Special Publication SJ 91-SP5

UPPER ETONIA CREEK HYDROLOGIC STUDY

PHASE I FINAL REPORT

from

Louis H. Motz and James P. Heaney
Faculty Investigators

William K. Denton and Geoffrey Leiter
Graduate Student Investigators

Departments of Civil Engineering and Environmental
Engineering Sciences
University of Florida

to

Douglas A. Munch
Project Manager

St. Johns River Water Management District
Palatka, Florida

Contract Number 90G126

1991

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

The Upper Etonia Creek Basin (UECB), located in parts of Alachua, Bradford, Clay, and Putnam counties, is part of the lower St. Johns River Basin. Many of the lakes in the UECB basin coincide with karst features formed by solution of the underlying limestone, and a hydraulic connection exists between the lakes and the underlying aquifers. In recent years, lake levels and groundwater levels have declined by significant amounts in some parts of the area. This has prompted Clay County and concerned citizens to request that the St. Johns River Water Management District (SJRWMD) investigate the water resources of the area. In January 1990, the SJRWMD authorized the University of Florida to conduct an investigation to evaluate long-term changes and trends in lake levels in the basin, including changes in rainfall, evapotranspiration, groundwater levels, and water use in the basin. To meet the objectives of the investigation, five tasks were performed: literature review and data inventory; compilation of existing data; assessment of long-term changes; review of hydrogeologic data and preliminary lake-stage simulations; and report preparation.

Long-term precipitation records at Gainesville and shorter-term records at Melrose, Palatka, and Starke indicate that the mean annual rainfall in the UECB from 1900 to 1989 is 50.74 inches, with a low of 29.22 inches in 1954 and a high of 68.99 inches in 1964. The mean annual pan evaporation at Gainesville is 61.63 inches, and the actual lake evaporation and evapotranspiration is approximately 20 to 30 percent less than the measured pan evaporation. The range in lake-stage variability in the UECB is remarkable. For the 13 lakes for which records are available, the range in stage over the periods of record is from 1.70 feet for Blue Pond to 31.16 feet for Pebble Lake. These two lakes are the most stable and least stable lakes (based on lake-level fluctuations), respectively, in the entire state. Potentiometric maps indicate that the Keystone Heights area is a major recharge area for the underlying Floridan aquifer and that groundwater

levels decreased by approximately 5 feet from 1978 to 1989 in the area. Groundwater is pumped in the UECB for public supply, agriculture, and mining, and the total estimated pumpage is approximately 6.7 million gallons per day. However, this pumpage has not been large enough for cones of depression to occur on a regional scale on potentiometric maps of the Floridan aquifer. Based on presently available data, the drawdown effects due to pumping from two sand mines in the UECB are on the order 0.3 to 1.4 feet at distances of 5,000 feet from the centers of pumping at the mines.

The declining lake levels during the recent dry period correlate quite closely with trends in precipitation and evaporation for the UECB. Exceptions to this trend were noted in the stage levels for Little Lake Johnson and Pebble Lake, which have stabilized and actually increased, respectively, during the last few years. Overall, it is apparent that low rainfall is a significant factor contributing to the declining lake levels in the UECB, based on the close correlation between lake-stage levels and precipitation patterns. In addition, Little Lake Johnson, Pebble Lake, and possibly other lakes may have been influenced by man's activities in the UECB.

Additional precipitation gages are needed in the UECB to provide a more accurate estimate of the spatial and temporal variability of precipitation in the basin. Also, a significant expansion in groundwater monitoring is needed to evaluate the impact of nature and man's activities on this resource. Pumping by the larger mining and agricultural activities needs to be metered to provide more accurate data for a hydrologic budget for the UECB. A second phase of this study is recommended to investigate some of the hydrologic factors in more detail. This would include collection and evaluation of additional hydrogeologic data, simulation of lake-stage levels, and development of a groundwater model and a simulations and operations model for the Brooklyn chain of lakes.

1.0 INTRODUCTION

1.1 Project Description

The Upper Etonia Creek Basin (UECB), located in parts of Alachua, Bradford, Clay, and Putnam counties, is part of the lower St. Johns River Basin. The headwaters of this basin include a series of lakes that flow from one to another at various stages. The western part of the basin is a highland region known as Trail Ridge in northeast Florida. This region consists of high sandhills and karst features formed by solution of the underlying limestone. Many of the lakes in this region coincide with the karst features, and a hydraulic connection exists between the surface waters and the underlying aquifers. The UECB is an important recharge area for the Floridan aquifer system, because of the net downward hydraulic gradient between the lake and surficial aquifer water levels and the potentiometric surface in the Floridan aquifer.

During the past sixty years, cultural and hydrologic changes have occurred within the basin. Recently, lake levels and groundwater levels have declined by significant amounts in some parts of the area. This has prompted Clay County and concerned citizens in the area to request that the St. Johns River Water Management District (SJRWMD) investigate the water resources of the area. In January 1990, SJRWMD authorized the University of Florida (UF) to investigate and evaluate long-term changes and trends in lake levels in the basin. This report presents the results of that investigation, including identifying the principal causes of lake-level declines in the UECB. Also, a second phase of the investigation is recommended to investigate some of the hydrologic factors in more detail.

1.2 Objectives

The investigation conducted by UF evaluated long-term changes and trends in lake levels. The objective of the investigation was to relate lake-level changes to changes that have occurred in rainfall, evapotranspiration, surface-water flows, groundwater levels, and water use and determine the principal cause(s) of lake-level declines in the UECB.

1.3 Tasks

The UF investigation initially consisted of four technical tasks:

(1) literature review and data inventory;

(2) compilation of existing data;

(3) assessment of long-term changes; and

(4) report of findings.

Task 1 consisted of reviewing published and unpublished reports that pertain to the UECB and detailing hydrologic, cultural, and topographic data. In Task 2, existing hydrologic data were compiled and evaluated to establish a data base. In Task 3, changes that have occurred in rainfall, evapotranspiration, streamflow, lake levels, and groundwater levels in the UECB were quantified using statistical techniques to understand the relationships among the various hydrologic parameters. Trends and cause-and-effect relationships in climatic factors, groundwater and surface-water conditions, and changes in water use were investigated. Task 4 consisted of preparing this report to present the results of the hydrologic assessment.

In August 1990, a fifth technical task was added to the scope of work. Task 5 consisted of a review and evaluation of hydrogeologic data in the vicinity of Lake Brooklyn and preliminary lake-stage simulations for Lake Brooklyn and

Lake Geneva. The results of this additional task are presented in Appendices A3 and A4 of this report.

1.4 Acknowledgements

This investigation was conducted by the Departments of Civil Engineering and Environmental Engineering Sciences in cooperation with the Florida Water Resources Research Center at the University of Florida.

Appreciation is extended to SJRWMD personnel for their help and assistance in the investigation. Appreciation is also extended to Clay County personnel and numerous local residents who provided valuable data and information about the study area.

2.0 REGIONAL SETTING

2.1 Physiography

The UECB lies between 29° 37′ and 29° 53′ north latitude and 81° 51′and 82° 04′ west longitude (Yobbi and Chappel 1979). The basin includes parts of Alachua, Bradford, Clay, and Putnam counties and has an area of 172 square miles (see Figure 2.1). It is located in the physiographic division of Florida known as the Northern Highlands (Puri and Vernon 1964). Prominent features of the basin's topography include high sand hills in the northwestern part of the area and a large depression, the Florahome Valley, in the eastern part of the area. Elevations range from above 150 feet, National Geodetic Vertical Datum of 1929 (ft, NGVD, formerly called mean sea level) to below 100 ft, NGVD, in the Florahome Valley. Numerous solution depressions occur throughout the area, and the lakes in the area have developed within these depressions.

2.2 Water-Management Problems

Rainfall and lake-levels in the UECB have fluctuated over the years. For example, the period from 1942 to 1974 is well-documented by local newspaper articles as well as U.S. Geological Survey (USGS) reports and is typical of the variable wet and dry periods that have occurred. In 1942, water levels began to rise throughout the basin, and by 1948 many lakes began to flood. A dry period from 1954 to 1957 caused many lakes to decline to their lowest recorded levels. The stage of Lake Brooklyn dropped by 20 feet, while Pebble Lake experienced a 32-foot decline from 1948 to 1956 (Clark et al. 1963). By contrast, in 1973 and 1974, many lakes recorded their highest levels of record. Halfmoon Lake flooded State Routes 26 and 100, and lake levels on Lakes Brooklyn and Geneva almost reached the tops of the boat docks on these lakes.

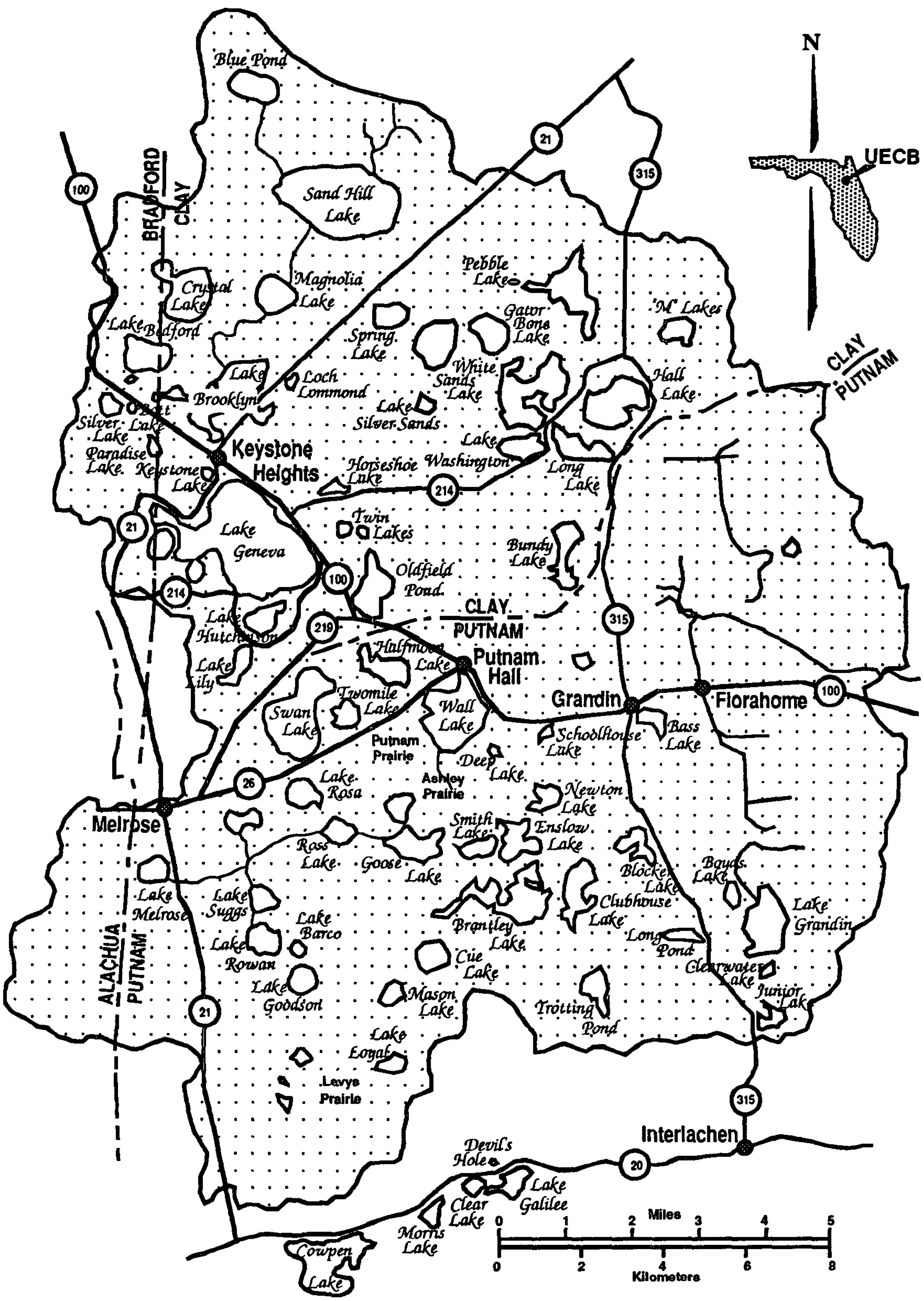


Figure 2.1 - Upper Etonia Creek drainage basin.
(Source: Yobbi and Chappell, 1979)

Man-made changes also have affected the lakes. A culvert from the ten-foot higher waters of Lake Brooklyn was installed to raise the level of Lake Geneva. When lake levels in Lake Geneva began to rise from excess rainfall, an outlet from Lake Geneva to Old Field Pond was enlarged. Although property owners around the pond successfully sued the City of Keystone Heights to reduce the inflow to the pond, the outlet remained enlarged. In 1966, Clay County enlarged the outlet from Old Field Pond to relieve the flooding problem in the pond, but this in turn caused flooding in Halfmoon Lake. In 1973, a court order mandated a maximum elevation of 105 ft, NGVD, for Lake Geneva, which affected downstream water levels. In another instance, outflow from Magnolia Lake was stopped by a court order, but this reduced downstream flow to Lake Brooklyn, Lake Geneva, Old Field Pond, and Halfmoon Lake. A summary of these changes is presented in Table 2.1.

2.3 Climate

The climate in the UECB is classified as humid subtropical (Yobbi and Chappel 1979). The basin lies in a zone of transition between the humid temperate climate of the southeastern U.S. and the tropical climate of the lower latitudes.

2.3.1 Precipitation

Annual rainfall in the UECB ranges approximately from 52 to 53.5 inches/year, based on the 1951-1980 period of record (see Figure 2.2). Rainfall varies seasonally, with June through September considered the wet season and October through May the dry season (see Figure 2.3). Statewide, rainfall varies considerably from year to year (Fernald and Patton, eds. 1984). Wetter periods for the state occurred in 1953-1954, 1957-1960, 1963-1965, and 1969-1970, but many stations have reported higher rainfalls in other years as well. Drier periods

Table 2.1. History of Early Water-Level Changes in the Upper Etonia Creek Basin.

Date	Event
2/20/48	Water began rising in 1942. Crystal Lake residents flooded in 1948. Crystal Lake has risen 15 feet since 1942. "It seems that some years ago when Lake Geneva at Keystone Heights was low, a culvert from the 10-foot higher waters of Lake Brooklyn was cut to fill Lake Geneva. But when Lake Geneva began to suffer from excess rain like the other lakes in the region, it was decided to increase the size of an outlet leading to Old Field Pond." Pond owners successfully sued the City of Keystone Heights but the outlet remained wider.
1961	Lake Brooklyn stage fell by 20 feet from 1954-1957.
1961	Pebble Lake had a 32-foot range from 1948-56.
11/24/66	Flood waters threaten Halfmoon Lake. Problem began when Clay County deepened and widened the outlet from Old Field Pond to relieve their flooding problem. The problem began six months earlier when residents of Lake Geneva were successful in getting permission to deepen and widen an outlet into Old Field pond in order to relieve their high water problem.
7/21/73	Rising lake levels pose problems to residents in the area. The most serious flooding problem is Halfmoon Lake.
7/21/73	Water levels almost to top of docks on Lakes Brooklyn and Geneva.
8/ 3/73	Flooding on Halfmoon Lake affecting SR's 100 and 26. Flooding of Putnam Hall
8/ 4/73	Court order mandates an elevation of 105 ft, NGVD, for Lake Geneva. This intensifies the downstream flooding problem.
9/13/73	"The state has also cut off the water flow from Magnolia Lake which feeds into Brooklyn, Lake Geneva, Old Field Pond and then into Halfmoon. They expect the water to rise about two or three feet in Magnolia but will not be of any danger to anyone in that area."

Sources: News clippings of Virginia Jordan and Florence Hutson, and Clark et al. (1964).

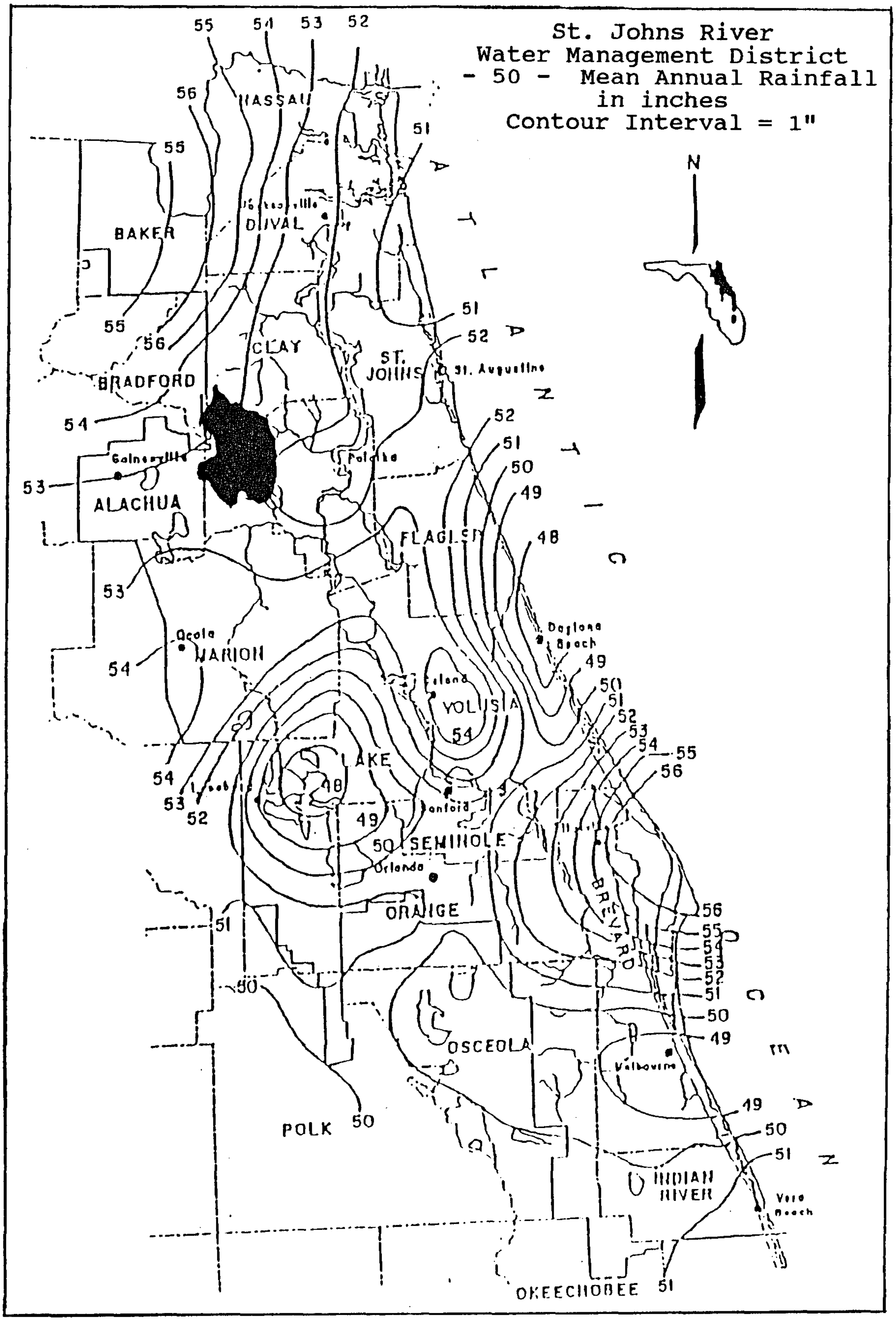


Figure 2.2 - Mean annual rainfall in St. Johns River Water Management District. (Source: Rao et al, 1984)

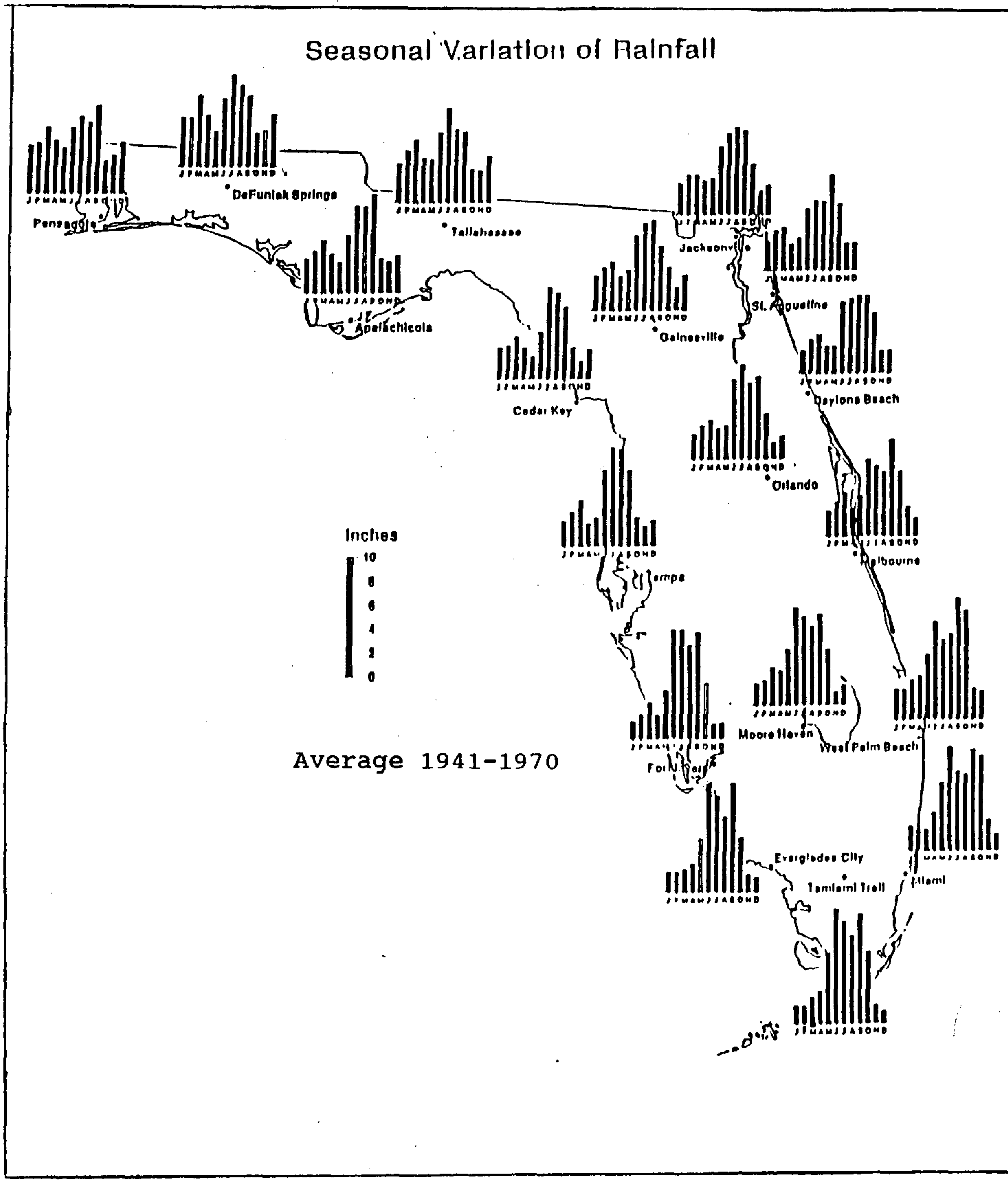


Figure 2.3 - Monthly variation of rainfall in state of Florida. (Source: Fernald and Patton, Eds., 1984)

occurred during 1954-1956, 1961-1962, and 1970-1971, but many stations reported lower values during other years.

Maximum rainfall for twelve consecutive months has been less in the UECB than in most of the remainder of the state, but the basin also has had a higher minimum rainfall over twelve consecutive months than most of the remainder of Florida, especially Putnam County. The maximum recorded monthly rainfall has ranged from 14.5 inches in September 1951 at Palatka, which is immediately east of the UECB, to 42.3 inches at Fort Lauderdale in October 1965 (Fernald and Patton, eds. 1984).

2.3.2 Evapotranspiration

Evapotranspiration is the process whereby water is returned to the atmosphere as vapor through direct evaporation and through transpiration by plants. The annual evapotranspiration loss in north-central Florida ranges from 40 to 44 inches/year. Annual lake evaporation is approximately 45 inches/year, and the mean pan evaporation rate is about 65 inches/year (Fernald and Patton, eds. 1984).

2.4 Lakes

2.4.1 Florida lakes

Florida has more than 7,800 lakes, of which approximately 3,500 are named (Fernald and Patton, eds. 1984). Many of the lakes are between 7 and 20 feet deep. The surface areas of these lakes range from approximately 1 acre to more than 10,000 acres (see Figure 2.4). The largest lake in the state, Lake Okeechobee, has a surface area of 436,000 acres. Nearly all lakes in Florida are formed naturally, and many of the lakes are formed over long-term geologic time by percolating surface water or groundwater dissolving subsurface limestone, causing a cavity to collapse and form a sinkhole. Two types of lakes are predominately

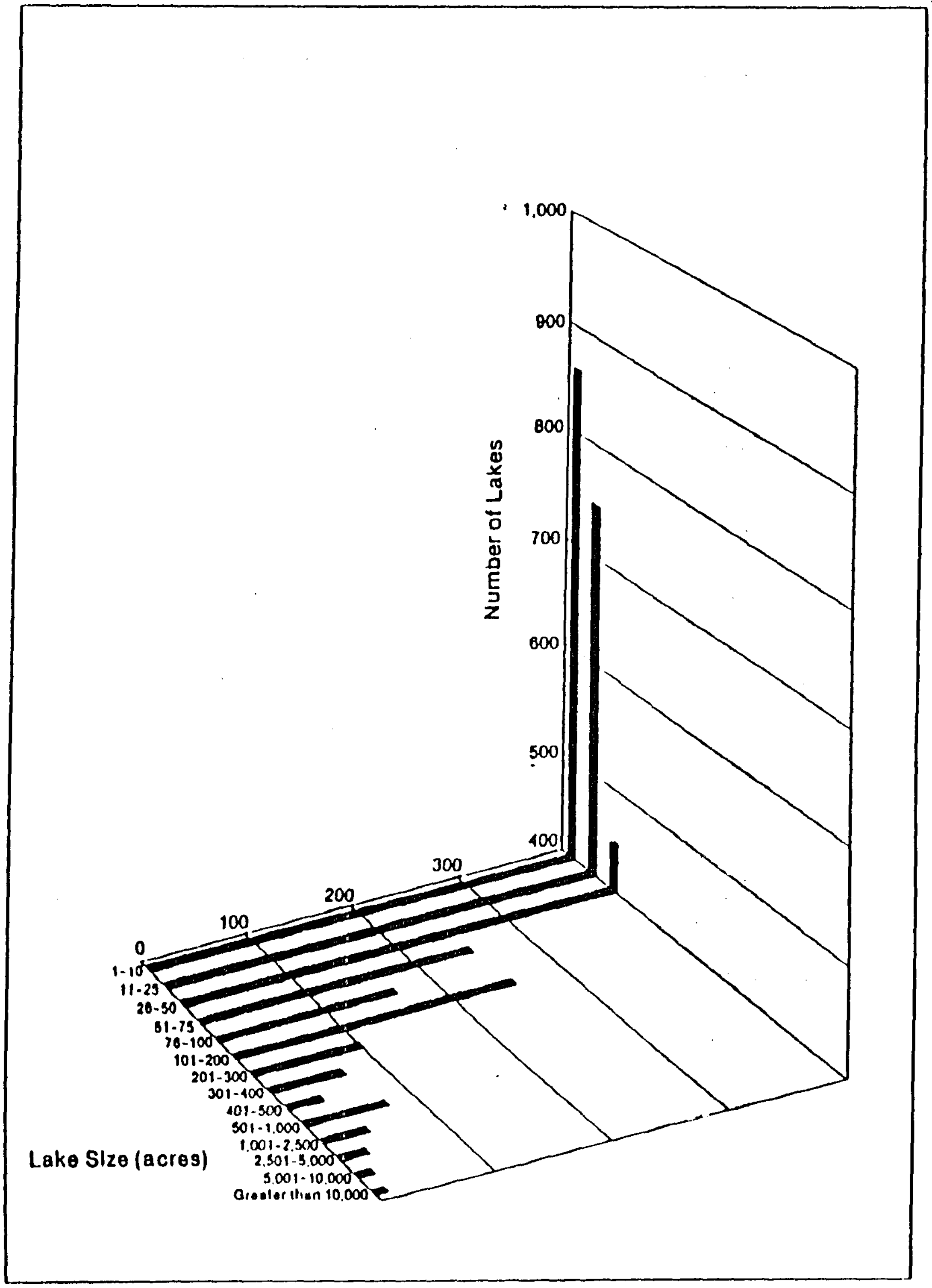


Figure 2.4 - Size distribution of named Florida lakes. (Source: Fernald and Patton, Eds., 1984)

found in Florida: those which are circular with a conical cross-section, and those which form from rapid erosion of the valley floor. The latter form an elongated, branching lake once the sinkhole has been plugged by deposition of sediments.

Generally, the hydrologic system of a lake involves four factors that make up the water budget of the lake. These factors are precipitation, evaporation, surface-water inflow and outflow, and exchange between the lake and the ground-water system. The main source of water for Florida lakes is groundwater seepage, and fluctuations in these lakes are dominated by changes in the water table (Fernald and Patton, eds. 1984).

Lake levels vary between wet and dry cycles. Some lake levels vary by only several feet over their entire period of record, while others vary by 30 feet or more. Eighty percent of Florida lakes have varied by 5 feet or less, while fewer than 5 percent have varied by more than 20 feet (Hughes 1974) (see Figure 2.5).

2.4.2 Lakes of the UECB

Lakes in the UECB included in this investigation are Blue Pond, Brooklyn, Crystal, Gator Bone, Geneva, Hall, Big and Little Johnson, Keystone, Magnolia, Pebble, Sand Hill, Silver, Smith, Swan, and White Sands. The basin contains more than 100 named or unnamed lakes, and the surface areas of most of the lakes are less than 200 acres (see Table 2.2). A chain of eight interconnected lakes forms part of the Etonia Creek drainage basin. In this chain, flow occurs from Blue Pond downstream to Sand Hill Lake, Magnolia Lake, Brooklyn Lake, Lake Keystone, Lake Geneva, Oldfield Pond, Halfmoon Lake, and then to Putnam Prairie (see Figure 2.6). The lakes are connected by perennial or intermittent streams. Stream-bed profile elevations range from more than 170 ft, NGVD, at Blue Pond to approximately 90 ft, NGVD, at the inlet to Putnam Prairie (Yobbi and Chappel 1979)(see Figure 2.7). Kingsley Lake, located outside the UECB approximately 5 miles north of Blue Pond, also was included in the investigation.

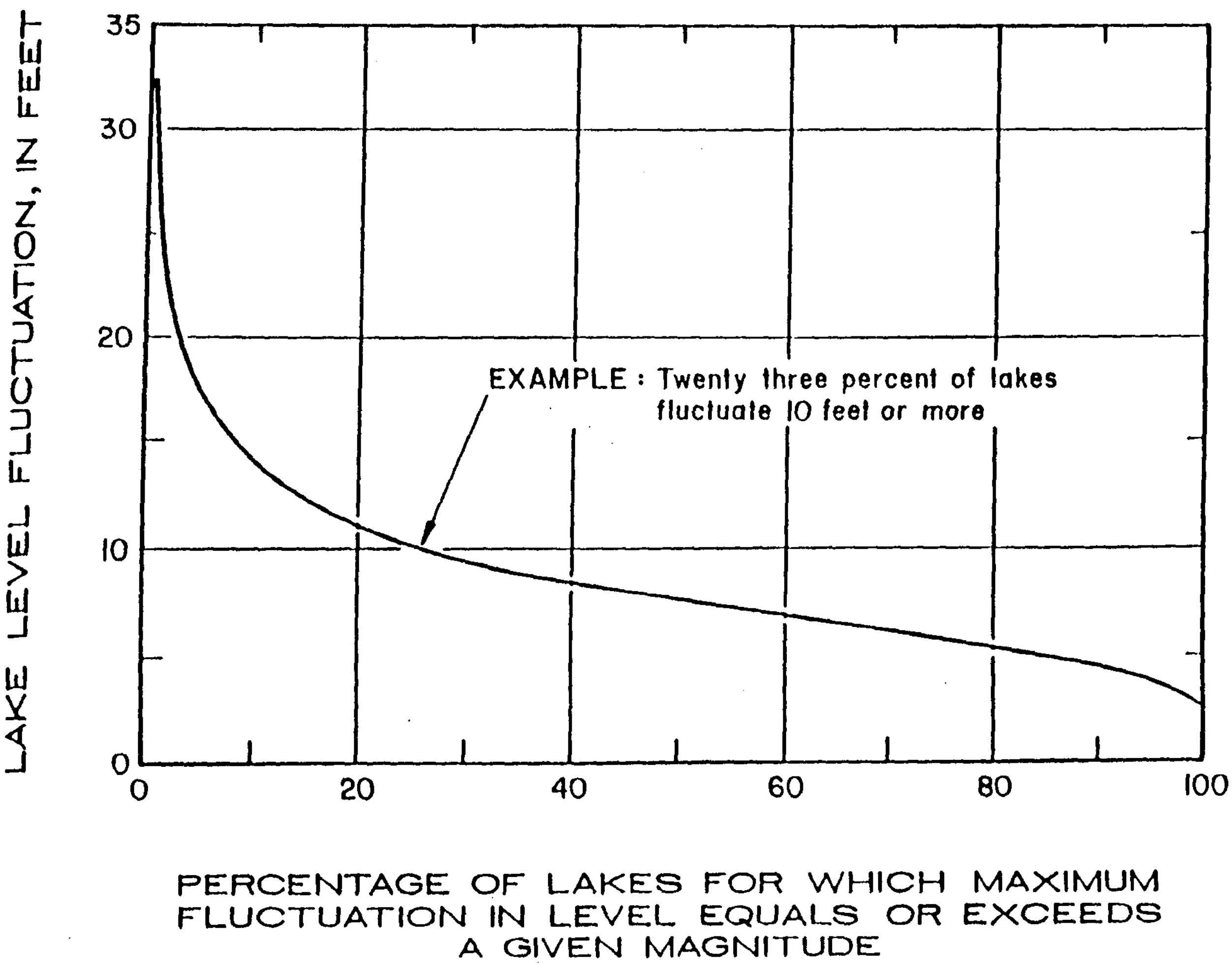


Figure 2.5 - Cumulative frequency distribution of maximum fluctuation in level of 110 lakes having stage records of 10 years or more. (Source: Hughes, 1974)

Table 2.2. General Physical Characteristics of Selected Lakes in the Upper Etonia Creek Basin.

Lake	Surface area, SA (acres)	Mean depth (feet)	Maximum depth (feet)	Drainage Area, DA (acres)	DA/SA	Bathymetry
Blue Pond			40			Yes
Brooklyn	635	18.9	47	11136	17.54	Yes
Crystal						
Gator Bone						
Geneva	1746	13.6		22720	13.01	
Johnson, Big	441			4077	9.24	
Johnson, Little	34.6					
Keystone						
Kingsley	1627	24.2	85	4378	2.69	Yes
Magnolia	201	26.5	47	9216	45.85	Yes
Pebble	9.5			122	12.80	
Sand Hill	1250	15.9	30	7040	5.63	Yes
Smith		24.2				
Swan	560					
White Sands		24.2				

References: Bentley (1977) and Yobbi and Chappel (1979).

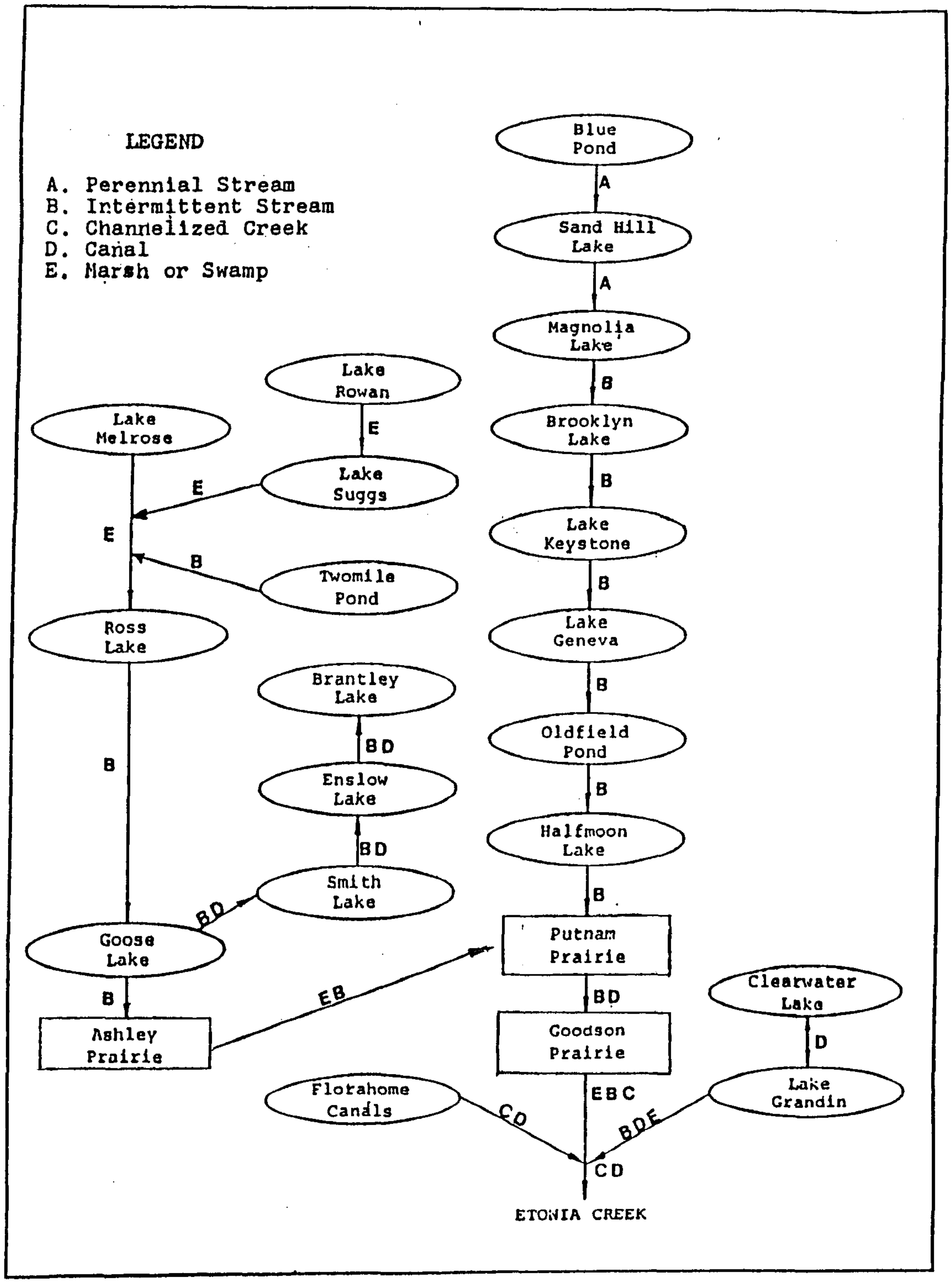


Figure 2.6 - Schematic of Upper Etonia Creek drainage network. (Source: Yobbi and Chappell, 1979)

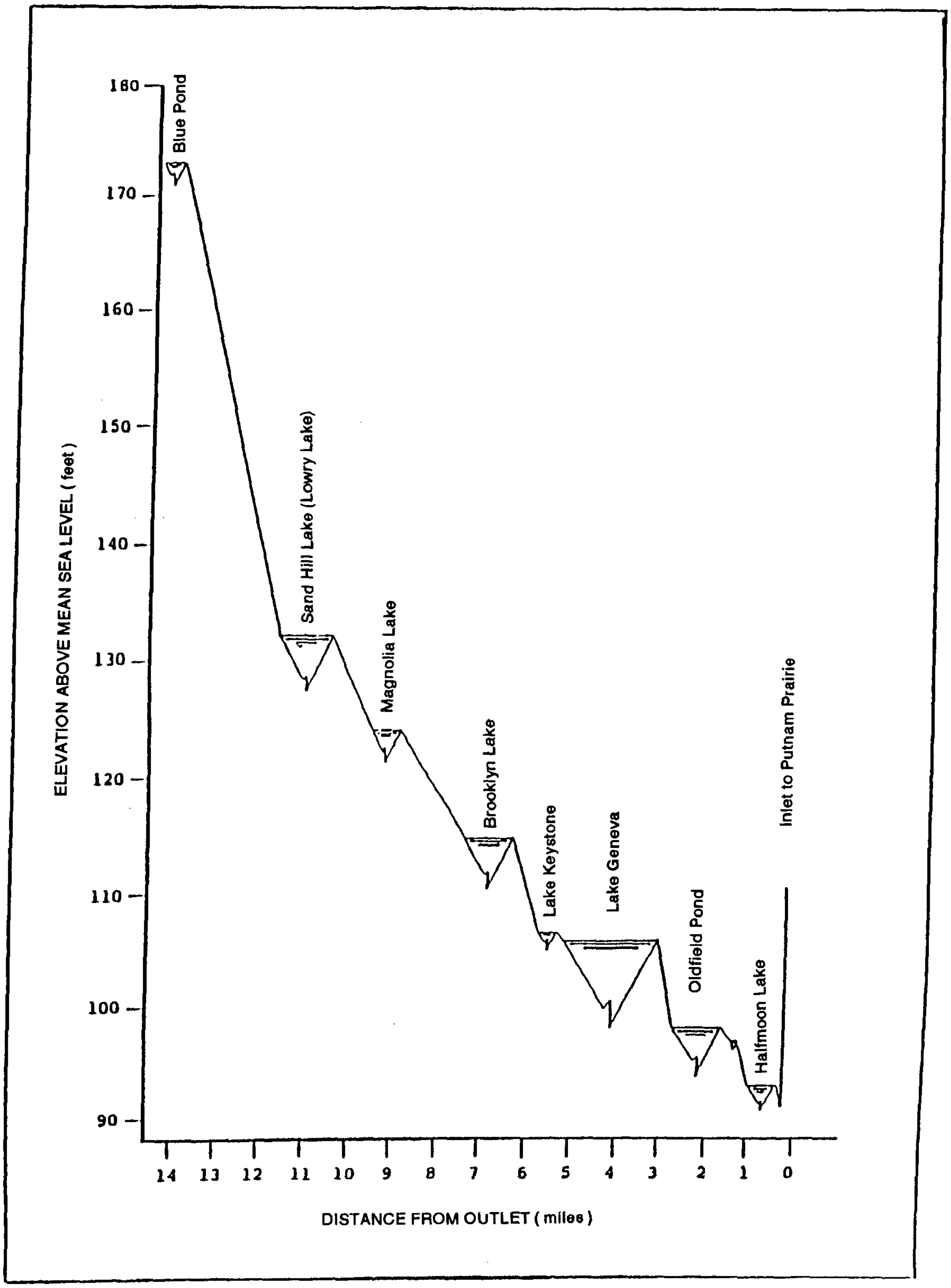


Figure 2.7 - Stream bed profile from Blue Pond to Putnam Prairie. (Source: Yobbi and Chappell, 1979)

The general physical characteristics of the UECB lakes are presented in Table 2.2. The sizes of the lakes vary greatly with a range from 10 acres (Pebble Lake) to 1746 acres (Lake Geneva). The mean depths of these lakes range from 13.6 feet (Geneva) to 26.5 feet (Magnolia). Maximum depths range from 30 feet (Sand Hill) to 85 feet (Kingsley). The ratio of drainage area to surface area shown in Table 2.2 gives a measure of the relative importance of surface runoff. These ratios range from a low of 5.63 acres of drainage area per acre of lake area for Sand Hill Lake to a high of 43.85 for Magnolia Lake.

Bathymetric information is available for five of the lakes, i.e., Blue Pond, Brooklyn, Kingsley, Magnolia, and Sand Hill. Blue Pond is elliptical in shape with relatively regular contours (see Figure 2.8). Brooklyn Lake, on the other hand, has a very irregular geometry with numerous bays and low points (see Figure 2.9). These numerous low areas may be indicative of direct connections to the lower aquifers (Lee 1990). Due to its irregular geometry and bathymetry, Lake Brooklyn divides into disconnected ponds at low elevations as shown in Figure 2.10, in which the lake is divided into ten ponds. Kingsley Lake is almost a perfect circular bowl in its geometry as shown in Figure 2.11. Magnolia Lake also has a similar circular perimeter and bowl-like bottom (see Figure 2.12). Sand Hill Lake is elliptical in shape, similar to Blue Pond (see Figure 2.13).

2.5 Hydrogeology

The UECB is underlain by several hundred feet of unconsolidated to semi-consolidated marine and non-marine deposits of sand, clay, marl, gravel, limestone, dolomite, and dolomitic limestone (Clark et al. 1964). These formations range in age from Eocene to Recent. These formations are, in ascending order, the Oldsmar, Lake City, Avon Park, and Ocala limestones of Eocene age, the

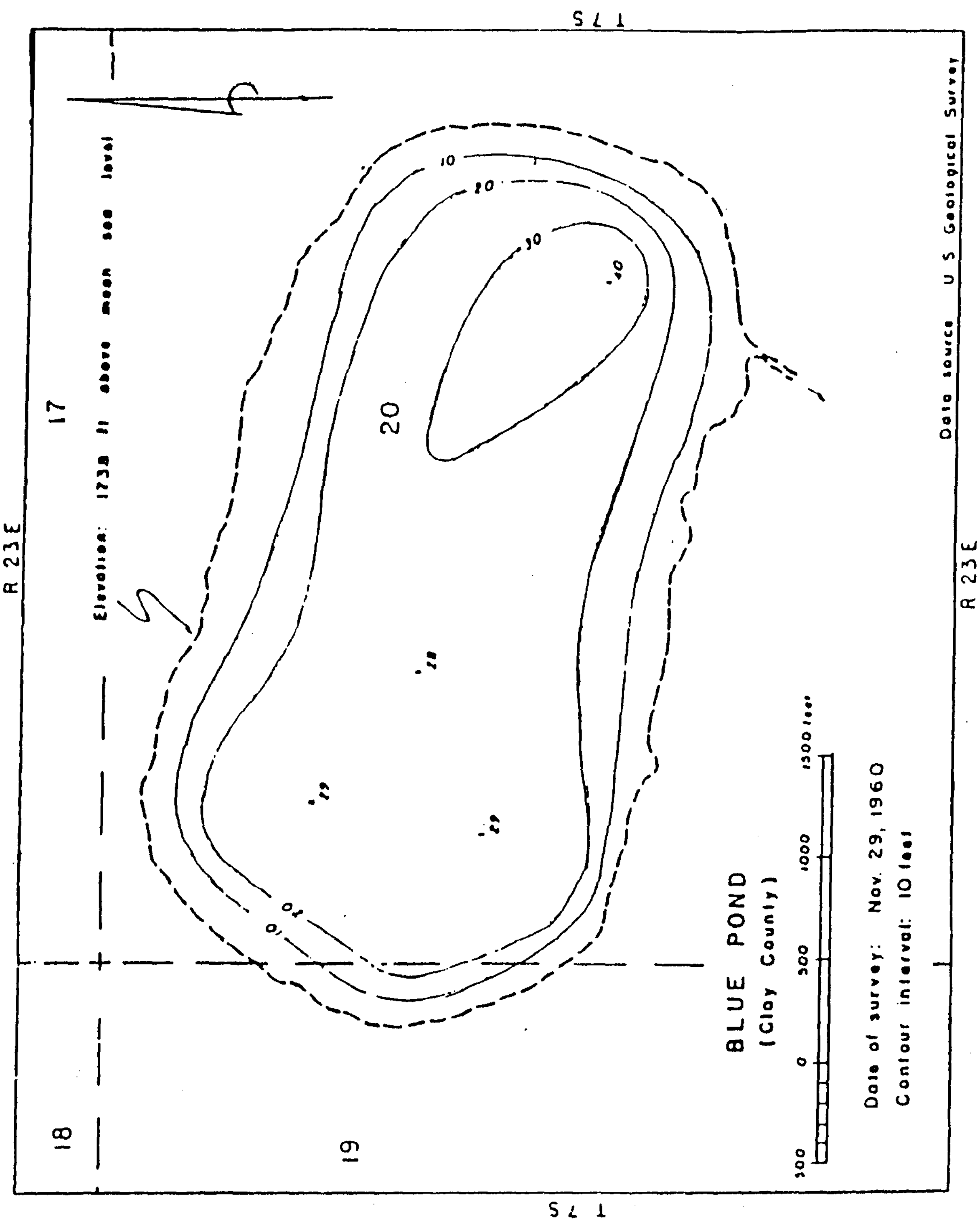


Figure 2.8 - Depth contours of Blue Pond.
(Source: Clark et al., 1963)

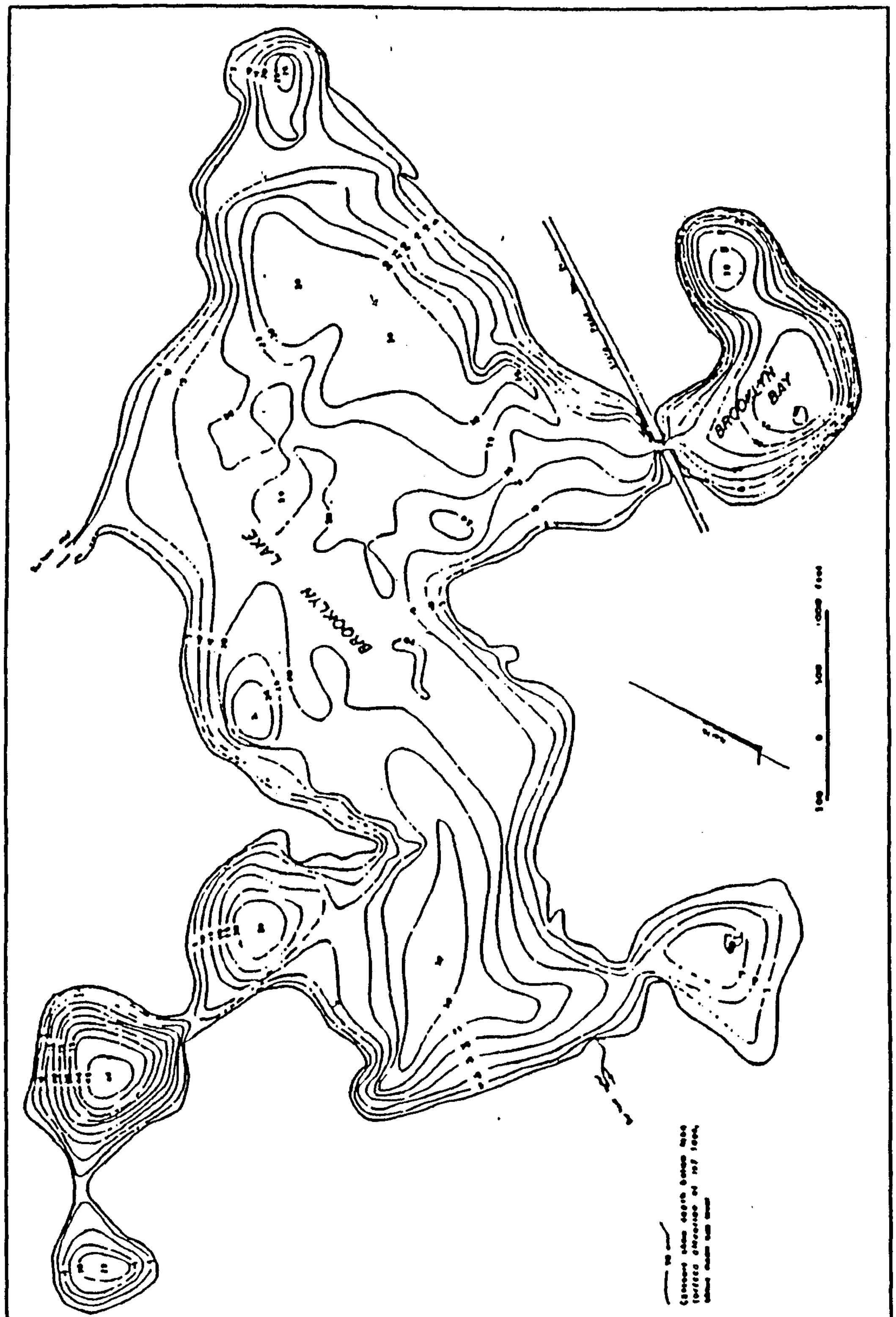


Figure 2.9 - Depth contours of Brooklyn Lake at 117 feet, NGVD. (Source: Clark et al., 1963)

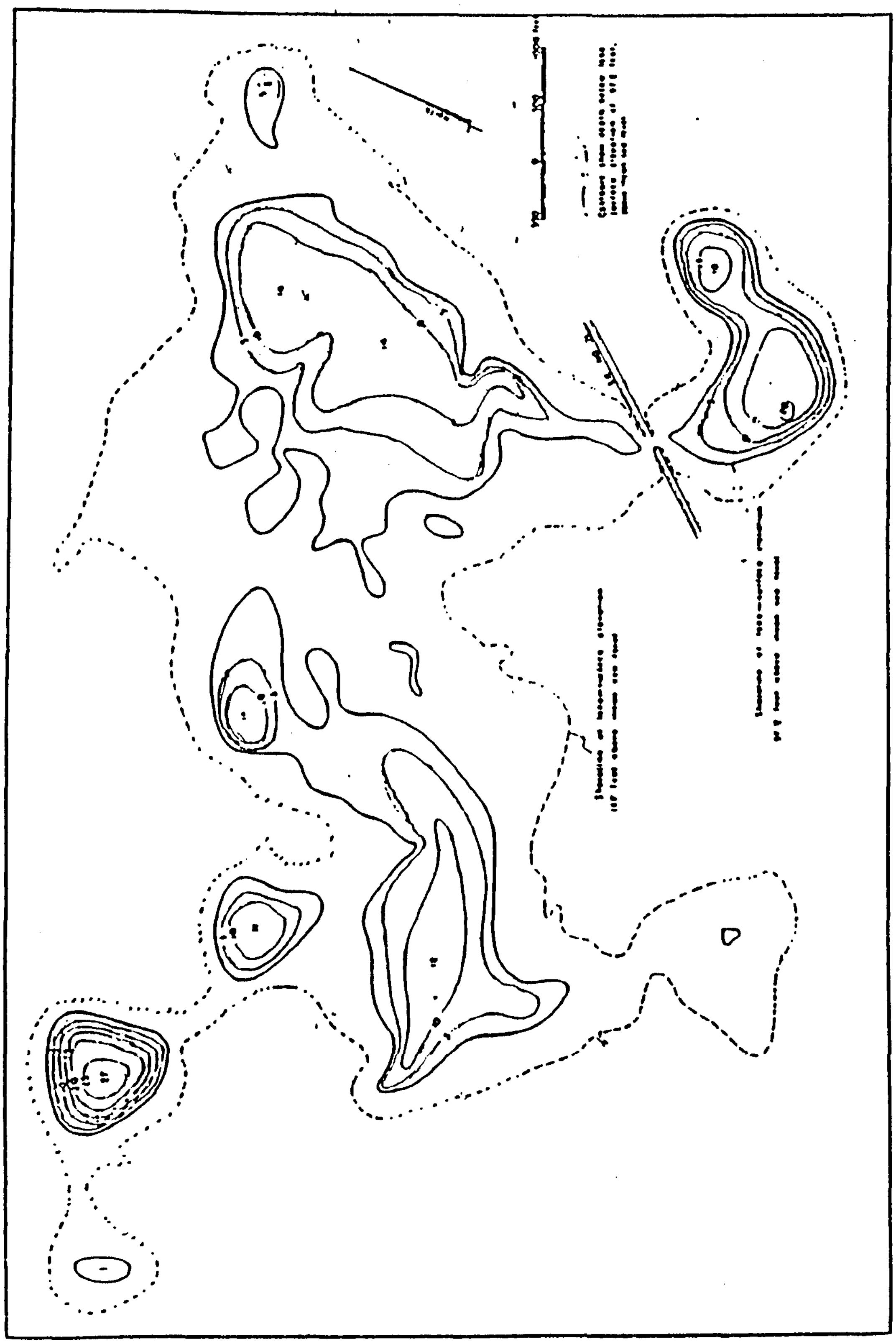
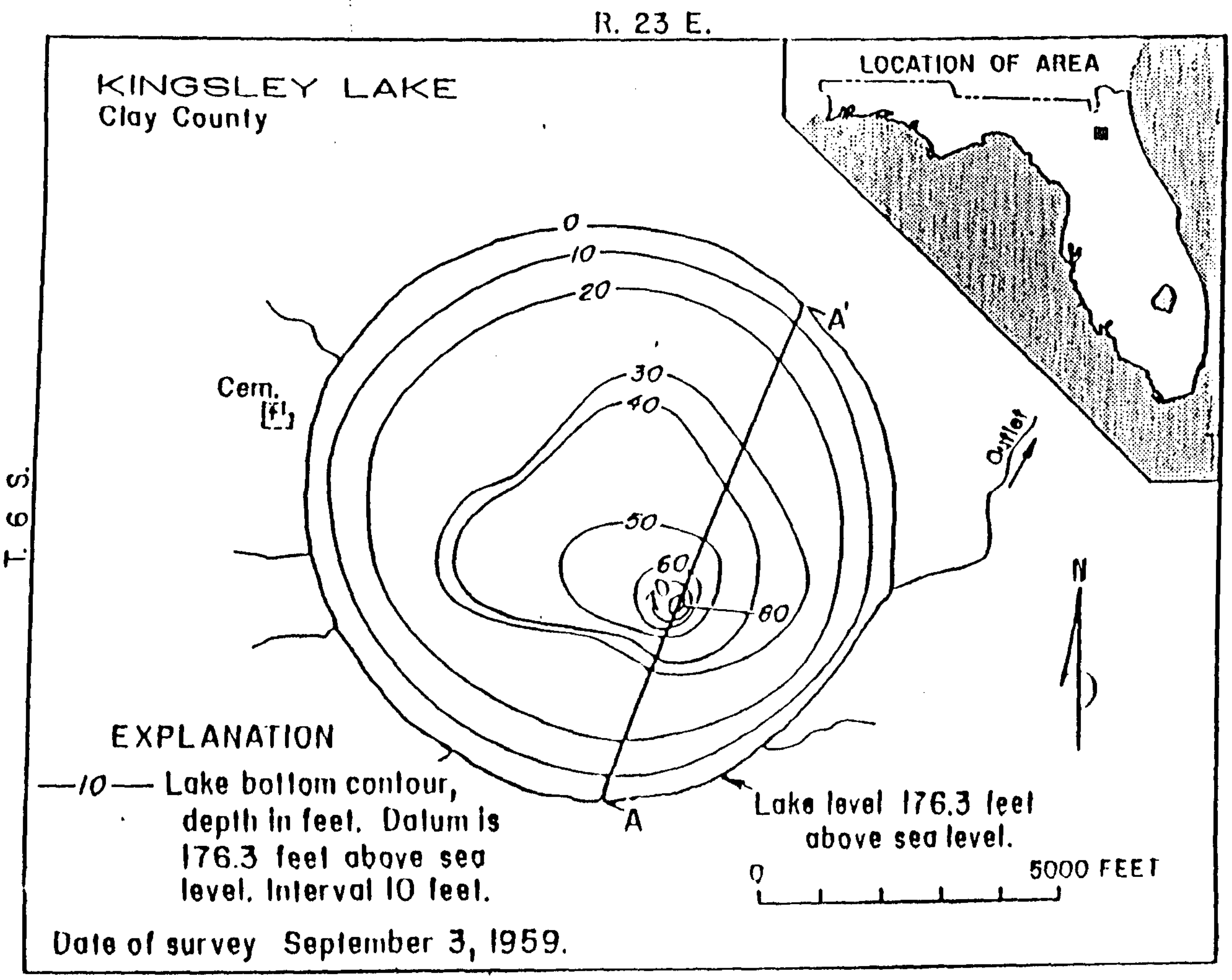


Figure 2.10 - Depth contours of Brooklyn Lake at 97.2 feet, NGVD. (Source: Clark et al., 1963)



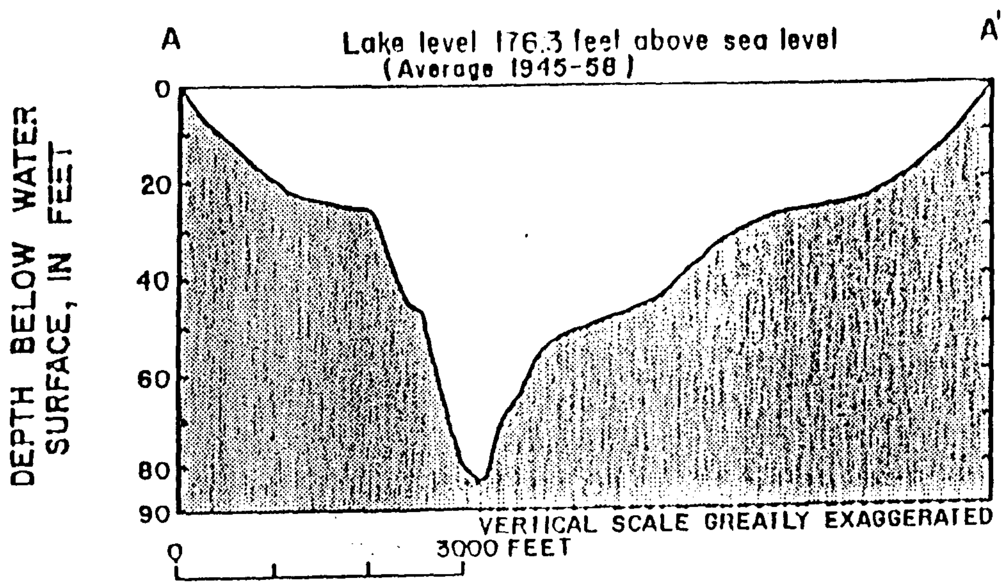


Figure 2.11 - Depth contours and cross section of Kingsley Lake. (Source: Clark et al., 1963)

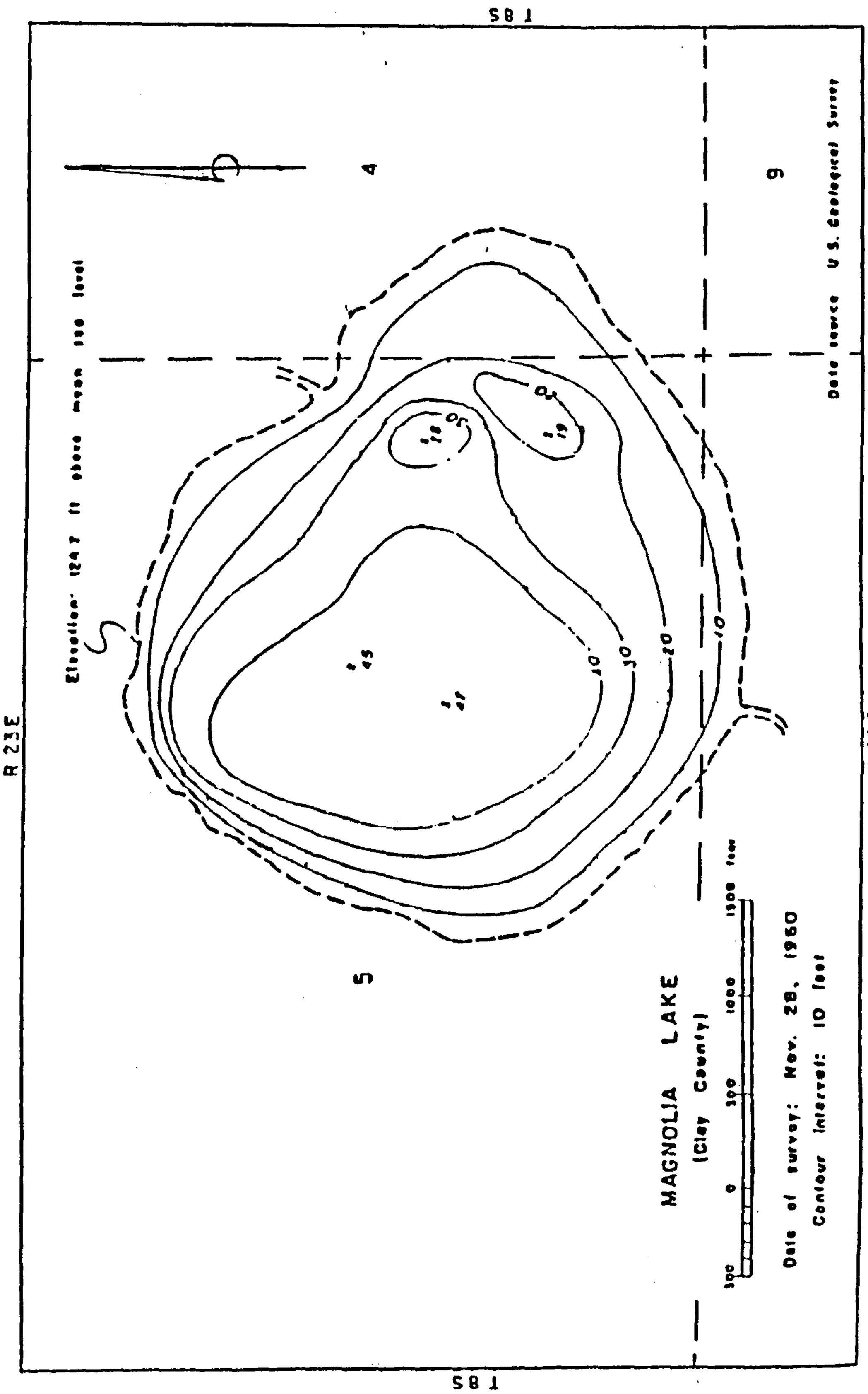


Figure 2.12 - Depth contours of Magnolia Lake.
(Source: Clark et al., 1963)

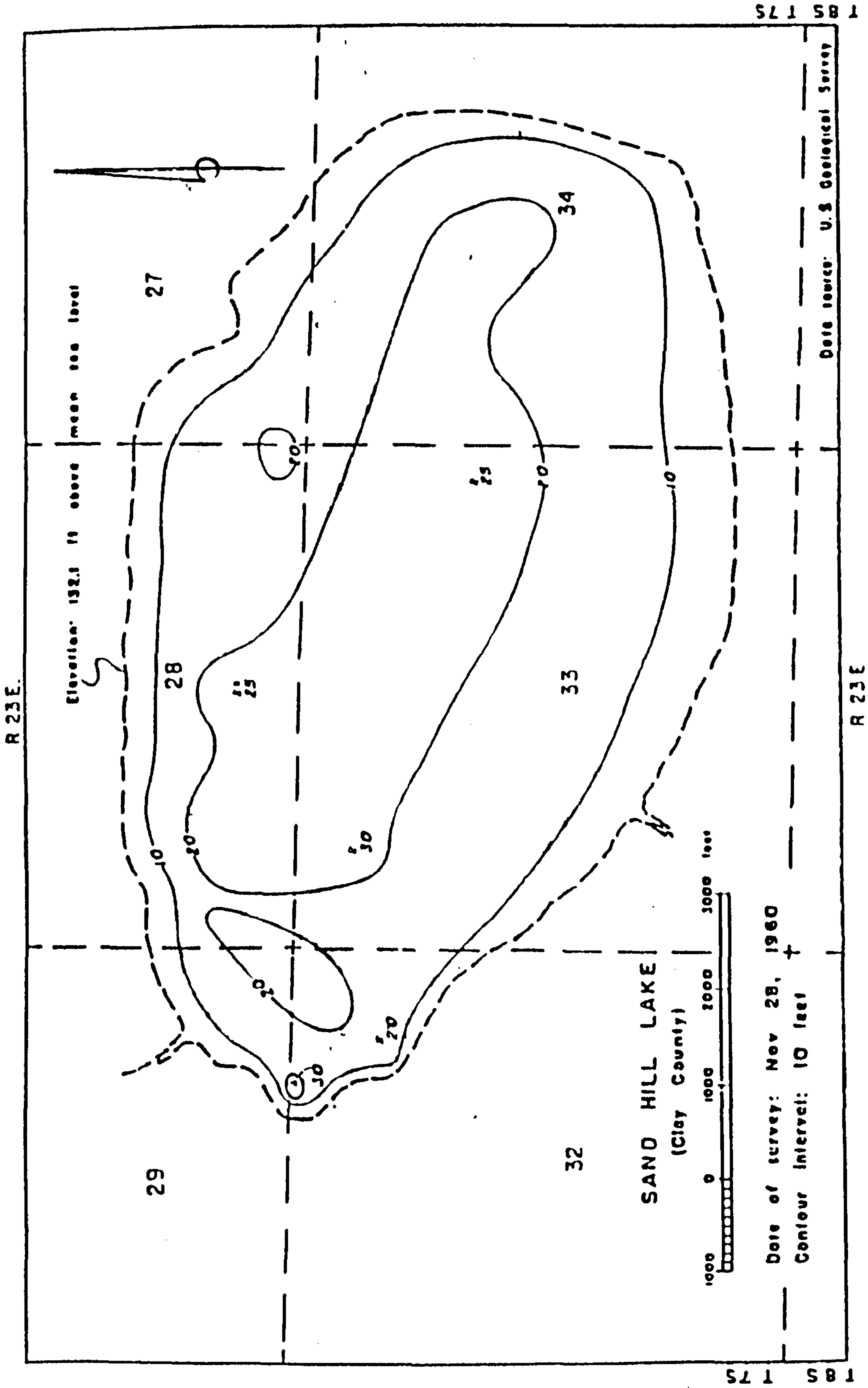


Figure 2.13 - Depth contours of Sand Hill Lake.
(Source: Clark et al., 1963)

Hawthorn and Choctawhatchee formations of Miocene age, and sediments and deposits of Pleistocene and Recent ages. The Lake City Limestone is the oldest and deepest formation in the region that supplies fresh water to wells. The top of the formation occurs at approximately -380 to -440 ft, NGVD, at Gainesville, at approximately -600 ft, NGVD, beneath the crest of Trail Ridge at Kingsley Lake, and approximately -700 ft, NGVD, at Green Cove Springs. The Avon Park Limestone overlies the Lake City Limestone, and its thickness ranges from 100 feet in southwestern Alachua County to more than 200 feet in other parts of the area. The thickness of the Ocala Limestone ranges from 200 to 250 feet, and its surface is a highly irregular karst plain. The approximate elevation of the top of the Ocala Limestone ranges from +25 ft, NGVD, in the southwestern part of the UECB to -100 ft, NGVD, in the eastern part of the basin (see Figure 2.14).

The Hawthorn Formation is comprised of clay, sandy clay, and discontinuous lenses of limestone and sandy limestone. Phosphatic pebbles occur throughout the formation. Its thickness ranges from 100 to 150 feet, and it generally thickens from southwest to northeast across the basin. The Choctawhatchee Formation has a maximum thickness of 40 feet, and it consists of a shell marl that overlies the Hawthorn Formation. The surficial sands and sediments ranging from Pleistocene to Recent ages include marine and estuarine terrace deposits and coarse clastics. These surficial deposits consist of sands, sandy clays, and some quartz gravel; they underlie the entire UECB and vary in thickness from 90 to less than 20 feet.

These geologic units form a hydrologic system comprised of the surficial aquifer system, the intermediate aquifer system and confining unit, and the Floridan aquifer system [Southeastern Geological Society (SEGS), 1986]. The Pleistocene- to Recent-age deposits comprise the surficial aquifer system. In the vicinity of Keystone Heights, the limestones of the Choctawhatchee Formation are part of the surficial aquifer system (Clark et al. 1964). This aquifer

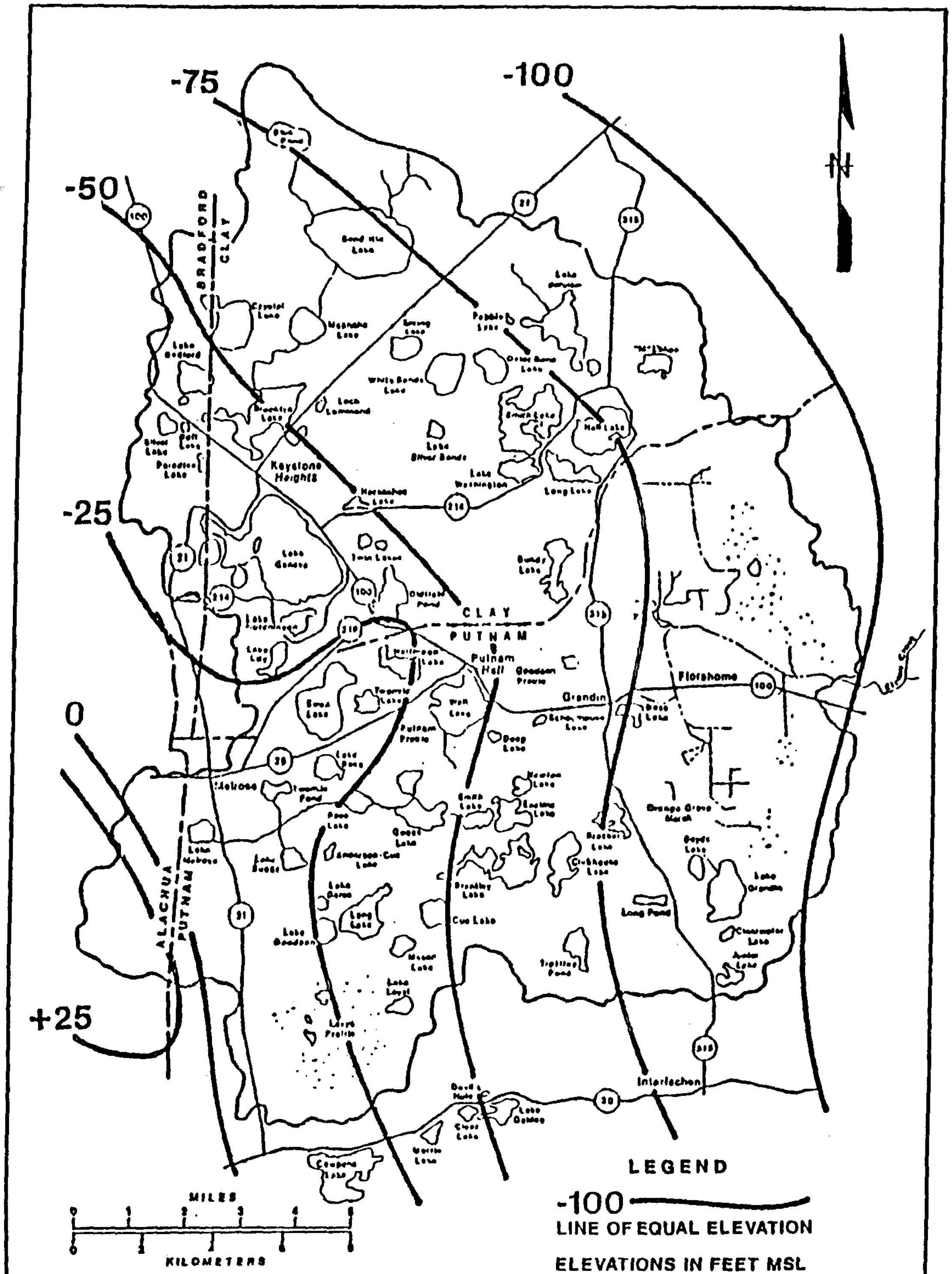


Figure 2.14 - Elevation of the top of the Ocala limestone in the UECB (Source: Yobbi and Chappell, 1979)

system is an unconfined aquifer under water-table conditions. Its thickness ranges from 50 to 130 feet in the UECB, and the water table generally conforms to the topography, but with reduced relief. The water-table elevation ranges approximately from 70 to 175 ft, NGVD. Recharge to the surficial aquifer occurs primarily due to infiltration of rainfall, and discharge occurs by means of evapotranspiration, seepage into lakes, downward leakage to the intermediate and Floridan aquifer systems, and pumping from shallow wells.

Limestone and sand layers in the Hawthorn Formation comprise the intermediate aquifer system (Clark et al. 1964). Limestone layers and shell beds in the Choctawhatchee Formation are also part of this system, except in the Keystone Heights area. Less permeable layers of clay in the Hawthorn Formation separate the water-bearing zones from each other and from the surficial and Floridan aquifer systems. The potentiometric surfaces of the intermediate aquifers generally are between the water table and the potentiometric surface of the Floridan aquifer. Water is recharged to the intermediate aquifers from the surficial aquifer system and from lakes whose bottoms intersect the Hawthorn Formation. Water in the intermediate aquifers is discharged by means of leakage to the Floridan aquifer system and by pumpage from domestic wells.

The Lake City, Avon Park, and Ocala limestones comprise the Floridan aquifer system in the UECB. Limestones in the lower part of the Hawthorn Formation are included in this system where they are hydraulically connected. The elevation of the top of the Floridan aquifer ranges from +40 ft, NGVD, in the southwestern part of the UECB to -80 ft, NGVD, in the northeastern part of the basin (see Figure 2.15). The Floridan aquifer system is confined by the overlying intermediate confining unit, and the hydraulic head in the Floridan aquifer

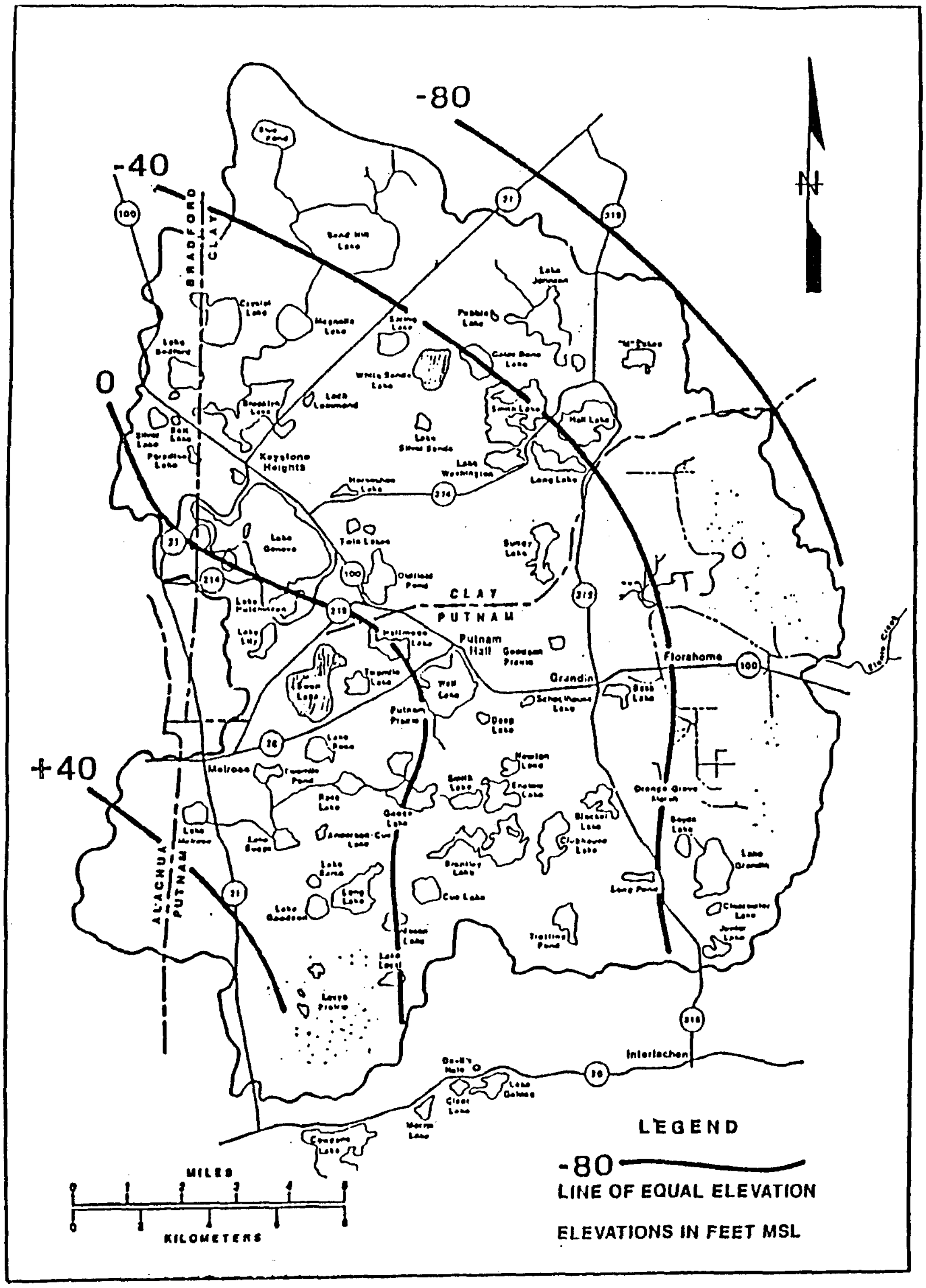


Figure 2.15 - Approximate elevation of the top of the Floridan Aquifer in the UECB. (Source: Yobbi and Chappell, 1979)

system in the UECB is on the order of +80 ft, NGVD, or more (see Figure 2.16). The UECB is a major recharge area for the Floridan aquifer system as indicated by the closed contours and potentiometric high that occur in the UECB area.

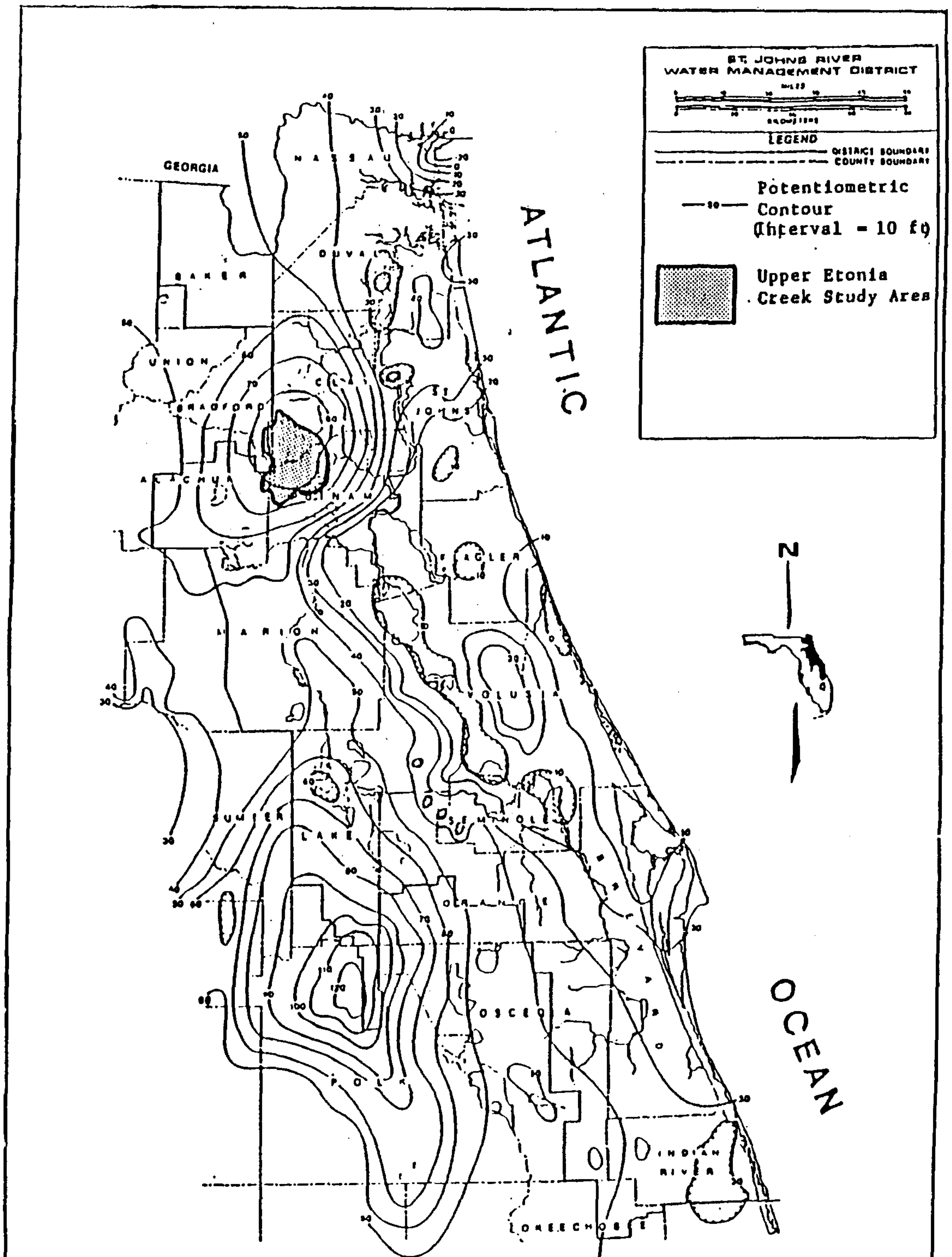


Figure 2.16 - Potentiometric surface of the Floridan Aquifer in the SJRWMD in May 1974. (Source: Yobbi and Chappell, 1979)

3.0 COMPILATION OF DATA

3.1 Availability of Data

Lake-level, precipitation, evaporation, and groundwater data were compiled from sources that included the National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center, USGS, and SJRWMD. Records were found for 13 lakes, 4 rain gages, 1 evaporation station, and 3 wells in and adjacent to the UECB (see Figure 3.1). Of the original study group of 17 lakes, no stage data were found for four lakes: Gator Bone, Keystone, Silver, and White Sands.

3.2 Precipitation

The precipitation data for Gainesville, Melrose, Palatka, and Starke were compiled to develop a rainfall record representative of the UECB. These four stations are the closest gages to the basin that have long-term records of rainfall measurements. Each station has a different period of record (see Table 3.1), and only the Gainesville gage is still in operation. The mean monthly rainfall at the four stations for their periods of record ranges from 4.38 inches per month for Melrose to 4.54 inches per month for Starke. The coefficient of variation (CV) in Table 3.1 was calculated from:

Equation 1: $CV = sd/mean$

where: CV = coefficient of variation, sd = standard deviation, and mean = average of the data.

The CV is a measure of the relative variability of the rainfall data. The CV's range from 0.69 to 0.75, indicating that the relative variability is quite similar.

The only part of the period of record for which data from all four gages are available is 1960-1969 (see Table 3.2). The statistical characteristics of

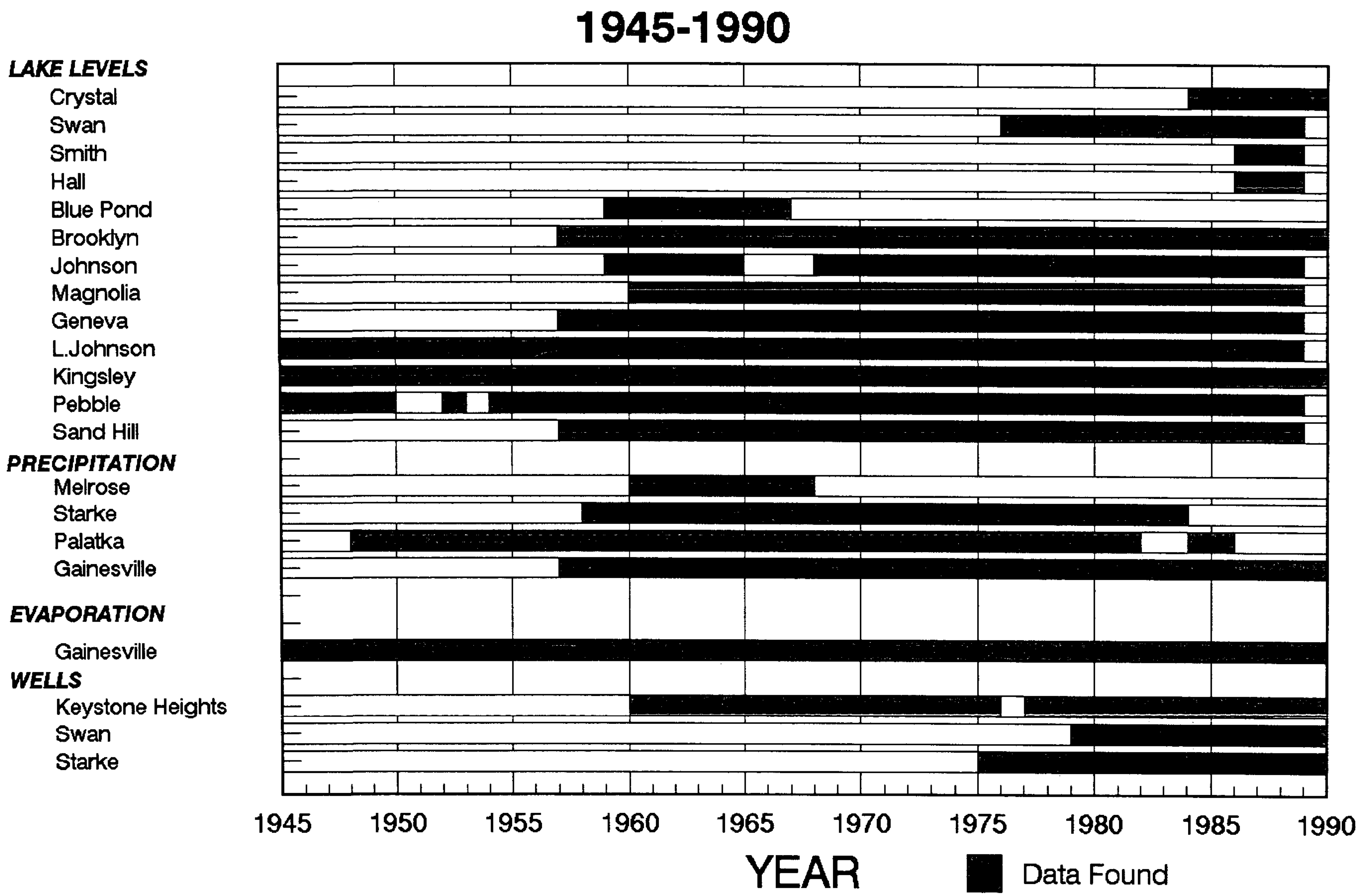


Figure 3.1 - Compilation of data for Upper Etonia Creek drainage basin: 1945-1990.

Table 3.1.

Monthly Precipitation Data.				
Rank Record Station	1 1959–1969 Melrose (in\month)	2 1958–1985 Starke (in\month)	3 1948–1986 Palatka (in\month)	4 1957–1989 Gainesville (in\month)
Max	13.06	17.21	15.57	15.74
Min	0.20	0.08	0.05	0.10
Mean	4.38	4.54	4.39	4.42
Std.dev.	3.28	3.12	3.16	3.10
C.V.	0.75	0.69	0.72	0.70
Max–Min	12.86	17.13	15.52	15.64

Table 3.2.

Rain Gage Stations.					
Year	Melrose (inches)	Starke (inches)	Palatka (inches)	Gainesville (inches)	Available Months
1960	40.06	35.58	40.20	42.58	9
1961	34.71	35.80	34.65	31.15	8
1962	26.34	32.12	26.21	27.85	7
1963	53.00	52.84	55.78	46.01	12
1964	49.76	50.41	60.00	44.99	9
1965	32.19	24.01	33.03	45.14	4
1966	13.63	13.25	14.55	16.18	2
1967	44.20	33.17	40.63	44.69	8
1968	41.15	49.60	41.01	41.92	12
1969	29.67	32.78	30.61	31.94	7
Mean	36.47	35.96	37.67	37.25	
Std.dev.	11.12	11.71	12.65	9.50	
C.V.	0.30	0.33	0.34	0.26	

these gages are similar for the 1960-1969 period, based on calculating and comparing the means, standard deviations, and coefficients of variation for each gage for this period of record (see Table 3.2). Comparison of the rainfall totals for each gage for the part of each year from 1960 to 1969 for which data were available at all stations also leads to the conclusion that the rainfall records at the four gages are similar (see Figure 3.2). The reader is cautioned that the data for this table only represent that part of the year for which records were available at all four stations. For example, only two months in the year 1966 contained data at all four stations. The overall means indicate that the total values at the four stations are very similar. Thus, it was concluded that a long-term rainfall record for the UECB could be compiled using data from the rain gage nearest the basin if these data were available or, otherwise, using data that were available from the next closest gage. This rainfall time series is referred to in this report as the Etonia rainfall.

Annual rainfall for 1900-1990 and average monthly rainfall for 1948-1989 were calculated for the UECB using this technique (see Figures 3.3 and 3.4). The mean annual precipitation for 1900-1990 is 50.74 inches/year. The wettest year was 1964 with 68.99 inches of rainfall, and the driest year was 1954 with 29.22 inches. The annual rainfall totals have varied by 39.77 inches over the 90-year period of record. The annual rainfall record was averaged using an exponential smoothing technique (see Figure 3.3). The equation used for exponential smoothing is (Carroll 1989):

Equation 2:

$$P_t = \alpha P_t + \alpha(1-\alpha)P_{t-1} + \alpha(1-\alpha)^2 P_{t-2} + \ldots$$

where P_t = precipitation in year t,

P_{t-1} = precipitation in year t-1, and

α = smoothing parameter with $0 \leq \alpha \leq 1.0$.

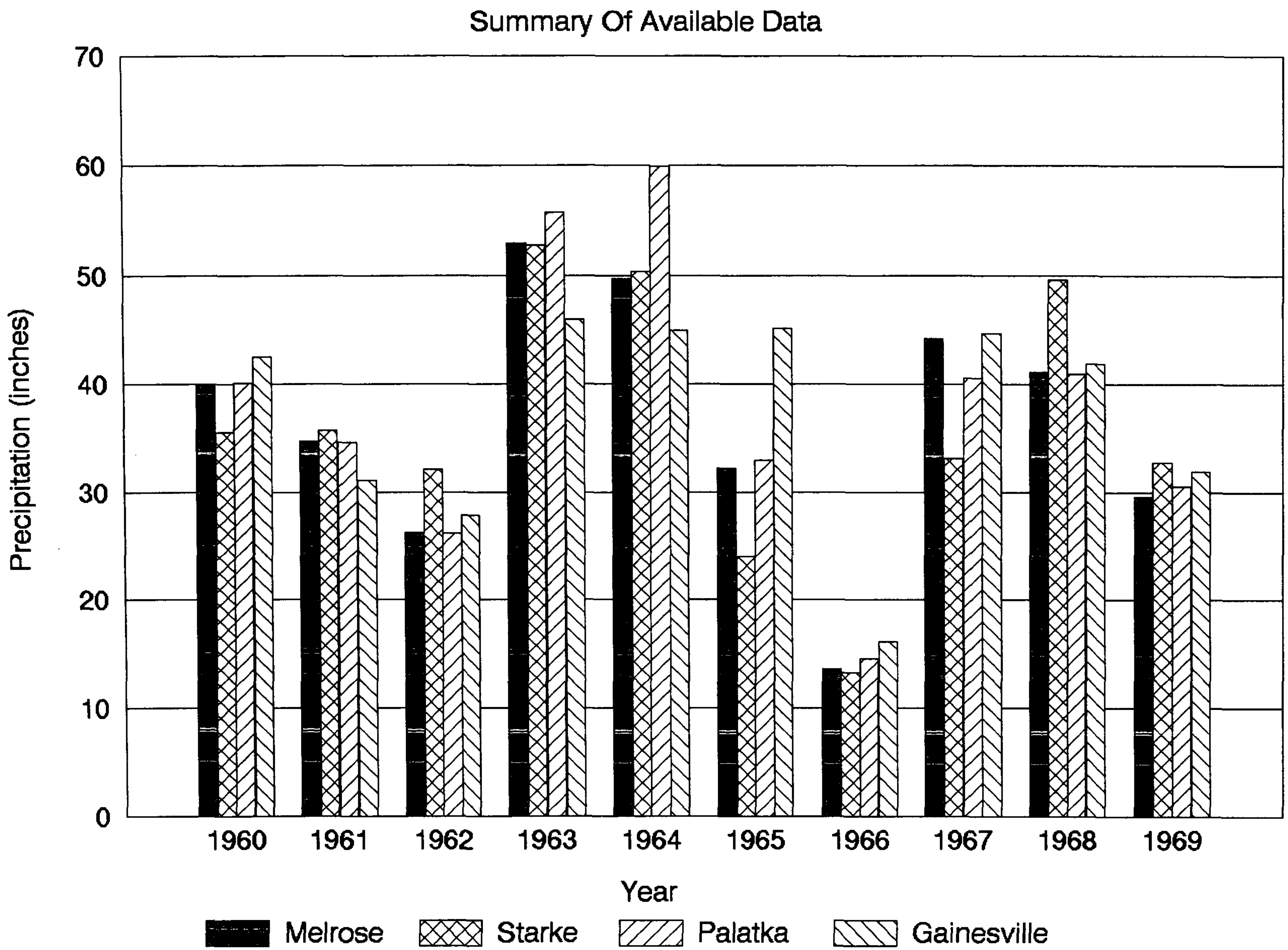


Figure 3.2 - Comparison of recorded precipitation: summary of available data.

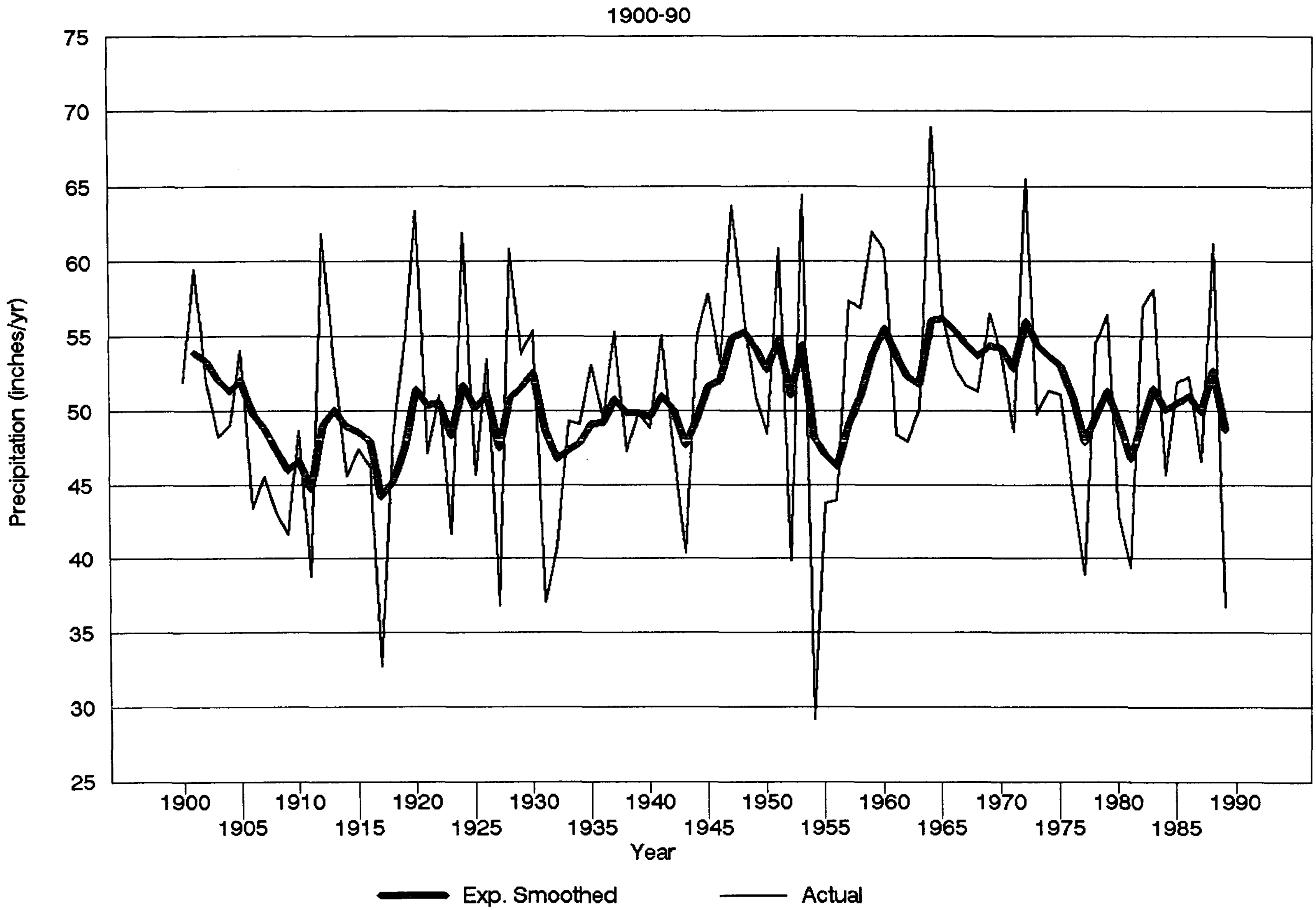


Figure 3.3 - Etonia yearly precipitation: 1900-90.

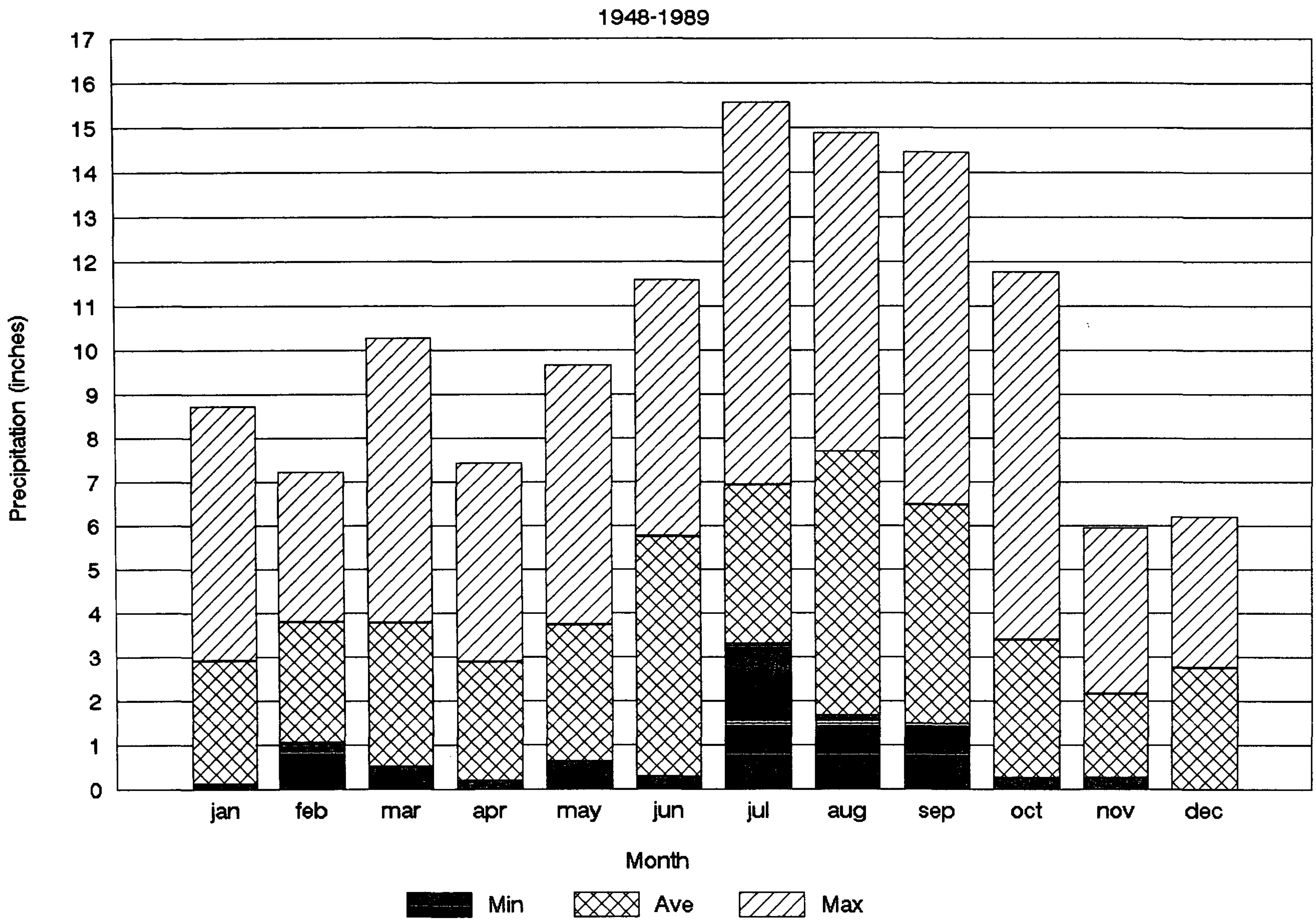


Figure 3.4 - Etonia monthly precipitation: 1948-1989.

If the smoothing parameter, α, is set equal to 1.0, then no smoothing occurs. For this case, an $\alpha = 0.25$ was used. Thus, the weights are as follows:

$$P_t = P_t/4 + 3P_{t-1}/16 + 9P_{t-2}/64 + \ldots$$

A simpler representation of equation 2 is to use the recursive form, which is very convenient for spreadsheet calculations, i.e.,

Equation 3:

$$P_t = \alpha P_t + (1-\alpha)P_{t-1}$$

The average monthly rainfall totals based on the "Etonia rainfall" (see Figure 3.4) indicate that approximately 50 percent of the annual rainfall occurs in the four-month wet season from June to September. On the average, August is the wettest month and November is the driest month. Wet and dry cycles are evident in the long-term Etonia rainfall record (see Table 3.3 and Figure 3.5). Extended dry periods occurred during the years 1906-1920, 1930-1944, and 1954-1957. Extended wet periods occurred during the years 1945-1953 and 1958-1976. Alternating dry and wet periods occurred from 1978 to 1990. The most significant cycle during the 20th century was the 19-year wet cycle that occurred from 1958 to 1976. This period corresponds to the time when many people settled in this lake region based on the perception of high lake levels.

3.3 Evaporation

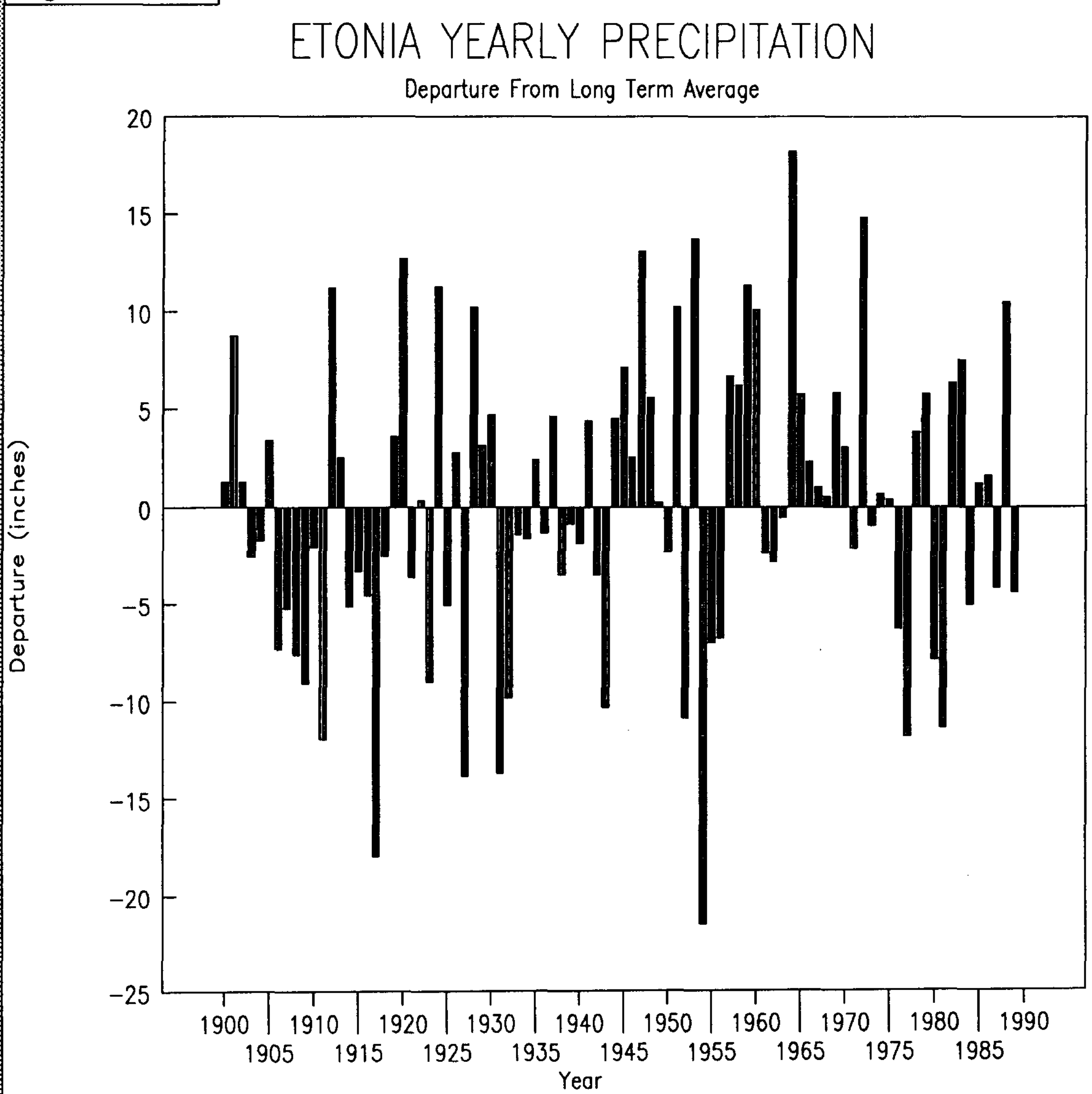
The weather station closest to the UECB that measures evaporation is Gainesville. Daily pan evaporation has been measured at this station from 1954 to the present. The mean annual evaporation at Gainesville is 61.63 inches/year,

Table 3.3.

Wet and Dry Cycles: 1900–90

Period	Years	Cycle	Average Rain (in/yr)	Average Difference (in/yr)
1906–20	15	Dry	47.64	-3.10
1930–44	15	Dry	48.92	-1.82
1945–53	9	Wet	55.09	4.35
1954–57	4	Dry	43.59	-7.15
1958–76	19	Wet	54.16	3.42
1977–90	13	Wet/Dry		
1900–90	90		50.74	

Figure 3.5.



but evaporation does vary from year to year (see Figure 3.6). The minimum evaporation of 54.48 inches per year occurred in 1983, and the maximum of 67.74 inches occurred in 1977. The six-year period from 1963 to 1968 had a relatively high rate of evaporation, and the seven-year period from 1982 to 1988 had a relatively low rate of evaporation. On the average, the five-month period from April through August has the greatest amount of evaporation during the year (see Figure 3.7). The minimum and maximum evaporation rates for March and June are relatively variable compared to the mean values for these months, while the minimum and maximum rates for January, September, and November are relatively less variable from the mean values for these months.

3.4 Lakes

Data for the 13 lakes with long-term records were compiled, and statistics for the lake stages were calculated (see Table 3.4). The periods of record for these lakes are variable, and there are gaps in the record for many of the lakes (see Figure 3.1). The lakes can be grouped based on fluctuations in stage, as discussed below.

3.4.1 Expected Variability in Stages for Florida Lakes

A summary of the lake-level ranges for the 13 lakes that have stage data is shown in Table 3.4. This updated database reveals a striking range of stages from as low as 1.70 feet for Blue Pond to 31.16 feet for Pebble Lake. The cumulative frequency distribution presented by Hughes (1974) was updated and expanded to include 121 Florida lakes. This updated lake database is included in Appendix A1. Table 3.5 shows the UECB lakes sorted by range and shows their rank among Florida lakes. Remarkably, the UECB contains the most stable lake in the state, Blue Pond, with a fluctuation of 1.70 feet, and the least stable lake, Pebble Lake, with a fluctuation of over 31 feet. Indeed, six of the twelve most stable

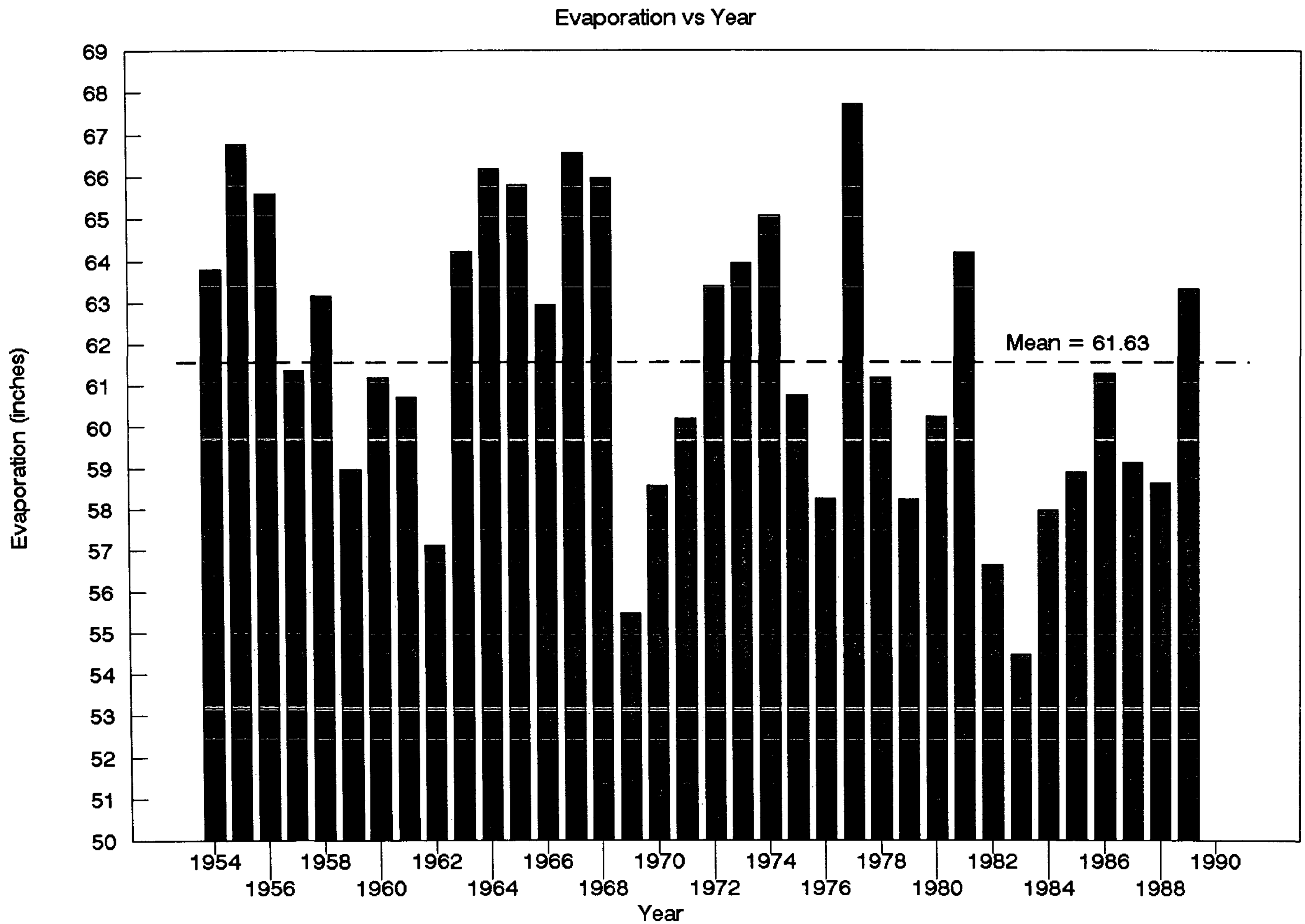


Figure 3.6 - Annual evaporation at Gainesville: evaporation vs. year.

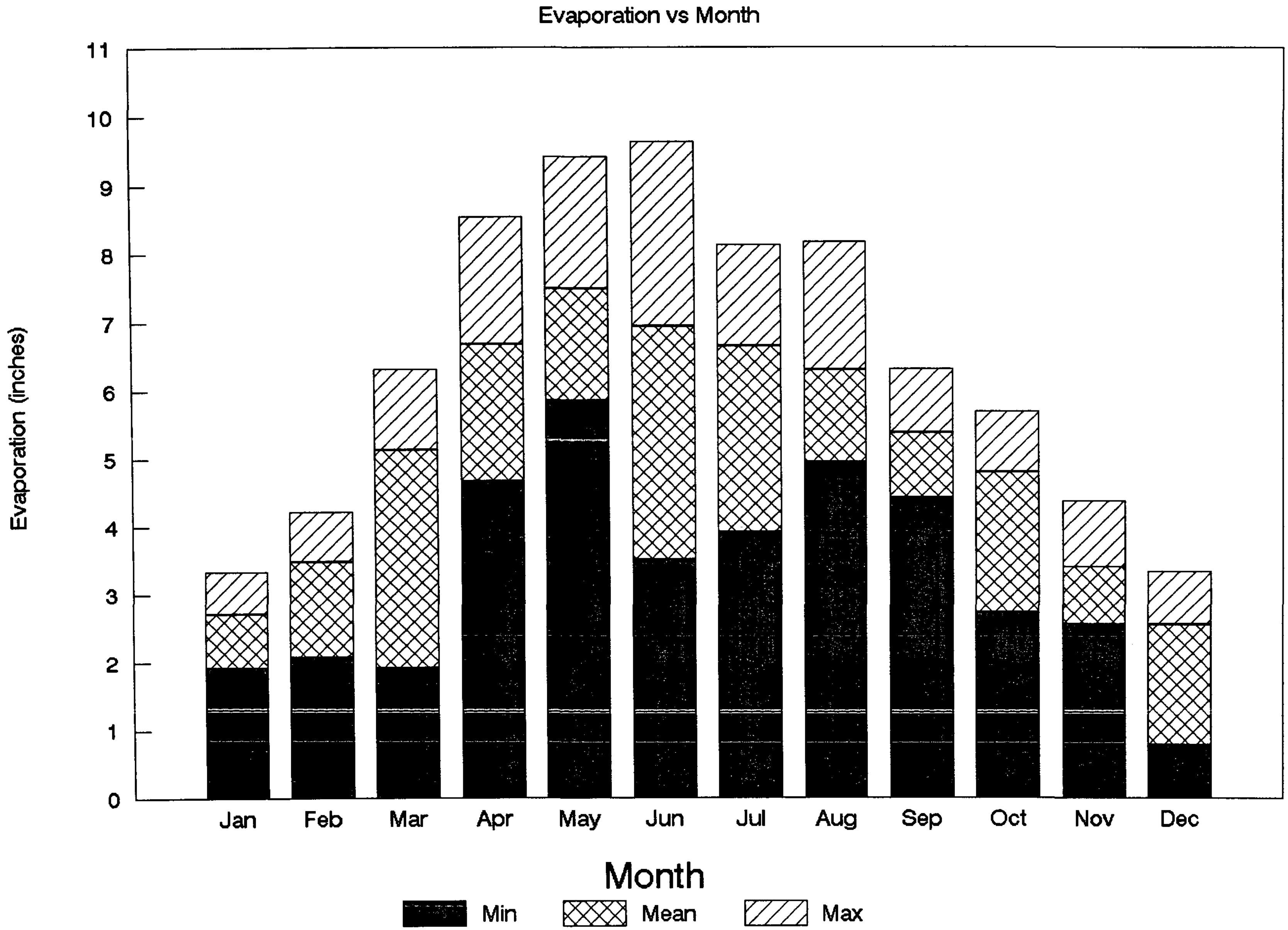


Figure 3.7 - Evaporation at Gainesville: evaporation vs. month.

Table 3.4 **Summary of Stage Data and Statistics for 13 Lakes in Upper Etonia Creek Basin.**

No.	Lake	Stage Data From	To	Yrs	Stages, ft. Mean	Min	Max	Range
1	Blue Pond	59	67	9	173.71	172.70	174.40	1.70
2	Brooklyn	57	89	33	109.07	95.13	117.41	22.28
3	Crystal	84	89	6	112.81	107.96	114.83	6.87
4	Geneva	57	89	33	102.22	96.39	107.10	10.71
5	Hall	86	89	4	80.56	78.90	81.70	2.80
6	Johnson, Big	59	89	31	92.08	87.54	98.51	10.97
7	Johnson, Little	45	89	45	96.12	91.02	105.00	13.98
8	Kingsley	45	89	45	176.15	174.42	177.45	3.03
9	Magnolia	60	89	30	124.60	122.41	125.77	3.36
10	Pebble	45	89	45	97.82	84.24	115.40	31.16
11	Sand Hill	57	89	33	131.71	130.79	132.73	1.94
12	Smith	86	89	4	82.11	80.30	83.50	3.20
13	Swan	76	89	14	89.63	86.70	93.10	6.40

Notes:
1. Sand Hill Lake is also known as Lowry Lake.
2. No database for lakes Gator Bone, Keystone, Silver, and White Sands.
3. Yrs column does not account for gaps in record.

Table 3.5 **Stage Data Sorted by Rank in Florida.**

No.	Lake	Stage Data From	To	Yrs	Stages, ft. Mean	Min	Max	Range	Rank
1	Blue Pond	59	67	9	173.71	172.70	174.40	1.70	1
2	Sand Hill	57	89	33	131.71	130.79	132.73	1.94	2
3	Hall	86	89	4	80.56	78.90	81.70	2.80	6
4	Kingsley	45	89	45	176.15	174.42	177.45	3.03	8
5	Smith	86	89	4	82.11	80.30	83.50	3.20	9
6	Magnolia	60	89	30	124.60	122.41	125.77	3.36	12
7	Swan	76	89	14	89.63	86.70	93.10	6.40	48
8	Crystal	84	89	6	112.81	107.96	114.83	6.87	58
9	Geneva	57	89	33	102.22	96.39	107.10	10.71	98
10	Johnson, Big	59	89	31	92.08	87.54	98.51	10.97	101
11	Johnson, Little	45	89	45	96.12	91.02	105.00	13.98	110
12	Brooklyn	57	89	33	109.07	95.13	117.41	22.28	117
13	Pebble	45	89	45	97.82	84.24	115.40	31.16	121

Notes:
1. Rank is from 1 (lowest range) to 121 (highest range).

lakes in the state of Florida are in this study area with fluctuations of less than 3.4 feet. Lakes Swan and Crystal fluctuate 6.4 feet and 6.9 feet over their period of record. These fluctuations are "typical" for Florida lakes, and they correspondingly rank 48 and 58 out of 121 lakes. Lakes Geneva, and Big and Little Johnson comprise the next category of local lakes with fluctuations in the range of 10.7 to 14.0 feet and corresponding ranks from 98 to 110. Lake Brooklyn ranks 117 out of 121 Florida lakes with a fluctuation of over 22 feet while Pebble Lake is the most widely fluctuating lake in Florida with a range in excess of 31 feet. A summary of these results is presented in Figure 3.8., which shows the percentage of the lakes whose fluctuations equal or exceed the indicated values. The relative location of the 13 UECB lakes is also shown on this figure, which indicates that the median (50 percent) range for Florida lakes is about seven feet.

3.4.2 Very Stable Lakes-Blue Pond and Sand Hill Lake

Blue Pond and Sand Hill Lake are the two most stable lakes in Florida with fluctuations of less than two feet. Blue Pond is farthest upstream in the chain of lakes that discharge into Putnam Prairie (see Figures 2.1 and 2.7). Outflow occurs from Blue Pond when the stage reaches approximately 173 ft, NGVD, and has occurred approximately 95 percent of the time for which data are available. Sand Hill Lake is the second lake in the interconnected chain of lakes (see Figure 2.7). The outlet elevation for Sand Hill Lake is 131 ft, NGVD, and outflow has occurred 97 percent of the time. The stages in Blue Pond and Sand Hill Lake do not appear to be declining (see Figure 3.9), nor is there any obvious shift in the other characteristics of the time series, e.g., variability.

3.4.3 Stable Lakes-Kingsley, Magnolia, Hall, and Smith Lakes

This category of lakes exhibits stage fluctuation ranges from two to six feet. The period of record is longest for Kingsley Lake. The fluctuations are

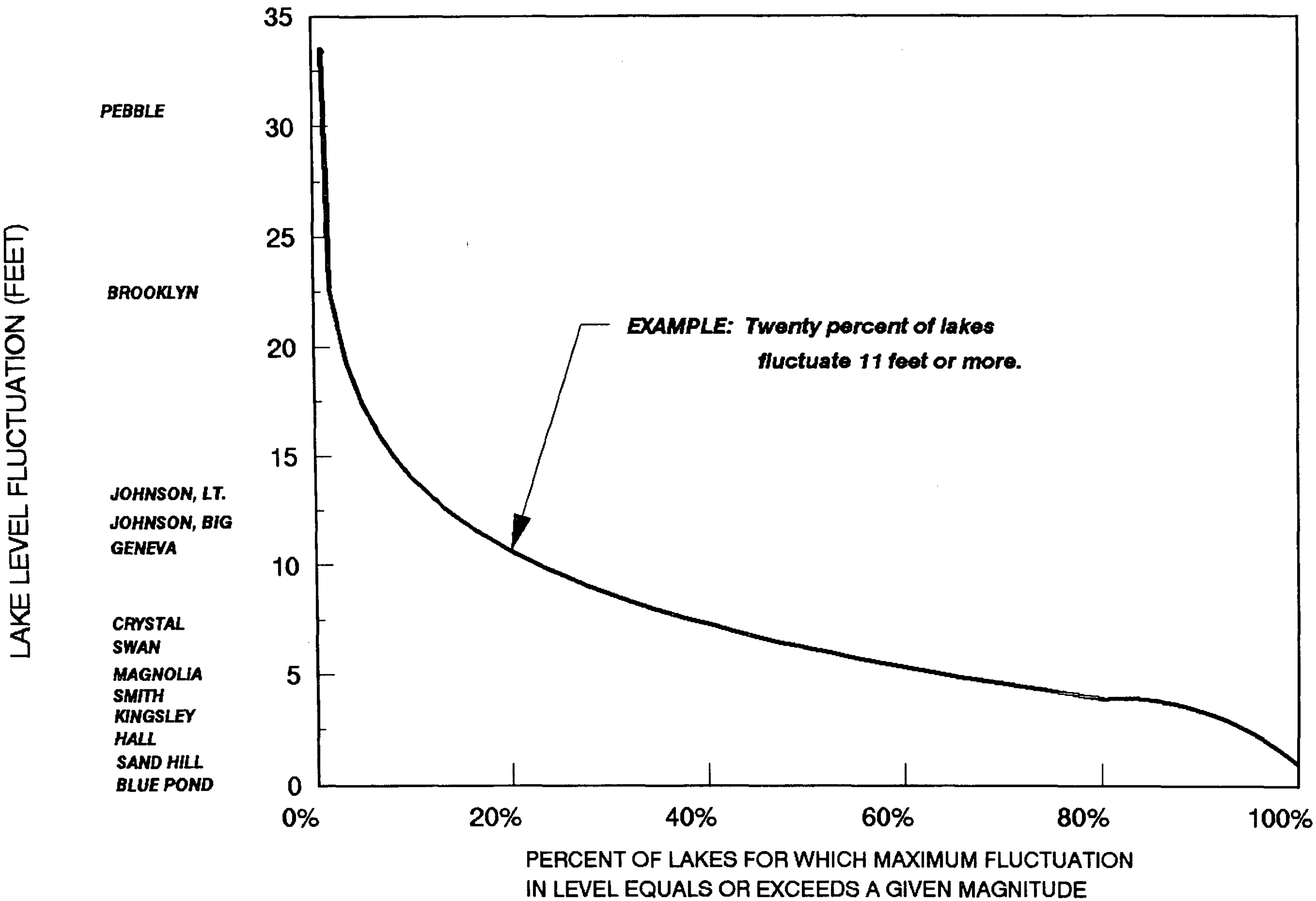


Figure 3.8 - Fluctuations for 121 Florida lakes.

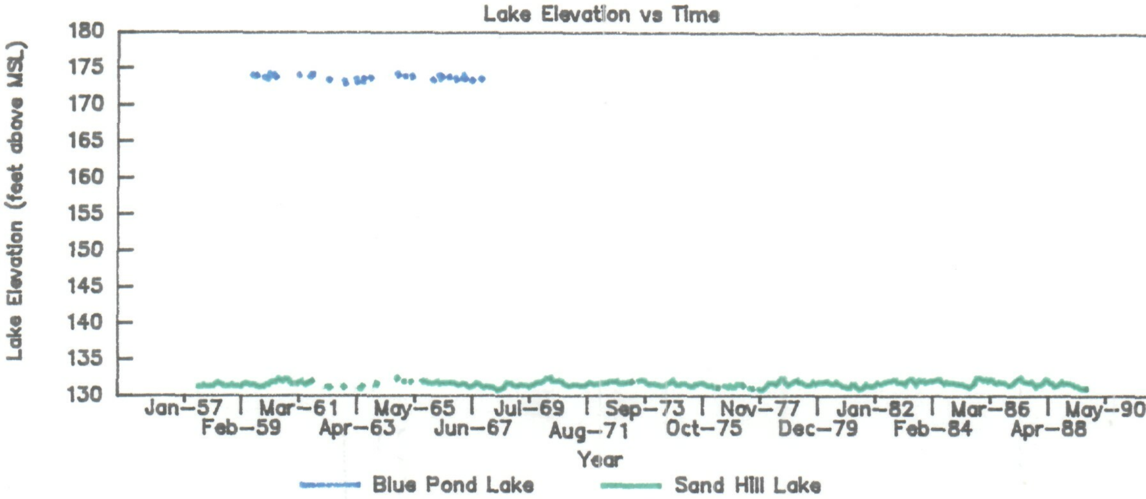


Figure 3.9 - Comparison of Blue Pond and Sand Hill Lake.

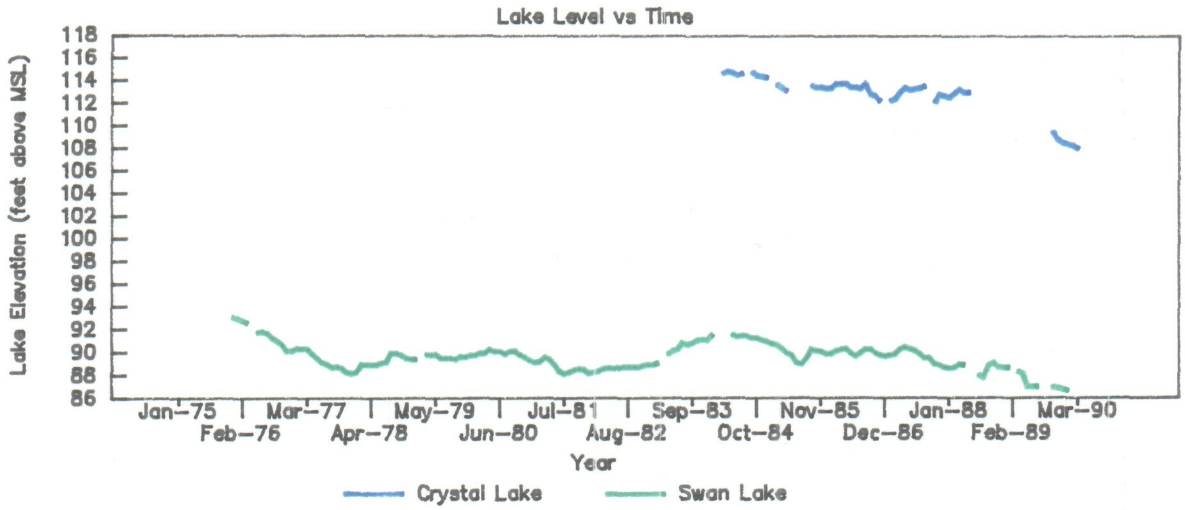


Figure 3.10 - Comparison of Crystal and Swan Lakes.

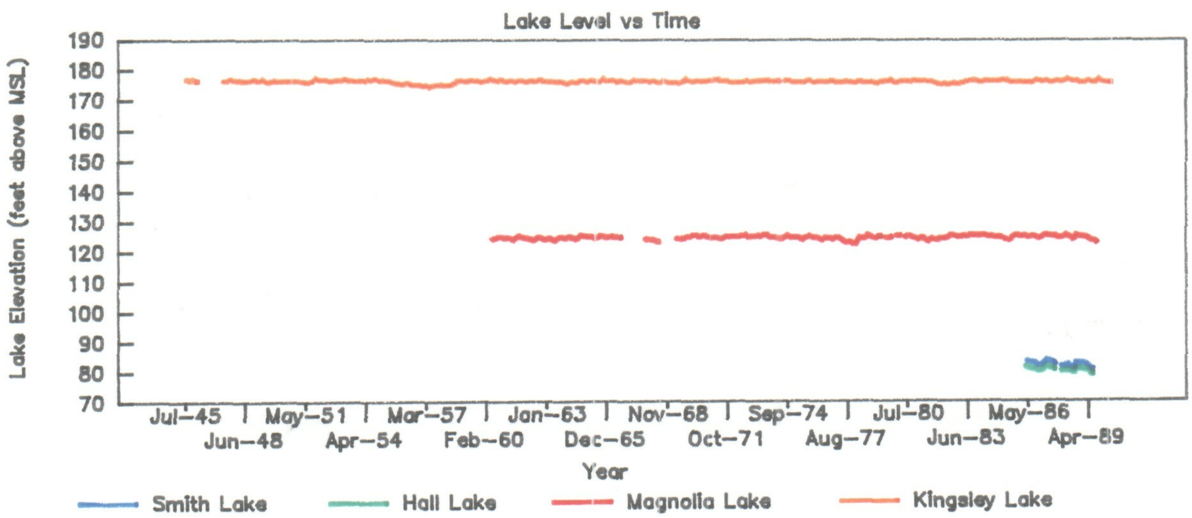


Figure 3.11 - Comparison of Smith, Hall, Magnolia and Kingsley Lakes.

shown in Figure 3.10. The scale of the y axis was set so that all of the lakes could be plotted on the same graph. This tends to reduce the extent of the variability. Even with this compression, it is apparent that the fluctuations are relatively small, and that no apparent trends over time exist.

3.4.4 **Typical Florida Lakes-Swan Lake and Crystal Lake**

Lakes Swan and Crystal fluctuate six to seven feet, which is typical of Florida lakes as discussed earlier in this section. As shown in Figure 3.11, both of these lakes have exhibited a downward trend in water levels since 1983, and the lakes are now at their lowest levels for the available period of record. Another reason that these trends are more apparent for these two lakes is that a smaller scale was used on the ordinate of the graph.

3.4.5 **Less Stable Lakes-Lake Johnson, Little Lake Johnson, and Lake Geneva**

The next category of lakes has fluctuated ten to fourteen feet during the period of record (see Figure 3.12). A long period of record exists for Little Lake Johnson in Gold Head State Park. The fluctuation pattern in Little Lake Johnson has undergone a definite change since about 1975, when it went from a widely fluctuating lake to one with little fluctuation. It is a good example of the influence of man's activities on lake stages. Little Lake Johnson was separated from Lake Johnson below an elevation of 95 ft, NGVD, by a shallow channel and earthen dam constructed in June 1957. Little Lake Johnson has a surface area of 35 acres, and Gold Head Branch flows into the lake. In August 1968, the channel into the lake was deepened, and a control structure with removable boards was constructed. On January 17, 1969, the dam was found partially washed out, and a new dam with a crest of approximately 96 ft, NGVD, was constructed in April 1969. The level of Little Lake Johnson is maintained at a stable level by directing the flow from Gold Head Springs into Little Lake Johnson. This stable

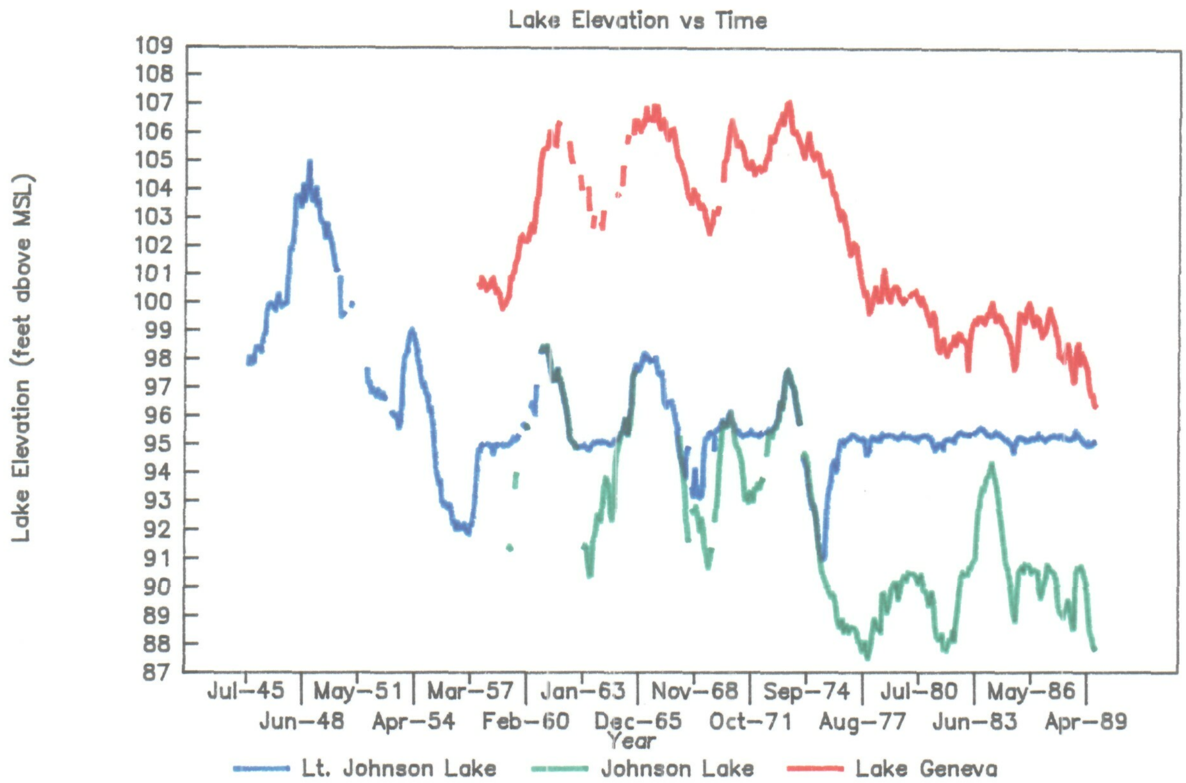


Figure 3.12 - Comparison of Geneva, Little Johnson, and Big Lake Johnson.

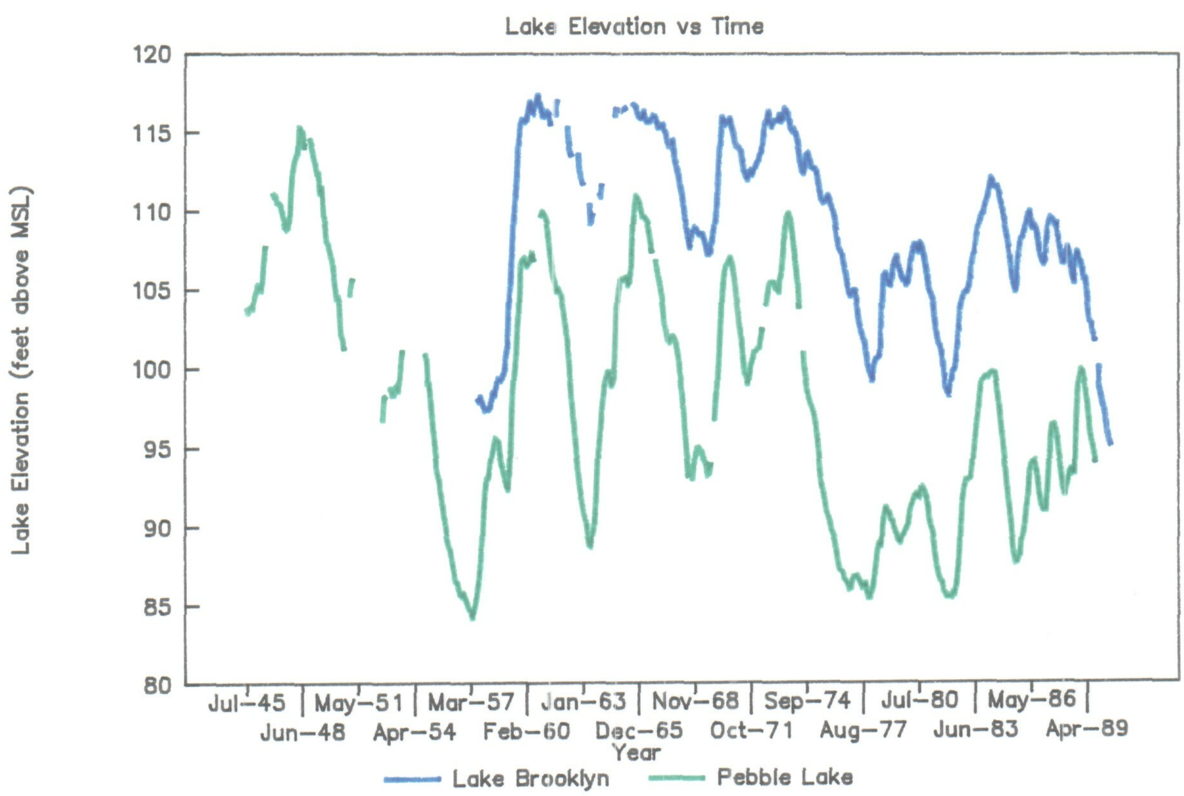


Figure 3.13 - Comparison of Pebble and Brooklyn Lakes.

lake level is highly desirable for swimming and boating in the State Park. By comparison, the levels of Lake Johnson have been lowered since preference is given to Little Lake Johnson. Thus, it is now at or near its all-time low level and looks more like a prairie than a lake.

Lake Geneva, the sixth lake in the Upper Etonia chain, has experienced declining water levels since about 1971 as shown in Figure 3.12. It is now at its record low level.

3.4.6 Unstable Lakes-Pebble Lake and Lake Brooklyn

The last category of lakes consists of Pebble Lake and Lake Brooklyn, which fluctuate more than twenty feet as shown in Figure 3.13. Prior to about 1984, these two lakes followed the same fluctuation pattern. However, in the past five years, while Lake Brooklyn has fallen to record low levels, the levels in Pebble Lake have increased. While the cause(s) of the increasing levels in Pebble Lake are still being evaluated, it could be influenced by some combination of the sand mining operations immediately to the west and/or the lake-level maintenance at Little Lake Johnson, which is located only about two hundred yards to the east of Pebble Lake.

3.5 Groundwater Levels

Potentiometric maps prepared by SJRWMD delineate a major groundwater mound in the Floridan aquifer system in the western part of the UECB (see Figures 3.14 through 3.17). This mound, or potentiometric high, is centered in the Keystone Heights area. Its presence, along with higher water levels in the surficial and intermediate aquifers (Yobbi and Chappel 1979), indicates that the lakes and surficial aquifer system in the area are a major source of recharge to the underlying Floridan aquifer system. The elevation of the potentiometric surface is

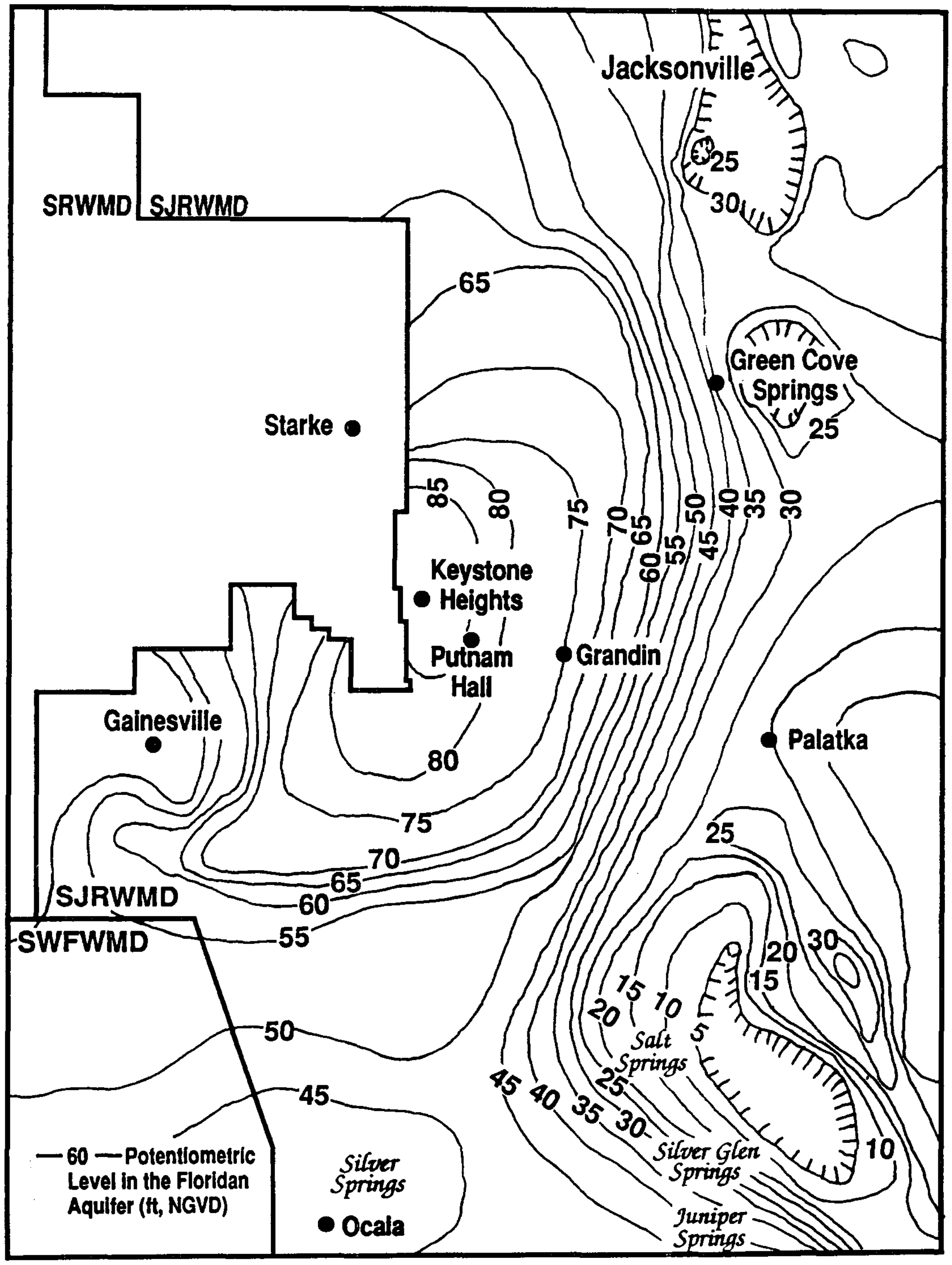


Figure 3.14 - May 1978 Potentiometric map of the Floridan Aquifer in vicinity of UECB and surrounding region. (Source: USGS, 1978)

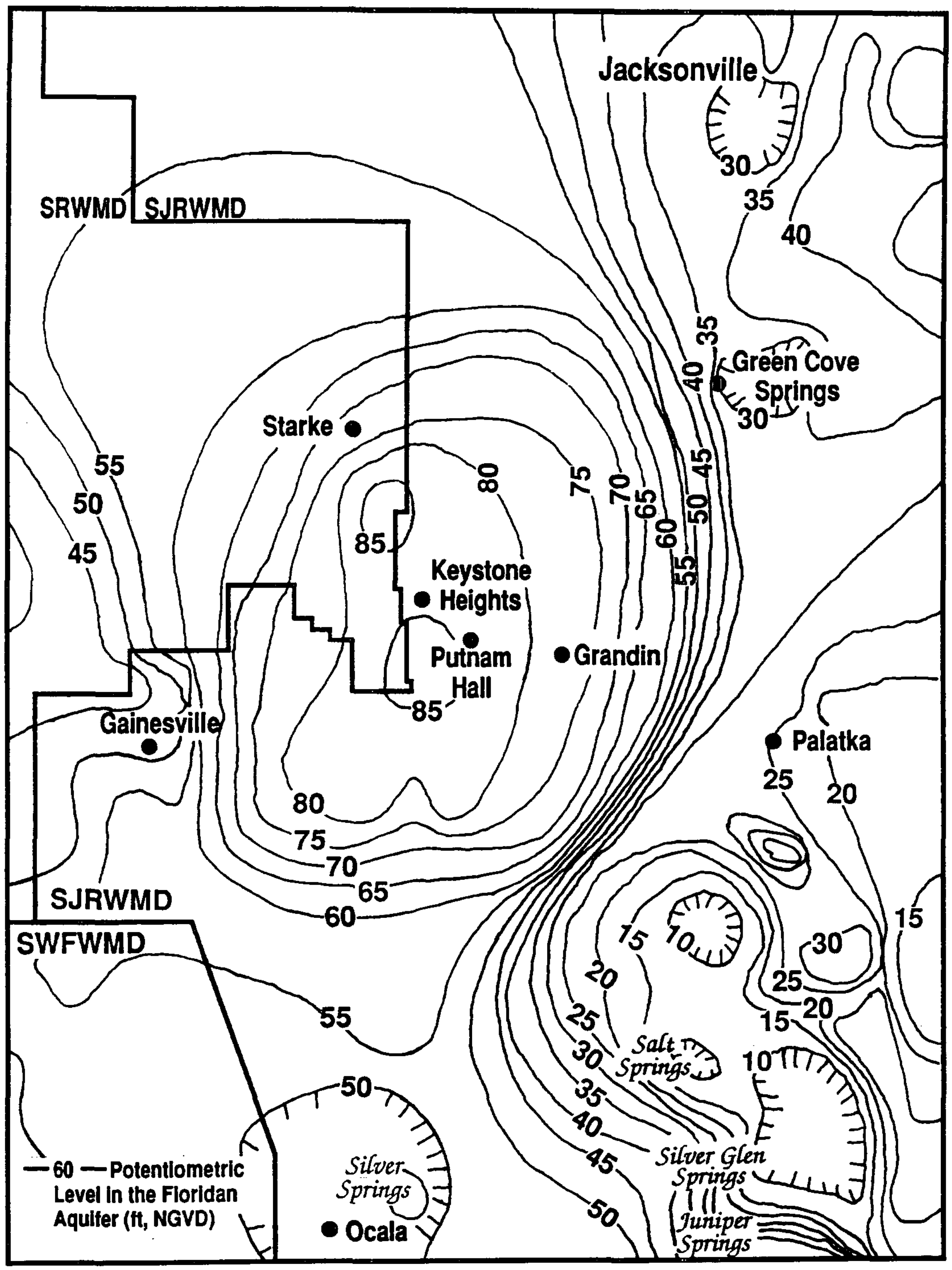


Figure 3.15 - September 1982 Potentiometric map of the Floridan Aquifer in vicinity of UECB and surrounding region. (Source: USGS, 1982)

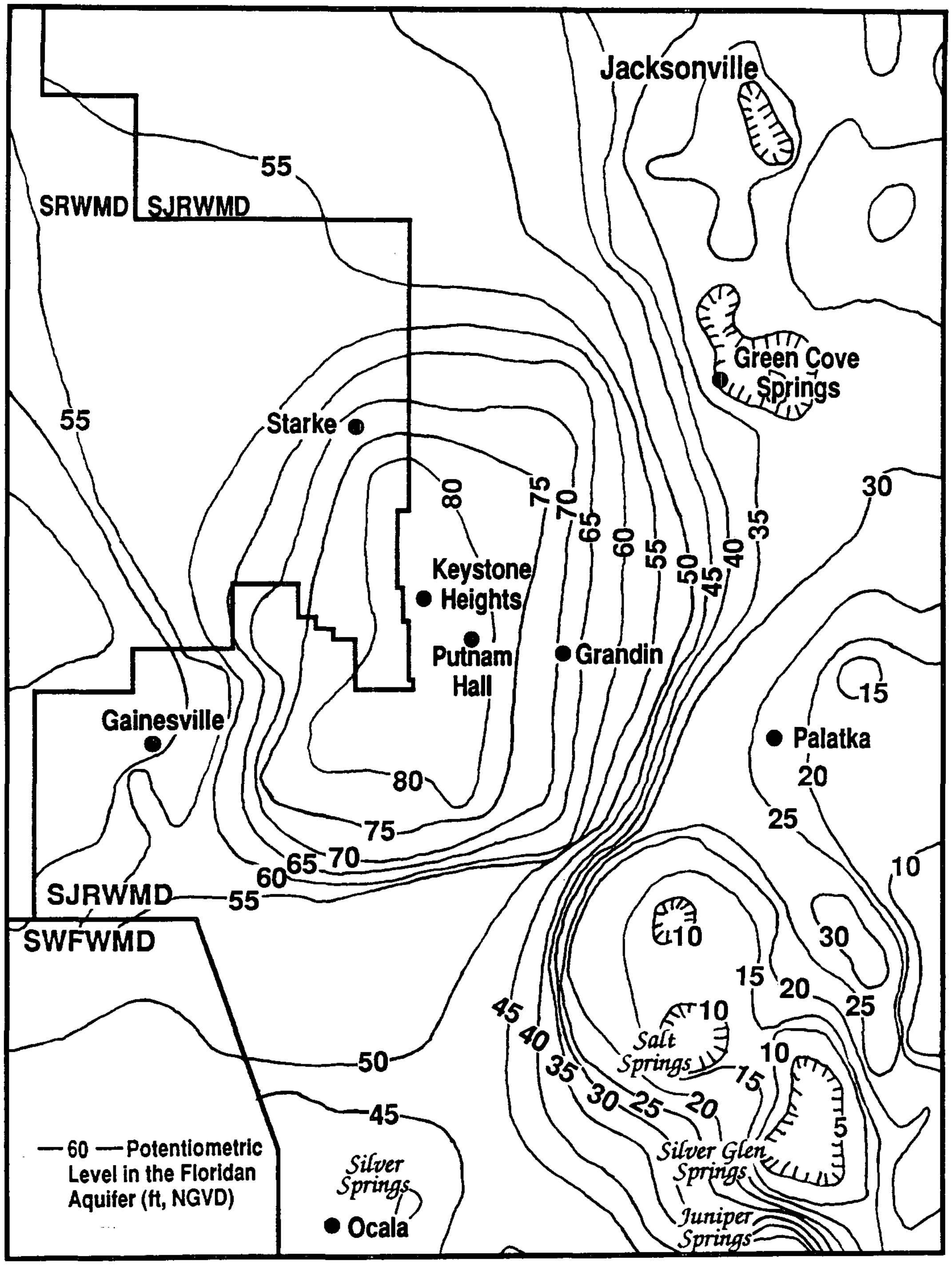


Figure 3.16 - September 1986 Potentiometric map of the Floridan Aquifer in vicinity of UECB and surrounding region. (Source: USGS, 1987)

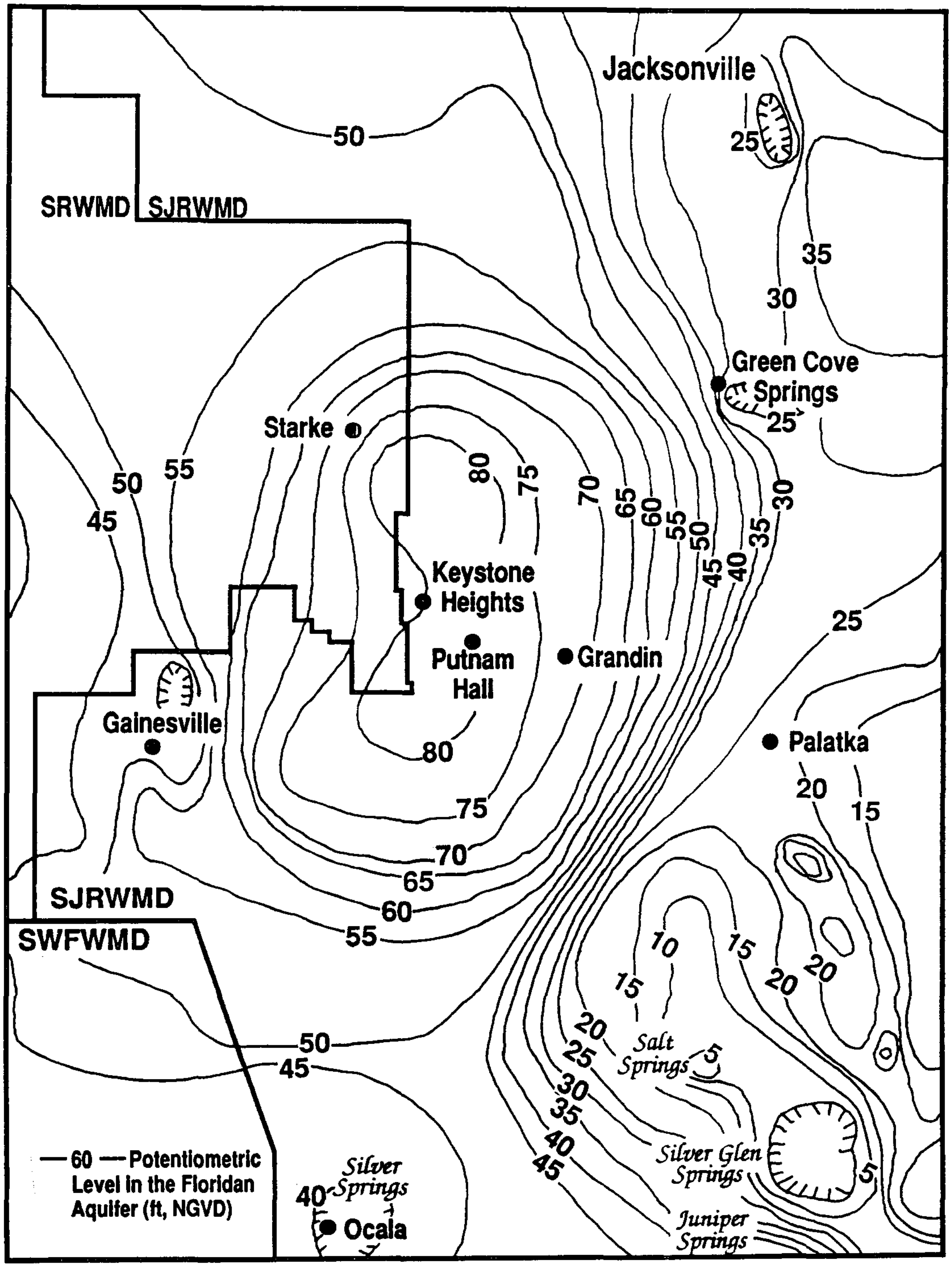


Figure 3.17 - September 1989 Potentiometric map of the Floridan Aquifer in vicinity of UECB and surrounding region. (Source: USGS, 1990)

greater than 80 ft, NGVD, in the Keystone Heights area, and decreases in all directions from the area. Groundwater flow in the Floridan aquifer system occurs downgradient and radially outward from the center of the area. Groundwater flow in the UECB occurs generally eastward and northeastward towards the St. Johns River.

Records of monthly groundwater levels were found for three Floridan aquifer wells in or near the UECB (see Figure 3.1). The Keystone Heights well is located on the northwest side of Lake Brooklyn. This well has the longest period of record of the three wells, extending from April 1960 to May 1990 with only a few gaps in the record. The maximum elevation in the period of record, 91.38 ft, NGVD, occurred in October 1960, and the level has declined ever since, dropping 13.0 ft to 78.38 ft, NGVD, in March 1990 (see Figure 3.18). The Swan well is located southeast of Swan Lake. Its period of record extends from December 1979 to March 1990 with several data gaps; the maximum elevation of 88.42 ft, NGVD, occurred in March 1984, and the minimum elevation of 80.85 ft, NGVD, occurred in March 1990 (see Figure 3.19). The Starke well is located outside of the UECB approximately 13 miles north-northwest of Keystone Heights. It has a period of record from June 1975 to March 1990 with several data gaps. The maximum elevation in this period of record, 88.50 ft, NGVD, occurred in May 1984, and the minimum elevation, 81.28 ft, NGVD, occurred in July 1989 (see Figure 3.20). An additional single value in the database outside this period of record indicates that an elevation of 90.74 ft, NGVD, occurred in November 1959 in the Starke well.

3.6 Water Use

Groundwater is pumped from the Floridan aquifer system in the UECB for public supply, agriculture, and mining (see Table 3.6). The largest groundwater

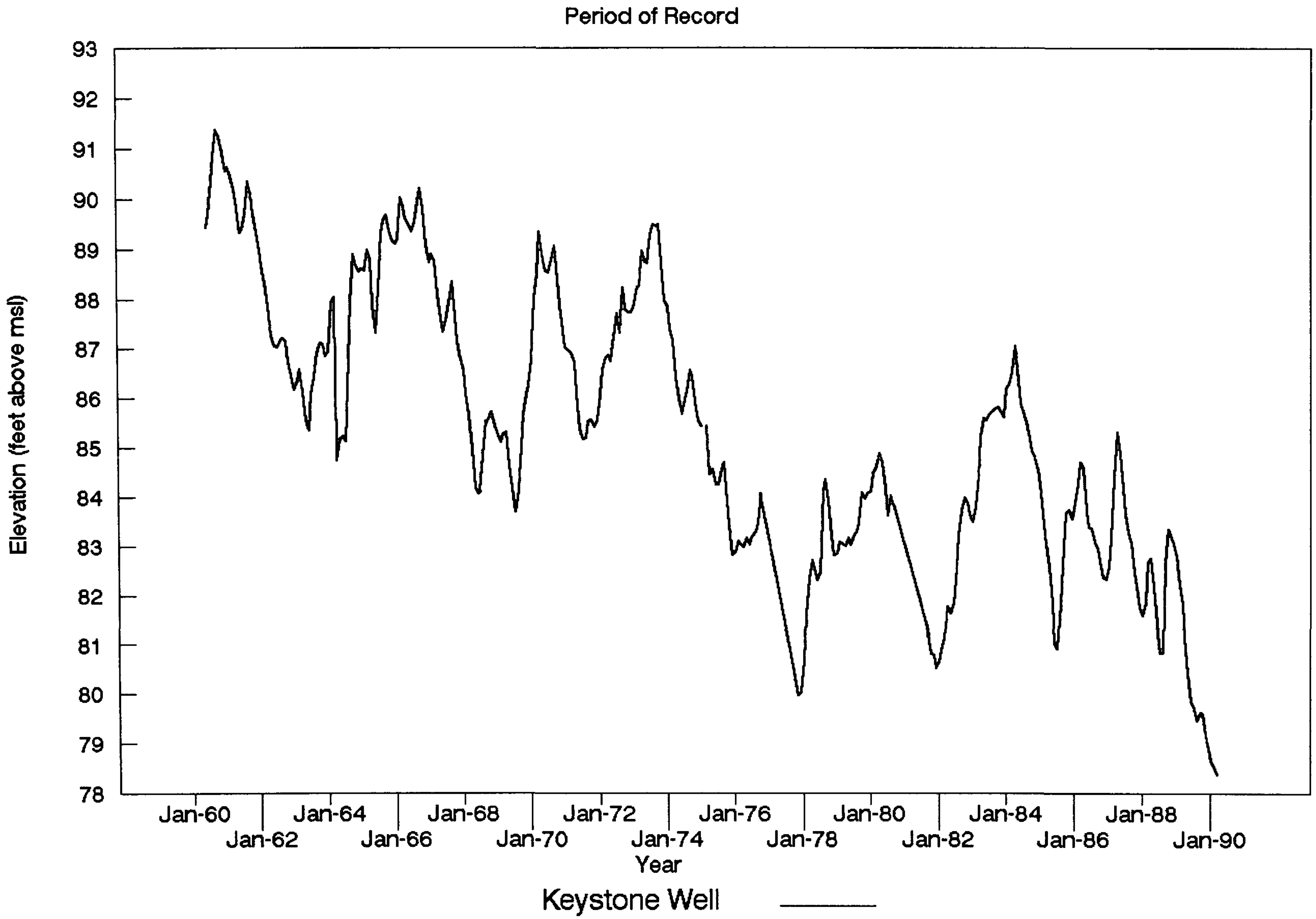


Figure 3.18 - Keystone well: period of record.

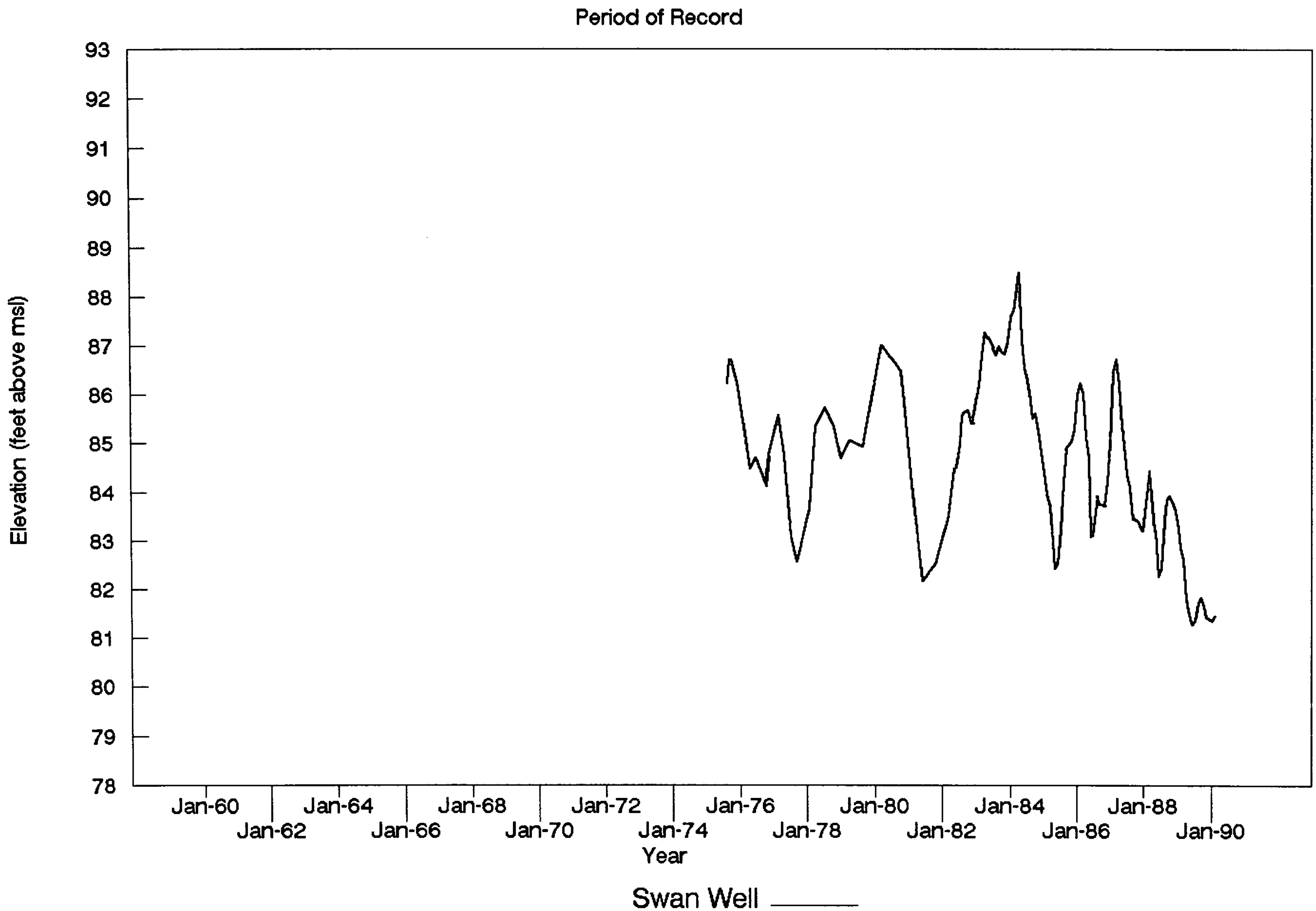


Figure 3.19 - Swan well: period of record.

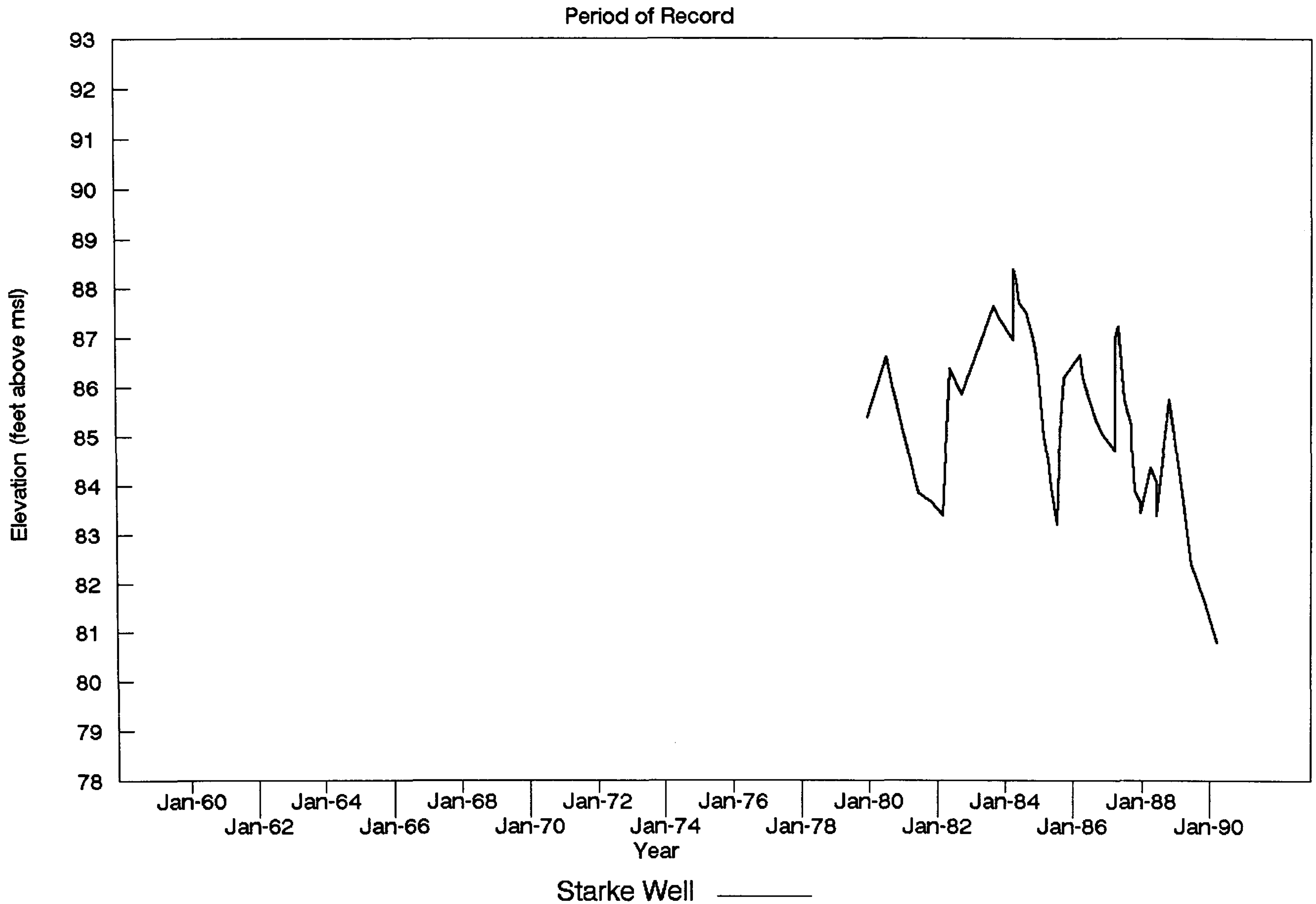


Figure 3.20 - Starke well: period of record.

Table 3.6 - Water Use in UECB.

	Owner	County	Pumpage MGD	Use
Water Use in Upper Etonia Creek Basin				
1	Southern States Utilities Corp.	Bradford	0.038	Pump from Floridan for public supply.
2	Camp Blanding military base	Clay	0.494	Pump from Floridan for public supply.
3	Keystone Water Company	Clay	0.394	Pump from Floridan for public supply.
4	Melrose Water Association	Putnam	0.067	Pump from Floridan for public supply.
5	State of FL (Gold-Head State Park)	Clay	0.021	Pump from Floridan for agriculture.
6	John W. McInarnay Jr.	Putnam	0.15	Pump from Floridan for agriculture.
7	Edgar Von Scheele R & R Peat Farms	Putnam	0.5	Pump from Floridan for agriculture.
8	E. I. Dupont De Nemours & Co.	Clay	2.341	Pump from Floridan for mining.
9	Carroll Phillips Partnership Florida Rock Industries (Keystone Sand Mine)	Clay	1.939	Pump from Floridan for mining.
10	Florida Rock Properties (Grandin Sand Mine)	Putnam	0.78	Pump from Floridan for mining.
		Total =	6.724	
Major Water Users Outside UECB				
11	City of Gainesville	Alachua	19.69	Pump from Floridan for public supply.
12	Palatka	Putnam	2.572	Pump from Floridan for public supply.
13	Georgia Pacific - Palatka Plant	Putnam	35.362	Industrial use.
14	Total Duval pumpage	Duval	173.06	Total county pumpage.

Land Use:	Source for pumpage data:
Florida Rock Properties (Grandin Sand Mine)	Marella, R.L., Annual Water Use Survey: 1987. Technical Publication SJ 90-4, SJRWMD, Palatka, FL, 1990.
Site area = 6690.00 acres Permitted pumpage= 1.94 MGD Use/area = 3.90 in/yr	
Carroll Phillips Partnership Florida Rock Industries (Keystone Sand Mine)	
Site area = 573.00 acres Permitted pumpage= 1.94 MGD Use/area = 45.49 in/yr	

user is Florida Rock Industries, which operates the Gold Head and Grandin sand mines (see Figure 3.21). The annual permitted pumping rates at these two mines total 2.719 million gallons per day (mgd). Dupont operates a mine that is permitted to pump 2.341 mgd, but its center of pumping is located generally north of the UECB (see Figure 3.21). Other relatively large groundwater users include Southern States Utilities Corporation, Camp Blanding, and the Keystone Water Company. The total pumpage from the Floridan aquifer system in the UECB is approximately 7 mgd. By comparison, groundwater pumping totals approximately 173 mgd in Duval County and 20 mgd at the Gainesville Regional Utilities (GRU) Murphree Wellfield.

Groundwater also is pumped from the intermediate aquifer system for domestic self-supply (Clark et al. 1964). Domestic water use in Clay County has increased from 2.49 mgd in 1979 to 3.64 mgd in 1987 (Marella 1981 and 1990); pumping in the UECB from the intermediate aquifer presumably has followed a similar, increasing trend.

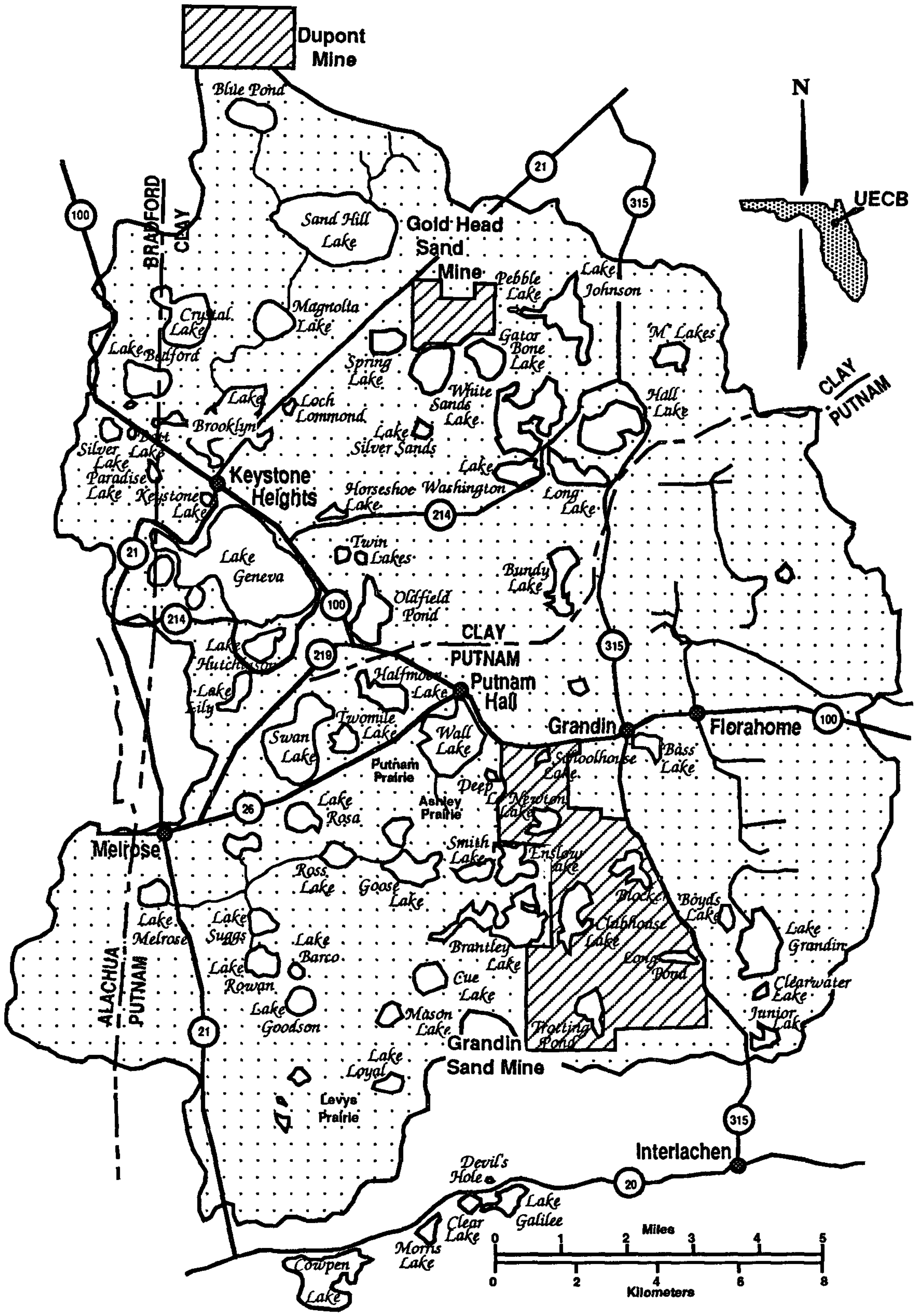


Figure 3.21 - UECB with locations of Florida Rock Sand Mines (Hashed Areas).
(Source: Yobbi and Chappel, 1979)

4.0 ASSESSMENT OF LONG-TERM CHANGES

4.1 Introduction

A preliminary assessment of the extent of long-term changes in the Upper Etonia Creek Basin (UECB) was conducted. The three components that were assessed are: precipitation and evaporation; surface-water responses; and groundwater responses.

4.2 Precipitation and Evaporation

Figure 4.1 shows the time series of annual rainfall, evaporation, and (rainfall)-(evaporation) from 1954 to 1989. During this century, the rainfall has ranged from a maximum of 68.99 inches in 1964 to a minimum of 29.22 inches in 1954. The mean rainfall is 50.74 inches. The corresponding statistics for evaporation for the period of record (1954 to present) are a maximum of 67.74 inches in 1977, a minimum of 54.48 inches in 1983, and a mean of 61.63 inches. The relative variability of the precipitation and evaporation was estimated by calculating the coefficient of variation from equation 1. The coefficients of variation for precipitation and evaporation are 0.15 and 0.06, respectively. Thus, the rainfall is two and one-half times more variable than the evaporation.

The worst combination of circumstances with respect to drought severity is the concurrent events of low rainfall and high evaporation. As shown in Figure 4.1, the worst case in recent years occurred in 1954. Other years with high deficits were 1977 and 1981. A comparison of rainfall and evaporation records indicates that these two phenomena may be treated as independent events.

Wet and dry periods do occur as discussed in Section 3.2. However, no long-term decreasing or increasing trends in rainfall or evaporation are apparent.

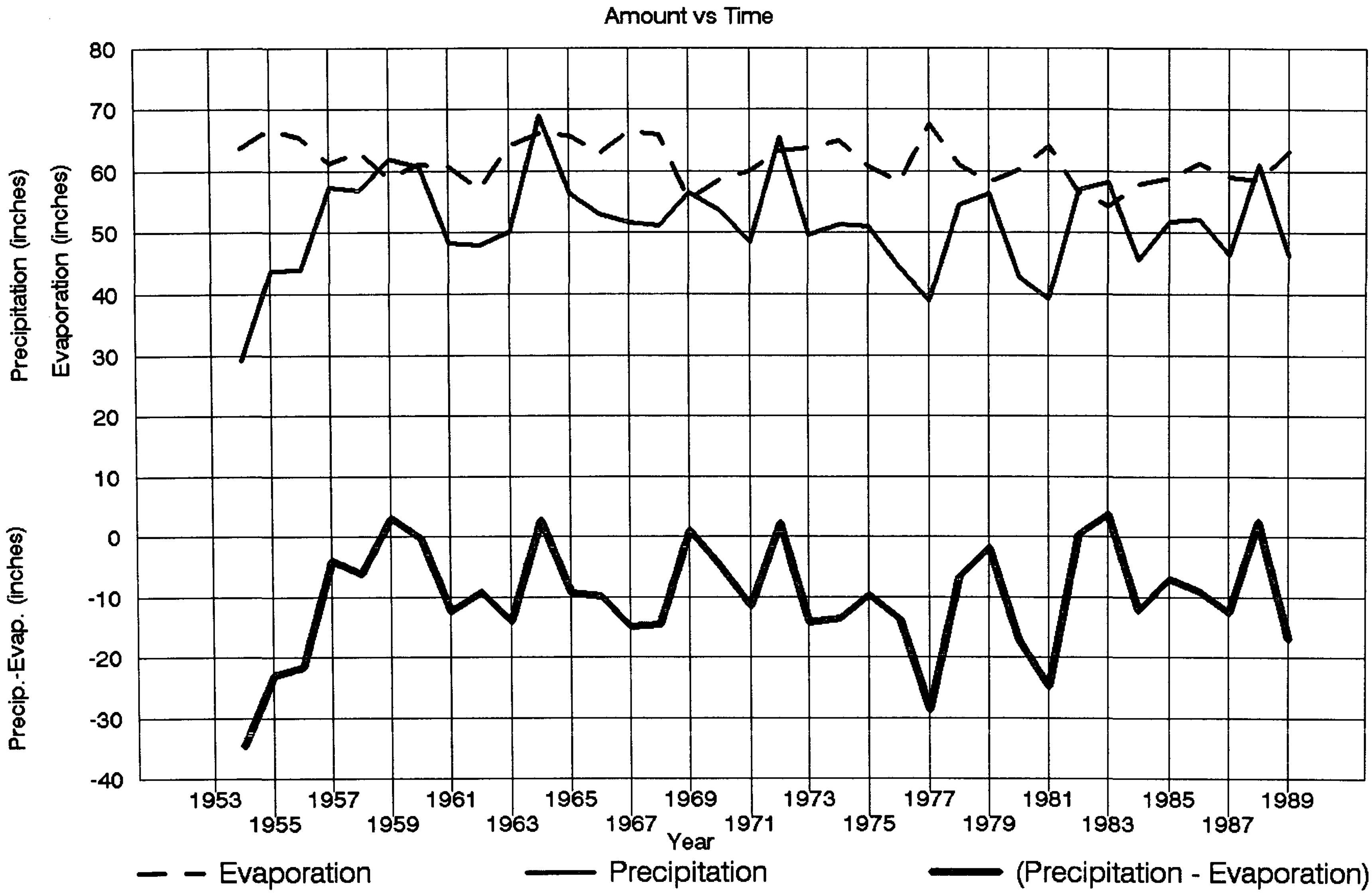


Figure 4.1 - Evaporation and precipitation and (precipitation)-(evaporation) vs. time.

4.3 Surface Water

As discussed in Section 3.4, the UECB lakes range from the most to least stable lakes in the state of Florida for 121 lakes for which long-term stage records exist. Figure 4.2 shows the stages of the Etonia chain of lakes for the period from 1957 to 1989. Two of the upstream lakes (Blue Pond and Sand Hill) are very stable, and Magnolia is stable, whereas the lower two lakes (Brooklyn and Geneva) are much less stable. Lakes Brooklyn and Geneva exhibit a persistent downward trend since about 1973, whereas the three stable lakes do not show such trends.

The exponentially smoothed annual rainfall is compared to the levels of Lake Brooklyn, Pebble Lake, Lake Geneva, Little Lake Johnson, and Big Lake Johnson in Figure 4.3. Up to the mid-1970's, the lakes rose and fell with the rainfall. After this time, Lake Brooklyn and Lake Geneva followed the downward trend in rainfall for this period. However, Pebble Lake exhibited an increasing trend through the 1980's; Little Lake Johnson's level was stabilized and Big Lake Johnson showed a decline. As explained in Section 3.4, the behavior of the Johnson lakes has been impacted by hydrologic modifications in Gold Head State Park. Some combination of these modifications and sand mining activity next to Pebble Lake appear to have influenced its behavior. More detailed study is needed to determine the magnitude of these changes.

4.4 Groundwater

4.4.1 Changes in the Floridan Aquifer Potentiometric Surface

The elevation of the groundwater mound in the Keystone Heights area decreased approximately five feet from May 1978 to September 1989 (see Figures 3.14 through 3.17). In May 1978, a relatively large area centered at Keystone Heights

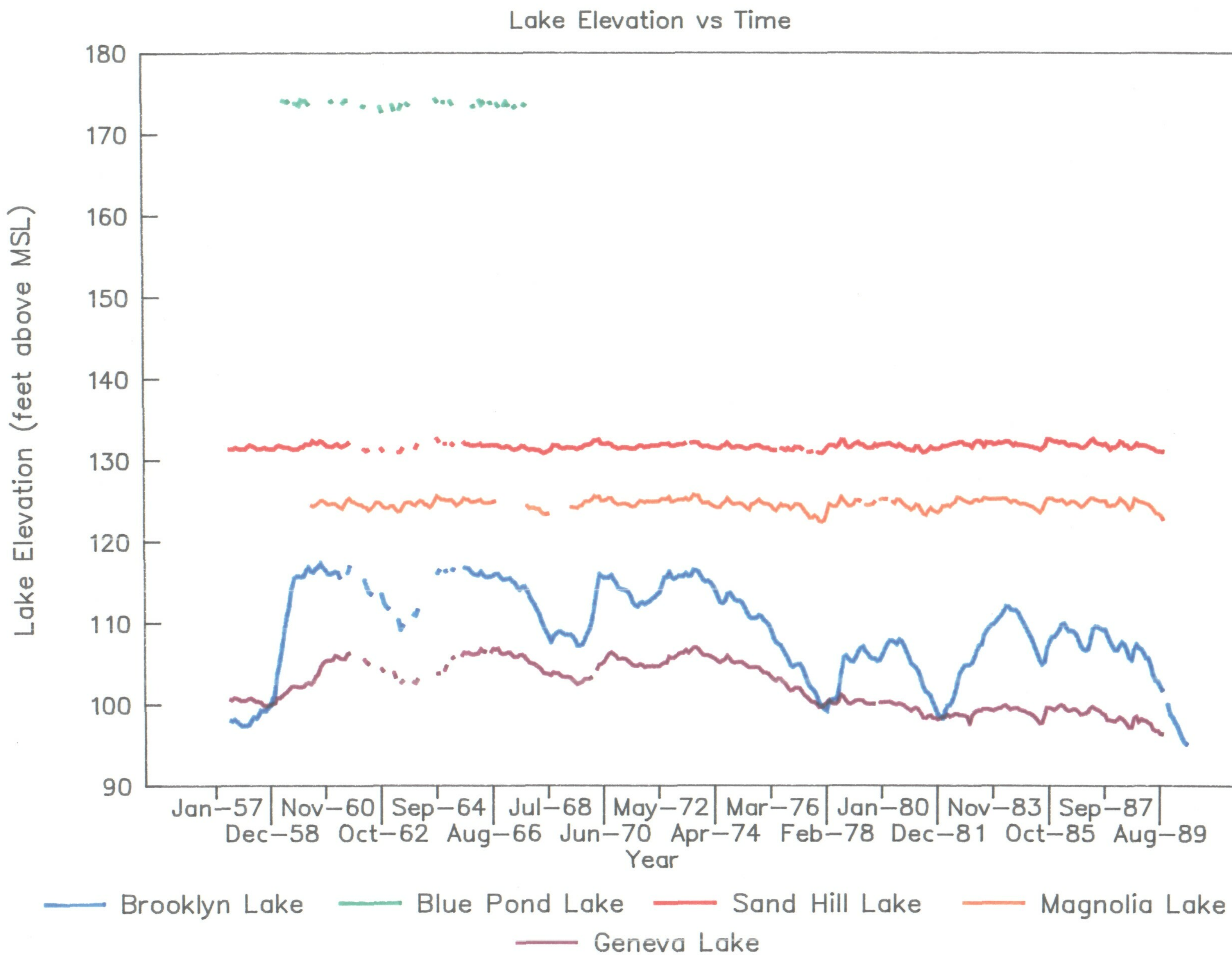


Figure 4.2 - Etonia chain of lakes: lake elevation vs. time.

Figure 4.3 - Rainfall and elevations of lakes with fluctuation from 10 to 30 feet.

was enclosed by the 85-ft, NGVD, contour. In September 1982, two smaller areas were enclosed by the 85-ft contour, and in September 1986, only one small area was enclosed. In September 1989, no area was enclosed within the 85-ft contour.

The decline in groundwater levels is also evident in the records of the three Floridan aquifer wells in the UECB (see Figures 3.18 through 3.20). Combining the hydrographs for these wells indicates that groundwater levels in the Swan and Starke wells have had approximately the same elevations as the Keystone Heights well and have fluctuated similarly for the period of record during which all three wells were measured (see Figures 4.4 and 4.5). Thus, it is reasonable to conclude that the Swan and Starke wells had approximately the same elevations and fluctuations as the Keystone Heights well prior to the middle 1970's and have experienced the same decline since the early 1960's.

4.4.2 Changes in Precipitation and Lake and Groundwater Levels

A comparison of the exponentially-smoothed Etonia precipitation, Lake Brooklyn stage levels, and groundwater levels in the Keystone Heights well indicates a strong correlation among all three records (see Figure 4.6). Lake Brooklyn and Floridan aquifer water levels respond directly to precipitation in the UECB, as indicated by the fluctuations in all three records. However, the trends in the levels of Lake Brooklyn and the Floridan aquifer cannot be explained entirely in terms of precipitation, since these levels have declined steadily over the last few years, while precipitation has been more nearly constant over the same period of time (see Figures 4.3 and 4.6).

4.4.3 Effects of Pumping

Closed depressions on a potentiometric map can indicate the location of major discharge areas such as pumping from a well-field or discharge to springs and wetland areas. Groundwater pumpage in the UECB is distributed over the area,

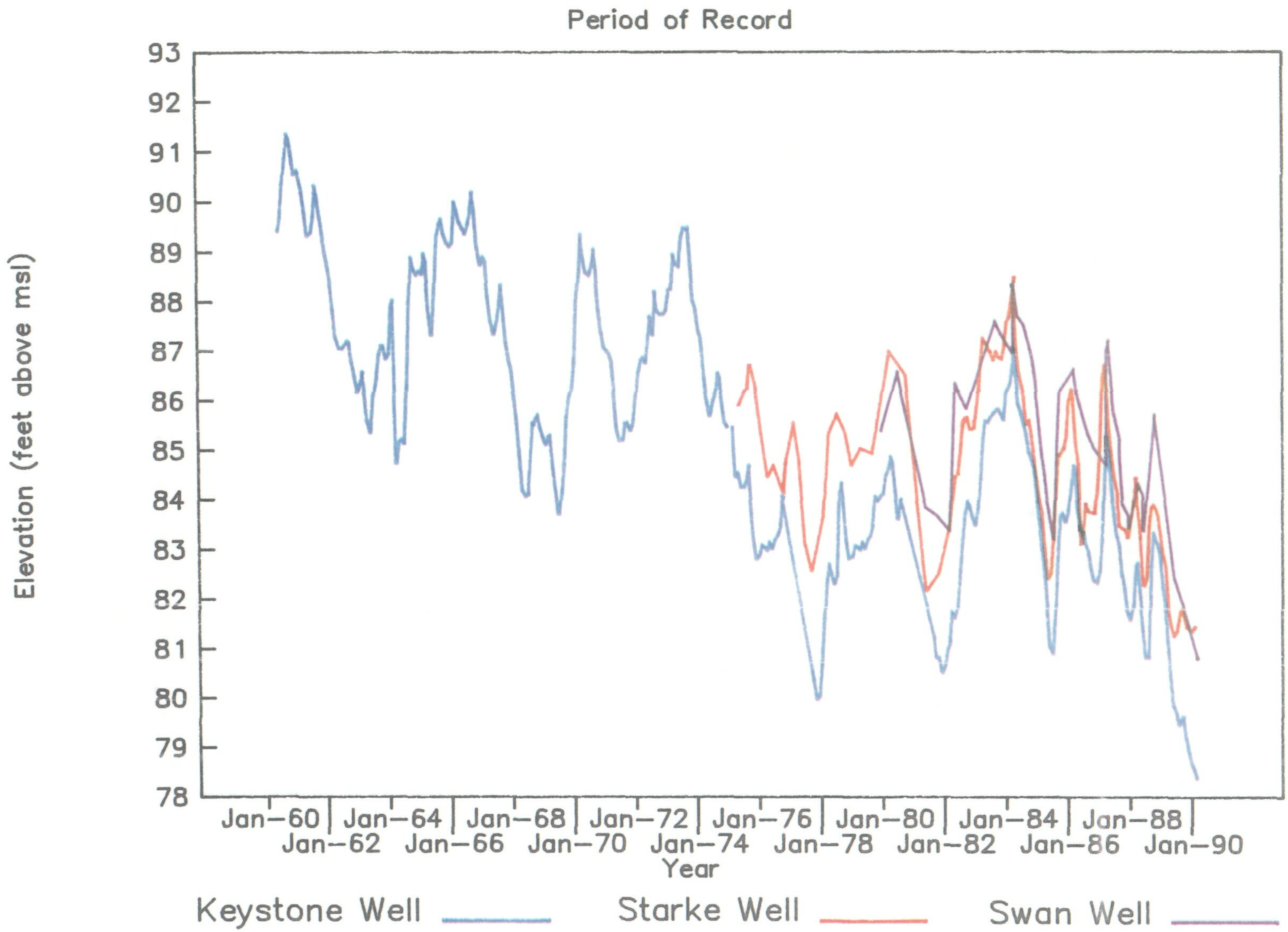


Figure 4.4 - Keystone, Swan, and Starke wells: period of record.

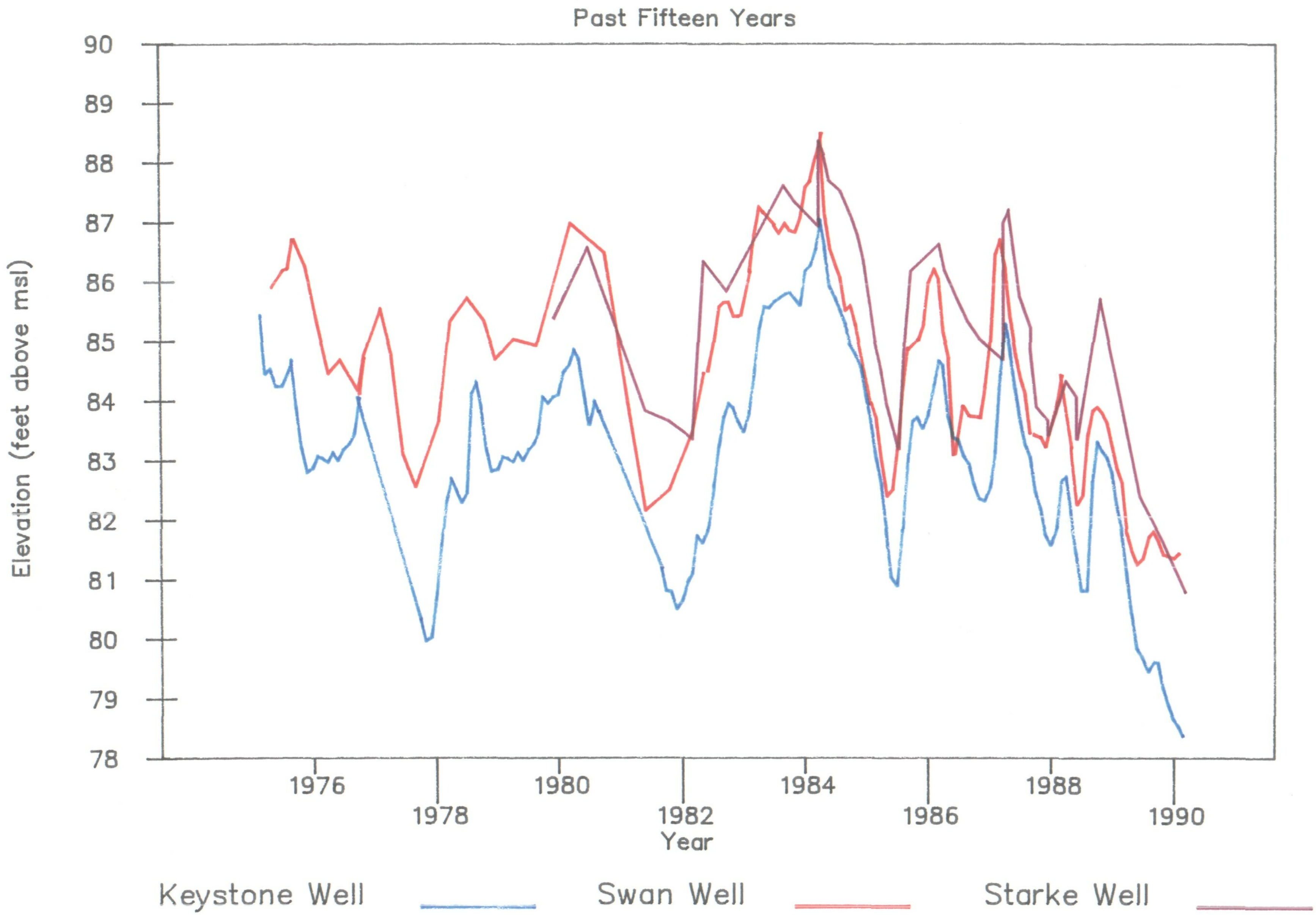


Figure 4.5 - Keystone, Swan, and Starke wells: past fifteen years.

Figure 4.6 - Lake Brooklyn: elevation and rainfall vs. time.

however, and major cones of depression have not developed in the potentiometric surface. Thus, these features are not evident in the SJRWMD potentiometric maps for the UECB (see Figures 3.14 through 3.17). However, these maps do indicate that a closed depression has formed on the potentiometric surface west of the UECB in eastern Alachua County. This cone of depression coincides with the location of the Gainesville Regional Utilities (GRU) Murphree Wellfield. Also, larger cones of depression occur east of the UECB in the Duval County area, reflecting the impacts that the naturally occurring discharges along the St. Johns River and relatively large pumping rates in Duval County have had on the potentiometric surface in that area.

The effects that pumping at Florida Rock's Gold Head and Grandin mines has had on Floridan aquifer and surficial aquifer water levels were estimated using an analytical model that calculates drawdowns in a pumped aquifer and, also, in an unpumped aquifer coupled to the pumped aquifer by a leaky confining bed (Motz 1978). Aquifer parameters were obtained from the results of two pumping tests that have been conducted at the mines and from published values representing the results of pumping tests and analyses at wellfields (see Table 4.1). The pumping rates used in the calculations represent the average annual pumping rates that are allowed by SJRWMD, based on the consumptive use permits for these mines. The wells at the Gold Head mine were aggregated into one center of pumping. Two wells are permitted at the Grandin mine, but only one well has been drilled and is in use. Thus, a single well was used in the analysis to indicate drawdown effects that might have occurred. A distance-drawdown plot indicates that the drawdown in the Floridan aquifer at a distance of 5,000 ft from the center of pumping at Gold Head mine is on the order of 0.3 ft at a pumping rate of 2.1 mgd (see Figure 4.7). Also, the drawdown in the Floridan aquifer at 5,000 ft from

Table 4.1 – Parameters Used for Drawdown Calculations.					
Gold Head Sand Mine			Grandin Sand Mine		
Parameter	Value	Source	Parameter	Value	Source
E =	1.5 E–4/day	Motz,1981	E =	1.5 E–4/day	Motz,1981
T1 =	321 ft^2/day	Motz,1981	T1 =	321 ft^2/day	Motz,1981
T2 =	49700 ft^2/day	Motz,1989	T2 =	32090 ft^2/day	Heninger & Ray,1985
K'/b' =	6.59 E–5/day	Motz,1989	K'/b' =	4.55 E–4/day	Heninger & Ray,1985
Q =	2.1 E6 gal/day	CUP File	Q =	1.5 E6 gal/day	CUP File

Note: E = evapotranspiration reduction rate
T1, T2 = transmissivity
K'/b' = leakance
Q = pumping rate

the well at the Grandin mine is on the order of 1.4 ft at a pumping rate of 1.5 mgd (see Figure 4.8). The drawdowns in the potentiometric surface of the Floridan aquifer would extend radially outward from the mines several thousand feet (see Figure 4.9). However, the magnitude of these drawdowns is not large compared to the drawdowns caused by such pumping centers as GRU's Murphree Wellfield (see Figure 3.14 through 3.17).

Drawdowns in the unpumped surficial aquifer due to pumping from the Floridan aquifer also were represented by distance-drawdown plots (see Figures 4.7 and 4.8). These drawdowns represent the maximum drawdowns that might occur in the surficial aquifer. These calculations are based on the assumption that all of the groundwater pumped is a consumptive loss and that none of it recharges the surficial aquifer. However, a significant amount of the water pumped is discharged to the surficial aquifer and ponds at the Florida Rock mines (see Figure 4.10). Thus, actual drawdowns in the surficial aquifer are probably considerably less than these calculated values, provided that recharge to the surficial aquifer takes place.

The drawdown calculations are based on the estimated pumping rates provided by Florida Rock at the time of the permit applications. The pumping rates at these wells are not measured. Thus, actual pumping rates may be more or less than the values used in the calculations, and, accordingly, the calculated drawdowns would be proportionally more or less, respectively, than the values obtained in this analysis. Also, the Floridan aquifer drawdowns are dependent primarily on the hydrologic parameters determined from the pumping tests conducted at the sand mines. If subsequent testing at the Gold Head mine indicates that the actual hydrologic parameters at the Gold Head mine are different from the parameters in Table 4.1, then the drawdown calculations for the Gold Head mine (Figures 4.7 and 4.9) may need to be revised.

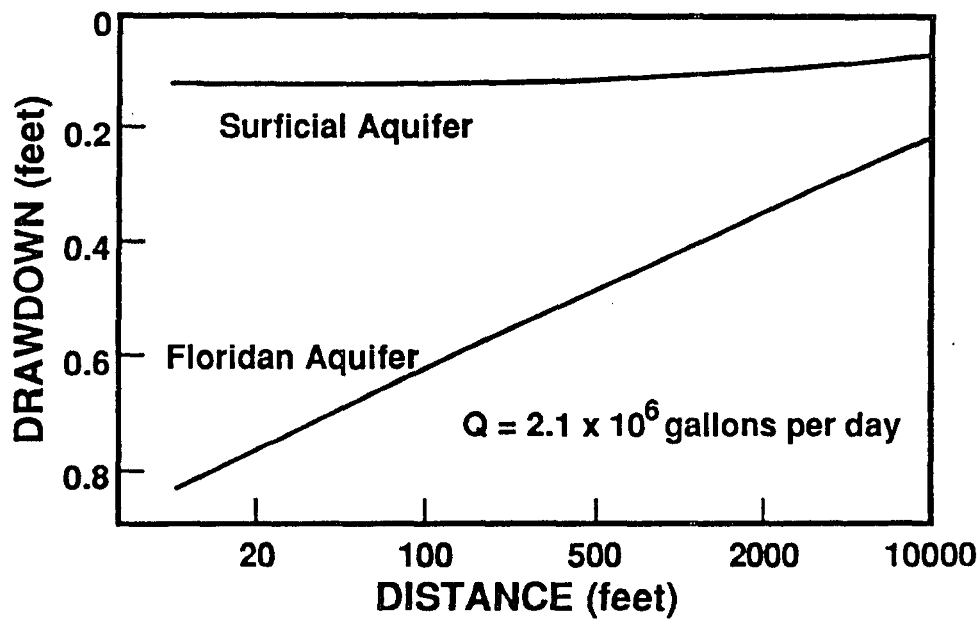


Figure 4.7 - Gold Head Sand Mine

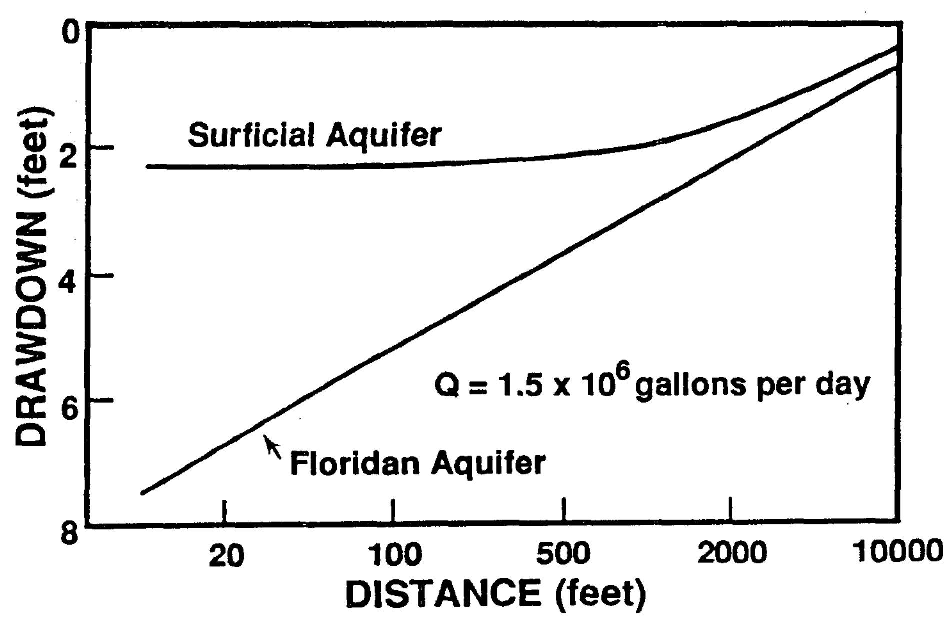


Figure 4.8 - Grandin Sand Mine

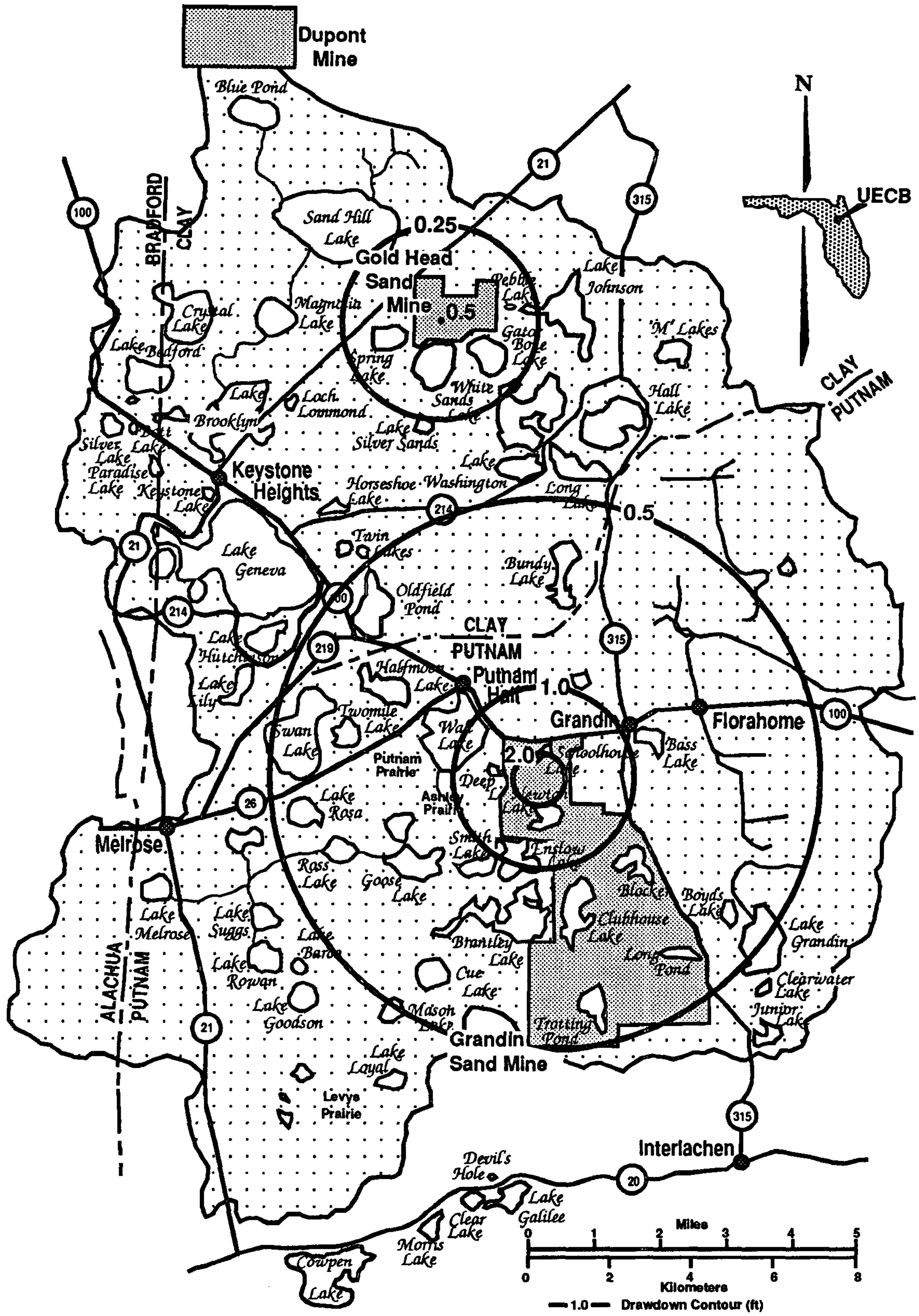


Figure 4.9 - Plan view of drawdown curves based on sand mine aquifer tests in UECB.

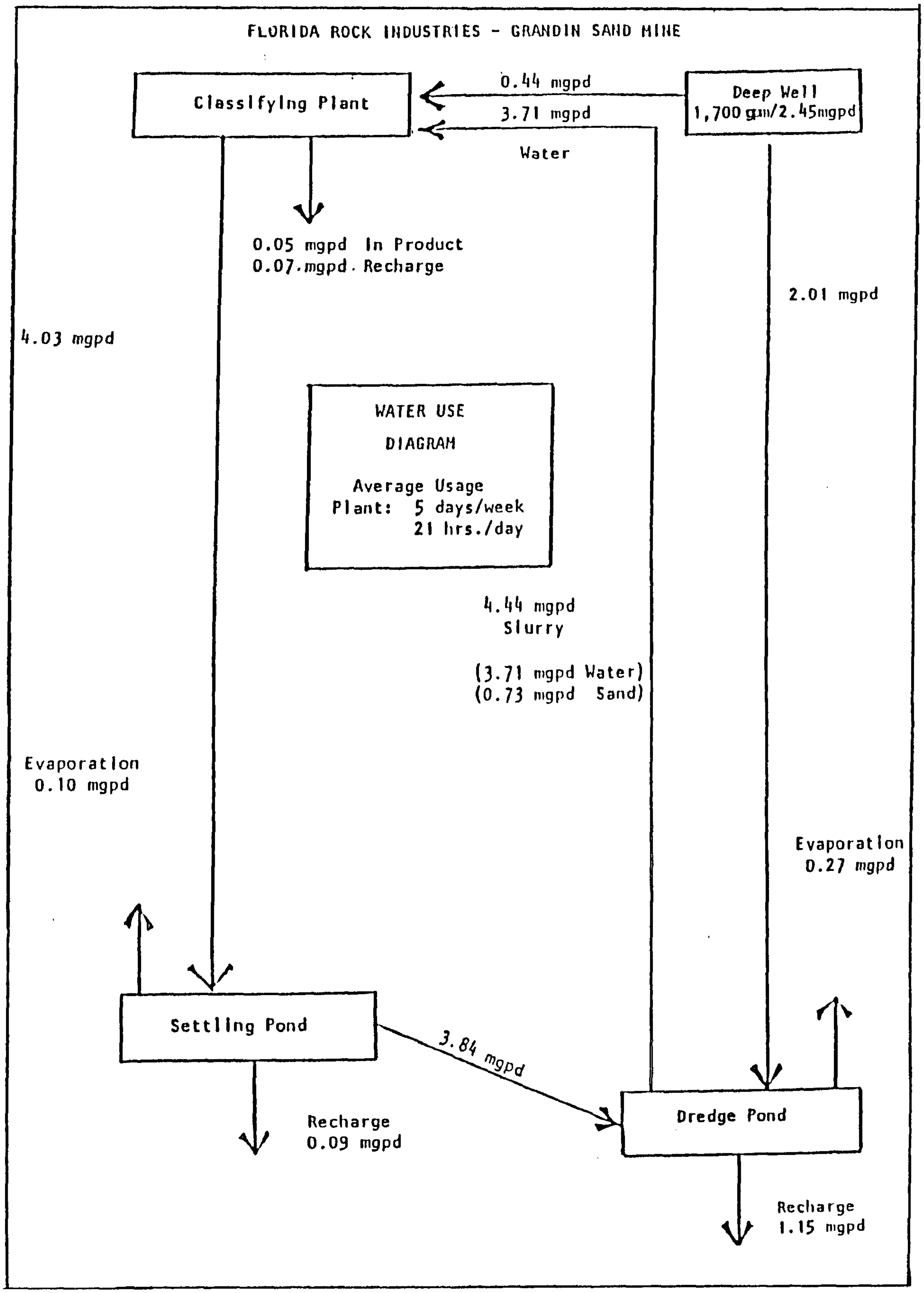


Figure 4.10 - Summary of Grandin sand mine operation.
(Source: SJRWMD CUP file, 1987)

5.0 SUMMARY AND CONCLUSIONS

5.1 Summary

The Upper Etonia Creek Basin (UECB), located in parts of Alachua, Bradford, Clay, and Putnam counties of Florida, is part of the lower St. Johns River Basin. The headwaters of this basin include a series of lakes that flow from one to another at various stages. The western part of the basin is a highland region known as Trail Ridge in northeast Florida. This region consists of high sandhills and karst features formed by solution of the underlying limestone. Many of the lakes in the region coincide with the karst features, and a hydraulic connection exists between the surface waters and the underlying aquifers. The UECB is an important recharge area for the Floridan aquifer, because of the net downward gradient between the lake and the surficial aquifer water levels and the potentiometric surface in the Floridan aquifer.

In recent years, lake levels and groundwater levels have declined by significant amounts in some parts of this area. This has prompted Clay County and concerned citizens to request that the St. Johns River Water Management District (SJRWMD) investigate the water resources of the area. In January 1990, the SJRWMD authorized the University of Florida (UF) to conduct an investigation to evaluate long-term changes and trends in lake levels in the basin, including changes in rainfall, evapotranspiration, groundwater levels, and water use in the basin. The findings of the UF investigation are summarized below.

Precipitation records are available from 1900 to the present for the City of Gainesville, located approximately 30 miles west-southwest from the UECB. Shorter-term records are available at the nearby towns of Melrose, Palatka, and Starke. The only part of the record for which all four of these stations were in operation was 1960-1969. The average annual rainfall for the period from 1900 to the present is 50.74 inches with a high of 68.99 inches in 1964 and a low of 29.22 inches in 1954. The wet season for the UECB, as for the rest of Florida, occurs during the summer months of June through September.

The annual precipitation does exhibit wet and dry cycles. During this century, three extended dry periods (1906-1920, 1930-1944, and 1954-1957) and two extended wet periods (1945-1953 and 1958-1976) have occurred. The wet period from 1958 to 1976 is the most significant cycle of the century. It occurred during a period when many people moved into the UECB and perhaps caused an overly optimistic view on the part of the local residents of the "typical" lake levels.

Evaporation measurements are available at Gainesville from 1954 to the present. The mean measured evaporation for this period is 61.63 inches per year. The actual lake evaporation and evapotranspiration is 20 to 35 percent less than the measured pan evaporation. Evaporation varies only 40 percent as much as precipitation and is greatest in the warmer months. No strong correlation was found between annual rainfall and evaporation.

The range in variability of lake stages in the UECB is remarkable. For the 13 lakes for which records are available, the stage range is from a low of 1.70 feet for Blue Pond to a high of 31.16 feet for Pebble Lake.

The UECB lakes with fluctuations less than 3.36 feet do not appear to be exhibiting any significant positive or negative trends in their levels. The typical lakes, Swan and Crystal, have been experiencing downward trends for the past several years. Lakes Geneva, Big Johnson, and Brooklyn have also been experiencing downward trends in recent years. However, Little Lake Johnson has been stable for the past 15 years, and Pebble Lake experienced an upward trend in its elevations during the 1980's.

A review of regional potentiometric maps prepared semi-annually indicates that a groundwater mound exists in the western part of the UECB. This mound is centered in the Keystone Heights area. This area is a major source of recharge to the underlying Floridan aquifer system. The elevation of the potentiometric surface is greater than 80 feet, NGVD, and decreases in all directions from the area. The elevation of the groundwater mound in the Keystone Heights area decreased by approximately 5.0 feet from May 1978 to September 1989. The local well levels have experienced similar declines.

Lake and groundwater levels closely follow the trends in precipitation with the exceptions of man's activities directly affecting lake stages.

Groundwater is pumped in the UECB for public supply, agriculture, and mining. The pumpage by public systems is metered, but the pumpage by agriculture and industry is not. The total estimated pumpage in the UECB is 6.724 mgd, the majority of which is for mining. This pumpage is not large enough to show a regional influence on the Floridan aquifer.

The effects of pumping at Florida Rock's Gold Head and Grandin mines on the Floridan aquifer were estimated using an analytical model that calculates drawdowns in a pumped aquifer and also in an unpumped aquifer coupled to the pumped aquifer by a leaky confining bed. Aquifer parameters were obtained primarily from two pumping tests.

5.2 Conclusions

The Gainesville precipitation station provides a reasonably accurate approximation of long-term precipitation in the UECB. However, significant short-term spatial and temporal variability exists in precipitation in the area. Thus, while the long-term records are very similar, significant variability may exist in individual storm events or monthly totals.

The 13 lakes in the UECB can be classified as to their stage ranges into the following groups based upon comparisons with 108 other Florida lakes:

Lakes	Range, feet	Rank
Blue Pond, Sand Hill	1.70-1.94	1,2
Hall, Kingsley, Smith, and Magnolia	2.80-3.36	6,8,9,12
Swan and Crystal	6.40-6.87	48,58
Geneva, and Big and Little Johnson	10.71-13.98	98,101,110
Brooklyn and Pebble	22.28-31.16	117,121

Thus, the UECB contains the entire range from most stable to least stable as measured by lake-level fluctuations.

The declining lake levels during the recent dry period correlate quite closely with trends in precipitation and evaporation for the UECB lakes which fluctuate more than about 3.5 feet with two notable exceptions, Little Lake Johnson and Pebble Lake. Little Lake Johnson's level has been stabilized by hydrologic modifications in Gold Head State Park. While it is not obvious why a positive trend in lake levels should be occurring at Pebble Lake, it may be influenced by nearby Little Lake Johnson and/or by the adjacent sand mining activity.

Only one long-term monitoring well located at Keystone Heights exists for the entire UECB. This well measures the potentiometric level in the Floridan aquifer. Short-term well records are available for two other wells at Swan Lake and Starke.

A distance-drawdown plot to estimate the influence of the sand mine pumpage indicates that the drawdown in the Floridan aquifer at a distance of 5,000 feet from the center of the pumping at Gold Head Mine is on the order of 0.3 feet, or 3.6 inches. Also, the drawdown in the Floridan Aquifer at 5,000 feet from the existing well at the Grandin mine is on the order of 1.4 feet. Drawdown estimates made for the surficial aquifer do not consider the amount of recycling of water that occurs in the mining operations. Thus, the surficial aquifer drawdowns would probably be less than the calculated values.

Overall, it is apparent that low rainfall is the primary cause for declining lake levels. This result is shown by the way that water levels in the lakes generally follow precipitation patterns. However, man's activities also influence lake levels as is dramatically shown by the changing behavior of Little Lake Johnson and Pebble Lake. Other lakes in the UECB may have been impacted by man's activities. However, with the available database, it is not possible to clearly detect these changes.

5.3 Recommendations

Additional precipitation gages are needed in the UECB in order to provide an accurate estimate of precipitation in the basin. Also, a closer look should be given to the behavior of Pebble Lake and Little Lake Johnson since they clearly show responses to man's activities.

With only one long-term well in the entire UECB, the groundwater monitoring database is very poor and severely limits our ability to evaluate the status and trends of regional groundwater movements. A significant expansion in groundwater monitoring activities is essential to evaluate this vital component of the hydrologic budget.

Pumpage by larger mining and agricultural activities needs to be metered in order to accurately perform a hydrologic budget for the UECB.

A second phase of this effort is recommended to investigate some of the hydrologic factors in more detail. This phase should include collection and evaluation of additional hydrogeologic data, simulation of additional lake-stage levels using water-budget data, development of a groundwater model, and development of a simulation and operations model for the Brooklyn chain of lakes.

6.0 REFERENCES

Bentley, C.B. 1977. Surface-Water and Ground-Water Features, Clay County, Florida, Water Resources Investigations 77-87, U. S. Geological Survey, Tallahassee, Florida.

Burtell, R.T. 1990. Potentiometric Surface Map of the Floridan Aquifer in the SJRWMD and Vicinity, Florida: September, 1989, Open-File Report 90-188, U.S. Geological Survey, Tallahassee, Florida.

Carroll, P.E. 1989. ForeCalc - The Add-In That Makes Accurate Forecasting Easy, Documentation Version 1.01, Business Forecast Systems, Inc., Belmont, MA.

Clark, W.E., Musgrove, R.H., Menke, C.G., and Cagle, J.W., Jr. 1963. Hydrology of Brooklyn Lake Near Keystone Heights, Florida, Report of Investigations No.33, Florida Geological Survey, Tallahassee, Florida.

Clark, W.E., Musgrove, R.H., Menke, C.G., and Cagle, J.W., Jr. 1964. Water Resources of Alachua, Bradford, Clay, and Union Counties, Florida, Report of Investigations No. 35, Florida Geological Survey, Tallahassee, Florida.

Fernald, E.A., and Patton, D.J., editors. 1984. Water Resources Atlas of Florida, Institute of Science and Public Affairs, Florida State University, Tallahassee, Florida.

Heninger and Ray Engineering Associates, Inc. 1985. Ground Water Impacts of Grandin Sand Mine. Written communication submitted to St. Johns River Water Management District.

Hughes, G.H. 1974. Water-Level Fluctuations in Lakes of Florida, Map Series 62, Florida Bureau of Geology, Tallahassee, Florida.

Lee, Terrie. 1990. U.S. Geological Survey, Tampa, Florida, personal communication.

Marella, R.L. 1981. Annual Water Use Survey - 1979, Technical Publication SJ 81-3, St. Johns River Water Management District, Palatka, Florida.

Marella, R.L. 1990. Annual Water Use Survey: 1987, Technical Publication SJ 90-4, St. Johns River Water Management District, Palatka, Florida.

Motz, L.H. 1978. Steady-State Drawdowns in Coupled Aquifers, Jour. of the Hydraulics Division, American Society of Civil Engineers, Vol. 104, HY7, p. 1061-1074.

Motz, L.H. 1981. Well-Field Drawdowns Using Coupled Aquifer Model, Jour. of Ground Water, Vol. 19, No.2, p. 172-179.

Motz, L.H. 1989. Review of Pumping Tests at Gold Head Sand Mine, Report submitted to St. Johns River Water Management District, 11 p.

Puri, H.S. and Vernon, R.O. 1964. Summary of the Geology of Florida and a Guide Book to the Classic Exposures, Special Publication No. 5, Florida Geological Survey, Tallahassee, Florida

Rao, D.V., Osburn, W., and Marella, R. 1986. Annual Report of Hydrologic Conditions: 1984 Water Year, Technical Publication SJ 86-1, St. Johns River Water Management District, Palatka, Florida.

Schiner, G.R., and Hayes, E.C. 1983. Potentiometric Surface Map of the Floridan Aquifer in the SJRWMD and Vicinity, Florida: September, 1982, Open-File Report 83-30, U.S. Geological Survey, Tallahassee, Florida.

Southeastern Geological Society. 1986. Hydrogeologic Units of Florida, Special Publication No. 28, Florida Geological Survey, Tallahassee, Florida.

Spechler, R.M. 1987. Potentiometric Surface Map of the Floridan Aquifer in the SJRWMD and Vicinity, Florida: September, 1986, Open-File Report 87-36, U.S. Geological Survey, Tallahassee, Florida.

Watkins, F.A., Laughlin, C.P., and Hayes, E.C. 1979. Potentiometric Surface Map of the Floridan Aquifer in the SJRWMD and Vicinity, Florida: May, 1978, Open-File Report 79-257, U.S. Geological Survey, Tallahassee, Florida.

Yobbi, D.K.,and Chappell, G.C. 1979. Summary of the Hydrology of the Upper Etonia Creek Basin, Technical Publication SJ 79-5, St. Johns River Water Management District, Palatka, Florida.

7.0 APPENDICES

A1. Lake stage data

Geoff Leiter

UPPER ETONIA CREEK DRAINAGE BASIN DATA:

Recorded Years>	84–89	76–89	86–89	86–89	59–67	57–90	45–89	59–89	60–89	57–89	45–90	45–89	57–89
Lake>	CRYSTA	SWAN	SMITH	HALL	BLUE PON	BROOKLY	LT JOHNSO	JOHNSO	MAGNOLI	GENEVA	KINGSLY	PEBBLE	SAND HILL
date	elev	elev	elev	elev	elev	elev	elev	elev	elev	elev	elev	elev	elev
Jul-45											177.16	103.62	
Aug-45							97.81				177.03	103.58	
Sep-45							98.08				176.86	103.88	
Oct-45							98.07				176.56	103.94	
Nov-45							97.87				176.52	103.84	
Dec-45							97.92				177.01	104.60	
Jan-46							98.43				176.62	104.90	
Feb-46							98.45				176.32	105.32	
Mar-46							98.38				176.32	105.20	
Apr-46							98.30					105.02	
May-46							98.63					105.86	
Jun-46							98.89					106.86	
Jul-46							98.96					107.81	
Aug-46							99.73						
Sep-46							99.94						
Oct-46							99.99				176.27		
Nov-46							99.94					111.15	
Dec-46							99.78					110.96	
Jan-47							99.75					110.98	
Feb-47							100.06					110.58	
Mar-47							100.30				176.46	110.54	
Apr-47							100.01					110.42	
May-47							99.89				176.46	110.02	
Jun-47							99.95				176.42	109.60	
Jul-47							99.97				176.46	108.96	
Aug-47							100.01				176.44	108.86	
Sep-47							100.83				176.90	108.96	
Oct-47							101.92				177.06	109.76	
Nov-47							101.91				176.58	111.46	
Dec-47							102.15				176.42	112.56	
Jan-48							102.73				176.68	113.16	
Feb-48							103.80				176.58	113.46	
Mar-48							103.81				176.78	113.76	
Apr-48							103.69				176.43	115.40	
May-48							103.44				176.60	115.16	
Jun-48							104.19				176.31	115.06	
Jul-48							103.62				176.49	114.16	
Aug-48							103.91				176.37	114.16	
Sep-48							103.90				176.43		
Oct-48							105.00				176.67	114.66	
Nov-48							103.85				176.91	114.36	
Dec-48							103.63				176.84	113.96	
Jan-49							103.61				176.45	113.46	
Feb-49							104.06				176.44	113.06	
Mar-49							103.46				176.64	112.46	
Apr-49							103.61				177.15	112.46	
May-49							102.93				176.71	111.16	
Jun-49							102.86				176.12	111.56	
Jul-49							102.81				175.93	109.76	
Aug-49							102.33				175.98	109.26	
Sep-49							102.78				176.42	108.11	
Oct-49							102.48				176.40	107.92	
Nov-49							102.31				176.66	107.46	
Dec-49							102.08				176.29	107.01	
Jan-50							101.68				176.41	106.56	
Feb-50							101.34				176.33	105.46	
Mar-50							101.13				176.48	104.51	
Apr-50											176.29	104.56	
May-50							100.91				176.44	104.16	
Jun-50							99.55				176.39	102.16	
Jul-50							99.63				176.30	101.86	
Aug-50							99.58				176.25	101.26	
Sep-50											176.20		
Oct-50											176.43		
Nov-50											176.33	104.68	
Dec-50							99.87				176.40	105.24	
Jan-51							100.00				176.31	105.71	
Feb-51											176.23		
Mar-51											176.12		
Apr-51											176.08		
May-51											176.02		
Jun-51											176.01		

Jul-51							97.76				175.85		
Aug-51											176.30		
Sep-51											176.41		
Oct-51							97.67				176.93		
Nov-51							97.21				177.45		
Dec-51							97.18				177.14		
Jan-52							96.86				176.79		
Feb-52							96.97				176.78		
Mar-52							96.87				176.75		
Apr-52							96.73				176.75		
May-52							96.93				176.79		
Jun-52							96.84				176.55		
Jul-52							96.68				176.30	96.84	
Aug-52							96.80				176.31	96.84	
Sep-52							96.66				176.55	98.24	
Oct-52							96.65				176.68	98.31	
Nov-52											176.74		
Dec-52											176.68	98.76	
Jan-53							96.13				176.79	98.76	
Feb-53							96.13				176.77	98.36	
Mar-53							96.03				176.90	98.36	
Apr-53							96.01				177.09	98.86	
May-53							96.05				176.80	98.96	
Jun-53							95.63				176.50	98.64	
Jul-53							95.80				176.69	100.06	
Aug-53							96.44				176.64	101.16	
Sep-53							97.66				176.40		
Oct-53							98.14				176.43		
Nov-53							98.27				176.57		
Dec-53							98.68				176.43		
Jan-54							98.97				176.29		
Feb-54							99.05				176.40		
Mar-54							98.93				176.65		
Apr-54							98.69				176.65		
May-54							98.35				177.06		
Jun-54							97.98				176.77		
Jul-54							97.77				176.60		
Aug-54							97.35				176.85		
Sep-54							97.08				177.19		
Oct-54							97.14				177.14	100.92	
Nov-54							96.80				176.75	100.56	
Dec-54							96.70				176.45	99.08	
Jan-55							96.21				176.52	99.10	
Feb-55							96.26				176.70	98.00	
Mar-55							95.79				176.51	96.64	
Apr-55							95.45				176.40	95.60	
May-55							94.69				176.41	94.62	
Jun-55							94.00				176.18	93.44	
Jul-55							93.64				175.93	93.00	
Aug-55							93.70				175.82	92.12	
Sep-55							93.02				175.59	91.36	
Oct-55							92.88				175.44	90.60	
Nov-55							92.91				175.54	90.04	
Dec-55							92.82				175.34	89.24	
Jan-56							92.77				175.17	88.78	
Feb-56							92.87				175.25	88.58	
Mar-56							92.66				175.56	87.76	
Apr-56							92.28				175.59	87.24	
May-56							92.30				175.52	86.54	
Jun-56							92.06				175.23	86.48	
Jul-56							92.25				174.96	86.07	
Aug-56							92.06				174.98	85.72	
Sep-56							92.08				175.01	85.61	
Oct-56							92.11				175.05	85.82	
Nov-56							92.20				175.02	85.44	
Dec-56							92.03				174.79	85.16	
Jan-57							91.92				174.61	84.91	
Feb-57							91.90				174.52	84.71	
Mar-57							92.17				174.78	84.64	
Apr-57							92.22				174.79	84.24	
May-57							92.46				174.42	84.92	
Jun-57							93.15				174.72	85.36	
Jul-57						98.09	94.11			100.69	174.69	86.16	131.33
Aug-57						97.95	94.83			100.58	175.12	86.86	131.40
Sep-57						98.24	94.84			100.89	175.00	87.84	131.40
Oct-57						97.93	95.00			100.79	174.91	89.18	131.60
Nov-57						97.66	95.03			100.66	175.18	91.15	131.41
Dec-57						97.40				100.48	175.30	92.50	131.34
Jan-58						97.47	95.04			100.54	175.07	93.16	131.40
Feb-58						97.43	95.04			100.57	174.92	93.18	131.40
Mar-58						97.58	94.98			100.81	174.88	94.16	131.70

Apr-58						98.08	94.98			100.88	174.95	94.77	131.90
May-58						98.53	94.70			100.61	175.13	95.30	131.72
Jun-58						98.35	94.99			100.39	175.18	95.62	131.55
Jul-58						98.84	95.01			100.44	175.58	95.53	131.35
Aug-58						99.36	95.01			100.33	175.82	95.42	131.40
Sep-58						99.32				100.01	176.48	94.64	131.43
Oct-58					173.40	99.29	95.04			99.81	176.55	94.04	131.61
Nov-58						99.63	94.96			99.92	176.70	93.54	131.41
Dec-58					174.10	99.93	94.99			99.99	176.33	93.02	131.35
Jan-59						100.81	94.99			100.14	176.19	92.66	131.39
Feb-59					174.00	101.39	95.00	91.38		100.25	176.19	92.38	131.36
Mar-59						103.89	95.03	91.45		100.89	176.23	93.28	131.70
Apr-59					174.00	105.43	95.09	91.32		100.88	176.62	95.92	131.86
May-59						107.14	95.14			101.13	176.71	98.42	131.71
Jun-59					174.15	109.51	95.25	93.50		101.42	176.58	99.62	131.57
Jul-59					174.00	110.96	95.19	94.00		101.59	176.28	100.88	131.63
Aug-59					173.90	112.20	95.23			101.99	176.33	102.73	131.55
Sep-59					174.10	114.28	95.34	95.25		102.31	176.48	103.58	131.40
Oct-59						115.59				102.37	176.18	106.66	131.26
Nov-59					173.80	115.85	95.74	95.70		102.23	176.01	106.94	131.38
Dec-59					173.70	115.81	95.68			102.19	176.16	107.02	131.41
Jan-60					173.50	115.73	95.63	95.70		102.19	176.28	106.74	131.67
Feb-60					174.20	115.83	95.59	95.60		102.28	176.56	106.53	131.64
Mar-60					174.00	116.51				102.67	176.51	106.78	132.04
Apr-60					174.10	116.97	96.36			102.79	176.95	107.00	132.05
May-60					173.60	116.34	96.49		124.44	102.55	176.80	107.40	131.98
Jun-60						116.26	96.24	96.20	124.26	102.88	176.67	106.94	132.38
Jul-60					174.20	116.80	96.13		124.50	103.57	176.73		132.16
Aug-60						116.93	97.10		124.73	103.81	176.54	107.26	132.04
Sep-60						117.41			125.02	104.73	176.39		132.38
Oct-60						116.91	98.30	98.35	125.08	105.17	176.92	109.76	132.30
Nov-60						116.55	98.44	98.47	124.79	105.45	176.78	110.04	132.00
Dec-60					173.68	116.07	98.35	98.39	124.52	105.49	176.32	109.90	131.70
Jan-61						116.06	98.35	98.37	124.54	105.50	176.15	109.72	131.65
Feb-61					173.96	116.21	98.47	98.51	124.71	105.61	176.18	109.48	131.59
Mar-61					174.10	116.34	98.33	98.19	124.63	106.07	176.37	108.74	131.85
Apr-61						116.26	97.98	98.01	124.40	105.91	176.53	107.84	132.09
May-61					173.47	115.56	97.58	97.61	124.17	105.71	176.53	106.92	131.77
Jun-61							97.30	97.31	124.01	105.63	176.23	105.94	131.59
Jul-61					173.76		97.43	97.43	124.57	105.59	176.03	105.54	131.81
Aug-61					174.18	116.13	97.32	97.31	125.15	106.31	176.39	104.90	132.00
Sep-61					174.16	117.07	97.67	97.64	125.36	106.41	176.52	105.12	132.26
Oct-61							97.34	97.38	124.88		176.55	104.89	
Nov-61					173.90	116.30	97.17	97.17	124.80	106.20	176.59	104.69	131.72
Dec-61							96.87	96.87	124.59		176.23	104.13	
Jan-62					173.50	115.62	96.61	96.63	124.49	105.79	176.03	103.50	131.40
Feb-62							96.36	96.33	124.49		176.06	102.77	
Mar-62					173.50	115.38	96.02	95.88	124.22	105.69	176.34	101.86	131.38
Apr-62					173.30	114.46	95.53	95.50	124.17	105.21	176.41	100.51	131.12
May-62						113.78	95.21	95.19	123.80	104.97	176.35	99.07	131.36
Jun-62					173.50	113.55	95.13	95.13	124.07		176.15	97.85	
Jul-62							95.07	95.09	124.41		176.16	96.69	
Aug-62					173.50	113.52	94.99	94.93	124.79	104.79	176.52	95.58	131.62
Sep-62							94.95	94.94	124.82		176.78	94.46	
Oct-62					173.40	113.66	94.91		124.52	104.49	176.67	93.41	131.50
Nov-62					172.70	112.53	94.94		124.15	104.04	176.13	92.38	131.06
Dec-62						112.07	94.93		124.07		176.21	91.62	
Jan-63					173.20	111.75	94.93	91.38	124.12	103.77	176.09	90.84	131.14
Feb-63							95.00	91.48	124.37		176.02	90.56	
Mar-63					173.70	111.58	94.92	91.40	124.36	104.07	176.13	90.18	131.50
Apr-63					172.90		94.84	90.75	123.96	103.30	176.08	89.37	
May-63						110.48	94.84	90.41	123.62		176.04	88.83	130.95
Jun-63					173.00	109.25	94.92	90.45	123.76	102.69	175.84	88.74	130.99
Jul-63					173.70	109.84	95.03	91.59	124.35	103.05	176.10	89.71	131.52
Aug-63							95.09	91.81	124.76		176.11	90.27	
Sep-63					173.80	110.84	95.08	92.04	124.83	103.13	176.20	91.57	
Oct-63					173.50		95.11	92.52	124.80		176.04	93.92	131.71
Nov-63						111.14	95.10	92.45	124.55	102.81	175.79	95.32	
Dec-63						110.98	95.09	92.34	124.40	102.68	175.46	96.28	131.37
Jan-64					174.10	111.72	95.13	92.95	124.76	103.22	175.37	97.54	131.96
Feb-64							95.10	93.51	125.01		175.51	98.32	
Mar-64					173.70	113.67	95.10	93.85	124.90	103.42	175.92	99.34	131.82
Apr-64							95.09	93.64	124.50		176.15	99.81	
May-64					173.50	113.74	95.05	93.34	124.50	103.25	175.93	99.85	131.58
Jun-64							95.02	92.66	124.18		175.73	99.31	
Jul-64					173.30	112.71	95.04	92.39	124.44	102.73	175.64	98.96	131.42
Aug-64							95.09	92.70	125.03		176.42	99.22	
Sep-64					174.40	116.11	95.20	94.27	125.59	103.83	176.52	101.36	132.73
Oct-64					173.90	116.60	95.20	94.78	125.34	103.89	176.43	103.80	132.23
Nov-64							95.20	95.06	125.12		176.34	105.06	
Dec-64					173.90	116.38	95.30	95.28	125.12	104.21	176.08	105.67	132.02

Jan-65					173.90	116.47	95.46	95.45	125.01	104.84	175.99	105.75	132.01
Feb-65							95.61	95.59	125.03		176.45	105.67	
Mar-65					174.10	116.66	95.91	95.91	125.15	105.70	176.61	105.82	132.08
Apr-65					173.60	116.50	95.88	95.88	124.82	105.94	176.49	105.87	131.84
May-65							95.42	95.38	124.40		176.24	105.33	
Jun-65					172.90	115.27	95.95	95.77	124.59		176.39	105.53	131.30
Jul-65							96.45	96.45	124.89	106.03	175.99	106.49	
Aug-65					174.00	116.90	97.44	97.44	125.34	106.45	176.07	108.82	132.23
Sep-65						116.79	97.60	97.60	125.13	106.33	176.53	110.29	131.92
Oct-65					173.90	116.70	97.84		125.18	106.43	177.16	111.04	132.02
Nov-65						116.28	97.67		124.82	106.20	176.58	110.88	131.74
Dec-65					173.30	116.04	97.66		124.81	106.13	176.37	110.63	131.79
Jan-66					173.50	115.94	97.78		124.89	106.29	176.39	110.15	131.82
Feb-66						115.94	97.95		125.03	106.36	176.31	109.68	131.90
Mar-66					174.20	116.36	98.25		125.17	106.89	176.42	109.68	132.09
Apr-66					173.60	115.91	98.07		124.75	106.56	176.50	109.54	131.73
May-66					174.00	115.69	98.15		124.71	106.49	176.19	109.34	131.81
Jun-66						115.73	98.06		124.73		175.84	108.82	131.84
Jul-66					173.80	115.76	97.98		124.77	106.46	175.98	108.16	131.84
Aug-66					173.90	115.91	98.01		124.89	106.96	176.34	107.44	131.93
Sep-66						116.11			124.99	106.81	176.47		131.80
Oct-66					173.80	116.09	98.12			106.93	176.17	106.90	131.86
Nov-66					173.30	115.69	97.79			106.37	176.02	106.28	131.66
Dec-66						115.34	97.54			106.21	175.80	105.76	131.48
Jan-67					173.50	115.39	97.48			106.33	175.81	105.16	131.58
Feb-67					174.00	115.52	97.54			106.48	176.04	104.62	131.77
Mar-67					173.40	115.54	97.30			106.41	176.27	103.93	131.63
Apr-67						115.16	96.50			106.04	176.72	102.83	131.35
May-67					173.20	114.96	96.37			105.82	176.32	102.43	131.23
Jun-67					173.50	114.36	96.50			105.95	176.55	101.80	131.38
Jul-67						114.14	96.54			106.15	176.46	101.66	131.52
Aug-67						114.47	96.54			106.18	176.50	102.03	131.80
Sep-67					173.70	114.52	96.40			105.94	176.46	102.07	131.65
Oct-67					173.40	114.00	96.11		124.42	105.49	176.29	101.94	131.39
Nov-67						113.23	95.77		124.01	105.16	176.38	101.64	131.15
Dec-67						112.71	95.60		124.11	105.05	176.19	101.09	131.33
Jan-68						112.28	95.00	95.30	124.10	104.98	175.91	100.33	131.30
Feb-68						111.64	94.62	94.64	123.95	104.75	176.09	99.44	131.18
Mar-68						111.07	94.34	94.13	123.98	104.54	176.36	98.40	131.18
Apr-68						110.29	94.09	93.53	123.60	104.26	176.18	97.18	130.99
May-68						109.44	93.88	92.60	123.25	103.87	175.91	95.59	130.79
Jun-68						108.91	94.79	92.09	123.33	103.79	175.70	94.41	130.95
Jul-68						108.34	94.93	91.65	123.42	103.75	175.67	93.19	131.12
Aug-68						107.71				103.57	175.99		131.24
Sep-68						108.44	93.49	92.74		104.03	176.40	93.02	131.84
Oct-68						108.74	93.23	92.65		103.86	176.07	93.56	131.78
Nov-68						109.04	94.15	92.85		103.83	175.78	94.46	131.74
Dec-68						108.94	93.56	92.65		103.57	175.52	95.05	131.48
Jan-69						108.72	93.19	92.39		103.39	175.65	95.07	131.40
Feb-69						108.55	93.16	92.01		103.38	175.78	94.92	131.43
Mar-69						108.63	93.20	92.41		103.44	175.70	94.77	131.59
Apr-69						108.63	93.54	92.09	124.19	103.32	175.70	94.44	131.50
May-69						108.33	94.71	91.44	124.23	103.04	175.56	94.24	131.51
Jun-69						107.90	95.24	91.21	124.14	102.79	175.41	94.06	131.44
Jul-69						107.26	95.28	90.72	124.04	102.50	175.66	93.32	131.26
Aug-69						107.28	95.42	91.00	124.39	102.74	175.98	93.40	131.58
Sep-69						107.41	95.48	91.39	124.45	102.86	176.42	94.06	131.55
Oct-69						108.12			124.92	103.23	177.02		131.87
Nov-69						108.75	94.84	92.35	124.99	103.20	176.52	96.80	131.94
Dec-69						109.37	95.53	92.77	124.94	103.20	176.42	97.95	131.93
Jan-70						110.37	95.56	93.27	125.14	103.42	176.11	98.84	132.06
Feb-70						112.32	95.61	94.36	125.63		176.04	100.75	132.44
Mar-70						114.24	95.73	94.99	125.40	104.36	176.18	102.91	132.44
Apr-70						116.04	95.89	95.78	125.56	105.00	176.42	104.84	132.55
May-70						115.77	95.71	95.67	124.97	105.08	176.29	105.91	132.02
Jun-70						115.58	95.75	95.67	124.97	105.32	176.23	106.54	131.99
Jul-70						115.69	95.77	95.70	125.12	105.83	176.11	106.64	132.00
Aug-70						115.68	96.04	95.99	125.40	106.23	176.06	106.86	132.14
Sep-70						115.95	96.19	96.15	125.36	106.47	176.28	107.10	132.00
Oct-70						115.41	95.87	95.82	124.87	106.20	176.29	106.74	131.64
Nov-70						114.95	95.72	95.53	124.65	105.97	176.53	106.03	131.52
Dec-70						114.35	95.55	95.07	124.48	105.60	176.49	105.21	131.37
Jan-71						114.17	95.50	94.94	124.61	105.59	176.60	104.38	131.48
Feb-71						114.09	95.50	94.84	124.68	105.70	176.69	103.57	131.58
Mar-71						114.02	95.43	94.61	124.63	105.59	176.97	102.60	131.54
Apr-71						113.88	95.36	94.42	124.53	105.42	176.69	101.85	131.52
May-71						113.34	95.32	93.82	124.32	105.12	176.86	100.76	131.41
Jun-71						112.58	95.35	93.10	124.21	104.87	176.22	99.73	131.42
Jul-71						112.22	95.39	93.23	124.34	104.78	176.13	99.44	131.40
Aug-71						112.05	95.38	93.00	124.66	104.78	176.20	99.05	131.65
Sep-71						112.50	95.42	93.34	125.03	105.02	176.35	99.66	131.87

Oct-71						112.62	95.50	93.33	124.90	104.89	176.38	100.33	131.74
Nov-71						112.36	95.41	93.05	124.78	104.57	176.03	100.62	131.56
Dec-71						112.60	95.39	93.44	124.97	104.75	175.78	101.08	131.72
Jan-72						112.79	95.38	93.45	124.89	104.78	175.58	101.13	131.72
Feb-72						113.10	95.36	93.63	124.93	104.81	175.70	101.27	131.85
Mar-72						113.28	95.32	93.50	124.90	104.69	175.82	101.34	131.77
Apr-72						113.64	95.38	93.69	124.93	104.75	175.83	101.92	131.82
May-72						113.77	95.44	93.84	124.97	104.78	175.82	102.56	131.85
Jun-72						114.80			125.27	105.06	175.67		132.07
Jul-72						115.66	95.46	94.67	125.25	105.22	175.75	104.08	132.03
Aug-72						115.70	95.47	94.82	125.18	105.20	175.99	104.66	131.98
Sep-72						116.38	95.57	95.46	125.53	105.93	176.22	105.39	132.10
Oct-72						115.69	95.52	95.32	124.85	105.75	176.32	105.51	131.70
Nov-72						115.43	95.52	95.32	124.92	105.78	176.04	105.54	131.71
Dec-72						115.66	95.63	95.60	125.09	106.04	175.98	105.51	131.90
Jan-73						115.83	95.70	95.65	125.11	106.23	176.20	105.14	131.93
Feb-73						115.84	95.88	95.84	125.18	106.40	176.22	105.08	132.00
Mar-73						115.78	95.97	95.94	125.09	106.42	176.35	104.91	131.94
Apr-73						116.17	96.52	96.52	125.35	106.72	176.23	105.77	132.16
May-73						115.76	96.35	96.34	125.01	106.37	176.27	106.32	
Jun-73						115.91	96.69	96.68	125.27	106.70	176.19	107.17	132.14
Jul-73						116.59	97.28	97.28	125.77	107.08	176.45	108.89	132.27
Aug-73						116.49	97.60	97.60	125.63	107.10	176.53	109.72	132.25
Sep-73						116.30	97.65	97.65	125.63	106.86	176.63	109.93	132.12
Oct-73						115.81	97.49	97.49	125.05	106.46	176.71	109.67	131.80
Nov-73						115.27	97.20	97.20	124.67	106.07	176.13	109.16	131.61
Dec-73						115.10	97.09	97.09	124.73	106.05	176.10	108.51	131.70
Jan-74						115.22	96.92	96.92	124.79	106.08	176.21	107.67	131.74
Feb-74						114.99	96.46	96.46	124.57	105.95	176.18	106.53	131.57
Mar-74						114.53	96.10	96.10	124.36	105.76	176.31	105.44	131.52
Apr-74						113.99	95.78	95.76	124.23	105.60	176.25	103.88	131.42
May-74						113.20			124.13	105.35	176.47		131.39
Jun-74						112.57	94.51	94.61	124.17	105.19		101.07	131.45
Jul-74						112.46	94.48	94.72	124.65	105.47	176.32	100.11	131.81
Aug-74						112.77	94.30	94.64	124.88	105.63	176.48	99.32	131.87
Sep-74						113.64	94.18	94.39	125.32	106.05	176.57	98.63	132.18
Oct-74						113.75	93.61	93.78	124.92	105.61	176.51	98.18	131.76
Nov-74						113.24	93.09	93.20	124.60	105.24	176.13	97.80	131.52
Dec-74						112.82	92.84	92.89	124.56	105.15	175.82	97.53	131.50
Jan-75						112.74	92.86	92.79	124.65	105.23	175.90	97.23	131.71
Feb-75						112.74	92.69	92.63	124.72	105.32	176.03	96.67	131.71
Mar-75						112.56	92.40	92.18	124.62	105.29	176.01	95.80	131.61
Apr-75						111.98	91.86	91.57	124.33	104.99	175.91	94.71	131.45
May-75						111.33	91.40	91.03	124.08	104.77	175.96	93.68	131.36
Jun-75						110.79	91.09	90.60	123.86	104.53	175.84	92.76	131.43
Jul-75						110.59	91.02	90.38	124.60	104.56	175.97	92.15	131.72
Aug-75						110.62	91.08	90.22	124.66	104.60	176.32	91.50	131.72
Sep-75						110.70	92.12	90.05	124.89	104.65	176.56	90.96	131.86
Oct-75						111.04	93.15	90.02	125.20	104.55	176.54	90.64	131.89
Nov-75						110.84	93.51	89.83	124.80	104.22	176.11	90.26	131.63
Dec-75		93.10				110.39	93.74	89.70	124.60	103.91	175.86	89.74	131.46
Jan-76		93.00				110.12	94.30	89.79	124.58	103.89	175.81	89.55	131.44
Feb-76		92.80				109.79	94.46	89.72	124.57	103.77	176.07	89.19	131.51
Mar-76		92.60				109.10	94.09	89.36	124.31	103.40	176.16	88.47	131.21
Apr-76						108.26	94.22	88.87	123.98	103.15	176.13	87.71	131.20
May-76		91.80				107.63	94.83	88.63	123.75	102.96	176.12	87.24	131.15
Jun-76		91.90				107.43	95.16	88.73	124.19	103.25	176.00	87.19	
Jul-76		91.70				107.28	95.19	88.88	124.59	103.16	176.03	87.10	131.48
Aug-76		91.30				106.73	95.05	88.46	124.33	102.82	176.09	86.66	131.38
Sep-76		91.00				106.17	95.18	88.69	124.46	102.54	176.10	86.59	131.20
Oct-76		90.70				105.66	95.21	88.70	124.35	102.15	176.34	86.44	131.50
Nov-76		90.10				104.84	95.28	88.45	123.95	101.75	176.37	86.02	131.22
Dec-76		90.10				104.66	95.28	88.58	124.23	101.85	176.05	86.07	131.20
Jan-77		90.40				104.95	95.40	88.64	124.62	102.15	175.83	86.63	131.66
Feb-77		90.40				105.03	95.39	88.62	124.57	102.10	175.95	86.86	131.56
Mar-77		90.30				105.00	95.35	88.59	124.48	102.01	176.03	86.85	131.62
Apr-77		89.90				104.43	95.31	88.44	124.05	101.50	175.92	86.89	131.27
May-77		89.50				103.71	95.22	88.12	123.66	101.15	175.90	86.69	
Jun-77		89.10				102.86	95.23	88.11	123.31	100.91	176.00	86.48	131.02
Jul-77		89.00				102.27	95.19	87.80	122.89	100.57	176.19	86.15	131.02
Aug-77		88.70				101.90	95.23	87.85	122.89	100.33	176.20	86.24	131.14
Sep-77		88.80				101.68	95.19	88.09	123.23	100.39	175.90	86.40	
Oct-77		88.60				100.99	94.69	87.67	122.97	100.11	175.91	85.85	131.03
Nov-77		88.30				100.21	94.69	87.54	122.45	99.68	175.81	85.45	130.85
Dec-77		88.10				99.82	94.81	87.76	122.41	99.75	175.52	85.44	130.88
Jan-78		88.30				99.54	95.20	88.04	122.59	100.00	175.76	85.80	131.12
Feb-78		89.00				99.25	95.31	88.47	123.53	100.25	176.08	86.17	131.53
Mar-78		89.00				100.37	95.28	88.91	124.62	100.58	176.06	87.04	131.88
Apr-78		88.90				100.62	95.21	88.75	124.35	100.23	176.07	87.81	131.80
May-78		89.00				100.69	95.20	88.58	124.29	100.08	175.74	88.60	131.79
Jun-78		89.10				100.77	95.29	88.56	124.28	100.11	175.58	88.98	131.56

Jul-78		89.20				101.43	95.22	88.47	124.71	100.40	175.68	88.79	131.88
Aug-78		90.00				103.86	95.41	89.80	125.48	101.21	175.69	90.11	132.49
Sep-78		90.00				105.94	95.34	89.82	125.00	100.95	175.76	90.84	132.44
Oct-78		89.80				106.08	95.37	89.57	124.71	100.56	175.94	91.26	131.82
Nov-78		89.50				105.60	95.35	89.15	124.35	100.19	175.63	90.92	131.48
Dec-78		89.40				105.37	95.39	89.37	124.34	100.11	175.42	90.91	131.63
Jan-79		89.40				105.31	95.39	89.71	124.52	100.34	175.46	90.46	131.95
Feb-79						105.79	95.35	90.09	125.11	100.52	175.71	90.36	132.10
Mar-79		89.90				106.52	95.33	90.17	125.09	100.59	176.06	89.93	132.26
Apr-79		89.80				106.95	95.29	90.02	124.94	100.60	176.15	89.64	131.89
May-79		89.90				107.16	95.30	90.16		100.53	176.04	89.38	131.92
Jun-79		89.50				106.60	95.24	89.61	124.52	100.22	176.36	89.18	131.62
Jul-79		89.50				106.26	95.30	89.86	124.37	100.13	176.16	89.00	131.45
Aug-79		89.50				105.83	95.36	90.25	124.47	100.04	176.22	89.38	131.52
Sep-79		89.40				105.62	95.42	90.41	124.61	100.15	176.75	89.53	131.54
Oct-79		89.70				105.69	95.30	90.36	124.91	100.11	176.29	89.80	131.98
Nov-79		89.60				105.37	95.30	90.27			175.80	89.99	131.68
Dec-79		89.80				105.52	95.33	90.54	125.12	100.31	175.56	90.19	131.93
Jan-80		89.80				106.08	95.32	90.52	125.30	100.30	175.61	91.04	131.97
Feb-80		90.00				106.88	95.28	90.51	125.26	100.38	176.01	91.38	132.00
Mar-80		90.00				107.42	95.26	90.50	125.17	100.38	176.23	91.70	132.04
Apr-80		90.30				107.93	95.22	90.43		100.43	176.20	92.01	132.12
May-80		90.10				107.90	95.26	90.36	124.90	100.26	176.05	92.09	131.85
Jun-80		90.10				107.69	95.20	90.16	124.66	100.09	176.25	91.92	131.70
Jul-80		89.90				107.45	95.30	90.34	125.20	100.00	176.13	91.86	131.62
Aug-80		90.10				108.03	95.34	90.47	125.18	100.23	176.10	92.46	132.00
Sep-80		90.20				107.82	95.34	90.18	124.79	100.04	176.03	92.58	131.72
Oct-80		89.80				107.27	95.37	89.91	124.50	99.93	176.44	92.36	131.56
Nov-80		89.60				106.60	95.37	89.87	124.23	99.66	176.53	92.00	131.31
Dec-80		89.30				105.89	95.37	89.78	124.13	99.49	176.20	91.42	131.30
Jan-81		89.10				105.07	95.28	89.42	123.87	99.27	176.31	90.47	131.15
Feb-81		89.20				104.80	95.30	89.59	124.13	99.51	176.34	90.04	131.20
Mar-81		89.60				104.54	95.17	89.85	124.52	99.68	176.20	89.73	131.70
Apr-81		89.40				104.12	94.99	89.53	124.37	99.49	176.41	89.04	131.64
May-81		89.00				103.18	94.87	88.65	123.84	98.92	176.39	88.18	131.20
Jun-81		88.40				102.25	94.94	88.29	123.35	98.42	176.11	87.36	130.93
Jul-81		88.10				101.60	95.06	88.18	123.19	98.32	175.92	86.85	131.06
Aug-81		88.30				101.46	95.07	88.20	123.82	98.66	176.03	86.56	131.27
Sep-81		88.50				101.12	94.98	88.36	124.18	98.74	176.03	86.46	131.64
Oct-81		88.60				100.38	94.90	87.85	123.78	98.37	175.74	85.90	131.40
Nov-81		88.50				99.64	95.19	87.88	123.65	98.34	175.48	85.75	131.32
Dec-81		88.20				98.79	95.23	87.81	123.52	98.18	175.31	85.52	131.37
Jan-82		88.30				98.55	95.21	87.98	123.89	98.37	175.15	85.49	131.52
Feb-82		88.40				98.34	95.24	88.18	124.39	98.57	174.98	85.61	131.82
Mar-82		88.60				99.26	95.20	88.16	124.31	98.58	175.25	85.49	131.72
Apr-82		88.70				99.89	95.22	88.48	124.47	98.84	175.47	85.82	131.76
May-82		88.60				99.98	95.17	88.16	124.29	98.57	175.48	85.74	132.00
Jun-82		88.70				100.42	95.33	88.78	124.63	98.73	175.12	86.33	132.05
Jul-82		88.80				101.39	95.38	89.21	124.87	98.95	175.09	87.07	132.16
Aug-82		88.80				102.51	95.46	89.72	125.45	98.93	175.36	88.26	132.10
Sep-82		88.80				103.90	95.49	90.38	125.37	98.73	175.50	90.26	132.31
Oct-82		88.70				104.43	95.44	90.56	125.12	98.72	175.55	91.76	132.26
Nov-82		88.90				104.85	95.40	90.45	124.98	98.66	175.24	92.57	131.92
Dec-82		89.00				104.92	95.41	90.49	124.79	98.51	175.31	93.02	131.92
Jan-83		89.00				104.90	95.39	90.48	124.70	97.66	175.22	92.98	131.87
Feb-83		89.10				105.21	95.40	90.71	124.80	98.73	175.53	93.07	131.56
Mar-83						105.79	95.39	90.70	125.12	99.08	175.77	93.12	132.12
Apr-83		89.90				106.72		90.86	125.17	99.29	175.84	93.90	132.42
May-83		90.20				107.32	95.43	90.96	124.96	99.42	176.15	94.85	132.40
Jun-83		90.30				107.46	95.47	91.05	124.99	99.32	176.05	95.75	132.06
Jul-83		90.90				108.55	95.51	92.22	125.43	99.51	176.36	96.84	131.60
Aug-83		90.70				109.15	95.57	92.76	125.28	99.50	176.47	97.62	132.26
Sep-83		90.90				109.50	95.62	93.24	125.19	99.50	176.60	98.57	132.12
Oct-83		91.10				109.85	95.59	93.48	125.19	99.38	176.62	99.26	132.18
Nov-83		91.20				109.95	95.56	93.46	125.22	99.32	176.39	99.40	131.94
Dec-83		91.10				110.34	95.49	93.67	125.24	99.46	176.05	99.53	132.05
Jan-84		91.60				110.75	95.44	93.88	125.28	99.62	175.90	99.58	132.22
Feb-84						111.02	95.38	93.92	125.22	99.61	175.82	99.49	132.11
Mar-84	114.64					111.56	95.38	94.16	125.35	99.90	176.05	99.73	132.24
Apr-84	114.83					112.15	95.32	94.38	125.28	100.02	176.34	99.80	132.33
May-84	114.70	91.60				112.01	95.35	94.04	124.96	99.68	176.45	99.82	132.30
Jun-84	114.46	91.40				111.65	95.39	93.83	124.77	99.39	176.16	99.74	132.07
Jul-84	114.64	91.50				111.58	95.47	93.58	125.00	99.56	176.13	99.32	131.78
Aug-84		91.50				111.62	95.43	93.14	124.98	99.60	176.30	98.50	132.06
Sep-84	114.79	91.30				111.30	95.43	92.73	124.69	99.55	176.31	97.67	131.84
Oct-84	114.41	91.30				110.68	95.37	92.37	124.54	99.34	176.32	96.67	131.90
Nov-84	114.34	91.10				110.15	95.32	91.86	124.66	99.26	176.22	95.50	131.82
Dec-84	114.23	91.00				109.65	95.25	91.39	124.59	99.18	176.12	94.46	131.76
Jan-85		90.80				109.04	95.20	90.86	124.42	98.97	176.27	93.46	131.72
Feb-85	113.64	90.70				108.50	95.22	90.70	124.33	98.91	176.55	92.44	131.62
Mar-85	113.36	90.40				107.87	95.13	90.40	124.20	98.71	176.37	91.47	131.62

Apr-85	113.09	90.00				107.11	95.09	90.09	124.01	98.49	176.45	90.40	131.46
May-85		89.80				106.23	95.02	89.60	123.79	98.12	176.72	89.33	131.44
Jun-85	112.36	89.10				105.44	94.76	89.09	123.55	97.70	176.20	88.26	131.22
Jul-85		89.00				104.98	95.04	88.85	123.96	97.83	175.98	87.70	131.50
Aug-85		89.50				105.35	95.19	89.71	124.76	98.83	175.97	87.75	131.80
Sep-85	113.59	90.30				107.04	95.30	90.59	125.30	99.67	176.00	88.04	132.62
Oct-85	113.38	90.20				107.82	95.31	90.67	125.34	99.63	175.93	88.22	132.62
Nov-85	113.45	90.10				108.36	95.28	90.75	125.32	99.58	176.00	89.14	132.42
Dec-85	113.30	89.90				108.44	95.23	90.57	125.00	99.37	175.90	89.66	132.22
Jan-86	113.32	89.90				108.77	95.24	90.83	125.00	99.56	175.88	90.30	132.36
Feb-86	113.79	90.20				109.27	95.18	90.80	125.05	99.88	175.80	91.34	132.12
Mar-86	113.73	90.30		81.70		109.89	95.18	90.81	125.20	100.03	175.77	92.06	132.32
Apr-86	113.78	90.40	83.30	81.60		110.07	95.21	90.70	124.85	99.85	175.71	93.58	132.22
May-86	113.39	90.00	83.00	81.20		109.48	95.26	90.54	124.53	99.47	175.77	94.00	131.90
Jun-86	113.38	89.70	82.80	80.90		109.01	95.27	90.62	124.70	99.25	175.74	94.16	131.78
Jul-86	113.27	90.00	82.80	81.00		109.14	95.24	90.63	124.98	99.38	175.56	94.23	132.00
Aug-86	113.72	90.30	82.50	80.70		108.98	95.27	90.59	124.94	99.54	175.97	93.67	131.86
Sep-86	112.76	90.30	82.50	80.80		108.71	95.27	90.56	124.76	99.48	176.38	93.12	131.92
Oct-86	112.62	90.00	82.10	80.40		107.97	95.42	90.01	124.51	99.19	176.71	92.14	131.70
Nov-86	112.20	89.80	81.70	80.10		107.21	95.33	89.65	124.22	98.84	176.40	91.37	131.52
Dec-86		89.70	81.70	80.20		106.84	95.29	89.81	124.40	98.94	176.29	91.09	131.56
Jan-87	112.22	89.80	82.00	80.40		106.66	95.22	90.18	124.74	99.03	176.02	91.04	131.80
Feb-87	112.38	89.90	82.30	80.60		106.89	95.18	90.37	125.06	99.21	176.13	91.05	132.14
Mar-87	112.98	90.30	83.10	81.30		108.14	95.25	90.81	125.40	99.60	176.33	92.29	132.50
Apr-87	113.38	90.50	83.50	81.70		109.37	95.27	90.71	125.35	99.83	176.40	93.87	132.70
May-87	113.17	90.30	83.20	81.50		109.66	95.32	90.59	125.11	99.58	176.09	95.67	132.20
Jun-87	113.27	90.20	83.10	81.20		109.58	95.34	90.59	125.04	99.42	175.72	96.48	132.04
Jul-87	113.33	89.90	82.80	81.00		109.38	95.37	90.52	124.93	99.23	175.84	96.54	131.96
Aug-87	113.54	89.50	82.20	80.60		109.19	95.34	90.36	125.02	98.91	176.03	96.19	131.88
Sep-87		89.50	82.40	80.70		109.26	95.33	90.07	125.04	98.78	176.22	95.64	132.10
Oct-87	112.08	89.00				108.49	95.31	89.37	124.37	98.15	176.41	94.70	131.70
Nov-87	112.78	88.90				107.79	95.37	89.13	124.35	98.11	176.18	93.96	131.30
Dec-87	112.66	88.70	81.50	80.10		107.31	95.37	89.11	124.47	98.05	176.01	93.28	131.63
Jan-88	112.53	88.60	81.40	80.10		106.75	95.33	88.97	124.50	97.97	176.11	92.41	131.63
Feb-88	112.88	88.70	81.50	80.20		106.73	95.25	89.15	124.83	98.21	176.30	92.05	131.88
Mar-88	113.23	89.00	81.90	80.40		107.30	95.25	89.29	125.36	98.57	176.58	92.64	132.33
Apr-88	112.92	88.90	82.20	80.40		107.78	95.23	89.55	125.02	98.35	176.92	92.92	132.18
May-88	112.92		81.60	80.20		107.44	95.22	89.35	124.80	98.05	176.76	93.52	131.84
Jun-88			81.30	80.10		106.71	95.24	88.98	124.43	97.66	176.47	93.68	131.80
Jul-88		88.00	80.60	79.80		105.85	95.27	88.58	123.97	97.24	176.25	93.39	131.44
Aug-88		87.80	80.60	79.80		105.49	95.29	88.61	124.25	97.30	176.42	93.43	131.52
Sep-88	113.06	88.90	82.70	81.00		106.84	95.52	90.54	125.31	98.47	176.36	96.01	131.72
Oct-88		89.10	82.80	81.10		107.46	95.45	90.72	125.07	98.58	176.26	98.46	132.07
Nov-88		88.70	82.50	80.80		106.98	95.33	90.68	124.84	97.91	175.72	99.52	131.74
Dec-88		88.70	82.60	80.90		106.85	95.29	90.78	124.84	98.26	175.78	99.99	131.85
Jan-89		88.70	82.40	80.60		106.41	95.19	90.61	124.72	98.15	175.89	99.85	131.78
Feb-89	112.48		82.20	80.50		105.74	95.11	90.39	124.61	98.01	175.88	99.31	131.70
Mar-89		88.40	82.00	80.40		105.74	95.08	90.21	124.51	97.83	176.16	98.69	131.62
Apr-89		88.10	81.50	80.20		104.84	95.02	89.80	124.21	97.63	176.53	97.98	131.44
May-89		87.00	80.90	79.80		103.75	95.11	88.98	123.90	97.01	176.29	96.94	131.40
Jun-89		87.00	80.50	79.00		102.99	95.03	88.42	123.44	96.77	175.99	95.85	131.14
Jul-89		87.00	80.30	78.90		102.85	95.05	88.24	123.36	96.77	175.78	95.21	131.04
Aug-89						102.23	95.11	87.94	123.16	96.43	175.80	94.69	131.06
Sep-89						101.78	95.15	87.84	122.61	96.39	176.26	94.10	131.04
Oct-89	109.43	87.00									176.88		
Nov-89	108.74	86.90				100.18					176.34		
Dec-89	108.45	86.80				98.80					176.06		
Jan-90	108.35	86.70				98.43					176.00		
Feb-90	108.24					97.84					175.90		
Mar-90	107.96					97.36					175.80		
Apr-90						96.64					175.77		
May-90						95.90					175.70		
Jun-90						95.38					175.61		
Jul-90						95.13							
Aug-90													
Sep-90													
Oct-90													
max	114.83	93.10	83.50	81.70	174.40	117.41	105.00	98.51	125.77	107.10	177.45	115.40	132.73
min	107.96	86.70	80.30	78.90	172.70	95.13	91.02	87.54	122.41	96.39	174.42	84.24	130.79
mean	112.81	89.63	82.11	80.56	173.71	109.07	96.12	92.08	124.60	102.22	176.15	97.82	131.71
std.dev.	1.70	1.18	0.82	0.63	0.36	5.59	2.38	2.88	0.58	2.93	0.48	7.93	0.36
C.V.	0.02	0.01	0.01	0.01	0.00	0.05	0.02	0.03	0.00	0.03	0.00	0.08	0.00
max-min	6.87	6.40	3.20	2.80	1.70	22.28	13.98	10.97	3.36	10.71	3.03	31.16	1.94

A2. Stage ranges for 121 Florida lakes

Ref.	Lake_Name	Period Of Record	Surface Area	Max Elev (ft above MSL)	Min Elev (ft above MSL)	Range	Rank
	Blue Pond	9	201	174.40	172.70	1.70	1
27	Sand Hill Lake	28	1250	132.73	130.79	1.94	2
78	Lake Catherine	20	137	99.76	97.49	2.27	3
93	Bay Lake	17	436	95.07	92.55	2.52	4
157	Lake Marion	27	2968	67.52	64.86	2.66	5
	Hall Lake	4		81.70	78.90	2.80	6
54	Lake Dorr	19	1712	44.44	41.52	2.92	7
24	Kingsley Lake	40	1627	177.45	174.42	3.03	8
	Smith Lake	4		83.5	80.3	3.20	9
174	Lake Smart	26	279	129.32	125.82	3.50	10
38	Lake Grandin	28	354	83.33	79.81	3.52	11
31	Magnolia Lake	27	201	125.91	122.3	3.61	12
161	Lake Whistler	15	78	138.12	134.5	3.62	13
188	Lake Pierce	37	3736	78.91	75.23	3.68	14
177	Lake Parker	36	2291	131.91	127.92	3.99	15
104	Lake Thomas	17	162	75.43	71.34	4.09	16
58	Lake Yale	26	4030	61.29	57.12	4.17	17
107	Lake Padgett	20	200	71.84	67.62	4.22	18
92	South Lake	16	128	94.85	90.59	4.26	19
100	Clear Lake	20	158	127.86	123.52	4.34	20
55	Lake Umatilla	15	165	68.66	64.2	4.46	21
2	Lake Seminole	31	37500	78.66	74.18	4.48	22
205	Lake Weohyakapka	27	7555	63.43	58.9	4.53	23
48	Lake Bryant	28	1261	54.8	50.2	4.60	24
66	Lake Dora	49	4437	65.2	60.59	4.61	25
99	Lake Brynn	16	210	100.33	95.64	4.69	26
46	Lake George	29	46780	4.3	-0.49	4.79	27
73	Lake Wekiva	16	190	87.04	82.09	4.95	28
150	Lake Gibson	21	477	145.4	140.4	5.00	29
50	Bowers Lake	13	633	58.52	53.5	5.02	30
116	Lake Harvey	15	21	63.28	58.19	5.09	31
203	Seminole Lake	35	684	8.22	3.12	5.10	32
171	Lake Thonotosassa	23	824	38.55	33.37	5.18	33
131	Turkey Ford Lake	15	93	54.93	49.74	5.19	34
76	Lake Apopka	49	30630	69.3	64.04	5.26	35
195	Lake Rosalie	29	4592	55.93	50.3	5.63	36
124	Keystone Lake	39	388	43.6	37.88	5.72	37
75	Cherry Lake	29	520	98.13	92.4	5.73	38
187	Alligator Lake	36	76	8.15	2.3	5.85	39
56	Lady Lake	15	190	66.6	60.7	5.90	40
65	Lake Garris	44	17650	64.81	58.87	5.94	41
221	Lake June-in-Winter	40	3662	77.58	71.62	5.96	42
102	Moon Lake	20	98	40.94	34.96	5.98	43
60	Lake Eustis	49	7806	64.84	58.82	6.02	44
51	Lake Weir	49	5760	59.6	53.46	6.14	45
202	Lake Marian	26	5727	61.63	55.36	6.27	46
140	Lake Tarpon	40	2534	7.08	0.7	6.38	47
	Swan Lake	14		93.1	86.7	6.40	48
207	Lake Buffum	13	1570	132.42	126.02	6.40	49
15	Deer Point Lake	23	5000	7.67	1.2	6.47	50
53	Lake Rousseau	20	4163	28.18	21.7	6.48	51
85	Lake Minnehaha	40	2410	99.04	92.49	6.55	52
216	Lake Jackson	40	3244	103.76	97.16	6.60	53

162	Ariana Lake	20	1019	137.9	131.28	6.62	54
64	Lake Panasoffkee	30	4821	44.28	37.65	6.63	55
90	Lake Conway	33	1079	89.1	82.44	6.66	56
158	Lake Arietta	15	764	143.34	136.5	6.84	57
	Crystal Lake	6		114.83	107.96	6.87	58
232	Lake Trafford	45	1485	22.79	15.9	6.89	59
71	Church Lake	16	155	87.66	80.72	6.94	60
227	Lake Placid	51	3381	96	88.95	7.05	61
52	Lake Winnemissett	20	169	61.01	53.93	7.08	62
45	Lake Kerr	46	4484	27	19.92	7.08	63
213	Lake Arbuckle	43	3787	58.3	51.15	7.15	64
88	Lake Butler	52	1665	101.78	94.62	7.16	65
87	Lake Louisa	28	3659	99.64	92.48	7.16	66
68	Little Lake	10	58	42.24	35.04	7.20	67
105	Alligator Lake	43	3401	66.81	59.52	7.29	68
112	Lake Helene	24	54	145.86	138.54	7.32	69
39	Newnans Lake	45	7350	71.21	63.87	7.34	70
179	Lake Hamilton	40	2170	124.34	116.89	7.45	71
175	Lake Fannie	18	833	125.98	118.51	7.47	72
220	Lake Istokpoga	44	27500	42.9	35.4	7.50	73
218	Lake Josephine	30	1240	76.8	69.09	7.71	74
172	Lake Carroll	39	195	40.08	32.35	7.73	75
97	Lake Mary Jane	35	1161	64.81	56.89	7.92	76
42	Lochloosa Lake	41	8800	61.94	53.88	8.06	77
194	Valrico Lake	11	130	47.1	39	8.10	78
49	Smith Lake	13	482	57.82	49.7	8.12	79
41	Lake Ocklawaha	17	10800	20.7	12.57	8.13	80
149	Lake Lowery	25	897	133.32	125.12	8.20	81
69	Lake Jessup	16	7792	7.75	-0.63	8.38	82
59	Lake Griffin	49	10660	60.74	52.14	8.60	83
47	Lake Winona	20	156	40.52	31.72	8.80	84
67	Tsala Apopka Lake	28	19000	44.22	35.24	8.98	85
230	Lake Okeechobee	54	136500	18.77	9.79	8.98	86
62	Lake Monroe	54	8840	8.5	-0.52	9.02	87
163	Lake Magdalene	39	232	51	41.96	9.04	88
98	Lake Poinsett	43	4293	17.55	7.99	9.56	89
165	Cypress Lake	43	4085	57.18	47.6	9.58	90
182	Lake Otis	31	144	129.18	119.56	9.62	91
159	Lake Alfred	17	736	132.08	122.4	9.68	92
193	Scott Lake	32	287	169.19	159.29	9.90	93
209	Lake Clinch	38	1194	110.2	100.28	9.92	94
121	Lake Washington	43	2665	20.39	9.88	10.51	95
74	Lake Apshawa	32	110	92.68	82.1	10.58	96
61	Tsala Apopka Lake	28	19000	42.94	32.3	10.64	97
34	Lake Geneva	28	1746	107.1	96.39	10.71	98
57	Tsala Apopka Lake	28	19000	41.74	30.92	10.82	99
91	Trout Lake	15	163	96.9	85.98	10.92	100
	Lake Johnson	31	441	98.51	87.54	10.97	101
101	Lake Tohopekaliga	43	18790	59.4	48.37	11.03	102
63	West Crooked Lake	15	107	71.48	60.3	11.18	103
43	Orange Lake	45	13160	61.95	50.38	11.57	104
3	Lake Iamonia	19	5680	106.22	94.6	11.62	105
6	Lake Miccosukee	20	6312	82.64	71	11.64	106
70	Lake Francis	26	33	66.22	53.3	12.92	107
86	Johns Lake	26	2411	99.32	85.57	13.75	108

208	Lake Kissimmee	59	34760	56.64	42.87	13.77	109
	Lt. Lake Johnson	45	35	105	91.02	13.98	110
143	Starvation Lake	24	50	54.55	40.23	14.32	111
114	Lake Dan	18	37	33.29	18.84	14.45	112
181	Lake Howard	40	634	128.28	113.19	15.09	113
151	Lake Deeson	27	116	135.49	119.81	15.68	114
204	Crooked Lake	40	5533	124.1	108.27	15.83	115
12	Lake Bradford	31	182	37.08	21	16.08	116
32	Brooklyn Lake	28	635	117.43	97.23	20.20	117
7	Lake Jackson	34	4001	96.16	75.68	20.48	118
10	Porter Lake	24	943	75.37	53.22	22.15	119
13	Lake Talquin	55	6850	71.16	48.7	22.46	120
28	Pebble Lake	40	10	116.36	84.24	32.12	121

A3. Review of Hydrogeologic Data

A3.1 Existing Data

Hydrogeologic data being collected by SJRWMD will be used by UF in subsequent tasks of the Etonia Creek hydrologic investigation. To supplement existing data in the UECB, SJRWMD is in the process of performing hydrogeologic mapping in the basin. This work has included using well logs from private and public wells. The well logs have been reviewed and used for defining the different geologic zones in the UECB. Some of these wells are identified in Table A1.

Also, a number of wells have been located and defined as surficial, intermediate, and Floridan aquifer wells depending on their depths and the immediate geology. At this time, 18 intermediate and 12 Floridan aquifer wells have been located. Potentiometric surfaces have been measured in these wells on a one-time basis. One set of nested wells, including a surficial well, has been determined to be in existence on the northwest side of Lake Brooklyn.

A3.2 New Data

SJRWMD is planning to expand the work already performed by implementing another phase of work. The work includes a program to identify locations and drill core holes in areas that are relatively unmapped geologically. The purpose of this mapping is to determine aquifer and confining bed thicknesses in these parts of the basin. A total of eight core holes have been planned. They are scattered over the UECB in areas where obtaining permission for these wells is favorable.

Also, a number of nested wells will be installed for a permanent monitoring program. This will enable SJRWMD to measure potentiometric levels of aquifers in the UECB. At this time, four sets of nested wells are planned with a possibility of others if needed.

Table A1. Geologic and Hydrogeologic Information.						
Existing						
Well #	Latitude	Longitude	Log Type	Depth Logged	Casing Depth	Remarks
C-0381	294958	815848	Gamma	201	90	
C-0382	294957	815849	Gamma	200		Entrance to Goldhead Mine
C-0386	294505	815736	Gamma			Hendrix Well
C-0383	294900	815812	Gamma			King Well
C-0384	294901	815818	Gamma	95		Burkhalter Well
C-0388	294916	815855	Gamma			Moses Well
C-0387	294937	815852	Gamma			Hamilton Well
C-0380	294912	815733	Gamma	68	68	FL Rock monitor well
G-34	293914	815727	Gamma	107	107	Owned by State of FL
P-0129	294814	815636	Gamma	298		Grandin Sand Mine

A3.3 Management

The existing data and new data to be acquired will be used for water resources management in the UECB. An important part of the management process will be the development by UF of a groundwater model for a part of the UECB. The computer model will consist of a two-dimensional vertical cross-section that is representative of the UECB. The cross-section chosen for the model will be dependent on available data from the geologic and hydrologic work being performed by SJRWMD at this time. Other factors will include groundwater levels and the direction of groundwater flow and the location of existing problem areas in the basin.

A4. Water Budget Calculations for Lakes Brooklyn and Geneva

A4.1. Water-Budget Calculations

Preliminary monthly water budgets and lake simulations have been performed for Lake Brooklyn and Lake Geneva. In general, water enters a lake from three sources: rainfall (R), surface inflow (I_s), and groundwater inflow (I_g). Water leaves a lake by means of surface evaporation (E), surface outflow (O_s), and groundwater outflow (O_g). The monthly change in storage (dS/dt) is:

Equation 4:

$$dS/dt = (R + I_s + I_g) - (E + O_s + O_g)$$

The components of the water budget are shown in Figure A1.

A4.2 Rainfall

The Etonia monthly precipitation values used in the water budget were discussed previously in this report. No rain gages with a long record are located in the basin. Although the closest station at Gainesville is used, these values do not always reflect actual precipitation falling on the lakes.

A4.3 Surface Inflow and Outflow

Lake Brooklyn periodically receives inflow from Magnolia Lake. When Magnolia Lake attains a sill elevation of 123.5 feet, NGVD, it begins to discharge. Lake Keystone discharges into Lake Geneva at an elevation of 106.3 feet, NGVD. However, the volume which may enter Lake Geneva from Lake Keystone is minor compared to the volume of Lake Geneva. A stage-discharge curve may be used to show this relationship.

When Lake Brooklyn attains a sill elevation of 115 feet, NGVD, it discharges into Lake Geneva. Lake Brooklyn has not recorded a discharge in over 15 years. Lake Geneva will discharge at an elevation of approximately 105 feet, NGVD.

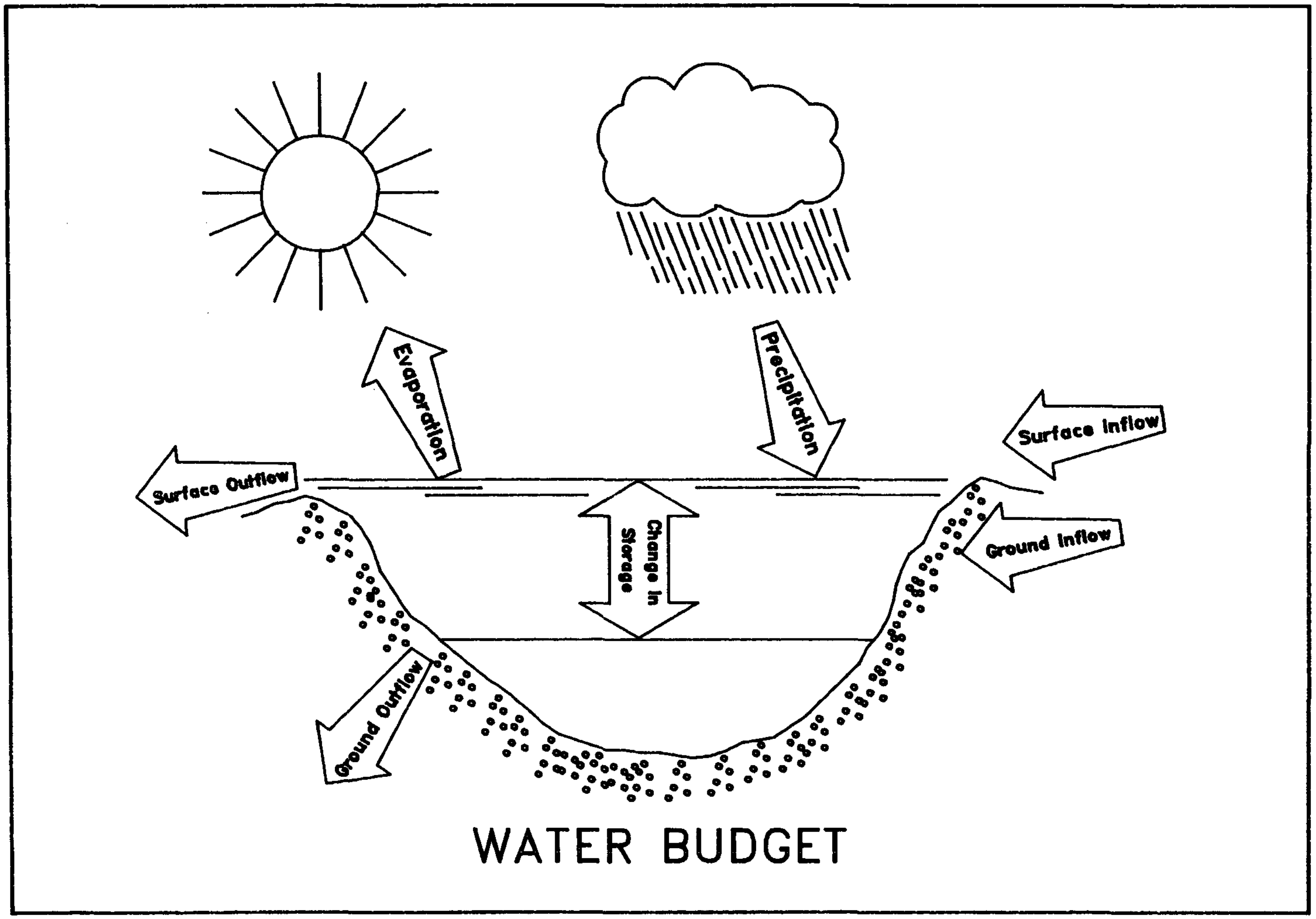


Figure A1 - Water-budget components.

Surface inflows into Lake Brooklyn and Lake Geneva are not measured. Therefore, the inflow that reaches these lakes from upstream gages must be estimated.

A4.4 Groundwater Inflow

Groundwater inflow to a lake may occur from discharge of an upstream lake which flows below the land surface into a receiving lake. Inflow may also occur if the surrounding water-table elevation is higher than the lake surface elevation.

The potentiometric surface of the Floridan aquifer has always remained below the lake levels of Brooklyn and Geneva, so inflow from the Floridan aquifer does not occur.

A4.5 Evaporation

Monthly evaporation data for the basin were obtained from the Gainesville station. The monthly evaporation data were multiplied by a pan coefficient to account for lake evaporation. The amount of lake evaporation varies as the lake surface area changes.

A4.6 Groundwater Outflow

Groundwater outflow consists of water leaving the lake below the surface. Outflow may consist of seepage to the surficial aquifer or leakage through the confining bed to the underlying Floridan aquifer. These values are difficult to determine and may vary considerably from one lake to another.

A4.7 Lake Simulation

The simulation model was calibrated by adjusting assumed values of the pan-evaporation coefficient, the surface runoff coefficient, and the leakance coefficient. In this manner, an approximate leakage volume was determined for each month. By forming a relationship between the leakage and the Floridan aquifer potentiometric surface elevation, a value for leakance (vertical hydraulic conductivity divided by confining bed thickness) was developed. This value is highly dependent on using an accurate value for the Floridan aquifer potentiometric surface elevation beneath the lake. These levels are available from the Keystone well for Lake Brooklyn. However, Lake Geneva does not have a well located on-site, so a factor was used to estimate the elevation of the Floridan aquifer potentiometric surface below the lake.

Once a value for leakance is determined, it can be used in the water budget calculations. With the capability to calculate the leakage every month, the lake elevation becomes the unknown.

Figures A2 and A3 show the Lake Brooklyn and Lake Geneva simulations obtained to date. These simulations show good correlations between observed and calculated values; the calibrations should improve as better data become available.

A4.8 Conclusion

A reliable water budget and simulation are highly dependent on accurate data. Rain gages set close to the lakes would increase the accuracy of rainfall values for each lake. Surface inflow should be measured at each lake to determine accurate inflow values. If wells are installed around the lakes, groundwater inflow and outflow through the surficial aquifer can be estimated. This value is important in determining if water is lost due to outflow to the surficial aquifer or from leakage through the bottom of the lake. Once these values are more accurately determined, the simulation model can be refined.

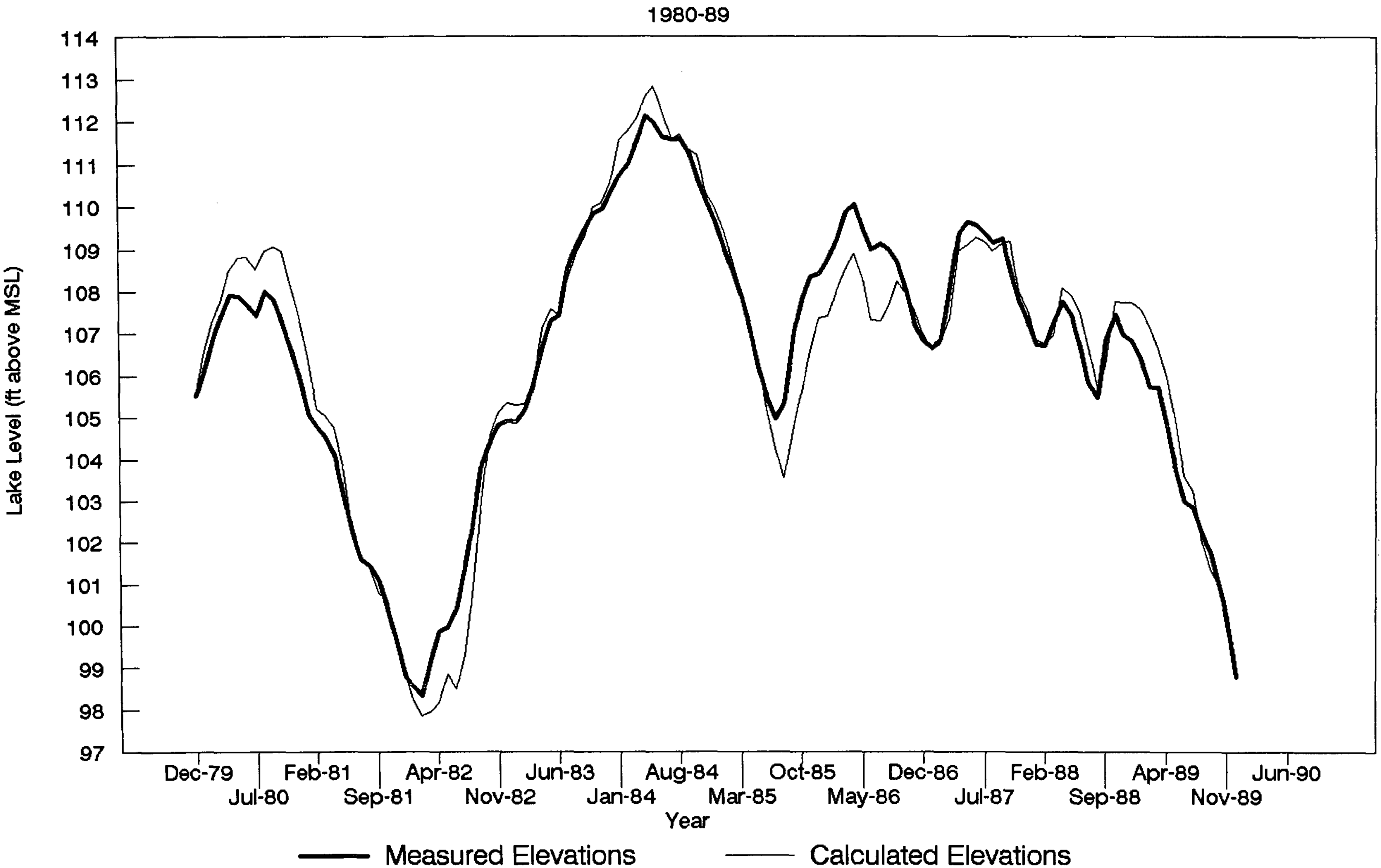


Figure A2 - Lake Brooklyn simulation: 1980-89

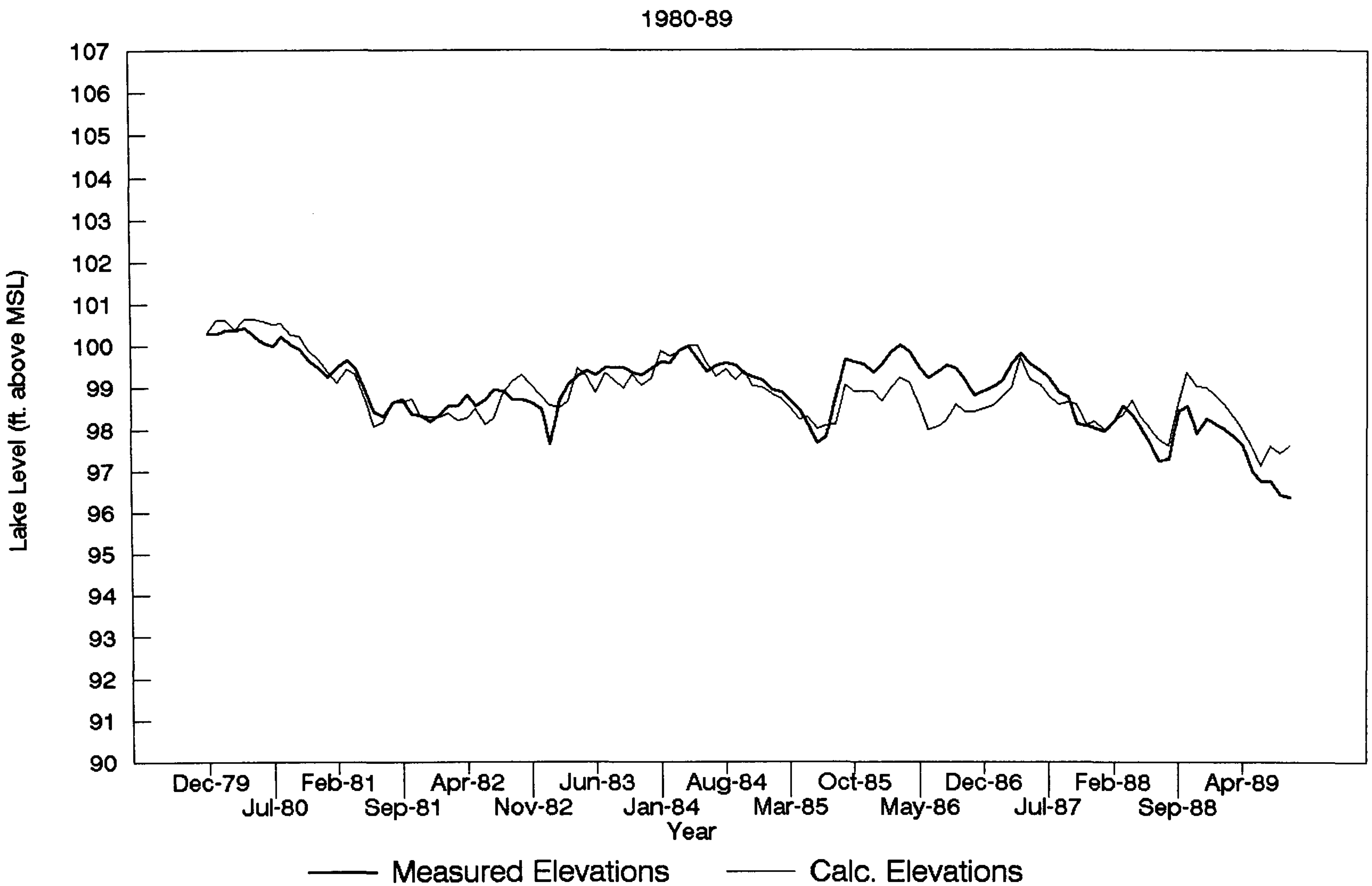


Figure A3 - Lake Geneva simulation: 1980-89