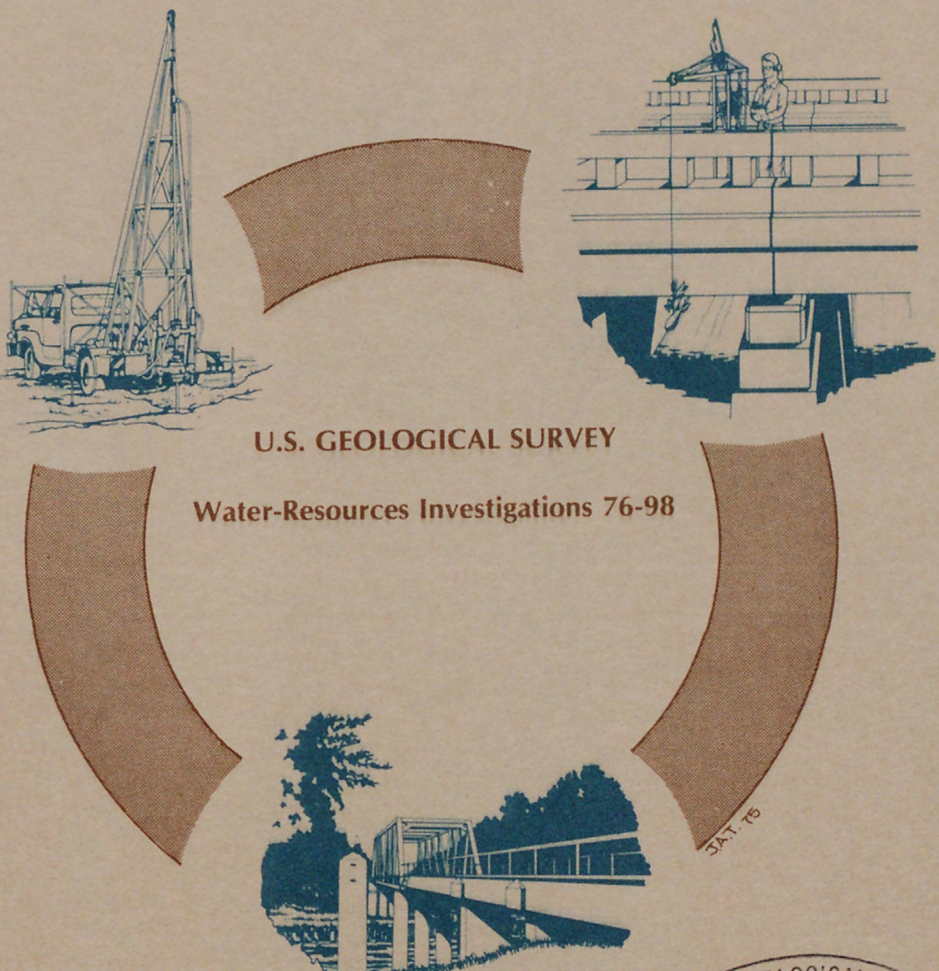
WRI 76-98 AVAILABILITY OF WATER IN THE FLORIDAN AQUIFER IN SOUTHERN DUVAL AND NORTHERN CLAY AND ST. JOHN'S COUNTIES, FLORIDA WRI 76-98

AVAILABILITY OF WATER IN THE FLORIDAN AQUIFER IN SOUTHERN DUVAL AND NORTHERN CLAY AND ST. JOHNS COUNTIES, FLORIDA



U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 76-98

Prepared in cooperation with the
CITY OF JACKSONVILLE,
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16. Abstracts
The Floridan aquifer is the major source of water supply in the area of investigation. The Floridan aquifer consists of 1,100 to 1,800 feet of limestone interbedded with hard, dense limestone and dolomite. Since 1949, water levels have declined as much as 14 ft in Clay and St. Johns Counties and more than 20 ft in Duval County. These trends will probably continue as withdrawals from the aquifer increase. Water-level depressions exist at Green Cove Springs and Jacksonville because of natural discharge and large scale withdrawals. Withdrawals from wells could result in well interference unless the wells are spaced at least 1,000 ft apart. Two- to four-in diameter wells drilled 100 ft or less into the aquifer yield 50 to 250 gal/min. Larger and deeper wells yield 1,000 gal/min or more. Hardness of water is generally less than 10 mg/L. Quality of water from wells sampled over a span of 10 to 30 years has not changed noticeably. Principal recharge to the Floridan occurs southwest of the area in a lake region where rainfall percolates directly into the aquifer.

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

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17b. Identifiers/Open-Ended Terms Florida, *Floridan aquifer, *Duval County, *Clay County, *St. Johns County

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IN SOUTHERN DUVAL AND NORTHERN CLAY AND ST. JOHNS

COUNTIES, FLORIDA

By Roy W. Fairchild

U.S. GEOLOGICAL SURVEY

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April 1977

UNITED STATES DEPARTMENT OF THE INTERIOR

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GLOSSARY

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

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

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

Permeability: Permeability is a measure of the relative ease with which a porous medium can transmit a liquid under a potential gradient (pressure).

Potentiometric surface: As related to an aquifer, it is a surface defined by the levels to which water will rise in tightly cased wells.

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

Storage coefficient: The storage coefficient is the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head (water level).

Transmissivity: The rate at which water is transmitted through a strip of the aquifer of unit width extending the full saturated thickness.

AVAILABILITY OF WATER IN THE FLORIDAN AQUIFER IN SOUTHERN DUVAL AND NORTHERN CLAY AND ST. JOHNS COUNTIES, FLORIDA

By
Roy W. Fairchild

ABSTRACT

From late 1948 to May 1972, water levels in wells tapping the Floridan aquifer declined as much as 14 feet (4 meters) in northern Clay and St. Johns Counties and more than 20 feet (6 meters) at Jacksonville in Duval County. During 1970-72 water-level fluctuations in 21 wells that tap the Floridan aquifer ranged from 2.0 to 15.2 feet (0.6 to 4.6 meters). Water levels usually are lowest during May and June and highest during January and February. The most intensive area of investigation was 400 square miles (1,040 square kilometers) in northern Clay and southwestern Duval Counties where the hardness of water in the Floridan aquifer was found to be 100 milligrams per liter or less and the chloride concentration was found to be 10 milligrams per liter or less.

The Floridan aquifer within the area of investigation consists of 1,100 to 1,800 feet (335 to 550 meters) of soft, porous limestone interbedded with hards, dense limestone and dolomite overlain by several hundred feet of confining beds. The confining beds consist of clay and sandy clay in the Hawthorn Formation and in the overlying shallow aquifer system.

Most of the recharge to the Floridan aquifer occurs southwest of the area of investigation in southwestern Clay and eastern Alachua Counties, in a lake region where rainfall percolates downward into the aquifer through sinkholes, solution pipes, and fractures in the confining beds. Some recharge occurs in western Duval and northern Clay Counties.

Discharge from the aquifer within the area of investigation is from wells and springs, and by upward leakage into overlying formations. In 1974 withdrawal from wells in the Floridan aquifer amounted to more than 250 million gallons per day (11 cubic meters per second) in Duval County and about 10 million gallons per day (0.4 cubic meter per second) in northern Clay County. The amount of withdrawal from wells in northern St. Johns County was not determined.

The beds that make up the Floridan aquifer are highly permeable in places and transmit large amount of water. The specific capacity of several wells that tap the Floridan aquifer in the area of investigation range from 1.3 to 410 gallons per minute per foot of drawdown.

The hardness of water in the Floridan aquifer ranges from 80 milligrams per liter to more than 750 milligrams per liter within the area of investigation. In an area of about 400 square miles (1,040 square kilometers) in northern Clay and southwestern Duval counties, the hardness is 100 milligrams per liter or less. The hardness ranges from 250 to over 300 milligrams per liter in the metropolitan Jacksonville area.

The chloride concentration of water in the Floridan aquifer ranges from 4 milligrams per liter in Clay County to as much as 46 milligrams per liter in Duval County. Although the chloride concentration varies areally within the area of investigation, there is little or no change with depth within that zone of the aquifer normally tapped by wells.

INTRODUCTION

One of the greatest assets of the Jacksonville area is its abundant supply of fresh water. Ground-water reservoirs in the Floridan aquifer are sources of large quantities of potable water for public, commercial, and industrial supplies. Like many other cities in Florida and in other parts of the nation, Jacksonville has had tremendous growth in population and industry in the last few decades. This increased growth has resulted in greater demands on the ground-water resources in the Jacksonville area. Concentrated withdrawal of water has caused water levels in wells tapping the Floridan aquifer there to decline more than 20 ft (6 m) during 1948-72. Because of the need to lower turbine pumps at some wells, or to replace centrifugal pumps with turbines, this decline represents as increase in the cost of producing water.

Purpose and Scope

The purpose of the investigation, which was conducted cooperatively with the Jacksonville Department of Public Works, was to obtain water-resources information useful in considering sources of future water supplies for Jacksonville. The U. S. Geological Survey investigated qualitatively and quantitatively an area in the Floridan aquifer in southern Duval and northern Clay and St. Johns Counties (fig. 1). The investigation, including test drilling, was done in 1970-72, and is a part of a long-term study of the area's water resources. This report is the result of that 3-year investigation.

The investigation included a detailed study of the geology and hydrology of the area with emphasis on the occurrence and source of potable ground water and on detailed mapping of those areas where good-quality water in sufficient quantities is available for industrial and municipal use.

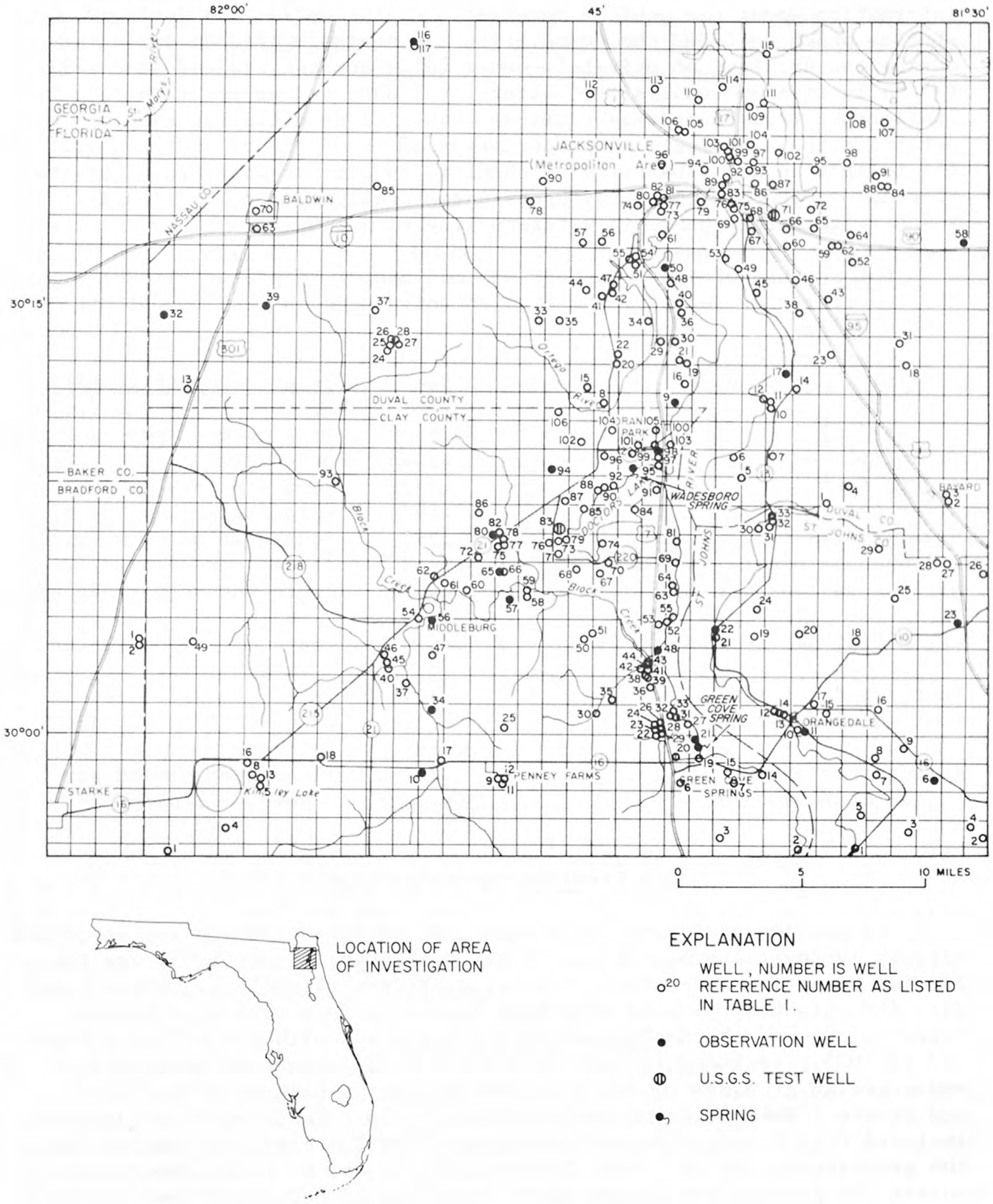


FIGURE 1.--MAP SHOWING LOCATION OF THE AREA OF INVESTIGATION AND WELLS AND SPRINGS CITED IN THIS REPORT.

The major phases of the investigation included: (1) an inventory of existing wells to determine their depth, diameter, location, and information about the aquifer penetrated by the wells; (2) geologic studies which included the compilation and analysis of data collected during the drilling of privately-owned wells and one project test well; (3) collection and analysis of water-level data and preparation of hydrographs from records as early as 1940; (4) quantitative studies to determine the hydrologic characteristics of the Floridan aquifer; and (5) collection and tabulation of chemical quality-of-water data for the Floridan aquifer in the study area, specifically to note any spatial and (or) temporal change in water-quality with pumping.

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

Multiply English unit	By	To obtain metric unit
inches (in)	25.4	millimeters (mm)
feet (ft)	.3048	meters (m)
square feet (ft^2)	.0929	square meters (m^2)
miles (mi)	1.609	kilometers (km)
square miles (mi^2)	2.590	square kilometers (km^2)
gallons per minute (gal/min)	6.309×10^{-2}	liters per second (l/s)
million gallons per day (Mgal/d)	.04381	cubic meters per second (m^3/s)
cubic feet per second (ft^3/s)	2.832×10^{-2}	cubic meters per second (m^3/s)
foot per day (ft/d)	.3048	meter per day (m/d)
foot squared per day (ft^2/d)	.0929	meter squared per day (m^2/d)
gallons per minute per foot (gal/min)/ft	.207	liters per second per meter (l/s)/m

Previous Investigations

The geology and hydrology of the area of investigation are described briefly in several publications of the U. S. Geological Survey and the Florida Department of Natural Resources, Bureau of Geology. Water-level data for this general area have been published in a series of Water-Supply Papers of the Geological Survey beginning with Water-Supply Paper 777 in 1935. Included in that series are measurements of water levels and artesian pressure in wells in Florida dating back to 1930. Clark and others (1964) describe the geohydrology in a four-county area which includes Clay County. Bermes and others (1963) include information on the geohydrology in St. Johns County and a report by Leve (1966) discusses the geology and ground-water resources of Duval and Nassau Counties.

Much of the subsurface geology in the area of study is described in papers by Puri (1957), Puri and Vernon (1964), and Chen (1965). Applin and Applin (1944) describe the regional subsurface stratigraphy, paleontology, and structure of Florida and southern Georgia. That report contains information about the area of this investigation.

Acknowledgments

The author is indebted to many peopole throughout the area for their cooperation and helpful assistance. Duval Drilling Company, Ricket's Well and Pump Company, Partridge Well Drilling Company, and Trout Well Drilling Service provided ready access to their records and permitted collection of drill cuttings.

Especially appreciated is the cooperation and assistance extended by the following: Mr. Ron Elder of the Jacksonville Water and Sewer Department who supplied information about many of the wells used in the city supply system; Mr. H. C. Stone of the Clay County Engineering Department who supplied information on benchmark and reference point locations; Mr. Bill Yon of the Florida Bureau of Geology who furnished geologic and geophysical logs of several wells in the area of investigation; and Mr. D. W. Beckwith and Mr. R. A. Langiotti of the Florida Department of Transportation who assisted in obtaining permission to drill a test well on state property.

The author is also grateful to the many residents in the area who supplied information on wells, use of water, and other pertinent data.

DESCRIPTION OF AREA

Location and Extent

The area of investigation as shown on figure 1 is located approximately between latitudes 29° 57' and 30° 25' north and longitudes 80° 30' and 82° 07' west and occupies about 1,300 mi^2 (3,400 km^2). The area includes southern Duval and northern Clay Counties and small parts of adjacent Baker, Nassau and Bradford Counties on the west and St. Johns County on the southeast.

Topography and Drainage

The area discussed in this report lies in two of the five topographic divisions of Florida as described by Cooke (1939, p. 15-23). The extreme western part is in the Central Highlands and the remaining part is in the Coastal Lowlands.

The Coastal Lowlands in the area of investigation is about 34 mi (55 km) wide in the northern part and 11 mi (18 km) wide in the southern part. The area ranges in altitude from less than 10 ft (3 m) along the St. Johns River in the northeastern part of the area to approximately 100 ft (30 m) in the western part where the lowlands terminate against prominent sand ridges which constitute the Central Highlands.

The surface of the Coastal Lowlands is marked by terraces which, according to Cooke (1945, p. 11), are the remnants of ancient shore lines "at 100, 70, and 42 ft above present sea level. A later invasion reached only 25 ft." These terraces which are indicated on figure 2 become progressively higher from east to west. As shown, these terraces have been modified by the present-day drainage pattern so that the original trends of the ancient shorelines are not everywhere distinguishable.

In the area of investigation the Central Highlands consists of high sand ridges of which the most prominent is Trail Ridge (fig. 2). It ranges in altitude from 100 ft (30 m) just west of the western terminus of the Coastal Lowlands along the Duval-Baker County boundary to 250 ft (76 m) just south and southwest of Kingsley Lake. From the highest point of 250 ft (76 m) above sea level, the land slopes southward toward a lake area near Keystone Heights (beyond the area shown on fig. 2). Many of the lakes in this area are sinkhole lakes which were formed by solution of limestone in underlying formations. The lake area is a part of the Central Highlands (Stringfield, 1966, p. 87).

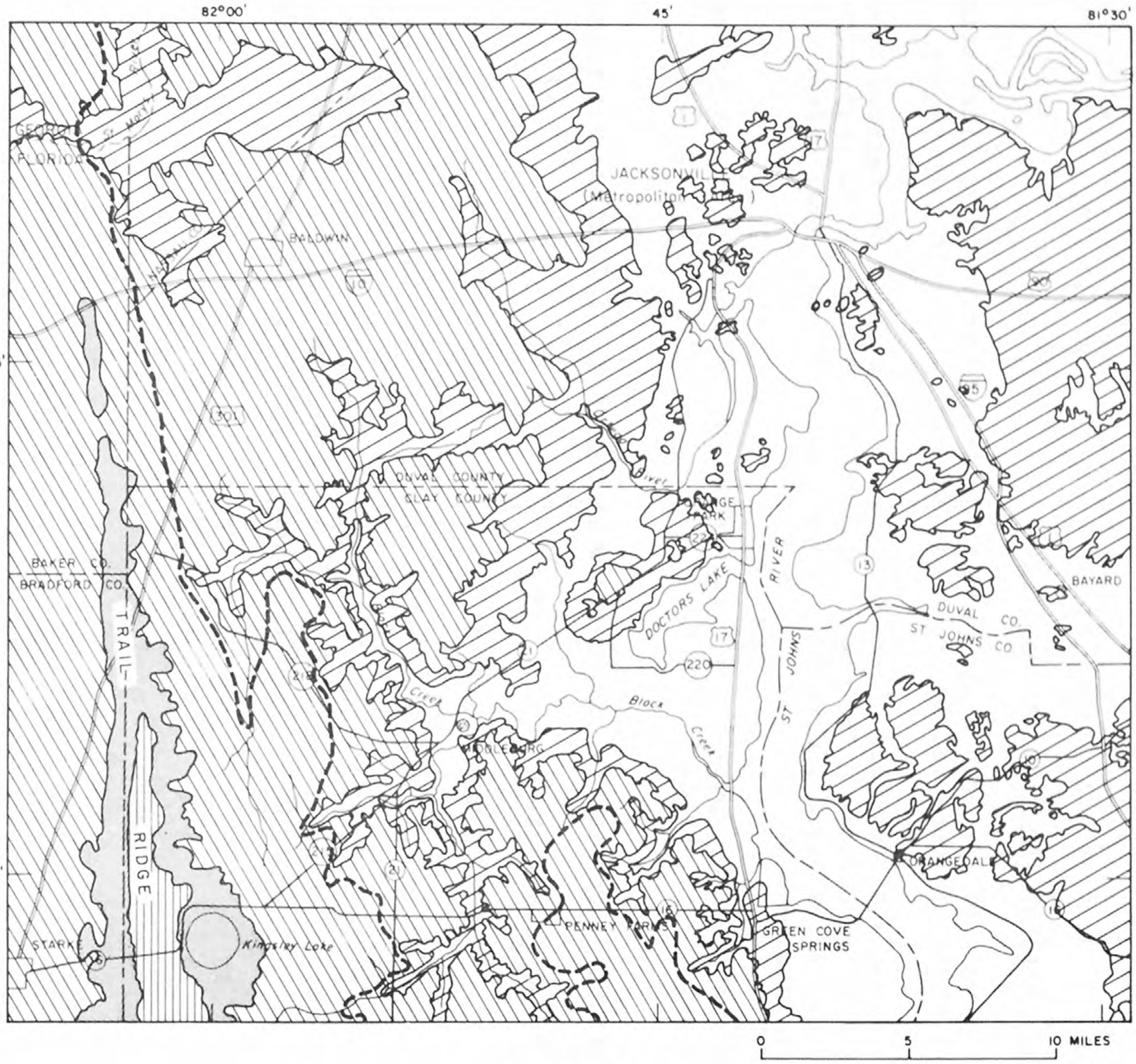
The surface of the Central Highlands, like to Coastal Lowlands, is marked by terraces; however, the terraces of the Highlands have been dissected to form the high sand ridges so that now much of the original form of the terraces are barely discernable and, in some places, they occur only as remnants.

Surface drainage is to the St. Johns River through its tributaries such as Black Creek. The St. Johns River is tidal throughout its reach in the area of investigation and its tributaries are tidal in their lower reaches. In the western part of the area of investigation the lineation of the sand ridges controls the direction of flow of the streams which is parallel to the ancient shorelines.

DATA COLLECTION

Well Inventory

An important part of the investigation was the collection of information on water wells. Information was obtained from an inventory of 117 wells in Duval County, 106 wells in Clay County, 33 wells in St. Johns County and 2 wells in Bradford County. The locations of the wells are shown on figure 1 and the information obtained on each is listed in table 1.



EXPLANATION

ALTITUDES OF TERRACES ABOVE MEAN SEA LEVEL, IN FEET.

SILVER BLUFF (0–6 FT.) AND PAMLICO (6–25 FT.).

COHARIE (170–215 FT.).

TALBOT (25–42 FT.) AND PENHOLOWAY (42–70 FT.).

HAZLEHURST (215–270 FT.).

WICOMICO (70–100 FT.), OKEFENOKEE (100–150 FT.) AND SUNDERLAND (150–170 FT.).

APPROXIMATE LOCATION OF BOUNDARY BETWEEN THE COASTAL LOWLANDS AND CENTRAL HIGHLANDS.

FIGURE 2.--PHYSIOGRAPHIC MAP OF THE AREA OF INVESTIGATION SHOWING THE PRINCIPAL LAND FEATURES DEVELOPED BY EROSION OF ANCIENT MARINE TERRACES (ALTITUDES OF TERRACES FROM STRINGFIELD, 1966, P. 68).

Table 1. Record of selected wells that tap the Floridan aquifer.

Well number: Number assigned to a well for reference in the text or as used in various illustrations in the report. The wells are numbered in sequence beginning with 1 in each county.

Survey number: The approximate latitude and longitude of the well is listed without the degree, minute, and second symbols for convenience. The number 300820N0813540.1 should be read 30°08'20" north latitude and 081°35'40" west longitude. The decimal (.1) means that only 1 well is at that approximate location.

Use of water: A, air cond.; C, commerical; H, domestic; I, irrigation; N, industrial; P, public supply; S, stock; T, institution; U, unused; Z, other.

Depth to top of aquifer: Feet below land surface. Asterisk (*) indicates well log in U. S. Geol. Survey files.

Water level: Feet above (+) or below land surface.

BRADFORD COUNTY

Well Number	Survey Number	Well Depth (ft)	Casing Diameter (in)	Casing Depth (ft)	Date Drilled (year)	Use of Water	Altitude of LSD (ft)	Depth to Top of Aquifer (ft)	Water Level (ft)	Date Water Level Meas.
1	300308N0820302.1	800	16	-		P	195	-	130	2-68
2	300302N0820304.1	800	16	442	1954	N	195	-	128	6-60

Table 1.--Continued

CLAY COUNTY

Well Number	Survey Number	Well Depth (ft)	Casing Diam-eter (in)	Casing Depth (ft)	Date Drilled (year)	Use of Water	Alti-tude of LSD (ft)	Depth to Top of Aquifer (ft)	Water Level (ft)	Date Water Level Meas.
1	295542N0820200.1	332	-	-	1968	U	239	314*	-	-
2	295557N0813642.1	-	4	-	-	H	5	-	28	11-70
3	295615N0813947.1	-	3	-	-	H	15	-	+23	7-70
4	295634N0815952.1	718	10	312	1941	P	229	-	151	5-41
5	295808N0815822.1	700	10	375	1940	T	160	370*	85	5-41
6	295824N0814129.1	704	8	378	1968	S	30	350*	+2	9-68
7	295831N0813903.1	600	12	301	1955	I	10	-	+13	3-55
8	295831N0815848.1	661	10	380	1940	T	166	373*	90	5-41
9	295835N0814852.1	550	6	260	-	P	95	-	-	-
10	295835N0815150.1	310	6	-	-	U	86	-	11	11-58
11	295837N0814834.1	402	3	280	1950	P	97	-	12	-
12	295837N0814834.2	445	8	275	1972	P	97	290*	23	1-72
13	295838N0815825.1	718	12	345	-	U	153	-*	77	10-58
14	295847N0813806.1	475	3	-	-	H	5	-	22	1-60
15	295848N0813922.1	650	8	318	1940	T	12	280*	+27	10-40
16	295849N0815916.1	522	12	380	1940	T	192	370*	117	5-41
17	295850N0815108.1	420	3	320	1969	S	30	-*	-	-
18	295853N0815558.1	450	4	-	1963	H	150	-	-	-
19	295900N0814032.1	-	-	-	-	C	10	-	+17	2-68
20	295913N0814142.1	605	12	463	1953	P	48	425*	10	4-53
21	295953N0814046.1	600	4	150	-	P	17	-	19	10-40
22	300006N0814157.1	-	4	-	-	S	15	-	+9	11-72
23	300007N0814148.1	546	4	-	1972	H	10	-	+13	11-72
24	300008N0814152.1	650	4	-	1963	H	20	-	+12	11-72
25	300009N0814835.1	5862	20	3538	1947	U	105	-*	-	-
26	300011N0814148.1	-	4	-	-	H	21	-	+16	11-72
27	300018N0814102.1	960	4	-	1955	H	10	-	+14	5-71
28	300022N0814150.1	425	3	-	1972	U	22	-	+17	11-72
29	300022N0814150.2	1110	16	399	1972	P	22	-	+17	11-72
30	300040N0814459.1	640	4	-	1961	S	65	-	-	-

Table 1.--Continued

CLAY COUNTY

Well Number	Survey Number	Well Depth (ft)	Casing Diameter (in)	Casing Depth (ft)	Date Drilled (year)	Use of Water	Altitude of LSD (ft)	Depth to Top of Aquifer (ft)	Water Level (ft)	Date Water Level Meas.
31	300047N0814141.1	525	4	-	1972	H	13	-	+15	11-72
32	300048N0814143.1	365	3	300	1956	H	11	-	+32	1-60
33	300049N0814137.1	-	4	-	-	H	11	-	+20	11-72
34	300057N0815135.1	400	3	-	-	S	30	-	+42	3-68
35	300119N0814402.1	420	3	-	1950	H	25	-	+19	5-71
36	300152N0814240.1	450	3	-	-	H	14	-	+29	2-68
37	300158N0815223.1	420	3	250	1970	H	15	260*	-	-
38	300213N0814245.1	-	3	-	-	P	15	-	+26	4-70
39	300213N0814245.2	-	3	-	-	U	15	-	+22	4-71
40	300217N0815307.1	-	3	-	1964	I	32	-	+23	5-70
41	300222N0814247.1	-	3	-	-	P	13	-	+30	4-70
42	300223N0814254.1	400	6	72	1934	P	13	-	43	7-40
43	300224N0814250.1	-	4	-	1964	P	10	-	+31	4-70
44	300227N0814256.1	335	3	126	1958	P	5	-	+38	4-70
45	300230N0815310.1	550	3	-	1963	H	60	-	+1	2-68
46	300242N0815320.2	-	2	-	1962	Z	-	-	+21	2-68
47	300255N0815130.1	550	2	-	-	H	10	-	30	2-68
48	300300N0814225.1	400	3	-	1959	H	10	-	+27	2-68
49	300322N0820100.1	3509	-	-	1963	U	175	-*	-	-
50	300335N0814513.1	-	3	-	-	S	20	-	+26	2-68
51	300336N0814501.1	450	4	80	-	H	18	-	43	5-34
52	300352N0814151.1	-	4	-	-	S	10	-	+24	2-68
53	300358N0814224.1	462	3	370	1970	H	15	-*	+25	8-70
54	300401N0815200.1	-	3	-	1960	N	36	-	+32	3-70
55	300402N0814138.1	500	4	137	1909	H	14	-	43	6-34
56	300408N0815139.1	498	3	300	1907	H	30	-	+44	8-40
57	300450N0814828.1	500	3	-	1966	H	5	-	+49	2-68
58	300455N0814747.1	484	3	421	1970	H	5	421*	+43	8-70
59	300501N0814742.1	480	3	-	1970	H	5	-	+44	8-70
60	300505N0815000.1	500	3	420	1965	H	22	-	+34	2-68

Table 1.--Continued

CLAY COUNTY

Well Number	Survey Number	Well Depth (ft)	Casing Diam-eter (in)	Casing Depth (ft)	Date Drilled (year)	Use of Water	Alti-tude of LSD (ft)	Depth to Top of Aquifer (ft)	Water Level (ft)	Date Water Level Meas.
61	300510N0815102.1	419	6	36	1927	H	22	-	40	7-40
62	300518N0815122.1	576	32	-	1964	H	-	-	+50	2-68
63	300522N0814145.1	600	2	480	1970	H	7	480	+35	10-70
64	300527N0814148.1	610	2	484	1970	H	6	484*	+31	10-70
65	300542N0814842.1	650	3	-	1960	U	24	-	+26	7-70
66	300542N0814842.2	600	4	-	-	H	24	-	+24	5-71
67	300543N0814443.1	615	3	-	1966	H	10	-	+29	3-70
68	300556N0814538.1	700	6	-	-	I	17	-	31	1-60
69	300604N0814126.1	750	3	-	-	S	-	-	+30	2-68
70	300604N0814415.1	500	3	440	-	S	14	-	+27	2-68
71	300605N0814633.1	484	3	420	1970	H	11	409*	+29	8-70
72	300616N0814943.1	481	4	80	1940	S	29	-	+39	8-40
73	300630N0814628.1	530	3	-	1972	H	12	-	+22	12-72
74	300641N0814433.1	550	3	-	1967	H	5	-	+33	7-70
75	300641N0814844.1	500	3	-	-	S	17	-	+20	4-71
76	300642N0814638.1	-	3	-	-	H	40	-	+15	1-68
77	300642N0814842.1	500	3	-	-	S	17	-	+22	4-71
78	300645N0814843.1	480	-	-	1953	H	-	-	+32	2-68
79	300646N0814604.1	600	3	-	1966	H	5	-	+39	4-70
80	300649N0814859.1	530	4	157	1938	H	24	-	+36	8-40
81	300651N0814149.1	609	3	-	1970	H	12	-	+30	4-70
82	300655N0814849.1	480	4	-	1965	U	-	-	+28	2-68
83	300656N0814634.1	1197	8	391	1972	U	46	340*	5	12-72
84	300752N0814324.1	473	8	-	1950	H	3	-	+39	1-59
85	300753N0814507.1	450	3	-	-	H	-	-	+34	1-68
86	300756N0814946.1	600	4	-	-	S	40	-	-	-
87	300816N0814600.1	457	3	346	1956	S	40	-	24	1-68
88	300831N0814445.1	864	12	358	1968	P	27	350*	-	-
90	300833N0814415.1	-	3	-	-	H	-	-	+17	1-68

Table 1.--Continued

CLAY COUNTY

Well Number	Survey Number	Well Depth (ft)	Casing Diam-eter (in)	Casing Depth (ft)	Date Drilled (year)	Use of Water	Alti-tude of LSD (ft)	Depth to Top of Aquifer (ft)	Water Level (ft)	Date Water Level Meas.
91	300834N0814213.1	550	3	-	-	H	-	-	+35	2-68
92	300847N0814411.1	560	6	343	1963	P	51	230*	+8	4-63
93	300850N0815520.1	330	3	300	-	U	35	-	+21	3-68
94	300919N0814645.1	440	6	-	1957	P	-	-	+13	2-68
95	300944N0814207.1	500	3	-	-	I	-	-	-	-
96	300947N0814445.1	800	6	-	-	T	-	-	-	-
97	300956N0814208.1	405	8	335	1941	H	22	270*	-	-
98	300957N0814235.1	450	3	-	1897	H	16	-	+27	11-58
99	300958N0814328	500	3	-	-	H	28	-	+13	4-70
100	301008N0814228.1	450	4	300	1912	H	8	-	47	5-34
101	301008N0814304.1	616	-	-	1969	U	15	-*	-	-
102	301015N0814528.1	500	4	-	1946	S	38	-	+11	1-60
103	301018N0814151.1	530	6	350	1910	H	12	-	+46	6-34
104	301039N0814418.1	1030	8	388	1958	P	60	373*	-	12-58
105	301058N0814238.1	862	8	309	1969	P	10	278*	+31	5-69
106	301120N0814624.1	-	3	-	-	-	20	-	-	-

Table 1.--Continued

DUVAL COUNTY

Well Number	Survey Number	Well Depth (ft)	Casing Diameter (in)	Casing Depth (ft)	Date Drilled (year)	Use of Water	Altitude of LSD (ft)	Depth to Top of Aquifer (ft)	Water Level (ft)	Date Water Level Meas.
1	300820N0813540.1	487	3	-	1955	H	-	-	+25	11-61
2	300824N0813054.1	-	4	-	-	H	24	-	31	9-40
3	300825N0813040.1	448	6	322	1931	H	22	355*	+32	12-31
4	300857N0813444.1	500	3	200	1960	H	-	-	+19	1-60
5	300902N0813900.1	-	3	-	-	I	18	-	+36	9-40
6	300947N0813918.1	730	3	-	1971	H	15	-	+14	5-71
7	300957N0813740.1	900	16	437	1955	H	20	-*	-	3-55
8	301134N0814427.1	600	4	-	-	S	-	-	-	-
9	301144N0814138.1	403	4	252	1940	T	16	260*	+37	8-40
10	301154N0813743.1	600	3	-	1940	H	22	-	+8	4-70
11	301157N0813744.1	720	8	460	1957	P	22	453	-	3-57
12	301158N0813828.1	975	6	447	1953	H	15	425	-	9-53
13	301203N0820115.1	425	4	-	-	N	-	-	-	-
14	301215N0813658.1	710	6	464	1954	H	24	460	-	4-54
15	301216N0814512.1	-	4	-	-	S	-	-	-	-
16	301220N0814107.1	645	12	271	1942	P	20	260*	+39	11-42
17	301255N0813710.1	650	3	-	1956	H	5	-	+32	1-61
18	301306N0813221.1	1060	12	510	1969	H	35	-*	+6	4-69
19	301308N0814107.1	1015	12	318	1940	P	24	-*	+46	7-50
20	301309N0814405.1	650	6	-	-	S	-	-	+25	1-68
21	301312N0814110.1	1005	12	380	1940	T	9	380	+45	8-40
22	301327N0814413.1	650	3	-	1958	H	15	-	+23	5-70
23	301335N0813526.1	625	4	461	-	H	25	466*	19	3-65
24	301339N0815312.3	887	12	400	1941	P	80	-	+30	-
25	301340N0815310.1	980	10	431	1941	P	80	-*	16	5-41
26	301342N0815310.1	1303	12	485	1956	P	85	480*	28	11-56
27	301345N0815255.1	1350	12	485	1965	P	75	-	35	2-68
28	301345N0815310.1	950	12	572	1953	P	75	465	22	6-53
29	301347N0814218.1	987	12	400	1942	P	5	-*	+4	9-42
30	301356N0814156.1	550	2	-	-	S	-	-	+18	2-68

Table 1.--Continued

DUVAL COUNTY

Well Number	Survey Number	Well Depth (ft)	Casing Diameter (in)	Casing Depth (ft)	Date Drilled (year)	Use of Water	Altitude of LSD (ft)	Depth to Top of Aquifer (ft)	Water Level (ft)	Date Water Level Meas.
31	301358N0813237.1	800	-	575	1964	P	39	-*	0	4-64
32	301434N0820214.1	708	6	-	1969	N	90	445	36	7-69
33	301435N0814705.1	1082	8	500	1963	P	75	480*	29	8-63
34	301443N0814244.2	535	3	180	1946	H	7	-	+28	8-65
35	301449N0814613.1	1150	-	-	-	P	80	-	-	-
36	301452N0814110.1	669	8	286	1922	P	-	400*	+42	6-22
37	301455N0815355.2	780	8	502	1942	I	80	-*	-	-
38	301458N0813654.1	706	-	-	-	P	26	-	+13	5-66
39	301458N0815818.1	708	6	444	1969	U	85	440*	31	4-69
40	301508N0814125.1	705	8	120	1928	P	5	-*	-	-
41	301521N0814439.1	1100	-	-	-	P	15	-	-	-
42	301523N0814411.1	-	-	-	-	H	18	-	+25	5-66
43	301525N0813525.1	1015	-	614	-	S	20	-	+20	5-66
44	301527N0814512.1	1000	12	460	1961	P	30	-	+7	5-62
45	301529N0813826.1	1187	10	757	1949	P	-	-*	+31	3-65
46	301534N0813656.1	739	8	538	1925	N	25	460*	+20	-
47	301537N0814419.1	1302	8	488	1968	P	10	476*	+30	9-68
48	301551N0814157.1	600	4	470	1938	H	9	-*	+40	7-40
49	301607N0813907.1	1264	6	470	1954	I	-	470*	+13	3-65
50	301617N0814216.1	729	8	476	1923	U	16	-	+40	8-30
51	301630N0814320.1	1332	12	525	1962	P	15	-	-	-
52	301637N0813431.1	-	10	-	-	H	10	-	+16	5-69
53	301640N0814050.1	-	-	-	-	Z	21	-	+12	5-66
54	301648N0814318.1	1332	12	-	1951	P	15	-	-	-
55	301648N0814325.1	1319	12	539	1951	P	15	-	-	-
56	301708N0814445.1	-	-	-	-	H	20	-	+23	5-68
57	301708N0814528.1	-	-	-	-	H	25	-	+18	5-66
58	301715N0813000.1	-	4	-	-	U	40	-	+2	12-61
59	301718N0813525.1	785	7	524	1939	H	29	-	27	6-39
60	301720N0813716.1	710	-	640	-	I	20	-	+14	5-66

Table 1.--Continued

DUVAL COUNTY

Well Number	Survey Number	Well Depth (ft)	Casing Diameter (in)	Casing Depth (ft)	Date Drilled (year)	Use of Water	Altitude of LSD (ft)	Depth to Top of Aquifer (ft)	Water Level (ft)	Date Water Level Meas.
61	301722N0814220.1	–	–	–	–	H	6	–	+31	5-66
62	301723N0813510.1	705	6	525	1967	P	20	520*	–	1-67
63	301725N0815845.1	750	10	433	1942	N	85	433	25	1-61
64	301737N0813437.1	1004	15	487	–	P	13	–*	–	–
65	301740N0813610.1	1234	18	515	1957	U	20	515	+27	9-60
66	301748N0813717.1	1210	6	530	–	I	26	–	+20	5-66
67	301748N0813848.1	1291	12	492	1953	P	5	–	–	–
68	301801N0813843.2	1348	10	505	1949	P	20	–*	+30	3-39
69	301802N0813917.1	500	4	–	–	I	–	–	+13	5-66
70	301808N0815825.1	716	8	460	1952	H	85	–*	–	–
71	301817N0813749.1	2486	8	752	1966	U	20	500*	–	5-66
72	301825N0813620.1	636	3	–	–	H	16	–	+28	2-39
73	301832N0814222.1	1320	12	–	1949	P	25	–	–	–
74	301833N0814318.1	900	6	–	–	U	25	–	+34	6-39
75	301839N0813924.2	1307	10	506	1943	P	5	–*	+33	6-56
76	301840N0813935.2	1286	10	510	1959	P	6	530*	+48	3-39
77	301842N0814220.2	1303	12	540	1947	P	20	–*	–	–
78	301843N0814733.1	1116	8	530	1965	P	46	512*	+2	4-65
79	301844N0814038.1	–	8	–	–	U	4	–	+43	11-38
80	301844N0814235.2	1260	10	–	1941	P	20	–*	–	–
81	301854N0814229.2	1247	10	–	1943	P	18	–	+26	5-66
82	301901N0814222.2	1245	10	–	1947	P	20	–	–	–
83	301902N0813946.1	760	8	510	1954	I	5	510*	+20	5-61
84	301906N0813325.1	875	6	400	1929	H	53	–	+7	8-30
85	301913N0815346.1	700	6	466	1968	S	90	–*	45	4-68
86	301918N0813839.1	1074	10	515	1942	N	–	515*	+42	7-42
87	301919N0813754.1	750	–	–	–	N	6	–	+28	5-66
88	301925N0813309.2	1016	8	600	1966	P	57	585*	12	1-66
89	301928N0813952.1	750	–	–	–	A	7	–	+24	5-66
90	301931N0814700.1	1060	6	583	1929	H	59	585*	+5	5-29

Table 1.--Continued

DUVAL COUNTY

Well Number	Survey Number	Well Depth (ft)	Casing Diam-eter (in)	Casing Depth (ft)	Date Drilled (year)	Use of Water	Alti-tude of LSD (ft)	Depth to Top of Aquifer (ft)	Water Level (ft)	Date Water Level Meas.
91	301938N0813333.1	1050	-	-	1943	U	55	-*	-	-
92	301948N0813933.1	753	8	516	1961	Z	22	-*	+12	10-61
93	301953N0813851.2	1302	12	514	1968	P	15	512*	-	-
94	301955N0814048.1	997	8	-	-	-	18	-	+15	5-66
95	301959N0813607.1	1270	-	-	-	P	28	-	+14	5-66
96	302000N0814219.1	-	4	-	-	H	+25	-	+24	2-39
97	302003N0813840.1	1297	12	-	1948	P	15	-	-	-
98	302005N0813452.1	765	4	-	1936	H	32	-	+31	6-39
99	302005N0813906.2	1250	10	485	1923	P	-	-*	+55	6-39
100	302016N0813921.1	-	12	-	-	N	7	-	+30	12-69
101	302026N0813934.2	1249	10	443	1944	P	15	-*	+29	6-39
102	302031N0813735.1	-	4	-	1894	N	5	-	+11	3-41
103	302033N0813945.2	1270	12	-	1941	P	7	-*	+37	5-56
104	302048N0813850.1	700	6	-	-	-	20	-	-	-
105	302107N0814110.1	1365	12	-	1949	P	25	-	-	-
106	302107N0814125.1	1300	12	-	1950	P	25	-	-	-
107	302142N0813307.1	610	4	522	1953	H	-	-	+33	-
108	302157N0813450.1	1104	12	620	1968	H	10	-*	+41	12-68
109	302209N0813840.1	1076	8	-	1923	I	22	-	+38	2-39
110	302228N0814058.1	-	-	-	-	H	20	-	+18	5-69
111	302233N0813805.1	760	16	545	-	N	7	-	+34	-
112	302235N0814507.1	620	4	-	-	H	28	-	+14	5-69
113	302250N0814241.1	-	-	-	-	T	19	-	+20	5-69
114	302253N0813955.1	550	-	-	-	N	18	-	+26	5-66
115	302351N0813902.1	700	2	560	1940	H	6	-	+43	7-40
116	302416N0815226.1	708	6	416	1969	Z	80	-*	42	1-69
117	302416N0815226.2	2230	10	444	1969	U	80	444*	25	2-70

Table 1.--Continued

ST. JOHNS COUNTY

Well Number	Survey Number	Well Depth (ft)	Casing Diam-eter (in)	Casing Depth (ft)	Date Drilled (year)	Use of Water	Alti-tude of LSD (ft)	Depth to Top of Aquifer (ft)	Water Level (ft)	Date Water Level Meas.
1	295556N0813421.1	300	4	-	1963	H	5	-	+32	8-70
2	295625N0812907.1	412	6	148	1956	T	27	241*	+7	4-56
3	295636N0813219.1	-	3	-	1959	H	8	-	+14	4-70
4	295657N0812950.1	300	4	280	1971	H	20	-	+12	5-71
5	295708N0813416.1	496	6	200	1956	T	11	304*	+17	4-56
6	295828N0813120.1	-	3	-	-	H	20	-	+17	8-70
7	295852N0813330.1	401	6	160	1955	H	-	335*	-	-
8	295906N0813345.1	-	3	-	1949	H	13	-	+13	4-70
9	295937N0813229.1	436	6	-	1930	H	22	222*	-	-
10	300015N0813640.1	450	4	-	1943	H	12	-	+13	3-68
11	300019N0813633.1	500	4	-	1968	H	-	-	+15	3-68
12	300033N0813710.1	360	3	263	1971	H	15	-*	19	1-71
13	300035N0813705.1	400	3	-	-	H	17	-	+18	1-71
14	300035N0813707.1	400	3	-	1968	H	17	-	+19	1-71
15	300050N0813542.1	-	3	-	1969	H	30	-	+2	4-70
16	300056N0813340.1	-	3	-	1945	H	22	-	9	5-71
17	300107N0813604.1	700	2	-	1948	H	31	-	+5	4-70
18	300322N0813428.1	600	2	-	1969	P	26	-	+13	4-70
19	300327N0813825.1	300	5	263	1943	U	30	-	+10	8-70
20	300338N0813643.1	-	3	-	-	H	26	-	+15	4-70
21	300341N0813954.1	700	4	-	1950	H	15	-	+23	4-70
22	300353N0813953.1	-	4	-	-	H	-	-	+26	3-68
23	300354N0813012.1	362	2	-	1963	H	25	-	+18	4-70
24	300435N0813812.1	445	2	278	1971	H	25	278*	+11	1-71
25	300458N0813251.1	-	4	-	1925	Z	21	-	+17	4-70
26	300556N0812910.1	336	6	240	-	I	18	240	+37	8-34
27	300613N0813056.1	330	3	-	-	H	22	-	+23	4-70
28	300614N0813101.1	600	3	-	1943	H	20	-	+18	5-71
29	300632N0813343.1	388	6	100	1916	S	19	-	+25	4-70
30	300717N0813810.1	580	3	-	1970	H	8	-	+31	4-70
31	300729N0813751.1	800	3	-	1967	H	5	-	+36	4-70
32	300733N0813745.1	514	3	367	1971	H	7	-*	-	-
33	300741N0813737.1	385	3	-	1950	H	10	-	+33	3-56

The wells for each county are numbered in sequence beginning with 1 to facilitate reference to specific wells in the text and on the illustrations of this report. Where reference is made to a well, both the name of the county and the sequential well number are given.

Geologic Information

Drillers' logs were obtained from a few well owners, drilling companies, and the files of the Florida Bureau of Geology. Where additional geologic information was needed, drill cuttings were collected during drilling operations. Wells for which logs are available are listed in table 1.

One test well (Clay 83) was drilled to a depth of 1,197 ft (365 m) to collect detailed geologic, hydrologic and water-quality data. Other pertinent information from this test is given in the appropriate sections of this report.

Water-Level Measurements

During the investigation, water levels in 21 wells that tap the Floridan aquifer were measured periodically, and in one well in northeastern Clay County, a water-level recorder was used to obtain a continuous record. Water levels were measured to determine long-term trends and seasonal fluctuations.

Water-quality Sampling

Water samples from selected wells that tap the Floridan aquifer were collected and anlyzed to determine the quality of water in the aquifer in the area of investigation. Water samples from 20 wells were analyzed for the most common chemical constituents, such as fluoride, chloride, calcium, magnesium and sulfate, and samples from 133 wells were anlyzed for chloride concentration and hardness. These analyses were used to prepare the water-quality maps in this report.

Aquifer Tests

Information on the transmissivity and storage coefficient (see Glossary) of the Floridan aquifer was obtained from an aquifer performance test made on a test well in the area of investigation. This test was made to determine the ability of the aquifer to transmit and store water. Some information on the specific capacity of several wells in the area was available from previous studies.

GEOHYDROLOGY OF THE FLORIDAN AQUIFER

The Floridan aquifer is the principal source of ground water in the area of investigation as it is throughout most of northeastern Florida. The aquifer consists of soft, porous limestone interbedded with hard, dense limestone and dolomite that ranges in thickness from 1,100 to 1,800 ft (335 to 550 m). The Floridan aquifer includes the following geologic units in order from oldest to youngest: Lake City Limestone, Avon Park Limestone, the Ocala Limestone, and the Suwannee Limestone. All except the Suwannee Limestone are of Eocene age. The Suwannee, of Oligocene age, is not continous throughout the area of investigation. In some parts of the area of investigation, the lower part of the Hawthorn Formation of Miocene age is permeable and is probably hydraulically connected to the Floridan aquifer. The limestones in these geologic units are not equally permeable, nor is the thickness of these limestones uniform.

The oldest formation penetrated by water wells in the area of investigation is the Lake City Limestone. Geologic and geophysical data obtained from test well Clay 83, which was drilled in the Lake City, are shown on figure 3.

The Oldsmar Limestone of Eocene age, which yields brackish water in the southern part of the Florida peninsula and which underlies the Lake City, may yield freshwater in the area of investigation. Leve and Goolsby report (1967, p. 21) that a test well at Jacksonville that penetrated the Oldsmar at a depth of about 1,300 ft (400 m) yielded water containing less than 20 mg/l of chloride.

The Hawthorn Formation generally contains beds of low permeability that confine the water in the Floridan aquifer under pressure, and hydraulically separate it from the shallow-aquifer system; however, the Hawthorn beds are permeable enough to allow movement of water as discharge or recharge through them. As mentioned earlier, only permeable beds in the lower part of the Hawthorn that may be hydraulically connected to the Floridan aquifer can be considered to constitute a part of that aquifer.

Depth Range of Water Wells

Wells inventoried during the investigation that tap the Floridan aquifer but do not necessarily totally penetrate it range in depth from 300 to 1,365 ft (90 to 415 m) below land surface. About 30 percent of the water wells range in depth from 300 to 500 ft (90 to 150 m), 40 percent range from 500 to 800 ft (150 to 240 m), 15 percent range from 800 to 1,100 ft (240 to 350 m) and only 15 percent are more than 1,100 ft (340 m) deep. Probably not more than 10 percent of all wells that tap the Floridan aquifer have been drilled into the Lake City Limestone. The 1,365-ft well (416-m) Duval 105, owned by the city of Jacksonville,

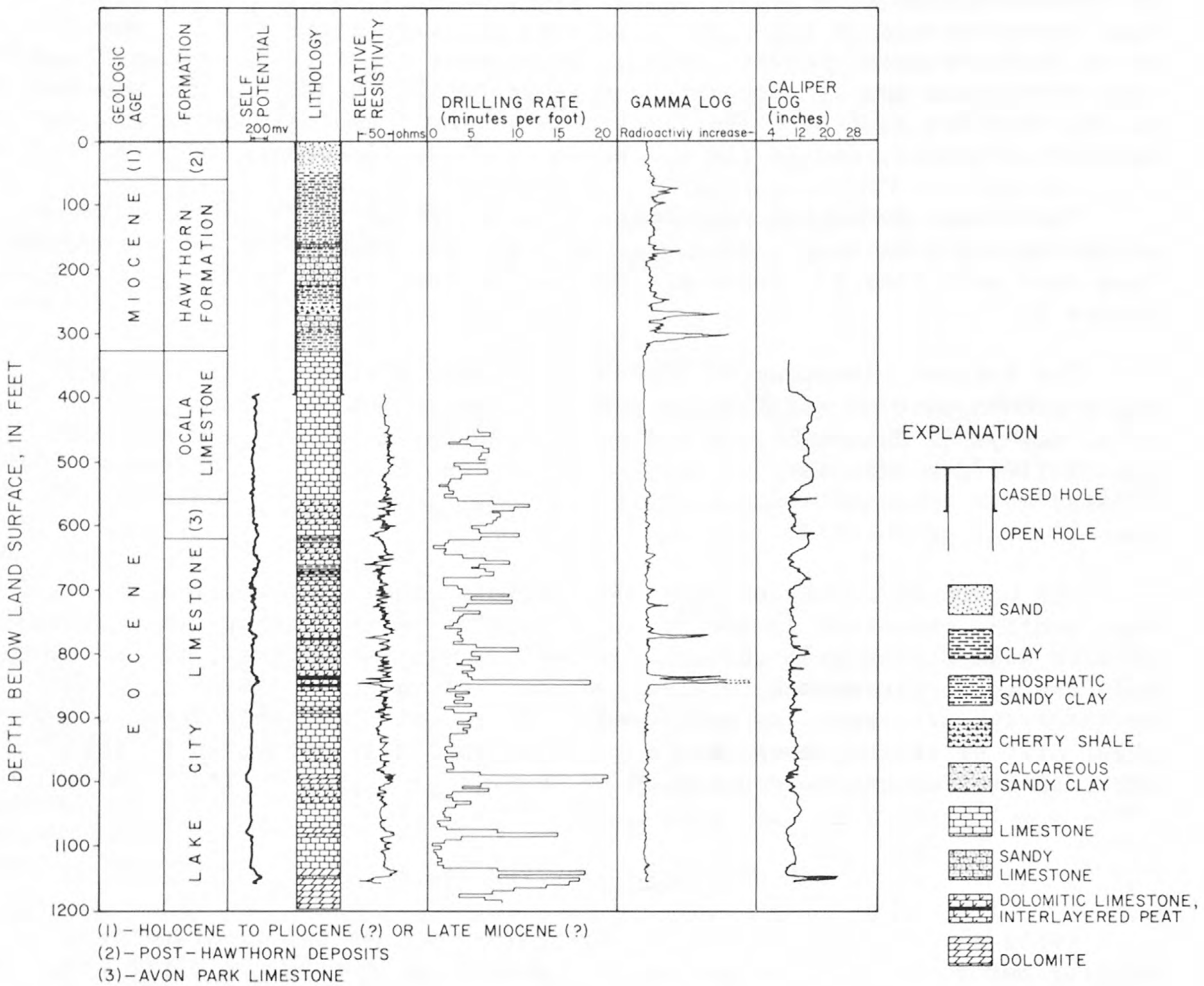


Figure 3.--Graphic well logs showing geologic and geophysical data for test well Clay 83 in Clay County.

penetrated 590 ft (180 m) of the Lake City Limestone. Water wells that yield some water from the Lake City Limestone are listed in table 2.

The Ocala Limestone generally is the first major unit of the Floridan aquifer to be penetrated by a water well. The top of the Ocala ranges from about 100 ft (30 m) below sea level southwest of Kingsley Lake to more than 500 ft (150 m) below sea level east of Jacksonville (fig. 4). The map on figure 4 can be used to estimate the amount of casing that will be required to close off all unconsolidated material in the Hawthorn above the Floridan aquifer where the Suwannee is missing. The length of casing required at a given site equals the sum of the altitude of the land surface and the depth to the top of the Ocala (below sea level).

Generally, a well must be drilled 20 ft (6 m) or more into the Ocala Limestone in the area of investigation to yield enough water for small supplies. Wells 2 to 4 in (50 to 100 m) in diameter, generally drilled for domestic purposes, usually tap 100 ft (30 m) or less of the Ocala and yield from 50 to 350 gal/min (3 to 22 l/s). Wells of larger diameter are generally drilled deeper in the Floridan aquifer to obtain higher yields for public, commercial and industrial supplies. It is generally accepted by users of large quantities of water in the area of investigation that a well, particularly one used for public supply, should yield at least 1,200 to 1,500 gal/min (75 to 95 l/s) to be considered successful.

Where the required quantity of water cannot be obtained from the upper part of the Floridan aquifer, drilling usually is continued deeper into the aquifer. Experience indicates, however, that most wells do not have to be drilled into the Lake City Limestone in order to obtain the desired water supply. Figure 5 shows that the top of the Lake City is more than 750 ft (230 m) below sea level in most of Clay and Duval Counties and is less than 600 ft (180 m) below sea level only locally within the area of investigation. The Lake City is 400-650 ft (120-200 m) thick.

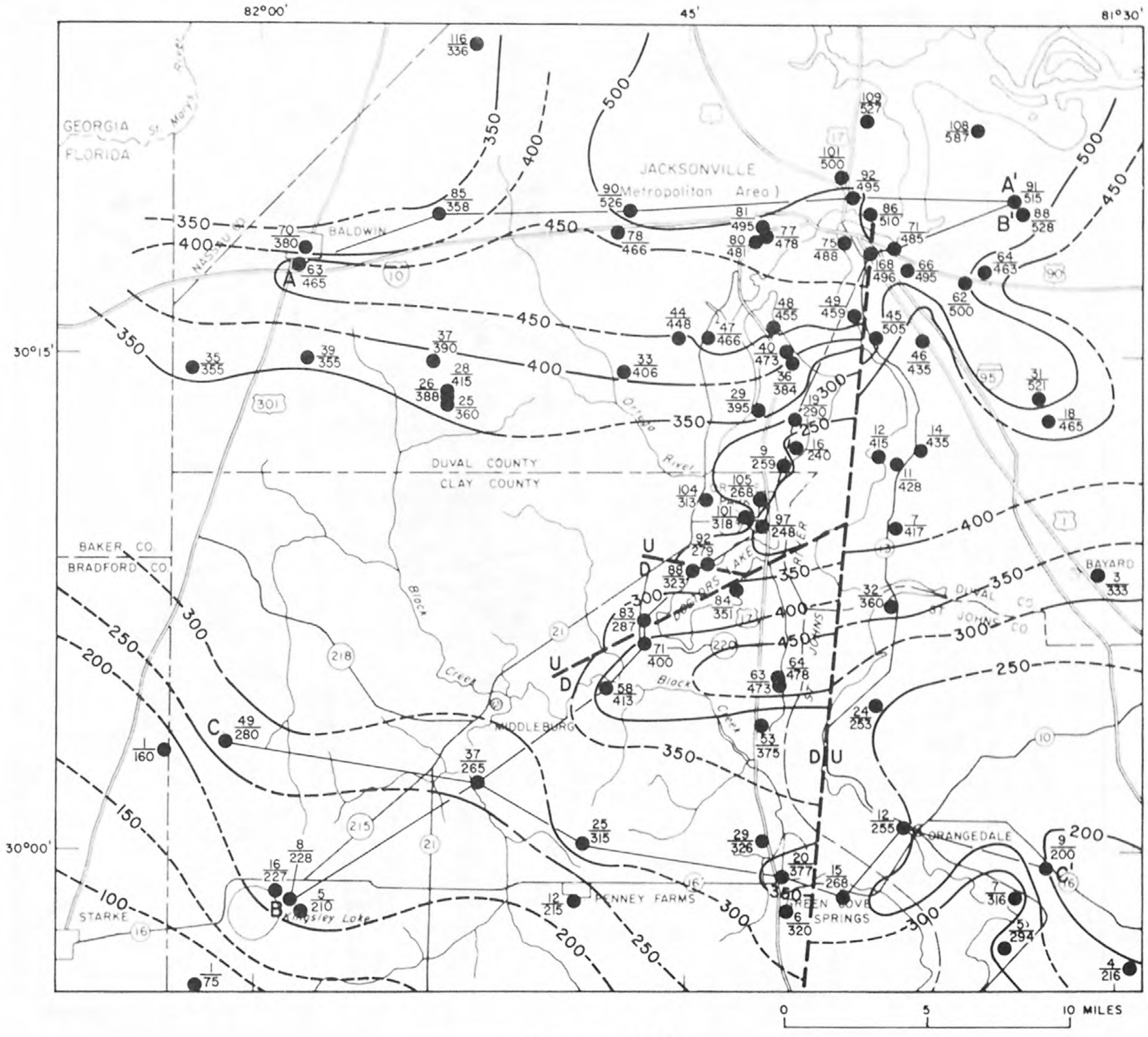
Geologic Structure

The area of investigation is on the eastern flank of an anticlinal fold or arch which is referred to as the Ocala uplift (Vernon, 1951, p. 54-58). Formations that comprise the Floridan aquifer have been subjected to deformation along this structure. Both figure 4 and 5 indicate faulting in parts of the area and figures 6 and 7 show that, although most of the displacement has occurred in deposits older than Hawthorn, some displacement has occurred in the Hawthorn Formation (fig. 6, section B-B').

Table 2. Wells listed in table 1 that tap the Lake City Limestone.

Well Number	Well Depth (ft)	Top of Lake City Limestone (ft below msl) 1/	Altitude of Land Surface (ft)	Source of Information 2/
		DUVAL COUNTY		
7	900	720	20	W-3464, D-83
19	1015	600	24	W-514, D-161
25	980	765	80	W-581, D-222
26	1303	745	85	W-4113, D-113
29	987	700	5	W-661, D-65
44	1000	744	30	USGS Log, D-286
64	1004	847	13	USGS Log, D-281
66	1210	790	26	USGS Log, D-311
68	1348	810	20	W-322, D-54A
71	2486	765	20	USGS Test Well D-425
78	1016	794e	46	Driller's Log, D-80
86	1074	805	5	W-649, D-64
90	1060	780	59	W-116, D-67
91	1050	865	55	USGS Log, D-414
101	1249	800	15	W-304, D-28A
109	1076	846	22	USGS Log, D-39
		CLAY COUNTY		
25	5862	725	105	W-1590, C-68
49	3509	685	175	W-6299, C-69
83	1197	587	46	USGS Test Well C-94
88	864	688	27	USGS Log, C-81
101	616	569	15	USGS Log, C-26
104	1030	690	60	W-4834, C-63
105	862	628e	10	Driller's Log, C-93

1/ e = estimated
2/ (W), Florida Bureau of Geol. well log number.
(D or C), U. S. Geol. Survey, Duval or Clay County local well number.



EXPLANATION

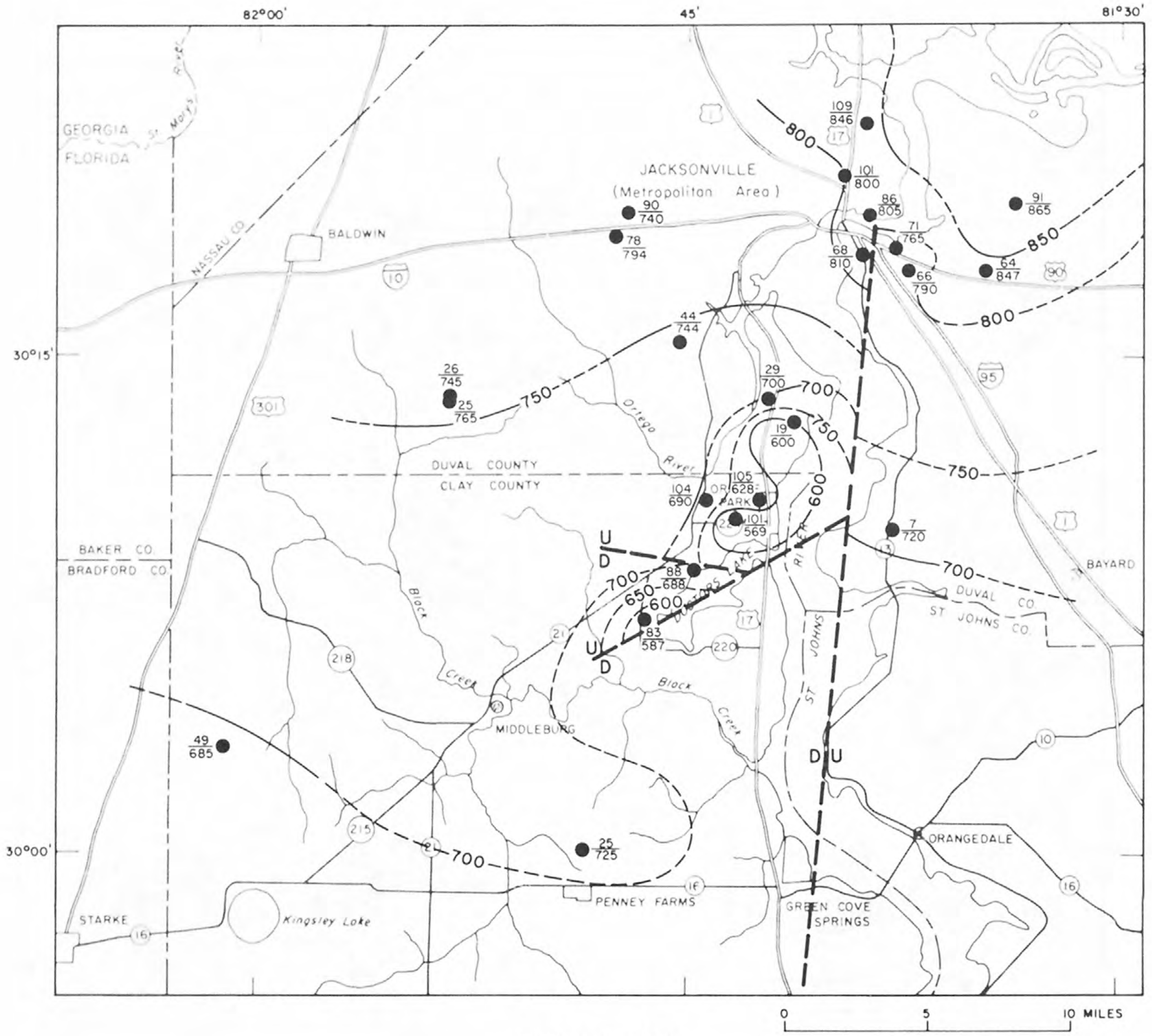
● $\frac{25}{315}$ — WELL NUMBER AS LISTED IN TABLE 1. ALTITUDE OF THE TOP OF THE OCALA GROUP, FEET BELOW MEAN SEA LEVEL.

—350- - - — STRUCTURE CONTOUR -- SHOWS ALTITUDE OF TOP OF OCALA GROUP. DASHED WHERE APPROXIMATELY LOCATED. CONTOUR INTERVAL 50 FEET. DATUM IS MEAN SEA LEVEL.

U/D — FAULT. U IS UPTHROWN SIDE. D IS DOWNTHROWN SIDE. DASHED WHERE INFERRED. (MODIFIED AFTER LEVE, 1966)

A ——— A' — LINE OF GEOLOGIC SECTIONS SHOWN ON FIGURES 6 AND 7.

FIGURE 4.--MAP SHOWING ALTITUDE OF THE TOP OF THE OCALA LIMESTONE IN THE AREA OF INVESTIGATION.



EXPLANATION

● $\frac{25}{725}$ WELL NUMBER AS LISTED IN TABLE I. / ALTITUDE OF TOP OF LAKE CITY LIMESTONE.

——700— — — STRUCTURE CONTOUR -- SHOWS ALTITUDE OF TOP OF THE LAKE CITY LIMESTONE. DASHED WHERE APPROXIMATELY LOCATED. CONTOUR INTERVAL 50 FEET. DATUM IS MEAN SEA LEVEL.

U/D —— — — FAULT. U IS UPTHROWN SIDE. D IS DOWNTHROWN SIDE. DASHED WHERE INFERRED. (MODIFIED AFTER LEVE, 1966)

FIGURE 5.--MAP SHOWING ALTITUDE OF THE TOP OF THE LAKE CITY LIMESTONE IN THE AREA OF INVESTIGATION.

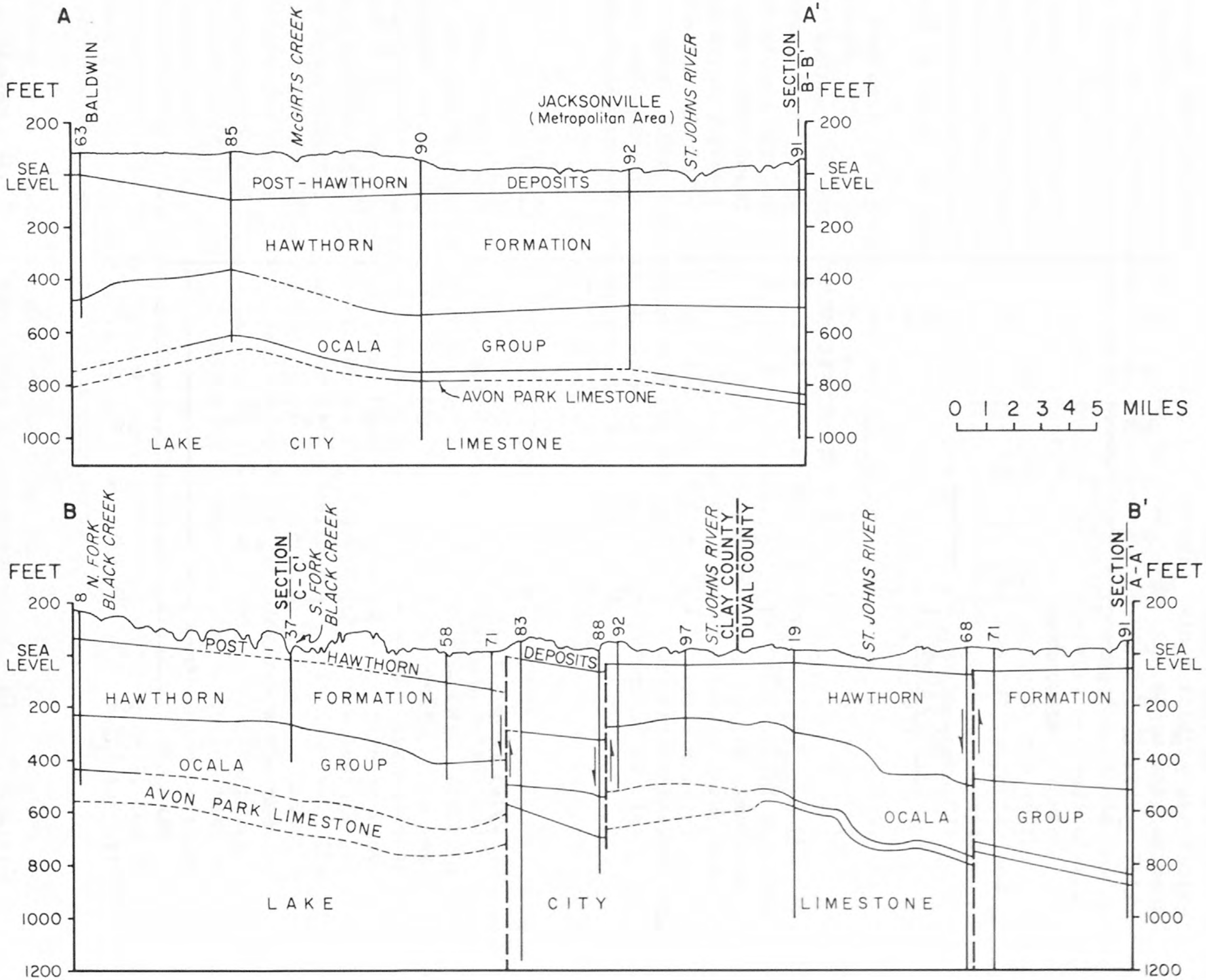


FIGURE 6.--GEOLOGIC SECTION ALONG LINES A-A' AND B-B' IN FIGURE 4.

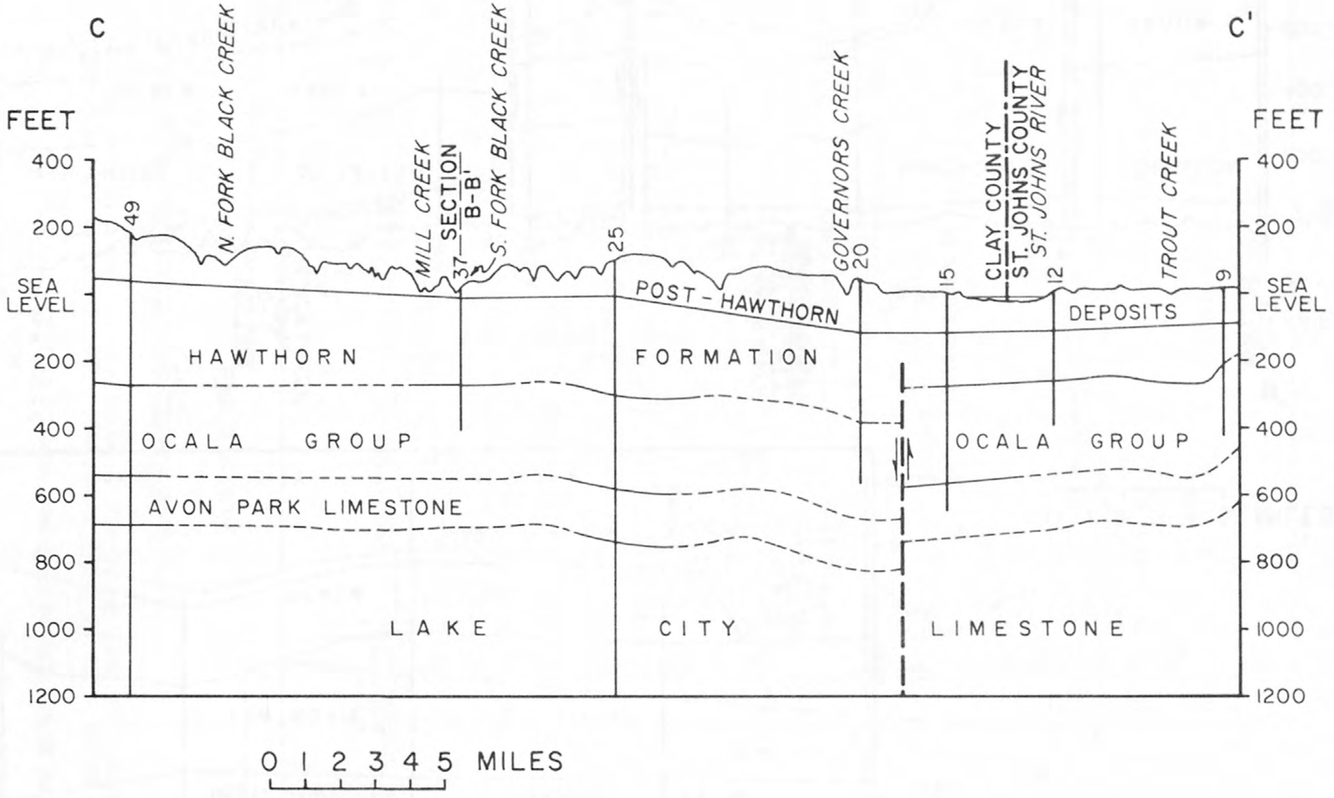


FIGURE 7.--GEOLOGIC SECTION ALONG LINE C-C' IN FIGURE 4.

The regional dip of the beds on the flank of the uplift is east-northeast and averages about 6 ft/mi (1.1 m/km). Minor folding and faulting locally causes variations in the regional dip. The major displacement by faulting is shown (figs. 4, 5) to lie along the St. Johns River. This displacement was reported by Leve (1966, p. 20). Geologic sections A-A' and C-C' (figs. 6 and 7) extend across the area generally perpendicular to the axis of the uplift and B-B' extends parallel to the axis. These sections show minor structures superimposed on the regional dip of the beds. Structural contours on figures 4 and 5 show the configuration and elevation of the top of the Lake City Limestone and the Ocala Limestone. A structural high in the vicinity of Orange Park in northwestern Clay County is shown on both structural contour maps.

Numerous faults and joint patterns have been mapped by Vernon (1951, p. 47-48, fig. 11) in the northern part of the Florida peninsula. Two major faults that were mapped extend into the project area; one trends northwestward and is parallel to the axis of the Ocala uplift, and the other trends northeastward. Fractures related to faults or joint patterns map contribute locally to increases in the permeability of the limestone. Those areas where the permeability may have been increased by structural deformation would be the best sites for future well fields. However, these areas could also be subject to saline-water contamination because the faults and fractures could be avenues of upward migration of highly mineralized water from deeper zones in the aquifer.

Water Levels and Water-level Fluctuations

Water level data were collected and evaluated for selected wells that tap the Floridan aquifer in the area of investigation to determine long-term trends and seasonal fluctuations. Of the 21 wells whose water levels were measured during the investigation, hydrographs are shown in figure 8 for three wells in Duval County, in figure 9 for five in Clay County and in figure 10 for three in St. Johns County. The average water-level fluctuation range for all 11 wells was 5.0 ft (1.5 m). The greatest fluctuation range was 8.1 ft (2.5 m) in well Duval 17 and the least was 3.6 ft (1.1 m) in wells Clay 48 and St. Johns 22. In the southeastern part of the area of investigation water levels fluctuate more than 15 ft (4.6 m) in response to irrigation just south of that area. The water levels generally are lowest during May and June each year and highest during January and February. Fluctuation of water levels in well Clay 65 in northeastern Clay County, as shown on figure 11, and at Jacksonville were partly in response to withdrawals from wells and partly in response to seasonal variations in rainfall.

Long-term trends of water levels in wells Clay 80, St. Johns 26 and Duval 50 that tap the Floridan aquifer are shown on the hydrographs on figure 12. The water levels in these wells, monitored since 1940, began to decline in about 1949 and continued to decline to about 1956. During

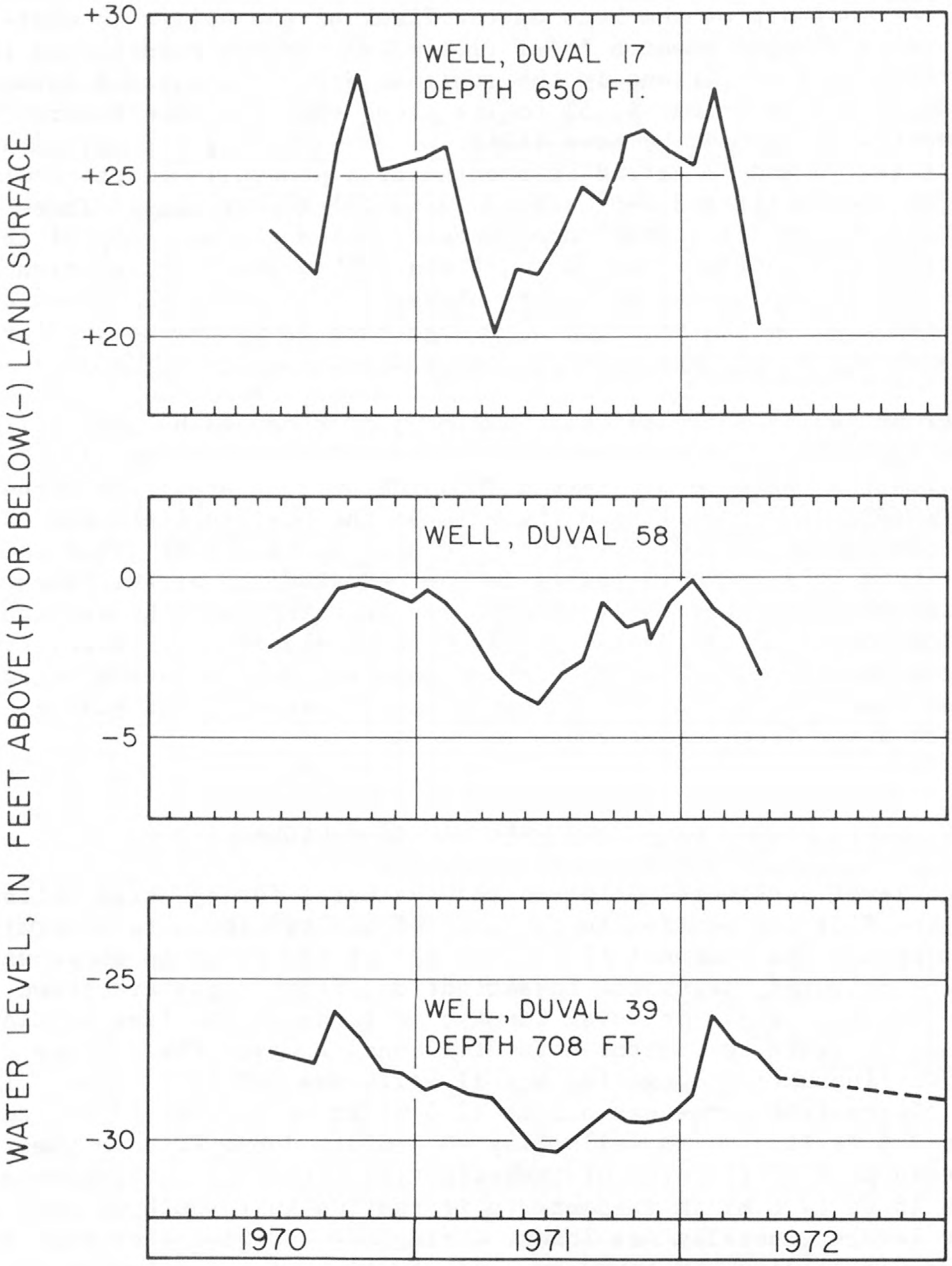


FIGURE 8.--HYDROGRAPHS OF SELECTED WELLS IN DUVAL COUNTY.

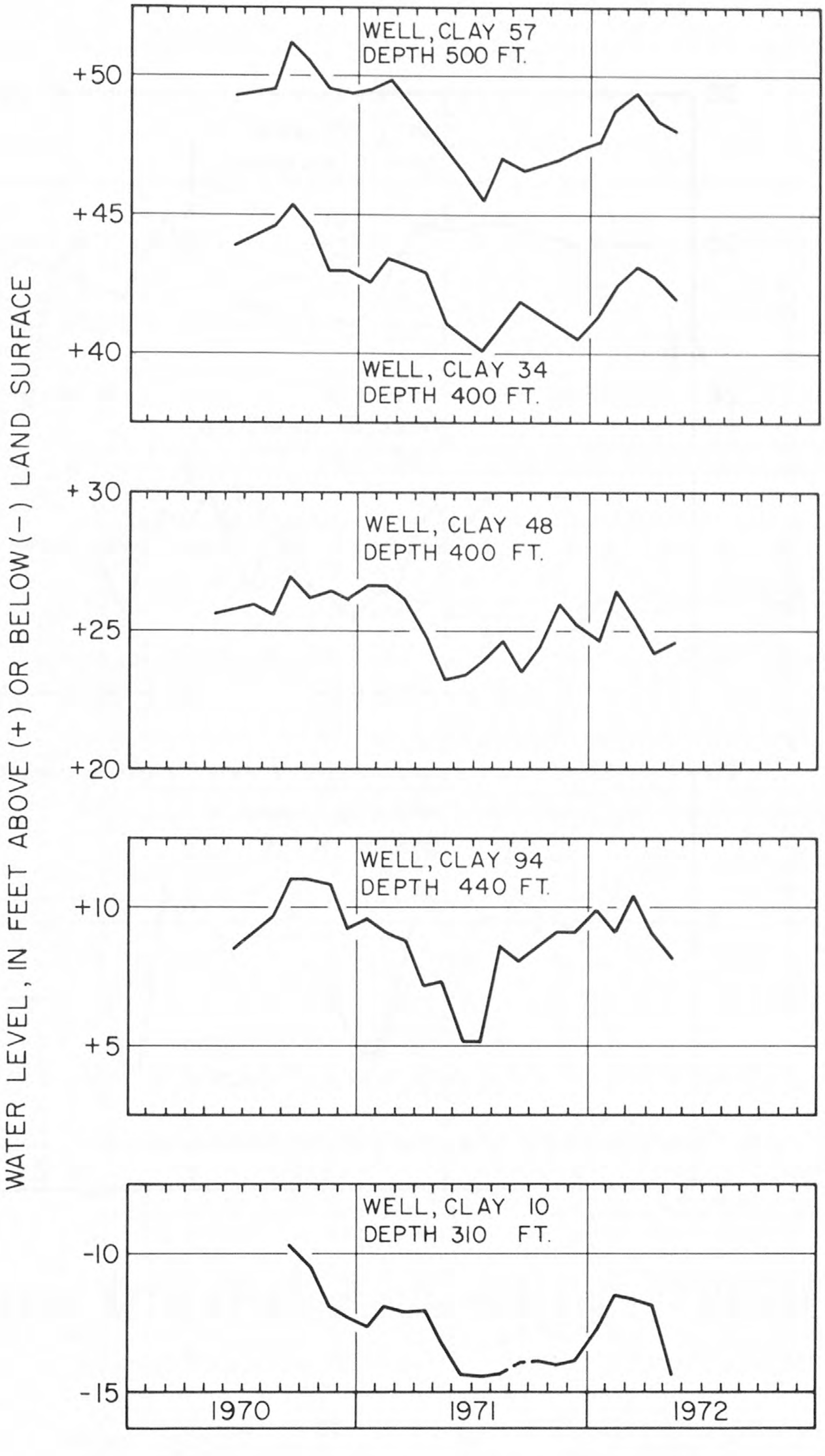


FIGURE 9.--HYDROGRAPHS OF SELECTED WELLS IN CLAY COUNTY.

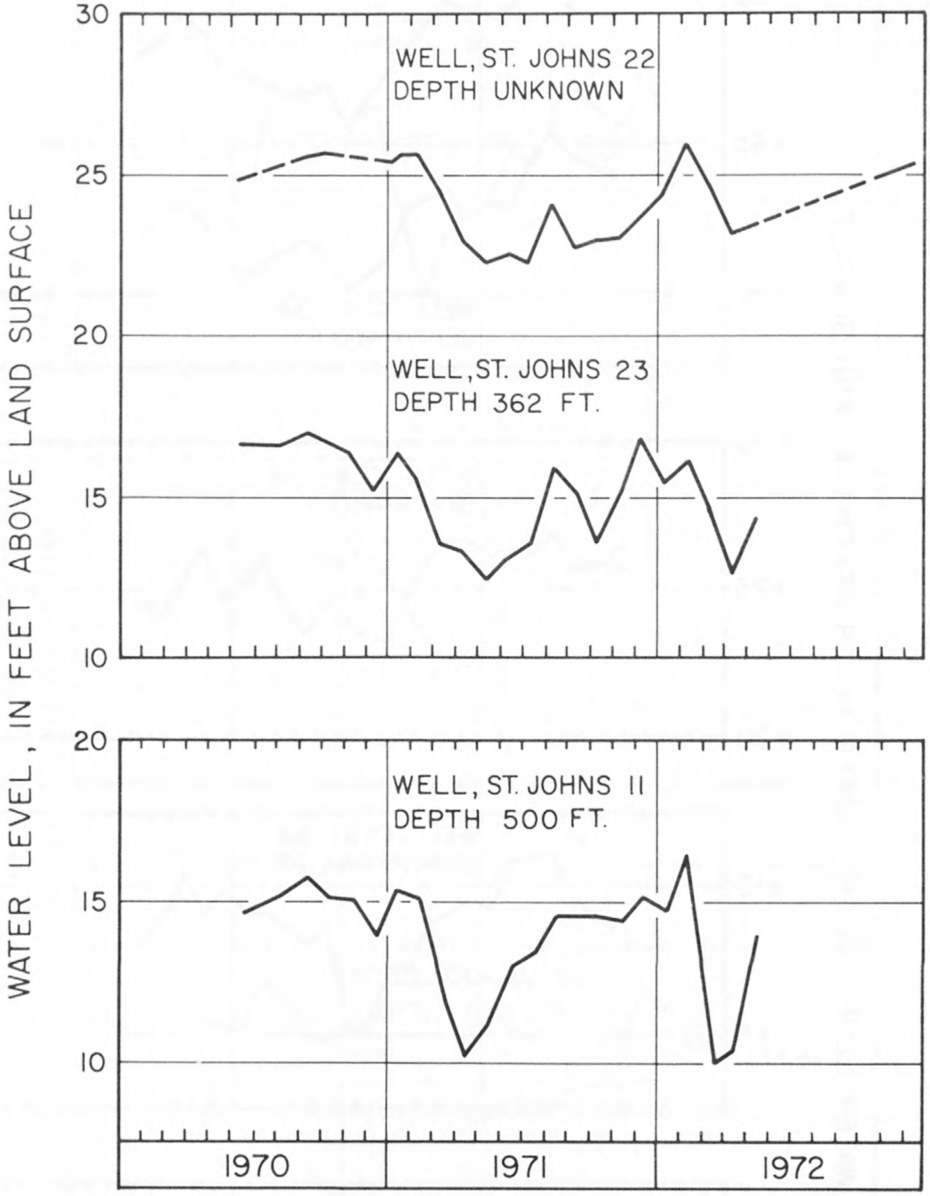


FIGURE 10.--HYDROGRAPHS OF SELECTED WELLS IN ST. JOHNS COUNTY.

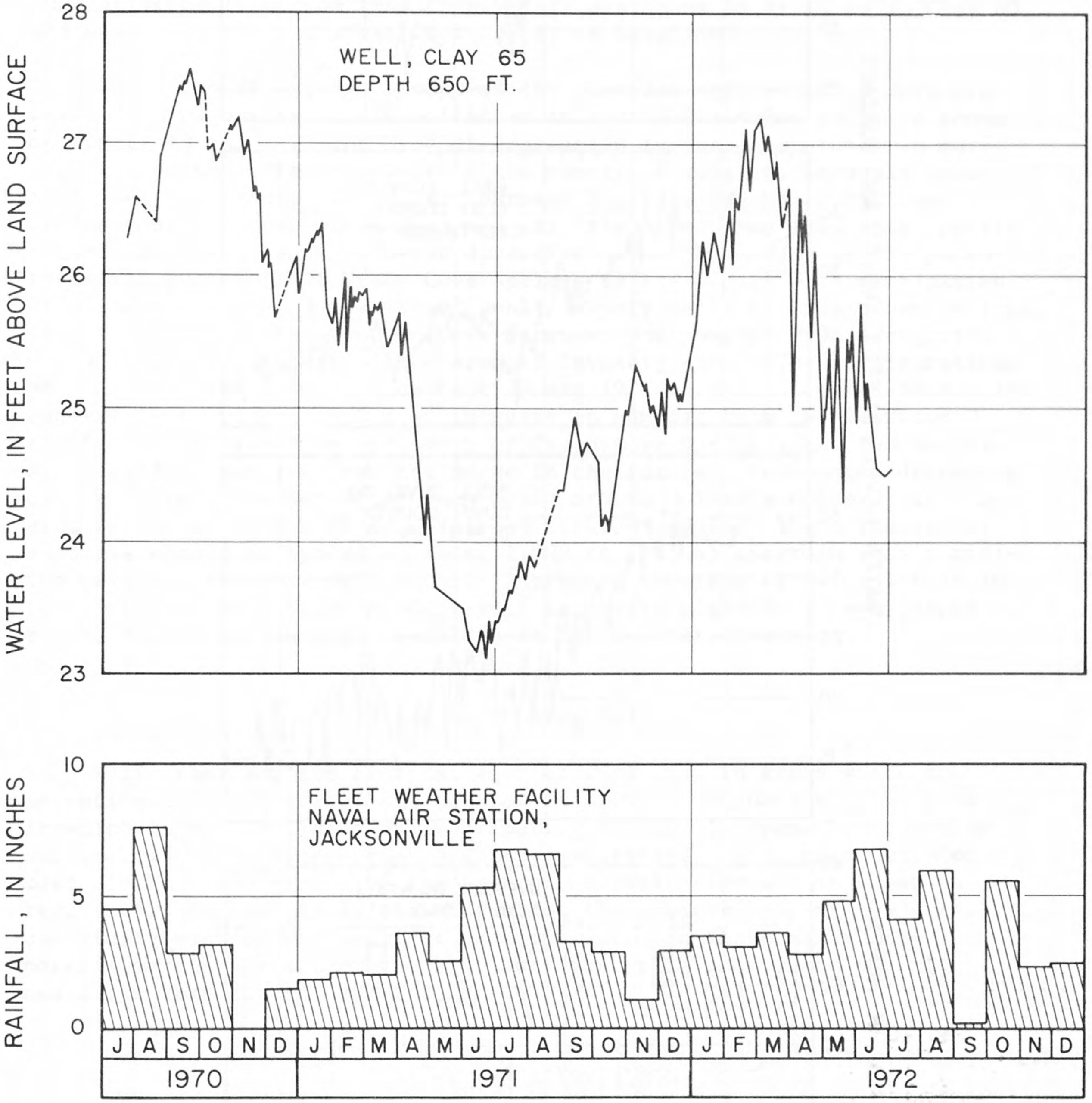


FIGURE 11.--HYDROGRAPH OF WELL CLAY 65 NEAR DOCTORS INLET AND GRAPH OF RAINFALL AT THE NAVAL AIR STATION, JACKSONVILLE.

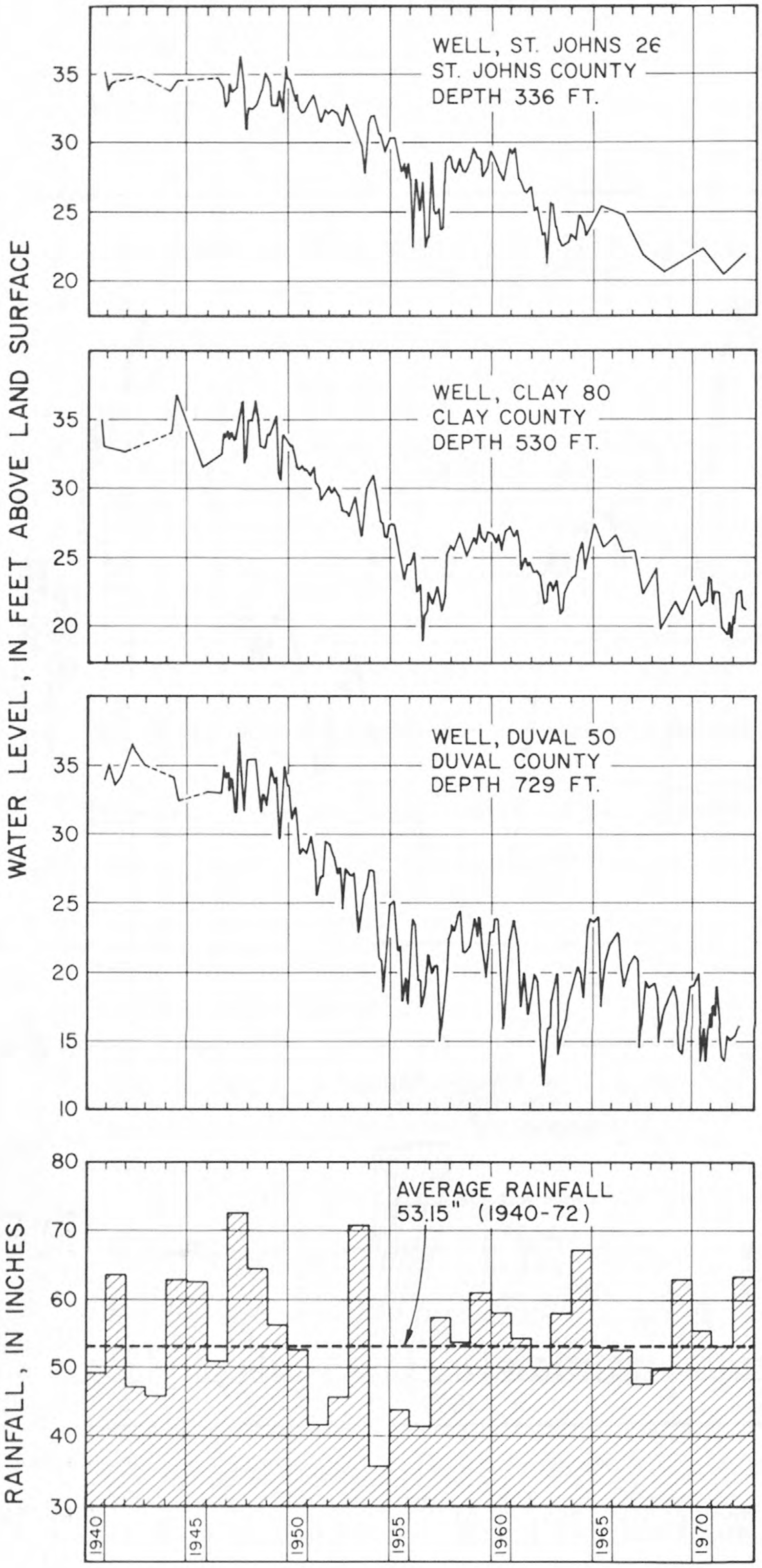


Figure 12.--Hydrographs of selected wells in Duval, Clay and St. Johns counties and a graph of the average of annual rainfall at U.S. Weather Bureau stations at Jacksonville, Starke, and St. Augustine.

this period, rainfall at the three index stations was below average for all years except 1949 and 1953. Water levels rose about 3 to 4 ft (1 to 1.2 m) from 1957 to about 1960; since then there has been a gradual decline of about 7 to 8 ft (2 to 2.4 m) to May, 1972. The rate of decline was less from 1957 to 1972 owing to an above-average rainfall for that period. The cumulative decline from 1949 to May 1972 was about 14 ft (4 m) in Clay 80 and St. Johns 26, and about 20 ft (6 m) in Duval 50.

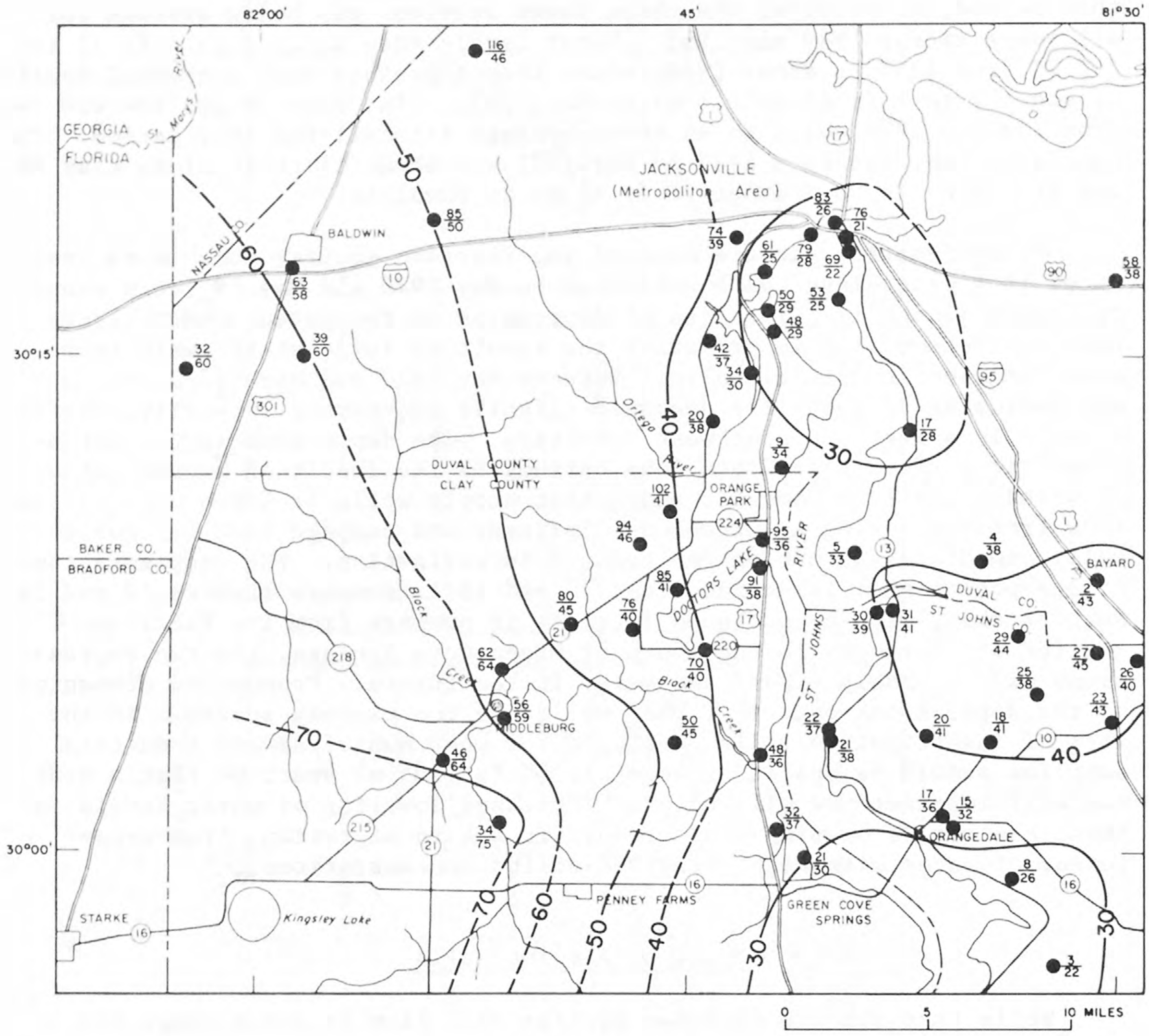
Potentiometric surface maps of the Floridan aquifer which were prepared from water-level data collected in May 1970 and May 1971 are shown on figure 13 and 14. The area of depression in the potentiometric surface at Jacksonville is primarily the result of large withdrawals from municipal and industrial wells. Between May 1970 and May 1971, the depression at Jacksonville deepened slightly and spread laterally, particularly in a west and southwest direction. The depression in the potentiometric surface near Green Cove Springs is the result of a combination of withdrawals from domestic and public supply wells at Green Cove Springs, flow from the spring at Green Cove Springs, and pumpage from irrigation wells immediately south of the area of investigation. The configurations of the potentiometric surface in 1970 and 1971 (compare figures 13 and 14) suggest that, with a continued increase in pumpage from the Floridan aquifer at Jacksonville and south of Green Cove Springs, the two depressions will probably expand and merge in the future. Pronounced deepening of the depressions can occur when wells are too closely spaced. In the area of investigation wells developed for most municipal and industrial supplies should be spaced at least 1,000 ft (305 m) apart so that a minimum well interference will occur. Increased lowering of water levels in those centers of pumping could result in upward migration, from deeper zones, of water with high dissolved-solids concentrations.

Areas of Flowing Wells

Wells that tap the Floridan aquifer will flow in areas where the potentiometric surface of the aquifer is above land surface. The area in which flowing wells occur is primarily in the St. Johns River valley and valleys along Black Creek and its tributaries. This area includes most of the eastern half of the area of investigation and is shown on figure 15. Several hills and ridges dot the eastern half of the area, especially east of metropolitan Jacksonville. In these areas, the potentiometric surface of the Floridan aquifer is below land surface and wells that tap the aquifer do not flow.

Aquifer Characteristics

The hydraulic characteristics of an aquifer describe its ability to store and transmit water and can be described in terms of storage coefficient and transmissivity. The specific capacity of a well is a measure of the ability of the aquifer to transmit water to the well. All the

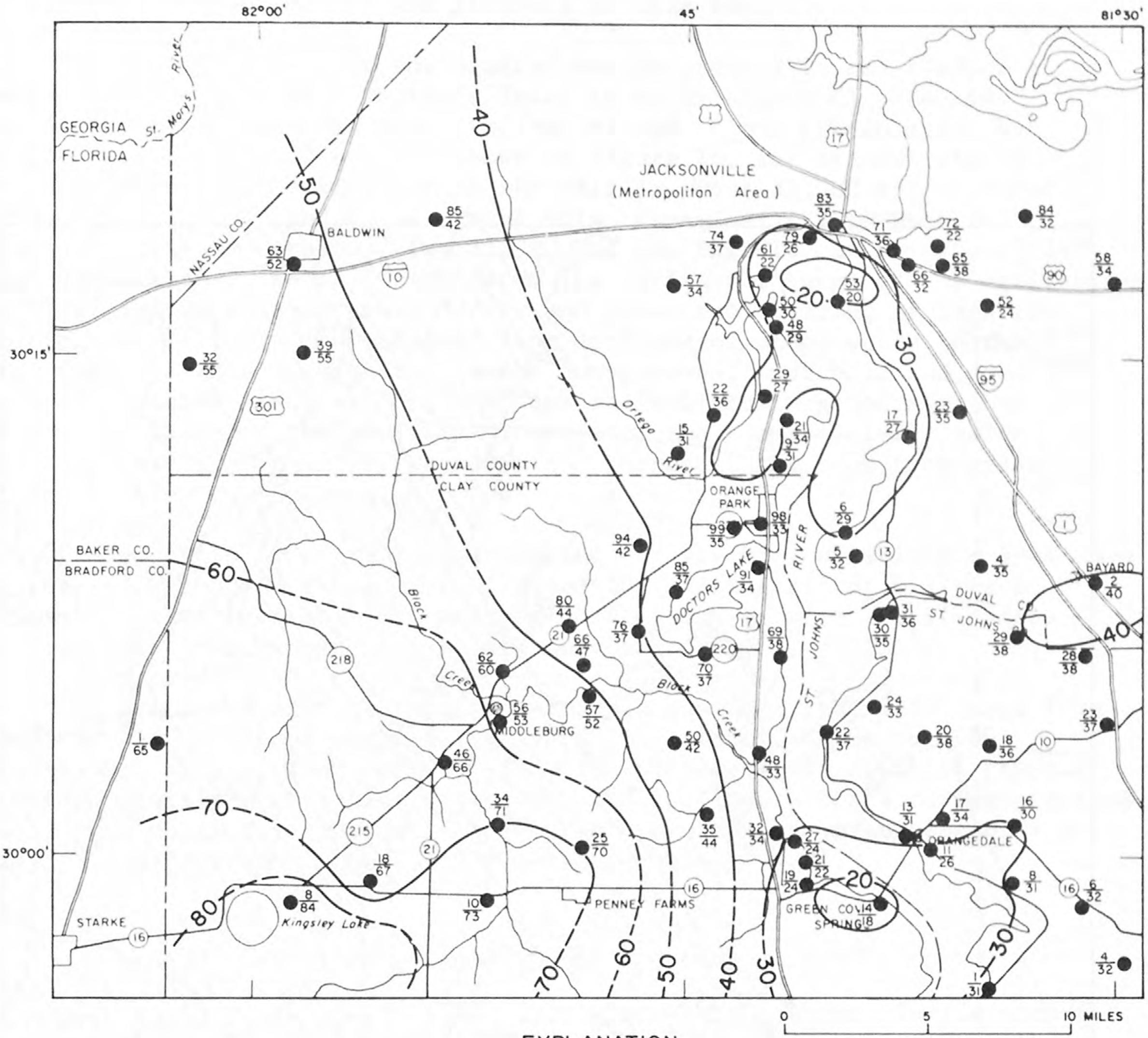


EXPLANATION

● 46/64 — WELL NUMBER AS LISTED IN TABLE 1. / WATER LEVEL, FEET ABOVE MEAN SEA LEVEL.

—50---- — POTENTIOMETRIC CONTOUR -- SHOWS ALTITUDE AT WHICH WATER LEVEL WOULD HAVE STOOD IN TIGHTLY CASED WELLS. DASHED WHERE APPROXIMATELY LOCATED. CONTOUR INTERVAL 10 FEET. DATUM IS MEAN SEA LEVEL.

FIGURE 13.--MAP SHOWING POTENTIOMETRIC SURFACE OF THE FLORIDAN AQUIFER IN THE AREA OF INVESTIGATION, MAY 1970.



EXPLANATION

● 50/42	WELL NUMBER AS LISTED IN TABLE 1. / WATER LEVEL, IN FEET ABOVE MEAN SEA LEVEL.
—30— – –	POTENTIOMETRIC CONTOUR -- SHOWS ALTITUDE AT WHICH WATER LEVELS WOULD HAVE STOOD IN TIGHTLY CASED WELLS. DASHED WHERE APPROXIMATELY LOCATED. CONTOUR INTERVAL 10 FEET. DATUM IS MEAN SEA LEVEL.

FIGURE 14.--MAP SHOWING POTENTIOMETRIC SURFACE OF THE FLORIDAN AQUIFER IN THE AREA OF INVESTIGATION, MAY 1971.

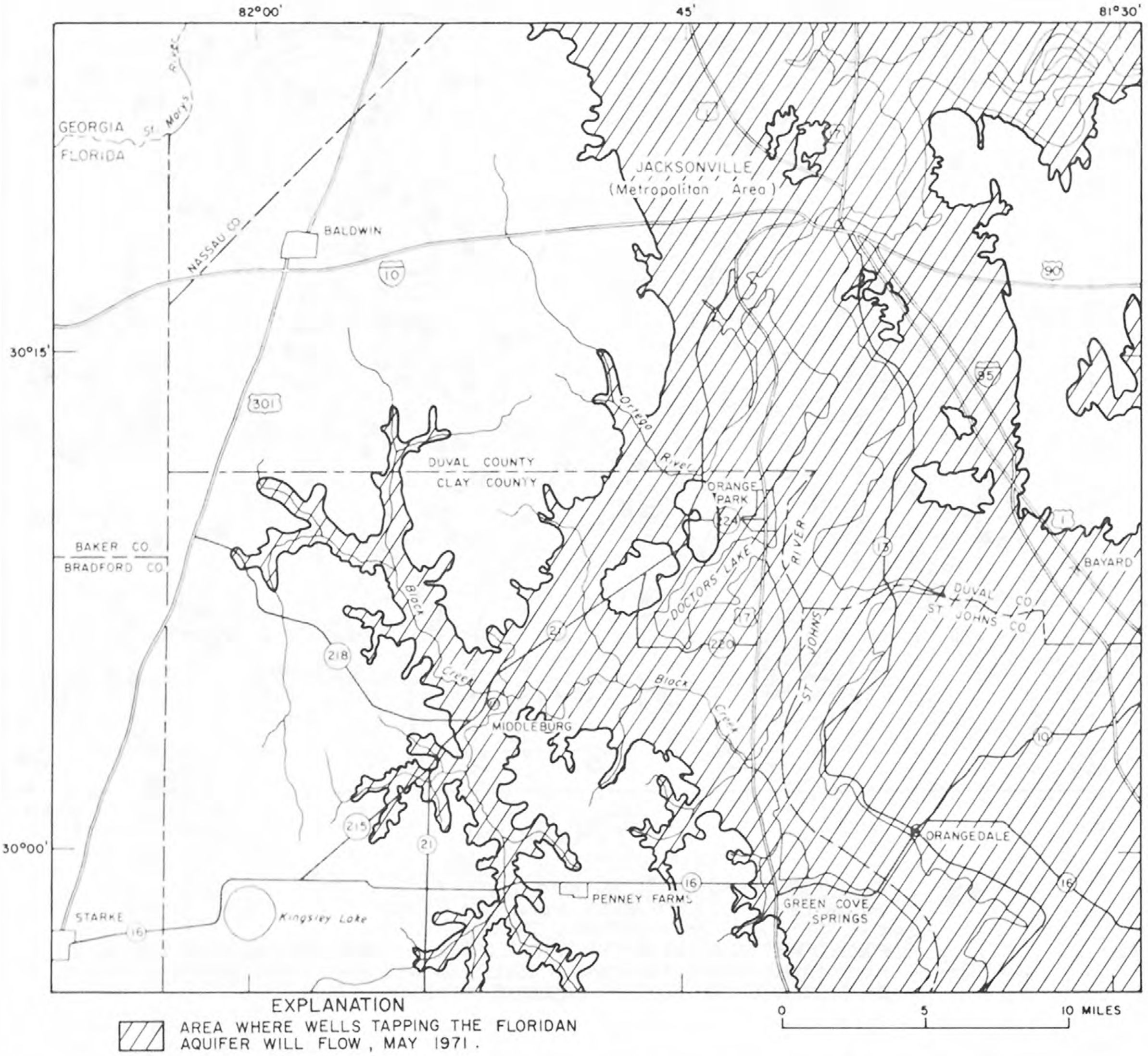


FIGURE 15.--MAP SHOWING APPROXIMATE AREA IN WHICH WELLS THAT TAP THE FLORIDAN AQUIFER WILL FLOW, MAY 1971.

above terms are defined in the glossary of this report.

The transmissivity of the aquifer was determined in the area of a test well (Clay 83) near Doctor's Inlet in northeastern Clay County. The depth of this well is 1,197 ft (365 m) and it penetrates about 850 ft (260 m) of the aquifer. As shown in figure 16, the transmissivity of the aquifer in the vicinity of the well is about 87,000 ft^2/d (8,100 m^2/d). The method used to determine this transmissivity assumes that the aquifer is homogeneous, isotropic, and has infinite areal extent. It also assumes that the well penetrates the entire thickness of the aquifer. Geologic information obtained during and after the drilling of this well and geologic information obtained from drilling of other wells in the area indicate that the aquifer is not homogeneous, isotropic and does not have an infinite areal extent, nor does the well fully penetrate the entire thickness of the aquifer. Therefore, the transmissivity value obtained from that aquifer test does not represent the true transmissivity of the aquifer in the area.

The specific capacity was determined for several wells in the area of investigation and ranges from 1.3 to 410 (gal/min)/ft or 0.27 to 85 (l/s)m of drawdown (table 3), which generally agrees with specific capacities in an earlier report by Clark and others (1964, p. 134).

The storage coefficients of water-table aquifers generally range from about 0.05 to 0.30 and artesian aquifers range from 0.00001 to 0.001 (Ferris and others, 1962, p. 76, 78). The storage coefficient of the Floridan aquifer at the test well was not determined. Tests during previous studies in northeast Florida indicate that the order of magnitude of the storage coefficient of the aquifer averages about 0.0001.

Recharge

Most recharge to the Floridan aquifer in northeastern Florida occurs west and southwest of Jacksonville. The ground-water reservoirs in the area of investigation are recharged primarily by rainfall outside the area and to a lesser extent by rainfall from within the area. The average annual rainfall in northeastern Florida is about 53 inches (1,350 mm), of which most occurs during June through October; rainfall is generally lowest during November through May.

According to Clark and others (1964, p. 125), principal recharge to the Floridan aquifer occurs in a 525-mi^2 (1,360-km^2) area in the lakes region of southwestern Clay County, eastern Bradford County and western Alachua County where the confining beds are either thin or missing. Clark and others (1964, p. 125) report that recharge in that area is at a rate of about 45 Mgal/d (2 m^3/s). Because the hydraulic gradient is in all directions away from the principal recharge area, only part of the water moves laterally down-gradient through the permeable beds of the aquifer

Table 3. Specific capacities of wells tapping the Floridan aquifer in the area of investigation.

Well Number	Depth (ft)	Casing Depth (ft)	Casing Diam. (in)	Static Water Level (ft) 1/	Draw-down (ft)	Pump Rate (gal/min)	Pump Time (hrs)	Specific Capacity [(gal/min)/ ft drawdown]
				DUVAL COUNTY				
25	980	431	10	- 16.5	1.3	533	4.6	410
				CLAY COUNTY				
4	718	312	10	-151	10	800	---	80
8	661	380	10	- 91	4.5	800	---	180
10	310	---	6	- 12.5	4.9	162	4.2	33
13	718	345	12	- 85	27	800	---	30
16	522	380	12	-117	4	300	---	80
29	1110	399	16	+ 20.0	65	2500	5	38
66	600	---	4	+ 22.6	37.4	190	2.7	5.1
77	500	---	3x2	+ 23	46	63	4.4	1.4
83	1197	391	12x8	- 5.22	12.2	1280	3	105
				BRADFORD COUNTY				
2	774	442	16	-125	36	2200	.5	61
1	725	330	16	-130	40	2200	3.8	55
				ST. JOHNS COUNTY				
9	500	---	4	+ 8.2	41.6	63	1.7	1.5

1/ Above (+) or below (-) land surface datum. Water level before test begun.

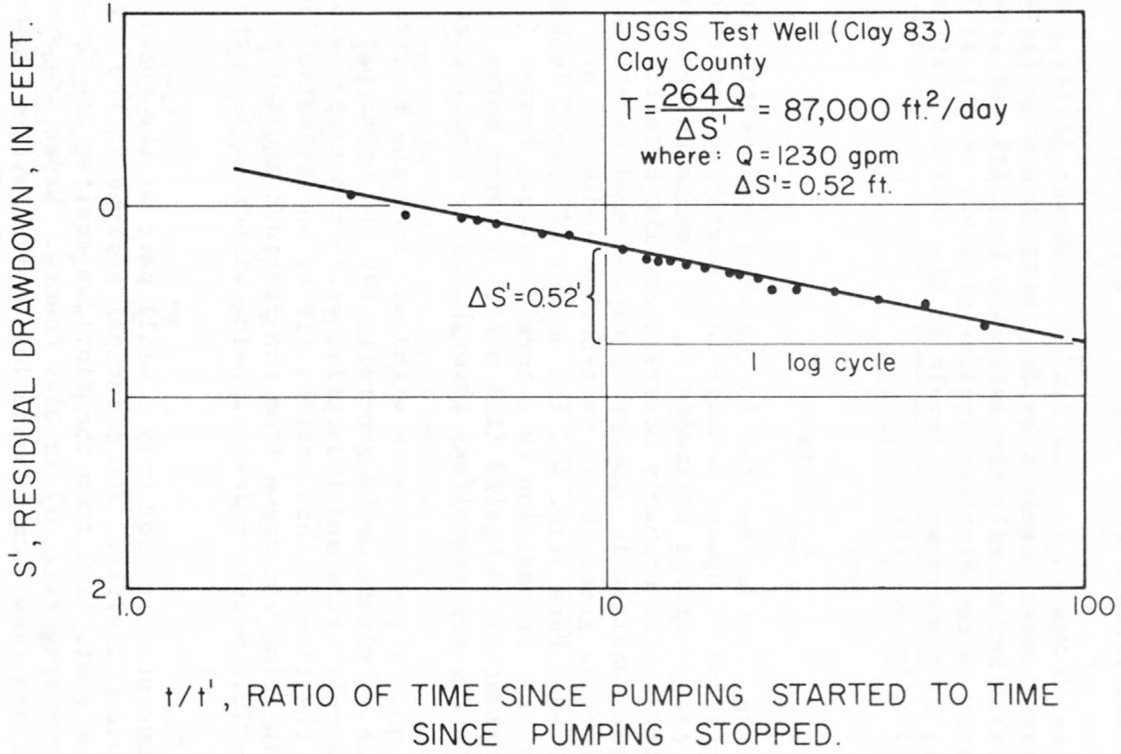


FIGURE 16.--GRAPH SHOWING SOLUTION OF COEFFICIENT OF TRANSMISSIVITY OF THE FLORIDAN AQUIFER AT THE SITE OF TEST WELL CLAY 83.

and reaches the area of investigation. The hydraulic gradient of the potentiometric surface of the Floridan aquifer in the area of investigation (figs. 13 and 14) is generally eastward and northeastward.

An estimate of recharge to the Floridan aquifer of 3 Mgal/d (0.1 m^3/s) was reported by Leve (oral commun., 1972) for a 270-mi^2 (700-km^2) area in eastern Baker County and western Duval County.

The range of 3 to 45 Mgal/d (0.1 to 2 m^3/s) recharge is far less than that required to prevent water levels from declining at a much faster rate than at present (1974). Undoubtedly the estimates by Clark and Leve are a minimum. Some recharge to the Floridan aquifer probably occurs as leakage through the confining beds where water levels in the shallow aquifers are above those in the Floridan aquifer.

Discharge

Discharge from the Floridan aquifer in the area of investigation is from wells and springs and by upward leakage into overlying formations. Upward leakage into the overlying sediments of the confining beds and beds of the shallow-aquifer system probably occurs where the potentiometric surface of the Floridan aquifer is above that of the shallow artesian aquifer and water table. In those places where post-Eocene sediments are the thinnest, such as near Orange Park (fig. 4), the amount of upward leakage would most likely be greatest. In addition to natural leakage, Foster (1961) estimates that approximately 30 Mgal/d (1.3 m^3/s) of water moves from the Floridan aquifer into the upper aquifers through poorly constructed wells.

A considerable quantity of water is withdrawn from the Floridan aquifer through wells. Private wells generally tap the upper part of the aquifer and public supply wells and industrial wells penetrate deeper parts of the aquifer. At the time of this writing (1974) an estimated 250 Mgal/d (11 m^3/s) of water is being withdrawn from the Floridan aquifer in Duval County and 10 Mgal/d (0.4 m^3/s) or less is being withdrawn from the aquifer in Clay County.

Flow from springs accounts for only a small part of the total discharge from the Floridan aquifer. The principal springs in the area that derive all or part of their flow from the Floridan aquifer are Green Cove Spring and Wadesboro Spring (fig. 1) in Clay County. Wadesboro Spring may derive a part of its flow from the shallow aquifer system; however, the source of flow has not been determined. Discharge from Green Cove Spring, which has been measured seven times since 1929, ranged from 2.68 to 5.40 ft^3/sec (0.08 to 0.15 m^3/sec) and averaged 3.71 ft^3/sec (0.11 m^3/sec).

Water Quality

The chemical quality of water from the Floridan aquifer in most of the area of investigation is suitable for most uses. Concentrations of most mineral constituents and chemical properties of the water are well below the limit recommended by the Florida Department of Pollution Control (1973). Recommended limits for some of the chemical constituents in public water supply are shown in table 4. The U. S. Geological Survey analyzed water samples from 153 wells in the area of investigation. Extremes in concentration of some of the more common chemical constituents in water from the Floridan aquifer within the area are as follows:

County	Extremes in concentration of common chemical constituents (mg/l)				
	Calcium	Magne- sium	Sulfate	Chloride	Hardness (as $CaCO_3$)
Duval	30-80	12-40	20-210	6-46	117-336
Clay	17-34	2.8-18	0.4-102	4-12	77-468
St. Johns	35-230	21-107	74-240	5-36	92-776

A comparison of concentrations of some of the chemical constituents in water from wells that tap the Floridan aquifer are shown below:

Well	Date Sampled	Chemical Constituents (mg/l) F	Ca	Mg	SO_4	Cl	Hardness
Duval 77	10-30-41	0.6	67	27	155	12	278
	06-17-71	.7	65	26	146	13	273
Clay 84	07-18-60	.4	19	11	13	--	92
	08-28-70	.3	18	11	13	7.0	91
Clay 7	08-26-60	.3	30	16	52	6.0	141
	09-27-70	.2	22	13	25	7.0	110
Clay 11	08-20-60	.1	24	6.1	1.6	5.0	85
	09-27-70	.0	23	6.5	.8	6.5	84

Table 4. Recommended quality standards for public water supplies.

Chemical substance	Limit not to be exceeded EPA 1/	DPC 2/
Physical		
Odor	Unobjectionable	24 units at 60°C
Color	75 Pt-Co units	
pH	5.0-9.0 units	6.0-8.5 units
Turbidity		50 units
Chemical	(mg/1)	(mg/1)
Chloride	250	250
Fluoride 3/	1.4-2.4	1.4-1.6
Iron	0.3	0.3
Nitrite-Nitrogen	10	
Nitrate-Nitrogen	1.0	
Sulfate	250	
Dissolved Solids (Residue)	500	500

1/ Environmental Protection Agency (Nat. Acad. Sci. and Nat. Acad. Eng., 1973)

2/ Florida, Department of Pollution Control (1973)

3/ The concentration of Fluoride should be between the limits expressed, depending on the annual average of maximum daily air temperatures at a location being considered.

On the basis of the paired analyses of samples from these wells, the chemical quality of water from these wells has not changed noticeably over a time span ranging from 10 years for wells Clay 84, Clay 7, and Clay 11, to 30 years for well Duval 77.

During the drilling of test well Clay 83, samples of water were collected at depths ranging from 475 to 1,200 ft (145 to 365 m) to determine changes in quality with depth of penetration of the Floridan aquifer. The samples were tested for specific conductance, hardness, and chloride concentration; the hardness and chloride concentration are shown on figure 17 and are plotted opposite the depths from which the samples were taken. As shown on figure 17, only a slight increase in hardness occurs with depth of penetration of over 800 ft (240 m) of the aquifer and there was no increase in the chloride concentration. The maximum hardness (106 mg/l) was at depths of 630 and 681 ft (192 and 208 m), and the minimum hardness (58 mg/l) was at 1,017 ft (310 m). The average hardness for all the samples collected from various depths was about 90 mg/l and the average chloride concentration was about 8 mg/l.

The depth to the base of potable water (water that does not contain more than 250 mg/l of chloride and 500 mg/l of dissolved solids) in the Floridan aquifer as shown on figure 18 decreases southward and southwestward from Jacksonville (Klein, 1971). Throughout most of northern Clay County the base of potable water is below the Oldsmar Limestone, but in northern St. Johns County saline water (water whose dissolved-solids concentration is at least 500 mg/l) is in the Oldsmar Limestone and may extend upward into the overlying Lake City Limestone.

In Jacksonville, the quality of fresh water changed only slightly down to a depth of 1,900 ft (580 m) in a 2,486-ft (758-m) test well, Duval 71 (Leve and Goolsby, 1967, p. 21), and actually improved in the zone from 1,900 to 2,050 ft (580 to 625 m). Below this depth the water became increasingly salty and the chloride concentration was as high as 7,300 mg/l at a depth of 2,458 ft (749 m).

The hardness of water in the Floridan aquifer as shown on figure 19 ranges from about 80 mg/l near Penney Farms in central Clay County to more than 750 mg/l near Orangedale in northwestern St. Johns County. In an area covering about 400 mi^2 (1,040 km^2) in northern Clay and southwestern Duval counties, the hardness of water is 100 mg/l or less. In metropolitan Jacksonville the hardness of water in the Floridan aquifer ranges from about 250 mg/l to more than 300 mg/l.

The chloride concentration of water in the Floridan aquifer as shown on figure 20 ranges from 4 mg/l in Clay County to more than 20 mg/l in St. Johns and Duval Counties. Water from well Duval 65 on the south side of metropolitan Jacksonville contains 46 mg/l of chloride which is the highest in the area of investigation.

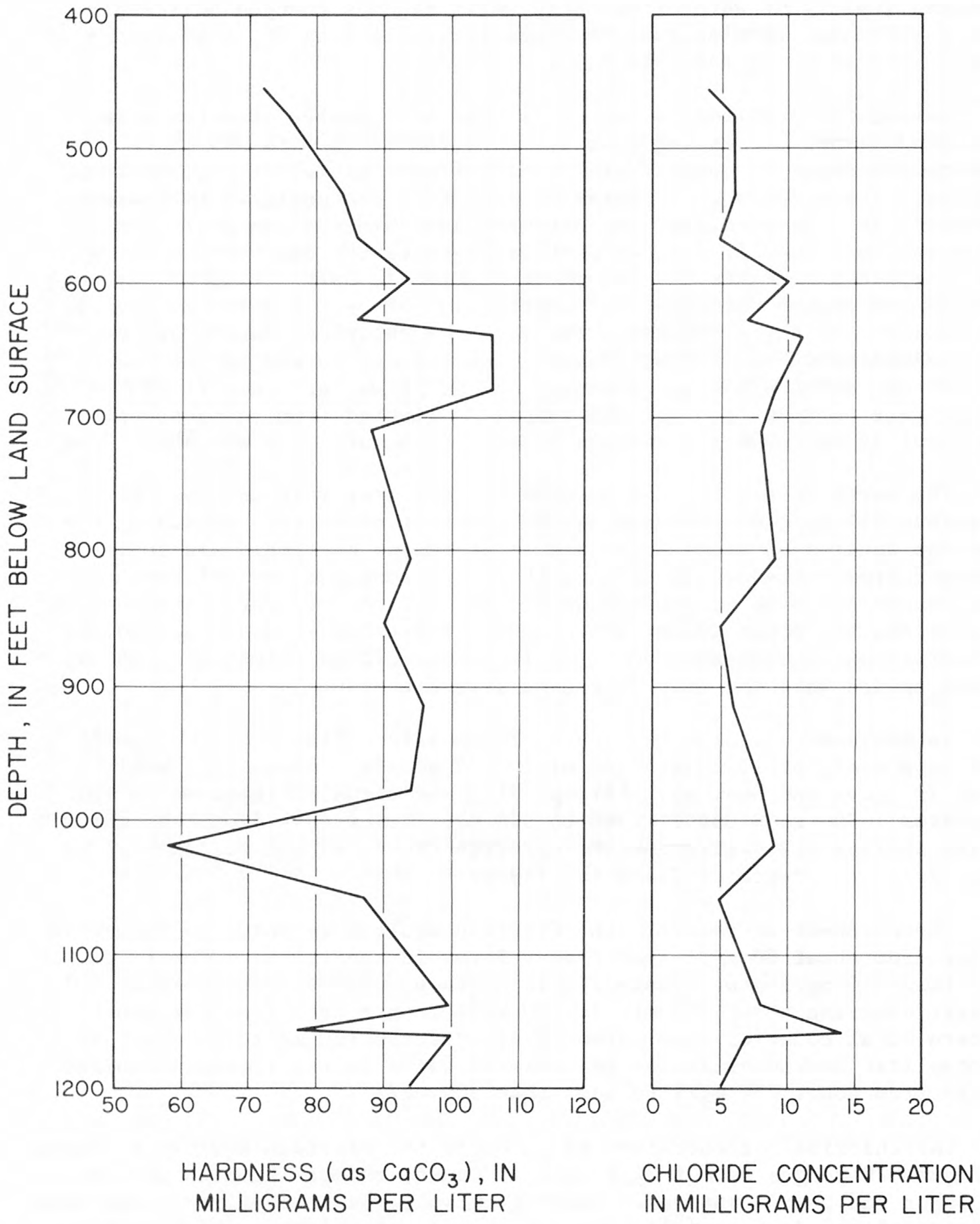
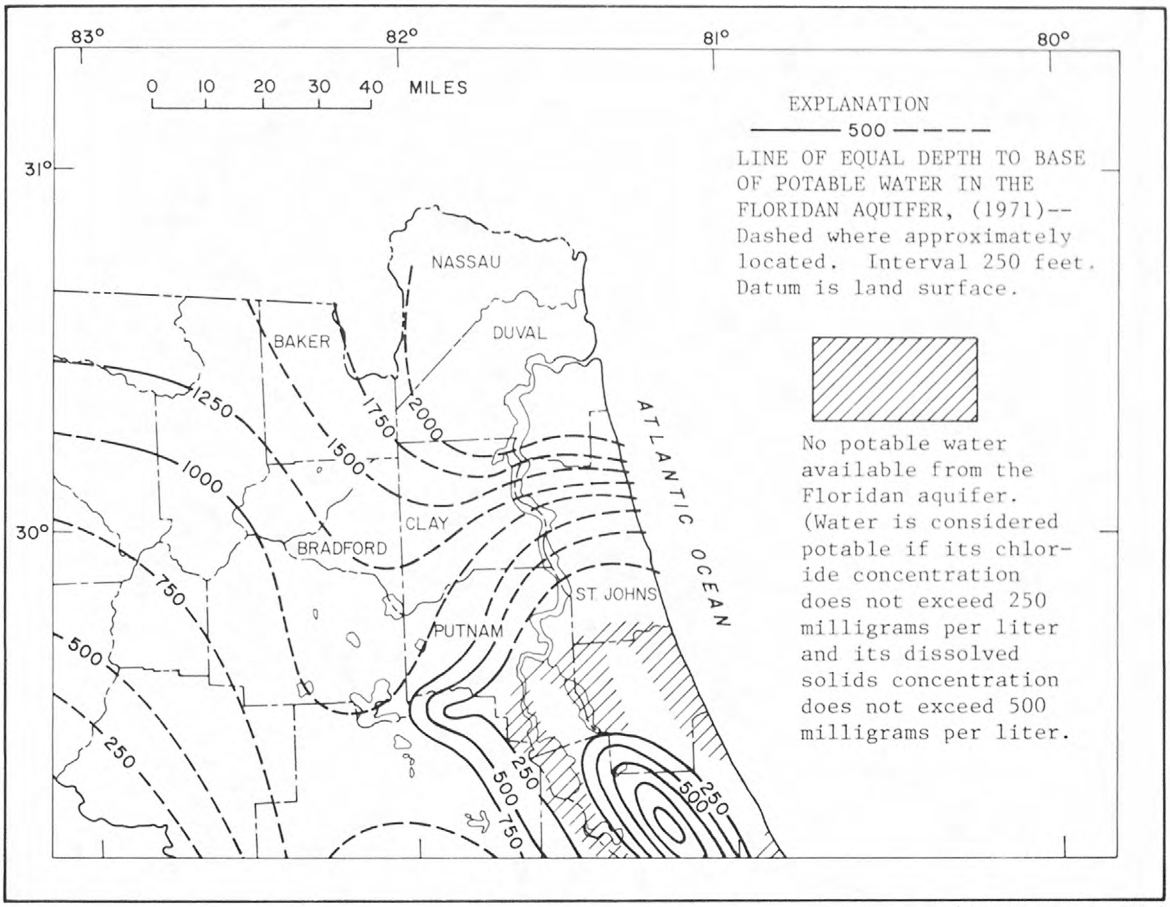
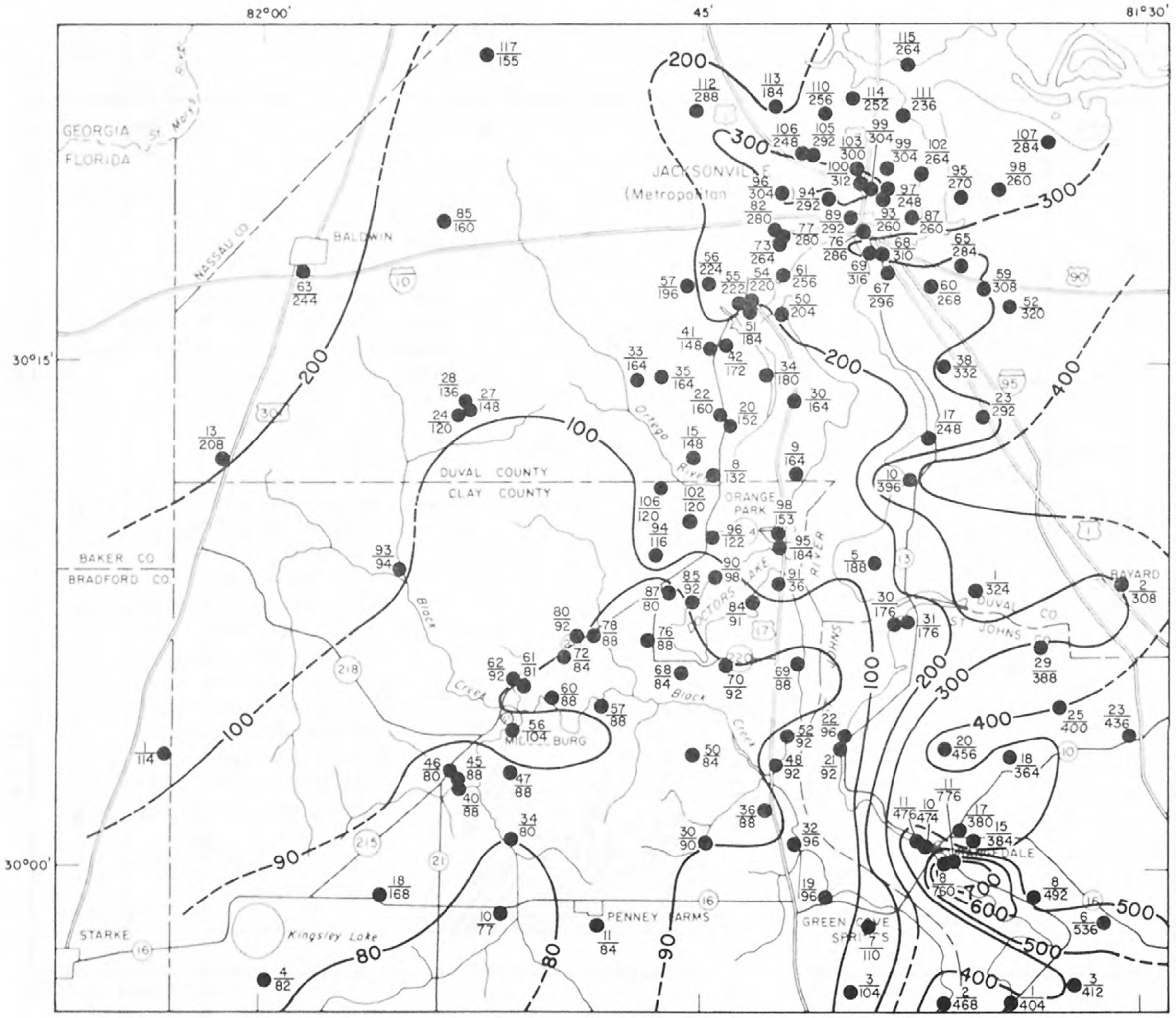


FIGURE 17.--GRAPH SHOWING HARDNESS AND CHLORIDE CONCENTRATION OF WATER VERSUS DEPTH IN TEST WELL CLAY 83 IN CLAY COUNTY.



(AFTER KLEIN, 1971)

FIGURE 18.--MAP SHOWING BASE OF POTABLE WATER IN THE FLORIDAN AQUIFER IN NORTH-EASTERN FLORIDA.



EXPLANATION

0 5 10 MILES

● 50/84 WELL NUMBER AS LISTED IN TABLE 1. / HARDNESS OF WATER IN MAY 1970.

—100--- LINE OF EQUAL HARDNESS -- DASHED WHERE APPROXIMATELY LOCATED. INTERVAL 10 AND 100 MILLIGRAMS PER LITRE.

Figure 19.--Map showing generalized distribution of hardness of water in wells that tap the Floridan aquifer in the area of investigation, May 1970.

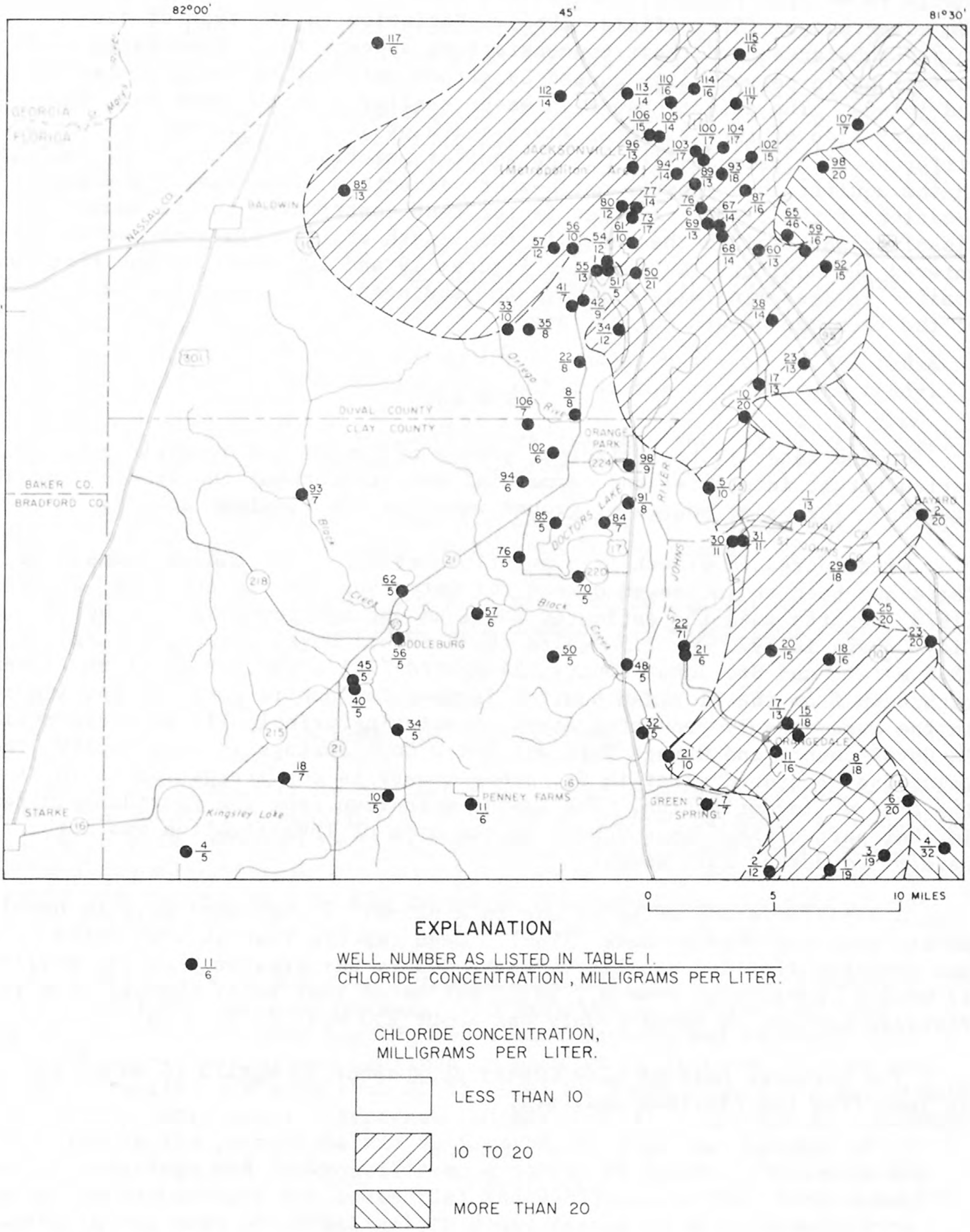


FIGURE 20.--MAP SHOWING GENERALIZED DISTRIBUTION OF CHLORIDE CONCENTRATION OF WATER IN WELLS THAT TAP THE FLORIDAN AQUIFER IN THE AREA OF INVESTIGATION, MAY 1970.

The areal variation in water quality within the aquifer is due mostly to natural factors, such as the kind of material through which the water passes (Stringfield, 1966). Variation in the type of dissolved substances and their concentrations appears to be associated with variations in permeability caused by structural features such as faults and joints. The abrupt change in water quality from the west side to the east side of the St. Johns River south of Jacksonville may be due to differences in permeability of the aquifer material as a result of faulting in the aquifer in a general north-south direction along the approximate location of the river. Another factor that contributes to the amount of dissolved material in the water is the length of time since the water entered the aquifer. As shown in figures 19 and 20, water in the Floridan aquifer is less mineralized toward the southwest. This is because much of the recharge occurs in that area.

WATER USE

Ground water is the principal source of supply for domestic,public agricultural, industrial and commercial uses throughout the area of investigation. The major source of ground water is the Floridan aquifer.

With increased growth in population and new or expanding industries there has been an increased demand for water supplies in the area. Pride (1973) reports that the estimated total amount of ground water used in Clay County in 1970 was 7.3 Mgal/d (0.32 m^3/s); Duval County, 133 Mgal/d (5.8 m^3/s); and St. Johns County, 24 Mgal/d (1.1 m^3/s). Most of the water withdrawn from the Floridan aquifer is used for public supplies and industry in the more densely populated areas, consisting principally of Jacksonville in Duval County and Orange Park and Green Cove Springs in Clay County. The major use of ground water in St. Johns County is for irrigation south of the area of investigation. The amount withdrawn from the Floridan aquifer in that part of St. Johns County in the area of investigation was not determined during this study.

A detailed study of water use in a 625-mi^2 (1,620-km^2) area in Duval County was conducted by Leve (1969). Leve reports that in 1966 water use from the Floridan aquifer in Duval County was greater than 160 Mgal/d (7 m^3/s). Leve (oral commun., 1972) estimated that total pumpage from the Floridan aquifer in Duval County was about 250 Mgal/d (11 m^3/s).

The northern half of Clay County uses about 10 Mgal/d (0.44 m^3/s), or less from the Floridan aquifer.

FUTURE STUDIES

Population and industrial growth trends in northeastern Florida and the Jacksonville area point to the need for additional quantitative information on the water resources of the area. Predictive models based on quantitative data could be constructed to aid water managers in the development and location of water supply. Implementing the following programs will help to obtain the information needed to meet future water resource demands:

a) Continued monitoring of water levels;
b) Collection of current and detailed information on the amount of withdrawal of ground water from the Floridan aquifer and its use;
c) Construction of a digital and (or) analog model of the Floridan aquifer in northeast Florida, including the area of this study.

In addition to the above quantitative studies, the following investigations could be made for alternative sources of water supply:

a) Study of surface water and its potential for storage and possible use by industry to relieve future demands upon ground water.
b) Detailed quantitative study of the shallow aquifer and its possible uses which could ease demands for water from the Floridan aquifer.

SUMMARY AND CONCLUSIONS

The Floridan aquifer is the major source of ground water for private, public, and industrial supplies in the area of investigation. It consists of 1,100 to 1,800 ft (335 to 550 m) of soft, porous limestone interbedded with hard, dense limestone and dolomite. Water in the aquifer is under artesian pressure because of the presence of several hundred feet of confining beds above the aquifer.

Artesian heads in wells in the area fluctuate from about 2 to 15 ft (0.6 to 4.6 m) each year primarily in response to rainfall and are lowest during May and June and highest during January and February. Since 1949 water levels have declined as much as 14 ft (4 m) in Clay and St. Johns Counties and more than 20 ft (6 m) in Duval County. These trends will probably continue with increased withdrawals from the aquifer. Depressions exist in the potentiometric surface of the Floridan aquifer at Green Cove Springs and Jacksonville as a result of natural discharge and large-scale withdrawals for industrial and public supplies. Development of wells in the area of investigation could result in well interference from drawdown if wells are not spaced at least 1,000 ft (305 m) apart.

Well yields generally increase with depth of penetration into the Floridan aquifer. Two- to 4-in (50- to 100-mm) diameter wells drilled 100 ft (30 m) or less into the aquifer yield from 50 to 350 gal/min(3 to 22 l/s) and have specific capacities of about 1 to 5 (gal/min)/ft [0.2 to 1.0 (l/s)/m] of drawdown. Larger diameter wells can be drilled deeper into the aquifer to obtain higher yields. For example, a 12-in (305-mm) test well drilled by the Survey in northeastern Clay County to a depth of 1,197 ft (365 m) penetrated 867 ft (264 m) of the aquifer. The well yielded 1,280 gal/min (81 l/s) and had a specific capacity of 105 (gal/min)/ft [22 (l/s)/m] of drawdown. Larger yields can be obtained from this well with greater drawdown.

Hardness of water in the Floridan aquifer ranges from about 80 mg/l to more than 750 mg/l within the study area. In an area covering about 400 mi^2 (1,040 km^2) in northern Clay and southwestern Duval counties, the hardness ranges from 250 to over 300 mg/l. In parts of northwestern St. Johns County, the hardness of water generally exceeds 200 mg/l and is as much as 750 mg/l.

The chloride concentration of water in the Floridan aquifer ranges from 4 m/l in Clay County to as much as 46 mg/l in one well on the south side of metropolitan Jacksonville in Duval County, but generally is 10 mg/l or less in the study area.

Water with the lowest concentration of hardness and other chemical constituents occurs in northern Clay County and extends into southwestern Duval County--an area which is located away from the center of pumping at Jacksonville. There is little or no change in quality of water with depth in the upper part of the aquifer nor has there been any noticeable change in quality of water from wells sampled over a span of from 10 to 30 years.

Information from deep wells in the Floridan aquifer at Jacksonville indicates that highly mineralized water is present in the aquifer below the freshwater zone. This highly mineralized water can move vertically upward when artesian pressures are reduced. It is possible therefore that, in the future as artesian pressures decline in response to withdrawals of large quantities of water from the aquifer, the quality of water may be affected by upwelling of highly mineralized water in deeper zones of the aquifer.

Principal recharge to the Floridan aquifer occurs southwest of the area of investigation in a lake region where rainfall percolates directly into the aquifer or downward through thin confining beds into the aquifer. Recharge within the area of investigation is by leakage through the confining beds. Preliminary estimates range from 3 to 45 Mgal/d (0.1 to 2 m^3/s) of recharge to the Floridan aquifer, less than that required to prevent water levels from declining.

Discharge from the Floridan aquifer is from wells, through springs, and by upward leakage into overlying formations. Jacksonville uses more than 250 Mgal/d (11 m^3/s) of water from the Floridan aquifer; the northern half of Clay County uses only about 10 Mgal/d (0.4 m^3/s) or less.

The greatest potential for development of future water supplies from the Floridan aquifer appears to be outside the areas of major withdrawal in western Clay and Duval Counties. Specific capacity tests of wells and aquifer tests indicate that the transmissivity of the Floridan aquifer generally is greatest in this area. Local areas of high transmissivity may be associated with faults in the eastern part of these counties; thus, extensions of these faults or still unmapped faults may be areas for development of high yield wells in western Clay and Duval Counties. However, these areas may be subject to saline-water intrusion if the artesian pressure is lowered excessively by large-scale withdrawals of water from the Floridan aquifer.

The mineral concentration in water from the Floridan aquifer is also less in these western areas and particularly in southwest Clay County which is closest to the area of major recharge for the aquifer. The base of the potable water in the study area is about 1,500 ft (460 m) or more below land surface; thus, there is ample depth for development of wells without the need to drill too close to the underlying more mineralized water. There are indications that mineralized water from the deeper zones may move upward along faults. Therefore, the faults, which may be zones of greatest yield to wells, may also be a hazard in serving as a conduit for mineralized water to move into potable-water zones of the Floridan aquifer.

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