Chapter 2: South Florida Hydrology and Water Management

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SUMMARY

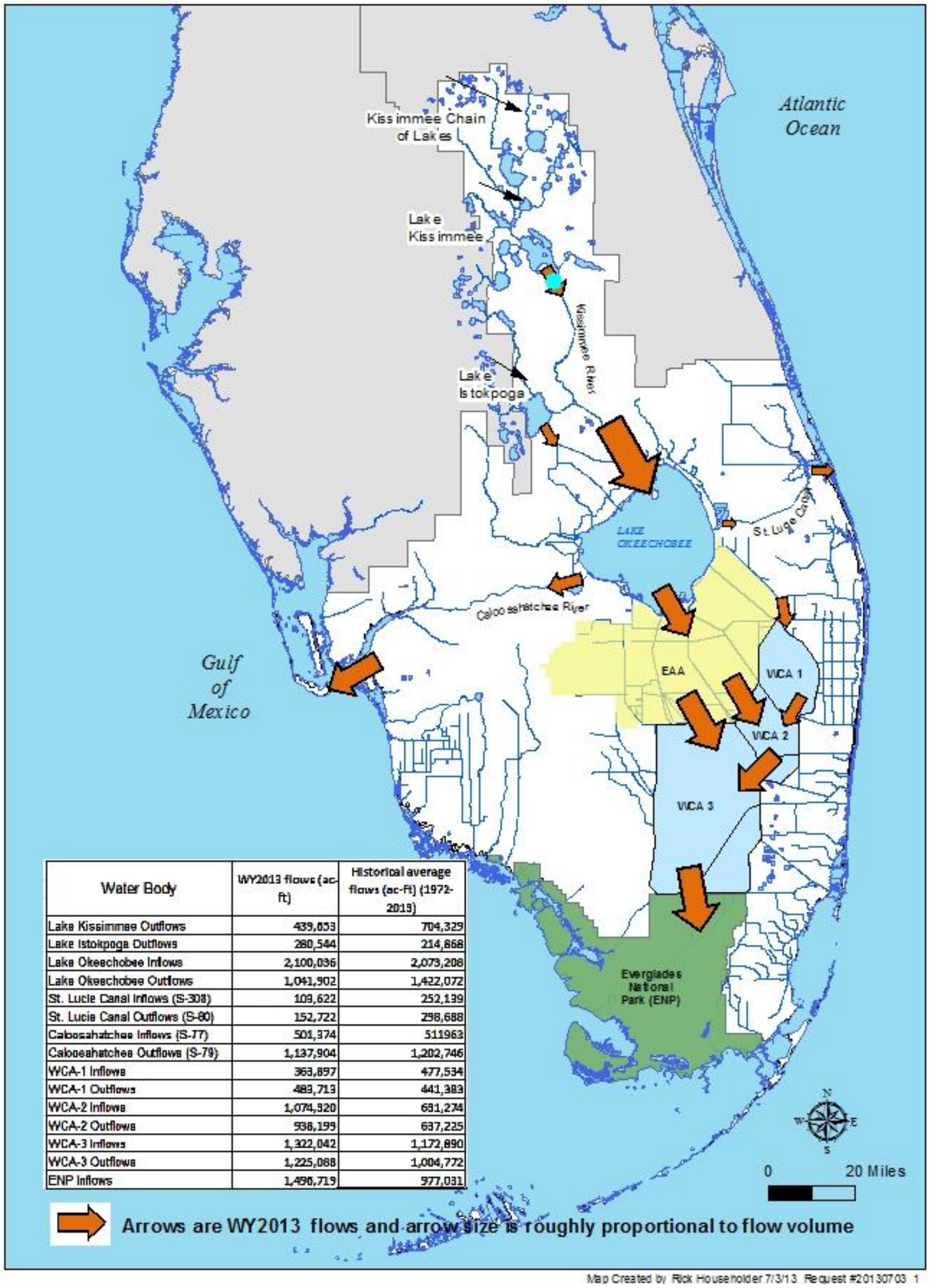
Given hydrology's significance to the entire South Florida ecosystem and all aspects of regional water management, this chapter presents hydrologic data and analysis for Water Year 2013 (WY2013) (May 1, 2012–April 30, 2013). Similar information from previous water years is available in Chapter 2 of the respective *South Florida Environmental Report* (SFER) – *Volume I.* This year's chapter includes a brief overview of the regional water management system, hydrologic impact WY2013 tropical systems with a major event from Tropical Storm Isaac, and WY2013 hydrology of several sub-regions and major hydrologic units within the South Florida Water Management District (SFWMD or District) boundaries. Appendices 2-1 through 2-7 of this volume provide supplementary information for this chapter. The broad influences of water year hydrology on various aspects of the region-wide system are covered in most other Volume I chapters. The El Niño-Southern Oscillation (ENSO) climatic phenomenon is linked to South Florida hydrology. The 2011 La Niña condition continued in the beginning of 2012. By spring 2012, the tropical Pacific west of Peru started warming and the El Niño trend was observed by late summer. From September to the end of 2012, neutral conditions continued and 2012 ended as a neutral ENSO year. Weak La Niña to neutral conditions prevailed in early 2013.

Meteorologically, WY2013 was average rainfall year but the rainfall distribution was spatially and temporally distributed unevenly. Temporally, on the average, six months experienced drought. Spatially, Upper Kissimmee (-2.95 inches), East Everglades Agricultural Area (-1.85 inches), West Agricultural Area (-1.61 inches), Martin/St. Lucie (-2.3 inches), East Caloosahatchee (-2.31 inches), and Southwest Coast (-3.3 inches) rainfall areas had below average rainfall for the water year. On the contrary, Lower Kissimmee (+7.88 inches), Lake Okeechobee (+1.25 inches), Water Conservation Areas 1 and 2 (+10.84 inches), Water Conservation Area 3A (+4.78 inches), Palm Beach (+1.06 inches), Broward (+3.1 inches), Miami-Dade (+9.25 inches), and the Everglades National Park (+3.27 inches) were wetter than average. Notably, five of the last seven water years had a rainfall deficit (-3.65 inches in WY2012, -12.39 inches in WY2011, -7.51 inches in WY2009, -3.8 inches in WY2008, and -12 inches in WY2007). This is part of a continuing trend over the past decade, in which drought frequency has increased with drier-than-normal conditions across the South Florida region.

Lake Okeechobee—the main storage of the regional water management system—was at a stage of 11.68 feet National Geodetic Vertical Datum of 1929 (ft NGVD) on May 1, 2012. The lake stage showed a minor increase in water levels from May to August 2012. It started rising through the summer and reached a maximum of 15.93 ft NGVD in October 2012, followed by a gradual decline through the dry season reaching 13.4 ft NGVD by the end of WY2013. During this period, there was no concern of water supply.

Figure 2-1 presents WY2013 surface water flows for major hydrologic components in the regional system with historical average flows shown for comparison. **Table 2-1** compares WY2013 flows to the last water year's flows and historical average flows. Generally, inflows and outflows to most major water bodies were above or close to the historical average and few were

below average. WY2013 flows were higher than WY2012, except for Lake Kissimmee outflow and C-24 Canal outflow through S-49.



Water Body	WY2013 flows (ac-ft)	Historical average flows (ac-ft) (1972-2013)
Lake Kissimmee Outflows	439,653	704,329
Lake Istokpoga Outflows	280,544	214,868
Lake Okeechobee Inflows	2,100,036	2,073,206
Lake Okeechobee Outflows	1,041,902	1,422,072
St. Lucie Canal Inflows (S-308)	109,622	252,139
St. Lucie Canal Outflows (S-80)	152,722	298,688
Caloosahatchee Inflows (S-77)	501,374	511963
Caloosahatchee Outflows (S-79)	1,137,904	1,202,746
WCA-1 Inflows	363,897	477,534
WCA-1 Outflows	483,713	441,383
WCA-2 Inflows	1,074,320	691,274
WCA-2 Outflows	938,199	637,225
WCA-3 Inflows	1,322,042	1,172,890
WCA-3 Outflows	1,225,088	1,004,772
ENP Inflows	1,496,719	977,031

Figure 2-1. Water Year 2013 (WY2013) (May 1, 2012–April 30, 2013) and historical average inflow and outflow (in acre-feet, or ac-ft) into major hydrologic units of the regional water management system. [Note: The three arrows depicted from Lake Okeechobee represent Lake Okeechobee outflows in inset; the inflow arrow into the ENP includes outflow from WCA-3 and inflows from the east.]

Table 2-1. Summary of flows for WY2013, the percent of historical average they represent, and their comparison to WY2012. [Note: Structures used to calculate inflows and outflows into the major hydrological units are presented in Appendix 2-6 of this volume.]

Location	WY2013 total flow (ac-ft*)	Percent of historical average	WY2012 total flow (ac-ft)*
Northern Everglades			
Lake Kissimmee Outflows	439,653	62	813,987
Lake Istokpoga Outflows	280,544	131	228,042
Lake Okeechobee Inflows	2,100,036	101	1,821,336
Lake Okeechobee Outflows	1,041,902	73	746,499
Flows into the St. Lucie Canal from Lake Okeechobee	103,622	41	47,201
Flows into the St. Lucie Estuary through the St. Lucie Canal	152,722	51	119
Flows into the Caloosahatchee Canal from Lake Okeechobee	501,374	98	180,461
Flows into the Caloosahatchee Estuary through the Caloosahatchee Canal	1,137,904	95	598,840
Southern Everglades			
Water Conservation Area 1 Inflows	363,897	76	170,256
Water Conservation Area 1 Outflows	483,713	109	14,812
Water Conservation Area 2 Inflows	1,074,320	170	386,176
Water Conservation Area 2 Outflows	938,199	147	378,071
Water Conservation Area 3 Inflows	1,322,042	113	899,567
Water Conservation Area 3 Outflows	1,225,088	123	571,304
Everglades National Park Inflows	1,496,719	153	744,176

INTRODUCTION

THE SOUTH FLORIDA WATER MANAGEMENT SYSTEM: A REGIONAL OVERVIEW

The ecological and physical characteristics of South Florida have been shaped by years of hydrologic variation—ranging from extreme drought to flood, sometimes within a relatively short time period. Regional hydrology 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 peninsula's coasts. Most of the municipal water supply is from groundwater that is sensitive to surface recharge through direct rainfall, runoff, or canal recharge. The general hydraulic gradient is north-to-south, where excess surface water flows from the Upper Kissimmee Basin in the north to the Everglades in the south, with water supply and coastal discharges to the east and west. The current hydraulic and hydrologic system includes lakes, impoundments, wetlands, canals, and water control structures managed under water management schedules and operational rules.

The development of South Florida requires a complex water management system to manage floods, droughts, and hurricane impacts. Excess water is stored in lakes, detention ponds, wetlands, impoundments, and aquifers, or is discharged to the coast by estuaries. Information regarding the operation of the South Florida water management system is summarized in Abtew et al. (2011). As a major component of this system, Lake Okeechobee's storage capacity is over 3.75 million acre-feet (ac-ft) at a lake level of 14.5 ft NGVD—the largest of any hydrologic feature in South Florida. The lake is critical for flood control during wet seasons and water supply during dry seasons. Lake outflows are received by the Everglades Agricultural Area (EAA), St. Lucie River and Estuary, Caloosahatchee River and Estuary, and sometimes the Everglades Stormwater Treatment Areas (STAs). In extreme drought conditions, some water is sent south for water supply. Further details of these sub-regional flows are presented in the *Water Levels and Flows* section of this chapter.

Over an 18,000-square-mile area, the District manages the region's water resources for flood control, water supply, water quality, and natural systems' needs under water management schedules based on specific criteria. The major hydrologic components are the Upper Kissimmee Chain of Lakes, Lake Istokpoga, Lake Okeechobee, EAA, Caloosahatchee and St. Lucie River basins, Upper East Coast (UEC), Lower East Coast (LEC), Water Conservation Areas, Lower West Coast (LWC), and Everglades National Park (ENP or Park). The Kissimmee Chain of Lakes (Lake Myrtle, Alligator Lake, Lake Mary Jane, Lake Gentry, Lake East Tohopekaliga, Lake Tohopekaliga, and Lake Kissimmee) is a principal source of inflow to Lake Okeechobee. Various groundwater aquifers are part of the water resources, with most of their water levels responding relatively quickly to changes in rainfall and surface water conditions.

Generally, the region is wet with an average annual rainfall of 53 inches. For water management purposes, the District has divided the region into 14 rainfall areas plus the ENP (**Figure 2-2**). Rainfall for each area is reported daily, and multiple and overlapping gauges are used to compute average rainfall over each area. Real-time rainfall observations over the rainfall areas aid real-time water management decisions. Due to the relatively low gradient of regional topography, pumping is necessary to move water in the system. Across the region, the average pumping volume for Fiscal Years (October 1–September 30) 1996 through 2012 was 2.77 million ac-ft (**Table 2-2)**. In many cases, the same water is pumped in and pumped out, as is the case with most of the Everglades STAs. The number of pump stations has increased from 20 to 69 since 1996, with additional temporary pumps that vary in number from time to time.

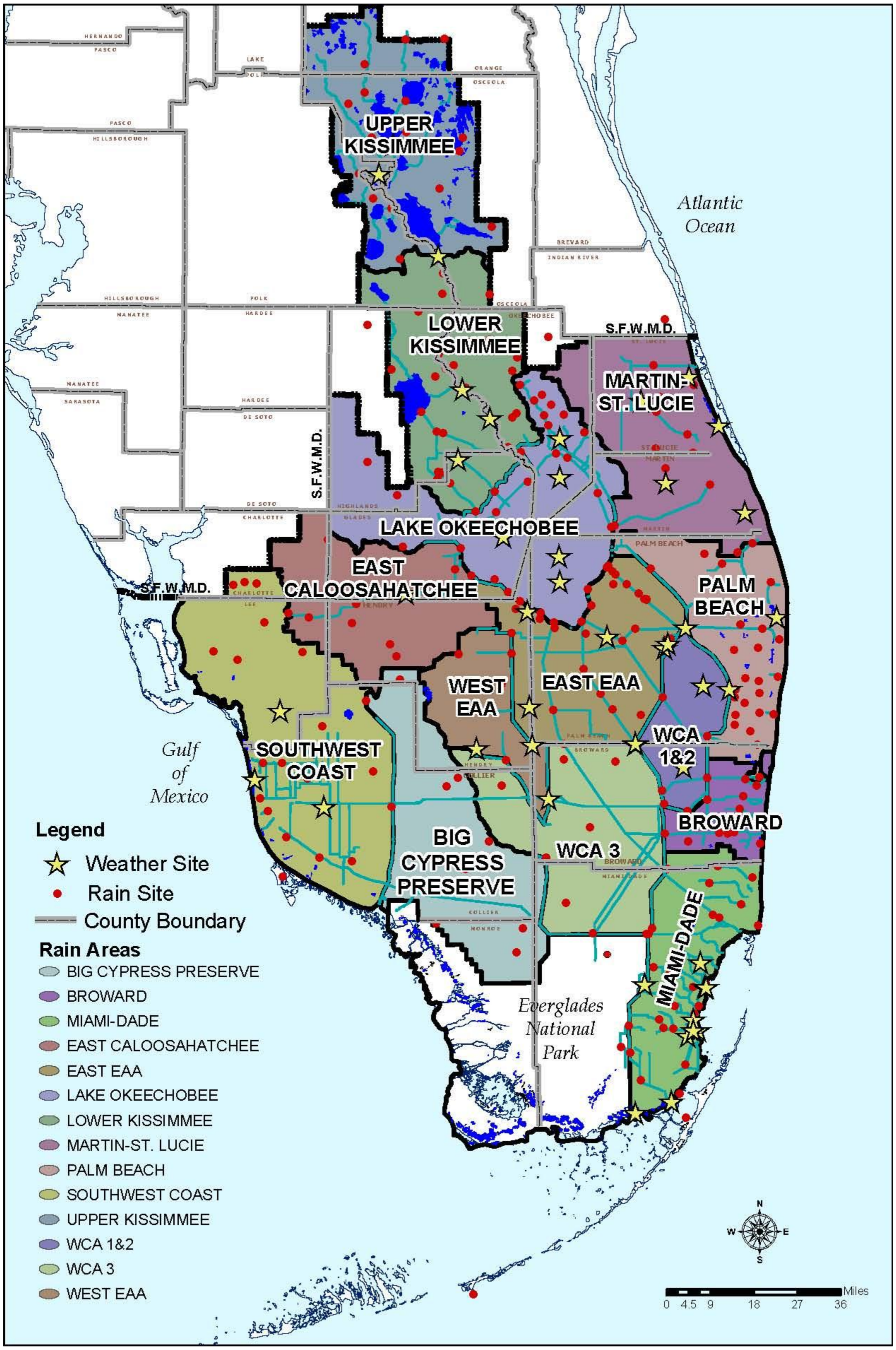


Figure 2-2. The South Florida Water Management District's (SFWMD or District) rainfall areas.

Table 2-2. District water pumping volumes for Fiscal Years 1996–2012 (October 1, 1995–September 30, 2012).

Fiscal 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	3,583,000
2007	1,281,000
2008	3,767,700
2009	3,660,000
2010	3,031,622
2011	1,584,057
2012	3,254,308
Average	2,767,746

STORAGE OF LAKES AND IMPOUNDMENTS

Storage is required for both flood control and water supply in the regional water management system. The amount of storage volume available varies significantly from year to year due to large variations in rainfall and runoff both temporally and spatially. The impact of variation in rainfall amount and timing is reduced by managing available storage. Regulation schedules provide guidance for water level/storage management of lakes and impoundments. The regulation schedule for each water body is covered in the following sections where WY2013 water levels are discussed. Temporary modifications from normal regulation schedules for WY2013 are also presented, if any. Regulation schedule deviations include environmental needs, such as snail kite needs and construction and maintenance activities.

The combined average storage of the major lakes and impoundments is over 5.2 million ac-ft; Lake Okeechobee provides about 68 percent of this storage volume. During wet conditions and high flow periods, storage between the actual stage and maximum regulatory stage is limited and water has to be released. The successful operation of the system depends on timely water management decisions and the constant movement of water. Excess water is mainly discharged to the Gulf of Mexico, St. Lucie Estuary, Atlantic Ocean, and Florida Bay. Stage-storage relationships of lakes and impoundments are critical information for managing water levels and storage and computing average hydraulic residence time. Appendix 2-2 in the *2007 South Florida Environmental Report* (SFER) – *Volume I* (Abtew et al., 2007a) presents the compiled charts for stage-storage for the major lakes and impoundments and stage-area relationships where data are available.

SELECTED HYDROLOGIC COMPONENTS

During WY2013, half of the District regions received above average rainfall and half below average. Conceptual descriptions of these areas are summarized in this section, while specific hydrology and structure flow information for each is presented in the *Water Management in Water Year 2013* section of this chapter.

Upper and Lower Kissimmee Basins

The Upper Kissimmee Basin comprises the Kissimmee Chain of Lakes with a drainage area of 1,596 sq mi (Guardo, 1992). Historically, the Kissimmee Chain of Lakes is hydraulically connected to the Kissimmee River; during the wet season, the lakes overflow into surrounding marshes and then into the river (Williams et al., 2007). Water from the Upper Kissimmee Basin is discharged into the Lower Kissimmee Basin as the outflow of Lake Kissimmee. Flows are through the restored segments of the Kissimmee River and C-38 Canal. Along the reaches of the river, there are four water control structures (S-65A, S-65C, S-65D, and S-65E) that regulate the river stage. Discharge from the S-65E structure flows into Lake Okeechobee as the main source of inflows to the lake. Overall, the Kissimmee Basin is an integrated system consisting of several lakes with interconnecting canals and flow control structures (see also Chapter 9 of this volume).

Lake Okeechobee

Lake Okeechobee is the largest lake in the southeastern United States. It is relatively shallow with an average depth of 8.9 ft and surface area of 436,200 acres at the average water surface elevation of 14.01 ft NGVD. Water levels are regulated through numerous water control structures operated according to a seasonally varying regulation schedule. The lake serves multiple functions for flood control, water supply, recreation, and environmental restoration efforts. Chapter 8 of this volume discusses the status of Lake Okeechobee.

Everglades Agricultural Area

The EAA is an agricultural irrigation and drainage basin where, generally, ground elevation is lower than the surrounding area. During excess rainfall, runoff has to be pumped out of the area; during dry times, irrigation water supply is needed. Irrigation water supply during dry seasons comes mainly from Lake Okeechobee, with the WCAs as secondary sources. On average, about 900,000 ac-ft of water is discharged from and through the EAA to the south and southeast, historically mostly discharging into the Everglades Protection Area (EPA) (Abtew and Khanal, 1994; Abtew and Obeysekera, 1996). Four primary canals (Hillsboro Canal, North New River Canal, Miami Canal, and West Palm Beach Canal) and three connecting canals (Bolles Canal, Cross Canal, and Ocean Canal) facilitate runoff removal and irrigation water supply. Currently, runoff/drainage from the EAA is discharged to the Everglades STAs for treatment and released to the EPA. Additional information on the EAA and STAs is presented in Chapters 4 and 5 of this volume, respectively.

Upper East Coast

The main canal in the UEC is the St. Lucie River (C-44 Canal). It runs from Lake Okeechobee to the St. Lucie Estuary. Inflows to the St. Lucie River are runoff from the basin and releases from Lake Okeechobee by operation of the S-308 structure according to regulation procedures described by the U.S. Army Corps of Engineers (USACE, 2008). Downstream of

S-308 is a gated spillway, S-80, that also receives inflows from the local watershed to the west and discharges to the estuary.

Lower East Coast

The LEC includes urban areas in Palm Beach, Broward, and Miami-Dade counties. The purposes of the major canals in the LEC are flood control, prevention of over-drainage in the area, prevention of saltwater intrusion into groundwater, and conveyance of runoff to the ENP when available. The system is also intended 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. The stages in canals are usually allowed to recede before supplemental water is introduced. Flow releases during major flood events are made according to established guidelines (USACE, 1995). Lake Okeechobee is connected to the LEC through the major canals. During dry periods, flows from the WCAs and Lake Okeechobee are released to raise canal and groundwater levels. During wet periods, the canal network is used to move runoff to the ocean as quickly as possible.

Lower West Coast

The main canal in the LWC is the Caloosahatchee River (C-43 Canal). It runs from Lake Okeechobee to the Caloosahatchee Estuary. Inflows to the Caloosahatchee River are runoff from the basin and releases from Lake Okeechobee by operation of the S-77 structure according to regulation procedures described by the U.S. Army Corps of Engineers (USACE, 2008). Downstream of S-77 is a gated spillway, S-78, that also receives inflows from the local watershed. The outflow from the Caloosahatchee River (downstream of S-78) is discharged into the estuary via S-79, a gated spillway and lock operated by the USACE. The operations of S-79 include managing stormwater runoff from the Caloosahatchee Watershed. The LWC includes large areas outside the drainage basin of the Caloosahatchee River.

WATER YEAR 2013 HURRICANE SEASON

HYDROLOGIC IMPACT OF TROPICAL STORMS DEBBY AND ISAAC AND HURRICANE SANDY ON SOUTH FLORIDA

Tropical Storm Debby

WY2013 hurricane season is documented in detail in Appendix 2-2 of this chapter. The first tropical system that contributed rainfall to the District area in WY2013 is Tropical Storm Debby (June 22-27, 2012). Tropical Storm Debby was formed in the eastern Gulf of Mexico and crossed to the Atlantic after drenching north Florida with as much as 24 inches of rainfall and creating flooding. It contributed a significant amount of rainfall to the District area to the south. The District received an average of 3 inches of rainfall associated with Tropical Storm Debby. The Upper Kissimmee rainfall area received 5.23 inches contributing to a wet June (12.18 inches). The runoff generated was limited as June followed a preceding drier months. Sites in Palm Beach and Upper Kissimmee received over 5 inches of rainfall in a 24-hour period. Rainfall received by each rain area from Tropical Storm Debby, daily rainfall, and maximum one-day rainfall are shown in Appendix 2-2.

Tropical Storm Isaac

South Florida was hit next by Tropical Storm Isaac from August 24 to August 28, 2012. Although the storm passed far to the west of South Florida, outer band chains of rainfall concentrated on the eastern coast resulting in record rainfall amounts especially in the C-51 and L-8 basins. Normally, as a storm moves away from a region, the impact decreases, but not in this case. The hydrologic impact of Tropical Storm Isaac on the District area was severe. The extreme rainfall from the storm resulted in wide-scale flooding and erosion of waterways. In Appendix 2-2, the spatial distribution and the magnitude of rainfall from the tropical storm is presented along with an estimate of frequency of occurrence. Water level rise at key water management system locations and surface water flows through major structures are also presented. The rainfall from the storm is compared to previous storms to show how extreme the event was.

In Palm Beach County, flooding occurred in many areas including Indian Trails Improvement District, City of Green Acres, the Village of Wellington, Royal Palm Beach, Boynton Beach and Jupiter farms. Areas such as Deer Run, the Acreage and Loxahatchee were flooded for several days. Many other neighboring streets in Palm Beach County were flooded limiting travelling from home to work. In St. Lucie County flooding in West St. Lucie and erosion of infrastructure were reported (TCPalm, August 28, 2012). In Broward County, there was concern from high rainfall events in the area of Lauderhill, Margate, Sunrise and Tamarac with flooding reported in Pembroke Pines and Lauderhill (The Miami Herald, August 28, 2012). In Okeechobee County, the city of Okeechobee had reports of flooding. In Miami-Dade County, high water conditions were reported in Homestead. In general, areas of primary concern for flooding were the C-51 basin, C-17, C-18, L-8 basin, areas north of Lake Okeechobee, C-13 and C-14.

Tropical Storm Isaac brought lots of rainfall at several locations in South Florida. The storm contributed an areal average rainfall of 5.74 inches over the District area. Rainfall areas with the most rainfall were Palm Beach (9.98 inches), Water Conservation Area 1 and 2 (9.41 inches), Martin/St. Lucie (8.42 inches), Broward (7.82 inches), East Everglades Agricultural Area (7.11 inches), Lake Okeechobee (6.58 inches), Lower Kissimmee (6.35 inches) and Miami-Dade (5.84 inches. From this monitoring network, the highest rainfall was at site C-18, 12.99 inches. But, sites from other monitoring network and radar rainfall observations have recorded higher amount of rainfall at various locations. Rainfall observations with 100-year return periods have been recorded at sites in C-51 basin for 3-day, 5-day and the month of August resulting in flooding. Typical flooding of neighborhoods where detention pond and local canals overflow into roads and yards leaving mostly the elevated houses dry is shown in Appendix 2-2. Also shown is flooding in the less developed areas of western Palm Beach County along the L-8. There were cases where houses were flooded although not widespread.

Comparison with Recent Storms

Comparing rainfall from Tropical Storm Isaac with recent storms that impacted the region provides perspective for the regional impact of the storm. Since 1998, thirteen storms (tropical storms and hurricanes) have affected the District area. The comparable storm to Tropical Storm Isaac is Hurricane Irene of 1999. Hurricane Irene (October 15 to 16, 1999) moved through Cuba, and the Florida Straits with landfall at Flamingo in the southwest. It moved across South Florida exiting to the east by Jupiter creating wide-scale flooding in Broward, Miami-Dade and Palm Beach counties. **Figure 2-3** depicts average rainfall over Palm Beach, Broward and Miami-Dade rainfall areas from tropical systems that impacted the region since 1998. Averaging rainfall over a rainfall area dampens extreme intensities at localities and sub-basins which are factors for flooding.

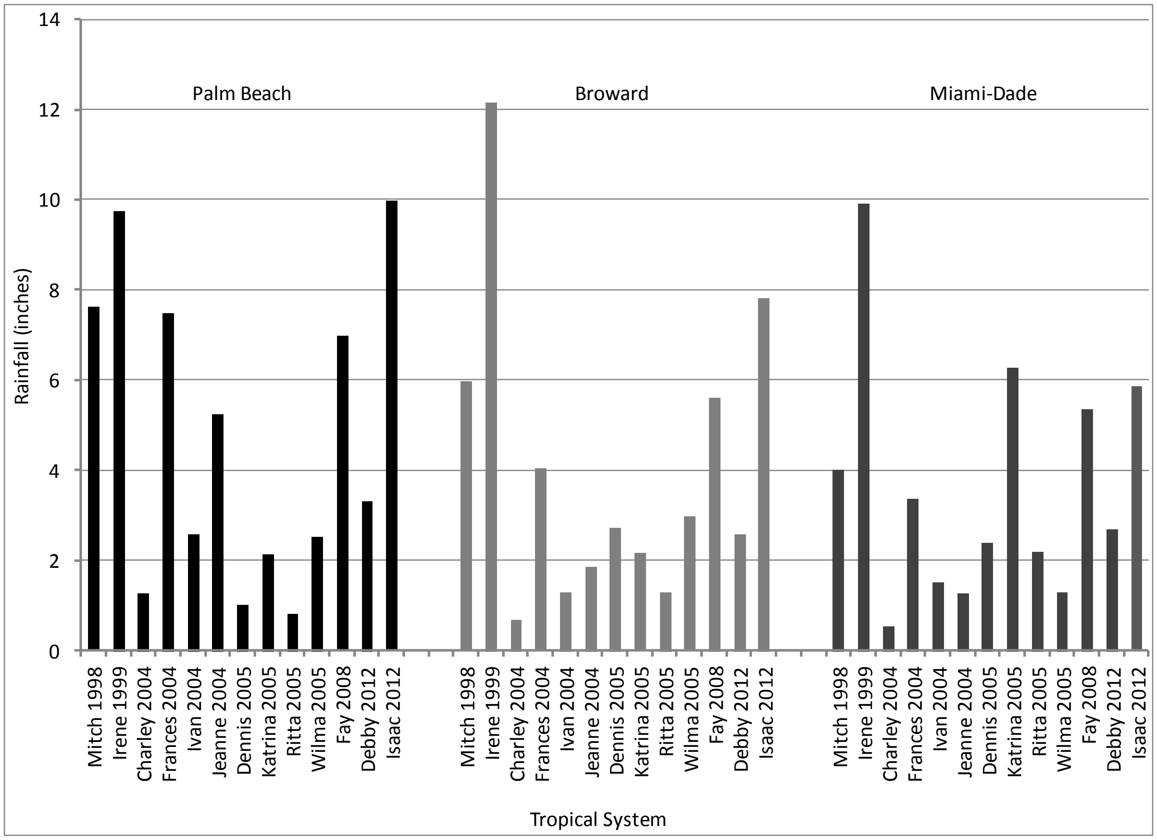


Figure 2-3. Average rainfall over Palm Beach, Broward and Miami-Dade rainfall areas from tropical systems since 1998.

Water Levels and Flows

High intensity rainfall from the storm resulted in a quick rise of water levels in canals, lakes and impoundments and surface water flow rates increased. Daily average water levels in L-8 Canal at the S-5A Complex (S-5AE_H) and at Lake Okeechobee, CULV10A_H (canal side) rose 4 to 5 ft. Daily average water levels rose in the West Palm Beach Canal at S-5A pump station (S-5AW_H), the West Palm Beach Canal at Big Mound, between Lake Okeechobee and S-5A pump station (WPBC), and the West Palm Beach Canal at Lake Okeechobee (S-352_T). Water level rose fast in the C-51 Canal.

Due to two consecutive years of below average rainfall, Lake Okeechobee water level was low at 11.68 ft NGVD on May 1, 2012. Net inflows into the lake were low at the beginning of the wet season, resulting in a water level rise of only 0.71 ft between May 1 and August 24, 2012. Saturation of the watershed, filling of surface and sub-surface storage, precedes substantial runoff generation that result in increased inflow into the lake. But as a result of high rainfall from Tropical Storm Isaac and other rainfall, the lake water level rose by 3 ft in one month (**Figure 2-6**).

Water Management during Tropical Storms

Water management during tropical storm events is very challenging for several reasons. The South Florida water management system has limited storage for excessive rainfall events. It is a constant challenge to hold enough water for water supply or draw down canals and water storage units to accommodate future runoff events. If an anticipated runoff event does not materialize, then the potential for water shortage increases due to discharging from storage and lowering canal levels. Water shortage results in water use restrictions, saltwater intrusion into utility wells, and shortage of water for environmental purposes. Operation during emergency events such as tropical systems faces uncertainties of the path of the storm, amount of rainfall over the District area, intensity and spatial distribution of rainfall, and water control infrastructure damages. Water control infrastructure damages include water control facilities damage, levee erosion, and canal blockage. Highest rainfall from Tropical Storm Isaac was concentrated on Palm Beach County, specifically the C-51 basin. The storm created excessive runoff that resulted in flooding and challenged the tertiary, secondary, and primary water management systems. A water conditions summary for Tropical Storm Isaac, with briefs of readiness, response and recovery, and an after action assessment, is available on the District's website at www.sfwmd.gov/isaac.

When storms approach, the District performs pre-storm operations. Based on weather forecasts, the District prepares the system to accept and convey rainfall runoff from anticipated storms. Additionally, facilities in the field are inspected, equipment and personnel are deployed, and regional canal levels are lowered to prepare room for anticipated runoff. The District coordinates its operations with local governments and the USACE. When storms are eminent, agency emergency operations are activated and key staff is put on lockdown to manage the impact of the storm. During the onslaught of the storm, the flood control system is operated with continuous monitoring. Coordination with local governments continues. Storm position and intensity changes are monitored and quantitative rainfall estimates are adjusted. Post-storm operations include estimating accumulated rainfall. Evaluate impact of storm to the regional system. Implement recovery operations and coordinate with local governments.

Hurricane Sandy

Hurricane Sandy started in the Caribbean and moved north passing east of the District from October 24 to 27, 2012. The impact to the District was limited to 0.83 inches of average rainfall from October 24 to 27, 2012. Some localities received significant amount of rainfall. Hurricane Sandy made landfall in New Jersey and New York on October 29, 2012, as an extra-tropical storm as a result of fusing with an arctic front that moved into the area in front of the hurricane. The storm caused loss of lives and severe property, infrastructure, coastal, and environmental damages. Other states along the eastern U.S. coast in its path were also dramatically affected by the storm.

THE EL NIÑO SOUTHERN OSCILLATION (ENSO): THE 2012 NEUTRAL ENSO EVENT

The 2011 La Niña condition continued in the beginning of 2012. By spring 2012, the tropical Pacific west of Peru started warming and the El Niño trend was observed by late summer. From September to the end of 2012, neutral conditions continued and 2012 ended as an ENSO neutral year. The beginning of 2013 (January through April) stayed negative and in neutral region. The hydrology during neutral years is not predictable. November 2012 for the District area was the driest since 1932. **Figure 2-4** depicts a cumulative sea surface temperature (SST) tracking index where positive values indicate the presence of El Niño and negative values indicate La Niña; values closer to zero indicate a neutral condition (Abtew et al., 2009). El Niño conditions create wind shear that weaken tropical systems and also influence the path of tropical storms to curve to the north and east away from land mass. La Niña conditions create favorable conditions for Atlantic tropical storms. ENSO influences South Florida dry season rainfall with likely to be wet during El Niño and dry during La Niña years (Abtew and Trimble, 2010). WY2013 dry season rainfall stayed well below average, as weak La Niña conditions developed in January and February 2013. A wet April reversed the drought condition.

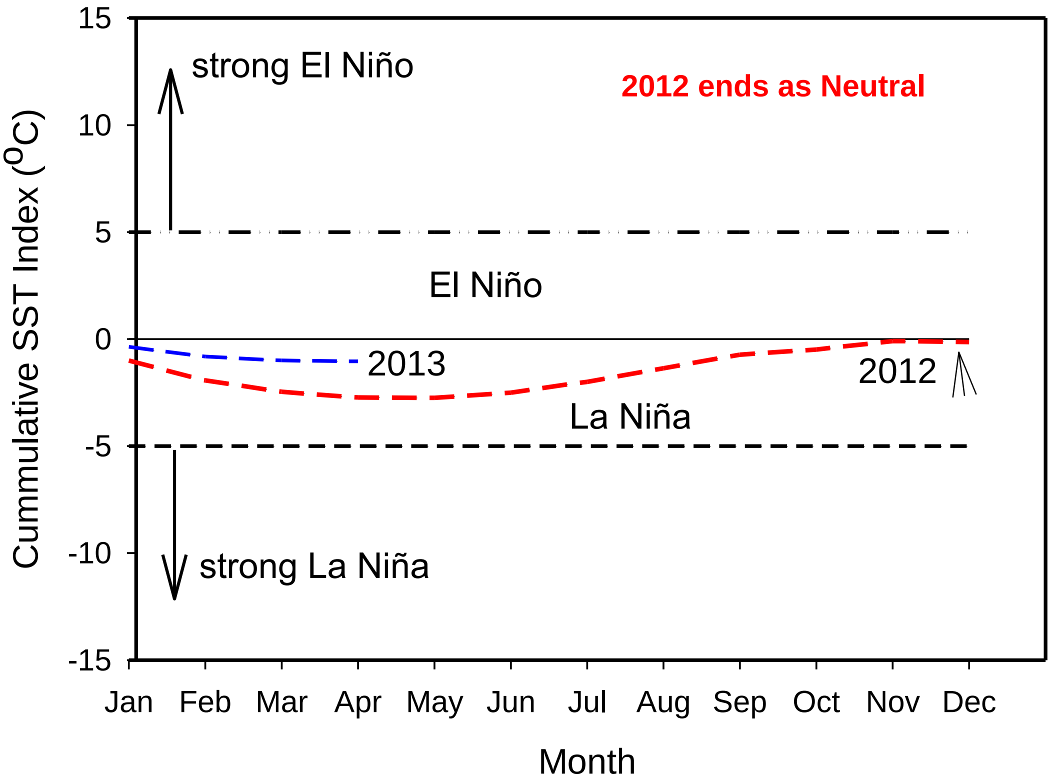


Figure 2-4. Calendar year 2012 and 2013 ENSO developments.

WATER YEAR 2013 HYDROLOGY

RAINFALL AND EVAPOTRANSPIRATION

Following the two below average rainfall years of WY2011 and WY2012, hydrologic conditions of South Florida improved with average rainfall in WY2013, 53.17 inches compared to annual average of 52.75 inches. The temporal and spatial distribution of the rainfall was uneven where there was flooding at one time and dry conditions at other time. Spatially, Miami-Dade and Water Conservation Areas 1 and 2 had close to 10 inches of rainfall over their respective averages while the Southwest and Upper Kissimmee had close to 3 inches of deficit. In WY2013, rainfall was below average in parts of the District for the Upper Kissimmee (-2.95 inches), East Everglades Agricultural Area (-1.85), West Agricultural Area (-1.61 inches), St. Lucie (-2.3 inches), East Caloosahatchee (-2.31 inches), and Southwest Coast (-3.3 inches). The areas that received above average rainfall were the Lower Kissimmee (+7.88 inches), Lake Okeechobee (+1.25 inches), Water Conservation Area 1 and 2 (+10.84 inches), Water Conservation Area 3 (+4.78 inches), Palm Beach (+1.06 inches), Broward (+3.1 inches), and Miami-Dade (+9.25 inches). The Everglades National Park also received above average rainfall (+3.27 inches).

Table 2-3 depicts monthly rainfall for each rainfall area for WY2013. **Table 2-4** presents dry and wet return periods of monthly rainfall in each rainfall area during WY2013. As shown in **Table 2-4**, most months were dry months with different return periods. Tropical Storm Isaac in August 2012 created extreme wet and flooding conditions in Palm Beach County. August rainfall in Lower Kissimmee, Lake Okeechobee, Water Conservation Areas 1 and 2, and Palm Beach had a 100-year wet return period. Generally, November 2012 was very dry, and January and March 2013 were dry months. The dry season was drier than normal, and the dry season would have been a drought if not for a wet April 2013 and May 2013.

Regionally, the balance between rainfall and evapotranspiration maintains the hydrologic system in either a wet or dry condition. ETp is potential evapotranspiration or actual evaporation for lakes, wetlands, and any feature that is wet year-round. In South Florida, most of the variation in evapotranspiration is explained by solar radiation (Abtew, 1996; Abtew and Melesse, 2013). Regional estimates of average ETp 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 Southern Everglades (Abtew et al., 2003; Abtew, 2005). Available ETp data from the closest site to a rainfall area was used to estimate ETp for the area. In WY2013, ETp was slightly lower than rainfall, 0.42 inches, reflecting wetter conditions during this period (**Table 2-6**). The difference was much higher in WY2012 (5.46 inches) and WY2011 (15.28 inches). **Table 2-5** shows ETp for each rainfall area, ENP, and District average. **Table 2-6** summarizes WY2012, WY2013, and historical average annual rainfall; WY2013 ETp; and WY2013 rainfall anomalies. Appendix 2-1 of this volume compares WY2012 and WY2013 monthly rainfall, historical average rainfall, and WY2013 ETp for each rainfall area.

Table 2-3. WY2013 monthly rainfall (inches) for each rainfall area. [Note: Data from each rainfall area is from the District's operations rainfall database, which accumulates daily rainfall data from 7:00 a.m. of the previous day through 6:59 a.m. of the data registration day, both in Eastern Standard Time; ENP rainfall is the average of eight stations: S-332, BCA20, S-18C, HOMESTEADARB, JBTS, S-331W, S-334, and S-12D.]

Year	Month	Upper Kissimmee	Lower Kissimmee	Lake Okeechobee	East Everglades Agricultural Area	West Everglades Agricultural Area	Water Conservation Areas 1,2	Water Conservation Area 3	Martin/St Lucie	Palm Beach	Broward	Miami-Dade	East Caloosahatchee	Big Cypress Preserve	Southwest Coast	Everglades National Park	District
2012	May	3.68	3.27	4.76	6.43	9.02	11.14	9.49	5.26	8.48	10.36	11.50	5.07	6.22	3.87	8.71	6.17
2012	June	12.18	9.59	7.10	5.95	4.36	6.08	6.64	5.44	7.49	6.27	8.72	7.02	6.67	6.72	8.95	7.46
2012	July	3.81	6.13	4.78	5.71	5.85	5.96	6.56	5.13	5.45	6.65	8.97	6.36	6.51	7.02	8.65	5.96
2012	Aug	9.90	12.28	12.00	11.52	8.96	16.49	10.07	13.12	16.30	12.45	12.01	10.44	9.15	10.40	10.38	11.48
2012	Sept	6.13	6.77	6.05	5.61	6.55	6.77	6.54	5.48	6.68	8.33	8.75	7.01	6.66	7.22	6.47	6.61
2012	Oct	3.59	4.44	3.86	4.92	5.21	5.98	6.66	6.30	6.47	6.47	6.52	2.39	7.85	5.84	6.38	5.32
2012	Nov	0.15	0.08	0.16	0.20	0.10	0.52	0.07	1.09	0.69	0.88	0.75	0.05	0.11	0.15	0.62	0.29
2012	Dec	2.02	3.60	1.71	2.10	2.60	0.44	1.23	2.20	1.64	0.81	0.59	1.48	2.03	2.28	0.88	1.93
2013	Jan	0.43	0.49	0.75	0.38	1.07	0.43	0.28	1.53	1.07	0.96	0.42	0.38	0.23	0.30	0.55	0.59
2013	Feb	1.03	1.12	1.84	2.40	2.47	2.43	1.81	2.03	2.71	1.65	1.82	2.00	1.80	2.22	1.07	1.91
2013	Mar	1.06	0.86	1.05	2.05	2.34	1.03	0.73	0.88	1.17	0.19	0.93	1.51	0.79	0.90	1.08	1.10
2013	Apr	3.16	3.70	3.16	4.36	4.81	5.53	6.07	3.38	4.45	6.21	5.38	4.66	6.01	3.90	4.75	4.35
Sum	**(inches)**	**47.14**	**52.33**	**47.22**	**51.63**	**53.34**	**62.80**	**56.15**	**51.84**	**62.60**	**61.23**	**66.36**	**48.37**	**54.03**	**50.82**	**58.49**	**53.17**

Table 2-4. WY2013 monthly rainfall dry and wet return periods for each rainfall area (derived from Ali and Abtew, 1999).

Month	Upper Kissimmee	Lower Kissimmee	Lake Okeechobee	East EAA	West EAA	WCA 1,2	WCA 3	Martin/St.Lucie	Palm Beach	Broward	Miami-Dade	East Caloosahatchee	Big Cypress Preserve	Sothwest Coast
May-12	<average	<average	>average	5-yr wet	<20-yr wet	<20-yr wet	≈10-yr wet	>average	<10-yr wet	≈10-yr wet	10-yr wet	>average	≈5-yr wet	<average
Jun-12	>10-yr wet	5-yr wet	≈average	≈5-yr dry	≈10-yr dry	<5-yr dry	<5-yr dry	<5-yr dry	<average	<5-yr dry	≈average	<5-yr dry	≈5-yr dry	≈5-yr dry
Jul-12	≈20-yr dry	≈average	≈5-yr dry	≈average	≈average	≈average	≈average	<5-yr dry	<5-yr dry	≈average	>5-yr wet	<5-yr dry	<5-yr dry	<5-yr dry
Aug-12	≈10-yr wet	100-yr wet	≈100-yr wet	<20-yr wet	<5-yr wet	>100-yr wet	10-yr wet	50-yr wet	100-yr wet	>10-yr wet	>10-yr wet	10-yr wet	<5-yr wet	5-yr wet
Sep-12	≈average	≈5-yr wet	<average	<5-yr dry	<5-yr dry	≈average	≈average	<5-yr dry	<5-yr dry	<5-yr dry	≈average	average	<5-yr dry	<average
Oct-12	≈average	≈5-yr wet	average	>average	≈5-yr wet	>average	<5-yr wet	≈average	<5-yr wet	<5-yr wet	<average	<5-yr dry	≈10-yr wet	<5-yr wet
Nov-12	< 20-yr dry	50-yr dry	10-yr dry	< 20-yr dry	< 20-yr dry	10-yr dry	100-yr dry	5-yr dry	< 20-yr dry	<10-yr dry	<10-yr dry	50-yr dry	< 20-yr dry	< 20-yr dry
Dec-12	average	20-yr wet	≈average	>average	<5-yr wet	5-yr dry	<5-yr dry	≈average	<5-yr dry	<5-yr dry	<5-yr dry	>average	<5-yr wet	5-yr wet
Jan-13	10-yr dry	>5-yr dry	<5-yr dry	<10-yr dry	<5-yr dry	<10-yr dry	< 20-yr dry	<5-yr dry	5-yr dry	<5-yr dry	<10-yr dry	>5-yr dry	<10-yr dry	<10-yr dry
Feb-13	<5-yr dry	≈5-yr dry	<average	>average	≈average	>average	<5-yr dry	<5-yr dry	average	<5-yr dry	<average	average	<5-yr dry	≈average
Mar-13	<average	>5-yr dry	5-yr dry	<5-yr dry	<5-yr dry	<5-yr dry	<10-yr dry	<10-yr dry	5-yr dry	< 20-yr dry	<5-yr dry	<5-yr dry	<5-yr dry	<5-yr dry
Apr-13	<5-yr wet	>5-yr wet	<5-yr wet	≈5-yr wet	>5-yr wet	>10-yr wet	>10-yr wet	>average	<5-yr wet	<10-yr wet	<10-yr wet	<10-yr wet	<20-yr wet	>5-yr wet
dry months	7	4	6	5	5	5	5	7	7	7	6	5	7	7
extreme dry		1					1					1		
wet months	3	4	2	6	5	4	4	2	3	4	4	4	5	4
extreme wet		2	1			1		1	1					
≈ average	2	1	3	1	2	2	2	2	1	1	2	2		1

extreme dry>= 20 yr dry
dry = < average
wet = > average
extreme wet >= 20-yr

Table 2-5. WY2013 monthly potential evapotranspiration (ETp, in inches) for each rainfall area.

Year	Month	Upper Kissimmee	Lower Kissimmee	Lake Okeechobee	East Everglades Agricultural Area	West Everglades Agricultural Area	Water Conservation Areas 1,2	Water Conservation Area 3	Martin/St Lucie	Palm Beach	Broward	Miami-Dade	East Caloosahatchee	Big Cypress Preserve	Southwest Coast	Everglades National Park	District
2012	May	5.60	5.52	5.94	5.48	5.49	5.06	5.49	5.73	5.48	5.49	5.41	5.86	5.63	5.66	5.41	5.55
2012	June	4.75	4.71	4.84	4.78	5.02	4.86	5.02	4.94	4.78	5.02	4.99	4.82	4.95	4.55	4.99	4.87
2012	July	5.58	5.42	5.92	5.50	5.57	5.44	5.57	5.83	5.50	5.57	5.11	5.45	5.42	4.64	5.11	5.44
2012	Aug	4.74	4.71	4.92	4.57	4.66	4.46	4.66	4.61	4.57	4.66	4.86	4.95	4.71	4.82	4.86	4.72
2012	Sept	4.15	4.16	4.51	4.26	4.57	4.08	4.57	4.45	4.26	4.57	4.22	4.42	4.40	4.00	4.22	4.32
2012	Oct	3.98	3.78	4.33	4.06	4.11	4.12	4.11	4.07	4.06	4.11	4.25	4.28	3.96	3.78	4.25	4.08
2012	Nov	3.30	3.27	3.59	3.12	3.51	3.57	3.51	3.47	3.12	3.51	3.66	3.73	3.49	3.77	3.66	3.49
2012	Dec	2.74	2.94	3.06	3.04	3.05	3.16	3.05	3.07	3.04	3.05	3.35	3.17	2.87	3.17	3.35	3.07
2013	Jan	2.97	3.07	3.14	3.07	3.23	3.26	3.23	3.25	3.07	3.23	3.48	3.39	3.00	3.51	3.48	3.22
2013	Feb	3.43	3.56	3.65	3.41	3.60	3.56	3.60	3.74	3.41	3.60	3.85	3.86	3.61	3.94	3.85	3.65
2013	Mar	5.14	5.00	5.14	5.09	5.38	5.19	5.38	5.10	5.09	5.38	5.09	5.28	5.09	5.08	5.09	5.17
2013	Apr	4.82	4.77	5.38	4.99	5.46	5.12	5.46	5.24	4.99	5.46	5.19	5.30	5.10	5.03	5.19	5.17
Sum	**(inches)**	**51.20**	**50.93**	**54.42**	**51.37**	**53.65**	**51.89**	**53.65**	**53.50**	**51.37**	**53.65**	**53.47**	**54.50**	**52.24**	**51.96**	**53.47**	**52.75**

Table 2-6. WY2013, WY2012, and historical average annual rainfall, WY2013 ETp, and WY2013 rainfall anomalies (inches) for each rainfall area.

Rainfall Area	WY2013Rainfall	WY2012 Rainfall	Historical Average Rainfall (Ali and Abtew, 1999)	WY2013 ETp	WY2013 Rainfall Anomaly
Upper Kissimmee	47.14	46.7	50.09	51.2	-2.95
Lower Kissimmee	52.33	44.29	44.45	50.93	7.88
Lake Okeechobee	47.22	36.55	45.97	54.42	1.25
East Everglades Agricultural Area	51.63	45.24	53.48	51.37	-1.85
West Everglades Agricultural Area	53.34	47.13	54.95	53.65	-1.61
Water Conservation Area 1, 2	62.8	53.87	51.96	51.89	10.84
Water Conservation Area 3	56.15	55.09	51.37	53.65	4.78
Martin/St. Lucie	51.84	48.94	54.14	53.5	-2.3
Palm Beach	62.6	51.76	61.54	51.37	1.06
Broward	61.23	60.92	58.13	53.65	3.1
Miami-Dade	66.36	61.44	57.11	53.47	9.25
East Caloosahatchee	48.37	47.39	50.68	54.5	-2.31
Big Cypress Basin	54.03	53.02	54.12	52.24	-0.09
Southwest Coast	50.82	52.46	54.12	51.96	-3.3
Everglades National Park[1]	58.49	53.82	55.22	53.47	3.27
SFWMD Spatial Average	**53.17**	**49.1**	**52.75**	**52.75**	0.42

[1]ENP historical average rainfall estimates from Sculley (1986).

WILDFIRES

One of drought's impacts on the South Florida environment is the development of conditions that promote and spread wildfires. The sizes and number of wildfires are generally correlated to dry conditions. Generally, drought years have above average total number of acres burned and number of acres burned per fire. For instance, the area burned by wildfire in 1989, 1990, 2001, and 2007 drought years was high. **Figure 2-5** depicts the number of acres burned per water year in the SFWMD area from wildfires that were 10 acres or larger for WY1982 to WY2013. Mostly, major droughts correspond to larger areas burned by wildfire. The number of acres burned in WY2013 was 31,412 acres. The average area burned in a year is 109,571 acres.

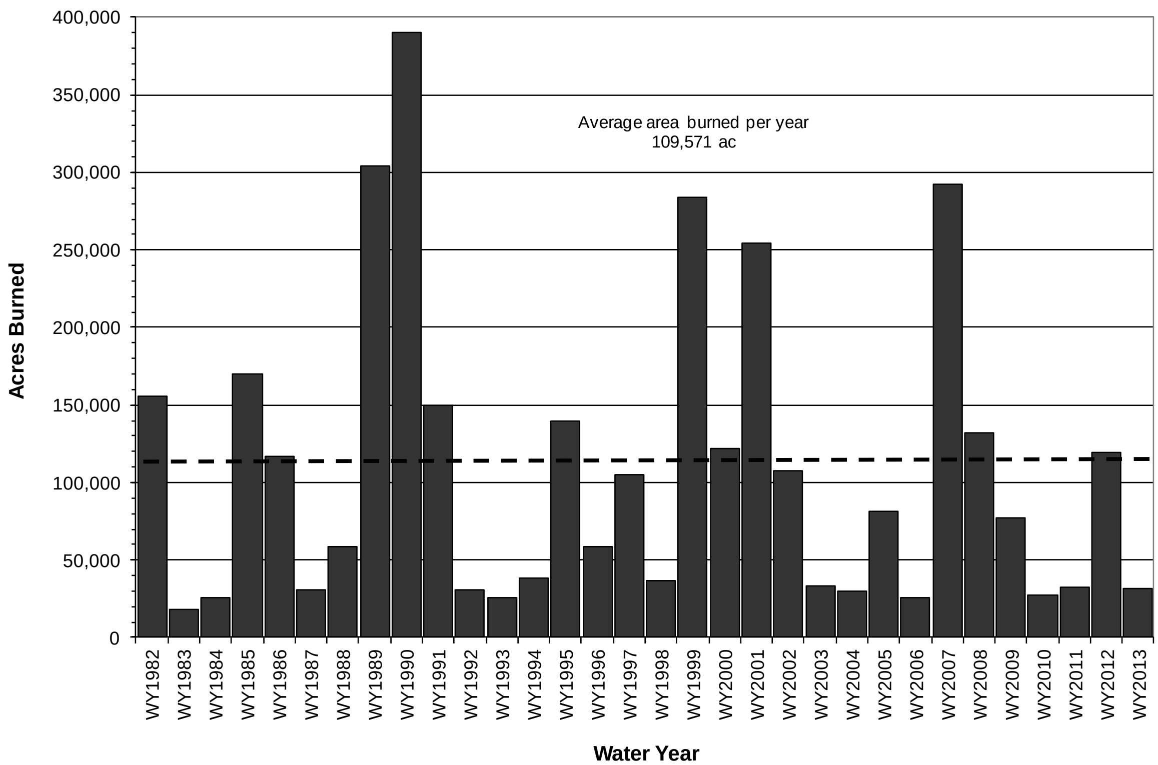


Figure 2-5. Number of acres burned per water year in the SFWMD area from wildfires that were 10 acres or larger (WY1982–WY2013).

GROUNDWATER

The District is divided into four major water resource planning regions (see Appendix 2-3, Figure 1). Each has aquifers that provide water for agricultural, commercial, industrial, and domestic use. The LEC principal groundwater source is the surficial Biscayne aquifer. The UEC principal source of groundwater is the surficial aquifer. The LWC relies on three aquifer systems for water supply, the surficial aquifer system (SAS), the intermediate aquifer system (IAS), and the Floridan aquifer system (FAS). The Lower Tamiami aquifer is part of the SAS; the sandstone and the mid-Hawthorne aquifers are part of the IAS (SFWMD, 2006). The Kissimmee Basin is served by a surficial or shallow aquifer and a deep aquifer, the FAS.

In general, WY2013 groundwater levels were higher than WY2012 in some regions or similar in others reflecting the wetter rainfall conditions. Representative groundwater level fluctuation observations from the U.S. Geological Survey are shown in Appendix 2-3 for the stations shown in Figure 1 of that appendix.

WATER MANAGEMENT IN WATER YEAR 2013

OVERVIEW

District-wide water management operations depend largely on the spatial and temporal distribution of rainfall across the South Florida region. Although water management of SFWMD facilities is performed according to prescribed operation plans, there are various constraints that are considered while developing and implementing shorter-term operating strategies. Flood control operation was conducted in the wet season with tropical storm events. Inflow and outflow operations were regularly conducted to bring water levels of the major water bodies closer to the respective regulation schedules. The water management system was operated in water supply mode for several months when rainfall was below average. November 2012 was an extreme drought month with less than 0.3 inches rainfall over the District. January and March 2013 were also dry months.

Water management is performed by using previously established regulation schedules that integrate different purposes. Regulation schedules are rule curves designed to manage the regional storage. In order to broadly satisfy flood control and water supply needs on a long-term basis, daily water level regulation schedules for each of the regional water bodies were developed by USACE and the District in cooperation with other agencies and stakeholders. The regulation schedules for the regional lakes and WCAs are published in detail in the 2007 SFER – Volume I, Appendix 2-6 (Abtew et al., 2007b). At times, deviations from the regular regulation schedules are made for a specific lake or WCA to manage water under particular infrastructural, environmental, or weather-related conditions. For WY2013, temporary operational modifications were established for some of the Kissimmee Chain of Lakes in the Upper Basin to protect and enhance snail kite breeding habitat.

Initiated in May 2008, the current regulation schedule for Lake Okeechobee, known as LORS2008 (USACE, 2008), incorporates current and future (outlook) climatic information in the decision making process. The regulation schedule has three main bands (**Figures 2-6** and **2-11**): High Lake Management Band, Operational Band, and Water Shortage Management Band. The Operational Band is further divided into high, intermediate, low, base flow, and beneficial use categories. In the High Lake Management Band, large flood control releases may be required and outlet canals may be maintained above their optimum water management elevations. In the Operational Band, substantial flood control releases may be implemented; outlet canals should be maintained within their optimum water management elevations. In the Water Shortage Management Band, outlet canals may be maintained below optimum water management elevations and water supply releases from the lake are restricted according to the severity of prolonged dry climate conditions. More information on LORS2008 is also presented in the *Lake Okeechobee* section of this chapter.

Water supply releases are made for various beneficial uses that include water supply for municipal and industrial use, irrigation for agriculture, deliveries to the ENP, salinity control, estuarine management and other environmental releases. 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 River, EAA, the Lower East Cast, and in some cases, the WCAs and STAs. **Figure 2-6** depicts Lake Okeechobee daily water level, regulation schedule and water management decisions. Based on the lake water level and other relevant factors, various water management decisions are depicted on the figure. Release from the lake through S-308 into the St. Lucie Canal which discharges into the St. Lucie Estuary through S-80; releases from the lake through S-77 and into the Caloosahatchee River, which discharges into the Caloosahatchee Estuary through S-79; and regulatory releases to WCAs are also shown on the figure. Further details of these sub-region flows are provided in the *Water Levels and Flows* section of this chapter.

During WY2013, water managers, scientists, and engineers from the District, USACE, and other federal and state agencies met weekly to discuss the state of the regional system and possible operational scenarios. Reports on the ecological and hydrological status of various areas (e.g., Kissimmee Basin, Lake Okeechobee, St. Lucie and Caloosahatchee estuaries, STAs, Everglades, water supply and groundwater conditions) were presented. How well the objectives of the Central and South Florida Flood Control Project (water supply, flood control, and protection of fish and wildlife) were met was also discussed. Meeting starts with previous week weather report and coming week rainfall predictions. The previous week's Lake Okeechobee operations were reported in each meeting. Operational recommendations were given to District managers for approval and then submitted to the USACE in a Weekly Environmental Conditions for Systems Operations memoranda.

The most significant hydrologic event in WY2013 was Tropical Storm Isaac, which created flooding in late August 2012 and initiated several days of flood control emergency operations. Lake Okeechobee was at 12.39 ft NGVD on August 24, 2012, at the start of the storm. The lake level rose to 15.0 ft NGVD by September 15, 2012, from runoff generated by the storm and rainfall from the following days. District performed pre-storm preparations that included canal drawdown, communication with 298 Districts, local governments and USACE. Pre-positioning District equipment and helicopters and manning pump stations on a 24-hour basis was part of the preparation. Constant meteorological and storm monitoring and forecasting to develop pre- and post-storm operational plans were part of the storm management operation.

Storm-related operations included east and west discharge of Western C-51 Canal, discharge into the L-8 Reservoir, discharge into Lake Okeechobee, discharge to the WCAs, discharge into the Everglades STAs, and discharge to tide. Emergency pumps were installed in western Palm Beach to relieve flooding. Under such emergency conditions, the District took various efforts to assist local flooded communities. For example, to relieve flooding in the community of Deer Run (**Figure 2-7**, panel a), the District installed two emergency pumps (12 and 24 inches) to supplement community flood pumping. High stages in the L-8 Canal hampered the Indian Trail Improvement District (ITID) flood discharge. District installed two pumps (24 and 30 inches) to provide additional conveyance (**Figure 2-7**, panel b). To remove excess water from the western side of the J. W. Corbett Wildlife Management Area (WMA), two 42-inche pumps, 200 cfs capacity, were installed and removed 302,400,000 gallons of water in three days. High stages in the J.W. Corbett WMA posed a potential risk of failure of an old local berm separating it from the Indian Trails Improvement District residential area. The District installed two 42-inch pumps and operated for over a week on a 24-hour basis to relieve the pressure. To increase the C-18 canal capacity to accept gravity discharge from Corbett area, three 24-inch and one 30-inch pumps were installed and moved 226,800,000 gallons of water in three days. J. W. Corbett WMA levee emergency repairs were made (**Figure 2-7**, panel c) and a 142-foot steel sheet pile weir was built to drain excess water from the Corbett area (**Figure 2-7**, panel d). Supplemental pumping was performed across the weir to increase the rate of flood removal.

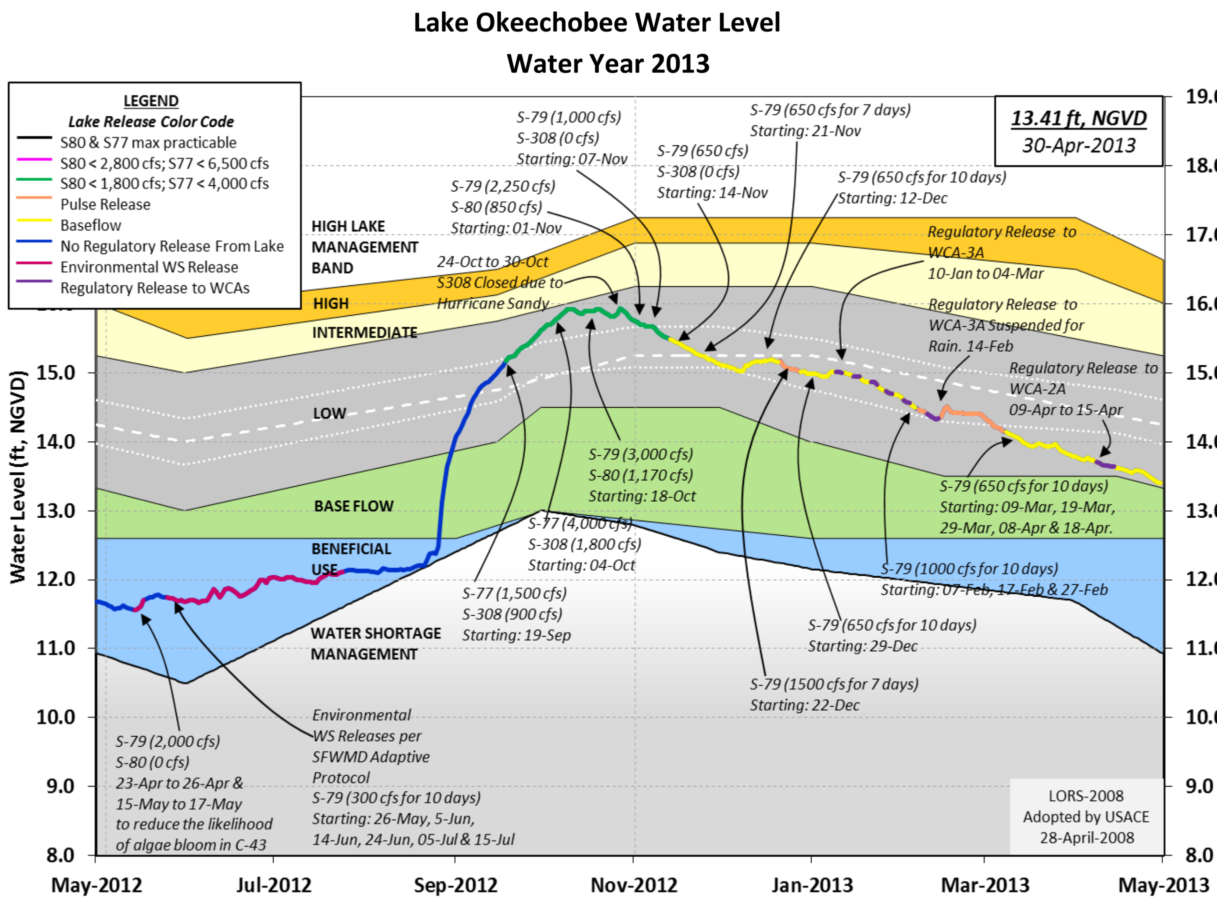


Figure 2-6. Daily Lake Okeechobee water levels, regulation schedule, and water management decisions.

Figure 2-7. District emergency flood control support for flooded communities in Palm Beach County following Tropical Storm Isaac: (a) flooding in the community of Deer Run, (b) flood pumping into the L-8 Canal from ITID, (c) Corbett Wildlife Management Area emergency levee repair, and (d) 142 ft steel sheet pile weir to drain the Corbett area (photos by the SFWMD, August–September 2012).

WATER LEVELS AND FLOWS

For parts of the WY2013 wet and dry seasons, most water control structures were operated under water supply mode due to rainfall deficit conditions but significant flood control operations dominated especially during the wet season high rainfall events. Period of record (POR) daily mean water levels (stage) graphs for lakes, impoundments, and the ENP are shown in Appendix 2-4. All water levels are expressed in ft NGVD in these and related publications. **Table 2-7** depicts WY2013, WY2012, and historical mean, maximum and minimum stages. WY2013 water levels were generally higher than historical average except Lake Okeechobee, WCA-2A, and East Lake Tohopekaliga. WY2013 water levels were higher than WY2012 levels except for Lake Mary Jane, East Lake Tohopekaliga, Lake Tohopekaliga and Lake Kissimmee levels. The average Lake Okeechobee water level was 1.98 ft higher than WY2012 and close to the historical average. Water levels in the WCAs and ENP were higher than historical average and WY2012. Comparison of monthly historical averages, WY2012, and WY2013 water levels are shown in Appendix 2-5. Water levels are also a measure of the amount of stored water. Relationships of water levels (stage) and storage for lakes and impoundments are presented in the 2007 SFER – Volume I, Appendix 2-2.

WY2013 surface water flow statistics were also compared to WY2012 and historical flow records (**Table 2-8**). WY2013 tropical storms contribution to flows was considerable. WY2013 flows were higher than WY2012 flows except for Lake Kissimmee outflows and S-49 discharge. Half of the water bodies flows were higher than the mean historical average flow. **Table 2-8** depicts WY2013, WY2012, and historical flow statistics for major impoundments. Monthly flows by structure are shown in Appendix 2-6. Comparison of historical, WY2012, and WY2013 monthly flows is shown in Appendix 2-7. Maps showing water control structures, canals, water bodies, and hydrologic units are available in previous SFERs.

Table 2-7. WY2013, WY2012, and historical stage statistics for regional major lakes and impoundments.

Lake or Impoundment	Beginning of Record	Historical Mean Stage (ft NGVD)	WY2013 Mean Stage (ft NGVD)	WY2012 Mean Stage (ft NGVD)	Historical Maximum Stage (ft NGVD)	Historical Minimum Stage (ft NGVD)
Alligator Lake	1993	62.56	63.04	62.90	64.33	58.13
Lake Myrtle	1993	60.85	61.05	60.88	65.22	58.45
Lake Mary Jane	1993	60.08	60.26	60.31	62.16	57.19
Lake Gentry	1993	60.68	60.94	60.73	61.97	58.31
East Lake Tohopekaliga	1993	56.63	56.46	56.83	59.12	54.41
Lake Tohopekaliga	1993	53.72	53.75	53.82	56.63	48.37
Lake Kissimmee	1929	50.38	50.44	50.63	56.64	42.87
Lake Istokpoga	1993	38.76	38.89	38.82	39.78	35.84
Lake Okeechobee	1931	14.01	13.85	11.87	18.77	8.82
Water Conservation Area 1	1953	15.65	16.49	15.69	18.16	10.00
Water Conservation Area 2A	1961	12.51	12.45	12.23	15.64	9.33
Water Conservation Area 3A	1962	9.57	10.24	9.56	12.79	4.78
Everglades National Park, Slough	1952	6.00	6.52	5.89	8.08	2.01
Everglades National Park, Wet Prairie	1953	2.15	2.99	2.55	7.1	-2.69

Table 2-8. WY2013, WY2012, and historical flow statistics for major impoundments, lakes, and canals.

Lake, Impoundment, Canal	Beginning of Record	Historical Mean Flow (ac-ft)	WY2013 Flow (ac-ft)	Percent of Historical Mean	WY2012 Flow (ac-ft)	Historical Maximum Flow (ac-ft)	Historical Minimum Flow (ac-ft)
Lake Kissimmee Outflow	1972	704,329	439,653	62%	813,987	2,175,297	16,195
Lake Istokpoga Outflow	1972	214,868	280,544	131%	228,042	637,881	26,559
Lake Okeechobee Inflow	1972	2,073,208	2,100,036	101%	1,821,336	4,905,838	377,671
Lake Okeechobee Outflow	1972	1,422,072	1,041,902	73%	746,499	3,978,904	176,566
St. Lucie (C-44 Canal) Inflow at S-308	1972	252,139	103,622	41%	47,201	1,117,159	4,061
St. Lucie (C-44 Canal) Outflow at S-80	1972	298,688	152,722	51%	119	1,192,782	0
Caloosahatchee River (C-43 Canal) Inflow at S-77	1972	511,963	501,374	98%	180,461	2,175,765	42,301
Caloosahatchee River (C-43 Canal) Outflow at S-79	1972	1,202,746	1,137,904	95%	598,840	3,615,526	86,895
Water Conservation Area 1 Inflow	1972	477,534	363,897	76%	170,256	1,307,517	152,641
Water Conservation Area 1 Outflow	1972	441,383	483,713	109%	14,812	1,433,399	14,812
Water Conservation Area 2 Inflow	1972	631,274	1,074,320	170%	386,176	1,754,710	113,225
Water Conservation Area 2 Outflow	1972	637,225	938,199	147%	378,071	1,729,168	93,564
Water Conservation Area 3A Inflow	1972	1,172,890	1,322,042	113%	899,567	2,177,198	393,233
Water Conservation Area 3A Outflow	1972	1,004,772	1,225,088	122%	571,304	2,581,129	245,951
Everglades National Park Inflow	1972	977,031	1,496,719	153%	744,176	2,838,481	165,372
Upper East Coast C-23 Canal Outflow at S-48	1995	117,929	85,778	73%	60,601	297,214	33,644
Upper East Coast C-24 Canal Outflow at S-49	1972	134,402	125,826	94%	140,927	274,827	10,591

Kissimmee Chain of Lakes

The Upper Kissimmee Basin is an integrated system of several lakes with interconnecting canals and flow control structures (Abtew et al., 2011). The major lakes are shallow with depths from 6 to 13 ft (Guardo, 1992). The Upper Kissimmee Basin structures are operated according to regulation schedules. The details of the water control plan for the Kissimmee River are presented in the Master Water Control Manual for Kissimmee River – Lake Istokpoga (USACE, 1994). Average stage for WY2013, WY2012 and historical observation statistics for the Kissimmee Chain of Lakes are shown in **Table 2-7**. Monthly historical average, WY2012, and WY2013 water levels for the lakes are shown in Appendix 2-5. In WY2013, the Upper Kissimmee Basin produced below average flow volume (439,653 ac-ft), which was 62 percent of the historical average.

Alligator Lake

The outflows from lakes Alligator, Center, Coon, Trout, Lizzie, and Brick are controlled by two structures: S-58 and S-60. S-58 is located in the C-32 canal that connects lakes Trout and Joel, and S-60 is located in C-33 canal between Alligator Lake and Lake Gentry. Culvert S-58 maintains stages in Alligator Lake upstream from the structure, while the S-60 spillway is operated to main the optimum stage lake-wide. These lakes are regulated between elevations 61.5 and 64.0 ft NGVD on a seasonally varying schedule. Daily water level observations for Alligator Lake over the last 20 years show that the most significant change in water levels occurred during the 2000–2001 drought, with water levels showing a big drop (Appendix 2-4, Figure 1). Generally, water level was below the regulation schedule most of the time. **Figure 2-8**, panel a, shows the WY2013 daily average stage at the headwater of S-60, daily rainfall, and flood regulation schedule for Alligator Lake.

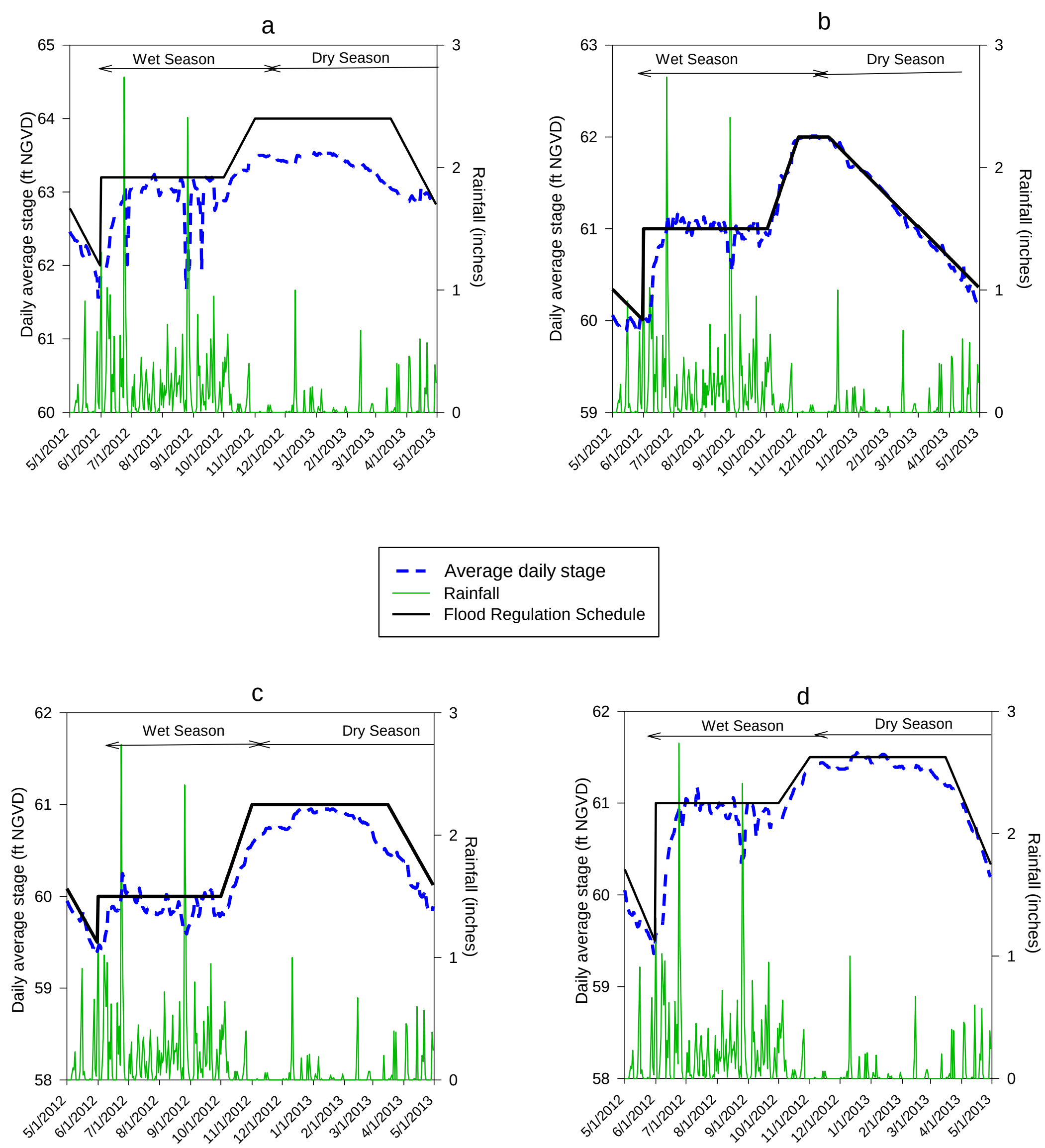


Figure 2-8. Average daily water levels (stage), regulation schedule, and rainfall for (a) Alligator Lake, (b) Lake Myrtle, (c) Lake Mary Jane, and (d) Lake Gentry.

Lakes Joel, Myrtle and Preston

Lakes Joel, Myrtle, and Preston are regulated by structure S-57. The S-57 culvert 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 2-8**, panel b, shows the WY2013 daily average stage at the headwater of S-57, daily rainfall, and regulation schedule for Lake Myrtle. The stages were mostly following the regulation schedule. Daily water level observations for Lake Myrtle over the last 20 years show that the most significant drop in water level occurred in June 2001 during a severe drought year (Appendix 2-4, Figure 2).

Lakes Hart and Mary Jane

Lakes Hart and Mary Jane are regulated by structure S-62. The S-62 spillway is located in the C-29 canal that discharges into Lake Ajay. The lakes are regulated between elevations of 59.5 and 61.0 ft NGVD according to a seasonally varying schedule. **Figure 2-8**, panel c, shows the WY2013 daily average stage at the headwater of S-62, daily rainfall, and flood regulation schedule for Lake Mary Jane. The stages were part of the year below the regulation schedule. Flow releases were made based on water supply needs and flood control. Daily water level observations for Lake Mary Jane over the last 20 years show that the most significant drop in water level occurred in May 2001 during a severe drought year (Appendix 2-4, Figure 3).

Lake Gentry

Lake Gentry is regulated by the S-63 structure, 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 of 59.0 and 61.5 ft NGVD according to a seasonally varying schedule. **Figure 2-8**, panel d, shows the WY2013 daily average stage at the headwater of the S-63 spillway, daily rainfall, and flood regulation schedule for Lake Gentry. The stages were generally close to the regulation schedule. Daily water level observations for Lake Gentry over the last 20 years show the most significant drop in water level in May 2001 during a severe drought year (Appendix 2-4, Figure 4).

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 maintained between 54.5 and 58.0 ft NGVD on a seasonally varying schedule. A weir structure was built downstream of the S-59 spillway to control the tailwater elevation at S-59. The weir crest is at an elevation of 51.0 ft NGVD. The weir is often submerged and therefore, the tailwater influences the headwater of S-59. **Figure 2-9**, panel a, shows the WY2013 daily average stage at the headwater of S-59, daily rainfall, regulation schedule, and ecological regulation schedule for East Lake Tohopekaliga. The stages were lower than the regulation schedule. Flow releases were based on water supply needs, flood control and maintaining the regulation schedule whenever possible. Daily water level observations for East Lake Tohopekaliga in the last 20 years are shown in Appendix 2-4, Figure 5.

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 the elevations of 51.5 and 55.0 ft NGVD on a seasonally varying schedule. The S-61 structure is used to maintain the optimum stage in Lake Tohopekaliga. **Figure 2-9**, panel b, shows the WY2013 daily average stage at the headwater of S-61, daily rainfall, regulation schedule, and ecological regulation schedule for Lake Tohopekaliga. Stages generally were at the regulation schedule part of the year and below the schedule the other part. Daily water level observations for Lake Tohopekaliga over the last 20 years show the most significant drop in water level occurred in June 2004 during the lake drawdown (Appendix 2-4, Figure 6).

Lakes Kissimmee, Hatchineha and Cypress

Lakes Kissimmee, Hatchineha, and Cypress are regulated by the S-65 spillway and lock structure located at the outlet of Lake Kissimmee and the head of the Kissimmee River (C-38 Canal). Lake Kissimmee covers approximately 35,000 acres and is regulated between 48.5 and 52.5 ft NGVD on a seasonally varying schedule. **Figure 2-9** (panel c) shows the daily average stage at the headwater of S-65, daily rainfall, regulation schedule, and ecological regulation schedule for Lake Kissimmee during WY2013. Stages were generally below the flood regulation schedule. Releases were made based on downstream water needs and flood control. Appendix 2-4, Figure 7 shows daily water level for 1929–2013.

The Upper Kissimmee Basin experienced a rainfall deficit of 2.95 inches resulting in below average discharge out of the lake, 439,653 ac-ft, 62 percent of historical average. There has been discharge from Lake Kissimmee to the Kissimmee River throughout the water year except one day. **Table 2-8** depicts WY2013, WY2012 and historical flow statistics for major impoundments. WY2013 monthly flows are shown in Appendix 2-6, Table 1. Monthly historical average, WY2012, and WY2013 flows are presented in Appendix 2-7, Figure 1.

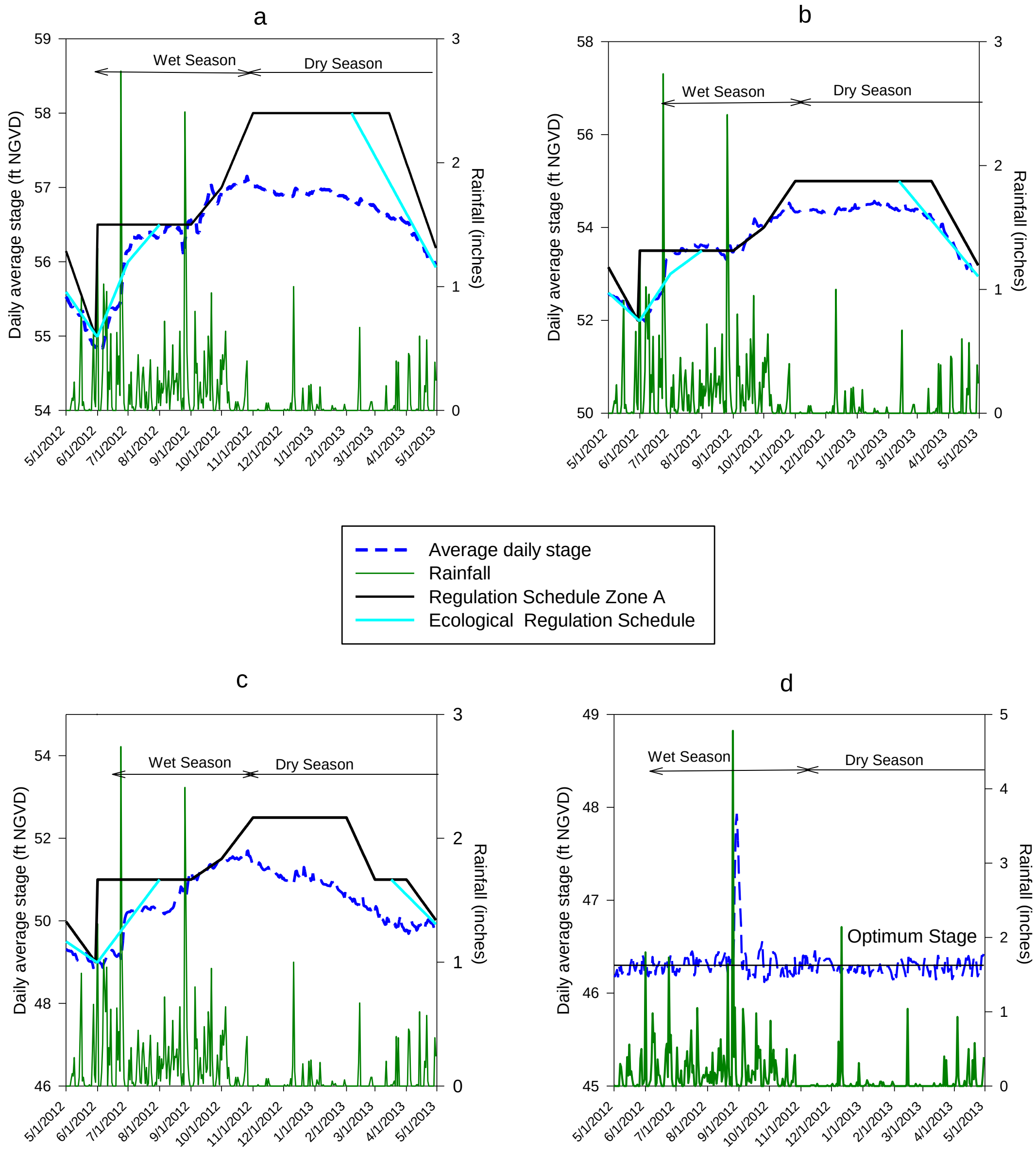


Figure 2-9. Average daily water levels (stage), regular regulation schedule, temporary modifications and rainfall for (a) East Lake Tohopekaliga, (b) Lake Tohopekaliga, (c) Lake Kissimmee, and (d) Pool A.

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, C, D, and E). These structures are operated according to optimum stages. 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 (Abtew et al., 2011). WY2013 conditions in the Kissimmee River system are covered in detail in Chapter 9 of this volume.

Pool A

Stages in Pool A are controlled by the S-65A gated spillway and lock, and the pool is downstream of the S-65 structure. In addition to S-65A, a culvert structure is located through the east tieback levee at the natural channel of the Kissimmee River. During water supply periods, minimum releases are made to satisfy water demands and maintain navigation downstream. The culvert also provides water to the oxbows of the natural river channel. **Figure 2-9**, panel d, shows the daily average stage at the headwater of S-65A, daily rainfall, and optimum stage for Pool A during WY2013. There was a brief spike in water level of more than 1.5 ft in September 2012 when upstream discharge from Lake Kissimmee was above average. Otherwise, stages remained at the optimum stage of 46.3 ft NGVD for the water year.

Pool C

Stages in Pool C are controlled by the S-65C gated spillway and lock, which is downstream of the S-65A structure. 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 WY2013, minimum and maximum headwater stages at S-65C were 33.70 and 36.04 ft NGVD, respectively.

Pool D

Stages in Pool D are controlled by the S-65D gated spillway and lock downstream of S-65C. During WY2013, headwater stages at S-65D ranged from 26.33 to 27.58 ft NGVD.

Pool E

Stages in Pool E are controlled by the S-65E gated spillway and lock, which is downstream of the S-65D. During WY2013, minimum and maximum headwater stages at S-65E were 20.80 and 21.23 ft NGVD, respectively with mean stage of 20.99 ft NGVD.

Lake Istokpoga

Lake Istokpoga has a surface area of approximately 27,700 acres. Stages in Lake Istokpoga are maintained in accordance with a regulation schedule that varies seasonally. The S-68 spillway, located at the south end of the lake, regulates the lake stage and discharges water to the C-41A canal (the Slough Canal). The C-41 canal (Harney Pond Canal), the C-40 canal (Indian Prairie Canal), and the C-39A canal (State Road 70 Canal) provide secondary conveyance capacity for the regulation of floods in the Lake Istokpoga Water Management Basin. The C-40 and C-41 canals flow into Lake Okeechobee, whereas the C-41A canal flows into the Kissimmee River which flows into Lake Okeechobee. Details of the Lake Istokpoga water control plan are available in the Master Water Control Manual for Kissimmee River – Lake Istokpoga Basin (USACE, 1994).

Figure 2-10, panel a, shows the daily average stage at the headwater of S-68, daily rainfall, and regulation schedules for Lake Istokpoga during WY2013. Appendix 2-4, Figure 8, shows daily water levels for the period from 1993–2013. Generally, the stages were close to the regulation schedule. Minimum releases, based on water supply needs, were made during drier periods and flood control releases during wet periods. WY2013 flows (280,544 ac-ft) were 131 percent of the historical average and 123 percent of WY2012. **Table 2-8** depicts WY2013, WY2012 and historical flow statistics for major impoundments. WY2013 monthly flows are shown in Appendix 2-6, Table 1. Monthly historical average, WY2012, and WY2013 flows are presented in Appendix 2-7, Figure 2.

Lake Okeechobee

Lake Okeechobee's water level is regulated to provide (1) flood control, (2) navigation, (3) water supply for agricultural irrigation, municipalities and industry, the EPA and the STAs, (4) regional groundwater control, (5) salinity control, (6) enhancement of fish and wildlife, and (7) recreation (Abtew et al., 2011). The regulation schedule accounts for varying and often conflicting purposes. The lake was regulated under a different regulation schedule in previous water years (Abtew et al., 2007b). An updated regulation schedule was adopted on April 28, 2008, for Lake Okeechobee, which was implemented on May 1, 2008 (USACE, 2008). Details of the current regulation schedule are discussed below and shown in **Figure 2-11**.

Lake Okeechobee has an approximate surface area of 436,200 acres at the historical average stage of 14.01 ft NGVD (1931–2013). At the beginning of the water year, the lake stage was 11.68 ft NGVD and the average stage was 13.85 ft NGVD for the water year almost 2 ft higher than WY2012. **Figure 2-10** (panel b) shows the daily average stage and daily rainfall for Lake Okeechobee during WY2013. The lake stage was 12.37 ft NGVD when Tropical Storm Isaac arrived. Runoff from the storm and following weeks' rainfall elevated the lake stage to 15.92 ft NGVD by October 10, 2012. Details on WY2013 hurricane season and storms are presented in Appendix 2-2. Appendix 2-4, Figure 9, shows daily water levels for Lake Okeechobee for the period of record, 1931–2013. Monthly historical average, WY2012, and WY2013 water levels are shown in Appendix 2-5, Figure 9. **Table 2-7** depicts WY2013, WY2012, and historical mean, maximum and minimum stages.

WY2013 inflows into Lake Okeechobee were close to the historical average (2,100,036 ac-ft), 101 percent of the historical average inflows. WY2013 outflows of 1,041,902 ac-ft were 73 percent of the historical annual outflows (1972–2013). **Table 2-8** depicts WY2013, WY2012 and historical flow statistics for major impoundments. WY2013 monthly inflows and outflows are shown in Appendix 2-6, Table 2 and Table 3, respectively. Monthly historical average, WY2012, and WY2013 inflows and outflows are shown in Appendix 2-7, Figures 3 and 4.

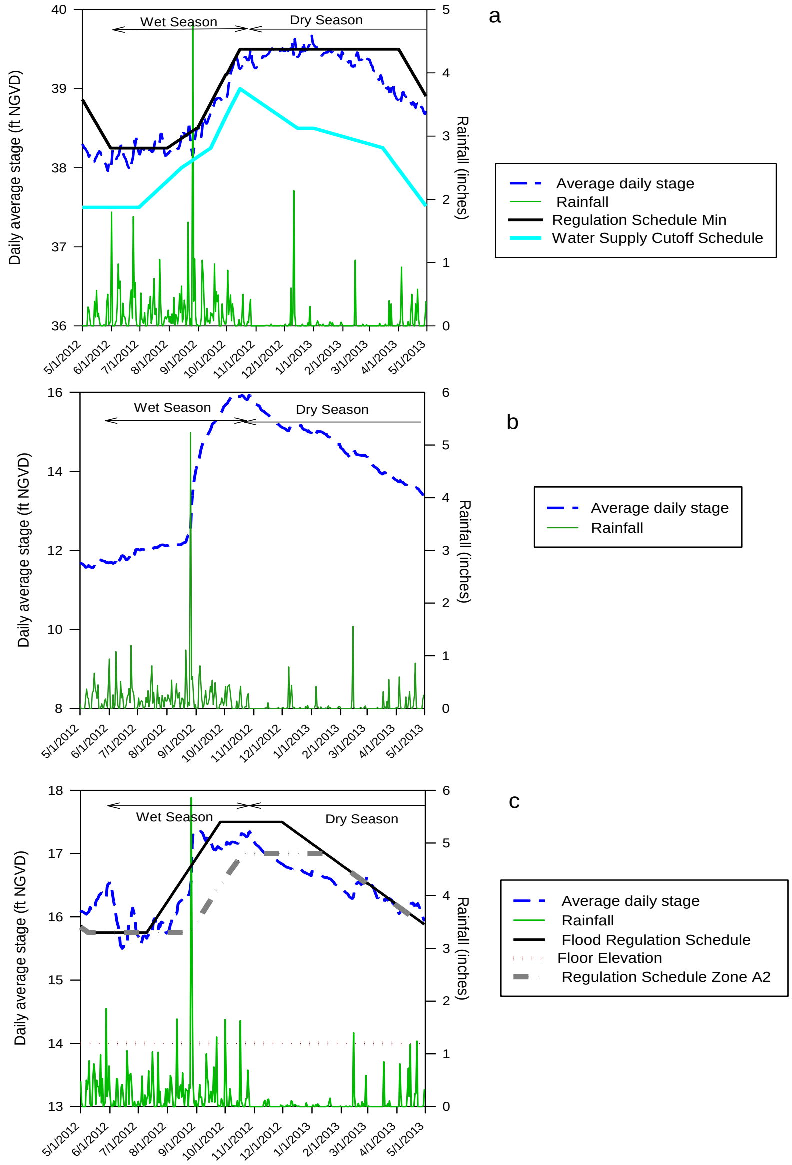


Figure 2-10. Average daily water levels (stage), regulation schedule, and rainfall for (a) Lake Istokpoga, (b) Lake Okeechobee, and (c) WCA-1.

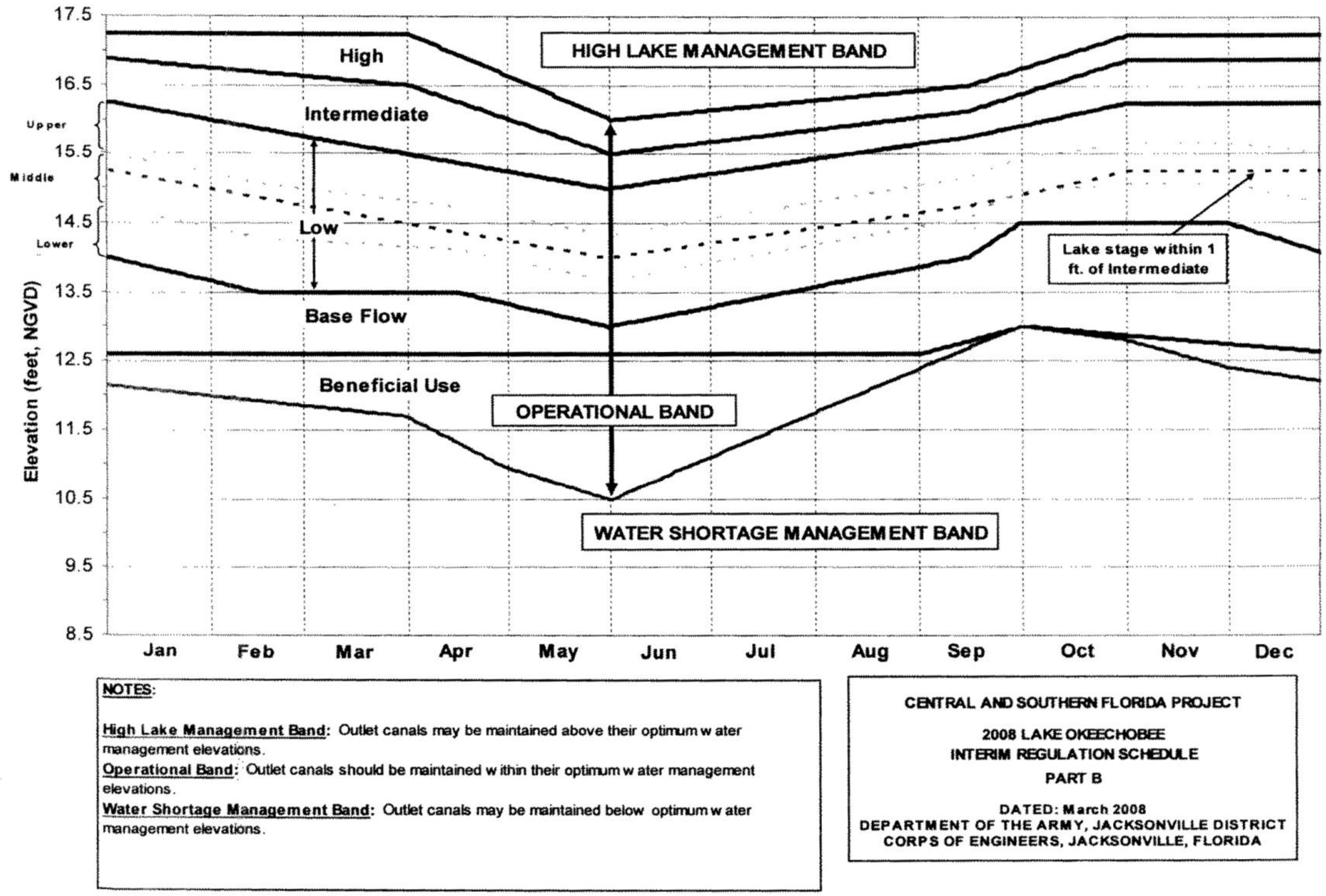


Figure 2-11. Lake Okeechobee's current regulation schedule (LORS2008).

As previous noted in the *Water Management in Water Year 2013* section of this chapter, the current regulation schedule for Lake Okeechobee is divided into three major bands: High Lake Management Band, Operational Band, and Water Shortage Management Band (**Figure 2-11**). The regulation schedule was developed by the USACE based on several key considerations including the lake's ecology and environmental needs, Caloosahatchee and St. Lucie estuaries' environmental needs, Everglades environmental needs, and structural integrity of the Herbert Hoover Dike and potential danger from hurricanes. While this regulation schedule attempts to balance the multipurpose needs of flood control, water supply, navigation, enhancement of fish and wildlife resources, and recreation, the dominant objective is public health and safety related to dike structural integrity. Notably, the 2008 regulation schedule has expanded operational flexibility throughout the year and allows Lake Okeechobee to be managed at lower levels than the previous regulation schedule. It is implemented through decision trees that consider lake water level, WCA water levels, tributary hydrologic conditions, multi-season climatic and hydrologic outlook, and downstream estuary conditions. The decision tree for establishing allowable lake releases to the WCAs and tide (estuaries) is shown in Abtew et al. (2011).

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 runoff from the basin (Abtew et al., 2011). 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 that is not used in the basin for water supply or canal stage maintenance is discharged into the estuary via the S-80 structure. As salinity is an important measure of estuary viability, volume and timing of freshwater flow at S-80 is a key feature of water management activities.

The C-23 canal discharges into the North Fork of the St. Lucie River at structure S-48. The C-24 canal discharges into the same fork at S-49. The C-25 canal discharges into the southern part of the Indian River Lagoon at structure S-50. Structure S-80 discharges water from the St. Lucie Canal into the South Fork of the St. Lucie River. Rainfall in Martin/St. Lucie rainfall area has improved from WY2013. Outflows from the C-23 canal (S-48), C-25 canal (S-50) and the St. Lucie Canal (S-80) were higher than WY2012 (**Table 2-8**). WY2013 monthly flows for S-48, S-49, S-50, and S-80 are shown in Appendix 2-6, Table 4. Monthly historical average, WY2012, and WY2013 flows are shown in Appendix 2-7, Figures 5–8.

Lower West Coast

Inflows to the Caloosahatchee River (C-43 Canal) are runoff from the basin watershed and releases from Lake Okeechobee by operation of S-77, a gated spillway and lock structure (Abtew et al., 2011). Structure S-77 operations use regulation procedures described by the USACE (2008). Environmental water supply releases from the lake to the Caloosahatchee occurred at various times (**Figure 2-6**). WY2013 flows from Lake Okeechobee to the Caloosahatchee River were 501,374 ac-ft, which is 98 percent of the historical average. WY2013 monthly Lake Okeechobee flows through S-77 are shown in Appendix 2-6, Table 5.

Downstream of S-77, S-78 is a gated spillway that also receives runoff 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 the USACE. The operations of S-79 include the runoff from the 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, the volume and timing of freshwater flow at S-79 is an important feature of water management activities. Water management decision regulating releases through S-79 into the Caloosahatchee Estuary is shown in **Figure 2-6**. The WY2013 discharge through S-79 to the coast, 1,137,904 ac-ft, was 95 percent of the historical average (1972–2013). WY2013 monthly flows for S-77 and S-79 are shown in Appendix 2-6, Table 5; monthly historical average, WY2012, and WY2013 outflows at S-79 are shown in Appendix 2-7, Figure 9. **Table 2-8** depicts Y2013, WY2012 and historical flow statistics for major impoundments.

Everglades Agricultural Area

Four major canals pass through the EAA: West Palm Beach, Hillsboro Canal, North New River Canal, and Miami Canal. Flows from Lake Okeechobee and runoff from the EAA are discharged via these four canals to relieve flooding for the local drainage area and into the Stormwater Treatment Areas (STAs) for water quality improvement. Discharges to the east coast occur through the West Palm Beach Canal. At times, when conditions do not allow for the STAs to treat all runoff water, diversion to the WCAs could occur. 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 not to exceed 12 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 WY2013, elevations ranged from 8.78 to 11.93 ft NGVD. The outflows from the four canals to the STAs are discharged through pump structures S-5A, S-319, S-6, G-370, and G-372. Outflows from STAs are inflows into WCAs. During the dry season and drier-than-normal wet seasons, water supply for agricultural irrigation is provided by these four primary canals, mainly through gravity release from Lake Okeechobee. During droughts, when Lake Okeechobee levels are low, forward pumping is required to withdraw water from the lake. At times, water is also supplied to the EAA from the WCAs. Farmers utilize a set of secondary and tertiary farm canals to distribute water from several gated culverts and pumps to their respective fields.

Everglades Protection Area

Water Conservation Area 1

The primary objectives of the WCAs are to provide (1) flood control; (2) water supply for agricultural irrigation, municipalities, industry, and the ENP; (3) regional groundwater control and prevention of saltwater intrusion, (4) enhancement of fish and wildlife; and (5) recreation. A secondary objective is the maintenance of marsh vegetation in the WCAs, which is expected to provide a dampening effect on hurricane-induced wind tides (Abtew et al., 2011). WCA-1 covers approximately 141,440 acres with a daily average water level of 15.65 ft NGVD (1960–2013). WCA-1 is regulated mainly by outflow structures S-10A, S-10C, S-10D, S-10E, and S-39; the regulation schedule for WCA-1 is provided by the USACE (1996). Water supply releases are made through the G-94 (A, B, C), G-300, G-301, and S-39 structures. The regulation schedule varies from high stages in the late fall and winter to low stages at the beginning of the wet season (Abtew et al., 2007b). The seasonal range allows runoff storage during the wet season and water supply during the dry season. Water levels in WCA-1 started from above the regulation schedule at 16.07 ft NGVD on May 1, 2012 partly due to a wet April and May on the Conservation Areas. Water level rose by 1 ft to a water year maximum of 17.35 ft NGVD (September 5, 2012) due to the rains and associated flows from Tropical Storm Isaac and stayed relatively high through the year. The mean water year stage was 16.49 ft NGVD, eight-tenth of a ft higher than WY2012 and the historical average. Four gauges (1-8C, 1-7, 1-8T, and 1-9) are used for stage monitoring. Daily water levels were compiled from the four gauges based on their regulation schedule uses. Site 1-8C was used from January 1–June 30, 2012, 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 of site 1-8C. **Figure 2-10c** depicts WY2013 daily average water level, daily rainfall, and regulation schedule for WCA-1. Daily average historical water levels are shown in Appendix 2-4, Figure 10, for the period of record (1960–2013). Monthly historical average, WY2012, and WY2013 water levels are shown in Appendix 2-5, Figure 10. **Table 2-7** depicts WY2013, WY2012, and historical mean, maximum and minimum stages.

The main inflows into WCA-1 are from Stormwater Treatment Area 1 West (STA-1W) through the G-251 and G-310 pump stations and from Stormwater Treatment Area 1 East (STA-1E) via pump station S-362. There are three diversion structures that can flow in both directions (G-300, G-301, and G-338). The main outflow from WCA-1 is to WCA-2 through the S-10 structures. The two diversion structures (G-300 and G-301) are also used to discharge water from WCA-1 to the north to the L-8 and C-51 Canals via the STA-1 inflow basin. Water is also discharged through S-39 to the east into the Hillsboro Canal. The G-94A, B, and C structures are used to make water supply releases to the east urban area.

Historical flows through each structure have varying lengths of period of record because new structures come online, or because existing structures may no longer contribute to the inflow and outflow of a system. The structures related to the STAs are relatively recent additions. WCA-1 is regulated between 14 and 17.50 ft NGVD. WY2013 inflows into WCA-1 (363,897 ac-ft) were 76 percent of the historical average. In WY2013, 54 percent of the inflow was from STA-1W through pump stations G-310 and 39 percent was from STA-1E through pump station S-362. No backflows occurred through the G-94s or S-10s. No inflow occurred through G-338. There was flood diversion inflow, 8 percent, through G-300 and G-301 during Tropical Storm Isaac in late August and September 2012 (Appendix 2-6, Table 6). Monthly historical average, WY2012, and WY2013 inflows are shown in Appendix 2-7, Figures 10.

WY2013 outflows from WCA-1 (483,713 ac-ft), 109 percent of the historical average, for the analysis period from 1972–2013. WY2012 outflows were record low, 14,812 ac-ft. Outflows from WCA-1 were mainly into WCA-2A through the S10 structures (74 percent) and to the east through the Hillsboro Canal (15 percent). Backflow through the G-300 structure for water supply into L-8 or C-51 Canal was 9 percent. There was some flow to the east through G-94A. **Table 2-8** depicts Y2013, WY2012 and historical flow statistics for major impoundments. WY2013 monthly outflows are shown in Appendix 2-6, Table 7. Monthly historical average, WY2012, and WY2013 outflows are shown in Appendix 2-7, Figures 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. Combined, WCA-2A and WCA-2B have a total area of 133,400 acres, with 80 percent of the area in WCA-2A. The regulation schedule for WCA-2A is provided by the USACE (1996). A regulation schedule is not used for WCA-2B because of high seepage rates. Releases 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 are made from spillway structure S-141 to the North New River Canal when the pool elevation in WCA-2B exceeds 11.0 ft NGVD. For WY2013, the water level in WCA-2A started at 11.74 ft NGVD, reached a maximum of 14.43ft NGVD in September 2012 after Tropical Storm Isaac passed, and declined to 11.71 ft NGVD by the end of the water year. Water level stayed above the regulation schedule throughout the water year. The average stage was 12.45 ft NGVD. Appendix 2-4, Figure 11 shows the daily water level for 1961–2013. **Figure 2-12**, panel a, depicts WY2013 daily average water level, daily rainfall, and regulation schedule for WCA-2A. **Table 2-7** depicts WY2013, WY2012, and historical mean, maximum and minimum stages. Monthly historical average, WY2012, and WY2013 water levels are shown in Appendix 2-5, Figure 11.

WY2013 inflows into WCA-2 (1,074,320 ac-ft) were 170 percent of the historical average. The major inflows to WCA-2A were STA-3/4 discharges through the S-7 pump station (36 percent), Outflow from WCA-1 through the S-10 structures (33 percent) and STA-2 discharges through pump station G-335 and G-436 (30 percent). Data shows some backflow from WCA-3 through S-11C. **Table 2-8** depicts Y2013, WY2012 and historical flow statistics for major impoundments.

WY2013 outflows from WCA-2 (938,199 ac-ft) were 147 percent of the historical average. Outflows from WCA-2 were primarily into WCA-3A through structures S-11A, B, and C (83 percent) and discharge to canals 13 and 14 through structure S-38 (16 percent). This water year, there was no backflow into the EAA from WCA-2. There was minor flow through the North New River Canal through structure S-34. There was small discharge to WCA-3A through the S-142. WY2013 monthly inflows and outflows are shown in Appendix 2-6, Tables 8 and 9. Monthly historical average, WY2012, and WY2013 inflows and outflows are shown in Appendix 2-7, Figures 12 and 13, respectively. **Table 2-8** depicts WY2013, WY2012 and historical flow statistics for major impoundments.

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. WCA-3A and WCA-3B combined have a total area of 585,560 acres, with 83 percent of the area in WCA-3A. The regulation schedule for WCA-3A is provided in USACE (1996). A regulation schedule is not used for WCA-3B because of high seepage rates. Indicator gauge Site 71 is used for monitoring WCA-3B and maintain water level not to exceed 8.5 ft NGVD. Flow releases into WCA-3B are from the S-142 and S-151 structures, 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.

Figure 2-12, panel b, depicts WY2012 daily average water level, daily rainfall, and regulation schedule for WCA-3A. The regulation schedule, which is known as Interim Operational Plan for the Protection of the Cape Sable Seaside Sparrow, is replaced by a new regulation schedule known as Everglades Restoration Transition Plan (ERTP) as of October 19, 2012. Water levels in WCA-3 (average of gauges 3-63, 3-64, 3-65) were above the regulation schedules in September–November 2012 and below the regulation schedule in the 2013 dry season. The average stage was 10.24 ft NGVD with a maximum of 11.64 ft NGVD and minimum of 9.18 ft NGVD far higher than WY2012 levels. Appendix 2-4, Figure 12, shows the daily water level for 1962–2013. Monthly historical average, WY2012, and WY2013 water levels are shown in Appendix 2-5, Figure 12. **Table 2-7** depicts WY2013, WY2012, and historical mean, maximum and minimum stages.

WY2013 inflows into WCA-3A (1,322,042 ac-ft) were 113 percent of historical average. The major inflows to WCA-3A in WY2013 were through S-11A, B, and C (59 percent) from WCA-2, and from STA-3/4 through structures S-8 and S-150 (15 percent). Inflows from the east through structures S-9 and S-9A accounted for 19 percent of the total inflow. The S-140 and S-190 structures to the northwest contributed 5 an 2 percent of the inflow to WCA-3A, respectively. There are possible inflows to WCA-3A through the L-4 borrow canal breach into the L-3 extension canal that is currently not gauged. The breach has a bottom width of 150 ft at an elevation of 3 ft NGVD (SFWMD, 2002).

WY2013 outflows from WCA-3A (1,225,088 ac-ft) were 122 percent of the historical average. Outflows from WCA-3A into the ENP were through structures S-12A, B, C, and D (61 percent); S-151 (13 percent); S-333 (12 percent) with potential flow to ENP to the south or flow east through S-334; S-30 (5 percent); S-31 (3percent); S-344 and S-343 (6 percent). There was minor flow through S-142, S-150 and S-337. There were no backflow through S-8. WY2013 monthly inflows and outflows are shown in Appendix 2-6, Tables 10 and 11, respectively. Monthly historical average, WY2012, and WY2013 inflows and outflows are shown in Appendix 2-7, Figures 14 and 15. **Table 2-8** depicts Y2013, WY2012 and historical flow statistics for major impoundments.

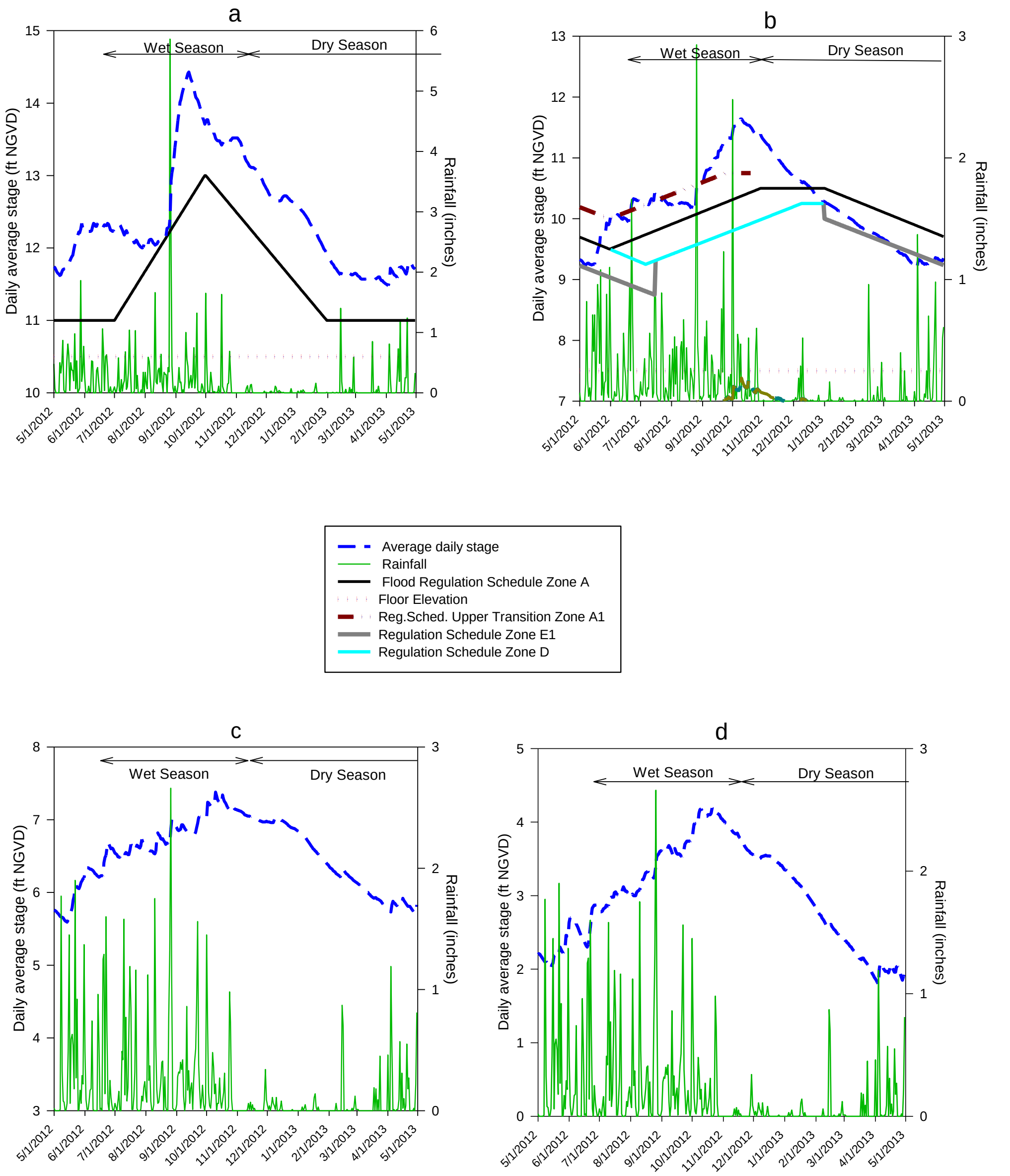


Figure 2-12. Average daily water levels (stage), regulation schedule, temporary deviation, and rainfall for (a) WCA-2A, (b) WCA-3, (c) gauge P-33, and (d) ENP (gauge P-34).

Everglades National Park

Everglades National Park is located south of WCA-3A and WCA-3B. Criterion for water delivery into the park was based on the Interim Operation Plan. The Interim Operational Plan for the Protection of the Cape Sable Seaside Sparrow is replaced by a new regulation schedule known as Everglades Restoration Transition Plan (ERTP) as of October 19, 2012. Water level monitoring at sites P-33 and P-34 has been used in previous 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 (Sklar et al., 2000). Historical water level data for sites P-33 (1952–2013) and P-34 (1953–2013) were obtained from the District's hydrometeorology database, DBHYDRO, and from ENP's database. Water level at both sites was higher than WY2012 and the historical average. WY2013 average water level at P-33 was 6.52 ft NGVD and at P-34, 2.99 ft NGVD. **Figure 2-12,** panels c and d, depict the daily average water level and rainfall at P-33 and P-34, respectively, for WY2013. Daily average historical water levels for P-33 and P-34 are shown in Appendix 2-4, Figures 13 and 14, respectively. Monthly historical average, WY2012, and WY2013 water levels for P-33 and P-34 are shown in Appendix 2-5, Figures 13 and 14. **Table 2-7** depicts WY2013, WY2012, and historical mean, maximum and minimum stages.

WY2013 inflow into the ENP (1,496,719 ac-ft) was 153 percent of the historical average and twice as much as WY 2012. Inflow into the ENP is mainly through structures S-12A, B, C and D, S-18C, S-332B, S-332C, S-332D and S-333. The major inflow (49 percent) was through the S-12 structures. The S-332B structure contributed (14 percent); S-332C (13 percent); S-18C (10 percent); S-332D (9 percent) and S-333 (5 percent). S-175 and S-332 had little flows. WY2013 monthly inflows are shown in Appendix 2-6, Table 12. Monthly historical average, WY2012, and WY2013 inflows are shown in Appendix 2-7, Figure 16. **Table 2-8** depicts WY2013, WY2012, and historical flow statistics for major impoundments.

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