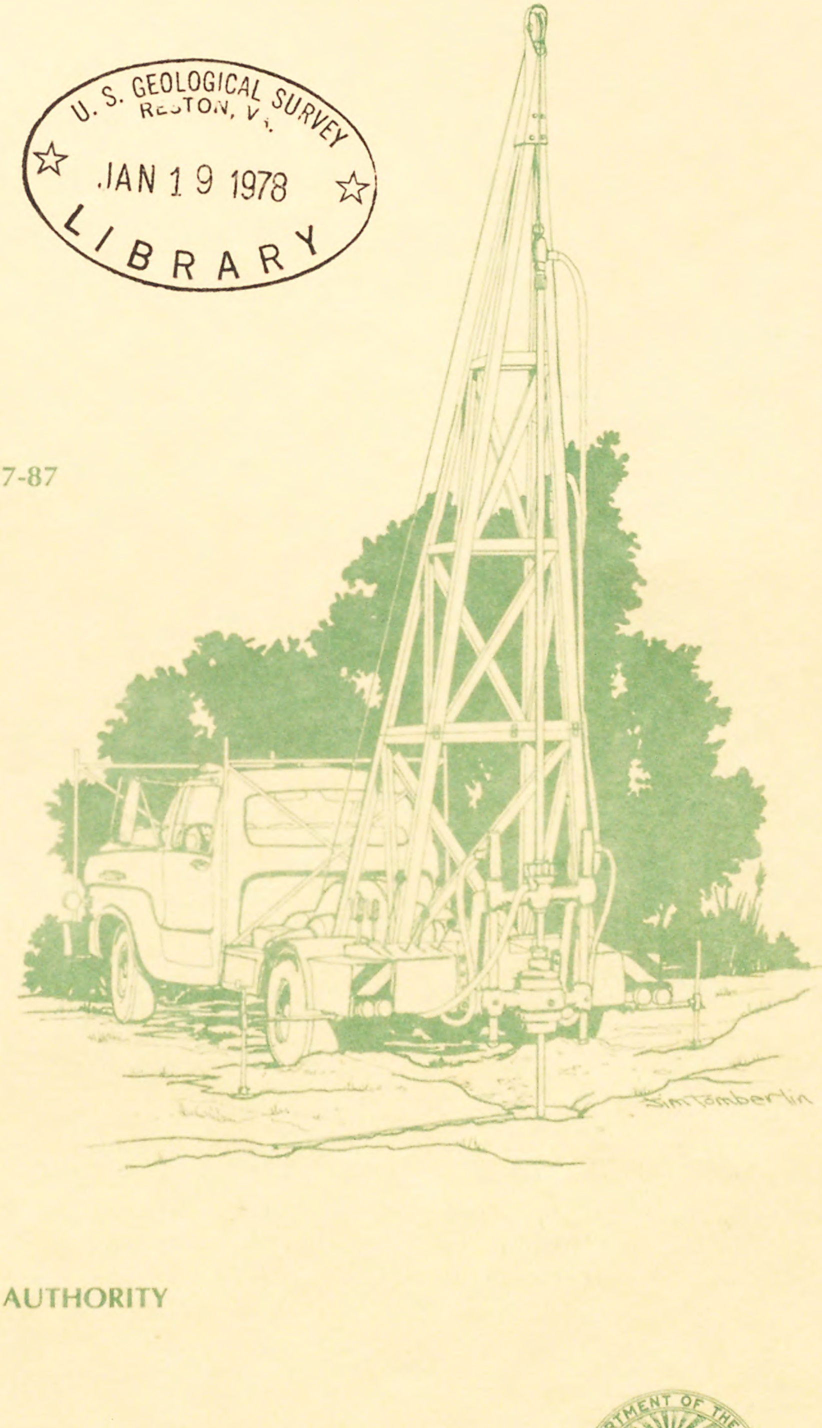
SURFACE-WATER AND GROUND-WATER FEATURES, CLAY COUNTY, FLORIDA



U.S. GEOLOGICAL SURVEY

Water Resources Investigations 77-87

Prepared in cooperation with
CLAY COUNTY DEVELOPMENT AUTHORITY

BIBLIOGRAPHIC DATA SHEET	1. Report No.	2.	3. Recipient's Accession No.

4. Title and Subtitle
Surface-water and ground-water features, Clay County, Florida

5. Report Date August 1977

6.

7. Author(s)
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8. Performing Organization Rept. No. WRI 77-87

9. Performing Organization Name and Address
U. S. Geological Survey, Water Resources Division
325 John Knox Road, Suite F-240
Tallahassee, Florida 32303

10. Project/Task/Work Unit No.

11. Contract/Grant No.

12. Sponsoring Organization Name and Address
U. S. Geological Survey, Water Resources Division
325 John Knox Road, Suite F-240
Tallahassee, Florida 32303

13. Type of Report & Period Covered

14.

15. Supplementary Notes
Prepared in cooperation with the Clay County Development Authority

16. Abstracts Clay County is a rapidly growing area in northeastern Florida. Surface water largely is undeveloped except for recreational use. Black Creek is the largest fresh-water stream in the county and has an average discharge of about 515 cubic feet per second. However, excessive color, iron concentration, hardness, and pH often make the water objectionable for many uses. Water from the lakes and streams in the Etonia Creek basin in southwestern Clay County generally is of good chemical quality.

Ground water occurs in the county in a water-table aquifer, secondary artesian aquifers, and the Floridan aquifer. Large withdrawals of water from the Floridan aquifer since the 1940's, especially in nearby metropolitan Jacksonville, have caused a decline of the potentiometric surface of up to 30 feet in the northeast corner of Clay County to less than 5 feet in the western part. The rate of decline in recent years at Orange Park has been about 0.7 of a foot per year. Ground water in the county generally is of good chemical quality and is suitable for most uses. The quality has not changed noticeably in the past several years since records have been kept.

17. Key Words and Document Analysis. 17a. Descriptors

Descriptors -- *Water resources, *Hydrology, *Surface waters *Streamflow, *Lake stages, *Ground Water, *Aquifers, *Water table, *Water quality, Florida, Gaging Stations, Rainfall-runoff Characteristics, Peak discharge, Artesian wells, Confined water, Geology, Limestone, Springs, Wells, Potentiometric level, Water consumption

17b. Identifiers/Open-Ended Terms

Identifiers -- *Clay County, Orange Park, Green Cove Springs, Jacksonville, Floridan aquifer, St. Johns River, Black Creek, Secondary artesian aquifers

17c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
No restriction on distribution	UNCLASSIFIED	68
	20. Security Class (This Page) UNCLASSIFIED	22. Price

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UNITED STATES DEPARTMENT OF THE INTERIOR

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GEOLOGICAL SURVEY

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GLOSSARY

Terms related to streamflow, water-quality, and other hydrologic data, as used in this report, are defined below. A table for converting English units to the International System of units (SI) is on page 5.

Acre-foot (acre-ft) is the quantity of water required to cover 1 acre to a depth of 1 foot and is equivalent to 43,560 cubic feet or about 326,000 gallons.

Aquifer is a formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

Artesian is synonymous with confined. An artesian well is a well deriving its water from an artesian or confined water body. The water level in an artesian well stands above the top of the artesian water body it taps.

Confining bed is a body of "impermeable" material stratigraphically adjacent to one or more aquifers.

Cubic foot per second (ft^3/s) is the rate of discharge representing a volume of 1 cubic foot passing a given point in 1 second and is equivalent to 7.48 gallons per second or 448.8 gallons per minute.

Discharge is the volume of water (or more broadly, total fluids) that passes a given point within a given period of time.

Daily mean discharge is the mean discharge for one day.

Mean daily discharge is the arithmetic mean of the daily mean discharges during a specific period.

Mean discharge (average discharge) is the arithmetic mean of individual daily mean discharges for a period of record.

Instantaneous discharge is the discharge at a particular instant of time.

Dissolved refers to the amount of a substance present in true chemical solution. In practice, however, the term includes all forms of the substance that will pass through a 0.45-micrometer membrane filter, and thus may include some very small (colloidal) suspended particles. Analyses are performed on filtered samples.

Drainage area of a stream at a specific location is that area, measured in a horizontal plane, enclosed by a topographic divide. It is the area from which precipitation drains or potentially drains by gravity into the stream above the specified point. Values of drainage area given herein include all closed basins, or noncontributing areas, enclosed by the topographic divide.

Drainage basin is a part of the surface of the earth that is occupied by a drainage system, which consists of a surface stream or a body of impounded surface water together with all tributary surface streams and bodies of impounded surface water.

Flood is an overflow of lands not normally covered by water and that are used or usable by man. Floods have two essential characteristics: The inundation of land is temporary; and the land is adjacent to and inundated by overflow from a river, stream, ocean, lake, or other body of standing water.

100-year flood is a flood having a chance of occurring once in 100 years. The flood may occur in any year.

Gaging station is a particular site on a stream, canal, lake, or reservoir where systematic observations of gage height or discharge are made.

Metamorphic rock includes all those rocks which have formed in the solid state from previously existing rocks in response to pronounced changes of temperature, pressure, and chemical environment.

Micrograms per liter (ug/L) is a unit expressing the concentration of chemical constituents in solution as weight (micrograms) of solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to one milligram per liter.

Milligrams per liter (mg/L) is a unit for expressing the concentration of chemical constituents in solution. Milligrams per liter represents the weight of solute per unit volume of water.

Partial-record station is a gaging station where noncontinuous streamflow or stage data are collected systematically.

Potentiometric surface, as related to an artesian aquifer, is a surface defined by the level to which water will rise in tightly cased wells.

Runoff in inches shows the depth to which the drainage area would be covered if all the runoff for a given time period were uniformly distributed on it.

Sedimentary rocks are formed by the accumulation of sediment in water or from air. The sediment may consist of rock fragments or particles of various sizes (conglomerate, sandstone, shale); of the remains or products of animals or plants (certain limestones and coal); of the product of chemical action or of evaporation (salt, gypsum, and so forth); or of mixtures of these materials. A characteristic feature of sedimentary deposits is a layered structure known as bedding or stratification.

Specific capacity of a well is the rate of discharge of water from the well divided by the drawdown of water level within the well.

Specific conductance is a measure of the ability of a water to conduct an electrical current and is expressed in micromhos per centimeter at 25°C. Specific conductance is related to the type and concentration of ions in solution and can be used for approximating the dissolved-solids content of the water. Commonly, the concentration of dissolved solids (in milligrams per liter) is about 65 percent of the specific conductance (in micromhos). This relation is not constant from stream to stream, and it may even vary in the same source with changes in the composition of the water (Durfor and Becker, 1964 p. 2729).

Stage-discharge relation is the relation between gage height and the volume of water per unit of time flowing in a channel.

Streamflow is the discharge that occurs in a natural channel. Although the term "discharge" can be applied to the flow of a canal, the word "streamflow" uniquely describes the discharge in a surface stream course. The term "streamflow" is more general than "runoff," as streamflow may be applied to discharge whether or not it is affected by diversion or regulation.

Surface area of a lake is that area outlined on the latest U.S. Geological Survey topographic map as the boundary of the lake and measured by a planimeter in acres. In localities not covered by topographic maps, the areas are computed from the best maps available at the time planimetered. All areas shown are those for stages when the various maps were made.

Total (as used in tables of chemical analyses) refers to the amount of a substance that is present both in solution and in suspension. Analyses are performed on representative samples of water-suspended sediment mixtures.

Transpiration is the process by which water vapor escapes from a living plant and enters the atmosphere.

SURFACE-WATER AND GROUND-WATER FEATURES, CLAY COUNTY, FLORIDA

By

C. B. Bentley

SUMMARY

Clay County, in northeastern Florida, is an area of rapidly expanding population and economic development. Surface water in the county largely is undeveloped except for recreational use. The principal surface-water feature in the county is the tide-affected St. Johns River, but its water often is too saline for most uses. Black Creek, with an average discharge of about 515 cubic feet per second, is the largest freshwater stream in the county; however, excessive color, iron concentration, hardness, and pH often make the water objectionable for many uses. Water from the lakes and streams in the Etonia Creek basin in southwestern Clay County generally is of good chemical quality.

Ground water occurs in the county in a water-table aquifer, secondary artesian aquifers, and the Floridan aquifer. The water-table aquifer and secondary artesian aquifers supply small to moderate quantities of water to domestic and livestock wells in the county. The principal source of water is the Floridan aquifer--a 1,000-foot plus thickness of permeable limestone which supplies water to more than 150 wells in the county in amounts as large as 2,500 gallons per minute. The Floridan aquifer is recharged partly by lakes in southwestern Clay County and adjoining counties and, more significantly, by seepage from the water-table aquifer through the confining beds in extensive areas where the potentiometric surface of the aquifer is lower than the water table. Large withdrawals of water from the aquifer since the 1940's, especially in nearby metropolitan Jacksonville, have caused a decline of the potentiometric surface of as much as 30 feet in the northeast corner of Clay County to less than 5 feet in the western part. The rate of decline in recent years at Orange Park has been about 0.7 foot per year.

Ground water in the county generally is of good chemical quality and is suitable for most uses. The quality has not changed noticeably in the last several years since records have been kept. Saline water underlies the freshwater zone in the Floridan aquifer at depths ranging from 500 feet below land surface in the southeast corner of the county to more than 2,000 feet below in the northeastern part.

The following investigations could be continued or implemented to obtain information to evaluate more accurately the county's water resources: continue to monitor the quality and quantity of streams and lakes; locate and evaluate water impoundment sites; monitor the quality of water in the St. Johns River; expand the network of monitor wells; conduct a detailed investigation of the Floridan aquifer; expand the U.S. Geological Survey's digital model of the Floridan aquifer for northeast Florida into Clay County; and evaluate the water potential of the water-table aquifer and the secondary-artesian aquifers.

INTRODUCTION

Purpose and Scope

Clay County is an area of rapidly expanding population and economic development, due largely to spillover from the growth of metropolitan Jacksonville, adjacent on the north. A compilation of existing water resources data of the county was undertaken in July 1976, by the U.S. Geological Survey in cooperation with the Clay County Development Authority in order to make a preliminary assessment of the water resources of the county. As a result of the investigation, which was completed in December 1976, areas where additional data collection is needed have been pinpointed to provide a basis for long range planning in Clay County. In this report existing published and unpublished data are summarized and the more comprehensive data required to accurately assess the water resources of the county are defined.

Location

Clay County, in northeastern Florida (fig. 1), contains the principal communities of Green Cove Springs, the county seat; Orange Park, in the northeast corner of the county adjacent to metropolitan Jacksonville; and Keystone Heights, in the southwest corner of the county.

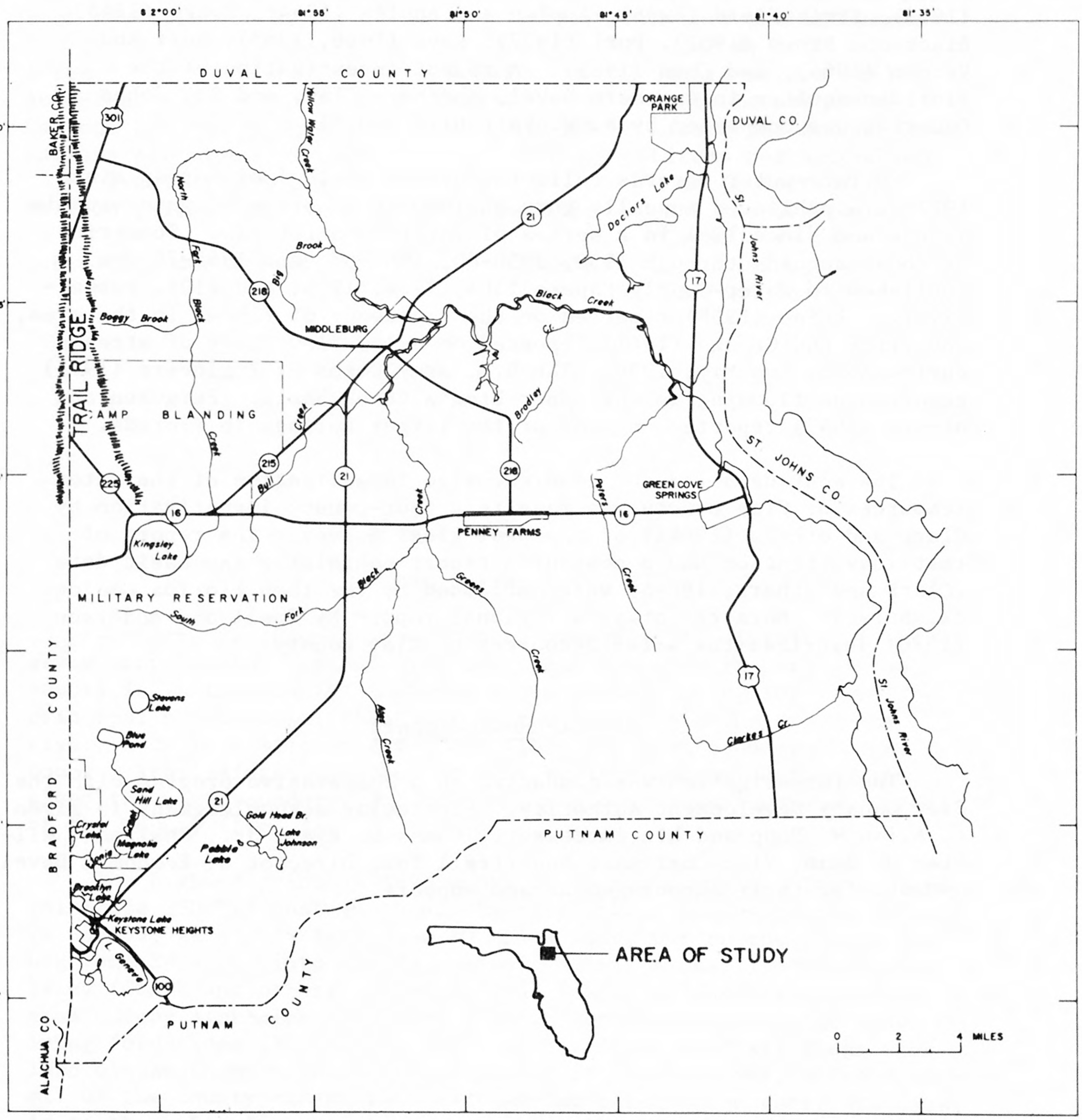

FIGURE 1.--Clay County and its location in Florida.

Previous Investigations

Hydrologic and geologic data have been collected in the county during the last several decades by the Geological Survey and by private and state agencies. Geology and the occurrence of ground-water have been described by Matson and Sanford (1913), Sellards and Gunter (1913), Stringfield (1936), Applin and Applin (1944), Cooke (1945), Black and Brown (1951), Puri (1957), Leve (1966, 1968), Puri and Vernon (1964), and Chen (1965). A recent investigation of the Floridan aquifer in southern Duval, northern Clay, and St. Johns Counties was completed by R. W. Fairchild (1977).

Surface-water records collected by the Geological Survey since 1927 were published annually through 1960 in a series of water-supply papers and since 1961 in a series of water-data reports. Summaries of those records through 1950, 1950-60, 1961-65, and 1965-70 are published in Water-Supply Papers 1304, 1724, 1905, and 2105, respectively. Pride (1958) reported on the frequency of floods in the area, and Pride and Crooks (1961) reported on a low-flow study of streams during April and May, 1956. The U.S. Army Corps of Engineers (1975) reported on flooding in the upper Etonia Creek basin. Ferguson and others (1947) reported on some of the larger springs in Florida.

The most detailed and comprehensive investigation of the water resources of Clay County was made in a four-county investigation by Clark and others (1964a) of the Geological Survey. The report of that investigation and a companion report containing the basic data (Clark and others, 1964b) were published by the then Florida Geological Survey. More recently, a regional report by Snell and Anderson (1970) describes the water resources of Clay County.

Acknowledgments

The investigation was conducted as a cooperative program with the Clay County Development Authority. Particular acknowledgment is given to Allan W. Popp and his successor, Thomas O. Ryan, Jr., Chairman; William M. Beam, Vice Chairman; and Virgil Fox, Director of Economic Development, for their encouragement and support.

For use of those readers who may prefer to use metric units rather than English units, the conversion factors for the terms used in this report are listed below:

Multiply English unit	By	To obtain metric unit
Inches (in)	2.54	Centimeters (cm)
Feet (ft)	.3048	Meters (m)
Miles (mi)	1.609	Kilometers (km)
Square miles (m^2)	2.590	Square kilometers (km^2)
Feet per mile (ft/mi)	.1894	Meters per kilometer (m/km)
Acres	4,047	Square meters (m^2)
Acre-feet (acre-ft)	1,234	Cubic meters (m^3)
Gallons per minute (gal/min)	.06309	Liters per second (L/s)
Gallons per minute per foot [(gal/min)/ft]	.207	Liters per second per meter [(L/s)/m]
Million gallons per day (Mgal/d)	.04381	Cubic meters per second (m^3/s)
Cubic feet per second (ft^3/s)	.02832	Cubic meters per second (m^3/s)

PHYSICAL SETTING

Physiography

Western Clay County is within the topographic division of the state known as the Central Highlands, and the eastern part of the county is in the Coastal Lowlands (Cooke, 1945, p. 8, 10, 11). The principal physiographic features of the county are the St. Johns River, a 2- to 4-mile wide estuary along the east boundary of the county; Trail Ridge, a series of sand hills trending north-south along the west boundary; and the lake region in the southwest corner of the county (fig. 1).

The highest point in the county is on the summit of Trail Ridge (altitude 250 ft) just south of Kingsley Lake. Northward the ridge is narrow, generally less than 10 miles wide, but to the south, the highland fans out into a wide area of sandhills that is dotted with lakes (Clark and others, 1964a, p. 10). Many of the lakes in that area occupy sinkholes formed by solution of limestone in the underlying formations (Fairchild, 1977, p. 6). East of Trail Ridge, the land slopes to mean sea level along the St. Johns River, which drains all of the county except that part of the lake region where drainage is to the subsurface and two or three small areas along the west boundary that are drained by the Sante Fe River in the Suwannee River basin.

Geology

Several thousand feet of sedimentary rocks of various geologic ages over a basement complex of metamorphic rocks underlie the surface of north Florida (Cooke and Mossom, 1929, p. 44,45). However, in Clay County the oldest formation that has been reached by water wells is the Lake City Limestone of Eocene age. The contact between the Lake City and the underlying Oldsmar Limestone, the lowermost formation of Eocene age, lies at relatively great depth beneath Clay County as indicated by wells in nearby counties.

The pertinent geology of Clay County has been described in detail by Clark and others (1964a, p. 11-28), and is summarized in table 1. Geologic sections (fig. 2) which show stratigraphic relations and variations in thickness of the geologic formations have been modified from that report.

The principal geologic structure in the pre-Pleistocene rocks is a regional dip across the county of about 6 ft/mi to the east-northeast (Clark and others, 1964a, p. 28). Local variations of the dip, as shown by the geologic sections (fig. 2), form structural terraces or monoclines. In the lake region of southwest Clay County, slumping of beds due to solution is believed to have caused large variations in the altitude of the top of the Ocala Limestone within short distances. Tight folding or faulting may have caused the structure (Clark and others, 1964a, p. 28).

SURFACE-WATER RESOURCES

Streamflow

Streamflow is that part of surface water that appears in natural channels. In general, it is closely related to precipitation, ground water, and other occurrences of surface water, such as lakes and canals. According to Clark and others (1964a, p. 36, 37), the average annual precipitation in a four-county area that includes Clay County is about 52 in. Annual rainfall at Gainesville, about 18 miles southwest of Clay County, varied from 37.27 to 76.95 during the 20-year period 1957-76 (fig. 3). About 12 in of the rainfall in Clay County leaves the area annually as streamflow. The remainder leaves as evaporation, transpiration by plants, or ground-water outflow. The average streamflow from Clay County into the St. Johns River is about 342 Mgal/d, mostly through Black Creek (Clark and others, 1964a, p. 36).

TABLE 1.--Geologic formations penetrated by water wells in Clay County, Florida.

(Modified from Clark and others, 1964a.)

Geologic age	Geologic unit	Estimated maximum thickness (feet)[1]	Physical characteristics
Holocene and Pleistocene	Younger marine and estuarine terrace deposits	80	Sand and clayey sand, grey, brown and black, disseminated organic matter; bed of clay marl, and sandy clay. Shell marl and concentrations of shell in some areas.
Pleistocene	Older Pleistocene terrace	140	Sand, white to yellow, grey to black, clayey, organic matter; varicolored clay, sandy clay and clayey sand.
	Unnamed coarse clastics	90	Sand and clayey sand, varicolored, locally contains quartz gravels, interbedded thin lenses of clay or kaolin.
Late and Middle Miocene	Choctawhatchee Formation	40	Clay and marl, yellow to cream, indurated in part, phosphate grains and pebbles, thin limestone and sand layers, some shells.
Middle Miocene	Hawthorn Formation	250	Clay and sandy clay, varicolored, interbedded sand and sandy,phosphatic limestone; disseminated grains and pebbles of phosphate. Very hard limestone, partly dolomitic, in the lower part of the Hawthorn in some areas.
Late Eocene	Ocala Limestone	250	Limestone, white, cream and tan, soft, granular, porous, fossiliferous, coquinoid in part. Some hard layers of limestone and dolomitic limestone mostly in lower part.
Middle Eocene	Avon Park Limestone	210	Dolomite, dark brown and tan, granular, hard, dense to porous; interbedded tan and cream limestone and dolomitic limestone.
	Lake City Limestone	440+	Limestone, dolomite, and dolomitic limestone, tan, grey, and brown.

1 Variations in thickness shown in more detail on figure 2.

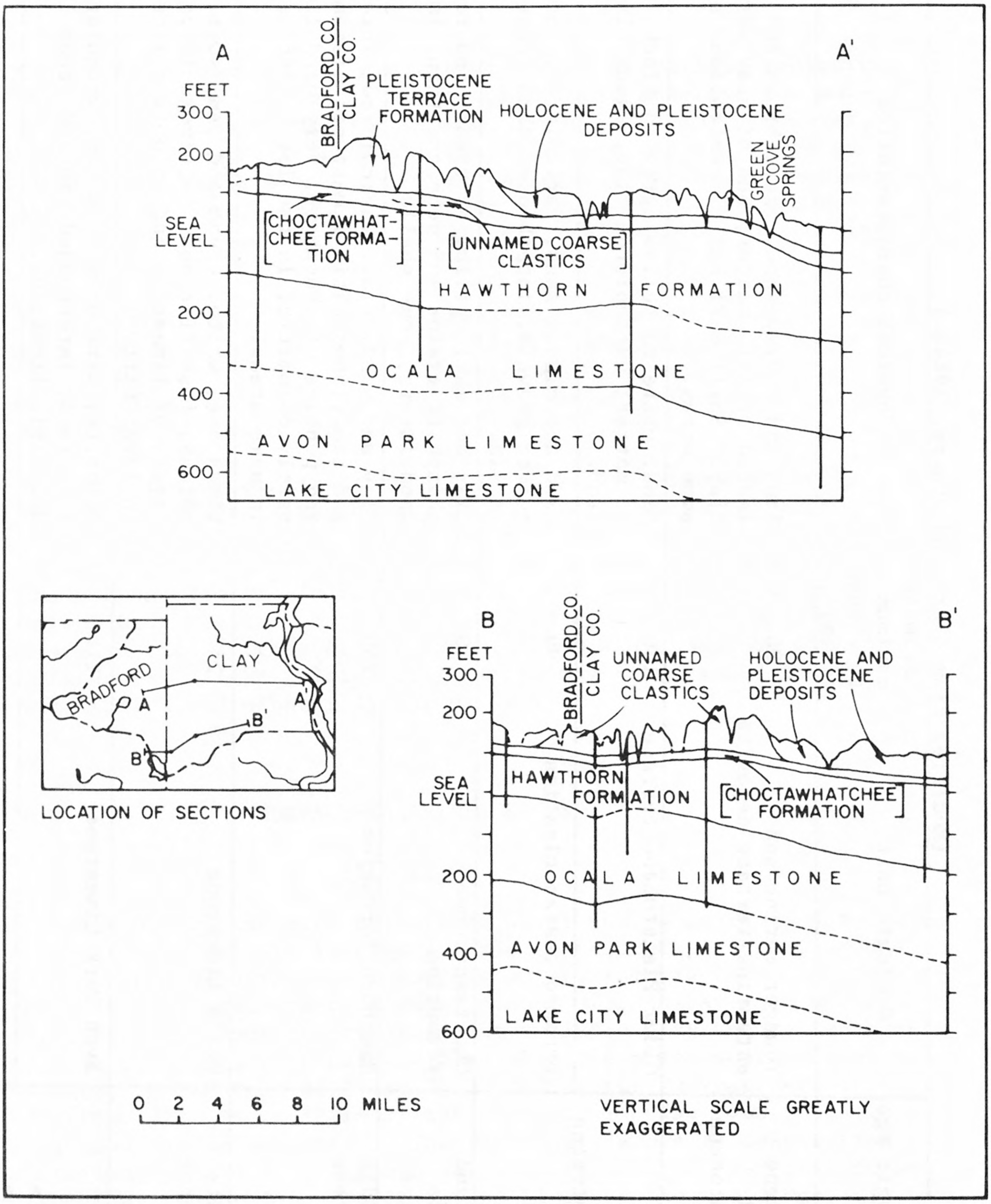

FIGURE 2.--Geologic sections in Clay County. (From Clark and others, 1964a, figs. 5, 6.)

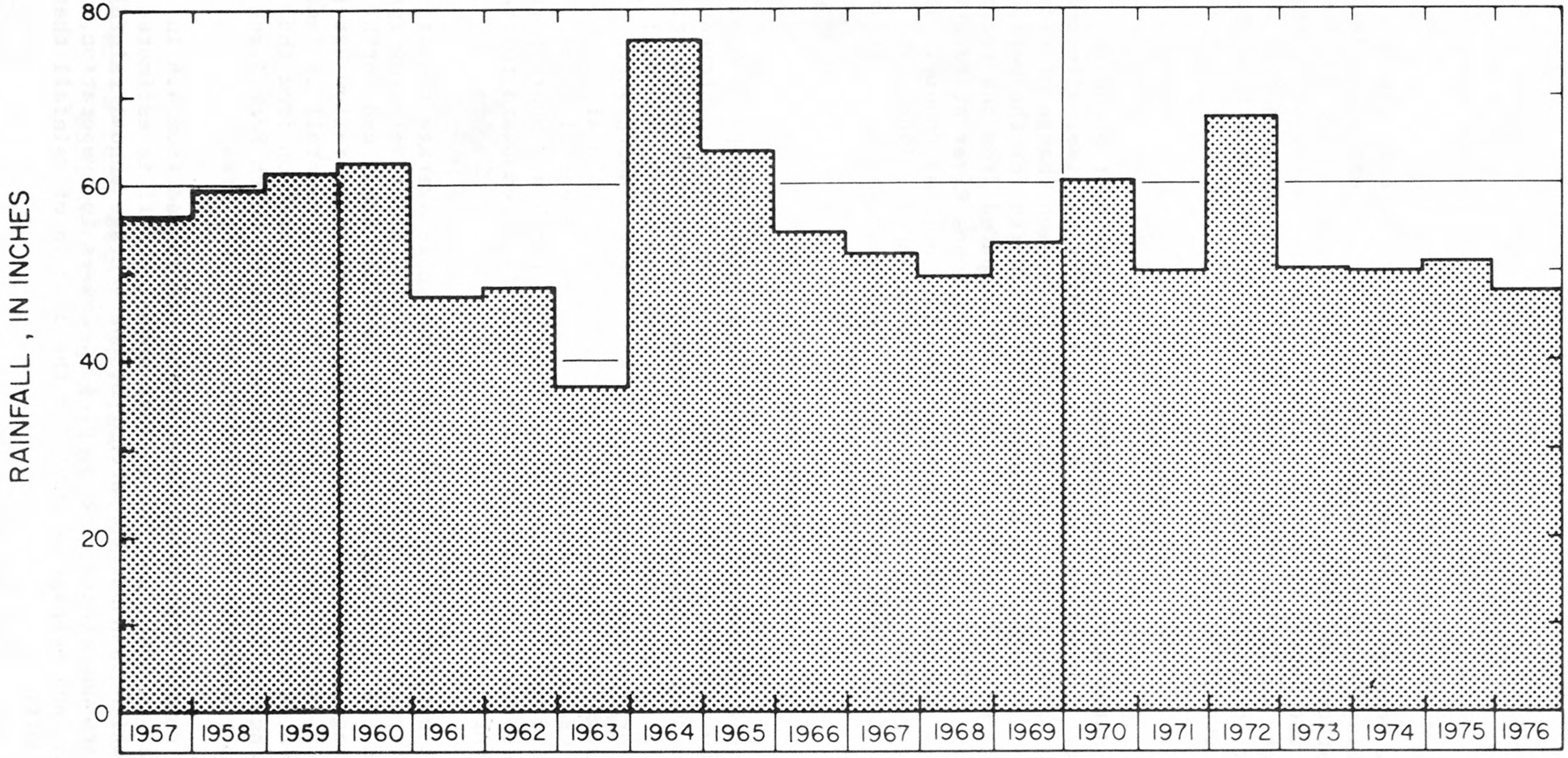

FIGURE 3.--Annual rainfall at Gainesville, Alachua County, 1957-76. (Data from National Weather Service.)

The U.S. Geological Survey has operated five stream gaging stations in Clay County for several years. Two are continuous daily discharge stations and three are crest-stage partial record stations. In addition, the Survey operates a crest stage partial record station in Duval County on Yellow Water Creek, a tributary of North Fork Black Creek. Their locations are shown on figure 4 and the data from the stations are summarized in table 2.

St. Johns River

The St. Johns River flows northward along the east boundary of the county. Its entire reach along the county is tidal affected and the stage of the river rises and falls with each change of tide. Reverse flows are common. A maximum daily discharge for the period 1968-75 of 31,300 ft^3/s on Nov. 5, 1970 was computed from the record of the Geological Survey's station on the St. Johns River at Palatka, about 10 miles upstream from the south boundary of Clay County. The maximum daily reverse flow was 20,400 ft^3/s on June 6, 1968. The average flow of the river at Palatka for the period was 7,613 ft^3/s.

Black Creek

Black Creek drains 488 mi^2, all in Clay County except 56.6 mi^2 in southern Duval County. South Fork Black Creek heads in Stevens Lake which is about 4 miles south of Kingsley Lake. Its major tributaries are Ates Creek and Greens Creek from the south, and Bull Creek, which drains the central part of the county. North Fork Black Creek heads in Kingsley Lake. Its principal tributary is Yellow Water Creek, which drains 10.5 mi^2 in north-central Clay County and 56.5 mi^2 in southern Duval County. North and South Forks join at Middleburg to form Black Creek, which flows eastward to the St. Johns River.

Figure 5 outlines Black Creek basin and shows average runoff, in inches per year, from areas within the basin. Relatively low runoff occurs in the headwater areas of Yellow Water Creek and North Fork Black Creek (Clark and others, 1964a, p. 39-41). Yellow Water Creek drains a flat swampy area, where much of the rainfall is lost to evaporation, transpiration, and seepage. Evaporation from the surface of Kingsley Lake in the headwater area of North Fork Black Creek primarily accounts for the low runoff in that area.

Average runoff from Black Creek basin has ranged from 4.6 in in 1955 to 33 in in 1948, and the average annual runoff is estimated to be 14.8 in, which is about 28 percent of the average annual rainfall of 52 in (Clark and others, 1964a, p. 43). Losses to evaporation, transpiration, and seepage account for the 37.2 in of rainfall that does not run off.

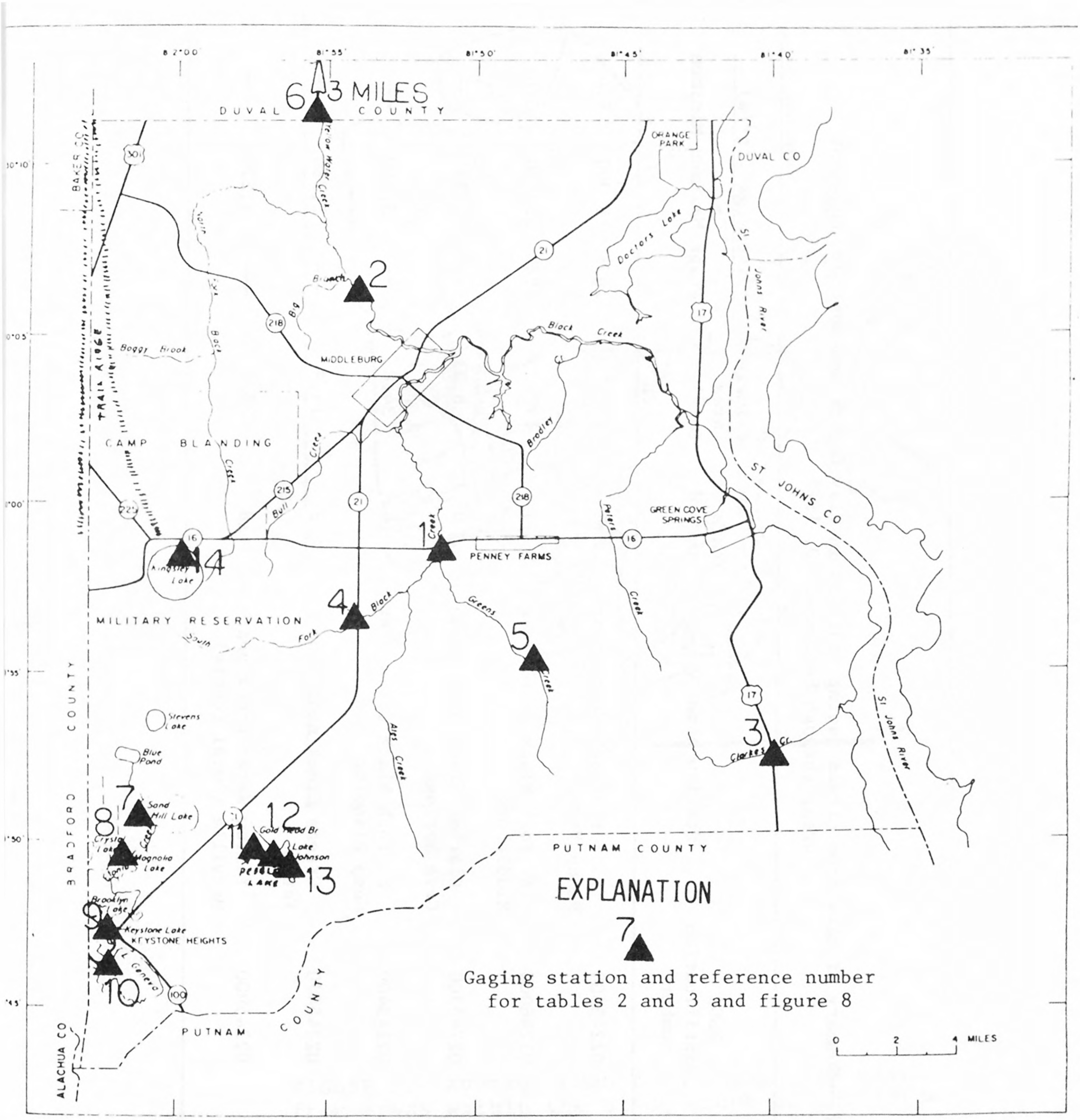

FIGURE 4.--Stream gaging and lake stage stations operated by the U.S. Geological Survey in Clay County.

TABLE 2.--Summary of data from stream gaging stations in Clay County and upstream adjacent areas through September 30, 1975.

Reference number (fig. 4)	USGS identification number	Station name	Years of record	Drainage area (mi^2)	Discharge (ft^3/s)		
					Average	Maximum	Minimum
1	02245500	S. Fork Black Creek near Penny Farms	36	134	163	13,900	9.4
2	02246000	N. Fork Black Creek near Middleburg	44	177	196	12,600	3.6
3	02245300	Clarkes Creek near Green Cove Springs	10	8.81	---	895	---
4	02245400	S. Fork Black Creek near Camp Blanding	18	34.8	---	3,240	---
5	02245470	Greens Creek near Penny Farms	18	14.9	---	1,780	---
6	02245900	Yellow Water Creek near Maxville (Duval County)	18	25.7	---	3,220	---

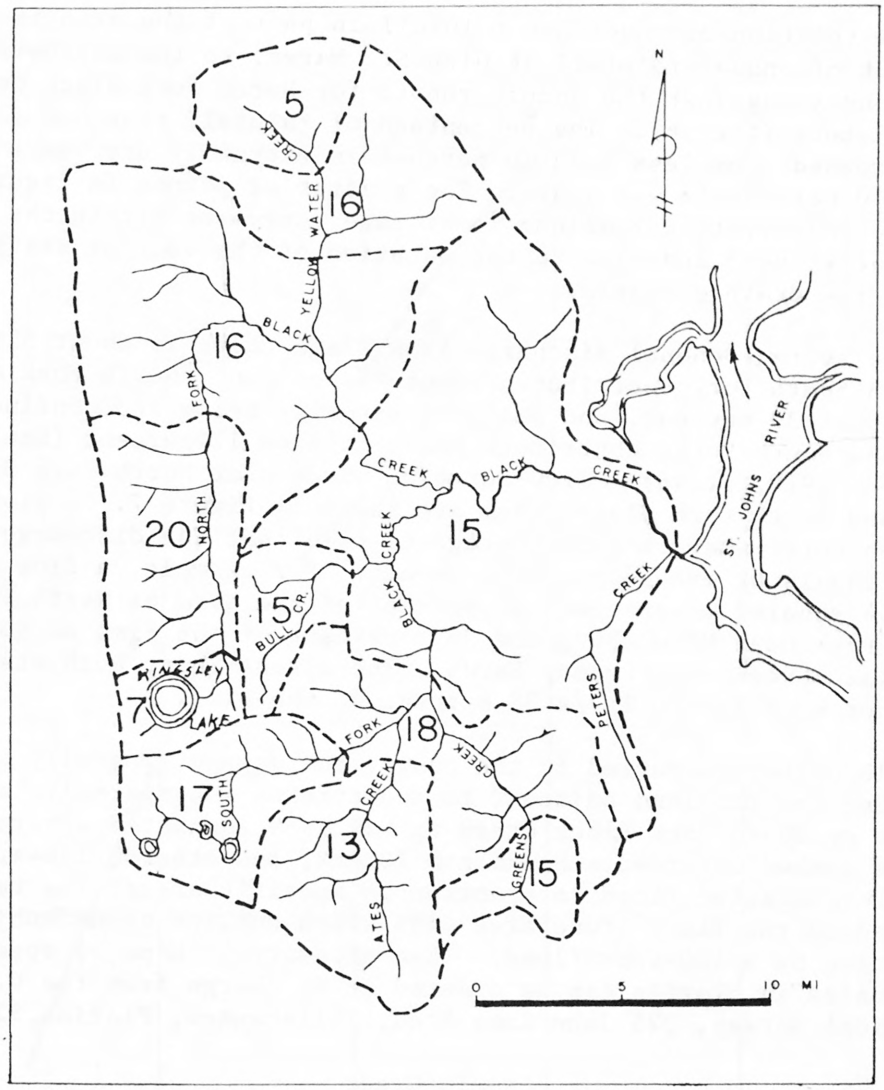

FIGURE 5.--Average runoff in inches per year from areas within the Black Creek basin. (From Clark and others, 1964a.)

The relation of runoff to rainfall in part of the area is shown by a plot of annual rainfall at Glen St. Marys, to the northwest in Baker County, against the annual runoff for North Fork Black Creek at Middleburg (fig. 6). The percentage of rainfall that becomes runoff increased from less than 10 percent in extremely dry years to nearly 40 percent in wet years. The scatter of points in figure 6 is due primarily to variations in storage carryover within the basin from year to year and also to the location of the weather station outside the drainage basin.

The average annual discharge from Black Creek is about 515 ft^3/s, of which South Fork contributes about 44 per cent, North Fork contributes about 39 percent, and small tributaries below the confluence of North and South Forks contribute the remaining 17 percent (Snell and Anderson, 1970, p. 46). Flow-duration curves for North Fork Black Creek and South Fork Black Creek are shown in figure 7. A flow-duration curve shows the percentage of time that the discharge of the stream equals or exceeds a given amount. For example, a flow of 20 ft^3/s is equaled or exceeded 90 percent of the time at North Fork Black Creek near Middleburg and 98.5 percent of the time at South Fork Black Creek near Penney Farms. The discharge at both stations equals or exceeds 100 ft^3/s 38 percent of the time.

Floods have occurred in the basin, but damage generally has been light because the land adjacent to the streams was sparsely settled. A flood on South Fork Black Creek in May 1959 inundated several bridges and washed out road embankments (Clark, and others, 1964a, p.46, 47). For detailed flood information in specific areas, the reader is referred to the flood prone area maps which outline areas subject to inundation by a 100-year flood. (See glossary.) Maps of specific quadrangles in Florida can be ordered at no charge from the U.S. Geological Survey, 325 John Knox Road, Tallahassee, Florida 32303.

Etonia Creek

The headwaters of Etonia Creek and its tributaries from the north drain about 90 mi^2 of southern Clay County. The upper 150 mi^2 of the basin in southwest Clay County and northwest Putnam County contain approximately 100 lakes, many of which have no surface outlet (Clark and others, 1964a, p. 60). Runoff from the upper part of the basin is extremely low primarily because of seepage to ground water and evaporation from the lakes. The estimated average annual discharge of Etonia Creek at Florahome in Putnam County, a drainage area of 172 mi^2, is 4 in (51 ft^3/s) [Clark, and others, 1964a, p. 65]. Floods in the upper part of the basin have occurred in several years, and in September 1946, a flood at Keystone Heights and Lake Geneva, caused by heavy rains throughout the summer, damaged homes, septic tanks, lawns and shrubs and flooded streets (U.S. Army Corps of Engineers, 1975, p. 9, 10).

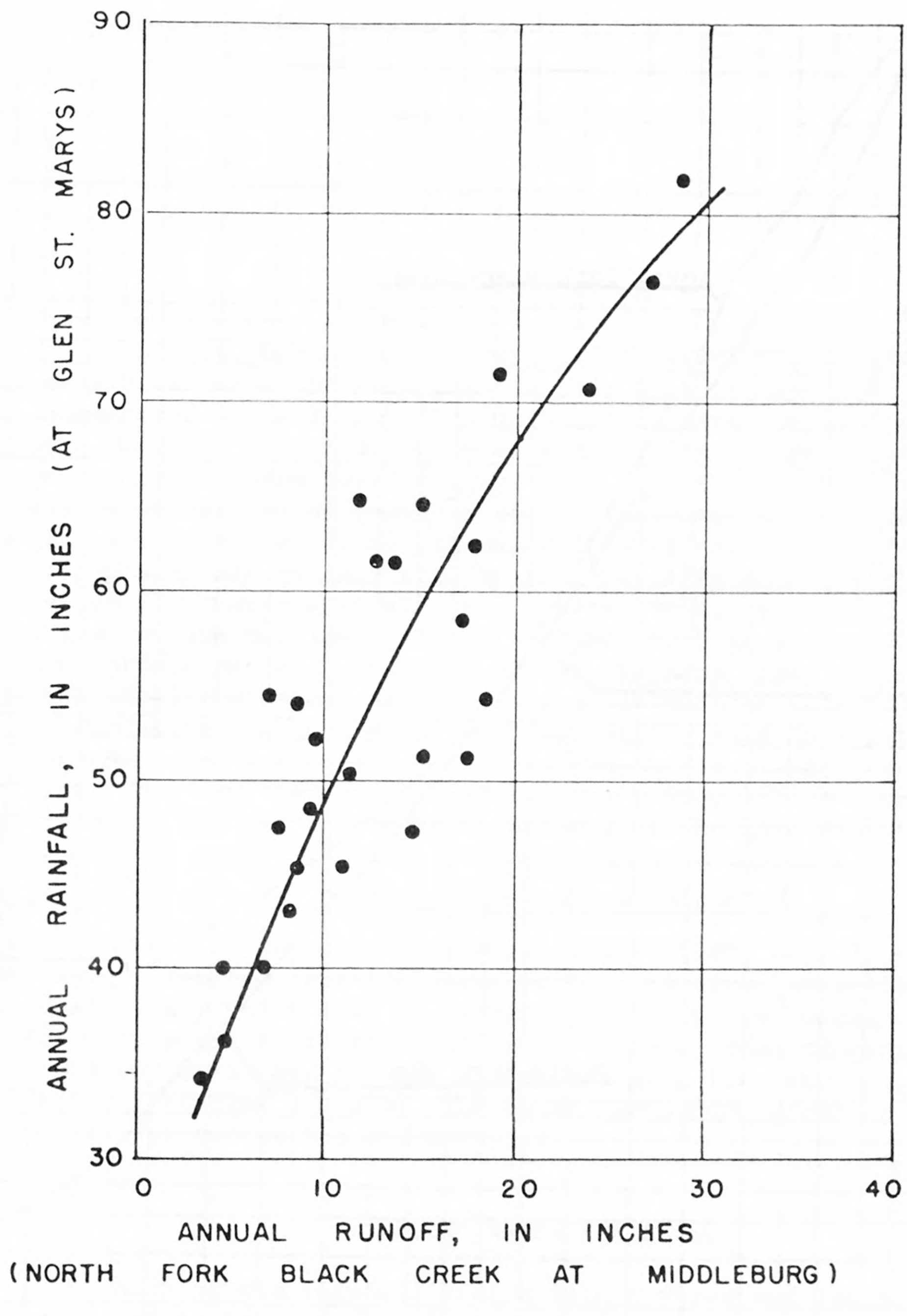

FIGURE 6.--Rainfall-runoff relation. (From Clark and others, 1964a, fig. 16.)

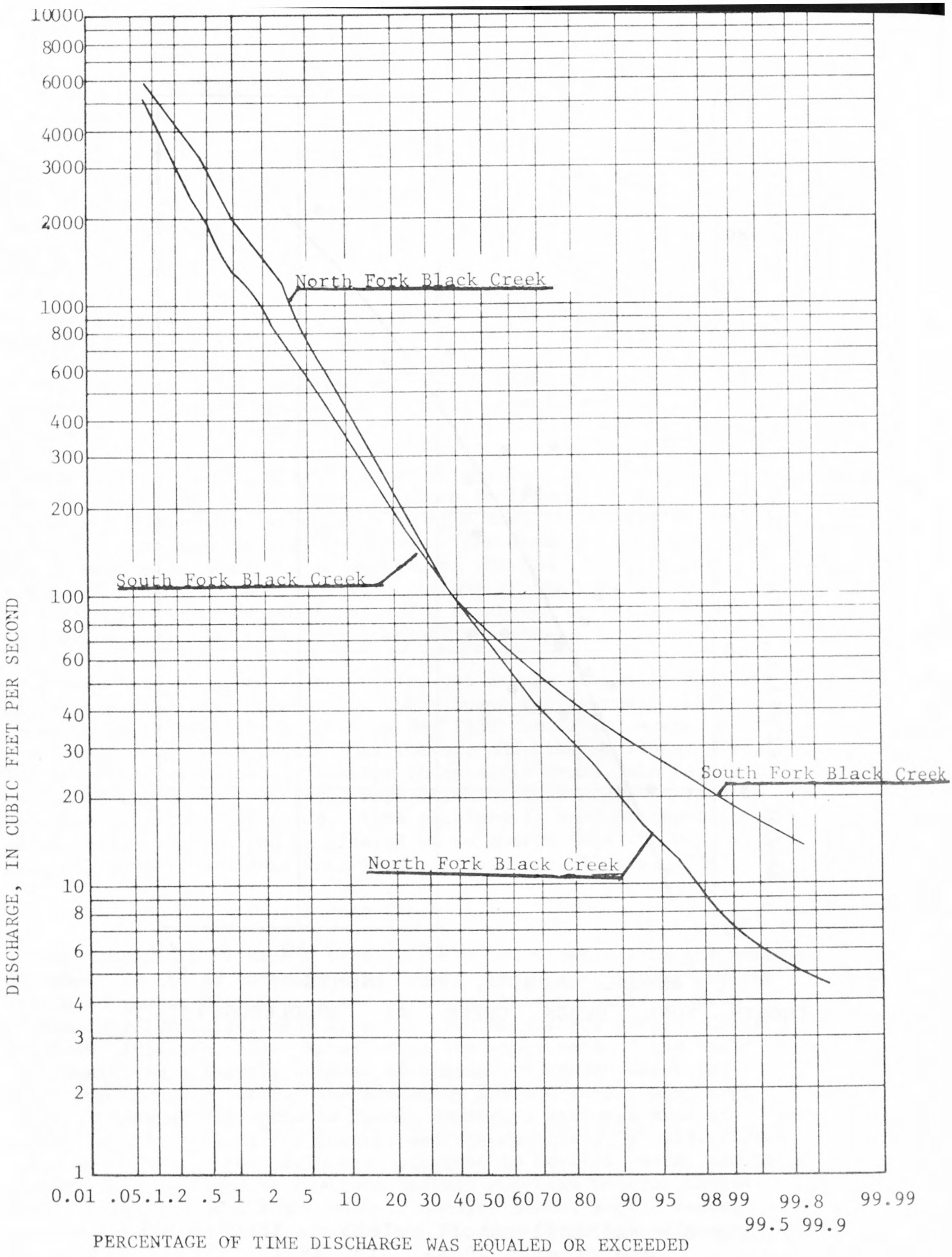

FIGURE 7.--Flow-duration curves for North Fork Black Creek near Middleburg and South Fork Black Creek near Penney Farms.

Lakes

The U.S. Geological Survey has collected stage records for several years at eight selected lakes in Clay County. The records are summarized in table 3. This detailed information can be obtained in the Survey's annual water-data reports. The range of stage varies considerably from lake to lake (fig. 8). Variation in rainfall (fig. 3) is the principal cause of stage fluctuations, but since all these lakes receive nearly identical amounts of rainfall, differences in topography and geology account for the differences in the range of stage fluctuations (Clark and others 1964a, p. 60-63). Lakes which have surface outflow tend to fluctuate much less than lakes that have no surface outlet. The size of the drainage area, the topography of the site, the nature of the geologic formations that underlie and surround the lake, and the altitude of the lake in relation to that of the local water table determine whether the lake has a surface outlet. Two reports by Clark and others (1963, 1964a) contain detailed illustrations and information on many of the lakes in Clay County.

Potenial Surface-Water Development

The U.S. Department of Agriculture (1969, sec. 7, p. 13-14, fig. 4) located fourteen stream sites and five lakes (fig. 9) in Clay County which they consider suitable for impoundments. The reservoirs would be fairly small with surface areas ranging from 200 to 2,000 acres and storage amounts ranging from about 1,200 to 33,700 acre-ft (tables 4 and 5). The water impounded would be used principally for recreation and irrigation.

GROUND-WATER RESOURCES

Much of the rainfall drains into streams and lakes. Some is absorbed by the soil and rocks and eventually moves downward through the ground to the zone of saturation, where the voids in the rocks are completely filled with water, referred to as ground water. Ground water moves laterally from the recharge areas to areas of lower hydrostatic head and eventually is discharged by evapotranspiration, seepage, springs or wells. It occurs under water-table and artesian conditions (See Glossary.) Ground water in Clay County occurs in a water-table aquifer, in secondary artesian aquifers, and in the Floridan aquifer (fig. 10).

TABLE 3. Summary of data from lake-stage stations in Clay County through September 30, 1975.

Reference number (fig. 4)	USGS site identification number	Station name	Years of record	Surface area (acres)	Drainage area (mi^2)	Maximum daily stage (ft) and date	Minimum daily stage (ft) and date	Remarks
7	02244600	Sand Hill Lake near Keystone Heights.	18	1,250	11.0	132.75 9/22/64	130.74 5/26/68	Also known as Lowry Lake.
8	02244650	Magnolia Lake near Keystone Heights.	17	201	14.4	125.91 9/12/73	123.08 5/25/68	Temporary earthen dam at lake outlet at time of maximum stage.
9	02244750	Brooklyn Lake at Keystone Heights.	18	635	17.4	117.43 10/1/60	97.23 2/24/58	Maximum stage 118.2 ft in 1948 reported.
10	02244800	Lake Geneva at Keystone Heights.	18	1,746	35.5	107.23 7/15/73	99.79 10/17/58	Maximum stage 109.1 ft in 1948 reported.
11	02244850	Pebble Lake near Keystone Heights.	30	9.5	0.19	116.36 7/11/48	84.24 4/28/57	Lake has no outlet.
12	02244900	Lake Johnson (Little Lake) near Keystone Heights.	30	34.6	6.37 (12 and 13 combined)	about 105 10/48	90.87 8/12/75	Gold Head Branch flows into Little Lake; Little Lake was first separated from Big Lake below an altitude of about 95 ft by a shallow channel and earthen dam, which was constructed June 30, 1957; the channel was deepened and a control with removable boards was constucted during August 1968. On January 17, 1969, the dam was found partially washed out and a new dam was constructed in April 1969; the top of the new dam is at an altitude of about 96 ft. Lake Johnson has no surface outlet.
13	02244905	Lake Johnson (Big Lake) near Keystone Heights.	16	441		98.3 3/4/66	89.98 9/29/75	
14	02245700	Kingsley Lake near Camp Blanding.	30	1,627	6.84	117.82 10/21/50	174.34 4/23/56	Lake outlet has fixed concrete (broken) weir with average crest altitude of about 176 ft.

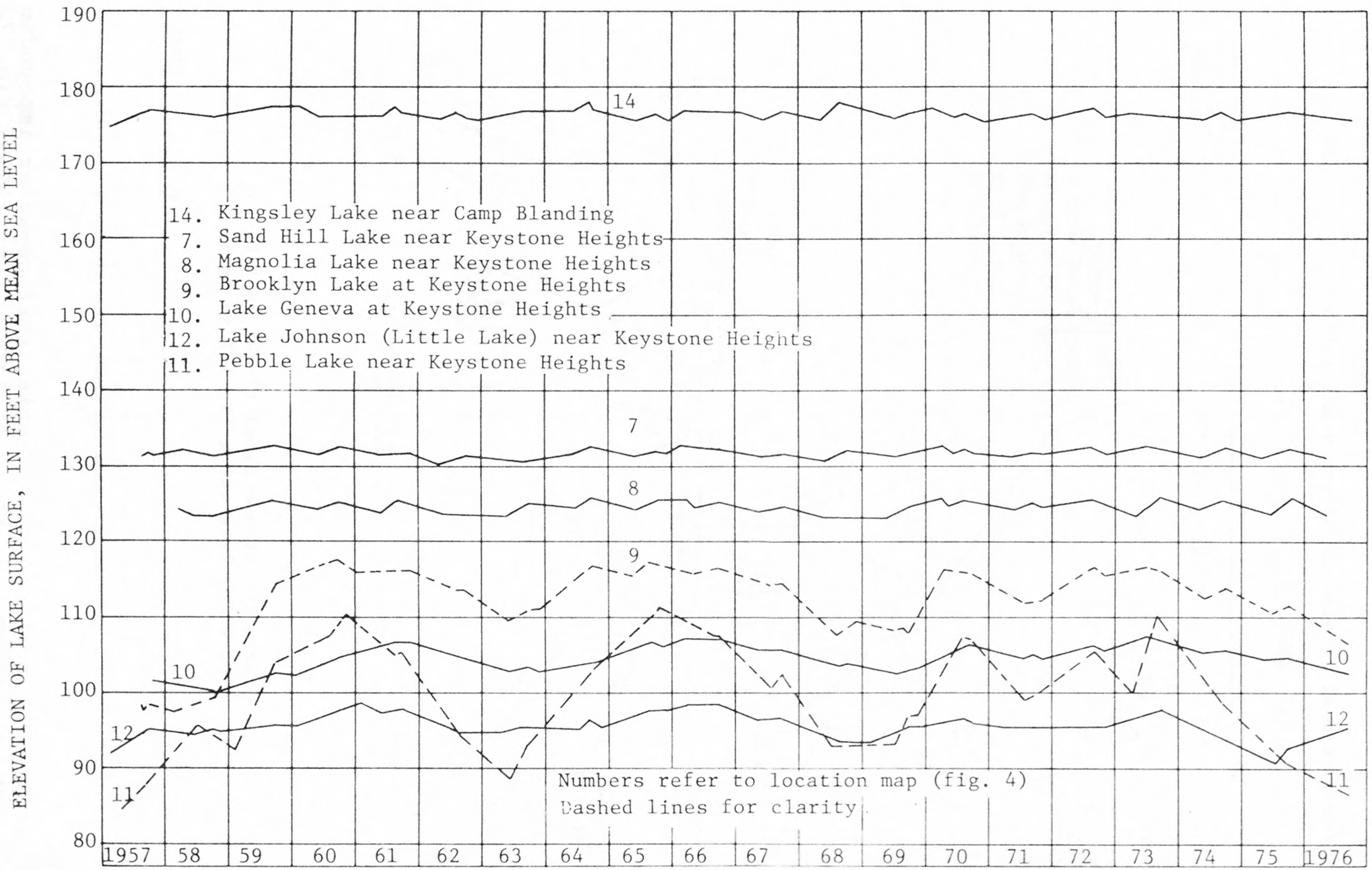

FIGURE 8.--Stage hydrographs of selected lakes in Clay County.

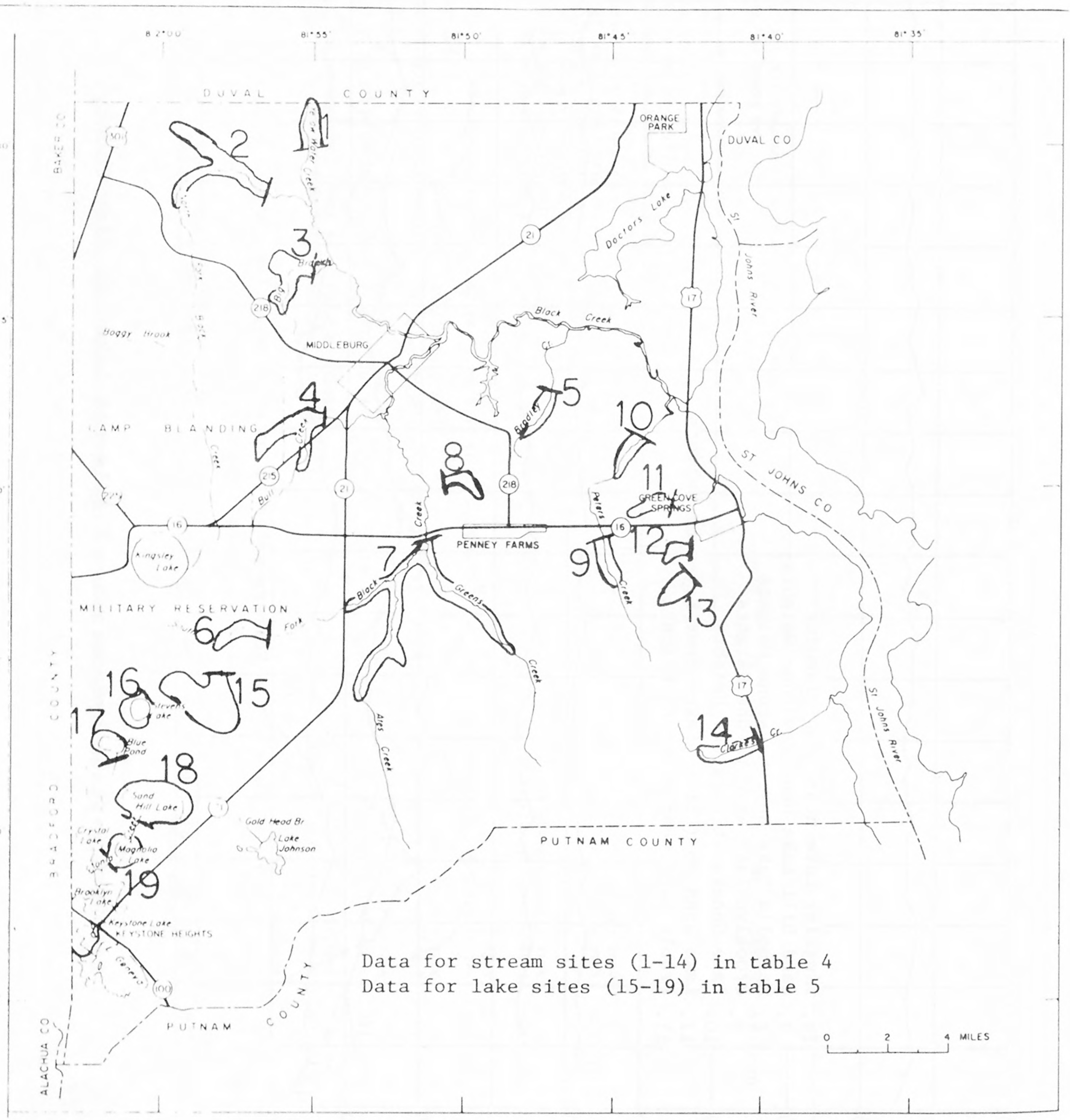

FIGURE 9.--Approximate locations of potential surface-water impoundment sites in Clay County. (From U.S. Dept. of Agriculture, 1969, fig. 7.4.)

TABLE 4.--Potential impoundments on streams in Clay County.

(From U.S. Department of Agriculture, 1969, table 7.14).

Reference number (fig. 9)	Name	Drainage area (mi^2)	Stage (Ft MSL)	Surface area (Acres)	Storage (Acre-ft)
1	Yellow Water Creek	68.0	50	1,000	12,000
2	North Fork Black Creek	84.0	60	1,200	33,700
3	Big Branch	9.4	60	700	11,300
4	Bull Creek	24.7	60	1,000	16,200
5	Bradley Creek	2.8	60	200	2,000
6	South Fork Black Creek	26.4	100	400	5,600
7	Do.	133.6	50	1,900	19,500
8	Tributary South Fork Black Creek.	9.9	60	400	6,000
9	Peters Creek	6.0	60	200	2,700
10	Do.	15.5	60	300	3,700
11	Unnamed, near Green Cove Springs.	3.2	60	200	3,500
12	Tributary Governors Creek	5.1	60	200	3,300
13	Governors Creek	18.7	25	600	6,600
14	Clarks Creek	8.9	60	400	5,500

TABLE 5.--Potential impoundment on lakes in Clay County.

(From U.S. Department of Agriculture, 1969, table 7.13.)

Reference number (fig. 9).	Name	Drainage area (acres)	Stage (ft)		Surface area (acres)		Additional storage with structure (acre-ft)
			Present	With structure	Present	With structure	
15	Varnes & Whitmore Lakes	9,678	110	130	342	1,311	16,530
16	Stevens Lake	1,620	155	160	225	301	1,315
17	Blue Pond	1,591	174	190	216	497	5,704
18	Sand Hill (Lowry) Lake	6,963	132	140	1,234	1,413	10,588
19	Magnolia Lake	8,585	125	130	198	280	1,195

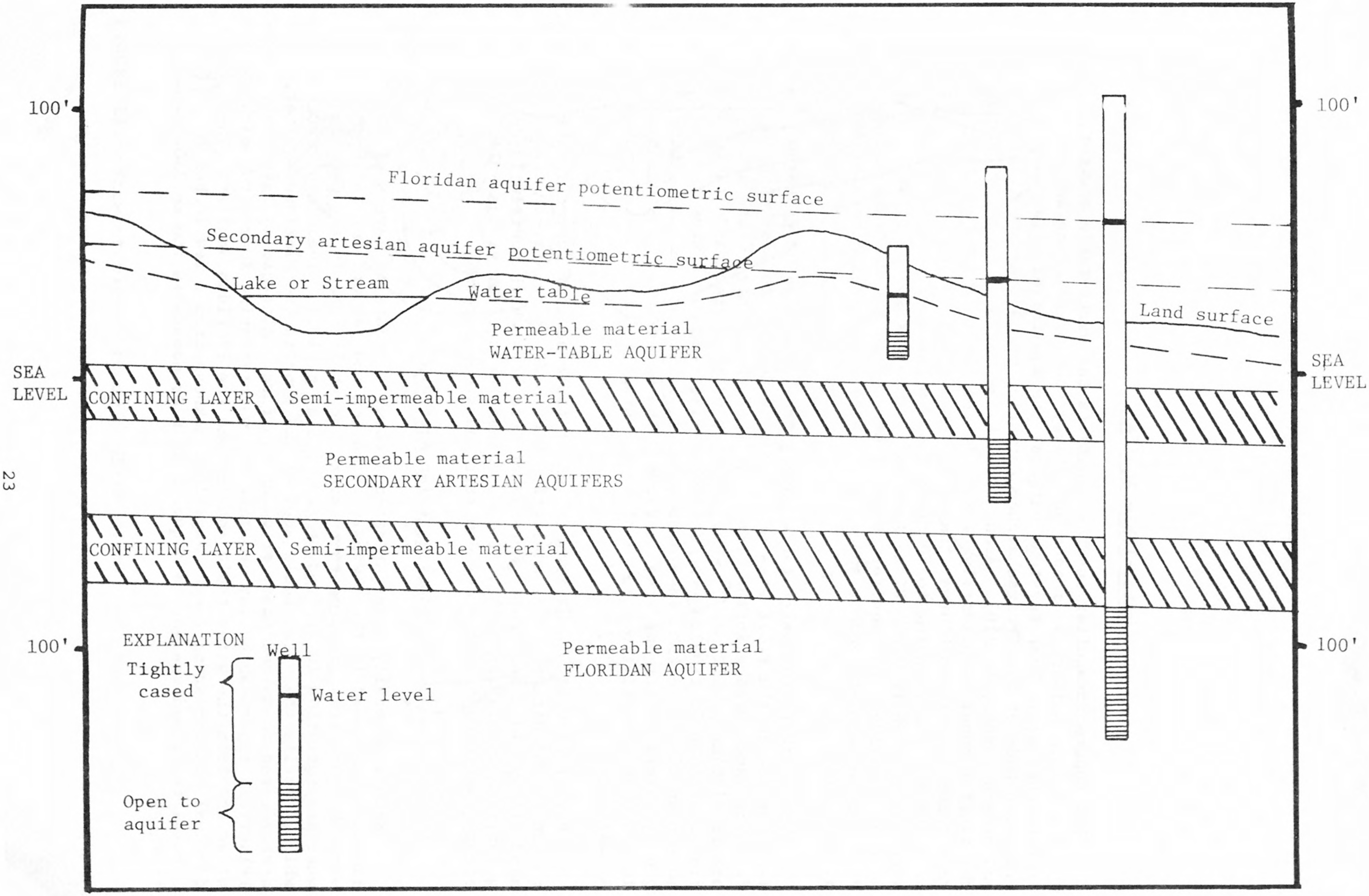

FIGURE 10.--Idealized section showing relation of aquifers in discharge areas of eastern Clay County.

Water-Table Aquifer

The uppermost aquifer in Clay County is the water-table aquifer, which consists primarily of sand and clayey sand of Holocene and Pleistocene, age. Near Keystone Heights, the aquifer also includes limestone beds of the Choctawhatchee Formation of Miocene age (Clark and others, 1964a, p. 110). Along Trail Ridge north of Kingsley Lake, the aquifer consists primarily of sand in the older Pleistocene terrace deposits. In that area, the aquifer has a maximum thickness of about 130 ft, thinning to 70 ft or less in the area south of Kingsley Lake where Trail Ridge fans out into a series of hills. East of the ridge, the aquifer consists of sand in the Holocene and Pleistocene deposits and is about 50 ft thick (Clark and others, 1964a, p. 110, 112).

The depth to the water table ranges from more than 20 ft below land surface in the ridge area near Keystone Heights to less than 10 ft below land surface in the eastern part of the county (Clark and others, 1964a, p. 112, 113). The altitude of the water table ranges from less than 40 ft along the St. Johns River and Black Creek to more than 200 ft in the ridge area (fig. 11). The aquifer is recharged by rainfall, streams, and lakes, and the water level fluctuates in response to variations in rainfall and stage in nearby lakes and streams.

Potential well yields from the water-table aquifer depend on the thickness and nature of the aquifer. Thick beds of relatively coarse sand will yield considerably more water than beds which contain large quantities of clay and silt. In most areas the aquifer yields sufficient quantities of water for domestic and stock purposes.

Secondary Artesian Aquifers

Water, generally under artesian pressure, occurs in layers of limestone and sand in the Hawthorn Formation and, except for the Keystone Heights area, in limestone layers and shell beds in the Choctawhatchee Formation (Clark and others, 1964a, p. 115). These aquifers, which underlie the water-table aquifer and overlie the Floridan aquifer, are referred to as secondary artesian aquifers. Alternating layers of relatively impermeable clay separate the water-bearing zones from each other and from the water table aquifer and the Floridan aquifer. Individual water-bearing zones range in thickness from a few inches to several feet, and the entire sequence in Clay County is 150 to 250 ft thick.

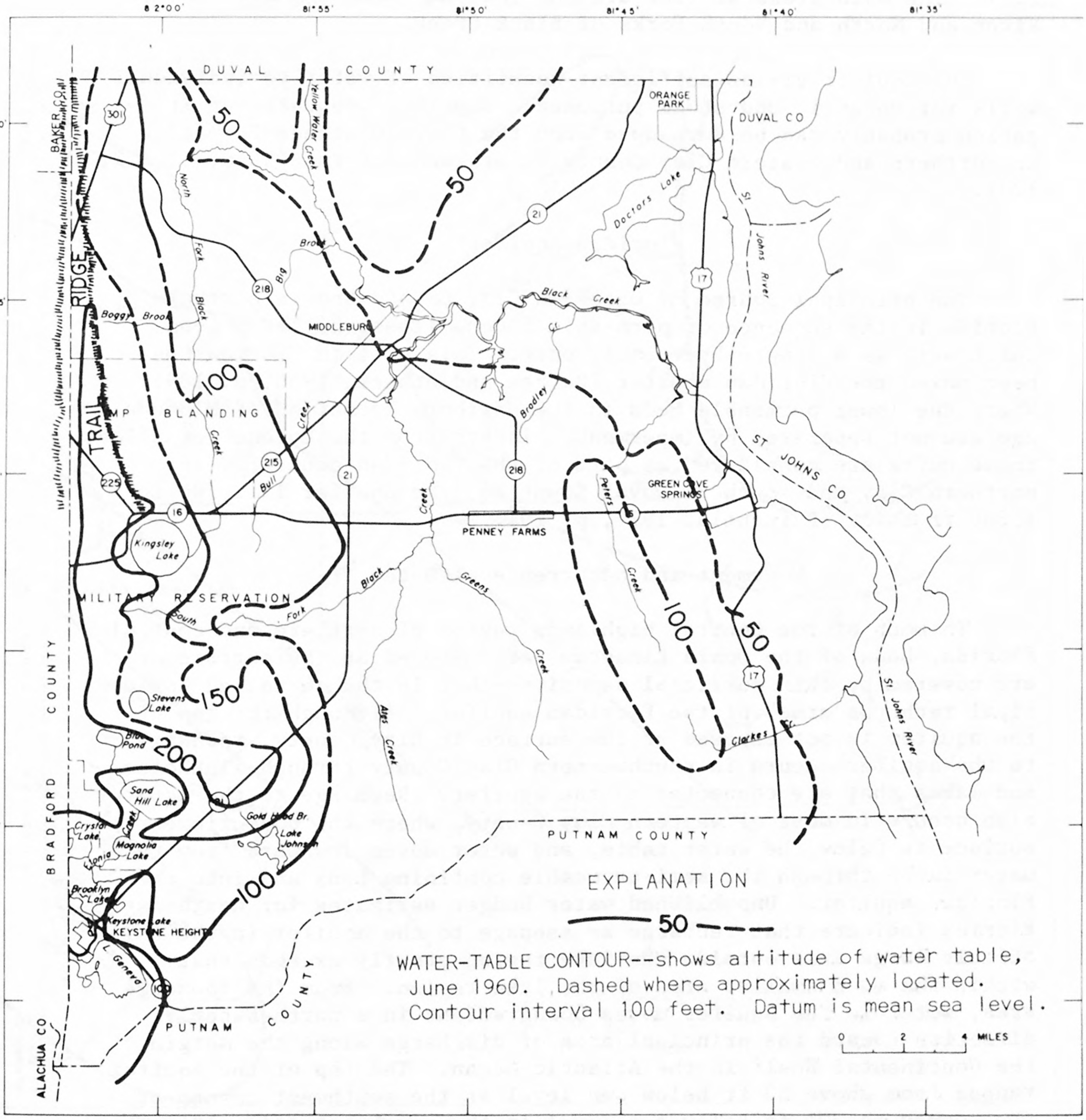

FIGURE 11.--Water-table altitude. (From Clark and others, 1964a, fig. 74.)

The potentiometric surfaces of the secondary artesian aquifers in Clay County generally are between the water table and the potentiometric surface of the Floridan aquifer. Wells that tap the secondary artesian aquifers will flow in most areas where wells that tap the Floridan aquifer will flow (Clark and others, 1964a, p. 115, 117). The main areas of flow are the lowlands near the St. Johns River and North and South Forks of Black Creek.

The aquifer yields sufficient quantities of water to individual wells for domestic and stock purposes. Supplies adequate for irrigation probably can be developed from the Choctawhatchee Formation in northern and eastern Clay County (Clark and others, 1964a, p. 118, 120).

Floridan Aquifer

The principal source of water in Clay County and in northern Florida is the sequence of permeable Eocene limestone formations which acts as a single hydrologic unit. This unit in Florida has been named the Floridan aquifer (Parker and others, 1955, p. 189). Where the lower permeable beds in the Hawthorn Formation of Miocene age are not separated by impermeable layers from the Eocene formations, these units are considered as part of the Floridan aquifer. In northern Clay and southern Duval Counties, the aquifer is 1,100 to 1,800 ft thick (Fairchild, 1977, p. 19).

Movement and occurrence of water

In much of the Central Highlands region of northern and central Florida, beds of the Ocala Limestone are exposed at the surface or are covered by thin surficial deposits--that is the so-called "principal recharge area" of the Floridan aquifer. Although the top of the aquifer is not exposed at the surface in Clay County, recharge to the aquifer occurs in southwestern Clay County through sinkholes and lakes that are connected to the aquifer. Recharge to the aquifer also occurs in most of western Clay County, where the potentiometric surface is below the water table, and water moves downward from the water table through the semi-permeable confining beds and into the Floridan aquifer. Unpublished water budget estimates for northeast Florida indicate that recharge as seepage to the aquifer in the relatively large area outside the lake region greatly exceeds that within the much smaller area of the lake region. From the recharge area, water in the aquifer moves downgradient in a northeasterly direction toward the principal area of discharge along the margin of the Continental Shelf in the Atlantic Ocean. The top of the aquifer ranges from above 50 ft below sea level at the southwest corner of the county to 300 ft below sea level in the northeast (fig. 12). The

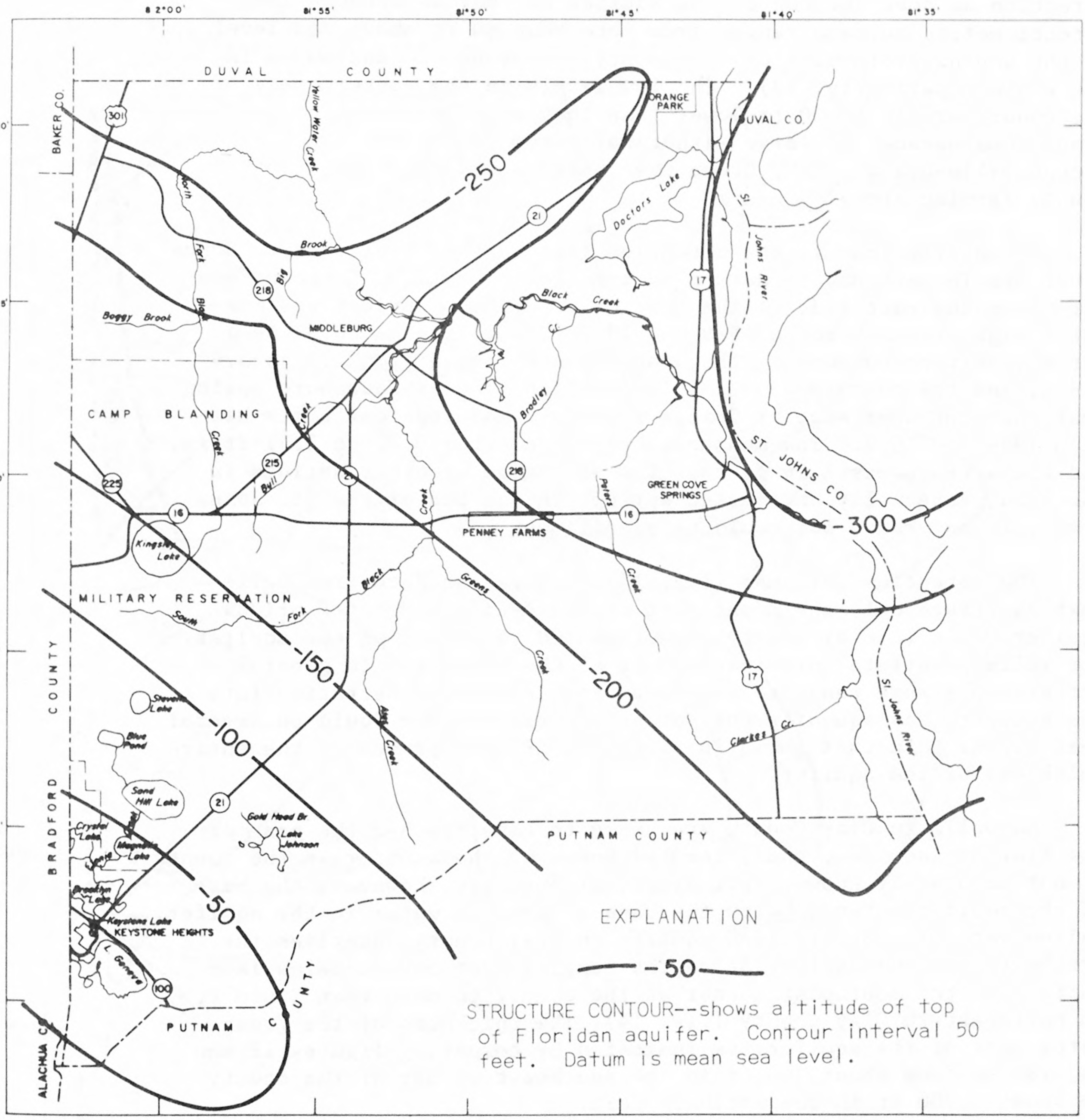

FIGURE 12.--Altitude of the top of the Floridan aquifer. (From Vernon, 1973.)

potentiometric surface of the aquifer slopes in the same general direction as does the top of the aquifer but not as steep. The potentiometric surface ranges from more than 80 ft above sea level in the southwestern part of the county to between 20 and 30 ft in the eastern part (fig. 13). The low levels in the eastern part of the county are 10 to 30 ft lower than they would be under natural conditions because of large withdrawals from the aquifer in the Jacksonville-Orange Park, Green Cove Springs and southern St. Johns County farming areas.

The depressions in the potentiometric surface near the St. Johns River are in part due to natural discharge. The flow of Green Cove Spring on the east side of the town of Green Cove Springs was measured eight times between 1929 and 1972 (J. C. Rosenau, U.S. Geol. Survey, written commun.). The measurements ranged from 2.2 to 5.4 ft^3/s, and the average was 3.52 ft^3/s. The flow at Wadesboro Spring near the southwest edge of Orange Park was measured four times between 1946 and 1972. The measurements ranged from 0.72 to 1.41 ft^3/s, and the average was 1.16 ft^3/s. The discharge of other springs in the area, especially undetected springs in the bed of the St. Johns River, is not known but could be significant.

The potentiometric map (fig. 13) is based on data from wells that penetrate only the upper part of the aquifer. Most Floridan aquifer wells in Clay County penetrate 100 to 300 ft of the aquifer. Few wells penetrate more than 400 ft of the aquifer. In general, artesian pressure tends to increase with depth of penetration into the aquifer; consequently the potentiometric surface would be several feet higher than that shown in Figure 13 if it represented the entire thickness of the aquifer.

No wells in Clay County are known to have reached the base of the Floridan aquifer; thus, the thickness of the aquifer in the county is not accurately known. For practical purposes, however, the base of the aquifer extends below the base of potable water in the aquifer. Saline water in the Floridan aquifer in Clay County underlies the freshwater in the aquifer at depths ranging from 500 ft below land surface in the southeast corner of the county to more than 2,000 ft in northeastern Clay County (fig. 14). The thickness of the freshwater part of the aquifer, as indicated by comparing figures 12 and 14, ranges from about 300 ft in the southeast corner of the county to about 1,700 ft in the northern part.

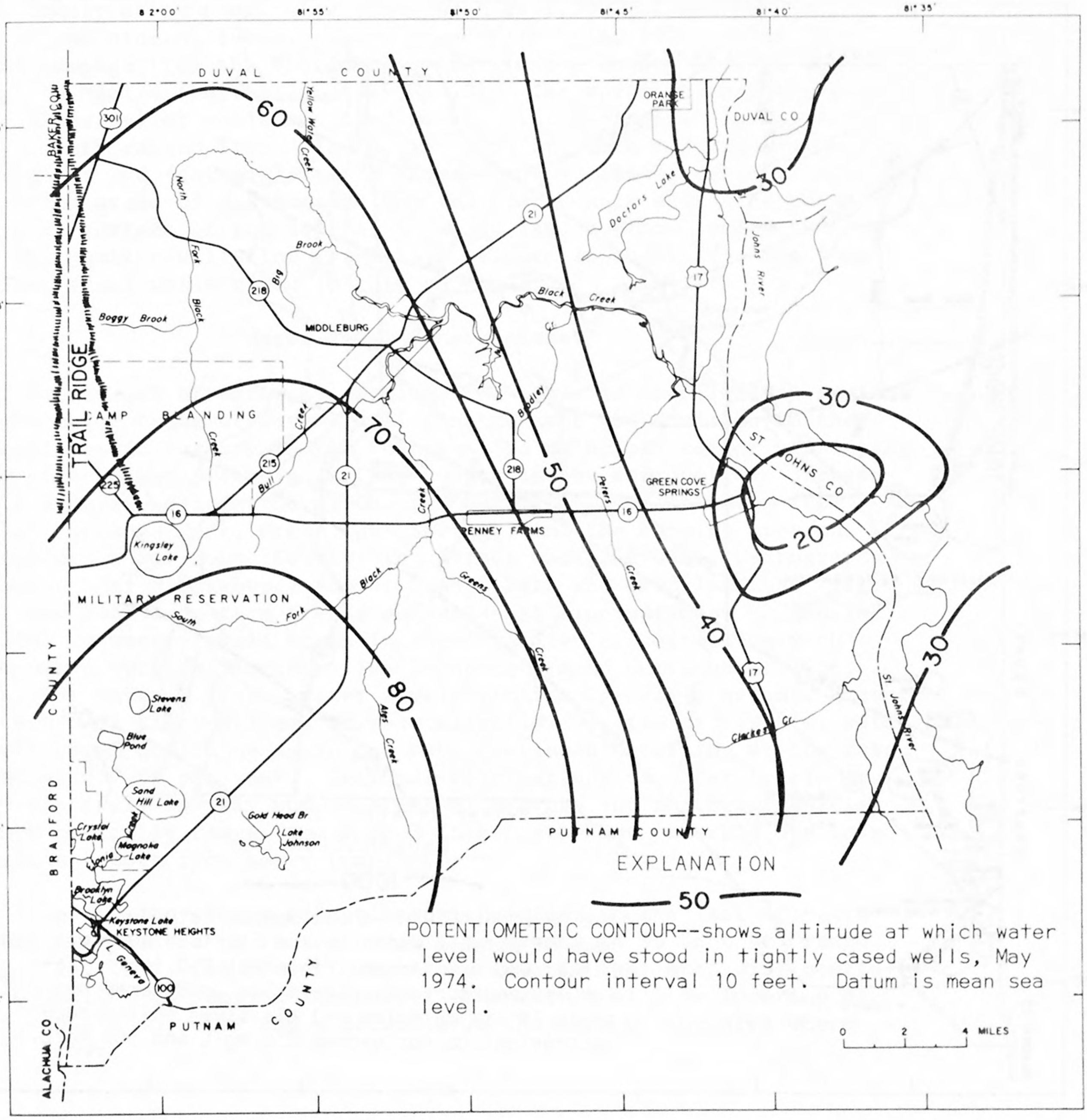

FIGURE 13.--Potentiometric surface of the Floridan aquifer. (From Healy, 1975.)

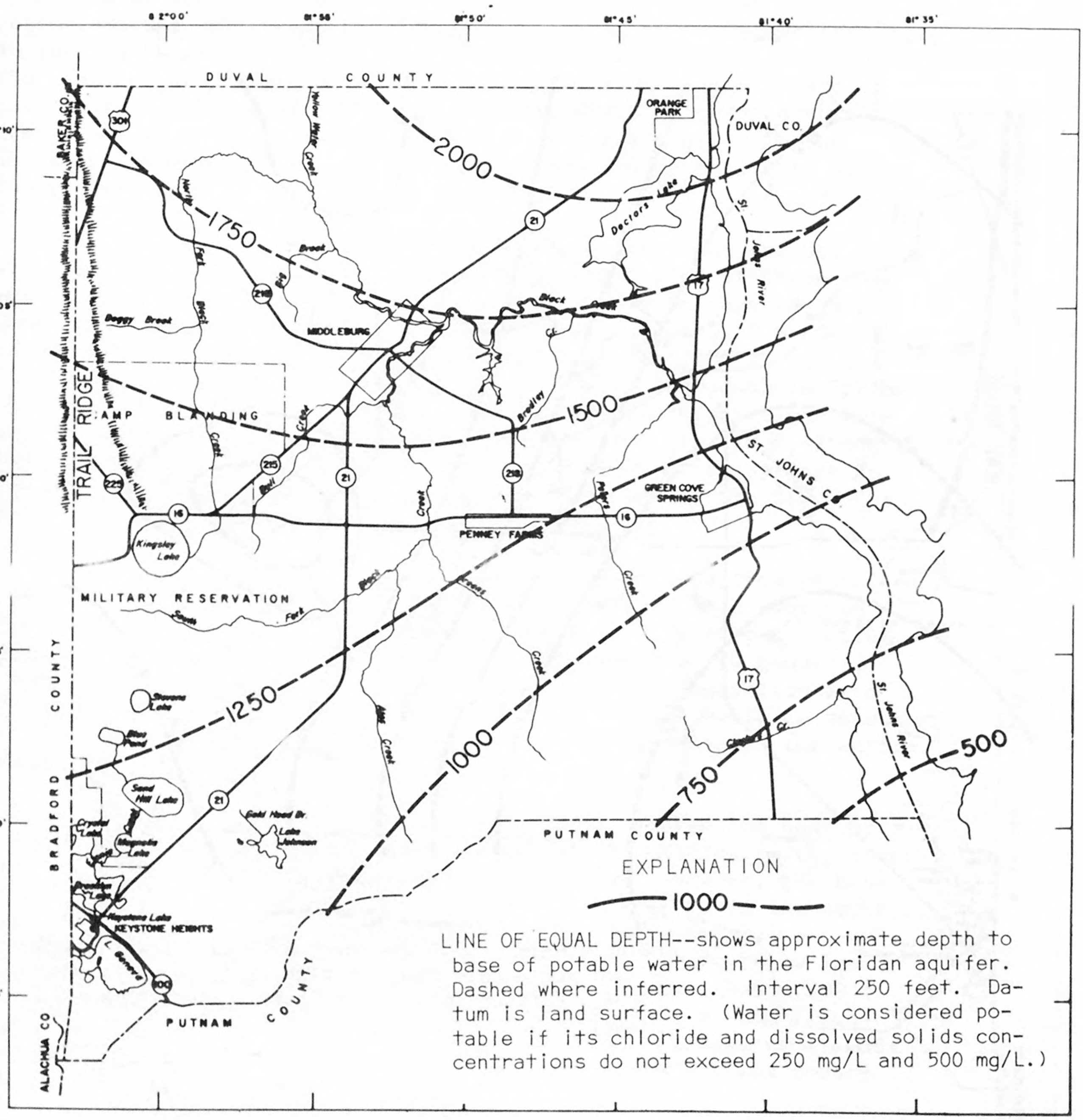

FIGURE 14.--Depth to base of potable water in the Floridan aquifer. (From Klein, 1975.)

Wells

The Floridan aquifer supplies water to more than 150 wells in Clay County at pumping rates of as much as 2,500 gal/min per well (Clark and others, 1964b, table 3; and Fairchild, 1977, table 3). Total pumpage from the Floridan aquifer in the county in 1974 was about 10 Mgal/d (Fairchild, 1977, p.40). The specific capacities (see Glossary) of wells measured by the U.S. Geological Survey in Clay County ranged from 2 to 20 (gal/min)/ft, with reported values as high as 300 (gal/min)/ft (Clark and others, 1964a, table 9). In low-lying areas of eastern and central Clay County where the potentiometric surface of the aquifer is above land surface, wells that tap the aquifer will flow (fig. 15). Figure 16 shows the locations of individual wells cited in this report.

Water-level fluctuations

Withdrawal of water by pumping from wells in the Floridan aquifer is the major cause of water-level fluctuations and declines in the potentiometric surface in the County. The principal center of pumping that affects water levels in Clay County is the metropolitan Jacksonville area in adjacent Duval County, but withdrawal of water from wells in Orange Park, Green Cove Springs, and the farming area in southwestern St. Johns County also affect water levels. Hydrographs of wells near Middleburg, and at Orange Park and Brooklyn Lake (fig. 17) show both long-term trends and seasonal fluctuations. A general decline in water levels began in the late 1940's, coinciding with post-war growth in Florida. The trend continued until about 1956; then, for several years, water levels remained nearly constant, except for seasonal fluctuations, or rose slightly. In the mid 1960's, water levels began declining again and have continued declining at the rate of about 0.7 ft per year. Seasonal fluctuations of water levels in the relatively heavily pumped areas of eastern and northeastern Clay County generally range from 2 to 3 ft per year and probably are less in areas remote from heavy pumping.

The decline of the potentiometric surface in the last 40 years ranges from near zero in southwest Clay County to 30 feet at Orange Park (fig. 18). The potentiometric surface in that area will continue to decline as pumping increases. The result will be lowering of water levels in wells and a decrease in the size of the area where wells flow.

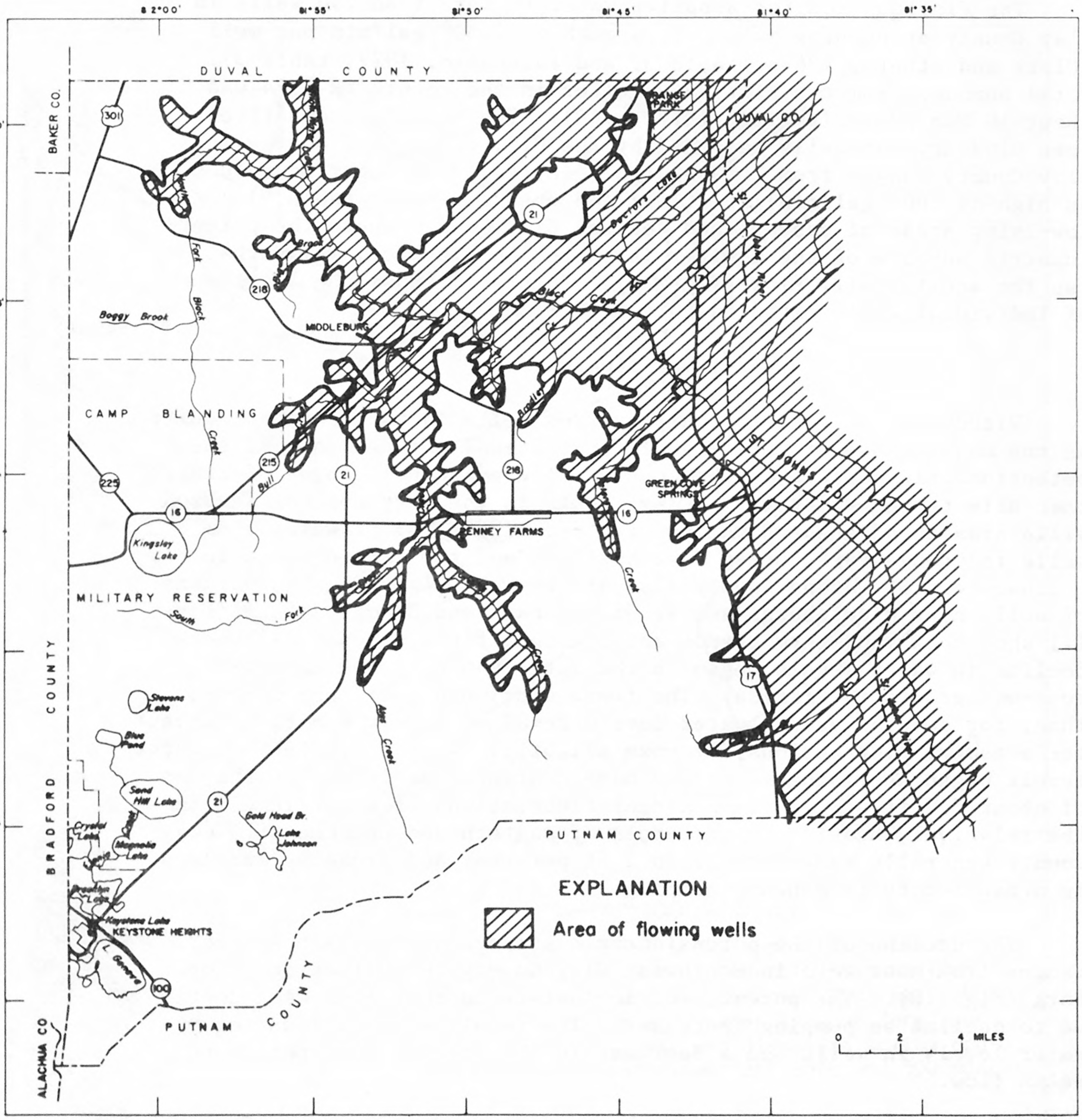

FIGURE 15.--The approximate area in Clay County were wells that tap the Floridan aquifer will flow, May 1974. (Modified from Fairchild, 1977, fig. 15)

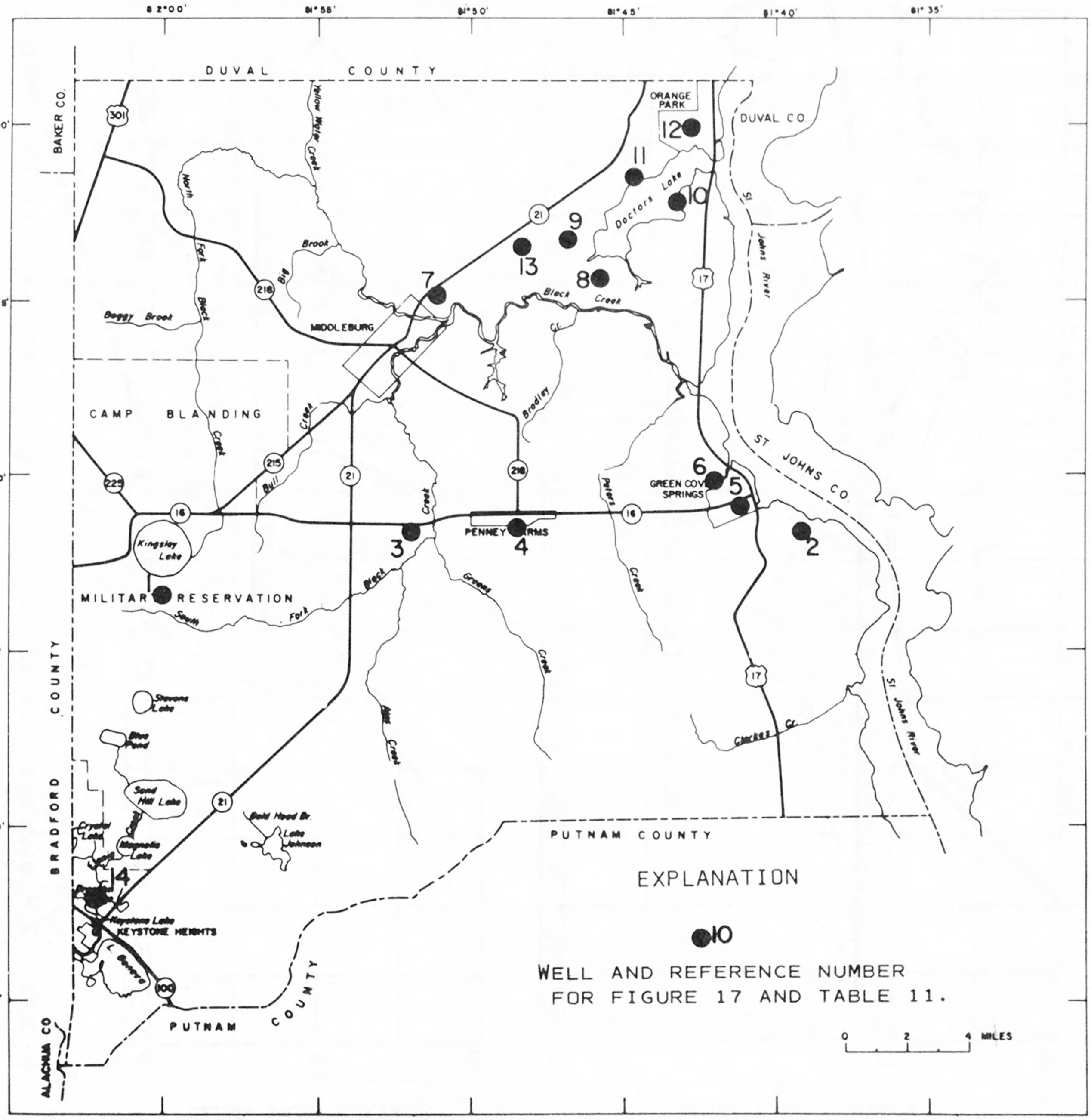

FIGURE 16.--Location of selected wells.

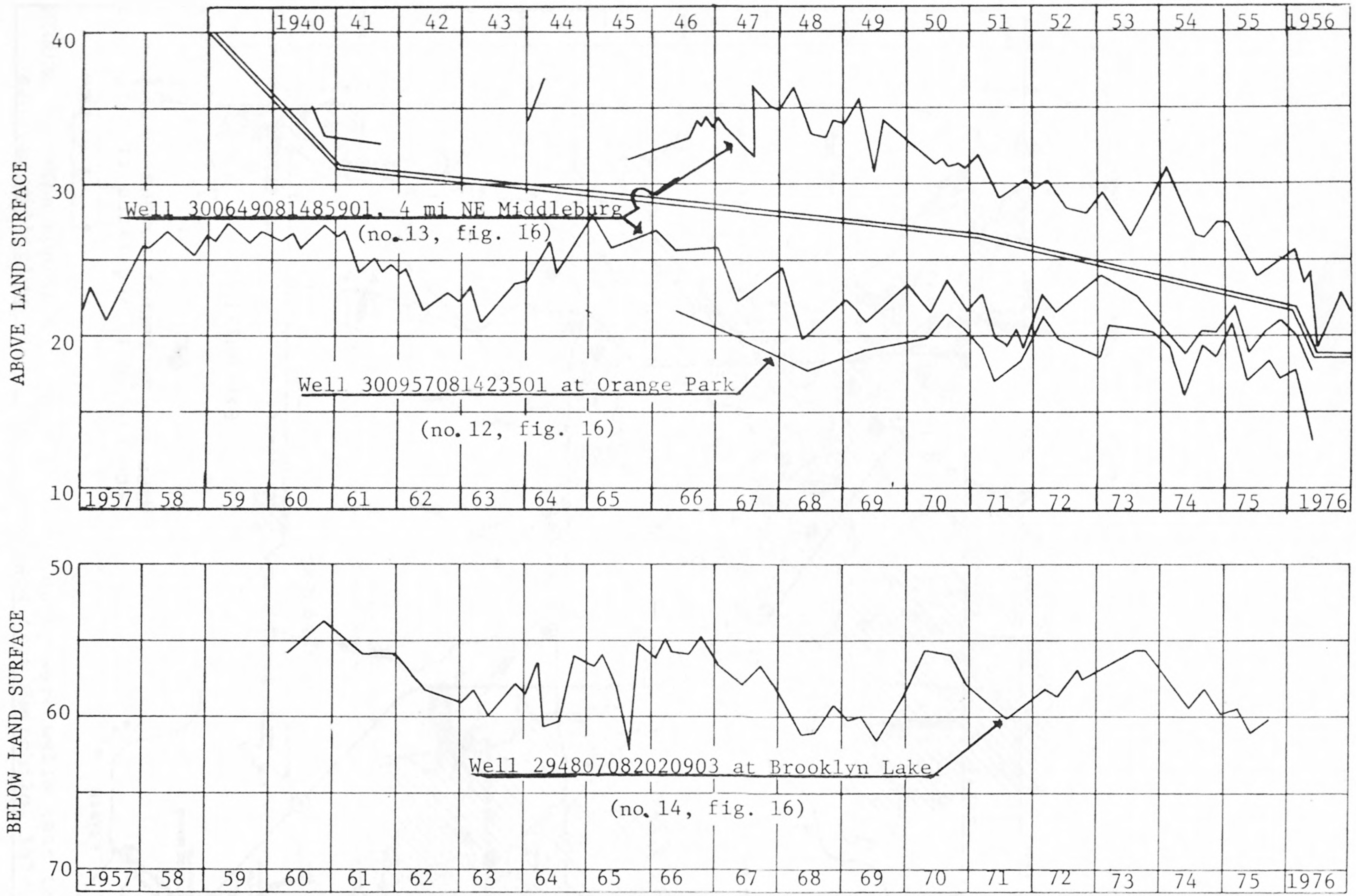

FIGURE 17.--Hydrographs of selected wells that tap the Floridan aquifer in Clay County.

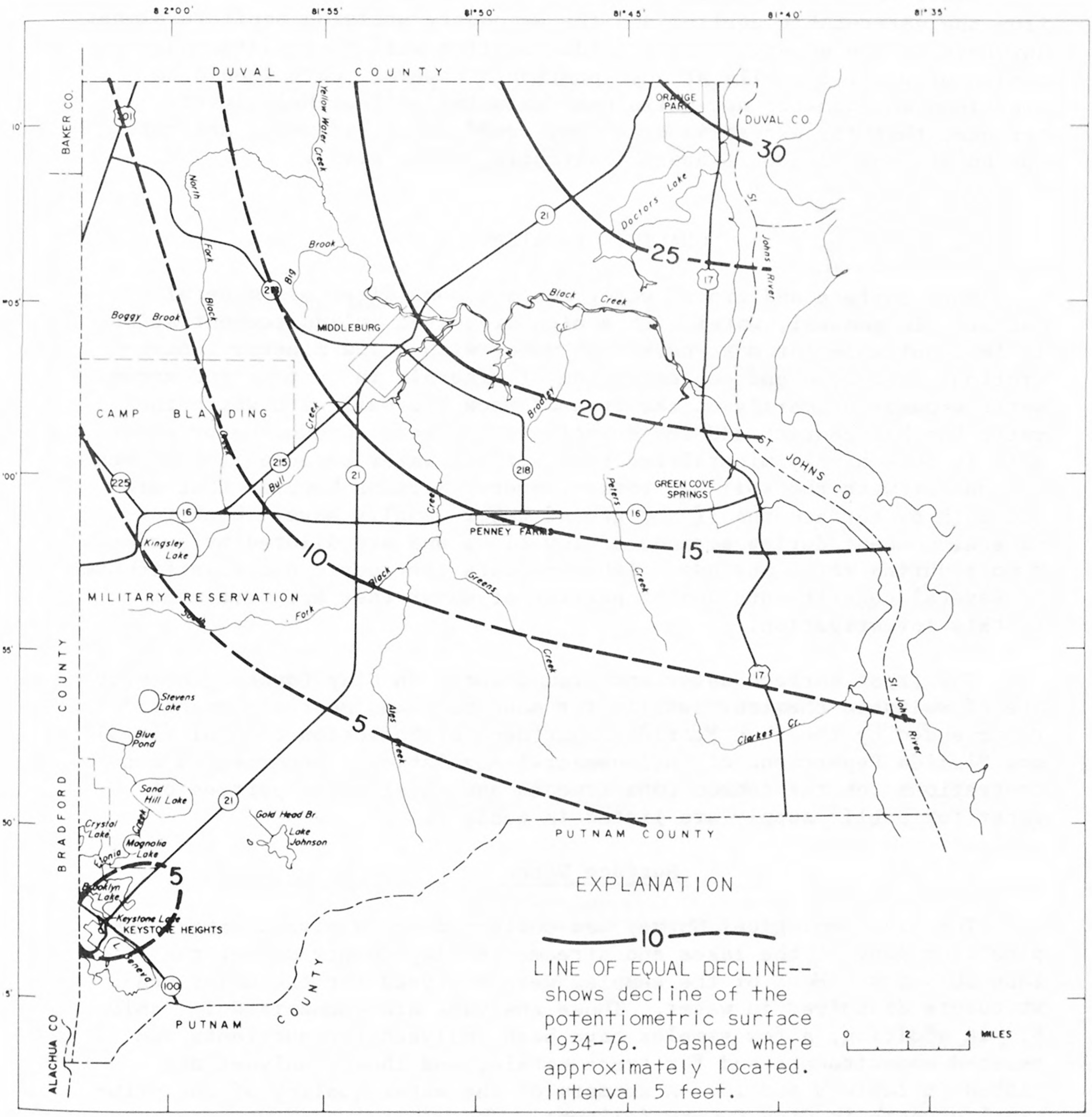

FIGURE 18.--Decline of the potentiometric surface of the Floridan aquifer.

Potential Ground-water Development

Small to moderate quantities of water probably can be developed from the water-table aquifer and the secondary artesian aquifers almost anywhere in the county. The Floridan aquifer will yield large quantities of water to wells at any location. However, care should be exercised in locating new wells near existing wells. Well interference, that is, excessive drawdown, could result if wells are not spaced at least 1,000 ft apart (Fairchild, 1977, p.49).

QUALITY OF WATER

Both surface and ground water contain some dissolved mineral matter. In general, water with a high dissolved solids concentration is less suitable for most uses than water with a low mineral concentration. The type and concentration of minerals in surface and ground water depends primarily on the type of rock and soil with which the water has had contact and the duration of contact. Ground-water generally is more highly mineralized than surface water because it has been in contact with the soil and rocks longer. Streams however that are fed both by surface runoff and ground water usually have a higher mineral content during periods of low flow, and are diluted by surface runoff during rainy periods. Table 6 lists the source and significance of several constituents and properties of water that are pertinent to this investigation.

The fresh surface water and ground water in Clay County generally are of suitable chemical quality for most uses and meet the standards recommended by the then Florida Department of Pollution Control (1973) now Florida Department of Environmental Regulation. Recommended concentrations for the common constituents and physical properties of water for public supply are listed in table 7.

Surface Water

The U.S. Geological Survey has collected and analyzed water samples from many of the lakes and streams in Clay County during the last 30 years. Most of the samples were analysed for the major constituents dissolved in water. Those analyses are summarized in table 8. In addition, a few samples have been analyzed for nutrients and related constituents and for trace metals, and those analyses are listed in table 9 and 10. A summary of the water quality of the principal streams in Clay County follows:

TABLE 6.--Source and significane of constituents and properties of water.

(Modified from U.S. Geol. Survey, 1976 table 4.)

Constituent or property	Source or cause	Significance
Alkalinity	Caused primarily by bicarbonate, carbonate, and hydroxide. Other weak acid radicals like borate, phosphate, and silicate may contribute to alkalinity.	Ability of water to neutralize strong acid. High alkalinity itself not detrimental but usually associated with high pH, hardness, and dissolved solids which can be detrimental.
Bicarbonate (HCO_3) and Carbonate (CO_3)	Produced by reaction of atmospheric carbon dioxide with water. Dissolved from carbonate rocks such as limestone and dolomite.	Bicarbonate and carbonate produce alkalinity. Bicarbonates of calcium and magnesium decompose in steam boilers and hot water facilities to precipitate as scale and release corrosive carbon dioxide gas. In combination with calcium and magnesium cause carbonate hardness.
Calcium (Ca) and Magnesium (Mg)	Dissolved from practically all soils and rocks, but especially from limestone, dolomite, and gypsum. Calcium and magnesium are found in large quantities in some brines. Magnesium is present in large quantities in seawater.	Cause most of the hardness and scale-forming properties of water; consume soap (see hardness). Water low in calcium and magnesium are desired in electroplating, tanning, dyeing, and in textile manufacturing.
Chloride (Cl)	Dissolved from rocks and soils. Present in sewage and found in large amounts in ancient brines, seawater, and industrial brines.	About 300 mg/L in combination with sodium gives salty taste to water. Increases the corrosiveness of water. U.S. Public Health Service drinking water standards (1962) recommend that the chloride content should not exceed 250 mg/L.
Color	Yellow-to-brown color of some water is usually caused by organic matter extracted from leaves, roots, and other organic substances. Objectionable color in water also results from industrial wastes and sewage.	Water for domestic and some industrial uses should be free from perceptible color. Color in water is objectionable in food and beverage processing and many manufacturing processes. Limits light pentration in water, thus preventing growth of some organisms.
Dissolved oxygen (DO)	Dissolved in water from air and from oxygen given off in the process of photosynthesis by aquatic plants.	Dissolved oxygen increases the palatability of water. The amount necessary to support fish life varies with species and age, with temperature, and concentration of other constituents in the water. Under average stream conditions, 5 mg/L is usually necessary to maintain a varied fish fauna in good condition. For many industrial uses, zero dissolved oxygen is desirable to inhibit corrosion.

TABLE 6.--Source and significance of constituents and properties of water--Continued

Constituent or property	Source or cause	Significance
Dissolved solids	Chiefly mineral constituents dissolved from weathering of rocks and soils.	USPHS drinking water standards (1962) recommend that the dissolved solids should not exceed 500 mg/L, however, 1,000 mg/L is permitted under certain circumstances. Waters containing more than 1,000 mg/L of dissolved solids are unsuitable for many purposes. The Geological Survey classifies the degree of salinity of these more mineralized bodies of water as follows (Swenson and Baldwin, 1965): Dissolved solids (mg/L) — Degree of salinity Less than 1,000...Nonsaline. 1,000 to 3,000....Slightly saline. 3,000 to 10,000...Moderately saline. 10,000 to 35,000..Very saline.
Fluoride (F)	Dissolved in small to minute quantities from most rocks and soils. Enters many waters from fluoridation of municipal supplies.	Fluoride in drinking water reduces the incidence of tooth decay when the water is consumed during the period of enamel calcification. However, it may cause mottling of teeth depending on the concentration of fluoride, the age of the child, amount of drinking water consumed, and susceptibility of the individual. (Maier, 1950).
Hardness (as $CaCO_3$)	In most waters nearly all the hardness is due to calcium and magnesium. All of the metallic cations other than the alkali metals also cause hardness.	Consumes soap before a lather will form. Deposits soap curd on bathtubs. Hard water forms scale in boilers, water heaters, and pipes. Hardness equivalent to the bicarbonate and carbonate is called carbonate hardness. Any hardness in excess of this is called non-carbonate hardness. Waters of hardness up to 60 mg/L are considered soft; 61 to 120 mg/L, moderately hard; 121 to 200 mg/L, hard; more than 200 mg/L, very hard.
Iron (Fe)	Iron is dissolved from many rocks and soils. On exposure to air normal basic waters that contain more than 1 mg/L of iron soon become turbid with the insoluble reddish ferric compounds produced by oxidation. Surface waters, therefore, seldom contain as much as 1 mg/L of dissolved iron, although some acid waters carry large quantities of iron in solution.	On exposure to air, iron in ground water oxidizes to reddish-brown sediment. More than about 300 ug/L may stain laundry and utensils reddish-brown. Objectionable for food processing, textile processing, beverages, ice manufacture, brewing and other processes. USPHS drinking water standards state that for esthetic reasons iron and manganese should not exceed 300 ug/L. Larger quantities cause unpleasant taste and favor growth of iron bacteria.

TABLE 6.--Source and significance of constituents and properties of water--Continued

Constituent or property	Source or cause	Significance
Ammonia nitrogen (N)	Includes nitrogen in the form of NH_3 and NH_4+. Found in many waters but usually only in trace amounts. Waters from hot springs may contain high concentrations. Found also in waters polluted with sewage and other organic waste.	Usually indicates organic pollution. Toxicity to fish is dependent on the pH of the water; 2.5 mg/L ammonia nitrogen can be harmful in the 7.4 to 8.5 pH range (Ellis and others, 1946). Ammonium salts are destructive to concrete made from portland cement.
Organic nitrogen (N)	Amino acids, proteins, and polypeptides. Derived from living organisms and their life processes and from wastes and sewage.	Sometimes indicates pollution. Increases nutrient content of water through decomposition and formation of other nitrogen forms.
Nitrate nitrogen (N)	Decaying organic matter, sewage fertilizers, and nitrates in soil.	Concentrations much greater than the local average may suggest pollution. There is evidence that more than about 10 mg/L of nitrate (N) may cause a type of methemoglobinemia in infants, sometime fatal. Water of high nitrate content should not be used in baby feeding (Maxcy, K.F., 1950). Nitrate has shown to be helpful in reducing intercrystalline cracking of boiler steel. It encourages growth of algae and other organisms which produce undesirable tastes and odors.
Nitrite nitrogen (N)	Unstable in the presence of oxygen and is present in only small amounts in most waters. Found in sewage and other organic wastes.	Presence of nitrite is usually an indication of recent organic pollution. Undesirable in waters for some dyeing and brewing processes.
Hydrogen ion concentration and pH	Hydrogen ions derived from ionization of weak and strong acids. Hydrogen ion concentration is expressed in terms of pH where pH = -log (H+). Acid generating salts and dissolved gases such as SO_2 and CO_2 increase the number of hydrogen ions. Carbonates, bicarbonates, hydroxides, phosphates, silicates, and borates reduce the number of hydrogen ions.	pH ranges between 0 and 14. A pH of 7.0 indicates solution having equal numbers of hydrogen and hydroxide ions. pH higher than 7.0 denotes predominance of hydroxide ions; Corrosiveness of water generally increases with decreasing pH. However, excessively alkaline waters may also attack metals.
Strontium, (Sr)	Dissolved from rocks and soils. Found in seawater and many brines. Present in waters of local areas where strontium minerals such as celestite and strontianite are present.	Naturally occurring strontium is similar chemically to calcium and only adds to the hardness of water. Radioactive isotopes of stronium, as from nuclear bomb fallout, can be harmful. These isotopes can be detected by radiometric measurements.

TABLE 6.--Source and significance of constituent and properties of water--Continued

Constituent or property	Source or cause	Significance
Sulfate (SO_4)	Dissolved from rocks and soils containing gypsum, iron sulfides, and other sulfur compounds. Usually present in mine waters and in some industrial waters.	Sulfate in water containing calcium forms hard scale in steam boilers. In large amounts, sulfate in combination with other ions gives bitter taste to water. Some calcium sulfate is considered beneficial in the brewing process. USPHS drinking water standards recommend that the sulfate content should not exceed 250 mg/L.
Temperature	Solar energy, thermal pollution from waste outfalls and heat from earth's core.	Affects usefulness of water for many purposes. For most uses, a water of uniformly low temperature is desired. Shallow wells show some seasonal fluctuations in water temperature. Ground waters from moderate depths usually are nearly constant in temperature, which is near the mean annual air temperature of the area. In very deep wells, the water temperature generally increases on the average about 1°C with each 100-foot increment of depth. Seasonal fluctuations in temperatures of surface waters are comparatively large, depending on the depth of water, but do not reach the extremes of air temperature.
Turbidity	Colloidal suspensions of sediment, precipitates, and other small particles.	Should be less than 5 Jackson units[1] for domestic use. Interferes with light penetration and limits growth of organisms. Also directly lethal to some life forms.
Zinc (Zn)	Dissolved from some rocks and soils. Found in high concentrations in some mine water having a low pH. Zinc is used in many commercial products and industrial wastes may contain large amounts. May be derived from zinc plated or galvanized metal products.	Small amounts are toxic to aquatic plants and animals. Zinc may have such a toxic action on purifying bacterial flora of streams as to present serious sewage pollution problems. USPHS drinking water standards recommend that zinc should not exceed 5,000 ug/L (5 mg/L).

[1] The standard method for the determination of turbidity is based on the Jackson candle turbidimeter and is a measure of the reduction of transparency due to the presence of suspended particulate matter in the sample.

TABLE 7.--Recommended quality standards for public water supplies.

(From Fairchild, 1977, table 4.)

Chemical substance	Limit not to be exceeded EPA[1]	DPC[2]
Physical		
Color	75 Pt-Co units	
pH	5.0-9.0 units	6.0-8.5 units
Turbidity		50 units
Chemical	(mg/L)	(mg/L)
Chloride	250	250
Fluoride[3]	1.4-2.4	1.4-1.6
Iron	0.3	0.3
Nitrite nitrogen	10	
Nitrate nitrogen	1.0	
Sulfate	250	
Dissolved solids (residue)	500	500

1 Environmental Protection Agency (Nat. Acad. Sci. and Nat. Acad. Eng., 1973).
2 Florida Department of Pollution Control (1973).
3 The concentration of fluoride should be between the limits expressed, depending on the annual average of maximum daily air temperatures at a location being considered.

TABLE 8.--Summary of standard chemical analyses of surface water in Clay County, November 1955 to December 1975.

(Quantities are in milligrams per liter, except as indicated.)

	Temperature (°C)	Turbidity (Jackson units)	Color (Platium-cobalt units)	Specific Conductance (umho/cm at 25°C)	Dissolved Oxygen	pH (units)	Alkalinity as $CaCO_3$	Silica (SiO_2)	Iron (Fe) (ug/L)	Calcium (Ca)	Magnesium (Mg)	Strontium (Sr) (ug/L)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (Fl)	Nitrate (NO_3)	Dissolved Solids: Residue at 180°C	Dissolved Solids: Sum of Constituents	Hardness: Ca, Mg	Hardness: Noncarbonate
									Sand Hill Lake near Keystone Heights 02244600														
Mean	24.5	1.6	6.9	26	10.0		2	2.7	16	0.7	0.5	30	2.8	0.2	2.5	1.6	4.4	0.07	0.15	17.7	14.9	3.6	1.5
Maximum	30.6	2	38	37	9.8	6.4	3	4.8	30	1.4	.7	60	3.6	.6	4.0	3.5	5.8	.2	.8	26	20	6.0	4.0
Minimum	13.0	1	0	22	7.7	4.8	0	.1	0	.4	.4	0	2.0	.0	.0	.0	3.0	.0	.0	9	11	.5	.0
									Magnolia Lake near Keystone Heights 02244650														
Mean	23.7	-	8.3	25	8.9		2	1.2	10	.9	.4	25	2.6	.16	3.2	1.3	4.3	.03	.2	17.2	12.5	3.7	1.0
Maximum	29.5	-	17	26	9.2	6.3	3	1.9	20	1.2	.6	50	2.9	.3	4.0	2.4	5.0	.1	.8	28	15	4.0	3.0
Minimum	13.0	-	3	23	8.4	5.4	0	.3	0	.5	.1	0	2.4	.0	.0	.0	3.2	.0	.0	10	10	3.0	.0
									Brooklyn Lake near Keystone Heights 02244750														
Mean	24.2	3.3	13	28	8.4		2	.85	6	1.0	.6	30	3.0	.23	2.6	2.8	5.6	.04	.12	19.1	15.0	4.7	2.6
Maximum	31.1	8	120	41	9.4	6.1	3	3.1	20	1.6	1.2	60	4.4	.8	4.0	5.5	9.3	.1	.8	34	21	9.0	8.0
Minimum	14.0	1	0	3	7.5	5.1	0	.0	0	.5	.2	0	2.3	.0	.0	.0	3.3	.0	.0	10	10	2.0	.0
									Lake Geneva at Keystone Heights 02244800														
Mean	25.2	4.4	3.6	50	7.8		2	1.1	23	1.5	1.0	45	5.3	1.2	2.8	5.9	8.3	.08	.15	28.8	25.5	7.9	5.2
Maximum	31.1	8	10	56	9.5	6.2	3	5.4	60	2.0	1.3	90	6.4	9.0	4.0	8.8	10.0	.2	.9	34	30	9.0	7.0
Minimum	12.5	2	0	45	7.0	5.1	1	.0	10	.8	.7	0	4.2	.0	1.0	3.0	5.0	.0	.0	17	21	7.0	4.0
									Pebble Lake near Keystone Heights 02244850														
Mean	24.9	2	4	24	8.5		4	1.8	20	1.0	.6	35	2.0	.18	4.2	1.6	3.6	.05	.24	14.7	13.0	5.0	.7
Maximum	30.0	2	10	44	9.6	6.6	16	4.7	70	3.5	1.9	70	3.4	.5	20	8.0	4.2	.1	1.5	24	24	16.0	2.0
Minimum	14.0	2	0	16	7.6	5.2	2	.6	0	.1	.1	0	.2	.0	1.0	.0	2.8	.0	.0	6	7	1.0	.0
									Lake Johnson near Keystone Heights (Little Lake) 02244900														
Mean	23.7	-	14	22	8.8		2	2.4	22	.7	.37	30	2.4	.21	2.8	1.5	3.8	.02	.18	16.8	13.2	2.2	1.0
Maximum	30.0	-	30	29	9.3	5.9	3	3.8	60	1.2	.5	60	3.0	.4	4.0	8.2	5.0	.1	.9	21	20	4.0	4.0
Minimum	12.0	-	5	20	7.9	5.2	0	.4	0	.4	.2	0	2.0	.0	.0	.0	3.2	.0	.0	12	11	.0	.0

Clarkes Creek near Green Cove Springs 02245300																							
Mean	20.0	3.4	40	78	6.5		24	8.7	-	9.1	.8	-	4.5	.4	29	1.6	8.2	.15	.0	50	49	26	2.5
Maximum	24.0	5	50	91	9.0	7.1	29	11.0	-	11.0	.9	-	4.5	.4	35	2.2	9.0	.2	.0	50	58	30	3.0
Minimum	9.5	2	30	65	5.2	6.6	19	7.5	-	7.2	.7	-	4.5	.4	23	1.0	7.5	.1	.0	50	40	22	2.0
S. Fork Black Creek near Camp Blanding 02245400																							
Mean	23.3	3.2	49	39	8.6		7	3.3	127	3.5	.6	55	3.0	.15	8.0	3.0	5.4	.12	.21	34	23	5.0	3.5
Maximum	-	3.4	90	62	10.0	6.5	10	5.3	150	5.8	.9	80	4.4	.3	12	4.0	7.2	.2	.5	46	31	8.0	5.8
Minimum	13.3	3.0	25	32	7.6	6.0	4	.6	110	2.5	.2	30	2.2	.0	5.0	.0	4.0	.0	.0	25	16	4.0	2.5
Ates Creek near Penny Farms 02245430																							
Mean	19.5	-	153	38	-		2	5.9	85	1.9	.6	-	4.4	.08	3	1.7	7.5	.18	.18	53	24	7.3	4.8
Maximum	24.0	-	220	55	-	5.6	4	7.9	110	2.9	1.1	-	5.9	.4	5	3.2	10.0	.3	.4	74	31	9.0	8.0
Minimum	12.8	-	80	27	-	4.7	1	2.9	60	.8	.1	-	2.7	.0	1	.5	4.5	.1	.1	38	14	4.0	2.0
Greens Creek near Penny Farms 02245470																							
Mean	19.2	3.5	124	59	4.0		10	5.7	376	4.2	.8	60	5.4	.24	13	.8	9.9	.13	.21	54	34	13.9	3.8
Maximum	24.0	4	260	80	6.2	6.8	24	11.0	630	9.2	1.6	60	7.0	.4	29	1.8	14.0	.2	.8	71	48	26	6.0
Minimum	9.0	3	60	31	1.8	4.7	0	.3	30	1.6	.0	60	3.0	.0	0	.0	4.2	.1	.0	36	12	4.0	.0
S. Fork Black Creek near Penny Farms 02245500																							
Mean	21.1	2	139	60	8.4		15	7.6	122	4.3	1.1	45	4.2	.27	19	3.8	7.1	.16	.32	61	34	20.4	5.3
Maximum	26.1	2	360	228	9.4	7.5	74	18.0	310	34	3.2	50	7.2	.7	90	22	13.0	.4	3.4	156	127	98	30
Minimum	13.0	2	10	18	7.7	5.3	3	1.4	20	1.0	.1	40	.4	.0	4	.0	3.0	.0	.0	28	12	3.0	.0
Bull Creek near Middleburg 02245600																							
Mean	16.8	-	127	55	-		12	6.4	70	4.3	1.5	-	3.8	.35	15	3.3	6.8	.2	.02	57	35	17	4.4
Maximum	22.0	-	200	71	-	7.0	25	7.8	80	7.6	2.2	-	4.6	1.0	31	5.0	9.0	.2	.1	64	49	28	7.6
Minimum	10.6	-	70	30	-	5.1	2	3.1	60	1.6	.6	-	2.9	.0	2	1.6	4.0	.2	.0	53	18	60	1.6
Kingsley Lake at Camp Blanding 02245700																							
Mean	23.9	14	12	57	9.0		10	1.5	43	4.0	.8	40	4.7	.44	12	4.9	8.1	.07	.05	38	32	13.6	4.4
Maximum	28.5	36	80	102	11.0	6.9	38	6.6	50	16	1.0	46	6.2	1.0	46	60	10.0	.1	.5	80	61	44	6.0
Minimum	15.0	1	0	47	7.3	5.9	6	.1	30	1.4	.7	0	4.0	.0	7	.4	6.4	.0	.0	17	24	7.0	3.0
N. Fork Black Creek near Highland 02245800																							
Mean	-	-	142	152	-		5	7.3	95	9.7	1.8	-	15.7	.53	6	42	7.7	.20	.68	126	84	31.6	26.4
Maximum	-	-	280	492	-	7.1	30	33.0	250	59	6.1	-	72	7.0	36	199	12.0	.4	20.4	336	316	157	146
Minimum	-	-	5	40	-	4.1	0	.8	0	2.4	.0	-	4.2	.0	0	4.0	3.8	.0	.0	54	26	8.0	.0
N. Fork Black Creek near Middleburg 02246000																							
Mean	20.4	3.4	154	106	8.5		13	6.5	113	9.0	1.9	80	8.8	.54	16	21.0	8.0	.21	.41	96	64	30.2	18.2
Maximum	29.0	16	1000	470	10.0	7.1	31	11.0	280	28	3.9	140	20	1.9	38	96	12.0	.4	1.7	184	170	86	68
Minimum	-	1	5	38	7.8	4.7	1	1.1	0	.8	.0	20	3.2	.0	1	.8	3.5	.1	.0	59	20	8.0	6.0

TABLE 9.--Summary of nutrient and related constituent analyses of surface water in Clay County, April 1956 to May 1971.

(Quantities are in milligrams per liter.)

	Organic nitrogen (N)	Total Ammonium (NH_3) as N	Dissolved Nitrate (NO_3) as N	Total Nitrate (NO_3) as N	Total phosphate (PO_4)	Orthophosphate (PO_4)	Tannin	Dissolved Ammonia (NH_4)	Dissolved Nitrate (NO_3)	Dissolved Nitrite (NO_2)	Total phosphous (P)
Sand Hill Lake near Keystone Heights 0224400											
Mean	0.09	-	0.017	-	0.07	0.06	-	0.07	0.15	0.01	0.04
Maximum	.14	-	.05	-	.07	.14	-	.12	.80	.01	.04
Minimum	.04	-	.00	-	.07	.00	-	.02	.00	.01	.04
Brooklyn Lake near Keystone Heights 02244750											
Mean	.11	.07	.018	.0	.06	.03	.10	.015	.12	.005	.025
Maximum	.19	.07	.05	.0	.08	.16	.10	.03	.80	.01	.03
Minimum	.06	.07	.00	.0	.04	.00	.10	.00	.00	.00	.02
Lake Geneva at Keystone Heights 02244800											
Mean	.19	.00	.022	.00	.06	.04	.00	.01	.15	.005	.03
Maximum	.33	.00	.05	.00	.07	.16	.00	.01	.90	.01	.04
Minimum	.06	.00	.00	.00	.05	.00	.00	.01	.00	.00	.02
Pebble Lake near Keystone Heights 02244850											
Mean	.22	-	.013	-	.10	.05	-	.08	.24	.01	.03
Maximum	.27	-	.02	-	.16	.17	-	.09	1.5	.01	.03
Minimum	.18	-	.00	-	.04	.00	-	.07	.00	.01	.03
Clarkes Creek near Green Cove Springs											
Mean	.35	-	.00	-	.14	.125	-	.04	.00	.02	.15
Maximum	.51	-	.00	-	.14	.13	-	.05	.00	.02	.15
Minimum	.19	-	.00	-	.14	.12	-	.03	.00	.02	.15
S. Fork Black Creek near Camp Blanding 02245400											
Mean	.31	-	.035	-	.25	.23	-	.03	.21	.03	.24
Maximum	.43	-	.07	-	.27	.33	-	.05	.50	.04	.24
Minimum	.20	-	.00	-	.23	.17	-	.01	.00	.02	.24
Greens Creek near Penny Farms 02245470											
Mean	.67	-	.03	-	.11	.07	-	.08	.21	.03	.09
Maximum	.93	-	.09	-	.13	.23	-	.12	.80	.03	.09
Minimum	.41	-	.00	-	.09	.00	-	.03	.00	.03	.09
S. Fork Black Creek near Penny Farms 02245500											
Mean	.255	-	.03	-	.34	.30	-	.04	.32	.015	.34
Maximum	.27	-	.09	-	.37	.40	-	.07	3.4	.02	.34
Minimum	.24	-	.00	-	.31	.10	-	.01	.00	.01	.34
Kingsley Lake at Camp Blanding 02245700											
Mean	.28	.10	.00	.00	.04	.01	.00	.03	.05	.01	.03
Maximum	.48	.10	.00	.00	.05	.10	.00	.06	.50	.02	.04
Minimum	.13	.10	.00	.00	.03	.00	.00	.00	.00	.00	.02
N. Fork Black Creek near Middleburg 02246000											
Mean	.37	-	.09	-	.27	.15	-	.04	.41	.02	.18
Maximum	.55	-	.25	-	.34	.50	-	.07	1.7	.02	.18
Minimum	.19	-	.02	-	.20	.00	-	.01	.00	.02	.18

TABLE 10.--Trace metal analyses of surface water in Clay County.

(Quantities shown are in micrograms per liter.)

Date of Collection	Location	USGS identification number	Arsenic (As)	Cadmium (Cd)	Chromium (Cr)	Cobalt (Co)	Copper (Cu)	Iron (Fe)	Lead (Pb)	Manganese (Mn)	Mercury (Hg)	Nickel (Ni)	Strontium (Sr)	Zinc (Zn)
8/22/67	Lake Geneva at Keystone Heights	02244800	–	–	–	0	0	20	–	0	–	0	90 (5/12/67)	0
4/17/72	Green Cove Spring at Green Cove Springs	02245342	0	0	0	0	0	10	0	0	0	–	–	280
8/21/67	Kingsley Lake at Camp Blanding	02245700	–	–	0	0	0	50	–	0	–	0	80 (5/12/67)	0

St. Johns River

The St. Johns River is tide affected throughout its entire reach in Clay County. Chloride in the water that results from the reverse flow of sea water generally exceeds 300 milligrams per liter (mg/L) during periods of high freshwater inflow and ranges from 300 to 2,000 mg/L at low flow (Snell and Anderson, 1970, fig. 3). The water is very hard and its color frequently exceeds 200 units. Pollution from municipal and industrial wastes also contributes to the general poor quality of the water.

North Fork Black Creek

Water from the upper reaches of North Fork Black Creek has a concentration of dissolved solids that averages about 30 mg/L, contains little organic matter, and is very soft. Swampy areas between Kingsley Lake and Boggy Branch cause the color of the water at times to exceed 100 platinum-cobalt units. Below the confluence of Boggy Branch, the average concentration of dissolved solids increases downstream to about 130 mg/L at Highland, then decreases to about 100 mg/L near Middleburg. Excessive color, iron concentration, hardness, and pH often makes the water objectionable for many uses (Clark and others, 1964a, p. 93-94).

South Fork Black Creek

Clark and others (1964a p. 95-99) report that the concentration of dissolved solids in water from Ates, Greens, and Bull Creeks for the period 1957-60 was 50, 60, and 57 mg/L, respectively, of which about 50 percent of that from Ates Creek and 45 percent from the other two streams was organic matter. Water from South Fork Black Creek near Penney Farms, below the confluence of Ates and Greens Creeks, during the same period was similar to that from those tributaries. The average concentration of dissolved solids was 58 mg/L, of which about 50 percent was organic matter. Color and iron were considered as probably the most objectionable water-quality characteristics for most uses. Hardness was low.

Etonia Creek

The water from lakes and streams in the Etonia Creek Basin in Clay County is of good chemical quality for most uses. In water from most of the lakes dissolved-solids concentration was less than 30 mg/L. Little organic matter was present in the water samples from the lakes and streams. Also, iron was absent, or was present only in insignificant amounts.

Ground Water

Water-table aquifer

Clark and others (1964a, p. 145) summarize more than 120 chemical analyses of water from the water-table aquifer in a four-county area which includes Clay County. The range of constituents given below are for the four county area but in general apply also to Clay County. Dissolved-solids concentrations ranged from 17 to 302 mg/L. Concentrations were highest in northern Clay County and lowest in the southern part (fig. 19). Hardness ranged from 3 to 246 mg/L. The water tended to be the hardest in the northern part of the county (fig. 19). Silica concentrations ranged from 0.0 to 58 mg/L. Iron concentrations ranged from 10 to 640 micrograms per liter (ug/L), but most of the concentrations were in the range of 10 to 300 ug/L. Bicarbonate generally was the dominant substance in the water samples, and concentrations ranged from 0 to 324 mg/L. Sulfate concentrations ranged from less than 1 to 72 mg/L, but most were 10 mg/L or less. Chloride concentrations ranged from about 1.5 to 92 mg/L, and half of the samples analyzed had concentrations of 10 mg/L or less. Fluoride concentrations ranged from 0.0 to 3.1 mg/L, and only six of 118 samples had concentrations higher than 1.5 mg/L. Unusually high concentrations of potassium were noted in some of the samples. Concentrations ranged from 0.0 to 29 mg/L. Some of the samples that had high potassium concentrations also had high nitrate concentrations. Nitrate concentrations ranged from 0.0 to 119 mg/L, although less than half of the samples had concentrations higher than 1.0 mg/L.

Secondary artesian aquifers

Clark and others (1964a, p. 145-147) summarize 144 chemical analyses of water from wells that draw water from the secondary artesian aquifers in the four-county investigation. The range of constituents given below are for the four county area but in general apply also to Clay County. Dissolved-solids concentrations ranged from 29 to 363 mg/L. Concentrations were lowest in the southwest corner of the county and highest in the southeastern part (fig. 20). Silica ranged from 0.5 to 73 mg/L. Hardness ranged from 4 to 248 mg/L, and the areal pattern was somewhat similar to that of the dissolved-solids concentrations (fig. 20). Iron concentrations ranged from 20 to 390 ug/L, but only 23 of the 140 samples that were analyzed for iron had concentrations in excess of 300 ug/L. Sodium ranged from 4.2 to 56 mg/L. Concentrations of bicarbonate ranged from 14 to 326 mg/L, and similar to the water-table aquifer, it generally was the most dominant substance in the water samples. Sulfate ranged from 0.0 to 12 mg/L. Chloride concentrations ranged from about 4.5 to 84 mg/L, but nearly half the samples had concentrations of 10 mg/L or less. Fluoride concentrations ranged from 0.0 to 2.1 mg/L. Six of the 142 samples had concentrations greater than 1.5 mg/L and all six

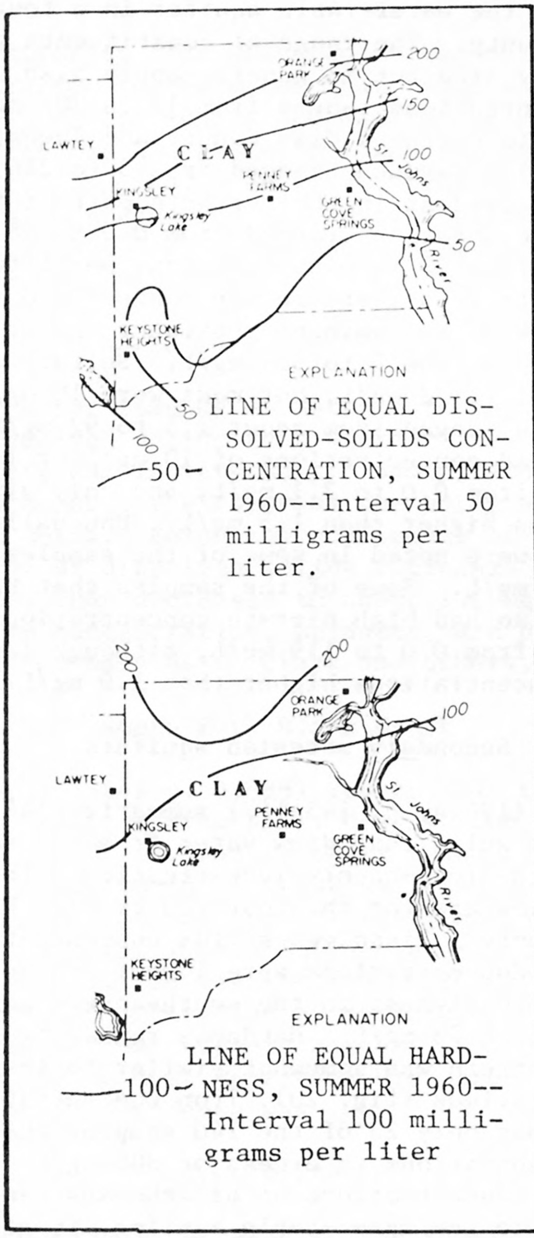

FIGURE 19.--Dissolved-solids concentration and hardness of water from the water-table aquifer. (From Clark and others, 1964a, fig. 89.)

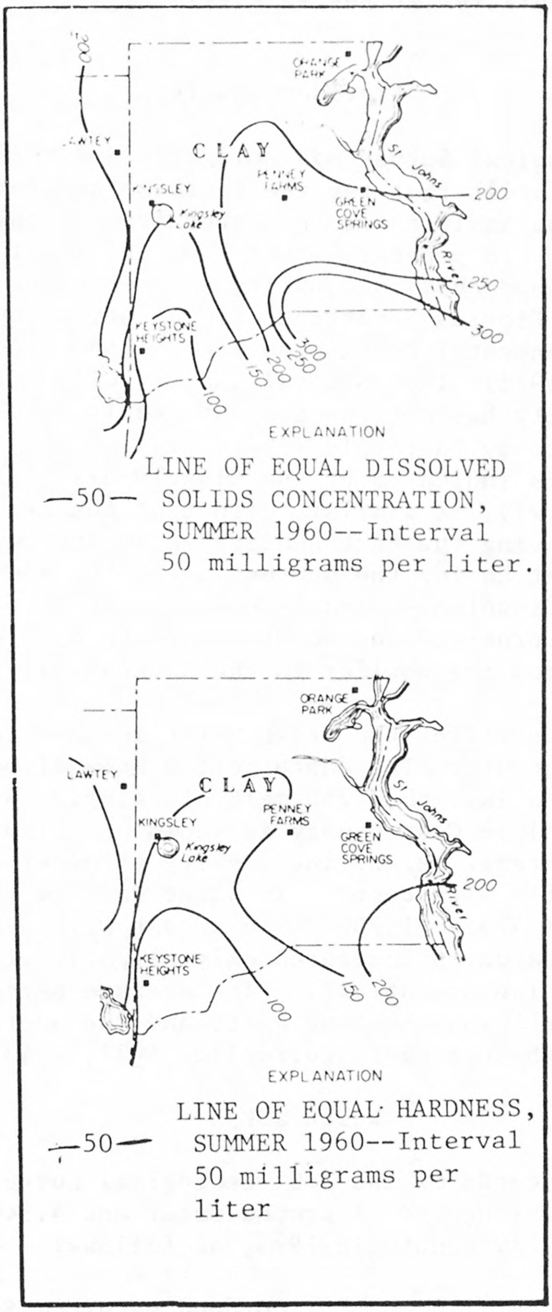

FIGURE 20.--Dissolved-solids concentration and hardness of water from the secondary artesian aquifers (From Clark and others, 1964a, fig. 90.)

were from wells in Clay County. Nitrate ranged from 0.0 to 37 mg/L. Concentrations in only two of the 15 samples analyzed were 10 mg/L or more.

Floridan aquifer

The U.S. Geological Survey has collected and chemically analyzed water samples from wells that tap the Floridan aquifer in Clay County for many years. The analyses of the water from 12 selected wells are listed in table 11. In general, water from the Floridan aquifer in Clay County is of good chemical quality and meets the standards recommended by the Florida Department of Pollution Control (1973) and the U.S. Environmental Protection Agency (Natl. Acad. Sci. and Natl. Acad. Eng., 1973). The chemical quality of water from the aquifer in the county has not changed noticeably from year to year, a feature noted also by Fairchild (1977, p.43). The areal variation in water quality, as indicated by the dissolved-solids concentration and hardness (fig. 21), is similar to that of the secondary-artesian aquifers. Water having the best quality is in the central part of the county, and that having the poorest is in the southeastern part. A relatively high dissolved-solids concentration in water in the extreme northeast corner of the county could be due to large withdrawals of water from the aquifer in the Jacksonville area.

Saline water underlies the fresh water in the Floridan aquifer everywhere in the county. The depth to the base of potable water (water that contains less than 250 mg/L of chloride and 500 mg/L of dissolved solids) in Clay County is shown on figure 14. Except near the base of potable water, the quality of water apparently does not change noticeably with depth. In water samples collected from depths ranging from 475 to 1,200 ft in a test well near Doctors Lake (no. 9, fig. 16), hardness increased only slightly with depth and chloride concentration not at all. The average hardness for all the samples from the well was about 90 mg/L, and the average chloride concentration was about 8 mg/L (Fairchild, 1977, p.43).

WATER USE

Unpublished records of the U.S. Geological Survey indicate that, on the average, 13.91 Mgal/d of ground water and 4.34 Mgal/d of surface water was used in Clay County in 1975, as follows:

Use	Ground water	Surface water
	(Million gallons per day)	
Municipal	5.00	--
Industrial	6.62	4.30
Rural domestic	1.81	--
Livestock	0.47	--
Irrigation	0.01	0.04

TABLE 11.--Chemical analyses of water from ells that tap the Floridan aquifer in Clay County.

(Quantities shown in milligrams per liter, except as indicated.)

Reference number (fig. 16)	Date of Collection	Location	USGS identification number	Temperature (°C)	Color (Platinum-Cobalt units)	Specific conductance (umho/cm at 25°C)	pH (units)	Carbon Dioxide (CO_2)	Alkalinity as ($CaCO_3$)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Calcium and magnesium hardness	Noncarbonate hardness	Calcium (Ca)	Magnesium (mg)	Sodium (Na)	Potassium (k)	Chloride (Cl)	Sulfate (SO_4)	Fluoride (Fl)	Silica (SiO_2)	Iron (Fe) (ug/L)	Strontium (Sr) (ug/L)	Residue at 180°C	Calculated sum of constituents
1	8/25/60	1 mi S.	295634081595201	-	-	173	7.3	8.0	82	100	-	81	0	23	5.7	-	-	-	-	.3	11	80	-	95	-
	9/29/70	Kingsley Lake		-	0	177	7.4	6.6	84	103	0	82	0	22	6.4	2.8	.9	5.0	.8	.0	12	-	0	101	101
2	9/29/70	2 mi SE Green Cove Springs	295831081390301	-	0	239	7.6	-	177	108	53	11	21	22	13	4.3	1.4	7.0	25	.2	12	-	8	139	191
3	5/ 4/71	3 mi W. Penny Farms	295835081515001	-	0	178	6.9	-	83	101	0	77	0	21	6.3	3.2	.4	5.0	1.2	.3	8.8	-	0	139	96
4	8/26/60	Penny	295837081483401	-	-	183	7.6	4.2	85	104	-	85	-	24	6.1	3.8	.1	5.0	1.6	.1	8.0	40	-	106	100
	9/29/70	Farms		-	0	179	7.4	13	167	102	50	84	1	23	6.5	3.2	.5	6.5	.8	.0	3.1	-	0	100	144
5	9/24/71	Green	295933081410601	24.0	0	215	6.2	-	83	101	0	94	12	18	12	4.0	1.6	5.0	20	.2	12	-	7	127	123
	8/20/76	Cove Springs		25.0	5	200	-	-	80	97	0	91	12	20	9.8	4.1	1.2	4.8	19	.4	11	-	680	140	119
6	11/ 3/75	Green Cove Springs	300022081415002	-	5	-	-	-	80	98	0	98	18	21	11	3.6	1.3	5.0	15	.3	11	10	530	112	117
7	7/29/60	2 mi NE	300510081510201	-	-	182	7.6	3.9	80	97	-	82	2	21	7.2	-	-	-	-	.6	11	20	-	107	-
	9/28/70	Middleburg		-	0	177	8.0	-	80	98	-	80	0	17	9.1	3.8	1.1	6.0	5.6	.3	12	-	5	107	103
	9/28/72			-	-	177	8.0	1.7	88	98	4	81	0	17	9.1	3.8	1.1	6.0	5.6	-	12	-	-	103	108
8	8/30/60	1 mi S.	300556081453801	-	-	187	7.6	3.9	80	97	-	84	4	18	9.5	-	-	-	10	.8	11	40	-	104	-
	9/28/70	Doctors		-	5	179	7.9	-	79	96	-	83	4	17	9.8	3.8	1.2	5.5	8.0	.2	12	-	6	111	105
	9/29/70	Lake		-	-	179	7.9	3.9	157	96	47	84	6	17	9.8	3.8	1.2	5.5	8.0	.2	12	-	-	105	152

9	10/19/72	1/2 mi W.	300656081463401	24.0	5	165	8.3	.6	66	80	0	72	6	15	8.1	5.0	4.0	4.0	10	.3	11	-	1300	115	98
	10/25/72	Doctors		24.0	5	192	7.8	2.4	79	96	0	96	17	23	9.0	6.1	1.7	7.0	10	.3	10	-	920	127	115
	11/ 9/72	Lake, S.		-	15	185	7.8	2.1	69	84	0	90	21	20	9.5	5.6	2.8	5.0	21	.5	12	-	800	136	119
	11/22/72	end		25.0	5	200	8.0	1.5	77	94	0	87	10	18	10	4.2	1.9	5.0	12	.5	12	-	1000	127	110
	11/28/72			25.0	10	170	7.6	2.3	48	58	0	77	29	14	10	4.8	1.9	7.0	24	.6	13	-	840	105	105
	12/ 6/72			-	10	200	8.0	1.6	82	100	-	94	12	19	11	3.7	1.4	5.0	16	.6	12	-	1000	106	119
10	7/18/60	SE Shore	300752081432401	-	-	203	7.9	2.1	84	103	-	91	8	.1	11	-	-	-	13	.4	.1	100	-	118	-
	8/28/68	Doctors		-	-	201	8.1	2.5	164	100	49	92	9	.1	11	5.1	1.6	7.0	13	.3	.1	-	-	119	137
	8/28/70			-	0	201	8.1	-	82	100	0	90	8	18	11	5.1	1.6	7.0	13	.3	13	-	8	119	118
11	6/ 5/68	3 mi SW Orange Park	300831081444501	26.0	5	287	7.7	-	89	108	0	130	38	26	15	5.8	2.2	11	41	.5	14	-	22	176	169
12	6/ 9/60	Orange	300957081423501	-	10	347	7.9	-	-	122	0	155	55	34	17	-	-	-	102	.6	15	130 (7/16/60)	-	-	-
	2/28/70	Park		-	-	322	8.1	3.0	193	118	58	153	56	30	18	6.6	2.2	9.0	56	.4	19	-	-	202	257
	8/28/70			-	0	322	8.1	-	97	118	-	150	52	30	18	6.6	2.2	9.0	56	.4	19	-	32	209	199

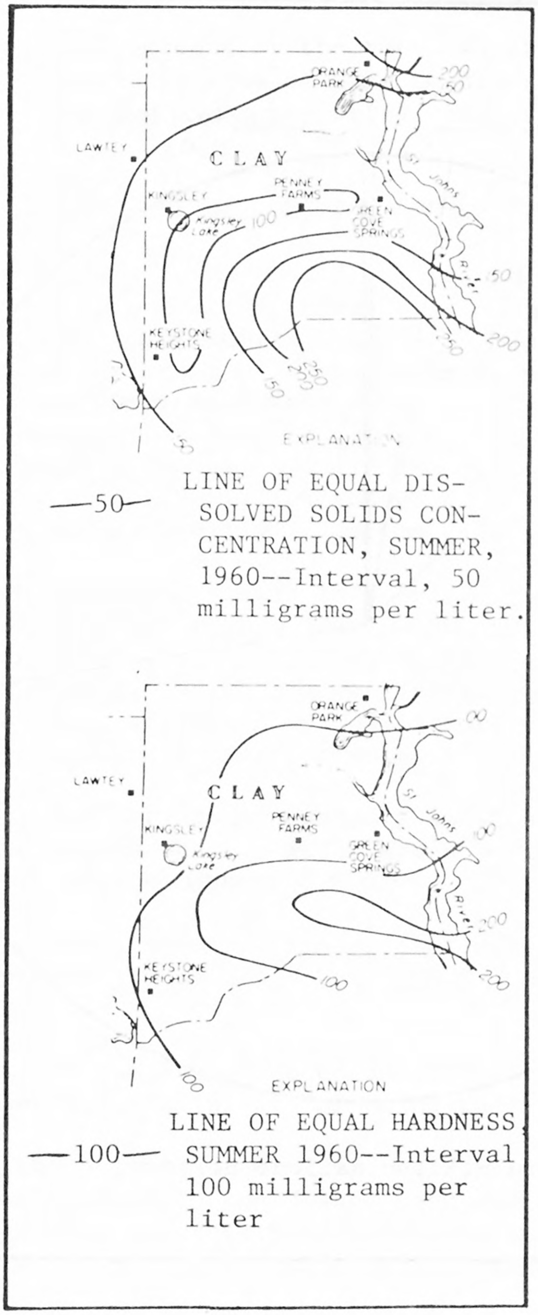

FIGURE 21.--Dissolved-solids concentrations and hardness of water from the Floridan aquifer. (From Clark and others, 1964a, fig. 91.)

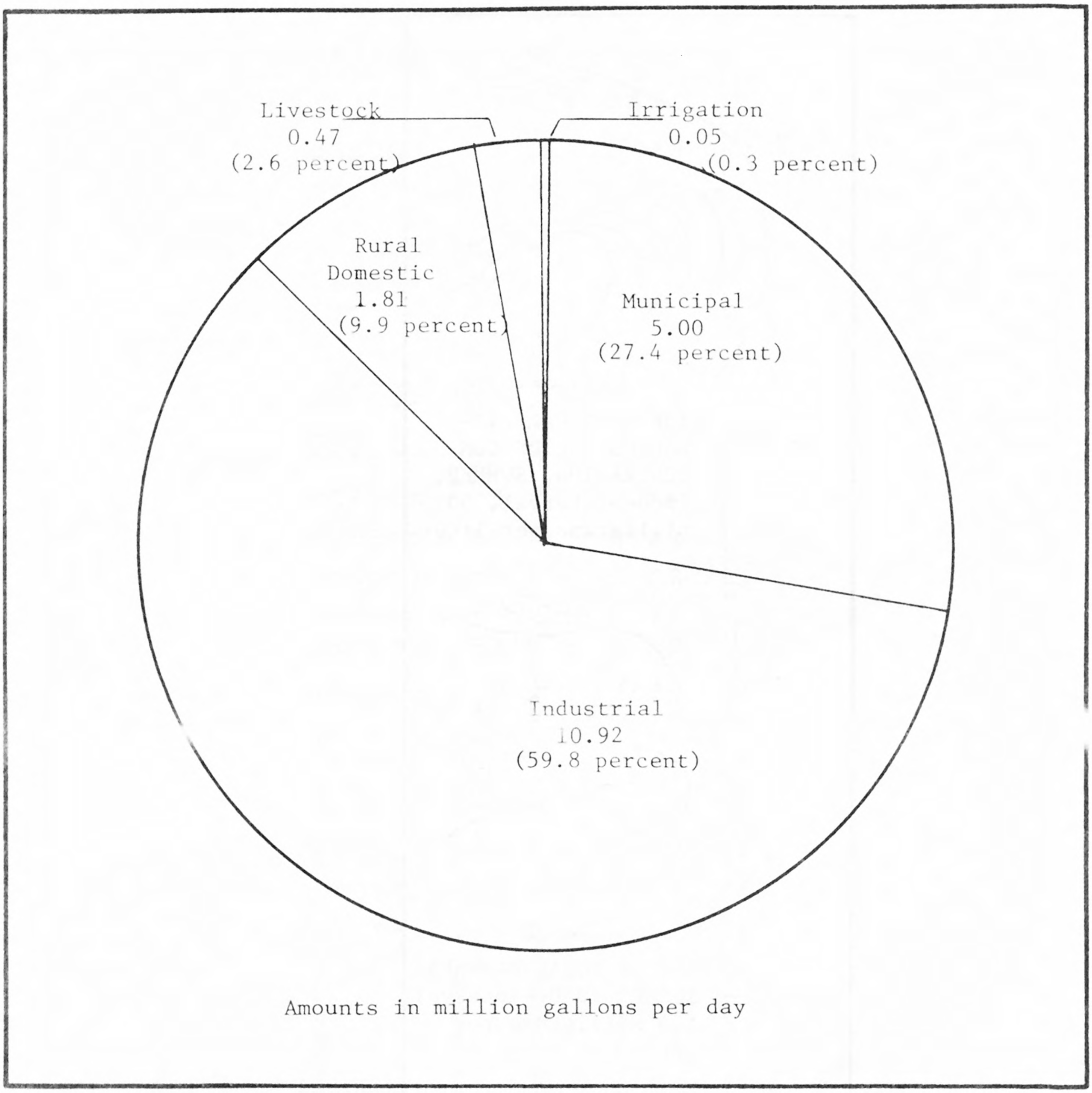

FIGURE 22.--Water use in Clay County, 1975.

About 4.9 Mgal/d or 27 percent of the total water use was consumptive use. The lakes and streams of Clay County also are used extensively for nonconsumptive uses, primarily recreation and water ransportation.

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER INVESTIGATIONS

Clay County appears to have sufficient water resources of good chemical quality for present and foreseeable anticipated needs. Surface-water use in the county in 1975 was 4.34 Mgal/d or 6.70 ft^3/s, which is equal to 1.3 percent of the average discharge of Black Creek. Ground-water use was 13.91 Mgal/d or 9,660 gal/min, which theoretically could be supplied by six to eight wells in the Floridan aquifer. Stresses on the aquifer in Clay County from water withdrawals outside the county, mainly at Jacksonville, undoubtedly are greater than those from within and probably will become even greater in the future.

The expected continued growth in population and industry in Clay County and in neighboring metropolitan Jacksonville warrants the need for additional information on the quantity and quality of the water resources in the county. To obtain the information needed to evaluate the county's water resources to meet future demands the following programs could be continued or implemented.

1. Continue monitoring the quantity and quality of surface water to assess the effect of man's activities on the streams and lakes of the county.

2. Locate and evaluate new impoundment sites and evaluate the sites previously selected by the U.S. Department of Agriculture.

3. Monitor the quality of water in the St. Johns River and determine the feasibility of using the brackish water.

4. Expand the network of monitor wells, especially for the Floridan aquifer in the Orange Park and Green Cove Springs areas to more accurately evaluate the effect of withdrawals on the occurrence and quality of the ground-water resource.

5. Conduct a detailed investigation of the Floridan aquifer, utilizing aquifer testing, geophysical logging, depth sampling, and other subsurface methods to determine:

    a) the hydraulic properties of the aquifer;
    b) net recharge to the aquifer, including leakance into and from the aquifer through the confining beds;
    c) the most suitable methods of well construction and well spacing for efficient development of the aquifer;

d) the nature, present depth, and the rate of migration (if any) of the base of potable water.

6. Extend the Geological Survey's nearly completed digital model of the Floridan aquifer for northeast Florida into Clay County to predict the effect of present and future stresses on the aquifer system.

7. Investigate the resource potential of the water-table and secondary-artesian aquifers throughout the county.

SELECTED REFERENCES

Applin, P. L., and Applin, E. R., 1944, Regional subsurface stratigraphy and structure of Floridan and southern Georgia: Am. Assoc. Petroleum Geologists Bull., v. 28, no. 12, p. 1673-1753.

Black, A. P., and Brown, Eugene, 1951, Chemical character of Florida's water-1951: Florida State Board Cons. Div. Water Survey and Research Paper 6, 119 p.

Chen, C. S., 1965, The regional lithostratigraphic analysis of Paleocene and Eocene rocks of Florida: Florida Geol. Survey Bull. 45, 105 p.

Clark, W. E., Musgrove, R. H., Menke, C. G., and Cagle, J. W., Jr., 1963, Hydrology of Brooklyn Lake near Keystone Heights, Florida: Florida Geol. Survey Rept. Inv. 33, 43 p.

_______________1964a, Water Resources of Alachua, Bradford, Clay and Union Counties, Florida: Florida Geol. Survey Rept. Inv. 35, 170 p.

_______________1964b, Water Resources data for Alachua, Bradford, Clay, and Union Counties, Florida: Florida Geol. Survey Inf. Circ. 43, 154 p.

Collins, W. D., and Howard, C. S., 1928, Chemical character of waters of Florida: U.S. Geol. Survey Water-Supply Paper 596-G, p. 177-233.

Cooke, C. W., 1945, Geology of Florida: Florida Geol. Survey Bul. 29, 339p.

Cooke, C. W., and Mossom, Stuart, 1929, Geology of Florida: Florida Geol. Survey 20th Ann. Rept., p. 29-227.

Durfor, C. N., and Becker, E., 1964, Public water supplies of the 100 largest cities in the United States; 1962: U.S. Geol. Survey Water-Supply Paper 1812, 20 p.

Ellis, M. M., Westfall, B. A., and Ellis, M. D., 1946, Determination of water quality: U.S. Fish and Wildlife Reserve Rept. 9.

Fairchild, R. W., 1977, Availability of water in the Floridan aquifer in southern Duval, and northern Clay and St. Johns Counties, Florida, U.S. Geol. Survey Water Resources Inv 76-98, 60 p.

Ferguson, G. E., Lingham, C. W., Love, S.K., and Vernon, R. O., 1947, Springs of Florida: Florida Geol. Survey Bull 31, 195 p.

Florida Department of Pollution Control, 1973, Rules of the Department of Pollution Control, chap. 17-3 supp. 23.

Healy, H. G., 1975, Potentiometric surface and areas of artesian flow of the Floridan aquifer in Florida, May 1974: Florida Dept. Nat. Resources, Bur. Geology Map Series 73.

Klein, Howard, 1975, Depth to base of potable water in the Floridan aquifer: Florida Dept. Nat. Resources, Bur. Geology Map Series 42, Revised.

Leve, G. W., 1966, Ground water in Duval and Nassau Counties, Florida: Florida Geol. Survey Rept. Inv. 43, 91 p.

_______________1968, The Floridan aquifer in northeast Florida: Ground Water, v. 6, no. 2, p. 19-29.

Lohman, S. W., and others, 1972, Definition of selected ground-water terms -- revisions and conceptual refinements: U.S. Geol. Survey Water-Supply Paper 1988, 21 p.

Maier, F. J., 1950, Fluoridation of public water supplies, Am., Water Works Assoc. Jour., v. 42, pt. 1, p. 1120-1132.

Matson, G. C., and Sanford, Samuel, 1913, Geology and ground water of Florida: U.S. Geol. Survey Water-Supply Paper 319, 445 p.

Maxcy, K. F., 1950, Report on the relation of nitrate concentrations in well water to the occurrence of methemoglobinemia: National Research Council, Bull. Sanitary Eng. and Environment, App. D., 271 p.

National Academy of Sciences and National Academy of Engineering, 1973, Water Quality Criteria 1972, U.S. Environmental Protection Agency rept. EPA R3 73 033, 594 p.

Parker, G. G., Ferguson, G. E., and Love, S. K., and others, 1955, 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, 965 p.

Pride, R. W., 1958, Floods in Florida -- Magnitude and frequency: U.S. Geol. Survey open-file report, 136 p.

Pride, R. W., and Crooks, J.W., 1961, Drought of 1954-56 -- Its effect on Florida's surface-water resources: Florida Geol. Survey Rept. Inv. 26 65 p.

Puri, H. S., 1957, Stratigraphy and zonation of the Ocala Group: Florida Geol. Survey Bull. 38, 248 p.

Puri, H. S., and Vernon, R. O., 1964, Summary of the geology of Florida and a guidebook to the classic exposures: Florida Geol. Survey Spec. Pub. 5, 312 p.

Sellards, E. H., and Gunter, Herman, 1913, The artesian water supply of eastern and southern Florida: Florida Geol. Survey 5th Ann. Rep., p. 103-290.

Snell, L. J., and Anderson, Warren, 1970, Water resources of northeast Florida: Florida Geol. Survey Rept. Inv. 54, 77 p.

Stringfield, V. T., 1936, Artesian water in the Florida peninsula: U.S. Geol. Survey Water-Supply Paper 773-C, p.115-195.

________________1966, Artesian water in Tertiary limestone in the southeastern states: U.S. Geol. Survey Prof. Paper 517, 226 p.

Swenson, H. A., and Baldwin, H. L., 1965, A primer on water quality: Washington, U.S. Govt. Printing Office, 27 p.

U.S. Army Corps of Engineers, 1975, Upper Etonia Creek basin, southwest Clay and Northwest Putnam Counties, Florida: U.S. Dept. Army Flood Plain Inf. Rept., 29 p.

U.S. Dept. of Agriculture, 1969, Report for St. Johns River Basin and intervening coastal areas, Florida: U S. Dept. Agr. unnumbered rept., 142 p.

U.S. Geological Survey, 1960, Compilation of records of surface waters of the United States to 1950 - Part 2-B, South Atlantic Slope and eastern Gulf of Mexico basins, Ogeechee River to Pearl River: U.S. Geol. Survey Water Supply Paper 1304, 399 p.

_____________1963, Compilation of records of surface waters of the United States, October 1950 to September 1960 - Part 2-B, South Atlantic Slope and eastern Gulf of Mexico basins, Ogeechee River to Pearl River: U.S. Geol. Survey Water Supply Paper 1724, 458 p.

_____________1970, Surface water supply of the United States, 1961-65 - Part 2, South Atlantic slope and eastern Gulf of Mexico basins - Vol. 2 Basins from Ogeechee River to Carrabelle River: U.S. Geol. Survey Water Supply Paper 1905, 772 p.

_____________1975, Surface water supply of the United State, 1966-70 - Part 2, South Atlantic slope and eastern Gulf of Mexico basins - Vol. 2, Basins from Ogeechee River to Carabelle River: U.S. Geol. Survey Water Supply Paper 2105, 797 p.

_______________1976, Water resources data for Florida, Water Year 1975: U.S. Geol. Survey Water Data Rept. FL-75-1, Vol. 1, northern Florida,769 p.

_______________1974, Water resources information needs for the St. Johns River Water Management District: U.S. Geol. Survey Open-File Rept. 75-44, 142 p.

U.S. National Oceanic and Atmospheric Administration, National Weather Service, 1958-1977, Climatological data, Florida, annual summary 1956-1976, v. 61, no. 13 through v. 80, no. 13.

U.S. Public Health Service, 1962, Drinking water standards: U.S. Dept. Health, Education, and Welfare, Public Health Service: Pub. 956, 61 p.

Vernon, R. O., 1973, Top of the Floridan artesian aquifer: Florida Dept. Nat. Resources, Bur. Geology Map Series 56.

*U.S. GOVERNMENT PRINTING OFFICE: 1977-744-738/734. Region 4..

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