

**STATE OF FLORIDA  
STATE BOARD OF CONSERVATION  
DIVISION OF GEOLOGY**

**FLORIDA GEOLOGICAL SURVEY**

Robert O. Vernon, *Director*

---

**REPORT OF INVESTIGATIONS NO. 33**

---

**HYDROLOGY OF BROOKLYN LAKE  
NEAR  
KEYSTONE HEIGHTS, FLORIDA**

By  
William E. Clark, Rufus H. Musgrove,  
Clarence G. Menke, and Joseph W. Cagle, Jr.

---

Prepared by the  
**UNITED STATES GEOLOGICAL SURVEY**  
in cooperation with the  
**FLORIDA GEOLOGICAL SURVEY**

**Tallahassee  
1963**

400.4  
F636~  
No. 33

**FLORIDA STATE BOARD  
OF  
CONSERVATION**

**AGRI-  
CULTURAL  
LIBRARY**

**FARRIS BRYANT**

*Governor*

**TOM ADAMS**

*Secretary of State*

**J. EDWIN LARSON**

*Treasurer*

**THOMAS D. BAILEY**

*Superintendent of Public Instruction*

**RICHARD ERWIN**

*Attorney General*

**RAY E. GREEN**

*Comptroller*

**DOYLE CONNER**

*Commissioner of Agriculture*

**W. RANDOLPH HODGES**

*Director*

## LETTER OF TRANSMITTAL



### *Florida Geological Survey* *Tallahassee*

February 18, 1963

Honorable Farris Bryant, *Chairman*  
Florida State Board of Conservation  
Tallahassee, Florida

Dear Governor Bryant:

The Florida Geological Survey is publishing, as Report of Investigations No. 33, a study on the "Hydrology of Brooklyn Lake near Keystone Heights, Florida." This report was prepared by a number of geologists and engineers, working with the U. S. Geological Survey, in cooperation with the Florida Geological Survey.

The study was undertaken, because of the serious depletion of water levels during the severe drought of 1954-58, as a means of determining the relationship of the lake water to shallow groundwater levels and to artesian water levels. This is a comprehensive study of these lakes and water levels, which will be helpful in designing control structures for the control of the levels of the series of lakes that extend from Blue Pond to Lake Geneva.

Respectfully yours,

Robert O. Vernon  
*Director and State Geologist*

Completed manuscript received  
December 20, 1962  
Published for the Florida Geological Survey  
Tallahassee, Florida  
1963

## PREFACE

This report was prepared by the Water Resources Division of the U. S. Geological Survey in cooperation with the Florida Geological Survey. The investigation was under the general supervision of M. I. Rorabaugh and C. S. Conover, successively district engineer, Branch of Ground Water; A. O. Patterson, district engineer, Branch of Surface Water; and J. W. Geurin, district chemist; and K. A. MacKichan, succeeding district engineer, Branch of Quality of Water, U. S. Geological Survey.



## TABLE OF CONTENTS

|                                                 |    |
|-------------------------------------------------|----|
| Abstract .....                                  | 1  |
| Introduction .....                              | 2  |
| Purpose and scope .....                         | 2  |
| Rainfall .....                                  | 4  |
| Physical description .....                      | 6  |
| Surface drainage .....                          | 6  |
| Stage fluctuations .....                        | 6  |
| Depths and storage .....                        | 9  |
| Chemical quality and temperature of water ..... | 10 |
| Relation of ground water to lake .....          | 15 |
| Water-table aquifer .....                       | 19 |
| Confining bed .....                             | 31 |
| Floridan aquifer .....                          | 32 |
| Water budget .....                              | 35 |
| Methods of controlling Brooklyn Lake .....      | 39 |
| Conclusions .....                               | 43 |

## ILLUSTRATIONS

| Figure                                                                                                                                             | Page |
|----------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 1 Location of Brooklyn Lake area .....                                                                                                             | 3    |
| 2 Bar graph of annual rainfall for the period 1900-60 at<br>Gainesville, Florida .....                                                             | 5    |
| 3 Surface drainage of Etonia Creek basin .....                                                                                                     | 7    |
| 4 Profile and location of chain of six lakes in the upper Etonia<br>Creek basin .....                                                              | 8    |
| 5 Stage graph of Brooklyn Lake .....                                                                                                               | 9    |
| 6 Brooklyn Lake showing lines of equal depth at lake-surface<br>elevation of 117 feet above sea level .....                                        | 11   |
| 7 Brooklyn Lake showing lines of equal depth at the record-low<br>elevation of 97.2 feet above sea level .....                                     | 12   |
| 8 Curve showing relation of lake stage to lake storage .....                                                                                       | 13   |
| 9 Relation of pH to depth of water occurrence, near Brooklyn Lake ..                                                                               | 15   |
| 10 Temperature profiles in Brooklyn Lake on May 9, 1960 and<br>November 28, 1960 .....                                                             | 16   |
| 11 Brooklyn Lake area showing locations of wells and giving<br>an explanation of the well-numbering system .....                                   | 17   |
| 12 Brooklyn Lake area showing the locations of sections A-A',<br>B-B', C-C', and D-D' .....                                                        | 19   |
| 13 Section showing geologic formations, hydrologic units, and<br>types of material in the Brooklyn Lake area along line A-A'<br>in figure 12 ..... | 20   |
| 14 Section showing hydrologic units in the Brooklyn Lake area<br>along line B-B' in figure 12 .....                                                | 20   |
| 15 Section showing hydrologic units in the Brooklyn Lake area<br>along line C-C' in figure 12 .....                                                | 21   |
| 16 Section showing hydrologic units in the Brooklyn Lake area<br>through a filled sink along line D-D' in figure 12 .....                          | 22   |

## ILLUSTRATIONS (Continued)

|    |                                                                                                           |    |
|----|-----------------------------------------------------------------------------------------------------------|----|
| 17 | Brooklyn Lake area showing contours on base of the water-table aquifer .....                              | 24 |
| 18 | Brooklyn Lake area showing contours on the water table on March 22, 1960 .....                            | 25 |
| 19 | Brooklyn Lake area showing contours on the water table on October 17, 1960 .....                          | 26 |
| 20 | Hydrographs of well 947-202-14 and Brooklyn Lake .....                                                    | 28 |
| 21 | Hydrographs of wells 948-202-5 and 948-202-7, and Brooklyn Lake .....                                     | 29 |
| 22 | Hydrographs of wells 948-201-8, 948-201-10, and 948-201-13, and Brooklyn Lake .....                       | 30 |
| 23 | Hydrograph showing the water level in well 947-201-4 .....                                                | 34 |
| 24 | Brooklyn Lake area showing contours on the piezometric surface of the Floridan aquifer in June 1960 ..... | 36 |
| 25 | Water budget of Brooklyn Lake for the period October 1957 to September 1960 .....                         | 38 |
| 26 | Stage graph of Santa Fe Lake and profile from Santa Fe Lake to Brooklyn Lake .....                        | 42 |

|                                                                                                                                        |      |
|----------------------------------------------------------------------------------------------------------------------------------------|------|
| Table                                                                                                                                  | Page |
| 1 Average, maximum, and minimum mineral content and temperature of Brooklyn, Magnolia, and Sandhill lakes .....                        | 14   |
| 2 Geologic formations, hydrologic units, and their water-bearing characteristics in the Brooklyn Lake area, Clay County, Florida ..... | 18   |

# **HYDROLOGY OF BROOKLYN LAKE NEAR KEYSTONE HEIGHTS, FLORIDA**

By

William E. Clark, Rufus H. Musgrove  
Clarence G. Menke, and Joseph W. Cagle, Jr.

## **ABSTRACT**

Brooklyn Lake receded about 20 feet during 1954-58 and reached its lowest stage of record (97.2 feet) in February 1958; this was the lowest stage in the memory of longtime residents. This unusually large recession was a result of deficient rainfall during more than a 3-year period, January 1954 to May 1957. However, by October 1959, after 2½ years of above normal rainfall, the lake had recovered and water was flowing through the surface outlet.

Brooklyn Lake is the fourth lake from the head of a chain of lakes situated in a group of high sandhills in the upper Etonia Creek basin. The sands covering this part of the basin are porous. Consequently, seepage rates are high and surface runoff is exceedingly low.

The dissolved solids content of Brooklyn Lake water ranged from 19 to 34 ppm (parts per million) during the period July 1957 to June 1960. The pH values of the water ranged from 5.1 to 5.7. Seepage from the lake is apparently effective in localized lowering of the pH of the ground water. Temperature measurements during November 1957 and May 1960 indicate seasonal variation in temperature and degree of stratification.

The sediments that underlie Brooklyn Lake comprise three hydrologic units—the water-table aquifer, the confining bed, and the Floridan aquifer. The water-table aquifer, the uppermost unit, is composed of sand, clay, limestone, and marl beds that have an aggregate maximum thickness of about 100 feet. The underlying confining bed is composed of relatively impermeable deposits that are as much as 130 feet thick. The lowermost unit, the Floridan aquifer, is composed of a series of permeable limestone, dolomite, and dolomitic limestone beds that are more than 900 feet thick. At places, the confining bed has been breached by collapse of the underly Floridan limestone, or displaced by what may be faults or fractures.

Brooklyn Lake both loses and gains water from the water-table aquifer. During the period March through October 1960, about 400 acre-feet more water left the lake than entered the lake through the water-table aquifer. Water leaks from the lake into the Floridan aquifer through old filled sinks that perforate the confining bed, and water also probably seeps downward to the Floridan aquifer through the confining bed especially where it is thin.

A water budget computed for a 3-year period, October 1957 through September 1960, indicated about 30,000 acre-feet of water entered the lake by surface inflow and precipitation directly to the lake. This is more than twice the amount of water than can be stored in the lake at any time. Slightly more than 10,000 acre-feet of the water entering the lake went to lake storage. The remaining 20,000 acre-feet was removed from the lake in three ways: seepage, 55 percent; evaporation, 35 percent; and surface outflow, 10 percent. Seepage accounted for an average daily loss of about 3 million gallons during the 3-year period. An average of about 8 mgd (million gallons per day) recharged the Floridan aquifer during the 8-month period, March to October 1960. The amount of water evaporated from the lake surface was essentially equal to that contributed directly by rainfall.

Three possible methods of increasing inflow to help maintain a normal lake stage during periods of deficient rainfall are: (1) by carefully pumping from the Floridan aquifer at strategic sites; (2) by increasing storage in upper lakes during periods of excess rainfall; and (3) by diversion of water from Santa Fe Lake. Plans to control the stage of Brooklyn Lake should be based on detailed engineering studies.

## INTRODUCTION

### PURPOSE AND SCOPE

The level of Brooklyn Lake, near the city of Keystone Heights in southwestern Clay County, fluctuates widely (fig. 1). As a consequence both permanent and summer residents, who have built many houses on its shores are concerned. Local organizations and officials realized the need for determining the reason for the wide fluctuations and prompted an investigation. This report explains why the lake level fluctuates widely and furnishes information for planning methods of regulating the lake level.

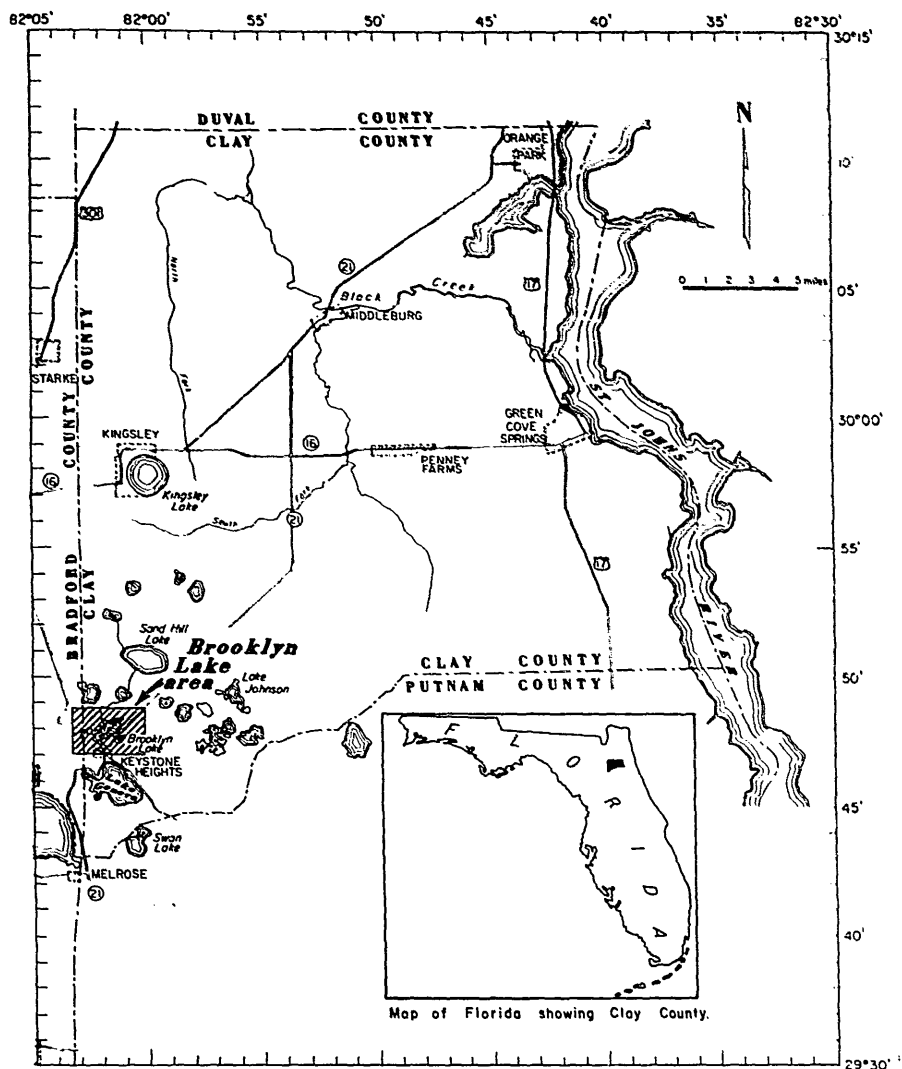


Figure 1. Location of Brooklyn Lake area.

The investigation was made by the U. S. Geological Survey at the request of and in cooperation with the Florida Geological Survey. The investigation of the lake was part of an investigation of the water resources of Alachua, Bradford, Clay, and Union counties. The results of this four-county study are contained in reports entitled "Water Resources of Alachua, Bradford, Clay, and

Union Counties, Florida," and "Water Resources Data of Alachua, Bradford, Clay, and Union Counties, Florida" by William E. Clark, Rufus H. Musgrove, Clarence G. Menke, and Joseph W. Cagle, Jr. to be published by the Florida Geological Survey. The report of the Brooklyn Lake area was prepared chiefly for the convenience of the reader who is interested primarily in that aspect of the investigation.

Information is given in this report on the surface drainage, fluctuation of stage, depth, mineral content, and temperature of Brooklyn Lake. The earth materials underlying and surrounding the lake are described, and the movement of water into and out of the lake from these materials is discussed. Various ways that the lake gains and loses water are discussed and evaluated to determine if downward leakage occurs. Finally, some methods for regulating the stage of the lake are considered.

#### RAINFALL

Brooklyn Lake receives all its water either directly or indirectly from rainfall. Rain falling on the lake surface is the direct source. The indirect source is surface inflow and ground-water inflow. The rainfall on Brooklyn Lake averages 52 inches per year, based on records from three U. S. Weather Bureau stations within 30 miles of the lake—Gainesville, Glen St. Mary, and Federal Point. This amount is essentially equal to that at Gainesville. Records for the period 1900-60 at Gainesville show that the rainfall there averages 51 inches and has ranged from 32.79 to 73.30 inches.

Figure 2 shows annual rainfall for the period 1900-60 at Gainesville. Periods of excessive and deficient rainfall occur in unpredictable cycles. Rainfall at Gainesville in 1953 was 73.30 inches, the highest annual rainfall of record for the area, and in 1954 the rainfall was 36.24 inches, the second lowest annual rainfall of record for the area. Also, 1954 marked the beginning of a prolonged period of deficient rainfall.

A period of more than 3 years of deficient rainfall from January 1954 to May 1957, coupled with high rates of seepage, caused Brooklyn Lake to recede to the low levels that existed in 1957-58. Rainfall during the 3-year period 1954 to 1956 was below normal by nearly 23 inches. Above-normal rainfall started in March 1957, but Brooklyn Lake did not begin to rise until March 1958 when surface inflow started.

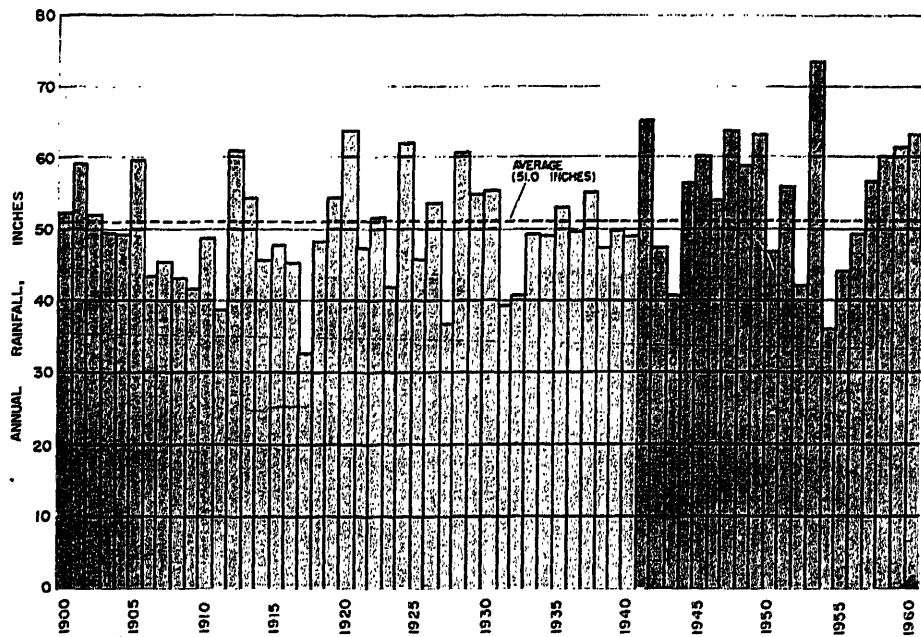
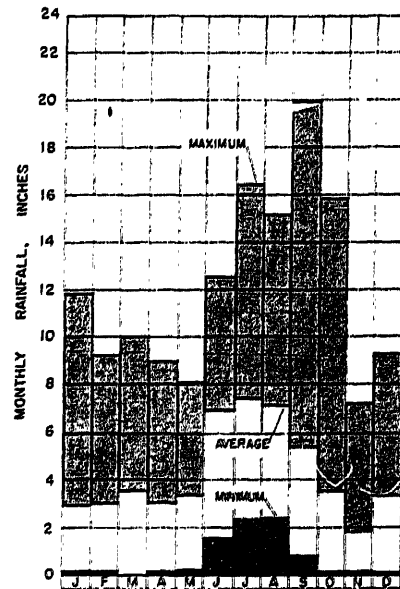


Figure 2. Bar graph of annual rainfall for the period 1900-60 at Gainesville, Florida.



## PHYSICAL DESCRIPTION

Brooklyn Lake is not unique in its behavior or physical structure, but it is somewhat unusual in both respects. Its range in stage is quite large for a Florida lake—about 20 feet—and it is one of the many lakes located in a group of high sandhills. Some of these lakes are landlocked; that is, they have no surface outlet; others are connected by surface channels and form a chain of lakes. Brooklyn Lake is in a chain of lakes. This lake region is characterized by hills and valleys covered with a thick mantle of sand. The highest of these hills, north of Blue Pond, is 225 feet above sea level. The highest land surface near Brooklyn Lake is about 170 feet above sea level.

## SURFACE DRAINAGE

Brooklyn Lake is the fourth from the head of a chain of six lakes that form the headwaters of Etonia Creek in southwestern Clay County. The upper Etonia Creek basin lies between the Santa Fe River basin to the west and the Black Creek basin to the northeast (fig. 3). The lakes, in a downstream order, are: Blue Pond, Sandhill Lake, Magnolia Lake, Brooklyn Lake, Keystone Lake, and Lake Geneva. The upper three of these are in the Camp Blanding Military Reservation. The lower three—Brooklyn Lake, Keystone Lake, and Lake Geneva—are at Keystone Heights.

Surface runoff from this group of lakes is exceedingly low. Surface flow occurs from the lower of these lakes only after prolonged periods of excess rainfall, even though the differences in lake elevations and slopes of the channels connecting them are sufficient to allow rapid runoff. In January 1961, after 3½ years of above-normal rainfall, the level of Lake Geneva was still below the outlet level. A profile showing water-surface elevations of these six lakes on two dates is given in figure 4. Brooklyn and Keystone lakes were lower than Lake Geneva in October 1958 even though they are above Lake Geneva in the chain. Low runoff from these lakes indicates that seepage into the ground and evapotranspiration from the basin take a heavy toll of the rainfall.

## STAGE FLUCTUATIONS

Lake surface elevations, and how they fluctuate with seasons, are important characteristics of any lake. If the rate of replenishment were to equal the rate of loss, the amount of water



stored in a lake would remain constant and the lake surface would not fluctuate. However, no lake remains at a constant stage. All lakes in Florida have some seasonal fluctuations. When stage fluctuations become so great that the utility of the lake is hampered, control measures are sought. In 1957 and 1958, Brooklyn Lake was at such a low level that control measures were desirable.

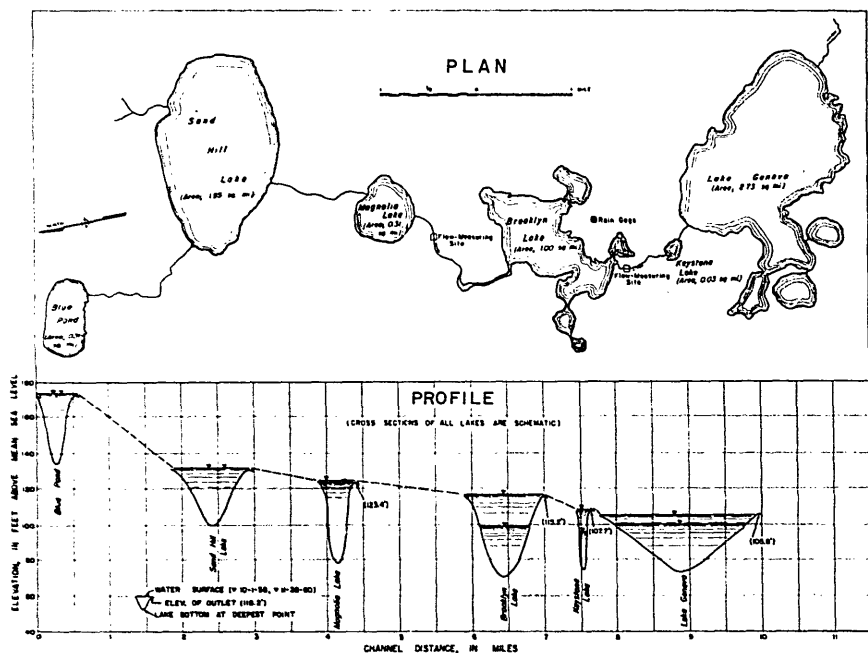


Figure 4. Profile and location of chain of six lakes in the upper Etonia Creek basin.

A stage graph of Brooklyn Lake for the period July 1957 to December 1960 is given in figure 5.

In 1957, after  $31\frac{1}{2}$  years of deficient rainfall, Brooklyn Lake had receded about 20 feet below a desirable stage. However, at the end of 1959, after  $21\frac{1}{2}$  years of excessive rainfall, the lake had filled and water was flowing from the outlet to Keystone Lake. Brooklyn Lake began its recovery in mid-March 1958 when surface flow from Magnolia Lake first started. The recovery was erratic during the last 9 months of 1958, partly because at the lowest stages the lake consisted of 10 separate pools that had to be filled. After these pools were filled and the lake became one continuous body of water, the recovery was fairly uniform through 1959.

Surface outflow from the lake began at elevation 115.2 feet in October 1959, after which the stage leveled off for several months. From October 1959 to December 1960, the stage fluctuated through a range of 2.2 feet. The highest known stage of Brooklyn Lake, which occurred in 1948, is 118.2 feet, 3 feet above the bottom of the outlet.

Flood and drought conditions occur in unpredictable cycles. These cycles coincide with periods of high and low rainfall. It is

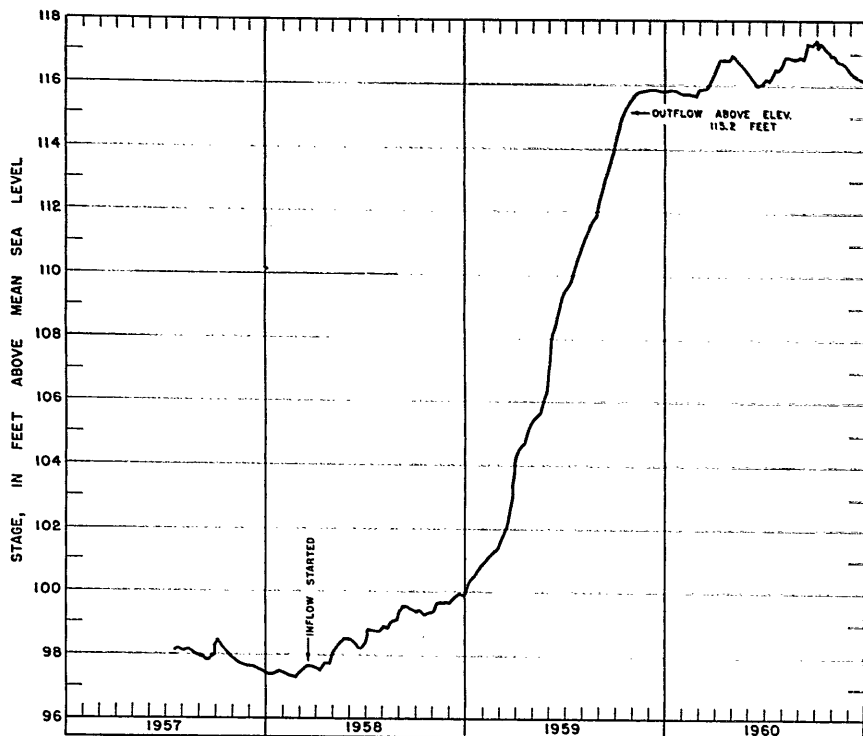


Figure 5. Stage graph of Brooklyn Lake.

possible for the cumulative deficiency for several consecutive years of slightly below-normal rainfall to cause a more serious drought condition than a large rainfall deficiency in a single year. Likewise, in this lake region, it is possible for the cumulative effect of slightly above-normal rainfall for several consecutive years to cause greater floods than those caused by 1 year of exceedingly high rainfall. Figure 2 shows that the rainfall at Gainesville was below normal during 1954-56. The end of the period of below-normal rainfall corresponds with the low lake levels that were measured in 1957. The graph in figure 2 also shows that the rainfall was below normal from 1906-11, 1914-18, and 1931-34. Presumably, the lake level was also low near the end of these periods.

#### DEPTHS AND STORAGE

Other physical aspects of Brooklyn Lake are shape, size, depth, and the related factor of storage. At the lake-full stage of 115.2

feet, the area of the lake is 1.0 square mile and the length of shoreline is 8.4 miles. At the low stage of 97.2 feet in February 1958, the composite water-surface area of the 10 separate pools for the lake was only 0.5 square mile.

The map given in figure 6 shows lines of equal depth at the stage of 117 feet. The map was drawn from data obtained from traverses of the lake with a sonic depth recorder. Maximum depths of the main body of the lake range from 20 to 34 feet. Several arms of the lake extend outward from the main body. The arm extending southwest toward Keystone Heights is the shallowest, with a depth of 20 feet. The deepest point in the lake, 47 feet, is the middle of the series of three depressions extending to the northwest. Brooklyn Bay, to the southeast of State Highway 21, has a depth of 40 feet.

The lake divided into 10 separate pools when it was at its lowest stage of 97.2 feet in February 1958. The maximum depth at that stage was 27 feet. Figure 7 shows the outline of the lake and lines of equal depth at the low stage of 97.2 feet.

Storage, or volume, of water in the lake is related to stage and has ranged from 2,200 to 13,000 acre-feet. (An acre-foot is the volume needed to cover 1 acre to a depth of 1 foot.) The storage curve in figure 8 shows the storage of Brooklyn Lake at any lake stage.

#### CHEMICAL QUALITY AND TEMPERATURE OF WATER

Chemical quality and temperature of Brooklyn Lake water for the period of record, July 1957 to June 1960, were determined by sampling about twice yearly. Table 1 shows the results of chemical analyses of water in Brooklyn Lake, Magnolia Lake, and Sandhill Lake. During periods when surface inflow occurs, water in Brooklyn Lake is a blend of waters from the upper lakes and possibly shallow ground water. Data for ground water were obtained as a part of the four-county study.

The water in Brooklyn Lake has a low dissolved solids content. The maximum concentration of dissolved solids was 34 ppm as determined by the weight of residue on evaporation at 180°C (table 1). The maximum change in dissolved solids content was 15 ppm as determined by the weight of residue. The chemical content appears to have a general inverse relation to lake stage. None of the individual constituents varied markedly during the period of record. The most highly concentrated constituent was chloride with a maximum of 7 ppm.

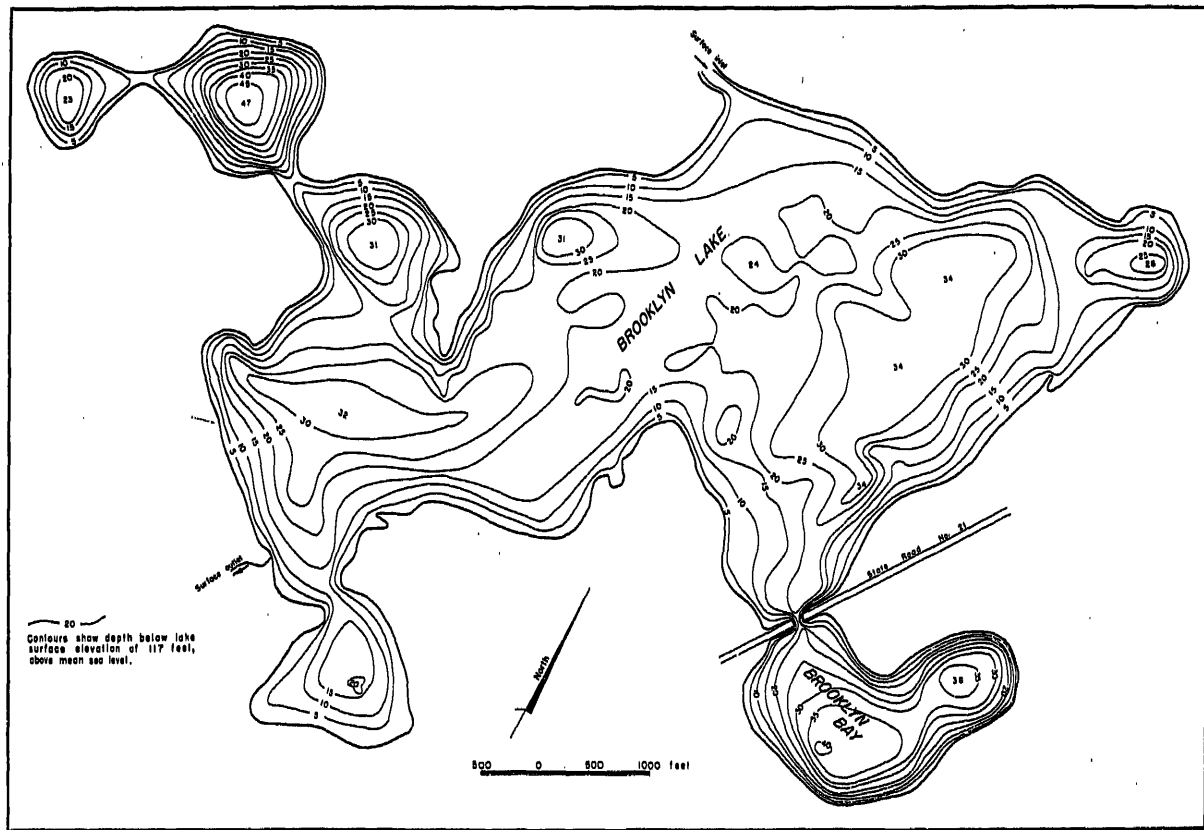
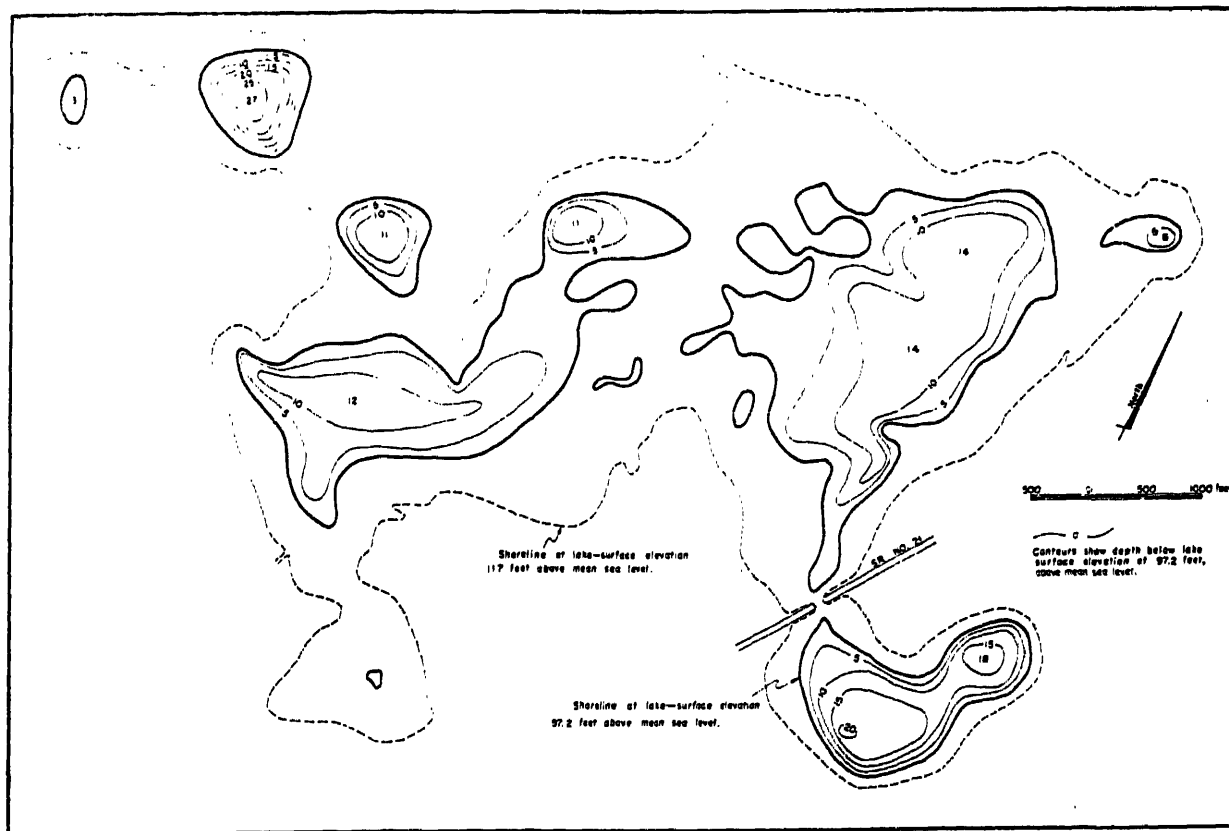


Figure 6. Brooklyn Lake showing lines of equal depth at lake-surface elevation of 117 feet above sea level.



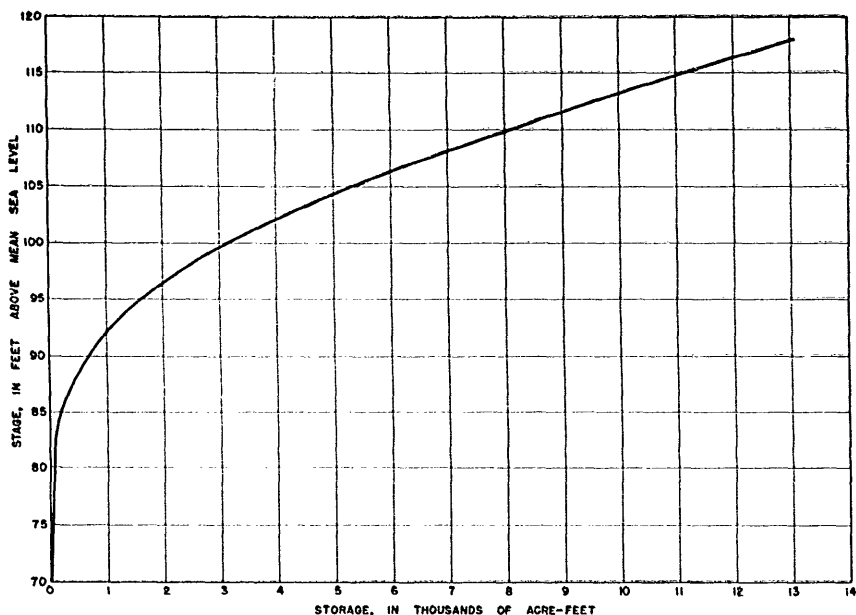


Figure 8. Curve showing relation of lake stage to lake storage.

The pH of the lake was low, averaging 5.5 with a range of 0.6 pH units. Figure 9 shows the relation of pH of the lake to that of ground water in the area. The data suggest that water from the lake has a slight effect on the pH of the ground water. In the vicinity of the lake, the average pH value of the water in the shallow aquifer is 0.1 to 0.2 units lower than the average pH value for water in that aquifer throughout Clay County. The total contribution of the lake and water-table aquifer to the secondary artesian aquifer apparently is effective in lowering the pH about 0.4 units in the vicinity of the lake. No direct chemical quality relation is obviously apparent between the Floridan aquifer and recharge sources in the vicinity of Brooklyn Lake.

The temperature of Brooklyn Lake fluctuates seasonally. Rain causes minor fluctuations in temperature of the lake surface. The temperature of shallow ground water that enters Brooklyn Lake ranges from 65° to 80°F. During the recent period of high lake stages, temperature measurements were made at selected spots in Brooklyn Lake to correlate water temperature with depth of water. The results of temperature measurements at the selected spots within the lake are shown as vertical temperature profiles in figure 10.

TABLE 1. Average, Maximum, and Minimum Mineral Content and Temperature of Brooklyn, Magnolia, and Sandhill Lakes. (Chemical analyses in parts per million except specific conductance, pH and color, July 1957 to June 1960.)

|                                                           | Temperature (°F)<br>near lake surface | Silica (SiO <sub>2</sub> ) | Iron (Fe) | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Bicarbonate (HCO <sub>3</sub> ) | Sulfate (SO <sub>4</sub> ) | Chloride (Cl) | Fluoride (F) | Nitrate (NO <sub>3</sub> ) | Phosphate (PO <sub>4</sub> ) | Sum of determined<br>mineral constituents | Residue on evapo-<br>ration at 180°C | Approximate organic<br>matter (solid-sum) | as CaCO <sub>3</sub><br>Hardness |               | Specific conductance<br>micromhos at 25°C | pH  | Color <sup>a</sup> |
|-----------------------------------------------------------|---------------------------------------|----------------------------|-----------|--------------|----------------|-------------|---------------|---------------------------------|----------------------------|---------------|--------------|----------------------------|------------------------------|-------------------------------------------|--------------------------------------|-------------------------------------------|----------------------------------|---------------|-------------------------------------------|-----|--------------------|
|                                                           |                                       |                            |           |              |                |             |               |                                 |                            |               |              |                            |                              |                                           |                                      |                                           | Calcium,<br>magnesium            | Non-carbonate |                                           |     |                    |
| Brooklyn Lake near Keystone Heights, Florida <sup>b</sup> |                                       |                            |           |              |                |             |               |                                 |                            |               |              |                            |                              |                                           |                                      |                                           |                                  |               |                                           |     |                    |
| Average                                                   | 75                                    | 0.9                        | 0.03      | 1.3          | 0.7            | 3.6         | 0.2           | 3                               | 4.1                        | 5.8           | 0.0          | 0.1                        | 0.0                          | 18                                        | 23                                   | 5                                         | 6                                | 4             | 35                                        | 5.5 | 4                  |
| Maximum                                                   | 88                                    | 1.4                        | .05       | 1.6          | 1.2            | 4.4         | .4            | 4                               | 5.5                        | 7.0           | .1           | .2                         | .1                           | 21                                        | 34                                   | 13                                        | 9                                | 8             | 41                                        | 5.7 | 10                 |
| Minimum                                                   | 60                                    | .2                         | .02       | 1.0          | .2             | 2.6         | .0            | 1                               | 2.5                        | 4.8           | .0           | .0                         | .0                           | 14                                        | 19                                   | 1                                         | 4                                | 2             | 26                                        | 5.1 | 2                  |
| Magnolia Lake near Keystone Heights, Florida <sup>c</sup> |                                       |                            |           |              |                |             |               |                                 |                            |               |              |                            |                              |                                           |                                      |                                           |                                  |               |                                           |     |                    |
| Average                                                   | 67                                    | 1.3                        | 0.05      | 1.0          | 0.3            | 2.8         | 0.1           | 3                               | 2.4                        | 4.6           | 0.0          | 0.1                        | 0.0                          | 14                                        | 20                                   | 6                                         | 4                                | 1             | 26                                        | 5.6 | 11                 |
| Maximum                                                   | 83                                    | 1.9                        | .07       | 1.2          | .6             | 2.9         | .2            | 4                               | 2.8                        | 5.0           | .1           | .5                         | .0                           | 15                                        | 28                                   | 14                                        | 4                                | 2             | 28                                        | 6.1 | 20                 |
| Minimum                                                   | 56                                    | .8                         | .02       | .8           | .1             | 2.6         | .0            | 2                               | 1.8                        | 4.0           | .0           | .0                         | .0                           | 13                                        | 15                                   | 2                                         | 4                                | 0             | 24                                        | 5.1 | 3                  |
| Sandhill Lake near Keystone Heights, Florida <sup>b</sup> |                                       |                            |           |              |                |             |               |                                 |                            |               |              |                            |                              |                                           |                                      |                                           |                                  |               |                                           |     |                    |
| Average                                                   | 74                                    | 2.5                        | 0.09      | 0.9          | 0.5            | 3.2         | 0.1           | 3                               | 2.0                        | 5.0           | 0.1          | 0.1                        | 0.0                          | 17                                        | 22                                   | 6                                         | 4                                | 2             | 28                                        | 5.4 | 10                 |
| Maximum                                                   | 87                                    | 4.0                        | .23       | 1.4          | .7             | 3.6         | .4            | 4                               | 3.5                        | 5.8           | .1           | .2                         | .0                           | 20                                        | 26                                   | 11                                        | 6                                | 4             | 37                                        | 5.7 | 38                 |
| Minimum                                                   | 55                                    | 1.3                        | .01       | .4           | .4             | 2.8         | .0            | 1                               | .3                         | 4.2           | .0           | .0                         | .0                           | 14                                        | 16                                   | 2                                         | 4                                | 0             | 24                                        | 4.8 | 2                  |

<sup>a</sup>Units, platinum-cobalt scale

<sup>b</sup>Six analyses

<sup>c</sup>Four analyses

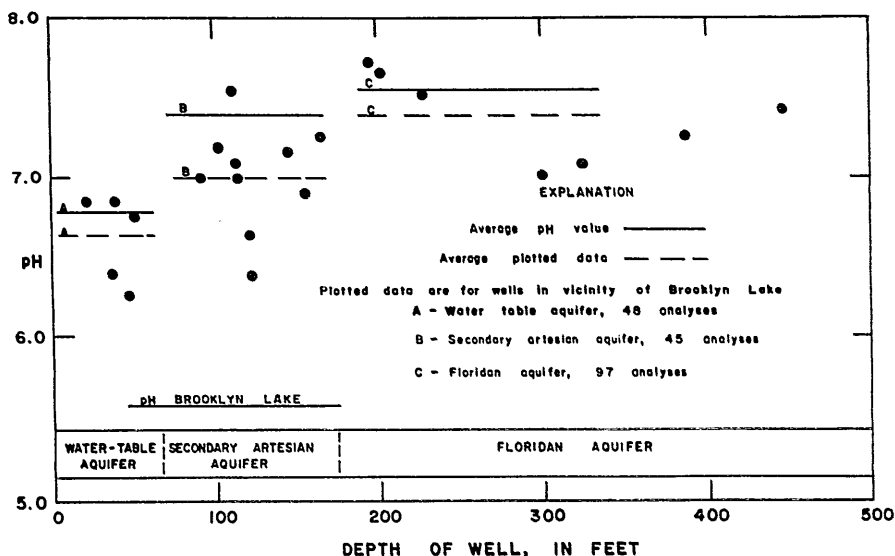


Figure 9. Relation of pH to depth of water occurrence, near Brooklyn Lake.

The temperature measurements for the two profiles were made at times of equal lake stages (about 117 feet above mean sea level) and reflect seasonal temperature fluctuations. Stratification was much more pronounced on May 9 than on November 28, 1960, which was probably due to the slower rate of warming of the deeper water during the spring months. On November 26, 1957, when the lake stage was about 20 feet lower, water temperature throughout the lake was essentially uniform; the maximum temperature of 67°F being near the lake surface and the minimum temperature of 65°F being near the lake bottom.

### RELATION OF GROUND WATER TO LAKE

The following sections describe the principal hydrologic units that underlie the Brooklyn Lake area—the water-table aquifer, the confining bed, and the Floridan aquifer—and describe the movement of ground water in the aquifers in relation to Brooklyn Lake. The two major aquifers, the water-table aquifer, and the Floridan aquifer, are separated by the confining bed. The geologic formations, the nature of the earth materials that comprise each hydrologic unit, and the hydrologic characteristics of each hydrologic unit are described. The interpretations of the relation of

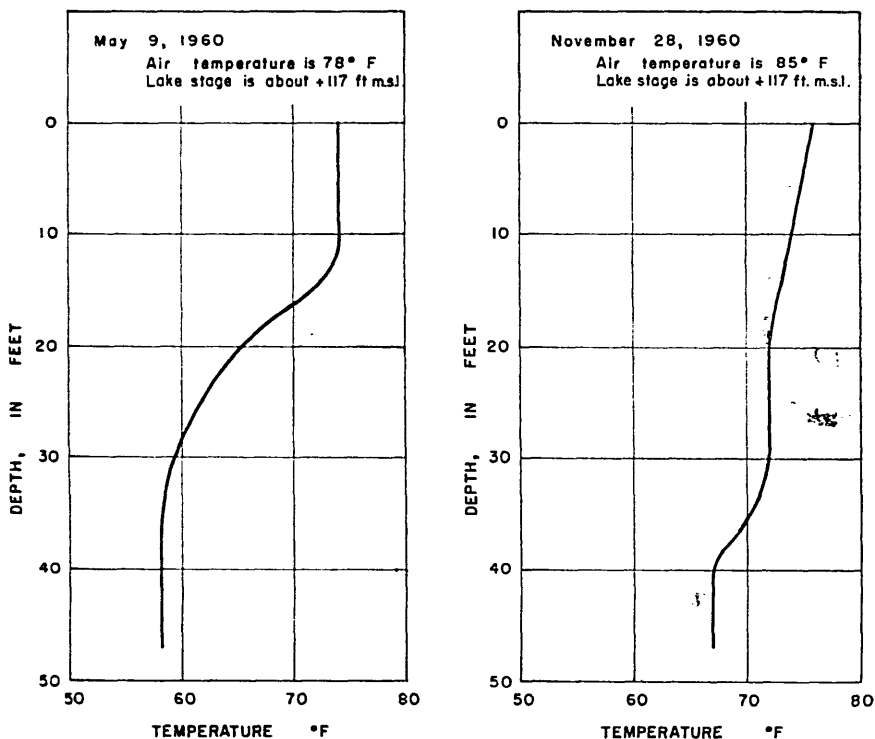
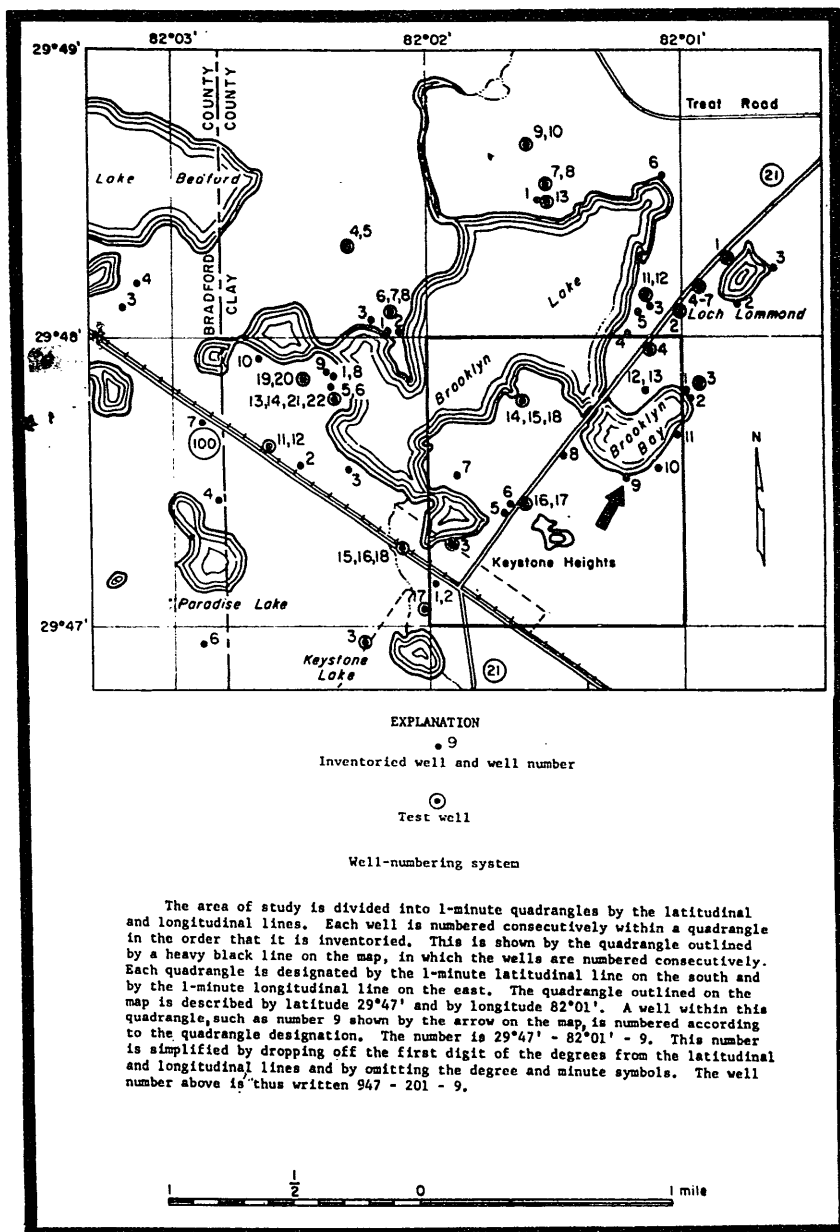


Figure 10. Temperature profiles in Brooklyn Lake on May 9, 1960 and November 28, 1960.

ground water to Brooklyn Lake, and also of the character and composition, thickness and structure, and extent of the geologic formations and hydrologic units are based on data from 39 test wells and many private wells. The locations of wells in the Brooklyn Lake area and an explanation of the well-numbering system are given in figure 11. Table 2 lists the geologic formations that comprise each hydrologic unit and summarizes the water-bearing characteristics of each unit.

Figure 12 shows the locations of sections A-A', B-B', C-C' and D-D'. Section A-A' (fig. 13) shows graphically the lithology of the formations and relates the geology to the hydrologic units and to the lake. Sections B-B' (fig. 14), C-C' (fig. 15), and D-D' (fig. 16) show the hydrologic units that underlie the Brooklyn Lake area. Figure 16 also shows a section through a filled sink.



Base taken from U.S.G.S.  
topographic quadrangle  
1949

Figure 11. Brooklyn Lake area showing locations of wells and giving an explanation of the well-numbering system.

TABLE 2. Geologic Formations, Hydrologic Units, and Their Water-Bearing Characteristics in the Brooklyn Lake Area, Clay County, Florida<sup>1</sup>

| Hydrologic unit     | Series      | Formation                          |                                                                     | Normal range in thickness | Physical characteristics                                                                                                                                                                                                                                                                                                                          | Water-bearing characteristics                                                                                                                                                                                                                                                                                                                                                                                                  |
|---------------------|-------------|------------------------------------|---------------------------------------------------------------------|---------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Water-table aquifer | Pleistocene | Older Pleistocene terrace deposits |                                                                     | 0-15                      | Sand, tan, yellow and brown, loose.                                                                                                                                                                                                                                                                                                               | Water in the aquifer is unconfined. The sands and sandy clays are of low to moderate permeability. The Choctawhatchee contains a few permeable zones.                                                                                                                                                                                                                                                                          |
|                     |             | Unnamed coarse clastics            |                                                                     | 30-67                     | Sand and clayey sand, varicolored, locally contains quartz gravels, interbedded thin lenses of clay or kaolin. Upper few feet in places is red and yellow sandy clay bed.                                                                                                                                                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                |
|                     |             | Choctawhatchee Formation           |                                                                     | 10-20                     | Clay and marl, yellow and cream, indurated in part, phosphate grains and pebbles, thin limestone and sand layers.                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                |
| Confining bed       | Miocene     | Hawthorn Formation                 |                                                                     | 115-155                   | Clay and sandy clay, varicolored, interbedded thin sands and sandy phosphatic limestones, disseminated grains and pebbles of phosphate. Some thick sand beds with limestone layers.<br><br>The lowermost 25 feet of the Hawthorn is composed of very hard tan and gray limestones and dolomitic limestones with interbedded clay and sand lenses. | Relatively impervious clays and limestones confine water in the Floridan aquifer under artesian pressure. Some sand and limestone beds that are interbedded in clay are of low to moderate permeability.                                                                                                                                                                                                                       |
| Floridan aquifer    | Eocene      | Ocala Group                        | Crystal River Fm. Williston Fm. Inglis Formation (Undifferentiated) | 210                       | Limestone, white, cream, and tan, soft, granular, porous, fossiliferous, coquina in part. Some hard layers of tan and gray crystalline limestone, dolomitic in part.                                                                                                                                                                              | Water in the Floridan aquifer is under artesian pressure. Beds in the lower part of the Hawthorn are the least permeable part of the aquifer. Limestones in the Ocala Group are highly porous and permeable and constitute the most productive part of the aquifer. The Avon Park, Lake City, and Oldsmar Limestones contain many relatively impervious beds, but the formations are generally moderately to highly permeable. |
|                     |             |                                    | Avon Park Limestone                                                 | 210                       | Dolomite, dark brown and tan, granular, hard, dense to porous; interbedded tan and cream limestone and dolomitic limestone.                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                |
|                     |             |                                    | Lake City Limestone                                                 | 450+                      | Limestone, dolomite, and dolomitic limestone.                                                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                |
|                     |             |                                    | Oldsmar Limestone                                                   | ?                         | Limestone, dolomite, and dolomitic limestone.                                                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                |

<sup>1</sup>The stratigraphic nomenclature used in this report conforms to the usage of the Florida Geological Survey.

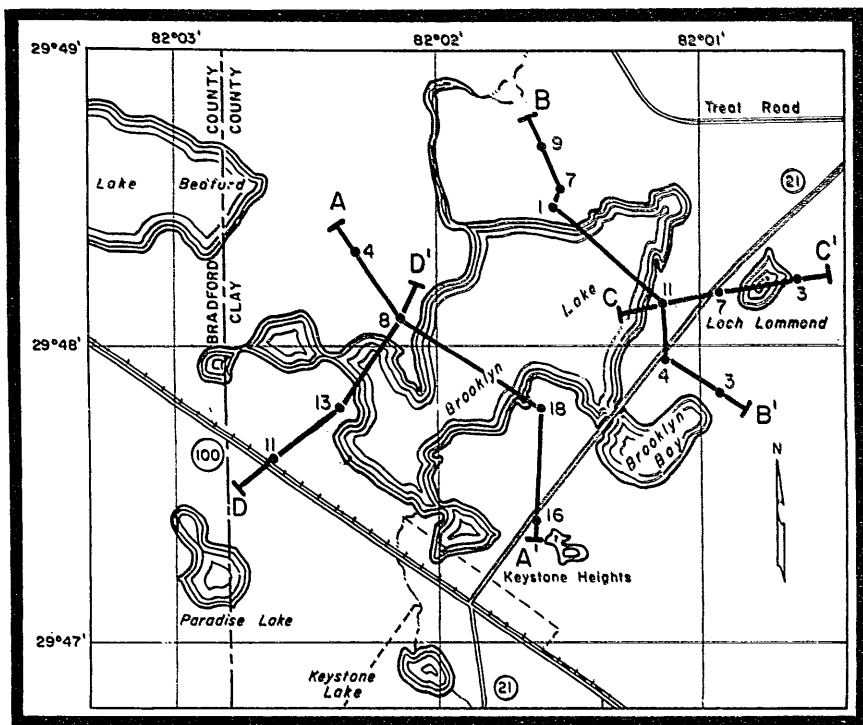


Figure 12. Brooklyn Lake area showing the locations of sections A-A', B-B', C-C', and D-D'.

### WATER-TABLE AQUIFER

The upper and middle parts of the water-table aquifer are composed predominantly of sands and clayey sands. These sands and clayey sands grade into soft clay and marl beds in the bottom part of the aquifer. From the surface downward the aquifer is made up of the older Pleistocene terrace deposits, the unnamed coarse clastics of Pleistocene age, and the Choctawhatchee Formation of Miocene age.

The older Pleistocene terrace deposits which lie at the surface are yellow, tan, and brown, fine to coarse; loose sands that are as much as 15 feet thick.

The underlying unnamed coarse clastic unit is composed of two parts. At most places, the upper part is a bed of coarse, red, yellow, and orange sandy clay that is from 6 to 16 feet thick. The

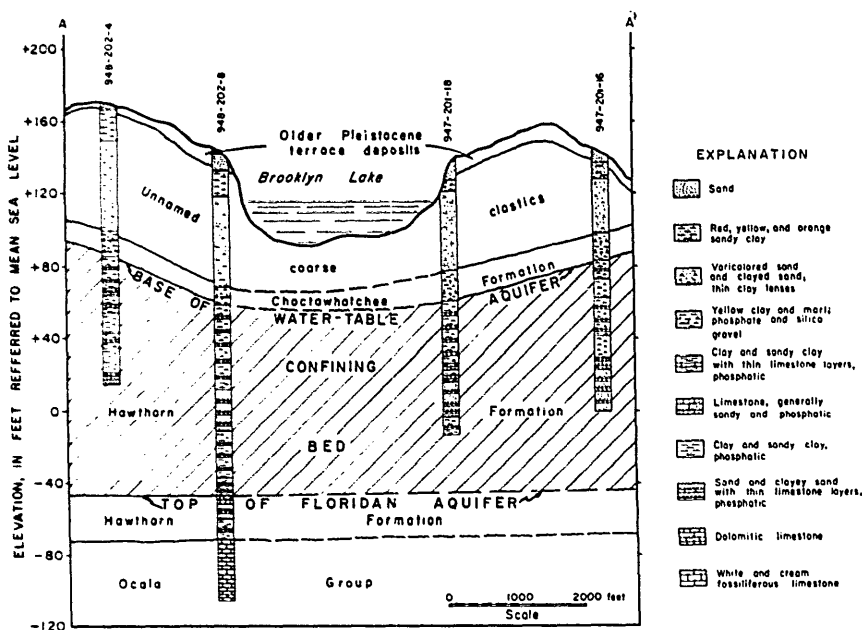


Figure 13. Section showing geologic formations, hydrologic units, and types of material in the Brooklyn Lake area along line A-A' in figure 12.

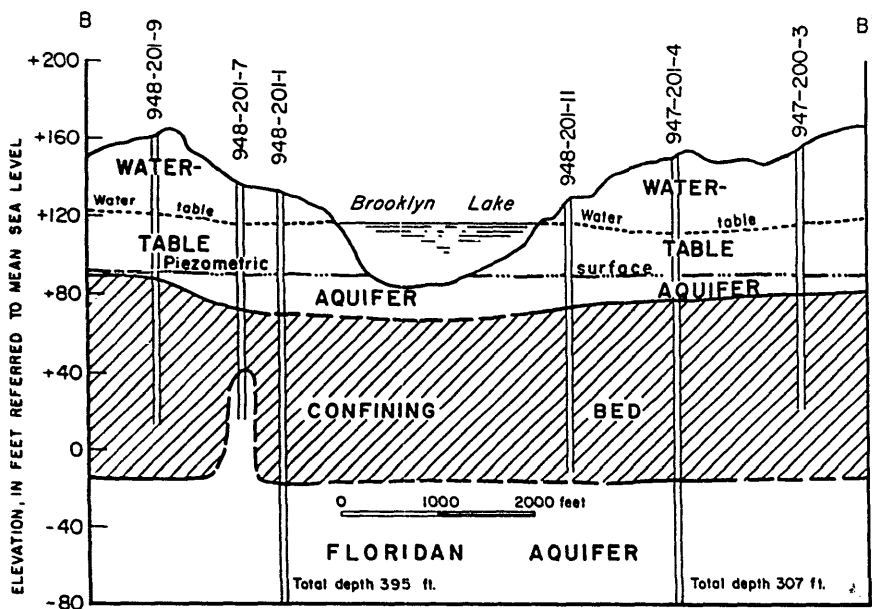


Figure 14. Section showing hydrologic units in the Brooklyn Lake area along line B-B' in figure 12.

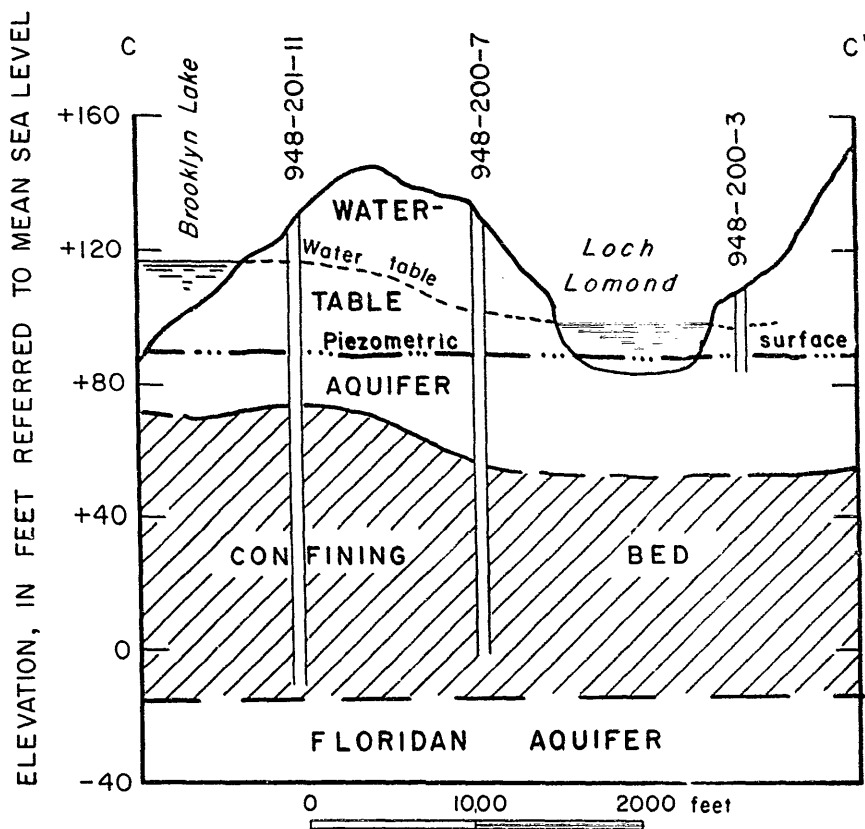


Figure 15. Section showing hydrologic units in the Brooklyn Lake area along line C-C' in figure 12.

bed was not penetrated at the sites of test wells 947-201-4 (east side of lake), 947-202-13 (southwest side of lake), and 948-200-1 and 4 (northeast side of lake near Loch Lomond), and 948-201-7 (north side of lake). The sandy clay either changes character or is absent in the area northeast from the lake and in the area generally north of test wells 948-201-9 and 948-202-4. The sediments that lie beneath the sandy clay bed and comprise the lower part of the unnamed coarse clastic unit are varicolored micaceous sands and clayey sands that contain thin lenses of kaolin clay and sandy clay, and locally contain quartz gravel. Where the sandy clay in the upper part of the unnamed coarse clastics units is absent, the varicolored sands and clayey sands are continuous with the overlying loose surface sands. Test wells penetrated 20 to 58 feet of the varicolored sands and clayey sands. The thickness of the

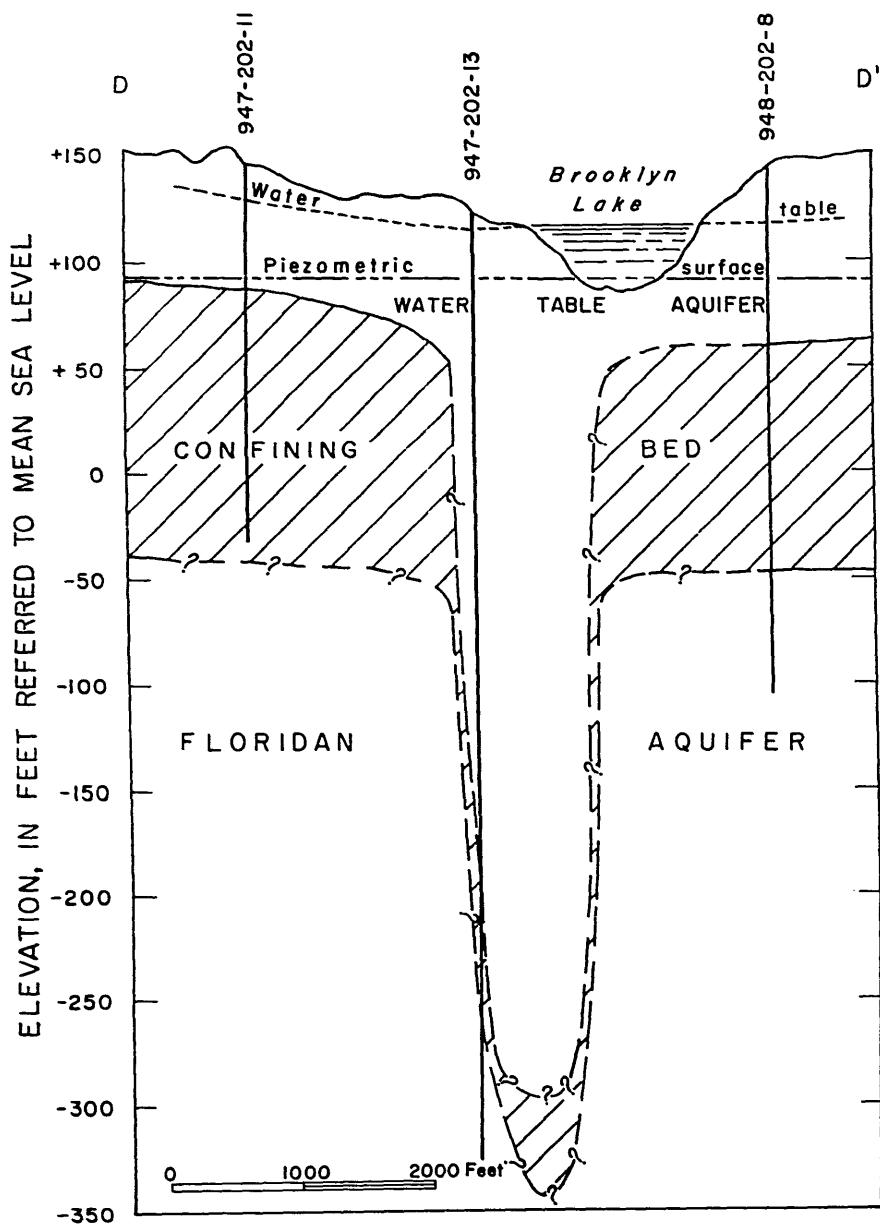


Figure 16. Section showing hydrologic units in the Brooklyn Lake area through a filled sink along line D-D' in figure 12.

unnamed coarse clastics including the sandy clay bed ranged from 30 to 67 feet.

The basal part of the aquifer, the Choctawhatchee Formation, is composed of 10 to 20 feet of soft, yellow, and olive sandy clay and partly indurated marl with some sand, red and brown phosphorite and silica gravel, thin limestone, and a few poorly preserved mollusk shells and impressions.

The water-table aquifer, as a composite of the above described materials and formations ranged in thickness in test wells from 50 to 85 feet. However, where deep filled sinks occur the aquifer is much thicker, as at the site of test well 947-202-13 (section D-D', fig. 16) where 319 feet of sediments were penetrated.

The sands that comprise the unnamed coarse clastic unit, the main part of the water-table aquifer, have a low to moderate permeability owing to clay that is disseminated in the bed. The predominantly clayey Choctawhatchee Formation, though it contains a few permeable zones, will transmit only very small amounts of water.

Figure 17 shows the configuration of the base of the water-table aquifer. Comparison of figure 17 with the contour map of the bottom of Brooklyn Lake (fig. 6) and figures 13, 14, 15, and 16 shows that nearly everywhere the bottom of the lake is in the water-table aquifer. The lake bottom generally lies from 15 to 25 feet above the base of the aquifer. Only in its deepest parts does the lake bottom extend to or slightly below the base of the water-table aquifer.

Water in the water-table aquifer is unconfined so that its surface is free to rise and fall. The water in the aquifer is derived from local rainfall and from water that at times flows into the aquifer from lakes and perhaps from streams. The clayey sand or sandy clay layer in the upper part of the aquifer, shown in figure 13, does not prevent water from moving downward. While test wells were being drilled near the lake, no water was found in the loose sand above this layer. Moreover, water placed in casings ending in the layer soon disappeared.

Figures 18 and 19 show the general configuration of the water table on March 22 and October 17, 1960, respectively. The water table and Brooklyn Lake on October 17 was higher than on March 22. In general, the water table slopes toward the lake on the northern, northwestern, western, and southwestern sides of the lake and slopes away from the lake on the eastern and southeastern sides of the lake. In March, a trough existed in the water table near the lake on the northern and northwestern sides of the lake.

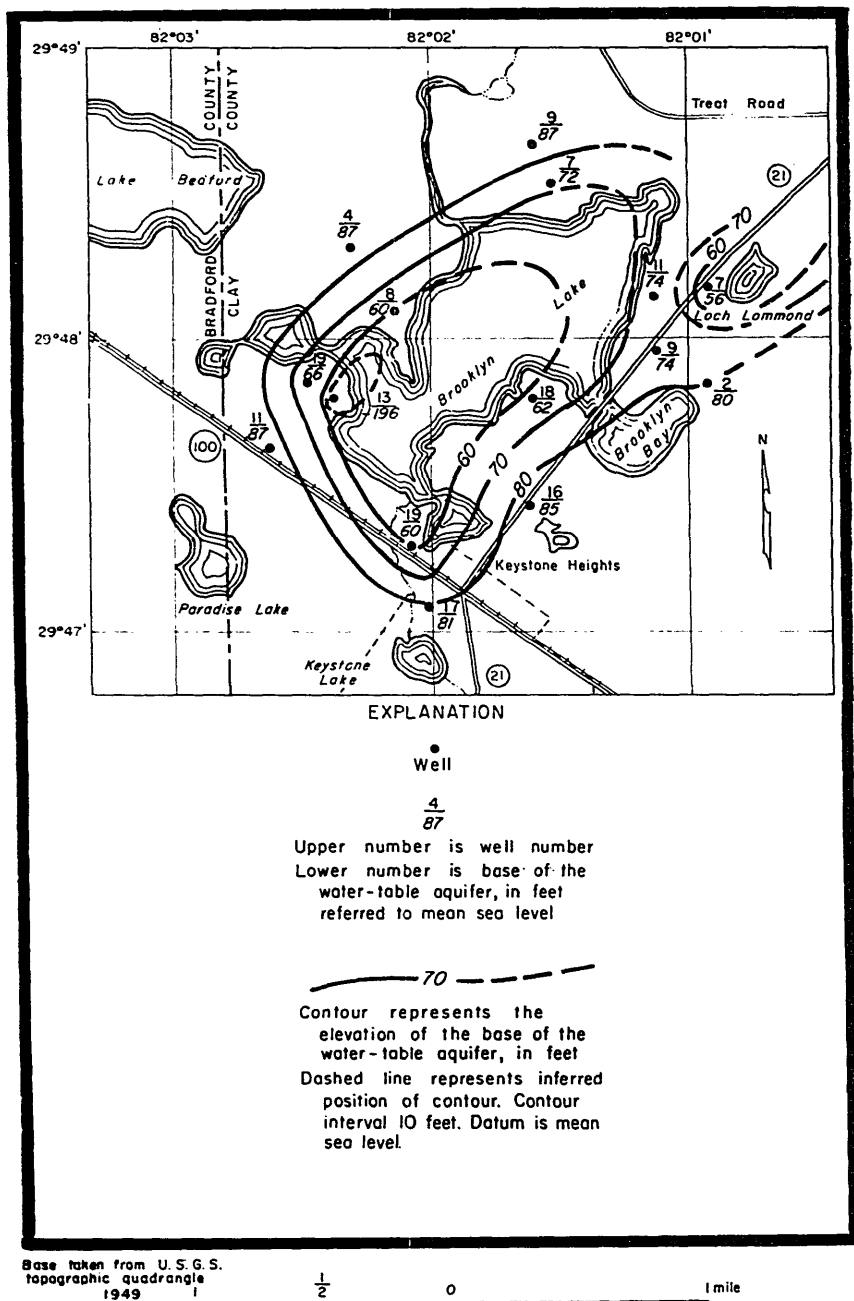
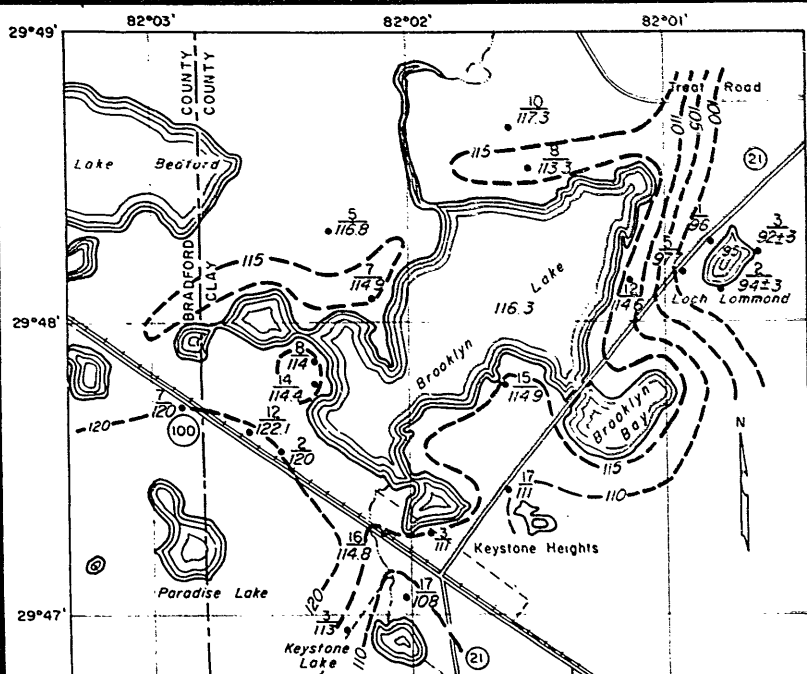


Figure 17. Brooklyn Lake area showing contours on base of the water-table aquifer.



## EXPLANATION

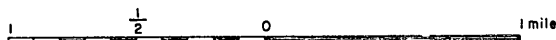
•  
Well

$\frac{15}{114.9}$

Upper number is well number  
Lower number is water level,  
in feet above mean sea level  
Number in lake is lake level,  
in feet above mean sea level

--- 115 ---

Contour represents the  
approximate elevation of the  
water table, in feet, March  
22, 1960. Contour interval 5  
feet. Datum is mean sea level.



Base taken from U.S.G.S.  
topographic quadrangle  
1949

Figure 18. Brooklyn Lake area showing contours on the water table on March 22, 1960.



Also, a depression exists on the water table on the western side of the lake.

Ground water moves downgradient in a direction at right angles to the contours on the water table. Thus, in general, water in the water-table aquifer moves toward the lake on the northern, northwestern, western, and southwestern sides of the lake and from the lake on the eastern and southeastern sides. While the trough in the water table on the northern and northwestern sides exists, however, water moves from the lake toward the trough. Also, water moves from the lake toward the depression in the water table on the western side of the lake.

Some conditions under which water moves into the lake from the water-table aquifer and from the lake into the water-table aquifer are illustrated by the movement of water in the aquifer at three sites near the lake.

The water levels in the wells and the contours north and northwest of the lake on the water table (fig. 18, 19) show that water in the aquifer several hundred feet north and northwest of the lake moved toward the lake during the period March through October 1960. However, near the lake as evidenced by the low ground-water levels, water moved from the lake into the aquifer. Before the rapid rise of the stage of the lake in 1959 (fig. 5), water probably moved into the lake in most places on the north and northwest sides of the lake.

The steepest slope of the water table toward the lake is on the southwestern side of the lake. On this side of the lake, water moved from the lake into the aquifer in most places for a time during and after the rapid rise of the lake level (fig. 5), but after a few months, water again began moving into the lake from the aquifer, except near well 947-202-13 where the confining bed has been breached as shown on figure 16.

Some conditions under which water moves into the lake from the water-table aquifer and from the lake into the water-table aquifer are illustrated by the movement of water in the aquifer at three sites near the lake.

The first site is at wells 947-202-13 and 947-202-14, which are about 3 feet apart and about 100 feet from the southwestern edge of the lake (fig. 11). Well 947-202-13 penetrated the filled sink shown in figures 16 and 17 and well 947-202-14 taps the water-table aquifer. A comparison of the fluctuation of the water level in well 947-202-14 and the fluctuation of the stage of the lake is shown in figure 20. The water level in well 947-202-14, reflects the water table of the water-table aquifer and seems to stay about 2 feet

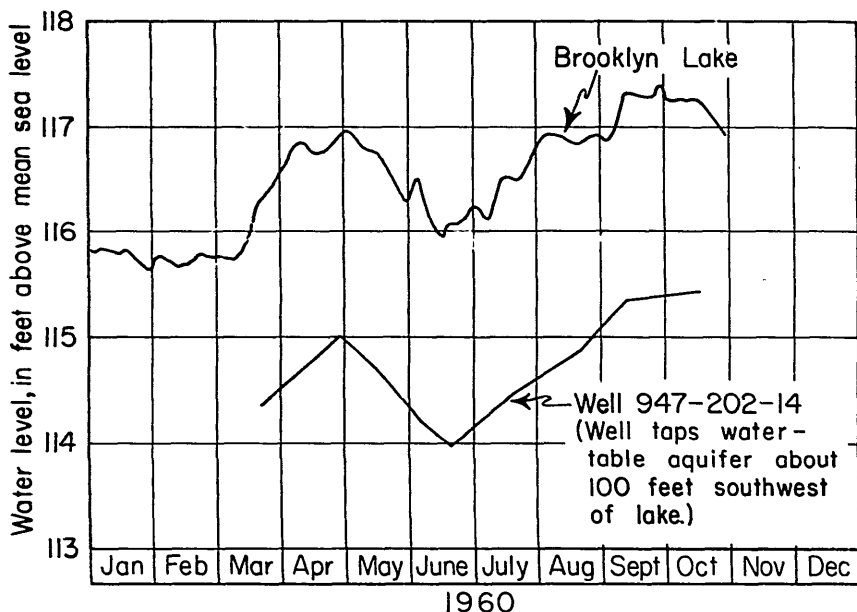


Figure 20. Hydrographs of well 947-202-14 and Brooklyn Lake.

lower than the level of the lake. Thus, the water table slopes from the lake toward the filled sink, and accordingly water moves from the lake into the water-table aquifer in the vicinity of the filled sink shown in figures 16 and 17.

The second site is at wells 948-202-7 and 948-202-8, which are about 3 feet apart. Well 948-202-8, which is shown on section A-A' in figure 13, penetrated a normal sequence of material. Figure 21 shows hydrographs of water-table well 948-202-5, which is about 1,500 feet northwest of the lake, and well 948-202-7, which is about 300 feet northwest of the lake, and a stage graph of Brooklyn Lake (fig. 11). The water level in well 948-202-5 stayed above the level of the lake; whereas, the water level in well 948-202-7 was slightly below the level of the lake from March through October 1960, indicating that during most of that period water at the second site moved from the lake into the aquifer. A reversal in the direction of water movement at this site is indicated in mid-October 1960 when the water level in well 948-202-7 reached a stage higher than that of the lake.

The third site is at wells 948-201-7 and 948-201-8, which are north of the lake and about 3 feet apart (fig. 11). Well 948-201-7 penetrated the Floridan aquifer at an unusually high elevation as

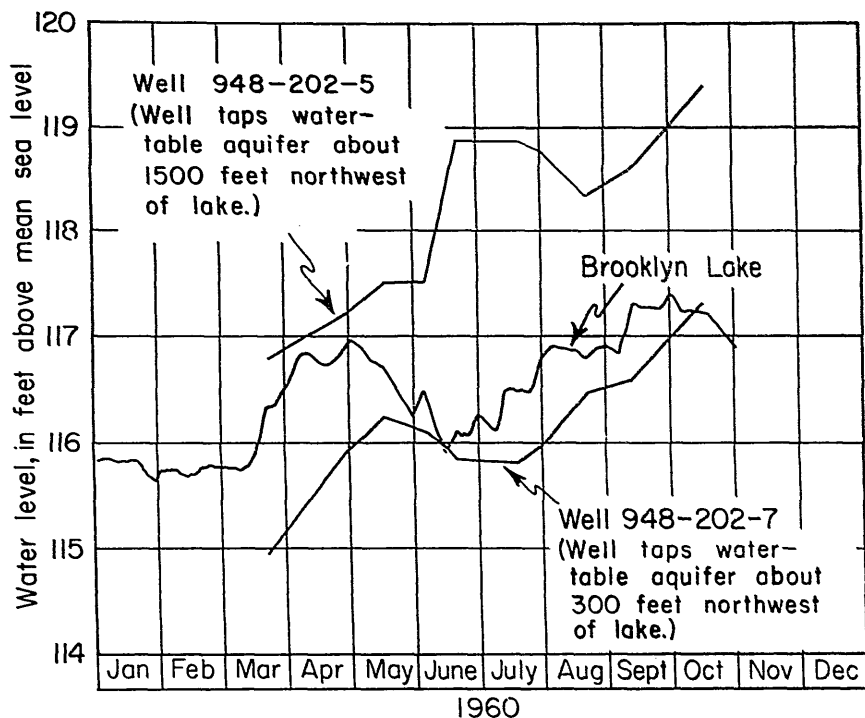


Figure 21. Hydrographs of wells 948-202-5 and 948-202-7, and Brooklyn Lake.

shown in figure 14. The hydrographs of wells 948-201-8, 948-201-10, and 948-201-13, and a stage graph of Brooklyn Lake are shown in figure 22. As indicated by the hydrographs the water level in well 948-201-13 stayed at about half a foot below the level of the lake, the water level in well 948-201-8 about 2 feet below the level of the lake, and the water level in 948-201-10 from 1 to 3 feet higher than the level of the lake. The water levels in these wells indicate that the water table slopes generally toward well 948-201-8 from the north and from the lake and that water probably moves toward well 948-201-8 from all directions.

The data at the three sites indicate that the water in the water-table aquifer moved from the lake, where normally it would have moved into the lake. This reversal of direction may have been caused by: (1) water percolating downward from the aquifer at, or near, these sites; (2) the water table being in the process of adjusting itself to the rapid rise of the level of the lake; or (3) both of the preceding two conditions.

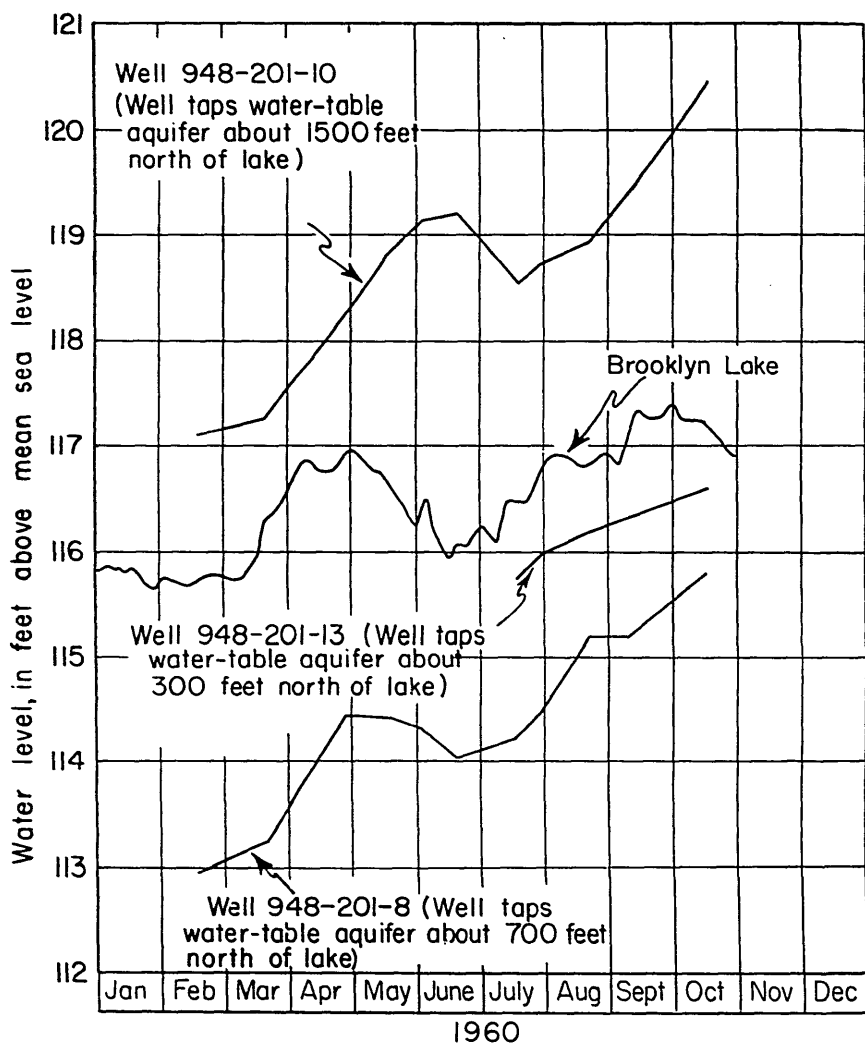


Figure 22. Hydrographs of wells 948-201-8, 948-201-10, and 948-201-13, and Brooklyn Lake.

The water level in well 947-202-14 at the site of the filled sink showed no indication of rising above the level of the lake, suggesting that most, if not all, of the time water probably percolates downward from the aquifer at this site. At the second site, where the normal sequence of materials was present, the water table was rising in such a way as to indicate that it might rise above the level

of the lake. The water table at this site, during the period March through October 1960, was probably in the process of adjusting itself to a higher stage of the lake. At the third site, where the Floridan aquifer extends to an unusually high elevation, the water table was rising, but whether the water table would rise above the level of the lake is problematical. Water at this site probably was percolating downward and the water table was probably adjusting itself to a higher level of the lake.

The relationship between water in the water-table aquifer and water in the lake is complex. The movement of water in the aquifer northwest of the lake at the second site, where the normal sequence of materials is present below the surface, is probably typical of the movement of water around most of the lake. At the second site water moved from the lake into the water-table aquifer during most of the period, March through October 1960. The normal direction of flow on the northern, northwestern, and southwestern sides of the lake is probably from the aquifer into the lake and was probably reversed by the rapid rise in lake stage in 1959. The flow from the lake into the aquifer was accelerated on the eastern and southeastern sides of the lake. This acceleration and the reversal of flow in some places around the lake are temporary conditions that will exist only while the water table is adjusting itself to a higher level of the lake. At other places near the lake, such as the first site at the location of the filled sink, water probably normally moves from the lake into the water-table aquifer and thence percolates downward.

### CONFINING BED

Relatively impermeable deposits of the Hawthorn Formation of Miocene age make up the confining bed. Limestone and dolomitic limestone beds in the bottom part of the Hawthorn, however, do not belong to the confining bed but are a part of the Floridan aquifer. The confining bed locally includes secondary artesian aquifers. The confining bed is composed mostly of various shades of green, gray, yellow, and blue phosphatic clay and sandy clay, containing sand and limestone lenses. The limestone lenses, which range in thickness from a few inches to about 6 feet, are gray, white and bluish gray, and are usually sandy and phosphatic.

In the southwestern half of the lake, which includes sections A-A' and D-D' (fig. 13, 16), the middle and lower parts of the confining bed, in most places, contain a bed of tan and gray, fine to coarse, sand and clayey sand. The middle and lower part of the

confining bed also contain some interbedded thin limestone layers whose thickness, permeability and relative position within the confining bed are variable. The sand is thickest and most permeable southwest of the lake. In well 947-202-11, shown on section D-D', figure 16, a thickness of 45 feet of fine to medium-grained sand and clayey sand was penetrated between depths of 135 and 180 feet, overlain by 75 feet of clay and limestone of the confining beds.

In the northeastern half of the lake, which includes sections B-B' and C-C' (fig. 14, 15), the confining bed is composed mostly of relatively "tight" clay and limestone. The limestone contains small cavities and, together with thin bedded sands, forms zones of relatively high permeability within the clay beds.

The confining bed is thinnest in the northeastern part at the site of test well 948-201-7 (section B-B', fig. 14) where only about 30 feet of clayey materials that comprise the bed overlie the Floridan aquifer. The greatest thickness of the confining bed was 120 feet in test well 947-202-11. The maximum thickness of the confining bed in the Brooklyn Lake area is estimated to be about 130 feet.

The confining bed is ordinarily the hydraulic barrier that separates the water-table aquifer from the Floridan aquifer. Although the bed is not completely impermeable, the vertical permeability of the bed is low and it will normally pass only comparatively small amounts of water. However, in the vicinity of Brooklyn Lake at two sites where test wells were drilled, water probably moves through the confining bed relatively easily. These two sites are at wells 947-202-13 and 948-201-7. Well 947-202-13 was drilled into a filled sink (fig. 16) and at the site of well 948-201-7 the confining bed is thin. At other sites around the lake and beneath the lake, similar conditions probably exist.

### FLORIDAN AQUIFER

The Floridan aquifer below the confining bed consists from top to bottom, of limestone in the bottom part of the Hawthorn Formation and limestone, dolomite, and dolomitic limestone in formations of Eocene age that include the Ocala Group, the Avon Park Limestone, the Lake City Limestone, and, in part, the Oldsmar Limestone. Nine wells shown on figure 11, 947-201-1, 2, and 4; 947-202-13 and 18; 948-201-1, 2, and 7; and 948-202-8 penetrate the Floridan aquifer. The deepest penetration of the aquifer, by well 948-201-1 (section B-B', fig. 14), is to the approximate base of the Ocala Group at 262 feet below mean sea level.

Wells drilled into the Floridan aquifer usually penetrate a tan to gray or brown, very hard limestone or dolomitic limestone of the Hawthorn Formation at the top of the aquifer. Interbedded with the hard limestones in the lower part of the Hawthorn are clays and thin sand lenses, the unit being about 25 feet thick. Beneath the limestones and clays of the Hawthorn is the Ocala Group, which is about 210 feet thick and composed predominantly of white and cream, soft, fossiliferous limestones. The underlying Avon Park Limestone, estimated to be about 210 feet thick, the Lake City Limestone more than 450 feet thick, and the lowermost Floridan unit, the Oldsmar Limestone which is of undetermined thickness, are composed of a series of dolomite, limestone, and dolomitic limestone beds. Limestone of the Hawthorn Formation is relatively impermeable, that of the Ocala Group is highly permeable, and the limestone of the Avon Park, Lake City, and Oldsmar Limestones is moderately to highly permeable.

Results of test drilling near Brooklyn Lake show that the Floridan aquifer probably had been breached. At test well 947-202-13 (fig. 16) the Floridan aquifer has been breached by a collapse of the underlying Eocene limestone. The breach has been filled with sediments of the confining bed and the water-table aquifer.

At test well 948-201-7 (fig. 14) where the Floridan aquifer is at an unusually high elevation, the Floridan aquifer and the confining bed seems to be breached. During the drilling of well 948-201-7, the water level rose to an elevation that corresponded to the elevation of the Floridan piezometric surface when the drill had penetrated only 30 feet of the confining bed at a depth of 96 feet below the land surface. The relatively thin 30-foot layer of clayey sediments of the confining bed that here separates the Floridan aquifer from the water-table aquifer is apparently underlain by about 54 feet of materials that normally would be a part of the confining bed but instead are hydrologically a part of the Floridan aquifer. The apparent breaching of the beds in well 948-201-7 that has allowed the hydrologic connection with the confining bed does not necessarily involve collapse as in well 947-202-13 but might be attributed to the displacement of the beds by faulting or fracturing.

Three conditions must exist if Brooklyn Lake is to leak substantial amounts of water to the Floridan aquifer: (1) the piezometric surface or the pressure head in the Floridan aquifer must be below the level of the lake; (2) a relatively permeable route from the lake to the Floridan aquifer must exist; and, (3) the

Floridan aquifer must be capable of transmitting the leaked water to other areas.

The piezometric surface of the Floridan aquifer is probably always below the water level of Brooklyn Lake. In October 1960, the piezometric surface of the Floridan aquifer near Brooklyn Lake was about 90 feet above mean sea level, more than 25 feet below the water level of the lake but about 20 feet above the bottom of the deepest part of the lake. Figure 23 shows a hydrograph of the water level in well 947-201-4, which taps the Floridan aquifer and is near Brooklyn Lake. During 1958 when the level of the lake was 97.2 feet above mean sea level, the lowest on record, the piezometric surface was presumably lower than it was during the period August through October 1960. Accordingly, the piezometric surface of the Floridan aquifer is probably never less than about 10 feet below the level of the lake and probably has never been below the bottom of the deeper parts of the lake.

The second condition, that a relatively permeable route from the lake to the Floridan aquifer exists, seems to be fulfilled. As has been discussed, a relatively permeable route to the Floridan

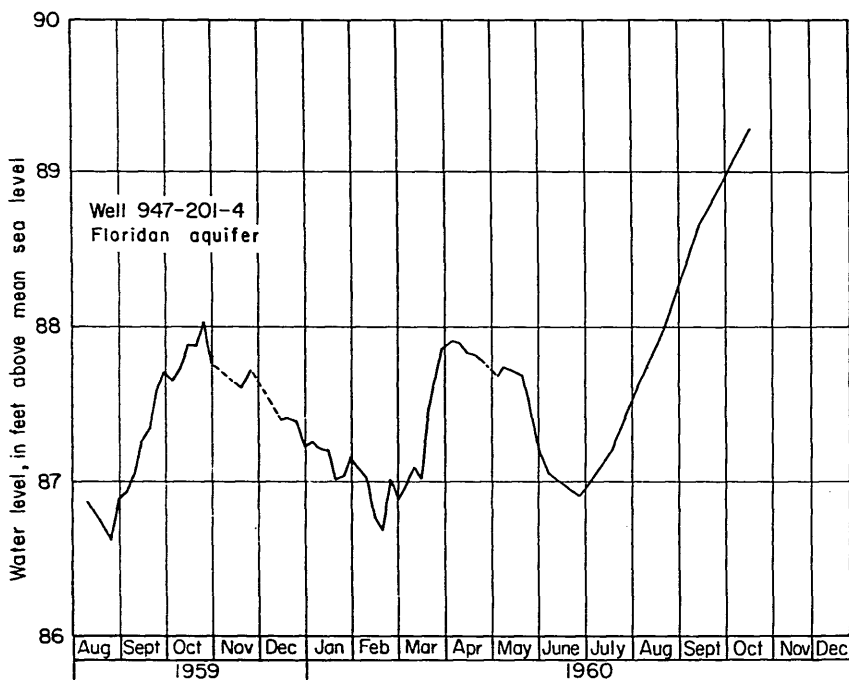


Figure 23. Hydrograph showing the water level in well 947-201-4.

aquifer apparently exists at the site of well 947-202-13, which is at the site of a filled sink, and at well 948-201-7, which is at a site where the confining bed is thin and the Floridan aquifer extends to an unusually high elevation.

The third condition, that the Floridan aquifer be capable of transmitting large amounts of water away from the lake, seems to be fulfilled also. The capability of the aquifer to transmit water is demonstrated by the ease with which large amounts of water are released to wells tapping the aquifer. Although no figures for the transmissibility, a measure of the ease with which the aquifer transmits water, are available for the Brooklyn Lake area, the transmissibility is probably more than 100,000 gpd (gallons per day) per foot.

Because these conditions are fulfilled with little question, it seems likely that Brooklyn Lake leaks substantial amounts of water to the Floridan aquifer. Further, Brooklyn Lake is in an area where the piezometric surface is high (fig. 24) indicating the artesian aquifer receives recharge and that substantial amounts of water enter the aquifer in the general vicinity of the lake.

### WATER BUDGET

A water budget for Brooklyn Lake is the accounting of water entering and leaving the lake. The difference in the amount of water entering and leaving the lake is reflected in the rise or fall of the lake level.

Water entering the lake is from three sources: (1) rainfall (R), (2) surface inflow (Is), and (3) ground-water inflow (Ig). Water leaving the lake is represented by: (1) evaporation from the surface of the lake (E), (2) surface outflow (Os), and (3) ground-water outflow (Og). These factors may be expressed in a formula as follows:

$$\Delta S = (R + Is + Ig) - (E + Os + Og)$$

where  $\Delta S$  is change in lake storage

Rainfall records were collected near the south shore of the lake by the Florida Forest Service (fig. 4). The rain gage was a plastic tube type, nonstandard gage. The records were adjusted to be consistent with records from three U.S. Weather Bureau stations (Gainesville, 20 miles southeast; Glen St. Mary, 35 miles north; and Federal Point, 30 miles east). It was assumed that the records from this gage were indicative of the amount of rain falling evenly on the lake surface, the area of which was adjusted for changes in lake level.

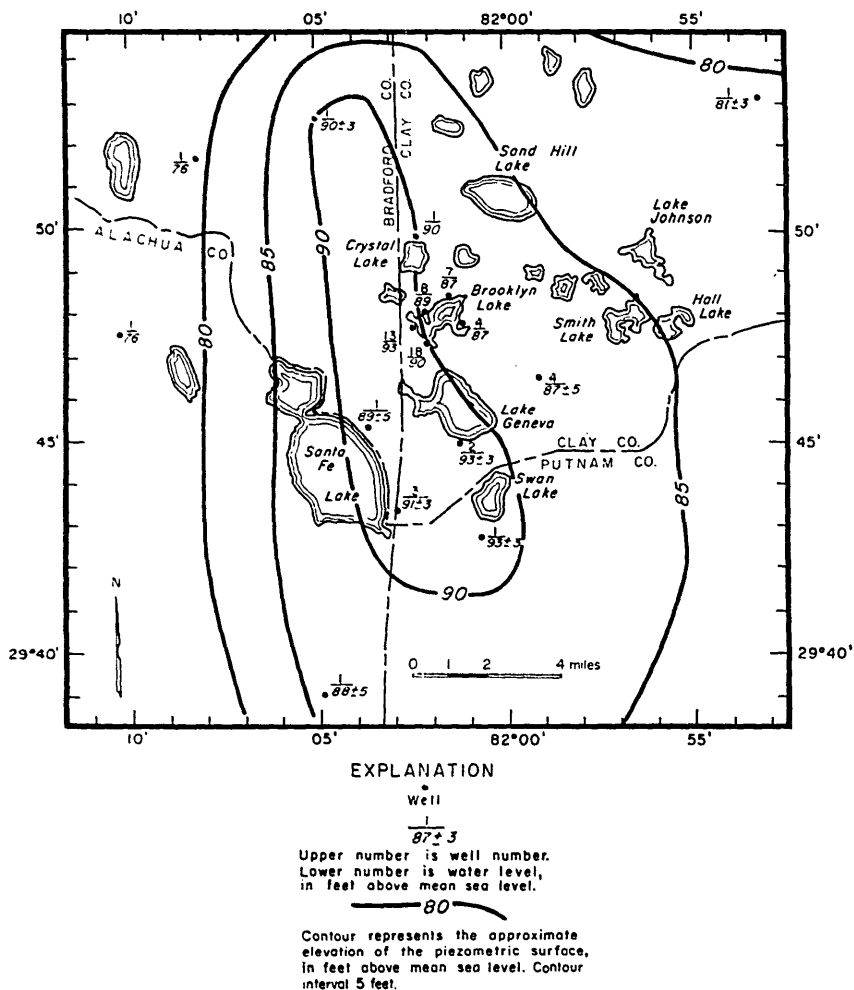


Figure 24. Brooklyn Lake area showing contours on the piezometric surface of the Floridan aquifer in June 1960.

Surface inflow was computed from a stage-discharge curve drawn on the basis of the stage record of Magnolia Lake and 12 discharge measurements made about 1 mile from Brooklyn Lake (fig. 4).

Surface outflow was computed from a stage-discharge curve drawn on the basis of the stage record of Brooklyn Lake and seven discharge measurements made at the outlet (fig. 4).

Lake evaporation was computed from records from a Class A pan collected at Gainesville by the U.S. Weather Bureau. The pan

evaporation was about 67.04 inches for the 1958 water year; about 61.50 inches for the 1959 water year; and about 66.49 inches for the 1960 water year. Records from the Class A pan were adjusted by monthly coefficients developed for the period 1940-46 for Lake Okeechobee, Florida, by Kohler (Kohler, M. A., 1954, Water loss investigations: Lake Hefner Studies, Technical Report: U.S. Geol. Survey Prof. Paper 269, p. 128.) These coefficients ranged from 0.69 for February to 0.91 for July and August. The mean annual coefficient was 0.81. Adjustments in evaporation were made to take account of the variation in lake surface due to changes in lake level.

Changes in lake storage were computed from the stage-storage curve given in figure 8. Data used to develop the stage-storage curve and the depth-contour map given in figure 6 were collected with a sonic depth recorder.

Data were not available, however, to determine ground-water inflow (Ig) and ground-water outflow (Og), they were combined into one factor net ground-water flow. This net ground-water flow was determined as a residual for three water years, October 1957 to September 1960. A water year is from October 1 to September 30. Annual figures for the water budget are given in the following table:

Values, In Acre-Feet, By Water Years

|                                 | 1958  | 1959   | 1960   |
|---------------------------------|-------|--------|--------|
| Rainfall                        | 1,600 | 3,100  | 3,400  |
| Surface inflow                  | 360   | 8,800  | 12,800 |
| Surface outflow                 | 0     | 0      | 2,000  |
| Evaporation                     | 1,600 | 2,200  | 3,000  |
| Change in storage               | +360  | +7,800 | +2,000 |
| Net ground-water flow from lake | 0     | 1,900  | 9,100  |

A schematic presentation of the water budget during the 3-year period is given in figure 25.

The net ground-water flow may be composed of ground-water inflow and outflow to and from the water-table aquifer and to and from the Floridan aquifer. Because the piezometric surface of the Floridan aquifer remains below the level of the lake, water cannot flow from the Floridan aquifer to the lake. Thus, the net ground-water flow is composed only of ground-water inflow and outflow to and from the water-table aquifer and ground-water outflow to the Floridan aquifer.

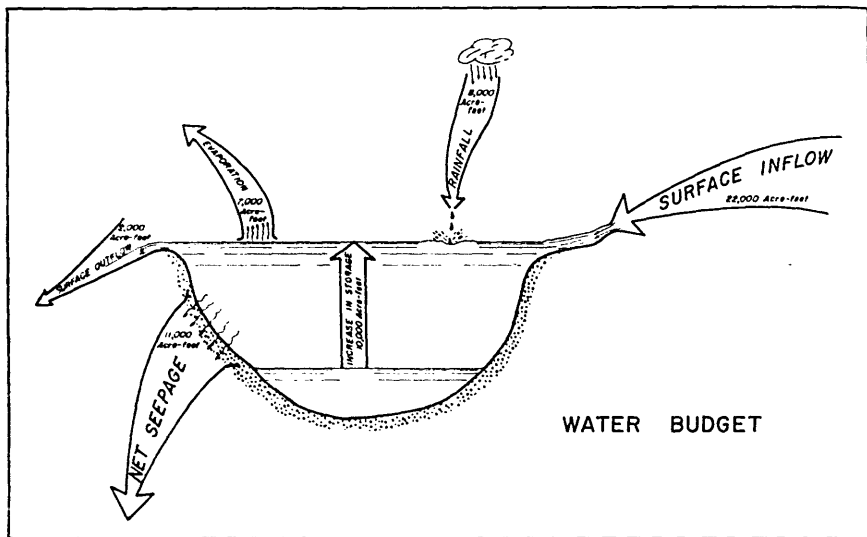


Figure 25. Water budget of Brooklyn Lake for the period October 1957 to September 1960.

In order to determine where the water that left the lake went, the ground-water inflow and outflow to and from the water-table aquifer were computed for the period for which data are available, March to October 1960. The flow was computed by the formula:

$$Q = T I W$$

where:

Q = the rate of movement of the water

T = Coefficient of transmissibility of the aquifer

I = the hydraulic gradient

W = the width of the flow section

The coefficients of transmissibility were computed from the permeability of samples of the materials composing the aquifer. The coefficients were determined by multiplying the permeability of each sample by the interval represented by the sample and by adding these products. The coefficients of transmissibility were computed at the sites of wells 947-201-18, 947-202-18, 948-200-7, and 948-202-8.

The width of the flow sections was taken from the map showing contours on the water table. The width of the sections through which water moves into the filled sink and into the area where the confining is thin was estimated to be about 1,000 feet. The hydraulic gradient was taken to be the slope of the water table, between the lake and a nearby well.

The movement of water into the lake, and from the lake, through the water-table aquifer was estimated for monthly intervals for the period March through October 1960. During this period about 70 acre-feet of water was estimated to have moved into the lake from the water-table aquifer on the southwestern side of the lake and about 200 acre-feet was estimated to have left the lake on the eastern side of the lake. During this period about 400 acre-feet more water was estimated to have left the lake than entered the lake through the water-table aquifer.

The lateral movement of water through the water-table aquifer from Brooklyn Lake, during the period March through October 1960, was computed to be less than 10 percent of the loss to the aquifers. Therefore, most of the net ground-water flow from the lake was to the Floridan aquifer.

The net ground-water outflow, most of which was outflow to the Floridan aquifer, was the largest loss from the lake. The net ground-water outflow was zero during the 1958 water year when the lake was low, and increased rapidly during 1959 and 1960 as the lake surface rose. The increase in the net ground-water outflow as the level of the lake rose may be accounted for by: (1) a decrease in inflow from and an increase in outflow to the water-table aquifer; and (2) an increase in outflow to the Floridan aquifer.

When the level of the lake was low, undoubtedly the flow to the Floridan aquifer was least; the inflow from the water-table aquifer was probably more, and the outflow less. The outflow to the Floridan aquifer is related to the difference in head between the lake level and the piezometric surface of the Floridan aquifer. An exact relation between the head difference and the outflow to the Floridan aquifer could not be determined. The difference in head was undoubtedly much less in 1958 than it was in 1960. The inflow from the water-table aquifer was probably larger when the lake was low because the gradient of the water table to the lake was probably greater. Likewise, the outflow was probably less because the gradient was probably smaller. Thus, the amount of inflow required to maintain the lake at a high stage is greater than that required to maintain the lake at a low stage.

## METHODS OF CONTROLLING BROOKLYN LAKE

Both high and low stages must be considered in any plan to control Brooklyn Lake. The problem is to prevent the stage from falling below or rising above desirable levels. Additional water diverted into the lake to supplement the natural inflow would

prevent critically low stages, but if allowed to remain during periods of high water, could overtax the conveyance of the natural outlet channel and cause flooding. Conversely, if the outlet channel was lowered and its capacity increased to carry off more water and prevent flooding, lake storage would be reduced and additional lowering of the lake during periods of deficient rainfall would result. A detailed engineering study would be required to determine the overall feasibility and cost of controlling the lake and to work out the details of hydraulics. The following is a general discussion of several possibilities for controlling the lake.

Low lake stages have created more serious problems in recent years than have flood stages. The extremely low stages that existed in 1957-59 were brought about because the rate of movement of water from the lake exceeded the rate at which it was entering the lake from rainfall and surface inflow. The solution to the problem would then seem to be to retard the losses or increase the inflow.

The water budget analysis indicates that water is removed from the lake by the following processes and in the following proportions: surface outflow, 10 percent; evaporation, 35 percent; and the net ground-water outflow, 55 percent. The amount flowing through the surface outlet is the only one that could be reasonably retarded. However, the control of the surface outflow would not solve the problem of low lake levels as outflow occurs only at high stages. In fact, surface outflow is then necessary as a relief measure to prevent flooding. Reduction of seepage and evaporation losses is not easily accomplished and probably not feasible. Therefore, measures other than preventing the usual natural water losses must be considered.

Increasing inflow is a possible method by which Brooklyn Lake could be prevented from falling below a desired level. In considering this method of control, the amount and source of supplemental inflow need to be determined.

Lake storage was reduced about 10,000 acre-feet during the recession of lake levels that ended in 1958. It is reasonable to assume that the period of this recession coincided with the 3½-year period of deficient rainfall. Therefore, a reduction in lake storage of 10,000 acre-feet during a 3½-year period is equivalent to an average rate of about 4 cubic feet per second, which is the average rate of loss and the apparent minimum rate of supplemental inflow needed to prevent such a recession. However, the greater difference in head between the lake surface and ground-water level that would be induced by control measures could cause a substantial increase

in the rate of seepage to the ground, which would increase the inflow requirements necessary to hold the lake at a constant level. Also, the greater average lake surface brought about by the higher average lake stage would increase the evaporation. The increase in evaporation would be essentially offset by the evaporation on the larger lake surface. Though the exact rate of inflow needed to hold the lake at a higher level is uncertain, any amount would be helpful.

Three possible ways in which additional water may be provided to Brooklyn Lake are: (1) by pumping from the Floridan aquifer; (2) by increasing the storage capacity of the lakes that are connected by channels above Brooklyn Lake (fig. 3); and, (3) by diverting water from Santa Fe Lake. A study would be necessary to determine the feasibility and cost of these methods and to determine the effects that each of these methods would have on the related bodies of water.

Enough water may be pumped from the Floridan aquifer to stabilize the level of the lake if the pumping of water from the aquifer does not induce appreciable increases in leakage. The leakage from the lake is proportional to the head difference between the lake and the Floridan aquifer. The pumping of water from the aquifer will create a cone of depression in the piezometric surface. If the cone of depression extends to where the lake leaks, it will create an additional head difference between the lake and the aquifer. Thus, the downward flow of water to the Floridan aquifer would increase and, in effect, part of the water pumped would be circulated.

The amount of additional leakage that will be induced by pumping from the Floridan aquifer was not studied. The greater the distance of the pumped wells from the lake the less additional leakage the pumping will induce. If, however, the water from the lake leaks into an extensive system of solutional channels, such as might be expected where large quantities of water enter a limestone aquifer, the pumping of water from wells may induce only small amounts of additional leakage from the lake. Accordingly, it may be feasible to supply the lake with the needed water by pumping from wells located at strategic sites adjacent to the lake.

Magnolia Lake (average surface area, 0.31 sq. mi.), Sandhill Lake (average surface area 1.95 sq. mi.), and Blue Pond (average surface area, 0.31 sq. mi.) are at higher elevations than Brooklyn Lake and are connected by channels. Storage in these upper lakes may be increased by low-head controls in the outlet channels. The combined area of these three lakes is 2.57 square miles compared

to the 1.00 square mile area of Brooklyn Lake. These lakes would supply only a relatively small amount of water.

Another possible source of supply is Santa Fe Lake which is in the headwaters of the Santa Fe River basin, the adjoining basin west of Brooklyn Lake. Santa Fe Lake has a surface area of 8.05 square miles and had a range in stage of 4.2 feet from 1957 to 1960. Santa Fe Lake fluctuated through a range in stage of only 4.2 feet during the period August 1957 to December 1960 while Brooklyn Lake fluctuated through a range of 20 feet (fig. 5, 26). The stage of Santa Fe Lake is higher than that of Brooklyn Lake by about 40 feet at low stages and about 25 feet at high stages. The map in figure 2 shows possible location of a diversion canal from Santa Fe Lake to Brooklyn Lake. The canal would extend from the northeast end of Little Santa Fe Lake through Silver Lake and Mid Lake and into the westernmost end of Brooklyn Lake. A profile showing elevations from Santa Fe Lake to Brooklyn Lake, and a stage depth graph of Santa Fe Lake, are given in figure 26.

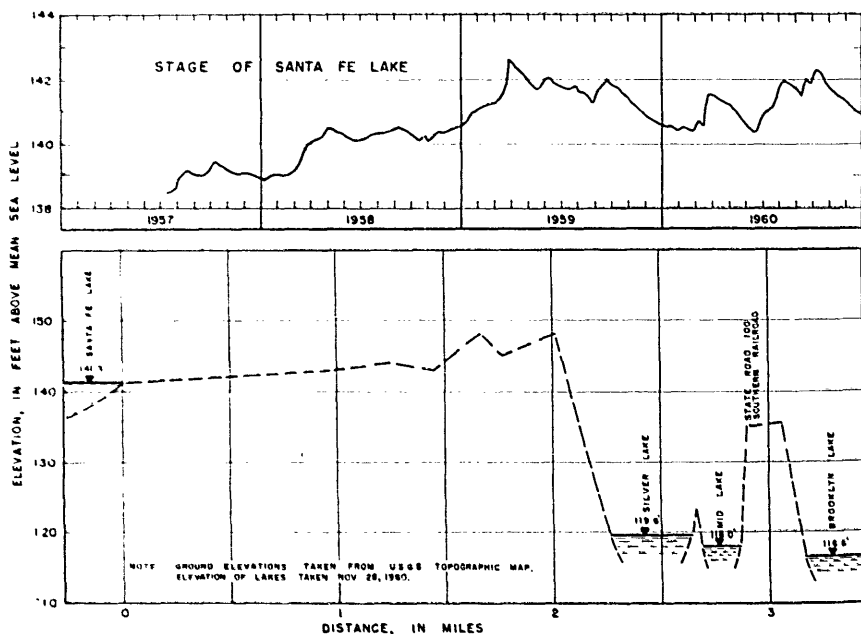


Figure 26. Stage graph of Santa Fe Lake and profile from Santa Fe Lake to Brooklyn Lake.

The methods suggested herein for controlling the stage of Brooklyn Lake have been based on the hydrologic data that have been collected for this study. Additional detailed engineering studies will be required to determine the most feasible method and to prepare plans for the construction and operation of any structures that are required.

## CONCLUSIONS

Brooklyn Lake receded about 20 feet during the period 1955-58. This period of recession coincided with, and was a direct result of, a period of deficient rainfall. Rainfall was deficient by nearly 23 inches during this period. The lack of rainfall upset the hydrologic balance that normally keeps the lake stage from falling, and allowed the rate of loss from the lake to far exceed the rate of replenishment.

The lake's source of replenishment is rain that falls directly on the lake surface and surface inflow from Magnolia Lake. During prolonged periods of deficient rainfall surface inflow ceases, which was the case during 1955-58. The lake received about twice as much water from the surface inflow as it did from rain directly on the lake surface during the 3-year period covered by this report.

Water leaves the lake through evaporation, surface outflow, and seepage. From October 1957 to September 1960, seepage was by far the greatest loss, accounting for 55 percent of all losses, or an average of more than 3 mgd. Evaporation took 35 percent, and surface outflow took 10 percent, of the total loss.

To prevent Brooklyn Lake from falling below a desirable stage during prolonged periods of deficient rainfall it will be necessary to divert water into the lake from other sources. Three possible ways to divert water into the lake are: (1) by pumping from the Floridan aquifer; (2) by increasing the storage in the three upper lakes during periods of excess rainfall and releasing it to Brooklyn Lake when needed; and (3) by diversion from Santa Fe Lake. Careful and thorough engineering studies should precede the adoption of any of these methods or any combination of them.



FLORIDA GEOLOGICAL SURVEY

## **COPYRIGHT NOTICE**

© [*year of publication as printed*] Florida Geological Survey [*source text*]

The Florida Geological Survey holds all rights to the source text of this electronic resource on behalf of the State of Florida. The Florida Geological Survey shall be considered the copyright holder for the text of this publication.

Under the Statutes of the State of Florida (FS 257.05; 257.105, and 377.075), the Florida Geologic Survey (Tallahassee, FL), publisher of the Florida Geologic Survey, as a division of state government, makes its documents public (i.e., *published*) and extends to the state's official agencies and libraries, including the University of Florida's Smathers Libraries, rights of reproduction.

The Florida Geological Survey has made its publications available to the University of Florida, on behalf of the State University System of Florida, for the purpose of digitization and Internet distribution.

The Florida Geological Survey reserves all rights to its publications. All uses, excluding those made under "fair use" provisions of U.S. copyright legislation (U.S. Code, Title 17, Section 107), are restricted. Contact the Florida Geological Survey for additional information and permissions.