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Droughts and Water Shortages in Central and South Florida

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by

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ABSTRACT

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. Currently, South Florida is under drought. Historical Palmer Drought Severity Index, annual rainfall, lake water levels, groundwater levels, stream flows and wild fire records mark occurrences of historical drought. Water management decision making needs to incorporate drought monitoring. Rainfall deficit, Palmer Drought Severity Index, climatological forecasts, surface and groundwater levels and water demand monitoring are essential. A systems approach is needed to effectively deal with wild fire mitigation, drought and water management.

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. Broadly, the water source could be soil moisture, rainfall, snow pack, stream flow, groundwater and surface water storage. Droughts are classified as agricultural, meteorologic, hydrologic and water management (Subrahmanyam, 1967; Benson and Gardner, 1974). Agricultural drought is an evapotranspiration deficit (Palmer, 1965). Agricultural drought is also characterized as short-term moisture deficiency in the shallow plant root zone. Meteorologic drought occurs when an extended period of below normal precipitation prevails. Hydrologic drought is the result of 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 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 1 to 3 months is short term; 4 to 6 months is intermediate and more than six months is considered long term (Golden and Lins, 1986).

The causes of droughts have three components. The first component 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 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, salt water intrusion into freshwater aquifers, fires, other economic losses associated with water use and ecological effects. This report summarizes historical and current droughts and water shortages in Central and South Florida.

CENTRAL AND SOUTH FLORIDA HYDROLOGIC SYSTEM

Historical Droughts

Droughts are a relatively common phenomena in North America occurring almost every year in a portion of the United States (Kogan, 1995). Almost every decade had major droughts. 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, 2000-01 (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 wild fires. Analysis of these parameters clearly indicates drought and water shortage occurrences and provide information for anticipation of future drought events.

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 (Figure 1). The center of the hydrologic system is Lake Okeechobee with an area of 680 square miles and a mean depth of 8.86 ft. Historically, Lake Okeechobee attained a maximum water level, 18.76 ft NGVD (November 2, 1947). The lowest water level record is being set in the current drought reaching 8.97 ft NGVD on May 24, 2001. The Lake provides water to the surrounding communities, the Everglades Agricultural Area, to the St. Lucie and Caloosahatchee basins, and replenishes canal levels in Palm Beach, Broward and Miami-Dade Counties. 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, Tohopokaliga and Lake Kissimmee) are principal sources of inflow to Lake Okeechobee. The Upper Kissimmee Watershed has an area of 1596 square miles (Guardo, 1992). Inflow into the Kissimmee River (C-38 canal) at structure S65 is on the average 69 % of the inflow into Lake Okeechobee through structure S65E at the northern end of the lake. The Lower Kissimmee River basin (727 square miles) also contributes flow through S65E. The Lake Istokpoga Surface Water Management Basin (418 square miles) drains into Lake Okeechobee as well. Lake Istokpoga is a 43.27-square mile shallow lake with outflow through structure S68 into the Surface

Water Management Basin. The remaining major water sources of Lake Okeechobee are direct rainfall, Fisheating Creek, Taylor Creek-Nubbin Slough Basin, reverse flow from Caloosahatche River, St. Lucie Canal and reverse pumping from the Everglades Agricultural Area.

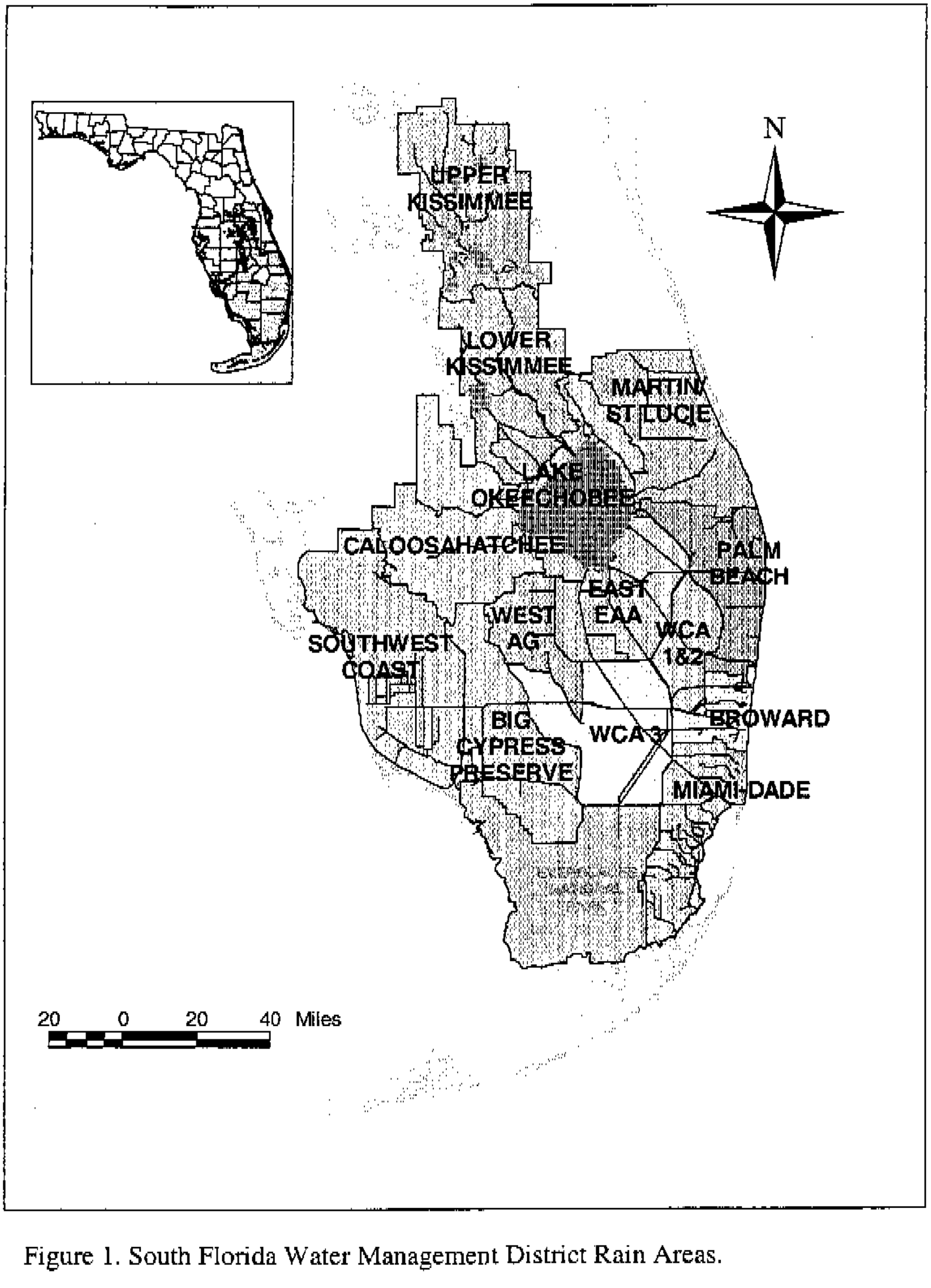

Figure 1. South Florida Water Management District Rain Areas.

In the south, Water Conservation Areas WCA1 (220 square miles) WCA2A (164 square miles) and WCA3A (767 square miles) 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 average rainfall in the South Florida Water Management District is 52.8 inches per year. Monthly rainfall statistics for 12 of the rainfall areas is shown in Table 1. Generally, June is the wettest month, followed by September. The wet season lasts from June through October and accounts for 66 % 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 has potential to occur in any month of the year.

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 the inland and West Coast of the District area. 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, 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 could result in drought. Temporal and spatial distribution of rainfall and water management are also additional factors that determine availability of water.

Table 1. Monthly average rainfall (inches) for each Rainfall Area and the District (Ali and Abtew, 1999).

Month	Upper Kissimmee	Lower Kissimmee	Lake Okeechobee	Martin/ St. Lucie	East EAA	West AG	Caloosa-hatchee	Southwest Coast	Palm Beach	Broward	Dade	WCA1&2	District
January	2.25	1.85	1.85	2.48	2.04	2.48	1.76	1.92	3.03	2.18	2.09	2.25	2.2
February	2.64	2.37	2	2.56	1.94	2.39	2.06	2.15	2.74	2.26	2.01	2.29	2.36
March	3.18	2.76	2.95	3.1	2.78	3.04	2.74	2.46	3.36	2.46	2.28	2.54	2.94
April	2.55	1.92	2.38	3.02	2.76	2.53	2.59	2.21	3.29	3.06	3.02	2.49	2.58
May	4.08	3.84	4.03	4.53	4.77	4.36	4.27	4.03	5.19	5.46	6.06	5.22	4.66
June	7.28	7.26	6.92	6.51	8.41	9.58	8.52	9.13	8.1	8.35	8.28	8.19	7.85
July	7.44	6.58	6.06	6.11	7.5	8.15	7.36	8.73	6.46	6.53	6.21	6.16	6.98
August	6.87	6.2	6.37	6.15	7.61	7.54	7.48	8.26	6.92	7.18	6.99	6.38	7.03
September	6.37	5.33	6.49	7.86	7.61	7.25	7.18	8.2	8.41	7.96	8.32	6.44	7.23
October	3.24	3.07	3.83	6.77	4.29	3.83	3.78	4.05	7.8	7.39	7.32	5.04	4.72
November	2.17	1.84	1.58	2.96	2.06	1.84	1.58	1.55	3.77	3.14	2.78	2.91	2.3
December	2.02	1.43	1.51	2.09	1.71	1.96	1.36	1.43	2.47	2.16	1.75	2.05	1.9
YEAR	50.09	44.45	45.97	54.14	53.48	54.95	50.68	54.12	61.54	58.13	57.11	51.96	52.75

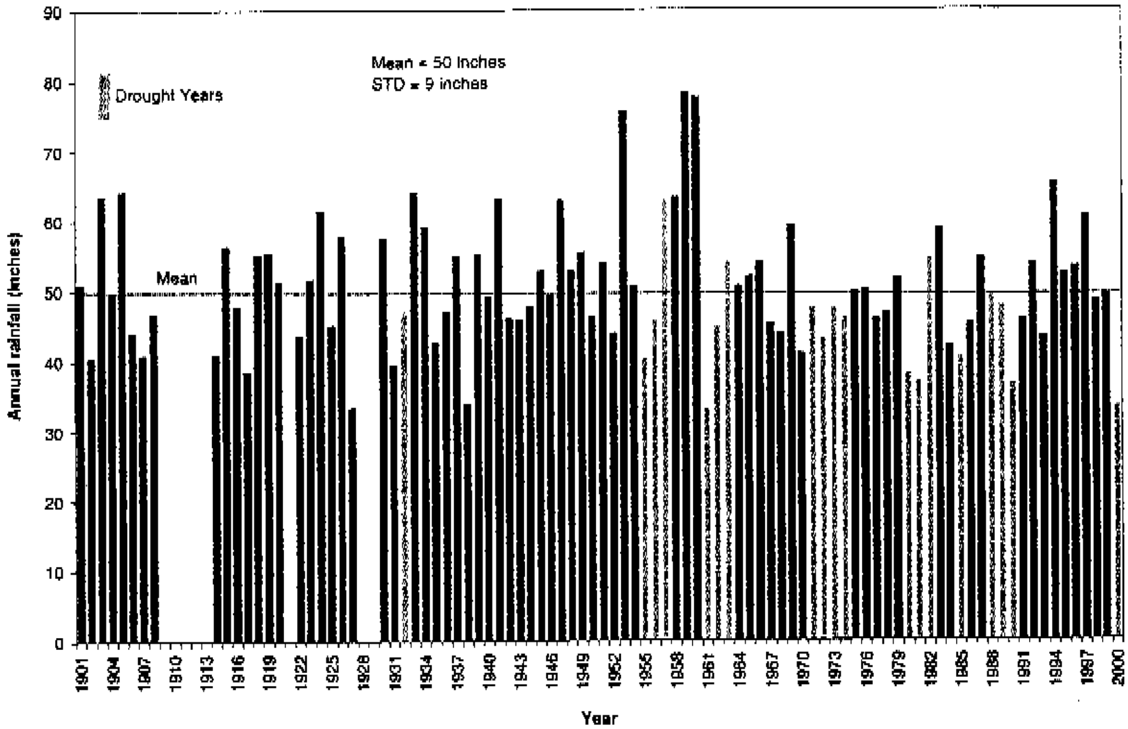

Figure 2. Historical Annual Rainfall for Upper Kissimmee Rain Area and Regional Drought Years.

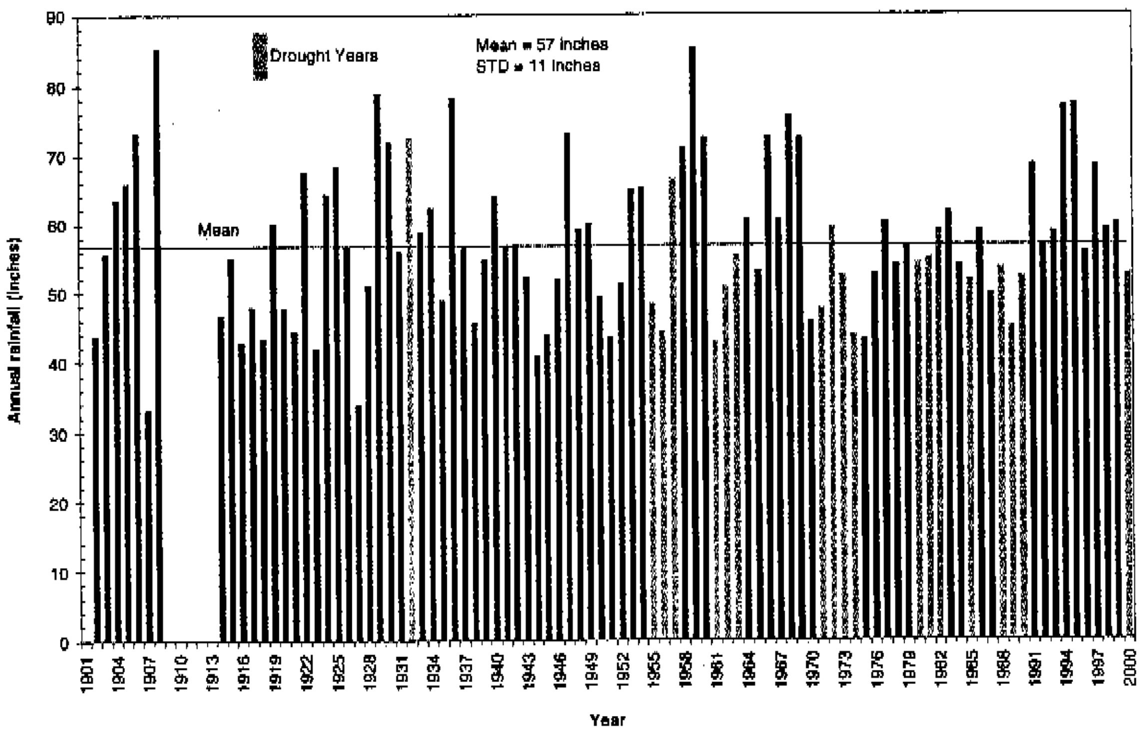

Figure 3. Historical Annual Rainfall for Miami-Dade Rain Area and Regional Drought Years.

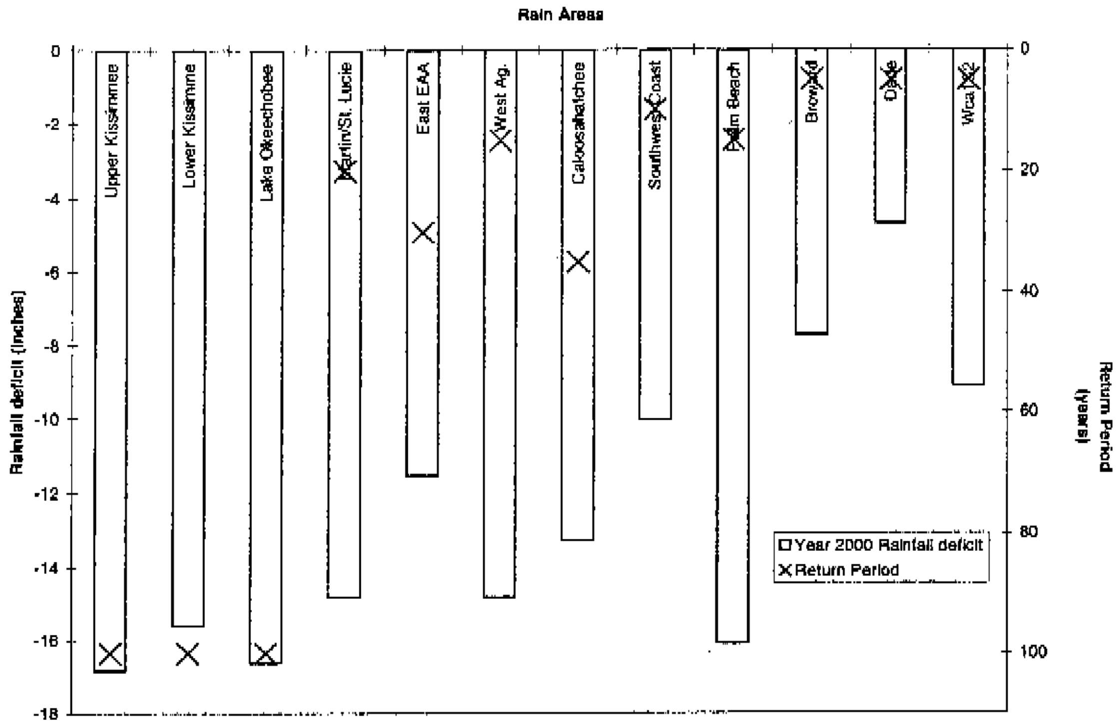

Figure 4. Rainfall Deficit for each Rain Area for Year 2000.

Palmer Drought Severity Index

The Palmer Drought Severity Index (PDSI) is used to monitor long-term drought conditions, those 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.

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 current 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 Upper Kissimmee area has been showing drought since the spring of 1998. Two of the divisions, those covering Upper Kissimmee and Lower Kissimmee areas are currently experiencing extreme drought conditions.

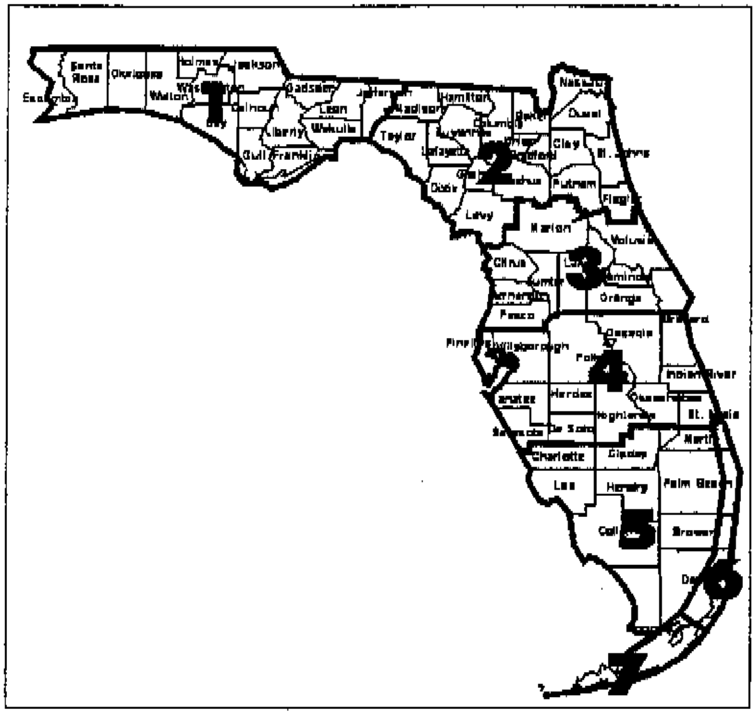

Figure 5. Florida Climatic Divisions (NOAA, Climatic Prediction Center).

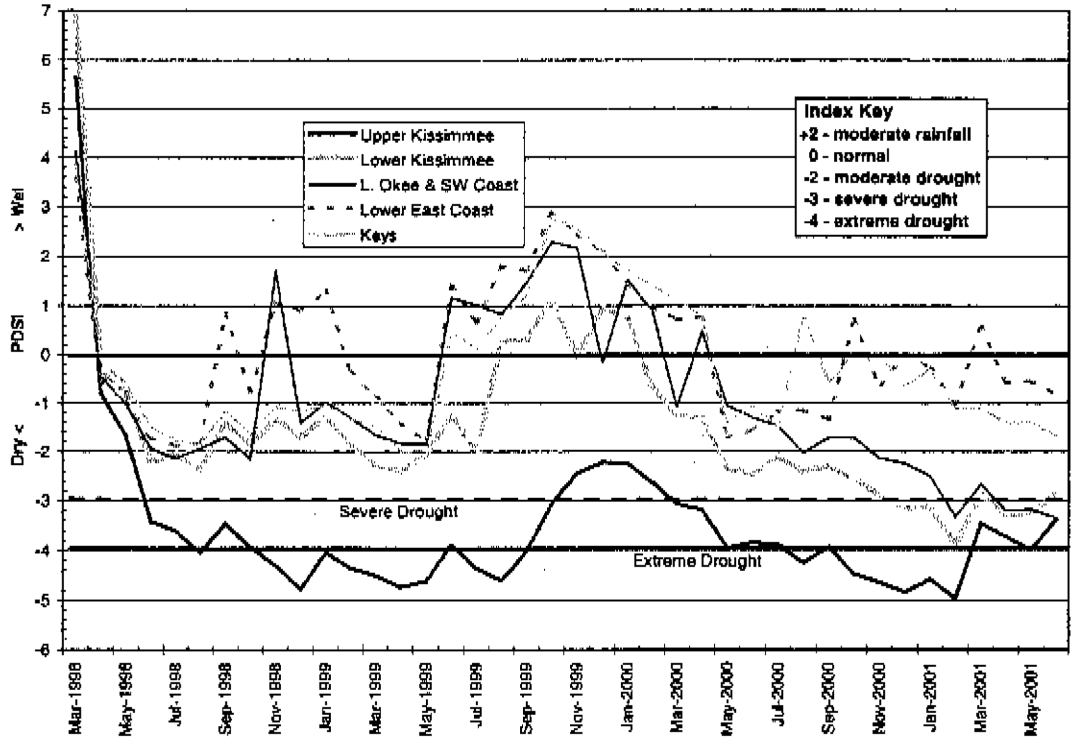

Figure 6. Palmer Drought Severity Index – Florida Climatic Divisions 3, 4, 5, 6 and 7 March 1998 – June 2001.

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 that this area experienced an extreme drought was in 1932. The variation in PSDI from 1895 to present for the Lower Kissimmee (Division 4), Lake Okeechobee, the Lower West Coast, the Agricultural (Ag) Areas and the Everglades (Division 5), the Lower East Coast (Division 6) and the Florida Keys (Division 7) is shown in Figures 8 through 11. Severe and extreme droughts are marked.

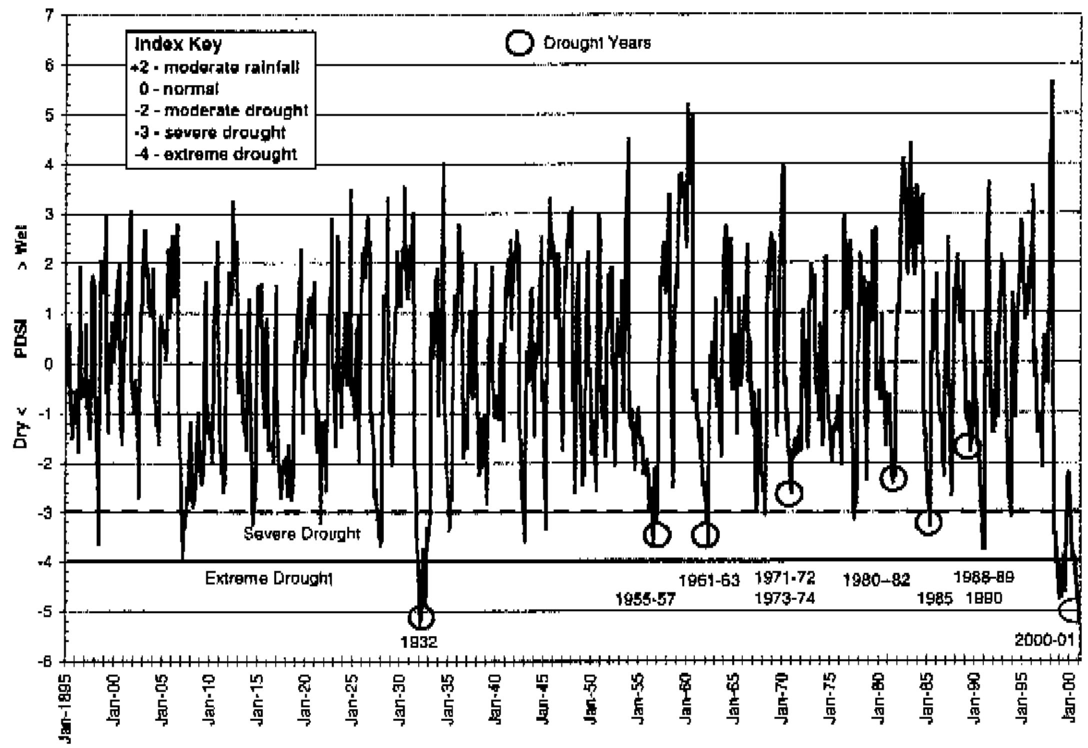

Figure 7. Palmer Drought Severity Index – Florida Climatic Division 3 (Upper Kissimmee Area) 1895-2001.

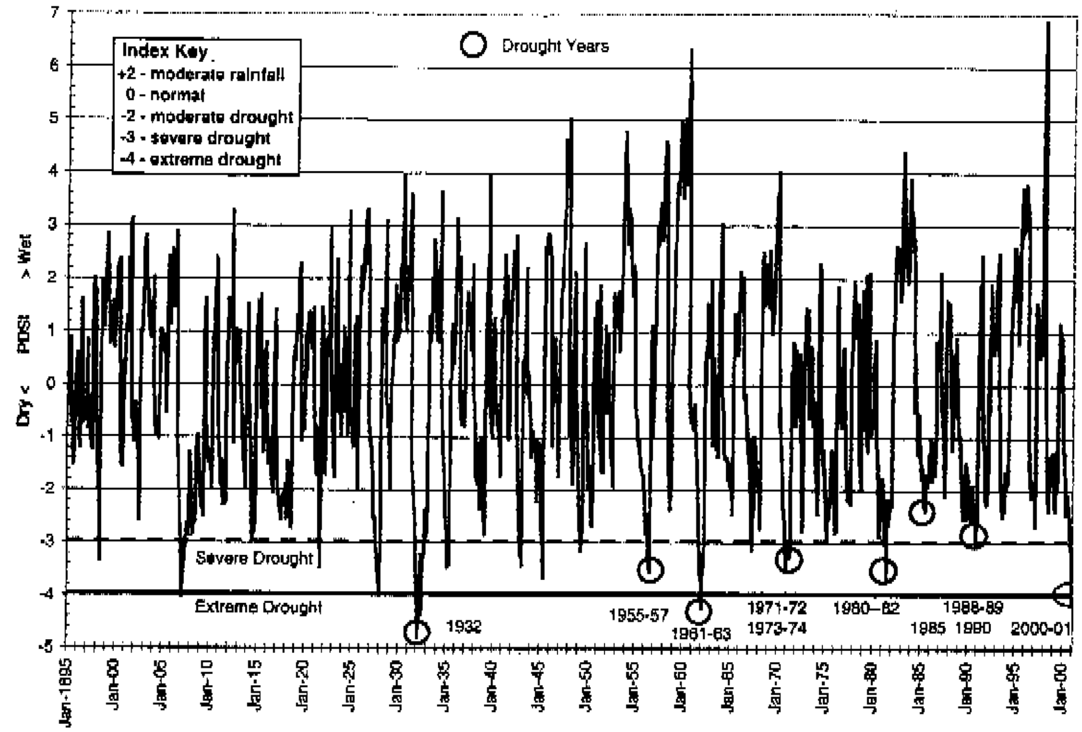

Figure 8. Palmer Drought Severity Index – Florida Climatic Division 4 (Lower Kissimmee Area) 1895-2001.

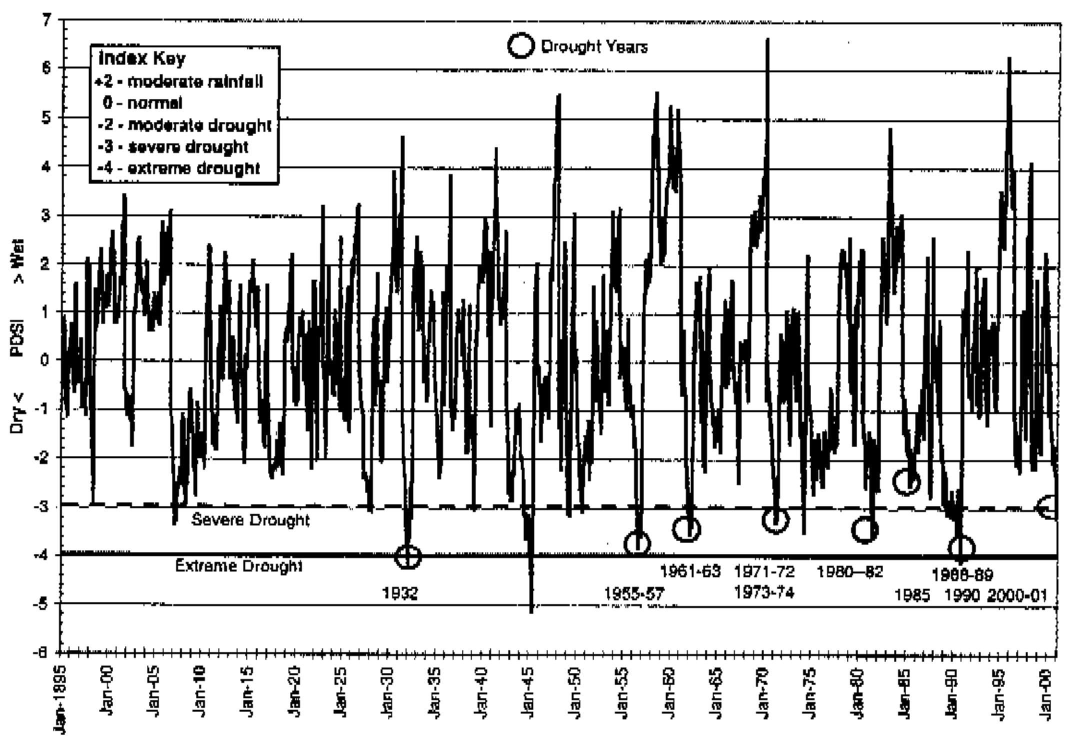

Figure 9. Palmer Drought Severity Index – Florida Climatic Division 5 (Lake Okeechobee, the Lower West Coast, the Agricultural (Ag) Areas and the Everglades) 1895-2001.

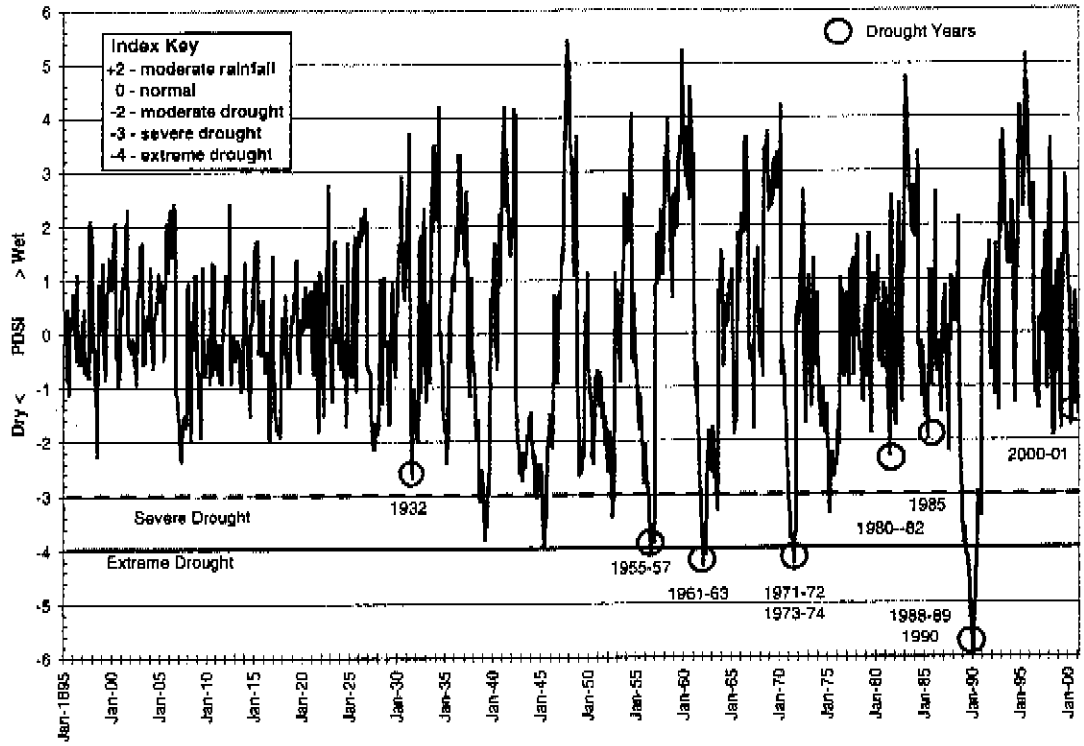

Figure 10. Palmer Drought Severity Index – Florida Climatic Division 6 (Lower East Coast) 1895-2001.

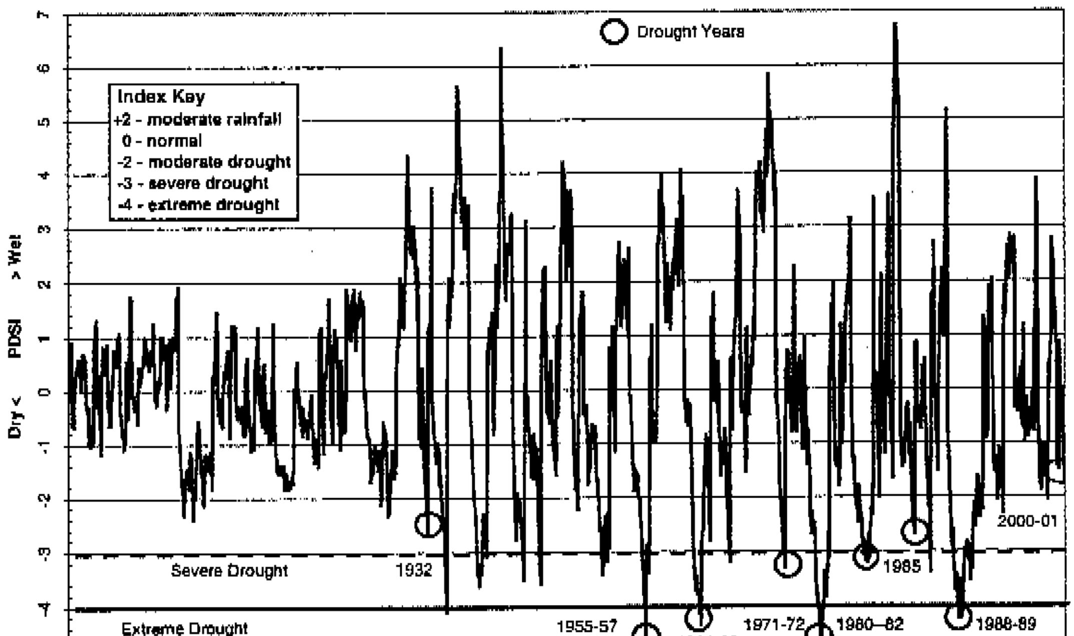

Figure 11. Palmer Drought Severity Index – Florida Climatic Division 7 (Florida Keys) 1895-2001.

Wildfires

One of the more significant impacts of drought on natural resources are the conditions which promote the spread of wildfires. Figure 12 shows the number of acres 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 acres burned correspond 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 12 although there was no declared drought that year.

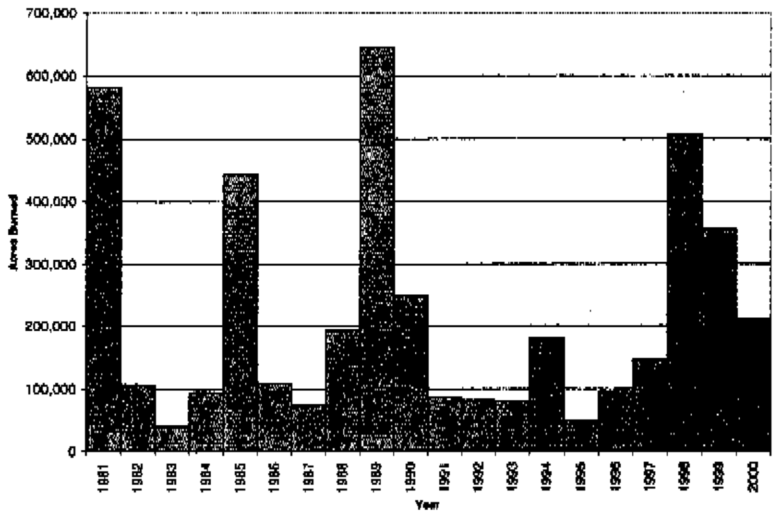

Figure 12. Acres Burned per Year by Wildfires in Florida.

Water Levels

Water levels in lakes and reservoirs are gages for drought and water shortage conditions. The major lakes and water holding areas (impoundments) in the South Florida Water Management District are Lake Okeechobee, Lake Istokpoga, Lake Kissimmee, Lake Mrytle, Alligator Lake, Lake Gentry. Lake Mary Jane, East Lake Tohopekaliga, Lake Tohopekaliga and Water Conservation Areas 1, 2, and 3. Water level data for Lake Okeechobee is available since 1931 (Figure 13). The minimum lake level for the period of record of 8.97 ft NGVD was reached on May 24, 2001. Figure 14 shows the number of consecutive days the lake was below 11.0 ft NGVD, the longest, 194 days, was achieved 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 11.00 ft NGVD, matches the drought years (Figure 14). The mean lake stage and standard deviation at the beginning of each month is shown in Figure 15. 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. 11 ft NGVD) can be used as a measure of criticality of Lake Okeechobee storage decline.

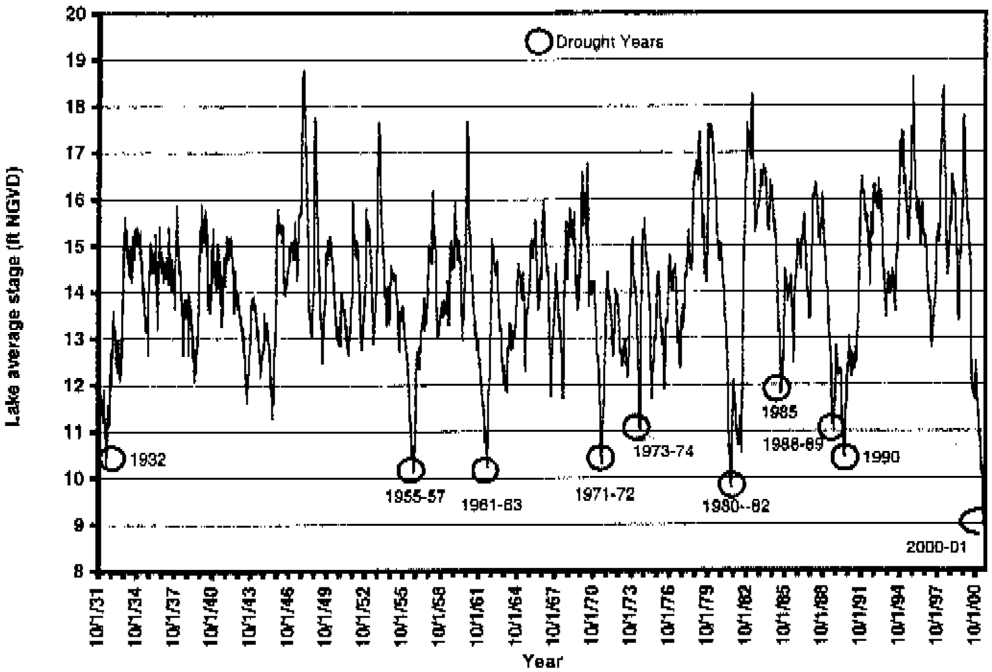

Figure 13. Average Daily Water Level for Lake Okeechobee.

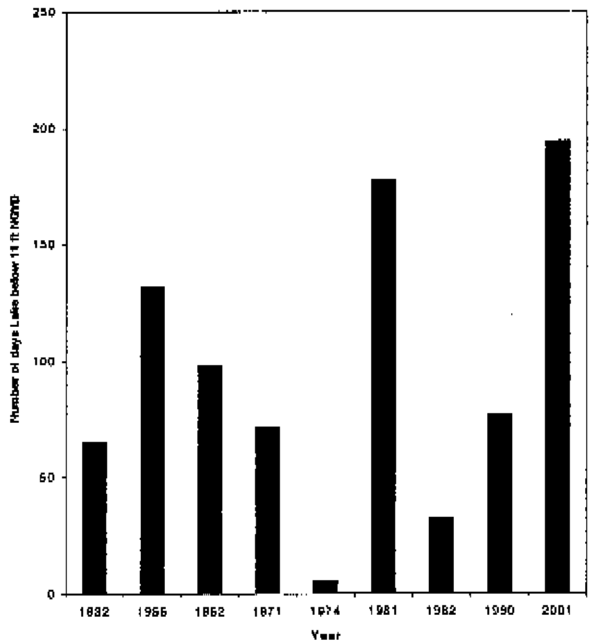

Figure 14. Number of Days Lake Okeechobee Water Level was below 11 ft NGVD.

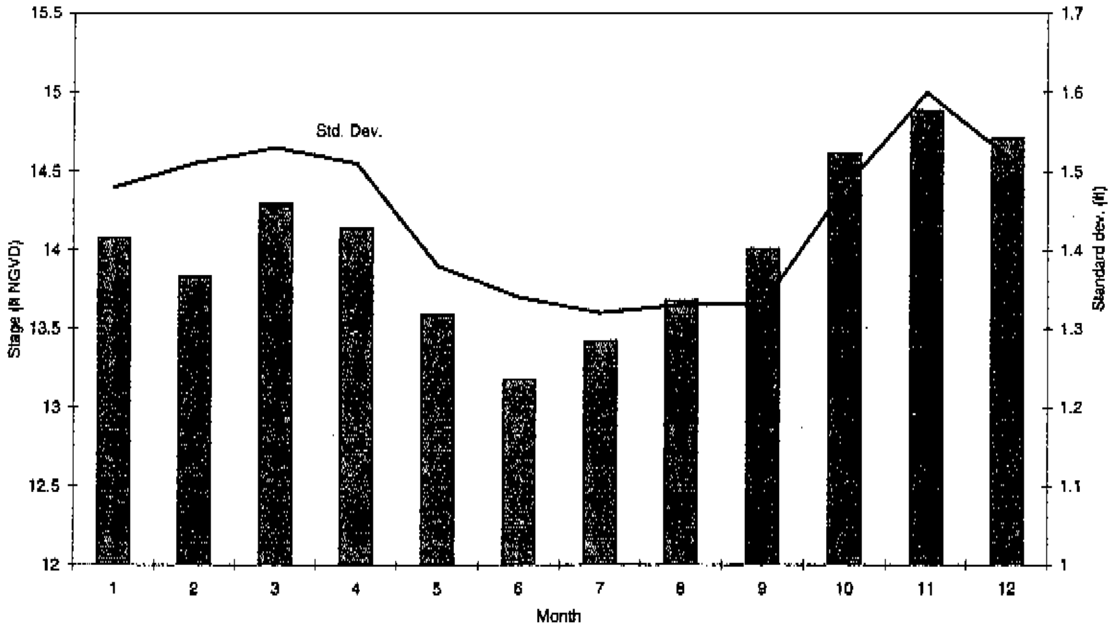

Figure 15. Mean Lake Water Level and Standard Deviations for Lake Okeechobee at the Beginning of the Month.

Flows

The main storage component in the 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%), Lake Istokpoga Water Management Area (9.1%), Fisheating Creek (8.4%), reverse flows from the Everglades Agricultural Area, Caloosahatchee Canal and St. Lucie Canal (16.1%) and 18.6% 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 of surface water was 1,994,184 ac-ft with an annual maximum of 3,320,075 ac-ft, minimum of 279,145 ac-ft and a standard deviation of 846,594 ac-ft. Average annual reverse inflow from the EAA, Caloosahatchee Canal and St. Lucie Canal was 321,059 ac-ft with a standard deviation of 143,893 ac-ft. Outflows are mainly through the south, southeast and southwest structures. From 1972 to 2000, the average annual outflow was 1,306,708 ac-ft with a standard deviation of 837,947 ac-ft; maximum annual outflow was 3,771,390 and minimum was 314,115 ac-ft. Monthly mean historical inflows and outflows are depicted in Figure 16. Figure 17 depicts historical annual inflows and outflows for Lake Okeechobee.

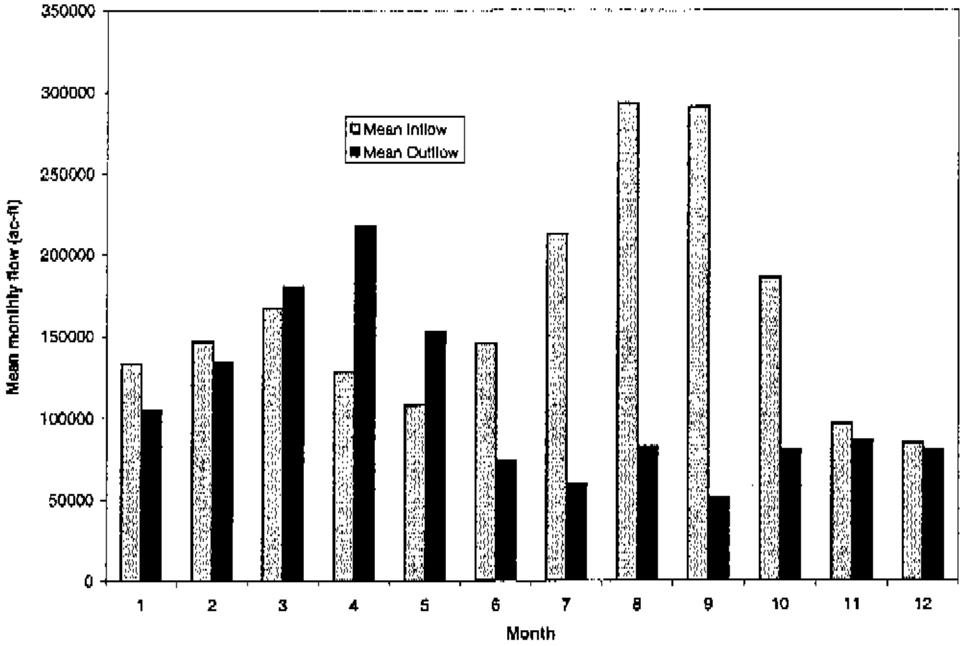

Figure 16. Monthly average Inflows and Outflows for Lake Okeechobee (1972-2000).

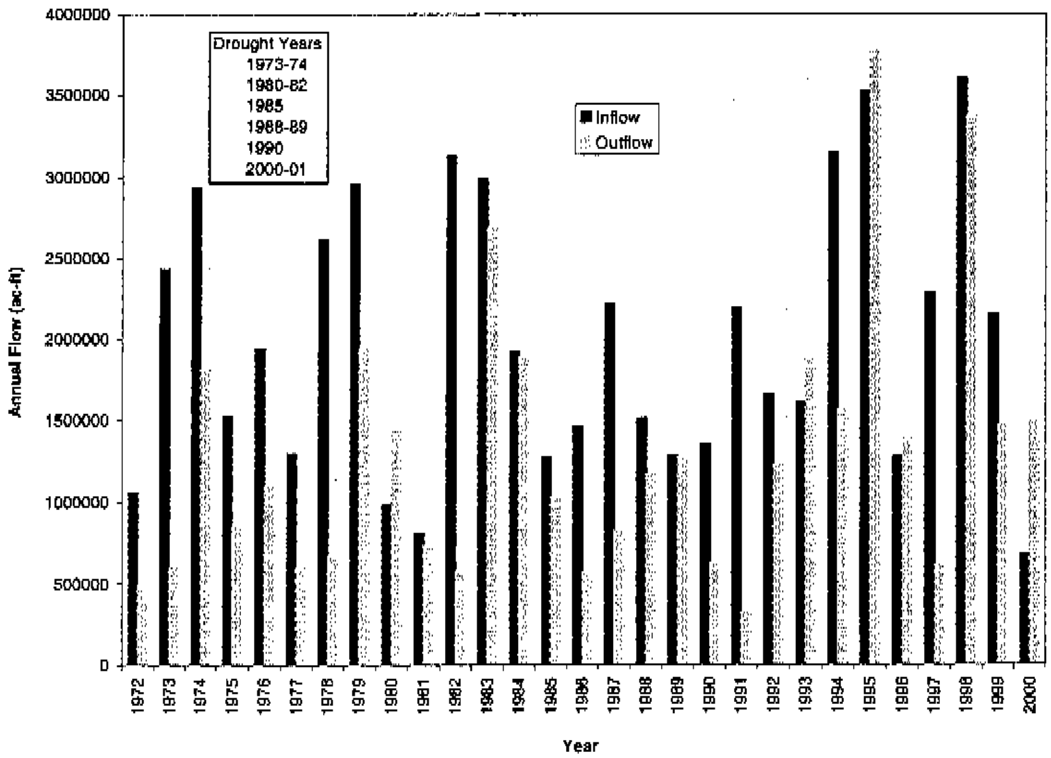

Figure 17. Annual Inflows and Outflows for Lake Okeechobee.

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 needs to incorporate drought monitoring. Rainfall deficit, Palmer Drought Severity Index, climatological forecasts, surface and groundwater levels and water demand monitoring are essential. A systems approach is needed to effectively deal with wild fire mitigation, drought and water management.

REFERENCES

Ali, A. and W. Abtew. 1999. Regional Rainfall Frequency Analysis for Central and South Florida. Technical Publication. WRE # 380. South Florida Water Management District. West Palm Beach, FL.

Benson, M. A. and R. A. Gardner. 1974. The 1971 Drought in South Florida and its Effect on the Hydrologic System. Water Resources Investigation 12-74. U. S. Geological Survey.

Central and South Florida Flood Control District. 1972. Summary of the Condition of South Florida Water Storage Areas in the 1970-71 and 1971-1972 Dry Seasons. July 1972.

Central and South Florida Flood Control District. 1974. Summary of the Condition of South Florida Water Storage Areas in the 1973-1974 Dry Seasons. July 1974.

Florida Department of Agriculture and Consumer Services. 2001. Division of Forestry, Forest Protection Bureau Fire Statistics Web Page, Tallahassee, FL, http://flame.fl-dof.com/General/firestat.html.

Golden, H. G. and H. F. Lins. 1986. Drought in the Southeastern United States, 1985-86. National Water Summary 1986-Ground-Water Quality: Selected Events. U.S. Geological Survey Water-Supply Paper 2325. PP 35-41.

Guardo, M. 1992. An Atlas of the Upper Kissimmee Surface Water Management Basins. Technical Memorandum. DRE 309. South Florida Water Management District. West Palm Beach, FL.

Kogan, F. N. 1995. Droughts of the Late 1980s in the United States as derived from NOAA Polar-Orbiting Satellite Data. Bulletin of the American Meteorological Society. Vol. 76 (5):655-668.

Lin, S., J. Lane and J. Marban. 1984. Meteorological and Hydrological Analysis of the 1980-1982 Drought. Technical Publication 84-7. South Florida Water Management District. West Palm Beach, FL.

Marban, J., S. P. Sculley and P. J. Trimble. 1989. Analysis of the 1988-1989 Drought. Special Report. Water Resources Division. South Florida Water Management District. West Palm Beach, FL.

Palmer, W. C. 1965. Meteorological Drought. Research Paper No. 45. U.S. Weather Bureau, Washington, D. C.

Subrahmanyam, V. P. 1967. Incidence and Spread of Continental Drought. World Meteorological Organization International Hydrologic Decade (IHD). WMO, Geneva, Switzerland.

South Florida Water Management District. 1985. Interim Drought Management Report. May 9, 1985 update. West Palm Beach, FL.