Special Report

ANALYSIS OF THE 1989-1990 DROUGHT

by

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Executive Summary

During the period of June 1989 through May 1990 rainfall averaged 44 inches over the entire South Florida Water Management District (District), which is 9 inches below normal. This represents a drought return frequency of 1 in 10 years. Only the Everglades National Park (ENP) has experienced a lack of rainfall more severe than the 10-year drought during this 12-month period. All other areas, including the Lower East Coast (LEC) and the Everglades Agricultural Area (EAA) continued to receive slightly below normal rainfall. The rainfall in the preceding months for this period were substantially below normal, leaving Lake Okeechobee and the Water Conservation Areas (WCAs) with less than average carryover storage. This lack of available water in storage contributed to the severity of the drought.

During this drought period, Lake Okeechobee had a 0.49 million acre-feet (AF) depletion of storage for the months of June through May. This represents the fifth largest storage loss for this period in the last 20 years. The surface inflow to the lake was 1.23 million AF, which is less than 75% of the normal inflow. The inflow from the Kissimmee River basin was less than 50% of normal and accounted for a major portion of the deficit. The WCAs gained 90,000 AF. The total system storage fell from 3.46 million AF on June 1, 1989 to 3.05 million AF on May 31, 1990, for a total loss in storage of 410,000 AF. WCA 3A has been at or near record low level since the month of June 1989. The increase in demands due to lack of rainfall combined with lack of storage in the WCAs would normally require large releases from Lake Okeechobee to both the EAA and the LEC, but the implementation of Supply Side Management in November and water shortage restrictions significantly reduced the releases from the lake. A total of 410,000 AF was released from the lake to EAA for supplemental agricultural demands, and 224,000 AF went to maintain the LEC canals at the proper stages and provide recharge to the coastal wellfields. A significant amount of water delivered to the LEC was used to keep the canals in the South Dade Conveyance System at design stages.

During this period, very little water went to Shark River Slough in ENP. A total of 68,000 AF was delivered to ENP: 29,015 AF through the S-12 structures, and 39,180 AF through S-333. Water has been delivered to ENP in accordance with the rainfall formula. The rainfall deficiency during this drought, as in the 1980-1981 drought, occurred during the wet season months, but the main difference is in the geographical distribution. The 1980-1981 drought was extremely severe in the Kissimmee River basin, Lake Okeechobee, and EAA. The 1988-1990 drought was Districtwide, but was particularly critical in the EAA. This is the lowest annual total of discharges to the ENP since the early 1960s.

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1. INTRODUCTION

The purpose of this report is to analyze and document the performance of the Central and Southern Florida (C&SF) surface water supply system under the below normal rainfall conditions that existed during the period June 1, 1989 through May 31, 1990. Comparisons with previous droughts are included. Meteorological droughts are defined as extended periods of below normal rainfall conditions. The impact of droughts on water supply is a function of the antecedent conditions, the level of demand and the adequacy of the water supply system to deliver water to the impacted areas.

The surface water supply system is part of the Central and Southern Florida Project for flood control and other purposes (C&SF Project) authorized by Congress in 1949 and built during the last four decades. This project as shown in Figure 1-1 interconnects a series of lakes used, in part, as water storage reservoirs with a series of canals that convey water to the agricultural and urban users.

The heart of the water supply system is Lake Okeechobee, a 730-square mile lake which provides water supply for much of south Florida. The Lake provides water to the Everglades Agricultural Area, portions of the St. Lucie and Caloosahatchee basins, and is also used to maintain canal levels in the coastal reaches of Dade, Broward and Palm Beach County canals, and the South Dade Conveyance System. These deliveries are made primarily during the critical dry months of March, April and May, and/or other times of significant below normal rainfall conditions. In the area supplied from the C&SF Project, the level of Lake Okeechobee is the most important indicator of the severity of a drought, and the ability of the water supply system to overcome it.

An important element of the water supply system is the Upper Kissimmee Chain of Lakes (UKL) which includes, among others, Lake Tohopekaliga, East Lake Tohopekaliga, and Lake Kissimmee. The water stored in the UKL is rarely used for water supply in the area surrounding the lakes since the majority of the users in that basin use groundwater as the main source of water supply, but it contributes to the water storage of Lake Okeechobee. In addition to the inflow coming from UKL, a significant amount of inflow to Lake Okeechobee comes from runoff in the Kissimmee River basin. These flows enter Lake Okeechobee through structure S-65E which is, after rainfall, the largest source of water for Lake Okeechobee. Under normal conditions, about 31% of annual inflow to Lake Okeechobee is from the UKL and the Kissimmee River basin. A substantial portion of this inflow occurs during the period of February through May when the regulation schedules of these lakes recede.

Lake Istokpoga west of the Kissimmee River is a shallow lake with a surface area of 43 square miles that provides water supply for the agricultural and urban users of the Indian Prairie Basin and, on occasions, provides inflow to Lake Okeechobee.

A critical component of the water supply delivery system is the Water Conservation Area (WCA) system which is composed of the three major water storage areas, WCA 1, WCA 2A, and WCA 3A, and two others, WCA 2B and WCA 3B, which are very inefficient for water storage.

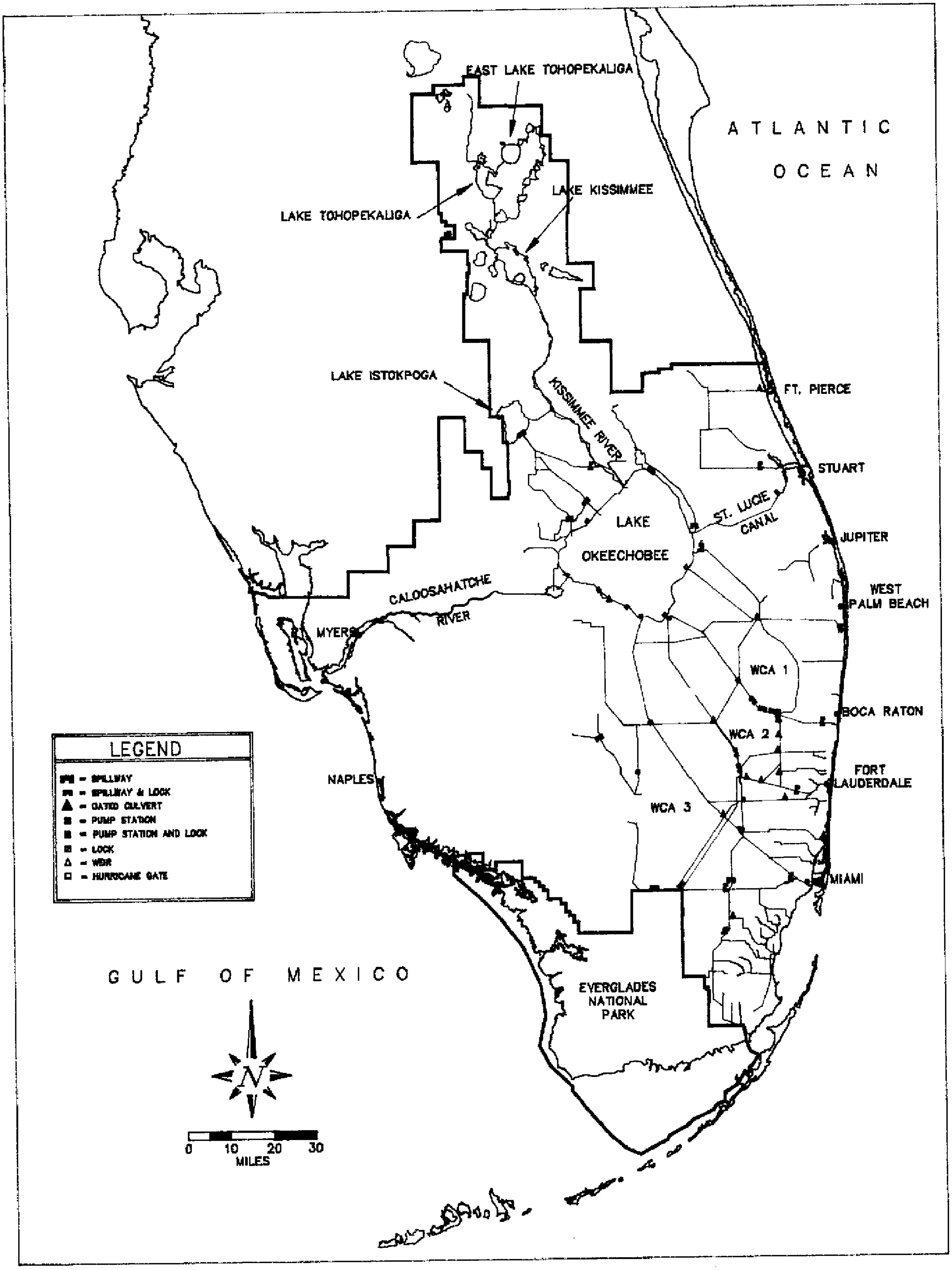

Figure 1-1 Central and Southern Florida Flood Control Project

The WCAs were originally part of the Everglades that were converted into water storage areas as part of the C&SF Project approved by Congress, while preserving their ecological values. Due to the large evapotranspiration rate and seepage, the Water Conservation Areas are generally inefficient for surface water storage during dry periods; their main function is to recharge the surficial aquifer east of these areas known as the Biscayne aquifer which provides the majority of the water supply for the urban population of the lower east coast of Florida. When the storage in these areas subsides, then their recharge capability significantly decreases and the burden of recharging the Biscayne aquifer and preventing saline intrusion to coastal wellfields falls on Lake Okeechobee.

An additional important function of the WCAs, particularly WCA 3A, is to provide sufficient flows to the Everglades National Park (ENP), and North East Shark River Slough (NESRS), to preserve their ecological integrity. The WCAs also provide water supply to the agricultural and urban interests in south Dade through the South Dade Conveyance System either directly or through wellfield recharge.

This report presents an analysis of the rainfall conditions from the period of June 1, 1989 to May 31, 1990, including a comparison with previous droughts. It also includes a water budget of the major reservoirs indicating the water supply distribution on a monthly basis. Finally, it presents a comparison of the storage efficiency of Lake Okeechobee and the Water Cconservation Areas.

This report represents an update of the special report *Analysis of the 1988-1989 Drought* by Marban, Sculley, and Trimble.

2. RAINFALL ANALYSIS

The District received 44 inches of rainfall from June 1989 through May 1990, 4 inches more than what was recorded during the first 12 months of the drought (September 1988 through August 1989). This reflects the trend observed in many of the basins which comprise the District: *Annual rainfall*[1] steadily declined from normal to record below-normal amounts from August 1988 until August 1989; it has moderated as of May 1990 but remains below normal. It is five times more likely for the District to have received an *annual rainfall* of 44 inches than to have received the amount that fell during the first 12 months of the drought; in terms of return period, the District-wide rainfall drought severity has moderated from a 1-in-50-year event to a 1-in-10-year event.

The special report, *Analysis of the 1988-1989 Drought*, documented the most severe 12-month duration of the rainfall drought and analyzed cumulative rainfall beginning in September 1988. This update traces the decline and subsequent moderation of rainfall on Lake Okeechobee and in five basins: Everglades Agricultural Area, Lower East Coast, Lower Kissimmee, Water Conservation Area 3 (A and B), and Everglades National Park. Rainfall is not presented on a cumulative basis as in the prior report; instead a moving 12-month "window" is used to show both drought development and recovery from near-normal conditions that existed in August 1988. Comparisons of seasonal rainfall from four of the basins are also presented. Table 2-1 contains monthly rainfall values from June 1989 through May 1990 and appears at the end of this chapter.

Everglades Agricultural Area

Annual rainfall over the 800 square-mile Everglades Agricultural Area (EAA) declined from near-normal (53 inches) as of August 1988 to a record below-normal amount (30.5 inches) as of August 1989. Since the conclusion of the 1990 dry season, however, *annual rainfall* has since exceeded the (1-in-)10-year below-normal amount. Figure 2-1 shows *annual rainfall* for the EAA since August 1988. Each box represents rainfall from a 12-month period ending with the month indicated on the horizontal axis. Bolstered by 12 inches of rainfall in September and October (compared to just over 2 inches during the same period in 1988) and 6 inches in May 1990, *annual rainfall* stood at 44 inches as of May 1990. This amount is 14 inches more than what fell during the 12 months prior to September 1989, but is 8 inches below normal and has a return period of less than ten years.

Figure 2-2 shows wet and dry season rainfall for the last ten years. Values (bars) are plotted relative to long-term averages. Average dry season (defined as November through May) rainfall in the EAA is just over 17 inches, based on historical records from 1929. Average wet season (which includes the five months of June through October) rainfall is 35 inches, or two-thirds of the annual average. Figure 2-2 indicates that in seven of the last ten years, including the last three seasons, the

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[1] In this report, *annual rainfall* refers to amounts observed in any consecutive 12-month period.

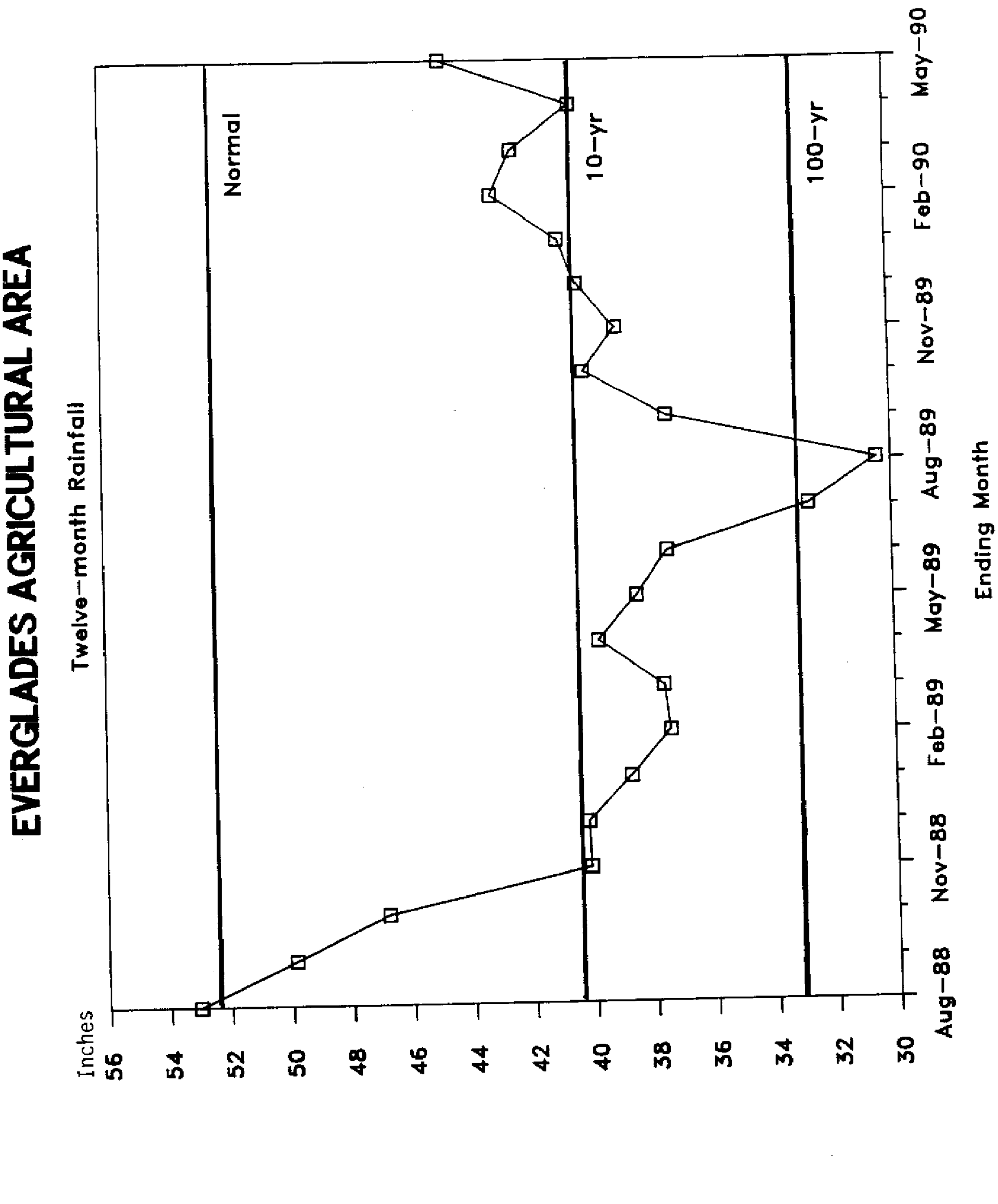


Figure 2-1 Everglades Agricultural Area 12-Month Rainfall

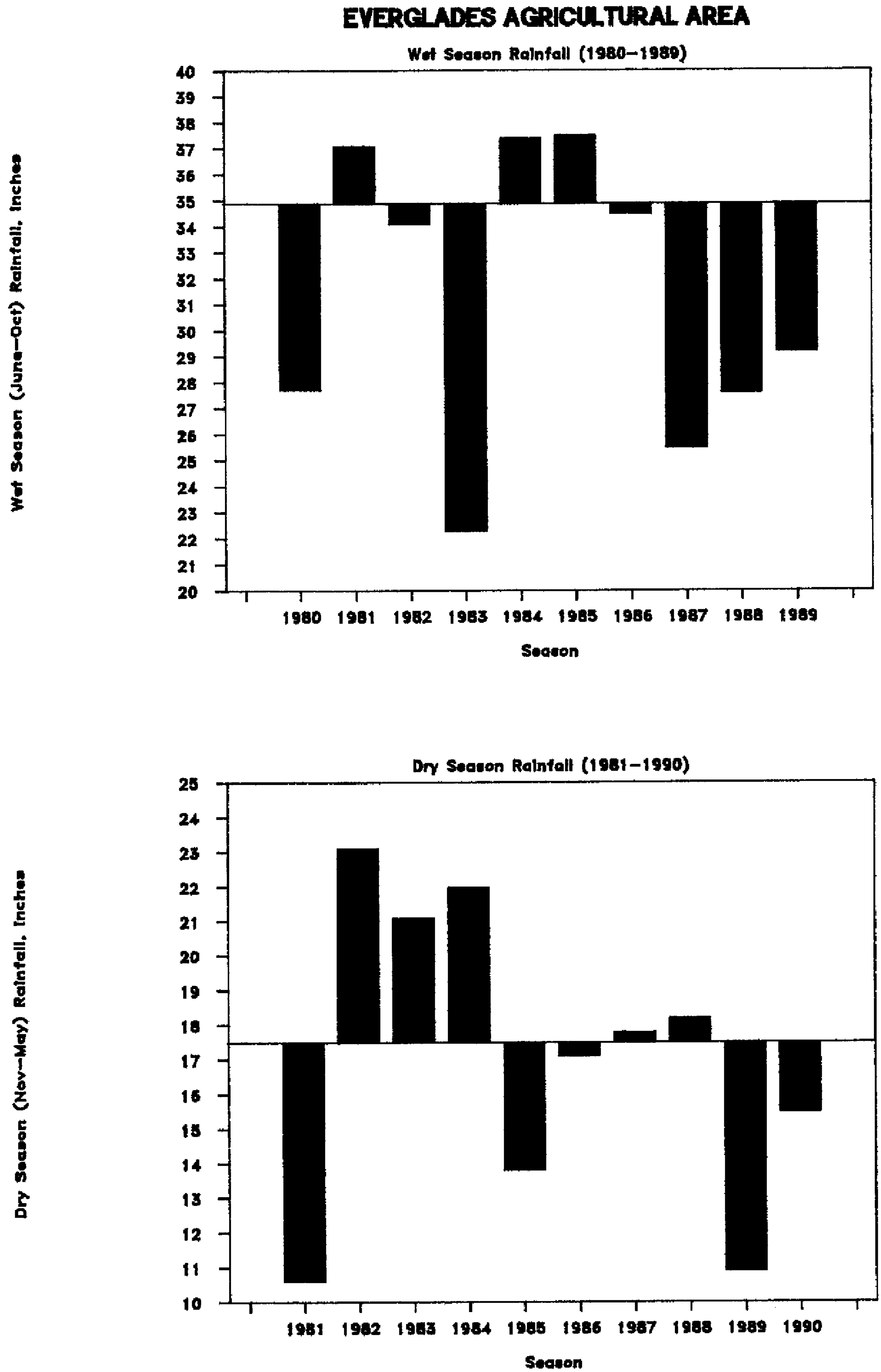


Figure 2-2 Everglades Agricultural Area Seasonal Rainfall

EAA has received below-average wet season rainfall. The 1988 wet season was marked by a very wet June, July, and August (26 inches total) followed by the inaugural drought months of September and October (2 inches total). Although there was a slight increase in 1989 wet season rainfall from the previous year, it was more than five inches below normal. Dry season rainfall in the 1980s does not appear to be atypical.

The two significant rainfall droughts during this decade (1980-1981 and 1988-1990) are noted by the consecutive below-normal wet and dry seasons. The 1980-1981 drought, in which just 39 inches fell between June 1980 and May 1981, ended abruptly with 37 inches falling during the 1981 wet season. Similarly, the 1983 wet season was one of the driest on record but was followed by above-normal rainfall over the next two seasons. The 1988-1990 drought, however, has been persistent and is indicated by below-normal rainfall in each of the last four seasons in the EAA.

Lower East Coast

This 1,920 square mile area consists of eastern Palm Beach, Broward, and Dade counties. Rainfall for this region has exhibited similar characteristics (Figure 2-3) to that of the EAA. Slightly above-normal rainfall in April 1989 gave an indication that the decline in rainfall may have reversed itself but instead was followed by four more months of decline. By August 1989, Lower East Coast (LEC) *annual rainfall* totaled only 38 inches and the drought severity exceeded 1-in-50-years. As of May 1990, LEC *annual rainfall* was over 48 inches. Slightly above-normal rainfall in May 1990 helped moderate the severity to less than a 10-year drought.

The LEC seasonal rainfall has even more pronounced anomalies than those from the EAA (Figure 2-4). Eight of the past ten wet seasons have been below-normal and four of the eight, including 1989, have been close to the 10-year drought rainfall of 28 inches. Unlike the EAA, the 1989 wet season was much drier than the 1988 wet season. Again, the 1988-1990 drought is characterized by below-normal rainfall in four consecutive seasons.

Lower Kissimmee

Annual rainfall in this basin returned to near-normal (50 inches) after October 1989 since having been at 10-year drought levels for ten months (Figure 2-5). The rainfall drought in this basin was not as severe nor as persistent as was experienced in the EAA and LEC basins.

Wet season rainfall for the Lower Kissimmee basin was below normal in each of the ten years during the 1980s (Figure 2-6). Thirty-two inches fell during the 1989 wet season--just under the 75-year average. It was the most recorded in any wet season during the decade. Dry season rainfall was not atypical.

Lake Okeechobee

Annual rainfall over the 730 square mile lake (estimated from perimeter gages) has fluctuated about the 10-year below-normal level of 34 inches since July 1989 (Figure 2-7). Lake rainfall since September 1989 was 21 inches. This is 4 inches below-normal, which is not considered to be significant.

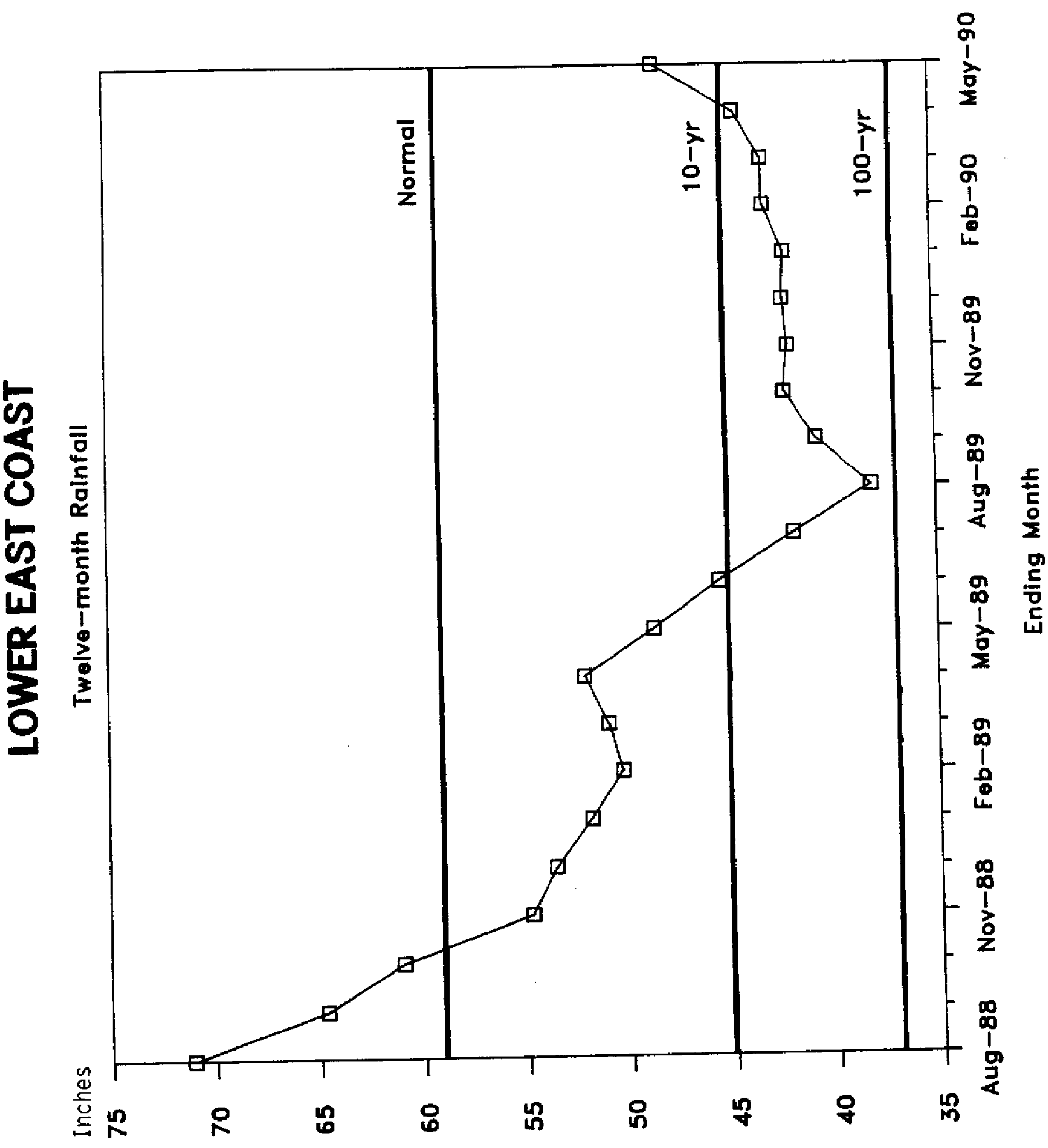
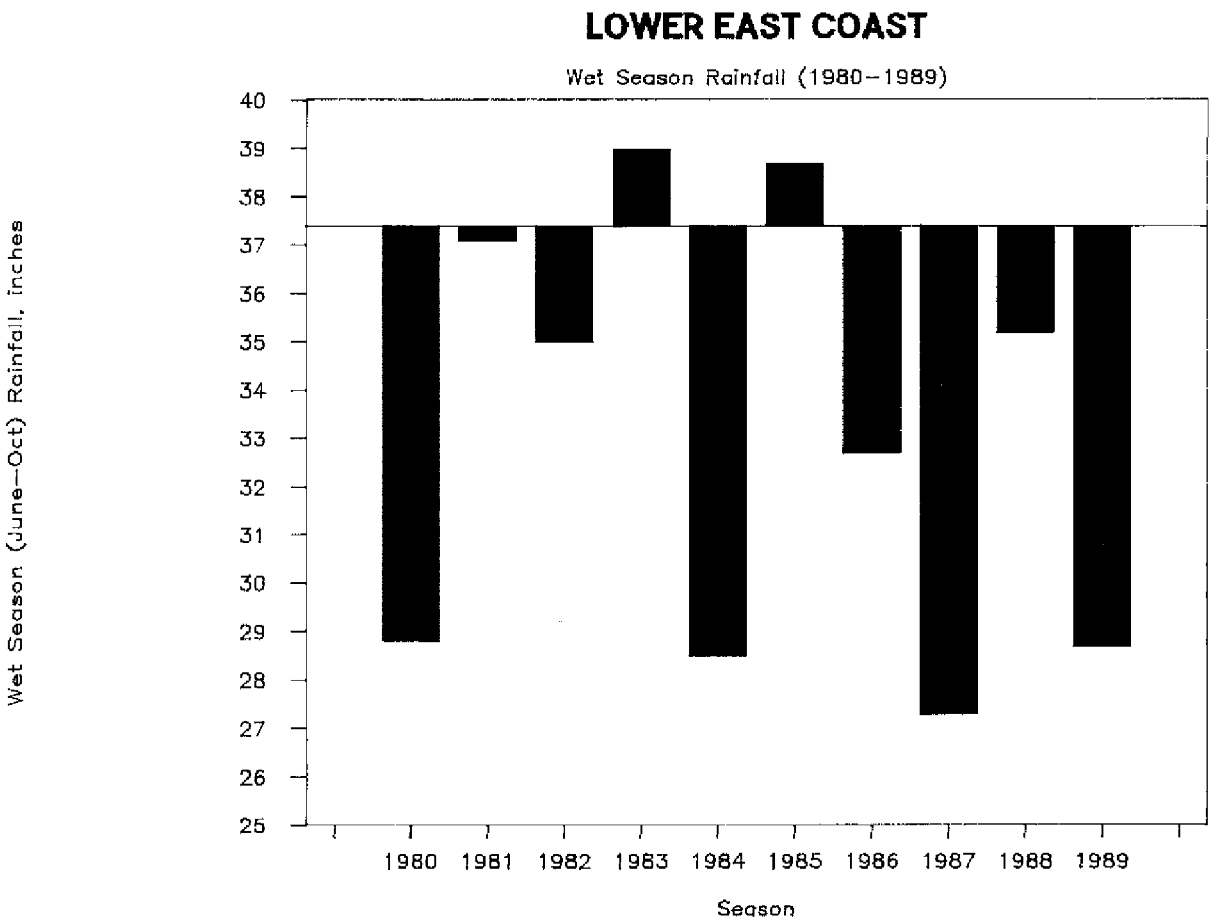


Figure 2-3 Lower East Coast 12-Month Rainfall



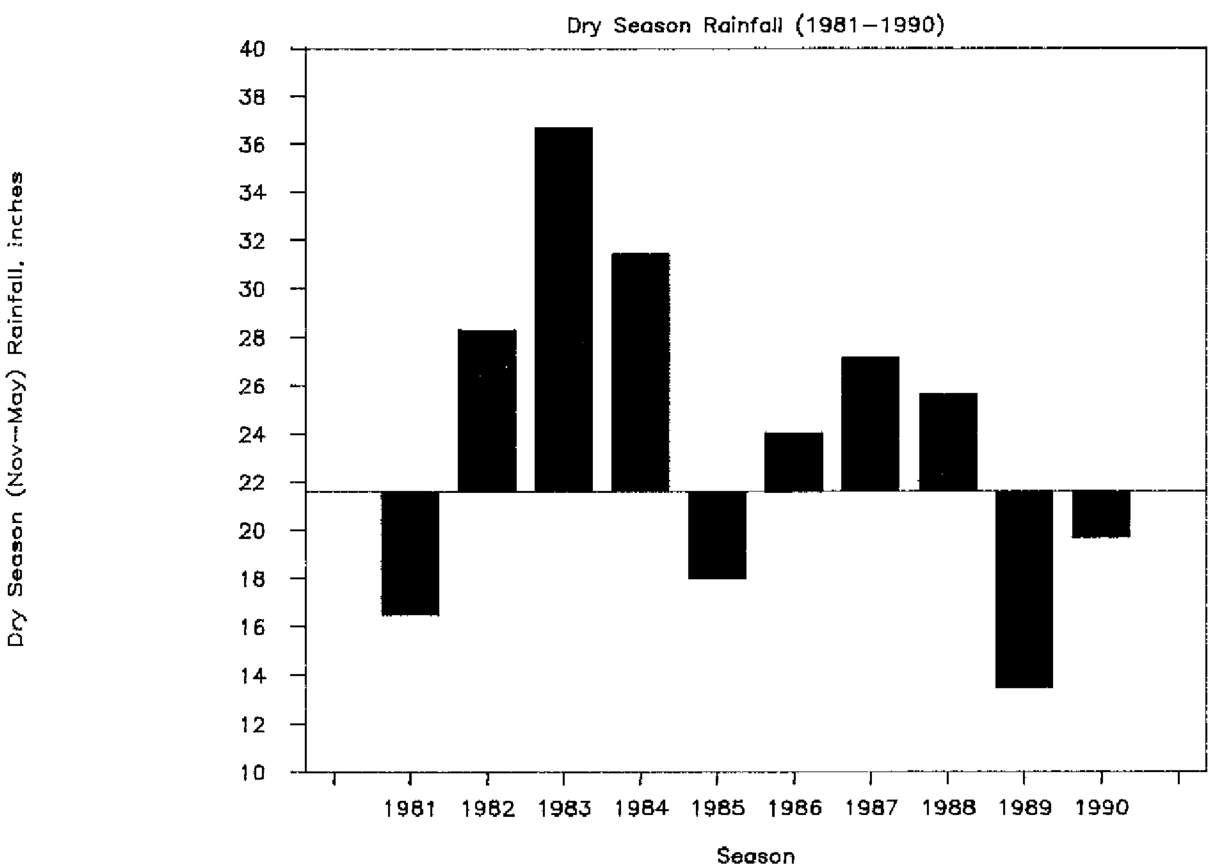


Figure 2-4 Lower East Coast Seasonal Rainfall Analysis

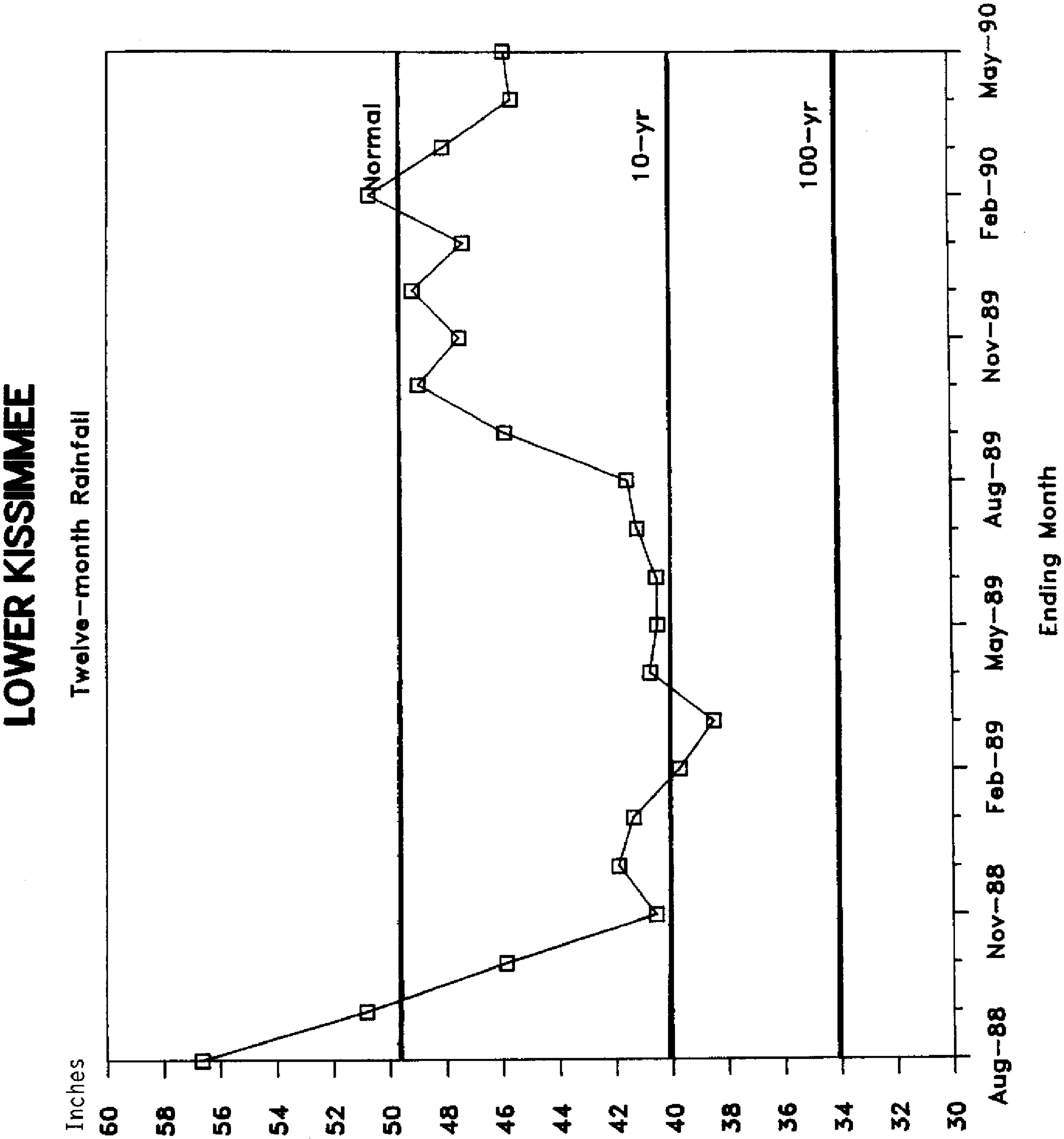
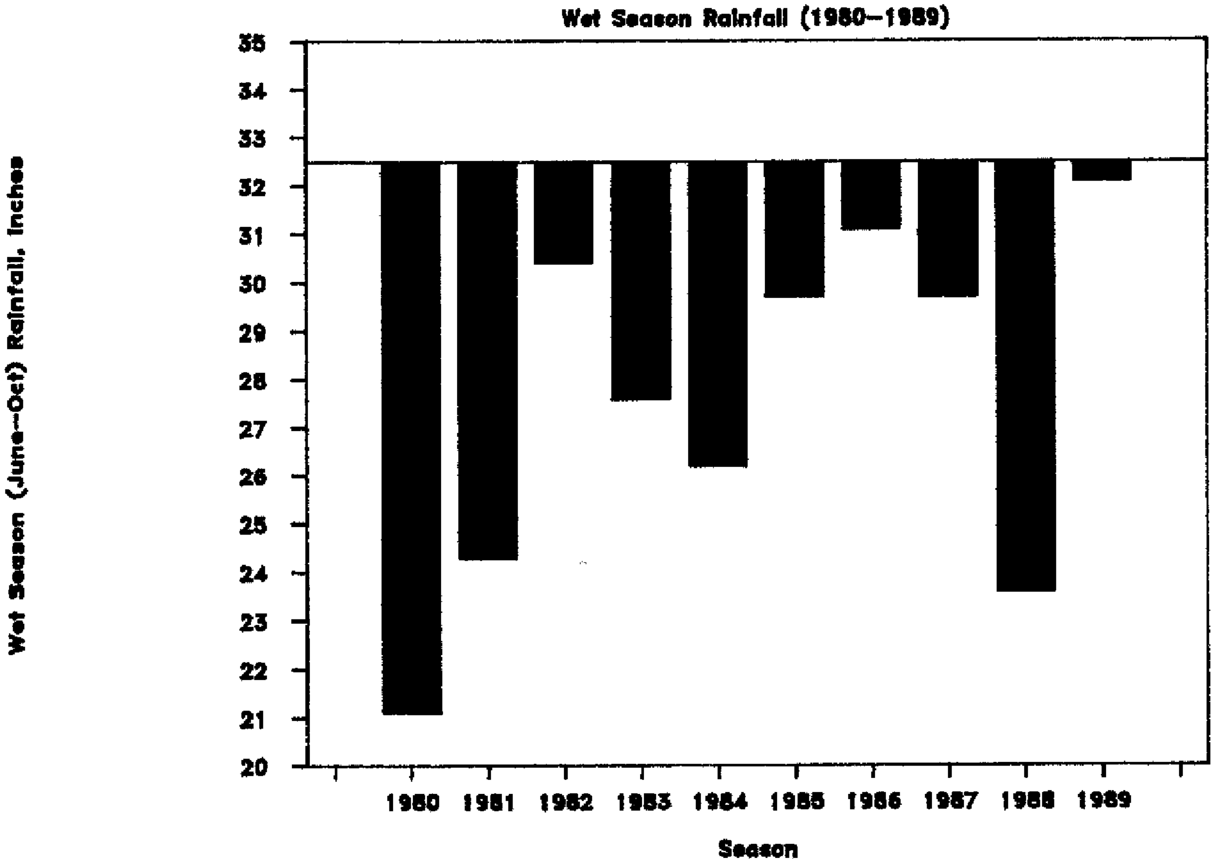


Figure 2-5 Lower Kissimmee 12-Month Rainfall

LOWER KISSIMMEE



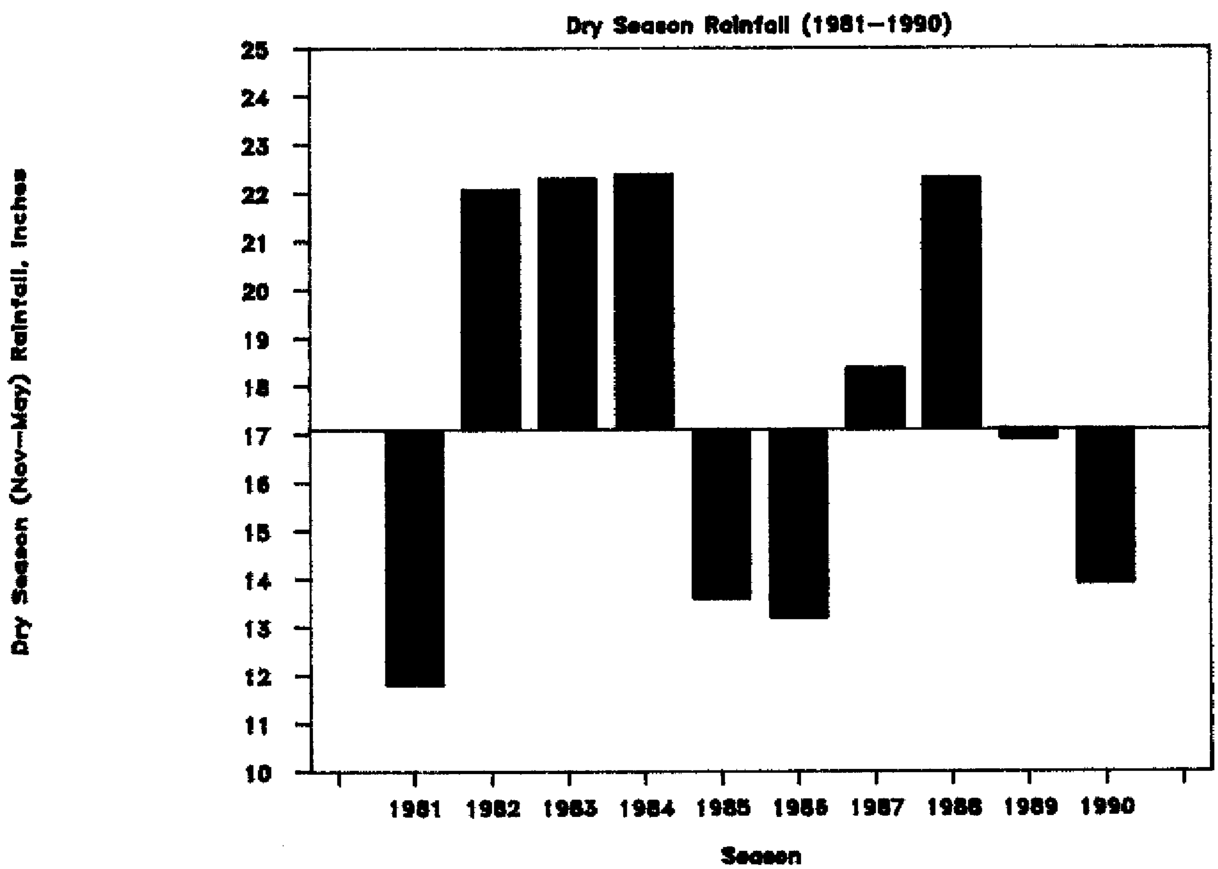


Figure 2-6 Lower Kissimmee Seasonal Rainfall

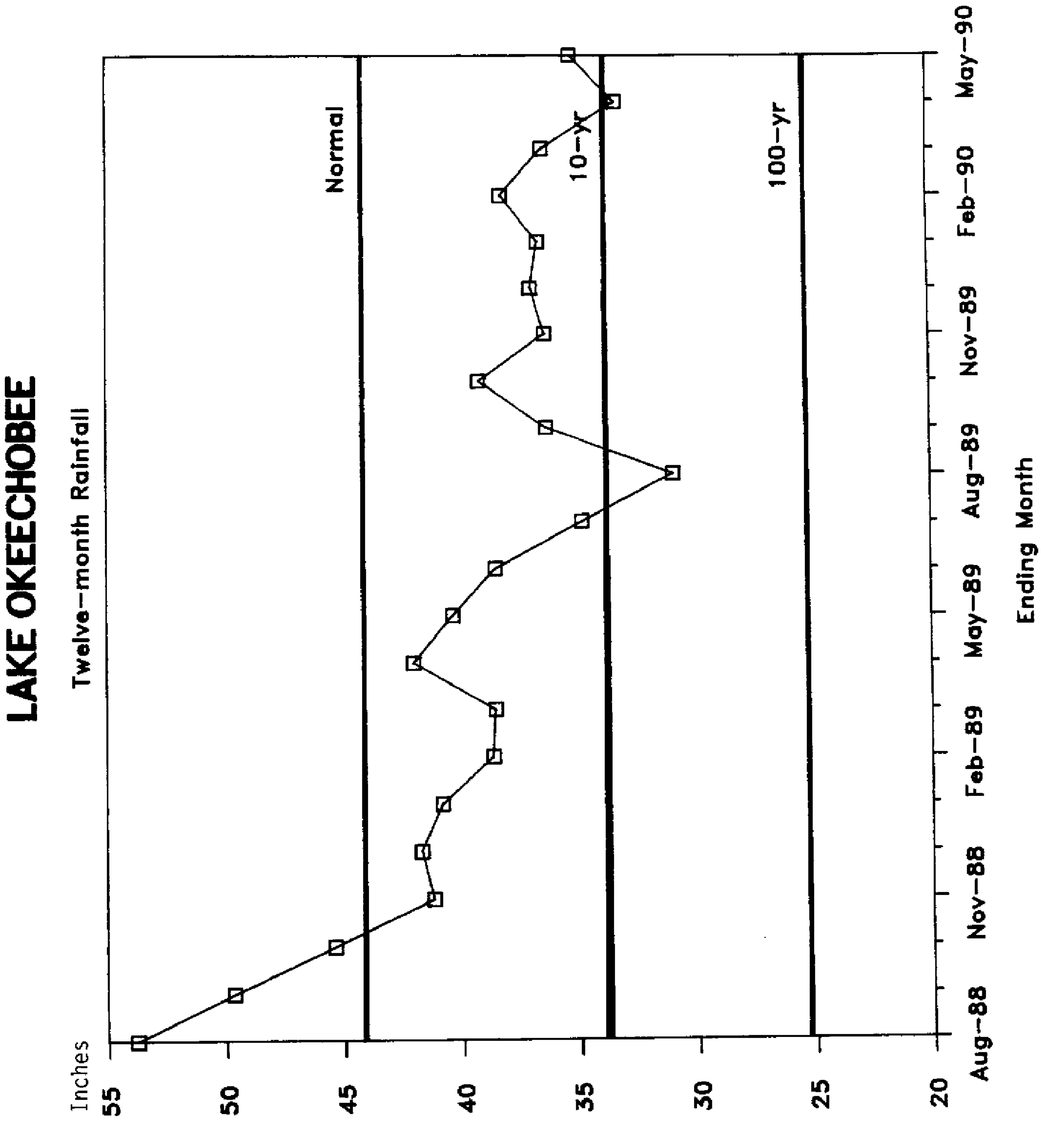


Figure 2-7 Lake Okeechobee 12-Month Rainfall

Water Conservation Area 3 (A and B)

Drought severity in WCA-3 has nearly recovered from 50-year drought conditions in August 1989. This is due to WCA-3 having received normal rainfall (24 inches) from September 1989 through May 1990, ten inches more than what fell during the same period one year earlier. *Annual rainfall* stood at 41 inches as of May 1990, 3 inches below normal (Figure 2-8). As was the case during the first 12 months of the drought, rainfall in Water Conservation Areas 1 and 2 (A and B) was not significantly below-normal and, therefore, was not presented in the original report. During the last 12 months (June 1989 through May 1990) slightly below-normal rainfall continued in both of these areas.

Everglades National Park

Until May 1990, *annual rainfall* in Everglades National Park (ENP) remained near the 20-year below-normal mark since August 1989 (Figure 2-9). Provisional data indicates that over twice the May 1989 amount fell in May 1990. The magnitude of the rainfall drought remains beyond the 10-year level of 43 inches.

Each of the last six ENP wet seasons produced rainfall below the 50-year average value of just over 38 inches (Figure 2-10). Three of the six (1984, 1985, and 1987) and the wet season of 1980 had amounts less than the 10-year drought rainfall of 30 inches. With the exception of the 1987 dry season, ENP has experienced below-normal seasonal rainfall since the beginning of the 1984 wet season.

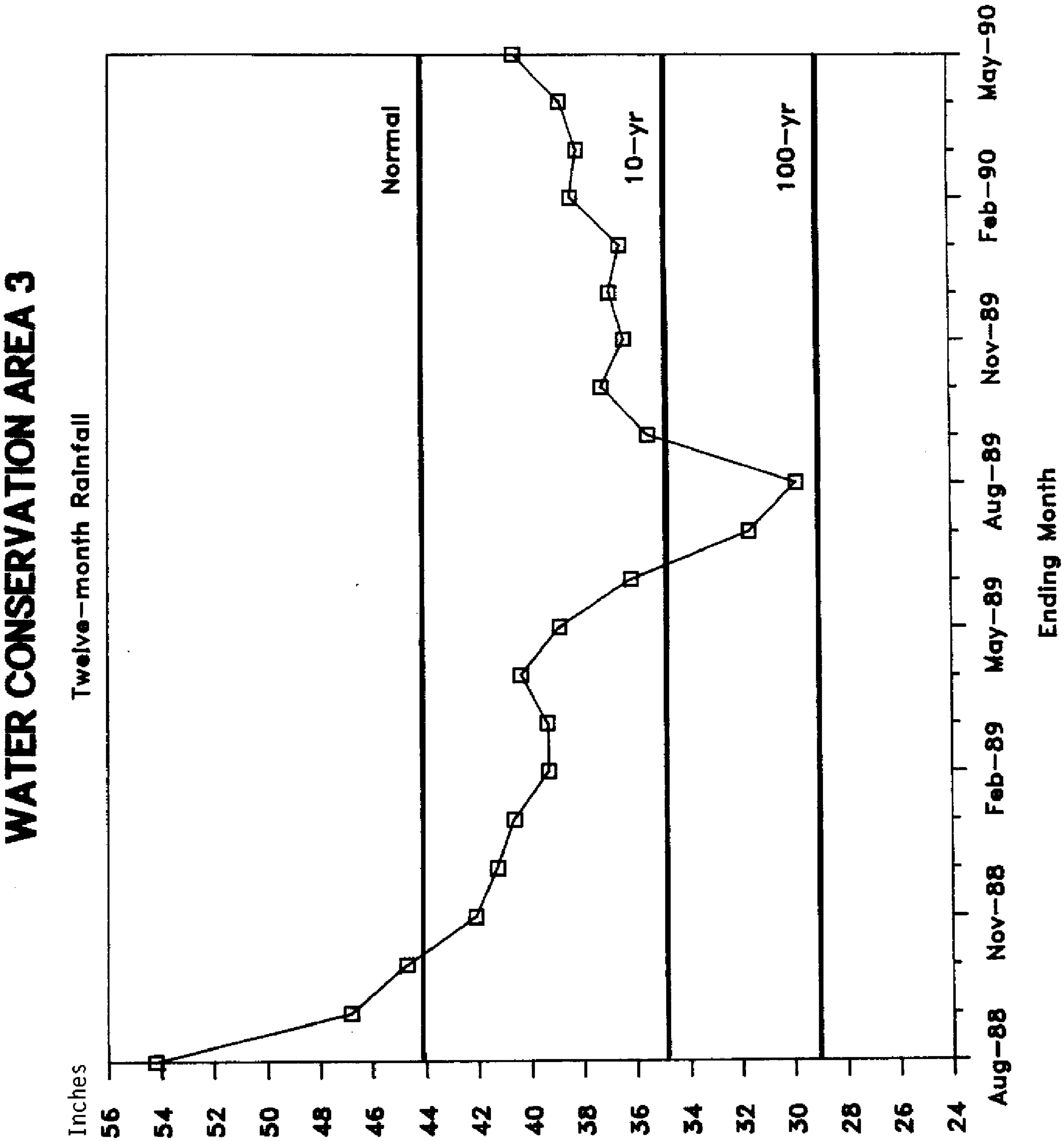


Figure 2-8 Water Conservation Area 3(A and B) 12-Month Rainfall

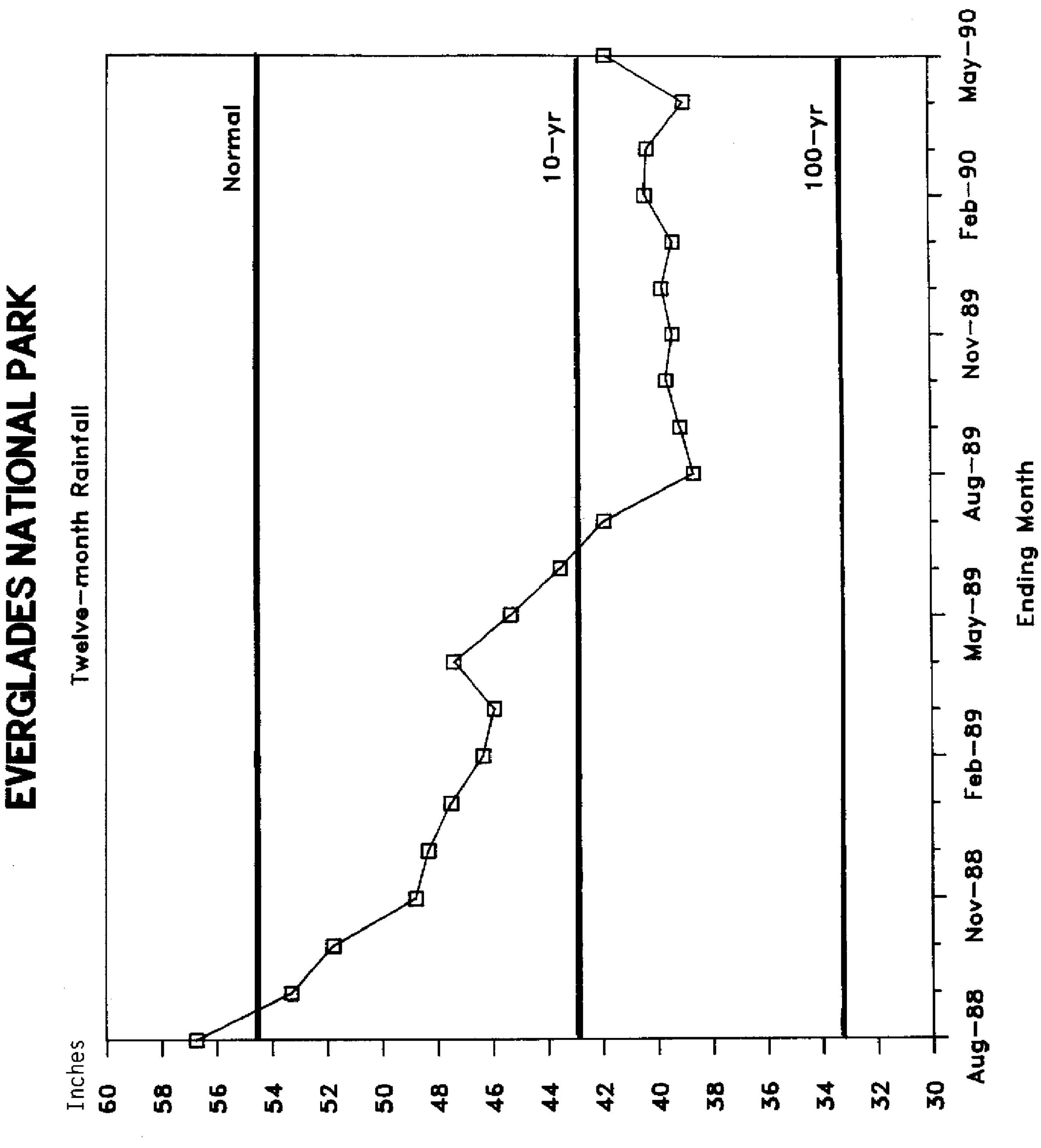


Figure 2-9 Everglades National Park 12-Month Rainfall

EVERGLADES NATIONAL PARK

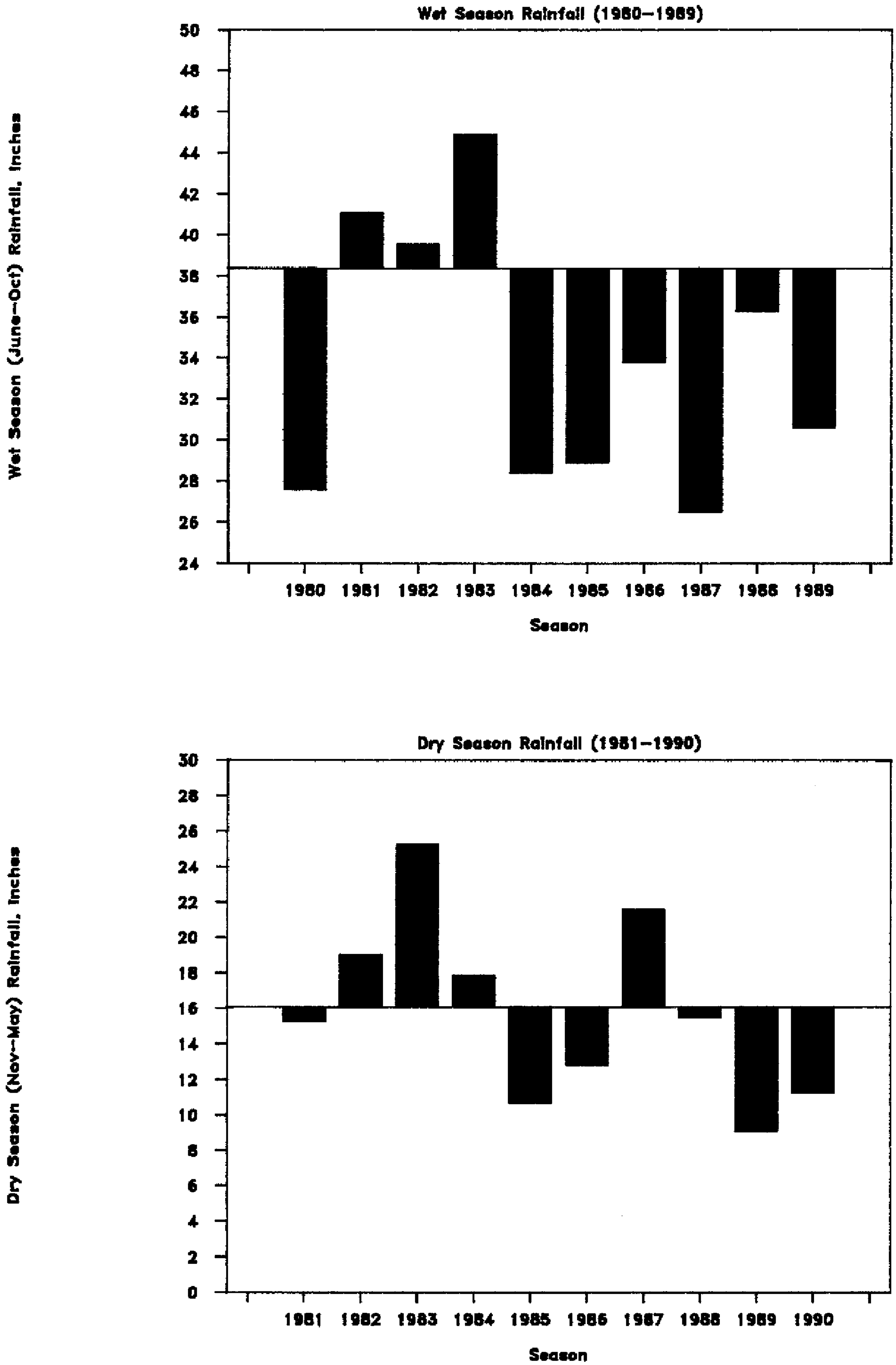


Figure 2-10 Everglades National Park Seasonal Rainfall

TABLE 2-1. 1989-1990 Drought Rainfall versus Normal Rainfall (inches)

Month	Everglades Agricultural Area		Lower East Coast		Lower Kissimmee		Lake Okeechobee		Water Conservation Area 3		Everglades National Park	
	89-90	Avg	89-90	Avg	89-90	Avg	89-90	Avg	89-90	Avg	89-90	Avg
June	5.0	7.6	7.3	8.1	5.7	7.5	4.3	6.8	4.9	7.9	7.8	9.4
July	5.5	7.7	6.0	6.8	7.3	7.8	4.0	6.5	5.1	6.6	7.9	8.1
August	6.9	7.3	7.1	6.8	7.5	6.8	6.0	5.9	6.9	6.0	7.3	7.7
September	8.8	7.6	4.8	8.4	7.4	7.0	6.6	5.7	7.6	5.7	5.7	8.8
October	3.1	4.2	3.5	7.7	4.2	3.6	3.5	3.7	2.9	3.5	2.1	4.9
November	0.7	2.0	2.1	3.0	1.5	1.7	0.4	1.6	0.6	2.0	1.1	1.9
December	1.8	1.7	1.2	2.0	3.3	1.6	1.5	1.5	0.9	1.4	0.7	1.4
January	*1.4*	1.7	*0.8*	2.4	*0.3*	1.9	*0.7*	1.7	*0.6*	1.5	*0.5*	1.6
February	*2.4*	1.9	*1.7*	2.1	*4.0*	2.3	*1.9*	2.0	*2.0*	1.7	*1.2*	1.7
March	*1.6*	1.9	*2.3*	2.8	*0.9*	2.8	*0.9*	2.7	*1.3*	2.3	*0.8*	1.9
April	*1.8*	2.6	*5.6*	3.4	*1.2*	2.6	*1.8*	2.1	*3.6*	1.9	*1.3*	2.3
May	*5.9*	4.8	*6.0*	5.8	*2.7*	4.2	*3.8*	4.4	*4.3*	4.4	*5.7*	5.4
Total	*44*	52	*48*	59	*46*	50	*35*	45	*41*	45	*42*	55

Rainfall values in *italics* are provisional.

Average monthly values are based on the following number of years of record for each basin:

Everglades Agricultural Area	60
Lower East Coast	74
Lower Kissimmee	74
Lake Okeechobee	37
Water Conservation Area 3	26
Everglades National Park	48

3. SURFACE WATER STORAGE IN MAJOR RESERVOIRS

This section presents an analysis of the storage in the South Florida Water Management District's major reservoirs, including a comparison with average conditions and previous years. An analysis of the net losses represented by the change in storage is also illustrated in this section. Three major reservoir systems were analyzed, the Upper Kissimmee Lakes including Lake Istokpoga, Lake Okeechobee, and the Water Conservation Areas (WCAs).

Analysis of Stage and Storage in the District's Major Reservoir

The dry season stages in the major reservoirs were significantly below normal for this drought period, particularly in Lake Okeechobee and the WCAs as shown in Figures 3-1, 3-2, 3-3, and 3-4. Lake Okeechobee was 2.5 feet below the historical average most of the dry season. WCA 1 was 2 feet below the historical average throughout the dry season. WCA 2A was 1.5 to 2 feet below average throughout this period and slightly below the present drawdown schedule. WCA 3A had record low stages during the early part of the dry season, and 1.5 feet below average during this period with up to 3 feet below average since June 1989. The Upper Kissimmee Lakes were at or near regulation throughout this drought period with the exception of Lake Kissimmee which was 1.5 feet to 2 feet below regulation schedule since the beginning of the dry season.

The stage of 10.65 feet in Lake Okeechobee as of June 1, 1990, was the fourth lowest for the period of record. In 1962 the stage was 10.31 feet, in 1971 the stage was 10.39 feet, and in 1981 the stage was 10.54 feet. The low lake stages in 1962 and 1971 were partially due to a much lower lake regulation schedule. The stage in WCA 3A was 7.71 feet on June 1, 1990, which was 0.5 feet below average. The storage in the surface water storage areas was very low compared to the last 20 years, but higher than the low storage conditions of 1981, as can be seen in Figure 3-5. Even though Lake Okeechobee and the WCAs presently have more storage than in 1981, the total available system storage was the third lowest of the last 20 years, as shown in Figure 3-6. The total available system storage as of June 1, 1990, was 1.11 million acre-feet, while for the same date in 1981 it was 0.97 million acre-feet.

Losses in Storage

The monthly change in storage is an indication of the severity of a drought. Figure 3-7 shows the monthly change in storage in the major surface water storage areas for the period of June 1989 through May 1990.

The Upper Kissimmee Chain of Lakes gained storage during the wet season and early dry season months, and lost storage in most of the dry season months, although these gains and losses were slightly below normal.

Lake Okeechobee experienced a steady decline in storage until July 1989 with a light recovery during the period July through November, as shown in Figure 3-7. The lake experienced losses in March and April due to below normal rainfall and late dry season demands. The supply-side management plan and water shortage restrictions were instrumental in reducing Lake Okeechobee losses by curtailing the water

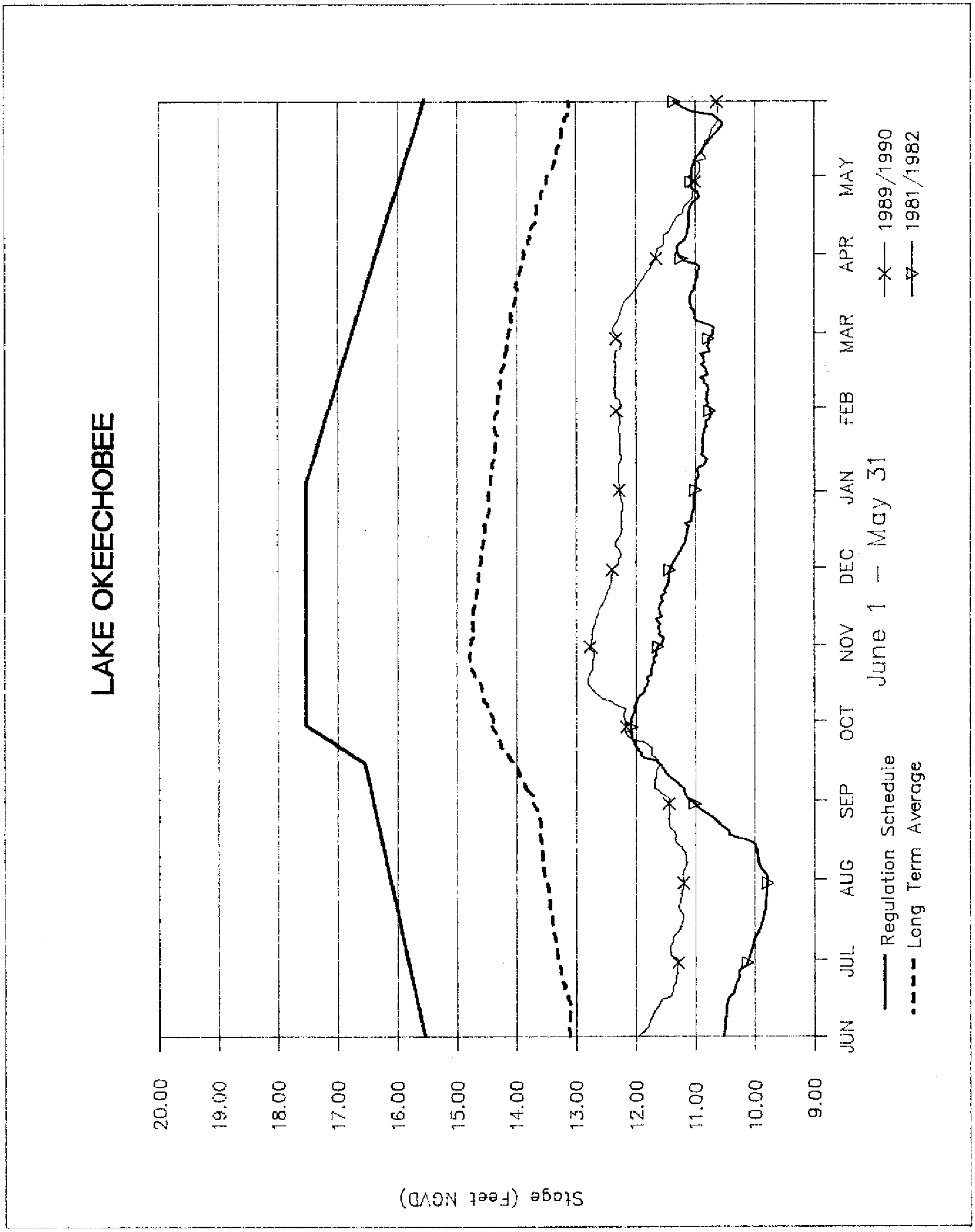


Figure 3-1 Lake Okeechobee

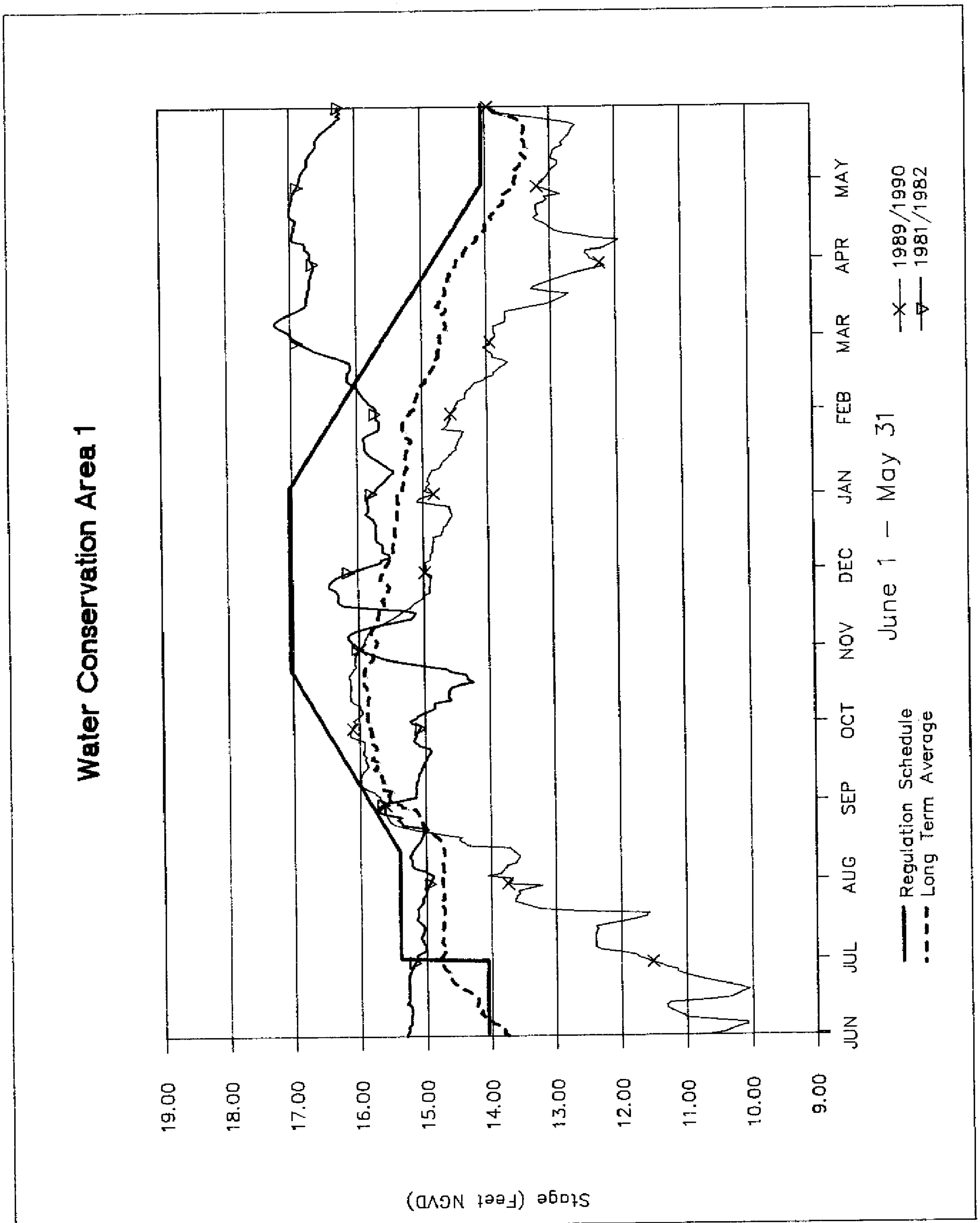


Figure 3-2 Water Conservation Area 1

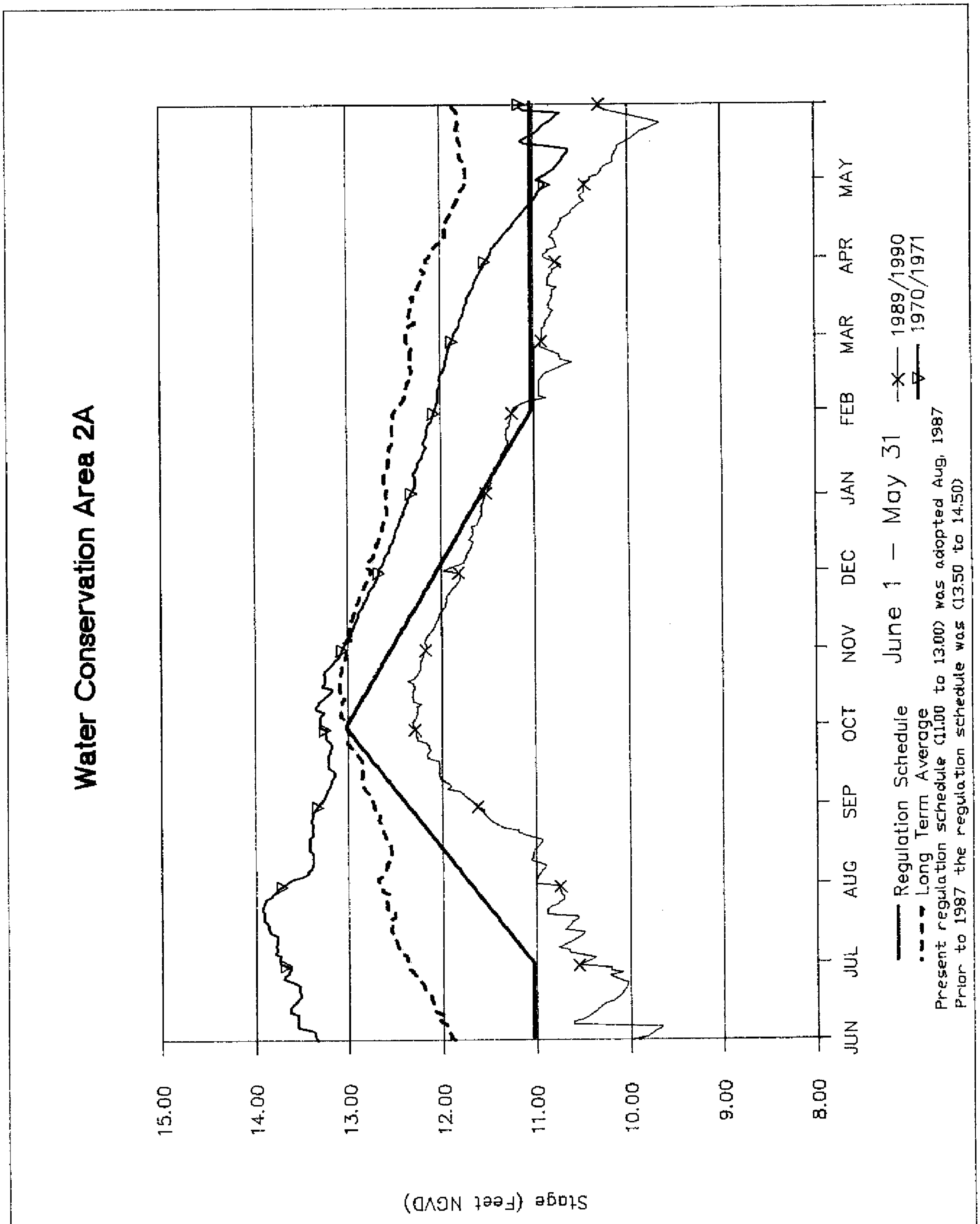


Figure 3-3 Water Conservation Area 2A

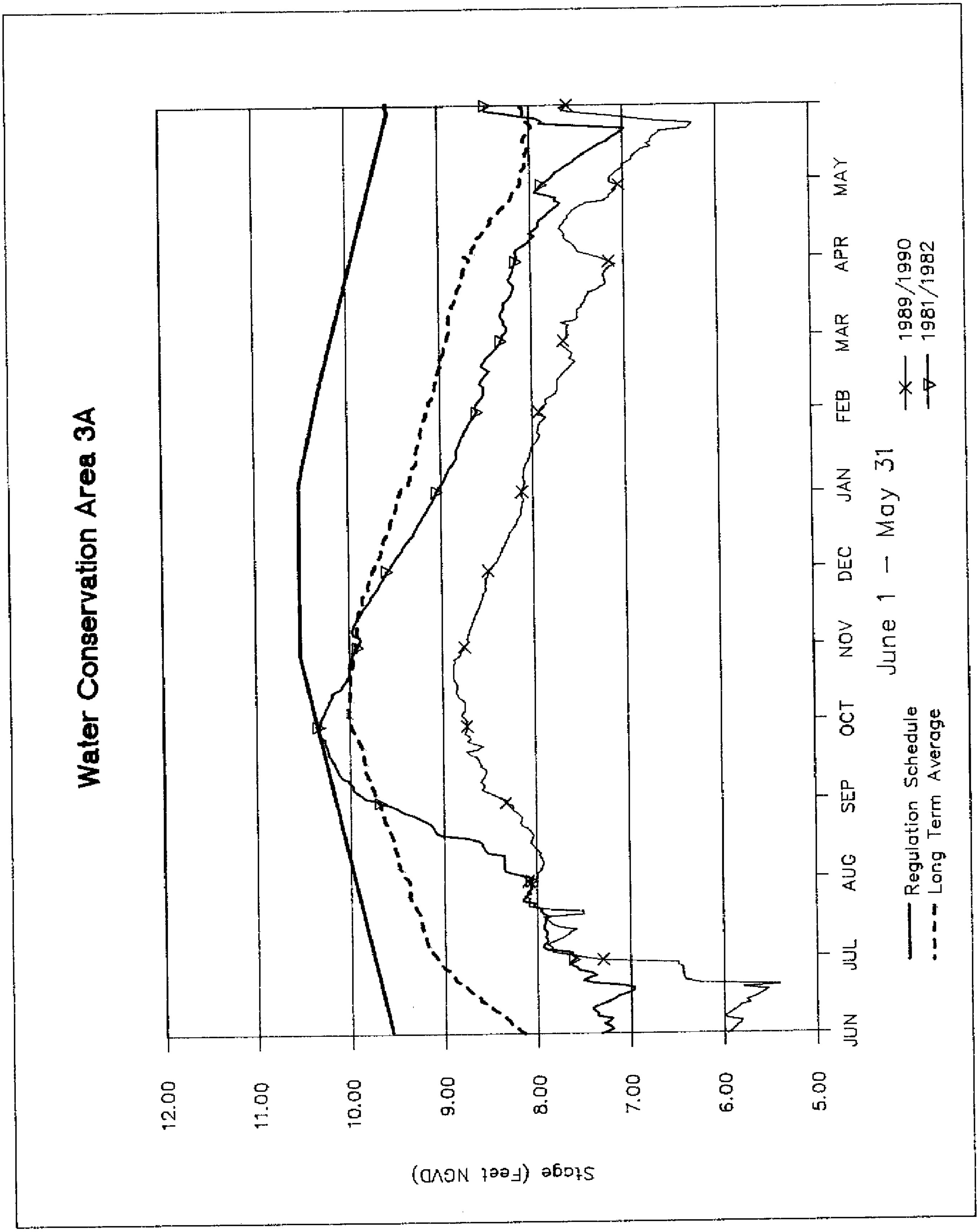


Figure 3-4 Water Conservation Area 3A

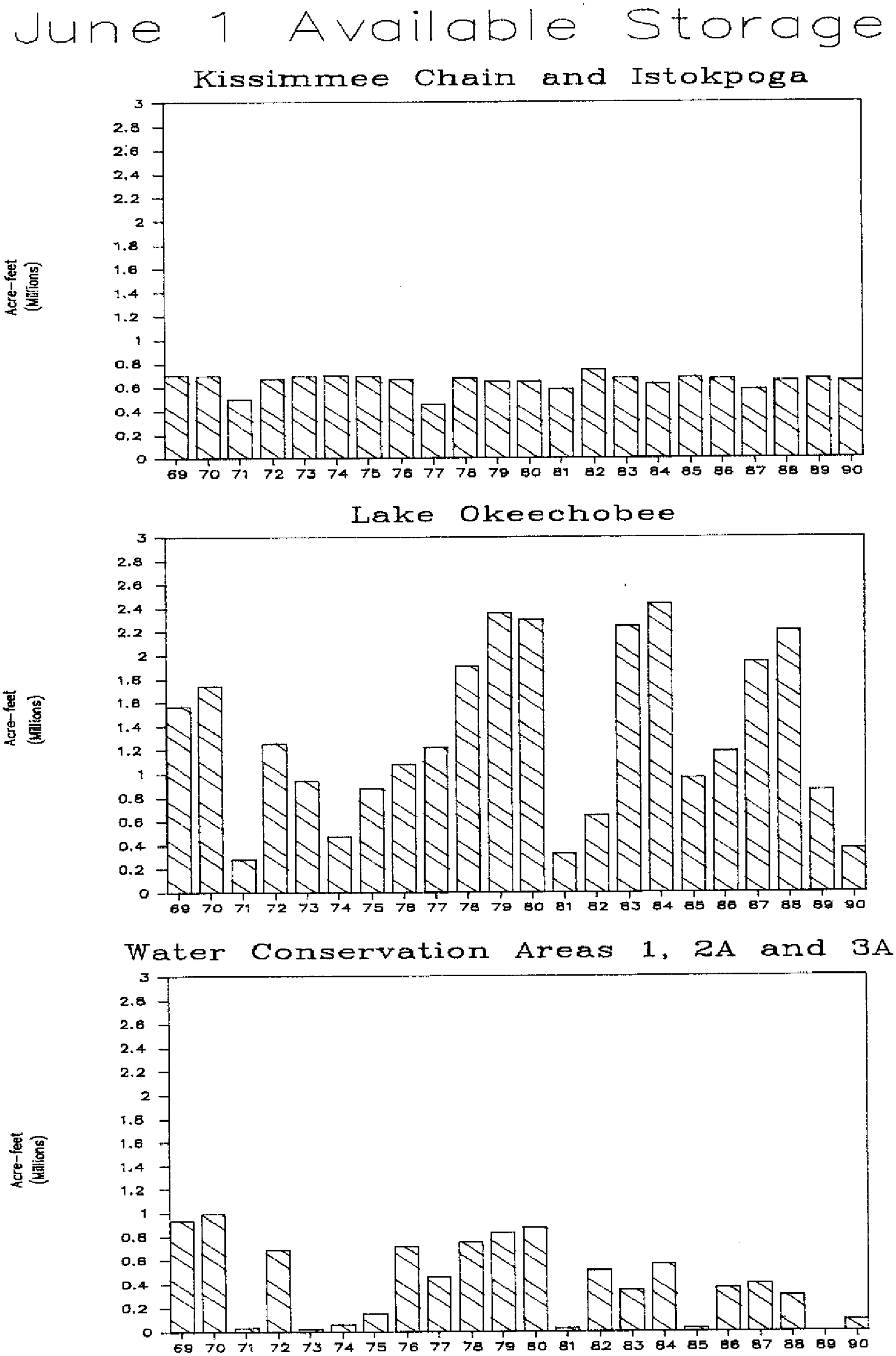


Figure 3-5 June 1 Available Storages

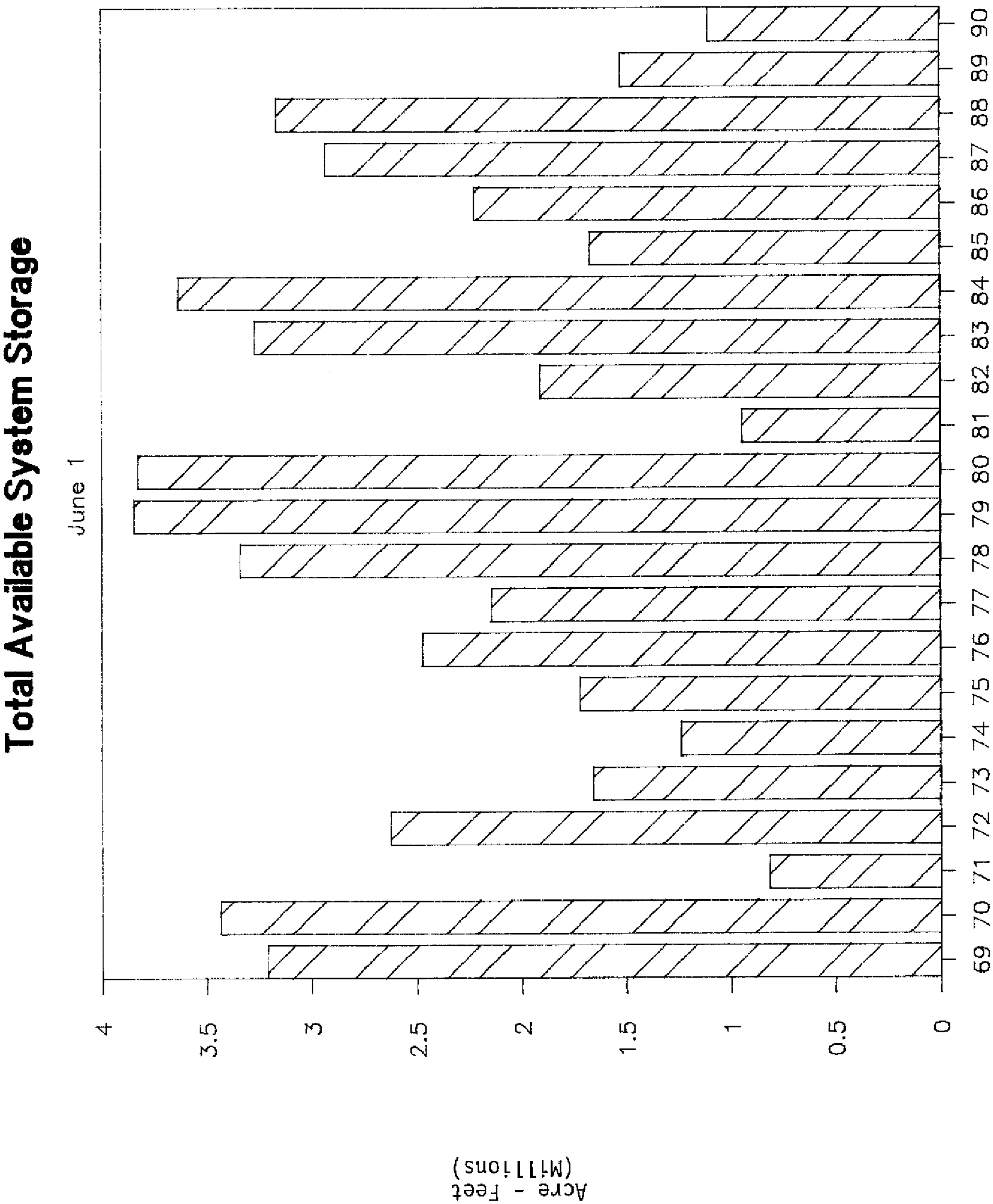


Figure 3-6 Total System Available Storages

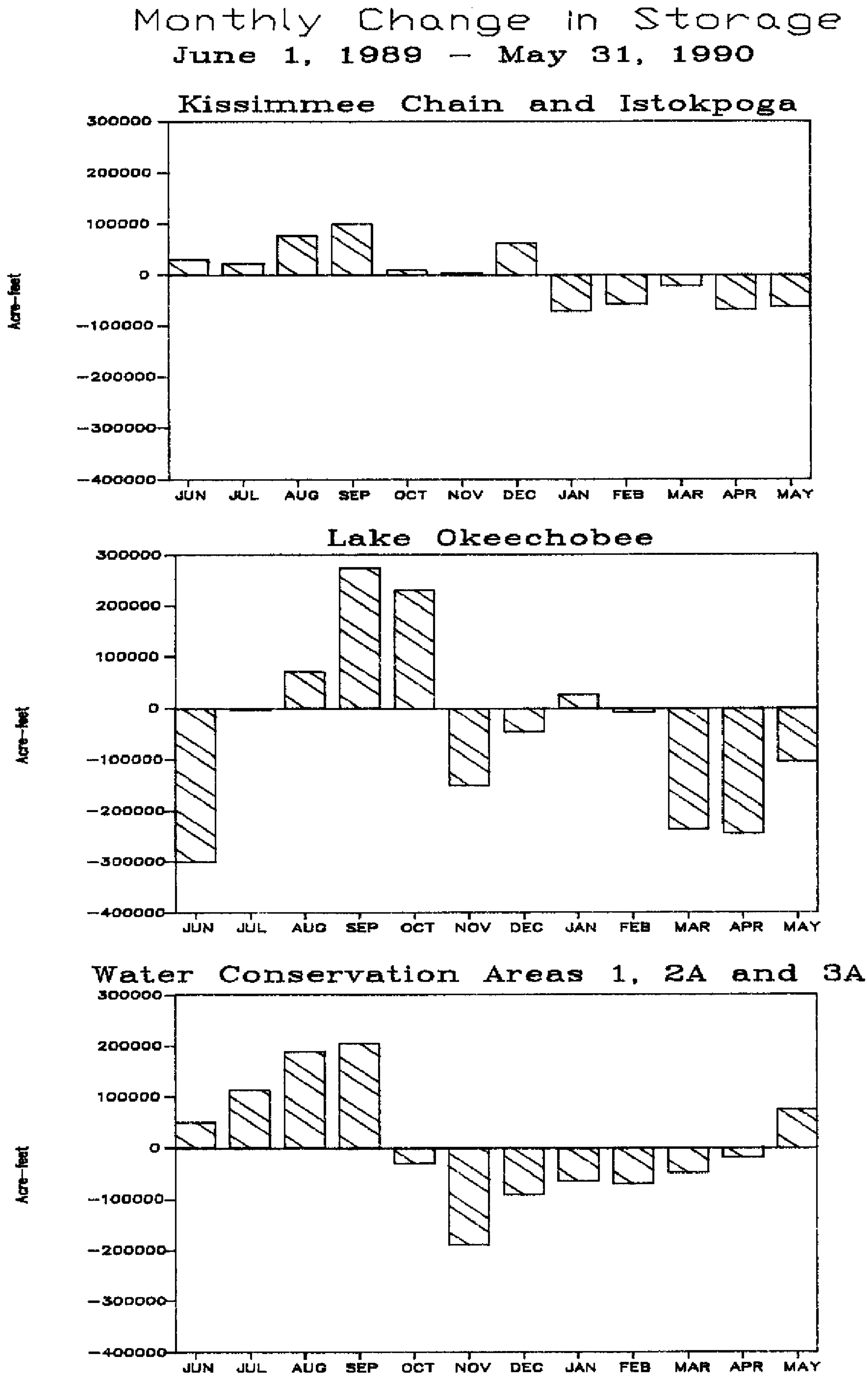


Figure 3-7 Monthly Changes in Storage June 1, 1989-May 31, 1990

supply releases. During the wet season months of June, July, and August in which the lake normally gains storage, it experienced a 200,000 acre-foot loss during 1989.

The WCA system experienced significant losses in storage between September 1989 and June 1990, although slight gains in storage occurred in May 1990, as shown in Figure 3-7. Those gains were primarily in WCA 1 and WCA 2A. WCA 3A still was well below the historical average. Figure 3-8 presents a comparison of the changes in storage for the study period in the major surface water supply areas. It shows that Lake Okeechobee for the second consecutive year experienced a deficit.

The monthly change in storage (1989-1990 versus average) in the total surface water supply system is illustrated in Figure 3-9. As can be seen in this figure, the total water supply system lost a significant amounts of storage during the dry season months and the wet season month of June. In June 1989, the Surface Water Supply System lost 279,000 acre-feet compared to the average historical gain of 364,000 for that month. This represents a difference of 643,000 AF. Likewise, in November 1989, the system lost 337,000 AF compared to the historical average loss of 225,000 AF, representing a difference of 112,000 AF. Large losses were also experienced in March and April 1990 although the drought management practices reduced those losses significantly. The total system storage dropped only 407,000 AF from June 1989 through May 1990 compared to 3.14 million from the period of September 1, 1988 to September 1, 1989.

Figure 3-10 illustrates the system change in storage during the period June through May for the last 20 years. The system loss of 0.4 million AF from June 1989 through May 1990 although significant, was not as dramatic as those changes in storage that occurred during the drought years of 1971, 1981, 1985, and 1989. The fact that this was the second consecutive year of storage deficit, made this 12-month period of critical importance.

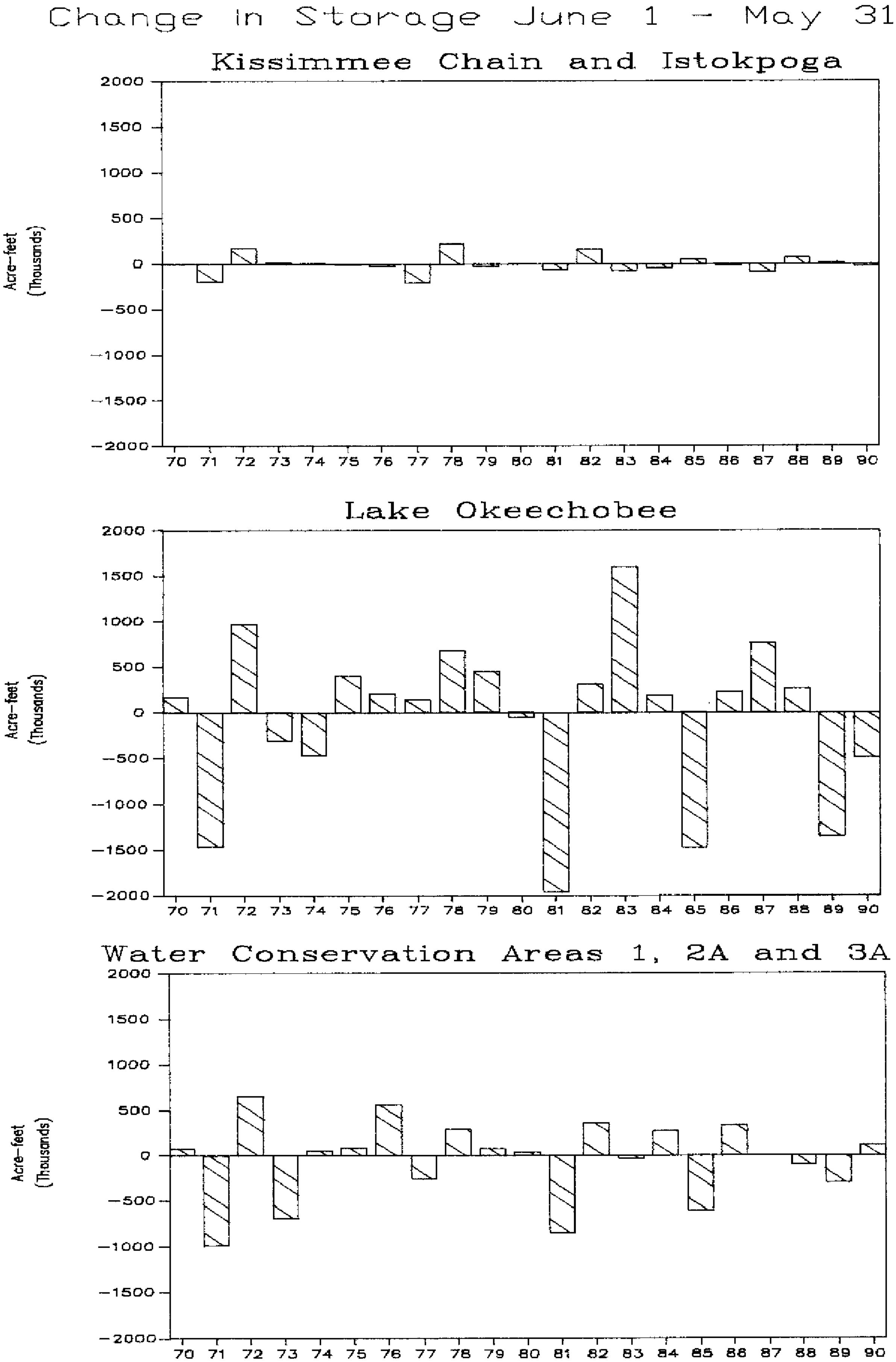


Figure 3-8 Change in Storage June 1, 1989 - May 31, 1990

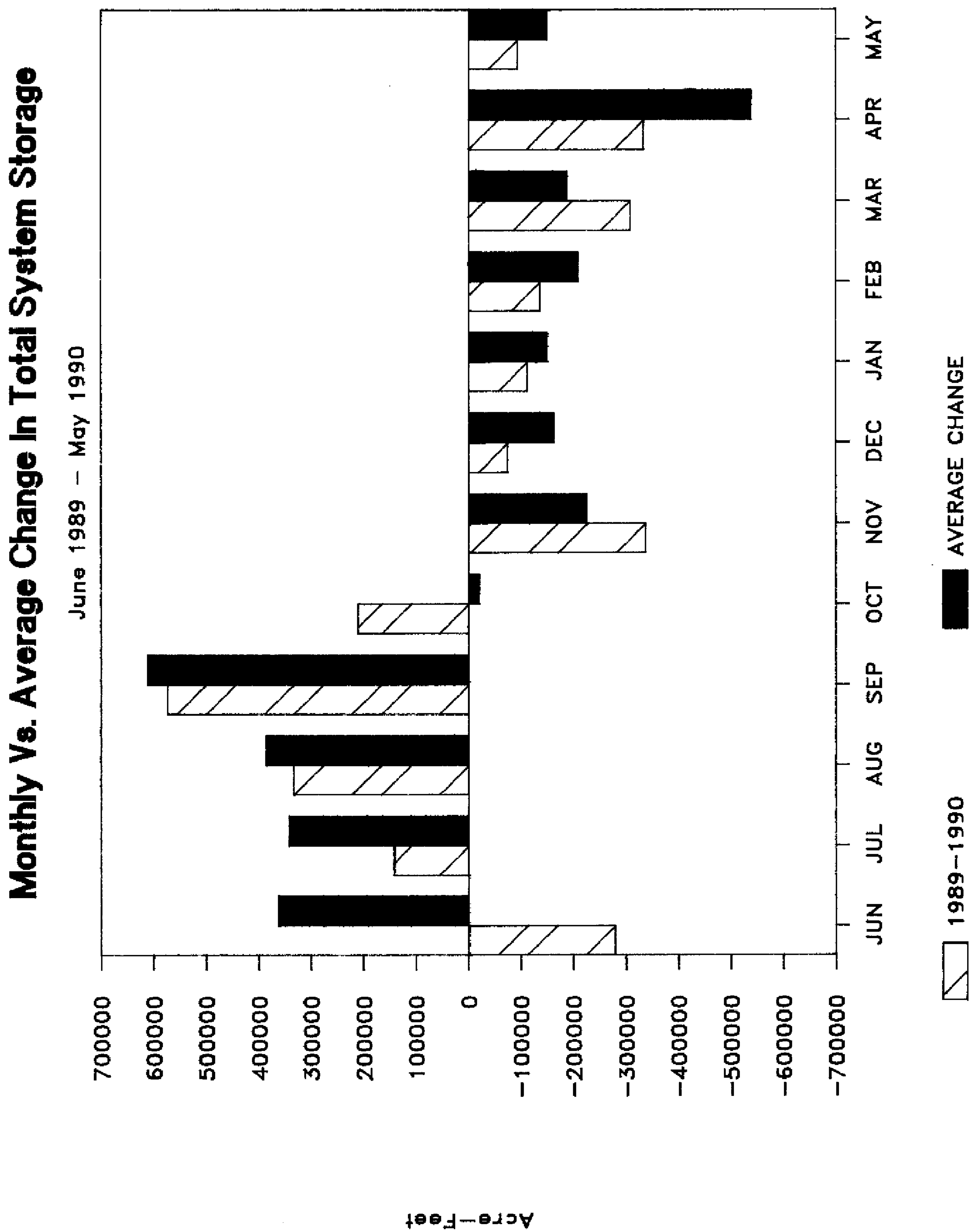


Figure 3-9 Total System Monthly vs Average Change in Storage

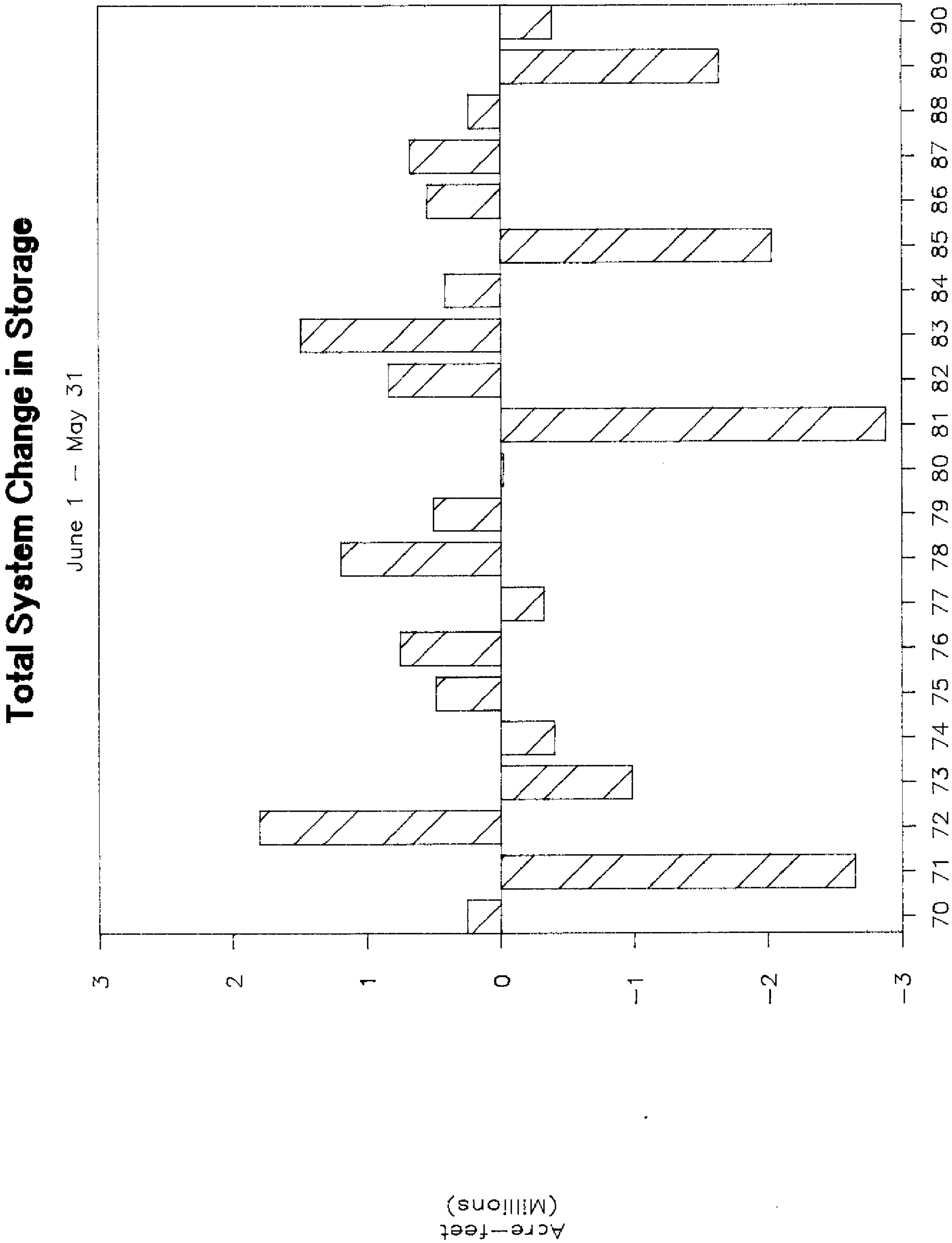


Figure 3-10 Total System Change in Storage June 1, 1989-May 31, 1990

4. WATER BUDGET ANALYSIS

A water budget normally is used to analyze the hydrologic behavior of a surface water reservoir. This type of approach summarizes all the inflows and outflows, including rainfall (RF) and evapotranspiration (ET), from the lake and each of the Water Conservation Areas to explain the net loss in storage for each storage area. In this section this technique will be used to illustrate the effect of the reduction in rainfall during the period of June 1989 through May 1990 in Lake Okeechobee and the Water Conservation Areas. A comparison with average conditions is also presented in this section.

Lake Okeechobee

A. Average Conditions

Lake Okeechobee is an enormous body of water covering a surface area of approximately 450,000 acres. A small decrease in RF or increase in ET can cause a tremendous loss of storage. Annual average ET as reported by the U. S. Corps of Engineers is 56 inches and exceeds the annual average rainfall of 45 inches by nearly a foot over the surface area of the lake. This one foot loss in stage is equivalent to a loss in storage of about 450,000 acre-feet (AF). In addition to the direct net loss in storage, the Lake also supplies water for agricultural and municipal use to regions surrounding the lake which are directly dependent on the lake for water supply. These regions are broken down into service areas that are defined by basin or a number of basins dependent on the lake for water supply. The principal service areas dependent on the lake for water supply are illustrated in Figure 4-1. The Everglades Agricultural Area, the Caloosahatchee River basin, and the St. Lucie Canal basin are the three largest users of the lake's water. Other service areas that also use significant amounts of water are, coastal north Palm Beach County which includes the city of West Palm Beach and the C-51 canal, and the northern rim of the lake which uses some water particularly during high lake stages. During extended dry periods, the lake is also a backup water supply for the three LEC service areas illustrated in Figure 4-1. Lower East Coast Service Area 1 is southern Palm Beach County, Service Area 2 is Broward County, and Service Area 3 is Dade County. During normal years minimal water is required from the lake for water supply to these coastal service areas as the water conservation area storage is sufficient for their needs. Normal water supply deliveries from the lake to its service areas are 600,000 AF.

The loss in storage due to water use and ET is usually replenished by the large surface water inflow that enters the lake from its large drainage basin. The tributary area to the north of the lake, which includes Fisheating Creek, Lake Istokpoga and its tributaries, the Kissimme River basin, Taylor Creek and Nubbin Slough, is over 3-million acres (shaded area in Figure 4-1). Historical average annual inflow from these basins is 1.63 million AF. The inflow from the Kissimmee River basin alone accounts for 950,000 AF based on data from 1965-1987. The summary of average annual inflows appears in Table 4-1. Normally, the lake experiences an annual net surplus in storage of 640,000 AF of water even after supplying the large consumptive needs of south Florida. This surplus usually occurs during the wet season which extends from June through mid-October.

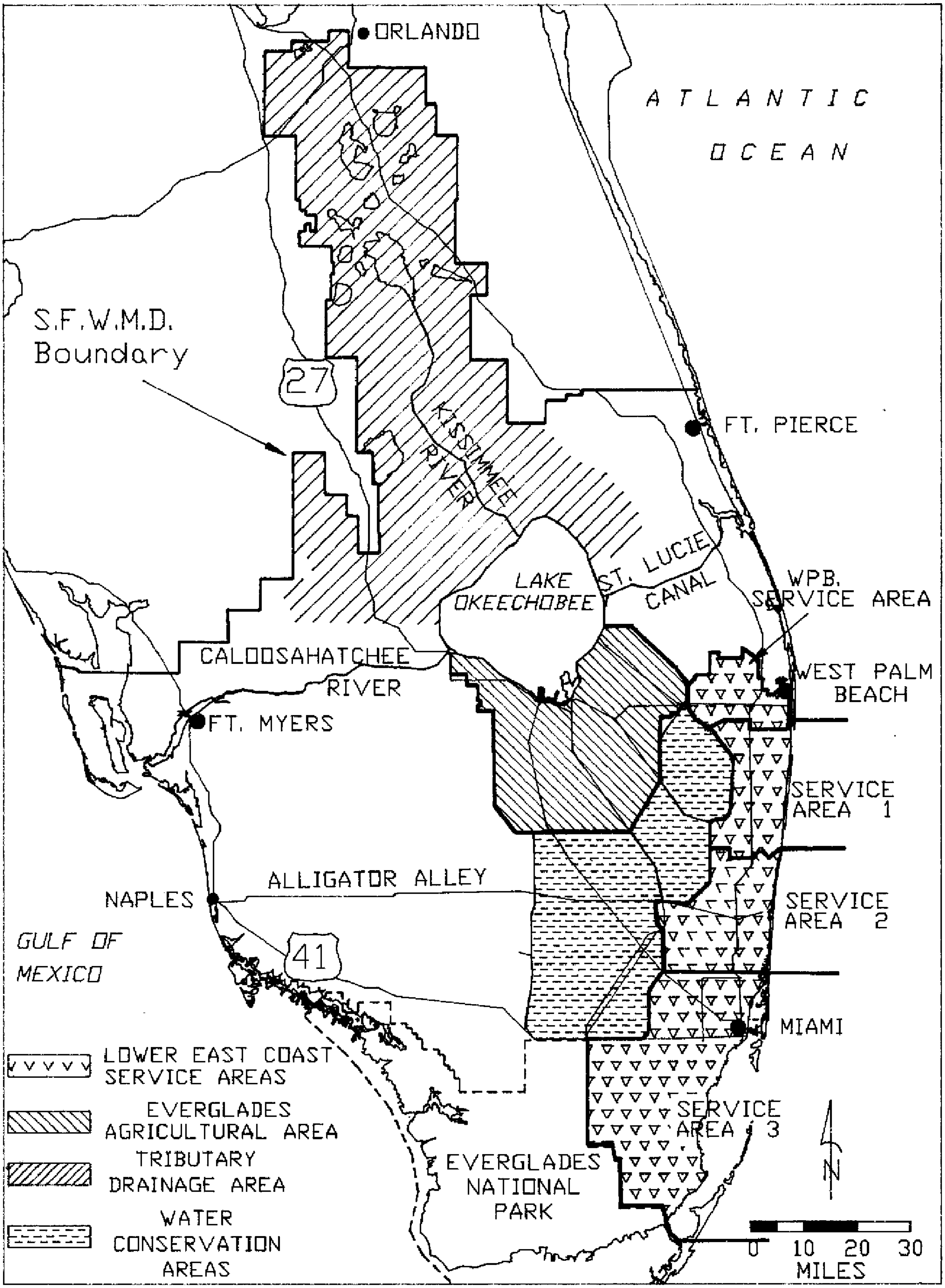


Figure 4-1 Major Tributary & Service Areas of Lake Okeechobee

TABLE 4-1
Summary of Average Historical Inflow
to Lake Okeechobee

Inflow Point	Volume (AF)
S-4	27,000
Indian Prairie	339,000
S-65E	950,000
Fisheating Creek	162,000
Others	210,000
TOTAL	1,690,000

B. June 1989 - May 1990 Hydrologic Conditions

The different components of the water budget for the lake during this period of prolonged drought conditions in South Florida appear in Figure 4-2. The dominant effect of RF and ET on the water budget is immediately noticeable. Rainfall during this period was 35 inches, or 10 inches less than normal rainfall. ET was about 55 inches. The difference between these two quantities alone would account for a 1.7-foot drop in stage (or loss in storage of 0.58 million AF). In addition to direct loses in storage, discharges were made for water use purposes which amounted to 0.86 million AF. Partially offsetting the large loss in storage due to ET and water use deliveries, was the large surface inflow from the basins that drain into the lake. Total surface inflow to the lake was about 1.23 million AF. This is about 75% of the normal expected 12-month surface inflow that appears in Table 4-1, and about .4 million AF greater than that which occurred during the 12-month period of September 1988 through August 1989. Surface inflows exceeded surface outflows by 0.37 million AF as compared to a deficit of 0.77 million AF during the 12-month period September 1988 through August 1989.

Table 4-2 compares inflows and outflows for the lake during this 12-month period to those of a normal year. Water use requirements on the lake by the agricultural industry and the public utilities are greatly magnified during drought periods as rainfall fails to replenish the local storage and satisfy local needs as it would normally. However, due to low lake levels and strict monitoring of water use deliveries, surface outflows were reduced from 1.61 million AF during the September 1988 through August 1989 period when water levels were initially higher, to 0.86 million AF during this period of analysis when water storage was at or near record low levels.

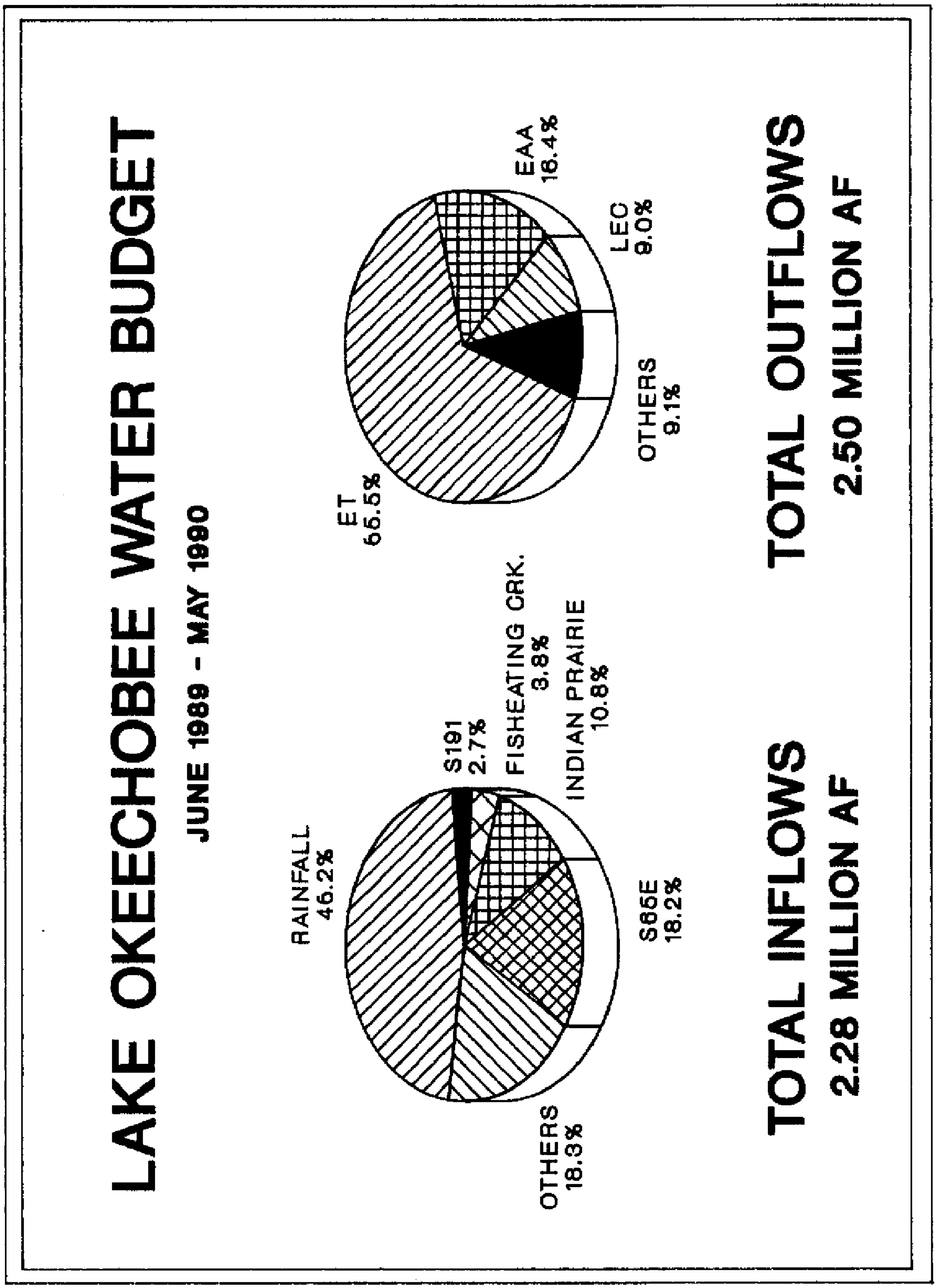


Figure 4-2 Lake Okeechobee Water Budget

TABLE 4-2
Comparison of Flows for 89-90 Versus a Normal Year (AF)
Lake Okeechobee

	Normal Year	1989-90	Net Effect
RF	1,640,000	1,052,000	-588,000
Surface Inflows	1,690,000	1,227,000	-463,000
ET	2,090,000	1,633,000	457,000
Surface Outflows	600,000	865,000	-265,000
TOTAL	640,000	-219,000	-859,000

In further analysis of the surface inflows to the lake, it should be noted that the deficit from the normal inflow occurred due to the below normal runoff entering the lake from the Kissimmee River through the S-65E structure, and from the Fisheating Creek basin. Inflows from the Kissimmee River normally peak biannually, once in the late summer and early autumn due to excess storage build up during the wet season months (June-October) and once in late winter months and early spring due to the decline in the regulation schedules of the Upper Kissimmee Chain of Lakes during this period of the year. Figure 4-3 compares the June 1989 through May 1990 period against the normal inflow computed with data since 1970 after the S-65 structure was built to regulate the Upper Kissimmee Chain of Lakes. It can be seen in this diagram that the largest portion of the deficit occurred during the wet season months. Substantial runoff entered the lake during the winter months. Figure 4-4 illustrates the accumulation of deficit in the S-65 flow since the onset of the present drought in September 1988.

Fisheating Creek experienced a similar deficit in the early wet season but generated substantial runoff later in the wet season. The cumulative deficit for the period of analysis was about 70,000 AF. Fisheating Creek inflow and accumulative inflow appear in Figure 4-5. A total of 0.144 million AF were backpumped into the lake during September and October 1989. This volume of water contributed significantly to the water supply available for allocations later in the 1990 dry season.

Water Conservation Areas

The water budgets for the three Water Conservation Areas (WCAs) appear in Table 4-3. All three WCAs had significant storage gains late in the wet season; however, due to the very dry antecedent conditions from the spring of 1989 and continued below normal rainfall throughout the District, storage gains were smaller than normal. Runoff from regions surrounding the WCAs were substantially below normal. The EAA, which is a major contributor of surface inflow to the WCAs, only produced slightly greater than 50% of its normal 1 million AF of outflow. The monthly outflow and accumulated monthly outflow appear in Figure 4-6. Like the major basins that drain into Lake Okeechobee, the EAA produced only limited amounts of outflow to the WCAs early in the wet season. The period of August through October outflow volumes were closer to normal; however, during the dry

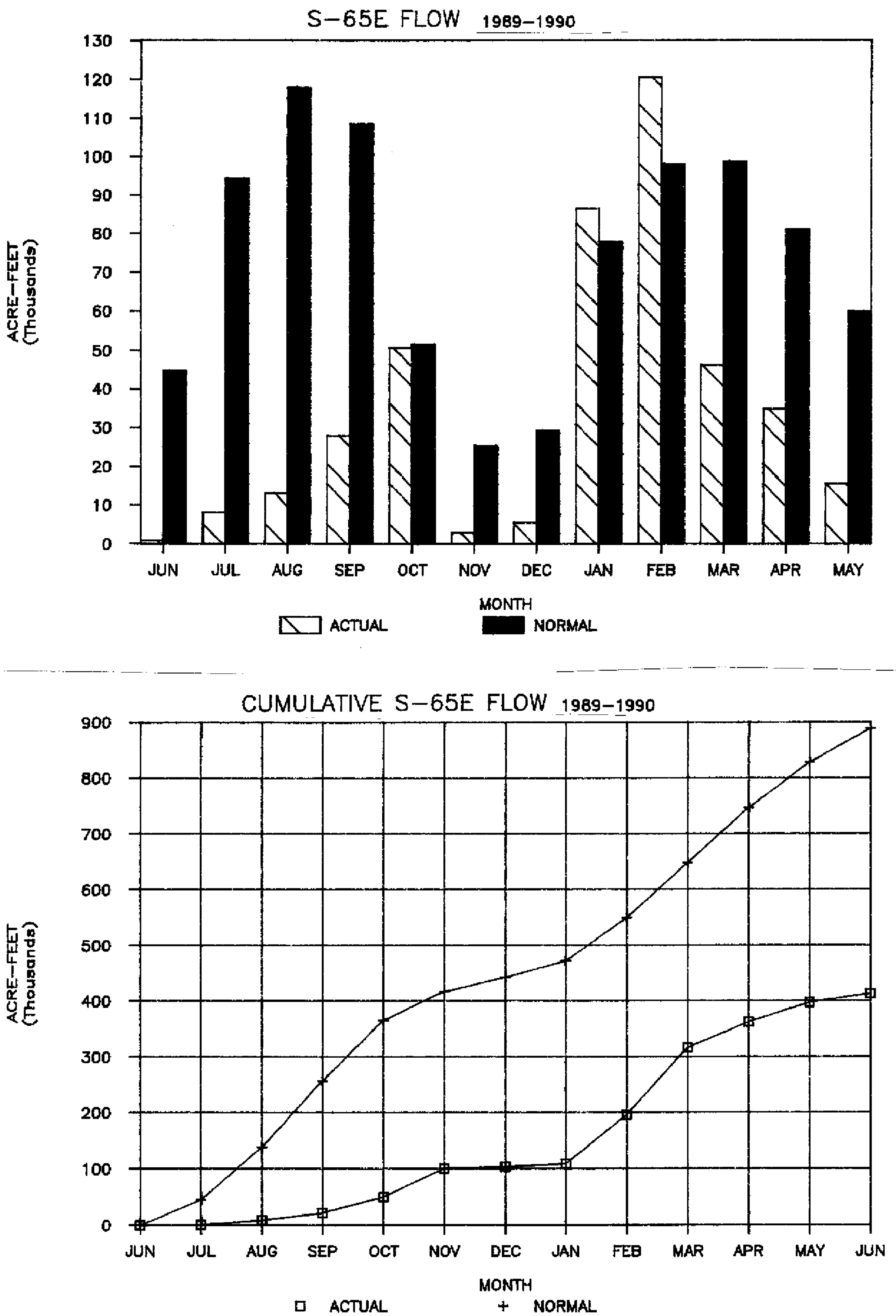


Figure 4-3. Summary of S-65E Flow

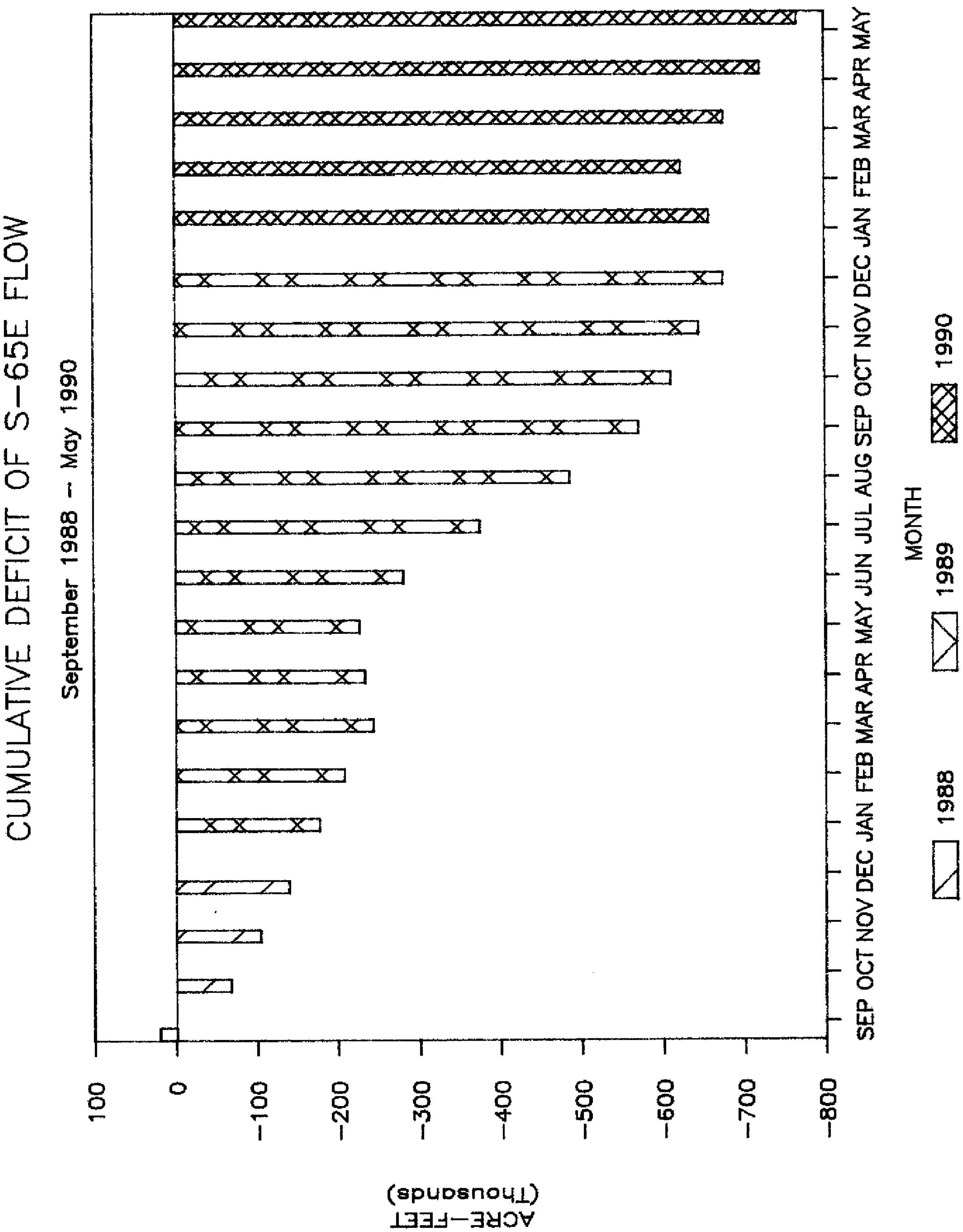
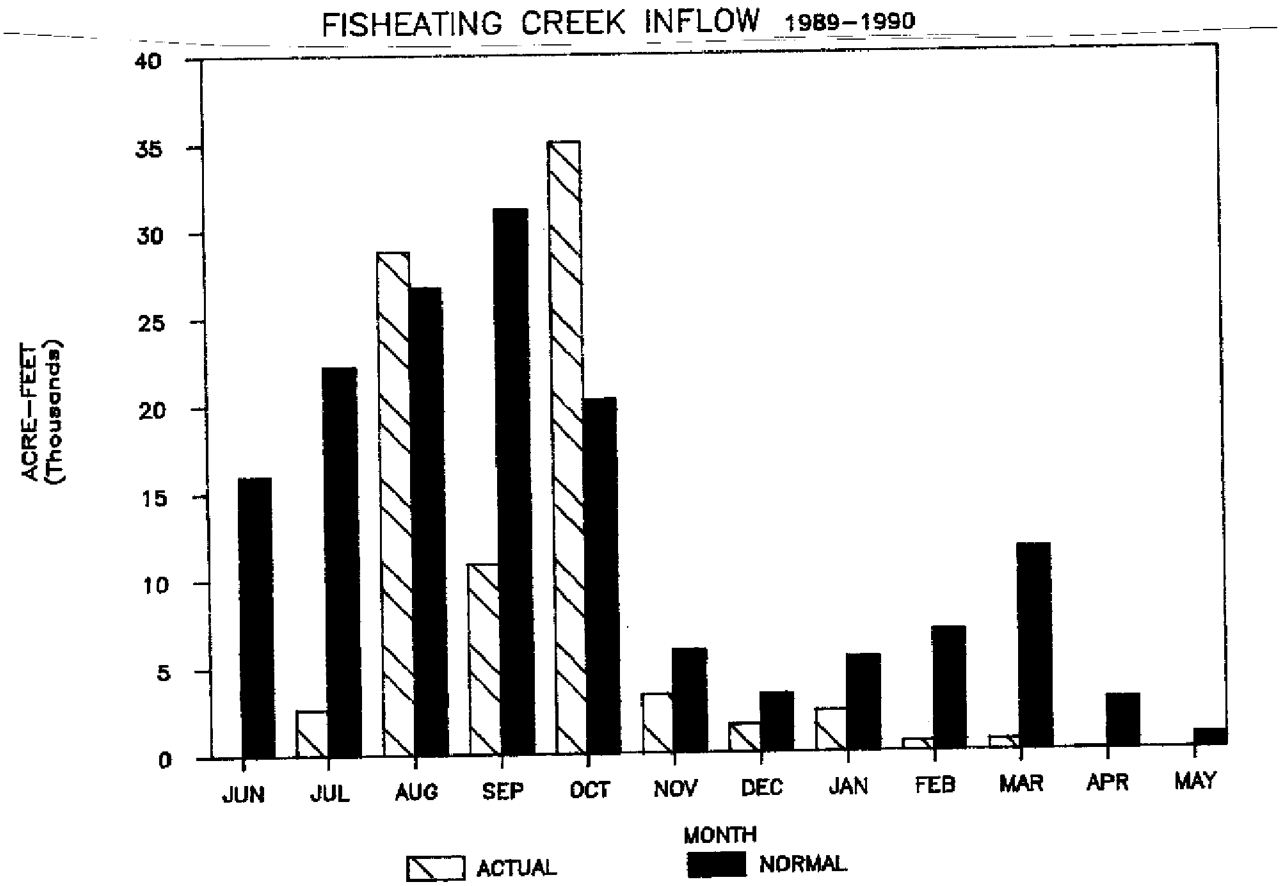


Figure 4-4. Cumulative Deficit of S-65E Flow



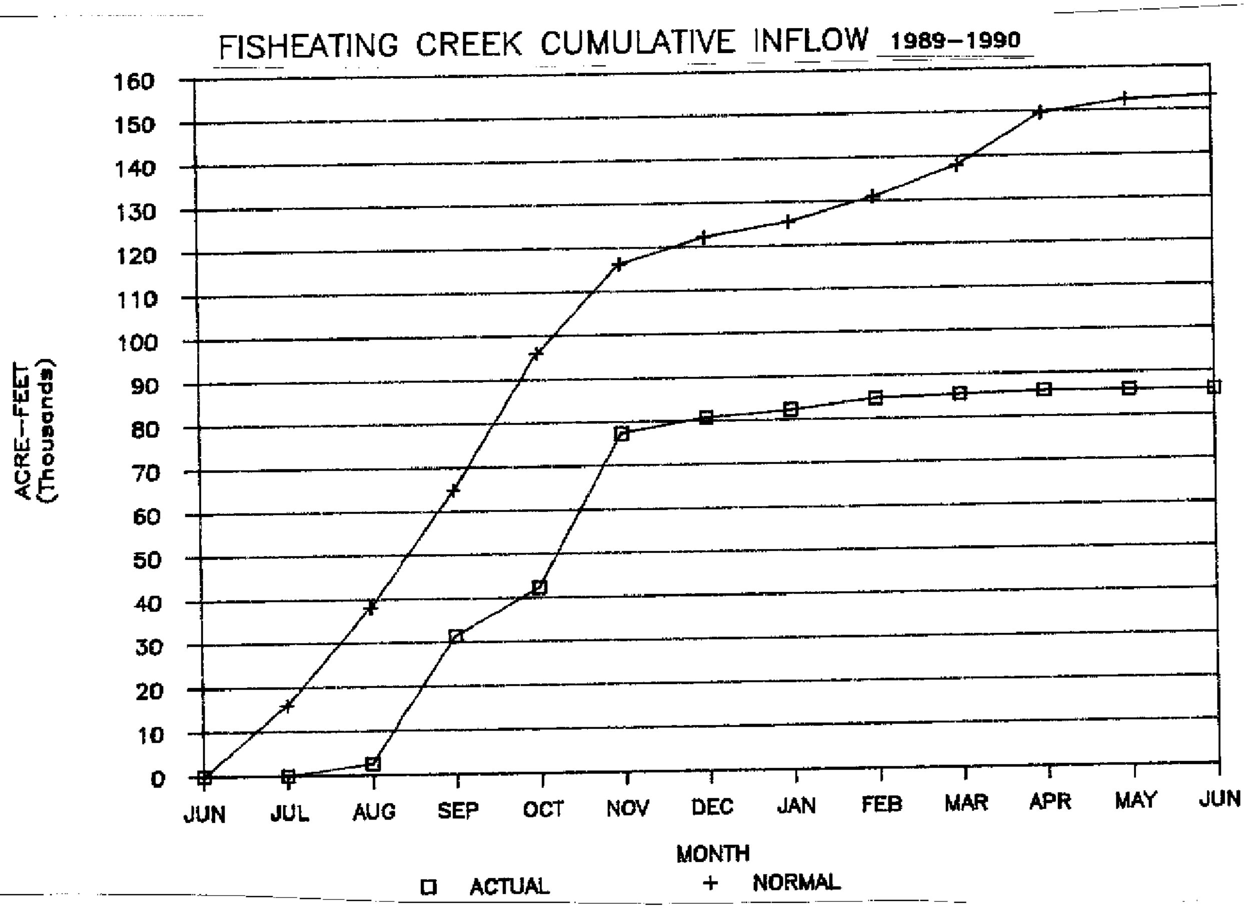


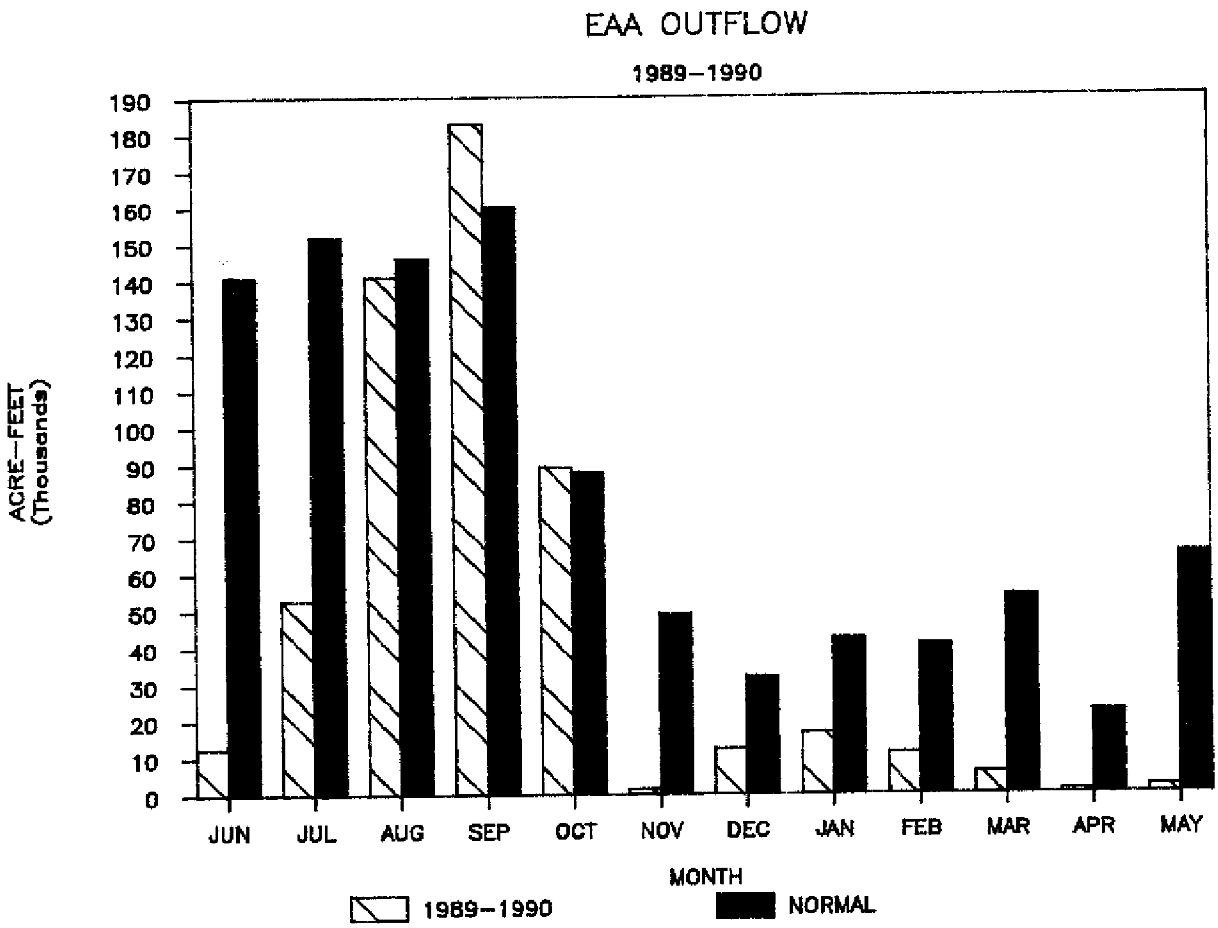
Figure 4-5. Summary of Fisheating Creek Inflow

TABLE 4-3
1989 - 1990 Water Conservation Area Computed Water Budgets (AF)

	RF	ET	Seepage	Inflow	Outflow	Net Change
WCA 1	258,000	190,000	91,000	194,000	137,000	34,000
WCA 2A	310,000	205,000	138,800	60,000	47,000	-20,000
WCA 3A	1,459,000	1,350,000	260,000	451,000	260,000	40,000
TOTAL	2,027,000	1,745,000	489,000	705,000	444,000	54,000

season the EAA produced little outflow due to below normal rainfall and agricultural water management practices within the EAA. By the end of the 1990 dry season available storage for water use was again depleted in the WCAs, although the water levels were slightly higher than the previous year.

The water budgets for WCA 1, WCA 2A and WCA 3A are illustrated in Figures 4-7, 4-8 and 4-9, respectively. The combined volume of ET and seepage were greater then the volume of rainfall received by 0.207 million AF. Surface inflows exceeded surface outflows by 0.261 million AF for a net computed gain in storage of 0.054 million AF for the period of analysis.



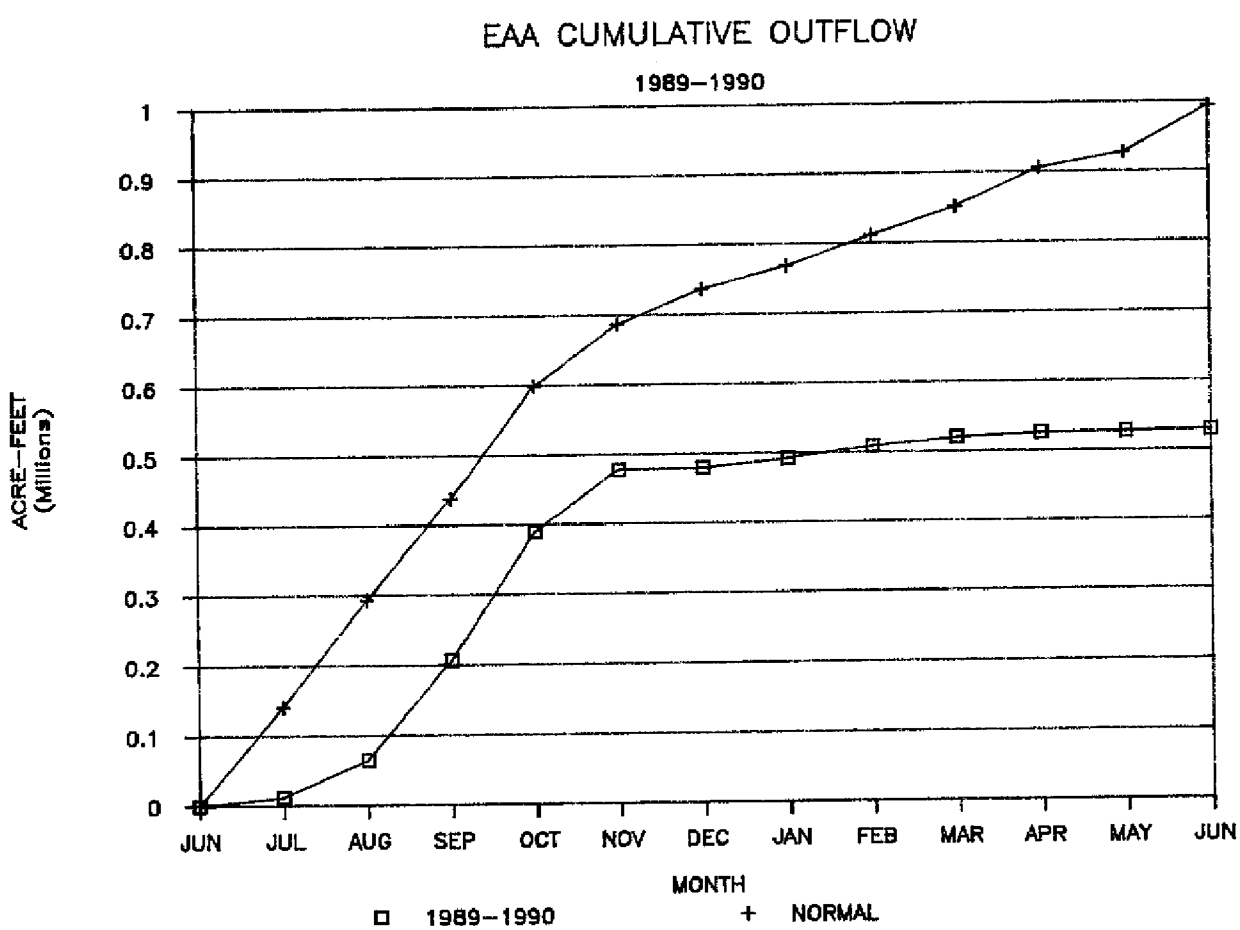


Figure 4-6. Summary of EAA Outflow

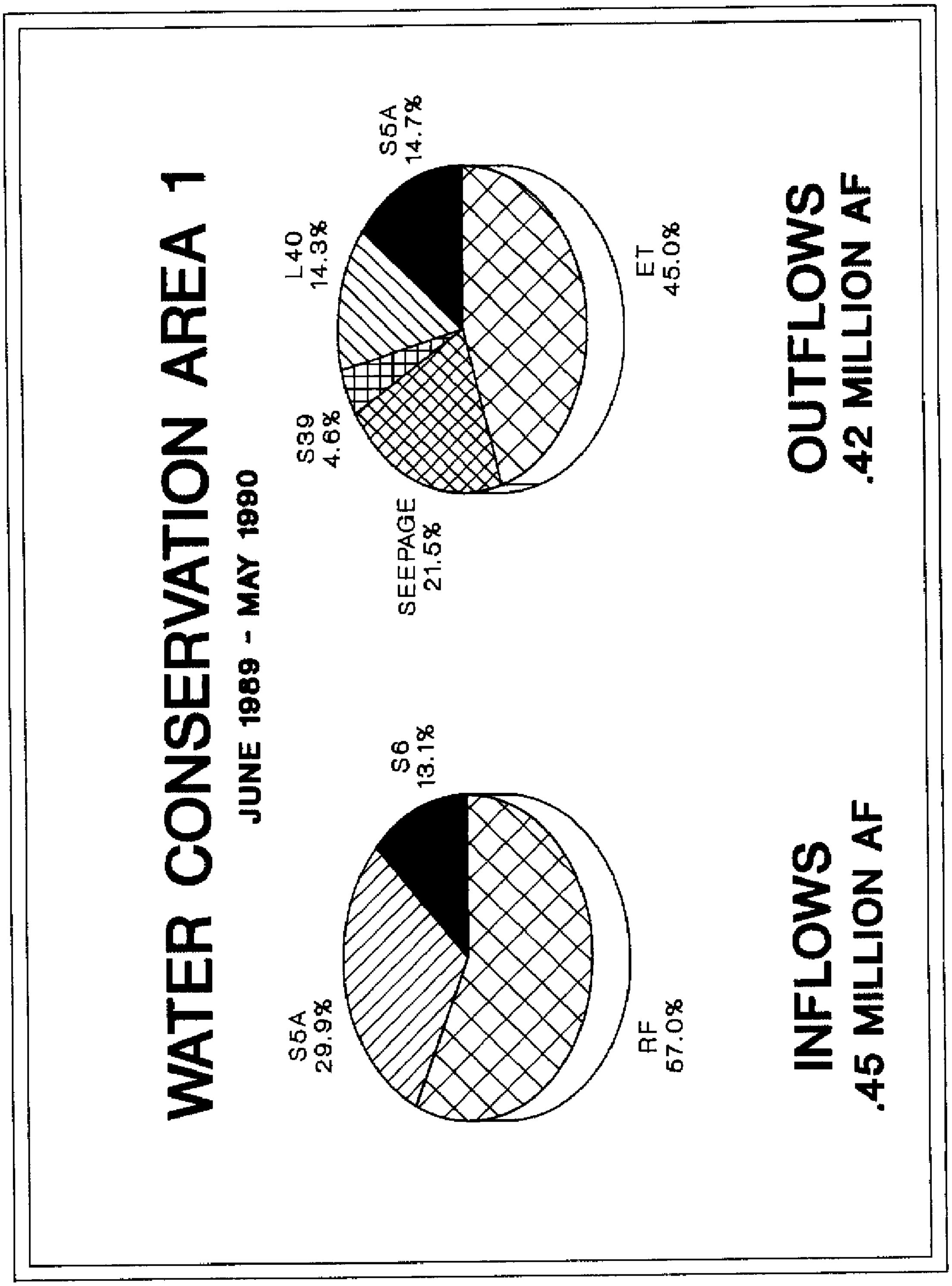


Figure 4-7. WCA-1 Water Budget

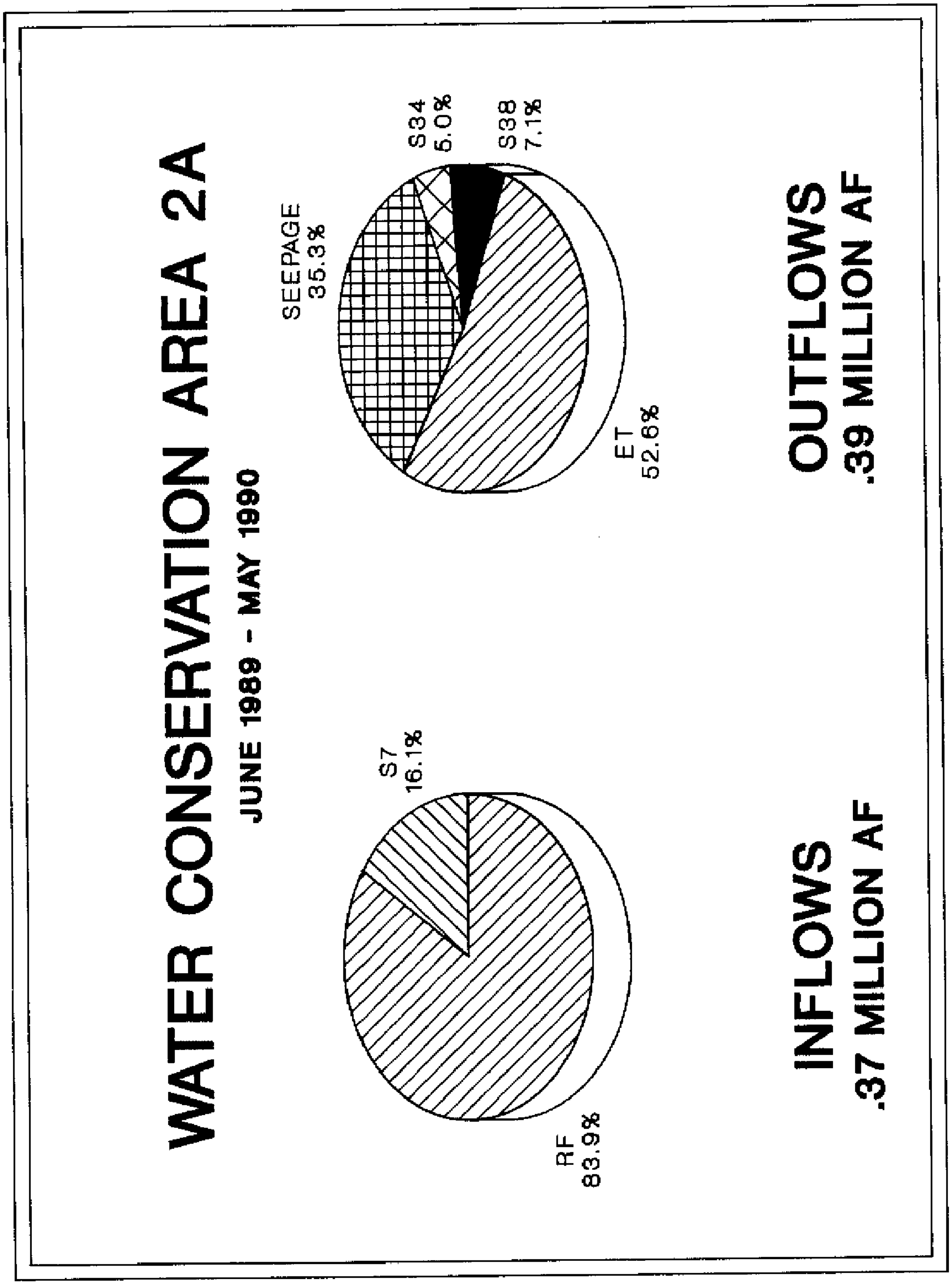


Figure 4-8. WCA-2A Water Budget

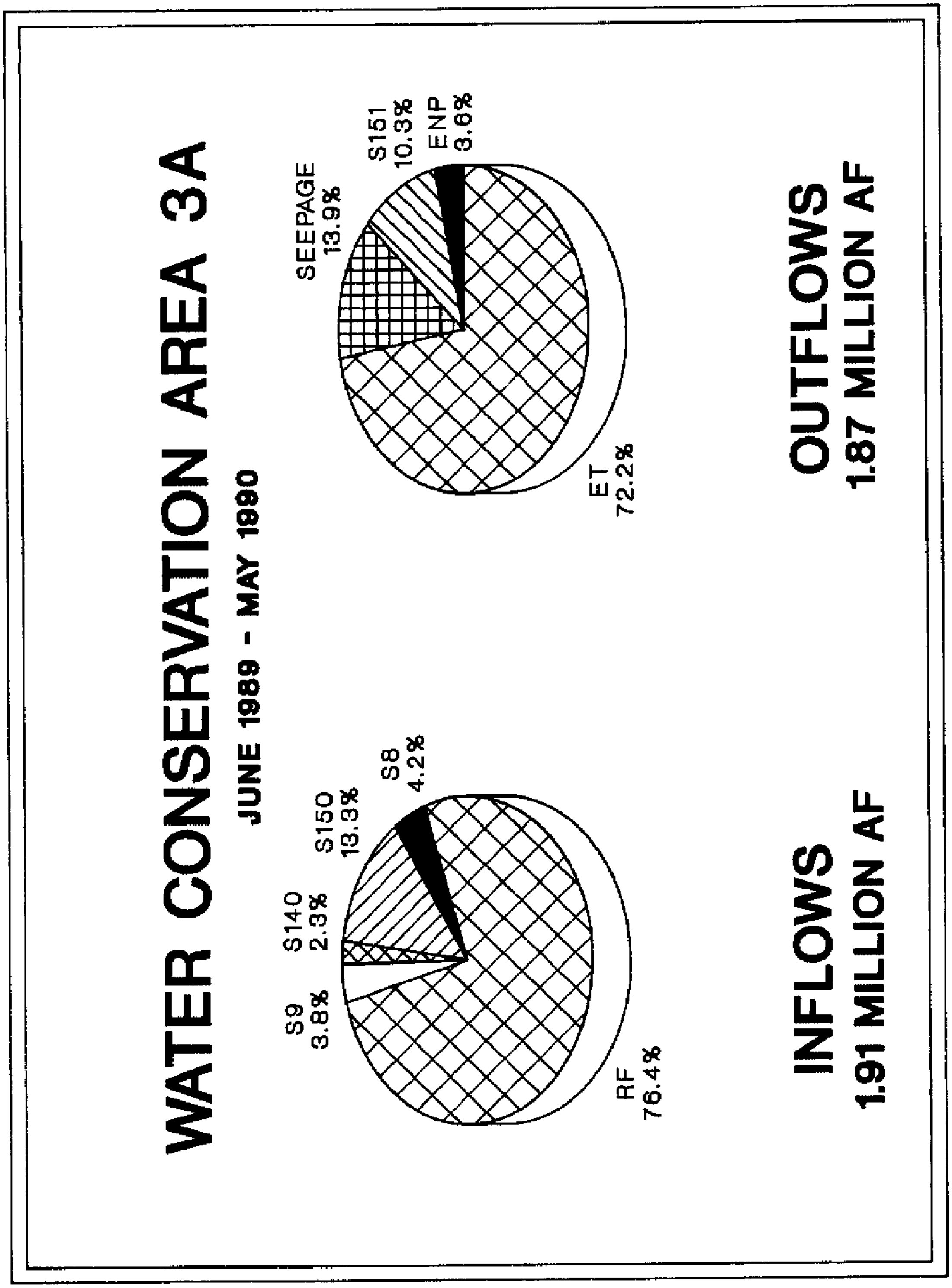


Figure 4-9. WCA-3A Water Budget

5. WATER SUPPLY DISTRIBUTION

This section presents an analysis of the water supply releases from Lake Okeechobee and the Water Conservation Areas during the drought period of June 1989 through May 1990. Figure 5-1 illustrates the distribution of water supplied from the lake and the WCAs during this period.

Lake Okeechobee

The water supply deliveries from the lake during this period of analysis were reduced to 0.865 million AF as compared the 1.612 million AF during the period beginning September 1988 and extending through August 31,1989. The EAA water uses were decreased from 0.790 million AF during the earlier period to 0.410 million AF during this period of analysis. Figure 5-2 illustrates the cumulative water use deliveries to the EAA during the critical 1989-1990 dry season versus that of 1988-1989 dry season when water levels were initially much higher. In addition, the other lake service areas decreased from 0.507 million AF during the earlier 12 month assessment period to 0.228 million AF this period of analysis. The actual water use deliveries to the lake service areas only slightly exceeded a normal water use year even though the below normal rainfall conditions during this period substantially increased water use requirements. This was achieved by careful water use monitoring and water conservation measures that were put into action. For the second straight year large deliveries had to be made from Lake Okeechobee to the Lower East Coast (LEC) service areas. During the period of this analysis 0.224 million AF were delivered to the LEC. During the earlier analysis period 0.310 million AF were needed. During a normal year the WCAs would have sufficient water storage to supply the LEC service areas. However, due to the very low water levels in WCA 3A, substantial releases had to be made through this water conservation area to Dade County (LEC Service Area 3).

The distribution of water supplied from the lake appears in Figure 5-3. The EAA, as in the earlier period of analysis, received about 50% of the water delivered for water supply from the lake, while the LEC received about 25% of the deliveries (primarily LEC Service Area 3). Deliveries to the St. Lucie Canal and the Caloosahatchee River along with other smaller service areas accounted for the final 25% of the water use deliveries from the lake.

Water Conservation Areas

Water deliveries from the WCAs to the LEC Service Areas appear in Figure 5-4. Releases from WCA 1 to the EAA are also included in this figure.

WCA 1 made a substantial recovery from the record low water levels of the 1989 dry season. This resulted in a significant quantity of water being available for releases to the LEC, the West Palm Beach service area, and even to the EAA. The total water releases from WCA 1 were 0.14 million AF. Of this volume of water, only 24,000 AF (0.024 million AF) originated from Lake Okeechobee, with the remainder of the supply coming directly from the WCA. A total of 19,000 AF (0.019 million AF) were made through the S-39 structure to the coastal Hillsboro Basin, 60,000 AF to the Lake Worth Drainage District (L-40), 42,000 AF to the L-8 canal for the West Palm Beach catchment area, and 17,000 AF to the EAA.

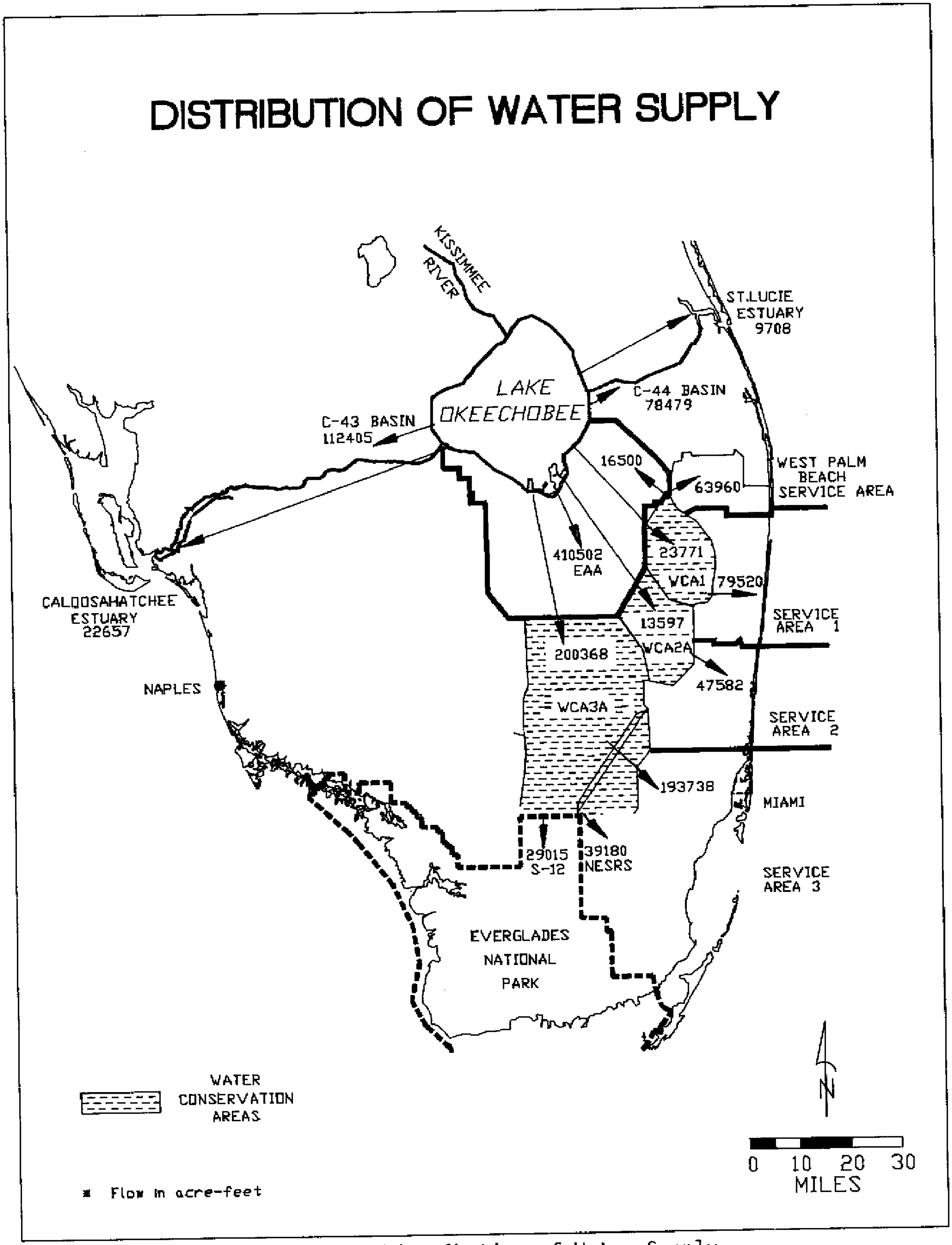


Figure 5-1 Distribution of Water Supply

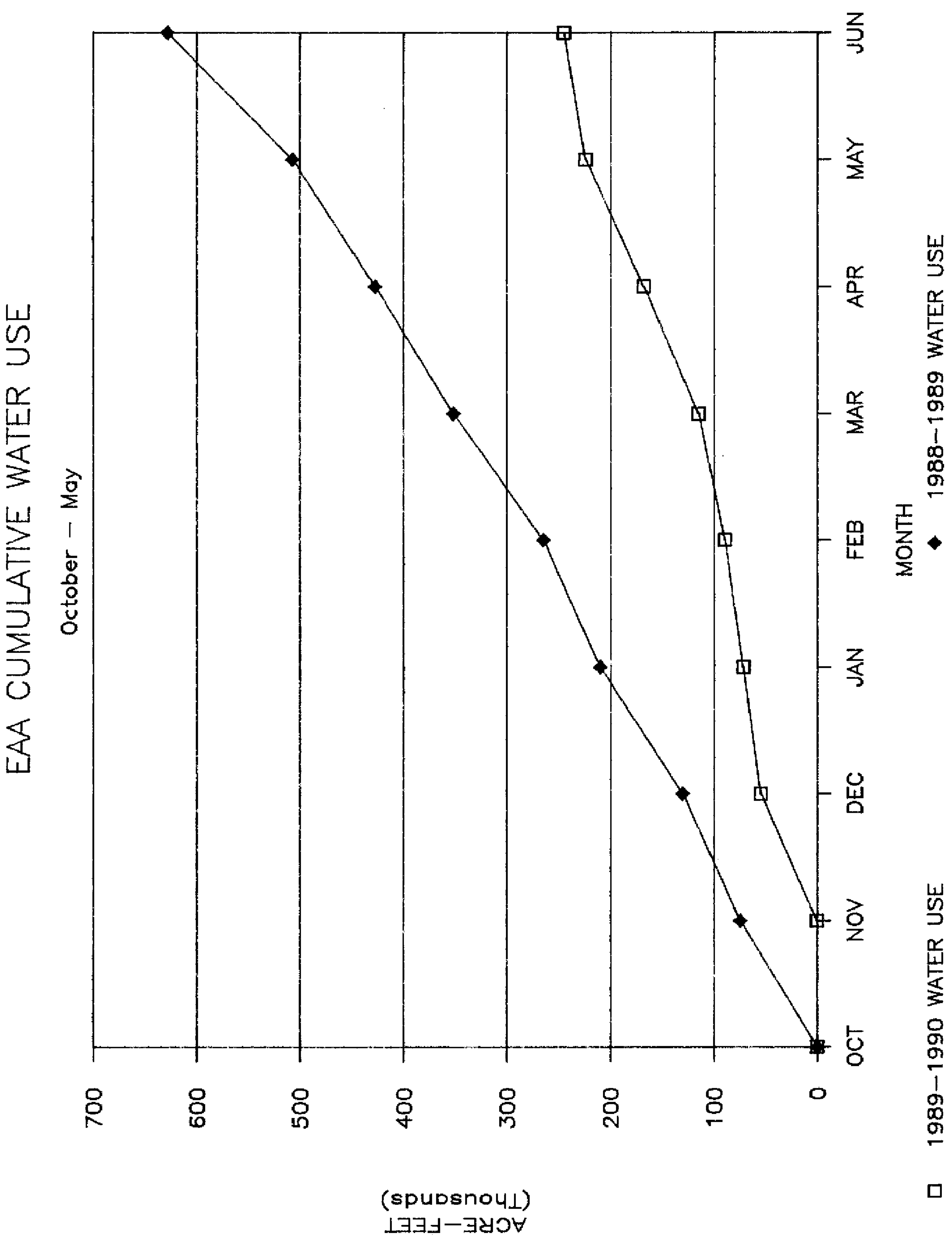


Figure 5-2 EAA Cumulative Water Use

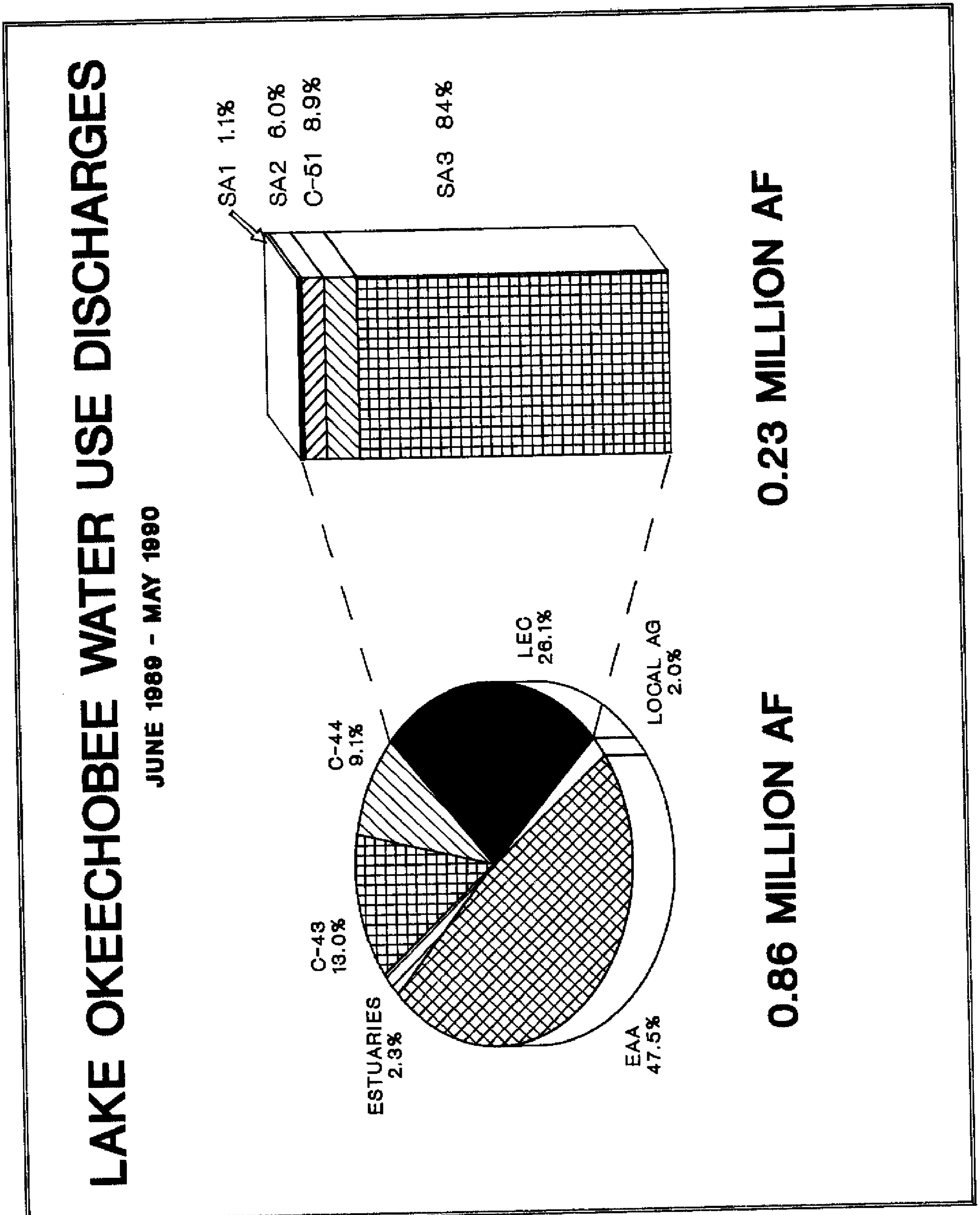


Figure 5-3 Lake Okeechobee Water Use Discharges

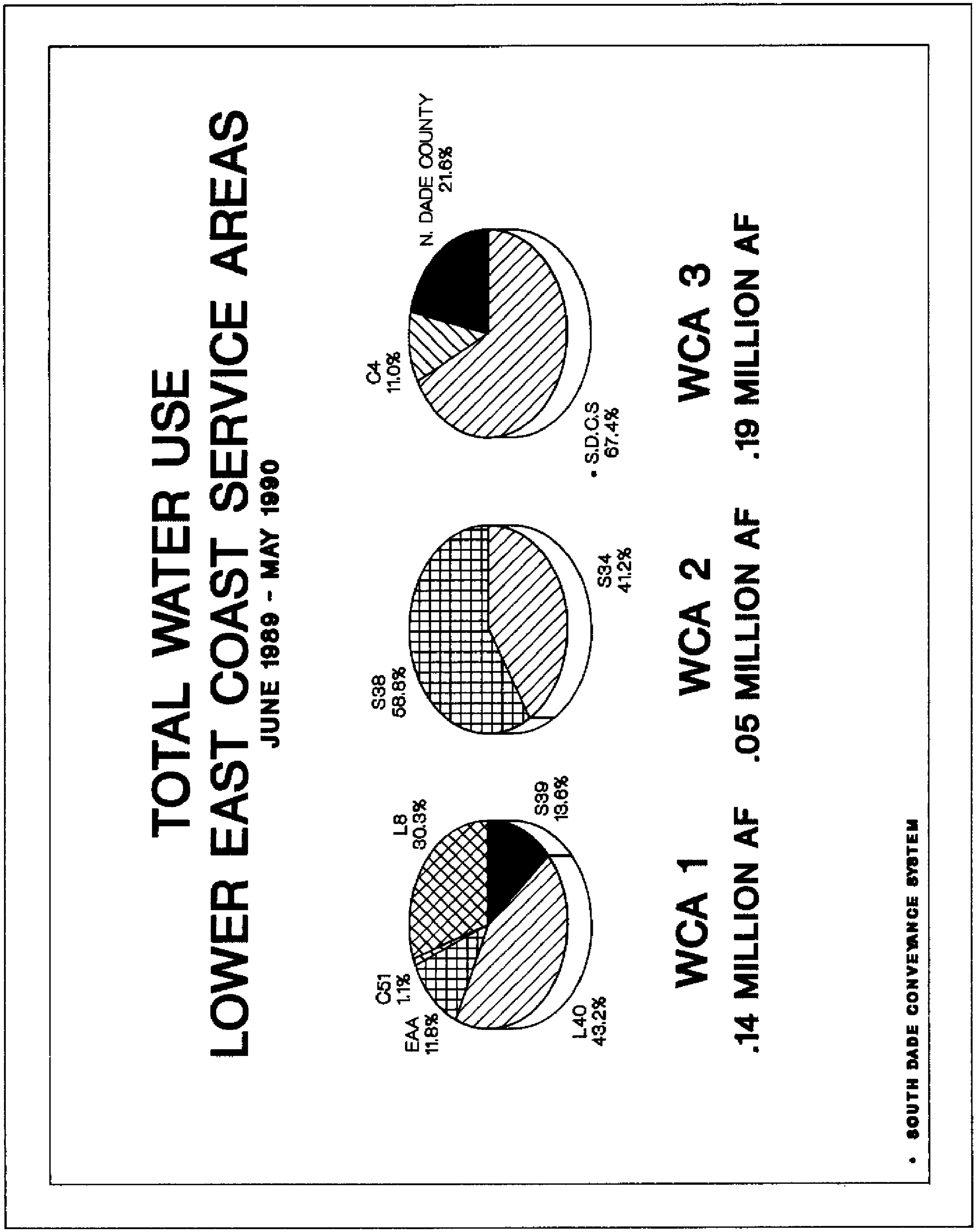


Figure 5-4 Water Conservation Area Water Use Discharges

An additional 20,000 AF were delivered directly from Lake Okeechobee to the West Palm Beach service area so that this service area received a total of 64,000 AF. The deliveries to EAA were made early in the dry season when WCA 1 was projected to reach regulation stage.

Water use deliveries to LEC Service Area 2 from WCA 2A were about 50,000 AF, of which 13,000 AF were delivered from the lake. Of the 50,000 AF delivered to eastern Broward County, 20,000 AF were delivered through the S-34 structure to the coastal North New River Canal and 30,000 AF through the S-38 structure.

The water use releases made to LEC Service Area 3 (Dade County) were made through the S-151 structure. These releases amounted to 193,000 AF. Of these releases, 130,000 AF were delivered to the South Dade Conveyance System, and 21,000 AF to the C-4 basin. The remainder of the water was used in north Dade County or lost to seepage. The dry season distribution of the releases to Dade County for this analysis period compared to the 1988-1989 dry season appear in Figure 5-5. The noticeable difference is that the releases were much smaller in the early portion of the dry season (during the 1989-1990 dry season) and the significant coastal rainfall in April 1990 reduced the need for the large releases to Dade County during April and May 1990. Table 5-1 summarizes the historic deliveries made through structure S-151. The recent trend of large water supply releases to Dade County is summarized in this table. Figure 5-6 illustrates the releases made to Everglades National Park. ENP continued to receive minimal deliveries as a result of the below normal rainfall conditions. The total deliveries to the ENP for this analysis period, was 68,000 AF. This is the lowest annual sum of water deliveries to the ENP since the early 1960s, before the minimum delivery schedule was enacted for deliveries to the Park. Figure 5-7 illustrates the 12-month running sums of deliveries to ENP. Prior to the establishment of the Rainfall Plan in June 1985, releases to ENP were made primarily through the S-12 structures.

On a seasonal basis, due to the late start of the wet season in the summer of 1989, large water releases had to be made to both the Lake Okeechobee and Lower East Coast Service Areas particularly during the month of June. Normally, water use deliveries are minimal during the wet season months. During the dry season the deliveries to the Lower East Coast Service Areas slightly exceeded those made to the EAA as illustrated in Figure 5-8.

†A water management plan for determining the amount, timing, and distribution of flow to ENP designed to restore more natural hydrologic conditions to ENP.

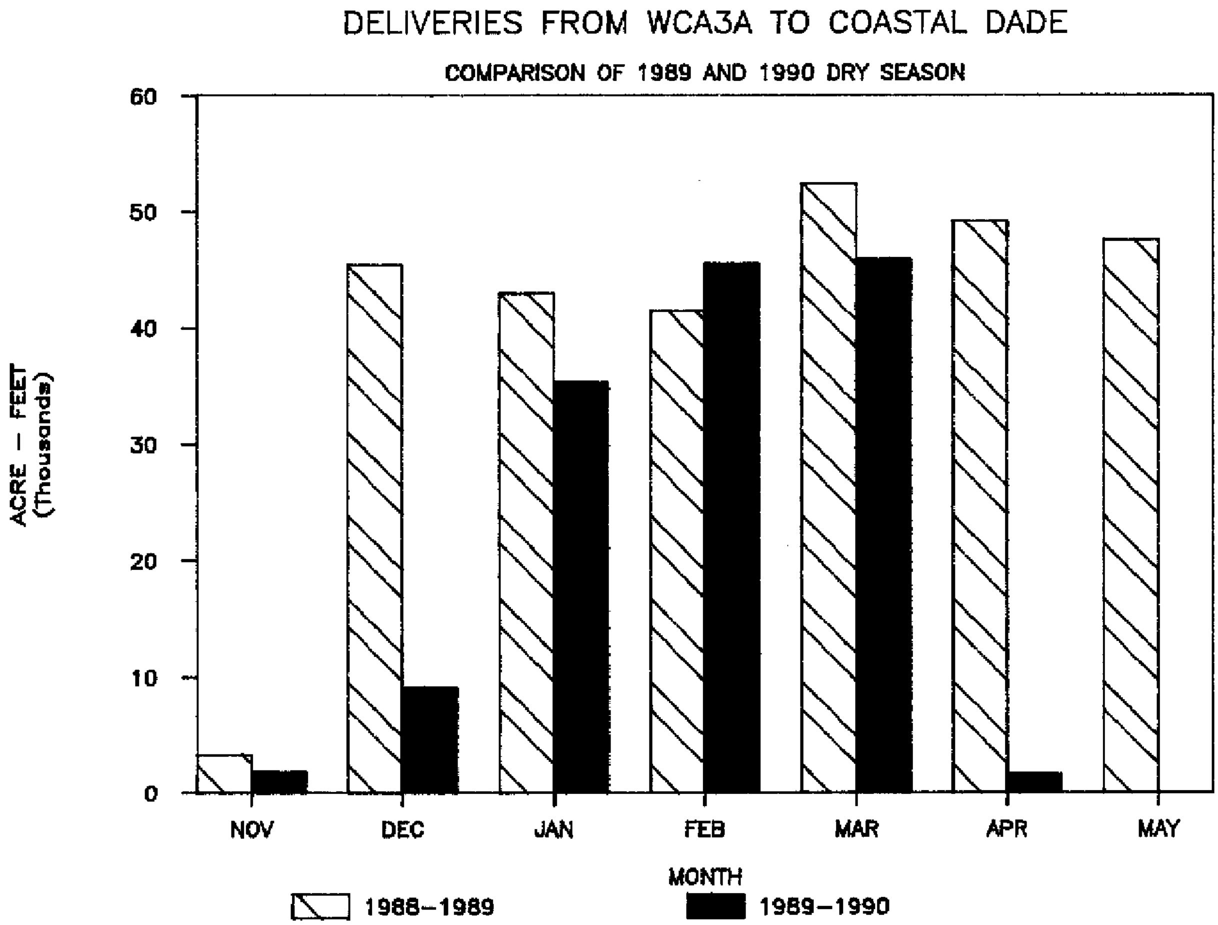


Figure 5-5 Deliveries from Water Conservation Area 3A to Coastal Dade

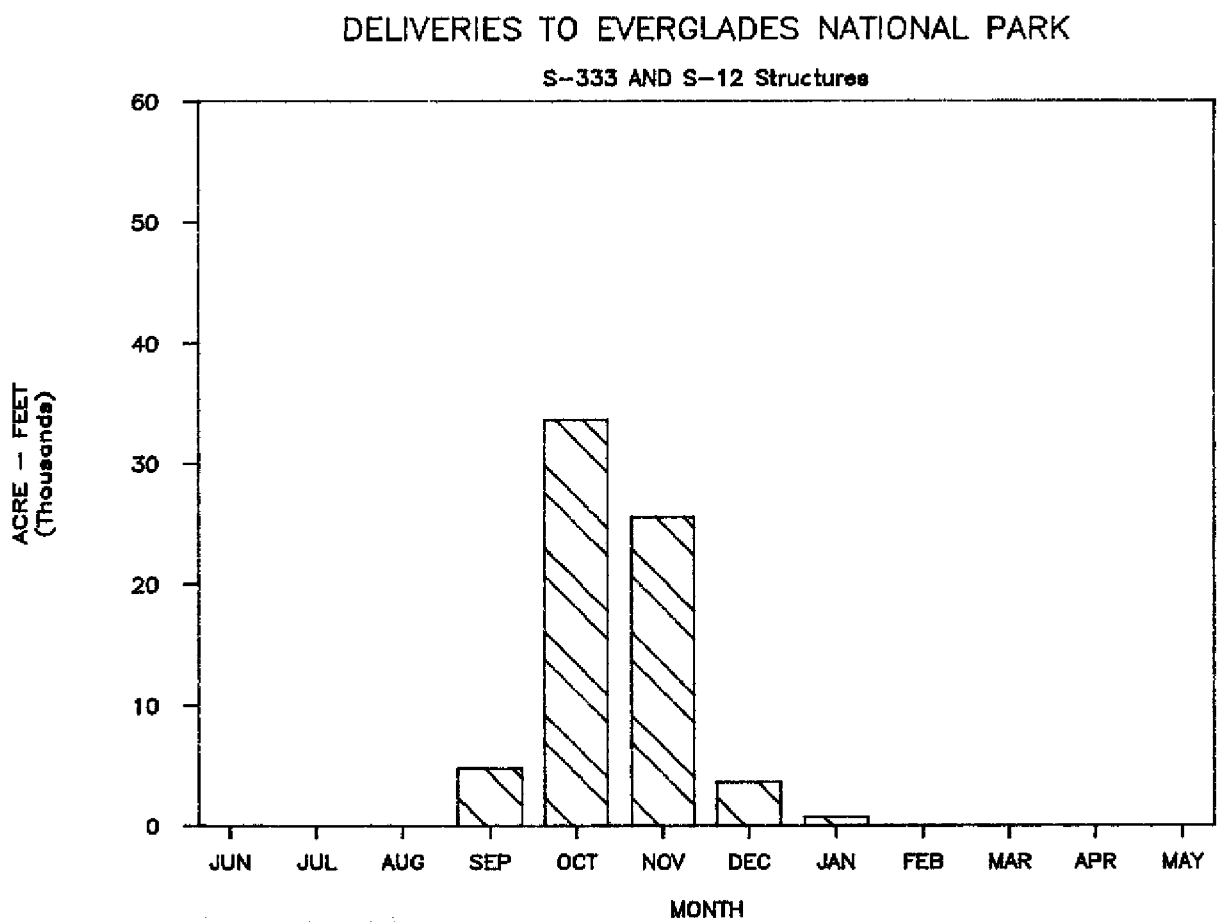


Figure 5-6 Deliveries to Everglades National Park

TABLE 5-1
S-151 Discharges in Acre-Feet
Period of Record: January 1962-May 1990

	Water Supply	Flood Control		Water Supply	Flood Control
1962	12,100	0	1976	14,800	0
1963	500	0	1977	5,500	0
1964	0	0	1978	0	90,700
1965	4,800	0	1979	0	93,350
1966	20	129,000	1980	106.512	0
1967	0	0	1981	55,750	0
1968	0	0	1982	15,000	153,350
1969	150	0	1983	32,300	360,400
1970	0	164,500	1984	119,346	19,200
1971	19,600	0	1985	126,510	60,232
1972	0	0	1986	68,000	216,500
1973	13,300	0	1987	64,000	62,200
1974	55,800	0	1988	202,200	78,700
1975	26,750	0	1989	299,000	0
			1990	128,455	0

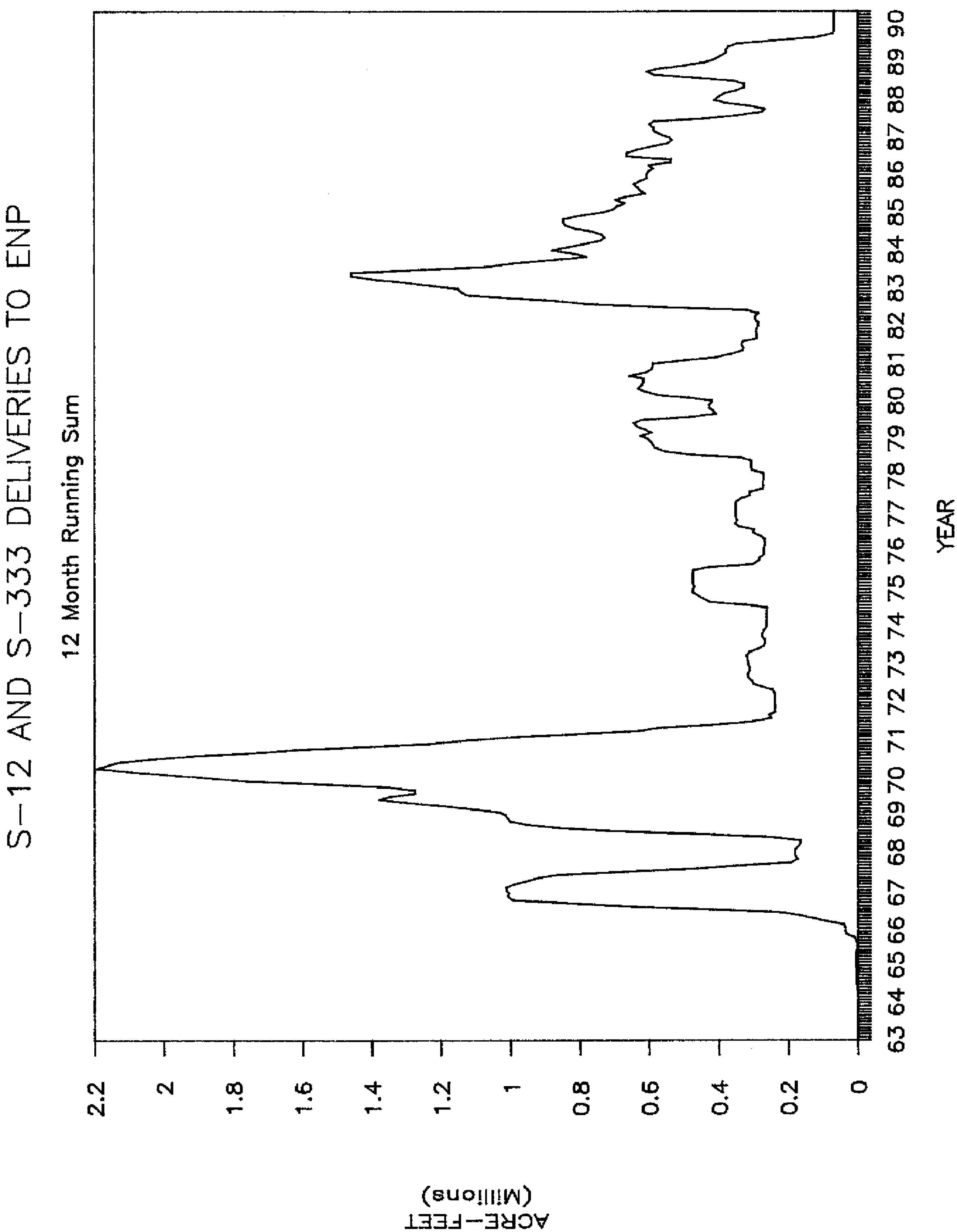


Figure 5-7 Historical 12 Month Deliveries to ENP

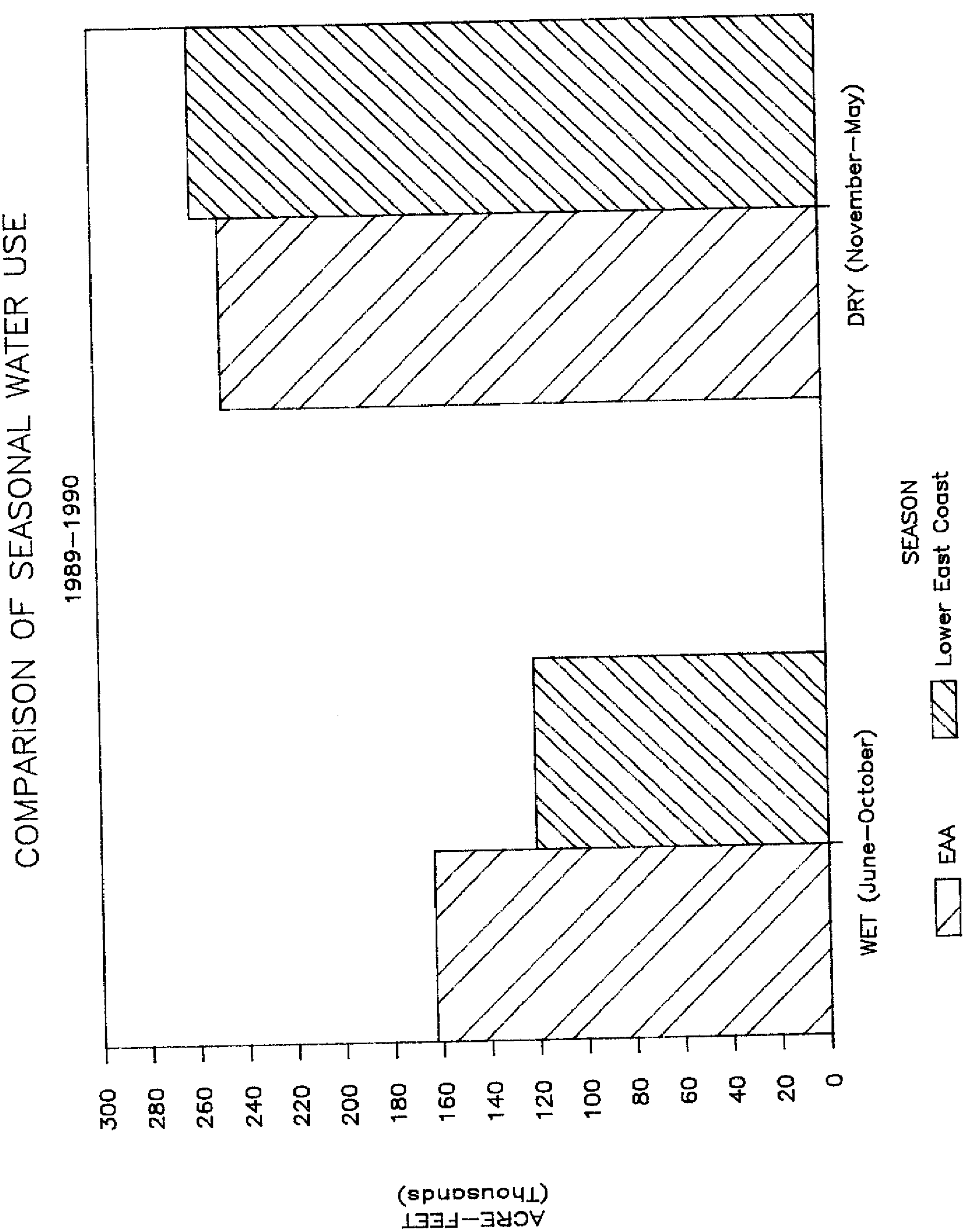


Figure 5-8 Comparison of Seasonal Water Use

6. STORAGE EFFICIENCY ANALYSIS

Introduction

In order to assess the relative storage efficiency of the major water storage areas operated by the District, a storage efficiency analysis was completed.

Storage efficiency (SE) is defined, in this analysis, as the ratio of the incremental volume stored in the reservoir to the incremental surface area. These incremental changes are caused by water inflows.

That is: $SE = \Delta V/\Delta A$

ΔV = incremental volume when stage rises as a result of water inflow into the reservoir.

ΔA = incremental surface area when stage rises as a result of water inflow into the reservoir,

Note that this storage efficiency concept addresses only hydrological (water quantity) efficiency.

If there are options to store water in different reservoirs, this concept can be applied to evaluate the efficiency of these reservoirs as water storage bodies, by comparing their respective SE coefficients. For example, if two reservoirs are compared, such as reservoir A and reservoir B, and if SE(A) is higher than SE(B), then reservoir A is more efficient than reservoir B. This is because when the same amount of water is added to each reservoir, the incremental increase of the surface area at A will be smaller than at B. On the other hand, if this added water causes the same increment of area at both reservoirs, the increment in volume stored will be larger at A than at B. Either one of these situations is favorable for efficient water management, from a water quantity perspective. *Therefore, the higher the storage efficiency of a reservoir, the higher the value of its SE for a given stage, and the more efficient a reservoir is.*

Water Storage Areas

Tables 6-1 and 6-2 show the variation of the storage capacity and of the open area when the stages of Lake Okeechobee and the three water conservation areas change with water inflow. They also show the value of their storage efficiencies (SE) at their different operational stages. Figures 6-1 through 6-4 are graphical representations of these variations, and Figure 6-5 is a comparison of the SE for Lake Okeechobee and the other major storage areas. An analysis of each curve indicates that, in most cases, the efficiency of the reservoir increases when the stage rises, as would be expected.

Comparing Lake Okeechobee storage efficiency with the storage efficiencies of the WCAs, it can be observed that, for example, Lake Okeechobee will be more efficient at 13.0-13.5 feet than WCA 1 at 16.0-16.5 feet. Further, if an increase of stage from 11.0 to 11.5 feet msl for each reservoir is considered, it can be noted that Lake Okeechobee will be more efficient than WCA 3, which, in turn, is more efficient than WCA 1, and which, in turn, is more efficient than WCA 2.

Table 6-1. Storage Efficiency Analysis
Lake Okeechobee

Changes in Stage (ft)		Change in		Storage Efficiency dV/dA
From	To	Volume 1,000 ac-ft	Area 1,000 acres	
9.5	10.0	155	9.2	16.8
10.0	10.5	164	10.0	16.4
10.5	11.0	163	13.0	12.5
11.0	11.5	178	16.0	11.1
11.5	12.0	178	16.0	11.1
12.0	12.5	193	12.6	15.3
12.5	13.0	193	11.4	16.9
13.0	13.5	209	22.0	9.5
13.5	14.0	210	19.0	11.1
14.0	14.5	228	7.8	29.2
14.5	15.0	225	4.4	51.1
15.0	15.5	220	2.0	110.0
15.5	16.0	225	2.0	112.5
16.0	16.5	225	1.9	118.4
16.5	17.0	225	1.7	132.4

Table 6-2. Storage Efficiency Analysis - Water Conservation Areas

Changes in Stage (ft)		Area 1			Area 2			Area 3		
		Change in		Storage Efficiency dV/dA	Change in		Storage Efficiency dV/dA	Change in		Storage Efficiency dV/dA
From	To	Volume 1,000 ac-ft	Area 1,000 acres		Volume 1,000 ac-ft	Area 1,000 acres		Volume 1,000 ac-ft	Area 1,000 acres	
6.5	7.0							10.0	23.0	0.4
7.0	7.5							38.0	75.0	0.5
7.5	8.0							66.0	72.0	0.9
8.0	8.5				1.4	0.6	2.3	96.0	52.0	1.8
8.5	9.0				2.0	1.5	1.3	140.0	48.0	2.9
9.0	9.5				3.4	1.2	2.8	192.0	45.0	4.3
9.5	10.0				5.0	5.6	0.9	240.0	39.0	6.2
10.0	10.5				11.0	14.2	0.8	215.0	30.0	7.2
10.5	11.0				16.0	17.5	0.9			
11.0	11.5	1.4	0.5	2.8	22.4	20.5	1.1			
11.5	12.0	1.8	0.7	2.6	36.1	24.5	1.5			
12.0	12.5	2.5	0.8	3.1	45.5	11.5	4.0			
12.5	13.0	3.6	3.1	1.2	54.0	7.5	7.2			
13.0	13.5	5.7	7.9	0.7						
13.5	14.0	8.8	14.0	0.6						
14.0	14.5	16.0	15.5	1.0						
14.5	15.0	26.0	20.5	1.3						
15.0	15.5	39.0	33.5	1.2						
15.5	16.0	58.0	28.5	2.0						
16.0	16.5	65.0	16.5	3.9						
16.5	17.0	70.0	3.5	20.0						

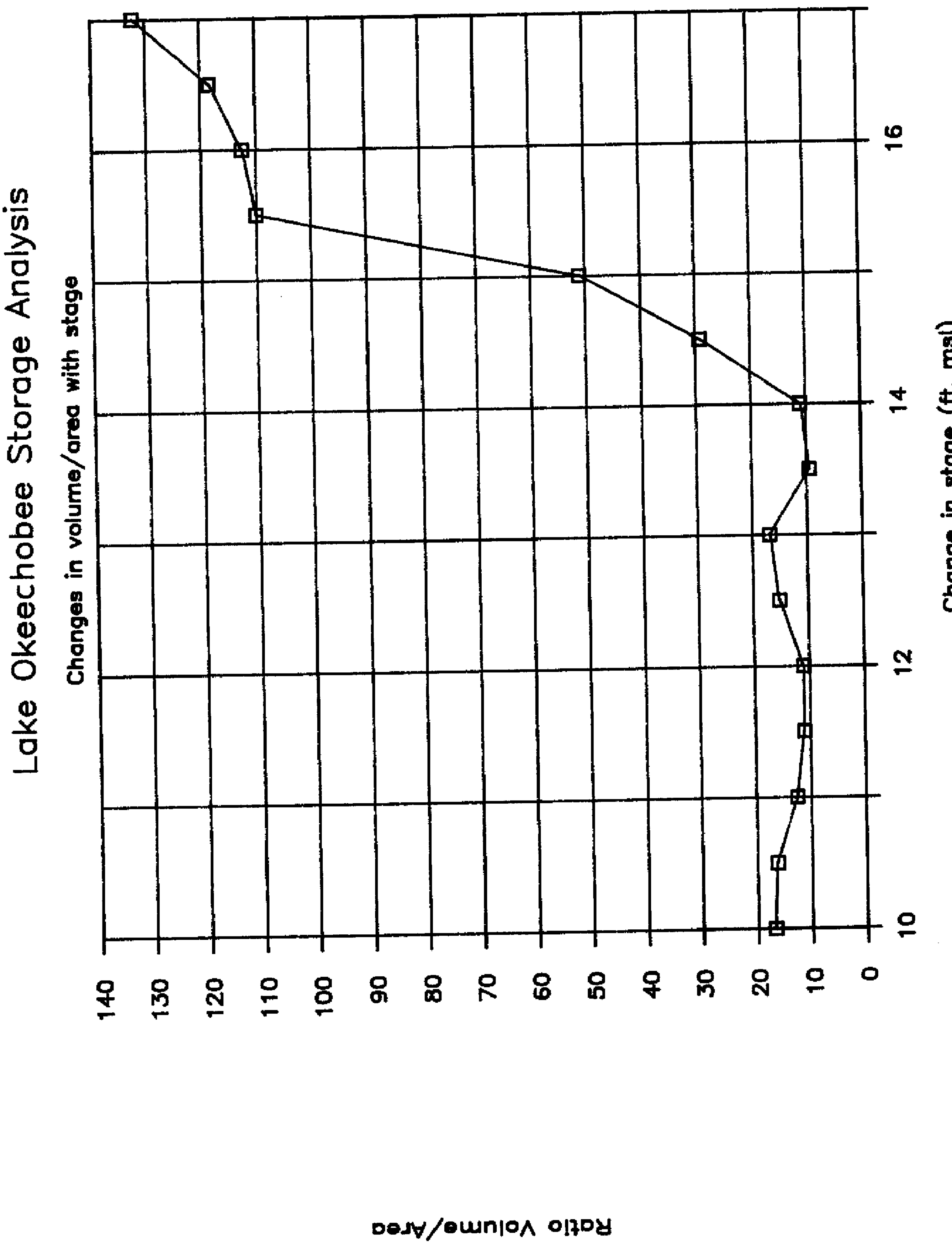


Figure 6-1. Lake Okeechobee Storage Analysis

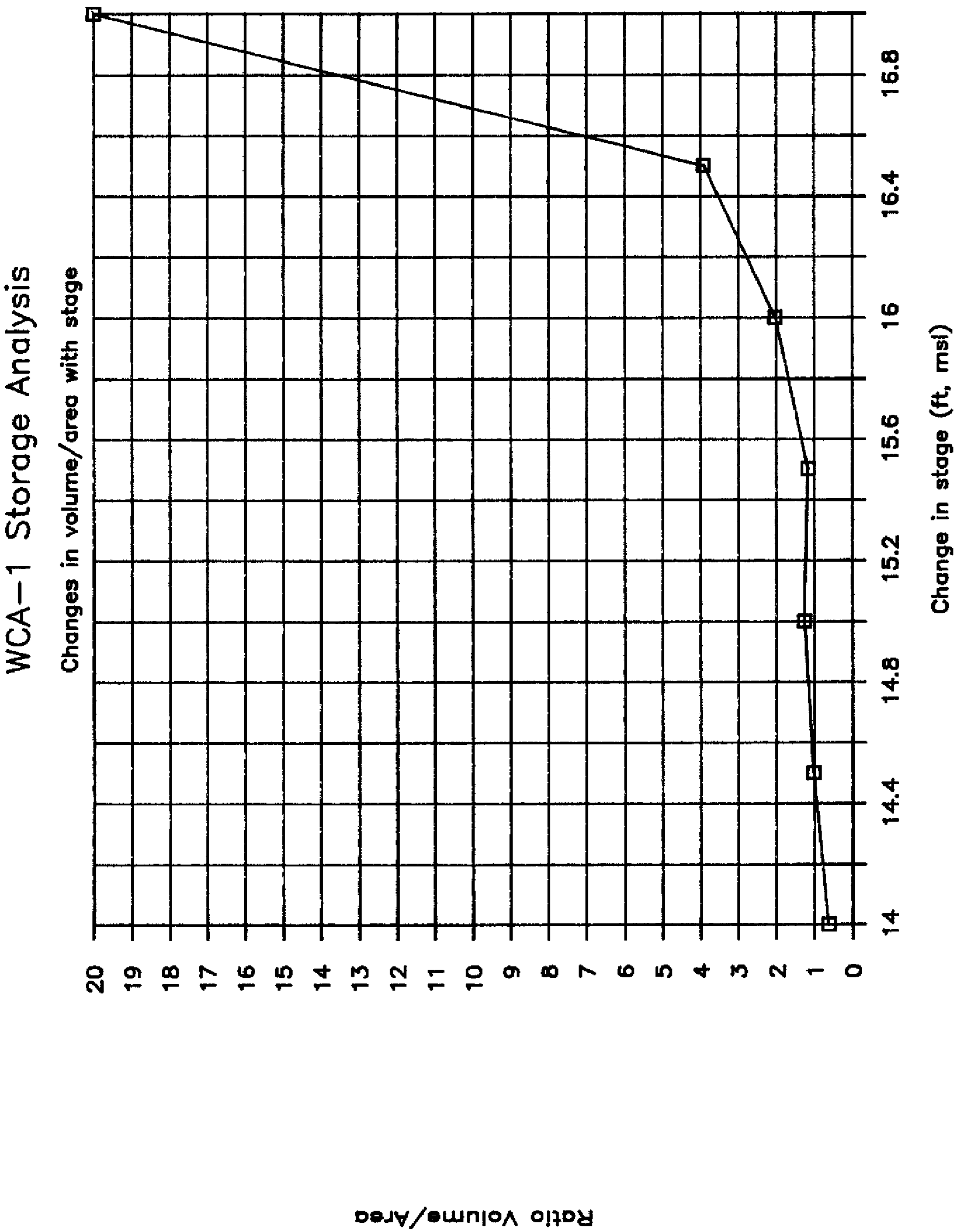


Figure 6-2. WCA-1 Storage Analysis

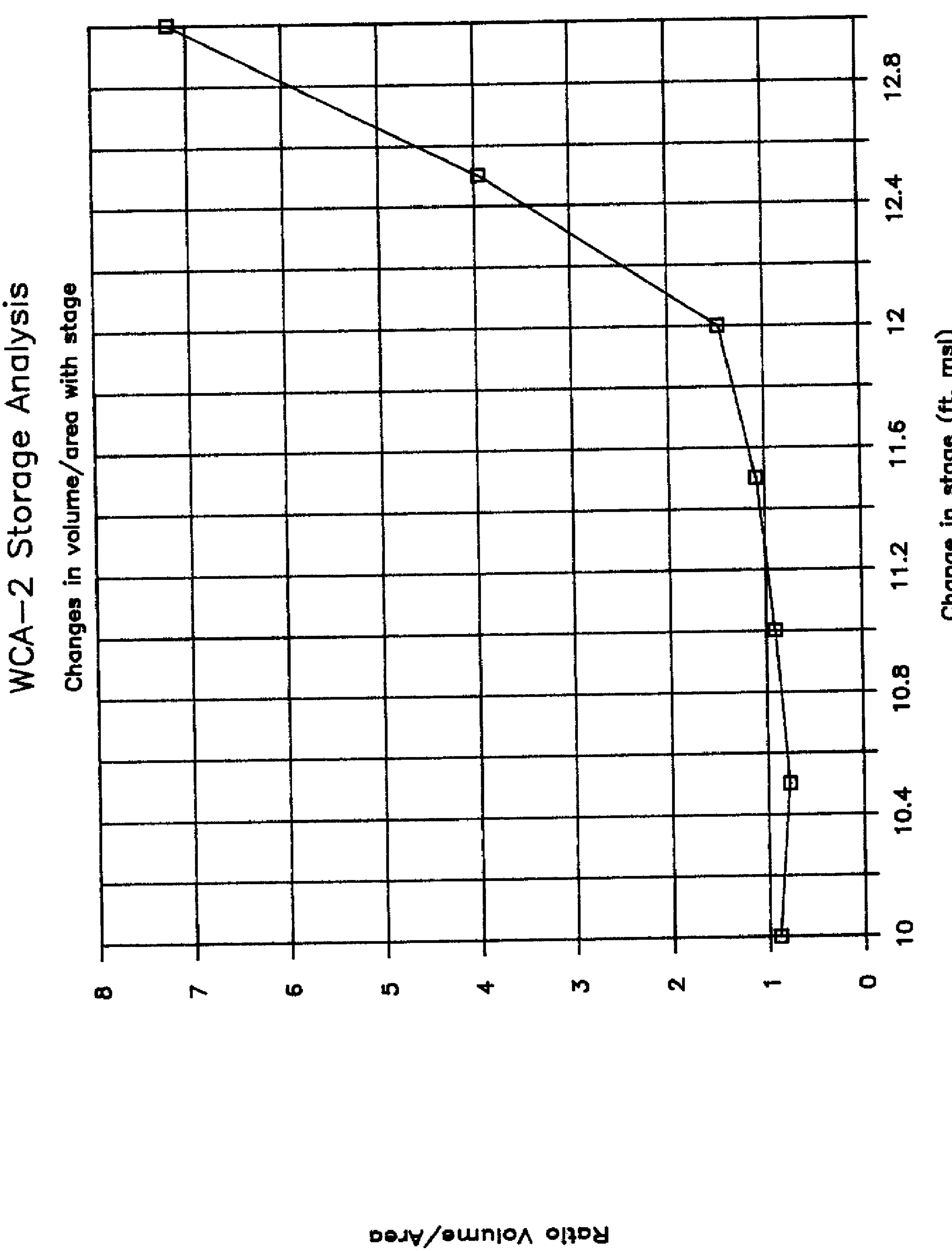


Figure 6-3. WCA-2 Storage Analysis

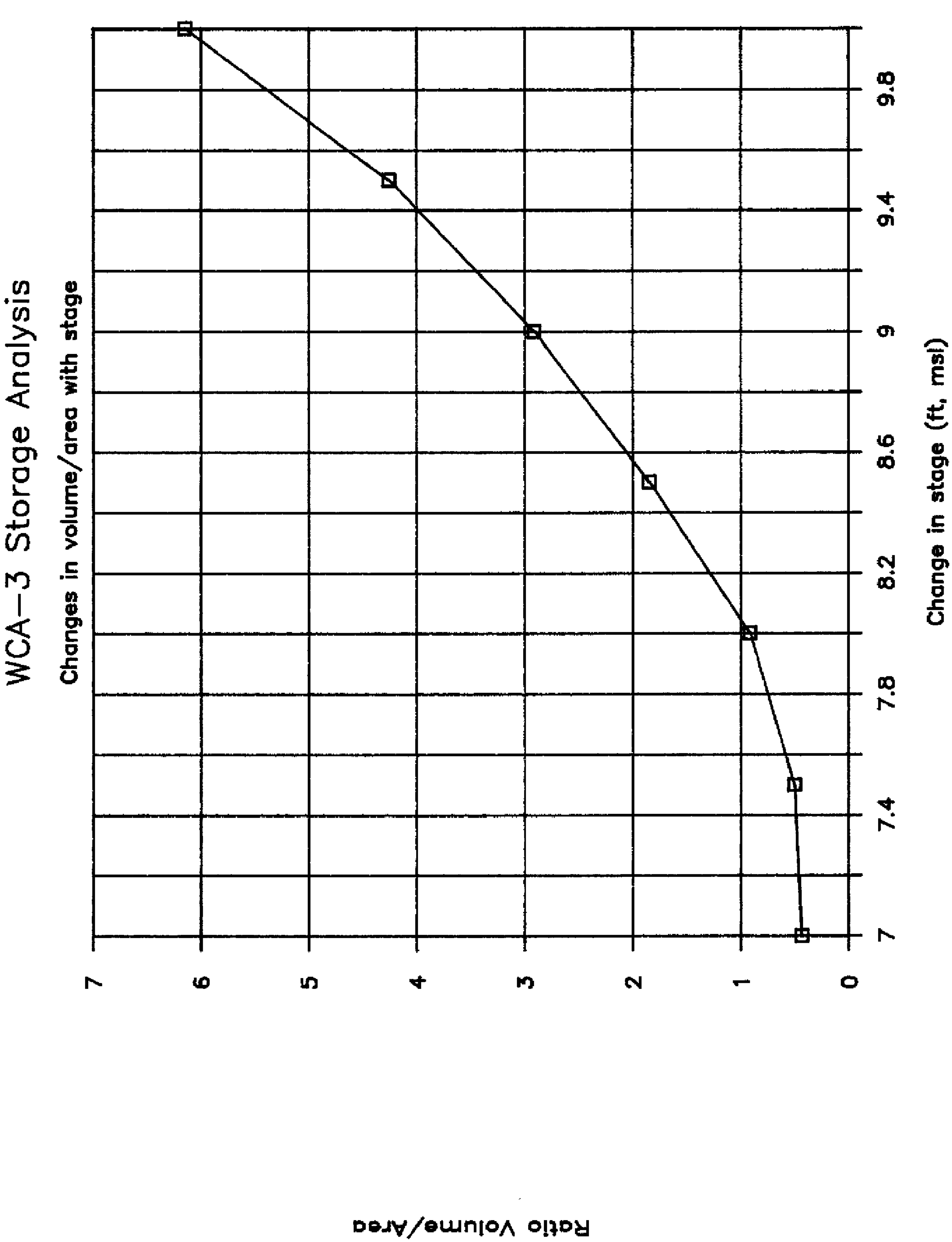


Figure 6-4. WCA-3 Storage Analysis

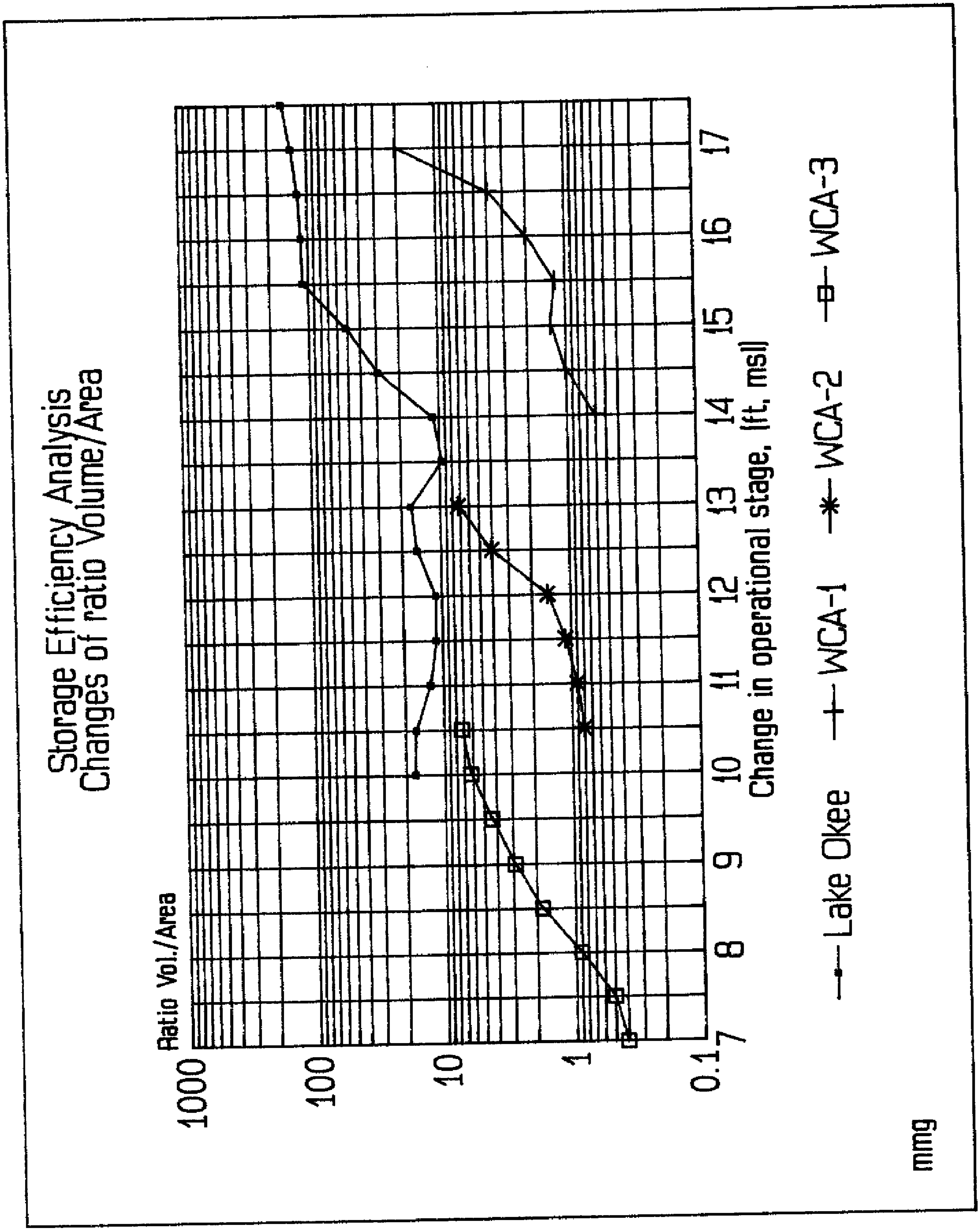


Figure 6-5. Storage Efficiency Analysis Changes of Ration Volume/Area

This volume to area ratio (SE) analysis shows that Lake Okeechobee is more efficient to store water than the Water Conservation Areas when the ratios are compared *within the operational stage ranges* of these water storage bodies. This is based on the physical principle that evaporation losses are directly proportional to surface area, that is, a larger open water surface will produce larger losses by evaporation, and in a direct proportion to the change in area.

The only circumstance in which Lake Okeechobee is exceeded in efficiency by which the WCAs as a surface water reservoir, is in the narrow set of conditions in which Lake Okeechobee is below 14.0 feet and WCA 1 is above 16.5 feet. Under these conditions, WCA 1 is slightly more efficient than Lake Okeechobee. However, this storage range in WCA 1 can only be utilized for a brief period (October 22 through December 31), and is not usually attained since this period is part of the normal dry season. In addition, when this narrow storage range in WCA 1 is exceeded, all efficiency advantage is lost with regulatory discharge to WCA 2A.

Other Considerations

This storage efficiency evaluation can be expanded if the two following factors are included:

a. Evaporation from marsh areas: Comparison of evaporation rates for open waters versus marsh areas have been cited in scientific literature (Shih, S.F., Water Budget Computation for a Shallow Lake - Lake Okeechobee, Florida; Benton, A. R., et al, Evapotranspiration from Water Hyacinth in Texas Reservoirs). These studies indicate that shallow lakes or water bodies that develop marsh vegetation, will have water losses both by evaporation from the open water surface and by evapotranspiration from the marsh zone. Applying this finding to Lake Okeechobee and considering that the District's water conservation areas are basically marsh areas, it can be implied that Lake Okeechobee would conserve more of the stored water than the WCAs under the same meteorological conditions.

b. Seepage: It has been estimated that seepage losses from WCA 3, for example, amount to 2,000 AF/day, while from Lake Okeechobee, amount to 200-500 AF/day depending on the water level. Similar, but narrower differences exist between the lake and other water conservation areas.

Conclusion

This analysis has clearly demonstrated that Lake Okeechobee is the most hydrologically efficient regional surface water storage reservoir in South Florida under practical conditions. Lake Okeechobee is more efficient than WCA 3A and WCA 2A within all operational stage ranges. Lake Okeechobee is also more efficient than WCA 1 except under a narrow range of stage that is of little practical value.

Given a choice of storing water in Lake Okeechobee or in one of the water conservation areas, it is clear that the best action (from a pure water quantity perspective) would be to store the excess in Lake Okeechobee. It should be recognized that water quality, environmental, and fire management considerations can and, in some cases, will override storage efficiency considerations and result in different management strategies.

7. SUMMARY AND CONCLUSIONS

Conclusions

1. The rainfall deficiency experienced during the period of June 1989 through May 1990 was 9 inches throughout the District. This represents a drought-return period of 10 years.

2. Rainfall has moderated since record below-normal 12-month amounts were recorded August 1989, but as of May 1990 still remains below normal. Rainfall in ENP continues to be less than the 10-year drought amount.

3. Loss in storage in Lake Okeechobee and the Water Conservation Areas was high for this period, particularly significant during the wet season and early dry season.

4. The entire surface water supply system experienced 0.4 million acre-feet in storage losses during this 12-month period of analysis. This is the second consecutive year of major losses inthe District's storage system.

5. Water releases from Lake Okeechobee for the EAA were 56% of the releases for the previous 12 months. Large releases were still needed to the WCA and LEC service areas.

6. The Water Conservation Areas experienced record low stages during this period. WCAs 1 and 3A were 4 feet below the historical average during the early wet season months,and were 1 to 2 feet below the historical average during the dry season.

7. Everglades National Park continued to receive very low releases due to below normal rainfall conditions. The 12-month releases to ENP for this period (June-May) were the lowest since the early 1960s.

APPENDIX A

DESCRIPTION OF THE SYSTEM AND OPERATIONAL CONSTRAINTS

This section describes the primary hydrologic basins that require water supply from Lake Okeechobee. It also describes the Water Conservation Area system and the Everglades National Park. The location of these are shown in Figures A-1 and A-2. The operational constraints are also addressed in this section.

S-3 Basin, Miami Canal

The S-3 drainage basin is 101.0 square miles in area and is located in west-central Palm Beach County (66.2 square miles) and east-central Hendry County (34.8 square miles).

The Project canals and water control structures affecting flow in the S-3 basin have five primary functions: (1) to remove excess water from the S-3 basin to storage in Water Conservation Area 3A (WCA 3A) , and under some flood conditions to storage in Lake Okeechobee; (2) to prevent over drainage of the S-3 basin; (3) to supply water from Lake Okeechobee to the S-3 and S-8 basins as needed for irrigation; (4) to provide conveyance for regulatory releases from Lake Okeechobee to be passed to storage in WCA 3A and for water supply releases from the lake to be passed to eastern Dade County and Everglades National Park; and (5) to receive discharges of excess water from the L-1 borrow canal (i.e., northeast Hendry County) when these discharges will not jeopardize flood control in the S-3 or S-8 basins. Pump stations S-3 and S-8 remove excess water from the S-3 basin and discharge it to Lake Okeechobee and WCA 3A respectively. Regulatory releases from Lake Okeechobee will be able to be made to the Miami Canal by way of S-354 after a projected completion date of April 13, 1990. On the rare occasions such releases are made, they are passed to WCA 3A by way of S-8. Water supply releases from Lake Okeechobee are made to the Miami Canal by way of S-354 and S-3. These releases are passed to WCA 3A, and subsequently to eastern Dade County and Everglades National Park, by way of S-8. Discharges from the L-1 borrow canal are made to the L-1E canal and subsequently to the Miami Canal.

The Miami Canal is the only Project canal in the S-3 basin. Two non-Project canals are important to the primary system in the basin. One is the Bolles Canal, built prior to the Project by the Everglades Drainage District, and the other is the L-1E canal built by the District from 1982 to 1987.

The Miami Canal connects Lake Okeechobee to WCA 3A. The connection to Lake Okeechobee is by way of S-3 and S-354 at the north end of the canal at the town of Lake Harbor. The connection to WCA 3A is by way of S-8, 15 miles west of U.S. Highway 27 on the Broward-Palm Beach County line.

Outlet capacity at S-354 due to present construction is limited to the capacity of four 60 inch x 160 foot corrugated metal pipe (CMP) culverts plus some siphoning through the S-3 pump.

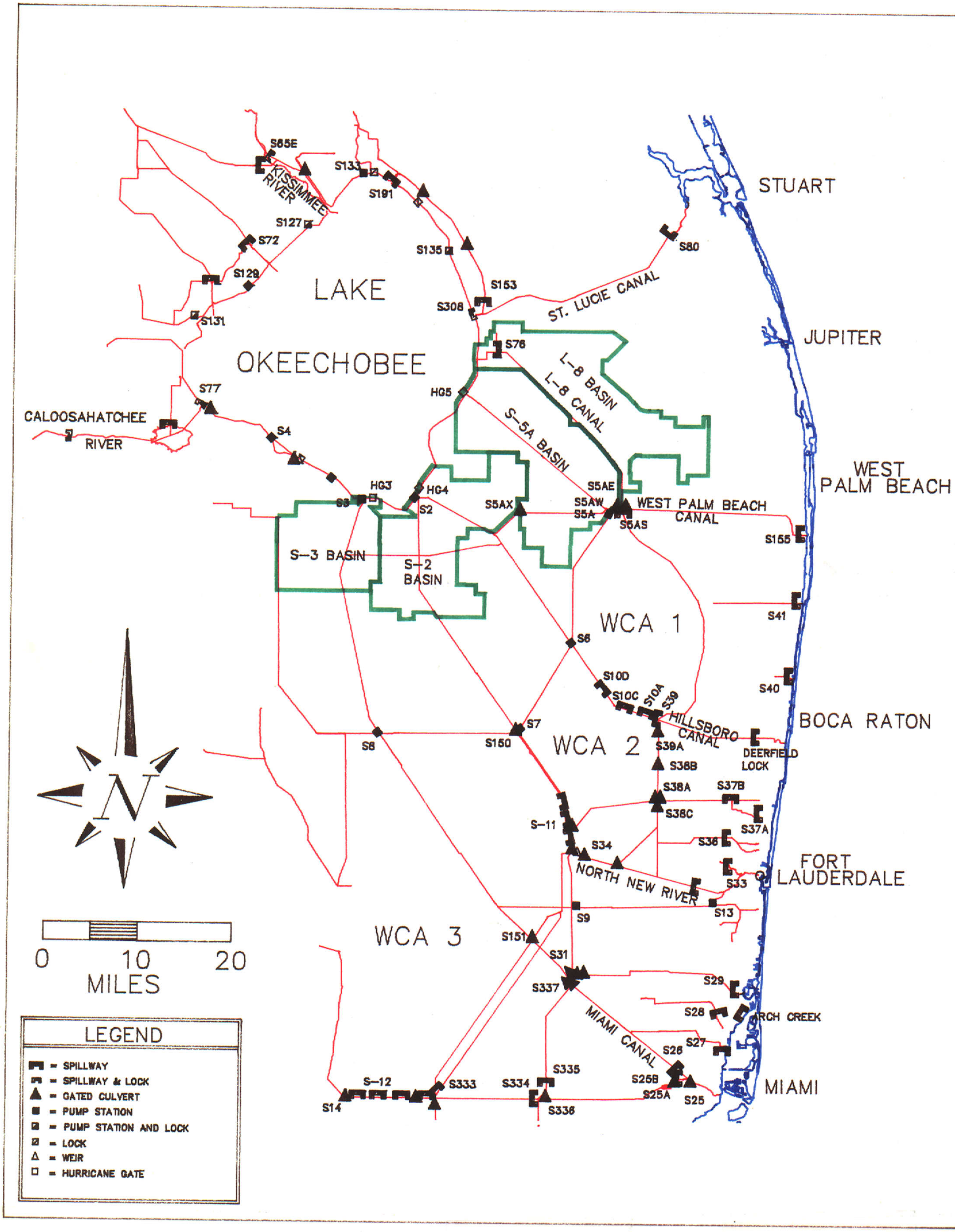


Figure A-1 Lake Okeechobee & Water Conservation Supply System

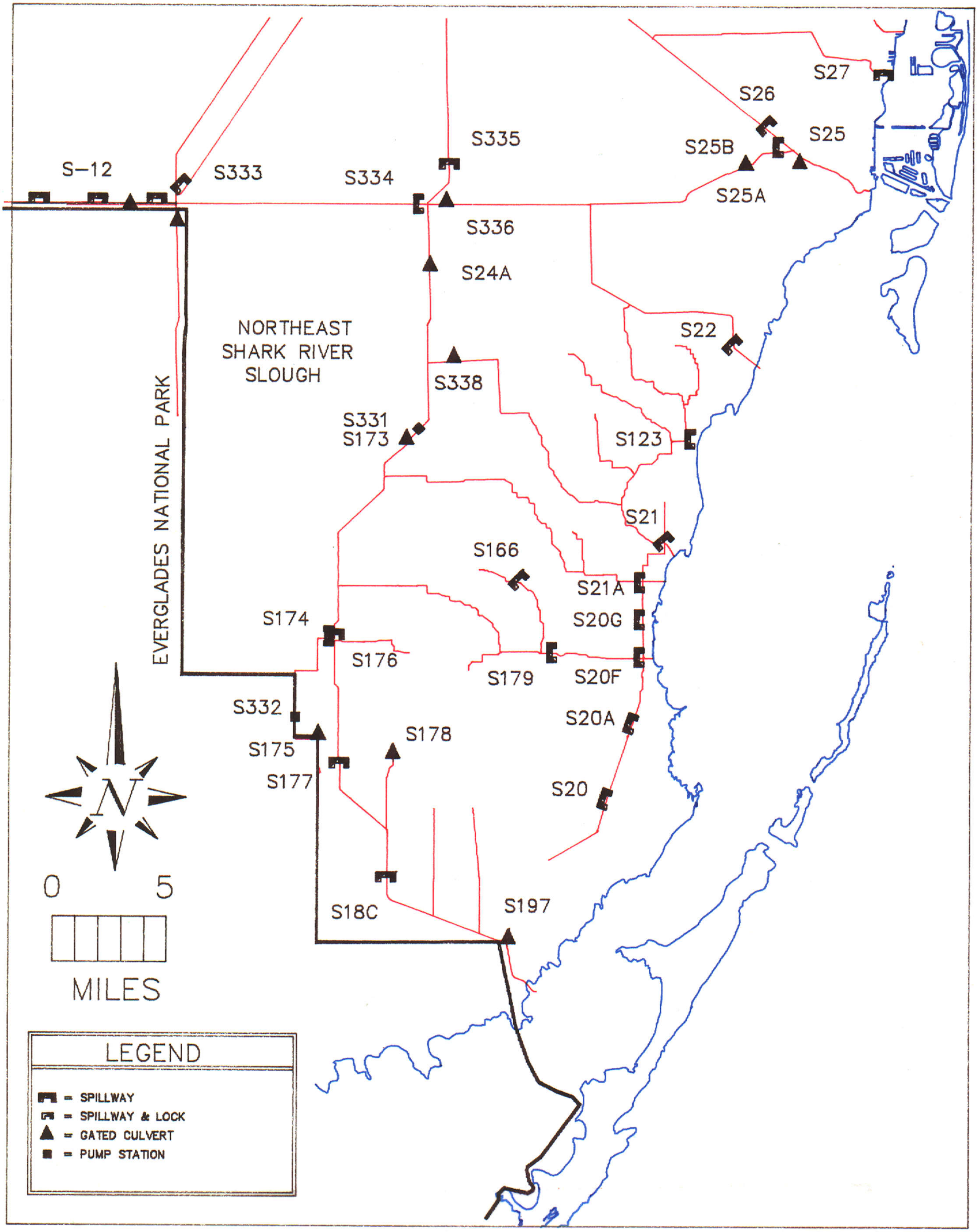


Figure A-2 ENP South Dade Conveyance System

At a Lake Okeechobee stage of 11.5 feet msl, the four culverts have a capacity of 400 cfs with 1.5 feet head loss. At the same time an additional 540 cfs could be siphoned through S-3. When the lake stage drops below 10.5 feet msl, the 1.5 feet head loss at S-3 will not be available; therefore, there would be very little water available to supply WCA 3A.

S-2 Basin, North New River and Hillsboro Canals

The S-2 drainage basin is 165.7 square miles in area and is located in west-central Palm Beach County.

The Project canals and water control structures affecting flow in the S-2 basin have four primary functions: (1) to remove excess water from the S-2 basin to storage in the Water Conservation Areas (WCAs), and under some flood conditions, to storage in Lake Okeechobee; (2) to prevent overdrainage of the S-2 basin; (3) to supply water from Lake Okeechobee to the S-2, S-6, and S-7 basins as needed for irrigation; and (4) to provide conveyance for regulatory releases from Lake Okeechobee to be passed to storage in the WCAs and for water supply releases from the lake to be passed to eastern Palm Beach and Broward counties. Pump stations S-2, S-6, and S-7 remove excess water from the S-2 basin and discharge it to Lake Okeechobee, WCA 1, and WCA 2A, respectively. Under some rare flood conditions, S-351 may discharge to Lake Okeechobee. S-150 allows gravity discharge to WCA 3A from the S-2 basin by way of the North New River Canal. Regulatory releases from Lake Okeechobee are made to the Hillsboro and North New River canals by way of S-351, formerly Hurricane Gate 4. On the rare occasions such releases are made, they are passed to WCA 1 by way of S-6, to WCA 2A by way of S-7, and to WCA 3A by way of S-150. Water supply releases from Lake Okeechobee are made to the Hillsboro and North New River Canals by way of S-351 and S-2. These releases are passed to the WCAs, and subsequently to eastern Palm Beach and Broward counties, by way of S-7 and on some occasions S-6.

There are two Project canals in the S-2 basin: the Hillsboro Canal and the North New River Canal. Two other, non-Project canals are important in the basin. These are the Bolles Canal and the Cross Canal. The Cross Canal is tributary to the Hillsboro Canal and the Bolles Canal is tributary to both the Hillsboro and the North New River canals.

The Hillsboro Canal connects Lake Okeechobee to WCA 1. The connection to Lake Okeechobee is by way of S-2 at the north end of the canal at South Bay west of Belle Glade. The connection to WCA 1 is by way of S-6 at the intersection of L-6 and L-7 on the west side of WCA 1.

The North New River Canal connects Lake Okeechobee to WCAs 2A and 3A. The connection to Lake Okeechobee is by way of S-2 at the north end of the canal at South Bay west of Belle Glade. The connection with WCA 2A is by way of S-7 at the intersection of L-5 and L-6, just east of U.S. Highway 27 on the Palm Beach-Broward County line. The connection with WCA 3A is by way of S-150 just west of S-7.

During April and May 1989, the average tailwater stage at S-150 was 10.3 feet msl and the average discharge equaled 700 cfs. Lake Okeechobee stage would need to be approximately 11.0 feet msl to supply 700 cfs. As Lake Okeechobee stage drops below 11.0 feet msl, the headwater stage at S-150 will drop to 10.0 feet msl or less and the discharge will drop to something less than 500 cfs. At these lower stages additional flow might be obtained by pumping S-7 and releasing flow to WCA-3A via the S-11 structures.

It would appear that as the lake stage drops below 11.0 feet msl, the flow south to Dade County will be very limited.

S-5A Basin

The S-5A drainage basin is 194.3 square miles in area and is located in northwestern Palm Beach County. The basin boundary relative to local roads and landmarks is shown on Map A.

The Project canals and water control structures in the S-5A basin have four primary functions: (1) to remove excess water from the S-5A basin to storage in Water Conservation Area 1 (WCA 1), and under some flood conditions, to storage in Lake Okeechobee; (2) to prevent over drainage of the S-5A basin; (3) to supply water from WCA 1, Lake Okeechobee, or the L-8 basin to the S-5A basin for irrigation; and (4) to provide conveyance for regulatory releases from the Lake Okeechobee to WCA 1 and for water supply releases from the lake to the C-51 basin for municipal and agricultural use and to maintain the optimum canal water level to prevent saltwater intrusion. Excess water is usually discharged from the basin to WCA 1 by way of S-5A. Under some very rare conditions, water can be discharged from the basin to Lake Okeechobee by way of S-352. Regulatory releases from Lake Okeechobee can be made to the L-10/L-12 borrow canal (i.e., the West Palm Beach Canal) by way of S-352. On the rare occasions such releases are made, they are passed to WCA 1 by way of S-5A. Water is supplied to the basin from Lake Okeechobee by way of S-352, from WCA 1 by way of S-5AS and S-5AW, and from the L-8 borrow canal by way of S-5AW. Under the rare circumstances that would make such a transfer possible and desireable, the L-8 borrow canal more likely would be used to make the transfer.

L-8 Basin

The L-8 drainage basin is 171.2 square miles in area and is located in northwestern Palm Beach County (168.1 square miles) and southwestern Martin County (3.1 square miles).

The Project canals and water control structures in the L-8 basin have four primary functions: (1) to protect the agricultural areas to the southwest of the L-8 basin by intercepting surface water flows originating in the L-8 basin, (2) to remove excess water from the L-8 basin to storage in either Lake Okeechobee or Water Conservation Area 1 (WCA 1), (3) to supply water from Lake Okeechobee or WCA 1 to the L-8 basin for irrigation of agricultural lands, and (4) to transfer water from storage in WCA 1 to Lake Okeechobee. Excess water can be discharged from the L-8 basin in one of three ways: (1) to Lake Okeechobee by way of Culvert #10A; (2) to tidewater by way of S-5AE; and (3) to WCA 1 by way of either S-5AS, or S-5AW and S-5A. Water is supplied to the L-8 basin from Lake Okeechobee by way of Culvert #10A, from WCA 1 by way of S-5AS, and from the S-5A basin by way of S-5AW. The L-8 borrow canal is used to transfer water from storage in WCA 1 to storage in Lake Okeechobee. These transfers are made by gravity flow from the WCA through S-5AS to the borrow canal and are subsequently discharged to the lake by way of Culvert #10 A. The conditions that make such a transfer desirable and possible rarely occur.

The Project canals and water control structures in the basin have two secondary functions: (1) to supply water from the L-8 basin, WCA 1, or Lake Okeechobee to the City of West Palm Beach water supply system and (2) to accept discharges of excess water from the West Palm Beach water supply system. Water is supplied to the City of West Palm Beach municipal water supply system from the L-8 basin by way of a city owned and operated pump station located at the junction of the L-8 Tieback Levee borrow canal and the City of West Palm Beach's "M" Canal. A spillway adjacent to this pump station discharges excess water from the "M" Canal to the L-8 basin.

As Lake okeechobee stage drops below 11.0 msl, it becomes difficult to supply water to the City of West Palm Beach pump station at a stage that the city can operate its pumps. Elimination of the sheetpile weir at the entrance to the L-8 tieback borrow canal will help to operate the flap-gate that allows water to enter the borrow canal.

Water Conservation Area 1

The Water Conservation Area 1 (WCA 1) basin has an area of 220.3 square miles and is located in south-central Palm Beach County. WCA 1 is also known as the Auther R. Marshall Loxahatchee National Wildlife Refuge.

WCA 1 and its associated Project structures have five primary functions: (1) to provide viable wetland habitat (i.e, the WCA is managed insofar as possible as a natural Everglades system), (2) to detain and store flood and drainage water during the wet season for water supply during the dry season, (3) to prevent floodwater accumulating in the Everglades from flooding urban and agricultural lands in Eastern Palm Beach County, (4) to receive and store regulatory releases from Lake Okeechobee, and (5) to provide conveyance for water supply releases from Lake Okeechobee to the Hillsboro Canal basin. Inflows to the WCA are from local rainfall, from the S-5A, L-8, and C-51 basins by way of S-5A and S-5AS, from the S-2 and S-6 basins by way of S-6, and from Lake Okeechobee by way of the L-10/L-12 borrow (i.e., the West Palm Beach Canal), the L-8 borrow, and the Hillsboro canals. When required by the WCA 1 regulation schedule excess water is discharged to WCA 2A by way of the four S-10 structures, to the Hillsboro Canal by way of S-39, and to C-51 by way of S-5AS and S-5AE. The S-10 structures provide the principal means of discharging water from WCA 1. The discharges at S-39 and at S-5AS are relatively minor. During periods of low natural flow, water stored in the WCA can be released by way of the S-10 structures to the WCAs to the south to supply basins in eastern Broward and Dade Counties and Everglades National Park, by way of S-39 to supply the Hillsboro Canal basin, and by way of S-5AS to supply the L-8, S-5A, and C-51 basins.

Water Conservation Area 2A

The Water Conservation Area 2A (WCA 2A) basin has an area of 164.7 square miles and is located in south-central Palm Beach County (65.5 square miles) and in north-central Broward County (99.2 square miles).

WCA 2A and its associated Project structures have five primary functions: (1) to provide viable wetland habitat (i.e., the WCA is managed insofar as is possible as a natural Everglades system), (2) to detain and store flood and drainage water during the wet season for water supply during the dry, (3) to prevent floodwater accumulating in the Everglades from flooding urban and agricultural lands in eastern Broward County (4) to receive and store regulatory releases from Lake Okeechobee and WCA 1, and (5) to provide conveyance for water supply releases from Lake Okeechobee to eastern Broward County. Inflows to the WCA are from local rainfall, from WCA 1 by way of the S-10 structures, and from the S-7 basin by way of S-7. When required by the WCA 2A regulation schedule excess water is discharged to WCA 3A by way of the three S-11 structures, to WCA 2B by way of S-144, S-145, and S-146, to the North New River Canal basin by way of S-143, and to the C-13 and C-14 basins by way of S-38. The S-11 structures provide the principal means of discharging water from WCA 2A. The discharge at all other structures is relatively minor. During periods of low natural flow, water stored in the WCA can be released for water supply by way of the S-11 structures to basins in eastern Broward and Dade Counties and to Everglades National Park, by way of S-143 to the North New River Canal basin, and by way of S-38 to the C-13 and C-14 basins. Additional outflows from the WCA are to the C-14 basin and to the Hillsboro Canal basin by seepage through L-36 to the L-36 borrow canal.

Water Conservation Area 2B

The Water Conservation Area 2B (WCA 2B) basin has an area of 43.8 square miles and is located in central Broward County

WCA 2B and its associated Project structures have five primary functions: (1) to provide viable wetland habitat (i.e., the WCA is managed insofar as is possible as a natural Everglades system, (2) to recharge regional groundwater (i.e., the Biscayne Aquifer), (3) to supply water to adjacent basins in Broward County, (4) to receive and store regulatory discharges from WCA 2A, and (5) to prevent floodwater accumulating in the Everglades from flooding urban and agricultural lands in eastern Broward County. Rainfall is the primary source of water to WCA 2B, but water can be supplied from WCA 3A as necessary to maintain WCA 2B as a wetland. There is not a regulation schedule for WCA 2B, but as a rule of thumb, when the water level in the WCA exceeds about 10.0 ft NGVD, excess water is discharged to the North New River Canal by way of S-141 if the extra discharge will not cause flooding in the North New River Canal basin. During periods of low natural flow and if the water is available in WCA 2B, water can be supplied to the North New River Canal by way of S-141 as needed to maintain the optimum stage in the canal.

Water Conservation Area 3A

The Water Conservation Area (WCA) 3A basin has an area of 767.3 square miles and is located in western Broward County (568.4 square miles) and in north-western Dade County (198.9 square miles).

WCA 3A and its associated structures have five primary functions: (1) to provide viable wetland habitat (i.e., the WCA is managed insofar as possible as a natural Everglades system), (2) to detain and store flood and drainage water during the wet season for water supply during the dry season, (3) to prevent floodwater accumulating in the Everglades from flooding urban and agricultural lands in eastern Dade County, (4) to receive and store regulatory releases from Lake Okeechobee and WCA 2A, and (5) to provide conveyance for water supply releases from Lake Okeechobee to eastern Dade County and Everglades National Park (ENP). Inflows to the WCA are from local rainfall, from WCA 2A by way of the S-11 structures, from the S-8 basin by way of S-8, from the S-7 basin by way of S-150, from the L-28 borrow canal by way of S-140, from the L-3 borrow canal by way of G-155, from the Feeder Canal basin by way of the L-28 Interceptor borrow canal, from the

L-28 Gap basin by way of sheet flow through the L-28 gap and by way of the L-28 Tieback Levee borrow canal, from the North New River Canal by way of G-123 and S-142, from the C-11 basin by way of S-9, and from the area between L-38E and L-38W by way of G-64. When required by the WCA 3A regulation schedule, excess water can be discharged to ENP by way of the S-12 structures and S-333, to the Tamiami Canal by way of the S-343 structures, to WCA 3B by way of S-151, and to the Big Cypress National Preserve by way of S-344. The S-12 structures, S-333, and S-151 provide the principal means of discharging water from WCA 3A. Discharges at the other structures are minor in comparison. During periods of low natural flow, water stored in the WCA can be released for water supply to ENP by way of the S-12 structures and S-333, to basins in southeast Dade County by way of S-333 and S-151, to WCA 3B by way of S-151, and to the Big Cypress National Preserve by way of S-344. Additional outflows of water from the WCA are to the C-11 basin by way of seepage through L-37 to the L-37 borrow canal.

Water Conservation Area 3B

The Water Conservation Area 3B (WCA 3B) basin has an area of 153.6 square miles and is located in south-central Broward County (30.5 square miles) and in north-central Dade County (123.1 square miles).

WCA 3B and its associated Project structures have seven primary functions: (1) to provide viable wetlands habitat (i.e., the WCA is managed insofar as is possible as a natural Everglades system), (2) to recharge regional groundwater (i.e., the Biscayne Aquifer), (3) to supply water to adjacent basins in Dade County, (4) to provide conveyance for water supply releases from Lake Okeechobee and WCA 3A to eastern Dade County and southeastern Everglades National Park, (5) to receive and store regulatory discharges from WCA 3A, (6) to prevent floodwater accumulating in the Everglades from flooding urban and agricultural lands in eastern Dade County, and (7) when WCA 3B can not store the regulatory discharges from WCA 3A, to provide conveyance for the discharges through the WCA for subsequent discharge to tidewater. Rainfall is the primary source of water to WCA 3B, but water can be supplied from WCA 3A or Lake Okeechobee by way of C-123 (i.e., S-151 as necessary to maintain WCA 3B as a wetland. Water supply releases from WCA 3A or Lake Okeechobee to eastern Dade County and southeastern ENP are passed through WCA 3B by way of C-304 (i.e., the Project name for the Maimi Canal in WCA 3B). Regulatory releases from WCA 3A are made to WCA 3B by way of S-151. These releases are stored in WCA 3B when capacity is available; otherwise, they are routed through WCA 3B to C-6 (i.e., the Project name for the Miami Canal east of WCA 3B) by way of C-304 and S-31. There is not a regulation schedule for WCA 3B, but as a rule of thumb, when the water level in the WCA exceeds about 9.5 ft NGVD, excess water is discharged to C-6.

Everglades National Park

The Everglades National Park (ENP) has an area of 1684.5 square miles and is located in western Dade County (886.5 square miles), in northwestern Monroe County (773.9 square miles), and southwestern Collier County (24.1 square miles).

Project structures are largely peripheral to the park and have as their primary function supply of water to the park. Only four Project structures are within the park: L-67 Extension , S-346 and S-347, and the plug in the Buttonwood Canal. The L-67 Extension borrow canal serves as a "get away channel" for discharges from the

S-12 structures. A get away channel allows water to move away from the outlet structure so that the tailwater stage at the structure does not rise high enough to prevent effective discharge of water through the structure. The plug in the Buttonwood Canal (at the boat basin in Flamingo) serves as a barrier to prevent very saline water in Florida Bay from moving up the Buttonwood Canal to Coot Bay.

Inflows to the ENP basin are from local rainfall, from WCA 3A to Shark River Slough in ENP by way of the S-12 structures and S-333, from the L-31W borrow canal to Taylor Slough by way of S-332 and S-175, and from C-111 to the South Unit of the East Everglades Wildlife Management Area and to the Panhandle of the Park by way of gaps in the south berm of C-111 between S-18C and S-197.

Water supply to Shark River Slough is determined as a function of rainfall, evaporation, the stage in WCA 3A, and the previous week's discharge. Discharge amounts are calculated on a week to week basis. Insofar as is possible, forty-five percent of the total calculated discharge is released to Shark River Slough on the west side of L-67 Extension by way of the S-12 structures. The remaining fifty-five percent is discharged to Northeast Shark River Slough by way of S-333 and the L-29 borrow canal. Flow passes from the L-29 borrow canal to the slough by way of culverts under U. S. Highway 41 between L-67 Extension and L-30. Water supply to Taylor Slough and to the Panhandle of the Park is required by law to be at least 55,000 acre-feet for year (35,000 acre-feet to Taylor Slough and 18,000 acre-feet to the Panhandle).

South Dade Conveyance System

Purpose of the System

The South Dade Conveyance System (SDCS) was mandated by an act of Congress. Its primary purpose is to supply 55,000 acre-feet of water per year to the Everglades National Park (ENP). Under District-wide drought conditions, if the water allocated to ENP cannot be supplied from storage, the ENP receives (by way of SDCS) 16 percent of the surface water supplied to District canals south of Lake Okeechobee.

A secondary purpose of the SDCS is to supply water to South Dade County canals to maintain water table elevations at high enough stages (2.0 ft NGVD at downstream control structures) to prevent saltwater intrusions into local fresh groundwaters. Design flows for the SDCS to South Dade County canals are adequate to replace seepage losses in the canals for a 2.0 ft NGVD stage.

Another purpose of the SDCS is to supply water to the Alexander Orr and the Florida City Wellfields. Placement of a wellfield near the intersection of C-1 and the L-31N borrow canal is being considered. SDCS would also supply this wellfield.

Description of the System and Its Operation

The South Dade Conveyance System (SDCS) supplies water to Everglades National Park (ENP) at all times and to District canals (C-6, C-4, C-1, C-102, C-103, C-113, and C-111) in Dade County during conditions of low natural flow. A schematic map of the SDCS is shown in Figure A-2.

The system was built using existing Project canals and structures. C-304, the L-30 borrow canal and the L-31N borrow canal were enlarged. S-151 was enlarged and S-335 was changed from 2 - 72 inch corrugated metal pipes to a gated spillway. Only S-336,S-337, and S-338 were constructed for the SDCS.

Under design conditions (1-10 year drought) water is released to the SDCS from storage in Water Conservation Area 3A at a stage of 7.5 ft NGVD. The design discharge is 1955 cfs. This discharge includes the amount allocated to ENP, the amount required to replace seepage losses in South Dade County canals, and the amount required to recharge the Alexander Orr and the Florida City Wellfields. 1350 cfs is discharged at S-333 into the L-29 borrow canal ,and 605 cfs is discharged at S-337 into the L-30 borrow canal.

The water discharged at S-333 is conveyed to the east by the L-29 borrow canal to S-334 at the intersection of the L-29 borrow canal and the L-30 borrow canal. The design tailwater stage at S-333 is 7.0 ft NGVD, and the design headwater stage at S-334 is 5.0 ft NGVD. 120 cfs of the 1350 cfs entering the L-29 borrow canal at S-333 is lost to flow to the south through culverts under U.S. Highway 41 between S-333 and S-334. 1230 cfs is discharged to the L-30 borrow canal from the L-29 borrow canal via structure S-334.

605 cfs is discharged by S-337 to the L-30 borrow canal. Flow in the L-30 borrow canal is to the south to S-335, just north of the intersection of the L-30 borrow canal with the L-29 borrow canal and C-4. 105 cfs are expected to be lost to seepage in the L-30 borrow canal between S-337 and S-335.

South of S-335, the 500 cfs from the L-30 borrow canal joins the 1230 cfs from the L-29 borrow canal. The combined discharge of 1730 cfs flows south in the L-31N borrow canal at a beginning stage of 4.7 ft NGVD. 145 cfs of this flow is discharged east through S-336 to C-4 for recharge of the Alexander Orr Wellfield east of C-2, 305 cfs is discharged to C-1, and 120 cfs is lost to seepage upstream of S-173. The headwater stage at S-173 is 3.0 ft NGVD. During drought flow S-173 is closed and the pump station, S-331, is used to raise the tailwater stage at S-173 to 6.0 ft NGVD. Between S-173 and the intersection of the L-31N borrow canal with the L-31W borrow canal, 260 cfs is supplied to C-102 at a stage of 5.4 ft NGVD, 210 cfs is supplied to C-103 at a stage of 4.7 ft NGVD, and approximately 205 cfs is lost to seepage. 485 cfs are left to be divided between the C-111 canal to the south and the L-31W borrow canal to the west.

210 cfs is discharged to the L-31W borrow canal by way of S-174. 160 cfs (37,000 acre-feet per year) is pumped to Taylor Slough by S-332. Any remaining flow, not lost to seepage, is discharged to the ENP through S-175.

275 cfs is discharged to C-111 from the L-31N borrow canal by structure S-176. The tailwater stage at S-176 is 3.0 ft NGV. South of 176, 140 cfs is supplied to C-113 (to recharge the Florida City Wellfield), 60 cfs is lost to seepage and 75 cfs (18,000 acre-feet per year) is discharged through S-18C at a stage of 2.0 ft NGVD. This flow is discharged to the panhandle portion of ENP through gaps in the south berm of C-111 between S-18C and S-197.

A summary of the design flows and stages in the SDCS is given in Table A-1.

TABLE A-1 South Dade Conveyance System
Design Flows and Stages

		Stage (ft NGVD)	Discharge (cfs)
L-29 @ S-333		7.0	1,350
L-20 @ S-334		5.0	1,230
L-30 @ S-337		5.2	605
L-30 @ S-335	upstream downstream	5.0 4.8	525 525
L-30 @ L-29 or L-31N		4.7	500
L-31N @ US 41		4.7	1,585
L-31N @ C-1	upstream downstream	3.5 3.5	1,490 1,185
L-31N @ S-331	upstream downstream	3.0 6.0	1,160 1,160
L-31N @ C-102	upstream downstream	5.4 5.4	1,115 855
L-31N @ C-103	upstream downstream	4.7 4.7	740 530
L-31N @ S-174	upstream downstream	4.6 3.1	485 210
L-31N @ S-176	upstream	4.6	275
C-111 @ S-176	downstream	3.0	275
C-111 @ C-113	upstream downstream	3.0 3.0	275 135
C-111 @ S-177	upstream downstream	3.0 2.0	135 135
C-111 @ C-111E	upstream downstream	2.0 2.0	97 97
C-111 @ C-18C	upstream downstream	2.0 1.4	75 75

Water Supply to the Caloosahatchee River

LaBelle and Ft. Myers obtain their water supply from the Caloosahatchee River. In the case of Ft. Myers, water is not only pumped from the Caloosahatchee to their wellfield, but additional water has to be released from time to time to eliminate salinity problems at the intake upstream of the Franklin Lock.

Several large groves on the south side of the Caloosahatchee get irrigation water from the canal. The Flaghole Drainage District gets their water supply from Lake Hicpochee which is a part of the Caloosahatchee River.

Water Supply to the St. Lucie Canal

The Florida Power & Light reservoir is maintained by water pumped from the St. Lucie Canal; however, the major demand on the St. Lucie Canal water will come from the thousands of acres of citrus groves along the banks of the canal. The St. Lucie Estuary Management Plan adopted by the District will require pulse releases from Lake Okeechobee when the salinity in the estuary is below 12 parts per thousand during the period from April through July depending on Lake stages.

APPENDIX B

SUPPORTING DATA

Lake Okeechobee Inflows (acre-feet)
June 1989-May 1990

Month	S-65E	Fisheating Creek	Indian Prairie	Taylor Creek/ Nubbin Slough	Other Inflows	Rainfall
June	916	0	1,043	0	748	128,222
July	8,142	2,612	10,251	1,438	51,343	116,278
August	13,135	28,832	18,052	8,128	89,160	172,550
September	28,043	10,925	25,098	15,626	151,900	200,531
October	50,850	35,060	67,874	31,784	88,243	113,254
November	2,896	3,382	5,244	484	12,272	11,880
December	5,528	1,582	13,811	1,678	9,683	46,608
January	86,608	2,372	12,518	323	6,561	20,801
February	120,603	573	43,365	1,511	5,591	59,092
March	46,281	615	49,165	0	222	28,286
April	34,878	48	10	0	325	50,750
May	15,537	0	551	0	1,505	104,188
Total	**413,417**	**86,001**	**246,982**	**61,062**	**417,553**	**1,052,440**

Indian Prairie = S-71,S-72 and S-84
Other inflows = S-127, S-129, S-133, S-135, S-4, S-235, S-2, S-3, S-77, S-308, L-8, S-441 and Agricultural inflows

Lake Okeechobee Outflows (acre-feet)
June 1989-May 1990

Month	Lower East Coast	EAA	S-308	S-77	Other Outflows	ET
June	50,643	120,793	0	9,199	3,423	190,103
July	13,251	25,521	208	9,281	761	167,765
August	8,056	15,142	3,967	2,128	43	143,260
September	1,550	860	694	1,160	0	142,674
October	0	392	23,760	2,088	0	140,846
November	0	54,330	35,857	13,245	0	104,031
December	569	17,224	10,338	15,213	0	76,525
January	24,972	17,982	1,071	1,706	47	90,768
February	54,983	25,376	3,297	18,167	2,870	108,704
March	59,482	57,644	3,017	18,964	7,424	150,443
April	24,207	54,528	5,988	33,819	5,460	167,910
May	23	20,710	0	10,100	0	150,030
Total	**237,736**	**410,502**	**88,198**	**135,072**	**20,028**	**1,633,058**

Other Outflows = C-51/L-8

Water Conservation Area 1 Inflows (acre-feet)
June 1989-May 1990

Month	S-5A	S-6	Rainfall
June	436	0	57,658
July	4,745	2,037	41,067
August	39,720	27,150	55,092
September	48,622	21,884	51,100
October	23,399	0	26,867
November	829	881	4,800
December	7,545	4,834	5,250
January	7,055	1,815	3,938
February	1,170	0	4,274
March	1,805	0	1,742
April	0	0	2,925
May	0	415	3,159
Total	**135,326**	**59,015**	**257,871**

Water Conservation Area 1 Outflows (acre-feet)
June 1989-May 1990

Month	ET	Seepage	S-10	S-39	L-40	S-5A
June	1,029	1,857	0	4,915	1,660	18,268
July	3,040	2,214	0	1,515	1,345	13,136
August	15,600	8,635	0	1,551	948	0
September	52,500	15,701	0	452	3,414	0
October	50,917	16,725	0	625	6,770	2,815
November	22,933	12,197	0	1,361	6,569	20,895
December	10,833	9,960	0	1,035	10,322	1,376
January	13,050	9,093	0	1,178	6,488	3,556
February	8,146	5,849	0	4,221	7,656	1,103
March	4,583	3,237	0	1,935	7,974	0
April	3,846	2,200	0	210	2,429	666
May	3,964	3,000	0	0	1,938	0
Total	**190,442**	**90,668**	**0**	**19,002**	**57,514**	**61,907**

Water Conservation Area 2A Inflows (acre-feet)
June 1989-May 1990

Month	S-7	S-10	Rainfall
June	8,353	0	2,000
July	11,381	0	67,367
August	18,665	0	55,631
September	8,475	0	70,502
October	0	0	23,023
November	0	0	9,585
December	0	0	6,300
January	0	0	4,200
February	3,310	0	4,300
March	7,063	0	981
April	1,305	0	22,313
May	863	0	1,775
Total	**59,416**	**0**	**308,997**

Water Conservation Area 2A Outflows (acre-feet)
June 1989-May 1990

Month	S-11	S-34	S-38	Seepage	ET
June	0	3,437	3,370	11,603	2,238
July	0	0	438	9,592	3,040
August	0	0	436	10,699	7,348
September	0	0	161	11,603	47,031
October	0	0	1,097	12,113	42,041
November	0	3,049	4,386	12,000	30,817
December	0	4,647	5,103	11,867	15,167
January	0	4,347	4,754	12,667	11,600
February	0	3,465	4,284	10,497	6,375
March	0	661	2,273	12,298	5,042
April	0	0	1,470	12,500	33,938
May	0	0	863	11,500	2,154
Total	**0**	**19,607**	**27,975**	**139,019**	**206,852**

Water Conservation Area 3A Inflows (acre-feet)
June 1989-May 1990

Month	S-8	S-150	S-11	S-9	Rainfall
June	4,505	47,634	0	2,620	181,875
July	14,948	28,293	0	13,081	191,250
August	22,766	34,773	0	7,797	258,750
September	7,811	0	0	12,456	283,500
October	0	0	0	5,843	110,250
November	0	0	0	0	22,875
December	0	0	0	0	33,000
January	3,258	29,788	0	0	24,375
February	14,275	39,545	0	3,820	75,000
March	8,846	39,097	0	15,144	42,667
April	2,191	15,407	0	4,879	119,000
May	712	0	0	7,049	142,000
Total	**79,314**	**234,537**	**0**	**72,691**	**1,484,542**

Water Conservation Area 3A Outflows (acre-feet)
June 1989-May 1990

Month	S-151	ENP	Seepage	ET
June	27,588	0	30,810	66,150
July	0	0	20,291	133,925
August	0	0	23,981	148,453
September	26,763	4,766	32,829	163,400
October	0	33,505	28,285	156,325
November	1,797	25,549	27,967	114,000
December	9,144	3,645	27,485	80,625
January	35,347	728	20,906	105,000
February	45,567	0	14,995	103,912
March	45,926	0	16,602	112,230
April	1,605	0	16,000	115,958
May	0	0	770	56,345
Total	**193,738**	**68,195**	**260,921**	**1,355,603**