stabilizing sediments and reducing suspended solids and nutrients, all of which can have negative impacts to the estuarine communities downstream. The proposed MFL criteria protect this community by providing sufficient fresh water needed to sustain it.

Protection of Fish and Wildlife Habitat

Maintenance of sufficient freshwater flows is needed to protect plant and animal communities in the river system. Oligohaline areas provide habitat for freshwater riverine species of fish that are important to both recreational interests and piscivores (e.g., wading birds). Species include largemouth bass, speckled perch, bluegill, shellcracker, redbreast, warmouth, bowfin, channel catfish, and many species of minnows. The riverine wetland community contains a number of species that provide spawning habitats important to these wildlife species.

Recreation

Recreational activities that occur on or along the river include boating, hiking, canoeing, camping, birding, and fishing. Maintenance of minimum levels is required in the river corridor to provide for adequate access (navigation) and enjoyable use of the resource. MFLs are also necessary to sustain the vegetation communities that provide the landscape and wildlife that support these recreational activities. Impacts on recreational uses may occur in the river due to low water levels that impair the ability to move boats downstream.

In addition to concerns about the impact of low water levels on navigation, excessive freshwater flows can cause shoaling in the estuary. This shoaling can impact navigation and biological communities.

Cultural Values

The upper segment of the St. Lucie River is noted for its cultural significance. The river is used extensively by local residents for recreation, as an employment base (e.g., fishing guides), and enjoyment. It plays a key role in the heritage and daily life of those whose families have lived in the area for generations. Establishment of MFLs for the river will, in conjunction with other preservation efforts, aide in maintaining the river's natural values for future generations.

Estuary

The primary resource functions provided by the St. Lucie Estuary include water supply, maintenance and improvement of water quality, the protection of fish and wildlife, and recreation.

Water Supply

Brackish estuarine communities in general require significant amounts of fresh water in order for desirable salinity concentrations to be sustained. The sources of this water can be from runoff, direct rainfall, seepage, or other means, but the majority of it originates from the river. The development of MFLs for the river must also consider the needs of the estuary in order to assure its health.

Typically, the St. Lucie Estuary has suffered from too much fresh water. Although the current effort to establish MFLs for the river will not address the issue of too much fresh water, they will set a minimum flow that will have more importance as freshwater resources in the region become increasingly divided among other uses in the future. Setting the MFL criteria while abundant freshwater sources are still available to the area will help ensure that amount required to sustain the river's resources can be adequately quantified and secured.

Water Quality

Nutrients

Freshwater inflow to the St. Lucie Estuary may provide an important source of inorganic nutrients that support the primary productivity of this system. While excess nutrients may be a concern in terms of eutrophication and potential for hypoxic or anoxic environments associated with organic loading, the St. Lucie Estuary also depends on a minimum input of new nutrients to this system to maintain productivity (Nixon, 1981). It seems unlikely that short-term limitation of new nutrients to the St. Lucie Estuary would lead to a reduction in productivity that would be harmful to the system, but the role of this input of new nutrients should be considered in determining MFLs.

The timing of freshwater inflows can also impact the nature of the phytoplankton community in an estuary. Experimental and theoretical evidence indicates that a pulsed freshwater release will ultimately result in greater production of fish and larger consumers compared to when water is allowed to “trickle” into the system. Larger planktonic primary producers are able to sequester a greater proportion of growth-limiting nutrients when they are presented at elevated concentrations over a short time interval (Suttle et al., 1988). Therefore, a pulsed nutrient supply will select for larger phytoplankton (Turpin and Harrison, 1980; Suttle et al., 1987). This results in a food web based on large-size phytoplankton, which is more efficient in transferring nutrients and energy to higher trophic levels than is a food web based on pico- or nanoplankton (Suttle et al., 1990).

Dissolved and Particulate Organic Carbon

Input of dissolved and particulate organic carbon to estuaries can come from terrestrial or riverine sources, as well as from primary and secondary production within the estuary. Terrestrial inputs of dissolved and particulate organic carbon to the St. Lucie Estuary will be impacted by minimum flow requirements. At this point, no information is available as to the relative importance of this imported carbon to the productivity of the St. Lucie Estuary, but it should also be considered when setting minimum flows. Relative importance of phytoplankton, sea grasses, and terrestrial carbon can be estimated by examining the stable carbon isotope ratios of particulate organic carbon and various marine organisms (e.g., Fry and Sherr, 1984). Reduced import of organic matter could also in turn affect rates of benthic nutrient flux and biological oxygen demand of sediments.

Inorganic Particles and Sediment Quality

Another factor to consider may be the impact of reduced flow on accumulation of low quality muck sediments. By reducing imported organic matter and nutrients, organic loading of muck type sediments in the St. Lucie Estuary may be reduced, and frequency of hypoxic and anoxic events might be reduced. Alternately, reduced flow might also encourage the accumulation of muck sediments in areas where they would otherwise be scoured and carried down stream during periods of higher flow.

Protection of Fish and Wildlife Habitat

Submerged aquatic vegetation, macro invertebrates, and shellfish form prominent components of the St. Lucie River and Indian River Lagoon ecosystems. Sea grass meadows provide habitat for many benthic and pelagic organisms, such as invertebrates and fishes (Thayer et al., 1984), increase benthic primary productivity, and stabilize sediments (Stoner, 1983; Virnstein et al., 1983; Gilmore, 1987; Fonseca and Fisher, 1986; Woodward-Clyde, 1998). Sea grass meadows also provide food sources for trophically and commercially important organisms (Dawes et al., 1995; Virnstein and Cairns, 1986) and can form the basis of detrital food chains (Zieman and Zieman, 1989). In the Indian River Lagoon, sea grasses provide the ecological basis for a fishery industry worth about a billion dollars a year (Virnstein and Morris, 1996). Sea grasses, including the federally-listed Johnson's sea grass (*Halophila johnsonii),* and oysters are sensitive to changes in water quality (Kemp et al., 1983; Twilley et al., 1985) and are often included in monitoring programs as indicators of estuarine health (Tomasko et al., 1996). Restoration and protection of sea grass and oyster beds are major goals of the *Indian River Lagoon Surface Water Improvement and Management (SWIM) Plan* (Steward et al., 1994).

Recreation

Recreational activities that occur in the estuary include boating, birding, and fishing. Maintenance of MFLs is required to sustain the aquatic communities that provide the landscape and wildlife that support these recreational activities.

ALTERATIONS

Hydrologic Changes

During the past century, many changes have occurred to the hydrology of South Florida driven by the need to improve agricultural and urban development, and commercial and recreational use. Changes made to provide drainage and flood protection for cities, homes, and farms; to provide water for irrigation; and to improve boat access for recreational and commercial use have irreversibly altered the structure and biological resources of the St. Lucie River and Estuary. These changes include the following:

- Dredging and filling of tidal and freshwater wetlands throughout the watershed have resulted in the destruction of these critical areas for production of fish and wildlife, and have reduced the capacity to store excess fresh water that falls during the rainy season for subsequent slow release to the estuary during dry periods.
- Loss of shoreline habitat due to dredging and filling of coastal waters has resulted in a dramatic decline in tidal marshes and swamps that provide a natural filter to remove sediments, nutrients, and pollutants from the water column.

- Channelization of tributary rivers and streams has resulted in the major restructuring of the volume, timing, and distribution of freshwater flows to the estuary.
- Construction of the St. Lucie Canal that connects the estuary to Lake Okeechobee has resulted in a major new source of freshwater discharge that did not occur historically.
- Stabilization of the St. Lucie Inlet has resulted in increased rate and volume of freshwater exchange with the ocean. This tidal exchange transformed what was historically a freshwater estuary into a variable salinity estuary.
- Dredging of the Intracoastal Waterway and navigational channels, including the removal of sand and oyster bars that typically inhibit the rate at which freshwater discharges from the river to the sea, have increased the rate of both freshwater and saltwater exchange with the Indian River Lagoon and the Atlantic Ocean.

Water Quality and Biological Changes

Prior to the opening of the St. Lucie Inlet, historical evidence indicates that the system was dominated by freshwater conditions. Natural channels were deep. This suggests that large amounts of fresh water entered the system from a productive watershed, but that sediment loads were low, perhaps the result of a pristine and flat terrain. Submerged aquatic vegetation was abundant, but oysters may have been rare. Fish and wildlife were also abundant.

Hydrologic changes during the past century have altered water quality and biological conditions in the estuary. The estuary has experienced increased loadings of sediments, nutrients, and pollutants; highly varying salinities; increased duration, frequency, and extent of hypoxia and anoxia; and low transparency due to high color. The combination of physical, hydrologic, and water quality changes has resulted in large-scale loss or destruction of habitats, especially tidal marshes, swamps, grass beds, and other benthic communities that naturally form the productivity basis of the food chain for estuarine and coastal ecosystems. Plant and animal communities in this ecosystem have been impacted by habitat alteration and destruction, resulting in increased duration and frequency of phytoplankton blooms, loss of submerged aquatic vegetation, probable expansion and then extirpation of oyster reefs, decline in abundance and catches of commercial and sport fisheries and overall decline in diversity and abundance of wildlife resources.

SUMMARY AND CONCLUSIONS

Based on evaluation of the functions and considerations of the St. Lucie River and Estuary watershed, it was determined that these systems are highly modified from their historical conditions. Without protection of natural resources in the St. Lucie River and Estuary watershed, water quality will become degraded, impacting riverine and estuarine communities downstream. Determination of the lower limit of flows that constitute significant harm to this riverine system, and to the estuary by downstream association, will be linked to the maintenance of salinity levels. Salinity is a major ecological variable that controls important aspects of estuarine community structure and food web (Myers and Ewel, 1990).

EXCLUSIONS

Section 373.0421(1)(b), F.S., provides exclusions from the MFL requirement by recognition that certain water bodies no longer serve their historical function and that recovery of these water bodies to historical conditions may not be feasible. District staff determined it was not appropriate to apply the exclusion in Section 373.0421(1)(b)1, regarding historic functions, to the establishment of minimum levels for St. Lucie River system. This area has been greatly altered by development and associated needs for water supply and flood protection to the extent that full recovery of water levels and flows in the river headwaters, the river itself, and the estuary may be technically and economically infeasible. However, the need to protect and enhance the remaining natural features in this system has been clearly identified. The considerations in Section 373.0421(1)(a), F.S., seem to adequately address the changes and alterations in water resource functions applicable to these areas. As a result, no apparent basis exists to invoke the exclusion in Section 373.0421(1)(b)1, F.S., or to document the economic and technical feasibility of recovery.

The remaining exclusions in subsections 373.0421(1)(b)2 through 3, F.S., pertain to water bodies less than 25 acres in size or constructed water bodies and, as such, are not applicable to the St. Lucie River and Estuary.

Chapter 4
METHODS FOR DEVELOPING MINIMUM FLOW CRITERIA

INTRODUCTION

The District has investigated resources and issues in the St. Lucie Estuary since 1973. The St. Lucie Estuary plays a pivotal role in the operation of the C&SF Project. This estuary is the receiving body for discharges from three canals of the primary water control system in South Florida and provides the eastern connection between the Intracoastal Waterway and the Okeechobee Waterway. In addition, the St. Lucie Estuary is one of two receiving bodies for most of the excess water that must be periodically discharged from Lake Okeechobee. The need for the District and USACE to study this system has been primarily driven by efforts to document the effects of water releases from major canals; provide better methods for release of excess water from Lake Okeechobee; stabilize the St. Lucie (C-44) Canal banks to prevent sloughing and subsequent dumping of sediments to the estuary; and better manage C&SF Project facilities to protect the resources of the St. Lucie Estuary and adjacent waters.

Examples of prior studies by the USACE to determine the effects of discharges from the St. Lucie Canal on the estuary include the following:

- Biological studies of resources in the estuary (Philips and Ingle, 1960; Philips, 1961)
- Studies of the effects of discharges from the canals on these resources (Murdock, 1954; Gunter and Hall, 1963)
- Studies of erosion of the St. Lucie Canal and associated sediment problems in the estuary (USACE 1976, 1994; Williams et al., 1986)

In addition, studies by the District have been conducted for more than 25 years to determine the following:

- Controlled experiments to measure the impacts of high volume releases of water on the estuary (Haunert and Startzman, 1980, 1985)
- An inventory of species and habitats (Woodward-Clyde, 1998, 1999)
- Assessment of bathymetry, sediments, water quality, and nutrient loading in the estuary (Morris, 1986; Haunert, 1988; Chamberlain and Hayward, 1996; Dixon et al., 1994; Schropp et al., 1994)
- Studies of relationships between hydrologic conditions and productivity (Doering,1996; Estevez et al., 1991)

- Literature surveys and mathematical modeling to determine historical watershed characteristics, runoff and salinity conditions in the estuary (see Van Zee in **Appendix D** and McVoy in **Appendix E**)
- Mathematical modeling to determine effects of present and future freshwater flow regimes on the estuary (Morris, 1987; Hu in **Appendix H**; Lin in **Appendix C**; and Qiu in **Appendix F**)

Recently, efforts have shifted toward the need to determine MFL requirements for this system to protect the estuary from significant harm. To initiate this effort, the District contracted with a consultant to conduct a literature review and examine methods being used elsewhere in Florida and nationwide to determine the best strategy for MFL development (Estevez, 2000). This review had several objectives:

- Suggest living resources that can be used as targets, indicators, or criteria for minimum flow determinations in river-dominated estuaries
- Determine how the selection of living resource targets may be affected if working in rivers with long histories of extreme structural and hydrologic alteration
- Summarize lessons learned by other Florida water management districts, other states, and other countries
- Provide an independent expert recommendation of approaches to develop flow management criteria, so as to improve water quality, increase habitat for key organisms, and sustain biodiversity

This effort resulted in specific analyses and recommendations concerning the development of MFLs for the St. Lucie Estuary, including a summary of the relevant goals and objectives, assessment of current knowledge concerning this system, assessment of resources that could provide a basis for establishing quantitative relationships between flows and impacts, and recommended technical approaches. This information was assessed by District staff and was then combined with new information, based on the approaches suggested in this review, to develop technical relationships for MFLs.

Management Goals

Several accounts made by or for the District portray ecological changes to the system during the previous century (Estavez, 2000). Chief among these changes were sedimentation, sediment contamination, altered seasonal flows, highly varying salinities, loss of submerged aquatic vegetation, changes in distribution and composition of oyster reefs, hypoxia and anoxia, phytoplankton blooms, low transparency, and declines in the abundance of valued fish and invertebrate species.

Taken as a whole, these changes may be understood as the consequence of two opposing trends that affect the St. Lucie Estuary. On the one hand, this estuary is becoming more saline during dry periods because an inlet was opened, channels were dug, sea level continues to rise, and local aquifers are salinized or depleted. On the other hand, this system receives more fresh water during wet periods because flood control canals were constructed, the estuary was connected to Lake Okeechobee, and runoff from farmland and impervious urban developments is increasing.

The District seeks to improve the management of freshwater inflow to the estuary. The minimum flow program will be used to define low flow regimes that cause significant harm. Efforts such as the CERP and the associated Indian River Lagoon Feasibility Study (USACE and SFWMD, 2001) provide means to manage high flow events and restore some of the system's lost hydrologic and ecological functions. To guide these efforts, the District has employed three sets of provisional or working goals for the estuary:

- **Set 1** - "Make the benthic environment continuously inhabitable by epifauna and infauna, in densities and diversities that exceed those typical of pollution-indicator communities," and also "make bottom and water conditions able to support some amount of submerged aquatic vegetation, where it presently does not occur in the estuary" (Estevez et al., 1991)
- **Set 2** - "Improve and maintain the health of the St. Lucie Estuary ecosystem (by) promoting and sustaining a healthy oyster population; freshwater, brackish, and marine submersed vegetation; juvenile marine fish and shellfish, and successful recreational and commercial fisheries" (Dixon et al., 1994)
- **Set 3** - "Protect, enhance, and rehabilitate estuarine ecosystems" (SFWMD, 1998b) by "improving water quality, increasing available habitat for key organisms, and sustaining biodiversity" (SFWMD, 1999)

Management Objectives

Based on this analysis, consideration of the impacts of hydrologic alterations that have occurred to the system, and assessment of existing resources (see below), hydrologic management objectives for the St. Lucie Estuary should address the following concerns:

- Reduce high level discharges that have severely impacted the central estuary and adjacent coastal waters by causing rapid and extreme fluctuations in salinity and deposition of large amounts of sand and organic sediments
- Improve water quality by limiting the amount of nutrients and pollutants that enter the estuary
- Protect and enhance hydrologic conditions in the remaining natural river systems and watersheds, especially the remaining North and South Fork systems
- Ensure maintenance of a persistent, but not necessarily extensive, oligohaline zone habitat

Development of MFL criteria provides one of many tools that are needed to address these goals and objectives. These criteria will specifically help maintain oligohaline areas, which will, in turn, help protect and enhance natural systems.

ESTABLISHING HYDROLOGIC MANAGEMENT CRITERIA

Conceptual Basis for Minimum Flows

River management is a complex process that requires consideration of a number of variables. Minimum flows are an important component of riverine flow characteristics. However, providing a minimum flow represents only one aspect of management and/or restoration of river hydrology. Focus on a single aspect of river hydrology (minimum flows) is an overly simplistic treatment of complex ecosystem interactions. Long-term hydrological data, especially measures of variability, have been under utilized in most management decisions aimed at river ecosystem protection or restoration (National Research Council, 1992).

Because of the intrinsic ecological complexity of estuaries, scientists and managers have also objected to the idea that minimum flows can be set for estuaries. Complexity in itself is not a sufficient reason to question the concept of minimum flows for estuaries. In fact, it simply supports the fact that complex biological systems, such as those in estuaries, require more study. Due to the lack of understanding and a shortage of previous attempts to establish minimum flows, estuarine scientists and managers do not have even simplistic minimum flow examples to study or criticize. Rather than waiting until all information is available before making a management decision, the best approach is adaptive: set inflows based on assumptions derived from conceptual and mathematical modeling using best available information, monitor the results for success or failure, continue research, and reevaluate flow targets.

Recent Advances in Flow Analysis

Restoring Natural Flow Regimes

Because modifications of hydrologic regimes in rivers are known to directly and indirectly alter the composition, structure, or function of riverine aquatic and wetland ecosystems, most river scientists tend to agree that it is better to approximate natural flow regimes and maintain entire ensembles of species, than to optimize water regimes for one or a few species. In reality, however, the great majority of in stream determinations have been based on one or a few species' requirements. It is now understood that native aquatic biodiversity depends on maintaining or creating some approximation of natural flow variability, and that native species and communities will perish if the environment is pushed outside the range of natural variability. Where rivers are concerned, a natural flow paradigm is gaining acceptance. It states "the full range of natural intra- and interannual variation of hydrologic regimes, and associated characteristics of timing, duration, frequency, and rate of change, are critical in sustaining the full native biodiversity and integrity of aquatic ecosystems" (Richter et al., 1997). A corollary idea is that ensembles of species and ensembles of habitats should be used to gage the effect of hydrological alteration. Sentiment for a similar paradigm for estuaries is growing. In river-dominated estuaries, it seems reasonable to evaluate both flows and salinities with respect to their multiple forms of variation.

Richter "Range of Variability" Criteria

A new and robust method was developed for determining hydrologic alterations in rivers (Richter et al., 1996). The "range of variability approach" is based on the calculation of means and coefficients of variability of 32 hydrologic variables grouped into five sets:

- Magnitude of monthly water conditions
- Magnitude and duration of annual extreme conditions
- Timing of annual extreme water conditions
- Frequency and duration of high and low pulses
- Rate and frequency of water condition changes

Comparisons are made between "before" and "after" modifications. In the absence of "before" data, models can be used to estimate water conditions. Some alterations affect only a few indicators, whereas others affect many. Patterns of alteration help managers determine the aspects of flow to modify.

This technique employs more variables and offers more promise in protecting ecosystem integrity. It is gaining in popularity and has been used extensively by the Northwest Florida Water Management District in its role in the Apalachicola-Chatahoochee-Flint Tri-State Compact (USACE, 1998). In cases where restoration is sought for a system with no "natural" flow data, it is necessary to employ hydrologic simulation models to estimate historical conditions. While such models may provide good estimates of impact magnitude, they do not illuminate their causes. Nevertheless, the method captures a number of features, especially rates of change, that are not commonly used in estuarine science and management, but may have important effects on estuarine ecosystems.

The "range of variability approach" can be applied, even when flow data are scant, to set initial river management targets for rivers in which the flow regime has been greatly altered by human developments such as dams and large diversions. If adequate stream flow records exist for at least 20 years of natural conditions, the method can be used directly. In the absence of all 20 years of data, missing data can be estimated. In the absence of any data, models may be employed or normalized estimates can be generated from nearby, similar streams. Some hydrologic variables cannot be generated by these latter methods, affecting the power of the technique.

The criteria for streams pose great difficulty for estuarine managers where tributary data are sparse; where tributaries have been extensively altered for long periods of time; or where regulated flows are only part of an estuary's total freshwater budget.

SYNTHESIS AND APPLICATION

Methods Considered for Use in the St. Lucie Estuary

Several general methods were identified that could be used to establish minimum flows for the St. Lucie River and Estuary. Components of five possible approaches are integrated in this study. These methods are described in general terms below, followed by assessments of their applicability.

1. In Stream Flow Methods. Historical flow, hydraulic, or habitat methods can be used to determine acceptable flows of individual tributaries to rivers. This approach presumes that an estuary's needs for fresh water can be met by providing sufficient water to the streams that flow into it. The approach requires that the majority of estuarine inflow be via streams or other gaged surface waters and that data are available or can be obtained.

2. Hydrological Variability Techniques. Following Richter et al. (1996) this approach extends the in stream techniques through a fuller analysis of flow characteristics. An untested but feasible application of the method would be its use with salinity data rather than flow data. Data requirements are large, but most types of salinity data could be generated through the use of models. Results of natural or historical conditions would be compared to existing or predicted conditions of salinity.

3. Habitat Approaches. Browder and Moore (1981) proposed the concept of analyzing the overlap of dynamic and stationary habitat elements for particular species. This approach could be developed more fully. If submerged aquatic vegetation was targeted, for example, the method would query the probability that appropriate depths, sediment types, salinities, and conditions of water clarity coincided under differing flow regimes.

4. Indicator Species. This approach relates a change in abundance, distribution, or condition of particular species to a flow or salinity. Criteria for selection may include a species' commercial, recreational, or aesthetic value; ecological importance; status as a species at risk (threatened, endangered, etc.), or endemism. Statistical methods attempt to match abundance values to appropriately time lagged inflow or salinity conditions.

5. Valued Ecosystems Component Approaches. An extension of the indicator species approach, valued ecosystem component (VEC) analysis also uses statistical methods, but accounts for more known or suspected intermediate variables. Recommended by the United States Environmental Protection Agency (1987) for national estuary programs to characterize constraints to living resources, VEC analysis plays an important part in a general model for the design of eutrophication monitoring programs in

South Florida estuaries. VEC is a goal driven approach that has the ability to focus research and provide managers with short-term alternatives in data poor estuaries.

Assessment of These Methods Relative to the St. Lucie Estuary

In stream flow methods have limited applicability in the St. Lucie Estuary because of physical changes wrought to natural tributaries and the overwhelming influence of canals. Prospects of using hydrological variability techniques also are poor, for the same reason. In order for this method to work, it would be necessary to employ a natural systems model of the St. Lucie watershed and compare the five Richter classes of hydrologic variability to present day conditions. Such hind cast models may not be reliable sources of data for every Richter comparison. Attempts to compare salinities computed from a natural systems model suffer even larger challenges. Although this modeling approach may not provide all of the information needed to manage water flows to the estuary, District staff felt that it could be used successfully to examine one aspect of flow, namely the MFL criteria.

Habitat approaches offer some promise in the St. Lucie Estuary. The District already is working with shoal grass (*Halodule wrightii*) and American oyster (*Crassostrea virginica)* in this regard. Based on a literature review (Woodward-Clyde, 1998), other St. Lucie Estuary species such as widgeon grass (*Ruppia maritima*) and tape grass (*Vallisneria americana*) merit consideration as part of an oligohaline submerged aquatic vegetation community. Although both of these species occur in the St. Lucie system, they are not widespread or persistent, probably due to rapid changes in salinity. District staff determined that although such approaches may be feasible in the future, not enough information is currently available concerning distribution, life histories, and salinity tolerance to establish quantitative relationships between low rates of freshwater flow and impacts on populations of these organisms in the St. Lucie Estuary.

Since a dominant issue within the St. Lucie Estuary is the prolonged duration and spatial expansion of oligohaline waters, a general "oligohaline habitat" merits formal spatial analysis. In light of District goals, the St. Lucie Estuary should possess a permanent low salinity reach, but not an extensive, persistent one. The difficulty of working with habitats that presently are rare or absent is acknowledged. In the St. Lucie Estuary, for example, it may be necessary to plant submerged aquatic vegetation or clutch for oysters to overcome historical recruitment bottlenecks, and then study their responses to managed flows and salinities. Flows could be varied experimentally, or adopted flows could be monitored through time so as to allow periodic assessments of progress and adjustments to flow.

Indicator species can be suggested in addition to submerged aquatic vegetation and oysters, using as guidance the size and value of existing literature for each and their previous successful use in other estuarine inflow studies. Sedentary species such as *Mercenaria*, *Mulinia*, *Corbicula*, or *Rangia* clams, migratory organisms such as blue crabs *(Callinectes sapidus*) and planktonic fish eggs and larvae have been suggested. The advantages of each include their relative ease of capture and estimation of abundance by fishery-independent methods, and the ability to analyze results against salinity and inflow by calculating their respective salinities of maximum abundance (Peebles et al.,1991). The main disadvantage of their use is the time required to collect adequate time series data, because statistical methods attempt to match abundance values to appropriately time lagged inflow or salinity conditions. Insufficient data are presently available to support the use of indicator species as a basis to establish MFL criteria.

Species identified under habitat approaches or indicator species may be taken as VECs. By the VEC method, empirical goals would be stated for the status of each. Causal links would be identified from the status of each species back through proximate and ultimate controlling factors. In a series of St. Lucie Estuary reports for the District (Estevez et al. 1991; Dixon and Hayward, 1995; Dixon et al. 1994; Hayward and Chamberlain, 1993), Mote Marine Laboratory developed and applied a model methodology incorporating VEC analysis.

Proposed Valued Ecosystem Component for the St. Lucie Estuary

The SFWMD Coastal Ecosystem Department's research program supports application of the resource-based management strategy defined as the VEC approach. This evaluation methodology is similar to a program developed as part of the National Estuary Program (USEPA, 1987). For the purposes of this study, the VEC approach is based on the concept that management goals for the St. Lucie River and Estuary can best be achieved by providing suitable environmental conditions that will support certain key species, or key groups of species, that inhabit this system.

A VEC can be defined as a species, community, or set of environmental conditions and associated biological communities that is considered to be critical for maintaining the integrity of this estuarine ecosystem. District staff propose that the oligohaline zone in the St. Lucie River and Estuary be used as a VEC for purposes of establishing minimum flow conditions for the North Fork of the St. Lucie River. Loss or reduction of this resource below a critical level is considered to constitute significant harm.

Potential VEC species within the St. Lucie Estuary

Potential VEC species within the St. Lucie Estuary may include oysters, submerged aquatic vegetation, juvenile marine fish and shellfish as well as commercially and recreationally important fish. The following analysis of the potential to use these organisms as VECs is extracted from the publication by Dixon and Hayward (1995).

Although there may be oysters in the St. Lucie Estuary, specific recent occurrences have not been reported. Benthic surveys in the St. Lucie Estuary have not listed oysters among the organisms identified (Graves and Strom, 1992; Haunert and Startzman, 1980; 1985). There are historical accounts of oyster reefs in the estuary near Stuart (Gunter and Hall, 1963) and of a commercial oyster fishery in Stuart in 1896 (Wilcox, 1896), but landings of the commercial fishery do not include specific harvesting locations. The management plan for the aquatic preserve in the North Fork lists some potential oyster habitat as an ecological feature of the area (Gardner, 1984).

Beds of submerged aquatic vegetation have been reported in the North Fork of the St. Lucie Estuary and along shorelines in the middle estuary. Historical accounts of submerged aquatic vegetation in the St. Lucie Estuary focus on areas of the estuary adjacent to the Indian River system (Gilmore et al., 1983; Phillips, 1961; Virnstein and Campbell, 1987; Young, 1975; Young and Young, 1977; Young et al., 1974). Phillips (1961) reported *Halodule* in the St. Lucie Estuary until freshwater releases removed the species. Historical references to submerged aquatic vegetation often do not include species identifications. The North Fork Aquatic Preserve Management Plan lists *Ruppia maritima* as the only documented species of sea grass in that area (Gardner, 1984).

Little quantitative information exists regarding the responses of submerged aquatic vegetation and oysters to rapid hydrological changes. Most take the form of static salinity ranges and variations where species are found most often, or of anecdotal reports of mortality following a particular drought or storm, with attendant extreme salinity dislocations. Optimum salinities for oysters depend not only on their requirements, but also on salinity tolerances of predators and phytoplankton food stocks. Little information also exists on the frequency and magnitude of acute salinity fluctuations that can be tolerated by the various submerged aquatic vegetation or oysters, although some species-specific guidelines for mean salinities and variations are summarized in Estevez and Marshall (1993). Much work is necessary to identify the dynamic salinity requirements of submerged aquatic vegetation and the effects of salinity stress on flowering, reproduction, and competition.

Historical data on juvenile marine fish and shellfish, as well as commercially and recreationally important fish, exist (Bureau of Sport Fisheries and Wildlife, 1959; Evermann and Bean, 1896; Gilmore, 1977; Gunter and Hall, 1963; Murdock, 1954; USACE, 1956; Van Os et al., 1981; Wilcox, 1896; Young, 1975; Young et al., 1974). Older historical data, although useful in providing a picture of the estuary as it existed, are of little use in range depictions or mapping efforts, due to a general lack of reference to areas sampled. Again historical species occurrences should be presented in context of the physical configuration of the estuary at the time.

Reasonably current data on juvenile and adult fish and shellfish are available (Haunert and Startzman, 1980; 1985). Samples of biota were collected during selected controlled releases of fresh water to identify hydrologic impacts on fisheries in the St. Lucie Estuary. Data from longer-term studies, generally biannual surveys which are conducted by SFWMD, are currently unreduced but could be used to develop seasonal and additional hydrological dependence of species distributions within the St. Lucie Estuary. These data should be reduced and examined together with flows, estuary physical configuration during the sampling, and literature values on environmental requirements of various life stages. Following the analysis, it may be desirable to sample additional selected seasons or discharges using similar methodologies. Environmental requirements of some important fish and shellfish species in the St. Lucie Estuary are summarized in **Table 8**.

Table 8. Environmental Requirements for Some Important St. Lucie Estuary Species[a]

Species	Salinity	Dissolved Oxygen	Substrate/Habitat	Food Items	Food For	Special Requirements
Striped Mullet' *Mugil cephalus*	0-75 ppt	>4 milligram per Liter (mg/l)		Larval and post larval: zooplankton; juvenile: add detritus; adult: eptbenth and benthic micro algae, macrophyte detritus, grazing seagrasses for epiphytes	Fish and birds	Spawn in deeper and cooler waters; larvae use inshore shallows; commercially important
Pink Shrimp *Penaeus duorarum duorarum*	Juvenile: >20 ppt		Sand, shell, and coral; use shallow grass beds in estuary as nurseries	Benthic organisms	Snook, spotted seatrout, and snappers	larval, postlarval, juveniles, and early adults use estuaries; recreationally and commercially important
Brown Shrimp *Penaeus aztecus*	2-40 ppt, but tied to temperature	>3 mg/l	Loose peat; sandy mud	Omnivores; detritus, small invertebrates, or fish, depending on life stages	Carnivorous fish and crustaceans	Commercially and recreationally important
Hard Clam *Mercenaria mercenaria*	12.5-35 ppt	6.8-7.4 mg/l ideal; anoxia - survived for some time	Sand; shelly sand	Currents important in transport of food items; removal of pseudofeces	Mammals, crabs, and fish	Commercially and recreationally important; can close tightly and respire anaerobically when stressed; longer survival time than oysters
King Mackerel *Scomberomorus cavalla* **Spanish Mackerel** *S. maculatus*	32-36 ppt			Menhaden (*Brevoortia sp.);* Anchovy (*Anchoa sp.*)	Tuna, dolphins, bottlenose dolphins, and sharks	Commercially and recreationally important
Spotted Seatrout *Cynoscion nebulosus*	0-37 ppt 20 optimum	>4 m/L	Prefer *Thalassia* and *Halodule* beds next to deep water	Copepods?, crabs; shrimp?, and fish based on size and availability	Fish and birds	Commercially and recreationally important; not migratory; especially vulnerable to abrupt changes in temperature and salinity
Blue Crab *callinectes sapidus*	fresh - 35 ppt; males fresher, females more saline; juveniles 2-21		Shallow salt marsh; small crabs prefer shallow estuary water with soft detritus bottom layer; large crabs prefer deeper estuary water with hard bottom	Omnivorous; cannibalistic	Mammals, fish, and birds	Commercially important
Snook *Centropomus undecimalis*	fresh to seawater		Mangroves	Opportunistic; carnivores; pelagic feeder	Mammals	Recreationally important
Bay Anchovy *Anchoa mitchilli*	0-44 ppt	1.5-11.9 mg/l	Shallow mud to muddy sand; high turbidity preferred	Zooplankton	Fish and sea birds	Not Commercially and recreationally important; important as a forage fish
American Oyster *Crassostrea virginica*	5-32 ppt; brackish water; 20 ppt provides refuge from marine predators	>I mg/l; anoxia -survived for brief periods	Shell, rocky, or thick mud bottoms preferred; soft mud not good	Currents important in transport of food items and removal of pseudofeces	Mammals, crabs, and fish	Commercially important; able to respire anaerobically for short periods; able to survive brief anoxic periods

a. Source - Dixon and Hayward, 1995

Selection of Species for Enhancement, Protection, and Management

Species selected for management should be drawn from native, noninvasive organisms that occur along a normal regional estuarine gradient, as exemplified by a suitable system in the region. The environmental requirements for sea grasses are less well known than for fish and shellfish and selecting a single species of submerged aquatic vegetation for protection and enhancement is a difficult task. Specific information on submerged aquatic vegetation coverage in the St. Lucie Estuary is lacking, but given the apparent general lack of submerged aquatic vegetation, a more appropriate approach would be to monitor management success based on the appearance of any species of submerged aquatic vegetation. Periodic surveys (annual and biannual) would assess coverage and condition of the beds.

Information on the commercial value and historical landings of various species is available in the literature (Wilcox, 1896) and more recently through trip tickets instituted under National Marine Fishery programs. Recreational value of various species is more difficult to establish, but a creel census (Van Os et al., 1981) in the early 1980s could be used to rank "recreationally desirable" species. Experience of District personnel and local marine extension agents could undoubtedly be used to summarize user groups (i.e., concerned citizens and commercial and recreational fishermen) input. A preliminary (unranked) list might include *Scomberomorus cavalla* and *S. maculatus* (king and Spanish mackerel), *Cynoscion nebulosus* (trout), *Sciaenops ocellatus* (redfish), *Centropomus undecimalis* (common snook), *Mugil cephalus* (striped mullet), *Megalops atlanticus* (tarpon), and *Trachinotus carolinus* (pompano).

Ecological importance is difficult to define and can emphasize top predators on the assumption that their presence indicates the health of the entire trophic structure, or keystone species on which others depend. Other important species are those that convert phytoplankton to fish biomass, forming the base of the trophic structure. A more representative approach would select several species from various feeding guilds to monitor the interactions of various trophic levels and perhaps trace any change in structure experienced by the estuary over time. Sufficient literature information exists to identify representatives of various trophic levels and to select these species from the species lists indigenous to the St. Lucie Estuary

In actual practice, the sampling and monitoring programs used to evaluate management effects on a single species, whether submerged aquatic vegetation or fisheries, will also effectively and economically gather information on multiple species. These data should be retained and used to evaluate overall success. Progress reports to user groups may choose to emphasize one species over another, but should not represent the entire evaluation process.

Management efforts could aim to provide suitable environmental conditions at areas of appropriate potential habitat for selected species. It should be recognized, however, that water quality goals may be achieved, while seasonal distributions, recruitment patterns, and recovery times may delay the return of the selected VEC.

PROCESS USED TO DEVELOP MFL CRITERIA

Literature Review

Importance of the Oligohaline Zone

Appendix B, a summary of available literature regarding species that occur in the oligohaline zones in estuaries, was prepared to assist in the development of criteria for the St. Lucie Estuary. Key findings based on this appendix are presented below. Based on results of this study, District staff infer that the oligohaline zone in the St. Lucie Estuary must be important because it provides critical habitat for many species that utilize the river, the adjacent Indian River Lagoon, and the offshore reefs.

An estuary is defined as the area where a river meets the ocean. Fresh water from the river carries nutrients and organisms into the estuary where they provide a nutritional basis for a highly productive transitional food chain. The resulting change in salinity conditions produces a stressful environment that, on the one hand, restricts the number of organisms, but on the other hand, provides a highly productive environment for species that are adapted to survive this stress.

The oligohaline zone in an estuary is an area where salinity conditions are low. Although the exact definition may vary among authors, it is generally considered to occur within the range from 0.5- to 5.0-ppt salinity. This zone is important because it supports important physical, chemical, and biological processes that are necessary to maintain the range of ecological, species, and habitat diversity in the region that includes the St. Lucie River system, the Indian River Lagoon, and the adjacent waters of the Atlantic Ocean. The oligohaline zone provides a buffer or interface between fresh and marine waters that provides habitat and a nursery function for juveniles and adults of both estuarine and marine organisms. These organisms include the juveniles and adults of fishes, shrimps, and crabs that support important regional food fisheries and sport fishing. A broader array of other species that provide necessary food sources and habitat, including aquatic vegetation, micro invertebrates, macro invertebrates, and insects also inhabit this zone. A list of representative fish and shellfish species that occur in oligohaline waters in the St. Lucie Estuary is provided in **Table 9**.

Included in the **Table 9** are species identified by Gilmore (1977) as common or abundant estuarine or marine species of the Indian River Lagoon. The Indian River Lagoon is a narrow estuarine lagoon system extending from Ponce de Leon Inlet in Volusia County south to Jupiter Inlet in Palm Beach County. It lies within the zone of overlap between two well known fish faunal regimes (i.e., the warm temperate Carolinian and the tropical Caribbean). A total of 454 fish species were identified in the study and were characterized by regional biotype in addition to relative abundance (rare, occasional, frequent, common, or abundant). For purposes of our investigation only those estuarine, oligohaline species collected in freshwater tributaries and canals and ranging in relative abundance from frequent to abundant were included in this list. The time of year or exact salinities in which these species were captured can not be determined from the publication.

Table 9. A Partial List of Fish and Shellfish Collected in Oligohaline Waters

Scientific Name	Common Name	Size Class			Location	Reference (Full citations included in Appendix B)
		Adult	Juvenile	Not Specified		
Achirus lineatus[a]	Lined sole			✔	St. Louis Bay, Missouri	Hackney and de la Cruz, 1981
Adinia xenica	Diamond killifish			✔	St. Louis Bay, Missouri	Hackney and de la Cruz, 1981
Albula vulpes[a]	Bonefish		✔		St. Lucie River, Florida	Haunert and Startzman, 1985
Alosa aestivalis	Blueback herring			✔	North Carolina	Rozas and Hackney, 1984
Alosa alabamae	Alabama shad			✔	Lake Maurepas, Louisiana	Hastings et al., 1987
Alosa chysochloris	Skipjack herring			✔	Lake Maurepas, Louisiana	Hastings et al., 1987
Alosa pseudoharengus	Alewife		✔		Parker River Estuary, Massachusetts	Hughes et al., 2000
Amia calva	Bowfin			✔	Lake Maurepas, Louisiana	Hastings et al., 1987
Anguilla rostrata	American eel			✔	Lake Maurepas, Louisiana Parker River Estuary, Massachusetts	Hastings et al., 1987 Hughes et al., 2000
Anchoa mitchilli[a]	Bay Anchovy	✔	✔		Not specified St. Lucie River, Florida York River, Virginia Barataria Basin, Louisiana St. Louis Bay, Missouri North Carolina Calcasieu Estuary, Louisiana Lake Maurepas, Louisiana. Old Fort Bayou, Missouri Little Manatee River, Florida	Gunter, 1961 Gunter and Hall, 1963 Markle, 1976 Day et al., 1981 Hackney and de la Cruz, 1981 Rozas and Hackney, 1984 Felley, 1987 Hastings et al., 1987 Peterson and Ross, 1991 Edwards, 1992
Apeltes quadracus	Four-spined stickleback			✔	Parker River Estuary, Massachusetts	Hughes et al., 2000
Aphredoderus sayanus	Pirate perch			✔	Lake Maurepas, Louisiana	Hastings et al., 1987
Aplodinotus grunniens	Freshwater drum			✔	Lake Maurepas, Louisiana	Hastings et al., 1987
Archosargus probatocephalus[a]	Sheepshead			✔	Lake Maurepas, Louisiana	Hastings et al., 1987
Arius felis[a]	Hardhead catfish	✔	✔	✔	Lake Maurepas, Louisiana Little Manatee River, Florida St. Lucie River, Florida	Hastings et al., 1987 Edwards, 1992 Gunter and Hall, 1963
Astroscopus sp.	Stargazer			✔	North Carolina	Rozas and Hackney, 1984
Bagre marinus[a]	Gafftopsail catfish			✔	Lake Maurepas, Louisiana	Hastings et al., 1987
Bairdiella chrysoura[a]	Silver perch			✔	York River, Virginia North Carolina	Markle, 1976 Rozas and Hackney, 1984
Brevoortia patronus	Gulf menhaden		✔		Grand and White Lakes, Louisiana Calcasieu Estuary, Louisiana Lake Maurepas, Louisiana Old Fort Bayou, Missouri	Gunter, 1961 Felley, 1987 Hastings et al., 1987 Peterson and Ross, 1991
Brevoortia smithii[a]	Fine-scale menhaden		✔		St. Lucie River, Florida	Gunter and Hall, 1963
Brevoortia tyrannus[a]	Atlantic menhaden		✔		North Carolina	Rozas and Hackney, 1984

a. Species found in the St. Lucie Estuary (Gunter and Hall, 1963; Haunert and Startzman, 1980, 1985)

Table 9. A Partial List of Fish and Shellfish Collected in Oligohaline Waters (Continued)

Scientific Name	Common Name	Size Class: Adult	Size Class: Juvenile	Size Class: Not Specified	Location	Reference (Full citations included in Appendix B)
Callenectes sapidus[a]	Blue crab	✔	✔		Grand and White Lakes, Louisiana Barataria Basin, Louisiana St. Louis Bay, Missouri	Gunter, 1961 Day et al., 1981 Hackney and de la Cruz, 1981
Caranx hippos[a]	Crevalle jack			✔	Lake Maurepas, Louisiana	Hastings et al., 1987
Carpoides carpio	River carpsucker			✔	Lake Maurepas, Louisiana	Hastings et al., 1987
Catostomus commersoni	White sucker		✔		Parker River Estuary, Massachusetts	Hughes et al., 2000
Centropomus undecimalis[a]	Snook		✔		St. Lucie River, Florida Indian River Lagoon, Florida Little Manatee River, Florida	Gunter and Hall, 1963 Haunert and Startzman, 1980, 1985 Peterson and Gilmore, 1991 Edwards, 1992
Citharichthys spilopterus[a]	Bay whiff			✔	Lake Maurepas, Louisiana	Hastings et al., 1987
Crangon septemspinosa	Sand shrimp			✔	Parker River Estuary, Massachusetts	Hughes et al., 2000
Cynoscion arenarius	Sand seatrout			✔	Lake Maurepas, Louisiana	Hastings et al., 1987
Cynoscion nebulosus[a]	Spotted seatrout		✔	✔	St. Louis Bay, Missouri Little Manatee River, Florida	Hackney and de la Cruz, 1981 Edwards, 1992
Cynoscion regalis[a]	Weakfish			✔	York River, Virginia	Markle, 1976
Cyprinodon variegatus[a]	Sheepshead minnow			✔	Lake Maurepas, Louisiana	Hastings et al., 1987
Cyprinus carpio	Common carp			✔	Lake Maurepas, Louisiana	Hastings et al., 1987
Dasyatis sabina[a]	Atlantic stingray			✔	Lake Maurepas, Louisiana	Hastings et al., 1987
Diapterus olisthostomus[a]	Sand perch			✔	St. Lucie River, Florida	Gunter and Hall, 1963
Diapterus plumieri[a]	Striped mojarraC			✔	Little Manatee River, Florida	Edwards, 1992
Dormitor maculatus	Fat St. Lucie Estuaryeper			✔	North Carolina	Rozas and Hackney, 1984
Dorosoma cepedianum[a]	Gizzard shad			✔	North Carolina St. Lucie River, Florida Lake Maurepas, Louisiana	Rozas and Hackney, 1984; Haunert and Startzman, 1985 Hastings et al., 1987
Dorosoma petenense[a]	Threadfin shad			✔	Lake Maurepas, Louisiana	Hastings et al., 1987
Elassoma zonatum	Banded pygmy sunfish			✔	Lake Maurepas, Louisiana	Hastings et al., 1987
Eleotris pisonis	Spinycheek St. Lucie Estuaryeper			✔	North Carolina	Rozas and Hackney, 1984
Elops saurus[a]	Ladyfish		✔	✔	James River, Virginia St. Lucie River, Florida Lake Maurepas, Louisiana	Govoni and Merriner, 1978; Haunert and Startzman, 1985 Hastings et al., 1987
Enneacanthus gloriosus[a]	Bluespotted sunfish			✔	Atlantic coast	Rozas and Hackney, 1983 citing Raney and Massmann, 1953

a. Species found in the St. Lucie Estuary (Gunter and Hall, 1963; Haunert and Startzman, 1980, 1985)

Table 9. A Partial List of Fish and Shellfish Collected in Oligohaline Waters (Continued)

Scientific Name	Common Name	Size Class: Adult	Size Class: Juvenile	Size Class: Not Specified	Location	Reference (Full citations included in Appendix B)
Esox niger	Chain pickerel			✔	Parker River Estuary, Massachusetts	Hughes et al., 2000
Euciniostomus juveniles[a]	Mojarra		✔		Little Manatee River, Florida	Edwards, 1992
Eucinostomus argenteus[a]	Spotfin Mojarra			✔	St. Lucie River, Florida	Gunter and Hall, 1963
Eucinostomus lefroyi	Mottled mojarra			✔	North Carolina	Rozas and Hackney, 1984
Evorthodus lyricus[a]	Lyre goby			✔	St. Louis Bay, Missouri North Carolina	Hackney and de la Cruz, 1981 Rozas and Hackney, 1984
Fundulus chrysotus	Golden topminnow			✔	Gulf Coast Lake Maurepas, Louisiana	Hastings et al., 1987
Fundulus confluentus[a]	Marsh killifish			✔	St. Louis Bay, Missouri	Hackney and de la Cruz, 1981
Fundulus diaphanus	Banded killifish			✔	Parker River Estuary, Massachusetts	Hughes et al., 2000
Fundulus grandis[a]	Gulf killifish			✔	St. Louis Bay, Missouri Lake Maurepas, Louisiana	Hackney and de la Cruz, 1981 Hastings et al., 1987
Fundulus heteroclitus	Mummichog			✔	North Carolina Plum Island Sound, Massachusetts Parker River Estuary, Massachusetts.	Rozas and Hackney, 1984 Deegan and Garritt, 1997 Hughes et al., 2000
Fundulus jenkinsi	Saltmarsh topminnow			✔	Old Fort Bayou, Missouri	Peterson and Ross, 1991
Fundulus luciae	Spotfin killifish			✔	North Carolina	Rozas and Hackney, 1984
Fundulus pulvereus	Bayou killifish			✔	Lake Maurepas, Louisiana Old Fort Bayou, Missouri	Hastings et al., 1987 Peterson and Ross, 1991
Fundulus seminolis[a]	Seminole killifish			✔	Little Manatee River, Florida	Edwards, 1992
Gambusia affinis[a]	Mosquitofish	✔	✔		St. Lucie River, Florida North Carolina St. Lucie River, Florida Lake Maurepas, Louisiana Little Manatee River, Florida	Gunter and Hall, 1963 Rozas and Hackney, 1984 Haunert and Startzman, 1985 Hastings et al., 1987 Edwards, 1992
Gobionellus boleosoma[a]	Darter goby			✔	St. Lucie River, Florida	Gunter and Hall, 1963
Gobionellus hastatus[a]	Sharptail goby			✔	North Carolina	Rozas and Hackney, 1984
Gobionellus shufeldti	Freshwater goby			✔	North Carolina Lake Maurepas, Louisiana	Rozas and Hackney, 1984 Hastings et al., 1987
Gobiosoma bosc[a]	Naked goby			✔	St. Louis Bay, Missouri Lake Maurepas, Louisiana	Hackney and de la Cruz, 1981 Hastings et al., 1987
Heterandria formosa[a]	Least killifish			✔	St. Lucie River, Florida Lake Maurepas, Louisiana	Gunter and Hall, 1963; Hastings et al., 1987
Ictalurus catus[a]	White catfish	✔	✔		St. Lucie River, Florida York River, Virginia North Carolina St. Lucie River, Florida	Gunter and Hall, 1963 Markle, 1976 Rozas and Hackney, 1984 Haunert and Startzman, 1985

a. Species found in the St. Lucie Estuary (Gunter and Hall, 1963; Haunert and Startzman, 1980, 1985)

Table 9. A Partial List of Fish and Shellfish Collected in Oligohaline Waters (Continued)

Scientific Name	Common Name	Size Class: Adult	Size Class: Juvenile	Size Class: Not Specified	Location	Reference (Full citations included in Appendix B)
Ictalurus furcatus	Blue catfish			✔	Lake Maurepas Louisiana	Hastings et al., 1987
Ictalurus melas	Black bullhead			✔	Lake Maurepas, Louisiana	Hastings et al., 1987
Ictalurus natalis	Yellow bullhead			✔	Lake Maurepas, Louisiana	Hastings et al., 1987
Ictalurus nebulosus[a]	Brown bullhead			✔	St. Lucie River, Florida	Gunter and Hall, 1963
Ictalurus punctatus[a]	Channel catfish			✔	York River, Virginia Lake Maurepas, Louisiana	Markle, 1976 Hastings et al., 1987
Ictiobus bubalus	Smallmouth buffalo			✔	Lake Maurepas, Louisiana	Hastings et al., 1987
Labidesthes sicculus	Brook silverside			✔	Lake Maurepas, Louisiana	Hastings et al., 1987
Lagondon rhomboides[a]	Pinfish			✔	North Carolina Little Manatee River, Florida	Rozas and Hackney, 1984 Edwards, 1992
Leiostomus xanthurus[a]	Spot			✔	York River, Virginia North Carolina Lake Maurepas, Louisiana Little Manatee River, Florida	Markle, 1976 Rozas and Hackney, 1984 Hastings et al., 1987 Edwards, 1992
Lepisosteus oculatus	Spotted gar			✔	Lake Maurepas, Louisiana	Hastings et al., 1987
Lepisosteus ossesus	Longnose gar			✔	North Carolina Hastings et al., 1987	Rozas and Hackney, 1984; Hastings et al., 1987
Lepisosteus spatula	Alligator Gar			✔	Lake Maurepas, Louisiana	Hastings et al., 1987
Lepomis gibbosus	Pumpkinseed	✔	✔		North Carolina	Rozas and Hackney, 1984
Lepomis gulosus	Warmouth			✔	Lake Maurepas, Louisiana	Hastings et al., 1987
Lepomis macrochirus[a]	Bluegill	✔	✔		St. Louis Bay, Missouri Lake Maurepas, Louisiana Little Manatee River, Florida Plum Island Sound, Massachusetts.	Hackney and de la Cruz, 1981 Hastings et al., 1987 Edwards, 1992 Deegan and Garritt, 1997
Lepomis meglaotis	Longear sunfish			✔	Lake Maurepas, Louisiana	Hastings et al., 1987
Lepomis microlophus[a]	Redear sunfish			✔	Lake Maurepas, Louisiana	Hastings et al., 1987
Lepomis punctatus	Spotted sunfish			✔	Lake Maurepas, Louisiana	Hastings et al., 1987
Lepomis symmetricus	Bantam sunfish			✔	Lake Maurepas, Louisiana	Hastings et al., 1987
Lucania parva[a]	Rainwater killifish			✔	St. Louis Bay, Missouri Lake Maurepas, Louisiana Little Manatee River, Florida	Hackney and de la Cruz, 1981 Hastings et al., 1987 Edwards, 1992
Lutjanus griseus[a]	Gray snapper			✔	St. Lucie River, Florida	Gunter and Hall, 1963
Megalops atlanticus[a]	Tarpon		✔		St. Lucie River, Florida	Haunert and Startzman, 1985
Membras martinica[a]	Rough silverside			✔	St. Louis Bay, Missouri	Hackney and de la Cruz, 1981
Menidia beryllina[a]	Inland or tidewater silverside			✔	North Carolina Calcasieu Estuary, Louisiana Lake Maurepas, Louisiana Old Fort Bayou, Missouri Little Manatee River, Florida	Rozas and Hackney, 1984 Felley, 1987 Hastings et al., 1987 Peterson and Ross, 1991 Edwards, 1992

a. Species found in the St. Lucie Estuary (Gunter and Hall, 1963; Haunert and Startzman, 1980, 1985)

Table 9. A Partial List of Fish and Shellfish Collected in Oligohaline Waters (Continued)

Scientific Name	Common Name	Size Class: Adult	Size Class: Juvenile	Size Class: Not Specified	Location	Reference (Full citations included in Appendix B)
Menidia menidia[a]	Atlantic silverside			✔	Plum Island Sound, Massachusetts Parker River Estuary, Massachusetts	Deegan and Garritt, 1997 Hughes et al., 2000
Microgobius gulosus[a]	Clown goby			✔	Lake Maurepas, Louisiana	Hastings et al., 1987
Micropogonias undulatus[a]	Atlantic croaker		✔	✔	Grand and While Lakes, Louisiana York River, Virginia Upper Barataria Basin, Louisiana North Carolina Lake Maurepas, Louisiana	Gunter, 1961 Markle, 1976 Day et al., 1981 Rozas and Hackney, 1984 Hastings et al., 1987
Micropterus salmoides[a]	Largemouth bass	✔	✔		St. Louis Bay, Missouri North Carolina Lake Maurepas, Louisiana	Hackney and de la Cruz, 1981 Hackney and Rozas, 1984 Hastings et al., 1987
Morone americana	White perch			✔	York River, Virginia Plum Island Sound, Missouri	Markle, 1976 Deegan and Garritt, 1997
Morone chrysops	White bass			✔	Lake Maurepas, Louisiana	Hastings et al., 1987
Morone mississippiensis	Yellow bass			✔	Lake Maurepas, Louisiana	Hastings et al., 1987
Morone saxatilis	Striped bass	✔	✔	✔	York River, Virginia North Carolina Lake Maurepas, Louisiana	Markle, 1976 Rozas and Hackney, 1984 Hastings et al., 1987
Mugil cephalus[a]	Striped mullet[a]		✔	✔	St. Lucie River, Florida St. Louis Bay, Missouri North Carolina Lake Maurepas, Louisiana Little Manatee River, Florida	Haunert and Starzman, 1980 Hackney and de la Cruz, 1981 Rozas and Hackney, 1984 Hastings et al., 1987 Edwards, 1992
Mugil curema[a]	Silver mullet[a]		✔		St. Lucie River, Florida	Gunter and Hall, 1963
Myrophis punctatus	Speckled worm eel			✔	North Carolina Lake Maurepas, Louisiana	Rozas and Hackney, 1984 Hastings et al., 1987
Notemigonus crysoleucas[a]	Golden shiner			✔	St. Lucie River, Florida Lake Maurepas, Louisiana	Hastings et al., 1987, 2000
Notropis emiliae	Pugnose minnow			✔	Lake Maurepas, Louisiana	Hastings et al., 1987
Notropis petersonii	Coastal shiner			✔	Old Fort Bayou, Missouri	Peterson and Ross, 1991
Noturus gyrinus	Tadpole madtom			✔	Lake Maurepas, Louisiana	Hastings et al., 1987
Oligoplites saurus[a]	Leatherjacket			✔	St. Louis Bay, Missouri	Hackney and de la Cruz, 1981
Osmerus mordax	Rainbow smelt			✔	Parker River Estuary, Massachusetts	Hughes et al., 2000
Palaemonetes bulgaris	Grass shrimp			✔	Parker River Estuary, Massachusetts	Hughes et al., 2000
Palaemonetes pugio	Grass shrimp	✔	✔		St. Louis Bay, Missouri North Carolina	Hackney and de la Cruz, 1981 Rozas and Hackney, 1984
Paralichthys lethostigma	Southern flounder		✔		North Carolina Calcasieu Estuary, Louisiana Lake Maurepas, Louisiana	Rozas and Hackney, 1984 Felley, 1987 Hastings et al., 1987

a. Species found in the St. Lucie Estuary (Gunter and Hall, 1963; Haunert and Startzman, 1980, 1985)

Table 9. A Partial List of Fish and Shellfish Collected in Oligohaline Waters (Continued)

Scientific Name	Common Name	Size Class: Adult	Size Class: Juvenile	Size Class: Not Specified	Location	Reference (Full citations included in Appendix B)
Farfantepenaeus aztecus[a]	Brown shrimp		✔	✔	Grand and White Lakes, Louisiana St. Lucie River, Florida Old Fort Bayou, Missouri	Gunter, 1961 Peterson and Ross, 1991
Farfantepenaeus setiferus	White shrimp		✔	✔	Grand and White Lakes, Louisiana Calcasieu Estuary, Louisiana Old Fort Bayou, Missouri	Gunter, 1961 Gunter and Hall, 1963 Felley, 1987 Peterson and Ross, 1991
Petromyzon marinus	Sea lamprey			✔	Parker River Estuary, Massachusetts	Hughes et al., 2000
Pleuronectes americanus	Winter Flounder			✔	Plum Island Sound, Missouri	Deegan and Garritt, 1997
Poecilia latipinna[a]	Sailfin molley			✔	Little Manatee River, Florida	Edwards, 1992
Pogonias cromis[a]	Black drum			✔	Lake Maurepas, Louisiana	Hastings et al., 1987
Polyodon spathula	Paddlefish			✔	Lake Maurepas, Louisiana	Hastings et al., 1987
Pomatomus saltatrix[a]	Bluefish			✔	North Carolina Plum Island Sound, Missouri	Rozas and Hackney, 1984 Deegan and Garritt, 1997
Pomoxis annularis	White crappie			✔	Lake Maurepas, Louisiana	Hastings et al., 1987
Pomoxis nigromacuatus[a]	Black crappie			✔	North Carolina St. Lucie River, Florida Lake Maurepas, Louisiana	Rozas and Hackney, 1984 Haunert and Startzman, 1985 Hastings et al., 1987
Pungitius pungitius	Nine-spined stickleback			✔	Parker River Estuary, Massachusetts	Hughes et al., 2000
Pylodictus olivaris	Flathead catfish			✔	Lake Maurepas, Louisiana	Hastings et al., 1987
Sciaenops ocellatus[a]	Red drum		✔	✔	St. Lucie River, Florida Little Manatee River, Florida	Haunert and Starzman, 1980 Edwards, 1992
Strongylura marina[a]	Atlantic needlefish			✔	North Carolina Lake Maurepas, Louisiana	Rozas and Hackney, 1984 Hastings et al., 1987
Symphurus plagiusa[a]	Blackcheek tonguefish			✔	Gulf and Atlantic Coasts	Rozas and Hackney, 1983 citing Rounsefell, 1964
Syngnathus fuscus	Northern pipefish			✔	Parker River Estuary, Massachusetts	Hughes et al., 2000
Syngnathus louisianae[a]	Chain pipefish			✔	Gulf Coast	Rozas and Hackney, 1983 citing Dahlberg, 1972
Sygnathus scovelli[a]	Gulf pipefish			✔	Lake Maurepas, Louisiana	Hastings et al., 1987
Synodus foetens[a]	Inshore lizardfish			✔	Gulf Coast	Rozas and Hackney, 1983 citing Dahlberg, 1972
Trinectes maculatus[a]	Hogchoker			✔	Grand and White Lakes, Louisiana York River, Virginia Lake Maurepas, Louisiana Little Manatee River, Florida	Gunter, 1961 Markle, 1976 Hastings et al., 1987 Edwards, 1992

a. Species found in the St. Lucie Estuary (Gunter and Hall, 1963; Haunert and Startzman, 1980, 1985)

The District conducted fish surveys (1975-1976 and 1981-1983) using an otter trawl and seine at nineteen locations throughout the St. Lucie Estuary (Haunert and Startzman, 1980; Haunert, 1987). These surveys documented 101 species of which many were found throughout the estuary and did not have a propensity for low salinity habitat in the dry season. However, the surveys also revealed that the juveniles of important forage fish did prefer low salinity habitat during the dry season (**Table 10**). In addition, juvenile redfish *(Sciaenops ocellata)*, an important game fish, was frequently captured only in low salinity waters from October to February.

Table 10. St. Lucie Estuary Juvenile Fish Species that Utilize Low Salinity Habitat during the Dry Season (October to May)[a]

Fish Species	Period of Utilization
Striped mullet (*Mugil cephalus*)	January to May
Bay anchovy (*Anchoa mitchilli*)	November to January
Silver perch (*Bairdiella chrysoura*)	April to May
Croaker (*Micropogonias undulatus*)	October to May
Redfish (*Sciaenops ocellata*)	October to February

a. Source: Haunert and Startzman, 1980

Location of Oligohaline Habitat

In his analysis of previous research studies that could provide a basis to establish flow criteria for the St. Lucie Estuary, Estevez (2000) concluded that the St. Lucie Estuary should possess a permanent, low salinity reach. Although most of the estuary may become oligohaline during high discharge periods, the areas where oligohaline habitat occurred under natural (predrainage) conditions were the upstream reaches of the major tributary streams and rivers. Many of the natural streams, such as Bessey Creek, have been channelized and their watersheds altered by dredging and filling. However, two relatively extensive riverine systems remain within the watershed: the North Fork River and the South Fork River.

Water Quality

In the St. Lucie Estuary, construction of major drainage canals has greatly increased the effective boundaries of the watershed. The canals thus contribute larger amounts of freshwater flow and higher levels of nutrient loading than occurred under historic conditions through the natural streams. Flows from the remaining natural streams and watersheds have been reduced.

Data collected by the SFWMD indicate that high levels of phosphorus and nitrogen loading occur periodically when these canals are discharging and the estuary is receiving excessive amounts of nutrients. The average concentrations of phosphorus and nitrogen observed in the St. Lucie Estuary are in the “poor” to “fair” range when compared to other Florida estuaries (Hand et al., 1990, 2001b; Chamberlain and Hayward, 1996).

Several lines of evidence suggest that sediments provide an additional internal source of nutrients in the St. Lucie Estuary. Nitrogen and phosphorus appear to be internally generated by resuspension of bottom sediments. This resuspension occurs during high wind conditions or when high volumes and rates of inflow occur from the canals and tributaries (Doering, 1996; Chamberlain and Hayward, 1996).

Analyses of ten years of data (SFWMD, 2001b) indicate that conditions throughout the estuary generally seem to be fairly stable. Increases in phosphorus concentrations and ammonia nitrogen may be occurring in both the North and South Forks, resulting in higher concentrations of chlorophyll *a*. Dissolved oxygen concentrations have increased in the South Fork while other areas show no significant trends over time.

Hypoxic and anoxic conditions occur fairly often in the St. Lucie Estuary. In some areas, more than 20 percent of samples are below the state standard for Class II waters of 4.0 milligrams per liter). Anoxic conditions tend to occur more frequently at stations that are located immediately downstream from the major canals than they occur downstream from the natural tributaries (SFWMD, 2001b). Studies by the FDEP indicate that water and sediments in these canals also often contain high concentrations of pesticides and heavy metals (FDEP, 2000c, 2000d; FDEP, 2001a).

Results of the above studies are consistent with the explanation that the various canals and tributaries that flow into the estuary transport fresh water and substantial amounts of nutrients, organic matter, tannins, and suspended solids. This fresh water mixes with increasing amounts of salt water as it is transported out of the estuary, resulting in increased concentrations of chlorophyll, decreased color, and increased turbidity.

Poor water quality conditions are often most apparent in areas where fresh water first interfaces with salt water, as is the case at the confluences of tributaries and canals with the estuary. This mixing zone is characterized by high rates of biological productivity, high levels of turbidity, decreasing color, and high levels of biological oxygen demand. Significant stratification may occur at such interfaces, especially during periods of low flow when less physical mixing occurs. Such stratification has been observed in the St. Lucie Estuary and forms a freshwater “lens” that floats across the surface of denser saline waters. High productivity, high turbidity, and reduced light penetration at the interface can result in low concentrations of dissolved oxygen near the bottom.

Based on these analyses, District staff cannot at this time determine the effects that implementing the proposed MFL criteria will have on water quality in the estuary. Providing additional freshwater flow to the estuary through the North and South Forks will provide additional influx of nutrients during these periods, but will also transport additional sediments and pollutants. Providing low rates of freshwater flow during dry periods may increase stratification and lower dissolved oxygen concentrations. Additional research is needed to define these relationships.

Assessment of Current and Historical Conditions

In order to assess the extent and nature of oligohaline conditions in the St. Lucie River and Estuary, assessments were made of present and past conditions in the system with respect to natural systems, land use, and hydrology. Present day conditions in the St. Lucie River and Estuary watershed were determined for use in the regional water supply plans (SFWMD, 1998a, 2000b). These analyses included assessment of current hydrologic conditions and operation of major canals and structures, recent land use throughout the watershed, and estimates of agricultural, urban, and industrial water use. This information for 1995 was compiled to produce the 1995 Base Case conditions that were analyzed in the regional water supply plans (SFWMD, 1998a; 2000b).

Historical land use/land cover conditions in the watershed were determined based on a review of historical accounts, maps, surveys, and other data collected from this region (**Appendix E**). Conclusions from this study are based on examination of field notes and plat maps for five of approximately 30 townships that comprise the watershed. Plat maps for a number of additional townships were examined briefly. Conclusions from this study include the following:

- Three main physiographic regions appear to have been present in the predrainage watershed: 1) an area of pinelands and seasonal ponds mosaic, 2) an area of prairie and seasonal ponds mosaic, and 3) an area referred to as the Halpatta Swamp, which was later named the Allapattah Flats.
- All three physiographic regions appear to have been very flat, with the elevation difference between pinelands and ponds probably often as little as two feet.
- The prairie mosaic was described primarily in the northern portion of the watershed. The sawgrass marshes and bordering forested wetlands that formed the Halpatta Swamp were present along the western edge of the watershed, along the eastern foot of the high northwest-southeast trending ridge. Cypress occurring in pond-like patches seems to have been confined to the southernmost townships of the watershed.
- Although there appeared to be some interconnection among the ponds in the watershed, generally, there does not appear to be a strong suggestion of extensive connection or extensive surface runoff.
- The watershed may have contributed more water to the St. Lucie River base flow through ground water discharge than through surface runoff. The long duration of standing water in ponds and even longer duration in the sawgrass marshes indicate that the base flow recession that occurred during dry periods was a gradual process.

The presence of extensive surface water throughout the watershed, the limited degree of surface runoff, and the overall similarity in land cover characteristics surrounding the headwaters, suggest that the North and South Forks of the St. Lucie River may have had similar discharges.

Hydrologic and Hydrodynamic Modeling

Since the amount of historical hydrologic data for this system is very limited, the District developed and adapted several mathematical models to provide tools necessary to estimate both historical and present conditions in the estuary. The models were calibrated and verified using available data and applied to estimate past and present conditions in the watershed and estuary.

Historical and current flow conditions throughout the St. Lucie Estuary were analyzed using watershed models to determine how flows vary over time. The watershed models then provided information, in the form of inflows, to an estuarine hydrodynamic/ salinity model to determine the extent and movement of the oligohaline zone (**Figure 13**). This section briefly describes each model and its interaction with other models.

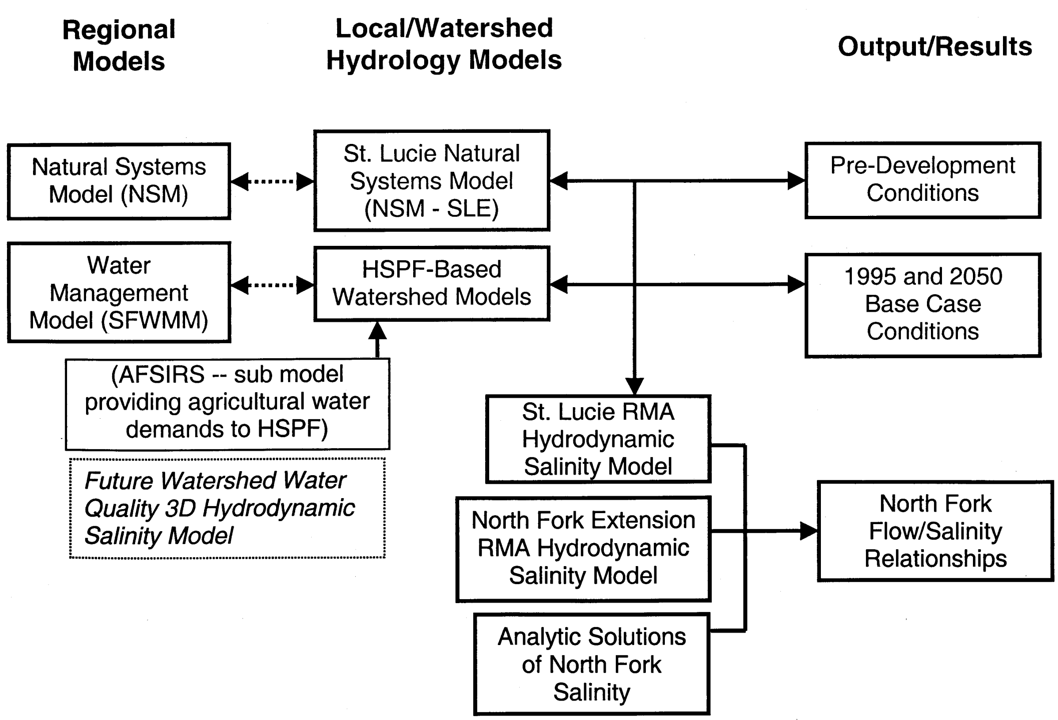


Figure 13. Model Interactions

Natural Systems Model - St. Lucie Estuary

A watershed-scale hydrologic model called the Natural Systems Model – St. Lucie Estuary (NSM - St. Lucie Estuary) defines the flows entering the estuary under undeveloped conditions (**Appendix D**). This model is fully explicit and models all hydrologic processes in the watershed including evapotranspiration, surface water runoff, and ground water flow. The hydrology is modeled continuously for each day over a 31-year simulation period.

The model needs ground surface elevations, soil hydraulic conductivity, and a predevelopment land use map of the area. The land use map is used to assign model parameters (e.g., root depths, crop-specific adjustment factors for evapotranspiration, surface runoff characteristics) to each modeled node.

The model predicts daily runoff over a 31-year simulation period. Attention is focused on flow entering into the North Fork of the St. Lucie River, where the oligohaline habitat is located. Statistical analysis of the NSM - St. Lucie Estuary flow time series was used to define minimum flow conditions.

Hydrologic Systems Program FORTRAN Model

A set of five basin-scale hydrologic models built with a model called the Hydrologic Systems Program FORTRAN[1] (HSPF) defines flows entering the estuary under current land use conditions (**Appendix C**). HSPF documentation appears in **Appendix C**. Like NSM, this model simulates all major flow components at a daily time step over a 31-year period. Unlike NSM, this model does not explicitly model the flow process, but instead relies on calibrated flow regression parameters to estimate surface water and ground water movement.

Data requirements are similar to those of NSM. The model does not explicitly use elevation data, but the model does require flow patterns and calibration of flow to measured data serves a similar function. The HSPF was used to simulate runoff from the five basins that flow into the St. Lucie River.

Resource Management Associates, Inc. (RAM) Model

Resource Management Associates, Inc. (RMA) developed the original code for a hydrodynamic model that can be used to represent water exchange processes in estuaries. This model was modified by the SFWMD for specific application in the St. Lucie Estuary. The RMA hydrodynamic models show how fresh water interacts with tidal forces within the estuary. Estuarine research focussed on the midestuary and the model domain was limited to the open water portion of the estuary. Two-dimensional hydrodynamic (RMA-2) and salinity (RMA-4) models were developed for this purpose (**Appendix H**). Since

1. FORTRAN is an abbreviation for Formula Translation Model

MFL issues focussed on the oligohaline zone, the model domain was expanded to include the riverine portion of the North Fork (**Appendix F**).

The hydrodynamic model has computer processing time and memory requirements that limit simulations to a few months. Therefore, the long-term watershed model results were scanned, a stereotypical MFL situation identified, and the hydrodynamic model simulated this shorter three-month period. Once the salinity behavior is known throughout a typical MFL period, the information can be used to convert a flow-frequency relationship into a salinity-frequency relationship that describes the likely extent and duration of oligohaline habitat.

The salinity model was used to locate the 5-ppt isohaline zone throughout the predevelopment MFL event. This was used to develop a salinity-frequency relationship for predevelopment conditions. The salinity-frequency relationship helped establish the minimal extent of the oligohaline zone under MFL conditions. The same methods were then reapplied using current (HSPF) hydrology. This established the minimal extent of the oligohaline zone under MFL conditions in today's watershed. Comparison of today's salinity-frequency relationship to the historical salinity-frequency relationship forms the basis of MFL recommendations.

Results of flow analyses for the North Fork, for historical and 1995 Base Case conditions, indicated that less water flowed to the North Fork under the 1995 Base Case than occurred under the NSM simulation. Further analysis indicated, however, that this reduction in flow occurred primarily during high flow periods and that, in fact, more water was being discharged from the North Fork to the estuary during low flow periods under the 1995 Base Case simulation than was discharged during similar periods under NSM simulation. Therefore, further analyses were conducted to characterize discharges to the estuary during very dry periods. Results of this analysis are discussed in **Chapter 5**.

Chapter 5
RESULTS OF HYDROLOGIC ANALYSES

SYSTEMWIDE EFFECTS

Large-scale effects of hydrologic alterations to the St. Lucie River and Estuary were analyzed through the use of models. The Natural Systems Model (NSM), as described in **Appendix D**, was used to simulate predevelopment conditions in the watershed. Other basin-scale analyses, based on Hydrologic Systems Program FORTRAN (HSPF) modeling (**Appendix C**), were used to estimate current (1995 Base Case) conditions.

The overall effects of structural changes in the watershed on flows to the St. Lucie Estuary are depicted in **Table 11**. This table shows the results of using the various models to determine present and historical flows from five tributaries and direct inflow into the estuary. The present day average flows (1965 to 1995) are based on the 1995 Base Case and the estimated historical flows are based on NSM.

Table 11. Summary of Flows to the St. Lucie Estuary for the 1965-1995 Period of Simulation for NSM and 1995 Base Case

Model Run	North Fork	C24	C23	C44	South Fork	Direct Inflow	TOTAL
Average Annual Values (acre-feet per year)							
NSM	271,584	9,540	7,781	8,363	82,138	88,486	467,892
1995 Base	165,417	127,520	167,298	88,739	64,203	40,371	653,549
Average Annual Values (cfs)							
NSM	1,475	52	42	45	446	481	2,541
1995 Base	898	692	909	482	349	219	3,549
Average Annual Values (inches per year)							
NSM	6.60	0.23	0.19	0.20	2.00	2.15	11.37
1995 Base	4.02	3.10	4.07	2.16	1.56	0.98	15.89
Average Annual Values (percent of NSM)							
1995 Base	61	1,337	2,150	1,061	78	46	140
Average Annual Values (percent of total)							
NSM	58	2	2	2	18	19	100
1995 Base	25	20	26	14	10	6	100

As indicated, flows to the remaining "natural" streams, the North Fork and South Fork of the St. Lucie River, have declined from 272,000 to 165,000 acre-feet per year (39 percent reduction) and from 82,000 to 64,000 acre-feet per year (22 percent reduction), respectively, and direct inflow has been reduced by about 46 percent from 88,000 to

40,000 acre-feet per year. Discharges to the channelized tributaries C-44, C-23, and C-24 have increased by factors of 11, 22, and 13, respectively.

This increase in channelized flow from C-23, C-24, and C-44 canals has increased total discharges to the estuary by 40 percent. The apparent decreases in flows from the North Fork, South Fork, and "direct inflow" are due primarily to channelization of streams and wetlands, filling of wetlands, and overall decline of the water table.

Further analysis of flow data (**Figure 14**) indicates that the increased flow occurs primarily in the form of increased duration and frequency of high flow events (above 2,000 cfs). In addition, flow has become more variable, as indicated by more flow events in the range from 500 to 1,500 cfs.

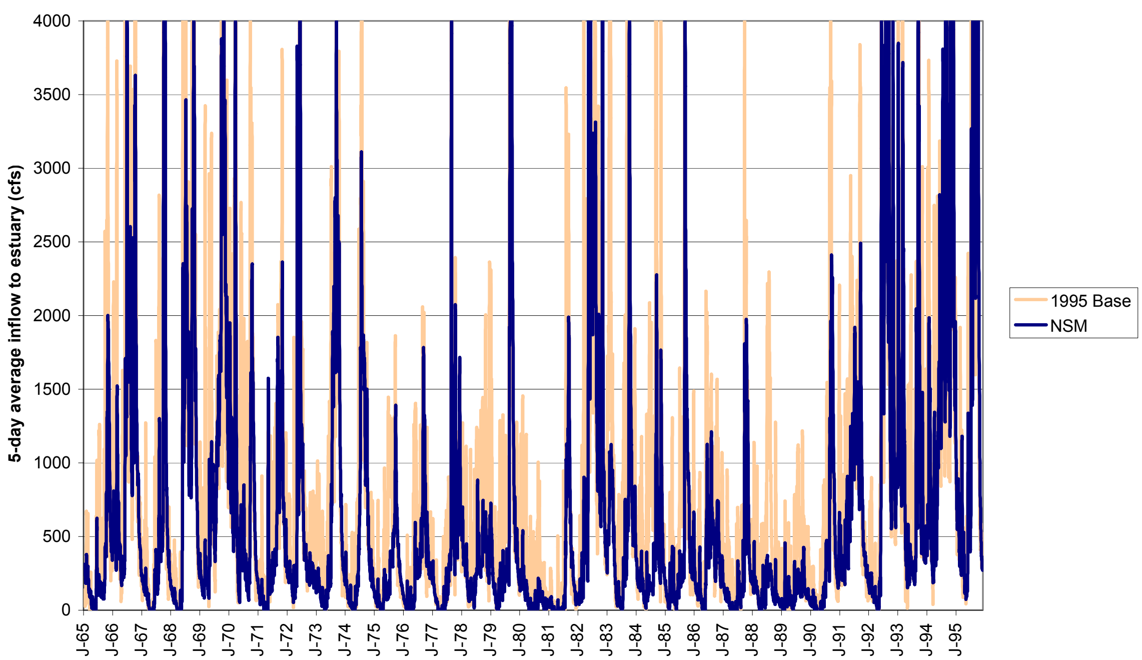


Figure 14. NSM and 1995 Base Case Flows to the St. Lucie Estuary for the 31-Year Period from 1965-1995 (25 occurrences of near-zero flow)

Another way to examine discharge is through the use of a frequency distribution curve as shown in **Figure 15**. When flows for the 1995 Base Case are compared with flows predicted by the NSM, it can be seen that the curve for the 1995 Base Case is shifted to the right.

The overall 40 percent increase in flows to the estuary (**Table 11**) is reflected at all rates of flow. For example for the NSM simulation, about 35 percent of flows to the estuary were above 500 cfs, whereas for the 1995 Base Case, 55 percent of the flows were above 500 cfs (**Figure 15**).

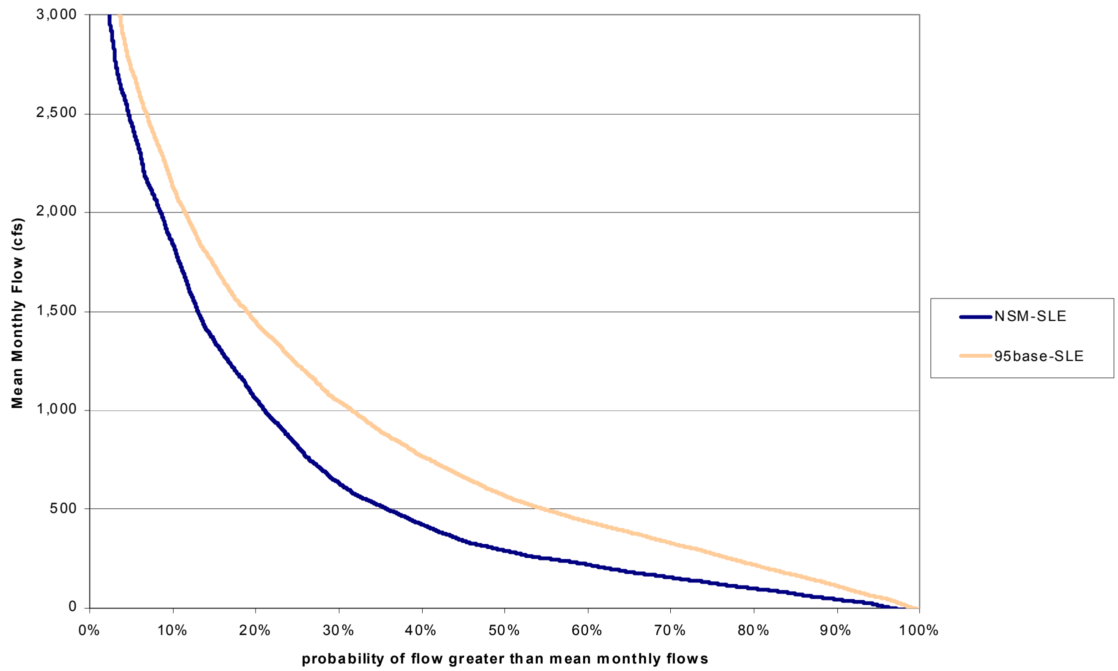


Figure 15. Frequency Distribution of Flows to the St. Lucie Estuary for NSM and 1995 Base Case Model Simulations for the Period from 1965 to 1995.

EFFECTS ON THE SOUTH FORK OF THE ESTUARY

Examination of the flow distribution for the South Fork of the St. Lucie Estuary (**Figure 16**) indicates a similar trend to that seen in the North Fork. Overall flows to this river have decreased about 22 percent (**Table 11**). The simulated flow data indicate that more flow is occurring to the river during dry periods. Examination of the frequency distribution curve (**Figure 17**) indicates that the overall decline in flows to the South Fork of the estuary of 22 percent (**Table 11**) has occurred primarily due to a decrease in high flow events.

The two curves shown in **Figure 17** cross each other at about 100 cfs. This shows that the probability of mean monthly flow rates above 100 cfs has declined under the 1995 Base Case conditions, whereas the probability of flows below 100 cfs has not changed significantly.

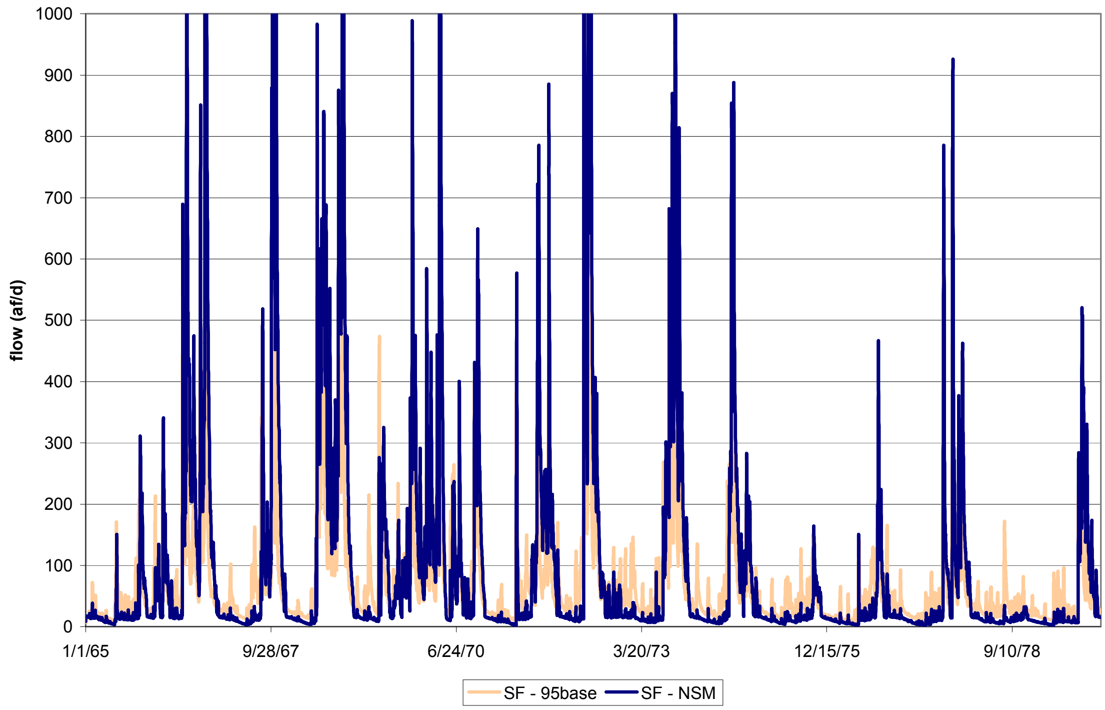


Figure 16. NSM and 1995 Base Case Flows to the South Fork of the St. Lucie Estuary for the 31-Year Period from 1965-1995

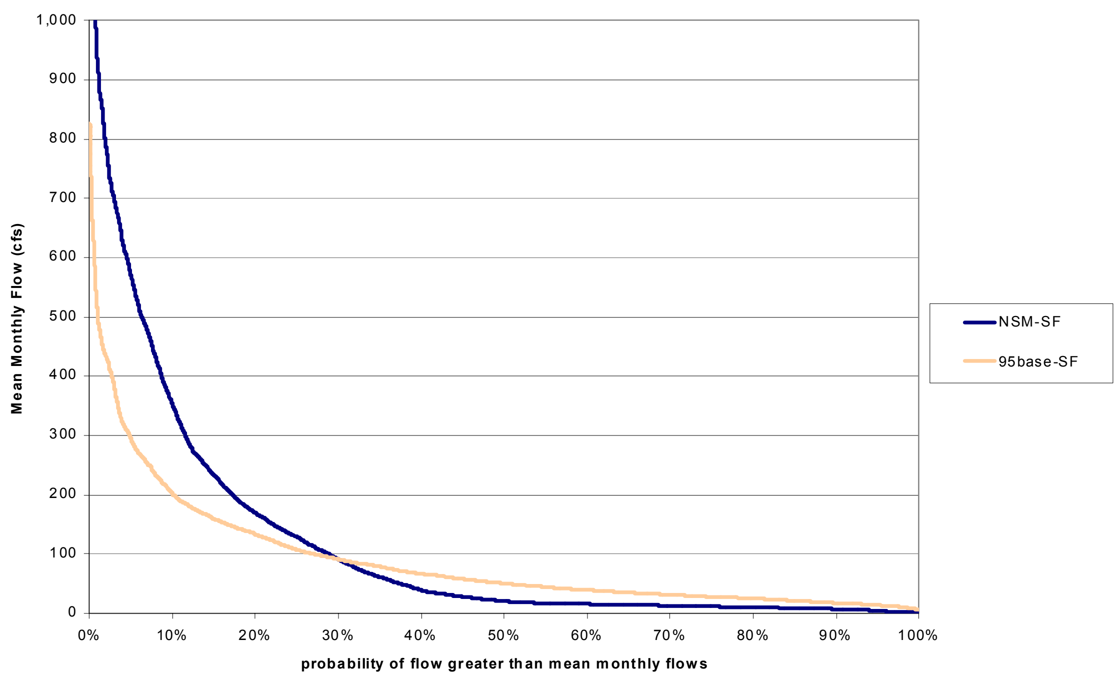


Figure 17. Frequency Distribution of Flows to the South Fork of the St. Lucie Estuary for NSM and 1995 Base Case Model Simulations for the Period from 1965 to 1995.

EFFECTS ON THE NORTH FORK OF THE ESTUARY

Figures 18 and **19** show the modeled historical and current pattern of flows to the North Fork of the St. Lucie Estuary. As with the South Fork, the overall decline in flows of 39 percent has occurred due to a reduction in high flow events.

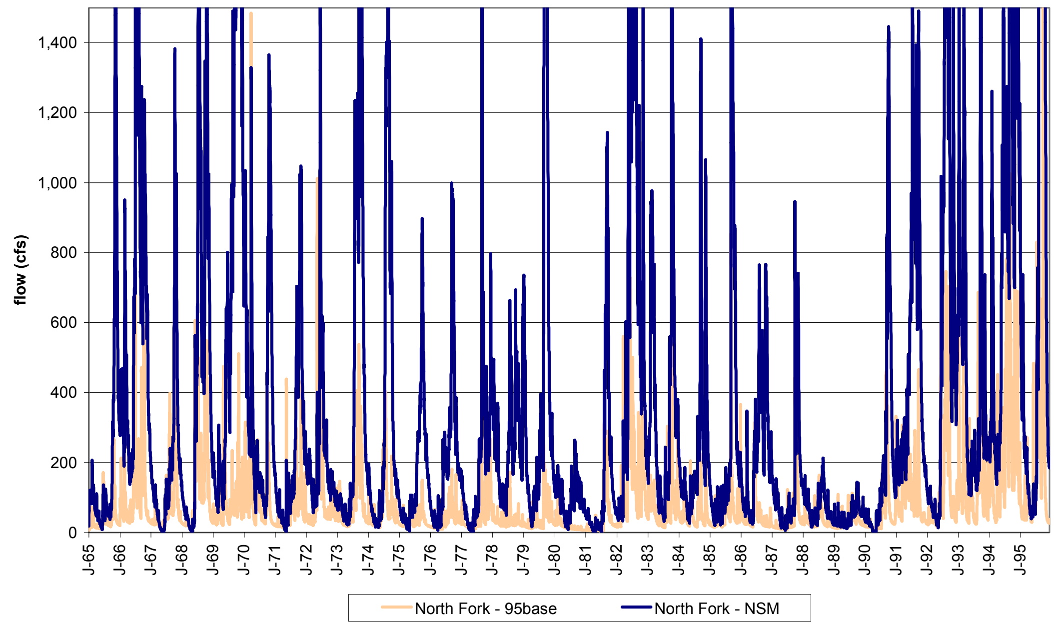


Figure 18. NSM and 1995 Base Case Flows to the North Fork of the St. Lucie Estuary

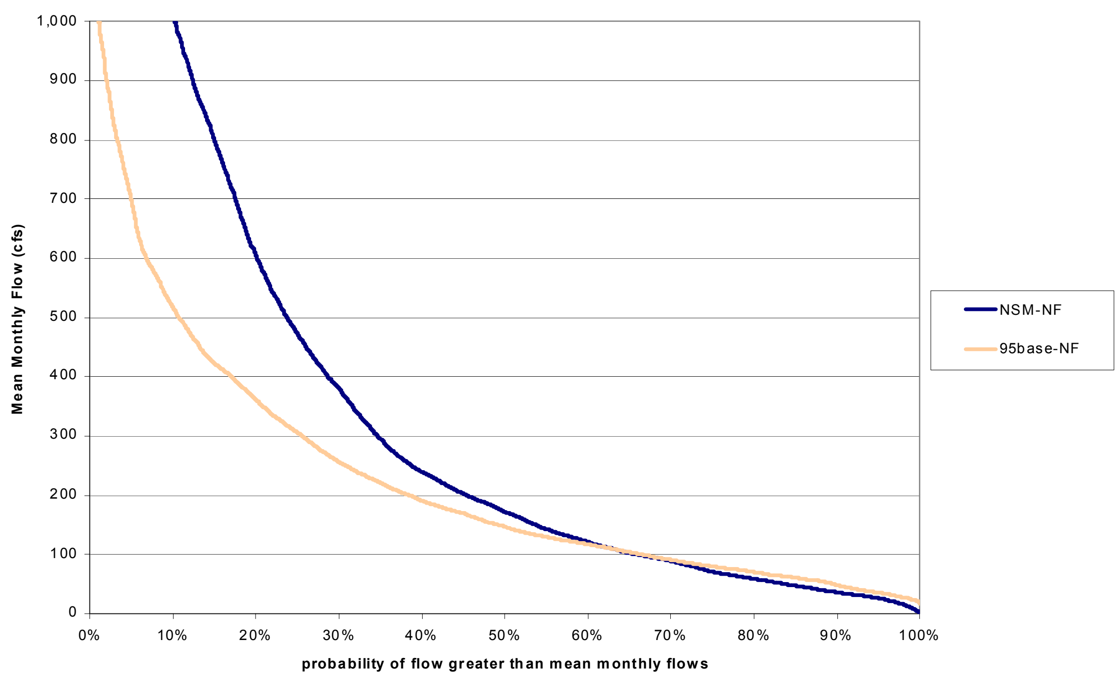


Figure 19. Frequency Distribution of Flows to the North Fork of the St. Lucie Estuary for NSM and 1995 Base Case Model Simulations for the Period from 1965 to 1995.

Peak discharges were of similar maximum rate. However, under NSM conditions, high discharge events typically persisted for longer periods of time. Total volume of discharge (as represented by the area under the curve) was greater for NSM conditions than for 1995 Base Case conditions. Periods of low freshwater release were of similar frequency and duration, but under the 1995 Base Case, more frequent pulses of fresh water were released due to local rainfall events. This resulted in greater variability of flow conditions that could lead to more rapid changes in salinity in the estuary.

The two curves shown in **Figure 19** cross each other at about 100 cfs. This shows that the probability of mean monthly flow rates above 100 cfs has declined under the 1995 Base Case conditions, whereas the probability of flows below 100 cfs has not changed significantly.

EFFECTS ON THE CENTRAL ESTUARY

As indicated in **Table 11**, flows to the central estuary through the major canals have increased by a factor of ten or more. This area of the estuary has been highly impacted by shoreline development and dredging and filling, resulting in loss or degradation of most of the remaining plant and animal communities. Establishment of minimum flow regimes is much less a concern than habitat restoration efforts and establishing maximum discharge criteria for these areas of the system. The limited shoreline and poor quality bottom sediments provide lower quality and less stable oligohaline habitat.

ANALYSIS OF FLOWS DURING DROUGHT CONDITIONS

Representative flow conditions that occur during a below average rainfall period were selected using total flows to the estuary as predicted by the NSM simulation. This flow period was defined as a three-month period or longer of unusually low flows. The 31-year period of record was examined and the period of below normal flows was selected from the final months of a below average (1-in-5 to 1-in-10 return period) dry season. **Figure 20** shows the selected dry period for both 1995 Base Case and predevelopment conditions.

Note that base flows for both are similar during the selected period, but the 1995 Base Case has a more extreme response to rainfall events, as compared to NSM conditions. Similar low-flow conditions in the range observed during the selected minimum flow period occur during most years, but generally do not persist for an extended period of time.

Table 12 shows the total monthly flow entering the estuary under NSM conditions for each month of the 31-year period of simulation. The five potential dry seasons (1973, 1976, 1977, 1987, and 1989) are shaded. The representative low flow period, as shown in the boxed cells in **Table 12**, extended from March 1 to May 31, 1987. During this period, average monthly flows declined from 96 cfs to -9 cfs. This pattern of decline is typical for the dry season in this estuary. The magnitude of decline is representative of approximately a 1-in-10 year drought condition.

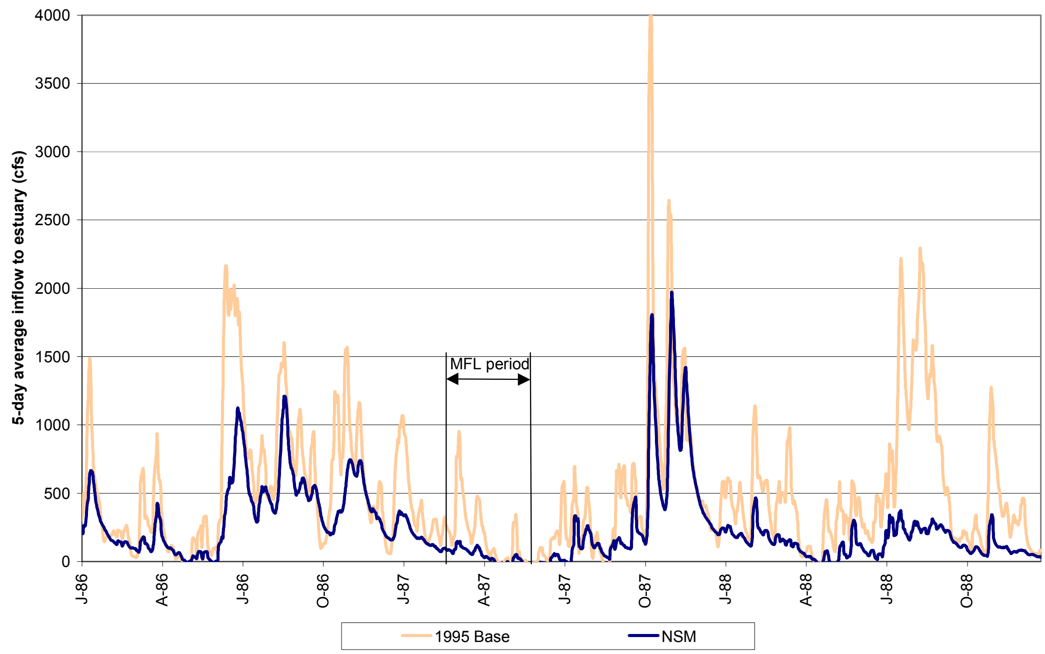


Figure 20. Selected Low Flow Period for 1995 Base Case and NSM Conditions (March 1, 1987, thorough May 31, 1997)

DEFINITIONS OF HARM AND SIGNIFICANT HARM

Flows at or below zero (light gray-shaded numbers in **Table 12**) occurred 14 times during the 31-year simulation period. Periods of low or even negative flow (negative flow occurs when the rate of evaporation from the estuary surface exceeds the rate of freshwater inflow from tributaries) may persist for one to nine months. During such periods, it can be expected that the oligohaline habitat will no longer be present.

Harm is defined to occur to this estuary system when freshwater flows are less than the rate of evaporation for a period of two consecutive months. Under these conditions, it is expected that most of the oligohaline zone will be lost or impacted.

Such conditions occurred five times during the period of simulation, representing a return frequency of about 6 years under natural system conditions. These five two-month periods occurred during the NSM simulation for 1965 to 1995 rainfall conditions. These events (indicated by light gray shading in **Table 12**) occurred during April and May of 1967, 1977, 1981, and 1990, and during May and June of 1987. Because such low flow and no flow events occurred under natural conditions as well as under present conditions, the extent to which such occurrences constitute “significant harm” to the ecosystem is based on the definition that has been formally adopted by the District:

<u>Significant Harm</u> occurs when freshwater flows to the estuary are less than the rate of evaporation for a period of two consecutive months during the dry season for two or more years in succession.

Such an event did not occur during the 31-year period of simulation for the St. Lucie Estuary under NSM conditions.

Table 12. Monthly Flows[a] to the St. Lucie Estuary for NSM Conditions[b]

Year	Month											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
1965	260	247	133	58	2	215	168	128	168	791	1,504	469
1966	608	652	751	303	264	1,273	2,284	1,812	1,405	2,349	915	387
1967	202	165	103	-1	-24	130	202	638	527	2,797	832	287
1968	136	90	27	-20	131	1,469	2,444	1,337	1,293	2,857	1,297	394
1969	245	132	288	148	696	891	533	1,200	1,677	3,590	3,128	1,462
1970	1,175	833	1,695	939	207	458	444	229	243	1,641	1,054	302
1971	140	108	45	2	353	170	274	388	1,246	1,108	1,185	464
1972	239	249	141	181	1,243	2,712	971	423	288	242	259	180
1973	175	179	73	45	68	213	665	1,855	2,738	2,039	792	287
1974	220	89	60	20	54	250	1,401	1,943	1,276	878	316	206
1975	100	79	42	-5	155	105	187	330	598	842	350	180
1976	82	50	19	32	39	364	274	430	1,144	689	395	260
1977	219	96	26	-22	-1	84	164	321	1,626	814	595	1,010
1978	569	328	273	99	139	104	293	458	294	546	465	282
1979	578	203	86	34	178	193	226	288	3,234	2,405	587	347
1980	186	245	154	120	23	-20	37	49	164	86	51	46
1981	35	51	0	-40	-3	1	32	585	1,352	596	263	107
1982	79	118	264	492	1,179	3,001	2,388	2,549	1,319	1,041	2,085	657
1983	419	721	931	428	102	99	23	266	383	1,984	1,346	544
1984	428	189	230	141	108	137	157	216	763	774	618	531
1985	199	71	108	195	116	99	222	238	2,019	1,554	619	292
1986	373	136	164	87	32	458	568	690	515	318	596	255
1987	226	97	96	8	-9	-1	101	114	186	666	1,172	349
1988	208	226	144	27	54	98	223	238	207	83	133	61
1989	36	13	151	126	65	40	167	210	147	261	144	101
1990	54	61	34	-14	-22	40	120	374	647	1,903	802	252
1991	298	319	312	577	520	830	1,246	1,337	1,080	1,476	530	305
1992	202	180	112	91	14	745	1,857	3,679	2,897	1,969	1,956	925
1993	1,502	1,386	1,632	1,310	305	293	302	243	925	2,645	739	480
1994	425	1,064	715	454	494	1,136	1,872	2,609	3,500	2,555	3,699	3,116
1995	1,473	698	414	495	218	378	536	3,853	4,247	7,134	1,781	371
Number of events less than or equal 0 cfs			1	6	5	2						

a. Monthly flows are determined from average daily cfs

b. Drier dry seasons are shaded dark gray and total flows to the estuary less than zero are shaded light gray.

A similar analysis was conducted for 1995 Base Case conditions and the results are shown in **Table 13**. As with the NSM simulation, the estuary experienced occasional periods of zero or negative flow. However, these periods of reduced flow occurred less often, were less severe (lower volume of deficit), and were of shorter duration than the periods of low flow that were simulated under natural systems conditions. In fact, during the 31 years of simulation, only two months (May 1965 and April 1981) had flows that were zero or below. Since these two events did not occur in consecutive months, the estuary (as a whole) did not incur harm, due to deficient freshwater flows, during this simulation.

Table 13. Monthly Flows[a] to the St. Lucie Estuary for 1995 Base Case Conditions[b]

Year	Month											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
1965	91	318	87	35	-13	403	704	395	784	1,923	1,471	356
1966	1,230	1,154	702	365	904	2,269	1,986	1,874	1,654	3,512	748	484
1967	313	505	243	15	8	549	966	1,373	765	2,525	493	310
1968	196	240	115	4	344	2,346	2,687	1,520	2,030	3,785	1,352	318
1969	534	362	1,352	274	2,109	893	542	1,369	2,023	3,797	2,497	1,463
1970	1,377	1,176	3,741	1,042	474	1,680	1,178	1,007	1,096	2,673	807	172
1971	209	346	124	37	306	444	651	866	1,032	1,303	1,550	561
1972	380	476	251	657	1,326	2,661	1,166	663	360	408	492	423
1973	515	559	230	186	243	844	1,746	1,504	2,485	2,355	597	241
1974	312	113	65	196	160	965	2,575	2,610	1,006	840	452	454
1975	131	202	109	20	457	415	1,069	859	1,094	671	224	125
1976	49	112	55	54	534	1,018	430	739	1,453	364	478	418
1977	294	180	79	12	104	237	372	478	1,841	829	763	939
1978	595	411	454	168	383	396	727	643	598	735	724	588
1979	1,480	337	197	129	733	535	713	678	4,721	1,897	633	548
1980	444	664	373	418	242	115	267	307	461	144	132	79
1981	46	138	3	-24	72	38	198	1,368	1,869	464	178	57
1982	114	312	1,069	1,674	1,360	2,456	2,284	2,760	1,264	1,284	2,128	640
1983	786	2,543	1,713	615	106	574	408	1,101	1,817	2,786	1,103	843
1984	699	340	697	302	321	661	1,296	863	2,196	909	1,325	645
1985	195	78	266	485	110	196	750	867	2,499	826	493	319
1986	569	188	389	101	138	1,336	811	947	689	708	741	418
1987	488	226	411	88	56	86	320	134	500	1,249	1,357	359
1988	443	542	483	75	308	320	948	1,557	550	171	566	208
1989	135	37	210	244	141	166	422	811	433	607	221	270
1990	206	171	70	26	89	259	429	851	1,604	1,862	485	122
1991	798	540	591	1,047	765	1,644	1,657	1,427	1,481	2,015	453	334
1992	155	411	224	215	28	1,708	1,692	4,158	3,038	1,762	1,554	699
1993	2,581	1,583	2,545	1,062	274	906	1,195	556	1,325	3,080	1,118	764
1994	1,115	2,029	770	921	896	2,000	1,697	2,055	3,981	2,280	3,884	3,753
1995	1,375	683	750	513	336	886	1,296	5,461	3,438	8,134	1,111	418
Number of events less than or equal to 0 cfs				1	1							

a. Average daily cfs

b. Drier dry seasons are shaded dark gray and total flows to the estuary less than zero are shaded light gray.

ADDITIONAL EXAMINATION OF THE NORTH AND SOUTH FORKS OF THE ST. LUCIE RIVER

Even though the estuary as a whole may not be impacted by a lack of freshwater inflow, particular areas within this system may be experiencing stress or damage during dry periods. To investigate this, District staff developed a more detailed analysis for the North and South Forks of the St. Lucie River. Both of these areas support fish, wildlife, and plant communities that are dependent on an influx of fresh water and have substantial, persistent oligohaline zones. For this analysis, data developed for the Indian River Feasibility Study (USACE and SFWMD, 2001) were heavily utilized. Prior District research efforts and development of feasibility study options have focused primarily on analysis of the North Fork, including specific models developed to simulate hydrologic conditions. By contrast, less is known about and much less effort has been spent on analysis of conditions in the South Fork. Conclusions derived for the South Fork are based on results obtained from the large-scale regional models and by extrapolation from the analysis of the North Fork. More detailed study of the South Fork and its watershed is warranted to further refine the initial criteria recommended for this system.

North Fork of the St. Lucie River

As shown in **Table 11**, overall discharges to the North Fork of the St. Lucie River have decreased by about 40 percent. This reduction in overall flow has occurred primarily due to a reduced frequency of high flow events, as floodwaters have been diverted into the C-24 Canal. Results of the analyses of salinity conditions and flow in the North Fork River indicate that there is a direct linkage between hydrologic conditions within the system and resulting salinity conditions in the estuary. By restoring historic hydrological flow patterns to the river, the District should be able to restore salinity regimes in the estuary to those that more closely resemble historical conditions (Estevez, 2000). Salinity conditions, in conjunction with suitable substrate and overall water quality, in turn will determine the ecosystems that can be expected to occur.

Therefore, establishment of proper salinity conditions can contribute to an overall improvement in plant and animal communities. In order to document or monitor such beneficial changes in the St. Lucie Estuary, it may be necessary to artificially establish submerged aquatic vegetation or oysters to overcome historical recruitment bottlenecks, and then study their responses to managed flows and salinities. Flows could be varied experimentally, or managed flow regimes could be monitored through time so as to allow periodic assessments of progress and adjustments to flow (Estevez, 2000). Analysis of predicted historical hydrologic conditions and careful documentation of the effects of future modified hydrologic conditions, using an adaptive management approach, can thus provide a means to achieve long-term benefits to the ecosystem.

Flows Needed to Maintain Oligohaline Habitat in the North Fork

A hydrodynamic model was developed for the St. Lucie Estuary to predict vertically-averaged salinity conditions based on tidal exchange, river flow, and basin configuration (Hu, 2000). This two-dimensional model was modified and extended to include the North Fork, from Kellstadt Bridge to the Gordy Road structure, a distance of about 15 miles (**Appendix F**). The model was used to develop a relationship between freshwater inflow and average salinity in the water column at various distances along the river (**Figure 21**). Inflow was from Ten Mile Creek, Five Mile Creek, rainfall, and ground water seepage.

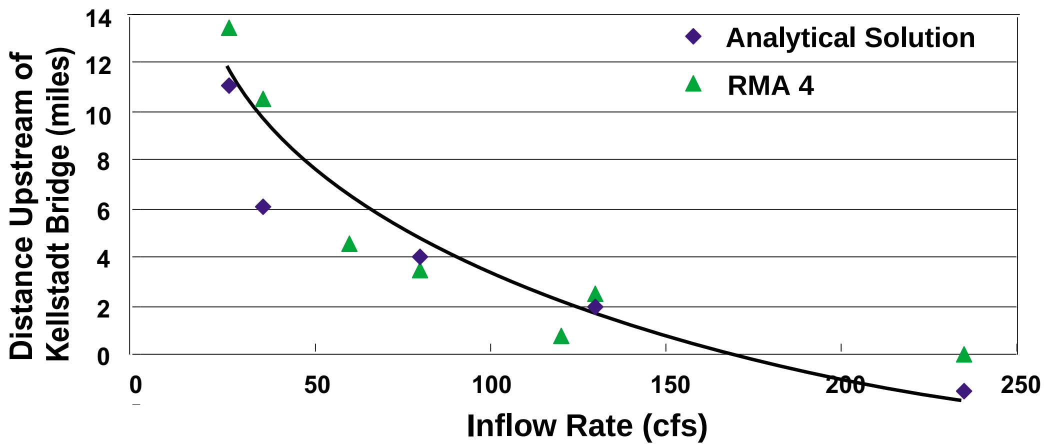


Figure 21. Location of the 5-ppt Isohaline Zone as a Function of Discharge from the Gordy Road Structure Based on the 1995 Base Case

Results of this analysis indicate how much flow is needed in order to maintain a 5-parts per thousand (ppt) oligohaline zone at different locations within the river. For example, to maintain the 5-ppt isohaline zone at or below the Kellstadt Bridge would require an estimated flow of 175 cfs or more. These flows were developed from mathematical models of the estuary, which in turn, were based on limited sets of measured flow and salinity data, and do not represent actual measured values. Due to limitations of the models, very low flows (less than 25 cfs) are not estimated accurately and need to be interpreted with caution.

During those periods when the NSM predicted that total flows to the estuary were zero or less (**Table 14**), flows from the North Fork were generally at or below 21 cfs. For example, during April and May of 1967, 1977, 1981, and 1990, the NSM predicted flows in the North Fork that ranged from 3 cfs (June 1965) to 21 cfs. An exception occurred during May 1987 when total flows to the estuary were -9 cfs while flows from the North Fork were 29 cfs. Of the total number of 13 months when average flows from the North Fork were below 21 cfs, 10 of these were associated with periods when total flows to the estuary were less than zero.

A similar analysis was conducted using the 1995 Base Case conditions. Results of this analysis are shown in **Table 15**. Flows to the North Fork ranged from 20 cfs to 1,863 cfs, representing both an increase in the amount of base flow and a dramatic decrease in maximum flows. Flows of 21 cfs or below only occurred twice, during April 1968 and April 1981. April 1981 was also a month when total flows to the estuary under 1995 Base Case conditions (**Table 13**) were less than zero. During May 1965, total flows to the estuary under 1995 Base Case conditions were -13 cfs (**Table 13**), while flows from the North Fork were 22 cfs (**Table 15**).

Table 14. Monthly Flows[a] to North Fork as Predicted by the Natural Systems Model[b]

Year	Month											
	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**June**	**July**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**
1965	98	112	69	51	23	62	70	54	72	414	1,270	403
1966	407	422	508	211	183	569	1,408	1,331	828	993	634	277
1967	147	98	63	21	3	47	93	168	236	926	350	169
1968	91	54	31	8	30	367	1,416	831	651	1,407	791	272
1969	168	90	185	119	208	631	436	989	1,440	###	2,453	1,212
1970	751	438	446	414	134	181	140	101	90	894	880	260
1971	120	70	42	25	51	69	107	158	501	703	634	273
1972	169	193	103	103	167	717	480	236	175	126	132	91
1973	82	92	52	41	42	98	345	1,088	1,426	1,325	559	195
1974	134	69	34	26	40	82	472	1,412	1,079	586	175	121
1975	69	45	34	17	59	67	96	254	449	587	253	146
1976	68	32	25	33	51	229	189	264	719	538	264	168
1977	136	71	40	13	19	49	67	235	946	329	242	459
1978	388	247	224	92	102	95	258	391	241	454	356	234
1979	564	211	94	36	94	138	210	267	###	1,969	391	241
1980	128	130	97	107	36	26	81	93	203	122	98	73
1981	48	45	22	4	17	18	25	217	847	416	177	80
1982	50	60	82	298	530	1,291	1,347	1,789	969	665	784	299
1983	207	558	774	323	103	100	49	126	215	1,248	847	327
1984	237	123	127	81	62	83	144	167	539	569	385	373
1985	141	62	47	61	49	58	95	119	1,260	1,238	534	188
1986	156	77	95	75	39	156	259	474	445	293	568	204
1987	191	96	106	51	29	18	34	50	64	325	536	213
1988	128	106	82	35	36	39	72	118	159	72	60	40
1989	35	24	39	31	28	21	33	60	56	90	67	60
1990	43	38	25	9	6	36	79	170	226	1,089	600	191
1991	145	195	210	263	247	432	908	1,038	870	1,020	405	203
1992	135	102	74	58	26	135	724	1,719	1,585	1,032	737	514
1993	800	816	855	793	185	148	219	169	226	1,144	393	300
1994	239	602	445	201	240	698	1,183	1,005	1,567	1,542	1,590	1,798
1995	965	487	250	160	73	69	96	1,126	2,756	3,879	1,344	268
Number of events less than or equal to 21 cfs (Total = 13)				**6**	**4**	**3**						

a. Average daily cfs
b. Periods when net freshwater flow to the estuary was less than zero are shaded dark gray.

Table 15. Monthly Flows[a] to North Fork as Predicted by the 1995 Base Case[b]

	Month											
Year	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**June**	**July**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**
1965	28	149	44	35	22	104	230	108	252	668	627	125
1966	393	365	202	122	293	619	596	409	239	575	160	109
1967	81	122	62	32	24	181	224	262	161	276	65	76
1968	73	58	35	20	57	409	405	185	285	517	185	64
1969	93	58	269	52	434	198	140	407	698	1,058	628	378
1970	205	189	393	129	119	116	134	115	205	659	255	59
1971	44	87	35	39	56	194	144	320	171	348	238	155
1972	103	218	100	205	188	571	223	162	62	110	97	73
1973	104	84	62	57	114	204	607	511	616	484	109	68
1974	64	31	26	88	52	230	704	687	191	108	52	80
1975	36	104	49	32	153	75	276	327	460	210	105	60
1976	33	51	36	35	276	322	132	304	576	107	133	120
1977	92	56	36	35	79	109	178	247	686	281	267	300
1978	237	137	172	75	233	184	355	294	329	342	270	247
1979	377	73	61	73	342	187	395	318	1,863	592	127	146
1980	120	177	149	202	90	83	145	152	272	89	90	59
1981	32	85	25	21	72	37	159	502	739	176	60	29
1982	59	115	346	782	519	796	851	1,000	357	269	195	93
1983	190	571	343	106	72	101	125	198	349	411	153	141
1984	79	115	135	62	130	208	375	181	766	269	366	139
1985	68	33	110	168	62	80	200	281	805	251	167	86
1986	105	40	114	30	65	426	181	118	143	268	298	131
1987	116	68	178	40	64	36	105	65	206	362	393	89
1988	108	98	134	55	100	80	244	282	135	54	93	67
1989	62	29	60	70	75	76	103	240	121	163	106	146
1990	67	70	34	43	92	140	206	274	462	618	183	62
1991	161	117	176	242	246	675	581	495	461	439	92	93
1992	69	143	58	81	26	335	341	1,041	429	243	376	140
1993	378	205	489	151	48	221	429	148	187	752	189	134
1994	176	614	182	132	136	433	456	401	767	341	389	782
1995	218	139	116	64	38	103	113	879	471	1,381	164	56
Number of events less than or equal to 21 cfs (Total = 2)				**2**								

a. Average daily cfs

b. Periods when net freshwater flow to the estuary was less than zero are shaded dark gray.

Summary

Results of these analyses indicate that whereas overall flows to the North Fork have declined from the NSM conditions to the 1995 Base Case, dry period discharges may have increased slightly in the 1995 simulation. Flow rates of 21 cfs or below in the North Fork generally occur during periods when the St. Lucie Estuary is experiencing zero or negative net inflow of fresh water. The incidence of very low flows (21 cfs or below) declines from 13 months under NSM conditions to two months under the 1995 Base Case conditions.

Relationship to Significant Harm

Within the North Fork of the St. Lucie River, the conditions that cause significant harm to oligohaline habitat do not occur. Thus, even under the driest conditions when oligohaline habitat does not exist in the main part of the estuary, some oligohaline habitat is likely to persist in the upper reaches of the North Fork. When monthly average discharges rates from the North Fork River, as predicted by the models, are 21 cfs or less, oligohaline habitat no longer exists in the estuary, but does occur nearly 10 miles upstream of the Kellstadt Bridge on the North Fork River. Based on model simulations, the extent of this persistent oligohaline habitat appears to be greater under present (1995 Base Case) discharge regimes than it was under NSM conditions.

South Fork of the St. Lucie River

A similar analysis of present and NSM conditions was conducted for the South Fork of the St. Lucie River. However, less information was available for this system in terms of historical flow measurements and salinity. No model is currently available to predict salinity conditions in the South Fork as a function of flow. The analysis was based strictly on the application of large-scale regional and subregional models.

NSM and 1995 Base Case Model Results

For NSM conditions (**Table 16**), flows in the South Fork River ranged from a minimum value of 1 cfs to a maximum of 1,220 cfs. During periods when total freshwater flow to the estuary (**Table 12**) was zero or less - April and May of 1967, 1977, 1981, and 1990, and May and June of 1987 - the NSM predicted flows in the South Fork that ranged from 1 cfs (April 1981 and June 1987) to 7 cfs (April 1967). Flows to South Fork were 7 cfs or less during 45 months or 12 percent of the simulation period.

For the 1995 Base Case (**Table 17**), flows ranged from a minimum of 6 cfs to a maximum flow of 795 cfs. Flows of 7 cfs or less occurred twice under the 1995 Base Case simulation. The South Fork River thus currently receives more water during dry periods and less water during high discharge events than occurred under NSM conditions.

Table 16. Monthly Flows[a] to South Fork as Predicted by the Natural Systems Model[b]

Year	Month											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
1965	16	17	13	9	6	22	15	14	15	87	81	16
1966	53	84	94	29	17	240	460	231	268	676	141	32
1967	15	14	12	7	5	10	14	158	110	884	280	39
1968	14	12	9	5	15	421	515	254	308	704	285	47
1969	16	13	16	11	158	125	24	74	69	232	332	113
1970	191	191	504	330	17	110	142	40	31	356	90	14
1971	11	11	9	5	85	15	21	85	382	180	267	81
1972	18	15	12	13	443	931	272	87	33	32	33	18
1973	17	23	12	9	9	16	87	342	606	335	111	21
1974	16	12	10	7	7	17	381	279	84	151	49	23
1975	14	12	9	6	13	9	14	13	18	80	32	14
1976	10	9	7	7	4	19	14	22	152	67	33	17
1977	16	12	8	5	4	8	13	13	213	198	148	236
1978	78	17	15	10	10	7	9	11	11	13	24	12
1979	9	6	5	5	12	11	9	8	247	212	81	30
1980	15	22	15	11	6	3	2	1	1	1	1	1
1981	2	3	2	1	2	2	5	91	166	62	20	13
1982	11	11	26	62	275	761	487	328	168	198	588	166
1983	71	36	39	44	10	8	5	23	25	200	259	76
1984	96	16	24	15	12	12	9	11	30	41	81	65
1985	15	11	14	22	22	11	16	17	217	129	17	19
1986	71	16	14	10	7	72	99	33	16	11	10	10
1987	9	7	4	2	1	2	13	12	22	88	249	46
1988	16	21	15	9	8	13	17	15	13	9	14	8
1989	6	5	18	14	11	8	18	19	17	51	24	13
1990	9	9	7	4	3	5	8	23	127	394	88	15
1991	26	30	23	133	123	164	154	133	85	203	43	28
1992	18	18	14	12	8	207	584	1,018	809	576	718	230
1993	313	313	367	278	24	35	22	15	311	658	130	48
1994	53	202	121	95	91	167	317	797	870	525	870	686
1995	264	91	62	154	60	130	216	1,089	724	1,220	242	27
Number of events less than 27 cfs (Total = 206)	**22**	**24**	**25**	**23**	**24**	**19**	**19**	**15**	**9**	**4**	**7**	**15**
Number of events less than or equal to 7 cfs (Total = 45)	**2**	**4**	**5**	**11**	**10**	**5**	**3**	**1**	**1**	**1**	**1**	**1**

a. Average daily cfs

b. Periods when net freshwater flow to the estuary was less than zero are shaded dark gray.

Table 17. Monthly Flows[a] to South Fork as Predicted by the 1995 Base Case[b]

Year	Month											
	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**June**	**July**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**
1965	15	34	19	16	11	62	34	34	40	131	51	24
1966	103	88	64	45	49	209	172	132	177	306	55	33
1967	27	43	35	17	17	52	75	175	88	357	83	37
1968	24	27	19	15	52	304	254	147	192	324	111	34
1969	38	33	94	29	214	59	43	96	81	179	123	81
1970	128	104	373	146	65	160	71	43	82	206	45	23
1971	20	31	20	14	122	42	83	68	153	89	154	66
1972	40	33	34	69	318	441	163	60	52	65	70	57
1973	64	70	32	25	31	63	134	155	294	184	61	34
1974	55	26	34	19	25	97	254	124	58	97	47	39
1975	23	30	22	16	52	26	49	40	63	72	27	19
1976	16	22	13	19	17	53	34	79	108	40	66	39
1977	40	22	17	15	17	31	40	34	171	117	87	121
1978	48	34	39	26	33	26	40	56	30	37	40	26
1979	22	15	17	25	43	35	20	19	155	70	58	41
1980	29	64	38	20	17	15	14	11	11	10	9	7
1981	9	11	8	6	15	10	18	167	165	56	31	20
1982	19	30	139	117	214	409	263	172	125	129	453	100
1983	83	103	91	55	25	29	19	76	92	230	103	86
1984	80	37	76	42	45	71	26	35	93	53	128	58
1985	24	17	40	52	26	31	80	66	230	83	35	55
1986	124	35	48	44	25	153	88	53	37	25	23	29
1987	23	14	17	11	11	17	35	31	38	141	142	33
1988	30	51	34	21	31	32	78	67	32	20	41	16
1989	14	12	34	39	22	21	60	77	50	88	34	23
1990	19	25	20	14	13	22	26	117	183	177	45	26
1991	106	99	64	194	130	176	123	129	97	170	41	42
1992	26	45	39	34	19	169	117	377	384	223	72	41
1993	221	146	241	145	70	122	66	43	283	479	141	80
1994	108	193	93	125	98	190	224	483	547	274	541	381
1995	128	54	66	106	64	132	134	657	345	795	136	33
Number of events less than or equal to 27 cfs (Total = 95)	**14**	**10**	**10**	**16**	**14**	**7**	**6**	**2**	**1**	**3**	**3**	**9**
Number of events less than or equal to 7 cfs (Total = 2)				**1**								**1**

a. Average daily cfs

b. Periods when net freshwater flow to the estuary was less than zero are shaded dark gray.

Relationship of NSM and 1995 Base Case Flows to Significant Harm Criteria

No evidence was found to show that the South Fork system experienced significant harm due to a complete loss of oligohaline habitat (zero flow) under historical conditions. The South Fork is also much less likely to experience such an impact under current conditions. During periods when zero net flow of fresh water was occurring to the St. Lucie Estuary, the South Fork had a flow rate of 7 cfs or less. Such flows occurred about 12 percent of the simulation period under NSM conditions, but less than 1 percent of the time (during 2 of 372 months) under current (1995 Base Case) conditions.

Chapter 6
PROPOSED MINIMUM FLOW CRITERIA, MONITORING, PREVENTION, RESEARCH, AND ADAPTIVE MANAGEMENT STRATEGIES

PROPOSED CRITERIA

As a result of the MFL criteria development process described in **Chapter 4** and **Chapter 5** of this document, District staff recommend a minimum mean monthly flow of more than 28 cfs from the North and South Forks of the St. Lucie River combined to maintain sufficient salinities in the St. Lucie Estuary. The ***harm*** criteria is exceeded when flows fall below the 28-cfs minimum for two consecutive months during the dry season (November through April). ***Significant harm*** occurs if the harm criteria are exceeded for two consecutive years. To protect low salinity areas in the upper reaches of the North and South Forks, these flows should be distributed to provide 21 cfs from the North Fork River and 7 cfs from the South Fork. A summary of flow salinity relationships that were used to determine these criteria is provided below.

St. Lucie Estuary

Net freshwater flows are the sum of surface and ground water inflows minus evaporation. Net freshwater flows to the estuary were at or below zero during 14 months of the 31-year NSM simulation period. During such events, which may persist for 1 to 3 months, it can be expected that the oligohaline habitat will no longer be present in the estuary.

Harm *is defined to occur when net freshwater flows to the estuary system are less than the rate of evaporation for a period of two consecutive months.*

Such conditions occurred 5 times during the period of simulation, representing a return frequency of about 6 years under natural system conditions. Because such low flow and no flow events occurred under natural conditions, as well as under present conditions, the extent to which such occurrences constitute "significant harm" to the ecosystem is based on the definition that has been formally adopted by the SFWMD:

Significant harm occurs when freshwater flows to the estuary are less than the rate of evaporation for a period of two consecutive months for two or more years in succession.

Such an event did not occur during the 31-year period for the St. Lucie Estuary under either current (1995 Base Case) or historic (NSM) simulations.

District staff recognize that these definitions are not exact. The concept is based on the presumption that any loss of oligohaline zone habitat beyond what occurred under natural conditions (as simulated by the NSM) represents some degree of ***harm*** to the system. The exact point at which this loss becomes ***significant harm*** cannot be determined without additional study of the hydrology of the system and the resources at risk. Lacking this precise knowledge, the selected approach represents a conservative standard.

North Fork

Results of modeling studies indicate that flows at or below 21 cfs occur in the North Fork during periods when significant harm is occurring in the St. Lucie Estuary. No evidence has been found to indicate that, under current operations, oligohaline habitat is being lost beyond the extent of the zone that occurred historically.

South Fork

Preliminary analyses of the limited amount of available information indicate that a flows at or below 7 cfs occur from the South Fork during periods when significant harm is occurring in the St. Lucie Estuary. Although these preliminary results indicate that no impacts are likely to occur in the South Fork as a result of current and proposed management actions, further analyses of this system are warranted to refine management targets for inclusion in future updates to the MFL criteria. These refinements should include more detailed analyses of basin topography and hydrography; assessment of biological communities in the river that need to be protected; improved modeling of flow from the watershed to the South Fork; and development of a model or mathematical relationship to determine salinity conditions in the South Fork as a function of flow.

ABILITY TO MEET THE PROPOSED CRITERIA

Data and modeling studies indicate that under current (1995 Base Case) conditions, more fresh water is being discharged into the North Fork during dry periods than was discharged historically. This increased flow during low flow periods has resulted in a decreased probability that net inflows of fresh water will equal zero cfs or less throughout the estuary. There is no evidence that the proposed significant harm criteria will be exceeded in this system under present conditions.

Examination of the North and South Forks indicates that both of these systems support viable oligohaline habitats. The exact extent and duration of the oligohaline zones in these systems is uncertain. Flows of less than 21 cfs from the North Fork occur during periods when net flow of fresh water to the estuary is zero or less. Flows from the North Fork should be maintained above this level during periods when other sources of freshwater input to the estuary are restricted.

Flows of less than 7 cfs from the South Fork occur during periods when net flow of fresh water to the estuary is zero or less. Flows from the South Fork should be maintained above this level during periods when other sources of freshwater input to the estuary are restricted. Currently, we are limited in the ability to both monitor South Fork flows and provide conveyance options to supplement flows.

MONITORING STRATEGY

During the peer review, the panel suggested that the ability to achieve the proposed MFL should be monitored. This monitoring should be based on a number of different approaches, each of which has certain advantages and disadvantages.

First, efforts should be made to improve monitoring of freshwater inflows from major streams and tributaries. In addition, the District should attempt to obtain better information on the amount of fresh water that enters the system through ground water. Such improved quantification of freshwater inflows will provide a better, although indirect, indication that oligohaline resources are being protected.

To provide further confirmation, salinity should be monitored at selected points within the rivers and estuary. Salinity measurements at selected points will not likely measure the exact location of the oligohaline zone and, therefore, must be used in conjunction with other information.

The hydrodynamic model should be run periodically, using current hydrologic and salinity data, to estimate the extent and relative stability of the oligohaline zone. The watershed models should also be run, using the improved surface and ground water flow data to develop periodic water budget analyses to determine the net inflow of fresh water to the system.

Finally, the ability to successfully prevent significant harm from occurring to oligohaline habitats within the system requires documenting species composition, locations of communities, and the relative abundance within the system of those species that utilize and/or depend on low salinity conditions for growth and reproduction.

Data Collection and Monitoring

The Gordy Road Structure within the North Fork of the St. Lucie River basin is currently monitored in conjunction with the Upper East Coast Water Quality Sampling Network. Continued data collection at this site is recommended to monitor North Fork flows. No structure currently exists to monitor flows on the South Fork of the St. Lucie River. Staff is proposing the addition of a flow station, at a suitable site that is still to be determined, located upstream of saltwater influence on the South Fork.

The District and other agencies also collect flow data from other tributaries and canals, and rainfall data in the watershed. These monitoring efforts need to be continued to provide additional hydrologic data that can be used to refine the existing and future models.

Other District programs are underway to collect ground water and water quality data in the St. Lucie Estuary and other areas. Such information can be used to provide better estimates of total freshwater input to the estuary and the effects of freshwater flow on water quality. Data from these programs needs to be further evaluated to determine whether they can be effectively used to monitor exceedances or refine MFL criteria.

Additional monitoring of biological communities is also needed within the estuary. Benthic communities are an important component of the system. Historically, these communities have been impacted by the influx of large amounts of sediments and suspended solids from canal and tributary inflows. Studies of the distribution and composition of benthic communities and effects of sedimentation provide a means to assess the extent and health of the oligohaline zone. Pelagic and planktonic communities also need to be monitored to document the spatial and temporal distribution and biomass of phytoplankton, zooplankton, and fishes within the system.

Determination of Compliance with Criteria

MFL Criteria will be met if the following is fulfilled:

- Inflow measurements from the North Fork of the St. Lucie River remain above the levels needed to prevent significant harm from occurring in the oligohaline zone
- Results of analyses using the watershed models indicate that adequate inflow of fresh water is occurring throughout the system to prevent significant harm from occurring to oligohaline habitat
- Monitoring indicates that biological communities in the river and estuary are not being adversely impacted by high salinity conditions

Failure to meet one or more of these conditions, to the extent that loss of oligohaline habitat occurs in the estuary for two successive months during the dry season, constitutes harm to the system. If system monitoring data indicates that such harm conditions exist during two years in a row, significant harm occurs.

PREVENTION STRATEGY

Since the proposed significant harm criteria are not presently being exceeded, a recovery strategy does not need to be developed for this system. Furthermore, changes that are proposed for the watershed as part of the Indian River Lagoon Feasibility Study (USACE and SFWMD, 2001) are designed to provide additional retention basins along the river. These retention basins will reduce the amount and frequency of high volume discharges and can potentially provide additional water for discharge to the river during dry periods. With these features in place, the probability of exceeding the proposed MFL in the future criteria may be further reduced.

However, the ability to better manage water in the watershed may also make it possible to capture and retain water from the watershed for allocation to other (e.g., urban and agricultural water supply) purposes. Under such conditions, future dry season flows to the estuaries could be reduced rather than increased. For this reason, the following management approach is proposed that is intended to ensure protection of the oligohaline zone in the North and South Forks:

- Discharges from the North Fork of the St. Lucie River should be maintained above 21 cfs to prevent significant harm from occurring in the St. Lucie Estuary. Discharges will be managed within the operational protocols of the Ten Mile Creek Project, scheduled to be completed by 2004 (Appendix K). Flow targets will be consistent with CERP performance requirements for Indian River Lagoon restoration.
- Discharges from the South Fork should be maintained above 7 cfs to prevent significant harm from occurring.
- Due to water quality and discharge location concerns, releases of water through the C-23, C-24, and C-44 Canals are not considered effective means of providing flows to prevent significant harm from occurring to the St. Lucie River and Estuary.
- Studies are under way to collect additional topographic and hydrologic data needed to improve the models that are used in the South Fork basin. Additional biological and water quality studies are also needed to determine the salinity conditions and the quality and extent of oligohaline habitat that are produced by various flow regimes. Assessments are also needed to identify particular resources in this river that need to be protected.
- Similarly, additional research and monitoring are needed to refine existing data and models, improve the flow estimates, and characterize biological resources within the North Fork. Research priorities are itemized in the next section.

RESEARCH STRATEGY

As previously stated in **Chapter 4**, the District supports the application of the valued ecosystem component (VEC), a resource-based management strategy approach. The VEC approach is based on the concept that management goals for the St. Lucie River and Estuary can best be achieved by providing suitable environmental conditions that will support certain key species, or key groups of species, that inhabit this system. Detailed below are relevant ongoing and anticipated research efforts in support of St. Lucie River and Estuary MFL development (Doering, 2001)

Watershed Modeling

The need for improved watershed modeling is driving a number of research efforts. Better models are being developed, including three-dimensional models, and additional hydrologic and topographic data are being collected to support these models. A water quality model of the estuary is also being developed, primarily to support the SWIM programs for the Indian River Lagoon and the St. Lucie Estuary. This model will also be used to help determine Pollutant Load Reduction Goals (PLRGs) and TMDLs for the St. Lucie Estuary and to assess the effects of the proposed MFL criteria on estuarine water quality.

Salinity Research

During Fiscal Year 2002, the District will initiate an investigation of the North Fork of the St. Lucie River and Estuary. The purpose of the study is to characterize 1) the extent of the oligohaline zone as a function of freshwater inflow, and 2) the spatial and temporal distribution of chlorophyll *a* (phytoplankton) biomass, zooplankton biomass, and larval and juvenile fish. The results will address the use of the North Fork as a nursery area. Also, during Fiscal Year 2003, investigations need to be undertaken in the South Fork to determine if similar conditions and resources exist in that portion of the system.

The responses of benthic plants and oysters to rapid changes in salinity will be examined in a series of controlled experiments. These experiments will be conducted at the Gumbo Limbo Mesocosm Facility.

Water Quality

The District has a water quality modeling program for the St. Lucie River and Estuary in place. Studies of phytoplankton productivity and respiration and the benthic input of nutrients have been completed as part of this program. Studies to quantify nutrient loads are still under way.

Sediments

The accumulation of fine grained muck sediments in the St. Lucie River and Estuary has been examined in the past. It is presently being revisited in anticipation of large-scale dredging by the United States Army Corps of Engineers.

Adaptive Management

Based on best available information, a minimum flow has been proposed for the St. Lucie River and Estuary with the understanding that more information is needed to refine assumptions used in criteria development. Ongoing and proposed research and monitoring in the St. Lucie River and Estuary watershed are designed to provide data to fill gaps in our understanding of the ecosystem, specifically targeted to the oligohaline zone as a VEC approach. This information will be incorporated into the next generation of hydrodynamic salinity models now under development. Improved models will provide District staff with an opportunity to reevaluate the proposed criteria and refine the St. Lucie River and Estuary MFLs in accordance with District regional water supply plan development.

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GLOSSARY

1995 Base Case A model simulation that provides and understanding of the how the 1995 water management system with 1995 land use and demands responds to historic (1965-1995) climatic conditions.

1-in-10 Year Drought A drought of such intensity, that it is expected to have a return frequency of once in 10 years. A drought in which below normal rainfall, which has a 90 percent probability of being exceeded over a twelve-month period. This means that there is only a ten percent chance that less than this amount of rain will fall in any given year.

1-in-10 Year Level of Certainty Probability that the needs for reasonable-beneficial uses of water will be fully met during a 1-in-10 year drought.

Acre-Foot The volume of water that would cover one acre to a depth of one foot; 43,560 cubic feet; 1,233.5 cubic meters; 325,872 gallons.

Agricultural Field Scale Irrigation Requirements Simulation (AFSIRS) A simple water budget model for estimating irrigation demands that estimates demand based on basin specific data.

Agricultural Self-Supplied Water Demand The water used to irrigate crops, to water cattle, and for aquaculture (fish production), that is not supplied by a public water supply utility.

Anoxic Denotes the absence of oxygen

Aquifer A portion of a geologic formation or formations that yield water in sufficient quantities to be a supply source.

Aquifer System A heterogeneous body of intercalated permeable and less permeable material that acts as a water-yielding hydraulic unit of regional extent.

Basin (Ground Water) A hydrologic unit containing one large aquifer or several connecting and interconnecting aquifers.

Basin (Surface Water) A tract of land drained by a surface water body or its tributaries.

Bathymetry The measurement of water depth at various places in a body of water.

Best Management Practices (BMPs) Agricultural management activities designed to achieve an important goal, such as reducing farm runoff, or optimizing water use.

Central and Southern Florida Project Comprehensive Review Study (Restudy) A five-year study effort that looked at modifying the current C&SF Project to restore the greater Everglades and South Florida ecosystem while providing for the other water related needs of the region. The study concluded with the Comprehensive Plan being presented to the Congress on July 1, 1999. The recommendations made within the Restudy, that is, structural and operational modifications to the C&SF Project, are being further refined and will be implemented in the Comprehensive Everglades Restoration Plan (CERP).

Central and Southern Florida (C&SF) Project A complete system of canals, storage areas, and water control structures spanning the area from Lake Okeechobee to both the east and west coasts, and from Orlando south to the Everglades. It was designed and constructed during the 1950s by the United States Army Corps of Engineers (USACE) to provide flood control and improve navigation and recreation.

Class I through V Surface Water Quality Standards As defined by Chapter 62-302.400 Florida Administrative Code, all surface waters in Florida have been classified according to designated use as follows:

- Class I Potable water supplies
- Class II Shellfish propagation or harvesting
- Class III Recreation, propagation, and maintenance of a healthy, well-balanced population of fish and wildlife
- Class IV Agricultural water supplies
- Class V Navigation, utility, and industrial use

Commercial and Industrial Self-Supplied Water Demand Water used by commercial and industrial operations using over 0.1 million gallons per day.

Comprehensive Everglades Restoration Plan (CERP) The implementation of recommendations made within the Restudy, that is, structural and operational modifications to the C&SF Project are being further refined and will be implemented through this plan.

Consumptive Use Permit A permit issued by the SFWMD allowing utilities to withdraw ground water for consumptive use.

Control Structure A man-made structure designed to regulate the level/flow of water in a canal (e.g., weirs, dams).

Epiphyton Plants that derive their moisture and nutrients from the air and rain and usually grow on other plants

District Water Management Plan Regional water resource plan developed by the District under Chapter 373.036, F. S.

Drawdown The drawdown at a given point is the distance the water level is dropped.

Estuary A water passage where the ocean or sea meets a river.

Eutrophication The gradual increase in nutrients in a body of water. Natural eutrophication is a gradual process, but human activities may greatly accelerate the process.

Evapotranspiration Water losses from the surface of soils (evaporation) and plants (transpiration).

Food Web The totality of interacting food chains in an ecological community.

Geographic Informations Systems (GIS) Mapping The abstract representation of natural (or cultural) features of a landscape into a digital database, geographic information system.

Governing Board Governing Board of the South Florida Water Management District.

Ground Water Water beneath the surface of the ground, whether or not flowing through known and definite channels.

Harm *(Term will be defined during proposed rule development process)* An adverse impact to water resources or the environment that is generally temporary and short-lived, especially when the recovery from the adverse impact is possible within a period of time of several months to several years, or less. Harm is defined to occur to this estuary system when freshwater flows are less than the rate of evaporation for a period of two consecutive months during the dry season. Under these conditions, it is expected that most of the oligohaline zone will be lost or impacted.

Hectare A unit of measure in the metric system equal to 10,000 square meters (2.47 acres).

Hypoxic A deficiency of oxygen reaching the tissues of the body.

Isohaline Zone Transition between the saltier mesohaline and the fresher oligohaline habitats; in this document it has a salinity of 5 parts per thousand and defines the downstream extent of viable oligohaline habitat under low flow situations.

Lagoon A body of water separated from the ocean by barrier islands, with limited exchange with the ocean through inlets.

Lake Okeechobee This lake measures 730 square miles and is the second largest freshwater lake wholly within the United States.

Marsh A frequently or continually inundated wetland characterized by emergent herbaceous vegetation adapted to saturated soil conditions.

Mesohaline Term to characterize waters with salinity of 5 to 18 parts per thousand, due to ocean-derived salts.

Minimum Flows and Levels (MFLs) The point at which further withdrawals would cause significant harm to the water resources/ecology of the area.

National Geodetic Vertical Datum (NGVD) A nationally established references for elevation data.

Natural Resources Conservation Service (NRCS) An agency of the U.S. Department of Agriculture (USDA) that provides technical assistance for soil and water conservation, natural resource surveys, and community resource protection.

Nekton Macroscopic organisms swimming actively in water, such as fish (contrast to plankton).

Phytoplankton The floating, usually minute, plant life of a body of water.

Oligohaline Low salinity region of an estuary where fresh and saline waters meet; salinity range is typically 0.5 to 5.0 parts per thousand.

Oligosaline Term to characterize water with salinity of 0.5 to 5.0 parts per thousand, due to land-derived salts.

Organics Being composed of or containing matter of, plant and animal origin.

Public Water Supply Demand All potable water supplied by regional water treatment facilities with pumpage of 0.5 million gallons per day or more to all customers, not just residential.

Reasonable-Beneficial Use Use of water in such quantity as is necessary for economic and efficient utilization for a purpose and in a manner that is both reasonable and consistent with the public interest.

RECOVER A comprehensive monitoring and adaptive assessment program formed to perform the following for the Comprehensive Everglades Restoration Program: restoration, coordination, and verification.

Recreational Self-Supplied Water Demand The water used for landscape and golf course irrigation. The landscape subcategory includes water used for parks, cemeteries, and other irrigation applications greater than 0.1 million gallons per day. The golf course subcategory includes those operations not supplied by a public water supply or regional reuse facility.

Regional Water Supply Plan Detailed water supply plan developed by the District under Section 373.0361, Florida Statutes.

Residential Self-Supplied Water Demand The water used by households whose primary source of water is private wells and water treatment facilities with pumpages of less than 0.5 million gallons per day.

Saltwater Water Intrusion This occurs when more dense saline water moves laterally inland from the seacoast, or moves vertically upward, to replace fresher water in an aquifer.

Serious Harm (*Term will be defined during proposed rule development process)* An extremely adverse impact to water resources or the environment that is either permanent or very long-term in duration. Serious harm is generally considered to be more intense than significant harm.

Significant Harm *(Term will be defined during proposed rule development process)* An adverse impact to water resources or the environment, relating to an established minimum flow or level for a water body; generally temporary but not necessarily short-lived, especially when the period of recovery from the adverse impact exceeds several months to several years in duration; more intense than harm, but less intense than serious harm. St. Lucie Estuary significant harm occurs when freshwater flows to the estuary are less than the rate of evaporation for a period of two consecutive months during the dry season for two or more years in succession.

Slough A channel in which water moves sluggishly, or a place of deep muck, mud, or mire. Sloughs are wetland habitats that serve as channels for water draining off surrounding uplands and/or wetlands.

Stage The elevation of the surface of a surface water body.

Standard Project Flood (SPF) A mathematically derived set of hydrologic conditions for a region that defines the water levels that can be expected to occur in a basin during an extreme rainfall event, taking into account all pertinent conditions of location, meteorology, hydrology, and topography.

Storm Water Surface water resulting from rainfall that does not percolate into the ground or evaporate.

Supply-Side Management The conservation of water in Lake Okeechobee to ensure that water demands are met while reducing the risk of serious or significant harm to natural systems.

Surface Water Water that flows, falls, or collects above the surface of the earth.

Surface Water Improvement and Management (SWIM) Plan Plan prepared according to Chapter 373, F.S.

Tidal Rivers Water bodies that receive fresh water from areas other than runoff (from the upstream watershed), are flushed to some extent during a tidal cycle, and are subject to saltwater intrusion from downstream areas.

Total Maximum Daily Load (TMDL) The level of loading to a body of water that will protect uses and maintain compliance with water quality standards (defined in the Clean Water Act).

Turbidity The measure of suspended material in a liquid.

Uplands An area with a hydrologic regime that is not sufficiently wet to support vegetation typically adapted to life in saturated soil conditions; nonwetland.

Vertical Migration The vertical movement of oil, gas, contaminants, water, or other liquids through porous and permeable rock.

Wastewater The combination of liquid and waterborne discharges from residences, commercial buildings, industrial plants and institutions together with any ground water, surface runoff or leachate that may be present.

Water Budget An accounting of total water use or projected water use for a given location or activity.

Water Conservation Reducing the demand for water through activities that alter water use practices, e.g., improving efficiency in water use, reducing losses of water, and reducing waste of water.

Water Conservation Areas (WCAs) That part of the original Everglades ecosystem that is now diked and hydrologically controlled for flood control and water supply purposes. These are located in the western portions of Miami-Dade, Broward, and Palm Beach counties, and preserve a total of 1,337 square miles, or about 50 percent of the original Everglades.

Watershed The drainage area from which all surface water drains to a common receiving water body system.

Water Shortage Declaration Water shortage declarations can be made by the District's Governing Board pursuant to Rule 40E-21.231, Florida Administrative Code, which states "If …there is a possibility that insufficient water will be available within a source class to meet the estimated present and anticipated user demands from that source, or to protect the water resource from serious harm, the Governing Board may declare a water shortage for the affected source class." Estimates of the percent reduction in demand required to match available supply is required and identifies which phase of drought restriction is implemented. A gradual progression in severity of restriction is implemented through increasing phases. Once declared, the District is required to notify permitted users by mail of the restrictions and to publish restrictions in area newspapers.

Weir A barrier placed in a stream to control the flow and cause it to fall over a crest. Weirs with known hydraulic characteristics are used to measure flow in open channels.

Wetlands Areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support a prevalence of vegetation typically adapted for life in saturated soil conditions.