STATE OF FLORIDA
STATE BOARD OF CONSERVATION
DIVISION OF GEOLOGY

FLORIDA GEOLOGICAL SURVEY
Robert O. Vernon, Director

REPORT OF INVESTIGATIONS NO. 27

GROUND-WATER RESOURCES OF SEMINOLE COUNTY, FLORIDA

By
Jack T. Barraclough
U. S. Geological Survey

Prepared by the
UNITED STATES GEOLOGICAL SURVEY
in cooperation with the
FLORIDA GEOLOGICAL SURVEY,
THE BOARD OF COUNTY COMMISSIONERS OF SEMINOLE COUNTY
and the
CITY OF SANFORD

TALLAHASSEE
1962

FLORIDA STATE BOARD
OF
CONSERVATION

LETTER OF TRANSMITTAL

Florida Geological Survey

Tallahassee

November 1, 1961

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

Dear Governor Bryant:

The Division of Geology is pleased to publish, as Florida Geological Survey Report of Investigations No. 27, a study of the "Ground-Water Resources of Seminole County, Florida." The study was made by Jack T. Barraclough, engineer with the U. S. Geological Survey, in cooperation with the Division of Geology, Seminole County commissioners, and the city of Sanford.

The limestones of the principal artesian aquifer underlie all of Seminole County and provide the water required for the extensive farming and industry of the county. This water probably originates in the recharge area of Polk and Orange counties and from local rainfall. The report has determined the long-range changes of water levels, provided seasonal fluctuations and related these to quality-of-water changes.

The study will provide the data required for expansion of pumping, location of well fields, and treatment of water.

Respectfully yours

Robert O. Vernon, *Director*
and State Geologist

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GROUND-WATER RESOURCES OF SEMINOLE COUNTY, FLORIDA

By

JACK T. BARRACLOUGH

ABSTRACT

Seminole County is in the east-central part of the Florida Peninsula. The climate is subtropical and the average annual rainfall is more than 50 inches. The area is well suited for the growing of winter vegetables, even though most of the rain falls during the summer months and the vegetables must be irrigated.

The surface deposits consist of sand of Pleistocene and Recent Age, which ranges in thickness from 10 to 75 feet. Beneath this sand are deposits of clay and shell beds, which are believed to be of late Miocene or Pliocene Age. The Hawthorn Formation of middle Miocene Age underlies the surface sand where the deposits of clay and shells are absent. A thick section of limestone of Eocene Age underlies the Hawthorn Formation, and, where the Hawthorn is absent, the limestone underlies the clay and shells of late Miocene or Pliocene Age. The sedimentary rocks extend to about 6,000 feet below sea level in Seminole County.

The upper part of the limestone section is composed, in descending order, of the Ocala Group[1] of late Eocene Age, the Avon Park Limestone of late middle Eocene Age, and the Lake City Limestone of early middle Eocene Age.

The section of limestone formations described above and the lower part of the Hawthorn Formation make up part of the Floridan aquifer, which is the most important source of ground water in Seminole County. Water in the Floridan aquifer is under artesian pressure, and wells that penetrate this aquifer flow at the surface in most of the lowland areas. The water in the Floridan aquifer in Seminole County is recharged in Polk, Orange, and Seminole counties.

Fluctuations of artesian pressure in Seminole County result mainly from differences in rainfall and variations in the rate of withdrawal of water from wells. In the Oviedo area the seasonal fluctuations of artesian pressures cause the water level to fluctuate as much as 12 feet. In the Sanford area, the maximum seasonal fluctuation of water level was about 7 feet. The minimum seasonal fluctuation of water level in the county was generally between 5 and 6 feet.

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[1]The stratigraphic nomenclature used in this report conforms to the usage of the Florida Geological Survey.

Comparisons of water-level measurements made during the period 1933-39 with measurements made during the period 1951-56 show that the average decline of the water level in the Sanford area, in the interval between those two periods, was about 1 foot. During the same interval, the average decline of the water level in the Oviedo area was about 3 feet.

The chloride content of water from artesian wells in Seminole County ranges generally from 5 ppm (parts per million) in the recharge areas near the towns of Lake Mary, Paola, Longwood, Oviedo, Chuluota, and Geneva to 7,500 ppm in the area near Mullet Lake. In most of the two truck farming areas of Sanford and Oviedo, the chloride content of the water from artesian wells ranges in different areas from about 10 ppm to slightly more than 1,500 ppm. The minimum observed seasonal variation of the chloride content of the artesian water in one well near Sanford was 35 ppm and the maximum observed seasonal variation in one well was 265 ppm. The minimum observed seasonal variation of the chloride content of the artesian water in one well near Oviedo was 16 ppm and the maximum observed seasonal variation in one well was 180 ppm. Comparisons of analyses made in 1933 and 1956 indicate that there has been little long-term change in the chloride content of the artesian water in Seminole County.

Chemical analyses show that ground water in parts of Seminole County would be classed as excellent for most uses, and ground water in other parts of the county would be classed as unusable for almost all purposes.

The artesian aquifer has an average coefficient of transmissibility of about 185,000 gpd (gallons per day) per foot.

INTRODUCTION

PURPOSE AND SCOPE OF INVESTIGATION

Salt-water encroachment is a problem of great concern to most users of ground water in Florida. In many coastal areas the lowering of water levels by heavy pumping contributes to lateral encroachment of salt water from the ocean. In some inland areas the water-bearing formations contain salty water at a moderate depth and excessive lowering of water levels causes upward encroachment of the salty water. Examples of inland areas with salt-water problems can be found along most of the St. Johns River.

An important part of the economy of Seminole County is the growing and marketing of winter vegetables. The most important farming areas are in the level lowlands adjacent to Lake Monroe and Lake Jessup, where adequate supplies of water for irrigation are available from the natural flow of artesian wells. In parts of the farming areas wells yield relatively salty water and, locally, the artesian pressure has declined excessively as a result of heavy withdrawal of water for irrigation and for vegetable processing. This decline in artesian pressure has resulted in a decrease in the size of the area of artesian flow and, in some places, has necessitated the use of pumps on wells that formerly produced an adequate supply of water by natural flow. The decline of artesian pressure may lead also to contamination of the existing supplies by causing encroachment of salty water from the formations that underlie the producing aquifer.

Recognizing these possibilities, the Board of County Commissioners of Seminole County requested the U. S. Geological Survey and the Florida Geological Survey to make an investigation of the ground-water resources of the county. An investigation was begun in October 1951 by the U. S. Geological Survey in cooperation with the Florida Geological Survey and the Board of County Commissioners of Seminole County. The city of Sanford shared in the cooperation from 1953 through 1955.

The principal purpose of the investigation was to collect and interpret basic information for the safe and efficient development of ground-water supplies of Seminole County. Special emphasis was placed on the problems associated with salt-water contamination and declining water levels.

The field work was begun in 1951 by Ralph C. Health, geologist, under the direct supervision of H. H. Cooper, Jr., district engineer. The author was assigned to the project in 1953, under the direct supervision of Mr. Heath, who was then acting district geologist of the Federal Survey. During the period 1955-58, the investigation was under the direct supervision of M. I. Rorabaugh, district engineer.

LOCATION AND EXTENT OF AREA

Seminole County comprises an area of about 321 square miles in the east-central part of the Florida Peninsula (fig. 1). Prior to 1913 the area in this report was part of Orange County. Sanford, the county seat, is in the northern part of Seminole County, along the St. Johns River.

PREVIOUS INVESTIGATIONS

The geology and ground-water resources of Seminole County are described in several reports published by the Florida Geological Survey, the Florida Academy of Sciences, and the U. S. Geological Survey.

A report by Matson and Sanford (1913, p. 376-381) contains a brief discussion of the geology and ground-water resources of Orange County, which at that time included the area that is now Seminole County. A

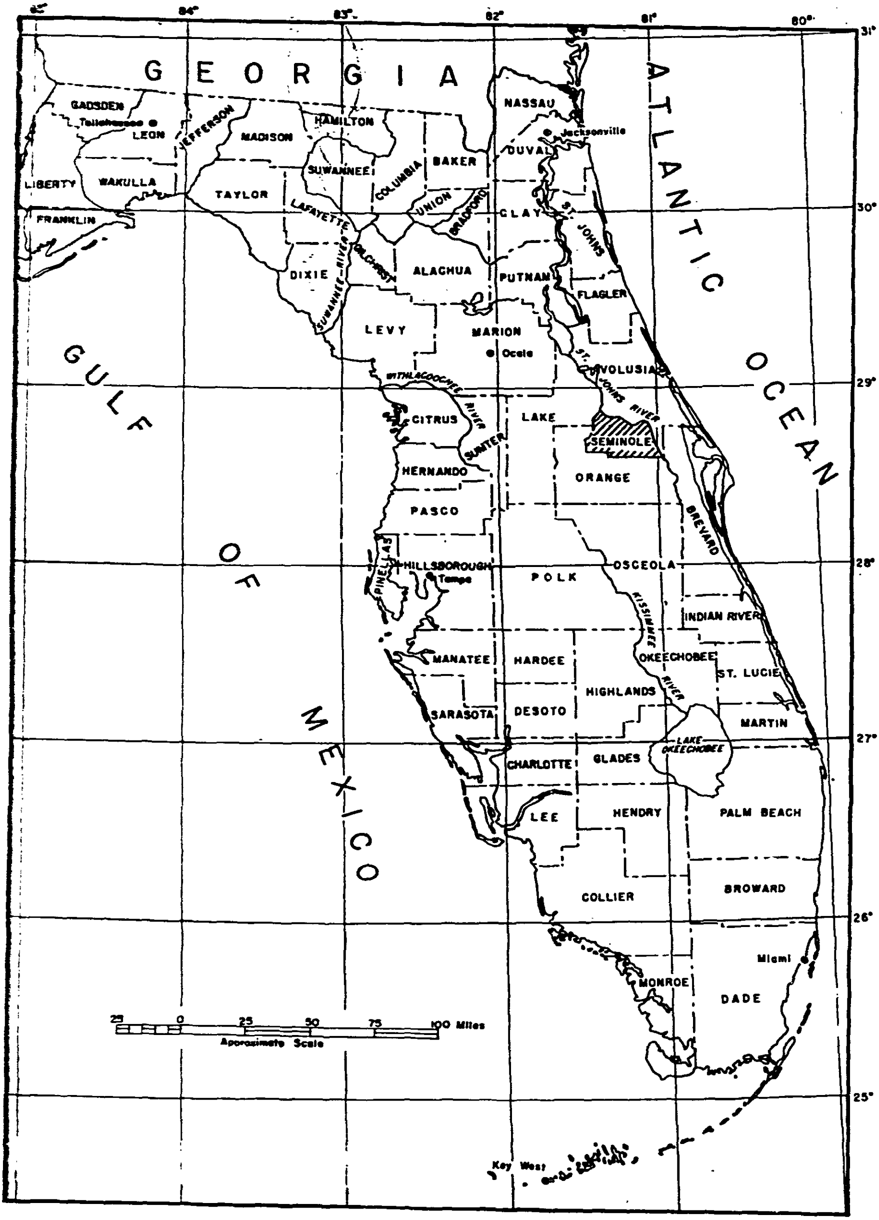


Figure 1. Location of Seminole County.

report by Sellards and Gunter (1913, p. 113) contains information on wells in Seminole County.

V. T. Stringfield (1934) made a brief investigation of the ground-water resources of Seminole County as part of a general investigation of the ground-water resources of the Florida Peninsula. The geology and ground water of Seminole County are also discussed by Stringfield (1936, p. 135-136, 162, 174, 188) in a report on the artesian water in the Florida Peninsula. This report includes a map showing the areas of artesian flow, a map showing the areas in which the artesian water contains more than 100 ppm of chloride, and the first published map of the piezometric surface of the principal artesian (Floridan) aquifer. A report on the geology and artesian-water supply of Seminole County by Stubbs (1937, p. 24-36) includes two maps of the piezometric surface, a map showing the areas of artesian flow, and a discussion of the geologic formations that underlie the county. As a part of his work in the county, Stubbs periodically measured the water levels in selected wells and analysed the chloride content of water samples collected from selected wells (S. A. Stubbs and Irving Feinberg, unpublished records in the files of H. James Gut, Sanford, Florida).

A report by Unklesbay (1944), describing ground-water conditions in Orlando and vicinity, includes records of 3 wells and 1 spring in Seminole County. The geology of the State, including formations in Seminole County, is described in a report by Cooke (1945, p. 225).

A report by Ferguson and others (1947, p. 149-154) contains descriptions of three of the largest springs in the county and chemical analyses of their waters. Chemical analyses of water from wells in Seminole County are contained in reports by Collins and Howard (1928, p. 228) and Black and Brown (1951, p. 104).

Heath and Barraclough (1954) prepared an interim report on the ground-water resources of Seminole County as a part of this investigation.

ACKNOWLEDGMENTS

The author wishes to express appreciation to the many residents of the county who readily gave information regarding their wells, and to those who permitted frequent measurements of water levels in their wells.

Mr. H. James Gut, former mayor and former city commissioner of Sanford, was chiefly responsible for the initiation of the investigation. In addition, Mr. Gut thoughtfully saved valuable information collected by Sidney A. Stubbs in 1937 and furnished these data and other information from his files for use during the investigation.

Thanks are extended to others in the county who have been especially helpful. These men include: Mr. C. S. Lee, Oviedo; Dr. Phillip Westgate, Central Florida Experiment Station, Sanford; Mr. Benjamin Wiggins, Soil Conservation Service, Sanford; Mr. Randall Chase, Sanford; and Mr. LeRoy Hennessey, Longwood. Mr. R. W. Estes (deceased) was also very helpful.

Appreciation is expressed for the support and cooperation of many well drilling contractors in the area. Mr. Ernest Hamilton, Lake Monroe, was especially helpful and cooperative during the investigation. Other drillers who helped by collecting rock cuttings included the following: Mr. M. G. Hodges, Paola; Mr. H. C. Long, Sanford; Mr. F. F. French, Longwood; the Libby and Freeman Drilling Company, Orlando; and the Layne-Atlantic Company, Orlando.

Dr. Herman Gunter, former director of the Florida Geological Survey, and Dr. Robert Vernon, director of the Florida Geological Survey, furnished much valuable information concerning the geology of the county.

WELL-NUMBERING SYSTEM

The well-numbering system used in this report is based on latitude and longitude coordinates. The well number was assigned by first locating each well on a map that is divided into 1-minute quadrangles of latitude and longitude, then numbering, consecutively, each inventoried well in a quadrangle. The well number is a composite of three numbers separated by hyphens: The first number is composed of the last digit of the degree and the two digits of the minute of the meridian of latitude on the south side of a 1-minute quadrangle; the second number is composed of the last digit of the degree and the two digits of the minute of the parallel of longitude on the east side of a 1-minute quadrangle; and the third number gives the order in which the well was inventoried in the 1-minute quadrangle. For example, well number 844-114-1 was the first well inventoried in the 1-minute quadrangle north of 28°44′ parallel of latitude and west of the 81°14′ meridian of longitude. Wells referred to in the text can be located on figure 10 by this system. Complete well descriptions, locations, and other data are to be published as Florida Geological Survey Information Circular No. 34, and may be obtained for $1.00 per copy.

GEOGRAPHY

TOPOGRAPHY AND DRAINAGE

The topography of Seminole County may be divided into two types: a flat lowland, characteristic of the area adjacent to Lake Monroe; and hilly uplands, characteristic of the area in the vicinity of Lake Mary.

The level lowland includes the area ranging from a few hundred feet to more than 2 miles wide adjacent to the Wekiva, St. Johns, and Econlockhatchee rivers and Lake Jessup. The land-surface altitude within this area ranges from about 5 feet above mean sea level near the St. Johns River to about 30 feet above sea level where the lowland area merges into the hilly upland.

The hilly upland includes the remainder of the county. The surface features of this area include many sandhills and lakes and some level areas. Many of the lakes probably were formed by the collapse of the surface sand and clay into caverns formed by the solution and removal of the underlying limestone by circulating ground water. The land surface in this area ranges from about 30 feet above sea level where the area adjoins the level lowlands to about 105 feet above sea level in the vicinity of Altamonte Springs.

The level lowlands and small areas of the hilly uplands are drained by the St. Johns River and its tributaries, which include Lake Jessup, the Wekiva River, and the Econlockhatchee River. The remainder of the hilly uplands drains into closed depressions. Many of these depressions are probably drained through permeable material into the underlying limestone aquifers.

CLIMATE

The climate of Seminole County is subtropical. The average annual precipitation at Sanford for the 49 years of record (1883-87 and 1913-56) is 52.89 inches, according to the records of the U. S. Weather Bureau. The maximum annual precipitation was 74.06 inches in 1953, and the minimum annual precipitation was 35.54 inches in 1938. The monthly distribution of rainfall at Sanford and the maximum and minimum rainfall of record are shown in figure 2. About 70 percent of the precipitation falls during the months of May through October.

Temperature records at Sanford have been collected by the weather bureau for 43 years. The mean annual temperature at Sanford is 72.2°F. The lowest mean monthly temperature is 61.4°F. in January; the highest mean monthly temperature is 82.2°F. in August. The average growing season is about 330 days.

POPULATION AND DEVELOPMENT

The 1950 census listed the population of Seminole County as 26,883. Sanford, the largest town and the county seat, had a population

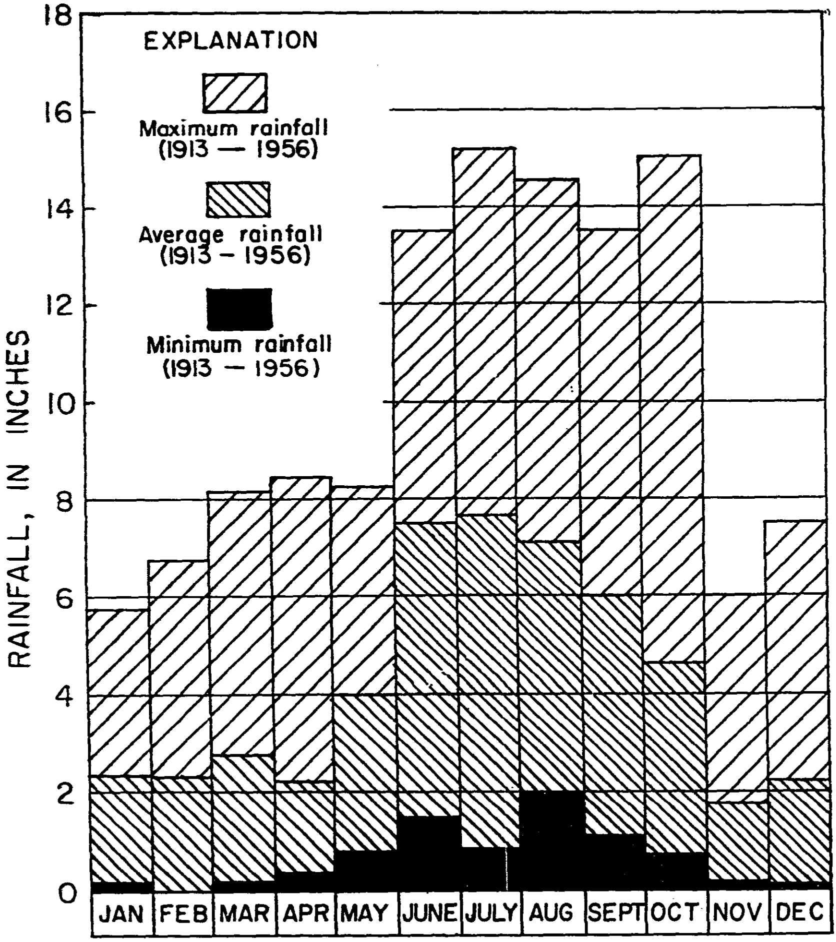


Figure 2. Monthly distribution of rainfall at Sanford.

of 11,935. The populations of the largest towns were as follows: Oviedo, 1,601; Altamonte Springs, 858; Longwood, 717; and Lake Mary, about 800.

Sanford is at the site of Camp Monroe, which was established in 1836 by troops of the U. S. Army to protect the settlers from the Seminole Indians. Fort Mellon, a more permanent base named to honor Captain Charles Mellon, soon replaced Camp Monroe. In 1870, General Henry S. Sanford purchased 12,535 acres of land west of Fort Mellon and laid out the town named for him. Sanford was incorporated in 1877 and included Fort Mellon.

Orange groves were set out in about 1840 and served as a main source of income. Other crops were grown until the "big freeze" of 1895 blackened most of the agriculture of the State. This freeze caused the settlers to depend on other crops because it was several years before the citrus trees would again bear fruit. Shortly after the "big freeze," a method of subirrigation of crops was developed for use in the level lowlands. This method of irrigation enabled the area to maintain an agricultural economy balanced between citrus crops and winter vegetables. According to the Florida State Marketing Bureau's annual fruit and vegetable report for the 1952-53 season (Scruggs and Scarborough, 1953), Seminole County had a total of 8,575 acres under cultivation and an additional 7,829 acres planted in citrus groves.

GEOLOGY

STRATIGRAPHY

The only geologic units exposed in Seminole County are deposits of Pleistocene and Recent Age, which cover the entire county. Information about the subsurface geology in the county was obtained from well cuttings from 69 wells, well logs studied by Sidney A. Stubbs in the late thirties, and well logs from surrounding counties. Most of the cuttings from the 69 wells were collected during this investigation and the remainder were obtained from the files of the Florida Geological Survey, Tallahassee, Florida.

The geologic formations and their water-bearing properties are described in detail in the following pages and described briefly in table 1. Two cross sections showing the formations penetrated by water wells are given in figure 3.

PRE-MESOZOIC ROCKS

The top of the pre-Mesozoic rocks in Seminole County is given by Applin (1951, fig. 2) as about 6,000 feet below sea level. Applin has classified these crystalline rocks as granite, diorite, and metamorphic

TABLE 1. Geologic Units in Seminole County

Age	Unit	Thickness (feet)	Physical Character	Water-Bearing Character
Pleistocene and Recent	Undifferentiated deposits	10- 75	Sand, containing some shells and clay	Furnishes water to shallow wells equipped with screens. Usually adequate for lawn irrigation, domestic and stock use. The water is softer and more corrosive than water from the Miocene and Eocene deposits.
Late Miocene or Pliocene	Undifferentiated deposits	0- 83	Sticky blue clay and shell beds	The shell beds yield small to moderate quantities of water to wells. Water from wells that tap these beds flow in most of the lower lands. The clay beds confine water under artesian pressure.
Miocene	Hawthorn Formation	0–150	Blue to gray calcareous clay; cream to gray sandy limestone; containing grains of cream to black phosphate rock and fragments of chert	The beds of sandy limestone yield substantial quantities of water to wells drilled for irrigation or domestic uses. The clay beds serve as an aquiclude.
Eocene	Ocala Group	0–190	Cream to tan-gray, soft to hard, granular, porous foraminiferal marine limestone	The second most productive formation in the county. The Ocala furnishes large quantities of water to many wells which tap it only and contributes considerable water to wells that tap both overlying or underlying formations also. It is the first limestone penetrated in most of the county.
Eocene	Avon Park Limestone	500±	Light-gray to brown, soft to hard, porous to dense, granular to chalky limestone and dolomitic limestone	The most productive formation in Seminole County. Yields water to all the deeper wells in the county and is the only part of the Floridan aquifer tapped by many wells. Very few wells draw water from the lower part of the Avon Park and very substantial additional supplies could be developed from that part of the formation.
Eocene	Lake City	Over 400	Hard, brown, porous, crystalline dolomite; hard, cream to tan chalky limestone and dolomitic limestone	A highly productive formation in the southwestern part of the county but tapped by only a few wells. No information is available about the hydraulic properties or the chemical quality of the water from this formation elsewhere in the county.

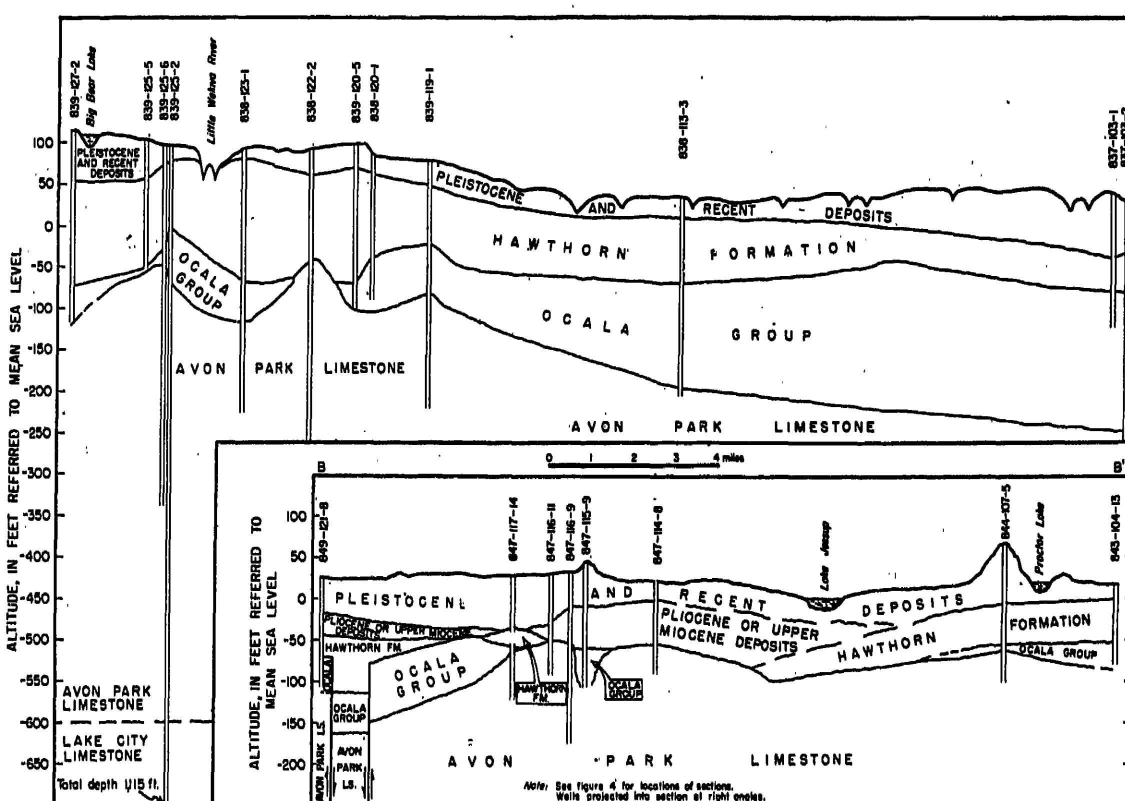


Figure 3. Geologic units penetrated by water wells in Seminole County.

rocks. They have been termed basement rocks in some publications on the Florida Peninsula. The depth to the crystalline rocks was determined from oil test wells in Volusia, Lake, and Osceola counties. The formations that overlie these crystalline rocks consist of shallow-water marine deposits, most of which are limestone.

EOCENE SERIES

The upper part of the Eocene Series in Seminole County consist of the Lake City Limestone, the Avon Park Limestone, and the Ocala Group (fig. 3, 4).

Figure 4 shows contours in altitude in feet below sea level of the top of the Eocene limestones in Seminole County. The amount of casing required to case a well to the uppermost limestone formation can be determined approximately from this map if the land-surface elevation is known. The upper surface of the Eocene Limestone ranges from 75 to about 190 feet below the land surface.

Lake City Limestone

Name: The name Lake City Limestone was given by Applin and Applin (1944, p. 1680) to a limestone of Claiborne (middle Eocene) Age penetrated in a well at Lake City, Florida.

Lithology: The Lake City Limestone consists of alternating layers of hard, brown, porous crystalline dolomite and hard, cream to tan chalky limestone and dolomitic limestone.

Distribution and thickness: Cooke (1945, p. 45-46) states that the Lake City Limestone underlies all of Florida except the northwestern part, where the limestone grades laterally into a clastic facies related to the Cook Mountain Formation of Claiborne Age.

According to Applin and Applin (1944), the Lake City Limestone ranges in thickness from 400 to 500 feet in the northern part of Florida and from 200 to 250 feet in the southern part. The Lake City is more than 400 feet thick in the southwestern part of Seminole County.

Stratigraphic relations: In most of the Florida Peninsula, the Lake City Limestone unconformably overlies the Oldsmar Limestone. In Seminole County, the Lake City is overlain by the Avon Park Limestone. In the southwestern part of Seminole County, the top of the Lake City Limestone was penetrated about 600 feet below sea level in well 839-125-2 (fig. 3).

Water-bearing characteristics: The Lake City Limestone is the oldest formation penetrated by water wells in Seminole County. Only a few wells have been drilled into this formation because adequate supplies of water can generally be obtained from the overlying deposits, although the Lake

City Limestone appears to be highly productive in Seminole County. The largest yield pumped from a well in Seminole County was reported to be 8,100 gpm (gallons per minute) and this was obtained from a well that penetrates more than 400 feet of Lake City Limestone and less than 200 feet of Avon Park Limestone.

Water from the Lake City is somewhat less mineralized than water from the overlying formations in the southwestern part of Seminole County and northern Orange County. This is probably not true where the overlying formations contain salt water. The good quality of the water from the Lake City Limestone may be due to the fact that the formation contains a considerable percentage of dolomite or dolomitic limestone which is less soluble in water than is limestone. No information is available concerning the chemical quality of the water in this formation in any area where the overlying formations contain salty water.

The Lake City Limestone could become an important aquifer in some areas of Seminole County if large quantities of ground water are required. In order to fully appraise the Lake City Limestone as an aquifer, it would be necessary to drill several wells into the formation in different parts of the county. The hydraulic properties of the formation and the chemical quality of the water could then be determined.

Avon Park Limestone

Name: The name Avon Park Limestone was given by Applin and Applin (1944, p. 1680) to a limestone of Claiborne (middle Eocene) Age penetrated in a well at the Avon Park Bombing Range in Polk County, Florida.

Lithology: The Avon Park Limestone consists of layers of light gray to brown, soft to hard, porous to dense, granular to chalky limestone. The formation has been irregularly dolomitized since deposition, but the original structures of the rock generally have been preserved.

Distribution and thickness: The Avon Park Limestone underlies most of the Florida Peninsula. It is exposed in parts of Citrus and Levy counties and is the oldest formation that crops out in Florida.

According to Applin and Applin (1944), the thickness of the Avon Park Limestone ranges from 50 feet or less in northeast Florida to 650 feet in the southern part of the Florida Peninsula. In the southwestern part of Seminole County, the Avon Park Limestone is more than 500 feet thick.

Stratigraphic relations: The Avon Park Limestone rests conformably upon the Lake City Limestone. In Seminole County, the Avon Park is unconformably overlain by the Ocala Group except where the Ocala is absent in the north-central part of the county. Here the Avon Park is overlain by the Hawthorn Formation or younger deposits.

Structure: Subsurface contours on the top of the Avon Park Limestone are shown in figure 5. This figure shows the top of the Avon Park Limestone to be 27 to about 100 feet below sea level in the area around Sanford and about 250 feet below sea level in the southeastern part of the county. The eroded surface of the Avon Park Limestone slopes south-southeast about 25 feet per mile in the area from Lake Jessup south and southeast toward Orange County. West of Sanford the surface of the Avon Park slopes west, toward the Wekiva River, about 20 feet to the mile.

Water-bearing characteristics: The Avon Park Limestone yields more ground water in Seminole County than any other formation. This is due principally to its wide areal extent, thickness, and high permeability. The Avon Park is the shallowest limestone formation that underlies all of Seminole County, and supplies water to most of the deeper wells. The large amount of water obtained from this limestone demonstrates its high permeability. Well 840-107-2, 2.1 miles north of Chuluota, flows about 350 gpm from the Avon Park (fig. 24).

Most of the existing wells penetrate only the upper part of the Avon Park Limestone; however, the lower part of the formation could become important if even larger quantities of water are needed.

Ocala Group

Name: The Ocala Limestone was named for limestone outcrops near Ocala, Marion County, by Dall and Harris (1892, p. 103), who believed that it was Eocene or Oligocene in age. Cooke (1926, p. 251-297) concluded that the limestone was of Jackson Age (late Eocene). Cooke and Mossom (1929, p. 47-48) defined the name Ocala as including all rocks of Eocene Age exposed in Florida. Applin and Applin (1944, p. 1683-1684) stated that it was possible to separate the Ocala Limestone into an upper and lower member, and listed some characteristic Foraminifera. On the basis of differences in lithology and fossil content of the Ocala Limestone, Vernon (1951, p. 156-171) restricted the name Ocala Limestone to the upper part and named the lower part the Moodys Branch Formation. He further subdivided the Moodys Branch Formation into the Williston Member at the top and the Inglis Member at the bottom. Recently, Puri (1953, p. 130) changed the name of the Ocala Limestone (restricted) to Crystal River Formation and raised the Williston and Inglis members of the Moodys Branch to the rank of formations. These three formations, the Crystal River, Williston, and Inglis, are now collectively referred to as the Ocala Group by the Florida Geological Survey.

Lithology: The Ocala Group consists of white-cream to tan-gray soft to hard, granular, porous foraminiferal marine limestones. In most places the Crystal River Formation is white to cream and parts of it are composed almost entirely of remains of large foraminifers. The Williston and Inglis Formations generally are harder, more granular and contain fewer large Foraminifera than the overlying Crystal River.

Distribution and thickness: The Ocala Group underlies most of Florida except the east-central part of the peninsula (Applin and Applin, 1944, p. 1685). It is thin or missing in the northern part and in a small area in the southwestern part of Seminole County. The thickness of the Ocala Group ranges generally from 0 to 190 feet. Vernon (1951, p. 57) states that the Ocala Group has been thinned by erosion along the flanks of a structural high near Sanford and removed from the crest of the high. The Sanford high is described by Vernon (1951, p. 57) as the upthrown side of a closed fold that has been faulted.

Stratigraphic relations: The Ocala Group lies unconformably on the Avon Park Limestone in the Florida Peninsula, and is overlain unconformably by the Hawthorn Formation. In places in the northern part of the county where the Ocala Group is present and the Hawthorn is absent, the Ocala is overlain unconformably by deposits of Pliocene or late Miocene Age.

Structure: The altitude of the top of the Ocala Group ranges from near sea level near the town of Lake Mary to about 113 feet below sea level near the village of Lake Monroe.

Water-bearing characteristics: The Ocala Group is a very productive part of the Floridan aquifer and next to the Avon Park Limestone is the most productive source of ground water in Seminole County. Hundreds of wells in the county tap only the Ocala Group. Wells penetrating the Ocala yield from a few gallons per minute to more than 500 gpm. Figure 27 shows that well 838-113-3, 2.5 miles southeast of Oviedo, flows 170 gpm from the Ocala. The Ocala yields about 200 gpm to well 842-111-6, 2.3 miles northeast of Oviedo, as illustrated in figure 28.

MIOCENE SERIES

Hawthorn Formation

Name: The name Hawthorn Formation was first applied by Dall and Harris (1892, p. 107) to rocks of early and middle Miocene Age that are exposed near Hawthorn in Alachua County, Florida.

Lithology: The Hawthorn Formation in Seminole County consists of beds of blue to gray, calcareous clay, alternating with beds of cream to gray sandy limestone containing numerous grains of black to cream phosphate rock and fragments of chert.

Distribution and thickness: The Hawthorn Formation apparently underlies the entire Florida Peninsula except in parts of the Ocala uplift and the Sanford high, where it has been eroded. It is present throughout Seminole County except in the northern part, along the St. Johns River, where it has been removed by erosion.

According to Bishop (1956, p. 27), the Hawthorn Formation has a maximum thickness of 650 feet in Highlands County, Florida. Cooke (1945, p. 145) states that the Hawthorn is about 400 feet thick in Nassau County, Florida. In Seminole County, the maximum observed thickness of the Hawthorn Formation was 150 feet in a well at the southwestern part of the county.

Stratigraphic relations: The Hawthorn Formation unconformably overlies the Ocala Group in most places. Where the Ocala is absent, the Hawthorn rests unconformly upon the Avon Park Limestone. The Hawthorn Formation is unconformably overlain by deposits of Pliocene or late Miocene Age or by deposits of Pleistocene Age. The study of well cuttings in Seminole County has not revealed any rocks representing the time interval between the Ocala Group and the Hawthorn Formation.

Water-bearing characteristics: The beds of sandy limestone in the Hawthorn Formation yield substantial quantities of water to some wells and are an important source of water for domestic and irrigation supplies. Well 842-111-6, 2.3 miles northeast of Oviedo (fig. 28), obtains at least 500 gpm of water from the Hawthorn Formation. However, the Hawthorn Formation includes clay beds of low permeability, which confine the water in the underlying limestones.

PLIOCENE OR UPPER MIOCENE DEPOSITS

Name: The beds of Pliocene Age exposed along the Caloosahatchee River in the vicinity of La Belle, Hendry County, Florida, were first recognized by Heilprin (1887). Dall (1887) described them as the Caloosahatchie beds. Matson and Clapp (1909) used the term Caloosahatchee marl for the deposits of Pliocene Age in the vicinity of the Caloosahatchee River but proposed the term Nashua Marl for the deposits of Pliocene Age they found in the valley of the St. Johns River. Cooke and Mossom (1929, p. 152) included the Nashua in the Caloosahatchee Marl.

Vernon (1951, fig. 13, 33) considered the Caloosahatchee Marl to be of late Miocene Age. As the correct age of these deposits has not been determined, they are referred to in this report as Pliocene or upper Miocene deposits.

Lithology: The Pliocene or upper Miocene deposits consist of sticky blue clay and shell beds.

Distribution and thickness: The deposits of Pliocene or late Miocene Age are found in wells in the northern part of Seminole County, especially along the St. Johns River valley, but do not crop out in Seminole County.

Stubbs (1937, p. 30) gives the maximum measured thickness of the Pliocene or upper Miocene deposits as about 70 feet in the St. Johns River valley, although he states that they may be thicker. Information from well cuttings examined during the present study shows the maximum thickness of these beds to be 83 feet.

Stratigraphic relations: The Pliocene or upper Miocene deposits lie unconformably upon the Hawthorn Formation where it is present, and upon the limestones of Eocene Age where the Hawthorn is absent. The Pliocene or upper Miocene deposits are overlain unconformably by deposits of Pleistocene Age.

Water-bearing characteristics: The shell beds yield small to moderate quantities of water to wells. Of the wells that penetrate the shell beds, some draw entirely from them, but most also are open to the underlying limestone and obtain water from both sources.

PLEISTOCENE AND RECENT DEPOSITS

Lithology: The Pleistocene and Recent deposits in Seminole County consist of clear to frosted, fine to coarse quartz sand. In areas near the St. Johns River, the deposits also include some shells and thin beds of clay. Beneath the level lowlands of Seminole County, thin layers of hardpan have been formed at a depth of 3 to 5 feet through cementation of sand by iron oxide.

Distribution and thickness: The Pleistocene and Recent deposits mantle the entire county. They range in thickness from 10 to 75 feet.

Stratigraphic relations: In Seminole County, the Pleistocene and Recent deposits rest unconformably upon deposits of Pliocene or late Miocene Age, and upon the Hawthorn Formation where the beds of Pliocene or late Miocene Age are absent.

Water-bearing characteristics: The Pleistocene and Recent deposits furnish water to shallow driven wells that are equipped with screens. The deposits will yield sufficient quantities of water to most wells for domestic use and lawn irrigation. Most of the wells screened in these deposits yield soft water that is more acid than water from the limestone formations. The water from many of the wells contains objectionable amounts of iron.

STRUCTURE

The contours in figure 4 show the configuration of the surface of the limestones of Eocene Age. The contours represent the surface of the Avon Park Limestone in the Sanford area and in an area south of Altamonte Springs where post-Eocene erosion removed all the Ocala Group. In the remainder of Seminole County, the contours represent the surface of the Ocala Group. This surface (fig. 4) has many irregularities because it has been eroded and because many sinkholes exist in the area. Some geologic evidence suggests that several of the irregularities actually may be faults.

Geologic data in Seminole and Volusia counties (Wyrick, 1960) suggest the presence of a downthrown fault block along the north edge of Seminole County and south edge of Volusia County. This fault block underlies part of the St. Johns River valley and most of Lake Monroe. A surface expression of this fault block is probably shown by the westerly offset of the St. Johns River along the northern part of the county. The upper part of the St. Johns River generally flows north-northwest until it reaches the northeast corner of Seminole County. The river turns at that point and flows in a westerly direction for about 18 miles. Then the river turns and continues in the original northerly direction.

GROUND WATER

Ground water is the subsurface water in the zone of saturation, the zone in which all pore spaces are filled with water under pressure greater than atmospheric. Ground water is derived almost entirely from precipitation. Part of the precipitation returns to the atmosphere by evaporation and the transpiration of plants and part drains from the land surface into lakes and streams; the remainder seeps into the soil zone where some is retained and some continues downward to the zone of saturation to become ground water. Ground water moves laterally, under the influence of gravity, toward places of discharge such as wells, springs, surface streams, lakes, or the ocean.

Ground water may occur under either nonartesian or artesian conditions. Where it is not confined its upper surface, the water table, is free to rise and fall and it is said to be under nonartesian or water-table conditions. Where the water is confined in a permeable bed that is overlain by a less permeable bed, so that its upper surface is not free to rise and fall, it is said to be under artesian conditions. The term "artesian" is applied to ground water that is confined under sufficient pressure to rise in wells above the top of the permeable bed that contains it, though not necessarily to or above the land surface. The height to which water will rise in an artesian well is called the artesian pressure head. The piezometric surface is an imaginary surface to which water from an artesian aquifer will rise in tightly cased wells that penetrate the aquifer. Where the piezometric surface is above the land surface, artesian wells will flow under natural pressure.

An aquifer is a formation, group of formations, or part of a formation—in the zone of saturation—that is permeable enough to transmit usable quantities of water to wells. Areas in which water enters the aquifers are called recharge areas and areas in which water is lost from aquifers are called discharge areas.

NONARTESIAN AQUIFER

Ground water in Seminole County occurs under either non-artesian or artesian conditions. The water in the surficial sands of Pleistocene and Recent Age is under nonartesian conditions in all parts of the county except a few small areas where the sands are overlain by thick beds of peat or clay.

Wells drawing water from these sands are used mainly for domestic supplies, although many of these wells are used for lawn and garden irrigation. Generally, these wells are equipped with hand pumps, but many of the hand pumps are being replaced with electric pumps. Probably not more than 400 wells draw water from the sands of Pleistocene and Recent Age in Seminole County.

The nonartesian aquifer is replenished by local precipitation. In addition to this recharge, some of the water discharged from the aquifer by pumping is returned to the aquifer by downward infiltration of irrigation water. Water is lost from the aquifer by natural discharge through springs into lakes and streams, by downward percolation into the artesian aquifer in areas where the piezometric surface is below the water table, and by withdrawal from wells. Water from the aquifer generally contains about 50 ppm of dissolved solids in those areas where the water in the aquifer has not been contaminated by highly mineralized artesian water. In many areas of the county, water from the nonartesian aquifer contains an excessive amount of iron, which can stain clothes, fixtures, and utensils.

ARTESIAN AQUIFER

The principal sources of water in Seminole County are deposits that form a part of the principal artesian aquifer of the Florida Peninsula and adjacent area. This aquifer in Seminole County is composed of beds of sand and shell in the lower part of the deposits of Pliocene and late Miocene Age, the permeable parts of the Hawthorn Formation, and limestone formations of middle and late Eocene Age.

Stringfield (1936) first described the principal artesian aquifer in Florida. The name Floridan aquifer, which will be used in this report, was proposed by Parker (Parker, et al., 1955, p. 188-189) to include "parts or all of the middle Eocene (Avon Park and Lake City limestones), upper Eocene (Ocala Limestone), Oligocene (Suwannee Limestone), and Miocene (Tampa Limestone, and permeable parts of the Hawthorn Formation that are in hydrologic contact with the rest of the aquifer)." The artesian water is confined by relatively impermeable layers in the limestones and by the overlying clay of Miocene Age which extends over most of the State. Differences in static head, chloride content, and temperatures of water at different depths in some parts of Seminole County suggest that relatively impermeable beds may be continuous over large areas, and that the Eocene limestones consist of several relatively thin aquifers rather than one thick aquifer.

The height to which water will rise in an artesian well is called the artesian pressure head. The head at any place in the artesian aquifer is controlled in part by the head in the recharge area, which in turn is determined by the amount of replenishment that reaches the aquifer from rainfall. Periodic measurements of the pressure head and the water levels in wells are an important part of a ground-water investigation. Stringfield (1936, p. 195) made a series of water-level measurements in selected wells in Seminole County. In 1937, Stubbs resumed measurements in several of the wells measured by Stringfield and also began measurements in other selected wells (S. A. Stubbs and Irving Feinberg, unpublished records in the files of H. James Gut, Sanford, Florida). Stubbs (1937, p. 33) stated that the minimum permanent loss of head within the flowing-well area ranged from 4 to 10 feet during the period 1912-37. During the current investigation measurements were resumed in many of the wells measured by Stringfield and Stubbs, to determine if there had been any progressive decline of artesian head. In addition, periodic measurements were made in 40 other wells to determine the seasonal fluctuations of the water level in different parts of the county.

PIEZOMETRIC SURFACE IN FLORIDA

The piezometric surface of the Floridan aquifer in Florida is shown by the contour lines in figure 6. The first map of the piezometric surface of the principal artesian aquifer in Florida was compiled by Stringfield (1936, pl. 12). The contours on the piezometric surface indicate the direction of movement of the artesian water. Water enters the aquifer in the areas in which the piezometric surface is high and

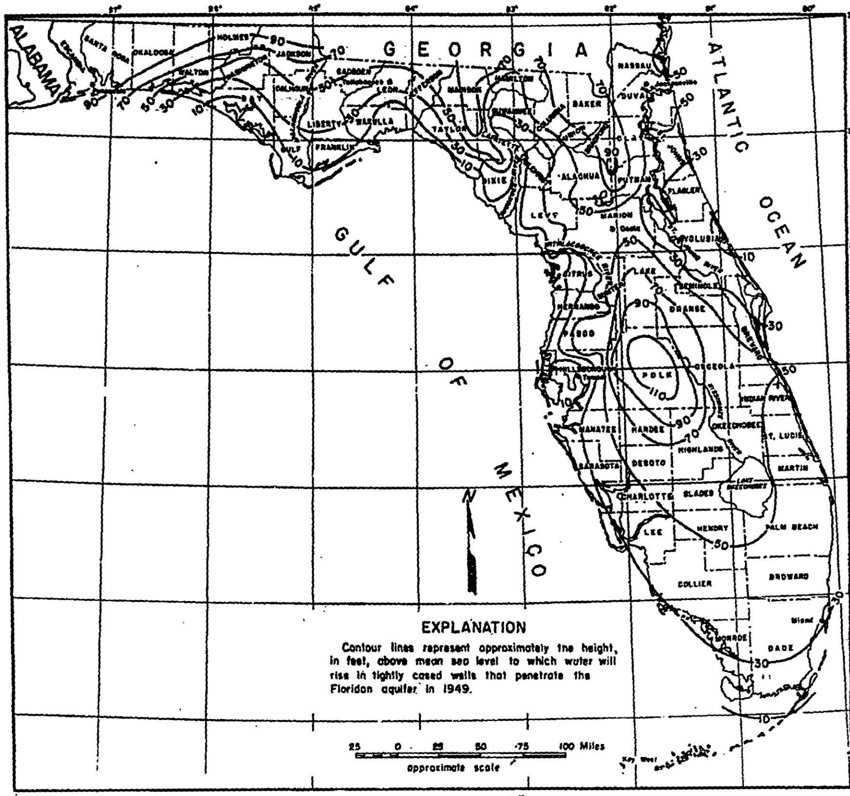


Figure 6. The piezometric surface of the Floridan aquifer, 1949.

moves in a direction approximately perpendicular to the contour lines toward the areas in which the piezometric surface is low. One of the most notable features of the piezometric surface in Florida is the dome centered in Polk County, which indicates that considerable recharge enters the Floridan aquifer in Polk County and some surrounding counties.

In Polk County, the western part of Orange County, and some parts of Seminole County, water enters the Floridan aquifer through numerous sinkholes that penetrate the Hawthorn and younger formations. The contours on figure 6 show that the artesian water flows northeast from the recharge area centered in Polk County toward Seminole County and the adjacent area. This map shows the principal recharge areas for the Floridan aquifer, but the map is not detailed enough to show the many small recharge areas that are known to exist.

PIEZOMETRIC SURFACE IN SEMINOLE COUNTY

The first published maps of the piezometric surface in Seminole County (Stubbs, 1937, p. 25-26) show in considerable detail the direction of ground-water flow in the county. Maps of the piezometric surface drawn during the current investigation generally agree with those drawn by Stubbs. One difference occurs in the area northeast of Oviedo where Stubbs' map shows a recharge area in an area of flowing wells. This discrepancy is believed to be due to an error in leveling by Stubbs or to using an incorrect benchmark elevation.

Figure 7 shows the piezometric surface of the Floridan aquifer in Seminole County during near record-high water levels in January 1954. The annual rainfall at Sanford in 1953 was 74.06 inches, which is the highest on record. Most of this rain, or 51.60 inches, fell during the period July 1 to December 31, 1953. The maximum artesian pressure measured in January 1954 was 66 feet above sea level in a well 6 miles southwest of Oviedo and the minimum pressure measured was 11 feet above sea level in a well 6 miles north of Geneva in the St. Johns River valley.

The piezometric map shows that in general the flow of water in the county is toward the northeast. The effect of ground-water discharge near Sanlando Springs, and in areas 2 miles south of Lake Mary and 2 miles northeast of Oviedo is shown by depressions in the piezometric surface (fig. 7). The effect of ground-water recharge in the areas near Geneva, south of Oviedo, near Chuluota, south of Sanford, and south of Paola is shown by mounds in the piezometric surface (fig. 7). The contours also indicate discharge into the St. Johns and Wekiva rivers and into the southwest part of Lake Jessup.

Figure 8 shows the piezometric surface of the Floridan aquifer at near record-low conditions in June 1956. The total rainfall at Sanford was only 16.45 inches for the 8-month period from October 1, 1955 to May 31, 1956. The difference in artesian pressure from the high level shown on figure 7 to the low level shown on figure 8 is generally about 5 feet, although one well showed a decline of 10 feet.

Figure 8 shows a piezometric high near Golden and Silver lakes, 3½ miles south of Sanford, which indicates that this is a recharge area. The highest water level measured in Seminole County during June 1956 was 53 feet above sea level in two wells located near Altamonte Springs. The lowest water level measured during this dry period was 7 feet above sea level in a well located 6 miles north of Geneva in the St. Johns River valley. As figures 7 and 8 show approximately the maximum and minimum conditions, respectively, the piezometric surface would usually be somewhere between these two extremes.

AREA OF ARTESIAN FLOW

Whenever the piezometric surface stands higher than the land surface, artesian wells will flow. The approximate areas of artesian flow in 1954 in Seminole County are shown in figure 9. The principal area of flow extends in an unbroken band along the Wekiva River to the St. Johns River and continues along the St. Johns River to a point about 4 miles east of Lake Jessup. The band includes both sides of Lake Jessup and the farming area southwest of Oviedo. East of Oviedo the area of flow extends down the valley of the Econlockhatchee River to the St. Johns River.

The area of artesian flow was probably larger prior to the agricultural development of the county. In fact, in parts of the farming area in the vicinity of Sanford, the boundary was probably more than half a mile farther south than it was in 1956. In most of the farming areas the boundary of the area of flow has receded onto the level lowlands, where a decline in artesian pressure of 1 foot results in a decrease of several hundred feet in the width of the area of flow.

Figure 9 shows also contours which represent the height, in feet, referred to land surface, to which water will rise in artesian wells penetrating the limestone aquifer. It shows that the maximum depth to water is more than 50 feet below land surface in an area near the southwest corner of the county and at Geneva. The artesian pressure head is more than 20 feet above the land surface in an area adjacent to the Little Wekiva River, the east edge of Lake Monroe, and around most of Lake Jessup. Along Howell Creek, at the south side of Lake Jessup, water from tightly cased wells drilled into the limestone aquifer will rise more than 30 feet above the land surface.

WELLS

One important phase of any ground-water investigation is the well inventory, or collection of data on wells. Figure 10 shows the location and distribution of 874 wells, which were inventoried during the investigation, and which represent 18 percent of the total number of wells in the county. Of this number, 50 wells draw water from the nonartesian aquifer and 824 wells, of which 424 flow, draw water from the Floridan aquifer. The following table shows a division of the wells according to their use.

The relative percentage of the wells of each diameter would probably remain about the same if all the wells in the county were inventoried. Table 3 shows that almost 47 percent of the inventoried wells are 2 inches in diameter.

TABLE 2. Use of Inventoried Wells

Use of well	*Number*
Domestic	322
Irrigation	312
Unused	137
Industrial and Public Supply	62
Stock	39
Other uses	2
Total	874

The following table shows a classification of the wells according to their diameter.

TABLE 3. Diameter of Inventoried Wells.

Well diameter (inches)	*Number of wells*	*Percent of total*
1¼	49	5.6
2	407	46.6
2½	28	3.2
3	173	19.8
4	123	14.1
5	9	1.0
6	47	5.4
8	21	2.4
over 8	17	1.9
Total	874	100.0

Artesian wells in the county range in depth from 33 to 1,122 feet but more than 90 percent of them are between 75 and 250 feet deep. More than 4,500 wells are believed to draw water from the artesian aquifer in Seminole County.

The relation between the height of the static head above the well outlet and the yield of four wells in the Sanford farming area is shown in figure 11. The measurements of yield in gallons per minute and artesian pressure in feet above sea level are shown as solid dots. Each graph is drawn as a wedge to cover the variations in the accuracy of the measurements.

The yield of a flowing well depends primarily upon the water-transmitting capacity of the formations penetrated by the well, the friction losses within the well, the thickness of aquifer penetrated by the well, and the height of the static head. The yield of different wells may be compared by using the specific capacity, which is the yield in gallons per minute per foot of drawdown. In flowing wells, the drawdown is approximately equal to the height of the static head above the well outlet. Therefore, the approximate specific capacity of these wells may be determined by dividing the yield of the wells in gallons per minute by the static head in feet.

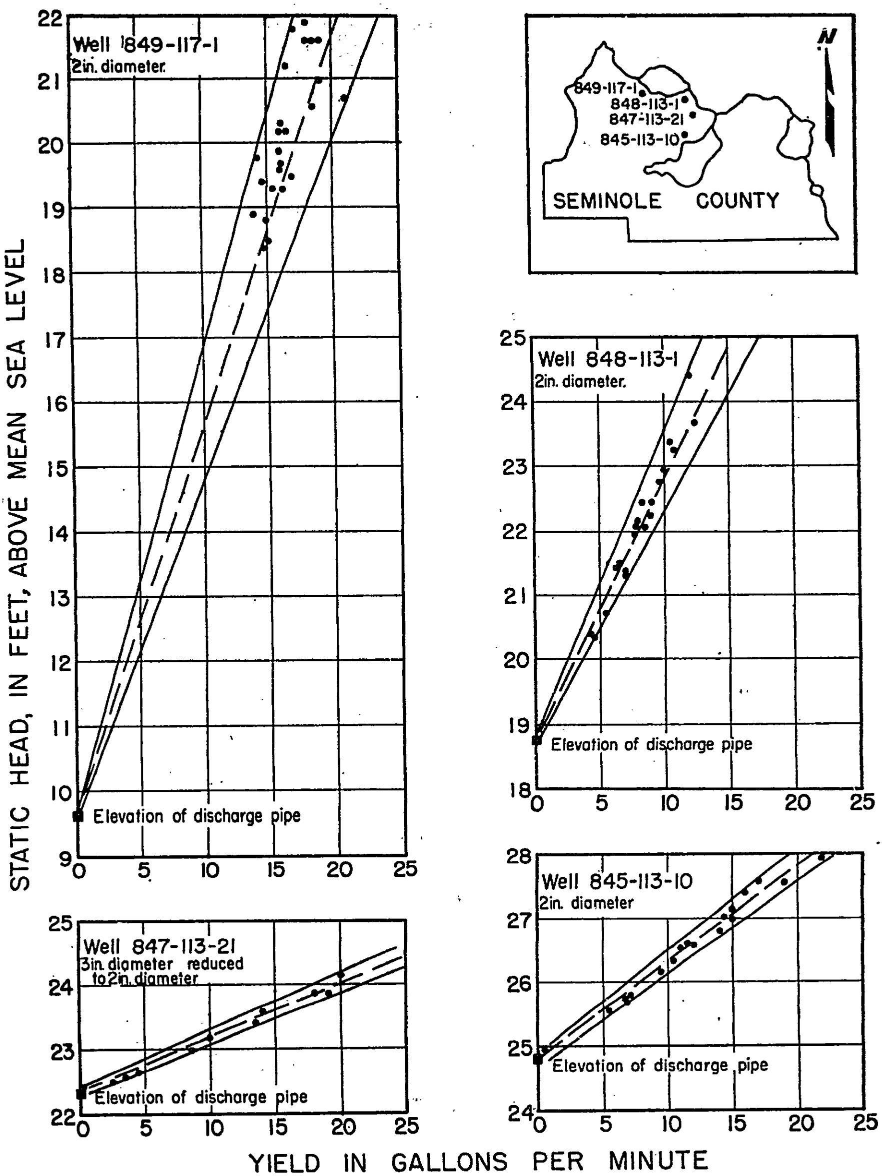


Figure 11. Relation between the static head and the yield of four flowing artesian wells in the area around Sanford.

The specific capacity of well 849-117-1 was only 1.7 gpm per foot of drawdown and the yield of the well ranged from 14 to 21 gpm as the artesian pressure increased 3.5 feet. Well 848-113-1 had a specific capacity of 2.5 gpm per foot of drawdown and the yield of the well ranged from 4.5 to 12.5 gpm as the artesian pressure increased 4 feet. Well 845-113-10 had a specific capacity of 6.6 gpm per foot of drawdown and the yield of the well ranged from 0.5 to 22 gpm as the artesian pressure increased 3 feet. Well 847-113-21, which is a 3-inch well reduced to a 2-inch outlet, had a specific capacity of 11.1 gpm per foot of drawdown and the yield ranged from 0 to 20 gpm as the artesian pressure increased 1.8 feet. The average specific capacity for the 2-inch wells for which data were available is 3.9 gpm per foot of drawdown.

Figure 12 is similar to figure 11 as it shows data on the specific capacity of three wells, 2 inches in diameter, which are located northeast of Oviedo and one well, 3 inches in diameter, which is located south of Lake Harney. The three wells northeast of Oviedo had specific capacities of 5.5, 7.2, and 10.1 gpm per foot of drawdown. The average specific capacity of the 2-inch wells was 7.6 gpm per foot of drawdown. The 3-inch well, south of Lake Harney, had a specific capacity of 15.8 gpm per foot of drawdown, and the yield rose from 7 to 65 gpm as the artesian pressure increased 3.1 feet.

The measurements of the yield of these selected wells show that the wells in the Oviedo area have a higher specific capacity than the wells in the Sanford area. The graphs show also the reduction in the yield of a well with each foot reduction in the static head. Thus, when the artesian pressure is lowered in an area of flowing wells by excessive draft or by dry weather conditions, some wells cease to flow and all wells yield less water.

SUBIRRIGATION

Subirrigation is the main method of irrigation used in Seminole County. This method is made possible because of several factors including: relatively level land, a layer of cemented sand (hardpan) from 3 to 5 feet below the land surface, and a layer of sand above the hardpan which absorbs and distributes the water.

Subirrigation is used to control the moisture in the soil so that the plants will have adequate available water. An advantage to subirrigation is that water in the soil can be effectively controlled so that soluble fertilizers are not washed beyond the reach of the plants. Another advantage is that during periods of excessive rainfall the ditches used for subirrigation can be used to drain the excess water from the ground and

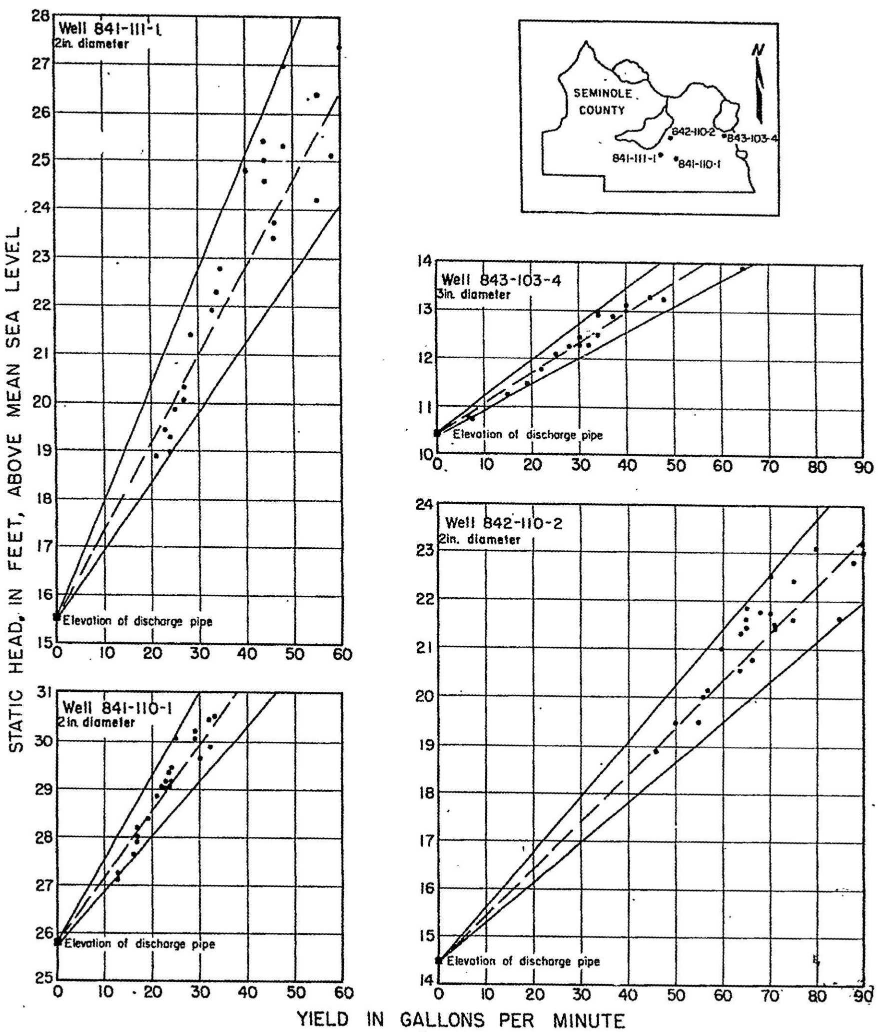


Figure 12. Relation between the static head and the yield of four flowing artesian wells in the eastern part of Seminole County.

prevent waterlogging of the soil, which destroys some beneficial soil bacteria and has other harmful effects.

The land is prepared for subirrigation by clearing and leveling. An artesian well is drilled at the highest point, and the water from the well flows into a concrete or terra cotta standpipe (supply pocket) that is connected to a tile main. Lines of tile laterals 18 to 24 feet apart are also connected to this tile main. A stop pocket is placed at the end of each lateral, opposite the main. A short tile line connects this pocket to an open drainage ditch or a large sewer tile which is used to drain the water from the field. The level of the water in the field can be controlled by the amount of water taken from the well, by plugging or partially unplugging the heads of the laterals, or by controlling the amount of water that is drained from the field. Additional information on subirrigation can be obtained from the Agricultural Extension Service, Gainesville, Florida. This method of irrigation uses very large quantities of water.

WATER-LEVEL RECORDS

A total of more than 4,500 water-level measurements were made of 563 wells during the investigation. Most of these measurements and the dates on which they were made are presented in table 1 of Florida Geological Survey Information Circular no. 34.

Fluctuations of the water level are caused principally by pumping, rainfall, and changes in atmospheric pressure. In order to obtain continuous records of the changes in the artesian pressure head in Seminole County, a water-level recorder was installed in 1952 on well 841-121-1, about 1.25 miles west-southwest of Longwood, in an area of little ground-water use. Another recorder was installed in 1952 on a flowing well (well 847-113-6), about 2.8 miles southeast of Sanford, in an area of extensive ground-water use.

Hydrographs for the two wells equipped with automatic water-level recorders, and the monthly rainfall at Sanford, are shown in figure 13. The most noticeable features on both hydrographs (fig. 13) are the high water levels during the fall and winter of 1953 and the low water levels during the spring of 1956. These features show near maximum and minimum water-level conditions. The hydrographs of the two wells shown in figure 13 correlate generally; however, after the high water levels during the period of September to December 1953, the water level in well 847-113-6 had reached the bottom of its sharp decline by the middle of February 1954, but the water level in well 841-121-1 did not reach a similar stage until the end of May. The hydrograph for well 847-113-6 shows more rapid fluctuations than the other hydrograph,

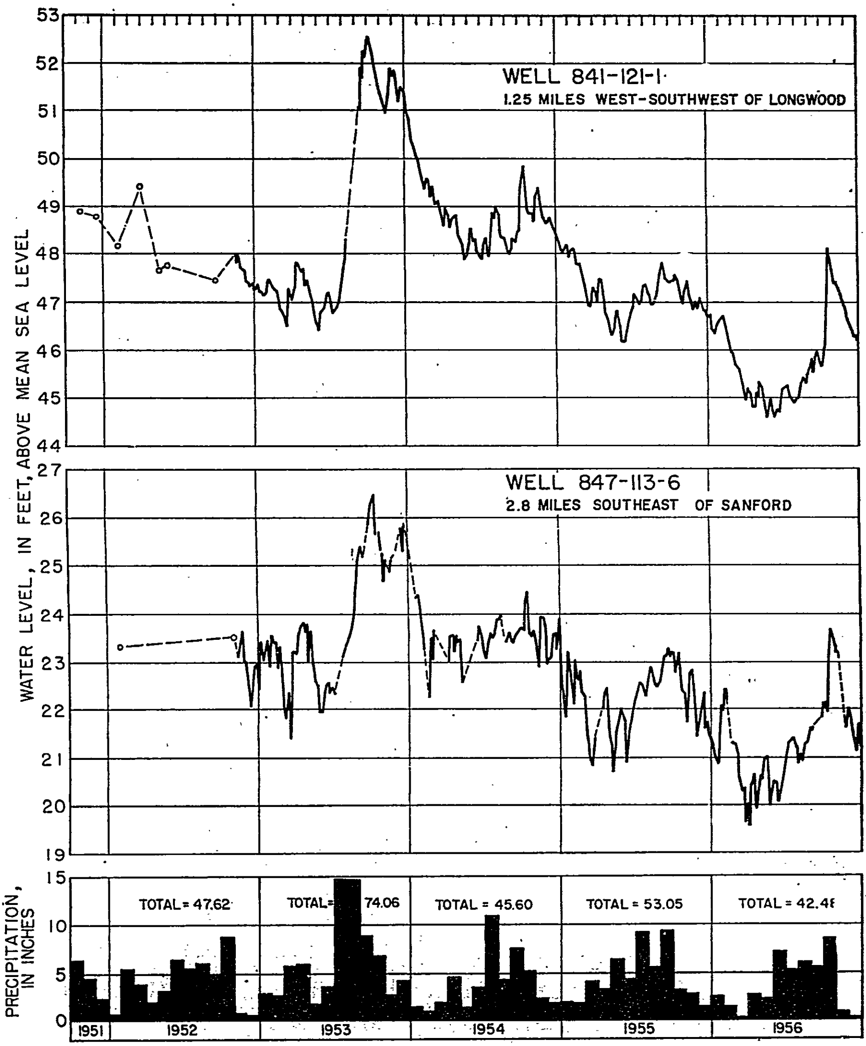


Figure 13. Hydrographs of the daily high water levels in wells 841-121-1 and 847-113-6 and the monthly rainfall at Sanford.

principally because of the large changes in the amount of ground water used near well 847-113-6. Water levels in well 847-113-6 ranged from a low of 19.58 feet above sea level to a high of 26.45 feet above sea level, or a fluctuation of almost 7 feet. Water levels in well 841-121-1 ranged from a low of 44.55 feet above sea level to a high of 52.49 feet above sea level, or a fluctuation of almost 8 feet. These hydrographs show the general trend of the water level during the period from 1951 through 1956, and they show also the relationship between rainfall and water levels.

An important part of the investigation in Seminole County involved comparison of current water levels with past water levels, to see if a progressive decline in water levels had occurred. All the water-level measurements were referred to mean sea level as a common datum for comparison. When evaluating rainfall records to detect progressive trends, it is essential to compare periods of similar rainfall. An inspection of rainfall records at Sanford shows that the rainfall a few years prior to 1938 might be compared to the rainfall prior to 1955. Thus, the average water levels on the hydrographs for the years 1937 and 1954 can be compared. Most of the difference in water levels between these 2 years can be attributed to factors other than rainfall differences.

Figure 14 shows the hydrographs of five wells and the monthly rainfall at Sanford. These hydrographs include measurements made in 1933 and 1935 by V. T. Stringfield, in 1937 by S. A. Stubbs, and in 1939 by Irving Feinberg. Well 846-116-11 is 2.9 miles south of Sanford near the north edge of Lake Ada and near the city of Sanford well field. The hydrograph shows a fluctuation of about 6 feet for the period of record. The data on the graph show that the water level has probably declined about 1 or 2 feet since 1937. Some of this decline might be the result of an increase in pumpage by the city of Sanford from an average of 0.67 mgd (million gallons per day) in 1938 to an average of 1.54 mgd in 1956.

Well 844-117-2 is 4.9 miles southwest of Sanford, near Elder Spring. This well shows water-level fluctuations similar to those of well 846-116-11. Well 843-118-2 is 5.9 miles southwest of Sanford and about one-fourth mile south of Five Points, or the junction of U. S. Highways 17 and 92 and State Highway 419. The hydrograph for this well shows a general decline in water level of 2 or 3 feet between 1935 and 1956. The 1935 water levels in both 844-117-2 and 843-118-2 are less than 1 foot below the water levels measured in the fall and winter of 1953, the highest water levels of record.

The hydrograph of well 842-117-2, at Wagner (south of Lake Jessup), shows the 1933 and 1935 water levels to be approximately the same as

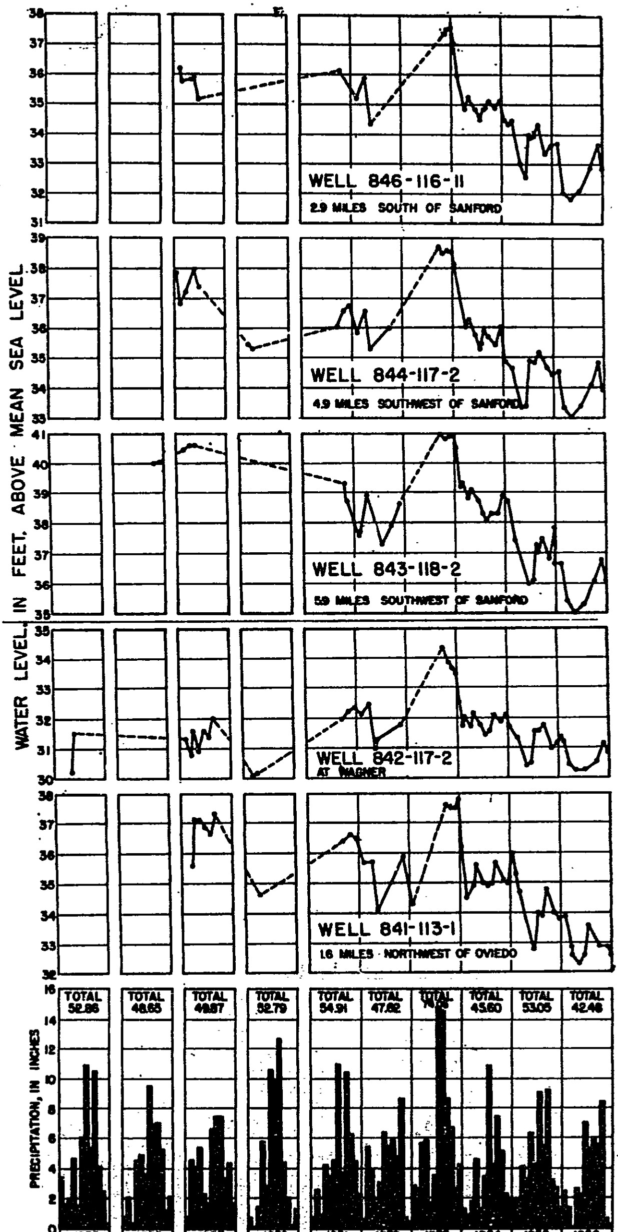


Figure 14. Hydrographs of wells 841-113-1, 842-117-2, 843-118-2, 844-117-2, 846-116-11, and the monthly rainfall at Sanford.

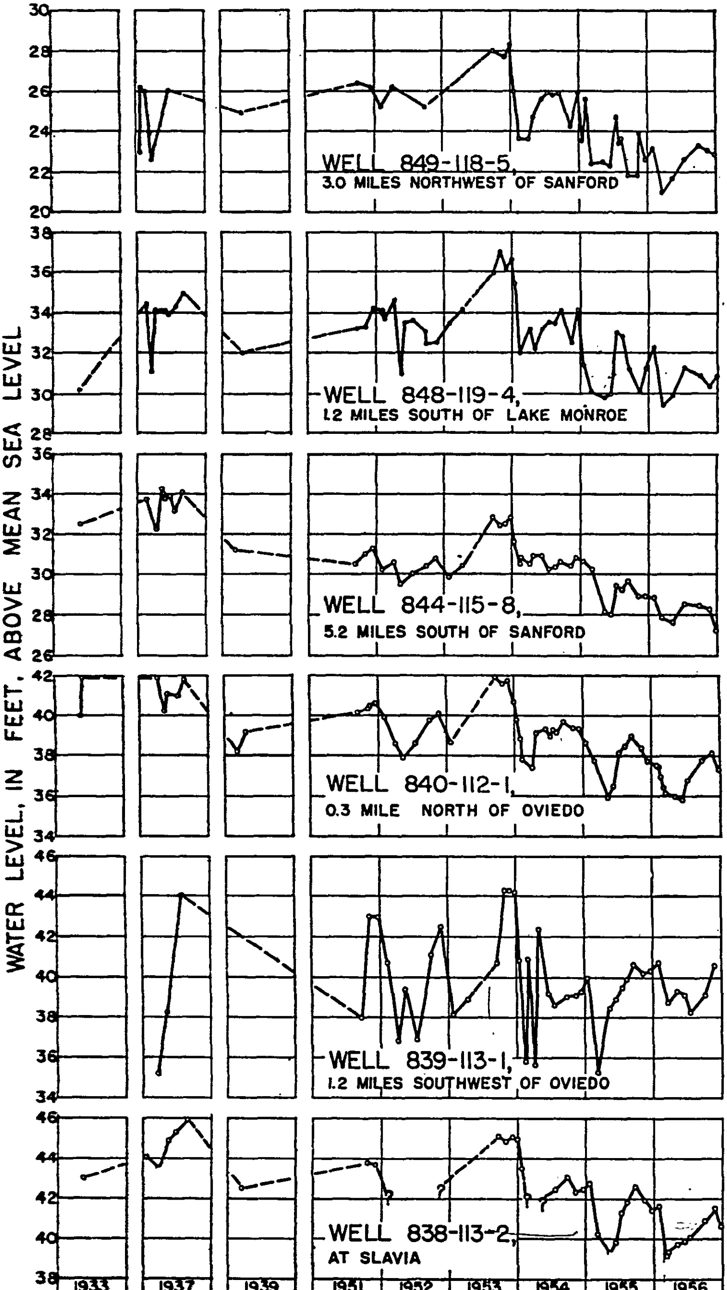


Figure 15. Hydrographs of wells 838-113-2, 839-113-1, 840-112-1, 844-115-8, 848-119-4, and 849-118-5.

those of 1955 and 1956. The hydrograph of well 841-113-1, 1.6 miles northwest of Oviedo, shows a water-level decline of 2 or 3 feet between 1937 and 1956. The water levels in 1937 are only about 1 foot lower than the high water levels during 1953. The 2- or 3-foot decline might be caused by the increased number of wells and the corresponding increased use of ground water in the farming area north of Oviedo.

Hydrographs of six wells are shown in figure 15. Well 849-118-5, 3.0 miles northwest of Sanford, and well 848-119-4, 1.2 miles south of Lake Monroe, both show water-level fluctuations of almost 8 feet. The hydrographs do not show any significant trend of water level over the period 1933-56.

The water level in well 844-115-8, 5.2 miles south of Sanford, fluctuated less than 6 feet during the period of record and declined about 4 feet between 1933 and 1956. This decline is probably due to increased use of water in the vicinity. The hydrograph of well 844-115-8 shows that the water level during 1937, a year with nearly normal rainfall, was almost 2 feet higher than the highest water level measured in 1953, the year of the highest rainfall ever recorded at Sanford.

Another well that shows a general water-level decline of about 3 or 4 feet for the period of record is well 840-112-1, 0.3 mile north of Oviedo. The hydrograph of this well and the hydrographs of wells 839-113-1 and 838-113-2 show evidence of increased use of water around Oviedo since 1937. Well 839-113-1, 1.2 miles southwest of Oviedo, is in an area of extensive ground-water use and has water-level fluctuations as large as 9 feet within short periods of time. These rapid changes in water level tend to mask out any general trend in the water level. Well 838-113-2, at Slavia, shows a water-level decline similar to that shown by well 840-112-1.

Hydrographs of 10 other wells that show past records of water levels are included in the section of this report entitled "Salt-Water Contamination."

An illustration of the relationship of the water level in an artesian well to the water level in a nearby nonartesian well is shown on figure 16. These wells are about 1½ miles west of Paola, in an area of very little ground-water use. Most of the water-level changes, therefore, are due to variations in the amount of rainfall. The artesian well obtains water from the Hawthorn Formation and the nonartesian well obtains water from the Pleistocene sands.

The hydrographs for the two wells show similar fluctuations. The elevation of the water level in the nonartesian well varies from 3.5 to 6 feet above the water level in the artesian well. Therefore, the shallow

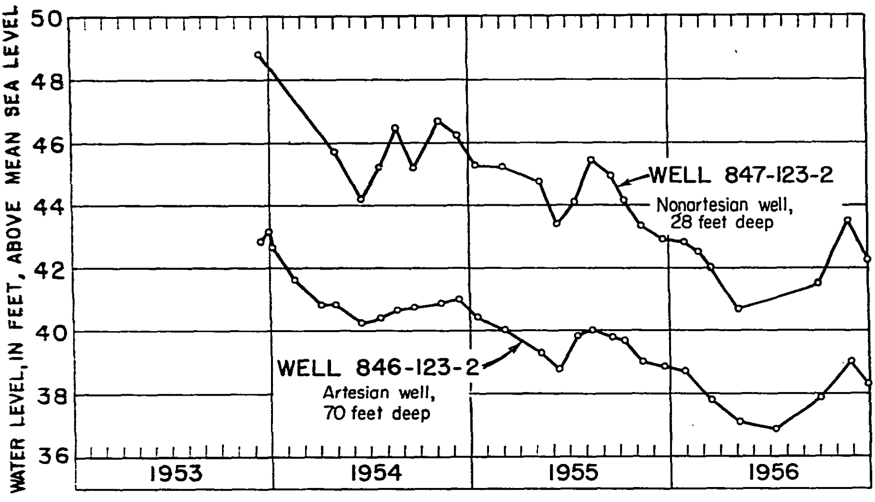


Figure 16. Hydrographs of wells 846-123-2 and 847-123-2, about 1½ miles west of Paola.

sand aquifer probably recharges the Hawthorn Formation in this area. The shallow well had a maximum water-level fluctuation of 8 feet and the deep well had a maximum water-level fluctuation of 6 feet during the period of record shown in figure 16.

SURFACE WATER

SPRINGS

Seminole County has several large artesian springs and several small nonartesian (water-table) springs. Most of the artesian springs are along the Little Wekiva or Wekiva rivers. These include Sanlando Springs, Palm Springs, and Sheppard Spring, all about 3 miles west of Longwood and along the Little Wekiva River.

ARTESIAN SPRINGS

Sanlando Springs is in the NE¼SE¼ sec. 3, T. 21 S., R. 29 E., on the east bank of the Little Wekiva River. The springhead forms an irregularly shaped pool about 50 feet in diameter. Ferguson, et al., (1947, p. 149-153) gives descriptions and data about Sanlando, Palm, and Sheppard springs. The temperature of the water from Sanlando Springs was 74°F., and the maximum depth of the water at the springhead was 13.2 feet on April 23, 1946. The average of three discharge measurements of the spring is 13.4 mgd. Table 4 and figure 33 show an analysis of the water from Sanlando Springs. The water is moderately hard and similar to water found in most artesian wells in the southwest section of Seminole County. It is classed as a calcium bicarbonate water and the total hardness (as $CaCO_3$) was 105 ppm.

Sheppard Spring is in the SW¼NW¼ sec. 2, T. 21 S., R. 29 E., 0.2 mile north of Sanlando Springs. The spring forms a pool about 70 to 80 feet in diameter. The temperature of the water was 74°F. and the yield was 11 mgd on July 25, 1944. Chemical analysis of the spring water collected on the above date shows the water to be very similar to the water from Sanlando Springs, having a mineral content only slightly higher. The spring is used as a private swimming pool by the owner.

Palm Springs is in the SW¼NW¼ sec. 2, T. 21 S., R. 29 E., 0.3 mile north of Sanlando Springs. The pool, formed by concrete retaining walls, is rectangular. The flow of the spring was 6.3 mgd on November 12, 1941, and 6.7 mgd on August 25, 1954. The spring is used for swimming.

Miami Springs is in the NW¼NW¼ sec. 32, T. 20 S., R. 29 E., 0.25 mile south of the Wekiva River. The spring forms an oblong pool which is used as a private swimming pool. Florida Geological Survey Bulletin No. 31 (Ferguson, et al., 1947, p. 179, table 4) gives data on Miami Springs but incorrectly lists the spring in Orange County. The flow of the spring was 3.7 mgd on August 8, 1945.

In the spring of 1957 land-clearing operations helped develop a new artesian spring in Seminole County. The spring is 0.4 mile southeast of Miami Springs and is called Sweet Water Spring. The spring, shown in figure 17, is in the NW¼ sec. 32, T. 20 S., R. 29 E., 100 feet north of the Wekiva Spring Road and about 25 feet west of Sweet Water Creek. Figure 17a shows the springhead pool and the short run into Sweet Water Creek, and figure 17b shows a closeup of the spring pool, which is about 8 to 10 feet in diameter, and the turbulence of the boil. The total flow of the main spring and several much smaller springs is estimated to be about 100 gpm.

A similar spring developed in the NE¼NE¼ sec. 36, T. 20 S., R. 30 E., about 100 feet south of Lake Jessup, in the spring of 1952. This spring, which was developed by dredging a small boat basin on property owned by William Crook, flowed about 2 mgd shortly after it formed. An attempt was made to measure the flow on November 4, 1952, but no measureable flow could be detected.

The water level in well 842-116-4, 700 feet south of the spring, was 39.78 feet above sea level on May 14, 1952. The well was measured on May 28, 1952, 3 days after the spring began flowing, at which time the water level was 35.62 feet above sea level. Most of the 4-foot decline of water level was probably caused by pressure relief due to flow of the

Figure 17. Sweet Water Spring: a, view of spring and surrounding area;

b, closeup view of spring.

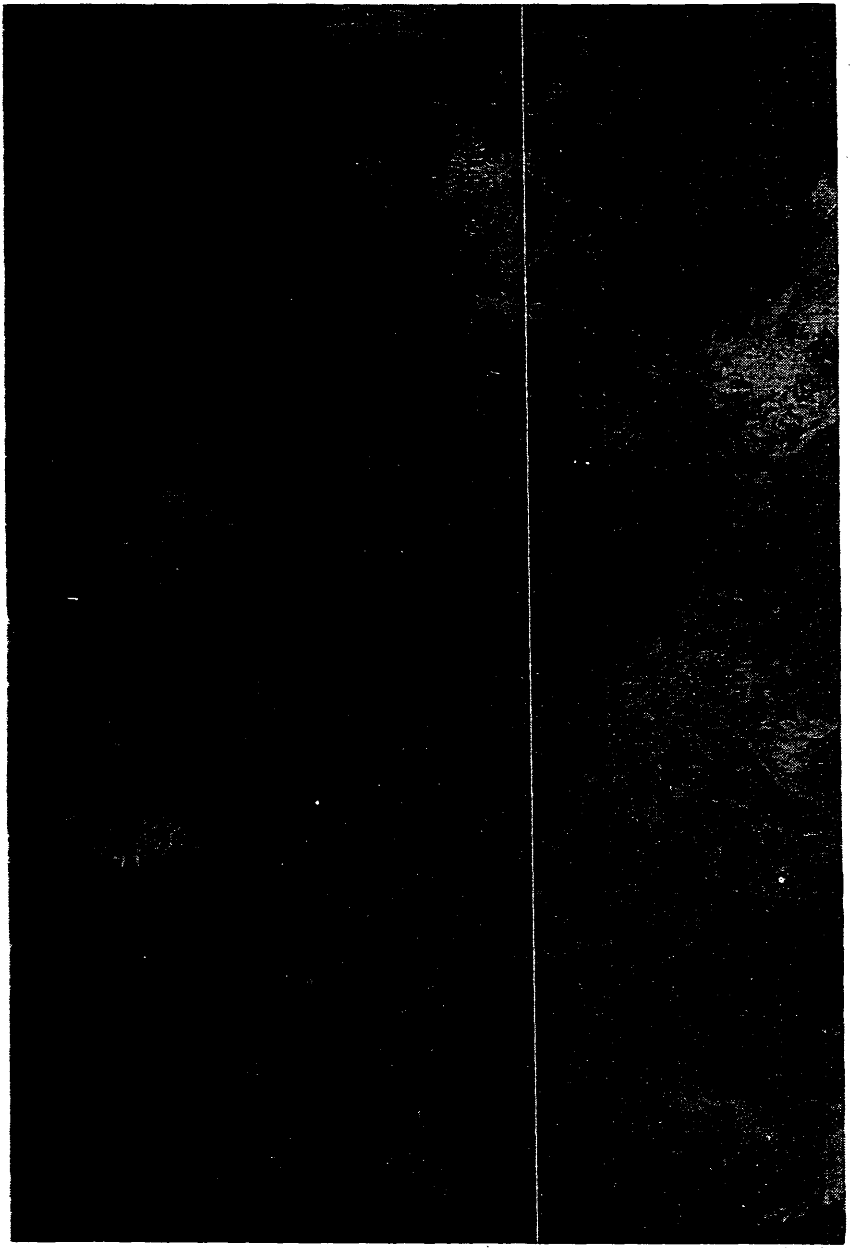


Figure 18. Heath Spring, 0.7 mile northwest of Geneva.

spring. At well 842-116-1, 0.65 mile southwest of the spring, the water level declined 3 feet from April 4, 1952, to May 28, 1952.

WATER-TABLE SPRINGS

Elder Spring is in the NE¼NW¼ sec. 23, T. 20 S., R. 30 E., about 5 miles south of Sanford. The flow of the spring is rather small, and a small pump and motor delivers the water to a building where it is bottled for sale. The chemical analysis of Elder Spring water is shown in figure 33 and table 3. The water is very soft, as the total hardness (as $CaCo_3$) is only 29 ppm and is classed as a calcium bicarbonate type.

Heath Spring is in the SW¼ sec. 16, T. 20 S., R. 32 E., 0.7 mile northwest of Geneva. The yield of the spring ranges from 5 to 10 gpm, and the water is occasionally used for drinking purposes and in storage batteries. Figure 18 shows a view of the main spring pool. A chemical analysis of the water, which is classed as a sodium chloride type, is shown in table 3 and figure 33. The water is very soft, the total hardness (as $CaCo_3$) being only 7 ppm. Figure 19 shows the temperature and the

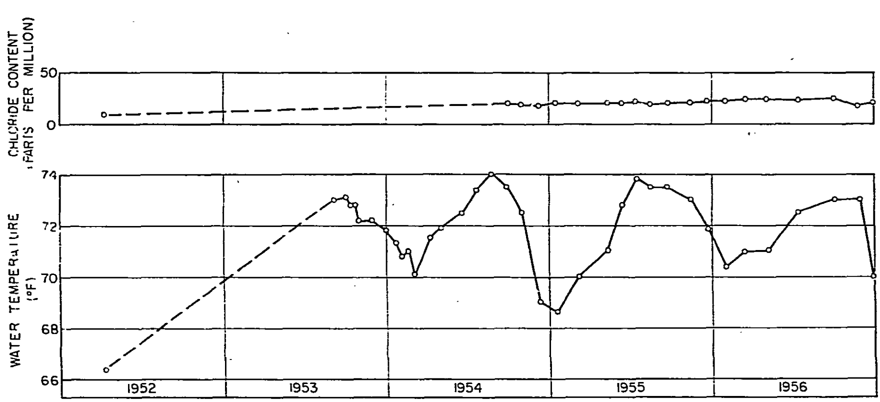


Figure 19. Temperature and chloride content of Heath Spring.

chloride content of water from Heath Spring. The water temperature ranges from 66 to 74°F. and varies according to the seasonal temperature changes. The chloride content ranges from 12 to 26 ppm and is probably influenced by the amount of rainfall and the direction of winds, which carry salt spray from the ocean.

LAKES

Water-level measurements of five lakes in Seminole County (fig. 20) were made for comparison with rainfall records, norartesian water levels, and artesian water levels.

Lake Geneva, half a mile east of Geneva, had the largest fluctuations

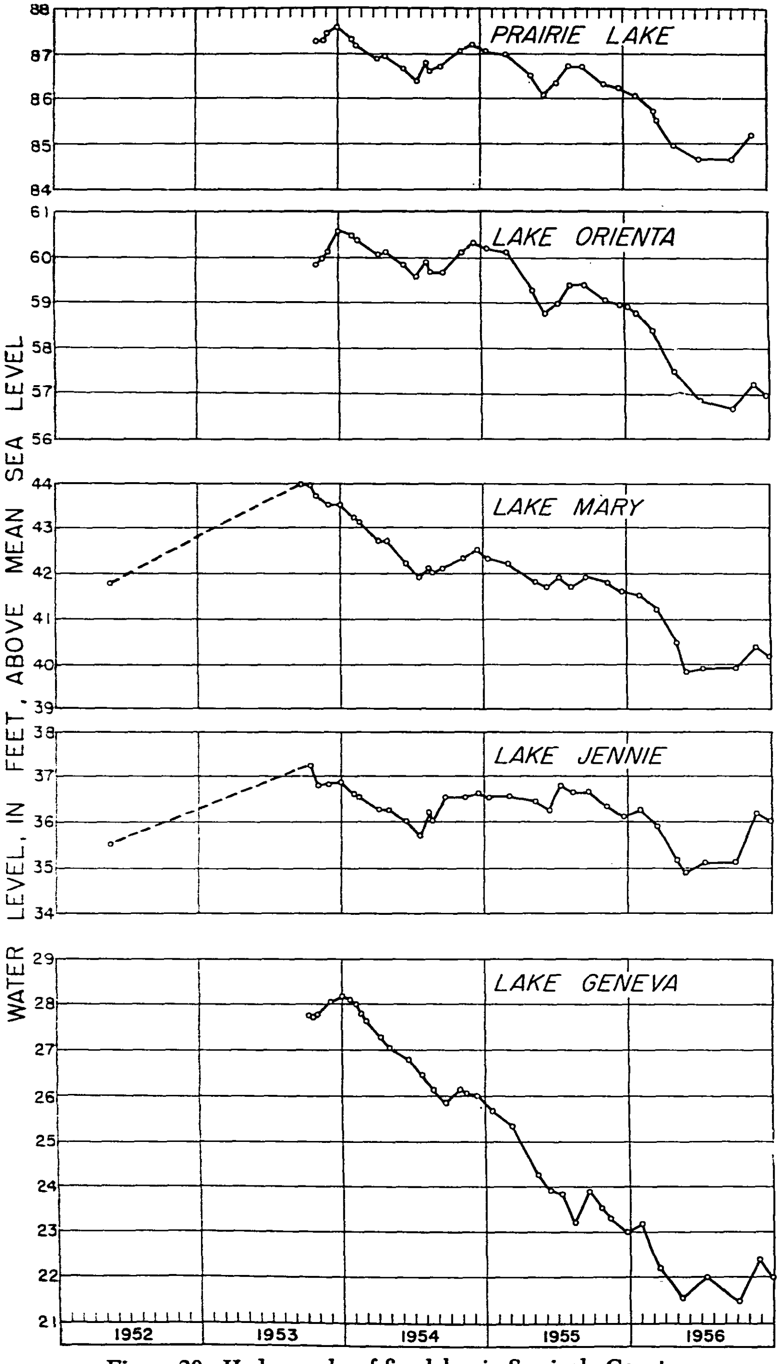


Figure 20. Hydrographs of five lakes in Seminole County.

of any lake measured. Measurements begun in the fall of 1953 and continued through 1956, indicate a fluctuation of almost 7 feet during this period. The lake levels ranged from a high of 28.2 feet above sea level to a low of 21.5 feet above sea level. During the period of record, the lake level was from 2 to 6 feet higher than the water level in nearby artesian wells, indicating that the water of Lake Geneva is obtained mostly from the nonartesian aquifer and in part directly from rainfall that falls on the lake. Figure 21, a photograph of Lake Geneva taken on August 13, 1957, shows a small boat dock that was unusable owing to the low water level at that time.

Lake Jennie, about 2 miles south of Sanford, had a fluctuation of less than 2½ feet during the period 1952-56 (fig. 20). The lake level usually stands from 4 to 7½ feet higher than the water level in well 847-116-1, an artesian well half a mile north of the lake. The water level in the lake stands from 7 to 10 feet higher than the water level in well 847-116-2, an artesian well 0.8 mile northeast of the lake, and from 0.8 foot below to 3.5 feet above the water level in well 846-116-11, an artesian well 0.3 mile south of the lake. The artesian pressure head in well 846-116-11 was higher than the lake level for only a few months during the fall of 1953. Most of the time, the lake level stands above the piezometric surface.

Lake Mary, about 0.2 mile southeast of the town of Lake Mary, fluctuated more than 4 feet during the period of record. At different times, the lake level stood either above or below the water level in well 845-119-1, an artesian well 0.25 miles northwest of Lake Mary. During wet periods the lake level was as much as 3 feet lower than the piezometric surface, and during dry periods, the lake level was as much as 2 feet above the piezometric surface. During dry periods, therefore, the lake is a potential source of recharge to the artesian aquifer, and during wet periods the artesian aquifer could contribute water to Lake Mary.

Lake Orienta, half a mile west of Altamonte Springs, fluctuated less than 4 feet during the period of record. Figure 22 shows a comparison of the lake level with the water level in artesian well 840-120-2, 1.6 miles east of the lake, and the water level in nonartesian well 839-122-1, 650 feet northwest of the lake. The lake level is generally about 2 to 4 feet higher than the water level in the artesian well, except during very wet periods when the water-level altitudes are about the same. However, in an artesian well (839-121-5) 400 feet north of Lake Orienta, the water level was below the lake level during both wet and dry periods. The lake level was generally 2 to 4 feet above the water level in the nonartesian well (839-122-1).

Figure 21. Lake Geneva showing the low water level on August 13, 1957.

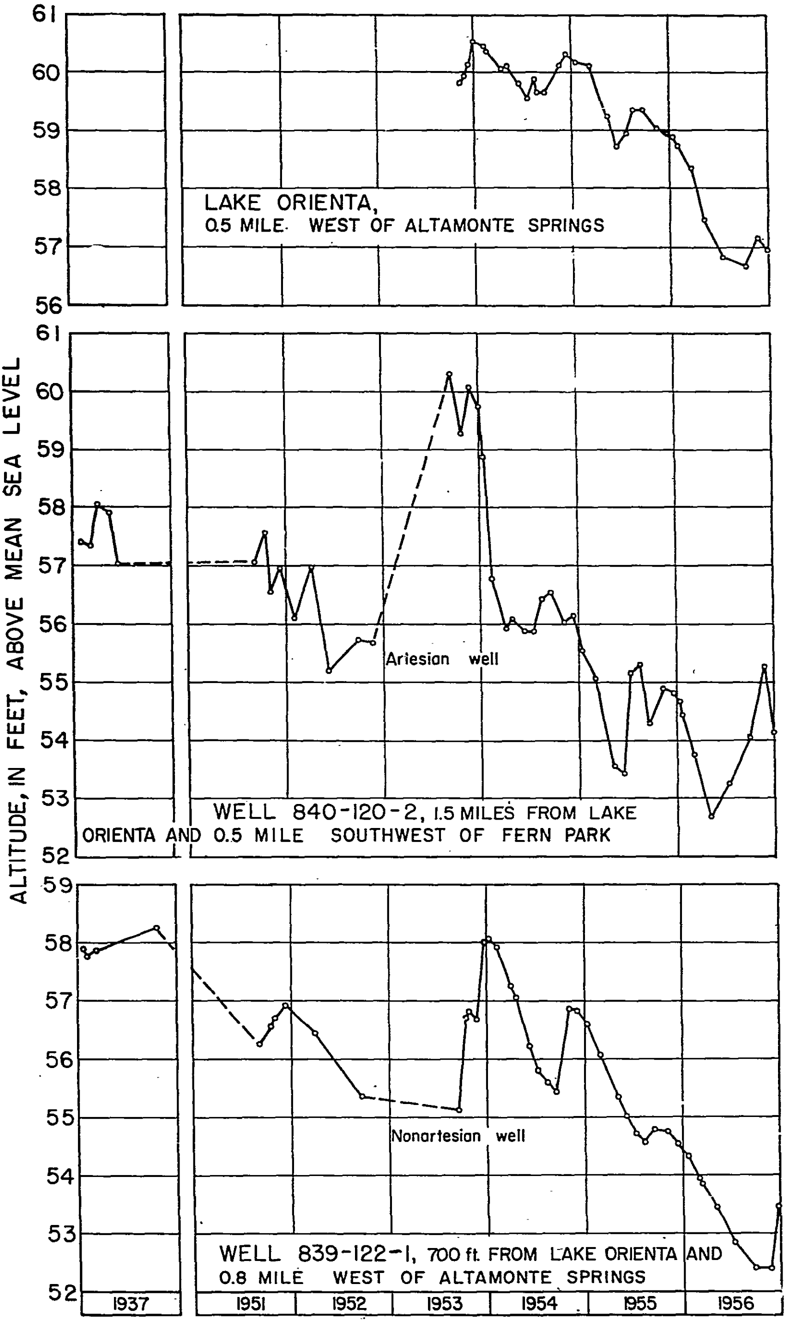


Figure 22. Hydrographs of wells 839-122-1, 840-120-2, and Lake Orienta.

Prairie Lake, 0.3 mile southeast of Altamonte Springs, fluctuated about 3 feet during the period of record. The lake level is about 30 feet higher than the piezometric surface in the vicinity.

WELL EXPLORATION

ELECTRIC LOGS

The electric log is a very useful aid in the identification of formations penetrated by a well and of fluids these formations contain. However, in limestone formations of the Floridan aquifer, electric logs preferably should be interpreted in conjunction with other aids such as well cuttings or drilling time logs. The electric log is a graph of the electrical properties of the rocks and fluids penetrated by the well. The electrical resistivity and self-potential are recorded with the depth as the abscissa of the graph.

Electrical resistivity is a measure of the resistance of material to the flow of an electric current. The term "relative resistivity" is used in this report because the electric logging equipment used was the single-electrode type which does not yield precise results.

Water is the main fluid that fills the void spaces in the limestone sediments and conducts electricity. Pure water has a very high resistivity but ground water has a much lower resistivity because of its dissolved mineral content. In general, in Seminole County, high relative resistivity indicates dense sediments that yield little water.

In Volusia County, Wyrick and Leutz (1956, p. 23) found a correlation between the dense layers of limestone, high relative-resistivity readings, and increased drilling time. These dense layers of limestone generally restrict the vertical movement of water. The application of the resistivity curve of electric logs made of limestone aquifers in Seminole County has been limited to the location of porous and dense sections in the limestone and to the determination of other lithologic changes.

The self (spontaneous) potential measures the difference in voltage between an electrode in the well and a ground at the surface. The potential differs according to the nature of the beds traversed. The self potential log is used to distinguish between permeable and impermeable deposits. In some wells the self-potential curve shows a difference between fresh and salty water. As the open-hole part of the wells logged in Seminole County was in limestone, the self-potential curves yielded little information.

RESISTIVITY, FLOW, SALINITY, AND TEMPERATURE MEASUREMENTS

Figure 23 shows an electric log, a current-meter traverse, and salinity measurements in well 845-117-10, about 3.6 miles south of Sanford. The

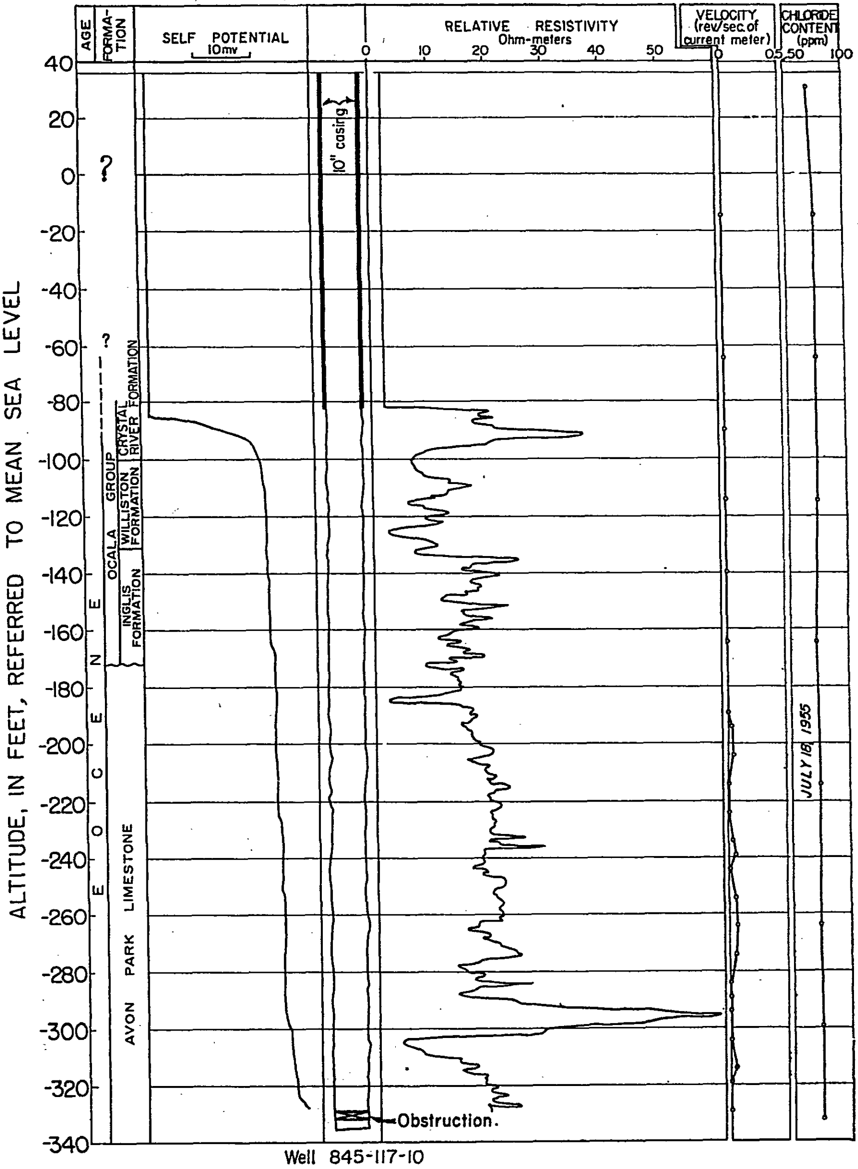


Figure 23. Electric log, current-meter traverse, and chloride content of water from well 845-117-10, 3.6 miles south of Sanford.

most noticeable feature of the relative-resistivity graph is the highly resistant zone at 290-300 feet below sea level, which represents a dense layer of limestone. This dense layer probably is relatively impervious, and restricts the vertical movement of water. The relative-resistivity graph was useful to the city of Sanford, as it contributed to the decision to deepen some city wells in the spring of 1956 when additional quantities of water were required. The Sanford well field is about half a mile east of well 845-117-10. Before 1956, the wells were not deepened because of the possibility of obtaining salty water. After exploring well 845-117-10, it appeared that the city wells could be deepened to about 280 feet below sea level without increasing the chloride content of the water. The confining layer would prevent salty water, if present at a lower depth, from moving upward and contaminating the water in the producing zone. Four wells in the field were deepened as much as 100 feet without any increase in the chloride content of the water. The bottom of the deepest city well is 180 feet below sea level.

The flow graph in figure 23 shows a slight flow in the well, although the well was not flowing at the surface. The current-meter revolutions were so slow that it was not possible to determine whether the flow was upward or downward. The chloride content of water samples collected at various depths in the well was relatively constant.

Similar information from well 840-107-2, about 2.1 miles north of Chuluota, is given in figure 24. It shows a layer of very dense limestone at about 340 to 365 feet below sea level. This dense limestone acts as a confining layer for the salty water below. The chloride content of water from the limestone below this dense layer is much higher than the chloride content of water from the limestone above the layer, presumably because the lower aquifer has not been flushed as completely as the upper aquifer.

The velocity graph shows that most of the water was coming from a very productive zone just below the dense layer. Even if the flow of water is constant within the well, variations in the velocity graph can be due to irregularities in the well diameter. Such irregularities are probably responsible for the apparent differences in flow. The velocity is more uniform in the cased part of the well, where the diameter of the well bore is constant; however, the diameter of the rest of the well bore differs because of caving of some of the relatively unconsolidated rocks penetrated by the well. However, the velocity declines as the water moves up the cased part of the well. This may be due to loss of head by pipe friction and as a result of lifting the water to the surface or small leaks in the casings. The chloride content of the water collected

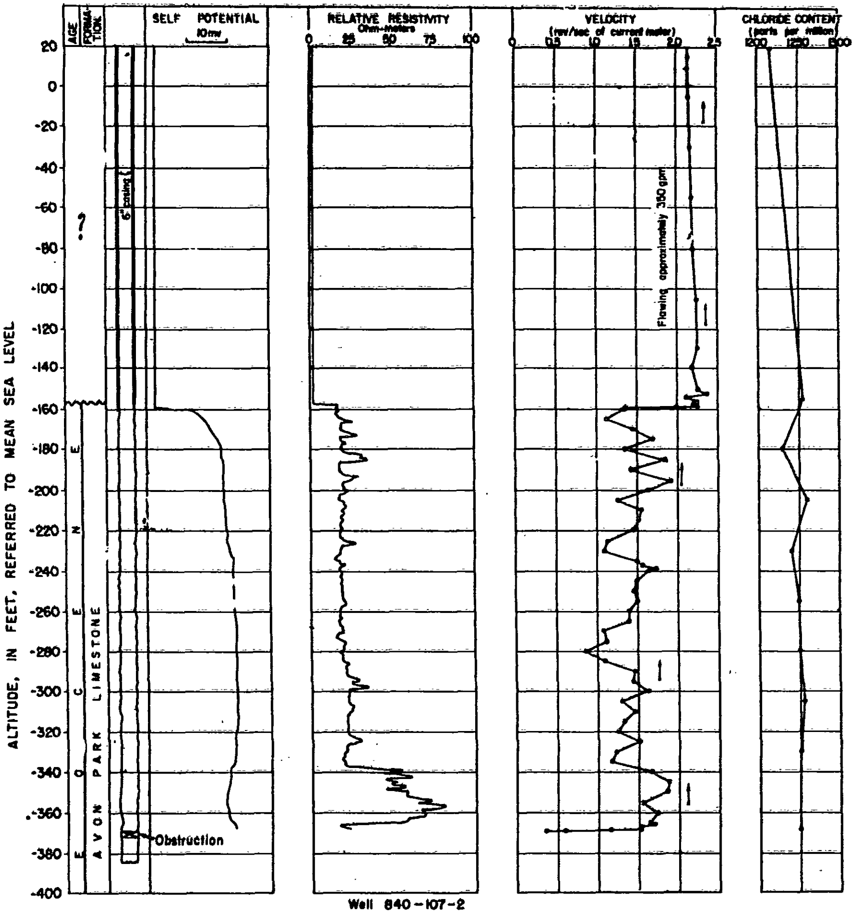


Figure 24. Electric log, current-meter traverse, and chloride content of water from well 840-107-2, 2.1 miles north of Chuluota.

at the surface was lower than the chloride content of water samples collected within the well. This may be due to a small error in the field determination of the chloride content of the water sample collected at the surface.

The graph of the relative resistivity in well 848-116-12 (fig. 25), about half a mile southwest of Sanford, indicates a dense layer of limestone at about 250 feet below sea level. This may be the same hard layer that is 40 to 50 feet lower in well 845-117-10 (fig. 23). The well was not flowing at the time of exploration and the current meter did not

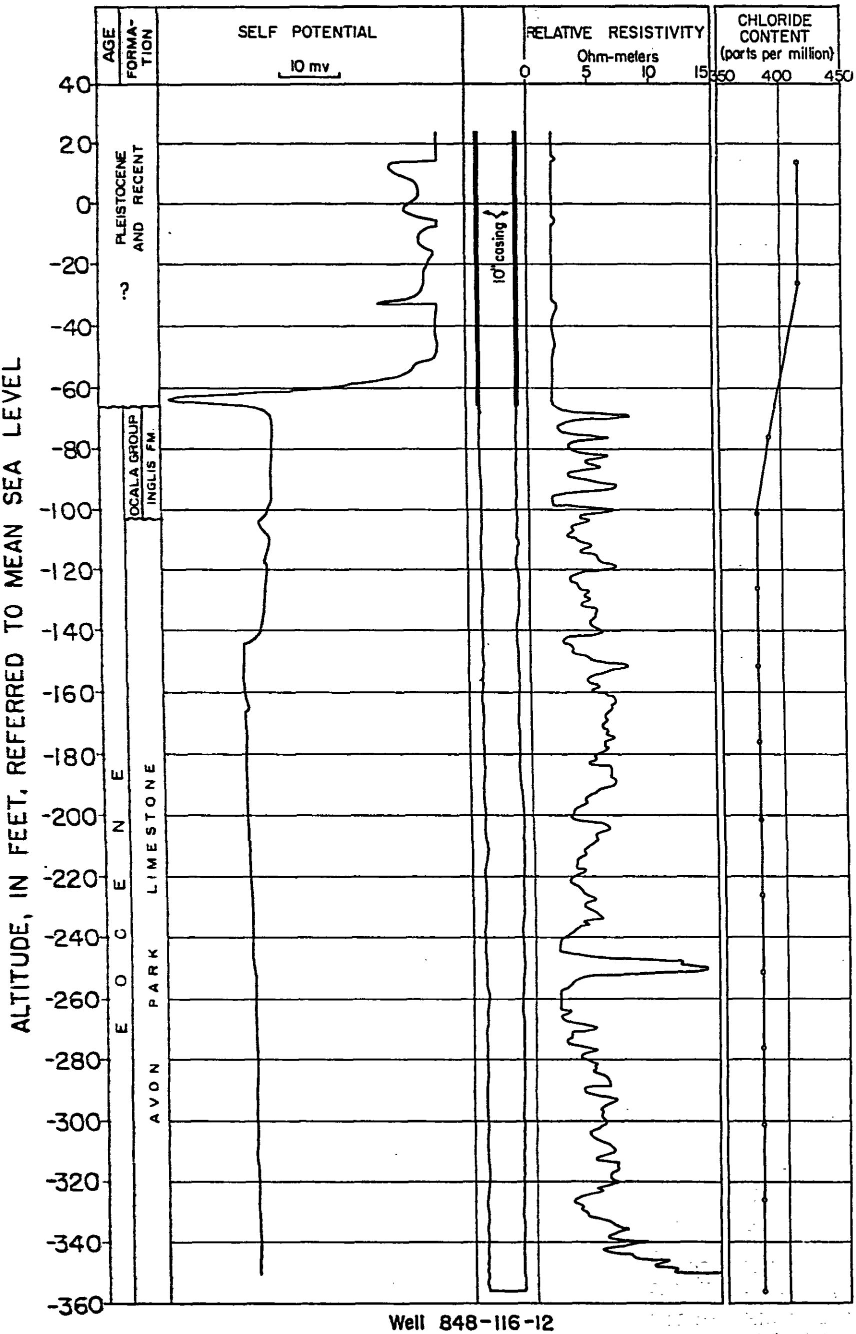


Figure 25. Electric log and chloride content of water from well 848-116-12, 0.5 miles southwest of Sanford.

indicate any movement of water within the well. The chloride content of the water collected within the well did not show any significant change at various depths in the uncased part of the well. The electric log contained some unusual graphs in the cased portion of the well. As the well is old and unused, the graphs might represent corroded zones or holes in the casing. Water leaking through these holes might explain the higher chloride content in the cased portion of the well.

A combination graph of well 841-110-12, about 2.7 miles northeast of Oviedo, is shown in figure 26. The graph of the relative resistivity

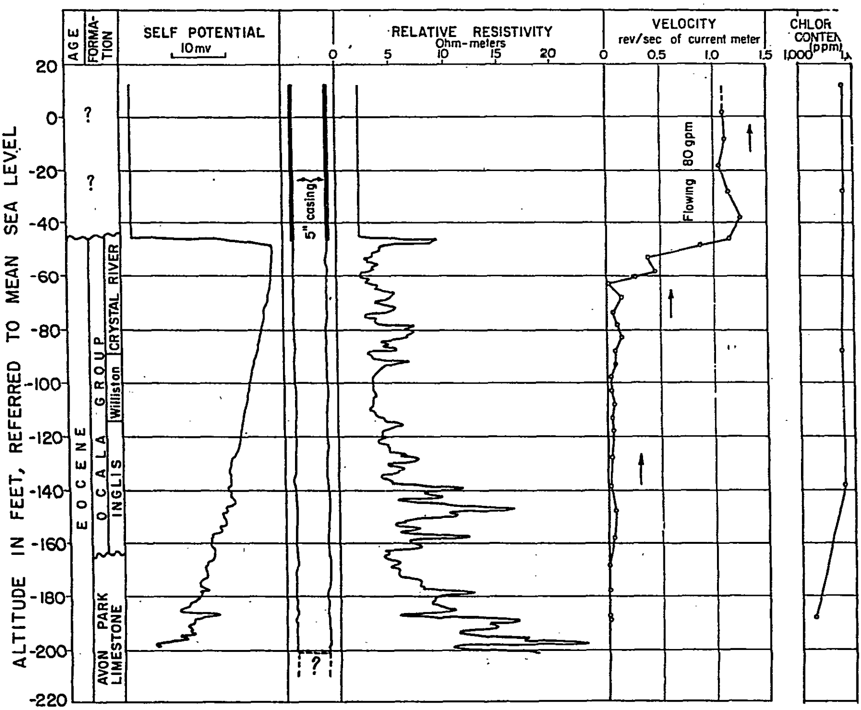


Figure 26. Electric log, current-meter traverse, and chloride content of water from well 841-110-12, 2.7 miles northeast of Oviedo.

indicates that the resistivity of the rocks increases generally with depth. The velocity graph shows that most of the flow apparently comes from the uppermost 20 feet of limestone below the bottom of the casing. The lower part of the well contributes only a very small amount of water and the bottom 40 feet of the well apparently contributes none. The chloride content of the water collected at various depths within the well showed no difference except in the sample from the bottom of the well, which contained about 55 ppm less chloride than the four shallower samples. This bottom sample was collected in the zone of no measurable flow.

The graphs for well 838-113-3, about 2.5 miles southeast of Oviedo (fig. 27), show that almost all the water is obtained from the uppermost

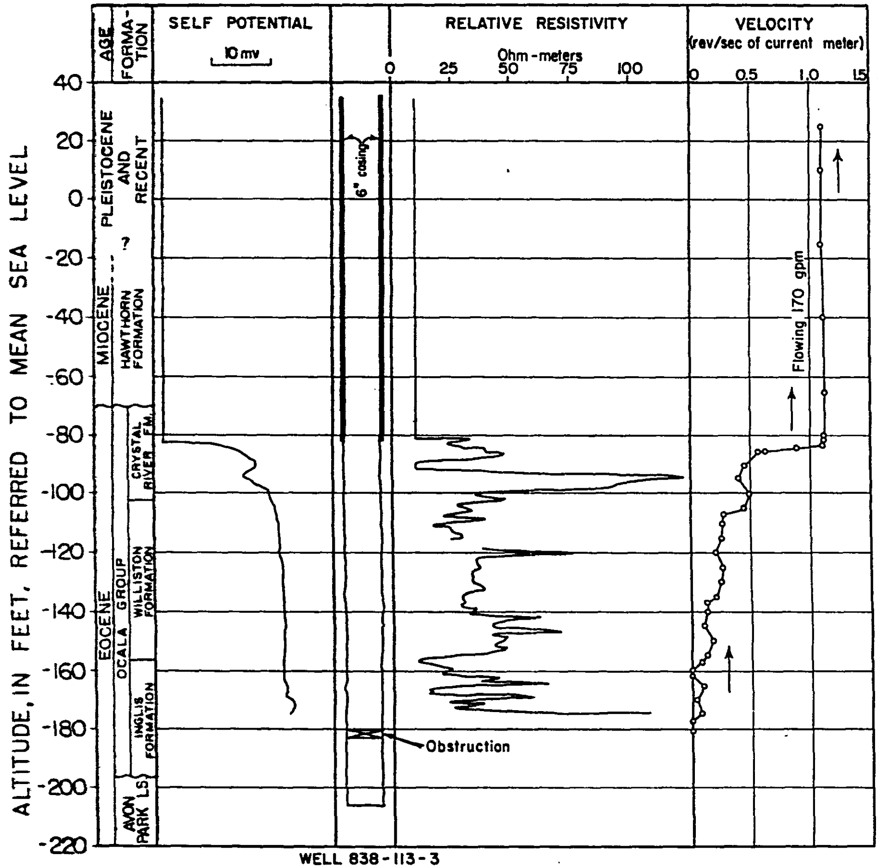


Figure 27. Electric log and current-meter traverse in well 838-113-3, 2.5 miles southeast of Oviedo.

80 feet of limestone below the bottom of the casing. The graph of the relative resistivity shows that many thin, dense layers are present in the limestone. Most of the flow seems to be obtained from the areas of low resistivity.

The combination graph of well 842-111-6, about 2.3 miles northeast of Oviedo (fig. 28), shows that most of the water is obtained from

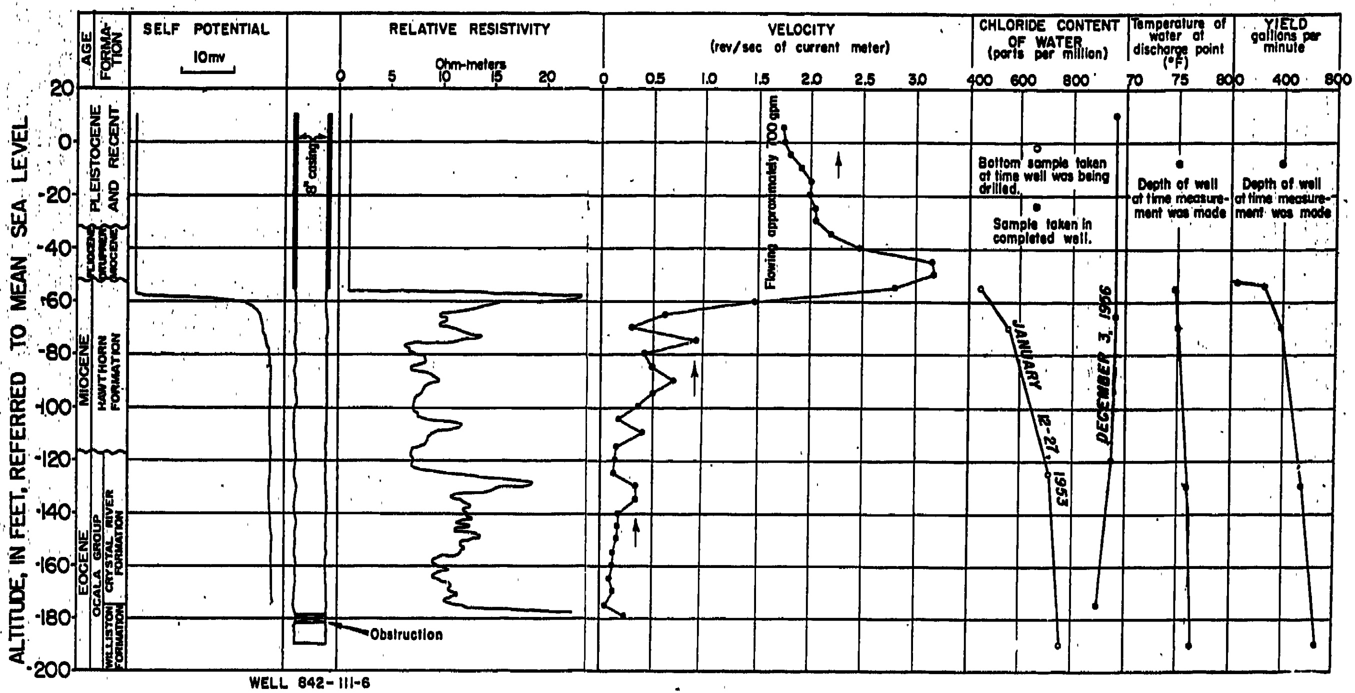


Figure 28. Electric log, current-meter traverse, chloride content, temperature, and yield of water from well 842-111-6, 2.3 miles northeast of Oviedo.

the Hawthorn Formation. The rest of the water is obtained from the limestones of the Ocala Group. Below the bottom of the casing, the points of higher velocity correspond with the layers of higher relative resistivity. These more resistant layers are hard and they are affected very little by caving; the well diameter, therefore, is generally smaller at these layers. The smaller diameter of the well bore restricts the flow and increases the velocity of the water.

A study of the current-meter traverse in the cased part of the well indicates that the casing may be leaking somewhere in the zone from 30 to 45 feet below sea level. The current-meter revolutions decreased from 3.2 per second at 45 feet below sea level to 2.0 revolutions per second at 30 feet below sea level. The velocity measurements within the casing were more uniform in the other wells that were explored.

Measurements of the chloride content of the water were taken at various depths within well 842-111-6 by two different methods. One set of water samples was collected from the bottom of the well with a bailer while the well was being drilled. The chloride content of these bottom-water samples increased from 450 ppm in a sample collected at 55 feet below sea level to 755 ppm in a sample collected at 190 feet below sea level. These samples were collected during the period January 12-27, 1953. On December 3, 1956, water samples were collected at various depths within the well. The chloride content of these samples ranged from 900 to 960 ppm. The composite sample of the chloride content of water collected at the surface was about 200 ppm above the highest chloride content measured while the well was being drilled in 1953.

The discharge temperature of the water, while the well was being drilled, increased from 74.5° to 76.5°F. from the bottom of the casing to the bottom of the well. This amounts to an increase of about 1°F. in the temperature of the water discharged for every 60 feet increase in well depth. However, these temperature measurements were made of the water discharged at the surface and do not represent the actual temperature of the water at depth in the well.

The graph of the increase in yield shows that the first flow of water was 50 gpm when the bottom of the well was 53 feet below sea level. The yield increased to almost 400 gpm during the next 12 feet of drilling. The well yield at the surface was 670 gpm when the well was completed. Almost 4 years later, the well yield was 700 gpm.

The graph of the relative resistivity of the rocks at well 847-113-31 (fig. 29), about 3.0 miles southeast of Sanford, indicates many thin resistant (dense) layers in the Avon Park Limestone. The graph of the chloride content of water samples collected within the well shows an

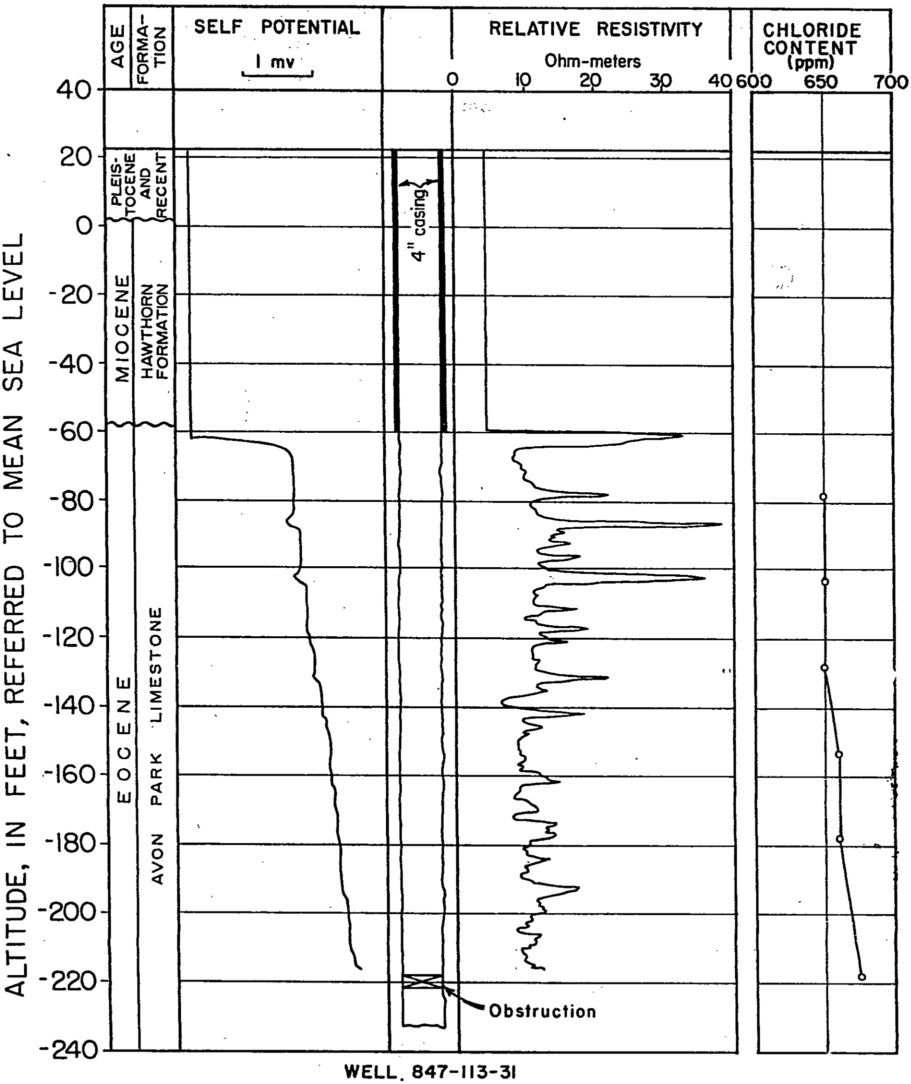


Figure 29. Electric log and chloride content of water from well 847-113-31, 3.0 miles southeast of Sanford.

increase of chloride content from 650 to 675 ppm as the depth increased about 90 feet. The well was not flowing at the surface when the water samples were collected. An attempt was made to determine if the well had any internal movement of water but an obstruction prevented the current meter from being lowered more than 23 feet below the surface.

Figure 30 shows the amount of casing, the depth, and current-meter traverses for two wells near Oviedo. Well 842-112-2, about 2.3 miles

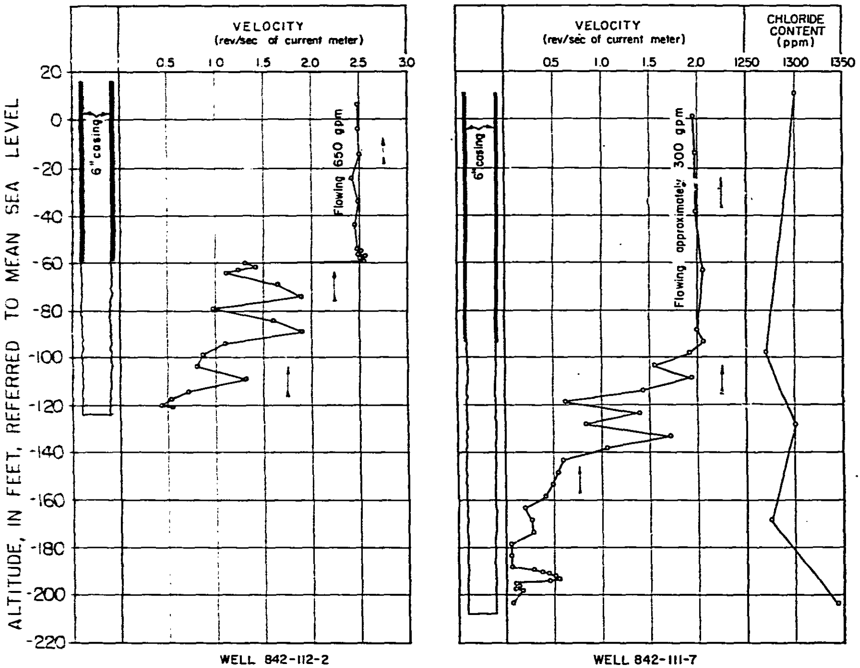


Figure 30. Current-meter traverse and chloride content of water from wells 842-112-2, 2.3 miles northeast of Oviedo, and 842-111-7, 2.3 miles northeast of Oviedo.

northeast of Oviedo, has about 65 feet of open hole in the Floridan aquifer below the bottom of the casing. The bottom measurement of the current meter in this well indicated a substantial flow which increased upward to the bottom of the casing.

The graph of the velocity in well 842-111-7, about 2.3 miles northeast of Oviedo, shows a small flow in the bottom 25 feet of the well. Most of the flow, however, is obtained from the zone between 100 and 180 feet below sea level. The chloride content of the water discharging at the surface was 1,300 ppm. The chloride content of water samples collected within the well ranged from 1,270 to 1,345 ppm. The sample at the surface represents a composite of the chloride content of water obtained from all the producing zones within the well.

QUALITY OF WATER

The wide range in the chemical composition of ground water in Seminole County is shown by analyses of samples of the water. Some of the ground water is excellent for ordinary use and some cannot be made suitable for general use by any practical treatment.

The amount of dissolved mineral matter in water from the Floridan aquifer ranges from low in the recharge areas of the hilly uplands to high in the discharge areas of the lowlands. Stubbs (1937, p. 27) concluded that the highly mineralized water in Seminole County was coming from the Coskinolina Zone (Avon Park Limestone). Information collected during this investigation has shown that the area in which the well is located is more important in regard to the dissolved solids content of water than the geologic formation that the well penetrates.

Samples of ground water for chemical analyses were collected in every section of the county, but the most intensive sampling was done in the areas in which the water is highly mineralized. These areas generally include most of the areas of artesian flow. The chemical analyses were made by the Quality of Water Branch of the U. S. Geological Survey.

The dissolved chemical constitutents of water are reported in parts per million (ppm). A part per million is a unit weight of a constitutent in a million unit weights of water. Thus, a water sample containing 1 ppm of iron (Fe) contains 1 pound of iron in a million pounds of the water sampled. In order to show water analyses graphically, the cations and anions may be expressed in chemically equivalent weights or equivalents per million (epm); parts per million may be converted to equivalents per million by dividing the parts per million by the combining weight of the respective cation or anion. Specific conductance is reported in reciprocal ohms (mhos); pH is reported in standard pH units; and color is reported in dimensionless units defined by the standard platinum cobalt scale.

The mineral constitutents of natural waters generally reflect the composition and solubility of the rock materials with which the waters have been in contact. In Seminole County, the minerals found in ground water are not obtained entirely from rocks and soils. Some of the mineralization of ground water in Seminole County probably comes either from sea water that entered the rocks during the interglacial periods of the Pleistocene Epoch, or from sea water that was trapped in the rocks when they were deposited.

COLOR

Color in water may be of natural mineral, animal, or vegetable origin. It may be caused by metallic substances, humus material, peat, algae, weeds or protozoa. Industrial wastes may also cause color; color may range from zero to several hundred units. Although color is not harmful to people, it is objectionable when present in noticeable amounts. Color begins to become undesirable in quantities above 20. All except 2 of the 22 samples on which color determinations were made had a color of less than 10. Color determinations of 22 ground-water samples in Seminole County ranged from 1 to 25 (table 4).

SPECIFIC CONDUCTANCE

The specific conductance is a measure of the ability of the water to conduct an electric current. The more dissolved mineral matter in the water, the better it will conduct an electric current. Thus, specific conductance indicates in a general way the relative mineralization of the water. The specific conductance of 179 ground-water samples in Seminole County was found to range from 135 to 21,900 micromhos at 25°C. (table 4).

SILICA

Most silica (SiO_2) in water is probably derived from silicate minerals other than quartz. Silica is of little significance in the range normally found except when the water is used for boiler feed water. A recommended upper limit of silica for boilers operating at 400 pounds per square inch or above is 1.0 ppm (Rainwater and Thatcher, 1960, p. 259). Silica in 20 ground-water samples in Seminole County was found to range from 7 to 21 ppm.

IRON

Iron (Fe) is dissolved from almost all rocks and soils by rainwater and ground water during the process of weathering. In addition, some of the iron detected in ground water may have been dissolved from the well casing and pipes. A concentration of more than about 0.3 ppm of iron in water is objectionable, as it stains porcelain, plumbing fixtures, and clothing. It imparts an undesirable taste, and oxidation of the iron forms a reddish brown sediment. Excess iron can usually be removed by aeration and filtration but some waters require more elaborate treatment.

The concentration of iron in the ground waters of Seminole County differs considerably from place to place. The highest iron concentrations are in artesian water from wells drilled in the lake regions. The presence of a considerable amount of iron is usually associated with the presence of a nearby recharge area. The total iron content in 38 ground-water samples in this area ranged from 0.00 to 5.9 ppm. Many of the shallow

TABLE 4. Chemical Analyses of Water from Wells in Seminole County

(Analyses in parts per million, except specific conductance, color, and pH, by U.S. Geological Survey)

Well No.	Date of collection	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180°C.)	Hardness as $CaCO_3$		Specific conductance (micromhos at 25°C.)	Color	pH	Hydrogen sulfide (H_2S)
														Calcium magnesium	Noncarbonate				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
836-102-1	2- 3-55	......	......	148	66	......	......	......	318	815	......	......	2,100	650	......	3,320	......	8.0	......
836-107-1	3- 1-54	......	......	58	1.7	......	......	......	1.0	8	......	......	180	152	......	303	......	7.8	......
836-113-1	2- 7-55	......	......	43	9	......	......	......	2.0	8	......	......	170	144	......	292	......	7.9	......
836-117-1	3- 1-54	......	......	29	11	......	......	......	8.0	7	......	......	140	116	......	242	......	7.6	......
837-101-1	11- 4-53	15	0.21	164	71	514	13	188	348	930	0.1	2.0	2,360	701	547	3,720	7	7.6	......
837-102-1	3- 1-54	......	......	97	29	......	......	......	132	308	......	......	900	362	......	1,520	......	7.3	......
837-102-3	2- 3-55	......	......	100	43	......	......	......	180	460	......	......	1,200	425	......	2,070	......	7.7	......
837-102-3	6-23-56	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	12
837-103-1	6-23-56	......	.46	......	......	......	......	312	......	12	.0	......	......	......	......	494	......	......	24
837-103-2	6-23-56	......	.14	......	......	......	......	264	......	80	.0	......	......	......	......	570	......	......	.6
837-109-1	2- 7-55	......	......	50	8	......	......	......	6.5	12	......	......	190	158	......	325	......	7.9	......
837-114-1	3- 1-54	......	......	34	7.3	......	......	......	1.0	8	......	......	150	115	......	251	......	7.8	......
837-115-1	3- 1-54	......	......	26	1	......	......	......	1.0	6	......	......	88	69	......	151	......	7.8	......
837-119-2	2- 5-55	......	......	43	7.4	......	......	......	2.0	7	......	......	170	138	......	288	......	8.0	......
838-103-1	3- 1-54	......	......	134	75	......	......	......	306	1,010	......	......	2,400	642	......	3,880	......	7.4	......
838-106-1	3- 1-54	......	......	53	5.1	......	......	......	4.0	7	......	......	180	153	......	304	......	7.8	......
838-106-2	2- 7-55	......	......	39	1.8	......	......	......	2.0	9	......	......	130	104	......	231	......	8.2	......
838-107-1	11- 5-53	12	.45	46	2.6	11	.6	153	1.5	18	.1	1.1	164	125	0	296	6	7.6	......
838-113-3	11- 5-53	10	.12	36	8.8	13	.9	142	8.0	24	.1	0	176	126	10	311	6	7.6	......
838-113-3	6-23-56	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	5.6
838-115-2	2- 5-55	......	......	36	8.3	......	......	......	10	8	......	......	160	124	......	268	......	7.7	......
838-116-2	2- 5-55	......	......	56	3.4	......	......	......	2.0	8	......	......	190	154	......	324	......	8.1	......
838-120-1	6-25-56	......	2.6	......	......	......	......	251	......	7	0.4	......	......	......	......	447	......	......	......
838-121-4	2-26-54	......	......	44	5.1	......	......	......	1.0	5	......	......	160	131	......	269	......	8.1	......
838-123-1	2- 3-55	......	......	45	12	......	......	......	2.0	6	......	......	200	164	......	351	......	8.5	......
838-125-1	2-24-54	......	......	30	16	......	......	......	2.0	8	......	......	160	140	......	275	......	7.7	......
838-126-1	2-24-54	......	......	22	11	......	......	......	4.0	9	......	......	140	106	......	236	......	7.9	......
839-102-1	2- 2-54	......	......	148	86	......	......	......	338	1,140	......	......	1,700	725	......	4,420	......	7.6	......
839-104-1	2- 2-55	......	......	84	33	......	......	......	112	435	......	......	1,100	345	......	1,860	......	7.7	......
839-109-1	3- 1-54	......	......	49	16	......	......	......	25	185	......	......	530	190	......	800	......	7.9	......

TABLE 4. (Continued)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
830-113-1	3- 1-54	......	......	53	11	......	......	......	28	142	......	......	420	170	......	714	......	7.6	......
830-116-1	2-26-54	......	......	39	5.5	......	......	......	1.0	7	......	......	150	120	......	250	......	7.6	......
830-120-1	2-26-54	......	......	50	20	......	......	......	1.0	6.5	......	......	220	207	......	385	......	7.2	......
830-120-4	6-25-56	......	1.7	......	......	......	......	334	......	10	0.3	......	......	......	......	515	......	......	......
830-125-1	6-25-56	......	......	......	......	......	......	70	......	8	.1	......	......	......	......	141	......	......	......
830-125-2	4-10-52	11	.08	26	7.8	8.1	0.2	121	5.0	7	.1	0.2	118	97	......	204	3	7.7	......
840-103-2	3- 1-54	......	......	143	88	......	......	......	304	1,460	......	......	3,000	722	......	4,910	......	7.4	......
840-107-3	3- 1-54	......	......	64	21	......	......	......	43	243	......	......	700	246	......	1,130	......	7.5	......
840-108-1	2- 3-55	......	......	48	14	......	......	......	20	82	......	......	340	176	......	570	......	7.8	......
840-110-8	2- 5-55	......	......	58	26	......	......	......	70	320	......	......	800	250	......	1,320	......	7.8	......
840-112-2	3- 1-54	......	......	44	6.1	......		......	4.0	29	......	......	200	135	......	340	......	7.6	......
840-115-1	2- 5-55	......	......	38	8.0	......	......	......	3.0	8.5	......	......	160	128	......	274	......	7.9	......
840-117-4	6-25-56	......	3.1	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
840-118-1	2-26-54	......	......	29	2.3	......	......	......	5.0	4.5	......	......	150	82	......	263	......	8.2	......
840-119-1	2-26-54	......	......	32	10	......	......	......	1.0	6	......	......	150	123	......	254	......	7.6	......
840-120-3	11- 5-53	11	.31	40	9.3	4.7	.6	158	1.8	8	.2	.5	158	138	9	270	7	7.3	......
840-124-1	2-24-54	......	......	31	9.1	......	......	......	1.0	10	......	......	140	115	......	244	......	8.0	......
840-125-3	2- 3-55	......	......	14	6.6	......	......	......	2.0	5.5	......	......	80	62	......	135	......	8.1	......
841-106-1	11- 4-53	17	3.30	68	8.6	16	1.4	251	6.5	22	.1	.6	269	205	0	457	4	7.5	......
841-109-2	2- 5-55	......	......	104	91	......	......	......	220	1,440	......	......	3,100	634	......	4,940	......	7.6	......
841-110-1	3- 1-54	......	......	82	60	......	......	......	145	938	......	......	2,150	452	......	3,370	......	7.4	......
841-110-2	3- 1-54	......	......	61	11	......	......	......	16	128	......	......	430	196	......	723	......	7.5	......
841-110-5	2- 5-55	......	......	90	72	......	......	......	170	1,100	......	......	2,500	520	......	3,940	......	7.7	......
841-110-5	6-23-56	......	......	94	83	......	......	......	172	1,090	......	......	2,500	576	......	3,940	......	8.2	......
841-110-9	11- 5-53	10	.77	102	46	400	9.8	156	113	765	.1	.9	1,720	444	316	2,790	6	7.7	......
841-110-9	6-23-56	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	12
841-110-12	11- 5-53	11	.44	94	68	572	16	154	172	1,070	.1	3.0	2,200	514	388	3,790	7	7.6	......
841-110-12	6-23-56	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	13
841-111-1	2- 5-55	......	......	43	26	......	......	......	34	149	......	......	440	215	......	742	......	7.8	......
841-112-2	3- 1-54	......	......	53	19	......	......	......	44	236	......	......	560	210	......	944	......	7.4	......
841-113-1	2- 5-55	......	......	43	15	......	......	......	33	121	......	......	380	170	......	649	......	7.8	......
841-114-1	2- 5-55	......	......	44	14	......	......	......	43	92	......	......	340	168	......	578	......	7.9	......
841-118-2	2- 5-55	......	......	29	8.6	......	......	......	2.0	6.5	......	......	150	108	......	250	......	8.1	......
841-120-2	6-25-56	......	.23	......	......	......	......	133	......	11	.2	......	......	......	......	234	......	......	1.7
841-120-5	7- 6-56	......	0	28.7	8	7	......	127	0	11	.2	......	108	104	0	......	10	......	......
841-122-1	2-24-54	......	......	27	15	......	......	......	1.0	7.5	......	......	150	129	......	251	......	7.8	......
841-125-1	2- 3-55	......	......	33	13	......	......	......	2.5	8.5	......	......	160	136	......	279	......	8.0	......
842-106-1	3- 1-54	......	......	42	2.9	......	......	......	1.0	10	......	......	150	117	......	251	......	7.7	......
842-106-2	3- 2-54	......	......	43	3.2	......	......	......	1.0	10	......	......	150	120	......	256	......	7.8	......
842-107-1	3- 1-54	......	......	78	1.2	......	......	......	1.0	11	......	......	240	200	......	403	......	7.3	......

TABLE 4. (Continued)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
842-110-2	2- 5-55	......	......	94	75	......	......	......	182	1,160	......	......	2,600	545	......	4,090	......	7.7	......
842-110-3	3- 1-54	......	......	69	46	......	......	......	111	680	......	......	1,620	360	......	2,550	......	7.6	......
842-111-4	2- 5-55	......	......	79	57	......	......	......	135	840	......	......	1,880	430	......	2,960	......	8.0	......
842-111-8	2- 5-55	......	......	96	73	......	......	......	172	1,100	......	......	2,450	540	......	3,870	......	7.7	......
842-112-1	3- 1-54	......	......	51	21	......	......	......	43	252	......	......	600	212	......	1,070	......	7.5	......
842-112-1	6-23-56	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	15
842-115-3	2- 5-55	......	......	39	11	......	......	......	14	18	......	......	180	144	......	308	......	7.8	......
842-116-1	2-26-54	......	......	38	9.0	......	......	......	2.0	9	......	......	170	132	......	290	......	7.6	......
842-116-1	6-23-56	......	......	......	......	......	......	162	......	12	0.1	......	......	......	......	276	......	......	......
842-117-1	2-26-54	......	......	38	8.8	......	......	......	1.0	8.5	......	......	160	131	......	274	......	7.7	......
842-117-3	6-23-56	......	......	......	......	......	......	159	......	10	.0	......	......	......	......	274	......	......	......
842-121-1	2-24-54	......	......	34	9.0	......	......	......	14	9.0	......	......	150	122	......	258	......	7.7	......
842-123-1	2-24-54	......	......	60	17	......	......	......	112	100	......	......	420	220	......	717	......	7.7	......
843-103-1	3- 2-54	......	......	277	330	......	......	......	840	5,440	......	......	10,500	2,050	......	16,500	......	7.4	......
843-103-4	2- 2-55	......	......	271	342	......	......	......	1,000	5,450	......	......	10,500	2,080	......	16,600	......	7.6	......
843-103-4	6-25-56	......	0.18	......	......	......	......	178	......	5,400	.0	......	......	......	......	16,200	......	......	14
843-104-1	3- 2-54	......	......	71	7.0	......	......	......	1.0	60	......	......	330	206	......	561	......	7.7	......
843-104-4	3- 2-54	......	......	135	107	......	......	......	240	1,750	......	......	3,530	776	......	5,780	......	7.4	......
843-104-8	2- 2-55	......	......	284	360	......	......	......	980	5,600	......	......	10,900	2,190	......	17,200	......	7.5	......
843-104-12	2- 2-55	......	......	138	120	......	......	......	288	1,910	......	......	4,100	840	......	6,520	......	7.8	......
843-106-2	2- 7-55	......	......	48	2.4	......	......	......	1.5	10	......	......	170	130	......	287	......	7.9	......
843-106-3	3- 2-54	......	......	56	1.9	......	......	......	1.0	10	......	......	180	148	......	308	......	7.7	......
843-106-4	3- 2-54	......	......	36	.5	......	......	......	1.0	10	......	......	120	92	......	205	......	7.9	......
843-106-5	6-25-56	......	.81	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
843-106-7	6-25-56	......	2.2	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
843-110-1	3- 1-54	......	......	106	97	......	......	......	237	1,570	......	......	3,400	664	......	5,370	......	7.4	......
843-111-7	2- 5-55	......	......	92	74	......	......	......	185	1,070	......	......	2,500	535	......	3,920	......	7.8	......
843-116-2	2-23-54	......	......	53	39	......	......	......	90	544	......	......	1,280	294	......	2,010	......	7.5	......
843-118-2	2-23-54	......	......	33	8.1	......	......	......	1.0	18	......	......	170	116	......	286	......	7.4	......
843-120-1	2-24-54	......	......	34	7.1	......	......	......	1.0	7	......	......	140	114	......	235	......	7.7	......
843-123-1	2-24-54	......	......	33	8.9	......	......	......	12	6.5	......	......	140	119	......	239	......	7.4	......
844-104-3	2- 2-55	......	......	123	92	......	......	......	200	1,440	......	......	3,170	685	......	5,000	......	7.7	......
844-104-4	2- 2-55	......	......	69	5.4	......	......	......	3	38	......	......	300	194	......	504	......	7.9	......
844-105-1	3- 2-54	......	......	69	2.4	......	......	......	3	20	......	......	230	182	......	406	......	7.5	......
844-105-3	2- 2-55	......	......	88	45	......	......	......	108	695	......	......	1,620	405	......	2,540	......	7.7	......
844-106-2	3- 2-54	......	......	40	.5	......	......	......	4	8.5	......	......	135	102	......	228	......	8.1	......
844-107-1	4- 9-52	21	.10	38	2.5	6.6	0.03	129	3.0	9	.0	0.1	150	105	......	234	2	7.7	......
844-114-4	2- 2-55	......	......	98	47	......	......	......	138	820	......	......	1,880	440	......	2,950	......	7.7	......
844-115-8	2-23-54	......	......	69	45	......	......	......	117	693	......	......	1,580	356	......	2,480	......	7.4	......
844-116-1	2- 3-55	......	......	58	44	......	......	......	100	685	......	......	1,410	325	......	2,220	......	7.8	......

TABLE 4. (Continued)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
844-116-1	6-25-56	...	0.37	62	46	...	...	...	95	565	...	...	1,300	344	...	2,100	...	7.4	12
844-117-8	3- 1-54	...	...	45	4.6	...	...	...	1.0	13	...	...	170	131	...	284	...	7.8	...
844-117-8	6-25-56	...	.40	...	...	...	...	163	...	13	0.1	...	...	...	...	292	...	...	...
844-120-1	2-24-54	...	...	46	6.1	...	...	...	1.0	7	...	...	170	140	...	285	...	7.7	...
845-107-1	3- 2-54	...	...	37	1.8	...	...	...	2.0	15	...	...	148	100	...	250	...	7.9	...
845-107-3	2- 7-55	...	...	64	8.7	...	...	...	8.0	25	...	...	240	196	...	407	...	7.7	...
845-108-3	2- 7-55	...	...	82	5.6	...	...	...	2.5	12	...	...	240	228	...	416	...	8.0	...
845-108-3	6-25-56	...	4.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
845-110-1	3- 2-54	...	...	130	65	...	...	...	205	1,200	...	...	2,560	616	...	4,460	...	7.4	...
845-113-1	2- 2-55	...	...	114	75	...	...	...	188	1,120	...	...	2,820	594	...	4,440	...	7.7	...
845-113-1	6-25-56	...	...	120	81	...	...	...	192	1,250	...	...	2,850	632	...	4,500	...	7.4	12
845-113-11	1-30-53	9.6	.05	108	71	632	14	142	188	1,170	.1	0.7	2,410	562	...	4,060	3	7.4	...
845-114-5	1-30-53	11	.04	70	25	227	5.6	154	64	408	.1	.7	950	278	...	1,620	4	7.6	...
845-114-6	1-31-53	8.7	.07	58	.7	11	.6	182	1.5	16	.1	.2	200	148	...	331	5	7.4	...
845-115-2	2-25-54	...	...	55	8.8	...	...	...	2.0	65	...	...	270	173	...	465	...	7.5	...
845-115-7	2-25-54	...	...	67	8.2	...	...	...	6.0	118	...	...	430	218	...	721	...	7.8	...
845-117-7	3-18-42	...	.11	43	8.5	37	...	159	9.5	58	...	...	246	138	...	...	10	7.5	...
845-117-10	8-28-51	7.0	.01	50	9.0	41	...	...	8.0	70	...	2.0	294	162	18	...	25	7.6	...
845-118-3	2-25-54	...	...	69	1.7	...	...	...	1.0	9.5	...	...	222	180	...	366	...	7.5	...
845-118-3	6-25-56	...	2.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
845-119-1	11- 5-53	14	5.9	58	7.4	6.4	2.0	219	22	7	.1	.1	204	175	0	351	9	7.3	...
845-121-2	2- 4-55	...	...	28	2.9	...	...	...	2.0	6.5	...	...	110	82	...	188	...	8.1	...
845-122-1	2-25-54	...	...	46	26	...	...	...	4.0	11	...	...	260	221	...	435	...	7.4	...
846-108-1	3- 2-54	...	...	99	25	...	...	...	60	405	...	...	1,010	352	...	1,790	...	7.2	...
846-112-5	2-23-54	...	...	107	54	...	...	...	142	960	...	...	2,110	490	...	3,330	...	7.4	...
846-112-6	2- 2-55	...	...	100	44	...	...	...	130	820	...	...	1,880	430	...	2,950	...	7.7	...
846-113-3	2- 7-55	...	...	99	48	...	...	...	118	725	...	...	1,780	445	...	2,800	...	7.7	...
846-115-9	2-25-54	...	...	110	12	...	...	...	24	131	...	...	560	324	...	943	...	7.3	...
846-116-5	2-25-54	...	...	66	32	...	...	...	90	430	...	...	950	298	...	1,660	...	7.8	...
846-116-11	8-28-51	7.0	0	66	25	193	...	...	68	345	...	1.0	868	268	138	...	15	7.7	...
846-116-11	2- 6-55	...	...	60	30	...	...	...	78	330	...	...	800	275	...	1,360	...	7.7	...
846-118-3	6-25-56	...	1.2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
846-118-4	2-25-54	...	...	61	.7	...	...	...	4.0	10	...	...	400	156	...	...	...	7.4	...
846-119-3	2-25-54	...	...	37	1.6	...	...	...	1.0	7.5	...	...	120	99	...	206	...	7.9	...
846-119-4	6-25-56	...	...	...	...	...	...	146	...	12	.1	...	...	...	...	263	...	...	...
846-121-2	6-25-56	...	...	...	...	...	...	132	...	...	.2	...	...	...	...	224	...	...	...
846-122-1	2-25-54	...	...	30	11	...	...	...	1.0	8.5	...	...	140	119	...	242	...	7.7	...
846-123-1	2-25-54	...	...	16	6.6	...	...	...	1.0	7.0	...	...	90	67	...	150	...	8.6	...
847-103-3	3- 2-54	...	...	37	1.6	...	...	...	4.0	13	...	...	140	99	...	236	...	6.4	...
847-107-1	2- 2-55	...	...	123	58	...	...	...	132	810	...	...	2,040	545	...	3,200	...	7.5	...

TABLE 4. (Continued)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
847-107-1	6-25-56	.....	.....	122	63	.....	.....	.....	112	755	.....	.....	1,920	564	.....	3,040	.....	7.3	.....
847-108-1	2- 2-55	.....	.....	326	441	.....	.....	.....	1,180	7,450	.....	.....	13,900	2,630	.....	21,900	.....	7.6	.....
847-108-1	6-25-56	.....	3.5	.....	.....	.....	.....	182	.....	7,700	0.0	.....	.....	.....	.....	20,500	.....	.....	13
847-110-1	4- 9-52	12	.10	144	80	730	10	148	218	1,390	.0	5.0	2,660	688	.....	4,950	2	7.3	.....
847-110-1	3- 2-54	.....	.....	157	70	.....	.....	.....	220	1,420	.....	.....	2,880	678	.....	4,930	.....	7.4	.....
847-112-7	2-23-54	.....	.....	107	50	.....	.....	.....	135	880	.....	.....	1,880	472	.....	3,100	.....	7.5	.....
847-113-5	2-23-54	.....	.....	24	29	.....	.....	.....	20	579	.....	.....	1,230	176	.....	1,940	.....	8.4	.....
847-113-5	6-25-56	.....	.....	58	37	.....	.....	.....	80	570	.....	.....	1,360	296	.....	2,140	.....	7.3	.....
847-113-21	2-23-54	.....	.....	84	33	.....	.....	.....	90	540	.....	.....	1,220	344	.....	2,120	.....	7.7	.....
847-114-3	2-23-54	.....	.....	79	17	.....	.....	.....	56	536	.....	.....	714	268	.....	1,250	.....	7.4	.....
847-114-3	6-25-56	.....	.....	80	22	.....	.....	.....	45	260	.....	.....	720	290	.....	1,240	.....	7.5	.....
847-114-6	3- 2-54	.....	.....	77	8.3	.....	.....	.....	90	518	.....	.....	1,150	326	.....	2,030	.....	7.7	.....
847-115-5	2-25-54	.....	.....	83	16	.....	.....	.....	30	163	.....	.....	560	272	.....	946	.....	7.6	.....
847-115-9	2-23-54	.....	.....	58	5.1	.....	.....	.....	24	94	.....	.....	359	166	.....	600	.....	7.5	.....
847-116-2	2- 7-55	.....	.....	89	12	.....	.....	.....	29	148	.....	.....	550	274	.....	935	.....	7.6	.....
847-116-6	2-23-54	.....	.....	65	15	.....	.....	.....	64	249	.....	.....	638	224	.....	1,130	.....	7.6	.....
847-116-11	2- 4-55	.....	.....	45	10	.....	.....	.....	11	47	.....	.....	250	154	.....	430	.....	7.9	.....
847-117-2	4- 9-52	11	.11	46	6.9	9.2	.6	175	4.0	10	.0	.1	188	143	.....	324	2	7.7	.....
847-118-7	2-25-54	.....	.....	42	3.4	.....	.....	.....	2.0	8	.....	.....	150	119	.....	259	.....	8.3	.....
847-119-2	2-25-54	.....	.....	33	3.9	.....	.....	.....	1.0	7.5	.....	.....	130	99	.....	215	.....	8.1	.....
847-120-3	6-25-56	.....	.....	.....	.....	.....	.....	167	.....	10	.1	.....	.....	.....	.....	281	.....	.....	.....
847-121-2	2- 4-55	.....	.....	24	7.3	.....	.....	.....	1.5	5.5	.....	.....	110	90	.....	185	.....	7.9	.....
847-123-1	2-25-54	.....	.....	22	9.2	.....	.....	.....	6.0	6.5	.....	.....	120	93	.....	197	.....	8.0	.....
848-112-2	2-23-54	.....	.....	86	26	.....	.....	.....	73	435	.....	.....	1,050	320	.....	1,680	.....	7.6	.....
848-112-2	6-25-56	.....	.....	.....	.....	.....	.....	145	.....	10	.1	.....	248	.....	.....	.....	.....	.....	.....
848-113-5	2- 7-55	.....	.....	82	36	.....	.....	.....	92	590	.....	.....	1,330	355	.....	2,100	.....	7.7	.....
848-113-5	6-25-56	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	12
848-114-4	2- 7-55	.....	.....	113	32	.....	.....	.....	98	582	.....	.....	1,410	415	.....	2,220	.....	7.7	.....
848-115-3	6-14-51	.....	1.9	104	41	380	.....	159	112	700	.1	.....	635	430	300	.....	5	7.7	.....
848-116-3	2- 4-55	.....	.....	112	50	.....	.....	.....	170	820	.....	.....	1,900	485	.....	2,990	.....	7.7	.....
848-117-8	2-23-54	.....	.....	101	48	.....	.....	.....	171	756	.....	.....	1,640	452	.....	2,690	.....	7.6	.....
848-117-8	6-25-56	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	4.9
848-118-2	2-23-54	.....	.....	47	9.0	.....	.....	.....	18	71	.....	.....	272	154	.....	495	.....	7.7	.....
848-119-2	2-23-54	.....	.....	39	6.6	.....	.....	.....	1.0	10	.....	.....	145	125	.....	263	.....	7.8	.....
848-120-2	2-23-54	.....	.....	51	2.2	.....	.....	.....	10	8	.....	.....	167	136	.....	295	.....	7.6	.....
848-122-1	2-23-54	.....	.....	27	10	.....	.....	.....	5.0	6.5	.....	.....	123	109	.....	232	.....	7.8	.....
849-105-1	2- 7-55	.....	.....	313	310	.....	.....	.....	680	5,100	.....	.....	10,000	2,060	.....	15,700	.....	7.5	.....
849-117-1	2- 4-55	.....	.....	129	64	.....	.....	.....	198	1,080	.....	.....	2,480	585	.....	3,930	.....	7.7	.....
849-117-1	6-25-56	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	3.3
849-118-5	2- 4-55	.....	.....	43	9.0	.....	.....	.....	1.5	50	.....	.....	240	144	.....	416	.....	8.1	.....

TABLE 4. (Continued)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
849-110-3	2-23-54	......	......	46	12	......	......	......	21	88	......	......	320	163	......	534	......	7.7	......
849-111-3	2- 4-55	......	......	44	11	......	......	......	1.5	74	......	......	280	156	......	478	......	8.0	......
849-120-2	2- 4-55	......	......	57	17	......	......	......	48	170	......	......	500	212	......	840	......	8.0	......
849-121-2	2-23-54	......	......	44	8.3	......	......	......	3.0	48	......	......	220	144	......	369	......	7.8	......
849-123-1	2-23-54	......	......	44	14	......	......	......	4.0	14	......	......	193	168	......	345	......	7.7	......
849-124-5	2-25-54	......	......	98	32	......	......	......	103	209	......	......	940	376	......	1,530	......	7.6	......
Elder Spring	....	2.8	0.60	8.4	1.6	1.8	......	16	4.1	8	......	4.8	58	29	11	....	......	6.4	......
Heath Spring...	4- 9-52	6.8	.10	.8	1.2	7.0	0.2	6	1.0	12	0.0	.3	40	7	......	60	1	5.9	......
Sanlando Springs...	4-23-46	13	.09	29	7.9	5.8	.6	125	3.3	8	.2	.1	123	105	......	228	6	7.2	......

wells driven into the Pleistocene sand yield water containing an objectionable amount of iron.

CALCIUM

Calcium (Ca) is dissolved from limestone, shells, and coral, which are composed largely of calcium carbonate. Calcium imparts the property of hardness to waters in the county. The concentrations of calcium in 170 ground-water samples ranged from 14 to 326 ppm.

MAGNESIUM

Magnesium (Mg) is dissolved from most rocks but especially from dolomite and dolomitic limestone, which contain large amounts of magnesium carbonate. As limestones in central Florida contain small amounts of magnesium carbonate, magnesium is usually found in much smaller quantities than calcium. Magnesium and calcium are the two major constitutents causing hardness in natural waters.

Magnesium is one of the principal constituents of sea water and it is found in relatively large quantities in ground water contaminated with sea water. The magnesium content of 170 ground-water samples from Seminole County ranged from 0.5 to 441 ppm.

SODIUM AND POTASSIUM

Sodium (Na) and potassium (K) are dissolved from many rocks, but because sea water is composed mainly of a solution of common salt (sodium chloride), large amounts of sodium are usually associated in Florida with ground water that has been contaminated with sea water or industrial wastes. The sodium content may be 5 to 20 ppm in ordinary ground water or more than several hundred ppm in a highly mineralized water. The potassium content is generally relatively small. Waters that contain only a few ppm of sodium are likely to contain about equal quantities of potassium. As the amount of these constituents increases, the proportion of potassium becomes less.

The sodium content in 23 ground-water samples in Seminole County ranged from 4.7 to 730 ppm, and the potassium content in 17 ground-water samples ranged from 0.2 to 16 ppm (table 4). This table probably does not show the highest concentrations because the more highly mineralized waters were not analyzed for sodium and potassium.

Sodium is not particularly significant in drinking water except for those persons who require sodium-free diets. A concentration of sodium greater than 100 ppm may cause foaming in steam boilers. Sodium may have some effect on the permeability of some soils, particularly clayey soils.

BICARBONATE

Bicarbonates are common to most waters because of the abundance of carbonate minerals in nature and because carbon dioxide, which helps dissolve bicarbonates, is readily available. Bicarbonate, in combination with calcium and magnesium, causes carbonate hardness.

Ground water from the Floridan aquifer in central Florida usually contains from 100 to 300 ppm of bicarbonate. The bicarbonate content of 36 ground-water samples from Seminole County ranged from 121 of 334 ppm (table 4).

SULFATE

Sulfate (SO_4) is dissolved in large quantities from gypsum (calcium sulfate) in the rocks and soil. Sulfate is also obtained from salts in sea water or from oxidation of iron sulfides.

Sulfate has little effect on the general use of water. The U. S. Public Health Service (1946) recommends that the sulfate concentration not exceed 250 ppm in drinking and culinary water on carriers subject to Federal quarantine regulations. Sulfate in hard water contributes to boiler scale and may have a laxative effect if present in quantities around 300 ppm. The sulfate content of 170 ground-water samples from Seminole County ranged from 1.0 to 1,180 ppm.

CHLORIDE

Chloride (Cl) is abundant in sea water and is dissolved in small quantities from rocks. The chloride content of ground water is generally a reliable index of contamination by sea water because about 91 percent of the dissolved solids content of sea water consists of chloride salts. The chloride content has little effect on the use of water for ordinary purposes unless it is present in large quantities.

Water from the artesian aquifer beneath most of the hilly upland in Seminole County has a chloride content of less than 25 ppm, which might be considered normal for this part of central Florida. Water having a chloride content above 25 ppm suggests mixing with connate salt water or salt water that entered the formations during higher stands of the sea during Pleistocene time.

The chloride content of the 2,062 ground-water samples from the county ranged from 4 to 7,950 ppm (tables 4, 5, 6). Additional chloride analyses are shown in table 2 of Florida Geological Survey Information Circular no. 34.

The U. S. Public Health Service (1946) recommends that the concentration of chlorides not exceed 250 ppm in water on carriers subject to Federal quarantine regulations. Water has a salty taste when the chloride content exceeds 500 ppm, and water high in chloride is corrosive

TABLE 5. Chloride Content of Water Samples Collected at Various Depths in Wells

Well Number	Date of measurement	Depth (feet)	Chloride content (ppm)	Date of measurement	Depth (feet)	Chloride content (ppm)	Date of measurement	Depth (feet)	Chloride content (ppm)
840–107–2	11–28–56	0	1,215	11–28–56	250	1,240	11–28–56	350	1,250
	11–28–56	175	1,255	11–28–56	275	1,250		389	1,250
	11–28–56	200	1,230	11–28–56	300	1,250			
	11–28–56	225	1,260	11–28–56	325	1,255			
840–120–1	7–19–55	25	9	7–19–55	100	9	7–19–55	170	10
	7–19–55	50	10	7–19–55	125	10			
	7–19–55	75	9	7–19–55	150	10			
841–110–12	12– 2–56	0	1,080	12– 2–56	100	1,075	12– 2–56	200	1,025
	12– 2–56	60	1,080	12– 2–56	150	1,080	12– 2–56	200	1,030
842–111–6	12– 3–56	0	960	12– 3–56	130	945			
	12– 3–56	75	960	12– 3–56	189	900			
842–111–7	12– 3–56	0	1,300	12– 3–56	140	1,300	12– 3–56	216	1,345
	12– 3–56	110	1,270	12– 3–56	180	1,275			
845–117–10	7–18–55	5	70	7–18–55	150	76	7–18–55	300	73
	7–18–55	50	74	7–18–55	200	73	7–18–55	335	75
	7–18–55	100	75	7–18–55	250	74	7–18–55	368	75
846–116–11	7–18–55	15	320	7–18–55	50	335	7–18–55	100	335
	7–18–55	30	320	7–18–55	75	330			
847–113–31	12– 1–56	100	650	12– 1–56	150	650	12– 1–56	200	660
	12– 1–56	125	650	12– 1–56	175	660	12– 1–56	240	675
848–116–12	7–19–55	10	415	7–19–55	175	380	7–19–55	300	380
	7–19–55	50	415	7–19–55	200	380	7–19–55	325	380
	7–19–55	100	390	7–19–55	225	380	7–19–55	350	380
	7–19–55	125	380	7–19–55	250	380	7–19–55	380	380
	7–19–55	150	380	7–19–55	275	380	....	....	....

TABLE 6. Chloride Content of Water That Was Collected as Wells Were Being Drilled

Well Number	Date of measurement	Depth (feet)	Chloride content (ppm)	Date of measurement	Depth (feet)	Chloride content (ppm)	Date of measurement	Depth (feet)	Chloride content (ppm)
837-103-1	4- 7-56	90	12	4- 7-56	105	17	4- 9-56	136	13
	4- 7-56	95	15	4- 7-56	110	16	4- 9-56	145	13
	4- 7-56	100	12	4- 9-56	124	14	4- 9-56	154	13
	4- 7-56	103	14	4- 9-56	130	14	4- 9-56	158	15
837-103-2	4-27-56	85	26	5- 7-56	142	78	5-30-56	184	80
	4-27-56	90	25	5- 7-56	153	80	5-30-56	186	80
	4-27-56	94	27	5- 7-56	157	79	5-30-56	190	80
	4-27-56	100	26	5- 7-56	157	78	5-30-56	197	85
	4-27-56	104	27	5-30-56	146	69	5-30-56	204	80
	4-27-56	104	28	5-30-56	148	65	5-30-56	210	80
	4-27-56	104	72	5-30-56	151	73	5-31-56	216	73
	4-27-56	105	74	5-30-56	153	73	5-31-56	224	75
	4-30-56	105	60	5-30-56	155	74	5-31-56	230	78
	4-30-56	105	62	5-30-56	156	74	5-31-56	238	80
	4-30-56	105	66	5-30-56	160	77	5-31-56	244	78
	4-30-56	105	67	5-30-56	164	73	5-31-56	251	83
	4-30-56	106	70	5-30-56	167	77	5-31-56	257	84
	4-30-56	106	70	5-30-56	170	74	5-31-56	265	83
	5- 7-56	108	75	5-30-56	171	77	5-31-56	270	73
	5- 7-56	115	78	5-30-56	172	80	5-31-56	272	72
	5- 7-56	124	77	5-30-56	177	80	6- 1-56	273	80
	5- 7-56	130	77	5-30-56	181	80			
841-110-9	12-28-52	106	640	12-31-52	130	645	1- 1-53	156	700
842-111-6	1-12-53	65	450	1-22-53	135	710			
	1-20-53	80	560	1-27-53	200	755			
843-104-13	12- 8-56	60	590	12- 8-56	61	600	12-29-56	62.3	710
	12- 8-56	60	600	12-29-56	62	705	12-29-56	62.5	715
	12- 8-56	61	600	12-29-56	62.2	700			
845-117-8	5- 8-56	159	50	5- 8-56	164	48	5- 9-56	180	49
	5- 8-56	160	48	5- 8-56	172	48	5- 9-56	187	51
	5- 8-56	161	48	5- 8-56	177	49	5- 9-56	190	49
	5- 8-56	163	51	5- 8-56	178	49	5- 9-56	191	47
846-115-15	6-25-56	115	26	6-26-56	145	30	6-26-56	165	90
	6-25-56	130	30	6-26-56	155	27	6-26-56	185	31
847-116-8	5-12-52	93	280	5-12-52	120	275	5-13-52	160	280
	5-12-52	104	280	5-13-52	160	280			
847-116-9	5-19-52	84	290	5-20-52	155	300	5-20-52	206	310
	5-19-52	107	295	5-20-52	187	310			
847-117-14	11-16-55	84	370	11-17-55	109	480	11-17-55	144	480
	11-16-55	90	370	11-17-55	119	480	11-17-55	144	460
	11-17-55	91	480	11-17-55	130	480	11-18-55	147	480
	11-16-55	92	470	11-17-55	140	470	11-18-55	151	470
	11-17-55	100	500	11-17-55	143	470			

to boilers and plumbing. A chloride content of more than 800 ppm is harmful to some irrigated crops (Westgate, 1950, p. 116-123).

FLUORIDE

Fluoride (F) is dissolved from soil and rocks, but the quantity in natural waters is generally very small. Fluoride concentrations of 34 ground-water samples from Seminole County ranged from 0.0 to 0.4 ppm.

Excess fluoride in water is associated with the dental defect known as dental fluorosis (mottled enamel) if children drink the water habitually during the formation of their permanent teeth. Recent studies have concluded that a fluoride concentration of 0.75 to 1.5 ppm has a beneficial effect on teeth by reduction of the incidence of dental caries (decay).

NITRATE

Nitrate (NO_3) is a relatively unimportant constitutent of most waters in Florida. Fertilizers may add nitrate directly to water resources. The presence of high nitrates suggests possible pollution by human and animal wastes. The nitrate concentration of 20 samples of ground water from Seminole County did not exceed 5 ppm. This small concentration has little effect on the use of water for ordinary purposes.

DISSOLVED SOLIDS

The residue of a water, on evaporation, consists of the mineral materials reported in the analyses. A small quantity of organic material or water of crystallization is sometimes included. The amount of dissolved solids found in 170 ground-water samples from Seminole County ranged from 80 to 13,900 ppm. Water that has less than 500 ppm of dissolved solids is usually satisfactory for domestic use. Water that has more than 1,000 ppm of dissolved solids is likely to have enough of certain constituents to produce a noticeable taste or make the water undesirable for many uses.

The dissolved solids content of water was used by Krieger, et al., (1957) to classify the degree of salinity of highly mineralized waters. The divisions used in this publication are as follows:

Description	*Dissolved solids (ppm)*
Slightly saline	1,000 – 3,000
Moderately saline	3,000 – 10,000
Very saline	10,000 – 35,000
Brine	35,000+

According to this classification, ground water in Seminole County can be classed as fresh (not saline) to very saline.

Figure 31 shows the dissolved-solids content of water from artesian wells in the county. The dissolved-solids content of the ground water is less than 500 ppm in all the hilly uplands. This area extends from the towns of Lake Monroe and Paola south to Orange County, and from Chuluota and Oviedo west to Orange County. An approximately circular area around Geneva is included also. Ground water having a dissolved-solids content of 500 to 1,000 ppm occurs in a relatively narrow band between the hilly uplands and the level lowlands. Ground water having a dissolved-solids content of 1,000 to 3,000 ppm occurs in some lands adjacent to Lake Monroe, Lake Jessup, and the Econlockhatchee River. The highest concentration of dissolved solids was in ground water adjacent to the St. Johns River, north and east of Geneva. A small area between Geneva and Oviedo contains ground water also very high in dissolved solids.

HARDNESS

The hardness of water is most commonly recognized by high soap consumption. It is caused by compounds of calcium and magnesium. These compounds also are active in the formation of scale in steam boilers.

There are two types of hardness in water—carbonate hardness and noncarbonate hardness. Carbonate hardness is that caused by calcium and magnesium bicarbonate. Most of this type of hardness can be removed by boiling or by treatment with lime. Noncarbonate hardness is caused primarily by sulfates, chlorides, and nitrates of calcium and magnesium and is more difficult to remove.

Water that has a hardness of less than 60 ppm may be rated as soft, and treatment for removing hardness is justified for few purposes. Hardness between 60 and 120 ppm may be classed as moderately hard, but does not interfere with the use of water for most purposes. Hardness between 120 and 200 ppm may be classed as hard and some form of softening is usually required for many industrial uses. Hardness above 200 ppm may be classed as very hard and is objectionable for most industrial and domestic uses.

The hardness of 170 ground-water samples from Seminole County ranged from 62 to 2,630 ppm as $CaCO_3$ (table 4). The hardness of water from the Floridan aquifer in Seminole County is shown in figure 32, which shows that ground water from the hilly uplands is softer than ground water from the level lowlands. The water has a hardness between 60 and 120 ppm in a large area between Paola and Longwood, and in smaller areas west of Altamonte Springs, southwest of Oviedo, east of Chuluota, and around Geneva. Ground water in the remaining areas of the hilly uplands has a hardness of 121 to 200 ppm. Ground water having a hardness of over 200 ppm occurs in most of the area adjacent to the St. Johns, Econlockhatchee, and Wekiva rivers and in the areas adjacent to Lake Jessup, Lake Monroe, and Lake Harney. The hardness of ground water exceeds 500 ppm in an area surrounding both sides of the northern half of Lake Jessup, and encircling the 4- to 6-mile area of lower hardness that surrounds Geneva. This area extends southward along the St. Johns River into Orange County.

HYDROGEN SULFIDE

Hydrogen sulfide (H_2S) is found in most artesian water in Seminole County. This gas has a very distinct taste and odor which has caused the water to be called sulfur water. Hydrogen sulfide in ground waters is probably caused by the bacterial reduction of sulfates, by water circulating through iron sulfide, and resulting from organic matter. It may usually be removed by aeration or by allowing the water to stand in an open container.

The amount of hydrogen sulfide in 15 samples of ground water ranged from 0.6 to 24 ppm (table 4). A strong odor is imparted by less than 1 ppm of H_2S in water. The amount of hydrogen sulfide differs considerably within Seminole County.

HYDROGEN-ION CONCENTRATION

The hydrogen-ion concentration of a water is a measure of the degree of acidity or alkalinity. This concentration is reported as pH. A pH of 7.0 represents neutrality, which means that the water is neither acid nor alkaline. A pH higher than 7.0 indicates increasing alkalinity and a pH lower than 7.0 indicates increasing acidity.

Most ground waters from the Floridan aquifer are slightly alkaline and the pH usually ranges from 7.0 to 8.0. In Seminole County, the pH of 163 artesian water samples ranged from 7.2 to 8.5 (table 4). The pH of water from shallow wells driven in the Pleistocene sands are usually in the acidic range from about 5.0 to 7.0. Water with a pH of less than 7.0 is likely to be more corrosive than water with a pH higher than 7.0.

CHEMICAL CHARACTER OF GROUND WATER

Figure 33 shows bar graphs of the 3 principal cations and 3 principal anions, in equivalents per million (epm) in water from 20 artesian wells and 3 springs in Seminole County. The water of low dissolved-solids content is of calcium bicarbonate type; as the dissolved-solids content increases, the water becomes of sodium chloride type. The sum of the cations and anions in artesian well water ranged from 2.29 to 46.50 epm. This upper range is not the maximum limit because the most highly mineralized water was not sampled. The analyses of water from two springs that obtain their water from Pleistocene sand showed that they contained 0.45 and 0.66 epm, which is a very small amount of dissolved minerals. The water from the only artesian spring sampled contained 2.36 epm and is of calcium bicarbonate type.

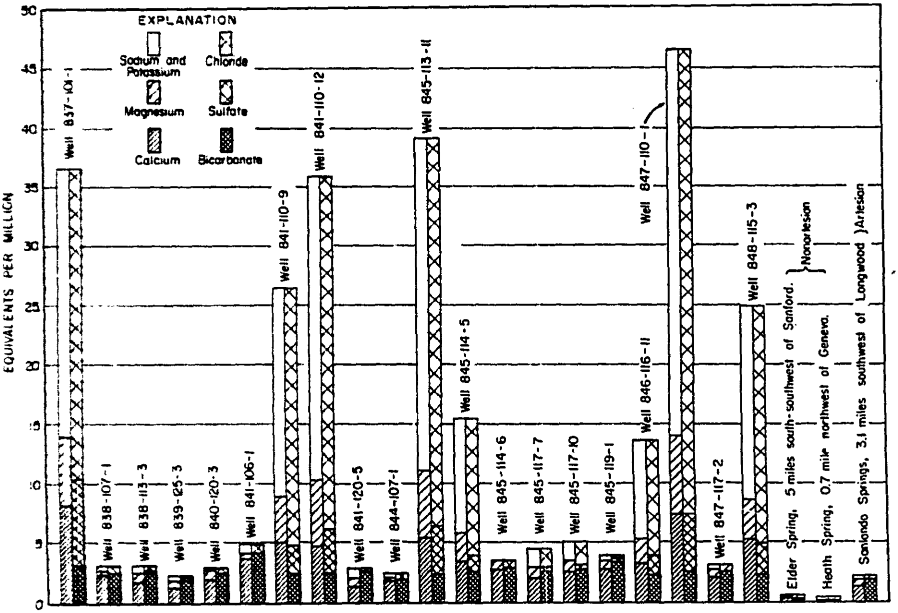


Figure 33. Bar graphs of the chemical analyses of water from 20 artesian wells and 3 springs.

The increase in chemical constituents with increased distance from the recharge area is shown in figure 34, and shows that the chloride content increases most. The concentration of chloride increased almost 30 times from well 845-114-6, near the recharge area, to well 845-114-5, and more than 80 times from well 845-114-6 to well 845-113-11. The sum of the sodium and potassium ions increased from 0.5 to 28 epm. Calcium is the principal cation in well 845-114-6, near the recharge area, and there is not enough magnesium to plot; the magnesium content in well 845-114-5 is more than one-half the calcium content; and the magnesium exceeds calcium in well 845-113-11. Most of the calcium is probably dissolved from the limestone formations and most of the magnesium probably comes from sea water that has not yet been flushed from the aquifer. (See the following section.) The sulfate content increased only slightly as compared to the above constituents. Bicarbonate is the only principal ion that decreased away from the recharge area.

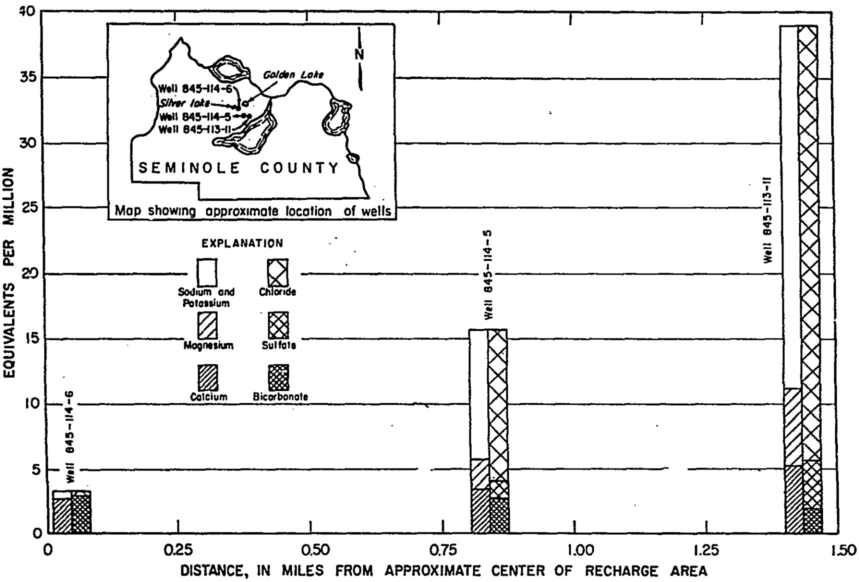


Figure 84. The relationship of the chemical constituents in ground water to the distance of the wells from a recharge area centered near Golden and Silver lakes.

SALT-WATER CONTAMINATION

Salty water is present in the Floridan aquifer in many parts of Florida. Although salty water could result from several causes, in Seminole County it appears to be the result of the infiltration of sea water into the aquifer during the Pleistocene time, when the sea stood higher than at present. Since the last decline of sea level, fresh water entering the aquifer has been slowly diluting and flushing out the salty water. Water samples collected from wells of different depths in the northern and central parts of the county show that flushing has progressed further in the upper part of the artesian aquifer than in the lower part. One of the most serious water problems facing the county is the danger that withdrawals from the upper part of the aquifer will cause water from the lower zones to move upward and contaminate the water in the upper part of the aquifer.

The last extensive stand of the sea over Florida was the Pamlico sea, which occurred during the mid-Wisconsin Glacial Stage of the

Pleistocene Epoch. This sea stood approximately 25 feet above present sea level and inundated about half of Seminole County (fig. 35).

Figure 35 is a map of Seminole County showing the relationship of the Pamlico shoreline (at 30 feet above sea level) and the 250 ppm isochlor. (An isochlor is defined as a line on a map connecting points at which the chloride content of ground water is equal.) This figure shows a definite relationship between the 250 ppm concentration of chloride in the artesian water and an altitude of 30 feet above sea level. Almost all the wells that yield water having a high chloride content are in areas where the land surface is less than 30 feet above sea level.

Analyses of samples from more than 700 wells show that the chloride content from the upper part of the Floridan aquifer ranges from 4 to 7,950 ppm. Several samples of water having a chloride content of 4.0 ppm were collected from wells near Paola, southwest of Lake Jessup, and in the area southeast of Lake Mary. The water having the highest chloride content was collected from a well at Mullet Lake Park, near the St. Johns River. The general results of these analyses are shown in figure 36. As may be seen from the figure, water from the Floridan aquifer beneath most of the hilly upland has a chloride content of less than 25 ppm. The relatively low chloride content of the artesian water in the hilly upland is probably due to the fact that this is a recharge area for the Floridan aquifer. Another reason for the low chloride content of the artesian water in this area may be that the last inundations from the ocean covered only the land at a lower altitude.

The low chloride content of artesian water in local recharge areas was first noted by Stringfield (1936, pl. 16) in his investigation of the artesian water in the Florida Peninsula. After making subsequent investigations in Seminole County and mapping the chloride content of the artesian water in the county (V. T. Stringfield, unpublished map in files of U. S. Geological Survey), he concluded that the low chloride content in the Geneva area was a result of flushing by local recharge (R. C. Heath, oral communication).

The areas in which the artesian water contains more than 25 ppm chloride include the northeastern half of the county (except for the hilly upland around Geneva) and a narrow belt along the valleys of the Wekiva and Little Wekiva rivers (fig. 36).

Water that has a chloride content ranging from 26 to 250 ppm is suitable for drinking, irrigation, and most industrial uses. A chloride content of more than 250 ppm exceeds the amount generally recommended for a municipal water supply. Areas in which the chloride content of ground water exceeds this limit include: a thin band from the Wekiva

River eastward to the St. John's River, the area adjacent to Lake Monroe on both sides of Sanford and extending around the north side of Lake Jessup, a small area 2 miles south of Sanford, a thin band circling Geneva and extending along part of the Econlockhatchee River, and an area northeast of Oviedo (fig. 36).

Ground water that has a chloride content ranging from 1,000 to 5,000 ppm is unsuitable for drinking, many industrial uses, and for the irrigation of most crops (Westgate, 1950, p. 116-123). Areas in which such ground water occurs include land adjacent to the Wekiva and St. Johns rivers in the northwest corner of the county, a very small area 2 miles northwest of Sanford, most of the land adjacent to the northwestern part of Lake Jessup, a semicircular area north of Geneva, and an area southeast of Geneva (fig. 36).

Water containing more than 5,000 ppm of chloride is almost unusable for any purpose. Such ground water is obtained from a small area extending from Mullet Lake northeast along the St. Johns River, and an area south of Lake Harney (fig. 36).

Chemical analyses of water samples collected periodically, coincident with measurements of artesian pressure, indicate that the chloride content of the artesian water may vary with changes in artesian pressure. Figure 37 illustrates changes in the chloride content and the water level of three wells south of Sanford. This figure includes data collected by Stringfield, 1936, Stubbs, 1937, and Irving Feinberg in 1939 (personal communication) as well as data collected during the present investigation. The graphs for well 845-113-1, 4.8 miles southeast of Sanford, illustrate the effect of water-level changes in the chloride content of the water from 1953 through 1956. The chloride content was lowest when the water level was highest during the latter part of 1953. After this date the water level declined as a result of decreased rainfall and the chloride content increased. The chloride content increased approximately 250 ppm during the period of record. In order to show what effect the period of flow prior to collecting the water sample had on the chloride content of the water, symbols were used in figure 37 to show different periods of flow. The period of flow apparently had little effect on the chloride content of the water from well 845-113-1.

The graphs for well 844-116-1, 5.3 miles south of Sanford, indicate no relation of the chloride content of the water to changes in the water level. The graphs show a decrease of about 100 ppm of the chloride content during the 20-year period of record, with decline of water level of approximately 1 foot during normal rainfall years.

The graphs for well 844-114-1, 4.4 miles south-southeast of Sanford,

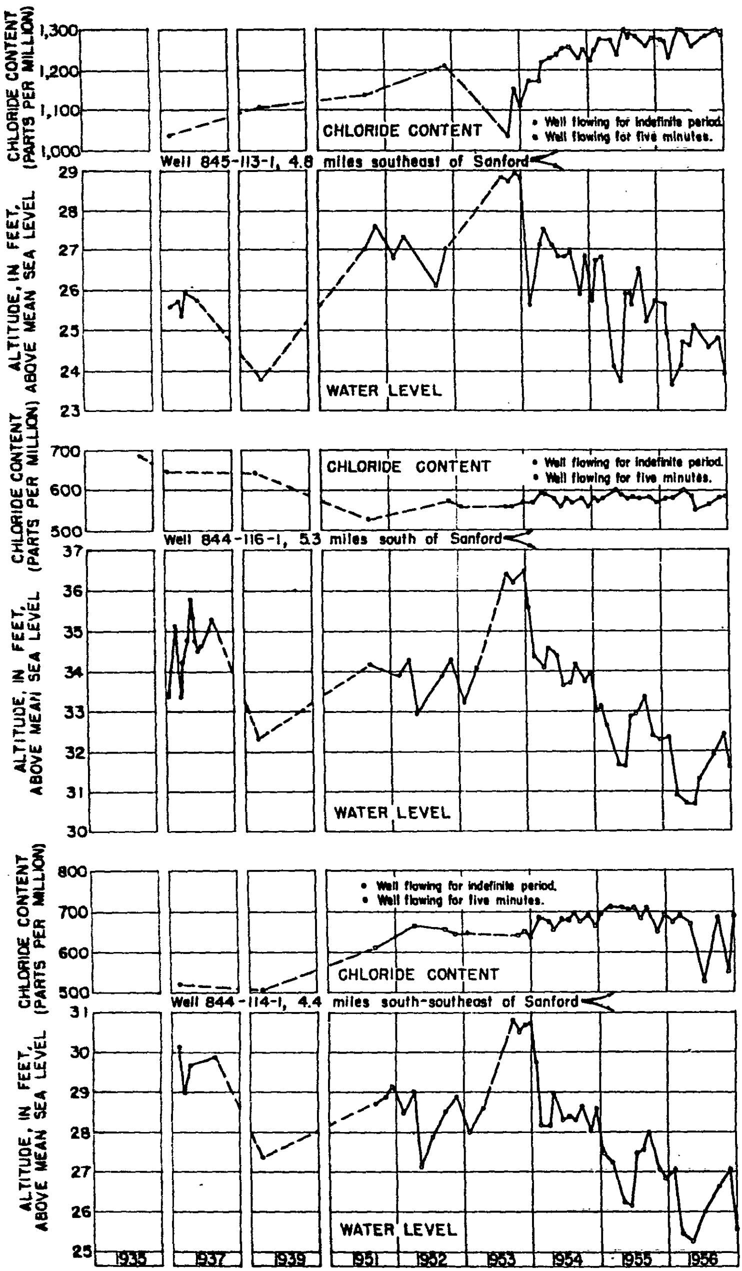


Figure 37. Hydrographs and chloride content of water from wells 844-114-1, 844-116-1, and 845-113-1.

show some correlation of the chloride content of the water to changes in the water level. The chloride content increased about 150 ppm from 1937 to 1954 with a corresponding decline in the water level of about 1 to 1½ feet. An indefinite period of flow prior to sampling seems to give a slightly higher chloride content than a 5-minute period of flow.

Graphs of water level and chloride content of the water in three wells west of Sanford are shown in figure 38. Well 849-119-3, 0.4 mile west of Lake Monroe, shows that the chloride content varied considerably during the period of record. This change in the chloride content bears some relation to the change in the water level, but the most important factor seems to be the period of flow prior to sampling. Since 1951 the chloride content had been less than 79 ppm when the well was sampled after flowing only 5 minutes. When the well was sampled after flowing longer than 5 minutes, the chloride content of the water ranged from 65 to 290 ppm. This amount of fluctuation would tend to mask any progressive trend in the chloride content. During the dry period of May 1939, the chloride content of the water was almost 250 ppm. The change in water level from 1937 and 1939 to 1956 seems to indicate a decline of about 1 foot during the period of record.

The graph for well 848-117-8, 1.9 miles west of Sanford, shows close correlation of the chloride content of the water to changes in the water level. The chloride increased about 150 ppm from 1937 to 1954 with a corresponding decline in the water level of about 1½ feet. In addition, many of the high water levels during the years 1952-56 correspond to low chlorides.

The graph for well 848-116-2, 0.4 mile west of Sanford, shows very little correlation of changes in the water level with changes in the chloride content. The vertical permeability must be relatively low near this well. The water level declined 6 feet from 1953 to 1956 and the chloride content did not change any significant amount.

Figure 39 shows the graphs of the chloride content and water level for two wells about 2.5 miles northeast of Oviedo. Although the wells are only 600 feet apart, they show considerable differences in both the water level and the chloride content. Well 841-110-12 is 213 feet deep and is cased to 58 feet. Well 841-110-9 is 156 feet deep and is cased to 53 feet. In January 1953 the level in the deeper well was about 8 feet above that in the other well. The chloride content in the deeper well was about 370 ppm higher than in the other well. In December 1956, the water level in the deeper well was only about 2 feet above the water level in the other well, and the chloride content was only 185 ppm higher than that of the other well. The fact that both the water

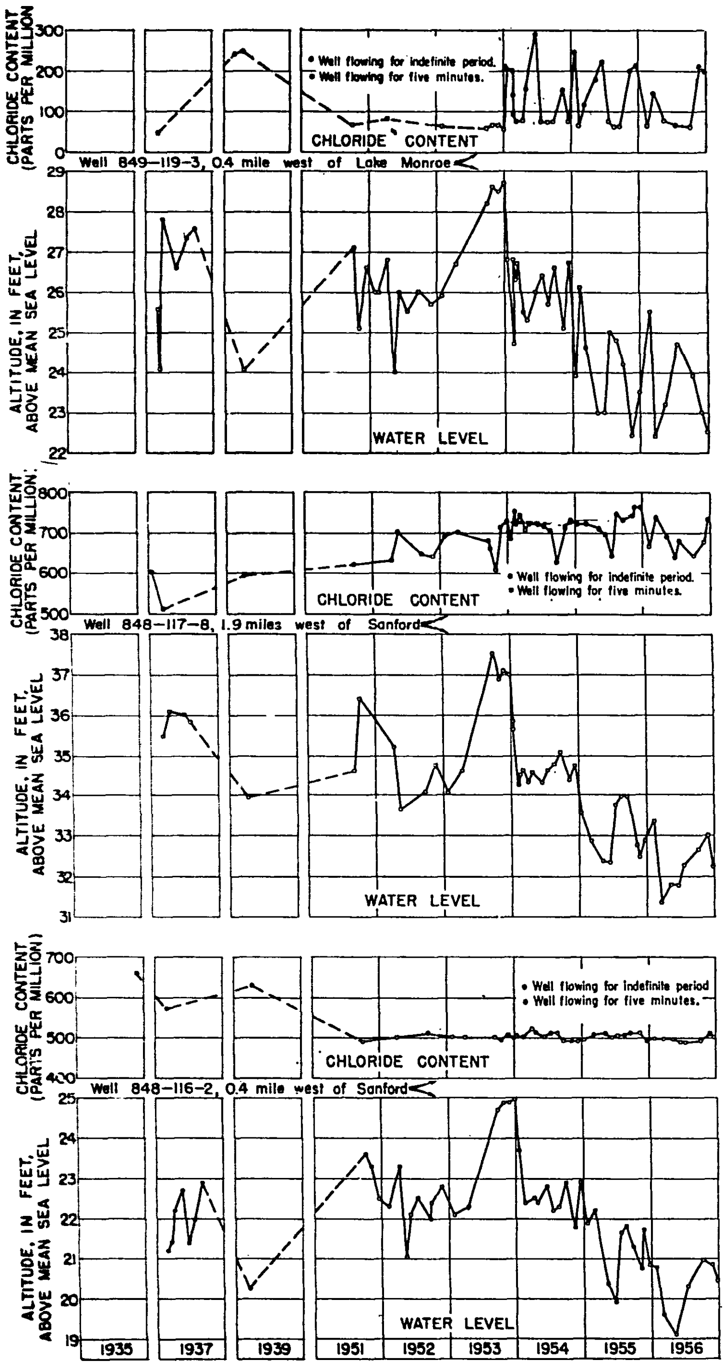


Figure 38. Hydrographs and chloride content of water from wells 848-116-2, 848-117-8, and 849-119-3.

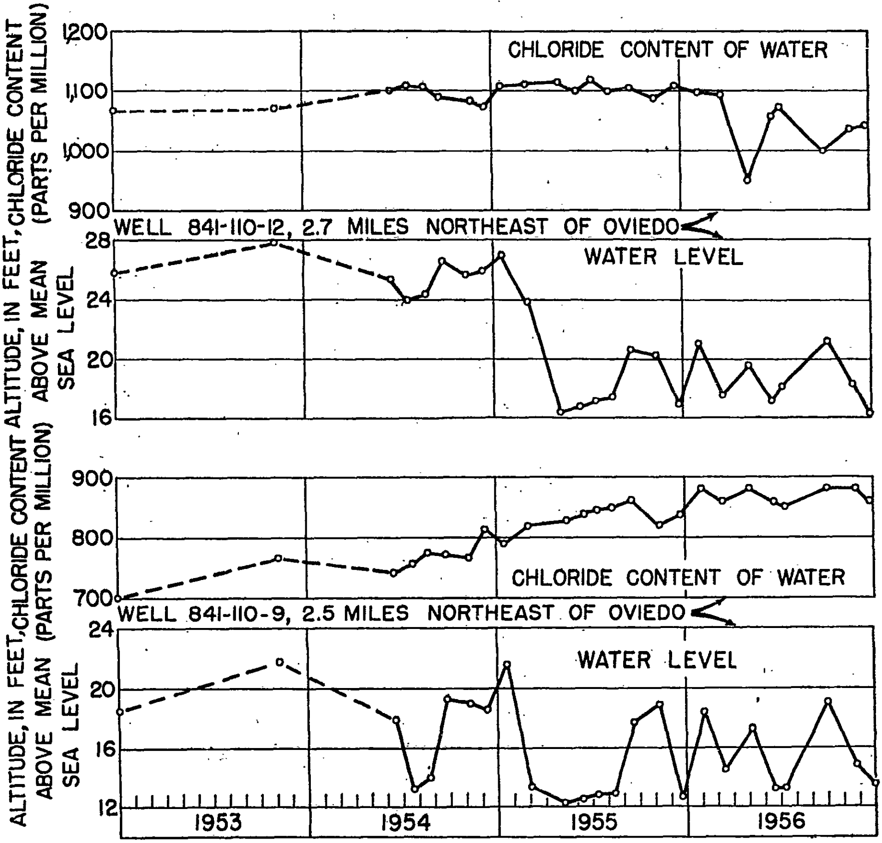


Figure 39. Hydrographs and chloride content of water from wells 841-110-9 and 841-110-12.

level and the chloride content of water from these two wells are approaching each other indicates the upper and lower water may be mixing. The usually effective confining bed may be penetrated by the bore hole of the deeper well. The water level in well 841-110-12 fluctuated through a range of 12 feet—the largest fluctuation measured in Seminole County during the investigation.

Graphs shown in figure 40 illustrate the chloride content of the water and the water level for two more wells in Seminole County. Well 846-112-5 is 4.2 miles southeast of Sanford and well 842-112-1 is 2.3 miles north of Oviedo. In general, figure 40 shows the significant changes that are seen on most graphs for wells in the two areas. Near Sanford, the water levels have remained about the same or declined slightly since 1939. The decline in water levels is probably due to an increase in

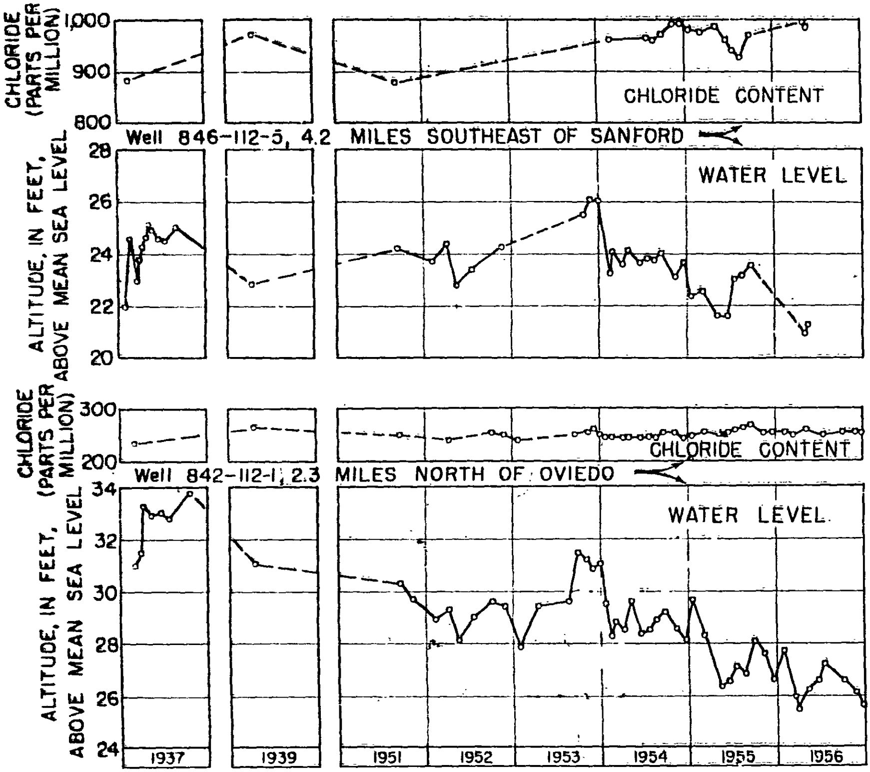


Figure 40. Hydrographs and chloride content of water from wells 842-112-1 and 846-112-5.

pumping in the area. The chloride content of the water shows more fluctuation in the Sanford area than around Oviedo. This can probably be attributed to an effective confining layer of dense limestone in the Oviedo area that retards the upward movement of salty water from below.

The hydrographs for wells around Oviedo indicate a decline in the water level of about 2 to 8 feet since 1939. This decline can be attributed to the increased use of water in the area near Oviedo.

Figure 41 presents data from four wells in the county. These data include information on the water level, chloride content of the water, temperature of the water, and yield of the well. In general, the graphs for these four wells show a very close relationship of the changes in water level and changes in yield of the well (subject to slight errors of measurement), but little change in temperature of the water, and little correlation of changes in the water level with changes in the

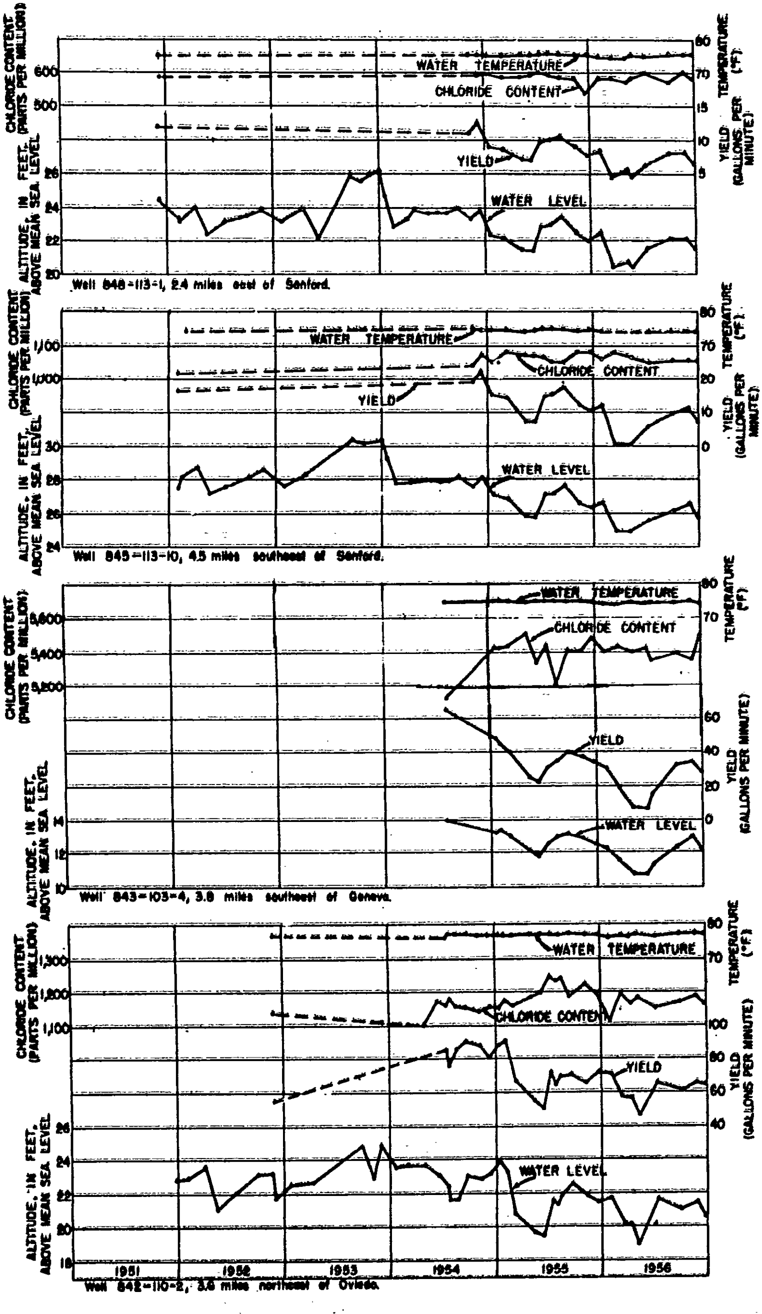


Figure 41. Data from wells 842-110-2, 843-103-4, 845-113-10, and 848-113-1.

chloride content of the water. The temperature of water from these flowing wells is almost constant during the year.

The data for the graphs plotted in figure 42 were collected in 1933 by V. T. Stringfield, in 1937 by S. A. Stubbs, and in 1939 by Irving Feinberg, and during the present investigation. The data are again used to compare measurements made in the past to those made more recently in order to observe any trends. The graphs for these three wells show information similar to the data given in figure 41.

The graphs for well 849-117-1, 1.7 miles northwest of Sanford, show little correlation between the changes in chloride content to changes in the water level. The chloride content increases about 100 ppm after the water flows for a long period which suggests that salty water may be moving up from deeper formations. An inspection of the water-temperature graph indicates an annual fluctuation of about 3°F. However, the variation reflects soil temperature because the well outlet is offset and the water travels through a horizontal pipe located about 1 foot below the surface. The water level in well 841-111-1, 1.8 miles northeast of Oviedo, has fluctuated as much as 15 feet during 1937-56 and as much as 11 feet during December 1953 to February 1954. The chloride content has remained almost constant during 1937-56. The water level in well 841-110-1, 2.6 miles northeast of Oviedo, has declined about 3 feet during 1951-56 while the chloride content has increased slightly during the period.

QUANTITATIVE STUDIES

The principal hydraulic properties of an aquifer are its capacities to transmit and store water, for all aquifers serve as both reservoirs and conduits. The Floridan artesian aquifer acts primarily as a conduit, transmitting water from recharge areas toward discharge areas; however, some of the water is yielded by compression of the aquifer material and the water.

The coefficient of transmissibility is a measure of the ability of an aquifer to transmit water. It is the quantity of water, in gallons per day, that will flow through a vertical section of the aquifer 1 foot wide and extending the full saturated height of the aquifer, under a unit hydraulic gradient, at the prevailing temperature of the water. The coefficient of storage is a measure of the capacity of an aquifer to store water, and is defined as the volume of water released from or taken into storage per unit surface area of the aquifer per unit change in head normal to that surface.

The withdrawal of water from an aquifer creates a depression of the water level in the vicinity of the point of withdrawal. This depression

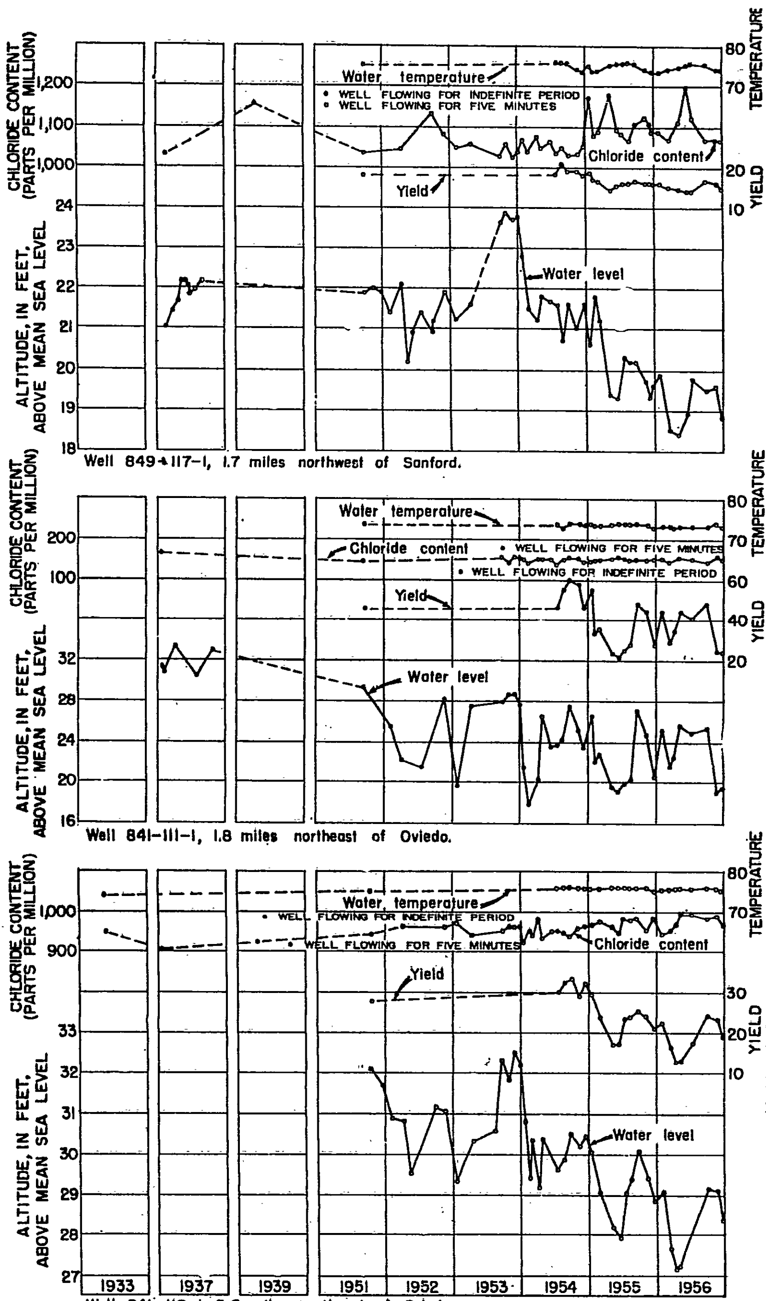


Figure 42. Data from wells 841-110-1, 841-111-1, and 849-117-1.

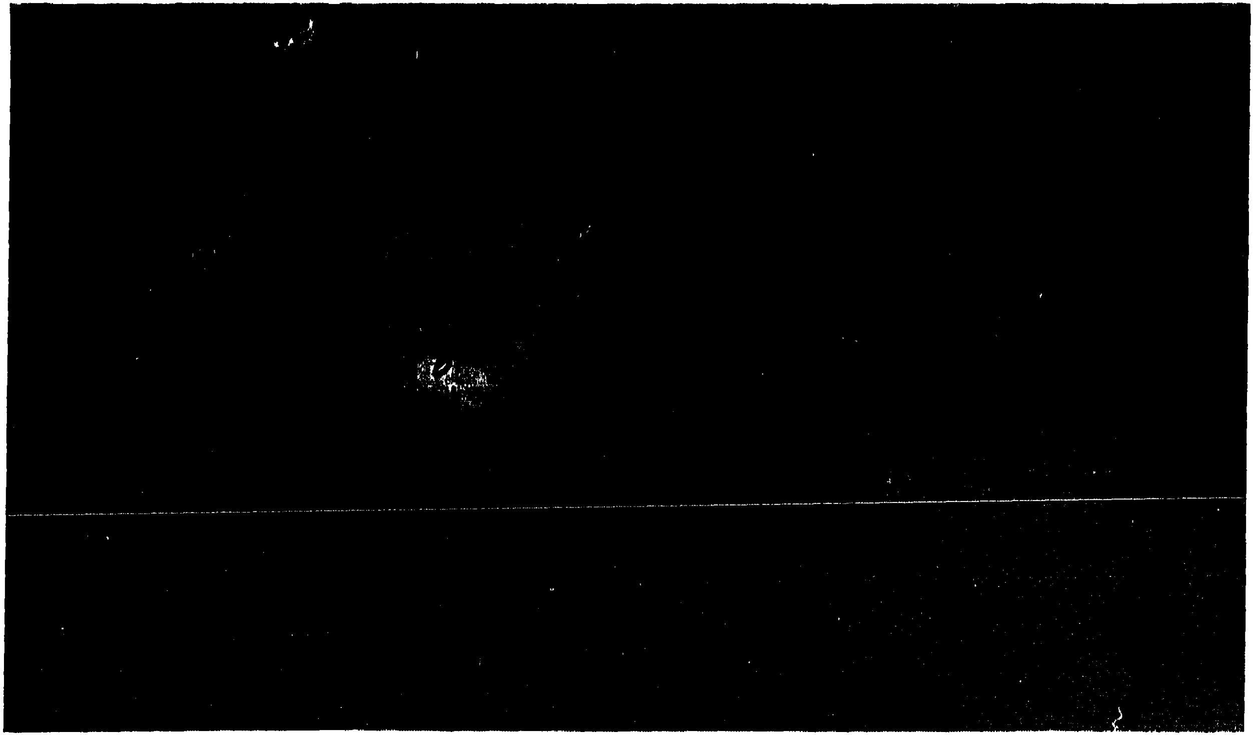


Figure 43. Flow-measuring apparatus (a, well valve with 4-inch discharge pipe; b, 4-inch dresser coupling; c, ¼-inch fitting to measure; d, quick-closing valve; e, 4-inch pipe, 4 feet long; f, ¼-inch piezometer tube; g, 4-inch by 2½-inch orifice; h, staff gage and tube to measure artesian pressure).

has the approximate form of an inverted cone and is referred to as the cone of depression. The distance the water level is lowered at any given point within this cone is known as the drawdown at that point. The size, shape, and rate of growth of the cone of depression depend on several factors, including (1) the rate of pumping, (2) the transmissibility and storage capacities of the aquifer, (3) the increase in recharge resulting from the lowering of the water level, and (4) the decrease in natural discharge due to the lowering of the water level.

A portable apparatus was constructed to measure the discharge of flowing wells and is shown in figure 43. This apparatus consisted of a 4-foot length of 4-inch diameter pipe, threaded at both ends, having a calibrated orifice fitting at one end of the pipe. The other end of the pipe was attached to a 3-inch valve by a 4-inch reducing coupling and a 3-inch nipple. "Dresser" couplings in 2-, 3-, and 4-inch sizes, together with appropriate pipe fittings, were used to connect the equipment to the discharge pipe of a flowing well.

In order to cover different ranges of flow two calibrated orifices were made from a 4-inch pipe coupling that was cut in half, and a plate of stainless steel was welded to each of the two pieces. A sharp-edge orifice opening was machined from the plates to exact diameters of 2½ and 3 inches. The 2½-inch orifice was used to measure flows ranging from 50 to 180 gpm and the 3-inch orifice was used to measure flows ranging from 100 to 300 gpm.

In order to open or close the flow rapidly a gate valve was machined and changed to a quick-closing valve operated by a lever. A ¼-inch hole was tapped in the center of the pipe, 2 feet from the orifice, and a piezometer tube consisting of a 5-foot length of clear plastic hose was connected to the hole. Another ¼-inch hole was tapped in the nipple used between the valve and dresser coupling, to measure the artesian pressure in the well when the valve was closed. A long piece of clear plastic hose was connected to this opening.

The results of eight recovery tests made by using this portable apparatus are shown on table 7. The table shows that the coefficients of transmissibility differ considerably throughout the county. The average of the coefficients of transmissibility determined from the 8 tests was 164,000 gpd per foot. If the transmissibility determined from the test at well 841-110-9 is not used, the average coefficient of transmissibility is 185,000 gpd per foot. Well 841-110-9 penetrates only a few feet of the aquifer, which accounts for the very low coefficient of transmissibility. A sample plot of the recovery data for well 841-113-3 is shown in

TABLE 7. Data From Recovery Tests of Artesian Wells in Seminole County

Well number	*Transmissibility (gpd per foot)*	*Yield of well (gpm)*	*Diameter of well (inches)*	*Time of test (minutes)*	*Specific capacity (gpm per foot)*	*T/Sp.C.*
838-114-8	253,000	96	4	60	22	12,000
841-110-9	9,100	40	4	60	8	1,100
841-113-3	98,000	26	2	90	3	33,000
842-110-7	223,000	50	3	90	8	29,000
843-118-4	315,000	68	3	120	13	24,000
845-113-1	82,000	68	3	75	8	11,000
847-112-7	193,000	44	2	20	4	47,000
849-118-5	134,000	71	4	40	12	11,000

figure 44. The formula used to determine the coefficient of transmissibility was the time-drawdown method of Cooper and Jacob (1946, p. 526-535), stated as $T = \frac{264\,Q}{\Delta S}$ where:

T=coefficient of transmissibility in gpd per foot
Q=yield in gpm
ΔS=difference in drawdown (or recovery) over one logarithmic cycle

A short aquifer test was made in August 1955 of well 845-113-15. The well was allowed to flow at 60 gpm for a period of 18 hours. Measurements of the artesian pressure were made periodically on well 845-113-16, 25 feet from the flowing well during the test.

The observed data for well 845-113-15 were analyzed by the Theis

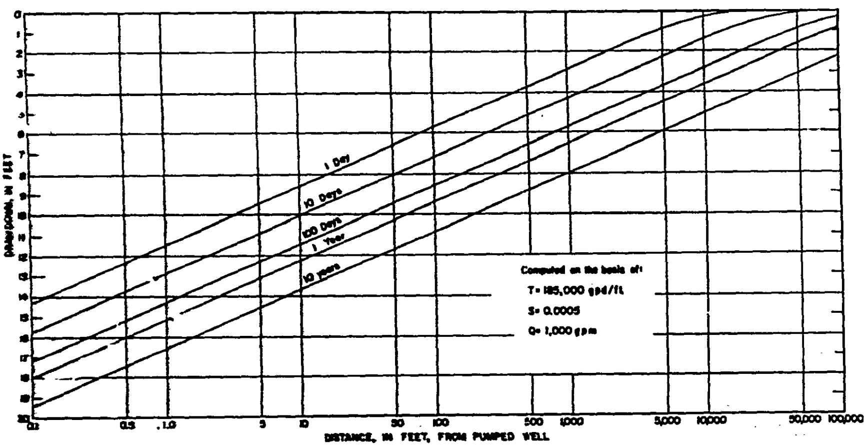


Figure 44. Semilog plot of recovery versus time in well 841-113-3.

graphical method, as described by Wenzel (1942, p. 87-89). This method involves the following formula, which relates the drawdowns in the vicinity of a discharging well to the rate and duration of discharge:

$$s = \frac{114.6Q}{T} \int_{u}^{\infty} \frac{e^{-u}}{u} du = \frac{114.6Q}{T} W(u)$$

where $u = \frac{1.87r^2S}{Tt}$

s = drawdown, in feet, at distance r and time t
r = distance, in feet, from pumped well
Q = pumping rate, in gpm
t = time since pumping began, in days
T = coefficient of transmissibility, in gpd per foot
S = coefficient of storage, a dimensionless ratio

The formula is based on certain assumptions, which include the assumptions that the aquifer is of uniform thickness, of infinite areal extent, and is homogeneous and isotropic (transmits water with equal ease in all directions). It is assumed also that there is no recharge to the formation or discharge other than that from the one well within the area of influence of the well, and that water may enter the well throughout the full thickness of the aquifer.

Inserting the values in the formulas $T = \frac{114.6\,Q}{s} W(u)$ and $S = \frac{uTt}{1.87r^2}$ gives a transmissibility of 51,000 gpd per foot and a storage coefficient of 0.000004. Data collected and analyzed from well 845-113-1 (table 7), located 150 feet away from well 845-113-15, show a value of 82,000 gpd per foot for the transmissibility. This value was calculated using the time-drawdown method. These values do not represent the transmissibility of the entire artesian aquifer as they are drilled only a relatively short distance into the artesian aquifer. Deeper wells would draw from a greater thickness of the aquifer and would, consequently, show higher values.

Values of coefficients of storage for artesian conditions in other areas range from about 10^{-4} to about 10^{-3}. The value of 4×10^{-6} obtained in this test is very small. However, Jacob and others (1940, p. 44) state that when the ratio of the lateral distance between the observation well and the pumped well to the depth of aquifer is small, the value of the computed storage coefficient is likewise small. Also, it is known that the values of storage coefficient obtained during short periods of pumping are comparatively small and that during prolonged pumping the computed storage coefficient increases in value. Both of the above conditions applied at the test site and a higher value of the storage coefficient for artesian conditions is believed to apply in Seminole County.

The selected average coefficient of transmissibility of the upper part of the Floridan aquifer in Seminole County is about 185,000 gpd per foot and an assumed value for the storage coefficient is about 0.0005 (a value halfway between 10^{-4} and 10^{-3} in the preceding paragraph). As the coefficients of transmissibility and storage may differ considerably from place to place, it is not practicable to predict drawdowns in one place on the basis of information collected in another place. However, in order to illustrate how water levels are affected in the vicinity of a pumped well, figure 45 was constructed. The figure shows theoretical

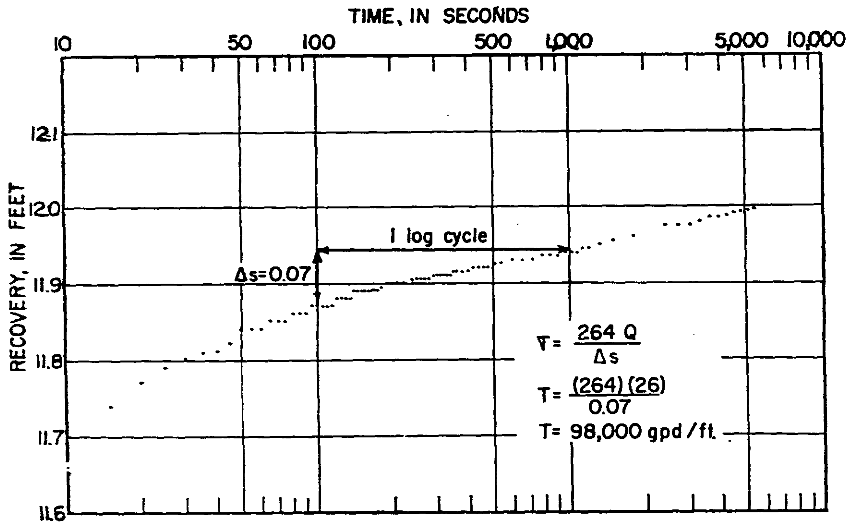


Figure 45. Theoretical drawdowns in the vicinity of a well being pumped at a rate of 1,000 gpm for selected periods of time.

drawdowns in the vicinity of a well pumping at a rate of 1,000 gpm from an aquifer having a coefficient of transmissibility of 185,000 gpd per foot and a storage coefficient of 0.0005.

As the drawdowns outside the pumped well vary directly with the discharge, drawdowns for greater or lesser rates of discharge can be computed from these curves. For example, under the assumed conditions the drawdown 100 feet from a well discharging at 1,000 gpm would be 8.6 feet after 100 days of discharge. If the well had discharged at 100 gpm for the same length of time, the drawdown at the same distance would have been only one-tenth as much, or 0.86 feet.

SUMMARY AND CONCLUSIONS

The principal source of ground water in Seminole County is the Floridan aquifer, which is a thick section of limestone that underlies the entire county. The upper surface of this aquifer ranges from 75 to about 150 feet below the land surface. The limestone is overlain by deposits of clay which differ in thickness from place to place. The clay is relatively impermeable and partially confines the water in the limestone. A deposit of sand, 10 to 75 feet thick, overlies the clay. Small supplies of water are obtained in almost all parts of the county from screened wells that penetrate only the deposits of sand.

Most of the ground water in Seminole county is probably derived from rain that falls on the recharge areas in Polk and Orange counties, although some is derived from rainfall in Seminole County. The areas of recharge in Seminole County are near the towns of Lake Mary, Geneva, Chuluota, Oviedo, Altamonte Springs, and Paola.

Natural discharge of ground water in Seminole County is through large artesian springs such as that at Sanlando, and through springs and seeps in the bottom of Lake Jessup, and the St. Johns and Wekiva rivers.

Records of the seasonal fluctuations of artesian pressure show that the piezometric surface is lowered as much as 12 feet in the Oviedo area during the periods of heaviest withdrawal. The maximum seasonal fluctuation in the Sanford area is about 7 feet, and the minimum seasonal fluctuation is about 5 feet.

Water-level measurements made in the 1930's, by Stringfield, Stubbs, and Feinberg were compared with measurements made during the present investigation—to determine long-term changes of water level. When similar rainfall periods are compared, the long-term trends of the water level usually reflect changes in pumpage other than variations in rainfall. In the area around Sanford, the average long-term decline of the water level in 14 wells was slightly greater than 1 foot. The trend of the water levels in these 14 wells ranged from a rise of about 1 foot in one well to a decline of about 4 feet in another.

The average long-term decline of the water level in five wells near Oviedo was about 3½ feet. The water level in one well did not show any decline but in another well it showed a decline of about 8 feet. The water level in a well at Wagner rose about 1 foot during the period of record, while in a well at Slavia it declined about 3 feet. The decline of water level in Seminole County was probably caused by an increase in the use of water in several areas. The seasonal fluctuations of water level are much greater than the long-term fluctuations.

Stubbs (1937, p. 33) stated that the minimum permanent loss of head within the flowing-well area ranged from 4 to 10 feet during the period 1912-37.

The chloride content of water from artesian wells in Seminole County ranges from 4.0 ppm near the recharge areas to more than 7,500 ppm near Mullet Lake. In most of the Sanford-Oviedo farming area, the chloride content ranges from about 10 ppm to slightly more than 1,500 ppm. The seasonal variation of the chloride content in the farming areas near Sanford was only 35 ppm in one well and as much as 265 ppm in another well. The seasonal change in the chloride content of water from wells near Oviedo is only 16 ppm in one well and as much as 180 ppm in another well. Analyses of water samples from wells of different depths show that the chloride content increases with depth in many areas.

Comparisons of chloride analyses made in the 1930's, by Stringfield, Stubbs, and Feinberg, with analyses made during the present investigation were used to determine the long-term trend of the chloride content. In the Sanford area, the average long-term increase in the chloride content of water from eight wells was about 30 ppm; the water from three of these wells showed an increase of about 150 ppm, the water from three other wells did not show any appreciable change, and the water from two wells indicated a decrease of about 100 ppm. The water from three wells near Oviedo did not show any appreciable change in chloride content during the period of record.

The data collected on chemical quality of water show that the ground water ranges from excellent in some parts of the county to unusable for most purposes in other parts of the county. The most highly mineralized water comes from the lowland areas of the county. The chloride content of the water generally serves as a good indication of the dissolved-solids content of the water.

Field determinations of the coefficient of transmissibility ranged from 9,100 to 315,000 gpd per foot; however, the lowest value was determined at a well that penetrates only a few feet of the aquifer. The average transmissibility coefficient determined from seven recovery tests was 185,000 gpd per foot. The transmissibility and storage coefficients determined by an aquifer test made of well 845-113-15 were 51,000 gpd per foot and 0.000004, respectively. However, the true value for the storage coefficient in the upper part of the Floridan aquifer in Seminole County is believed to be about 0.0005. The tests show that the coefficients differ considerably throughout the county.

REFERENCES

Applin, E. R. (see Applin, P. L.)

Applin, P. L.
1944 (and Applin, E. R.) Regional subsurface stratigraphy and structure of Florida and southern Georgia: Am. Assoc. Petroleum Geologists Bull., v. 28, no. 12, p. 1673-1753.
1951 Preliminary report on buried pre-Mesozoic rocks in Florida and adjacent states: U. S. Geol. Survey Circ. 91, 28 p.

Barraclough, J. T. (see Heath, R. C.)

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

Black, A. P.
1951 (and Brown, Eugene) Chemical character of Florida's waters—1951: Florida State Board Cons., Div. Water Survey and Research Paper 6.

Brown, Eugene (see Black, A. P.)

Clapp, F. G. (see Matson G. C.)

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

Cooke, C. W.
1926 Geology of Alabama; the Cenozoic formations: Alabama Geol. Survey Spec. Rept. 14, p. 251-297, 5 pts.
1945 Geology of Florida: Florida Geol. Survey Bull. 29.

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

Cooper, H. H., Jr. (see also Jacob, C. E.)
1946 (and Jacob, C. E.) A generalized graphical method for evaluating formation constants and summarizing well-field history: Am. Geophys. Union Trans., v. 27, no. 4.

Dall, W. H.
1887 Notes on the geology of Florida: Am. Jour. Sci., ser. 3, v. 34, p. 161-170.
1892 (and Harris, G. D.) The Neocene of North America: U. S. Geol. Survey Bull. 84, 349 p., 3 pls.

Ferguson, G. E. (see also Parker, G. G.)
1947 (and Lingham, C. W., Love, S. K., and Vernon, R. O.) Springs of Florida: Florida Geol. Survey Bull. 31.

Gunter, Herman (see Sellards, E. H.).

Harris, G. D. (see Dall, W. H.)

Hatchett, J. L. (see Krieger, R. A.)

Heath, R. C.
1954 (and Barraclough, J. T.) Interim report on the ground-water resources of Seminole County, Florida: Florida Geol. Survey Inf. Circ. 5.

Heilprin, Angelo
1887 Explorations on the west coast of Florida and in the Okeechobee wilderness: Wagner Free Inst. Sci. Trans., v. 1, 134 p.

Howard, C. S. (see Collins, W. D.)

Jacob, C. E. (see also Cooper, H. H., Jr.)
1940 (and Cooper, H. H., Jr.) Report on the ground-water resources of the Pensacola area, Escambia County, Florida, with a section on the geology by S. A. Stubbs: U. S. Geol. Survey open-file report.

Krieger, R. A.
1957 (and Hatchett, J. L., and Poole, J. L.) Preliminary survey of the saline-water resources of the United States: U. S. Geol. Survey Water-Supply Paper 1374, 172 p. 2 pls., 3 figs.

Leutze, W. P. (see Wyrick, G. G.)

Lingham, C. W. (see Ferguson, G. E.)

Love, S. K. (see Ferguson, G. E.; Parker, G. G.)

Matson, G. C.
1909 (and Clapp, F. G.) A preliminary report on the geology of Florida with special reference to the stratigraphy: Florida Geol. Survey 2d Ann. Rept., 1908-09, p. 25-173.
1913 (and Sanford, Samuel) Geology and ground waters of Florida: U. S. Geol. Survey Water-Supply Paper 319.

Mossom, Stuart (see Cooke, C. W.)

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

Poole, J. L. (see Krieger, R. A.)

Puri, Harbans, S.
1953 Zonation of the Ocala group in peninsular Florida (abstract): Jour. Sed. Petrology, v. 23, p. 130.

Rainwater, F. H.
1960 (and Thatcher, L. L.) Methods for collection and analysis of water samples: U. S. Geol. Survey Water-Supply Paper 1454.

Sanford, Samuel (see Matson, G. C.)

Scarborough, E. F. (see Scruggs, F. H.)

Scruggs, F. H.
1953 (and Scarborough, E. F.) Annual fruit and vegetable report; production, transportation, and marketing analysis: Florida State Marketing Bur., Jacksonville, Florida.

Sellards, E. H.
1913 (and Gunter, Herman) The artesian water supply of eastern and southern Florida: Florida Geol. Survey 5th Ann. Rept.

Stringfield, V. T.
1934 Ground water in Seminole County, Florida: Florida Geol. Survey Rept. Inv. 1.
1936 Artesian water in the Florida peninsula: U. S. Geol. Survey Water-Supply Paper 773-C.

Stubbs, S. A.
1937 A study of the artesian water supply of Seminole County, Florida: Florida Acad. Sci. Proc., v. 2.

Thatcher, L. L. (see Rainwater, F. H.)

Unklesbay, A. G.
1944 Ground-water conditions in Orlando and vicinity, Florida: Florida Geol. Survey Rept. Inv. 5.

Vernon, R. O. (see also Ferguson, G. E.)
1951 Geology of Citrus and Levy counties, Florida: Florida Geol. Survey Bull. 33.

Wenzell, L. K.
1942 Methods for determining permeability of water-bearing materials, with special reference to discharging well methods, with a section on direct laboratory methods and bibliography on permeability and laminar flow, by V. C. Fishel: U. S. Geol. Survey Water-Supply Paper 887.

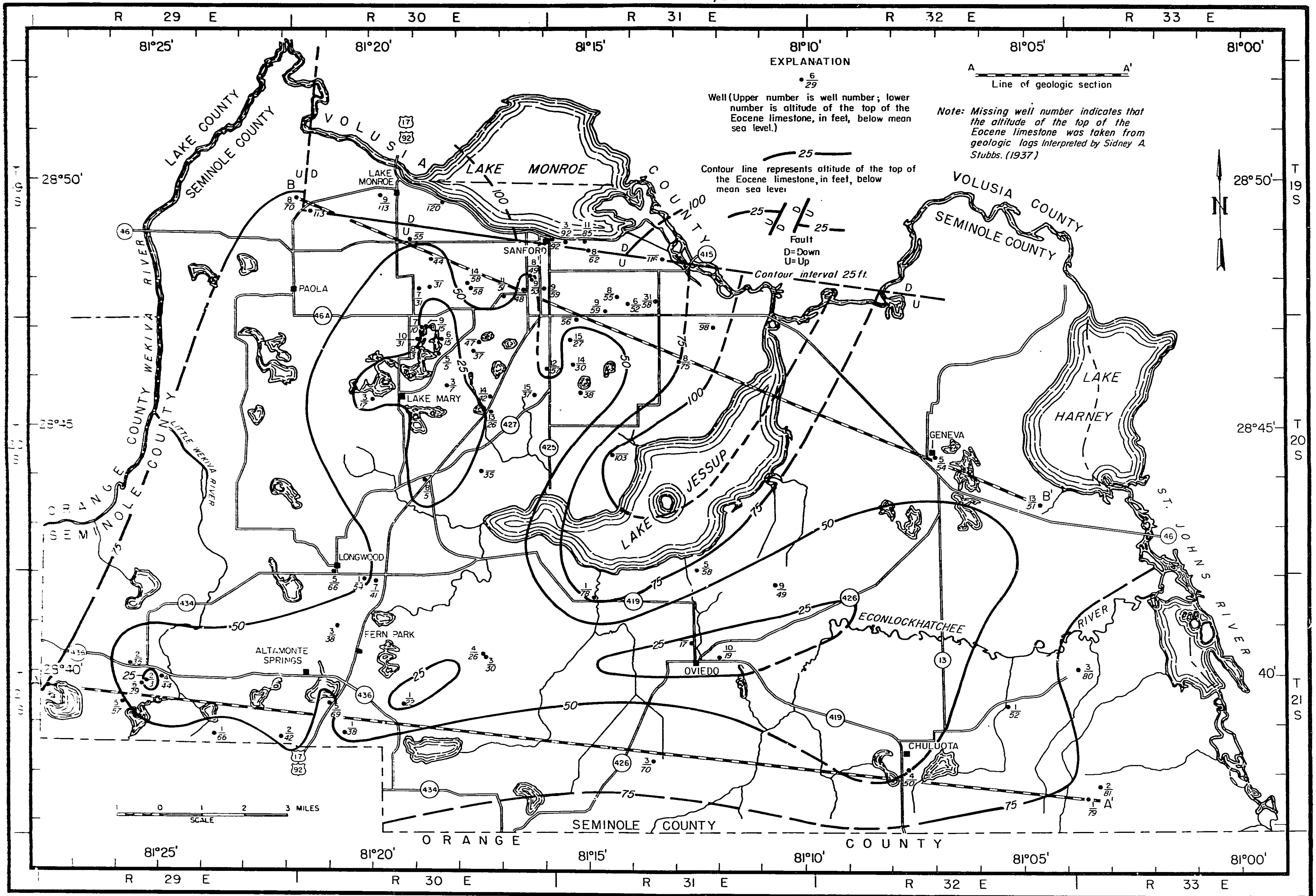
Westgate, P. J.
1950 Effects of soluble soil salts on vegetable production at Sanford: Florida State Hort. Soc. Proc., Oct.-Nov. 1950.

Wyrick, G. G.
1956 (and Leutze, W. P.) Interim report on ground-water resources of the northeastern part of Volusia County, Florida: Florida Geol. Survey Inf. Circ. 8.
1960 The ground-water resources of Volusia County, Florida: Florida Geol. Survey Rept. Inv. 22.

UNITED STATES DEPARTMENT OF INTERIOR
GEOLOGICAL SURVEY

FLORIDA GEOLOGICAL SURVEY
R. O. Vernon, Director

REPORT OF INVESTIGATIONS NO. 27



Base taken from maps of Florida State Road Department.

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Figure 4. Configuration and altitude of the top of the Eocene limestones.

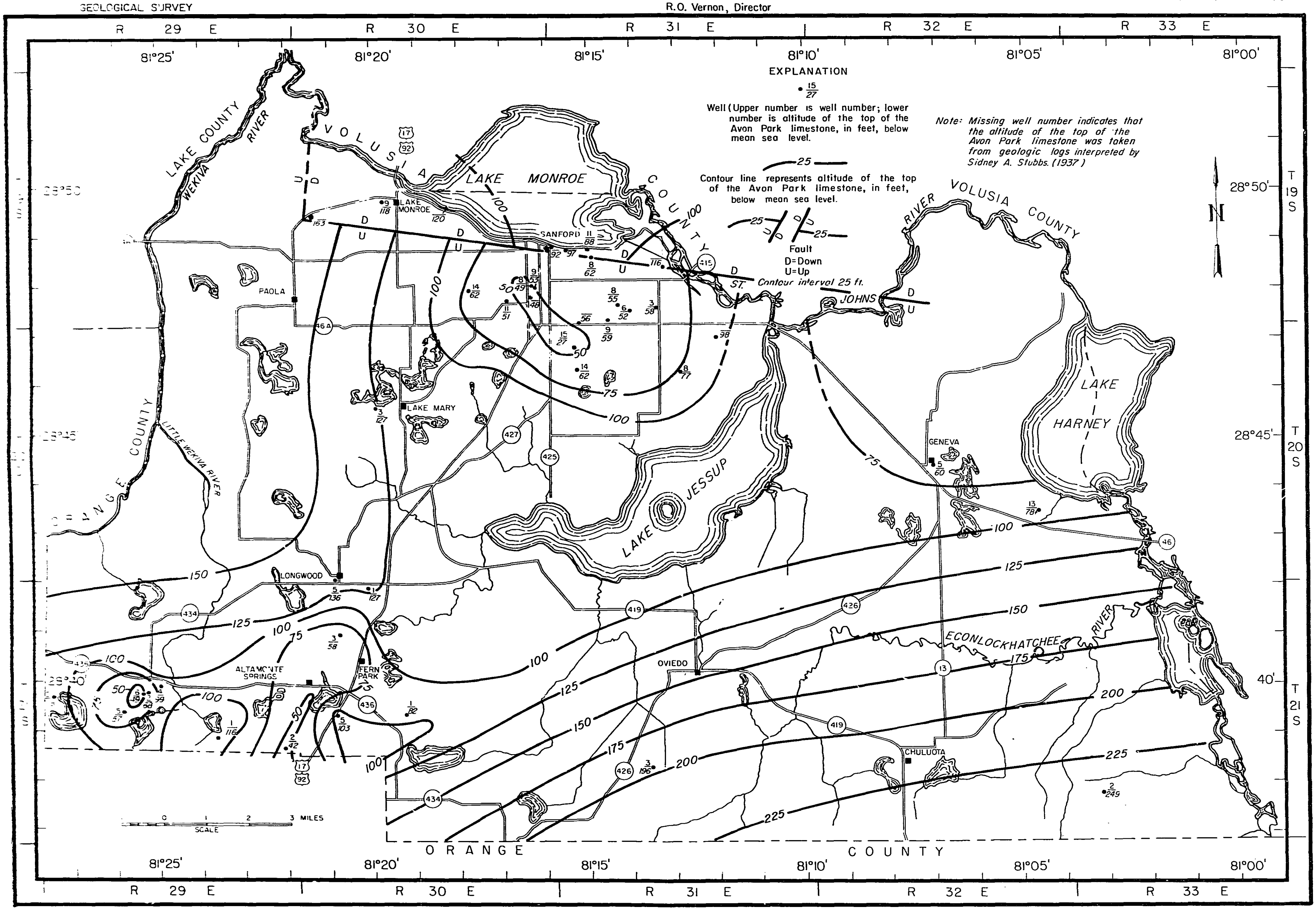

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Figure 5. Configuration and altitude of the top of the Avon Park Limestone.

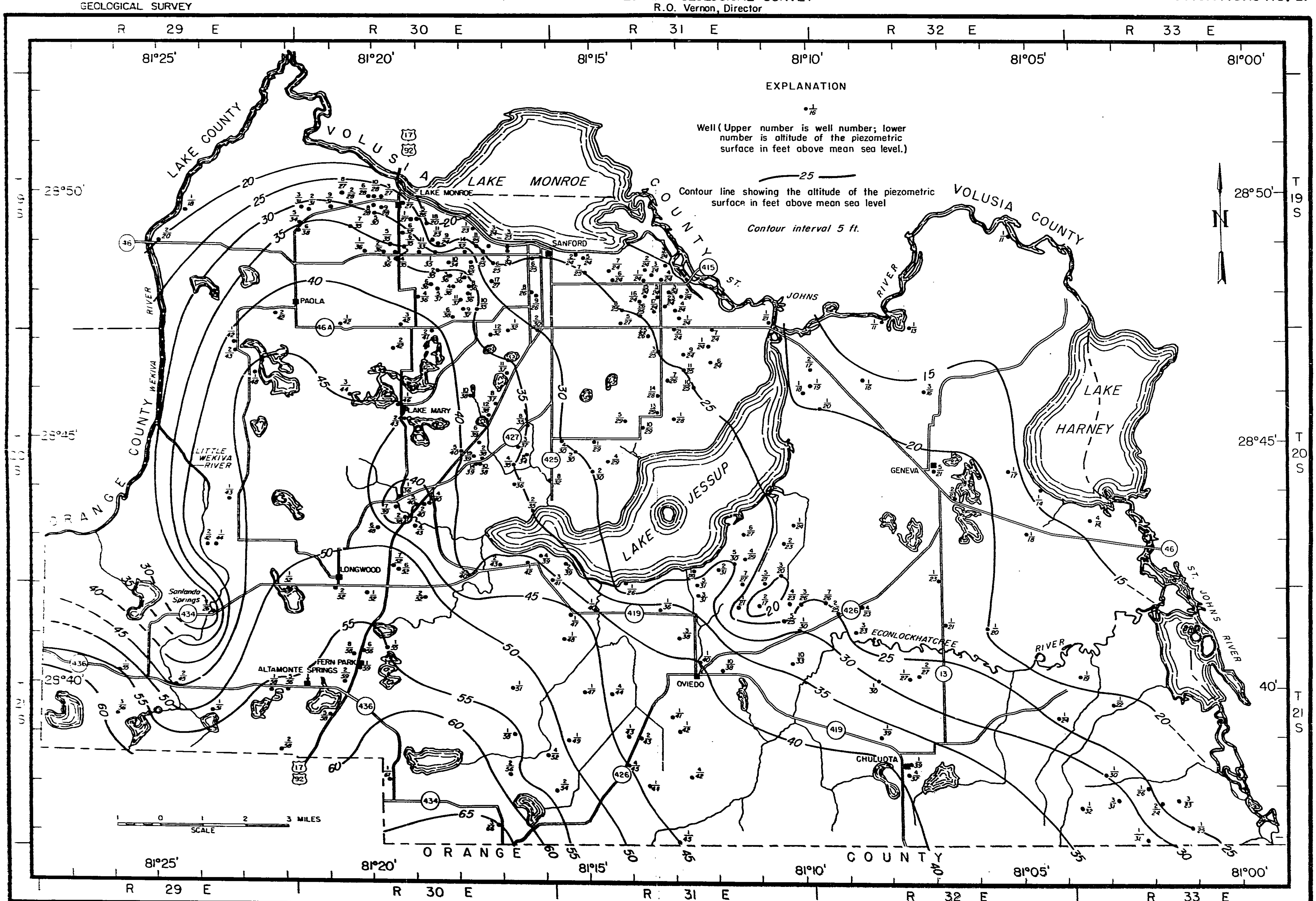

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Figure 7. The Piezometric surface of the Floridan aquifer in January 1954.

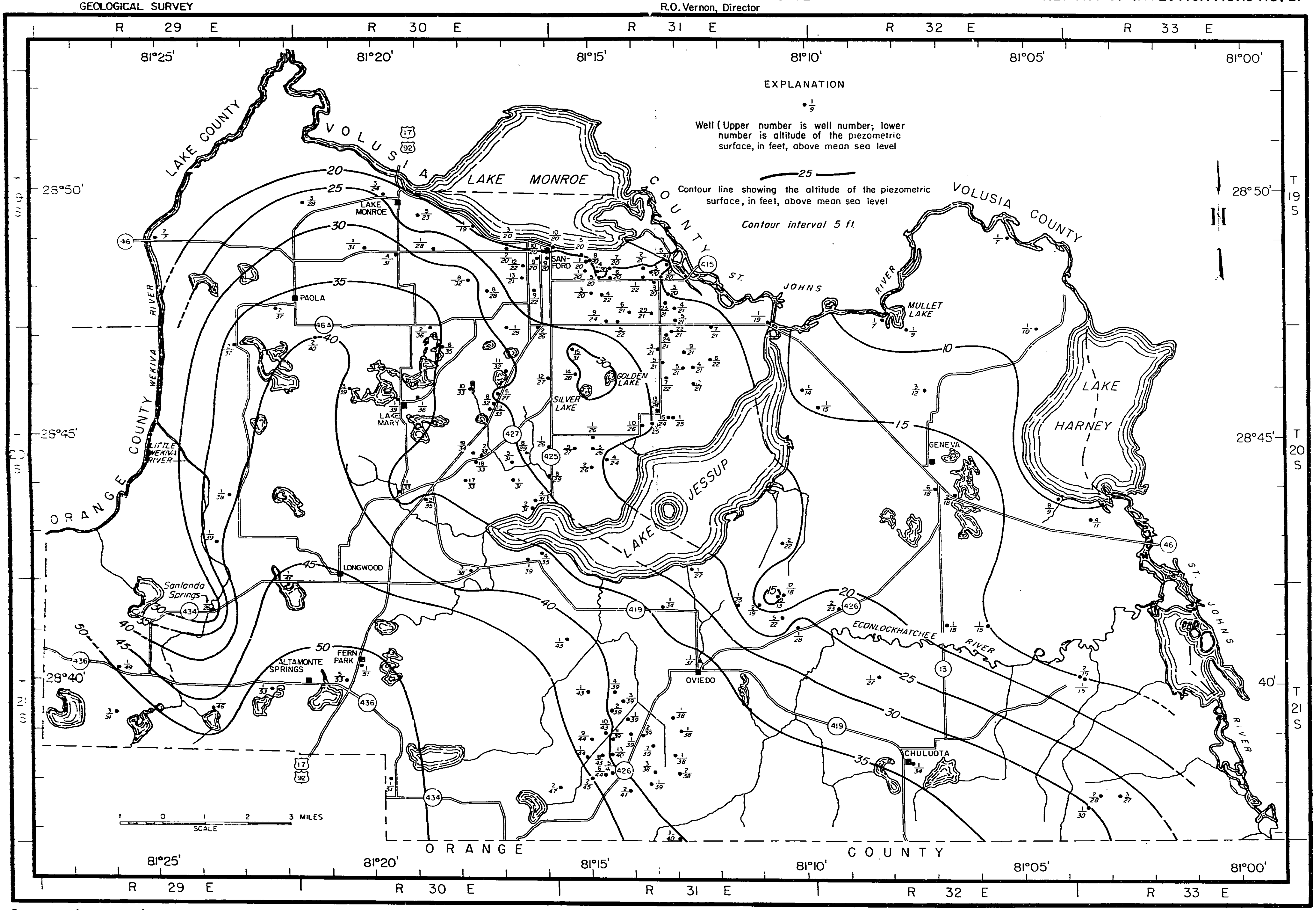

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Figure 8. The Piezometric surface of the Floridan aquifer in June 1956.

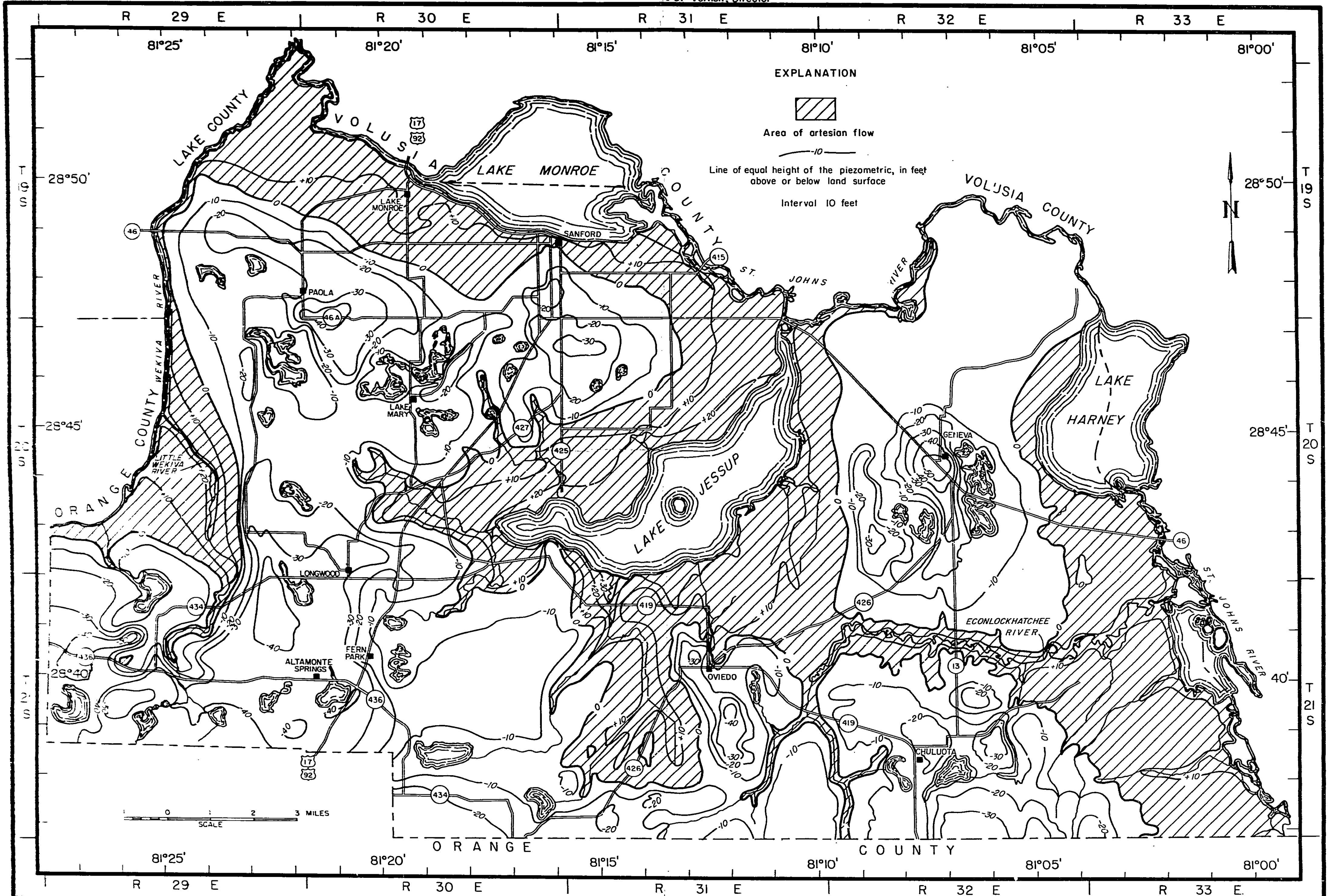

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Figure 9. Areas of artesian flow and the height of the piezometric surface, in feet, referred to land surface in 1954.

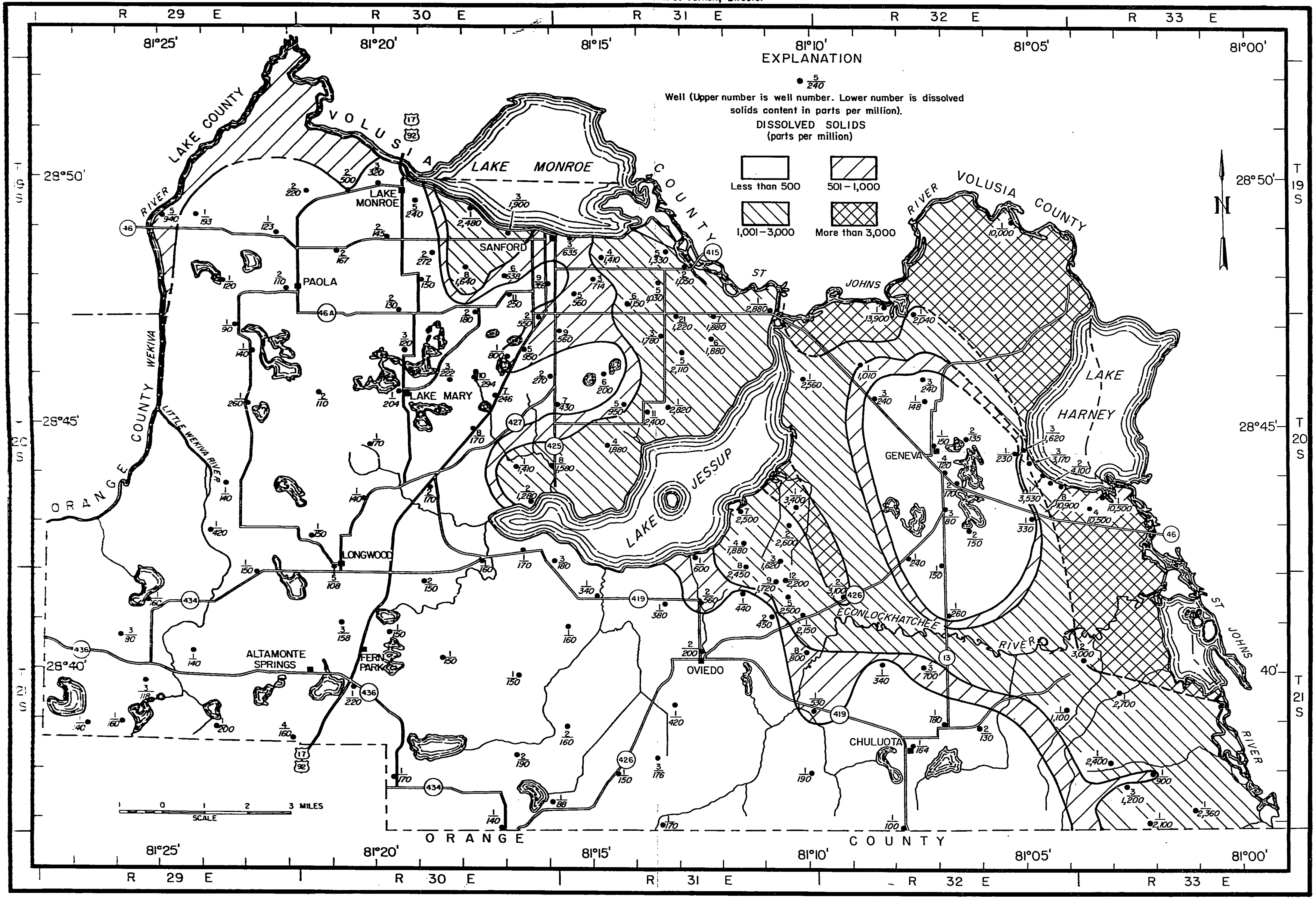

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Figure 31. The dissolved-solids content of water from the Floridan aquifer.

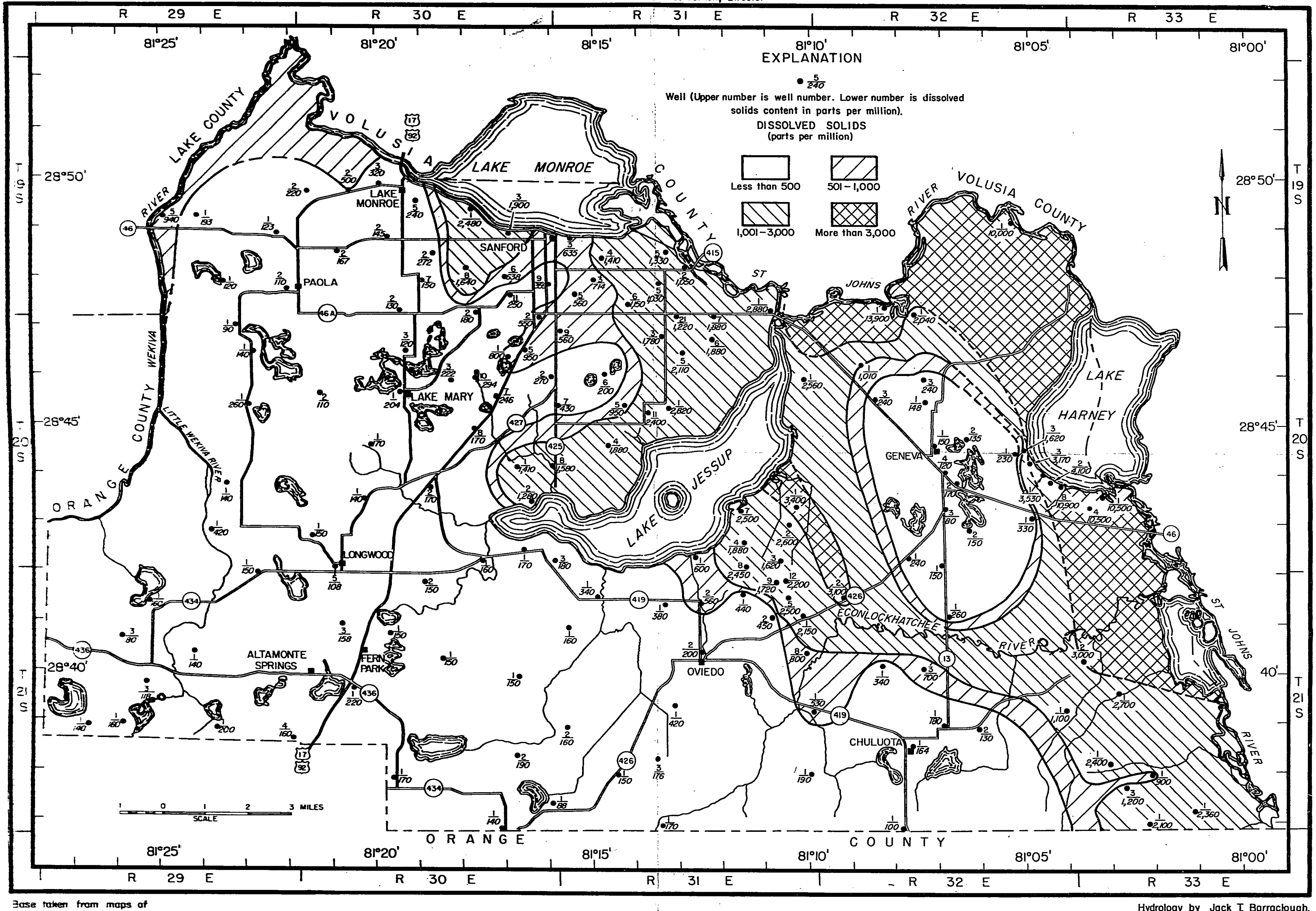
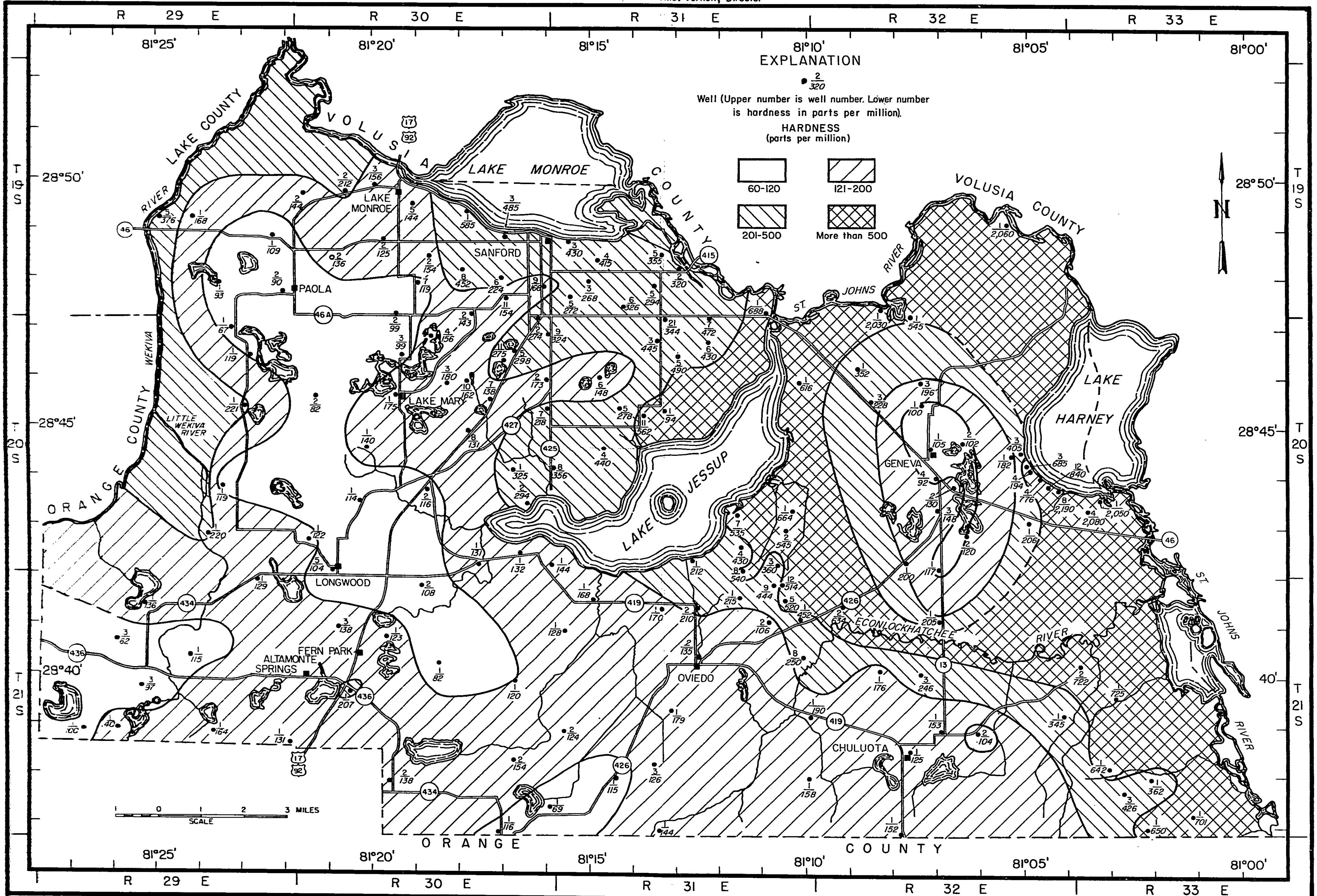


Figure 31. The dissolved-solids content of water from the Floridan aquifer.



Base taken from maps of Florida State Road Department

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Figure 32. Showing the hardness of water from the Floridan aquifer.

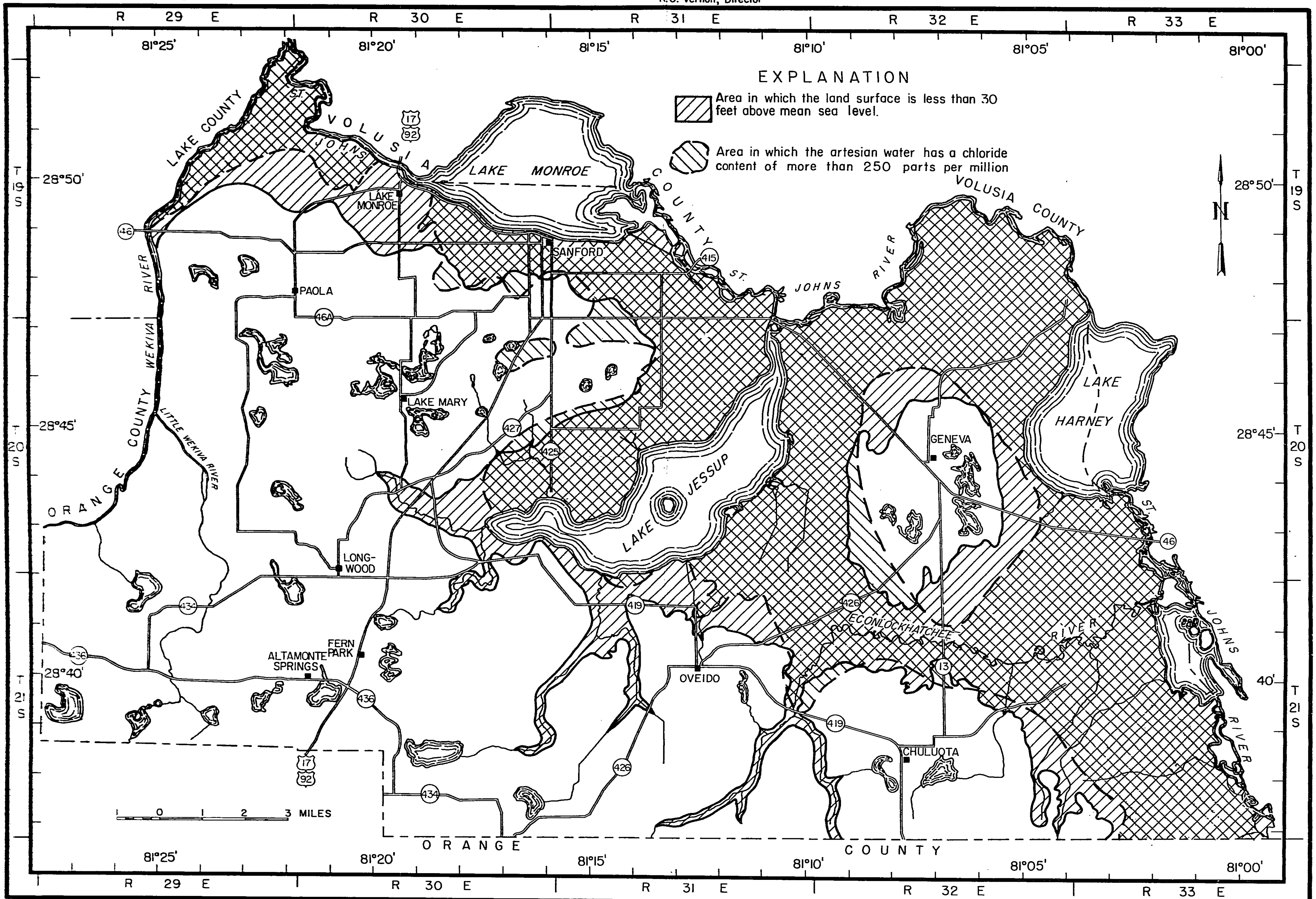

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Figure 35. The relationship of the chloride content of artesian water to the land-surface altitude.

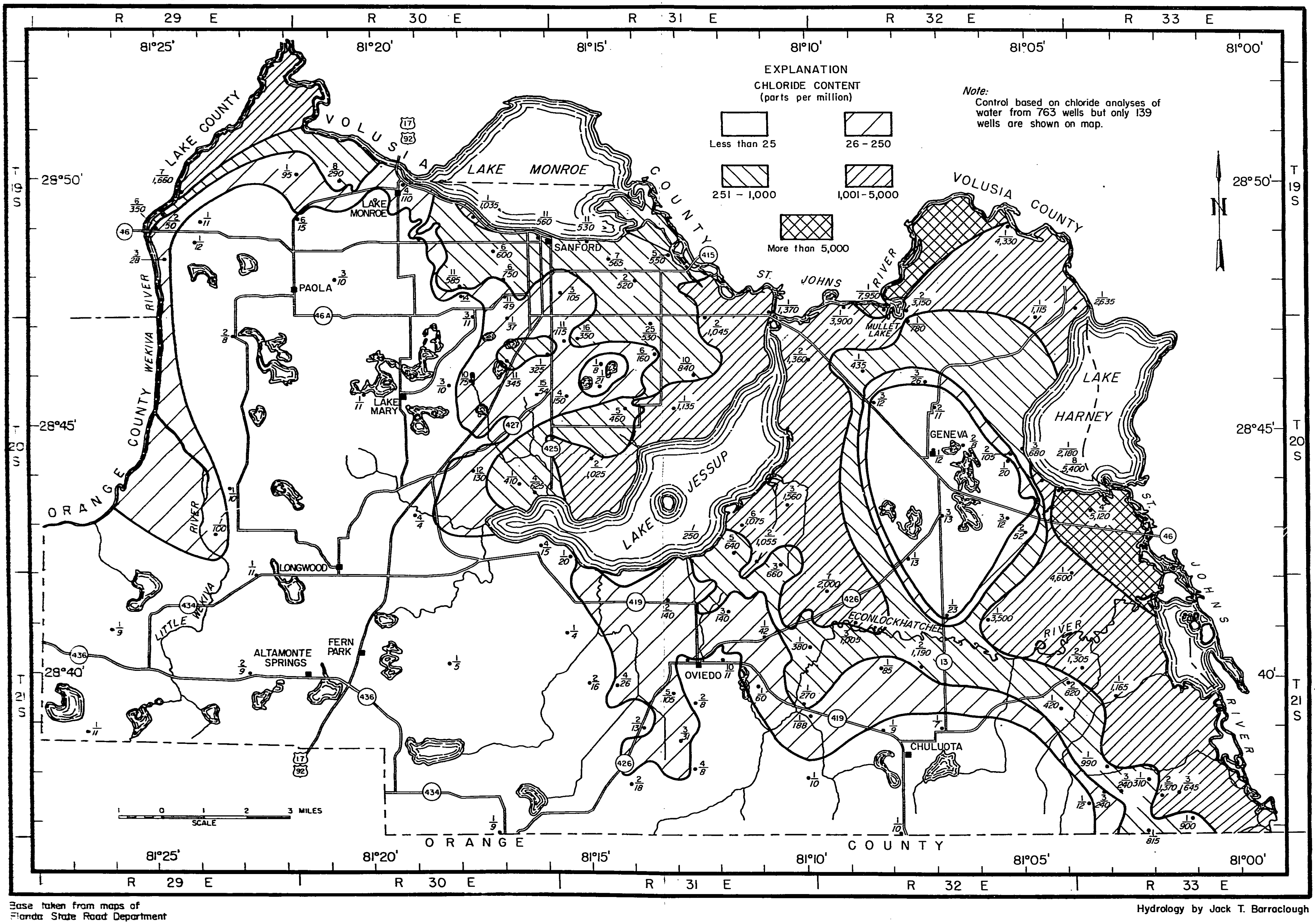

Figure 36. The chloride content of water from the upper part of the Floridan aquifer.

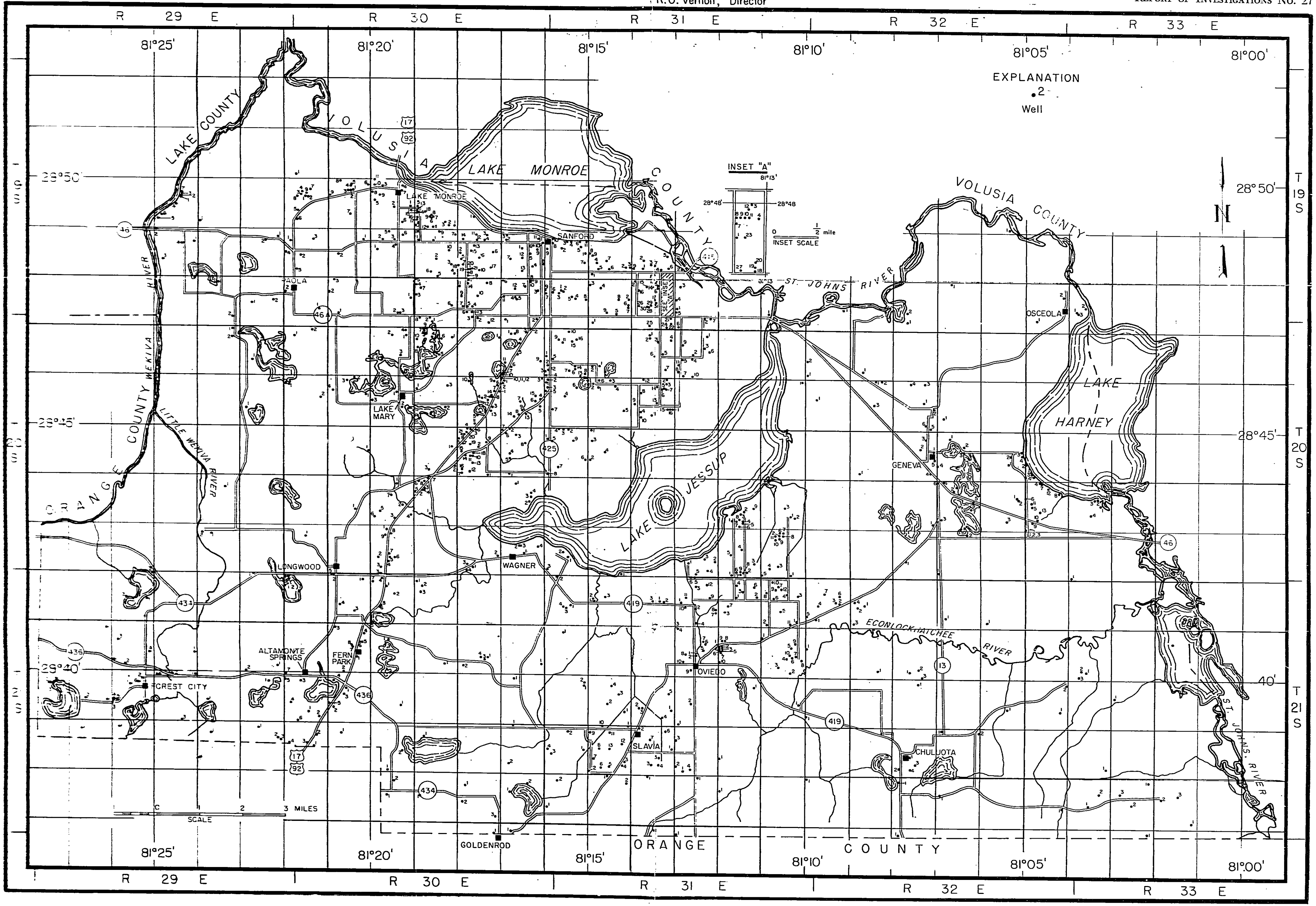

Figure 10. Locations of Wells.