Technical Documentation to Support Development of Minimum Flows and Levels for the Caloosahatchee River and Estuary

South Florida Water Management District

Water Supply Division

September 6, 2000 Draft

Table Of Contents

List of Figures

List of Tables

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 a minimum flow and level (MFL) for the Caloosahatchee River and Estuary.

The District Water Management Plan (DWMP) for South Florida (SFWMD, 2000a) includes a schedule for establishing MFLs for priority water bodies within the District. Section 373.042(2), F.S., requires the water management districts to annually review this list and schedule and make any necessary revisions. This list requires that MFLs for the Caloosahatchee River and Estuary be established by 2000.

These MFLs are being developed pursuant to the requirements contained within the "Florida Water Resources Act", and specifically, Sections 373.042 and 373.0421, F.S., as part of a comprehensive water resources management approach geared towards assuring the sustainability of the water resources. The proposed MFL's are not a “stand alone” resource protection tool; but 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 relationship between 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., which also include recommendations for establishment of minimum flows and recovery and prevention strategies (SFWMD 2000b, 2000c and 2000d).

Establishing *minimum* levels alone will not be sufficient to maintain a sustainable resource or protect it from significant harm during the broad range of water conditions occurring in the managed system. For the Caloosahatchee 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 water needs for sustainability. The necessary hydrologic regime for restoration of the Caloosahatchee River and estuary ecosystem must also be defined and implemented through the use of water reservations and other water resource protection tools. Achieving the required water levels throughout this system is an overall, long-term restoration goal (USACEand SFWMD 1999). *Maximum* flows for the Caloosahatchee River and estuary are controlled by regulation schedules for Lake Okeechobee and the structure S-79, but the overall ability of these schedules to protect the resource is uncertain, especially during above normal rainfall years due to the limited water storage capacity of the regional system. As a result, new or revised maximum freshwater flow criteria are being considered as part of the regional water supply plan implementation process. Recently, changes have been made to the maximum water level for Lake Okeechobee, as determined by the regulation schedule (USACE 2000).

As a first formal step to establish a MFL for the Caloosahatchee 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 Caloosahatchee River and Estuary.

This document will receive independent scientific peer review pursuant to Section 373.042, F.S. Initial rule development workshops are currently being held (August 15, 15, 24 and 25, 2000) to discuss concepts proposed for the Caloosahatchee River and Estuary. Persons who wish to receive notice of these workshops, as well as any public meetings conducted during the independent scientific peer review process, should notify the District.

PROCESS AND BASES FOR ESTABLISHMENT OF MINIMUM FLOWS AND LEVELS

Process Steps and Activities

The process for establishing a minimum flow for the Caloosahatchee River and Estuary can be summarized as follows:

1. Through the development of the Lower West Coast Regional Water Supply Plan, the Caloosahatchee River Water Management Plan and the Lower East Coast Regional Water Supply Plan and concurrent staff research and analysis, a methodology and technical basis for establishment of the MFL was developed.
2. Further public consideration of a technical basis and methodology for establishing the MFL and review of the first draft of the rule was conducted during rule development workshops in August 2000.
3. A scientific peer review of the rule and technical documents will be conducted during September 2000 to verify the criteria pursuant to Section 373.0421(2), F.S.
4. In October 2000 revisions to the MFL report recommended by the panel, as appropriate, will be incorporated into the criteria.
5. A final rule draft will be presented to the Governing Board for establishment in December 2000.

Legal and Policy Bases 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." Section 373.042(1)(a)-(b), F.S. The statute further directs water management districts to use the best available information in establishing a MFL level. 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.

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

A. What are the priority functions of each water resource and what is the baseline condition for the functions being protected?

B. 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 a MFL 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., which includes flood control, water quality protection, water supply and storage, fish and wildlife protection, navigation, and recreation.

The State Water Resource Implementation Rule, Section 62-40.405, F.A.C, outlines specific factors to consider including protection of water resource 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:

- 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 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 4 of the MFL document provides a detailed description of the relevant water resource functions of the Caloosahatchee 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 MFL, 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 4, to examine their applicability to the minimum levels that are proposed for the Caloosahatchee River and estuary.

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 play one part in this framework. Determination of the role of MFLs and the protection that they offer, versus other water resource tools available to the District, are 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)), and aquifer zoning to prevent undesirable uses of the ground water (Section 373.036). 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 playing a role in the ultimate goal of achieving a sustainable water resource.

The conceptual relationship among the terms harm, significant harm, and serious harm proposed by the District is 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 that take multiple years to recover, which result from a change in surface water or ground water hydrology.*

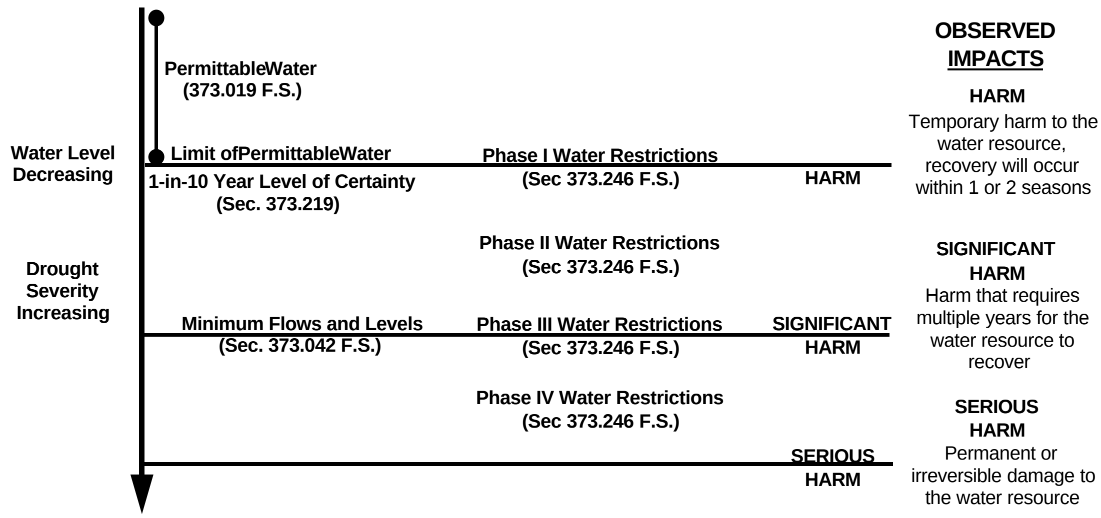

Figure 1. Conceptual Relationships among the Terms Harm, Significant Harm and Serious Harm

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 - Harm Standard

The resource protection criteria used for Consumptive Use Permitting (CUP) 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 without harm. 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., all together define the harm standard for purposes of consumptive use allocation. These harm criteria may be applied using climate conditions that represent an assumed level of certainty. The level of certainty used in the Lower West Coast, Lower East Coast, and Upper East Coast Regional Water Supply Plans (SFWMD 2000b, 2000c and 2000d) is a 1-in-10 year drought frequency, as defined in the District's permitting rules. The 1-in-10 year drought level of certainty is also the water supply planning goal that was established in Section 373.0361, F.S. The standard for harm used in the CUP process is considered as the point at which adverse impacts to water resources cannot be restored within a period of one to two years of average rainfall conditions. These short-term adverse impacts are addressed for the CUP program, which calculates allocations to meet demands for use during relatively mild, dry season events, defined as the 1-in-10 year drought.

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 that was 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.

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, which increases water shortage restrictions for users. These increased withdrawals increase the potential for serious harm to the water resource.

The District has implemented its water shortage authority by restricting consumptive uses based on the concept of shared adversity 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 SFWMD'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 restriction.

MFL RECOVERY AND PREVENTION STRATEGY

Upon establishment of the MFL through rulemaking, it is implemented through a multifaceted recovery and prevention strategy, developed pursuant to Section 373.0421(2), F.S. A recovery and prevention strategy was developed for the Caloosahatchee in the Lower East Coast Regional Water Supply Plan (approved May 2000) and the Caloosahatchee Water Management District (approved April 2000), and will be implemented following establishment of the MFL.

Section 373.0421(2), F.S., provides that if it is determined that water flows or levels will fall below an established MFL within the next 20 years or is 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 plan horizon for the subject area and the strategy is to be developed in concert with that planning process.

The goal of the 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 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.

Depending on the existing and projected flows or levels, from a regulatory standpoint, 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 depending on the cause of the MFL exceedances, e.g., consumptive use withdrawals, poor surface water conveyance facilities or operations, over drainage, or a combination of the above.

Incremental measures to achieve the MFL must be included in the recovery and prevention strategy, include a timetable for a 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 consideration of economic and technical feasibility of potential options. Additional information about the specific recovery and prevention strategy recommended for the Caloosahatchee River and Estuary is provided in Chapter 4.

DOCUMENT STRUCTURE

The following chapter of this report describes the geographic setting, the resources at risk, and major issues concerning the use and conservation of resources within the Caloosahatchee River and Estuary. Chapter 3 documents the methods that were used to establish significant harm criteria for the different areas, resources and functions. Chapter 4 describes the specific hydrologic criteria, with frequency, duration, and depth components, that were developed to indicate the point at which significant harm occurs and includes an analysis of the specific relevant factors and implications of the proposed definition of significant harm. Conclusions and recommendations are presented in Chapter 5 and the literature cited is in the final chapter. Technical Appendices A through F are provided in a separate volume and include more detailed descriptions and analysis of available data, literature, and issues raised during the review process.

Chapter 2
DESCRIPTION OF THE WATER BODY

INTRODUCTION

The Caloosahatchee River and Estuary and its upstream watershed are located along the lower west coast of Florida within the Caloosahatchee Watershed Planning Area (**Figure 2**). This watershed drains an area of over 1,300 square miles extending 66 miles from Lake Okeechobee to the mouth of the Caloosahatchee Estuary (San Carlos Bay). The Caloosahatchee River (C-43), along with the St. Lucie Canal (C-44) are important components of the Central and Southern Florida (C&SF) Project and are used primarily for water releases from Lake Okeechobee when lake levels exceed United States Army Corps of Engineers (USACE) regulation schedules (USACE 2000b) established for flood protection. In addition to regulatory discharges for flood protection, the river also receives water deliveries from the lake to maintain water levels for river navigation and water supply for agriculture and urban users (SFWMD, 2000d).

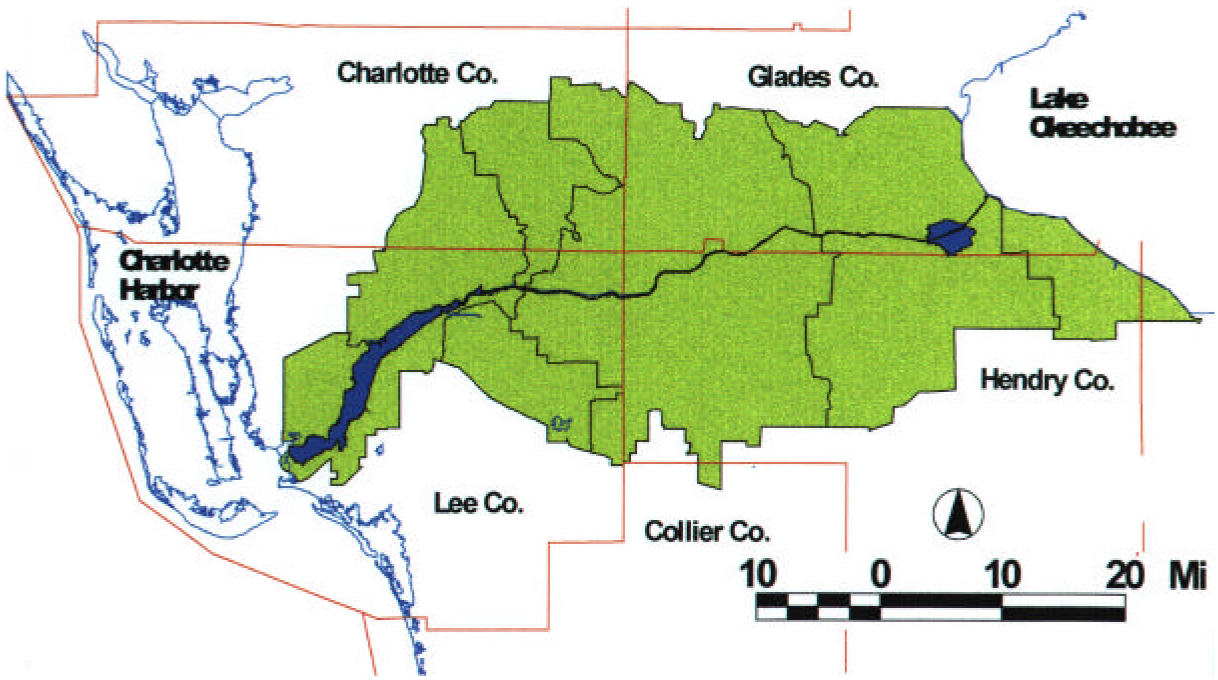

Figure 2. Caloosahatchee Watershed Planning Area

CLIMATE, RAINFALL AND SEASONAL WEATHER PATTERNS

The hydrology of Southwest Florida is strongly affected by its climate, rainfall and seasonal weather patterns. The climate of the Caloosahatchee watershed is classified as subtropical. The annual average temperature is about 74°F with monthly averages ranging from near 63^{o}F in winter to near 83^{o}F during summer (**Table 1).** Winters are mild with warm days and moderately cool nights. Occasional cold fronts can bring temperatures near 32^{o}F, but very seldom result in a hard freeze. During summer average maximum temperatures near 90^{o}F and, under rare circumstances, maxima have recorded as high as 100^{o}F. The mean values of temperature, precipitation, winds, and relative humidity for Ft. Myers are given in **Table 1**.

Table 1. Normal Monthly Values of Temperature and Precipitation at Ft. Myers

Month	Temperature (^{o}F)	Precipitation (In.)
January	63.5	1.52
February	65.2	2.21
March	68.2	2.62
April	72.8	2.64
May	77.4	3.85
June	80.8	8.96
July	82.2	9.08
August	82.7	7.38
September	81.3	8.50
October	76.1	4.09
November	69.2	1.20
December	65.0	1.29
	Average 73.7	**Total 53.3**

Rainfall averages 53 inches annually, with heaviest precipitation during the summer **(Table 1).** Based on precipitation, a “wet” and “dry” season can be established. Most (71 percent) of the annual precipitation (38 inches) falls during the wet season, which extends from June to October. In contrast only 29 percent (15.3 inches) of this total falls during the dry season. During the winter and early spring dry season there some years in which there are long periods of time in which there is little or no rainfall resulting in a regional drought. In contrast, the passage of tropical storms or hurricanes over the area can result in 6 to 10 inches of rainfall in one day. Thunderstorms are infrequent from November to April but they occur on an average two out of three days from June through September. Storms are usually brief but intense and peak during the late afternoon or early evening (SFWMD, 2000d).

There is also a high variability in rainfall at different locations in the watershed. The inland portion of the watershed receives more rain than the coast during the dry season (**Figure 3)**. On average the wet season rainfall is greater along the coast. Although November is the driest month, April is the month with the greatest water use demand.

Tropical storms and hurricanes that affect the area originate in the Atlantic Tropical Cyclone Basin. This area includes the North Atlantic Ocean, the Caribbean Sea, and the Gulf of Mexico. Hurricane season extends from June through November and peaks in September and October when ocean temperatures are warmest and humidity is highest. Major effects from these storms are flooding, from rainfall and wind-generated tides and waves, storm surge, wind damage, and flushing of the river and estuary.

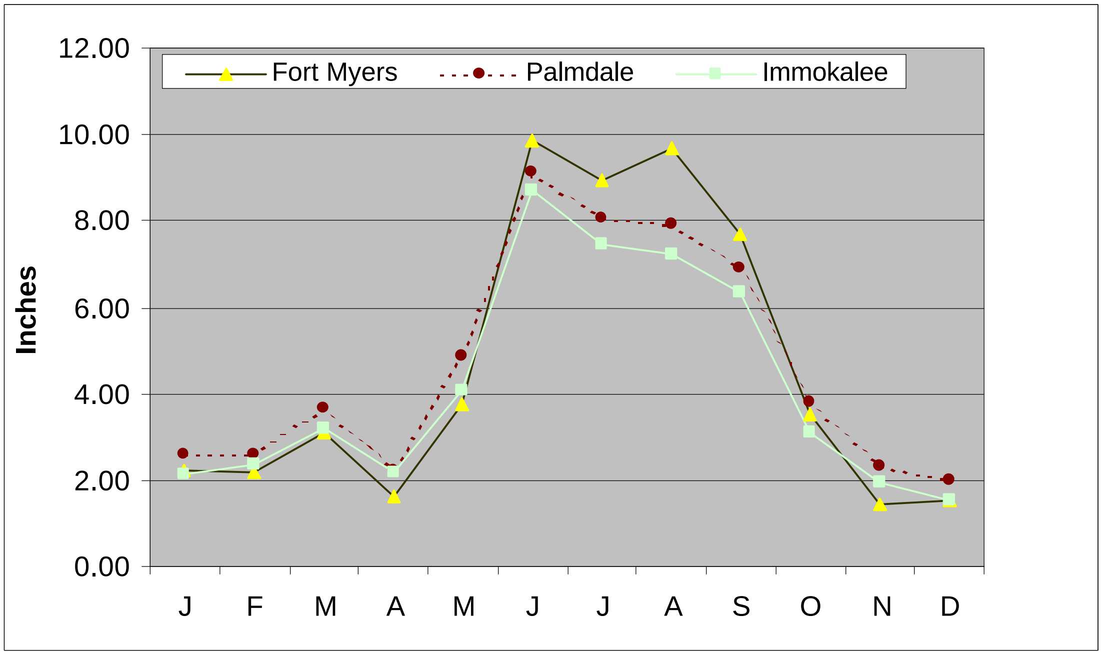

Figure 3. Spatial Variability of Average Monthly Rainfall in the Caloosahatchee Basin.

MAJOR BASINS

Caloosahatchee River and Upstream Watershed

The upstream freshwater portion of the river extends east from the W.P. Franklin Lock (S-79) to the S-77 structure located on the southwestern shore of Lake Okeechobee, a distance of 44 miles. Along this stretch of the river C-43 ranges from 50 to 140 yards in width with water depths ranging from 20 to 30 feet deep. Many of the original bends in the river remain today as oxbows along both sides of the canal. The pattern and period of flow within the river is highly variable based on the need for regulatory discharges from Lake Okeechobee, surface water runoff from the surrounding watershed and the need for irrigation and water supply for urban areas.

Prior to development of the region, the Caloosahatchee River was a sinuous river extending from Beautiful Island to a waterfall at the west-end of Lake Flirt. A sawgrass marsh extended from Lake Flirt to Lake Okeechobee. The pre-development landscape had few tributaries east of LaBelle and Twelve-mile Slough connected the Okaloacoochee Slough to the Orange River (**Figure 4**).

The area east of LaBelle was flat and there were few creeks to provide drainage. These waters moved westward eventually spilling over falls and wandering slowly through a series of oxbows before entering the upper reaches of the tidally driven downstream estuary. The estuary accepted overland sheet flow during the dry season as well as an occasional deluge of water during the wet season as a result of a passing hurricane or tropical storm. This range of flows largely determined what portions of the river system would become estuarine in nature characterized by a mixing zone of fresh and brackish water of low salinity. This area of fresh/brackish water moved unimpeded landward under low flow conditions and seaward with increasing flows (Haunert et al. in review).

Over the past century, the hydrology of the Caloosahatchee watershed has been strongly affected by regional drainage improvements, land use changes and development. Beginning in the late 1800's, Hamilton Disston excavated a canal to connect Lake Okeechobee to the Caloosahatchee River and Gulf of Mexico to improve transportation and lower the lake for development. In 1918, three major locks were constructed along the canal to improve navigation, and from 1920-1930 the river channel was enlarged to a six-foot depth and ninety feet width (USACE 1957). To accommodate navigation, flood control, and land reclamation needs, the freshwater portion of the river was reconfigured into a canal known as C-43. Numerous canals were constructed along the banks of the river in support of agricultural communities located along the river. In addition, three lock-and-dam structures (S-77, S-78, and S-79) were added to control flow and stage height.

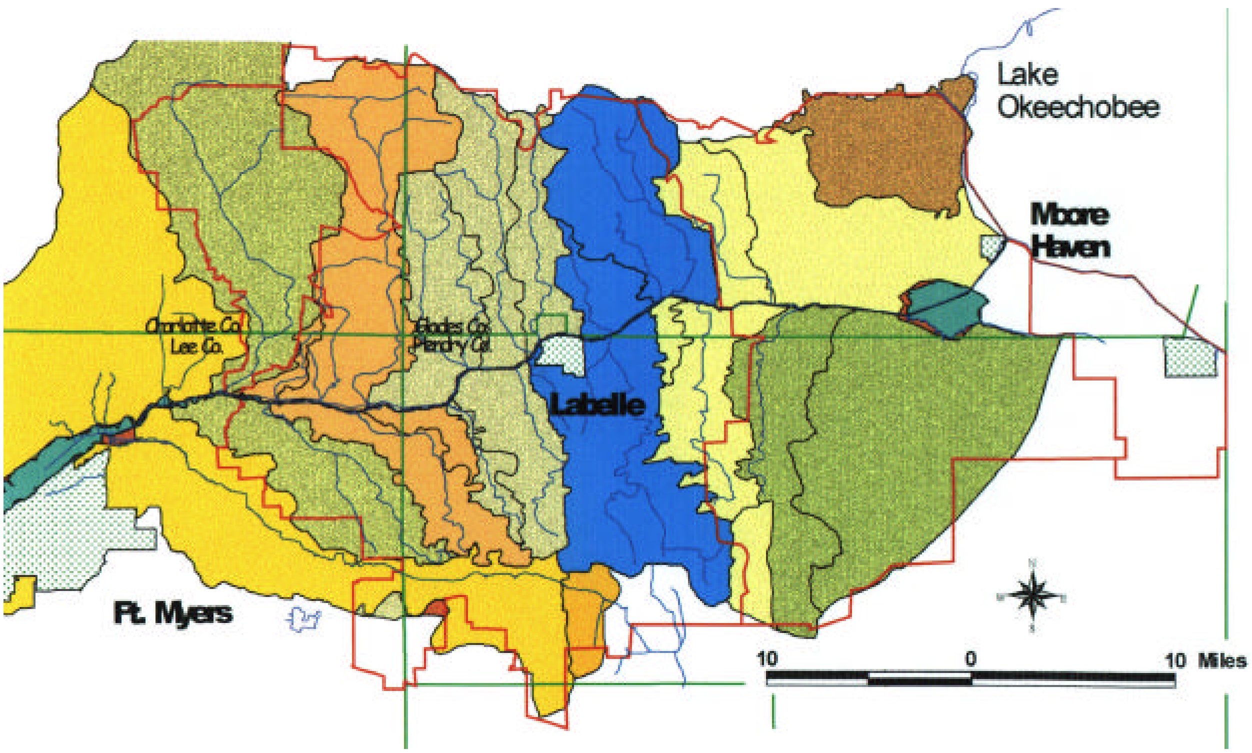

Figure 4. Pre-Development Hydrology in the Caloosahatchee Basin

The final downstream structure (S-79) marks the beginning of the Caloosahatchee Estuary. Also called the W.P. Franklin Lock and Dam, this structure maintains specified water levels upstream, regulates freshwater discharge into the estuary, and acts as an impediment to saltwater intrusion to the upstream portion of the river. The Moore Haven Lock (S-77), located on the southwest shore of Lake Okeechobee, regulates lake waters. The Ortona Lock (S-78) aids in control of water levels on adjacent lands upstream and separates C-43 into two distinct hydrologic units, the East and West Basins (**Figure 5**). These basins include portions of Lee, Charlotte, Collier, Glades, and Hendry Counties. Tributary drainage in the East Basin is more complex than the West Basin. Irrigation for agriculture is the most important water use the East Basin and is controlled by an extensive network of canals that recharge the water table during the dry season and drain floodwaters during the wet season. Land use in the West Basin is also largely agricultural.

Today, the C-43 Canal (Caloosahatchee River) is the most significant source of surface water in the Caloosahatchee Basin. The C-43 Canal receives water from Lake Okeechobee, runoff from the watershed and base flow from the Surficial Aquifer System. The river in turn supplies water for public supply, agriculture, and the environment. This source can be unreliable during the dry season or periods of inadequate rainfall, when releases are required from Lake Okeechobee to meet demand. The U.S. Army Corps of Engineers manages the C-43 Canal via a regulation schedule, which presently accommodates navigational, flood protection, water supply, and environmental needs.

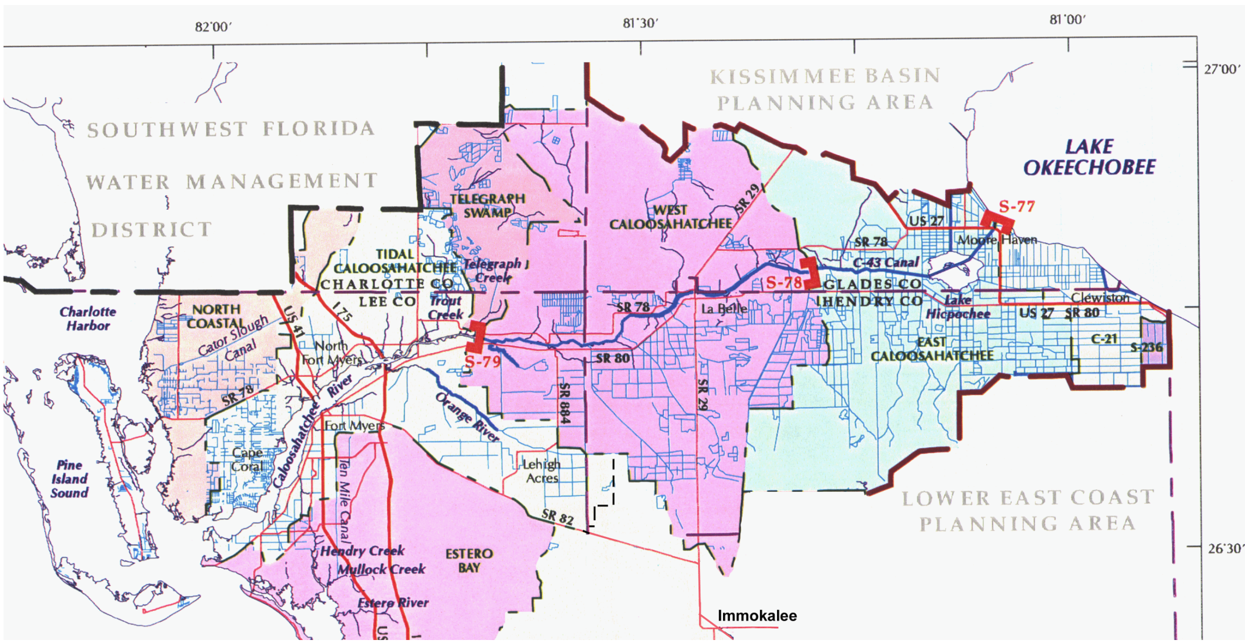

Figure 5. Major Basins and Water Management Features in the Caloosahatche Basin

The Lake Okeechobee Demand (Service) Area, which is defined as the area that is or could be supplied by surface water from the Caloosahatchee River, is the primary source for agricultural irrigation and potable surface supply water in the Caloosahatchee watershed. This area extends from the Franklin Lock (S-79) eastward to the Moore Haven Lock (S-77) and includes land in Lee, Glades, and Hendry counties.

Other surface water bodies located within the Caloosahatchee Planning Area include lakes, rivers, and canals. These areas provide storage and allow conveyance of surface water. Lake Hicpochee is the largest lake in the planning area and is bisected by C-43 just west of Lake Okeechobee (**Figure 5).** Numerous canals and tributaries in the planning area drain into the Caloosahatchee River. The major tributaries are the Orange River and Telegraph Slough, which drain into C-43 in the western portion of the watershed, near W. P. Franklin Lock and Dam (S-79). The majority of the canals in the watershed were constructed as surface water drainage systems rather than for water supply purposes.

Caloosahatchee Estuary

The Caloosahatchee Estuary is a large estuarine ecosystem where the waters of the Gulf of Mexico mix with the freshwater inflows from the river, sloughs, and overland sheet flow from the upstream basin **(Figure 6**). The area is characterized by a shallow bay, extensive seagrass beds, and sand flats. Extensive mangrove forests dominate undeveloped areas of the shoreline. The width of the estuary varies from 175 yards in the upper portion, to more than 1.5 miles wide downstream at San Carlos Bay (Scarlatos 1988). The tidal portion of the river includes parts of Lee and Charlotte Counties. The estuary length between the Franklin Lock and Shell Point is 26 miles and is bordered by Fort Myers on the south shore and Cape Coral on the north shore (**Figure 6).** Water discharges from the Caloosahatchee passes Shell Point and enters the Gulf of Mexico at San Carlos Bay. Because of the irregular, long, slender shape of the system, relatively small changes in wind, tide, runoff, or precipitation can have dramatic effects on flow, water depth, salinity, and turbidity.

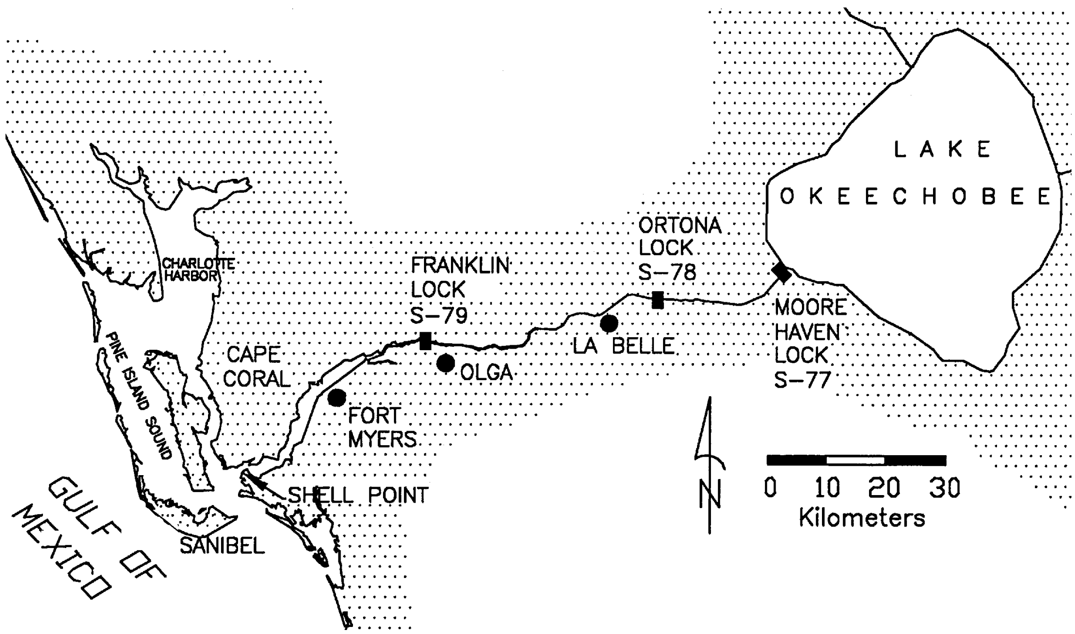

Figure 6. General Plan View of the Caloosahatchee River and Estuary

The river provides the primary source of fresh water for the estuary through structure S-79, although local basin runoff may exceed river flow during periods of heavy local rainfall. The freshwater, upstream portion of the river extends east from S-79 and connects with Lake Okeechobee. The downstream, estuarine portion of the river extends west from S-79 and empties into San Carlos Bay at Shell Point (Figure 6). The river (canal C-43) bisects the Caloosahatchee watershed and functions as a primary canal that conveys storm water runoff, regulatory releases from Lake Okeechobee, provides navigation for large boats along the Okeechobee Water Way and provides recreational opportunities for boating, fishing and wildlife observation. The estuary is an important nursery ground for many commercially and recreationally important fish and shellfish species. The estuary also provides foraging areas and wetland habitat for a large number of Florida's rare, endangered, and threatened species.

Maintenance of appropriate freshwater inflows is essential for a healthy estuarine system. Preliminary findings indicate that optimum inflows to the Caloosahatchee Estuary should have mean monthly values that range between 300 and 2,800 cubic feet per second (cfs) (Chamberlain et al., 1995). Average daily flows between January 1988 and June 1999 were approximately 500 cfs. Low flows of 0 cfs and high flows as high as 17,283 cfs were recorded during the same period. Excessive freshwater inflows to the estuary result in imbalances beyond the tolerances of estuarine organisms. The retention of water within upland basins for water supply purposes can reduce inflows into the estuary and promote excessive salinities. Conversely, the inflow of large quantities of water into the estuary due to flood control activities can significantly reduce salinities and introduce stormwater contaminants. In addition to immediate impacts associated with changes in freshwater inflows, long-term cumulative changes in water quality constituents or water clarity may also adversely affect estuarine communities (Doering and Chamberlain, 1999).

Estuarine biota are well adapted to, and depend 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 serve as freshwater reservoirs for the maintenance of base flow discharges into the estuaries, providing favorable salinities for estuarine biota. During the wet season, upstream wetlands provide pulses of organic detritus, which are exported downstream to the brackish water zone. These materials are an important link in the estuarine food chain.

Tape grass, *Vallisneria americana*, is one of the dominant submerged aquatic plants in the upper Caloosahatchee River Estuary, and occurs in well-defined beds in shallow waters. *V. americana* has been identified as important habitat for a variety of freshwater and estuarine invertebrate and vertebrate species, including some commercially and recreationally important fish (Bortone and Turpin 1998). Additionally, it can serve as a food source for the Florida manatee.

Estuaries are important nursery grounds for many commercially important fish species. Many freshwater wetland systems in the planning area provide base flows to the estuary. Wetlands as far inland as the Okaloacoochee Slough in Hendry County contribute to the base flows entering the estuarine system. Maintenance of these base flows is crucial to propagation of many fish species, such as grouper, snapper, and spotted seatrout, which is the basis of extensive commercial and recreational fishing industries.

The estuarine environment is sensitive to freshwater releases, and disruption of the volume, distribution, circulation, and temporal patterns of freshwater discharges could place severe stress on the entire ecosystem. "Such salinity patterns affect productivity, population distribution, community composition, predator-prey interactions, and food web structure in the inshore marine habitat. In many ways, salinity is a master ecological variable that controls important aspects of community structure and food web organization in coastal systems" (Myer and Ewel,1990). Other aspects of water quality, such as turbidity, dissolved oxygen, nutrient loads, and toxins, also affect functions of these areas (Myers and Ewel, 1990).

LAND USE

Land use within the watershed is predominantly rural and agricultural in nature in the eastern portion of the watershed, and urban in the western portion. The predominant land use within the Caloosahatchee Water Management Planning Area is agricultural and is expected to remain so in the future (SFWMD, 2000d). Citrus is the dominant irrigated crop in the basin and occupies over 91,000 acres, according to SFWMD 1995 land use data. Over the past two decades, Southwest Florida has had the fastest growing citrus acreage in the state. This is associated with the movement of citrus southward from Central Florida following several severe winter freezes in the mid-1980s.

Sugarcane, with an estimated 75,000 acres, according to the 1995 Land Use Coverage, closely follows citrus in dominance. It is produced in the Caloosahatchee watershed in close vicinity to Lake Okeechobee, in Hendry and Glades counties, where transportation costs to the mills can be minimized. Sugarcane acreage has continued to increase since 1995, and is expected to continue to increase in the future.

Native/natural land uses are also predominant in the basin, however this land use can be expected to decrease as the watershed is further transformed into agriculture and urban uses. Urban land use follows behind, and is predominant in the western portion of the basin (SFWMD, 2000d). The distribution of general land use and natural features is shown in **Figure 7.**

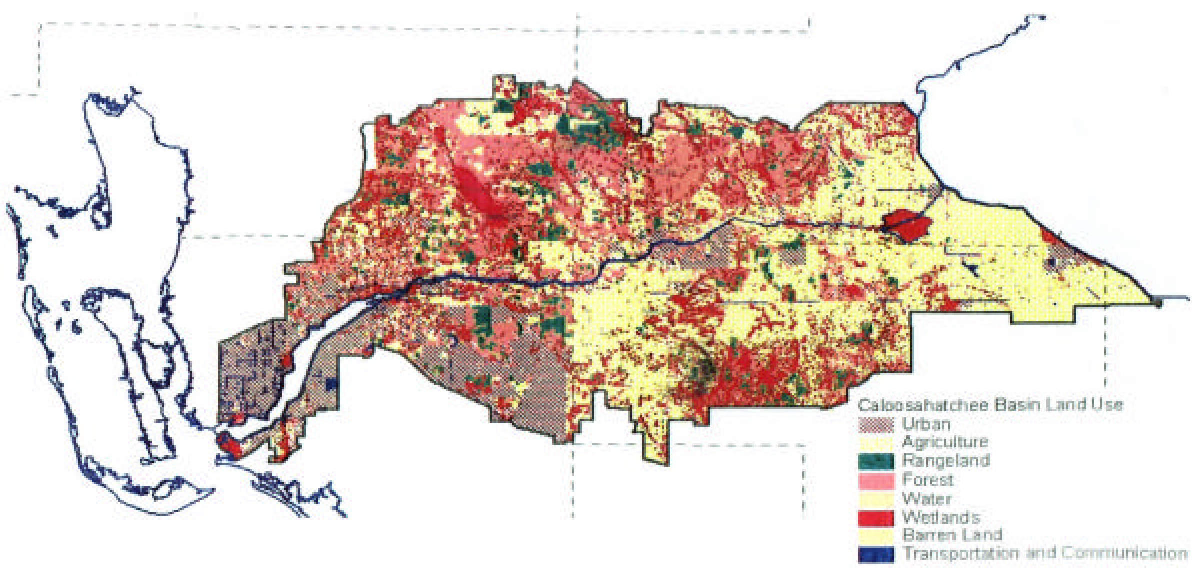

Figure 7. Land Use in the Caloosahatchee Watershed

WATER RESOURCES

Surface Water Systems

Surface water flows in the watershed are derived from rainfall within the basin and from discharge from Lake Okeechobee. Runoff from the West Caloosahatchee Basin is slightly higher than runoff from the East Caloosahatchee Basin indicating the greater flow attenuation in eastern basin due to the flatness and thick, sandy soils (Fan and Burgess, 1983). There is little water storage in the watershed. The intensive drainage on the south side of the river provides little storage. The north side of the river is largely undeveloped west of Lake Hicpochee and although there is considerable wetland water storage, it is not managed water storage.

Lake Okeechobee

Lake Okeechobee, which covers 730 square miles, is the largest freshwater lake in the southeastern United States. The lake receives significant volumes of runoff from the Kissimmee River, which begins near Orlando, the Upper Chain of Lakes, Lake Istokpoga and numerous small inflows along the north shore of the lake in the wet season. During the pre-development period, Lake Okeechobee discharged to the south and west, into the Everglades and the Caloosahatchee watershed during high water periods. The United States Army Corps of Engineers (USACE) and the SFWMD now control the outfall from the lake. Numerous canals connect the lake to the East and West Coasts as well as the Everglades.

The Caloosahatchee River (Canal C-43) receives water from Lake Okeechobee for flood control and water supply. Regulatory discharges via C-43 to lower lake-stage for flood protection, is 37% of total surface water discharge from Lake Okeechobee (Fan and Burgess, 1983). In wet years, this has resulted in discharge as great as the total runoff from the watershed. Water is also released to control algal blooms in the river (Miller *et al*., 1982). At low flow, alga blooms develop in the canal between S-78 and S-79, producing poor drinking water quality for Ft. Myers and Lee County water supplies. Water is released from the lake to flush this water out of the river. Water also is released to push salt water out of the river section that has entered through the locks. The air bubbling system, when adequately maintained, assists in alleviating the problem. This salinity approaches federal drinking water standards at the fresh water intakes. Flushing has been shown to be effective and has been reduced due to use of the air curtain. The standard water release schedule from Lake Okeechobee through S-77 to avoid dangerously high lake stages is as follows (**Figure 8**):

Zone A: Release up to 7800 cfs, the maximum capacity of S-77

Zone B: Release 6500 cfs

Zone C Release non-harmful discharge, up to 4500 cfs

Zone D: No regulatory release.

In addition there are pulse releases prescribed in Zone D that 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 I to Level III as shown in **Table 2**. The level of release is determined by stage in Lake Okeechobee.

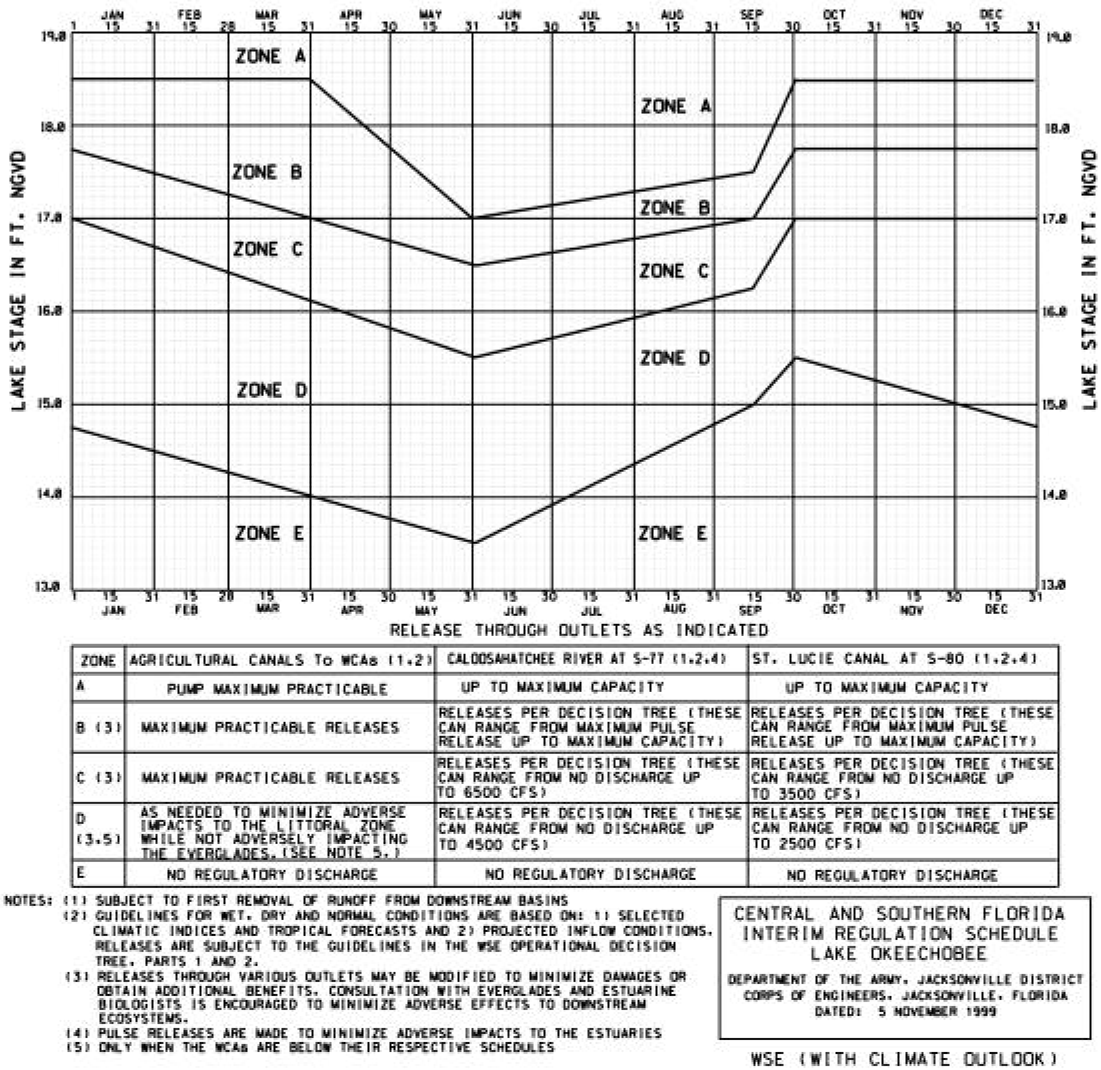

Figure 8. Lake Okeechobee Regulation Schedule

Table 2. Caloosahatchee River Pulse Release Schedule for Zone D of the Lake Okeechobee Regulation Schedule

Day of Pulse	Level 1	Level 2	Level 3
Cfs =cubic feet per second			
1	1,000	1,500	2,000
2	2,800	4,200	5,500
3	3,300	5,000	6,500
4	2,400	3,800	5,000
5	2,000	3,000	4,000
6	1,500	2,200	3,000
7	1,200	1,500	2,000
8	800	800	1,000
9	500	500	500
10	500	500	500

Lake Okeechobee is an important feeding and roosting area for wading birds and migratory waterfowl and is highly regarded for it's recreational and commercial fishing. Winter visitors from the northern United States who value the recreational fishing and the slower pace of interior South Florida visit the lake.

Groundwater and Aquifer Systems

Groundwater is an important component of agricultural water supply within the watershed. The groundwater resources in the area include the Surficial Aquifer System (SAS), the Intermediate Aquifer System (IAS), and the Floridan Aquifer System (FAS) as shown in **Table 3.** The yield and storage of the groundwater is highly variable throughout the watershed. Where possible, surface water has been used for irrigation. The SAS is used for some irrigation in eastern Hendry and Glades counties. The IAS is used primarily for irrigation in the western portion of Hendry County. There is local recharge to both the SAS and the IAS. The FAS is used in northern Glades County for irrigation and in the northwest corner of the watershed and mixed with surface water for irrigation. The water from the FAS is too highly mineralized elsewhere in the watershed. This deep aquifer is recharged from outside the area.

Table 3. Generalized Hydrogeology of the Caloosahatchee Watershed

Hydrogeologic System	Hydrogeologic unit	Aquifer thickness (feet)	Water Resources Potential
Surficial Aquifer System (SAS),	Water Table aquifer	20-75	Important source of local irrigation
	Tamiami Confining Zone	20-75	
	Lower Tamiami Aquifer	50-150	Important irrigation source in eastern Hendry County, disappears in western Hendry and Glades County
Intermediate Aquifer System (IAS)	Upper Hawthorn Confining Zone	300-500	
	Sandstone Aquifer		Water source in western Glades and Hendry County, however, low yield and highly variable
	Mid-Hawthorn Confining Zone		
	Mid-Hawthorn Aquifer		Water source in western Lee County, absent elsewhere.
	Lower-hawthorn Confining Zone		
Florida Aquifer System (FAS)		Insufficient data	Important irrigation source in northern Glades County, elsewhere too mineralized.

Source: (Herr and Shaw, 1989)

Surface Water/Groundwater Relationships

The SAS is unconfined and directly connected with surface waters. The Water Table Aquifer is recharged from infiltration and deep seepage from wetlands and canals. As such, surface water management has a direct impact on the Water Table Aquifer. Excessive drainage may divert water to the estuary rather than to groundwater recharge. The Water Table Aquifer is hydraulically connected to the Lower Tamiami Aquifer and surface water management directly affects recharge to the Lower Tamiami.

The IAS is partially connected with surface waters. The Sandstone Aquifer is separated from the Caloosahatchee River by confining layers; however, the Sandstone Aquifer is recharged from surface water in southeastern Lee County. Recharge also occurs in the Immokalee area from the Water Table Aquifer and flows in a northwest direction toward the river as well as to the south. The Mid-Hawthorn Aquifer is recharged from an area as far away as 100 miles north of the basin. The FAS is not hydraulically connected naturally to surface water or the other aquifer systems. However, there are approximately 200 flowing wells that discharge water into surface waters. Many of these wells are uncased or have corroded casings that allow mixing of highly mineralized water of the FAS with the IAS.

Protection of the Lower West Coast Aquifer System

As part of the Central and Southern Florida (C&SF) Project, the Caloosahatchee River plays a critical role as a source of fresh water to maintain coastal ground water levels which prevent saltwater intrusion of the Lower West Coast Aquifer system. During dry periods when freshwater supplies are depleted along the lower west coast of Florida, fresh water is discharged from interior storage areas such as Lake Okeechobee to the Caloosahatchee river system. These water releases help maintain a freshwater head within the coastal ground water aquifers that prevents inland movement of the saltwater front. Saltwater intrusion can occur whenever water levels within the Caloosahatchee river or the aquifer drop below the elevation needed to stabilize the adjacent saltwater front.

Water Supply

The Caloosahatchee River is the primary source of surface water in the region. The river is supplied by three major sources: precipitation, releases from Lake Okeechobee, and ground water seepage. The principle water use/loss mechanisms are evaporation, evapotranspiration (including irrigation), discharge to the estuary for environmental needs and public water supply. The freshwater portion of the river (C-43 Canal) extends eastward from the Franklin Lock and Dam (S-79) towards Lake Okeechobee. West of S- 79, the river mixes with estuarine water as it empties into the Gulf of Mexico.

Water for urban and agricultural uses in the Caloosahatchee Watershed Planning Area is supplied from both groundwater and surface water systems. Surface water is used primarily for agricultural irrigation, with groundwater being used in areas that do not have access to the river. In addition, the Caloosahatchee River is a source for potable water supply in Lee County (SFWMD, 2000d)..

Non-environmental surface water demands within the basin are primarily agricultural with some public water supply, commercial and industrial uses. The commercial and industrial demands vary greatly by type of business. In the Caloosahatchee Watershed Planning Area commercial and industrial demands are about one percent (1%) of the overall water demands. Because the demand is relatively small and difficult to generalize, an average demand is not calculated for this use category. The emphasis is placed on estimation of agricultural and public water supply uses.

In estimating public water use for 1995, metered data of withdrawals from the C-43 for the City of Fort Myers and Lee County Utilities at Olga were obtained from SFWMD records. Based on the 1995 data and planned future developments that the City of Fort Myers and Lee County utilities will serve, the 2020 public water supply use from the C-43 was also estimated.

A different procedure was adopted for estimating agricultural use in the Caloosahatchee Planning Area because measured withdrawal data were not available. The procedure used estimated current water use based on three approaches; evaluation of permitted water use allocation records, Agricultural Field Scale Irrigation Requirements Simulation (AFSIRS) water demand modeling, and integrated surface water/groundwater modeling using MIKE SHE.

In each approach, the demand was related to current land use. The resulting demands from each approach were reviewed to evaluate reasonableness. Based on the comparison, a methodology was developed that used both AFSIRS and MIKE SHE simulations to determine the current and 2020 agricultural demands.

The estimate of 2020 agricultural demand is dependent on the 2020 agricultural land use projections. Analysis of land use data was therefore a crucial component of the agricultural demand estimation within the Caloosahatchee Planning Area.

In all cases when and where possible, information from the Caloosahatchee Advisory Committee, representatives of public water supply utilities, representatives of the agricultural community and other stakeholders, was used to augment or verify the estimates generated by SFWMD staff.

Public Water Supply Demands

The primary public water supply utilities utilizing water from the C-43 Canal within the Caloosahatchee Planning Area are the City of Fort Myers and Lee County utilities. The City of Fort Myers withdraws water from the river at Olga to recharge the surficial aquifer at its wellfield. The water is then pumped from the aquifer for treatment using membrane-softening technology. The 1995 withdrawals by the City of Fort Myers are summarized in **Table 4** below. Lee County Utilities withdraws surface water from the C-43 Canal at Olga and treats the water using lime softening technology at its Olga water treatment plant. The Lee County Utilities withdrawals are also summarized in **Table 4** below. The combined surface water usage by both utilities was approximately 10.5 MGD on average and more than 16-MGD maximum in 1995.

Table 4. Monthly Public Water Supply Use from C-43 for 1995

Month	Fort Myers			Lee County Olga Plant		
	Total (MG)	Avg (MGD)	MAX (MGD)	Total (MG)	Avg (MGD)	MAX (MGD)
Jan.- 95	272.35	8.79	10.23	104.89	3.38	3.82
Feb.- 95	252.75	9.03	10.21	104.11	3.72	4.13
Mar.- 95				112.64	3.63	4.03
Apr.- 95	299.73	9.99	12.16	107.04	3.57	4.03
May- 95	314.93	10.16	11.66	98.89	3.19	3.76
Jun.- 95	22.57	7.42	11.34	84.88	2.83	3.17
Jul.- 95	117.62	5.73	11.33	82.87	2.67	3.28
Aug.- 95	106.09	3.42	8.26	75.81	2.45	3.18
Sep– 95	109.77	3.66	9.36	75.01	2.50	2.88
Oct. - 95	124.80	4.03	9.36	85.68	2.76	3.46

Nov.– 95	275.41	9.18	11.05	97.75	3.26	3.78
Dec.- 95	288.98	9.32	11.93	98.24	3.17	3.79
Summary 1995	2,445.00	7.34	12.16	1127.82	3.09	4.13
Permitted	4,043	11.08	15.72	1124.2	3.08	5.00

Agricultural Water Demands

Agricultural water use depends on the crops that are grown in the watershed and on how those crops are managed and irrigated. An important factor in accurately estimating agricultural water use is determining the location and acreage of crops. Land use in the Caloosahatchee Planning Area is mostly agricultural and is expected to remain so in the future (SFWMD, 2000d).

Citrus is the dominant irrigated crop in the basin and occupies more than 91,000 acres, according to the SFWMD's 1995 Land Use Coverage. During the past two decades, Southwest Florida has had the fastest growing citrus acreage in the state. This growth is associated with the movement of citrus southward from Central Florida following several severe winter freezes in the early-1980s.

Sugarcane, with an estimated 75,000 acres, according to the SFWMD's 1995 Land Use Coverage, closely follows citrus in dominance of land area. Sugarcane is primarily grown in close vicinity to the Everglades Agricultural Area, in Hendry and Glades counties, where transportation costs to sugar mills can be minimized. Sugarcane acreage has continued to increase since 1995, and is expected to continue in the future (SFWMD, 2000d).

Based on the recommended development of water management and storage infrastructure to effectively capture and store the surface water flows in the Caloosahatchee Basin, the projected surface water needs of this basin and the estuary can be met (SFWMD, 2000d). Supplemental agricultural demands from surface water sources within the basin are projected to increase from 200 MGD to 285 MGD (230,000 to 320,000 ac-ft/yr) based on projected 2020 land use and public water supply needs from the Caloosahatchee River are projected to increase from 12 to 16 MGD (13,000 to 18000 ac-ft/yr) by 2020. The environmental needs of the Caloosahatchee Estuary have been estimated at 400 MGD (450,000 ac-ft/yr) while average flows to the estuary are estimated to be approximately 580 MGD (650,000 ac-ft/yr. Flow to the estuary in excess of the needs can, therefore, be as high as 180 MGD (200,0000 ac-ft/yr) on average.

WATER QUALITY

A critical relationship exists between water quality and human activity, including the withdrawal of water for supply. Increased withdrawals may cause a rise in the concentrations of impurities in the remaining water. Other human activities such as waste disposal and pollution spillage have the potential of degrading ground and surface water systems.

Water quality within the Caloosahatchee River basin is threatened by altered freshwater inputs, nutrient loads from agricultural activities, anthropogenic organic compounds, trace elements, as well as overall urban growth and development within the watershed. The integrity of riverine and estuarine ecosystems is dependent on water quality. As water quality diminishes, so does the overall quality of the system (SFWMD, 2000d)

In 1976 it was determined that water quality data was needed to determine the health of the Caloosahatchee River. A baseline water quality database was created in 1978, yielding a database, which has helped the SFWMD determine management practices within the Caloosahatchee basin and watershed. Recently, data has been collected and complied from Lee County, the City of Cape Coral, East County Water Control District, and SFWMD to evaluate the water quality from the urban portion of the Caloosahatchee watershed. Average nutrient concentrations were calculated for individual sub-basins and primary basins, and average nutrient loads were calculated for the primary basins.

The SFWMD is continuing water quality monitoring within the Caloosahatchee River through contracts with local and state agencies. Several projects incorporate water quality monitoring, including the SFWMD's VEC (Valued Ecosystem Component) study, and the South Florida Restudy.

The Florida Center for Environmental Studies (FCES) is currently monitoring eight water quality sites within the Caloosahatchee River and estuary system. These sites are between Shell Point, at the mouth of the river, to just above S-79 (W.P. Franklin Lock). Each of the eight sitess are monitored monthly and samples are taken from two fixed depths within the water column. The FCES is also performing water quality biomonitoring using the freshwater grass *Vallisneria americana* (tape grass) to determine the effects of freshwater pulsing from Lake Okeechobee. This data will help to refine the current pulse release schedule that will help protect the integrity of the *Vallisneria* community as well as the estuarine ecosystem.

Environmental Research and Design Inc., a consulting firm from Orlando, will conduct event sampling. Their data will be used to determine nutrient loading in the Caloosahatchee Estuary and the response of estuarine nutrient concentrations to external inputs. By identifying rates of nutrient loading from wastewater treatment facilities, and rivers and streams, nutrient inputs can be ranked in order of importance. The project will provide a data set that can be used to quantify the degree to which nutrient concentrations in the estuary depend on loading from external sources.

The U.S. Geological Service was contracted to sample bottom sediments from 35 sites in the Caloosahatchee Estuary, including upstream of S-79. This project will provide the SFWMD with a complete assessment of total nitrogen, phosphorus, and potential toxic substances within the estuary. Other sample sites for this project are located in San Carlos Bay, Estero Bay, and Pine Island Sound. A final report was submitted to the SFWMD in 1999 (SFWMD 2000d)

NATURAL SYSTEMS

Wetlands

Wetlands in the Caloosahatchee Basin

Inland portions of the Caloosahatchee Basin include freshwater swamps, sloughs, and marshes. These wetland areas serve as important habitat for a wide variety of wildlife and have numerous hydrological functions.

Before the development of Southwest Florida, inland areas were comprised of vast expanses of cypress and hardwood swamps, freshwater marshes, sloughs, and flatwoods.

Scattered among these systems were oak/cabbage palm and tropical hammocks, coastal strand and xeric scrub habitats. A large portion of the area contained seasonally flooded wetlands in which fresh water sheet flowed from northeast to southwest. Water bodies within the Caloosahatchee Basin include natural lakes, man-made impoundments, rivers, and creeks.

Wetlands perform a number of hydrologic and biological functions valuable to man including flood protection and prevention of erosion, receiving and storing surface water runoff, natural biological filtration for water quality improvement, ground water recharge-discharge areas, and serve as important habitat for a wide variety of aquatic dependent wildlife including a number of rare threatened or endangered species.

Two significant natural wetland systems in the Caloosahatchee Basin are Twelve Mile Slough and the Okaloacoochee Slough. Both are located south of the river. The Twelve-Mile Slough is located in Hendry County and is a tributary to the much larger and regionally significant Okaloacoochee Slough. It covers 3,300 acres and contains a mosaic of freshwater wetlands, as well as pine flatwoods and oak/cabbage palm hammocks. Surface water storage in the numerous wetlands provides for groundwater recharge of the underlying Surficial Aquifer and provides surface water supply to the Caloosahatchee River. A portion of the Okaloacoochee Slough is located in the Caloosahatchee watershed, in Hendry County. It flows both north, toward the Caloosahatchee River, and south toward Collier County and is a major headwater for the Fakahatchee Strand and the Big Cypress National Preserve. This slough system is composed largely of herbaceous plants with trees and shrubs scattered along its fringes and central portions. Its extensive network of sloughs and isolated wetlands store wet-season runoff from the surrounding uplands and provide year-round base flow to downstream natural areas. The Okaloacoochee Slough, Harn’s Marsh, and Orange River system provide habitat for a variety of wildlife such as the endangered Florida panther.

Wetland systems north of the river include portions of Fisheating Creek and Telegraph Cypress Swamp. Fisheating Creek is a major wetland in western Glades County. It is an extensive riverine swamp system that forms a watershed covering hundreds of square miles.

Although Fisheating Creek is located in the Kissimmee Basin Planning Area, it delineates the northern boundary of the Caloosahatchee Basin. Fisheating Creek is the only free flowing tributary to Lake Okeechobee. The creek attenuates discharges from heavy storm events and improves water quality before the storm water enters the lake. The creek also serves as a feeding area for wading birds such as the endangered wood stork, white ibis, and great egrets, when stages in the marshes surrounding Lake Okeechobee are too high.

Telegraph Cypress Swamp is located in eastern Charlotte County. It is a diverse system with a mixture of hydric flatwoods, cypress strands, and marshes. Within Lee County there are several free flowing creeks that enter the river west of S-79 such as Hancock, Yellow Fever, Powell, Doughtrey, Bedman and Hickey. The headwaters for Hancock, Yellow Fever, Powell, and Doughtrey creeks are in Charlotte County.

Thirty-five side channels, or oxbows, of various sizes and geomorphic configurations are found along the channelized river from the town of LaBelle down to the W.P. Franklin Lock and Dam. The ecological condition of these oxbows varies from reasonably good, in those few with significant flow-through, to very poor in those where flow is restricted or blocked and significant organically rich sediments have accumulated (Cummins and Merritt, 1999). The long-term management objective for oxbows is to enhance their capacity as water quality filters and for off-channel water storage during wet periods by rehabilitating them to flow-through conditions.

Research is being conducted to assess the present ecological state of the river's oxbows. Ten oxbows have been selected for a study that includes water quality sampling; remote sensing and GIS mapping; channel geomorphic and plant bed measurements; plant bed and sediment macroinvertebrate functional groups; and fish diversity and functional groups. To date, the macroinvertebrate analysis has been completed and recommendations have been made for oxbow restoration based on this data. Other components of the study are to be completed in April 2000. At that time, final recommendations for oxbow restoration will be made (SFWMD 2000d).

Wetland Protection Criteria

In order to assess the potential harmful impacts of cumulative water use on the environment and ground water resources using the ground water modeling tools, the potential impacts must be defined in terms of water levels and duration and frequency of drawdowns. These water levels are referred to as resource protection criteria. The resource protection criteria are guidelines used to identify areas where there is potential for cumulative water use withdrawals to cause harm to wetlands and ground water resources. In areas where simulations show the resource protection criteria are exceeded for the selected level of certainty, the water resource may not be sufficient to support the projected demand under the constraints.

The District’s Resource Protection Criteria are designed to prevent harm to the resources up to a 1-in-10-drought event. These criteria are not intended to be a minimum flow and level. For drought conditions greater than a 1-in-10 event, it may be necessary to decrease water withdrawals to avoid causing significant harm to the resource. Water shortage triggers, or water levels at which phased restrictions will be declared under the SFWMD’s water shortage program, can be used to curtail withdrawals by water use types to avoid water levels declining to and below a level where significant harm to the resource could potentially occur. The District’s wetland protection criterion is defined as follows:

> *Ground water level drawdowns induced by cumulative pumping withdrawals in areas that are classified as a wetland should not exceed one foot at the edge of the wetland for more than one month during a 12-month drought condition that occurs as frequently as once every 10 years*.

For planning purposes, this criterion was applied to surficial aquifer drawdowns in areas that have been classified as a wetland according to the National Wetlands Inventory.

The District’s Basis of Review for water use permit applications (SFWMD 1997a), requires that withdrawals of water must not cause adverse impacts to environmental features sensitive to magnitude, seasonal timing and duration of inundation. Maintaining appropriate wetland hydrology (water levels and hydroperiod) is scientifically accepted as the single most critical factor to maintain a viable wetland ecosystem (Duever, 1988; Mitch and Gosselink, 1986; Erwin, 1991). Water use induced drawdowns under wetlands potentially affect water levels, hydroperiod, and areal extent of the wetland. A guideline of no more than one foot of drawdown at the edge of a wetland after 90 days of no recharge and maximum day withdrawals is used currently for consumptive use permitting purposes to indicate no adverse impacts. Wetlands for CUP purposes are delineated using statewide methods described in Chapter 62-340, F.A.C.

Uplands

Upland communities in the Caloosahatchee Basin include pine flatwoods, tropical hammocks, mesic oak, dry prairie, and xeric scrub communities, with flatwoods being the dominant upland habitat. Flatwood communities are divided into two types: dry and hydric. Dry flatwood communities are characterized by an open canopy of slash pine with an understory of saw palmetto. However, dry flatwoods are located in a slightly higher elevation in the landscape and are rarely inundated.

Hydric flatwood communities (wetlands) are vegetatively similar to dry flatwoods. Large areas of flatwoods are found throughout Hendry and Lee counties, as well as portions of Charlotte, Glades, and Collier counties. Upland flatwoods are the native habitats most affected by the expansion of citrus into southwest Florida. Flatwoods are important habitat for a number of threatened and endangered species such as the Florida panther, Florida black bear, eastern indigo snake, red-cockaded woodpecker and the gopher tortoise. Pine flatwoods have a greater richness of vertebrate species than either sand pine or dry grass prairies (Myers and Ewel, 1990).

Tropical hammocks are rare in the basin. This diverse woody upland plant community occurs on elevated areas, often in Indian shell mounds along the coast, or on marl or limestone outcroppings inland. As a result of urban development, tropical hammocks are among the most endangered ecological communities in South Florida

Xeric, sand pine, and oak scrub communities most commonly occur along ridges and ancient dunes. They are often associated with relic sand dunes formed when sea levels were higher. These well-drained sandy soils are important aquifer recharge for coastal communities. The sand pine and oak scrub is the most endangered ecological community present within the planning area. It is rapidly being eliminated by conversion to other land uses.

Upland plant communities serve as recharge areas, absorbing rainfall into soils where it is distributed into plant systems or stored underground within the aquifer. Groundwater 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 event. With few exceptions, the functions and values attributed to wetlands also apply to upland systems. Upland/wetland systems are ecological continuums, existing and adapting to geomorphic variation. The classification of natural systems is artificial and tends to convey a message that they survive independently of each other. In reality, wetland and upland systems are interdependent. To preserve the structure and functions of wetlands, the linkage between uplands and wetlands must be maintained (Mazzotti et al., 1992).

Fauna

Southwest Florida, in general, has a rich diversity of native fauna. These include endemic and sub-tropical species that cannot be found anywhere else in the United States. The Caloosahatchee Basin supports a diverse and abundant array of fish and wildlife species, including many endangered and threatened species (**Table 5).**

Table 5. Listed Faunal Species in the Caloosahatchee Basin

Scientific Name	Common Name	Federal Status	State Status
AMPHIBIANS .			
Rana capito	Gopher frog		SSC
REPTILES			
Alligator mississippiensis	American alligator	T(S/A)	SSC
Caretta caretta	Loggerhead sea turtle	T	T
Chelonia caretta	Green sea turtle	E	E
Dermochelys coilacea	Leatherback sea turtle	E	E
Drymarchon corais couperi	Eastern indigo snake	E	T
Eretmochelys imbricata	Hawksbill sea turtle	E	E
Gopherus polyphemus	Gopher tortoise		SSC
Lepidochelys kempii	Kemp's ridley sea turtle	E	E
Crocodylus acutus	American crocodile	E	E
Pituophis melanoleucus mugitus	Florida pine snake		SSC
BIRDS,			
Ajaia ajaia	Roseate spoonbill		SSC
Aphelocoma coerulescens	Florida scrub-jay	T	T
Aramus jzuarauna	Limpkin		SSC
Caracara plancus	Audubon's crested caracara	T	T
Charadrius alexandrinus tenuirostris	Southeastern snowy plover		T
Charadrius melodus	Piping plover	T	T
Egretta caerulea	Little blue heron		SSC
Egretta thula	Snowy egret		SSC
Egretta tricolor	Tricolored heron		
Eudocimus albus	White ibis		SSC
Falco peregrinus tundrius	Arctic peregrine falcon	E	E
Falco sparverius paulus	Southeastern American kestrel		T
Grus canadensis pratensis	Florida sandhill crane		T
Haematopus palliatus	American oystercatcher		SSC
Haliaeetus leucocephalus	Bald eagle	T	T
Myctetia americana	Wood stork	E	E
Pelecanus occidentalis	Brown pelican		SSC
Picoides borealis	Red-cockaded woodpecker	E	T
Rhyncops niger	Black skimmer		SSC
Rostrhamus sociabilis plumbeus	Everglades snail kite	E	E
Speotyto cunicularia floridia	Florida burrowing owl		SSC
Sterna antillarum	Least tem		T
MAMUALS			
Blarina brevicauda shermanii .	*Sherman's* short-tailed shrew		SSC
Felis concolor coryi	Florida panther	E	E
Felis concolor	Mountain lion	T	E
Mustela vison evergladensis	Everglades mink		T
Oryzomys palustris sanibelli	Sanibel Island rice rat	E	SSC
Podomys floridanus	Florida mouse		SSC
Sciurus niger avicennia	Big Cypress fox squirrel		T
Trichechus manatus latirostris	Florida manatee (subspecies of the West Indian manatee)	E	E
Sciurns niger shennani	Sherman's fox squirrel		SSC
Ursus americanus floridanus	Florida black bear		T
FISH			
Acipenser oxyrhynchus	Atlantic sturgeon	SSC	T
Centropomus undecimalis	Common snook SSC	SSC	
Cyprinodon variegatus hubbsi	Lake Eustis pupfish SSC	SSC	

T = Threatened E = Endangered SSC = Species of Special Concern
S/A = Due to similarity of appearance to endangered species.
Source: (USFWS 1998 & FGFWFC 1997)

The Caloosahatchee Estuary serves as a particularly important center of abundance in the state for the Florida Manatee. Likewise, Telegraph Swamp and Corkscrew Regional Ecosystem are Strategic Conservation Areas for the Florida Panther (Cox et al., 1994).

The Florida Fish and Wildlife Conservation Commission in their Closing the Gaps in Wildlife Habitat Conservation System (GAPS) described habitat in Florida that should be conserved if key components of the state's biological diversity are to be maintained. Habitat areas identified for each species are called Strategic Habitat Conservation Areas (SHCA) because of their importance in providing some of Florida's rarest species with the habitat needed for long-term persistence (Cox et al., 1994).

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 possibly the most important area in Florida in terms of maintaining several wide-ranging species that make up an important component of wildlife diversity in the state. Furthermore, the southwest 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.

WATER RESOURCE ISSUES

The major water resource issues associated with management of the Caloosahatchee River and estuary include the following:

Hydrologic Alteration of the Watershed

The hydrological alterations of the watershed have dramatically changed the natural quantity, quality, timing and distribution of flows to the Caloosahatchee Estuary with limited regard to maintaining the biological integrity of the ecosystem. The Lake Okeechobee SWIM Plan (SFWMD 1989, 1997b), recognized that adverse impacts to the Caloosahatchee Estuary occur when regulatory releases are made through C-43 Canal for lake flood protection purposes. Large, unnatural freshwater releases from the lake through the C-43 to the Caloosahatchee Estuary alter the estuarine salinity gradient and transport significant quantities of sediment to the estuary. Biota within the Caloosahatchee Estuary, and near-shore seagrass beds have been impacted by these high volume discharges (USFWS 1957: Harris et al. 1985; Haunert and Chamberlain 1994; Hoffacke 1994).

During the wet season, rainfall runoff that was historically retained and/or evaporated within the watershed now reaches the estuary in greater volume and less time (USACE 1957). During the dry season, agriculture and urban water supply demands result in reduced flows to the estuary. In addition to changing the flow characteristics of the watershed, the construction of S-79 truncated the estuary by blocking the natural gradient of freshwater/saltwater that historically extended into the upper reaches of the estuary during the dry season from November to May. Under current dry season conditions, it is common to observe waters immediately downstream of S-79 to be nearly one-third the salt content of the Gulf of Mexico while those immediately upstream of the structure are fresh. The loss of the fresh-brackish water habitat has resulted in the loss of an important water resource function of the estuary during the dry season.

There is evidence that water management practices have impacted the estuary and its biota. Alterations in the delivery of freshwater at S-79 cause salinity to vary widely in time and space. Depressed salinity during large discharge events results in the emigration of certain finfish and the mortality of non-mobile benthic invertebrates (USFWS 1957). Analysis of historical vegetation maps indicates a significant decrease in submerged aquatic (vascular) vegetation (SAV) downstream of Shell Point (Harris *et al*. 1983). Submerged aquatic vegetation within the estuary, upstream of Shell Point, have been shown to be sensitive to salinity and freshwater inflow (McNulty *et al*. 1972; Haunert and Chamberlain 1994; Hoffacker 1994; Chamberlain Doering 1998a, 1998b).

Water Supply

The water needed to meet MFL requirements represents a substantial requirement within the basin. During wet years, much more than the minimum flow amount of water is available for discharge to the estuary. In fact, the problem becomes that of too much water. During average years, more than sufficient water is available from the basin to meet the needs of agriculture urban residents and natural systems. During dry periods, however, more water is used in the basin than can be obtained from local rainfall. Water is delivered from Lake Okeechobee as needed to maintain water levels in the River and meet agricultural and urban demands in the Caloosahatchee River. Use of water from the Lake must compete with other regional demands in the Upper East Coast and Lower East Coast Planning Areas.

Water use in the Caloosahatchee Basin was estimated as part of the Caloosahatchee Water Management Plan (SFWMD 2000d). Agricultural demands from surface water sources within the basin are estimated to increase from 230,000 acre-feet per year (200 MGD) based on 1995 land use, to approximately 320,000 acre-feet per year (285 MGD) on average based on projected 2020 land use. Public water supply needs from the Caloosahatchee River are projected to increase from 13,000 (12 MGD) in 1995 to 18,000 acre-feet per year (16 MGD) on average by 2020. The environmental needs of the Caloosahatchee Estuary have been estimated at 450,000 acre-feet (400 MGD) while average flows to the estuary are estimated to be approximately 650,000 acre-feet per year (580 MGD

As water levels decline in Lake Okeechobee, the Supply-Side Management plan is activated and water use may be restricted according to the District's water shortage plan. This plan provides for progressive, phased restrictions on water use that are designed to protect the resource from incurring significant harm or serious harm. When drought conditions are of sufficient magnitude that water resources begin to experience harm, the SFWMD Governing Board may require restrictions on operational deliveries and water uses, pursuant to the Water Shortage Rule 40E-21 F.A.C.

Development of water management and storage infrastructure to effectively capture and store the surface water flows in the Caloosahatchee Basin is proposed as part of the Caloosahatchee Water Management Plan (SFWMD 2000d) and the Lower East Coast Regional Water Supply Plan (SFWMD 2000 b) and the Comprehensive Everglades Restoration Plan (USACE and SFWMD 1999). With these facilities in place, the projected future (2020) 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 drought event.

In the short-term, an adaptive water management strategy is proposed in this report as a means to provide minimum flows to the estuary when water is available from Lake Okeechobee.

Water Quality Degradation

Water quality within the Caloosahatchee River basin is threatened by altered freshwater inputs, nutrient loads from agricultural activities, anthropogenic organic compounds, trace elements, as well as overall urban growth and development within the watershed. The integrity of riverine and estuarine ecosystems is dependent on water quality. As water quality diminishes, so does the overall quality of the system. The Florida Department of Environmental Regulation (DeGrove 1981, DeGrove and Nearhoof 1987, Baker 1990) reported that the estuary had reached its nutrient loading limits as indicated by elevated chlorophyll a and depressed dissolved oxygen.

Need for *Maximum* Flow Criteria

Establishing *minimum* levels alone will not be sufficient to maintain a sustainable resource or protect it from significant harm. For both Lake Okeechobee and the Caloosahatchee Estuary, floods or extended periods of high water result in the need to release large volumes of water to the 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 reservations and other water resource protection tools. Achieving the required water levels and flows throughout this system is an overall, long-term restoration goal of the Comprehensive Everglades Restoration Program (CERP), the LEC and LWC Water Supply Plans and the Caloosahatchee Water Management Plan.

Under current conditions, *Maximum flows* delivered to the estuary are controlled largely by the Lake Okeechobee regulation schedule and pulse releases for these estuaries. The overall ability of these schedules to protect the resource is uncertain due to the limited water storage capacity of the regional system, especially during high rainfall years. As a result, new or revised minimum and maximum flow criteria are being considered for both the Caloosahatchee and St. Lucie estuaries as part of the regional water supply planning process and CERP.

Navigation

The Caloosahatchee River (C-43 Canal) flows east to west across the northern portion of the LWC planning area connecting Lake Okeechobee in the east and the Gulf of Mexico in the west. The Caloosahatchee River is supplied by inflows from Lake Okeechobee and runoff from within it's own basin. As a result, water levels in the river are low during dry times, when demand is highest and the river is almost entirely dependent on Lake Okeechobee. However, during the rainy season, when demands are minimum, significant volumes of excess water are discharged into the Gulf of Mexico. To maintain navigation at the W.P. Franklin Lock (S-79), the USACE releases water as needed from Lake Okeechobee to maintain a minimum water level of 3.0 ft, NGVD (27 ft channel depth) above S-79. However, the Corps may lower stages at S-79 below 3.0 ft, NGVD in advance of a major storm as part of their emergency action plans.

Control of Saltwater Intrusion

During extreme dry periods (usually the months of April and May) flows within the Caloosahatchee River may be reduced to near zero flow. When this condition prevails, navigation lockages through the W.P. Franklin Lock (S-79) result in a saltwater wedge that moves upstream of S-79 into the freshwater reach of the river. Increased boat lockages result in more salt water moving upstream. Eventually, the chloride content of the water entering the municipal water intakes of Ft. Myers and Lee County exceeds the drinking water standard of 250 ppm. When this happens, the SFWMD requests the USACE to release water from Lake Okeechobee to flush out the salt water with a short-term high rate of discharge from the lake. A “pulse release” type of discharge approach has been used as well as smaller lower volume releases (e.g., 300 cfs monthly average) to reduce chloride levels within the river and provide benefits to the downstream estuary. During a declared water shortage period, the SFWMD has requested the USACE to initiate reduced hours of boat lockages through S-79 to prevent an increase in chloride levels upstream of S-79. (Lake Okeechobee Master Water Control Manual, USACE, 2000,).

Control of Algae Blooms

Again, during dry periods (months of December to April) flows within the Caloosahatchee River have been diminishes to the point that the river acts more like a reservoir than a flowing river system. Under these conditions occasional algae blooms (some severe) have been reported to develop in the river above the Franklin Lock and Dam. The City of Ft. Myers and Lee County both have municipal water intakes in this area which could be clogged by the algae or result in taste and odor problems that need to be addressed as part of the water plant treatment process. Short-term high rates of discharge from Lake Okeechobee have been required to break up the algae bloom. This is done by the USACE whenever requested by the SFWMD.

Chapter 3
METHODS FOR DEVELOPING MINIMUM FLOW CRITERIA

Minimum flow criteria developed for the Caloosahatchee River and Estuary were based on six sources of information: (1) development of the Valued Ecosystem approach for establishing the minimum flow, (2) a review of the literature, (3) development of flow/salinity relationships for the estuary, (4) review of the results from field, laboratory, and growth rate studies, (5) development of a *Vallisneria* growth model (6) application of the SFWMM model to produce flow scenarios for the Caloosahatchee River under various base case and future case conditions, and (7) review of the District's Estuarine research programs underway within the Caloosahatchee estuary.

VALUED ECOSYSTEM COMPONENT (VEC) APPROACH

The SFWMD's Caloosahatchee Estuary research program supports application of a resource-based management strategy similar to the Valued Ecosystem Component (VEC) approach developed by the U.S. Environmental Protection Agency as part of its National Estuary Program (USEPA 1987). There are several definitions of a Valued Ecosystem Component in the literature, For example:

1. *"A resource or environmental feature that is important (not only economically) to a local human population, or has national or international profile, or if altered from its existing status, will be important for the evaluation of environmental impacts of development and the focusing of administrative efforts"*
2. *"Any part of the environment that is considered important by the proponent, public, scientists and government involved in the assessment process. Importance may be determined on the basis of scientific concern or based on cultural values"*.

For the purposes of this study, the VEC approach was based on the concept that estuary management goals can best be achieved by providing suitable environmental conditions for selected key species or key groups of species that inhabit the estuary. In this case, the key species identified to be protected against significant harm is submerged aquatic vegetation, specifically *Vallisneria sp*. (commonly known as tape grass or wild celery) present within the upstream fresh/brackish water portion of the river. Submerged aquatic vegetation are important to the ecosystem in that they sustain an important water resource function by providing food, and habitat for forage fish, shellfish, and serve as nursery areas for many juveniles species of fish that are recreationally or commercially important (Day *et al*., 1989; Heck et al., 1995; Kemp et al., 1984; Lubbers et al. 1990; Orth et al. 1984). This approach assumes (a) that environmental conditions suitable for VEC will also be suitable for other desirable species; and, (b) that enhancement of VEC will lead to enhancement of other species. Through this strategy, management objectives will be attained by providing a minimum flow that will protect this community against significant harm.

The VEC approach was applied to the Caloosahatchee River and Estuary based on the following scientific assumptions: Seagrass (*Thalassia testudinum*, *Halodule wrightii*) meadows are prevalent at the seaward/outer end of the system where salinity can be significantly impacted by high volumes of freshwater discharged to the estuary from S-79 or from local basins. Therefore, these seagrass communities represent the VEC for assessing the impact of high flows within the estuary. At the other end of the spectrum, beds of *Vallisneria americana* (wild celery or tape grass) are prominent in the fresh-brackish water (low salinity) portion of the inner estuary. These communities are sensitive to increased salinity values that result from reduced volumes of water low discharged to the estuary during low rainfall periods. Since this report focuses on establishing a minimum flow that will the protect the ecosystem against significant harm, *Vallisneria* was selected as the VEC of choice in that it represents a number of the primary water resource functions that need protection during low flow periods.

LITERATURE REVIEW

- A literature review (Estevez, 2000) was conducted for the Caloosahatchee Estuary to review and evaluate the following: (a) existing information that may be available for determining a MFL for the estuary, (b) approaches that have been used by other water management districts or agencies to establish an MFL, and (c) the validity of using the VEC approach (as discussed above) to define a minimum inflow. The scope of work included the following: (1) identify individual species or biological communities that could be used as indicators, targets, or criteria for determining a minimum flow for a riverine estuary; 2) determine how these indicator species or indicator communities have been affected in estuaries that have long histories of structural and/or hydrologic alteration; 3) review lessons learned by other water management districts, other states, and other counties with respect to establishment of MFLs for estuaries; and 4) evaluate the District's VEC approach to establish a MFL for the Caloosahatchee River/Estuary.
- The libraries of the SFWMD, Mote Marine Laboratory and the author (Estevez, 2000) were reviewed for relevant citations. Electronic searches were performed using open-access, limited-access and subscription-access databases, including BIOSIS, First Search, Cambridge Scientific Abstracts, DIALOG, and federal agency sources. Key words were searched to cover rivers, estuaries, tidal rivers, instream flow, minimum flow, dams, barrages and related terms. Journals that would typically publish relevant papers were also reviewed.
- An additional literature review was also conducted to identify (a) the key species or groups of organisms that may benefit from utilizing Vallisneria grass bed communities within the Caloosahatchee estuary, (b) life histories of these species, and (c) tolerances of these species to low salinity levels. Key documents reviewed included Chamberlain and Doering 1998a, 998b; Patillo *et al*. 1994; Bartone and Smith 1998; Day *et al.* 1989; Harris *et al*. 1983; Hoffacker 1994; McNulty *et al.* 1972; Carter and Rybicki 1985; Gunter and Hall 1967; Heck *et al.* 1995; Jassby *et al*. 1995; Irlandi *et al.* 1995; Kemp *et al*. 1984; Killgore *et al.* 1989; Lubbers *et al*. 1990; Orth *et al.* 1984; Phillips and Springer 1960; Twilley *et al.* 1875; USFWS 1957; Wagner and Austin 1999; and Zieman and Zieman 1989.

DEVELOPMENT OF FLOW/SALINITY RELATIONSHIPS

A one dimensional hydrodynamic/salinity model (Bierman 1993) was completed for the Caloosahatchee River and estuary and was used in the previous efforts, however, this model does not provide a satisfactory relationship of salinity and flow from S-79 under low flow (0 to 500 cfs) conditions for the inner estuary. In response, District staff developed an empirical relationship between salinity at a given location within the estuary as a function of flow (memo from Ken Konyha, June 29, 2000, **Appendix A**). The model was developed using measured flow from S-79 and salinity at the Ft. Myers Marina (22 km upstream of Shell Point) for the period from January, 1992 to November, 1999. The relationship is an improvement over Bierman's earlier numerical 1-dimensional modeling of salinity which ignored contributions of flows from the tidal watershed and therefore overestimated salinity under low flow conditions. A comparison of Chamberlain's predicted salinity to Bierman's predicted salinity under uniform flow conditions is provided in a memo from Ken Konyha, June 29, 2000, **Appendix A**. Chamberlain's relationship of salinity to S-79 flow is as follows:

y=a(exp(-bx)+c(exp(-dz)), where

y = salinity (ppt)

x = 30-day back-averaged flow (cfs) at S-79 [During calibration it was found that the 30-day back-averaged flow provides the best overall estimate of salinity in the estuary. This simpler estimate of flow replaces the more complex rule proposed in the draft document of December 16, 1999.]

z = distance upstream of Shell Point (km)

a,b,c, and d are empirical coefficients with a = 19,b = 0.002, c = 150, and d = 0.25

The model was coded as an Excel spreadsheet and has an instruction worksheet, a flow worksheet (with data imported from an external source), a salinity worksheet, and a graphical display worksheet. The salinity worksheet, when exported as a comma-separated-variable file (*.csv) becomes an input file for the *Vallisneria* model. For this application salinity is determined at 1 km intervals along the length of the estuary beginning 12 km upstream of Shell Point and ending 32 km upstream of Shell Point (memo from Ken Konyha, June 29, 2000, **Appendix A**)

Field and Laboratory Studies

Vallisneria is a freshwater aquatic grass that is tolerant to low salinities and, therefore, is frequently found in the transitional zone from freshwater to oligohaline habitats. Since *Vallisneria* grass beds are sedentary and salinity varies in response to inflows, understanding its tolerance to salinity is important in predicting its distribution and density. A literature search was conducted on the biology and life history of *Vallisneria* to determine if its salinity tolerance information was adequate to avoid the need for additional field and laboratory efforts (Bortone *et. al*., 1998; Doering et al. 1999). While there have been several determinations of the salinity tolerance of *Vallisneria* (Bourn 1932, 1934; Haller et al. 1974, Twilley and Barko 1990) estimates did not agree and there was little information concerning factors that might modify salinity tolerance. However, qualitative data for the Caloosahatchee indicates that shoot (leaf) densities decline when salinity is above about 10 ppt (Chamberlain et al. 1996) and growth ceases at 15 ppt (Doering *et al.* 1999). Since limited detailed information was available on the effects of varying salinity and duration of exposure of salinity on *Vallisneria,* a field sampling program, was initiated to measure salinity and *Vallisneria* shoot density as well as other growth parameters at four locations along the salinity gradient. During the first year (1998) of field sampling (Bortone 1999), plants thrived since they were not exposed to high enough salinities to cause mortality. During 1999, however, dry season salinity data documented the effects of salt water, thus providing a data set for calibration of a *Vallisneria* growth and mortality model being developed with data from laboratory experiments. The District conducted laboratory experiments that simulated typical saltwater intrusions during the dry season (Doering *et al.* 2000).

Development of a *Vallisneria* Growth Model

In addition to above work, *Vallisneria* daily growth rate algorithms were developed relating changes in blade length, blade density and shoot density to salinity (Doering, memo dated March 22, 2000, Appendix A). Although algorithms were established for all growth parameters, this evaluation only used shoot density predictions since it is the most appropriate measure of abundance. The main purpose of the evaluation was to predict decreases in abundance (mortality) due to salinity and not to reproduce the annual cycle of *Vallisneria* abundance. Because the model was not intended to reproduce an annual cycle of abundance, shoot density was 'reset' each year to a specified value every October. In general then, a 31-year simulation of *Vallisneria* shoot density identifies those years in which dry season salinity would have caused decreases in abundance. Specifically, the model best represents effects of salinity on the abundance of *Vallisneria* during the early spring portion of the dry season when this VEC or resource function is most needed. The form of the Growth Rate algorithm is identical for each of the tape grass characteristics, only the coefficients change. The Growth Rate equation is:

$$N_{(t+1)} = N_{(t)} \exp^{(r*((K-N(t))/K)))}$$

Where

$N_{(t+1)}$ = quantity on current day
$N_{(t)}$ = quantity on previous day
K = scaling factor (maximum value)
rbar = growth coefficient function

The growth coefficient function, rbar, used in the above equation is the average of the daily growth coefficient function, r. r is defined as:

$r = r1 – r2*y$,
r1 = seasonal zero-order growth coefficient
r2 = seasonal first-order growth coefficient
y = daily salinity (mg/l).

Table 6. *Vallisneria* Growth Response Parameters

N	K	Wet Season Coefficients		Dry Season Coefficients	
		r1	r2	r1	r2
Blade Length (cm)	20	0.051	0.0039	0.017	0.0039
Blade Density (/m2)	8000	0.0673	0.00557	0.034	0.0052
Shoot Density (/m2)	110	0.084	0.0031	0.035	0.0052

Source: Doering, 2000

This algorithm has seasonably variable growth coefficients. Dry season coefficients apply from September 30 through April 14; wet season coefficients apply from April 15 through September 30. All parameters have been calibrated to measured data collected in the Caloosahatchee Estuary.

The model also simulates some seasonal effects. It simulates a sloughing of leaves at the start of the dry season by resetting blade length (to 25 cm), shoot density (to 80 shoot/m^2) and by reducing blade density (to 50% of the previous day's density). It simulates a recovery at the start of the wet season that sets the minimum blade density (to 350 blades/ m^2); if the blade density is increased, blade length is also reset (to 4 cm).The plant response model was written in Fortran. Details pertaining to development of the model are provided in **Appendix A** (memo from P. Doering, March 22, 2000)

Application of Flow/Salinity and Growth Rate Models into the SFWMM

Model Integration

The above two companion models developed by District staff to evaluate flow salinity relationships and simulate *Vallisneria* growth were incorporated into the South Florida Water Management District Model (SFWMM v. 3.7). The SFWMM is a regional-scale computer model (SFWMD, 1999) that simulates the hydrology and management of the water resources of South Florida ranging from Lake Okeechobee to Florida Bay and includes water deliveries and environmental targets (including meeting low flow criteria) for both the Caloosahatchee River/Estuary and the St. Lucie Estuary (SFWMD, 1999). The combination of these three models was used to simulate flow scenarios and *Vallisneria* growth response for the Caloosahatchee Estuary for a 31-year period of record.

Developing a 1995 Base Case and Future (2020) Case Flow Scenarios

The first flow scenario developed included the historic (1965-1995) rainfall record, 1995 land use and current SFWMD operations to produce a time series of flows through S-79 as a Base Case (1995). A second scenario was developed for the future (year 2020) incorporating future land use and components of the "Comprehensive Everglades Restoration Program (CERP)" designed to improve the operation of the Central and Southern Florida (C&SF) Project, restore the Everglades system, and provide for other water related needs of the region (USACE and SFWMD, 1999). The 2020 with CERP scenario produced flows from the Caloosahatchee watershed to the river and estuary and incorporating the low flow environmental needs of the estuary (Konyha memo; June 1999, October 1999,and January 2000, Appendix A). These estuarine environmental requirements were determined from previous District research and included the desired range of flows of 300 to 2,800 cfs with consideration of a natural variation within this range as well as values below and above this range. Details of this modeling effort and results are available in Appendix A (Konyha memo; June 1999, and June 2000.

SUMMARY OF ESTUARY RESEARCH

The SFWMD's effort in managing flows to the Caloosahatchee Estuary has focused on the development of ecological criteria. Oysters and submerged aquatic vegetation (SAV) have been selected as key indicators of a "healthy" estuarine system because they provide food and/or habitat for much of the estuarine community. Accordingly, the SFWMD is evaluating ways to establish healthy, self-perpetuating populations of these organisms in the Caloosahatchee Estuary. Hydrodynamic salinity models have been developed which can predict salinity regimes in estuaries based on freshwater inflows (Scarlatos 1988). Geographic Information System coverages (including substrate type, shoreline features, and current SAV and oyster distributions) are being developed for the estuary. Comparing these coverages with salinity model output will help refine where oysters and SAV could occur once flow management strategies are in place. Optimization models (Otero et al. 1995) are being used to help predict how much water must be held back in the watershed, as well as to determine schedules for releasing the stored water to meet the salinity requirements of oysters and SAV. Ultimately this information will be coupled with watershed models to evaluate specific "in watershed" management scenarios needed to meet the inflows necessary to maintain healthy SAV and oyster community requirements.

Research is being conducted by the Florida Center for Environmental Studies, in conjunction with the SFWMD, to investigate the *in situ* influence of freshwater inflow and salinity on tape grass (*Vallisneria sp.*) to determine if freshwater inflow requirements are needed to permit a "healthy", thriving ecosystem in the upper portions of the Caloosahatchee Estuary. This work will help the SFWMD in its charge to make informed management decisions regarding optimal flow volumes and discharge schedules to preserve, increase, or maintain existing submerged aquatic vegetation present in the upper portions of the Caloosahatchee Estuary as well as the communities of organisms associated with it.

Also, the SFWMD and the U.S. Army Corps of Engineers (USACE) are conducting a research study to characterize seasonal fluctuations of submerged aquatic vegetation (SAV) in the upper Caloosahatchee Estuary, lower Caloosahatchee Estuary, San Carlos Bay and Pine Island Sound. SAV will be mapped, on the basis of distribution and proximity to significant freshwater input, using Submersed Aquatic Vegetation Early Warning System, which was developed by scientists at the USACE-Waterways Experiment Station. This project will provide information on spatial and temporal variations in biotic communities needed to determine biotic status and trends. Furthermore, the project will provide information on the effect of management actions on ecosystems to researchers and managers assessing the success of future water management policies designed to protect and enhance SAV communities.

Additionally, researchers at the University of Florida Coastal and Oceanographic Engineering Department are developing a coupled circulation/water quality model for the Charlotte Harbor Estuarine system for the SFWMD. The model will be developed in three phases. Phase I includes a preliminary 3-D circulation model will be developed and calibrated with available hydrodynamic data and then applied to address the impact of the Caloosahatchee River Estuary on circulation in Pine Island Sound, with particular focus on the effect of the Sanibel Causeway. This is scheduled for completion December 1999. Phase II will review and analyze available water quality data and a 3-D water quality model will be developed. An assessment of the effects of the Sanibel Causeway on circulation and salinity will be accomplished. Phase III will calibrate the coupled hydrodynamics and water quality models and apply them to address the impact of loading from the Caloosahatchee watershed on the water quality in the Caloosahatchee Estuary,San Carlos Bay, and Pine Island Sound. Phase II is scheduled for completion in late 2000 and Phase III in 2001.

Previous SFWMD research provided the foundation for development of a MFL concept for the Caloosahatchee River and Estuary. Results of these research efforts produced two important findings:

1. A flow of about 300 cfs discharged from structure S-79 was needed to maintain a freshwater-brackish salinity regime that will support a healthy submerged aquatic vegetation community (Vallisneria sp.) within the inner estuary, and
2. A minimum flow less than 300 cfs if sustained for a period of time, would result in increased salinity levels that will cause mortality of *Vallisneria* communities in the region of its greatest coverage (Chamberlain et al. 1995; Chamberlain and Doering 1998a, 1998b). Therefore, river flows within the range of 300 cfs can be considered a threshold flow that needs to be maintained to avoid *Vallisneria* mortality. Results of these studies indicated the need for a more detailed understanding of the effects low flows and their duration on submerged aquatic vegetation in order to define significant harm for the estuary.

The procedures for establishing a more detailed understanding of the effects of low flows and its impact on submerged aquatic vegetation communities were to:

(1) Determine the relationship between low-level freshwater discharges from S-79 (0 to 500 cfs) and salinity in the inner estuary where *Vallisneria* is found in abundance

(2) Develop a more comprehensive understanding of the salinity tolerances of Vallisneria by conducting a thorough literature search. This done under a contract (Estevez, 2000)

(3) Implement a field monitoring program and conduct laboratory experiments designed to ascertain the response of *Vallisneria* to varying salinity levels and durations

(4) Conduct modeling scenarios using the South Florida Water Management Model (SFWMM) to analyze the levels of freshwater discharge from S-79 that would have occurred over the last 31 years using historical rainfall and today’s land use to provide a base case scenario that examines the effect of these discharges on *Vallisneria* over the 31-year simulation.

(5) Identify engineering solutions to be implemented within in the watershed that would provide the appropriate freshwater discharges from S-79 for development of a MFL recovery and prevention strategy

(6) Develop a management strategy based on SFWMM output that predicts the response of Vallisneria to: (a) a 31-year base case of simulated flows; (b) a 31-year base case of simulated flows with additional flows added to avoid significant harm and; (c) 31-years of flows modeled for a recovery and prevention strategy.

Chapter 4
PROPOSED MINIMUM FLOWS AND LEVELS CRITERIA

The following chapter presents the MFL criteria as required in Chapter 373, Florida Statutes for the Caloosahatchee River and Estuary. This chapter provides a summary of the scientific approach and technical relationships that were evaluated in defining significant harm for the water body and a detailed presentation of the proposed MFL criteria with supporting documentation. This section also describes changes and structural alterations (considerations as set forth in Section 373.0421(1)(a), F.S.) that have occurred in the watershed and existing hydrologic constraints. For the purposes of this study, significant harm is defined as a loss of specific water resource functions resulting from a change in surface water or ground water hydrology that takes multiple years for recovery (see Chapter 1 for further discussion of the definition of significant harm).

The purpose of the following sections are to (a) identify the watershed considerations and water resource functions that were evaluated in the development of the proposed minimum flow criteria for the Caloosahatchee River and Estuary; (b) identify the technical relationships considered in defining significant harm; (c) provide a definition of significant harm; and (d) provide a discussion of the District's proposed MFL Recovery and Prevention Strategy.

WATERSHED CONSIDERATIONS AND RESOURCE FUNCTIONS

The Caloosahatchee River system can be divided into four components as follows that affect, or are affected by the need to establish Minimum Flows and Levels (MFLs).

- Lake Okeechobee
- The River Itself,
- The River and Estuary Watershed
- The Estuary

Based on examination of the functions of these components, a Caloosahatchee River and estuary MFL is proposed, based on providing minimum flows necessary to protect the estuary from significant harm. The analysis determined that the Caloosahatchee estuary is highly dependent upon sufficient water flows and is sensitive to high salinity levels. The health of this estuary is also an indicator of health of the watershed. The estuary also has a high probability of experiencing significant harm due to lack of sufficient freshwater flows before structural solutions that part of the Comprehensive Everglades Restoration Plan are complete. Short-term and long-term recovery strategies are proposed.

Lake Okeechobee

Major Features and Uses

Lake Okeechobee provides a source of freshwater flow to meet water needs in the Caloosahatchee River basin during dry periods and a source of excess during wet periods. The amount of excess water discharged from Lake Okeechobee depends on the Lake's regulation schedule and conveyance capacities to alternative discharge sites. The regulation schedule is based on the need to protect Lake levees from storm damage. The use of alternative discharge sites depends on the ability to discharge water south through the EAA and the other primary emergency release site -- the St. Lucie Canal and estuary. Availability of water from Lake Okeechobee during dry periods is constrained by regional water supply needs. Water from the Lake is also used to meet reservations and Minimum Flows and Levels established for the Lower East Coast Planning Area, most notably Lake Okeechobee, the Everglades and the Biscayne Aquifer. For a detailed discussion and consideration of these functions and related issues, see the MFL document developed for Lake Okeechobee, the Everglades and the Biscayne Aquifer (SFWMD 2000e)

Water Resource Functions.

The primary functions of Lake Okeechobee that need to be considered in the development of MFLs for the Caloosahatchee River and estuary include water supply, flood protection, navigation, recreation, natural systems, protection of fish and wildlife habitat and water quality.

Water Supply. Constraints on providing MFL deliveries from Lake Okeechobee to the Caloosahatchee River are based on consideration of the needs of the lake as a water supply reservoir for South Florida. Sufficient water must be stored in the lake to meet water reservations, MFL and water supply needs of the LEC, as well as to prevent saltwater intrusion of Lower East Coast coastal canals and the Biscayne aquifer. The amount of water in the lake available for releases to the estuary is dependent on discretionary release policies contained within the regulation Water Supply and Environmental (WSE) schedule (USACE 2000b), the amount of water stored in the Lake based on Supply-Side Management policies (Hall, 1991), and the physical constraints of release structures. The average requirement from Lake Okeechobee to meet public water supply demands in the Caloosahatchee basin is currently about 13,000 acre-ft per year. The average amount needed for agricultural use is about 111,000 acre-ft per year (SFWMD, 2000d).

Flood Protection. (no significant constraints on ability to provide MFL releases)

Navigation. Maintenance of minimum levels in the Lake and perimeter canal needed to provide navigational access. When lake levels fall below 12.56 ft. NGVD, navigation of the Okeechobee Waterway becomes impaired (USACE, 1957).

Recreation. Impacts on recreational uses may occur in the Lake due to low water levels (below 11.0 ft. NGVD) and these would be aggravated by additional water releases to the Caloosahatchee River.

Protection of Fish and Wildlife Habitat. Maintenance of sufficient water depth and hydroperiod within the Lake is needed to protect littoral zone plant and animal communities and fisheries resources. Eleven feet NGVD is also the minimum level for protecting Lake Okeechobee's littoral zone (SFWMD 2000e).

Water Quality. When discharge from Lake Okeechobee is the primary source of water being discharged at S-79, water quality is better than when most of the water comes from the Caloosahatchee Basin. Nutrient concentrations are higher in water from the watershed than in water derived from the Lake.

Other Considerations. Other demands on the lake include the need to provide water supply to Everglades Agricultural Area, the Seminole Indian tribe, Everglades National Park and the Caloosahatchee and St. Lucie basins.

Operational Protocols Established to Protect Resources

Four primary protocols are used by the District and the USACE to protect resources of Lake Okeechobee as follows:

- MFL criteria provide a basis to protect resources in the lake from significant harm;
- A regulation schedule is used to manage water levels in the lake and requires periodic discharges of excess water from the lake to coastal estuaries to protect integrity of the levees.
- A Supply-Side Management Plan (Hall, 1991) is used to manage water deliveries from Lake Okeechobee during dry periods.
- A newly adopted WSE (Water Supply and Environmental) schedule has been adopted for Lake Okeechobee that provides additional flexibility for discretionary releases of water from the Lake to provide environmental benefits (USACE 2000b)

Caloosahatchee River

Major Features and Uses

The Caloosahatchee River watershed covers approximately 1,400 square miles and includes significant areas in Glades and Hendry counties, a part of Lee County and a small part of Collier, Charlotte and Palm Beach counties.

The primary system consists of the C-43 Canal (Caloosahatchee River) and the C-19 canal, which were excavated as part of the Central and South Florida Flood Control Project (USACE, 1957) (**Figure 5)**. There are several structures on these canals, which are designed to maintain upstream water levels (**Table 7).** The canals and water control structures were designed to provide 33 cfs per square mile or 1.25 inches of drainage for the Caloosahatchee watershed.

The River itself is divided into two segments as water flows from east to west. The eastern segment extends from the Moore Haven Locks at the edge of Lake Okeechobee for a distance of 16 miles to the Ortona Locks, near LaBelle. The western segment extends for 28 miles from the Ortona Locks to the Franklin Locks. Under normal operating conditions, water levels in Lake Okeechobee may range from 13 to 17 ft NGVD. Downstream from the Moore Haven Locks, water levels are maintained from 10.8 to 11.3 ft NGVD. The western segment of the River is generally maintained at elevations from 2.8 to 3.4 ft NGVD **(Table 7).**

Table 7 Operating Schedules for the Primary Canal System

Structure	Canal	Operating Rule
S-77	C-43	Discharge rule follows Lake Okeechobee regulation schedule.
S-78	C-43	Maintain upstream canal stage between 10.8 and 11.3 feet NGVD
S-79	C-43	Maintain upstream canal stage between 2.8 and 3.4 feet NGVD. Rules allow lowering stage to 2.2 feet to accommodate anticipated runoff, however stage maintained above 2.5 feet to provide water for Lee Co. water supply intakes.
S-47D	C-19	Maintain upstream water between 12.5 and 13.0 ft NGVD
S-47B	C-19	Maintain upstream water between 14 and 15.5 ft. NGVD When below
S-342	C-19	Maintain upstream water above 16 ft NGVD
C-5		Release water from lake when Lake Okeechobee is above 14.5 and basin below 12.0 ft NGVD
C-5A	L-41	Release water from lake when Lake Okeechobee is above 14.5 and basin below 12.0 ft NGVD
S-235	C-43 & LD1	Kept open when possible to provide water and drainage for S-4 basin. Stage maintained in S-4 borrow canals 11-14 feet NGVD

The River functions as a conveyance channel to distribute water to various users during dry periods, remove excess stormwater from the basin during wet periods, convey regulatory discharges from Lake Okeechobee to tide water, and provide freshwater flows needed to maintain a highly-productive downstream estuary. The River also contains significant wetland systems in the Lake Hicpochee area in the eastern (upstream) river basin and along the shore of various oxbows in the western portion of the River. These areas provide food and habitat for wading birds and other water-dependent plants and animals, including some threatened and endangered species. The River provides navigational access from Lake Okeechobee through LaBelle to Fort Myers and adjacent communities and supports recreational fishing and boating. Water is also removed from the River through intakes upstream from the Franklin Locks to recharge wellfields owned by Lee County and the City of Fort Myers. Water quality problems in the River (excess salinity or algal blooms) may require occasional releases from Lake Okeechobee to "flush out" the contaminated water.

Water Resource Functions

The primary functions of the river that need to be considered in the development of MFLs thus include water supply, flood protection, navigation, recreation, protection of natural systems and water quality.

Water Supply. Total water needs of agricultural and urban users within the Caloosahatchee Basin were identified in the Caloosahatchee River Water Management Plan (SFWMD, 2000d). Current (1995) agricultural water use was projected to range from 225,000 to 290,000 acre-ft per year. Public Water Supply use was estimated to range from 10-16 MGD (11,000-18,000 acre-ft/year). The ability to meet existing and future water supply needs in this basin was addressed in the LEC and LWC Regional Water Supply plans. (SFWMD 2000b and 2000c). In the short run, these needs will be met through water generated in the basin and water delivered from Lake Okeechobee. In the longer term, completion of regional water storage projects proposed in the Comprehensive Everglades Restoration Plan (CERP) and water supply plans will allow future water needs to be met almost entirely from sources within the Caloosahatchee River watershed (USACE and SFWMD 1999). At the maximum allowable stages within the basin (3.4 ft NGVD above the Franklin Locks and 11.3 ft NGVD above the Ortona Locks), the River contains no significant water storage, so demands are met by periodically releasing water from Lake Okeechobee. The minimum water deliveries that are required to the River to meet water supply demands in the Caloosahatchee basin vary by season, with an average of 600 cfs and a maximum of 2800 cfs during a 1-in-10 year drought event (SFWMD 2000d)

Flood Protection. The need to provide flood protection within the basin requires maintenance of certain maximum levels within the River and thus places an upper limit on the amount of water that can be stored in surface water canals in the basin. At the minimum allowable stages within the basin (2.2 ft NGVD above the Franklin Locks and 10 ft NGVD above the Ortona Locks), the River contains no appreciable flood storage, so excess runoff is discharged to tide.

Navigation. Maintenance of minimum levels in the River is needed to provide navigational access for the Okeechobee Waterway and provides a lower limit for withdrawals from the River. The lowest levels that can be maintained in the River without impairing navigational use are 10 ft NGVD above the Ortona Locks (25 foot channel depth) and 3 ft NGVD above the Franklin Locks (27 foot channel depth). Water is also released from the River to the estuary when boats pass through the locks. Lockages may be restricted during periods when water levels are low in Lake Okeechobee or when saltwater intrusion affects local water supply intakes near S-79.

Recreation. Impacts on recreational uses may occur in the river due to low flows, increased incidence of blue-green algae blooms and degraded water quality conditions that may impact fisheries. In general, steps taken to address water quality problems in the river (see below) will also improve fisheries.

Natural Systems. Maintenance of sufficient water levels and flows in the River are needed to protect plant and animal communities and fisheries resources in oxbows and adjacent riverine wetland systems. In general, maintenance of sufficient water levels in the river that are needed to provide water supply and meet navigational requirements will also be sufficient to protect natural systems.

Water Quality. Water in the River is generally of good quality, with the exception that the lower stretches of the River, immediately upstream from the Franklin Locks in the area where water is withdrawn for water supply (Lee County) to recharge local wellfields (City of Fort Myers), may occasionally become saline above the locks or may experience periodic algal blooms that impair its use for public water supply (Miller 1980).

Operational Protocols Established to Protect Resources

During such periods when poor water quality conditions occur in the vicinity of water utility intakes, upstream of the Franklin locks, releases of fresh water are made from Lake Okeechobee to "flush" poor quality water downstream. Such releases generally are made only once or twice during the dry season. These operational protocols have been developed and are implemented by the SFWMD and The United States Army Corps of Engineers (USACE) to address water quality problems in the River. In the past, 3 to 4 day discharges from S-79 have been made to reduce salinity at the Lee County water plant during the dry season. The rate of discharge ranged from about 3,000 to 7,700 cfs per day. The total volume of these discharges ranged from 15,000 to 25,000 ac ft of water per event. Experimental releases from S-79 have been made to try and reduce the volume of water needed to flush the saltwater downstream and implement the discharges in a more environmental friendly manor. Results indicate that flows for 3 to 4 days are needed as follows: Day 1 – 1000cfs, Day 2 – 2800 cfs, and Day 3 – 3100 cfs with Day 4 (2000 cfs) optional depending on salt readings at the water plants. The total volume for such a 3-day event is 13,800-acre feet (see **Table 2**)

Chapter 7 of the Lake Okeechobee Master Water Control Manual (USACE 20000b) was recently revised by the USACE to include the new regulation schedule for Lake Okeechobee (WSE). The following are excerpts from pages 7-2 and 7-3 (paragraphs 7-02e and 7-02f):

Algae Blooms - During the seasonally dry months from December to April of each year, the Caloosahatchee River flow diminishes to the point that an occasional severe algae bloom develops in the river above Franklin Lock and Dam (Miller 1980). The City of Ft. Myers and Lee County both have municipal water intakes in this area which could be clogged by the algae. Short-term high rates of discharge from Lake Okeechobee are required to break up the algae bloom. This is done by the Corps whenever requested by the SFWMD.

Salinity Intrusion - During the extreme dry months of April and May the Caloosahatchee River flow may drop to near zero. When this condition prevails, navigation lockages through the W.P. Franklin Lock allow a saltwater wedge to move upstream. More lockages result in more salt water moving upstream. Eventually, the chloride content of the water entering the municipal water intakes of Ft. Myers and Lee County exceeds the drinking water standard of 250 ppm. When this happens, SFWMD requests the Corps to flush out the salt water with a short-term high rate of discharge from Lake Okeechobee. A pulse release type of approach and a smaller steady release, such as 300 cfs monthly average, have also been used for these events to benefit the estuaries.

Reduced Lockages. During a declared water shortage period, the SFWMD requests that the Corps go to reduced hours of lockages.

These procedures have worked effectively in the past to protect the quality of water in the river as a source of supply for Lee County and the City of Fort Myers water utilities.

Watershed

Major Features and Uses.

The River watershed upstream of Franklin Locks is largely developed for agricultural use, including citrus, row crops and cattle ranching (unimproved pasture) with very limited urban development, primarily near the towns of Moore Haven and LaBelle. The 1995 land use in the Caloosahatchee Basin is summarized in **Table 8** (SFWMD 2000d). Total water use from surface and groundwater sources in the eastern and western basins is estimated as 582,000 acre-ft/yr. The watershed is the primary source of base flow to the river, estimated as 918,000 acre-ft of surface water runoff (SFWMD 2000d) from measured sources and approximately and equal amount of flow from unmeasured sources and groundwater seepage through the shallow aquifer (Fan and Burgess, 1983). Land uses in the watershed create a substantial demand for supplemental irrigation water during dry periods and require capacity for releases of stormwater to the River during wet periods to prevent flooding. Runoff from agricultural land also results in periodic water quality degradation of the River due to contamination by nutrients and pesticides (Miller 1980; Degrove and Nearhoff 1987; Baker 1990; Doering and Chamberlain, 1999).

The estuary watershed downstream of the Franklin Locks also plays an important role in this system. This area provides base flows of surface water runoff and groundwater that depend on local rainfall conditions and may have significant effects on salinities in the tidal portion of the estuary. Large amounts of runoff may be generated from these basins during flood events. In addition, urban development in this area may contribute to water quality problems in the estuary and adjacent waters. Docks and marinas (largely for recreational use, but also including some significant commercial fishing traffic) in this basin are a primary destination for boats leaving and entering the river and traffic from the Gulf of Mexico and adjacent areas. Portions of this subbasin are also within the service area for utilities that withdraw water from the River and thus the dense urban and residential populations contribute to the high dry-season water demands from the River.

Table 8. Land Use and Sources of Water Supply within the Upper Caloosahatchee Basin

Basin	Water Supply Source	Land Use (acres)								
		Citrus - crown flood irrigated	Citrus - microjet irrigated	Sugar Cane sub-seepage irrigated	Tomato - 4 month with micro-spray	Pasture - (assumed to be like citrus)	Other Pasture	Upland Forest	Wetland	TOTAL
ecal-d	C-43	4,754	5,231	20,590	4,082	4,836	67,734	12,125	19,859	*139,211*
wcal-d	C-43	8,153	8,970	0	2,811	3,231	45,593	7,615	8,534	*84,907*
ecal-gw	Ground water	6	7	282	147	2,555	41,281	19,275	15,628	*79,179*
wcal-gw	Ground water	5,477	6,026	0	4,792	7,542	118,816	72,094	57,054	*271,799*
ecal-lok	Lake Okee.	0	0	3,057	18	258	3,157	503	748	*7,741*
TOTAL		***18,390***	***20,234***	***23,929***	***11,850***	***18,422***	***276,580***	***111,612***	***101,822***	***582,838***

Water Resource Functions

The primary functions that need to be considered in the watershed during development of MFLs thus include protection of water supply, flood protection, protection of natural systems and water quality.

Protection of Water Supply. An estimated 111,000 acre-ft of surface water from C-43 canal is used in the eastern and western Caloosahatchee River Basins each year for irrigation of agricultural lands and 9,000 acre-ft of surface water from Lake Okeechobee is used in the eastern basin. Significant amounts of groundwater (36,000 acre-ft) are used for agricultural irrigation. Limited amounts (16 MGD or about 17,000 acre-ft/yr) of groundwater is consumed for urban uses by Lee County and the City of Fort Myers utilities (SFWMD, 2000d). A year-round average base flow of about 190 cfs is thus required in the river to meet these average annual water supply needs in the watershed

Flood Protection. The need to provide adequate drainage and flood protection within the basin requires that excess water from the watershed is discharged to the river. That portion of irrigation water and excess rainfall from the eastern and western basins that is not lost to evaporation, is discharged to the River as runoff and contributes 918,000 acre-feet or about 1,300 cfs of average annual flow. Runoff from the tidal basin contributes an estimated significant (but not documented) amount to the annual flow on average and may contribute substantial flows for several days or weeks during peak discharge periods.

Protection of Fish and Wildlife Habitat. Maintenance of sufficient water levels and flows in the upstream watershed are needed to protect wetland plant and animal communities and fisheries resources in adjacent wetlands. The eastern and western Caloosahatchee River basins contain approximately 102,000 acres of lakes and wetlands and 112,000 acres of upland plant communities that provide habitat for native fish and wildlife, including a number of threatened and endangered species. In general, maintenance of sufficient water in the river needed to provide water supply and to meet navigational requirements will also be sufficient to protect natural systems in the watershed. The District's Consumptive Use Permit criteria are designed so that withdrawals will not allow more than 1 foot of drawdown to occur beneath wetlands (SFWMD 1997b).

Protection of Water Quality. Water in the River is generally of good quality, with the exception that the lower stretches of the River, immediately upstream from the Franklin Locks in the area where water is withdrawn to recharge local wellfields, may occasionally become saline due to intrusion of saltwater above the locks or may experience periodic algal blooms during low flow or stagnant conditions that impair its use for public water supply. The quality of runoff water from the eastern water sheds is periodically contaminated by pesticides and suspended solids. Runoff quality from coastal watershed is largely unknown, but may contain significant contamination from fertilizers, pesticides, oil and gas residues and commercial/industrial chemicals.

Operational Protocols Established to Protect Resources

The primary operational actions that are taken by the District and USACE to protect resources in the watershed are designed to address the drainage (flood control) and water supply functions

- Water levels in the primary canal system may be lowered prior to the onset of a major storm in order to provide additional storage for flood waters in the River channel.
- Water deliveries may be made from Lake Okeechobee during dry periods to meet supplemental irrigation demands.

Caloosahatchee Estuary

Major Features and Uses.

The Caloosahatchee Estuary provides a water conveyance and navigational link from the River to the Gulf of Mexico and supports a highly productive estuarine ecosystem, including both sport and commercial fisheries. Failure to provide sufficient freshwater flow adversely impacts this system by destroying its estuarine character, shifting the benthic communities that provide the normal basis of the food chain from estuarine to marine species. The low-salinity or freshwater habitat in the upper reaches of the estuary also provides some degree of protection for developing stages and juveniles of both estuarine and marine species. Too little discharge of freshwater may thus result in loss of estuarine species of plants and animals and a decline in species diversity. Tape grass (*Vallisneria*) has been identified as a key species in this system that provides important benthic habitat downstream from the Franklin Locks. This species is proposed as an overall indicator of estuarine "health." Field and laboratory research, modeling and hydrologic studies have been conducted to determine flow rates that are needed to support this community.

Water Resource Functions.

The primary functions that need to be considered in the estuary during development of MFLs thus include protection natural systems and water quality.

Protection of Fish and Wildlife Habitat. Maintenance of sufficient flows of freshwater into the estuary is needed to protect plant and animal communities and fisheries. The environmental needs of the Caloosahatchee estuary have been estimated as 450,000 acre-ft/year (400 MGD), while actual flows to the estuary average about 650,000 acre-ft/year (580 MGD) (SFWMD 2000b). In general, maintenance of sufficient flow to meet the needs of the estuary will also meet upstream water supply and navigational requirements and address water quality concerns in the river.

Water Quality. Water in the Estuary is generally of good quality. Releases of freshwater from coastal rivers and canals generally contain high levels of nutrients and trace metals that increase primary productivity in adjacent estuaries and coastal waters.

Operational Protocols Established to Protect Resources

The primary operational protocols that have been adopted to protect the estuary are designed to limit the rate of discharge for regulatory releases. These considerations have been incorporated into the zone designations, discretionary releases policies, water release schedules and and pulse release protocol of the Lake Okeechobee Regulation Schedule (USACE 2000b).

Summary and Conclusions

Based on evaluation of the functions and considerations of the river and watershed, District staff reached the following conclusions:

- Due to the highly altered condition of the river and watershed and human management of the system, District staff feel that considerations, as defined in Section 373.0421(1)(a) F.S., adequately address the changes and alterations in water resource functions applicable to the Caloosahatchee watershed and river.
- Based on the full range of functions provided by the River and watershed, it was determined that these systems are highly modified from their historic condition. Rivers and streams have been channelized, the watershed has been greatly expanded by connection to Lake Okeechobee and water control structures have been added to create a series of impoundments rather than a

free-flowing water course. The present day hydrology of the system is carefully managed and regulated to ensure that navigation, water supply and drainage/flood control functions are met on a continuing basis.

- The upstream watershed also contains significant fish and wildlife resources that need to be addressed. Although these natural systems may not be performing the same functions at the same levels as occurred historically, current management practices in the basin appear to provide adequate protection.
- In spite of the protection of most resource functions of the River and watershed provided by current management practices, at least two functions seem to be occasionally compromised to an extent that could potentially constitute harm as follows:

  1. Impacts on the water supply function, i.e. the ability to provide adequate quality water to meet urban water supply needs upstream of Franklin locks due to periodic deterioration of water quality, and
  2. Impacts on the navigation and recreation functions derived from the need to periodically reduce lockages through S-79 as a means to control upstream movement of saline water.

- Actions will be taken to alleviate these problems over the next 10 to 20 years through the Comprehensive Everglades Restoration Project. In the meantime, The district is developing and implementing operational protocols for water resource protection purposes to achieve an optimal salinity envelope, with the existing constraints and alterations in the system, prior to the structural solutions under the CERP. Maximum discharges from Lake Okeechobee will be mitigated in the future through implementation of WSE (formally initiated June 2000) Lake Okeechobee Regulation Schedule that recognizes the ability to provide MFL releases to estuaries when Lake levels are in discretionary release zones.
- In recent years, attention has been given to the need to manage resources in the estuary more effectively during low flow conditions to protect water quality and fish and wildlife habitat functions of these sensitive systems. Past management practices have not provided adequate protection for fish and wildlife habitat functions in the estuary during periods of deficient rainfall. Due to development and water use in the watershed, dry season basin flows to the estuary have been reduced and access of estuarine species to fresh water environments has been greatly reduced
- A rationale has been developed in this report, based on a survey of resources available within the region, historic conditions and comparison with similar river systems, to provide sufficient flow in the river during the winter and spring months that will maintain a viable low salinity environment downstream from the S-79 structure.
- Evidence is also presented to show that providing flows necessary to maintain such a community in the estuary will also help reduce the occurrence of poor water quality conditions (elevated chloride concentrations and algae blooms) in the river, the need to make special water releases from Lake Okeechobee, and the need to limit lockages.

- The Caloosahatchee estuary is highly dependent upon sufficient water flows and is very sensitive to high salinity levels. The health of this estuary is also an indicator of health of the watershed, since it receives runoff from the entire basin, and it serves as a nursery ground for many estuarine and coastal plants and animals. This estuary also has a high probability of experiencing significant harm due to lack of sufficient freshwater flows before the CERP structural solutions are complete. A proposed Caloosahatchee River and estuary MFL and associated management strategy were therefore developed, based on providing minimum flows necessary to protect the estuary from significant harm.

TECHNICAL RELATIONSHIPS CONSIDERED IN DEFINING SIGNIFICANT HARM

Sources of Additional Information

Results of the literature search (Estevez, 2000) produced a bibliography containing approximately 300 citations. Major findings of the literature review were that very few published or unpublished accounts exist to inform the establishment of minimum flows in highly altered riverine estuaries, especially when honoring the constraint that such minimum flow methods rely on living resources (Estevez, 2000).

Once the water resource functions of the river and estuary that needed to be protected by establishment of the MFL were identified, specific technical relationships were developed and considered to define significant harm for the water body. Lacking specific guidance from previous studies, the following process was used to develop these technical relationships with supporting documentation. These following sources of information were reviewed:

1. Development of a Valued Ecosystem Component (VEC) approach (EPA, 1987) to establish a minimum flow regime at S-79 that will protect the system from significant harm. (Chamberlain et al. 1995; Haunert et al. in review).
2. In addition to the literature search (Estevez 2000), District staff reviewed information available concerning key species or groups of organisms that may benefit from using *Vallisneria* grass bed communities within the Caloosahatchee estuary, including their life histories and tolerance to low salinity levels.
3. Review of available information obtained from the District's Caloosahatchee estuarine research programs including results from field, laboratory mesocosm, and growth rate studies conducted within the watershed.
4. Development of an empirical relationship between salinity at a given location in the estuary as function of flows through S-79.
5. Development of a Vallisneria growth rate algorithm relating changes in blade length, blade density and shoot density to salinity at various locations in the estuary.
6. The above algorithms were converted to computer code and incorporated into the South Florida Water Management Model (SFWMM) to simulate Vallisneria growth response under different flow scenarios for current (1995) base case and future 2020

with Restudy conditions (See memos from Peter Doering, March 22, 2000, and Ken Konyha, June 29, 2000, Appendix A).

Valued Ecosystem Component (VEC) Approach

The SFWMD's Caloosahatchee Estuary research program supports application of a resource-based management strategy similar to the Valued Ecosystem Component (VEC) approach developed by the U.S. Environmental Protection Agency as part of its National Estuary Program (USEPA 1987*)*. For the purposes of this study, the VEC approach is based on the concept that estuary management goals can best be achieved by providing suitable environmental conditions for selected key species or key groups of species that inhabit the estuary. In this case, the key species identified to be protected against significant harm is submerged aquatic vegetation (SAV), specifically *Vallisneria sp*. (commonly known as tape grass or wild celery) present within the upstream fresh/brackish water portion of the river. Submerged aquatic vegetation are important to the ecosystem in that they sustain an important water resource function by providing food, and habitat for forage fish, shellfish, and serve as nursery areas for many juveniles species of fish that are recreationally or commercially important (Day *et al*., 1989; Heck et al., 1995; Kemp et al., 1984; Lubbers et al. 1990; Orth et al. 1984). This approach assumes (a) that environmental conditions suitable for VEC will also be suitable for other desirable species; and, (b) that enhancement of VEC will lead to enhancement of other species. Through this strategy, management objectives will be attained by providing a minimum flow that will protect this community against significant harm.

The VEC approach was applied to the Caloosahatchee River and Estuary based on the following scientific assumptions: Seagrass (*Thalassia testudinum, Halodule wrightii*) meadows are prevalent at the seaward/outer end of the system where salinity can be significantly impacted by high volumes of freshwater discharged to the estuary from S-79 or from local basins. Therefore, these seagrass communities represent the VEC for assessing the impact of high flows within the estuary. At the other end of the spectrum, beds of *Vallisneria americana* are prominent in the fresh-brackish water (low salinity) portion of the inner estuary. These communities are sensitive to increased salinity values that result from reduced volumes of water low discharged to the estuary during the dry season. Since this report focuses on establishing a minimum flow that will the protect the ecosystem against significant harm, *Vallisneria* was selected as the VEC of choice in that it represents a number of the primary water resource functions that need protection during low flow periods. The District has published several studies using this resource-based approach to define a preliminary estimate of optimum freshwater flows that should be delivered to the Caloosahatchee Estuary (Chamberlain *et al.* 1995, Chamberlain and Doering 1998a, 1998b). Major findings of this work were:

- A minimum inflow of 300 cfs will not be harmful to *Vallisneria* communities and other estuarine biota, however inflows greater than 2,500-3,000 cfs will be detrimental to these communities anytime of the year (**Table 9).**

Table 9. Summary of Recommended Flows through Structure S-79 for Maintaining Ecological Health of Key Species within the Caloosahatchee River/Estuary System.

Species	Low flow Limit (cfs)	Preferred Inflow range (cfs)	Upper Inflow Limit (cfs)	Important Months
Vallisneria	300	300-800	<3,000	Dry Season (Nov-May)
Halodule, Thalassia	---	----	3,000	
Fish (general)	300	300-1,300	3,000	Dry season
Larval Fish	---	300-800	<2,500	March- July
Fish eggs	---	150-600	<2,500	All Year
Pink Shrimp & Blue Crabs	300	300-800	<3,000	All year
Shrimp & Crab larvae	---	<1,300	<2,500	All year; (esp. spring-July)
Benthic invertebrates (including oysters)	---	300-800	<3,000	All year

(from: Chamberlain and Doering, (1998)

- A distribution of inflows that has the greatest frequency of falling within the range of 300 to less than 1,500 cfs, with a peak flow range of 300-800 cfs, should be generally beneficial to all biota evaluated **(Table 9).**
- Since normal monthly wet season inflows are generally greater than 300 cfs, meeting this minimum flow limit only needs to be considered during the dry season.
- Some taxa (redfish, pink shrimp, blue crabs and benthos associated with *Vallisneria)* will receive the greatest benefit by being provided optimum inflows throughout the dry season, including winter months. However the majority of estuarine species are most productive and dependent on the estuary during the late dry season.
- Therefore, the greatest priority should be given to making the desired delivery in February to ensure that optimum conditions are available in the spring, and the required salinity regime has been established for *Vallisnaria* when it is most needed (Chamberlain *et al.* 1995).

Resource Functions Provided By Submerged Aquatic Vegetation

The beds of submerged aquatic vascular plants (SAV) that occur in rivers, lakes, estuaries and marine bays serve several important ecological functions which can be broadly categorized as 1) production and accumulation of organic matter; 2) creation of habitat structure; 3) reduction of wave and current energies; and 3) temporal buffering of nutrient cycles (Kemp *et al*.1984).

These grass beds add a physical complexity to shallow water habitats, provide a refuge from predation (Orth *et al*. 1992; Peterson 1982; Irlandi et al 1995) and serve as a nursery for young fish (Kemp *et al*. 1984). Leaves provide a substrate for settlement of invertebrate larvae (Heck *et al.* 1995) and growth of epiphytic algae (Kemp *et al*. 1984). In many aquatic ecosystems, submerged aquatic vegetation forms the basis for plant-based and detritus-based food webs (Zieman and Zieman 1989; Thayer et al 1984; Carter and Rybicki 1985). Given these ecological functions it is not surprising that the abundance and production of fish, invertebrates and waterfowl tends to be higher in grass beds than in adjacent unvegetated areas (Lubbers *et al*. 1990; Wicker and Enders 1995; Heck *et al*. 1995; Killgore *et al* 1989).

Submerged aquatic vascular plants can also provide water quality improvements. By baffling water motion, these grasses enhance sedimentation while their root/rhizome system stabilizes sediment (Carter *et al*. 1988; Fonseca and Fisher 1986). These effects on sediments result in reduced turbidity and enhanced water clarity (Ward *et al*. 1984; Carter *et al*. 1988). These SAV communities are also capable of rapid removal of nutrients from the water column. This buffering capability may damp nutrient input pulses from runoff events and reduce the potential for phytoplankton blooms (Kemp *et al.* 1984). The decay of vascular plant material proceeds at a relatively slow rate and thus creates a lower oxygen demand and releases nutrients back to the water column at a slower rate than more labile sources of detritus, such as phytoplankton (Twilley *et al*. 1985).

Freshwater inflows commensurate with healthy beds of *Vallisneria* also provide an open-water low salinity environment that serves a number of valuable resource functions. The larval and juvenile stages of many marine and estuarine species have adapted to withstand salinities of lower strength than adults. This adaptation allows these early life stages to occupy a low salinity region relatively free of predators (Gunter 1967). The strong relationships between size and salinity observed for many estuarine dependent species of fish and crustaceans indicates the value of low salinity regions for early life stages (e.g. Wagner and Austin, 1999). The presence of grass beds in tidal freshwater and low salinity regions greatly enhances utilization of these areas (Killgore *et al* 1989; Kemp *et al.* 1984). The longitudinal position of this low salinity zone has been used as an effective management tool of estuarine biological resources (Jassby *et al.* 1995).

Therefore, loss of the habitat functions listed above as a result of reduced dry season flows and increased salinity have the potential to result in some level of harm to Caloosahatchee estuary submerged aquatic vegetation communities and their associated fauna.

Literature Review Findings

One of the requirements for developing the MFL is to use “best available information.” A literature review was therefore conducted to (1) evaluate different approaches used to establish minimum flow requirements for other estuarine ecosystems, and (2) review the validity of using the Valued Ecosystem Component (VEC) approach to define MFLs for the Caloosahatchee Estuary. The literature review incorporated the following objectives (Estevez, 2000):

1. Identify those living estuarine resources that could potentially be used as indicators, targets, or criteria for determining a minimum flow in a riverine estuary
2. Determine how the selection of a living resource target may be affected in a system that has experienced a long history of extreme structural and/or hydrologic alteration.
3. Determine how to best apply lessons learned by other water management districts, other states, and other counties in establishing minimum flow criteria
4. Provide the District with an independent evaluation of the District’s approach for establishing a MFL within the Caloosahatchee River and Estuary. These recommendations are contained in the document entitled “A Review and Application of Literature Concerning Freshwater Flow Management in Riverine Estuaries” (Estevez, 2000).

Results of the literature review indicated the following:

- Very few published or unpublished accounts exist regarding the establishment of minimum flows in highly-altered riverine estuaries, especially when honoring the constraint that such a methodology must rely primarily on living resource.
- A literature of moderate size exists documenting specific estuarine impacts of flow alterations, but the majority of these address flow reductions. Contemporary work by other water management districts elsewhere in Florida is still in progress or being planned.
- Even though literature directly related to the Caloosahatchee River and Estuary is limited, the review provided relevant insights gathered from: (1) river science and instream flow determinations; (2) basic and applied estuarine ecology; (3) Texas estuaries studies; and, (4) Florida minimum flows and levels work in progress.
- A synthesis and application of these insights for the Caloosahatchee River and Estuary revealed that "habitat and indicator species approaches are working well in the Caloosahatchee River and
- The District has conducted important scientific work on *Vallisneria* (tapegrass) and *Thalassia* (seagrass) and has included considerations of shoal grass, oysters, and salinity variations in the Caloosahatchee River and Estuary.
- In light of the District goals, the Caloosahatchee River and Estuary should possess a permanent tidal freshwater, but not an extensive, persistent one. District work on submerged aquatic vegetation as a valued ecosystem component (VEC) has accomplished much and offers greater promise."
- The review provided two key observations: (1) the VEC approach is an appropriate method to use to determine a minimum flow and (2) the Caloosahatchee Estuary should possess a fresh-brackish water habitat. The VEC, *Vallisneria*, is indicative of this habitat and the water resource function the District desires to maintain.

Summary of Estuary Research Findings

Flow/Salinity Relationship

A one dimensional hydrodynamic/salinity model (Bierman 1993) was completed for the Caloosahatchee River and estuary and was used in the previous efforts, however, this model did not provide a satisfactory relationship of salinity and flow from S-79 under low flow (0 to 500 cfs) conditions for the inner estuary. Bierman's model was predicting higher salinity than was being observed in the Caloosahatchee River and estuary during low flow conditions. Therefore, District staff developed an empirical relationship between salinity at a given location in the estuary as a function of flow at S-79 (see memo from Ken Konyha, June 29, 2000, **Appendix A**). Flow data was obtained using measured flow from S-79 and salinity at the Ft. Myers Marina (22 km upstream of Shell Point) for the period from January, 1992 to November, 1999. The Ft. Myers Marina salinity station is located near a *Vallisneria* sampling station and is near the down stream boundary of the area with the greatest potential for growth of *Vallisneria*. Therefore, this salinity station was chosen for calibration of the statistical model. A scatter plot of modeled data vs. observed data reveals an R^2 of 0.76 (**Figure 9)** while **Figure 10** traces modeled data and observed data for the period of record.

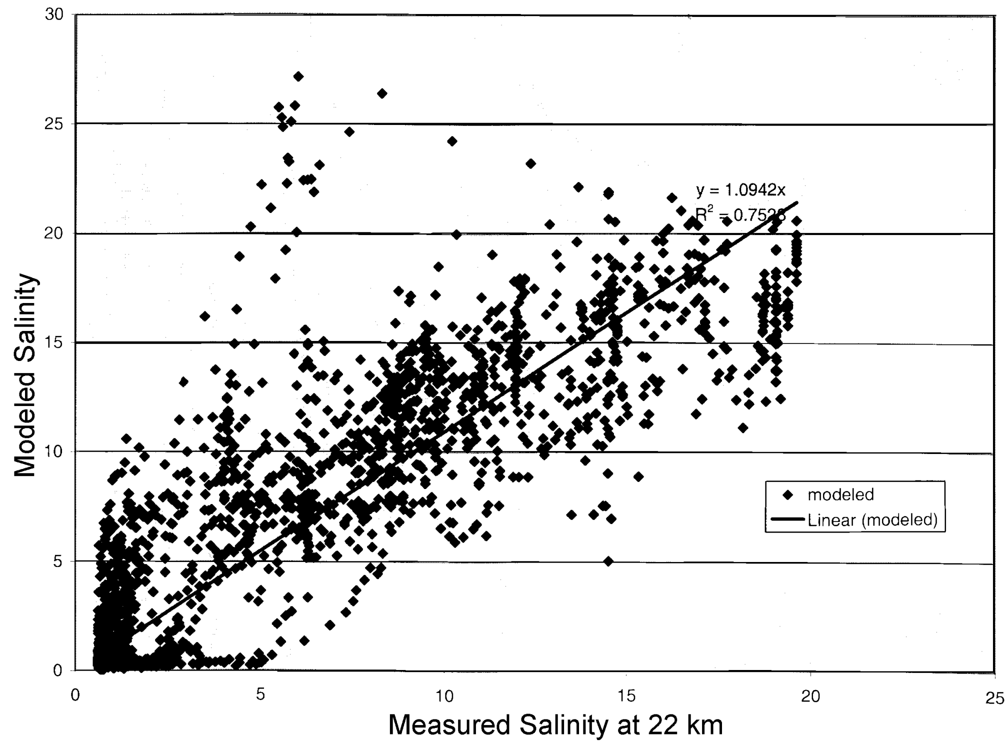

Figure 9. Scatter Plot of measured versus Modeled Salinity at 22 km upstream of Shell Point, Caloosahatchee Estuary

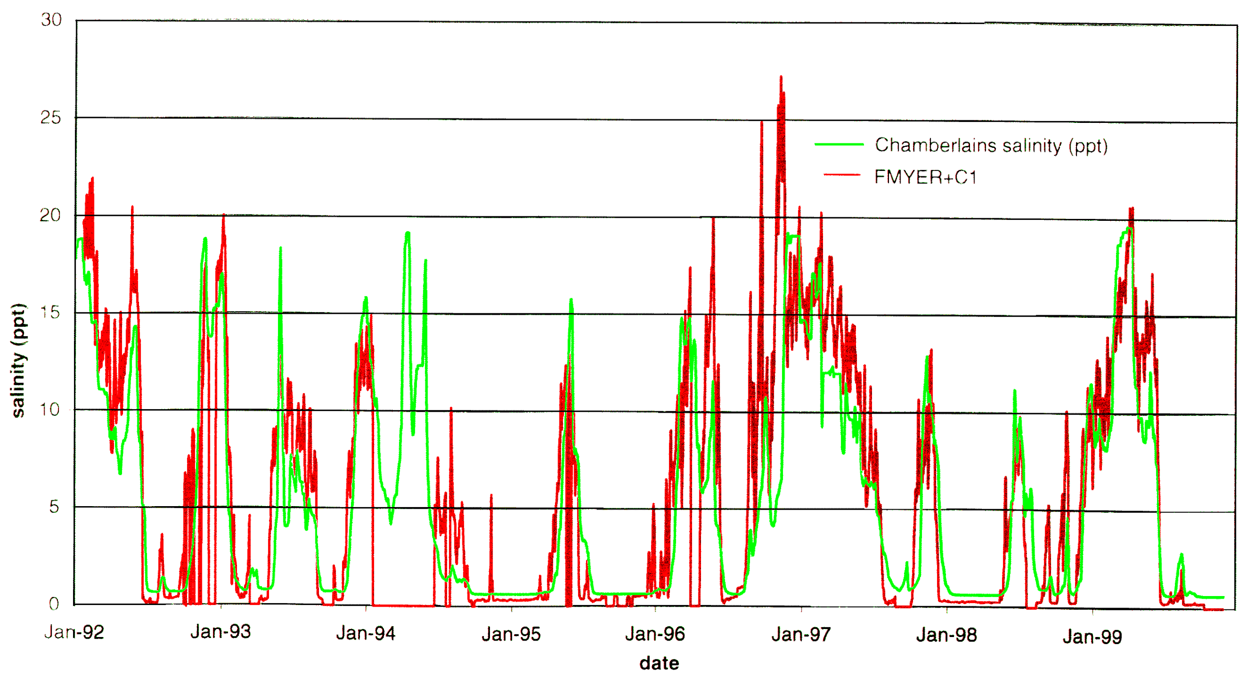

Figure 10. Comparing modeled to measured salinities at x = 22 km (based on Chamberlain's algorithm)

A comparison of predicted salinity from the two models in the area of concern, under steady state low flow conditions reveals that the District's model predicted significantly lower salinity under low flow conditions which better represented field observations. Therefore, this model was used to estimate salinity resulting from the predicted time series of flows from S-79.

Field and Laboratory Research

Vallisneria is a freshwater aquatic grass that is tolerant to low salinity and therefore, is frequently found in the transitional zone from freshwater to oligohaline habitats. Since *Vallisneria* grass beds are sedentary and salinity varies in response to inflows, understanding its tolerance to salinity is important in predicting its distribution and density. A literature search was conducted on the biology and life history of *Vallisnaria* to determine if its salinity tolerance information was adequate to avoid the need for additional field and laboratory investigations (Bortone, 1998; Doering *et al.*, 1999). While there have been several determinations of salinity tolerance of *Vallisnaria*, (Bourn, 1932; 1934; Haller *et al*., 1974; Twilley and Barko, 1990) estimates did not agree and there was little information about factors that might modify salinity tolerance. However, qualitative data for the Caloosahatchee Estuary indicate that densities decline when salinity is above 10 ppt and growth ceases at 15 ppt (Doering *et al*., 1999).

Qualitative data collected from the Caloosahatchee Estuary are consistent with these limits and indicates that densities decline when salinity is above 10 ppt. Since limited detailed information was available on the effects of varying salinity and duration of salinity exposure on *Vallisneria,* a field sampling program, was initiated to measure salinity and *Vallisneria* shoot density as well as other growth parameters at four locations along the salinity gradient. During the first year (1998) of field sampling (Bortone 1999), plants thrived since they were not exposed to salinity high enough to cause mortality. During 1999 however, dry season salinity data documented the effects of salt water intrusion, thus providing a data set for calibration of a *Vallisneria* growth and mortality model being developed with data from laboratory experiments.

In addition, the District conducted laboratory experiments (mesocosm studies) that simulated typical saltwater intrusions during the dry season (Doering *et al*., 2000). The results of these efforts are summarized as follows:

- In general, short duration intrusions (1, 5, 11 days) retarded *Vallisneria* growth, but did not cause significant mortality. Longer-term intrusions (20, 30, 50, 70 days) caused mortality, with the degree of mortality proportional to the duration of the intrusion.

- A 70-day exposure to 18 ppt caused an 80 percent loss of shoots. Nevertheless, observation of plants for another month at a favorable salinity (3 ppt) showed that viable plants remained even after 70 day at 18 ppt.

- Results of this field work indicate that *Vallisneria* can probably survive most salinity intrusions in the upper estuary. These studies also indicate that a 70-day intrusion is near the limit of what might be tolerated without a net population reduction during the winter. It would take the remaining plants 90-days of growth to reach pre-intrusion levels. The intrusion and recovery from it (70 + 90 =160 days) would occupy nearly the entire dry season (180 days).

- These experiments helped to not only to quantify the magnitude of minimum flows, but also provide information about the duration and timing of their delivery.

***Vallisneria* Growth Rate Algorithms**

In addition to above work, *Vallisneria* daily growth rate algorithms were developed relating changes in blade length, blade density and shoot density to salinity (memo from P. Doering, March 22, 2000 **Appendix A**). Although algorithms were established for all growth parameters, this evaluation only used shoot density predictions since it is the most appropriate measure of abundance. The main purpose of the evaluation was to predict decreases in abundance (mortality) due to salinity and not to reproduce the annual cycle of *Vallisneria* abundance. Because the model was not intended to reproduce an annual cycle of abundance, shoot density was 'reset' each year to a specified value every October. In general then, a 31-year simulation of *Vallisneria* shoot density identifies those years in which dry season salinity would have caused decreases in abundance. Specifically, the calibrated model best represents effects of salinity on the abundance of *Vallisneria* during the early spring portion of the dry season when this resource function is most needed. More details and results of this work are presented in **Appendix A (**memo from P. Doering, March 22, 2000; memo from K. Konyha , June 29, 2000).

PROPOSED MFL CRITERIA FOR THE CALOOSAHATCHEE RIVER AND ESTUARY

The following minimum flow criteria were developed for the Caloosahatchee River and Estuary based on the following assumptions and interpretation of data.

Importance to the Region

Tape grass (*Vallisneria americana)* beds located within the upper Caloosahatchee Estuary represent an extremely important estuarine habitat found within the greater Charlotte Harbor area. This submerged aquatic vascular plant community serves as critical nursery habitat during the spring months for a wide variety of estuarine species that are both commercially and recreationally important to the region (Bortone and Turpin 1998). The largest abundance of *Vallisneria* (640 acres) occurs from Beautiful Island to just past the Ft. Myers bridge. *Vallisneria* grass beds have been documented as an important component of upper and mid-estuary for more than 43 years (Phillips and Springer 1960; Gunter and Hall 1962). Its distribution and abundance varies in response to salinity, light penetration, and the amount of freshwater input (Chamberlain *et al*. 1995, Hoffacker, 1994; Doering *et al.* 1999). It is well documented that submerged aquatic vegetation, such as *Vallisneria,* provides important habitat for benthic invertebrates, small forage fish and shellfish and serves as a nursery area for many juvenile species that are commercially or ecologically important (Day *et al.* 1989). Previous research (Chamberlain *et al.* 1995) concluded that the majority of estuarine species within the upstream estuary are most productive and dependent on *Vallisneria* grass beds during the spring. Therefore, maintaining *Vallisneria* shoot density during this critical time period is a key issue for protecting this community against significant harm. In addition, the West Indian manatee, a federally protected endangered species, have been observed feeding in these grass beds during the winter months. Therefore, this area may also be an important feeding location close to a warm water refuge (FP&L power plant) for this protected species.

Definition of Impact

During dry periods when the river provides extended low flow or zero flow conditions, salinity within these grass bed communities gradually increase and over time, result in leaf defoliation and a reduction in the density (number of shoots/m^2) of *Vallisneria* (Doering *et al*. 1999; Doering *et al*. 2000). In this regard, loss of this habitat function within the estuary for several years in succession implies that the organisms that depend on it experience some level of harm each time this event occurs and do not have the opportunity for full recovery until suitable habitat is again present during the critical months. If loss of the habitat function continues indefinitely, then the species/life history stages that depend on it will eventually be eliminated from, or greatly reduced in numbers within this estuary. Best professional judgment was used to derive a threshold density of 20 shoots/m^2, below which the *Vallisneria* community no longer provides adequate habitat for estuarine organisms (Haunert *et al.* in review).

Significant harm to the habitat function implies that the organisms that would have utilized *Vallisneria* grass beds will be harmed or damaged or eliminated to an extent that multiple years will be required for the population to recover. Loss of a single year class of organisms could be significant harm if there was evidence that it would take several years for the population to recover from this setback. However, we do not have sufficient quantitative population data to make this determination for any species or group of organisms within the Caloosahatchee estuary.

Flow/Salinity Requirements

Results of District research efforts (see Konyha memo June 26, 1999 in **Appendix A**) have concluded that to maintain *Vallisneria* habitat that will support both estuarine and juvenile marine organisms, a minimum mean monthly flow of at least 300 cfs is required to be delivered to the estuary between the months of November – March (dry season). This requirement is based on Chamberlain *et al.* 1995 who reported the following:

- A minimum (mean monthly) flow of 300 cfs for *Vallisneria* will not be harmful to the various types of estuarine biota found within the estuary (**Table 9**), but [mean monthly] inflows greater than 2,500–3000 cfs would be detrimental to the community anytime of year.
- If the vast majority of flows range between 300 and 800 cfs, then the minimum discharge necessary to support *Vallisneria* will be attained.
- Since normal wet season mean monthly flows are usually greater than 300 cfs, meeting this inflow limit only needs to be considered during the dry season.

DEFINITION OF HARM AND SIGNIFICANT HARM

In order to establish technical criteria for determining a minimum flow for the Caloosahatchee River and estuary, it is necessary to define harm and significant harm for the habitat function of the *Vallisneria* community. Minimum flow and level criteria for the Caloosahatchee estuary are based on protection of submerged aquatic vegetation, *Vallisneria americana*. Previous research (Chamberlain *et al.* 1995) concluded that the majority of estuarine species within the upstream estuary are most productive and dependent on tape grass beds during the spring (November – March). Therefore, maintaining *Vallisneria* shoot density during this critical time period is the focus of this evaluation. At present, our best available information on the freshwater needs of *Vallisneria* is based on results obtained from a review of the literature and the three models described above -- a hydrologic model, a salinity model and a *Vallisneria* growth model. Definitions of harm and significant harm have been developed (Haunert *et al*. in review) based on predicted impacts to the habitat function of the *Vallisneria* community:

Definitions

- *Vallisneria* shoot density in critical grass bed areas (between 15 and 19 mile upstream of Shell Point) may periodically fall below 20 shoots/m^2 during the months of March, April and May. Such events may be stressful, but are considered to be within the range of normal fluctuation and do not constitute harm. Organisms have the ability to recover during the following wet and dry seasons in response to increased flow.
- It is the expert opinion of District biologists that ***harm*** occurs if such an event happens during two consecutive years. This degree of habitat loss will impact local populations within the Caloosahatchee estuary of species that live for one or two years and are highly dependent on this freshwater habitat during the spring months to successfully grow or reproduce (**Table 10**).

Table 10. Fish and Crustaceans that may Benefit from Low Salinity and Utilization of *Vallisneria* Habitat within the Caloosahatchee Estuary during the Spring.

Species	Relative Abundance	Spawning	Relative Utilization	Life Span
Important Forage for Game Fish				
Penaeus duoraum (Pink shrimp)	Abundant as juveniles	Apr-Sep	High	2 yrs
Palaemonetes pugio (Grass shrimp)	Highly abundant (eggs, larvae, juveniles, adults)	Feb-Oct	High	1 yr
Callinectes sapidus (Blue Crab)	Highly abundant juveniles; abundant adults	Apr-May; Sep-Oct	High	3-4 yrs
Brevoortia smithi (Yellowfin menhaden)	Common as juveniles	Feb-Mar	High	5-12 yrs
Anchoa mitchilli (Bay anchovy)	Highly abundant all life stages	Feb-Mar; Jun-Aug	High	1-2 yrs
Fundulus grandis (Gulf killifish)	Common all life stages	Nov-May	High	3 yrs
Menidia sp. (Silversides)	Highly abundant all life stages	Mar-May; Oct-Nov	High	1-2 yrs
Lagodon rhomboides (Pinfish)	Highly abundant as juveniles; common as adults	Oct-Feb	High	?
Mugil cephalus (Striped mullet)	Highly abundant as juveniles	Dec-Feb	High	7-8 yrs
Game Fish				
Megalops atlanticus (Tarpon)	Abundant as juveniles	Mar-Apr	Medium	15 yrs
Centropomus undecimalis (Snook)	Abundant as juveniles; common as larvae	Jun-Jul	Low	5-7 yrs
Bairdiella chrysoura (Silver perch)	Abundant larvae and juveniles	Mar-Apr; Aug-Sep	Medium	6 yrs
Cynoscion arenarius (Sand seatrout)	Abundant as juveniles	Mar-May; Aug-Sep	High	3 yrs
Cynoscion nebulosus (Sea trout)	Common as juveniles and larvae	Apr-Jun; Aug-Sep	Low	15 yrs
Pogonias cromis (Black drum)	Common as larvae and juveniles	Jan-Apr	High	58 yrs
Sciaenops ocelatus (Red drum)	Common as larvae; abundant as juveniles	Sep-Oct	High	Over 37 yrs

Source: Patillo, M.E. et al. 1994. Distribution and abundance of fishes and invertebrates in Gulf of Mexico Estuaries, Vol. II: Species Life history summaries. ELMR Rept. No. 11. NOA/NOS Strategic Environmental Assessments Division, Silver Spring, MD. 355 p.

- Similarly, it is the expert opinion of District biologists that ***significant harm*** occurs if the habitat function of this community is lost for three consecutive years or more. Many estuarine and marine species which utilize this habitat have life spans of three years or less and represent important forage organisms which support higher trophic level species (**Table 10)**. These organisms are highly dependent on this freshwater habitat during the spring months and may fail to reproduce successfully during their lifetime if this habitat is lost or reduced.

Support for the levels of harm discussed above are derived from a review of the life histories of important forage species and game fish that utilize either open-water or grass bed habitats in the low salinity region of the Caloosahatchee estuary during the spring (**Table 10).** The forage species that typically have the highest biomass are: bay anchovies, silversides, and pink shrimp. The life span of these species is about two years. The most estuarine dependent game fish (sand sea trout) has a life span of three years. All of these species have a bimodal or extended spawning cycle. Usually the spring spawn is the most intense and therefore most important. One purpose of the proposed MFL is to provide favorable habitat and sufficient productivity to support larval/juvenile development during this important spring spawning and growout period. Loss of this habitat over consecutive years will adversely affect the secondary productivity of the estuary especially for those species with short life spans (i.e., 2-3 years). Based on the available information, District staff believe that loss of the spring spawn/growout for one life span may constitute harm for a particular species but that three consecutive years of loss of this habitat constitutes significant harm for the *Vallisneria* community.

In addition, Estevez (2000) reports that it is now understood that native aquatic biodiversity depends on maintaining or creating some semblance of natural flow variability, and that native species and natural 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. The full range of natural intra- and interannual variation of hydrologic regimes are critical in sustaining the full native biodiversity and integrity of aquatic ecosystems. There is a growing sentiment for a similar paradigm in estuaries. In riverine estuaries it seems reasonable to evaluate both flows and salinity with respect to their multiple forms of variation. The District is in the process of developing a natural systems model for the Caloosahatchee Basin which predicts 30 years of flow with natural landscape features in the watershed prior to drainage and development of the region. In concert with salinity and plant growth models, this model will be used to develop a better understanding of historic return frequencies of low flow conditions that impacted *Vallisneria* communities prior to construction of the C-43 canal.

Modeling *Vallisneria* Response to Simulated Flow Conditions

The next step taken by District staff was to incorporate Chamberlain's empirical flow/salinity relationship and Doering's *Vallisneria* growth rate algorithms into a regional hydrologic model (South Florida Water Management Model or SFWMM) to simulate tape grass growth under simulated flow conditions at various locations within the estuary. Using the above definitions of harm and significant harm, District staff determined how often these criteria would be exceeded under current and future conditions.

Regional Modeling Approach

Several regional and sub-regional plans have been recently completed for South Florida by the SFWMD and the United States Army Corps of Engineers (USACE). The USACE and the District developed the "Comprehensive Everglades Restoration Program" (CERP a.k.a. the "Restudy"), which provides engineering solutions (improvements) to address water management problems in South Florida (USACE & SFWMD, 1999). The SFWMD, while considering CERP, also developed a number of regional water supply plans for the Lower East Coast, Lower West Coast and Caloosahatchee planning areas (SFWMD, 2000b, 2000c, 2000d). Major efforts were made to develop these plans using consistent data and performance measures. The Caloosahatchee estuary watershed is within the geographical boundaries of all four plans. A common base case and future base case scenarios were generated for these plans using the South Florida Water Management Model (SFWMD 1999).

The 1995 base case includes a 31-year historical period of record (1965-1995) with 1995 land use and current water management operations. A future base case (2020 with Restudy) was also developed and includes future 2020 land uses as well as the majority of the CERP improvements (reservoirs, aquifer storage and recover, and back pumping) planned for the C-43 basin. Therefore, both of these modeling scenarios can simulate flows discharged from S-79 to the Caloosahatchee estuary under current and future with Restudy conditions.

IN the 2020 with Restudy simulation, a number of environmental flow requirements were incorporated into the model scenario for the Caloosahatchee watershed (see Konyha memo, June 1999, October 1999, and January 2000, **Appendix A).** These estuarine flow requirements were determined from previous District research and included the desired range of flows of 300 to 2800 cfs plus natural variation outside of this desired range (Chamberlain *et al.* 1995). **Figure 11** shows a frequency distribution of flows for both the 1995 and the 2020 with Restudy cases.

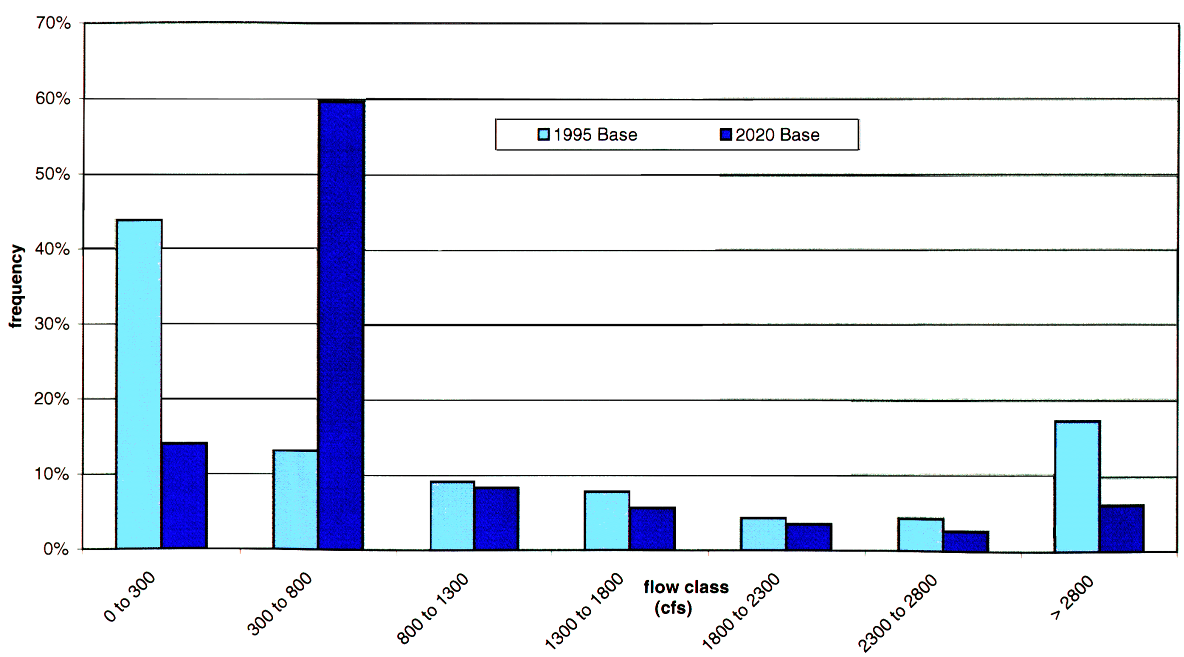

Figure 11. Frequency Distribution of Monthly Flows for the 1995 Base Case and 2020 with Restudy Components

The major changes in flow shown in the 2020 with Restudy histogram included a dramatic increase in base flows and flows within the range of 300 to 800 cfs, and a significant decrease in flows greater than 2800 cfs. All of these changes in flows are consistent with District estuarine research recommendations.

Modeling *Vallisneria* Response to S-79 Flows

Incorporation of the flow/salinity relationship and *Vallisneria* growth rate algorithms into the SFWMM, the District could then simulate tape grass growth under various simulated flow conditions to assess (a) how often levels of harm and significant harm were exceeded as well as (b) determine how much additional flow would be needed to deliver to the estuary to prevent significant harm. This was simulated using three 31-year time series of flows to simulate *Vallisneria* shoot density in areas where it would grow when favorable salinity conditions exists. The three time series included: (a) the 1995 base case, used to determine how frequently *Vallisneria* communities are impacted under current conditions, and how frequently additional flows would be needed to be delivered to the estuary to avoid significant harm; (b) the 1995 base with additional flows to avoid significant harm; and (c) the 2020 with Restudy future case, which included the CERP improvements in the watershed as a MFL Recovery and Prevention Strategy to avoid significant harm conditions.

The first area downstream of S-79 that has high potential (appropriate depths and bottom types) for *Vallisneria* to flourish is from 15 to 19 mi upstream from Shell Point. In this area, *Vallisneria* currently populates about 640 acres with the greatest portion of this acreage occurring within the first several km (**Figures 12 and 13)**. The three time series of flows were used to predict salinity in this 640 acre area. **Figure 14** reveals that predicted salinity at the boundaries of the 640 acre area (15 and 19 km) for the base case differed by less than 1 ppt. Due to this limited difference in salinity, the predicted *Vallisneria* shoot density was also limited. Therefore, shoot density (abundance) at the most downstream location (15 km) will be considered a conservative indication of the abundance in the 640 acre area.

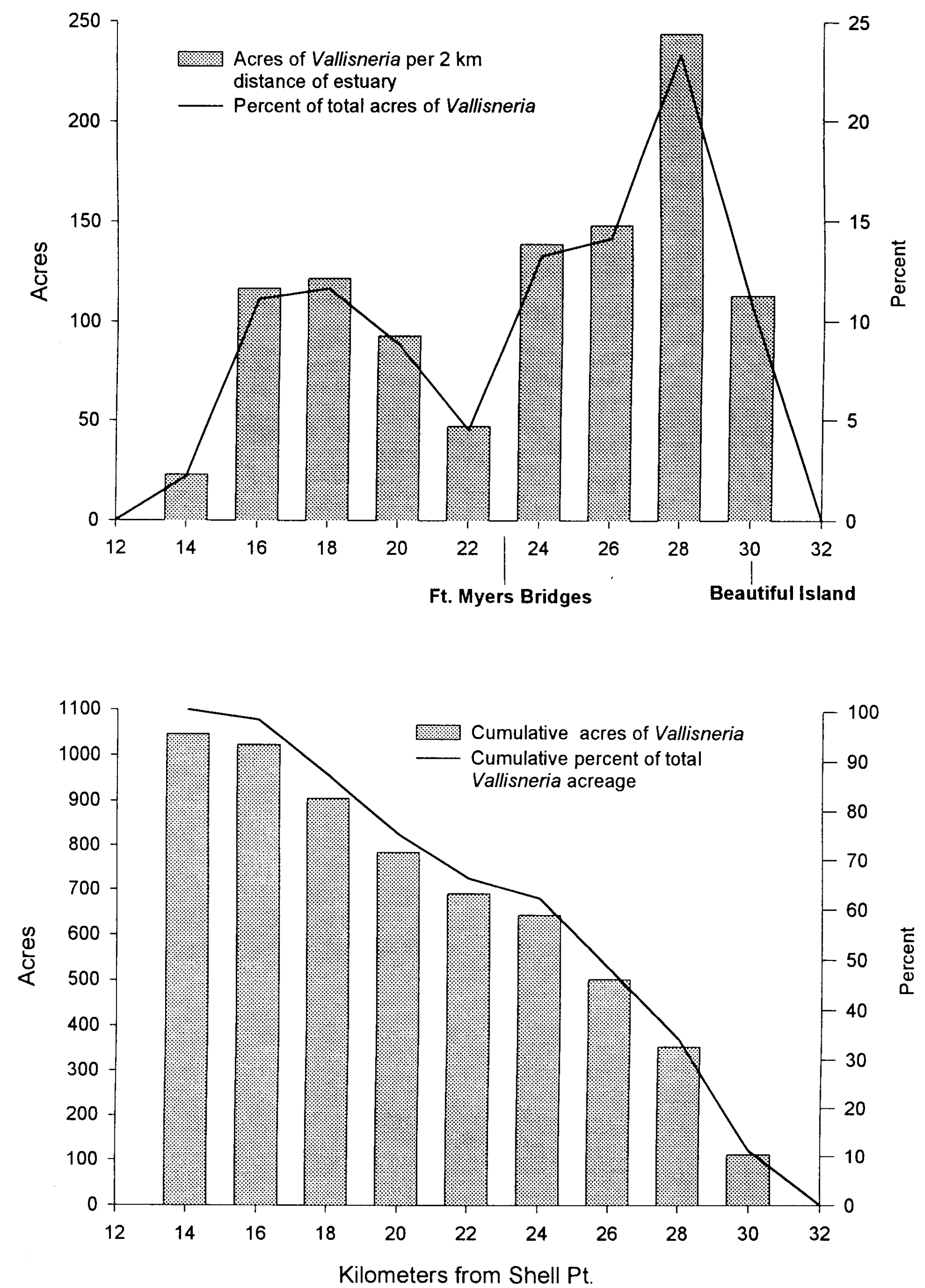

Figure 12. Estimated maximum *Vallisneria americana* coverage in the Caloosahatchee Estuary during ideal environmental conditions.

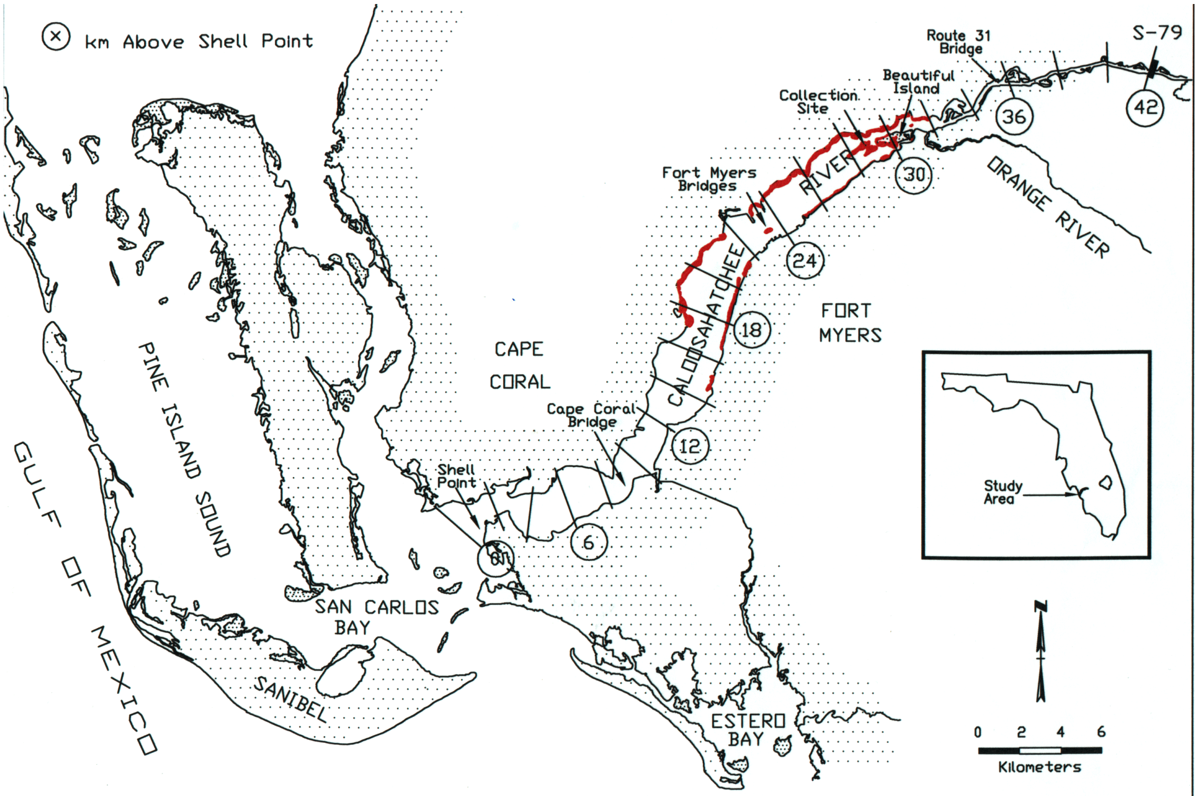

Figure 13. ***Vallisneria americana*** **distribution in the Caloosahatchee estuary**

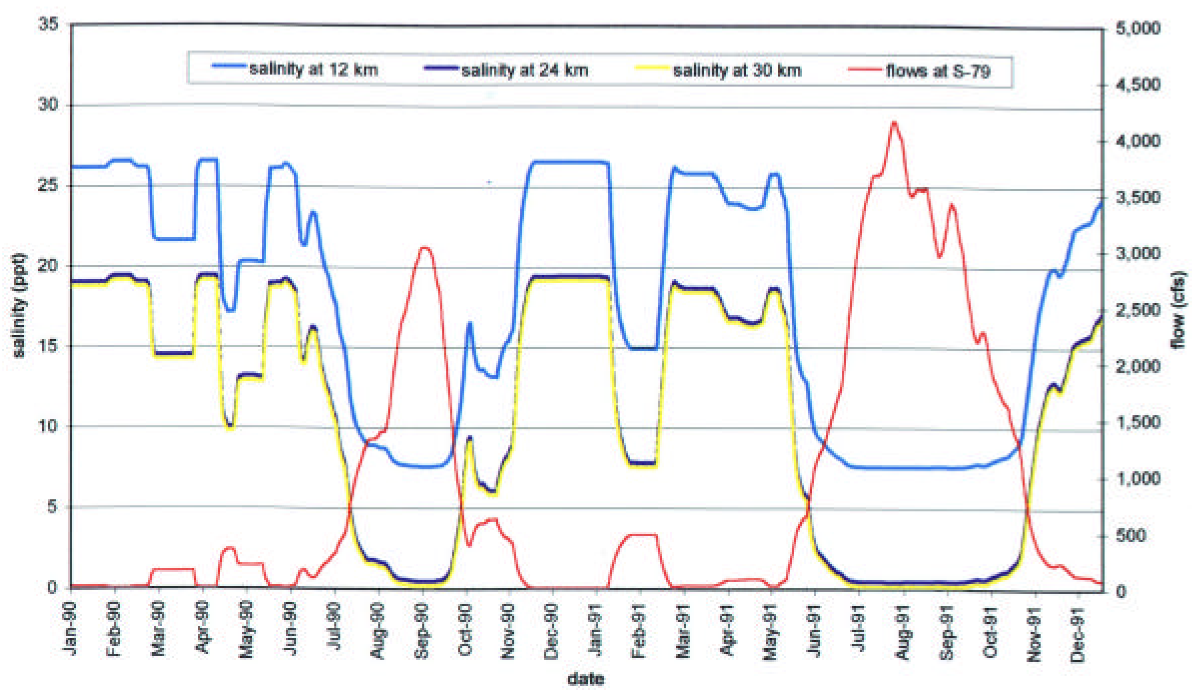

Figure 14. Salinity estimates based on 1995 base case flows at. S-79 at three locations upstream of Shell Point, Caloosahatchee Estuary

Exceedances of Harm and Significant Harm

By reviewing SFWMM output for the 1995 Base Case flows, predicted salinity values at15 miles (24 km) upstream from Sheell Point, and predictions of *Vallisneria* shoot density and salinity a determination was made of conditions that were associated with low shoot densities in the spring (**Figures 15 and 16).**

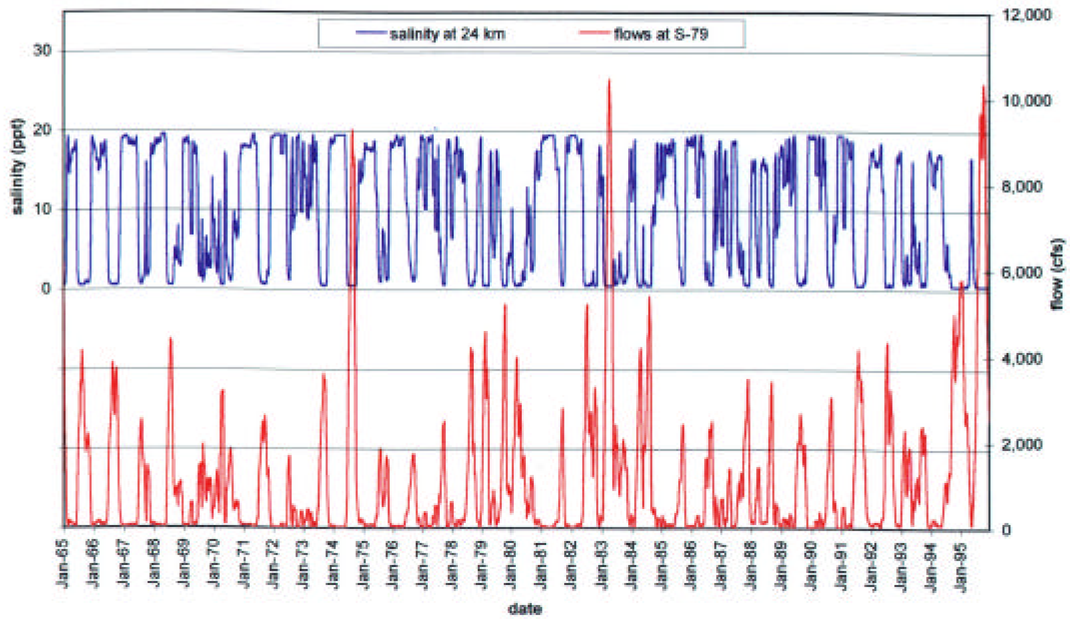

Figure 15. Salinity estimates based on 1995 Base Case flows at S-79, 15 Mi. upstream of Shell Point, Caloosahatchee Estuary

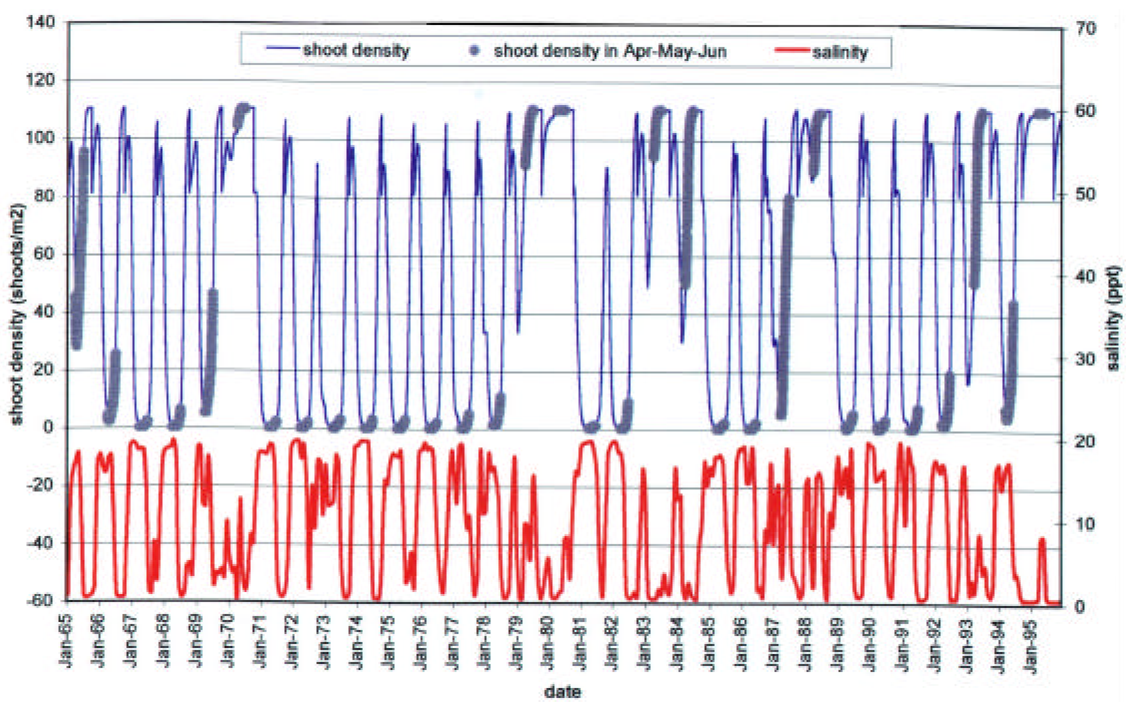

Figure 16. 1995 base case- *Vallisneria* shoot density and salinity 15 Miles upstream of Shell Point, Caloosahatchee Estuary

The data were further analyzed to determine how often the proposed *harm* and *significant harm* definitions were exceeded within the Caloosahatchee estuary under the 1995 Base Case. **Figure 16** shows the predicted *Vallisneria* shoot densities 15 mi upstream of Shell Point resulting from 1995 Base Case flows from S-79. These densities indicate the response of *Vallisneria* to current District water management operations. Using the threshold shoot density of less than 20 shoots/m^2 to indicate loss of the habitat function during the spring, the 1995 Base Case (**Figure 16)** showed that current water management operations result in 22 events when shoot densities decline below 20 shoots/m^2 during the 31-year simulation (frequency of once every 1.4 years). The conditions of ***harm*** defined above (loss of habitat function two years in succession with less than 20 shoots/m2) occurred 16 times (once every 1.94 years) (**Table 11, Figure 16**). ***Significant harm*** (loss of habitat function three years in succession with less than 20 shoots/m2) occurred 11 times (once every 2.8 years) during the period of record **(Table 11**).

Table 11. Determining Years that Could be Managed to Avoid Significant Harm - Current Conditions (1995 BASE) and Restored Conditions (2020 RESTUDY).

	1995 Base			Adaptive Water Management Approach			2020 RESTUDY		
Year	Stress[1]	Harm[2]	Significant Harm[3,4]	Stress[1]	Harm[2]	Significant Harm[3]	Stress[1]	Harm[2]	Significant Harm[3]
1965									
1966	Y			Y					
1967	Y	Y		Y	Y				
1968	Y	Y	Y	*					
1969	Y	Y	Y	Y					
1970									
1971	Y			Y					
1972	Y	Y		Y	Y				
1973	Y	Y	Y	Y*	Y	Y	Y		
1974	Y	Y	Y	Y					
1975	Y	Y	Y	Y	Y				
1976	Y	Y	Y	*					
1977	Y	Y	Y	Y					
1978	Y	Y	Y	Y	Y				
1979									
1980									
1981	Y			Y			Y		
1982	Y	Y		Y	Y				
1983									
1984									
1985	Y			Y					
1986	Y	Y		Y	Y				
1987	Y	Y	Y	*					
1988									
1989	Y			Y			Y		
1990	Y	Y		Y	Y		Y		
1991	Y	Y	Y	*			Y		
1992	Y	Y	Y	Y					
1993									
1994	Y			Y					
1995									
total	22	16	11	17	7	1	4	0	0

[1]Stress occurs if the minimum shoot density in Apr-May-Jun is <20 shoots per square meter
[2]Harm occurs if there is stress in two consecutive years.
[3]Significant harm occurs if there is stress in three consecutive years.
[4]Effective management during critical years would eliminate significant harm

* Water added to 1995 Base Case in an effort to avoid significant harm

Results of this analysis indicate that under current operating conditions, as simulated by the 1995 Base Case, additional flows are needed during most years to prevent ***harm*** and ***significant harm*** from occurring to the resource function provided by the *Vallisneria* community in the Caloosahatchee Estuary. Therefore a MFL Recovery and Prevention strategy is required.

MFL RECOVERY AND PREVENTION STATEGY

Adaptive Water Management Approach

Since benefits from the implementing the MFL Recovery and Prevention Strategy (described below) will not occur until 2012, when structural elements of CERP are completed, the District should consider implementing an interim water management strategy to address MFLs. In the LEC Regional Water Supply Plan, the following description of a recovery strategy for the Caloosahatchee estuary was provided (SFWMD 2000 Planning Document, P 228)

> "In the period of time prior to construction of these facilities, the District will utilize water in Lake Okeechobee, when available, for releases to the Caloosahatchee River to prevent MFL violations, which are projected to occur only during extreme droughts. In implementing this interim recovery and prevention strategy, releases to prevent significant harm will occur as follows: if a die back of *Vallisneria* grass beds occurs in the area identified in the MFL criteria during one year, for at least one of the following two years, an average of 300 cfs of water will be delivered at the S-79 structure during the months of February through April"

The goal of the Adaptive Water Management Strategy (AWMS) proposed below is provide the details of how such an interim strategy can be implemented to better meet the MFL criteria. The intent is to reduce the occurrence of significant harm to the 640 acres of *Vallisneria* beds that are located between 15 and 19 mi upstream of Shell Point. To determine the flow rate and duration needed to achieve this goal, additional flows were added to the 1995 Base Case flow time series as needed. These flows were then used to predict salinity in the 640-acre area and the *Vallisneria* growth model was applied to predict abundance resulting from the additional flows.

A number of different flow rate and duration regimes (**Table 12**) were attempted with the models to arrive at the most favorable combination (see Konyha memo June 26, 2000 in **Appendix A**). Results from this effort revealed that eight combinations of flow rate and duration were able to eliminate 10 of the 11 occurrences of significant harm: combination b, d, e, f, l, q, r, and s. These had flows of 300 cfs, 350 cfs, 400 cfs, or 550 cfs. Effective starting and ending months depend on the flow threshold. These results showed:

- Flows of 300 cfs need to be applied from November through March (run f).
- Flows of 400 cfs need to be applied from December through March (run s).
- Flows of 550 cfs can be applied from December through February (run l).

The volume of supplemental flow was similar for all thresholds (68,000, 75,000, and

78,000 acre-feet for runs f, s, and l, respectively).

Of these three flow thresholds, the 300 cfs value is preferred because it requires less water and longer application periods are more likely to have incidental benefits. Such benefits may include: (a) improved water quality in areas of the river that are used for municipal water supply, and (b) a greater chance that basin runoff will reduce the demand for flow from the Lake.

It is a common practice to release large volumes of water from Lake Okeechobee over short time periods during the dry season to protect municipal water supply from salt water and/or undesirable algae blooms. The proposed minimum flow proposed in this report should help reduce the occurrence salt water intrusion and undesirable algal blooms in the river, thus eliminate or greatly reduce the need to make short-term, high volume releases in the dry season.

Table 12. Comparing the Effectiveness of Potential MFL Release Rules for Reducing the Occurrence of Significant Harm under "1995 BASE WITH MFL FLOWS".

RUN	Minimum Flow	High susceptibility period		Occurrences of significant harm		water added (ac-ft/y)
		Start	End	Count	Years	
a	0	-	-	11	(see Table 11)	0
b	300	Nov	Ma	1	1973	93,119
c	250	Nov	Ma	3	1968, 1973, 1976	76,027
d	350	Nov	Ma	1	1973	110,558
e	300	Nov	April	1	1973	81,295
f[1]	**300**	**Nov**	**March**	**1**	**1973**	**68,214**
g	300	Nov	Feb	4	1968, 1973, 1976, 1991	53,059
h	350	Nov	Feb	2	1968, 1973	63,032
i	300	Dec	Feb	4	1968, 1973, 1976, 1991	39,726
j	350	Dec	Feb	4	1968, 1973, 1976, 1991	47,219
k	500	Dec	Feb	2	1973, 1991	70,205
l	550	Dec	Feb	1	1973	78,003
m	300	Dec	March	4	1968, 1973, 1976, 1991	54,881
n	300	Dec	April	4	1968, 1973, 1976, 1991	67,962
o	300	Dec	Ma	4	1968, 1973, 1976, 1991	79,786
p	350	Dec	Ma	2	1973, 1991	94,746
q	400	Dec	Ma	1	1973	109,938
r	400	Dec	April	1	1973	93,247
s	400	Dec	March	1	1973	75,361
t	400	Dec	Feb	4	1968, 1973, 1976, 1991	54,804
u	400	Dec	Jan	4	1968, 1973, 1976, 1991	37,213
v	350	Dec	March	2	1973, 1991	65,065
w	400	Jan	March	4	1968, 1973, 1976, 1991	53,804
x	500	Jan	March	3	1968, 1973, 1991	68,783
y	550	Jan	March	2	1973, 1991	76,384
z	600	Jan	March	2	1973, 1991	84,029
aa[2]	300	Nov/Oct	March	0		71,829

[1]Run "f" is the best performing MFL release rule.

[2]Run "aa" eliminates significant harm in 1973 by starting releases in October, 1972 instead of November. Otherwise, run "aa" is identical to run "f."

Figure 17 shows the shoot density of *Vallisneria* resulting from implementing the recommended minimum flows that avoided significant harm 10 out of 11 times. An exceptional spring event occurred in 1973, when the season began with a shoot density below 20 shoots/m^2. In spite of this adverse condition, significant harm was nearly avoided by implementing the proposed water releases. Therefore, as a general adaptive rule, and considering that the methods used are not refined, District staff believe that the recommended flow rates and duration provide an acceptable level of resource protection.

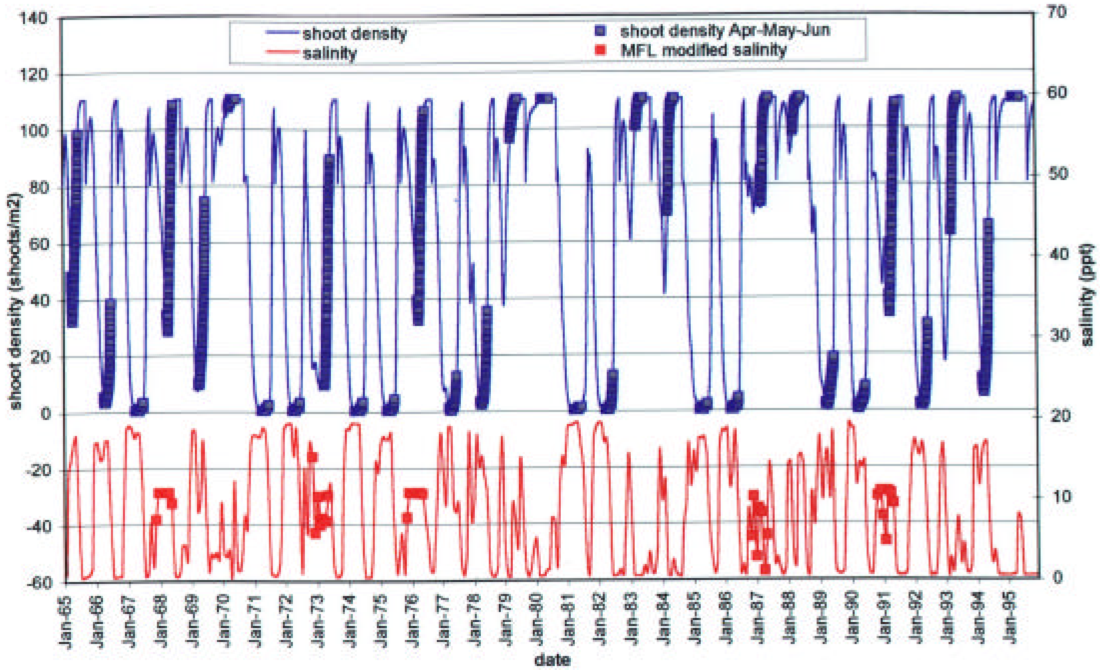

Figure 17. 1995 Base Case with MFL Flows – *Vallisneria* Shoot Density and Salinity at 15 mi Upstream of Shell Point, Caloosahatchee Estuary

With the present infrastructure and water demands, the flows needed to meet this goal come from Lake Okeechobee. Each November, the District should consider examining water supply conditions throughout the District and the status of *Vallisneria* communities within the Caloosahatchee Estuary over the last several years to determine the possibility making recommended minimum flow releases to the estuary. A biological monitoring program will be needed to continually assess the condition and response of *Vallisneria* and organisms that utilize this habitat, in relation to S-79 flow and salinity conditions within the 640 acre area. The District presently has real-time access to both flow and salinity data in this area, and ongoing *Vallisneria* studies are also in progress within the area. With information from these monitoring programs, we can fine-tune the relationship between flow/salinity and *Vallisneria* abundance and thus adapt District operational protocol to make these deliveries in order to avoid significant harm to water resource functions of the Caloosahatchee estuary.

Water management operational rules for meeting minimum flow criteria from S-79 must be provided to ensure that the MFL goal for the estuary is met, while conserving water from Lake Okeechobee and using watershed runoff to the maximum practical extent. The total volume of water for a 30-day month with a flow rate of 300 cfs is 17,820 acre feet. Therefore, the operational procedure proposed to meet minimum flows is as follows:

1. Determine total volume of releases from S-79 for the previous three weeks
2. If volume is below 13,365 ac ft., an average pulse release of 300 cfs (i.e. ranging from 100 to 600 cfs) for the following week
3. If volume is between 13,365 and 124,835 ac ft., an average pulse release of 200 cfs for the following week
4. If volume is between 14,835 and 16,305 ac ft., an average pulse release of 100 cfs for the following week
5. If volume is between 16,305 and 17,820 ac ft., an average pulse release of 50 cfs for the following week
6. If volume is greater than 17,820 ac ft., do not release minimum flows for the following week
7. If during a minimum flow release a storm event provides significant runoff to the estuary, minimum flows should be terminated until the following weeks evaluation.

This procedure would be followed in concert with the monitoring program to ensure adaptability in meeting the MFL goal.

Recovery and Prevention Strategy

Because the proposed minimum flow criteria can not be met every year under current conditions, a Recovery and Prevention Strategy is needed. As previously mentioned, the SFWMD is involved in four major water management plans that require a consistent future water management scenario for the Caloosahatchee Estuary watershed. The proposed future development of water resources within the Caloosahatchee watershed will be designed to reduce the watershed's reliance on Lake Okeechobee water while providing optimal flows (including dry season flows nearly every year) as described in Haunert *et al.* (in review), to the estuary. The future year 2020 with Restudy scenario includes the following design elements within the Caloosahatchee watershed as outlined in CERP (USACE and SFWMD, 1999).

Reservoir – The reservoir is 10,000 acres in area with a 16 ft depth and a capacity of 160,000 acre-feet. Waters are pumped from the C-43 canal into the reservoir using a pump with a 2,500 cfs capacity. The reservoir is located in the West Caloosahatchee Drainage Basin. The operating rules for the reservoir are based on reservoir storage and basin runoff.

Aquifer Storage and Recovery (ASR) Wells - There are 22 sets of ASR wells each with a capacity of 10 mgd. These wells are used to inject waters from the reservoir or withdraw waters as needed from the aquifer. A 75% recovery is assumed, regardless of the period stored underground. It is assumed, that there is no mixing with higher salinity aquifer water. The operating rules of the ASRs are based on reservoir storage.

Backpumping – A set of pumps near the S-78 Structure lift waters from the reservoir and the West Caloosahatchee basin into the East Caloosahatchee basin. A second set of pumps lifts waters from the East Caloosahatchee basin through a storm-water treatment area (STA) into Lake Okeechobee. The pump capacity of these facilities is 1,000 cfs. Operating rules for the pumps are based on the reservoir storage volume.

These are generic design elements that may be replaced by alternate design elements in the future; however, the same optimal flow requirements for the Caloosahatchee estuary will be met regardless of a change in elements.

The schedule for construction of these facilities can be found in the "Central and Southern Florida Project Comprehensive Review Study (CERP), Appendix M, Implementation Plan Scheduling and Sequencing"(USACE and SFWMD 1999). In short, the construction of the reservoir and ASRs is scheduled to begin in 2005 and be completed in 2012. Construction of the backpumping facilities is planned to begin in 2012 and be completed in 2016.

Once the facilities are operational, the optimal flow requirements for the Caloosahatchee estuary will be realized. **Figure 18** shows the flows from S-79 and salinity at 15 mi upstream of Shell Point when the above construction elements are completed (2020 Restudy).

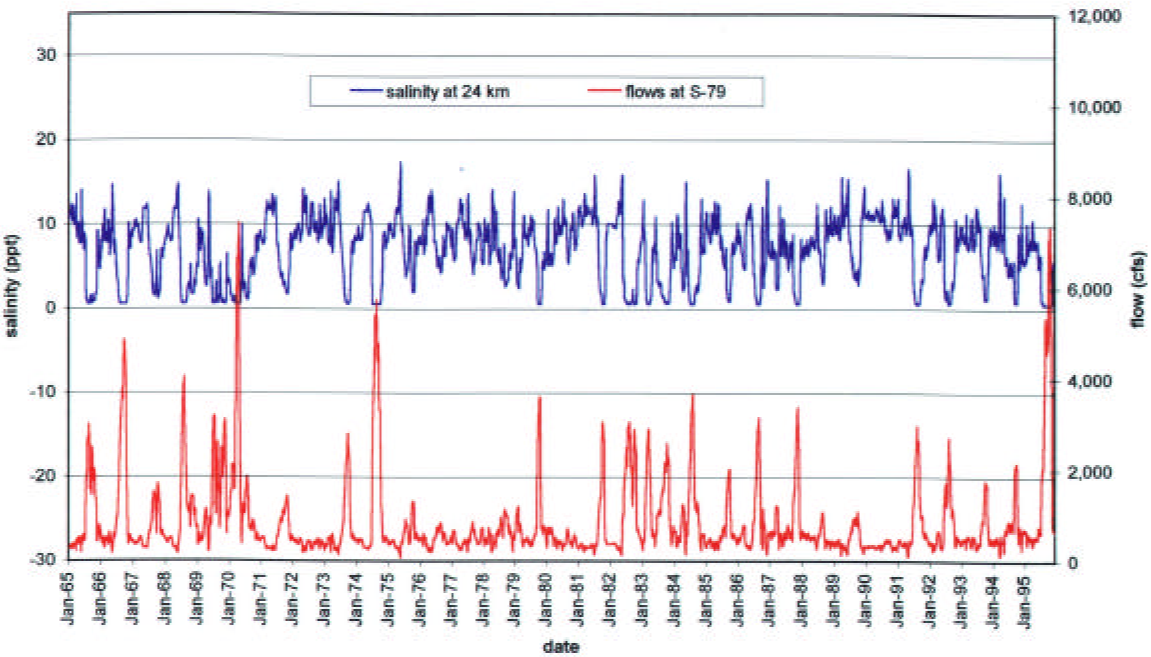

Figure 18. Salinity Estimated Based on 2020 with Restudy Flows at S-79, 15 mi Upstream of Shell point, Caloosahatchee Estuary

This 31-year time series reveals that the base flow of about 300 cfs is achieved for the majority of the simulation and that a significant reduction occurs in flows greater than 2,800 cfs, relative to the 1995 Base Case conditions in **Figure 16**. The proposed CERP components would largely accomplish the goals of promoting recovery and preventing significant harm to water resource functions of the Caloosahatchee Estuary. The base flows were sufficient to maintain salinity below 10 ppt most of the time in the 640 acre area that supports growth of *Vallisneria*. The predicted effect of these flows and salinity on shoot densities at location 15 mi is shown in **Figure 19** and **Table 11**. Using the definitions of ***harm*** and ***significant harm*** provided in this report, flows delivered to the estuary under 2020 with Restudy conditions result in only one exceedance of the ***significant harm*** criteria, and two exceedances of the ***harm*** criteria, over the 31-year simulation. Therefore, the proposed construction elements and revised operational features can be considered, in general, a major improvement compared to the 1995 Base Case condition (**Figure 16**). Implementation of this proposed adaptive management strategy (**Figure 17**), and the deployment of the proposed Caloosahatchee Basin Reservoir, ASR and Backpumping elements and their operational criteria by 2016, constitute a MFL Recovery and Prevention Strategy for the Caloosahatchee Estuary (Haunert *et al.* in review).

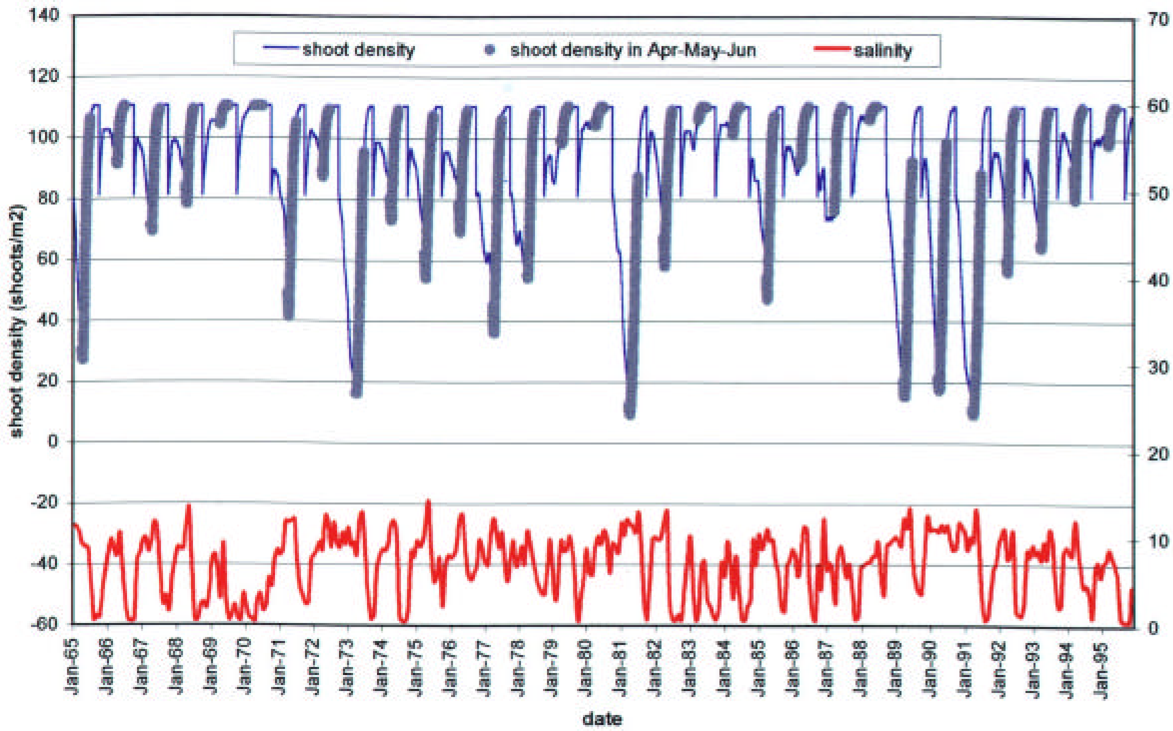

Figure 19. 2020 with Restudy- *Vallisneria* Shoot Density and Salinity, 15 mi Upstream of Shell Point, Caloosahatchee Estuary.

Chapter 5
CONCLUSIONS

GENERAL

- Minimum Flows and Levels (MFLs) were developed to prevent significant harm from occurring to the Caloosahatchee River and estuary.
- Structural changes or alterations that have occurred to the Caloosahatchee River and its watershed, the effects of these changes, and the constraints they impose on the water resource were considered as part of the process for developing the proposed MFL.
- Significant harm is defined as loss of a specific water resource functions that take multiple years to recover, which result from a change in surface or groundwater hydrology.

SYSTEM COMPONENTS AND FUNCTIONS

- Four components of the Caloosahatchee River system were identified that are affected by the need to establish Minimum Flows and Levels (MFLs). These components and their identified water resource functions were:

    1. Lake Okeechobee provides water supply, flood protection, navigation, recreation, natural systems, protection of fish and wildlife habitat and water quality functions
    2. The Caloosahatchee River: provides functions of water supply, flood protection, navigation, recreation, protection of natural systems and water quality.
    3. The Caloosahatchee River watershed functions include protection of water supply, flood protection, natural systems and water quality.
    4. The functions of the Caloosahatchee River estuary include fish and willife habitat and water quality.

CONSIDERATION OF STRUCTURAL CHANGES AND ALTERATIONS

- The river, estuary and upstream watershed are highly modified from their historic condition. The River has been channelized, the watershed has been greatly expanded by connection with Lake Okeechobee and water control structures have been added to create a series of impoundment rather than a free-flowing watercourse. The present day hydrology of the system is carefully managed and regulated to ensure that navigation, water supply and drainage/flood control functions are met on a continuing basis.
- At least two functions of the River and watershed are occasionally compromised and could potentially constitute harm. These include impacts on the water supply function due to periodic deterioration of water quality (algae blooms and elevated chloride concentrations), and

impacts on the navigation and recreation functions based on the need to periodically reduce lockages through S-79. However, adequate protection is provided, in terms of operational protocols to prevent significant harm from occurring to these resources.

- The Caloosahatchee estuary is sensitive to high salinity levels and receiving sufficient water flows during the dry season. The health of this estuary is also an indicator of health of the watershed, since it receives runoff from the entire basin, and it serves as a nursery ground for many estuarine and coastal plants and animals. This estuary also has a high probability of experiencing significant harm due to lack of sufficient freshwater flows before the CERP structural solutions are complete. A proposed Caloosahatchee River and estuary MFL and associated management strategy were therefore developed, based on providing minimum flows necessary to protect the estuary from significant harm.
- Providing flows necessary to maintain a fresh/brackish water community within the estuary will also help maintain water quality conditions in the river and reduce the need to make special water releases from Lake Okeechobee or limit lockages.

TECHNICAL RELATIONSHIPS CONSIDERED IN DEFINING SIGNIFICANT HARM

Sources of Information Examined

- A Valued Ecosystem Component (VEC) approach (EPA, 1987) was used as the basis to establish a minimum flow regime at S-79 that will protect the system from significant harm.
- Several published District studies used this resource-based approach to define a preliminary estimate of optimum freshwater flows that should be delivered to the Caloosahatchee Estuary.
- Results of a literature search produced a bibliography containing approximately 300 citations.
- Review of information available concerning key species or groups of organisms that may benefit from using Vallisneria grass beds.
- Review of the District's Caloosahatchee estuarine research programs including results from field, laboratory mesocosm, and growth rate studies.

Information Analysis and Modeling

- An empirical relationship was developed between salinity at a given location in the estuary as function of flows through S-79.
- A Vallisneria growth rate algorithm was derived, to relate changes in blade length, blade density and shoot density to salinity.
- The above algorithms were converted to computer code and incorporated into the South Florida Water Management Model (SFWMM) to simulate Vallisneria growth response under current (1995) future (2020) conditions.

DEFINITION OF HARM AND SIGNIFICANT HARM

Basis for Defining Harm

- Minimum flow and level criteria for the Caloosahatchee estuary are based on protection of submerged aquatic vegetation, Vallisneria americana. Previous research concluded that many estuarine are dependent on Vallisneria grass beds during the spring (November–March). Therefore, maintaining Vallisneria shoot density during this critical time period was the focus of this evaluation.
- Definitions of harm and significant harm were developed based on predicted impacts to the habitat function of the Vallisneria community:

Levels of Harm

- Vallisneria shoot density in critical grass bed areas (between 15 and 19 mile upstream of Shell Point) may periodically fall below 20 shoots/m2 during the months of March, April and May. Such events may be stressful, but are considered to be within the range of normal fluctuation and do not constitute harm. Organisms have the ability to recover during the following wet and dry seasons in response to increased flow.
- Harm occurs if such an event happens during two consecutive years. This degree of habitat loss will impact local populations within the Caloosahatchee estuary of those species that live for one or two years and are highly dependent on this freshwater habitat during the spring months to successfully grow or reproduce.
- Significant harm occurs if the habitat function of this community is lost for three consecutive years or more. This based on the fact that many estuarine and marine species which utilize this habitat have life spans of three years or less and represent important forage organisms which support higher trophic level species. These organisms are highly dependent on this freshwater habitat during the spring months and may fail to reproduce successfully during their lifetime if this habitat is lost or reduced. Support for the levels of harm discussed above are derived from a review of the life histories of important forage species and game fish that utilize Vallisneria grass beds located within the Caloosahatchee estuary during the spring.

MFL RECOVERY AND PREVENTION STRATEGY

Because the proposed minimum flow criteria cannot be met every year under current conditions, a Recovery and Prevention Strategy is needed. District staff have identified short-term and long-term approaches to implementing the proposed MFL critieria and protecting the resource from significant harm

Short-Term Recovery Strategy

- An Adaptive Water Management Approach is recommended for the Caloosahatchee estuary to avoid exceedance of the MFL criteria over the short-term (next 10-15 years) and reduce occurrence of significant harm to the Vallisneria community.
- A number of different flow rate and duration regimes were analyzed with the models to arrive at a favorable combination.
- A flow rate of 300 cfs, extending from November through March is recommended, since less water is required and using the longer application period is more likely to have benefits such as: improved water quality, reduced demands on the Lake, reduction in the occurrence of salt water intrusion and algal blooms in the river. Results of these model simulations indicate that these recommended minimum flow rate and duration provide an acceptable level of resource protection.
- Each year at the onset of the dry season, water supply conditions throughout the District and the status of *Vallisneria* communities within the Caloosahatchee Estuary should be examine to determine if there is a need to make minimum flow releases to the estuary.
- Specific operational procedures are proposed in this plan to meet Caloosahatchee estuary MFLs based on maintaining an average monthly discharge of 300cfs.

Long-Term Recovery Strategy

- Proposed future development of water resources within the Caloosahatchee watershed will be designed to reduce the watershed's reliance on Lake Okeechobee water while providing optimal dry season flows to the estuary nearly every year.
- The future year “2020 with Restudy” scenario includes the following elements (a) a 10,000 acre reservoir, (b) Aquifer Storage and Recover wells, and (c) backpumping projects as outlined in the Comprehensive Everglades Restoration Plan.
- The schedule for construction of these facilities indicates that construction of the reservoir and ASRs is scheduled to begin in 2005 and be completed in 2012. Construction of the backpumping facilities is planned to begin in 2012 and be completed in 2016.
- Results of the model simulations show that once the proposed facilities are operational, MFL flow requirements for the Caloosahatchee estuary will be met. Using the definitions of harm and significant harm provided in this report, flows delivered to the estuary under 2020 with Restudy conditions result in only one exceedance of the significant harm criteria, and two exceedances of the harm criteria, over the 31-year simulation. (Watch this space for future content)

Chapter 6
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