Chapter 12: Management and Restoration of Coastal Ecosystems

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SUMMARY

This chapter provides an overview of the management and restoration activities associated with coastal ecosystems within the South Florida Water Management District (SFWMD or District). In addition to this year's consolidated reporting efforts, this chapter's coverage of coastal ecosystems supports the overall objective of the *2006 South Florida Environmental Report – Volume I* (SFER) to provide a comprehensive view of the South Florida environment within the District's boundaries. As an update to Chapter 12 of the 2005 SFER – Volume I, the information covered in this chapter focuses on Water Year 2005 (WY2005) (May 1, 2004 through April 30, 2005), but also includes historical trends for some ecosystems.

Overall, one of the District's primary goals is to manage freshwater discharge to South Florida's estuaries in a way that preserves, protects and, where possible, restores essential estuarine resources. The District seeks to ensure that estuaries receive not only the right amount of water at the right time, but also clean high quality water. Presently, the District and the scientific community are conducting interdisciplinary research to produce a broad range of data, information, and tools that will assist in achieving this goal.

Coastal ecosystem science and engineering projects undertaken by the District focus on developing enhanced knowledge and tools for the management of freshwater resources. Primary investigations continue to focus on analysis of freshwater discharges on seagrasses and oyster beds. These have been chosen as key variables for several reasons: (1) both are stationary features with some historical data available, (2) they represent consistent features of the estuarine landscapes in South Florida, and (3) much of the subtidal structure in South Florida's estuaries is biological (e.g., coral reefs, seagrass beds, oyster beds). The information developed through these investigations allows the District to work closely with scientists from other agencies, such as fisheries and wildlife experts, to better understand the links between water management impacts on estuarine habitats and utilization by higher trophic levels.

In a continuing effort to support the Comprehensive Everglades Restoration Plan activities, as well as other critical needs, the District has organized resources and developed a focal point for coastal science. Within the Coastal Watersheds Program, the Coastal Ecosystems Division (CED)

is responsible for the development and application of science-based information and tools, as well as the design and implementation of projects that reduce scientific uncertainty and provide enhanced predictive capability for management of coastal ecosystems. The primary objectives of the CED are to characterize and delineate the impact of freshwater discharges on estuaries, and to develop models which will provide a scientifically valid basis for water management decisions that impact coastal resources. Emphasis has been placed on watershed dynamics and the downstream impacts associated with quantity, quality, timing, and distribution of fresh water. These factors are being examined to quantify linkages, and to provide information to decision makers that will allow them to protect and restore estuarine resources. To accomplish this mission, the CED is committed to partnerships with local, state, and federal agencies, collaboration and peer review with the professional community, and consistent communication with stakeholders.

South Florida's coastal ecosystems are comprised of several major ecosystems within the District. Each ecosystem, informally named by the coastal water body in which it resides, possesses unique hydrologic, biologic, and anthropogenic features. These ecosystems are the Southern Indian River Lagoon, including St. Lucie River and Estuary; Loxahatchee River and Estuary; Lake Worth Lagoon; Biscayne Bay; Florida Bay and Florida Keys; Naples Bay; Estero Bay; Caloosahatchee River and Estuary; and Southern Charlotte Harbor (**Figure 12-1**). Presently, the District conducts scientific research and monitoring for the majority of these ecosystems, which have been identified as priority coastal water bodies. The District also works closely with other local, state, and federal partnering agencies for those areas where the District is not the lead agency. Restoration and management efforts are being implemented at varying levels of activity for each ecosystem due to the availability of resources and the need to address priorities reflected in the District's Strategic Plan.

Currently, there are many assumptions and uncertainties regarding the physical, chemical, and biological dynamics necessary for the long-term sustainability of coastal ecosystems. However, it is clear that South Florida's coastal ecosystems are impacted by three major issues: (1) disruption of the natural magnitude and timing of freshwater discharges, (2) increasing input of nutrients and other materials of concern, and (3) continued loss of critical ecosystem habitats and their biological communities. Together, the cumulative impact of these changes has resulted in altered ecosystem structure and impaired function.

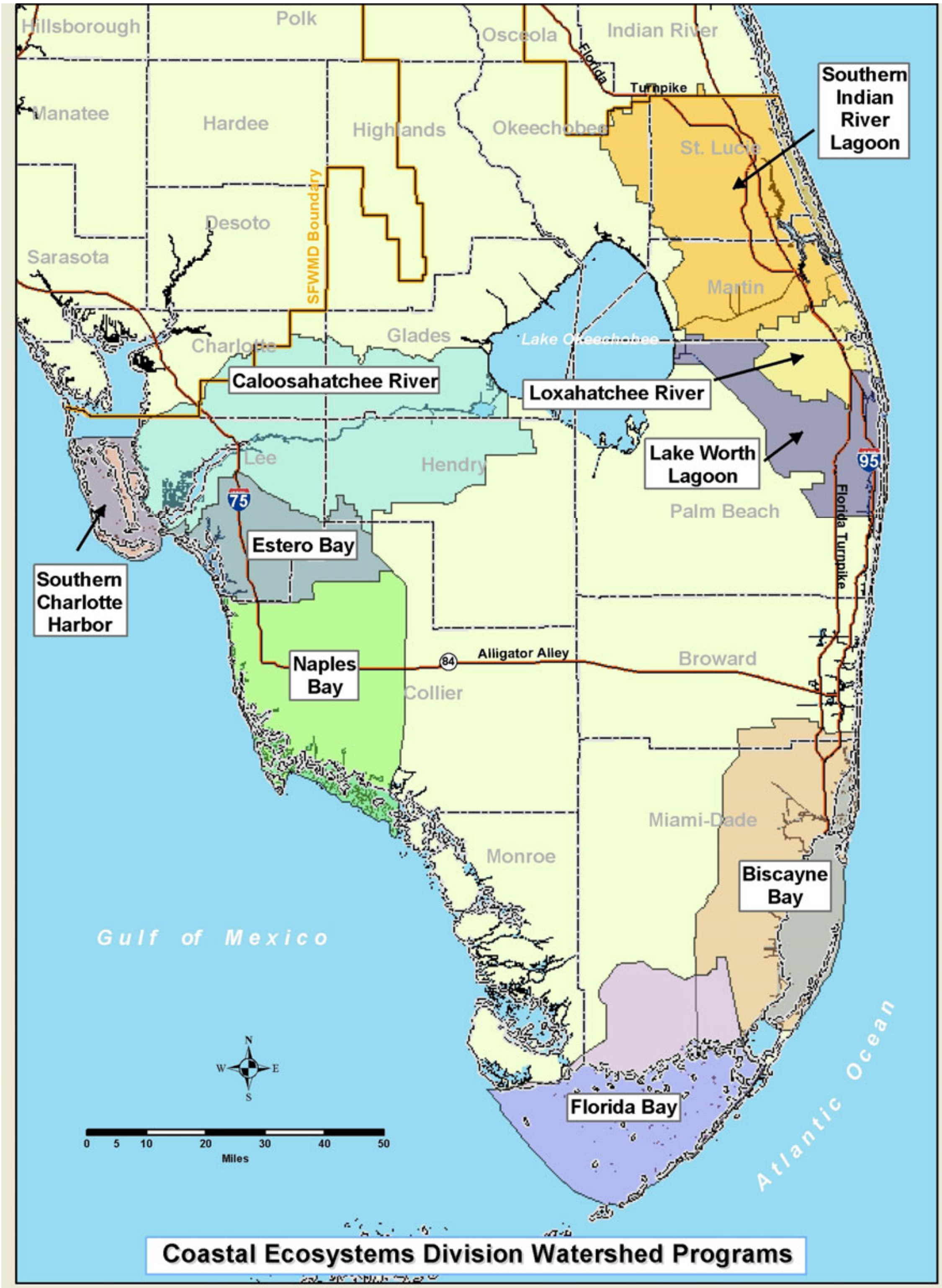


Figure 12-1. Coastal ecosystems in the South Florida Water Management District.

INTRODUCTION

Maintaining the health and biodiversity of coastal ecosystems is essential to the sustainable development of both coastal and economic resources. Coastal ecosystems are complex, and the challenges and threats associated with these systems occur on many levels. There are continuing widespread concerns over several key issues related to coastal ecosystems including (1) the impact of continued habitat loss; (2) accelerating population growth; (3) management of water quantity and quality; (4) providing infrastructure critical to economic and ecosystem sustainability; (5) the impact of sea level rise; (6) the impact of exotic species; and (7) the cumulative impact of multiple watershed stressors. These issues are not specific to South Florida but are common to most coastal systems that support significant human populations. South Florida's coastal ecosystems continue to be negatively impacted by altered delivery of freshwater, continued habitat loss, and declining water quality.

The coastal estuaries, bays, and lagoons that surround the jurisdictional boundaries of the South Florida Water Management District (SFWMD or District) are distinguished from similar systems elsewhere in the world by their connection to a vast water management system originally designed to provide flood protection and water supply. The hydrological system has become a complex of canals, water control structures, levees, and impoundments extending from Central Florida through the Everglades to Florida Bay delivering fresh water to estuaries through (1) artificial connections to Lake Okeechobee, (2) artificial connections to additional drainage basins, and (3) construction of water control structures. Lake Okeechobee is the largest freshwater lake in the southeastern United States and is the heart of the system. The lake functions as the system's central water supply and floodwater reservoir. When the lake level climbs above a predetermined height mandatory releases are made to tide. These releases combined with stormwater runoff from drainage basins can result in discharges high enough to turn some systems entirely oligohaline, resulting in significant mortality and changes in species composition (Haunert and Startzman, 1985). Adding to the problem has been the development of an intricate network of secondary canals that drain surrounding urban and agricultural land.

By contrast, agricultural and municipal demands for fresh water during the dry season can severely curtail freshwater discharge, resulting in significant intrusion of ocean water. Compounding this problem has been the placement of water control structures near the heads of estuaries. Because these structures block the upstream mixing of ocean water with fresh water, near-marine salinities can prevail throughout most of the estuary during dry periods. Anthropogenic modifications have altered freshwater discharge to the estuaries in South Florida without proper regard for the volume, timing, frequency, duration, or water quality necessary to maintain downstream biological integrity.

Florida's coastline is flat, with little topographic relief on either large or small spatial scales. Estuarine habitats that have physical relief tend to be biological and include mangrove prop roots, grass beds, and oyster bars. It is important to note that these habitats are distributed along the estuarine salinity gradient with different habitat-forming species occupying different portions of the salinity gradient. The success of these habitat-forming species is thus critical to the success of the many other species that utilize the habitats and the salinity zones in which they occur. The combined effects of urban and agricultural development, alteration of freshwater supply, construction of water control structures, and dredging have resulted in loss of biological habitat.

Estuarine water quality can determine the viability of estuarine biological communities (Dennison et al., 1993; Stevenson et al., 1993). Perhaps the severest threat to estuarine water quality is eutrophication by nutrient inputs from wastewater treatment facilities, urban and agricultural runoff, and other sources (Gray, 1982; 1992; Cloern, 2001). Eutrophication results in altered species composition, reductions in macrophytes, and ultimately anaerobic conditions and mass mortality. Both the St. Lucie and Caloosahatchee estuaries have shown signs of eutrophication (Graves and Strom, 1992; Baker, 1990).

Estuarine water quality is a function not only of the quantity and quality of water entering the system, but also the processes occurring in the estuary itself. It has been shown theoretically (Cifuentes, et al., 1990) and empirically in the field (Magnien et al., 1992) that changes in the quality of freshwater input are reflected in estuarine receiving waters. Internal rate processes such as primary productivity and nutrient recycling by sediments have also been shown to depend on material supplied by rivers and other external sources (e.g., Oviatt et al., 1984; Boynton et al., 1995). Thus, management of external inputs can improve estuarine water quality and ecosystem function. It has also become clear in recent years that estuaries are intimately coupled to their watersheds and that successful management of riverine and groundwater inputs must occur at this scale. The District has adopted this watershed-scale approach to estuarine management.

The following sections of this chapter consist of a brief introduction, followed by descriptions of District-related activities that are under way in each coastal ecosystem. Key areas of the District's coastal ecosystem management and restoration efforts include the following:

- Environmental monitoring and assessment of status and trends focused largely on salinity, seagrass, and other biological indicators.
- High-quality applied science and tool development for analysis and prediction of habitat response to the Comprehensive Everglades Restoration Plan (CERP), Pollutant Load Reduction Goals (PLRGs), Minimum Flows and Levels (MFLs), and Total Maximum Daily Loads.
- Implementation of restoration projects for coastal watersheds and estuaries through collaborative partnerships and local initiatives.

The coastal systems covered in the chapter include (**Figure 12-1**) the Southern Indian River Lagoon and St. Lucie Estuary, Loxahatchee River and Estuary, Lake Worth Lagoon, Biscayne Bay, Florida Bay, Naples Bay, Estero Bay, Caloosahatchee River and Estuary, and Southern Charlotte Harbor.

SOUTHERN INDIAN RIVER LAGOON AND ST. LUCIE RIVER AND ESTUARY

INTRODUCTION

The Indian River Lagoon (IRL), located on the southeast coast of Florida (**Figure 12-2**), has been considered one of the most biologically diverse ecosystems in North America. The St. Lucie Estuary (SLE) is the largest tributary to the Southern Indian River Lagoon (SIRL). The ecological health of these estuaries depends largely on the quantity, quality, timing, and distribution of stormwater runoff from the watersheds, which are drained largely through the District's primary canals including C-44, C-23, C-24, and C-25. The C-44 canal connects Lake Okeechobee with the SLE, and provides a conduit for freshwater releases from the lake into the estuary. The objective of this section is to evaluate the status of the estuarine ecosystem during Water Year 2005 (WY2005) (May 1, 2004 to April 30, 2005) and to provide a description of the District's environmental management programs and projects in support of the SIRL restoration and preservation efforts.

ENVIRONMENTAL ASSESSMENT CRITERIA

This District employed a Valued Ecosystem Component (VEC) approach to define the environmental assessment criteria for oysters and seagrasses in the SIRL/SLE. The salinity tolerance of oysters (*Crassostrea virginica*) is defined in **Table 12-1** with respect to the stress level of the life history of oysters (eggs, larvae, spat, and adults) in relation to salinity and the duration of exposure. Most of these salinity values and durations were obtained from the literature were determined for areas other than Florida. However, an effort was made to include recently obtained data on juvenile and adult oysters from the Caloosahatchee and St. Lucie estuaries (Volety et al., 2003; Roesijadi, 2004). A recent study of oyster life history in the St. Lucie Estuary (Wilson et al., 2004) was utilized for the timing of life stages. In that study, a major spawn occurred in the spring of the year (March and April) with no documented spawning in the fall. Therefore, a distinctive year class of oysters is revealed in **Table 12-1** where larval presence from March to May follows egg development and spawning, and spat and juvenile oysters are present from April to August. Since oysters in South Florida usually live two to three years, adults are present throughout the year. Oysters are known to spawn in South Florida from March to September. However, Wilson's work shows that, if protracted spawning occurs, the sampling device (oyster shell hanger) does not document significant spat recruitment beyond the spring.

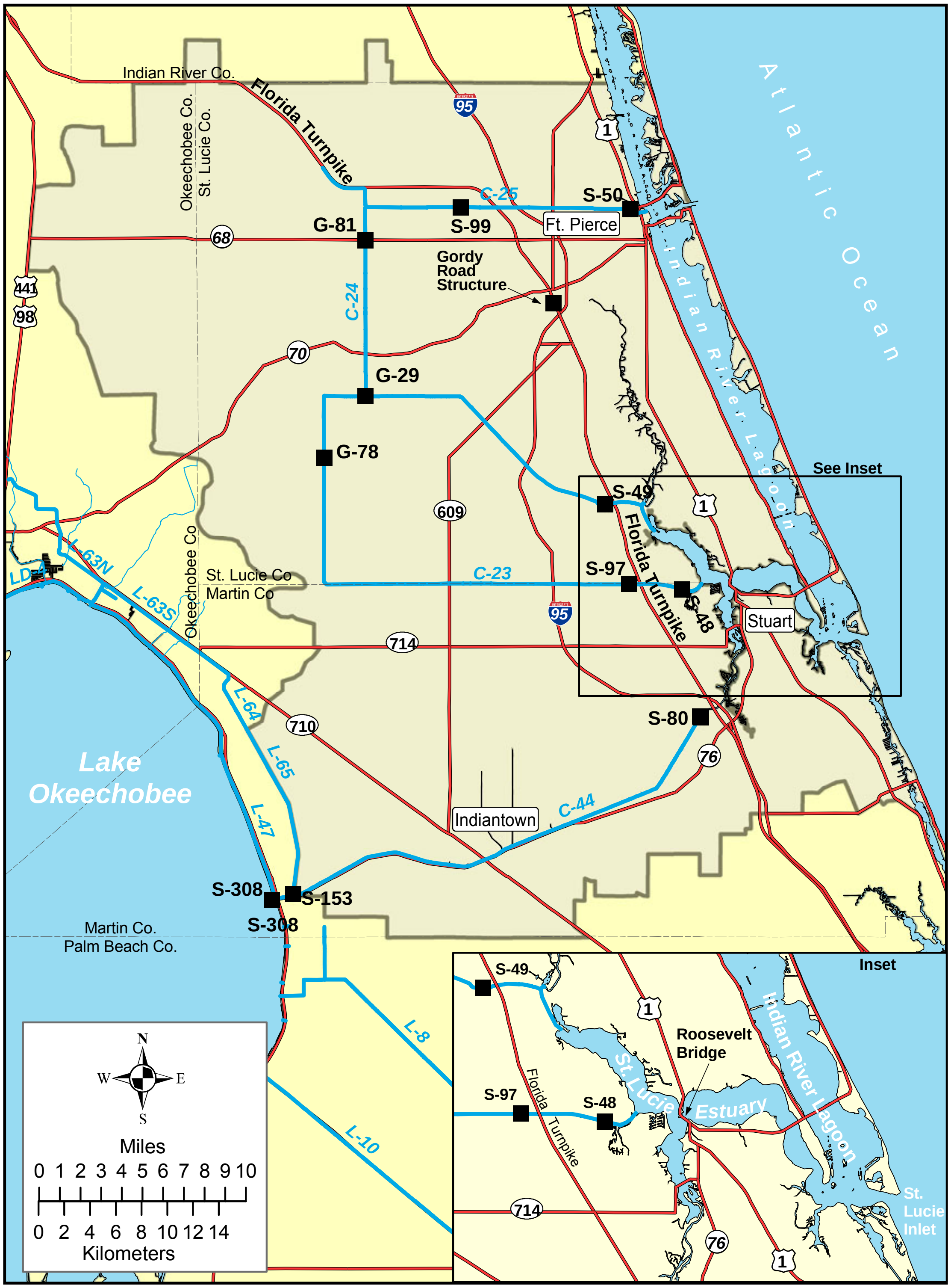


Figure 12-2. Geographic location of the Southern Indian River Lagoon (SIRL) and St. Lucie Estuary (SLE).

Table 12-1. Salinity tolerances during the life history of the American oyster.

Life Stage	Salinity (ppt)	Duration (days)	J	F	M	A	M	J	J	A	S	O	N	D	Reference
Eggs			X	X	X	X									**Wilson et al., 2004**
Harm	7.5 - 10.0	1													**Burrel, 1986**
Mortality	0.0 - 7.5	1													**Burrel, 1986**
Larvae					X	X	X								**Wilson et al., 2004**
Stress	10.0 - 12.0	1													**Loosanoff, 1965; Davis, 1958**
Harm	0.0 - 10.0	1													**Davis 1958**
Mortality	0.0 - 10.0	14													**Davis, 1958**
Spat & Juveniles						X	X	X	X						**Wilson et al., 2004**
Stress	5.0 - 10.0	1													**Ray and Benefield, 1997**
Harm	0.0 - 5.0	1													**Loosanoff, 1953**
Mortality	0.0 - 5.0	7													**Volety et al., 2003**
Adults			X	X	X	X	X	X	X	X	X	X	X	X	
Stress	7.5 - 10.0														**Woodward-Clyde International Americas, 1998**
Harm	5.0 - 7.5	1													**Loosanoff, 1953, 1965**
Mortality	2.0 - 5.0	28													**Loosanoff, 1953; Volety et al, 2003**
Mortality	0.0 - 2.0	14													**Roesijadi, 2004**

Similarly for seagrasses, salinity tolerances were obtained from the literature or unpublished studies, and the results are summarized in Table 12-2. The documented salinity tolerances were grouped into three performance measure categories: (1) no stress, (2) potential stress, and (3) stress. Salinities within the "no stress" category are expected to provide optimal conditions for the seagrasses; no adverse impacts are expected to occur when salinities occur within this category. Salinities at which impacts to seagrasses have been documented, in either laboratory or field studies, fall within the "stress" category. All other salinities were placed in a "potential stress" category for the performance measure evaluation.

Table 12-2. Salinity performance measures for four species of seagrasses[a].

Seagrass Species	Level of Salinity Stress	Salinity Threshold (ppt)*	Justification for stress level	Reference
Shoal grass (*Halodule wrightii*)	No Stress	≥ 24	A literature review indicated that ≥ 24 ppt provided optimal conditions for shoal grass.	Woodward Clyde International Americas, 1998
	Potential Stress	13–23	This represents the range between optimal conditions and documented stress.	
	Stress	< 12	Very little growth occurred between 6 and 12 ppt in a laboratory experiment; blade mortality occurred below 6 ppt.	Doering et al., 2002; McMahan,1968
Manatee grass (*Syringodium filiforme*)	No Stress	≥ 23	A literature review indicated that ≥ 23 ppt provided optimal conditions for manatee grass.	Woodward Clyde International Americas, 1998
	Potential Stress	16 to 23	This represents the range between optimal conditions and documented stress.	
	Stress	≤ 15	Two separate laboratory studies showed impacts at this threshold (in one experiment blade densities declined rapidly in another study leaf extension rates declined rapidly).	Unpublished SFWMD, 1999; Lirman and Cropper, 2003
Turtle grass (*Thallasia testudinum*)	No Stress	≥ 25	This value is based on optimal conditions stated in a literature review.	Woodward Clyde International Americas, 1998
	Potential Stress	20–24	This represents the range between optimal conditions and documented stress.	
	Stress	≤ 19	In one study, limited growth was observed between 16-19 ppt and in another study photosynthesis decreased by one third at 18 ppt. Growth parameters were negatively impacted in a laboratory experiment at salinities between 6 and 12 ppt.	Woodward Clyde International Americas, 1998; Doering and Chamberlain, 2000
Johnson's seagrass (*Halophila johnsonii*)	No Stress	≥ 25	This value is based on optimal conditions stated in a literature review.	Woodward Clyde International Americas, 1998
	Potential Stress	15–24	The documented range stated in the Final Recovery Plan for this threatened species is 15–43 ppt so this evaluation assumes that below optimal conditions and within the documented range there is potential for stress.	National Marine Fisheries Service, 2002
	Stress	≤ 14	The documented range stated in the Final Recovery Plan for this threatened species is 15–43 ppt so this evaluation assumes that salinities below 15 ppt would be stressful for this threatened species.	National Marine Fisheries Service, 2002

[a]Only the lower limit of the "no stress" zone is included in this table.

ENVIRONMENTAL CONDITION

Freshwater Inflows

Figure 12-3 depicts freshwater inflows measured during WY2005 at the major water control structures that discharge into the SIRL/SLE. Together these structures capture and control runoff from approximately 70 percent of the contributing watershed. Discharge from the areas downstream from these structures is not included in the measurements. Note that extremely high discharges (over 2,000 cubic feet per second, or cfs) were measured at all canals in September and October 2004. These high discharges were induced by the three major hurricanes (Frances, Jeanne, and Ivan) that occurred in September of 2004. The strong impact of these storms during this period is vividly depicted in the discharge hydrographs.

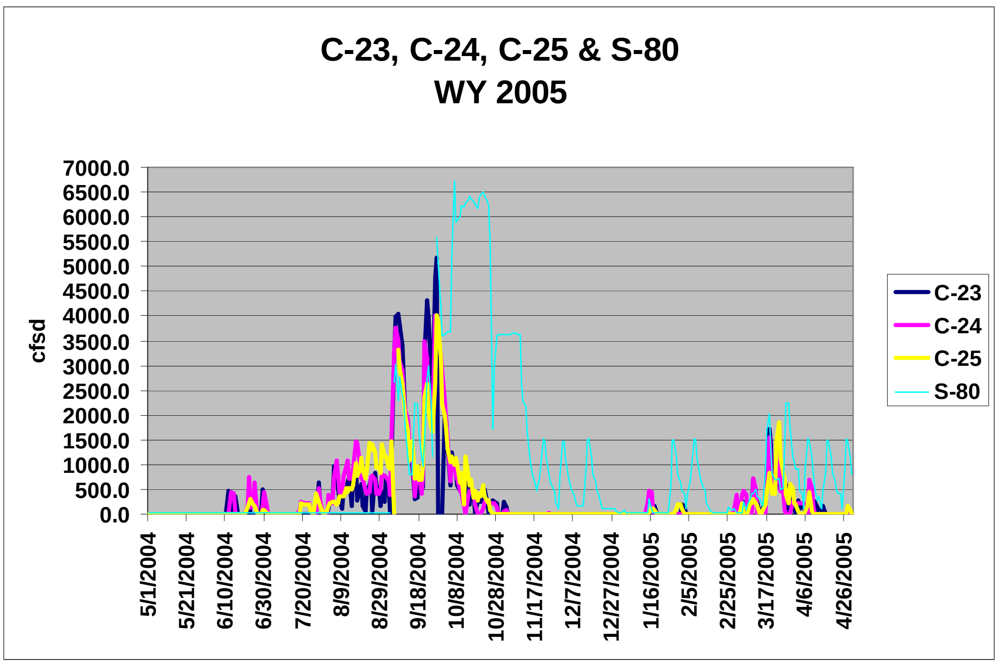


Figure 12-3. Freshwater discharge from the major control structures in the SIRL and SLE watersheds during Water Year 2005. Note that C-25 discharges directly into the SIRL.

Significant discharge of fresh water from the C-44 canal at S-80 began during early September and peaked in October and November. The discharge was further partitioned into watershed runoff and the regulatory release from Lake Okeechobee (Figure 12-4). Water discharged during September and early October originated primarily as surface runoff from the C-44 watershed. Following that period, almost all of the subsequent discharge throughout the remainder of the year was due to releases from Lake Okeechobee. Lake Okeechobee releases accounted for approximately three-quarters of the total freshwater releases from S-80 during the period from September 1 through December 31. Pulse releases from the lake continued into the spring of 2005 and remained the primary source of freshwater release from S-80.

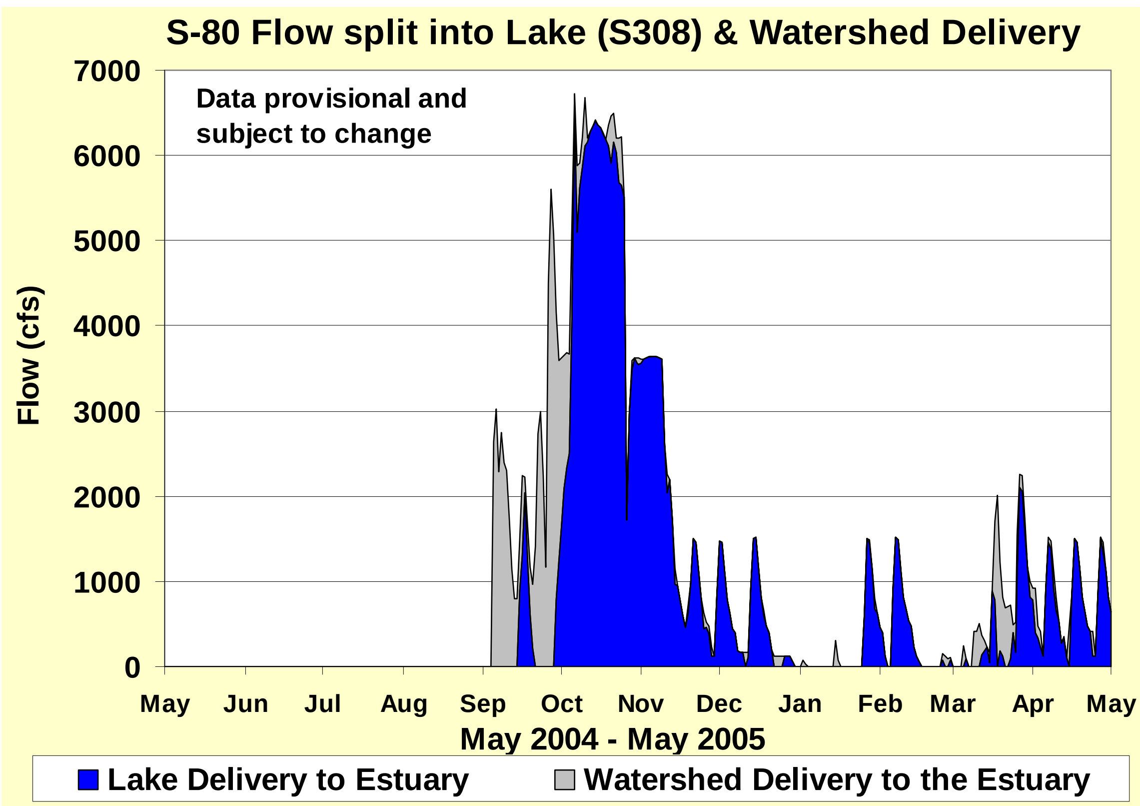


Figure 12-4. Total discharge to the SLE at S-80. The portion of the total derived from watershed runoff into C-44 is depicted in gray. The portion of the total attributable to regulatory releases from Lake Okeechobee is depicted in blue.

Salinity

Figures 12-5 and **12-6** show the mean daily salinity measured by the District at the Roosevelt Bridge on U.S. Highway 1 and the A1A bridge in Stuart. Salinity measurements here are used as a means to understand the estuarine salinity condition for the assessment of oyster stress and seagrass in the SILR/SLE. The preferred salinity envelope was included in the figures for the ease of evaluation. It is clear that the desired salinities were not attained during the period of heavy releases during late summer and early fall of 2004. Salinities declined dramatically in late August and remained at or near 0 parts per thousand (ppt) at Roosevelt Bridge into November. The discharges also significantly lowered salinities at the A1A station, which is closer to the mouth of the SLE, during the same period. The freshwater releases following the hurricanes were of sufficient magnitude to drop salinity levels at the A1A location to zero for short periods in September and October. It is clear that desirable salinity conditions at this location were not achieved for the September through November period coincident with the freshwater releases from the watershed. The hurricanes and subsequent discharge adversely impacted seagrass beds in the vicinity of the St. Lucie Inlet.

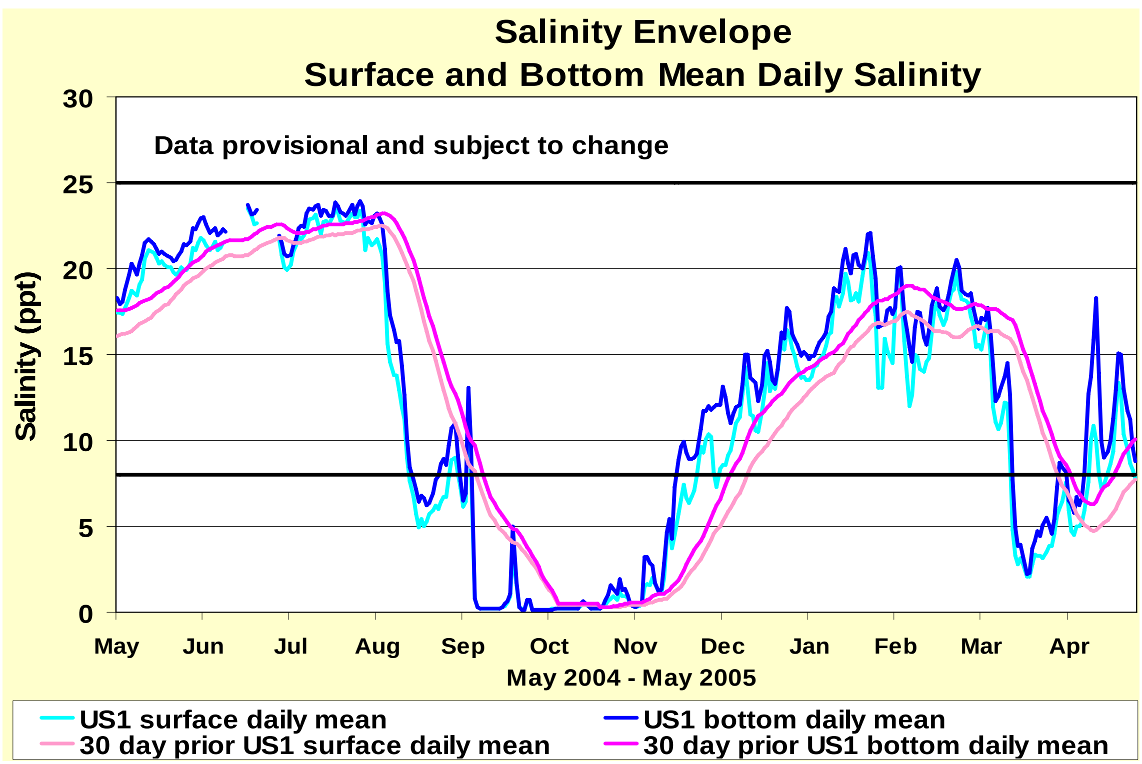


Figure 12-5. Surface and bottom salinities at the Roosevelt Bridge (U.S. 1) during Water Year 2005 (WY2005) (May 1, 2004 through April 30, 2005).

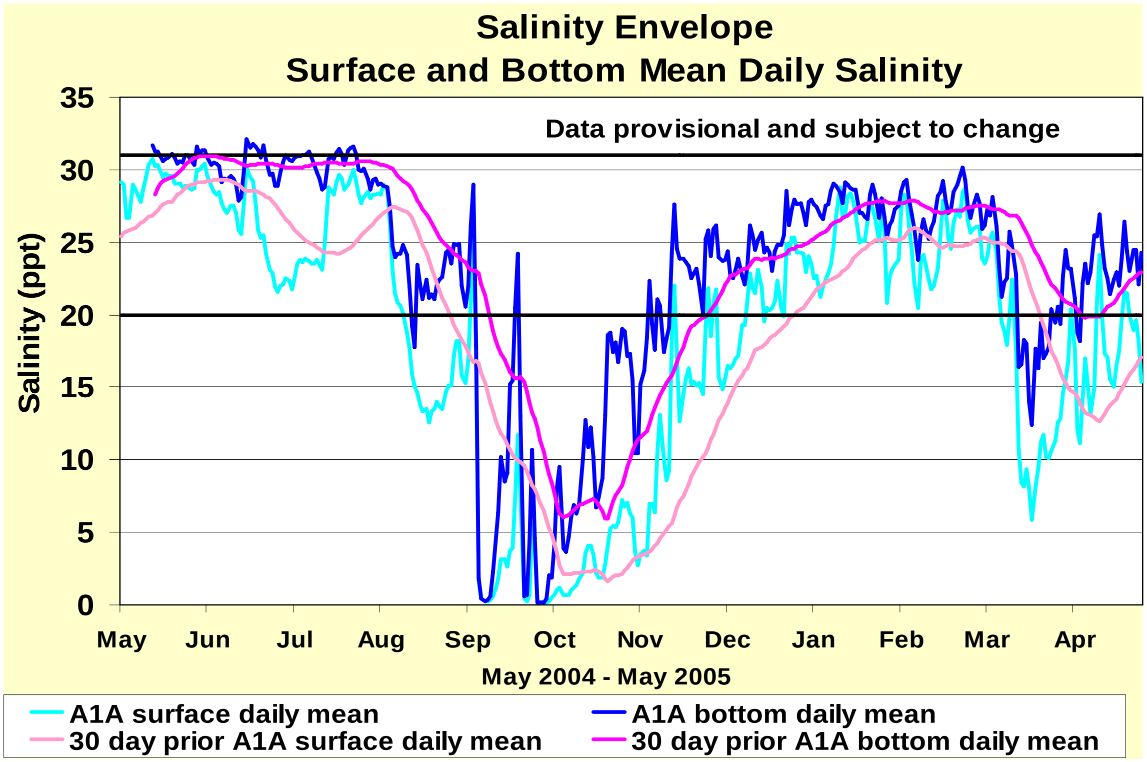


Figure 12-6. Surface and bottom salinities at the A1A bridge during WY2005.

Oysters

In WY2004, oysters began spawning in the St Lucie Estuary at the end of February. In WY2005, recruitment of oyster spat was monitored at two locations just downstream of the Roosevelt Bridge from March to the end of May. Shell hangers were deployed every two weeks during this period. Salinity was depressed in March by an unusually heavy rainstorm. The lack of any spat recruitment between March and May and visual inspection of adult oysters indicated that spawning was delayed at least to the beginning of June. The extended long period of low salinity regimes in SLE (starting in September 2004) resulted in mortality of adult oysters in WY2005.

Seagrasses

In WY2005, the District continued the monthly seagrass monitoring at two of the four sites initiated in August 2002 (**Figure 12-7**). The purpose of this monitoring is to document seasonal changes in seagrass and associated macro-algae (epiphytes, attached algae, and drift algae) near the mouth of the St. Lucie River. Data collected is used to better understand (1) the natural seasonal variability of seagrass and macro-algae in the study area and (2) the response of the seagrass community to freshwater discharge.

The two seagrass sites (Sites 2 and 3) monitored monthly near the St. Lucie Inlet (**Figure 12-7**) showed significant signs of damage. Shoot counts and canopy heights declined dramatically at Site 2 following these hurricanes. Site 3 became blanketed with mud and sand, and only a nearshore narrow fringe of *Halodule wrightii* could be found at this site post-hurricanes. Before the hurricanes the site was mostly dominated with *Syringodium*, some *Halophila johnsonii,* and *Halodule wrightii*. In addition, Sites 1 and 4, previously monitored monthly from August 2002 to August 2003, were inspected after the hurricanes in November. The seagrasses in these areas were found to be sparse, and canopy heights greatly reduced.

Figure 12-7. Seagrass monitoring stations near the St. Lucie Inlet.

Other St. Lucie Inlet area sites were also inspected in October and November 2004. Hurricane impacts were apparent at all sites except for the most northern site located at the Old Florida Institute of Technology (FIT) campus, approximately 4.5 miles north from the mouth of the St. Lucie Inlet. The remaining sites on **Figure 12-8** show notable signs of hurricane impacts as recorded below.

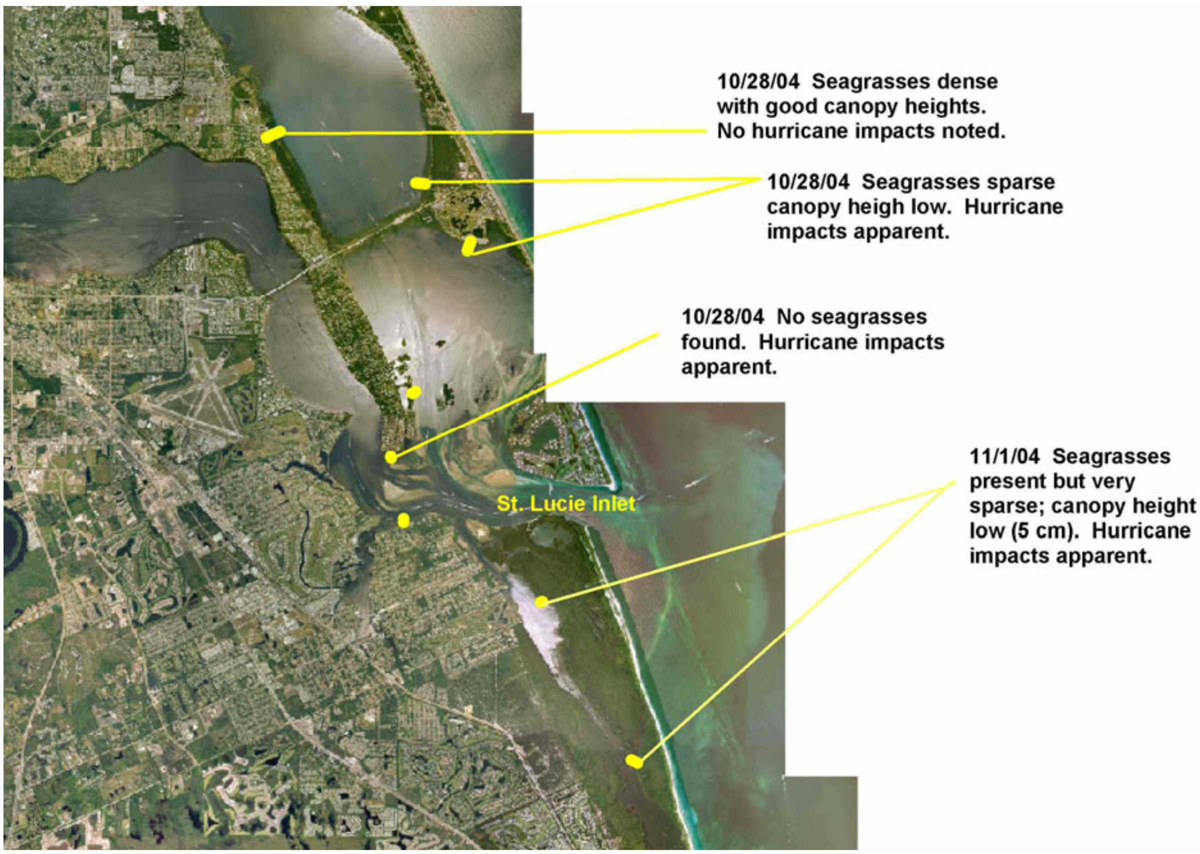


Figure 12-8. Post-hurricane inspection sites near the St. Lucie Inlet.

As of May 2005, seagrass recolonization was under way at Site 3, with new plants appearing on the fringes of the site. Seagrasses at Site 2 continued to recover from the hurricanes, but were still less dense and smaller in May 2005 than in May of the two previous years. This project is expected to continue for a minimum of three years. Shoot count and canopy height data from the two sites currently being monitored are presented in **Figure 12-9** and **Figure 12-10**. Rapid declines in shoot counts and canopy height occurred from July through September 2003. Possible causes for the declines include low salinity (a low of 14 ppt from an average of 30 ppt) and extreme low tides which exposed seagrasses.

Post-hurricane inspections along the Indian River Lagoon, from Ft. Pierce to the Loxahatchee River, indicated that there was no noted damage to seagrass beds at any of the several sites inspected near the Ft. Pierce Inlet, Hobe Sound, or Jupiter Inlet areas, although post-hurricane seagrass surveys in the Loxahatchee Estuary did show signs of reduced shoot counts and very short canopy heights. Areas that were densely populated with *Halophila johnsonii* in the summer of 2004 had few if any *Halophila* shoots present after the hurricanes. Significant hurricane impacts were most visible about 3.5 miles to the north and south of the St. Lucie Inlet. The impacts noted included seagrasses blanketed with mud and sand; seagrasses gone from areas where they had previously been documented; and where seagrasses were still present, they were very sparse with extremely short canopies.

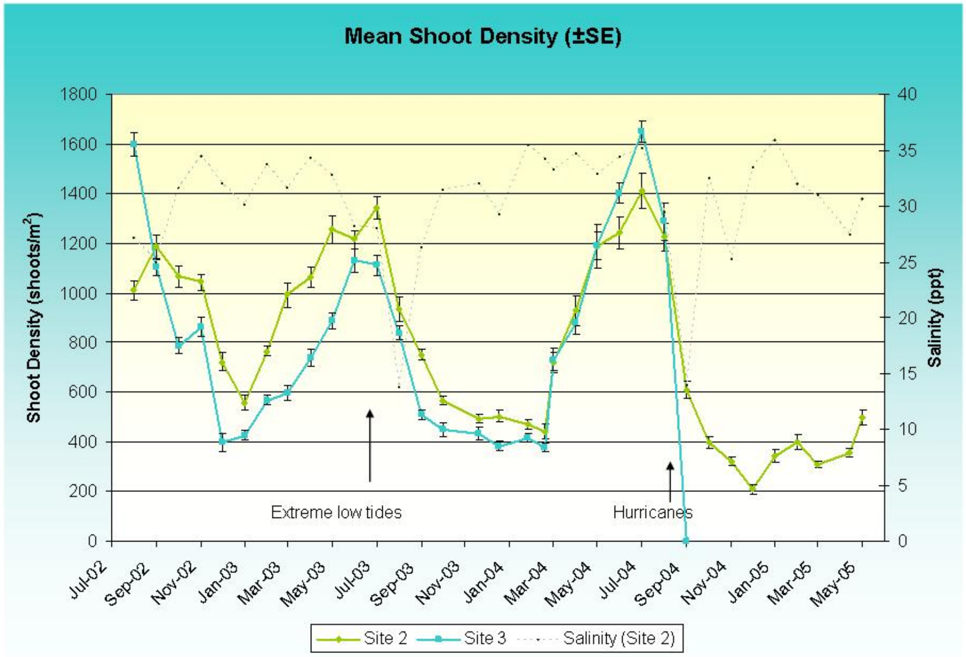


Figure 12-9. Mean shoot densities observed at Sites 2 and 3.

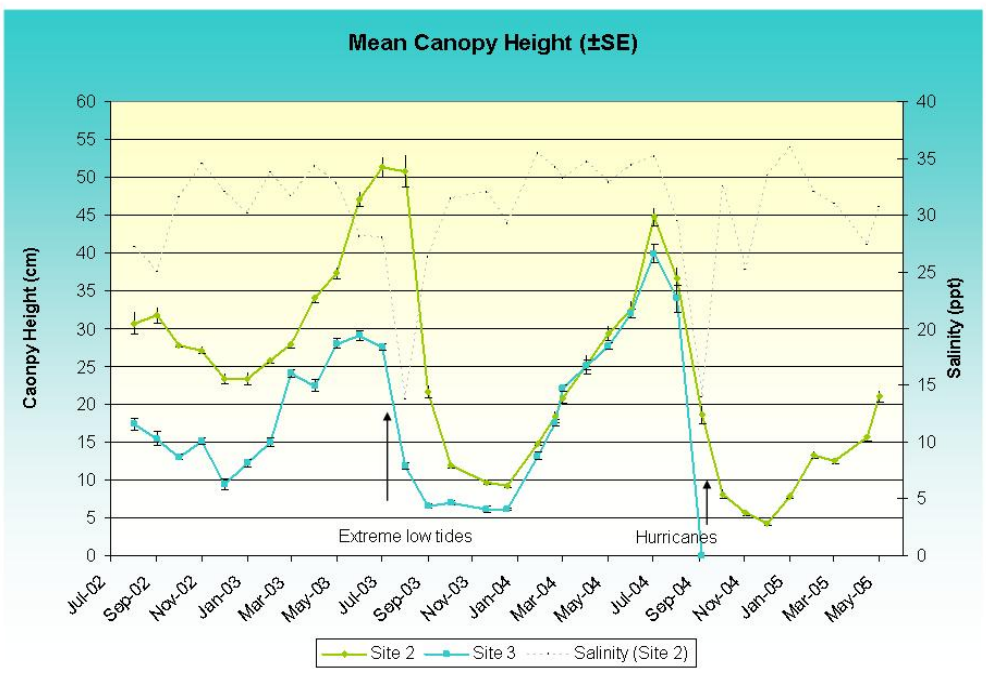


Figure 12-10. Mean canopy heights observed at Sites 2 and 3.

CURRENT SCIENCE, ENGINEERING, AND RESTORATION

Resource Assessment

MONITORING

Monitoring of flow and water quality at the major flow structures of C-44, C-23, C-24, and C-25 is in the District long-term monitoring program. The District, in partnership with local governments (Martin and St Lucie counties and the city of Port St. Lucie) is also conducting an intense three-year monitoring effort to measure flow and nutrient concentrations in the portions of the watershed that are not covered by these structures. Salinity monitoring at Roosevelt Bridge and A1A bridge in the SLE is also an ongoing effort of the District.

Routine oyster monitoring is now being performed under The Restoration Coordination and Verification (RECOVER) in alignment with the requirements of the Monitoring and Assessment Plan (MAP), which prioritizes monitoring components and long-term assessment needs. Additional information regarding RECOVER is presented in Chapter 7 of the 2006 SFER – Volume I. It is anticipated that any new information will be included in the RECOVER Systems Status Report that is scheduled for production in 2006.

The St. John's River Water Management District (SJRWMD) and the SFWMD have an ongoing project to map seagrasses in the IRL every two to three years since 1986. The maps are prepared through photo interpretation of aerial photographs with limited ground-truthing. This data allows evaluation of trends and variability over time. The SFWMD and SJRWMD are working cooperatively to prepare a 2005 Indian River Lagoon seagrass map.

RESEARCH

The District funds the University of Florida, Indian River Research and Education Center (IRREC) in Ft. Pierce, a multiyear project to evaluate the performance of water treatment cells in a newly renovated citrus grove in the C-24 basin. This is part of an investigation of the effectiveness of a potential retrofit water treatment practice on groves that have been in existence prior to having to meet current regulatory criteria for onsite detention or retention of storm water. As of April 2005, samples had been collected for water quality analyses for two events. Laboratory analytical results are not yet available. The status of this, and other BMP-related research conducted at the university can be obtained through reports and publications provided by faculty and staff at the IRREC in Ft. Pierce.

The SFWMD has also been working with Martin County to establish artificial reefs for oyster restoration in the middle estuary. In March 2005, oyster cultch (clean fossil coral and shell) and other artificial reef materials (reef balls) were placed in the estuary at the locations shown in **Figure 12-11**. Nine patches of cultch of equal size (approximately 6 cubic yards, 6 inches thick) were placed approximately 30 feet apart at each location. The District will evaluate the success of deploying cultch to enhance brood stock by monitoring density and size distribution of oysters within each patch.

Figure 12-11. General locations of artificial reef materials placed for oyster restoration in the SLE.

Engineering and Construction

COMPREHENSIVE EVERGLADES RESTORATION PLAN

Restoration of the SIRL/SLE ecosystem through the Comprehensive Everglades Restoration Plan (CERP) is predicated on the implementation of the current IRL – South Plan (see Chapter 7A of this volume). This plan aims to reestablish an appropriate salinity regime and improve water quality conditions in the estuary through construction of large regional reservoirs and Stormwater Treatment Areas (STAs), rehydration of large tracts of former wetlands, and the removal of existing muck deposits. During WY2005, the following major actions and milestones have occurred or been achieved:

1. Land acquisition for reservoir storage and STAs. Approximately 80 percent of the land has been acquired for the C-23/C-24 Reservoir/STA Project. The U.S. Army Corps of Engineers (USACE) has done the geotechnical and topographic boundary surveys for the STA area. Acquisition activities have been initiated and an agreement reached with the landowner for purchase of land for the C-44 project under the Acceler8 program.
2. Construction activities. The Ten-Mile Creek Project, for which construction began in October 2003, is approximately 75 percent complete. The project is designed to capture about 37 percent of the basin runoff and reduce concentrations of nitrogen and phosphorus in water processed through the system.
3. Allapattah Ranch restoration. Restoration activities during WY2005 included the elimination of approximately two miles of internal ditches and removal of associated culverts, thus restoring more natural surface flow conditions on those portions of the site.

IRL License Plates Program

Since 1995, when the Florida legislature enacted the Indian River Lagoon License Plate legislation to help restore and protect the lagoon, a total $4,015,990 has been raised by the sale of the “Snook Tag” sold throughout the state of Florida. Approximately 44 percent or $1,760,837 of the total dollars raised has been directed for spending in the SIRL region, covering St. Lucie, Martin, and Palm Beach counties. Funds for these three counties are administered by the SFWMD to government and not-for-profit organizations for habitat restoration, water quality improvements, and environmental education projects. **Table 12-3** lists the six projects that were completed during WY2005.

Table 12-3. IRL License Plate Program projects completed in WY2005.

Organization	Project Description	Funding
Martin County		
The Nature Conservancy Blowing Rocks Preserve	Restore hydrologic conditions by reconnecting wetlands to IRL and also creating an education exhibit explaining this process.	$34,556
St. Lucie County		
St. Lucie County Mosquito Control	Enhancing water quality of 360 acres of wetlands by increasing the pumping capacity through the system and allowing nutrient exchange and marine organisms' habitat. Also providing public access and awareness to the lagoon within 3 parks.	$53,490
Environmental Learning Center	The planting and establishment of about 140 mangroves along the IRL in St. Lucie County.	$2,775
Palm Beach County		
FDEP, Division of Parks and Recreation	The treatment of 161 acres of exotics (Old World Climbing Fern and Brazilian Pepper) and the filling in of 3 ditches allowing water to be retained and filtered before draining to the Loxahatchee Reservoir.	$75,148
Palm Beach County Parks and Recreation	Shoreline restoration by the removal of 231 Australian Pines along the IRL shore and replanting with native vegetation.	$75,150
	Total	**$241,120**

LOXAHATCHEE RIVER AND ESTUARY

INTRODUCTION

The Northwest Fork of the Loxahatchee River and Estuary (**Figure 12-12**) contains one of the last examples of a pristine subtropical riverine cypress swamp in South Florida. Protection of this resource requires reducing or reversing the current trend of saltwater intrusion and the subsequent transition from cypress to mangrove within the upstream freshwater portion of the Northwest Fork. Maintenance of freshwater habitats in the upper reaches of the river is also desirable to protect existing populations and distribution of wildlife (e.g., fishes, alligators, turtles, and otters) that require freshwater habitat.

The combination of the permanent opening of Jupiter Inlet and the construction of the C-18 canal, which reduced dry season flows in the Northwest Fork of the Loxahatchee River, has allowed salt water to migrate upriver. This has caused increasing levels of salinity in the Northwest Fork of the Loxahatchee River. In this segment of the river, there appears to be a strong relationship between elevated salinity levels and cypress tree die-off.

The objective of this section is to provide a status report on the District's hydrologic and ecologic data collection and modeling efforts and restoration programs for the Loxahatchee River and Estuary.

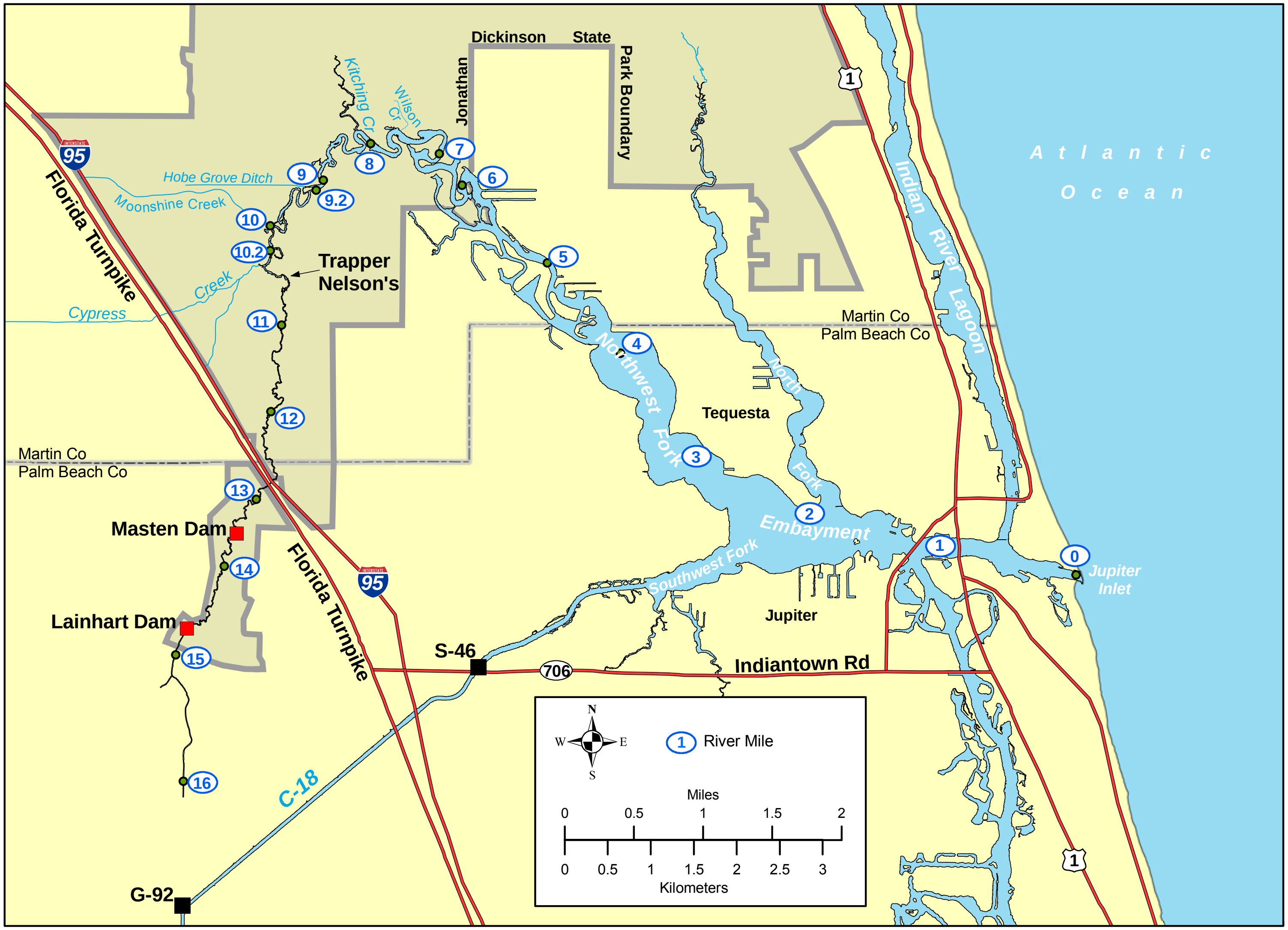


Figure 12-12. Aerial view of the Loxahatchee River.

ENVIRONMENTAL ASSESSMENT CRITERIA

Valued Ecosystem Components

A number of Valued Ecosystem Components (VECs) for freshwater and estuarine segments of the Loxahatchee River system have been tentatively selected but not yet officially adopted. More information can found in the Chapter 4 of the Draft Evaluation of Restoration Alternatives for the Northwest Fork of the Loxahatchee River on the District's web site at www.sfwmd.gov/site/index.php?id=18.

MINIMUM FLOW AND LEVEL RULE

The Minimum Flow and Level (MFL) Rule, Chapter 40E-8, Florida Administrative Code (F.A.C.), sets forth criteria on which the minimum flow for the Northwest Fork is based. Section (4) Northwest Fork of the Loxahatchee River states:

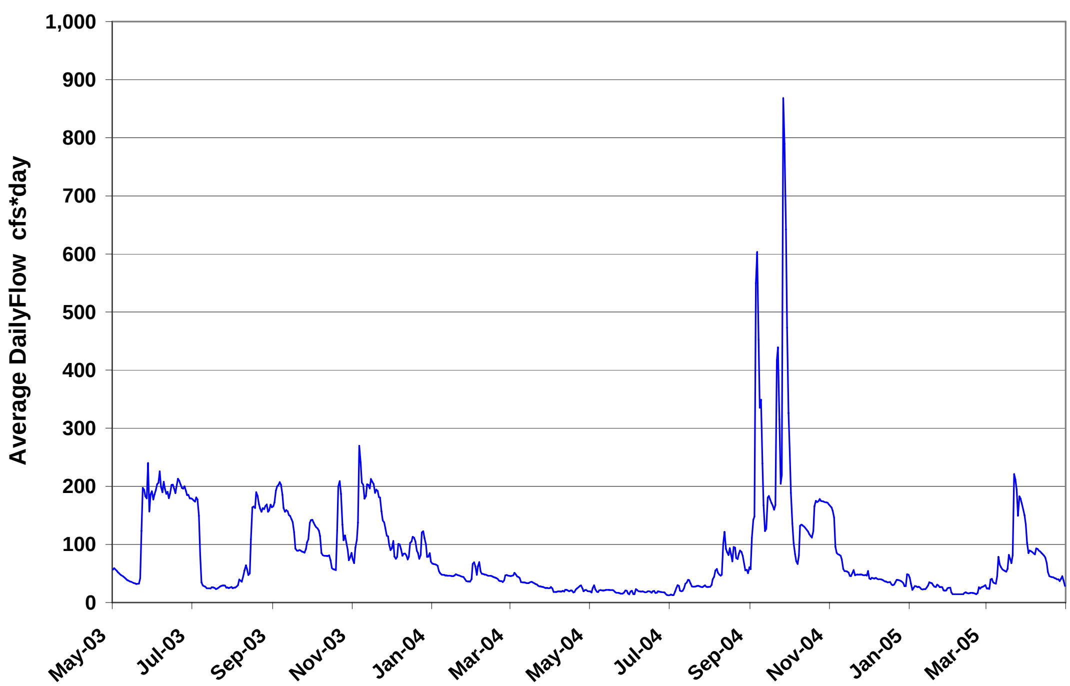
> (a) An enhanced freshwater regime is necessary to prevent significant harm to the water resources and ecology of the Northwest Fork of the Loxahatchee River, pursuant to Sections 373.042 and 373.042, Florida Statutes (F.S.), by establishing the MFL set forth in subsections (b) and (c), along with implementation of the associated recovery strategy, it is the interim goal of the District to provide sufficient freshwater flows to create at River Mile (RM) 9.2 the freshwater regime found at RM 10.2.
>
> (b) An MFL violation occurs within the Northwest Fork of the Loxahatchee River when an exceedance, as defined in subsection (c), occurs more than once in a six-year period.
>
> (c) An MFL exceedance occurs within the Northwest Fork of the Loxahatchee River when:
>
> 1. Flows over Lainhart Dam decline below 35 cfs for more than 20 days; or
>
> 2. The average daily salinity concentration expressed as a 20-day rolling average exceeds two parts per thousand. The average daily salinity will be representative of mid-depth in the water column (average of salinities measured at 0.5 meters below the surface and 0.5 meters above the bottom) at RM 9.2.

Data collection and monitoring continue to take place in support of the minimum flow. In early 2006, a report will be issued with the results of the analysis based on the last two years of data (**Figure 12-13**).

ENVIRONMENTAL CONDITION

Minimum Flow and Level

Flow and salinity data have been collected over the past two years to establish baseline conditions and begin monitoring in support of the MFL Rule (**Figure 12-3**).



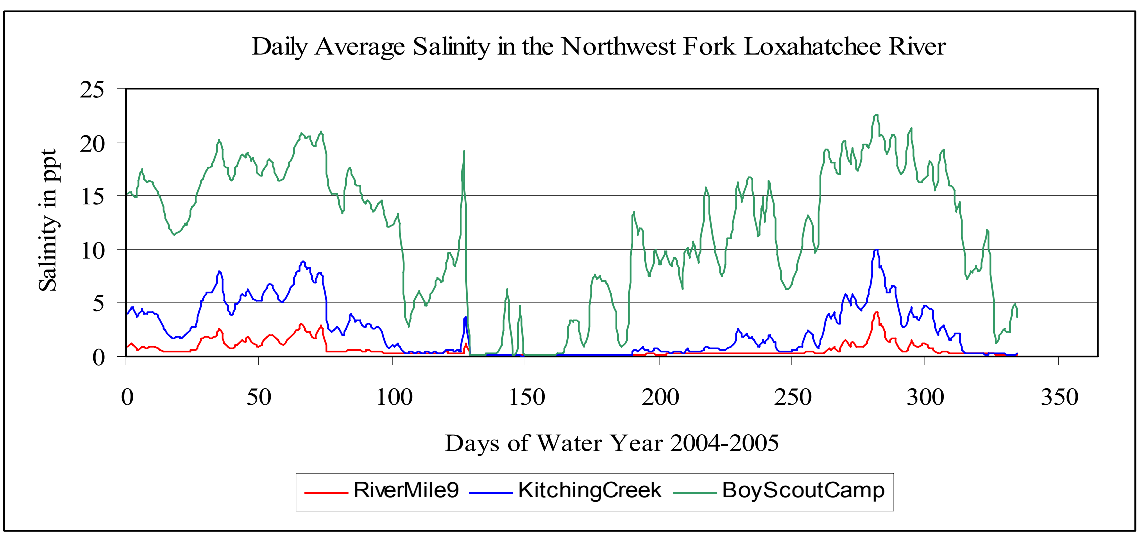


Figure 12-13. Examples of flow data from Lainhart Dam and salinity data from the downstream estuary collected to support the Minimum Flow and Level (MFL) Rule. Two years of data will be summarized in WY2006.

Water Quality

In general, the water quality in the Northwest Fork was good, based on the rolling eight-year period of record. For further information please go to www.RiverFirst.com.

CURRENT SCIENCE, ENGINEERING, AND RESTORATION ACTIVITIES

Resource Assessment

VEGETATION

The floodplains of the Northwest Fork of the Loxahatchee River consist of tropical and temperate zone riparian forest. Floodplains provide storage and filtration of surface water, diverse habitats for plants and animals, corridors for the movement of animals and dissemination of plants, and a source of nutrients to estuarine environments (Darst et al., 2003). Riparian forests contain diverse vegetation that varies along gradients of inundation frequency. These forests are generally considered to be more productive than the adjacent upland forest because they receive a periodic inflow of nutrients especially when inundation is seasonal rather than continuous (Mitsch and Gosselink, 1999). On the Northwest Fork, the riparian forest vegetative communities vary from dry (uplands and mesic hammock) to occasionally inundated (hydric hammock, bottomland hardwood, and swamp) as the system reacts to local rainfall events.

The vegetation and groundwater studies are being conducted jointly by the SFWMD and Florida Department of Environmental Protection, Florida Park Service (FDEP-FPS). The objectives of this joint monitoring program are to (1) determine the composition and structure of floodplain plant communities and their associated surface and groundwater hydrological and chemical characteristics; (2) identify short-term indicator plant species for salinity; (3) identify key chemical parameters in the soils that are indicative of the various forest types; (4) examine the influence of exotic plants on this system; and (5) determine if additional dry season freshwater flows sent down the river system are improving or changing the structure of the vegetative communities and/or groundwater, which would verify the success or failure of established restoration performance measures.

The 2003 Vegetative Transect Study provided a reevaluation of six previously sampled floodplain vegetative transects plus the inclusion of four new locations of the Loxahatchee River and three of its tributaries, the North Fork, and Kitching and Cypress creeks (**Figure 12-14**). In the Northwest Fork, the transect locations are representative of a freshwater riverine floodplain and upper and lower tidal floodplain communities. For the analysis of the data, the floodplain was divided into three distinct reaches or segments: riverine and upper and lower tidal. The reaches are distinguished by vegetation, hydrological conditions, and soils. The study examined plant abundance, diversity, richness, and basal area covered by canopy, scrub, and groundcover for each transect. Additional information was obtained on seedlings, leaf litter, hummocks, snags, and fallen logs by plot. Future monitoring of the 10 floodplain vegetation transects is needed to compare current species distributions with future distributions. Further information is available in the Draft Evaluation of the Restoration Alternatives for the Northwest Fork of the Loxahatchee River on the District’s web site at www.sfwmd.gov/site/index.php?id=18.

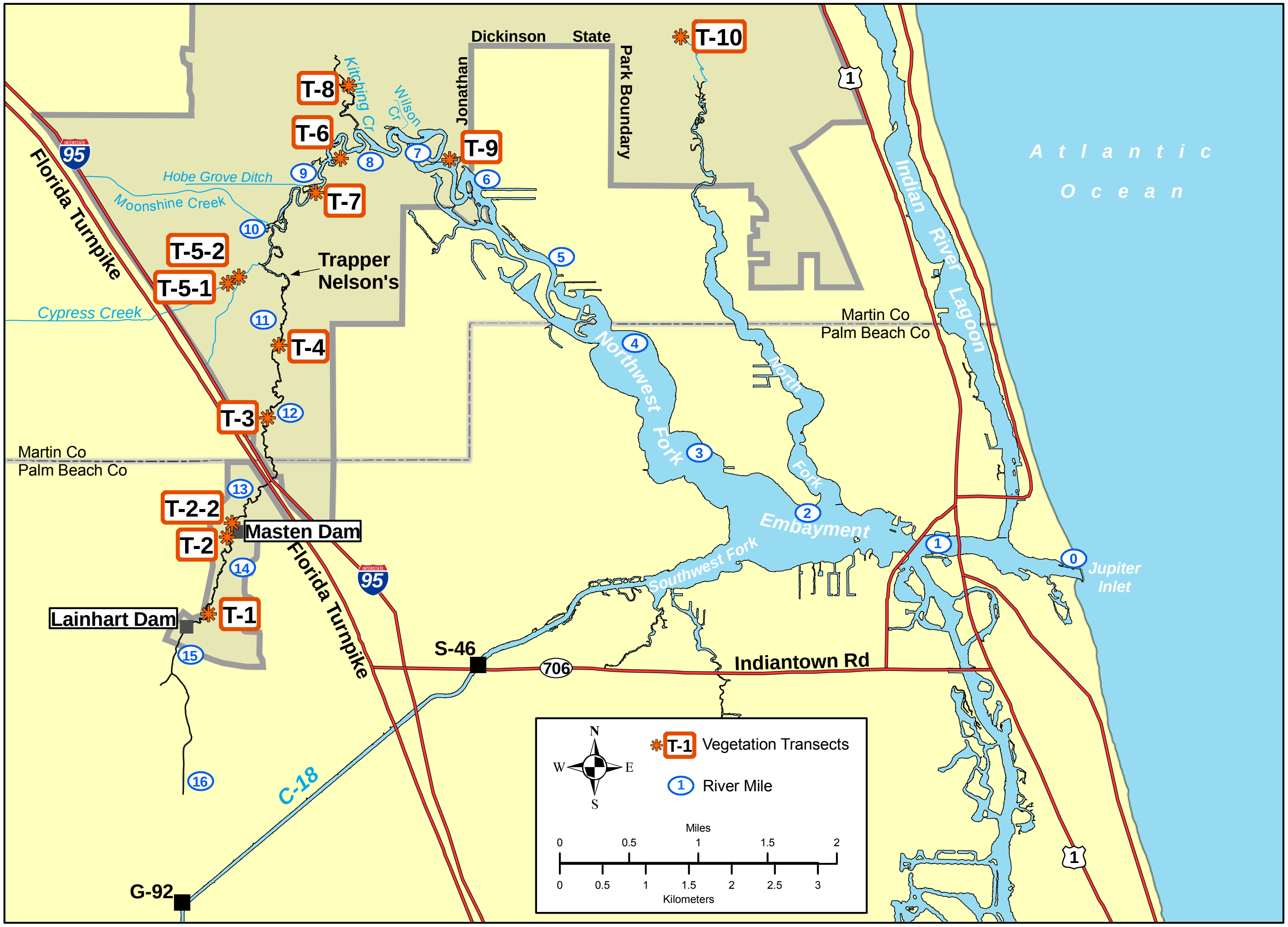


Figure 12-14. Vegetation transects in the freshwater and tidal segments of Northwest Fork of the Loxahatchee River.

GROUNDWATER

The SFWMD and the Florida Park Service at Jonathan Dickinson State Park have installed 12 shallow groundwater wells along vegetation transects 1 (RM 14.5), 3 (RM 12.07), 7 (RM 9.10), 8 (on Kitching Creek) and 9 (RM 6.46). They have been in place since July 2003. Groundwater levels (stages), temperature, and conductivity of groundwater are monitored electronically at 15- to 20-minute intervals. The wells are 2 inches in diameter and installed to a depth of 5 to 15 feet below the existing ground surface.

The monitoring provides data on groundwater levels and salinity, which are essential to comprehend the impact of saltwater intrusion on the rooted vegetation of the upper and lower tidal floodplains. In addition, these data provide a detailed account of hydroperiods within all of the floodplain sections. The data collected supports ongoing research on vegetative changes, modeling of flows, salinity and soils in the Northwest Fork. Data obtained from the wells will be used to develop and calibrate hydrologic and hydrodynamic models, which also are essential in understanding the influence of flow changes on the ecological processes of the Northwest Fork. Long-term monitoring of the groundwater wells is proposed to coincide with continued river channel stage and salinity monitoring stations. A groundwater monitoring report may be issued in the next water year.

GROUNDWATER FLUX

Saltwater intrusion and changes in groundwater discharge may result in increasing salinity and changing redox conditions through buildup of reduced sulfur species in sediment pore water and shallow groundwater in the Loxahatchee River floodplain. The higher salinities and decreased redox conditions from buildup of reduced sulfur species may be involved in the stress or death of cypress trees along the river, and other changes in the rooted vegetation in the floodplain. SFWMD contracted with the U.S. Geological Survey (USGS) to examine groundwater input and biogeochemical characteristics in the Loxahatchee River and floodplains.

The Groundwater Flux Project addressed (1) a retrospective analysis on existing information on groundwater conditions in the Loxahatchee River Study area and (2) the collection and interpretation of new data necessary to better understand the effects of pore water and shallow (less than about 20 feet) groundwater salinity and other water quality constituents. A draft report is being prepared for issuance in WY2006.

SOILS

To more clearly understand the relationship of soils and cypress seedlings, the SFWMD contracted with University of Florida Institute of Food and Agricultural Sciences (UF/IFAS) Tropical Research and Education Center to study soils and cypress seedlings on the Loxahatchee River floodplains. Soil profiles were collected from each major forest type within each transect. Soil moisture (percent saturation), soil texture, conductivity, nitrogen, potassium, phosphorus, pH, cation exchange capacity, and percent organic matter will be determined for each composite sample. In March and April 2004, a soil survey was conducted to determine soil classifications, drainage class, and soil sampling locations for the transects and selected areas of the riverbed. Soil profiles were collected within each transect. A report is being prepared for issuance in WY2006. Further information is available in the Draft of the Evaluation of Restoration Alternatives for the Northwest Fork of the Loxahatchee River from the District's web site at www.sfwmd.gov/site/index.php?id=18.

CYPRESS SEEDLING STUDY

This study is being conducted by the University of Florida. It was initiated in late 2004 and is scheduled for completion in 2008. The response of local bald cypress seedling communities to variations in salinity stress and flooding is being studied. It will provide information to better understand how well cypress seedlings will fare in saltwater-impacted portions of the Northwest Fork riverine floodplain once the restoration hydrologic flows are implemented.

LOXAHATCHEE RIVER WATER QUALITY MONITORING

The Loxahatchee River District (LRD) has established a comprehensive water quality monitoring network in the freshwater and tidal segments of the Loxahatchee River. Nutrients and other parameters are monitored. The District is working together with the LRD to determine the long-term trend of water quality in the Loxahatchee River and Estuary.

Loxahatchee Estuary Seagrass Monitoring

The LRD and SFWMD continue to work cooperatively to evaluate potential impacts of proposed upstream restoration efforts on the seagrass resources in the Loxahatchee Estuary. Beginning in June 2003, the LRD began a project to monitor seasonal trends in seagrass at three sites in the Central Embayment of the Loxahatchee Estuary (**Figure 12-15**) to better understand the natural seasonal variability of seagrass in the study area and the response of the seagrass community to freshwater discharge. The monitoring is conducted monthly and includes shoot counts, canopy height, percent cover, species diversity, species shifts, and species depth distribution. This project is expected to continue for a minimum of three years.

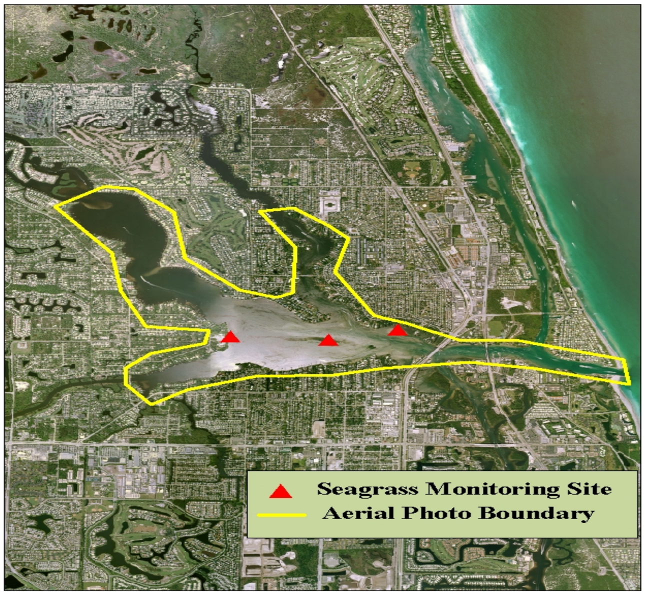


Figure 12-15. Boundary of seagrass mapping study and location of seagrass monitoring stations.

Numerous seagrass mapping efforts based on aerial photographs have been conducted in the Loxahatchee Estuary since the early 1980s. These mapping activities provide general maps of the seagrass resources, but do not meet accuracy standards currently used by the SFWMD for seagrass mapping. Since seagrasses provide important habitat, and are indicators of a healthy estuarine system, it is necessary to obtain current and accurate maps to document existing conditions, and to monitor changes in seagrass coverage over time. In July 2003, the SFWMD began mapping seagrasses in the Central Embayment (see project boundary in **Figure 12-15**) using more accurate benthic mapping methods consistent with those used for the adjacent Indian River and Lake Worth lagoons (mapping from aerial photographs by simultaneously interpreting/rectifying the habitat polygons using an analytical stereoplotter). Mapping was also conducted in 2004, and is planned for 2005. Data produced through these efforts will be compared to determine whether to continue annual mapping or adopt the two- to three-year mapping schedule used for the Indian River Lagoon. The 2004 seagrass coverage is shown in **Figure 12-16**.

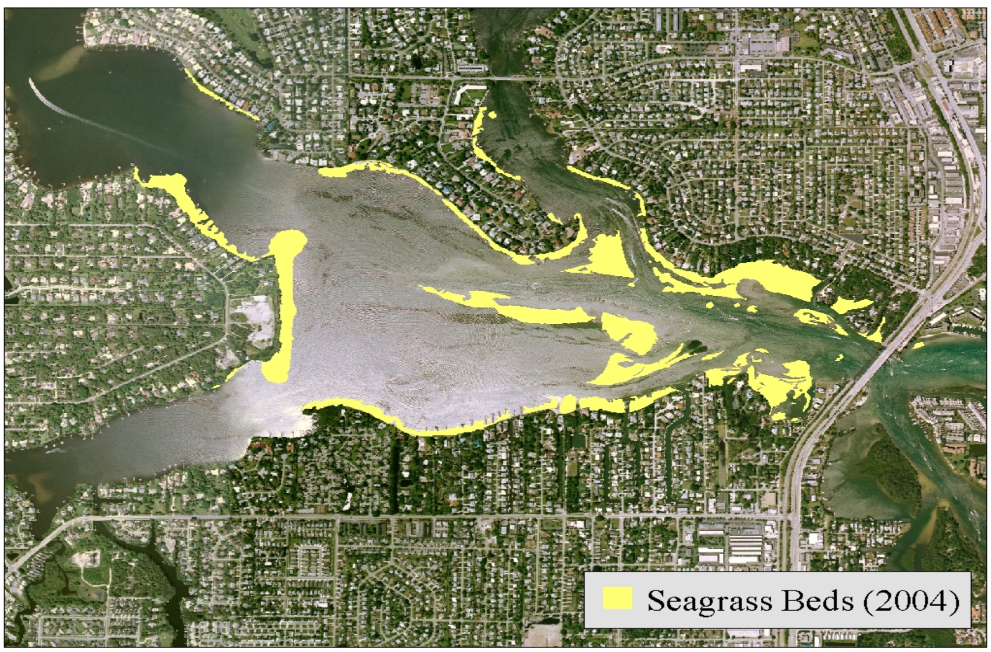


Figure 12-16. Map of 2004 seagrass coverage prepared through photointerpretation of aerial photography.

LOXAHATCHEE ESTUARY OYSTER MONITORING

The Comprehensive Everglades Restoration Program is being implemented as a means of reinitiating to the greatest degree possible natural freshwater flow to coastal waters on both coasts of South Florida. The Monitoring and Assessment Program (MAP) component of CERP is designed to provide an approach to documenting and describing the impacts of changed freshwater flow to the flora and fauna of coastal waters. Because of their wide distribution, historical context, and essential habitat value, the Eastern oyster (*Crassostrea virginica)* is included as a target species for monitoring. Changes in oyster distribution and abundance will be monitored in the Loxahatchee River (Northwest Fork, between RM 3 and 6) by the Molluscan Fisheries Research Group at the Florida Marine Research Institute. Data generated will be analyzed to determine if the health and spatial extent of oysters is changing with time.

The main objective of this project is to implement a long-term monitoring program for *C. virginica*. Four aspects of oyster ecology will be monitored: spatial and size distribution patterns of adult oysters, distribution and frequency patterns of the oyster diseases *Perkinsus marinus* ("dermo") and *Haplosporidium nelsoni* (MSX), reproduction and recruitment, and juvenile oyster growth and survival. Monthly water quality sampling will be conducted in conjunction with field sampling at each study site. Parameters to be monitored will include water depth, temperature, salinity, conductivity, pH, dissolved oxygen (DO), and turbidity.

SALINITY MONITORING

Through an agreement with the USGS, the SFWMD is able to monitor salinities at RM 8.2 and RM 9.1 to measure compliance with the minimum flow rule, and to assess the benefits of additional dry season flows in terms of salinities in the Northwest Fork.

Modeling Freshwater Inflow and Salinity in the Northwest Fork of the Loxahatchee River

To identify restoration alternatives for the Northwest Fork of the Loxahatchee River and its corridor, the SFWMD has initiated several projects for data collection and model development over the past few years. Today, three models have been developed to simulate freshwater inflows and salinity conditions in the Loxahatchee River and Estuary. These models include a watershed hydrologic model (WaSh) simulating long-term freshwater inflows from all tributaries into the Northwest Fork, a two-dimensional (2-D) estuarine hydrodynamic and salinity model (RMA) that simulates the influence of the freshwater inflows and tide on salinity conditions within the Loxahatchee River and Estuary, and a Long-Term Salinity Management Model (LSMM) that predicts daily salinity conditions according to freshwater inflows from the Loxahatchee River watershed.

The Loxahatchee Watershed (WaSh) Model was developed to simulate freshwater flow from each of the tributaries into the Northwest Fork. The WaSh model is based on restructuring HSPF (Hydrologic Simulation Program – FORTRAN) into a cell-based system with the addition of a groundwater model and a full dynamic channel routing model (Wan et al., 2003). The model is capable of simulating surface and groundwater hydrology in watersheds with high groundwater tables and dense drainage canal networks. Using long-term flow data collected at S-46, Lainhart Dam, Cypress Creek, Hobe Grove Ditch, and Kitching Creek, the WaSh model was calibrated and validated. The daily flow outputs from the 39-year simulation (1965–2003) provide the basis for the base condition and flow restoration scenarios evaluated.

As previously reported, the Loxahatchee River Hydrodynamics/Salinity (RMA) model (**Figure 12-17**) was developed to simulate the influence of freshwater flows on salinity conditions in the Loxahatchee River and Estuary. The RMA model is based on the RMA-2 and RMA-4 and was calibrated against field data from five locations and provided salinity predictions for many other sites where field data are not available. Tide/salinity data collected since 2002 have provided a field database for the investigation of the impact of freshwater inflow on the salinity regime in the Northwest Fork.

The Long-Term Salinity Management Model (LSMM) was developed to predict salinity and calculate several other performance parameters under various ecosystem restoration scenarios. Field data, regression analyses, and results from multidimensional hydrodynamic computer models were integrated into the salinity management model as a system simulation and management tool. This salinity management model contains several functions, such as the calculation of additional freshwater demand for salinity management and the nutrient loading that would occur under various restoration scenarios.

Appendix 12-1 contains detailed information about these models and the results of model calibration and validation. Flow restoration scenarios were formulated with the WaSh model and the associate daily salinity was predicted using the LSMM over the 39-year period. Such long-term simulations are required to investigate ecosystem response and assess the effectiveness of proposed restoration approach.

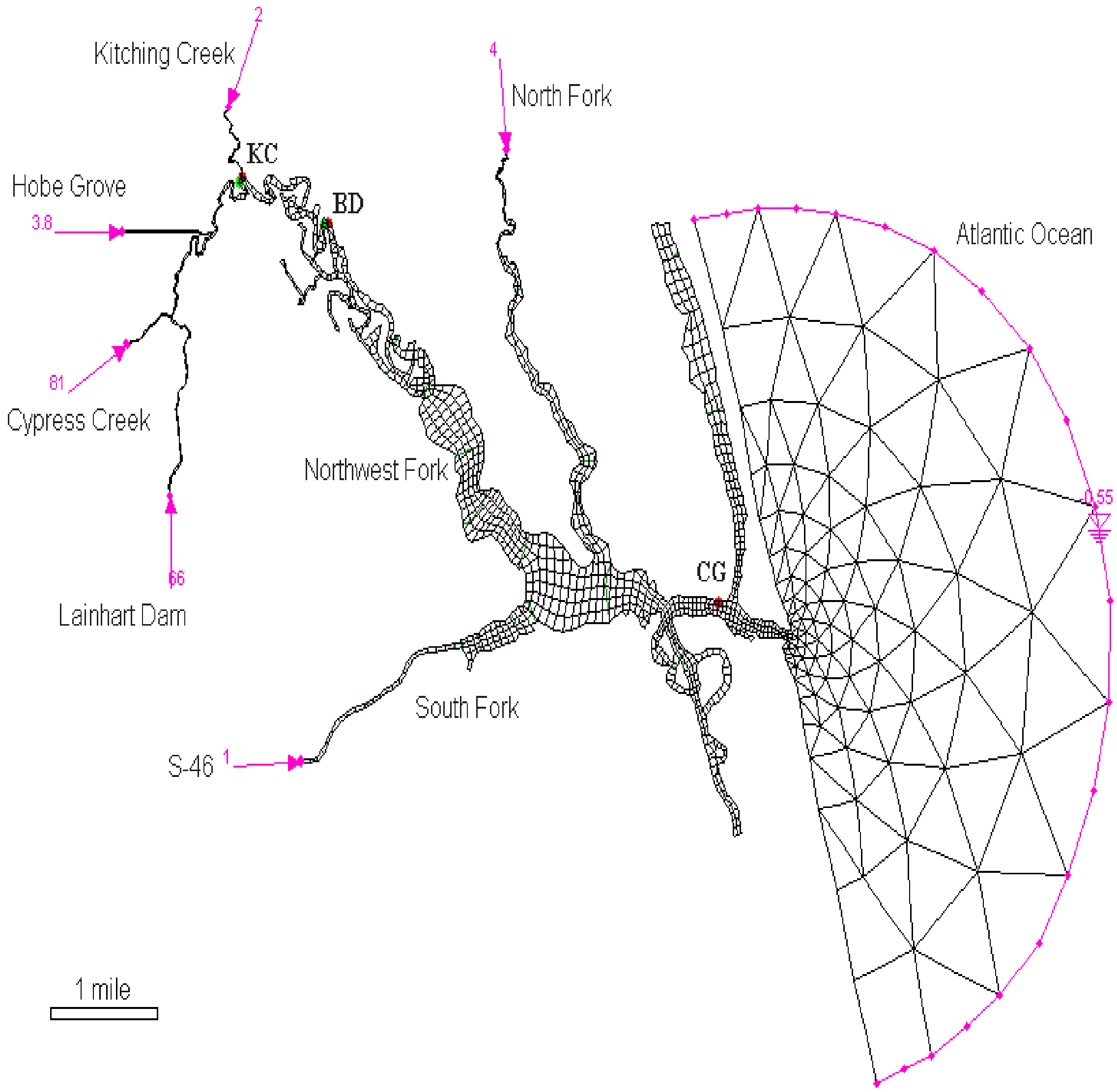


Figure 12-17. Domain map of Loxahatchee River Hydrodynamics/Salinity Model (RSM). For illustrative purposes, the pink lines indicate flows and the pink numbers are examples of discharge data, in cubic feet per second, used in the model.

Restoration Activities

Several plans have been developed and are being implemented to improve and protect the water quality and quantity, timing, and distribution in the Loxahatchee River watershed, as summarized below.

RESTORATION PLAN FOR THE NORTHWEST FORK OF THE LOXAHATCHEE RIVER

Over the past several years, plans have been developed by the SFWMD (both individually and in partnership with other agencies) for the Loxahatchee watershed. The Restoration Plan for the Northwest Fork of the Loxahatchee River was undertaken in 2004, in partnership with the FDEP, Jonathan Dickinson State Park, and the Loxahatchee River District. The first draft of Chapters 1–5 was distributed for review in March 2005, and Chapters 6–8 in May 2005. The plan is expected to be presented to the SFWMD's Governing Board and the secretary of the FDEP for approval by December 2005. Draft Chapters 1–8 can be found at www.sfwmd.gov, Coastal Ecosystems.

NORTHERN PALM BEACH COUNTY COMPREHENSIVE WATER MANAGEMENT PLAN

The Northern Palm Beach County Comprehensive Water Management Plan (known as the Northern Plan) was accepted by the SFWMD Governing Board in May 2002, and can be found on the District's web site at www.sfwmd.gov/org/wsd/npbcwmp/npbcwmp-doc.htm. The plan projects future water supplies for urban, agricultural, and environmental uses for 2020, and identifies projects that will bring supplemental water into the area upon completion.

Last year, the G-160 structure on the C-18 canal in the Loxahatchee Slough was completed. The G-161 structure located at Northlake Boulevard is the critical link between the Grassy Waters Preserve and the Loxahatchee Slough. The design for G-161 has been completed and construction is expected to begin in October 2005. Regional reservoir storage at the Palm Beach Aggregates site in the southern L-8 basin remains at 47,000 acre feet (ac-ft). This plan forms the basis for the North Palm Beach County CERP Project – Part 1, as summarized below (also, see Chapter 7A of this volume).

NORTH PALM BEACH COUNTY COMPREHENSIVE EVERGLADES RESTORATION PLAN PROJECT – PART 1

The overall purpose of the North Palm Beach County CERP Project – Part 1 is to (1) increase water supplies to the Grassy Waters Preserve and Loxahatchee Slough, (2) provide flows to enhance hydroperiods in the Loxahatchee Slough, (3) increase base flows to the Northwest Fork of the Loxahatchee River, and (4) reduce high discharges to the Lake Worth Lagoon (LWL) and Loxahatchee Estuary. Currently, the Project Implementation Report (PIR) is in the final stages of approval at the USACE. Additional information is available on the CERP web site at http://www.evergladesplan.org/pm/program_docs/mgmtplns.cfm.

CONCLUSIONS AND RECOMMENDATIONS

Data collection and analysis for vegetation in the biological communities of the Northwest Fork of the Loxahatchee River has made progress with baseline information established and trends documented in some areas. Continued monitoring will allow future trends to be identified, but most importantly, it will measure and quantify the response of the biological communities to restorative flows in the Northwest Fork. It is also clear that our knowledge of the flora and fauna within the biological communities of the riverine, upper and lower tidal, and estuarine segments of the Northwest Fork of the Loxahatchee River must be expanded. These data and subsequent analysis will be used to develop operational protocols, to support project design, as a basis for future modeling, and to capture the ways in which the ecological systems of the Northwest Fork can be protected, enhanced, and restored.

LAKE WORTH LAGOON

INTRODUCTION

The Lake Worth Lagoon (LWL) extends for approximately 20 miles in central Palm Beach County, Florida (**Figure 12-18**). The LWL is typically 6 to 10 feet in depth. The Atlantic Intracoastal Waterway channel runs the entire length of the lagoon.

The LWL watershed is highly urbanized, and encompasses over 450 square miles that ultimately drain to the North Lake Worth (Palm Beach) Inlet and South Lake Worth (Boynton) Inlet. This watershed includes the communities of North Palm Beach, Lake Park, Riviera Beach, Magnolia Park, Palm Beach Shores, West Palm Beach, Palm Beach, South Palm Beach, Lake Worth, Lantana, Hypoluxo, Manalapan, Boynton Beach, and Ocean Ridge.

Sources of water include the Atlantic Ocean, watershed runoff from primary and secondary canal systems, and precipitation. The major sources of fresh water are the C-17 canal (Earman River), C-51 canal (West Palm Beach Canal), and the C-16 canal (Boynton Canal). The C-51 canal contributes approximately 50 percent of the fresh water that reaches the lagoon, with 75 percent of the flow northward and 25 percent southward (Chui et al., 1970).

Similar to many of South Florida's heavily urbanized coastal areas, the Lake Worth Lagoon has been negatively impacted by anthropogenic changes. Currently, the LWL receives too much runoff in the wet season and fewer freshwater discharges during the dry season, and it is subjected to extreme salinity fluctuations and high levels of turbidity and sedimentation.

ENVIRONMENTAL ASSESSMENT CRITERIA

SFWMD assessment criteria for Lake Worth Lagoon relate to the effects of hydrology on (1) freshwater flows and salinity regimes; (2) water quality; and (3) biological resources, i.e., seagrasses and oysters. Monitoring and assessment associated with each of these areas is dependent on multiagency cooperative efforts organized under RECOVER. The RECOVER MAP prioritizes monitoring components and long-term assessment needs (see www.evergladesplan.org). Additional information regarding RECOVER is presented in Chapter 7B of this volume.

The CERP North Palm Beach County – Part 1 Project is developing performance measures for freshwater discharges to LWL and evaluating redirection of flows and additional retention of storm water from the C-51 basin and sediment removal and control technologies within the C-51 canal. Additional evaluations are focused on removal or trapping of existing sediment deposits in the lagoon downstream of the S-155 structure. Further information on this project is available online at www.evergladesplan.org. Additional information regarding CERP is presented in Chapter 7A of this volume.

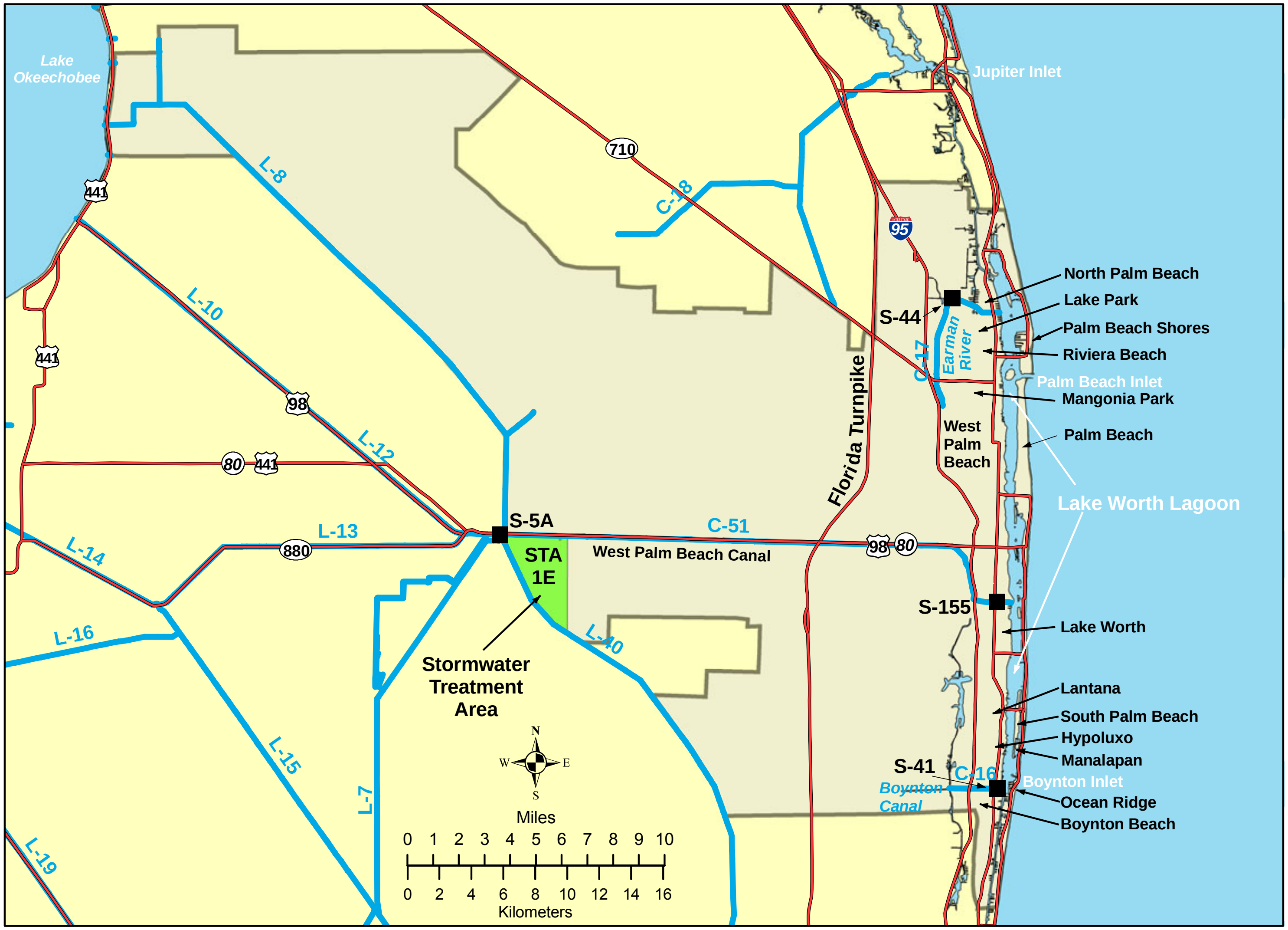


Figure 12-18. Lake Worth Lagoon watershed.

ENVIRONMENTAL CONDITION OF THE LAKE WORTH LAGOON

Freshwater Inflows

WY2005 inflows were impacted briefly by the two hurricanes, Frances and Jeanne, which made landfall on the East Coast. However, overall inflows at coastal structures were consistent with the long-term period of record. Water quality was also consistent with previous years.

Environmental Conditions

Considerable physical damage from the hurricanes was documented. Both public and private infrastructure was impacted, and there were a significant number of vessels that were disabled or sunk, and had to be removed from the lagoon. Overall, the lagoon appears to have suffered some short-term impacts from the meteorological and hydrological events of WY2005.

CURRENT SCIENCE, ENGINEERING, AND RESTORATION ACTIVITIES

Resource Assessment

The SFWMD coordinates activities with Palm Beach County Department of Environmental Resources Management, and the FDEP, the lead agencies for LWL habitat management and restoration. The LWL Management Plan currently focuses on the need for watershed management and improved habitat restoration in the lagoon in order to attain and maintain water and sediment quality that support the integrity of the ecosystem. In addition, this plan addresses the need for continued planning, regulation, local stormwater improvement projects, and increased public education and awareness. Further details on this plan can be found on Palm Beach County's web site at www.co.palm-beach.fl.us/erm/enhancement/lwlagoon.asp.

The SFWMD, in cooperation with the FDEP and Palm Beach County, continues to collect data on freshwater discharges, water quality, and seagrasses in the LWL (see www.pbcgov.com/erm/enhancement/Images/PDF_Documents/LWL_Report.pdf for reporting on past years' activities). FDEP has recently evaluated LWL under the TMDL evaluation process and included it on the adopted list of waters to be proposed for delisting from the 1998 303(d) list.

Under the requirements of RECOVER, existing water quality data (1990–2004) is currently being compiled and evaluated. It is anticipated that a full analysis of LWL water quality trends will be included in the RECOVER Systems Status Report, scheduled for production in 2006.

ENGINEERING

In WY2005, the recently completed Stormwater Treatment Area 1 East (STA-1E) was utilized to capture stormwater discharges from the southern L-8 and western C-51 basins during the hurricane events. Full operation of these facilities is awaiting final permitting approvals. Once this facility, and the associated pump station, is fully approved for operation, it will capture and redirect a large volume of the flows historically being discharged to the east and received by the lagoon.

RESTORATION

Palm Beach County has undertaken an ambitious program for habitat restoration and public recreation in the Lake Worth Lagoon. In WY2005, the Snook Islands Nature Area (www.pbcgov.com/erm/enhancement/snook.asp) and Johns Island Restoration projects were completed, and the Peanut Island Restoration Project is scheduled for completion in the summer 2005 (see http://www.aicw.org/land/pifactsheet.htm and www.pbcgov.com/erm/enhancement/facts.asp).

The SFWMD participates in the LWL Partnership Grant Program and supports lagoon outreach activities. Additional information on the Partnership Grant Program can be found at www.co.palm-beach.fl.us/erm/enhancement/Images/PDF_Documents/grantposter2.pdf.

In WY2005, the SFWMD provided $615,000 in grant funds to Palm Beach County for the continuation of LWL restoration and assessment, recreation, and public outreach activities (**Table 12-4**).

Table 12-4. SFWMD Fiscal Year 2005 (FY2005) (October 1, 2004 through September 30, 2005) funding – Lake Worth Lagoon Grant.

Project	Total Cost	District Share	County Share	Other Share
Lake Osborne Restoration	$ 1,732,041	$ 200,000	$ 1,532,041	---
Ocean Ridge Natural Area Restoration	$ 2,924,190	$ 310,000	$ 2,007,190	$ 607,000
Lake Worth Lagoon Public Outreach	$ 66,650	$ 45,000	$ 21,650	---
Water Quality Monitoring Equipment	$ 10,735	$ 10,000	$ 735	---
Peanut Island Breakwater/ Artificial Reef Expansion	$ 150,000	$ 50,000	$ 100,000	---
TOTAL	**$ 4,883,616**	**$ 615,000**	**$ 3,661,616**	**$ 607,000**

INFORMATION GAPS AND FUTURE NEEDS

It is anticipated that existing information gaps relative to resource assessment of LWL will be addressed through the investigation now under way through RECOVER and the CERP North Palm Beach County Project – Part 1 study. However, significant long-term improvement to existing environmental conditions in LWL is dependent upon approval and subsequent funding for implementation of the CERP North Palm Beach County Project recommended actions.

BISCAYNE BAY

INTRODUCTION

Biscayne Bay is a large, shallow subtropical estuary located along the eastern shoreline of Miami-Dade County, directly adjacent or in close proximity to highly urbanized coastal areas (**Figure 12-19**). Much of the bay is enclosed along the east by a series of barrier islands. All of Biscayne Bay has been designated as Outstanding Florida Water and lies within a State Aquatic Preserve, National Park or National Marine Sanctuary.

Historically the Everglades, Florida Bay, and Biscayne Bay were part of a larger hydrologically connected system of coastal lagoons and wetlands in which Biscayne Bay served as the eastern hydrologic outlet of the Everglades. Fresh water flowed overland from the Everglades to the bay through natural sloughs and rivers and as groundwater through the Biscayne Aquifer. During the last century, the pattern has been altered by regional drainage, canal and levee construction and operation, and urban development. As a result, salinity patterns have changed in Biscayne Bay.

Biscayne Bay varies considerably in a variety of physical characteristics, including width, depth, water quality, and degree of connection to the open marine waters of the Atlantic Ocean or Florida Straits. Six distinct subregions of the bay have been identified for the purpose of MFL development (**Figure 12-20**). The bay is narrower in the most northerly reaches but is over 14 km wide in the south-central area. Water depths vary, from less than 1 m in intertidal shoreline areas to over 12 m in dredged navigation channels, although average depth is about 2 to 3 meters. In general, water quality within the bay is good to excellent except within a few tributaries (Alleman, et al. 1995). Tidal exchange with offshore waters is sufficient to influence both water quality and the ecology of the bay. Hundreds of species utilize the bay at some point during their life cycles. The salinity gradients and clear water are essential in maintaining these dependent habitats. Additional information on Biscayne Bay is available online at www.DiscoverBiscayneBay.org.

ENVIRONMENTAL ASSESSMENT CRITERIA

New information on the variability of salinity in south-central Biscayne Bay, particularly in the nearshore environment, was collected in WY2005. Salinity is a good environmental assessment criterion for Biscayne Bay. It is a conservative (i.e., not influenced or affected by biological activity) indicator of ecosystem health that is greatly influenced by the freshwater inputs from canal flows managed by the SFWMD. Because many species inhabiting the bay require estuarine conditions at some point in their life cycle, the maintenance of salinities below marine levels are crucial in establishing habitat suitability for these species. Examples of such estuarine-dependent species for the south-central bay region are listed in **Table 12-5**.

The impact of the volume, timing, and distribution of managed canal flows on the salinity in Biscayne Bay may be altered to meet the salinity requirements of estuarine species within the bay. However, although salinity preferences and/or tolerances ranges (and some information on the timing for life stages) for some species have been identified, the duration of the salinity ranges required for the survival and success of these species is not well documented.

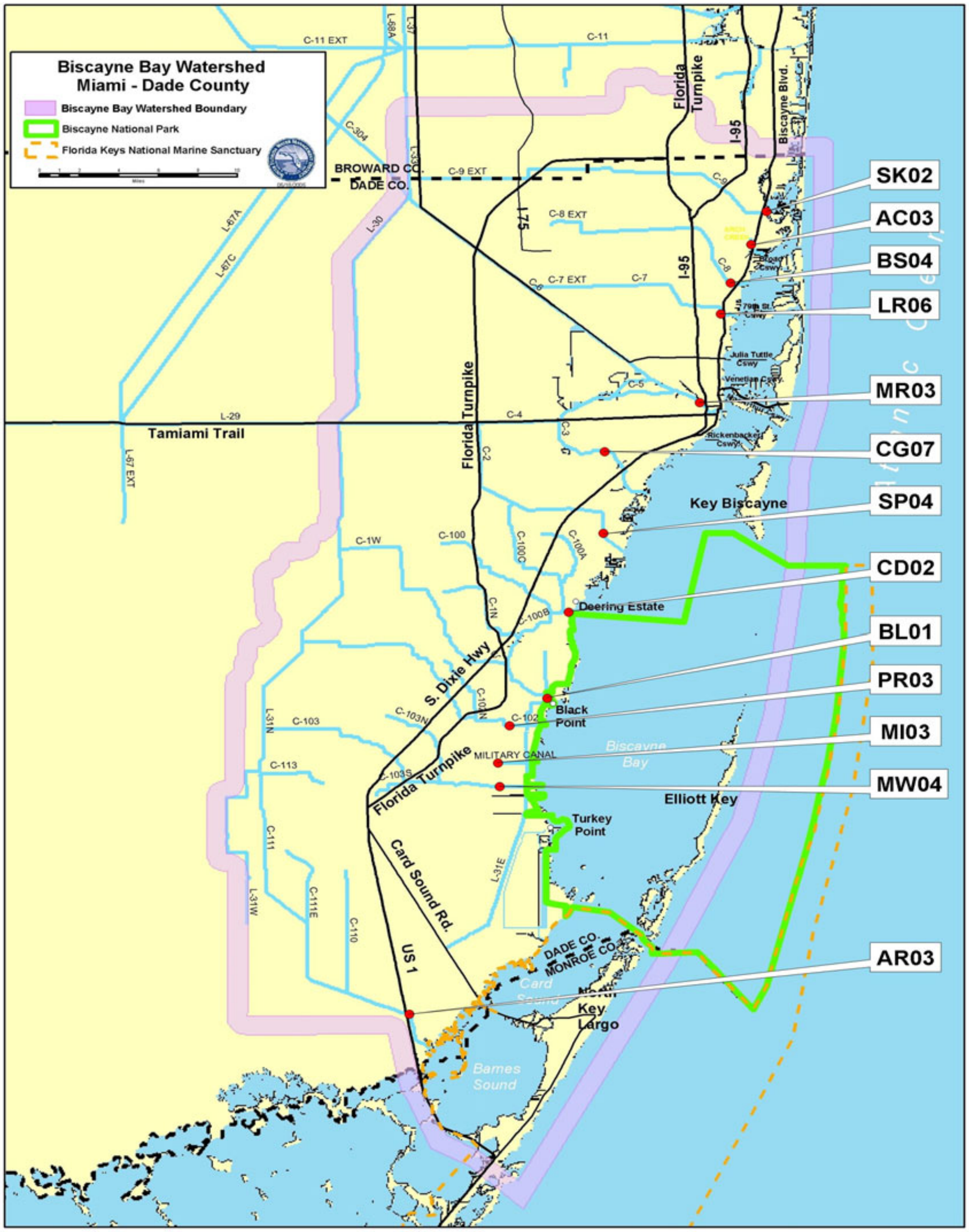


Figure 12-19. Biscayne Bay watershed and water body. Miami-Dade County Department of Environmental Resources Management (DERM) water quality monitoring stations – Biscayne Bay tributaries.

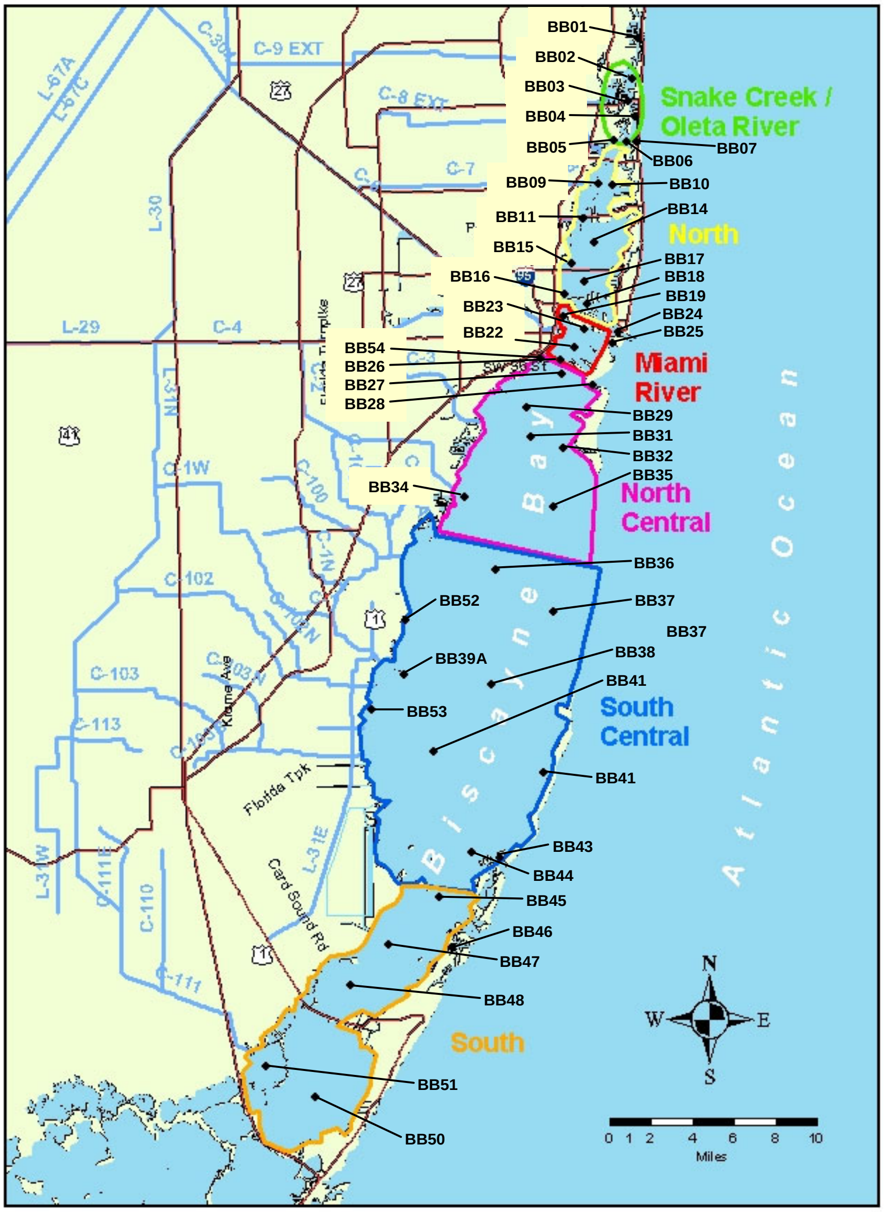


Figure 12-20. Biscayne Bay subregions proposed for the development of Biscayne Bay Minimum Flows and Levels (MFLs). Symbols indicate Miami-Dade County DERM water quality monitoring stations within Biscayne Bay.

Table 12-5. Salinity preferences and tolerances for selected species found in south-central Biscayne Bay (SFWMD, 2004).

Indicator	Life Stage	Preference	Tolerance
American Crocodile (*Crocodylus acutus*)	hatchling(<200g) juveniles(>200g) adults	<4 ppt (at least weekly) <20 ppt <20 ppt	40 ppt; or unlimited with freshwater source nearby
Eastern Oyster (*Crassostrea virginica*)	eggs spat larval adult	7-39 ppt 15-26 ppt 25 – 29 ppt 14 – 30 ppt	42 ppt
Pink Shrimp (*Farfantepenaeus duorarum*)	larvae juvenile adult	12-37 ppt 20-37 ppt 25-45 ppt	45-47 ppt
Blue Crab (*Callinectes sapidus*)	egg hatch larvae juveniles adults	22-28 ppt 22-28 ppt 5-28 ppt 0-34 ppt	42 ppt
Spotted Sea Trout (*Cynoscion nebulosus*)	juveniles adults	1-25 ppt 5-37 ppt	Unknown
Silver Perch (*Bairdiella chrysoura*)	adult	5-25 ppt	Unknown …
Silver Jenny (*g.Eucinostomus*)	adult	0-30 ppt	Unknown
Common Snook (*Centropomus undecimalis*)	juvenile adult	0-25 ppt 5-37 ppt	45ppt
Tarpon (*Megalops atlanticus*)	juvenile adult	1-10 ppt 5-37 ppt	Unknown
Shoal Grass (*Halodule wrightii*)		6-40 ppt; less than *Thalassia*	70 ppt
Wigeon Grass (*Ruppia maritima*)		0 – 39 ppt	60 ppt

ENVIRONMENTAL CONDITION OF BISCAYNE BAY

Climate conditions in South Florida were unusual for WY2005. The wet season (normally May–October) was delayed by approximately two months, which resulted in lower-than-average canal flows into the bay and unusually high bay salinities (**Figure 12-21**, Panels a-f). This was evident in monthly salinity measurements averaged for all Miami-Dade Department of Environmental Resource Management (DERM) stations within the south-central Biscayne Bay region. South-central salinities were higher than long-term averages early in the wet season due to below-average canal flows into the bay for the same time period (**Figure 12-21**, Panel f). The late onset of the wet season (end of July 2004) was followed by higher-than-average canal flows into the bay from August through December, which is two months into the average November–April dry season (**Figure 12-21**, Panel e). Continuous salinity measurements (one record every 15 minutes) collected at various stations in the south-central region (**Figure 12-22**) during WY2005 and averaged on a daily basis have provided new insight into the variability of salinity in the nearshore environments. Salinity variability is highest at the station nearest shore and decreases with distance from shore (**Figure 12-23**). Contributing to the increase in salinity variability was the series of hurricane events (Frances, Ivan, and Jeanne) that occurred in September and October of 2004, which resulted in an extended period of above-average canal flows into the south-central region, and was reflected in periods of low salinities observed in September and October (**Figure 12-23**).

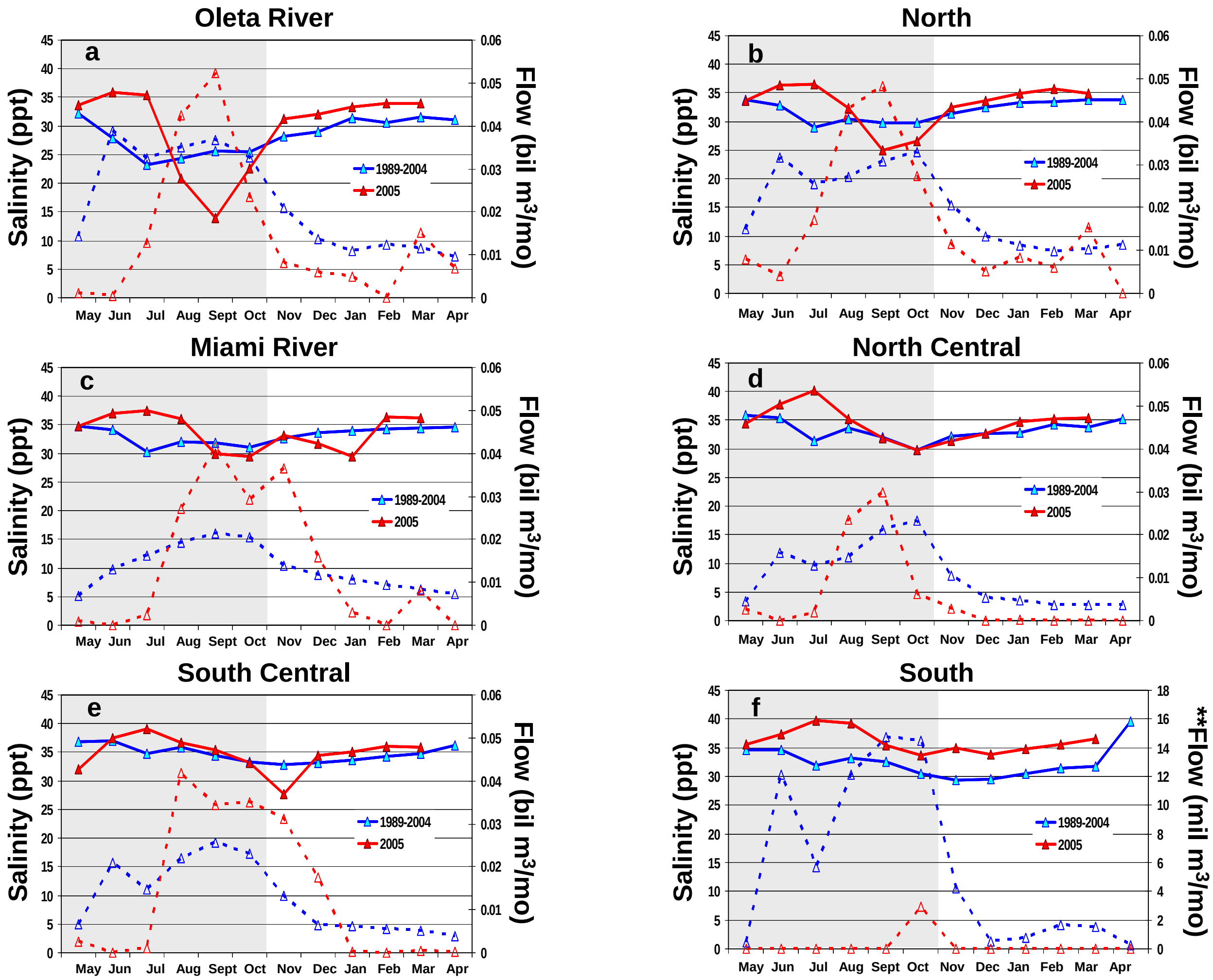


Figure 12-21. Comparison of WY2005 (red) monthly averages to long-term monthly averages (blue) for six subregions of Biscayne Bay. Graphs show canal flows into the bay (dashed lines) and salinity within the bay (solid lines). Shaded areas indicate average wet season months. Note: Flow for South Bay is in units of millions of cubic meters per month; flow for all other regions is in units of billions of cubic meters per month.

Figure 12-22. Biscayne National Park nearshore continuous salinity monitoring sites. Monitoring network includes 32 additional meter sites (not shown).

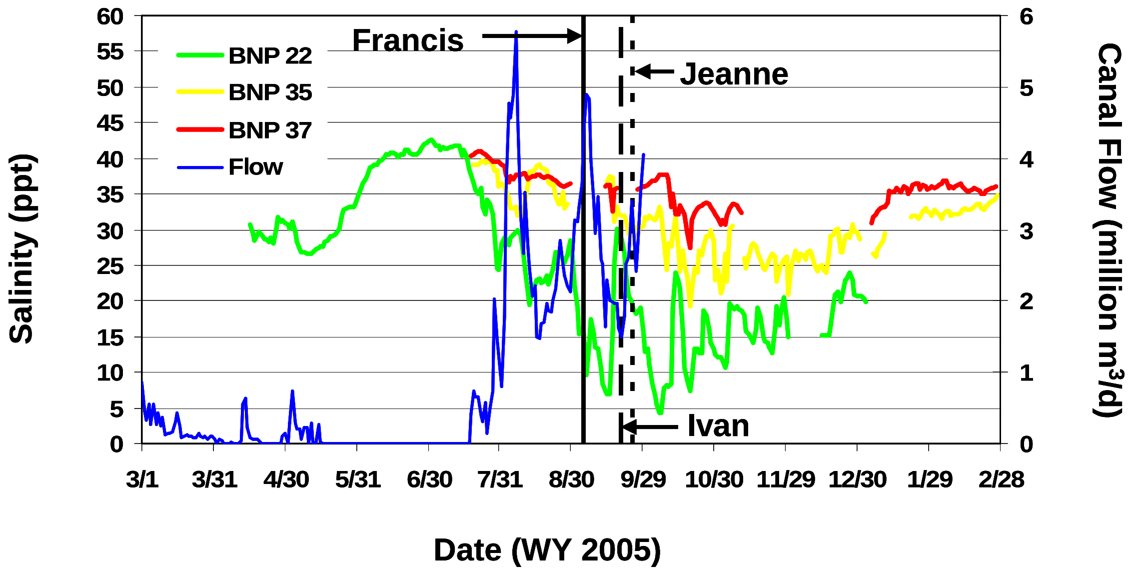


Figure 12-23. South-central Biscayne Bay continuous salinity monitoring data for WY2005 (3/04–2/05). The three sites illustrate the difference in salinity variability with distance from shore (highest variability at the nearshore station (22) and the lowest salinity variability at the station farthest from shore (37).

Salinity

Viewing the salinity patterns for WY2005 in nearshore south-central Biscayne Bay environments, along with salinity ranges and tolerances of a few species found within that region, illustrates the importance of identifying the duration of salinity ranges required for the survival and success of these species (**Figure 12-24**). Examination of the salinity patterns for the three stations shown in **Figure 12-24**, combined with the information in **Table 12-5**, indicate that, while many species may have been able to survive the high salinities measured between May and July 2004, these salinities were above the preferred salinity ranges for earlier life stages. If the salinities observed prior to the wet season in WY2005 were of sufficient duration, and extended into the breeding and/or juvenile growth season for any or all of these species, the result could be the loss of an entire generation. Such high salinity events, even when occurring only occasionally, could have serious effects on populations of species, particularly sessile species (e.g., oysters) that are unable to migrate to areas of lower salinity.

Once the salinity ranges and durations for the estuarine species are identified, models can be used to predict and calculate alternative scenarios for managing the volume, timing, and distribution of the freshwater canal flows into Biscayne Bay in a way that effectively maintains salinities required for species habitat suitability in the bay. Such models require adequate data quantifying freshwater inputs (canal flow, rain, surface runoff, and groundwater) and exports (evaporation) on appropriate time and space scales. Limited resources (i.e., funding and personnel) for the collection and analysis of data required for the development of predictive models have resulted in gaps in the existing datasets, as well as data collected over timescales too coarse to identify daily or weekly salinity responses to freshwater inputs into the bay. For example, although DERM has been monitoring salinity throughout the bay since 1979, data are collected at each station only once per month, which prohibits the calculation of accurate salinity patterns on smaller timescales. This is particularly important for the nearshore areas and areas around canal outflows, where salinity is variable on daily and weekly timescales (**Figure 12-23**). Also, canal flows are estimated based on stage heights and gate activity rather than measured directly. A study currently in progress is measuring flow directly from canal outflows in an effort to increase the accuracy of flow estimates in selected locations (see Science, Engineering, and Restoration Activities). Freshwater inputs into the bay via groundwater are also estimated based on groundwater stage height rather than actual flows, and need to be more directly quantified. Recent studies have begun to address this issue, but have not yet provided quantitative data (see *Science, Engineering, and Restoration Activities* section).

Hypersalinity has been detected recently in nearshore areas of southern Biscayne Bay at the end of the dry season in May and June. The causes and sources of the hypersalinity are unknown at this point, but the District is planning on conducting hydrodynamic and hydrologic analyses to see if it is related to management of water in the watershed.

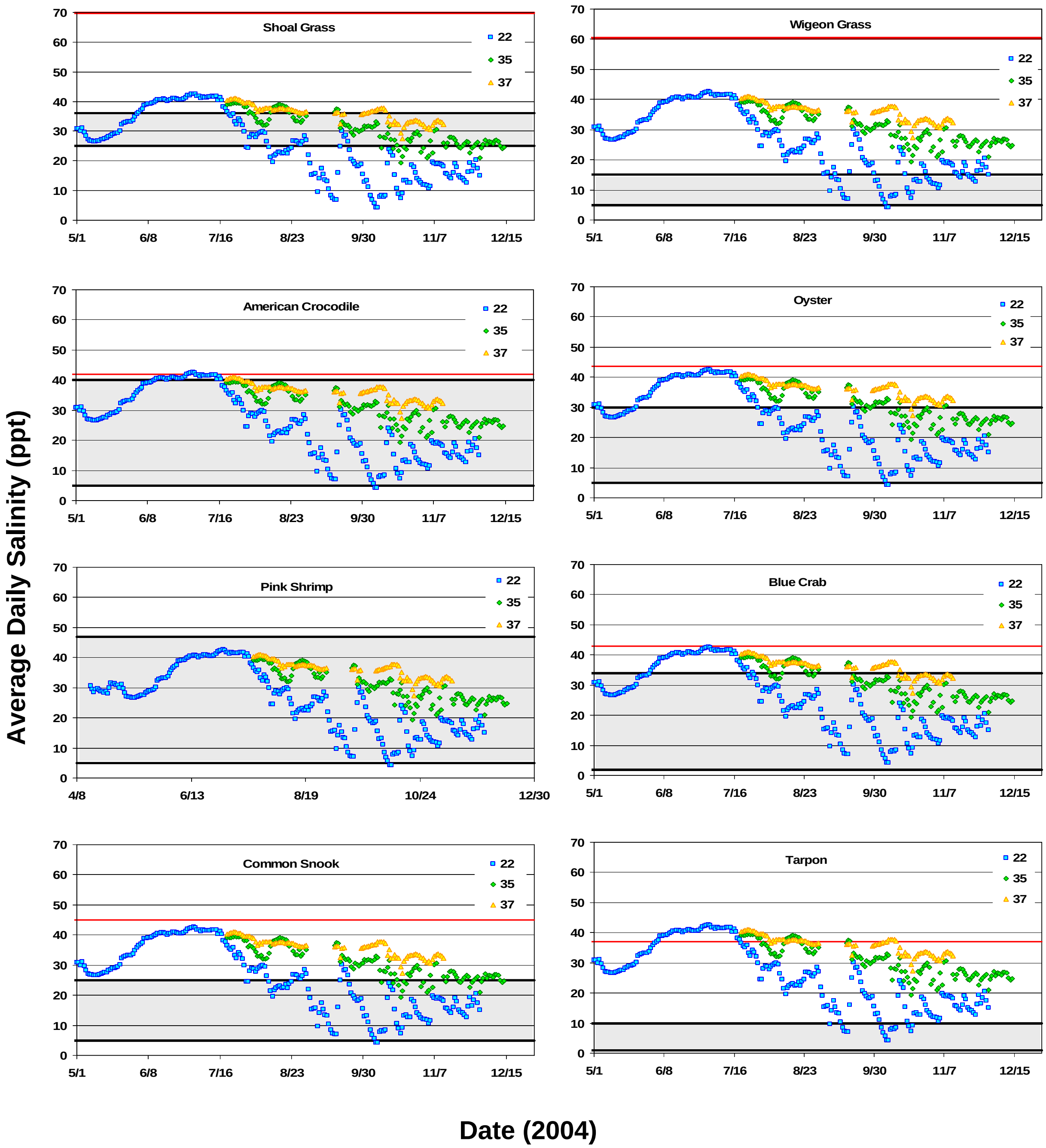


Figure 12-24. Daily salinity for three stations in south-central Biscayne Bay. Stations located along a transect with increasing distance offshore from Military Canal outflow. Blue (22) is nearest shore and yellow (37) is farthest from shore. Shaded areas indicate salinity preference for each species. Red lines indicate upper salinity tolerance for each species. Upper salinity tolerance for Pink Shrimp is unknown.

Biscayne Bay Water Quality

Freshwater from canals and rivers flowing into Biscayne Bay is a source of nutrients to the Bay. Excessive loading of nutrients into coastal regions can have consequences at the ecosystem scale. Specifically, high concentrations of nutrients, especially nitrogen and phosphorus, can result in the formation of high concentrations of primary producers (i.e algae and seagrasses). The decomposition of high levels of primary producers can result in low levels of oxygen (hypoxia or anoxia) throughout the sediments and lower water column, which can cause stress or harm to aquatic organisms (i.e. fish, invertebrates, etc.). While this scenario does not currently appear to be a concern in Biscayne Bay, these and other water quality parameters are monitored to detect changes within the Bay ecosystem.

Canal and river discharge water quality from 1991–2004 was compared to measures given in the Biscayne Bay SWIM Plan (Alleman et al., 1995). The datasets were updated with results from April 2003–December 2004 that were not in the last year's report. Specific water quality targets are given in the Biscayne Bay SWIM Plan for ammonia (NH_3 + NH_4^+) nitrogen (0.5 milligrams per liter, or mg/L, throughout the bay; 0.1 mg/L within Biscayne National Park) and nitrate/nitrite (NO_2^- + NO_3^- = NO_x) nitrogen (0.05 mg/L within Biscayne National Park). Where no targets were specified, trends were examined for degradation of ambient quality based on the Outstanding Florida Water Rule concept. The data was analyzed with the seasonal Kendall test and visual inspection of plotted time series. Trends that were flat or declining were considered favorable. Results in **Tables 12-6** and **12-7** are from monitoring stations (**Figure 12-19**) located in tributaries that discharge into Biscayne Bay using the monthly DERM data. For a description of DERM's monitoring program, see Alleman et al., 1995. Results were summarized for Snake Creek (C-9), Arch Creek, Biscayne Canal (C-8), Little River (C-7), Miami River, Coral Gables Waterway (C-3), Snapper Creek (C-2), Cutler Drain (C-100), Black Creek (C-1), Princeton Canal (C-102), Military Canal, Mowry Canal (C-103), and Aerojet Canal (C-111).

Notable water quality results for stations in Biscayne Bay tributaries are:

- More favorable results than last year are reported at four sites: Arch Creek, Little River, Miami River, and Coral Gables Waterway:
    - Ammonia category was changed from red to yellow for Arch Creek, because 92 percent of the results in 2004 were at or below target (<0.5 mg/L), and the long-term trend did not indicate increasing concentrations.
    - NOx category was changed from red to yellow for Little River because no increasing trend was detected.
    - Ammonia category was changed from yellow to green for the Miami River, because 100 percent of results met the target for the last three years, and a decreasing trend was detected.
    - NOx category was changed from red to yellow in the Miami River, because no trend was detected after 1992; however, concentrations were slightly higher than prior to 1992.
    - NOx category was changed from red to green for the Coral Gables Waterway, because no trend was detected.
- The favorable trend of decreasing or steady total phosphorus concentrations.
- NOx concentrations continued to increase at five of the canals: Arch Creek, Cutler Drain, Black Creek, Princeton Canal, and Mowry Canal.

Table 12-6. Summary of monthly water quality results and trends at specific locations within tributaries that discharge into Biscayne Bay. TP= total phosphorus; AMM = total ammonia nitrogen; NOx = nitrate and nitrite nitrogen.

🟩 = water quality concentrations met targets as described in the text and exhibited a favorable trend.
🟨 = water quality concentrations met targets some of the time as described in the text and may have exhibited an uncertain trend.
🟥 = water quality concentrations did not meet targets as described in the text and may have exhibited an unfavorable trend.

Station Location	TP	AMM	NOx
Snake Creek (C-9) at SK02	🟩	🟩	🟩
Arch Creek at AC03	🟩	🟨	🟥
Biscayne Canal (C-8) at BS04	🟩	🟩	🟩
Little River (C-7) at LR06	🟩	🟨	🟨
Miami River (C-6) at MR03	🟩	🟩	🟨
Coral Gables Waterway (C-3) at CG07	🟩	🟥	🟩
Snapper Creek (C-2) at SP04	🟩	🟩	🟩
Cutler Drain (C-100) at CD02	🟩	🟩	🟥
Black Creek (C-1) at BL01	🟩	🟥	🟥
Princeton Canal (C-102) at PR03	🟩	🟩	🟥
Military Canal at MI03	🟩	🟨	🟥
Mowry Canal (C-103) at MW04	🟩	🟩	🟥
Aerojet Canal (C-111) at AR03	🟩	🟩	🟩

Table 12-7. Summary of water quality results at specific locations within the tributaries that discharge into Biscayne Bay. TP = total phosphorus; AMM = total ammonia nitrogen; NOx = nitrate and nitrite nitrogen; POR = period of record; N = number of results; Mean = arithmetic average (mg/L); Std = standard deviation. Statistics from Final Status and Trends Report for the Biscayne Bay Water Quality Status and Trends, Miami-Dade County DERM, 2005.

Station	Test	POR	N	Mean	Std	Median
SK02	TP	7/88-9/03	185	0.013	0.019	0.009
	AMM	7/88-9/03	184	0.12	0.01	0.06
	NOx	7/88-9/03	173	0.24	0.14	0.22
AC03	TP	7/88-9/03	171	0.15	0.11	0.13
	AMM	7/88-9/03	171	0.80	0.52	0.78
	NOx	7/88-9/03	171	0.12	0.12	0.08
BS04	TP	7/88-9/03	171	0.019	0.017	0.019
	AMM	7/88-9/03	171	0.12	0.11	0.08
	NOx	7/88-9/03	170	0.22	0.18	0.20
LR06	TP	1/89-9/03	166	0.026	0.015	0.023
	AMM	1/89-9/03	165	0.40	0.07	0.38
	NOx	1/89-9/03	156	0.27	0.12	0.25
MR03	TP	1/88-9/03	175	0.020	0.011	0.017
	AMM	1/88-9/03	175	0.24	0.13	0.21
	NOx	1/88-9/03	175	0.16	0.08	0.15
CG07	TP	1/89-9/03	157	0.047	0.035	0.037
	AMM	1/89-9/03	156	0.29	0.41	0.14
	NOx	1/89-9/03	146	0.26	0.26	0.18
SP04	TP	7/91-9/03	136	0.012	0.031	0.006
	AMM	7/91-9/03	136	0.08	0.07	0.05
	NOx	7/91-9/03	136	0.15	0.07	0.14
CD02	TP	1/89-9/03	167	0.011	0.016	0.007
	AMM	1/89-9/03	166	0.04	0.04	0.02
	NOx	1/89-9/03	158	0.11	0.11	0.08
BL01	TP	1/88-9/03	174	0.012	0.012	0.008
	AMM	1/88-9/03	174	0.26	0.20	0.22
	NOx	1/88-9/03	174	0.13	0.15	0.08
PR03	TP	7/91-9/03	140	0.009	0.028	0.003
	AMM	7/91-9/03	140	0.04	0.04	0.02
	NOx	7/91-9/03	136	4.09	0.70	4.17
MI03	TP	7/89-9/03	181	0.015	0.020	0.010
	AMM	7/89-9/03	176	0.05	0.05	0.03
	NOx	7/89-9/03	169	0.59	0.45	0.53
MW04	TP	8/91-9/03	143	0.009	0.026	0.004
	AMM	8/91-9/03	144	0.03	0.03	0.02
	NOx	8/91-9/03	139	2.34	0.83	2.25
AR03	TP	8/89-9/03	156	0.005	0.008	0.004
	AMM	8/89-9/03	156	0.06	0.05	0.05
	NOx	8/89-9/03	156	0.05	0.05	0.03

Additional information on Miami-Dade County DERM water quality results that have exceeded Florida water quality criteria from the period from 1988–2003 is summarized in Appendix 12-2.

At the subregional scale (**Figure 12-20**), water quality within Biscayne Bay for WY2005 differed from long-term monthly averages in several ways:

- Monthly average WY2005 ammonium concentrations were generally higher than long-term monthly averages throughout the bay (**Figure 12-25**).
- Monthly average WY2005 total phosphorus concentrations were generally lower than long-term monthly averages throughout the bay (**Figure 12-26**).
- Monthly average WY2005 turbidity levels were generally lower than long-term monthly averages throughout the bay (**Figure 12-27**).
- Monthly average WY2005 nitrate plus nitrite concentrations were similar to long-term monthly averages throughout the bay (**Figure 12-28**).

Long-term annual average water quality trends within Biscayne Bay, including data for WY2005 for the six subregions are included in Appendix 12-3.

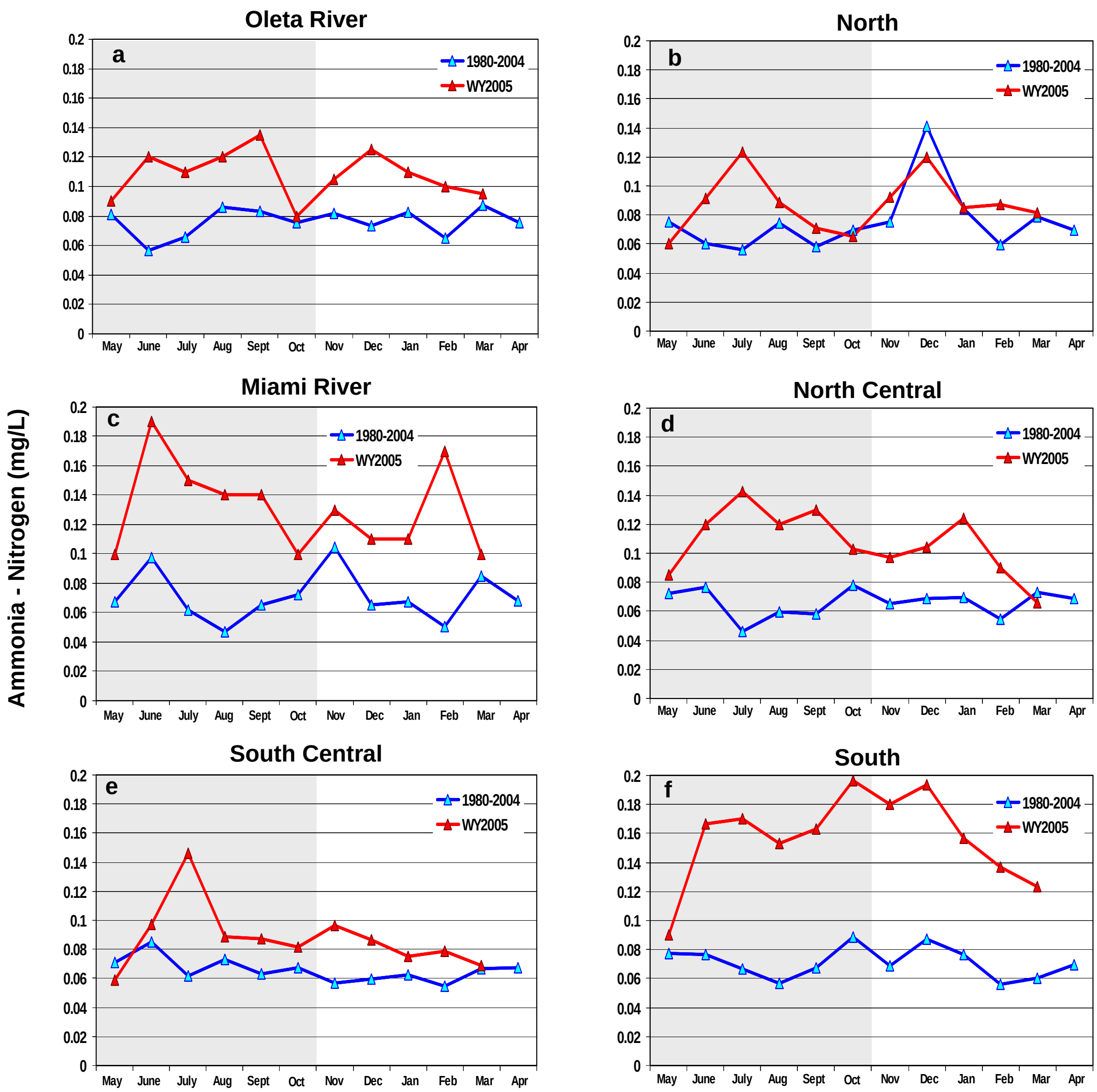


Figure 12-25. Comparison of WY2005 (red) monthly averages to long-term monthly averages (blue) for six subregions of Biscayne Bay. Graphs show ammonia (NH_3 plus NH_4^+) – nitrogen. Shaded areas indicate average wet season months.

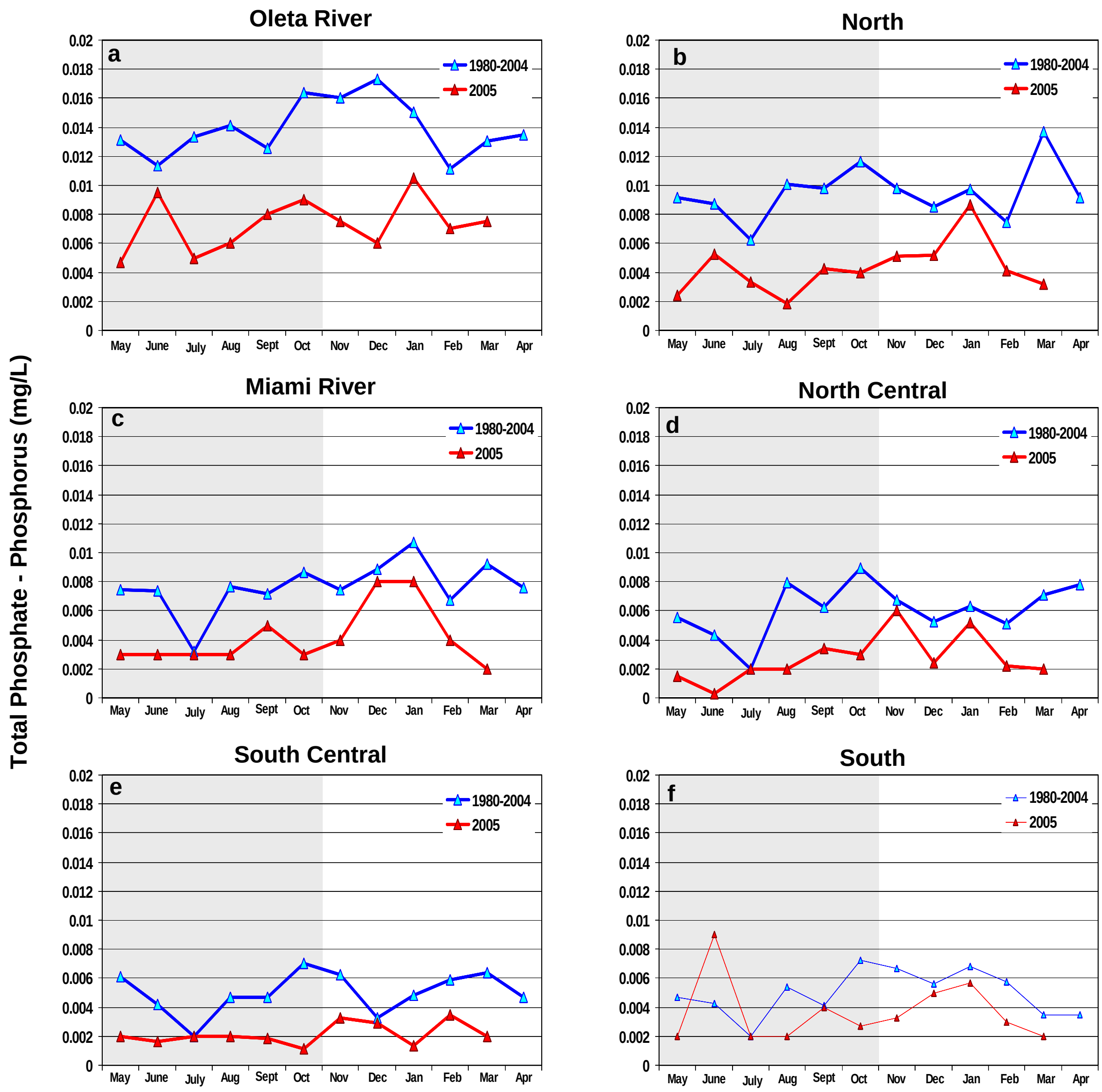


Figure 12-26. Comparison of WY2005 (red) monthly averages to long-term monthly averages (blue) for six subregions of Biscayne Bay. Graphs show total phosphate – phosphorus. Shaded areas indicate average wet season months.

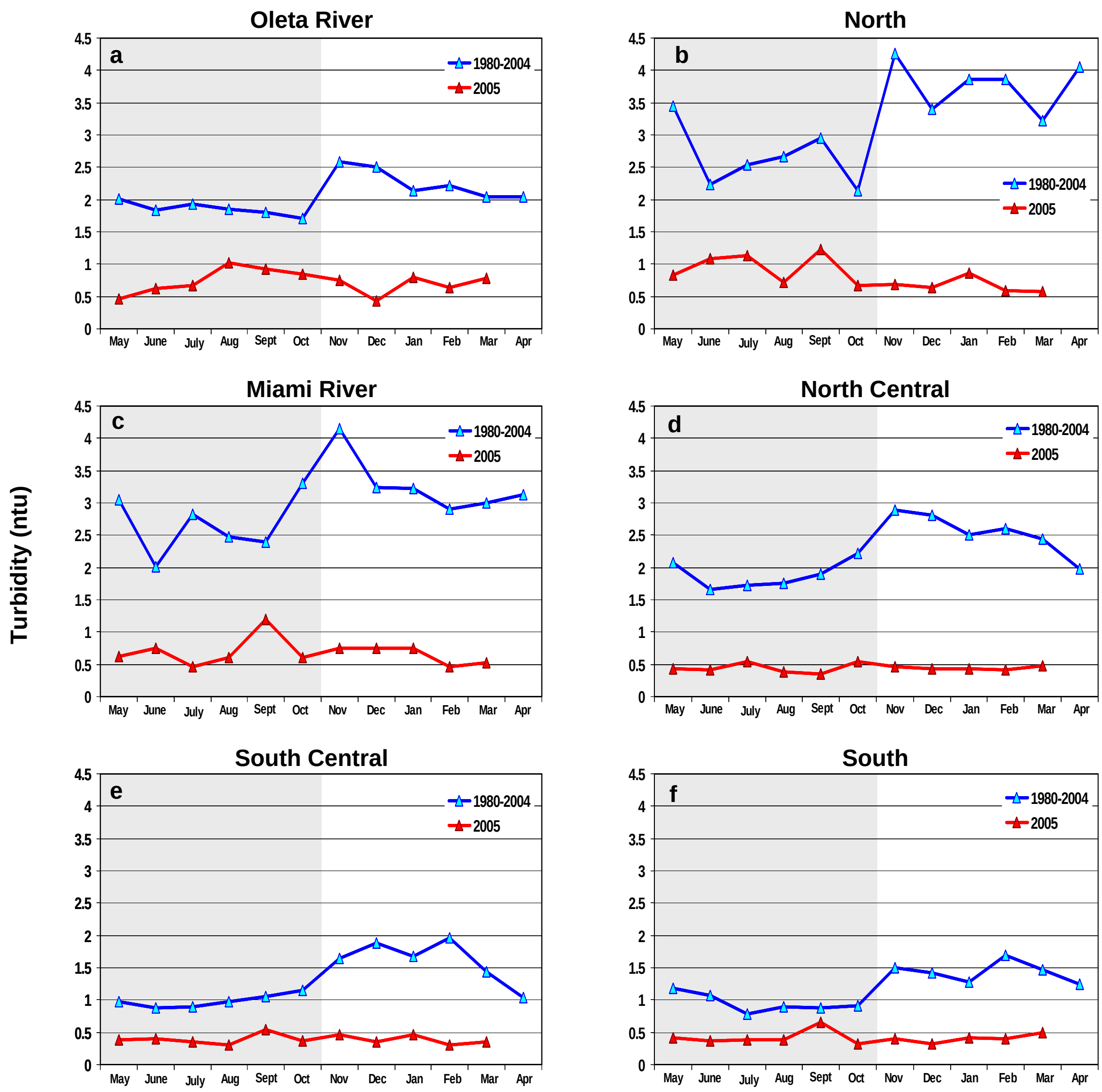


Figure 12-27. Comparison of WY2005 (red) monthly averages to long-term monthly averages (blue) for six subregions of Biscayne Bay. Graphs show turbidity. Shaded areas indicate average wet season months.

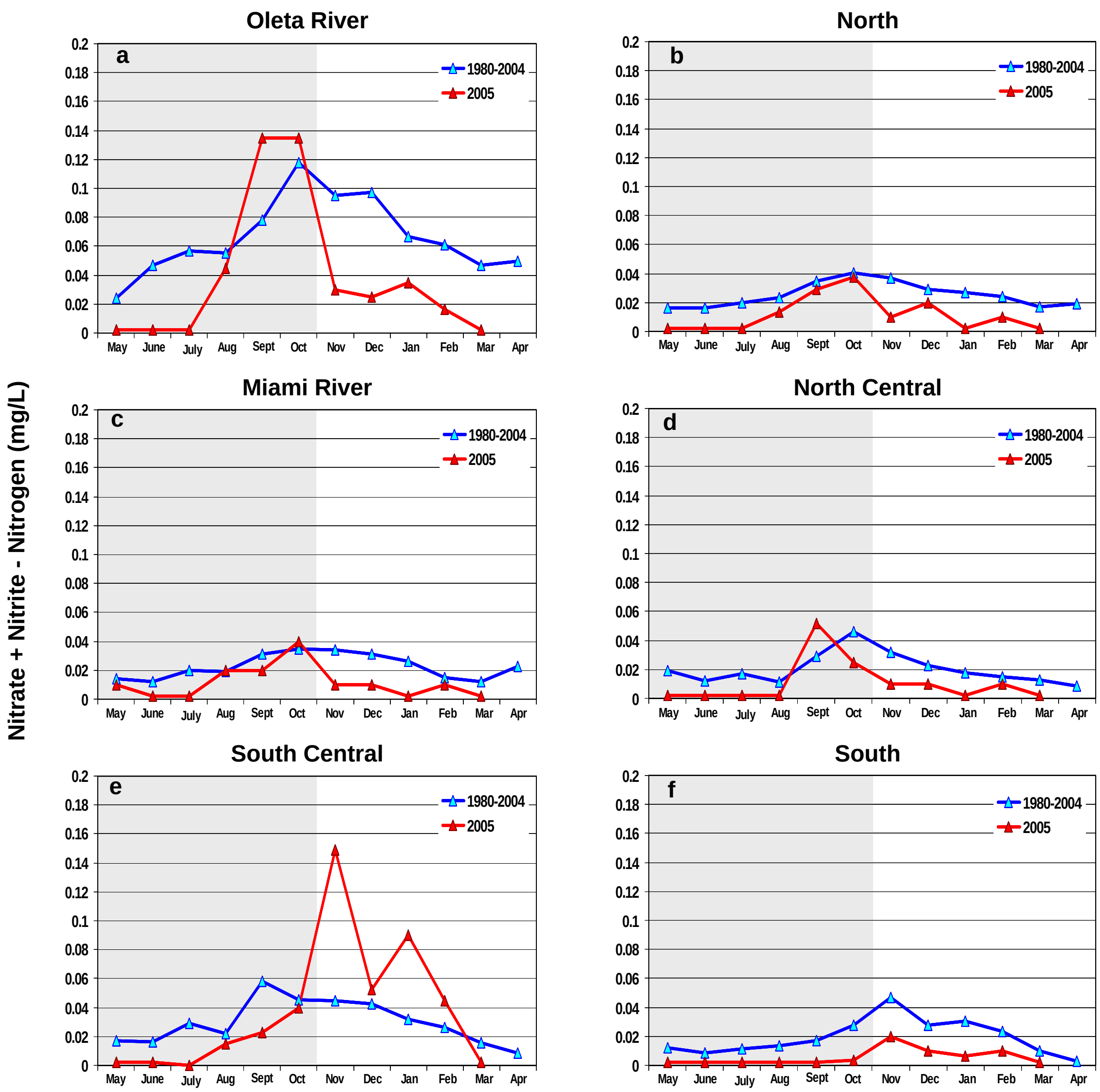


Figure 12-28. Comparison of WY2005 (red) monthly averages to long-term monthly averages (blue) for six subregions of Biscayne Bay. Graphs show nitrate + nitrite (NO_3^- plus NO_2^-) – nitrogen. Shaded areas indicate average wet-season months.

CURRENT SCIENCE, ENGINEERING, AND RESTORATION ACTIVITIES

Resource Assessment

BISCAYNE BAY MINIMUM FLOWS AND LEVELS

Minimum Flow and Level criteria are being developed for the south-central region of Biscayne Bay. The minimum flow is defined as the "...limit at which further withdrawals [of fresh water] would be significantly harmful to the water resources or ecology (i.e., resources or ecology not recovered within two years) of the area." If needed, separate MFL criteria will be developed for different subregions of Biscayne Bay (**Figure 12-20**) because of varying ecological needs, physical constraints, and specific resources of those subregions. The south-central area of the bay is associated with a watershed that includes the Cutler Drain (C-100), Black Creek (C-1), Princeton Canal (C-102), and Mowry Canal (C-103) primary drainage basins. Completion of the criteria for the south-central area of the bay is currently scheduled for 2006.

MIAMI RIVER COMMISSION

The District continued its support of the Miami River Commission (MRC) through District Governing Board Member participation as chair of the Commission and through staff support to the MRC Stormwater and Dredging subcommittees. The District has also assisted the MRC with outreach and technical support as well as financial support for operating and nonrecurring expenses. Such nonrecurring expenses include funding of investigations of storm sewer lines along Wagner Creek and funding for operations of a waterborne cleanup vessel. More information on the Miami River Commission can be found at www.miamirivercommission.org/.

The Miami River Dredging Project (described below) is the top priority of the MRC, and MRC is a key lobbyist on behalf of the project, working at the federal, state, and local levels to obtain funding for it. The following are some of the MRC's most notable 2005 accomplishments:

- Coordinated the construction of sections of the Miami River Greenway – first projects (approximately 20 percent of the total greenway) commenced. Completion of the first projects expected in 2007.
- Completed the Wagner Creek Isolation Survey – meant to assist in determining the source of high coliform levels in Wagner Creek.
- Recognized by *Miami Today* as the Best Non-Profit Organization in Miami.
- Awarded community stewardship by 1,000 Friends of Florida.

SOUTH MIAMI-DADE WATERSHED STUDY AND PLAN

The District continued its support as one of the lead agencies on the South Miami-Dade Watershed Study and Plan with Miami-Dade County. This study is a collaboration between the District, Miami-Dade County, and the South Florida Regional Planning Council to plan future growth of an area of about 400 square miles over the next 50 years, with an emphasis on sustainability of the region and protection of Biscayne Bay. Specific tasks related to formulating and assessing possible alternative land use plans have been completed, and the task of formulating a preferred plan is currently under way.

During Fiscal Year 2005 (FY2005) (October 1, 2004 through September 30, 2005) the formulation of the three test scenario land uses and maps for the planning periods 2025 and 2050 were completed. From these test scenarios, assessments of 21 parameters, including water quality and quantity, schools, transportation capacity, and economic changes, will be completed. The results of these assessments will lead to formulation of the "preferred" scenario and to proposed updates to Miami-Dade County's Comprehensive Master Plan. This project is estimated to be completed by the end of the 2005 calendar year. Completed work for this project can be found online at www.southmiamidadewatershed.com.

Restoration Activities

COMPREHENSIVE EVERGLADES RESTORATION PLAN BISCAYNE BAY COASTAL WETLANDS PROJECT AND ACCELER8

The primary ecosystem restoration project for Biscayne Bay is the CERP Biscayne Bay Coastal Wetlands Project (BBCW). The BBCW Project is an interagency cooperative effort currently in the planning phase with completion anticipated in 2016. Further information on this project can be found online at www.evergladesplan.org/pm/projects/docs_28_biscayne_bay.cfm. Its primary purpose is to redistribute freshwater runoff to Biscayne Bay in a more natural way. The project will seek to restore some of the creek system in the coastal wetlands, improve hydroperiods in low-lying wetlands near the bay, and partially compensate for the reduction in groundwater seepage to the bay by increasing managed water stages. The proposed improvements are expected to restore or enhance freshwater wetlands, tidal wetlands, and nearshore bay habitat.

The District's Acceler8 program has been implemented to facilitate the completion of several additional CERP projects deemed to be the most critical ahead of schedule. One of the projects is a portion of the BBCW Project: to design and construct essential components included in the Deering Estates Flow-Way and Cutler Wetlands near Black Point, and possibly along levee 31-east. Completion is scheduled in 2009. Additional information on Acceler8 can be obtained online at www.evergladesnow.org.

An important component of the CERP Biscayne Bay Coastal Wetlands Project is the continued acquisition of lands within the boundaries of the project, which is considered critical toward meeting the project goals. To date, about 33,000 acres, which comprises the majority of the project area, are in public ownership.

BISCAYNE BAY REGIONAL RESTORATION COORDINATION TEAM

The Biscayne Bay Regional Restoration Coordination Team (BBRRCT) is a cross-functional team and subgroup of the Working Group of the South Florida Ecosystem Restoration Task Force. It was created as a result of the Biscayne Bay Partnership Initiative Report to act as a unifying voice for the bay; to integrate and coordinate restoration, enhancement, and preservation projects, plans, and activities; and work toward maintaining a functioning ecosystem while promoting a sustainable region.

The BBRRCT completed an action plan for Biscayne Bay, which sets forth objectives and overarching goals, as well as defines specific initial action items to be completed in the near term in support of a sustainable Biscayne Bay ecosystem. Completing the action plan and gaining consensus on it was a major accomplishment for this team to move forward on their mission. By the end of FY2005, the action plan will be finalized and presented to the South Florida Ecosystem Restoration Task Force (SFERTF) Working Group.

CHAPMAN FIELD HABITAT RESTORATION

The District provided $100,000 of state-appropriated funding to Miami-Dade County DERM, in partnership with Miami-Dade County Parks Department to restore and enhance impacted mangrove and coastal wetlands near the coast of central Biscayne Bay. Specifically, the design specifications, cost estimates, and permitting have been completed for this project. The current project phase – restoration of approximately 4 acres – is expected to be completed in March 2007. DERM recently received additional funding for the Chapman Field Habitat Restoration Project and will continue restoration and enhancement activities throughout the remaining area for restoration in FY2006. This project will restore the habitat of the park for a variety of marine and bird species while also improving water quality in Biscayne Bay by reducing the point source discharge of landfill pollutants.

Engineering Activities

MIAMI RIVER DREDGING

The District, through partnerships with Miami-Dade County, the Florida legislature, and the Florida Inland Navigation District (FIND), provided nearly $3 million for the Miami River Dredging Project. By February, 2005 the USACE, with local sponsorship from Miami-Dade County and in cooperation with the District, the state of Florida, the city of Miami, and FIND, completed the dredging of 15 segments of the Miami River. While dredging is expected to primarily benefit navigation, tons of contaminated sediments were removed from the river bottom that threatened the ecological health of Biscayne Bay. Sediments that have accumulated within the Miami River were found to become suspended in the water column by shipping traffic and carried downstream toward the bay by outgoing tides. Dredging of additional sections of the river are planned to continue through 2007. Project completion is anticipated for August 2007.

Miami-Dade County Stormwater Retrofit Projects

In FY2005, through state appropriations and *ad valorem* funding sources, the District, provided over $10 million to Miami-Dade County municipalities for stormwater retrofit and flood mitigation projects, ranging from the development of stormwater master plans for newly incorporated cities to large-scale upgrades and retrofits for older existing systems (**Table 12-8**).

Table 12-8. Stormwater retrofit and flood mitigation projects for Miami-Dade County municipalities funded in FY2005.

MUNICIPALITY	PROJECT NAME	ESTIMATED COMPLETION
Aventura	Hospital District South Collector Stormwater Management Improvements	December 2006
Bay Harbor Islands	Stormwater System Improvements, Phase I	May 2006
Biscayne Park	Stormwater Drainage System Improvements – NE 9th Court, between NE 109th and 115th Streets and NE 113th Street, between NE 9th and 10th Avenues	February 2006
Coral Gables	Citywide Stormwater System Improvements	August 2006
Doral	Stormwater Management Master Plan	February 2007
El Portal	Seawall/Canal Bank Stabilization	February 2007
Florida City	Friedland Manor Stormwater Improvement	February 2006
Golden Beach	Local Flood Mitigation Project	July 2006
Hialeah	Storm Drainage and Street Improvements – East 16th, 18th, 19th, 20th Streets and Curtis Drive, between, Palm Avenue and East 1st Avenue	January 2006
Homestead	Stormwater System Improvements	October 2006
Miami	Avalon Storm Sewer Project, Phases I & II	June 2007
Miami Beach	Stormwater Drainage System Improvements – Washington Avenue, between NE 5th Street and Lincoln Road	January 2008
Miami Gardens	Stormwater Master Plan	July 2006
Miami Lakes	Stormwater Improvements – NW 154th Street, Lake Glen Ellen and Lake Cynthia Areas	April 2006
Miami Shores Village	NE 96th Street Stormwater Drainage Improvements	July 2008
Miami Springs	Flood Control Project – Basin 14	March 2006
Miami-Dade County	Miami River Dredging – Acceptance Sections 3 and 4	September 2005
North Miami	Biscayne Canal West Drainage Basin System Retrofit	June 2007
North Miami Beach	Eastern Shores and Highlands Village Storm Drainage Improvements	March 2007
Opa-Locka	NW 38th Court Stormwater Drainage Improvements	July 2006
Palmetto Bay	Drainage Improvement Project, Sub-Basin #7	April 2007
South Miami	Water Distribution System Improvements	February 2006
Sunny Isles Beach	Center Island Storm Drainage Improvements	March 2006
Sweetwater	Stormwater Drainage System Improvements – NW 107th to NW 112th Avenues, between NW 7th and NW 8th Streets	February 2008
Virginia Gardens	Citywide Flood Mitigation Project	January 2006
West Miami	Local Flood Mitigation Project – SW 62nd to SW 67 Avenues, between SW 8th Street and Coral Way	June 2006

Science Activities

BISCAYNE BAY DOPPLER OPERATION AND MAINTENANCE

A Horizontal Doppler System continues to monitor flow at water control structures located in District-operated canals near coastal outfalls. This system continuously monitors freshwater discharge rates to Biscayne Bay. The purpose of this project is to obtain data that can be used to recalibrate or modify and improve the accuracy of the equations currently used to estimate discharge rates through the salinity control structures. The improved discharge rate estimates will be applied toward improving the predictive capabilities of Biscayne Bay modeling tools. The data collected by Doppler meters are of particular use in the south-central Biscayne Bay region, where continuous salinity meters maintained by Biscayne National Park are collecting data sensitive to canal flows (**Figure 12-23**) within the same time period (see the *Salinity Monitoring in the South-Central Nearshore Area of Biscayne Bay* section). These complementary datasets can be used in the development of models that predict salinity variations in nearshore environments more accurately than currently available models.

NEARSHORE BISCAYNE BAY STUDIES

Recently, a number of principle studies conducted through the District have added to the current collective knowledge of the nearshore areas of south-central Biscayne Bay, the main area targeted for restoration through CERP's Biscayne Bay Coastal Wetlands Project. These studies are summarized below.

Restoration of the Black Creek Coastal Wetlands and Adjacent Nearshore Estuarine Zone of Biscayne Bay

The purpose of this study was to determine the freshwater requirements for coastal and nearshore restoration alternatives of an area known as Black Point wetlands. Results of the study provided estimates of the daily volume of fresh water required to rehydrate the coastal wetlands and provide an estuarine zone in Biscayne Bay during both wet and dry seasons (**Table 12-9**). However, these discharge volumes could vary by 50 percent, due to the normal daily variation of most of the calculation parameters addressed, as well as the availability of stormwater retention volume, system bypass capabilities, gradient, and the head at the treatment discharge sites. Discharged volumes also could vary depending on the type of restoration attempted; whether sheetflow or creek rehydration is a priority objective, or some ratio between the two types.

Table 12-9. Estimates of the volume (acre-feet/day) of fresh water required to rehydrate the coastal wetlands. The calculation was based upon estimates for water losses (evapotranspiration, potential evaporation, tidal volume lost daily), bay volume and water replacement times, Biscayne Bay salinity, and water gains (rainfall and groundwater discharge) and assumed spring tide conditions in the wet and dry seasons.

Hydrology Restoration	Wet Season Salinity = 5–15 ppt	Dry Season Salinity = 10–19 ppt
Tidal Creeks Only	94.8	69.8
Tidal Creeks and Wetlands	1,139.4	209

Biscayne Bay Coastal Community Performance Measures

Baseline fish and macroinvertebrate communities' conditions and abundance in the coastal and nearshore areas of southern Biscayne Bay are being characterized. A third year of collaborative studies continued the project. A primary objective is to use the results to relate salinity habitat to species abundance and location. Objectives of this project are to:

1. Quantify fish and macroinvertebrate density and diversity in the shallow nearshore habitat in central and southern Biscayne Bay.
2. Compare pink shrimp population dynamics between a shallow (< 1 m) water nearshore zone and the deeper (> 1 m) zone.
3. Evaluate the influence of salinity on fish and macroinvertebrate community structure and pink shrimp population dynamics in Biscayne Bay. Some of the preliminary findings are listed below.

The findings of this study to date include the identification of the following dominant and abundant fish and invertebrate species in the shallow water nearshore zone:

Fishes
Lucania parva (rainwater killifish)
Lagodon rhomboides (pinfish)
Eucinostomus gula (silver jenny, a mojarra)

Shrimp
Farfantepenaeus duorarum (pink shrimp)
Thor manningi (grass shrimp)
Hippocampus zostericola (grass shrimp)
Thor floridanus (grass shrimp)

Crabs
Eurypanopeus (mud crab)
Clibanarius (hermit crab)
Callinectes similes (lesser blue crab)
Callinectes sapidus (blue crab)

All of these species are important constituents of other similar shallow water systems in South Florida. Greatest numbers occurred in shallow inshore waters, less than about 1 m deep. Initial analyses suggest that the influence of salinity in the distribution and abundance of dominant fauna in the study area is small compared to that of benthic habitat and other unknown factors. Salinity explains only a relatively small proportion of the variance in density for the dominant species observed thus far.

Salinity Monitoring in the South-Central Nearshore Area of Biscayne Bay

Biscayne National Park has deployed 45 continuous recording salinity meters, seven of which were positioned at locations adjacent to the shoreline (**Figure 12-24**). The purpose of this project is to document salinity ranges that occur in the shallow waters near coastal wetlands. Until now, very little salinity data have been collected in this critical area of Biscayne Bay. General statistics of the data qualified to date are in **Table 12-10**.

Table 12-10. Salinity statistics (ppt) from recorders adjacent to the mainland wetlands in Biscayne National Park (BNP).

Station	POR	Mean	Stdev	Median	Min	Max
M1/14	4/16/04-2/15/05	25.4	10.7	26.7	2.0	44.0
M2/22	4/16/04-1/3/05	25.3	10.2	25.8	3.0	43.2
M3/28	4/16/04-2/22/05	25.2	10.2	25.9	1.4	44.2
M4/40	4/20/04-2/22/05	24.7	10.7	24.9	1.8	45.7
M5/50	4/20/04-2/16/05	28.3	9.4	29.5	6.7	45.4
M6/56	4/20/04-2/16/05	29.5	9.2	30.2	8.1	46.4
M7/62	4/21/04-2/16/05	28.8	6.5	29.0	0.3	43.0

Note: Examination of salinity measured at three stations located at increasing distance from shore indicate high variability within monthly timescales (**Figure 12-29**) that is not captured in the monthly DERM sampling.

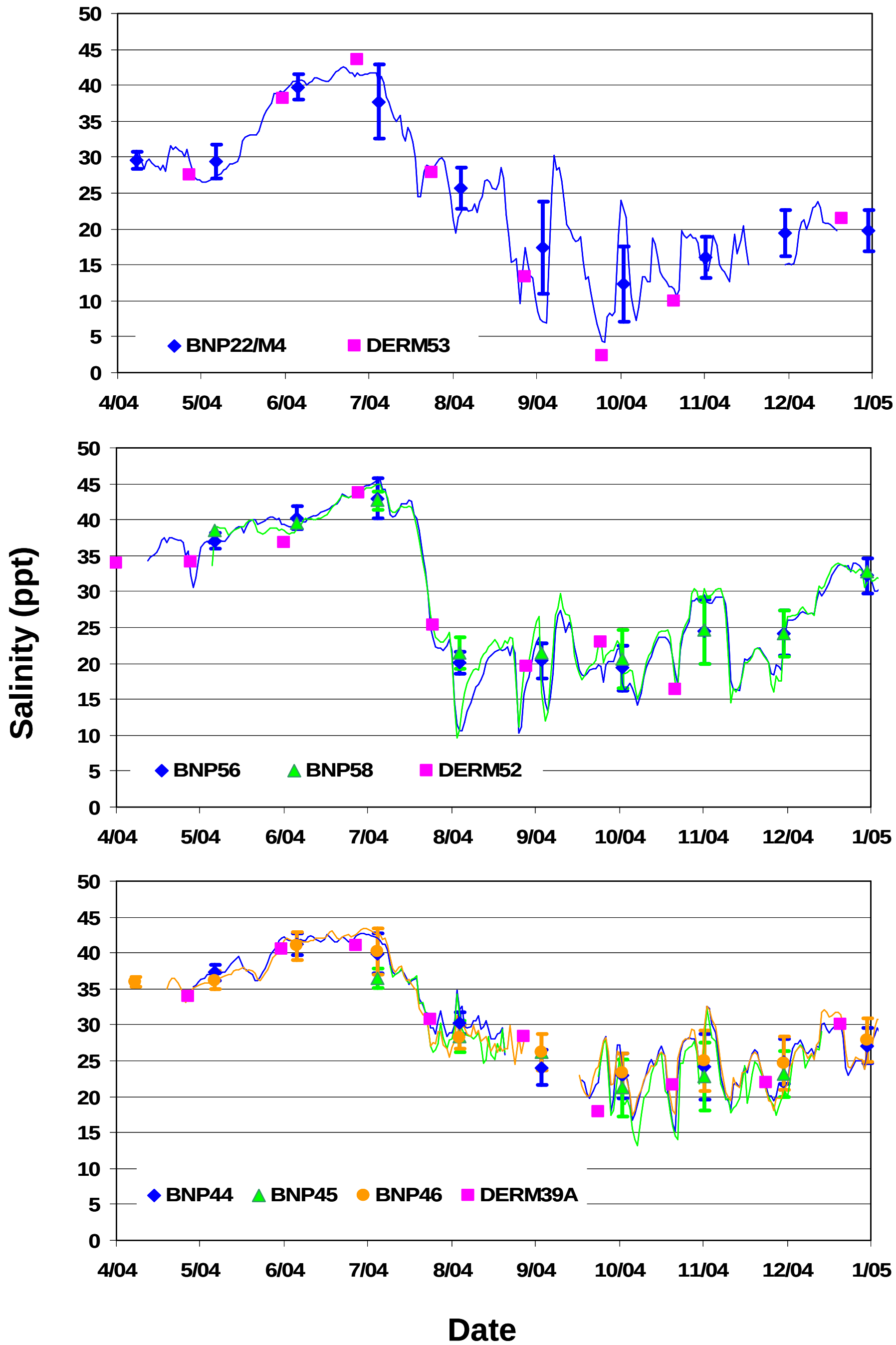


Figure 12-29. Comparison of BNP station average daily salinity (lines) and average monthly salinity (symbols with error bars – standard deviation) to monthly DERM salinity measurements (pink squares) during WY2005.

Detection, Mapping, and Characteristics of Groundwater Discharges to Central and South Biscayne Bay

The purpose of this study was to document locations of active subterranean springs in Biscayne Bay and to characterize the spring water. The study ended in December 2004. Researchers documented about 19 locations where groundwater upwelling was focused enough to identify, at least qualitatively. One hole was about 2 to 3 m in size. Salinity in the water emanating from this hole, and one other hole varied, but fell below 10 ppt regularly. Future work is needed to (1) quantify freshwater flows into the bay from subterranean spring sources and (2) characterize water quality of these flows for determination of nutrient and toxicant loads into the bay from these freshwater sources.

Biscayne Bay Paleoecological Salinity Study

A primary component in any restoration plan is the identification of a restoration target; a condition, or set of conditions, that existed in the past, and to which an ecosystem may be returned or restored. Because the hydrology of South Florida ecosystems has been altered by human activity over the last century, little quantitative information exists on the ecosystems prior to the hydrologic changes. Knowledge and understanding of historic environmental conditions is an important first step in the development of water management alternatives for the purpose of ecosystem restoration. An ongoing study by the USGS' Ecosystem History of Biscayne Bay Research Project, has utilized sediment core dating techniques to focus on (1) examining historical changes in the Biscayne Bay ecosystem at selected sites on a decadal-centennial scale and (2) correlating these changes with natural events and anthropogenic alterations in the South Florida region. Specific emphasis is being placed on historical changes to (1) amount, timing, and sources of freshwater influx and the resulting effects on salinity and water quality; (2) shoreline and subaquatic vegetation; and (3) the relationship between sea-level change, onshore vegetation, and salinity. A total of 11 sediment cores from central and southern Biscayne Bay have been analyzed, six collected specifically for the current project (Wingard et al. 2003; Wingard et al. 2004).

A general trend has emerged from the multiproxy analyses of all the cores examined – increasing salinity during the twentieth century. Although the timing and onset of increased salinity varies at the different core sites, there are no exceptions to this trend. In the nearshore sites, the increase in average salinity has been accompanied by an increase in variability of salinity. In contrast, the central bay sites have shown increasingly stable salinity over the last century, indicated in part by the influx of increasing numbers of marine species. These trends could be a result of several factors including rising sea level; changes in fresh water flow into the bay either through surficial or groundwater processes; changes in average rainfall or rates of evaporation; changes in sedimentation rates; or a combination of factors. The timing of changes at some of the nearshore sites suggests that both anthropogenic and natural factors were involved.

CONCLUSIONS AND RECOMMENDATIONS

It is recognized that additional hydrologic and ecologic research, data, and information is needed to more adequately focus on and address specific water resources issues in Biscayne Bay. Models used as tools in the development of possible water management alternatives require more accurate and detailed data to improve the accuracy of their predictive capabilities in terms of the impacts of the quantity, quality, timing, and distribution of freshwater flows into Biscayne Bay on the bay ecosystem. However, due to ever-increasing resource limitations (i.e., funds and staff), these issues are not currently being addressed at this time.

FLORIDA BAY AND FLORIDA KEYS

INTRODUCTION

Florida Bay covers a triangular area of 2,200 square kilometers at the southern tip of the state, between the Everglades and the Florida Keys (**Figure 12-30**). About 80 percent of this estuary is within the Everglades National Park (ENP). The bay is shallow, with an average depth of about 1 meter. Much of the bay's bottom is covered by seagrass, which is habitat for many invertebrate and fish species. Starting the in late 1980s, a series of ecological changes were apparent, including widespread seagrass die-off, the occurrence of algal booms and high turbidity in what had been clear waters, widespread mortality of sponges, and decreases in some other invertebrates and fish species (Fourqurean and Robblee, 1999). It is generally thought that historical decreases in freshwater inflow from the Everglades and resultant increases in salinity have contributed to these ecological changes. The role of changing nutrient inputs on the ecosystem are less clear, but also may have contributed to long-term ecological changes (Rudnick et al. 2005).

The District has sustained a program of monitoring, research, and modeling since the early 1990s to better understand the importance of water management as a driver of these and other ecological changes, to improve the ability to predict the impacts of changing water management, and to improve management structures and operations for the protection and restoration of the Florida Bay ecosystem. During WY2005, five projects/programs related to Florida Bay have been particularly active: (1) Florida Bay Minimum Flows and Levels, (2) Combined Structural and Operational Plan (CSOP) of the Central and Southern Florida Flood Control (C&SF) Project, (3) CERP's Florida Bay and Florida Keys Feasibility Study (FBFKFS), (4) RECOVER, and (5) Florida Keys Stormwater and Wastewater Program.

ENVIRONMENTAL ASSESSMENT CRITERIA

Hydrologic and ecological performance measures pertaining to Florida Bay have been adopted by three separate CERP projects: RECOVER, FBFKFS, and the C-111 Spreader Canal Project. These may be found in detail at www.evergladesplan.org. For the purposes of describing the environmental condition of Florida Bay during WY2005, we have focused on salinity, water quality, and seagrasses.

ENVIRONMENTAL CONDITION OF FLORIDA BAY

Precipitation and Freshwater Flow to Florida Bay

Inputs of fresh water to Florida Bay via rainfall and Everglades runoff were very low in WY2005. Eastern bay rainfall was calculated as the mean of Little Madeira and Duck Key stations and central bay rainfall was calculated as the mean of Whipray Basin and Terrapin Bay stations (**Figure 12-30**). During WY2005, eastern and central Florida Bay had precipitation totaling only 27.8 and 23.8 inches, respectively compared to recent annual average totals of 44.5 and 47.0 inches (WY1997–2004) in the eastern and central bay. Precipitation totals were well below average for the rainiest months of June, August, and September yielding a large rainfall deficit for the water year as a whole. Rainfall was also unusually low over the southern Everglades (40.2 inches, see Chapter 5 of the 2005 SFER – Volume I), but higher than over the bay itself.

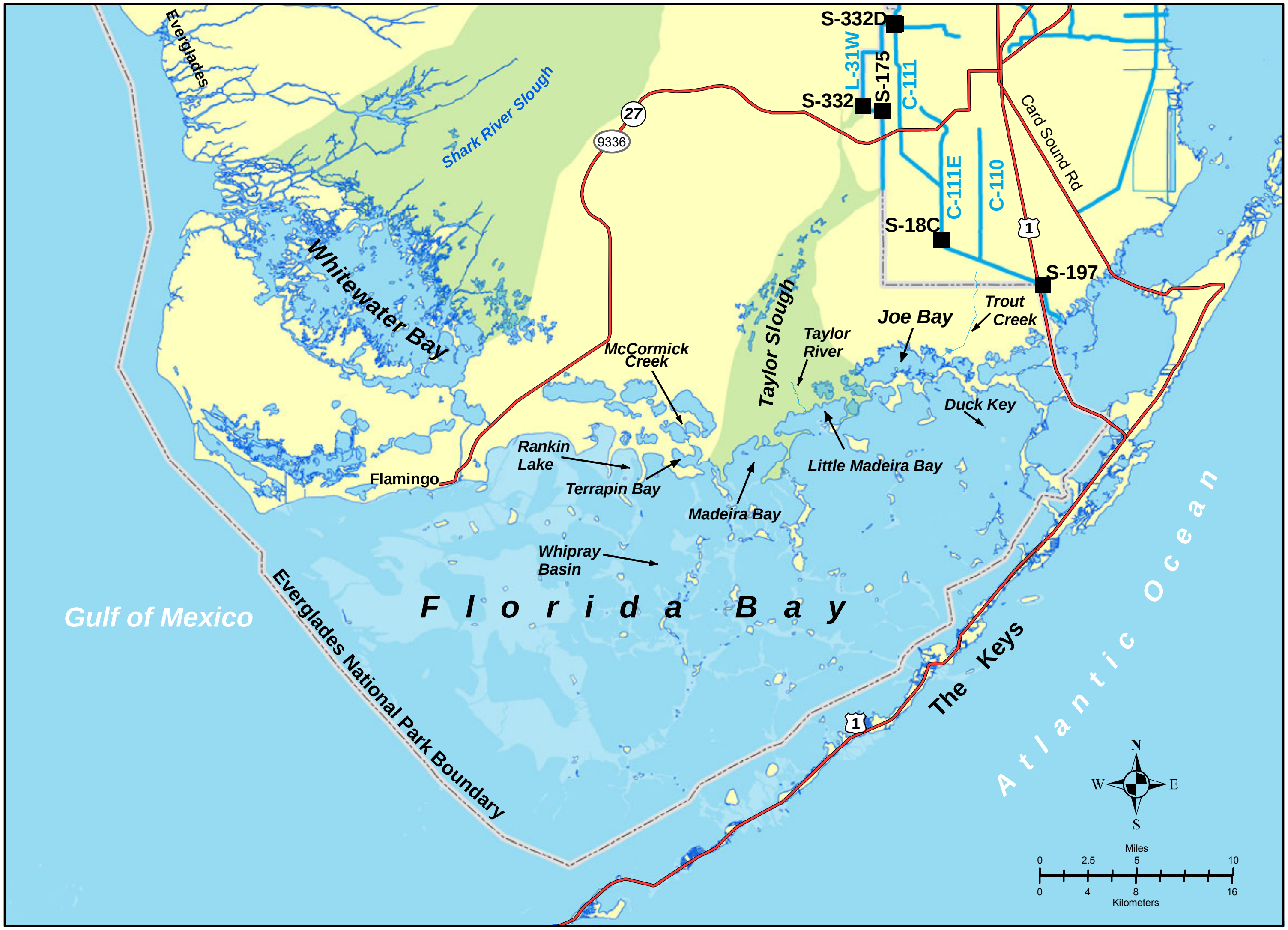


Figure 12-30. Geographic location of Florida Bay and Florida Keys.

Discharges into the ENP wetlands from canals that are likely to impact freshwater flow into Florida Bay are presented in **Figure 12-31**, comparing monthly flows during 2005 to average monthly flows over the period of 1997–2004 (note that this period of record was chosen because the USGS measurements of flows into Florida Bay started in 1996). Flow into the Everglades panhandle was calculated from the C-111 structures as flow at S-18C minus flow through S-197. Flow into Taylor Slough from canals was calculated as the sum of discharge from the L-31W structures, either as S-332 plus S-175 (from 1997–1999) or S-332D plus S-174 (from 2000–2004), into ENP at the Taylor Slough headwaters. Similar to the trends in rainfall described above, discharge from these canals was very low in WY2005, especially during the early part of the wet season (**Figure 12-31**). Annual combined flow for the Taylor Slough and C-111 structures in WY2005 was only 253 million m^3, compared with the long-term (1985–2004) annual average of 364 million m^3. This historic average includes the low flows of the drought years 1990 (120 million m^3) and 1991 (150 million m^3).

Flows from three major creeks that flow into the bay, Trout Creek and Taylor Creek (both flowing into the eastern bay) and McCormick Creek (flowing into the central bay), are shown in **Figure 12-32**. As described for the flows into the wetlands (through the Taylor Slough and C-111 structures), very little fresh water flowed from the wetlands into the bay through these creeks in WY2005, especially during the earliest part of the water year (May–July). Trout Creek had much higher flow than the other two creeks, with an annual discharge of 67 million m^3 in WY2005. While still serving as the major contributor of flows into the bay, Trout Creek saw just over one-third of its long-term (WY1997–2004) average annual discharge of 197 million m^3. This flow deficit was evident during nearly all months of the water year, especially in the wet season, when there were unusual periods of reverse flow (bay water moving into the creeks). Discharge at the mouth of Taylor River measured 22 million m^3, while flow through McCormick Creek was just over 8 million m^3 for WY2005 (compared to long-term averages of 37 and 18 million m^3, respectively). These creeks also had reverse flows (bay water flowing into the wetlands) during the months of June and July, when fresh water is typically moving out toward the bay.

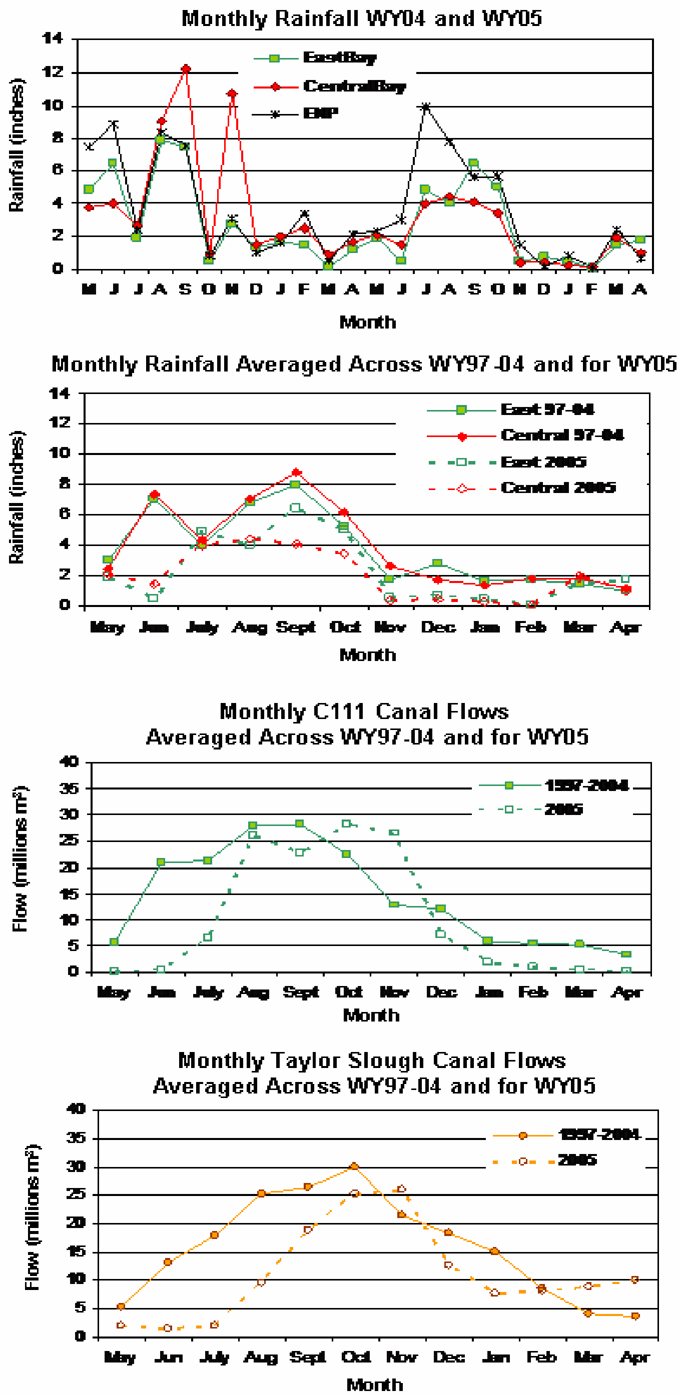


Figure 12-31. Sources of freshwater input to Florida Bay, with rainfall over the southern ENP and over eastern and central Florida Bay, as well as flow from canals into the southern Everglades.

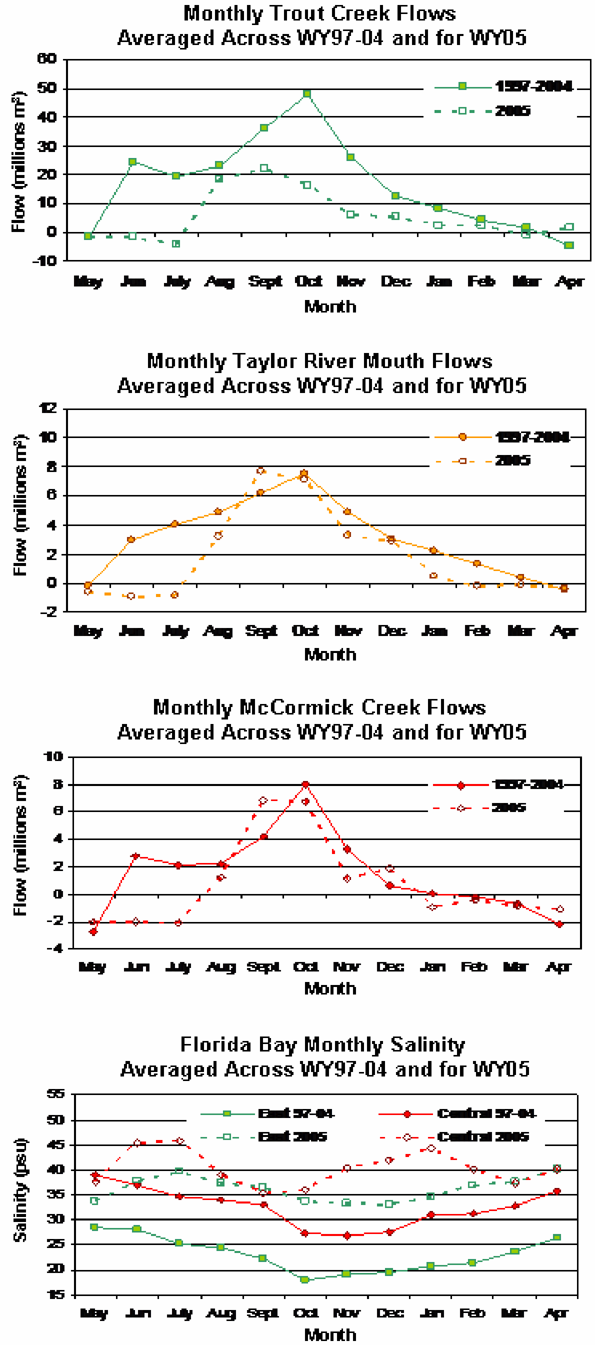


Figure 12-32. Flow of water into Florida Bay from the Everglades through three major creeks (USGS measurements) and salinity in eastern and central Florida Bay.

Freshwater flow into Florida Bay through mangrove creeks was very low in WY2005 and considerably lower than freshwater flow into the southern Everglades from canals. Inputs to the wetlands in WY2005 were 253 million m^3 and outputs from these wetlands to the bay (only via these creeks) was 97 million m^3 (38 percent of the discharge into the wetlands). This can be compared with the 1997–2004 annual average of 360 million m^3 discharged into the wetlands and 252 million m^3 flowing into the bay via these creeks (70 percent of the discharge into the wetlands). Based on measurements of nine mangrove creeks flowing into northern Florida Bay (most only measured occasionally), the three creeks presented here were estimated to account for about 60 percent of all creek flow (Hittle et al., 2001). Assuming this ratio existed in WY2005, this yields an estimated 161 million m^3 of creek flow towards the bay, or 91 million m^3 less than the discharge into the wetlands from canals. This water deficit is likely caused by evaporation exceeding precipitation and lower contributions from other Everglades water sources (groundwater seepage and sheetflow from northeast Shark Slough). Results from WY2005 are in contrast to those from WY2004, when estimated total creek flow was over 70 million m^3 higher than what was measured flowing into the wetlands from canals.

Salinity in Florida Bay

The combination of low rainfall and incoming freshwater flows in WY2005 contributed to a year of unusually high salinity in Florida Bay. Monthly average values reached as high as 46.0 practical salinity units (psu) in Whipray Basin in the central bay in July 2004 (**Figure 12-32**). Eastern Bay salinity (measured at Trout Creek, Duck Key, and Little Madeira Bay) reached 39.7 psu at that time, and remained unusually high throughout the wet season (averaging 14 psu above the long term WY1997–2004 average), such that a peak monthly mean of 40.2 psu occurred in April 2005. Daily mean salinity reached higher maxima than monthly means, reaching 52.5 psu in the central bay (July) and 42.4 psu in the eastern bay (April). These peak values were lower than values observed during the severe 1989–1990 drought, when salinities reached 63 psu and 56 psu in the central bay and eastern bay, respectively.

Water Quality in Florida Bay

Water quality monitoring in Florida Bay as well as along the mangrove rivers and estuaries of the southwest Everglades coast continued in WY2005. Nutrient analysis of monthly samples is incomplete and is only briefly described here. A more detailed description of long-term trends, including the trend of decreasing nutrient concentrations [total nitrogen (TN) and (total phosphorus (TP)] and chlorophyll *a* concentrations since 1994, is presented in Chapter 12 of the 2005 SFER – Volume I. During the first eight months of WY2005, monthly average TN was 41 µM and TP was 0.28 µM in the central bay, the region with the highest nutrient and chlorophyll concentrations. This TN concentration is only slightly higher than the minimum annual average of 34 µM, observed in 2002. This TP concentration in the central bay is lower than any annual average since monitoring began in 1991. Chlorophyll *a* concentrations (averaging 1.5 µg/L) in the central bay in WY2005 were also near record low concentrations.

Submerged Aquatic Vegetation in Florida Bay

Submerged aquatic vegetation (SAV) is central to the structure and function of Florida Bay, especially with regard to primary productivity and provision of habitat for higher trophic level species. SAV has been identified as an essential performance measure for the Florida Bay MFL, CERP, and other restoration programs. Florida Bay monitoring programs use the Braun-Blanquet (BB) cover index to track changes in benthic habitat over time. The BB index is a visually determined index of ground cover that is used to quickly quantify the density of benthic vegetation in estuarine systems without resorting to destructive techniques, such as biomass sampling. The index ranges on a scale of 0 to 5 with 0 equaling no present ground cover and 5 equaling 75 percent or greater cover.

Trends in SAV from two basins along the northeast Florida Bay coast are presented here (**Figure 12-33**). These basins, Joe Bay and Little Madeira Bay, receive much of the freshwater flow from the southeast Everglades, and the salinity of these basins is strongly influenced by this flow. As can be seen in **Figure 12-33**, Joe Bay has a consistently lower mean salinity than Little Madeira Bay, but the maximum salinity is as high, or higher, than Little Madeira; the salinity regime of Joe Bay is highly variable. The magnitude and variability of salinity strongly influences SAV species composition. Three SAV species found in the northeast zone of Florida Bay: *Thalassia testudinum*, *Halodule wrightii*, and *Ruppia maritima*. In Joe Bay, SAV cover is sparse and *H. wrightii*, a species that thrives over a wide salinity range, is the dominant species. *Ruppia maritima*, a species that thrives in low salinity (oligohaline and mesohaline) conditions, is also found in this coastal embayment. *Thalassia testudinum*, a species that thrives with marine salinity, is not present in Joe Bay, probably because nearly fresh conditions (< 1 psu) persist each wet season. In WY2005, salinity was unusually high in Joe Bay (**Figure 12-33**), which may account for the observed increase in *H. wrightii* and decrease in *R. maritima.*

The SAV community of Little Madeira Bay is dominated by *T. testudinum* and *H. wrightii*. Since 1999, *T. testudinum* cover has decreased, while *H. wrightii* cover has increased. No distinctive change in cover occurred in WY2005. Cause-and-effect relationships between salinity and density, as estimated by the BB index, are not clearly indicated. Salinity stress does not cause immediate changes in seagrass density, but rather a gradual decline that would not be evidenced in a coarse index (such as the BB index) until significant loss is incurred. In addition, the variability in the BB index caused by random sampling of spatial patchiness, makes it difficult to draw conclusions of density change in the short term. However, long-term trends are easy to detect. Both of these difficulties (the lag in effect of salinity stress and the short-term variability in the index) prevent any statements about the effect of the 2005 drought on the seagrass community in these two basins. Nevertheless, the post-1998 trend may be associated with a lagged response to relatively high rainfall and flow, with relatively low salinity, in the mid-1990s. The Florida Bay seagrass model, developed for MFLs and the Florida Bay and Florida Keys Feasibility Study, indicates that responses to salinity by *T. testudinum* and *H. wrightii* are mediated by competitive relations between these species.

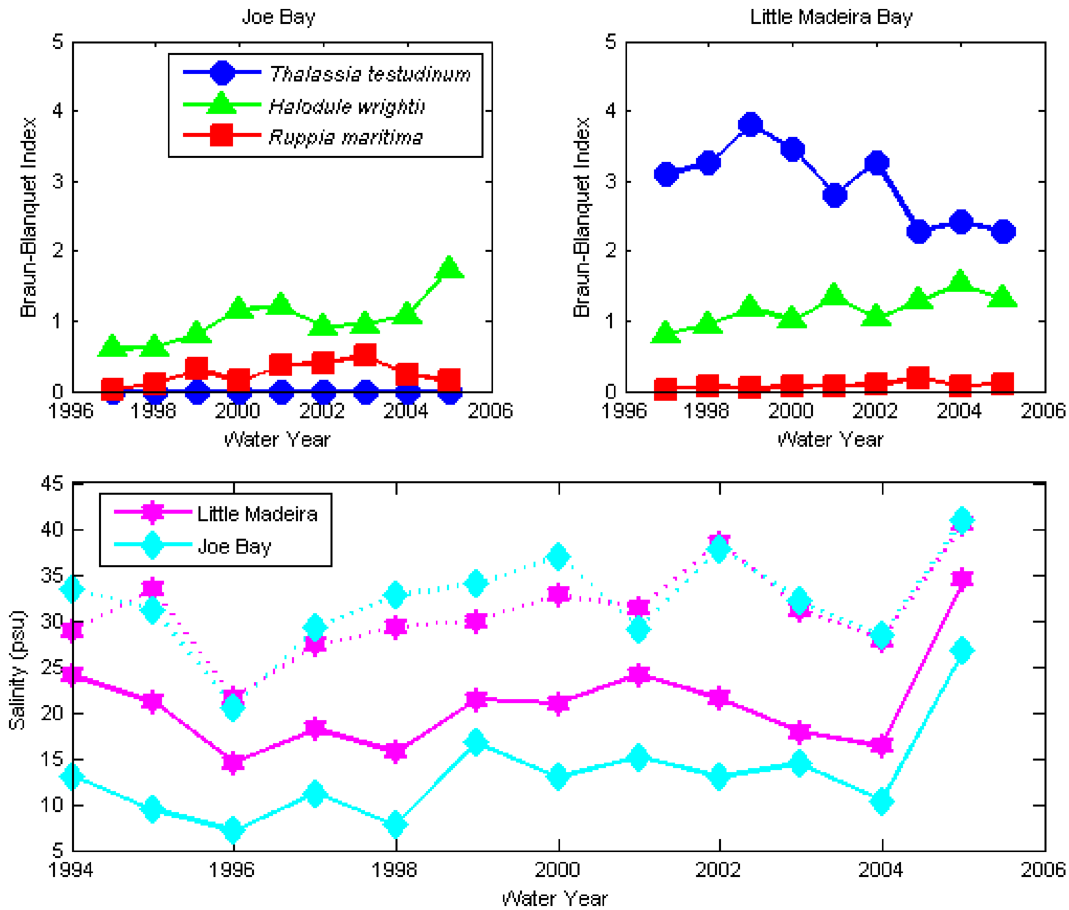


Figure 12-33. Mean seagrass cover and salinity by water year (May–April) for two basins in northeast Florida Bay: Joe Bay and Little Madeira Bay. The bottom panel shows the mean salinity (solid line) as well as the maximum daily salinity encountered each water year (dotted line). Minimum salinities in Joe Bay approach freshwater conditions in a normal year (< 1 psu), and minimum salinities in Little Madeira Bay are usually less than 10 psu.

CURRENT SCIENCE, ENGINEERING, AND RESTORATION ACTIVITIES

Scientific Activities

This section provides brief descriptions of ongoing projects intended to provide a scientific basis for the protection and improvement of Florida Bay. Progress in WY2005 included the development of several numerical models to integrate information and provide predictive power.

The District's scientific program for Florida Bay is part of a coordinated interagency effort to provide a sound scientific basis for management and restoration of the bay. The Florida Bay Interagency Program Management Committee (PMC) guides this effort, with the planning, coordination, communication, and review of monitoring, research, and modeling. Such a collaborative program helps the District by minimizing information gaps and costs, and maximizing information quality and sharing. Additional documentation on the Florida Bay program can be found online at www.aoml.noaa.gov/flbay/.

The District's emphasis within the PMC program is on water quality monitoring, nearshore seagrass monitoring (in areas most affected by water management), measuring and assessing how changing freshwater flow affects nutrient loading, water quality, and plant community responses in the salinity transition zone (mangrove zone) and nearshore waters, and modeling seagrass community dynamics.

During the past year, program-related efforts have included the following:

- Continuation of water quality monitoring at fixed stations in the bay, and along the southwest coastal estuaries [contract with Florida International University (FIU)].
- Continuation of seagrass monitoring in southern Biscayne Bay and northeast Florida Bay coastal basins (contract with Miami-Dade Department of Environmental Resource Management).
- Upstream monitoring of Taylor Slough and C-111 basin water quality, periphyton, and plant community status (contracts with FIU, ENP, and SFWMD staff).

  This project has produced an extensive dataset on nutrient concentrations in the waters of the southern Everglades, marsh plant productivity and species composition, and soil salinity and nutrient characteristics as well as nutrient discharges to Florida Bay (see below). A final report from the FIU contract and related data files were delivered. The report presents an analysis of water quality and wetland habitat quality from data collected over periods of three to seven years, capturing responses to natural and managed changes in the environment. Results indicate that water quality is good in water flowing over the marsh, and that plant and periphyton communities in the southern Everglades are in good health. Increasing water depths may be promoting a shift from *Cladium* (sawgrass) to *Eleocharis*.
- Monitoring of freshwater and nutrient discharge from mangrove creeks into Florida Bay (contract with FIU, in cooperation with the USGS).

- Fate of dissolved organic nutrients that flow into Florida Bay from the Everglades (Coastal Ecosystem Division research).

  Most of nitrogen flowing into the bay from the Everglades is in the form of dissolved organic nitrogen (DON). The effect of this form of nitrogen on the bay, particularly the potential to stimulate phytoplankton blooms, depends upon the rate at which this dissolved organic matter is decomposed by microorganisms minus its bioavailability. Research on DON bioavailability is called for as part of the RECOVER Monitoring and Assessment Plan and is also needed as a parameter of the Florida Bay water quality model for CERP's Florida Bay and Florida Keys Feasibility Study. Experiments on DON bioavailability by the SFWMD continued during WY2005, but results are incomplete at this time. Preliminary results appear similar to those from earlier experiments, which found about 15 percent of the dissolved organic matter from a mangrove pond north of the Florida Bay coast was bioavailable, with decay rates of about 1 percent per day to 2 percent per day (see Chapter 12 of the 2005 SFER – Volume I for details).

- Application of rapid, fine scale water quality mapping technology for monitoring nearshore conditions (SFWMD), including four coastline surveys during WY2005.

- Measurement of diel DO metabolism in Florida Bay (cooperative work with the University of Maryland) to provide data for FBFKFS water quality model.

- Literature and data review of submerged aquatic vegetation in Florida Bay and water bodies within salinity transition zone (saline wetlands) between the bay the southern Everglades, detailing response of *Thalassia*, *Halodule*, *Syringodium*, *Ruppia* and selected macroalgae species to high salinity. This review is a contribution to the MFL report.

- Continued development of dynamic model of seagrass community (SFWMD with grant from USGS and ENP). This model is being applied to the MFL and FBFKFS and is described in more detail below in the MFL summary.

- Field measurement of nearshore seagrass productivity and respiration (three sets of dissolved oxygen measurements by SFWMD in WY2005) to support model development.

- Laboratory measurement of salinity, sulfide, and temperature effects on seagrass productivity, respiration, and mortality [contract with Florida Atlantic University (FAU)] to support simulation model development.

  This project has provided an in-depth analysis of responses of *Thalassia* and *Halodule* in Florida Bay to various ecological stresses. Two interim reports were submitted during WY2005. The project demonstrates the importance interactive stress factors – that high salinity makes seagrasses more susceptible to other stresses, such as thermal stress and sulfide toxicity.

- Measurements of phosphorus allocation and partitioning in *Thalassia* plants in situ in Florida Bay [work done in cooperation with FAU; funded by National Oceanic and Atmospheric Administration (NOAA)] is supporting seagrass model development.

- Development and application (for MFL) of a mass balance hydrologic model, Flux Accounting and Tidal Hydrology at the Ocean Margin (FATHOM) to predict Florida Bay salinity (contract with Environmental Consulting and Technology, Inc.).
- Development of wetland hydrologic model Tides and Inflows in the Mangrove Ecotone (TIME) for southern Everglades (contract with USGS) for FBFKFS.
- Development of hydrodynamic models for Florida Bay EFDC and boundary oceanic waters Hybrid Ocean Coordinate Model (HYCOM) (contracts with Tetra Tech and NOAA) for FBFKFS.
- Literature and data review of higher trophic levels in Florida Bay, detailing the relationship of salinity to snook, grey snapper, bay anchovy, spotted sea trout, and pink shrimp (for MFL report).
- Development of statistical models of Florida Bay fish species and juvenile pink shrimp for MFLs and roseate spoonbill statistical model for CSOP (contracts with NOAA and National Audubon Society).
- Continued interagency scientific collaboration through the Florida Bay PMC; continued participation in the Florida Coastal Everglades Long-Term Ecological Research (FCE-LTER) program (including design of future long-term experiments).

Restoration Activities

FLORIDA BAY MINIMUM FLOWS AND LEVELS

A draft report providing a technical basis for Minimum Flow and Level criteria recommendations was completed over the last year. Florida Bay is a priority water body for the development of an MFL under Section 373.042(2), F.S. The District committed to the state that rules would be developed in 2005, in conjunction with water supply plans, to protect Florida Bay from significant harm. Drafting an MFL technical report was the sole responsibility of the Coastal Ecosystems Division and the highest priority of the Division's Florida Bay unit in WY2005. MFL analyses included literature and data reviews and synthesis, model development, and model application. The types of models used for this project were: statistical models of Everglades water levels and nearshore salinity, mass-balance hydrologic models of the southeastern Everglades and Florida Bay (PHAST and FATHOM), statistical models of salinity and SAV, a dynamic model of the Florida Bay seagrass community, and statistical models of major fish and invertebrate species. Analyses with these models has pointed toward a salinity threshold in the mangrove-dominated salinity transition zone, and in northeastern Florida Bay, that triggers the loss or degradation of SAV habitat and can be used to for designation of significant harm to the greater bay ecosystem. A summary of highlights from this study are presented below (also, see ftp://ftp.sfwmd.gov/pub/rbennet/docs/FLBayMFL_TechCrit.pdf).

COMBINED STRUCTURAL AND OPERATIONAL PLAN

During the past year, alternative CSOP designs have been tested via hydrologic modeling. Performance measures for Florida Bay have included salinity values (minimizing hypersalinity and maximizing the frequency of low salinity, with target ranges specific for a given basin; and the timing of salinity change, with a target of minimizing early dry season salinity values). Baseline information for this plan and its implementation is being provided by ongoing hydrologic, water quality, and biological monitoring in Taylor Slough, the C111 basin, and in Florida Bay.

FLORIDA BAY AND FLORIDA KEYS FEASIBILITY STUDY

The Florida Bay and Florida Keys Feasibility Study (FBFKFS) of CERP is the cornerstone of Florida Bay restoration. The purpose of the FBFKFS is to evaluate the ecological state and needs of Florida Bay, determine the sufficiency of the current CERP projects and operations to meet these needs, and recommend any modifications that may be needed to restore the bay ecosystem. The FBFKFS includes the development of hydrologic, hydrodynamic, water quality, and ecological models that will provide the District with the ability to predict responses to changing freshwater flow, nutrient inputs, or potential physical alterations, such as the removal of fill between the Florida Keys. During the past year, hydrodynamic models of Florida Bay (EFDC) and adjacent oceanic waters (HYCOM) and a hydrologic model of the southern Everglades (TIME) were developed. These physical models will provide inputs to a water quality model and biological models that will be completed within the next two years. Portions of a Florida Bay seagrass community model (for two of the four major species) were completed this year and will be briefly described in the MFL section of this chapter.

RECOVER

Portions of RECOVER's Monitoring and Assessment Plan were implemented during the past year (see CERP/RECOVER, Chapters 7A and 7B of this volume, respectively). For Florida Bay and the southern estuaries, this includes SAV and higher trophic level species monitoring. One key component of the MAP was the identification of key uncertainties that need to be addressed. One of these uncertainties [the fate and effect of Everglades dissolved organic nitrogen (DON) in Florida Bay]has been the focus of research during the past year. Experiments have been run to determine the decomposition rate (bioavailability) of this DON and how this rate varies as a function of freshwater source, phosphorus availability, and sedimentary particles. Addressing the uncertainty of DON bioavailability is necessary because of concerns that increased freshwater flow with restoration will also increase nitrogen loading and algal blooms in the bay.

FLORIDA KEYS STORMWATER AND WASTEWATER PROGRAM

Water quality improvements for the Florida Keys marine environment and protection of their coral reefs have been central to plans adopted by the federal, state, and county governments. During the past year, the District has executed contracts to help implement the Water Quality Protection Plan for the Florida Keys National Marine Sanctuary (sanctuary). These contracts will improve stormwater treatment at several sites in the Florida Keys and include: (1) Stormwater Improvement Project (City of Marathon); (3) Canal Water Quality Improvement Project (Village of Islamorada); and (3) New Stormwater Management Systems (Monroe County).

In addition, the District continues to function as the local sponsor with USACE for the $100M FL Keys Water Quality Improvements Program (FKWQIP). The primary objective of this program is to improve the quality of nearshore waters within the sanctuary, the nation's largest marine-protected area. Up to $100M in federal funding has been authorized to carry out projects for the planning, design, and construction of wastewater and stormwater treatment works within the sanctuary. The Program Management Plan (PMP) and the Final Programmatic Environmental Impact Statement (PEIS) for the FKWQIP were both completed this year.

Highlights of Florida Bay Minimum Flows and Levels Analyses

As described above, development of a technical basis for MFL criteria recommendations was a top priority for the Coastal Ecosystems Division in WY2005. An overview of the approach leading to these recommendations is as follows:

1. Hydrologic models were used to develop a water budget and predict surface water flows and salinity response from ponds in the Everglades-Florida Bay transition zone downstream into Florida Bay.
2. The ecological effects of salinity levels were evaluated along a gradient representing three zones of Florida Bay: the Everglades-Florida Bay transition zone, the northeastern coastal embayment area, and the open water area of northeastern Florida Bay. This area is the focus because a relationship between inflow and salinity could be established.
3. *Ruppia maritima,* a dominant SAV species in the salinity transition zone, was selected as an indicator of the transition zone and Florida Bay. When salinity conditions are too high to allow *R. maritima* survival in the transition zone, the loss of the all SAV habitat in this zone is an expected consequence (other SAV species in this zone are less salinity tolerant).
4. A link between the ecological health of *R. maritima* in the transition zone and concurrent effects on Florida Bay seagrass communities is presented. When high salinity events cause the loss of *R. maritima* within the Everglades-Florida Bay transition zone, negative ecologic impacts to northeastern Florida Bay can also be inferred, based on ecologic modeling of the SAV and higher trophic level species.
5. Based on these results, a definition of significant harm was developed for Florida Bay.

Portions of MFL technical analyses are briefly described below.

MFL Hydrologic Modeling

A simple hydrologic model (FATHOM) was refined and applied for Florida Bay MFL development during WY2005. FATHOM is based on mass balance calculations for water and salt in a set of bay basins (Cosby et al., 1999). FATHOM simulates monthly salinity distribution and variation in Florida Bay based on hydrologic inputs that include monthly rainfall, evaporation, runoff, sea level and salinity, and hourly tides at the model boundaries. Inputs were updated to include spatially distributed rainfall and tides and direct measurements of freshwater runoff, reflecting a significant improvement in detail and reliability of the model (Cosby et al., 1999). For the salinity transition zone along the northern Florida Bay coast, salinity was estimated by a multiple linear regression (MLR) (Marshall, 2004).

These models were used to estimate a 31-year historical record (1970–2000) of inflows and corresponding salinities. This period included low-flow and high-flow conditions, resulting from weather patterns and low-flow due to water management activities. Analysis of historical data indicated that high salinity periods (associated with significant ecological harm) occurred five times during this 30-year period at the Taylor River site. Further analyses were conducted to estimate inflow of fresh water to Florida Bay during, and prior to, these high salinity periods. Salinities generally exceeded 30 psu in the transition zone during periods when flows entering northeastern Florida Bay were less than 128 million m^3/y and less than 4.3 million m^3 during the preceding three-month period.

MFL Analysis of Transition Zone SAV

Submerged aquatic vegetation habitat of the Everglades-Florida Bay salinity transition zone is sensitive to salinity, with loss of all major species (*Ruppia maritima*, *Chara* sp., *Najas* sp., and *Utricularia* sp.) occurring above 30 psu. *Ruppia maritima*, the dominant vascular SAV of this region, is the most salinity tolerant of this assemblage. The loss of this species occurs near 30 psu and is not only related to mortality of seedlings and adult plants, but also to inhibition of seed germination and reproductive success above this salinity level. A laboratory germination study using *R. maritima* seeds from Florida Bay (Koch and Durako, 2004) showed that seed germination did not occur at any salinity treatment higher than 30 psu, even when salinity was slowly increased to allow time for acclimation *Ruppia* is proposed as an indicator species for MFL criteria development.

MFL Analysis of Florida Bay SAV – Simulation Modeling

An ecological simulation model of the Florida Bay seagrass community was developed to project seagrass growth and species composition under various salinity regimes and management strategies. The initial version of the model includes two interacting species, *Thalassia testudinum* and *Halodule wrightii*, and has been calibrated for six Florida Bay basins: Little Madeira Bay, Eagle Key Basin, Duck Key, Rankin Lake, Trout Cove, and Rabbit Key Basin. The model consists of coupled ordinary differential equations of the following variables: *Thalassia* aboveground and belowground biomass, *Halodule* total biomass, epiphytes, water column dissolved phosphorus, and sedimentary pools of organic carbon and phosphorus. Forcing variables include temperature, salinity, light, P inputs, and water column and porewater dissolved nitrogen. For MFL analyses, salinity inputs were FATHOM model outputs.

The seagrass model was used to produce a 31-year retrospective simulation of SAV trends, which showed clear responses of seagrasses to salinity (**Figure 12-34**) as *Thalassia* became dominant during periods when salinity was elevated. During the three periods of the simulation, when salinity remained above 40 psu for two or more consecutive years at the inner Little Madeira site, *Thalassia* growth was favored at the expense of *Halodule*. Immediately following extended periods of elevated salinity, increased freshwater flow from Taylor Slough resulted in lowered salinities and by the late 1990s, *Thalassia* was nearly eliminated from the Little Madeira Bay site. These dynamics differ from what would be expected based on mesocosm experiments on salinity tolerances, which indicated that *Halodule* is at least as tolerant of high salinity as *Thalassia*. The difference between results in single species experiments and numerical modeling is probably a consequence of interspecific interactions; the model implies that salinity effects are the indirect result of effects on competition between *Thalassia* and *Halodule* (e.g., for nutrients and light). Under hypersaline conditions (above 40 psu), *Thalassia* is predicted to become dominant in the field, while under mesohaline conditions (less than 18 psu), *Halodule* is predicted to become dominant. Salinity values of about 40 psu in Little Madeira Bay and northeastern Florida Bay are generally concurrent with Taylor River (transition zone) salinity values of about 30 psu. Thus hydrologic conditions that result in the loss of *Ruppia* in the transition zone are also likely to result in the decline of *Halodule* in northeastern Florida Bay.

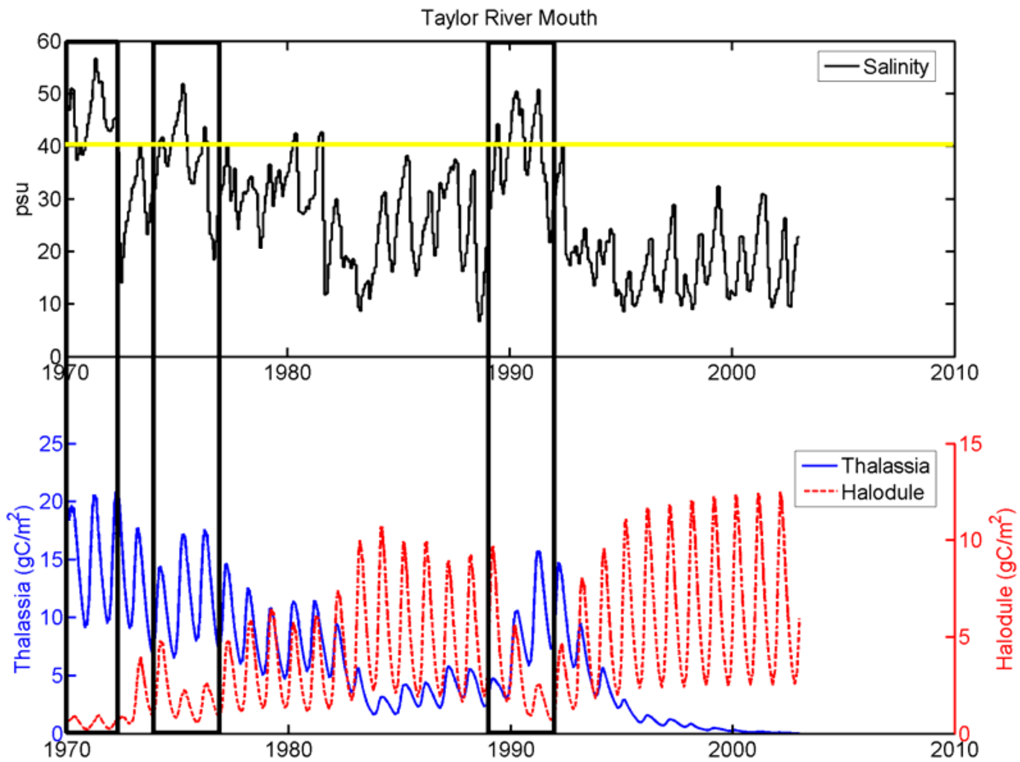


Figure 12-34. The Florida Bay seagrass model was applied to (a) Little Madeira Bay. Three periods correspond to loss of *H. wrightii* are shown in the boxed area: (1) 1970–1971 drought, (2) mid-1970s, and (3) 1989–1990 drought. In all cases, marine to hypersaline conditions prevail for > 1 year. Note: the development of monospecific *Thalassia* beds in the early 1990s and then decline in wetter years, mid-1990s.

MFL Analysis of Higher Trophic Level Species of Northeastern Florida Bay

The quantitative and qualitative composition of the SAV community appears to have an impact on many fish and invertebrate species of Florida Bay. Statistical models (General Additive Modeling) for 17 common Florida Bay forage species and 3 predator species (2 that were represented in the database as juveniles) were developed from a multi-decadal dataset (Johnson et al., 2005). Results from these models indicate not only that salinity has a significant (though widely varying) effect on these fauna, but also that almost all fauna benefit from increased *Halodule* cover. Analyses indicate that increasing salinity from mesohaline toward marine and hypersaline conditions decreases the overall abundance of the forage base for piscivorous sport fish species and birds in Florida Bay because of both direct salinity effects on these forage base species and SAV habitat loss. Maintaining an estuarine condition (salinity commonly less than marine levels) will thus be protective of both habitat and faunal resources. Combined with inferences from SAV modeling, it appears that protection of *Ruppia* in the transition zone will likely also protect northeastern Florida Bay resources (SAV habitat and fauna).

NAPLES BAY

INTRODUCTION

Located in western Collier County, Naples Bay drains a watershed of approximately 120 square miles (**Figure 12-35**). It is a relatively narrow and shallow estuarine water body ranging in width from 100 to 1,500 feet and in depth from 1 to 23 feet. The historical watershed was predominately a patchwork of swamps, marshes, and sloughs. Both the primary water inlets, including the Gordon River, Rock Creek, and Haldeman Creek, and the historic flow-ways to Naples Bay have been altered by road and drainage development over the last 40 years (**Figure 12-36**). Like many other overdrained systems, storm water runs off to tide rapidly, causing severe fluctuations in salinity. During the dry season, the estuarine character of the Bay may be compromised by lack of freshwater inflow. The following sections provide descriptions of restoration projects and resource assessment projects conducted in Naples Bay during WY2005.

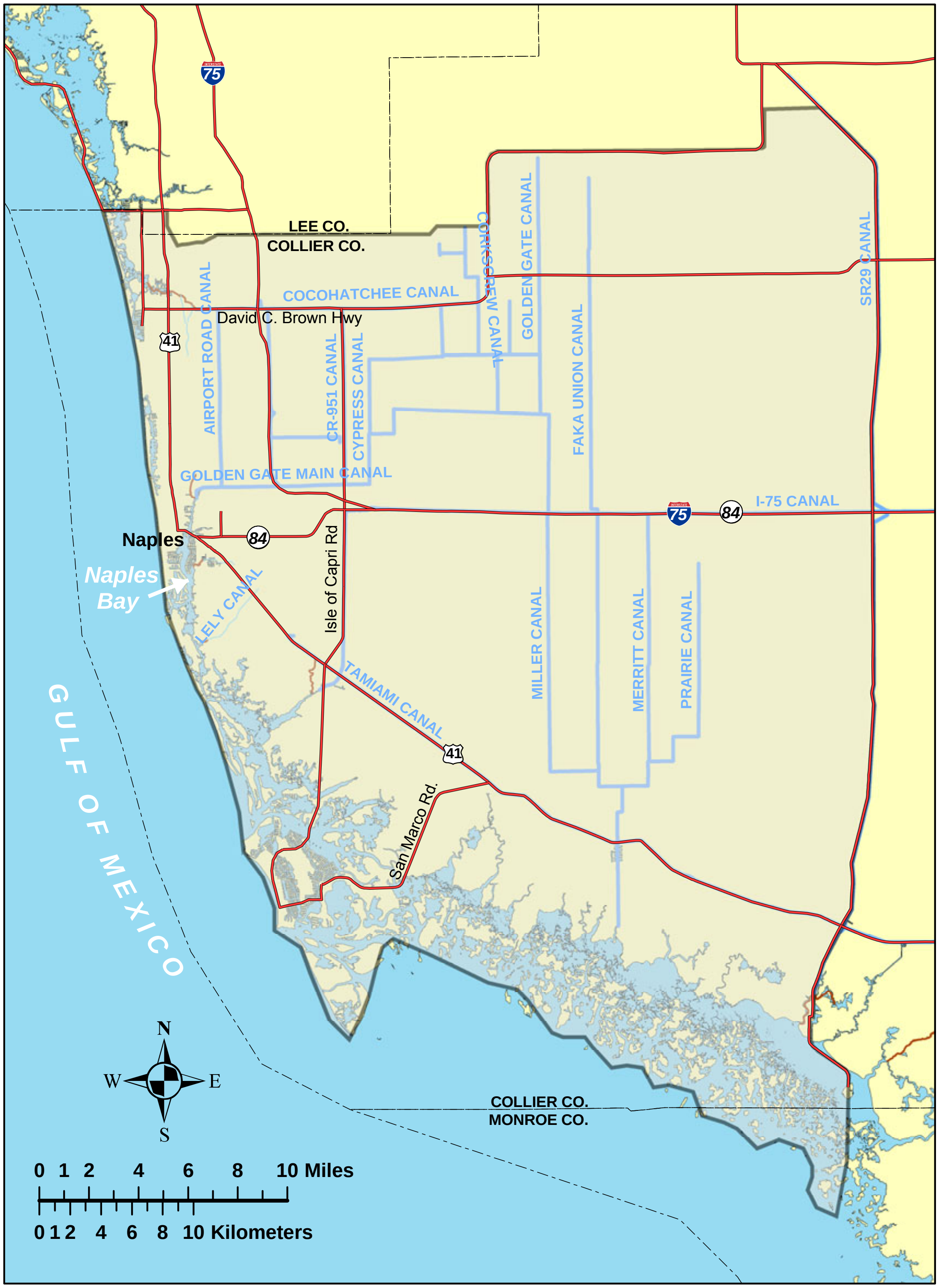


Figure 12-35. Geographic location of Naples Bay.

Figure 12-36. Naples Bay.

ENVIRONMENTAL ASSESSMENT CRITERIA

Valued ecosystem components have not been identified for Naples Bay. No hydrologic performance measures have been established for the major freshwater tributaries.

CURRENT SCIENCE, ENGINEERING AND RESTORATION ACTIVITIES

Resource Assessment

WATER QUALITY MONITORING

As part of large water quality monitoring project (South Florida Coastal Water Quality Monitoring Network) funded by the District, two stations in the Naples Bay area are sampled on a monthly basis. One station is inside the bay, while the other is in the Gulf of Mexico at the mouth of the bay; both have been sampled since 1999.

Water quality data, collected from 1965–2003, from 165 stations throughout Naples Bay and adjacent tributaries, has been compiled by Taylor Engineering into a water quality database (Appendix 12-4). Data revealed that sampling programs in the bay have been intermittent in period, location, and parameters sampled.

Assessment of current conditions was based on the water quality data from 1999 and 2003, which proved to be the most comprehensive and consistent of the entire period of record. Dissolved oxygen, nitrogen, phosphorous, copper, iron, lead, and zinc often exceed state water quality standards. Nutrient parameters also frequently exceed nutrient criteria defined for Charlotte Harbor to the north and Indian River Lagoon to the east. Chlorophyll *a* concentrations and fecal coliform counts were often elevated relative to state or regional criteria.

Examination of the entire record for water quality parameters reveals that total nitrogen in the lower bay has decreased since 1990. Additionally, the data seem to indicate that DO concentrations have decreased slightly, given the number of exceedances measured recently. However, this decrease may reflect the greatly increased sampling effort since 1999. Upper Naples Bay did not show the same change in nitrogen concentrations as seen in the lower bay. As in the lower bay samples, exceedances of dissolved oxygen standards commonly occurred throughout the record.

Less data was available from the tributaries. Golden Gate Canal showed a decline in annual median nitrogen levels since the 1990s. Other tributaries did not show that change and generally exhibited a history of water quality problems. Naples Bay and the Gordon River are on the Environmental Protection Agency’s 1998 and 2002 303(d) list of impaired waters due to DO, five-day Biochemical Oxygen Demand (BOD5), nutrients, and coliform bacteria above legislated levels. It was also concluded that there is sufficient hydrologic information to develop boundary conditions for a hydrodynamic model, but that an additional data collection program would be necessary to adequately calibrate the model. The current monthly sampling program throughout most of the bay could provide data for verification of water quality simulations. Three additional monthly water quality sample stations would be necessary to ensure complete coverage of water quality conditions and dynamics in Naples Bay.

BATHYMETRIC SURVEYS

The development of a hydrodynamic and water quality model of Naples Bay is necessary to better understand the bay for restoration and protection. To facilitate development of a useful model, updated bathymetry has been obtained. In WY2004, the District contracted Taylor Engineering to collect the bathymetric data and develop a present-day bathymetry of Naples Bay. Bathymetric maps will be available early in WY2006.

HISTORIC HABITAT DISTRIBUTION

In 2004, the District contracted the Conservancy of Southwest Florida to assess past and present distribution of estuarine communities within Naples Bay, including the seagrasses, mudflats, and oyster reefs (e.g., benthic habitats). As part of this contract, the conservancy will produce a chronological account of human development of Naples Bay and changes to the mangrove shoreline, including the timing of habitat changes as well as their effects on hydrogeological and biogeochemical cycling within the system. The final report is due in WY2006.

Restoration Activities

OYSTERS

One of the major goals of Naples Bay restoration is the protection and restoration of oyster reefs. Substrate mapping was conducted in Naples Bay in WY2005 by Florida Gulf Coast University using Chirp and side scan sonar. Through this process a number of potential oyster reef restoration sites were identified. Two sites will be chosen for shell cultch deployment by the city of Naples and Florida Gulf Coast University in WY2006: (1) in a brackish water setting, at or just downstream of the bay's junction with Haldeman Creek; and (2) at a more upstream setting, closer to the mouth of the Gordon River. Each of the cultch substrates will be seeded with approximately 10,000 juvenile oysters in the early fall of WY2006, and monitored quarterly during the first year for natural recruitment of oysters and through the second year for reef health.

SURFACE WATER IMPROVEMENT AND MANAGEMENT PLAN

The development of a Surface Water Improvement and Management Plan (SWIM) Plan for Naples Bay was authorized by the SFWMD's Governing Board in 2003. A Naples Bay SWIM Reconnaissance Report was authorized in WY2005 and will be finalized early in WY2006. The reconnaissance report characterizes the watershed, both past and present, and reviews information pertinent to the development of a SWIM plan. It is an assessment and inventory of monitoring data, modeling efforts, studies, projects, plans, and programs within the study area.

GATEWAY TRIANGLE DRAINAGE IMPROVEMENTS

The Gateway Triangle is a highly urbanized residential/commercial area adjacent to Naples Bay. The existing stormwater management facility is old, inadequate, and unable to provide relief from urban flooding. Uncontrolled/untreated stormwater runoff continues to carry heavy loads of pollutants directly into Naples Bay. In WY2005, the District provided funding to Collier County to design drainage and construction plans in order to attenuate flooding by reducing flows and durations of water events in the Gateway Triangle, while improving water quality, wetland habitat, and groundwater recharge. The final plans may consist of combinations of several management actions, including modification of channels, construction of networks of stormwater retention areas, creation of filter marshes, removal of exotic vegetation from flood plains, and retrofitting of existing facilities. A final plan is schedule to be submitted to the District in WY2006.

GORDON RIVER WATER QUALITY PARK

The SFWMD is working with Collier County to design, permit, and construct the Gordon River Water Quality Park. The purpose of the park is to attenuate flooding by reducing flows and durations of water events in the Gordon River Basin while improving water quality, wetland habitat, and groundwater recharge. The project will attempt to maximize the public's participation in all phases of the project process and develop a system which promotes environmental protection and provides recreational opportunities. Construction will begin in WY2006 and should be completed in WY2008. The park is envisioned to entail a potential pump station and/or larger culvert delivering water from the Goodlette Frank Road, a series of interconnected, cascading ponds making up the treatment train to include littoral shelves, landscape planting, and a means of mixing actions to accelerate the normal biological and chemical water quality improvement processes, a bypass structure, and a discharge structure. The bypass structure will allow bypassing the water quality park in the case of severe storm events and allow the water to be returned to the Goodlette-Frank Canal which eventually discharges to the Gordon River.

WESTLAKE OUTFALL IMPROVEMENTS AND TWIN LAKES INTERCONNECT

The District provided funding in WY2005 to Collier County for the construction and construction management of the Westlake Outfall Improvement and the Twin Lakes Interconnect. The purpose of these stormwater management system improvements is to mitigate flooding by providing enhanced conveyance capabilities to the Goodlette-Frank Canal while improving water quality through the addition of a water control structure for each area. The implementation of these projects will result in tangible improvements to flood mitigation and stormwater quality in the Gordon River Basin. Current conditions make the Westlake and Twin Lakes subdivisions highly susceptible to chronic flooding. Both projects are expected to be complete in WY2006.

ESTERO BAY

INTRODUCTION

Estero Bay is a long, narrow, and shallow body of water, with its northwestern border beginning at Bowditch Point on Estero Island, and reaching as far as Bonita Beach on the south. The watershed of the bay includes central and southern Lee County and parts of northern Collier and western Hendry counties (**Figure 12-37**). The lagoon, or bay, is oriented along a north-south axis with freshwater tributaries distributed along the eastern shore and passes to the Gulf along the western shore. Estero Island, Black Island, Long Key, Lover's Key, and Big Hickory Island are the barrier islands that separate the bay from the Gulf of Mexico (**Figure 12-38**). The principal freshwater inflows come from Hendry Creek, Mullock Creek, Estero River, Spring Creek, and the Imperial River. The tributaries are estuarine in character. Thus, salinity gradients in the bay and those in the tributaries can form a complex temporal and spatial mosaic.

To manage and preserve the Estero Bay ecosystem, it is necessary to understand the salinity patterns of the bay in relation to freshwater inflow and water exchange with the Gulf of Mexico, describe the mixing and freshwater residence times within the bay, and estimate sediment inputs and resuspension. Such information is necessary to facilitate management decisions geared toward defining flow and sediment loading limits that provide desirable ranges in salinity and water quality by providing necessary hydrological information.

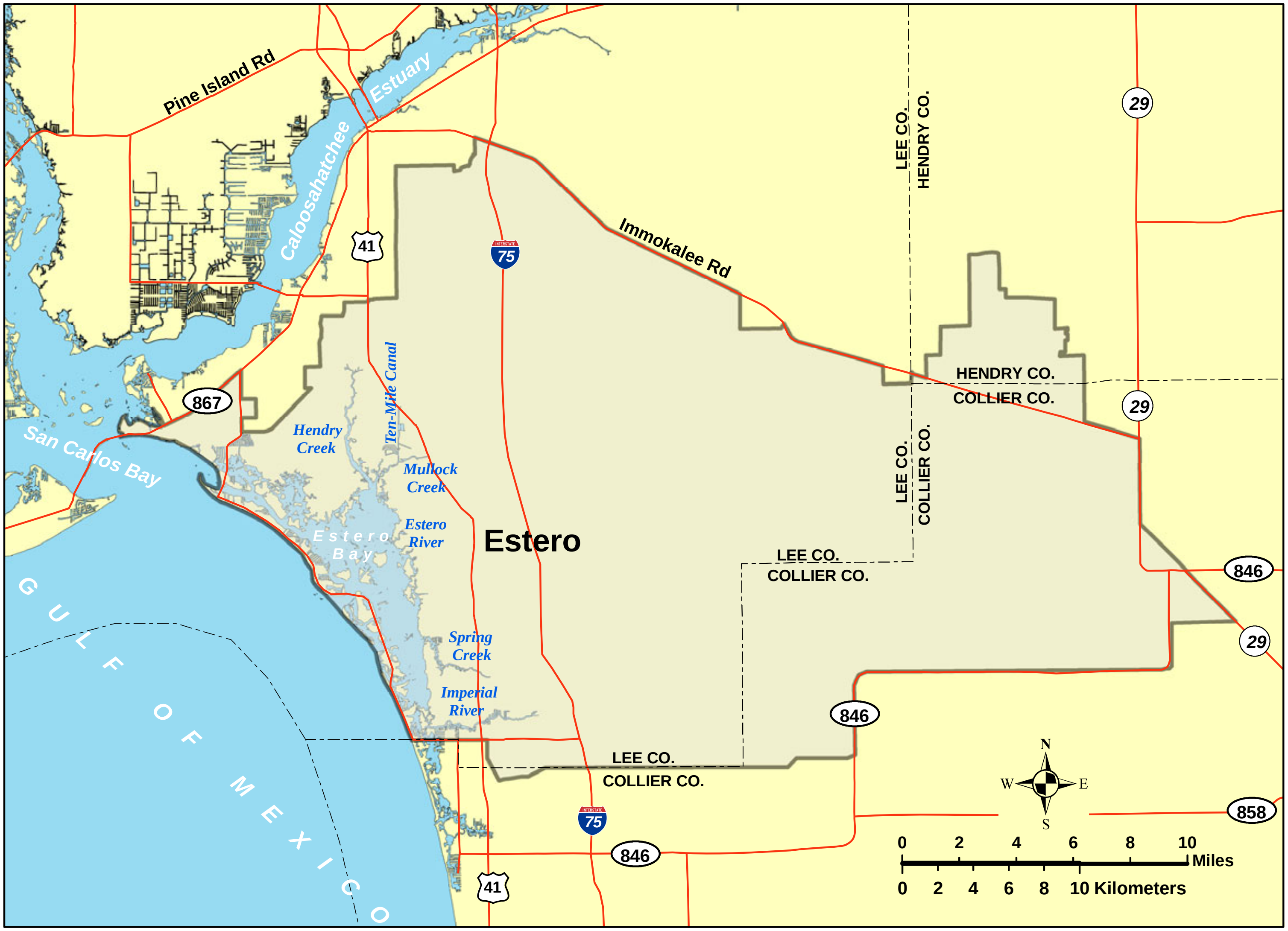


Figure 12-37. Geographic location of Estero Bay.

Figure 12-38. Geographic location of Estero Bay.

The following sections describe the environmental and biological criteria that are used to assess the health and condition of Estero Bay. The performance of the system during WY2005 is evaluated using these criteria.

ENVIRONMENTAL ASSESSMENT CRITERIA

Freshwater Inflow

As part of the CERP Southwest Florida Feasibility Study (SWFFS), acceptable flow ranges are being used to evaluate flows for three of the major tributaries to Estero Bay (**Table 12-11**): Ten-Mile Canal, the Estero River (South Branch), and the Imperial River. The flow ranges are based on the salinity tolerances of the Eastern oyster (*Crassostrea virginica*) and are being used to define flow envelopes that maintain appropriate salinity at creek mouths where oysters are located. The minimum flow results in salinities between 15 and 25 ppt, which are optimal for adults. Flows greater than the maximum result in salinities below 5 ppt, which are lethal to juvenile oysters (Volety et al 2003). Ten-Mile Canal is a source of water for Mullock Creek. Mullock Creek eventually empties into Estero Bay. Discharges from Ten-Mile Canal create appropriate salinity at the mouth of Mullock Creek.

Table 12-11. Minimum flow needed to maintain salinities between 15 and 25 parts per thousand (ppt).

Tributary Control Station	Monitoring Station	Minimum Flow for Salinities 15–25 ppt	Maximum Flow for Salinities > 5 ppt
Ten-Mile Canal	Mullock Creek Downstream monitoring station	4–50 cfs	Not to exceed 215 cfs
South Branch Estero River	Estero River mouth monitoring station	3–9 cfs	Not to exceed 32 cfs
Imperial River	Imperial River mouth monitoring station	8–26 cfs	Not to exceed 94 cfs

Valued Ecosystem Components

Both oysters and seagrass are present in Estero Bay, are being monitored, and have been selected as VECs for managing inflows into the bay.

ENVIRONMENTAL CONDITION OF ESTERO BAY

Freshwater Inflow

Rainfall in the Southwest Coast region was 55.05 inches in WY2005, or 102 percent of average. Freshwater inflow to the selected tributaries that were evaluated as part of the SWFFS were further examined regarding their historical deviation from the SWFFS recommended flows (**Table 12-12**). In WY2005, the number of days that high and low flow criteria were met was within the historical range (95 percent confidence interval, or 95% C.I.) for the Ten-Mile Canal and the South Branch of the Estero River. For the Imperial River, relatively fewer days fell in the low flow range, while the maximum flow was exceeded more often.

Two data collection recorder units were installed in WY2005 by the USGS on Lee County Park system property, known as Lakes Park, to collect water level, calibrate, and prepare a base rating including shift-diagrams to monitor flows for two independent salinity control weirs which drain into Hendry Creek. The recorders provide both daily and 15-minute stage and discharges to Hendry Creek.

Table 12-12. Hydrologic and salinity ranges for tributary inflow into Estero Bay. The number of days in WY2005 when flow was within low flow range is compared to the historical mean ± 95% C.I. The number of days in WY2005 when flow exceeded the recommended maximum is compared to the historical mean ± 95% C.I.

	Historical (Days)	**POR Water Year**	**2005 (Days)**
Imperial River			
4–26 cfs	166.2 ± 15.7	1988–2004	237
> 94 cfs	111.7 ± 13.5	1988–2004	79
South Estero			
3–9 cfs	70.4 ± 9.2	1988–2004	48
> 32 cfs	40.2 ± 6.2	1988–2004	57
Ten-Mile Canal			
4–50 cfs	144.9 ± 10.1	1988–2004	165
> 215 cfs	35.5 ± 6.5	1988–2004	49

Seagrasses

Aerial surveys flown in WY1999 and WY2003 were summarized in the 2005 SFER – Volume I. Sampling of SAV by the SFWMD began in WY2005 using hydroacoustic methodology. Sixteen locations that have paired sampling transects were established throughout the bay to monitor SAV coverage and canopy height relative to seasonal trends and freshwater inflows. The stations are distributed to differentiate between: (1) north and south gradients; (2) eastern shores, mid-bay areas, and western locations; and (3) SAV proximity to freshwater creeks and saltwater inlets. Routine sampling is planned for WY2006.

Oysters

Historical information on the aerial extent of oyster reefs in Estero Bay is not available. Based on WY2004 data, there are currently about 60 acres of oysters in Estero Bay and about 8,269 acres of accommodation space within the bay. Accommodation space is defined as the surface area of the Bay that has annual mean salinities of greater than 10 ppt, and where oysters are not currently found in the estuary, but potentially could be if substrate was available. This translates to 0.72 percent coverage of total surface area available in the estuarine portion.

CURRENT SCIENCE, ENGINEERING, AND RESTORATION ACTIVITIES

Resource Assessment

HYDRODYNAMIC MODELING

The District is developing a 2-D hydrodynamic/salinity model of Estero Bay for the SWFFS. This model will be used to help assess the impact of CERP projects on the estuary. The model is derived from a larger CH3D Charlotte Harbor model developed by University of Florida. This project (contracted with the University of Florida) develops a 2-D version of the CH3D and extends the calibration to Estero Bay. The Salinity Sediment Runoff Monitoring Project and the Bathymetric Survey Project, described below, support model development.

SALINITY AND SEDIMENT RUNOFF MONITORING

This study is a cooperative effort between SFWMD and the USGS. Some of the sites and equipment were damaged during Hurricane Charley. However, they have been replaced and are operational. Data collection under this cooperative agreement will end in September 2005 and a final data report will be completed a year later.

The objectives of this study are to (1) describe the salinity patterns of the bay in relation to freshwater inflows (tributary flow and rainfall) and tidal exchange with the Gulf of Mexico; (2) further study the use of acoustic and turbidity instruments for the estimation of continuous record of suspended sediment concentrations (SSC) in estuarine environments; (3) understand the relationship of total suspended solids (TSS) to Acoustic Backscatter Strength (ABS) and turbidity at the tributary sites.

BATHYMETRIC SURVEYS

In a cooperative agreement with the District, the USGS has collected the bathymetric data and developed a present day bathymetry of Estero Bay. In WY2005, MACTEC Engineering and Consulting, Inc., provided professional surveys and mapping services to produce bathymetries of the five major tributaries flowing into Estero Bay: Hendry Creek, Mullock Creek, Estero River, Spring Creek, and Imperial River.

HYDROLOGIC HISTORY OF ESTERO BAY

Estero Bay exists because of the barrier island system that defines it geographically. Such systems are typically dynamic, being influenced by storms, sea level rise and fall, and terrestrial sediments. Efforts to protect Estero Bay must consider and account for natural change. Therefore, an historical study was conducted to characterize the kinds of changes that have occurred in Estero Bay over time.

A contract was issued to Florida Gulf Coast University (FGCU) to address four central questions: (1) How has the coast and estuarine-scape evolved through the late Holocene (last 5,000 years) as sea level rise rates have varied? (2) What role has reef development played in this evolution? (3) How has fluvial sedimentation and freshwater delivery varied during this time interval? (4) How have sedimentation rates changed over recent history since human development? The work was completed and a final report was delivered in November 2004 (Appendix 12-5). The most significant results and their implications include the following:

1. Progradation (lateral outbuilding of sediment strata in a seaward direction) has generated the estuarine ecology and coastal geomorphology we see today in Estero Bay. Oyster reef development plays a critical role in progradation. Progradation has occurred in a mosaic pattern despite the modest rate of sea level rise (< 10 cm/100 years) over the last 3,000 years.

2. Current rates of sea level rise (since the beginning of industrialization) are an order of magnitude higher than they were in the 3,000 previous years. If the current rate of sea level rise persists, oyster reef development will become less prolific, coastal geomorphology will change considerably, and the oyster-reef-based estuarine ecology will cease to exist.

3. Study results support the hypotheses that the inner bay margins are in a metastable state, likely to move landward due to storm-induced erosion of the mangrove fringe. Recent step-backs of the inner bay margins were evident from core samples as a result of the passage of tropical storms.

4. There is some evidence supporting the interpretation of the estuary as having a more open, unprotected western margin 2,300 years before present (ybp). Cores show reef autogenic successional histories, whereby high energy marine reefs were first constructed by vermetiform gastropods beginning 2,700 ybp, and was gradually altered to the low-energy brackish-water oyster-only reefs constructed by the American oyster 470 ybp.

5. The Imperial River has been a formidable supplier of detrital sediment to southern Estero Bay for at least 460 years. The southern end of the bay is composed of an aggregated infilling of the back-barrier environment, as well as progradation through development of oyster reefs to mangrove forests.

6. Measurement of sedimentation demonstrates that rates have been high since 1950 and have accelerated over the last 50 years, particularly for the southern bay in the Imperial River watershed, and may reflect shifts in the Imperial River’s navigational channel. The timing of the watershed development has coincided with accelerated sedimentation and implies that river-based sediments could be treated as estuarine pollutants subjected to TMDL controls.

Bivalve Survey

Bivalve community composition is being monitored in Estero Bay to indicate and quantify responses to changes in salinity. Three east-west, cross-bay transects are sampled monthly. The placement and orientation of the transects allow comparison between regions of the Bay that experience different seasonal fluctuations in salinity. The study will end in December 2005. A multivariate statistical package, Primer®, was purchased in WY2005 to facilitate analysis. If results are encouraging, sampling will continue in the Imperial River and Ten-Mile Canal.

Submerged Aquatic Vegetation Monitoring

The monitoring of submerged aquatic vegetation in Estero Bay is performed using spatially and thematically accurate Arc/INFO seagrass SAV databases. These databases were created by Avineon for the coastal waters of the District, from Boca Grande south to Wiggins Pass, using December 1999 and January 2003 true-color aerial imagery. Aerial images were taken again in January 2004, and maps will be created in WY2006. New aerial photographs will be taken in the winter of WY2006, and used to update the seagrass database. At that time, trend analyses will be performed.

Oyster Monitoring

Florida Gulf Coast University continues to monitoring oyster reefs in Estero Bay, through their restoration program, for spat recruitment, growth rates, predation, and disease.

Fisheries Monitoring

In a cooperative agreement with the District, the Florida Fish and Wildlife Conservation Commission (FWC) Research Institute expanded its Fisheries Independent Monitoring Program to cover Estero Bay in WY2005. This program targets juvenile and subadult fishes that have not been subjected to fishing pressure, in order to provide less biased estimates of trends in fish stocks.

Freshwater Inflow and Ecology Studies

In FY2004, Florida Gulf Coast University began two studies, in cooperation with the District, to examine the effects of freshwater inflow on the ecology of Estero Bay. Basing acceptable tributary flow ranges on salinity requirements of oyster bars located at creek mouths assumes that these bars are ecologically important. The first study examines the growth and condition of oysters on these reefs and the use of these reefs by fish as feeding sites. The second study examines the relationship between freshwater inflow and the utilization of Estero Bay and its tributaries by commercially important juvenile and larval fish and shrimp, adult and juvenile blue crabs, and other important members of the water column food web. Data collected through these studies will support the continued development of hydrologic and ecological performance measures and targets in Estero Bay.

RESTORATION ACTIVITIES

Restoration of Shellfish in Estero Bay

In an ongoing project, Florida Gulf Coast University, through funding from the District, National Fish and Wildlife Foundation, and NOAA, constructed two oyster reefs (10 m^2 each) in northern Estero Bay in WY2005. Reefs are constructed using recycled oyster shell and stabilizing mesh in order to establish suitable substrate for oyster recruitment. This community-based restoration involved other agencies, the general public, as well as high school and undergraduate students. In WY2004, three reefs were constructed within the bay and tributaries. An ongoing monitoring program is in place to determine restoration success.

Imperial Bonita Estates Stormwater Retrofit

The SFWMD has provided funds to the city of Bonita Springs for drainage enhancements in the Imperial Bonita Estates area to alleviate flooding and to provide water quality improvements for the stormwater runoff that enters the Imperial River and ultimately Estero Bay. The project will be completed in June of 2005. The project improved an existing drainage ditch along the east side of Imperial Bonita Estates, upsized the culvert pipes within the ditch, and constructed ditch checks and weirs to naturally filter and decelerate water flow to improve water quality before it enters the Imperial River. A swale along the north boundary of the area has been extended to the west, cleared of vegetation and debris, and a berm breach repaired so that improper discharge from a pond in the subdivision to the north can be linked to a Lee County Department of Transportation storm sewer.

Bonita Villas Stormwater Repairs

The District provided funds to the city of Bonita Springs for the restoration of the stormwater system of the Bonita Golf Club Villas. The restoration efforts involved (1) removing vegetation from the perimeter berm and rebuilding that berm; (2) removing overgrown vegetation from a retention lake; (3) cleaning, repairing, and replacing the interiors of the intake structures and discharge pipes; (4) cleaning and re-grading the outfall swale to the proper elevation; and (5) installing a new trash rack at the intake structure. The project was completed in October 2004.

CALOOSAHATCHEE RIVER AND ESTUARY

INTRODUCTION

The Caloosahatchee Estuary is located on the southwest coast of Florida (**Figure 12-39**). The major source of fresh water is the Caloosahatchee River, which runs 65 kilometers from Lake Okeechobee, to the head of the estuary at the Franklin Lock and Dam (S-79). Geographically, the estuary extends about 42 kilometers downstream to Shell Point, where it empties into San Carlos Bay. Major environmental concerns for the Caloosahatchee are altered freshwater inflows, nutrient enrichment, and habitat loss. For a more complete summary of background information regarding problems and related historical research, please see the *Caloosahatchee River and Estuary* section in Chapter 12 of the *2005 South Florida Environmental Report – Volume I*. In WY2005, four hurricanes made landfall in Florida. Hurricane Charlie struck the west coast of Florida in mid-August.

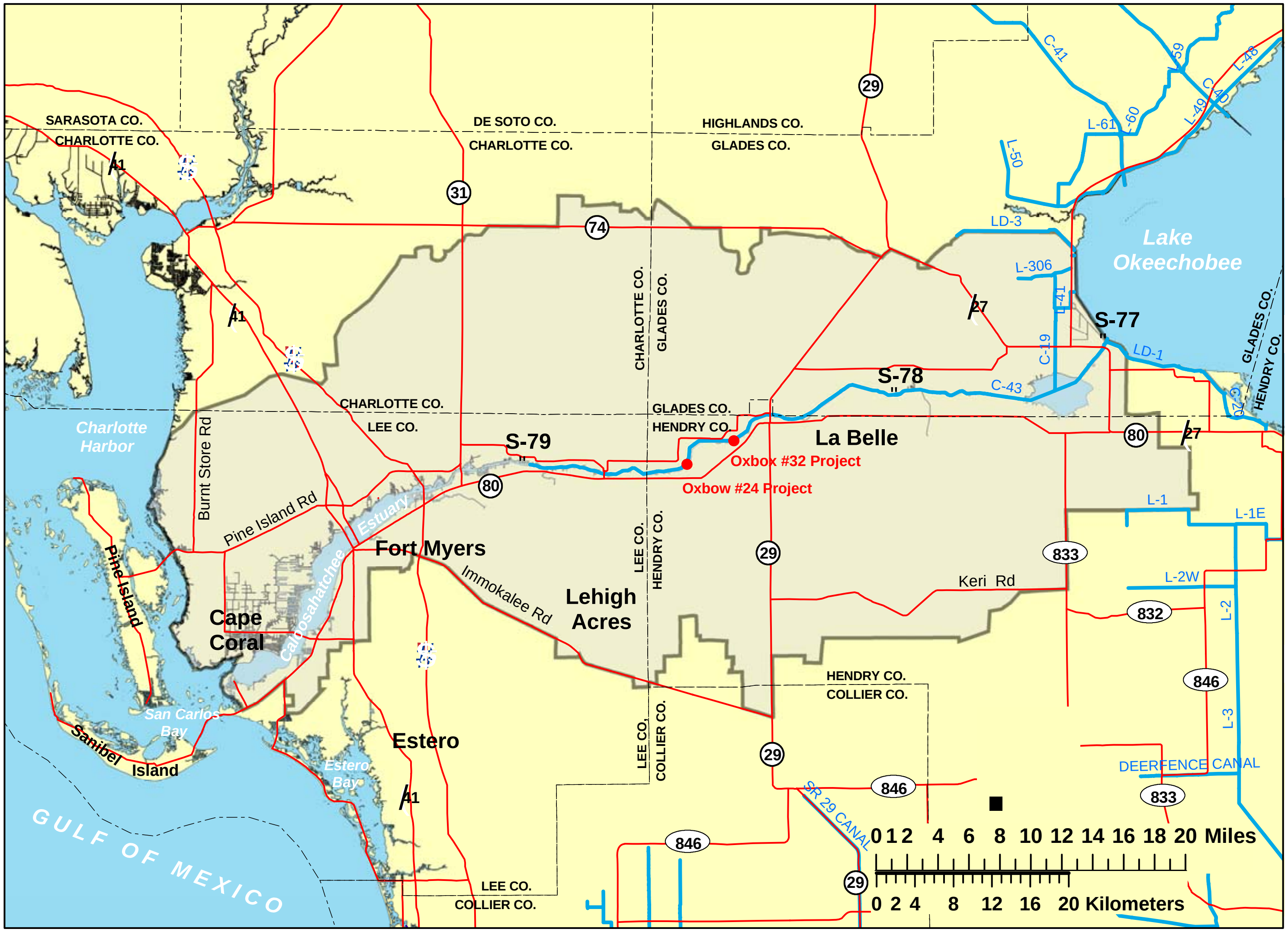


Figure 12-39. The Caloosahatchee River watershed area and important landmarks.

The following sections describe the environmental and biological criteria that are used to assess the health and condition of the Caloosahatchee Estuary. The performance of the system during WY2005 is evaluated using these criteria. Descriptions of restoration projects and significant findings of resource assessment projects conducted over WY2005 also are provided.

Hurricane Charley

Hurricane Charley swept through the area on August 13, 2004. The resulting rainfall and runoff quickly depressed salinity throughout the inner estuary, at least to Cape Coral Bridge (**Figures 12-40** and **12-41**). The winds and water forces related to the hurricane destroyed the continuous salinity sensors at the Sanibel Causeway Draw Bridge. The remainder of the wet season also was very wet and resulted in high runoff from the watershed and Lake Okeechobee (**Figure 12-42**), which caused continued low salinity conditions (**Figure 12-41**). Not long after Hurricane Charley passed, an environmental assessment team was dispatched. On this trip, water quality was collected from historic sampling sites that extend from above S-79 to San Carlos Bay. In addition, the submerged aquatic vegetation (SAV) was inspected (non-qualitative) through this same range. The water quality results are being evaluated and will be compared to before and post event samples, as well as historic water quality values to determine hurricane impacts. The SAV inspection indicated no immediate physical disturbance that was wide spread. However, seagrass density did decline throughout most of the areas during subsequent months. A hydroacoustic survey of SAV was conducted in October as part of the routine survey and monitoring effort (RECOVER). This survey's results will be compared to the previous 9 years of collections to help detect unusual changes.

Figure 12-40. Caloosahatchee Estuary salinity sensors and important landmarks.

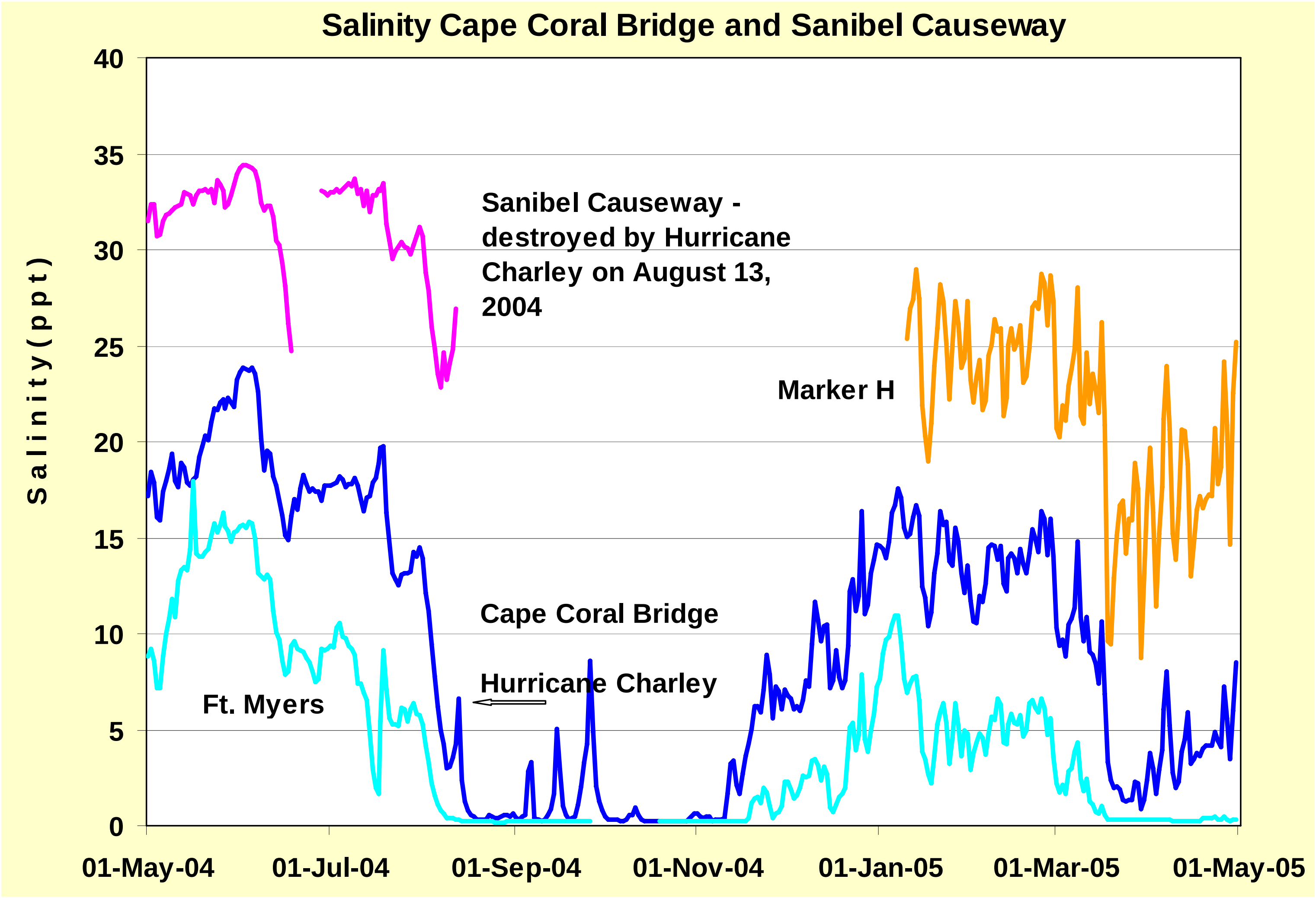


Figure 12-41. Daily average salinity at four locations in the Caloosahatchee Estuary collected by continuous sensors. Locations: Sanibel Causeway Draw Bridge; Marker H (Shell Point); Cape Coral Bridge; and Ft. Myers Yacht Basin.

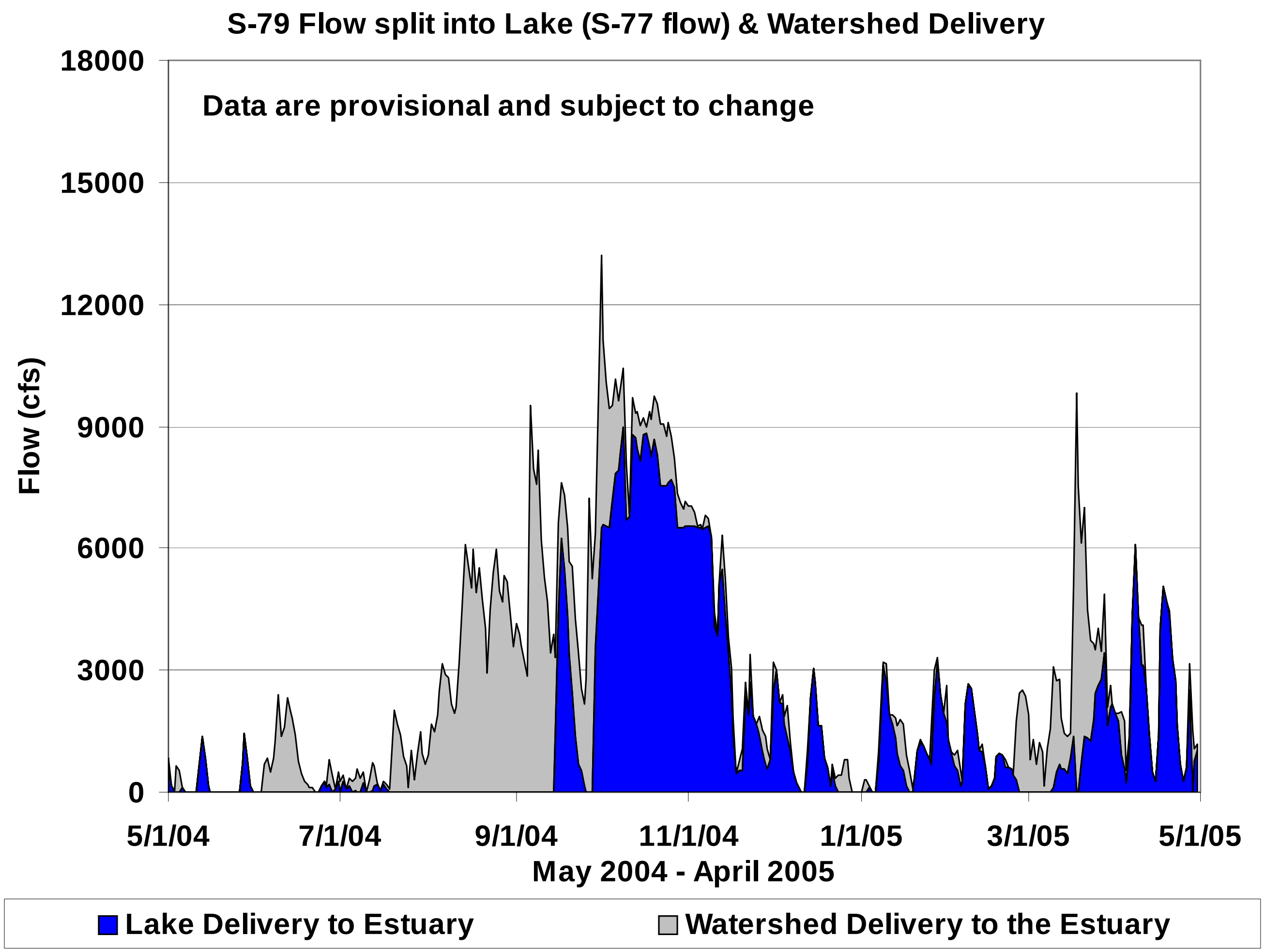


Figure 12-42. Total discharge into the Caloosahatchee Estuary at S-79. the portion of discharge accounted for by regulatory releases from Lake Okeechobee is shown in blue. Note the high discharges from the watershed (gray) that began in mid-August, following Hurricane Charley.

ENVIRONMENTAL ASSESSMENT CRITERIA

Recent research and modeling conducted by the District has resulted in revised flow criteria and performance measures for discharge at S-79 that are being used for CERP (C-43 BSR, 2005), SWFFS (2005) and operation of Lake Okeechobee (**Table 12-13**). These revisions will better support the salinity criteria for the Caloosahatchee River and Estuary MFL (SFWMD, 2002). These criteria and performance measures were derived from relationships between the distribution, abundance, growth, and survival of estuarine organisms and changes in salinity or freshwater discharge. Salinity tolerances of submerged grasses were initially used to identify minimum and maximum inflows at S-79. Mean monthly flows less than 300 cfs were thought to allow salinity in the upper estuary to exceed the tolerance of tape grass (*Vallisneria americana*) (targets: monthly average salinity ≤ 10 ppt at Ft. Myers Yacht Basin, daily average < 20 ppt). However, this minimum flow amount depends on an additional inflow of 200 cfs from the tidal basin downstream of S-79. During extended dry conditions, flows from the tidal basin are significantly less than 200 cfs, which causes violations of the MFL salinity criteria. Therefore, a new low-flow limit of 450 cfs from S-79 has been established and adopted as a performance measure for CERP and the SWFFS (**Table 12-13**). The MFL salinity criteria were initially designed to protect tape grass upstream of Fort Myers, but are also beneficial for other organisms that utilize the low salinity region of the estuary (Chamberlain and Doering, 1998a; Doering et al., 2002), as well as species downstream, such as oysters (Volety et al., 2003). Flows greater than 2,800 cfs depress salinity in the lower estuary and threaten the marine shoal grass (*Halodule wrightii*) typical of this region (Chamberlain and Doering 1998a; Doering et al., 2002).

Several prominent species have been identified for long-term monitoring and environmental assessment because they constitute important habitat in the Caloosahatchee, San Carlos Bay, Matlacha Pass, and Pine Island Sound. In addition to tape grass which serves as an indicator of estuarine health in the upper estuary (**Figure 12-43**), these are oysters and marine seagrasses representing the more downstream seaward portions of the system.

Table 12-13. CERP and SWFFS performance measures for freshwater discharge at S-79 and MFL salinity criteria at Fort Myers, Florida (C-43 BSR, 2005; SWFFS, 2005).

Freshwater Discharge At S-79	CERP Performance Measure
Low Flow for Estuary (mean monthly)	Number of months ≤ 450 cfs
High Flow for Estuary upstream of Shell Point (mean monthly)	Number of months ≥ 2800 cfs
Discharge from Lake Okeechobee	Minimize number of days of regulatory discharges
Low Flow Duration	Frequency of consecutive months ≤ 450 cfs (1 month, 2 months etc.)
High Flow Duration	Frequency of consecutive months ≥ 2800 and 4500 cfs (1 month, 2 months, etc.)
Optimum distribution of inflow	Closeness to identified preferred frequency distribution
Minimum Flow and Level at Ft Myers, FL	
Salinity Criteria (daily average)	Shall not exceed 20 ppt in a given year
Salinity Criteria (30-day average)	Shall not exceed 10 ppt in a given year

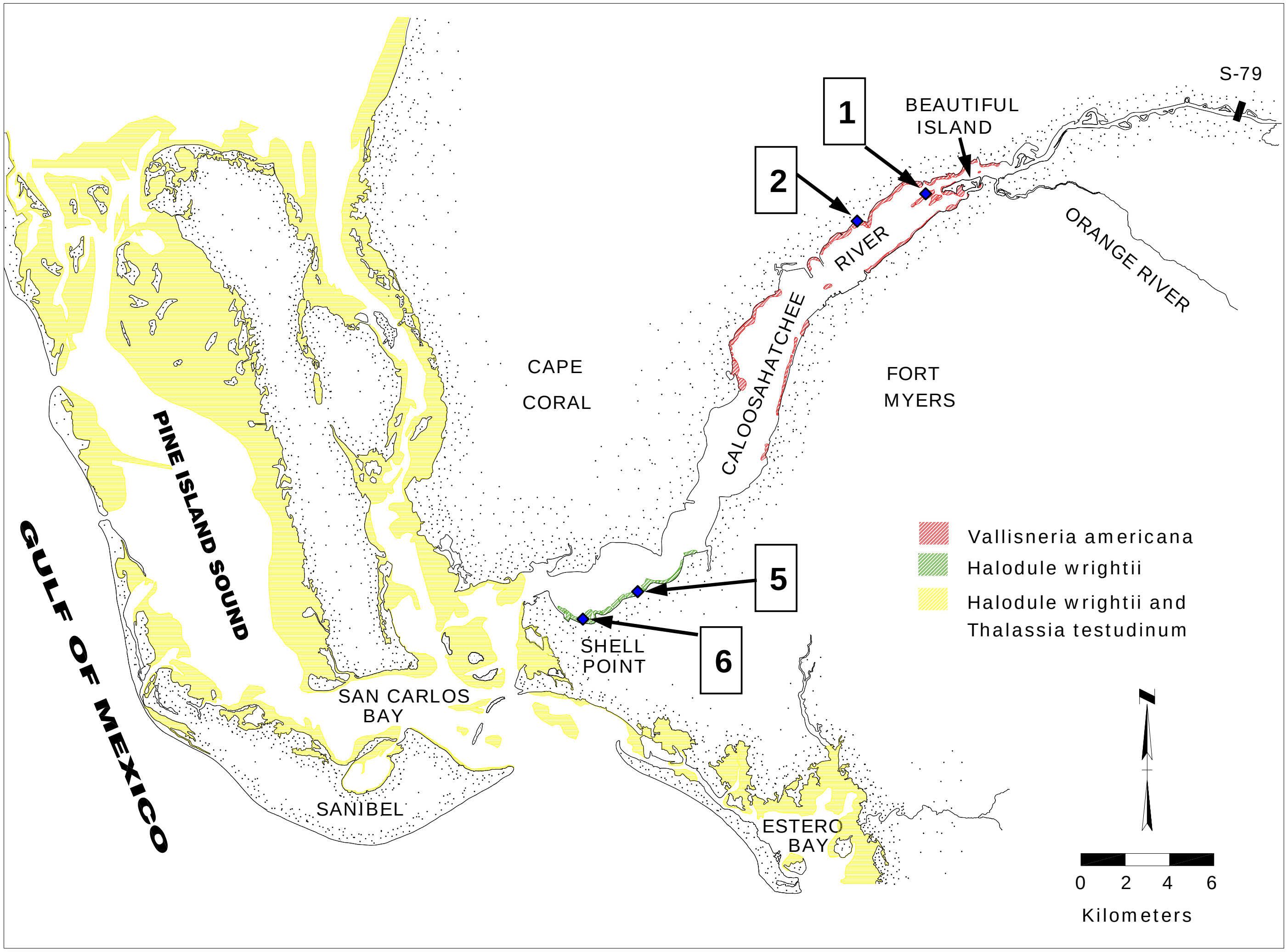


Figure 12-43. Caloosahatchee estuary SAV monitoring stations. The general historic range of dominant SAV species are indicated, when conditions are good for maximum distribution (*Vallisneria Americana* is found farthest upstream at stations 1 and 2; the seagrass *Halodule wrightii* is found at stations 5 and 6 near the downstream mouth at Shell Point). Oysters are present from just upstream of Shell Point (potentially near or upstream of Station 5) into the San Carlos Bay region.

ENVIRONMENTAL CONDITION OF THE CALOOSAHATCHEE ESTUARY

Freshwater Inflow at S-79

Freshwater inflow at S-79 was relatively low during the early wet season (**Figure 12-42**). Rain associated with Hurricane Charlie caused high discharges at S-79 in mid- and late August. Water levels in Lake Okeechobee rose precipitously with Hurricanes Frances and Jeanne (September 2004). These high water levels necessitated regulatory releases from Lake Okeechobee that continued for the remainder of WY2005. The long-term average discharge at S-79 is approximately 1.2 million ac-ft per year. In WY2005, discharge at S-79 was 2.0 million ac-ft with about 1.2 million ac-ft coming from Lake Okeechobee (see Chapter 5 of this volume).

In an ordinary year, flows average less than 450 cfs for 4.2 months and greater than 2,800 cfs for 2.5 months (**Table 12-14**). Thus, mean monthly flows outside the 450 cfs–2,800 cfs envelope occurs for about seven months per year. In WY2005, mean monthly flows outside the envelope occurred for six months. Eighty-three percent of the occurrences outside the preferred flow range were above 2,800 cfs, placing ecological resources in the lower, more marine end of the estuary at greater risk. Therefore, the upper, low-salinity region of the estuary was less likely to suffer high salinity conditions that threaten tape grass.

Table 12-14. C-43 and SWFFS hydrologic performance measures for mean monthly flows.

Performance Measure	Historical (WY1966–WY2004)	WY2005
Less than 450 cfs	4.24 +/ - 0.84	1
Greater than 2800 cfs	2.55 +/ - 0.76	5

Salinity at Fort Myers

Evaluation of the MFL salinity criteria determined that the upper Caloosahatchee Estuary experienced daily average salinities > 10 ppt (**Table 12-15**). The period of record for salinity at Fort Myers extends back to 1991. During the 14 years of record, WY1995 and WY2004 were the only two years in which neither of the two criteria was exceeded (criteria: moving 30-day average salinity of < 10 ppt at Ft. Myers Yacht Bain; daily average of < 20 ppt). During WY2005, only the 30-day average criteria were unmet.

Table 12-15. Caloosahatchee MFL salinity criteria at Fort Myers from WY1992–WY2005.

Water Year	Maximum Daily Average	Maximum 30-Day Average
1992	20.86	17.82
1993	18.68	16.01
1994	13.77	12.05
1995	5.47	5.26
1996	14.23	12.90
1997	23.34	17.30
1998	16.30	14.29
1999	19.40	17.14
2000	18.41	16.26
2001	24.62	23.31
2002	26.74	25.62
2003	16.16	14.34
2004	9.63	6.74
2005	17.98	14.76

Tape Grass in the Upper Caloosahatchee

Due to high salinity experienced during the 2001 drought, tape grass beds (*Vallisneria americana*) in the upper Caloosahatchee Estuary (**Figure 12-43**) essentially vanished, and have been in recovery since that period (**Figure 12-44**). During WY2004, the beds began to recover during the spring-summer growing season, coinciding with favorable salinity conditions. Similar seasonal growth has returned in spring 2005.

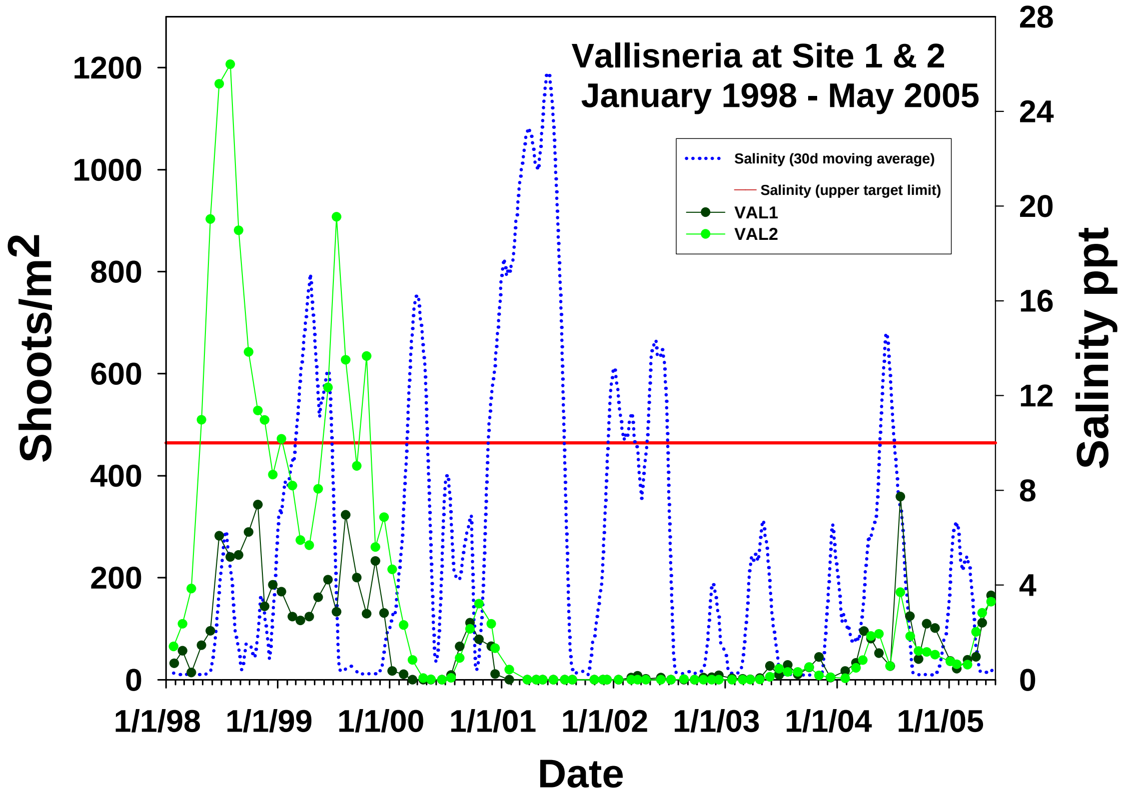


Figure 12-44. Tape grass (*Vallisneria americana*) shoot density in the upper Caloosahatchee Estuary. Data are from stations maintained by the Sanibel-Captiva Conservation Foundation and Mote Marine Laboratory. Location 1 is near Beautiful Island. Location 2 is located near the terminus of Old Bridge Road in North Fort Myers. Salinity data are from a recorder located in Fort Myers.

Oysters

See Chapter 12 of the 2005 SFER – Volume I for a historical perspective and discussion of oyster coverage limits. Based on WY2004 aerial surveys, there are presently only 3.02 acres of Eastern oysters in the Caloosahatchee Estuary. Most of these are located in the Shell Point region. A preliminary target for the aerial extent of oyster reefs in the lower estuary is a 40-acre increase in the next 10–15 years with the proper changes in flow and salinity. With the addition of hard substrate, this target can be increased to 200–300 acres of oyster reefs. Volunteers from Florida Gulf Coast University, concerned citizens, SFWMD, and other state, federal, and local agencies placed shell-bags at two locations in WY2005 to provide recruitment substrate for oyster reef development.

Monitoring of oysters' health and recruitment began in 2000. The health of oysters is assessed by measuring intensity and prevalence of the parasite *Perkinsus marina*, condition index, density, and live/dead ratio. Results indicate that oysters in the Caloosahatchee Estuary spawn continuously from April–October, a period that coincides with freshwater releases into the estuary. Just upstream of Shell Point, sub-tidal locations exhibited good spat recruitment, low disease intensity, and higher juvenile growth rates compared to downstream, intertidal sites. Recruitment to sites upstream of Shell Point begins and usually peaks earlier than downstream sites, as does an increase in the gonadal index (reproductive state). High freshwater flows flush out oyster larvae and spat from upstream areas with suitable cultch and/or reduce salinities to levels that are unfavorable for spat settlement and survival. Recruitment during WY2005 was among the lowest observed (Volety; personal communication, 2005) especially regarding early season activity in spring of 2004 (beginning of WY2005) and again during the 2005 spring start-up (end of WY2005). However, the high flows associated with Hurricane Charley did not appear to decrease recruitment below normal, possibly because flows are usually high during this season and may normally exceed the flushing volume threshold. Additional important information regarding survival and gonadal index response were not available for this report that may delineate oyster impacts from the storm.

Marine Seagrass

Aerial surveys of seagrass were conducted in 1999, 2002–2003, and 2004. The results of these surveys were summarized in Chapter 12 of the 2005 SFER – Volume I. No aerial surveys were conducted during WY2005, partially due to poor weather condition during the time window available for sampling.

Manual (in-water) seagrass monitoring by the Sanibel-Captiva Conservation Foundation Marine Laboratory (**Figure 12-45**) indicates it was another poor year for seagrass upstream of Shell Point. Shoot density remained below 200 m^{-1} at the most downstream location (Site 6) and actually declined during the peak of the growing season at the upstream location (Site 5) where lower salinity and associated poor water quality had a greater impact.

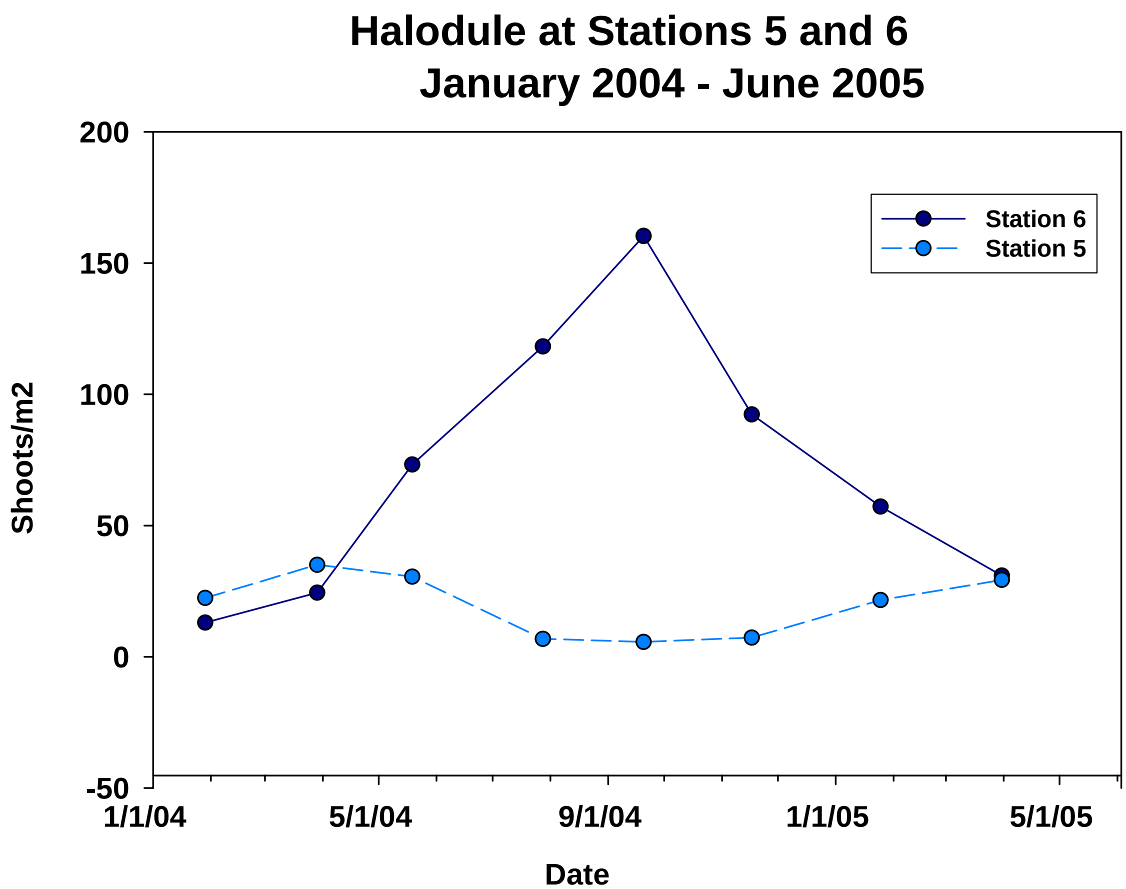


Figure 12-45. Density of the seagrass, *Halodule wrightii* (shoal grass), at two stations upstream of Shell Point (Stations 5 and 6).

CURRENT SCIENCE, ENGINEERING, AND RESTORATION ACTIVITIES

Resource Assessment

SALINITY MONITORING

The District continues to maintain a series of electronic monitoring stations that collect salinity and temperature data every 15 minutes (Chamberlain and Doering, 1998b). Since 1992 there have been five operational sites: S-79, Route 31 Bridge, Ft. Myers Yacht Basin, Shell Point, and the Sanibel Causeway (**Figure 12-40**). The Shell Point site was damaged in 2000 and was replaced in December 2004. The Sanibel Causeway site was destroyed August 13, 2004 by Hurricane Charley and efforts are under way to relocate it on the adjacent hardened shoreline. An additional site was added at the Cape Coral Bridge in July 2002, and another site is planned at the I-75 Bridge. Data are used to (1) monitor compliance with the Caloosahatchee MFL, (2) support water management of Lake Okeechobee, (3) aid in ecosystem evaluations, and (4) support development of hydrodynamic and water quality models.

WATER QUALITY MONITORING

For a historical perspective see Chapter 12 of the 2005 SFER – Volume I. The District continues routine water quality data collection via contract in order to quantify effects of releases of water from Lake Okeechobee to the Caloosahatchee at 11 stations from S-79 to San Carlos Bay. CERP also funds Lee County to collect water quality at four sites distributed between S-79 and the Mid-Point Bridge. Analysis of this data continues with the goal to establish water quality and nutrient loading targets for CERP and the SWFFS.

SUBMERGED AQUATIC VEGETATION MONITORING

For an historical perspective, see Chapter 12 of the 2005 SFER – Volume I. As indicated above, the Sanibel-Captiva Conservation Foundation Marine Laboratory has begun a long-term program for manual monitoring SAV and associated water quality in the upper estuary (three sites), lower estuary (two sites), and San Carlos Bay (two sites). In addition to this contractual effort, eight SAV sites located from Beautiful Island to Pine Sound have been surveyed since 1996, using hydroacoustic technology (Sabol et al., 2002). The first four sites are located near the manual SAV sampling sites (1, 2, 5, and 6) depicted in **Figure 12-42**. This methodology allows for a greater spatial coverage of sampling for the same effort as traditional manual methods (Chamberlain et al., 2005). GIS analysis of this data was completed in WY2005. Presentation and publication of the results are planned for WY2006.

Using data from both experimental research and field collection, progress continues in the ecological modeling of *Vallisneria* by the District (Hunt and Doering, 2005). Contractual work for the District by the University of Florida are interfacing with this modeling effort as part of the university's larger goal to predict monthly and long-term changes in coverage of SAV related to freshwater inflow and associated water quality conditions.

OYSTER MONITORING

Oysters are also monitored in the Caloosahatchee Estuary, as discussed above and in the *Southern Charlotte Harbor* section.

GRASS BED HABITAT

Submerged grass beds provide important habitat in both the low and high salinity areas of the Caloosahatchee Estuary. Beds of tape grass (*Vallisneria americana)* are located in the upper, low salinity zone of the estuary, while marine seagrasses (shoal grass, *Halodule wrightii,* and turtle grass, *Thalassia testudinum*) inhabit the more saline marine reaches of the system (**Figure 12-43**). These habitats are being sampled through contract with Mote Marine Laboratory to ascertain the extent of utilization by estuarine animals (e.g., fish and shellfish), and to determine how this utilization is affected by freshwater discharge from the Caloosahatchee River. Information from these studies will contribute to better management of discharges from Lake Okeechobee as well as the operation of the reservoirs and storage wells that are planned for the C-43 basin under CERP.

HYDRODYNAMIC MODELING

The District is continuing to make improvements to the Caloosahatchee Hydrodynamic/Salinity Model. The District employed this model to predict salinity distribution in Caloosahatchee River and Estuary for Acceler8, C-43 (Caloosahatchee River) West Reservoir project. The CH3D hydrodynamic model will be utilized to evaluate alternatives and sizing the reservoir. This project extended the calibration of CH3D model to 16 months. In addition, the runoff from tidal basin area was distributed to 10 segments and incorporated into the freshwater input. A regression model was developed at 19 stations from Caloosahatchee River to San Carlos Bay and Pine Island Sound vicinity. The regression model was further calibrated with a continuous daily salinity data at seven stations. At the other 12 stations, the regression model was calibrated with 16 months of CH3D results. The regression model allows salinity in the estuary to be estimated from long-term (36-year) discharge scenarios associated with alternative designs and configurations of CERP projects.

HABITAT UNITS

The University of Florida developed a habitat suitability model for assessing alternative management scenarios related to CERP and the SWFFS efforts. The model uses habitat suitability indexes (HSI) related to salinity and freshwater inflow to predict changes in the environmental components SAV, blue crabs, oysters, sea trout, and zooplankton. Model output is in habitat units for each these components, which depend on the flow output from CERP models and the salinity from the hydrodynamic/salinity model discussed above. Most of the HSIs were determined during WY2005. The remaining will be completed next year, prior to also running the HSI model and evaluating the habitat units produced for each alternative.

WATER QUALITY ASSESSMENT

In estuaries and other aquatic systems, excessive nutrient inputs are commonly expressed as phytoplankton blooms. Using data from several monitoring programs, the potential use of chlorophyll *a* as an indicator of eutrophication was examined to address the relationship between nutrient loading and chlorophyll *a*, the role of chlorophyll *a* in light attenuation, and the relationship between chlorophyll *a* and DO concentration. The relationship between nutrient loading and chlorophyll *a* varied spatially, being negative at the head of the estuary and positive in San Carlos Bay (**Figure 12-46**). In the estuary, color and/or total suspended solids explained most of the variability in light extinction, while chlorophyll *a* was most important in San Carlos Bay. Because of spatial variability in the relationships between chlorophyll and nutrient loading and light attenuation, the implications of nutrient load reductions may be different for different regions of the Caloosahatchee system (see Appendix 12-6). Using the same datasets, preliminary nutrient loading targets at S-79 have been proposed for the C-43 BSR Acceler8 project.

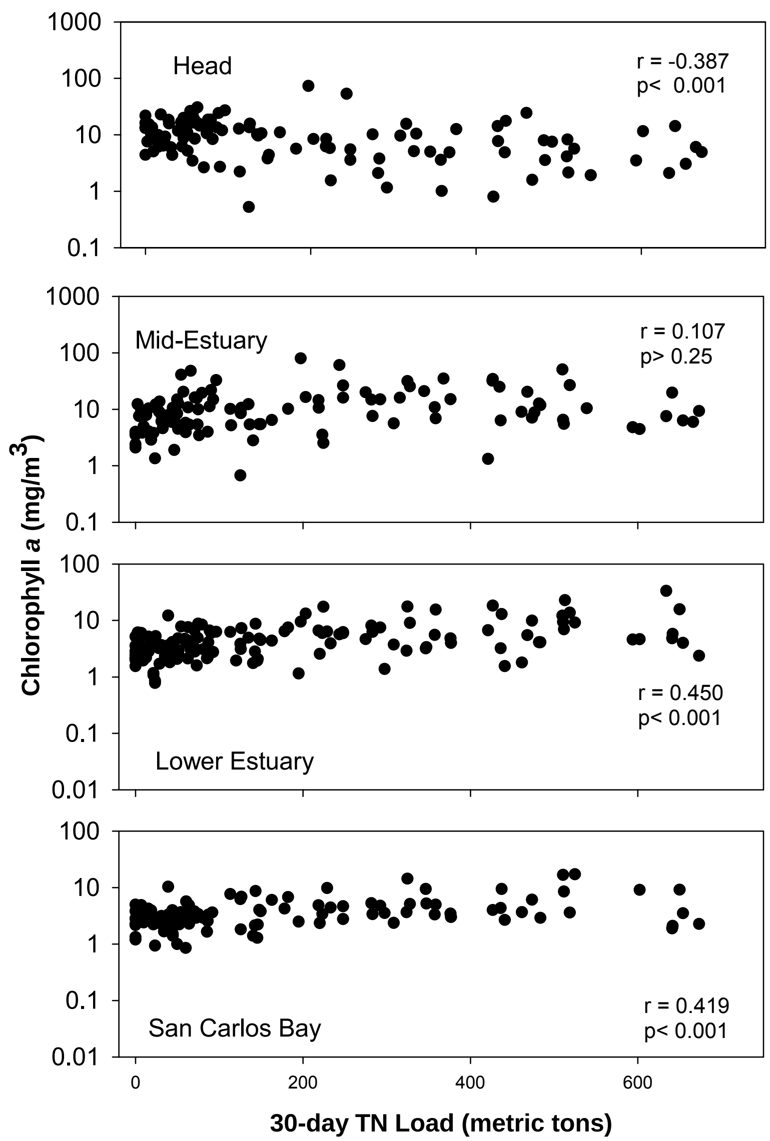


Figure 12-46. Concentration of chlorophyll *a* as a function of total nitrogen loading at S-79 for the 30 days prior to sampling.

RESTORATION ACTIVITIES

Caloosahatchee River Oxbows

The Caloosahatchee oxbows are all that remain of the original, narrow meandering river after the channel dredging conducted by the USACE in the 1930s and 1950s. Prior to channelization and dredging, the river bends slowed the water, facilitating the deposition of sediment and absorption of nutrients in the water column, and provided habitat for native fauna and flora. Following the channelization, water flowed directly down the straight deepened channel, creating vertical banks without littoral habitat. Today, the oxbows, historic remnant meanders, represent the best aquatic habitat left in the riverine system.

Of the 35 oxbows between WP Franklin Lock in eastern Lee County and SR 29 in Hendry County, about 18–20 are in need of restoration to recover aquatic productivity and function. SFWMD funded the physical restoration of the Old Fort Denaud Oxbow (Caloosahatchee Oxbow #24 Restoration, **Figure 12-39**) and a performance assessment plan for restoring and monitoring future oxbow restoration projects. This project will provide for the removal of an earthen fill road and accumulated sediments from the bed of the oxbow. The shoreline will be restored by removing the exotic species, including Brazilian Pepper, and the littoral zone will be restored with native aquatic vegetation. The project will be completed by September 30, 2005. The Tully/Dunlop Property Oxbow (#32, **Figure 12-39**) Restoration Project was approved at the May Governing Board meeting and has been contracted with Hendry County.

Orange River

Lehigh Acres is located in the Orange River Basin (**Figure 12-39**) and within the service area of the East County Water Control District (ECWCD). Harn's Marsh is a 578-acre flood detention facility within ECWCD boundaries. The Harn's Marsh Restoration project is a result of a comprehensive hydrologic study of the area to identify problems and solutions. Construction of a control weir is planned at the outlet of Harn's Marsh into the Orange River, which will raise water levels in Harn's Marsh, restrict flows from Harn's Marsh, and lower peak flow discharge into the Orange River. In addition, control weirs that currently discharge into Harn's Marsh will be repaired, modified, or replaced to allow flexible operation to provide maximum flood storage in the marsh. Separate wet and dry season control elevations will be maintained. Higher water levels year-round due to these improvements will provide the BMPs for the marsh. The improvements will create an additional 1,450 ac-ft of storage and longer detention times in Harn's Marsh, and will improve water quality being discharged into the Orange and eventually Caloosahatchee rivers.

East Lee County Caloosahatchee Tributaries Restoration

The Lee County Surface Water Master Plan recommends that the county's rivers and creeks be cleaned of fallen debris and exotic vegetation to allow optimum performance of outfalls and avoid flooding while still maintaining good quality aquatic habitat. Lee County and the District have worked together in a cost-sharing arrangement for the cleaning of numerous creeks and rivers throughout the county. As part of this continuing cooperative effort, Lee County and the District have agreed that numerous tributaries flowing into the Caloosahatchee River east of the W.P. Franklin Locks are in danger of becoming seriously infested with exotic vegetation. While the removal of exotic vegetation is considered necessary to improve drainage, it is also acknowledged that removal of the vegetative growth from the banks may leave them susceptible to erosion. Replanting those areas with desirable native vegetation is now an important consideration. In addition to bank stabilization, replanting is important for maintaining or improving water quality, as well as reestablishing habitat for the native wildlife.

SOUTHERN CHARLOTTE HARBOR

INTRODUCTION

Charlotte Harbor is Florida's second largest open-water estuary, and one of the state's major environmental features. It is bordered by three counties (Lee, Charlotte, and Sarasota) and has a broad barrier island chain and a largely intact mangrove shoreline with significant parts in public ownership and management. It is the site of three National Wildlife Refuges and four aquatic preserves. Its watershed stretches from the headwaters of the Peace River in Polk County to the southern end of Estero Bay in Lee County, a distance of more than 100 miles.

Charlotte Harbor and its adjoining lands and waters constitute a comparatively large ecosystem. The Charlotte Harbor Estuarine System includes Charlotte Harbor, Pine Island Sound, Matlacha Pass, San Carlos Bay, and the Caloosahatchee Estuary (**Figure 12-47**). Only the southern portion of the Charlotte Harbor system lies within the District's boundaries. Southern Charlotte Harbor (within District boundaries) includes southern portions of Pine Island Sound and Matlacha Pass, San Carlos Bay, and the Caloosahatchee Estuary.

The Charlotte Harbor estuarine system is dominated by the rivers that flow into the coastal areas. Unlike other estuaries in Southwest Florida that are primarily influenced by the Gulf of Mexico, these rivers create Charlotte Harbor's special characteristics. Large fluctuations in river flows between the wet and dry seasons affect its salinity and other water characteristics. In Southern Charlotte Harbor, the Caloosahatchee River meets the harbor at Shell Point.

In 1987, the Surface Water Improvement and Management Act (SWIM) Chapters 373.451–373.4595, F.S., was enacted. The law directed the state's water management districts to prioritize water bodies, develop plans for their management, and fund restoration projects in these special watersheds. The Southwest Florida Water Management District (SWFWMD) designated Southern Charlotte Harbor watershed as a SWIM water body, one of 29 watersheds in Florida. The SFWMD has added the Southern Charlotte Harbor watershed to this list of priority water bodies.

Figure 12-47. Geographic location of Southern Charlotte Harbor.

Hurricane Charley

In 2004, the entire Southern Charlotte Harbor region was impacted by Category-4 Hurricane Charley. Currently, the damage inflicted by Charley is being assessed by several federal agencies and principally investigated by the U.S. Geological Survey. Damage assessments can be viewed on their web site: www.coastal.er.usgs.gov/hurricanes/charley/.

Category-4 Hurricane Charley came ashore on the southwest coast of Florida on August 13, 2004. The USGS, NASA and USACE are cooperating in a research project investigating coastal change that occurred during Hurricane Charley. On August 15, 2004, aerial video and still photography were acquired from Venice to Marco Island, Florida. On August 16, 2004, coastal topography and bathymetry of the same region were surveyed using NASA's EAARL (Experimental Advanced Airborne Research Lidar), a laser mapping system. These data will be compared to an earlier survey conducted in June 2004 by the USACE using CHARTS (Compact Hydrographic Airborne Rapid Total Survey). The comparison will detect the magnitude and spatial variability of coastal changes such as beach erosion, overwash deposition, and island breaches. These data will be used to develop and test predictive models of coastal impacts from severe storms. The data will be made available to local, state and federal agencies for purposes of disaster recovery and erosion mitigation.

ENVIRONMENTAL ASSESSMENT CRITERIA

The following sections describe the environmental and biological criteria that are used to assess the health and condition of Southern Charlotte Harbor. The performance of the system during WY2005 is evaluated using these criteria. Descriptions of restoration projects and significant findings of resource assessment projects conducted over WY2005 are also given.

Freshwater Inflow

For establishment of flow criteria, see the *Caloosahatchee Estuary* section.

A performance measure and target for freshwater discharge at S-79 has been set to meet salinity criteria in San Carlos Bay (**Table 12-15**). Flows greater than 4500 cfs depress salinity in San Carlos Bay and threaten the marine turtle grass (*Thalassia testudinum*) typical of this region (Chamberlain and Doering 1998a).

Table 12-15. Performance measure and target for freshwater discharge at S-79.

Performance Measure	Freshwater Discharge at S-79	Target
High Flow (mean monthly)	Number and frequency of months > 4,500 cfs	Not to exceed one consecutive month in three years

Seagrass and Oysters

While no performance measures for seagrasses or oysters have been formally accepted, both are monitored as indicators of the health of Charlotte Harbor. Preliminary targets for oysters have been suggested and are presented below.

ENVIRONMENTAL CONDITION OF CHARLOTTE HARBOR

Freshwater Inflow at S-79

Historically, flows have averaged greater than 4,500 cfs for 1.34 months per year (**Table 12-16**). In WY2005, mean monthly flows greater than 4,500 cfs occurred for two months. Mean monthly flows exceeded the set target of "not to exceed one consecutive month" once in WY2004, placing ecological resources in San Carlos Bay and Lower Charlotte Harbor at risk.

Table 12-16. Number of months S-79 discharge exceeded 4,500 cfs.

Performance Measure	Historical (WY1966–WY2004)	WY2005
Greater than 4500 cfs	1.34 ± 0.62	2

SEAGRASSES

In support of CERP projects, a manual seagrass monitoring program at Sites 7 and 8 (**Figure 12-47**) began in 2004 to establish a baseline prior to project implementation. The entire period of record for *Thalassia testudinum* and *Halodule wrightii* in San Carlos Bay is shown below (**Figure 12-48**). The short length of the record precludes evaluation at this time; although the decline in both species observed following Hurricane Charley (August 13, 2004) suggests a storm effect.

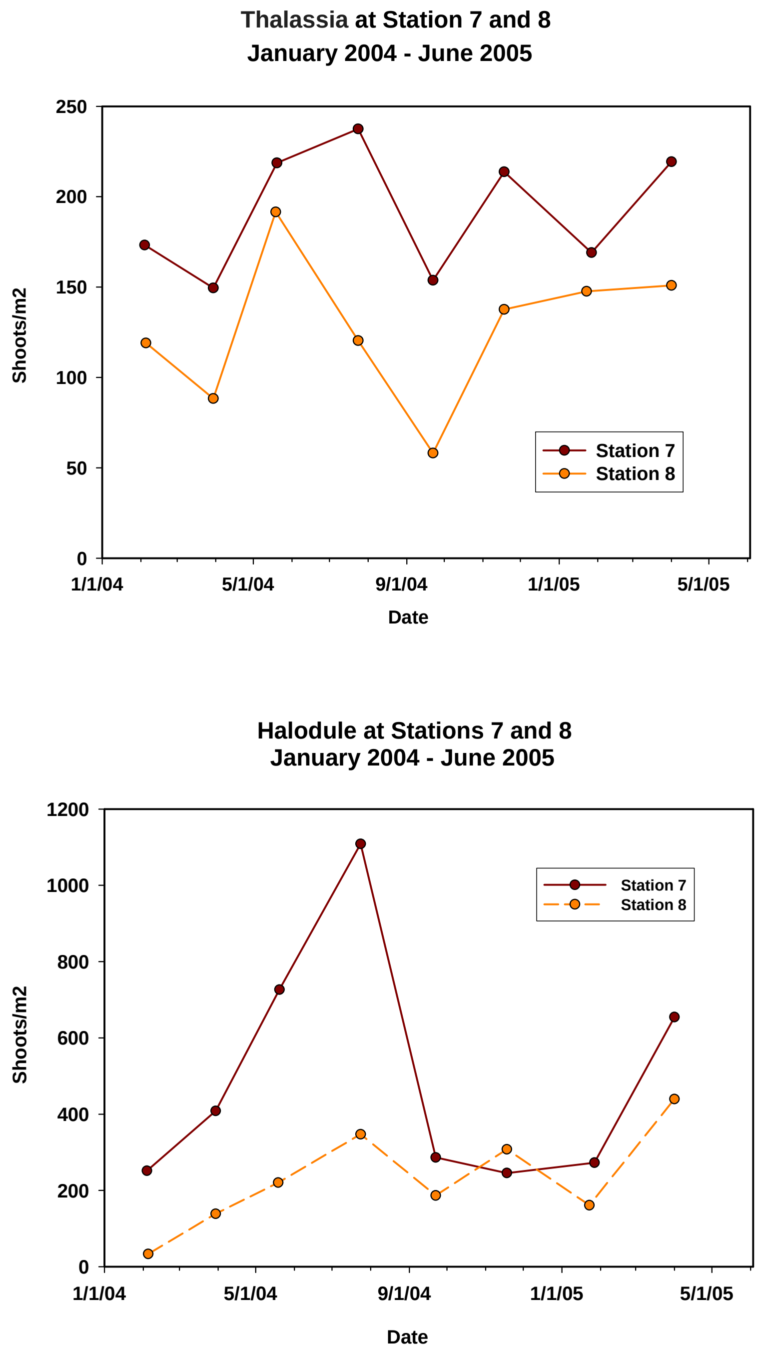


Figure 12-48. Turtle grass, *Thalassia testudinum*, in San Carlos Bay (top panel). Shoal grass, *Halodule wrightii*, in the lower Caloosahatchee and San Carlos Bay (bottom panel).

Oysters

Historical information on the aerial extent of oyster reefs in Charlotte Harbor is not available. Based on WY2004 data, there are presently 15.04 acres of oysters in Lower Charlotte Harbor . A preliminary target for aerial extent of oyster reefs in Lower Charlotte Harbor is a sixty acre increase in the next 10–15 years with the proper changes in flow and salinity. With the addition of hard substrate, this target can be increased to 150–200 acres of oyster reefs.

CURRENT SCIENCE, ENGINEERING, AND RESTORATION ACTIVITIES

Resource Assessment

SALINITY MONITORING

The District maintains a series of electronic monitoring stations that collect salinity and temperature data every 15 minutes (Chamberlain and Doering, 1998a). There are currently two sites located in Charlotte Harbor: one is located on the Sanibel Causeway and the other is located just inside of Shell Point. Category-4 hurricane Charley came ashore in the vicinity of Sanibel Captiva and completely destroyed our Sanibel causeway monitoring station. It is scheduled to be rebuilt in latter part of 2005. Data are used to monitor compliance with the Caloosahatchee MFL, support water management of Lake Okeechobee, and support development of hydrodynamic and water quality models.

SUBMERGED AQUATIC VEGETATION MONITORING

Monitoring SAV in Charlotte Harbor is performed using spatially and thematically accurate Arc/INFO seagrass (SAV) databases. These databases were created by Avineon for the coastal waters of the District, from Boca Grande south to Wiggins Pass, using January 2003 true-color aerial imagery. This area was flown again in January 2004. New seagrass databases will be created using these images and trend analyses will be preformed.

As indicated above, the Sanibel-Captiva Conservation Foundation Marine Laboratory has begun a long-term program for manual monitoring SAV and associated water quality in San Carlos Bay (Sites 7 and 8, **Figure 12-47**). In addition to this contractual effort, eight SAV sites have been surveyed since 1996 by the SFWMD using hydroacoustic technology (Sabol et al., 2002). Four sites are located upstream of Shell Point and two locations are near the manual SAV sampling sites 7 and 8 depicted in **Figure 12-47**. The remaining two location are at sites 9 and 10 in lower Pine Island Sound. This methodology allows for a greater spatial coverage of sampling for the same effort as traditional manual methods (Chamberlain et al., 2005) and will help determine freshwater inflow influence on seagrass density and depth distribution.

OYSTER MONITORING

In Southwest Florida, eastern oysters (*Crassostrea virginica*) have been identified as a VEC. Oysters are natural components of southern estuaries and were documented to be abundant in the system. This project is in response to the CERP Monitoring Assessment Plan (MAP) (see Chapter 7 of the 2005 SFER – Volume I). Florida Gulf Coast University has been contracted to conduct a long-term program for monitoring oysters in the lower Caloosahatchee Estuary (two sites) and San Carlos Bay (three sites) in order to determine if the restoration of beneficial patterns of freshwater inflow, salinity, and water quality to the Caloosahatchee Estuary will achieve the expected distribution, community structure, and viability of oysters. Adult abundance and health, spat recruitment, and juvenile growth and survival are measured twice annually, monthly (March–October), and monthly (year-round) respectively. Water quality measurements are taken during monitoring events.

Fisheries Enhancement and Assessment

The fisheries resources in Southern Charlotte Harbor and the Caloosahatchee Estuary are poorly understood. In early 2004, the Florida Marine Research Institute expanded their Fisheries Independent Monitoring (FIM) Program into Lower Charlotte Harbor. This District contract is a component of the MAP. The FIM Project is long term and is designed to estimate relative abundance of fish and to provide information on the status and trends of fish populations. This project will also provide information on fish community composition and estuarine habitat use.

In addition, the District has contracted Sanibel-Captiva Conservation Marine Laboratory to determine the preferred habitat for juvenile red drum and the optimum release strategy, including life stage, for hatchery-reared fish in Lower Charlotte Harbor. This project will help establish the fisheries enhancement potential in local waters, determine the tag retention rate survivorship of juvenile redfish, and determine the effect that habitat type for site release as it relates to survivorship. **Figure 12-49** shows the established sample sites currently being sampled for the Regional Redfish Stock Enhancement Program, funded through the Charlotte Harbor Initiative. The Charlotte Harbor Initiative is a program authorized by the Florida legislature that funds stormwater management and environmental restoration projects in the harbor.

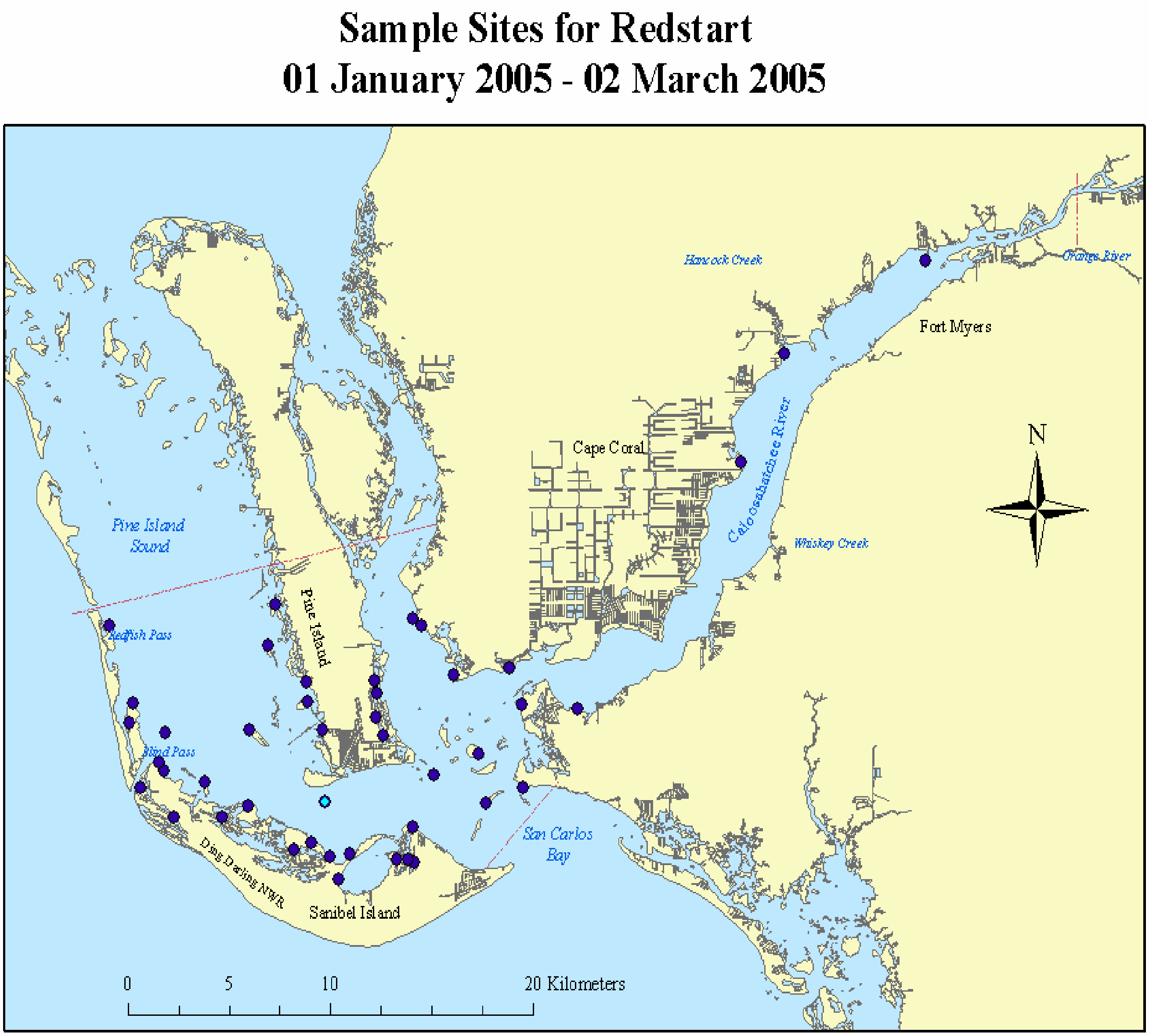


Figure 12-49. Established sample sites currently being sampled for the Regional Redfish Stock Enhancement Program.

RESTORATION ACTIVITIES

Reestablishing Mangroves along Disturbed Shorelines

In many Southwest Florida coastal areas, development has left behind a shoreline that, while damaged, is capable of being restored to a productive mangrove shoreline. Recently, methods have been developed that insure success in planting mangroves from seedlings along a variety of disturbed coastal areas. Sanibel-Captiva Conservation Foundation Marine Laboratory was contracted to conduct a pilot study in Clam Bayou on Sanibel Island to determine if restoration can be achieved in the Charlotte Harbor system. The Marine Lab incorporated volunteers to replant red mangroves in the Dinkins Bayou using this new technique to help ensure seedling success. During this restoration pilot, (Milbrandt, 2005) showed that there were no significant differences in the effects of soil amendments, and the effectiveness of polyvinyl chloride (PVC) sleeves on mangrove seedlings growth rates or survivability. In addition, Milbrandt (2005) recommended using locally adapted plants from Dinkins Bayou, or Pine Island Sound, for the Clam Bayou shoreline restoration effort in order to improve survivability. The results of the Clam Bayou restoration pilot indicated that Clam Bayou's shoreline, being protected from wave action, would be an ideal candidate for shoreline restoration (Milbrandt, 2005). This project was funded through the Charlotte Harbor Initiative.

Removal of Exotics and Reestablishment of Native Vegetative Mosaic

The Charlotte Harbor Buffer Preserve is one of the last regional holdouts for some rapidly disappearing ecosystems, and provides a matrix of increasingly rare habitats for a host of state and federally listed endangered and threatened species such as the piping plover, wood stork, bald eagle, gopher tortoise, eastern indigo snake, golden leather fern, and beautiful pawpaw. Exotic pest plants such as Melaleuca, Brazilian pepper, Australian pine, Earleaf acacia, and aquatic soda apple are threatening these habitats, and these exotics have led to a loss of fish and wildlife habitat. Removal of exotic species can improve the environmental integrity of the Charlotte Harbor area, as well as preserve, restore, and enhance seagrass beds, coastal wetlands, and functionally related uplands. It can also contribute to improved water quality. In 2004, the District assisted in the removal of exotics in the Charlotte Harbor Buffer Preserve through funding from the Charlotte Harbor Initiative. Additional information regarding exotic species is presented in Chapter 9 of this volume.

Lee County Drainage Improvements

The Gator Slough and Powell Creek watersheds have been altered by urbanization, construction of roadway grades, and diking for agricultural activities over the last thirty years. This has resulted in unnatural diversions and decreased base flows. The large volume of runoff entering Matlacha Pass is also having detrimental effects on the vegetative and aquatic life at the Gator Slough discharge point. Through the Charlotte Harbor Initiative, funding has been secured to assist in the construction of a system to capture excess runoff in the Gator Slough system and prevent runoff into Matlacha Pass and for the environmental clean-up and drainage improvement of Powell Creek. Planned improvements will not only provide for a hydrologic restoration to the Gator Slough/Powell Creek System, but will also restore a more historic base flow condition in the lower reaches of the natural Powell Creek system.

Northwest Lee County Surface Water Improvements

Funds have been provided to Lee County through the Charlotte Harbor Initiative to develop a surface water management plan for the northwest region of Lee County that includes an overall assessment of existing conditions. This region consists of four principle watersheds: Yucca Pen, Durden Creek, Greenwell Branch, and Longview Run. These watersheds drain into Charlotte Harbor. This plan will involve delineation and development of hydrologic/hydraulic models. The surface water management plan will include identification of issues of concern, existing level of service deficiencies for flooding, and evaluation and sizing of all proposed control structures along Burnt Store Road to convey the 25-year flood for the projected capacity at build-out.

Restoration of Shellfish in Charlotte Harbor

Florida Gulf Coast University, in collaboration with the Lee County School District, the SFWMD, Florida Sea Grant, and the city of Cape Coral, constructed five oyster reefs (10 m^2 each) in the lower Caloosahatchee River (two sites) and San Carlos Bay (three sites) using recycled oyster shell and stabilizing mesh in order to establish suitable substrate for oyster recruitment. This community-based restoration involved the general public, as well as high school and undergraduate students (52 volunteers and 11 boats). Reefs will be monitored to determine restoration success. This project was funded through the Charlotte Harbor Initiative.

Sanibel-Captiva Road Culvert Connection Project

This project provided the city of Sanibel with matching funds to assist in an environmental restoration project designed to improve tidal flow and water quality in Clam Bayou and Dinkins Bayou at the west end of Sanibel Island by connecting them with a culvert under Sanibel-Captiva Road. Road construction since the 1920s on Sanibel closed off this historic connection, which was once the main channel of Blind Pass. Clam Bayou, an extraordinarily productive mangrove-lined estuary, is now completely blocked off from tidal flows except when rare and ephemeral tidal pass connections to the Gulf of Mexico occur during and just after major storm events. This has left Clam Bayou in an impounded condition, with fish kills and very serious mangrove die-offs occurring when major rainfall volumes are trapped in the basin. Oyster bars and submerged marine seagrass beds in the bayou are extremely stressed by degraded conditions. Over 116 acres of red mangrove forest were killed during a 2001 water impoundment event. Dinkins Bayou is still connected to Pine Island Sound at Blind Pass, but is also degraded, in that it is suffering from low tidal circulation and poor water quality due to the closure of that pass. This project involves the removal of invasive exotic tree species and the removal of fill roads in wetlands.

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