Chapter 5: Hydrology of the Everglades Protection Area

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SUMMARY

Hydrology of the Everglades Protection Area (EPA) is a new chapter in the *2004 Everglades Consolidated Report*. In this chapter, the contemporary hydrology of the Everglades Protection Area is presented, with the main objective of depicting Water Year 2003 (May 1, 2002 to April 30, 2003). In cases where historical hydrologic analysis or compiled data are available, comparisons with hydrology from the last few decades are presented. This chapter does not include comparisons of current hydrology with predevelopment hydrology.

For the current reporting year, rainfall in Water Conservation Areas 1 and 2 was 14 percent below historical average. Rainfall in Water Conservation Area 3 was close to the average. Everglades National Park rainfall was slightly higher than historical average. Evapotranspiration was close to expected values. Water levels were generally higher than historical averages except in Water Conservation Area 2A. Major flows occurred during the wet season. In most cases, the highest flows were during the month of July. No major hydrologic events occurred during Water Year 2003. The recent drought (2000-2001) is over, and this year a minor El Niño was observed, with no significant direct effect on the EPA.

INTRODUCTION

The Everglades Protection Area is part of the area managed by the South Florida Water Management District (SFWMD or District). The SFWMD area extends from Central Florida to the Florida Keys. The system comprises lakes, impoundments, wetlands, and canals that are managed under a water management schedule based on flood control, water supply, and environmental enhancement. The general surface water direction of flow is from north to south, but there are water supply and coastal discharges to the east and to the west.

The Upper Kissimmee Chain of Lakes (Lakes Myrtle, Alligator, Mary Jane, Gentry, East Tohopekaliga, Tohopekaliga, and Kissimmee) are principal sources 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 1,596 square miles (sq mi) (Guardo, 1992). 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-Nubbin Slough basin, reverse flow from the Caloosahatchee River, the St. Lucie Canal, and backpumping from the Everglades Agricultural Area (EAA) (Abtew et al., 2002).

Lake Okeechobee (688 sq mi) is the center of the hydrologic system. Since 1931, the average water level elevation was 14.1 feet (ft) NGVD (National Geodetic Vertical Datum), ranging from a maximum of 18.77 ft NGVD on November 2, 1947 to a minimum of 8.97 ft NGVD on May 24, 2001. The annual average inflow to Lake Okeechobee (based on data from the years 1972–2001) was about 2 million acre-feet (ac-ft), while the annual average outflow was about 1.3 million ac-ft. Outflows are mainly through the south, southeast, and southwest structures. About 10 percent of the outflow is lake water flow through the EAA, with most of the outflow reaching the EPA (Abtew and Khanal, 1994; Abtew et al., 2002).

The Everglades Agricultural Area is the main source of surface water inflow into the Everglades Protection Area. On average, about 900,000 ac-ft of water are discharged from the EAA to the south and southeast, with most of it going into the EPA (Abtew and Khanal, 1994; Abtew and Obeysekera, 1996).

The EPA starts at the southern and eastern edges of the EAA and extends south to Florida Bay. The EPA comprises several defined regions: the Arthur R. Marshall Loxahatchee National Wildlife Refuge, which contains Water Conservation Area 1 (WCA-1) (221 sq mi); Water Conservation Areas 2A and 2B (210 sq mi); Water Conservation Areas 3A and 3B (915 sq mi); Everglades National Park (2,150 sq mi); and Florida Bay, as shown in Redfield et al. (2003). The extent and components of the EPA are depicted in **Figure 5-1**. The EPA receives additional surface water inflows from the urban areas in the east and from the southeast and northwest sources currently identified as non-ECP stormwater flows. (Non-ECP structures are those associated with the EPA but outside the Everglades Construction Project [ECP].) Surface water flow into and out of the EPA is determined by weather factors and by multi-objective water management decisions that include fixed regulation schedules, deviations, agreements, obligations, and emergency management. Emergency management relates to issues such as flood control during high rainfall events, water supply during drought periods, saltwater intrusion, and environmental concerns.

The District has developed an intensive hydrologic monitoring network and related database. The hydrometeorological database, DBHYDRO, also stores data from other agencies, such as the United States Geological Survey (USGS), United States Army Corps of Engineers (USACE), National Oceanographic and Atmospheric Administration (NOAA), Everglades National Park (ENP), Florida Forestry Service (FFS), Florida Department of Environmental Protection (FDEP), and others. Details of hydrometeorological monitoring by the District are presented in Crowell and Mtundu (2000).

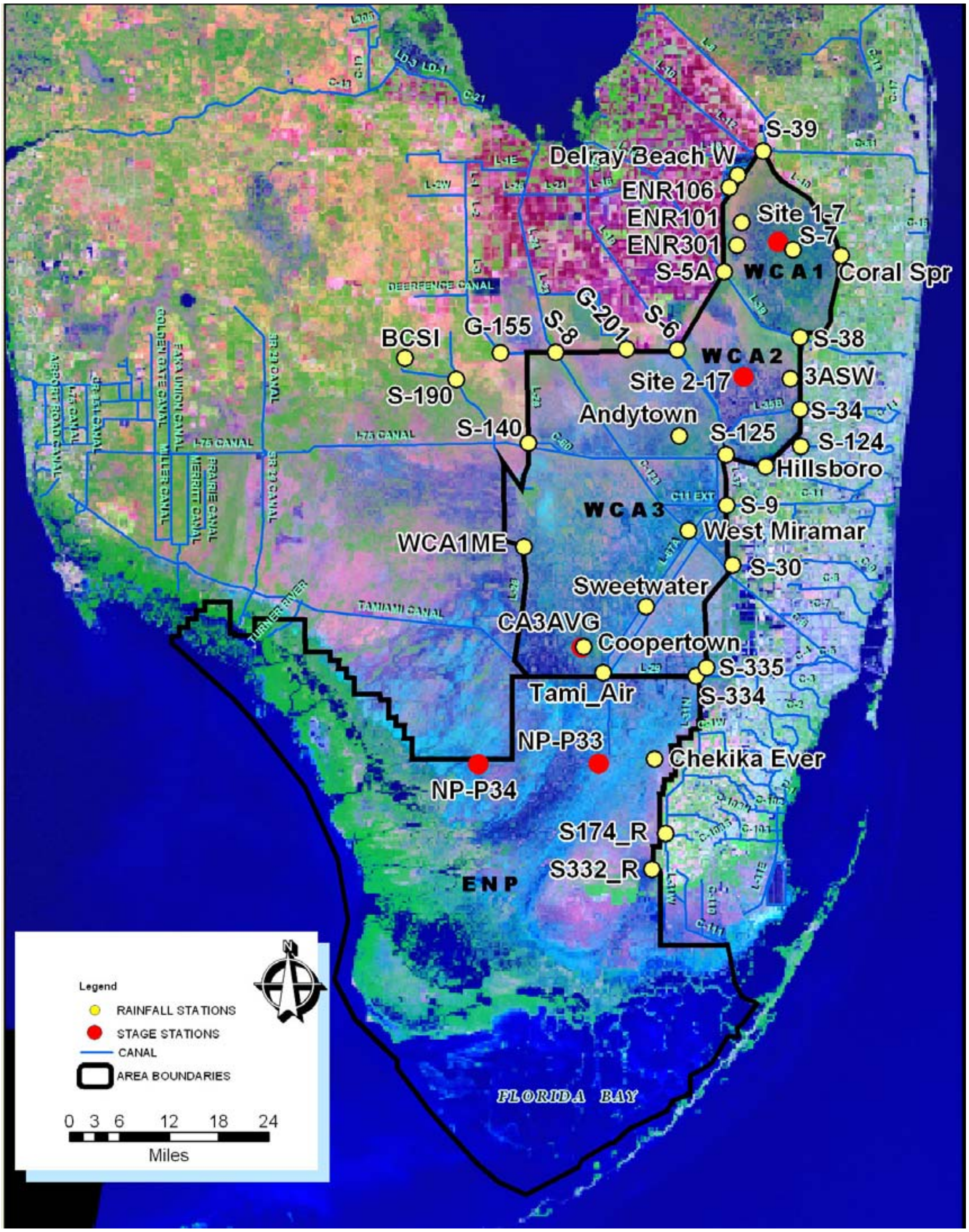

Figure 5-1. The Everglades Protection Area (EPA), with rainfall and stage stations used in this study.

HYDROLOGY

RAINFALL

South Florida is a high-rainfall area, with frontal, convective, and tropical system-driven rainfall events. The heaviest rains in South Florida are produced by mesoscale convective systems – extra-tropical in the dry season and tropical in the rainy season (Rosenthal, 1994). In Central and South Florida (excluding the Florida Keys), 57 percent of total summer rainfall occurs on undisturbed sea breeze days, 39 percent on disturbed days, and 4 percent on highly disturbed days (Burpee and Lahiff, 1984). The annual average rainfall on the entire area managed by the South Florida Water Management District is 52.8 inches. Average annual rainfall, by specific rainfall area, is depicted in **Figure 5-2**. The source of annual rainfall statistics is from Ali and Abtew (1999), except for the Big Cypress Basin and WCA-3, which are from the meteorological analysis section of the District's Operations Division. The annual basin rainfall for Everglades National Park was estimated from MacVicar (1981) average annual rainfall isohyetal map for Central and South Florida and from Sculley (1986) basin rainfall statistics. The areal rainfall statistics were developed from varying lengths of record for each rainfall station and from a varying number of rainfall stations. The periods of record were 1900–1995 (Ali and Abtew, 1999), 1901–1980 (McVicar, 1981), 1941–1985 (Sculley, 1986), and 1971–2000 (SFWMD).

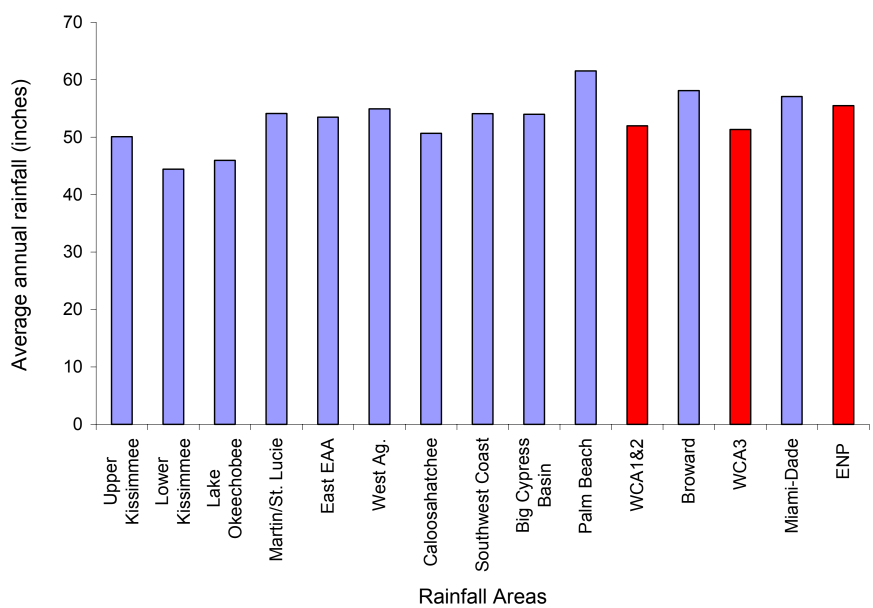

Figure 5-2. Average annual rainfall for SFWMD rainfall areas.

In the Everglades Protection Area, June is generally the wettest month, followed by September. December is the driest month, followed by January or February. The wet season lasts from June through October and accounts for 66 percent of annual rainfall (Abtew et al., 2002). The dry season runs from November through May. During El Niño years, high rainfall occurs in the dry season, resulting in water level increases in the Everglades Protection Area (Huebner, 2000). Extreme hydrometeorological and related events have significant effects on the region. El Niño conditions, hurricanes, and tropical systems are associated with high-rainfall events or seasons, and La Niña conditions and drought events result in dry conditions. El Niño occurs about once every three to four years (Huebner, 2000). Tropical systems are a frequent occurrence. The general area of the South Florida Water Management District has been affected by 42 hurricanes, 32 tropical storms, and 9 tropical cyclones (a term used before modern hurricane categories were established) from the years 1871 to 1999 (Abtew and Huebner, 2000). Other conditions, such as local convective systems and regional frontal systems, also have been associated with high rainfall events.

Droughts are characterized by a significant decline in annual rainfall. They also promote the development and spread of wildfires. In Central and South Florida, severe droughts were reported in 1932, 1955–57, 1961–63, 1971–1972, 1973–1974, 1980–1982, 1985, 1988–1989, 1990, and 2000–2001 (Abtew et al., 2002). A minimum of one severe drought can be expected every 10 years. Historical droughts are identified by the historical Palmer Drought Severity Index, annual rainfall, lake water levels, groundwater levels, stream flow, and wildfire records. Fire is an important ecological process in the Everglades (Wu et al., 1996). Frederick and Ogden (2001) reported that pulsed breeding of long-legged wading birds occurs following severe drought in the Everglades. Everglades water-level decline of one standard deviation below the mean is stated as the hydrological indicator.

For Water Year 2003 (May 1, 2002 to April 30, 2003), rainfall data were obtained from the District's Operation and Maintenance Department rainfall report and from the DBHYDRO database (**Figure 5-1**). Rainfall in WCA-1 and WCA-2 was 44.5 inches, 14 percent lower than the historical average rainfall of 52 inches for the area (**Figure 5-3**). The occurrence is less than the five-year dry return-period (Ali and Abtew, 1999). Water Conservation Area 3 received 51.6 inches of rainfall, close to the historical average rainfall of 51.4 inches (**Figure 5-4**). Everglades National Park area rainfall was 57.6 inches, estimated as the average of four stations: S174_R, TAMIAMIR_R, S332_R, and Chekika (**Figure 5-5**). This was 2.6 inches higher than the reported annual average rainfall of 55 inches for the area (MacVicar, 1981; Sculley, 1986). The occurrence is less than the five-year wet return-period.

The month of June had the highest rainfall in all basins, followed by July. Water level and flow increased during and following these months. The wet season is June through October, and the dry season is November through May. In all basins, June, July, and March rainfall were higher than average.

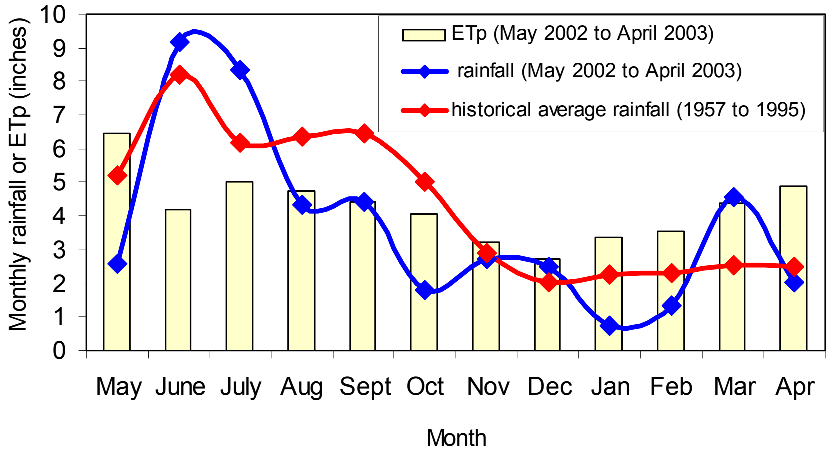

Figure 5-3. Rainfall and potential evapotranspiration (ETp) for WCA-1 and 2.

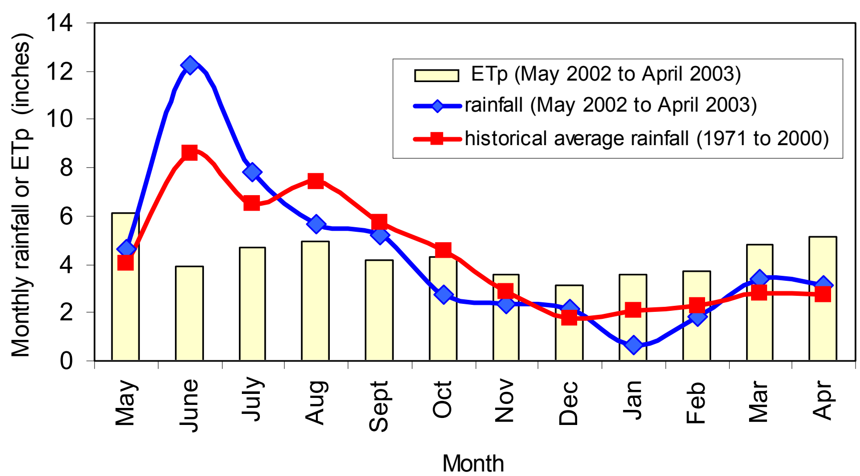

Figure 5-4. Rainfall and potential evapotranspiration (ETp) for WCA-3.

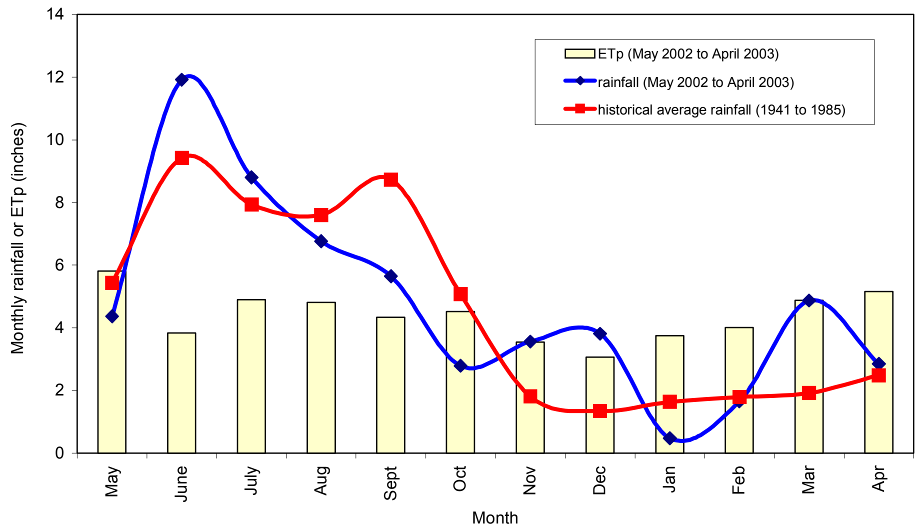

Figure 5-5. Rainfall and potential evapotranspiration (ETp) for Everglades National Park (ENP).

EVAPOTRANSPIRATION

Rainfall and evapotranspiration are the main parameters in the hydrologic balance of the Everglades Protection Area. The delicate balance between rainfall and evapotranspiration maintains the hydrology system in either a wet condition or a 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 water and wetlands that do not dry out range from 48 inches in the northern section of the District to 54 inches in the Everglades (Abtew et al., 2003). Model-estimated evapotranspiration for WY2003 for WCA-1 and 2, WCA-3, and Everglades National Park (ENP) are 51.1, 52.1, and 52.6 inches, respectively. Monthly distributions of evapotranspiration for these locations are shown in **Figures 5-3**, **5-4**, and **5-5**.

WATER LEVEL

The Water Conservation Areas (WCAs) are shallow impoundments, with a total area of approximately 861,440 acres. 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 commitments. Water Conservation Area 1 (WCA-1) is 141,440 acres in area, with a daily average water level of 15.59 ft NGVD. The maximum daily average water level of 18.19 ft NGVD was attained on October 16, 1999 during Hurricane Irene. The minimum water level of 10 ft NGVD in WCA-1 was reached on June 1, 1962, a drought year. For Water Year 2003, the average stage in WCA-1 was 16.51 ft NGVD, with a maximum daily average of 17.02 and a minimum of 15.6 ft NGVD. Comparisons of historical monthly average water level, current reporting year's average stages, current regulation schedule, and station elevation (Price et al., 2001) are shown in **Figure 5-6**. Stage monitoring sites used for current reporting year water levels are shown in **Figure 5-1**.

Water Conservation Areas 2A and 2B (WCA-2A and 2B) combined are 133,400 acres in area, with 80 percent of the area in WCA-2A. WCA-2A has an average water level of 12.58 ft NGVD. The maximum water level of 15.64 ft NGVD was attained on November 18, 1969, and the minimum was 9.33 ft NGVD, attained on April 29, 1989 during a severe drought year. Comparisons of historical monthly average water level, current reporting year's average stages, current regulation schedule, and station elevation (Price et al., 2001) are shown in **Figure 5-7**.

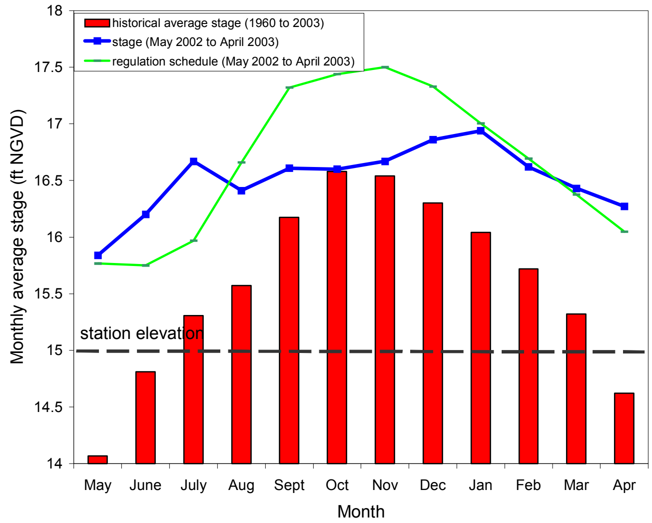

Figure 5-6. Historical average and current year average stages in WCA-1 (monitoring site 1-7).

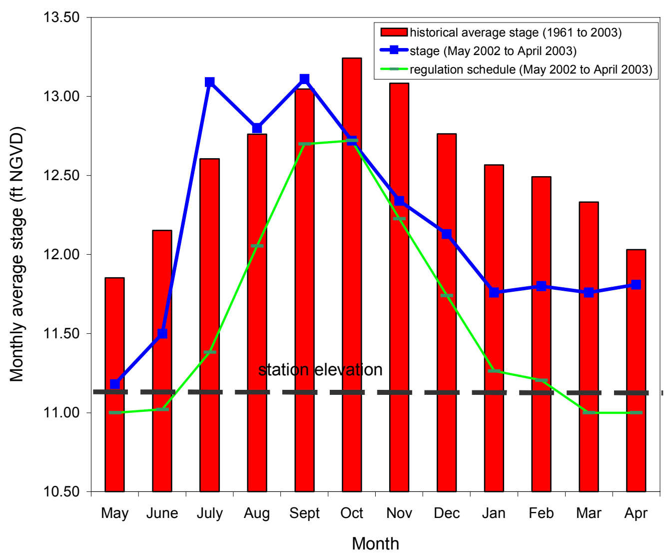

Figure 5-7. Historical average and current year average stages in WCA-2A (monitoring site 2-17).

Water Conservation Areas 3A and 3B (WCA-3A and 3B) combined are 585,560 acres in area, with 83 percent of the area in WCA-3A. WCA-3A has an average water level of 9.48 ft NGVD. The maximum water level of 12.79 ft NGVD was attained 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. Comparisons of historical monthly average water level, average stages for WY2003, current regulation schedule, and station elevation are shown in **Figure 5-8**. Site elevation is average for sites 63, 64, and 65 (Price et al., 2001; United States Geological Survey, personal communication, 2000).

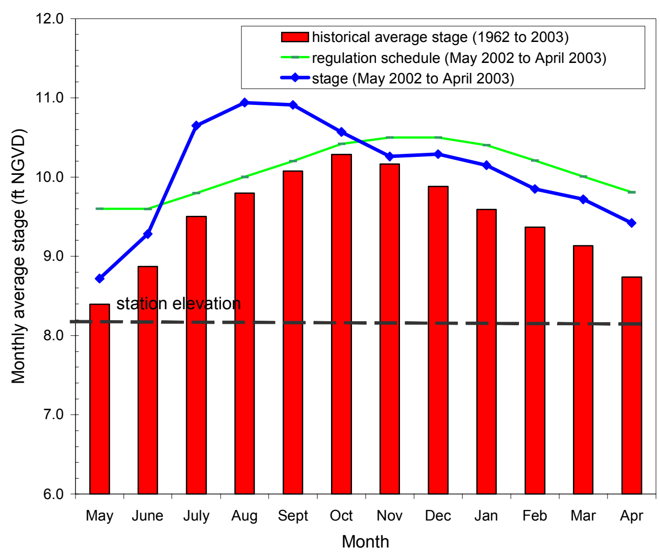

Figure 5-8. Historical average and current year average stages in WCA-3A (monitoring site CA3AVG).

The Everglades National Park (ENP) is about 1,376,000 acres in area (Redfield et al., 2003). Water level monitoring at the P33 and P34 sites has been used in previous ECRs as representative of slough and wet prairie, respectively (Sklar et al., 2003). Station elevations for P33 and P34 are 5.06 ft NGVD and 2.09 ft NGVD, respectively, as shown in Sklar et al. (2000). Historical water level data for P33 (1952–2003) and P34 (1953–2003) were obtained from DBHYDRO (the District's hydrometeorological database) and from Everglades National Park through the Park's database staff. **Figure 5-9** depicts the historical monthly average water level, the current reporting year monthly average water level, and station elevation for station P33. **Figure 5-10** depicts the historical monthly average water level, the monthly average water level for WY2003, and station elevation for station P34.

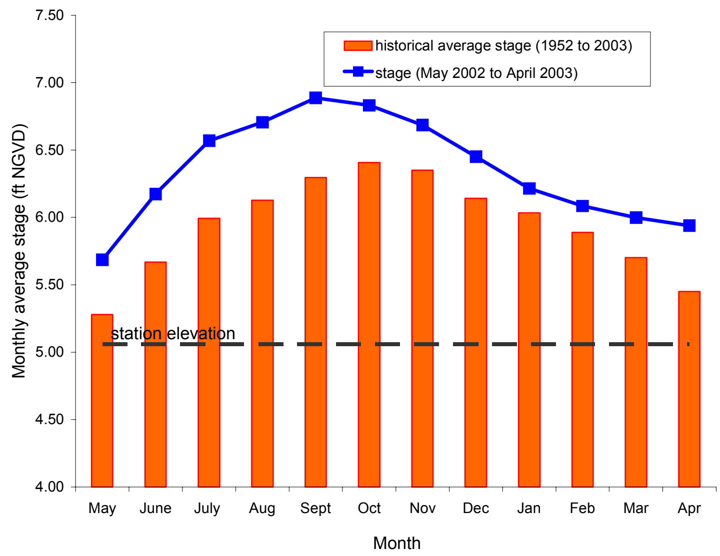

Figure 5-9. Historical average stage, current year average stage, and station elevation for P33 in ENP.

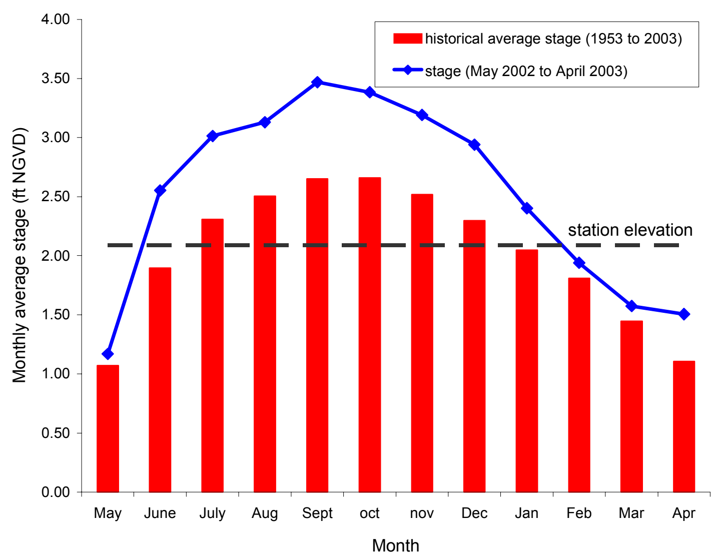

Figure 5-10. Historical average stage, current year average stage, and station elevation for P34 in ENP.

SURFACE WATER INFLOWS AND OUTFLOWS

Inflow and outflow structures throughout the WCAs are operated based on regulation schedules and other water management decision factors. Inflow and outflow structures used in this report are depicted in **Figure 5-11**.

The total inflow to WCA-1 for WY2003 was 620,131 ac-ft. The major inflows (96 percent) were from Stormwater Treatment Area 1 West (STA-1W) through pump stations G-310 and G-251. ACME 1 and ACME 2 sources from Wellington to the east contributed 3 percent of the total flow. The remaining 1 percent of the flow was through structures G-300 and G-301, which discharge from the inflow and distribution impoundment of STA-1W, where almost all the source is the S-5A pump station. Monthly inflows to WCA-1 are shown in **Figure 5-12**. Monthly inflows to WCA-1 by water control structure are shown in Appendix 5-1, Table 1. There was no diversion of flow from S-6 to WCA-1 through structure G-338.

Outflows from WCA-1 are mainly into WCA-2A through structures S-10A, C, D, and E (47 percent); into the Hillsboro Canal through structure S-39 (40 percent); and discharge to the Lake Worth Drainage District through structures G-94A, B, and C (11 percent). The remaining 2 percent of outflows for this reporting year were backflow to the STA-1W inflow and distribution through structures G-300 and G-301. The total outflow for WY2003 was 515,099 ac-ft. Monthly outflows to WCA-1 are shown in **Figure 5-12**. Monthly outflows from WCA-1 from each water control structure are shown in Appendix 5-1, Table 2. There were no flows through structures G-94A and G-94B.

The total inflow to WCA-2 for WY2003 was 692,989 ac-ft. The major inflows (44 percent) were from Stormwater Treatment Area 2 (STA-2) through pump station G-335. WCA-1 discharges through the S-10A, C, D, and E structures are inflows to WCA-2A (35.5 percent). Twenty percent of the inflow was from the EAA through the S-7 structure. The remaining 0.5 percent of inflow was through structure G-339, a bypass structure at STA-2. Monthly inflows to WCA-2A are shown in **Figure 5-13**. June and July inflows to WCA-2 account for 58.5 percent of the year’s total inflow. As shown in **Figure 5-3**, the highest rainfall amounts were in June and July. Monthly inflows to WCA-2 by water control structure are shown in Appendix 5-2, Table 1.

Outflows from WCA-2 are primarily into WCA-3A through structures S-11A, B, and C (59 percent); into the North New River Canal through structure S-34 (21 percent); discharge to the North New River Canal through structure S-143 (12 percent); and discharge to canals 13 and 14 through structure S-38 (6 percent). The remaining 2 percent of outflow for this reporting year was backflow to the EAA through the S-7 structure. The total outflow for WY2003 was 533,400 ac-ft. Monthly outflows to WCA-2 are shown in **Figure 5-13**. Monthly outflows from WCA-2 from each water control structure are shown in Appendix 5-2, Table 2.

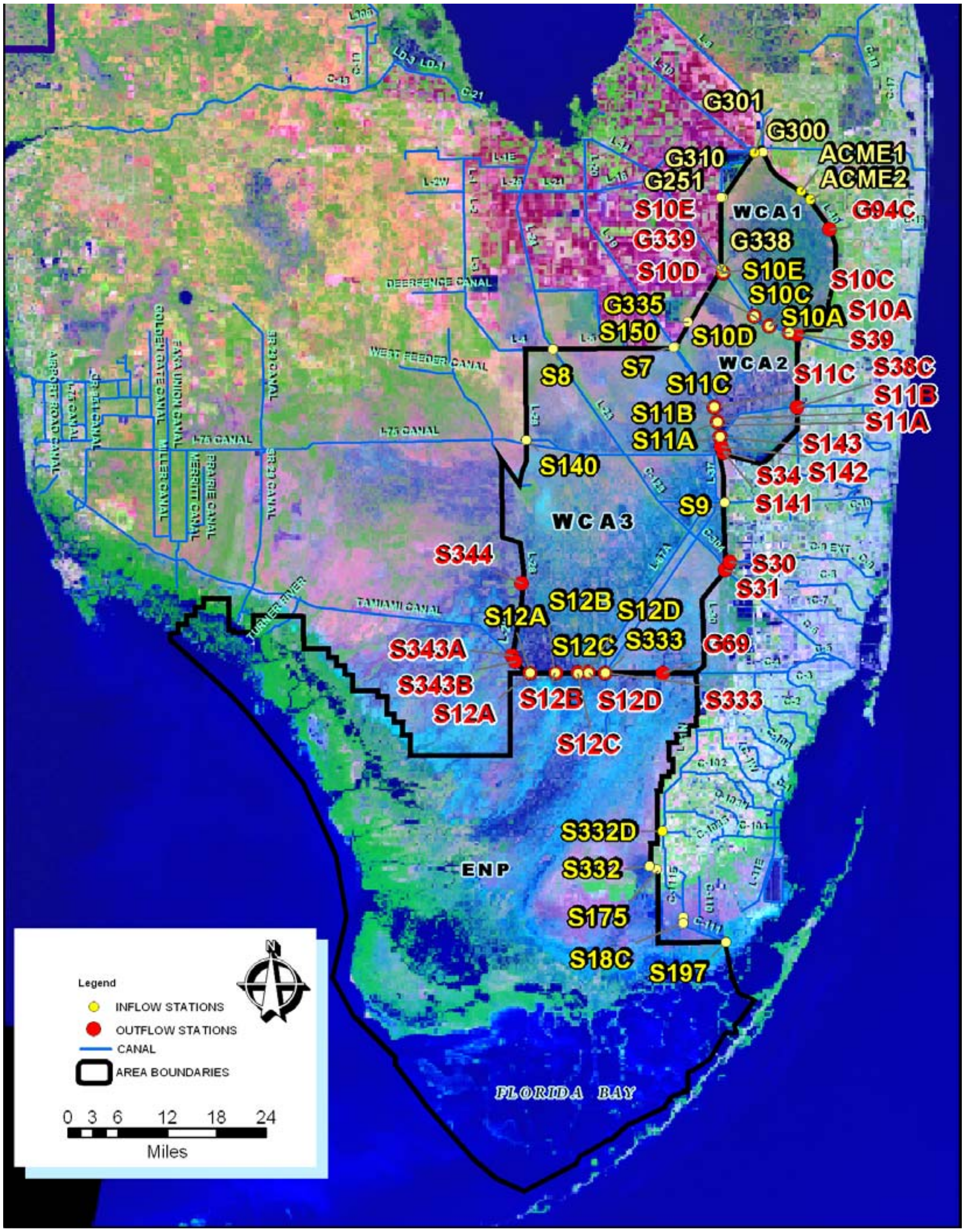

Figure 5-11. Everglades Protection Area (EPA) with flow stations used to compute inflows and outflows.

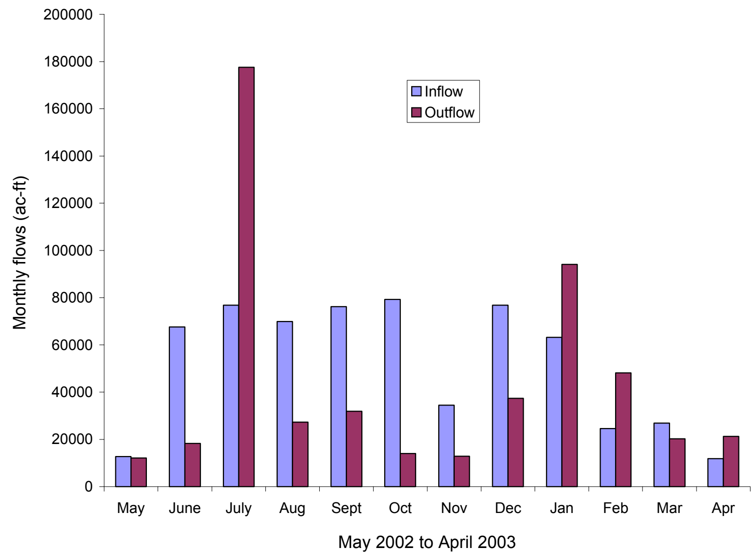

Figure 5-12. Inflows and outflows to WCA-1.

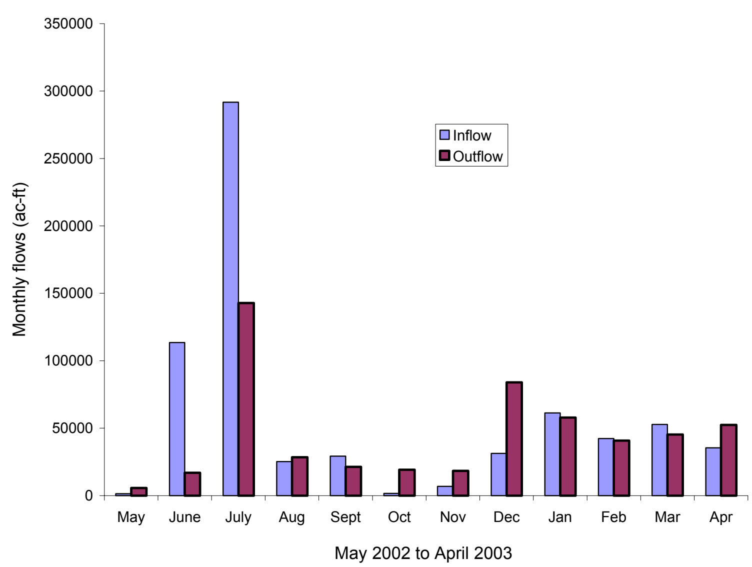

Figure 5-13. Inflows and outflows to WCA-2A.

The total inflow to WCA-3 for WY2003 was 1,073,727 ac-ft. The major inflows (33 percent) were from the EAA through structures S-8 and S-150. WCA-2A outflows through structures S-11A, B, and C are inflows to WCA-3 (29 percent). Discharges from the east through structure S-9 accounted for 25 percent. The S-140 structure to the northwest contributed 13 percent of the inflow to WCA-3A. Minor inflows were through structures G-69 and S-142. Monthly inflows to WCA-3A are shown in **Figure 5-14**. June, July, and August inflows to WCA-3 account for 56 percent of the water year's total inflow. There are ungauged inflows to WCA-3A through the L-4 borrow canal breach into the L-3 extension canal. The breach has a bottom of 150 ft at an elevation of 3.0 ft NGVD (SFWMD, 2002). Monthly inflows to WCA-3 by water control structure are shown in Appendix 5-3, Table 1.

Outflows from WCA-3A are mainly into Everglades National Park (ENP) through structures S-12A, B, C, and D (67 percent). S-333 discharged 22.5 percent, with potential directions of flow to south and east Miami-Dade County, Shark River Slough, and Taylor Creek of the ENP. Discharges into the North New River Canal through structure S-142 accounted for 5 percent of the total outflow. There are minor outflows through structures S-344 and G-69. The total outflow for WY2003 was 924,089 ac-ft. Monthly outflows to WCA-3A are shown in **Figure 5-14**. Monthly outflows from WCA-3 from each water control structure are shown in Appendix 5-3, Table 2.

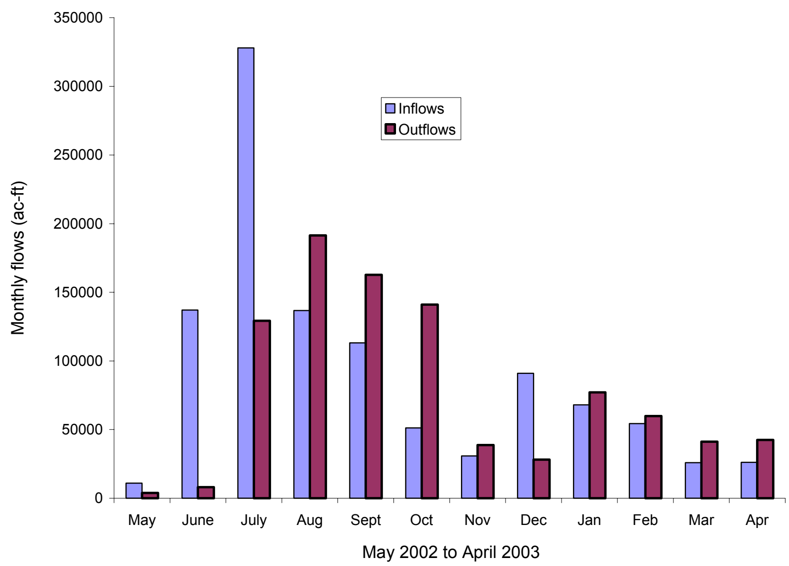

Figure 5-14. Inflows and outflows to WCA-3A.

Inflow into the Park is mainly through structures S-12A, B, C, D, and E, S-18, S-197, S-332, S-175, S-332D, S-333, and S-334. The major inflow (68 percent) was through the S-12 structures. These structures are operated by the South Florida Water Management District for the U.S. Army Corps of Engineers in accordance with the Rain-Driven Water Deliveries Plan to the ENP and the Regulation Schedule of WCA-3A. The rainfall-plan discharges through the S-333 and S-12A, B, C, and D structures are estimated a week in advance using a computer program. A weekly report is posted by SFWMD (http://www.sfwmd.gov/org/ema/reports/sharkriver/index.html). The objective of the rainfall plan is to restore a more natural hydroperiod and hydropattern in the northeast Shark River Slough. Also, structural and operational modifications were made on the delivery plan based on the Interim Operation Plan (IOP) for protection of the Cape Sable seaside sparrow (http://hpm.saj.usace.army.mil/i6ssueweb/Sparrow/fiopeis.htm). Flows through S-18 accounted for 15 percent of the total. Structures S-333 and S-332 contributed 15 percent, with S-197 adding 2 percent. The total surface water inflow to the Park for WY2003 was 913,207 ac-ft. Monthly inflows to the Park are shown in **Figure 5-15**. July, August, September, and October inflows to the Park accounted for 76 percent of the water year's total inflow. Monthly inflows to ENP by water control structure are shown in Appendix 5-4, Table 1.

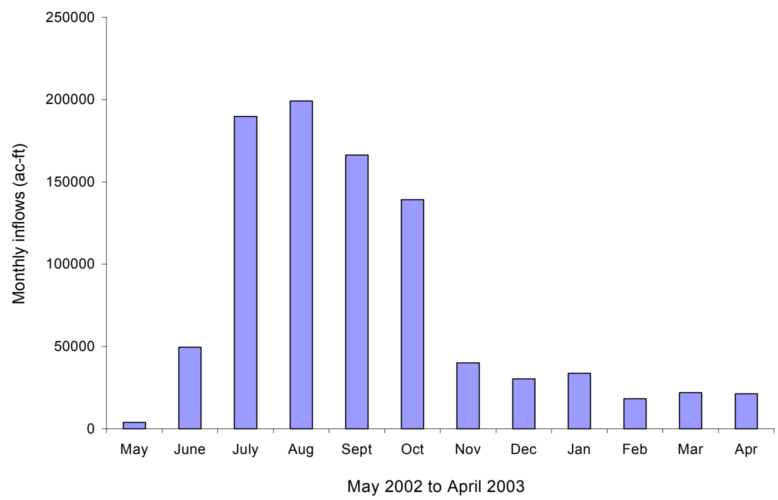

Figure 5-14. Inflows to Everglades National Park (ENP).

CONCLUSIONS

Rainfall in Water Conservation Areas 1 and 2 for Water Year 2003 was 14 percent below historical average. Water Conservation Area 3 rainfall was close to the average. Everglades National Park rainfall was slightly higher than historical average. Evapotranspiration was close to expected values. Water levels were generally higher than historical averages except in Water Conservation Area 2A. Major flows occurred during the wet season. In most cases, the highest flows were during the month of July. No major hydrologic events occurred during the water year. The recent drought (2000–2001) is over, and this year a minor El Niño was observed without a significant direct effect on the EPA. This report provides limited historical comparisons due to time limitations; it mainly concentrates on the current year reporting period.

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