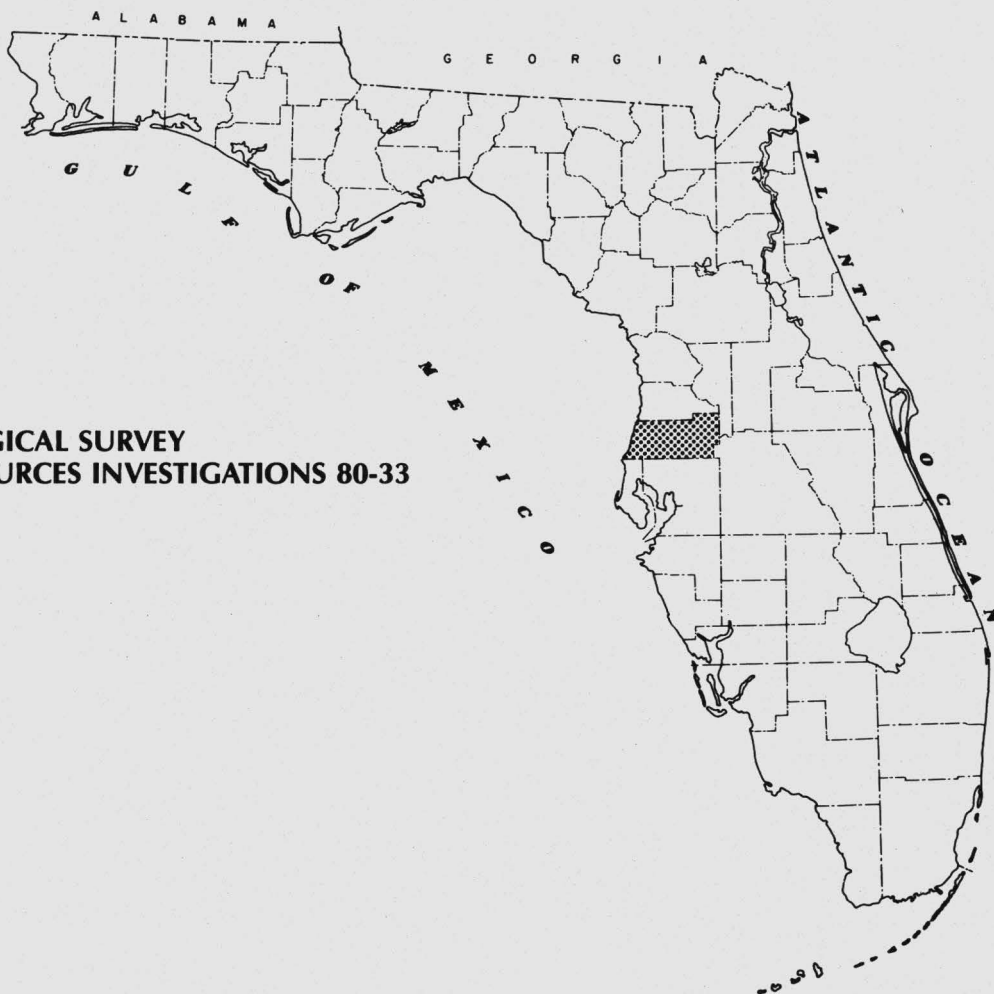


GROUND-WATER HYDROLOGY OF THE DADE CITY AREA, PASCO COUNTY, FLORIDA, WITH EMPHASIS ON THE HYDROLOGIC EFFECTS OF PUMPING FROM THE FLORIDAN AQUIFER

U.S. GEOLOGICAL SURVEY
WATER-RESOURCES INVESTIGATIONS 80-33



Prepared in cooperation with the
SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT



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1980

UNITED STATES DEPARTMENT OF THE INTERIOR

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CONTENTS

	Page
Conversion Factors.....	vi
Abstract.....	1
Introduction.....	2
Purpose and scope.....	2
Previous studies.....	2
Acknowledgments.....	4
Well-numbering system.....	4
Description of the area.....	10
Climate.....	12
Geologic setting.....	12
Ground water.....	24
Surficial aquifer.....	24
Floridan aquifer.....	25
Potentiometric surface.....	27
Quality of water.....	27
Ground-water use.....	43
Geohydrology.....	43
Hydrologic significance of ground-water withdrawals in the Dade City area by Lykes-Pasco Packing Co.....	49
Summary and conclusions.....	61
Selected references.....	61

ILLUSTRATIONS

Figure 1. Map of Florida showing location of study area.....	3
2. Map showing locations of wells used in this report..	5
3. Map showing generalized topography and surface drainage in the Dade City area.....	11
4. Hydrograph showing average monthly rainfall at St. Leo, Florida.....	13
5. Map showing locations of geologic sections shown in figures 6-13.....	14
6. Sketch of geologic section A-A'.....	15
7. Sketch of geologic section B-B'.....	16
8. Sketch of geologic section F'-A''.....	17
9. Sketch of geologic section A'-A''.....	18
10. Sketch of geologic section C-C'.....	19
11. Sketch of geologic section D-D'.....	20
12. Sketch of geologic section E-E'.....	21
13. Sketch of geologic section F-F'.....	22
14. Map showing altitude of top of the Floridan aquifer in the Dade City area.....	26
15. Graph showing altitude of bottoms of inventoried wells in the study area.....	28

ILLUSTRATIONS - Continued

	Page
Figure 16. Hydrographs showing monthend potentiometric levels in selected Floridan aquifer wells, monthly rainfall at St. Leo, cumulative departure from average monthly rainfall at St. Leo, discharge of Dade City Canal near Dade City, and pumping by Lykes-Pasco Packing Co., January 1959-December 1977.....	30
17. Map showing potentiometric surface and areas of artesian flow of the Floridan aquifer in west-central peninsular Florida, May 1974.....	31
18. Map showing potentiometric surface of the Floridan aquifer in the Dade City area, 1934.....	32
19. Map showing potentiometric surface of the Floridan aquifer in the Dade City area, June 15-18, 1976...	33
20. Map showing potentiometric surface of the Floridan aquifer in the Dade City area, July 21-22, 1976...	34
21. Map showing potentiometric surface of the Floridan aquifer in the Dade City area, September 9-10, 1976.....	35
22. Map showing potentiometric surface of the Floridan aquifer in the Dade City area, April 27-28, 1977..	36
23. Graph showing hardness, dissolved solids concentration, and specific conductance of water at various depths in well 50, December 16-17, 1975.....	38
24. Map showing dissolved solids concentration in water from wells that tap the Floridan aquifer at depths of 650 feet or less in the Dade City area.....	39
25. Map showing hardness of water from wells that tap the Floridan aquifer at depths of 650 feet or less in the Dade City area.....	40
26. Map showing sulfate concentration in water from wells that tap the Floridan aquifer at depths of 650 feet or less in the Dade City area.....	41

ILLUSTRATIONS - Continued

	Page
Figure 27. Graph showing relation of sulfate concentration to altitude of bottoms of selected wells in the study area.....	42
28. Map showing results of low-flow investigation of Withlacoochee River, May 23-25, 1961.....	45
29. Graph showing well depth versus potentiometric surface of the Floridan aquifer in the vicinity of Lykes-Pasco Packing Co., February 2-3, 1977....	50
30. Graph showing relation of flow in Dade City Canal near Dade City to pumping by Lykes-Pasco Packing Co.....	51
31. Hydrographs showing daily high potentiometric levels in selected Floridan aquifer wells in the Dade City area, monthly rainfall at St. Leo, and pumping by Lykes-Pasco Packing Co., January 1976 to December 1977.....	53
32. Graphs showing estimated drawdown versus time in response to increase in pumping rate by Lykes-Pasco Packing Co., December 6-20, 1976.....	55
33. Graphs showing double-mass curves of rainfall at St. Leo versus discharge of Withlacoochee River at Trilby, discharge of Weekiwachee Springs near Brooksville, and discharge of Crystal Springs near Zephyrhills.....	57
34. Graph showing double-mass curve of rainfall at St. Leo versus potentiometric level in well 42....	58

TABLES

Table 1. Index to well numbers and to geologic and drillers' logs used in this report.....	6
2. Geologic formations and their water-bearing characteristics in the Dade City area.....	23

TABLES - Continued

	Page
Table 3. Floridan aquifer wells in the Dade City area for which caliper logs are available.....	29
4. Floridan aquifer ground-water use in Pasco County, 1975, and in the study area, 1975-77.....	44

CONVERSION FACTORS

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

<u>Multiply inch-pound units</u>	<u>By</u>	<u>To obtain metric units</u>
ft (foot)	0.3048	m (meter)
ft ² /d (foot squared per day)	0.0929	m ² /d (meter squared per day)
ft ³ /s (cubic foot per second)	2.832X10 ⁻²	m ³ /s (cubic meter per second)
gal/min (gallon per minute)	6.309X10 ⁻²	L/s (liter per second)
Mgal/d (million gallon per day)	0.0438	m ³ /s (cubic meter per second)
in. (inch)	2.540X10 ⁺¹	mm (millimeter)
in./yr (inch per year)	2.540X10 ⁺¹	mm/yr (millimeter per year)
mi (mile)	1.609	km (kilometer)
mi ² (square mile)	2.590	km ² (square kilometer)

Temperature in degrees Farenheit (°F) can be converted to degrees Celsius (°C) as follows:

$$^{\circ}\text{C} = \frac{^{\circ}\text{F}-32}{1.8} .$$

National Geodetic Vertical Datum (NGVD) of 1929 as used in this report describes what is more commonly known as mean sea level.

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ABSTRACT

The Dade City area, northeast Pasco County, Florida, is an area of about 260 square miles. Almost all water used in the area is pumped from the Floridan aquifer. Of the approximately 32 million gallons per day pumped from the aquifer in the area in 1975 about 16 million gallons per day were pumped from an area of about 0.25 square miles by a citrus processing plant. Peak, or instantaneous pumping rates, have been as high as 66 million gallons per day (April 28, 1964). Since 1972, the citrus processing plant has made increased use of recycled water and, thus, has reduced ground-water withdrawals. There are essentially two producing zones in the Floridan aquifer in the Dade City area. The upper zone is from about 10 feet above NGVD of 1929 (National Geodetic Vertical Datum of 1929) to about 150 feet below NGVD of 1929. The lower producing zone is from about 300 feet to about 500 feet below NGVD of 1929. There is some evidence that either trenching by ancient surface streams or deep vertical solution activity has resulted in the interconnection of the upper and lower zones of the Floridan aquifer. This appears to be highly significant in terms of the geohydrology of the Floridan aquifer in the area, particularly with regard to its ground-water flow pattern, water quality, and aquifer hydraulic characteristics. In the immediate vicinity of the citrus processing plant, aquifer transmissivity may range from 200,000 feet squared per day to as much as 400,000 feet squared per day. It is also probable the Floridan is only semiconfined in the immediate vicinity of the plant. High aquifer transmissivity in the area is the reason why there are only a few feet of drawdown of the Floridan potentiometric surface even near the center of the plant's well field. The long-term effects of the plant's pumping since about 1942 are not discernible from available well records. Fluctuations of the potentiometric surface of the Floridan are due mainly to variations in recharge due to the seasonal variations in the amount of rainfall. The data indicate that the relation of rainfall at Saint Leo to the flow of Weekiwachee Springs near Brooksville has changed. Since about 1950, the spring has discharged more water for a given amount of rainfall than for the period of record prior to 1950.

INTRODUCTION

The Dade City area, herein referred to as the study area, is an area of 260 mi² in northeast Pasco County (fig. 1). Almost all water supplies pumped in the Dade City area are from the Floridan aquifer, an areally-extensive limestone aquifer that underlies all of Florida and parts of Alabama, Georgia, and South Carolina. Most of the ground water used in Dade City area is for industrial use in the form of citrus processing. The largest user of ground water in the area is Lykes-Pasco Packing Co. In 1975, this citrus processing plant pumped an average of 16 Mgal/d from the Floridan aquifer from an area of less than 0.25 mi², a relatively large withdrawal rate as compared to the 1.06 Mgal/d pumped for public supply by Dade City (Healy, 1977) in an area of about 2 mi².

The Dade City area is on the northeast fringe of an area of heavy ground-water development that partially supplies the Tampa Bay area. The Southwest Florida Water Management District (SWFWMD) has the responsibility for the regulation and permitting of water use in the District whose total area includes both the Tampa Bay and Dade City areas.

Purpose and Scope

The purpose and scope of this study is to describe the ground-water hydrology of the Dade City area and to evaluate the effects of relatively large ground-water withdrawals on the local ground-water regimen. This report represents the results of about 16 months of field study.

The studied area surrounds the major center of pumping, the Lykes-Pasco citrus processing plant at Dade City which is the main focus of the study because it is the largest single water user in the area.

The results of this study should help water managers in making informed decisions in planning for future allocations of ground-water withdrawals in the area.

Previous Studies

The Dade City area has been investigated, to some degree, in four previous geohydrologic studies. Wetterhall (1964) made a geohydrologic reconnaissance of Pasco and south Hernando County. The Dade City area is included on the west fringe areas of two studies describing the hydrology of the Green Swamp area (Pride and others, 1966; Grubb and Rutledge, 1978). William F. Guyton and Associates (1974) estimated the likely effects of pumping from proposed well fields in south-central and southwest Pasco County.



Figure 1.--Location of study area.

Other investigators have included Pasco County and the Dade City area in relatively broad-scoped regional or statewide hydrologic studies. Sellards (1908), Sellards and Gunter (1913), Matson and Sanford (1913), Gunter and Ponton (1931), Stringfield (1935, 1936, 1966), Stringfield and Cooper (1950), and Cooper and others (1953) have included the area in their hydrologic reports.

The potentiometric surface of the Floridan aquifer in the SWFWMD has been mapped and published by the U.S. Geological Survey -- intermittently from 1934 to January 1964, every other year from May 1969 to May 1973, annually from May 1973 to May 1975, and in May and September beginning in May 1975.

Hydrologic data on surface water, ground water, and quality of water are published annually in the U.S. Geological Survey series, "Water resources data for Florida." In addition, flow-duration, low-flow, and high-flow characteristics for selected gaged streams in the area have been tabulated in a report by Heath and Wimberly (1971).

Some of the more important geologic and geomorphologic studies that include the Dade City area are those of Cooke (1939, 1945), Carr and Alverson (1959), White (1958, 1970), Yon and Hendry (1972), and Randazzo (1972).

Acknowledgments

The authors express their appreciation to Norvell W. Hunt, Director of Environmental Control, Lykes-Pasco Packing Co., for his assistance and many helpful comments during the investigation.

The authors are grateful to Lykes-Pasco Packing Co. for furnishing pumping data and information on their wells. Thanks are also extended to the many ranchers, grove operators, and other land owners who permitted access to their land and allowed the sampling of water and measuring of water levels in their wells.

Well-Numbering System

In this report, well data are used that are taken from files and publications of several agencies. Each agency has its own well-numbering system. Hence, to attain a consistent well-numbering system in this report, the wells used here in (fig. 2) are assigned numbers in sequential format. Table 1 is used to cross-reference the wells to their respective agencies.

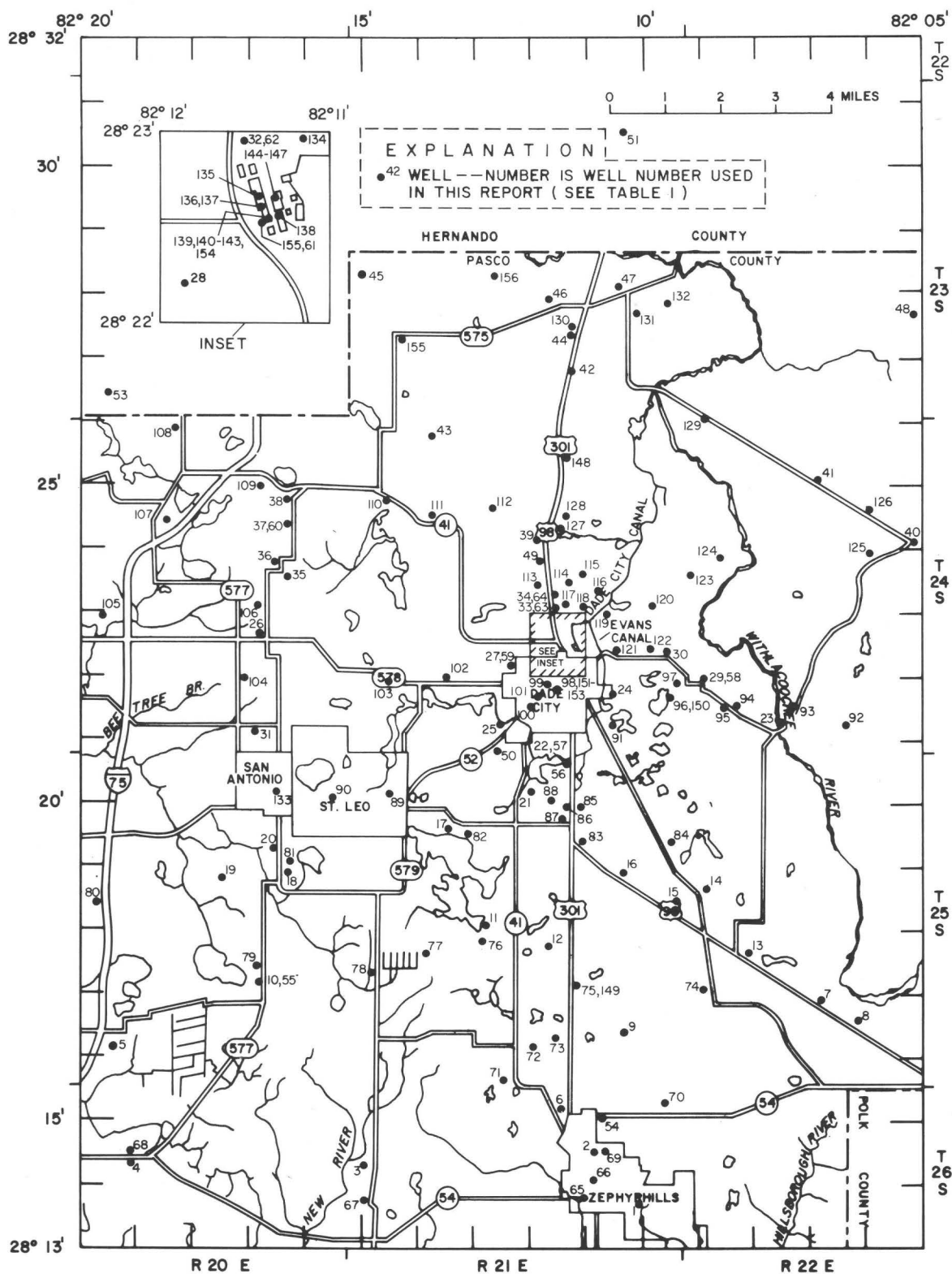


Figure 2.--Locations of wells used in this report.

Table 1.--Index to well numbers and to geologic and drillers' logs used in this report

WELL NUMBER	U.S. GEOLOGICAL WATER RESOURCES DIVISION	SURVEY NUMBER GEOLOGIC DIVISION ^{1/}	FLORIDA BUREAU OF GEOLOGY WELL NUMBER	SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT NUMBER	FLORIDA DEPART- MENT OF NATURAL RESOURCES NUMBER	OTHER NUMBER ^{2/}
1	-	-	-	-	-	813-210-01
2	-	-	W- 2972	-	-	-
3	281414082145901	-	-	-	-	814-214-01
4	281419082190601	-	-	-	-	814-219-01
5	281608082192401	-	-	-	-	816-219-01
6	-	-	W- 3284	-	-	-
7	281654082065901	-	W- 5350	-	-	816-206-01
8	-	G110	-	-	-	-
9	-	-	W-12536	-	-	-
10	281715082164401	-	W- 7466	-	-	817-216-01
11	-	-	-	-	-	819-212-01
12	281749082112701	-	W- 2160	-	-	817-211-01
13	-	G111	-	-	-	-
14	281846082085501	-	-	72- 1643	-	818-208-01
15	-	G112	-	-	-	-
16	-	G113	-	-	-	-
17	-	-	W- 5282	-	-	-
18	-	-	W- 5977	-	-	-
19	-	-	W- 5863	-	-	-
20	-	-	W- 5865	-	-	-
21	-	-	W-10617	-	-	-
22	282038082112001	-	-	-	-	820-211-01
23	282109082073301	-	-	-	-	821-207-03
24	282141082101901	-	-	-	3289	821-210-02
25	-	-	W- 6504	-	-	-
26	282234082164401	-	-	73-10989	-	822-216-01
27	282212082121801	-	W- 2707	-	-	822-212-01
28	-	-	W- 5124	-	-	-
29	282153082085602	-	-	73-13441	-	821-208-04
30	282220082093301	-	-	-	-	822-209-02
31	-	-	W- 8507	-	-	-
32	282258082113101	-	-	72- 1438	-	822-211-16
33	282303082113401	-	-	72- 4464	-	823-211-02
34	-	G114	-	-	-	-
35	-	-	W- 5866	-	-	-
36	-	-	W- 5942	-	-	-
37	282418082161301	-	-	72- 4044	-	824-216-03
38	-	-	W- 2199	-	-	-
39	-	-	W- 8840	-	-	-
40	282408082051401	-	-	-	-	824-205-01

41	282505082065501	-	-	-	-	825-206-01
42	282641082112001	-	-	-	-	826-211-01
43	-	-	-	72- 4231	-	-
44	-	-	W-11593	-	-	-
45	-	-	W-10298	-	-	-
46	-	-	W- 6470	-	-	-
47	-	-	-	72- 8946	-	-
48	282740082050801	-	-	-	-	827-205-01
49	282346082114901	-	-	-	29710	823-211-05
50	282048082123301	-	-	-	-	820-212-01
51	283050082105001	-	W- 4410	-	-	830-210-01
52	282905082163401	-	-	-	-	829-216-01
53	-	-	W- 8426	-	-	-
54	281504082104801	-	-	ROMP DP 86	-	815-210-01
55	281715082164402	-	-	-	-	817-216-02
56	282036082112101	-	-	-	-	820-211-02
57	282037082111601	-	-	-	-	820-211-03
58	282153082085601	-	-	-	-	821-208-03
59	282212082121802	-	-	-	-	822-212-02
60	282418082162001	-	-	-	-	824-216-01
61	282230082112202	-	-	-	-	822-211-18
62	282258082113102	-	-	-	-	822-211-17
63	282302082113401	-	-	-	-	823-211-01
64	282315082113601	-	-	-	-	823-211-03
65	281348082110201	-	-	-	-	813-211-01
66	281404082105201	-	-	-	-	814-210-02
67	281331082145301	-	-	-	-	813-214-01
68	281425082190801	-	-	-	-	814-219-02
69	281431082104701	-	-	-	-	814-210-01
70	281513082094601	-	-	-	-	815-209-01
71	281545082122001	-	-	-	-	815-212-01
72	281610082115901	-	-	-	-	816-211-02
73	281621082113001	-	-	-	-	816-211-01
74	281704082085201	-	-	-	-	817-208-01
75	281730082111101	-	-	-	-	817-211-02
76	281755082124501	-	-	-	-	817-212-01
77	281743082135101	-	-	-	-	817-213-01
78	281725082144801	-	-	-	-	817-214-01
79	281725082164401	-	-	-	-	817-216-03
80	281827082194501	-	-	-	-	818-219-01

¹/ Carr and Alverson (1959).

²/ Wetterhall (1964).

Table 1.--Index to well numbers and to geologic and drillers' logs used in this report - Continued

WELL NUMBER	U.S. GEOLOGICAL WATER RESOURCES DIVISION	SURVEY NUMBER GEOLOGIC DIVISION ^{1/}	FLORIDA BUREAU OF GEOLOGY WELL NUMBER	SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT NUMBER	FLORIDA DEPART- MENT OF NATURAL RESOURCES NUMBER	OTHER NUMBER ^{2/}
81	281906082161601	-	-	-	-	819-216-01
82	281929082131301	-	-	-	-	819-213-01
83	281927082111201	-	-	-	-	819-211-01
84	281930082093701	-	-	-	-	819-209-01
85	281958082110201	-	-	-	-	819-211-05
86	281955082111701	-	-	-	-	819-211-04
87	281942082113101	-	-	-	-	819-211-03
88	282005062112801	-	-	-	-	820-211-04
89	282007082142901	-	-	-	-	820-214-01
90	282005082153501	-	-	-	-	820-215-01
91	282114062103101	-	-	-	-	821-210-01
92	282117062062001	-	-	-	-	821-206-01
93	282121062071101	-	-	-	-	821-207-02
94	282130082082401	-	-	-	-	821-208-02
95	282130082082901	-	-	-	-	821-208-01
96	282143062093201	-	-	-	-	821-209-02
97	282153082092601	-	-	-	-	821-209-01
98	282147082113001	-	-	-	-	821-211-01
99	282152062114101	-	-	-	-	821-211-05
100	282132082115901	-	-	-	-	821-211-06
101	282138082115201	-	-	-	-	821-211-07
102	282155082132601	-	-	-	-	821-213-01
103	282154082142401	-	-	-	-	821-214-01
104	282158082170801	-	-	-	-	821-217-01
105	282258082193601	-	-	-	-	822-219-01
106	282304082164401	-	-	-	-	823-216-01
107	282428082182801	-	-	-	-	824-218-01
108	282552082181201	-	-	-	-	825-218-01
109	282459082164301	-	-	-	-	824-216-02
110	282443082143201	-	-	-	-	824-214-01
111	282428082134501	-	-	-	-	824-213-01
112	282442082124401	-	-	-	-	824-212-01
113	282319082115001	-	-	-	-	823-211-04
114	282326082112001	-	-	-	-	823-211-09
115	282332082110101	-	-	-	-	823-211-06
116	282319082105201	-	-	-	-	823-210-02
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121	282221082103001	-	-	-	-	822-210-01
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123	282336082091001	-	-	-	-	823-209-02
124	282352082083501	-	-	-	-	823-208-01
125	282353082055301	-	-	-	-	823-205-01
126	282434082055801	-	-	-	-	824-206-01
127	282425082112901	-	-	-	-	824-211-01
128	282430082112101	-	-	-	-	824-211-02
129	282601082083901	-	-	-	-	826-208-01
130	282728082111001	-	-	-	-	827-211-01
131	282742082100701	-	-	-	-	827-210-01
132	282735082095201	-	-	-	-	827-209-01
133	282011082162701	-	-	-	-	820-216-01
134	282259082110901	-	-	-	-	822-211-19
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137	282235082112302	-	-	-	-	822-211-06
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139	282233082112203	-	-	-	-	822-211-01
140	282233082112204	-	-	-	-	822-211-03
141	282233082112201	-	-	-	-	822-211-04
142	282233082112202	-	-	-	-	822-211-12
143	282233082112206	-	-	-	-	822-211-13
144	282240082112001	-	-	-	-	822-211-08
145	282240082112002	-	-	-	-	822-211-09
146	282240082112003	-	-	-	-	822-211-10
147	282240082112004	-	-	-	-	822-211-11
148	282527082112301	-	-	-	-	825-211-01
149	281713082111501	-	-	-	-	817-211-03
150	282143082093301	-	-	-	-	821-209-03
151	282147082113002	-	-	-	-	821-211-02
152	282147082113003	-	-	-	-	821-211-03
153	282147082113004	-	-	-	-	821-211-04
154	282233082112205	-	-	-	-	822-211-14
155	282230082112201	-	-	-	-	822-211-02
156	282717082142001	-	-	-	-	827-214-01
157	282816082123701	-	-	-	-	828-212-01
158	282127082022501	-	-	-	-	821-202-02
-	-	-	-	-	-	-
-	-	-	-	-	-	-

^{1/}Carr and Alverson (1959).

^{2/}Wetterhall (1964).

DESCRIPTION OF THE AREA

The study area is mostly rural. According to the Pasco County Planning Department (David Pettrow, written commun., August 24, 1978), of the estimated 46,000 people living in the entire 260 mi² area as of July 1, 1977, about 10,500 live in the 10 mi² of incorporated areas comprised by San Antonio, St. (Saint) Leo, Zephyrhills, and Dade City. The rural population consists of about 36,000 people living in an area of about 250 mi², a population density of about 140 people per mi² as opposed to about 1,050 people per mi² in the incorporated areas.

Much of the area north and east of U.S. Highway 98 and east of Zephyrhills is flat and swampy and is generally used only for cattle ranching and timber harvesting for pulpwood. In the past, the area was extensively logged for cypress. Most of the remainder of the study area is also in agricultural use; citrus and cattle ranching being the predominant land-use categories.

The study area is on the west flank of Cooke's (1939, 1945) Central Highlands. A more specific physiographic breakdown is made by referring to White (1970, pl. 1-B) and figure 3: The part of the study area that has surface altitudes greater than about 100 ft is herein considered part of the Brooksville Ridge, the dominant topographic feature in the area. An adjacent area consisting of an approximately 2- to 3-mile-wide swath dissected by the Withlacoochee River and extending from the north limit of the study area to about the south latitude of Dade City is part of the Tsala Apopka Plain. The remainder of the study area is in the Western Valley.

The topography of the study area ranges from virtually flat to steeply rolling. Land surface altitudes range from 301 ft above NGVD of 1929 6 mi northwest of Dade City to about 60 ft above NGVD of 1929 along the flood plain of the Withlacoochee River in the northeast. Scattered throughout the south-central part of the area are relatively small, topographically high "islands," some of which are 50 to 60 ft higher than the surrounding area.

In terms of surface drainage, the extreme northwest part of the study area is drained by tributaries to the Pithlachascotee River, the west and south parts are drained by the Hillsborough River and its tributaries, and the remainder of the area is drained by the Withlacoochee River and its tributaries (fig. 3).

At high stages there is diversion of water from the upper Withlacoochee River basin into the headwaters of the Hillsborough River. According to Pride and others (1966), at high stages more than one-fourth of the flow from the upper Withlacoochee is diverted into the Hillsborough.

CLIMATE

The climate of central Florida is classed as subtropical humid and is characterized by long, warm, relatively wet summers and mild, relatively dry winters.

According to the National Oceanographic and Atmospheric Administration records for St. Leo, the average annual rainfall is 56.36 in./yr. For the period of record, 1902 through 1977, the maximum yearly rainfall was 81.93 in. in 1945 and the minimum was 36.61 in. in 1961.

Rainfall is unevenly distributed during the year. About 55 percent of the annual rainfall occurs during four summer months, June, July, August, and September (fig. 4). In addition to the uneven temporal distribution of the rainfall, it can also be unevenly distributed throughout the area at any given time, especially during the summer. This is because most of the summer rainfall is derived from local showers or thunderstorms that occur in a generally random manner throughout the area. Many of those local storms wet only a relatively small part of the total study area. The summer rainfall can be substantially augmented by tropical storms and hurricanes that pass through or near the Florida peninsula from time to time.

Winter rainfall generally results from cold air masses from the north (in the form of fronts) moving south through the area causing the resident warm air masses to lose their moisture, almost always in the form of rain. Winter rainfall generally occurs over wide areas and thus is not as spotty as summer rainfall.

The average annual temperature at St. Leo is about 72°F. Monthly mean temperatures range from about 61°F in January to about 82°F in August. Most years have a few days of freezing temperatures but the minimum daily temperature rarely falls below 20°F. The maximum temperature frequently exceeds 90°F but only occasionally exceeds 100°F.

GEOLOGIC SETTING

As noted in the section on previous studies, the geology of the area has been described by several investigators including Wetterhall (1964) and Pride and others (1966). The geologic information in this report is mainly a summary of the data obtained by those previous investigators. Those data in addition to information from numerous drillers' logs on file with the Florida Bureau of Geology, Southwest Florida Water Management District, and the Florida Department of Natural Resources are used to construct several geologic sections (figs. 6-13), the locations of which are shown in figure 5. The generalized water-bearing characteristics of the various geologic formations are described in table 2.

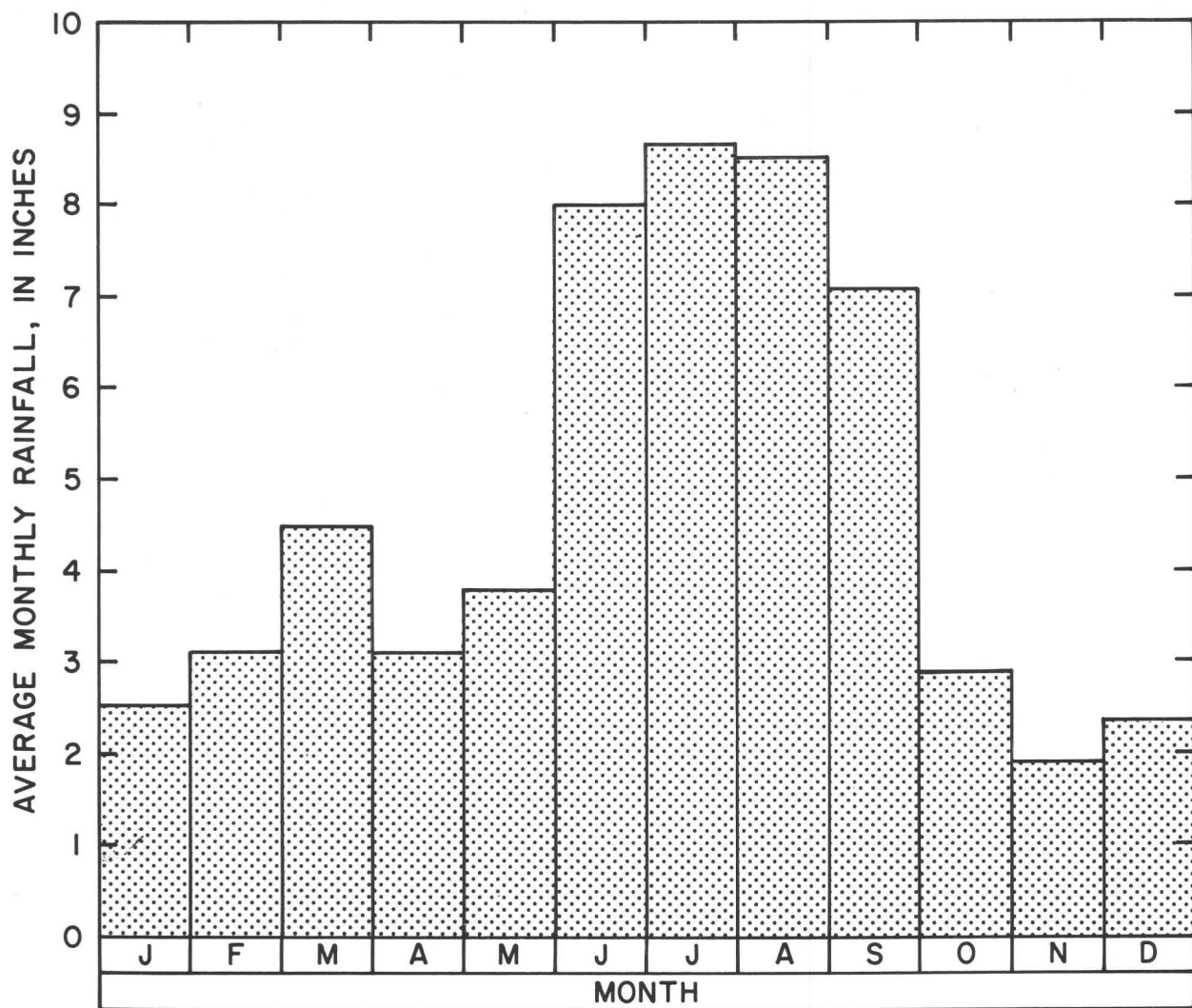


Figure 4. Average monthly rainfall at St. Leo, Florida.

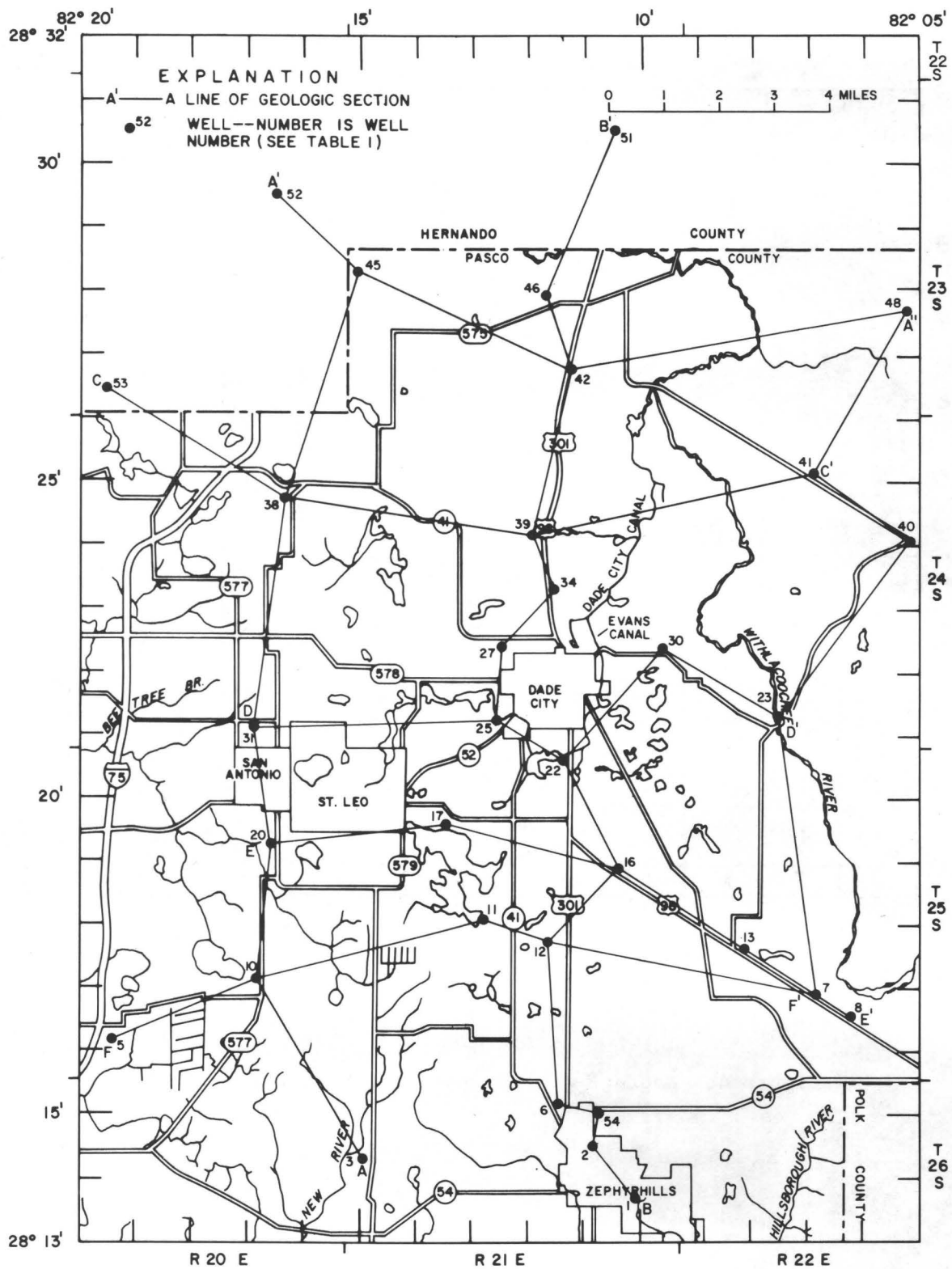


Figure 5.--Locations of geologic sections shown in figures 6-13.

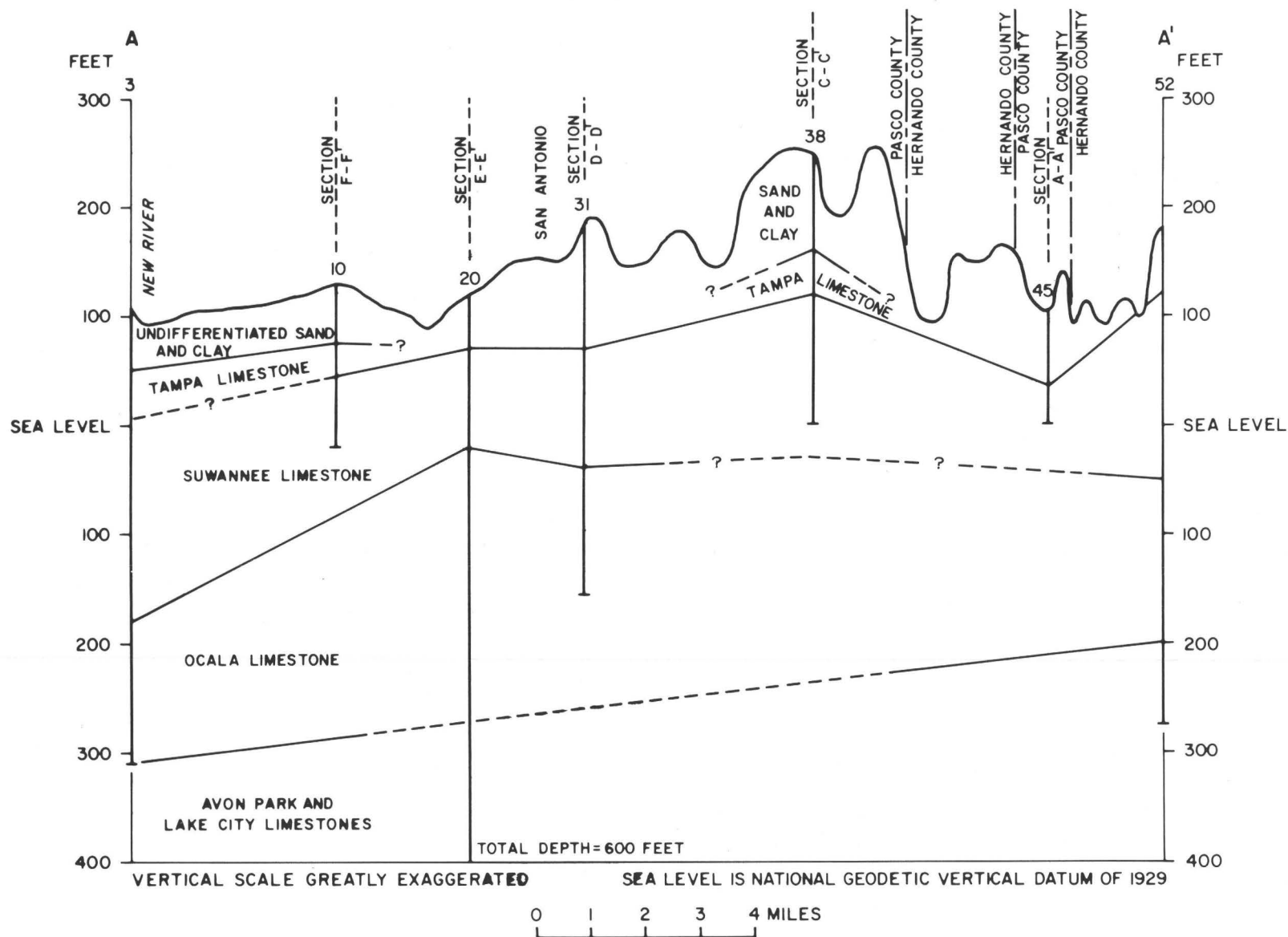


Figure 6.--Geologic section A-A'.

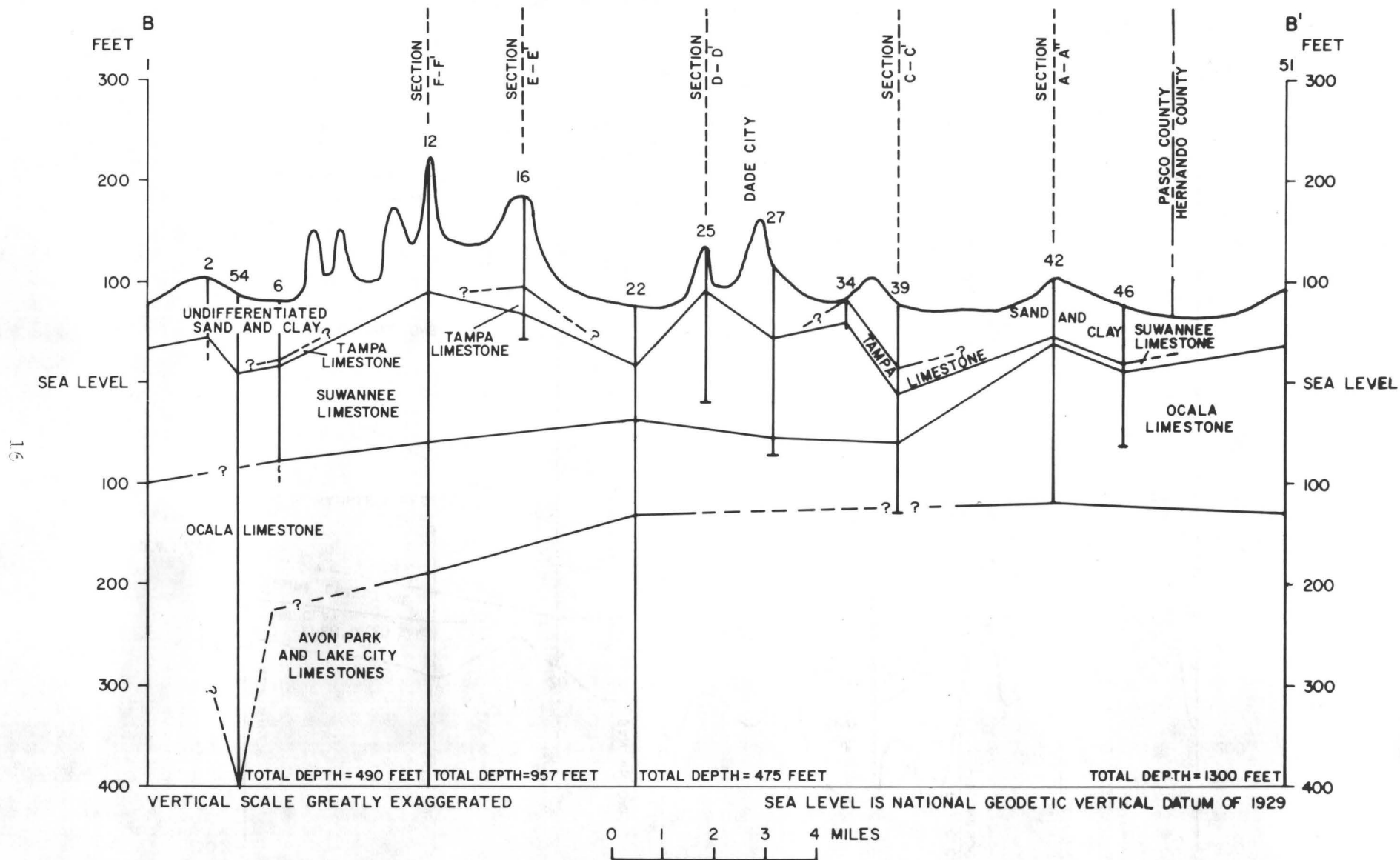


Figure 7.--Geologic section B-B'.

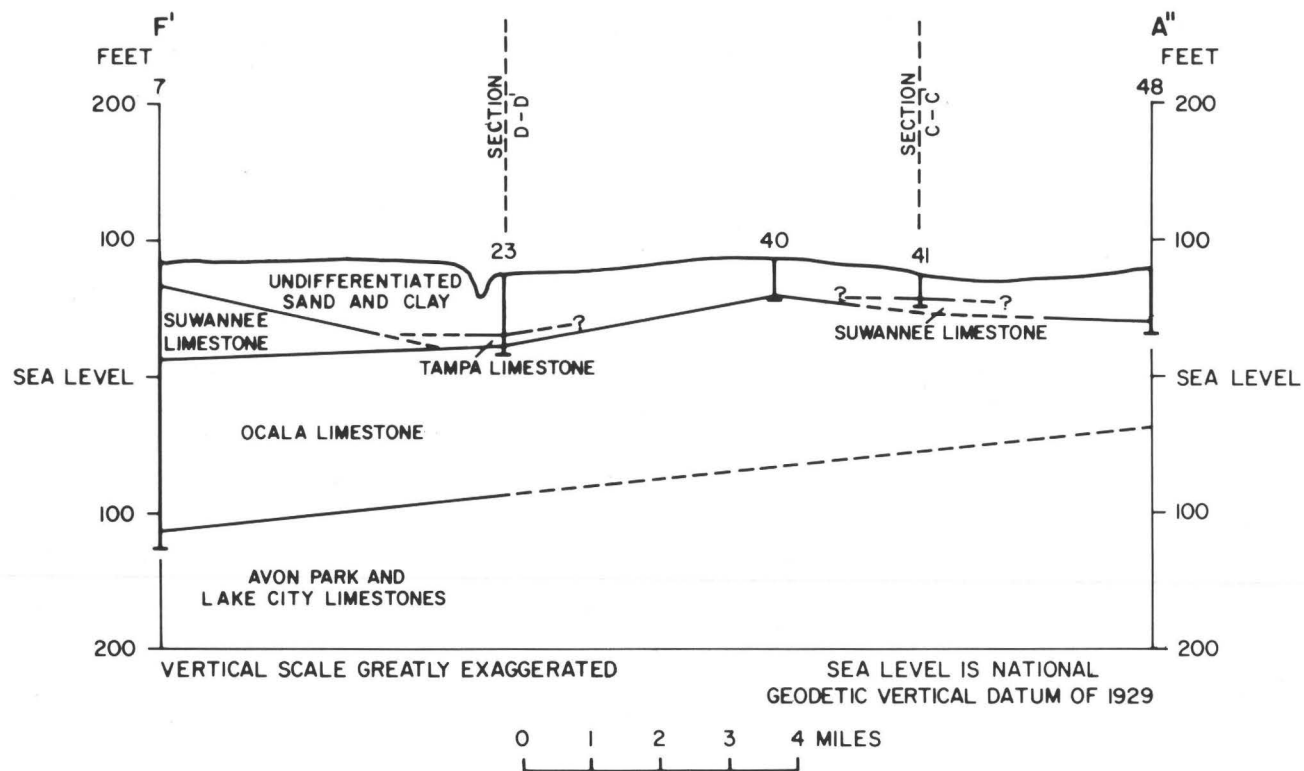


Figure 8.--Geologic section F'-A''.

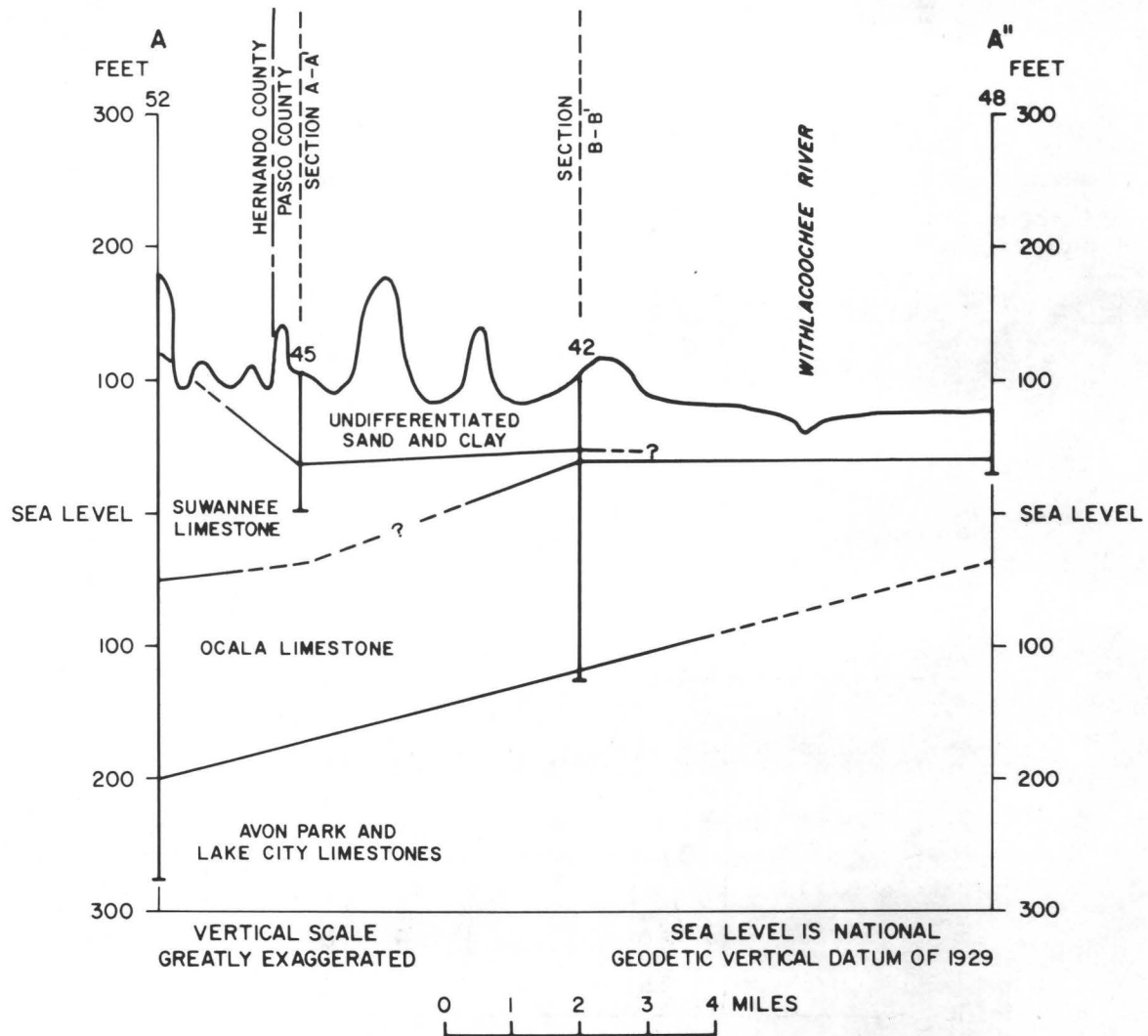


Figure 9.--Geologic section A'-A''.

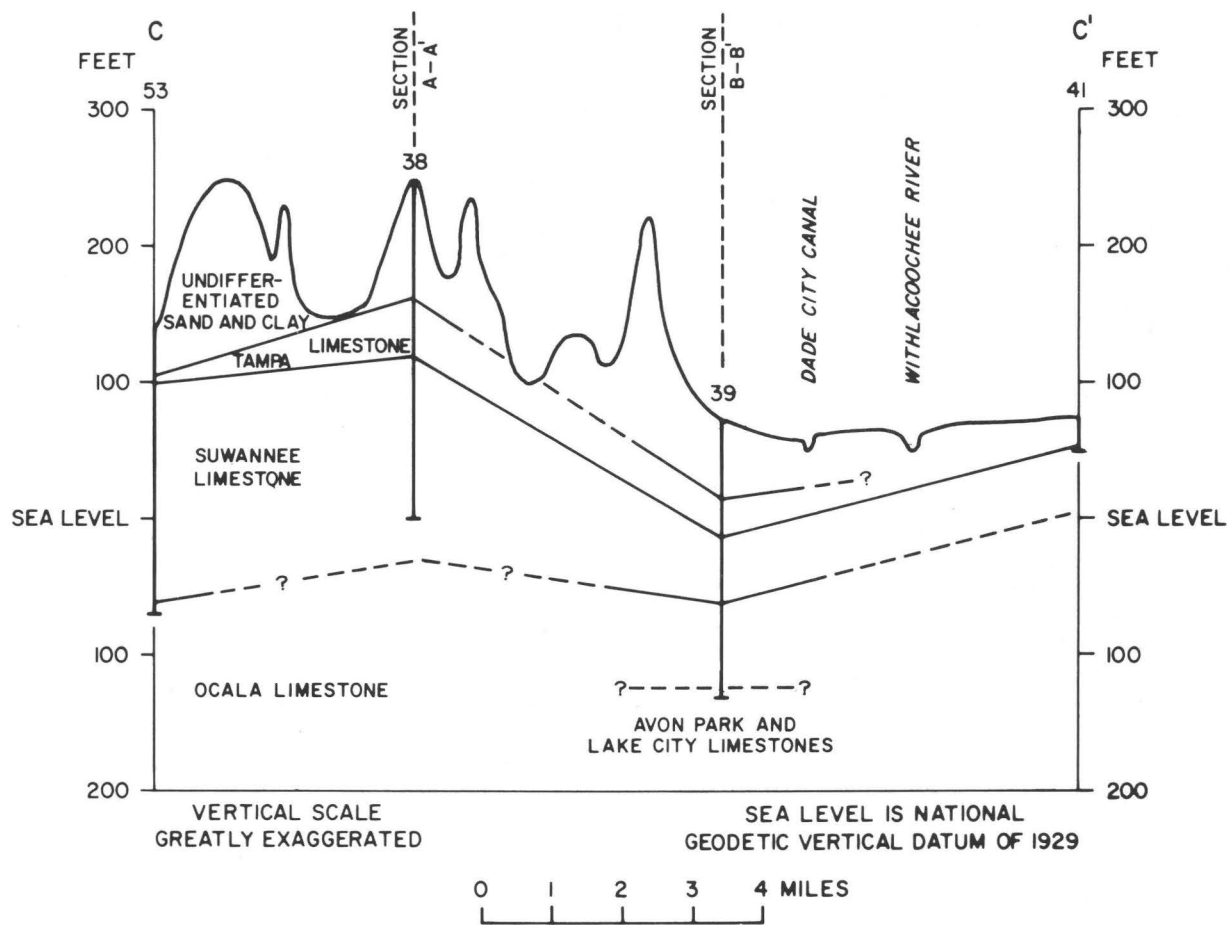


Figure 10.--Geologic section C-C'.

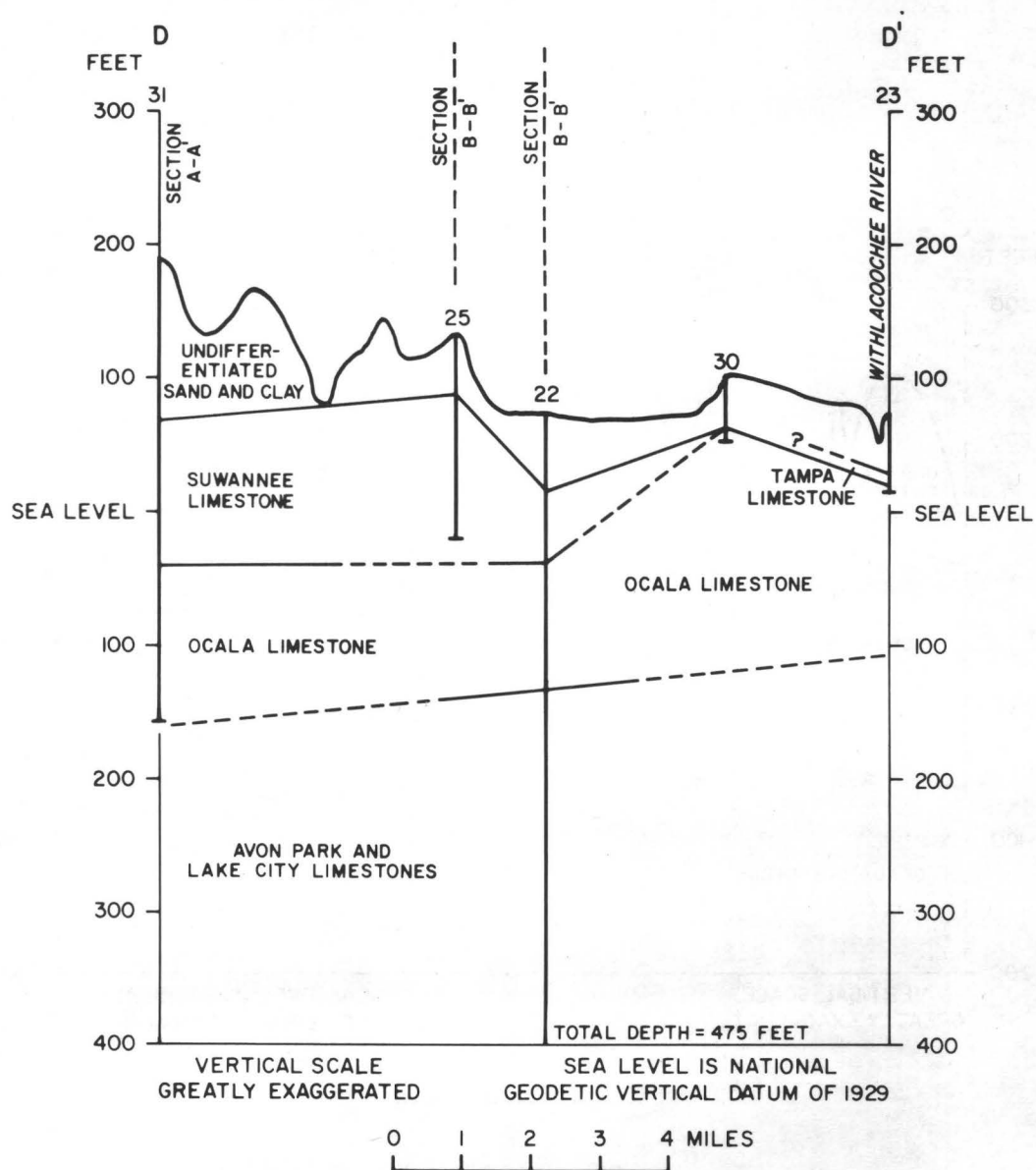


Figure 11.--Geologic section D-D'.

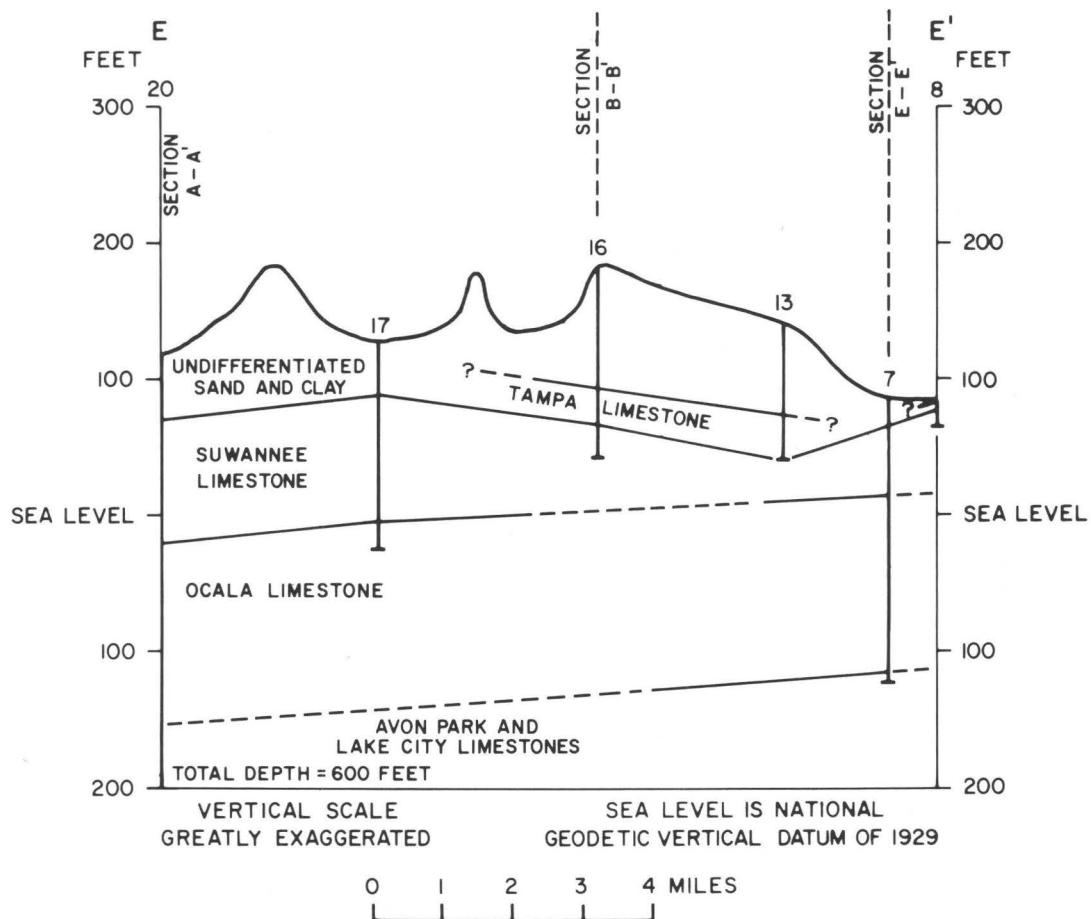


Figure 12.--Geologic section E-E'.

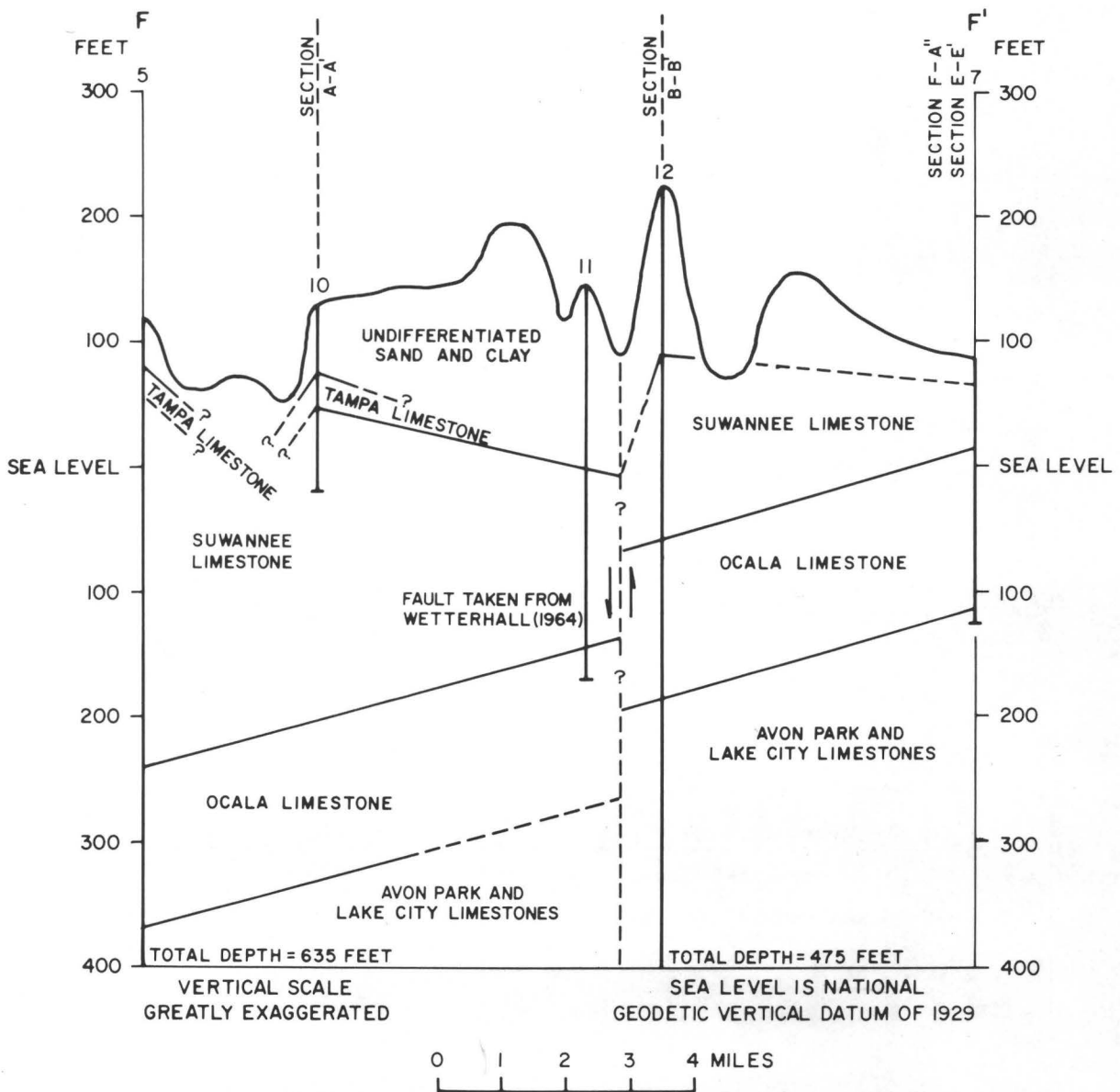


Figure 13.--Geologic section F-F'.

Table 2.--Geologic formations and their water-bearing characteristics in the Dade City area

Age	Formation	Lithology	Quality of water	Use
Holocene and Pleistocene	Undifferentiated sand and clay	Interbedded sand and clay up to 250 feet thick.	Objectionable concentration of iron and high organic color are common.	Only a few small domestic wells.
Miocene	Tampa Limestone	White to gray, sandy, fossiliferous limestone.	Generally satisfactory for domestic supplies without treatment.	Most domestic and many irrigation wells produce water from the basal Suwannee Limestone. Some wells in southwestern Pasco County produce water from the Tampa Limestone if the Suwannee Limestone contains salty water.
Oligocene	Suwannee Limestone	Fossiliferous, yellow to white, finegrained limestone. Hard at bottom.		
Eocene	Ocala Limestone	Soft, chalky, white to tan co-quinoid limestone.	Not well known but probably similar to water from Suwannee Limestone in most areas.	Only a few wells produce water from local cavities.
		Hard, fossiliferous, brown to gray dolomitic limestone.	Contains more sulfate than water from overlying formations but probably does not exceed public health limits in most of area.	Most wells that produce more than 1,000 gal/min penetrate the lower part of the Ocala Limestone and/or part of the hard brown dolomitic section of the Avon Park and Lake City Limestones.
	Avon Park Limestone	Soft to hard, fossiliferous, brown limestone with dark brown beds of dolomitic limestone. Some sapropel.		
	Lake City Limestone			

GROUND WATER

In the study area, ground water occurs under nonartesian and artesian conditions. Nonartesian conditions occur where the upper surface of the zone of saturation (water table) is free to rise and fall in direct response to local rainfall (recharge) and to discharge. Artesian conditions occur where the water in an aquifer is confined by a bed of less permeable material and will rise, in a tightly cased well, above the base of the confining bed. The level to which the water will rise defines the altitude of the aquifer's potentiometric surface, or head, at that location. If the head is above land surface, the well will flow. Measurements of the water level in many artesian wells are used to define the configuration of the potentiometric surface over broad areas.

Surficial Aquifer

The surficial aquifer in the study area is unconfined and consists of sedimentary deposits of white-to-tan, fine to medium-fine quartz sands that grade downward into orange-to-red clayey sand. At some depth below the water table the sand and clayey sand generally grade into a zone of blue or gray-green clay and sandy clay that acts as a confining bed for the underlying limestones that comprise the Floridan aquifer.

The saturated thickness of the surficial aquifer is variable. Its thickness ranges from virtually zero near where the Withlacoochee River borders Hernando County to as much as 90 ft in the topographically-high sand hills northwest of Dade City (fig. 3).

The water table in the surficial aquifer ranges from at or near land surface in the lowlands to a depth of several tens of feet in the sand hills northwest of Dade City. Where the surficial aquifer is thin or where it is underlain by relatively impermeable materials, the water table can stand near land surface even though in the sand hills. For example, about 2 mi south of St. Leo, in a topographically high area (fig. 3) there is a network of drainage ditches used to help maintain the water table at levels lower than it would stand under natural conditions.

The surficial aquifer is recharged by local rainfall, irrigation, septic-tank effluent, and, in areas where the potentiometric surface of the Floridan aquifer is above the water table, from the Floridan by upward leakage through confining beds. Water leaves the surficial aquifer by seepage to lakes, ditches, and streams; by evapotranspiration where the water table is near land surface; by pumpage; and, where the potentiometric surface of the Floridan aquifer is below the water table, by downward leakage to the Floridan.

In terms of the potable water supply of the Dade City area, the most important function of the surficial aquifer is to store water, some of which recharges the Floridan aquifer. The surficial aquifer is little used as a direct source of ground water because, relative to the Floridan aquifer, its permeability is low resulting in relatively low yields to wells. Also, according to Wetterhall (1964), water from the surficial aquifer often contains objectionable concentrations of dissolved iron and is likely to be highly colored.

Floridan Aquifer

In the Dade City area, the principal artesian aquifer is the Floridan aquifer, an approximately 2,000-foot-thick limestone and dolomitic limestone. The top of the Floridan (fig. 14), as used in this report, is characterized by the first vertically persistent occurrence of consolidated carbonate rocks.

In the Dade City area, the Floridan consists of those parts of the Tampa Limestone that meet the above criterion, the Suwannee Limestone, Ocala Limestone, Avon Park Limestone, and part, or, perhaps, all of the Lake City Limestone.

The base of the aquifer and top of the sub-Floridan confining unit is defined as the top of the first vertically persistent anhydrite beds or, in their absence, the top of the transition of the generally permeable carbonate sequence to the much less permeable gypsiferous and anhydritic carbonate beds and beds of chalk. The supra-Floridan confining unit in the Dade City area generally consists of the blue to gray-green clay and sandy clay that, where present, extends from the base of the surficial aquifer to the top of the Floridan.

The Floridan aquifer is recharged (1) by downward leakage from the surficial aquifer in areas where the water table is above the potentiometric surface of the Floridan and where the supra-Floridan confining beds are semipermeable, thin, or breached by sinkholes and (2) by direct rainfall in areas where the Floridan crops out. Discharge from the Floridan occurs by pumping wells, springflow, and by upward leakage to the surficial aquifer in areas where the potentiometric surface of the Floridan is above the water table.

The geologic sections (figs. 6-13) show only one vertical displacement in the Floridan aquifer that could be attributable to faulting (fig. 13) but this does not rule out the possibility of jointing or solution activity causing high transmissivity lineations and, thus, preferential vertical and horizontal flow patterns due to such lineations. The map showing altitude of the top of the Floridan aquifer (fig. 14) shows two generally north-south trending troughs or trench-like features. These features and their hydrologic significance are discussed in later sections of this report.

Figure 15 shows the depths of wells inventoried in the study area by the U.S. Geological Survey. If the well depths shown in figure 15 are considered representative of typical well depths in the study area and if it is assumed that wells are generally drilled no deeper than the depth at which the required amount of water is obtained, then figure 15 suggests that there are essentially two primary producing zones in the Floridan. One zone is from about 10 ft above NGVD of 1929 to 150 ft below NGVD of 1929 and another zone is from about 300 ft to 500 ft below NGVD of 1929. Ryder (1978, fig. 3, p. 7) found nearly the same vertical distribution of water bearing zones in an area about 14 mi southwest of Dade City in the Cypress Creek well-field area. Caliper logs of a few wells (table 3) indicate the presence of cavities in the Floridan aquifer at about the same depths as suggested by figure 15.

Potentiometric Surface

The altitude of the potentiometric surface is constantly changing, mainly in response to changes in rates of recharge and discharge and, to a lesser extent, barometric fluctuations and earth tides. Major fluctuations of the potentiometric surface are seasonal and in response to rainfall or the lack of rainfall. Hydrographs of the two wells in figure 16 show that ground-water levels follow a cyclical pattern of rise and fall that, in general, corresponds with the wet and dry seasons of the year. The long-term trends of water levels of the Floridan aquifer in the Dade City area show no large decline in spite of generally below-normal rainfall since mid-1966 (fig. 16).

Figure 17 shows the regional configuration of the potentiometric surface of the Floridan aquifer in west-central peninsular Florida. The regional flow of ground water in the Floridan aquifer is from areas of high altitude of the potentiometric surface to areas of low altitude, and from areas of recharge to areas of discharge. In the study area, water in the Floridan aquifer flows toward the center from east and west and flows out of the area to the north and south. A north-south trending "trough" in the potentiometric surface in the center of the study area was shown as early as 1934 (fig. 18) by Stringfield (1936, pl. 12). The trough shown by Stringfield is also present in the more recent and detailed Floridan potentiometric maps constructed during this investigation (figs. 19-22). Possible reasons for the occurrence of the trough are: (1) pumping by wells and natural Floridan aquifer discharge, (2) higher aquifer transmissivity in a narrow north-south-trending zone, or (3) a combination of (1) and (2). Reasons (1) and (2) are discussed in the section on "Geohydrology."

Quality of Water

The chemical characteristics of ground water are mostly determined by the types of rocks with which it is in contact, and the length of time the water has been in contact with the rocks.

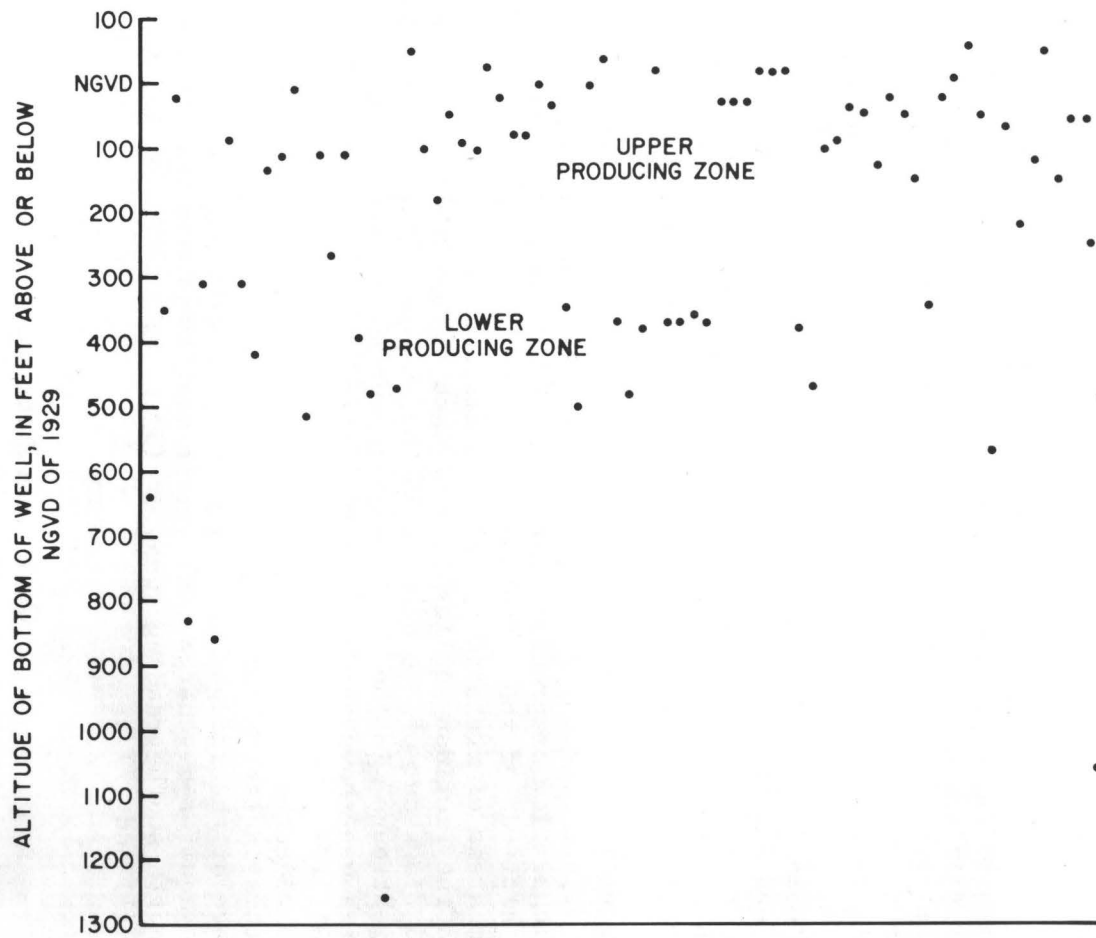


Figure 15.--Altitude of bottoms of inventoried wells in the study area.

Table 3.--Floridan aquifer wells in the Dade City area for which caliper logs are available

Well (see table 1)	Depth interval logged (feet)		Total depth (feet)	Altitude of land surface (feet above NGVD of 1929)
	from	to		
¹ 50	64	1425	1434	175.66
² 139	248	460	461	88.56
³ 62	62	178	178	77.43
⁴ 61	116	171	176	85.27

¹Krissman's well; logs furnished by Craig Helpling, Florida Department of Environmental Regulation.

²Lykes-Pasco Packing Co.; potable supply.

³Lykes-Pasco Packing Co.; fire well test hole.

⁴Lykes-Pasco Packing Co.; observation well.

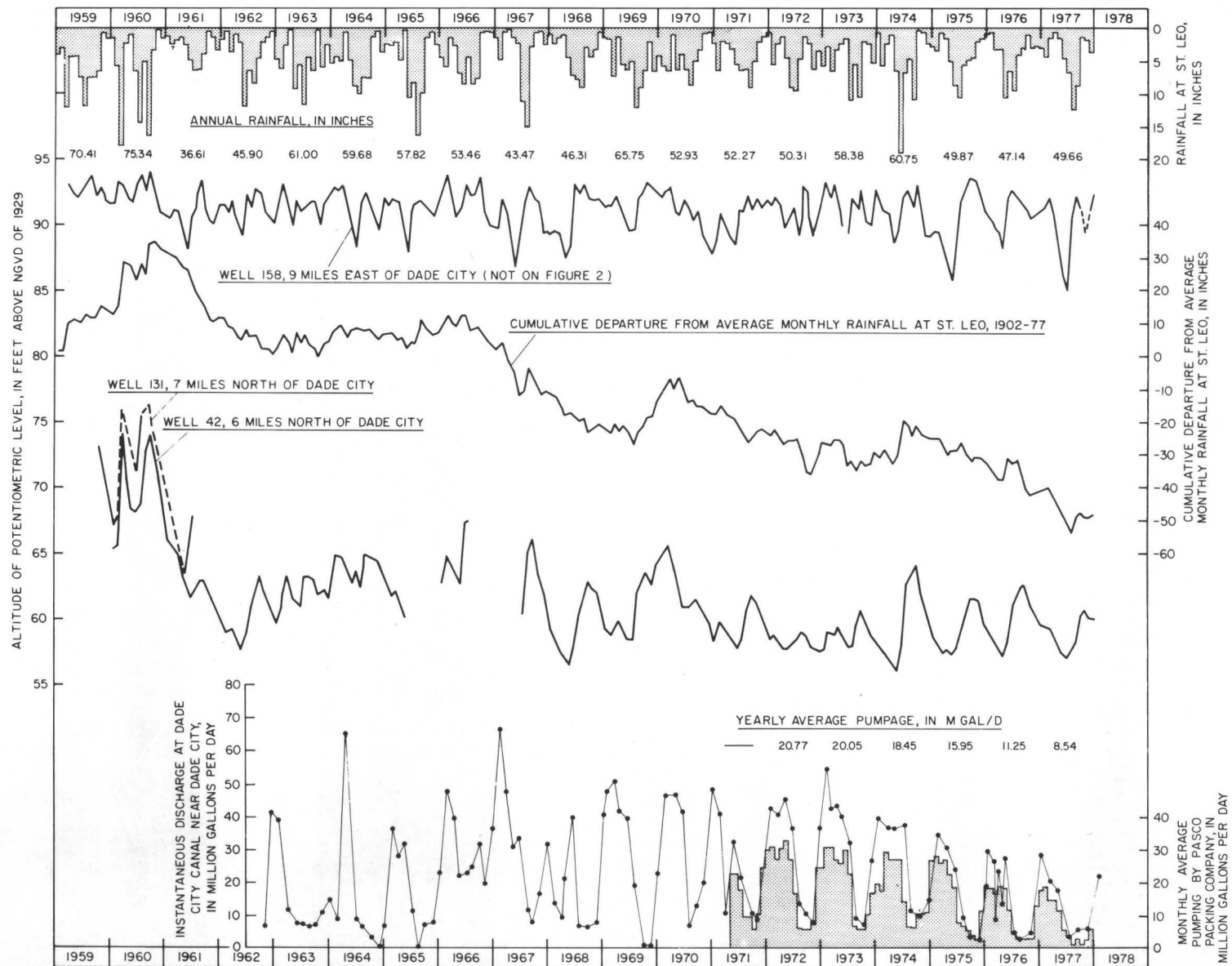


Figure 16.--Monthend potentiometric levels in selected Floridan aquifer wells, monthly rainfall at St. Leo, cumulative departure from average monthly rainfall at St. Leo, discharge of Dade City Canal near Dade City, and pumping by Lykes-Pasco Packing Co., January 1959-December 1977.

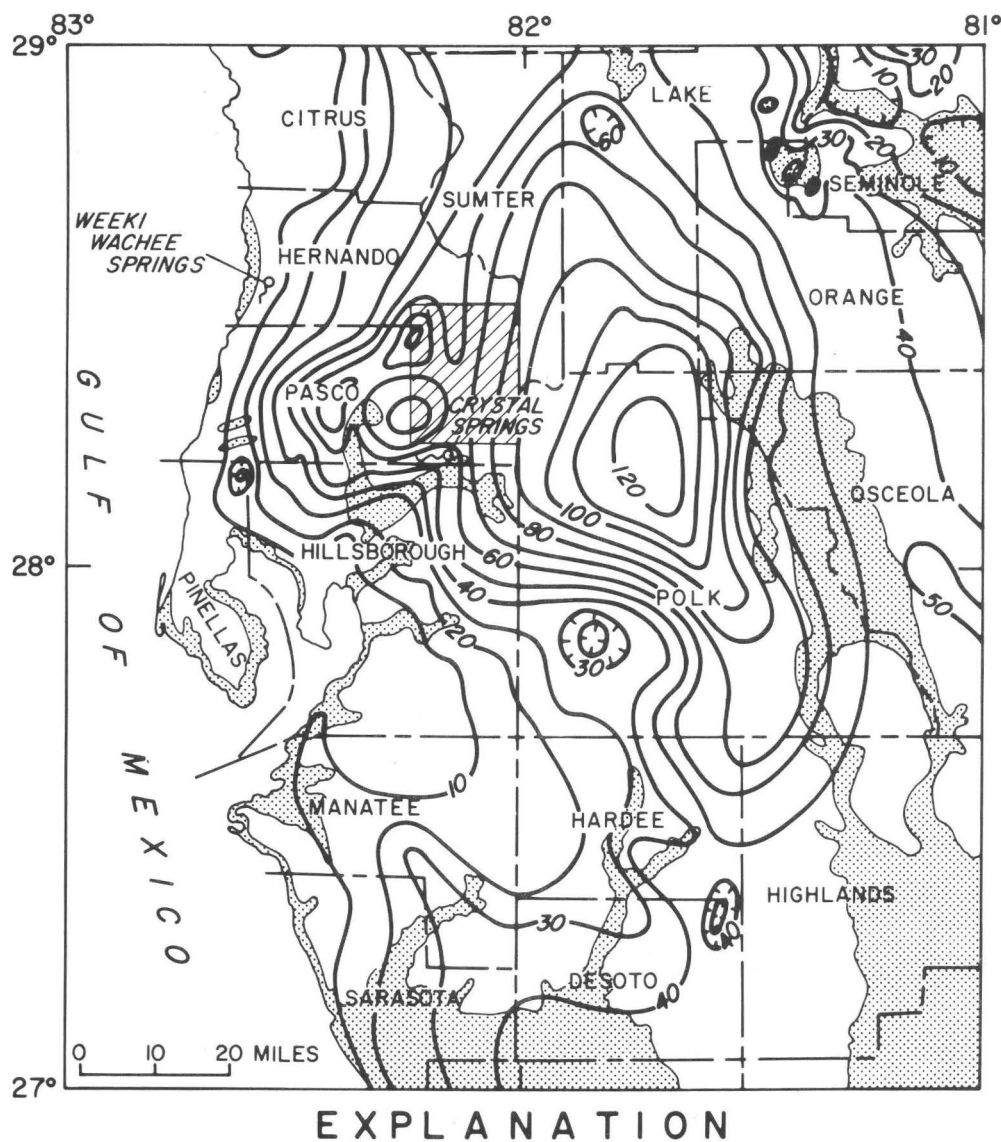


Figure 17.--Potentiometric surface and areas of artesian flow of the Floridan aquifer in west-central peninsular Florida, May 1974.

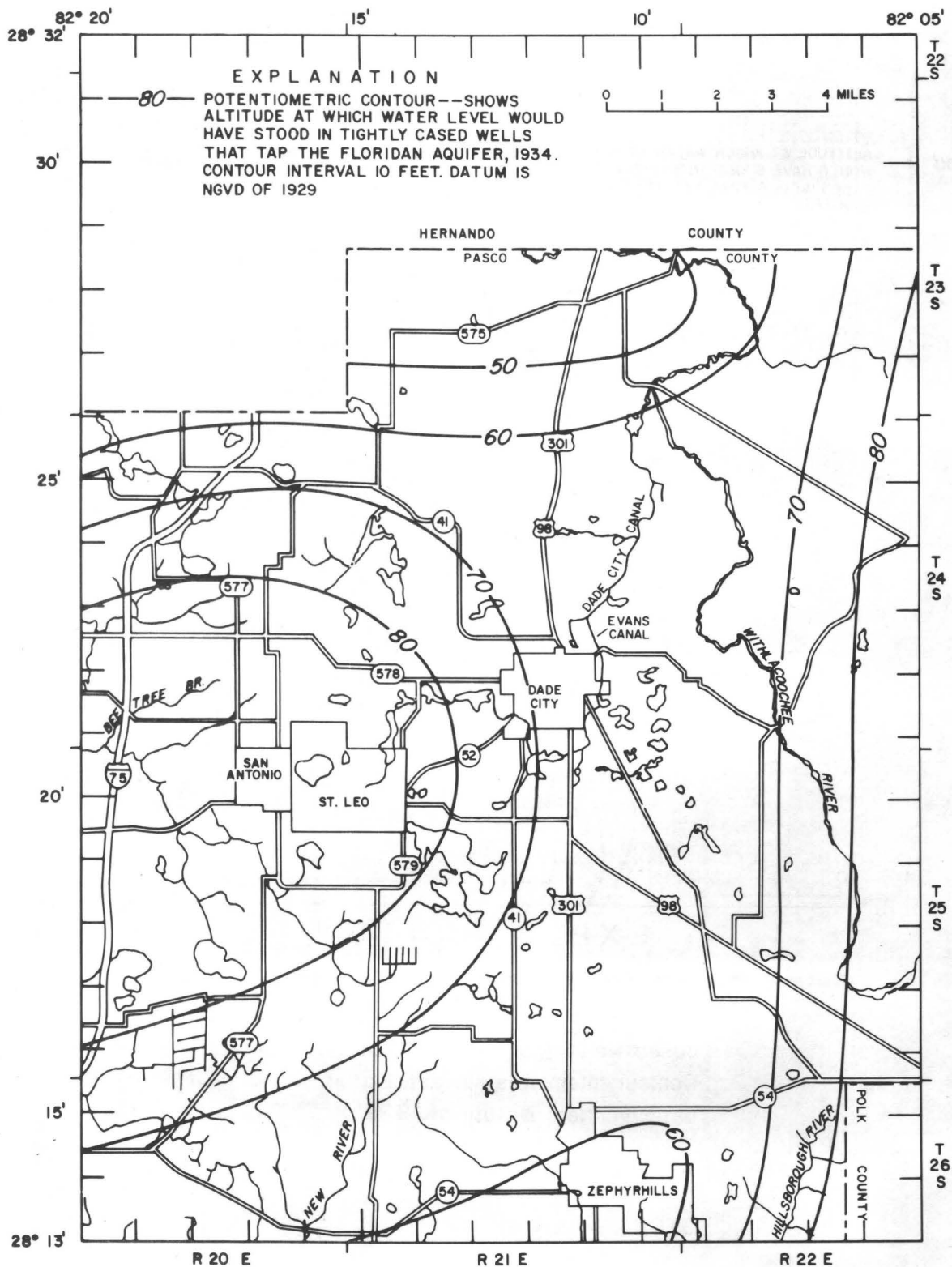


Figure 18.--Potentiometric surface of the Floridan aquifer in the Dade City area, 1934 (adapted from Stringfield, 1936).

In general, the mineralization of water in the Floridan aquifer in the study area tends to increase with depth. An example of such increase in mineralization is given by figure 23. Note that, below an altitude of about 650 ft below NGVD of 1929, the mineralization of the water in well 50, as represented by its hardness, dissolved solids concentration, and specific conductance, increases rather steeply. This indicates that, at altitudes of less than about 650 ft below NGVD of 1929 the Floridan aquifer flow system is relatively sluggish as compared to the flow system at shallower depths.

Though mineralization tends to increase with depth, the chemical quality of Floridan aquifer water also varies from place to place within the study area. The chemical characteristics of Floridan aquifer water at depths of 650 ft or less with respect to dissolved solids, hardness, and sulfate in the Dade City area are shown in figures 24-26. Those parameters vary areally and definite patterns are readily apparent.

The hardness of water and the dissolved solids concentration is greatest on the east and west flanks of the study area and lowest in the center to the north and south of Dade City (figs. 24 and 25). The sulfate concentration in the water is greatest in the immediate vicinity of Dade City and least to the west, south, and east of Dade City (fig. 26). Within any of the patterned areas of figures 24-26 the concentration or value of the chemical parameter is, in general, greater in the deeper wells. Where the values are considered anomalously high for a particular area they are ignored in the overall interpretation but remain as data points on the figures. The data values are flagged as "not representative." Examples of such wells are the northernmost wells sampled in Zephyrhills (well 69) and well 60, 2 mi south of Hernando County and 2 mi east of Interstate Highway 75 (figs. 24-26).

The sulfate concentration is relatively high in water from relatively shallow Floridan aquifer wells in the immediate vicinity and to the north and south of Lykes-Pasco Packing Co. (figs. 26 and 27). The reason for the occurrence of these relatively shallow, high-sulfate waters, usually indicative of water at greater depths, is not known but it could be the result of joints or solution channels in the limestone. It is possible that such joints or channels could provide an avenue for upward movement of deeper waters in response to pumping. Some indirect evidence for interconnection of zones of the Floridan aquifer in the immediate vicinity of Lykes-Pasco is presented in the "Geohydrology" section of this report. An alternative explanation for the relatively shallow, high-sulfate waters is that unreported beds of gypsum or anhydrite (sulfate-bearing rocks) might exist at shallow depths in the area.

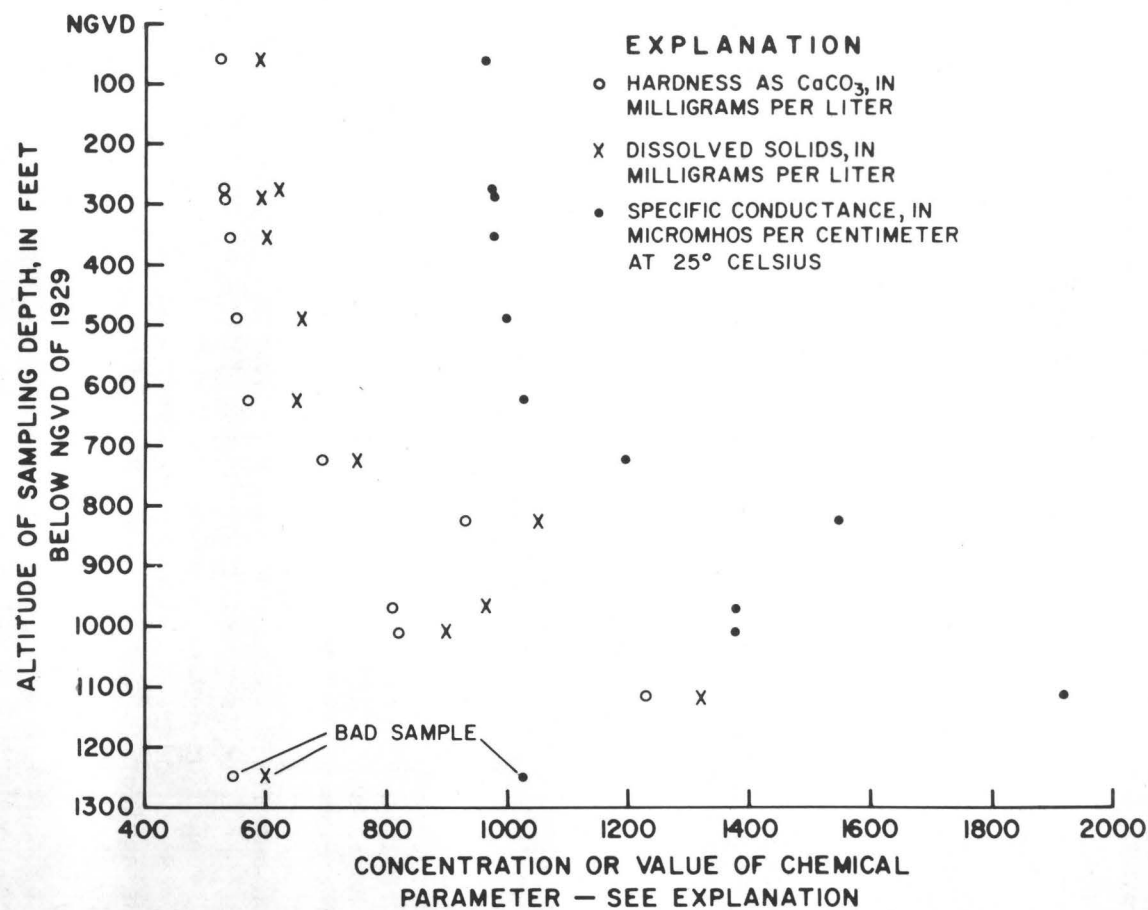


Figure 23.--Hardness, dissolved solids concentration, and specific conductance of water at various depths in well 50, December 16-17, 1975.

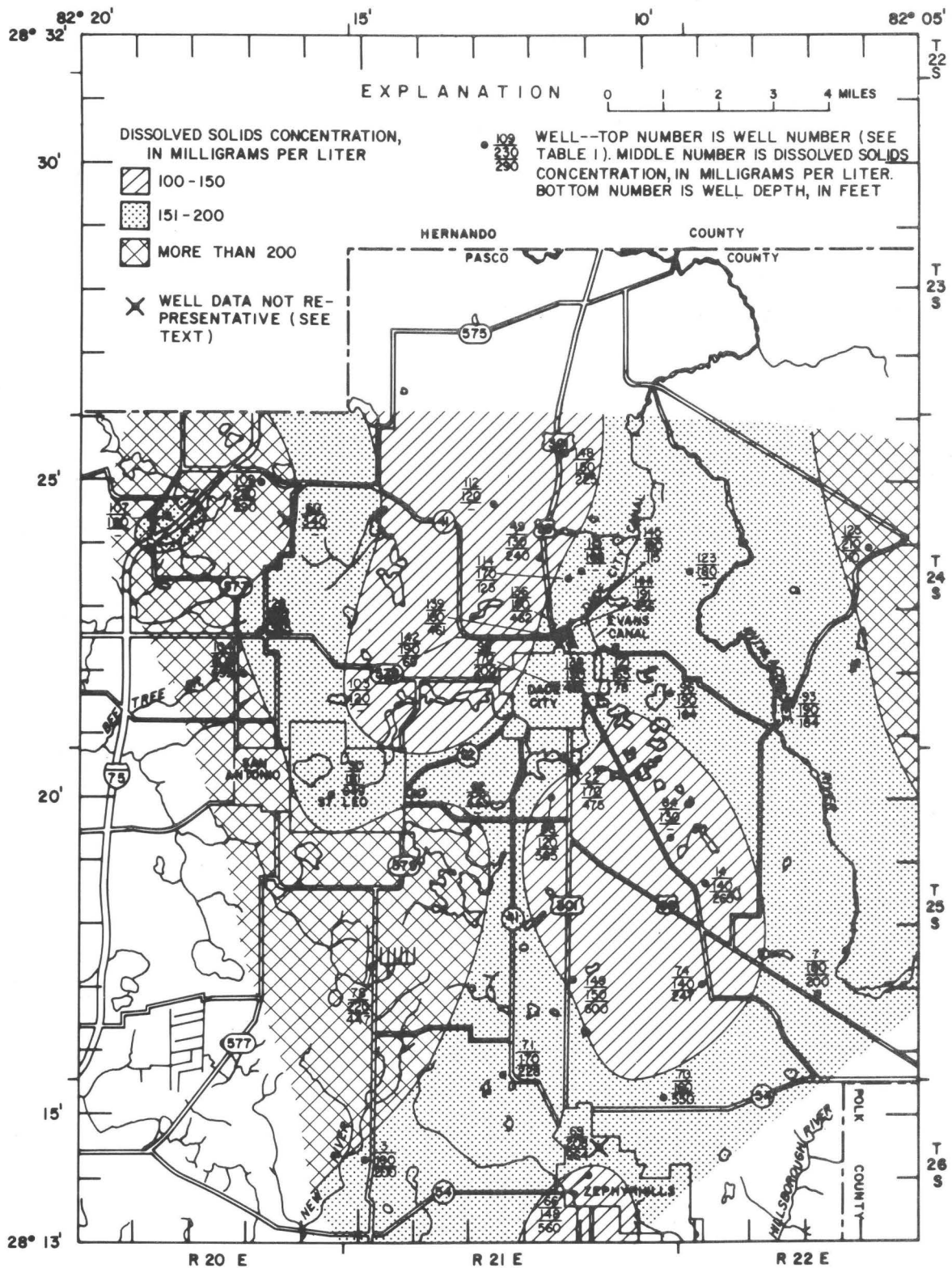


Figure 24.--Dissolved solids concentration in water from wells that tap the Floridan aquifer at depths of 650 feet or less in the Dade City area.

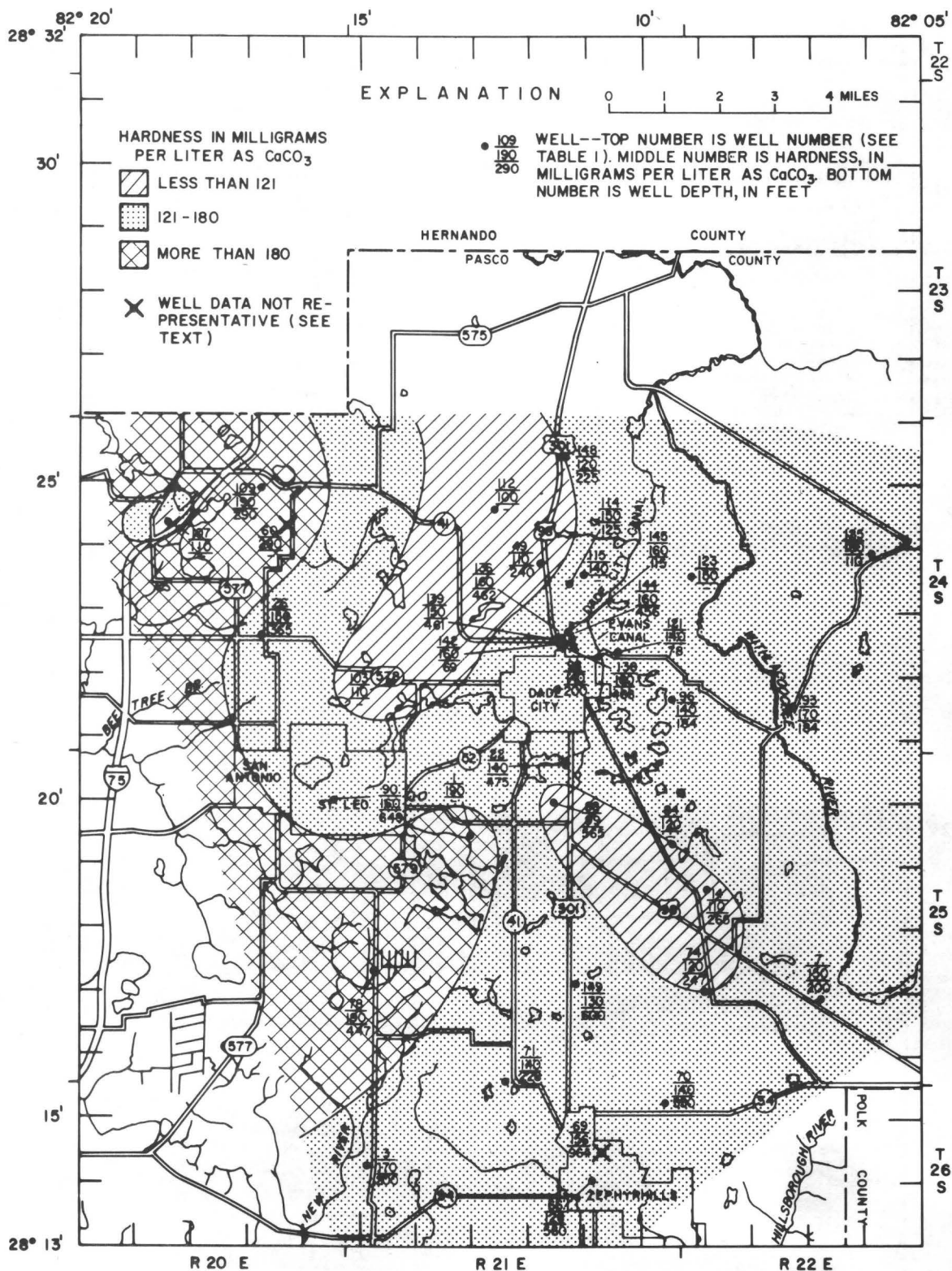


Figure 25.--Hardness of water from wells that tap the Floridan aquifer at depths of 650 feet or less in the Dade City area.

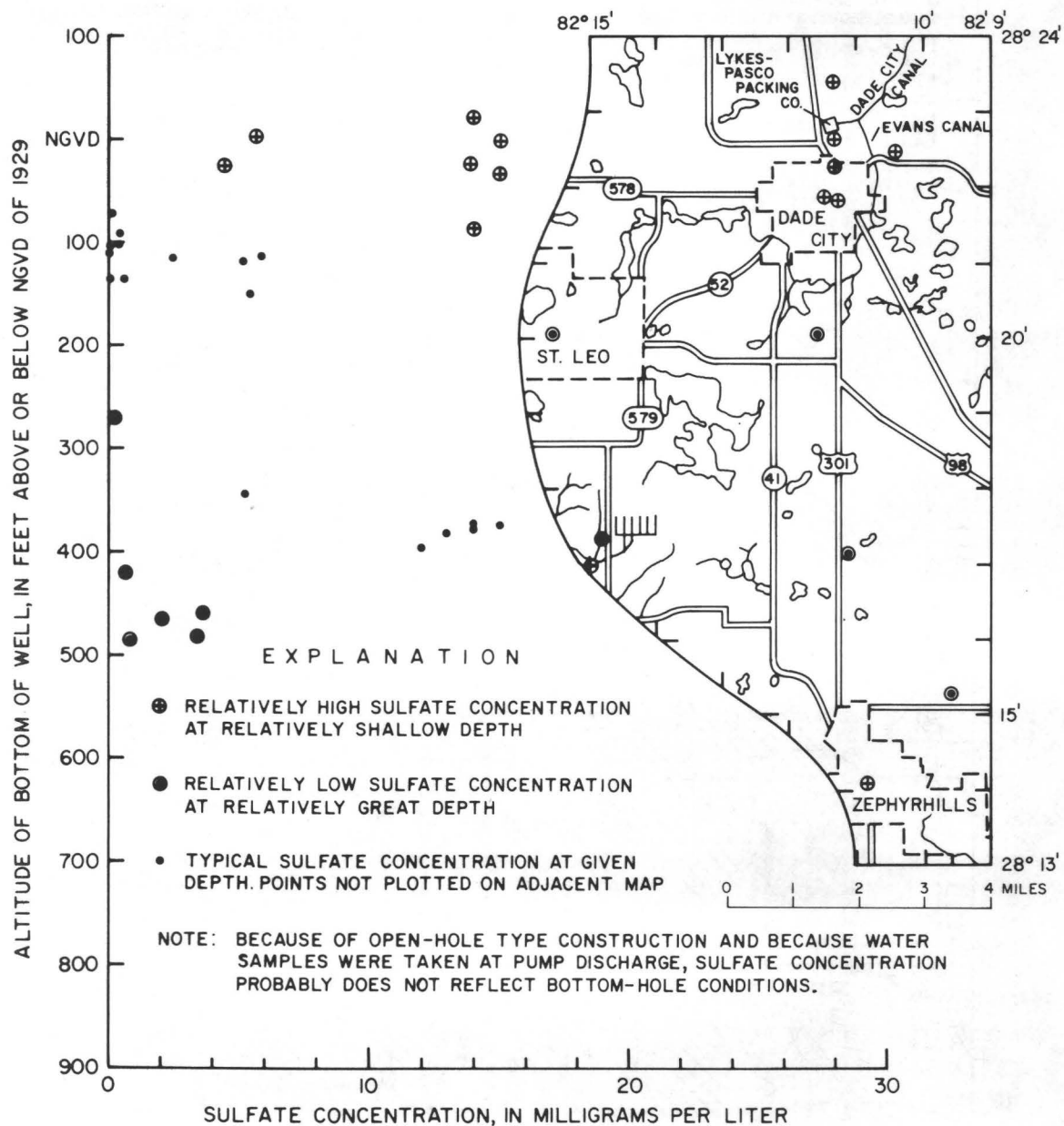


Figure 27.--Relation of sulfate concentration to altitude of bottoms of selected wells in the study area.

Ground-Water Use

Virtually all ground water used in the study area is pumped from wells that tap the Floridan aquifer. In 1975, about 32 Mgal/d were pumped from the Floridan in the Dade City area, whereas about 75 Mgal/d were pumped in the county as a whole (table 4). The largest single user of ground water in the study area is Lykes-Pasco Packing Co. Of the approximately 19.8 Mgal/d pumped by self-supplied industry in 1975 (table 4) in the study area, about 16 Mgal/d were pumped by this citrus processing plant about 1 mi north of Dade City (fig. 2). From 1975 to 1977, pumping by self-supplied industry has apparently declined (table 4). This decline is primarily because Lykes-Pasco has been recycling their process water so that less new "make-up" water is required (Norvell W. Hunt, written commun. June 8, 1977). According to Mr. Hunt, Lykes-Pasco began recycling water in 1971. This is shown by the reported water use data shown in figure 16.

GEOHYDROLOGY

The north-south trending trough in the potentiometric surface of the Floridan aquifer (figs. 17-22) existed as early as 1934 (fig. 18), about 7 years prior to the beginning of pumping by Lykes-Pasco. The trough could be caused by a line sink of discharge along the orientation of the trough or by points of discharge near each end of the trough. Since the potentiometric surface is below land surface throughout almost the entire area of the trough, the line sink is ruled out because it is probable that recharge, rather than natural discharge, is taking place over most of that area. The following discussion concerns the occurrence of Floridan aquifer point discharges at or near the ends of the trough.

On May 25, 1961, during a period of low flow, there was about 12 ft³/s measured increase in the flow of the Withlacoochee River between station 42 at U.S. Highway 301 and at station 41, approximately 5 mi upstream (fig. 28). Pride and others (1966, p. 81) indicated there was a Floridan aquifer spring at the confluence of Gator Hole Slough and the Withlacoochee River, downstream from Dade City and between stations 41 and 42 (fig. 28). This spring is probably the source of most of the 12 ft³/s increase in stream-flow. These low-flow measurements were made during a period of extreme low flow (Pride and others, 1966, p. 38). Therefore, there was little if any surface inflow and probably only minor amounts of seepage from the surficial aquifer.

In addition to the approximately 12 ft³/s of apparent Floridan aquifer discharge into the Withlacoochee River between stations 41 and 42 (fig. 28) there apparently was an additional 39 ft³/s of Floridan discharge into the river between stations 42 and 44. The Little Withlacoochee River flows into the Withlacoochee between stations 42 and 44 but only 0.10 ft³/s was measured as inflow to

Table 4.--Floridan aquifer ground-water use in Pasco County, 1975, and in the study area, 1975-77 (estimated except where noted)

	Pumping rate, in (Mgal/d)		
	Study area (county ¹) 1975	Study area 1976	Study area 1977
Public supply	¹ 1.06 (2.96)	1.1	1.2
Rural domestic	3.2 (10.39)	3.4	3.6
Self-supplied industry ²	19.8 (24.03)	15.1	12.4
Irrigation	8 (37.75)	8	8
Total	32.1 (75.13)	27.6	25.2

¹From Healy (1977).

²Includes Lykes-Pasco Packing Co. (see fig. 16).

the Withlacoochee River from the Little Withlacoochee River (station 43, fig. 28). Since the Little Withlacoochee River was not the source of the increase in flow between stations 42 and 44, the increase is probably due to Floridan aquifer discharge into the Withlacoochee River.

At station 40, upstream from the confluence of Dade City Canal, only 0.53 ft³/s was measured whereas at station 41A on Dade City Canal downstream from Lykes-Pasco Packing Co., 74.8 ft³/s was measured. Though no records of pumping by Lykes-Pasco are available for May 1961, it is possible that almost all the water flowing in Dade City Canal was discharged by Floridan aquifer wells at Lykes-Pasco Packing Co.

Thus, in May 1961 there probably was about 126 ft³/s of Floridan aquifer discharge into the Withlacoochee River near the north end of the trough in the Floridan aquifer potentiometric surface. The Withlacoochee shows a loss of about 3 ft³/s between stations 41A and 41 (fig. 28) but the difference in measured flow could be due to measurement error. Measurement error affected all the measurements to some extent.

The 12 ft³/s water discharged into the Withlacoochee River between stations 41 and 42 is apparently from the Floridan aquifer because according to the equation:

$$Q_{41}C_{41} + Q_p C_p = Q_{42}C_{42}$$

where:

Q_{41} = 71.8 ft³/s (discharge at station 41),
 C_{41} = 177 mg/L (concentration of dissolved solids at station 41),
 Q_p = 12.2 ft³/s (increase in flow between station 41 and 42),
 C_p = dissolved solids concentration of flow increase between stations 41 and 42,
 Q_{42} = 84 ft³/s (discharge at station 42),
 C_{42} = 189 mg/L (concentration of dissolved solids at station 42),
and solving for C_p , the concentration of dissolved solids in the 12 ft³/s increase in flow between stations 41 and 42, $C_p = 260$ mg/L. This is approximately the dissolved solids concentration of water in the Floridan aquifer along the reach of the Withlacoochee River between stations 41 and 42 (Pride and others, 1966, fig. 45). The Floridan aquifer crops out or is within 10 ft of land surface along the reach of the Withlacoochee River from stations 41 to 44 (fig. 28) (Pride and others, 1966, fig. 31; Grubb, 1977, fig. 6) so it is probable that the Withlacoochee River has incised the Floridan (fig. 14).

Crystal Springs (fig. 17), a Floridan aquifer spring near the south end of the potentiometric trough, about 5 mi south of the north city boundary of Zephyrhills on the left bank of the Hillsborough River, discharges, on the average, about 59 ft³/s into the Hillsborough River (U.S. Geological Survey, 1977).

Lykes-Pasco pumping and upward leakage from the Floridan to streams are points of Floridan discharge north of the Dade City area. The flow of Crystal Springs is a point of discharge from the Floridan south of Dade City. Thus, there is point discharge near each end of the Floridan potentiometric trough in the study area. But, according to the low-flow analysis of Pride and others (1966), there could be as much as 48 ft³/s of naturally-occurring Floridan discharge near the north end of the potentiometric trough between stations 41 and 44 (fig. 28).

The potentiometric trough could also be due to a north-south trending zone of relatively high aquifer transmissivity. This zone could act as a lateral drain and cause a depression in potentiometric head which in turn would cause a trough in the potentiometric surface. Water would then flow toward the trough from the east and west and leave the trough to the north and south under very small hydraulic gradients. There is some evidence of north-south trending joints or solution channels in the limestone of the Floridan aquifer. Topographic maps in the U.S. Geological Survey's 7½-minute series show several lakes along an 8-mi alignment paralleling U.S. Highway 98 and U.S. Highways 98 and 301. These lakes were probably formed by solution of the underlying limestone but the lakes themselves are probably not open to the limestone. The solution activity that formed these lakes may have been enhanced in the geologic past by the Withlacoochee incising a channel along the lakes' alignment rather than in its present channel. White (1958, p. 19-27) suggests that, in the geologic past, the Withlacoochee may have been alternately submergent and emergent because of major oscillations of sea level during glacial and interglacial periods and that the Withlacoochee River could have trenched deeply during glacial periods of low sea level. Such trenching could have incised the limestone of the Floridan aquifer. He also suggests that, not only did the Withlacoochee follow another course in the Tsala-Apopka Lake area in Citrus County, but that it actually flowed south and joined with the Hillsborough River.

The water-quality maps showing dissolved solids concentration, hardness, and, to some extent, sulfate concentration (figs. 24-26) show definite north-south lineations along the general orientation of the potentiometric trough (figs. 18-22). In general, the dissolved solids concentration and hardness are least along the trough except in the immediate Dade City area and near Lykes-Pasco, whereas the sulfate concentration tends to be greater there than to the east and west. There appears to be a contradiction here because the lower dissolved solid concentration and hardness imply vigorous downward circulation of recently recharged water whereas the higher sulfate waters are usually indicative of water that has been in the aquifer for a long time or water that has come in contact with beds of gypsum or anhydrite. These beds usually occur at relatively great depth, usually near the base of the Floridan aquifer or, at least, near the base of the Lake City Limestone (Wetterhall, 1965, p. 9).

The relatively high sulfate concentration in water at shallow depths in the immediate Dade City area is perhaps indicative of some interconnection of deep and shallow aquifer zones.

There is a cone of depression in the Floridan aquifer potentiometric surface near U.S. Highway 301 about 2 mi north of Zephyrhills (figs. 20-22). Wetterhall (1964, fig. 1) noted a similar depression on his 1960 map. There is no appreciable pumping from the Floridan aquifer in the area of the depression so pumping apparently is not the cause. On all recent maps where the depression is shown, the interpretation is based upon water levels measured in only one well. However, Wetterhall measured a different well (well 12) than was used in this study (well 149), thus some degree of corroboration is implied. The well Wetterhall measured is 18 in. in diameter and 957 ft deep (verified by Florida Geological Survey -- now Florida Bureau of Geology -- well log W-2160). The depth of the well measured in this study is unknown. However it is only 4 in. in diameter so it is unlikely that it is more than a few hundred feet deep. In most of the study area where the potentiometric surface of the Floridan aquifer is below land surface, the deeper Florida aquifer wells have lower water levels than shallower Floridan wells in the same immediate vicinity. For example, well 50 near State Highway 52 near the southwest city limit of Dade City (fig. 2) is 1,434 ft deep, cased to a depth of 64 ft, and its water level stood at about 59 ft above NGVD of 1929 July 1976, whereas, according to the potentiometric contours (fig. 20), the water level in a well tapping only the upper part of the aquifer would have stood at about 66 ft above NGVD of 1929. The water level measured in well 50 was not used to construct the map in figure 20 because of its low water level and the fact that its depth was known to be unusually deep compared to the other wells used to construct the map.

It is possible that the cone of depression shown in this study (figs. 20-22) and in Wetterhall (1964, fig. 1) using the water levels in wells 149 and 12, respectively, could be a misinterpretation. This could be because both wells are so deep that they have water levels that are not representative of the potentiometric surface in the upper part of the Floridan. This probably is the case in Wetterhall's (1964, fig. 1) potentiometric map but the depth of the well used in this study is not known so the validity of the interpretation remains in question. If in fact the cone of depression shown in figures 20-22 and in Wetterhall (1964, fig. 1) does represent head levels in the upper Floridan, then there is reason to suspect that there is an exceptionally good interconnection of the upper and lower producing zones in the Floridan aquifer as shown in figure 15. This would tend to depress the head in the upper zone because water would tend to leak downward into the lower zone at a rate somewhat faster than in areas where the interconnection of the zones is not as effective.

In the immediate vicinity of Lykes-Pasco Packing Co., the upper and lower producing zones of the Floridan aquifer (fig. 15) appear to be in good hydraulic connection. In figure 29, the water levels in selected wells on February 2-3, 1977, are plotted against their respective well depths referenced to NGVD of 1929. The main center of pumping for Lykes-Pasco is near wells 141 and 61 and inside a trough that describes the altitude of the top of the Floridan aquifer (figs. 14 and 29). Note that water levels in 3 of the 4 groups of wells are nearly the same, regardless of their depths. The exceptions are wells 121 and 119. Though these wells are approximately the same distance to the center of pumping and are both relatively shallow wells, well 119 has a water level that is about 1.5 ft lower than that of well 121. Both wells are on the east flank of the trough in the surface of the Floridan aquifer. Their different heads could be attributable to lateral anisotropy or aquifer heterogeneity.

The geohydrologic information in this report is representative, primarily, of the upper producing zone of the Floridan aquifer. There is little information available on the lower producing zone. Information on the lower zone is difficult to obtain because there are relatively few deep wells and they are usually equipped with turbine pumps which are difficult to remove. Hence, geophysical logging is precluded and it is often difficult to obtain accurate water level measurements. Since many of the wells are irrigation wells in remote areas, it is sometimes difficult to have the owners present to operate the pumps so that water samples can be obtained.

HYDROLOGIC SIGNIFICANCE OF GROUND-WATER WITHDRAWALS IN THE DADE CITY AREA BY LYKES-PASCO PACKING CO.

Lykes-Pasco Packing Co. began citrus processing operations in 1942 but pumpage records are available only since about mid-1971. Estimates of ground-water withdrawals prior to 1971 can be made because most of the flow in Dade City Canal near Dade City (fig. 2) is ground water pumped by this citrus processing plant. Periodic measurements of that flow have been made and recorded since late 1963 (fig. 16). There is a good relation between average annual flow in Dade City Canal and average annual discharge by the plant from 1972-77 (fig. 30A). The regression equation describing that relation is used to estimate the average annual pumping by the plant from 1963-71 (fig. 30B). There is no satisfactory method to estimate pumping by Lykes-Pasco prior to 1963.

Of the 16 Lykes-Pasco production wells, 9 tap the lower Floridan producing zone. Of that nine, at least three are cased through the upper producing zone and, thus, are open only to the lower zone while the cased depths of six are unknown. Thus it is possible that six wells are open to both the upper and lower zones. Seven wells are open only to the upper producing zone.

EXPLANATION

— 50 — STRUCTURE CONTOUR— SHOWS ALTITUDE OF TOP OF FLORIDAN AQUIFER. CONTOUR INTERVAL 25 FEET. DATUM IS NGVD OF 1929.

○ 141 WELL— NUMBER IS WELL NUMBER (SEE TABLE I).

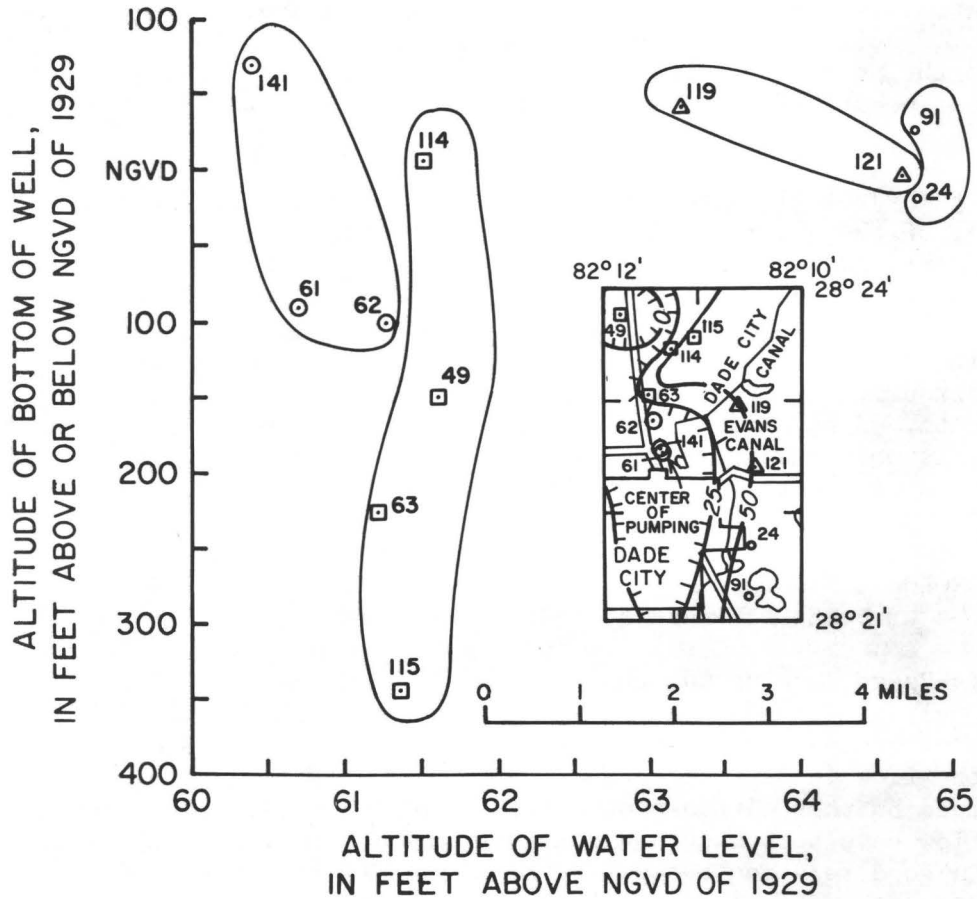


Figure 29.--Well depth versus potentiometric surface of the Floridan aquifer in the vicinity of Lykes-Pasco Packing Co., February 2-3, 1977.

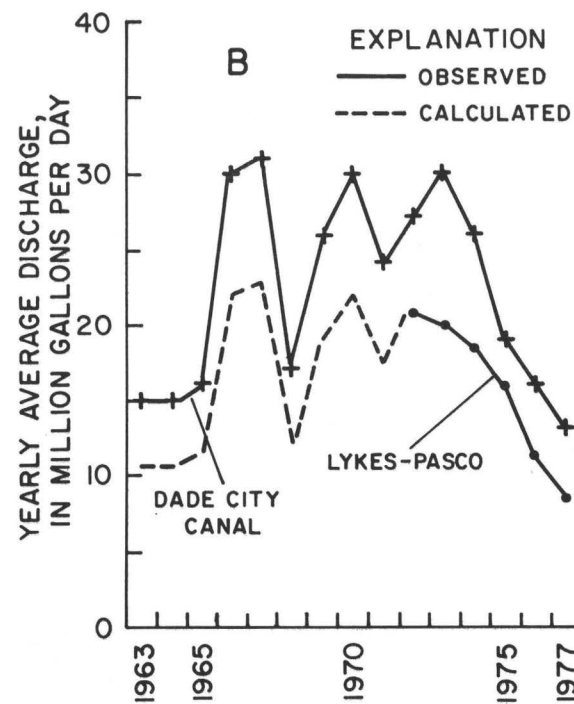
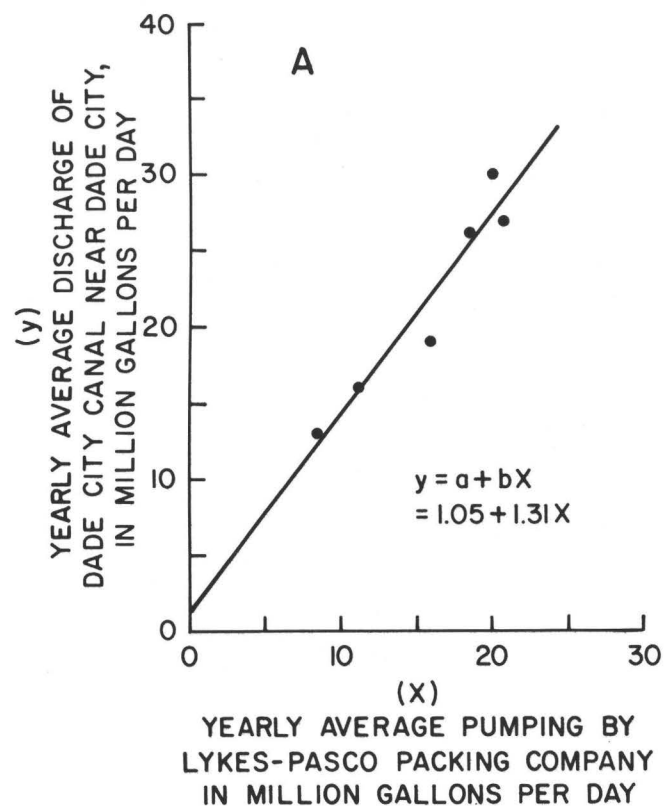


Figure 30.--Relation of flow in Dade City Canal near Dade City to pumping by Lykes-Pasco Packing Co.

The individual pumping rates of the production wells are unknown. Also, the periods of pumping of the various wells are mixed. This lack of information plus the uncertainty of the producing zones tapped by the wells precludes an exact determination of the amounts of water taken from each of the Floridan producing zones. Ryder (1978, p. 8) states that field tests in the Cypress Creek well field, 14 mi southwest of Dade City, indicate that the lower producing zone may supply most of the water to pumping wells that are open to both zones.

During 1963-77, the maximum annual pumping rate was about 30 Mgal/d and probably occurred in either 1966 or 1967 (fig. 30B). Peak, or instantaneous, pumping rates have been as high as 66 Mgal/d (April 28, 1964, fig. 16). Since 1972, annual pumping has steadily declined and, by 1977, was about 9 Mgal/d. According to Mr. Norvell Hunt, Director of Environmental Control, Lykes-Pasco Packing Co. (oral commun.) the lower pumping rates reflect the plant's increased use of recycled water during citrus processing.

From early 1976 through December 1977, water levels were measured continuously in four Floridan aquifer wells in and near the center of pumping of the citrus processing plant (fig. 31). In January-April 1976, water levels declined at a rate of about 0.02 ft/d. During this period the plant was pumping at about 20 Mgal/d (figs. 16 and 31) and rainfall was about 8 in. below normal. During May-September 1976 water levels rose about 7 ft because (1) of seasonal increases in rainfall that, in addition, were about 7 in. above normal and (2) the citrus processing plant had decreased their pumping rate to about 3 Mgal/d. In the first 9 months of 1976, seasonal variations in rainfall and in pumping by the plant were somewhat in phase and it is not possible to separate their effects on water levels in the observation wells (fig. 31). However, in October-November 1976, at the beginning of the seasonal dry period, water levels began to decline at a rate of about 0.03 ft/d even though the plant was still pumping at a reduced rate of about 3 Mgal/d. Rainfall during September-October 1976 was about 8 in. below normal. Rainfall during November-December 1976 was about normal for this ordinarily dry period. On December 6, 1976 the plant increased the pumping rate. It is estimated from the discharge record at Dade City Canal that, by December 7, the plant was pumping at a rate of about 25 Mgal/d, an increase of about 22 Mgal/d. On December 6, water levels in the three observation wells began to decline, clearly in response to the increased pumping rate. The 25 Mgal/d pumping rate remained relatively constant for about 3 days (through December 10). After that time the pumping rate was reduced intermittently.

The drawdown resulting from the increased pumping rate is estimated by extrapolating the trend of declining water levels (prior to pumping) past the time at which pumping began and, at any given time, subtracting the altitude of the observed water level (after

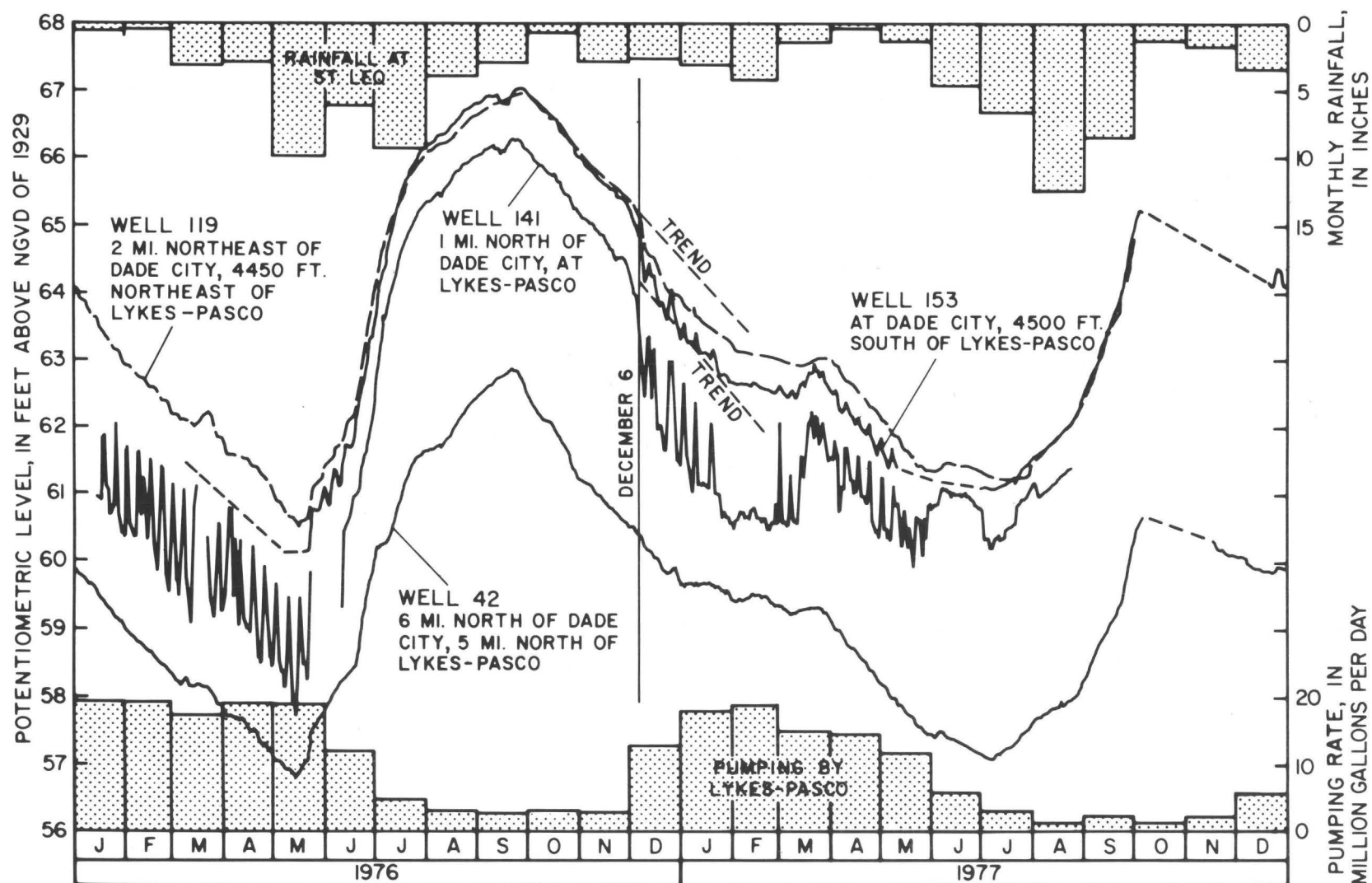


Figure 31.--Daily high potentiometric levels in selected Floridan aquifer wells in the Dade City area, monthly rainfall at St. Leo, and pumping by Lykes-Pasco Packing Co., January 1976 to December 1977.

smoothing the hydrograph) from that which is estimated that would have occurred had there been no increase in pumping (fig. 31). Drawdowns are thus calculated at several times after pumping started and are used to construct a graph of estimated drawdown versus time (fig. 32). Only the first 4 data points corresponding to the first 4 days of pumping are considered valid for the increased pumping rate of 22 Mgal/d.

In the immediate vicinity of the citrus processing plant the upper and lower producing zones (as suggested by figs. 15 and 29) of the Floridan are probably in good hydraulic connection. This is also implied by (1) figures 24 and 27 that show sulfate concentration in water from the deep and shallow Floridan wells to be virtually the same and (2) the apparent trenching on the top of the aquifer (fig. 14) that could be indicative of deep-seated interconnection of zones caused by solution activity. This was discussed in the section of this report entitled "Geohydrology." Further evidence of a good hydraulic connection between aquifer zones is implied by the almost instantaneous decline in water levels in the three wells closest to the center of pumping; wells 153 and 119 are about 4,500 ft from the pumping center and well 141 is near the center of pumping. The fourth well (well 42) is 5 mi from the center of pumping and the short-term drawdown effects, if any, are so small as to be undetectable.

Distance-drawdown analytical techniques or techniques that require the plotting of drawdown versus time divided by the square of the effective distances of the observation wells cannot be used to calculate Floridan aquifer coefficients of transmissivity, storage, and leakance. This is because two of the wells are at virtually the same distance from the center of pumping and also because the effective distance of the well nearest the center of pumping is unknown. The effective distance is unknown because the actual discharge rates of the various Lykes-Pasco wells are unknown and it is also unknown as to exactly which wells were actually pumping. Another consideration that makes the analysis of the drawdown data difficult is that, in the immediate vicinity of the plant, it is probable the aquifer is poorly confined. That is, the top of the upper producing zone of the Floridan is within a few tens of feet from land surface and the sediments that overlie the aquifer are probably fairly permeable. However, it is believed possible to obtain a rough estimate of aquifer transmissivity using the modified Theis (1935) nonequilibrium formula developed by Cooper and Jacob (1946). In this method the slope of the straight-line segment of drawdown in the observation well versus the logarithm of time (semilogarithmic plot) is used to calculate an estimate of aquifer transmissivity (fig. 32).

Computation of transmissivity was made only from the drawdown data for the nearest observation well (well 141). However, drawdowns for the other observation wells follow the same trend with time as those

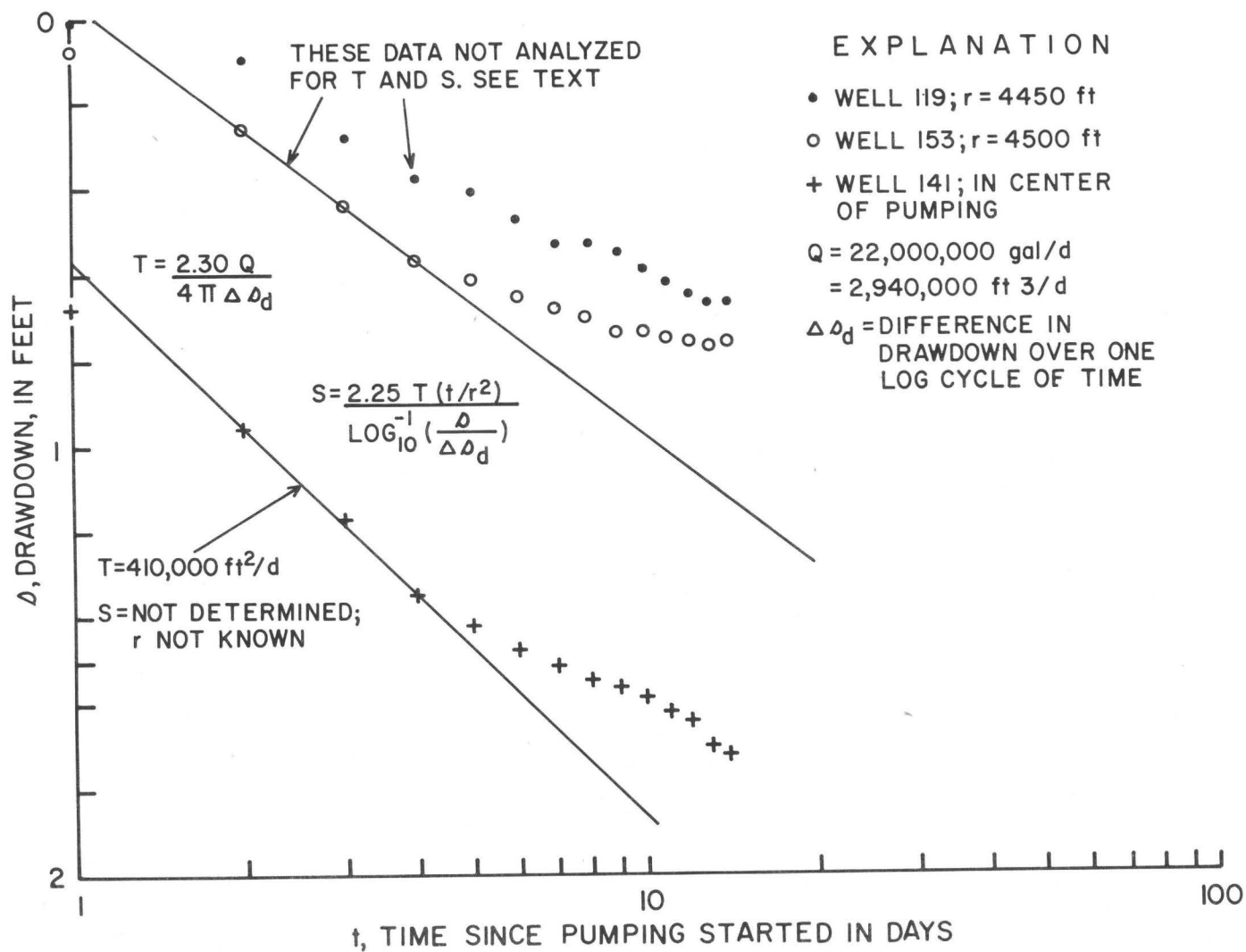


Figure 32.--Estimated drawdown versus time in response to increase in pumping rate by Lykes-Pasco Packing Co., December 6-20, 1976.

for well 141, and thus their analysis would yield somewhat comparable values for transmissivity. But because of the leaky nature of the Floridan aquifer in the area of the plant, the best estimate of transmissivity is obtained from drawdowns in the well nearest to the center of pumping. Leakage from the surficial aquifer would affect the more distant wells to a greater degree.

As stated by Lohman (1972, p. 22), the straight-line solution employed here is applicable only when μ is less than or equal to about 0.01 and

$$\mu = \frac{r^2 S}{4Tt}$$

Taking the estimate of transmissivity (T)=400,000 ft²/d (rounded), determined from figure 32; assuming a storage coefficient (S) of 0.001, a value near the upper end of typical values for the Floridan aquifer where it is confined; and taking radii (r) ranging from, say, 50 ft for well 141 to 4500 ft for well 153; it is seen that observations made at times (t) about 1 day or more after the beginning of pumping may be used in the straight-line plot method, considering even the most distant well. As observations made 2 to 4 days after pumping began were used to define the slope of the straight-line, the criterion of μ being less than or about equal to 0.01 is satisfied.

The transmissivity of 400,000 ft²/d estimated in figure 32 may be too high because of the effect that downward leakage may have had on reducing observed drawdown. Also, the drawdown observed may not have been representative because the observation wells did not penetrate the full thickness of aquifer that is tapped by most of the Lykes-Pasco supply wells. This would also cause the calculated transmissivity to be too high. Nevertheless, it is believed the transmissivity of the Floridan aquifer can be at least estimated to be greater than 200,000 ft²/d and perhaps as high as 400,000 ft²/d in the immediate vicinity of the citrus processing plant.

Several double-mass plots were compiled to indicate hydrologic trends of rainfall, streamflow, springflow, and water levels and to see if the hydrologic effects of pumping by the plant could be discerned. Figure 33 shows long-term double-mass plots of rainfall at St. Leo versus discharge of the Withlacoochee River at Trilby (fig. 29, station 42), discharge of Weekiwachee Springs (fig. 17), and discharge of Crystal Springs near Zephyrhills, about 13 mi south of Dade City, on the left bank of the Hillsborough River. Figure 34 shows a double-mass curve of rainfall at St. Leo versus water level in well 42, 6 mi north of Dade City and 5 mi north of Lykes-Pasco Packing Co. (fig. 2). Though not shown, the rainfall record for St. Leo was double-massed against rainfall at Gainesville and also against the annual average flow of Silver Springs. Those double-mass relations showed that rainfall at St. Leo is suitable for use in the double-mass curve analyses presented herein.

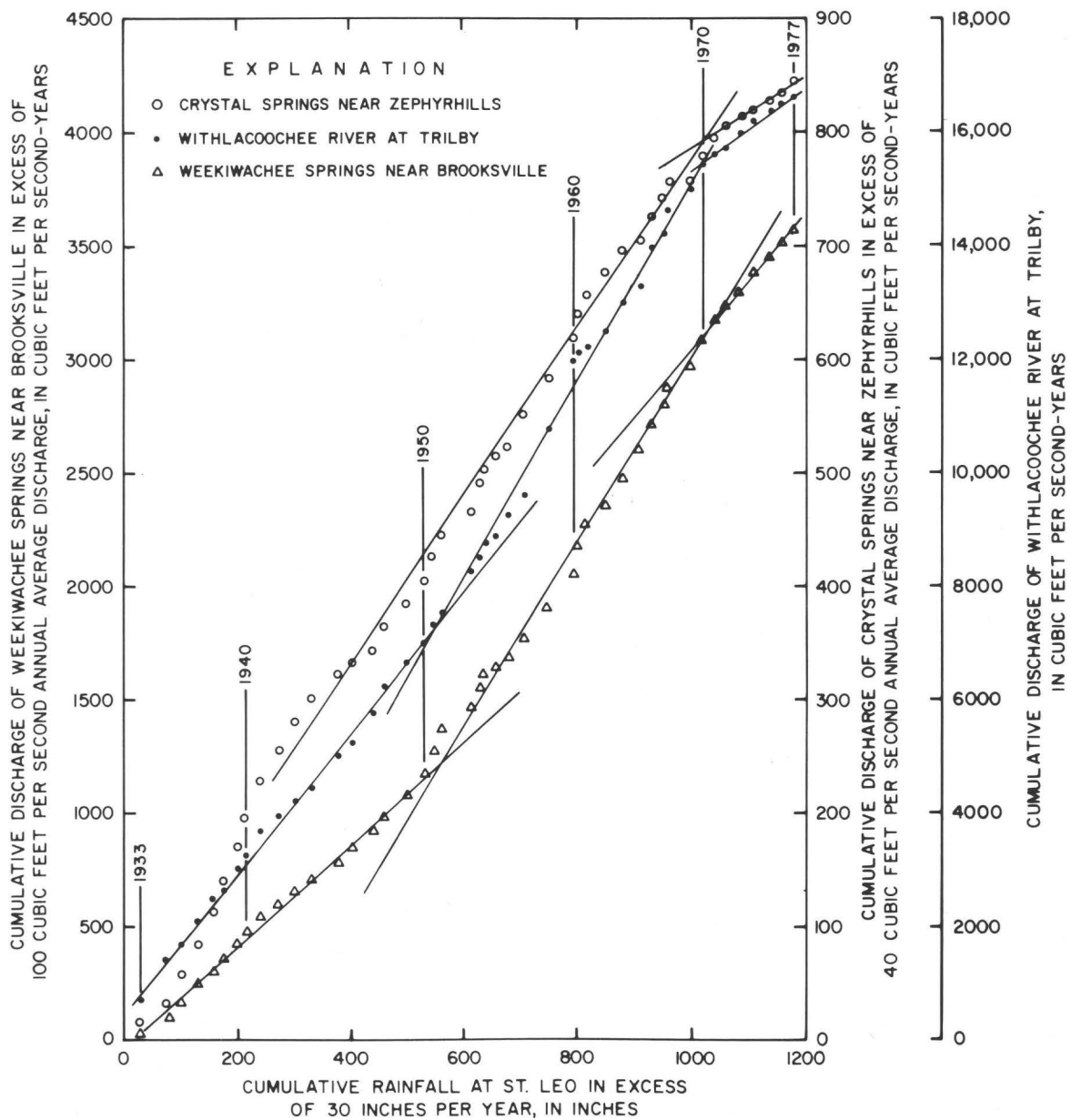


Figure 33.--Double-mass curves of rainfall at St. Leo versus discharge of Withlacoochee River at Trilby, discharge of Weekiwachee Springs near Brooksville, and discharge of Crystal Springs near Zephyrhills.

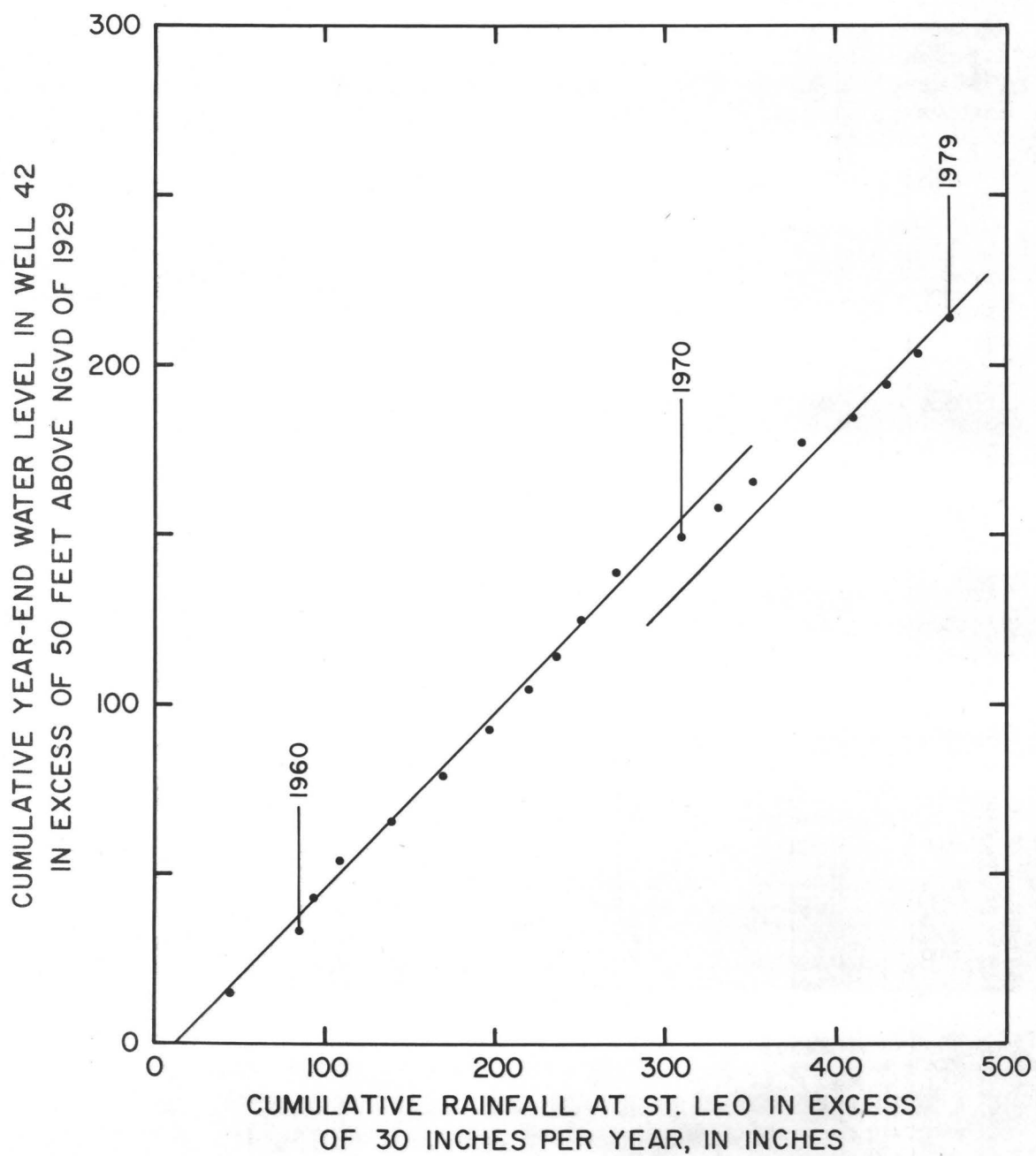


Figure 34.--Double-mass curve of rainfall at St. Leo versus potentiometric level in well 42.

The effects of the citrus processing plant discharging into Dade City Canal should be detectable by increased flow at the Withlacoochee River at Trilby that would be indicated by an increase in slope of the double-mass plot. An increase in slope apparently occurred about 1951 or 1952. From about 1952 until about 1971 that slope remained essentially constant. From 1971 to 1977 a decrease in slope occurred. That could be due in part to the decrease in pumping by the plant that began in about 1972 (fig. 30).

Weekiwachee Springs and Crystal Springs are the nearest, largest-yielding springs downgradient from the citrus processing plant for which long-term discharge records are available. If pumping by the plant caused a reduction of the flow in the regional Floridan groundwater flow system a resultant reduction in the slope of the springs double-mass plots (fig. 33) should occur. In about 1951 there is an apparent increase in slope of the double-mass plot for Weekiwachee Springs indicating that, since about 1950, the spring discharged more water for a given amount of annual rainfall than for the prior period of record. This obscures the effect that pumping by the citrus processing plant might have had on the regional Floridan aquifer flow system but it also results in the interesting implication that increased Floridan aquifer discharge in the form of springflow could, in turn cause the natural lowering of potentiometric levels over a spring's entire drainage area. The phenomenon of apparent increased springflow compared to rainfall was also observed by Anderson and Hughes (1975) in the flow of the Wekiva River near Sanford whose base flow of about $200 \text{ ft}^3/\text{s}$ is derived almost entirely from springflow. There, the rainfall-springflow relation changed in about 1960. Presumably, this could have been caused by the extraordinarily high springflows of 1959 and 1960 flushing out silt and debris in the spring vents and, hence, improving their conveyance thereby reducing the amount of hydraulic head or pressure necessary for water to flow through the vents. The vents of Weekiwachee Springs could have been flushed out by the high flows of the late 1940's and early 1950's or by man's activities in and around the spring while it was being prepared as a tourist attraction. Reductions in backpressure on spring vents would cause water levels to decline elsewhere in the spring basins. An analysis of this phenomenon is beyond the scope of this report but further study is recommended.

The double-mass curve for Crystal Springs (fig. 33) shows a rather constant rainfall-springflow relation from 1933 to about 1942. Since 1942 there is a reduction in the slope of the curve. That reduction in slope indicates less springflow in relation to rainfall than for the period prior to 1942. The time at which the rainfall-springflow relation changed coincides with the beginning of pumping by Lykes-Pasco. But it also coincides with the time at which pumping by the phosphate mining industry in a 30 mi wide area (about 12 mi to the south and southeast of Crystal Springs) began increasing from a rather constant rate of about 36 Mgal/d prior to 1942 to about 140 Mgal/d by

1960, an annual rate of increase of about 4 Mgal/d per year (Robertson and Mills, 1974, fig. 3). About 1960, pumping by the phosphate industry sharply increased and by 1968 was about 280 Mgal/d. That sharp increase was not accompanied by a reduction in slope of the double-mass curve of Crystal Springs, probably because the 1960-68 increases in pumping occurred further from Crystal Springs than did the 1942-60 increases. In 1970, there was another reduction in the slope of the double-mass curve. This reduction in springflow in relation to rainfall is perhaps due to an increase in pumping from the Floridan aquifer in the vicinity of Crystal Springs. The increase in pumping is probably due to increased withdrawals for public supplies or irrigation because, according to Robertson and Mills (1974), since about 1968 pumping by the phosphate mining industry has declined because of increased use of recirculated water in mining operations.

The effect of pumping by Lykes-Pasco is not apparent in the double-mass plot of water levels in well 42 (fig. 34) probably because its period of record is so short (1959-77) that any decrease in slope of the double-mass curve caused by pumping would have occurred prior to the beginning of record. The relatively recent decline in pumping by Lykes-Pasco from 1972-77 should have caused an increase in slope. However, no such marked change in slope is shown in figure 34.

Records of water levels in Floridan aquifer wells in the study area show no major decline. For example, since mid-1966, the water level in well 42 has declined only about 4 ft (fig. 16). Most of that decline is probably due to a cumulative rainfall deficiency of about 40 in. since mid-1967 (fig. 16).

It seems as if the hydraulic characteristics of the upper part of the Floridan aquifer in the study area are affected primarily by amounts of rainfall (recharge) and by natural discharge. These controls mask the hydrologic effects of pumping by Lykes-Pasco Packing Co. It is possible that the upper and lower producing zones are in good hydraulic connection in the immediate vicinity of the plant but elsewhere the connection is not as effective. If that is the case and if most of the water pumped by the plant is taken from the lower producing zone, then the hydraulic effects, or drawdown resulting from that pumping, would extend primarily to only the lower zone except in the immediate vicinity of the plant. The drawdown in the lower zone would cause water from the upper zone to leak into the lower zone at a rate faster than that which would occur were there no pumping from the lower zone but the leakage would occur over a large area and thus not appreciably lower the potentiometric surface of the upper zone. But, as discussed previously, except for the work done by Ryder (1978) there is very little information available on the lower zone on an areal basis, so it is not known if the preceding hypothesis is valid. However, such a hypothesis would explain why the long-term effects of pumping by the plant are difficult to detect in the upper zone of the Floridan aquifer in the study area.

SUMMARY AND CONCLUSIONS

1. Lykes-Pasco Packing Co. is the largest single water user in the Dade City area. During the period 1963-77, the maximum annual pumping rate by this citrus processing plant was about 30 Mgal/d and occurred in either 1966 or 1967. Peak, or instantaneous pumping rates have been as high as 66 Mgal/d.
2. Since 1972, annual pumping rates by the plant have declined because of the company's efforts to recycle water. By 1977, the annual pumping rate was about 9 Mgal/d.
3. There are two major producing zones in the Floridan aquifer in the Dade City area. These zones are apparently in fairly good hydraulic connection in the immediate vicinity and to the south of Lykes-Pasco.
4. The transmissivity of the Floridan aquifer in the immediate vicinity of Lykes-Pasco is considered high compared to that in other nearby areas. The transmissivity is estimated to range from 200,000 ft²/d to as much as 400,000 ft²/d.
5. It is believed that Lykes-Pasco pumps most of its water from the lower Floridan producing zone. Water levels in the study area are measured in the upper producing zone. Drawdown of potentiometric surface of the lower zone extends to the upper producing zone but it is believed to be somewhat attenuated except in the immediate vicinity of the plant.
6. Thus, the vertical zonation of the aquifer and also its high transmissivity are the reasons why Lykes-Pasco's pumping has not resulted in large drawdowns of the potentiometric surface of the upper producing zone in the study area.
7. The effects that the plant's pumping has on the potentiometric surface of the Floridan aquifer are masked by the natural, seasonal fluctuations in levels caused by naturally-occurring recharge and discharge. Records of water levels in the area show no major declines that can be attributed to pumping.

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