Chapter 2: Hydrology of the South Florida Environment

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SUMMARY

Given hydrology's significance to the entire South Florida ecosystem, this chapter updates hydrologic data and analysis for Water Year 2007 (WY2007) (May 1, 2006–April 30, 2007). WY2006 hydrology is available in the *2007 South Florida Environmental Report – Volume I, Chapter 2* (Abtew et al., 2007a). This report includes a section on the active severe drought from 2006 through 2007 in South Florida, followed by the hydrology of WY2007. A draft summary on the South Florida Hydrologic Monitoring Network is also included with this year's chapter appendices (Appendix 2-1).

Challenges in multi-objective water management are created by hydrologic variation. Too much or too little water creates flooding, water shortage, or ecological impacts. Although South Florida is a wet region, serious droughts have occurred such as the current drought, and there is potential for periodic water shortages. Impacts from hydrologic variation can be mitigated with storage capacity and conveyance capacity increases.

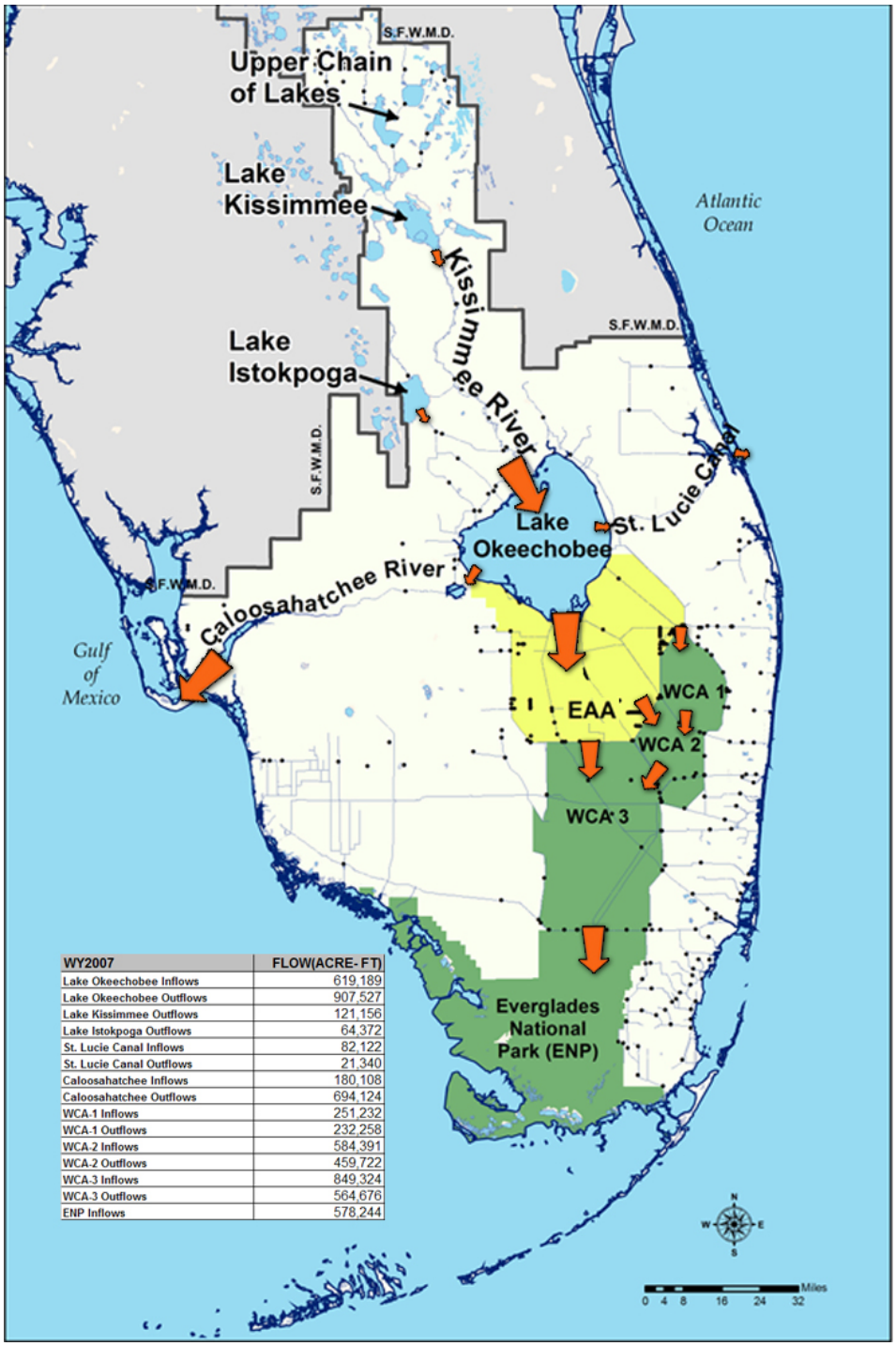
The hydrology of South Florida for WY2007 can be summarized as a severe drought year with rainfall below average in all the rainfall areas and far below average in most of the rainfall areas. Lake Okeechobee, East Everglades Agricultural Area and Martin St. Lucie rainfall areas had low rainfall with a drought frequency of 100-year return period. Relatively, the Southeast (Broward, Miami-Dade, Everglades National Park), the Big Cypress Preserve and the Southwest Coast received more rain compared to the respective average rainfall. Upper Kissimmee and Lower Kissimmee were dry resulting in only 619,189 acre-feet (ac-ft) inflow to Lake Okeechobee. This inflow is 29 percent of the historical average and 17 percent of WY2006 inflow. Outflows were also reduced due to the limited storage in Lake Okeechobee and the reduced inflows. WY2007 outflow from Lake Okeechobee was 907,527 ac-ft, 60 percent of the average outflow and 16 percent of WY2006 outflow. Lake Okeechobee water level declined to 9.65 feet National Geodetic Vertical Datum, the second lowest stage in a year since 1931. The low lake level restricted gravity discharge and 14 temporary pumps were installed to discharge water from the lake into the major canals to the south and pumped 52,174 ac-ft from March to April 2007. The low lake level and deficit of rainfall resulted in a series of water conservation measures that included restrictions to water use.

The drought resulted in significant reduction to flows through the region:

- Lake Kissimmee did not have significant discharge for 173 consecutive days and the water year total outflow of 121,156 ac-ft is 17 percent of the historical average.
- Lake Istokpoga water year outflow of 64,372 ac-ft is 29 percent of the historical average.
- Discharge into the estuaries decreased as a result of the drought.

- The St. Lucie Canal discharged 21,340 ac-ft through the S-80 structure: 4 percent of the historical average.
- Discharge through the Caloosahatchee Canal into the estuary through the S-79 structure was 694,124 ac-ft, less than half of the historical average.
- Inflow into Water Conservation Area 1 was 251,232 ac-ft, 49 percent of the historical average.
- Inflow into Water Conservation Area 2 was 584,391 ac-ft, 93 percent of the historical average.
- Outflow from Water Conservation Area 2 was 459,722 ac-ft, 74 percent of the historical average.
- Inflow into Water Conservation Area 3 was 849,324 ac-ft, 70 percent of the historical average.
- Outflow from Water Conservation Area 3 was 564,676 ac-ft, 55 percent of the historical average.
- Inflow into Everglades National Park was 59 percent of the historical average and 30 percent of WY2006.

Figure 2-1 presents surface water flows for the entire system for major hydrologic components.



WY2007	FLOW(ACRE-FT)
Lake Okeechobee Inflows	619,189
Lake Okeechobee Outflows	907,527
Lake Kissimmee Outflows	121,156
Lake Istokpoga Outflows	64,372
St. Lucie Canal Inflows	82,122
St. Lucie Canal Outflows	21,340
Caloosahatchee Inflows	180,108
Caloosahatchee Outflows	694,124
WCA-1 Inflows	251,232
WCA-1 Outflows	232,258
WCA-2 Inflows	584,391
WCA-2 Outflows	459,722
WCA-3 Inflows	849,324
WCA-3 Outflows	564,676
ENP Inflows	578,244

Figure 2-1. Water Year 2007 (WY2007) inflow and outflow into major hydrologic components.

INTRODUCTION

THE SOUTH FLORIDA REGIONAL WATER MANAGEMENT SYSTEM: A REGIONAL OVERVIEW

The South Florida Water Management District (SFWMD or District) area extends from Orlando in the north to the Florida Keys in the south (**Figure 2-2**). The District's water management system consists of lakes, impoundments, wetlands, and canals that are managed under a water management schedule based on flood control, water supply, and environmental restoration. The general surface water direction is from the north to the south, but there are also water supply and coastal discharges to the east and the west. The major hydrologic components comprise of the Upper Kissimmee Chain of Lakes, Lake Okeechobee, Lake Istokpoga, the Everglades Agricultural Area (EAA), the Caloosahatchee Basin, St. Lucie Basin, the Lower East Coast, and the Everglades Protection Area (EPA).

The Upper Kissimmee Chain of Lakes (Lake Myrtle, Lake Alligator, Lake Mary Jane, Lake Gentry, East Lake Tohopekaliga, Lake Tohopekaliga, and Lake Kissimmee) are a principal source of inflow to Lake Okeechobee. On average, 48 percent of inflow into Lake Okeechobee is through the Kissimmee River (C-38 canal) (Abtew et al., 2002). The Upper Kissimmee watershed has an area of approximately 1,620 square miles (sq mi). The Lower Kissimmee River basin (727 sq mi) also contributes inflows to Lake Okeechobee. Additional inflows to Lake Okeechobee are from the Lake Istokpoga Surface Water Management Basin (418 sq mi), Fisheating Creek, the Taylor Creek-Nubbin Slough Basin, reverse flows from the Caloosahatchee River, the St. Lucie Canal, and the EAA (Abtew et al., 2002). Lake Istokpoga is a 43-sq-mi shallow lake with outflow through structure S-68 into the Surface Water Management Basin.

Lake Okeechobee is in the center of the South Florida hydrologic system with an area of 730 sq mi and a mean depth of 8.86 feet (ft). Since 1931, the average water level elevation has been 14.41 feet National Geodetic Vertical Datum (ft NGVD) with a maximum 18.77 ft NGVD set on November 2, 1947, in a hurricane season. The lowest water level on record for the lake was 8.97 ft NGVD set on May 24, 2001, during the 2000–2001 drought. During the current drought (2006–2007), Lake Okeechobee has already reached the now-second lowest water level on record of 9.65 ft NGVD on April 30, 2007. Further decline in water level is persisting with outflows from the lake exceeding inflows. A historical record low water level was already recorded in WY2008 (on July 2, 2007, 8.82 ft NGVD). The annual average inflow to Lake Okeechobee (based on data from 1972 through 2007) is about 2.1 million acre-feet (ac-ft), while the average outflow is about 1.5 million ac-ft. Outflows are mainly through the south, southeast, and southwest structures. The EAA is the main source of surface water inflow into the EPA. An average of 900,000 ac-ft of water is discharged from the EAA to the south and southeast, mostly discharging into the EPA (Abtew and Khanal, 1994; Abtew and Obeysekera, 1996). About 10 percent of the outflow is lake water flow through the EAA, with most of it reaching the EPA (Abtew and Khanal, 1994; Abtew et al., 2002).

The EPA begins at the southern and eastern edges of the EAA and extends south to the Florida Bay. The EPA consists of several defined regions: Water Conservation Area 1 (WCA-1) (221 sq mi), which contains the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge); WCA-2A and WCA-2B (210 sq mi); WCA-3A and WCA-3B (915 sq mi); Everglades National Park (ENP or Park) (2,150 sq mi); and Florida Bay, as shown in Redfield et al. (2003). The EPA receives additional surface water inflows from the urban areas in the east and the southeast and northwest sources currently identified as non-Everglades Construction Project (non-ECP) stormwater flows. Surface water flow in and out of the EPA is determined by weather-related factors and multi-objective water management decisions that include fixed regulation

schedules, deviations, commitments, and emergency management. Emergency management includes flood control during high rainfall events, water supply during drought periods, saltwater intrusion prevention, and environmental issues. From north to south, flood control and water supply are managed through a system of canals, stormwater detention ponds, lakes, impoundments, and water control structures. The extent of the EPA and major hydrologic components are shown in **Figure 2-2**.

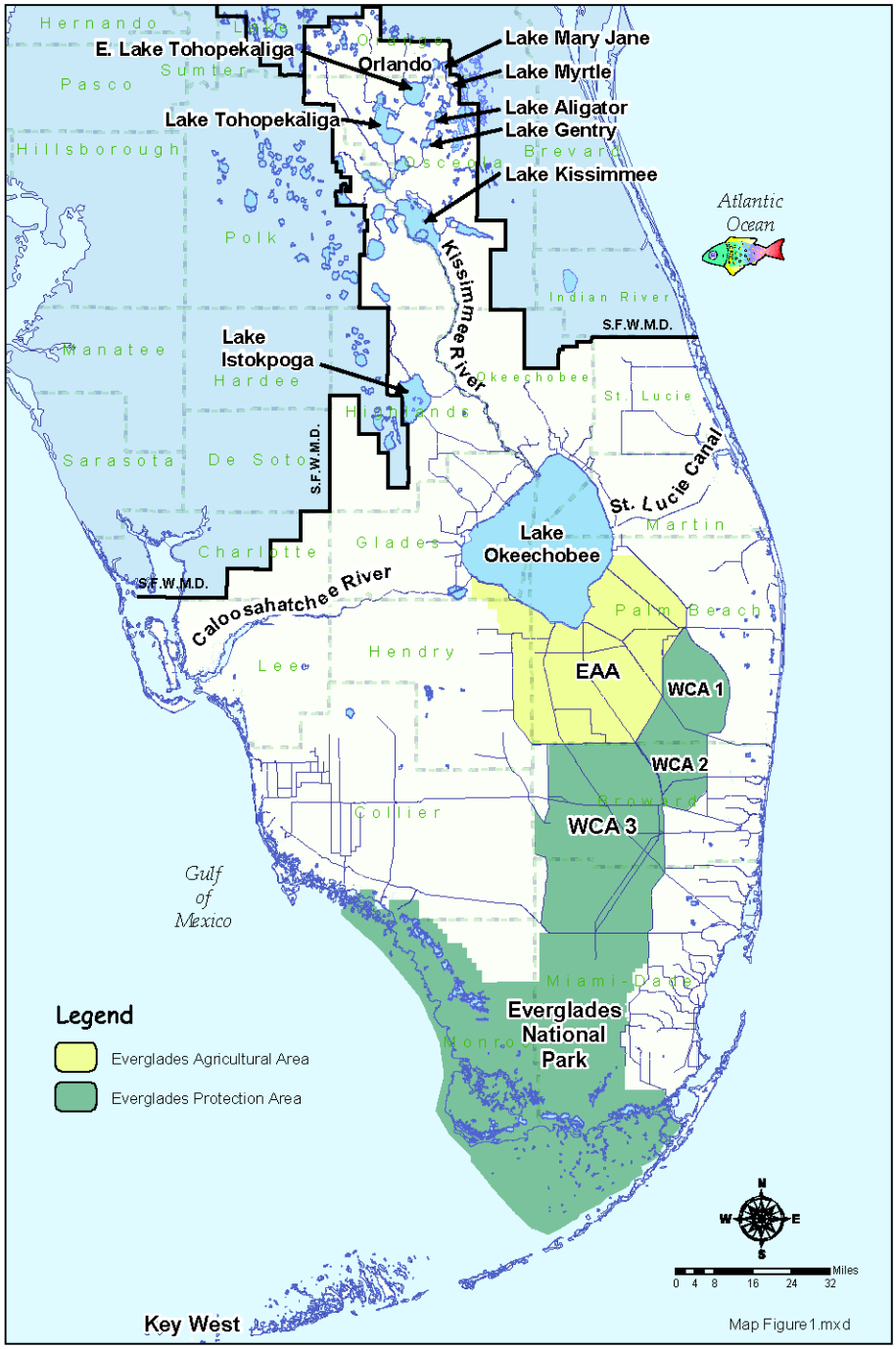


Figure 2-2. The Everglades Protection Area (EPA) and major hydrologic components of the South Florida water management system.

The hydraulic components of the water management system are composed of storage and conveyance systems. The major storage components are lakes, impoundments, ponds and wetlands. The surface area and storage in a lake or impoundment are functions of the water level. Stage-storage and stage-area relationships (curves) for the major lakes and impoundments are published in the *2007 South Florida Environmental Report (SFER), Appendix 2-2* (Abtew et al., 2007b). The conveyance system is composed of canal networks and water control structures. Water is moved throughout the water management system by gravity and pumps. Table 2-1 shows the volumes of water pumped by the District for Fiscal Years 1996–2006 (FY1996–FY2006); the District's fiscal year is from October 1st through September 30th. The general hydraulic gradient as represented by average water levels is from north to south, from Lake Tohopekaliga to the Florida Bay with a drop of 54 ft in elevation for a distance of about 250 miles. On average, the water level drop from Lake Okeechobee to the Caloosahatchee Estuary, 70 miles to the west, is 14.41 ft. From Lake Okeechobee to the St. Lucie Estuary, the average water level drop 35 miles to the east is 14.41 ft.

Table 2-1. District water pumping volumes for Fiscal Years 1996–2006 (FY1996–FY2006).

Year	Volume of Water Pumped (ac-ft)
1996	2,480,000
1997	1,840,000
1998	2,020,000
1999	2,090,000
2000	2,517,000
2001	2,131,000
2002	3,131,000
2003	3,339,000
2004	3,404,000
2005	3,938,000
2006	3,583,095

The District has an exhaustive hydrologic monitoring network and database. The District's hydrometeorologic database, DBHYDRO, also stores data from other agencies such as the U.S. Geological Survey (USGS), the U.S. Army Corps of Engineers (USACE), National Oceanic and Atmospheric Administration (NOAA), the ENP, Florida Forestry Service (FFS), Florida Department of Environmental Protection (FDEP), and others. Summary details of hydrometeorological monitoring by the District are presented in Appendix 2-1. (Additional information on DBHYDRO is available on the District's web site at www.sfwmd.gov under the *What We Do, Environmental Monitoring, DBHYDRO Browser* section.)

South Florida experiences hydrologic variation that ranges from extreme drought to flood. The hydrology of the area is driven by rainfall, rainfall-generated runoff, groundwater recharge and discharge, and evapotranspiration. Surface water runoff is the source for direct and indirect recharge of groundwater, lake and impoundment storage, and replenishments of wetlands. Excess surface water is discharged to the coast. Hydrologic variation in South Florida is extensively presented in the *2007 SFER – Volume I* (Abtew et al., 2007a). A synopsis of the hydrology and hydraulics of South Florida is presented in Abtew et al. (2007c).

Water Management and Hydrologic Variation

The South Florida water management system is a network of natural and constructed storage and water conveyance systems. In many cases, due to extraordinarily increased cost, water management storage and conveyance systems are designed and built to handle a fixed, limited degree of hydrologic variation. Temporary storage and timely removal of excess water is the key for water management in South Florida. Hydrologic variations in South Florida and the regional hydrologic variation indicators are key elements that impact water management. Hydrologic variation in South Florida is presented in Abtew et al., 2007a. In South Florida, rainfall can vary at a site from 30 inches annually during drought years to 100 inches annually during wet years. Not only does the magnitude of annual rainfall impact water management but also the spatial and temporal distribution of the rainfall as well. The amount and impact of generated runoff during wet periods is also dependent on precedent and antecedent conditions. These conditions determine amount of sub-surface and surface storage available, conveyance capacities and state of areas used for temporary storage.

WATER MANAGEMENT

Water management is accomplished by operating hundreds of water control structures across the District. It is complicated by many factors including surface water-groundwater interaction, rainfall-runoff relationships, topography, errors in measurements, and/or estimates of hydrologic components such as flow, rainfall, evapotranspiration, storage and seepage, multiple competing objectives, and the uncertainty of forecasting meteorological events and climatic outlook. In addition, there are significant spatial and temporal variations of hydrologic components across the District.

Water management is performed for meeting various purposes by using previously established regulation schedules that integrate different purposes. Regulation schedules are rule curves designed to manage the regional available storage. In order to broadly satisfy flood control and water supply needs on a long-term basis, water level regulation schedules for each of the water bodies were developed by the District and USACE in cooperation with other agencies and stakeholders. Detailed regulation schedules for lakes and impoundments are published in *2007 SFER, Volume I, Appendix 2-6* (Abtew et al., 2007d).

A group of water managers, scientists, and engineers from the District, USACE, and other federal and state agencies meet via telephone weekly to discuss the state of the water management system and possible operational scenarios. The focus is on making recommendations that consider the environmental impacts of operational decisions. Weather reports that include the previous week's rain amounts and upcoming week's rain forecast are presented in the meeting. In addition, longer-term climatic outlooks for rainfall produced by NOAA's Climate Prediction Center (CPC) are reviewed. Reports on the ecological and hydrological status of different areas of the system, such as the Kissimmee Basin, Lake Okeechobee, the estuaries, and the Everglades, are presented. Considering all the reports and predictions, an operational recommendation for the week is prepared by the team and submitted to District managers for their approval. The Weekly Environmental Recommendation for System Operations is then provided to USACE and used to guide decisions on regulatory discharges from major impoundments including Lake Okeechobee (SFWMD, 2000).

Purposes of Water Management

Flood control and water supply are the two major purposes of water management in the District. During the wet season, the primary purpose is flood control. During the dry season, the water management system operates primarily to satisfy various water supply demands that include environmental deliveries, irrigation and utilities requirements, and the prevention of salt water intrusion in groundwater.

Use of Regulation Schedules for Water Management

The amount of storage volume available for water management varies significantly year to year due to large variations in rainfall. This variation causes large gaps between available water volume generated from rainfall runoff and water demands. For any given year, up to 30 to 40 percent of the Standard Project Flood is met for flood control while most of the water supply needs of the District are met. In order to broadly satisfy flood control and water supply needs on a long-term basis, monthly water level regulation schedules for each of the water bodies were developed by the District and USACE in cooperation with other agencies and stakeholders. These regulation schedules are designed to balance the multiple and sometimes competing purposes of the system. The regulation schedules account for physical capacities of the upstream and downstream levees, canals, and water control structures. In addition, appropriate and relevant constraints, such as salinity intrusion and water quality, are also incorporated in the regulation schedule. These regulation schedules are revised when necessary to better balance system objectives.

Occasionally, temporary deviations from the normal regulation schedules are granted. This is to accommodate changing weather, hydrologic and ecological conditions, structure malfunction, and/or emergency conditions for a short interval with a start and end date. The deviations are typically requested by District managers and/or the USACE's district engineer.

Elements of Water Management

The District is the local sponsor for the Central and Southern Florida (C&SF) Project designed and built by the USACE and is in charge of the daily maintenance and operation for the majority of the system. The USACE maintains flood control and navigation operating authority for the primary waterway structures. **Table 2-2** shows a list of major water control structures operated by the USACE.

Table 2-2. Water control structures operated by the U.S. Army Corps of Engineers.

BASIN OR AREA	WATER CONTROL STRUCTURES
Lake Okeechobee	CULV 1, CULV 1A, CULV 2, CULV 3, CULV 4A, CULV 5, CULV 5A, CULV 6, CULV 7, CULV 8, CULV 9, CULV 10, CULV 10A, CULV 11, CULV 12, CULV 12A, CULV 13, CULV 14, and CULV 16
	S351, S352, S354 (only during a hurricane)
	S310 Lock (only during a hurricane)
	S77, S78, S79
	S308, S308B, S308C, S80
Water Conservation Areas	S10A, S10C, S10D
	S11A, S11B, S11C
	S12A, S12B, S12C, S12D
	S356
Lower East Coast	S332C

Operation of Water Control Structures

The operation of structures is performed daily using current conditions and following a set of previously established operating rules as guidelines. The operational rules of structures are available in water control manuals. Water managers pay close attention to the safety of people and property as a result of operations, specifically during extreme storm events. This requires knowing and understanding the physical capacity and capability of water control structures, levees and canals.

Operations of water control structures include adjustment of gate openings for gated spillways and gated culverts and the starting and stopping of pumps. Gated structure operations are classified into three groups. The first consists of Derived Data Set Point sites, which are computer controlled and operated from the Operations Control Center (OCC). The second consists of automatic sites, which are operated by computers or mechanical devices at the structure site not controlled from the OCC. The third group consists of manually operated gated structures.

Staff is dispatched by the OCC operator from the appropriate field station to open or close the manually operated gated structures. Pumps are controlled by the operators housed at the respective pump stations, while some of the unmanned pump stations are operated by the dispatched field station. Although these stations are typically operated during regular work hours, some must be operated after hours during extreme weather events and during most of the wet season.

Tools Used for Operations and Water Management

Currently, there are two tools used in OCC operations. The first is a computer-based system called the Supervisory Control and Data Acquisition system, also known as Telvent. This system provides real-time data acquired from field sensors that is then graphically displayed for a group

of structures. The data include upstream and downstream stages, gate openings, and pump speed. Structures are grouped by the Field Operations Centers or operational sub-region.

The second tool, the Auxiliary Operator Display, displays real-time data on computer monitors for a specific structure or site. This display provides detailed information about the structure, including upstream and downstream stages, gate openings, pump speed, flow, alarm setting, and power availability.

Use of Data and Decision Making for Operations

Several pieces of data and information are used in operational decision making. The most important data is real-time stage and gate opening or pump operation data from the water body in consideration. A water control manual or operating plan provides operations criteria for each water control structure. While it is necessary to follow the operations criteria, water managers are required to make decisions using sound engineering judgment when physical conditions dictate and make temporary deviations from these criteria when necessary. At the District, water management decisions for operations are made in two primary modes — flood control and water supply. In both modes, daily and/or hourly rainfall amounts that vary from one geographic area to another are critical in decision making for operations. In addition, groundwater flow to and from water bodies has a significant role in maintaining a specific gate opening or pump operation. Water managers have learned from experience how much influence groundwater flow has on the stage of a lake or a canal and, in turn, on the gate or pump operations.

Management and Operations of Lake Okeechobee Water Levels

The regulation of lake water levels is performed by the USACE in consultation with the District. Flood control releases from Lake Okeechobee are made to the west through the Caloosahatchee River, to the east through the St. Lucie Canal, and southward to the Everglades.

Since the early 1900s until the middle of 2000, the lake was operated using a variety of calendar-based regulation schedules. During the 1990s, the District and USACE conducted a study to develop and implement a more robust regulation schedule. Instituted in July 2000, the Water Supply and Environment (WSE) Lake Okeechobee regulation schedule has several major constraints which makes it complex. The schedule includes tributary hydrologic conditions and climatic forecasts into operational guidelines for use with the WSE Operational Guideline Decision Tree, and integral part of the regulation schedule. Part 1 of the Decision Tree defines Lake Okeechobee discharges to the WCAs. Part 2 defines Lake Okeechobee discharges to estuaries or tidewater. The Decision Tree also provides essential supplementary information to be used in conjunction with the WSE regulation schedule. The operational flexibility of the WSE regulation schedule allows for adjustments to be made in the magnitude and timing of the Lake Okeechobee regulatory discharges based on conditions in the lake, in the tributary basins, and long term climatic outlooks. These conditions are valuable for determining whether the appropriate window of opportunity exists to “hedge” water management practices by taking advantage of climatic forecasting. For example, if forecasts suggest that a drought is likely, water might be held back in the lake; conversely, if forecasts suggest higher than average rainfall, water might be released.

The schedule is divided into five zones (A, B, C, D, and E). Flood control zone A of the WSE regulation schedule for Lake Okeechobee describes maximum, practicable discharge of floodwater from the lake. Flood flow releases from flood zones A, B, C, and D are performed in conjunction with the conditions that are described in Water Control Plan for Lake Okeechobee and EAA (USACE, 2000). In flood zones B, C, and D, three levels of 10-day pulse releases are made for the St. Lucie and the Caloosahatchee estuaries. The pulse release emulates a natural rain storm event within the basins. Similarly, the receiving estuary is expected to respond to the pulse

release as if a storm had generated runoff from the upstream watershed. Details of the discharges from the three levels of pulse release for Lake Okeechobee are shown in **Table 2-3.**

Water supply releases are made in zone E for various beneficial uses that includes water supply for municipal and industrial use, irrigation of agriculture, Everglades National Park, salinity control, and estuarine management. No flood releases are required in zone E. Releases are made to the St. Lucie Canal and Caloosahatchee River to maintain navigation depths if sufficient water is available in Lake Okeechobee. The outflows from Lake Okeechobee are received by the St. Lucie Canal, Caloosahatchee Canal, EAA, and WCAs. The details of these sub-regions flows are provided in the *Water Levels, Flows and Water Management* section of this chapter. A more detailed presentation on the features and capabilities of the WSE regulation schedule is presented in USACE (2000) and Trimble et al. (2006).

Normal Lake Okeechobee operation level is below 16.5 ft NGVD. Levee inspections at intervals of seven to 30 days are initiated when water levels are between 16.5 and 17.49 ft. When water levels are in the range of 17.5 to 18.5 ft NGVD, levee inspections are conducted at intervals of one to seven days, depending upon location. Levees are inspected daily when levels are above 18.5 ft NGVD.

Although flood control releases are made under the USACE's authority, water supply deliveries from Lake Okeechobee for agriculture, human consumption, or environmental needs are made under the District's water supply authority. Supply-Side Management provides guidelines for apportioning of lake releases among different water users and release points when extreme drought conditions persist and cutbacks are imposed by the District.

Water Management in Water Year 2007

Water management operations of District facilities depend largely on the spatial and temporal distribution of rainfall. Although water management of the District facilities is performed according to prescribed operation plans, there are various constraints that need to be considered while developing and implementing shorter-term operating strategies.

During wet and dry seasons of Water Year 2007 (WY2007), operations of most water control structures were under water supply mode due to significant rainfall deficit conditions. Typically, during wet seasons, operations are performed under flood control mode. Because of the drought, wet and dry season operations were made under water supply mode. Instead of implementing flood control operations during the wet season, water supply deliveries were made for environmental, agricultural, and salt water intrusion control purposes. Details of the drought and its impact on flows and water levels are provided in subsections of this chapter.

The District has been in drought conditions since the dry season of WY2006 that received only 11.6 inches of rain, approximately 62 percent of the normal rainfall. The District average annual rainfall is 52.75 inches. Calendar year 2006 received 40.6 inches compared to 39.0 inches in 1956 and 39.5 inches in 2000. The Kissimmee Basin, major inflow source to Lake Okeechobee, received approximately 70 percent of the annual rainfall during wet season months of 2006; the wet season rainfall of 29.42 inches was one of the driest wet seasons on record.

Based on the rainfall for the wet season and the dry season of WY2007, this year's drought was ranked in the top six of the most notable droughts (SFWMD, 2007). As of June 1, 2006, much of the District experienced rainfall deficits. The Upper East Coast rainfall area had the largest rainfall deficit at 22.26 inches, followed by Palm Beach County at 18.52 inches and the Everglades Agricultural Area East at 18.31 inches. The rainfall areas that had smaller rainfall deficits included Big Cypress Preserve at 2.23 inches, Miami-Dade at 4.41 inches and Southwest Coast at 3.91 inches.

Lake Okeechobee flow releases were made by the USACE until mid-January 2006 to minimize damages to the Herbert Hoover Dike from high stages resulting from Hurricane Wilma in 2005. In January 2006, the Lake Okeechobee stage started at 15.69 ft (NGVD 29). During the first half of January, level one pulse releases to the estuaries and approximately an average of 3,660 ac-ft per day releases to south were made from Lake Okeechobee. The lake stages from October 2005 through May 2007 are shown in **Figure 2-3**. Details of the discharges from the three levels of pulse release for Lake Okeechobee are shown in **Table 2-3**.

Lake Okeechobee stage was 14.00 ft on April 18, 2006. The flow releases by the US Army Corps of Engineers (USACE) from the lake to estuaries during the spring of 2006 were primarily to create room for new storm water generated during the upcoming wet and hurricane seasons. The goal of USACE was to bring the lake stage at 13.00 ft by May 1, 2006, for this purpose. This was due to the USACE's concern for the safety of the Herbert Hoover Dike which sustained damage from Hurricane Wilma in 2005. The USACE made releases under a temporary deviation to the regulation schedule until the stage fell below regulation schedule on April 25, 2006. The lake stage continued to fall through May, even though the USACE discontinued releases on April 25, 2006. The stage fell to 13.02 ft on May 12, 2006.

Table 2-3. Three levels of pulse releases for Lake Okeechobee as shown in cubic feet per second (cfs).

Day of Pulse	Level I		Level II		Level III	
	St. Lucie S-80 (cfs)	Caloos. S-77 (cfs)	St. Lucie S-80 (cfs)	Caloos. S-77 (cfs)	St. Lucie S-80 (cfs)	Caloos. S-77 (cfs)
1	1200	1000	1500	1500	1800	2000
2	1600	2800	2000	4200	2400	5500
3	1400	3300	1800	5000	2100	6500
4	1000	2400	1200	3800	1500	5000
5	700	2000	900	3000	1000	4000
6	600	1500	700	2200	900	3000
7	400	1200	500	1500	600	2000
8	400	800	500	800	600	1000
9	0	500	400	500	400	500
10	0	500	0	500	400	500
Average Flow	**730**	**1600**	**950**	**2300**	**1170**	**3000**
Volume (ac-ft)	14,480	31,736	18,843	45,621	23,207	59,505
*Equivalent Depth (ft)	0.03	0.07	0.04	0.10	0.05	0.13

*Volume-Depth conversion based on average lake surface area of 467,000 acres

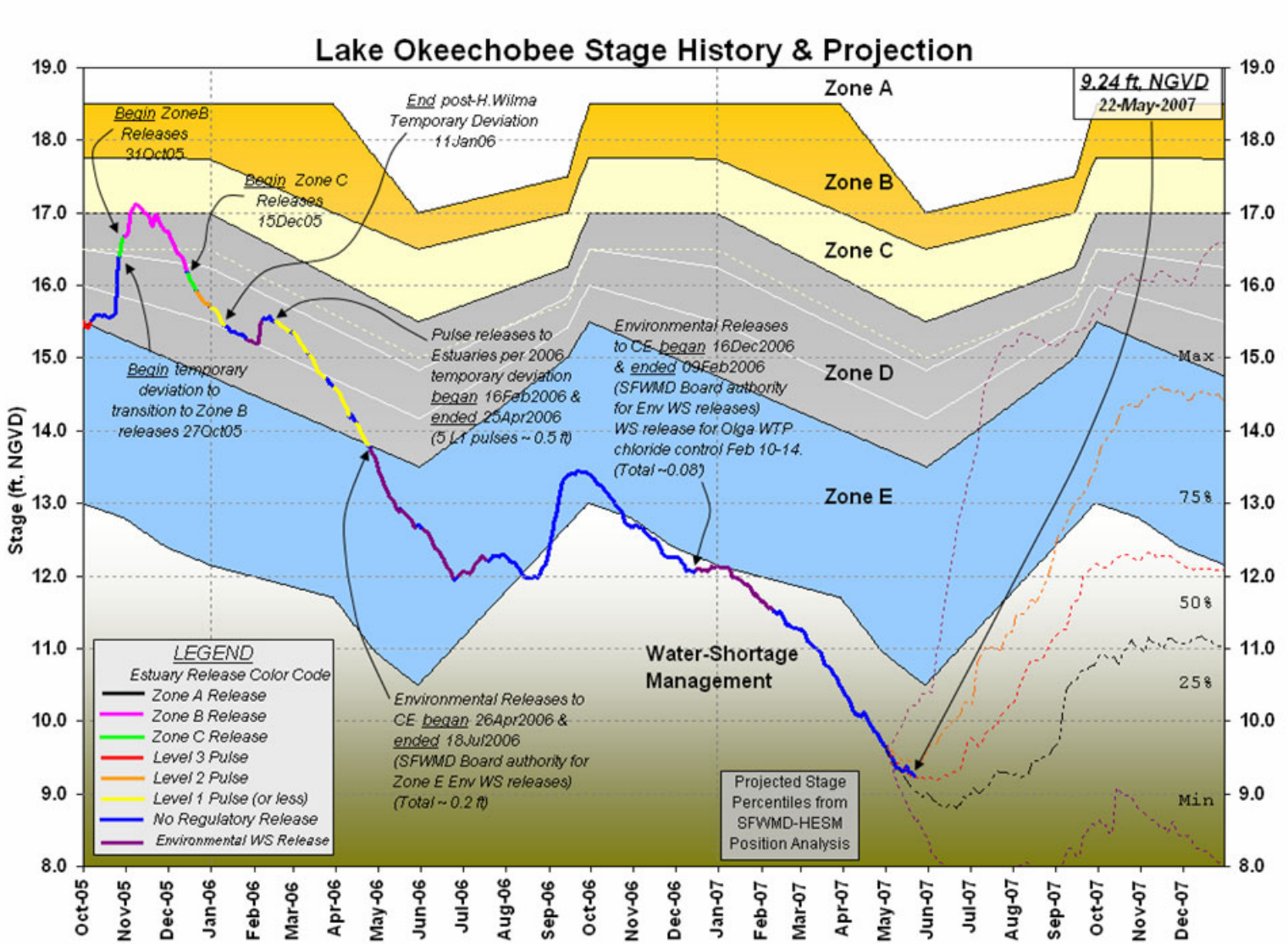


Figure 2-3. Daily Lake Okeechobee stages from October 2005 through May 2007 and operational details.

From February to April 2006, the SFWMD's Staff Environmental Advisory (SEA) Team recommended modified level one pulse release to Caloosahatchee estuary and minimum releases to St. Lucie Estuary to maintain salinity envelop. Between May and June, the Team recommended one-half level one pulse release to Caloosahatchee estuary and no releases to St. Lucie Estuary. The Water Resources Advisory Commission (WRAC) recommended to the SFWMD Governing Board to make environmental releases to Caloosahatchee Estuary. At the request of the SFWMD, the USACE began lake releases on April 25, 2006, and ended on July 18, 2006, that were half level one pulses averaging about 800 cubic feet per second (cfs). These were considerably larger than normal environmental releases that average 300 cfs over a 10-day period. However, these flows prevented an exceedance of the Caloosahatchee MFL salinity criteria at Ft. Myers. In July and mid-August, the SEA Team recommended three-day release to Caloosahatchee Estuary to maintain salinity at S-79 and no releases to St. Lucie Estuary.

The Lake Okeechobee stage receded to 12.00 ft and, thus, into the Water Shortage Management Zone on August 14, 2006. Due to some rain in August and September 2006, the stages temporarily rose above the Water Shortage Management Zone, reaching a peak stage of 13.45 ft on September 22, 2006. The lake stage again fell below the Water Shortage Management Zone on October 25, 2006. In addition, environmental releases to Caloosahatchee Estuary were made from February 10 through February 14, 2007, for chloride control for the Lee County, Olga Water Treatment Plant and were recommended by WRAC to the SFWMD Governing Board. From mid-February to May 2007, the Team recommendation included no releases to Caloosahatchee and St. Lucie Estuaries.

During August, September and October 2006, an El Niño was anticipated by NOAA's Climate Prediction Center (CPC) in the drier months of November 2006 through April 2007. El Niño typically indicates an increased chance for wetter than normal rainfall conditions during the November–April period. However, during these dry months, the moderate El Niño did not produce the expected higher than normal rainfall. From December 2005 through April 2006, there were no suggestions or indications from NOAA's CPC that upcoming wet season would be lower than normal rainy season.

The lake released a total of 907,527 ac-ft of water in WY2007. During the wet season, from May through October, a total of 449,251 ac-ft of water were released from the lake. From November through April 2007, outflow from the lake was approximately 458,276 ac-ft.

The U.S. Army Corps of Engineers (USACE) recently proposed revision to Lake Okeechobee operational guidance (USACE, 2007). At the time of this report, the USACE was in the process of preparing an Environmental Impact Statement prior to its implementation of guidance and that was planned for late 2007.

EMERGING TOPICS

THE SOUTH FLORIDA HYDROLOGIC MONITORING SYSTEM

The District collects, validates, and archives hydrologic data used for real-time water management and data analysis. As presented in Appendix 2-1, this is accomplished by using the hydrologic monitoring network of the District, which is divided into five parts: (1) the meteorological monitoring network; (2) the rainfall monitoring network; (3) the surface water stage monitoring network; (4) the surface water flow monitoring network; and (5) the groundwater monitoring network. The Hydrologic Monitoring Network of the South Florida Water Management District Report (see Appendix 2-1) details the sensors and instruments used; the number and location of instruments; frequency of data collection; time interval of the available data; and optimization or design of the network. As noted in this report, the monitoring networks at the District have evolved over the years and have been periodically optimized as the result of numerous studies.

As of April 30, 2007, the District operated an extensive network of 287 active rain gauges. The District has been acquiring radar rainfall (NEXRAD) data coverage from OneRain, Inc. since 2002. The District also has a meteorological monitoring network that includes 45 active weather stations. Meteorological data such as air temperature, barometric pressure, humidity, solar radiation, wind speed, and water temperature are collected and are available on breakpoint (instantaneous) and daily time intervals. In addition, daily potential evapotranspiration (ETp) data are available for 19 weather stations. The ETp data were estimated using the Simple Method (Abtew, 2005; Abtew, 1996).

As of April 30, 2007, a network of 1,265 active surface water stage gauges provides the data for various water bodies. Additionally, the District maintains a network of 446 active surface water flow monitoring sites that provide data for 15-minute instantaneous and mean daily flow estimates.

The groundwater monitoring network contains a total of 907 groundwater wells that are monitored on a 15-minute continuous, monthly, or greater than 1-month interval basis as of April 30, 2007. The District is solely responsible for monitoring, maintenance, quality assurance/quality control (QA/QC), data archival, and funding for 568 of these wells. The USGS is responsible for the remaining 339 wells (see Appendix 2-1).

The data from these networks are collected, summarized, stored, and published. The data are stored in two different databases. Breakpoint data are stored in the Data Collection/Validation Pre-Processing (DCVP) database, while daily summary and 15-minute data are published in the DBHYDRO database. District data users can retrieve data using a web browser via District's intranet. DBHYDRO data are also accessible to external users via the Internet on the District's web page (see Appendix 2-1).

THE 2006–2007 DROUGHT

DROUGHTS IN SOUTH FLORIDA

Droughts are important hydrometeorological events in most parts of the world. The type and severity of a drought varies from place to place. Droughts are classified as agricultural, meteorologic, hydrologic, and/or water management (Subrahmanyam, 1967; Benson and Gardner, 1974). Agricultural drought is an evapotranspiration deficit (Palmer, 1965). Agricultural drought is also characterized as a short-term moisture deficiency in the shallow plant root zone. Meteorologic drought occurs when an extended period of below-normal precipitation prevails. Hydrologic drought is the result of reductions in surface water and groundwater due to the amount and/or spatial and temporal distribution of precipitation. Hydrologic drought has long-term effects on regional and local surface water and subsurface water supplies. Water management drought is characterized as water deficiency that occurs because of the inability to develop and manage an integrated surface and subsurface water supply system to overcome water deficits (Benson and Garner, 1974). Other types of drought cited in the literature are climatologic and atmospheric. A drought lasting from one to three months is considered short-term; a drought lasting from four to six months is considered intermediate; and a drought lasting more than six months is considered long-term (Golden and Lins, 1986).

Drought is a relatively common phenomenon in North America, occurring almost every year in some part of the United States (Kogan, 1995) and in nearly every decade. In Central and South Florida, severe droughts were reported in 1932, 1955–1957, 1961–1963, 1971–1972, 1973–1974, 1980–1982, 1985, 1988–1989, 1990, 2000–2001, and now 2006–2007 (Benson and Gardner, 1974; Lin et al., 1984; Marban et al., 1989; CSFFCD, 1972; 1974; SFWMD, 1985, Abtew et al., 2002). Historical droughts and water shortages are marked by declines in lakes, reservoirs, and groundwater levels, decline in rainfall and runoff, and increase in the number and magnitude of wildfires (Abtew et al., 2002).

The severe drought of 1971 resulted in a water restriction declaration on May 3, 1971 (CSFFCD, 1972). Lake Okeechobee reached a minimum stage of 10.29 feet NGVD on June 7, 1971. Average rainfall deficit of 43 percent was reported for Lake Okeechobee and the Northern, Central, and Southern Everglades for the eight-month period from October 1970 to May 1971. For the same period, the Lake Okeechobee Service Area water demand and delivery was reported to be 734,477 ac-ft. Tropical Storm Dawn impacted the Southeast Florida Coast on September 5, 1972 (Abtew et al., 2006).

The 1973–1974 drought is comparable to the 1971–1972 drought for the same months. The rainfall deficit was 47 percent but with different distribution. Lake Okeechobee Service Area water delivery was 774,568 ac-ft for the period of October 1973 to May 1974 (CSFFCD, 1974). The minimum Lake Okeechobee stage was 10.98 ft NGVD on May 31, 1974 (Abtew, et al., 2002).

The 1980–1982 drought was one of the most severe droughts that affected South Florida. A more than 20-inches deficit over two years resulted in the decline of Lake Okeechobee stage from a high of 17.46 ft NGVD on January 1, 1980 to 9.79 ft NGVD on July 31, 1981. The drought for Water Conservation Areas (WCAs) and the Lower East Coast was relieved by Tropical Storm Dennis (Lin et al., 1984). Tropical Storm Dennis moved through Cape Sable to Cape Canaveral on August 17 to 19, 1981, dumping 20 inches of rainfall in Kendall (Abtew et al., 2006).

The 1985 drought occurred as a result of rainfall deficits in the 1984 wet season and the 1984–1985 dry season. The Upper Kissimmee, Lower Kissimmee, and Lake Okeechobee rainfall areas had an average deficit of 14 inches. Lake Okeechobee water level declined from 15.14 ft

NGVD on January 1, 1985 to 11.82 ft NGVD on June 12, 1985. The District suspended the Interim Action Plan which limited back pumping from the Everglades Agricultural Area into Lake Okeechobee, and initiated back pumping into the lake to increase water supply (Abtew et al., 2002).

The 1988–1989 drought was a severe drought that affected South Florida from September 1988 to August 1989. There was a 21-inch rainfall deficit in the Everglades Agricultural Area and the Lower East Coast. Lake Okeechobee water level declined from 15.95 ft NGVD on September 1, 1988 to 11.06 ft NGVD on August 8, 1989. During the same period, a record storage depletion of 1.89 million ac-ft was reported for Lake Okeechobee and 1.15 million ac-ft for the Water Conservation Areas (Marban, et al., 1989).

The 1990 drought was a continuation of the 1988–1989 drought. A 9-inch District-wide rainfall deficit occurred for the period from June 1989 to May 1990. The drought was most severe in Everglades National Park. Lake Okeechobee supply-side management and water restrictions were implemented to conserve lake water (Trimble et al., 1990). Lake Okeechobee stage declined from 12.25 ft NGVD on January 1, 1990 to 10.47 ft NGVD on June 21, 1990.

The 2001–2002 drought was an extreme drought in the Upper and Lower Kissimmee area and impacted most of the District. Rainfall deficit in the main Lake Okeechobee watershed (Upper Kissimmee, Lower Kissimmee and Lake Okeechobee rainfall areas) had a 100-year dry return period. Early indications of this drought can be traced back to November 1999, the beginning of the 1999–2000 dry season. The hydrologic drought, the managed recession of Lake Okeechobee in the spring of 2000, and the high water demand resulted in the lowest recorded stage of the lake, 8.97 ft NGVD on May 24, 2001. Water use restrictions up to Phase III level was implemented. Due to low water levels in Lake Okeechobee, gravity discharge was not possible anymore and 14 temporary pumps were installed to aid water flow to the south. The 2000–2001 drought is documented in Abtew et al., 2002.

THE 2006–2007 DROUGHT

The 2006–2007 drought in South Florida is one of the most severe droughts the area has experienced. Due to low rainfall and declining storage in Lake Okeechobee and other water storages, a series of water conservation measures have been taken. Signs of the drought go back to December of 2005, when rainfall was far below average in 13 of the 14 rainfall areas, and in January 2006, when rainfall was far below average in all 14 rainfall areas and Everglades National Park (ENP or Park). The District-wide calendar year 2006 rainfall deficit was 12 inches, which has an estimated 50-year drought return period. Calendar year 2007 rainfall deficit in the first four months has all indications of a severe drought with only 49 percent of average rainfall for the four-month period. Summer and fall rainfall will determine the status of calendar year 2007 rainfall and the drought. Water year 2007 rainfall includes eight months of calendar year 2006 (May through December) and four months of calendar year 2007 (January through April). WY2007 rainfall deficits are shown in **Figure 2-4** with corresponding drought return periods in years. The most severe drought is in the Lake Okeechobee, East Everglades Agricultural Area (East EAA), and Martin/St. Lucie rainfall areas where the drought return period is 100-year or more. All 14 rainfall areas and the ENP are in rainfall deficit ranging from 2.37 inches in Big Cypress Preserve to 22.26 inches in the Martin/St. Lucie rainfall area. District-wide deficit rainfall for WY2007 was 12.13 inches.

Month by month rainfall analysis shows the severity of the drought. **Table 2-4** shows monthly rainfall for each rainfall area and frequency in years of return period. The drought period covers the whole water year. Very few months were wetter than average. Although the drought return period for each month might not look extreme, the cumulative impact of drought months determines the severity of the drought in the water year.

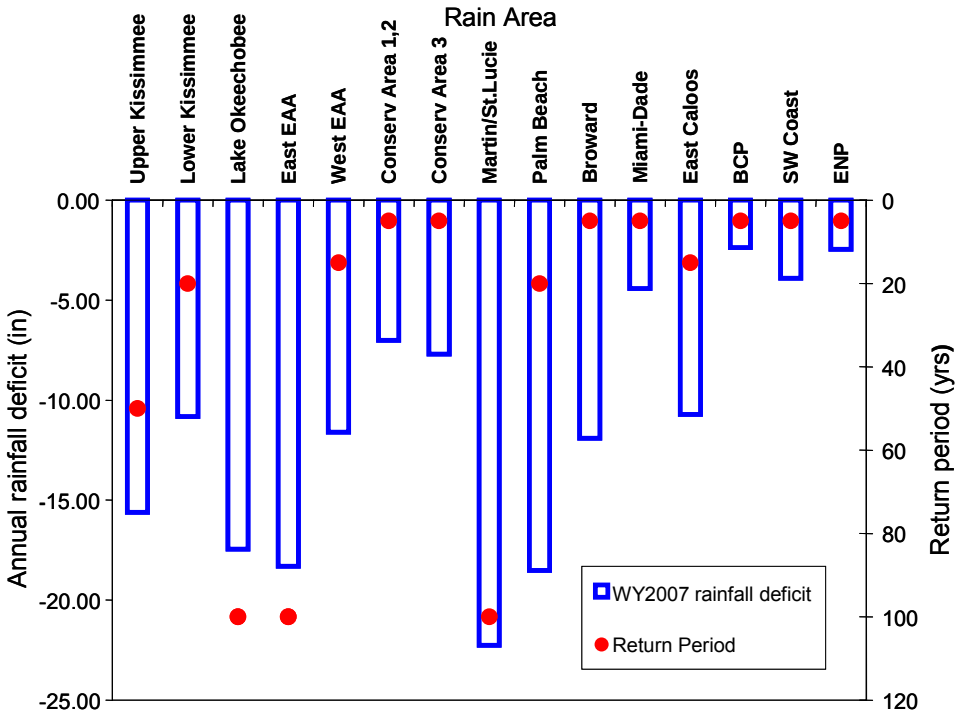


Figure 2-4. WY2007 rainfall deficit and drought frequency for each rainfall area.

Table 2-4. WY2007 monthly rainfall and return periods for each rainfall area.

Month	Upper Kissimmee	Lower Kissimmee	Lake Okeechobee	East EAA	West EAA	Conservation Area 1,2	Conserv Area 3	Martin/St.Lucie	Palm Beach	Broward	Miami-Dade	East Caloos	Big Cypress Preserve	SW Coast
May-06	≈ 5 yr	> 10 yr	≈ 10 yr	< 5 yr	< 5 yr	< 5 yr	< 5 yr	> 5 yr	< average	> average	< average	≈ 10 yr	< average	< 5 yr
Jun-06	≈ average	< 5 yr	< 20 yr	< 20 yr	5 yr	< 10 yr	< 5 yr	< 5 yr	≈ 5 yr	< 20 yr	≈ 5 yr	≈ 5 yr	< average	> average
Jul-06	< 10 yr	< average	< average	< average	< average	> 5 y wet	> 10 yr wet	< average	< average	> 5 yr wet	> 10 yr wet	> average	> average	> average
Aug-06	< average	≈ 10 yr wet	≈ 5 yr wet	≈ 5 yr wet	> 5 yr wet	> average	> 5 yr wet	> average	> average	< average	> average	≈ 20 yr wet	≈ 10 yr wet	≈ 10 yr wet
Sep-06	> 5 yr	< 5 yr	5 yr	> 5 yr	≈ average	> average	< average	> 5 yr	< 5 yr	> average	< average	< average	< average	> average
Oct-06	< 10 yr	< 10 yr	< 10 yr	> 10 yr	< 10 yr	< 20 yr	< 20 yr	> 20 yr	> 50 yr	< 20 yr	> 10 yr	10 yr	10 yr	< 10 yr
Nov-06	< 5 yr	> 5 yr	5 yr	< 5 yr	< 5 yr	< 5 yr	5 yr	5 yr	< 5 yr	< 5 yr	< 5 yr	< 5 yr	average	< 5 yr
Dec-06	> average	≈ average	≈ average	≈ average	< average	>10 yr wet	< average	≈ 5 yr wet	>10 yr wet	< 5 yr wet	≈ 5 yr wet	> average	> average	≈ average
Jan-07	< average	≈ 5 yr	10 yr	≈ 10 yr	< 20 yr	≈ 5 yr	> 5 yr	< 20 yr	< 10 yr	< 5 yr	< 5 yr	10 yr	5 yr	5 yr
Feb-07	< average	< 5 yr	< 5 yr	< 5 yr	< 5 yr	< 5 yr	< 5 yr	10 yr	< 5 yr	> 5 yr wet	> average	< 5 yr	< 5 yr	< 5 yr
Mar-07	10 yr	< 5 yr	20 yr	< 50 yr	< 20 yr	10 yr	10 yr	< 10 yr	> 10 yr	< 5 yr	< 5 yr	20 yr	< 5 yr	> 10 yr
Apr-07	< average	> average	< 5 yr	< 5 yr	> average	< 5 yr	> average	< 5 yr	< 5 yr	< 5 yr	5 yr wet	< 5 yr	> average	< 5 yr
dry months	11	10	10	9	9	8	9	9	9	7	7	8	7	7
extreme dry	0	0	0	1	0	0	0	1	1	0	0	1	0	0
wet months	0	1	1	1	2	4	3	2	2	5	5	3	4	4
≈ average	1	1	1	1	1	0	0	0	0	0	5	0	1	1

Additional drought indicators are the Palmer Drought Severity Index, decrease in runoff flows, lakes and reservoirs water level decline, groundwater level decline and increase in number and size of wildfires. The Palmer Drought Severity Index (PDSI) is commonly used to determine the occurrence of drought and its magnitude. The PDSI uses antecedent moisture conditions, precipitation, temperature, field capacity, and weather trends to compute an index value. Near normal conditions are represented by an index value between ±0.49; severe drought has an index value of -3 or less; and extreme drought events have a value of -4 or less. The historical PDSI for Florida Climatic Division 5 (Lake Okeechobee, the Lower West Coast, the EAA, the East Coast, and the Everglades) is shown in **Figure 2-5.** A PDSI of greater than zero is on the wet side, with a magnitude of wetness indicated by sequentially higher (positive) numbers. Dry periods in Florida result from stable atmospheric conditions that are often associated with high-pressure systems (Winsberg, 1990). These conditions can occur in any season, but are most common in the winter and spring.

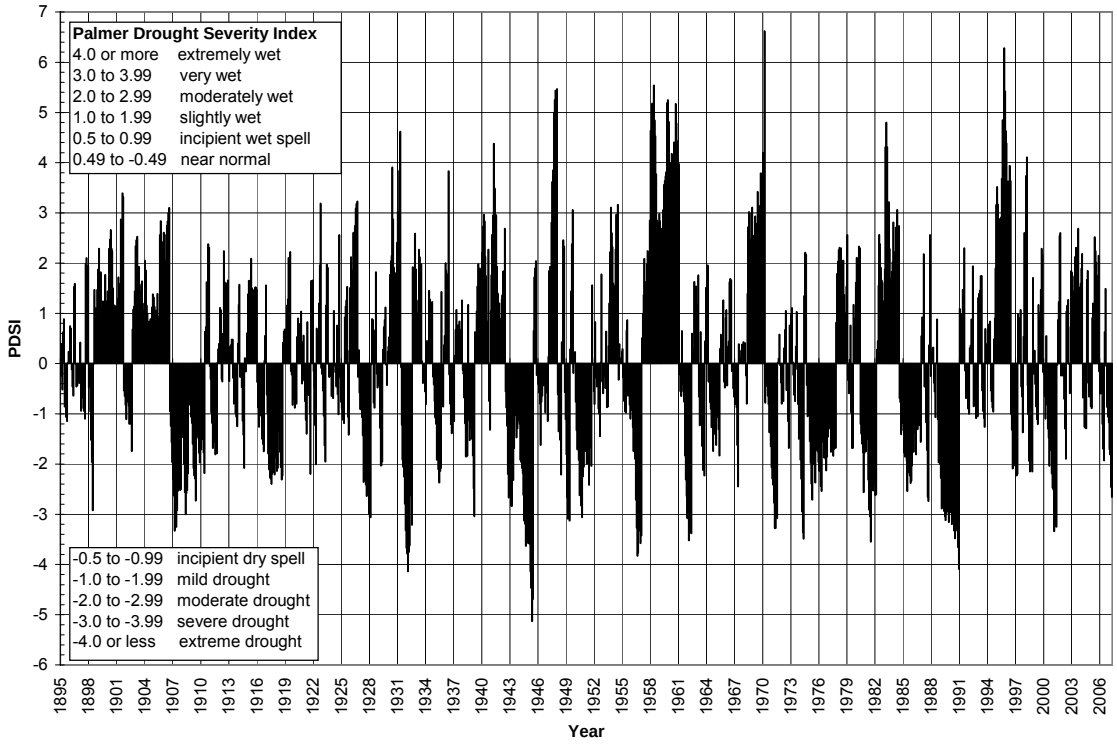


Figure 2-5. Historical Palmer Drought Severity Index for Florida Climatic Division 5 [Lake Okeechobee, the Lower West Coast, the Everglades Agricultural Area (EAA), the East Coast, and the Everglades].

Inflow into Lake Okeechobee for WY2007 was 619,189 ac-ft, this was the second lowest inflow since 1972 — only preceded by the inflows of 2000–2001 drought (408,575 ac-ft). Lake Okeechobee daily water level fluctuation is shown in **Figure 2-6**. Drought years 1932, 1955–1957, 1961–1963, 1971–1972, 1973–1974, 1980–1982, 1985, 1988–1989, 1990, 2000–2001, and 2006–2007 are marked by low water level of Lake Okeechobee. The second annually lowest lake water level of 9.65 ft NGVD was reached at the end of WY2007 on April 30, 2007, in the current drought. The record lowest water level of 8.97 ft NGVD was reached on May 24, 2001, during the 2000–2001 drought. The lake water level is still declining; a record low water level will be reached in the coming water year (WY2008). Current and past drought years are marked by low lake water levels. Ground water level decline is also an indicator of drought conditions. The sizes and number of wildfires are generally correlated to drought moisture conditions. Drought years have above average area of acres burned. Areas burned by wildfire in 2006 are about the same burned area as in 1990, also a drought year. **Figure 2-7** depicts the number of acres burned by wildfires that were 10 acres or larger in the District area since 1981. Major droughts correspond to larger sizes of area burned by wildfire.

As in the 2000–2001 drought, 14 temporary pumps were installed to pump water out of Lake Okeechobee. Lake Okeechobee normally discharges by gravity. As water level reached 10.5 ft NGVD, temporary pumping started at the end of March 2007. Lake Okeechobee daily stage decline is shown in the *Water Levels, Flows and Water Management* section in this chapter.

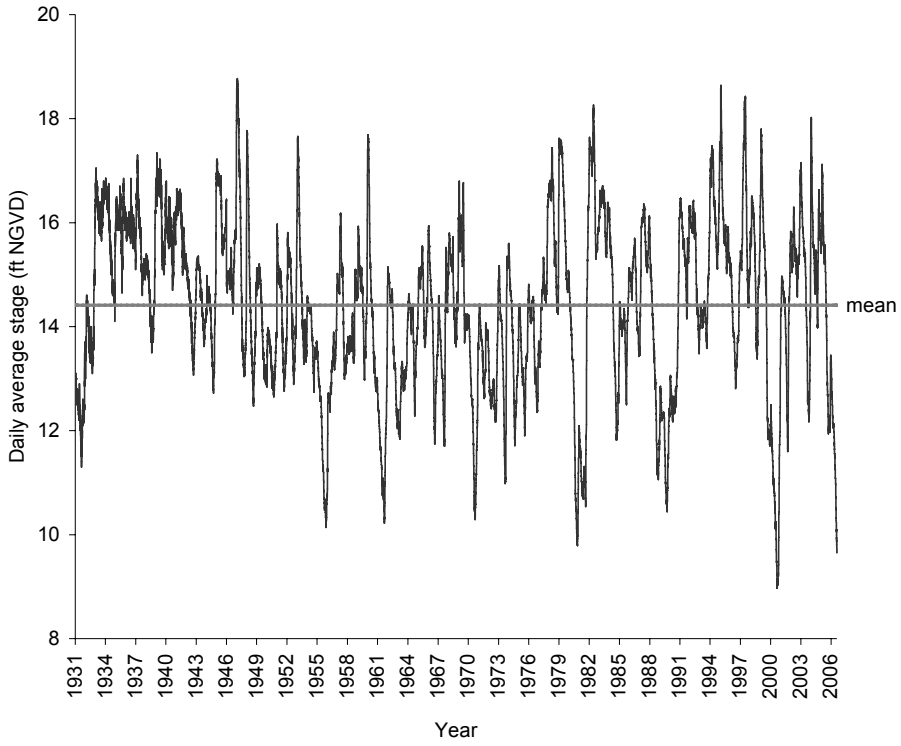


Figure 2-6. Historical daily water level variation of Lake Okeechobee.

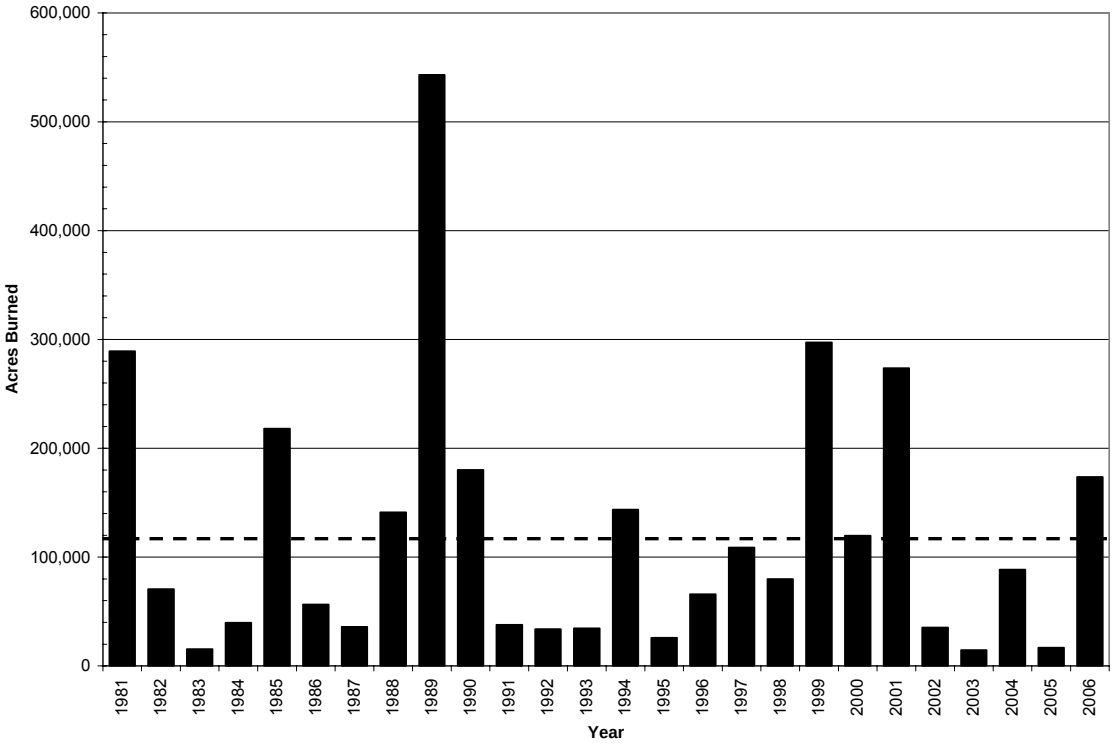


Figure 2-7. Number of acres burned per calendar year in the District area from wildfires that were 10 acres or larger (1981–2006).

WATER YEAR 2007 HYDROLOGY

RAINFALL AND EVAPOTRANSPIRATION

Unlike WY2005 and WY2006, there were no hurricanes in South Florida during WY2007. The lack of tropical system rains in the summer and a drier dry season resulted in severe drought. The only significant rainfall from a tropical system was from Tropical Storm Ernesto. Ernesto landed in southwestern Miami-Dade County on August 30, 2006, and passed through the center of South Florida, exiting to the northeast near Cape Canaveral (Knabb, R.D. and M. Mainelli, 2006). In WY2007, South Florida received an area average of 40.62 inches which is 12.13 inches below the average for the area. All 14 rainfall areas and the ENP got below-average rainfall. District-wide rainfall for WY2007 was lower than the WY2006 rainfall (54.75 inches) by 14.13 inches. Rainfall data of several stations computed as Thiessen averages was obtained from the District's Operations rainfall data report (see July 23, 2007, data from the District web site at www.sfwmd.gov under the W*eather & Water Conditions, Historical Data* section, under the *Rainfall* tab).The District Operations rainfall database accumulates daily rainfall between 7:00 am of the previous day through 6:59 am of the data registration day (both in Eastern Standard Time). The ENP area rainfall was estimated as a simple average of eight stations: S332, S174, S18C, HOMESTEADARB, JBTS, S331W, S334, and S12D.

The balance between rainfall and evapotranspiration maintains the hydrology system of South Florida in either a wet or dry condition. In South Florida, most of the variation in evapotranspiration is explained by solar radiation (Abtew, 1996). Regional estimates of evapotranspiration from open water and wetlands that do not dry out range from 48 inches in the District's northern section to 54 inches in the Everglades (Abtew et al., 2003; Abtew, 2005). ETp is actual evaporation for lakes, wetlands, and any feature that is wet year-round. Available ETp data from the closest site to a rainfall area was used to estimate ETp for the area. This year, evapotranspiration was far higher than rainfall, 11.7 inches. The only systems that stayed wet year-round are those with enough storage and surface water inflow. The driest rainfall areas with greater than 15 inches rainfall deficit are Upper Kissimmee, Lake Okeechobee, East Everglades Agricultural Area (East EAA), Martin/St. Lucie, and Palm Beach (**Figure 2-4**).

The driest rainfall area is Martin/St. Lucie with a rainfall deficit of 22.26 inches. The rainfall areas with the least rainfall deficit are Big Cypress Preserve (BCP), the Southwest Coast and the ENP. **Table 2-4** depicts monthly rainfall for each rainfall area with the rainfall return period for each month independently. The Upper Kissimmee rainfall area had 11 dry months and the Lower Kissimmee and Lake Okeechobee rainfall area had 10 out of 12 dry months. Although the dry return periods for each month may not look extreme, the joint probability of having consecutive dry months will be of higher return period, less frequent event. Comparison of the WY2007 rainfall to historical averages and WY2006 rainfall (**Table 2-5**) shows that every rainfall area had below average and far lower than WY2006 rainfall. **Table 2-6** depicts WY2007 monthly rainfall, **Table 2-7** shows ETp for each rainfall area, the ENP, and District average. Comparison of WY2007 monthly rainfall, historical averages, WY2006 monthly rainfall, and WY2007 ETp for each rainfall area is shown in **Figures 2-8** through **2-22**. Rainfall deficits are shown in the legend.

Table 2-5. Comparison of WY2007, WY2006, historical average annual rainfall for each rainfall area, and WY2007 potential evapotranspiration (ETp).

Rain Area	WY2007 (inches)	WY2006 (inches)	Historical average (inches)	WY2007 Etp (inches)
Upper Kissimmee	34.48	**52.91**	50.09	54.47
Lower Kissimmee	33.64	**48.5**	44.45	54.12
Lake Okeechobee	28.51	**47.33**	45.97	54.94
East EAA	35.17	48.24	53.48	51.11
West EAA	43.35	**58.29**	54.95	53.04
Conservation Area 1_2	44.94	47.96	51.96	51.39
Conservation Area_3	44.26	**53.39**	51.37	51.98
Martin-St. Lucie	31.88	**61.7**	54.14	54.01
Palm Beach	43.02	57.8	61.54	51.11
Broward	46.22	56.67	58.13	51.98
Miami-Dade	52.7	57.44	57.11	49.78
East Caloosahatchee	39.97	**56.91**	50.68	54.84
BCP	51.75	**58.75**	53.98	51.38
SW Coast	50.21	**60.56**	54.12	51.24
ENP	52.76	**57.27**	55.22	49.78
District	40.62	**54.72**	52.75	52.34

Table 2-6. WY2007 monthly rainfall (inches) for each rainfall area.

Month	Upper Kissimmee	Lower Kissimmee	Lake Okeecbobee	East EAA	West EAA	WCA 1,2	WCA 3	Martin/St. Lucie	Palm Beach	Broward	Miami-Dade	East Caloo-sahatchee	BCP	SW Coast	ENP	District
May-06	1.83	1.11	1.56	3.35	3.38	4.47	3.97	1.86	4.09	5.69	5.57	1.52	3.69	2.63	5.41	2.81
Jun-06	7.12	5.28	2.99	3.7	5.81	4.09	6.14	4.13	4.48	2.7	4.8	5.42	8.06	9.91	4.95	5.75
Jul-06	4.99	6.19	5.84	7	7.91	8.14	10.34	5.39	6.03	9.41	10.14	9.07	10.7	10.03	11.47	7.83
Aug-06	6	8.47	8.04	9.24	10.56	7.71	8.73	6.64	7.32	6.7	7.85	12.04	11.66	11.54	7.66	8.92
Sep-06	3.06	3.98	3.98	4.88	7.19	7.23	5.96	4.16	6.68	8.53	7.91	5.78	7.6	9.2	7.25	5.87
Oct-06	0.73	1.01	1.03	0.94	1.11	0.94	0.81	1.18	1.48	1.43	2.03	0.93	0.81	0.99	1.55	1.05
Nov-06	1.04	0.51	0.38	0.77	0.93	1.84	0.97	1.1	2.27	1.57	1.89	0.49	1.56	0.59	1.57	1.02
Dec-06	2.96	1.68	1.7	1.67	1.76	5.47	1.73	3.43	5.47	3.23	2.68	1.81	1.66	1.58	2.12	2.39
Jan-07	1.94	0.63	0.28	0.35	0.29	0.74	0.57	0.38	0.74	0.98	1.34	0.24	0.44	0.43	2.05	0.65
Feb-07	1.75	1.19	0.79	1.12	1.34	1.91	1.5	0.57	1.31	3	2.35	0.98	1.73	1.25	2.16	1.36
Mar-07	0.7	1.15	0.28	0.25	0.46	0.54	0.58	0.84	0.51	1.09	1.47	0.15	0.93	0.22	1.36	0.61
Apr-07	2.36	2.44	1.64	1.9	2.61	1.86	2.96	2.2	2.64	1.89	4.67	1.54	2.91	1.84	5.21	2.36
Sum	**34.48**	**33.64**	**28.51**	**35.17**	**43.35**	**44.94**	**44.26**	**31.88**	**43.02**	**46.22**	**52.70**	**39.97**	**51.75**	**50.21**	**52.76**	**40.62**

Table 2-7. WY2007 monthly ETp (inches) for each rainfall area.

Month	Upper Kissimmee	Lower Kissimmee	Lake Okeecbobee	East EAA	West EAA	WCA 1,2	WCA 3	Martin/St. Lucie	Palm Beach	Broward	Miami-Dade	East Caloo-sahatchee	BCP	SW Coast	ENP	District
May-06	6.19	5.93	6.33	5.80	6.08	5.70	5.66	5.93	5.90	5.66	5.70	6.27	5.99	5.76	5.70	5.91
Jun-06	5.34	5.08	5.76	5.03	5.36	4.79	4.71	5.08	4.94	4.71	4.78	5.33	5.00	4.99	4.78	5.05
Jul-06	5.18	4.95	5.39	4.80	4.79	4.92	4.51	5.21	5.09	4.51	4.70	4.89	4.65	4.75	4.70	4.87
Aug-06	5.37	5.16	4.75	5.20	4.89	4.92	4.78	5.05	5.06	4.78	4.60	5.04	4.62	4.61	4.60	4.90
Sep-06	4.68	4.72	4.69	4.62	4.63	4.36	4.51	4.82	4.39	4.51	3.85	4.68	4.46	4.39	3.85	4.48
Oct-06	4.63	4.70	4.56	4.28	4.44	4.37	4.60	4.50	4.30	4.60	4.19	4.81	4.30	4.35	4.19	4.45
Nov-06	3.40	3.40	3.28	3.08	3.24	3.09	3.18	3.27	3.09	3.18	3.02	3.28	2.99	3.11	3.02	3.18
Dec-06	2.56	2.68	2.68	2.54	2.56	2.53	2.72	2.70	2.58	2.72	2.58	2.58	2.51	2.40	2.58	2.59
Jan-07	3.07	3.21	3.23	2.86	3.24	3.08	3.26	3.17	3.11	3.26	3.15	3.22	3.13	3.03	3.15	3.14
Feb-07	3.46	3.49	3.40	2.95	3.29	3.24	3.40	3.43	3.16	3.40	3.05	3.43	3.27	3.24	3.05	3.28
Mar-07	4.98	5.18	5.12	4.18	4.87	4.89	5.01	5.11	4.82	5.01	4.70	5.21	4.89	4.92	4.70	4.91
Apr-07	5.62	5.63	5.75	5.76	5.64	5.51	5.65	5.75	5.42	5.65	5.47	5.91	5.58	5.68	5.47	5.63
Sum	**54.47**	**54.12**	**54.94**	**51.11**	**53.04**	**51.39**	**51.98**	**54.01**	**51.86**	**51.98**	**49.78**	**54.64**	**51.38**	**51.24**	**49.78**	**52.38**

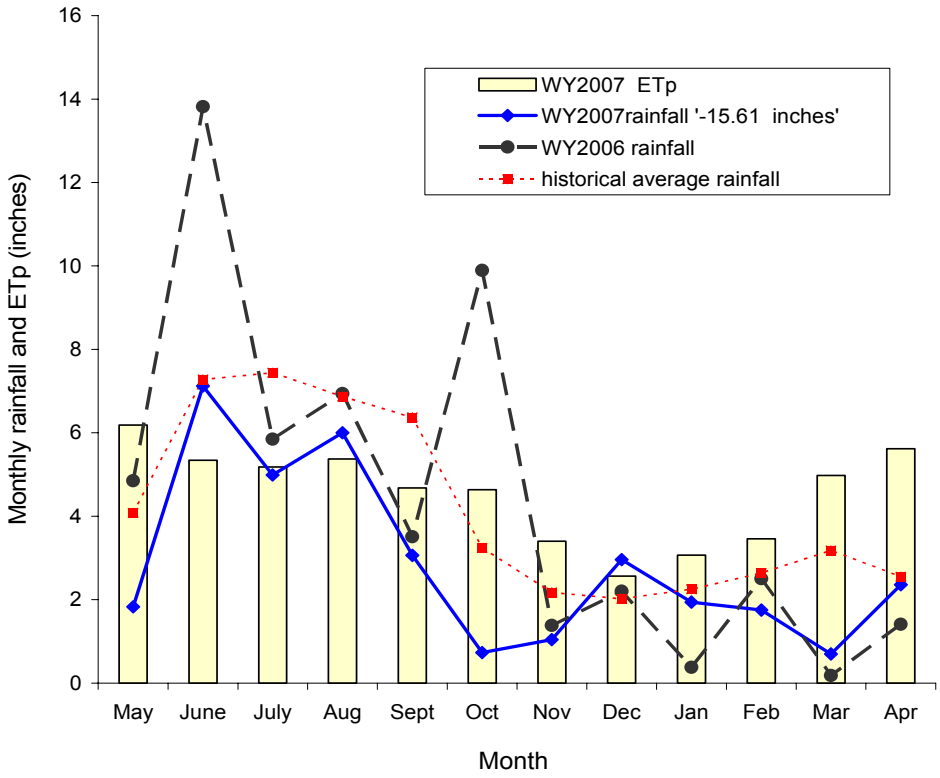


Figure 2-8. Monthly rainfall and potential evapotranspiration (ETp) for the Upper Kissimmee rainfall area.

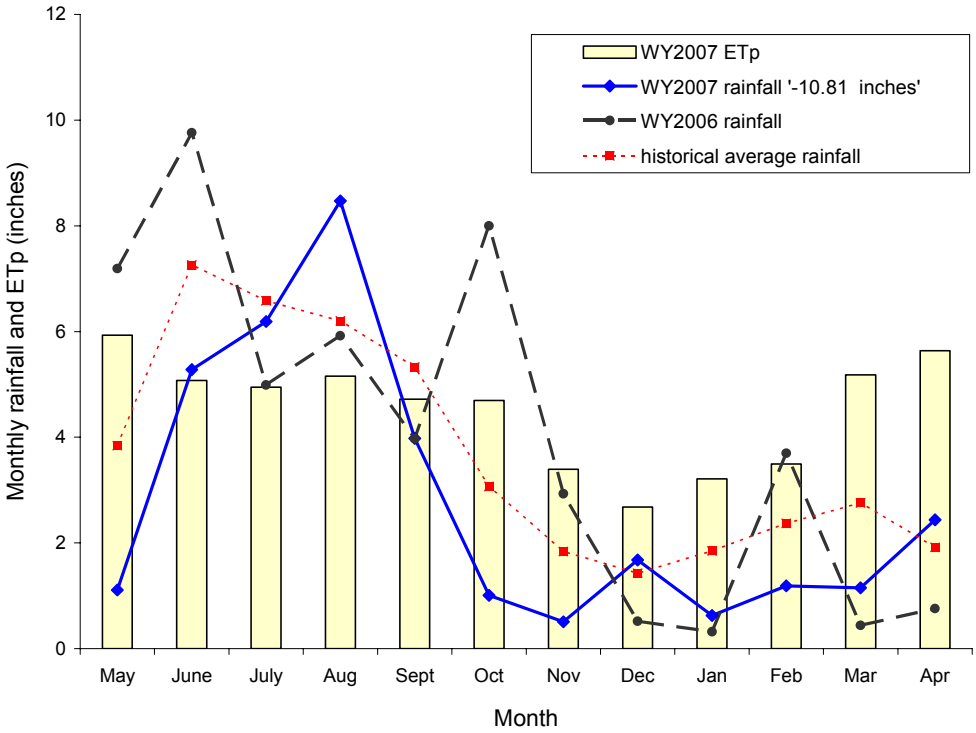


Figure 2-9. Monthly rainfall and ETp for the Lower Kissimmee rainfall area.

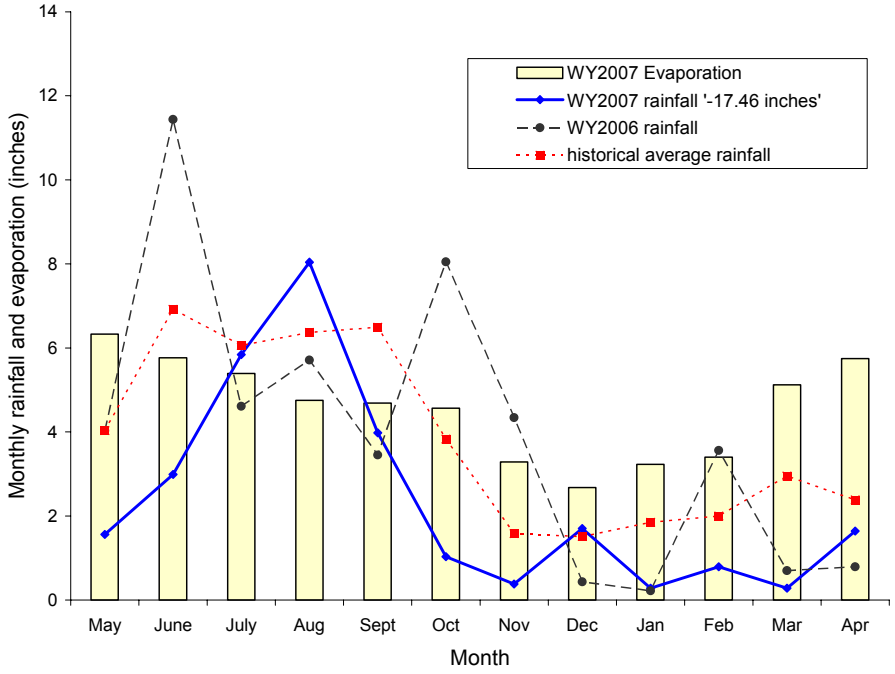


Figure 2-10. Monthly rainfall and ETp for the Lake Okeechobee rainfall area.

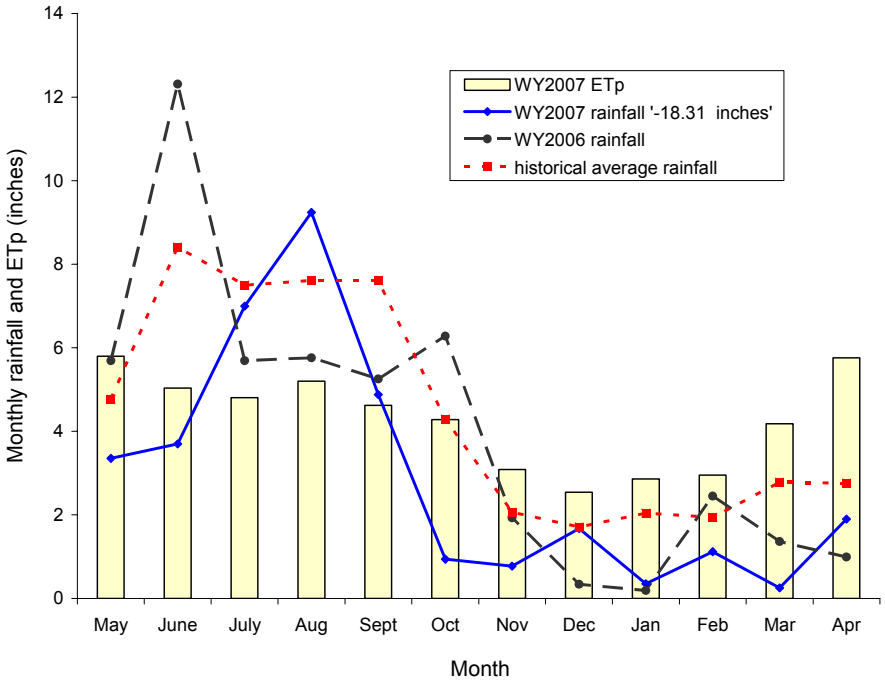


Figure 2-11. Monthly rainfall and ETp for the East EAA rainfall area.

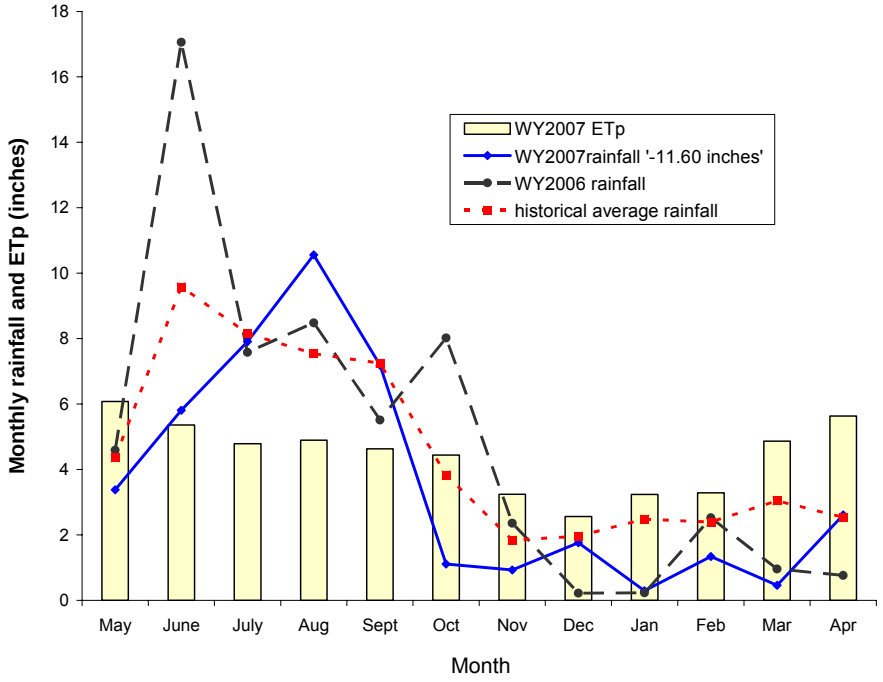


Figure 2-12. Monthly rainfall and ETp for the West EAA rainfall area.

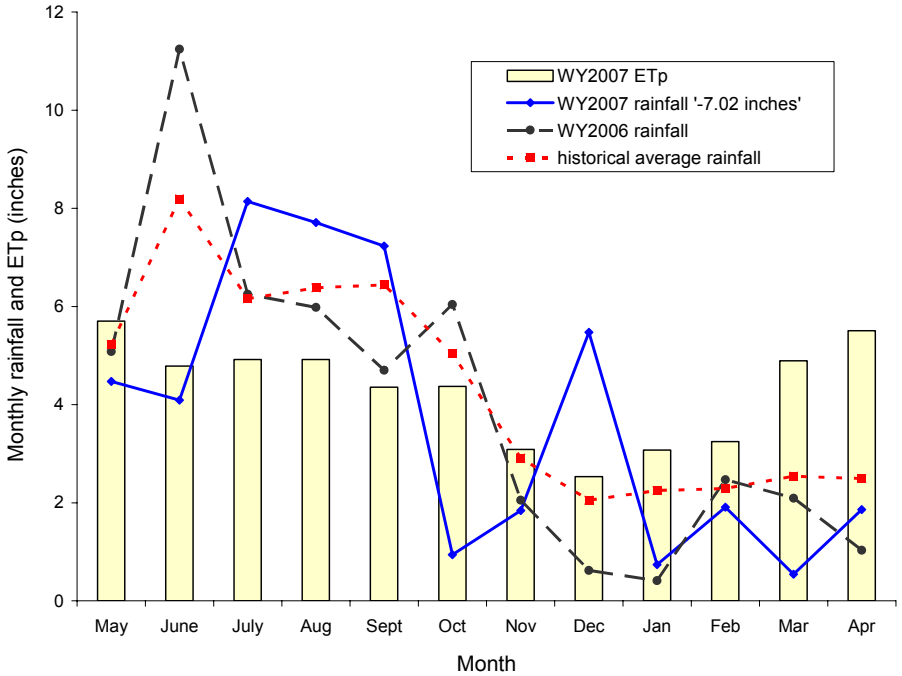


Figure 2-13. Monthly rainfall and ETp for WCA-1 and WCA-2 rainfall area.

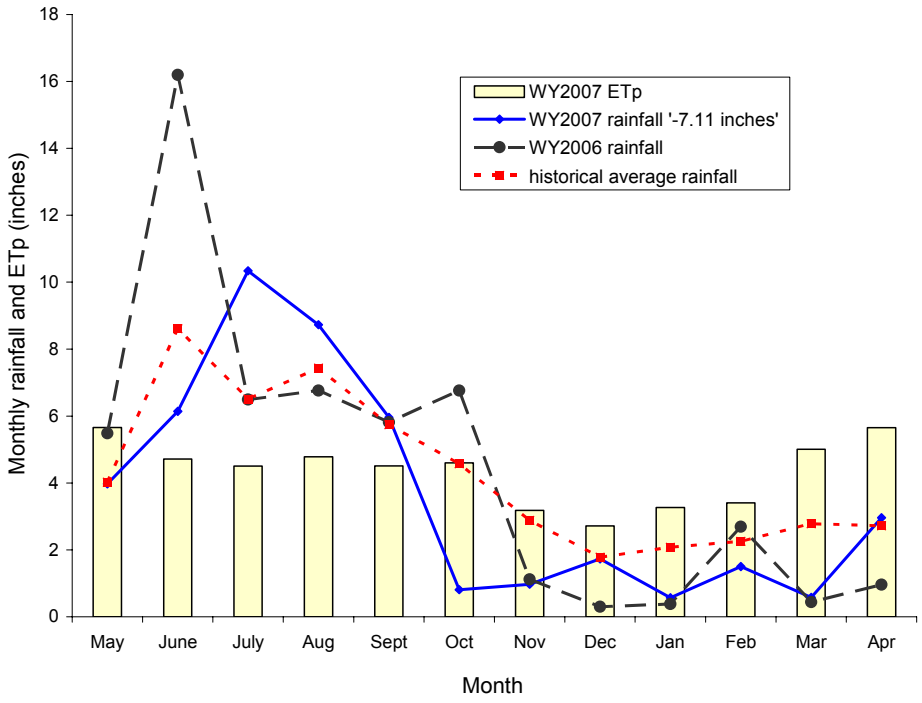


Figure 2-14. Monthly rainfall and ETp for WCA-3 rainfall area.

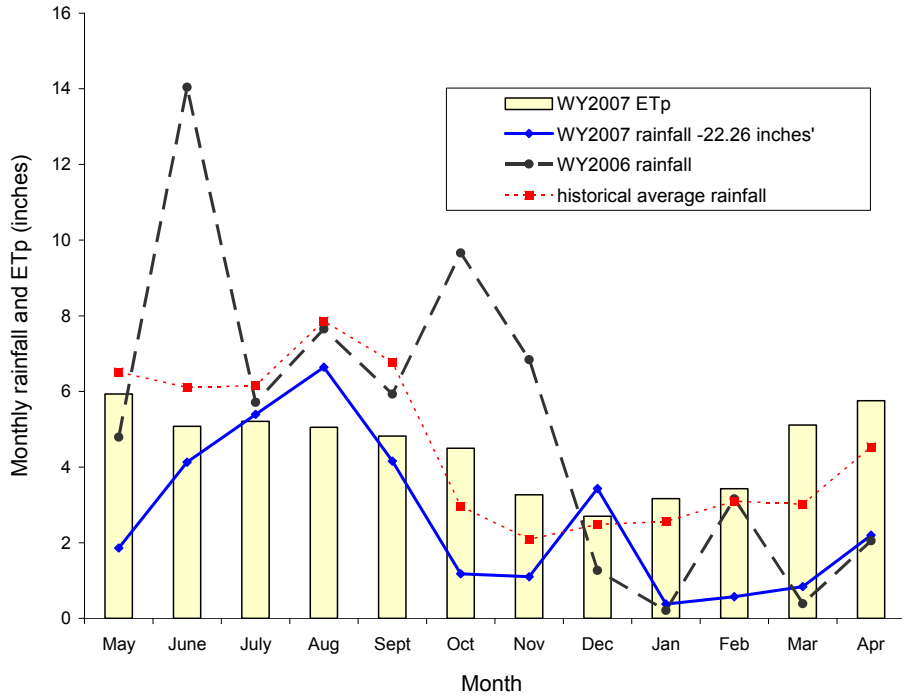


Figure 2-15. Monthly rainfall and ETp for Martin/St. Lucie rainfall area.

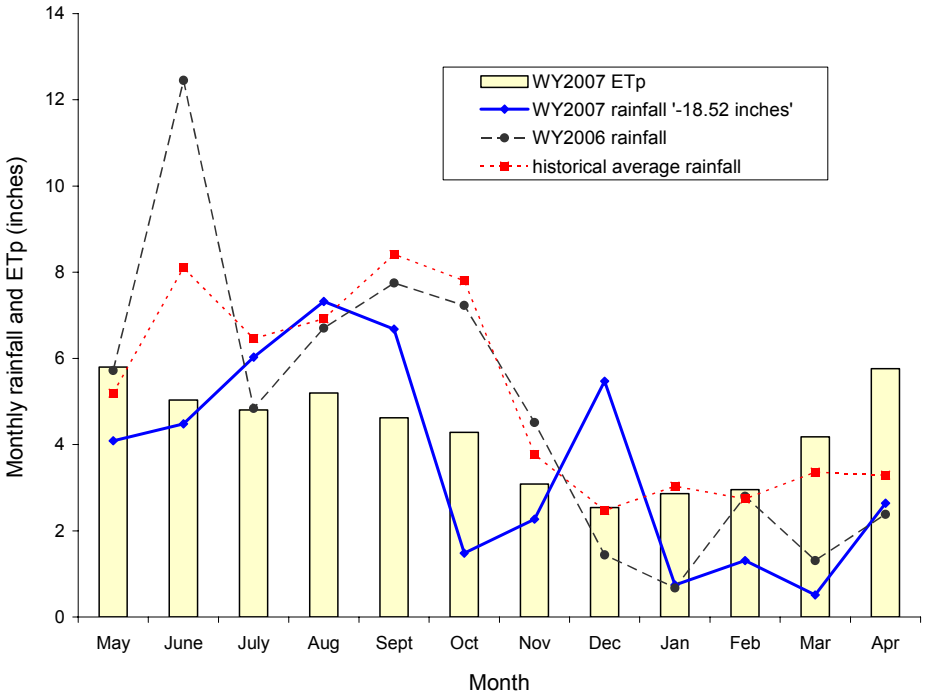


Figure 2-16. Monthly rainfall and ETp for the Palm Beach County rainfall area.

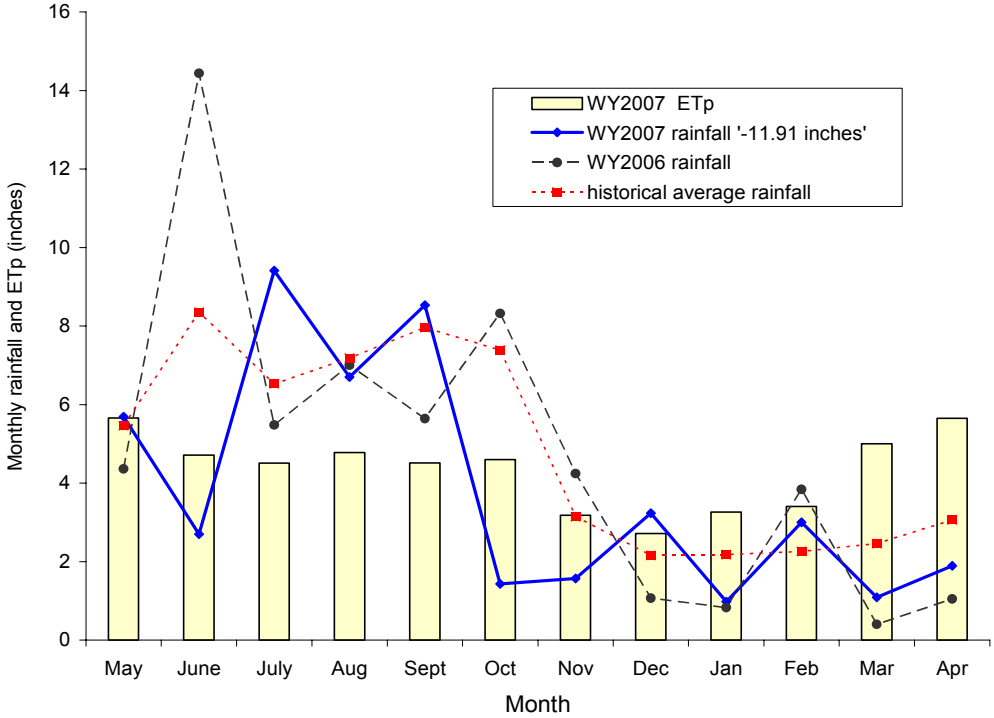


Figure 2-17. Monthly rainfall and ETp for the Broward County rainfall area.

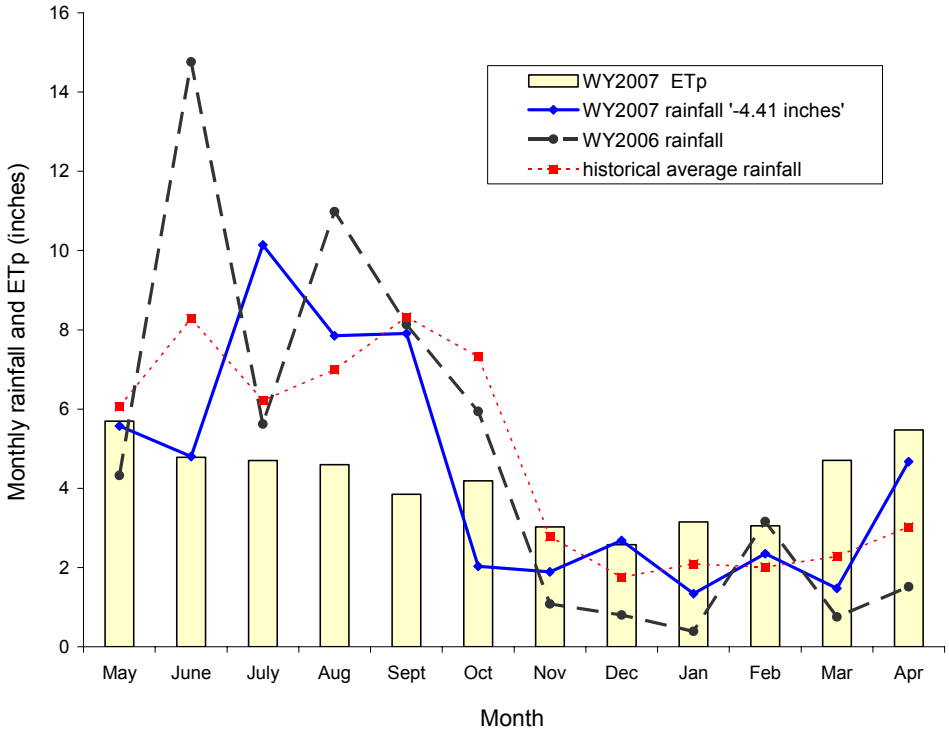


Figure 2-18. Monthly rainfall and ETp for the Miami-Dade County rainfall area.

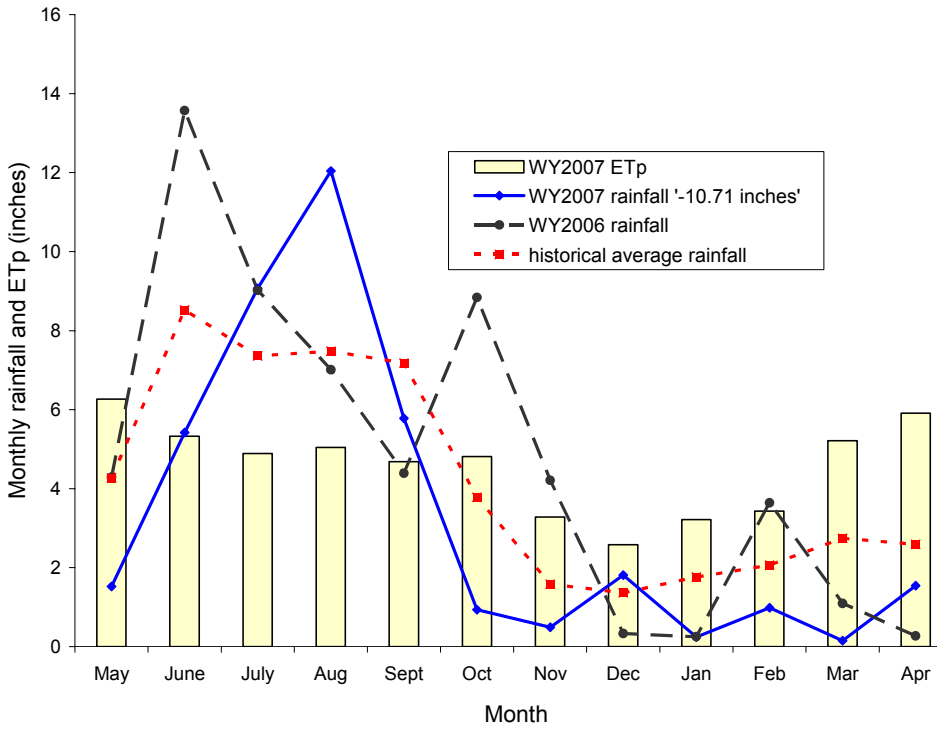


Figure 2-19. Monthly rainfall and ETp for the Caloosahatchee rainfall area.

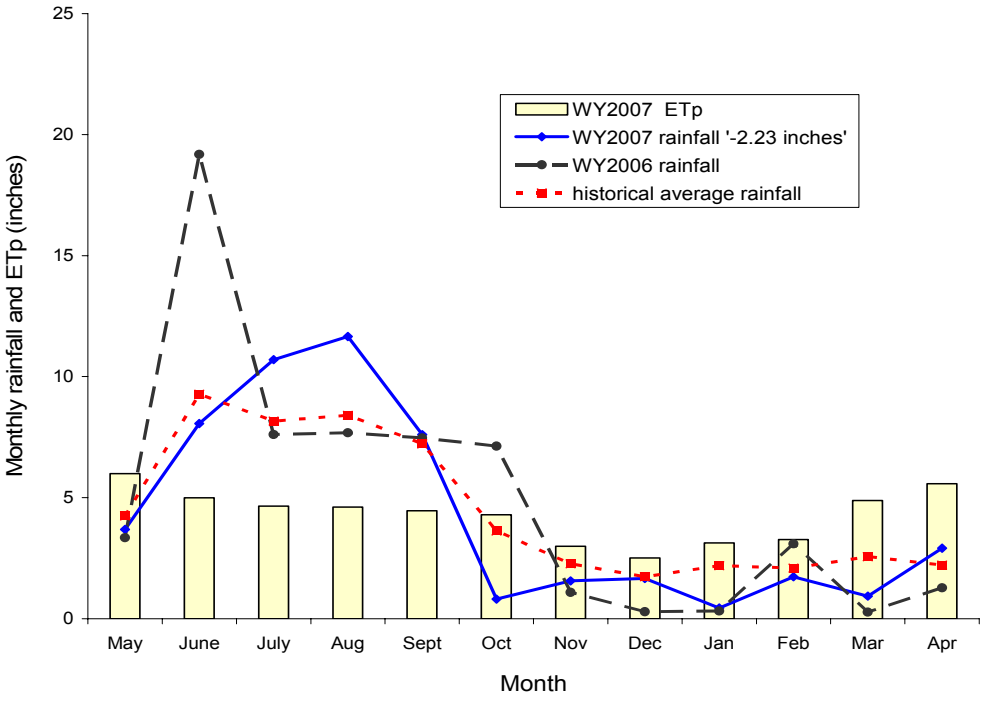


Figure 2-20. Monthly rainfall and ETp for the Big Cypress Preserve rainfall area.

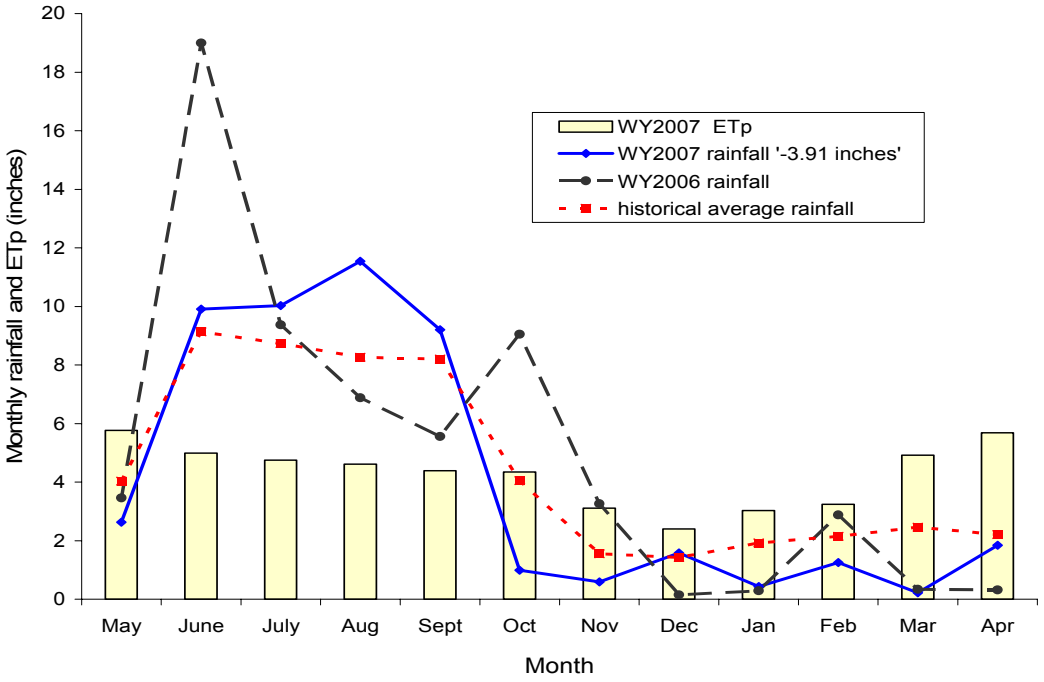


Figure 2-21. Monthly rainfall and ETp for the Southwest Coast rainfall area.

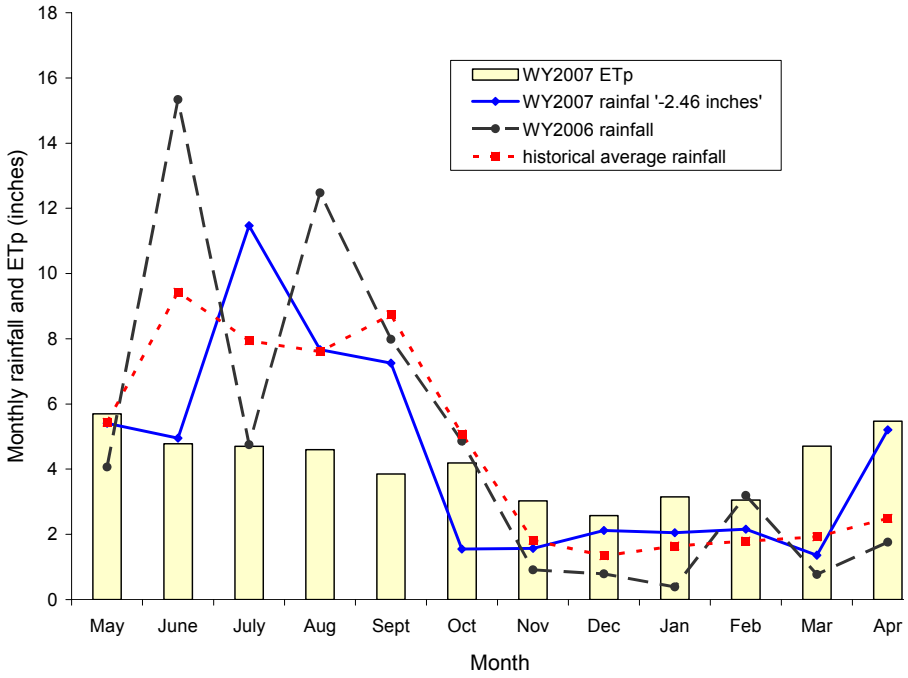


Figure 2-22. Monthly rainfall and ETp for the ENP.

Rainfall and evapotranspiration are the main parameters in the hydrologic balance of the Everglades. The delicate balance between these two parameters maintains the hydrological system of South Florida in either a wet or dry condition. Evaporation from open water and transpiration from vegetation are functions of solar radiation, temperature, wind speed, humidity, atmospheric pressure, characteristics of the surrounding environment, and type and condition of vegetation. In South Florida, most of the variation in evapotranspiration is explained by solar radiation (Abtew, 1996). Various measurements and estimates of evapotranspiration have been reported in the literature for various locations in Central and South Florida. Regional estimates of evapotranspiration from open waters and wetlands that do not dry out range from 48 inches in the District's northern section to 54 inches in the Everglades (Abtew et al., 2003; Abtew, 2005). Model estimates of annual ETp from the District's hydrometeorologic database, DBHYDRO, are depicted in **Figures 2-8** through **2-22**. WY2007 monthly ETp for each rainfall area is shown in **Table 2-7**. The closest site to a rainfall area with available ETp data was used to estimate ETp for the entire area. ETp is actual evaporation for lakes, wetlands, and any feature that is wet year-round. The model that is used to estimate potential or wetland and open water evapotranspiration (ET) is presented as follows (Abtew, 1996):

$$ET = K_1 \frac{Rs}{\lambda}$$

ET is daily evapotranspiration from wetland or shallow open water (millimeters per day), where *Rs* is solar radiation [mega joules (MJ) per square meters per day], λ is latent heat of vaporization (MJ per kilogram), and K_1 is a coefficient (0.53). Estimates for WY2007 are shown in **Tables 2-5** and **2-7**. Generally, ETp increases north to south and decreases with cloud cover duration and timing. The quality of solar radiation data at the weather station where ETp is computed from determines the quality of the ETp estimates.

WATER LEVELS, FLOWS, AND WATER MANAGEMENT

Water levels are the measure of regulation schedules for lakes, impoundments, wetlands, and canals. Period of record (POR) daily mean water levels (stage) graphs for lakes, impoundments, and the ENP are shown in Appendix 2-2. Regulation schedules for lakes, impoundments are published in the Chapter 2 of the *2007 SFER – Volume I, Appendix 2-6* (Abtew, et al., 2007d). In this section, daily average water levels and corresponding regulation schedules for WY2007 are presented for the major lakes and impoundments. All water levels are expressed in ft NGVD. Also, current year water level statistics are compared to the previous water year and historical water level records. Comparison of monthly historical average, WY2006 and WY2007, water levels are shown in Appendix 2-3. Water levels are also a measure of the amount of water in storage. Relationships of water levels (stage) and storage for lakes and impoundments was presented in the *2007 SFER – Volume I, Chapter 2, Appendix 2-2* (Abtew et al., 2007b).

In the District's water management system, surface water flow is generally regulated through water control structures and operational guidelines, such as the different regulation schedules for the major lakes, impoundments, and canals. It is a delicate system that can change from a flooding state to a water shortage, or to situations of environmental impact, in a relatively short period. Water levels and flows are regulated from the Upper Kissimmee Chain of Lakes to the Everglades. At times, temporary deviations are requested to operate the system outside the bounds of the regulation schedule to manage water quantity, quality, and storage and conveyance system integrity. For example, Lake Okeechobee was being operated under a temporary planned deviation from the regulation schedule for the period January 26, 2006 to December 31, 2006 (USACE, 2006). The objective of the deviation was to minimize the risk of high lake levels by expanding the conditions under which releases were made. Another example is WCA-1 that operated under temporary deviation from April 22, 2005 through July 31, 2006. The main element of this deviation was to suspend the requirement of an equivalent volume of inflow into WCA-1 before the release of water supply under the conditions of the schedule (USACE, 2005). Appendix 2-4 contains tables of WY2007 monthly flow volumes for the systems discussed below. Appendix 2-5 presents comparisons of historical monthly average, WY2006 and WY2007 monthly flows for each lake or impoundment. In most areas, the impact of the 2006–2007 drought is distinctly shown by significant reduction in flows.

Upper Kissimmee Chain of Lakes

The Kissimmee Basin is an integrated system consisting of several lakes with interconnecting canals and flow control structures (**Figure 2-23**). The Upper Kissimmee Basin structures are operated according to regulation schedules. The details of the water control plan for the Kissimmee River can be obtained from Master Water Control Manual for Kissimmee River – Lake Istokpoga (USACE, 1994).

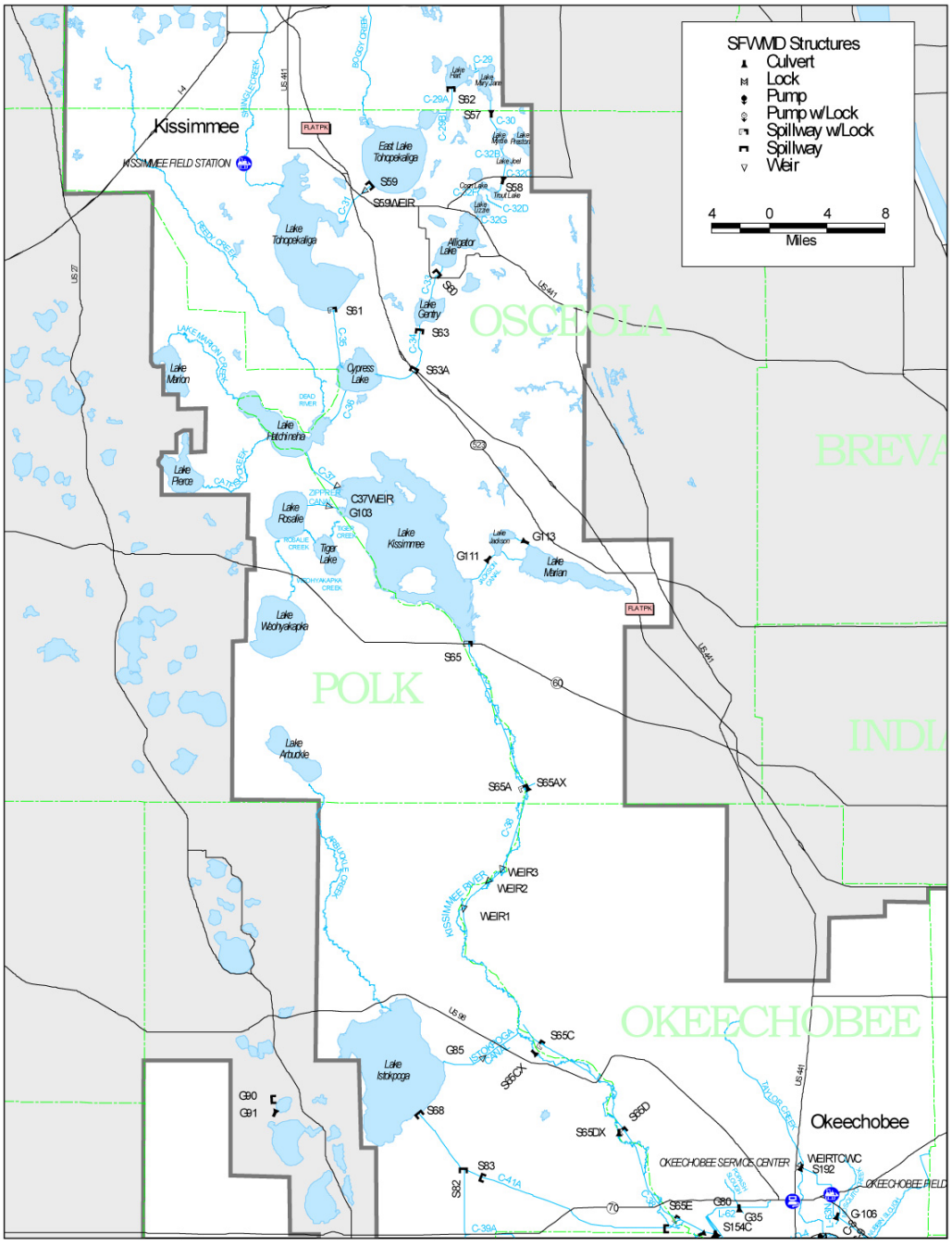


Figure 2-23. Upper and Lower Kissimmee System, Lake Istokpoga, and Harney Prairie areas.

Lake Alligator

The outflows from Lake Alligator, Center, Coon, Trout, Lizzie, and Brick are controlled by two structures S-58 and S-60. S-58 is located in C-32 Canal that connects Lakes Trout and Joel and S-60 is located in C-33 Canal between Lakes Alligator and Gentry. S-58 maintains stages in Lake Alligator upstream from the structure, while S-60 is operated to main the optimum stage on Lake Alligator. These lakes are regulated between elevations 61.5 and 64.0 ft NGVD on a seasonally varying schedule. Lake Alligator has had an average water level (stage) of 62.48 ft NGVD since 1993 (site S-60 headwater). The daily average stage for WY2007 was 62.58 ft NGVD, compared to 63.29 ft NGVD for WY2006. The maximum daily average water level was 64.17 ft NGVD (December 20, 1999) and the minimum was 58.13 ft NGVD; the minimum stage was reached during the 2000–2001 drought in South Florida. Daily water level observations for Lake Alligator in the last 14 years show that the most significant change in water levels occurred in the 2000–2001 drought (Appendix 2-2, Figure 1). **Figure 2-24** shows daily average stage at headwater of S-60 and regulation schedule for Lake Alligator during WY2007. In spring 2006, the stage recession started earlier than regulation schedule due to previously scheduled maintenance-related construction work for inflow and outflow structures S-60, S-63, and S-63A. From May to mid-September, the stages were below regulation due to below normal rainfall in the spring and summer of 2006. Maximum stages were in the second half of September. From October, the stages receded and were also below the regulation schedule due to lower than normal rainfall in wet season of 2006. Minimum releases, based on water supply needs, were made during this period to bring stages back to regulation schedule whenever possible. Monthly historical average, WY2006, and WY2007 water levels are shown in Appendix 2-3, Figure 1.

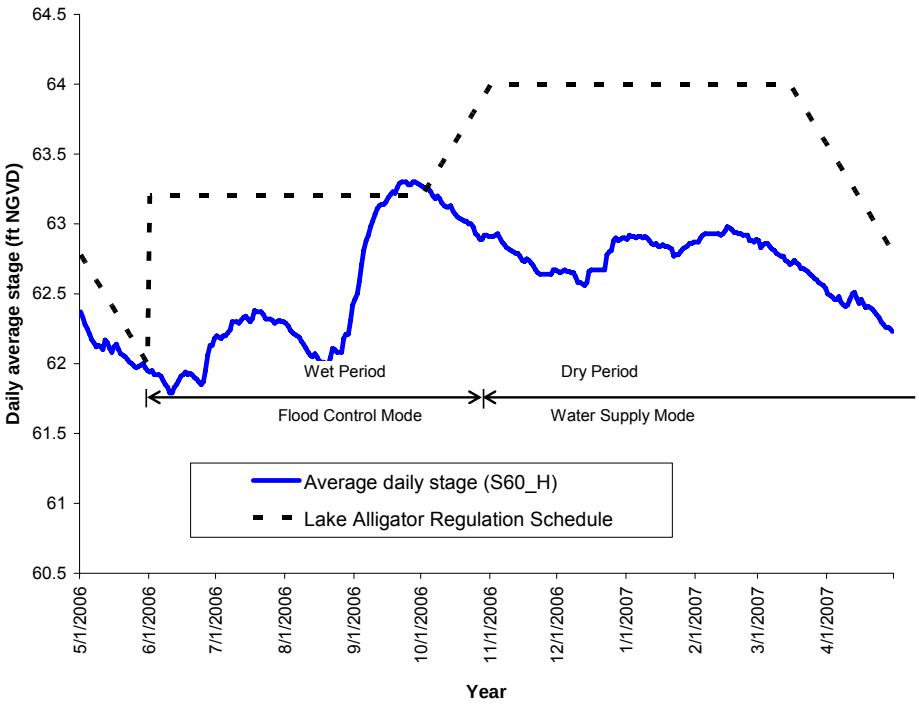


Figure 2-24. Average daily water levels (stage) and regulation schedule for Lake Alligator.

Lakes Joel, Myrtle, and Preston

Lakes Joel, Myrtle, and Preston are regulated by structure S-57. S-57 is located in the C-30 canal that connects Lakes Myrtle and Mary Jane. The lakes are regulated between 59.5 and 62.0 ft NGVD on a seasonally varying schedule. **Figure 2-25** shows daily average stage at the headwater of S-57 and regulation schedule for Lake Myrtle during WY2007. From May to mid-September, the stages were below regulation due to below normal rainfall in the spring and summer of 2006. Maximum stages were in the second half of September. From October until February, the stages receded and were also below the regulation schedule due to lower than normal rainfall in the 2006 wet season. Due to some rainfall and limited flow releases, the stage was close to the regulation schedule in February and thereafter the stages followed regulation stages.

Lake Myrtle has an average water level (stage) of 60.91 ft NGVD since 1993 (site S-57 headwater). The maximum daily average water level, 65.22 ft NGVD, was reached during the 2005 hurricane season (WY2006). The minimum stage was 58.45 ft NGVD, which was reached during the 2000–2001 drought. Daily water level observations for Lake Myrtle in the last 14 years show that the most significant drop in water level occurred in 2001 (Appendix 2-2, Figure 2). The daily average stage for WY2007 was 60.61 ft NGVD, compared to 61.48 ft NGVD for WY2006. Monthly historical average, WY2006, and WY2007 water levels are shown in Appendix 2-3, Figure 2**.**

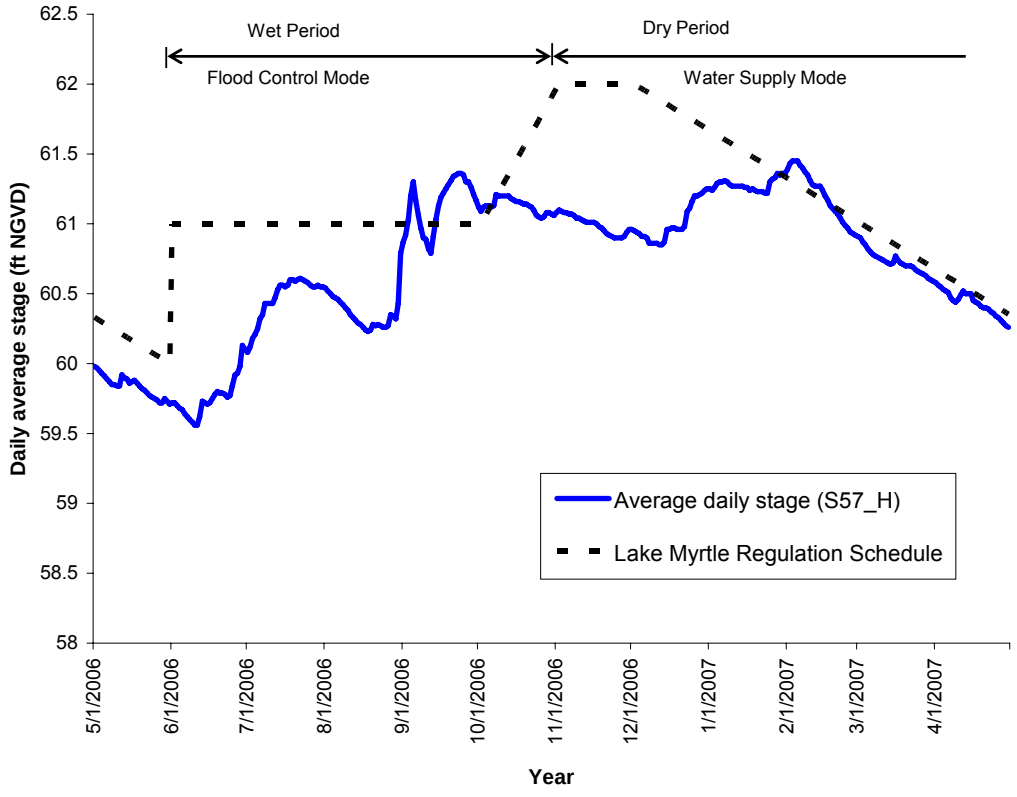


Figure 2-25. Average daily water levels (stage) and regulation schedule for Lake Myrtle.

Lakes Hart and Mary Jane

Lakes Hart and Mary Jane are regulated by structure S-62. S-62 is located in the C-29 Canal that discharges into Lake Ajay. The lakes are regulated between elevations 59.5 and 61.0 ft NGVD according to a seasonally varying schedule. **Figure 2-26** shows daily average stage at the headwater of S-62 and regulation schedule for Lake Mary Jane during WY2007. From June 2006 to April 2007, the stages were below regulation due to below normal rainfall in the spring and the summer of 2006 and spring of 2007. Minimum releases, based on water supply needs, were made during this period to bring stages back to regulation schedule when possible.

Lake Mary Jane has had an average water level (stage) of 60.05 ft NGVD since 1993 (site S-62 headwater). The maximum daily average water level was 62.16 ft NGVD, reached on October 28, 2005, during the 2005 hurricane season (WY2006). The minimum was 57.19 ft NGVD, which was reached during the 2000–2001 drought. Daily water level observations for Lake Mary Jane in the last 14 years show that the most significant drop in water level occurred in 2001 (Appendix 2-2, Figure 3). The daily average stage for WY2007 was 59.82 ft NGVD, compared to 60.44 ft NGVD for WY2006. Monthly historical average, WY2006, and WY2007 water levels are shown in Appendix 2-3, Figure 3.

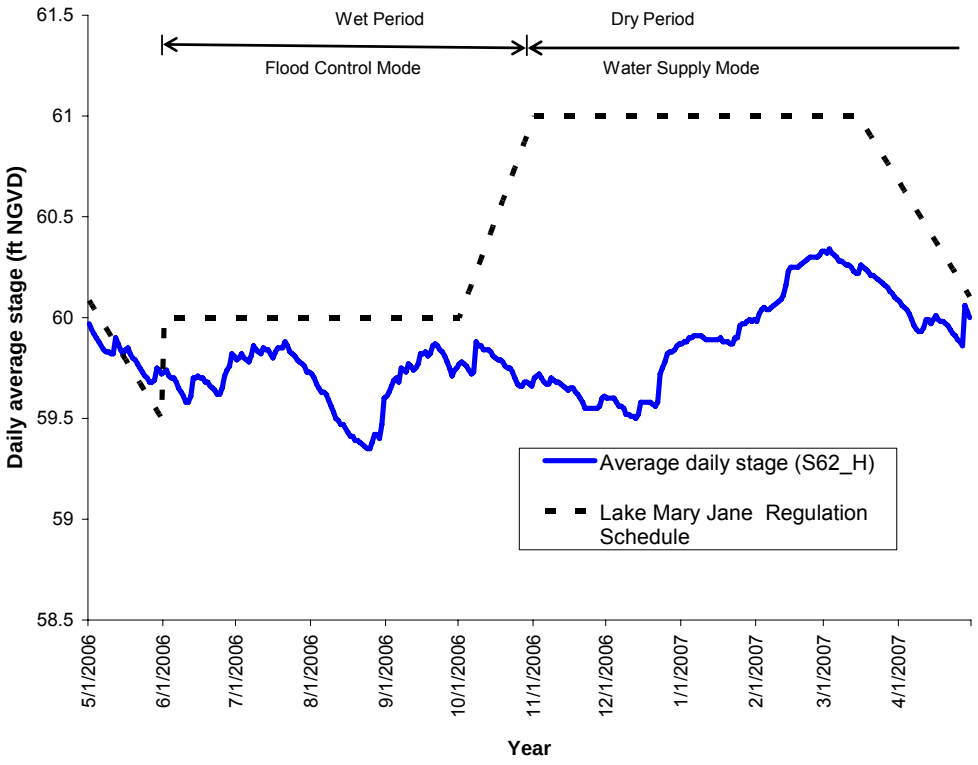


Figure 2-26. Average daily water levels (stage) and regulation schedule for Lake Mary Jane.

Lake Gentry

Lake Gentry is regulated by structure S-63, located in the C-34 canal at the south end of the lake. The stages downstream of S-63 are further lowered by S-63A before the canal discharges into Lake Cypress. The lake is regulated between elevations 59.0 and 61.5 ft NGVD according to a seasonally varying schedule. **Figure 2-27** shows daily average stage at headwater of S-63 and regulation schedule for Lake Gentry during WY2007. In spring 2006, the stage recession started earlier than regulation schedule due to previously scheduled maintenance-related construction work for inflow and outflow structures S-60, S-63, and S-63A. From May to March, the stages were below regulation due to below-normal rainfall in summer 2006 and WY2007. Due to some rainfall and minimum releases based on water supply needs stages were brought back to regulation schedule in April.

Lake Gentry has had an average water level (stage) of 60.63 ft NGVD since 1993 (site S-63 headwater). The maximum daily average water level was 61.97 ft NGVD, which was reached in October 2005 during the 2005 hurricane season. The minimum was 58.31 ft NGVD, which was reached during the 2000–2001 drought. Daily water level observations for Lake Gentry in the last 14 years show that the most significant drop in water level occurred in 2001 (Appendix 2-2, Figure 4). The daily average stage for WY2007 was 60.51 ft NGVD, compared to 61.01 ft NGVD for WY2006. Monthly historical average, WY2006, and WY2007 water levels are shown in Appendix 2-3, Figure 4.

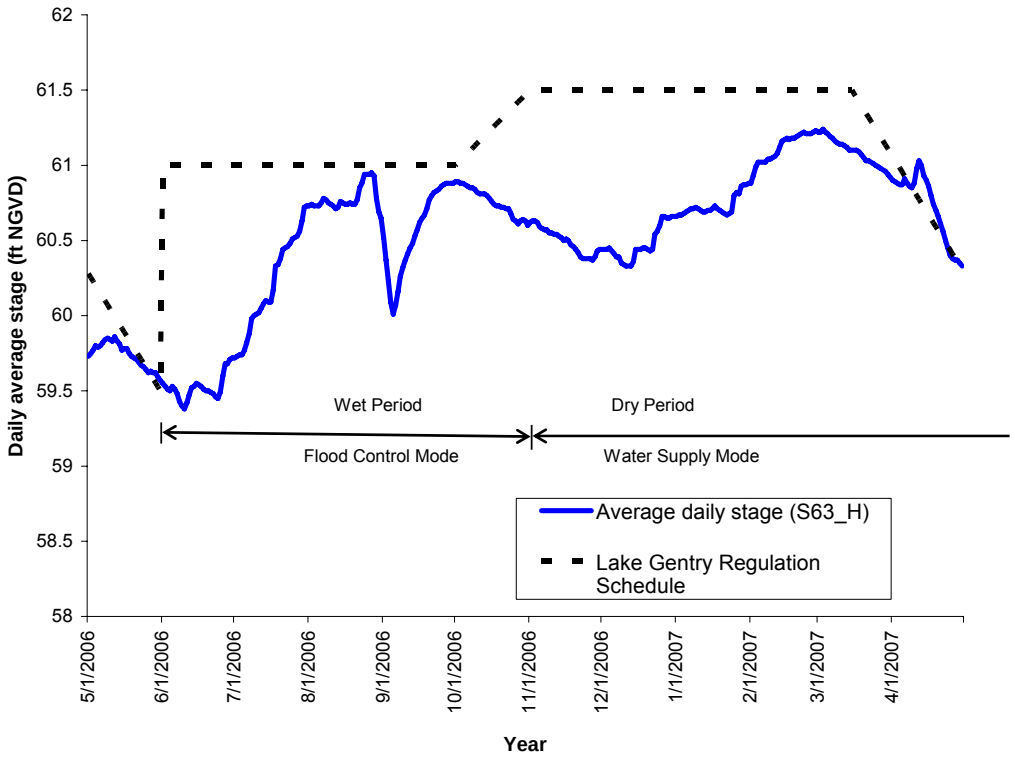


Figure 2-27. Average daily water levels (stage) and regulation schedule for Lake Gentry.

East Lake Tohopekaliga

East Lake Tohopekaliga and Lake Ajay are regulated by structure S-59, located in the C-31 canal between East Lake Tohopekaliga and Lake Tohopekaliga. The lakes are regulated between 54.5 and 58.0 ft NGVD on a seasonally varying schedule. A weir structure was built downstream of S-59 to control the tailwater elevation at S-59. The weir crest is at elevation 51.0 ft NGVD. The weir is often submerged and therefore, the tailwater influences the headwater of S-59. **Figure 2-28** shows daily average stage at the headwater of S-59 and regulation schedule for East Lake Tohopekaliga during WY2007. From May to April, the stages were below the regulation due to below normal rainfall in the spring 2006 and WY2007. Minimum releases, based on water supply needs, were made during this period to bring stages back to regulation schedule whenever possible.

East Lake Tohopekaliga has had an average water level (stage) of 56.63 ft NGVD since 1993 (site S-59 headwater). The maximum daily average water level was 59.12 ft NGVD, reached in December 1997 during an El Niño year. The minimum was 54.41 ft NGVD, which was reached in May 1997. Daily water level observations for East Lake Tohopekaliga in the last 14 years are shown in Appendix 2-2, Figure 5. The daily average stage for WY2007 was 55.76 ft NGVD, compared to 57.03 ft NGVD for WY2006. Monthly historical average, WY2006 and WY2007 water levels are shown in Appendix 2-3, Figure 5.

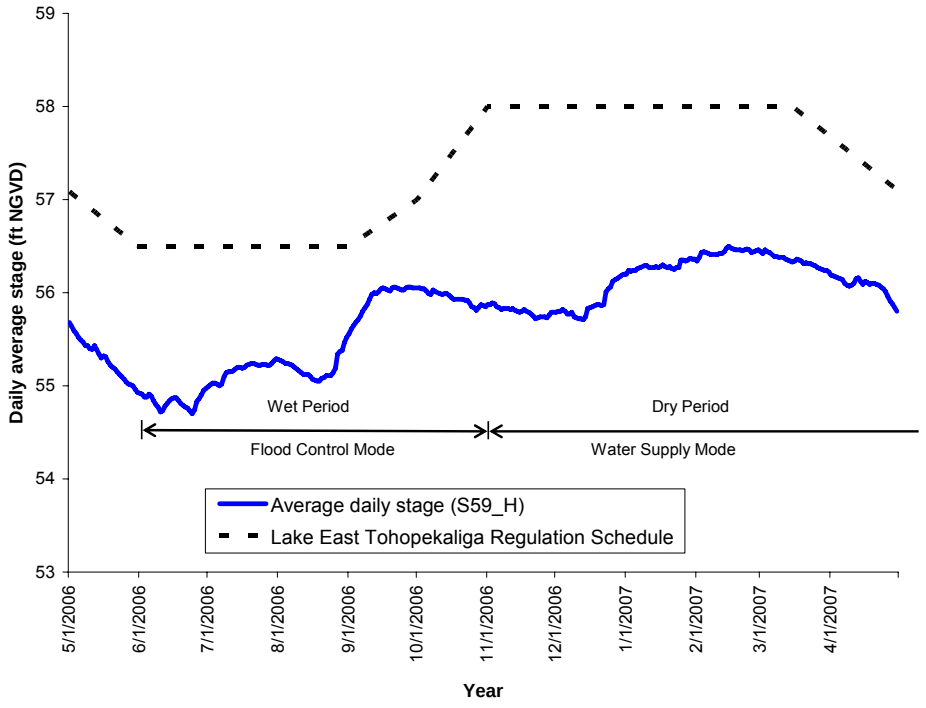


Figure 2-28. Average daily water levels (stage) and regulation schedule for East Lake Tohopekaliga.

Lake Tohopekaliga

Lake Tohopekaliga is regulated by structure S-61, located in the C-35 canal at the south shore of the lake. The lake is regulated between elevations 51.5 and 55.0 ft NGVD on a seasonally varying schedule. S-61 is used to maintain the optimum stage in Lake Tohopekaliga. **Figure 2-29** shows daily average stage at the headwater of S-61 and regulation schedule for Lake Tohopekaliga during WY2007. From May to April, the stages were below regulation due to below normal rainfall for spring 2006 and WY2007. Minimum releases, based on water supply needs, were made during this period to bring stages back to regulation schedule in April.

Lake Tohopekaliga has an average water level (stage) of 53.64 ft NGVD since 1993 (site S-61 headwater). The maximum daily average water level was 56.63 ft NGVD, reached during the 2004 hurricane season (WY2005). The minimum was 48.37 ft NGVD, which was reached in June 2004, following the implementation of a planned lake drawdown done in cooperation with the Florida Fish and Wildlife Conservation Commission in November 2003 to facilitate muck and tussock removal from the lake bed. Daily water level observations for Lake Tohopekaliga in the last 14 years show that the most significant drop in water level occurred in 2004, during the lake drawdown (Appendix 2-2, Figure 6). The daily average stage for WY2007 was 53.13 ft NGVD, compared to 54.15 ft NGVD for WY2006. Monthly historical average, WY2006 and WY2007 water levels are shown in Appendix 2-3, Figure 6.

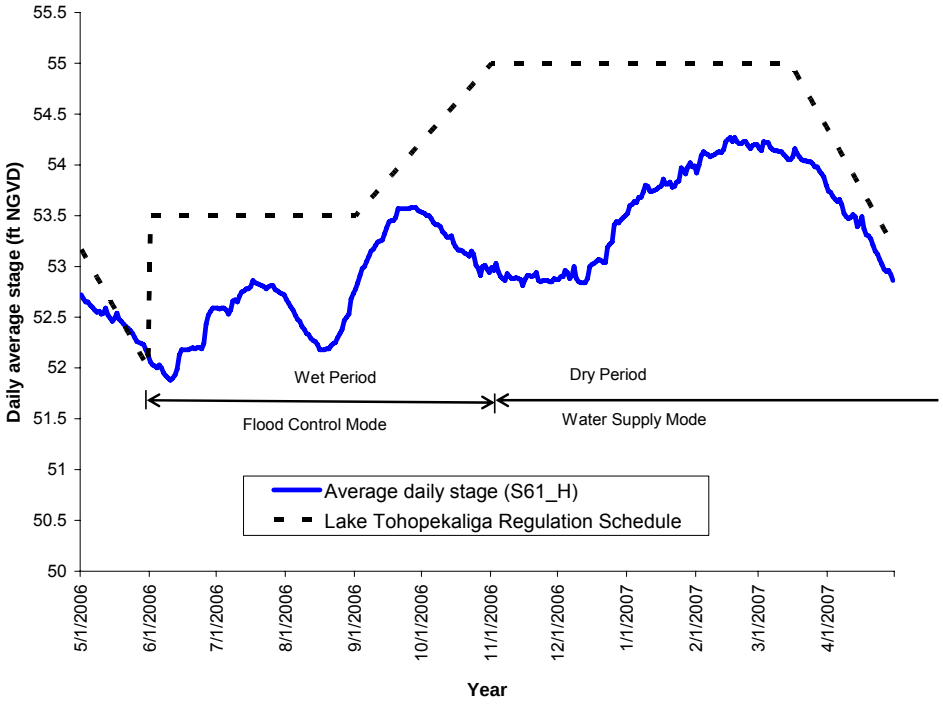


Figure 2-29. Average daily water levels (stage) and regulation schedule for Lake Tohopekaliga.

Lakes Kissimmee, Hatchineha, and Cypress

Lakes Kissimmee, Hatchineha, and Cypress are regulated by structure S-65, located at the outlet of Lake Kissimmee and at the head of the C-38 canal. Lake Kissimmee is regulated between elevations 48.5 and 52.5 ft NGVD on a seasonally varying schedule. **Figure 2-30** shows daily average stage at the headwater of S-65 and the regulation schedule for Lake Kissimmee during WY2007. From May to April, the stages were below the regulation schedule due to below normal rainfall for the spring 2006 and WY2007. Minimum releases, based on water supply needs (or no releases), were made during this period to bring stages back to regulation schedule in April.

Lake Kissimmee covers an area of approximately 35,000 acres. The lake has had a historical average water level (stage) of 50.38 ft NGVD, based on data starting in 1929 (site S-65 headwater). The maximum daily average water level was 56.64 ft NGVD observed in 1953, and the minimum was 42.87 ft NGVD observed in 1977. The average daily water level in WY2007 was 49.09 ft NGVD, compared to 51.11 ft NGVD for WY2006. Appendix 2-2, Figure 7, shows daily water level for the POR from 1929 to 2006. Historical average, WY2006, and WY2007 water levels are shown in Appendix 2-3, Figure 7.

Lake Kissimmee outflow is regulated through structure S-65. Based on flow data from January 1, 1972, through April 30, 2007, the average annual outflow from Lake Kissimmee was 715,403 ac-ft. The minimum annual flow of 7,942 ac-ft occurred during the 1981 drought in South Florida, and the maximum annual outflow of 1,694,513 ac-ft occurred in 2005 during an intensive hurricane year. During WY2007, the flow volume from Lake Kissimmee was 121,156 ac-ft, 8 percent of WY2006 flows (1,474,547 ac-ft) and one-sixth of the historical average flow. The impact of the 2006–2007 drought is distinctly shown by the reduced flow from Lake Kissimmee, which is the smallest since 1981. During the water year, there was no discharge from Lake Kissimmee from November 9, 2006 to April 30, 2007, 173 days, except for minor flows on two events. WY2007 monthly flows are shown in Appendix 2-4, Table 1. Monthly historical average, WY2006, and WY2007 flows are shown in Appendix 2-5, Figure 1.

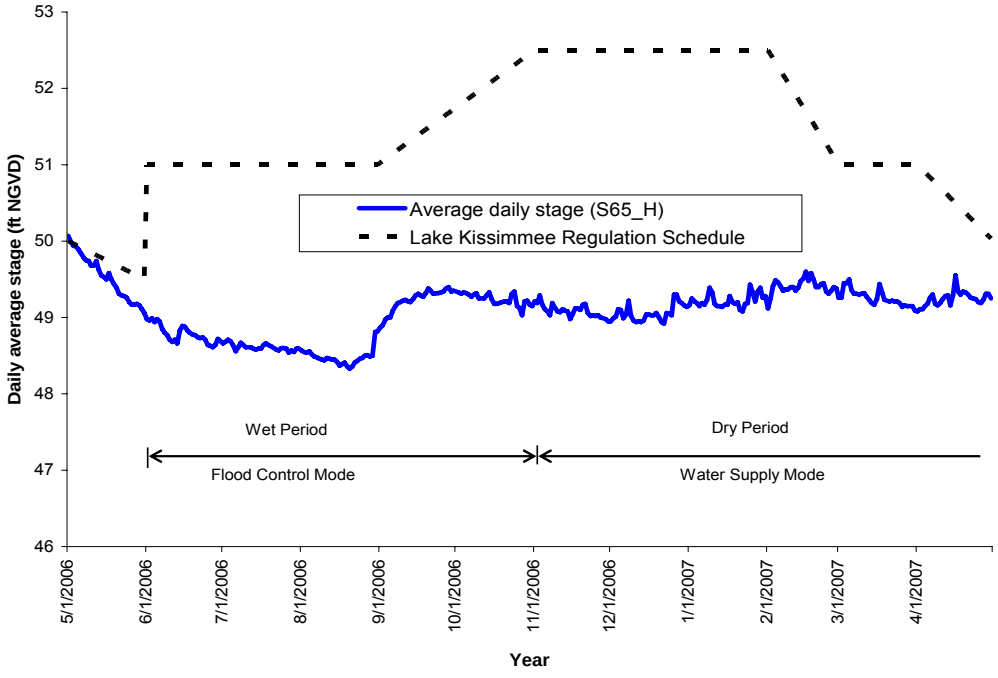


Figure 2-30. Average daily water levels (stage) and regulation schedule for Lake Kissimmee.

The Lower Kissimmee System

The Lower Kissimmee System consists of the Kissimmee River (C-38 canal) and four structures (S-65A, S-65C, S-65D, and S-65E) that form four pools (A, BC, D, and E). These structures are operated according to the optimum stages. The optimum stages for S-65A, S-65C, S-65D, and S-65E are 46.3, 34.4, 26.8, and 21.0 ft NGVD, respectively.

Pool A

Stages in Pool A are controlled by S-65A and the pool is located downstream of S-65. S-65A is a gated spillway and lock structure that normally maintains an optimum headwater at elevation 46.3 ft NGVD. In addition to S-65A, there is a culvert structure that is located through the east tieback levee at the natural channel of the Kissimmee River. The culverts are two 66-inch barrels each with slide gates. During water supply periods, minimum releases are made to satisfy irrigation demands and maintain navigation downstream. The culvert also provides water to the oxbows of the natural river channel. **Figure 2-31** shows daily average stage at the headwater of S-65A and optimum stage schedule for Pool A during WY2007. During the wet period, from May through October, stages were close to regulation schedule. However, from November to April, the stages were below regulation due to below-normal rainfall in WY2007. Minimum releases, based on water supply needs, were made during this period. During WY2007, headwater stages at S-65A ranged from 44.78 to 46.88 ft NGVD.

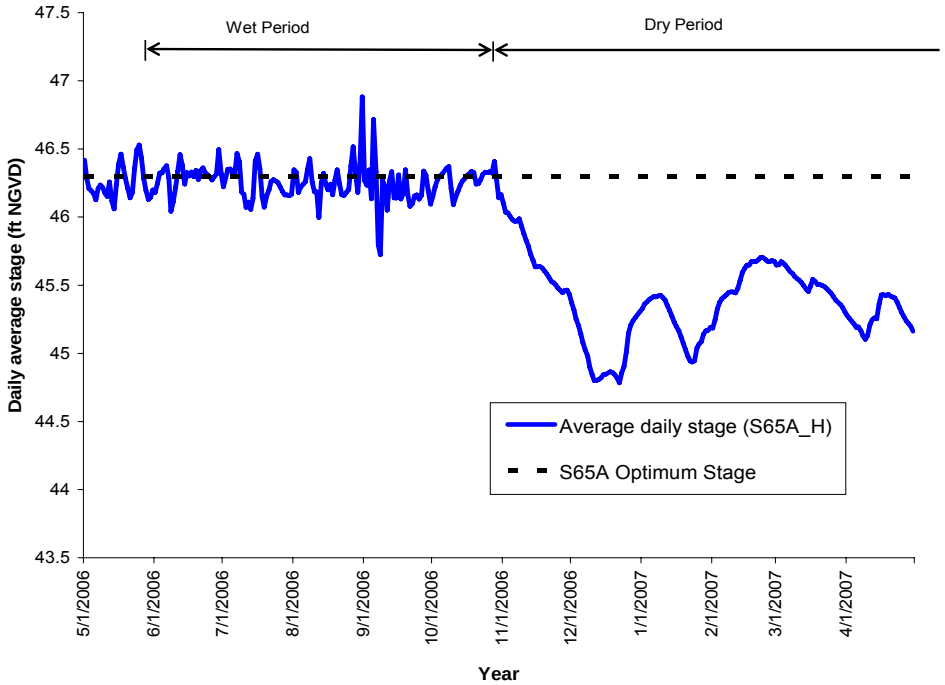


Figure 2-31. Average daily stage and optimal stage schedule at S-65A.

Pool BC

Stages in Pool BC are controlled by S-65C which is located downstream of S-65A. S-65C is a gated spillway and lock structure that normally maintains an optimum headwater at elevation 34.0 ft NGVD. In addition to S-65C, there is a culvert structure that is located through the east tieback levee at the natural channel of the Kissimmee River. During WY2007, headwater stages at S-65C ranged from 33.78 to 35.81 ft NGVD.

Pool D

Stages in Pool D are controlled by S-65D which is located downstream of S-65C. S-65D is a gated spillway and lock structure that normally maintains an optimum headwater at elevation 26.8 ft NGVD. During WY2007, headwater stages at S-65D ranged from 25.82 to 27.48 ft NGVD.

Pool E

Stages in Pool E are controlled by S-65E which is located downstream of S-65D. S-65E is a gated spillway and lock structure that normally maintains an optimum headwater at elevation 21.0 ft NGVD. During WY2007, headwater stages at S-65E ranged from 19.50 to 21.01 ft NGVD.

Lake Istokpoga

Stages in Lake Istokpoga (**Figure 2-23**) are regulated by the S-68 spillway located at the south end of the lake. Lake Istokpoga is regulated in accordance with the regulation schedule that varies seasonally. S-68 maintains the optimum water stages in Lake Istokpoga. S-68 discharges water from Lake Istokpoga to C-41A (the Slough Canal). The Harney Pond Canal (C-41 Canal), Indian Prairie Canal (C-40 Canal), and State Road 70 Canal (C-39A) provide secondary conveyance capacity for the regulation of floods in Lake Istokpoga. C-40 and C-41 flow into Lake Okeechobee whereas C-41A flows into the Kissimmee River. The details of the Lake Istokpoga water control plan can be obtained from Master Water Control Manual for Kissimmee River – Lake Istokpoga Basin (USACE, 1994). **Figure 2-32** shows daily average stage at the headwater of S-68 and regulation schedule for Lake Istokpoga during WY2007. During the month of May, stages were within the minimum and maximum regulation schedules. During the month of September, stages were almost at the maximum regulation schedule due to good rainfall partly from Tropical Storm Ernesto at the end of August and beginning of September, 2006. However, for several months, the stages were below the minimum regulation schedule due to below-normal rainfall.

Lake Istokpoga has a surface area of approximately 27,700 acres. It has an average water level (stage) of 38.79 ft NGVD, based on data collected since 1993 (site S-68 headwater). The maximum daily average water level was 39.78 ft NGVD reached during the 2005 hurricane season (WY2006). The minimum was 35.84 ft NGVD (observed during the 2001 drought). The low water level observed in June 2001 coincided with the environmental enhancement project that removed muck and tussocks from the lake bed. The average daily water level in WY2007 was 38.29 ft NGVD compared to 39.06 ft NGVD average stage in WY2006. Appendix 2-2, Figure 8, shows daily water level for the period from 1993 to 2007. Monthly historical average, WY2006 and WY2007 water levels are shown in Appendix 2-3, Figure 8.

Lake Istokpoga outflow is regulated through structure S-68. The lake's regulation schedule varies between 37.0 and 39.5 ft NGVD. Based on flow data from January 1, 1972–April 30, 2007, the average annual outflow from Lake Istokpoga was 219,228 ac-ft. The maximum discharge of 561,924 ac-ft occurred during the 1998 El Niño year. Minimum annual outflow of 17,790 ac-ft occurred during the 1981 drought in South Florida. During WY2007, the outflow volume from Lake Istokpoga was 64,372 ac-ft. This outflow was 29 percent of the historical average as a result of the drought. WY2007 monthly flows are shown in Appendix 2-4, Table 1. Monthly historical average, WY2006, and WY2007 flows are shown in Appendix 2-5, Figure 2.

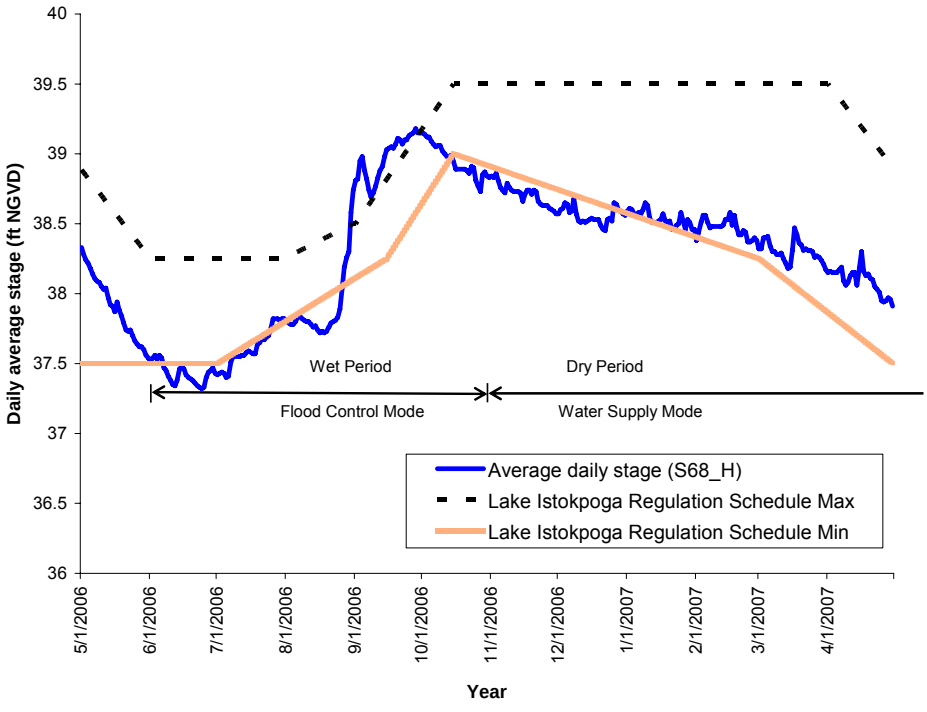


Figure 2-32. Average daily water levels (stage) and regulation schedule for Lake Istokpoga.

Lake Okeechobee

Lake Okeechobee (**Figure 2-33**) water is regulated to provide (1) flood control, (2) navigation, (3) water supply for agricultural irrigation, municipalities and industry, and the EPA, (4) regional groundwater control, (5) salinity control, (6) enhancement of fish and wildlife, and (7) recreation. The regulation schedule accounts for varying and often conflicting purposes. Regulation schedule details can be obtained from Water Control Plan for Lake Okeechobee and Everglades Agricultural Area (USACE, 2000).

Lake Okeechobee has an approximate surface area of 442,700 acres at the historical average stage of 14.41 ft NGVD (1931–2007). The maximum daily average water level was 18.77 ft NGVD, observed in 1947 during an active hurricane season, and the minimum was 8.97 ft NGVD, recorded in the 2001 drought. The average daily water level in WY2007 was 12.06 ft NGVD, which is 3.47 ft lower than the 15.53 ft NGVD average stage in WY2006 and 2.35 ft NGVD lower than the historical average of 14.41 ft NGVD. **Figure 2-34** shows daily average stage and regulation zones for Lake Okeechobee during WY2007. From May to August, the stages were below regulation schedule D due to below-normal rainfall in the spring and summer of 2006, but remained above regulation schedule E. The lake stages increased in the month of September due to some rain events. Maximum stage occurred on September 22, 2006, (13.45 ft NGVD); the water year started on May 1, 2006 at 13.46 ft NGVD. From October until April the stages continued to recede and were also below regulation schedule D due to the lower than normal rainfall in both seasons of the year. In the months of September and October, the stages were above regulation schedule E. The lake stage fell below regulation schedule E on October 25, 2006. As soon as the lake stage fell below regulation schedule E, water shortage management tasks were undertaken by the District. Summer 2006 recessions were due to discharges from the lake for flood control and environmental purposes. Spring's sharp decline in stage was associated with dry conditions and water supply withdrawals. During dry periods the lake water level decline was steep due to withdrawals and evapotranspiration while rainfall and inflows were low. Also, since storage decreases as the water level recedes, water level decline was sharper at lower lake level, due to the cone effect. For WY2007, the minimum lake stage of 9.65 ft NGVD was reached on April 30, 2007. The decline in lake stage continued into WY2008 and a new record low stage is expected. The low lake level restricted gravity discharge and 14 temporary pumps were installed to discharge water from the lake into the major canals to the south. Temporary pumps started operating at the end of March 2007 at about 10.54 ft NGVD lake stage. The practice will continue until the lake stage rises to where gravity discharge is possible. The only other time temporary pumps were used was during the 2000–2001 severe drought.

Lake Okeechobee was operated under a temporary planned deviation from the Water Supply and Environment regulation schedule. The first deviation began environmental releases to the Caloosahatchee Estuary on April 26, 2006, and ended on July 18, 2006. The second deviation began environmental releases to the Caloosahatchee Estuary on December 16, 2006, and ended on February 9, 2007. In addition, environmental releases to the Caloosahatchee Estuary were made from February 10–14, 2007, for chloride control at the inflows to the Olga Water Treatment Plant. Appendix 2-2, Figure 9, shows daily water level for Lake Okeechobee for the period of record of 1931–2007. Monthly historical average, WY2006, and WY2007 water levels are shown in Appendix 2-3, Figure 9.

Based on flow-data records dating from May 5, 1972 through April 30, 2007, the annual average inflow into Lake Okeechobee is 2,114,743 ac-ft with a maximum annual inflow of 3,707,764 ac-ft in WY2006, an active hurricane year. Based on water-year-to-water-year comparison, the minimum historical annual inflow for a water year was 377,671 ac-ft, which occurred in WY1981 during the 1980–1981 severe drought. In WY2007, the volume of inflow to

Lake Okeechobee was 619,189 ac-ft, which is 30 percent of the historical average and 17 percent of WY2006 inflows (3,707,764 ac-ft). WY2007 inflows are the third-smallest water year inflows on record since 1972. The droughts of 1980–1981 and 2000–2001 had smaller inflows. During WY2007, 907,527 ac-ft of water was released from the lake; out of which 52,175 ac-ft was via the 14 temporary pumps. The volume of outflow from Lake Okeechobee in the previous water year (WY2006) was 3,978,904 ac-ft, which was a record high water year discharge in the period since 1972. Based on data from 1972–2007, the historical annual average discharge from Lake Okeechobee is 1,517,992 ac-ft with the minimum annual discharge level of 263,875 ac-ft in water year 1991 (a drought year). WY2007 monthly inflows and outflows are shown in Appendix 2-4, Table 2 and Table 3, respectively. Monthly historical average, WY2006, and WY2007 inflows and outflows are shown in Appendix 2-5, Figures 3 and 4.

Upper East Coast and the St Lucie Canal and Estuary

Inflows to the St. Lucie Canal are received from Lake Okeechobee by operation of S-308C, a gated spillway, the Port Mayaca lock (S-308B), and the basin watershed **(Figure 2-33)**. Three levels of 10-day pulse releases are made to the St. Lucie Canal, in flood zones B, C, and D of the Lake Okeechobee regulation schedule. The pulse releases emulate natural rain storm events within the basin. The optimum water control elevations for the St. Lucie Canal vary between 14.0 and 14.5 ft NGVD. The outflow from the St. Lucie Canal is discharged into the estuary via the S-80 structure. The S-80 structure is a gated spillway operated by USACE. The operation of S-80 includes the storm runoff from the C-44 basin and tidal St. Lucie watersheds. S-80 operations use regulation procedures that vary with zones A, B, C, D, and E of the Lake Okeechobee regulation schedule (USACE, 2000). Since salinity is an important measure of estuary viability, freshwater flow at S-80 is an important feature of water management activities.

The C-23 canal discharges into the North Fork of the St. Lucie River at structure S-48. During WY2007, 51,374 ac-ft of water was discharged at S-48 compared to 297,214 ac-ft in WY2006. WY2007 discharge was 35 percent of the historical average discharge of 146,198 ac-ft (1995–2007). The C-24 canal discharges into the North Fork of the St. Lucie River at S-49. During WY2007, 41,878 ac-ft of water was discharged at S-49 compared to 259,534 ac-ft in WY2006. WY2007 discharge was 32 percent of the historical average flow of 132,703 ac-ft (1962–2007). The C-25 canal discharges into the southern part of the Indian River Lagoon at structure S-50. During WY2007, 33,596 ac-ft of water was discharged at S-50 compared to 227,680 ac-ft in WY2006. This amount was 25 percent of the historical average discharge of 134,755 ac-ft (1965–2007). The impact of the drought is significant due to reduction of flows.

Structure S-80 discharges water from the St. Lucie Canal into the south fork of the St. Lucie River. Flow at this structure comes from the C-44 basin and Lake Okeechobee. Lake Okeechobee discharged 82,122 ac-ft into the St. Lucie Canal through structure S-308 in WY2007 compared to 907,187 ac-ft in WY2006. During WY2007, only 21,340 ac-ft was discharged from the St. Lucie Canal at S-80 compared to 1,192,782 ac-ft in WY2006. A discharge of 21,340 ac-ft is 4 percent of the average historical flow of 524,451 ac-ft (1953–2007). The impact of the drought is significantly shown by significant reduction of flows. WY2007 monthly flows for S-48, S-49, S-50 and S-80 are shown in Appendix 2-4, Table 4. Monthly historical average, WY2006, and WY2007 flows are shown in Appendix 2-5, Figure 5-8.

Figure 2-33. The Lake Okeechobee, Upper East Coast, and St. Lucie Canal and Estuary system.

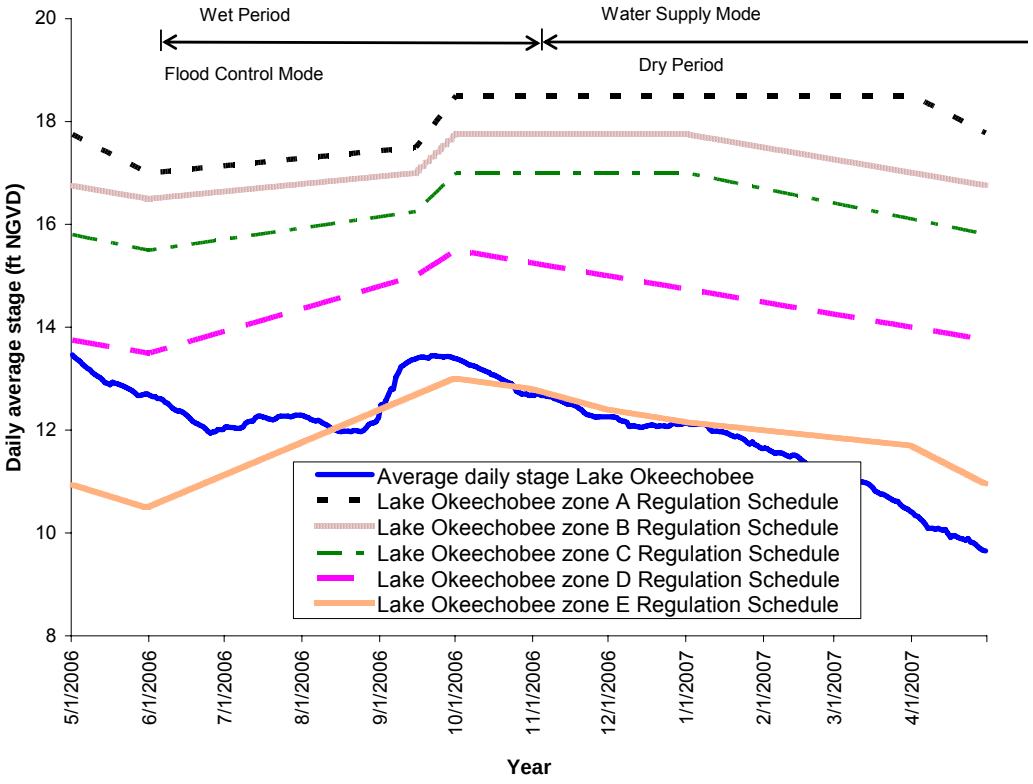


Figure 2-34. Average daily water levels (stage) and regulation schedule for Lake Okeechobee.

The Caloosahatchee Canal and Estuary

Inflows to the Caloosahatchee Canal (C-43) are runoff from the basin watershed and releases from Lake Okeechobee by operation of S-77, a gated spillway and lock structure (**Figure 2-35**). S-77 operations use regulation procedures described in USACE (2000). In flood zones B, C, and D of Lake Okeechobee, three levels of 10-day pulse releases are made to the Caloosahatchee Canal. The pulse releases emulate natural rain storm events within the basin. Downstream of S-77 is S-78, a gated spillway that also receives inflows from the east Caloosahatchee watershed, its local watershed. The optimum water control elevation for this portion of the Caloosahatchee Canal (upstream of S-78 and downstream of S-77) is between 10.6 and 11.5 ft NGVD. The outflow from the Caloosahatchee Canal (downstream of S-78) is discharged into the estuary via S-79, a gated spillway and lock operated by USACE. The operations of S-79 include the stormwater runoff from west Caloosahatchee and tidal Caloosahatchee watersheds. The optimum water control elevations near S-79 range between 2.8 and 3.2 ft NGVD. Because salinity is an important measure of estuary viability, freshwater flow at S-79 is an important feature of water management activities.

The last structure on the Caloosahatchee Canal that controls discharges into its estuary is S-79. The average annual flow volume at S-79 is 1,264,122 ac-ft, based on the 1972–2007 record. In WY2007, 694,124 ac-ft of water was discharged through S-79, compared to the WY2006 discharge of 3,615,526 ac-ft. The WY2007 discharge volume is less than one-fifth of WY2006 discharges and less than half of the historical average as a result of the 2006–2007 drought. For WY2007, Lake Okeechobee discharge into the Caloosahatchee Canal through the S-77 structure was 180,108 ac-ft compared to WY2006 discharge of 2,175,467 ac-ft. WY2007 monthly flows for S-77 and S-79 are shown in Appendix 2-4, Table 5. Monthly historical average, WY2006, and WY2007 outflows at S-79 are shown in Appendix 2-5, Figure 9.

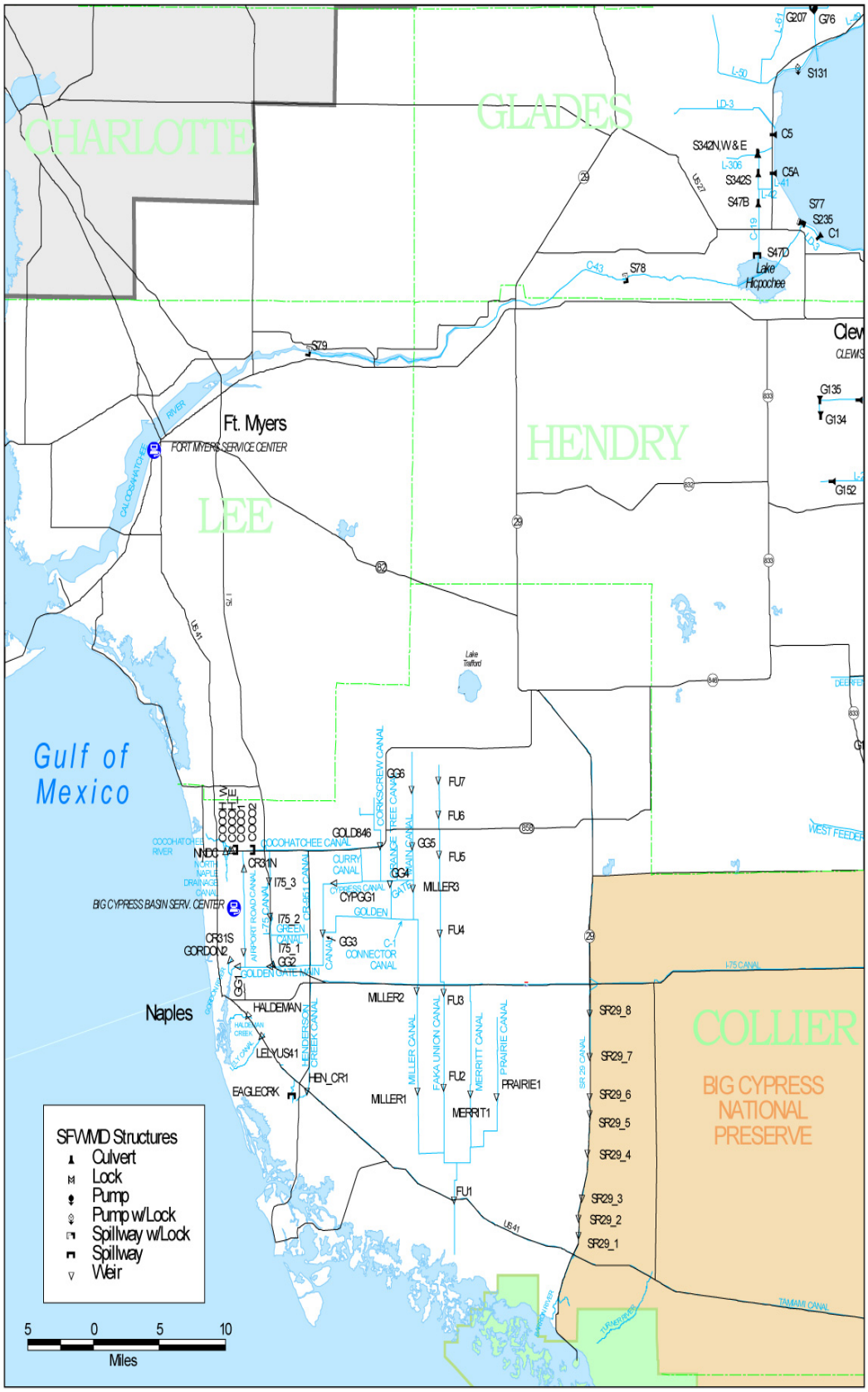


Figure 2-35. The Caloosahatchee Canal and Estuary, Big Cypress Basin, and Southwest Area.

The Everglades Agricultural Area

There are four major canals that pass through the EAA (**Figure 2-36**): Hillsboro Canal, North New River Canal, West Palm Beach Canal, and Miami Canal. Flows from Lake Okeechobee and runoff from the EAA to the Stormwater Treatment Areas (STAs) are discharged via these four canals to relieve flooding from the local drainage area. The inflows from Lake Okeechobee to these canals are from structures S-351, S-352, and S-354. These structures are gated spillways with a maximum tailwater elevation that does not exceed 12.0 ft NGVD for Lake Okeechobee operation. The optimum water control elevations for S-351 and S-354 range between 11.5 and 12.0 ft NGVD. During WY2007, elevations ranged from 9.01 to 12.29 ft NGVD. The outflows from the four canals to the STAs are provided by pump structures S-5A, S-319, S-6, G-370, and G-372. Outflows from STAs are inflows into the WCAs. During the dry season, water supply for agricultural irrigation uses is provided by these four primary canals mainly through gravity release from Lake Okeechobee. Due to too-low lake levels during the 2006–2007 drought, 14 temporary pumps were installed at the lake to supply water to these canals. Farmers utilize a set of secondary and tertiary farm canals to distribute water from several gated culverts and pumps to their respective fields.

The Water Conservation Areas

The Water Conservation Areas (WCAs) are shallow impoundments with a total area of approximately 860,400 acres (**Figure 2-36)**. Water levels in the WCAs change due to drought, rainfall, evapotranspiration, seepage, and surface water management. Surface water management in the WCAs is based on regulation schedules that vary with the time of year, hydrologic conditions, and other needs.

The primary objective of the WCAs is to provide flood control; water supply for agricultural irrigation, municipalities, industry, and the ENP; regional groundwater control and prevention of saltwater intrusion; enhancement of fish and wildlife; and recreation. The second objective is to maintain marsh vegetation in the WCAs, which provides a dampening effect on hurricane-induced wind tides. The regulation schedule represents the monthly and seasonal storage limits for planning purposes. The regulation schedule levels vary from high stages in the late fall and winter to low stages at the beginning of the wet season. The seasonal range allows runoff storage during the wet season and water supply use during the dry season. The regulation schedule must take into account various and often conflicting purposes (USACE, 1996). There are also several major constraints for WCA regulation.

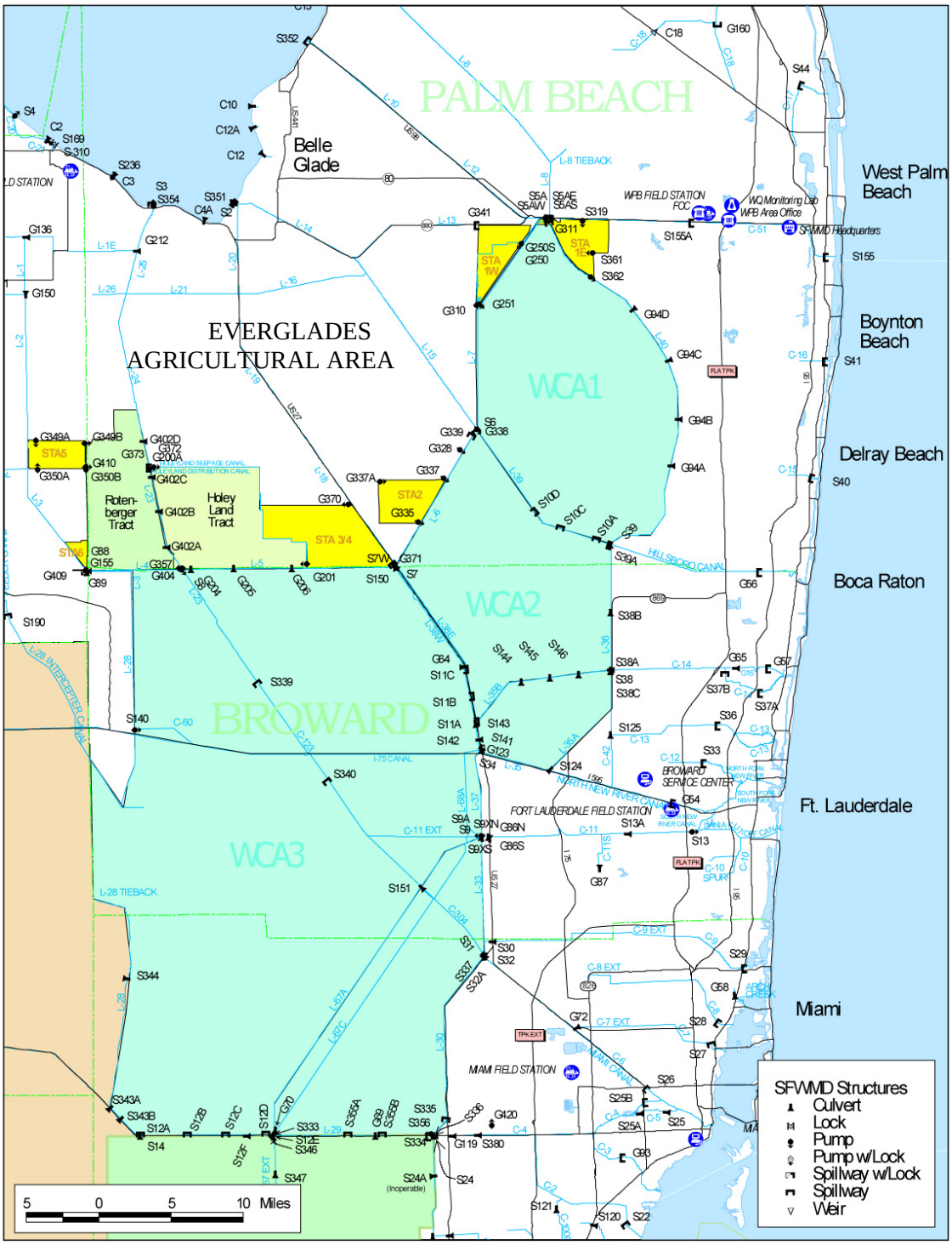


Figure 2-36. The Everglades Agricultural Area (EAA) and Water Conservation Areas 1, 2, and 3 (WCA-1, WCA-2, and WCA-3).

Water Conservation Area 1

WCA-1 covers a 141,440-acre area with a daily average water level of 15.58 ft NGVD. WCA-1 is regulated by outflow structures S-10A, S-10C, S-10D, and S-10E; the regulation schedules for WCA-1 are provided in the Master Water Control Plan – Water Conservation Areas, Everglades National Park, and the ENP-South Dade Conveyance System – Volume 4 (USACE, 1996). The main inflows into WCA-1 are from STA-1 West (STA-1W) through the G-251 and G-310 pump stations and from STA-1 East (STA-1E) via pump station S-362. There are three diversion structures which can flow in both directions (G-300, G-301, and G-338). The S-10 structures outflow into WCA-2A. The two diversion structures (G-300 and G-301) are also used to discharge water from WCA-1 to the north, the STA-1 inflow basin. Water can also be discharged through S-39 to the east into the Hillsboro Canal using four stage gauges (1-8C, 1-7, 1-8T, and 1-9) as indicator gauges. Different stage gauges are used in different months and conditions. For example, daily water levels were compiled from the four stage gauges based on their regulation schedule uses. Site 1-8C was used from January 1, 2006 through June 30, 2006, while the remaining sites 1-7, 1-8T, and 1-9 were used to calculate the average water level for the year, but only if the average was lower than that calculated from site 1-8C. A maximum daily average water level of 18.16 ft NGVD was reached on October 17, 1999, during Hurricane Irene. A minimum water level of 10 ft NGVD was reached on June 1, 1962, a drought year. For WY2007, average stage in WCA-1 was 15.99 ft NGVD, which was lower than WY2006 (16.18 ft NGVD) but higher than the historical average (15.58 ft NGVD). For WY2007, the maximum daily average stage of 17.08 ft NGVD was reached in September 2006 and the minimum of 14.07 ft NGVD was reached at the end April, 2007, during the current drought. **Figure 2-37** depicts the WY2007 daily average water level and regulation schedule level for WCA-1. Daily average historical water levels are shown in Appendix 2-2, Figure 10, for the POR from 1960 through 2007. Monthly historical average, WY2006 and WY2007 water levels are shown in Appendix 2-3, Figure 10.

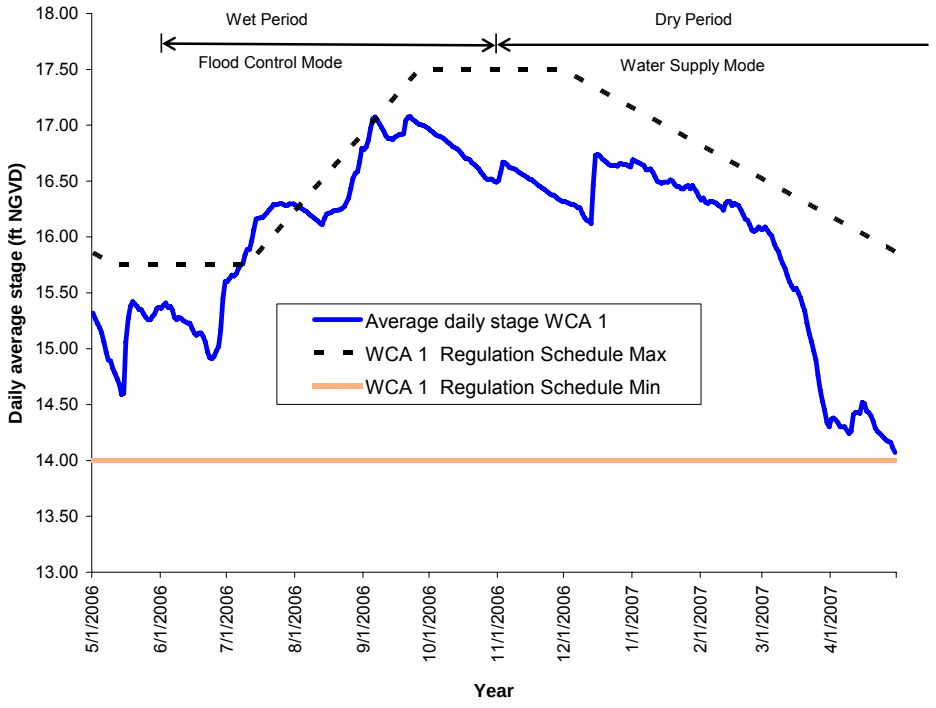


Figure 2-37. WY2007 daily average water level (stage) and regulation schedule for WCA-1.

Inflow and outflow structures throughout the WCAs are operated based on regulation schedules. Historical flows through each structure have varying lengths of PORs because of new structures coming online or existing structures that no longer contribute to the inflow and outflow of a system. The structures related to the STAs are relatively recent additions. Historical average inflows and outflows were computed from 1972 through 2006. WCA-1 is regulated between 14 and 17.50 ft NGVD. The average historical inflow was 513,829 ac-ft. The total inflow for WY2007 was 251,232 ac-ft, about the same as WY2006 inflows (252,201 ac-ft). The major inflows (50 percent) were from STA-1W through pump stations G-310 and G-251. The inflow from STA-1E through the structure S-362 was 39 percent. ACME1 and ACME2 sources (pump stations) from the Village of Wellington to the east contributed 11 percent of the total inflow. There was no inflow through structures G-300 and G-301. There was no diversion of flow from S-6 to WCA-1 as discharge has been diverted from WCA-1 into STA-2 since May 2001.

Outflows from WCA-1 were mainly into WCA-2A through structures S-10A, C, and D (56 percent) and into the Hillsboro Canal through the S-39 structure (9 percent) and discharge to the Lake Worth Drainage District through structures G-94A, B, and C (8 percent). There were significant backflows to the STA-1 inflow basin through structures G-301 (27 percent). The total outflow for WY2007 was 232,258 ac-ft compared to WY2006 outflow of 205,503 ac-ft. The average historical outflow is 469,241 ac-ft. WY2007 monthly inflows and outflows are shown in Appendix 2-4, Tables 6 and 7, respectively. Monthly historical average, WY2006, and WY2007 inflows and outflows are shown in Appendix 2-5, Figures 10 and 11.

Water Conservation Area 2

WCA-2 is located south of WCA-1. An interior levee across the southern portion of the area subdivides it into WCA-2A and WCA-2B, reducing water losses due to seepage into the extremely pervious aquifer that underlies WCA-2B and precludes the need to raise existing levees to the grade necessary to provide protection against wind tides and wave run-up. The regulation schedules for WCA-2A are provided in USACE (1996). A regulation schedule is not used for WCA-2B because of high seepage rates. Release to WCA-2B from S-144, S-145, and S-146 are terminated when the indicator stage gauge 99 in WCA-2B exceeds 11.0 ft NGVD. Discharges from WCA-2B area are made from spillway structure S-141 to North New River Canal when pool elevation in WCA-2B exceeds 11.0 ft NGVD.

WCA-2A and WCA-2B combined have a total area of 133,400 acres, with 80 percent of the area in WCA-2A. WCA-2A has a historical average water level of 12.55 ft NGVD (site 2-17). A maximum water level of 15.64 ft NGVD was reached on November 18, 1969, and a minimum level of 9.33 ft NGVD was reached on April 29, 1989, during a severe drought year. Appendix 2-2, Figure 11, shows the daily water level for the POR from 1961 through 2007. For WY2007, the average stage in WCA-2 was 11.91 ft NGVD, lower than WY2006 (12.62 ft NGVD) and lower than average (12.55 ft NGVD). WY2007 maximum daily average stage was 13.97 ft NGVD, and the minimum was 10.42 ft NGVD. **Figure 2-38** depicts WY2007 daily average water level and regulation schedule level for WCA-2A. Monthly historical average, WY2006, and WY2007 water levels are shown in Appendix 2-3, Figure 11.

The total inflow to WCA-2 for WY2007 was 584,391 ac-ft compared to 895,488 ac-ft in WY2006 and the 625,621 ac-ft historical average. The major inflows (41 percent) were through the S-7 pump station with flows mainly from STA-3/4. STA-2 discharges through pump station G-335 accounted for 37 percent of the inflows into WCA-2A. WCA-1 discharges through the S-10A, C, and D structures are inflows to WCA-2A (22 percent). Inflows through structure G-339, a bypass structure at STA-2, were minimal. There was no flow from WCA-3A to WCA-2 through structure S-142.

Outflows from WCA-2 were primarily into WCA-3A through structures S-11A, B, and C (80 percent) and backflow through the S7 structure (13 percent) into the EAA. Discharge to canals 13 and 14 through structure S-38 was 5 percent. There was no discharge to WCA-3A through S142. Due to the drought there was significant back flow to the EAA. The total outflow for WY2007 was 459,722 ac-ft, which is 42 percent of the total outflows in WY2006 (1,109,149 ac-ft) and 74 percent of the historical average outflow of 622,098 ac-ft. WY2007 monthly inflows and outflows are shown in Appendix 2-4, Tables 8 and 9, respectively. Monthly historical average, WY2006, and WY2007 inflows and outflows are shown in Appendix 2-5, Figure 12 and 13, respectively.

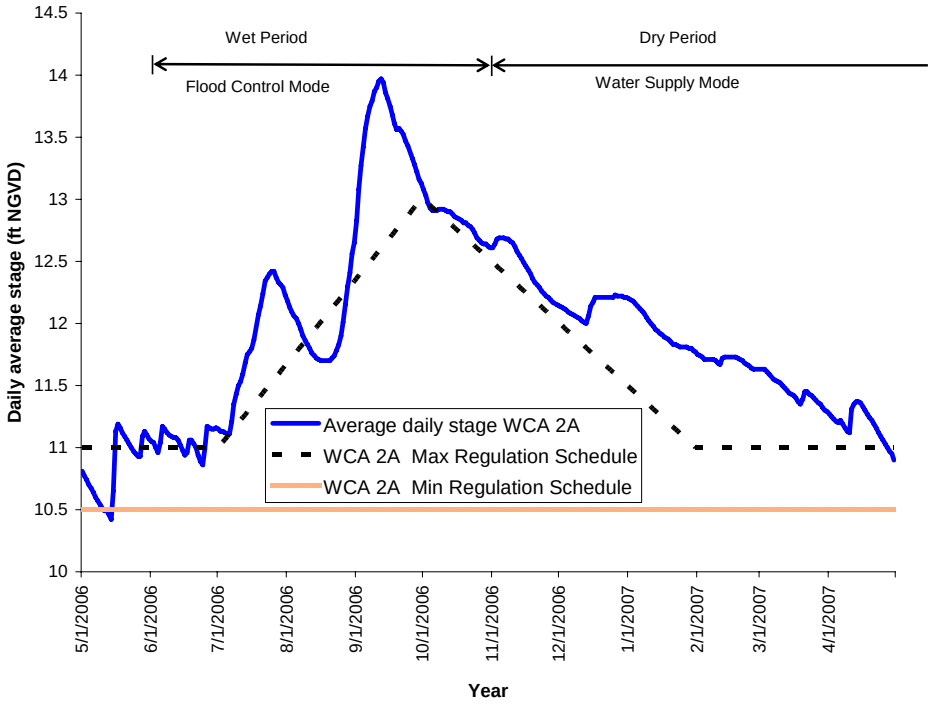


Figure 2-38. WY2007 daily average water level (stage) and regulation schedule for WCA-2A.

Water Conservation Area 3

WCA-3 is located south and southwest of WCA-2A. Two interior levees across the southeastern portion of the area subdivide it into WCA-3A and WCA-3B. These levees reduce water losses due to seepage into the extremely pervious aquifer that underlies WCA-3B. The regulation schedules for WCA-3A are provided in USACE (1996). A regulation schedule is not used for WCA-3B because of high seepage rates. Indicator gauge 3B-2 is used for WCA-3B. Flow releases into WCA-3B are from S-142 while releases from WCA-3B are through S-31 or S-337. Discharges from WCA-3B are rarely made from culvert L-29-1 for water supply purposes. Daily average historical water levels for WCA-3A are shown in Appendix 2-2, Figure 12, for the POR from 1961 through 2007. Monthly historical average, WY2006, and WY2007 water levels are shown in Appendix 2-3, Figure 12.

WCA-3A and WCA-3B combined have a total area of 585,560 acres, with 83 percent of the area in WCA-3A. WCA-3A has a historical average water level of 9.54 ft NGVD. The maximum water level of 12.79 ft NGVD was reached on January 22, 1995, during an El Niño year, and the minimum level of 4.78 ft NGVD was reached on June 6, 1962, during a drought year. Daily average historical water levels are shown in Appendix 2-2, Figure 12. For WY2007, average stage in WCA-3 was 9.61 ft NGVD, which was lower than WY2006 (10.58 ft NGVD). The WY2007 maximum daily average stage was 11.26 ft NGVD and the minimum was 8.4 ft NGVD. **Figure 2-39** depicts WY2007 daily average water level and regulation schedule for WCA-3A. Monthly historical average, WY2006 and WY2007 water levels are shown in Appendix 2-3, Figure 12.

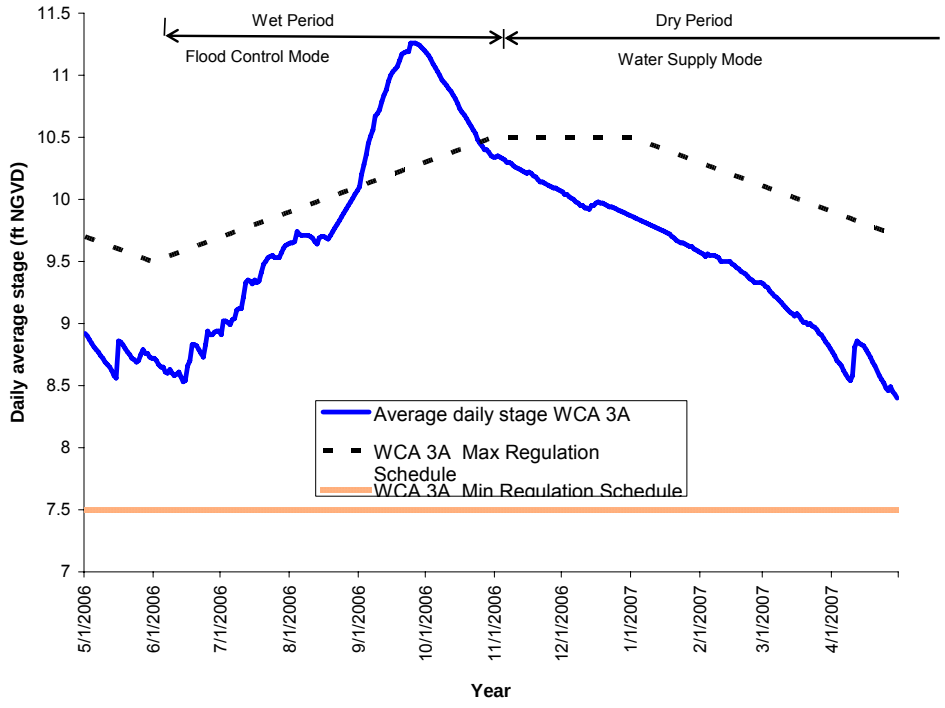


Figure 2-39. WY2007 daily average water level (stage) and regulation schedule for WCA-3A.

The WY2007 inflows to WCA-3A were 849,324 ac-ft, which was 50 percent of WY2006 inflows (1,685,358 ac-ft). The historical average inflow is 1,219,665 ac-ft. The major inflows were through S-11A, B, and C (44 percent) from WCA-2, and from STA-3/4 through structures S-8 (20 percent) and S-150 (3 percent). Discharges from the east through structure S-9 and S-9A accounted for 15 percent of the total inflow. The S-140 and S-190 structures to the northwest contributed 10 percent and 8 percent of the inflow to WCA-3A, respectively. There are currently ungauged potential inflows to WCA-3A through the L-4 borrow canal breach into the L-3 extension canal. The breach has a bottom width of 150 ft, at an elevation of 3 ft NGVD (SFWMD, 2002).

Outflows from WCA-3A are mainly into the ENP through structures S-12A, B, C, D, and E (55 percent). S-333 discharged 24 percent, with potential directions of flow in the ENP to the south and east: Shark River Slough and Taylor Creek. Outflow from WCA-3A through S-151 was 18 percent. There was no discharge into the North New River Canal through structure S-142.

The remaining smaller outflows were through structures S-150, S-337 and G-69. The total outflow for WY2007 was 564,676 ac-ft, which is 31 percent of the total outflows in WY2006 (1,821,029 ac-ft). The average historical outflow is 1,024,817 ac-ft. WY2007 monthly inflows and outflows are shown in Appendix 2-4, Table 10 and Table 11, respectively. Monthly historical average, WY2006, and WY2007 inflows and outflows are shown in Appendix 2-5, Figures 14 and 15.

Everglades National Park

The ENP is located south of WCA-3A and WCA-3B (**Figure 2-40**). The land is a federal property operated and maintained by Everglades National Park, a federal entity within the jurisdiction of the U.S. Department of Interior, National Park Service. The original operational criteria that were used by the District and USACE are presented in USACE, 1996. Later, it was modified and presented in the Interim Operational Plan (IOP) (USACE, 2002). The IOP will be superseded when all the elements of the Modified Water Deliveries Project are built and capable of operating and when the record-of-decision for the Combined Structural Operational Plan is signed (USACE, 2002).

The 1972 federal requirement for minimum monthly water deliveries to Shark River Slough was superseded in 1985 by an operational plan referred to as the "Rain-Driven Plan". This plan addresses the overall objectives of providing water deliveries that vary in response to hydrometeorological conditions in the basin (USACE, 1996). The operation plans for S-333 and S-12A, B, C, and D are presented in the IOP (USACE, 2002).

The ENP water delivery goals are connected to water levels upstream and downstream, and rainfall amounts in WCA-3A. Flows to the ENP are made via S-333 and S-12A, B, C, and D. The operational plan for these structures is the Rain-Driven Plan also known as the "Rainfall-Based Management Plan of WCA-3A" that integrates the target flows required to be released from these structures. Because of complexities involved with the IOP, regulation schedules are not developed or used for Everglades National Park.

The Rainfall-Based Management Plan of WCA-3A is used to operate water control structures that discharge from WCA-3A to the ENP. The objective of the plan is to restore a more natural hydroperiod and hydropattern in the northeast Shark River Slough and the ENP. A mathematical model is being used to define flow targets for the operation of five water control structures (S-333 and S-12A, B, C, and D) along the southern boundary of WCA-3A subject to upstream hydrologic conditions and downstream hydrologic and ecologic constraints. Pathak and Palermo (2006) detail the mathematical model used to compute target weekly flow volumes to be released from WCA-3A. The model uses weekly rainfall data from 10 rain gauges, weekly evaporation data from three pan evaporation gauges, and weekly average stage data from three water level gauges.

Water deliveries to Taylor Slough are made via several seepage reservoirs and structures including the S-332B, C, and D pump stations. These pump stations are components of the C-111 Canal Project. Their operation plans are presented in the IOP (USACE, 2002). Water deliveries to the eastern panhandle are made via the C-111 canal. The S-18C structure maintains a desirable freshwater head against saltwater intrusion through the C-111 canal to act as a control point to the eastern panhandle of the ENP. The optimum water stages range between 2.0 and 2.6 ft NGVD upstream of S-18C while making minimum water discharges. Additionally, S-197 maintains optimum water control stages in C-111 canal and prevents saltwater intrusion during high tides. S-197 is closed most of the time and diverts water from S-18C overland flow to the panhandle. S-197 releases flows during major flood events according to established guidelines in the IOP (USACE, 2002).

The ENP is approximately 1,376,000 acres in size (Redfield et al., 2003). Water level monitoring at sites P-33 and P-34 has been used in previous consolidated reports as representative of slough and wet prairie, respectively (Sklar et al., 2003). Station elevations for P-33 and P-34 are 5.06 and 2.09 ft NGVD, respectively (Sklar et al., 2000). Historical water level data for sites P-33 (1952–2007) and P-34 (1953–2007) was obtained from the District's hydrometeorologic database DBHYDRO and from the ENP's database. For WY2007, the average stage at site P-33 in the ENP was 6.15 ft NGVD, which was lower than WY2006 (6.65 ft NGVD) and the historical average stage (5.98 ft NGVD). For WY2007, the maximum daily average stage at site P-33 was 6.67 ft NGVD, and the minimum was 5.45 ft NGVD. **Figure 2-41** depicts daily average water level at P-33 for WY2007. Daily average historical water levels for P-33 and P-34 are shown in Appendix 2-2, Figures 13 and 14.

For WY2007, the average stage at site P-34 in the ENP was 2.65 ft NGVD, which was lower than WY2006 (3.22 ft NGVD) and higher than the historical average stage (2.09 ft NGVD). For WY2007, maximum daily average stage was 3.75 ft NGVD, and minimum was 1.15 ft NGVD. **Figure 2-42** depicts daily average water level at P-34 for WY2007. Monthly historical average, WY2006 and WY2007 water levels for P-33 and P-34 are shown in Appendix 2-3, Figures 13 and 14.

Inflow into the ENP is mainly through structures S-12A, B, C, D, and E; S-18C; S-332B; S-332C; S-332D; S174; S175 and S-333. The major inflow (54 percent) was through the S-12 structures. These structures are operated by the District for the USACE, in accordance with the Rain-Driven Water Deliveries Plan to the ENP and the Regulation Schedule of WCA-3A. This plan determines discharges through the S-333 and through S-12 structures a week in advance using a computer program. A weekly report is posted by the SFWMD and is available on the District's web site at www.sfwmd.gov under the *What We Do, Environmental Monitoring, Reports* section, under the *WCA-3A* tab. The objective of this plan is to restore a more natural hydroperiod and hydropattern in the northeast Shark River Slough. Structural and operational modifications were also incorporated into the delivery plan based on the IOP for Protection of the Cape Sable Seaside Sparrow (http://www.saj.usace.army.mil/h2o/lib/documents/index.htm. Flows through S-18C accounted for 14 percent of the total flow. Structure S-332D contributed 8 percent of the inflows, S-332B contributed 2 percent, and structure S-332C contributed 5 percent. Inflow from S-333 was 17 percent. There were minor inflows through S-174 and S175. The total surface water inflow to the ENP for WY2007 was 578,244 ac-ft, which is 30 percent of WY2006 inflows (1,901,386 ac-ft). The historical average inflow is 986,431 ac-ft (1972-2006). WY2007 monthly inflows are shown in Appendix 2-4, Table 12. Monthly historical average, WY2006 and WY2007 inflows are shown in Appendix 2-5, Figure 16.

The Lower East Coast

The Lower East Coast System includes the South Dade Conveyance System (**Figure 2-40**). The purpose of the system is flood control from the drainage area. The system provides water control to prevent over drainage in the area; prevent saltwater intrusion; and provide facilities to convey runoff to the ENP when available. The purpose of the system is also to improve water supply and distribution to the ENP. It was designed to supply water during a 10-year drought, and deliver minimum water needs to Taylor Slough and the C-2, C-4, C-1, C-102, C-103, and C-113 basins. Based on operational experience, the stages in canals are usually allowed to recede before supplemental water is introduced into the system. Flow releases during major flood events are made according to established guidelines in USACE (1995).

Figure 2-40. Map showing the ENP and Lower East Coast.

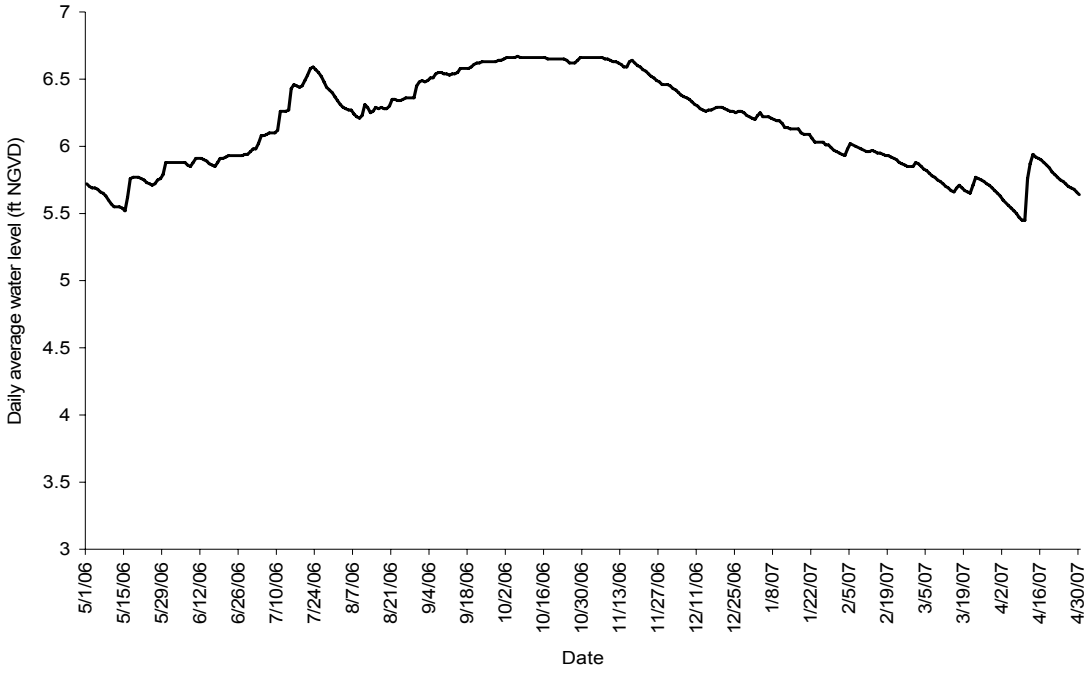


Figure 2-41. WY2007 daily average water level (stage) for gauge P-33 in the ENP.

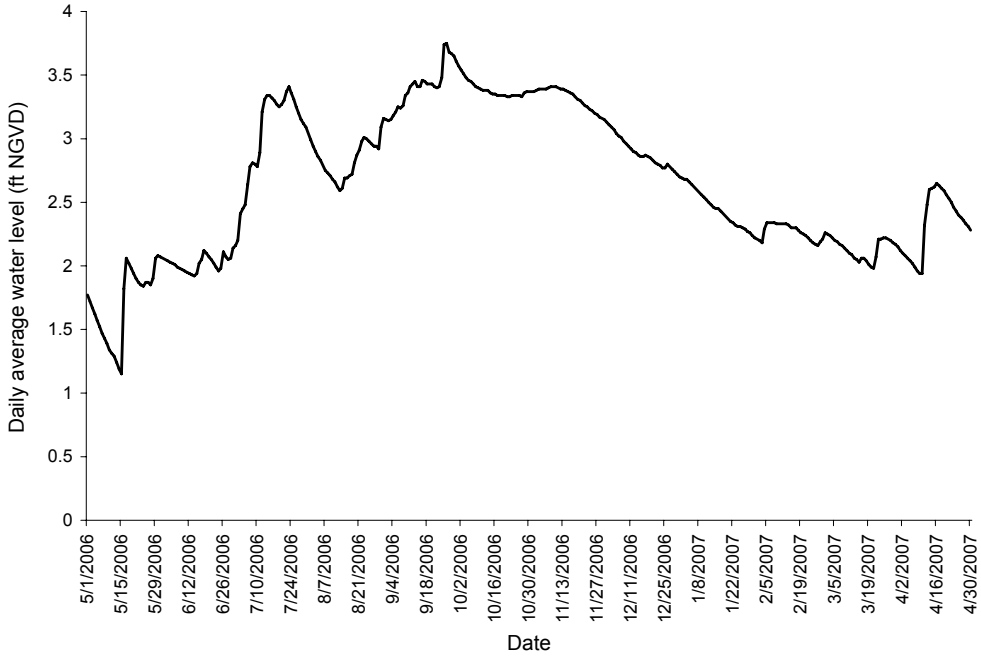


Figure 2-42. WY2007 daily average water level (stage) for gauge P-34 in the ENP.

CONCLUSIONS

Water Year 2007 was a severe drought year with over a foot rainfall deficit over the region. The drought varied from rainfall area to rainfall area. Generally, Lake Okeechobee, East EAA and Martin/St. Lucie counties had severe droughts as rare as the 100-year return period. Relatively, the southeast (Broward, Miami-Dade, Everglades National Park), Big Cypress Preserve and the southwest coast received more rain compared to the respective average rainfall. Upper Kissimmee and Lower Kissimmee were dry, resulting in only 619,189 ac-ft inflow to Lake Okeechobee. This inflow is 29 percent of the historical average and 17 percent of WY2006 inflow. Outflows were also reduced due to the limited storage in Lake Okeechobee and reduced inflows. WY2007 outflow from Lake Okeechobee was 907,527 ac-ft, 60 percent of the average outflow and 16 percent of WY2006 outflow. Lake Okeechobee water level declined to 9.65 ft NGVD by the end of the water year, April 30, 2007. The lake level decline continued into WY2008. The low lake level restricted gravity discharge so 14 temporary pumps were installed to discharge water from the lake into the major canals to the south. The temporary pumps discharged 52,174 ac-ft from the end of March through April 30, 2007. The low lake level combined with the rainfall deficit resulted in a series of water conservation measures that included restrictions on water use.

The drought resulted in significant reduction to flows through the region. Lake Kissimmee did not have significant discharge for 173 consecutive days, and the water year total outflow of 121,156 ac-ft is 17 percent of the historical average. The Lake Istokpoga water year outflow of 64,372 ac-ft is 29 percent of the historical average. Discharge into the estuaries decreased as a result of the drought. The St. Lucie Canal discharged 21,340 ac-ft through the S-80 structure, 4 percent of the historical average. Discharge through the Caloosahatchee Canal into the estuary through the S-79 structure was 694,124 ac-ft, less than half of the historical average. Inflow in WCA-1 was 49 percent of the historical average. Inflow in to WCA-2 was 584,391 ac-ft, 93 percent of the historical average. Inflow in to WCA-3 was 849,324 ac-ft, 70 percent of the historical average. Inflow into Everglades National Park was 578,244 ac-ft, 57 percent of the historical average and 30 percent of WY2006 flows. Overall, water management was drought management for this water year.

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