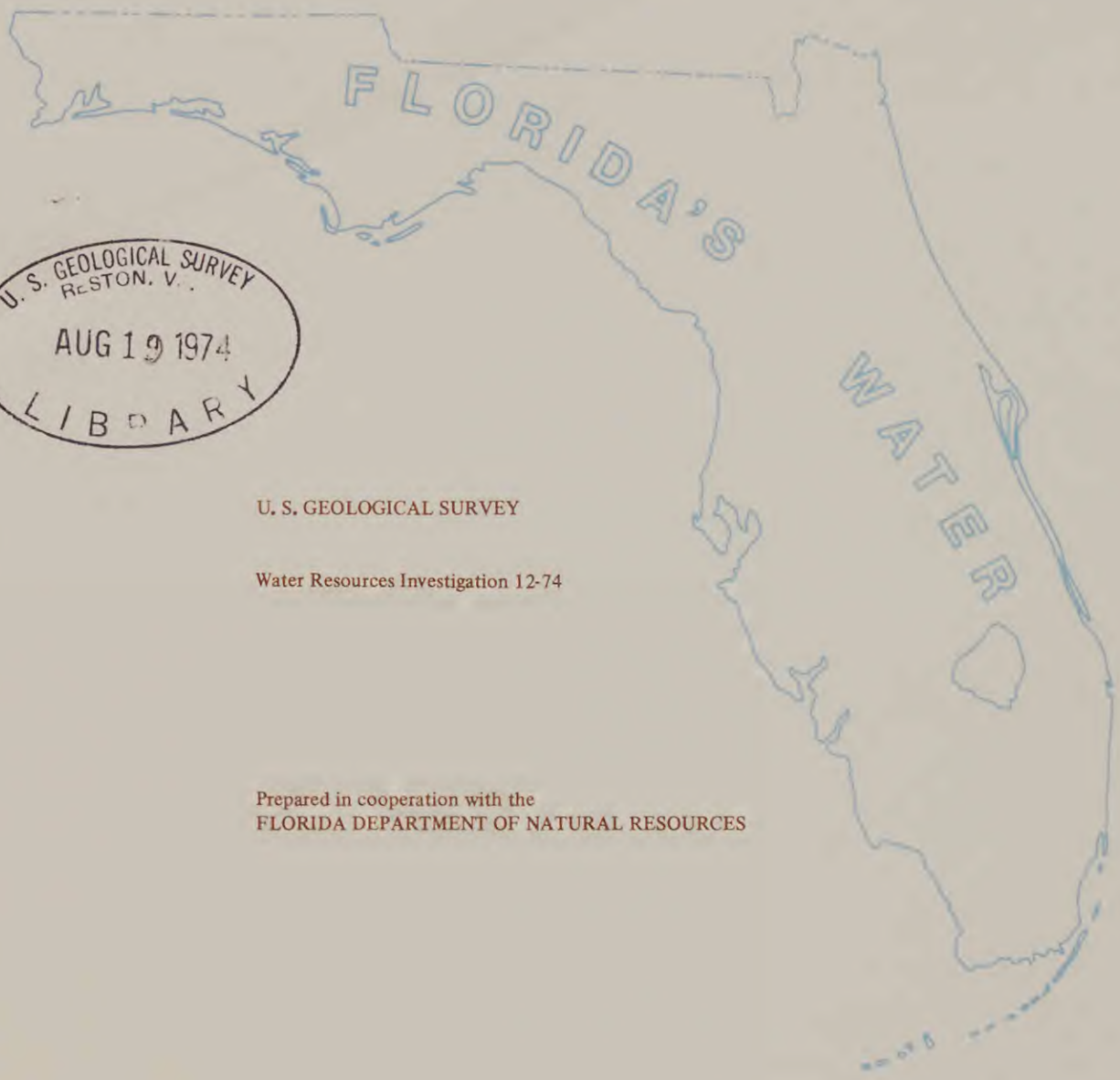
THE 1971 DROUGHT IN SOUTH FLORIDA AND ITS EFFECT ON THE HYDROLOGIC SYSTEM



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Water Resources Investigation 12-74

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By M. A. Benson and R. A. Gardner

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Water Resources Investigations 12-74

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July 1974

UNITED STATES DEPARTMENT OF THE INTERIOR

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CONTENTS

ILLUSTRATIONS

ILLUSTRATIONS (Continued)

TABLES

FACTORS FOR CONVERTING ENGLISH UNITS TO INTERNATIONAL SYSTEM (SI) UNITS

The following factors may be used to convert the English units published herein to the International System of Units (SI). Subsequent reports will contain both the English and SI unit equivalents in the station manuscript descriptions until such time that all data will be published in SI units.

Multiply English units	By	To obtain SI units
	Length	
inches (in)	25.4	millimeters (mm)
	.0254	meters (m)
feet (ft)	.3048	meters (m)
yards (yd)	.9144	meters (m)
rods	5.0292	meters (m)
miles (mi)	1.609	kilometers (km)
	Area	
acres	4047	square meters (m^2)
	.4047	*hectares (ha)
	.4047	square hectometer (hm^2)
	.004047	square kilometers (km^2)
square miles (mi^2)	2.590	square kilometers (km^2)
	Volume	
gallons (gal)	3.785	**liters (l)
	3.785	cubic decimeters (dm^3)
	3.785×10^{-3}	cubic meters (m^3)
million gallons (10^6 gal)	3785	cubic meters (m^3)
	3.785×10^{-3}	cubic hectometers (hm^3)
cubic feet (ft^3)	28.32	cubic decimeters (dm^3)
	.02832	cubic meters (m^3)
cfs-day (ft^3/s-day)	2447	cubic meters (m^3)
	2.447×10^{-3}	cubic hectometers (hm^3)
acre-feet (acre-ft)	1233	cubic meters (m^3)
	1.233×10^{-3}	cubic hectometers (hm^3)
	1.233×10^{-6}	cubic kilometers (km^3)
	Flow	
cubic feet per second (ft^3/s)	28.32	liters per second (l/s)
	28.32	cubic decimeters per second (dm^3/s)
	.02832	cubic meters per second (m^3/s)
gallons per minute (gpm)	.06309	liters per second (l/s)
	.06309	cubic decimeters per second (dm^3/s)
	6.309×10^{-5}	cubic meters per second (m^3/s)
million gallons per day (mgd)	43.81	cubic decimeters per second (dm^3/s)
	.04381	cubic meters per second (m^3/s)
	Mass	
ton (short)	.9072	tonne (t)

* The unit hectare is approved for use with the International System (SI) for a limited time.

** The unit liter is accepted for use with the International System (SI).

THE 1971 DROUGHT IN SOUTH FLORIDA AND ITS EFFECT ON THE HYDROLOGIC SYSTEM

By

M. A. Benson and R. A. Gardner

ABSTRACT

The 1971 dry season rainfall in south Florida was low enough that the public media and concerned public officials unanimously characterized the event as a severe drought.

Rainfall over all of south Florida during the 1970 wet season and the 1970-71 dry season was less than 85 percent of normal, as was the 1971 wet season on the heavily populated southeast coast of Florida. Rainfall during the dry season ranged from 20 to 63 percent of normal and recurrence intervals for dry season rainfall of this magnitude ranged from 100 years to several hundred years.

Canal flow and ground-water levels reflected the drought conditions but in most cases did not set record lows. No permanent undesirable effects occurred as a result of the drought.

INTRODUCTION

During the early part of 1971, Florida, and particularly south Florida, experienced a memorable drought. It was a drought in the sense that rainfall was markedly deficient, surface and subsurface water levels were critically low, agricultural and domestic water supplies were seriously threatened and wildlife was under severe stress in the area covered by this report (fig. 1).

Rainfall records in south Florida show a typical seasonal pattern, a dry winter season and a wet summer season. The graphs in figure 2 show that on the average the dry season begins abruptly in November and continues through April or May, but there is some geographical variation in the start of the wet season. The normal annual rainfall (fig. 3) ranges from 50 to 63 inches (1270 to 1600 mm) and about 75 percent falls in the wet season.

If uniformly distributed through the year, the 50 to 63 inches (1270 to 1600 mm) of rainfall would provide year-round abundant supplies. However the bulk of the rainfall during the wet season runs off rapidly to the ocean and thus is not available for use. A large part of the State's agricultural produce is grown during the driest part of the year requiring regular irrigation from surface or subsurface storage.

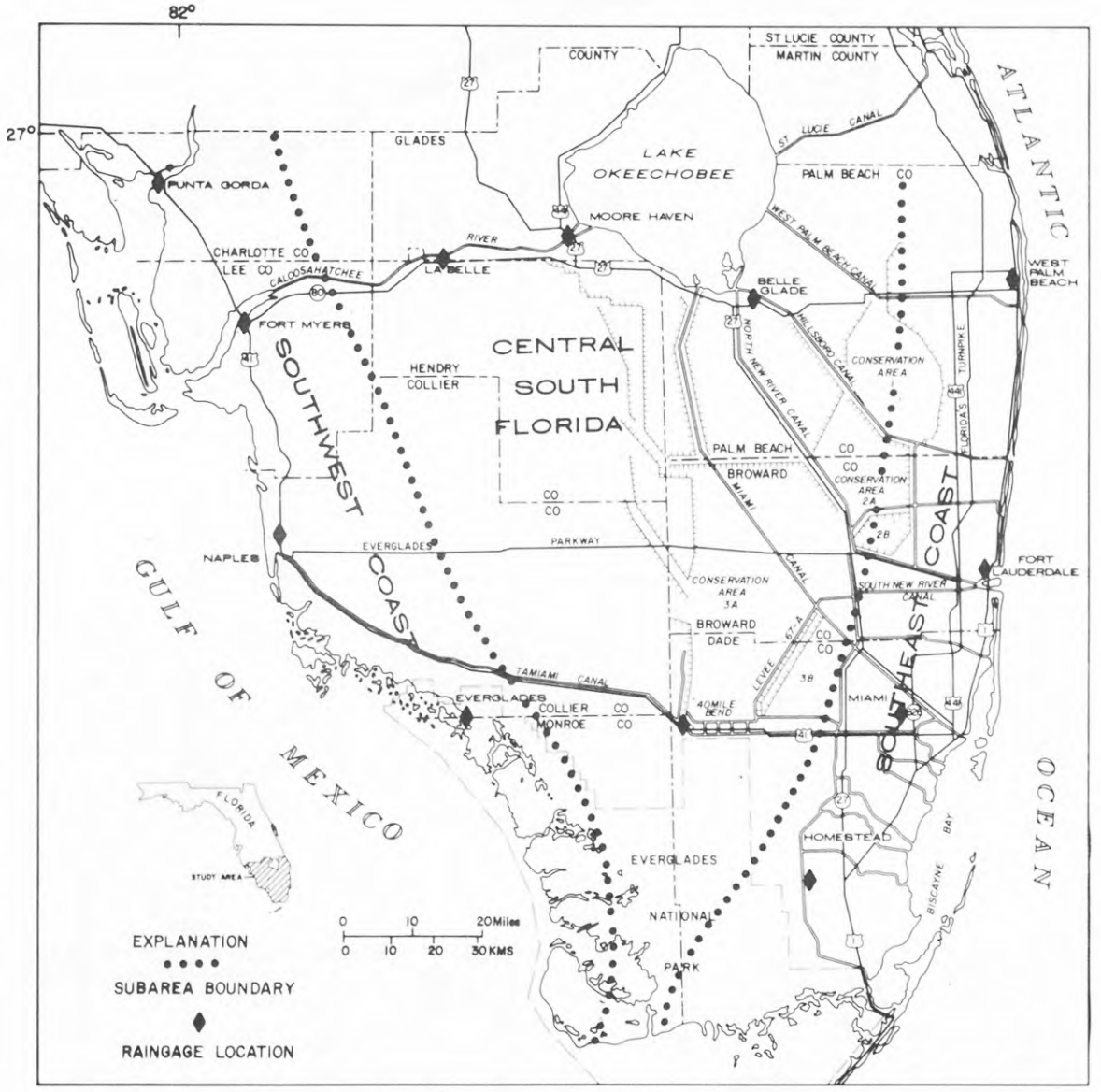

Figure 1.--Area and location of rain gages and subareas.

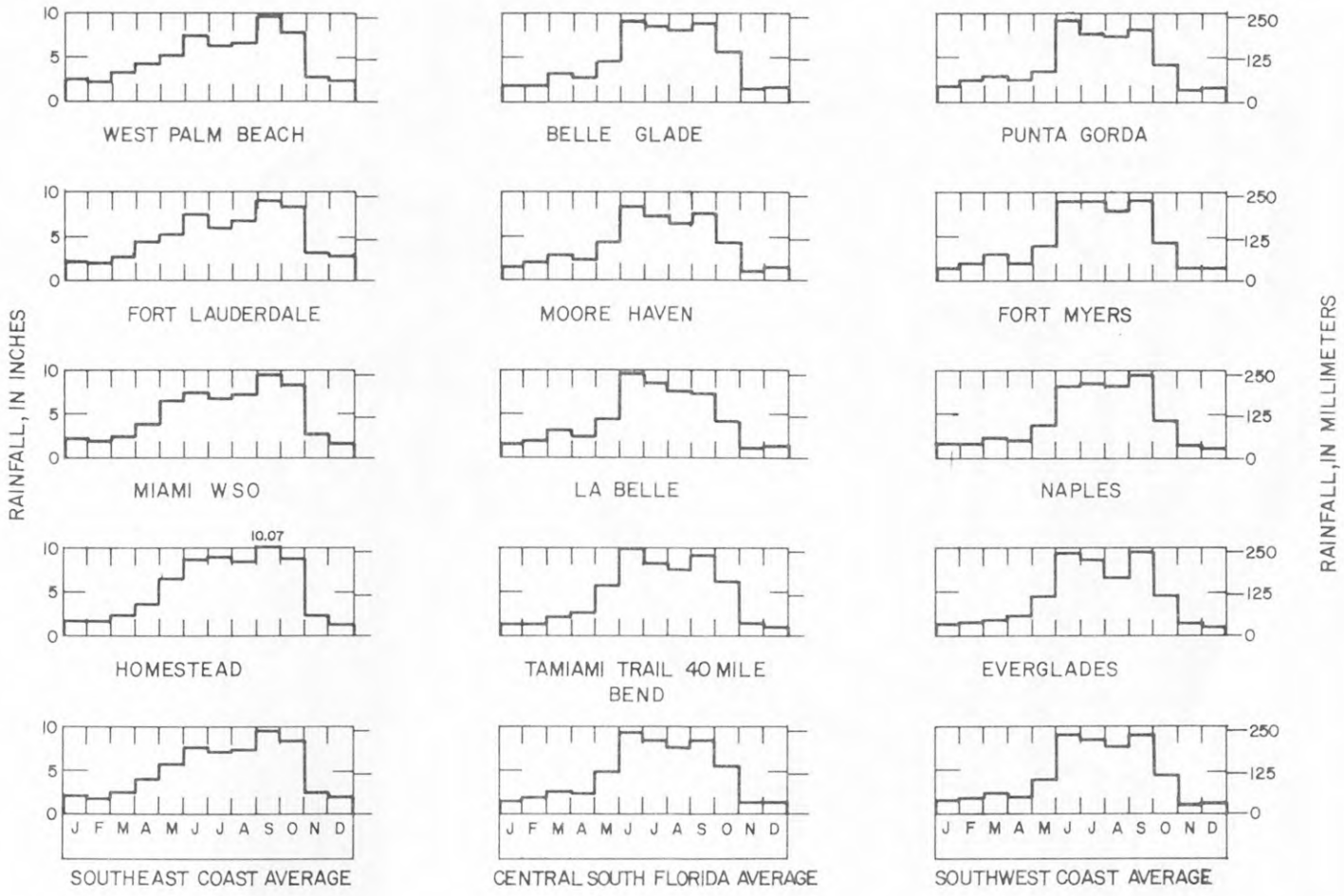

Figure 2.--Normal monthly rainfall.

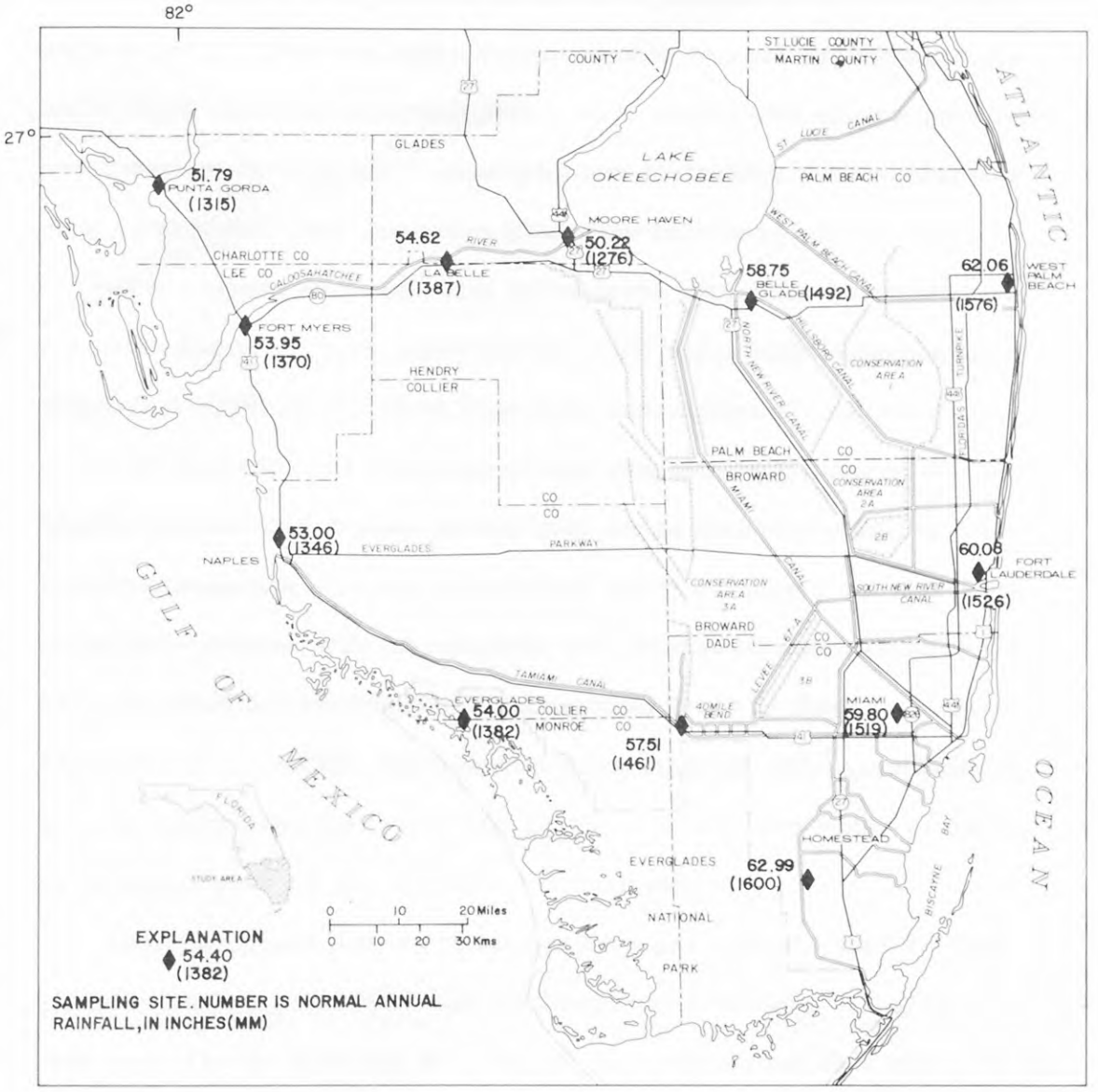

Figure 3.--Normal annual rainfall distribution.

If water could be stored during wet periods and released during dry periods, the water management problems of inadequate rain distribution seemingly could be solved. Yet nature often conflicts with man's planning: heavy rains may fall during a dry period, or the wet season of a particular year may have little rainfall. With sufficient records, normal annual and seasonal rainfall can be predicted with fair accuracy, but over short periods rainfall occurs erratically and cannot be predicted accurately more than a few hours in advance.

Although the occurrence of events such as the 1970-71 drought cannot be predicted, records can be analyzed to determine the average frequency with which they can be expected to occur. These analyses are useful to those responsible for the management of water resources; therefore, the analyses in this report were undertaken as a part of the Resource And Land Information Study of South Florida (U. S. Department of Interior, 1973).

CHARACTERISTICS AND DEFINITION OF DROUGHT

Drought is a natural phenomenon of a critical condition, and as such it occupies a place with equal standing among floods, hurricanes, tornados, earthquakes, tidal waves, and other disastrous natural events. All these phenomena are instances of nature departing drastically from its usual course.

Droughts are characterized by long duration when compared to the suddenness of other catastrophes, and their starting and ending times are difficult to identify. Rainfall deficiency is the basic cause of droughts, but there may be a long time lag between deficiencies and visible harmful effects on crops, wildlife, and water supplies.

The dictionary defines drought as (1) a prolonged period of dryness, or (2) a prolonged and chronic shortage. The first definition involves only the supply; the second is more comprehensive and recognizes the needs and the failure to meet the needs as being an integral part of the concept of a drought.

Meteorologists and hydrologists have defined droughts in many different ways, all add to the dictionary definitions by being very specific in defining dryness, or in identifying what constitutes a prolonged period or what the shortages may be with respect to

selected needs. Types of drought have been defined as follows (Subrahmanyam, 1967):

a. Meteorologic drought -- defined only in terms of precipitation deficiencies in absolute amounts, for specific durations.

b. Climatological drought -- defined in terms of precipitation deficiencies, not in specific quantities but as a ratio to mean or normal values.

c. Atmospheric drought -- definitions involve not only precipitation, but possibly temperature, humidity, or wind speeds.

d. Agricultural drought -- definitions involve principally the soil moisture and plant behavior, perhaps for a specific crop. As Yevjevich (1967) states: "A drought for tomatoes, for instance, may not be a drought in the eyes of the grower of potatoes."

e. Hydrologic drought -- defined in terms of reduction of stream-flows, reduction in lake or reservoir storage, and lowering of ground-water levels.

f. Water-management drought -- this classification is included to characterize water deficiencies that may exist because of the failure of water-management

practices of facilities such as integrated water-supply systems and surface or subsurface storage to bridge over normal or abnormal dry periods and equalize the water supply through the year. To a large extent, the recent drought in the northeastern United States was a water-management drought. During that drought, large amounts of water were in storage in aquifers, but means for withdrawing these supplies had not been developed.

The U.S. Geological Survey has customarily identified droughts on the basis of meterologic records (Thomas, 1962). J. C. Hoyt (1938) states:

> "In general, however, in humid and semiarid States there are no serious drought effects unless the annual precipitation is as low as 85 percent of the mean - that is, unless there is an annual deficiency of 15 percent or more."

Hoyt notes, however, that a deficiency in annual precipitation is not necessarily among the good criteria for determining the existence of a drought since within-year distribution of rainfall is a factor to be considered. He concludes that the seasonal deficiencies would be a better measure of the existence of drought

conditions or the lack of them. In this report drought conditions are considered to exist if seasonal rainfall (wet season or dry season) is 85 percent or less of the normal seasonal rainfall.

The study area is divided into three subareas (fig. 1). They are the southwest coast, central south Florida, and southeast coast. In each subarea four rainfall stations, for which 1941-70 normals have been computed (U. S. Department of Commerce, 1973), were used as the basis for computing normal rainfall and for evaluating rainfall deficiencies during the drought period. Normal monthly rainfall for each subarea was computed as the unweighted average of the normal monthly rainfall of the four stations in the area (table 1). Areal rainfall data used in the frequency study are the averaged seasonal rainfall recorded at the four stations in each area for 1941 to 1971.

Table 1. Normal and 1970-71 rainfall and seasonal rainfall deficiencies for south Florida.

Month	Southeast coast rainfall (inches)					Central south Florida rainfall (inches)					Southwest coast rainfall (inches)				
	Normal	1970-71 Recorded	Recorded percent normal	Seasonal percent (normal) wet	Seasonal percent (normal) dry	Normal	Recorded	Recorded percent (normal)	Seasonal percent (normal) wet	Seasonal percent (normal) dry	Normal	Recorded	Recorded percent (normal)	Seasonal percent (normal) wet	Seasonal percent (normal) dry
Jan.	2.12	3.57	144			1.76	3.57	203			1.77	3.24	183		
Feb	2.00	2.87	122			1.96	2.28	116			2.00	1.46	73		
Mar	2.73	7.03	204			2.89	11.73	406			2.55	12.57	493		
Apr	4.02	.67	15			2.71	.35	13			2.21	.02	1		
May	5.82	7.80	153			4.90	5.54	113			4.04	5.85	145		
June	7.80	7.49	98			9.15	6.80	74			8.92	6.28	70		
July	7.04	3.68	56	78		8.11	7.48	92	85		8.31	6.20	75	82	
Aug	7.22	5.06	75			7.51	7.53	100			7.47	5.50	74		
Sep	9.68	7.84	81			8.28	4.34	52			8.94	8.17	92		
Oct	8.32	4.58	58			5.14	4.99	97			4.36	2.40	55		
Nov	2.79	.34	12			1.41	.14	10			1.36	4.05	298		
Dec	2.09	.26	10			1.47	.24	16			1.37	.27	20		
Jan	2.12	.59	24		20	1.76	.58	32	27		1.77	.76	43		63
Feb	2.00	1.02	43			1.96	1.57	80			2.00	1.28	64		
Mar	2.73	.33	10			2.89	.51	18			2.55	.37	15		
Apr	4.02	.50	12			2.71	.30	11			2.21	.40	18		
May	5.82	3.83	75			4.90	4.26	86			4.04	2.25	56		
June	7.80	7.57	99			9.15	11.03	120			8.92	5.33	60		
July	7.04	4.42	66	74		8.11	6.56	81	99		8.31	6.86	83	95	
Aug	7.22	4.91	72			7.51	7.89	105			7.47	9.43	128		
Sep	9.68	7.95	83			8.28	6.85	82			8.94	10.51	118		
Oct	8.32	5.64	71			5.14	5.96	115			4.36	5.69	131		
Nov	2.79	4.87	170			1.41	1.75	124			1.36	.77	59		
Dec	2.09	2.79	108			1.47	1.14	78			1.37	.53	39		

THE 1971 DROUGHT IN SOUTH FLORIDA

The average rainfall during October varies geographically and ranges from 4 to 9 inches (102 to 229 mm) whereas in November it ranges from 1 to 4 inches (25 to 102 mm). By the end of November 1970 the newspapers were making what seemed to be uncannily accurate predictions of the drought that actually occurred.

> Miami Herald, Nov. 27: "A severe drought next spring is in the making for south Florida. Nothing can avert it but heavy rains this winter, which would be very unusual."
>
> Miami Herald, Nov. 30: "With the dry season just beginning and the rainy season more than six months away, Central and South Florida teeter on the brink of a third major drought since 1961."

The predictions are not unduly surprising, however, because the stage for the drought was set at a much earlier date by both the vagaries of nature and the uncertainties inherent in managing water resources with only limited storage capacity available and the necessity of providing for both flood control and water supply with the same storage system.

In March 1970 unseasonal heavy rains fell day after day. Over the whole of the Everglades and the southwest coast 12.15 inches (309 mm) fell, on the average. Rain over the lower east coast averaged 7.03 inches (179 mm). Farms were waterlogged, and deer and other wildlife in the Everglades were critically threatened. The water contained in the storage system of the Central and Southern Florida Flood Control District was much above schedule prior to the start of the normal rainy season, and the threat of flooding loomed.

The decision was then made to release water from storage to lower water levels to the scheduled elevation in anticipation of the rainy season. Rainfall, however, was deficient (85 percent or less of normal) during the 1970 wet season and the following dry season throughout south Florida, and along the southeast coast during the 1971 wet season (table 1).

Accompanying this period of deficient rainfall were substantial losses from storage in the surface-and ground-water storage systems in the area. The resulting shortages were accompanied by other effects such as landward movement of the salt-water front in the Biscayne aquifer of southeast Florida and with fires in the Everglades. These and other characteristics and effects of the drought are discussed in the following sections.

Rainfall

During early 1970 south Florida accumulated excess rainfall, averaging from 4 to 10 inches (102 to 254 mm) over the area. There ensued a period of rainfall deficiencies beginning in June 1970 and continuing through the following dry season and along the southeast coast through the 1971 wet season. The length and magnitude of the rainfall deficiencies combined to make this a record drought for south Florida. Rainfall deficiencies for May 1970 through October 1971 are shown in figure 4.

The 1970 wet season rainfall deficiencies in south Florida were, when compared to subsequent events, about uniform over the area with rainfall ranging from 78 to 85 percent of normal. During the ensuing dry season (November 1970 through April 1971) rainfall was 63 percent of normal on the southwest coast, but 27 percent of normal in central south Florida and 20 percent of normal on the heavily populated southeast coast.

The 1971 wet season saw an abatement of the drought in central south Florida and along the southwest coast with rainfall in those areas 95 percent or more of normal. Rainfall along the southeast coast was 74 percent of normal during the 1971 wet season, less than that of the 1970 wet season. During the 1971-72 dry season, rainfall on the southeast coast was 174 percent of normal and the long period of rainfall deficiency was broken.

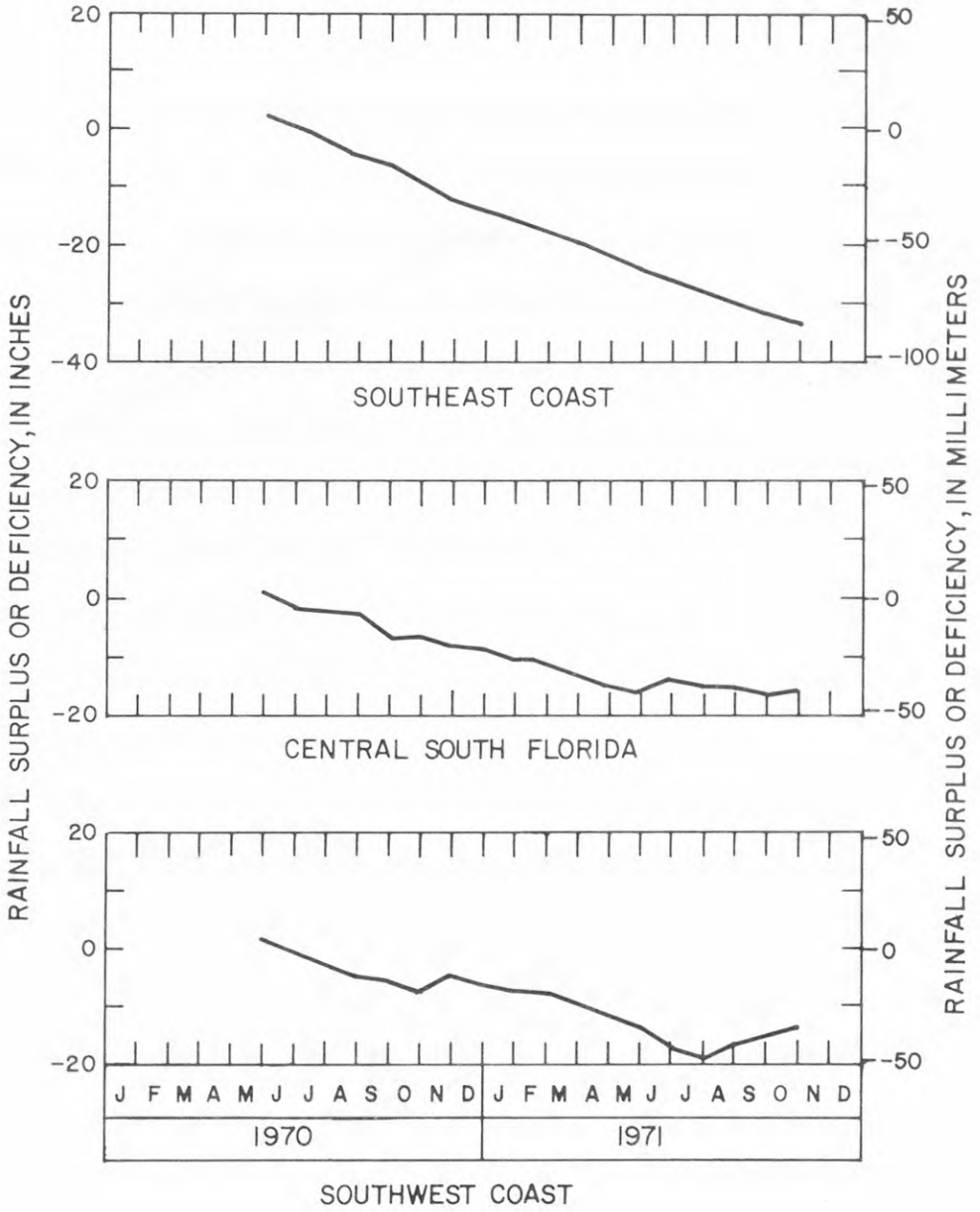

Figure 4.--Rainfall deficiency May 1970 - October 1971.

One particular period is of special interest, the 1970-71 dry period. Although periods of minor rainfall deficiencies are not rare, extreme deficiencies such as the dry 1970-71 season deficiency are very rare; consequently, much of the following discussion is an evaluation of this 6-month period and an evaluation of the average frequency with which a period having the rainfall characteristics of this 6-month period can be expected.

Rainfall Frequency

The recorded November to April rainfall for each subarea for 1941 to 1971 was analyzed statistically to develop a frequency relation for each, so as to determine the average recurrence interval of the 1971 dry-period rainfall. Frequency relations could be fitted satisfactorily to the data by using a log-Pearson Type III distribution. This was accomplished by the use of a computer program developed by the U. S. Geological Survey. The developed frequency curves and original data are shown in figures 5 to 7 for each of the three subareas. The fit is good indicating the suitability of the log-Pearson Type III distribution for fitting low-rainfall data such as these.

The computed recurrence interval of the 1971 dry-season rainfall on southwest coast is 100 years. Computed recurrence intervals of the 1971 dry-season rainfall for the southeast coast and central south Florida are several hundred years each. These analyses indicate that the 1971 dry-season rainfall in south Florida was indeed a rare event.

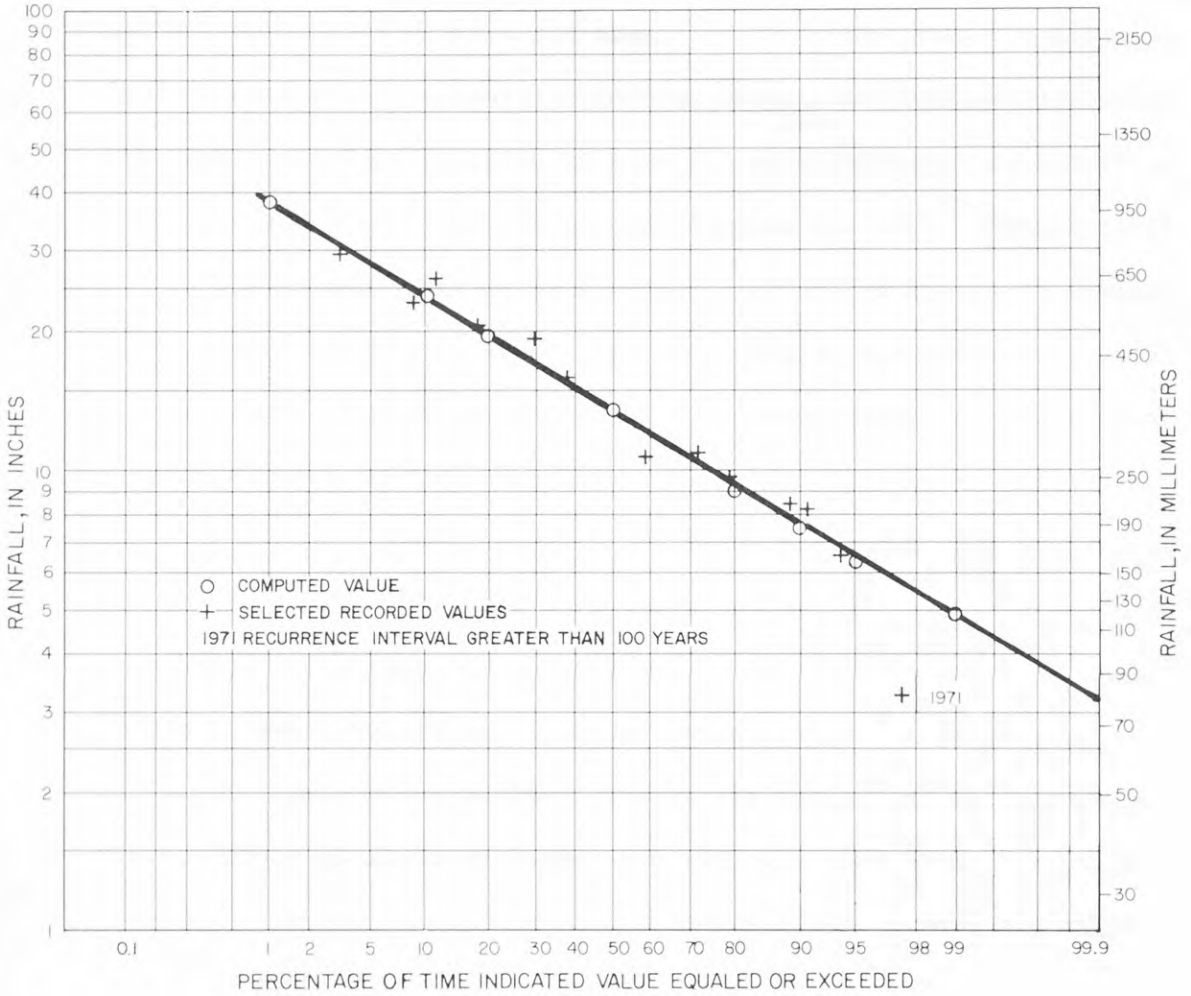

Figure 5.--November to April rainfall frequency for southeast coast of Florida.

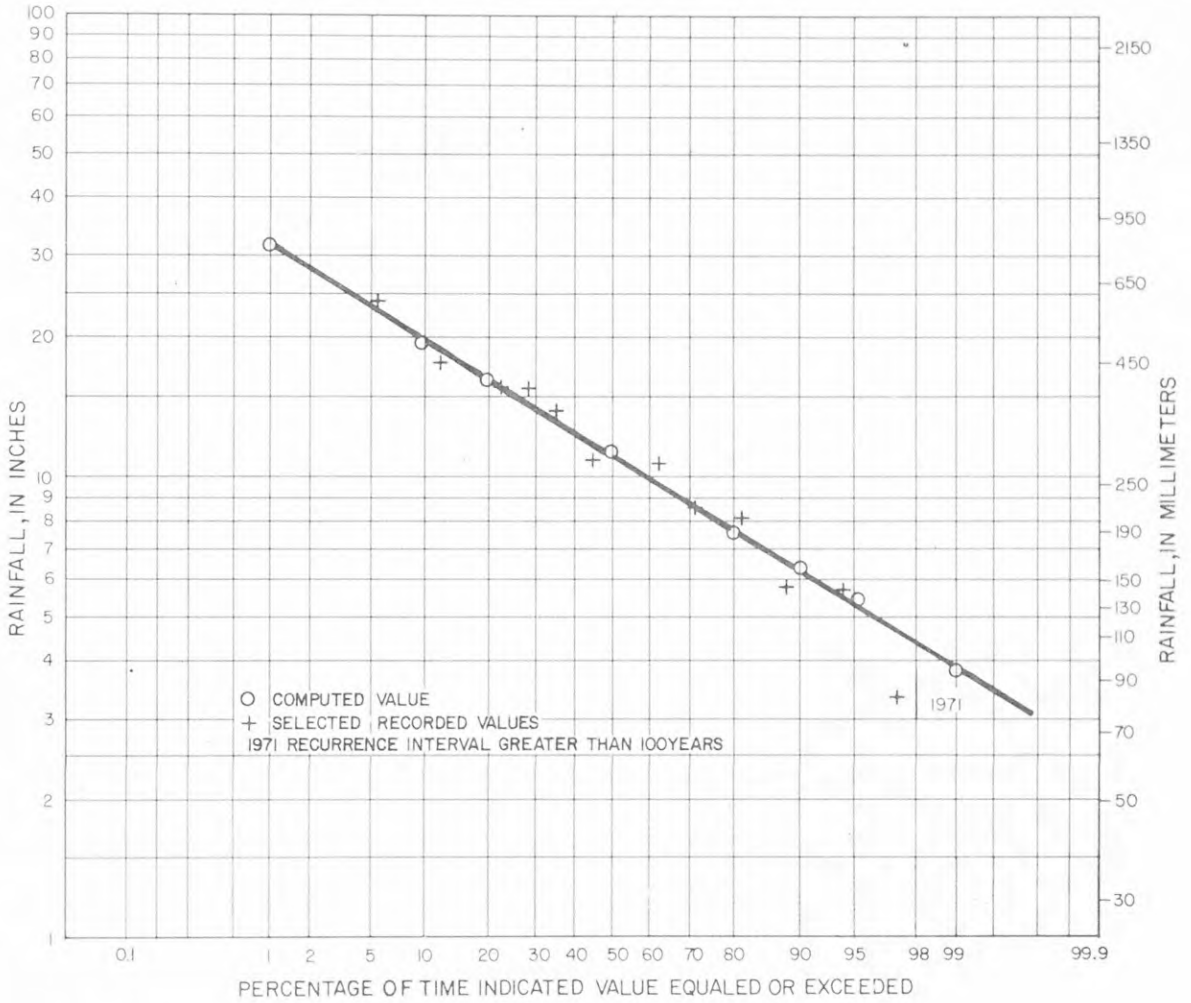

Figure 6.--November to April rainfall frequency for south-central Florida.

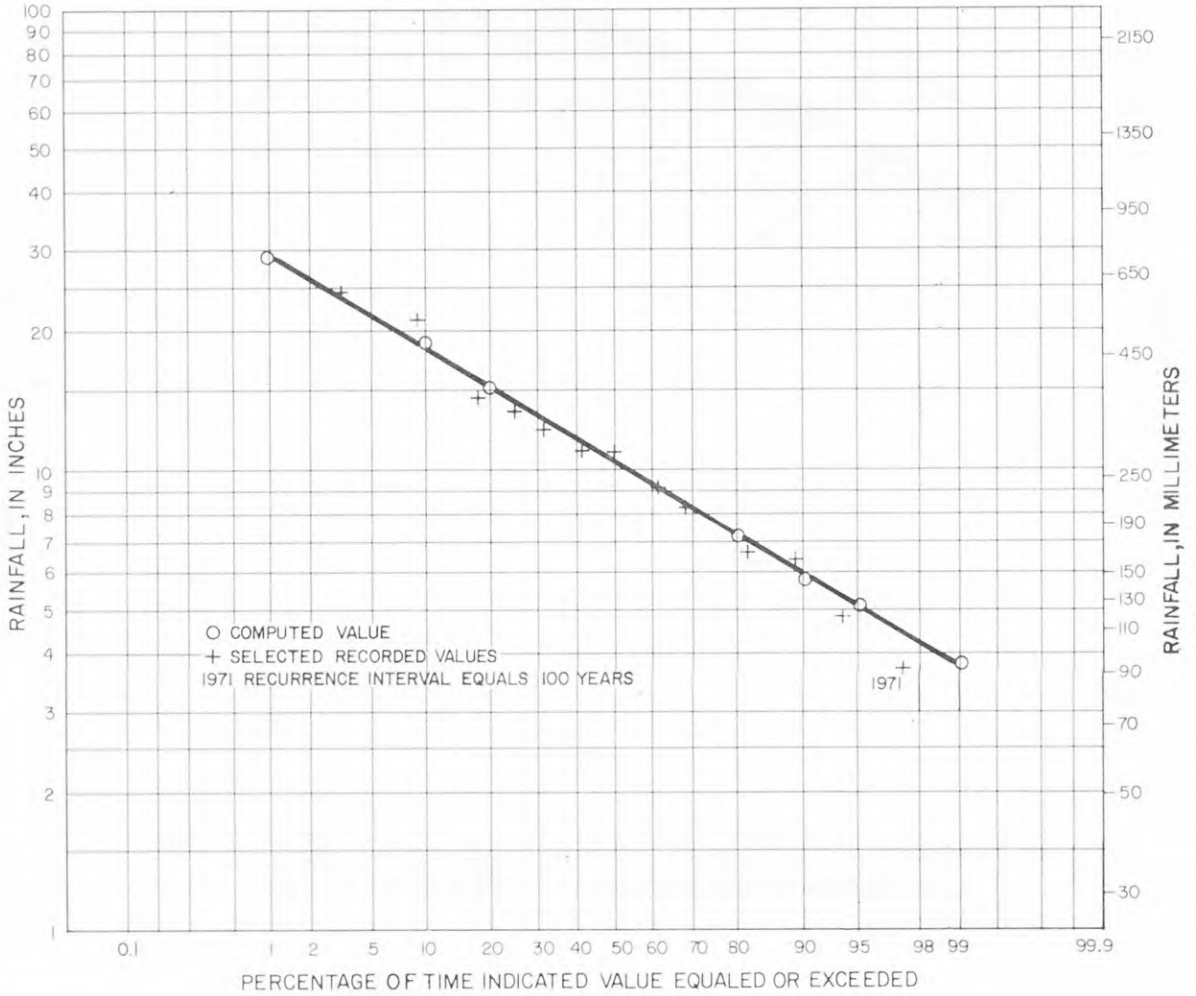

Figure 7.--November to April rainfall frequency for southwest coast of Florida.

Runoff

Since the magnitude of the 1971 dry-season rainfall was found to represent a very rare meteorologic event, it was also of interest to investigate the corresponding magnitudes of runoff in surface-water channels. The lack of sufficient storage reserves possibly might have resulted in deficient runoff in the area and that, on the average, the surface runoff might have been almost, if not entirely, as deficient as the rainfall.

Runoff in south Florida is highly controlled. Over the years, water control and management practices have altered natural drainage patterns by canal construction, damming, diversions, and by transfer of water between the surface-water and ground-water parts of the system. In addition, water levels in some wetlands have been lowered, and artificial surface storage areas (the conservation areas) built, each of which influences evapotranspiration and hence the runoff. In addition, water use by man has increased steadily. Therefore, the runoff records through the years represent a summation of the results of constantly changing conditions.

The monthly runoff pattern in terms of percentage of annual flow was analyzed at seven streamflow stations in south Florida. These stations had between 29 and 32 years of record.

Graphs of monthly flows at six streamflow stations, in percentage of annual flow, are shown in figure 8. The low-runoff season through most of south Florida lags the 6-month low rainfall season by 1 month; that is, the 6-month low-runoff period extends from December through May.

At six of the seven stations the flow during December-May in several recent years was lower than that during 1971.

The streamflow records analyzed, except station 02289040 (Tamiami Canal Outlets, levee 67A to 40-mile bend), had dry season flows during 1971 ranging from 5 to 23 percent of the mean dry season flow (table 2). Station 02289040 and station 02289060 combined are used to measure the southward flow from conservation areas 3A and 3B (fig. 9). Changes in the facilities for regulating storage in the two conservation areas have resulted in changes in the flow regimens at those stations after 1962. The results of these changes are a factor in the high ratio of the 1971 dry season flow to average dry season flow for station 02289040. The combined 1971 dry season flow from stations 02289040 and station 02289060 is 17 percent of the combined average dry season flow (concurrent record 1940 through 1970).

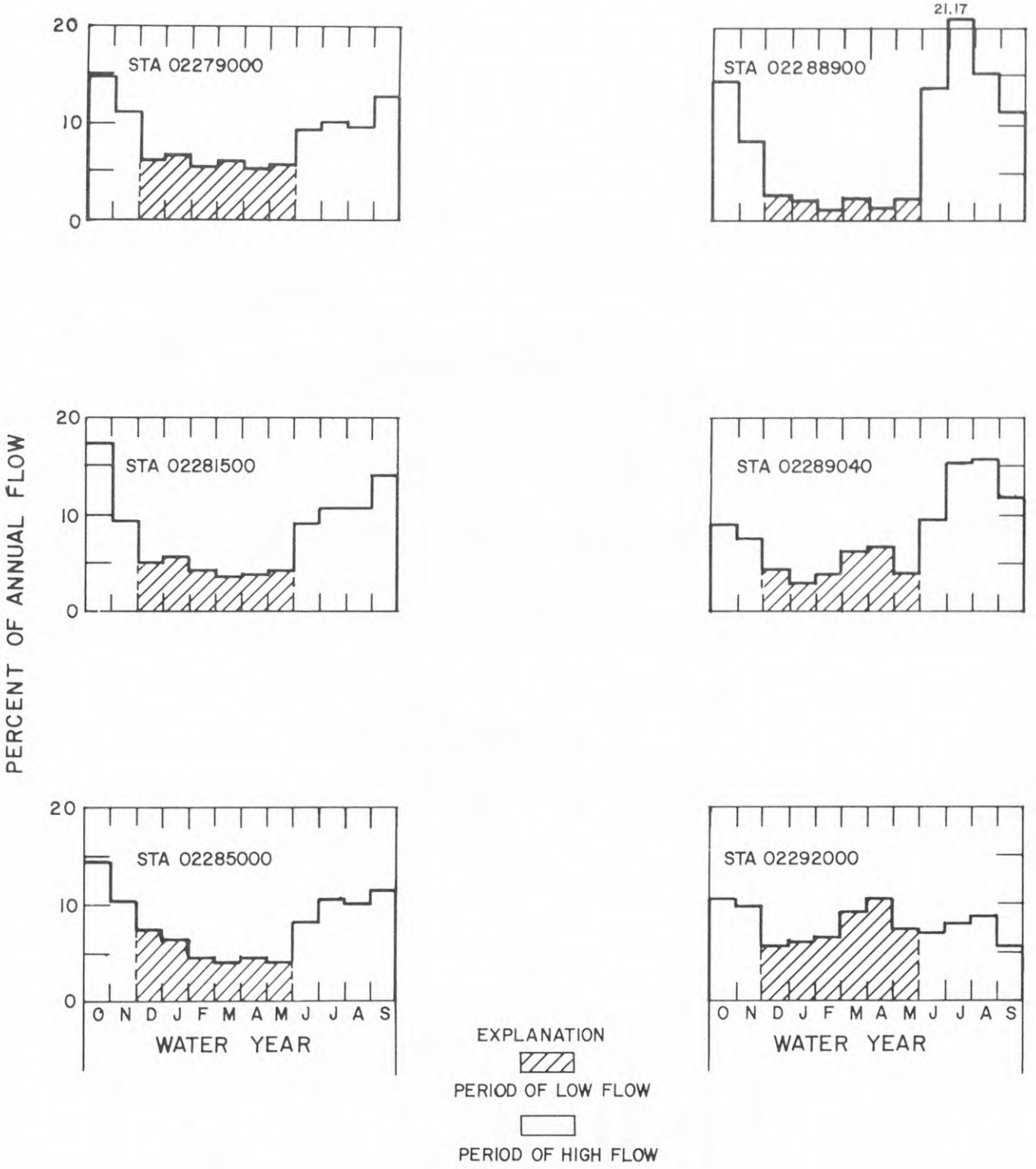

Figure 8.--Monthly runoff patterns at six streamflow stations.

Table 2. December-May runoff at long-term canal flow stations, south Florida.
(mean daily discharge in cubic feet per second)

Station Name and Number	Length of record (years)	Average Dec.-May runoff	1971 Dec.-May runoff	Ratio of 1971 runoff to average
West Palm Beach Canal at West Palm Beach 02279000	30	583	28	0.048
Hillsboro Canal near Deerfield Beach 02281500	30	199	35	.176
North New River Canal near Fort Lauderdale 02285000	30	322	15	.047
Tamiami Canal Outlets 40 mi bend to Monroe 02288900	31	75	15	.200
Tamiami Canal Outlets levee 67A to 40 mi bend 02289040	31	187	208	1.11
Tamiami Canal Outlets levee 30 to levee 67A 02289060	29	1780	117	.066
Caloosahatchee Canal at Moore Haven 02292000	32	1086	248	.228

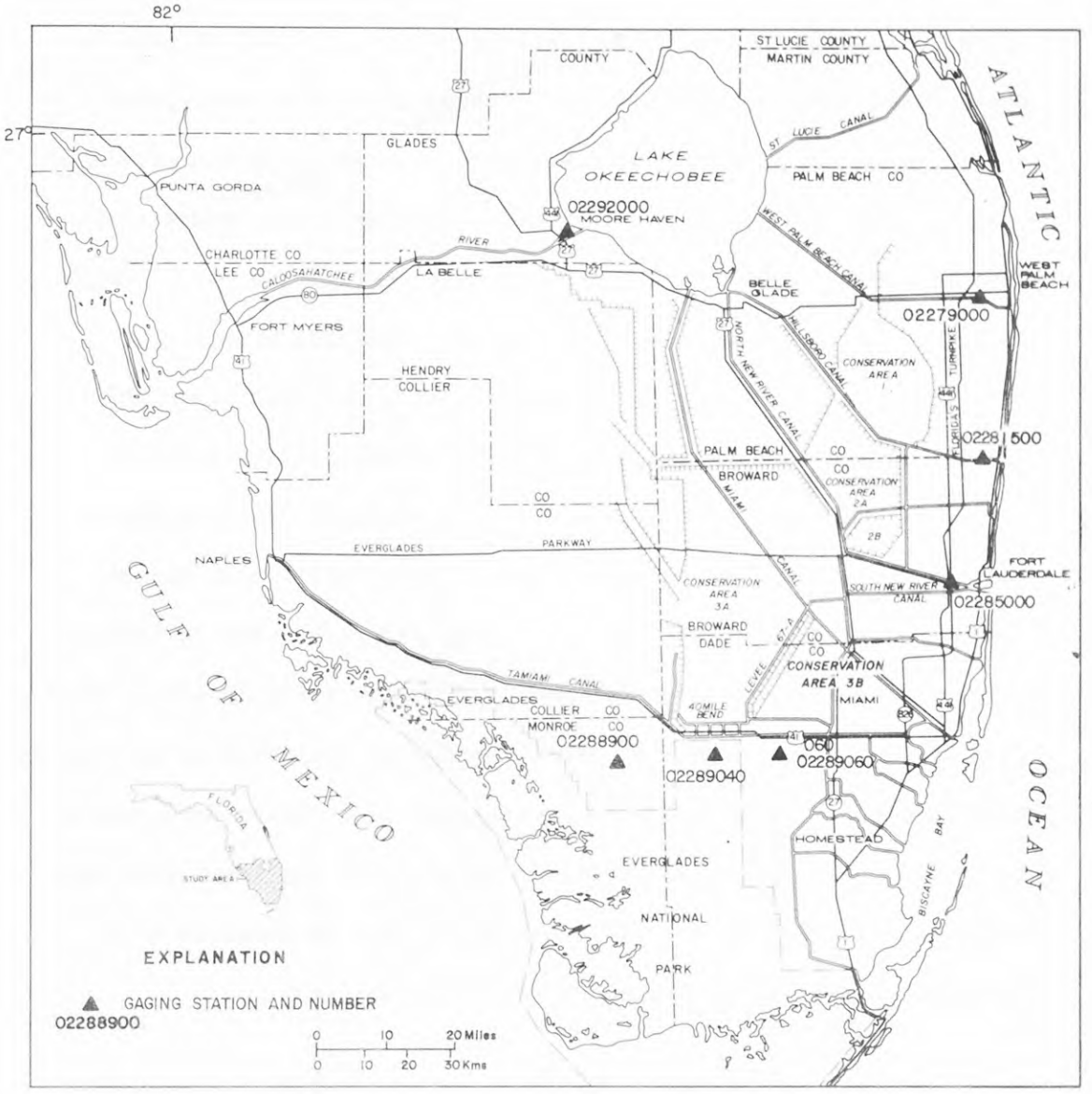

Figure 9.--Location of streamflow stations.

Water Levels in Lake Okeechobee

During the 1971 drought, the newspapers carried information of the alarming and continuous fall of the water level in Lake Okeechobee. The information was in terms of either water-level elevation or the number of acre-feet in storage below the scheduled amount. Examination of the previous record of water levels shows that the 1971 levels represented a notable deficiency in scheduled storage, but in no way were they a record-breaking event.

The record of water levels since 1915 shows that comparable periods of low lake stages had occurred in 1932, 1956, and 1962 (fig. 10). Table 3 shows comparative water-level data for these and for the 1971 drought. The minimum water levels were almost the same in 1932 and 1971, but they were slightly lower in 1956 and 1962. The number of days that the levels were below 12 and 11 feet (3.7 and 3.4m) show that, at least insofar as indicated by storage in Lake Okeechobee, 1956 and 1962 represented far greater deficiencies in storage than 1971. In addition, during 1932 the lake level was below 12 feet (3.7 m) for 311 consecutive days as compared with 145 days in 1971 (fig. 11, and table 3).

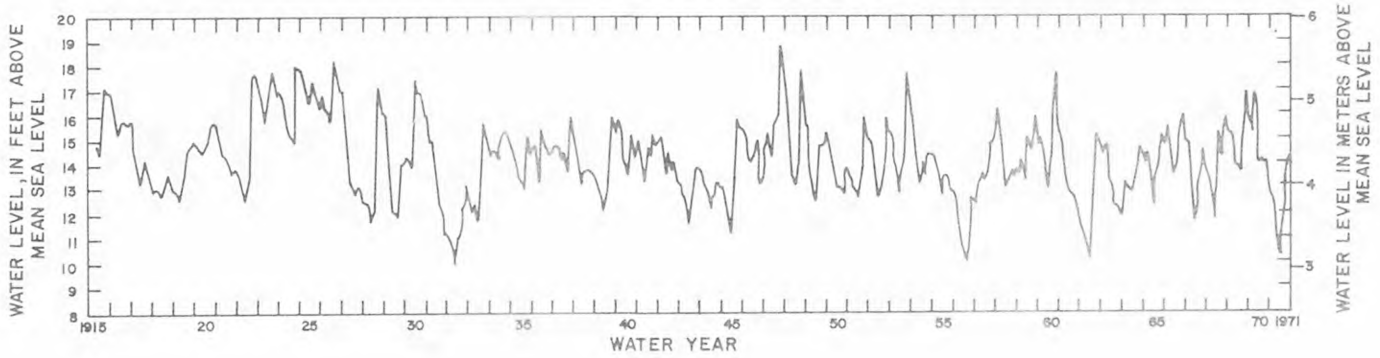

Figure 10.--Hydrograph of Lake Okeechobee, 1915-71.

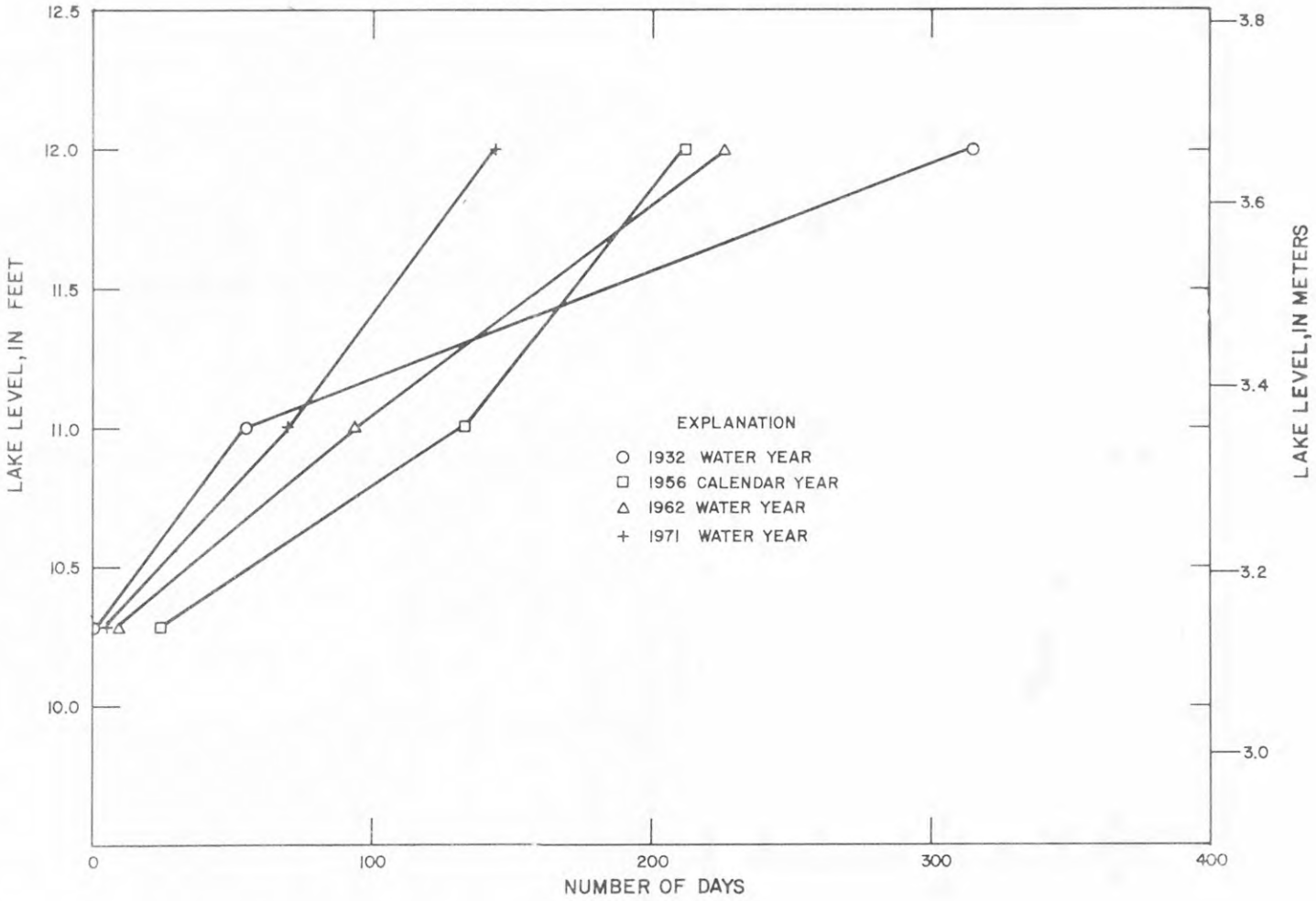

Figure 11.--Number of days water-surface elevation in Lake Okeechobee was at or below indicated levels in 1932, 1956, 1962, and 1971.

Table 3.-- Water levels during drought periods of Lake Okeechobee at St. Lucie Canal.

Year	Days water level below		Minimum stage for the year	
	12.00 ft	11.00 ft	Stage (feet)	Date
1932	311	55	10.3	5/17/32
1956	211	132	10.14	8/17/56
1962	224	95	10.22	6/ 7/62
1971	145	70	10.24	6/6-7/71

Ground-Water Conditions

Ground-water reservoirs are the immediate source of water for most municipal and part of the agricultural needs. The eastern part of the area depends on a shallow permeable aquifer (Biscayne aquifer) consisting primarily of limestone and sandy limestone which has a direct connection to the sea. The coastal sections contain salty water and the position of the fresh water-salt water interface shifts in response to changes in water levels in the aquifer. The water levels in the aquifer fluctuate in response to rainfall and water-management practices. Canals provide an important source of recharge to the aquifer in areas of large withdrawals of ground water during dry periods (Meyer, 1972).

Annual water-level fluctuations in selected wells in the study area are shown in figure 12. The annual cyclic nature of the water-level fluctuations is evident. The average seasonal range in water-level fluctuations in the Biscayne aquifer in Dade County is shown in figure 13. In north Dade County where water use is concentrated the range in seasonal water levels is relatively small as compared with the range in seasonal water levels to the south. This is attributed to the fact that water-management practices in the north provide for supplying the aquifer with water from conservation area 3 through the canals during the dry season. These facilities are not yet available to the south part of the county.

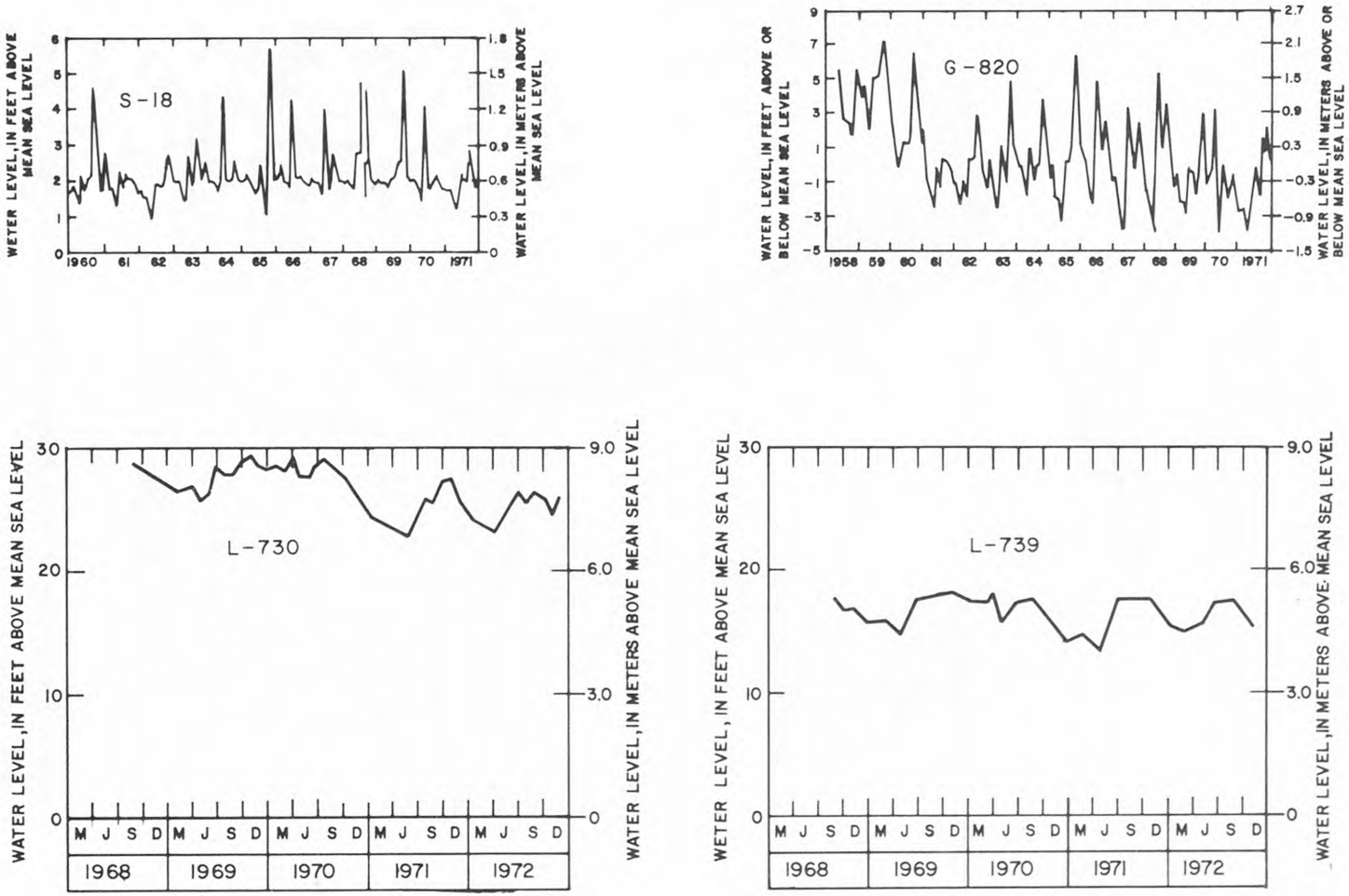

Figure 12.--Selected wells in the study area.

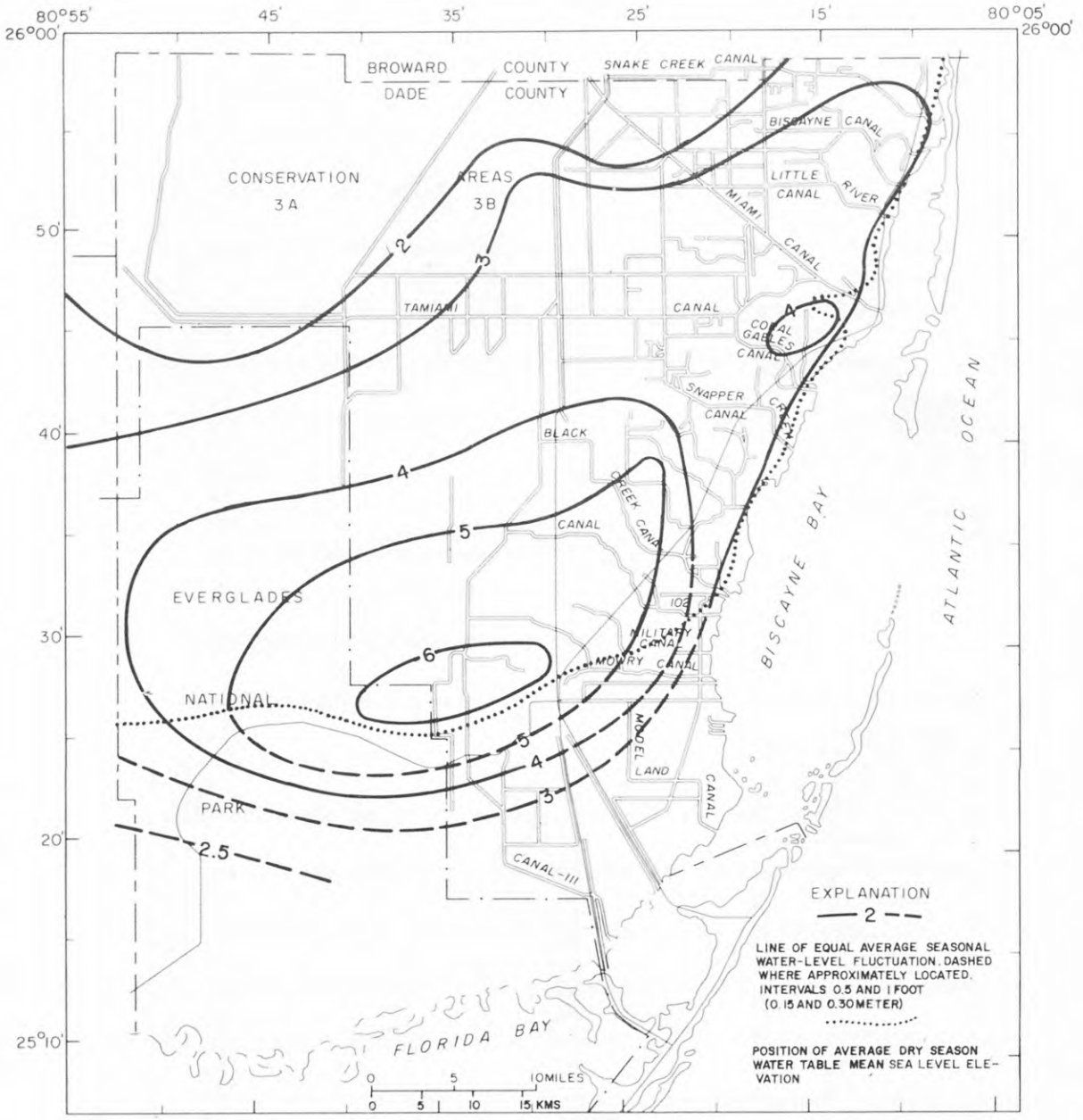

Figure 13.--Seasonal fluctuation of water levels in the Biscayne aquifer in Dade County.

Water-level records have been collected in 18 wells in southeast Florida for 20 to 40 years (fig. 14). In nine of these wells levels have been lower in 2 or more years.

The vulnerability of the Biscayne aquifer to further advances of sea water gave rise to concern about the falling water levels in 1971. The net change in water levels in the Biscayne aquifer in Dade County between May 1970 and May 1971 is shown in figure 15. The net decline ranged from 0.5 to 4 feet (0.15 to 1.22 m) and was a foot or more over much of the area. By September 1971 (fig. 16) water levels in all but western Dade County were at or above average elevations.

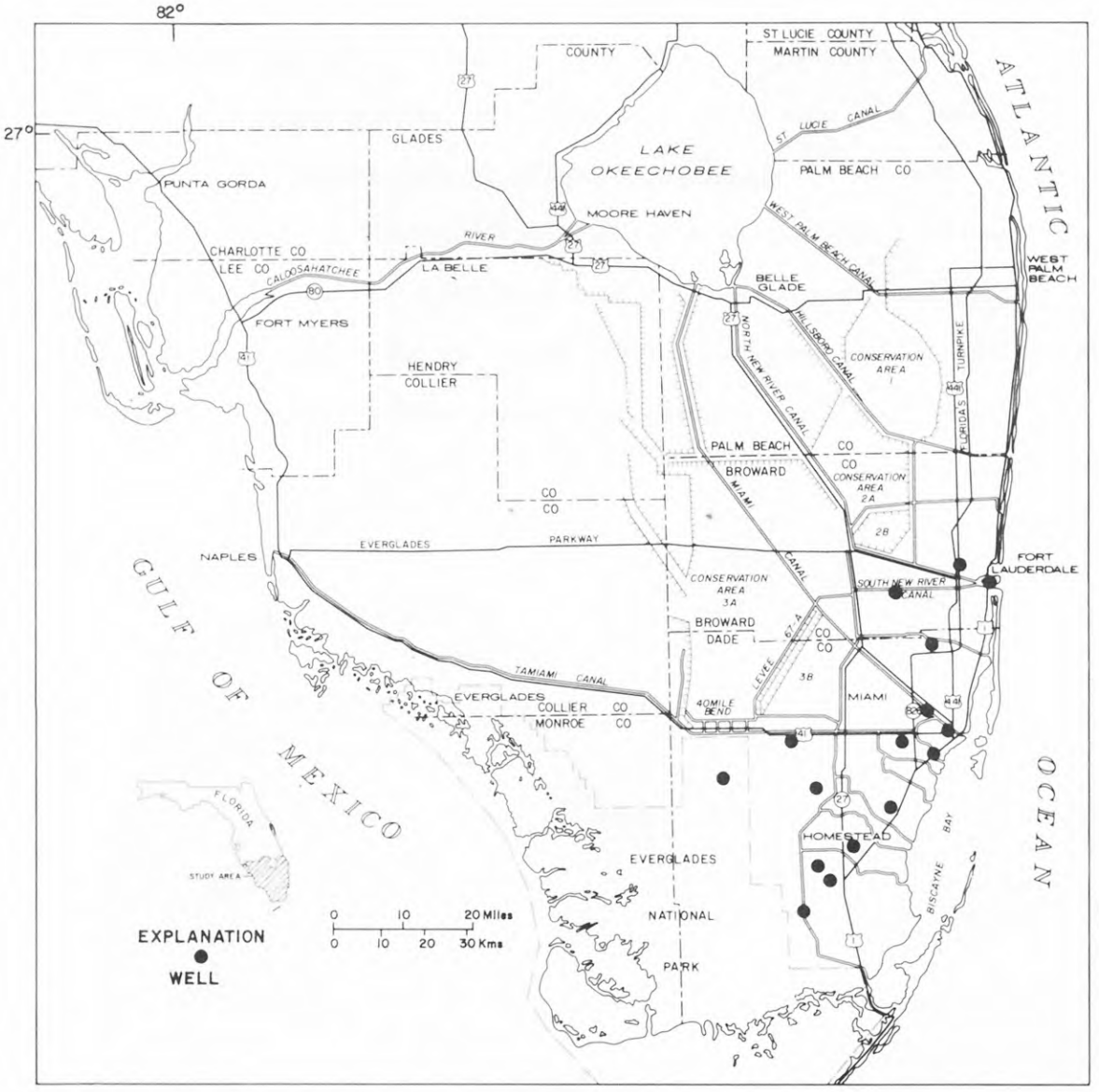

Figure 14.--Location of wells in study area with 20 to 40 years of record.

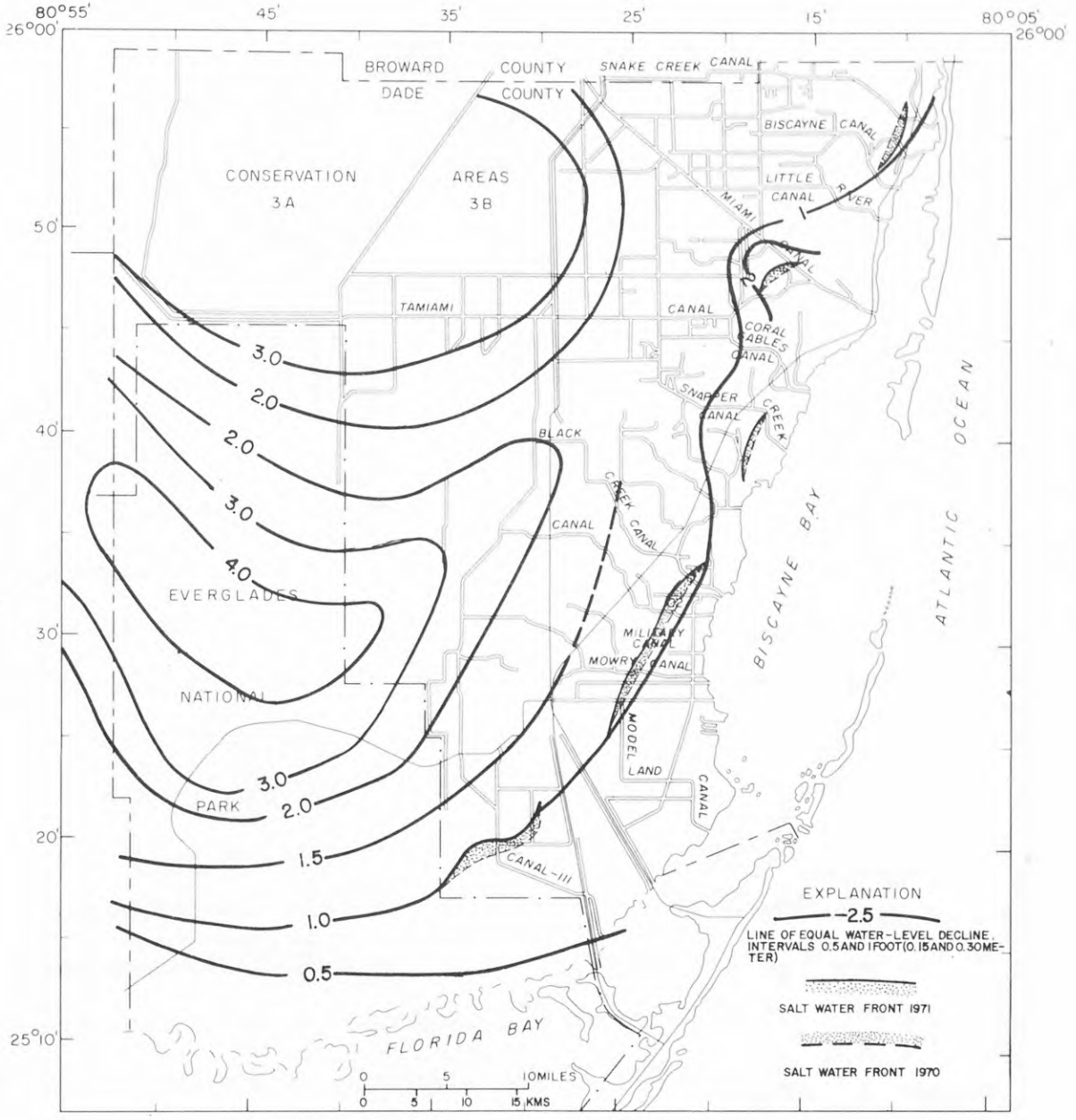

Figure 15.--Net decline in water levels in Biscayne aquifer, May 1970 to May 1971.

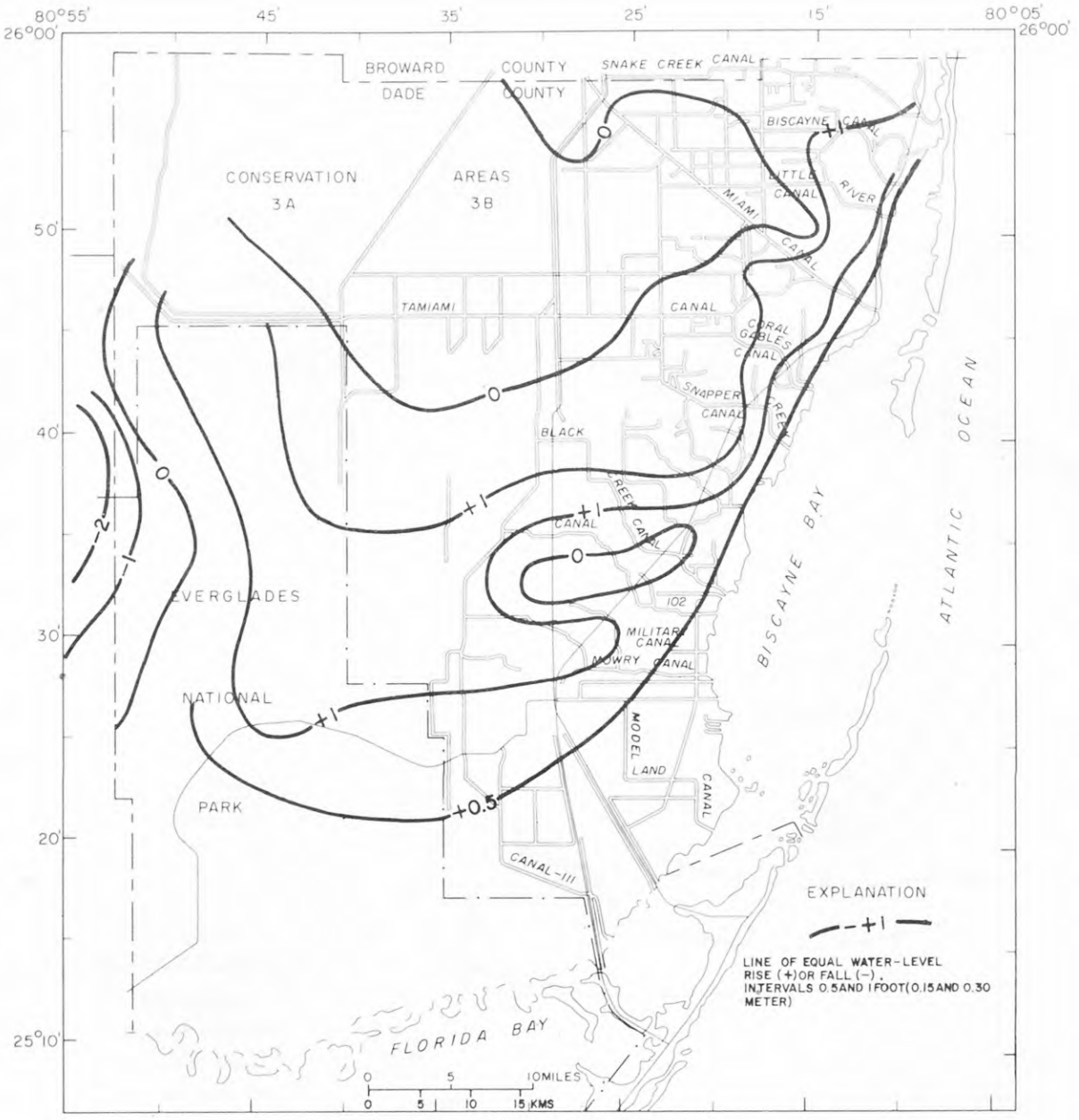

Figure 16.--Difference between September 1971 water levels and average water levels in the Biscayne aquifer, Dade County.

Sea-water Intrusion

The problem of sea-water intrusion into the Biscayne aquifer was considered as a constant threat during the course of the drought. By March 22, 1971, the U. S. Geological Survey had reported evidence (Miami Herald) of intrusion in both the Miami Canal and the Little River Canal in Dade County. On May 1 the city of Miami reported (Miami Herald) that sea-water intrusion had not affected water from its wells, but had moved to within a mile of them. On May 5 U. S. Geological Survey hydrologists reported (Miami Herald) that no major well field in Dade County appeared to be endangered by sea-water intrusion.

In addition to showing water-level changes in Dade County, figure 15 also shows the areas of greatest inland movement of salt water in the Biscayne aquifer. The inland movement was greatest in south Dade County where water levels in the interior declined to as much as 1.5 feet (0.46 m) below sea level by May 1971. With the ensuing rainfall water levels began to rise and by September, they had returned to normal as indicated in figure 16. As water levels rose, the increased fresh-water head began to move the fresh-water - salt water interface seaward.

Fires

Grass and muck fires and smoke-blackened skies were common during the late months of the 1971 drought. Natural fires occur regularly in south Florida. Many fires are started by lightning and some are started inadvertently by man. Controlled burning is used in land management. On March 22, 1971, the Miami Herald reported that 300 fires had already blackened more than 250,000 acres (101,174 hectares) in Dade, Broward, Palm Beach, and Collier Counties. However, it said that, "Florida always turns brown at this time of the year. There are always fires." On April 11, 1971, an official of the Central and Southern Florida Flood Control District said about fires, "So far things haven't been too bad if we had rains now it would be fine." The Washington (D.C.) Post of May 14 said on its front page that, "By one recent count 7,366 fires have swept 560,518 acres of south Florida this year in the course of the 6-month drought. In wide areas the earth itself is destroyed and the pungent smoke from the burning muck often blackens the skies of Miami."

Information furnished by the National Park Service provides data on fires within the Everglades National Park (465,500 acres or 188,365 hectares of fire potential) and an adjacent protection zone outside the Park (266,100 acres or 107,689 hectares). Records maintained since 1947 show the following acreages burned over by fires during years of many fire occurrences:

	Acres	Percent of total potential
1950	120,600	16
1962	192,300	26
1963	90,900	12
1971	83,300	11

It is thus seen that since 1947 more extensive burning than in 1971, at least in the Everglades Park area, occurred in 3 other years.

Cloud Seeding

The threat of dwindling water supplies led the Central and Southern Florida Flood Control District to ask (Miami Herald, December 14, 1970) "that rain-making conferences be set up with U. S. scientists who have been seeding rain clouds with a view more towards breaking up hurricanes than breaking droughts." State officials requested Congress to increase financing for a Miami-based cloud seeding project with the Experimental Meteorology Laboratory of the National Oceanic and Atmospheric Administration. In January tentative clearance was received from Washington to begin such efforts. However, it was planned to start the actual seeding in April, when clouds appear of the proper type for seeding.

More than 120 rain gages were installed in an experimental area north of Lake Okeechobee. Between April 4 and May 26, a total of 196 seeding passes were made in the test area (Simpson, Woodley, and White, 1972). Circumstances prevented the use of controls and reduced the size of the original test area. The experimental design did not permit specific conclusions as to the actual amount of increased precipitation, if any, that resulted from seeding.

However, it was estimated by the National Oceanic and Atmospheric Administration research team that seeding probably increased the precipitation in the test area between 5 and 10 percent during April and May. The two major conclusions of the study (the first had been anticipated) were: (1) That no cloud seeding method can break a drought (the proper type of clouds must be present); and (2) that dynamic seeding can probably provide worthwhile local drought mitigation in Florida, but that its real efficacy remains to be established by continuation of randomized research experiments.

SUMMARY AND CONCLUSIONS

The 1971 drought in south Florida received outstanding news coverage during its course and for long afterward. It was considered to be a major crisis and was prominent in the minds of the public and of officials responsible for managing the water resources. Even before it had progressed very far, the possibility of a major water shortage loomed large. The virtual absence of rainfall during the dry season provided strong grounds for the apprehension. Yet a study of the consequences of the very dry dry season and the actual deficiencies that developed show that fears were not entirely justified and that management was successful in averting or preventing serious results.

The drought period was a very rare event that (within at least part of south Florida) would be expected to recur only at average time periods measured in centuries. In spite of this, the only water shortages that developed were localized. Restrictions in water use were exercised by governing officials toward the end of or following the dry season and for the most part were in the form of requests for voluntary curtailment of water use rather than the application of mandatory restrictions or actual shutting off of supplies.

Canal levels were maintained generally no lower than levels previously experienced, in comparison to rainfall that was much less than previously experienced.

Ground-water levels were noticeably affected by the drought. Low water levels were accompanied by temporary advances of the salt-water front in the Biscayne aquifer in Dade County. Wide fluctuations in water levels in the aquifer are a seasonal phenomenon, however, and by September 1971 water levels in most of the area were at or above average.

The level of Lake Okeechobee, the principal water-storage reservoir, declined, but comparable levels had been reached three other times within the past 55 years (1932, 1956, and 1962). During 1956 and 1962 levels had been slightly lower than in 1971. Based on the number of days the lake level was below 11 and 12 feet (3.4 and 3.7 m) during the four drought periods, the other three periods represent much more serious deficiencies in storage than did 1971; however, the population and the water demands in 1971 were much greater.

Although fires in 1971 were widespread, data on acreage burned in the Everglades National Park area show that the 1971 acreage burned was exceeded during 3 other years since 1947: 1950, 1962, and 1963.

During the drought, there was constant fear on the part of local agencies of serious and irreparable encroachment of the salt-water front. Salt content increased in the lower reaches of some canals and the salt-water front in the Biscayne aquifer temporarily advanced inland about one-half mile (0.8 km) in a part of south Dade County. However, water from the major well fields that supply the large urban areas did not increase in salinity.

Recurrent fears of drought during each of the dry seasons since 1971 are based on the realization that water needs are increasing rapidly in south Florida, and that shortages may occur at times even though rainfall may be normal for the season. It will be seen that if such shortages occur in a humid region of abundant annual rainfall, they are not droughts except in the sense that water needs and the distribution of rainfall are not balanced. Such balance can be achieved by continual expansion of water-management practices, based on already available techniques, or those that may be developed in the future.

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