WATER RESOURCES AND EFFECTS OF DEVELOPMENT IN HERNANDO COUNTY, FLORIDA

By J. D. Fretwell

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GLOSSARY

Cone of depression.--A conical depression on a water table or potentiometric surface produced by pumping.

Consumptive water use.--Use of water that reduces the supply from which the water is drawn.

Permeability.--Measure of the ability of rock or soil to transmit water.

Potentiometric surface.--An imaginary surface connecting points to which water would rise in tightly cased wells from a given point in an aquifer.

Section.--One of the 1-square-mile subdivisions of a 36-square-mile township.

Sinkhole.--A closed depression in the land surface that is formed by solution of near-surface limestone and similar rocks and by subsidence or collapse of overlying surficial material into underlying solution cavities.

Specific yield.--The ratio of (1) the volume of water that the rock or soil, after being saturated, will yield by gravity to (2) the volume of the rock or soil.

Storage coefficient.--The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head.

Transition zone.--A zone of mixed water between fresh and salty ground water.

Transmissivity.--The rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient.

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ABSTRACT

Hernando County, on the west-central coast of Florida, has a hill and valley terrain that ranges in altitude from sea level along the Gulf of Mexico to slightly more than 270 feet above sea level near the center of the county. The largest incorporated area is Brooksville, which has 13 percent of the county's population. The principal perennial streams are the Withlacoochee and Little Withlacoochee Rivers that form part of the county's eastern boundary and Weeki Wachee River near the coast. Weeki Wachee River is fed by Weeki Wachee Springs that discharges an average of 176 cubic feet per second.

The Floridan aquifer system is composed of carbonate rock of Tertiary age. Only the upper part of the system is tapped for water supplies in Hernando County. Formations comprising the Upper Floridan aquifer in Hernando County are, in ascending order, the Avon Park Formation, the Ocala Limestone, and the Suwannee Limestone. These formations represent the freshwater part of the Floridan aquifer system in Hernando County. The aquifer is overlain by surficial deposits of sand and clay that range from zero to about 100 feet in thickness.

Water enters the Upper Floridan aquifer as infiltration from precipitation or as ground-water flow into the county from the east and south. Flow in the county is generally westward toward the Gulf of Mexico, although some flow is northward out of the county.

The Upper Floridan aquifer is generally unconfined, and its potentiometric surface changes slightly between wet and dry seasons. Transmissivity of the aquifer ranges from 9×10^4 feet squared per day just north of the county to 2.1×10^6 feet squared per day at Weeki Wachee Springs.

Chemical quality of water is generally good (concentrations of constituents are less than the maximum recommended limits for drinking water) except near the coast where concentrations of chloride are high due to the proximity of the Gulf of Mexico. A few wells yield water that has objectionable concentrations of iron and hydrogen sulfide.

Water from the Upper Floridan aquifer accounted for 87 percent of the water used for irrigation, industry, and rural and public supply in 1982. Sixty-seven percent of this water was used by industry. Rock mining, the major industry, used 99 percent of the industrial water.

The anticipated increase in population between 1982 and 2000 will place increased demands on water-supply systems. These demands will cause only a 1 percent reduction of springflow at Weeki Wachee Springs and will have little effect on ground-water levels, lake levels, or saltwater intrusion based on the results of a ground-water flow model.

INTRODUCTION

Future demands on the water resources of Hernando County by a rapidly increasing pouplation will require additional water-supply facilities in the form of expanded or new well fields. The county needs to know the quantity and quality of water available for development.

Water-resource concerns to the county include the potential for (1) introduction of poor quality water to the freshwater aquifer through sinkholes and as a result of ground-water development, (2) saltwater intrusion into the aquifer along the coast, (3) reduction in springflow, and (4) lowering of ground-water levels and lake levels. Also of concern is the high concentration of dissolved iron of greater than 300 μg/L (micrograms per liter) in water from several wells in the eastern part of the county.

Purpose and Scope

The purpose of this report is to describe (1) the availability of water, (2) the extent of water-quality problems in surface and ground water, (3) the interconnection between surface and ground water, and (4) the effects of pumping on the hydrologic system, such as reduction of flow of water in coastal springs, lowered lake and ground-water levels, and possible intrusion of saltwater into the freshwater aquifer in Hernando County.

This report includes descriptions of the geography, geology, water use, and surface-water and ground-water resources, including water quality and hydraulic properties of the Upper Floridan aquifer. Possible impacts from ground-water development are also evaluated. Information is based on data collected during the study (1981-83), historical data from the files of the U.S. Geological Survey and the Southwest Florida Water Management District, and from previously published reports as referenced. The intent of this report is to provide an understanding of the hydrology and water resources of Hernando County and to provide a basis for management of the resources. The report is intended for the use of water managers, county officials, and others concerned with managing and protecting the water resources of Hernando County.

Acknowledgments

The author gratefully acknowledges assistance provided by many organizations and individuals in conjunction with this investigation. Hernando County personnel were helpful in providing information and assistance when necessary.

Valuable assistance was provided by the county's consultant, Coastal Engineering, and their drilling contractor, Marshall Crum. The Southwest Florida Water Management District personnel also provided valuable information. The author is grateful to the many well owners who permitted access onto their land and allowed sampling of water and measuring of water levels in their wells.

DESCRIPTION OF STUDY AREA

Geographic Setting, Topography, and Drainage

Hernando County, an area of about 500 mi^2, is on the coast of west-central Florida (fig. 1). Of these 500 mi^2, about 480 mi^2 is land and 20 mi^2 is inland water. The county is bounded on the west by the Gulf of Mexico and on the east, in part, by the Withlacoochee and Little Withlacoochee Rivers. To the north, it is bounded by Citrus County and to the south by Pasco County.

Land-surface altitudes range from sea level at the coast to about 250 feet above sea level at several places near Brooksville (fig. 2). At least two hills have altitudes higher than 270 feet above sea level. The 100-foot contour generally denotes the northwest trending Brooksville Ridge. Topography is very irregular along the ridge with rolling hills and valley terrain. East of the ridge, altitudes taper off to about 50 feet above sea level at the Withlacoochee River and about 85 feet above sea level along the Little Withlacoochee River.

The karst terrain in Hernando County is characterized by numerous sinkholes that are the result of dissolution of limestone and dolomite. These sinkholes can provide a direct path for water to flow from land surface to the underlying freshwater aquifer. Surface drainage is absent or poorly developed in most of the county, but water from coastal springs and the Withlacoochee and Little Withlacoochee Rivers flows through well-defined stream channels. Weeki Wachee Springs, a first-order magnitude spring (average flow more than 100 ft^3/s), heads the Weeki Wachee River that flows almost 6 miles to the Gulf. The coastal area is characterized by a saltwater marsh and swamp that are drained by many tide affected creeks and channels. Freshwater swamps and many small lakes and ponds occur in the eastern part of the county along the Little Withlacoochee River. Numerous small lakes dot the county.

Climate

The climate of Hernando County is characterized by short, mild winters and long, humid summers. Average monthly temperatures range from 60°F in January to 82°F in July and August (National Oceanic and Atmospheric Administration, 1983); average annual temperature is 72°F.

Hernando County probably receives more rainfall than any other county in west-central Florida. The average annual rainfall over the county as a whole is about 56 inches. The maximum average annual rainfall is about 58 inches occurring at Brooksville as based on records for 1931-60 (Bradley, 1976). A declining trend in rainfall has occurred since 1960 and has reduced the average at Brooksville to about 56 inches per year (fig. 3). About 52 percent, or 29 inches of rainfall, occurs from June to September as thundershowers. As can be seen in figures 3 and 4, the study period was one of above average rainfall.

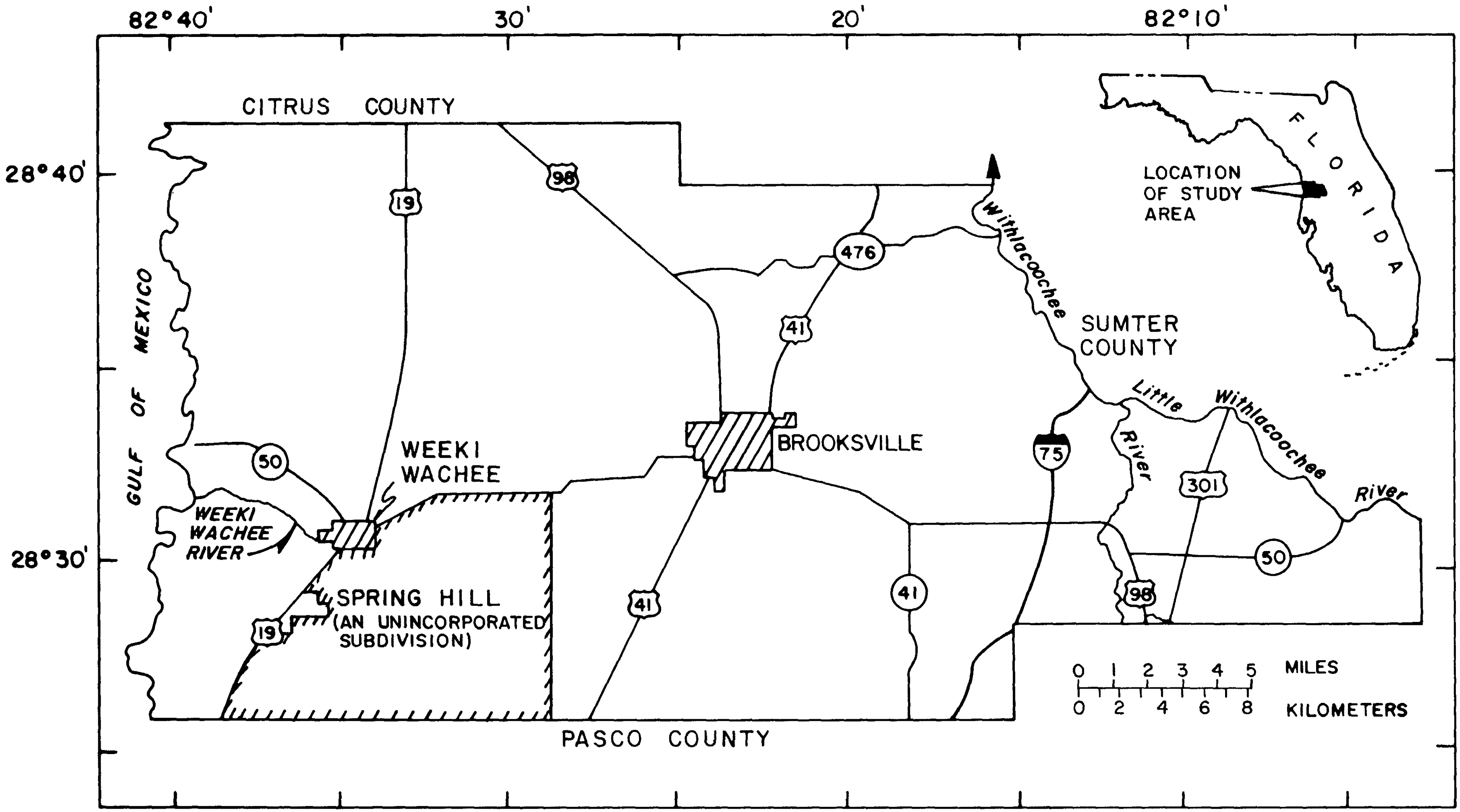

Figure 1.--Hernando County--the study area.

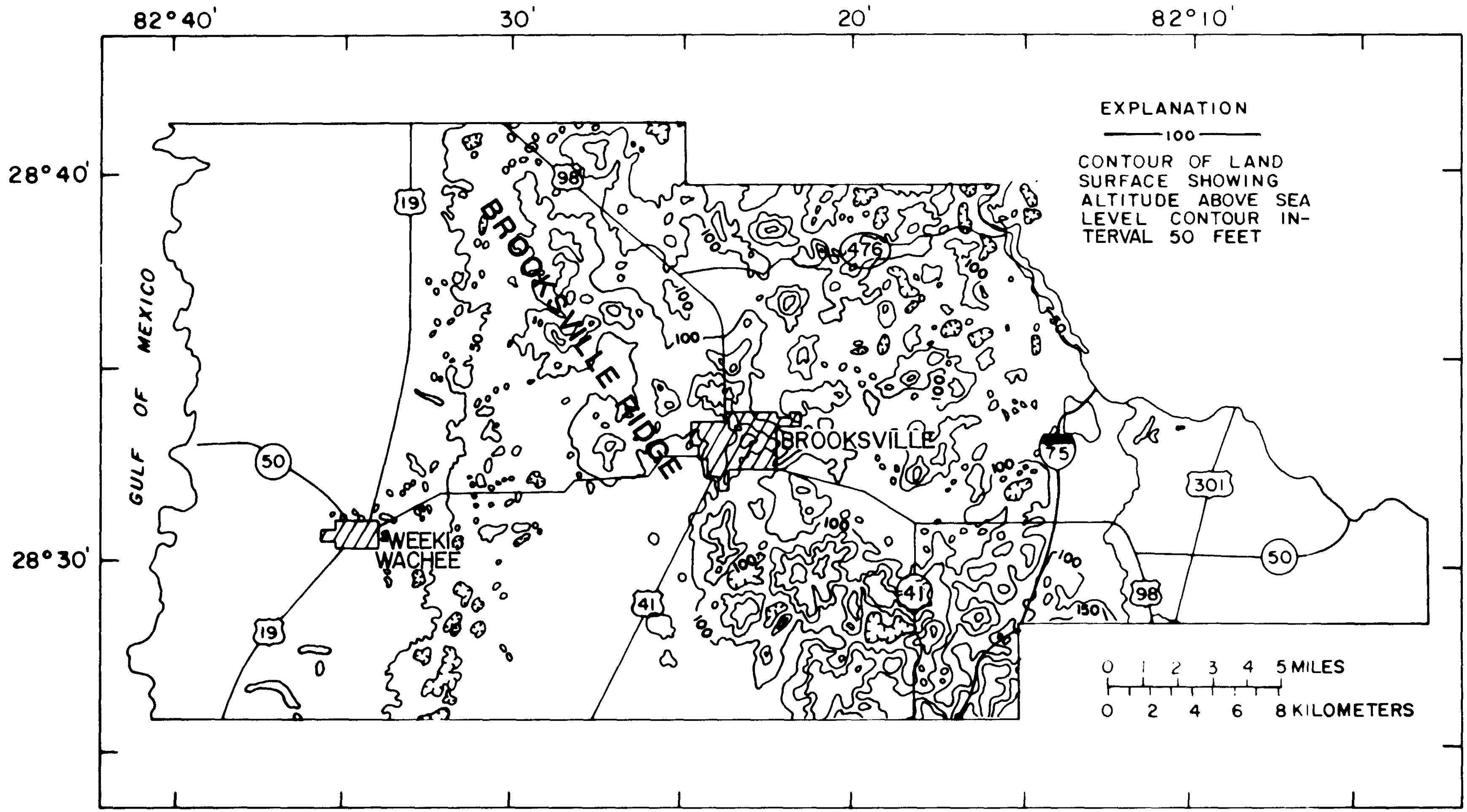

Figure 2.--Topography of Hernando County.

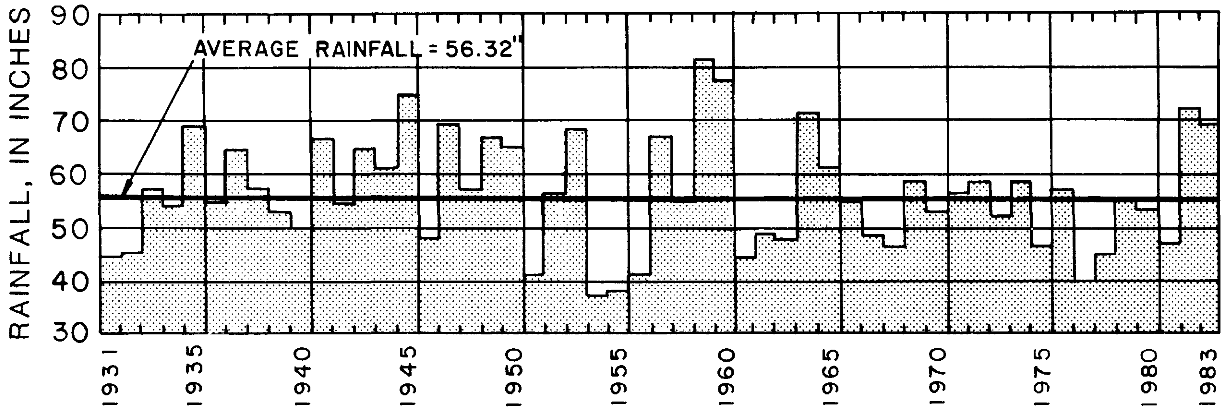

Figure 3.--Annual rainfall at Brooksville, 1931-83.

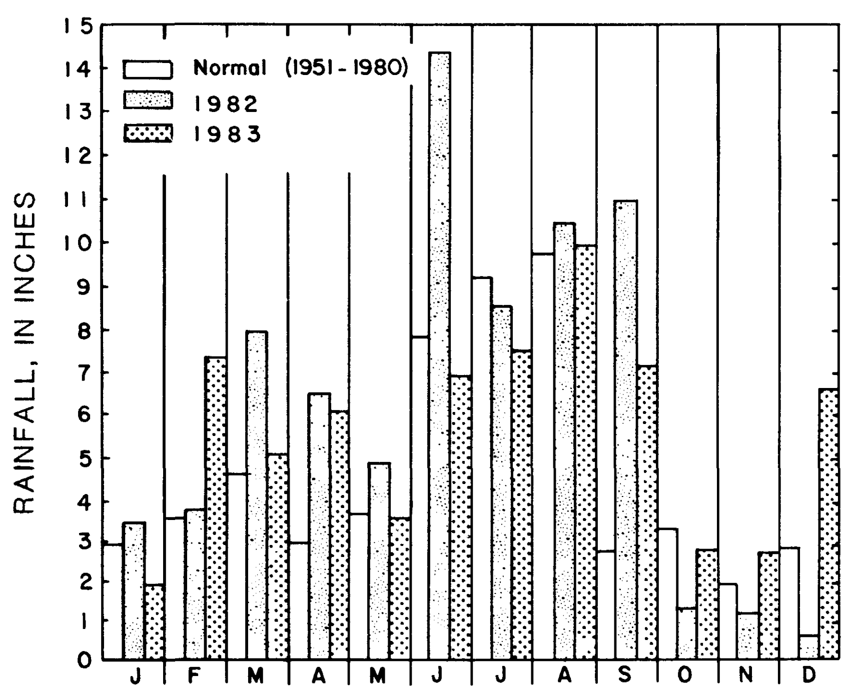

Figure 4.--Normal monthly and monthly rainfall for 1982 and 1983 at Brooksville.

Population and Development

The present (1984) population of Hernando County is about 57,000. Of this, 13 percent reside in the incorporated areas of Brooksville and Weeki Wachee. Population growth during the past 15 years, as evidenced by census data reported by the University of Florida (1983), has been rapid (fig. 5). Population projections by the University of Florida indicate that this growth trend will continue into the future. This influx of people has been accompanied by new and expanded industry. Growth in housing developments is occurring both along the coast and inland toward Brooksville, and urbanization is spreading from Brooksville toward the coast. Shopping centers, restaurants, and public utilities are being built to meet the needs of the people. Tourism is a major industry throughout Florida, and Hernando County's Weeki Wachee Springs is among the State's major attractions. The county is host to many weekend residents who work in metropolitan areas to the south and seasonal residents who spend winters in Florida.

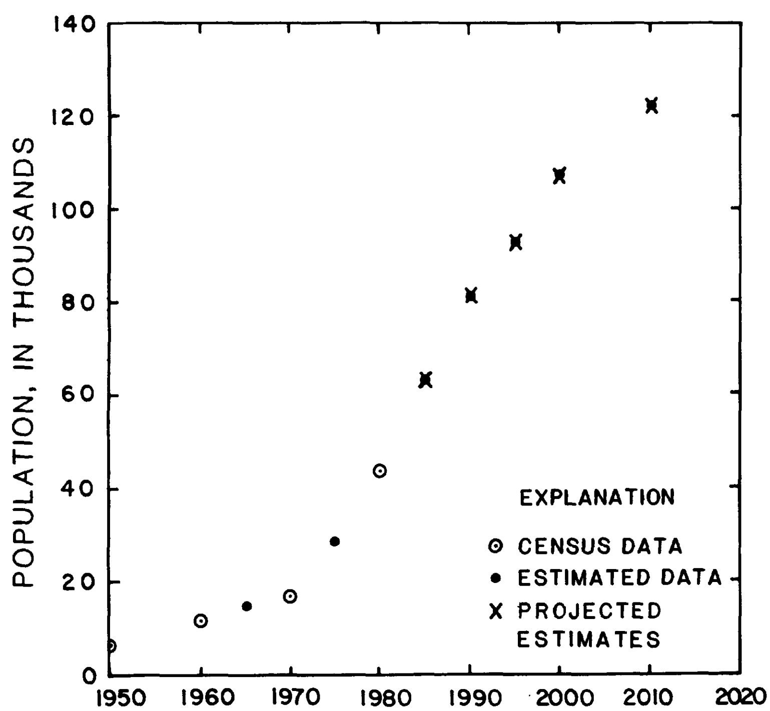

Figure 5.--Past and projected population (University of Florida, 1983).

Land Use

Undeveloped land; including wetlands, forest, and barren land; still exists, especially in western Hernando County (fig. 6). However, much of this land has been platted for residential development. About one-third of the eastern part of the county is used for growing citrus and as pastureland; much of the remainder is occupied by the Withlacoochee State Forest. Rock mines and associated industries occur in all parts of the county. Other industries make up only a small fraction of industrial land use.

DATA-COLLECTION SITES

Data from 157 wells were used in this study (table 1). Fifty-three wells were sampled during the study for common inorganic constituents including calcium, magnesium, potassium, sodium, chloride, fluoride, silica, sulfate, iron, nitrite, and nitrate. Also determined at the time of sampling were temperature, specific conductance, and pH. Potentiometric surfaces for September 1982 and May 1983 were determined from measurements made at 35 wells. Selected wells from which water-level and water-quality data were collected prior to the study have also been included in table 1. The locations of wells from which ground-water data are available are shown in figure 7.

Twenty-four sites that include 2 streams, 16 lakes, and 1 sinkhole were sampled during the study for the same inorganics as for the wells. They were also sampled for nutrients including nitrogen, phosphorus, and orthophosphate. Water levels were measured periodically on 10 lakes and 2 streams during the study. Selected sites from which water-level and water-quality data were collected prior to the study include an additional 1 stream, 1 lake, 18 springs, and 3 sinkholes. Flow of three streams was measured during the study. The locations of surface features where water-level, water-quality, and springflow data were collected are shown in figure 8. Table 2 provides a list of these sites.

WATER USE

Freshwater use for irrigation and industrial, public, and rural supplies in Hernando County in 1982 was 47 Mgal/d (Richard Owen, Southwest Florida Water Management District, oral commun., 1984). Of this, 87 percent was ground water and 13 percent was surface water. Pumping varies from year to year and from season to season primarily as a function of the amount and distribution of rainfall. This is especially true of pumping for irrigation, which is greatest during the spring growing season when rainfall is small. Seasonal fluctuations in the number of tourists also accounts for variations in pumping. As population continues to grow, pumping for public supply will increase.

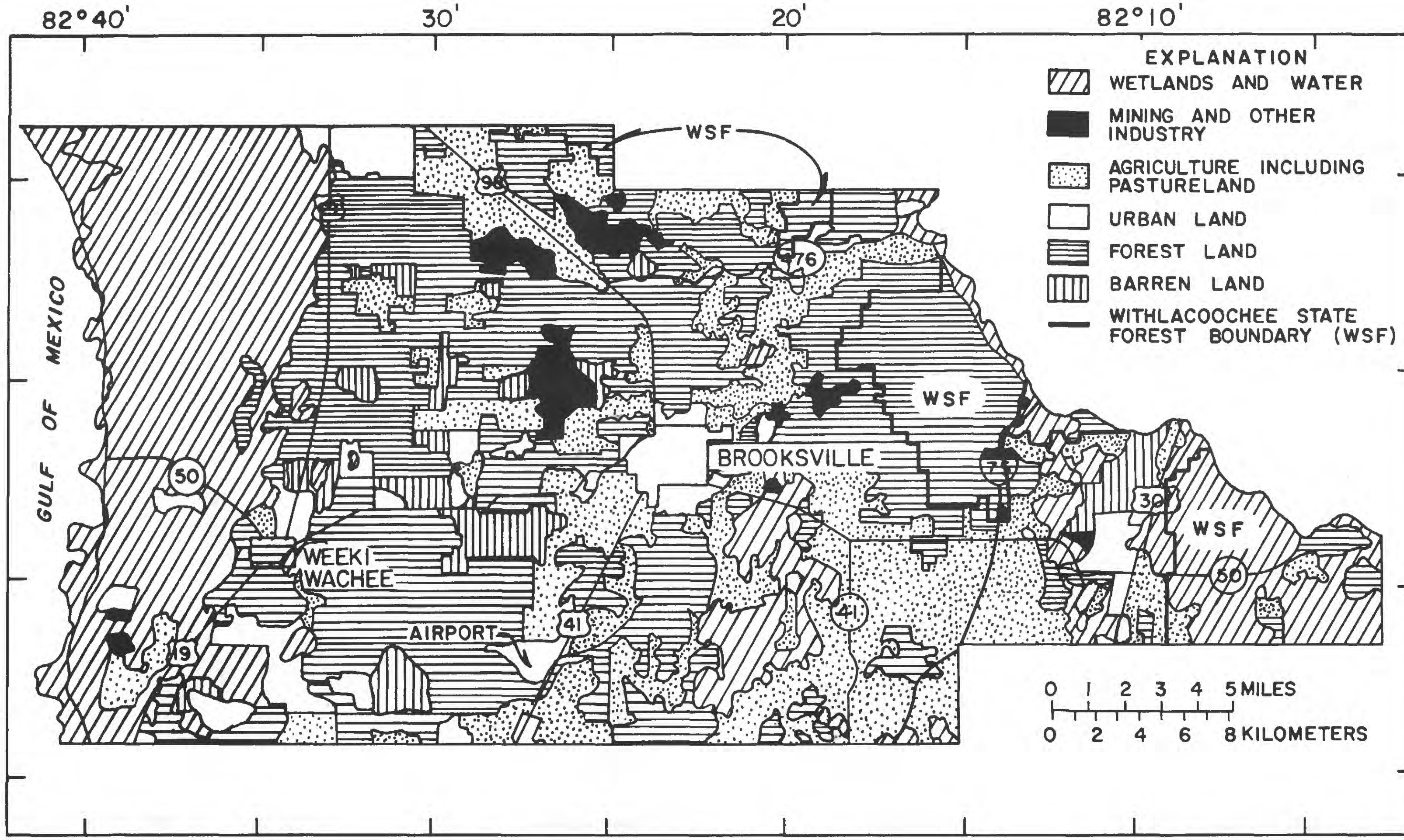

Figure 6.--Land use (modified from Southwest Florida Water Management District, 1976).

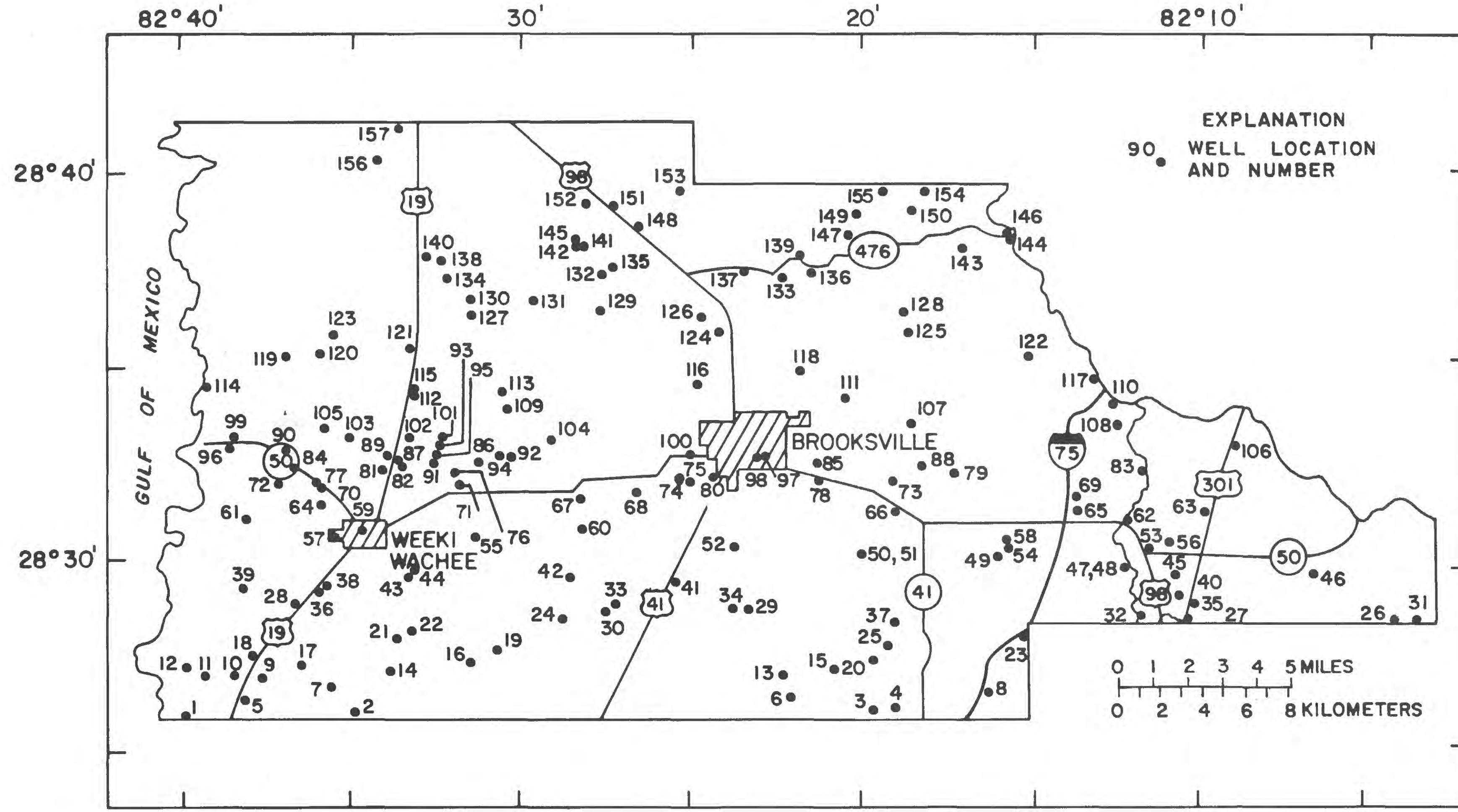

Figure 7.--Location of wells where ground-water data were collected. (Name, depth of well, and depth of casing are given in table 1.)

Table 1.--Wells from which ground-water data were collected

Well	Station identification	Well name	Depth of well (feet)	Depth of casing (feet)	Altitude of land surface[1/] (feet)
1	282601082395101	Herman Dosing	118	--	2
2	282605082345801	ROMP 97	355	310	31.48*
3	282620082193801	Lakewood Retreat	209	--	136.68*
4	282622082190701	Wegman	206	63	150
5	282627082380801	Dandelion NW deep	80	--	21.85*
6	282636082221401	Weeki Wachee deep well 11	69	68	101
7	282650082363301	Spring Hill well #6	275	--	38
8	282652082161701	Aich & Aich	275	177	232
9	282654082373801	Conner deep	--	--	30
10	282657082382501	Raulerson	101	63	10
11	282659082391101	ROMP TR 18-2	500	--	7
12	282704082394301	Aripeka well	195	176	2
13	282708082221701	Haney Farms	200	98	95
14	282708082335201	Spring Hill well #12	395	125	37
15	282723082204901	Shamrock Farms	365	--	242
16	282726082311801	Deltona #4	335	113	57
17	282726082363701	Spring Hill well #2	373	209	35
18	282742082375901	ROMP TR 18-1	580	67	13
19	282748082303801	Deltona #7	320	160	63
20	282803082191201	Norris Aldridge	340	--	196.76*
21	282810082333701	Power Line well	--	--	35
22	282818082330901	Spring Hill well #18	290	70	37
23	282827082150801	Johnny Melton	200	--	100
24	282838082284801	Florida Hills Memorial	400	166	70
25	282839082190801	Russell Blackett	428	--	119.94*
26	282847082042801	Boyette #2	--	--	84
27	282847082103401	Tallisman Estates	--	--	60.90*
28	282847082364101	Bobhill Spring Park	250	--	22
29	282849082232201	Altizer	230	--	190
30	282849082273501	Airport Industrial	300	--	70
31	282851082035301	E. H. Boyette	83	--	86.28*
32	282851082115101	Riverdale County well	--	--	80
33	282851082271601	Airport well	251	80	65.50*
34	282858082234801	Robinson	208	46	154
35	282911082101001	Fort Dade Mobile Home Park	135	--	76.82*
36	282917082355701	Weeki Wachee Woodlands	170	60	29
37	282921082181101	Wayne Thomas	260	--	205
38	282923082355201	Weeki Wachee Woodlands #1	--	--	32
39	282923082380301	Hernando Beach Supply	180	--	7
40	282925082103201	Fort Dade Mobile Home Park	--	--	75

Footnote is at end of table.

Table 1.--Wells from which ground-water data were collected--Continued

Well	Station identification	Well name	Depth of well (feet)	Depth of casing (feet)	Altitude of land surface[1/] (feet)
41	282932082253301	Imperial Estates deep well	275	65	82
42	282936082283501	Spring Wood County well	190	--	72
43	282938082332001	Deltona Corporation well	380	--	38
44	282941082330801	Spring Hill well #13	484	245	42
45	282959082105201	Ridge Manor 3 South Plant	300	--	66
46	283001082064702	WSF-Richloam Fire Tower	97	--	76.50*
47	283003082122201	Foster well #1	60	--	60
48	283003082122202	Foster well #2	125	--	60
49	283022082160701	Susan Hedstrand	421	--	175
50	283026082200801	Hernando County well	195	--	125
51	283027082200801	Cedar Lane County well	445	--	120
52	283027082244501	Young	--	--	210
53	2830300821i4101	Ridge Manor North	200	--	73
54	283033082154101	Samuel Ognibene	199	--	138.62*
55	283033082312001	Spring Hill well #17	400	134	60
56	283036082105502	Ridge Manor #2	820	150	88.15*
57	283038082352701	River Country Estates	86	--	28
58	283041082154201	Samuel Ognibene #2	160	--	150
59	283057082342901	Holiday Inn at Weeki Wachee	315	62	25
60	283058082281001	Zirkels Estates well	--	--	58
61	283105082380001	Joe Smith	68	--	5
62	283108082123401	Le:compte	--	--	64.50*
63	283125082100501	Carl Asbel	95	--	75.25*
64	283127082355101	Weeki Wachee Campground	--	--	20
65	283130082134901	Sherman Hi	600	--	75
66	283138082191701	SR 50	175	--	78
67	283143082281801		116	80	78
68	283159082263701	Clark	140	--	75
69	283200082134801	Ridge Manor West	602	--	100
70	283200082354101	Weeki Wachee Water	--	--	11
71	283201082315601	Weeki Wachee well	259	176	35.97*
72	283203082370201	Presbyterian Youth Camp	75	66	8.99*
73	283206082190601	Lakeside Acre	370	--	82
74	283208082250201	McIntyre #1	55	--	72
75	283208082250202	McIntyre #2	--	--	72
76	283208082315601		--	--	42
77	283208082354701	Weeki Wachee E. County well	--	--	11
78	283213082212101	Talis Lewis	180	72	172
79	283222082171701	Steinecker	194	--	85
80	283223082241601	Twin Pines	46	--	85

Footnote is at end of table.

Table 1.--Wells from which ground-water data were collected--Continued

Well	Station identification	Well name	Depth of well (feet)	Depth of casing (feet)	Altitude of land surface[1/] (feet)
81	283223082335901	Royal Highlands	--	--	21
82	283228082333501	Summer Specialties	192	147	22
83	283231082115101	H. E. Watson	200	--	54.94*
84	283233082364104		165	126	5
85	283235082212701	Lawer	--	--	95
86	283235082311801	Highpoint #3 County well	250	94	90
87	283236082334901	Camp A Wyle Park	212	--	30
88	283237082181901	Wayne Thomas Munden Hill	259	--	253.21*
89	283240082335801	Royal Palm Beach deep	245	217	20
90	283243082365701	ROMP TR 19-2	302	277	6.99*
91	283247082322901	#2 Power Pole Company	250	140	30
92	283250082302401	D. Geoffrion	250	--	92
93	283250082322801	WHCWS PW3	400	135	36.98*
94	283251082304201	Norman Crum	195	--	92
95	283253082322401	WHCWS monitor well #1	620	100	35.20*
95A	283253082322402	WHCWS deep monitor	613	598	35.19*
95B	283253082322403	WHCWS intermediate monitor	392	377	34.97*
95C	283253082322404	WHCWS shallow monitor	280	104	35.20*
96	283253082383701	Abbott	54	40	15
97	283258082231901	Brooksville #1	602	478	133
98	283258082232201	Brooksville #2	757	300	133
99	283258082383101	Pine Island Water Company	--	--	15
100	283259082250101	Paff Nursery	500	--	82
101	283301082322401	WHCWS PW4	275	97	36.13*
102	283308082331901	Barrett well	125	--	25
103	283313082350101	ROMP TR 19-3	604	--	12
104	283317082290501	Brookridge #2	325	120	70
105	283326082355201	S. Hernando Sportsman Club #3	101	--	15
106	283338082092401	Massey	--	94	70
107	283345082183701	Hack Street well	131	--	90
108	283356082123301	WSF-Crooked River Campground	--	--	72
109	283406082303101	Sun Road Company well	247	122	90
110	283408082123801	WSF-Cypress Glen Camp	--	--	65.85*
111	283421082203301	Brooksville CC well #2	300	--	105
112	283426082331501	Britton	200	--	25
113	283433082303801	Robert Groff	117	100	100
114	283433082391301	Plummer	33	32	3
115	283435082331501	Fleckney & McGreery	--	--	28
116	283442082250001	Hans Sirius Kennels	220	--	152
117	283454082131301	WSF-Boat Ramp Croom Road	65	--	56.17*

Footnote is at end of table.

Table 1.--Wells from which ground-water data were collected--Continued

Well	Station identification	Well name	Depth of well (feet)	Depth of casing (feet)	Altitude of land surface[1] (feet)
118	283508082215101	Clarence Smith	361	--	91
119	283527082365701	Weeki Wachee well 2	125	123	9
120	283529082355801	Weeki Wachee well 3	140	133	8
121	283532082331201	SWFWMD well	--	--	22
122	283537082151501	ROMP deep well 103	198	--	98.78*
123	283555082352901	Weeki Wachee well 1	110	110	8.26*
124	283607082241501	Seven Hills well	--	--	90
125	283613082184301	Delmas Nix	219	--	60.92*
126	283632082245101	Seaboard Coastline RR	231	--	96.70*
127	283637082313301	Carlie Padgett	145	42	47
128	283640082190201	Sims	188	--	110
129	283648082275201	Community Church	250	--	133
130	283650082313301	ROMP Centralia	170	122	38
131	283706082292101	Ross	150	--	112
132	283719082273801	Sokolski	173	--	110
133	283728082222801	USDA drainage well	360	124	168
134	283729082321301	Youngblood well	126	--	30
135	283732082272001	Tom Levija	165	--	98
136	283743082213801	Jack Franklin	149	--	85
137	283747082233201	Adam	286	236	101
138	283803082323001	Alan Craft	160	--	32
139	283806082214801	Eden Christian School	155	--	91.90*
140	283808082324801	Nangel	127	--	28
141	283815082281701	Brooksville Rock #2	600	--	173
142	283815082282201	Brooksville Rock Company	899	130	170
143	283819082170801	USDA Farm	205	110	105.72*
144	283827082154801	Roy Wright	--	--	60
145	283828082283301	Florida Mining and Material	--	--	172
146	283840082154801	Barnhart	140	--	59.37*
147	283840082203401	McKethan Lake deep	65	60	70
148	283840082264401	Ward	275	194	110
149	283908082201301	WSF Environmental Center	143	125	97.71*
150	283917082183601	Beaver Street well	95	--	130
151	283924082272301	ROMP deep well 107	240	140	116.03*
152	283932082281201	McKethan Cattle Company	255	62	72
153	283940082253201	Rivenbark	93	--	88
154	283957082181001	W. A. Blizzard	140	95	18.64*
155	284000082192701	County Line well	134	130	10
156	284040082342301	Lamar Chapman Hunting Camp	--	--	9
157	284125082333401	Hoppmeyer	218	--	10

[1]Extrapolated from U.S. Geological Survey topographic maps having 5- and 10-foot contour intervals except where noted by *.

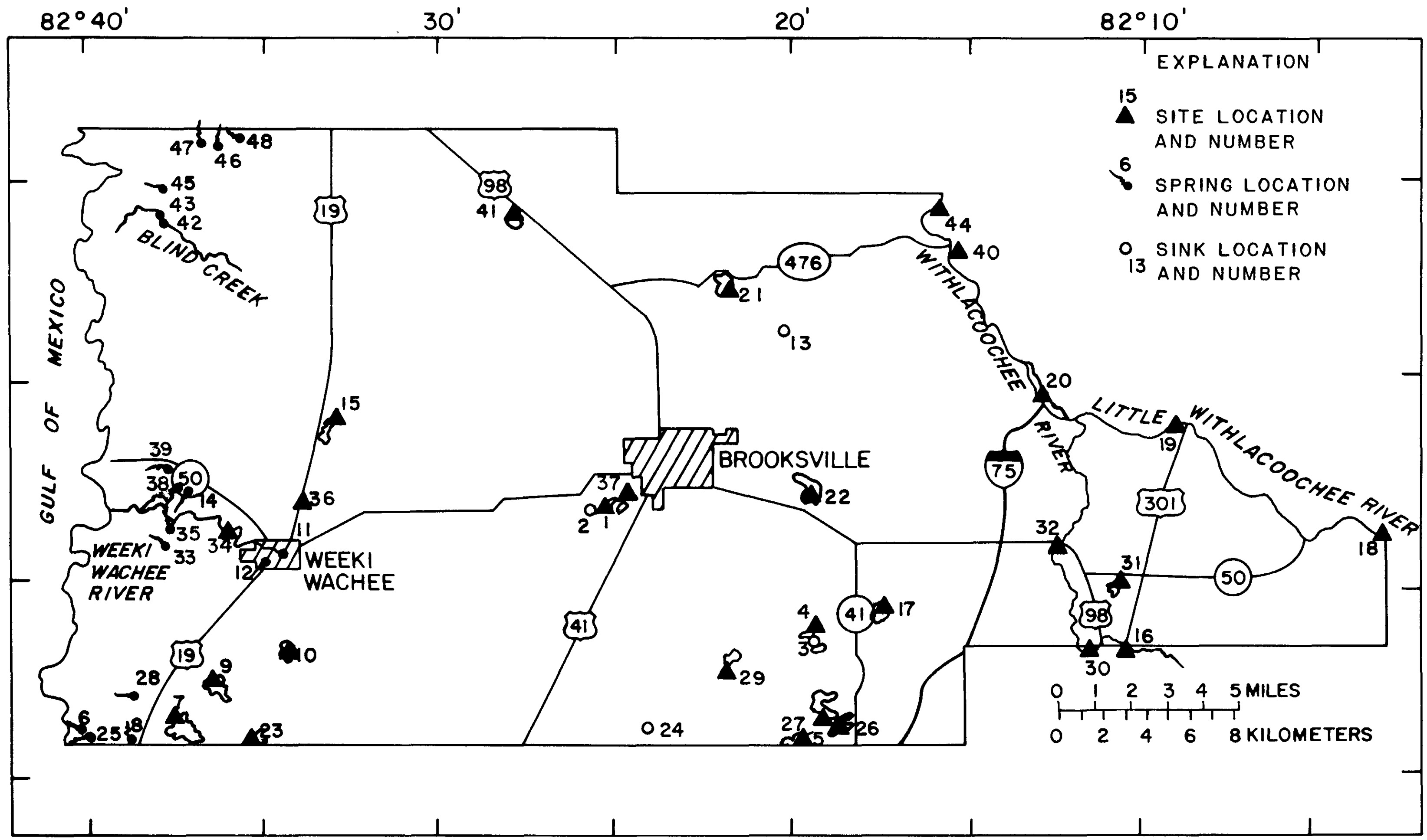

Figure 8.--Data-collection sites on streams, lakes, springs, and sinkholes. (Site identification and name are given in table 2.)

Table 2.--Data-collection sites on streams, lakes, springs, and sinkholes

Site	Station identification	Site name
1	02310210	Horse Lake
2	02310212	Peck Sink drain
3	02310219	Neff Lake Sink
4	02310220	Neff Lake
5	02310232	Lake Hancock
6	02310380	Boat Spring
7	02310400	Hunters Lake
8	02310405	Bobhill Spring
9	02310449	Hog Pond (same as Citrus Lake)
10	02310490	Weeki Wachee Prairie Lake
11	02310500	Weeki Wachee Springs
12	02310505	Little Springs
13	02310530	Blue Sink drain
14	02310562	Salt Spring
15	02310616	Tooke Lake
16	02312000	Withlacoochee River at Trilby
17	02312100	Spring Lake
18	02312180	Little Withlacoochee River near Tarrytown
19	02312200	Little Withlacoochee River at Rerdell
20	02312500	Withlacoochee River at Croom
21	02312520	Lake Lindsey
22	02312527	Bystre Lake
23	282558082363100	Major Shear Pond
24	282600082240000	Squirrel Prairie Sink area
25	282603082395700	Unnamed spring 1
26	282638082184100	St. Clair Lake
27	282650082190700	Nicks Lake
28	282703082382600	Unnamed spring 2
29	282759082215900	Gold Lake outlet
30	282832082114500	Withlacoochee River at U.S. Highway 98
31	283024082105200	Lake Geneva
32	283109082123500	Withlacoochee River at Rital
33	283113082375400	Unnamed springs 4 and 5
34	283125082354800	Weeki Wachee River below Weeki Wachee
35	283150082373000	Unnamed spring 3
36	283212082340700	Pond at The Heathers
37	283217082245600	Bonnet Pond
38	283246082373000	Mud Spring
39	283254082373500	Unnamed spring 6
40	283839082152700	Withlacoochee River at Nobleton

Table 2.--Data-collection sites on streams, lakes, springs, and sinkholes--Continued

Well	Station identification	Site name
41	283927082275700	Skinner Lake
42	283928082380500	Blind Spring
43	283934082381000	Unnamed spring 7
44	283938082275200	Withlacoochee River at Istachatta
45	284017082380800	Unnamed spring 8
46	284112082363800	Unnamed spring 12
47	284113082362000	Unnamed springs 10 and 11
48	284133082354100	Unnamed spring 9

In 1982, industry used the largest amount of water, 31.36 Mgal/d (fig. 9), and all but a small fraction of that amount was used for rock mining. About 81 percent of the water used by industry was from ground-water sources; 19 percent was from surface-water sources and constitutes essentially all surface-water use in Hernando County. Industrial use, 67 percent of the total county water use, has remained relatively constant since 1975.

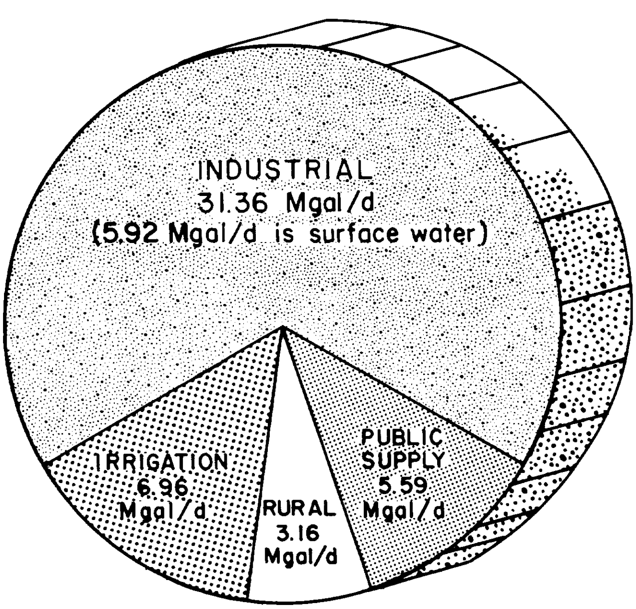

Figure 9.--Estimated freshwater use in 1982.

Irrigation is the second largest category of water use. This is mainly irrigation for crops and pastureland, but also includes irrigation for golf courses, nurseries, cemetaries, and public facilities. Use for this purpose in 1982 was 6.96 Mgal/d (based on consumptive use permitted by the Southwest Florida Water Management District and from data collected at selected sites by the U.S. Geological Survey).

Public-supply water use includes all water pumped for the public-supply systems of Brooksville, Spring Hill subdivision, Hernando County, and for small suppliers that are permitted to pump more than 100,000 gal/d. All water used for public supply in 1982 was from ground-water sources. Public-supply use in 1982 was 173 gal/d per capita.

Rural water use was the smallest water-use category in 1982. Domestic and livestock freshwater use is included in this category. Domestic water use is self-supplied household water and is based on an average per capita water use of 100 gal/d. The number of rural domestic users, for this report, is the difference between the total population and the number of people served by major public-supply systems. Water used by livestock, based on livestock population, includes drinking and washing water for commercially raised animals. Rural water use has varied little in the past 7 years.

Lake augmentation is not shown as a category of water use in figure 9, but it does occur. Ground-water withdrawals of 82,000 gal/d for augmentation of a lake near Brooksville have been permitted by the Southwest Florida Water Management District. Actual use, however, is seldom as much as permitted.

Permitted Pumping Rates

Since 1975, the Southwest Florida Water Management District has required a permit to withdraw ground water for consumptive use for new wells that are 6 inches in diameter or larger, or produce more than 0.1 Mgal/d. The permit is for average and maximum daily pumping rates. The permit system was developed to protect the environment, prevent excessive depletion of water from the Floridan aquifer system, and prevent interference with nearby wells.

Locations of pumping centers and permitted average daily withdrawal rates are shown in figure 10 (Southwest Florida Water Management District, written commun., 1983). The amounts shown do not reflect seasonal variations and do not include active irrigation wells that were installed prior to 1975 (before permitting was required). Although pumping rates are frequently less than permitted, the data in figure 10 serve to define areas of major stress. At present, the largest withdrawals are northwest of Brooksville.

Projected Ground-Water Withdrawals

Projections indicate that the population of Hernando County will be about 107,000 by the year 2000 (fig. 5). Of this population, it is assumed for this study that 80 percent will be served by public-supply systems. Water-use rates

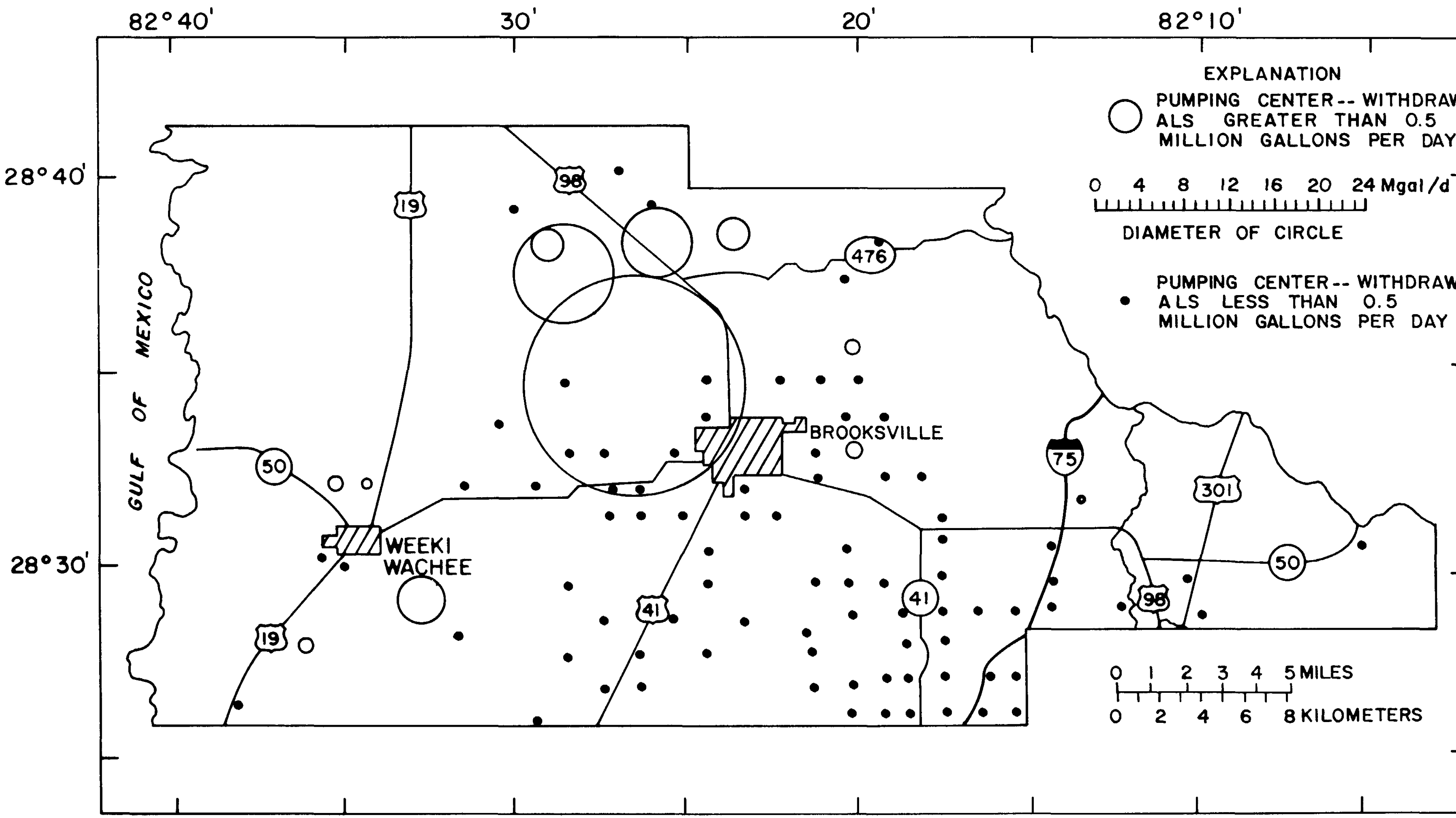

Figure 10.--Pumping centers and permitted average daily withdrawals of ground water in 1983.

of 173 gal/d per person (Duerr and Trommer, 1981, p. 31) for urban users and 100 gal/d per person for rural users were used to estimate water demands. Water used for irrigation, industry, and rural supplies is expected to remain relatively constant. Ground-water withdrawals are predicted to increase from about 41 Mgal/d in 1982 to 50 Mgal/d in 2000. The increase is attributed exclusively to an increase in public-supply water use. During the period from 1982 to 2000, new housing developments and commercial development may initially obtain water from local supplies, but eventually, they will be serviced by public-supply systems. The greatest increases in projected water-use rates tend to be in coastal areas.

Projecting the location of water-withdrawal centers is more difficult than projecting quantities of water to be used. It is assumed that current (1984) withdrawal sites will continue to be in use in 2000. Some withdrawal locations planned for future development were considered to be sources of water for the year 2000. Some additional supplies may be developed north of the present production wells near Weeki Wachee. Also, the county may develop a withdrawal site near the Withlacoochee State Forest east of Brooksville (fig. 6). Spring Hill Utilities will add wells to their subdivision. The existing Spring Hill wells are generally scattered throughout the subdivision, and it is assumed the new wells will also be scattered.

Rural water-use centers are scattered throughout the county. Therefore, the amount of projected rural water use is assumed to be scattered throughout areas that are not served by public-supply systems, excluding unused land. Locations of irrigation water-use centers are based on consumptive-use permits from the Southwest Florida Water Management District files and from land-use maps (Southwest Florida Water Management District, 1976). Expansion of mining operations into new locations before 2000 is not expected.

Figure 11 shows the distribution of 1982 withdrawal rates and estimated withdrawal rates for 2000 for each node of a flow model described later in this report. The projected increase in water use between 1982 and 2000 is 9 Mgal/d.

GEOLOGIC FRAMEWORK

A thick sequence of sedimentary rocks underlies Hernando County. Chemically precipitated deposits of limestone and dolomite that contain shells and shell fragments of marine origin were laid down throughout the Tertiary Period. Early in the Miocene Epoch, terrestrial deposits of sand, silt, and clay were brought in by rivers from the north and were intermixed with the upper Tertiary limestone deposits. By late Miocene time, the clastics were the dominant type of deposit.

During the Pleistocene Epoch (ice-age), a series of marine terraces was formed along the coast by wave erosion and deposition. These terraces are former bottoms of shallow seas and are composed primarily of well-graded quartz sand.

The sequence of carbonate rocks that is hydrologically significant to this study ranges in age from Eocene to Oligocene and comprises, in ascending order, the following formations: Avon Park Formation, Ocala Limestone, and Suwannee

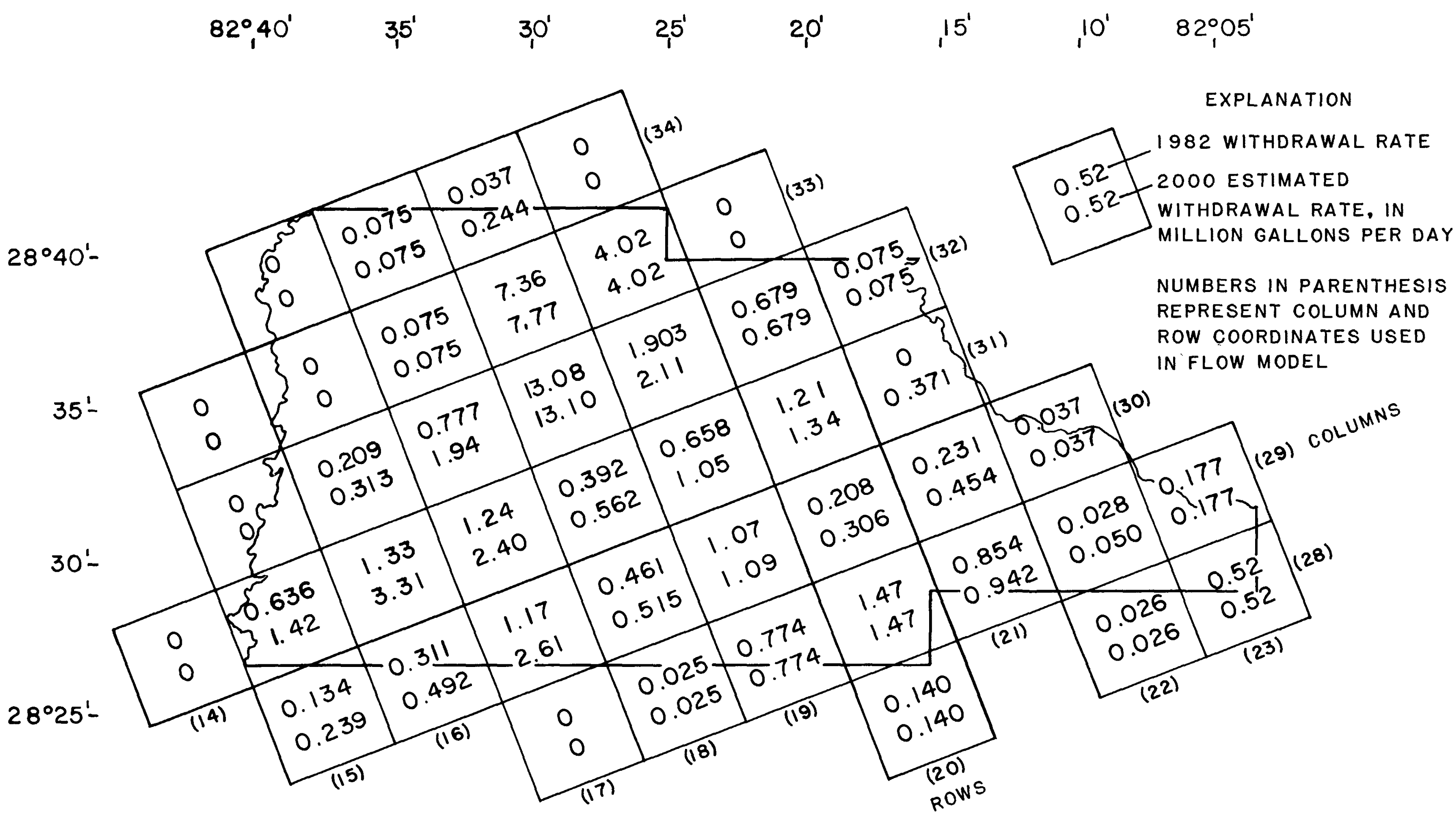

Figure 11.--Areal withdrawal rates for 1982 and projected withdrawal rates for 2000.

Limestone. Lithologic characteristics and water-supply properties of the formations are summarized in table 3. Figure 12 shows the relative positions and thicknesses of the formations. The Ocala Limestone is the uppermost rock unit in the eastern and northwestern parts of the county. Where present, the Suwannee Limestone increases in thickness to the south and in the Brooksville Ridge area. Depth to limestone from land surface ranges from zero at the coast to slightly more than 100 feet along the Brooksville Ridge. The average depth is about 50 feet below land surface. The formations generally dip from northeast to southwest.

The Tampa Limestone of Miocene age is generally absent, but does overlie the Suwannee Limestone in a few places along the Brooksville Ridge. Where present, it is generally unsaturated and is only a few tens of feet thick.

The Hawthorn Formation of Miocene age and Alachua Formation of Pliocene age are part of a predominantly clay unit that contains some sand, limestone, phosphatic clay, marl, calcareous sandstone, and limestone residuum that overlies the carbonate strata throughout most of the county and locally may be exposed at the surface. The unit ranges from zero to 100 feet in thickness; it is generally thickest beneath the Brooksville Ridge (fig. 13).

Surficial deposits of soil, sand, and clay, composed predominantly of sand and referred to in this report as the surficial sand unit, occur at land surface throughout most of the county. This unit ranges in thickness from zero to about 100 feet (fig. 14) and has an average thickness of about 50 feet.

Figures 13 and 14 were delineated using the average thickness determined from drillers' logs of wells in each section. The maps are highly generalized, and deviations from the thicknesses shown can be expected.

SOLUTION CAVITIES AND SINKHOLES

A network of cavities in the carbonate rocks has developed under previous and present hydrologic conditions. Dissolution is most active at the water table or in the zone of water-table fluctuation where carbonic acid contained in atmospheric precipitation reacts with limestone and dolomite (Carroll, 1970, p. 101-102). Because the altitude of the water table shifted in response to changes in sea level several times during the Pleistocene Epoch, many vertical and lateral paths have developed. Many of these features lie below the present water table and greatly facilitate ground-water flow.

Large vertical shafts were formed by water percolating through the carbonate rocks that were above the water table at a time when sea level was lower than at present. The present water table lies above some vertical shafts. Percolating water slowly dissolves the rock and water movement tends to concentrate along these flow paths. Eventual collapse of the roofs over cavities, channels, caverns, or shafts forms sinkholes (Sinclair, 1978, p. 10), many of which are in evidence today. Peck's sink (site 2, fig. 8), one of the better known sinks in the county, consists of three vertical shafts that carry surface water to the ground-water system. A fairly well-developed stream channel runs several miles to this sink. Water flows in this channel only during wet periods.

Table 3.--Generalized hydrogeologic column

System	Series	Stratigraphic unit	Thickness (feet)	Lithology	Water-producing characteristics
Quaternary	Holocene and Pleistocene	Undifferentiated deposits	0-100	Soil, sand, and clay of marine and estuarine terraces, alluvial, lake, and windblown deposits.	Generally not a source of water.
Tertiary	Pliocene and Miocene	Alachua and Hawthorn Formations and Tampa Limestone	0-100	Predominantly clay; some grayish-green, waxy; some interbedded sand and limestone, phosphatic clay, marl, calcareous sandstone, limestone residuum.	Confining layer in some places; generally not a source of water.
	Oligocene	Suwannee Limestone	0-150	Limestone, cream to tan colored, fine-grained, fossiliferous, thin-bedded to massive, porous.	Many domestic and irrigation wells produce water from the lower part.
	Eocene (upper)	Ocala Limestone	100-500	Limestone, white to tan fossiliferous, massive, soft to hard, porous.	Yields large quantities of water to wells completed above evaporites.
	Eocene (middle)	Avon Park Formation	200-800	Limestone and dolomite. Limestone is light- to dark-brown, highly fossiliferous, and porosity is variable in lower part. Dolomite is gray to dark-brown, very fine to microcrystalline and contains porous fossil molds, thin beds of carbonaceous material, and peat fragments. Formation generally contains evaporites in lower part.	

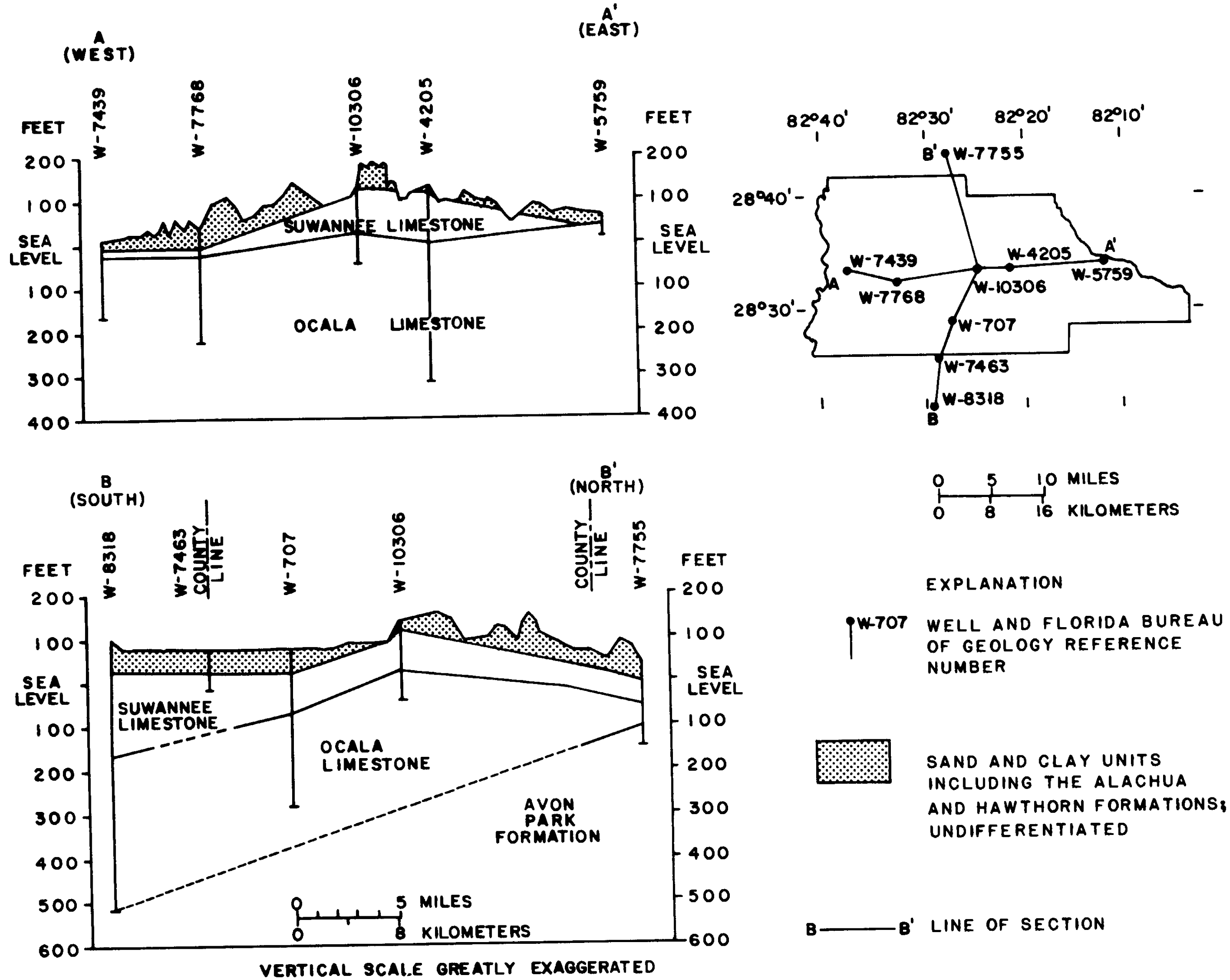

Figure 12.--Generalized geologic sections.

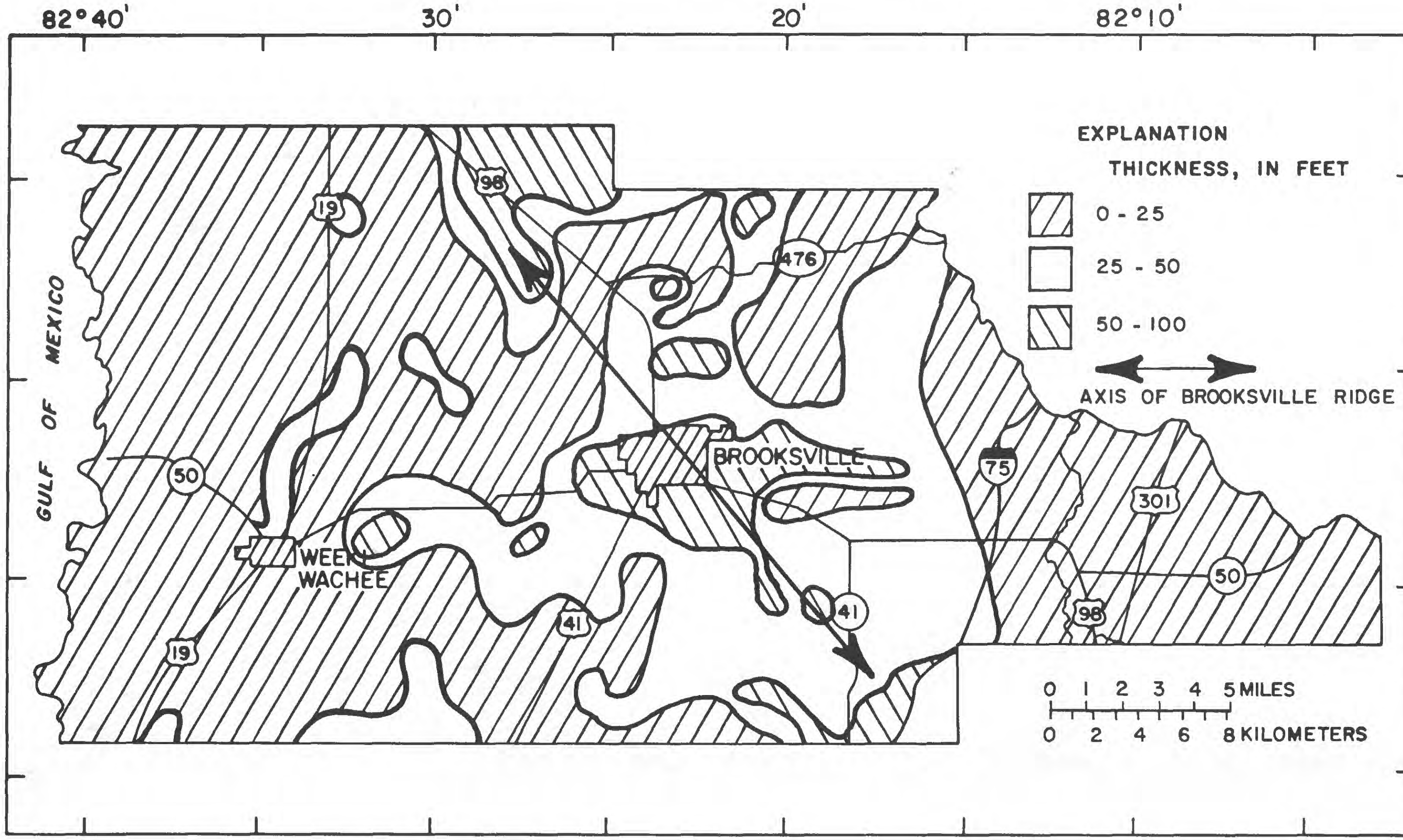

Figure 13.--Generalized thickness of clay unit that overlies the Floridan aquifer system.

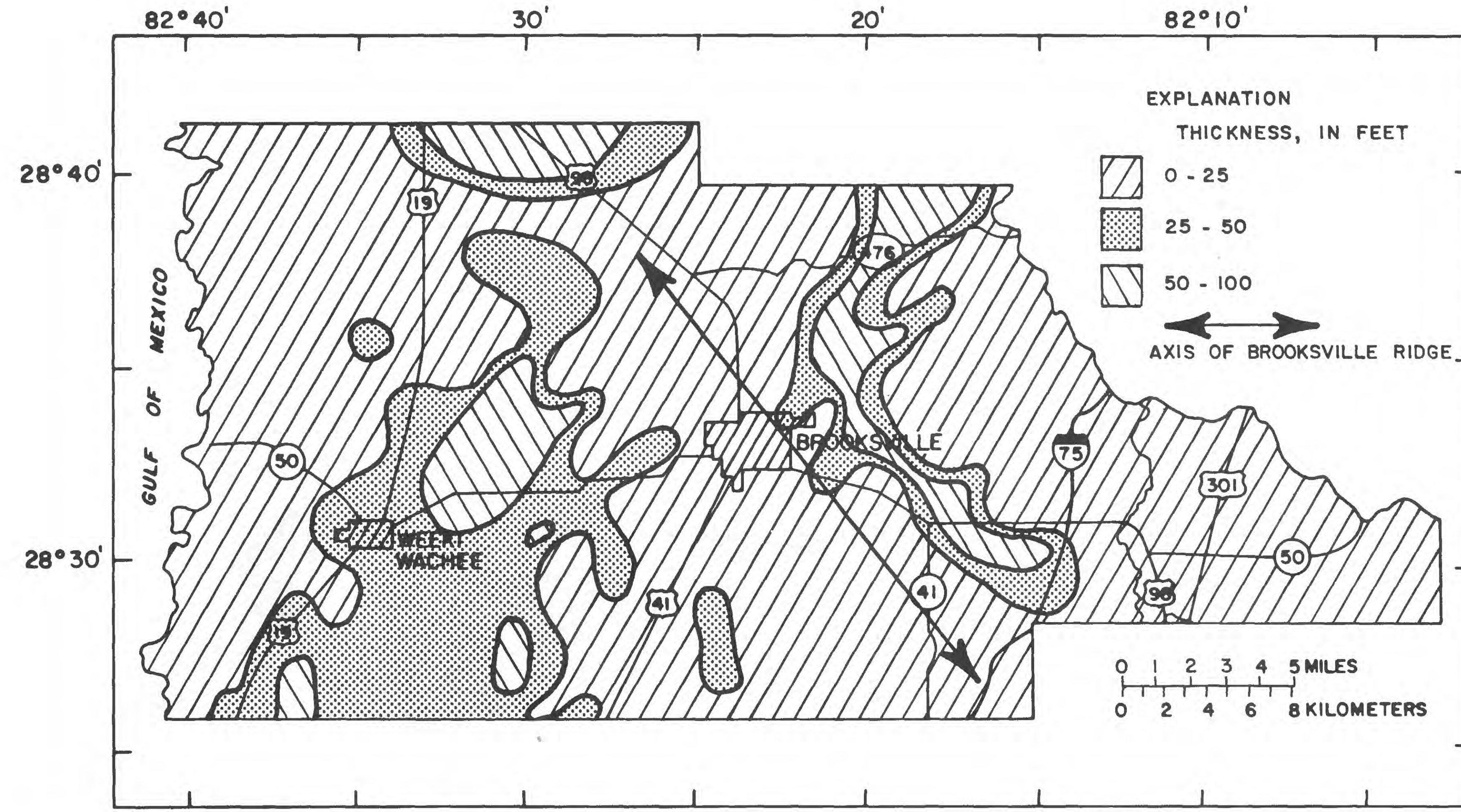

Figure 14.--Generalized thickness of surficial sand unit.

SURFACE WATER

Most drainage in Hernando County is internal, as is typical in karst terrain. Rainfall percolates through sand and clay to recharge the underlying Floridan aquifer system. After heavy rainfall, small intermittent streams flow to sinkholes where the water either percolates rapidly or ponds to form prairie lakes. During dry periods, these channels and lakes are usually dry. During wet periods, flooding may occur if the rate of rainfall exceeds the rate of percolation, or if the potentiometric surface of the aquifer rises to or above the bottom of the sinkholes. This is particularly a problem where the altitude of the land surface is close to that of the potentiometric surface.

The Withlacoochee and Little Withlacoochee Rivers are the only perennial streams inland from the coast. Above their confluence in the southeastern part of the county, the two rivers cut through sand and clay. Below their confluence, the Withlacoochee River flows in a limestone channel.

The potentiometric surface of the Floridan aquifer system is generally higher than the water surface of the Withlacoochee River in the reach south of Interstate Highway 75 (fig. 15). Figure 15 shows the relative water levels on May 16-17, 1979, during a period of fairly high water conditions in the river. At that time, the discharge of the Withlacoochee River at U.S. Highway 301 averaged 278 ft^3/s, a discharge that was exceeded only 30 percent of the time for the period 1931-1981 (K. M. Hammett, U.S. Geological Survey, written commun., 1984). The differences in the water levels shown in figure 15 suggest that water from the Floridan aquifer system generally is discharging to the river in the southern part of the county, and river water generally is recharging the Floridan aquifer system in the northern part of the county.

The only other perennial streams are those that are fed by springs along the coast. Most coastal streams are affected by Gulf tides. The largest of these streams is the Weeki Wachee River (fig. 1) that receives its water from Weeki Wachee Springs.

Many small lakes occur in Hernando County. Some lakes appear to be surface expressions of water tables perched on impermeable materials; others are directly connected to the Floridan aquifer system through sinkholes and reflect the potentiometric surface of the aquifer. The largest lake entirely within the county is Bystre Lake (site 22, fig. 8). It has a surface area of 307 acres (Gant, 1982, p. 20). Hunters Lake (site 7, fig. 8) is almost as large and has a surface area of 302 acres (Gant, 1982, p. 9). The largest lake included in the study, Lake Hancock (site 5, fig. 8), 519 acres (Gant, 1982, p. 20), lies mostly within Pasco County.

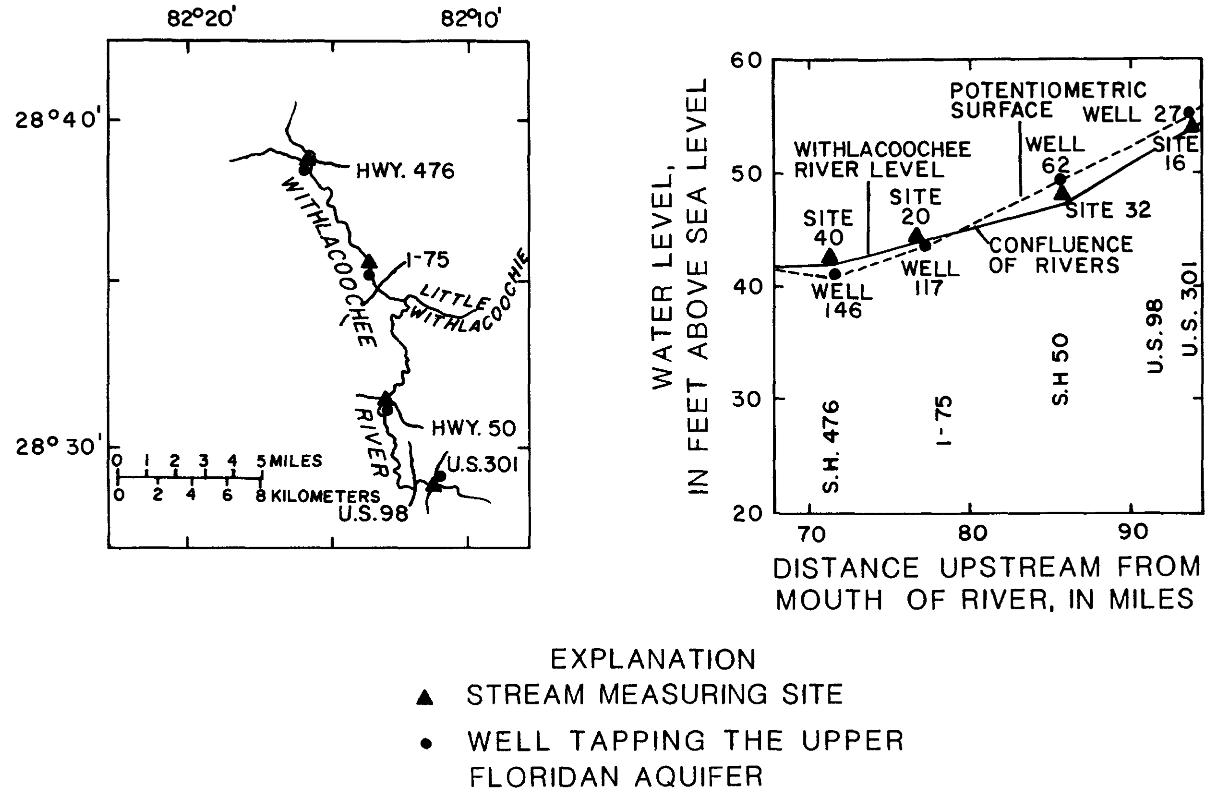

Figure 15.--Water levels of the Withlacoochee River and potentiometric surface of the Upper Floridan aquifer along the river, May 16-17, 1979 (from Anderson and Laughlin, 1982).

Water levels of Lake Lindsey (site 21, fig. 8) and Horse Lake (site 1, fig. 8) were measured weekly during part of the study. Figure 16 shows changes in water levels for each lake during 1982-83. Also shown are water levels in nearby well 126 (fig. 7) and rainfall at Brooksville. Water levels of Lake Lindsey rose from May through September 1982 as a result of above normal rainfall and subsequently remained high. A similar response is seen in well 126, which suggests some connection between the lake and the Floridan aquifer system. Levels of Horse Lake peaked in June 1982 and subsequently receded, indicating a more rapid response than Lake Lindsey to climatic conditions.

Water levels in eight lakes, measured several times during wet and dry seasons between April 1982 and June 1983, are shown in figure 17. Levels in several lakes responded to climatic conditions in the same way as water levels in the Floridan aquifer system by rising with the heavy rainfall in 1982, declining slightly during the fall and early winter months between 1982 and 1983, and then rising again as rainfall increased in the spring of 1983.

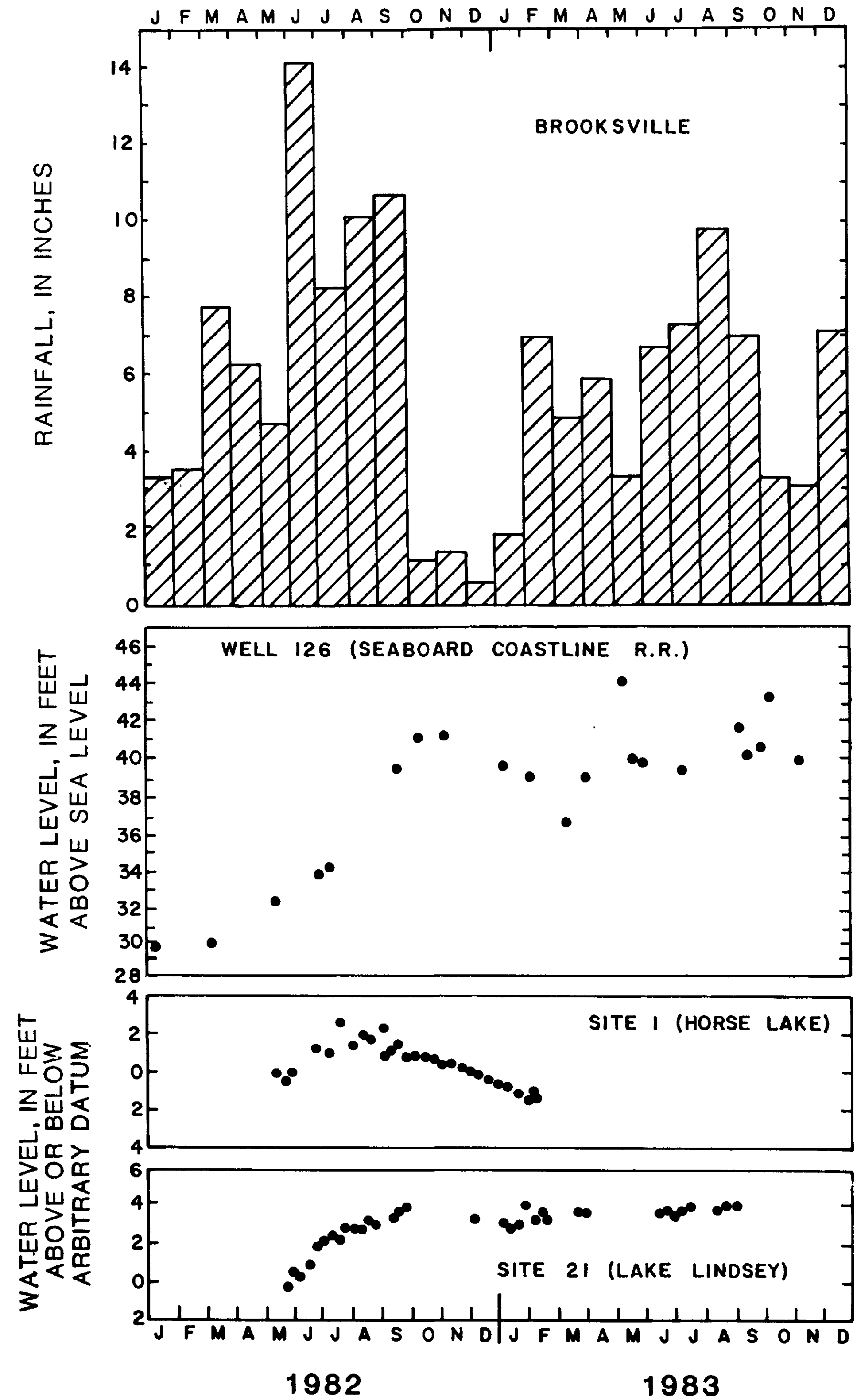

Figure 16.--Rainfall at Brooksville and water levels in well 126, Horse Lake, and Lake Lindsey.

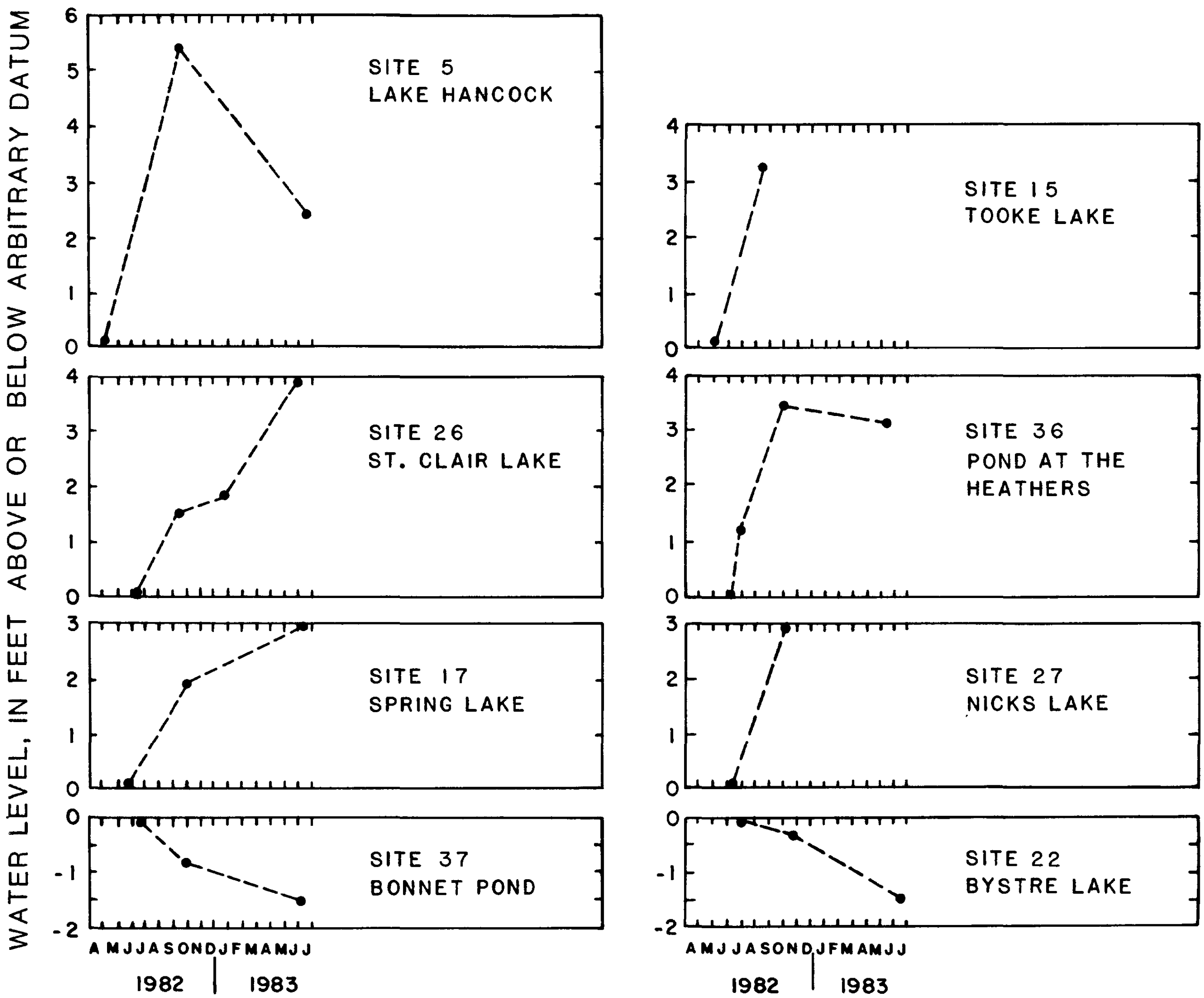

Figure 17.--Water levels in eight lakes during the period April 1982-June 1983.

Changes in lake levels between April 1982 and June 1983 ranged from a 5.4-foot increase in Lake Hancock to a 1.4-foot decline in Bonnet Pond. Although most lakes had very high water levels in September 1982, Skinner and Bystre Lakes and Bonnet Pond had lower levels in September 1982 than in June 1982. At Skinner Lake, the gage was on dry land in September. A pond in the southern part of the county went completely dry during the same period. Residents near Nicks Lake indicated that this lake has gone dry during periods when water levels of St. Clair Lake were high. This, however, was not observed.

It is possible that lakes that show a decline in water levels may reach a certain level at which the water body becomes heavy enough to force out sediments that had formed a plug in the sinkholes beneath the lake beds. As water flows from the lake into the Floridan aquifer system, sediment is redeposited, a new plug is formed, and the lake again accumulates water. In the case of the pond in the southern part of the county, the plug did not reform, and the pond remained dry through the end of the study period. Other factors that affect the rapid lowering of lake levels during times of heavy rainfall are the relation of water levels in the lake to the potentiometric surface of the Floridan aquifer system, premeability of the lake bottom, and availability of water from storage in adjacent sand hills. Lakes that have a direct connection with the Floridan aquifer system could be potential sources of contamination to the aquifer.

SPRINGS

Weeki Wachee Springs is centrally located in the coastal area of Hernando County. Discharge from the spring has ranged from 101 ft^3/s (65 Mgal/d) to 275 ft^3/s (178 Mgal/d) for the period of record, 1931 to 1984, and averages 176 ft^3/s (114 Mgal/d). Other springs that discharge more than 10 ft^3/s (6.5 Mgal/d) are Salt, Mud, Blind, and unnamed springs No. 7 and No. 9, sites 14, 38, 42, 43, and 48, respectively, in figure 8 (Rosenau and others, 1977, p. 140-154). Long-term average discharge through coastal springs in Hernando County, as reported by Ryder (1982, table 4, p. 21), is about 357 ft^3/s (230 Mgal/d). Upward leakage in marsh areas near the coast, according to Ryder (1982, p. 21-58), accounts for about 77 ft^3/s (49 Mgal/d).

Springflow is related to the altitude of ground water. Correlation between discharge from Weeki Wachee Springs and water levels in well 71 (fig. 7) is shown in figure 18. For every foot of water level change in the well, a change of about 12.5 ft^3/s of discharge occurs at the spring. The graph includes all discharge measurements from August 1966 through 1982, the period for which water-level data are available for well 71.

GROUND WATER

In most of west-central Florida, including Hernando County, the Floridan aquifer system is the principal source of water for domestic, agricultural, and industrial supplies. At a few locations in Hernando County, a surficial aquifer occurs in the sand overlying the Floridan aquifer system. In some places, as on some hills in the Brooksville Ridge area, a perched water table in the surficial aquifer of limited areal extent occurs above the Floridan aquifer system due to separation of the sand from the underlying limestone by clay of very low permeability. In most parts of the county, there are sufficient breaches in the clay layer to allow percolation of water from the sand into the underlying limestone. In areas where saturated sand lies directly above limestone, water in the sand is hydraulically connected to the Floridan aquifer system.

Surficial Aquifer

In some places, the sand contains water only during the wet season. Water levels in the sand change rapidly, which suggests hydraulic connection with the limestone and leakage through clay layers where present. Twenty-eight wells

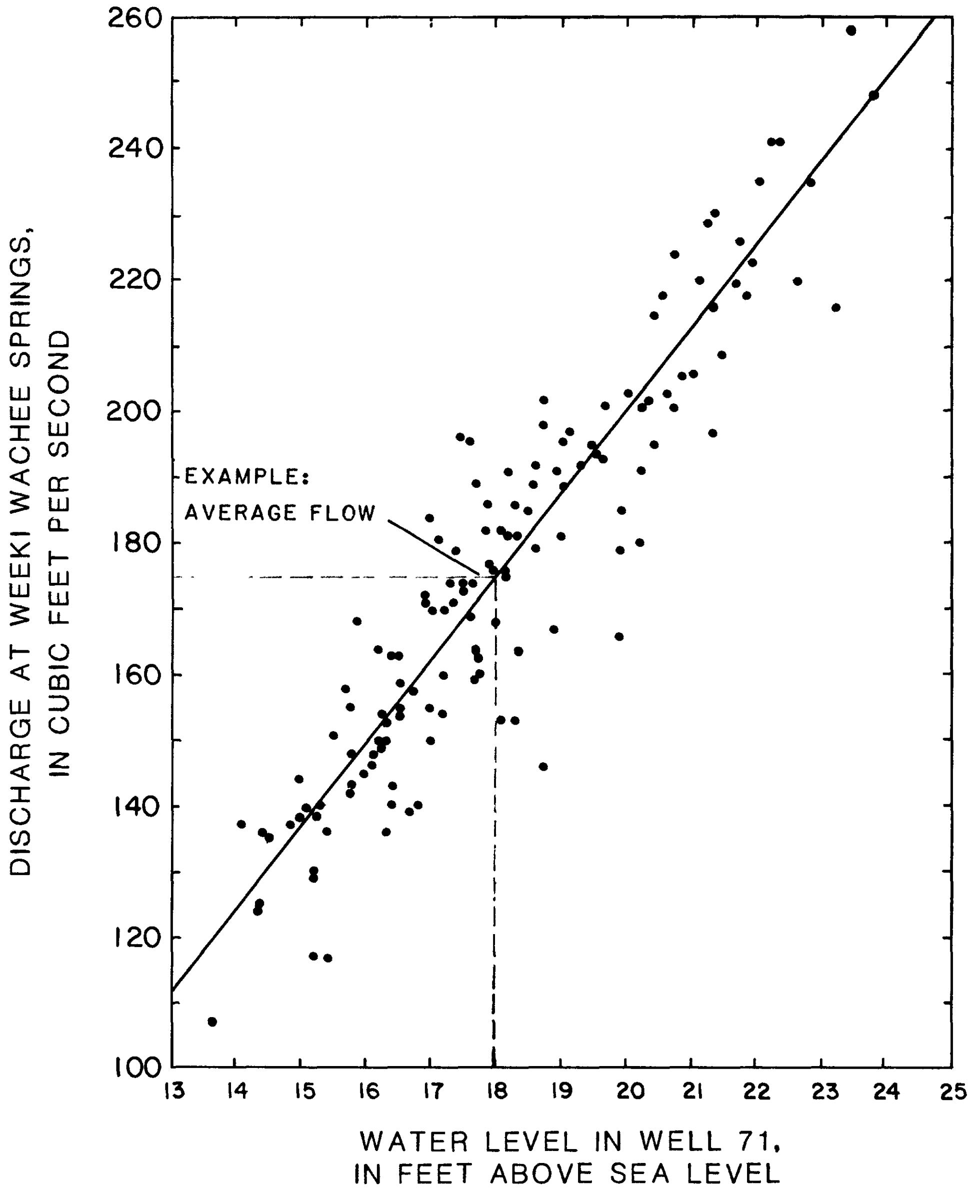

Figure 18.--Relation between discharge of Weeki Wachee Springs and water levels in well 71.

that range in depth from 10 to 70 feet were drilled in May 1982 during a dry period. Of these wells, only seven contained water; however, by the following month, eight of the wells contained water. All but one of these wells were quickly dewatered when pumped at a rate of less than 5 gal/min. Locations of these wells and other surficial aquifer wells measured in May and June 1982 are shown in figure 19. An area in the southwest part of the county (area A, fig. 19) contains numerous shallow wells that were drilled for a study of Hunters Lake (S.E. Henderson, U.S. Geological Survey, written commun., 1984). Most of these wells also contained water in May 1982. In this area, the water table is

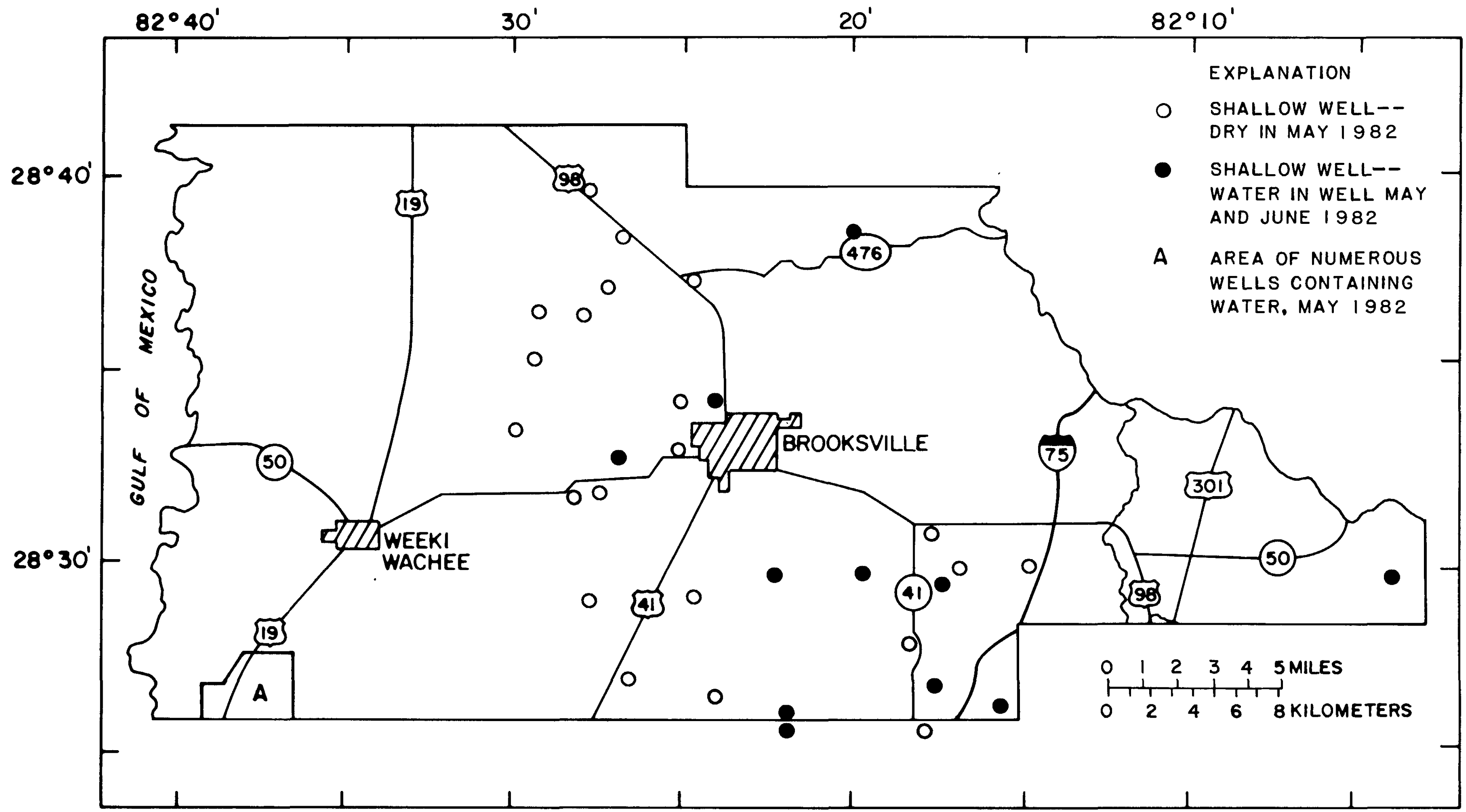

Figure 19.--Locations of selected surficial aquifer wells.

in the sand that lies directly above the Floridan aquifer system and is probably in hydraulic connection with the Floridan aquifer system. Sand throughout the county generally yields insufficient quantities of water to wells to be of economic importance.

Floridan Aquifer System

The Floridan aquifer system is a thick sequence of carbonate rocks that in the past has been generally referred to as the Floridan aquifer. The aquifer system extends from Florida to parts of Georgia, Alabama, and South Carolina. Originally defined by Parker and others (1955), the Floridan aquifer includes, in ascending order, highly permeable rocks of all or parts of the Lake City, Avon Park, Ocala, and Tampa Limestones and highly permeable parts of the Hawthorn Formation that are in hydrologic contact with the rest of the aquifer.

The Floridan aquifer, based on drilling and hydrologic testing on a regional basis, has been redefined by Miller (1984) as the Floridan aquifer system that comprises: "a vertically continuous sequence of carbonate rocks of generally high permeability that are mostly of middle and late Tertiary age, that are hydraulically connected in varying degrees, and whose permeability is, in general, an order to several orders of magnitude greater than that of those rocks that bound the system above and below.

"... (in peninsular Florida), less-permeable carbonate units of subregional extent separate the system into two aquifers, herein called the Upper and Lower Floridan aquifers." In Hernando County, the freshwater-bearing part of the Floridan aquifer system is the Upper Floridan aquifer that is comprised of the following formations, in ascending order: Avon Park Formation, Ocala Limestone, and Suwannee Limestone (fig. 12, table 3). The Tampa Limestone is generally missing, either because of erosion or lack of deposition. Where present, it is generally unsaturated and not significant as part of the aquifer. The lower part of the Avon Park Formation, formerly known as the Lake City Limestone, contains evaporites consisting of gypsum and anhydrite that reduce permeability of the rock and are considered to be the base of the Upper Floridan aquifer. The lower part of the Avon Park Formation and rocks below it contain salty water; therefore, it is the lowermost unit studied. The Upper Floridan aquifer is generally unconfined in Hernando County, but it may be locally confined where it is overlain by thick clay beds or low permeability limestone that retard vertical flow of water.

The top of the Floridan aquifer system is at land surface near the coast; it is more than 100 feet below land surface in the Brooksville Ridge area. Thickness of the Upper Floridan aquifer ranges from a little less than 700 feet at the coast to a little greater than 800 feet in the ridge area (Miller, 1982).

A highly developed secondary porosity system exists in the vicinity of Weeki Wachee Springs and other large springs. In these areas, dissolution of limestone produced cavities and channels. Small passages in the limestone coalesced until water from many successively larger passages began moving through a single major channel toward a discharge point, or spring. A well in such a major channel will yield more water than a well developed in the immediately adjacent, less permeable part of the aquifer even though both may be constructed identically, be within a few tens of feet of each other, and be equipped with identical pumps.

Potentiometric Surface

The potentiometric surface of the Upper Floridan aquifer fluctuates in response to changes in the rates of recharge and the rates of discharge. Some factors in this process are rainfall, pumping, and, near the coast, tidal fluctuations. Figure 20 shows potentiometric surfaces of the Upper Floridan aquifer for September 1982 and May 1983. September is normally the end of the wet season; May, the end of the dry season. Generally, most stress is placed on the aquifer in May because seasonal rains have not yet begun and crop irrigation is heaviest. Also, tourism is at its peak in late winter and early spring and places additional demands on the freshwater supply at a time when rainfall is least. However, the amount of rainfall is the most important factor in dictating the altitude of the potentiometric surface of the Upper Floridan aquifer.

In west-central Florida, the potentiometric surface usually shifts slightly gulfward between May and September as the Floridan aquifer system is recharged by summer rains and pumping is minimal. This shift is generally very small in Hernando County and was actually reversed, except very close to the coast, between September 1982 and May 1983 (fig. 20) due to unusually heavy rainfall in the spring.

Ground water moves from potentiometric-surface highs to areas where the surface is low, such as at the coast. One such high occurs in the Green Swamp area a few miles southeast of Hernando County (fig. 20). Here, the potentiometric surface in September 1982 was as much as 130 feet above sea level and in May 1983 as much as 120 feet above sea level. Another potentiometric-surface high occurs near the south boundary of the study area where the potentiometric surface was about 90 feet above sea level in both September 1982 and May 1983. Recharge to the aquifer occurs throughout most of Hernando County, generally through highly permeable surficial sand and sinkholes.

Ground water flows downgradient perpendicular to the potentiometric contours to areas of discharge (fig. 20). Reentrants of the contours indicate concentrated discharge. Such reentrants occur around Weeki Wachee Springs and the Withlacoochee River that lies in a trough between the two potentiometric-surface highs.

Hydrographs for four wells are shown in figure 21. The hydrographs, particularly for well 71, show a normal seasonal trend with minimum water levels in late spring. Departures from the norm are illustrated by the peak that occurred in late 1969 and lasted through 1971 and the almost steady decline in 1972 and 1973. Even though water levels have fluctuated seasonally over the years, the hydrographs do not indicate any long-term trend toward higher or lower levels. Water-level peaks in 1982 and 1983 correspond with annual rainfall that exceeded the average by nearly 10 inches (fig. 4). The difference between the potentiometric surface in 1964 and that in 1980 was less than 10 feet anywhere in the study area (Yobbi, 1983).

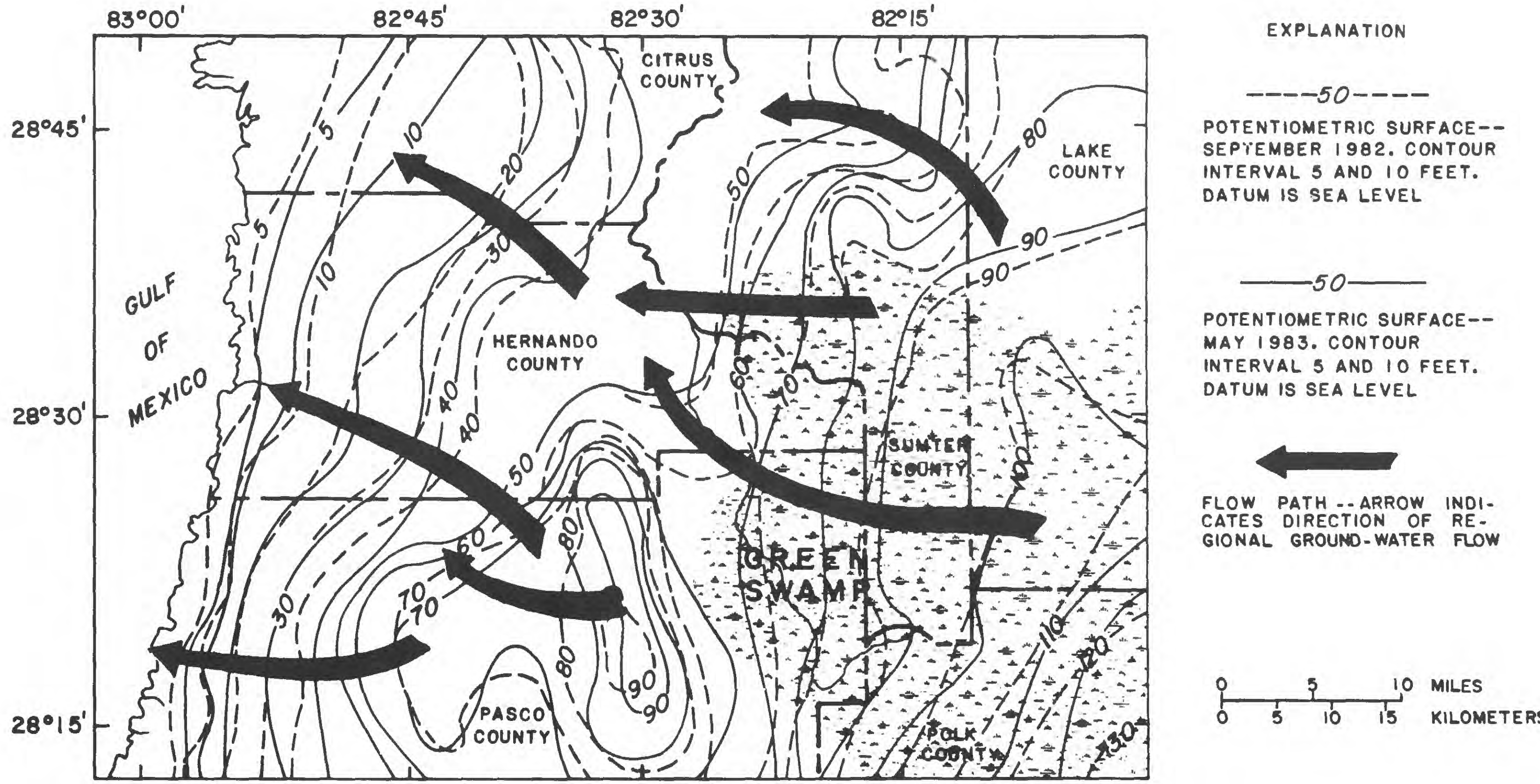

Figure 20.--Potentiometric surface of the Upper Floridan aquifer in the vicinity of Hernando County showing flow paths, September 1982 and May 1983 (modified from Barr and Schiner, 1982; 1983).

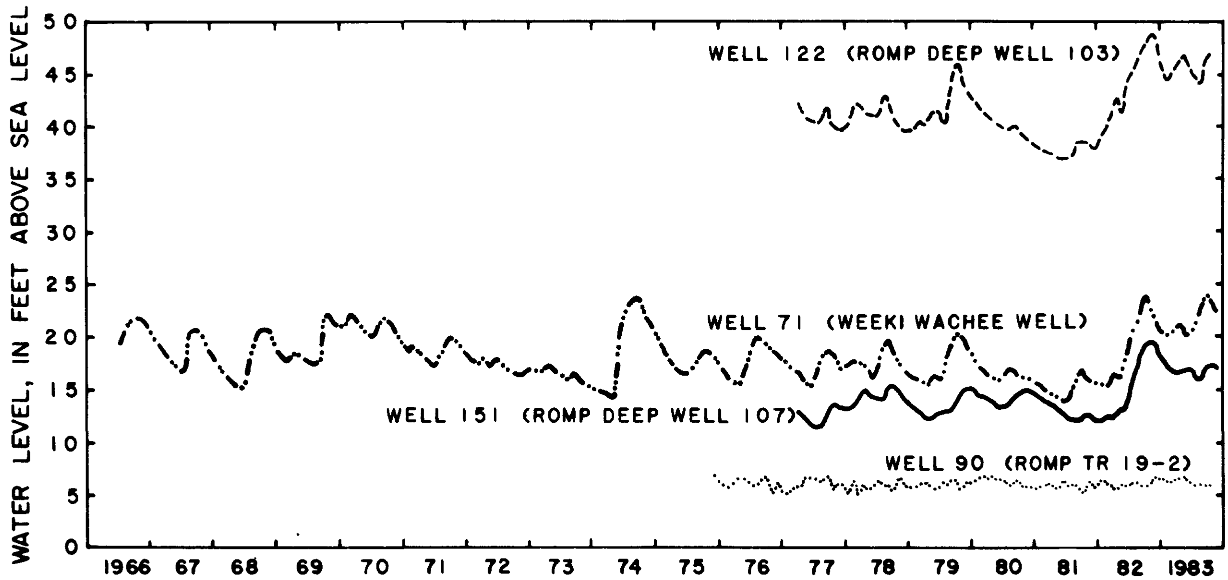

Figure 21.--Water levels in four wells.

Recharge

Faulkner (1970) suggests a rate of recharge to the Floridan aquifer system in the Silver Springs and Rainbow Springs basins, east and north of Hernando County, of about 15 inches per year. Both the opportunity for recharge and the amount of rainfall available for recharge is probably greater in Hernando County than in these basins. Thus, recharge in Hernando County can be conservatively estimated to be at least 15 inches per year, and because there is hardly any runoff from the county, recharge could be as much as 20 inches per year if average evapotranspiration is considered to be 36 inches per year. Cherry (1970) computed evapotranspiration in the midgulf area as 38.6 inches, which subtracted from 56 inches of rain gives 17.4 inches of recharge. At 15 inches, average daily recharge would be $363 \text{x} 10^6$ gal; at 17.4 inches, $422 \text{x} 10^6$ gal. In addition, several million gallons per day enter from Sumter and Pasco Counties, particularly at the Withlacoochee-Pasco high reentrant (fig. 20). Water flows from the potentiometric high in the Green Swamp area of Sumter County and the potentiometric high in Pasco County toward the trough along the Withlacoochee River. Water enters Hernando County through this potentiometric low.

Aquifer Properties

Transmissivity is a measure of an aquifer's ability to transmit water. Figure 22 shows locations where transmissivity has been determined for the Upper Floridan aquifer. Table 4 lists these transmissivities. Transmissivity

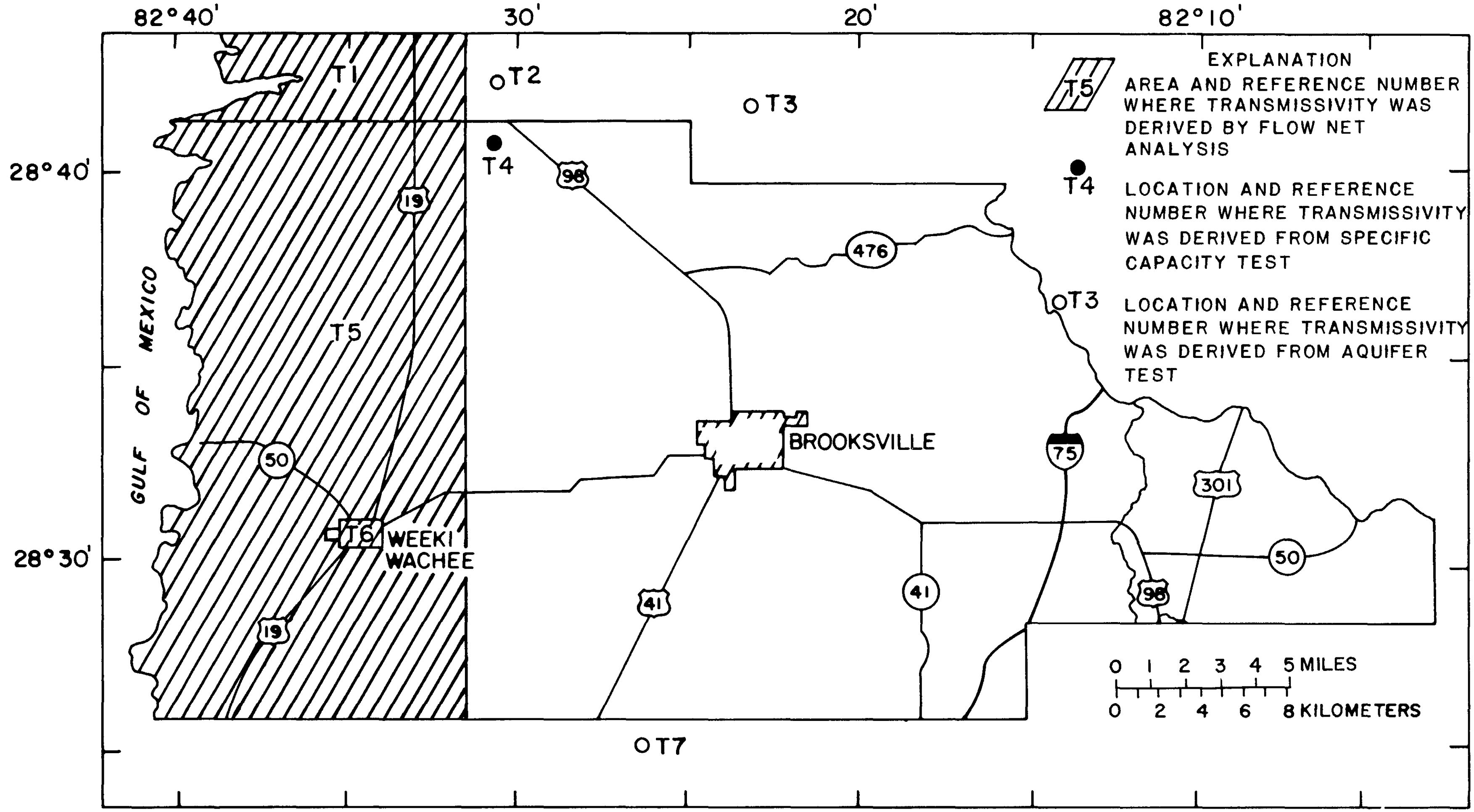

Figure 22.--Area and sites where transmissivity of the Upper Floridan aquifer was derived. (Values for transmissivity are given in table 4.)

Table 4.--Transmissivity of the Floridan aquifer system

[Locations are shown in figure 22]

Reference number	Transmissivity (ft^2/d)	Reference
T1	$2.0x10^6$	Cherry and others (1970, p. 59 and 75).
T2	$9.0x10^4$ to $2.8x10^5$	Seaburn and Robertson, Inc. (1980).
T3	$1.2x10^6$	Parker (written commun., 1980).
T4	$9.4x10^5$	Ryder (1982, p. 13).
T5	$6.7x10^5$	Cherry and others (1970, p. 59 and 75).
T6	$1.2x10^6$ to $2.1x10^6$	Sinclair (1978, p. 17).
T7	$8.6x10^5$	Leggette, Brashears and Graham, Inc. (1979).

is generally high at springs and decreases away from the springs (Faulkner, 1975). At Weeki Wachee Springs (site T6), transmissivity of the Upper Floridan aquifer is estimated to be between $1.2x10^6$ and $2.1x10^6$ ft^2/d (Sinclair, 1978, p. 17). Transmissivities calculated from aquifer tests other than flow-net analyses in Hernando County and surrounding areas range from $9x10^4$ ft^2/d at site T2 to $8.6x10^5$ at site T7. A well open within a tight zone of the Upper Floridan aquifer may show more drawdown than expected for a well open to a more transmissive zone.

Storage coefficient is approximately equal to specific yield for the Upper Floridan aquifer in Hernando County. The aquifer is generally unconfined and most of the water is released from storage by gravity drainage, given sufficient time. The specific yield is estimated to be 0.15 based on findings in other counties by Stewart (1966, p. 113) and Hickey (1979, p. 5).

When a well is pumped, water levels in the well and in the aquifer are lowered. The greatest drawdown is at the pumped well. The amount of drawdown decreases radially away from the well. The depressed water surface forms a cone known as "the cone of depression" (fig. 23). At some distance from the well, drawdown due to pumping is virtually nonexistent. Distance from the pumped well to the point of no drawdown varies with (1) length of time of pumping, (2) aquifer characteristics, (3) slope of the water surface, and (4) amount of recharge or natural discharge available for capture in the area of influence. The cone of depression will expand until natural discharge is captured or recharge is induced in sufficient quantities to balance pumping.

Problems may result from pumping where the cones of depression intercept (1) a surface-water body, such as a lake; (2) the saltwater-freshwater transition zone; or (3) another cone of depression, such as that developed by another pumping well or a spring. If a lake is intercepted and the lake bottom is fairly permeable, water levels in the lake may be lowered or the lake may be completely drained. If the saltwater-freshwater transition zone is intercepted,

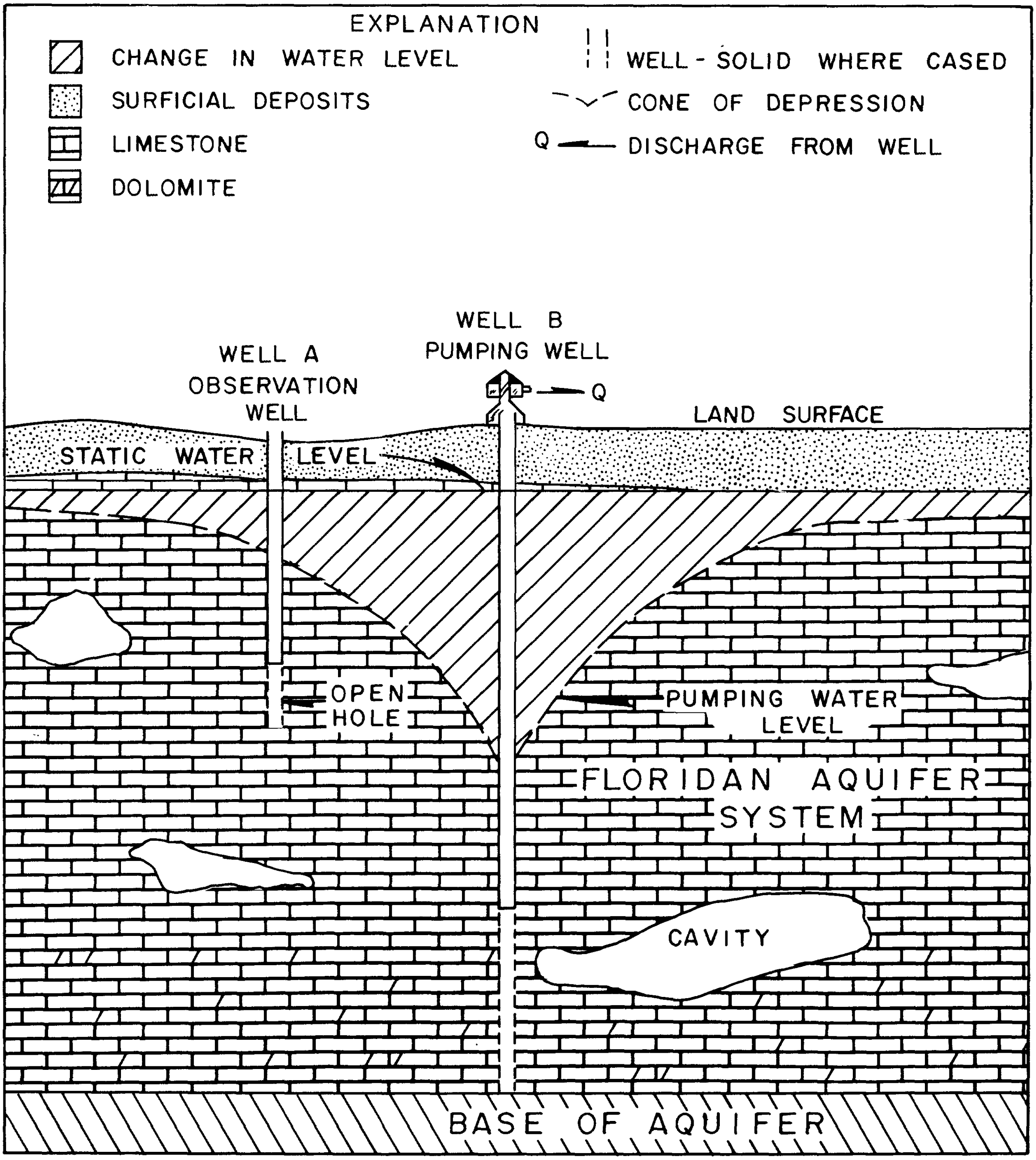

Figure 23.--Changes in water level resulting from pumping.

salty water may be drawn to the well and contaminate the water in it. If another cone of depression is intercepted, drawdowns of the two cones become additive. If a spring is intercepted, the spring head would be lowered, the rate of flow would be reduced, and a potential for saltwater intrusion would develop if the spring is near the coast.

Two aquifer tests were performed near Weeki Wachee Springs as part of this study to determine the aquifer properties at wells 93 and 101 (fig. 7, table 5). A hydrogeologic section through the pumping wells and the wells used for water-level observation are shown in figure 24. Table 5 describes the wells used in the test.

For the first aquifer test, well 93 was pumped at 1,080 gal/min for 48 hours. Water-level measurements were made in the pumped well and in observation wells 95 and 101 throughout the pumping period and after pumping ceased until water levels in the pumped well had fully recovered. A drawdown of 55 feet was measured in the pumped well at the end of the pumping period. Ninety percent of the drawdown occurred in the first minute of pumping. No drawdown was measured in wells 95 or 101, 309 feet and 1,063 feet away, respectively. Water levels in well 95 were measured for two zones, an intermediate zone 95B and a deep zone 95A. No appreciable change was detected in specific conductance of water during the test. Conductance ranged from 180 to 235 μmho/cm.

After the water level had recovered in well 93, well 101 was pumped at 1,850 gal/min for a 48-hour period. Drawdown at the end of the test was 5.4 feet. Ninety percent of the drawdown occurred in the first 1.5 minutes of pumping. No drawdown was measured in wells 93, 95, or in three shallow wells in the sand within 100 feet of the pumped well. Also, no appreciable change occurred in specific conductance of water from the pumped well during the test; conductance ranged from 155 to 185 μmho/cm.

The aquifer tests indicate that the Upper Floridan aquifer in this area can yield large quantities of water without the development of extensive cones of depression. Because no drawdown occurred in the observation wells, aquifer characteristics could not be determined. Water levels in both production wells approached steady state (no change with time) by the end of the 48-hour pumping period. This indicates that nearly sufficient water was captured to balance the well discharge and that further drawdown would have been very small if pumping had continued at the same rate.

Water quality did not change significantly during the test period even though the bottom of well 93 is at a 400-foot depth and is close to the saltwater-freshwater interface that occurs at a depth of about 500 feet. The trace for fluid conductance and resistance logs for well 95 shows a shift at a little below 500 feet in depth (fig. 25) that is believed to be the saltwater-freshwater transition zone. Conductivity data collected during the aquifer test suggest that mixing with freshwater from highly productive zones above the interface may dilute any water drawn upward and that during short periods of pumping there would be no significant deterioration of water quality.

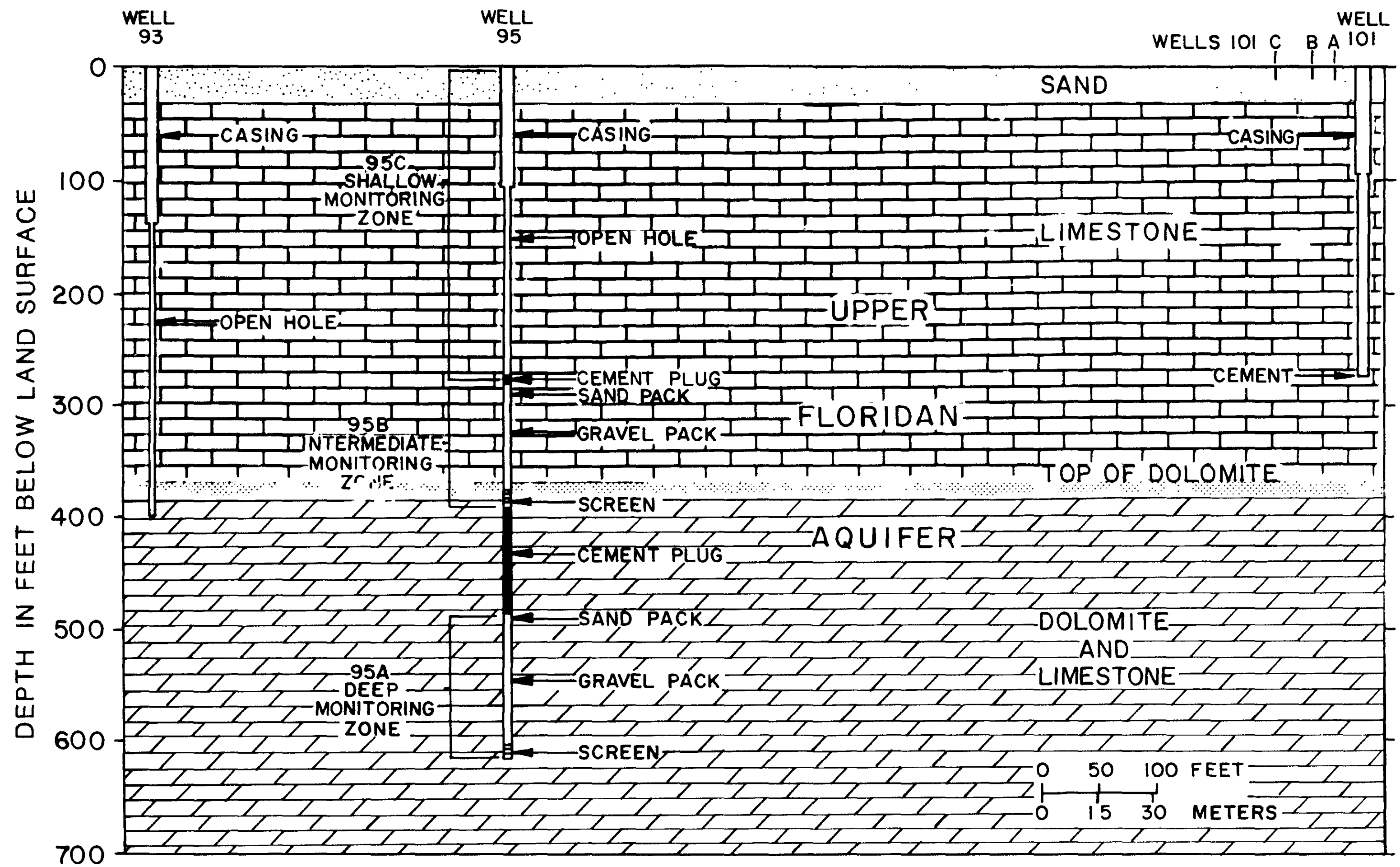

Figure 24.--Lithology and description of wells used in aquifer tests near Weeki Wachee, 1983.

Table 5.--Description of wells used in aquifer tests

Well	Well name	Description of well	Depth (feet)	Distance from pumped well, test 1 (feet)	Distance from pumped well, test 2 (feet)	Remarks
101	Production well 4	12-inch casing 8-inch open hole	0-97 97-275	1,063	0	Pumped well test 2.
93	Production well 3	10-inch casing 6-inch open hole	0-135 135-400	0	1,063	Pumped well test 1.
95A	WHCWS monitor well deep	2-inch pvc 6-inch screen	0-598 598-613	309	753	Triple zone monitor well originally drilled to 620 feet and cased to 104 feet.
95B	WHCWS monitor well intermediate	2-inch pvc 2-inch screen	0-377 377-392	309	753	Deep and intermediate wells are formed of pvc in the annulus and sealed to monitored zone. The shallow well is the annulus that is sealed below 280 feet.
95C	WHCWS monitor well shallow	8-inch casing 6-inch open hole	0-104 104-280	309	753	
101A	Shallow well 1	1-1/4-inch pvc 1-1/4-inch screen	0-13 13-17	--	18	Open in sand.
101B	Shallow well 2	1-1/4-inch pvc 1-1/4-inch screen	0-9 9-13	--	36	Open in sand.
101C	Shallow well 3	1-1/4-inch pvc 1-1/4-inch screen	0-9 9-13	--	72	Open in sand.

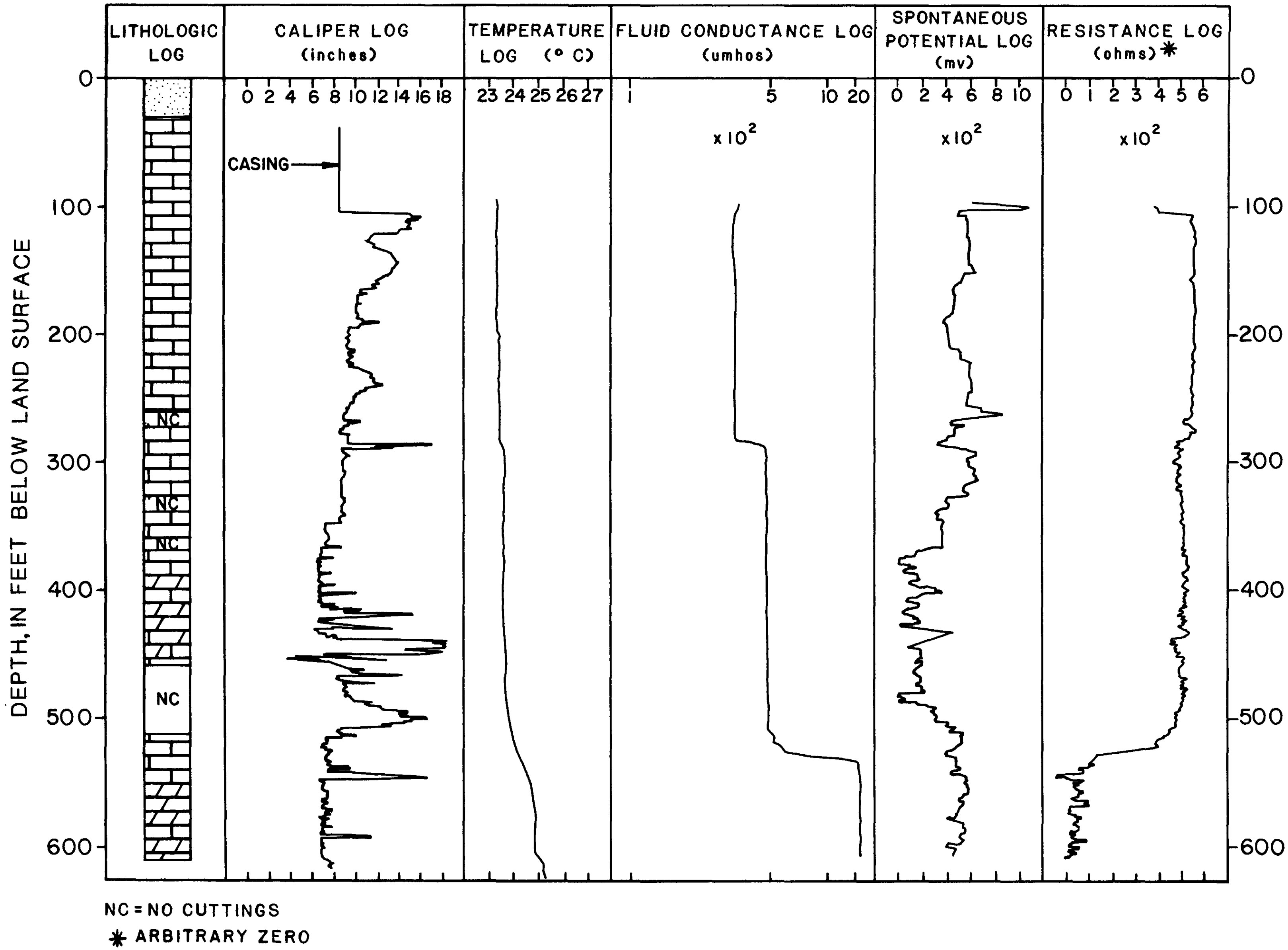

Figure 25.--Lithologic and geophysical logs for well 95 near Weeki Wachee.

WATER QUALITY

Chemical characteristics of ground water and surface water are affected by many factors. Composition and solubility of soil and rocks over and through which water flows and the length of time water is in contact with these materials largely determine the degree of mineralization. Ions from atmospheric precipitation contribute to mineralization of these waters. The nature and extent of interconnection of sinkholes, ponds, lakes, rivers, and the Gulf with the Upper Floridan aquifer affect the degree of mineralization of aquifer and surface water. Aquifer water will be diluted by surface water or vice versa depending on the nature of the interconnection. The mixing of freshwater and saltwater in coastal areas affects the quality of water in the Upper Floridan aquifer and the quality of water in channels along the Gulf.

Chemical characteristics of water may influence its use. The Florida Department of Environmental Regulation (1982) has established primary drinking-water regulations. These regulations set minimum standards for the quality of drinking water distributed by public water systems for human consumption. Secondary drinking-water recommendations (Florida Department of Environmental Regulation, 1983) recommend limits on certain chemical constituents that are not directly related to health, but rather to the esthetic quality of water. Criteria have also been developed for evaluating quality of water to be used for industrial and irrigation purposes (McKee and Wolf, 1963).

Chemical analyses of water samples from 54 selected wells, 16 lakes or ponds, and 3 rivers were made for this study. Results of these analyses and of analyses of samples collected previously from these and other sites are listed in tables 6 and 7. Sampled wells range in depth from 33 to 757 feet and are distributed areally within the county. Water generally meets recommended limits of constituent concentrations set by the Florida Department of Environmental Regulation (1982; 1983) except along the coast where saltwater is present in the Upper Floridan aquifer and in tidal reaches of the rivers.

Concentrations of most constituents increase toward the coast and with depth. Silica concentrations are generally higher in inland areas and are probably related to percolation of water through sand and clay. Iron concentrations are generally highest in the eastern part of the county near the rivers and in the western part of the county near the coast. Sites where iron concentrations were observed to exceed the recommended limits of 300 ug/L are shown in figure 26.

High iron concentrations appear to be associated with wells that have shallow casings. Iron is commonly found as a product of a reducing environment in swamps and marshes. Water from shallow sources such as these is easily drawn to shallow cased wells. Increasing casing lengths might alleviate some high iron-concentration problems. Hydrogen sulfide was detected in water from several wells near the Withlacoochee River. Hydrogen sulfide is found in a similar environment to that in which iron is found. This constituent, although not measured for the study, can be detected in small concentrations by its odor.

Table 6.--Chemical analyses of water from wells open to the Floridan aquifer system

[mg/L, milligrams per liter; µg/L, micrograms per liter; µmhos, micromhos per centimeter at 25° Celsius; pCi/L, picocuries per liter]

Well	Station	Date of sample	Depth of well (feet)	Silica, dissolved (mg/L as SiO_2)	Iron, dissolved (µg/L as Fe)	Calcium, dissolved (mg/L as Ca)
2	282605082345801	5-21-80	355	7.9	--	8.6
4	282622082190701	1-14-83	206	14	50	36
5	282627082380801	1-25-83	92	5.0	70	93
6	282636082221401	1-28-83	69	6.3	400	83
7	282650082363301	1-25-83	275	7.2	10	35
8	282652082161701	11-02-82	275	8.1	400	41
9	282654082373801	1-25-83	--	7.8	50	25
10	282657082382501	7-13-60	101	-	--	--
14	282708082335201	11-02-82	395	5.3	0	30
17	282726082363701	11-02-82	373	5.3	50	32
19	282748082303801	11-03-82	320	6.8	0	38
20	282803082191201	9-19-78	340	19	270	80
23	282827082150801	11-02-82	200	9.6	0	41
24	282838082284801	5-30-80	400	7.7	70	54
25	282839082190801	9-19-78	428	0.9	790	27
26	282847082042801	1-14-83	--	7.4	830	63
29	282849082232201	5-30-80	230	-	20	86
30	282849082273501	11-03-82	300	11	20	82
32	282851082115101	11-03-82	--	8.6	--	64
34	282858082234801	11-02-82	208	12	0	84
35	282911082101001	9-18-78	135	5.6	30	56
37	282921082181101	9-20-78	260	6.8	90	45
40	282925082103201	11-03-82	--	5.3	600	54
41	282932082253301	5-30-80	275	8.7	520	77
42	282936082283501	11-03-82	190	6.8	30	33
43	282938082332001	5-31-80	380	5.9	230	48
44	282941082330801	11-03-82	484	9.2	10	52
45	282959082105201	9-20-78	300	6.0	<10	53
46	283001082064702	9-18-78	97	11	4,000	120
		1-14-83	97	9.3	2,900	120
47	283003082122201	11-01-82	60	5.6	--	21
48	283003082122202	11-01-82	125	3.9	160	35
49	283022082160701	9-19-78	421	9.7	<10	33
50	283026082200801	9-20-78	195	18	<10	87
51	283027082200801	11-03-82	445	18	20	95

Table 6.--Chemical analyses of water from wells open to the Floridan aquifer system--Continued

Well	Station	Date of sample	Depth of well (feet)	Silica, dis-solved (mg/L as SiO_2)	Iron, dis-solved (µg/L as Fe)	Calcium, dis-solved (mg/L as Ca)
53	283030082114101	11-03-82	200	6.8	20	41
55	283033082312001	11-03-82	400	7.7	30	26
57	283038082352701	5-31-80	86	8.1	0	51
58	283041082154201	9-19-78	160	9.1	20	31
63	283125082100501	9-19-78	95	6.8	3,500	110
64	283127082355101	11-19-80	--	-	--	44
65	283130082134901	9-19-78	600	7.8	70	44
68	283159082263701	11-02-82	140	11	0	80
69	283200082134801	11-03-82	602	8.3	90	47
71	283201082315601	5-21-80	259	6.6	50	--
72	283203082370201	11-01-82	75	3.4	1,300	120
73	283206082190601	11-03-82	370	10	10	39
75	283208082250202	12-14-82	--	9.6	10	96
77	283208082354701	11-03-82	--	7.5	30	49
78	283213082212101	9-20-78	180	8.3	230	60
79	283222082171701	11-01-82	194	9.6	35	31
		1-14-83	194	-	--	--
86	283235082311801	11-02-82	250	8.6	0	48
89	283240082335801	6-25-80	245	6.8	10	36
		11-02-82	245	7.3	0	43
90	283243082365701	5-07-80	302	10	2,800	38
91	283247082322901	11-03-82	250	6.6	30	36
95	283253082322401	11-03-82	620	-	--	--
97	283258082231901	3-09-62	602	11	20	66
		2-19-80	602	11	--	60
		5-30-80	602	10	10	--
		1-14-83	602	11	10	65
		10-19-83	602	-	--	--
98	283258082232201	9-01-71	757	10	--	61
100	283259082250101	5-30-80	500	11	10	70
102	283308082331901	6-18-80	125	5.3	630	41
104	283317082290501	11-02-82	325	7.7	0	41
106	283338082092401	1-14-83	--	6.3	2,800	86
108	283356082123301	9-20-78	--	6.5	20	41
109	283406082303101	11-02-82	247	7.7	0	45

Table 6.--Chemical analyses of water from wells open to the Floridan aquifer system--Continued

Well	Station	Date of sample	Depth of well (feet)	Silica, dis- solved (mg/L as SiO_2)	Iron, dis- solved (µg/L as Fe)	Calcium, dis- solved (mg/L as Ca)
110	283408082123801	12-08-82	--	8.8	30	58
111	283421082203301	11-01-82	300	8.8	35	38
112	283426082331501	1-13-83	200	6.3	530	54
113	283433082303801	5-31-80	117	6.6	1	37
114	283433082391301	6-18-80	33	7.6	8,100	270
116	283442082250001	11-02-82	220	9.6	0	72
118	283508082215101	9-20-78	361	9.9	0	45
120	283529082355801	6-16-80	140	1.5	50	25
122	283537082151501	1-28-79	198	10	<10	23
		1-12-83	198	7.8	20	30
124	283607082241501	5-30-80	--	9.2	10	30
127	283637082313301	5-31-80	145	7.3	0	76
128	283640082190201	1-14-83	188	7.3	50	35
129	283648082275201	5-30-80	250	13	10	38
130	283650082313301	1-13-83	170	.4	--	48
131	283706082292101	1-13-83	150	8.9	20	11
132	283719082273801	1-13-83	173	10	20	72
133	283728082222801	1-13-83	360	5.2	560	52
136	283743082213801	9-21-78	149	8.5	<10	47
		12-14-82	149	8.8	10	--
		1-14-83	149	-	--	--
137	283747082233201	11-01-82	160	11	0	56
139	283806082214801	9-21-78	155	8.5	<10	37
140	283808082324801	6-18-80	127	5.4	0	26
141	283815082281701	1-13-83	600	10	20	87
142	283815082282201	6-26-80	899	9.7	--	76
143	283819082170801	9-20-78	205	6.9	<10	73
144	283827082154801	1-14-83	--	-	--	84
145	283828082283301	1-13-83	--	8.9	20	28
148	283840082264401	1-13-83	275	6.1	3,000	73
149	283908082201301	9-20-78	143	8.0	<10	30
150	283917082183601	1-14-83	95	6.9	20	33
152	283932082281201	12-14-82	255	2.1	10	32
153	283940082253201	5-30-80	93	11	0	55
154	283957082181001	9-20-78	140	6.7	<10	36
157	284125082333401	11-01-82	218	8.1	50	43

Table 6.--Chemical analyses of water from wells open to the Floridan aquifer system--Continued

Well	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)
2	0.8	10	3.8	36	8.9	3.9	0.1
4	9.3	4.2	.2	123	.4	6.5	.1
5	1.4	2.9	0	250	0	5.2	0
6	1.2	4.1	.2	198	2.0	10	.1
7	2.0	2.6	.2	90	6.4	5.2	.1
8	4.4	4.9	.3	--	0	8.4	.1
9	2.2	3.5	.3	71	2.4	6.3	.1
10	-	-	-	--	-	-	-
14	2.0	2.3	.1	80	5.0	3.8	.1
17	1.4	3.0	.2	84	5.6	5.3	0
19	2.1	2.9	.1	99	4.4	4.8	.1
20	11	6.5	.4	210	1.4	19	-
23	6.0	4.7	.2	120	4.0	9.6	.1
24	5.1	15	.5	160	9.3	6.5	.1
25	1.2	3.3	.3	64	1.4	5.0	.3
26	1.0	4.4	.2	167	3.2	7.0	0
29	1.7	4.0	.2	210	1.6	6.5	.1
30	7.6	4.3	.2	226	7.8	13	.2
32	3.1	5.1	.3	167	8.8	8.0	.1
34	8.4	6.4	.3	243	2.2	10	.2
35	1.1	3.5	.1	140	1.2	5.6	<.1
37	4.1	5.3	.8	120	1.4	9.7	.1
40	1.1	2.7	.1	135	2.4	4.8	.1
41	1.6	4.8	.3	180	.8	6.4	.2
42	1.6	2.2	.1	80	5.2	3.4	.1
43	2.6	2.8	.2	130	1.5	4.8	.1
44	7.5	3.2	.3	157	6.9	5.4	.1
45	1.1	2.8	.1	130	1.8	4.3	.1
46	4.3	8.0	.2	300	1.4	15	.1
	4.2	8.6	.2	312	.4	13	.1
47	.5	2.0	.1	50	.8	3.5	.1
48	.5	2.0	0	89	2.6	3.8	.1
49	6.9	3.3	.3	98	5.5	5.1	.1
50	11	9.9	.6	250	4.9	16	.2
51	12	9.4	.3	278	5.8	17	.2

Table 6.--Chemical analyses of water from wells open to the Floridan aquifer system--Continued

Well	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)
53	0.9	2.6	0.1	100	1.6	4.4	0.1
55	2.4	2.3	.1	69	4.4	3.5	.1
57	7.3	3.1	.4	130	7.3	4.9	.1
58	4.7	3.8	.1	82	3.7	6.9	.1
63	2.3	7.4	.1	260	2.1	15	.1
64	7.2	-	-	130	7.5	-	-
65	4.6	3.7	.1	110	12	5.8	.1
68	1.6	4.2	.1	207	2.2	6.8	.1
69	5.3	4.2	.2	124	15	6.2	.1
71	-	-	-	--	-	-	-
72	44	350	9.3	121	70	720	.2
73	12	3.9	.2	138	7.1	6.2	.2
75	1.8	5.6	0	247	2.4	8.0	.1
77	3.6	3.3	.2	134	4.2	5.7	.4
78	3.3	6.7	.8	160	<1.0	10	.1
79	5.6	3.7	.1	90	4.8	5.5	.2
	-	-	-	--	-	-	-
86	6.0	3.2	.2	140	7.0	5.4	.1
89	2.5	3.1	.2	100	3.6	4.6	.1
	4.9	3.0	.1	121	6.3	5.1	.1
90	23	52	9.9	130	19	100	.2
91	2.8	2.7	.1	94	3.4	4.8	.6
95	-	-	-	--	-	-	-
97	-	-	-	--	-	-	-
	9.8	5.6	.3	180	13	9.2	-
	-	5.3	.2	180	16	10	-
	12	6.4	.1	180	16	9.8	-
	-	-	-	--	-	-	-
98	10	5.4	.3	187	11	9.0	.2
100	7.8	5.1	.2	190	9.8	9.2	.2
102	5.2	4.8	1.5	120	-	8.8	0
104	3.7	3.0	.1	112	6.4	4.8	.1
106	2.3	12	.3	220	0	25	0
108	1.0	2.5	.1	98	4.4	3.8	.1
109	3.7	3.0	.1	122	5.1	4.8	.1

Table 6.--Chemical analyses of water from wells open to the Floridan aquifer system--Continued

Well	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)
110	2.5	4.7	0.2	139	25	7.0	0.1
111	6.7	3.7	.1	112	5.6	5.7	-
112	1.2	4.1	.2	143	0	6.4	-
113	2.7	2.7	.1	90	3.9	4.2	-
114	310	1,300	91	520	670	5,300	.1
116	10	6.2	.2	213	8.0	13	.2
118	9.1	4.0	.1	130	8.6	6.5	.1
120	6.5	35	.8	85	.1	52	.1
122	2.7	7.4	.5	70	7.3	4.9	-
	3.4	3.5	.1	85	6.0	4.7	0
124	5.7	5.0	9.2	200	5.7	9.2	.2
127	4.1	2.8	.1	96	4.1	4.8	-
128	4.0	2.8	0	108	4.0	3.5	-
129	11	3.7	.2	150	7.8	5.4	.3
130	4.9	3.7	.3	45	.8	6.0	.1
131	5.3	5.7	.1	190	4.8	11	.1
132	13	4.5	.2	175	8.4	7.0	.1
133	3.8	1.3	5.6	133	.4	3.0	.1
136	6.8	3.1	.4	110	6.3	5.2	.1
	7.2	3.9	.1	111	4.8	5.8	0
	-	-	-	--	-	-	-
137	7.3	5.8	.4	171	5.4	6.2	.3
139	5.7	3.0	.4	110	6.0	5.0	.1
140	2.2	3.1	.1	65	1.1	5.0	.1
141	11	6.4	.2	244	6.8	10	.1
142	9.7	6.2	.4	210	7.9	.4	.2
143	2.6	2.7	.2	71	5.8	4.4	.1
144	1.4	4.4	0	184	4.8	7.0	0
145	10	6.8	.6	239	11	11	.1
148	2.8	6.4	.9	192	.4	12	0
149	5.2	3.3	.1	82	5.3	4.7	.1
150	2.7	3.3	0	89	5.2	5.5	0
152	2.3	5.9	.4	80	7.2	9.3	.3
153	14	6.0	.3	170	8.7	11	.2
154	2.2	2.9	.1	90	4.1	4.2	.1
157	12	3.6	.3	154	4.5	5.8	.2

Table 6.--Chemical analyses of water from wells open to the Floridan aquifer system--Continued

Well	Nitrogen NO_2+NO_3, dis-solved (mg/L as N)	Phos-phorus, dis-solved (mg/L as P)	Solids, sum of constit-uents, dis-solved (mg/L)	Hardness (mg/L as $CaCO_3$)	Hardness noncarbo-nate (mg/L as $CaCO_3$)	Specific conduc-tance (µmhos)	pH (units)
2	0.01	0.02	67	26	0	112	8.1
4	1.4	.01	170	130	--	240	7.9
5	0	0	260	240	--	450	7.7
6	-	-	230	210	--	405	7.3
7	.13	0	110	96	--	195	7.9
8	-	-	140	120	--	245	7.5
9	0	-	90	72	--	153	7.8
10	-	-	--	107	6	205	7.3
14	-	-	97	83	--	175	7.7
17	-	-	100	86	--	187	7.6
19	-	-	120	100	--	208	7.6
20	-	-	266	250	32	468	7.3
23	-	-	150	130	--	260	7.0
24	.09	.01	195	160	0	347	7.2
25	-	-	79	72	8	163	7.5
26	-	-	190	160	--	315	7.4
29	.02	.03	235	220	12	408	7.4
30	-	-	260	240	--	445	7.5
32	-	-	200	170	--	--	7.4
34	-	-	270	250	--	463	7.9
35	-	-	157	140	5	278	7.4
37	-	-	147	130	6	262	7.3
40	-	-	150	140	--	271	7.5
41	.05	.01	193	200	--	378	7.2
42	-	-	100	89	--	175	7.5
43	0	0	133	130	--	265	7.6
44	-	-	180	160	--	312	7.5
45	-	-	148	140	6	285	-
46	-	-	342	320	22	580	7.4
	-	-	320	320	--	586	7.1
47	-	-	64	55	--	112	7.1
48	-	-	97	89	--	170	7.0
49	-	-	123	110	13	231	7.8
50	-	-	296	260	17	550	7.4
51	-	-	320	290	17	560	7.3

Table 6.--Chemical analyses of water from wells open to the Floridan aquifer system--Continued

Well	Nitrogen NO_2+NO_3, dissolved (mg/L as N)	Phosphorus, dissolved (mg/L as P)	Solids, sum of constituents, dissolved (mg/L)	Hardness (mg/L as $CaCO_3$)	Hardness noncarbonate (mg/L as $CaCO_3$)	Specific conductance (µmhos)	pH (units)
53	-	-	120	110	--	210	7.3
55	-	-	88	75	--	155	7.3
57	0.02	0.01	148	160	0	304	7.6
58	-	-	109	97	15	207	7.4
63	-	-	305	280	22	600	7.3
64	-	-	--	140	--	--	-
65	-	-	147	130	14	270	7.7
68	-	-	230	210	--	400	7.8
69	-	-	160	140	--	275	7.4
71	.01	0	--	--	--	300	7.9
72	-	-	1,400	480	--	2,780	7.6
73	-	-	160	150	--	285	7.5
75	-	-	270	250	--	442	7.4
77	-	-	150	140	--	270	6.9
78	-	-	189	160	0	347	7.3
79	-	-	110	100	--	205	6.9
	-	-	--	--	--	--	-
86	-	-	160	150	--	289	7.6
89	.012	.01	118	100	0	229	7.7
	-	-	140	130	14	251	7.6
90	0	.01	334	190	60	620	8.0
91	-	-	110	100	--	196	6.8
95	-	-	--	--	--	1/ 2,500	-
97	-	-	233	210	20	410	7.8
	-	-	218	190	10	385	7.3
	.43	.03	--	--	--	402	-
	-	-	228	210	--	390	7.4
	-	-	--	--	--	350	7.5
98	-	-	220	193	6	389	6.5
100	.34	-	218	210	0	397	7.6
102	0	.01	140	120	4	274	7.8
104	-	-	130	120	--	237	7.5
106	-	-	260	220	--	459	7.4
108	-	-	119	110	8	272	7.7
109	-	-	140	130	--	259	7.6

1/ After 4 minutes of pumping.

Table 6.--Chemical analyses of water from wells open to the Floridan aquifer system--Continued

Well	Nitrogen NO_2+NO_3, dis- solved (mg/L as N)	Phos- phorus, dis- solved (mg/L as P)	Solids, sum of constit- uents, dis- solved (mg/L)	Hardness (mg/L as $CaCO_3$)	Hardness noncarbo- nate (mg/L as $CaCO_3$)	Specific conduc- tance (µmhos)	pH (units)
110	0.04	0.01	190	150	--	313	7.6
111	-	-	140	120	--	245	7.0
112	-	-	160	140	--	260	7.8
113	.06	-	114	110	--	205	7.7
114	.04	.50	10,100	2,000	1,400	19,600	6.5
116	-	-	250	220	--	440	7.9
118	-	-	162	150	19	300	7.7
120	0	.01	173	90	5	368	8.2
122	-	-	98	69	0	182	8.2
	-	-	110	89	--	179	8.6
124	.46	.06	--	210	--	421	7.5
127	.36	.02	113	100	0	219	7.8
128	-	-	120	110	--	210	2.9
129	.02	.02	172	170	0	321	7.6
130	-	-	54	48	--	95	8.6
131	-	-	220	200	--	381	7.4
132	.08	.01	200	180	--	341	7.7
133	.03	.88	150	130	--	265	7.6
136	-	-	126	110	0	232	7.7
	-	-	--	120	--	230	8.0
	-	-	--	--	--	230	8.0
137	-	-	190	170	--	342	7.2
139	-	-	135	120	1	240	7.7
140	.53	.01	84	74	9	--	7.8
141	.76	.02	280	60	--	457	7.8
142	.33	-	239	230	20	--	-
143	-	-	--	--	--	--	-
144	-	-	213	190	--	359	7.4
145	.75	.02	280	250	--	457	7.8
148	-	-	220	190	--	389	7.6
149	-	-	106	97	15	198	7.9
150	-	-	110	94	--	191	8.0
152	0	.03	110	89	--	193	7.4
153	.79	0	201	200	0	388	7.6
154	-	-	111	99	9	207	7.7
157	-	-	170	160	--	305	7.3

Table 6.--Chemical analyses of water from wells open to the Floridan aquifer system--Continued

Well	Temperature (°C)	Strontium, dissolved (μg/L as Sr)	Bicarbonate IT-lab (mg/L as HCO_3)	Carbonate IT-lab (mg/L as CO_3)	Gross alpha, dissolved (pCi/L as U-nat)	Gross beta, dissolved (pCi/L as CS-137)	Nitrogen, organic, dissolved (mg/L as N)
2	25.0	1,100	--	--	-	-	-
4	22.5	82	150	0	<3.3	<1.9	0.05
5	-	170	300	--	-	-	0
6	23.0	76	242	0	-	-	0
7	-	200	110	0	-	-	-
8	22.0	78	148	0	-	-	-
9	-	--	86	0	-	-	0
10	-	--	124	0	-	-	-
14	24.5	110	98	0	-	-	-
17	24.0	90	102	0	-	-	-
19	24.0	110	121	0	-	-	-
20	23.5	160	260	0	-	-	-
23	22.5	130	147	0	-	-	-
24	24.0	150	--	--	-	-	-
25	23.0	50	78	0	-	-	-
26	21.5	62	204	0	-	-	-
29	25.5	80	--	--	-	-	-
30	24.0	230	276	0	-	-	-
32	23.5	170	204	0	-	-	-
34	-	340	296	0	-	-	-
35	23.5	90	170	0	-	-	-
37	23.5	90	150	0	-	-	-
40	24.5	60	165	0	-	-	-
41	25.5	170	--	--	-	-	-
42	24.5	180	98	0	-	-	-
43	25.5	140	--	--	-	-	-
44	25.0	200	191	0	-	-	-
45	23.5	80	160	0	-	-	-
46	23.5	140	360	0	-	-	-
	23.5	110	380	0	-	-	-
47	24.5	26	61	0	-	-	-
48	23.5	22	108	0	-	-	-
49	24.0	230	120	0	-	-	-
50	23.0	170	300	0	-	-	-
51	21.5	120	339	0	-	-	-

Table 6.--Chemical analyses of water from wells open to the Floridan aquifer system--Continued

Well	Temperature (°C)	Strontium, dissolved (µg/L as Sr)	Bicarbonate IT-lab (mg/L as HCO_3)	Carbonate IT-lab (mg/L as CO_3)	Gross alpha, dissolved (pCi/L as U-nat)	Gross beta, dissolved (pCi/L as CS-137)	Nitrogen, organic, dissolved (mg/L as N)
53	24.0	50	122	0	-	-	-
55	24.5	190	84	0	-	-	-
57	24.0	190	--	--	-	-	-
58	23.0	130	100	0	-	-	-
63	24.0	180	320	0	-	-	-
64	-	--	--	--	-	-	-
65	24.5	230	140	0	-	-	-
68	22.5	190	252	0	-	-	-
69	23.5	390	150	0	-	-	-
71	25.0	530	--	--	-	-	-
72	23.0	1,400	147	0	-	-	-
73	24.5	110	169	0	-	-	-
75	23.0	160	302	0	-	-	-
77	24.0	120	164	0	-	-	-
78	23.0	110	200	0	-	-	-
79	23.5	90	110	0	-	-	-
	-	--	--	--	2.9	<1.1	-
86	24.0	220	170	0	-	-	-
89	25.0	90	--	--	-	-	-
	24.0	150	148	0	-	-	-
90	21.0	660	--	--	-	-	-
91	23.0	90	114	0	-	-	-
95	-	--	--	--	-	-	-
97	-	--	232	0	-	-	-
	23.0	230	--	--	-	-	-
	26.0	200	--	--	-	-	-
	24.0	290	220	0	<5.5	<3.0	-
	23.0	--	--	--	-	-	-
98	-	0	228	0	-	-	-
100	26.0	210	--	--	-	-	-
102	25.0	90	--	--	-	-	-
104	24.0	180	136	0	-	-	-
106	21.5	160	268	0	-	-	-
108	23.0	100	120	0	-	-	0.12
109	24.0	--	149	0	-	-	-

Table 6.--Chemical analyses of water from wells open to the Floridan aquifer system--Continued

Well	Temperature (°C)	Strontium, dissolved (µg/L as Sr)	Bicarbonate IT-lab (mg/L as HCO_3)	Carbonate IT-lab (mg/L as CO_3)	Gross alpha, dissolved (pCi/L as U-nat)	Gross beta, dissolved (pCi/L as CS-137)	Nitrogen, organic, dissolved (mg/L as N)
110	25.5	--	170	0	-	-	-
111	24.0	110	137	0	-	-	-
112	21.5	77	174	0	-	-	0.63
113	25.0	100	--	--	-	-	-
114	27.5	2,500	--	--	-	-	-
116	22.5	240	260	0	-	-	-
118	23.5	170	160	0	-	-	-
120	24.0	450	--	--	-	-	-
122	23.0	180	85	0	-	-	-
	24.0	290	100	2	-	-	-
124	24.5	130	--	--	-	-	-
127	26.5	100	--	--	-	-	-
128	22.0	130	132	0	-	-	-
129	26.0	120	--	--	-	-	-
130	24.0	68	55	0	-	-	-
131	21.0	130	232	0	-	-	-
132	22.5	250	214	0	-	-	.19
133	21.5	72	161	0	-	-	.62
136	23.5	170	130	0	-	-	-
	24.0	140	135	0	-	-	-
	24.0	--	--	--	<3.1	1.8	-
137	24.5	130	208	0	-	-	-
139	24.0	160	140	0	-	-	-
140	28.0	50	--	--	-	-	-
141	22.0	180	298	0	-	-	.14
142	23.5	270	--	--	-	-	-
143	23.5	130	87	0	-	-	-
144	20.5	77	224	0	-	-	-
145	22.5	190	292	0	-	-	.09
148	22.5	83	234	0	<5.2	<3.0	-
149	23.5	170	100	0	-	-	-
150	23.0	100	108	0	-	-	-
152	23.0	67	98	0	-	-	0
153	25.5	120	--	--	-	-	-
154	24.0	110	110	0	-	-	-
157	24.0	160	188	0	-	-	-

Table 6.--Chemical analyses of water from wells open to the Floridan aquifer system--Continued

Well	Nitrogen, ammonia, dissolved (mg/L as N)	Phosphate, ortho, dissolved (mg/L as PO_4)	Nitrogen, nitrite, dissolved (mg/L as NO_2)
2	-	-	-
4	0.04	0.03	0
5	.14	0	0
6	-	-	-
7	.01	0	0
8	-	-	-
9	.01	-	-
10	-	-	-
14	-	-	-
17	-	-	-
19	-	-	-
20	-	-	-
23	-	-	-
24	-	-	-
25	-	-	-
26	-	-	-
29	-	-	-
30	-	-	-
32	-	-	-
34	-	-	-
35	-	-	-
37	-	-	-
40	-	-	-
41	-	-	-
42	-	-	-
43	-	-	-
44	-	-	-
45	-	-	-
46	-	-	-
	-	-	-
47	-	-	-
48	-	-	-
49	-	-	-
50	-	-	-
51	-	-	-

Table 6.--Chemical analyses of water from wells open to the Floridan aquifer system--Continued

Well	Nitrogen, ammonia, dissolved (mg/L as N)	Phosphate, ortho, dissolved (mg/L as PO_4)	Nitrogen, nitrite, dissolved (mg/L as NO_2)
53	-	-	-
55	-	-	-
57	-	-	-
58	-	-	-
63	-	-	-
64	-	-	-
65	-	-	-
68	-	-	-
69	-	-	-
71	-	-	-
72	-	-	-
73	-	-	-
75	-	-	-
77	-	-	-
78	-	-	-
79	-	-	-
	-	-	-
86	-	-	-
89	-	-	-
	-	-	-
90	-	-	-
91	-	-	-
95	-	-	-
97	-	-	-
	-	-	-
	-	-	-
	-	-	-
	-	-	-
98	-	-	0
100	-	-	-
102	-	-	-
104	-	-	-
106	-	-	-
108	-	-	-
109	-	-	-

Table 6.--Chemical analyses of water from wells open to the Floridan aquifer system--Continued

Well	Nitrogen, ammonia, dissolved (mg/L as N)	Phosphate, ortho, dissolved (mg/L as PO_4)	Nitrogen, nitrite, dissolved (mg/L as NO_2)
110	0.01	0.03	0
111	-	-	-
112	.90	.03	0
113	-	-	-
114	-	-	-
116	-	-	-
118	-	-	-
120	-	-	-
122	-	-	-
	-	-	-
124	-	-	-
127	-	-	-
128	-	-	-
129	-	-	-
130	-	-	-
131	-	-	-
132	.01	.03	0
133	.54	2.10	0
136	-	-	-
	-	-	-
	-	-	-
137	-	-	-
139	-	-	-
140	-	-	-
141	.02	.06	0
142	-	-	-
143	-	-	-
144	-	-	-
145	.01	-	-
148	-	-	-
149	-	-	-
150	-	-	-
152	.04	.03	-
153	-	-	0
153	-	-	-
157	-	-	-

Table 7.--Chemical analyses of water from streams, lakes, springs, and sinkholes

[μmhos, micromhos per centimeter at 25° Celsius; mg/L, milligrams per liter; μg/L, micrograms per liter]

Site	Station identification	Date	Temperature (°C)	Color (platinum-cobalt units)	Specific conductance (μmhos)	pH (units)
1	02310210	12-02-82	26.5	50	75	5.6
3	02310219	6-27-83	-	--	--	-
4	02310220	11-17-82	24.0	160	68	6.0
5	02310232	12-02-82	28.0	40	85	5.7
7	02310400	1-25-83	25.0	10	114	7.6
9	02310449	12-01-82	27.0	35	56	5.1
10	02310490	12-01-82	28.0	15	58	5.8
15	02310616	11-22-82	27.5	45	93	6.2
16	02312000	12-06-82	27.0	110	251	6.4
17	02312100	11-17-82	24.0	10	170	6.8
18	02312180	12-06-82	25.0	260	67	4.2
19	02312200	4-20-81	24.0	10	288	5.9
20	02312500	12-08-82	26.0	110	--	7.2
21	02312520	11-23-82	23.0	80	49	5.8
22	02312527	11-22-82	25.0	35	220	7.3
23	282558082363100	4-05-83	-	--	458	-
26	282638082184100	11-17-82	25.0	40	62	5.8
29	282759082215900	10-05-77	20.0	--	62	-
32	283109082123500	4-14-81	24.5	10	340	-
34	283125082354800	12-15-82	23.5	0	270	7.8
36	283212082340700	11-22-82	25.0	35	202	7.3
37	283217082245600	12-02-82	26.0	10	88	6.1
41	283927082275700	11-23-82	25.5	5	167	8.7
44	283938082275200	12-15-82	21.0	80	279	7.5

Table 7.--Chemical analyses of water from streams, lakes, springs, and sinkholes--Continued

Site	Hardness (mg/L as $CaCO_3$)	Calcium, dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L as Mg)	Sodium, dis-solved (mg/L as Na)	Potas-sium, dis-solved (mg/L as K)	Chlo-ride, dis-solved (mg/L as Cl)	Sulfate, dis-solved (mg/L as SO_4)
1	35	12	1.1	1.5	0.6	2.8	4.8
3	--	-	-	-	-	-	-
4	20	4.8	2.0	4.4	2.1	8.6	-
5	27	6.5	2.7	5.3	1.3	13	4.9
7	43	15	1.4	4.8	.8	9.8	11
9	20	6.6	.8	2.9	.3	5.2	6.2
10	25	8.5	.9	2.3	.1	3.8	4.3
15	27	9.0	1.1	4.8	.5	8.5	13
16	130	45	3.8	7.8	.6	13	6.4
17	58	13	6.2	7.4	5.4	20	12
18	23	7.1	1.3	5.3	.2	14	7.7
19	120	46	2.1	6.6	.2	11	.5
20	130	46	3.1	6.1	.4	9	5.1
21	15	3.9	1.2	2.9	1.2	5.4	-
22	110	43	1.6	3.4	.6	6.0	8.0
23	--	84	5.2	-	-	29	130
26	14	2.4	1.9	5.8	0	11	4.0
29	--	-	-	-	-	-	-
32	160	58	3.9	7.8	1.0	5.0	9.3
34	140	48	5.8	3.5	0	5.7	7.2
36	110	43	1.6	3.4	.6	6.0	8.0
37	40	14	1.1	1.8	1.0	3.2	.6
41	67	24	1.7	6.3	.9	9.7	7.2
44	140	50	3.3	7.2	.5	14	5.6

Table 7.--Chemical analyses of water from streams, lakes, springs, and sinkholes--Continued

Site	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Iron, dissolved (µg/L as Fe)	Specific conductance (lab) (µmhos)	Alkalinity (mg/L as $CaCO_3$)	Bicarbonate (mg/L as HCO_3)	Carbonate (mg/L as CO_3)
1	0.2	2.1	260	74	28	34	0
3	-	-	--	--	--	--	-
4	.2	6.0	230	64	12	15	0
5	.2	.2	50	83	15	18	0
7	.1	0	20	109	27	33	0
9	.1	.2	30	56	10	12	0
10	.1	.2	0	58	18	22	0
15	.2	.2	20	86	12	14	0
16	.2	7.1	470	260	115	141	0
17	.2	0	35	170	39	48	0
18	.2	.9	70	66	2	3	0
19	.2	1.4	--	--	--	--	-
20	.2	6.4	470	255	120	146	0
21	.2	.2	60	48	8	9	0
22	.2	.9	40	220	103	126	0
23	-	-	--	--	--	--	-
26	.2	.6	55	62	5	6	0
29	-	-	--	--	--	--	-
32	.1	1.0	--	--	154	188	0
34	0	8.2	0	270	134	164	0
36	.2	.9	40	220	103	126	0
37	.2	.6	0	86	35	43	0
41	.7	.6	0	175	59	72	0
44	.1	7.5	50	279	128	156	0

Table 7.--Chemical analyses of water from streams, lakes, springs, and sinkholes--Continued

Site	Strontium, dissolved (μg/L as Sr)	Solids, residue at 180°C, dissolved (mg/L)	Solids, sum of constituents, dissolved (mg/L)	Nitrogen, organic, total (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia, total (mg/L as N)	Nitrogen, nitrite, dissolved (mg/L as N)
1	30	76	20	1.70	0.200	0.200	0
3	--	--	--	-	-	-	-
4	15	72	36	.84	.012	.120	.010
5	17	74	43	.74	.010	.010	0
7	70	75	63	.66	.010	.010	0
9	20	62	30	1.10	.030	.030	0
10	20	47	31	.54	.020	.020	0
15	40	76	44	.65	.020	.020	0
16	120	197	150	.59	.040	.040	.010
17	33	113	88	.76	.410	.430	0
18	10	128	38	1.30	0	0	.010
19	110	161	143	-	-	-	-
20	100	191	150	.38	.060	.060	.010
21	30	76	20	1.70	.200	.200	0
22	100	157	130	.44	.100	.120	0
23	--	--	--	-	-	-	-
26	21	48	29	-	.030	.030	-
29	--	--	--	1.40	-	.050	-
32	360	203	179	-	-	-	-
34	170	158	160	.02	.010	.010	.010
36	100	157	130	.44	.100	.120	0
37	13	71	44	1.20	.100	.100	.010
41	70	84	91	.27	.010	.010	0
44	160	189	170	.49	.050	.050	.010

Table 7.--Chemical analyses of water from streams, lakes, springs, and sinkholes--Continued

Site	Nitrogen, nitrate, dissolved (mg/L as N)	Nitrogen, ammonia, organic, total (mg/L as N)	Nitrogen, NO_2+NO_3, dissolved (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as NO_4)	Nitrogen, nitrate, dissolved (mg/L as NO_3)	Nitrogen, nitrite, dissolved (mg/L as NO_2)	Phosphate, ortho, dissolved (mg/L as PO_4)
1	0	0.69	0.02	0.14	0	0.07	0.02
3	-	-	-	-	-	-	-
4	.02	.96	.03	.15	.10	.03	.03
5	0	.75	0	.01	0	0	0
7	0	.67	.01	.55	0	0	.03
9	.31	1.13	.31	.04	1.40	0	.31
10	0	.56	0	.03	0	0	0
15	0	.65	0	.03	0	0	0
16	.24	.63	.25	.05	1.10	.03	.25
17	.06	1.19	.06	.53	.30	0	.06
18	.02	1.30	.03	0	.10	.03	.03
19	-	-	-	-	-	-	-
20	.15	.73	.16	.08	.70	.03	.16
21	.02	1.90	.02	.26	.10	0	.02
22	.02	.56	.02	.13	.10	0	.02
23	-	-	-	-	-	-	-
26	.01	.41	.01	.04	0	0	.01
29	-	-	-	-	-	-	-
32	-	-	-	-	-	-	-
34	.11	.03	.11	.01	.50	0	.11
36	.02	.56	.02	-	.010	0	0
37	0	1.30	.01	.13	0	.03	.01
41	0	.28	0	.01	0	0	0
44	.15	.54	.16	.06	.70	.03	.16

Table 7.--Chemical analyses of water from streams, lakes, springs, and sinkholes--Continued

Site	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)	Nitrogen, ammonia, dissolved (mg/L as NO_4)
1	0.160	0.020	0	0.14
3	-	-	-	-
4	.130	.110	.100	.15
5	.020	.010	0	.01
7	.030	.020	.010	.01
9	.020	.070	.120	.04
10	.130	.010	0	.03
15	.030	.010	0	.03
16	.110	.090	.080	.05
17	.020	.010	.010	.53
18	.020	.030	.020	0
19	-	-	-	-
20	.100	.070	.050	.08
21	.030	.020	.010	.26
22	.020	0	0	.13
23	-	-	-	-
26	.020	.020	.010	.04
29	-	-	-	-
32	-	-	-	-
34	.020	.020	.010	.01
36	.020	0	0	.13
37	.100	.020	.010	.13
41	.020	.010	0	.01
44	.070	.060	.050	.06

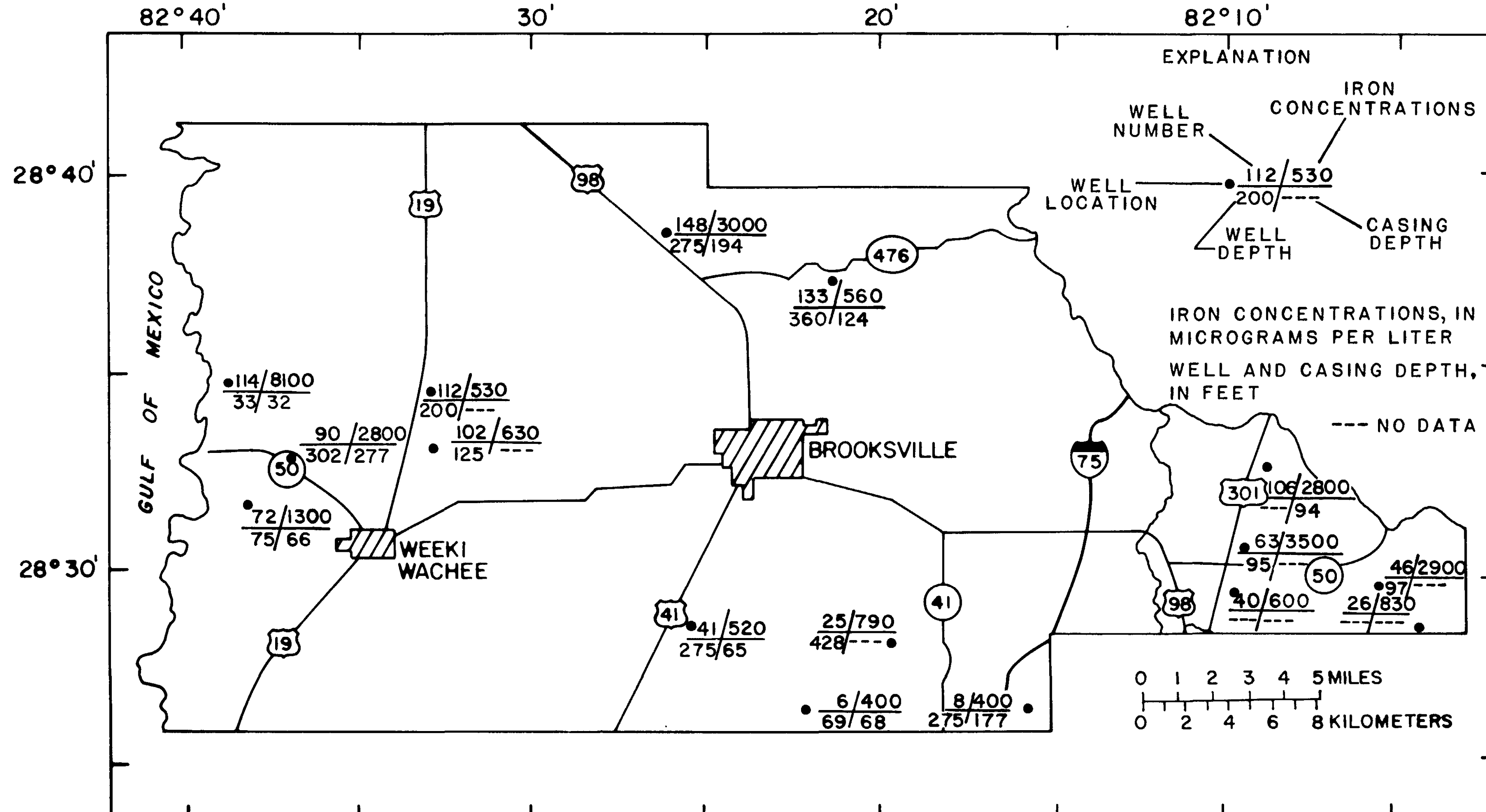

Figure 26.--Sites where concentrations of dissolved iron were greater than 300 micrograms per liter in water from the Upper Floridan aquifer.

Concentrations of constituents were almost always higher for ground water than for surface water except near the coast (tables 6 and 7). Ground water generally is in contact with rocks and minerals for longer periods of time than surface water, which results in higher mineral content. High concentrations of dissolved solids in water are found only near the coast. Figure 27 shows the areal distribution of specific conductance in the Upper Floridan aquifer. Specific conductance is generally proportional to dissolved solids. Highest values of conductance are found in the coastal area.

Increases in specific conductance or chloride concentrations may indicate areas of potential contamination by saltwater. A chloride concentration of 250 mg/L is the recommended maximum limit for drinking water (Florida Department of Environmental Regulation, 1983). Several wells along the coast have been monitored periodically for specific conductance and chloride concentration. Figure 28 shows changes in chloride concentration with time in three wells. Water from well 72 shows a gradual increase in concentration. Scatter in concentration is likely related to tidal cycles. The upward trend in chloride concentrations in water from well 72 indicates saltwater encroachment.

Saltwater encroachment threatens the quality of ground water along the coast. Here, saltwater underlies freshwater in a wedge that diminishes in thickness in the landward direction (Cooper and others, 1964). A zone of mixing between saltwater and freshwater, caused by mechanical dispersion and molecular diffusion, is referred to in this report as the transition zone. The transition zone contains water that ranges from saltwater (about 19,000 mg/L chloride) to freshwater (less than 25 mg/L chloride). The zone is not static; it shifts with changes in recharge to and discharge from the aquifer (Causseaux and Fretwell, 1983, p. 9).

In the vicinity of the coast, the landward advance of saltwater is held in dynamic equilibrium as it is eroded by overriding freshwater moving seaward. The volume of seawater moving inland is balanced by the eroded seawater moving seaward in admixture with freshwater in the zone of transition (Cooper and others, 1964). The general shape of the transition zone at one section along the coast is shown in figure 29. The section was constructed using well data within a 5-mile-wide band. Most data were collected in 1983, but data collected as early as 1965 were also used. At its steepest part, the interface drops about 250 feet per mile.

Encroachment of seawater results from a lowering of head in the aquifer caused by man or from natural causes, such as increased withdrawals from the aquifer or reduced rainfall and recharge. The rate and extent of landward movement of saltwater are determined primarily by the net hydraulic gradient (the difference between the freshwater head and the saltwater head) and hydraulic characteristics of the aquifer.

Chloride concentrations in water from wells in or very near the transition zone will increase if the freshwater head is reduced by deficient rainfall. If the natural balance of the system is not disturbed and mixing due to pumping does not occur at the wells, chloride concentrations may return to near their original concentrations after the return of normal rainfall. However, if mixing has occurred due to pumping of water from the transition zone, high concentrations of chloride may continue for a long period of time.

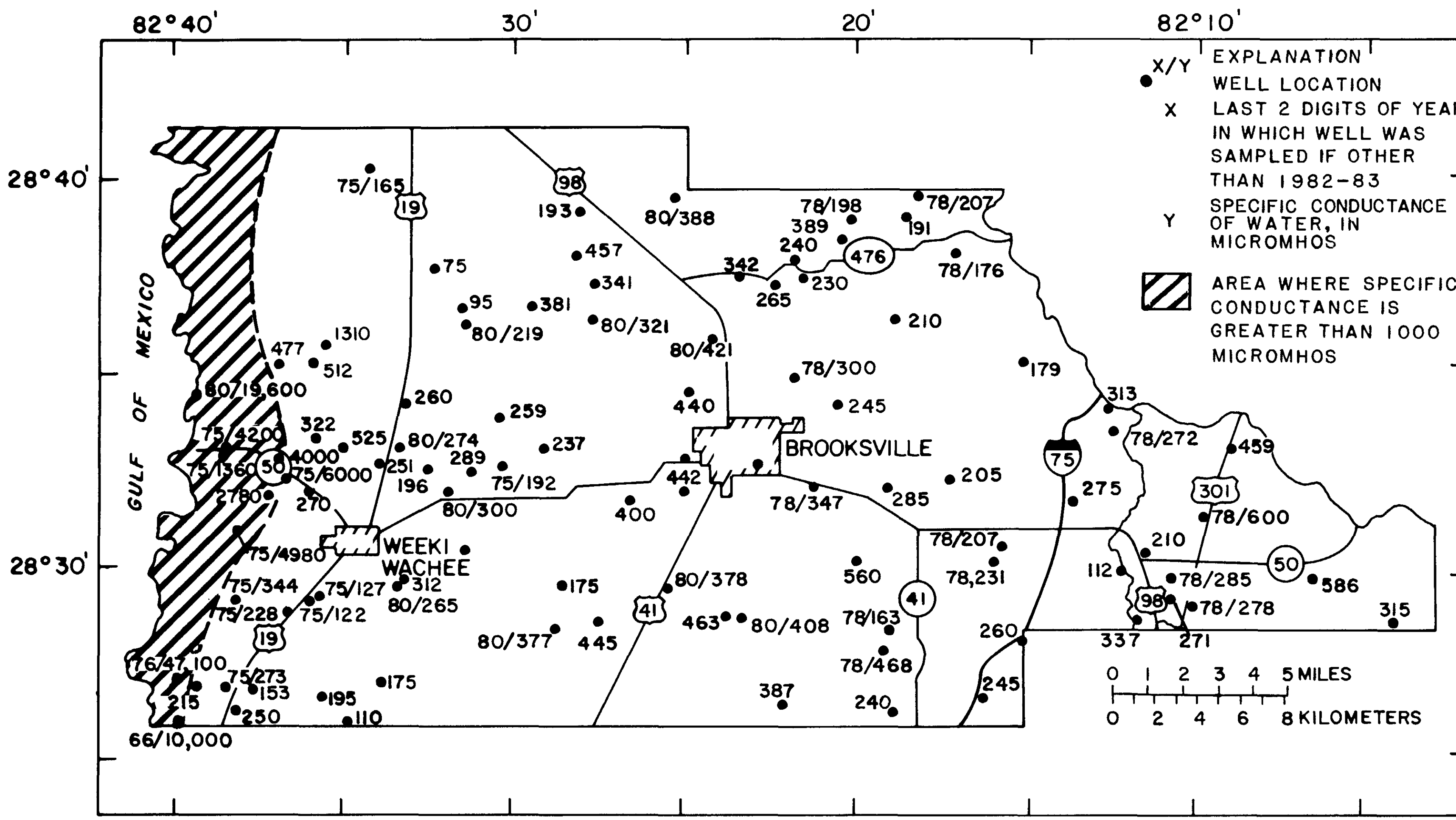

Figure 27.--Specific conductance of water in the Upper Floridan aquifer.

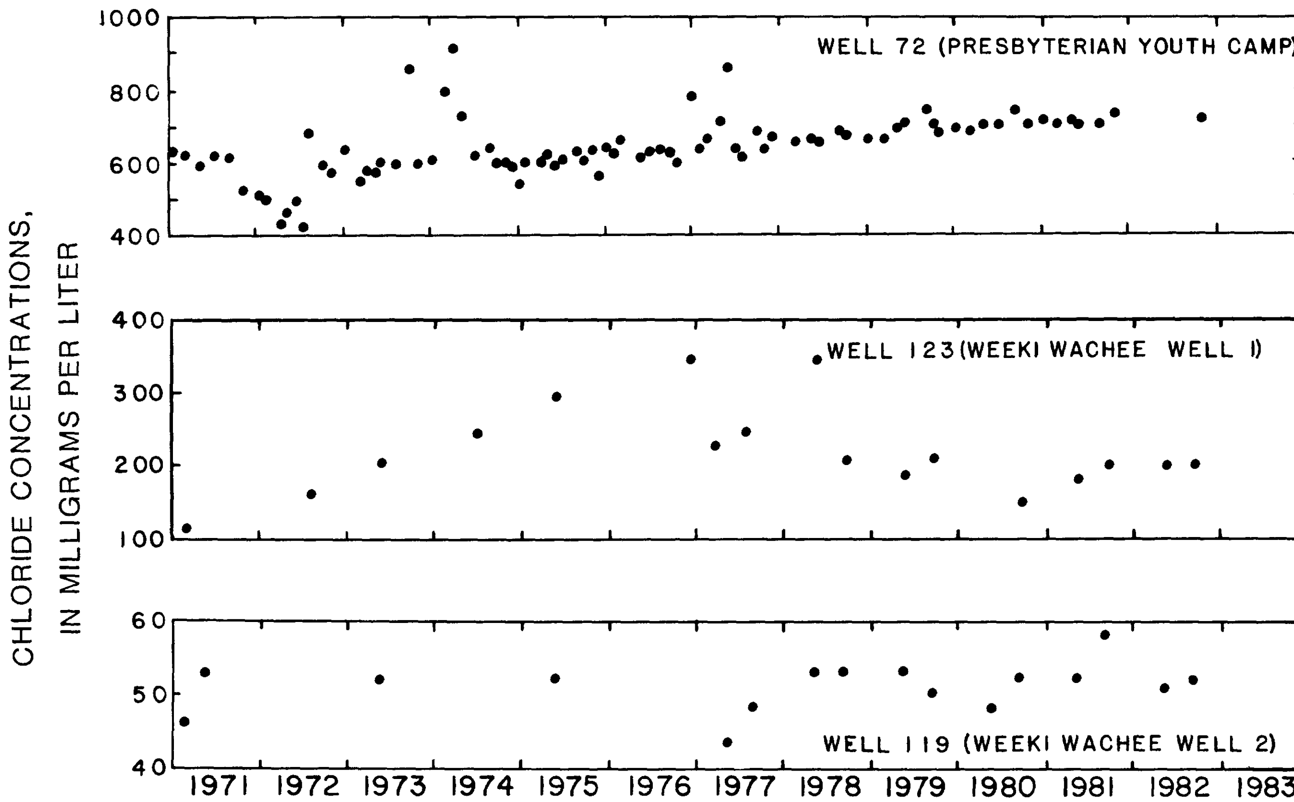

Figure 28.--Concentrations of chloride in water from three wells in the coastal area, 1971-83.

In coastal areas, chloride concentrations fluctuate in rivers and springs with tide. During rising tide, seawater flows up stream channels and often rises in springs that feed these streams. This causes increases in chloride concentrations in the lower reaches of streams and at some springs farther upstream until the tide again recedes.

EFFECTS OF FUTURE DEMANDS ON WATER RESOURCES

Ground-Water Flow Model

The Trescott-Larson (1976) quasi-three-dimensional ground-water flow model, as applied in west-central Florida and used in this study to determine impacts of ground-water development, is described in detail by Ryder (1982). Briefly, the model consists of a sequence of two-dimensional ground-water flow models that

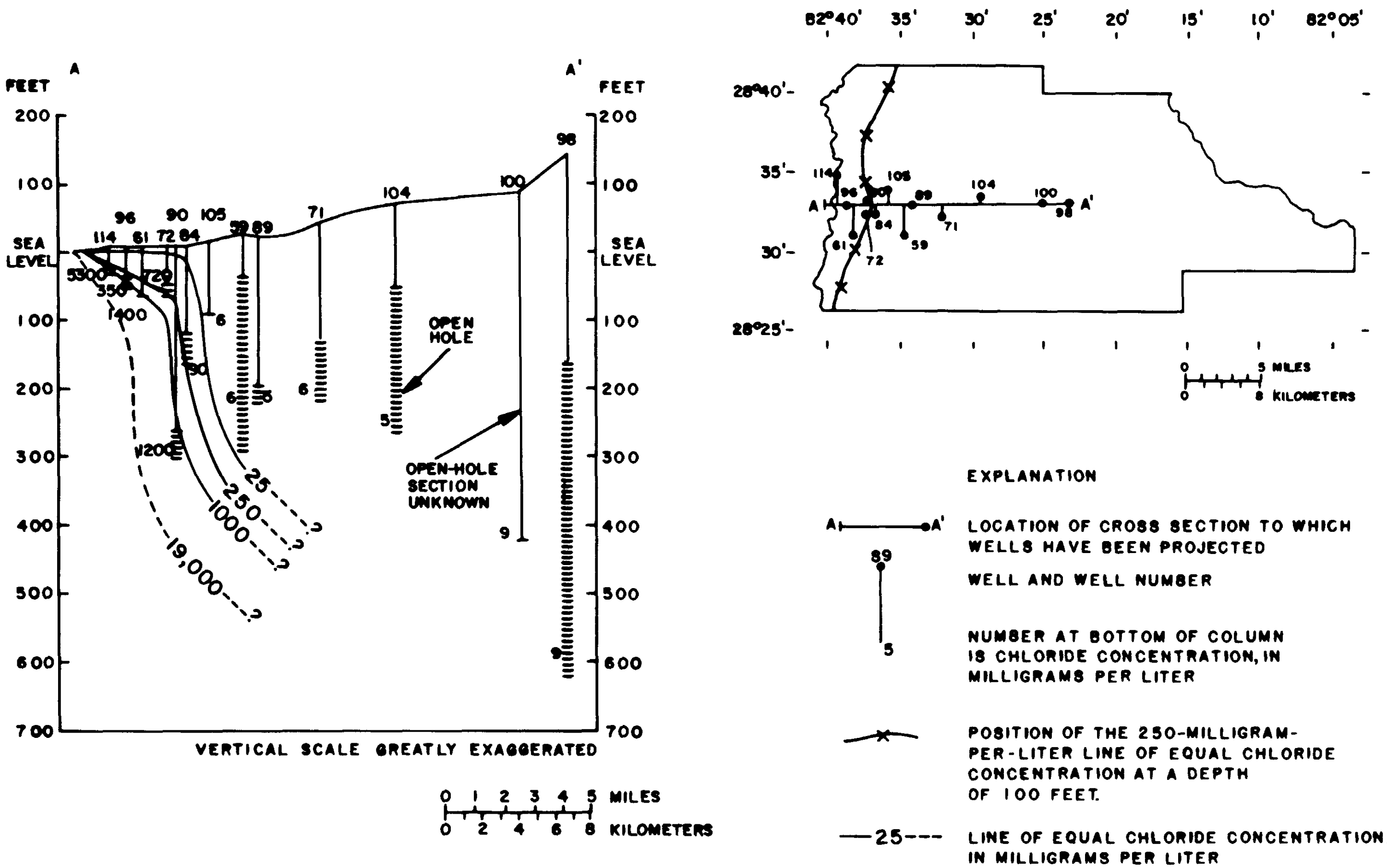

Figure 29.--Saltwater-freshwater transition zone in the Upper Floridan aquifer (from Mills and Ryder, 1977; Causseaux and Fretwell, 1982; Fretwell, 1983).

are connected by allowing vertical leakage to occur through confining beds between each layer. In areas where a water-table aquifer does not overlie the Floridan aquifer system, as is the case in Hernando County, direct recharge replaces leakage to the aquifer.

A model for simulating steady-state conditions in southwest Florida, including the Hernando County area, was developed by Ryder (1982). The model has a uniform grid spacing of 4 miles, and input values are averaged over 16-mi^2 areas (fig. 30). Input to the model, as used for this study, includes (1) estimated annual recharge to the Floridan aquifer system, (2) estimated transmissivity of the aquifer, (3) spring-pool elevations, and (4) a hydraulic conductance that describes the linear relation between head difference and flow rates at each spring.

For purposes of simulation, the aquifer system was assumed to be homogeneous and isotropic; it was treated as a single layer with water moving in a horizontal plane. The following assumptions and limitations are inherent to the model developed by Ryder (1982).

1. The base of the Floridan aquifer system is that part of the rock column where gypsum or anhydrite consistently fill pores in the carbonate rocks and restrict flow of water. In the model, this base is treated as a no-flow boundary. No upward leakage is assumed through the base of the aquifer.

2. Only the freshwater-flow system was modeled. Highly saline water (chloride greater than 10,000 mg/L) is assumed static and, therefore, not part of the flow system.

3. The saltwater-freshwater interface defines the coastal boundary of the model and is also treated as a no-flow boundary. The interface is in equilibrium; thus, its position is fixed, and as the limiting flow line, it represents the seaward extent of the freshwater-flow system.

4. All other lateral boundaries are no-flow.

Figure 31 shows transmissivities of the Floridan aquifer system derived from the model.

The model was used to predict reduction in head in the Upper Floridan aquifer that would result from pumping. Drawdowns in the aquifer from predevelopment conditions to the year 2000 were estimated based on expected demands on water resources, as previously described. Modeled drawdowns can be used to evaluate the impact of projected withdrawals, on saltwater encroachment, and reduction in springflow.

The model developed by Ryder (1982) was not calibrated specifically for Hernando County because sufficient data were not available to accurately define aquifer properties, but rather used exactly as developed. Aquifer properties, as defined by Ryder as a result of extensive calibration simulations, are within realistic limits when compared with field data for the study area. Hence, the model was considered to be a suitable tool to predict effects of projected pumping rates on ground-water levels in the Upper Floridan aquifer and on spring discharges. Because the saltwater-freshwater interface is a no-flow boundary, movement of saltwater due to pumping has to be estimated based upon the resultant lowering of the potentiometric surface caused by pumping in the vicinity of the transition zone.

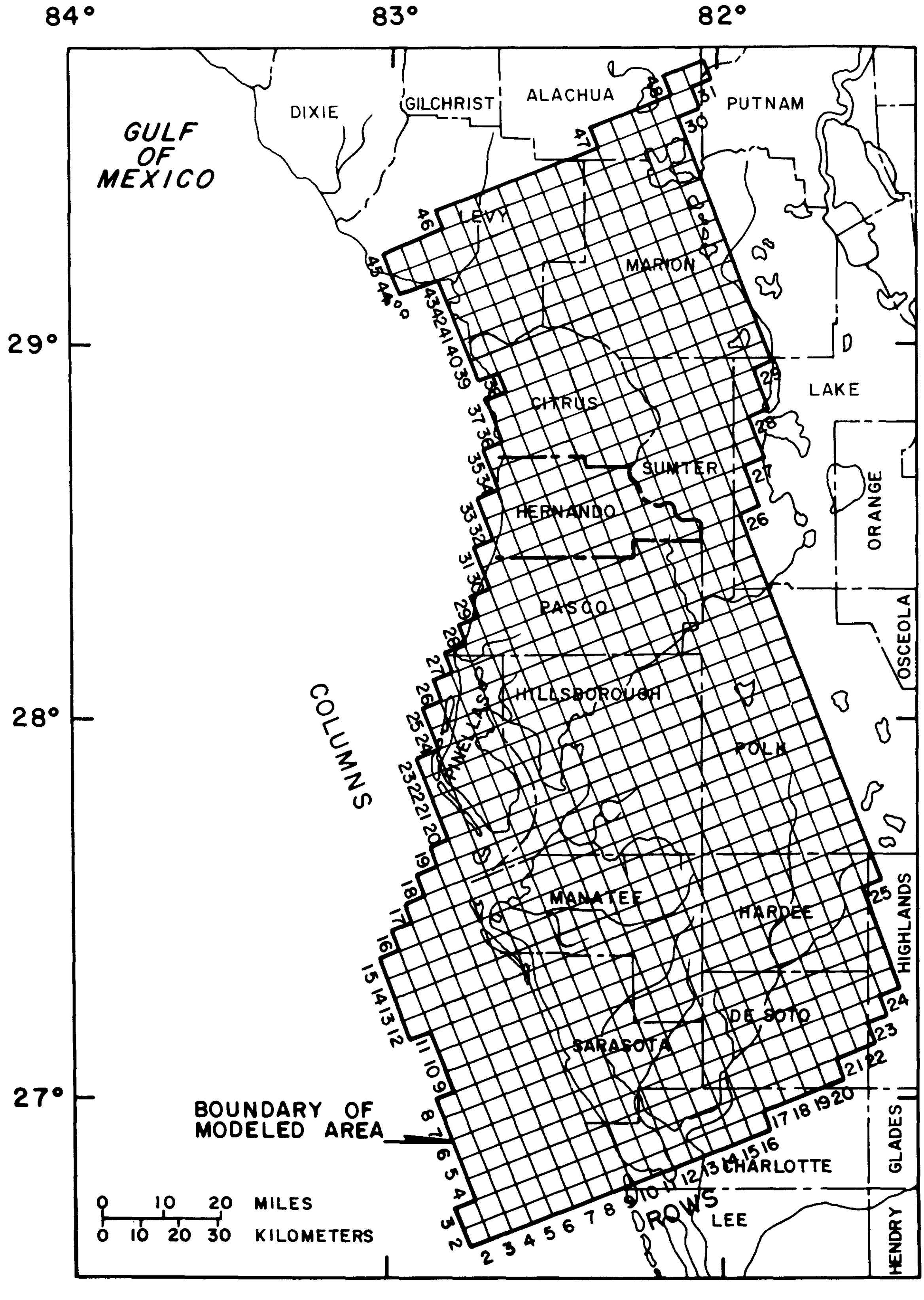

Figure 30.--Area, grid, and boundaries of the Floridan aquifer system modeled by Ryder (1982).

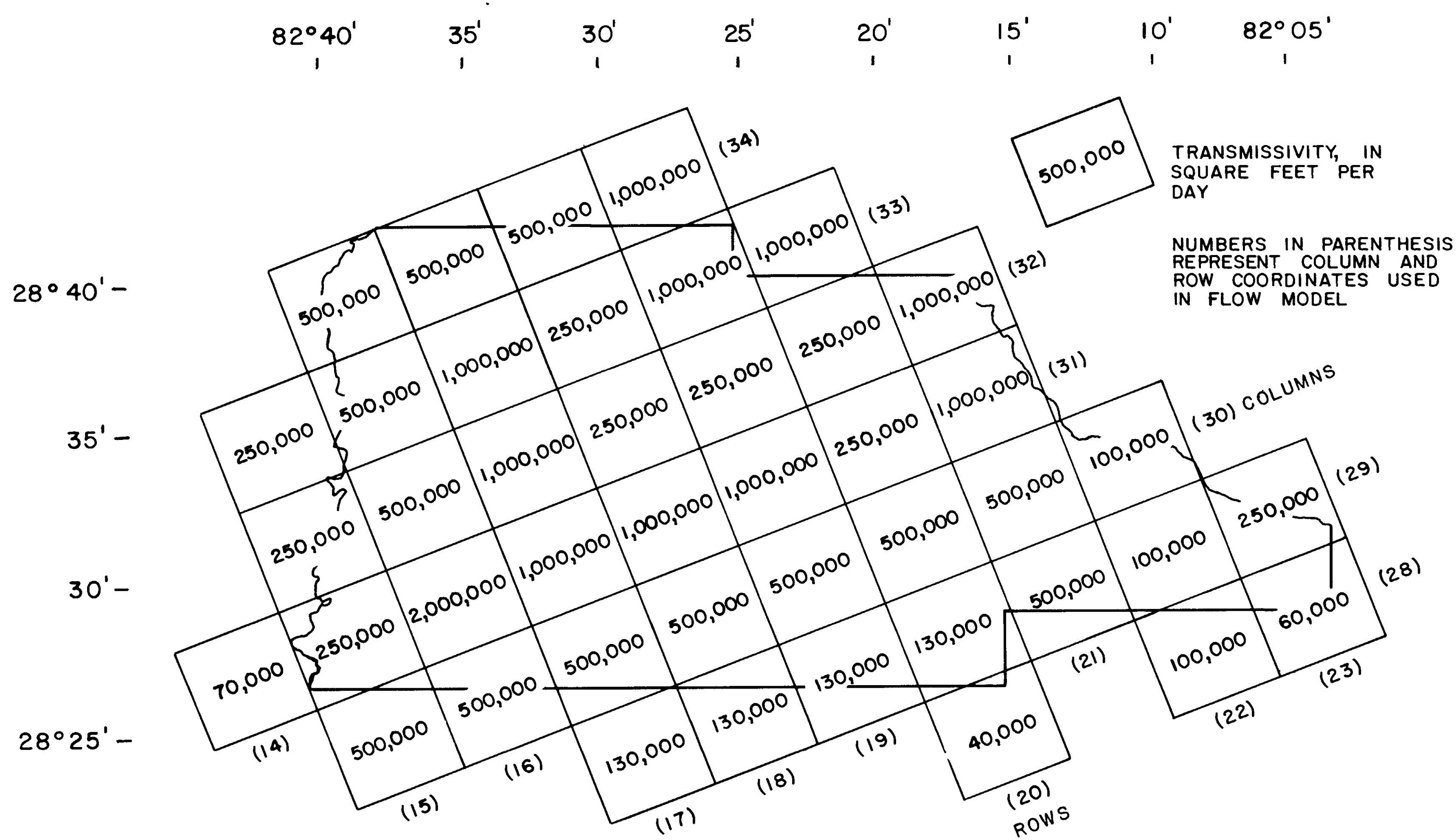

Figure 31.--Transmissivities used in the model.

Additional and perhaps more detailed analyses than those discussed may be necessary if population growth is larger than projected or if irrigation, mining, or other industries expand and water demands increase considerably over current projections.

Impact of Development

The above analyses indicate that future development of ground-water resources will have only a small effect on lake levels, springflow, and ground-water levels and, because of small changes in ground-water level, only little effect on saltwater intrusion. Results of the digital model simulations are shown in figures 32 and 33. Figure 32 shows reductions in head and in springflow in the Upper Floridan aquifer between predevelopment conditions and 2000. The greatest reduction in head, nearly 3 feet, is in node (18,32), an area of large ground-water pumping for mining. Changes of more than 1 foot in a 16-mi^2 grid block occur mostly in irrigation and mining areas. All nodes in the coastal area show reductions in head of less than 1 foot even though this area is the fastest growing in the county. Model simulations indicate that springflow near Weeki Wachee Springs is reduced by about 17 ft^3/s (11.0 Mgal/d).

Figure 33 shows reduction in head in the aquifer between 1982 and 2000. As shown, reductions will be minimal. The maximum reduction is 0.36 foot in node (17,30). Thirty-one of the nodes show changes of less than 0.20 foot, and the countywide average change is about 0.15 foot. Reduction in springflow ranged from 0.17 ft^3/s (0.11 Mgal/d) in node (16,33) to 5.12 ft^3/s (3.3 Mgal/d) in node (16,31). Major areal changes in water levels or springflow are not expected by the year 2000 as a result of ground-water development.

Pumping from the new county well field located in node (17,32) will not cause any significant change in the flow of Weeki Wachee Springs. Pumpage from the well field represents 1 percent of the total flow to the springs, and not all pumpage will intercept springflow. Pumping large quantities of water from the Upper Floridan aquifer should have little effect on water levels in nearby lakes because of the small drawdowns incurred in the aquifer.

The largest drawdown predicted in any node within which the transition zone lies near land surface is 0.19 foot in node (15,31). In theory (Hubbert, 1940), an upconing of saltwater of about 8 feet could occur in the node, possibly increasing chloride concentrations in water from some wells. Upconing in other nodes in which the transition zone lies near the surface would be less than 8 feet. Chloride concentrations in water from wells open to or very close to the transition zone (fig. 29) may increase.

The model analysis is based on a calibrated regional model of average annual conditions and its application here is intended only to show a general picture, not a specific one. Further analysis is necessary to accurately predict change in site-specific locations.

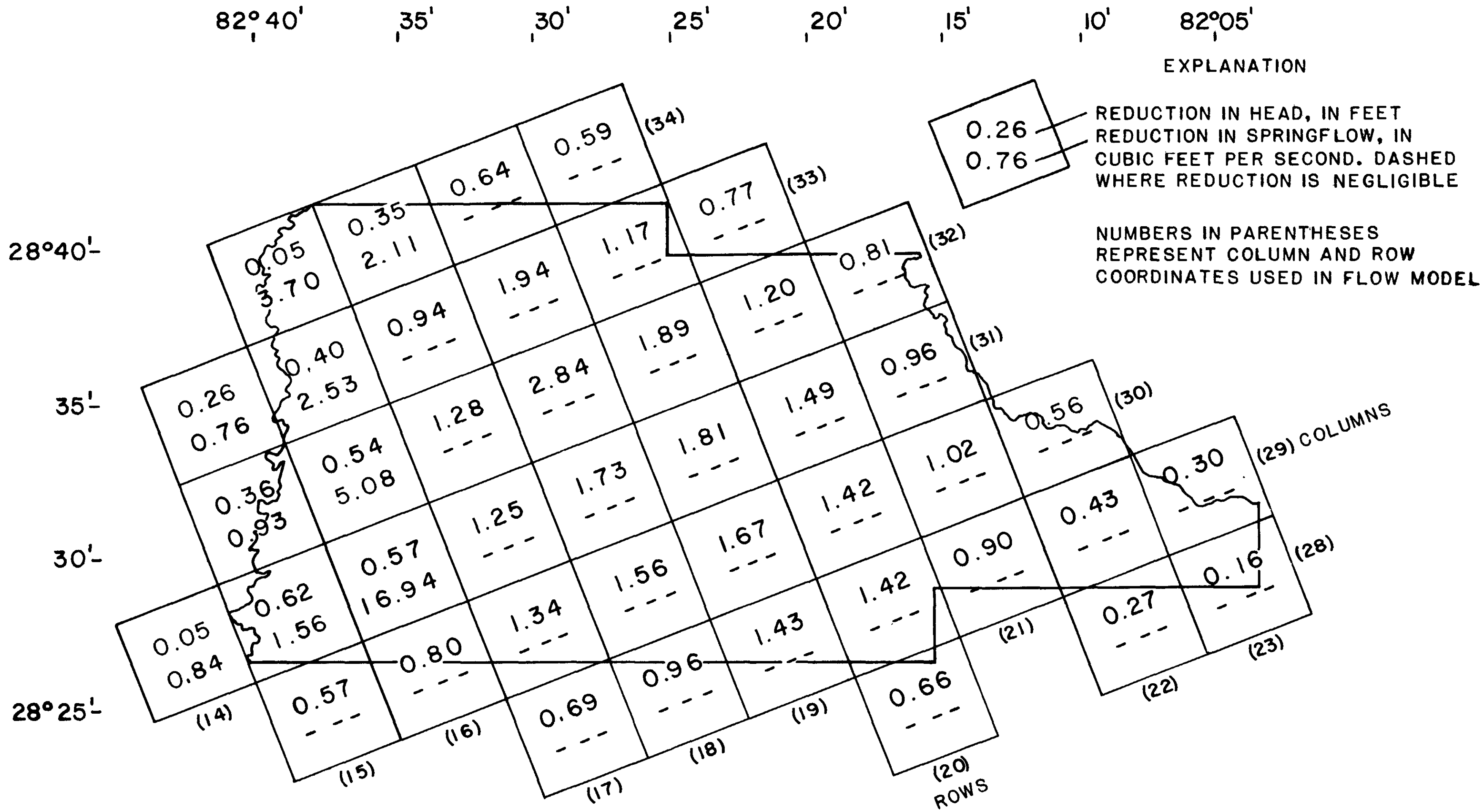

Figure 32.--Simulated reductions in head and in springflow between predevelopment conditions and the year 2000.

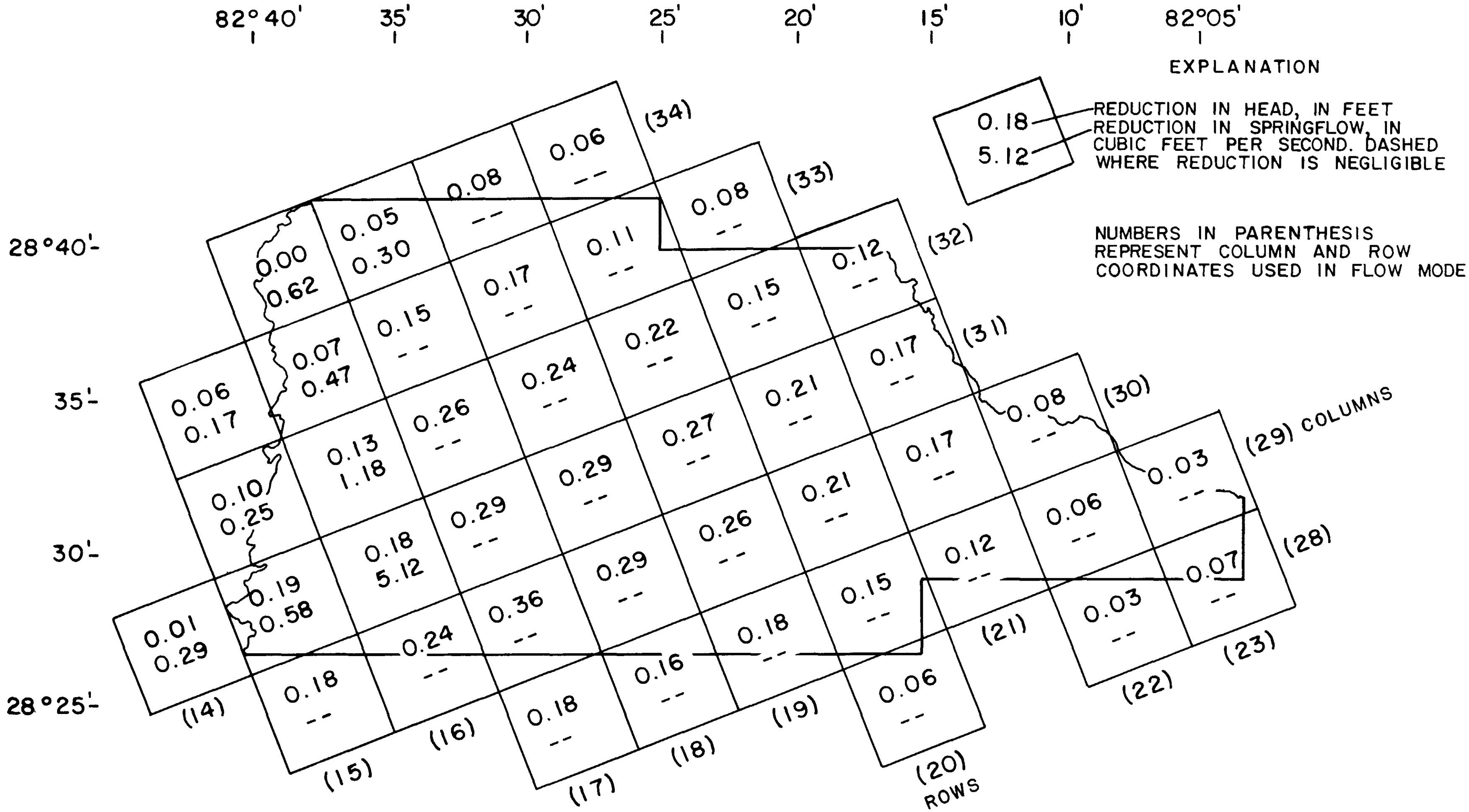

Figure 33.--Simulated reductions in head and springflow from 1982 to 2000 as a result of pumping.

SUMMARY AND CONCLUSIONS

A hydrologic investigation of Hernando County was initiated in October 1981 to determine (1) the availability of water, (2) the extent of water-quality problems in surface and ground water, (3) the interconnection between surface and ground water, and (4) the effects of pumping on the hydrologic system. Areas of concern were the impacts of development upon possible reduction of flow of water to Weeki Wachee Springs and other coastal springs, lowered lake levels, and intrusion of saltwater into the Upper Floridan aquifer.

The Upper Floridan aquifer, 700 to 800 feet thick, is virtually the only freshwater aquifer in the county. In places, the aquifer is overlain by thick layers of sand and clay. However, the clay is discontinuous and does not effectively retard vertical flow of water from rainfall to the aquifer. A network of interconnected fractures and solution cavities in the Upper Floridan aquifer serve to transport ground water from inland areas to the coast where it is discharged through coastal springs and upward leakage in marshes. Solution of limestone accounts for the many sinkholes that occur throughout the county. Many sinkholes provide direct paths for surface water to recharge and possibly contaminate the Upper Floridan aquifer. Water from the Upper Floridan aquifer discharges to the Withlacoochee River in the southern part of the county, and water from the river recharges the aquifer in the northern part of the county. Water from the aquifer discharges to coastal springs and Weeki Wachee River in the western part of the county. In their lower reaches near the coast, rivers and streams are tide affected, as are several springs near the coast.

Lakes in Hernando County have varying degrees of interconnection with the Upper Floridan aquifer. Most respond to climatic changes in the same way as the aquifer. A few, however, respond differently than the aquifer and are lower or even dry up during wet periods. This suggests a good connection with the Upper Floridan aquifer through sinkholes that are open during wet periods. Prairie lakes exist only after heavy rainfalls when water is temporarily ponded.

The Upper Floridan aquifer is generally unconfined throughout the county. The potentiometric surface of the aquifer responds to climatic conditions and is generally lowest during May or June and highest in September or October. Ground water flows northwest into the county from areas to the south and east and out of the county to areas to the north and west to the Gulf of Mexico.

Eighty-seven percent of the 47 Mgal/d of water used for irrigation, industrial, public, and rural supply is ground water. The other 13 percent is surface water that is used in mining operations (considered industrial use). Industrial use was 31.36 Mgal/d; irrigation water use, 6.96 Mgal/d; public supply water use, 5.59 Mgal/d; and rural water use, 3.16 Mgal/d.

Surface-water and ground-water quality in the county is generally very good and meets recommended limits for drinking water, except near the coast where water is high in chlorides (greater than 250 mg/L). Water from a few wells in the eastern part of the county has objectionably high concentrations of iron and hydrogen sulfide. High concentrations of iron are also present in water from wells in the coastal area.

Water from only one well in the saltwater-freshwater interface zone has shown increases in chloride concentration over time. These increases are due to less than normal rainfall and reflect encroachment of saltwater.

Transmissivities of the Floridan aquifer system are estimated to range from $9x10^4$ ft^2/d to $2.1x10^6$ ft^2/d. Aquifer tests at the Hernando County well field near Weeki Wachee indicate generally high transmissivity.

Increases in the amount of ground-water use by the year 2000 will be primarily for public supply. Water needed for public supply is predicted to increase from 5.59 Mgal/d in 1982 to 14.92 Mgal/d by 2000. The amount of water used for industry, irrigation, and rural supply are expected to remain constant through 2000.

A computer model was used to determine the effects of predicted increase in ground-water withdrawals on water levels. The ground-water flow model indicates that little change in water levels will occur between 1982 and 2000. The areas of largest projected water-use increase (along the coast) show less than 1 foot of drawdown in any 16-mi^2 node. Increased withdrawals in a well field would intercept only 1 percent of the discharge of Weeki Wachee Springs.

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