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REPORT OF INVESTIGATIONS NO. 19

HYDROLOGIC FEATURES OF THE LAKE ISTOKPOGA AND LAKE PLACID AREAS HIGHLANDS COUNTY, FLORIDA

Prepared by the
UNITED STATES GEOLOGICAL SURVEY
in cooperation with the
CENTRAL AND SOUTHERN FLORIDA FLOOD CONTROL DISTRICT
and the
FLORIDA GEOLOGICAL SURVEY

TALLAHASSEE, FLORIDA
1959

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Florida Geological Survey

Tallahassee

May 27, 1959

MR. ERNEST MITTS, *Director*
FLORIDA STATE BOARD OF CONSERVATION
TALLAHASSEE, FLORIDA

DEAR MR. MITTS:

The Florida Geological Survey is publishing as Florida Geological Survey Report of Investigations No. 19, a report entitled, "Hydrologic Features of the Lake Istokpoga and Lake Placid Areas, Highlands County, Florida." This report was prepared by F. A. Kahout and F. W. Meyer, in cooperation with the U. S. Geological Survey and the Central and Southern Florida Flood Control District.

The report presents the hydrologic features of a fairly comprehensive area in Highlands County, partially to evaluate the effect on the ground water in the Highlands Ridge by the construction of a canal to drain the Istokpoga-Indian Prairie Basin. The study in the Lake Placid area is concerned primarily with lakes of the area and contributes considerable data to an understanding of the relations of climatology, hydrology and geology as factors in controlling levels of lakes. The data here presented will be useful in planning for further development of these areas.

Respectfully yours,

ROBERT O. VERNON, *Director*

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ABSTRACT

The hydrologic features in a 165 square mile area surrounding Lake Istokpoga, Florida, were studied during the fall of 1952, to evaluate the effect of a proposed drainage canal south of Lake Istokpoga on ground-water conditions in the Highlands Ridge and Lake Istokpoga areas. An investigation of the influence of the ground-water reservoir in the Lake Placid area on the water level of the lake was started in the fall of 1955.

The Istokpoga-Indian Prairie Basin is a poorly drained area of low topographic relief extending southeastward from Lake Istokpoga; its western boundary is marked by a scarp that rises to a sandy upland region of relatively great relief, referred to as the Highlands Ridge.

In the first investigation, described in Part I, lithologic and hydrologic data were obtained from lines of wells and test holes. A nonartesian aquifer and several shallow artesian aquifers occur within the area of this investigation. Unconfined ground water moves toward Lake Istokpoga, except at the southern end of the lake where the ground water moves, under a low gradient, in a southeasterly direction. The movement of water in the shallow artesian aquifers is eastward from the scarp, but because of leakage through the overlying confining beds, artesian pressure decreases rapidly with increasing distance from the scarp.

The findings of the investigation indicate that the amount of ground-water pickup in a canal extending southward from Lake Istokpoga would not be excessive; also, because of evapotranspiration losses, less ground water and surface water will be picked up by a canal located at some distance from the scarp than by a canal at the base of the scarp. If the proposed canal is routed through locations where the expected altitudes of its water surface coincide with the altitudes of the water table, the canal will not intercept and drain the shallow ground water. If no excess ground-water drainage occurs because of the canal, the water table in the ridge section will not be affected and upward leakage from the shallow artesian aquifers will not increase. Penetration of the artesian gravel aquifer which approaches the ground surface south of State Highway 70, would pose the greatest threat to the water levels of the lakes in the ridge section. If the gravel aquifer were penetrated, the large drawdowns produced by the discharge could conceivably extend upgradient beneath the ridge and affect the water levels of the lakes.

In Part II, water-table contour maps and graphs of the fluctuations of water level in Lake Placid and well 14 show that the lakes of the ridge section are visible expressions of the water table. A method of predicting the water level of Lake Placid after an extended period without rainfall makes use of curves based on ground-water recession rates. However, comparison of hydrographs of an artesian well and Lake Placid indicates that the lake level responds to pumping from the Floridan aquifer. The hydrographs show an increasing utilization of water from the artesian system, and this change in the hydrologic regimen may change the future recession rate of Lake Placid.

In rising stages, the relation between water levels in well 14 and Lake Placid is not consistent because of hydrologic conditions existing on the west and south sides of the lake, where there is little room for additional ground-water storage because the water table is close to the land surface. The ground-water storage capacity has a direct relation to floodings in the Lake Placid basin, because as soon as the water table rises to the land surface all further recharge to the aquifer is rejected, and direct runoff to Lake Placid occurs.

Consideration is given to the quantity of water that percolates downward from Lake Placid to the Floridan aquifer. A summation, obtained by balancing the estimated quantities of inflow and outflow, the evaporation, and the change in stage of Lake Placid, indicates that the downward leakage from the lake during the first half of 1956 amounted to about two to three inches per month.

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GENERAL INTRODUCTION

The hydrologic information presented in this report relates primarily to the nonartesian and shallow artesian aquifers in Highlands County, Florida, and is the result of two separate investigations. The report is therefore divided into two parts: Part I covers the area surrounding Lake Istokpoga, and Part II covers an adjoining area, in the Highlands Ridge section, lying immediately west of the scarp separating the ridge section from the Istokpoga-Indian Prairie Basin. The two areas overlap slightly along their common side, and certain phases of the two investigations also overlap.

The investigations have different objectives, were made at different times, and are therefore considered separate entities. Information that pertains to both is presented in the general introduction, and specific information concerning each investigation is presented separately in Parts I and II.

LOCATION AND EXTENT OF AREA

The area described in this report is in Highlands County, in the central part of Florida (figs. 1, 2). The Lake Istokpoga region contains approximately 165 square miles, and the Lake Placid region contains approximately 65 square miles—a total of 230 square miles.

PREVIOUS INVESTIGATIONS

The general geology of the area has been described by Parker and Cooke (1944), Cooke (1945), Parker, Ferguson, Love and others (1955), and many others. A report by Stringfield (1936) describes the occurrence of artesian water in the principal artesian aquifer (Floridan aquifer) in peninsular Florida.

A study by Bishop (1956) describes the geology and ground-water resources of Highlands County, and a study by the Engineering Department of the Central and Southern Florida Flood Control District gives much information on the control of floods in the area investigated. These publications have been used freely in the preparation of this report.

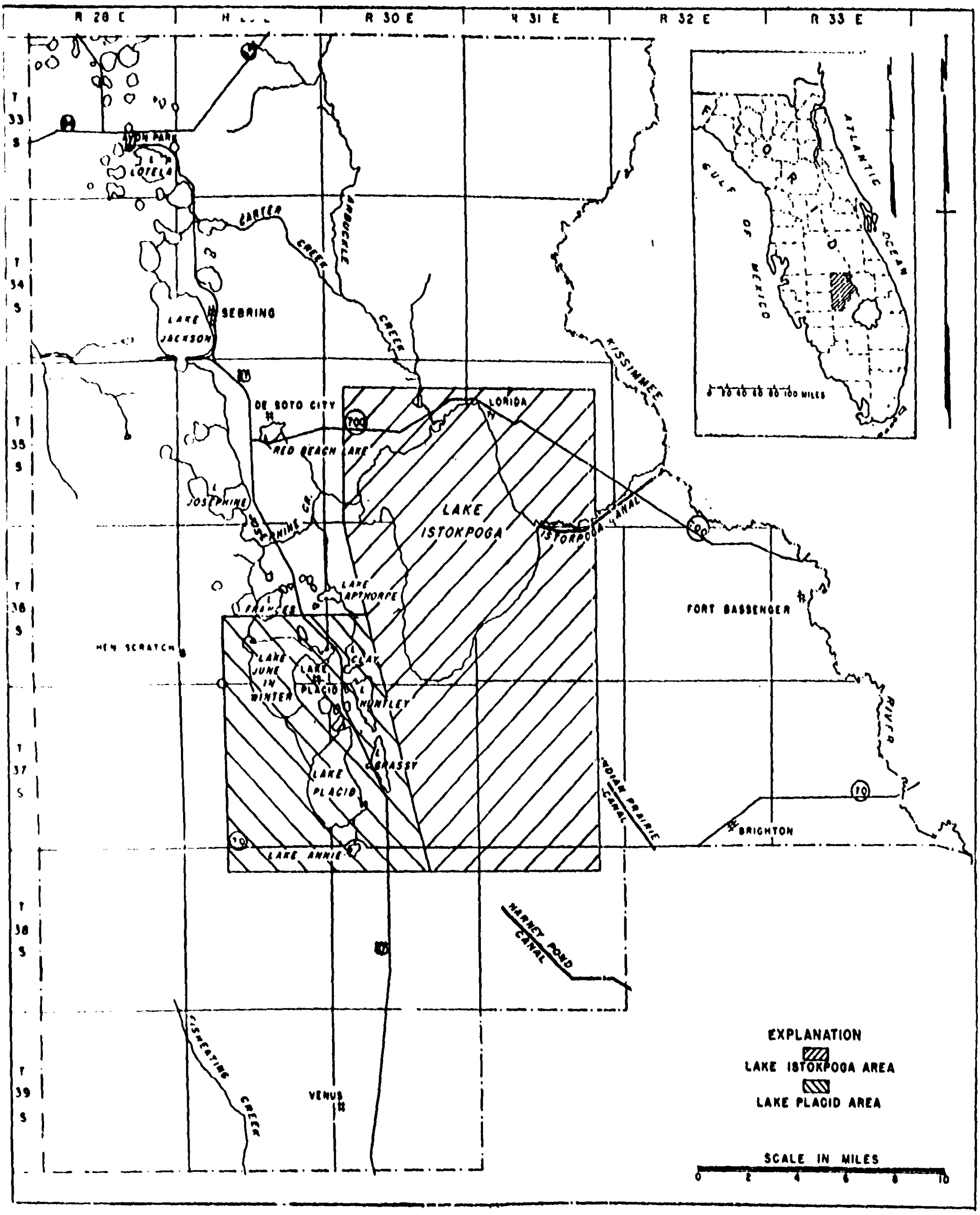

Figure 1. Map of Highlands County, Florida, showing areas covered by this report.

PERSONNEL AND ACKNOWLEDGMENTS

The authors are indebted to many persons who contributed information and assistance in the field. Messrs. T. J. Durrance and J. C. Durrance provided background information on ranches in the Istokpoga-Indian Prairie Basin during the first field investigation, described in Part I of this report. Mr. L. E. Tisdale, grove manager for Consolidated Naval Stores Company, helped in the reclamation of grove wells for observation purposes during the investigation described in Part II.

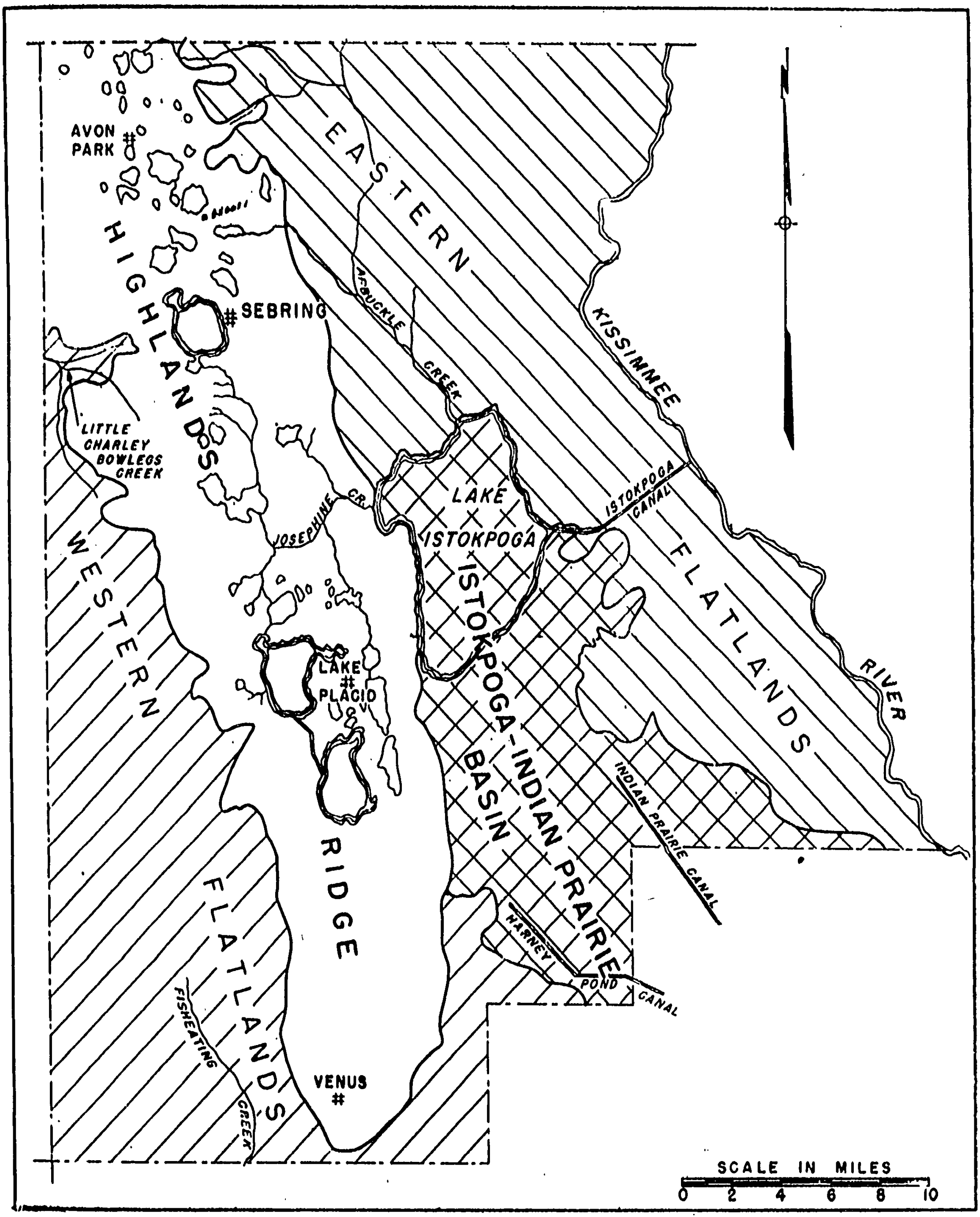

Figure 2. Map of Highlands County showing physiographic regions.

The field work upon which Part I of the report is based was accomplished with the able assistance of E. W. Bishop, formerly with the U. S. Geological Survey and now with the Florida Geological Survey, and C. B. Sherwood, Jr., of the U. S. Geological Survey; H. J. Voegtle of the U. S. Geological Survey aided in the field work for Part II of the report. Thanks are extended also to A. O. Patterson and Richard C. Heath, U. S. Geological Survey, and to Robert L. Taylor, of the Central and Southern Florida Flood Control District, for supplying water-level and discharge data on the lakes and streams of the area.

WELL-NUMBERING SYSTEM

The wells in this report are numbered consecutively to conform with the numbering system used in the past for Highlands County. The number thus assigned is the office number. Because the wells in the first area are arranged in lines, a field number also has been assigned to each well. The field number consists of a letter corresponding to the designation of the line and the position of the well in the line; thus, well N-2 is the second well in line N. Both field and office numbers are given in the table of well records (table 4), but in Part I only the field number is referred to.

In the second area of investigation, staff gages installed in ponds or lakes were used as observation points and these are indicated in Part II by a number prefixed by the letters "OP" (table 5). Uncased holes that were drilled to determine lithology are indicated by the letter "T".

The locations of wells and staff gages are shown in the well-location maps for the separate parts of the report.

GEOGRAPHY

CLIMATE

The climate of Highlands County is subtropical and is characterized by warm summers and moderately cool winters. The rainfall is seasonal, approximately 75 percent of it occurring during the months from May through October.

The U. S. Weather Bureau has collected climatological data at Avon Park, about 25 miles northwest of the area of this report, since 1892, and at the city of Lake Placid since about 1937. Because of the intermittent nature of the record at Lake Placid, that at Avon Park was selected to indicate the average climate of the area.

The mean annual temperature at Avon Park is 73.1°F, the mean January temperature is 63.2°F, and the mean August temperature is 82.0°F. The average annual rainfall for 58 years of complete record (1893-1896, 1902-1955) is 52.22 inches. In 1953, the wettest year on record, the total rainfall was 80.08 inches; in 1955, the driest year on record, the total rainfall was 34.86 inches.

A comparison of the annual rainfall at Avon Park with that at Lake Placid, for the years of complete record at both stations, is shown in the following table.

Year	Rainfall at Lake Placid (inches)	Rainfall at Avon Park (inches)	Difference (inches)
1938	37.53	37.12	0.41
1939	71.12	62.51	8.61
1943	56.73	51.01	5.72
1944	36.68	47.68	11.00
1945	50.65	54.66	4.01
1946	34.57	50.70	16.13
1947	72.83	74.29	1.46
1952	49.32	55.89	6.57
1953	74.71	80.08	5.37
1954	52.77	54.55	1.78
1955	39.10	34.86	4.24

The relatively large differences in rainfall between stations only 25 miles apart indicate the erratic distribution of rainfall in the area.

LAND USE

Within the area of this report, the land is used principally for agriculture. Citrus fruit, the major export crop, is grown near the lakes of the ridge section, and the lake water is used for irrigation during the dry winter season, when the fruit ripens. A large part of the Istokpoga-Indian Prairie Basin south of Lake Istokpoga is used for raising cattle. Cattle are raised also in those parts of the ridge section which have not been converted to grove land. New land is being cleared for both types of agriculture, but there is a trend to increase the grove acreages at the expense of grazing acreage. Nursery plants such as caladiums and Easter lilies are grown in the dark peat soils (referred to as muck) along the scarp between the ridge section and the Lake Istokpoga flat. These plants are exported to northern floral shops, and the proceeds are a relatively small but important part of the income of the area.

The value of property along the shorelines of the numerous lakes of the ridge section has increased greatly in recent years, because of the rapidly expanding tourist trade. Maintenance of the water levels of the lakes at desirable altitudes is a primary concern of property owners surrounding the lakes. This report considers the water levels of the lakes in relation to the ground-water regimen of the area.

PHYSIOGRAPHY

TOPOGRAPHY

Highlands County has been subdivided by Davis (1943, p. 45-51, fig. 1) into four physiographic regions as follows: (1) the Western Flatlands, (2) the Highlands Ridge, (3) the Istokpoga-Indian Prairie Basin, and (4) the Eastern Flatlands. The geographic locations of the four physiographic regions are shown in figure 2 (reproduced after Bishop, 1956, fig. 2). The area investigated for this report includes the Highlands Ridge section and the Istokpoga-Indian Prairie Basin; therefore, the topography of only these regions will be described.

The Highlands Ridge section is an undulating upland area having an outline similar to that of the Florida Peninsula as a whole. The underlying materials consist predominantly of sand. The collapse of caverns formed in the limestone underlying the ridge at depth causes the formation of circular lakes or sinks, and in places a typical karst topography has been formed. The sediments forming the surface of the ridge have been reworked by wind and wave action and quiescent sand dunes and sand bars are well preserved. The altitude of the ridge section in the area ranges from 40 to 160 feet, making the total relief about 120 feet.

The Istokpoga-Indian Prairie Basin is a flat, poorly drained, swampy area extending southeastward from Lake Istokpoga. The underlying materials consist of peat, sand, or sandy clay, according to the locality. In the part of the basin investigated for this report, the altitude of the land surface ranges from 30 to 40 feet above mean sea level.

DRAINAGE

With the exception of Lake Grassy, the large lakes of the ridge are connected by small streams or drainage canals (fig. 1). Lakes Annie, Placid, June in Winter, and Frances are referred to as the upper chain of lakes, and they drain northward through a tributary of Josephine Creek. Lakes Grassy, Huntley, Clay, and Apthorpe are referred to as the lower chain of lakes, and also they drain northward to Josephine Creek. At present, Lake Grassy has no surface outlet to Lake Huntley, but tentative plans propose that it will be included in the drainage system of the lower chain of lakes by the construction of a culvert between it and Lake Huntley. Lake Grassy overflows eastward from its northeastern edge, across a shallow divide in the ridge section, during periods of extremely high water levels. The water moves through the troughs between sand dunes, more or less as sheet flow, and then discharges into the Lake Istokpoga basin over the scrap separating the ridge and basin.

The runoff of all the lakes in the ridge section except Lake Grassy is drained eastward through Josephine Creek or southeastward through Arbuckle Creek to Lake Istokpoga. Under normal conditions, this runoff passes through the Istokpoga Canal to the Kissimmee River and thence southeastward to Lake Okeechobee. Under heavy recharge conditions accompanying the passage of a hurricane, the combined runoff is too great to be handled by the present drainage system; then Lake Istokpoga swells out of its banks and floods large areas to the southeast.

Part I

LAKE ISTOKPOGA AREA, HIGHLANDS COUNTY, FLORIDA

By

F. A. Kohout

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Part I

HYDROLOGIC FEATURES OF THE LAKE ISTOKPOGA AREA, HIGHLANDS COUNTY, FLORIDA

INTRODUCTION

The Lake Istokpoga area of Florida is in the Istokpoga-Indian Prairie Basin section of Highlands County. The western boundary generally parallels and lies immediately west of the scarp that separates the Highlands Ridge section from the Lake Istokpoga basin.

The Lake Istokpoga area is approximately 18 miles long and ranges in width from about 10 miles at the northern extremity, slightly north of the north shore of Lake Istokpoga, to about 7 miles at the southern extremity, just south of State Highway 70.

PURPOSE AND SCOPE OF INVESTIGATION

The Lake Istokpoga-Indian Prairie Basin is a poorly drained area of low topographic relief. Lake Istokpoga rises out of its banks, during periods of heavy rainfall, and floods vast areas of land to the south. Prior to the construction of the Indian Prairie and Harney Pond canals, surface water moved southward toward Lake Okeechobee by sheet flow. Since installation of the canals, the flow tends to be confined to definite channels. A part of the excess water is drained into the Kissimmee River through the Istokpoga Canal, and this increases flooding in the Kissimmee River valley below the canal outlet.

To help alleviate the flooding of both the Indian Prairie Basin and the Kissimmee River valley, the U. S. Corps of Engineers proposed that a levee be constructed around the southeast side of Lake Istokpoga. The floodwaters from the Arbuckle-Josephine Creek drainage system then would be diverted southward from the Istokpoga Canal - Kissimmee River system directly to Lake Okeechobee, via canals. One proposed canal would be an extension of the Harney Pond Canal (fig. 1).

Because of suspected geologic conditions, it was anticipated that improper construction of a canal in the area south of Lake Istokpoga might adversely affect ground-water conditions as well as the operation of the canal. It was decided that an investigation should be made by the U. S. Geological Survey, in cooperation with the Central and Southern Florida Flood Control District, to gain an understanding of the problems that might be encountered. The ultimate objective of the investigation was to determine what effect canals would have on ground-water conditions in the Lake Istokpoga and Highlands Ridge areas. Among the questions to be answered were the following:

1. What is the relation of the water table to the water surface of Lake Istokpoga? Would the ground water tend to flow through the canal into (rather than out of) Lake Istokpoga because of a water-table gradient toward the lake?

2. Would the amount of ground-water pickup in the canal be large enough to negate the usefulness of such a canal in discharging ponded surface water?

3. What effect would ground-water drainage in the Lake Istokpoga area have on the water table of Highlands Ridge and the water levels of the lakes in the ridge section?

4. What would be the approximate increase in the upward leakage from the several shallow artesian aquifers, and what effect would the leakage have on the water levels of the lakes in the ridge section?

Most of the basic data were gathered during a 3-week period in the latter part of September 1952. The investigation was made under the general supervision of A. N. Sayre, Chief of the Ground Water Branch of the U. S. Geological Survey, and under the immediate supervision of N. D. Hoy, District Geologist for southern Florida at the time of the investigation.

METHOD OF INVESTIGATION

Around the northern two-thirds of Lake Istokpoga the investigation was limited to establishing the altitudes of existing wells and measuring water levels, in order to determine the water-table gradient in relation to the water surface of the lake. The area around the southern part of the lake, southward to State Highway 70, was studied in greater detail.

Lithologic and hydrologic data were obtained from east-west lines of wells and test holes perpendicular to the scarp of Highlands Ridge. The wells and test holes were installed by the jetting technique. The wells were constructed of ¾-inch pipe and finished with an attached brass strainer. Each well was pumped with a pitcher pump after installation, to make sure that the well was open so that accurate measurements of water level could be obtained. Permeability of samples of the sand aquifers was determined by the permeameter method in the laboratory. Altitudes of all wells were determined by spirit level and were referred to mean sea level or to the water surface of Lake Istokpoga.

The lines of wells, starting at the northwest corner of Lake Istokpoga, are designated as follows: C, A, O (along State Highway 621), P-O (on the south side of the lake), N (along east-west Parker Island Road), M (along State Highway 70), and Q and Z (on the east side of the lake) (fig. 3).

LITHOLOGY AND GROUND-WATER MOVEMENT ALONG WELL LINES

GROUND WATER RELATED TO LAKE ISTOKPOGA

Figure 4 shows the slope of the water table along lines C, A, P-O, and Z in relation to the water surface of Lake Istokpoga. The water-table gradient is toward the lake on all lines except the north-south line P-O, at the south end of the lake. Thus, ground-water movement is toward the lake except at the extreme southern end where a small quantity of water moves in a southeasterly direction. Analysis of cross sections for line O (fig. 6) and line P-O (fig. 7) shows that the greatest component of slope and ground-water movement is in an easterly direction from the southern end of the lake, and that very little water moves southward.

Hydrographs showing the average monthly water levels in shallow water-table wells 10 and 11 and Lake Istokpoga are presented in figure 5. The close correlation of the hydrographs, the water-table gradients of figure 4, and the subsurface geology indicate that Lake Istokpoga is a surface expression of ground water—where the water table intersects a natural land-surface depression. The lake is within the pattern of regional southeastward movement of ground water from the ridge section.

LINE O

LITHOLOGY

The lithology of the rocks along O line, along State Highway 621, is shown in generalized form in figure 6. Bed 1, a thick section of sand penetrated by well O-1, thins and interfingers with peat

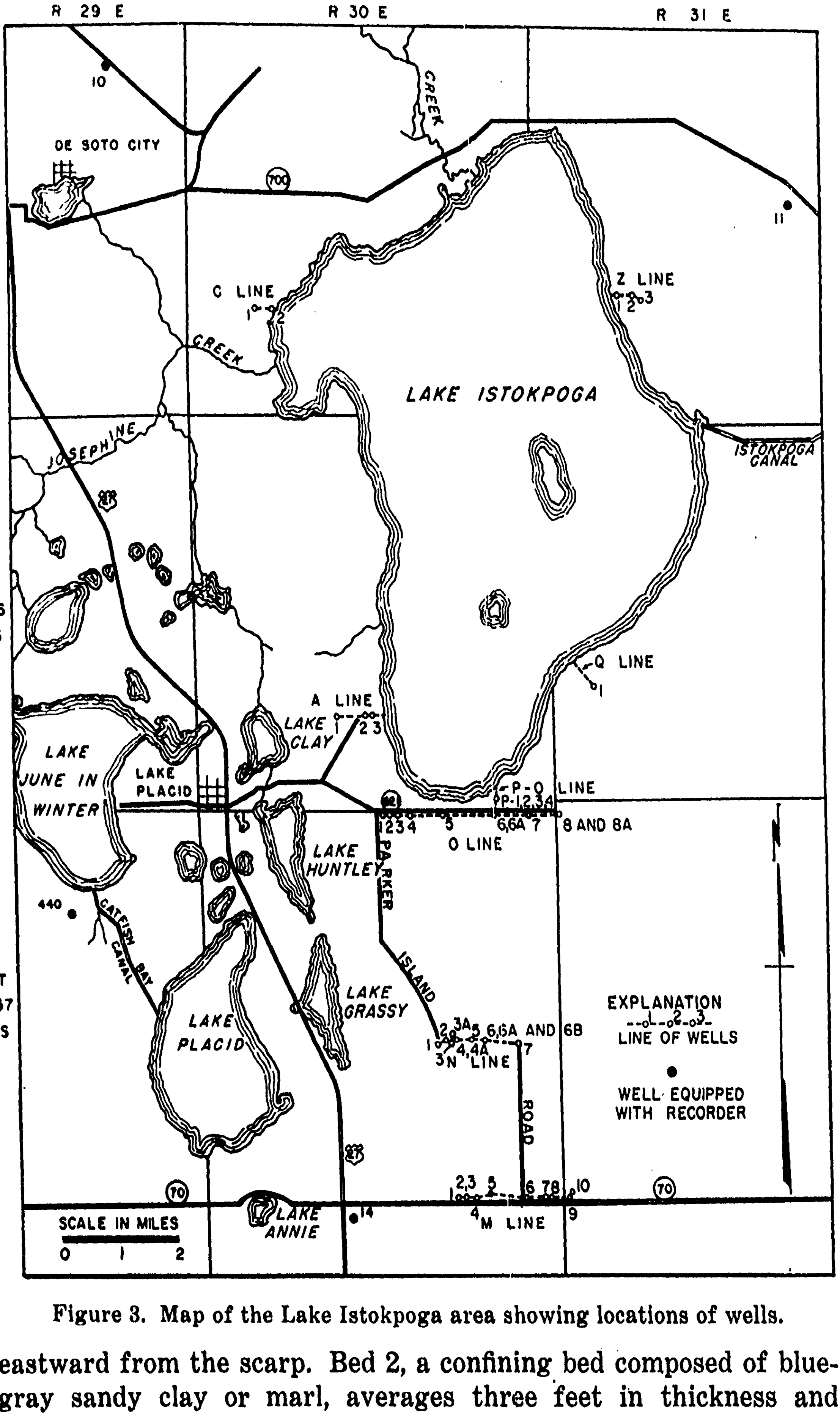

Figure 3. Map of the Lake Istokpoga area showing locations of wells.

eastward from the scarp. Bed 2, a confining bed composed of blue-gray sandy clay or marl, averages three feet in thickness and underlies the sand and peat. Bed 3, an aquifer, consists of fine to

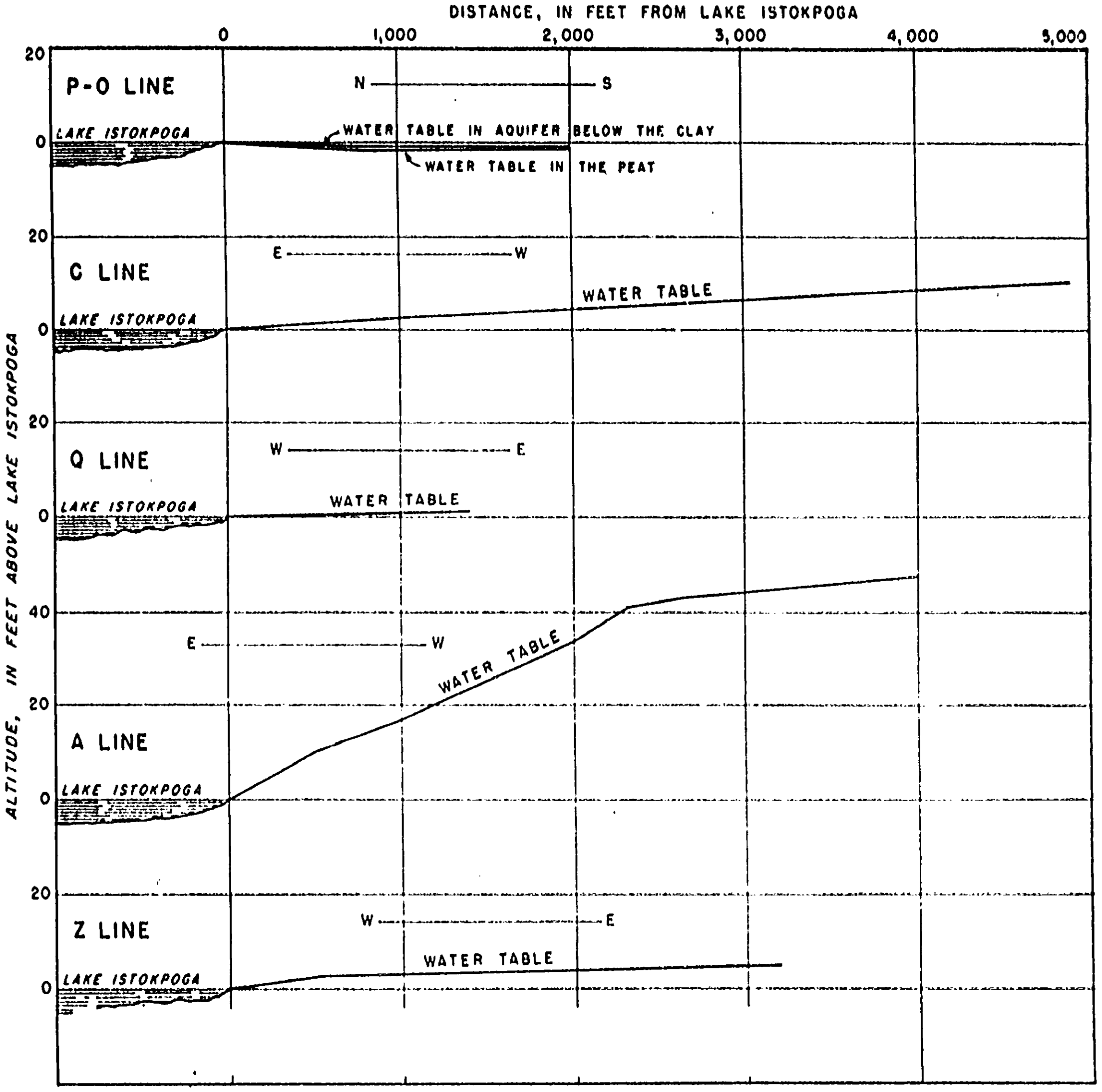

Figure 4. Cross sections showing slope of the water table along well lines in relation to the water surface of Lake Istokpoga.

coarse sand. Bed 4, a confining bed, is mainly very fine blue-gray sandy clay interbedded with shell layers. Bed 5, the aquifer of well O-7, is relatively permeable, but its constituents are unknown.

GROUND WATER

The water levels in wells are referred to mean sea level and the short dashed line in figure 6 indicates the position of the water table in the observation wells. The gradient of the water table along the scarp is steeper than it is in the Istokpoga flat. This is due mostly to the fact that the land surface is much higher west of the scarp, and the water table conforms generally to the configuration of the land surface.

Ground-water movement is from west to east, downgradient. The ground-water divide is obviously a considerable distance west

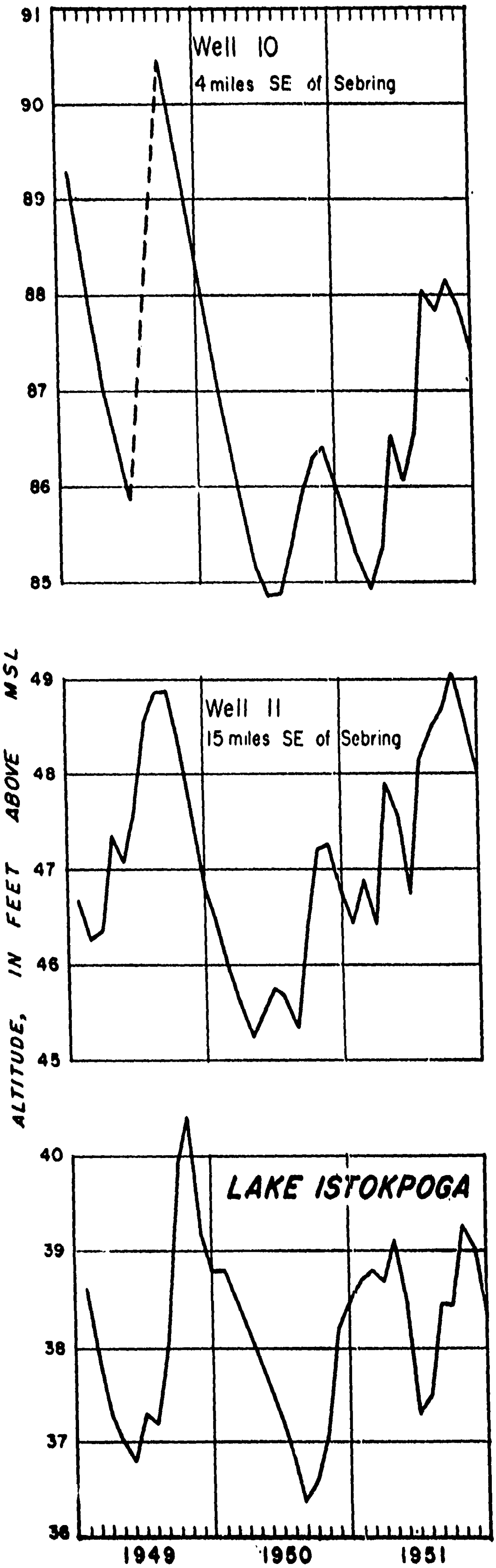

Figure 5. Hydrographs showing average monthly water levels in wells 10 and 11 and Lake Istokpoga.

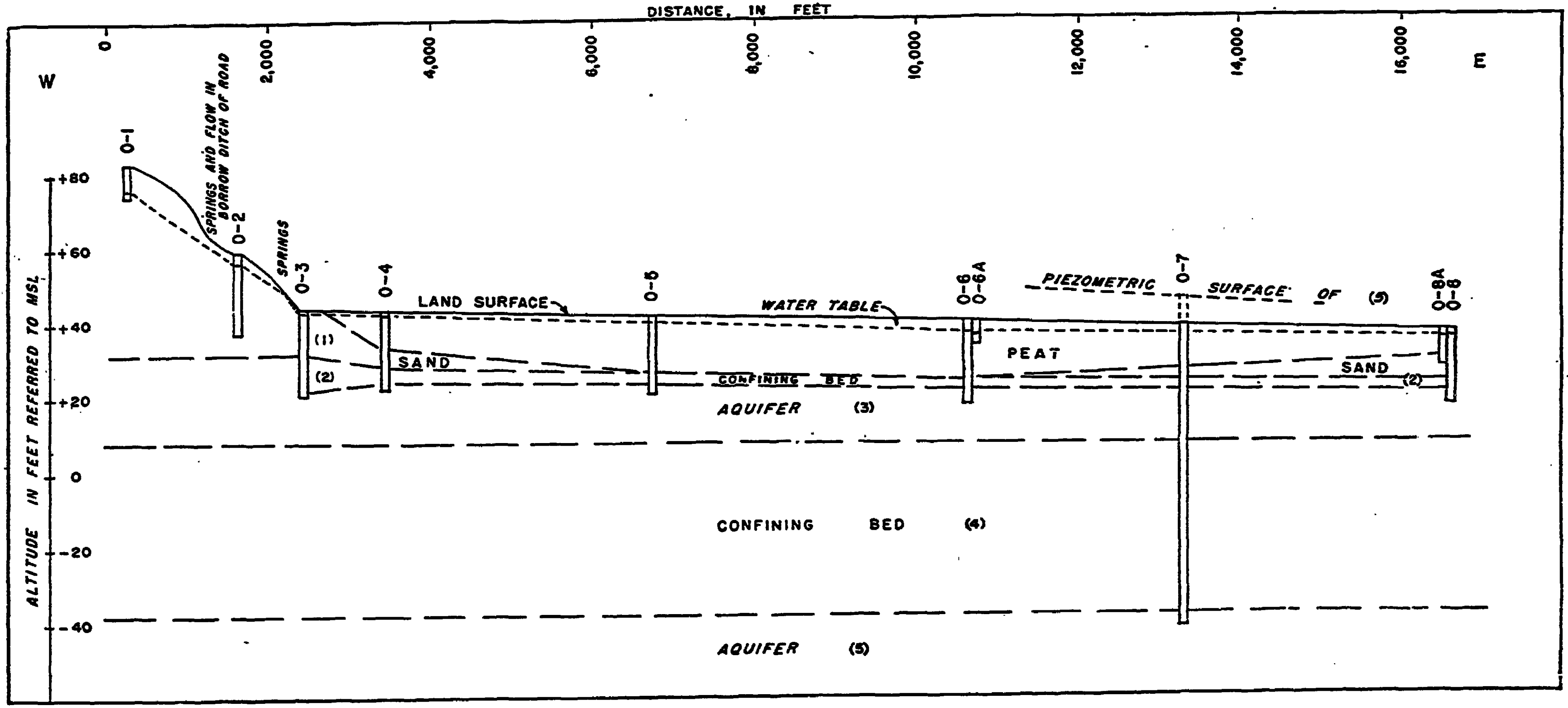

Figure 6. Cross section showing lithologic and hydrologic characteristics from west to east, along line O.

of well O-1, beneath Highlands Ridge. Bed 2 probably pinches out a short distance west of the scarp. Ground-water flow is thus split by bed 2. Part of the ground water flows above bed 2, through the sand (bed 1) and the peat, and part flows beneath it through bed 3. Bed 5, like bed 3, also has a hydraulic connection with the recharge area on the ridge.

Water levels in the peat (see well O-6A) are slightly lower than in bed 3. This is probably caused by ditches surrounding diked fields, which drain the peat but have little effect on water levels below the confining bed. The differences in water level are not great, however, and all the section between land surface and bed 4 may be considered to belong to the nonartesian aquifer.

The relatively impermeable bed 4 holds the water of bed 5 under confinement, so that ground water that has entered bed 5 under the ridge is under pressure and has a tendency to leak upward through bed 4. Well O-7, which penetrates bed 5, flows at the land surface. Its water level rises to the pressure (piezometric) surface shown in figure 6.

LINE P-O

GROUND WATER

A north-south cross section from the southern end of Lake Istokpoga through wells P-1, 2, 3, 4 (all at the same location) to wells O-6 and O-6A is shown in figure 7. The lithology is similar to that along line O.

Attention is called to the divergence of water levels at various depths. The low water level in the peat is probably caused by shallow drains, which have little effect below bed 2. The water level of well P-3 in bed 4 is only slightly higher than that of well P-2 in bed 3. The small difference in head causing upward movement of water from bed 4 to bed 3 indicates that the upward leakage from the artesian aquifer penetrated by well P-4 is not large.

LINE N

LITHOLOGY

The peat in the section of line N (fig. 8) occurs as a wedge against the scarp and thins rapidly eastward to become a thin mantle of organic detritus and soil. Bed 1 consists of clayey sand and is underlain by a blue sandy clay or marl (bed 2) which pinches out against the scarp. Bed 3, an aquifer, is composed of medium

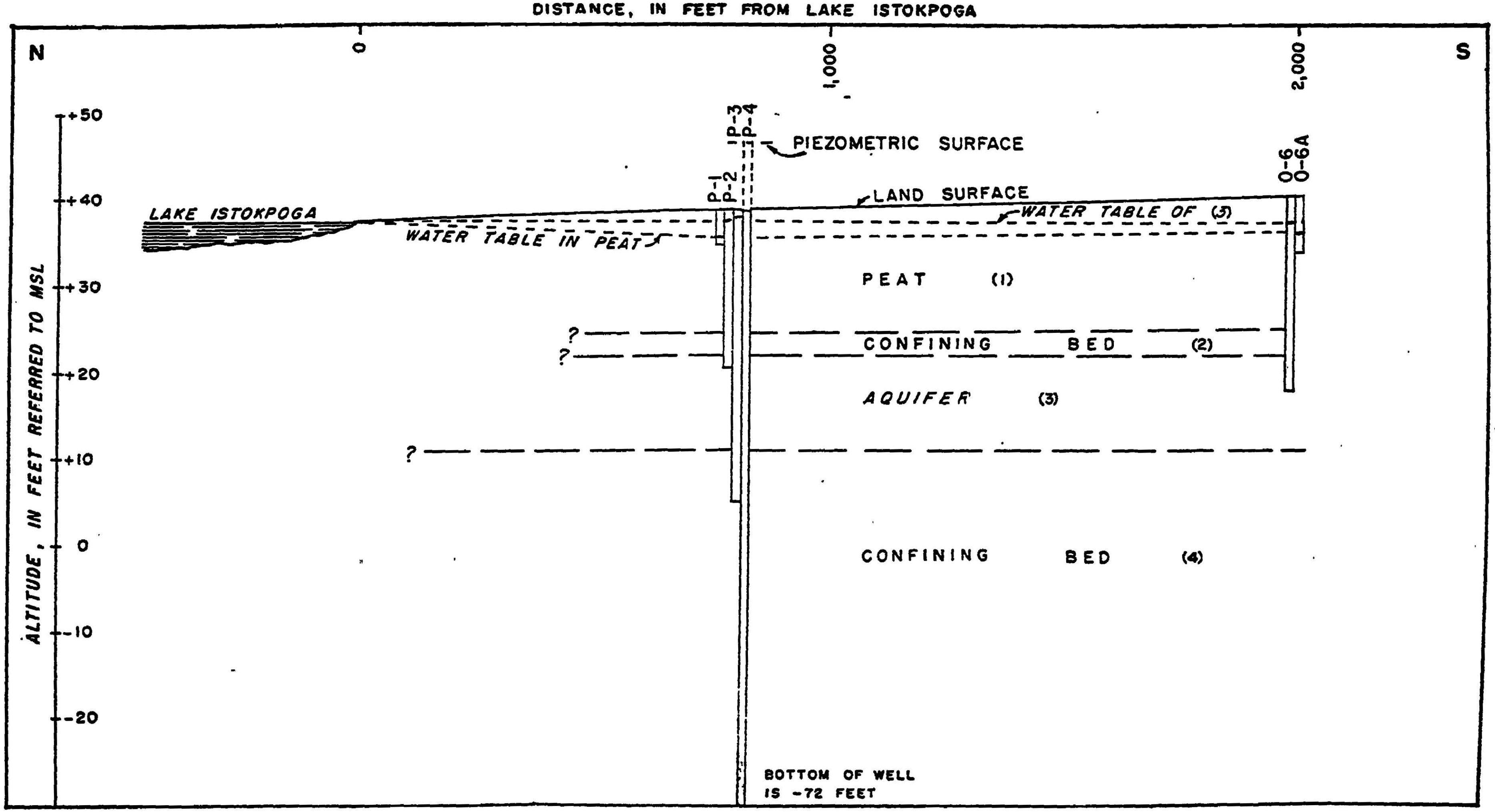

Figure 7. Cross section showing lithologic and hydrologic characteristics from north to south, along line P-O.

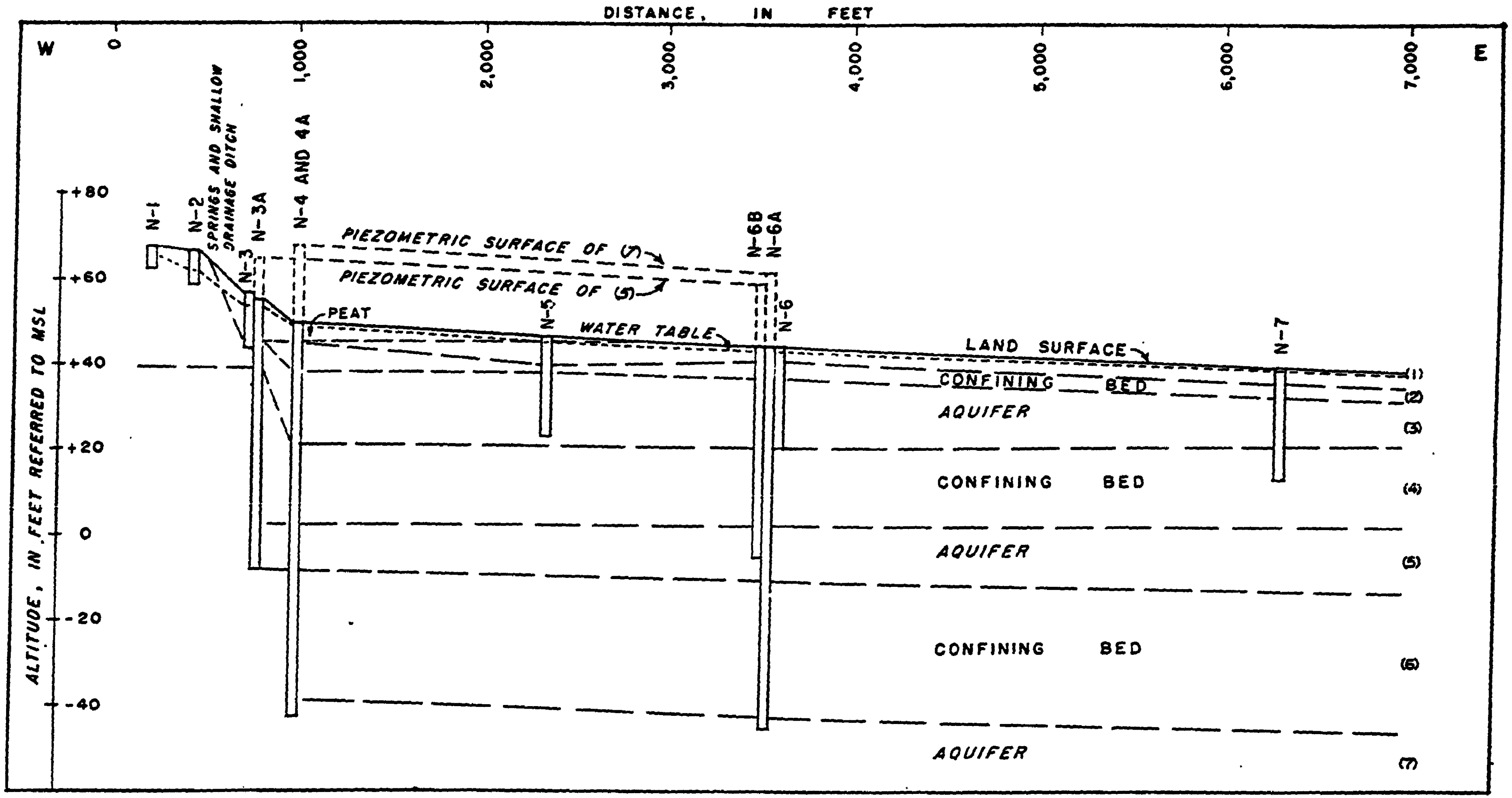

Figure 8. Cross section showing lithologic and hydrologic characteristics from west to east, along line N.

to coarse sand and extends westward beneath the scarp. Bed 4 is an impermeable blue-gray sandy clay which grades laterally into a very fine white sand, mixed with kaolin and mica flakes, beneath the scarp. The coarse sand of bed 5 is moderately permeable, and wells N-3A and N-6B, which penetrate it, flow at the surface. Bed 6 consists of blue-gray sandy clay. Bed 7 is a highly permeable white quartz gravel containing pebbles up to half an inch in diameter. It is penetrated by flowing wells N-4A and N-6A.

GROUND WATER

Shallow ground water underlying the area traversed by line N moves eastward from the scarp in accordance with the water-table gradient. This movement occurs both above and below bed 2. No significant difference was noted in the water levels of beds 1 and 3; therefore, all the material down to bed 4 is considered to belong to the nonartesian aquifer.

The piezometric surfaces in wells drilled through the confining layers into beds 5 and 7 show the height to which water rises in wells that penetrate these beds (fig. 8). The coarse sand of bed 5 is much less permeable than the gravel of bed 7. Although the difference in head between the two aquifers is only three feet, the wells in bed 7 flow an estimated 100 gpm as compared with 20 and 3 gpm for wells N-3A and N-6B, respectively.

LINE M

LITHOLOGY

The peat of line M (fig. 9) forms a wedge which thins rapidly eastward from a maximum thickness of about 17 feet adjacent to the scarp. Bed 1 is a confining lens of blue sandy clay. Bed 4 consists of medium to coarse quartz sand. Bed 3, which interfingers with bed 4, is a lens of very coarse sand and white quartz pebbles. Bed 2 has the same coarse grains as beds 3 and 4 but contains considerable clay or marl, which markedly decreases its permeability. Bed 5 consists of blue-gray sandy clay to pure clay and interbedded shells and phosphate pebbles. Bed 6 is composed of white quartz gravel and coarse sand which becomes clayey eastward from the scarp.

GROUND WATER

Although locally confined, all the material from the land surface down to the top of bed 5 constitutes the nonartesian aquifer. The

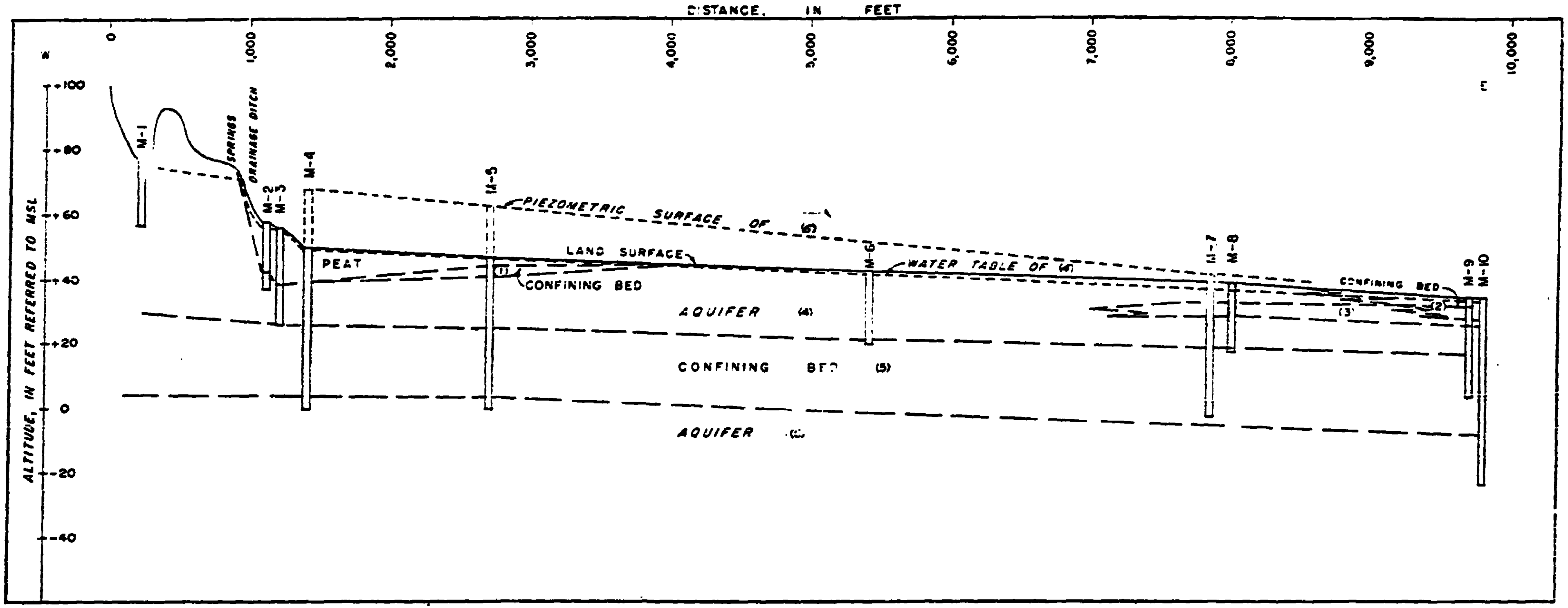

Figure 9. Cross section showing lithologic and hydrologic characteristics from west to east, along line M.

shallow water table intersects the land surface at the scarp, where ground water appears as springs. The piezometric surface of bed 6 has a relatively steep gradient, which declines about 30 feet within a distance of 9,000 feet. The steep gradient is probably caused by upward leakage near the scarp.

HYDROLOGY

According to Darcy's law, the discharge through a cross-sectional area of water-bearing material can be computed by the following formula:

$$Q = PIA$$

where: Q = the quantity of discharge, in gallons per day
P = the permeability of the material
I = the hydraulic gradient
A = the cross-sectional area through which the water passes.

In using Darcy's law to determine the approximate magnitude of flow through a particular cross section, the area (A) is equal to the thickness of water-bearing material multiplied by the length of section (one mile for convenience) measured perpendicular to the direction of ground-water movement. The hydraulic gradient (I) is taken directly from the cross section and is equal to the water-table gradient in feet per foot. The permeability of the materials penetrated during installation of the observation wells was determined in the laboratory by the permeameter method and is shown in tabular form below:

Well No.	Depth (feet) From	To	Permeability (P) (gpd per sq. foot)
O-1	0	5.5	915
O-2	0	14	725
O-3	11.5	14	1,080
O-3	21	22	660
N-1	4	4.5	785
N-3	10	12	850
N-3	30	42	[1]270
N-3	54	55	580
N-7	11.5	16	660
M-1	3	5.5	850
M-3	19	21	520
M-3	23	25	310
M-9	6	8	280

[1]Laboratory determination much too high because kaolin, present in layers in the bed, was washed out of the sample during jetting.

SHALLOW NONARTESIAN AQUIFER

As ground water moves eastward from the recharge area on Highlands Ridge, the gradient of the water table is increased at the scarp. A part of the total quantity of shallow ground water flowing eastward from Highlands Ridge is lost to surface springs and the remainder moves below the scrap, as ground water, to the Istokpoga flat. The slope of the water table down the scarp cannot be used in determining the quantity of ground-water discharge because it is affected by surface discharge along the scarp as well as by the movement of ground water. The relatively flat gradient below the scarp can be used to approximate the magnitude of ground-water flow through the shallow nonartesian aquifer. Data from well N-7 are used in the computation. The total thickness of beds 1 and 3 is 15 feet. Bed 2 contributes very little water and is disregarded in the computation. The permeability of bed-3 samples, taken from well N-7, is 660. This permeability is doubled for the computation, to allow for the possibility that the sample is not representative and that the average is higher. The gradient of two feet per thousand feet is taken directly from the cross section in figure 8.

$$Q = PIA$$

$$Q = 1{,}320 \times \frac{2}{1000} \times 15 \times 5{,}280$$

$$Q = 210{,}000 \text{ gpd per mile or } 0.32 \text{ cfs}$$

The computed flow is representative of the general magnitude of ground-water movement below the scarp on all well lines.

A drainage ditch three to four feet deep extends approximately 1.7 miles southward from State Highway 70 along the lower part of the scarp. Since September 1952, four eastward outlet ditches from the main drain have been measured periodically by the U. S. Geological Survey. The total flow from the four outlets probably represents the flow from springs farther up the scarp plus the ground-water pickup in the drainage ditch. The total flow, in cubic feet per second, on various dates in 1952 was a follows:

Sept. 11	4.1
Oct. 10	4.4
Oct. 24	5.5

Dividing by 1.7 miles, the length of the intercepting drain, the flow ranges from 2.4 to 3.3 cfs per mile.

By comparing the computed ground-water flow below the scarp (0.32 cfs) with the measured amount of pickup in the drain

(3.3 cfs) it becomes obvious that most of the flow above the scarp escapes by discharge from springs.

When the water is discharged from the springs, near the base of the scarp, it evaporates rapidly. The abundant vegetation in the marshlands along the base of the scarp transpires a large amount of ground water into the atmosphere. The peat along the base of the scarp acts as a spongelike confining bed, and, by holding the ground water near the surface, it contributes greatly to the large amount of evapotranspiration near the scarp. Because of these great losses by evapotranspiration, the amount of water available for interception by a canal diminishes with distance from the scarp.

If a drainage canal were constructed at the base of the scarp, most of the water formerly lost by evapotranspiration would be transferred immediately to the drain. Reports from local residents indicate that this actually happens. Shallow drains being dug in the peat are reported to show a very sudden increase of flow when they pass below the bottom of the peat.

The amount of ground water that a drainage canal will pick up depends on the water level that is maintained in the canal. Suppose, for example, that in the area south of Lake Istokpoga the water level in a canal constructed parallel to the scarp (normal to the direction of ground-water movement) is maintained at the level of the water table. Ground water entering from the upgradient side moves across the width of the canal and leaves through the downgradient side; thus, the net pickup of ground water is zero, although ground water is in transit across the canal.

If the water level in the canal is lower than the water table, a gradient exists from both sides toward the canal and ground water will drain into the canal. Drawdowns will extend progressively farther away from the canal until natural discharge is salvaged or recharge is increased in quantities large enough to balance the drainage from the canal. Ground-water loss through seeps and springs along the scarp is a form of discharge from the nonartesian aquifer. If a drain were constructed near the base of the scarp, no lowering of the water table in the ridge section would occur unless the amount of ground water discharged by the drain were greater than the discharge that could be salvaged from the spring flow and evapotranspiration along the scarp. Thus, the scarp would act as a sort of barrier or buffer that would tend to reduce the drawdown that would extend upgradient into the ridge area.

With the data available in 1956, it was not feasible to predict the amount of ground-water pickup to be expected in a drainage ditch located along the scarp. However, the effect on ground-water levels high in the ridge section would probably be negligible, provided the water level in the drain were maintained within reasonable proximity of the present water table. A canal constructed a mile or more from the scarp would intercept less ground water than a canal near the scarp and would have no effect on water levels in the ridge section.

Analysis of well line P-O (fig. 7) shows that the water table has a slight gradient to the south. The P-O section is almost parallel to the ground-water contour lines, and the apparent gradient is a component of the regional southeastward water-table gradient. The following table shows the altitude of the water table at wells in the eastern part of each well line on October 3, 1952.

Well No.	Altitude of water table (feet above msl)
Lake Istokpoga	37.75
P-2	37.47
O-6	37.32
N-7	38.77
M-9	32.81
M-6	41.82

It is assumed here that, in order to drain water from Lake Istokpoga, a canal having water-surface gradient of one foot in six miles will be required. The distance from Lake Istokpoga to State Highway 70 is six miles; hence, the water surface of the canal must drop one foot in this distance, to a level of 36.75 feet. By use of the preceding table it can be determined tentatively that a canal starting from Lake Istokpoga should pass slightly west of P-2 and O-6, east of well N-7, and, at State Highway 70, between wells M-9 and M-6 but closer to well M-6. The figures in the table are presented to show that the canal can be located and designed so that it will drain surface water but will have no effect upon ground-water levels. There will be no effect on ground-water levels if the water level in the canal is maintained at the level of the water table. If, however, the drain were constructed so that the northern part passed through well O-3 (water-table altitude of 43.45 feet), ground water would flow into the drain from both sides and a general lowering of the water table would occur on both sides of the ditch. If the southern part of the drain were constructed through the locality of well M-9 (water-table altitude 32.81 feet), the water in the canal (water-surface altitude 36.75 feet) would leak to the water table under a head of almost four feet. The recharge thus provided to the nonartesian aquifer would produce a general rise in ground-water levels in the vicinity of well M-9.

LEAKAGE FROM ARTESIAN AQUIFERS

The piezometric surface of an aquifer is the surface to which water will rise in tightly cased wells that are open to the aquifer. The piezometric surfaces of several shallow artesian aquifers are indicated in figures 6, 7, 8, and 9, which show that the hydraulic gradient is from west to east, from Highlands Ridge to the Lake Istokpoga flat.

The hydraulic gradient along the several well lines is modified by the amount of upward leakage from the aquifer through the confining bed and by changes in the horizontal permeability of the aquifer. For example, the relatively steep gradient along line M may be due to a high rate of discharge by upward leakage, or it may be due to only a moderate or low rate of discharge in an area where the permeability of the aquifer is low and the steep gradient is necessary to maintain flow through the aquifer.

Upward leakage from an artesian aquifer along any of the cross sections can be calculated by use of Darcy's law if the vertical permeability of the confining bed is known. The head difference between the artesian aquifer and the nonartesian aquifer is dissipated through the thickness of the confining bed; thus, the ratio of head difference to the thickness of the confining bed is the hydraulic gradient (the value "I" in the Darcy formula). The area (A) through which the leakage occurs can be of any size. Because the permeability of the confining bed is not known, the magnitude of upward leakage cannot be determined. The magnitude of upward leakage in 1956 is not important, however, because this leakage is already occurring and will not be changed if the position of the water table is not changed. The important questions, therefore, are: (1) What effect will drainage have on the magnitude of upward leakage? (2) Will the change in leakage affect the levels of lakes in the Highlands Ridge section? The following assumptions are made for computing the change in upward leakage from bed 5 caused by a drainage canal passing near well N-6B:

1. After construction of the canal, the water level in the drainage canal is maintained at a lower level than the present water table, and drainage is occurring.

2. At a distance of 1,000 feet up and down the gradient from the canal the drawdown in the nonartesian aquifer is zero.

3. The water table is lowered an average of two feet throughout the area affected by drainage.

4. The permeability of the confining bed is one gpd (gallon per day) per square foot.

5. The head differential between well N-6B and the water table, 16 feet, is average for the area considered.

6. The average thickness of the confining bed is 18 feet.

7. The area is one mile long by 2,000 feet wide. Leakage under these conditions is computed as follows:

$$Q = PIA$$

$$Q = 1 \times \frac{16}{18} \times 5{,}280 \times 2{,}000$$

$$Q = 9{,}400{,}000 \text{ gpd}$$

After construction of the drain, the water table is lowered an average of two feet and leakage increases by 2/18, the increase in gradient.

$$Q = PIA$$

$$Q = 1 \times \frac{18}{18} \times 5{,}280 \times 2{,}000$$

$$Q = 10{,}600{,}000 \text{gpd}$$

The net increase of leakage from the artesian aquifer is the difference between the computed leakages, namely, 1,200,000 gpd, or 1.8 cfs. This computation is based on many assumptions and is presented only as a basis for a qualitative discussion of the principles.

An increase of leakage from an artesian aquifer will cause a drawdown of the piezometric surface that will extend both upgradient and downgradient from the drainage canal until a new equilibrium is established. Because drawdown decreases with distance from the discharge point, it is doubtful that any effect of increased leakage (in the magnitude suggested by the computation) would be felt in the artesian aquifer several miles upgradient beneath Highlands Ridge. Even if a drawdown did occur beneath the ridge, so that the rate of vertical percolation from the nonartesian aquifer to the shallow artesian aquifer in the ridge were increased, the lakes probably would not be affected. Permeable sand underlies the ridge. During periods of heavy rainfall, practically all the water is immediately absorbed as recharge, but some is rejected and becomes surface runoff when the nonartesian aquifer is completely filled. This rejected recharge is available to replace water lost by downward percolation. The levels of the lakes, therefore, could not be affected permanently by increased percolation to the artesian aquifer beneath the ridge unless the percolation were sufficiently large to exceed the amount of rejected recharge.

CONCLUSIONS

The conclusions of the investigation are here presented in the form of answers to the questions stated on page 14 in the introduction.

1. The water table slopes toward Lake Istokpoga in each of the test areas except at the southeast corner of the lake. In the areas south of the lake, a proposed canal extending northward from the Harney Pond Canal would generally parallel ground-water contour lines. If the canal were located immediately adjacent to the scarp, it would intercept ground water at an altitude greater than that of the present water level of Lake Istokpoga. Water in a canal at this position, therefore, would tend to flow toward Lake Istokpoga. However, the low permeability of the materials underlying the Istokpoga flat indicate that the canal would have the strongest influence upon the water levels of that region. Drainage would occur and ground-water levels would decline, and the water table would adjust to a new pattern consistent with the gradient of the canal; but the amount of ground water drained would not be large. Therefore, it is doubtful that the ground-water pickup would be large enough to permanently maintain flow in the canal toward Lake Istokpoga. It is readily seen, however, that lowering the water level of the lake in preparation for hurricane rains would be more difficult if the canal were located close to the scarp, where it would salvage water from evapotranspiration and spring flow.

2. The present flow of ground water through the materials underlying the Istokpoga flat is very small. If the water level in the canal and the water table are held at roughly the same level, the amount of ground-water pickup will be negligible and will not affect the capacity of the canal to discharge ponded surface water.

The data presented previously, however, show that more pickup will occur close to the scarp.

3. The extent to which the water table of the ridge section will be affected by construction of a canal in the Lake Istokpoga area depends entirely on how much ground water discharges into the canal. If the water level in the canal is maintained at the level of the water table (by draining water from Lake Istokpoga), no ground water will be discharged directly into the canal. This condition probably will not be fully realized. If the canal is properly designed, however, the amount of ground-water drainage will be small and salvage of the rejected recharge that takes place through springs along the scarp and of water now evaporated and transpired will act as a buffer to reduce lowering of the water table in the ridge section. As drawdown varies inversely with distance from a drainage canal, it would be advantageous to construct the canal as far from the scarp as it can be placed and still fulfill its primary purpose.

4. Calculations show that the increase in upward leakage from a shallow artesian aquifer, caused by the proposed drainage canal, would probably have no effect on the water levels of the lakes in the ridge section. It is again emphasized that, if the water table remains unchanged by drainage, no change will occur in the upward leakage from the artesian aquifer.

The greatest danger to the water levels of the ridge section would result from the penetration of one of the artesian aquifers by the drainage canal. In the area of this investigation, the least distance between land surface and a known artesian aquifer is 40 to 45 feet (along lines N and M). A canal 20 feet deep would cut the vertical distance between the bottom of the drain and the top of the artesian aquifer to 20 or 25 feet. This decrease in distance would have no effect on the leakage because the confining bed would not be cut. If part of the confining bed were penetrated, its effective thickness would be reduced and leakage would increase.

Along line N (figs. 3, 8) the depth to an artesian aquifer composed of white quartz gravel is approximately 90 feet. Along line M (figs. 3, 9) a white quartz gravel occurs at a depth of 40 feet. It is not known whether these two occurrences represent a single stratum, but if they do the stratum dips northward. A projection of the plane of the upper surface of such a stratum would bring it near the surface south of line M. Thus it is possible that a canal

20 feet deep south of line M would cut through the confining bed and into the aquifer itself. No data are available for the area south of line M.

A review of the cross sections shows that the difference in head between the artesian and nonartesian aquifers decreases rapidly with distance from the scarp. Obviously then, the ground-water pickup that would result from cutting into the artesian aquifer would be far greater near the scarp than at a distance from the scarp.

To construct a canal immediately adjacent to the scarp would be dangerous at best. To construct a canal too far from the scarp would probably result in leakage of water from the canal to the water table, thus recharging the water-table aquifer and causing a general rise of ground-water levels. The best solution, to avoid interchange between the canal and the ground water, would be to construct the canal where its water surface would coincide with the water table. As the water table is within a few feet of the land surface in the area studied, a general rule of thumb would be to use the land-surface altitude as a rough indication of the altitude of the water table. Inspection would reveal those areas where the water table is at the land surface.

Part II

LAKE PLACID AREA, HIGHLANDS COUNTY, FLORIDA

By

F. A. Kohout

and

F. W. Meyer

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ILLUSTRATIONS

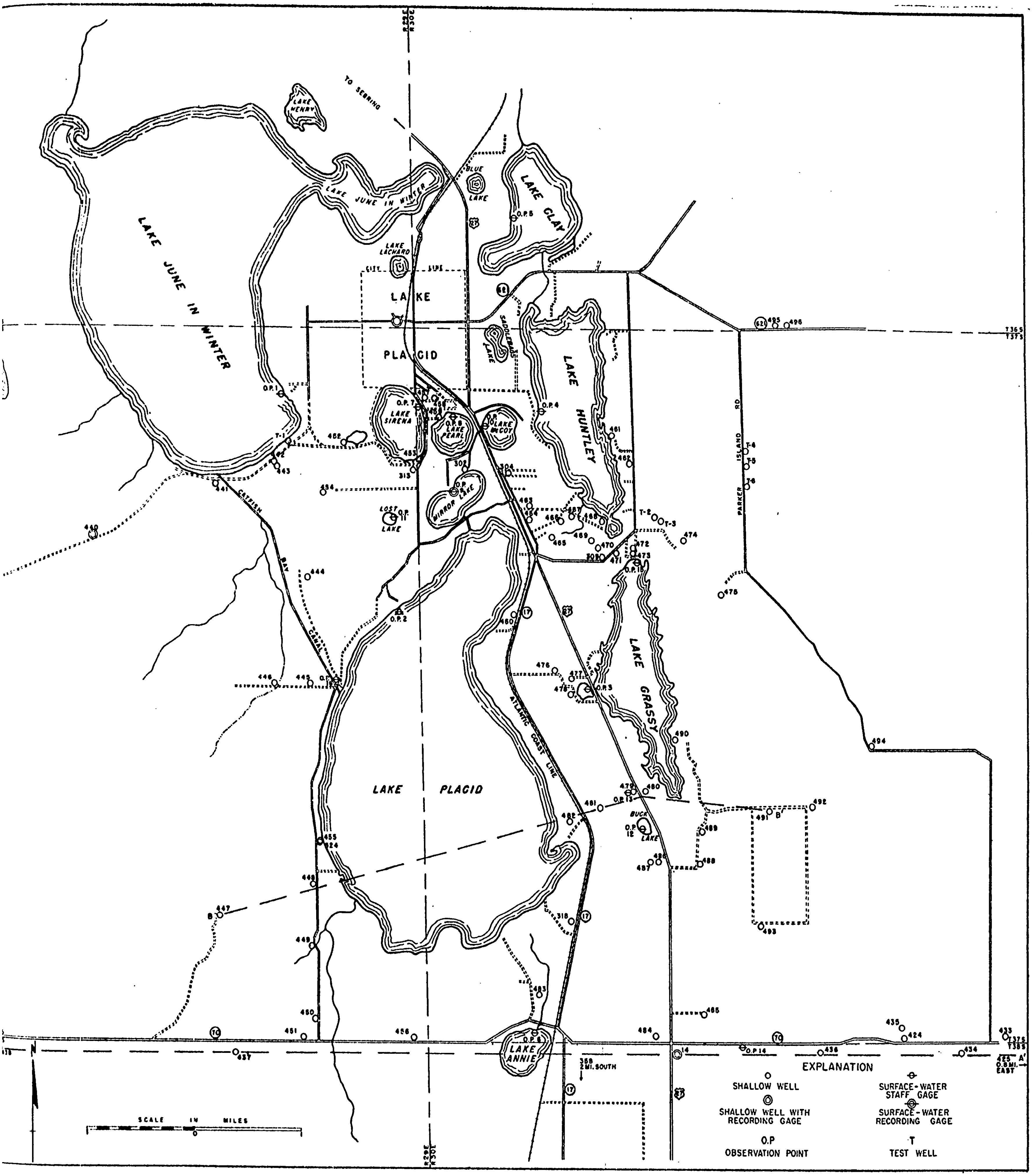

Figure 10. Map of the Lake Placid area showing locations of wells.

Part II

HYDROLOGIC FEATURES OF THE LAKE PLACID AREA, HIGHLANDS COUNTY, FLORIDA

INTRODUCTION

The Lake Placid area of Florida is in the Highlands Ridge section of Highlands County. The eastern boundary generally parallels the scarp that separates the ridge section from the Lake Istokpoga area and constitutes the western boundary of that area. The length of Lake Placid area is approximately nine miles, and the width ranges from about six miles at the northern extremity, slightly north of the town of Lake Placid, to about eight miles at the southern extremity, just south of State Highway 70.

PURPOSE AND SCOPE OF INVESTIGATION

In recent years, residents of the area have given much attention to the water levels of the many lakes of the ridge section. During periods of heavy rainfall, the areas around the lakes are flooded and lakeshore homes and crops are damaged. During periods of deficient rainfall, the lake levels are so lowered that boating facilities are left high and dry; at the same time, the demand for irrigation water for citrus groves and other crops is at its greatest and the pumping of water from the lakes contributes to the decline of lake levels.

At the request of the Central and Southern Florida Flood Control District, the U. S. Geological Survey started an investigation, in October 1955, to determine the influence of the ground-water reservoir on the water levels of the lakes. One phase of the investigation was to establish the relationship of the water table to lake levels and, if possible, to devise some method by which this relationship could be used to predict the water level of a given lake after an extended period without rainfall. Lake Placid was selected as the lake of primary interest, but it was decided that an investigation of adjacent areas was necessary in order to ascertain correctly the hydrologic characteristics effecting Lake Placid.

A tentative plan is under consideration for the construction of a closed drain through the narrow strip of land separating Lake Huntley and Lake Grassy. Also, the canals or drainageways connecting Lake Apthorpe, Lake Clay, and Lake Huntley are to be improved and control structures are to be built, so that the water levels of the entire lower chain of lakes can be controlled. As Lake Huntley and Lake Grassy fall within the scope of this report, computations based on assumed conditions will be presented to clarify the effect produced upon the ground-water reservoir and lake levels by undue lowering of water levels in the lower chain of lakes.

During this study, special consideration was given to the occurrence of ground water in the nonartesian aquifer, the direction of ground-water movement, and the relation of ground-water levels to the water levels of the lakes.

The investigation was made under the general supervision of A. N. Sayre, Chief of the Ground-Water Branch of the U. S. Geological Survey, and under the immediate supervision of M. I. Rorabaugh, District Engineer for Florida.

METHOD OF INVESTIGATION

All wells in the area were inventoried to obtain pertinent information. In areas of sparse information, supplementary lithologic and hydrologic data were obtained from wells and test holes installed by jetting. The wells were constructed of ¾-inch pipe with a brass strainer at the bottom. Each well was pumped with a pitcher pump, after installation, to assure that the well was open to the aquifer and thus was showing the true water level. Permeability of sand aquifers was determined by the permeameter method in the laboratory. The altitudes of water levels in 73 wells and of observation points (see well locations, fig. 10) were determined by spirit level, and a map showing the configuration of the water table was prepared from this information.

GEOLOGY

GENERAL FEATURES

The sedimentary rocks exposed in the Lake Placid area range in age from Miocene to Recent. Outcrops of rocks of Miocene age are seen in clay pits and the deep road cuts of the ridge section (Bishop, 1956). Pleistocene sand, forming the major part of the surficial sediments, mantles the Miocene deposits as a veneer less than 30 feet thick. Deposits of Recent age are exposed in places; they consist of peat and organic soil formed after the last lowering of sea level, at the end of the Pleistocene epoch.

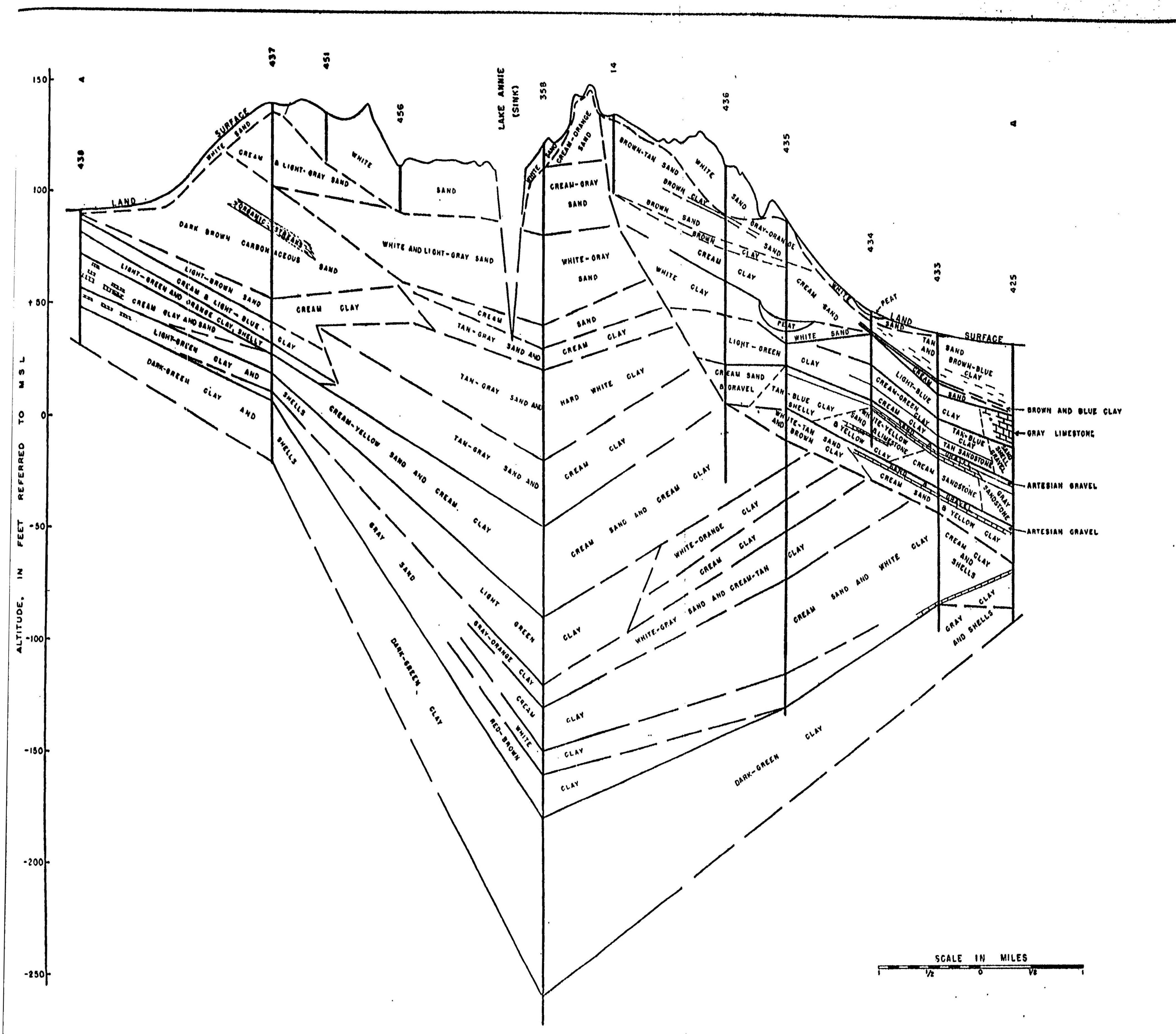

Figure 11. Cross section showing lithofacies of Highlands Ridge section, along State Highway 70.

The core of the Highlands Ridge consists of a thick deposit of deltaic sand, gravel, and clay which thins and interfingers with marine clay to the east and west. (See lithologic cross section, fig. 11.) The dark green clay that forms a basinlike floor for the main sand body is of Miocene age and is underlain at a depth of about 500 feet below sea level by a thick section of limestone of Oligocene and Eocene age. In topographically low areas, along the flanks of the ridge, this green clay (interbedded with permeable material forming local, shallow artesian aquifers) confines the water in the underlying limestone under artesian pressure. The limestone extends from 500 feet to more than 1,100 feet below sea level in the Lake Placid area and forms the major part of the Floridan aquifer (Parker and others, 1955, p. 189).

The areas surrounding the lakes are underlain at shallow depth by thin beds of red to black indurated sand (hardpan) and peat (fig. 12). Because these beds have a low permeability, they restrict the downward movement of water and may contribute to local flooding.

GEOMORPHOLOGY AND STRUCTURE

The ridge section contains many lakes of various sizes and depths. Many of the lakes are circular in outline; this shape, plus their relatively great depth, indicates that they are sinkhole lakes formed by solution and collapse of the underlying limestone. Marine terraces, formed by changes in sea level during the Pleistocene interglacial stages, flank the ridge. Shoreline features such as dunes, wave-cut benches, scarps, and sandbars are prominent. Sea level was estimated by Cooke (1939, p. 34) to have fluctuated between 270 feet above present sea level and about 300 feet below.

Parker and Cooke (1944, pl. 3) recognized five terraces in Highlands County; four of these, the Wicomico (100 feet in altitude), Penholoway (70 feet), Talbot (42 feet), and Pamlico (25 feet), are included in or border the area of this investigation. The terraces can be traced on topographic maps, and in some areas they slope and appear to merge, indicating subsidence caused by solution in the underlying limestone or, possibly, faulting. In the Lake Placid area, the upper surfaces of the terraces are highly distorted as a result of a combination of solution subsidence, tilting and faulting, and shifting of sand by wind action. These surface irregularities are illustrated in figure 11, which shows also the lithologic characteristics of the subsurface sediments along State Highway 70.

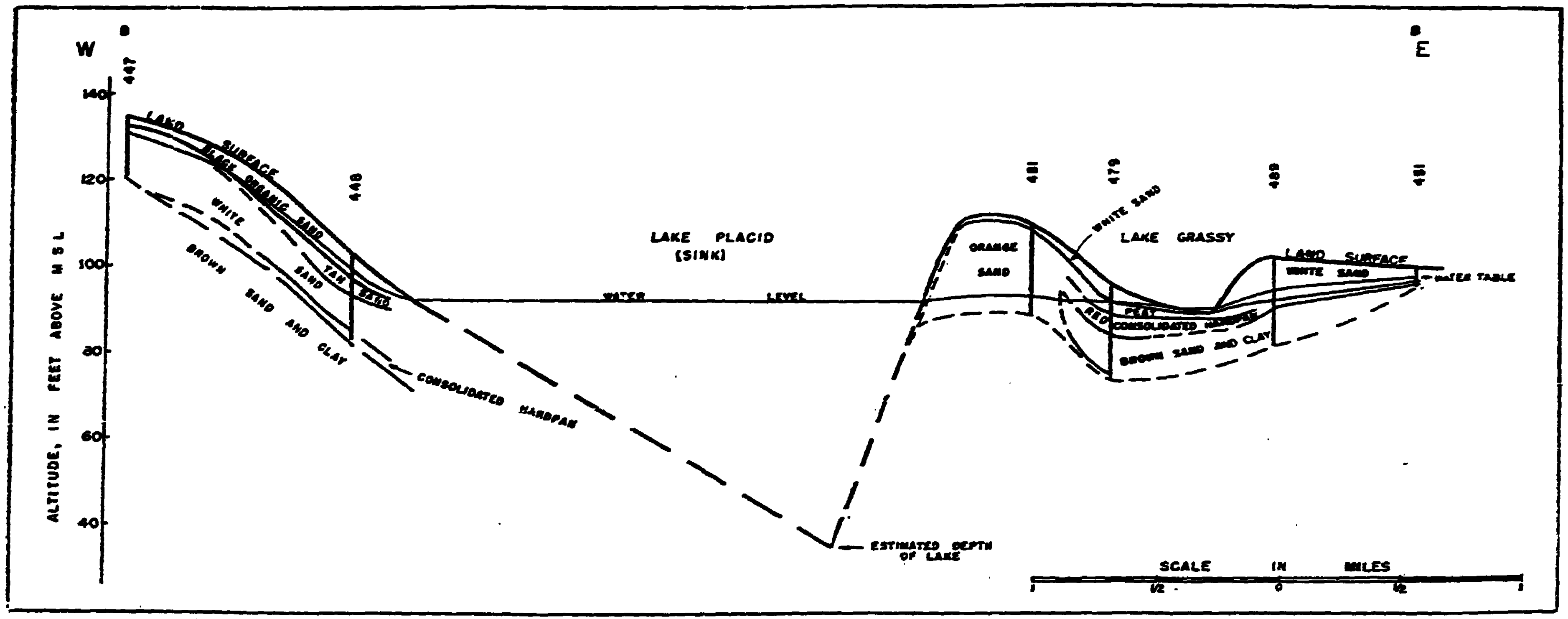

Figure 12. Cross section showing lithology of the nonartesian aquifer along an east-west line across Lake Placid.

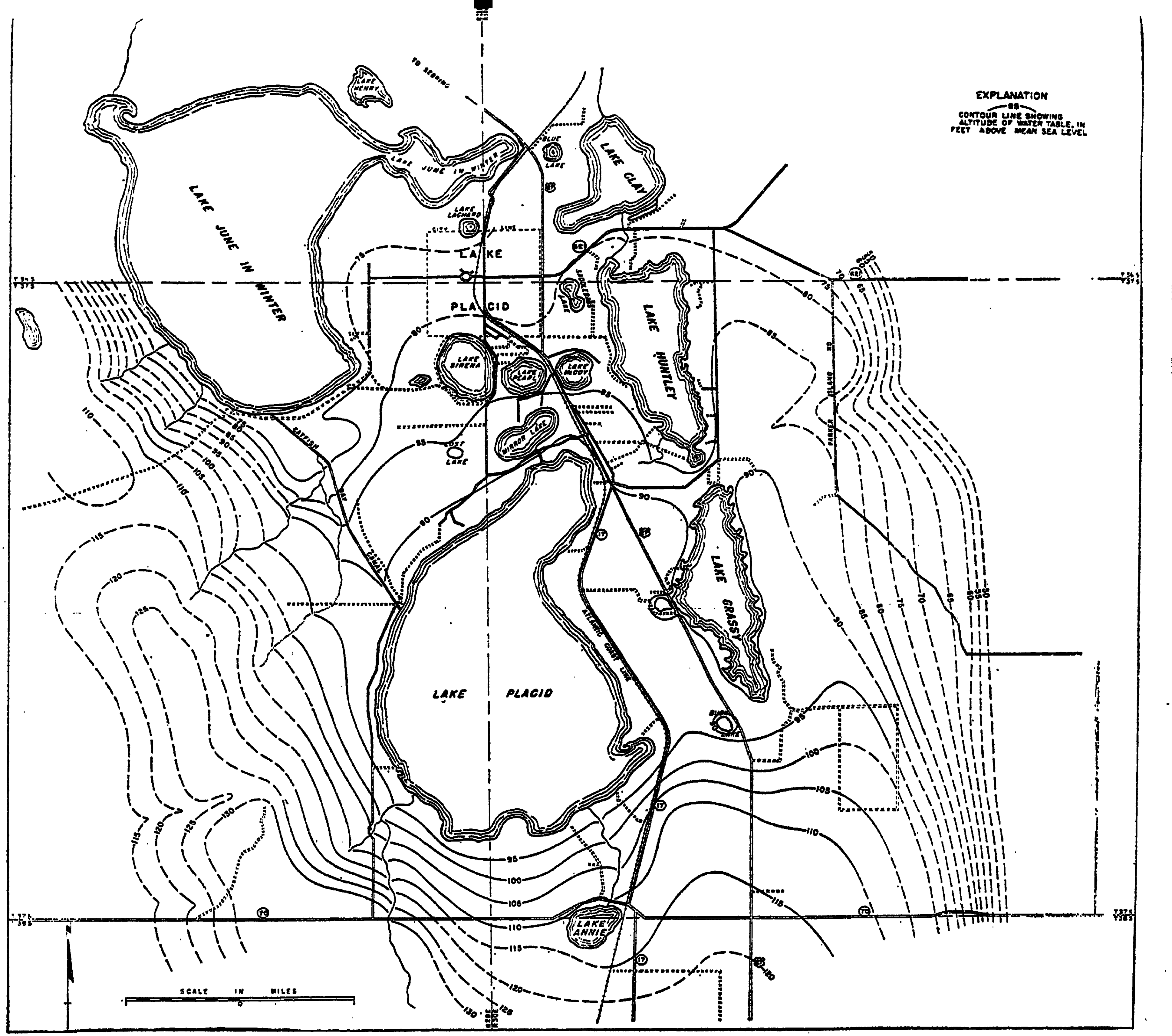

Figure 13. Map of the Lake Placid area showing altitude of the water table on March 13, 1956.

GROUND WATER

The aquifers in the immediate vicinity of the area described in this part of the report may be divided into three general groups: (1) the principal artesian (Floridan) aquifer, (2) the shallow artesian aquifers, and (3) the unconfined or nonartesian aquifer. Of these, only the nonartesian aquifer is considered in detail.

The principal artesian (Floridan) aquifer occurs throughout the Florida Peninsula and has been described by Stringfield (1936) and by Parker (Parker and others, 1955, p. 189). It consists of porous limestone and in the area of this report is approximately 600 feet below the land surface. Beds of sand, marl, and clay, which have a relatively low permeability, overlie the Floridan aquifer. In the Lake Placid area the nonartesian aquifer has a higher head than the Floridan aquifer, and water from the nonartesian aquifer percolates vertically downward to provide recharge for the Floridan aquifer. It is thought that most of the recharge supplied to the Floridan aquifer percolates through the bottoms of the lakes of the ridge section, where the confining beds have been breached by the collapse of caverns in the underlying limestone. Evidence presented in a following section indicates that drawdown caused by pumping from the Floridan aquifer produces a small but recognizable effect upon the water levels of the lakes.

The shallow artesian aquifers are localized strata occurring downslope from the scarp surrounding the Highlands Ridge region. The aquifers are not of great areal extent, and because of upward leakage through the overlying confining beds they frequently lose their artesian head within a few miles of the scarp. The hydrologic characteristics of several shallow artesian aquifers in an adjacent area have been considered in Part I of this report.

NONARTESIAN AQUIFER

RECHARGE AND DISCHARGE

Rainfall, which averages about 53 inches per year, is the principal source of recharge to the nonartesian aquifer. Because of high land and a high water table to the south and west, recharge to the Lake Placid area is provided by ground-water underflow from those directions. Surface runoff, resulting from rejected recharge in the areas to the south and west, also provides recharge to the Lake Placid area during periods of extremely heavy rainfall.

Ground water is discharged from the nonartesian aquifer by underflow into lakes and adjacent, lower deposits to the west, north, and east; by evaporation from places where the water table is shallow; by transpiration from vegetation; and by springs where the water table intersects the land surface. Drainage canals or natural streams connecting the upper and lower chains of lakes provide an exit for the discharge of ground water in two ways: (1) ground water flows directly into the canals and thence downstream as runoff, and (2) the canals lower the water levels of the various lakes by discharging excess water, thus producing a lakeward ground-water gradient which induces the discharge of ground water into the lakes.

Pumping from wells and lakes accounts for a considerable quantity of ground-water discharge. Most of the residents of the area depend upon ground water for their domestic and stock supplies. The town of Lake Placid pumps about 70,000 gallons per day (gpd) from Lake Sirena into its municipal water-supply system. As Lake Sirena has no surface inlet or outlet, this pumping causes discharge from the ground-water reservoir. Large quantities of water are pumped from the lakes of the area to irrigate citrus groves and other crops. This pumping causes a significant discharge of ground water. A part of the irrigation water pumped from the lakes returns to the ground-water reservoir by seepage from the irrigated fields, but the major part is lost by evapotranspiration. The lowering of ground-water levels around Buck Lake by the withdrawal of approximately 1,200 gpm of water from the lake is of sufficient magnitude to be shown on the water-table contour maps (figs. 13, 14).

MOVEMENT

Unconfined ground water moves along the path of least resistance from a position of higher water-table altitude to a position of lower altitude. The direction of movement coincides with the maximum slope of the water table. Water-table contour maps for March 13 and July 10, 1956, are shown in figures 13 and 14. In not all places is there adequate control, but the essential characteristics of shape and slope of the water table are well defined. Ground water moves into the area from the west and south and discharges principally northward and eastward.

Although the surface of a lake might seem to be a horizontal plane, small hydraulic gradients exist in the lakes and permit the passage of ground water across them. For example, ground water enters Lake Placid on its south and southwest sides, moves across the lake, and finally leaves it on its northwest, north, and northeast

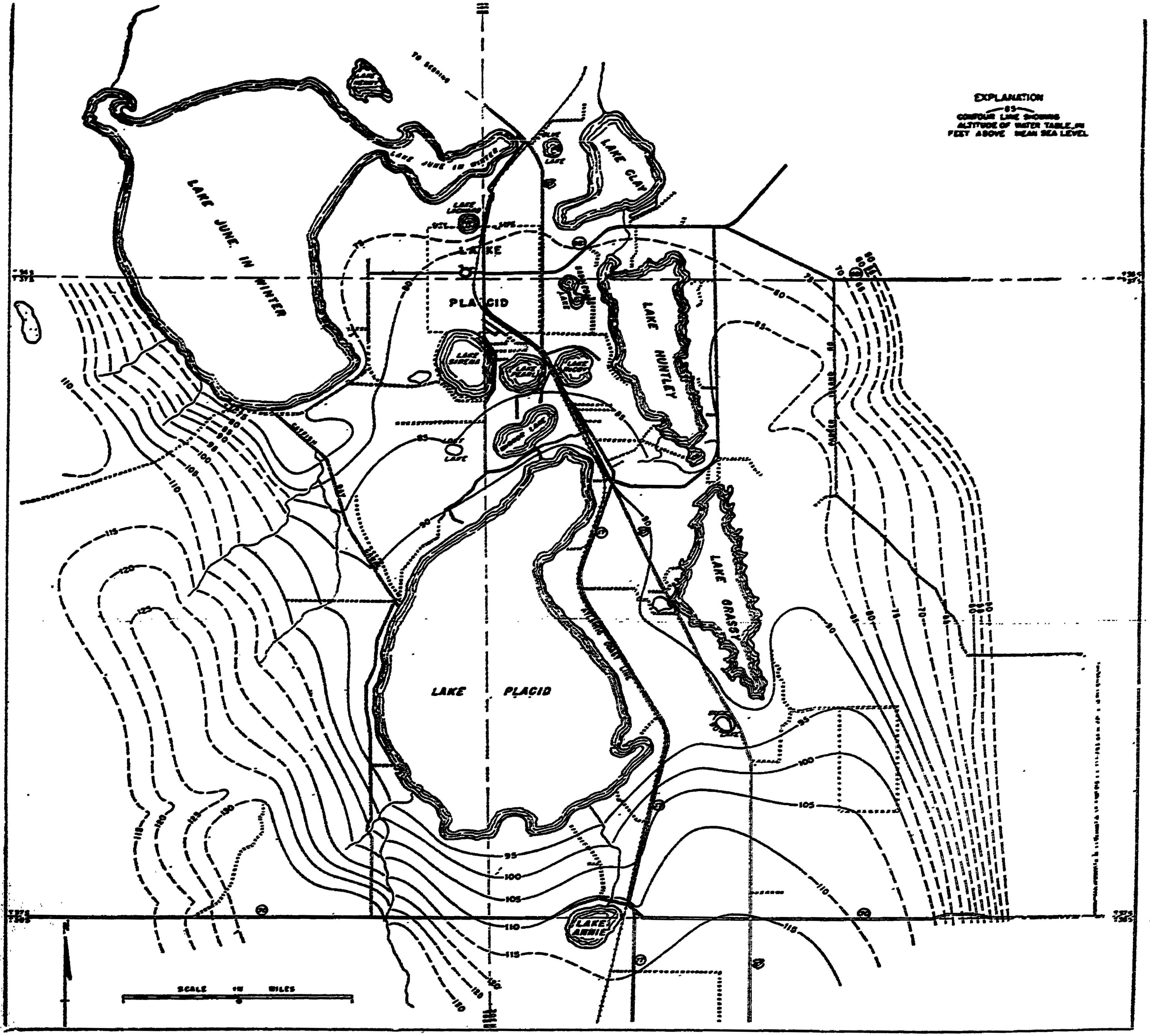

Figure 14. Map of the Lake Placid area showing altitude of the water table on July 10, 1956.

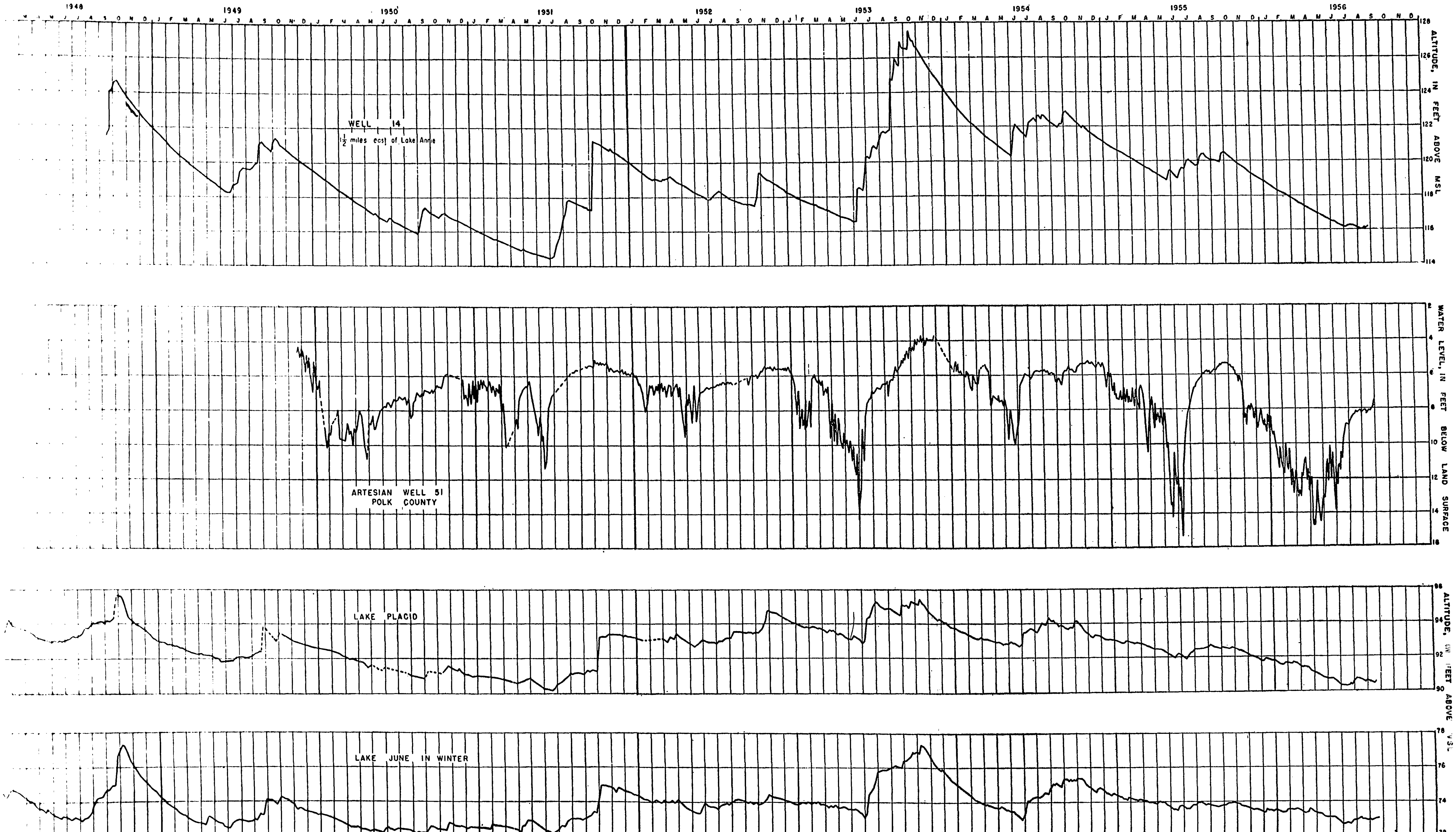

Figure 15. Hydrographs of Lake Placid, Lake June in Winter, well 14, and well 51, in Polk County.

sides. Thus, the water surfaces of the lakes are surface expressions of ground water where the water table intersects natural depressions in the land surface. During this investigation, no excessive differences were noted between the altitudes of water levels in the lakes and those in the surrounding wells. Thus, in controlling the level of a given lake consideration must be given to the way in which ground water will affect the effort at control; the situation is more complex than if the lake were (strictly speaking) ponded surface water. For example, in the dry season, ground water moves from Lake Placid to Lake Grassy—as indicated by the water-table gradient. If the water level of Lake Grassy were lowered excessively, the hydraulic gradient between the lakes would be increased, more water would flow underground between Lake Placid and Lake Grassy, and the water level of Lake Placid would probably be lowered.

RELATION OF LAKE LEVELS TO GROUND WATER

PREDICTION OF WATER LEVEL IN LAKE PLACID

One of the primary purposes of this part of the report is to evaluate the fluctuations of the water surface of Lake Placid with reference to ground-water storage and, if possible, to develop a correlation that will serve as an index for controlling the water levels of the lakes by means of a system of drainage canals and control structures. The general plan of the flood-control works is thoroughly covered in a report prepared by the Central and Southern Florida Flood Control District (1953).

Hydrographs of water levels in Lake Placid, Lake June in Winter, well 14, and artesian well 51, in Polk County, are plotted in figure 15. The water level in well 14, approximately two miles southeast of Lake Placid, has been recorded continuously since September 1948. Because of its length, the record from this well is used in developing the water-level relation between Lake Placid and the water table. However, it is believed that the water level of well 440, one mile southwest of Lake June in Winter, will in the future provide a better correlation than that of well 14. In figure 16 the water levels of the two lakes, well 440, and well 14 are compared with the rainfall at the Lake Placid weather station; obviously, well 440 responds more quickly to rainfall at the Lake Placid station than does well 14. The water-level record for well 440 (beginning in February 1956) is not yet long enough, however, for the preparation of ground-water recession curves.

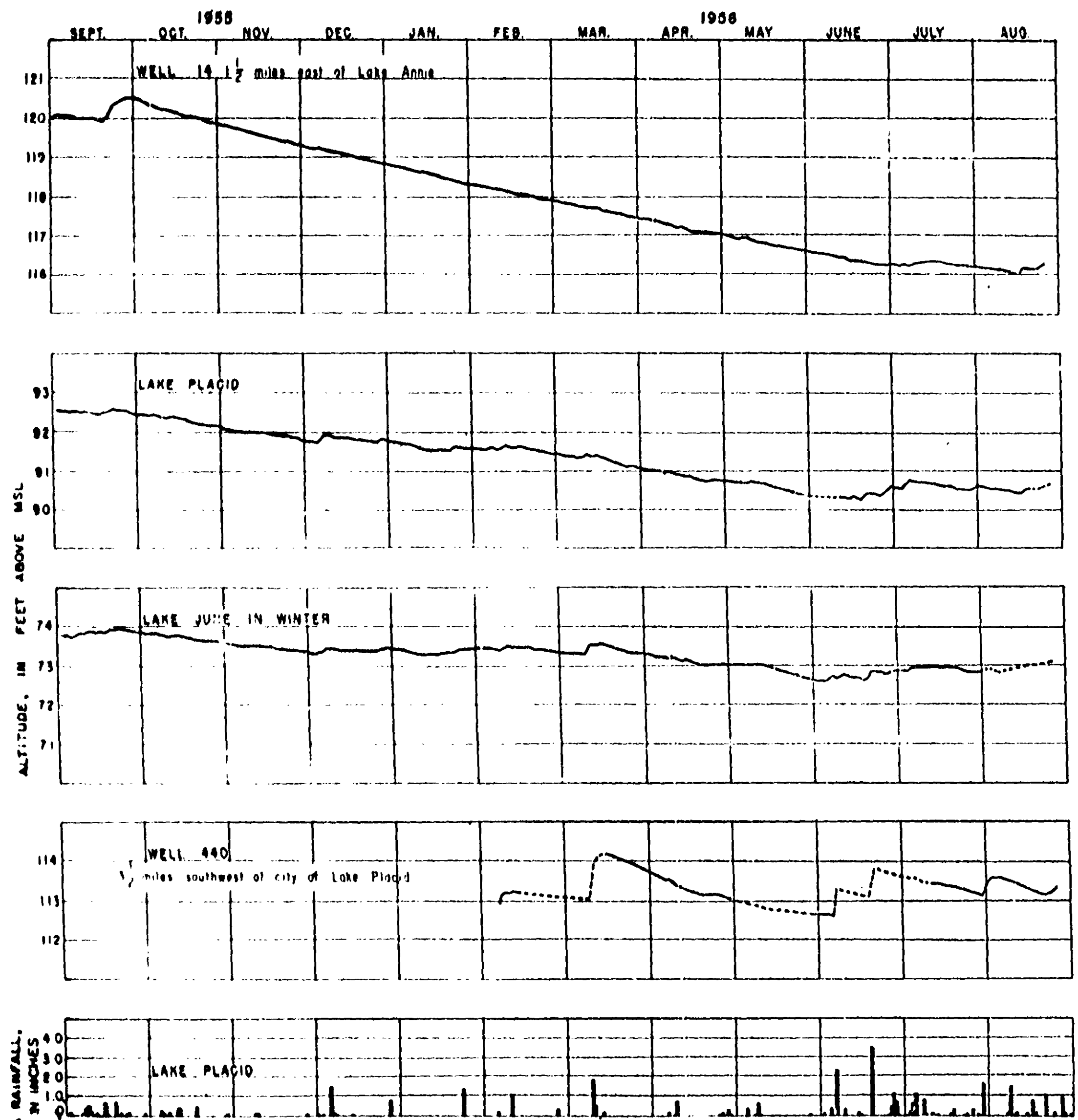

Figure 16. Hydrographs of Lake Placid, Lake June in Winter, well 440, and well 14 compared with rainfall at the Lake Placid weather station, 1955-56.

In general, the recession of the water table follows a logarithmic curve. This recession is interrupted, of course, by periods of recharge, but by plotting the decline of the water table against time—for numerous recessions—an average recession curve is constructed. The composite recession curve for well 14 (fig. 17) was prepared in this manner. A curve of this type allows us to predict, within reasonable limits, the water level of the well at some date in the future. For example, if, after a period of heavy recharge, the water level in well 14 stands at 127.7 feet above mean sea level, the water level one year later, in the absence of rainfall, would be approximately 117.7 feet above mean sea level.

The basic problem that confronts us is to be able to predict the water level of Lake Placid after a given period without rainfall. It is apparent that after a period of recharge the water levels at

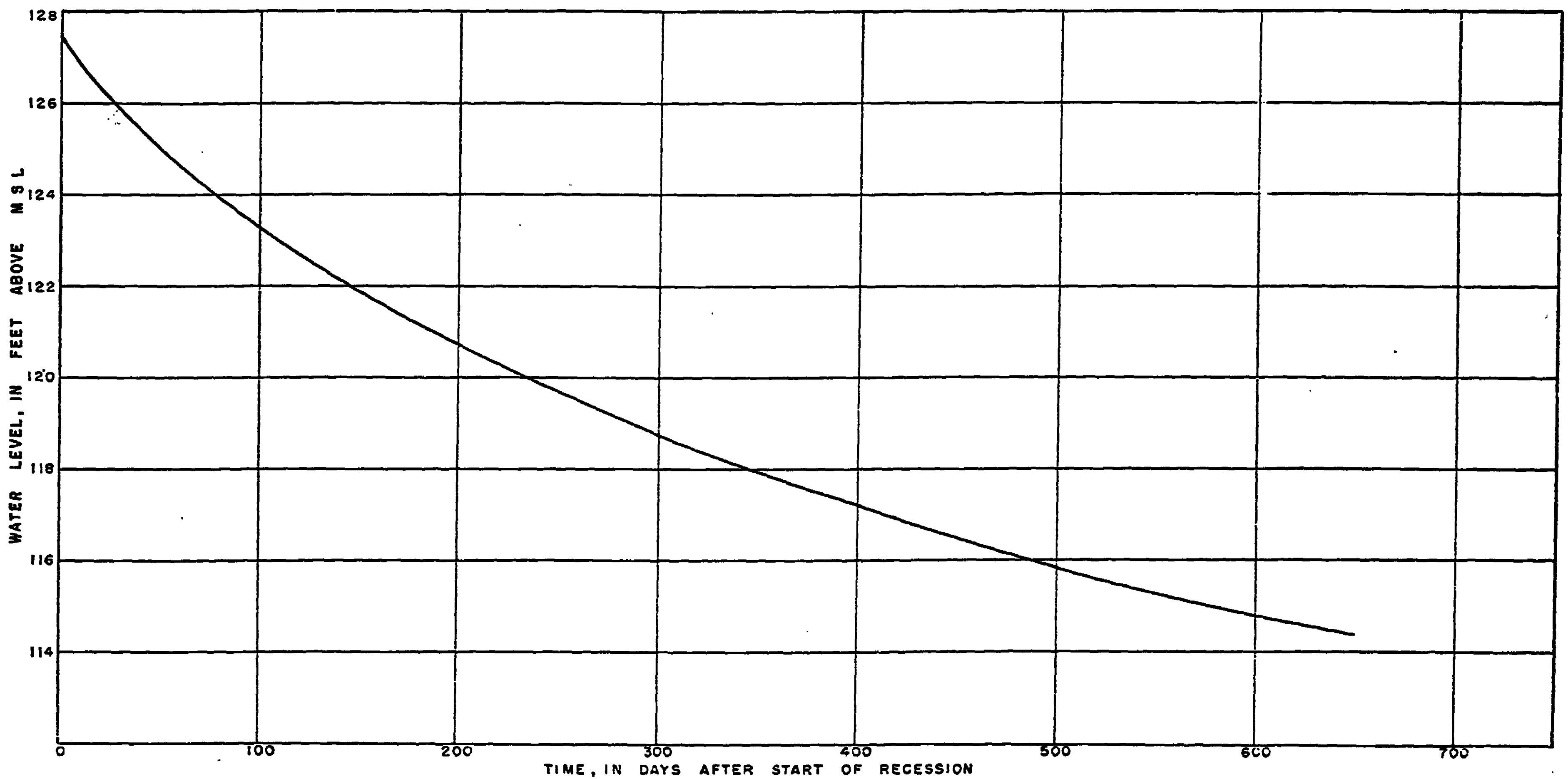

Figure 17. Graph showing recession of the water level in well 14.

two points on the water table cannot be correlated immediately. Uneven distribution of rainfall, nonuniform rates of infiltration to the water table, depth to the water table below the land surface, and many other factors cause the ground-water reservoir to be in a condition of nonequilibrium. After recharge stops, the water table begins to decline at every point, and the rate of decline at each point is directed toward the establishment of a condition of equilibrium. After this equilibrium is established, the water levels continue to decline at consistent rates. A pattern can be developed, by statistical analysis, that allows the prediction of water level at one place in terms of the known rate of decline at another place. It should be appreciated, however, that a significant change in the hydraulic regimen, such as the construction of a drainage canal or an increased rate of percolation to an underlying artesian aquifer would produce a change in the correlation curve.

The relation of the water-level recession curves for Lake Placid and well 14, for several long-term recessions, is shown in figure 18. It is noted that several curved plots of data approach the average curve tangentially. These curved lines represent the nonequilibrium condition and are caused either by unequal distribution of rainfall or by hydrologic conditions (described later) on the west side of the lake. For example, in the recession from October 1948 to June 1949 the water level of Lake Placid was considerably higher, in comparison to the water level of well 14 than would be expected from the average curve, but then it declined at a relatively great rate until the equilibrium condition was established. Further decline followed the average curve.

Prediction of the water level of Lake Placid after an extended period without rainfall is made possible by using figures 17 and 18, conjunctively. To use the graphs it is necessary to know the altitudes of the water levels of both Lake Placid and well 14. To illustrate the use of the graphs, we will assume that shortly after the end of a recharge period, on November 1, the water levels of Lake Placid and well 14 are 95.5 and 126.0 feet above mean sea level. It is anticipated that the dry season will be a long one and that there will be no rainfall until August 1 of the following year. The expected time without recharge is 273 days, and, for the purpose of operating a control structure in the canal between Lake Placid and Lake June in Winter, we need a prediction of the approximate water level of Lake Placid in the latter part of July.

Referring to figure 17, we see that if the head in well 14 is 126.0 feet above sea level at the start of the recession, 273 days

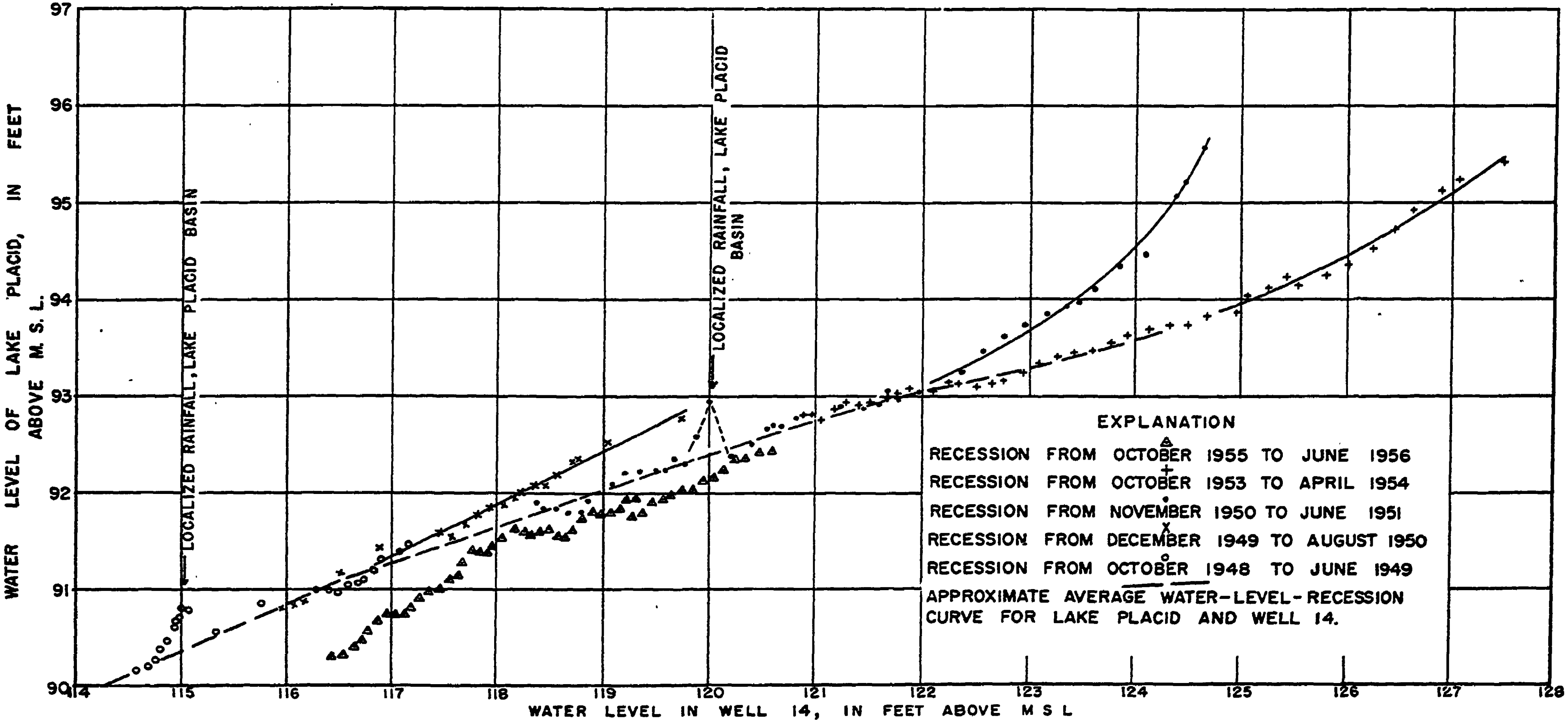

Figure 18. Graph showing the comparative recession of water levels in Lake Placid and well 14.

later (approximately at the 300-day line on the recession graph) it will be about 118.7 feet above. In figure 18, when the head in well 14 is 118.7 feet above mean sea level, the water level of Lake Placid is approximately 92 feet above.

The prediction is based upon the assumption that no recharge occurs at either locality during the recession. Localized rainfall in areas of the Lake Placid basin remote from the area of well 14 causes a short-duration departure that plots above the average recession curve. The lines formed by circles and dots in figure 18 illustrate two examples of this.

It is believed that the entire decline of the water level of Lake Placid can be predicted with reasonable accuracy. Starting at the intersection of the 95.5 and 126.0 lines, representing the heads in Lake Placid and well 14 shortly after the end of the recharge period, the recession would probably form an intermediate curve between those shown for the 1948-49 and the 1953-54 recessions (fig. 18). By relating the heads for Lake Placid and well 14 along the assumed intermediate recession curve to the time required for the equivalent declines of water level in well 14 (fig. 17), the approximate hydrograph for Lake Placid can be estimated.

It is emphasized, however, that a change in the hydrologic regimen will tend to invalidate the recession graphs. It appears that such a change may be responsible for the deviation of the 1955-56 recession from previous recessions (fig. 18). In figure 15, the hydrograph of artesian well 51 is plotted for comparison with the hydrographs of the lakes and well 14. Well 51 is the nearest artesian well to the Lake Placid area for which long-term records of water level are available. It is 490 feet deep and taps the Floridan aquifer at the town of Frostproof, in Polk County, 35 miles north of Lake Placid. The hydrograph for well 51 shows that the water level in the Floridan aquifer is lowered by pumping during the winter and spring months of each year. This period corresponds with the dry season, when there is extensive irrigation. Careful comparison of the points of maximum drawdown in well 51 with the hydrographs for Lake Placid and Lake June in Winter indicates that the water levels of the lakes may respond to pumping from the artesian aquifer. Especially noteworthy are the corresponding drawdowns in May of 1953 and 1954 and May and June of 1955. This correlation cannot be stated without qualification, however, because direct pumping from the lakes might produce a decline of lake levels at the same time that maximum drawdown occurs in the Floridan aquifer, Also, when there is rainfall, the lake level will rise because of recharge and the water level in the artesian aquifer will rise because of the cessation of pumping. No work has been done to separate the various factors that might account for the correlation of drawdown in Lake Placid, Lake June in Winter, and Mirror Lake (hydrograph not shown) with that in the Floridan aquifer. However, the writers think that the correlation might not be fortuitous because of the manner in which the recession curve (fig. 18) for 1955-56 deviates from the recession curves for previous years. Water-level fluctuations in well 51 indicate that pumping from the Floridan aquifer increases each year. The extensive drawdown of water level in the Floridan aquifer in 1955 and 1956 is thought to have increased downward leakage from the lakes and caused the deviation of the recession curve in these years (fig. 18). If pumping from the Floridan aquifer is increasing in the manner indicated by the hydrographs, a new recession pattern may be developing, and average recessions of previous years may be of little value in predicting the dry-weather water levels of Lake Placid.

CONSERVATION OF WATER IN LAKE PLACID

In 1956 no control structure existed in the canal between Lake Placid and Lake June in Winter, but during low stages a sandbar at the edge of Lake Placid blocks the flow of surface water from the lake. During high stages, water flowing over the sandbar erodes it, and the deepened channel lowers the lake below the stage at (or above) which flood damage occurs. If this happens at the close of a rainy season, water normally conserved for the coming dry season is wasted. The relation between the water levels of Lake Placid and well 14 indicates that, after all surface discharge from the lake ceases, the water level of Lake Placid continues to decline because of ground-water discharge. However, if surface-water discharge through the canal could be stopped as soon as the lake declined to the "damage level," further loss of water from the lake by surface flow would be slowed down and the lake could be maintained at a relatively high level during the subsequent recession. Thus, the slope of the average recession curve in figure 18 probably would not change, but the position of the curve might be shifted slightly upward by converting the loss of water from the surface-water to the ground-water phase as soon as the lake level is low enough that flood damage becomes negligible.

The flow through the culvert connecting Lake Placid and Mirror Lake is almost continuously four to six cfs (Central and Southern

Florida Flood Control District, 1953, p. 3-4), except at very low lake stages. The water-table contour maps (figs. 13, 14) show that not all discharge from Lake Placid would be stopped by discontinuing the flow through the culvert, as ground-water flow would continue through the narrow strip of land separating the lakes. A reduction in discharge would occur, however, because of the conversion from surface flow to ground-water percolation, and the level of Lake Placid would decline more slowly during the dry season than it would if the culvert continued to discharge water from that lake.

Mirror Lake has no surface outlet; hence, the present flow from Lake Placid reduces the head difference between the lakes and, in effect, by tending to raise the level of Mirror Lake, increases the ground-water gradient and discharge northwest of Mirror Lake. Closing the Placid-Mirror outlet would probably cause a readjustment of ground-water contours to form a more uniform gradient. The head differential between the lakes would be increased, Lake Placid would rise, and the underground outflow from that lake would increase. This might tend to offset the effect on Mirror Lake and the water table immediately to the northwest of the lake; thus control of the culvert may cause no substantial lowering of the water level of Mirror Lake. The water level of Lake Placid, however, could be maintained at a higher level, during dry periods, than is possible without control of the Placid-Mirror outlet.

FACTORS AFFECTING THE RISE OF WATER LEVEL IN LAKE PLACID

Lack of uniformity in the rise of water levels in lakes of the ridge section is noted in the flood-control report prepared by the Central and Southern Florida Flood Control District (1953, p. 5). Comparison of the magnitudes of flood-producing storms with their effects on the lake levels indicates that antecedent rainfall is almost as important in causing a flood as is the storm itself. In the case of Lake Placid, antecedent rainfall in the area to the west and south of the lake is believed to have the greatest influence on the rise in lake level.

The correlation between the water levels of well 14 and Lake Placid on a rising stage is poor. Rainfall of 10 inches at the Lake Placid station on June 6, 1953, produced rise in water level of about two feet in well 14 and a rise of about 1.4 feet in Lake Placid (fig. 19). Subsequent rains caused Lake Placid to rise to flood proportions toward the end of June, whereas the water level of well 14 remained considerably below its later peak. A moderate rain on August 27 produced a much greater rise in the well than in the lake. The above inconsistencies are considered to be evidence of unequal distribution of rainfall.

With equal recharge, the rise of water level in a well always should be considerably greater than the rise in a surface-water body. Because the volume of voids in an aquifer is only a fraction —for example, 20 percent—of the total volume of the aquifer, equal recharge would cause the ground-water level to rise more—in this example, five times as much—than the surface-water level. Factors such as evapotranspiration and absorption of water by clay particles as the water percolates through unsaturated sediments reduce the water that eventually reaches the water table to an amount less than the rainfall. Regardless of the cause, the fact remains that well 14 cannot be used as an index for predicting an imminent flood in the Lake Placid basin.

Well 440, on the high terrace west of Lake June in Winter, will in the future give a better correlation with Lake Placid than does well 14. It may be that climatic factors affect both Lake Placid and well 440 to the same degree, but the correlation can probably be attributed to the fact that well 440 reflects hydrologic conditions in the highland areas west and south of the lake which are of singular importance in producing flood conditions.

Figure 20 is a map giving the depth to water in the Lake Placid area. The depth to water is generalized and approximate because of the relatively high topographic relief in the area. The map was prepared by superimposing water-table contours over land-surface contours. The difference in altitude between the contours gives the depth to the water table below land surface or, in other words, the thickness of unsaturated material. The amount of recharge that can be accepted by the ground-water reservoir depends on the thickness of unsaturated material, because as soon as the water table rises to the surface of the ground, no further water will be stored. Any additional rainfall is rejected, and the water flows downhill over the surface.

Inspection of the depth-to-water map shows that the water table in large areas of the upland terrace west of Lake Placid is shallower than five feet. The potential ground-water storage capacity in this area is small, because the map represents conditions existing in May 1956, at the height of the dry season. This small ground-water storage capacity is believed to account for the non-uniformity in the rise of water level in Lake Placid. Much of the

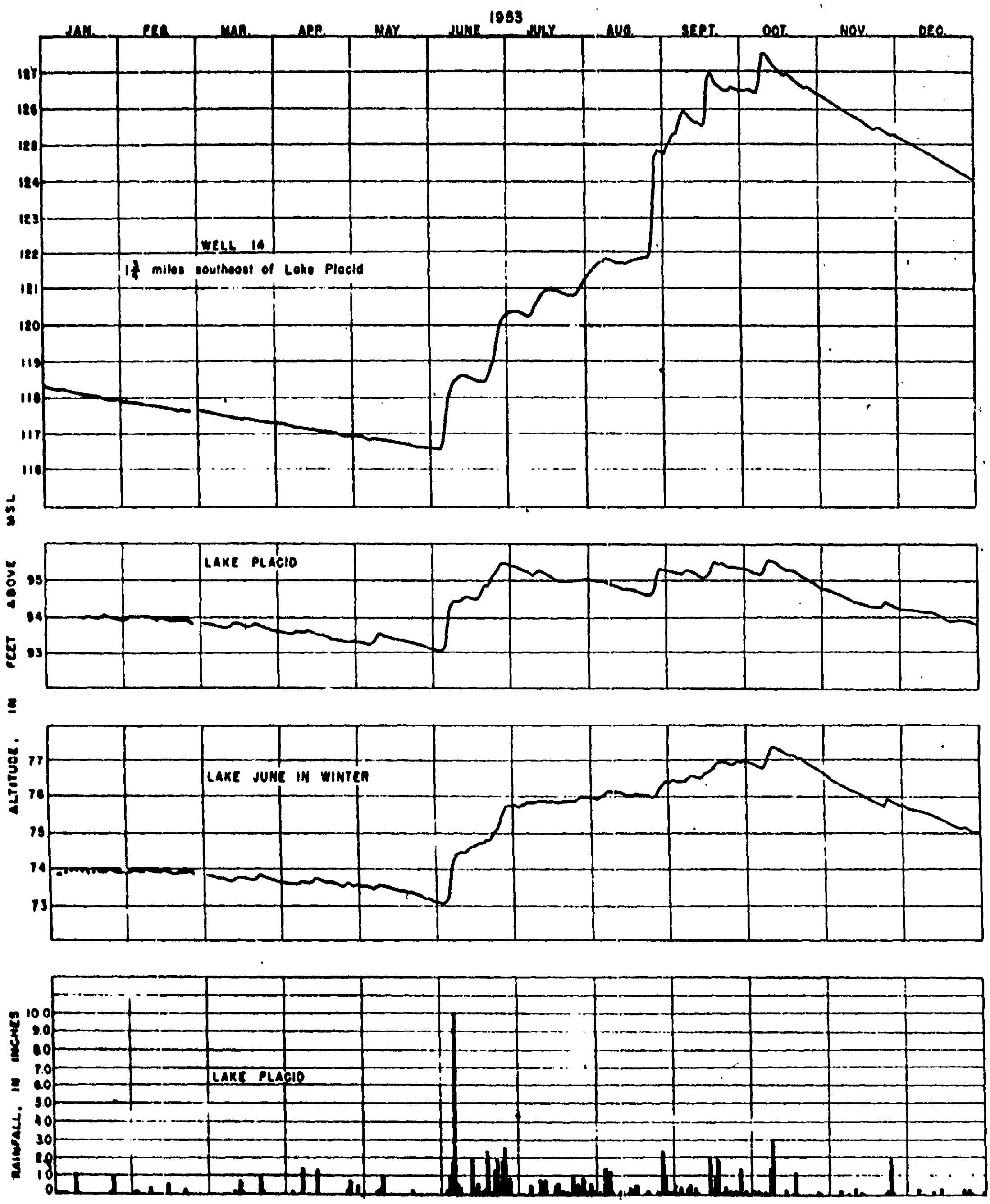

Figure 19. Hydrographs of Lake Placid, Lake June in Winter, and well 14 compared with rainfall at the Lake Placid weather station, 1953.

rainfall from a single heavy storm, occurring under dry conditions shown, would be absorbed, and little would be rejected. However, a number of small rains preceding a heavy storm would cause a decrease in gound-water storage capacity, and when the heavy storm struck most of the rainfall would be rejected as recharge. This rejected recharge would then move downhill, as channelized or sheet flow, to produce maximum stages in Lake Placid.

Conditions in the area south and east of Lake Grassy are similar to those in the area west and south of Lake Placid. However, the pattern of surface runoff in the sand-dune terrane south and

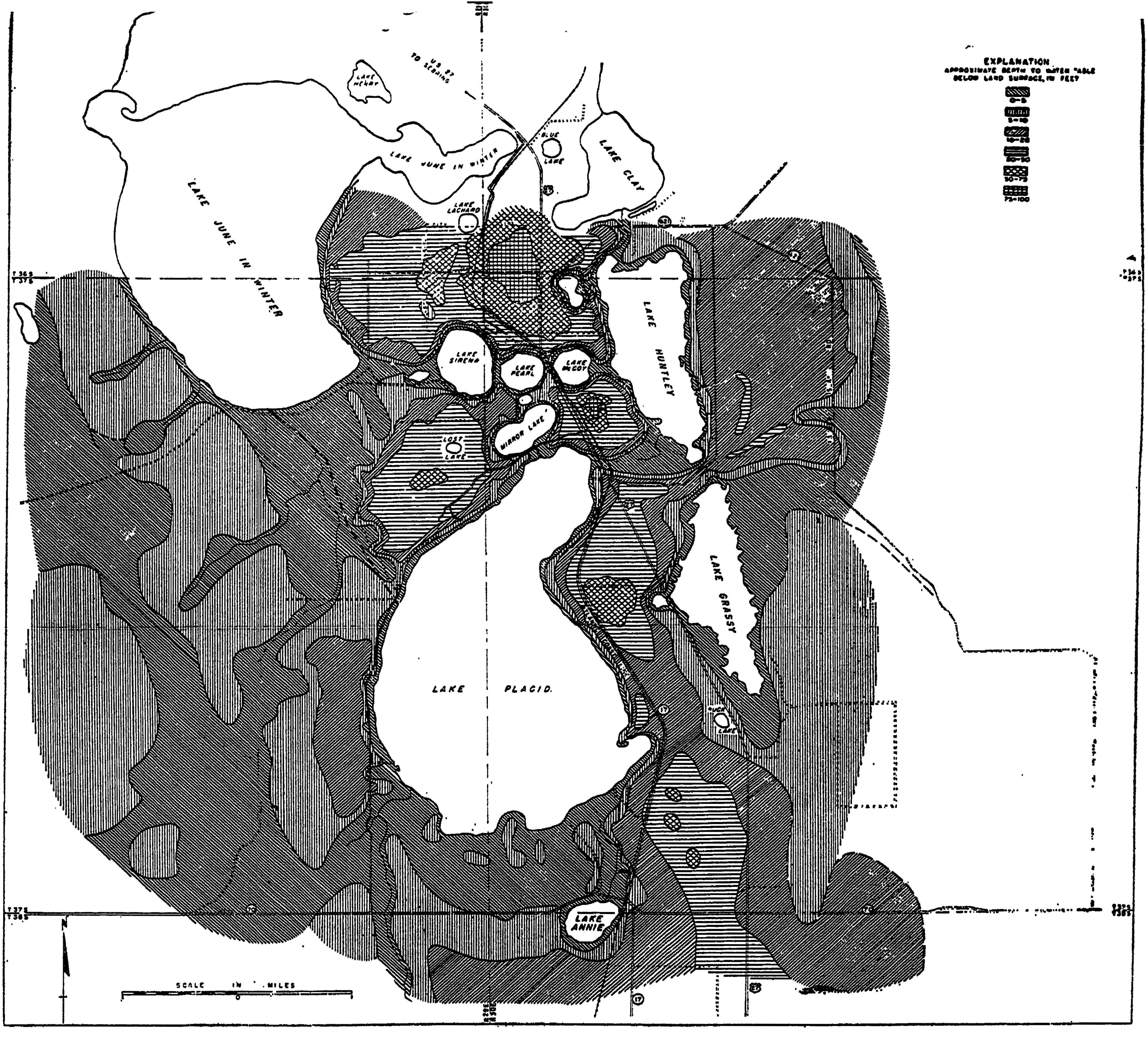

Figure 20. Map of the Lake Placid area showing approximate depth to the water table below land surface.

east of Lake Grassy is not as clearly defined as in the area near Lake Placid. Ponds are formed in the depressions between sand dunes when the water table rises to the land surface. Most of these ponds remain unconnected until, during wet years, the water rises high enough to form a continuous sheet of water across the divides between depressions. Excess water then flows out of the dune area into the Lake Grassy basin. Under extreme flood conditions, the water, blocked by a ridge at the north end of Lake Grassy, flows eastward across a low divide and down to the Lake Istokpoga flat.

Obviously, the key to predicting an imminent flood in the Lake Placid and Lake Grassy basins lies in the ground-water storage characteristics of the areas discussed. When a sufficiently long water-level record is available for well 440, criteria can probably be established for predicting flood conditions in both Lake June in Winter and Lake Placid. However, judging from the depth-to-water map, a well equipped with a recording gage, located south or southeast of Lake Placid along State Highway 70, would provide the best indication of the potential ground-water storage capacity, and thus would better forewarn of potential flooding of Lake Placid. A recorder well located in the area of shallow water table south of Lake Grassy would provide good information on ground-water storage capacity there. The water table at well 14 ranges from 10 to 20 feet in depth; thus, well 14 does not quickly reflect conditions that contribute to rejected recharge and help to flood Lake Grassy.

HYDROLOGY

The lakes of the ridge section cannot be considered simply as isolated ponds of surface water. Their bottoms consist mostly of sand, and the water of the lakes has direct hydraulic connection with the water in the ground-water reservoir. Obviously, controlling the lake level by a drainage canal will also effect a control on the ground-water reservoir. Conversely, the ground-water reservoir influences the manner in which the level of a lake is controlled.

The purpose of the following discussion is to provide quantitative estimates of the movement of ground water in various parts of the area, so that the canals and control structures in the system of lakes may be designed with an insight into the ground-water problems involved.

The materials penetrated during the installation of the observation wells consist predominantly of sand. In some areas the sand is slightly consolidated by iron compounds or organic material to form hardpan. Except for wells 442 and 443, all wells screened in materials above and below a hardpan indicated that the hardpan did not act effectively as a confining layer. Therefore, it is believed that the nonartesian aquifer includes all the sand from land surface to a depth of approximately 100 feet below mean sea level in the ridge section (fig. 11). The bottoms of the upper chain of lakes have an average altitude of approximately 35 feet above mean sea level (Central and Southern Florida Flood Control District, 1953, table 1, p. 2). Actually, this depth is not the base for ground-water flow, but it is believed that most of the horizontal ground-water flow affecting the water levels of the lakes passes through the water-bearing section extending from the water table to the bottoms of the lakes. Because of this assumption, the discharges indicated by the following computations are minimum values.

The permeability of the materials penetrated during installation of the observation wells was determined by the permeameter method, in the laboratory (table 1). The average permeability of all samples, excluding those from well 440 which contained driller's mud, is about 700 gpd per square foot. Because the intention here is to provide only a general idea of the magnitude of ground-water flow under the existing gradients in different parts of the area, this average permeability is used in all computations. Comparison of the permeability at each locality (table 1) with the average permeability for the entire area is left to the discretion of the reader.

TABLE 1. Permeability of Sediments Penetrated by Observation Wells

Well No.	Depth (feet) From	To	Permeability (P)
T-1	1	17	790
	17	22	1,000
T-2	1	2	640
	4	5	700
	8	9	540
	16	16.5	610
T-3	0	2	590
	5	6	560
	11	13	650
T-4	1	1.5	800
	3	3.5	940
	5	6	900
T-5	1	1.5	600

TABLE 1. (Continued)

Well No.	Depth (feet) From	To	Permeability (P)
	4	4.5	540
T-6	3	4	490
440	0	12	[1]120
	12	21	[1]31
442	2	7	1,300
	7	14	420
443	16	21	520
444	7	13	700
448	0	5	830
	5	17	610
	18	20	520
449	10	12	750
	15	16	700
	17	17.5	570
450	12	13	710
	15	16	500
456	0	1	690
	3	5	570
	15	18	750
462	10	12	910
	13	15	750
	18.5	19	840
471	12	13	580
472	1	5	650
	15	20	560
474	0	5	710
	5	7	820
	7	12	860
	15	16	670
	16.5	19	810
475	3	4	1,000
479	2	3	[2]190
	5	6	840
	10	17	760
481	2	3	820
	15	16	550
489	10	12	840
	11	17	600
491	3	3.5	510
	4.6	5	530
492	1	2	740
493	2.5	3	870

[1]Permeability greatly reduced by bentonitic drilling mud in sample.
[2]Organic hardpan.

The water-table gradients west and south of Lake Placid are steep, and, as it is of interest to determine the amount of ground water flowing into Lake Placid from these directions, we will compute the flow through a section of the aquifer one mile long, measured along the 100-foot water-table contour west of Lake Placid. The thickness of the flow section is the distance from the water table (+100 feet, msl) to the bottom of the lakes (+35 feet, msl), or 65 feet. The average distance between the 110- and the 100-foot contour lines is approximately 1,000 feet; therefore, the gradient in feet per foot is 10/1,000. Substituting in the Darcy formula:

$$Q = PIA$$
$$Q = 700 \times 10/1{,}000 \times 65 \times 5{,}280$$
$$Q = 2{,}400{,}000 \text{ gpd per mile or } 3.7 \text{ cfs per mile}$$

If the quantity of ground water flowing into Lake Placid through a strip of the aquifer one mile in length, 3.7 cfs, is multiplied by four (the number of miles over which there are steep gradients around the west and south sides of Lake Placid), the total ground-water flow into Lake Placid is found to be 15 cfs. Of this amount, a small quantity flows through the culvert to Mirror Lake, but part of this water returns to the aquifer on the down-gradient side of Mirror Lake. The ground-water flow leaving the combined lakes can be calculated as follows: The average gradient for a mile length of the aquifer along the 85-foot contour in the vicinity of Lost Lake is 5/2,500. The thickness of the flow section is the difference between the water table (+85 feet, msl), and the lake bottoms (+35 feet, msl), or 50 feet. Substituting in the Darcy formula:

$$Q = PIA$$
$$Q = 700 \times 5/2{,}500 \times 50 \times 5{,}280$$
$$Q = 370{,}000 \text{ gpd per mile or } 0.57 \text{ cfs per mile}$$

When 0.57 cfs is multiplied by five, the number of miles around the northwest, north, and east sides of Lake Placid where discharge is taking place, a total discharge of only 2.8 cfs results.

Obviously, when 15 cfs of water flows into a lake and 2.8 cfs flows out, a large quantity of water either is being stored in the lake or is being lost from the lake. The suggestion that water is being stored in the lake is not valid, of course, because the stage of the lake is not continuously rising. The discrepancy between ground-water inflow to and outflow from Lake Placid must be attributed to losses from evapotranspiration, pumping of lake water for crops, and downward seepage of water to the Floridan aquifer.

A similar situation exists at Lake Grassy. The length of the flow section between the two noses in the 95-foot contour line, east and west of the south side of Lake Grassy, is approximately 7,000 feet. The gradient is approximately 5/1,500, and the thickness of the flow section is about 60 feet. Substituting in the Darcy formula:

$$Q = PIA$$
$$Q = 700 \times 5/1{,}500 \times 60 \times 7{,}000$$
$$Q = 980{,}000 \text{ gpd or } 1.5 \text{ cfs}$$

Thus, the ground-water inflow to Lake Grassy amounts to about 1.5 cfs.

The water-table contours at the north end of Lake Grassy indicate that most of the discharge from the lake moves to Lake Huntley through a flow section approximately 1,500 feet wide. The thickness of the flow section is approximately 55 feet. The water-level difference between the lakes is 7.3 feet and this amount of head is lost in the 1,200-foot distance separating the lakes. Using the Darcy formula:

$$Q = PIA$$
$$Q = 700 \times 7.3/1{,}200 \times 55 \times 1{,}500$$
$$Q = 350{,}000 \text{ gpd or } 0.54 \text{ cfs}$$

Comparison of the calculated inflow to and outflow from Lake Grassy indicates that approximately one cfs more water flows into the lake than flows out of it. The loss of this water is not difficult to explain. Irrigation water pumped from Buck Lake during the dry season amounts to about 1,200 gpm, and water pumped from the arm of Lake Grassy on the west side of U. S. Highway 27 amounts to about 3,500 gpm. The total withdrawal from the pumping stations is approximately 10.4 cfs, an amount much greater than the rate of ground-water inflow to the area. Under these conditions, there is a decline of water level in Lake Grassy and a loss in ground-water storage within the area. Of course, some of the water returns to the ground-water reservoir by seepage from the irrigated groves.

The above computations indicate that there is some need for the conservation of water. Obviously, very little can be done to reduce the loss of water during the dry season because evapotranspiration, natural ground-water discharge, and irrigation of crops cannot be completely stopped. However, by proper control of the outlets from the various lakes, much of the water now unnecessarily wasted—after flood damage ceases at the end of the rainy season—can be conserved for use during the following dry season. Water conservation, in the form of closing surface-water outlets from the lakes, should begin as soon as danger from flooding can be reasonably assumed to be past.

Under the present, natural conditions, the sandy materials separating Lake Grassy and Lake Huntley have sufficiently low permeability to hold the water level of Lake Grassy approximately seven feet above that of Lake Huntley. The proposed construction of a culvert from Lake Grassy to Lake Huntley necessitates the removal of the sand overburden, installation of the culvert, and backfilling of the excavated hole. A certain amount of danger exists in the operation because the natural orientation of materials below the present water table would be disturbed, and the permeability of this section might be increased. If this should occur, the ground-water discharge through the disturbed part of the aquifer would be increased, and it might be impossible to maintain the present head differential between the lakes.

Let us consider the change in hydrologic conditions in the strip of land separating Lake Grassy and Lake Placid as a result of an inadvertent lowering of water level in Lake Grassy. The water-table contour maps (figs. 13, 14) show that a hydraulic gradient exists between the two lakes. This is a somewhat oversimplified picture, because the eastward bulge of the 90-foot contour suggests that a small ground-water mound may be present in the area north of the center line of Lake Grassy and south of the junction of State Highway 17 and U. S. Highway 27. This mound is probably reduced to negligible proportions during the dry season, and ground water moves from Lake Placid to Lake Grassy.

The above discussion shows that, although a hydraulic gradient may exist between the two lakes during the dry season, the gradient is quite small; therefore, the discharge of water from Lake Placid to Lake Grassy is negligible under these conditions. The assumption is made that after construction of the culvert between Lake Grassy and Lake Huntley the discharge from the former will be increased and the relative head difference between the lakes will decrease by three feet. This will produce a 3-foot increase in the head difference between Lake Placid and Lake Grassy, and an increased amount of ground water will flow through the strip of land separating the lakes. The flow section between the lakes has a north-south width of about two miles and a thickness of about 55 feet. The average distance between the lakes is 4,000 feet and the new head differential is dissipated over that distance. The increased discharge between the lakes may be calculated as follows:

$$Q = PIA$$
$$Q = 700 \times 3/4{,}000 \times 55 \times 2(5{,}280)$$
$$Q = 300{,}000 \text{ gpd or } 0.47 \text{ cfs}$$

Under the assumed circumstances, an additional 0.47 cfs of water will be discharged from Lake Placid to Lake Grassy. This additional discharge will be much greater, of course, than the negligible discharge under present conditions; but considering the steep water-table gradients and large discharge entering Lake Placid from the west and south, the chance that the additional discharge will affect the water level of Lake Placid seems remote.

DOWNWARD LEAKAGE FROM LAKE PLACID TO THE FLORIDAN AQUIFER

Previously, comparison of the hydrograph of artesian well 51 with the hydrographs of Lake Placid and Lake June in Winter (fig. 15) indicated that the hydraulic connection through the sand-filled sinkholes was sufficiently good to show a correlation between lake level and drawdown in the artesian aquifer. Of course, other factors such as rainfall, evaporation, ground-water inflow and outflow, and surface-water inflow and outflow affect the altitude of the lake surface at any given time. Although the basic data were incomplete, it was believed that some indication of the magnitude of downward leakage could be obtained by balancing the various known quantities of inflow to and outflow from the lake against the observed change in storage in the lake. If the equation were consistently unbalanced by a certain amount, this amount might represent the downward leakage to the underlying artesian aquifer. An inflow-outflow equation was set up for Lake Placid which would allow insertion of the various known (or estimated) quantities of inflow and outflow, as follows:

Downward leakage = Rainfall − evaporation + (ground-water inflow − ground-water outflow) + (surface-water inflow − surface-water outflow) − (change in storage)

The equation was formulated so that the algebraic sums of the quantities at the right side of the equation were positive, if the leakage was downward, and negative, if the leakage was upward.

Rain falls directly on the lake and produces an increase in storage; rainfall, therefore, is always a positive value (table 2). Evaporation subtracts water from the lake and is therefore always negative. A pan coefficient of 0.7 is applied to correct the pan

TABLE 2. Downward Leakage from Lake Placid to the Floridan Aquifer
(All values in inches. E, estimated)

Year	Month	Rain-fall (+)	Evapo-ration (−)	Net ground-water inflow (+)	Net surface-water outflow (−)	Change in lake stage	Down-ward leakage
1955	Jan.	3.10	2.39	2.58	3.0	−0.60	+0.89
	Feb.	1.67	2.51	2.58	2.4	−2.04	+1.38
	Mar.	.78	3.71E	2.52	1.8	−3.60	+1.39
	Apr.	.97	4.34E	2.50	1.2	−3.60	+1.53
	May	4.50	6.14	2.49	1.0	− .60	+ .45
	June	9.20	5.08	2.51	1.1	+4.20	+1.33
	July	4.85	4.55E	2.53	1.4	+1.20	+ .23
	Aug.	6.76	3.92E	2.55	1.8	− .60	+4.19
	Sept.	3.18	4.42E	2.54	1.4	−1.50	+1.40
	Oct.	1.48	3.71E	2.59	1.2	−4.10	+3.26
	Nov	.24	2.42E	2.56	1.0	−3.60	+2.98
	Dec.	2.37	1.80E	2.52	.9	+ .40	+1.79
1956	Jan.	1.37	2.09	2.49	.7	−2.20	+3.27
	Feb.	1.40	2.86	2.44	.7	−1.80	+2.08
	Mar.	2.39	4.28	2.44	.5	−4.30	+4.35
	Apr.	1.34	4.33	2.42	.3	−3.50	+2.63
	May	1.03	5.18	2.41	.2	−4.30	+2.36
	June	9.19	4.30	2.41	.1	+2.60	+4.60
	July	5.69	4.75	2.36	.2	+ .80	+2.30

evaporation to lake evaporation (Linsley, Kohler, and Paulhus, 1949, p. 163). The climatological data were obtained from records of the U. S. Weather Bureau for the Lake Placid station. The evaporation data are complete except for several months in 1955. The missing data were estimated by use of a rating curve established for the Lake Placid and Moore Haven weather stations.

The flow of ground water changes with changes in the gradient of the water table. In order to estimate the different quantities of ground-water inflow and outflow, the average monthly water levels of Lake Placid were compared with those of well 14 (for inflow) and Lake June in Winter (for outflow). The percentage difference in gradient between well 14 and Lake Placid, as compared to the gradient of March 1956 (used as the base gradient for the discharge computations), allowed adjustment of the ground-water inflow for the months for which water-table contour maps were not available. Similarly, the percentage difference in gradient, as indicated by comparison of the average monthly water levels of Lake Placid and Lake June in Winter (fig. 15), permitted the adjustment of ground-water discharge from Lake Placid. The adjusted differences between inflow and outflow were then calculated to determine the rise (in inches) of Lake Placid caused by ground-water flow for all months (table 2).

On the basis of stage and discharge graphs for Lake Placid for the years 1948 through 1951 (Central and Southern Florida Flood Control District, 1953, pl. 5-7), a surface-water-outflow rating curve was constructed for Lake Placid. The average monthly water levels of Lake Placid were then used to estimate the discharge from Lake Placid; the outflow of surface water, of course, lowered the lake level and was therefore a negative value in the equation. Unfortunately, no data were available for surface inflow to Lake Placid, and the net effect of surface-water flow upon the level of the lake could not be determined. However, at stages of Lake Placid below about 93 feet above mean sea level, there was very little surface inflow, and at stages below 92 feet, practically none. The accuracy in determining the downward leakage, therefore, was greatest at the lowest stages of the water table, when the unknown surface inflow was negligible.

The change in stage of Lake Placid for each month was determined directly from the hydrograph (first and last days of month, fig. 15), and converted to inches of rise (+) or fall (—). The plus or minus values were subtracted algebraically from the total change in stage attributable to the other agencies in the inflow-outflow equation. Thus, if all influences upon the lake level in a given month were known perfectly and if there were no downward leakage, the elements at the right side of the equation would balance out to zero. However, a positive summation would indicate downward leakage to the Floridan aquifer and a negative summation would indicate upward leakage (obviously impossible because the piezometric surface is about 30 feet below lake level).

The final summations are shown in the downward-leakage line of table 2. Surface-water inflow could not be included in the equation because no data were available. At low stages of the water table, surface-water discharge from Lake Annie (fig. 13) does not reach Lake Placid as channelized flow; rather, it disappears by infiltration into the aquifer and by evapotranspiration. The authors noted very little other surface-water inflow during late 1955 and 1956. Thus, the error produced by the omission of surface-water inflow in the downward-leakage figures is believed to be negligible.

Because the evaporation data for the last part of 1955 are estimated, consideration of the possible sources of error will be given to only the 1956 computations. Comparison of the rises in stage of Lake Placid with the recorded rainfall at the Lake Placid weather station (fig. 16) shows good correlation and indicates that the rainfall data are representative of the entire lake. The evaporation data, using a 0.7 pan coefficient, should be nearly correct. Surface-water outflow was very small in 1956 and surface-water inflow can be considered negligible. The change-in-stage measurements are quite accurate, as they are taken from the automatic recording gage on Lake Placid; therefore, all these elements of the equation should be essentially correct.

It appears that the major sources of error in the downward-leakage figure are in the calculation of horizontal ground-water movement and pumpage from the lake. Pumping from the lake is not continuous, of course, and the error from this unaccounted-for loss of water can be minimized by averaging the downward leakage over a period of months. If the permeability as determined from the permeameter method is in error by 100 percent, compared with the field permeability, the following table gives the range of validity of the final leakage figure for the months January to July 1956:

	Average downward leakage (inches over lake surface)	Average ground-water inflow (inches over lake surface)
As determined	3.1	2.4
Permeability doubled	5.5	4.8
Permeability halved	1.9	1.2

According to the table, the average monthly downward leakage beneath Lake Placid in January-July 1956 may have ranged from 1.9 to 5.5 inches; the true value, of course, might be either higher or lower than this range, but it seems rather doubtful that it is. Because direct pumpage from the lake is not taken into consideration, however, the average leakage figure is high; therefore, it is estimated that downward leakage from the lake is less than three but probably not less than two inches per month.

This is equivalent to a rate of recharge to the Floridan aquifer of 6,400,000 gpd (10 cfs) to 9,500,000 gpd (15 cfs).

CONCLUSIONS

Ground water in the thick deposits of sand underlying the Lake Placid area is unconfined and is therefore under nonartesian conditions. The water surfaces of the lakes are visible expressions of the water table where it intersects the land surface.

Fluctuations of water level in Lake Placid and well 14 correlate reasonably well during a recession of the water table, and statistical analysis of the average rates of decline at the two locations permits approximate prediction of the water level of Lake Placid after an extended period without rainfall. However, the hydrograph of well 51, in Polk County, seems to be responding to the effects of a progressive increase of pumping from the Floridan aquifer. Because lowering of head in the artesian system increases the loss of water from Lake Placid by increasing the gradient of downward leakage, it is possible that average recessions before 1956 will be of little value in predicting the dry-weather water levels of Lake Placid in the future.

In a rising stage, the relation between water levels in Lake Placid and well 14 cannot be used to forewarn of imminent flooding to the Lake Placid basin. A map showing the approximate depth to the water table below the land surface indicates that the potential ground-water storage capacity in large areas west and south of Lake Placid is small. As soon as the water table in these areas rises to the surface of the ground, all further recharge to the aquifer is rejected, and the excess water moves rapidly downhill to flood the Lake Placid basin. It is believed that imminent flood danger to Lake Placid can best be ascertained by means of a recording gage on a well located along State Highway 70 south or southeast of the lake. In this manner, current data reflecting the available ground-water storage capacity of the aquifer can be used as supplemental criteria for operation of a control structure in the canal between Lake Placid and Lake June in Winter.

Conservation of water is an important reason for maintaining the water levels of the lakes at desirable altitudes. After all surface-water discharge from a lake is stopped, the water level of the lake continues to decline because of ground-water discharge, evapotranspiration, and pumping. Conservation of water, by converting surface flow to much slower ground-water flow as soon as possible after flood danger passes, will help to maintain the water level of the lake at relatively high altitudes during the ensuing dry season.

Calculations based upon assumed sets of circumstances give some idea of the relative magnitudes of ground-water discharge in various parts of the area. These calculations indicate that ground-water movement is a factor to be considered in designing the drainage system for the lakes. The rates of ground-water discharge are believed not to be of sufficient magnitude, however, to hinder seriously the successful control of lake levels.

Using an inflow-outflow equation for Lake Placid, measured or estimated values for rainfall, evaporation, net shallow ground-water inflow, and net surface-water outflow were balanced against the change in stage of Lake Placid. The result indicates that downward leakage to the Floridan aquifer from Lake Placid averaged two to three inches per month during the first half of 1956.

REFERENCES

Anonymous

1953 *Flood control and water supply studies for Lake Placid, Lake June in Winter, Lake Frances, all in Highlands County, Florida:* Central and Southern Florida Flood Control District, West Palm Beach, Florida.

Bishop, E. W.

1956 *Geology and ground-water resources of Highlands County, Florida:* Florida Geol. Survey Rept. Inv. 15.

Cooke, C. Wythe (see also Parker, 1944)

1939 *Scenery of Florida interpreted by a geologist:* Florida Geol. Survey Bull. 17.

1945 *Geology of Florida:* Florida Geol. Survey Bull. 29.

Davis, John H., Jr.

1943 *The natural features of southern Florida, especially the vegetation and the Everglades:* Florida Geol. Survey Bull. 25.

Ferguson, G. E. (see Parker, 1955)

Kohler, Max A. (see Linsley)

Linsley, Ray K., Jr.

1949 (and Kohler, Max A., and Paulhus, Joseph L. H.) *Applied hydrology:* New York, McGraw-Hill Book Company.

Love, S. K. (see Parker, 1955)

MacNeil, F. Stearns

1949 *Pleistocene shorelines in Florida and Georgia:* U.S. Geol. Survey Prof. Paper 221-F.

Parker, G. G.

1944 (and Cooke, C. Wythe) *Lake Cenozoic geology of southern Florida, with a discussion of the ground water:* Florida Geol. Survey Bull. 27.

1955 (and Ferguson, G. E., Love, S. K., and others) *Water resources of southeastern Florida, with special reference to the geology and ground water of the Miami area:* U.S. Geol. Survey Water-Supply Paper 1255.

Paulhus, Joseph L. H. (see Linsley)

Stringfield, V. T.

1936 *Artesian water in the Florida Peninsula:* U.S. Geol. Survey Water-Supply Paper 773-C.

TABLE 3. Water-Level Measurements in Observation Wells

Well	Date	Water level below measuring point, in feet[1]
14	11-22-55	19.85
	12-15-55	20.21
	1-25-56	20.84
	3-13-56	21.56
	5-29-56	22.66
	7-10-56	23.00
273	9-22-52	+12.6
	1-19-56	+14.1
274	9-18-52	+17.0
275	9-23-52	+12.8
276	9.23-52	+16.6
	1-19-56	+15.5
283	9-29-52	+ 4.8
302	11-22-55	11.0
	12-15-55	11.02
	1-25-56	11.38
	3-13-56	11.88
	5-29-56	13.43
	7-10-56	13.34
309	11-22-55	25.09
	12-15-55	25.17
	1-25-56	25.21
	3-13-56	25.53
	5-29-56	26.47
	7-10-56	26.23
313	11-22-55	14.98
	12-15-55	15.24
	1-25-56	15.40
	3-13-56	15.75
	5-29-56	16.62
324	11-22-55	12.61
	12-15-55	12.66
	1-25-56	12.88
	3-13-56	13.14
	5-29-56	14.11
	7-10-56	12.76
331	10-22-52	+12.5
424	9-26-52	4.75
	10- 3-52	4.78
	12-15-55	3.73
	1-25-56	4.32
	3-13-56	4.25
	5-29-56	4.54
	7-10-56	4.07
429	8-22-52	5.78
430	8-22-52	6.52
432	8-22-52	4.60
440	2- 8-56	9.00
	3-13-56	7.92
	5-29-56	9.33
	7-10-56	8.50
441	11-22-55	4.56
	12-15-55	4.78
	1-25-56	4.51
	1-13-56	4.60
442	12-15-55	7.27
	1-25-56	7.19
	3-13-56	6.96
	5-29-56	8.15
	7-10-56	6.81
443	12-15-55	5.75
	1-25-56	5.73
	3-13-56	5.57
	5-29-56	6.59
	7-10-56	5.65
444	12-15-55	6.35
	1-25-56	6.49
	3-13-56	6.66
	5-29-56	7.13
	7-10-56	5.87
445	11-22-55	7.21
	12-15-55	7.35
	1-25-56	7.64
	3-13-56	7.86

Table 3. (Continued)

Well	Date	Water level below measuring point, in feet[1]
	5-29-56	8.56
	7-10-56	6.83
446	11-22-55	5.51
	12-15-55	5.66
	1-25-56	5.99
	3-13-56	6.28
	5-29-56	7.17
	7-10-56	5.29
447	12-15-55	3.58
	1-25-56	3.67
	3-13-56	3.87
	5-29-56	4.95
	7-10-56	3.29
448	12-15-55	4.97
	1-25-56	5.72
	3-13-56	6.34
	5-29-56	7.13
	7-10-56	5.58
449	12-15-55	3.57
	1-25-56	3.87
	3-13-56	4.09
	5-29-56	4.31
	7-10-56	3.20
450	12-15-55	5.16
	1-25-56	5.37
	3-13-56	5.62
	5-29-56	6.22
	7-10-56	5.22
451	12-15-55	3.94
	1-25-56	4.34
	3-13-56	5.19
	5-29-56	5.81
452	11-22-55	9.01
	12-15-55	8.96
	1-25-56	9.23
	3-13-56	9.29
	5-29-56	10.22
	7-10-56	9.24
453	11-22-55	9.18
	12-15-55	9.52
	1-25-56	9.81
	3-13-56	10.04
	5-29-56	10.84
	7-10-56	10.80
454	11-22-55	5.81
	12-15-55	5.67
	1-25-56	5.90
	3-13-56	5.89
	5-29-56	6.61
	7-10-56	5.43
455	11-22-55	14.16
	12-15-55	14.24
	1-25-56	14.44
	3-13-56	14.70
	5-29-56	15.68
	7-10-56	14.33
456	12-15-55	3.57
	1-25-56	4.12
	3-13-56	4.64
	5-29-56	3.1
457	12-15-55	18.56
458	10-10-55	24.52
459	11-22-55	7.41
	12-15-55	7.51
	1-25-56	7.75
	3-13-56	7.96
	5-29-56	8.97
	7-10-56	8.75
460	11-22-55	21.29
	12-15-55	21.56
	1-25-56	21.84
	3-13-56	22.07
	5-29-56	22.92
	7-10-56	22.71
461	11-22-55	8.54
	12-15-55	8.37

Table 3. (Continued)

Well	Date	Water level below measuring point, in feet[1]	Well	Date	Water level below measuring point, in feet[1]
	1-25-56	8.33	468	11-22-55	5.09
	3-13-56	8.35		12-15-55	4.92
	5-29-56	9.10		1-25-56	4.76
	7-10-56	8.76		3-13-56	4.84
				5-29-56	5.62
462	12-15-55	3.82		7-10-56	5.30
	1-25-56	3.93			
	3-13-56	4.30	469	11-22-55	2.78
	5-29-56	5.29		12-15-55	2.75
	7-10-56	4.83		1-25-56	2.38
				3-13-56	2.95
463	11-22-55	30.05		5-29-56	3.51
	12-15-55	30.15		7-10-56	2.89
	1-25-56	30.36			
	3-13-56	30.55	470	11-22-55	4.96
	5-29-56	31.31		12-15-55	4.84
				1-25-56	4.69
464	11-22-55	16.48		3-13-56	4.99
	12-15-55	16.40		5-29-56	5.57
	1-25-56	16.54		7-10-56	5.12
	3-13-56	16.74	471	12-15-55	12.45
	5-29-56	17.60		1-25-56	12.53
	7-10-56	17.19		3-13-56	12.79
				5-29-56	13.80
465	11-22-55	3.81		7-10-56	13.57
	12-15-55	3.74			
	1-25-56	3.64	472	12-15-55	3.15
	3-13-56	4.02		1-25-56	3.20
	5-29-56	4.71		3-13-56	3.67
	7-10-56	4.24		5-29-56	5.00
				7-10-56	4.93
466	11-22-55	5.79	473	12-15-55	4.74
	12-15-55	5.71		1-25-56	4.80
	1-25-56	5.56		3-13-56	5.28
	3-13-56	5.95		5-29-56	6.63
	5-29-56	6.59		7-10-56	6.55
	7-10-56	6.06			
			474	12-15-55	2.30
467	11-22-55	4.33		1-25-56	2.70
	12-15-55	4.30		3-13-56	2.99
	1-25-56	4.09		5-29-56	4.43
	3-13-56	4.43		7-10-56	4.31
	5-29-56	5.02	475	1-25-56	4.60
	7-10-56	4.60		3-13-56	4.25

Table 3. (Continued)

Well	Date	Water level below measuring point, in feet[1]	Well	Date	Water level below measuring point, in feet[1]
	5-29-56	5.95	484	12-15-55	18.42
	7-10-56	5.90		1-25-56	18.64
476	11-22-55	65.06		3-13-56	19.37
	12-15-55	65.28		5-29-56	20.44
	1-25-56	65.73		7-10-56	20.80
	3-13-56	66.09	485	11-25-55	4.76
	5-29-56	66.65		12-15-55	5.00
	7-10-56	67.06		1-25-56	5.74
477	11-22-55	43.51	486	11-25-55	18.88
	12-15-55	43.70		12-15-55	19.40
	1-25-56	44.38		1-25-56	19.93
478	11-22-55	22.19		3-13-56	20.41
	12-15-55	22.38		5-29-56	21.47
	1-25-56	23.67		7-10-56	21.13
	3-13-56	23.01	487	11-25-55	20.93
	5-29-56	24.04		12-15-55	21.40
479	12-15-55	2.94		1-25-56	21.73
	1-25-56	3.09		3-13-56	22.46
	3-13-56	3.37		5-29-56	23.52
	5-29-56	4.53		7-10-56	23.18
480	11-22-55	5.58	488	12-15-55	4.88
	12-15-55	5.66		1-25-56	5.54
	1-25-56	5.76		3-13-56	5.93
	3-13-56	6.04		5-29-56	7.04
481	12-15-55	16.45		7-10-56	6.97
	1-25-56	17.22	489	12-15-55	7.08
	3-13-56	16.93		1-25-56	7.49
	5-29-56	17.45		3-13-56	7.13
	7-10-56	17.99		5-29-56	7.99
482	11-22-55	47.18		7-10-56	7.63
	12-15-55	47.33	490	11-25-55	7.34
	1-25-56	42.91		12-15-55	7.35
	3-13-56	47.44		1-25-56	7.42
483	12-15-55	3.07		3-13-56	7.51
	1-25-56	3.35		5-29-56	9.42
	3-13-56	3.62		7-10-56	9.12
	5-29-56	5.31	491	1-25-56	7.98
	7-10-56	3.25		3-13-56	8.10

Table 3. (Continued)

Well	Date	Water level below measuring point, in feet[1]
492	1-25-56	2.58
	3-13-56	2.82
	5-29-56	3.99
	7-10-56	4.28
493	1-25-56	4.58
	3-13-56	4.94
	5-29-56	6.51
	7-10-56	6.64
494	10- 3-52	7.99
	1-25-56	8.24
	3-13-56	8.04
	5-29-56	8.60
	7-10-56	8.27
495	9-26-52	5.47
	10- 3-52	5.39
	1-25-56	5.48
	3-13-56	5.54
	7-10-56	5.54
496	9-26-52	4.48
	10- 3-52	4.48
	1-25-56	4.73
	3-13-56	4.72
	7-10-56	4.68
497	9-26-52	5.72
	10- 3-52	4.82
498	10- 3-52	4.50
499	9-26-52	4.13
	10- 3-52	3.43
500	9-25-52	+7.5
501	9-26-52	5.62
	10- 3-62	5.37
502	9-26-52	3.10
	10- 3-52	3.20
503	9-26-52	2.72
	10- 3-52	2.74
505	10- 3-52	4.50
506	10- 2-52	0.50
508	9-26-52	1.28
	10- 3-52	1.70
509	9-26-52	6.72
	10- 3-52	6.45
510	9-26-52	5.80
	10- 3-52	5.79
512	9-26-52	4.09
	10- 3-52	4.08
514	9-26-52	5.08
	10- 3-52	5.27
515	9-26-52	11.88
	10- 3-52	10.53
518	9-26-52	5.45
	10- 3-52	5.05
519	9-26-52	3.17
	10- 3-52	2.86
520	10- 3-52	3.67
521	10- 3-52	5.10
522	8-21-52	1.23
523	8-21-52	6.28
524	8-21-52	1.17
526	10- 3-52	3.64
527	10- 3-52	5.58

[1]Feet above measuring point when prefaced by plus sign.

TABLE 4. Record of Wells

Type of well: B, bored; D, dug; Dn, driven; Dr, drilled; J, jetted. Type of casing: BI, black iron; GI, galvanized iron. Type of pump: C, centrifugal; Cy, cylinder; J, jet; N, none; P, pitcher. Type of power: E, electric; F, natural flow; H, hand; N, none. Use of well: D, domestic; I, irrigation; O, observation; P, public supply; S, stock; T, test. Measuring point description: Bp, base of pump; Bs, base of spout; LS, land surface; N, nail; Tca, top of casing. Altitude: e, estimated.

Well No.	Field No.	Owner	Location	Type of well	Depth of well (ft.)	Diameter of well (in.)	Type of casing	Type of pump	Type of power	Use of well	Measuring Point: Description	Measuring Point: Distance above or below (—) land surface (ft.)	Measuring Point: Altitude (feet above MSL)	Remarks
14		U.S.G.S.	NE¼NW¼ sec. 4, T. 38 S., R. 30 E.	Dr	35	6	BI			O	Tca	3.3	139.31	Equipped with recording gage
273	N-3A	J. J. Hendry	SW¼NW¼ sec. 23, T. 37 S., R. 30 E.	Dr	65	2	GI		F	I	Tca	3.0	52.20	Flows 20 gpm
274	N-4A	J. D. Mitchel	SW¼NW¼ sec. 23, T. 37 S., R. 30 E.	Dr	92.0	2	GI		F	I	Tca	1.0	50.73	Flows 100 gpm
275	N-6B	F. J. Wise	SW¼NE¼ sec. 23, T. 37 S., R. 30 E.	Dr	49.5	1¼	GI		F	D	Tca	2.2	46.20	Flows 3 gpm
276	N-6A	Hendry	SW¼NE¼ sec. 23, T. 37 S., R. 30 E.	Dr	89.2	2	GI		F	D	Tca	1.4	44.95	Flows 100 gpm
283	O-7	Melvin Brothers Co.	NE¼NW¼ sec. 1, T. 37 S., R. 30 E.	Dr	83.7	4	BI		F	D,S	Tca	2.2	41.19	Flows 1 gpm
302	......	Unknown	NE¼NW¼ sec. 7, T. 37 S., R. 30 E.	Dn	18.3	2	GI	P	H	O	Bp	3.5	100.93	
304	......	J. A. Cook	NE¼NE¼ sec. 7, T. 37 S., R. 30 E.	Dr	78.4	6	BI	N	N	P	Tca	1.6	133.01	
309	......	R. Fitzgerald	SW¼SE¼ sec. 8, T. 37 S., R. 30 E.	Dn	31.2	1¼	GI	N	N	O	Tca	2.2	111.52	
313	......	C. L. Sowell	NE¼NE¼ sec. 12, T. 37 S., R. 29 E.	Dn	17.0	1¼	GI	P	H	D	Bp	2.2	101.61	
324	......	Edna Carlton	SW¼NW¼ sec. 25, T. 37 S., R. 29 E.	Dr	95.8	2	GI	C	E	D	Tca	.5	104.93	
331	M-4	W. W. Womble	NW¼NE¼ sec. 2, T. 38 S., R. 30 E.	Dr	50.0	2	GI	N	F	D	Tca	1.0	50e	Flows 5 gpm
358	......	Sebring Packing Co.	Center sec. 17, T. 38 S., R. 30 E.	Dr	1,550	12	BI	..	..	I	Tca	.0	182e	
424	M-2	U.S.G.S.	SE¼SW¼ sec. 35, T. 37 S., R. 30 E.	Dr	21	6	BI	N	N	O	Tca	3.0	60.70	
425	M-10	—do—	SW¼SW¼ sec. 31, T. 37 S., R. 31 E.	Dr	125.0	4	BI	...	..	T	Tca	.	34e	Well destroyed
429	Z-2	Unknown	NW¼NE¼ sec. 29, T. 35 S., R. 31 E.	Dn	37.8	1¼	GI	...	...	T	Tca	1.5	......	
430	Z-1	—do—	NE¼NW¼ sec. 29, T. 35 S., R. 31 E.		48.7	1¼	GI	P	H	T	Bp	3.0	......	
432	Z-3	—do—	NE¼NE¼ sec. 29, T. 35 S., R. 31 E.	Dn	10.7	1¼	GI	N	N	S	Tca	.8	......	
433	......	U.S.G.S.	SE¼SW¼ sec. 36, T. 37 S., R. 30 E.	Dr	130	3	None	....	...	T,O	LS	0.0	40e	Test hole for lithologic information.
434	......	—do—	NE¼NE¼ sec. 2, T. 38 S., R. 30 E.	Dr	60	3	None	...	...	T,O	LS	.0	50e	Do.
435	......	—do—	SE¼SW¼ sec. 35, T. 37 S., R. 30 E.	Dr	220	3	None	....	....	T,O	LS	.0	90e	Do.
436	......	—do—	NW¼NE¼ sec. 3, T. 38 S., R. 30 E.	Dr	140	3	None	....	....	T,O	LS	.0	113e	Do.
437	......	—do—	NW¼NW¼ sec. 2, T. 38 S., R. 29 E.	Dr	160	3	None	....	....	T,O	LS	.0	140e	Do.
438	......	—do—	NE¼NE¼ sec. 5, T. 38 S., R. 30 E.	Dr	60	3	None	....	....	T,O	LS	.0	91.5	Do.
440	......	—do—	SW¼SW¼ sec. 10, T. 37 S., R. 29 E.	Dr	220	6	BI	N	N	O	Tca	2.8	121.98	Equipped with recording gage
441	......	Tobler	SW¼NW¼ sec. 11, T. 37 S., R. 29 E.	Dn	6.3	1¼	GI	P	H	D	Bp	1.9	78.37	
442	......	U.S.G.S.	NW¼NE¼ sec. 11, T. 37 S., R. 29 E.	J	14.0	¾	GI	N	N	O	Tca	3.0	83.26	
443	......	—do—	NW¼NE¼ sec. 11, T. 37 S., R. 29 E.	J	20.5	¾	GI	N	N	O	Tca	.9	80.98	
444	......	—do—	NE¼NE¼ sec. 14, T. 37 S., R. 29 E.	J	12.5	¾	GI	N	N	O	Tca	2.3	93.36	
445	......	—do—	NE¼NE¼ sec. 23, T. 37 S., R. 29 E.	Dn,J	11.2	1¼	GI	N	N	O	Tca	2.3	99.77	
446	......	—do—	NW¼NE¼ sec. 23, T. 37 S., R. 29 E.	J	23.3	1¼	GI	P	H	O	Tca	2.6	99.46	
447	......	—do—	SW¼SW¼ sec. 2, T. 37 S., R. 29 E.	J	12.7	¾	GI	N	N	O	Tca	1.1	135e	
448	......	—do—	NE¼SE¼ sec. 26, T. 37 S., R. 29 E.	J	20.6	¾	GI	N	N	O	Tca	1.0	103.96	
449	......	—do—	NE¼NE¼ sec. 35, T. 37 S., R. 29 E.	J	21.0	¾	GI	N	N	O	Tca	.5	110.42	
450	......	—do—	SE¼SE¼ sec. 35, T. 37 S., R. 29 E.	J	21.4	¾	GI	N	N	O	Tca	.7	137.46	
451	......	—do—	SE¼SW¼ sec. 35, T. 37 S., R. 29 E.	J	22.5	¾	GI	N	N	O	Tca	7.7	138.19	
452	......	—do—	SE¼SW¼ sec. 1, T. 37 S., R. 29 E.	J	13.7	¾	GI	N	N	O	Tca	3.8	90.76	
453	......	J. Reichardt	NE¼NE¼ sec. 12, T. 37 S., R. 29 E.	J	12.4	1¼	GI	N	N	O	Tca	2.7	94.45	
454	......	U.S.G.S.	SW¼NW¼ sec. 12, T. 37 S., R. 29 E.	J	23.9	¾	GI	N	N	O	Tca	1.6	87.06	
455	......	Edna Carlton	SW¼NW¼ sec. 25, T. 37 S., R. 29 E.	Dn	77.1	1¼	GI	P	H	D	Bp	2.0	106.46	
456	......	U.S.G.S.	SW¼SE¼ sec. 36, T. 37 S., R. 29 E.	J	19.2	¾	GI	N	N	O	Tca	2.4	114.28	
457	......	Jesse Durrance	NW¼SW¼ sec. 6, T. 37 S., R. 30 E.	Dn	27.4	1¼	GI	C	E	D	Tca	2.1	102.71	
458	......	Chambers	NW¼SW¼ sec. 6, T. 37 S., R. 30 E.	Dn	31.2	1¼	GI	P	H	D	Bp	2.0	108.48	
459	......	H. Roberts	NW¼SW¼ sec. 6, T. 37 S., R. 30 E.	Dn	41.1	2	GI	....	....	O	Tca	1.9	92.50	
460	......	J. C. Durrance	SE¼NE¼ sec. 18, T. 37 S., R. 30 E.	Dn	70.0	2	GI	C	E	D	Tca	.0	113.48	
461	......	J. A. Reninger	SE¼SE¼ sec. 5, T. 37 S., R. 30 E.	Dn	9.0	1¼	GI	P	H	D	Bp	4.1	91.30	
462	......	U.S.G.S.	NE¼NE¼ sec. 8, T. 37 S., R. 30 E.	J	21.4	¾	GI	N	N	O	Tca	.2	89.84	
463	......	H. H. Brown	SE¼NE¼ sec. 7, T. 37 S., R. 30 E.	Dn	38.3	1¼	GI	P	H	D	Bp	3.9	118.80	
464	......	V. P. Davis	NW¼SW¼ sec. 8, T. 37 S., R. 30 E.	Dn	40	1¼	GI	P	H	D	Bp	2.3	105.28	
465	......	S. Hawthorn	NW¼SW¼ sec. 8, T. 37 S., R. 30 E.	Dn	10.6	1¼	GI	P	H	D	Bp	2.0	90.93	
466	......	E. Albritton	NE¼SW¼ sec. 8, T. 37 S., R. 30 E.	Dn	11.5	1¼	GI	P	H	D	Bp	1.6	91.54	
467	......	L. Henderson	NE¼SW¼ sec. 8, T. 37 S., R. 30 E.	Dn	9.5	1¼	GI	P	H	I	Bp	3.1	88.47	
468	......	B. J. Harris	NW¼SE¼ sec. 8, T. 37 S., R. 30 E.	Dn	38.4	2	GI	P	H	I	Bs	1.6	87.49	
469	......	E. Albritton	SW¼SE¼ sec. 8, T. 37 S., R. 30 E.	Dn	6.7	1¼	GI	P	H	I	Bp	1.3	88.86	
470	......	R. A. Fitzgerald	SW¼SE¼ sec. 8, T. 37 S., R. 30 E.	Dn	14.9	1¼	GI	P	H	I	Bp	2.3	90.88	
471	......	U.S.G.S.	SE¼SE¼ sec. 8, T. 37 S., R. 30 E.	J	21.3	¾	GI	N	N	O	Tca	.2	99.35	
472	......	—do—	SE¼SE¼ sec. 8, T. 37 S., R. 30 E.	J	20.7	¾	GI	N	N	O	Tca	1.1	91.52	
473	......	—do—	SE¼SE¼ sec. 8, T. 37 S., R. 30 E.	J	6.4	¾	GI	N	N	O	Tca	2.7	93.22	
474	......	—do—	SE¼SW¼ sec. 9, T. 37 S., R. 30 E.	J	21.4	¾	GI	N	N	O	Tca	.0	92.70	
475	......	—do—	NE¼NE¼ sec. 16, T. 37 S., R. 30 E.	B	3.8	¾	GI	N	N	O	Tca	3.0	92.58	
476	......	Consolidated Naval Stores	SW¼SW¼ sec. 17, T. 37 S., R. 30 E.	Dn	71.1	2	GI	N	N	O	Tca	.3	157.80	
477	......	G. Kelsey	SE¼SW¼ sec. 17, T. 37 S., R. 30 E.	Dr	80.0	3	GI	J	E	D	Tca	0.5	135.21	
478	......	Consolidated Naval Stores	NE¼NW¼ sec. 20, T. 37 S., R. 30 E.	Dn	27.0	2	GI	P	H	D	Bp	4.1	113.03	
479	......	U.S.G.S.	SE¼SE¼ sec. 20, T. 37 S., R. 30 E.	J	23.7	¾	GI	N	N	O	Tca	.0	94.82	
480	......	N. H. Edgemon	SW¼SW¼ sec. 21, T. 37 S., R. 30 E.	Dn	10.5	1¼	GI	P	H	D	Bp	2.3	97.60	
481	......	U.S.G.S.	NW¼NE¼ sec. 29, T. 37 S., R. 30 E.	B	27.2	1¼	GI	N	N	O	Tca	—.1	110.28	
482	......	Consolidated Naval Stores	NE¼NW¼ sec. 29, T. 37 S., R. 30 E.	Dn	54.1	2	GI	N	N	O	Tca	3.4	143.10	
483	......	U.S.G.S.	NW¼SW¼ sec. 32, T. 37 S., R. 30 E.	D	4.7	¾	GI	N	N	O	Tca	1.9	110.64	
484	......	Unknown	SW¼SW¼ sec. 32, T. 37 S., R. 30 E.	Dn	24.3	1¼	GI	P	H	D	Bp	2.9	135.66	
485	......	J. J. Roosevelt	NW¼SE¼ sec. 33, T. 37 S., R. 30 E.	Dn	28.0	2	GI	C	E	D,S	Tca	1.7	121.61	
486	......	E. L. Taylor	SW¼NW¼ sec. 28, T. 37 S., R. 30 E.	Dn	29.4	1¼	GI	N	N	O	Tca	1.3	117.77	
487	......	—do—	SW¼NW¼ sec. 28, T. 37 S., R. 30 E.	Dn	23.4	1¼	GI	P	H	I	Bp	3.4	120.10	
488	......	U.S.G.S.	SW¼NE¼ sec. 28, T. 37 S., R. 30 E.	J	15	¾	GI	P	H	O	Tca	.0	105.19	
489	......	—do—	SW¼NW¼ sec. 28, T. 37 S., R. 30 E.	J	21.0	¾	GI	P	H	O	Tca	.6	102.63	
490	......	Palm Corp.	SE¼NW¼ sec. 21, T. 37 S., R. 30 E.	Dr	14.6	2	GI	N	N	O	Tca	.4	98.77	
491	......	U.S.G.S.	SE¼SW¼ sec. 22, T. 37 S., R. 30 E.	D	5.0	¾	GI	N	N	O	Tca	4.6	105.68	
492	......	—do—	SW¼SE¼ sec. 22, T. 37 S., R. 30 E.	D	3.6	¾	GI	N	N	O	Tca	2.2	85.85	
493	......	—do—	SW¼SW¼ sec. 27, T. 37 S., R. 30 E.	D	3.5	¾	GI	N	N	O	Tca	4.1	112.10	
494	N-2	Negro Labor House	SW¼NW¼ sec. 23, T. 37 S., R. 30 E.	Dn	8.0	1¼	GI	P	H	D	Bp	3.0	69.47	
495	O-2	U.S.G.S.	SE¼SW¼ sec. 34, T. 36 S., R. 30 E.	J	21.9	¾	GI	N	N	O	Tca	4.0	63.71	
496	O-3	—do—	SE¼SW¼ sec. 34, T. 36 S., R. 30 S.	J	6.8	¾	GI	N	N	O	Tca	3.7	47.93	Initially jetted to 23 ft. for lithologic information; well finished at 6.8 ft.
497	P-1	—do—	NW¼SW¼ sec. 36, T. 36 S., R. 30 E.	B	3.0	4	None	N	N	O	N	4.7	42.49	
498	P-2	—do—	NW¼SW¼ sec. 36, T. 36 S., R. 30 E.	J	17.9	¾	GI	N	N	O	Tca	3.5	41.97	
499	P-3	—do—	NW¼SW¼ sec. 36, T. 36 S., R. 30 E.	J	30.9	¾	GI	N	N	O	Tca	2.2	41.20	
500	P-4	Unknown	NW¼SW¼ sec. 36, T. 36 S., R. 30 E.	Dr	111.6	2	GI	....	F	S	Tca	1.6	40.50	Flows 20 gpm
501	Q-1	U.S.G.S.	NW¼NE¼ sec. 30, T. 36 S., R. 31 E.	J	20.3	¾	GI	N	N	O	Tca	4.5	43.21	
502	M-1	—do—	NE¼NW¼ sec. 2, T. 38 S., R. 30 E.	J	8.4	¾	GI	N	N	O	Tca	1.7	78.08	Initially jetted to 20 ft. for lithologic information; well finished at 8.4 ft.
503	M-3	—do—	NE¼NW¼ sec. 2, T. 38 S., R. 30 E.	J	26.5	¾	GI	N	N	O	Tca	2.5	58.33	Initially jetted to 30 ft. for lithologic information; well finished at 26.5 ft.
504	M-5	—do—	SE¼SE¼ sec. 35, T. 37 S., R. 30 E.	J	21.0	¾	None	N	N	O	LS	.0	47e	Test hole for lithologic information.
505	M-6	—do—	SE¼SW¼ sec. 36, T. 37 S., R. 30 E.	J	6.3	¾	GI	N	N	O	Tca	3.5	46.32	Initially jetted to 28 ft. for lithologic information; well finished at 6.3 ft.
506	M-7	Durrance	NW¼NE¼ sec. 1, T. 38 S., R. 30 E.	Dr	42.1	1¼	GI	P	H	S	Tca	1.8	40.91	
507	M-8	U.S.G.S.	NW¼NE¼ sec. 1, T. 38 S., R. 30 E.	J	21.0	¾	None	N	N	O	LS	.0	39e	Test hole for lithologic information.
508	M-9	—do—	SW¼SW¼ sec. 31, T. 37 S., R. 31 E.	J	15.9	¾	GI	N	N	O	Tca	2.8	34.51	Initially jetted to 27 ft. for lithologic information; well finished at 15.9 ft.
509	N-1	—do—	NW¼SW¼ sec. 23, T. 37 S., R. 30 E.	B	5.0	¾	GI	N	N	O	Tca	4.0	71.78	
510	N-3	—do—	SW¼NW¼ sec. 23, T. 37 S., R. 30 E.	J	12.0	¾	GI	N	N	O	Tca	3.0	59.47	Initially jetted to 57 ft. for lithologic information; well finished at 12.0 ft.
511	N-4	—do—	SW¼NW¼ sec. 23, T. 37 S., R. 30 E.	J	23.0	¾	GI	N	N	O	Tca	—2.0	46.94	Located in drainage ditch.
512	N-5	—do—	SE¼NW¼ sec. 23, T. 37 S., R. 30 E.	J	23.2	¾	GI	N	N	O	Tca	3.0	49.07	
513	N-6	—do—	SW¼NE¼ sec. 23, T. 37 S., R. 30 E.	J	23.0	¾	None	N	N	O	LS	.0	44.07	Test hole for lithologic information
514	N-7	—do—	NW¼SW¼ sec. 24, T. 37 S., R. 30 E.	J	12.9	¾	GI	N	N	O	Tca	4.3	44.04	Initially jetted to 26 ft. for lithologic information; well finished at 12.9 ft.
515	O-1	—do—	NW¼NW¼ sec. 3, T. 37 S., R. 30 E.	B	8.7	¾	GI	N	N	O	Tca	3.5	86.76	
516	O-4	—do—	NW¼NW¼ sec. 3, T. 37 S., R. 30 E.	J	21.0	¾	None	N	N	O	LS	0.0	44e	Test hole for lithologic information.
517	O-5	—do—	NW¼NW¼ sec. 2, T. 37 S., R. 30 E.	J	21.0	¾	None	N	N	O	LS	.0	43e	Do.
518	O-6	—do—	SE¼SE¼ sec. 35, T. 36 S., R. 30 E.	J	22.2	¾	GI	N	N	O	Tca	2.0	42.37	
519	O-6A	—do—	SW¼SW¼ sec. 36, T. 36 S., R. 30 E.	B		4	None	N	N	O	LS	.0	39.05	
520	O-8	—do—	NW¼NW¼ sec. 6, T. 37 S., R. 30 E.	J	19.8	¾	GI	N	N	O	Tca	1.7	39.26	
521	O-8A	—do—	NW¼NE¼ sec. 6, T. 37 S., R. 31 E.	J	9.1	¾	GI	N	N	O	Tca	2.9	40.33	
522	A-1	—do—	NE¼SW¼ sec. 28, T. 36 S., R. 30 E.	J	15.6	1¼	GI	N	N	O	Tca	.6	85.83	
523	A-2	—do—	NE¼SE¼ sec. 28, T. 36 S., R. 30 E.	J	11.1	1¼	GI	N	N	O	Tca	5.1	77.31	
524	A-3	—do—	NE¼SE¼ sec. 28, T. 36 S., R. 30 E.	J	8.0	1¼	GI	N	N	O	Tca	1.1	56.80	
525	A-4	—do—	SE¼NE¼ sec. 28, T. 36 S., R. 30 E.	J	8.9	1¼	GI	N	N	O	Tca	3.3	58.58	
526	C-1	—do—	NW¼NW¼ sec. 20, T. 35 S., R. 30 E.	J	4.3	¾	GI	N	N	O	Tca	1.6	50.96	
527	C-2	—do—	NE¼NE¼ sec. 29, T. 35 S., R. 30 E.	J	18.9	¾	GI	N	N	O	Tca	1.1	45.66	
528	T-1	—do—	SE¼SE¼ sec. 2, T. 37 S., R. 29 E.	J	22.0	¾	None	N	N	T	LS	.0	....	Test hole for lithologic information.
529	T-2	—do—	NW¼SW¼ sec. 9, T. 37 S., R. 30 E.	B	7.5	4	None	N	N	T	LS	.0	95e	Do.
530	T-3	—do—	NE¼SW¼ sec. 9, T. 37 S., R. 30 E.	B	6.0	4	None	N	N	T	LS	.0	128e	Do.
531	T-4	—do—	NW¼NW¼ sec. 10, T. 37 S., R. 30 E.	B	5.0	4	None	N	N	T	LS	.0	105e	Do.
532	T-5	—do—	NW¼NW¼ sec. 10, T. 37 S., R. 30 E.	B	4.0	4	None	N	N	T	LS	.0	105e	Do.
533	T-6	—do—	NW¼NW¼ sec. 10, T. 37 S., R. 30 E.	B	3.0	4	None	N	N	T	LS	.0	105e	Do.

TABLE 5. Record of Surface-Water Observation Points

Number	Owner	Location	Datum of gage, in feet above MSL	Remarks
OP-1	U.S.G.S.	NE¼SE¼ sec. 2, T. 37 S., R. 30 E.	65.38	Lake June in Winter, Surface Water Branch staff gage
OP-2	—do—	NE¼NE¼ sec. 13, T. 37 S., R. 29 E.	79.66	Lake Placid, Surface Water Branch staff gage and continous recorder
OP-3	—do—	SW¼SE¼ sec. 17, T. 37 S., R. 30 E.	68.90	Lake Grassy, Surface Water Branch staff gage
OP-4	—do—	SW¼NW¼ sec. 5, T. 37 S., R. 30 E.	68.92	Lake Huntley, Surface Water Branch staff gage
OP-5	—do—	NE¼NE¼ sec. 31, T. 36 S., R. 30 E.	68.94	Lake Clay, Surface Water Branch staff gage
OP-6	—do—	SW¼SW¼ sec. 31, T. 37 S., R. 30 E.	100.19	Lake Annie, Surface Water Branch staff gage
OP-7	—do—	NW¼SW¼ sec. 6, T. 37 S., R. 30 E.	74.63	Lake Sirena, Surface Water Branch staff gage
OP-8	—do—	NE¼SW¼ sec. 6, T. 37 S., R. 30 E.	78.96	Lake Pearl, Surface Water Branch staff gage
OP-9	—do—	SE¼NW¼ sec. 7, T. 37 S., R. 30 E.	84.41	Mirror Lake, Surface Water Branch staff gage and continuous recorder
OP-10	—do—	NW¼SE¼ sec. 6, T. 37 S., R. 30 E.	78.76	Lake McCoy, Surface Water Branch staff gage
OP-11	—do—	NE¼SE¼ sec. 12, T. 37 S., R. 29 E.	85.32	Lost Lake, temporary staff gage
OP-12	—do—	NE¼NE¼ sec. 29, T. 37 S., R. 30 E.	88.56	Buck Lake, temporary staff gage
OP-13	—do—	SE¼SE¼ sec. 20, T. 37 S., R. 30 E.	91.48	Excavation, temporary staff gage
OP-14	—do—	NE¼NE¼ sec. 3, T. 38 S., R. 30 E.	112.95	Do.
OP-15	—do—	SW¼SW¼ sec. 9, T. 37 S., R. 30 E.	89.67	Lake Grassy, temporary staff gage
OP-16	—do—	SW¼SW¼ sec. 13, T. 37 S., R. 30 E.	90.35	Catfish Bay Canal, temporary staff gage