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DIVISION OF GEOLOGY

FLORIDA GEOLOGICAL SURVEY
Robert O. Vernon, Director

REPORT OF INVESTIGATIONS NO. 43

GROUND WATER IN DUVAL AND NASSAU COUNTIES, FLORIDA

By
Gilbert W. Leve, Geologist

Prepared by the
UNITED STATES GEOLOGICAL SURVEY
in cooperation with the
DIVISION OF GEOLOGY
and
DUVAL COUNTY
and the
CITY OF JACKSONVILLE

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Florida Geological Survey

Tallahassee

May 19, 1966

Honorable Haydon Burns, *Chairman*
State Board of Conservation
Tallahassee, Florida

Dear Governor Burns:

The Division of Geology, of the State Board of Conservation, will publish as Report of Investigations No. 43, a detailed report on "Ground Water in Duval and Nassau counties, Florida." This report was prepared by Gilbert W. Leve, Geologist with the U. S. Geological Survey, in cooperation with this Division, Duval County, and the City of Jacksonville.

It has been discovered that there are at least three aquifers in the area, a shallow ground-water aquifer and two distinctive aquifers in the Floridan aquifer system. Water under high pressure, but of less satisfactory quality, is available throughout the area, even though the pressures of the upper artesian aquifer have been reduced as much as 100 feet. About 200 million gallons of water per day is used from these aquifers in the vicinity of Jacksonville. Some concern was felt that salt-water intrusion had begun, but the study shows that there is little danger of contamination of these supplies and that Duval and Nassau counties have adequate water for the future, if properly managed and utilized.

Respectfully yours,
Robert O. Vernon
Director and State Geologist

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ABSTRACT

This report describes an area of about 2,000 square miles in northeast Florida and extreme southeast Georgia. The topography is controlled by a series of ancient marine terraces, and surface drainage is through the St. Johns, Nassau, and St. Marys Rivers and through brackish-water streams that empty either into the intracoastal waterway or directly into the ocean.

Practically all the water used in the area is supplied from the rock formations that underlie the surface. These formations, in ascending order, are the Oldsmar Limestone, the Lake City Limestone, the Avon Park Limestone, and the Inglis, Williston, and Crystal River Formations of the Ocala Group, all of Eocene Age; the Hawthorn Formation of Middle Miocene Age; deposits of late Miocene or Pliocene Age; and undifferentiated deposits of Pleistocene and Recent Age. The formations of Eocene Age and the limestone at the base of the Hawthorn Formation compose the Floridan aquifer system. Surficial sand beds and a zone of limestone, shell, and sand at the base of the upper Miocene or Pliocene deposits are the most extensive aquifers in the shallow aquifer system.

Increased pumpage from numerous wells in the shallow aquifers has caused a steady decline of water levels in these aquifers. However, additional water may be obtained from shallow aquifers by proper well construction and by artificial recharge.

The principal source of fresh water in northeast Florida is the Floridan aquifer system. The top of this aquifer is between 300 and 550 feet below sea level and water is confined under artesian pressure in the aquifer by impermeable beds in the Miocene to Recent deposits. At least three permeable zones separated by hard, relatively impermeable zones, occur within the Floridan aquifer system. More water, possibly of less satisfactory quality but under higher artesian pressure, can usually be obtained from the deeper zones than from the shallower zones in the aquifer.

Most of the recharge of water to the aquifer is outside of Duval and Nassau counties where the overlying confining beds are thin or missing. Discharge is by seepage into the ocean and by numerous wells throughout Duval and Nassau counties. Between 150 and 200 mgd (million gallons per day) is discharged by wells in the vicinity of Jacksonville, and between 50 and 70 mgd is discharged by wells at Fernandina Beach, causing depressions in the piezometric surface in these areas. The piezometric surface has been depressed from less than 30 feet above sea level to more than 15 feet below sea level, and artesian pressures in wells declined between 50 and 60 feet at Fernandina Beach during the period 1939 to 1963 and between 12 to 22 feet at Jacksonville during the period 1946 to 1963.

Water from both the shallow and Floridan aquifer systems is suitable for most uses. The chloride content of water from wells in the Floridan aquifer system ranges from less than 10 ppm (parts per million) to more than 40 ppm in wells less than 1,250 feet deep, and it exceeds 1,100 ppm in wells more than 1,250 feet deep at Fernandina Beach. The chloride content of water from most wells increased only 2 to 14 ppm during the period 1940 to 1962 except in some deep wells at Fernandina Beach, where it increased from 20 to 1,350 ppm during the period 1955 to 1962.

At present serious salt-water contamination is limited to a few deep wells at Fernandina Beach, where salt water is migrating laterally from a highly mineralized zone within the fresh-water zone and vertically from highly mineralized zones below the fresh-water zones. Proper well construction and spacing controlled discharge, and careful development of the deeper water-bearing zones may retard, and prevent further, salt-water contamination.

Future studies will include investigations of the shallow aquifer system, quantitative studies of the Floridan aquifer system, and detailed analysis of the spread of salt-water contamination in northeast Florida.

INTRODUCTION

Ground water is the principal supply of fresh water in northeast Florida. Practically all water for municipal, industrial, and agricultural use is obtained from wells. In recent years, expanding industry and increasing population in the area have considerably increased the use of ground water. To supply the increased need for water many new wells have been drilled, many existing wells have been deepened, and large-capacity pumps have been installed of wells that previously produced an adequate supply by natural flow.

Correlated with the increase in water use is the continued decline in artesian pressures. Records of water levels in northeast Florida show that since 1880 pressures have declined more than 60 feet in some parts of the area. In many parts of Florida and Georgia, similar declines in artesian pressures have resulted in salt-water intrusion into the fresh-water supply. The constant decline in water pressure and the possibility of salt-water contamination of the aquifers pose a threat to the future development of the fresh water in northeast Florida. A shortage of fresh ground water could inhibit the area's economic growth and result in hardship for the population.

Recognizing the need for a comprehensive appraisal of the ground-water resources of northeast Florida, an investigation was begun in 1959 by the U.S. Geological Survey in cooperation with the Florida Geological Survey. The purpose of this investigation was to provide the basic information necessary for the safe and efficient development of ground water, one of the most important natural resources of northeast Florida.

This report presents and interprets the information concerning the location and availability of ground water collected by the U.S. Geological Survey previous to and during this study. The report is a convenient reference for those persons charged with the responsibility of developing and protecting water supplies and for those who use or control water in significant quantities in Duval and Nassau counties.

The investigation was begun under the immediate supervision of M. I. Rorabaugh, the previous District Engineer, Ground Water Branch of the U.S. Geological Survey, and completed under C. S. Conover, the present District Engineer.

PREVIOUS INVESTIGATIONS

The occurrence and quantity of ground water in northeast Florida are briefly mentioned in reports by Matson and Sanford (1913) and Sellards and Gunter (1913) as part of generalized investigations of ground water in Florida. A report by Stringfield (1936) includes maps of the Florida Peninsula showing the area of artesian flow, areas in which the artesian water contains more than 100 ppm of chloride, and the first published map of the piezometric surface of the Floridan aquifer. Reports on ground-water resources in southeastern Georgia by Stewart and Counts (1958) and Stewart and Croft (1960) include information on ground-water discharge and maps of the piezometric surface in the Fernandina Beach area. Ground-water resources in northeast Florida are described in generalized reports by Stringfield, Warren and Cooper (1941), and by Cooper, Kenner, and Brown (1953).

Chemical analyses of water from wells in northeast Florida are included in reports by Collins and Howard (1928), Black and Brown (1951) and the Florida State Board of Health (1960). A report by Black, Brown, and Pearce (1953) includes a brief discussion on the possibility of salt-water intrusion in northeast Florida. The surface-water resources of Baker County are described in a comprehensive report by Pride (1958).

Geologic information on northeast Florida is included in reports by Cooke (1945), Vernon (1951), and Puri (1957). The reports by Vernon and Puri both contain generalized cross sections that include northeast Florida, and the report by Vernon also contains a generalized subsurface structural map of northern Florida. Stratigraphic and paleontological studies of an oil-test well in Nassau County are described in a report by Cole (1944).

Detailed studies of the ground-water resources and geology of northeast Florida were made by Pirnie (1927) and Cooper (1944). Eugene Derragon of the U.S. Geological Survey made a reconnaissance of the area in 1955. Many of the data collected by Cooper and Derragon were used in preparing this report.

During this study preliminary reports of the ground-water resources of northeast Florida (Leve, 1961a) and the Fernandina Beach area (Leve, 1961b) were prepared to determine the extent of declines of water levels and salt-water intrusion in the area. Most of the data presented in these preliminary reports are included in this report.

ACKNOWLEDGMENTS

The author wishes to express his appreciation to Mr. D. M. French, Duval Drilling Co., who supplied drilling information and assisted in sampling and conducting tests on wells; to Mr. T. Oliver, power superintendent, Container Corp. of America; to Mr. H. G. Taylor, chief chemist, Rayonier Inc.; and to Mr. C. Washburn, chief engineer, and Mr. D. C. Hendrickson, associate engineer, Jacksonville Department of Electric and Water Utilities, all of whom provided valuable data and either permitted or assisted in conducting tests, sampling, and measuring of wells.

Appreciation is expressed to the many consultants, well drillers and members of the Florida State Board of Health who made available many valuable data included in this report.

Special thanks are extended also to the many residents in the area who permitted access to their properties.

WELL-NUMBERING SYSTEM

Wells inventoried during this investigation were each assigned an identifying number. Figure 1 is a diagram illustrating the well-numbering system. As shown in the diagram, the first two segments of the well number identify the 1-minute quadrangle of latitude and longitude in which the well is located. Thus, well 021-139 shown in the figure is located in a quadrangle bounded by latitude 30°21'N on the south and longitude 81°39'W on the east.

The third segment of the well-location number is based upon dividing the 1-minute quadrangles into quarters, sixteenths, and sixty-fourths, which are numbered 1, 2, 3, 4 in the following order: northwest, northeast, southwest, and southeast. The first digit in the third segment of the well number locates the well within the quarter, the second digit locates the well within the quarter-quarter tract, and the third digit locates the quarter-quarter-quarter tract. If a well could not be located accurately within the smallest tract, then a zero is used for the third digit of the third segment of the well number. Similarly, a zero is used for the second and first digits of the third segment if the well could not be located more accurately within the 1-minute quadrangle. With this system, a well referred to by number in the text can be located on figure 2.

GEOGRAPHY

LOCATION AND AREA

This report describes an area of about 2,000 square miles in he northeastern part of Florida and includes the bordering south-astern part of Georgia (fig. 1). The area extends from 30°05′ arallel north latitude northward into southern Georgia and from 2°10′ meridian of west longitude eastward to the Atlantic Ocean. t includes all of Duval and Nassau counties, eastern Baker, and orthern Clay and St. Johns counties, Florida, and the extreme outhern portions of Camden and Charlton counties, Georgia.

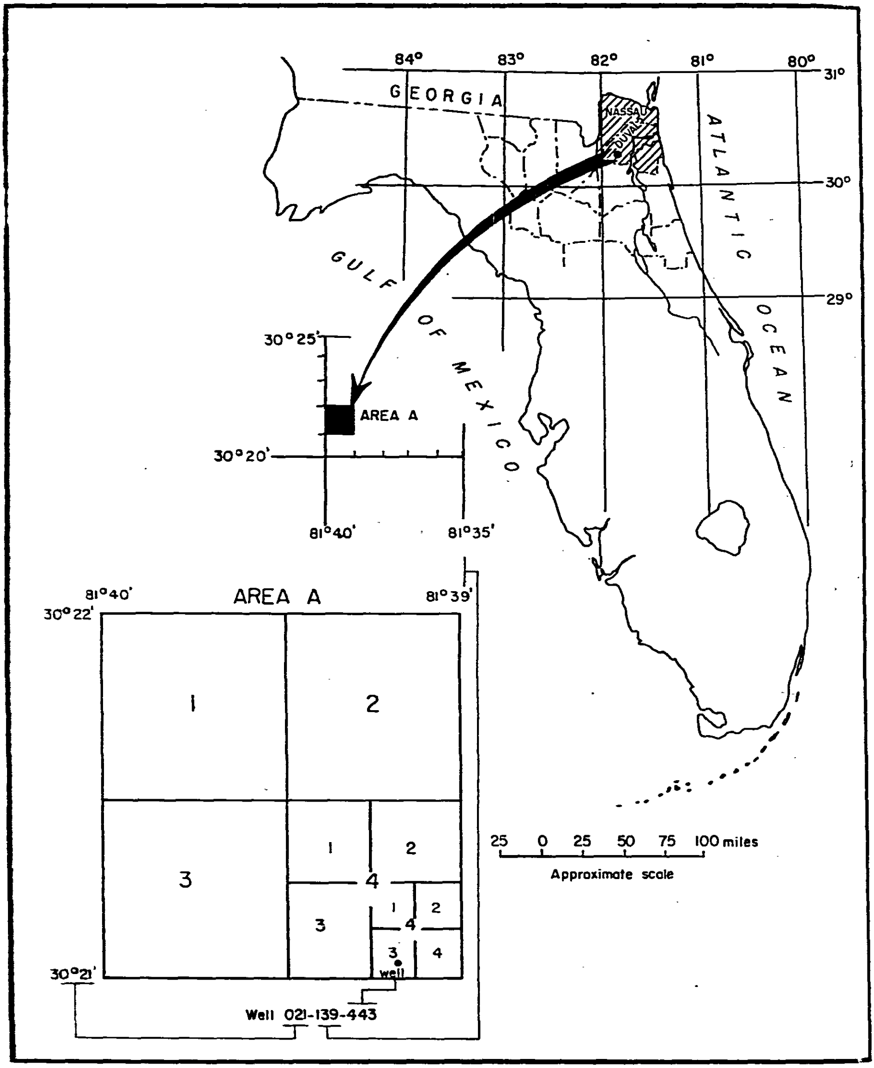

Figure 1. Map of peninsular Florida showing the location of Duval and Nassau counties and illustrations of well-location numbering system.

CLIMATE

The climate of the area is humid subtropical. According to records of the U.S. Weather Bureau, the mean temperature is 69°F near the coast and about 68°F inland. The lowest mean monthly temperature at Jacksonville is 55.9°F, in January; the

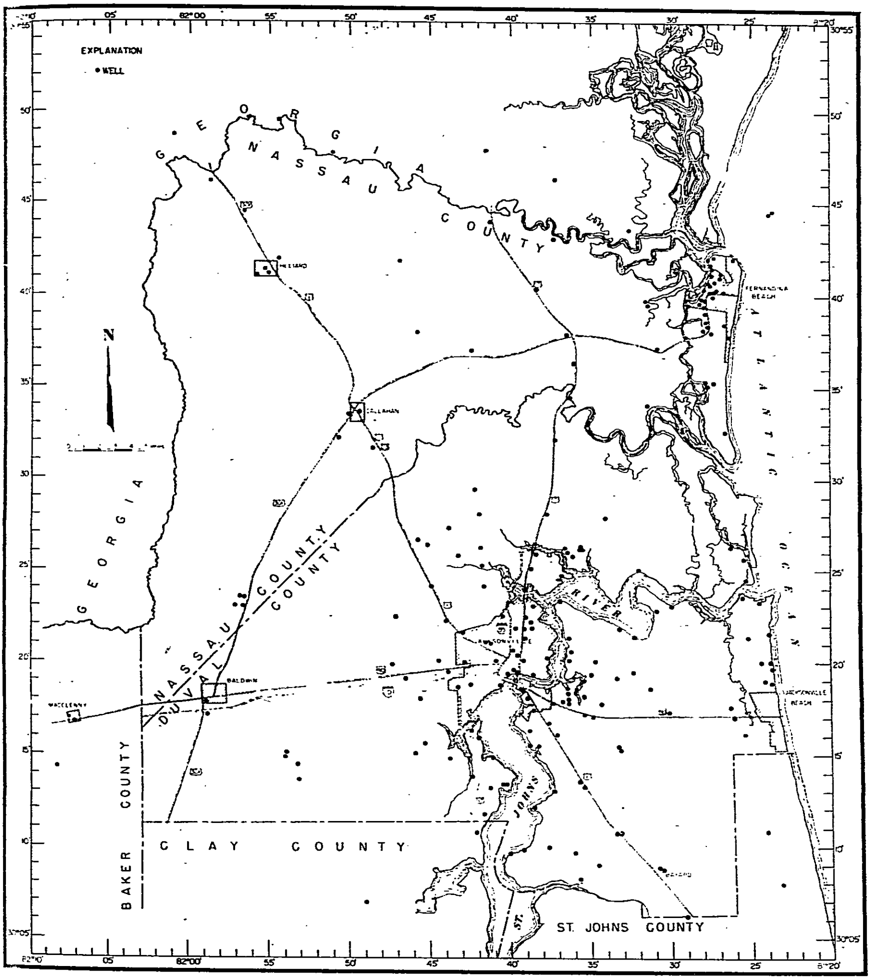

Figure 2. Map of Duval and Nassau counties showing the location of wells for which information was obtained.

highest mean monthly temperature is 82.6°F, in July. The average annual precipitation in the area is about 52 inches, of which 60 to 70 percent falls between June 1 and October 31.

POPULATION AND INDUSTRY

Jacksonville, Jacksonville Beach, and Fernandina Beach are the three largest cities in the area. Most of the population is along the St. Johns River in and near Jacksonville and along the coast in Duval County. Table 1 shows the population of Jacksonville and

Duval County and of Fernandina Beach and Nassau County in 1940, 1950, 1960, and 1962 based on records of the U.S. Census Bureau. The table also shows the percentage increase in population between 1940 and 1962.

The economy of Fernandina Beach and Nassau County is based upon the production of wood pulp and paper. Two large processing plants, Rayonier Inc. and Container Corp. of America, are located in Fernandina Beach, and their expansion has been a major reason for the population increase in Nassau County.

Greater Jacksonville in Duval County is one of the major metropolitan areas in the southeastern United States. A natural harbor near the mouth of the St. Johns River and a vast network of transportation facilities make Jacksonville the distribution center for northern Florida and southeastern Georgia. A wide range of products are manufactured and processed in Jacksonville. Some of the major industries are paper manufacturing, shipbuilding and repair, processing and packaging of food products, manufacturing of cigars, chemicals and paint, building products, truck bodies, steel castings, and furniture. In addition, there are 18 home and regional offices of insurance companies and 3 major naval facilities in the area.

An index of industrial growth of the Jacksonville area is the total nonagricultural wages and employment of salaried workers in the area as determined by the Bureau of Labor Statistics, U.S. Department of Labor. These figures are given in table 2 for every 2 years since 1950.

PHYSIOGRAPHY

The topography of northeast Florida is controlled by a series of ancient marine terraces (Cooke, 1945) which were formed at times in the Pleistocene when the sea was relatively stationary at various higher levels than the present sea level. When the sea dropped to a lower level, the sea floor emerged as a level plain or terrace and the landward edge of each terrace became an abandoned shoreline, which is generally marked by a low scarp.

Seven terraces are recognized in northeast Florida; in descending level they are the Coharie, Sunderland, Wicomico, Penholoway, Talbot, Pamlico and Silver Bluff terraces. The original shorelines and the level plains of the terraces have been modified and destroyed by stream erosion and only remnants of the original terraces can be seen. The general configuration of these terraces shown on figure 3 was mapped from topographic maps primarily

TABLE 1. Population of Jacksonville, Duval County, Fernandina Beach, and Nassau County, 1940-62

Population unit	1940	1950	1960	1962	Percent increase 1940-62
Jacksonville	173,065	204,517	201,030		
Duval County	210,143	304,029	455,411	482,600	130
Fernandina Beach	3,492	4,974	7,276		
Nassau County	10,826	12,811	17,189	18,300	69

by their elevation above present msl (mean sea level) and from aerial photographs.

The highest and oldest terraces, the Coharie, Sunderland and Wicomico, are in the western part of the area. They form an upland that ranges in elevation from 70 to more than 200 feet above msl. The highest and most prominent surface feature is a high sandy ridge, called "Trail Ridge," that extends northward through eastern Baker County into Georgia. The ridge, a remnant of the Coharie terrace, ranges in altitude from 170 to more than 200 feet. The Sunderland terrace in eastern Baker County and extreme southwestern Duval County is poorly developed and is modified by erosion. Remnants of this terrace consist of rolling, eroded hills that range in altitude from 100 to 170 feet. The most extensive occurrence of the uplands in the western part of the area consists of an irregular flat plain from 70 to 100 feet above msl which is the

TABLE 2. Nonagricultural wages and salaried employment in the Jacksonville area.

Year	Total salaried workers employed in nonagricultural work
1950	98,600
1952	110,800
1954	116,400
1956	127,800
1958	134,000
1960	144,100
1962	148,100
Percent increase 1950-1962	50.2

remnant of the Wicomico terrace. The outer boundary of this terrace extends northwestward through south-central Duval County and western Nassau County into Georgia.

The Penholoway and Talbot terraces in the area are not clearly defined in northeast Florida because they have been severely modified by the numerous streams that drain the higher and older terraces. Scattered remnants of these terraces occur in a belt that extends through central Nassau County, north-central Duval County and southeastern Duval County east of the St. Johns River. They form a coastal ridge at altitudes from about 25 to 70 feet which is particularly well defined east of the St. Johns River in southeastern Duval County. Ancient dunes on the coastal ridge form a series of narrow sandy ridges and low intervening swampy areas which are elongate parallel to the coastline.

The Pamlico and Silver Bluff terraces form a low coastal plain throughout most of the central and eastern part of northeast Florida. The altitude of the plain ranges from slightly above sea level to 25 feet; however, some dunes along the present coastline are more than 50 feet above msl. In Nassau County and in northern Duval County, the plain slopes irregularly eastward toward the ocean. In central and southern Duval County, the plain slopes toward the St. Johns River west of the coastal ridge and toward the ocean east of the ridge.

Adjacent and parallel to the present coastline, remnants of the Pamlico terrace form a series of offshore bars or islands. These bars range in width from less than a few hundred feet to about 2 miles and are separated from the mainland by a series of tidal lagoons and streams. Many of these tidal streams comprise the Intracoastal Waterway.

Surface drainage in the western and central parts of the area is through the St. Johns, Nassau, and St. Marys rivers and their tributaries. East of the coastal ridge, drainage is primarily by numerous small brackish-water streams that empty either into the channel of the Intracoastal Waterway or directly into the ocean. Much of the relatively flat Pamlico, Silver Bluff, and Wicomico terraces is marshland because drainage is poor.

OCCURRENCE OF AQUIFER SYSTEMS

GENERAL PRINCIPLES

Rainfall on the land surface may be returned directly to the atmosphere by transpiration and evaporation, drained off into surface bodies of water, or absorbed by the soil and rocks. Some of the water that is drained into lakes and streams or is absorbed by the soil and rocks eventually moves downward through the ground to the zone in which the interstices of the rocks are completely saturated with water, where it becomes a part of the ground-water body. Ground water moves laterally from zones of higher hydrostatic head, such as recharge areas where the water is replenished, to areas of lower hydrostatic head, such as discharging wells and springs.

Ground water occurs under either nonartesian or artesian conditions. Nonartesian water is unconfined, so that its upper surface is free to rise and fall; artesian water is confined under pressure, so that its upper surface is not free to rise and fall. The height to which artesian water will rise above its confined surface in a tightly cased well is called the artesian pressure head. The imaginary surface coinciding with the altitude of such artesian pressure heads in wells is called the piezometric surface.

Ground water occurs in rocks in the zone of saturation; however, only aquifers transmit usable quantities of water to wells. An aquifer may be a formation, group of formations, or part of a formation that is porous and relatively permeable. Relatively impermeable rocks that restrict the movement of water are called aquicludes. Thin, discontinuous, relatively impermeable zones that locally separate permeable zones are called confining beds. A series of similar aquifers or permeable zones together with associated confining beds and aquicludes constitute an aquifer system.

In northeast Florida, ground water occurs in two separate aquifer systems: the shallow aquifer system and the Floridan aquifer system. Although both aquifer systems were studies during this investigation, the Floridan aquifer system is described in greater detail in this report because it is the principal source of ground water in the area.

GEOLOGIC SETTING[1]

Fresh-water supplies in Duval and Nassau counties are obtained entirely from wells drilled into the rock formations that compose the aquifer systems. Therefore, an essential part of this study

[1]The stratigraphic nomenclature used in this report conforms to the usage by Cooke (1945) with revisions by Vernon (1951) except that the Ocala Limestone is referred to as the Ocala Group. The Ocala Group, and its subdivisions as described by Puri (1953), has been adopted by the Florida Geological Survey. The Federal Geological Survey regards the Ocala as a formation, the Ocala Limestone.

was to differentiate the formations and to determine their water-bearing properties. This was done by collecting rock cutting from a number of water wells drilled in the area and examining these cuttings to determine the texture, mineral composition, and fauna of the different formations. Additional geologic information was obtained from drillers' logs, and from lithologic and electric logs on file with the Florida Geological Survey. Current-meter traverses were made in a number of wells to locate the water-bearing zones and to determine the relative yield of water from the different formations.

The rock formations that are tapped by water wells in the area include, in ascending order, the Oldsmar Limestone, the Lake City Limestone, the Avon Park Limestone, and the Inglis, Williston, and Crystal River Formations of the Ocala Group—all of Eocene age; the Hawthorn Formation, of middle Miocene age; deposits of late Miocene or Pliocene age; and, exposed at the surface, undifferentiated deposits of Pleistocene and Recent age. These rocks are listed in table 3 and their lithologic character and water-bearing properties are described briefly.

Rock formations older than the Oldsmar Limestone have not been tapped by water wells in northeast Florida because sufficient water can be obtained from the overlying formations and the water from the deeper rocks is more highly mineralized. One deep oil-test well in northwestern Nassau County penetrated rocks deeper than the Oldsmar Limestone. In this well, marine dolomite and limestone beds of Eocene age are 2,235 feet thick and extend to a depth of 2,640 feet below msl. A sample of water collected between the depths of 2,100 and 2,130 feet below msl and analyzed for mineral content was found to contain 33,600 ppm of chloride which is about 1½ times the chloride content of sea water.

The following discussion of the formations include only rocks penetrated by water wells in Duval and Nassau counties. The cross sections in figure 4 show these geologic formations.

OLDSMAR LIMESTONE

The Oldsmar Limestone of early Eocene age (Applin and Applin, 1944, p. 1699) is the deepest and oldest formation utilized as a source of water in northeast Florida.

The only well in the area that completely penetrates the Oldsmar Limestone is a deep oil-test well, 044-156-110, in northwestern Nassau County (Cole, 1944). The top of the Oldsmar

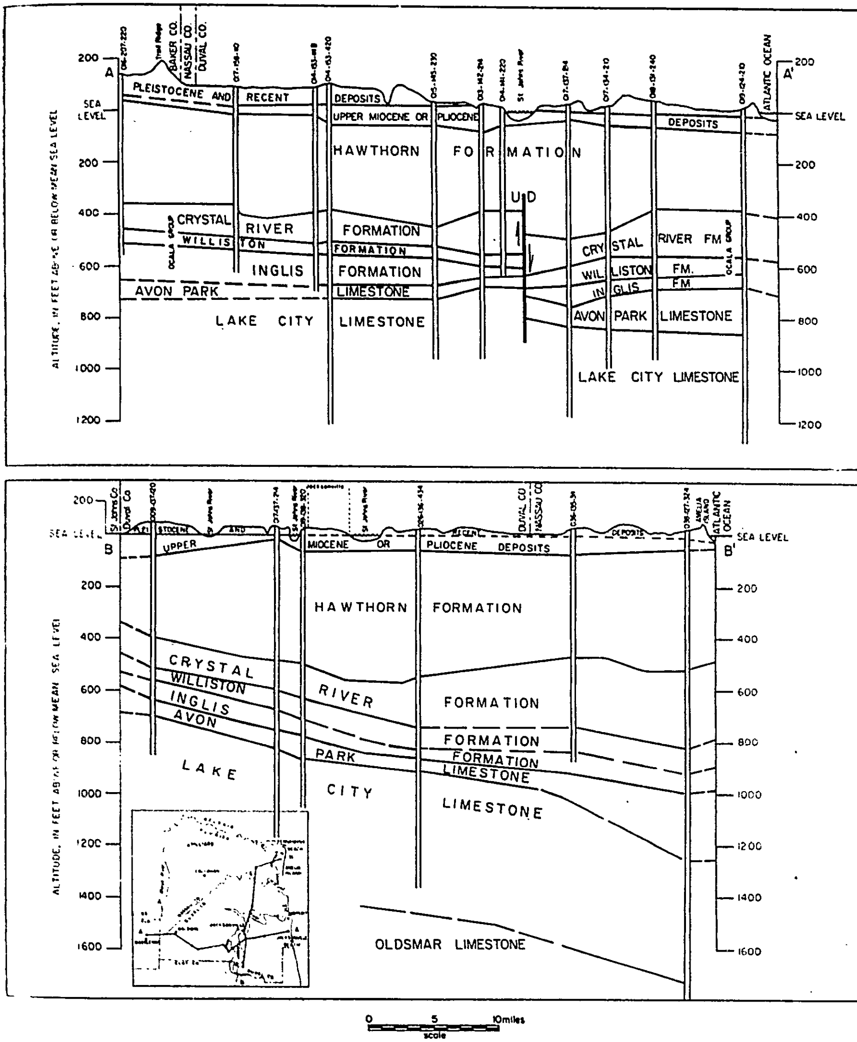

Figure 4. Geologic cross sections showing the formations penetrated by wells in Duval and Nassau counties, Fla.

imestone is about 1,270 feet below msl in this well and the rmation is 846 feet thick. Well 038-127-324, in Fernandina each (fig. 4), reached the top of the Oldsmar Limestone at 1,746 et below msl and penetrated more than 340 feet of the formation ithout reaching older formations.

In wells in northeast Florida, the Oldsmar Limestone consists of a cream to brown, soft, massive to chalky granular limestone, and cherty, glauconitic, massive to finely crystalline, sugar-textured dolomite. The formation is lithologically similar to the overlying Lake City Limestone and is differentiated from the Lake City by its fossil content. The top of the Oldsmar Limestone is picked by the first occurrence of the foraminifer species *Helicostegina gyralis* Barker and Grimsdale.

LAKE CITY LIMESTONE

Lake City Limestone is the name applied by Applin and Applin (1944) to limestone of early middle Eocene age that conformably overlies the Oldsmar Limestone in peninsular Florida.

Depths to the top of the Lake City Limestone in northeast Florida range from about 580 feet below msl in south-central Duval County to about 1,260 feet below msl at Fernandina Beach. Only a few wells in northeast Florida completely penetrate the Lake City Limestone. The Lake City is 486 feet thick in a well (044-156-110) in northwestern Nassau County and 475 feet thick in a well (038-127-324) at Fernandina Beach. A well in southwestern Duval County (014-153-420) penetrates more than 490 feet of Lake City Limestone without reaching older formations.

Lithologically, the Lake City Limestone consists of alternating beds of white to brown, purple tinted lignitic, chalky to granular limestone and gray to tan massive to finely crystalline, sugar-textured dolomite. It contains beds consisting entirely of cone-shaped (*Valvulinidae*) foraminifers and locally contains thin beds of lignite.

The Lake City Limestone contains abundant fossil foraminifers that are different from those in the underlying Oldsmar Limestone and overlying Avon Park Limestone. The most distinctive fossil of the Lake City Limestone is *Dictyoconus americanus* which was selected by Applin and Applin (1944) as a guide fossil for the formation. The fossils most often found in well cuttings from the Lake City Limestone include *Dictyoconus americanus* (Cushman), *Fabularia vaughani* Cole and Ponton, *Discorbis inornatus* Cole, *Fabiania cubensis* Cushman and Bermudes, *Archaias columbiensis* Applin and Jordan.

AVON PARK LIMESTONE

Deposits of late middle Eocene age penetrated by wells in Polk County were named Avon Park Limestone by Applin and Applin (1944). Outcrops of the formation in Citrus and Levy counties were later recognized and described in detail by Vernon (1951, p. 95).

The Avon Park Limestone ranges in thickness from 150 feet to more than 700 feet in central and southern Florida; however, it has been considerably thinned by erosion in northeast Florida. The geologic cross sections in figure 4 show that the formation averages only about 50 feet in thickness throughout the western and central parts of northeast Florida. It thickens toward the coast and is about 190 feet thick in a well (019-124-210) at Atlantic Beach and more than 250 feet thick in a well (038-127-324) at Fernandina Beach.

The Avon Park Limestone unconformably overlies the Lake City Limestone and unconformably underlies the Ocala Group. Contours constructed on the irregular upper surface of the Avon Park Limestone in northeast Florida are shown on figure 5. As shown, the top of the formation is less than 500 feet below msl in south-central Duval County and more than 950 feet below msl in northeastern Nassau County.

The lithology of the Avon Park Limestone varies both laterally and vertically throughout northeast Florida. In the western and central parts of the area where the formation has been considerably thinned by erosion, it consists predominantly of tan to brown, hard, massive dolomite beds containing thin zones of tan granular, fossiliferous limestone. In the eastern part of the area where the formation is thickest, it consists of alternating beds of tan hard, massive dolomite; brown to cream granular, calcitic limestone; and brown, finely crystalline, sugar-textured dolomite.

The top of the formation usually can be detected during the drilling of wells because the hard dolomite beds in the upper part of the formation retard the drilling rate. In addition, the Avon Park Limestone can be identified and differentiated from the other formations of Eocene age by its fossil content. The following diagnostic foraminifers were identified in the Avon Park Limestone from well cuttings in the area: *Coskinolina floridana* Cole, *Dictyoconus cookei* (Mobert), *Dictyoconus gunteri* Cole, *Lituonella floridana* Cole, *Spirolina coryensis* Cole.

OCALA GROUP

Cooke (1915, p. 117; 1945, p. 53) defined all deposits of late Eocene age in Florida as one formation; the Ocala Limestone. These deposits were later redefined by Vernon (1951, p. 111-171) as two formations; the Moodys Branch Formation and the Ocala Limestone. More recently Puri (1953, p. 130; 1957, p. 22-24) divided the late Eocene limestone into three separate formations. These are, in ascending order, the Inglis, the Williston, and the Crystal River Formations. These three formations are now referred to collectively as the Ocala Group by the Florida Geological Survey.

All three formations of the Ocala Group are fragmental marine limestones and were differentiated in cuttings from wells in northeast Florida by slight changes in lithology and on the basis of fossil content. However, in some wells from which cuttings were collected and examined, it was not possible to differentiate each of these formations because of lithological similarities and the absence of diagnostic fossils in the cuttings.

INGLIS FORMATION

The Inglis Formation lies unconformably on the Avon Park Limestone and ranges in thickness from about 40 feet to about 120 feet in northeast Florida. As shown on the geologic cross section in figure 4, it is thickest west of the St. Johns River in western and central Duval County.

Lithologically, the Inglis Formation is a tan to buff granular, calcitic, marine limestone. It contains beds consisting entirely of a coquina of Miliolidae foraminifers. These coquina beds are loosely cemented and porous and have a mealy texture. Thin, discontinuous zones of gray to brown, hard, crystalline dolomite are prevalent near the base of the formation.

The lithologies of the Inglis and the overlying Williston Formations are similar and in many sets of cuttings from wells in the area the upper contact of the Inglis is not clearly defined. However, in most cases it was possible to differentiate the formations on the basis of changes in fossil content. The following diagnostic fossils were used as guide fossils (Puri, 1957, p. 48) to identify the Inglis Formation in cuttings from wells in the area: *Fabiana cubensis* Cushman and Bermudez, *Periarchus lyelli* (Conrad), *Spiroloculina seminolensis* Applin and Jordan, *Spirolina coryensis* Cole.

WILLISTON FORMATION

The Williston Formation lies conformably between the underlying Inglis and the overlying Crystal River Formations. It ranges in thickness from about 20 feet to 100 feet and has an average thickness of about 50 feet throughout northeast Florida.

The lithology of the Williston Formation is similar to that of the underlying Inglis Formation, consisting of a tan to buff granular, marine limestone. However, the Williston is generally more indurated and does not contain the mealy-textured coquina beds that are found in the Inglis Formation.

The Williston Formation can further be differentiated from the other formations in the Ocala Group by a distinct fossil assemblage. The following fossils were identified in well cuttings: *Amphistegina pinarensis cosdeni* Applin and Jordan, *Operculinoides moodybcranchensis* (Gravell and Hanna), *Operculinoides willcoxi* (Heilprin), *Operculinoides jacksonensis* (Gravell and Hanna), *Nummulites vanderstoki* Rutten and Vermunt, *Heterostegina ocalana* Cushman.

Several of these species of fossils occur in the other formations of the Ocala Group but not as frequently nor in as great numbers as in the Williston Formation. The top of the formation was determined by the first appearance in well cuttings of *Amphistegina pinarensis cosdeni,* which is the most diagnostic fossil of the Williston Formation in northeast Florida.

CRYSTAL RIVER FORMATION

The Crystal River Formation is the youngest Eocene formation generally penetrated by wells in northeast Florida. It conformably overlies the Williston Formation and unconformably underlies the Hawthorn Formation of middle Miocene age. The thickness of the formation varies considerably throughout the area and, as shown by the geologic cross sections in figure 4, ranges from less than 100 feet in central and western Duval County to 300 feet in well 038-127-324 at Fernandina Beach.

Lithologically, the Crystal River Formation is a white to cream, chalky massive fossiliferous, marine limestone. It is lighter in color, less granular, and more friable than the underlying Williston Formation, and contains abundant Molluscan shells and relatively large foraminifers that are not common in the underlying formations of the Ocala Group. The fossils identified in well cuttings from the Crystal River Formation include: *Lepidocyclina ocalana*

Cushman, *Lepidocyclina ocalana pseudomarginata* Cushman, *Operculinoides ocalana* Cushman, *Operculinoides floridensis* (Heilprin), *Sphaerogypsina globula* (Ruess), *Nummulites vanderstoki* Rutten and Vermunt, *Heterostegina ocalana* Cushman.

HAWTHORN FORMATION

Rocks of middle Miocene age in peninsular Florida were first named the Hawthorn Formation by Dall and Harris (1892, p. 107). The Hawthorn Formation lies unconformably on the eroded surface of the Ocala Group throughout all of northeast Florida.

As shown in the geologic cross sections in figure 4, the thickness of the Hawthorn Formation ranges from about 250 feet in southern Duval County to about 500 feet in north-central Duval and central Nassau counties. Locally, the formation may vary in thickness by as much as 50 feet where it fills depressions in the irregular surface of the Crystal River Formation.

The Hawthorn Formation consists of gray to blue-green calcareous, phosphatic sandy clays and clayey sands, interbedded with thin, discontinuous lenses of fine to medium phosphatic sand, phosphatic sandy limestone, and gray hard dolomite. The limestone and dolomite lenses are thicker and more prevalent near the base of the formation than in the higher parts. They occasionally contain some poorly preserved mollusk casts and molds. The only other fossils in the formation are sharks' teeth, which are most often found in the clay beds.

UPPER MIOCENE OR PLIOCENE DEPOSITS

Deposits overlying the Hawthorn Formation in peninsular Florida were described by Cooke and Mossom (1929, p. 152) and Cooke (1945) as being Pliocene in age. They have been more recently described by Vernon (1951, figs. 13,33) as late Miocene in age. Because their age has not been determined exactly, they are referred to in this report as Pliocene or upper Miocene deposits.

Pliocene and upper Miocene deposits are the oldest rocks exposed at the surface in northeast Florida. They are exposed in road cuts, excavations, and the banks and beds of many streams in the area. As shown in the geologic cross sections (fig. 4), these deposits are about 100 feet thick adjacent to the St. Johns River in central Duval County and in central and eastern Nassau County, and less than 20 feet thick in western Duval and eastern Baker counties.

The Pliocene or upper Miocene deposits consist of interbedded gray-green calcareous silty clay and clayey sand; fine-to medium-grained, well-sorted sand; shell; and cream to brown soft, friable limestone. They differ from the underlying Hawthorn Formation in that they contain little or no phosphate. The limestone is most prevalent at the base of the deposits and together with sand and shell form a laterally extensive, continuous, relatively permeable zone which locally is as much as 40 feet thick.

The contact between the Pliocene or upper Miocene deposits and the Hawthorn Formation is an unconformity generally marked by a course phosphatic sand and gravel bed. However, the contact between the Pliocene or upper Miocene deposits and the overlying Pleistocene and Recent deposits is not clearly defined. In some wells, particularly in the eastern and northern parts of the area, the contact appears to be gradational.

PLEISTOCENE AND RECENT DEPOSITS

Undifferentiated sediments of Pleistocene and Recent age blanket most of northeast Florida, except where they have been completely eroded by streams. As shown in the geologic cross sections (fig. 4), the deposits are more than 150 feet thick in eastern Baker County and average about 20 feet in thickness in central and eastern Duval and Nassau counties.

The Pleistocene and Recent deposits in the western part of the area consist primarily of fine- to medium-grained, poorly sorted sand and clayey sand, locally stained yellow or orange by iron oxide. In the central and eastern parts of the area, the deposits are predominantly loose sand and gray to green clayey sand, containing some shell beds near the coast.

STRUCTURE

The structural contour lines in figure 5 reflect the eroded surface of the Avon Park Limestone and Crystal River Formation. At the contour interval shown in the figure, the small irregularities in the surface of the formations are not apparent and the configuration of the lines reflects the approximate subsurface structure of the formations. As shown, the surface of the Avon Park Limestone strikes approximately northwest-southeast and dips northeast at about 9 feet per mile in the western part of the area, and strikes northeast-southwest and irregularly dips northwest about 16 to 20 feet per mile in the eastern part.

Although the surface of the Crystal River Formation has been modified by erosion more than the surface of the Avon Park Limestone, the contour lines on the top of the Crystal River Formation in figure 5 generally reflect the configuration of the underlying Avon Park Limestone. The top of the Crystal River Formation ranges from less than 300 feet below msl in southern most Duval County to more than 550 feet below msl in north-central Duval County. The Crystal River Formation is the initial limestone of Eocene age penetrated by wells in the area, and in most areas it is also the top of the Floridan aquifer system. Therefore, these contour lines also show the top of the Floridan aquifer system in Duval and Nassau counties.

The limestone formations of Eocene age in the western part of the area, sloping northeastward, and in the eastern part of the area, sloping northwestward, form an irregular trough or basin extending from south-central Duval County northeastward into northeastern Nassau County. A fault extends generally along the axis of this basin, the upthrown side to the west. In southern Duval County, the vertical displacement of the top of both the Ocala Group and the Avon Park Limestone by the fault is about 125 feet. The vertical displacement decreasess northward and the fault probably does not extend farther north than northern Duval County.

The irregularities in the surface of the Eocene limestone formations were filled and blanketed by the thick series of post-Eocene sediments (fig. 4), and there is no surface reflection of the subsurface structural features in the area.

SHALLOW AQUIFER SYSTEM

The shallow aquifer system consists of the limestone and sand aquifers in the clayey sand and sandy clay confining beds in the upper part of the Hawthorn Formation, the shell, limestone, and sand aquifers in the Pliocene or upper Miocene deposits and the sand and shell aquifers in the Pleistocene and Recent deposits (table 3).

The lithology of these deposits changes laterally as well as vertically and the aquifers and confining beds are discontinuous. In some part of northeast Florida, particularly in western Duval, Nassau, and eastern Baker counties, the shallow aquifer system may consist of a single, relatively thick aquifer extending downward from the water table to the aquiclude in the Hawthorn

Formation. In other parts of the area, particularly in central and eastern Duval and Nassau counties, the shallow aquifer system may consist of a series of relatively thin permeable zones separated locally by a number of relatively thin confining beds.

The most laterally extensive aquifer in the shallow aquifer system occurs as either a limestone, a shell, or a sand bed near the base of the Pliocene or upper Miocene deposits. It is about 10 to 40 feet thick and is 50 to 150 feet below the surface throughout most of Duval and Nassau counties.

AQUIFER CHARACTERISTICS

Although ground water in the shallow aquifer system is generally under nonartesian conditions, some shallow wells located in low areas immediately adjacent to the St. Johns River and its tributaries yield artesian water. These local artesian conditions are caused by confining beds that confine water under pressure in an underlying aquifer, particularly in shell and limestone beds near the base of the Pliocene or upper Miocene deposits.

The shallow aquifer system is recharged chiefly by local rainfall. Discharge from this system occurs by evaporation, transpiration by plants, seepage into surface bodies of water, leakage downward into the underlying rocks, and discharging wells.

The fluctuations and seasonal trends of water levels in wells in the shallow aquifer system indicate the gain and loss of water to and from the system. The hydrographs in figure 6 show the fluctuations and seasonal trends of water levels in two wells in the shallow aquifer system in northeast Florida. Part A of the figure shows a hydrograph of the semi-daily water levels in well 040-127-211A, at Fernandina Beach, and a bar graph of the daily rainfall at Fernandina Beach in April 1961. The graphs show the effect of local rainfall on the water level in the well. For example, the rise in water of more than 1 foot on April 15 reflects recharge to the aquifer from a rain of 2.70 inches the same day. The overall decline in the water level between April 20 and 30 reflects depletion of water in the aquifer system by the pumping from other shallow wells in the area and by the lack of rainfall after April 16.

Part B of figure 6 shows a hydrograph of the water levels in well 017-136-241B and a bar graph of the monthly rainfall at Jacksonville between February 1961 and December 1962. As shown graphically, the water level in the well generally declined

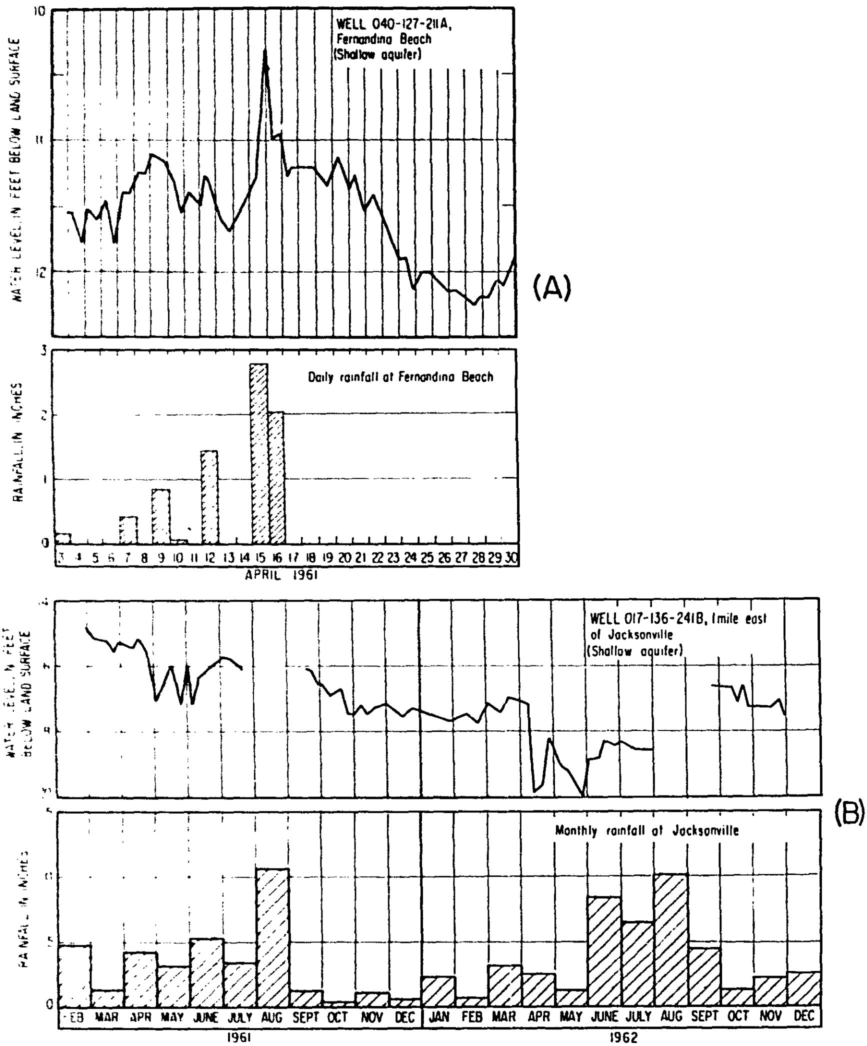

Figure 6. Graphs showing rainfall at Fernandina Beach and Jacksonville and the water levels in well 040-127-211A at Fernandina Beach and well 017-136-241B near Jacksonville.

even during periods when the rainfall increased. For example rainfall during June and July 1962 was almost 7 inches greater than during the same period in 1961; however, the water levels in the well were about 2 feet lower in June and July 1962 than during the same period in 1961. The decline in water level was irregular and generally months of greater rainfall resulted in slightly higher water levels. This general decline in water levels was partly a result of a deficiency in total rainfall during 1961 and 1962 compared to rainfall in 1960. However, as indicated by the lower water levels during periods of increased rainfall, the decline was caused partly also by increased pumping from more shallow wells in the area.

WATER SUPPLIES

Water in the shallow aquifer system is generally obtained from two separate aquifers: (1) from surficial sand beds and (2) from a limestone, sand, and shell zone near the base of the Pliocene or upper Miocene deposits.

Some water for lawn irrigation, stock and domestic use is obtained from the surficial sand deposits by using "surface" sandpoint wells constructed of galvanized casing from ½ to 2 inches in diameter. The casing is either driven or jetted 10 to 30 feet below the surface to put the well screen below the water table. The yields of the surface wells differ in different parts of the area, primarily because of lateral changes in the water-transmitting character of the aquifer. In most of northeast Florida, typical surface wells 1¼ inches in diameter yield between 10 and 15 gpm (gallons per minute). However, some wells in relatively thick and permeable beach sands along the coast yield as much as 25 gpm.

Most of the water from the shallow aquifer system is obtained near the base of the Pliocene or upper Miocene deposits. Water is obtained from this aquifer by "rock" wells, generally 2 inches in diameter and 50 to 150 feet deep. The casing is either driven or jetted to the top of the aquifer and the bottom of the casing is left open. An open hole is then drilled into the aquifer below the casing and water enters the well throughout the entire length of the open hole. Typical 2-inch "rock" wells throughout most of northeast Florida yield 15 to 20 gpm. Locally, where the aquifer is relatively thick and composed of permeable limestone or shell, a 2-inch well may yield as much as 80 gpm. A few 4-inch rock wells in Jacksonville and a few 5-inch wells in Fernandina Beach yield 50 to 80 gpm.

Water from the surficial sands generally contains iron (Fe), which gives it a pronounced taste and stains plumbing fixtures. Surface wells near brackish water are in danger of contamination by lateral encroachment of such water. Water from the "rock" wells is generally of good quality and suitable for most domestic, irrigation, and industrial uses.

The shallow aquifer system presently supplies only small to moderate amounts of water to small-diameter wells. However, properly constructed large-diameter gravel-packed wells in the shallow sand aquifers may be capable of supplying large amounts of water. The shallow aquifer in northeast Florida could become an important source of water to supplement the supplies that are presently obtained from the Floridan aquifer system. Although the areal extent of the relatively thick aquifer at the base of the upper Miocene or Pliocene deposits was not determined by this study, it appears to underlie most of the area. It is possible that this shallow aquifer could be artificially recharged locally with surface water. When the aquifer is not completely saturated, rainfall stored in shallow surface reservoirs could percolate downward into the aquifer to replace the water discharged from shallow wells.

FLORIDAN AQUIFER SYSTEM

The Floridan aquifer system is the principal source of fresh water in northeast Florida; therefore, most of the information collected and studied during this investigation was concerned with this aquifer system. It includes part or all of the Oldsmar, Lake City, and Avon Park Limestones, the Ocala Group, and a few discontinuous, thin aquifers in the Hawthorn Formation that are hydraulically connected to the rest of the aquifer system. The Floridan aquifer system is separated from the shallow aquifer system by the extensive aquiclude in the Hawthorn Formation and in the Pliocene or upper Miocene deposits. Water in the Floridan aquifer system is artesian.

PERMEABLE ZONES

The water-bearing zones within the Floridan aquifer system consist of soft, porous limestone and porous dolomite beds. The hard, massive dolomite and limestone are relatively impermeable and act as confining beds that restrict the vertical movement of water. Where the confining beds are continuous for a considerable distance, they isolate these water-bearing zones.

The Ocala Group is one homogeneous sequence of permeable hydraulically connected marine limestone beds that contain few hard dolomite or limestone beds to restrict vertical movement of water. The Avon Park Limestone consists almost entirely of hard, relatively impermeable dolomite beds that restrict the vertical movement of water between the overlying and underlying permeable zones. The Lake City and Oldsmar Limestones each contain alternating hard, relatively impermeable dolomite confining beds and soft, permeable limestone and dolomite water-bearing zones.

The separation of the permeable zones in the Floridan aquifer system in the vicinity of Jacksonville is indicated by the difference in artesian pressure at different depths in the aquifer system. Figure 7 shows hydrographs of three wells located within 40 feet of each other and drilled and cased to different depths within the Floridan aquifer system. The lowest artesian pressures were recorded in well 026-135-342C which is open to the top 250 feet of the Ocala Group. The highest artesian pressures were recorded in well 026-135-342B which is open to about 175 feet of the Avon Park and the Lake City Limestones. The water pressure in this well was between 0.5 and 1.5 feet higher than that in well 026-135-342C between January 1960 and February 1963. This difference in pressure suggests that the zones supplying water to these wells are isolated from each other.

Well 026-135-342A, drilled to 1,390 feet and cased to 584 feet below the surface, is open to permeable zones in both the Ocala Group and the Lake City Limestone. The artesian pressure

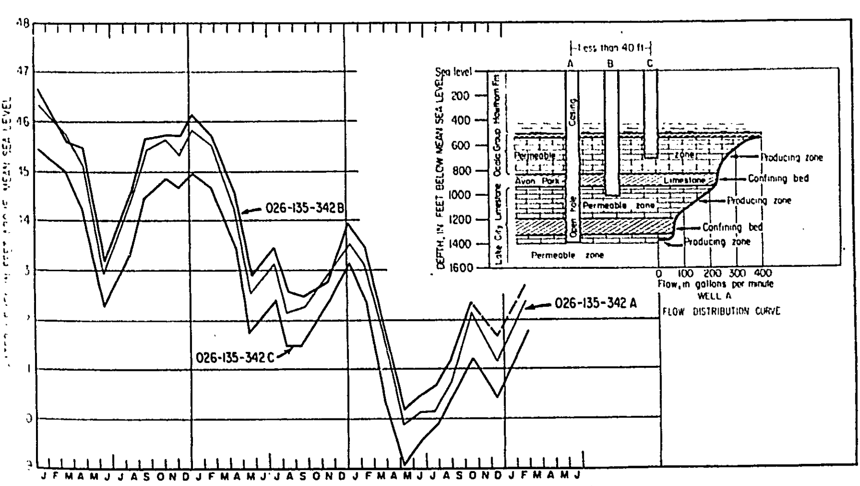

Figure 7. Hydrographs and geologic data from wells 026-135-342 A, B, and C, about 4 miles northeast of Jacksonville.

measured at the well head reflects the pressure in the permeable zones in the Lake City Limestone modified by internal dissipation into the Ocala Group, where the pressure is lower.

This internal dissipation of water within wells that penetrate more than one aquifer in the Florida aquifer system was indicated by current-meter traverses in wells 019-124-210, 021-141-423, 026-135-342A, and 038-127-324, as shown in figures 8 and 9. Water moved from permeable zones of higher artesian head to those of lower head when the flow was shut off at the well head. In all wells the water moved upward, and, except in well 021-141-423, the water moved from lower formations into the Ocala Group. These zones

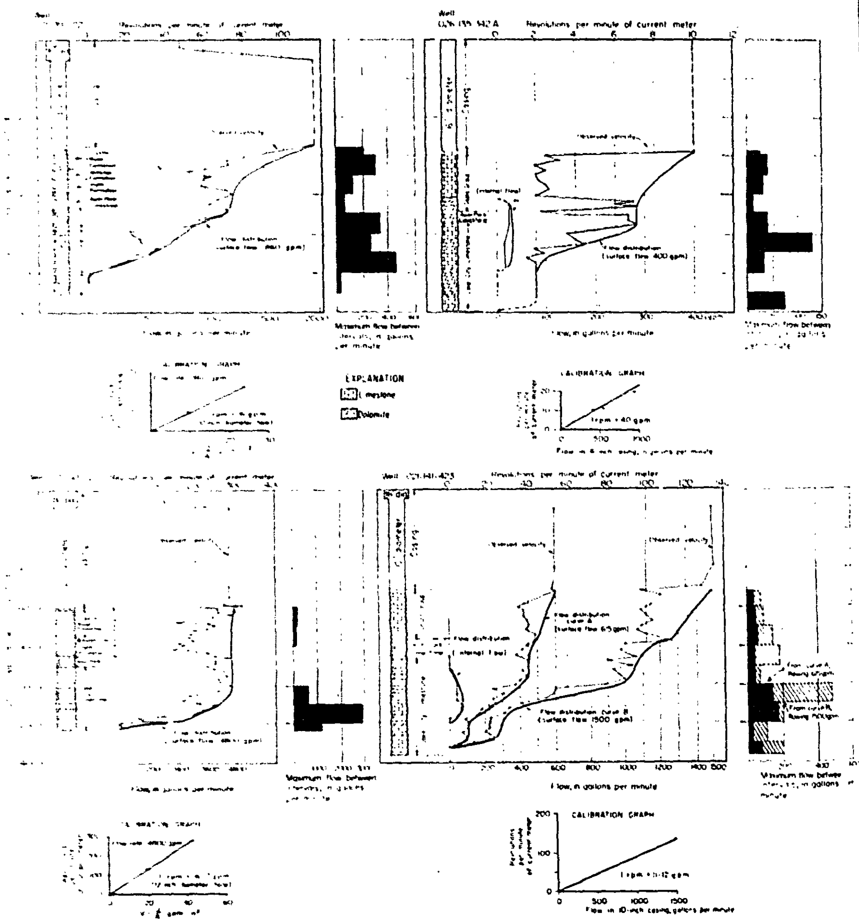

Figure 8. Diagrams showing geologic and current-meter data from wells in Duval County.

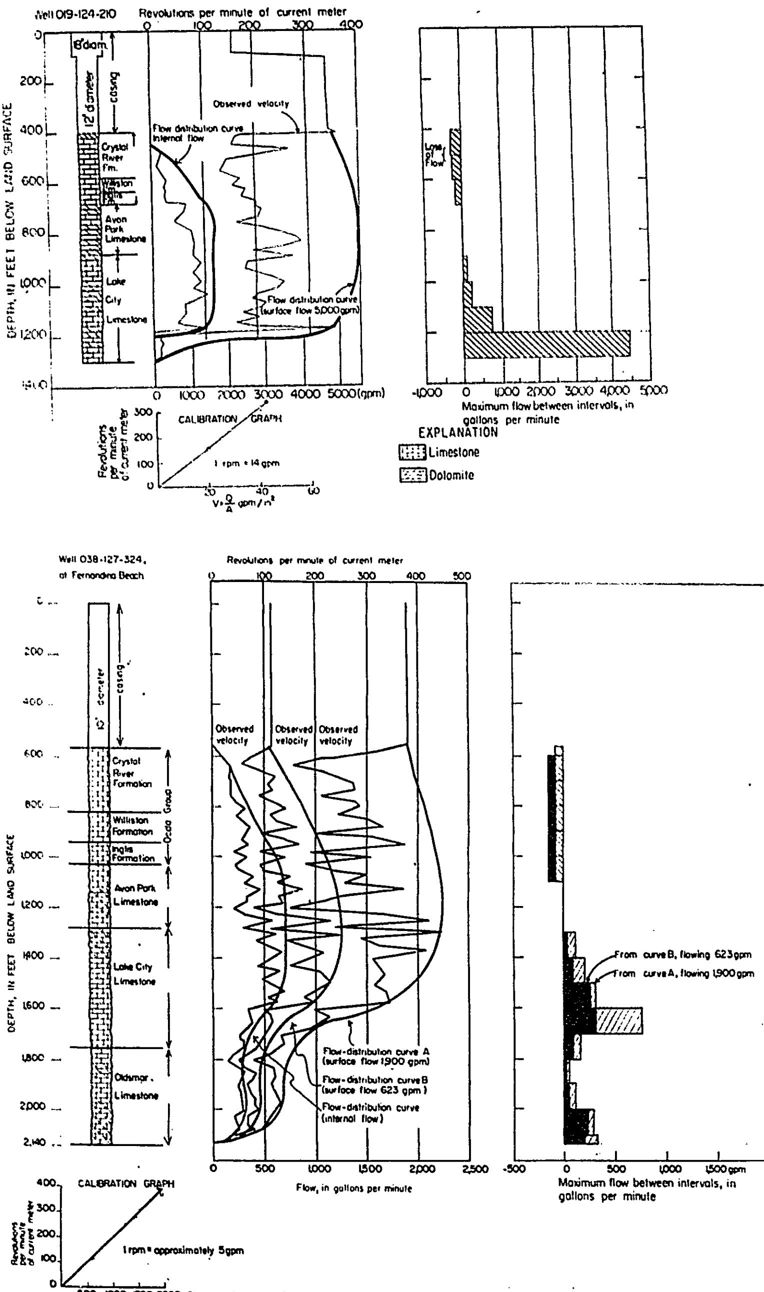

Figure 9. Diagrams showing geologic and current-meter data from wells in Duval and Nassau counties.

containing water under different artesian pressure are separated by hard, relatively impermeable limestone and dolomite beds within the aquifer system.

CURRENT-METER STUDIES

In order to determine the depth, thickness, and relative yield of the different water-bearing zones or separate aquifers within the Floridan aquifer system, current-meter traverses of several wells in the area were analyzed by flow-distribution curves. The relative velocity of the water at different depths in a well was determined from current-meter traverses. The actual rate of flow of water at different depths is calculated by the formula $q = av$, in which **q** is the quantity of water per unit time, **a** is the cross-sectional area of the well at a given depth, and v is the mean velocity of water at that depth as indicated by the current meter. Because the cross-sectional area of a well bore is not the same at all depths below the casing, relative velocity graphs are insufficient to determine **q**. The flow-distribution curve is constructed from the velocity graph by connecting the points of maximum velocity on the graph. The velocity is a maximum where the diameter is a minimum, which is generally where the resistant hard limestones and dolomites occur. Inasmuch as the minimum diameter of the well is about the diameter of the bit used in drilling the well, the diameter of these zones can only be equal to or greater than the diameter of the bit. The flows calculated at these hard zones using the bit diameter will be equal to or less than actual flow. Therefore, these zones, which are all assumed to have the same diameter, are utilized as markers in constructing flow-distribution curves. The configuration of the curves also depends on the geologic characteristics of the formations penetrated by the well.

Figures 8 and 9 show the geologic data, relative velocities, flow distribution, and relative yield or loss of water between regular intervals of the Floridan aquifer system for six wells in Duval and Nassau counties. The flow-distribution graphs were drawn by determining the rate of flow from the flow-distribution curves for each well at approximately 100-foot intervals below the casing. The increase or decrease in the rate of flow over each interval indicates the quantity of water that entered or left the well bore within that interval. The current meter was calibrated in each well to convert relative velocity to rate of flow by recording the revolutions per minute of the meter while water flowed or was pumped at different rates, or by recording the revolutions per minute of the current meter in two casings of different diameters in each well while the rate of flow was kept constant.

The flow-distribution curves and bar graphs for wells 021-139-222, 021-141-423, 025-143-220, and 026-135-342A indicate at least two separate permeable zones in the Floridan aquifer system. One zone is in the Ocala Group at depths between the bottom of the casing in each well and about 800 feet below land surface. The other zone is in the Lake City Limestone at depths between about 950 feet and 1,200 feet below land surface. These two zones are separated by about 100 to 200 feet of hard limestone and dolomite, mostly in the Avon Park Limestone but also at the base of the Ocala Group and at the top of the Lake City Limestone. Within this impermeable zone little or no water enters the wells. A third permeable zone occurs within the Lake City Limestone between about 1,250 feet below the surface and the bottom of wells 021-141-423 and 026-135-342A. This third permeable zone is separated from the overlying permeable zone by about 100 feet of impermeable hard limestone and dolomite in the Lake City Limestone.

As shown by the flow-distribution curves and the bar graphs in figures 8 and 9, the yield of water from the permeable zones in the Ocala Group is considerably less than that from the other, deeper zones. Generally, less than 30 percent of the total water produced from each well comes from the Ocala Group. In well 025-143-220, less than 200 gpm of the 4,800 gpm produced by natural flow is from the Ocala Group. The major water-bearing zone in the wells tested in the vicinity of Jacksonville is in the Lake City Limestone at depths between about 950 feet and 1,200 feet below land surface. As shown by the flow-distribution curves and the bar graphs in the figure, this zone yields 50 to 98 percent of the water produced by each well. In wells 021-141-423 and 026-135-342A, the flow-distribution curves and bar graphs show that about 15 to 20 percent of the water from each of these wells comes from the aquifer in the Lake City Limestone at depths of more than 1,250 feet below land surface.

In well 019-124-210 at Atlantic Beach, the water-producing zone between 1,100 feet and 1,290 feet below land surface in the Lake City Limestone can be correlated with the major water-producing zone in the Lake City Limestone in the vicinity of Jacksonville. In well 038-127-324, at Fernandina Beach, the water-bearing zone between 1,300 feet and 1,700 feet below land surface in the Lake City Limestone can be correlated with the two aquifers in the Lake City Limestone penetrated by the wells tested in the vicinity of Jacksonville. The confining beds separating the two zones in the Lake City Limestone in the vicinity of Jacksonville are absent in Fernandina Beach.

The flow-distribution curves and bar graphs of well 038-127-324, at Fernandina Beach, show that there is another permeable zone in the Floridan aquifer system below the Lake City Limestone, in the Oldsmar Limestone. This zone, which is separated from the overlying zone in the Lake City Limestone by relatively impermeable dolomite beds in the Oldsmar Limestone, yields about one-third of the water produced in the well. It has not been penetrated by any of the wells tested in the vicinity of Jacksonville.

Information obtained while wells 019-124-210, at Atlantic Beach, and 038-127-324, at Fernandina Beach, were being drilled indicates that in both wells the Ocala Group yielded water before the deeper water-bearing zones were reached. However, current-meter traverses made in both wells after they were drilled indicate that the Ocala Group does not yield any water to the wells, but instead, much water from zones of higher artesian pressure in the Lake City Limestone and Oldsmar Limestone flows through the well bore into zones of lower artesian pressure in the Ocala Group. As shown by the flow-distribution curves and bar graphs in well 019-124-210 when there was no flow of water at the surface, about 1,600 gpm entered the Ocala Group through the well bore from the zone in the Lake City Limestone; and when flow was 5,000 gpm at the surface, about 500 gpm entered the Ocala Group. In well 038-127-324, when there was no flow of water at the surface, about 700 gpm entered the Ocala Group through the well bore from the deeper zones; but when the well flow was 623 gpm at the surface, 650 gpm entered the Ocala Group; and when the well flow was 1,900 gpm at the surface, only about 350 gpm entered the Ocala Group.

The great difference in artesian pressures within the Floridan aquifer system in well 019-124-210, at Atlantic Beach, and well 038-127-324, at Fernandina Beach, and to a lesser extent in wells in the vicinity of Jacksonville, indicate that in these areas the confining beds are extensive and the zones are separated and somewhat isolated from each other. Presently, the deeper zones yield more water, under higher pressure, than the zones in the Ocala Group. However, as additional wells are drilled or deepened into the deeper zones, internal leakage within the well bores and withdrawal of water from the lower aquifers will probably equalize the pressures in the upper and lower zones.

WATER SUPPLIES

Wells in the Floridan aquifer are generally cased to the top of the aquifer, which in most areas is the top of the Crystal River Formation. The wells are then completed without casing into the Floridan aquifer system so that water may enter the open hole from the various water-bearing zones penetrated. The diameter of the casings ranges from 2 inches in small domestic wells to as large as 20 inches in some industrial wells.

The approximate depth to the top of the Floridan aquifer system in Duval and Nassau counties is shown in figure 5. The figure also shows contours on the top of both the Crystal River Formation and the Avon Park Limestone. Exact depths to the top of the Floridan aquifer system can be computed for any specific locations in the area by using the contours on the top of the Crystal River Formation in figure 5 in conjunction with the land-surface altitude.

The Ocala Group is the first permeable zone in the Floridan aquifer and its thickness may be determined at any specific location in the area by comparing the contours on the top of the Crystal River Formation and on the top of the Avon Park Limestone. This thickness added to the depth below land surface to the top of the Floridan aquifer system and the approximate thickness of the Avon Park Limestone, taken from the geologic cross sections (fig. 4), is the approximate depth to the major water-producing zone in the Lake City Limestone.

The yield of wells in northeast Florida depends greatly on the depth of the wells. Wells drilled into the deeper zones in the Floridan aquifer system generally yield more water than those drilled only into the shallower zones. Table 4 shows the artesian flow and pressure in five Jacksonville municipal wells recorded before and after each well was deepened to penetrate the major water-producing zone in the Lake City Limestone. In each well there was a considerable increase in yield by natural flow and in artesian pressure after the wells were deepened. Wells 020-139-413 and 020-139-322, in central Jacksonville, originally penetrated about 520 feet of the Floridan aquifer system, which includes the permeable zones in the Ocala Group and the top of the permeable zone in the Lake City Limestone. After these wells were deepened

TABLE 4. Artesian flow and pressure in five Jacksonville municipal wells before and after each well was deepened.

Well number and location	Depth of well (feet)		Amount deepened (feet)	Flow (thousand gpd)			Pressure (lb/ft^2)		
	Before deepened	After deepened		Before	After	Increase	Before	After	Increase
018-139-231 Cedar St. between Flagler and Naldo Sts.	1,048	1,307	259	1,985	3,420	1,435	15	16	1
018-142-211 Corner of Plum and Shearer Sts.	1,040	1,246	206	1,914	4,338	2,424	15½	17½	2
020-139-322 Corner of Fourth and Pearl Sts.	1,009	1,249	240	468	1,900	1,432	5	14	9
020-139-413 Corner of Third and Silver Sts.	1,039	1,244	205	647	1,988	1,341	8	15	7
021-141-423 Corner of Fairfax and 20th Sts.	1,050	1,356	306	1,732	2,707	975	10	11½	1½

to penetrate about 750 feet of the aquifer system to include most of the second permeable zone in the Lake City Limestone, the artesian flow increased about 300 and 400 percent, respectively, and the artesian pressure virtually doubled.

The yield of wells in the Floridan aquifer system in Duval and Nassau counties depends upon well construction, the artesian pressure head, and the water-transmitting capacity of the zones penetrated by the well. The average yield by natural flow of typical small domestic wells between 2 and 6 inches in diameter is generally less than 500 gpm. However, some 6-inch wells yield as much as 1,000 gpm. The average natural flow of wells between 8 and 12 inches in diameter is generally less than 2,000 gpm. In some 10- and 12-inch-diameter wells in the deeper zones the natural flow may be as much as 5,000 or 6,000 gpm. Some industrial wells between 14 and 20 inches in diameter in Fernandina Beach and in the vicinity of Jacksonville are equipped with deep turbine pumps and continually yield 4,000 to 5,000 gpm.

RECHARGE AND DISCHARGE

The general areas of recharge and discharge and the direction of ground-water movement were determined by constructing a contour map on the piezometric surface. A piezometric surface is an imaginary surface to which water from an artesian aquifer will rise in tightly cased wells that penetrate the aquifer. The ground water moves from recharge areas, where the piezometric surface is relatively high, to discharge areas, where the piezometric surface is relatively low, in a direction approximately perpendicular to the contour lines.

Figure 10 shows a generalized map of the piezometric surface of the Floridan aquifer in Florida. The principal recharge area of the aquifer system in northeast Florida is the area marked by a piezometric high in western Putnam and Clay counties and eastern Alachua and Bradford counties. Within this recharge area water enters the Floridan aquifer through breaches in the aquiclude caused by sinkholes, by downward leakage where the aquiclude is thin or absent, and directly into the aquifer where it is exposed at the surface. From this recharge area, the piezometric surface slopes toward discharge areas. In Duval and Nassau counties, water is discharged from the Floridan aquifer system primarily by numerous wells that penetrate the aquifer system. There is

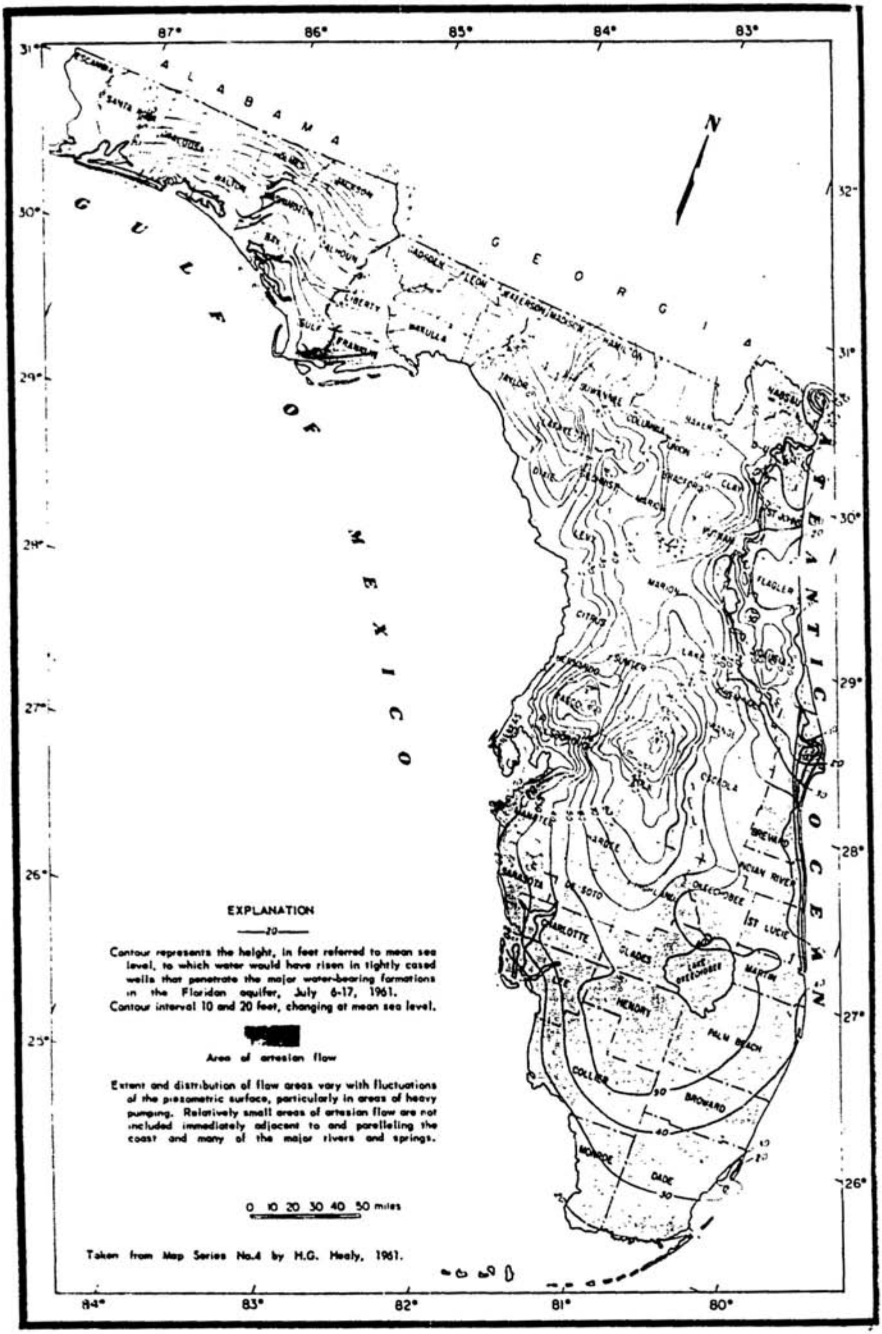

Figure 10. Map of Florida showing the generalized piezometric surface of the Florida aquifer.

probably natural discharge from the aquifer system into the Atlantic Ocean off the coast of northeastern Florida.

Artesian pressures rise in response to recharge and decline in response to discharge. Water levels in wells close to recharge areas show more response to rainfall than those further away. The reduction of artesian pressure induced by a discharging well decreases with distance from the well.

The effect of variations in discharge on artesian pressure head in wells in Duval and Nassau counties is shown in figure 11. Well 019-140-421 is near the center of the discharge area at Jacksonville. The monthly municipal pumpage at Jacksonville compared with the hydrograph for well 019-140-421 shows that as the pumpage increases the artesian pressure in well 019-140-421 declines, and vice versa. Seasonal fluctuations of more than 10 feet are common, particularly during the late spring and summer when municipal pumpage is greatest. Well 033-150-242 is at Callahan, more than 20 miles from the heavily pumped areas at Jacksonville and Fernandina Beach. At this distance from the center of the discharge area, the seasonal fluctuations due to pumping are small and do not mask the fluctuations in response to recharge by rainfall. A comparison of the average monthly and annual rainfall at three stations in the recharge area with the hydrograph of well 033-150-242 shows that periods of relatively high and low artesian pressure in well 033-150-242 generally occur about 6 months after corresponding periods of high and low rainfall. This lag probably indicates the time necessary for the rainwater to leak into the Floridan aquifer system. The greatest declines in artesian head in well 033-150-242 occurred during the years of least rainfall and the greatest increases in head occurred during years of highest rainfall. It is possible that pumpage at Jacksonville and Fernandina Beach, both more than 20 miles from this well, also affect the rise and decline of artesian head to some extent.

The effects of discharge in northeast Florida on the piezometric surface of the artesian aquifer system are shown in detail in figure 12. As artesian pressures are continually changing, the altitude and configuration of the piezometric surface in 1962 shown in this figure are only an approximate representation of the surface.

The closed contour lines at Fernandina Beach and in the vicinity of Jacksonville (fig. 12) indicate depressions in the piezometric surface. These depressions, termed "cones of depression," are a result of well discharge which lowers the artesian

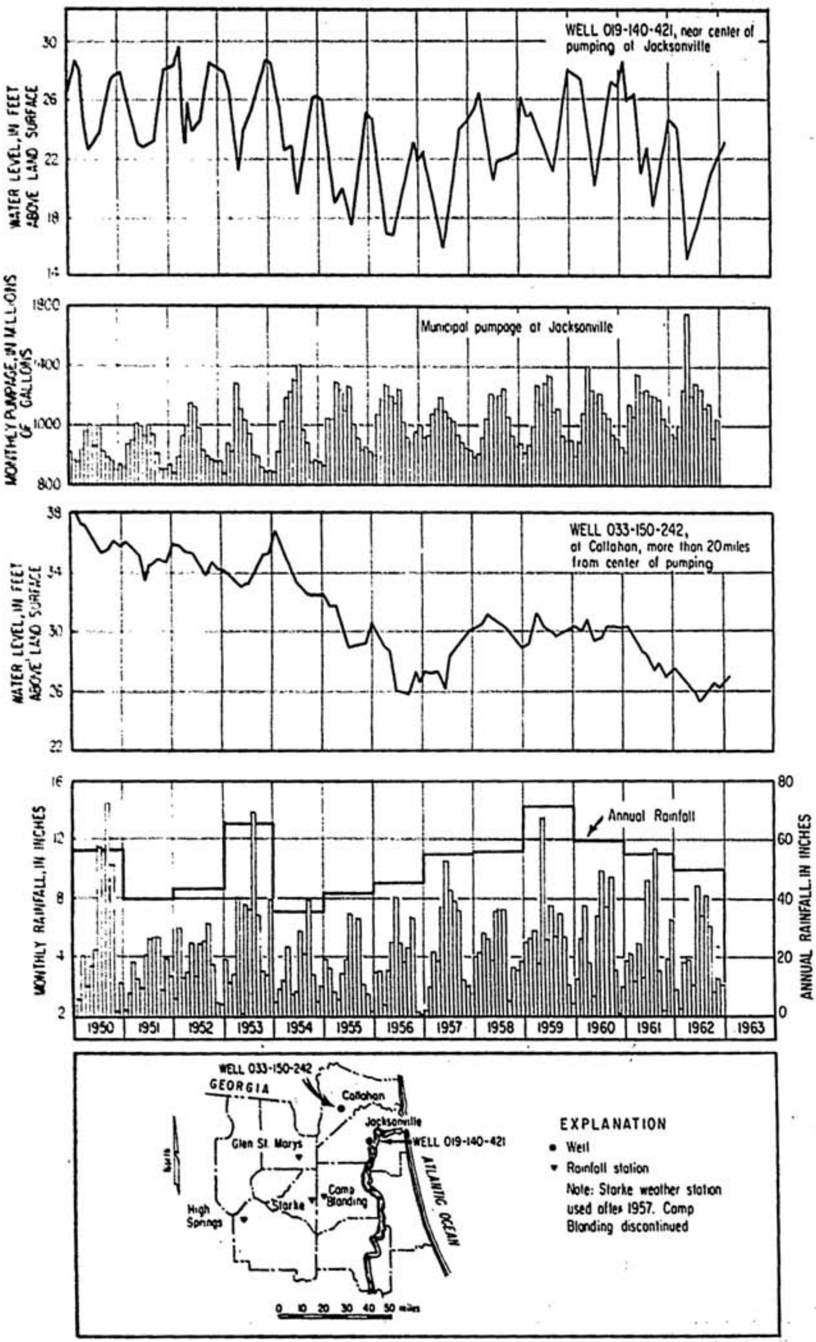

Figure 11. Graphs showing relation of water levels in wells 019-140-421 and 033-150-242, to pumping and precipitation, Jacksonville area, Fla.

head, thus creating a hydraulic gradient toward the points of discharge. In Jacksonville, the altitude of the piezometric surface within the center of the cone of depression is less than 20 feet above sea level and the hydraulic gradient toward the center of the cone is irregular. The slightly steeper gradient on the west side of the cone indicates recharge to the aquifer system from the west. The north-south elongation of the cone of depression may indicate that recharge from the west is partially blocked in the aquifer by the geologic fault. (See figs. 4 and 5). The cone of depression is partly prevented from expanding to the west of the fault and, therefore, expands to the north and south of the center of discharge.

About 3 miles northeast of Jacksonville, at Eastport, withdrawals by industrial wells have created a relatively small cone of depression. In this area, the altitude of the piezometric surface has been depressed to about 30 feet above sea level. Along the coast, east of Jacksonville, discharge from municipal and private wells has lowered the piezometric surface to less than 40 feet above sea level.

The most pronounced depression in the piezometric surface shown on figure 12 is at Fernandina Beach, where it is below mean sea level over an area of about 15 square miles and is more than 15 feet below sea level over about 3 square miles of the area. As shown by the configuration of the 40-foot contour line in central Nassau and north-central Duval counties, the piezometric surface has been depressed as far as 20 miles southwest of the center of the cone of depression by discharge from wells at Fernandina Beach. The steeper hydraulic gradient on the east side of the cone may indicate either recharge to the aquifer system from that direction or rocks with better water-transmitting properties east of the center of the depression.

AREA OF FLOW

Figure 12 also shows the approximate areas of artesian flow in northeast Florida in May 1962. Artesian wells flow where the piezometric surface stands higher than the land surface. As shown on the figure, artesian flow occurs principally on the low coastal plain in eastern and central Duval and Nassau counties. Areas on the coastal plain in which the wells will not flow are on high sand ridges east of Jacksonville, where the land surface is higher than the piezometric surface, and in the vicinity of Jacksonville and Fernandina Beach, where the piezometric surface has been depressed below land surface by discharging wells. In the hilly uplands in western Duval and Nassau counties and in Baker County, artesian flow occurs only in wells along some stream valleys.

Because the altitude of the piezometric surface is continuously changing, the area of flow shown on figure 12 is only an approximation of the area of flow at other times. The greatest changes in the areas of flow occur in the vicinity of Jacksonville and Fernandina Beach, where the piezometric surface is about the same as the land surface. A slight decrease or increase in the altitude of the piezometric surface considerably reduces or increases the area of flow in these areas.

WATER USE

All the public water and most of the industrial and private water supplies in Duval and Nassau counties are obtained from wells developed in the Floridan aquifer system.

PUBLIC WATER USE

Jacksonville is one of the largest cities in the world to obtain its entire water supply from deep artesian wells. The city uses water from 46 wells whose depths range from about 1,000 to 1,500 feet. Water from seven well fields in the city is pumped into seven elevated reservoirs. In 1962 they produced an average of 38 mgd as compared to 27 mgd in 1950.

In addition to municipal wells, there are about 100 privately owned water utilities in the vicinity of Jacksonville, each of which has at least one artesian well. Their combined yield is estimated to average 15 to 20 mgd.

Jacksonville Beach uses an average of about 2 mgd of water that is obtained from seven wells ranging in depth from 600 to 1,000 feet.

Each naval facility in the area has its own water system. U.S. Naval Air Station, Jacksonville, uses water from 12 wells between 400 and 1,096 feet deep, which produce an average of about 3½ mgd. Cecil Field Naval Air Station in western Duval County uses an average of about 700,000 gpd obtained from five wells that range in depth between 800 and 1,350 feet. U.S. Naval Station, Mayport, uses an average of 1½ mgd from two wells about 1,000 feet deep.

Fernandina Beach uses about 1 mgd of water that is supplied by six wells ranging in depth between 700 and 1,200 feet.

Other small towns in the area, such as Hilliard, Callahan, Baldwin, Atlantic Beach, and Neptune Beach, each use water from at least one well drilled into the Floridan aquifer system.

INDUSTRIAL WATER USE

The greatest industrial use of ground water in Duval and Nassau counties is for the processing of wood pulp. In Fernandina Beach, Rayonier Pulp and Paper Inc. uses an average of 32 mgd from 11 wells that range in depth from 1,050 to 1,400 feet. Container Corp. of America uses an average of 21 mgd from six wells between 930 and 1,865 feet deep. In the vicinity of Jacksonville, St. Regis Paper Co. uses an average of 18 mgd from eight wells between 1,350 and 1,400 feet deep.

Other industries in the area that have their own water-supply system from the Florida aquifer system include chemical and paint manufacturing, dairies, laundries, icemaking, shipbuilding and food processing. Many of the larger industries use 5 to 10 mgd.

COMMERCIAL AND PRIVATE WATER USE

Many of the larger commercial buildings and stores have their own wells, which produce water for drinking, heating and cooling, kitchen and toilet, lawn irrigation, and washing. For example, May-Cohens Department Store and the Prudential Life Insurance Building in Jacksonville each uses an average of 60,000 to 80,000 gpd from wells about 750 feet deep.

Numerous private wells, generally 6 inches or less in diameter and less than 750 feet in depth, are scattered throughout Duval and Nassau counties, particularly near Jacksonville and Fernandina Beach. These wells provide water for drinking, lawn irrigation, and swimming pools.

The amount of water produced by all the wells in the Floridan aquifer system in Duval and Nassau counties was estimated on the basis of a general survey of the water used by municipal and private water utilities, major industries, large commerical buildings, and individual well owners. It is estimated that an average of 150 to 200 mgd is discharged from wells in the vicinity of Jacksonville and 50 to 70 mgd from wells at Fernandina Beach.

DECLINE IN ARTESIAN PRESSURE

Artesian pressure has been measured periodically in northeast Florida in 7 wells since before 1934, in 18 wells since 1938, and in 4 wells since 1951. Hydrographs of a few selected wells in Duval and Nassau counties, shown in figures 13 and 14, show the seasonal fluctuations and the long-term trends of the artesian pressure head. All the hydrographs show an irregular but continual decline in artesian head.

The greatest declines in artesian pressure are in wells closest to the center of the cones of depression in Jacksonville and Fernandina Beach. In wells 038-127-344 and 040-126-332 at Fernandina Beach, artesian pressure declined 50 to 60 feet between 1939 and 1963. In wells 018-143-234 and 018-140-123 at Jacksonville, artesian pressure declined about 12 to 22 feet between 1946 and 1963.

Long-term changes in artesian pressure throughout northeast Florida from 1940 to 1962 and short-term changes from July 1961 to May 1962 are shown by contours and cross sections in figure 15. As shown by the contours in the figure, there has been a general decline in the piezometric surface throughout northeast Florida of about 10 feet to more than 25 feet between 1940 and 1962 and from less than 2 to more than 10 feet between July 1961 and May 1962. The cross section of the piezometric surfaces in the figure show that the general slope of the piezometric surface has remained approximately the same except in the vicinity of Jacksonville and Fernandina Beach. In these areas the cones of depression in the piezometric surface have been deepened and considerably enlarged.

The general decline in the artesian pressures in Duval and Nassau counties is attributed primarily to a great increase in the use of artesian ground water in the area and to a lesser extent to relatively long-term declines of rainfall on the recharge areas in northcentral Florida.

Figure 16 shows the average annual rainfall at three stations in the recharge area and the annual discharge of artesian water by municipal wells in Jacksonville from 1940 to 1962. The annual discharge by the city wells is only a fraction of the total amount of artesian ground water discharged by all wells in the Jacksonville area. However, it serves as an index to determine the trend of ground-water discharge. As shown by the bar graphs in the

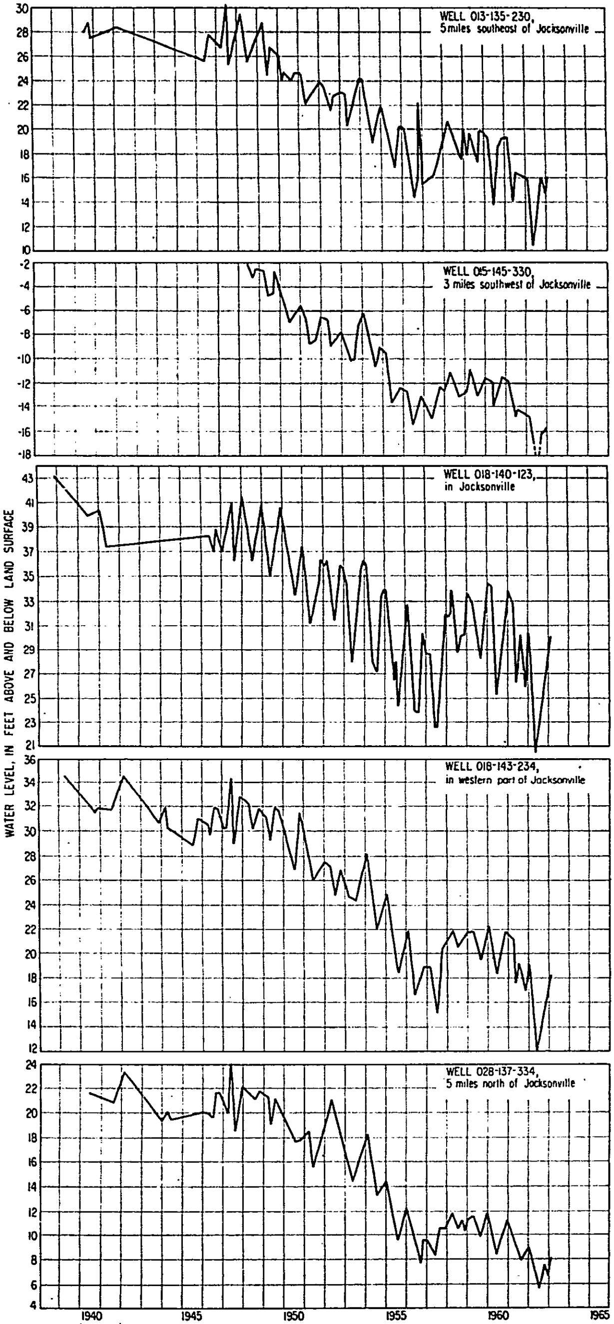

Figure 13. Hydrographs of selected wells in Duval County.

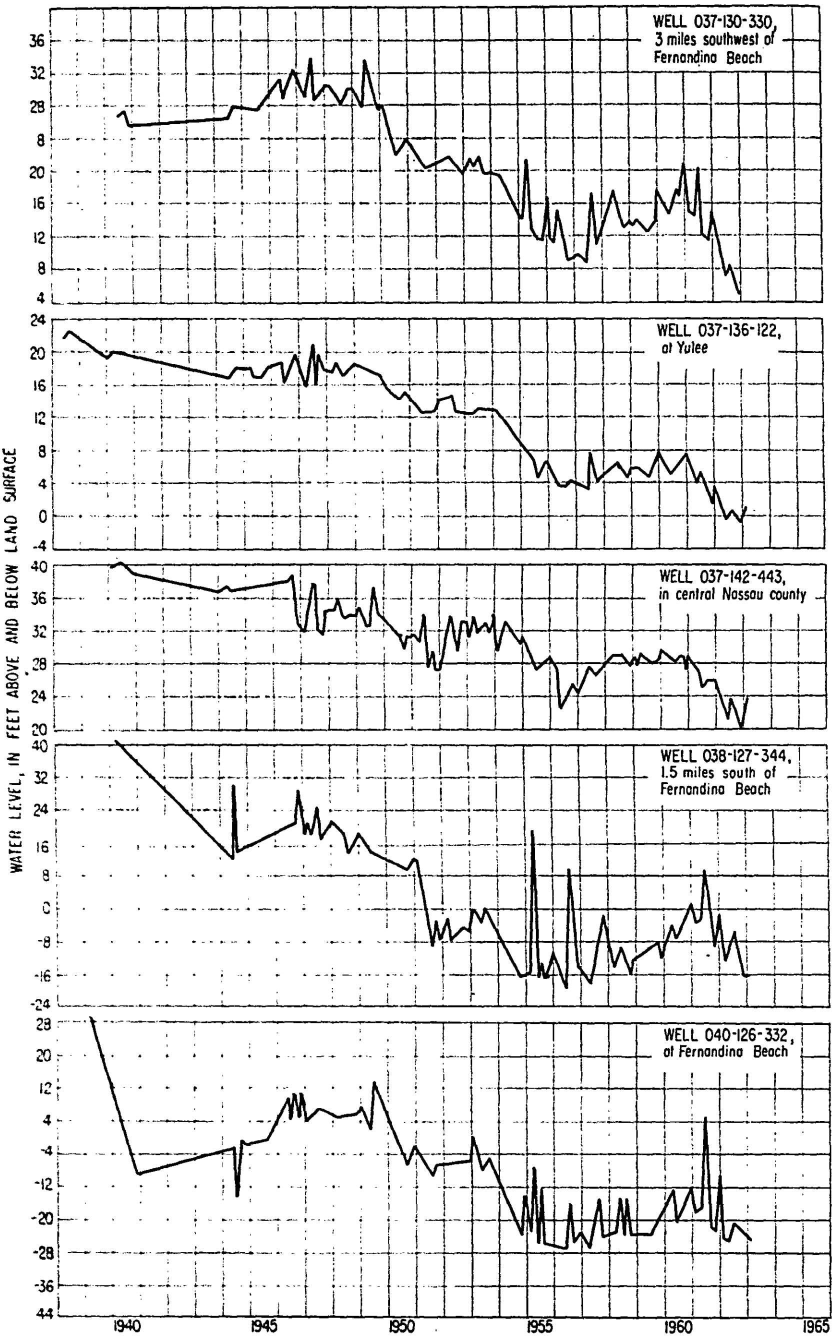

Figure 14. Hydrographs of selected wells in Nassau County.

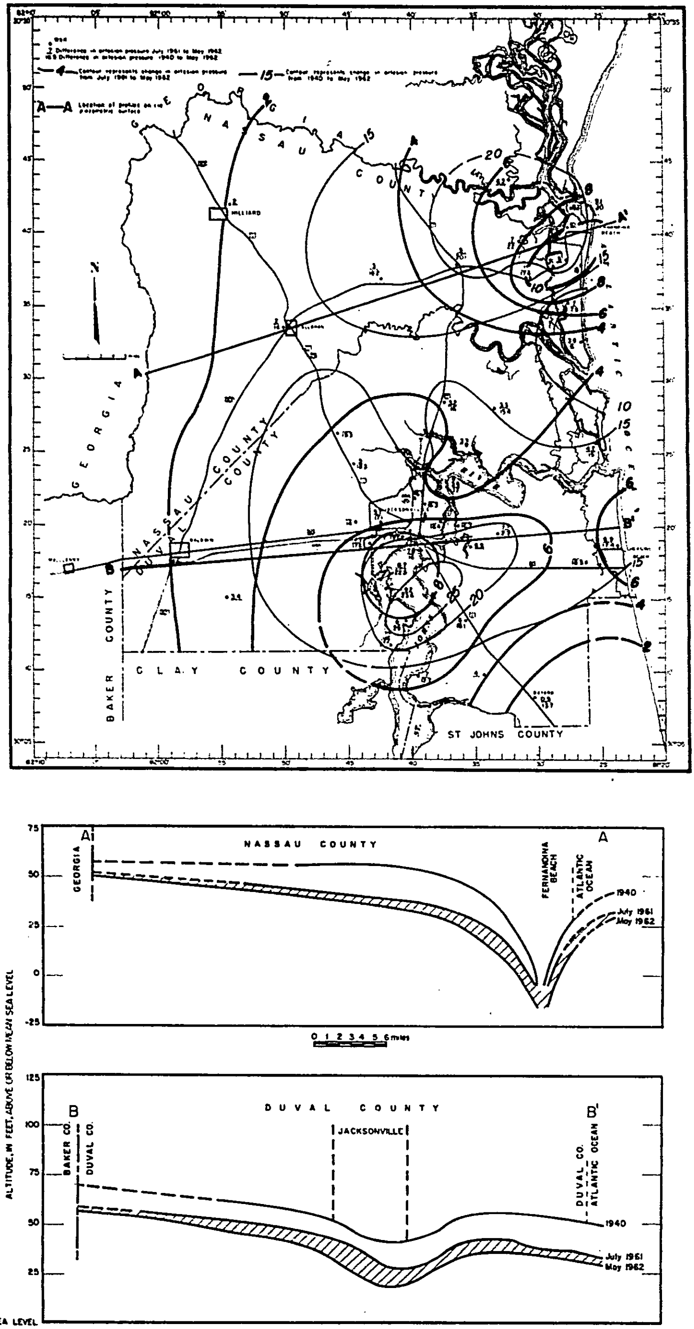

Figure 15. Map and cross sections of Duval and Nassau counties showing the change in artesian pressure from July 1961 to May 1962 and from 1940 to May 1962.

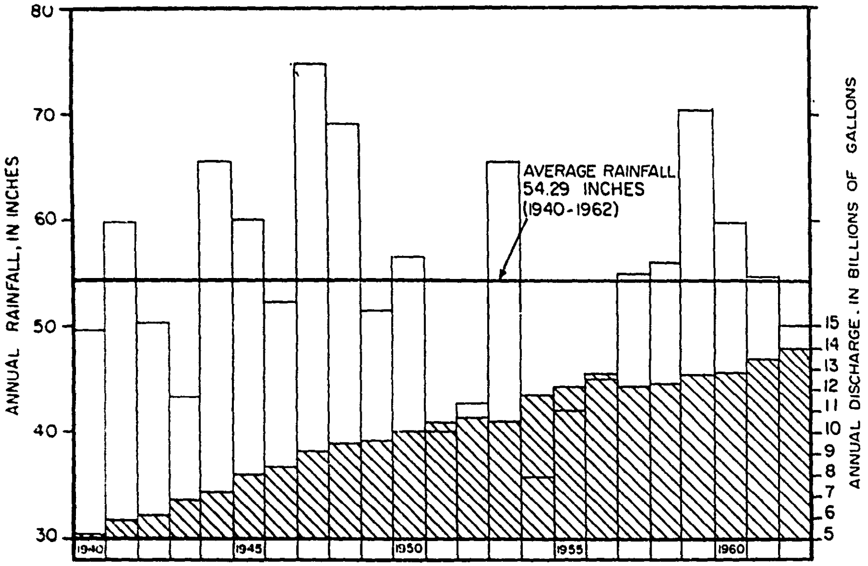

Figure 16. Graph showing annual discharge of artesian water by municipal wells in Jacksonville and average annual rainfall at three weather stations in the recharge area.

figure, pumpage from city wells progressively increased from about 5 billion gallons in 1940 to almost 14 billion gallons in 1962.

A comparison of the rainfall and discharge shown in figure 16 with water levels in wells shown in figures 13 and 14 indicates that between 1940 and 1957 artesian pressures declined even during years of above-average rainfall. This decline was probably due to the progressive increase in the use of ground water. A combination of below-average rainfall and greatly increased discharge during 1954, 1955, and 1956 resulted in the rapid decline of artesian pressures during those years and the low artesian pressures in 1956 and 1957. From 1957 to 1960, above-average rainfall and nearly constant discharge resulted in a slight rise of artesian pressure. However, a decrease in rainfall and steady increase in discharge during 1961 and 1962 caused a rapid decline of artesian pressure in 1962, to the lowest of record in most wells in northeast Florida.

The amount of decline in artesian pressure in northeast Florida varies in the different zones within the artesian aquifer system. Three wells near Jacksonville, 026-135-342A, B, and C, are within 40 feet of each other but product from three different zones. Well

C was developed in a shallow zone, well B was developed in a middle zone, and well A was developed in both of these zones plus a third, deep-lying zone (fig. 7). In these wells the trend of artesian pressures is the same, because the different zones are interconnected through well A, but the artesian pressure in well C, which is developed in the Ocala Group, is always considerably less than the pressure in the other two wells, which tap the deeper zones.

In areas where there is little or no interconnection by wells between the zones in the artesian aquifer system, the difference in decline of artesian pressure in the different zones is even more pronounced. Figure 17 shows hydrographs of wells 038-127-324 and 038-127-142 at Fernandina Beach which are located about 2,000 feet from each other near the center of the cone of depression. The artesian pressures in both wells are drawn down by the many discharging industrial wells in the area. Well 038-127-142 taps only the permeable zone in the Ocala Group and well 038-127-324 taps that zone and the deeper zones in the artesian aquifer system. As shown by the figure, between November 1960 and October 1961 the artesian pressure in well 038-127-142 ranged from only 11 feet above msl to 3 feet below msl,

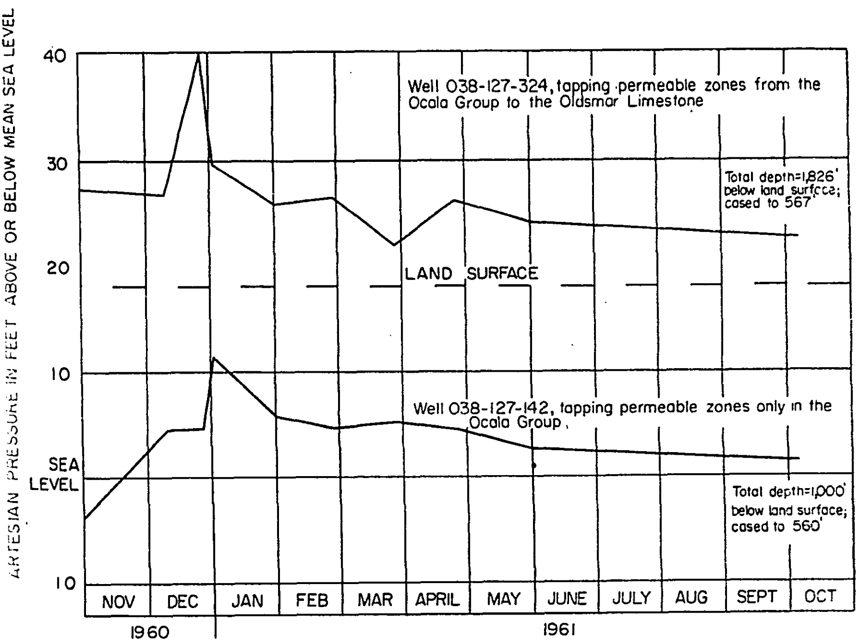

Figure 17. Graphs showing the artesian pressure in two wells at Fernandina Beach.

while during the same period the artesian pressure in well 038-127-324 ranged from 40 to 22 feet above msl. In addition, water in well 038-127-324 remained higher than the land-surface datum while water in the surrounding shallower artesian wells was drawn down below the land surface.

The use of artesian water can be expected to increase and the artesian pressure will continue to decline; however, the amount of decline within a specified period is beyond the scope of this report. The rate of decline will be faster during years of below-average rainfall than during years of normal or above-normal rainfall, and the pressure may even increase during years of above-average rainfall. However, if the rate of discharge in northeast Florida continues to increase, eventually the artesian pressure will probably decline even during cycles of above-average rainfall.

The decline in artesian pressure in Duval and Nassau counties alone is not a serious threat to the availability of water in the area. At the present rate of decline, approximately 0.5 to 2.0 feet per year, it would take 100 to 400 years to lower the water 200 feet in most wells in the Floridan aquifer. This does not mean that the wells would then cease to yield water but merely that they would not flow at the surface, and that they would require pumping to yield water at the surface. A much greater danger than lowered pressure is that highly mineralized water would enter the zone of reduced pressure, either vertically from deeper highly mineralized zones in the aquifer system or laterally from the ocean, and contaminate the existing fresh-water supplies in the aquifers.

QUALITY OF WATER

The chemical character of ground water depends largely upon the type of material with which the water comes in contact and upon mixing with other water. Rainfall is only slightly mineralized when it first enters the ground; but as it moves through the ground, it dissolves mineral matter from the rocks it contacts.

Table 5 shows analyses of water from wells that do not penetrate the Floridan aquifer system in the area and table 6 shows analyses of water from wells that do penetrate the Floridan aquifer. The dissolved chemical constituents are expressed in parts per million; 1 ppm is equivalent to a pound of dissolved matter in a million pounds of water; specific conductance is expressed in reciprocal ohms (mhos); hydrogen-ion concentration is expressed

TABLE 5. Analyses of water from aquifers overlying the Floridan aquifer system in Duval and Nassau counties.

Source of analysis: (1) Container Corp. of America; (2) Florida State Board of Health; (4) Southern Analytical Laboratory, Jacksonville.

(Chemical analyses in parts per million except pH and color.)

Well number	Date of collection	Depth of well (feet)	Depth of casing (feet)	Iron (Fe)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$ (total) Calcium, magnesium	Hardness as $CaCO_3$ (total) Noncarbonate	pH	Color	Source of analysis	Remarks
DUVAL COUNTY																					
014-143-180	1-18-53	185	----	0.3	----	44	9	----	----	----	176	0	9	0.7	185	144		7.6	5	(2)	
	6-23-53	185	----	.1	----	46	10	----	----	----	188	0	6	.7	210	158		7.5	5	(2)	
016-137-100	10-30-53	70-100	----	1.5	----	52	6	----	----	----	303	0	19	----	337	154		7.1	5	(2)	
016-138-310	2-20-55	99	----	----	----	34	9	----	----	----	151	10	11	.05	159	124		7.1	5	(2)	
018-135-340	7-20-53	80	----	2.1	----	63	11	----	----	----	249	----	10	.4	280	202		7.2	5	(2)	
019-135-480	6-17-53	200	----	----	----	39	7	----	----	----	132	----	18	.1	290	124		7.5	5	(2)	
021-136-400	8-14-50	90	----	0.2	----	39	11	----	----	----	176	0	11	.1	195	142		7.6	5	(2)	
021-142-100	6- 6-58	80	----	3.0	----	63	12	----	----	----	224	17	19	.25	280	216		7.3	100	(2)	
023-129-330	4- 8-57	200	----	0.07	----	36	5	----	----	----	146	6	16	.15	146	112		7.5	5	(2)	
	2-20-59	200	----	.06	----	42	8	----	----	----	139	2	15	.15	152	138		7.4	10	(2)	
024-141-340	6-27-49	70	----	----	----	46	12	----	----	----	156	0	8	----	265	165		8.1	----	(2)	
NASSAU COUNTY																					
028-156-100	6- 3-37	201	100	0.60	26	94	8.9	----	----	----	0	0	17	----	340	270		----	----	(4)	Na + K + CO_3 = 17 ppm
028-156-100	6-23-37	96	96	.20	22	104	15	----	----	----	0	96	19	----	444	323		----	----	(4)	Na + K + CO_3 = 29 ppm
040-127-211	11- 1-56	93	----	.3	26	----	----	----	----	----	----	66	----	----	290	138		7.9	----	(1)	

in standard pH units; and color is in units defined by the standard platinum cobalt scale. In all analyses determined by the Florida State Board of Health, the total dissolved-solids content was found by weighing the residue after the water had evaporated at 103° to 105°C and in all other analyses the total dissolved-solids content was found from the residue after evaporation of the water at 180°C.

QUALITY OF WATER IN THE SHALLOW AQUIFER SYSTEM

Water in the shallow aquifer system is generally not as hard and contains less dissolved mineral matter than water from the Floridan aquifer system in the same area. The sulfate content is generally negligible and the amount of magnesium is considerably smaller than the calcium content. The iron content of water from the shallow aquifers is generally greater than that from the Floridan aquifer system in the same area.

In some parts of northeast Florida, the chemical composition of the water from both the shallow aquifer system and the underlying Floridan aquifer system is similar. For example, the water in both the shallow and Floridan aquifers is similar in western Nassau County, where the Floridan aquifer is closer to the recharge area and the water is not as highly mineralized as in the central or eastern part of the area. The water in both aquifer systems is similar in sections of eastern Duval and Nassau counties, where water from the shallower aquifers has been mineralized by mixing with bodies of brackish surface water or sea water.

Water from the shallow aquifers is generally suitable for domestic use and for most industrial uses. Because it contains relatively few impurities, it does not generally require treatment though it occasionally contains enough iron to impart a bad taste and to stain household equipment, clothes, and buildings. Iron can be removed from water by aeration or chlorination followed by filtration.

QUALITY OF WATER IN THE FLORIDAN AQUIFER SYSTEM

The chemical analyses of water from 50 selected wells that penetrate the Floridan aquifer system in the area (table 6) show that the quality of the water varies according to location, depth of the aquifer sampled, and date of sampling.

TABLE 6. Analyses of water from the Floridan aquifer in Duval, Nassau, and Baker counties.

Source of analysis: (1) U.S. Geological Survey; (2) Florida State Board of Health; (3) Black Laboratories Inc.; (4) Commercial Chemists, Inc.; (5) Southern Analytical Laboratory, Inc.; (6) St. Regis Paper and Pulp Co.; (7) Pittsburgh Testing Laboratory; (8) Rayonier Inc.; (9) Permuit Co.

Dissolved solids: Residue at 103°C State Board of Health analyses. Residue at 180°C for all other analyses.

(Chemical analyses in parts per million except pH and color.)

Well number	Date of collection	Depth of well (feet)	Depth of casing (feet)	Iron (Fe)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color	Source of analysis	Remarks
											DUVAL COUNTY													
008-130-310	6-16-25	353	......	0.19	28	......	......	......	......	......	172	187	18	......	......	......	478	336	......	......	......	......	(1)	
013-135-400	6- 8-60	610	510	.10	......	71	37	......	......	......	162	188	21	......	......	......	451	330	......	......	7.1	5	(2)	
013-140-414A	6-20-62	1,005	380	.01	18	52	22	8.8	2.4	0.00	138	101	10	0.5	0.1	0.1	354	220	107	461	7.9	2	(1)	
013-140-414B	6-20-62	708	......	.00	18	42	21	9.7	2.3	.00	137	74	10	.6	.1	.5	301	192	80	404	7.7	3	(1)	
013-153-240	1942	990	......	.02	17	29	12	......	......	......	124	27	6.5	......	......	......	163	122	20	......	......	......	(3)	NA + K = 7.6 ppm
	1-18-54	990	......	.02	14	27	12	8.1	......	.00	124	22	6.0	.5	.0	......	148	117	15	258	7.6	4	(1)	
015-138-230	10-10-49	1,187	757	......	......	68	6	......	......	......	158	165	15	......	......	......	456	287	......	......	7.9	6	(3)	Crystal River Fm. cased off
	6-13-62	1,187	757	.00	21	75	31	14	2.3	.00	156	176	16	.8	.0	......	477	314	186	634	7.6	5	(1)	
	1-17-63	1,187	757	.00	......	63	32	......	......	.00	161	134	8	.65	......	......	447	314	184	......	7.6	5	(2)	

TABLE 6. (Continued)

Well number	Date of collection	Depth of well (feet)	Depth of casing (feet)	Iron (Fe)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color	Source of analysis	Remarks
015-138-314	6-13-62	1,264	470	.00	22	74	28	14	2.0	.00	164	154	15	.7	.0	—	442	300	165	605	7.7	5	(1)	
015-145-280	2-22-61	1,000	460	.5	1	35.7	15.7	—	—	—	—	34.6	14.2	.6	—	—	228	154	83	—	7.7	3	(4)	Na + K = 37 ppm
017-126-440	10- 8-56	400	—	.93	—	76	33	—	—	—	183	193	20	.65	—	—	548	328	—	—	7.3	5	(2)	
	4-11-58	400	—	.1	—	77	34	—	—	—	170	193	19	.75	—	—	572	334	—	—	7.3	5	(2)	
017-135-418	6-28-39	785	524	.008	19.4	75	31	—	—	.00	163	210	10	.45	—	—	490	312	178	—	8.2	1	(5)	Na + K = 25 ppm
017-138-142	6-13-62	1,500	—	.00	21	75	30	13	1.9	.00	156	168	16	.8	.0	—	448	310	182	634	7.7	5	(1)	
017-158-430	10-29-42	750	433	—	19	31	12	—	—	—	137	22	8	—	—	—	170	127	15	—	—	—	(3)	Na + K = 9.0 ppm
	11- -50	750	433	—	26	40	20	—	—	—	205	18	38	—	—	—	263	182	—	—	7.1	—	(3)	Na + K = 27 ppm
017-158-110	1-16-63	630	—	.1	—	34	14	—	—	—	129	12	25	.45	—	—	232	144	38	—	7.0	5	(2)	
018-124-222	9-24-41	622	382	.12	23	72	35	12	3.4	.00	160	190	14	.7	.30	—	455	324	—	—	—	—	(1)	
018-136-241	1-10-42	685	508	0.55	—	66	28	—	—	—	166	146	15	—	—	—	379	272	—	—	7.5	5	(2)	
018-138-343	5-20-50	1,348	504	—	21	75	31	12	—	—	167	184	8	—	—	—	438	313	—	—	7.5	—	(1)	
	3-31-60	1,348	504	—	—	—	—	12	—	0.00	164	—	11	—	—	—	462	320	186	631	7.8	—	(1)	
019-124-210	8- 7-62	1,300	407	.4	—	55	26	—	—	—	183	158	27	0.65	—	—	450	248	98	—	7.6	10	(2)	
019-139-230	9-27-41	655	491	1.9	21	79	33	11	3.2	.00	151	209	14	.7	0.00	—	468	332	—	—	—	—	(1)	
	9-31-60	655	491	—	—	—	13	—	—	.00	71	—	12	—	—	—	100	47	0	169	7.0	—	(1)	
020-139-443	9-27-41	1,250	—	—	27	61	23	—	—	—	178	96	16	—	—	—	325	246	—	—	—	—	(1)	
	5-20-50	1,250	—	—	—	60	22	—	—	—	190	83	14	—	—	—	348	240	—	—	7.6	—	(1)	
	3-31-60	1,250	—	—	—	—	13	—	—	.00	188	—	18	—	—	—	349	244	90	519	7.6	20	(1)	
	8-29-61	1,250	—	.15	26	60	22	14	1.6	.00	187	87	17	.7	.0	—	373	240	87	504	7.9	5	(1)	
022-130-112	12- 4-62	1,000	462	.2	—	64	26	—	—	—	190	63	19	.65	—	—	412	270	114	—	7.6	10	(2)	

025-125-231	9-26-41	840	450	.06	31	73	36	47	3.4	.00	186	142	94	.6	.05	..	574	330	....	.....	....	...	(1)	
025-138-210	6- 3-41	992	660	.02	—	56	24	—	—	.00	189	64	20	—	.0	—	262	238	—	—	..	15	(1)	Na + K = 5.2 ppm
	1- 9-43	992	660	.10	26	76	24	—	—	—	197	72	4	—	—	—	308	289	—	—	7.2	—	(1)	
	5-20-50	992	660	.08	27	55	24	—	—	—	204	98	22	—	—	—	317	236	—	—	7.4	-	(1)	Na + K = 6.4 ppm
	6-10-58	992	660	.07	—	55	22	—	—	—	163	63	26	.45	—	—	392	232	98	—	7.8	5	(2)	
26-135-342A	10-20-55	1,393	584	—	20	66	23	—	—	.00	166	67	—	—	—	—	318	258	—	—	7.9		(6)	
	6-13-62	1,393	584	0.25	20	30	22	17	2.00	.00	140	48	22	.6	.0	—	254	166	51	385	8.0	5	(1)	
26-135-342B	10-20-55	700	450	.0	27	60	25	—	—	—	162	69	—	—	—	—	322	252	—	—	7.7	—	(6)	
	6-13-62	700	450	.01	18	53	22	17	1.2	.00	200	48	21	.7	.0	—	310	222	58	438	8.0	5	(1)	
26-135-342C	10-20-55	1,025	850	.5	28	61	24	—	—	.00	164	67	—	—	—	—	320	252	—	—	7.9	—	(6)	Crystal River Fm.
	6-13-62	1,025	850	.00	1.6	11	4.3	—	—	.00	54	0	—	—	—	—	90	45	0	165	8.0	5	(1)	cased off
026-145-420	9-10-42	658	—	.5	31	57	25	—	—	—	200	84	23	—	—	—	351	245	—	—	7.25	—	(3)	Na + K = 18 ppm
028-137-334	11- 8-52	500+	—	.1	30	53	—	9	—	—	183	2	18	—	—	—	212	136	—	—	7.8	—	(7)	

NASSAU COUNTY

023-056-430	9-20-50	650	—	—	33	83	12	—	—	—	342	1.3	22	—	—	—	348	258	—	—	—	—	(3)	Na + K = 25 ppm
033-149-140	9- 4-59	600 800	—	0.11	—	61	33	—	—	—	192	53	25	0.55	—	—	503	290	132	—	7.8	10	(2)	
037-136-122	9-10-42	1,000	450	.60	35	63	37	—	—	—	200	148	28	—	—	—	456	309	—	—	7.3	—	(2)	Na + K = 22 ppm
038-126-320	6-25-37	1,203	572	.40	—	64	37	—	—	—	198	177	33	—	—	—	—	312	—	—	7.2	—	(2)	Na + K = 37 ppm
	5-30-50	1,203	572	—	34	68	38	—	—	—	195	168	30	—	—	—	478	326	—	—	7.5	—	(2)	Na + K = 25 ppm
	4-17-56	1,203	572	—	—	79	35	—	—	—	158	—	34	—	—	—	504	343	—	—	—	-	(2)	
	12- 6-56	1,203	572	—	—	64	38	—	—	—	—	141	23	—	—	—	504	317	—	—	—	—	(2)	
	8- 7-57	1,203	572	—	—	67	37	—	—	—	—	145	24	—	—	—	679	319	—	—	—	—	(2)	
	8-20-57	1,203	572	.0	—	63	34	—	—	—	197	153	27	.65	—	—	471	300	138	—	7.4	5	(2)	
	4- 1-59	1,203	572	.0	—	69	34	—	—	—	192	134	29	.65	—	—	464	316	158	—	7.3	5	(2)	
038-127-324	4-17-56	1,826	567	—	—	178	86	—	—	—	—	360	644	—	—	—	1,955	790	—	—	—	—	(8)	
	12- 6-56	1,826	567	—	—	166	96	—	—	—	—	375	687	—	—	—	2,475	808	—	—	—	—	(8)	
	8- 7-57	1,826	567	—	—	163	85	—	—	—	—	355	770	—	—	—	2,805	758	—	—	—	—	(8)	
	3- 7-58	1,826	567	—	—	170	94	—	—	—	—	364	790	—	—	—	2,375	812	—	—	—	—	(8)	
	12- 1-58	1,826	567	—	—	168	104	—	—	—	—	379	865	—	—	—	2,365	849	—	—	—	—	(8)	
	3-10-59	1,826	567	—	—	170	101	—	—	—	—	372	860	—	—	—	2,748	841	—	—	—	—	(8)	
	6-18-59	1,826	567	—	—	172	105	—	—	—	—	382	960	—	—	—	3,095	864	—	—	—	—	(8)	
	9- 3-59	1,826	567	—	—	170	101	—	—	—	—	403	864	—	—	—	3,050	841	—	—	-	—	(8)	
	6-13-62	1,100	567	.02	30	212	100	688	10.	—	180	400	1,150	.7	0.0	—	3,020	940	793	4,490	7.6	5	(1)	Plugged back, but plug leaking.

TABLE 6. (Continued)

Well number	Date of collection	Depth of well (feet)	Depth of casing (feet)	Iron (Fe)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color	Source of analysis	Remarks
039-127-114	4-17-56	1,700	545	—	—	62	37	—	—	—	—	169	44	—	—	—	694	308	—	—	—	—	(8)	
	12- 6-56	1,700	545	—	—	79	35	—	—	—	—	168	38	—	—	—	579	341	—	—	—	—	(8)	
	8- 7-57	1,700	545	—	—	70	39	—	—	—	—	152	47	—	—	—	611	334	—	—	—	—	(8)	
	3- 7-58	1,700	545	—	—	72	35	—	—	—	—	177	47	—	—	—	605	324	—	—	—	—	(8)	
	12- 1-58	1,700	545	—	—	74	38	—	—	—	—	184	52	—	—	—	622	344	—	—	—	—	(8)	
	3-10-59	1,700	545	—	—	73	41	—	—	—	—	172	50	—	—	—	629	351	—	—	—	—	(8)	
	6-18-59	1,700	545	—	—	73	41	—	—	—	—	184	51	—	—	—	548	352	—	—	—	—	(8)	
	9- 3-59	1,700	545	—	—	74	44	—	—	—	—	177	50	—	—	—	622	367	—	—	—	—	(8)	
038-127-120	1- 8-24	750	—	0.06	37	73	40	—	—	—	194	173	31	—	—	—	496	346	—	—	—	—	(2)	Na + K = 28 ppm
	4- 1-59	750	—	.0	—	80	37	—	—	—	197	163	33	0.6	—	—	527	354	192	—	7.4	5	(2)	
	6-13-62	750	—	.0	31	72	33	22	2	—	190	144	30	.7	0.0	—	507	315	160	676	7.5	5	(1)	
039-127-344	4-17-56	1,820	545	—	—	92	36	—	—	—	—	190	107	—	—	—	820	376	—	—	—	—	(8)	
	12- 6-56	1,820	545	—	—	80	45	—	—	—	—	185	99	—	—	—	730	388	—	—	—	—	(8)	
	8- 7-57	1,820	545	—	—	80	45	—	—	—	—	197	112	—	—	—	874	386	—	—	—	—	(8)	
	3- 7-58	1,820	545	—	—	84	43	—	—	—	—	206	112	—	—	—	788	387	—	—	—	—	(8)	
	12- 1-58	1,820	545	—	—	85	48	—	—	—	—	197	127	—	—	—	760	409	—	—	—	—	(8)	
	3-10-59	1,820	545	—	—	85	46	—	—	—	—	198	121	—	—	—	754	400	—	—	—	—	(8)	
	6-18-59	1,820	545	—	—	92	48	—	—	—	—	203	126	—	—	—	800	436	—	—	—	—	(8)	
	9- 3-59	1,820	545	—	—	84	48	—	—	—	—	182	125	—	—	—	860	409	—	—	—	—	(8)	
039-128-131	1- 8-24	1,065	550	—	—	66	29	—	—	—	193	167	29	—	—	—	470	284	—	—	—	—	(8)	Na + K = 41 ppm
	8- 7-57	1,065	550	—	—	67	37	—	—	—	—	145	35	—	—	—	621	319	—	—	—	—	(8)	
	3- 7-58	1,065	550	—	—	66	35	—	—	—	—	131	32	—	—	—	487	308	—	—	—	—	(8)	
	12- 1-58	1,065	550	—	—	67	38	—	—	—	—	156	40	—	—	—	514	323	—	—	—	—	(8)	
	3-10-59	1,065	550	—	—	63	38	—	—	—	—	152	35	—	—	—	527	316	—	—	—	—	(8)	
	6-18-59	1,065	550	—	—	66	38	—	—	—	—	152	37	—	—	—	613	323	—	—	—	—	(8)	
	9- 3-59	1,065	550	—	—	67	36	—	—	—	—	149	34	—	—	—	540	315	—	—	—	—	(8)	
039-128-241	5-30-50	1,054	549	—	36	69	38	—	—	—	198	161	30	—	—	—	490	326	—	—	7.5	—	(8)	Na + K = 20 ppm
	4-17-56	1,054	549	—	—	40	51	—	—	—	—	152	32	—	—	—	540	311	—	—	—	—	(8)	
	12- 6-56	1,054	549	—	—	64	37	—	—	—	—	126	30	—	—	—	533	312	—	—	—	—	(8)	

	3- 7-58	1,054	549	—	—	68	36	—	—	—	—	157	37	—	—	—	520	318	—	—	—	—	(8)	
	12- 1-58	1,054	549	—	—	68	49	—	—	—	—	161	41	—	—	—	500	372	—	—	—	—	(8)	
	3-10-59	1,054	549	—	—	65	38	—	—	—	—	163	41	—	—	—	518	318	—	—	—	—	(8)	
	6-18-59	1,054	549	—	—	66	40	—	—	—	—	165	38	—	—	—	562	332	—	—	—	—	(8)	
	9- 3-59	1,054	549	—	—	65	38	—	—	—	—	182	38	—	—	—	653	320	—	—	—	—	(8)	
040-127-432A	9-28-37	1,100	—	.32	22	60	44	—	—	—	195	159	33	—	—	—	—	330	—	—	7.3	—	(2)	Na + K = 19 ppm
	9-27-49	1,100	—	.0	—	82	35	—	—	—	205	162	30	—	—	—	570	350	—	—	7.4	—	(2)	Na + K = 14 ppm
	4- 2-50	1,100	—	.01	34	66	39	—	—	—	204	160	36	—	—	—	467	326	—	—	7.3	—	(2)	Na + K = 27 ppm
	5-15-59	1,100	—	.04	—	61	34	—	—	—	192	224	29	—	—	—	524	296	—	—	7.4	—	(2)	
040-127-432B	9-27-49	1,025	500	0.10	—	80	35	—	—	—	205	161	30	—	—	—	520	334	—	—	7.4	—	(2)	Na + K = 16 ppm
	4- 2-50	1,025	500	.0	34	69	41	—	—	—	204	168	34	—	—	—	463	338	—	—	7.3	—	(2)	Na + K = 23 ppm
	4- 1-59	1,025	500	.0	—	72	42	—	—	—	190	153	33	—	—	—	520	356	—	—	7.3	—	(2)	
040-127-432C	9-28-37	731	540	.31	22	60	44	—	—	—	195	159	33	—	—	—	—	330	Total	—	7.3	—	(9)	Na + K = 19 ppm
	4- 2-50	731	540	.01	33	71	39	—	—	—	200	166	—	—	—	—	480	334	170	—	—	—	(3)	
	4- 1-59	731	540	.06	—	72	28	—	—	—	202	144	29	0.65	—	—	509	300	134	—	7.4	5	(2)	
040-127-432D	4- 1-59	1,205	550	.09	—	77	40	—	—	—	192	157	38	.55	—	—	570	360	202	—	7.3	5	(2)	
041-126-333	6-13-62	1,961	1,328	.04	32	88	42	43	2.7	0.0	186	198	76	.7	0.0	—	715	392	240	928	7.7	5	(1)	Ocala Group cased off
041-155-421	4- 2-59	857	—	.17	—	69	34	—	—	—	185	138	32	.55	—	—	467	314	162	—	7.4	5	(2)	
042-125-333	5-15-59	800	500	.06	—	76	37	—	—	—	192	228	36	.55	—	—	583	344	186	—	7.5	5	(2)	
042-127-344	5-15-59	800	550	.0	—	72	32	—	—	—	190	198	33	.65	—	—	535	316	160	—	7.5	5	(2)	
042-127-443	5-15-59	800	520	.06	—	72	34	—	—	—	180	193	32	—	—	—	552	320	—	—	7.3	—	(2)	
044-141-430	4- 2-59	—	—	.17	—	75	37	—	—	—	202	155	32	.50	—	—	501	340	174	—	7.4	10	(2)	

BAKER COUNTY

014-208-400	4-16-59	650	600	—	—	40	23	—	—	—	151	65	14	0.45	—	—	202	196	72	—	7.7	5	(2)
016-207-120	1-31-63	700	460	—	—	36	17	—	—	—	148	less than 10	25	.5	—	—	217	160	38	—	7.6	5	(2)

Generally, water from wells closer to the recharge area is not as hard, and contains less mineral matter than water from wells farther away. As shown in table 6, except in the vicinity of Fernandina Beach, the total hardness as $CaCO_3$ of water from the Floridan aquifer system in the area ranges from 117 ppm in well 013-153-240, in southwestern Duval County to 336 ppm in well 008-130-310, at Bayard. The dissolved-solids content ranges from 90 ppm in well 026-135-342C near Jacksonville to 574 ppm in well 025-125-231 in eastern Duval County.

In the vicinity of Fernandina Beach, in eastern Nassau County, the quality of water from wells in the Floridan aquifer system varies considerably with depth or with the aquifer sampled (Leve, 1961b). Water from the deeper wells is more mineralized than water from the shallower wells. In well 040-127-432C at Fernandina Beach, which is 731 feet deep, the water contained 300 ppm hardness as $CaCO_3$ and 509 ppm dissolved solids on April 1, 1959. In well 040-127-432D, which is 1,205 feet deep and about 100 yards away from well 040-127-432C, the water contained 360 ppm hardness as $CaCO_3$ and 570 ppm dissolved solids on the same date.

The date of sampling generally makes only a slight difference in the quality of the water, except in the deeper wells in the vicinity of Fernandina Beach where changes in the quality of water are caused by large variations in the piezometric head. As shown in table 6, water from well 038-127-324 at Fernandina Beach, 1,826 feet deep, ranged in hardness (as $CaCO_3$) from 790 to 864 ppm and in dissolved-solids content from 1,960 to 3,100 ppm between April 17, 1956, and June 18, 1959. This well was plugged back to 1,100 feet in depth in 1962 and as shown in table 6, the hardness of the water increased to 940 ppm and the dissolved-solids content was 3,020 ppm.

An indication of the quality of water below the Eocene formations is given by the analysis of samples of water from oil-test well 044-156-100 in western Nassau County. The well was drilled to 4,800 feet and samples of water were taken from 2,205 to 2,230 feet within the Cedar Keys Formation, of Paleocene Age. The hardness of the water was 9,660 ppm and the dissolved-solids content ranged from 64,300 to 100,900 ppm. The chloride content ranged from 33,600 to 60,200 ppm, which is 1½ times to more than twice the chloride content of sea water.

Except in a few deep wells in Fernandina Beach, water from the Floridan aquifer system in Duval, Nassau, and Baker counties is suitable for domestic use and for most industrial uses. However, locally, one or more of the chemical characteristics of the water exceed the maximum limit of concentration recommended by the U.S. Department of Health, Education, and Welfare (1962). Some of the more important of these chemical characteristics are discussed below.

CHLORIDE

Most of the water tested in the area contained less than 30 ppm of chloride, which is well below the maximum limit of concentration suggested by the U.S. Department of Health, Education, and Welfare for public supplies. However, water from well 038-127-324, in Fernandina Beach, contained between 644 and 1,150 ppm of chloride (table 6). Such large quantities of chloride in ground water in areas where the content is generally much lower indicate contamination by saline water, which will be discussed in detail in the section "Salt-Water Contamination."

DISSOLVED SOLIDS

The dissolved-solids content of water shown in tables 5 and 6 is the residue of mineral matter left after evaporation of the water and is an indication of the degree of mineralization of the water. Water that contains less than 500 ppm of dissolved solids is usually satisfactory for domestic use. In the wells sampled in Duval County, only well 025-125-231 contained water with more than 500 ppm of dissolved solids. Many wells in Nassau County contain water with more than 500 ppm of dissolved solids. However, only the deeper wells in Fernandina Beach contained water with extremely large amounts of dissolved solids.

HARDNESS

There are two types of hardness in water: (1) carbonate harness caused mainly by calcium and magnesium bicarbonates and (2) non-carbonate hardness caused primarily by sulfates, chlorides, and nitrates of calcium and magnesium. Water with a hardness of more than 100 ppm as $CaCO_3$, which is present in all wells tested in the area, may be classed as hard to very hard. Hardness of water retards the cleaning action of soaps and forms a precipitate or scale on plumbing fixtures, boiler pipes, and utensils when the water is heated. Carbonate hardness can easily be removed from the water by heating or by common soda-ash or lime-soda softening processes. Noncarbonate hardness is more difficult to remove, but it can be reduced by certain commercial softening processes.

HYDROGEN SULFIDE GAS

Although the water samples shown in table 6 were not analyzed to determine the amount of hydrogen sulfide gas present, most of the water from wells in the Floridan aquifer system in the area has the sulfur odor indicative of this gas. Hydrogen sulfide has a corrosive effect on plumbing and it is undesirable in drinking water. It can be removed easily from the water by simple aeration or by natural dissipation to the atmosphere from an open tank or pool.

SALT-WATER CONTAMINATION

Most of the water used in Duval, Nassau, and Baker counties is from the Floridan aquifer system, and hence the following discussion will include salt-water contamination of only that system.

In northeast Florida as well as other parts of Florida, salt water is present within the Floridan aquifer system. In most areas this salt water entered the aquifer system during past geologic time when the sea stood above its present level, or the salt water was trapped within the rocks when they were deposited. Subsequently, fresh water entered the aquifer system and diluted or flushed out most of the salt water. The salt water that remains where the flushing was not completed is a source of contamination of the fresh ground water.

About 91 percent of the dissolved-solids content of sea water consists of chloride salts. The chloride content of ground water, therefore, is generally a reliable indication of the extent to which normally fresh ground water has become contaminated with sea water. Water samples were collected from most of the wells that were inventoried and were analyzed for chloride content. From many wells, water was sampled periodically to determine if the chloride content had changed.

The maps of figures 18 and 19 shown the chloride content of water from wells in the Floridan aquifer system in northeast

Florida in 1940 and in May 1962. As may be seen, the chloride content of the water is lowest close to the recharge area in southern Duval County and in Baker County, and progressively higher away from the recharge area toward the north. A comparison of both maps shows that the chloride content of the water from wells in the Floridan aquifer system has increased since 1940. In 1940, wells throughout all of southwestern Duval County and eastern Baker County contained water with a chloride content of less than 10 ppm, and the chloride content of water from wells sampled in Duval County did not exceed 20-29 ppm. In 1962, only one well in south-central Duval County contained water with a chloride content of less than 10 ppm, and wells near the mouth of the St. Johns River and near the center of the cones of depression at Jacksonville and Eastport contained water whose chloride content was over 30 ppm. In 1940, the chloride content of water from wells sampled in Nassau County did not exceed 30-39 ppm, except possibly in wells north of Hilliard. In 1962, the chloride content of water from wells north of Hilliard and near the center of the cone of depression at Fernandina Beach was 40 ppm or more. Water in the deep wells at Fernandina Beach had the highest chloride content shown in figure 20, ranging from 53 to 1,180 ppm in May 1962 in wells more than 1,250 feet deep.

A comparison of the maps in figures 18 and 19 with the map of change in artesian pressure in figure 15 shows that the increase in chloride content of water from the Floridan aquifer system in northeast Florida can generally be correlated with the decline of artesian pressure in the area. In most parts of eastern Baker County and western Duval and Nassau counties, where the artesian pressure has declined less than 15 feet since 1940, the increase in chloride content has been small. However, in the cones of depression at Jacksonville, Eastport, and Fernandina Beach where the piezometric surface has declined more than 15 feet since 1940, the increase is greater, particularly in the deep wells near the center of the cone of depression at Fernandina Beach.

Table 7 shows the chloride content of water from wells that penetrate the Ocala Group and from wells that penetrate formations deeper than the Ocala Group in Duval and Nassau counties between the years 1940 and 1962. In Duval County and in most of Nassau County, the chloride content of water from wells that penetrate the Ocala Group and from wells in deeper formations has increased only slightly, 2 to 14 ppm. However, in the vicinity of Fernandina Beach, the chloride content of water from wells

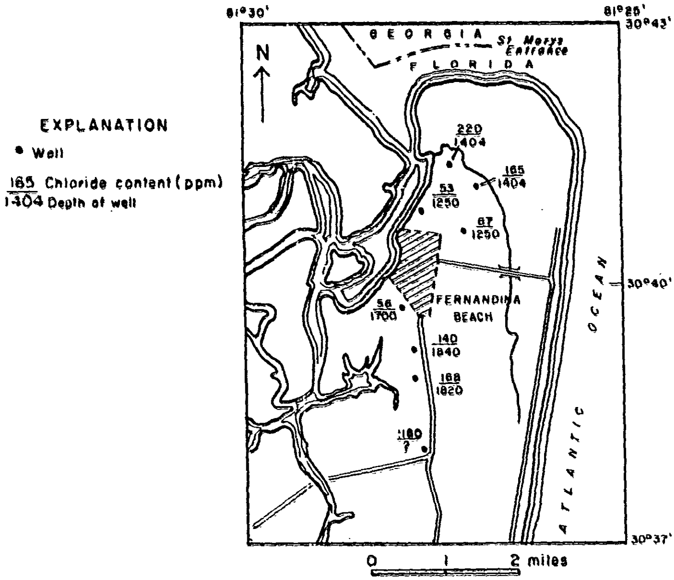

Figure 20. Map showing the chloride content of water from deep wells at Fernandina Beach, May 1962.

that penetrate formations deeper than the Ocala Group has increased at a faster rate. Between 1952 and 1962 the chloride content of water in wells 039-127-321 and 039-127-114 at Fernandina Beach approximately doubled, and that in well 038-127-324 at Fernandina Beach increased to more than four times the amount measured in 1952.

Figure 21 shows graphically the increase in chloride content of water from four wells at Fernandina Beach that penetrate formations deeper than the Ocala Group. The increase was only slight between 1955 and 1962 in well 039-128-241, which is 1,054 feet deep and penetrates the Ocala Group and the top of the Avon Park Limestone, and in well 039-127-114, which is 1,700 feet deep and penetrates the Ocala Group, the Avon Park Limestone, and the Lake City Limestone. The chloride content of the water increased much more rapidly in well 038-127-324, which is 1,826 feet deep and penetrates the Ocala Group, the Avon Park Limestone, the Lake City Limestone, and a part of the Oldsmar Limestone, and in well 041-126-333A, which is 1,961 feet deep and open to the Lake City and Oldsmar Limestones. In well 038-127-324 it increased 1,320 ppm, from 550 to 1,800 ppm.

TABLE 7. Chloride content of water, in parts per million, from wells in the Floridan aquifer system in Duval and Nassau counties.

Well number	Well depth (feet)	Cased (feet)	1940	1948	1950	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962
WELLS IN THE OCALA GROUP																
Duval County																
011-141-141	403	252	1	—	—	—	—	—	12	—	—	—	—	12	—	—
013-135-230	625	461	14	15-18	—	—	—	—	—	—	—	—	—	15-20	17-22	17-21
015-141-111	600	470	10	10	—	—	—	—	—	—	—	—	—	11	14-18	15
017-126-232	550	480	—	—	—	—	—	—	17	—	—	—	—	22	—	20
018-123-123	585	357	—	14-20	—	—	—	—	20	—	—	—	—	24	—	—
019-132-411	762	509	15	17-18	—	—	—	—	18	—	—	—	—	16	—	—
019-140-421	785	—	—	14	—	—	—	—	—	—	—	—	—	14-25	26-37	21
020-136-434	690	560	—	—	—	—	—	—	14	—	—	—	—	21	—	20
020-144-430	630	500	11	—	—	—	—	—	16	—	—	—	—	18	—	17
021-123-133	575	—	15	—	—	—	—	—	18	—	—	—	—	22	—	29
023-125-142	510	—	18	—	—	—	—	—	22	—	—	—	—	23	—	—
024-136-136	800	—	18	18	—	—	—	—	—	—	—	—	—	21	—	—
024-144-320	625	500	—	18	—	—	—	—	—	—	—	—	—	19	—	20
025-141-300	725	500	11	—	—	—	—	—	19	—	—	—	—	24	—	—
026-126-423	455	—	19	19	—	—	—	—	20	—	—	—	—	24	—	25
026-145-420	658	—	21	—	—	—	—	—	25	—	—	—	—	29	—	27
027-143-314	610	446	23	—	—	—	—	—	26	—	—	—	—	30	—	28
028-137-334	—	—	22	24	—	—	—	—	—	—	—	—	—	17-19	16-18	19-26

TABLE 7. (Continued)

Well number	Well depth (feet)	Cased (feet)	1940	1948	1950	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962
Nassau County																
032-126-142	680	—	23	—	—	—	—	—	—	—	—	—	23	28	—	—
033-150-242	580	—	26	28-29	—	—	—	—	—	—	—	—	—	30-32	29-32	31-32
035-127-310	580	350	25	26-31	—	—	—	—	—	—	—	—	30	26-31	—	—
035-127-330	540-560	—	—	—	—	—	—	—	26	—	—	—	27	—	—	—
037-126-214	—	—	28	28	—	—	—	—	29	—	—	—	36	39	—	—
037-129-242	578	—	27	—	—	—	—	—	27	—	—	—	28	30	—	31
037-130-330	540	504	27	28	—	—	—	—	—	—	—	—	33	29-32	29-32	30-31
037-142-430	569	—	24	24-26	—	—	—	—	—	—	—	—	—	24-27	26-30	28-30
039-127-120	750	—	26	—	—	—	—	—	—	—	—	—	32-33	—	—	34
039-131-231B	—	—	—	—	—	—	—	—	29	—	—	—	30	33	—	—
040-127-211B	900	530	—	—	—	—	—	—	—	54-58	52-56	—	32	—	36	—
040-138-410	500	—	29	—	—	—	—	—	—	—	—	—	—	35	—	33
042-125-333	800	550	32	—	—	—	—	—	—	—	—	—	36-40	—	—	40
042-127-443	800	534	28	—	—	—	—	—	30	—	—	—	32-33	—	—	34
WELLS IN FORMATIONS DEEPER THAN THE OCALA GROUP																
Duval County																
009-139-230	650	—	—	—	—	—	—	—	10	—	—	—	—	15	—	22
013-141-441	1,015	318	9	—	—	—	—	—	—	—	—	—	—	16	—	14

TABLE 7. (Continued)

Well number	Well depth (feet)	Cased (feet)	1940	1948	1950	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962
019-140-241	785	—	—	14-16	—	—	—	—	—	—	—	—	—	14-22	26-37	21
020-139-443	1,250	—	17	—	—	—	—	—	—	—	—	—	—	22	—	24
021-138-121	1,060	543	13	—	—	—	—	—	—	—	—	—	—	23	—	21
021-141-414	1,053	530	16	—	—	—	—	—	—	—	—	—	—	18	—	19
026-135-342A	1,393	584	—	—	—	—	—	—	—	—	—	—	—	24-26	24-27	24-29
Nassau County																
037-136-122	1,000	450	—	30	—	—	—	—	28	—	—	—	—	30	30-32	33
038-126-320	1,203	572	—	—	—	—	—	—	—	—	27	—	29-30	—	—	—
038-127-324	1,826	567	—	—	—	420-450	480-580	—	560-630	644-687	770	790-865	860-1,060	1,550-1,690	1,370-1,780	1,180-1,800
039-127-344	1,820	545	—	—	—	104	106-127	—	—	99-107	112	112-127	121-140	128-131	143-156	168
039-127-321	1,840	551	—	—	—	65-68	70-77	77-85	82-96	89-90	99	102-116	109-130	113-122	125-139	140
039-127-114	1,700	545	—	—	—	32-38	36-43	40-43	37-43	38-44	47	47-52	50-55	56-60	51-58	56
039-128-131	1,065	550	—	—	30	—	—	—	30-32	30-32	35	32-40	33-37	34-40	32-37	32
039-128-241	1,054	549	30	—	—	—	—	—	30-35	29-32	26	38-40	35-38	36-37	33-36	—
040-127-432A	1,100	—	29	—	36	—	—	—	—	—	—	—	26-29	—	—	—
040-127-432B	1,025	500	30	—	34	—	—	—	—	—	—	—	33-35	—	—	35
041-126-333A	1,961	1,328	—	—	—	—	—	—	—	—	—	—	—	—	74-89	91-97
041-126-333B	1,404	550	—	—	—	—	—	—	—	142-148	112-118	—	120	—	152-161	150-165

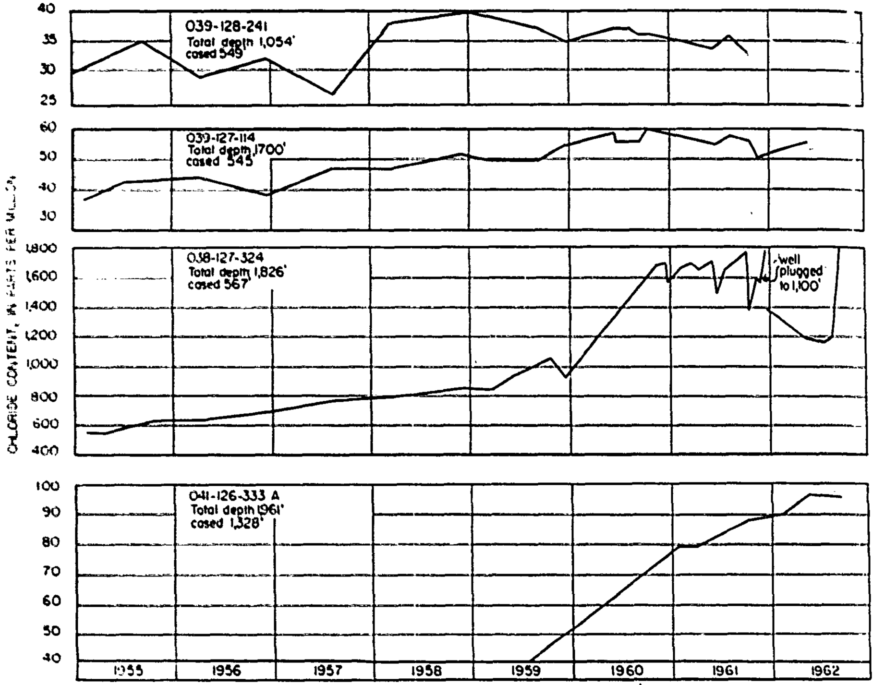

Figure 21. Graphs of the chloride content from selected wells at Fernandina Beach that penetrate formations below the Ocala Group.

The increase in chloride content of water from wells in the Floridan aquifer system and the decline in artesian pressure indicate that salt water is gradually moving into the zones of reduced pressure and contaminating the existing fresh-water supply. However, the relatively low chloride content of water samples from most wells in the area indicates that serious contamination is restricted at present to a few deep wells at Fernandina Beach. The rapid increase in these deep wells shows that the contamination is proceeding at a faster rate in the deeper aquifers in the Floridan aquifer system in this area.

Water samples collected at depths between 2,205 and 2,230 feet in well 044-156-100 near Hilliard (p. 77), show that highly saline water is present in the deeper aquifers in Nassau County. The fresh water has a lower density than the saline water and will remain above the saline water if it is undisturbed. When the fresh water is withdrawn from the aquifer system, the salt water will cone up and enter the zone of reduced pressure by vertical migration. However, analysis of water samples taken at different depths in wells at Fernandina Beach gives evidence that all or some of the contamination of water in deep wells is by lateral migration from a salt-water zone or zones within the upper part of the Floridan aquifer system.

Figure 22 shows graphically the chloride content of water samples collected at various depths during the construction of wells 038-127-324 and 041-126-333A at Fernandina Beach. Water enters well 038-127-324 from the Ocala Group, and the Avon Park, Lake City, and Oldsmar Limestones, but in well 041-126-333A the Ocala Group, Avon Park Limestone, and part of the Lake City Limestone are cased off and water enters the well only from part of the Lake City and Oldsmar Limestones. The chloride content of water found in both wells in a zone at the bottom of the Avon Park Limestone and the top of the Lake City Limestone ranged from about 100 ppm to about 430 ppm. The water was considerably fresher immediately above and immediately below this zone, which indicates that water in this zone is isolated from water in the rest of the aquifer system. Although the maximum chloride content of the water in this zone was about 150 ppm in well 038-127-324 and 430 ppm in well 041-126-333A when the wells were constructed, the rapid increase with pumping (fig. 21) suggests that salt water is entering the zone. Therefore, this zone is probably a source of salt-water contamination of the fresh water in wells at Fernandina Beach. Discharging wells that are drilled into the Lake City and Oldsmar Limestones and are open to this zone may induce lateral migration of relatively saline water into the wells. Uncontaminated fresh water can be obtained from below if salt water is prevented from entering the well bore by casing off this zone.

The graphs in figure 22 also show that the chloride content of water from both wells gradually increased below about 2,000 feet. This indicates that salty water is present below this depth also and wells drilled deeper than 2,000 feet in Fernandina Beach will probably encounter highly saline water.

Except at Fernandina Beach, no wells in the area have been drilled sufficiently deep to encounter salt water, and none of the wells drilled into the Lake City Limestone have encountered the salt-water zone at the base of the Avon Park Limestone and the top of the Lake City Limestone. However, as more fresh water is withdrawn from the aquifer system and the artesian pressure

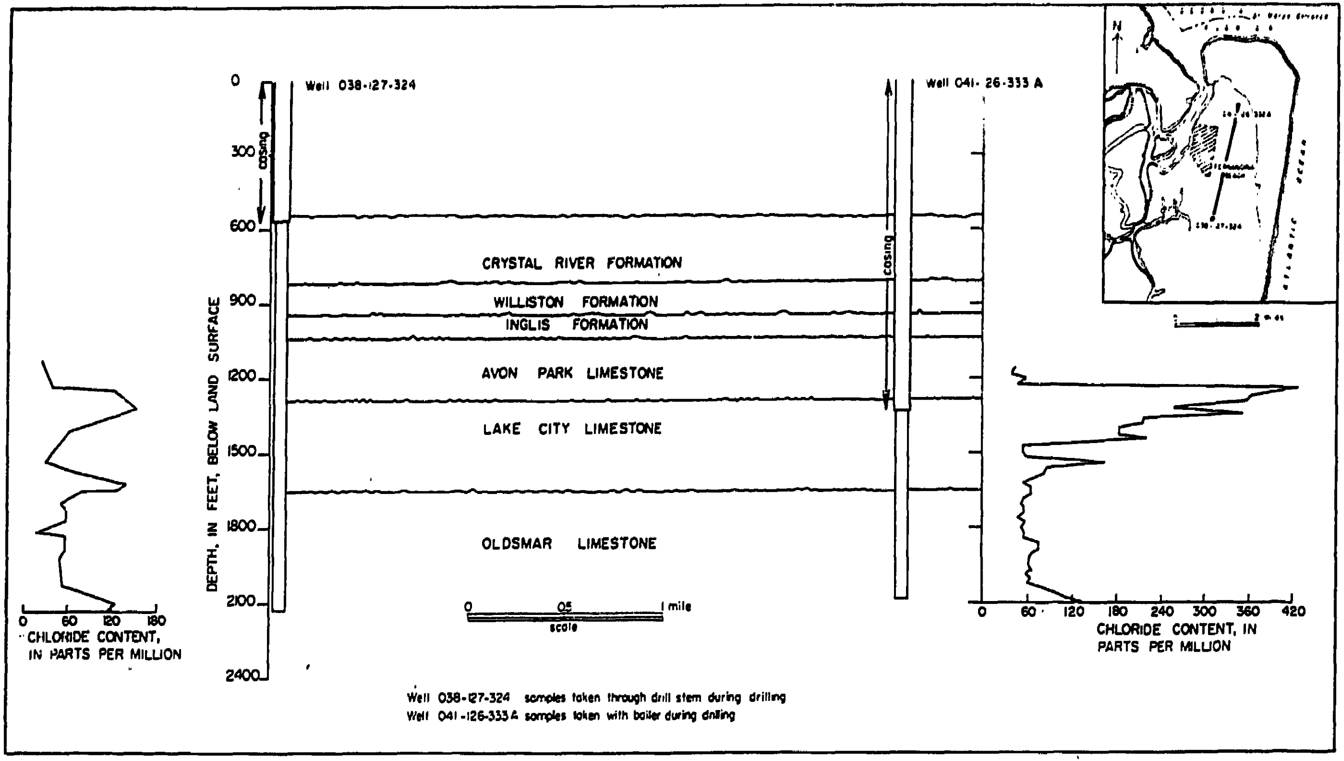

Figure 22. Graphs of the chloride content of water at different depths in wells in the Floridan aquifer system at Fernandina Beach.

continues to decline, more salt water may migrate either vertically or laterally, or both vertically and laterally, into the fresh-water zones in the upper part of the aquifer system. Then the fresh water will become progressively saltier until, eventually, it may become unsuitable for domestic and most industrial uses.

It is possible to retard or even to prevent vertical and lateral encroachment of salt water by properly spacing wells and controlling discharge rates to avoid excessive drawdowns. The confining beds in the Avon Park, Lake City, and Oldsmar Limestones will retard or even prevent vertical movement of water in the aquifer system in most of the area. However, if these relatively impermeable beds are penetrated by a well, any salt water present will move upward at a faster rate. Therefore, caution should be taken in developing the deeper water-producing zones in the aquifer. More detailed information on the geologic and hydrologic characteristics of these deeper zones and the depth to salt water needs to be obtained before there is any extensive development of these zones. Such information will insure proper development of the deeper zones in the aquifer and lessen the possibility of salt-water contamination.

SUMMARY

Water supplies in northeast Florida are obtained almost entirely from ground-water sources. The rocks usually penetrated by water wells are thick limestone and dolomite beds of Eocene age which underlie the surface at depths ranging from 300 to 550 feet below msl. These rocks, in ascending order, are the Oldsmar Limestone; the Lake City Limestone; the Avon Park Limestone; and the Inglis, Williston, and Crystal River Formations which compose the Ocala Group. The limestones of Eocene age are overlain by the Hawthorn Formation, which is composed of beds of clay, phosphatic clay, sandy clay, phosphatic sand, limestone, and dolomite of early and middle Miocene age. The Hawthorn Formation is overlain by beds of calcareous silty clay, limestone, shell, and sand of late Miocene or Pliocene age and of Pleistocene and Recent age.

A fault extending along the St. Johns River in Duval County displaces the top of the limestones of Eocene age a maximum of about 125 feet. West of the fault the top of the Avon Park Limestone dips northeastward about 16 to 20 feet per mile.

The shallow aquifer system, which is 300 to 550 feet thick in the area, extends from the surface into the Hawthorn Formation. The aquifers within the system consist of relatively discontinuous, porous limestone, shell, and sand lenses within the Hawthorn Formation, the upper Miocene or Pliocene deposits, and the Pleistocene to Recent deposits. The aquifers are recharged directly by local rainfall and by downward infiltration of water from shallower aquifers in the system.

The aquifers in the shallow aquifer system most utilized by wells in the area are the surficial sand beds and a relatively continuous limestone, shell, and sand zone at the base of the upper Miocene or Pliocene deposits. As the thickness and lithology of these aquifers vary both vertically and laterally, the amount of water available from them depends on the location and depth of the well. Generally, the surficial sand beds yield about 10 to 25 gpm, and the aquifer at the base of the upper Miocene or Pliocene deposits yields between 15 and 20 gpm to small-diameter wells.

As more information is obtained on these aquifers, it may be possible to determine the proper location and construction of wells to obtain more water. It may also be possible to recharge artificially one or more of the aquifers so that more water is available to wells. These aquifers may become a major source of ground water, particularly if the water in the underlying Floridan aquifer system becomes contaminated by salt water.

The Floridan aquifer system, which is composed primarily of limestones of Eocene age, is the principal source of fresh water in northeast Florida. The top of the Floridan aquifer system, which ranges from 300 to 550 feet below msl, is overlain by an aquiclude of relatively impermeable clay, sandy clay, and dolomite beds in the Hawthorn Formation and in the upper Miocene or Pliocene deposits that separate it from the shallow aquifer system.

Current-meter studies and information obtained while wells were being constructed indicate that there are at least three separate permeable zones within the Floridan aquifer system in northeast Florida. The first zone includes all the formations of the Ocala Group and, locally, limestone at the base of the Hawthorn Formation and at the top of the Avon Park Limestone. In the vicinity of Jacksonville, the second zone is in the top part of the Lake City Limestone, and the third zone is within the Lake City Limestone, below a depth of about 1,200 feet. However, in Fernandina Beach, the Lake City Limestone contains only one permeable zone, and a third zone is present below the Lake City

Limestone in the Oldsmar Limestone. These zones are separated by hard, relatively impermeable dolomitic limestone and dolomite beds.

Water is generally under higher artesian pressure in the lower zones than in the Ocala Group. The deeper zones yielded 50 to 98 percent of the total amount of water from the wells tested in the vicinity of Jacksonville, and water was lost into the zone in the Ocala Group from the deeper zones in the well tested at Fernandina Beach.

The yield of water from wells in the Floridan aquifer system in the area depends largely upon the depth, the well construction, the artesian pressure, and the transmitting properties of the permeable zones. The natural flow of wells 2 to 6 inches in diameter is generally less than 500 gpm, and that of wells 8 to 12 inches in diameter is generally less than 2,000 gpm. As much as 4,000 or 5,000 gpm may be pumped from some wells larger than 12 inches in diameter that penetrate to the second or third permeable zones.

Water enters the Floridan aquifer system in north-central Florida through breaches in the aquiclude by sinkholes, by downward leakage from surface bodies of water or from shallower aquifers where the aquiclude is thin or absent, and directly into the aquifers where they are exposed at the surface. The water moves generally northeastward through the aquifer system into northeast Florida, where some of it is discharged artificially through numerous wells, and some is probably discharged naturally into the ocean off the coast. Cones of depression have formed in the piezometric surface in northeast Florida as a result of discharging wells which lower the artesian head and create a hydraulic gradient toward the discharging wells. Major cones of depression have developed in Duval County at Jacksonville and Eastport and in Nassau County at Fernandina Beach. The piezometric surface has been depressed to less than 30 feet above msl at Jacksonville and to more than 15 feet below msl at Fernandina Beach.

In parts of Duval and Nassau counties where the piezometric surface is higher than the land surface, the wells that penetrate the Floridan aquifer system will flow. The size of the area in which artesian flow will occur varies greatly with only slight changes in the elevation of the piezometric surface.

Public water supplies in the vicinity of Jacksonville are obtained from 46 municipal wells and more than 100 private utility wells that are drilled into the Floridan aquifer system. The smaller towns in the area and the three large Navy facilities also obtain water from the Floridan aquifer system. The three major paper manufacturers in the area, many other industries, and a number of the larger commercial buildings have wells in the Floridan aquifer system. Many private residences also obtain water from wells in this aquifer system. The total amount of water discharged by artesian wells is estimated to average from 150 to 200 mgd in the vicinity of Jacksonville and from 50 to 70 mgd at Fernandina Beach.

Water-level records show an irregular but continual decline in artesian pressure in the area. The greatest decline is in wells in the shallower permeable zones in the Floridan aquifer system near the centers of the cones of depression. At Fernandina Beach, artesian pressure declined 50 to 60 feet during the period from 1939 to 1963, and at Jacksonville, artesian pressure declined 12 to 22 feet during the period 1946 to 1963. The piezometric surface declined 10 to 25 feet in all of northeast Florida during the period 1940 to 1962. During the period July 1961 to May 1962, the piezometric surface fell 1 to 10 feet because of below-normal rainfall and increased withdrawals of artesian water. Artesian pressure in the area will continue to decline if withdrawals of water continue to increase. However, the decline of artesian pressure does not pose an immediate threat to the availability of water in the area. A much greater danger is that highly mineralized water will enter the zone of reduced pressure and contaminate the existing fresh water in the aquifers.

Water from most wells in the shallow aquifer system and in the Floridan aquifer system is suitable for domestic use and for most industrial uses. Water from wells in the shallow aquifer system is generally softer, contains less dissolved mineral matter and more iron than water from wells in the deeper Floridan aquifer system. Wells in the Floridan aquifer system closest to the recharge area in southwestern Duval County generally contain softer water with less dissolved mineral matter than wells in the central and northern parts of the area. In the vicinity of Fernandina Beach, there is considerable variation in the quality of water from wells of different depths in the Floridan aquifer system. Water from the deeper wells is harder and contains a higher dissolved-solids content than water from the shallower wells.

The chloride content of water from wells in the Floridan aquifer system ranges from less than 10 ppm in the southwestern part of the area, where the piezometric surface is highest, to more than 40 ppm in wells less than 1,250 feet deep, and to more than 1,180 ppm in some wells more than 1,250 feet deep at Fernandina Beach, where the piezometric surface is the lowest. Except in some of the deeper weels at Fernandina Beach, the increase in chloride content of water from most wells in the area ranged from 2 to 14 ppm during the period 1940 to 1962. In many of the deeper wells at Fernandina Beach, the chloride content of water increased about 20 to 1,320 ppm between 1955 and 1962.

The increase in chloride content of the water from artesian wells correlated with the decline of artesian pressure indicates that salt water is gradually moving into the zones of reduced pressure and contaminating the fresh-water supplies. At present, serious contamination is limited to a few deep wells at Fernandina Beach, where salt water is migrating laterally into the aquifer from a highly mineralized zone at the base of the Avon Park Limestone, and vertically from highly mineralized zones more than 2,000 feet below land surface.

Contamination of the fresh water will increase in northeast Florida if the artesian pressure continues to decline. Further contamination can be retarded and even prevented if, in the future, wells are propertly spaced and their discharges controlled in a manner that prevents excessive lowering of the artesian pressure. The impermeable beds and the higher water pressure zones in the Avon Park Limestone, Lake City Limestone, and Oldsmar Limestone presently prevent upward coning of salt water from the lower part of the Floridan aquifer system. Careful well construction and proper development of these aquifers should be employed to keep these natural barriers effective. Contamination in some of the deep wells in Fernandina Beach may be retarded by casing off the highly mineralized zone at the base of the Avon Park Limestone.

FUTURE STUDIES

Many topics essential to completing the study of the ground-water resources of northeast Florida are beyond the scope of this investigation. The findings from the following investigations to complete this study will be reported in the future.

1. A detailed investigation of the shallow aquifer system, particularly the aquifer at the base of the upper Miocene or Pliocene deposits, to determine its potential as a primary or supplemental source of water. This investigation will include test

drilling to determine the areal extent and thickness of the aquifers and pumping tests to determine their water-bearing properties.

2. Quantitative permeability investigations of each of the separate permeable zones in the Floridan aquifer system to predict the results of using water from the deeper zones and to determine the best method of developing these zones without causing salt-water intrusion. This investigation will include pumping tests to determine the water-transmitting and water-storing capacities of each of these zones and mathematical and graphic analyses of the aquifer system.

3. An investigation to determine the relation of water-level declines to the amount of water being discharged from the Floridan aquifer system in order to predict future declines. This investigation will include continued measurement of water levels and a detailed inventory of wells in the area to determine more exactly the amount of water being used.

4. An investigation to detect any increase or spread of salt-water contamination in the area. This will include continued sampling and chloride analysis of water from wells throughout the area. If possible, a deep well will be drilled near the center of the cone of depression at Jacksonville to locate the exact depth to salt water. This well will be sampled periodically at various depths to detect any vertical movement of salt water into the fresh-water zones in the upper part of the Floridan aquifer system.

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Warren, M. A. (See Stringfield, V. T.)

TABLE 8. Record of wells in Duval and Nassau counties.

Well number: See figure 1 for explanation of well-numbering system.
Owner: C, county; I, industry; M, municipality; O, church; P, private; S, State; U, U.S. Government.
Depth of well: Reported unless otherwise noted by M, measured by U.S. Geological Survey.
Well finish: O, cased to aquifer, open hole in aquifer; S, sand point.
Method of drilling: C, cable tool; J, jetted; R, rotary; X, other or unknown.
Type of pump: C, centrifigal; J, jet; N, none; T, turbine.
Use of water: A, air conditioning; D, domestic; F, fire protection; I, industrial; M, mining; N, none; P, public supply or municipal; R, irrigation; S, stock; T, test or observation.
Aquifer(s): D, Floridan aquifer (deeper than Ocala only); F, Floridan aquifer (Ocala Group); FD, Floridan aquifer (Ocala Group and deeper than Ocala); Sr, shallow aquifer, rock well; Ss, shallow aquifer, surface well.

Altitude of land surface: To tenth of a foot if determined by precision leveling; otherwise, to nearest foot.
Water level: To tenth of a foot if measured by wet-tape method or if taken from recorder chart. To nearest foot, if measured by pressure gage or air line. P, periodic measurement; R, recorder on well. Date of measurement applies also to temperature, chloride, specific conductance, and hardness, unless otherwise noted in Remarks column.
Chloride: P, periodic determination.
Chemical analyses available: C, complete; D, complete and radiochemical; M, multiple-complete and partial; P, partial.
Yield and drawdown: Reported unless noted by M, measured by U.S. Geological Survey; F, yield by natural flow; P, yield by pumping.
Remarks: W- or Wgi-, Florida Geological Survey well number. Logs available: A, chloride or conductivity; C, caliper; D, drilling time; Dr, driller's log; E, resistivity and/or spontaneous potential; L, geologists's log and/or samples; V, current meter.

Well number	Owner	Year completed	Depth of well (feet)	Casing		Well finish	Method of drilling	Type of pump	Use of water	Aquifer(s)	Altitude of land-surface above mean sea level (feet)	Water level		Chloride (Cl) (parts per million)[1]	Chemical analyses available	Temperature (°F)	Yield (gallons per minute)	Drawdown	Period of discharge (hours)	Remarks
				Depth (feet)	Diameter (inches)							Above or below (-) land surface (feet)	Date of measurement[1]							

TABLE 8. (Continued)

008-130-131	P	—	545	—	4	O	X	N	D	F	23.6	31.3 18.5	9-23-40 1- 4-60	—	—	—	—	—	—	
08-130-310	P	—	—	—	4	O	X	N	D	F	23.5	23.0 20.5 17.2 17.7	9-27-40 1- 4-60 7-11-61 5-14-62	- - 22	—	—	—	—	—	
08-134-120	P	1960	500	200	3	O	C	N	D	F	26	18.5 16.3 12.0	1- 5-60 7-11-61 5-14-62	31	—	—	—	—	—	
08-135-340	P	1961	487	—	3	O	X	N	D	F	22	25.5 20.5	11- 1-61 5-14-62	23	—	—	—	—	—	
09-136-244	O	—	600	—	6	O	R	N	D	F	—	21.7	1- 8-61	21	—	—	—	—	—	
09-137-120	P	1955	900	337	6	O	R	—	P	FD	38	—	—	—	—	—	—	—	—	W-3464, L
09-139-230	P	—	—	—	3	O	X	N	DR	F	16.5	35.8 23.7 20.3 13.1	9-28-40 1- 7-60 7-11-61 5-14-62	—	—	—	—	—	—	
09-140-240	P	1936	650	500	3	O	X	C	DR	F	2.1	50.0 41.8	9-28-40 1- 7-60	10 15	—	—	—	—	—	C1, 11-4-55
10-133-244A	P	1953	555	457	3	O	X	C	DR	F	25	20.0 12.0	3- 1-61 5-14-62	24	—	—	—	—	—	
10-133-244B	P	—	100	—	1	O	X	N	N	SR	—	8.8	3- 1-61	21	—	—	—	—	—	
11-138-211	P	1945	651	425	6	O	R	C	DR	F	20	21.0 10.0	1- 5-61 5-14-62	15	—	—	—	—	—	
11-141-141	U	1940	403	252	6	O	R	N	DF	F	16.1	28.0 16.4 17.5 15.8	8- 7-40 10-13-55 1- 4-60 5- 7-62	- - 12 12	—	71	320FM	—	—	
12-137-221	P	1956	650	—	3	O	J	N	D	F	10	31.5 18.6	1- 5-61 5-14-62	13	—	—	—	—	—	

[1]Only the earliest and latest measurements and chloride values are shown on table.

TABLE 8. (Continued)

Well number	Owner	Year completed	Depth of well (feet)	Casing		Well finish	Method of drilling	Type of pump	Use of water	Aquifer(s)	Altitude of land-surface above mean sea level (feet)	Water level		Chloride (Cl) (parts per million)[1]	Chemical analyses available	Temperature (°F)	Yield (gallons per minute)	Drawdown	Period of discharge (hours)	Remarks
				Depth (feet)	Diameter (inches)							Above or below (-) land surface (feet)	Date of measurement[1]							
013-135-230	P	——	625	461	4	O	R	N	D	F	25.2	28.6 P 7.4	7-30-40 5- 9-62	14 18	—	77	——	—	—	L
013-135-400	P	1957	610	510	4	O	R	C	AFRI	F	—	—	——	—	C	—	——	—	—	L
013-140-414A	U	1940	1,005	380	12	O	R	C	PF	FD	9.2	45.2 37.2 30.3 26.0	8- 5-40 1-14-60 7-12-61 5-17-62	10 16	—	76	3,000FM	—	—	Cl, 11-15-40
013-140-414B	U	——	708	—	10	O	R	C	PF	FD	—	—	——	—	C	—	——	—	—	
013-141-441	U	1940	1,015	318	12	O	R	C	PF	FD	20.9	.... 23.0 11.3	—— 1-14-60 5-17-62	9 16 14	—	74	4,150FM	—	—	W-514, L; Cl, 11-15-40
013-142-214	U	1942	988	400	12	O	R	—	N	FD	16-20	—	——	—	—	—	——	—	—	W-661, L
013-153-240	U	1941	990	—	10	O	R	—	PF	FD	79.2	—16.23	5-19-41	—	—	—	——	—	—	W-581, L
014-141-220	P	1922	669	286	8	O	X	—	DR	F	16	—	——	—	—	—	1,500F	—	—	W-27, L
014-143-130	P	——	185	—	—	O	X	—	P	SR	—	—	——	—	C	—	——	—	—	
014-153-111A	U	1944	1,005	467	20	O	R	N	N	FD	79.8	—23.72 —26.12 —29.54	10-13-60 7-14-61 5-17-62	—	—	—	780P	21	6	L
014-153-111B	U	1942	780	439	10	O	R	N	N	F	80	—	——	—	—	—	——	—	—	W-731
014-153-420	U	1956	1,305	485	20	O	R	T	PF	FD	85	—28	11- 7-56	—	—	78	1,000P	35	24	W-4113, L
015-133-421	P	1957	1,246	520	18	O	R	T	MI	FD	50	— 3.35	3- 1-61		—	—	2,000P	—	—	

015-133-443	P	1957	1,254	520	18	O	R	T	MI	FD	56	—10.3 —19.6	3- 1-61 5-14-62	21 25	—	—	2,600P	—	—	
015-138-314	P	1954	1,264	470	6	O	R	N	DR	FD	22	19 11.9	2-24-61 5-14-62	20 20	C	—	960F	—	—	
015-138-410	P	1949	1,187	757	12	O	R	T	P	D	14	23	5-22-62	19	C	—	2,700FM	—	—	Ocala Group cased off.
015-141-111	P	1938	600	470	4	O	X	N	DN	F	8.6	41 P 16.4	7- 5-40 5- 9-62	10 15	—	74.5	450FM	—	—	
015-145-230	P	1961	1,000M	460	18	O	R	T	P	FD	33	7.36	5-17-62	13	—	—	2,500FM	—	—	L
015-145-330	P	1923 1924	1,920 1,690	800-1,000	12	O	X	N	T	FD	64.9	— 3.6 R —17.16	4-16-41 5- 2-62							Plugged at 1,920 feet Recorder record
016-125-431	P	1959	615	332	6	O	R	C	P	F	4	38 29.4	2-27-61 5-15-62	18 20	—	—	950	—	—	
016-137-100	P	—	70-100	—	2	O	X	J	DN	SR	—	—	—	—	C	—	—	—	—	
016-137-444	P	1953	733	531	6	O	R	C	DA	F	—	11.7 9.2	2-24-61 7-12-61	17	—	—	400F	—	—	
016-138-310	P	—	99	—	2	O	X	J	D	SR	—	—	—	—	C	—	—	—	—	
016-142-414	M	1923	729	476	8	O	X	C	PN	F	16.2	40 P 9.2	8-22-30 5- 9-62	— 16	—	—	—	—	—	
017-126-232	P	1939	550	480	3	O	X	N	D	F	11.6	40.6 32.3 22.3	9- 6-40 1- 7-60 5-15-62	17 22 20	—	73	—	—	—	Cl. 10-7-55
017-126-440	P	—	400	—	—	O	X	C	P	F	—	—	—	—	C	—	—	—	—	
017-130-442	P	—	—	—	4	O	X	N	DN	F	40	1.6 — 1.34	12-19-61 5-15-62	— —	— —	— —	— —	— —	— —	
017-134-210	P	1960	1,004M	487	15	O	R	—	P	FD	13	—	—	21	—	—	2,000FM	—	—	L; Cl. 12-2-60
017-134-331	P	1939	675	—	7	O	R	N	DR	F	24.1	29.5 18 4.9	6- 7-39 1- 5-60 5-14-62	18 24 22	—	71.5	475F	—	—	Cl. 10-13-55
017-135-413	C	1939	785	524	10	O	R	J	P	F	26.7	26.8	6- 5-39	15	C	—	—	—	—	L, Dr; Cl. 11-15-40
017-136-124	P	—	56	—	1¼	O	J	N	N	SR	23	—14.76P —19.25	2-23-61 5-14-62	13	—	—	—	—	—	

TABLE 8. (Continued)

Well number	Owner	Year completed	Depth of well (feet)	Casing: Depth (feet)	Casing: Diameter (inches)	Well finish	Method of drilling	Type of pump	Use of water	Aquifer(s)	Altitude of land-surface above mean sea level (feet)	Water level: Above or below (-) land surface (feet)	Water level: Date of measurement[1]	Chloride (Cl) (parts per million)[1]	Chemical analyses available	Temperature (°F)	Yield (gallons per minute)	Drawdown	Period of discharge (hours)	Remarks
017-136-241A	M	1957	1,234	515	18	O	R	N	PN	FD	23	30.3 R 19.5	9-27-60 5-14-62		—	—	3,050FM	—	—	Pressure recorder installed 9-26-60, removed 2-3-62
017-136-241B	P	1957	245	200	1½	O	X	N	N	SR	23	— 6.29P —13.18	2-16-61 5-14-62		—	—	—	—	—	
017-137-214	P	1962	1,210M	530	8	O	R	C	R	FD	26	—	—	—	—	—	—	—	—	L
017-138-142	M	1955	1,500	500	12	O	R	C	P	FD	20	—	—	—	C	—	—	—	—	V (incomplete)
017-158-110	M	1957	715	465	12	O	R	T	P	F	85	—35	3- 5-57	—	—	—	—	—	—	W-4202
017-158-430	P	1942	750	433	10	O	X	T	I	F	85	—25.05 —29.4	1-11-61 5-17-62	36	—	—	—	—	—	
018-123-123	M	1934	585	357	8	O	X	N	PN	F	11.1	42.4 P 21.6	10-14-39 5-19-62	— 24	—	—	—	—	—	
018-124-222	M	1938	622	382	10	O	X	C	P	F	10	40.3	12-12-38	—	—	72.5	2,130FM	—	—	W-392, L
018-131-240	P	1959	1,002	427	16	O	R	T	P	FD	42	—	—	—	—	—	—	—	—	L, Dr.
018-135-433	M	—	600-650	—	6	O	X	C	PN	F	17	19.2 R	9-27-60	—	—	—	—	—	—	Pressure recorder installed 9-27-60, removed 10-31-61
018-136-241	O	—	685	508	4	O	X	—	P	F	—	—	—	—	C	—	—	—	—	

018-136-411	P	—	630	—	3	O	X	C	D	F	16.2	27.9 14 1	2-22-39 1- 5-60 5-15-62	17 18 31	—	75	—	—	—	Cl, 10-6-55
018-138-343	M	1939 1949	1,071 1,348	505	10	O	R	T	P	FD	20.5	30 17 16.9	3-23-39 1-12-60 7-13-61	12 20	—	—	—	—	—	W-322, L; Cl, 11-7-40
018-139-230	M	1935 1943	583 1,307	500 —	10	O	X	T	P	P FD	— 7	—	—	—	—	—	—	—	—	W-306, L
018-139-233	M	1939 1959	1,037 1,280	508	10	O	R	T	P	FD	5.1	43.9 39.1 35.3	3-23-39 1-12-60 7-13-60	12 16 19	—	—	—	—	—	L, Dr; Cl, 11-7-40 Cl, 5-21-41
018-140-123	P	—	—	—	10	O	X	N	D	F	4.5	43.2 P 18.2	11-26-38 5- 9-62	— 20	—	—	—	—	—	
018-142-210	M	1931 1943	736 1,247	479	10	O	X	C	P	F FD	14	—	—	—	—	—	1,700F	—	—	W-169, L
018-143-234	M	—	900	—	6	O	X	N	PN	FD	24.6	30.7 P 10.1	11-28-40 5- 9-62	17						
018-145-340	P	—	80	—	2	O	X	J	DA	SR	—	—	—	—	C	—	—	—	—	
019-123-111	P	1937	650	—	3½	O	X	N	R	F	12.6	41.5 32.6 20	2-25-39 1- 7-60 5-15-62	20 19 22	—	71	—	—	—	Cl, 10-6-55
019-123-130	P	1938	—	—	3	O	X	N	R	F	10	42.9 34.8	2-25-39 1- 7-60	22						
019-124-210	M	1962	1,300M	407	18	O	R	N	P	FD	12	30	6- 4-62	28	CM	—	5,000FM	—	—	A, C, E, L, V, packer tests
019-132-411	P	1929	762	509	5	O	X	N	R	F	38.4	17.7 7.3	6- 7-39 11-18-60	15 18 18 16	—	—	—	—	—	Cl, 11-19-40 Cl, 4-7-48 Cl, 10-7-55
019-133-433	P	1929	875	400	6	O	X	C	DR	F	53.04	1.8 P —21.94	6-10-39 5- 9-62	—	—	—	—	—	—	
019-134-310	P	1938	635	520	3	O	C	N	DN	F	24.1	31.5 20.2 9.5	6- 8-39 1- 6-60 5-16-62	18	—	76	—	—	—	Cl, 10-14-55
019-135-430	P	—	200	—	16		—	—	P	SR	—	—	—	—	C	—	—	—	—	

TABLE 8. (Continued)

Well number	Owner	Year completed	Depth of well (feet)	Casing: Depth (feet)	Casing: Diameter (inches)	Well finish	Method of drilling	Type of pump	Use of water	Aquifer(s)	Altitude of land-surface above mean sea level (feet)	Water level: Above or below (-) land surface (feet)	Water level: Date of measurement[2]	Chloride (Cl) (parts per million)[1]	Chemical analyses available	Temperature (°F)	Yield (gallons per minute)	Drawdown	Period of discharge (hours)	Remarks
019-138-320	P	1942	1,074	508	16	O	X	—	I	FD	4	42	7-20-42	—	—	—	2,000F	—	—	W-649, L
019-139-124	P	1961	753M	516	16	O	C	C	DA	F	22.1	— 0.1	5-17-62	22	—	—	150FM	—	—	L, D
019-139-230	P	1939	655	491	6	O	X	C	DR	F	3.5	30.3	3- 8-39	—	C	73	—	—	—	L, Dr
019-139-334	P	1954	760	510	8	O	R	C	PRA	F	4	19.5	5-15-62	19	—	—	—	—	—	L, Dr
019-140-421	P	—	785	—	6	O	X	N	T	F	8.3	32.1 PR 13.3	11-25-38 5- 9-62	13 21	—	73	—	—	—	Cl, 10-15-30
019-142-111	M	1911	1,075	—	10	O	X	N	PN	FD	22.8	39.2 P 13.2	8-13-30 5- 9-62	— 16	—	73	—	—	—	
019-143-131	P	—	—	—	4	O	X	C	I	F	21.9	36.8 25.5	7-16-40 1-13-60	13 16	—	72.5	—	—	—	Cl, 10-12-55
019-146-340	P	1938	612	501	2½	O	X	C	DR	F	44.1	15.1 4.45 3.97 1.88	7-23-40 1- 3-60 12-22-60 7-14-61	12 12	—	—	—	—	—	Cl, 10-12-55
019-147-210	P	1929	1,060	583	6	O	X	—	D	FD	59	3.1	7- ?-29	—	—	—	—	—	—	W-116, L
020-134-334	P	1936	765	—	4	O	X	N	DR	F	30.3	30.8 10.7 11.3 5.67	6- 8-39 1- 6-60 7-12-61 5-16-62	18 18 19	—	76.5	—	—	—	Cl, 10-14-55
020-136-240	P	1932	750	—	3	O	J	N	DR	F	34.2	23.5 12.8 2.1	6-11-39 1- 6-60 5-15-62	— 19 21	—	76	—	—	—	

020-136-434	P	1940	690	560	3	O	X	N	R	F	29.4	23.5 15.5 9.2 6.8	8-23-40 1- 6-60 7-12-61 5-15-62	14 21 20	—	76	—	—		Cl, 11-4-55
020-137-340	P	—	—	—	4	O	X	C	I	F	14.7	40.0 34.5 18.0	2-16-34 7- 4-40 5-21-62	— 18 23	—	—	—	—	—	Cl, 11-3-55
020-139-132	M	1911	1,015	438	10	O	X	N	PN	FD	5.9	36.8 30.3 18.3	6-16-39 1-12-60 5-24-62	13 16 21 24	—	77	—	—	—	Cl, 11-7-40 Cl, 5-21-41
020-139-322	M	1936	1,035	494	10	O	X	C	P	FD	5.5	35.5	9-23-36	—	—	—	1,135F	—	—	W-304, L
020-139-443	M	1907 1923	980 1,250	—	10	O	X	C	P	FD	4	49.0 36.8 33.5 34.2	6-13-39 1-12-60 7-13-61 5-24-62	17 17 22 24	—	83	—	—	—	Cl, 11-7-40 Cl, 5-4-44
020-140-330	P	—	1,150	—	6	O	X	N	I	FD	24.1	27.3 25.2 14.6	2- 6-39 1-11-60 5-17-62	17 18	—	83	200-300F	—	—	Cl, 10-?-55
020-144-430	P	—	630	500	3	O	X	N	DR	F	24.7	25.9 18.6 11.9	7-23-40 1-13-60 5-18-62	11 16 18 17	—	81	—	—	—	Cl, 10-12-55
021-128-133	P	1937	575	—	6	O	X	N	R	F	9.1	43.6 34.4 26.3	2-25-39 1- 7-60 5-15-62	15 18 22 29	—	72	—	—	—	Cl, 11-19-40 Cl, 10-7-55
021-125-421	P	1961	703M	396	8	O	R	—	P	F	7.0	32.3 26.5	5-19-61 5-16-62	22 22	—	—	930FM	—	—	L, D
021-132-410	P	1937	540	475	3	O	X	N	R	F	17.0	37.7 21.3	8-24-40 1- 6-60	20 22	—	—	—	—	—	Cl, 10-14-55
021-133-220	P	1953	610	522	4	O	J	N	DR	F	15	31.4 23.3	9-28-60 5-16-62	20 24	—	—	—	—	—	
021-136-400	P	—	90	—	-		—	J	DR	SR	—	—	—	—	C	—		—	—	
021-138-121	P	1938	1,060	543	10	O	X	C	R	FD	16.7	39.5 27.2 16.1	2- 7-39 1-12-60 5-21-62	13 23 21	—	78	2,160F	—	—	Cl, 11-13-40

TABLE 8. (Continued)

Well number	Owner	Year completed	Depth of well (feet)	Casing: Depth (feet)	Casing: Diameter (inches)	Well finish	Method of drilling	Type of pump	Use of water	Aquifer(s)	Altitude of land-surface above mean sea level (feet)	Water level: Above or below (-) land surface (feet)	Water level: Date of measurement[1]	Chloride (Cl) (parts per million)[1]	Chemical analyses available	Temperature (°F)	Yield (gallons per minute)	Drawdown	Period of discharge (hours)	Remarks
021-139-120	P	1939	730	473	8	O	X	N	N	F	21.3	31.2 24 14.4	7- 1-40 1-12-60 5-21-62	16 21	—	—	—	—	—	Cl, 10-5-55
021-139-222	P	1962	1,303M	550	16	O	R	—	R	FD	20	23.0	2- 8-62	—	—	—	1,900FM	—	—	L, V
021-139-424	M	—	—	—	8	O	X	N	N	F	19.0	35.2 27.7 18.9	7- 1-40 1-11-60 5-21-62	17 18 19	—	78	—	—	—	Cl, 10-5-55
021-141-414	M	1939	1,053	530	10	O	X	T	P	FD	16.4	40.8 26 20.11	6-14-39 1-12-60 5-24-62	16 18 19	—	80	—	—	—	Cl, 5-21-41; W-830, L
021-141-423	M	1939 1941	1,055 1,356	513	16	O	R	T	P	FD	24.4	32.9	6-14-39	—	—	78	1,500FM	—	—	L, V
021-142-100	P	—	80	—	—		X	J	DR	SR	—	—	—	—	C	—	—	—	—	
022-130-112	P	1959	1,000	462	16	O	R	T	P	FD	39	7.2	9-25-60	—	—	—	900F 2,000P	— 21	— 3	L, Dr
022-138-400	P	1923	1,076	—	8	O	C	C	R	FD	19.2	37.7 26.8 15.3	2- 8-39 1-12-60 5-21-62	18 20	—	76	—	—	—	Cl, 10-5-55
022-139-244	P	1915	700	510	6	O	–	N	D	F	16.4	37.3 25.9 22.5 15.7	2-11-39 1-12-60 7-13-61 5-21-62	18 18 21	—	—	—	—	—	Cl, 10-5-55
022-140-410	M	1951	1,303	—	12	O	R	C	P	FD	22.4	26 19	1-12-60 5-24-62	22 23	—	—	—	—	—	
022-143-320	P	1940	690	469	6	O	X	—	R	F	10.5	—	—	—	—	—	1,020F	—	—	W-532, L

022-147-240	P	1953	630	—	3	O	X	N	S	F	23	24.5 18.6	10-19-60 5-17-62	15 18	—	—	—	—	—	
023-124-320	U	1962	1,001	435	18	O	R	N	PF	FD	6.7	30.3	5-16-62	31	—	—	2,500F	—	—	W-5823
023-125-142	U	1939	510	—	6	O	X	N	N	F	8.0	41.3	6- 9-39	18	—	73	—	—	—	Flowing wild; Cl, 11-19-40
												36.4	1- 7-60	22 23						Cl, 10-7-55
023-129-330	U	—	200	—	2		X	J	DRF	SR	—	—	—	—	C	—	—	—	—	
023-136-310	P	1930	—	—	4	O	X	N	R	F	3.12	53.2 P 32.2	6-12-39 5- 9-62	— 21	—	—	—	—	—	
023-138-344	M	1925	905	570	8	O	X	N	N	FD	14.9	47.0 PR	6-22-30	16	CD	—	—	—	—	Pressure recorder installed 1-3-62, removed 3-26-62; Cl, 5-20-41; Tritium
												23.7	5-10-62	16						Cl, 1-7-60
023-139-220	P	1940	700	560	3	O	X	N	N	F	6.0	43.8 P 28.8	7-27-40 5-10-62	15	—	73.5	—	—	—	
024-125-233	S	—	—	—	3½	O	X	N	N	F	4	28	5-21-62	—	—	—	—	—	—	Flowing wild
024-136-130	P	1929	800	—	6	O	X	N	R	F	29.2	28.0 P 3.4	6-25-40 5-18-62	18	—	75	—	—	—	
024-141-340	P	—	70	—	2		X	—	DR	SR	—	—	—	—	C	—	—	—	—	
024-144-320	P	1939	625	500	3	O	X	N	D	F	20.7	35.3 23.3 17.0	7-24-40 1-18-60 5-18-62	18 19 20	—	—	—	—	—	Cl, 10-12-55
025-125-231	P	1930	840	450	8	O	X	C	DR	FD	15.7	45.2 P 25.8	8-19-30 5-10-62	90 122	— —	80 —	— —	— —	— —	Cl, 11-21-40 Cl, 9-19-60
025-132-444	P	—	—	—	4	O	X	N	DR	F	4.2	42.3 36.2	1-21-60 5-21-62	35 25	—	—	—	—	—	
025-136-220	P	1910	556	—	8	O	X	—	IN	F	8.8	44.5 P 18.3	3-22-51 5-10-62	25	—	—	—	—	—	Cl, 3-8-60
025-138-210	M	1942	942	660	8	O	X	C	PRI	FD	19.9	21.7 23.6 18.5	1-20-60 7-13-61 5-18-62	28 25	—	—	—	—	—	

TABLE 8. (Continued)

Well number	Owner	Year completed	Depth of well (feet)	Casing		Well finish	Method of drilling	Type of pump	Use of water	Aquifer(s)	Altitude of land-surface above mean sea level (feet)	Water level		Chloride (Cl) (parts per million)[1]	Chemical analyses available	Temperature (°F)	Yield (gallons per minute)	Drawdown	Period of discharge (hours)	Remarks
				Depth (feet)	Diameter (inches)							Above or below (-) land surface (feet)	Date of measurement[1]							
025-138-333	M	1941	1,019	434	10	O	X	C	PRI	FD	14.5	31.15 29.5 24.5	1-20-60 7-13-61 5-18-62	25 24	—	—	1,830F	—	—	W-544, L
025-141-300	P	1932	725	500	6	O	X	N	R	F	17.7	39.2 26.8	6-12-40 1-18-60	11 19 24	—	74	—	—	—	Cl, 11-14-40 Cl, 10-3-55
025-148-220	P	1962	1,280M	605	18	O	R	C	P	FD	25	—	—	—	—	—	4,800FM	—	—	L, V
026-126-423	S	1921	455	—	8	O	X	C	D	F	12.2	42.1 36.5 30.0	9-12-40 1-19-60 5-21-62	19 19 20 24 25	—	73	......	—	—	Cl, 11-21-40 Cl, 6-20-41 Cl, 10-25-55
026-135-342A	P	1951	1,393	584	6	O	R	N	T	FD	17.3	37.0 P 22.5	6-12-51 5-10-62	24 27	C	—	930F	—	—	W-606, L, V, E; Cl, 1-7-60
026-135-342B	P	—	1,025	850	4	O	R	N	T	D	16.96	33.1 P 23.2	1-13-54 5-10-62	25	C	—	—	—	—	L, Dr; Ocala Group cased off; Cl, 12-9-60
026-135-342C	P	—	700	450	4	O	R	N	T	F	16.87	32.9 P 22.2	1-13-54 5-10-62	25	C	—	—	—	—	L, Dr; Cl, 12-9-60
026-136-432	P	1956	1,373	612	20	O	R	T	I	FD	16.2	28.8	5-31-56	—	—	—	—	—	—	W-3974, L
026-136-434	P	1956	1,390	605	26	O	R	T	I	FD	14.1	27.72	4-20-56	—	—	—	6,700	—	—	W-3869
026-141-310	C	1952	700	601	8	O	R	C	P	F	25.2	17.8	5-24-62	24	—	—	455F	—	—	W-2410, L

026-145-100	P	1954	750	430	6	O	R	N	S	F	25	27.2 27.8	1-11-56 1-18-60	— 30	—	—	530F	—	—	W-3345
026-145-420	P	1917	658	—	6	O	X	N	S	F	23.6	34.3 21.1 15.0	7-24-40 1-18-62 5-18-62	21 25 29 27	—	73	—	—	—	Cl, 11-14-40 Cl, 10-12-55
027-134-220	P	1936	642	—	3	O	X	—	DS	F	20.8	35.0 P 18.4	6-26-40 5-10-62	24 25	—	—	—	—	—	Cl, 3-8-60 Cl, 9-19-60
027-143-314	P	—	610	446	4	O	X	N	DS	F	21.8	35.1 16.2	6-24-40 1-18-60	23 26 30 28	—	—	—	—	—	Cl, 11-14-40 Cl, 10-12-55 Cl, 5-18-62
028-137-334	C	—	—	—	2	O	X	—	PN	F	34.8	22.2 P 5.58	7-24-40 5-10-62	22 20	—	74	—	—	—	Cl, 11-14-40
028-141-333	P	—	—	—	3	O	X	N	SN	F	22	13	4-25-62	28	—	—	—	—	—	
029-142-240	P	—	—	—	3	O	X	N	DS	F	24	12.7	4-25-60	29	—	75.5	—	—	—	
032-137-410	P	1935	485	—	3	O	X	N	N	F	26.4	22.8 16.4 11	1-16-40 10-25-55 1-18-60	22 28	—	71	—	—	—	Flowing wild; Cl, 11-14-40
023-156-100A	P	—	96	96	1½	S	X	—	D	SS	66	1	4- 9-34	—	C	70	—	—	—	
023-156-100B	P	1928	201	100	2	O	X	—	D	SR	68	2.5	4- 9-34	—	C	70	—	—	—	
023-156-430	P	1900	650	—	6	O	X	J	D	F	69	0.0	3- 1-51	—	C	—	—	—	—	
031-148-120	P	—	500	—	3	O	X	N	D	F	20	22.7	5- 9-62	—	—	—	—	—	—	
032-126-142	P	1937	680	—	4	O	X	N	D	F	13.70	41.75P 18.8	3-24-39 5-10-62	23 26 28	—	72	—	—	—	Cl, 11-23-40 Cl, 3-8-60 Cl, 9-19-60
032-150-300	P	—	500	—	3	O	X	N	DS	F	20	27.7	1-12-61	31	—	—	—	—	—	
033-149-140	M	—	600-800	—	-	O	X	—	P	F	20	—	—	—	C	—	—	—	—	
033-150-242	P	1938	580	—	2	O	X	—	D	F	18.8	40.2 P 25.2	1-18-40 5-10-62	26 31	—	72	—	—	—	Cl, 11-22-40

TABLE 8. (Continued)

Well number	Owner	Year completed	Depth of well (feet)	Casing: Depth (feet)	Casing: Diameter (inches)	Well finish	Method of drilling	Type of pump	Use of water	Aquifer(s)	Altitude of land-surface above mean sea level (feet)	Water level: Above or below (-) land surface (feet)	Water level: Date of measurement[1]	Chloride (Cl) (parts per million)[1]	Chemical analyses available	Temperature (°F)	Yield (gallons per minute)	Drawdown	Period of discharge (hours)	Remarks
034-131-433	P	1920	800	——	3	O	X	N	D	F	17	22.2 P	5- 8-62	27	—	——	——	—	—	
034-136-233	P	192-	480	——	2	O	X	N	D	SR	6	10.0	5- 8-62	29	—	71.4	——	—	—	May be Floridan aquifer, leak in casing
035-127-310	P	1932	580	350	3	O	X	N	R	F	9.9	41.1 P 19.8	3-23-39 5-10-62	25 31	—	72.5	——	—	—	Cl, 11-23-40 Cl, 12-9-60
035-127-330	P	——	540-640	——	3	O	X	N	D	F	14.7	39.7	3-22-39	26 27	...	——	——	—	—	Cl, 9-5-55 Cl, 11-10-59
035-127-410	P	1932	580	350	3	O	X	N	R	F	15.4	38.5 21.8	3-23-39 1-25-60	27	—	——	——	—	—	Cl, 9-7-55
036-135-311	P	1953	905	480	16	O	R	—	I	F	25	——	——	---	—	——	865F	—	—	W-2964, L
037-126-214	P	1939	——	——	3	O	X	N	DR	F	16.9	36.8 4.0 2.5 3.77 — 0.67	3-25-39 9- 8-55 11- 4-59 1-25-60 5-21-62	28 29 36 39	—	73	——	—	—	Cl, 11-23-40
037-129-242	S	1927	578	——	2	O	X	N	DRS	F	6.0	46.3 4.9 3.8 7.4 4.55	3-28-39 9-15-55 11- 5-59 1-25-60 5-21-62	27 27 28 30 31	—	72.5	——	—	—	Cl, 11-23-40
037-130-330	P	1940	540	504	2	O	X	N	D	F	12.6	26.7 P 9.3	6-26-40 5-10-62	27 30	..	71.5	——	—	—	Cl, 11-23-40

037-136-122	I	—	1,000	450	4	O	X	C	I	FD	34.8	19.2 P — 2.34	1-16-40 5-10-62	28 33	—	74.5	—	—	—	Cl, 9-10-42 Cl, 1-3-62
037-142-430	P	1938	569	—	2	O	X	N	DR	—	17.8	40.3 P 20.9	1-18-40 5-10-62	24 31	—	71.5	—	—	—	Cl, 11-23-40
038-126-320	M	—	1,203	572	12	O	R	T	P	FD	15	—	—	27	—	—	1,284P	38	8	W-4310, L, Dr; Cl, 8-20-57
														29 30						Cl, 4-1-59 Cl, 10-28-59
038-127-142A	I	1940	2,130	567	10	O	R	T	I	FD	19.1	8.22 P	11- 1-60	1,680	C	—	1,900F	—	—	W-890, L, A, E, V; packer tests complete & partial chemical analyses, artesian head and flow measurements made at different depths while the well was being drilled in 1940. Packer tests and current-meter traverses made in 1945.
		1946	1,826									3.72	10- 5-61	1,180	MC					Plugged at 1,826 ft, Cl, 5-8-62
		1962	1,100												P					Plugged at 1,100 ft
038-127-142B	I	1940	1,100	—	26	O	R	N	IN	F	19	—22.2 P —24.66	11-10-59 5-10-62	26 27 29 29	— MC	—	—	—	—	Cl, 11-29-40 Cl, 10-5-52 Cl, 12-27-60 Cl, 9-6-62

TABLE 8. (Continued)

Well number	Owner	Year completed	Depth of well (feet)	Casing: Depth (feet)	Casing: Diameter (inches)	Well finish	Method of drilling	Type of pump	Use of water	Aquifer(s)	Altitude of land-surface above mean sea level (feet)	Water level: Above or below (-) land surface (feet)	Water level: Date of measurement[1]	Chloride (Cl) (parts per million)[1]	Chemical analyses available	Temperature (°F)	Yield (gallons per minute)	Drawdown	Period of discharge (hours)	Remarks
038-127-330	P	—	725	—	2	O	X	N	DN	F	9.9	2.67 — 2.64 — 5.05 — 1.46 — 5.46	11-23-40 9- 8-55 11- 4-59 1-25-60 5-10-62	—	—	—	—	—	—	
038-127-344	P	1938	640	—	2	O	R	—	D	F	13.0	40.9 P —12.64	3-25-39 5-10-62	30 28 62	—	—	—	—	—	Cl, 4-7-48 Cl, 10-7-48 Cl, 11-10-59
038-145-330	D	192-	480	—	2	O	X	N	DS	F	15	32.4	5- 9-62	38	—	—	—	—	—	
039-127-111	I	1938 1946	1,100 1,700	545	26	O	R	T	I	FD	6.8	43.5	3-15-39	33P 56	MC	75	—	—	—	Cl, 2-15-38 Cl, 5-31-62; deepened to 1,700 ft
039-127-120	PM	1937	750	—	8	O	R	T	I	F	15	34.9	11-30-40	26 33 32 34	MC	—	1,792F	—	—	W-343, L Cl, 4-1-59 Cl, 10-28-59 Cl, 5-31-62
039-127-321	I	1938	1,072	551	26	O	R	T	I	FD	13.7	37.4	3-15-39	33 P	MC	—	—	—	—	Wgi-10, L, Dr, Cl, 2-15-38
		1946	1,840											140						Cl, 5-7-62; deepened
039-127-344	I	1938	1,073	545	26	O	R	T	I	FD	18.1	34.5	3-15-39	33P	MC	—	1,880F	—	—	Wgi-12, L, Dr; Cl, 6-25-37
		1946	1,820											168						Cl, 5-31-62; deepened

039-128-131	I	1942	1,065	550	26	O	R	T	I	F	11	—	—	30P 32	MC	—	—	—	—	W-690, L; Cl, 5-30-50 Cl, 5-31-62
039-128-241	I	1938	1,054	549	30	O	R	T	I	F	8.8	42.6	3-15-39	34P	MC	—	3,158F	—	—	Wgi-9, L, Dr; Cl, 1-19-38
														33						Cl, 10-12-61
039-131-231A	P	1938	—	—	3	O	X	N	DR	F	9.8	25.4 5.58 10.4 3.46	1-17-40 9- 7-55 7-17-61 5-21-62	— 33	—	72	—	—	—	
039-131-231B	P	—	—	—	3	O	X	C	DR	F	10	5.05 6.95	11- 2-59 1-25-60	30 33						
040-126-332	P	1939	—	—	3	O	X	N	DN	F	20.4	29.5 P —24.58	3-28-39 5-10-62	33	—	72	—	—	—	Cl, 4-7-48
040-127-211A	I	—	93	—	10	O	X	N	IN	SR	5	—13.00R —11.4	3-10-61 5-28-62	—	MP	—	—	—	—	Pressure recorder installed 3-9-61
040-127-211B	I	1937	900	530	24	O	R	T	I	F	15	—	—	33P	MP	—	—	—	—	W-391, L, Dr; Cl, 11-12-56
														45						Cl, 5-17-62
040-127-212	I	—	100	80	5	O	R	C	I	SR	5	—10.86	3- 7-61	—	MP	—	—	—	—	
040-127-313	P	1925	—	—	3	O	R	N	N	F	5.87	43.0 —25.51 —16.93 —18.52 —14.01 —23.67	6-19-39 9-14-55 11- 5-59 1-25-60 7-17-61 5-21-62	—	—	73	—	—	—	
040-127-432A	PM	—	1,100	—	8	O	R	T	P	FD	27.9	17	3-28-39	29P 26	MC	72.5	—	—	—	Cl, 1-8-24 Cl, 10-28-59
040-127-432B	PM	—	1,025	500	8	O	R	T	P	FD	—	—	—	39P 35	MC	—	—	—	—	Cl, 9-28-37 Cl, 5-31-62
040-127-432C	PM	—	731	—	8	O	R	T	P	F	—	—	—	—	C	—	—	—	—	
040-127-432D	PM	1953	1,205	550	12	O	R	T	P	FD	24.9	—	—	—	C	—	—	—	—	W-2918, L, Dr

TABLE 8. (Continued)

Well number	Owner	Year completed	Depth of well (feet)	Casing: Depth (feet)	Casing: Diameter (inches)	Well finish	Method of drilling	Type of pump	Use of water	Aquifer(s)	Altitude of land-surface above mean sea level (feet)	Water level: Above or below (-) land surface (feet)	Water level: Date of measurement[1]	Chloride (Cl) (parts per million)[1]	Chemical analyses available	Temperature (°F)	Yield (gallons per minute)	Drawdown	Period of discharge (hours)	Remarks
040-138-410	I	1936	500	—	2	O	X	N	DR	F	20.2	23.4 23.3 15.4	9-14-55 1-20-60 5-22-62	20 35 33	—	72	—	—	—	Cl, 11-22-40
041-126-333A	I	1959	2,100	1,450	30	O	R	T	I	D	15	—	—	80P	MP	—	—	—	—	Ocala Group cased off; Cl, 2-1-61; A (5-ft. interval)
		1959	1,961	1,328										97	C					Cl, 5-17-62
041-126-333B	I	1955	1,408	550	20	O	R	T	I	FD	15	......	......	142P 165	—	—	—	—	—	Cl, 11-12-56 Cl, 5-17-62
041-127-142	I	1930	500	—	3	O	R	C	I	F?	7.8	41.3 9.36 3.01 1.24	6-21-39 9-14-55 11- 5-59 1-25-60	36	—	76	—	—	—	This well may not be completed in the Floridan aquifer. Cl, 5-21-62
041-127-322	I	—	753M	510	4	O	R	N	IN	F	6	—11.25R —22.43	11-18-60 5-21-62	36	—	—	—	—	—	Float recorder installed 11-18-60; E; Cl, 5-21-62
041-127-430	I	1955	1,410	550	-	O	R	T	I	FD	—	—	—	202 195 220	—	—	—	—	—	Cl, 10-7-61 Cl, 2-13-62 Cl, 5-17-62
041-147-220	P	—	450	—	3	O	-	N	N	F	19	30.9 26.1	10- 9-58 5- 9-62	34 33	—	75.5	90F	—	—	

[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]	O	R	N	DN	F	80.7	—21.54 —26.24	6-19-44 1-20-60	—	—	—	—	—	...	Float recorder installed 6-19-44, removed between 1953-1956
041-155-421	M	1955	821	448	10	O	R	T	P	F	80	—	—	—	C	—	—	—	—	W-3586, L; chemical analyses-4-2-59
041-155-424	M	1961	738M	520	16	O	R	T	P	F	80	—	—	—	—	—	350P	10	2	L
042-125-333	S	1938	800	550	4	O	R	N	PN	F	7.8	43.1 P 3.64	3-27-39 5-21-62	32 40	—	72	270	—	—	W-391, L; Cl, 11-23-40
042-127-334	S	—	800	534	4	O	X	C	PF	F	7.5	44.3	3-27-49	28 33 32 34	—	72	270FM	—	—	L, Dr; Cl, 1-25-40 Cl, 5-15-59 Cl, 11-4-59 Cl, 5-21-62
042-127-443	S	1938	800	520	4	O	X	C	PF	F	6	42.7 23.2	3-27-39 1-16-40	30 32 32	—	72	245FM	—	—	L, Dr; Cl, 9-8-55 Cl, 5-15-59 Cl, 11-4-59
042-154-430	U	1960	700	405	8	O	R	T	PFA	F	52	— 3.82 — 6.07 — 8.06	10-21-60 7-13-61 5-22-62	32 34	[illegible]	—	—	—	—	
043-137-441	I	—	—	—	3	O	X	N	D	F	14	17.2	5- 8-62	37	—	—	—	—	—	
044-141-430	S	—	—	—	3	O	X	C	P	F?	15	—	—	32	C	—	—	—	—	May not be completed in Floridan aquifer; Cl, 4-10-59
044-156-100	P	1940	4,824	4,645	6⅝	-	R	N	T	FD	99.2	—	—	33,600	C	—	—	—	—	W-336, L. Analysis of water sample taken at 2205-2230 ft below land-surface datum. Cl, 8-24-37
046-158-300	P	—	450	—	3	O	X	C	D	F	60	— 5.7	5- 9-62	46	—	—	—	—	—	

TABLE 3. Stratigraphic units and aquifer systems in Duval, Nassau, and and Baker counties.

Geologic age	Stratigraphic unit	Approximate thickness (feet)	Lithologic character	Aquifer systems	Water-bearing properties
Recent and Pleistocene	Recent and Pleistocene deposits	0-150	Soil, muck, coarse to fine sand, shell, and some clayey sand	Shallow aquifer system	Surficial sand yields small amounts of water. Sand and shell bed along coast yields moderate quantities.
Pliocene?	Pliocene or Upper Miocene deposits	20-110	Gray-green calcareous, silty clay and clayey sand; contains shell beds and white soft, friable limestone beds		Limestone, sand, and shell bed near base of deposits yield moderate to (locally) large amounts.
Miocene	Hawthorn Formation	260-490	Gray to blue-green calcareous phosphatic, sandy clays and clayey sands; contains fine to medium phosphatic sand lenses and limestone and dolomite beds, particularly near the base of the formation	Aquiclude	Relatively impermeable clays and marls in both the late Miocene or Pliocene deposits and the Hawthorn Formation confines the artesian water in the Eocene limestone and in the limestone and shell beds above the Eocene limestone. Yields small to moderate supplies.
Eocene	Ocala Group: Crystal River Formation	50-300	White to cream chalk, massive fossiliferous marine limestone.	Floridan aquifer system	Marine limestone foamrtions utilized as the primary source of water in the area.
	Ocala Group: Williston Formation	20-100	Tan to buff granular, marine limestone		
	Ocala Group: Inglis Formation	40-120	Tan to buff granular, calcitic, marine limestone; contains thin dolomite lenses and zones of **Miliolidae** foraminiferal coquina		
	Avon Park Limestone	50-250	Alternating beds of brown to tan hard, massive dolomite, brown finely crystalline dolomite, and granular calcitic limestone	Aquiclude	Massive dolomite beds restrict vertical movement of water.
	Lake City Limestone	425-500+	White to brown, purple-tinted lignitic, granular limestone and gray hard, massive dolomite; contains lignite beds and zones of **Valvulinidae** foraminiferal coquina		Limestone and porous dolomite beds yield large to very large quantities of water. Hard dolomite and limestone beds restrict vertical movement of water within certain zones. Potentially the greatest source of water in the area.
	Oldsmar Limestone	846	Cream to brown massive to chalky, granular limestone and tan to brown massive to finely crystalline dolomite		

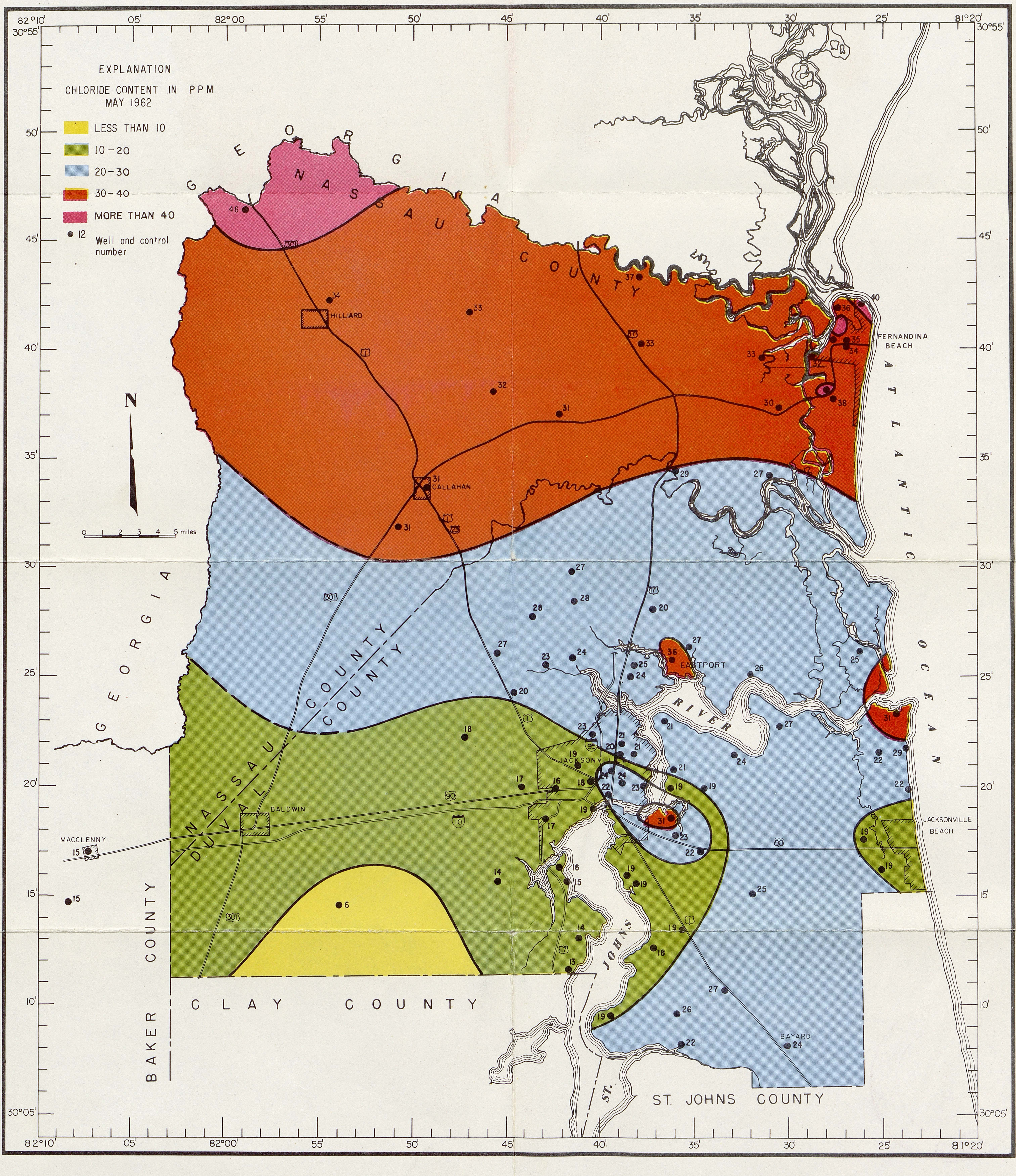

Figure 19. Map of Duval and Nassau counties showing the approximate chloride content of water from aresian wells in May 1962.

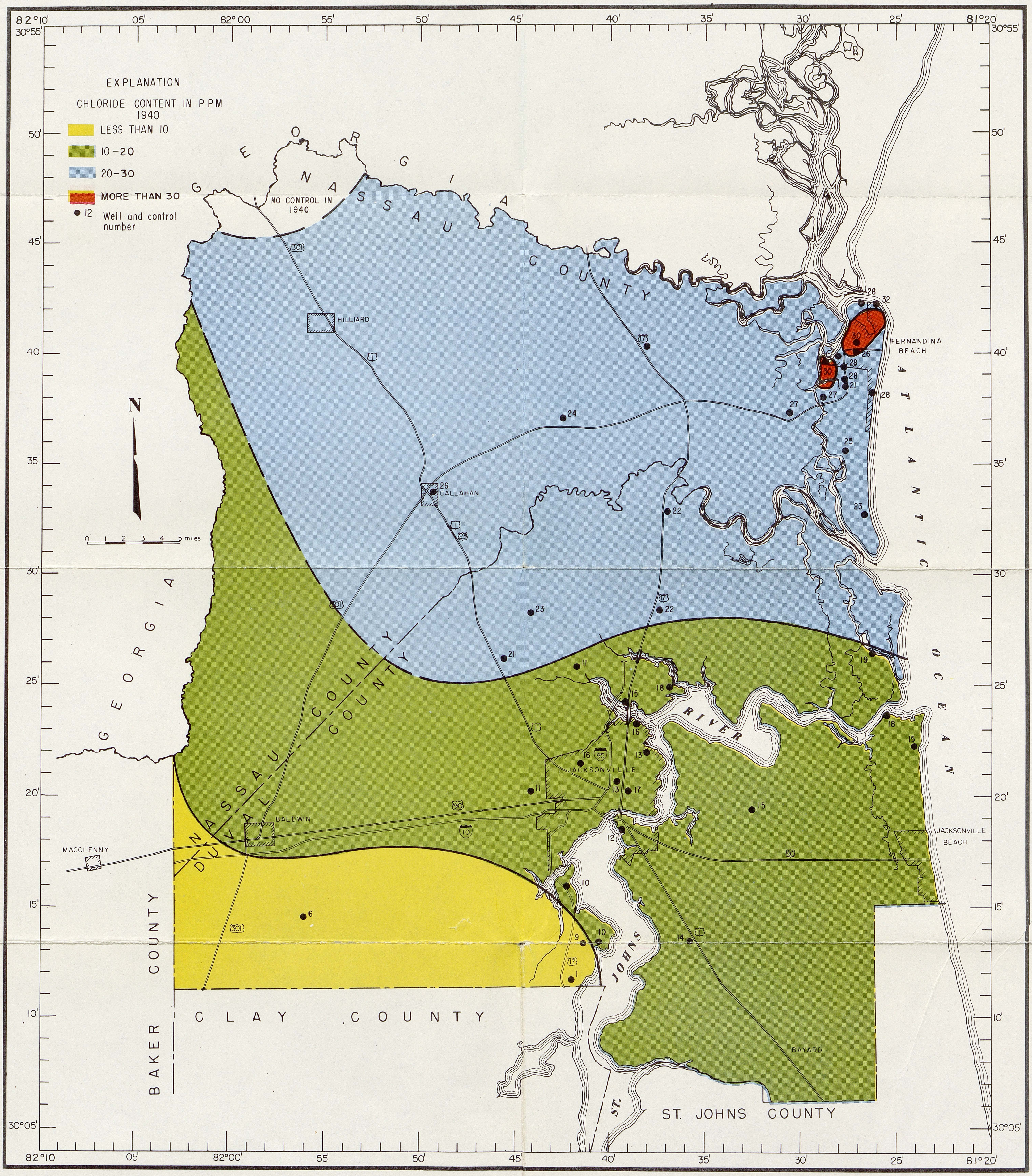

Figure 18. Map of Duval and Nassau counties showing the approximate chloride content of water from artesian wells in 1940.

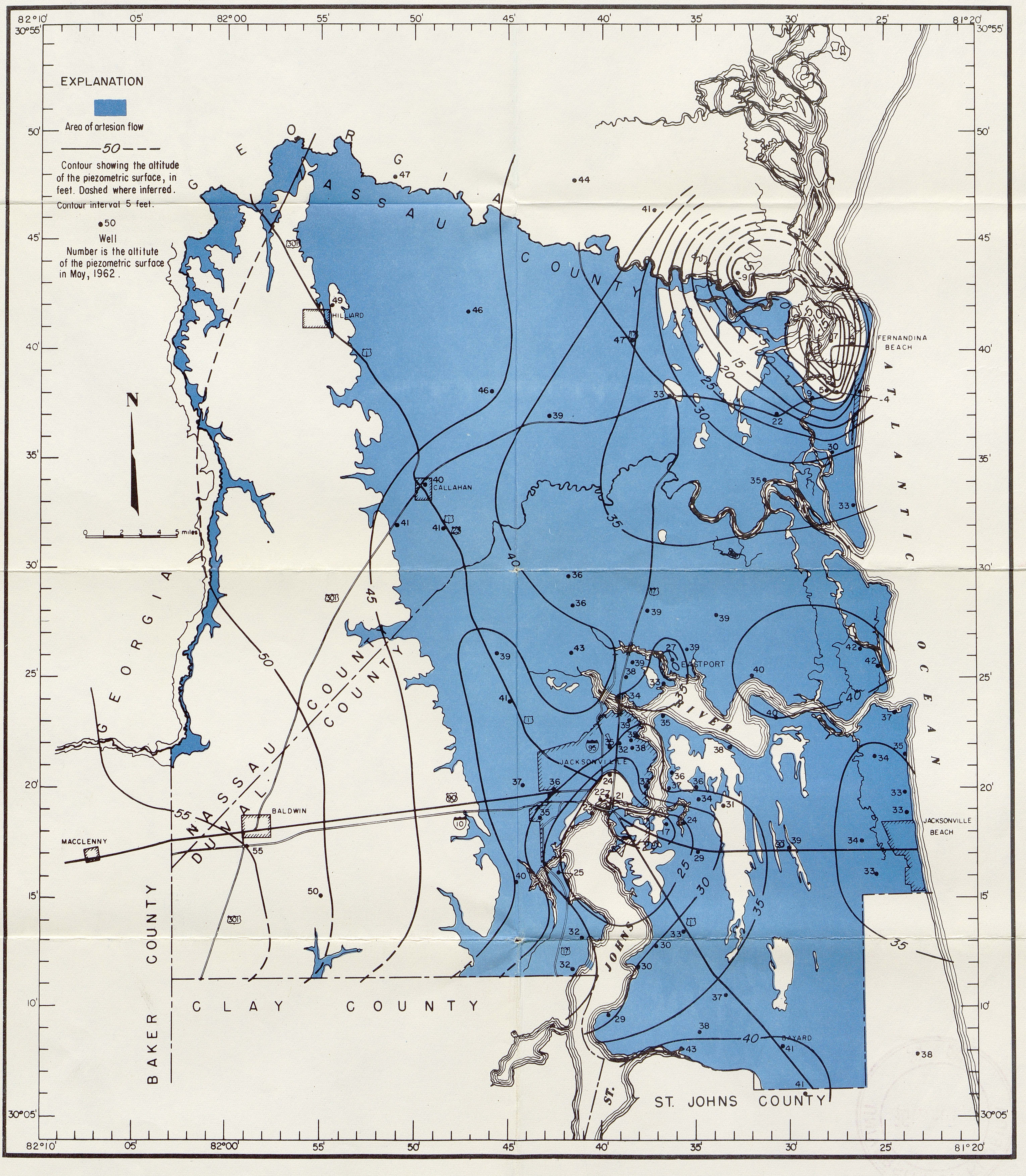

Figure 12. Map of Duval and Nassau counties showing the piezometric surface of the Florida aquifer system and the area of artesian flow in May 1962.

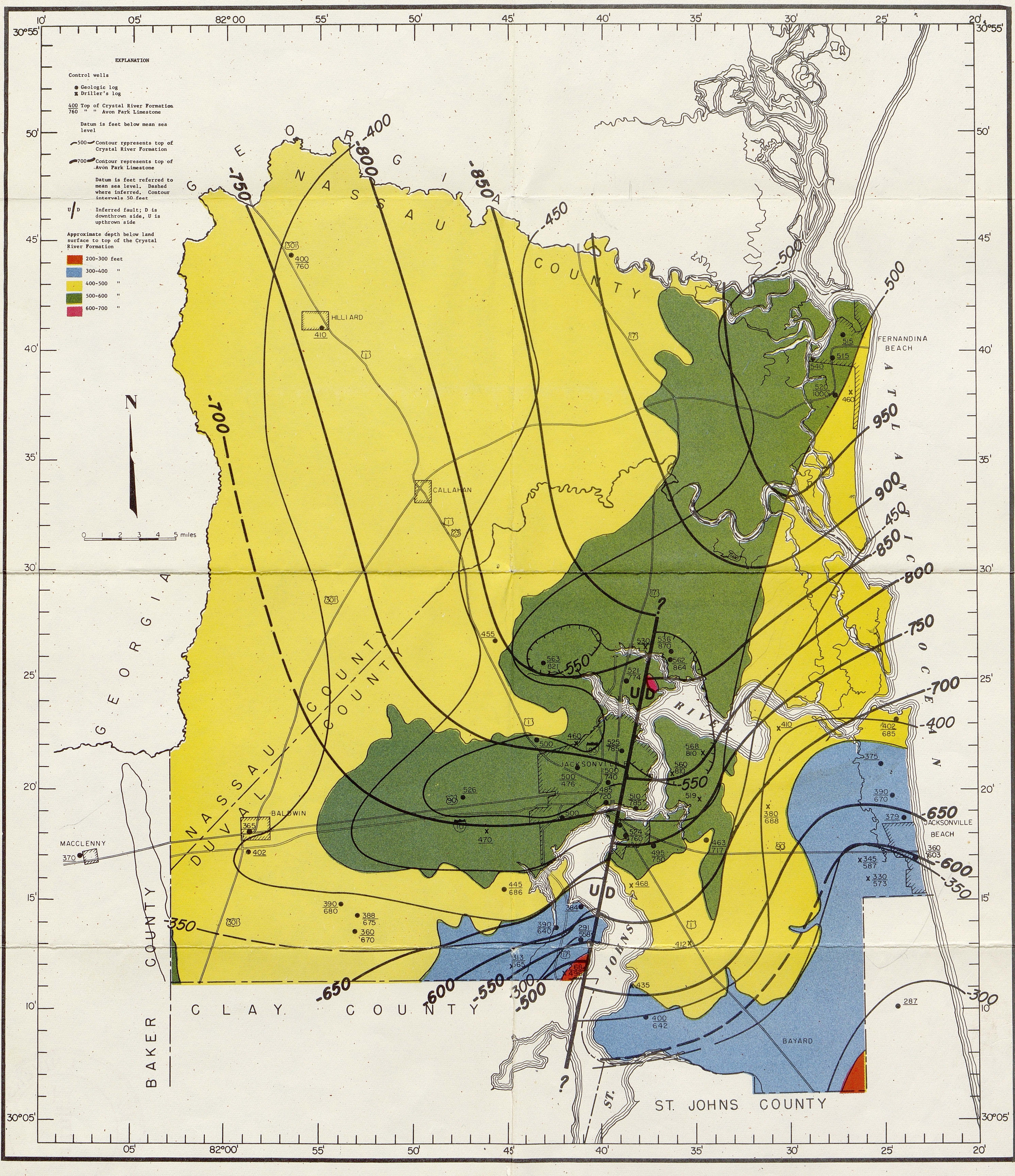

Figure 5. Map showing the altitude of the top of the Crystal River Formation and the Avon Park Limestone and the approximate depth below land surface to the top of the Crystal River Formation, Duval and Nassau counties, Fla.

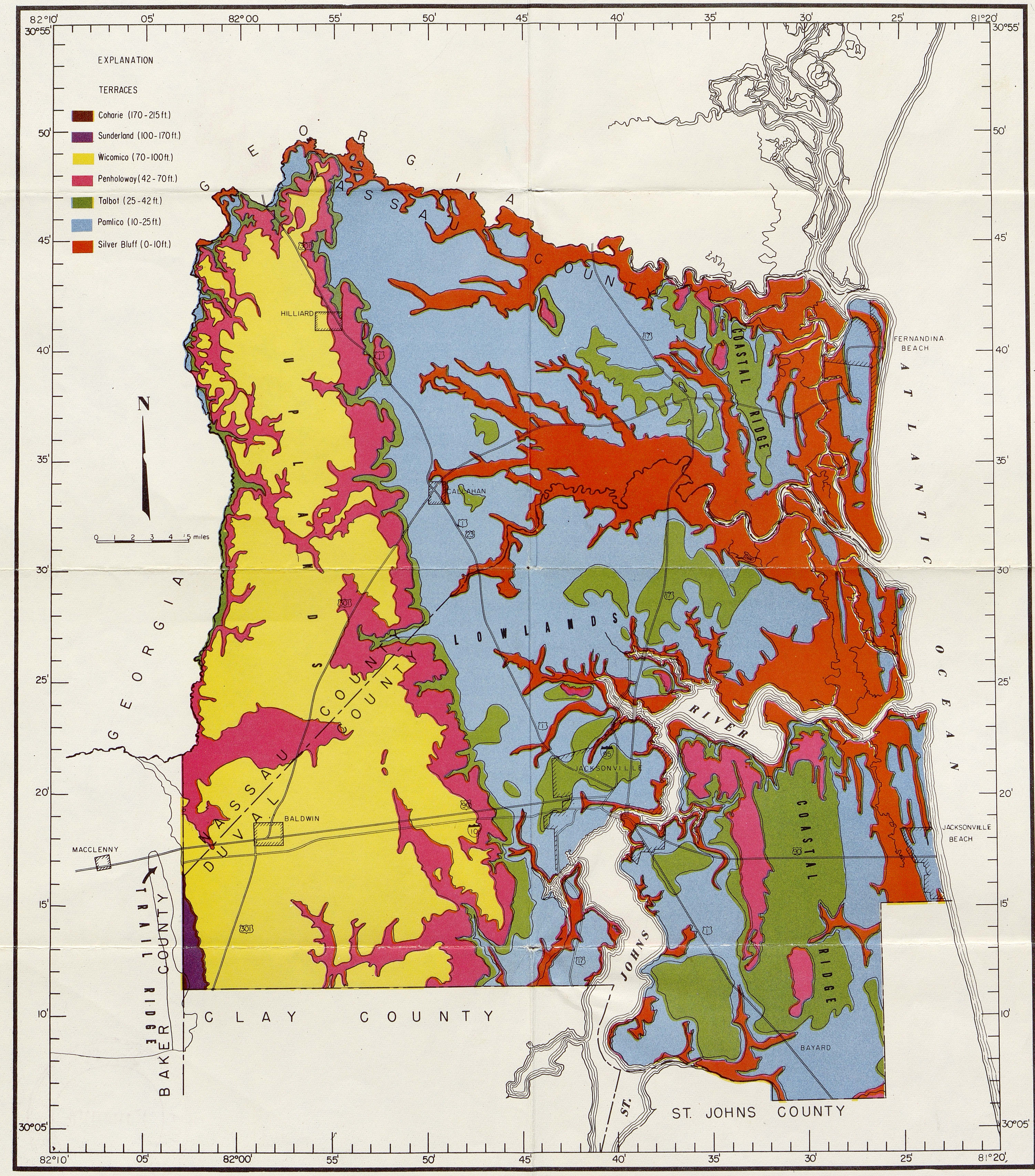

Figure 3. Map of Duval and Nassau counties, Fla. showing the Pleistocene marine terraces.