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Droughts and Water-Shortages in the Humid Region of Central and South Florida

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by

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Droughts and Water-Shortages in the Humid Region of Central and South Florida

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Abstract

Droughts and water shortages have the potential to increase in severity and frequency as water demand increases in South Florida. A minimum of one severe drought in every decade can be expected. In 2000 and 2001, South Florida was under severe drought, resulting in water-use restrictions. The historical Palmer Drought Severity Index, annual rainfall, lake water levels, groundwater levels, stream flows and wildfire records mark occurrences of historical drought. Water-use restriction, water shortages and their effect on production and services can measure the magnitude of drought and water shortage. Water management decision-making process needs to incorporate drought monitoring. Rainfall deficit, the Palmer Drought Severity Index, climatological forecasts, surface and groundwater levels and water demand monitoring and forecasting are essential. A systems approach in water management is essential for effective drought and wildfire mitigation.

Introduction

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

The causes of droughts have three dimensions. The first dimension is change in the magnitude and temporal distribution of water sources, such as precipitation; the second is the change in amount and temporal variation of water use or demand; and the third is society's

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ability to develop and optimally manage an integrated water supply system. Historical comparison of hydrometeorologic data has to be coupled with historical changes in land use, water use (demand) and the water management system for comparative analysis of droughts. Drought impacts can be measured in loss of agricultural products, inadequate public water supply, loss of soil by wind erosion and subsidence, salt water intrusion into freshwater aquifers, fires and other economic losses associated with water use and ecological effects. This paper summarizes historical and current droughts and water shortages in Central and South Florida.

Historical Droughts. Droughts are relatively common phenomena in North America occurring almost every year in a portion of the United States (Kogan, 1995). In almost every decade major droughts occur. In Central and South Florida, severe droughts were reported in 1932, 1955-57, 1961-63, 1971-72, 1973-74, 1980-82, 1985, 1988-89, 1990 and 2000-2001 (Benson and Gardner, 1974; Lin et al., 1984; Marban et al., 1989; CSFFCD, 1972, 1974; SFWMD, 1985). Historical droughts and water shortages are marked by declines in lakes, reservoirs and groundwater levels, declines in rainfall and runoff, and increases in the number and magnitude of wildfires. Analysis of these parameters clearly indicates drought and water shortage occurrences and provides information for anticipation of future drought events and mitigation planning.

Central and South Florida Hydrologic System

Hydrologic System. The area under water resources management of the South Florida Water Management District extends from Orlando in Central Florida to the Florida Keys in the south (Figure 1). The center of the hydrologic system is Lake Okeechobee, with an area of 1,763 square km and a mean depth of 2.7 m. Historically, Lake Okeechobee attained a maximum water level of 5.72 m NGVD (November 2, 1947). The lowest recorded water level was set in the latest drought, reaching 2.73 m NGVD on May 24, 2001. The Lake provides water to the surrounding communities, the Everglades Agricultural Area (EAA) and the St. Lucie and Caloosahatchee basins. It replenishes canal levels in Palm Beach, Broward and Miami-Dade Counties, recharging surface and groundwater supplies. Lake Okeechobee has been managed under a regulation schedule that ranges between water supply and flood control. The history of water levels in the Lake are good indicators of wet conditions and drought. Low Lake levels correspond to historical droughts.

The Upper Kissimmee chain of lakes (Lakes Myrtle, Alligator, Mary Jane, Gentry, East Tohopekaliga, Tohopekaliga and Lake Kissimmee) is a principal sources of inflow to Lake Okeechobee. The Upper Kissimmee Watershed has an area of 4,139 square km (Guardo, 1992). Inflow into the Kissimmee River (C-38 canal) from Upper Kissimmee is, on the average 69 percent of the inflow into Lake Okeechobee through structure S65E at the northern end of the Lake. The Lower Kissimmee River Basin (1,887 square km) also contributes flow through S65E. The Lake Istokpoga Surface Water Management Basin (1,084 square km) drains into Lake Okeechobee, as well. Lake Istokpoga is a 112 square km shallow lake, with outflow through structure S68. The remaining major water sources of Lake Okeechobee are direct rainfall, Fisheating Creek, Taylor Creek-Nubbin Slough Basin, reverse flow from the Caloosahatche River, the St. Lucie Canal and reverse pumping from the Everglades Agricultural Area.

In the south, Water Conservation Areas WCA-1 (570 square km), WCA-2A (425 square km) and WCA-3A (1,989 square km) are part of the water storage and distribution system with specific regulation schedules. From north to south, flood control and water supply are regulated through three systems of canals, stormwater detention ponds, lakes, impoundments and water control structures.

Rainfall. The South Florida Water Management District is divided into 14 Rainfall Areas for operational purposes. The Rainfall Areas are shown in Figure 1. The region 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, which are extratropical 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 average rainfall in the South Florida Water Management District is 134 cm per year. Generally, June is the wettest month, followed by September. The wet season

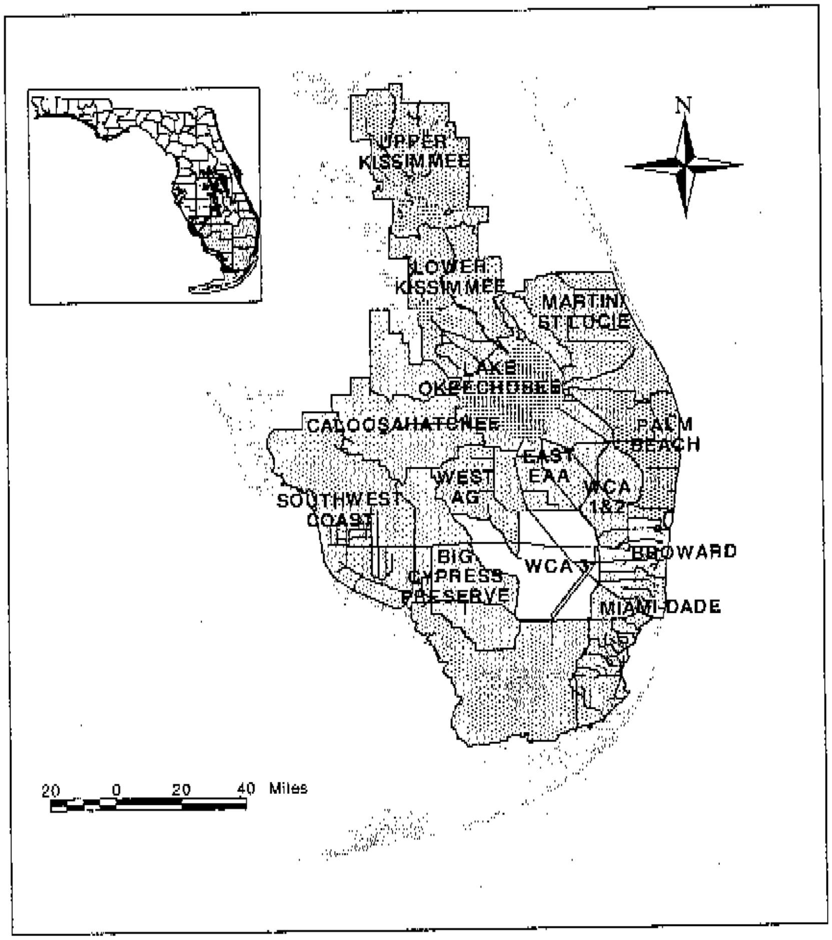

Figure 1. South Florida Water Management District Rain Areas.

lasts from June through October and accounts for 66 percent of the annual rainfall. The driest month is December, followed by January. Generally, runoff generated from the wet season rainfall and high rainfall events during the dry season is stored in ponds, lakes, impoundments and aquifers. Excess water is discharged to the ocean to control flooding. At times, critical decision making is required to manage flooding and avoid potential water shortages. Both water shortage and flooding have the potential to occur in any month of the year. Dry periods in Florida result from stable atmospheric conditions, which are often associated with high-pressure systems (Winsberg, 1990). This condition can occur in any season, but is more common in winter and spring.

The Palm Beach Rain Area has the highest rainfall, followed by Broward and Miami-Dade Rain Areas. It can be concluded that the East Coast gets more rain than either inland or the West Coast of the District area (Ali and Abtew, 1999). Even during drought years, there were cases where the coastal rainfall was close to or above average. This was indicated by Palm Beach Rain Area rainfall in 1931, 1932 and 1972; Miami-Dade Rain Area rainfall in 1931; and Broward Rain Area rainfall in 1962 and 1967. Since there are no large impoundments in the coastal urban area, runoff is discharged to the ocean. The historical rainfall record of each rainfall area indicates that drought years have a significant decline from the mean annual rainfall. Figures 2 and 3 depict historical annual rainfall for the Upper Kissimmee and Miami-Dade Rain Areas, respectively. They also show the rain area annual average rainfall amounts and regional drought years. Figure 4 depicts rainfall deficit for each Rain Area for the 2000 drought and the frequency of occurrence in years of return period. Fifteen percent or higher annual rainfall deficit would result in drought. Temporal and spatial distribution of rainfall and water management are also additional factors that determine availability of water. Table 1 depicts monthly average hydrologic parameters.

Table 1. Monthly District area average rainfall and Lake Okeechobee water level, inflow and outflow.

Month	Rainfall cm	Water Level m NGVD	Inflow ha-m	Outflow ha-m
January	5.59	4.29	16,453	13,013
February	5.99	4.22	18,129	16,541
March	7.45	4.36	20,635	22,245
April	6.55	4.31	15,810	26,901
May	11.84	4.14	13,332	18,864
June	19.94	4.02	18,014	9,153
July	17.73	4.09	26,266	7,338
August	17.86	4.17	36,195	10,185
September	18.36	4.27	35,892	6,353
October	11.99	4.46	22,863	9,981
November	5.84	4.54	11,912	10,645
December	4.83	4.48	10,477	9,967

Palmer Drought Severity Index

The Palmer Drought Severity Index (PDSI) is used to monitor long-term drought conditions occurring over a period of several months (Palmer, 1965). The method uses antecedent moisture condition, precipitation, temperature, field capacity and weather trends to compute an index value. Near-normal conditions are represented by an index value between ± 0.49; severe droughts have an index value of -3.0 or less. Index values are maintained by the National Climatic Data Center (NCDC) of the National Oceanic and Atmospheric Administration (NOAA). Monthly values are available back to 1895.

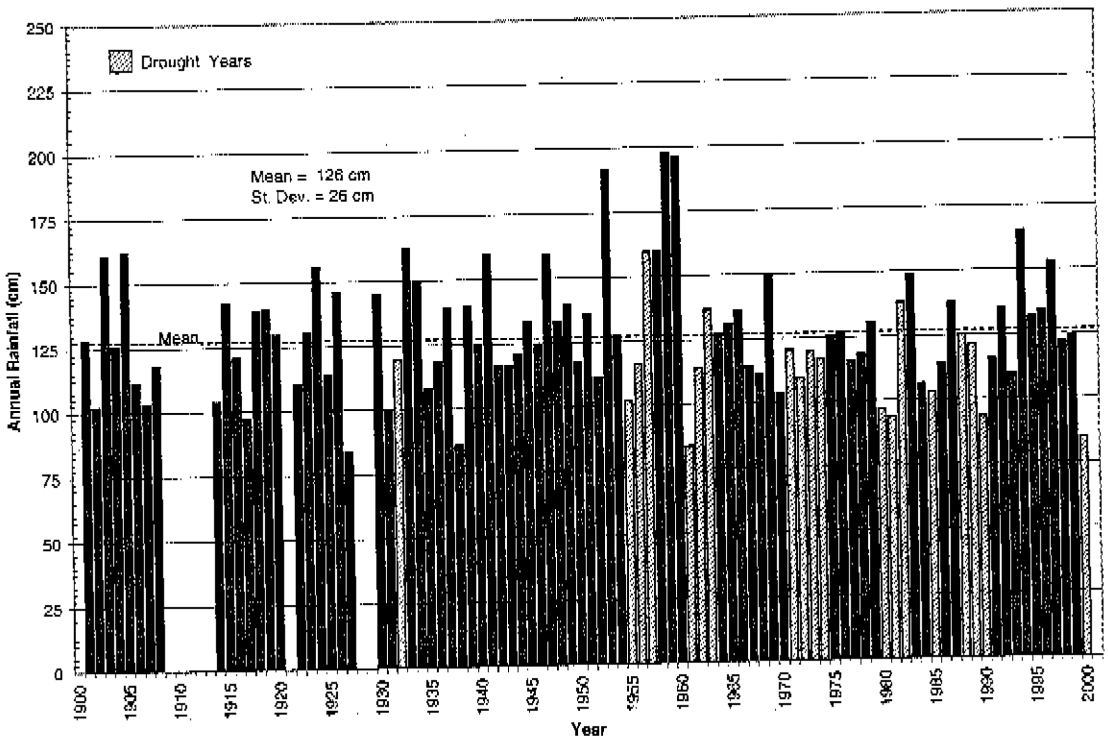

Figure 2. Historical annual rainfall for Upper Kissimmee Rain Area and regional drought years.

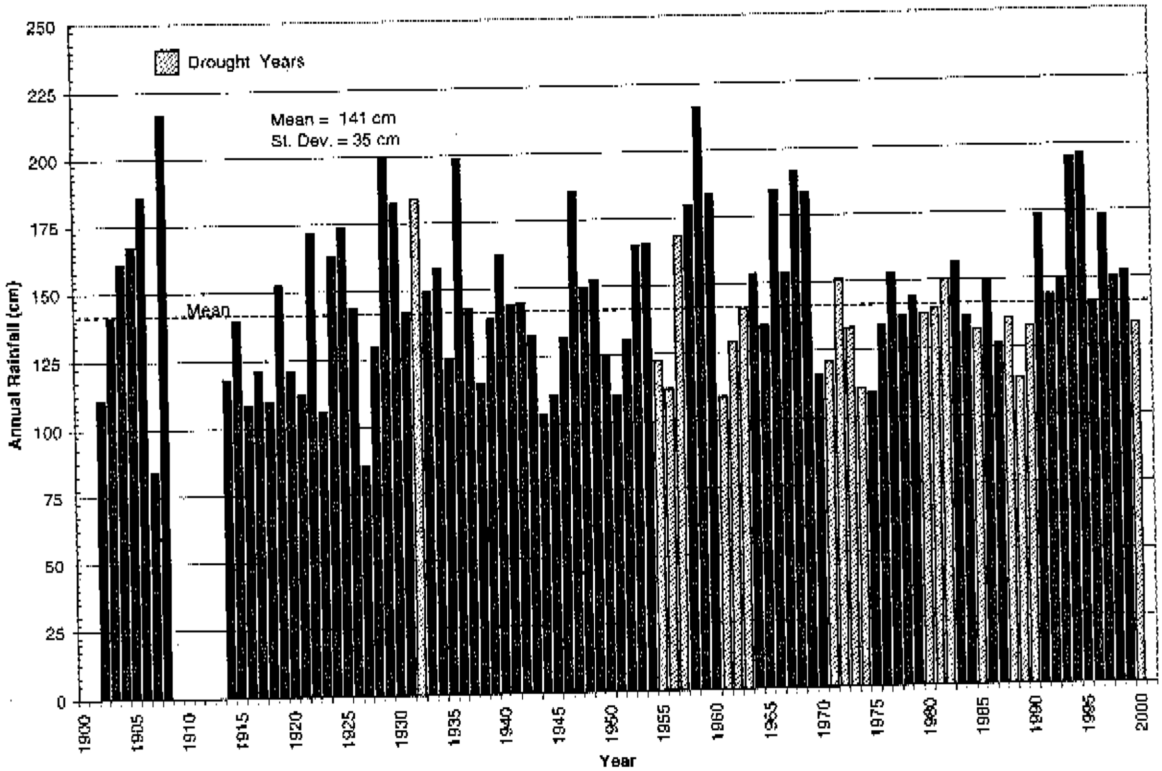

Figure 3. Historical annual rainfall for Miami-Dade Rain Area and regional drought years.

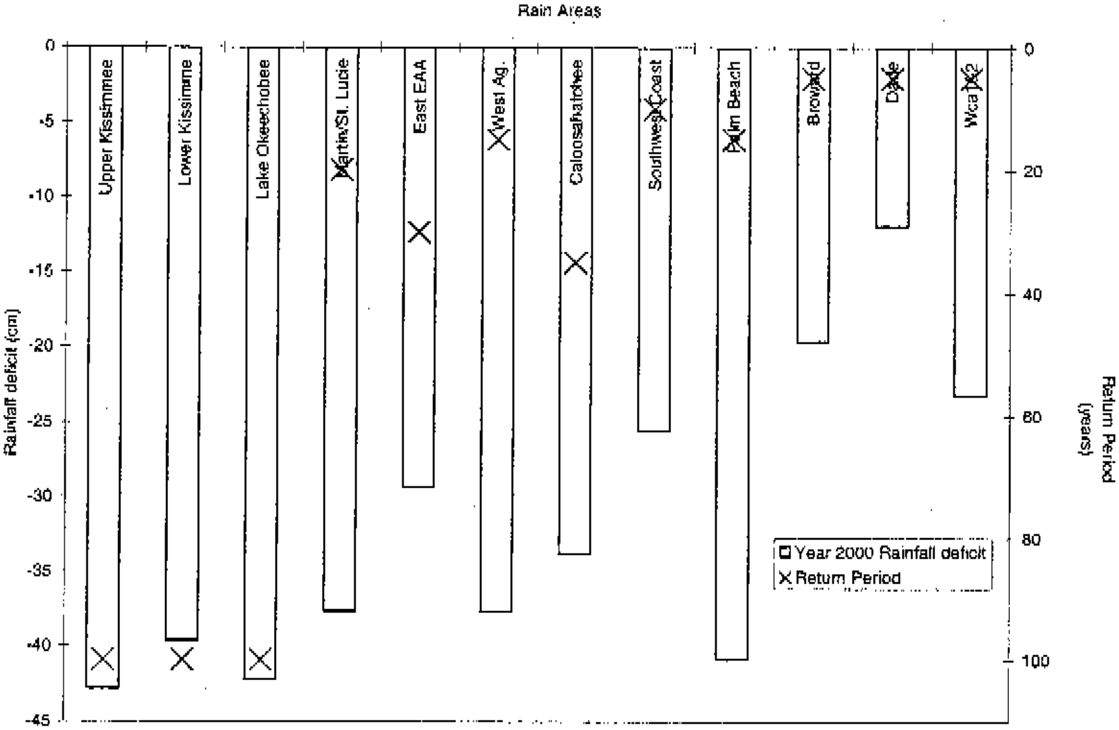

Figure 4. Rainfall deficit for each Rain Area for 2000.

The index is standardized to local conditions, allowing it to be used nationally for drought reporting. It is applied to 350 climatic divisions in the United States and Puerto Rico. Florida has seven climatic divisions. The South Florida Water Management District is in Florida Divisions 3 through 7 (Figure 5). Figure 6 shows the index values for the five divisions covering the District at the onset of the latest drought through February 2001. The drought index started declining at the end of 1999 and has been most severe in Division 3, the region covering the Upper Kissimmee area. Actually, the index for the Upper Kissimmee area has been showing drought since the spring of 1998. Two of the divisions, those covering Upper Kissimmee and Lower Kissimmee areas, have recently experienced extreme drought conditions.

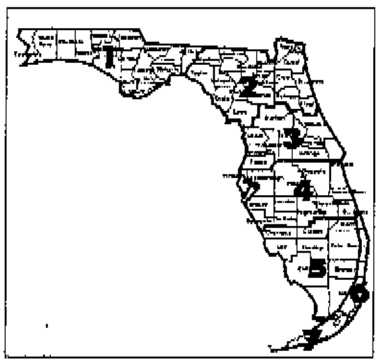

Figure 5. Florida climatic divisions (NOAA, Climatic Prediction Center).

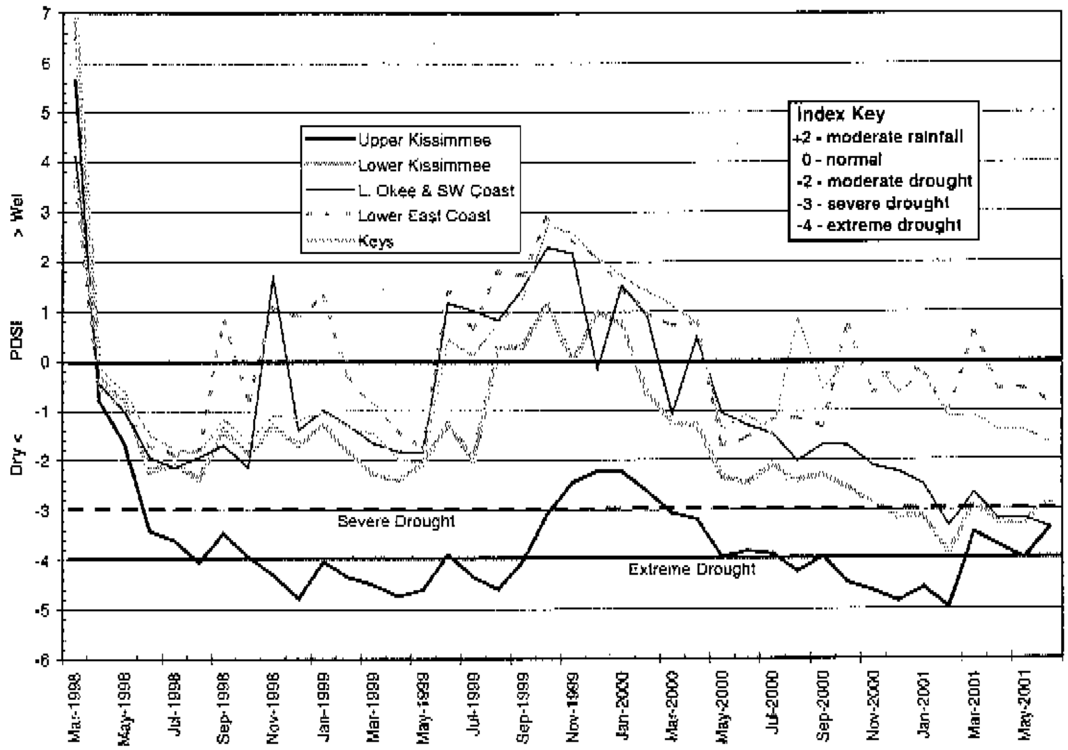

Figure 6. Palmer drought severity index – Florida climatic divisions 3, 4, 5, 6 and 7 March 1998 – June 2001.

Figure 7 shows the PDSI for the entire period of record for Division 3 (Upper Kissimmee area). As shown in Figure 6, this climatic division has had the longest and most severe drought during the current period. The last time this area experienced an extreme drought was in 1932. Severe and extreme droughts are marked.

Wildfires

One of the significant impacts of drought on natural resources is the creation of conditions which promote the spread of wildfires. Figure 8 shows the number of hectares burned per year as the result of wildfires for the period 1981-2000 (Florida DOACS, Division of Forestry, 2001). The values are for all causes of wildfires, including those that were anthropogenic. The largest number of hectares burned corresponds directly to drought years 1981, 1985, and 1989. The effects of the La Niña weather pattern, which brought lower than expected rainfall to the District in 1998, are also shown in Figure 8, although there was no declared drought that year.

Water Levels

Water levels in lakes and reservoirs are gages for drought and water-shortage conditions. Water-level data for Lake Okeechobee is available since 1931 (Figure 9). The minimum Lake level for the period of record of 2.73 m NGVD was reached on May 24, 2001. The maximum water level

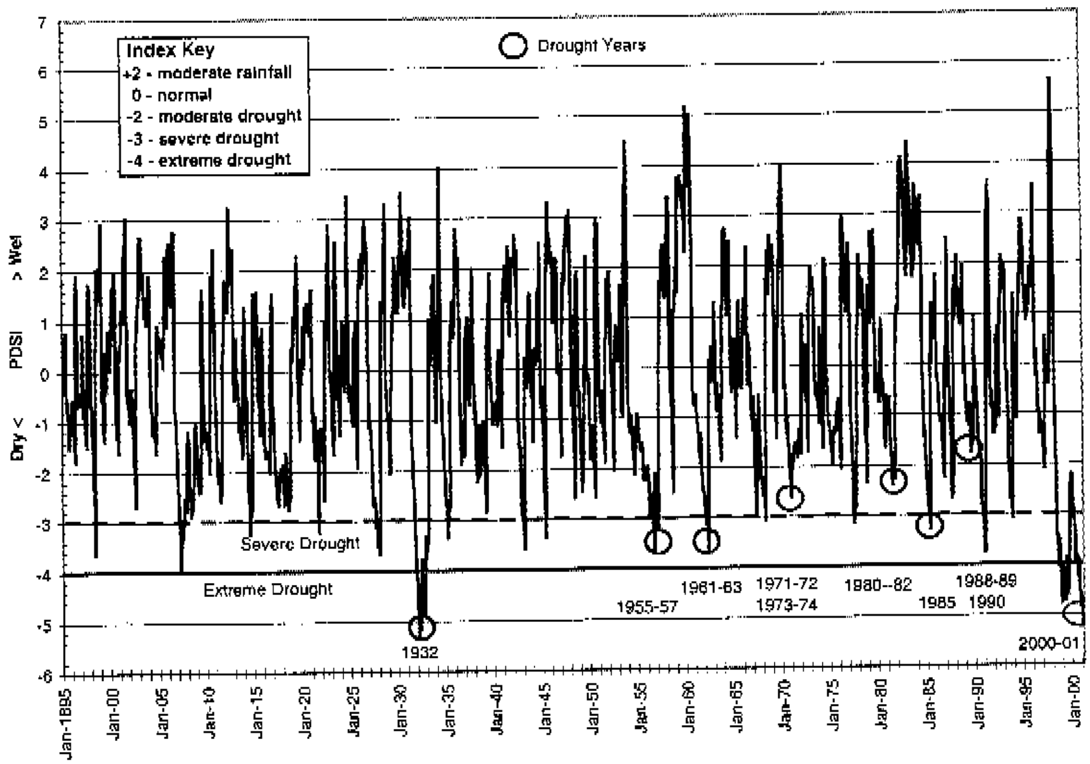

Figure 7. Palmer drought severity index – Florida climatic division 3 (Upper Kissimmee Area), 1895-2001.

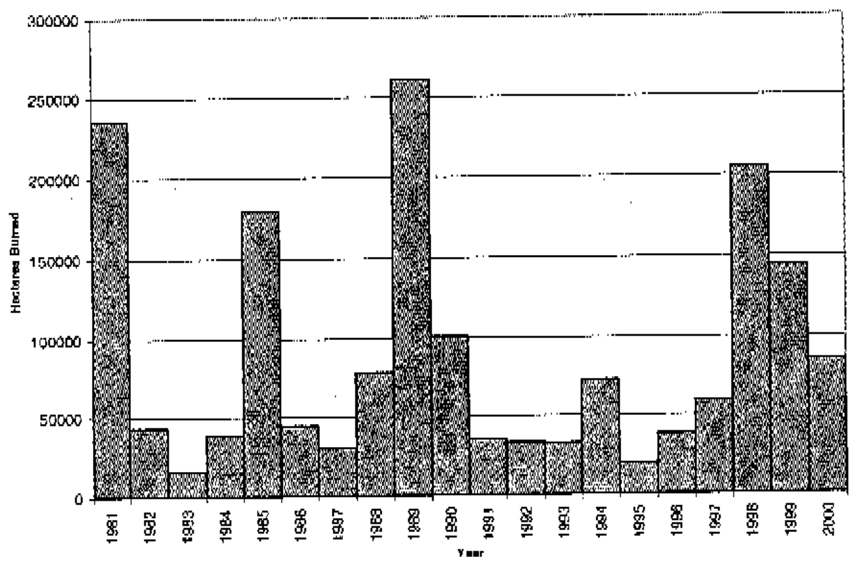

Figure 8. Area burned per year by wildfires in Florida.

of 5.72 m NGVD was reached on November 2, 1947. The Lake water level was at or below 3.35 m NGVD for 3 percent of the days since 1931. Figure 10 shows the number of consecutive days the Lake was below 3.35 m NGVD; the longest, 194 days, occurred in 2001.

Analysis of these data shows the periods of drought and water shortage. The consecutive number of days the Lake stage has been below 3.35 m NGVD matches the drought years (Figure 10). A stage decline of two standard deviations from the mean can be taken as a measure of the criticality of Lake Okeechobee storage decline. Also, the number of days below a given stage (ex. 3.35 m NGVD) can be used as a measure of the criticality of Lake Okeechobee storage decline.

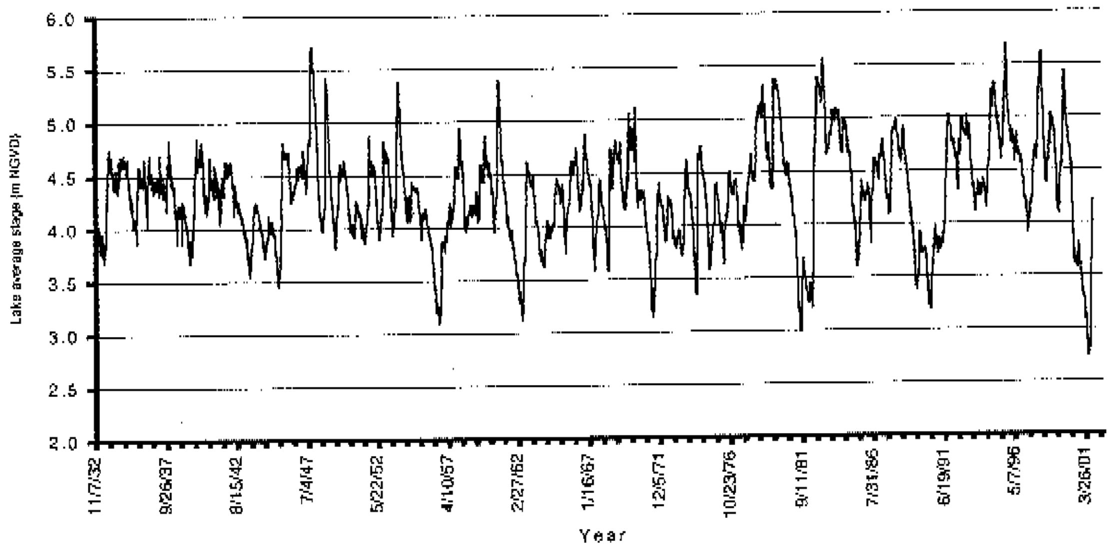

Figure 9. Average daily water level for Lake Okeechobee.

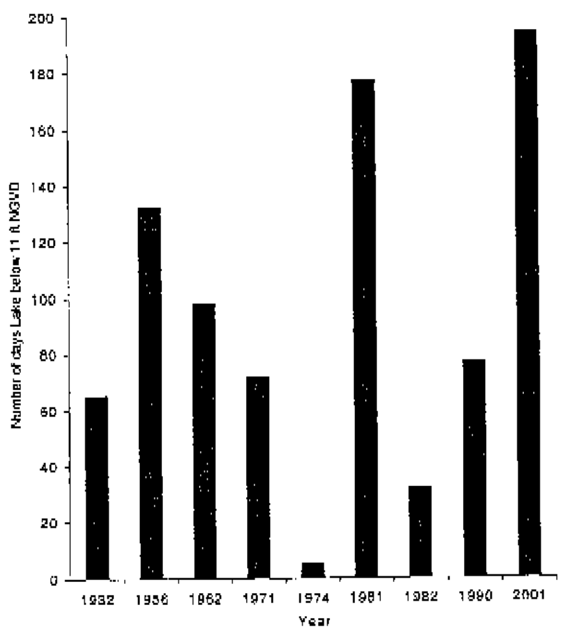

Figure 10. Number of days Lake Okeechobee water level was below 3.35 m NGVD.

Flows

The main storage component in the South Florida hydrologic system is Lake Okeechobee. Inflows come from the Upper and Lower Kissimmee watersheds, Nubin Slough and Taylor Creek basins, Lake Istokpoga Water Management Area, Fisheating Creek, the Caloosahatchee Canal, the St. Lucie Canal, the Everglades Agricultural Area and other smaller drainage basins. Major surface inflows are from Upper and Lower Kissimmee Watersheds through structure S65E (47.8 percent), Lake Istokpoga Water Management Area (9.1 percent), Fisheating Creek (8.4 percent), reverse flows from the Everglades Agricultural Area, Caloosahatchee Canal and St. Lucie Canal (16.1 percent) and 18.6 percent from other structures around the Lake. Based on 1972-2000 inflow data from the north and northwest, and reverse inflow from the south, southwest and southeast, the average total annual inflow was 245,989 ha-m, with a maximum of 409,542 ha-m, a minimum of 34,433 ha-m and a standard deviation of 104,430 ha-m. Average annual reverse inflow from the EAA, Caloosahatchee Canal and St. Lucie Canal was 39,604 ha-m, with a standard deviation of 17,750 ha-m. Outflows are mainly through the south, southeast and southwest structures. From 1972 to 2000, the average annual outflow was 161,187 ha-m, with a standard deviation of 103,363 ha-m; maximum annual outflow was 465,213 ha-m, and minimum was 38,784 ha-m. Monthly mean historical inflows and outflows are depicted in Table 1. Figure 11 depicts historical annual inflows and outflows for Lake Okeechobee.

Drought Mitigation

It is important to develop a drought-monitoring system that will serve as an alert to the imminence of drought and incorporate drought management as part of water supply planning and operational decision making. At the onset of drought, the impact can be reduced by implementing drought-mitigation measures. The three classifications of drought mitigation measures are: a) increasing supply, b) reducing demand and c) minimizing the impact (Rossi, 2000). Increasing the supply includes relaxation of minimum and maximum lake levels, developing new or less-used sources, reuse of water, etc. Demand reduction includes water-use restrictions, water conservation methods application, etc. Impact minimization includes temporary reallocation of water resources, subsidy, etc.

Summary

Droughts and water shortages have the potential to increase in severity and frequency as the water demand increases in South Florida. A minimum of one severe drought in every decade can be expected. Water management decision-making process needs to incorporate drought monitoring with recurrence probability. Rainfall deficit, the Palmer Drought Severity Index, climatological forecasts, surface and groundwater levels and water-demand monitoring and projection are essential. A systems approach to water management is essential for effective mitigation of drought and wildfire.

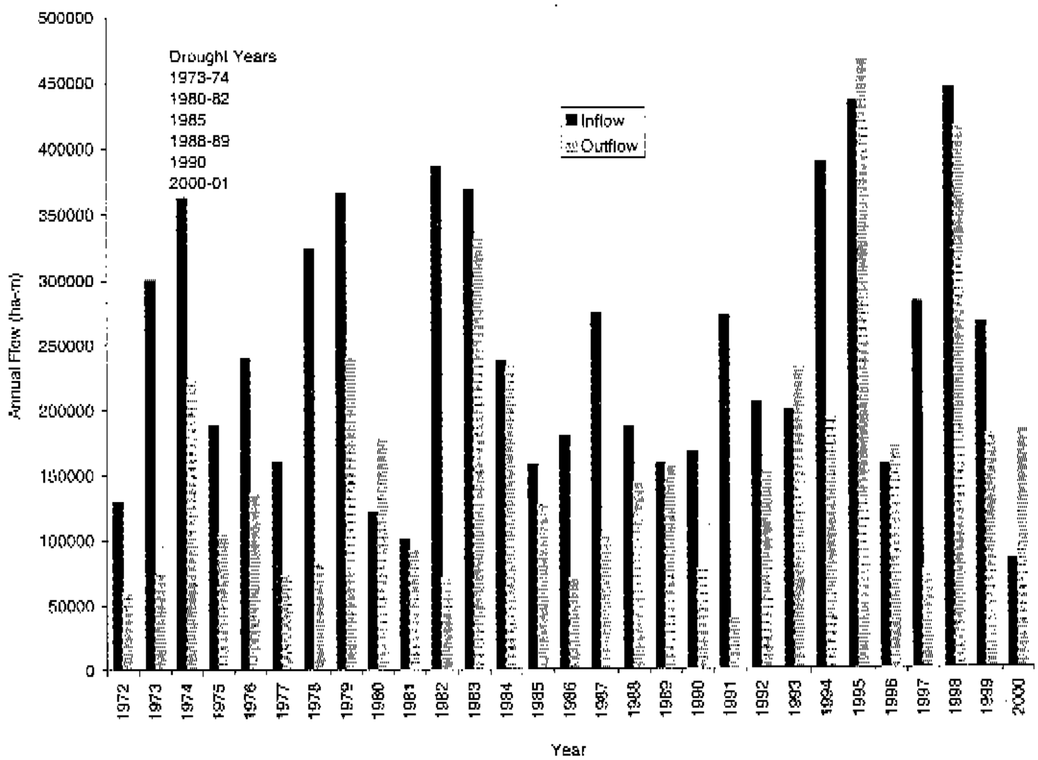

Figure 11. Annual inflows and outflows for Lake Okeechobee.

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