EFFECTS OF SURFACE RUNOFF AND TREATED WASTEWATER RECHARGE ON QUALITY OF WATER IN THE FLORIDAN AQUIFER SYSTEM, GAINESVILLE AREA, ALACHUA COUNTY, FLORIDA

By G.G. Phelps

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ABSTRACT

Rates of recharge to the Floridan aquifer system at four sites in Alachua County were estimated and water samples were analyzed to determine if the recharge water had any effects on the water quality of the aquifer. A total of about 33 million gallons per day recharges the upper part of the aquifer system at Haile Sink, Alachua Sink, and drainage wells near Lake Alice. At the Kanapaha Wastewater Treatment Plant, injection wells recharge an average of 6.1 million gallons per day into the lower zone of the system.

The samples of water entering the aquifer system collected at the four sites generally conformed to the drinking water standards recommended by the U.S. Environmental Protection Agency in 1983. Bacteria and nutrient concentrations were more variable in the recharge water than were other constituents. Organic compounds such as diazinon, lindane, and malathion were occasionally detected in all recharge water, but concentrations never exceeded recommended limits.

Bacteria were detected in most wells sampled near the Gainesville recharge sites. The highest counts were from wells near Alachua Sink. At only one site was there a significant difference between the quality of the recharge water and water from the wells sampled, although the recharge water tended to be lower in calcium and iron than water from the Floridan aquifer system. A sample from a well about 150 feet downgradient of a drainage well near Lake Alice consisted of turbid water with a total phosphorus concentration of 75 milligrams per liter and a total nitrogen concentration of 57 milligrams per liter. Water flowing into the drainage well from the lake had a total nitrogen concentration of 1.6 milligrams per liter. Apparently, nutrient-rich suspended sediment in inflow to the drainage well settles out of the water and accumulates in cavities in the limestone.

Estimated loads entering the aquifer include 3,500 kilograms per day of chloride, less than 0.4 kilogram per day of lead, 310 kilograms per day of nitrogen, and 150 kilograms per day of phosphorus. The effects of the loads were not detected in most monitor wells. Apparently, some of the constituents may settle out, some may be adsorbed by aquifer materials, and the remainder diluted and dispersed by the extremely large volume of water in the aquifer.

INTRODUCTION

Alachua County, in north-central Florida (fig. 1), is an area of recharge to the Floridan aquifer system (Phelps, 1984, fig. 2). The predominant landform in the area is called karst, which is developed by the dissolution of limestone occurring at or near land surface. In a typical karst area, few surface streams flow from the area. Instead, runoff flows into streams that drain to sinkholes, and thus into the limestone aquifer.

In Alachua County, streams bearing treated wastewater and stormwater runoff drain into the limestone of the Floridan aquifer system, which is the main source of potable water in the area. Water affected by man's use also enters the aquifer through gravity injection wells designed to dispose of wastewater and through gravity drainage wells drilled to accept surface runoff.

In 1964, a well in the Gainesville downtown well field (fig. 1) was reported to yield water with high bacteria count, color, and turbidity (R. Ferland, Gainesville Regional Utilities, oral commun., 1982). A cavity in the well at a depth of 305 feet was found to be the source of the poor-quality water. A liner was installed to case off the cavity, which alleviated the water-quality problem but reduced the yield of the well. Consultants to the city of Gainesville (Black, Crow, and Eidsness, 1965) concluded that the source of the problem in the downtown well field was recharge from Alachua Sink, about 2 miles south of the well field (fig. 1). In 1968, a new well field was established north of the city and the old well field was abandoned.

In the late 1970's, concern about organic wastes from a pine-tar-products plant, now closed, prompted an investigation of Hogtown Creek, which drains into Haile Sink (fig. 1). That investigation (Huber and others, 1981) focused primarily on the quality of the water in Hogtown Creek. No wells were sampled.

Although such specific water-quality problems have been recognized, the effects of recharge from surface runoff and treated wastewater on the quality of water in the Floridan aquifer system have not been studied in detail.

Purpose and Scope

The purposes of this study are:

- To estimate the rate of recharge to the Floridan aquifer system at each of several recharge sites.
- To determine the chemical quality of the recharge water at each site.
- To estimate from the geohydrology of the area where chemical effects of the recharge water might be found, and analyze water samples from wells downgradient of the recharge sites to determine if the recharge water affects their quality.

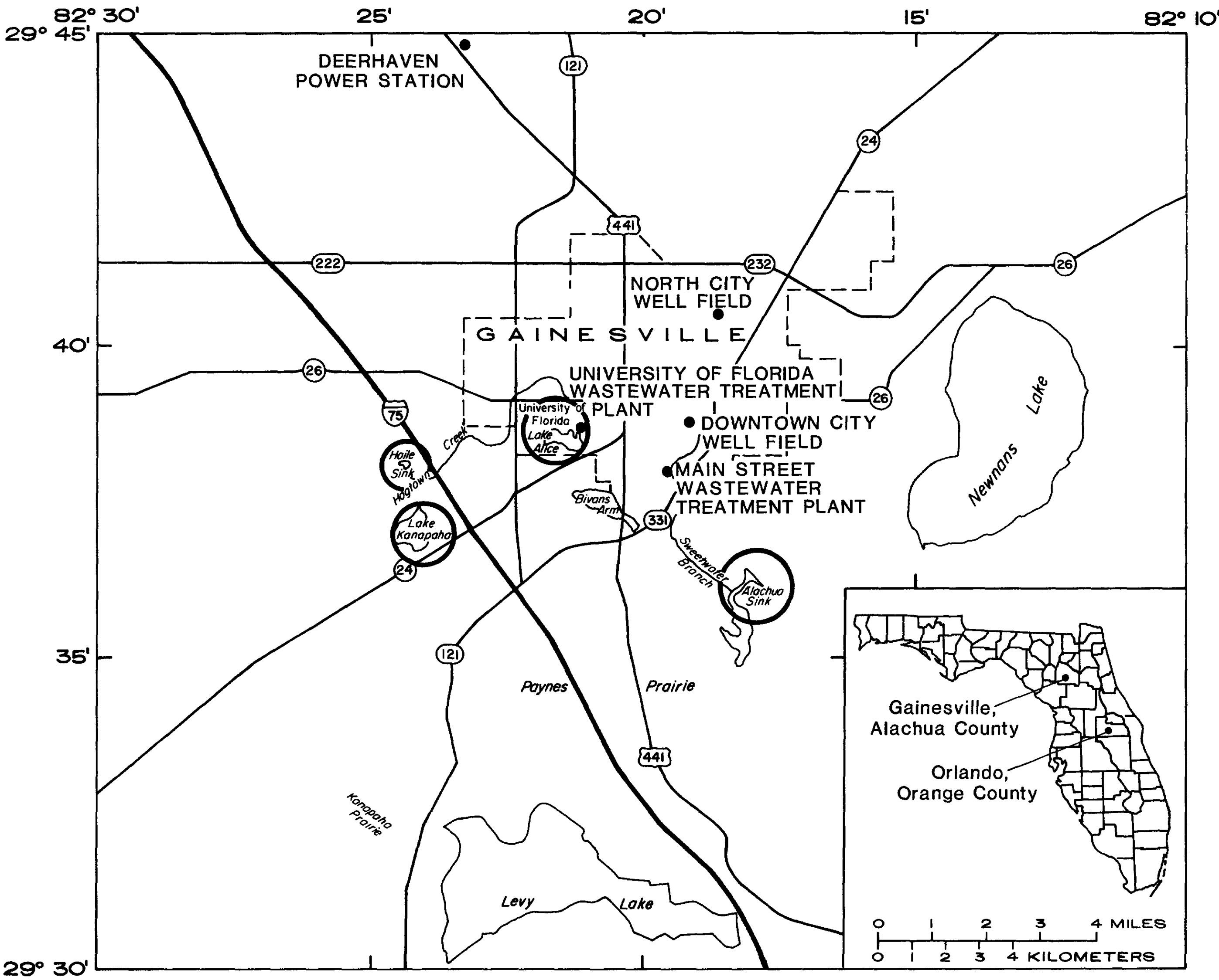

Figure 1.--Location of study sites.

Four sites in Alachua County were selected for study: Alachua Sink, Haile Sink, Lake Alice drainage wells, and the injection wells at the Kanapaha Wastewater Treatment Plant.[1] Locations of the sites are shown in figure 1. Alachua Sink and Haile Sink are natural recharge sites. The wells at Lake Alice and Kanapaha were specifically designed to accept stormwater and wastewater, respectively. Data were collected from April 1982 to September 1983 to supplement continuous data collected by the U.S. Geological Survey at Haile Sink and by Gainesville Regional Utilities (GRU) at the Kanapaha injection wells. Knowledge of the effects on the quality of water in the aquifer that result from disposal of storm and wastewater through sinks and drainage wells can provide the information necessary to plan for water-resource use in the Gainesville area and in other areas of similar geohydrologic conditions.

This report is the final report of the investigation. In it, the geohydrology of the four sites is described, the rates of recharge and chemical loads into the aquifer at each site are estimated, and the results of chemical analysis of recharge water and water from the Floridan aquifer system are tabulated and discussed.

Previous Investigations

The water resources of Alachua, Bradford, Clay, and Union Counties were described by Clark and others (1964). Maps showing the potentiometric surface of the upper part of the Floridan aquifer system were compiled semiannually from 1978 to 1980 by Navoy and Batts (1980a and 1980b) and Navoy (1980a, 1980b, and 1981).

Description of Area

Alachua County is located in the north-central part of the Florida Peninsula (fig. 1). The area of the county is about 892 square miles (Clark and others, 1964, p. 10). In 1975, the population was about 69,000 (Clark and others, 1964, p. 10). In 1980, the population of the county was about 151,000, and the county seat, Gainesville, had a population of about 81,000 (University of Florida, 1984). The University of Florida, which has about 32,000 students, is located in Gainesville. The remainder of the county is predominantly rural.

The climate of Alachua County is humid subtropical. Average annual temperature is 69.8 °F and rainfall averaged 50.91 inches for the period 1903 through 1982. Water use in 1983 was about 32 million gallons per day, about half of which was ground water used for public-water supply (Marella, 1984, p. 28).

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[1]The use of industry or firm names in this report is for location purposes only, and does not impute responsibility for any present or potential effects on the natural resources.

GEOHYDROLOGY

Gainesville is located near the boundary of the Northern Highlands and the Alachua Lake Cross Valley physiographic provinces. A scarp that forms the boundary is aligned generally east-west through Alachua County, just south of the city of Gainesville (White, 1970, p. 155). The scarp (fig. 2) was shaped mostly by stream erosion and dissolution of limestone, which is the predominant rock type in most of the Florida Peninsula. In Gainesville and northward (Northern Highlands province), the topography is gently rolling, but southward (Alachua Lake Cross Valley province) the land is low in altitude, flat, and characterized by prairies that contain ephemeral lakes.

The geologic formations that are penetrated by wells in Alachua County are shown in table 1, and the outcrops are shown in figure 2. The formations of most importance to the hydrology of the area are the Eocene Ocala Limestone, which in most areas is the uppermost unit of the Floridan aquifer system, and the Miocene Hawthorn Formation, which forms a discontinuous confining layer over the Floridan.

Figure 2 shows locations of geologic sections in the Gainesville area and figures 3 through 5 show the geologic sections. The principal geologic structure in the study area is the Ocala Uplift, an anticline or arch, whose crest is just west of Alachua County. Tertiary rocks have been arched, bringing the Ocala Limestone to the surface along the crest and flanks of the uplift. Near Gainesville the Ocala dips northeast, away from the axis of the uplift. The top of the Ocala Limestone is an erosional surface that consists of soft, crumbly limestone.

Where the Hawthorn Formation is absent, the limestone has been eroded to a mostly flat surface that has formed low-lying plains or prairies that contain ephemeral lakes. The largest of such areas are Paynes Prairie (formerly called Alachua Lake), Kanapaha Prairie, and Levy Prairie (sometimes called Levy Lake) (fig. 1). Their total area is about 50 square miles.

Localized dissolution and collapse of the limestone underlying the Hawthorn Formation has caused numerous sinkholes to form. Most are ancient and inactive at present, but sinkholes continue to form as evidenced by the collapse of a sinkhole near Gainesville during the drought of 1981.

The Floridan aquifer system is the main source of potable water in the Gainesville area. In places (fig. 2), the aquifer contains water under artesian conditions (the water level in the aquifer rises above its top). But in most of Gainesville and to the west of the city, the aquifer is unconfined. The confining unit is the Hawthorn Formation. It is discontinuous and thin in places so that artesian conditions in the Floridan do not correspond directly to the mapped area of the Hawthorn Formation.

The Floridan is about 1,500 feet thick in the Gainesville area. Its base is defined by the occurrence of an areally extensive zone of very low-permeability strata (Miller, 1982a). A change of water quality from fresh to salty (Geraghty and Miller, 1978, p. 1-4) occurs at about 1,500 feet below land surface. Although Miller (1982a) does not show an areally extensive intra-aquifer low-permeability zone in the Gainesville area, borehole flow data from the Kanapaha injection wells in 1975-76 shows that permeability is lower at about the 720 to 950 foot depth than in the overlying or underlying strata (R. Ferland, Gainesville Regional Utilities, written commun., 1982).

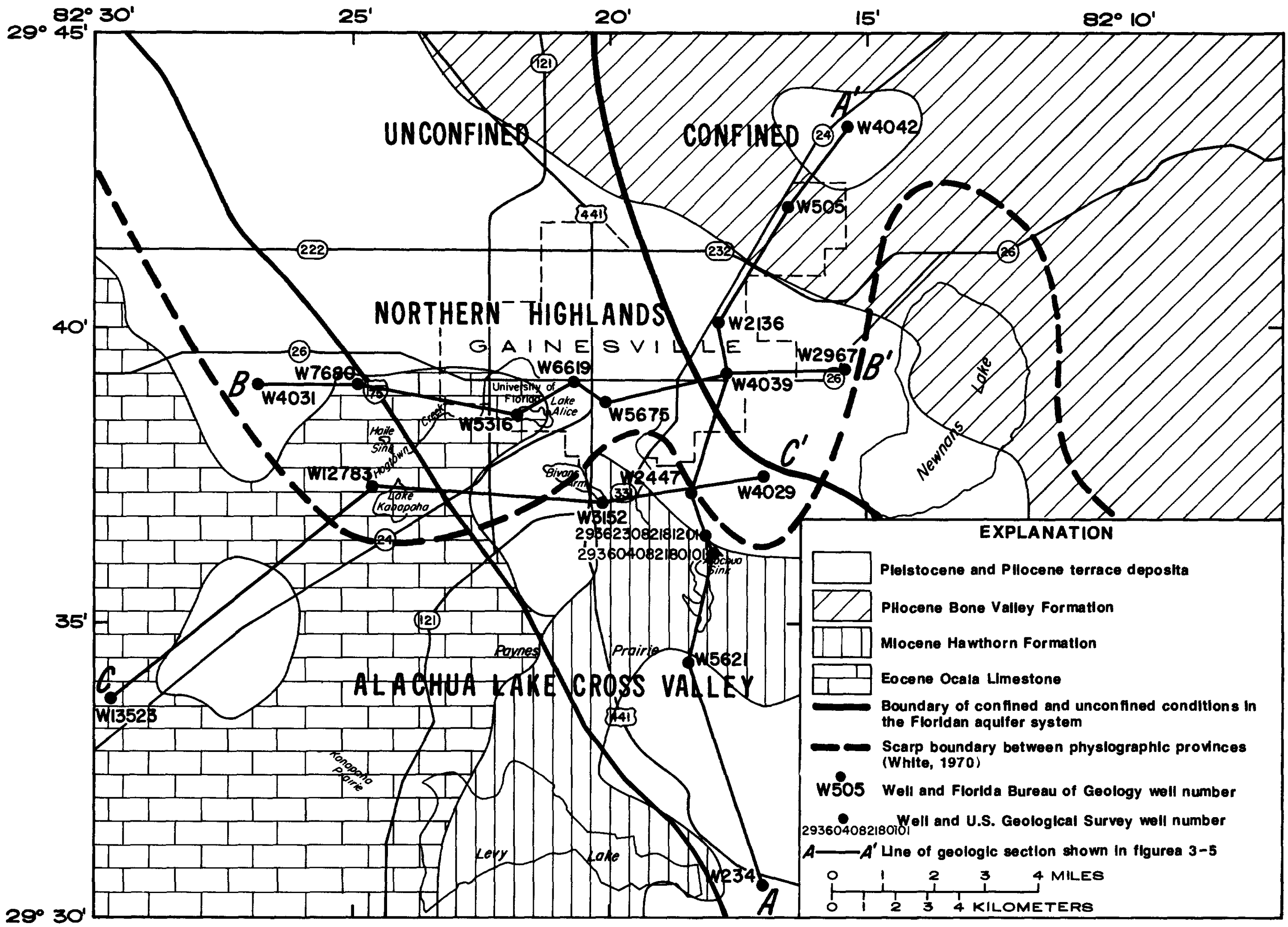

Figure 2.--Geologic map of the Gainesville area (from Brooks, 1981) and locations of geologic sections.

Table 1.--Post-Cretaceous geologic formations penetrated by wells in Alachua County[1]

System	Series	Formation	Estimated maximum thickness (feet)	Description	Hydrologic unit
Quaternary	Pleistocene	Marine and estuarine terrace deposits	50	Sand and clayey sand, gray, brown and black, disseminated organic matter; beds of clay marl and sandy clay. Shell marl and concentrations of shell in some areas.	Surficial aquifer system
	Pliocene	Bone Valley Formation	35	Sand, clay, and phosphate; boulders of siliceous limestone, flint, and phosphate; vertebrate fossils.	Confining unit
	Miocene	Hawthorn Formation	200	Clay and sandy clay, varicolored, interbedded sand and sandy, phosphatic limestones; disseminated grains and pebbles of phosphate. Very hard limestone, partly dolomitic in the lower part in some areas.	
Tertiary	Oligocene	Suwannee Limestone	50	Limestone, white to tan, soft to hard, porous, in part fossiliferous and dolomitic.	Floridan aquifer system
	Eocene	Ocala Limestone	250	Limestone, white, cream and tan, soft, granular, porous, fossiliferous. Some hard layers of limestone and dolomitic limestone mostly in lower part.	
		Avon Park Formation	700	Dolomite, dark brown and tan, granular, hard, dense to porous; interbedded tan and cream limestone and dolomitic limestone.	
		Oldsmar Formation	530	Dolostone, cryptocrystalline to medium, light tan to dark brown, calcite cavity filling, moderately to well indurated; interbedded limestone, white to gray, light tan, poorly to moderately indurated.	
	Paleocene	Cedar Keys Formation	277	Dolostone, microcrystalline, cream to gray, vugs filled with gypsum, trace anhydrite; interbedded oolitic limestone poorly to moderately indurated.	Extremely low permeability unit

[1]Compiled from Clark and others (1964, table 1), Geraghty and Miller (1978, table 2), and Brooks (1981).

Thus, wells less than about 700-feet deep tap the upper zone of the Floridar aquifer system. The zone from about 950 to 1,500 feet is the lower zone of the system. Most public-supply wells in the Gainesville area tap the upper zone and are about 500 to 550 feet deep. Domestic wells are shallower, generally tapping only the upper hundred feet or less of the aquifer.

The natural vertical hydraulic gradient in the Floridan aquifer system is almost always downward where the aquifer is under water-table conditions and upward where artesian conditions prevail. Data from a deep well drilled to investigate the feasibility of injecting cooling water from the Deerhaven Power Station northwest of Gainesville (fig. 1) indicate that there, movement is probably downward but at a low rate (D. Fisk, Suwannee River Water Management District, oral commun., 1979). Vertical circulation between the upper and lower zones of the aquifer system probably are not significant in the study area.

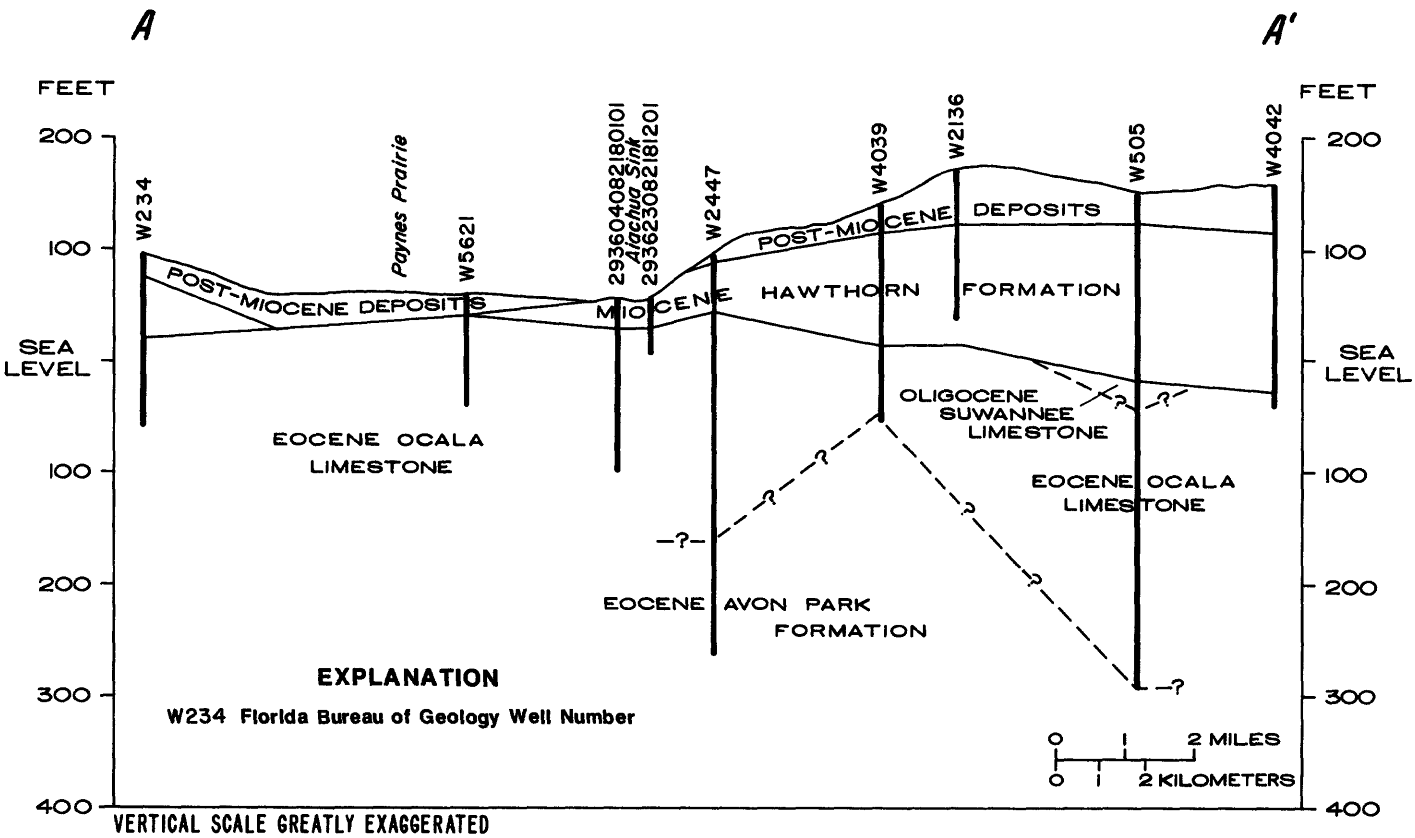

Figure 3.--Geologic section A-A' (trace of section in fig. 2).

Significant amounts of recharge to the Floridan aquifer system occur in the area of the potentiometric-surface high at the intersection of Alachua, Bradford, Clay, and Putnam Counties (fig. 6) (Phelps, 1984); in Paynes and Levy Prairies south of Gainesville; and probably also in a karst area north of Gainesville, as indicated by the deflection of the potentiometric contours to the east of Gainesville. Flow in the aquifer is generally to the west and northwest toward discharge points along the Santa Fe River.

Figures 7 and 8 show the potentiometric surface of the upper part of the Floridan aquifer system in May and September 1981, and May and September 1983, respectively. The potentiometric surfaces for 1981 show the effects of drought in 1980 and 1981. Rainfall at Gainesville was 38.82 inches in 1980 and 35.25 inches in 1981 compared to an average annual rainfall of 50.91 inches for the years 1903-82. In 1982, rainfall was 61.13 inches and in 1983, 65.35 inches. Figure 9 shows rainfall at Gainesville from 1903 through 1983. The above-average rainfall in 1982 and 1983 caused a rise in the potentiometric surface of about 5 to 9 feet over the 1981 surface. All rainfall data presented in this report are from the National Oceanic and Atmospheric Administration climatological data annual summaries for Florida.

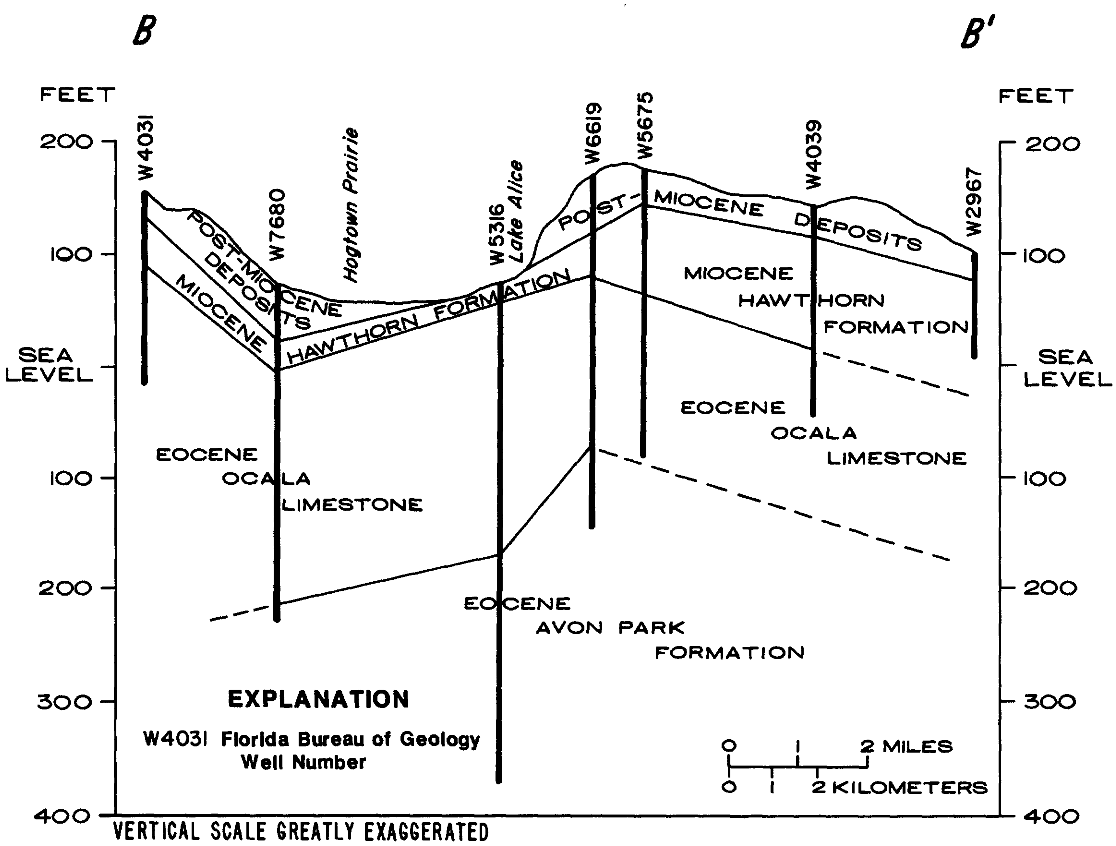

Figure 4.--Geologic section B-B' (trace of section in fig. 2).

Regional potentiometric surface maps do not show the effects of numerous localized recharge areas (many of them at sinkholes) that occur in the Gainesville area. Detailed potentiometric surface maps of Alachua County were prepared by Navoy (1980a, 1980b, and 1981), and Navoy and Batts (1980a and 1980b), to determine the direction of ground-water flow from recharge sites such as Alachua and Haile Sinks.

Sixty-six wells were inventoried and water levels measured during this study. Well locations and well inventory data are shown in figure 10, and in table 2, respectively. A potentiometric surface map, compiled from water-level measurements made in August 1982, is shown in figure 10.

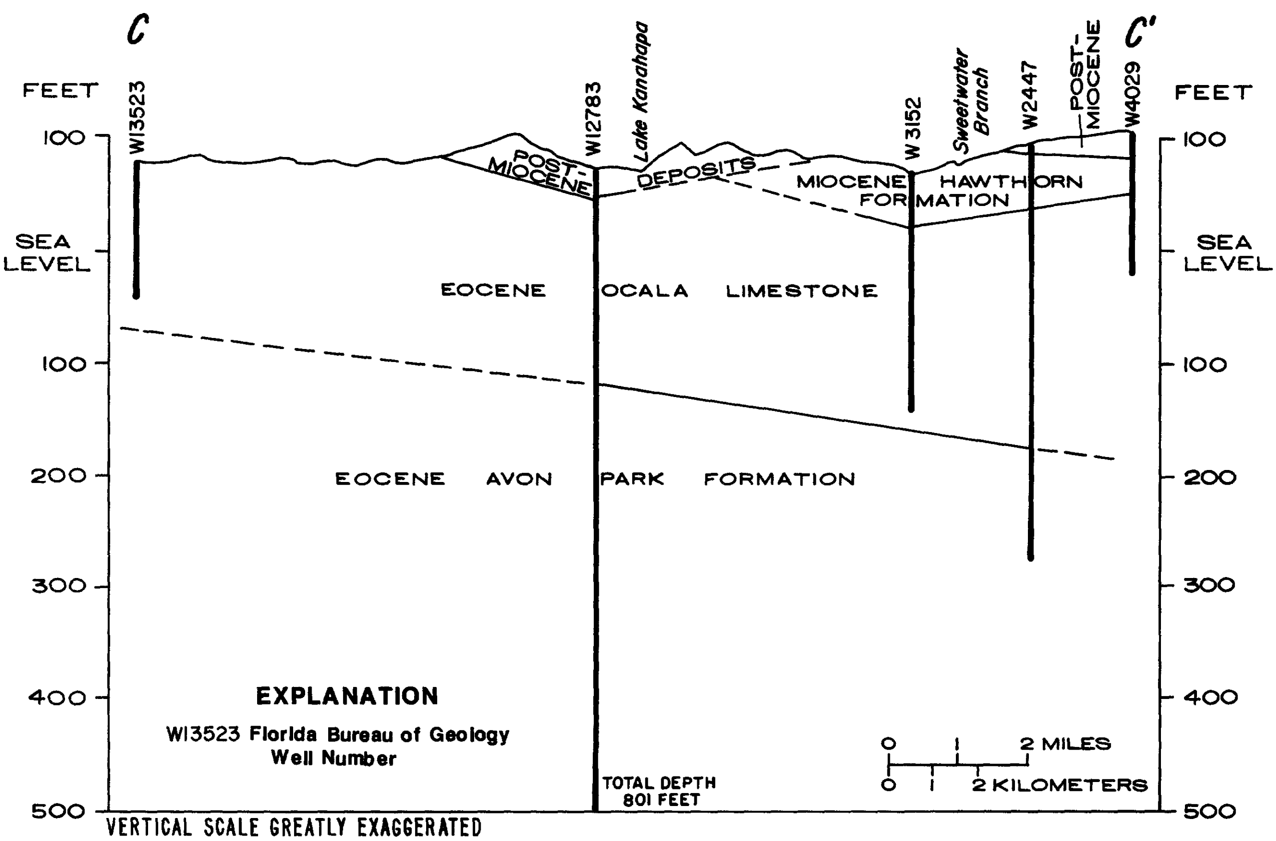

Figure 5.--Geologic section C-C′ (trace of section in fig. 2).

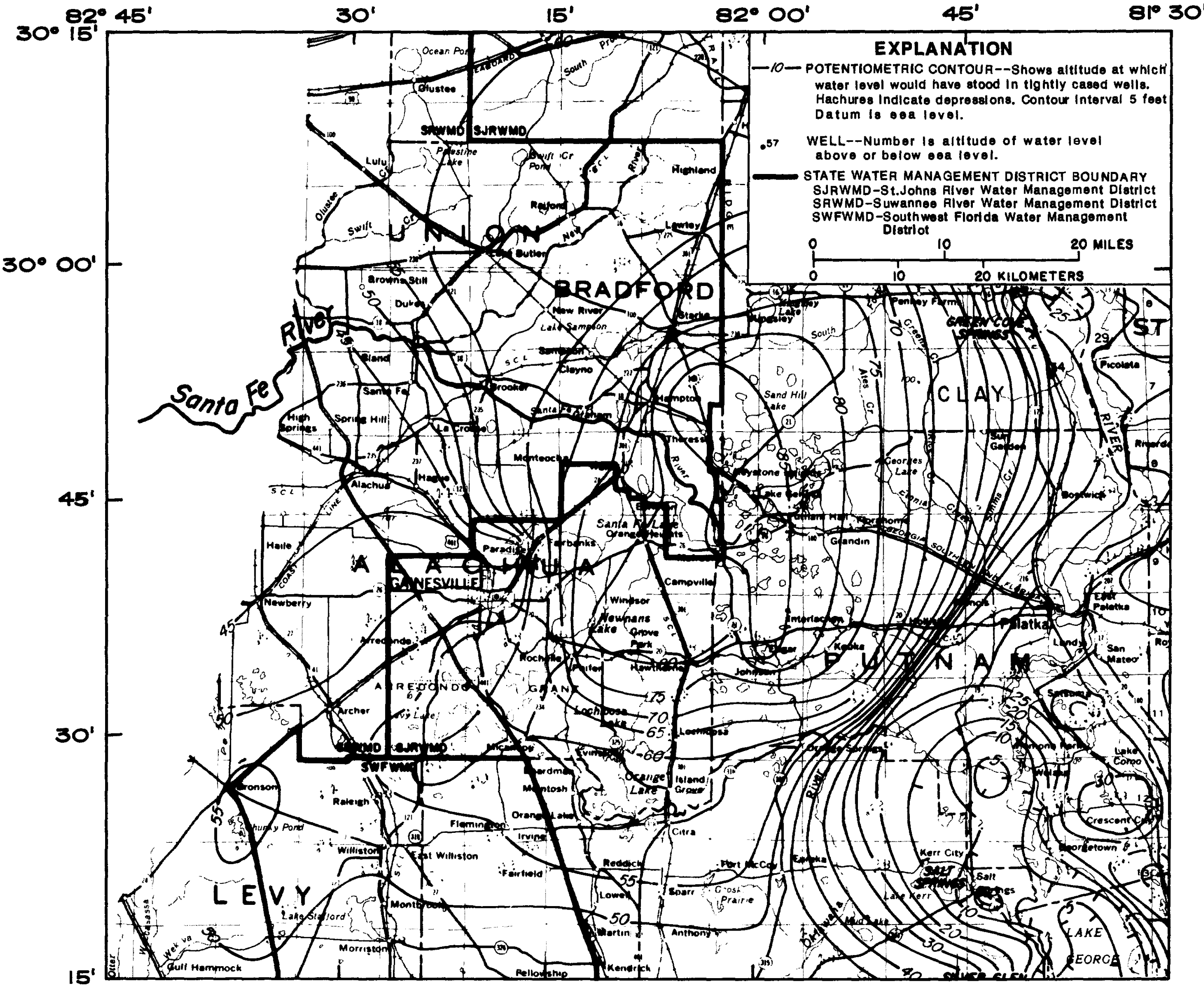

Figure 6.--Potentiometric surface of the Floridan aquifer system in part of north-central Florida, May 1983 (from Schiner and Hayes, 1983a).

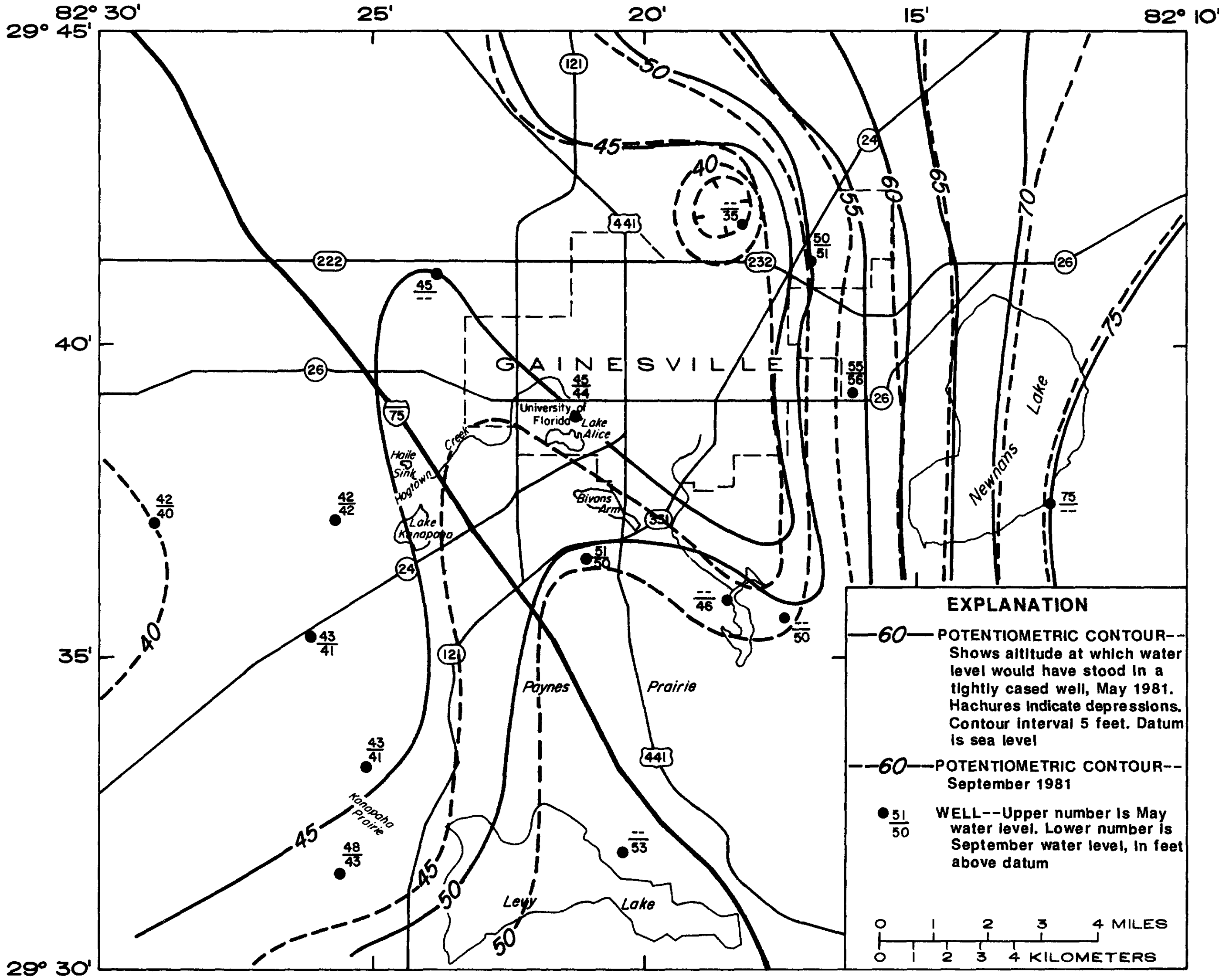

Figure 7.--Potentiometric surfaces of the Floridan aquifer system in the Gainesville area, May and September 1981 (from Schiner and Hayes, 1981 and 1982).

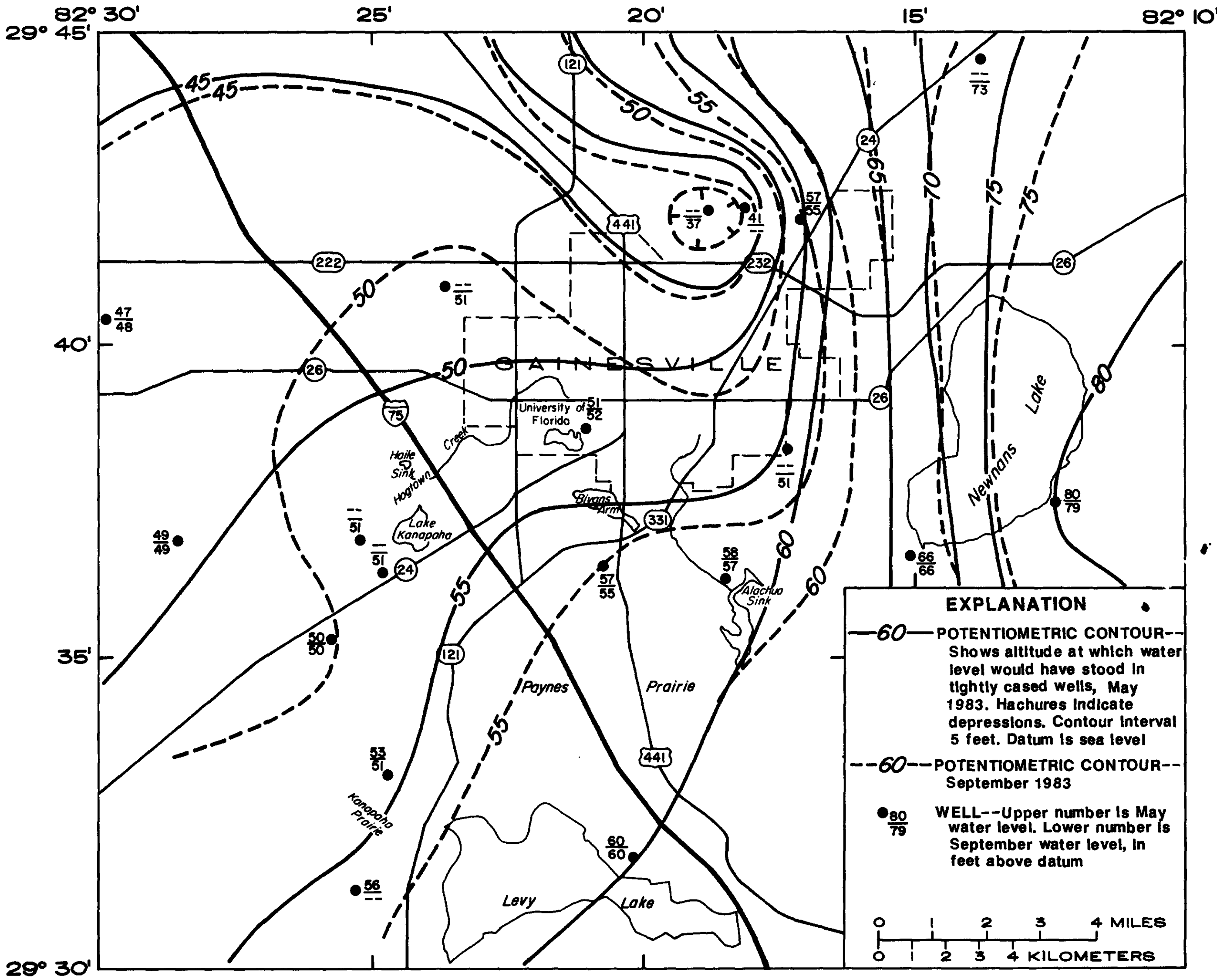

Figure 8.--Potentiometric surfaces of the Floridan aquifer system in the Gainesville area, May and September 1983 (from Schiner and Hayes, 1983a and 1983b).

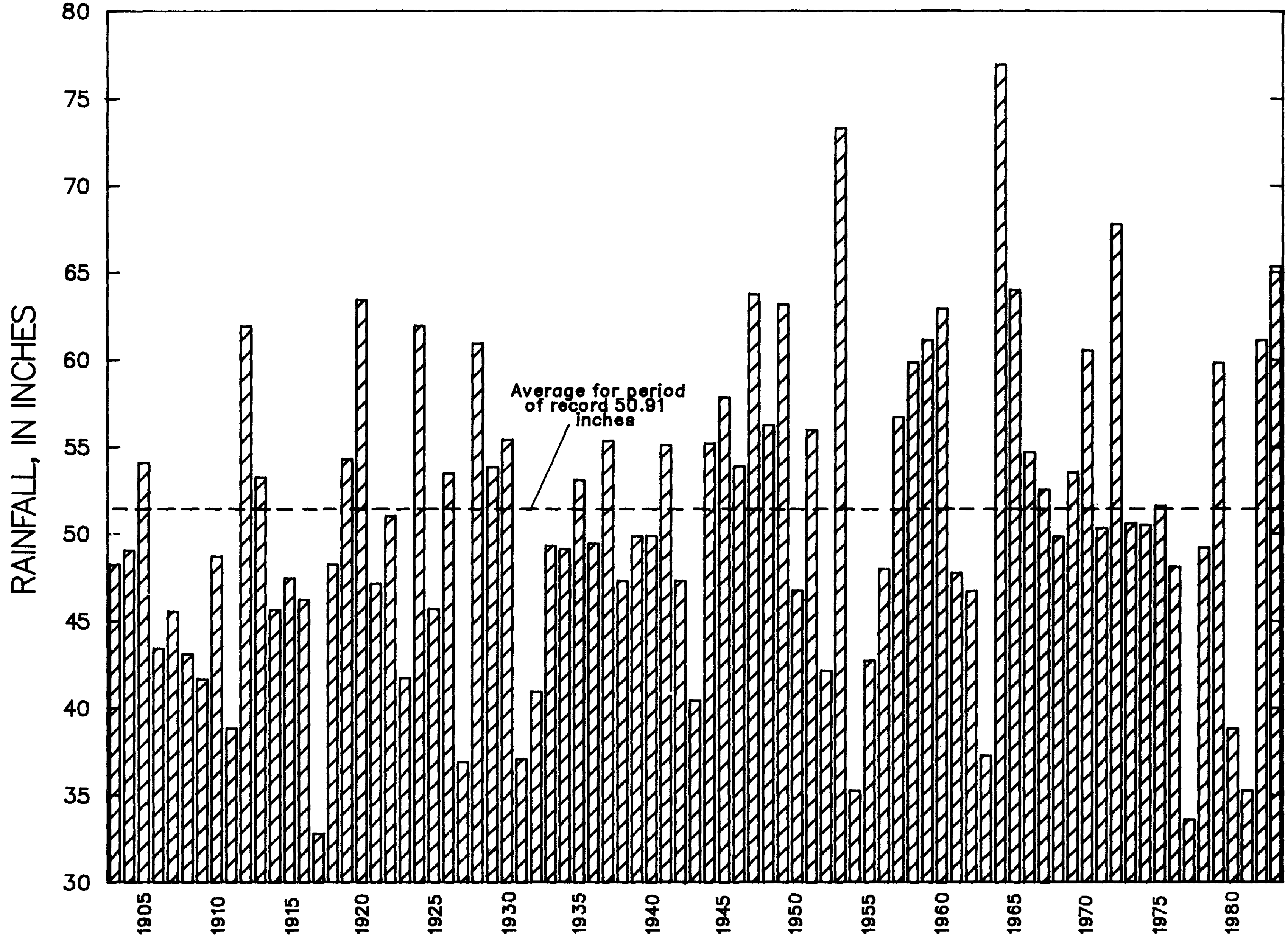

Figure 9.--Rainfall at Gainesville, 1903-83.

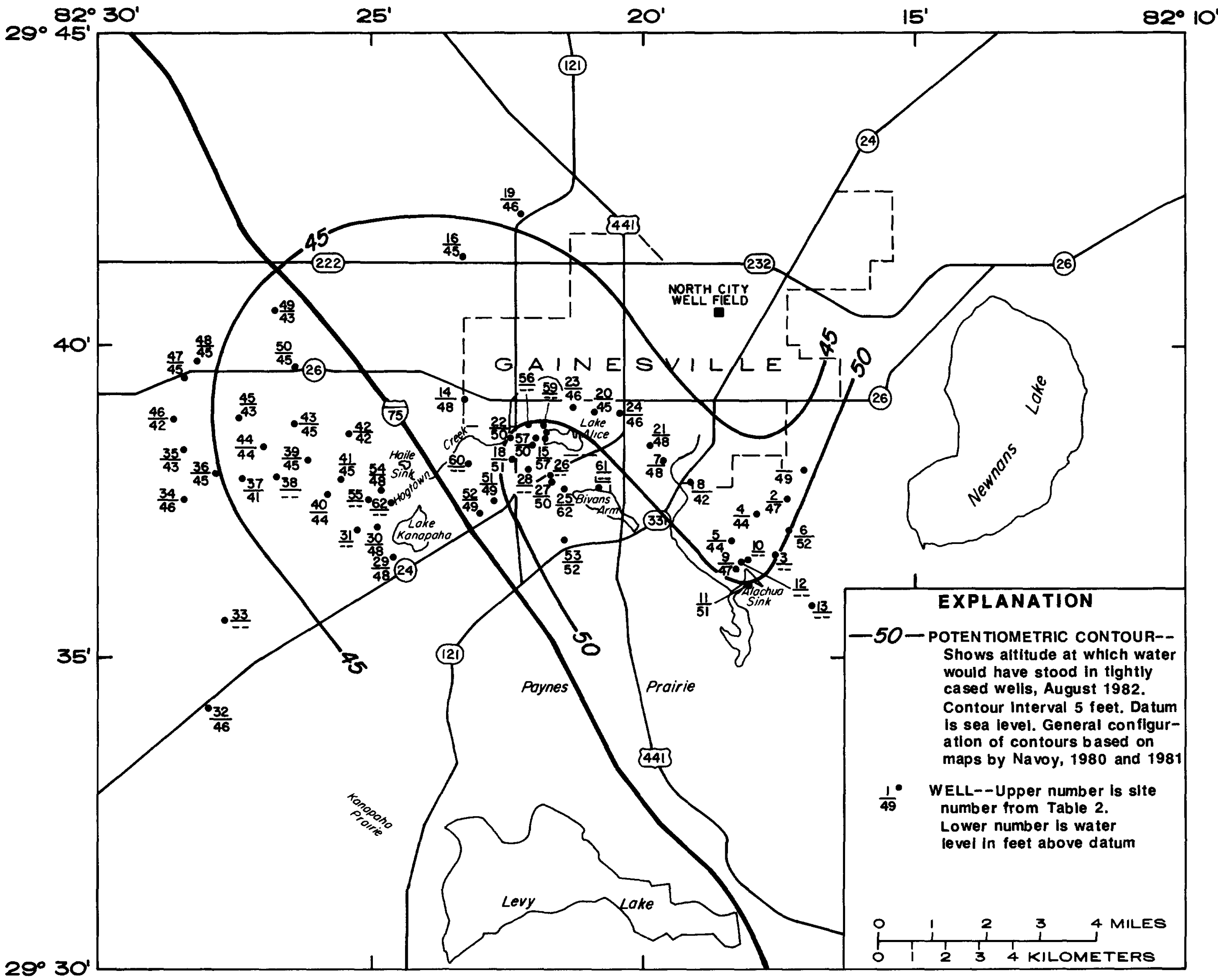

Figure 10.--Well locations and numbers, and potentiometric surface of the Upper Floridan aquifer in the Gainesville area, August 1982.

Table 2.--Well inventory

Site	Site identification No.	Well name	Depth (feet)	Casing depth (feet)	Land surface altitude (feet)	Water level Aug. 1982 (feet above sea level)
1	293754082170301	Quinn	193	88	159.07	48.60
2	293726082172001	WDVH	90	---	82	47.24
3	293633082173201	Ware	200	---	122	40.57
4	293712082175201	Melton	---	---	120	43.55
5	293645082182201	Kite	90	76	83	44.44
6	293657082171701	Joyner Constr.	---	---	105	51.56
7	293803082193401	Main St. STP	370	96	99.09	48.13
8	293745082190301	Evergreen Cem.	300	---	121	41.6
9	293625082181001	DNR Dist. 3 Sup.	---	---	80.74	46.62
10	293631082180501	ACPCD #3 Powerline	150	119	102.69	46.61
11	293604082180101	ACPCD #1 "No name"	161	139	59.92	51.27
12	293623082181201	ACPCD #2 Shed	52	40	60.63	47.46
13	293544082165101	DNR Windmill	98	---	62	36.5
14	293904082231501	Kronmiller	65	40	66.14	48
15	293816082221001	U Fla I-11	275	82	94.89	50.52
16	294121082231801	Pine Grove Church	---	---	165.17	44.91
17	293836082214601	R2 Drainage well	350	243	71.63	64.77
17a	293832082215001	R1 Drainage well	235	83	71.77	---
18	293804082222301	Bristol	90	---	82	50.9
19	294202082221101	Northwood WP	---	---	183.94	46.15
20	293851082205101	U Fla C-14 Reed	238	82	137.22	45.33
21	293818082195001	U Fla E-3 Wave	300	---	115.16	48.41
22	293826082222501	U Fla E-8 Animal	84	---	67.46	50.63
23	293855082211401	U Fla Perry Field	---	---	142.18	45.94
24	293850082202401	U Fla I-5 Ocala	523	260	151.34	46.46
25	293737082212501	U Fla E-6 Ent.	65	34	85.21	61.94
26	293750082213901	U Fla E-1 Swine	105	60	94.04	49.74
27	293743082213801	U Fla I-19 Solar	167	---	81.90	49.93
28	293757082220301	U Fla C-15 Surge	194	79	80	57.2
29	293644082244201	GRU Monitor 1 (Shallow)	250	150	89.34	48.08
29	293644082244202	GRU Monitor 1 (Deep)	1,050	450	89.34	---
30	293723082245701	GRU Monitor 2 (Shallow)	250	150	78	47.50
30	293723082245702	GRU Monitor 2 (Deep)	1,050	450	78	---
31	293719082250801	GRU Monitor 3 (Shallow)	250	150	83	48.74
31	293719082250802	GRU Monitor 3 (Deep)	1,050	450	83	---

Table 2.--Well inventory--Continued

Site	Site identification No.	Well name	Depth (feet)	Casing depth (feet)	Land surface altitude (feet)	Water level Aug. 1982 (feet above sea level)
32	293408082280201	West	80	---	65	46.1
33	293531082274001	Childress	---	---	86	43.16
34	293728082282401	Parker Rd. Baptist	103	80	86	45.56
35	293816082282301	Johns	85	---	90	43.25
36	293753082274701	MacGregor	---	---	83	45.47
37	293748082272001	Vacant site	---	---	88	41.0
38	293748082264101	Vacant trailer	---	---	79.39	43.85
39	293805082260801	King	88	---	76.95	44.82
40	293734082254601	Harrington	---	---	119.39	44.01
41	293746082253201	Runkle	120	---	97.15	44.92
42	293830082252201	GRU Monitor 4 (Shallow)	250	150	74	41.46
42	293830082252202	GRU Monitor 4 (Deep)	1,050	450	74	---
43	293840082262401	Hurst	110	---	72.96	44.91
44	293818082265801	Bassett	110	---	98	43.49
45	293845082272301	Peck	104	---	124.22	43.3
46	293845082283501	Fink	88	21	86	42.18
47	293925082282401	McGraw	88	---	89.92	45.11
48	293939082281101	McNealy	130	---	96.74	45.14
49	294030082264501	Keen	160	55	137.17	43.12
50	293934082262101	Ft. Clark Church	---	---	163.96	44.72
51	293724082224401	Archer Rd Village	158	90	72.71	48.57
52	293713082230001	Town & County	445	243	65.34	40.83
53	293647082212401	SW United Meth.	---	80	90.56	51.95
54	293744082244401	Modell house	---	---	64.51	---
55	293744082245501	Dickenson pasture	---	---	70	---
56	293854082221001	UF Golf Course	320	---	70	---
57	293833082215201	Museum Dr. Test	140	108	68.55	---
58	293836802214801	Test nr R2	65	20	78.97	---
59	293837082214901	Garden Test	105	45	80.35	---
60	293807082231301	GRU Monitor 5 (Shallow)	250	150	64.82	---
60	293807082231302	GRU Monitor 5 (Deep)	1,050	450	64.82	---
61	293746082210501	Wing	80	---	81.22	---
62	293736082244301	Dickenson house	77	---	70.87	---

DESCRIPTION OF STUDY SITES AND RECHARGE RATES

The four sites were chosen so that different types of sites and quality of recharge water could be studied. Alachua Sink and Haile Sink are natural recharge areas, whereas the wells at Kanapaha and Lake Alice were designed to dispose of unwanted water. At Alachua Sink and Lake Alice, both surface runoff and treated wastewater recharge the aquifer. At Haile Sink, only surface water enters the aquifer and at Kanapaha, only treated wastewater.

Kanapaha Injection Wells

The Kanapaha Wastewater Treatment Plant (fig. 12), operated by GRU, is on the western edge of Lake Kanapaha, about 3-1/2 miles southwest of the city of Gainesville (fig. 1). The area is flat and a part of the Hogtown Prairie. There, the limestone of the Floridan aquifer system is at or near land surface. Four wells, each cased to a depth of 450 feet below land surface and having total depths ranging from 1,028 to 1,050 feet, are used to inject treated wastewater by gravity drainage.

Figure 11 shows a generalized section of the construction of the injection wells, which are cased into the Avon Park Formation. A flow meter survey, conducted by consultants to GRU, shows the alternating zones of low and high permeability characteristic of the Avon Park Formation. The treated wastewater is injected into the Avon Park, which is also tapped by the city of Gainesville for water supply. However, the Gainesville north well field is located on the opposite side of a potentiometric high from the injection wells. All the local residents within about a 2-mile radius of the treatment plant have city water, therefore, few private wells exist near the plant. Five pairs of monitor wells were constructed by GRU (sites 29, 30, 31, 42, and 60). One well of each pair was completed in the injection zone (Avon Park Formation) and one in the upper part of the aquifer system (the Ocala Limestone). Locations of well pairs are shown in figures 10 and 12, the latter being a more detailed map of the well sites. Site 60 is upgradient of the injection site, sites 29 and 30 are equipotential to the site, and sites 31 and 42 are downgradient.

The treatment plant began operating in 1978. Injection flow rates for January 1982 through February 1984 were: average flow 6.1 Mgal/d; minimum 5.1 Mgal/d in May 1982; and maximum 7.2 Mgal/d in October 1983. The advanced treatment provided at the plant includes: (1) extended aeration to achieve nitrification, (2) clarification, (3) denitrification using deep-bed filtration, (4) postaeration, and (5) chlorination.

Hydrographs of four pairs of monitor wells for 1979-84 are shown in figure 13. The water level in the deep (injection) zone at site 29 is lower than water levels in the upper zone, even during the drought of 1981. Throughout the drought, water levels in the upper zone dropped drastically because of below average rainfall (fig. 9) and increased pumping, whereas in the deep zone, injection continued at a nearly constant rate. At the other three monitor well sites, the vertical gradient reversed during the drought, and at site 42 the water level in the lower zone continued to be higher than in the upper zone through at least May 1984. Without continued monitoring of water levels at site 42, it is not possible to determine if injection has sustained reversal of the natural vertical gradient.

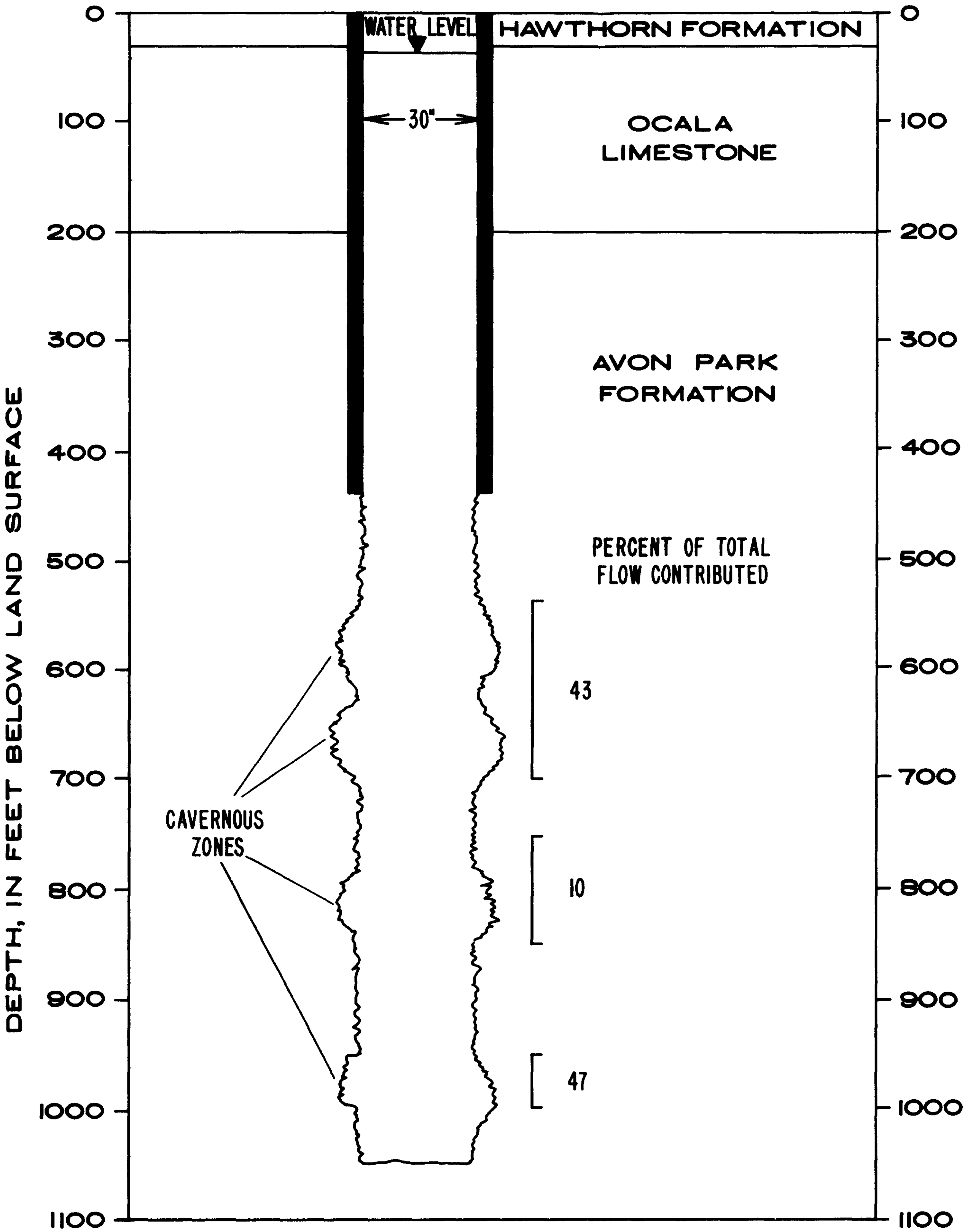

Figure 11.--Typical injection well construction at the Kanapaha Wastewater Treatment Plant (geohydrologic data provided by Gainesville Regional Utilities).

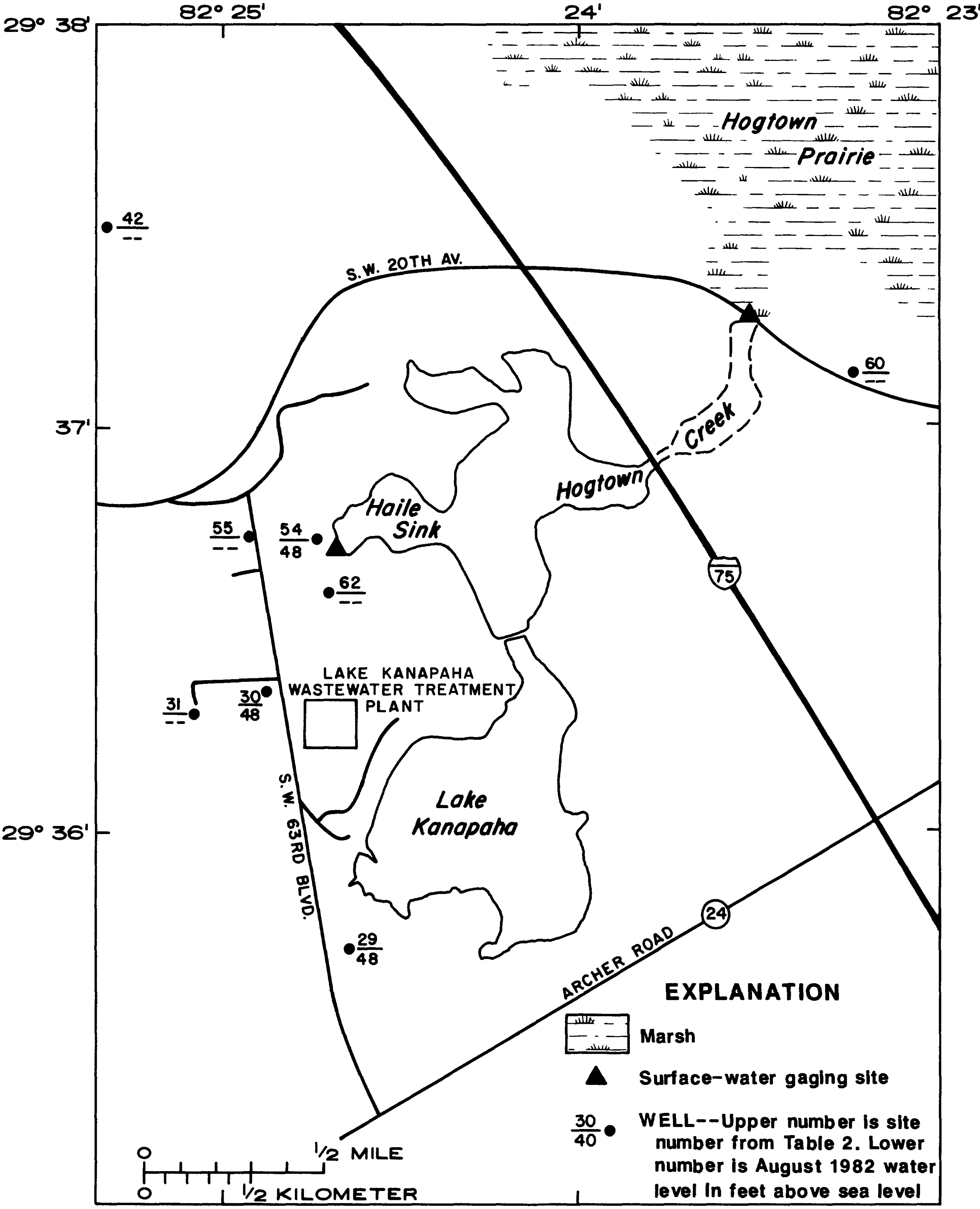

Figure 12.--Haile Sink and Lake Kanapaha areas and locations of wells, surface-water features, and gaging sites.

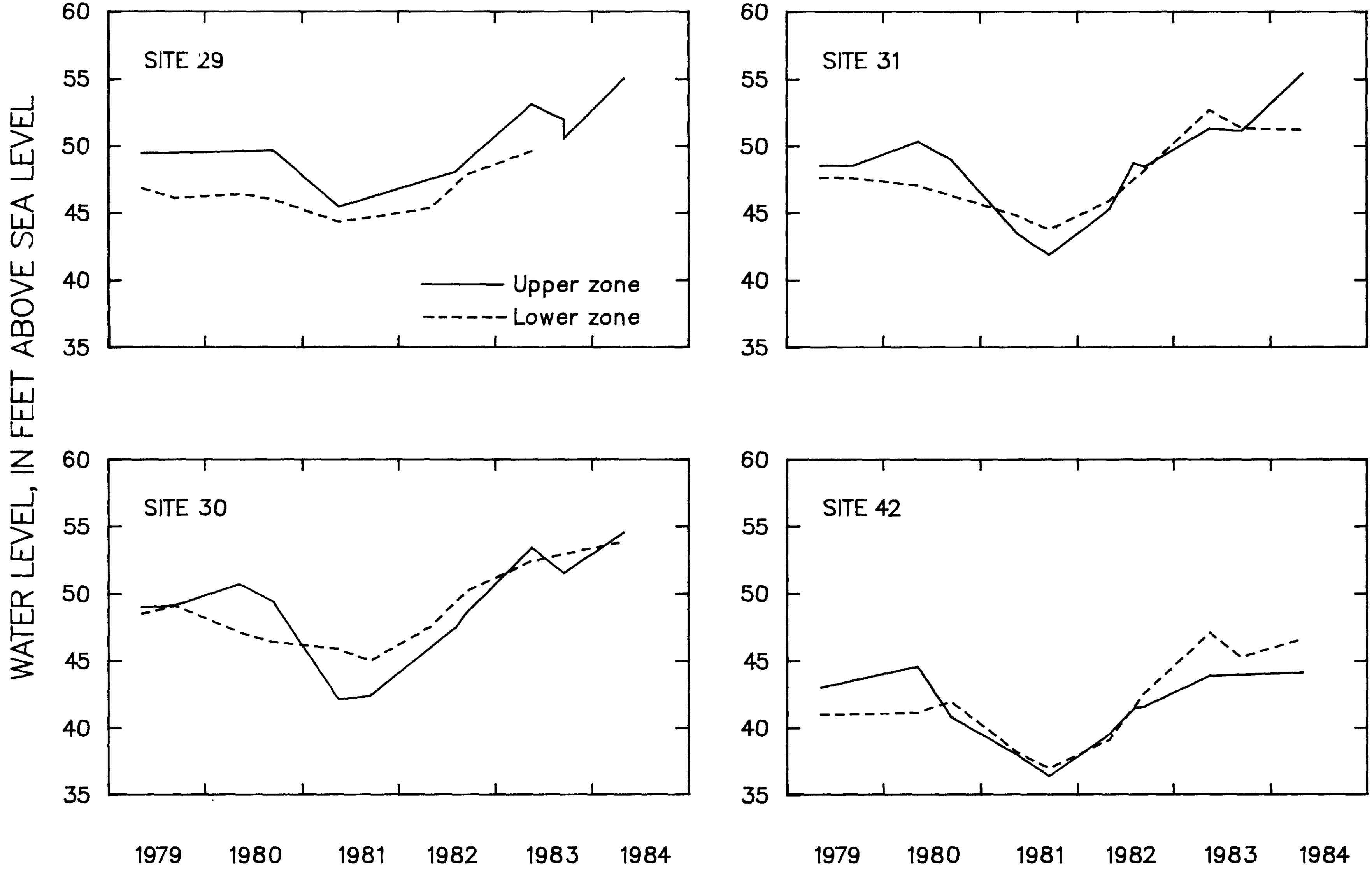

Figure 13.-Water levels in monitor well pairs near the Kanapaha injection wells, 1979-84.

Alachua Sink

Paynes Prairie is a topographically low, swampy, area of about 12,000 acres south of Gainesville. Two sinkholes at the north end of the Prairie, one in the northwest arm of Alachua Sink and the other in the southeast arm, allow drainage into the Ocala Limestone (fig. 14).

The Paynes Prairie depression was caused by erosion of the limestone bedrock which was covered by only about 10 to 50 feet of Miocene and post-Miocene sediments (White, 1958, p. 66-73). The prairie is usually marshy with some areas of open water during rainy seasons when the available water is greater than the capability of the sinkhole to accept the water. From about 1870 to 1891, abundant rainfall and probable clogging of the sinkholes caused water to accumulate in the Paynes Prairie depression and Alachua Lake to form (Florida Bureau of Geology, 1910). In late summer 1891, the sinkholes are reported to have become unclogged and the level of the lake dropped 8 feet in 10 days, leaving thousands of dead fish on the former lakebed. The Prairie has not become a lake again since that time. It is now a State wildlife preserve with a diverse wildlife population including many varieties of water fowl and wading birds, hawks, otters, and alligators.

Flow measurements to the sinkholes can be made in a narrow channel at low stage (fig. 14), but during rainy seasons drainage from the prairie predominates and accurate direct flow measurements are impossible due to a combination of high stage and very low velocities in the channel and sheetflow in an undefined channel. In addition to runoff from the prairie, flow to the sinkhole also comes from Sweetwater Branch. About 5 Mgal/d of secondary treated wastewater is discharged from the Gainesville Main Street Wastewater Treatment Plant to Sweetwater Branch. During dry conditions, Sweetwater Branch flows in a well-defined channel to its confluence with the discharge from Paynes Prairie, but at high water stage most of the area shown as marsh in figure 14 is inundated, including the area northeast of the control structure.

Because of the difficulty in making a suitable measurement at high stages, flow to the sinks could not be rated for all stages. Two discharge measurements were made at Alachua Sink during the study (table 3). On August 3, 1982, flow to the sinks was 26.0 ft^3/s (16.8 Mgal/d). The rainy summer season of 1982 caused high water on the Prairie in September 1982. Flow could not be measured near the gaging site because of very low-flow velocities due to backwater from the sink, but the flow through the culverts from Paynes Prairie and Sweetwater Branch was estimated by current meter on September 27, 1982. The estimated total flow is 35.7 ft^3/s (23 Mgal/d)--26.4 ft^3/s (17 Mgal/d) of which came from Paynes Prairie and 9.3 ft^3/s (6 Mgal/d) from Sweetwater Branch. Figure 15 shows the water-level hydrograph from the gaging station at Sweetwater Branch from April 1982 through September 1983.

On October 6, 1982, 9 days after the flow estimate discussed above, the water level difference between the sink and well 12 (fig. 16) was only 0.11 foot, the smallest gradient measured during the study. After that date, water levels in both the sink and the well began to recede (fig. 16), although the water level on Paynes Prairie remained high. The lag in the sink level recession after the end of the rainy season, apparent in figure 16, is indicative of the large amount of water stored on Payne's Prairie, which drains to the sink and, thus, to the Floridan.

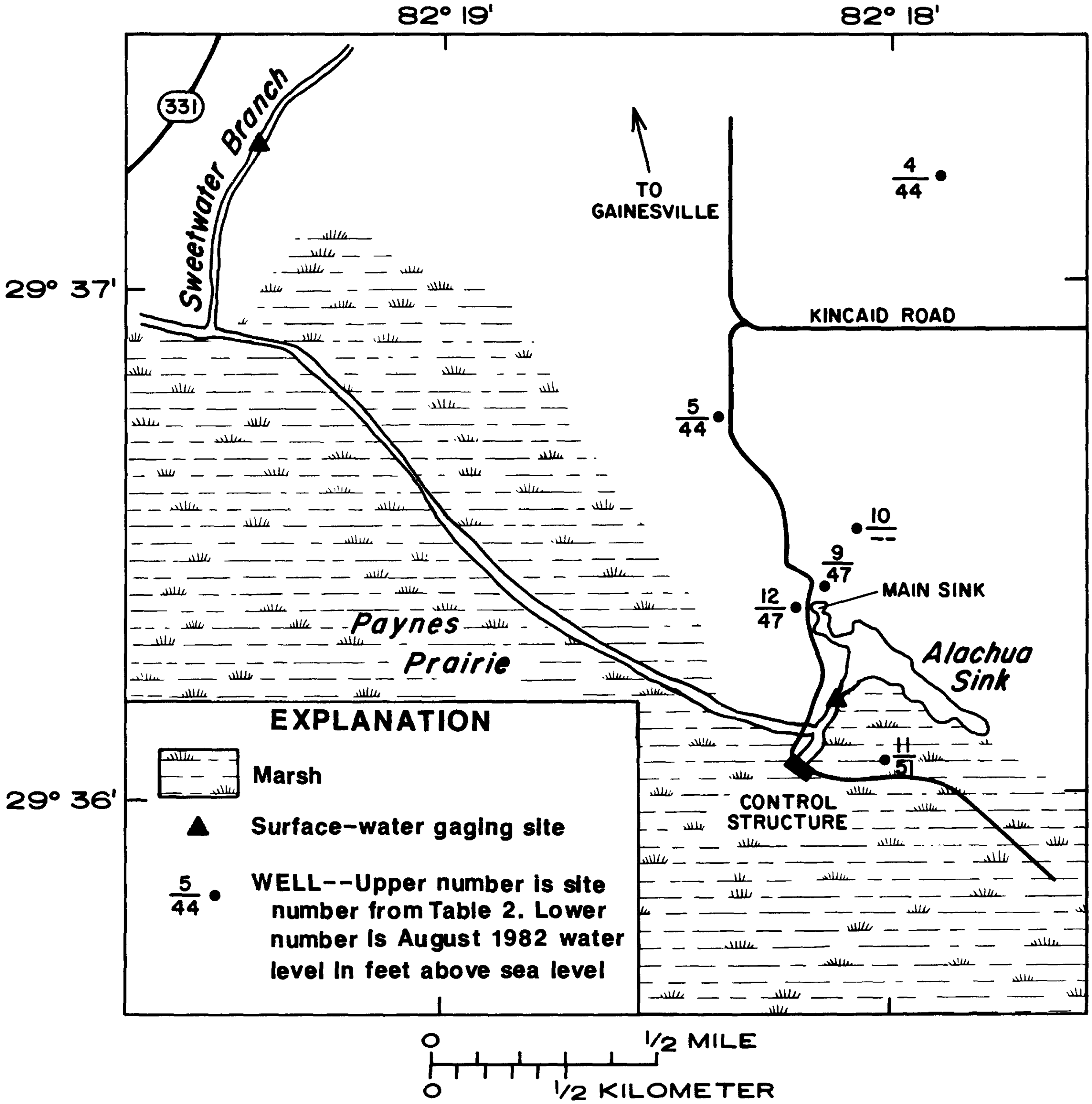

Figure 14.--Alachua Sink area and locations of wells, surface-water features, and gaging sites.

On February 9, 1983, flow to the sink was 15.3 ft^3/s (9.9 Mgal/d). At that time, the water level in the sink was probably lower than the water level in well 12 (fig. 16) and, thus, the sink was probably not taking water. Estimating the average recharge rate through Alachua Sink is a complex problem.

Table 3.--Summary of flow rates to the recharge sites

[E denotes estimated flow]

Site	Date or period of record	Flow rate ft^3/s	Flow rate Mgal/d
Lake Alice at drainage well R1	08-03-82	4.2	2.7
	10-06-82	1.9	1.3
	11-17-82	0	0
	02-09-83	1.8	1.1
	05-10-83	3.8	2.5
	07-14-83	0	0
Lake Alice at drainage well R2	08-03-82	4.4	2.9
	10-07-82	3.9	2.5
	11-17-82	3.0	1.9
	02-09-83	3.8	2.4
	05-10-83	2.2	1.4
	07-14-83	4.4	2.9
Sweetwater Branch	08-03-82	18.0	11.6
	10-06-82	17.1	11.0
	11-17-82	16.4	10.6
	05-11-83	16.4	10.6
	07-14-83	18.4	11.9
Alachua Sink	08-03-82	26.0	16.8
	09-27-82	35.7 (E)	23.0 (E)
	02-09-83	15.3	9.9
Kanapaha injection wells[1]	Jan 1982 to Feb 1984 (mean)	9.4	6.1
	Oct 1983 (maximum monthly mean)	11.1	7.2
	May 1983 (minimum monthly mean)	7.9	5.1
Haile Sink (Hogtown Creek)	1972 to 1983 (mean)	19.2	12.4
	08-26-72 (maximum daily mean)	671	433
	05-23-81 (minimum daily mean)	1.2	.8

[1]Flow summaries provided by Gainesville Regional Utilities.

Lake Alice Drainage Wells

Lake Alice (fig. 17) is located on the campus of the University of Florida (fig. 1). Williams and others (1977, p. 31) believe that Lake Alice once covered a larger area than it does at present and was a tributary to Hogtown Creek. Eventually its drainage was captured by the opening of a small sink. The lake accepts street runoff from part of the campus and secondary treated effluent from the University's wastewater treatment plant. During some high water stages, flow crosses the drainage divide to Bivens Arm and eventually reaches Sweetwater Branch, and thus, Alachua Sink (fig. 1).

In 1959 and 1960, two drainage wells (R1 and R2) were drilled to control flooding of Lake Alice. Well R1 is 235-feet deep and has 83 feet of 24-inch casing. Well R2 was drilled to a depth of 450 feet, with 243 feet of 20-inch casing. Geophysical logs made in 1981 showed that the well was backfilled to 350 feet.

In the area of Lake Alice the Floridan aquifer system is unconfined, therefore, the potentiometric surface of the Floridan is the water table. Because of the karstic geology, the top of the limestone ranges from about 20 feet to more than 140 feet below land surface. The top of the limestone is very weathered and cavernous, and in some areas the potentiometric surface of the Floridan is 5 to 10 feet below the top of the limestone. Three test wells (wells 57, 58, and 59) were drilled near the drainage wells. Because of the soft, crumbly nature of the limestone, the test wells near R2 (wells 58 and 59) were abandoned before the injection zone was penetrated. Test well 57, near R1, taps the upper part of the drainage-well zone.
15

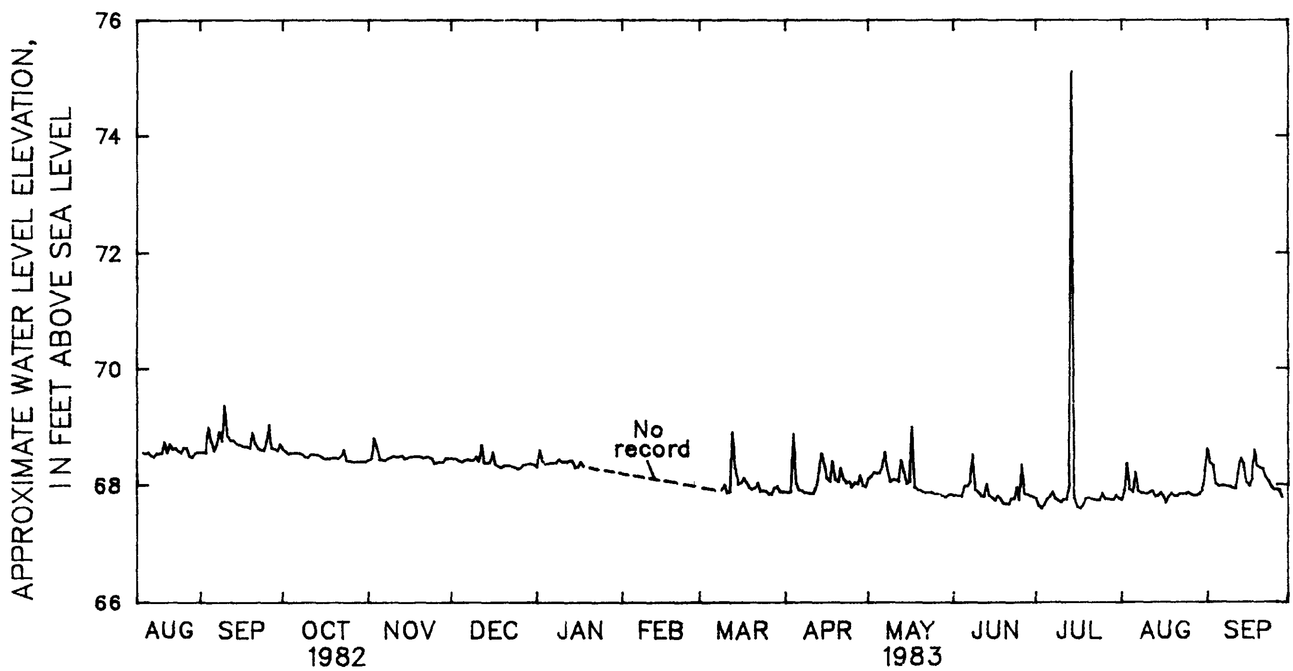

Figure 15.--Water levels in Sweetwater Branch near Alachua Sink, August 1982-September 1983.

Water levels for Lake Alice for April 1982 through September 1983 are shown in figure 18. Measured flow rates to wells R1 and R2 are shown in table 3. The observed flow to R1 ranged from 0 during extremely dry weather to 2.7 Mgal/d. Flow to R2 ranged from 1.4 to 2.9 Mgal/d. The combined total measured inflow to both wells thus ranged from about 1.9 to about 5.6 Mgal/d during the study.

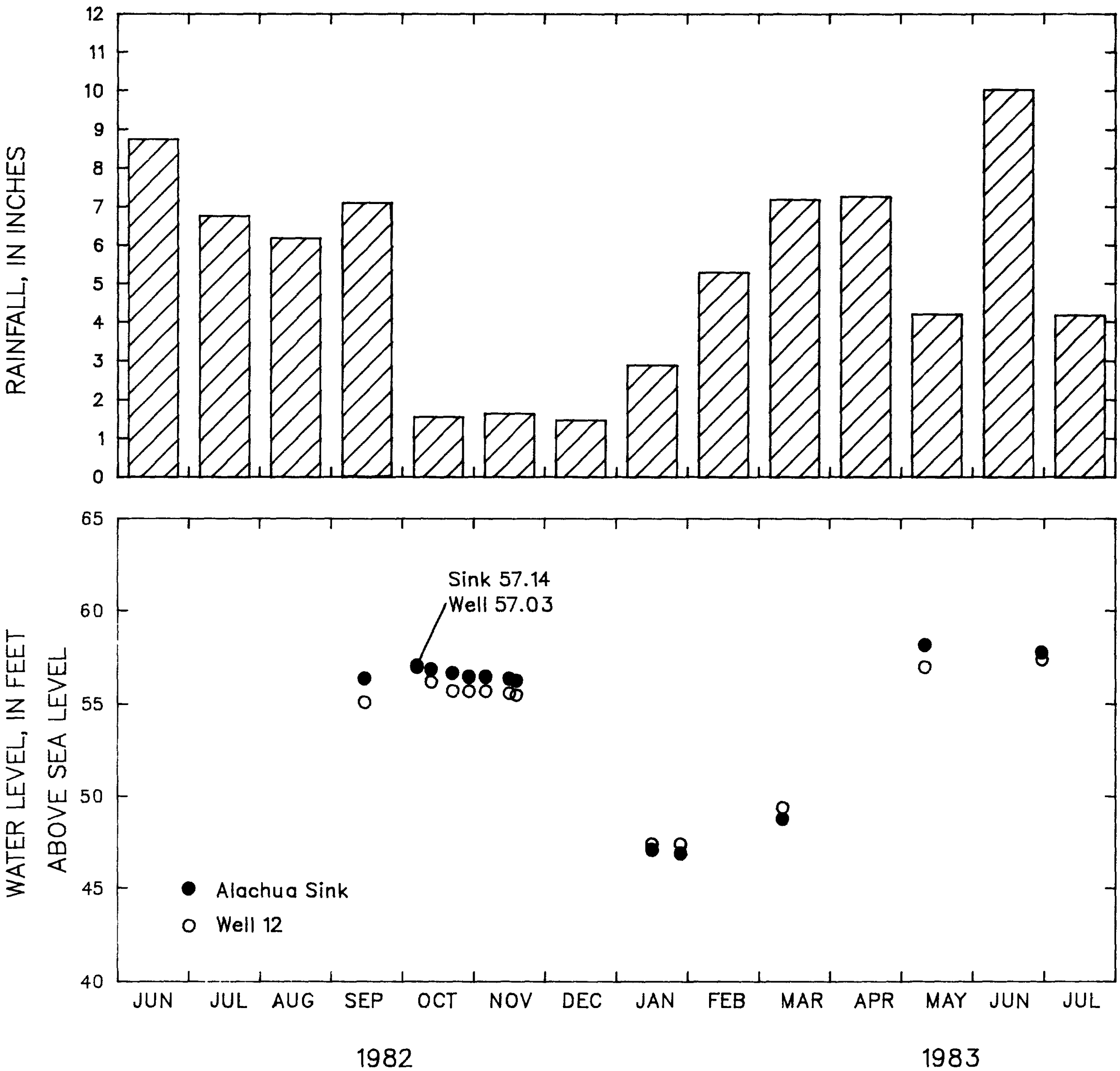

Figure 16.--Water levels in Alachua Sink and well 12, and monthly rainfall at Gainesville, June 1982-July 1983.

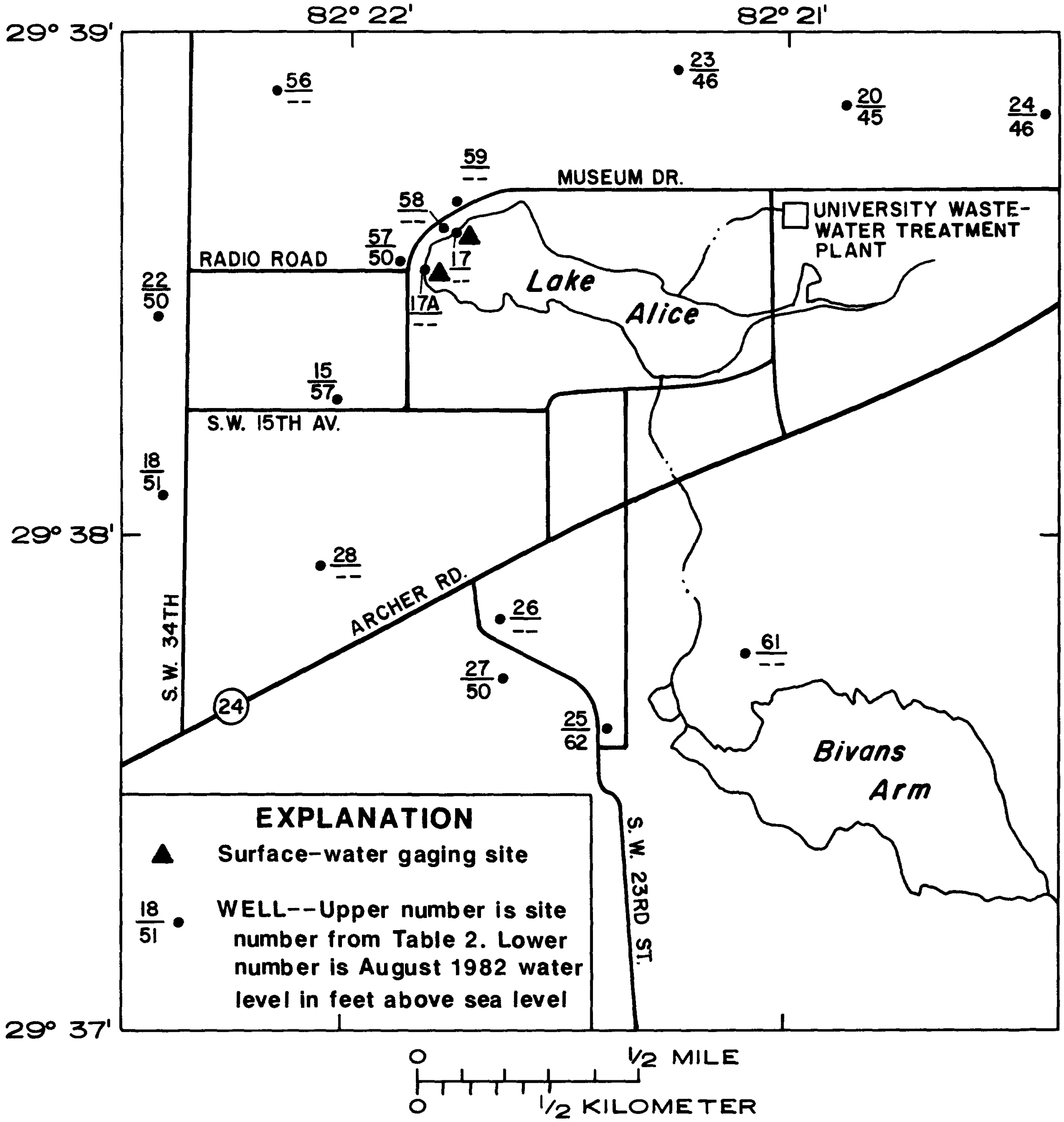

Figure 17.--Lake Alice and Bivans Arm areas and locations of wells, surface-water features, and gaging sites.

Haile Sink

Haile Sink, located north of Lake Kanapaha at the southwest end of Hogtown Prairie (fig. 12), is a naturally occurring recharge site. Hogtown Creek drains into Hogtown Prairie, which in turn drains into Haile Sink. The creek is about 10 miles long and drains an area of about 23 mi^2 of the western part of Gainesville. Land use in the Hogtown Creek basin is mostly residential with some commercial and light industrial use. Highway runoff from much of the basin flows into the creek. During the 1950's and 60's, pine-tar products were produced at a site in the northern part of the Hogtown Creek basin. After the plant closed in 1966, the waste lagoons were subsequently covered. In December 1979, the U.S. Environmental Protection Agency found phenol concentrations as high as 1,500 μg/L in Hogtown Creek near the plant site (Huber and others, 1981, p. 17).

The U.S. Geological Survey has gaged the flow of Hogtown Creek near Haile Sink since December 1971. Discharge at Hogtown Creek is shown in figure 19. The mean flow for the period of record is 19.2 ft^3/s (table 3). Maximum flow for the period of record was 671 ft^3/s on August 26, 1972, and the minimum was 1.2 ft^3/s on May 23, 1981. The maximum discharge during water year 1982 (October 1981 through September 1982) was 442 ft^3/s on April 9, 1982, and the minimum for the water year was 2.0 ft^3/s on October 21-24, 1981. It is assumed that the entire flow at the Hogtown Creek gaging station enters the Floridan aquifer system through Haile Sink, which is reported by local residents to be 180 feet deep.

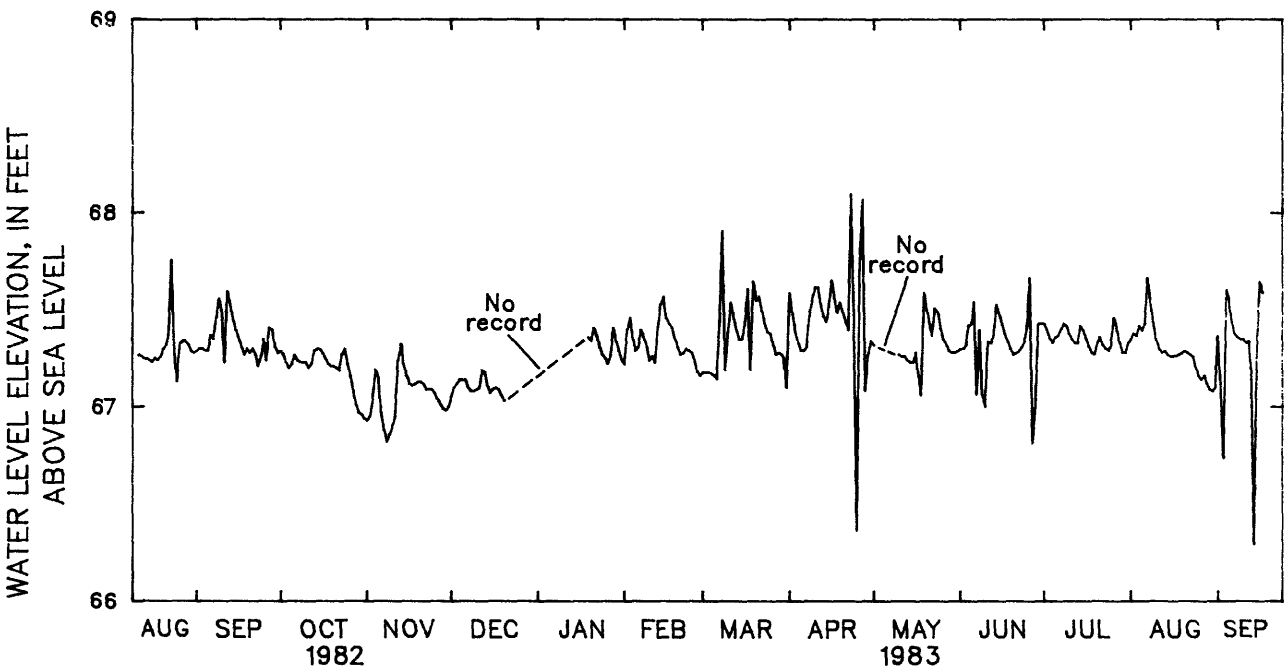

Figure 18.--Elevation of Lake Alice near drainage well R1, April 1982-September 1983.

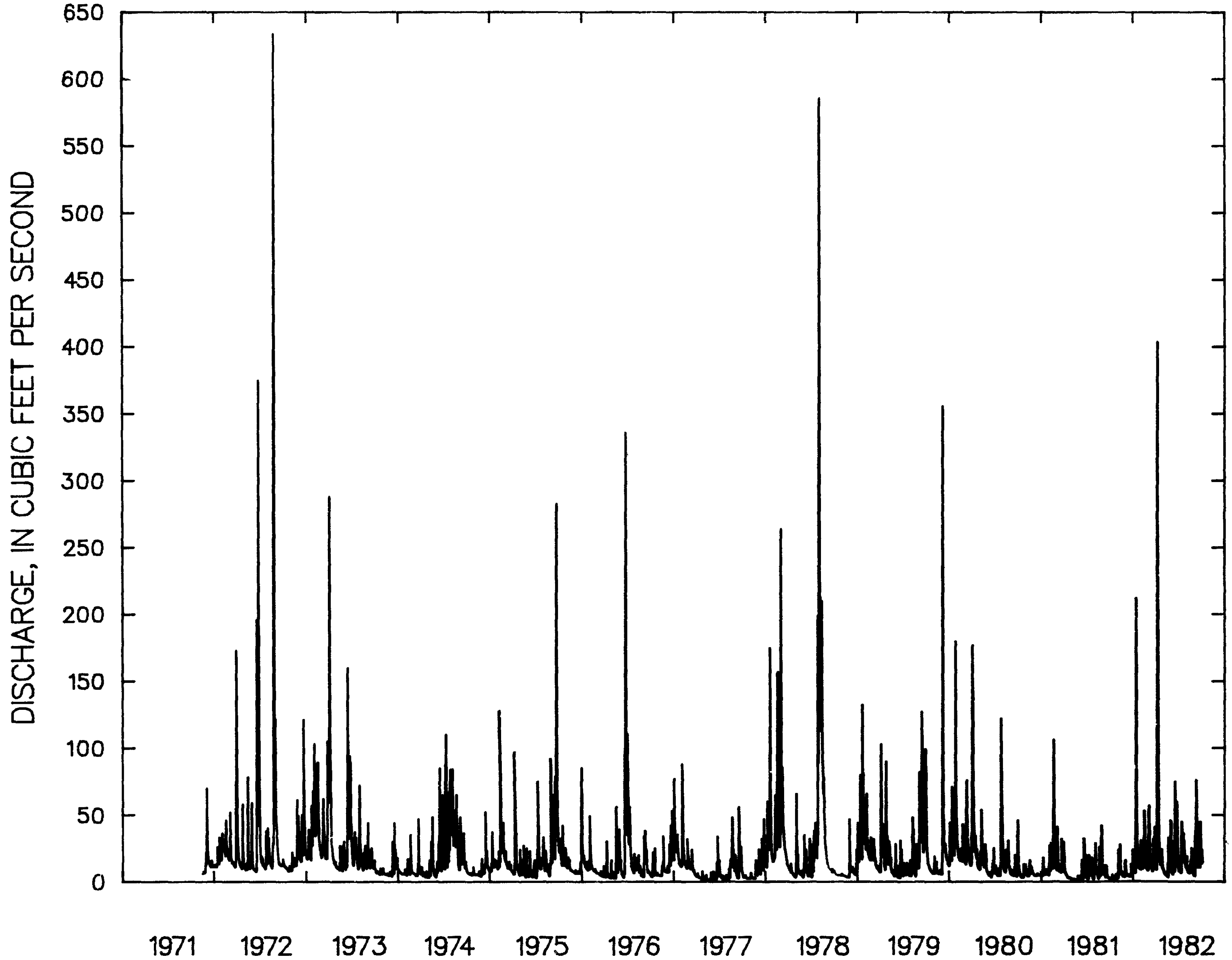

Figure 19.--Daily discharge of Hogtown Creek near Haile Sink, October 1971-September 1982.

Summary of Recharge Rates

Lake Alice, Haile Sink, and Alachua Sink contribute recharge to the upper zone of the Floridan aquifer system. The injection wells at the Kanapaha site recharge the lower zone. Total recharge estimated for Lake Alice, Alachua Sink, and Haile Sink averages about 33 Mgal/d, of which about 7 Mgal/d is treated wastewater which was originally withdrawn from the Floridan. Bush (1982, fig. 5) estimated a yearly recharge rate of 15 to 20 inches in the Gainesville area under predevelopment conditions (before wells tapped the aquifer). The total drainage area of Lake Alice, Haile Sink, and Alachua Sink is about 48 mi^2. Fifteen to 20 inches of recharge per year over an area of about 48 mi^2 is equivalent to a recharge rate of about 34 to 36 Mgal/d. Thus, if the recharge rate were 15 in/yr, the three sites mentioned could account for about 75 percent of the recharge occurring in the study area. The geology of the area and the presence of other known sinkholes indicate that recharge is occurring by downward leakage through thin confining beds, by infiltration of rainfall on the outcrop, and through the other sinkholes, so the estimate of 15 to 20 in/yr probably represents the lower limit of recharge to the upper Floridan in the study area. No estimates of recharge to the lower zone of the Floridan aquifer system from the upper zone have been made, but it is assumed that because the vertical hydraulic gradient is generally downward, recharge to the lower zone occurs by downward leakage from the upper zone in the Gainesville area.

QUALITY OF SURFACE RUNOFF AND TREATED WASTEWATER RECHARGE

The quality of surface runoff and treated wastewater recharge was determined by previous sampling and from samples collected during this study. Analyses of major ions, physical properties, trace elements, bacteria and nutrient concentrations, and organic compounds appear in this section.

Previous Sampling

All the study sites were sampled at least once by others. In 1977, Black, Crow and Eidsness (1977), working as consultants to GRU, sampled Alachua Sink, Haile Sink, Lake Alice, and Lake Kanapaha. Also, Huber and others (1981) sampled numerous sites in the Hogtown Creek basin, including Haile Sink. Data from both studies are summarized in tables 4 and 5, respectively.

Samples Collected During This Study

Sampling was done by both the U.S. Geological Survey and GRU. The latter regularly samples both the injection water at Kanapaha and the water from monitor wells near the injection site. The U.S. Geological Survey sampled water from the other three sites at least once, and some sites were sampled several times. Haile Sink, Alachua Sink, and Lake Alice were sampled for major ions, trace elements, nutrients and bacteria, and organic compounds. Sweetwater Branch and Paynes Prairie (the two sources of flow to Alachua Sink) were also sampled for the same constituents but Paynes Prairie was not sampled for organic compounds. Inflow to Lake Alice from the University of Florida Wastewater Treatment Plant was also sampled.

Table 4.--Concentrations of selected constituents of surface waters near Gainesville, April-July, 1977[1]

	Conductivity (μS/cm at 25 °C)	Chloride (mg/L)	pH units	Sulfate (mg/L)	Dissolved oxygen (mg/L)	Ammonia (mg/L as N)	Nitrate plus nitrite (mg/L as N)	Organic nitrogen (mg/L as N)	Reactive phosphate (mg/L as P)	Total phosphorus (mg/L as P)	Total coliform (MF col/ 100 mL)	Fecal coliform (MF col/ 100 mL)	Fecal streptococci (MF col/ 100 mL)
No. of samples	6	6	6	6	5	6	6	6	6	6	6	6	6
Alachua Sink													
Maximum	730	91	7.50	63	3.8	17.9	2.04	2.98	6.15	24.0	60,000	1,900	7,000
Minimum	227	26	6.20	7.8	.4	1.82	.06	1.72	1.04	1.22	400	33	48
Mean	591	65	7.00	46	2.5	12.2	.61	2.10	4.76	8.64	24,000	880	1,600
Lake Alice													
Maximum	448	44	8.85	37	>15	.20	.10	1.65	1.79	5.15	6,000	1,300	240
Minimum	340	35	6.90	12	7.4	<.02	.01	.12	.23	1.70	1,500	110	13
Mean	401	40	7.65	32	11	.07	.05	1.09	1.35	2.42	2,800	470	120
Haile Sink													
Maximum	328	22	8.25	34	9.2	.13	.43	1.35	.67	.82	1,000	1,100	70
Minimum	285	14	6.80	10	7.0	<.02	.12	.25	.48	.58	100	15	10
Mean	297	17	7.80	17	8.1	.03	.22	.62	.57	.72	330	230	39
Lake Kanapaha													
Maximum	217	39	9.60	1.1	14.8	.20	.05	6.48	.14	.50	20	3	50
Minimum	161	18	7.65	<1.0	5.7	.04	<.01	1.83	.04	.14	2	1	1
Mean	183	26	8.30	<1.0	10.3	.13	.03	3.64	.09	.28	12	2	15

	Arsenic (μg/L)	Fluoride (mg/L)	Barium (μg/L)	Cadmium (μg/L)	Chromium (μg/L)	Copper (μg/L)	Iron (μg/L)	Lead (μg/L)	Manganese (μg/L)	Mercury (μg/L)	Selenium (μg/L)	Silver (μg/L)	Zinc (μg/L)
No. of samples	1	1	1	1	1	1	1	1	1	1	1	1	1
Alachua Sink	<6	0.74	60	<2	18	20	1,540	<32	43	0.2	<2	4	61
Lake Alice	<6	.66	<20	<2	<3	10	90	<8	23	<.2	<2	<4	10
Haile sink	<6	.28	<20	<2	<3	<10	216	10	18	<.2	10	<4	10
Lake Kanapaha	<6	.23	<20	<2	<3	10	290	<8	23	<.2	<2	<4	10

[1]Data from Black, Crow, and Eidsness, Inc., 1977, tables 3-1, 3-2, and 3-4.

Table 5.--Concentrations of selected constituents of a water sample from Haile Sink, May 14, 1980

[Data from Huber and others, 1981, Appendix E]

Turbidity (JTU)	8.3
Color (Pt-Co units)	145
Specific conductance (μS/cm)	195
Dissolved oxygen (mg/L)	7.4
Biochemical oxygen demand (mg/L)	1.0
pH (standard units)	7.6
Alkalinity (mg/L as $CaCO_3$)	79
Ammonia (mg/L as N)	.014
Nitrogen dioxide (mg/L as N)	.009
Total Kjeldahl nitrogen (mg/L as N)	.755
Orthophosphate (mg/L as P)	.930
Total phosphate (mg/L as P)	.930
Total organic carbon (mg/L as C)	24
Calcium (mg/L as Ca)	34
Magnesium (mg/L as Mg)	4.4
Sodium (mg/L as Na)	7.5
Potassium (mg/L as K)	.6
Chloride (mg/L as Cl)	12
Sulfate (mg/L as SO_4)	14
Total coliform (MPN/100 mL)	1,740
Fecal coliform (MPN/100 mL)	800
Fecal streptococci (MPN/100 mL)	157

Summaries of the data are shown in tables 6, 7, and 8. Table 6 shows a summary of data collected by GRU from injection water and the three downgradient monitor well pairs. Tables 7 and 8 show major constituents, physical properties, trace element concentrations, bacteria, and nutrient concentrations from the surface-water sites studied.

The amount of rainfall prior to sampling might be expected to influence the chemical quality of water sampled. Figure 20 shows monthly rainfall at Gainesville for 1980-83 and the months during which surface-water samples were collected. There were not a sufficient number of samples collected at each site to determine relations between water quality and antecedent rainfall. Figures 21 and 22 show the maximum and minimum values of selected constituents for recharge waters at each of the four sites and for wells near each site. The horizontal scales on the figures do not correspond to distance from the recharge site, although the wells are plotted in order of distance away from the recharge site.

Table 6.--Summary of chemical data for water from the Kanapaha injection wells and three monitor well pairs, 1978-83

[All data provided by Gainesville Regional Utilities. Pre-startup concentrations are the mean of samples collected before the plant began injections]

	Chloride (mg/L)	Sulfate (mg/L)	Sulfide (µg/L)	Nitrate (mg/L)	Nitrogen (total Kjeldahl) (mg/L)	Color Pt-Co (units)	Arsenic (µg/L)	Cadmium (µg/L)	Copper (µg/L)	Iron (µg/L)	Lead (µg/L)	Mercury (µg/L)	Zinc (µg/L)	Fluoride (µg/L)	Chromium (µg/L)
Injected water															
Mean value	56	62	155	2.3	1.23	9	5	1.2	19	78	<7	0.3	52	674	<4
No. of samples	33	29	33	36	21	24	66	65	38	40	60	32	36	44	68
Maximum	76	97	750	11.0	3.7	35	20	13	90	440	<40	.6	300	850	<40
Minimum	22	12	10	.04	.6	10	1	.2	1	24	<1	.1	<10	80	<1
Site 29, monitor well 1 (shallow)															
Pre-startup	9	21	30	--	.07	175	15	<2	40	5,000	380	<.2	167	50	<3
Mean value	10	10	<122	.12	<.22	17	<7	1.6	<12	736	<11	<.33	<114	192	<5
No. of samples	22	12	27	26	36	18	27	27	17	19	32	21	17	43	27
Maximum	14	16	290	.49	.90	<50	16	<13	<90	1,400	50	<.6	<300	750	<40
Minimum	2.5	7	<10	<.02	<.03	3	<2	<.2	<2	110	<1	<.2	10	20	<.5
Site 29, monitor well 2 (deep)															
Pre-startup	8	5	570	--	.38	--	<6	2	35	130	30	<.2	500	740	<3
Mean value	10	10	513	<.18	<.33	5	4	<1.4	<14	125	<9	<.31	92	684	<5
No. of samples	24	19	28	45	43	16	36	35	25	23	37	27	18	43	36
Maximum	20	31	1,300	.70	.70	40	12	<13	125	1,300	40	<.60	500	1,080	<40
Minimum	1.5	1	180	<.02	<.03	<1	<1	<.2	<2	5	<1	<.20	6	100	<.5
Site 30, monitor well 2 (shallow)															
Pre-startup	13	3.2	<20	--	.24	81	6	<2	8	3,070	17	<.2	165	90	<3
Mean value	40	36	108	.56	.35	33	14	1.4	9.6	1,344	9	<.3	127	460	5
No. of samples	43	21	35	49	62	23	36	35	23	24	41	27	17	44	36
Maximum	58	40	390	2.9	1.5	50	31	13	90	3,070	<40	<.6	350	1,380	<40
Minimum	20	8	10	.02	.10	5	5	<.2	<2	250	<1	<.2	<10	90	<1
Site 30, monitor well 2 (deep)															
Pre-startup	14	8.2	<20	--	.30	67	<6	<2	29	300	227	<.2	123	450	<3
Mean value	51	59	208	.40	.48	8	13	1.4	10.7	122	14	<.3	84	783	6
No. of samples	43	19	35	48	63	23	36	35	23	24	41	27	17	45	36
Maximum	72	120	850	3.2	1.1	20	46	13	90	300	227	<.6	300	1,580	<40
Minimum	28	26	10	.02	.10	5	2	<.2	<2	28	<1	<.2	<10	160	<1
Site 31, monitor well 3 (shallow)															
Pre-startup	9	5.1	240	--	.02	19	<6	<2	21	450	78	<.2	104	70	<3
Mean value	37	29	137	.23	.42	21	21	1.5	10.5	1,020	10	<.3	98	184	6
No. of samples	33	17	31	39	55	22	33	32	21	22	38	24	17	40	33
Maximum	51	37	410	.70	1.0	50	78	13	90	1,970	78	<.6	300	280	<40
Minimum	15	7	10	.02	.10	5	3	<.2	<2	450	<1	<.2	10	70	<1
Site 31, monitor well 3 (deep)															
Pre-startup	10	21	710	--	.48	4	<6	<2	14	70	33	<.2	393	720	<3
Mean value	26	23	628	.17	.37	5	4	1.3	9.6	59	9	<.3	78	473	5
No. of samples	43	19	35	48	63	23	36	35	23	24	41	27	17	45	36
Maximum	45	36	1,300	.70	1.4	15	7	13	90	250	<40	<.6	393	1,030	<40
Minimum	1	5	70	.01	<.1	1	<1	<.2	<2	30	<1	<.2	10	160	<1
Site 42, monitor well 4 (shallow)															
Pre-startup	6	10.5	60	--	.02	27	<6	<2	22	820	39	<.2	185	50	<3
Mean value	7	6	123	.18	.21	22	4	1.6	11	533	10	<.3	110	179	6
No. of samples	26	12	30	27	49	22	30	30	20	20	32	20	16	38	31
Maximum	10	20	510	.70	.80	100	7	13	90	1,210	<40	<.6	300	1,190	<40
Minimum	4	2	10	.02	.03	3	<1	<.2	<2	140	<1	<.2	<30	10	<1
Site 42, monitor well 4 (deep)															
Pre-startup	63	35	1,430	--	.35	10	<6	12	34	100	67	<.2	2,158	760	<3
Mean value	9	26	1,527	.23	.36	5	4	2.0	12	119	11	<.3	209	637	5
No. of samples	27	13	30	26	49	23	30	30	20	20	32	20	16	39	31
Maximum	16	66	2,320	1.3	.80	10	7	13	90	560	67	<.6	2,158	1,090	<40
Minimum	4	2	420	.01	.03	2	<1	<.2	<2	13	<1	<.2	<30	110	<1

Table 7.--Major inorganic chemical constituents, physical properties, and trace element concentrations of water from selected surface-water sites near Gainesville

Station No.	Site name	Date of sample	Specific conductance (μS/Cm)	pH (standard units)	Color (platinum-cobalt units)	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L $CaCO_3$)	Calcium, dissolved (mg/L)	Magnesium, dissolved (mg/L)	Sodium, dissolved (mg/L)	Potassium, dissolved (mg/L)	Alkalinity, lab (mg/L as $CaCO_3$)
02240956	Haile Sink	08-05-82	200	7.0	60	93	6	31	3.9	5.6	1.0	86
293559082182600	Paynes Prairie	09-27-82	90	5.8	100	32	11	10	1.9	4.5	.6	21
		02-09-83	90	7.0	75	32	7	9.9	1.9	5.9	2.4	25
293623082181001	Alachua Sink	05-08-81	250	6.5	70	80	34	22	6.1	20	6.0	--
		07-30-81	--	7.2	65	94	37	24	8.5	21	9.2	--
		08-03-82	295	7.0	110	116	34	33	8.1	18	2.5	82
		09-27-82	150	6.1	100	52	13	15	3.7	9.6	1.7	39
		02-09-83	410	7.0	20	115	30	28	11	32	5.7	85
		06-28-83	152	6.6	--	--	--	--	--	--	--	--
293726082191700	Sweetwater Branch	08-03-82	425	7.0	20	133	44	35	11	31	4.5	82
		09-01-82	--	--	--	--	--	--	--	--	--	9.0
		09-27-82	410	6.8	40	118	49	32	9.3	25	4.8	69
293826082210301	Inflow to Lake Alice	05-08-81	420	6.6	20	148	87	36	14	32	6.4	--
		07-30-81	290	7.3	10	87	39	21	8.5	19	4.4	--
293832082215001	Lake Alice near R1	08-03-82	375	--	20	134	41	37	10	21	2.7	92
		06-28-83	270	7.0	--	98	25	27	7.5	14	3.4	73
293836082214601	Lake Alice near R2	05-07-81	370	7.0	30	146	50	37	13	27	4.3	--
		07-30-81	390	7.9	20	152	48	41	12	23	3.8	--
		08-03-82	380	6.9	15	134	35	37	10	20	2.8	92

Station No.	Site name	Date of sample	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Solids, residue at 180°C, dissolved (mg/L)	Arsenic, dissolved (μg/L as As)	Barium, dissolved (μg/L as Ba)	Cadmium, dissolved (μg/L as Cd)	Chromium, dissolved (μg/L as Cr)
02240956	Haile Sink	08-05-82	4.0	9.4	0.40	8.9	144	2	5	<1	10
293559082182600	Paynes Prairie	09-27-82	8.0	7.5	.10	3.7	88	1	7	<1	10
		02-09-83	<5.0	11	.20	5.1	102	--	--	--	--
293623082181001	Alachua Sink	05-08-81	28	27	1.4	6.8	--	--	--	--	--
		07-30-81	28	29	--	--	--	--	--	--	--
		08-03-82	23	20	10	18	226	1	12	<1	10
		09-27-82	14	12	.30	6.8	127	1	10	<1	10
		02-09-83	37	39	.60	20	266	--	--	--	--
		06-28-83	--	--	--	--	--	--	--	--	--
293726082191700	Sweetwater Branch	08-03-82	42	36	1.6	23	279	1	12	1	10
		09-01-82	--	--	--	--	--	--	--	--	--
		09-27-82	40	33	.60	18	266	1	11	1	10
293826082210301	Inflow to Lake Alice	05-08-81	57	57	1.3	27	--	--	--	--	--
		07-30-81	37	33	--	--	--	--	--	--	--
293832082215001	Lake Alice near R1	08-03-82	36	31	2.1	6.9	231	1	8	<1	10
		06-28-83	26	24	.70	5.9	181	1	<100	<1	10
293836082214601	Lake Alice near R2	05-07-81	52	42	1.1	7.8	--	--	--	--	--
		07-30-81	43	37	--	--	--	--	--	--	--
		08-03-82	36	31	.70	8.1	234	1	9	<1	10

Table 7.--Major inorganic chemical constituents, physical properties, and trace element concentrations of water from selected surface-water sites near Gainesville--Continued

Station No.	Site name	Date of sample	Copper, dissolved (µg/L as Cu)	Iron, dissolved (µg/L as Fe)	Lead, dissolved (µg/L as Pb)	Manganese, dissolved (µg/L as Mn)	Mercury, dissolved (µg/L as Hg)	Selenium, dissolved (µg/L as Se)	Silver, dissolved (µg/L as Ag)	Strontium, dissolved (µg/L as Sr)	Zinc, dissolved (µg/L as Zn)
02240956	Haile Sink	08-05-82	4	120	<1	10	0.2	<1	<1	49	5
293559082182600	Paynes Prairie	09-27-82	4	140	3	18	<.1	<1	<1	24	26
		02-09-83	--	150	--	--	--	--	--	26	--
293623082181001	Alachua Sink	05-08-81	--	--	--	--	--	--	--	--	--
		07-30-81	--	--	--	--	--	--	--	--	--
		08-03-82	11	270	3	19	.2	<1	<1	150	18
		09-27-82	3	120	3	42	<.1	<1	<1	55	8
		02-09-83	--	150	--	--	--	--	--	170	--
		06-28-83	--	--	--	--	--	--	--	--	--
293726082191700	Sweetwater Branch	08-03-82	9	68	3	12	.1	<1	<1	210	14
		09-01-82	--	120	1	--	--	--	--	--	--
		09-27-82	7	--	--	12	.2	<1	<1	170	20
293826082210301	Inflow to Lake Alice	05-08-81	--	--	--	--	--	--	--	--	--
		07-30-81	--	8	2	--	--	--	--	--	--
293832082215001	Lake Alice near R1	08-03-82	4			11	.1	<1	<1	220	5
		06-28-83	11	30	7	<10	.8	<1	1	160	30
293836082214601	Lake Alice near R2	05-07-81	--	--	--	--	--	--	--	--	--
		07-30-81	--	--	--	--	--	--	--	--	--
		08-03-82	3	3	2	12	.1	<1	<1	220	<4

Major Ions, Physical Properties, and Trace Elements

The physical properties, concentrations of major ions, and trace elements for water from Haile Sink, Paynes Prairie, Sweetwater Branch, Alachua Sink, Lake Alice, and inflow to Lake Alice are shown in table 7. The color of many of the samples exceeded the recommended limits for drinking water set by the U.S. Environmental Protection Agency (1983) (table 9). The only other constituent that exceeded the recommended limits was fluoride (concentration of 10 mg/L) at Alachua Sink on August 3, 1982. This concentration and other apparent anomalies of that sample will be discussed in a later section of this report.

Table 6 shows the summary of analyses of water injected at the Kanapaha site. The mean concentrations of all the constituents are below the EPA recommendations for drinking water, although the maximum reported values for some constituents exceed the recommended limits:

Constitutent	Maximum reported value	Recommended limit
Nitrate	11 mg/L	10 mg/L
Color	35 Pt-Co units	15 Pt-Co units
Cadmium	13 µg/L	10 µg/L
Iron	440 µg/L	300 µg/L

It should be noted that much of the natural ground water in Florida exceeds the recommended limits for iron concentration.

Table 8.--Biochemical oxygen demand, bacteria counts, and nutrient concentrations of water at selected surface-water sites near Gainesville

Station No.	Site name	Date of sample	Oxygen demand, bio-chemical, 5 day (mg/L)	Coli-form, total, imme-diate (col/100 mL)	Coli-form, fecal, 0.7 μm-MF (col/100 mL)	Strep-tococci fecal, KF agar (col/100 mL)	Nitro-gen, nitrate total (mg/L as N)	Nitro-gen, nitrite total (mg/L as N)	Nitro-gen, $NO_2 + NO_3$ total (mg/L as N)
02240956	Haile Sink	08-05-82	0.9	[1]110	[1]200	<1	0.02	0.010	0.03
293559082182600	Paynes Prairie	09-27-82	1.0	270	70	[1]<1	.00	.010	.01
		02-09-83	--	--	--	--	.01	.010	.02
		02-09-83	--	--	--	--	--	.040	<.10
29362308218100	Alachua Sink	05-08-81	3.6	2,500	35	--	.66	.220	.88
		07-30-81	4.5	1,760	144	--	.98	.460	1.4
		08-03-82	1.4	[1]8,500	[1]850	9,200	1.7	.040	1.7
		09-27-82	2.2	650	[1]110	<1	.22	.040	.26
		02-09-83	--	--	--	--	2.0	1.90	3.9
		02-09-83	--	--	--	--	3.1	1.00	4.1
		06-28-83	--	--	[1]20	[1]50	.01	.010	.02
293726082191700	Sweetwater Branch	08-03-82	1.6	[1]10	<1	30	5.6	.060	5.6
		09-27-82	3.5	<1	<1	<1	4.6	.090	4.6
293826082210301	Inflow to Lake Alice	05-08-81	3.6	2,800	1,233	--	1.3	.240	1.5
		07-30-81	7.6	--	--	--	1.4	.070	1.4
293832082215001	Lake Alice near R1	08-03-82	3.7	280	[1]80	[1]130	.01	.010	.02
		06-28-83	--	--	100	[1]100	--	.010	<.02
293836082214601	Lake Alice near R2	05-07-81	7.3	600	140	--	.00	.000	.00
		07-30-81	4.3	1,175	250	--	.01	.010	.02
		08-03-82	3.1	700	560	510	.05	.010	.06

Station No.	Site name	Date of sample	Nitro-gen, ammonia, total (mg/L as N)	Nitro-gen, organic, total (mg/L as N)	Nitrogen, ammonia, organic, total (mg/L as N)	Nitro-gen, total (mg/L as N)	Phos-phorus, total (mg/L as P)	Phos-phorus, ortho, total (mg/L as P)
02240956	Haile Sink	08-05-82	0.020	0.96	0.98	1.0	0.700	0.650
293559082182600	Paynes Prairie	09-27-82	.060	.98	1.04	1.0	.160	.130
		02-09-83	.010	1.0	1.01	1.0	--	--
		02-09-83	.030	1.0	1.10	--	--	--
293623082181001	Alachua Sink	05-08-81	1.80	1.6	3.40	4.2	1.40	1.10
		07-30-81	1.70	.90	2.60	4.0	1.70	1.60
		08-03-82	.070	1.6	1.67	3.4	1.50	1.30
		09-27-82	.060	1.2	1.26	1.5	.600	.500
		02-09-83	3.80	.21	4.01	7.9	--	--
		02-09-83	3.60	1.9	5.50	9.6	--	--
		06-28-83	.030	.78	.81	.83	.480	.420
293726082191700	Sweetwater Branch	08-03-82	.440	1.3	1.74	7.4	2.00	1.90
		09-27-82	3.20	.30	3.50	8.1	3.80	3.40
293826082210301	Inflow to Lake Alice	05-08-81	4.70	2.3	7.00	8.5	2.40	1.80
		07-30-81	1.20	1.4	2.60	4.0	2.20	1.00
293832082215001	Lake Alice near R1	08-03-82	.040	1.6	1.64	1.6	1.10	1.00
		06-28-83	.040	.60	.64	--	1.00	.970
293836082214601	Lake Alice near R2	05-07-81	.010	1.5	1.51	1.5	1.80	1.40
		07-30-81	.030	1.9	1.93	1.9	1.40	1.30
		08-03-82	.080	1.5	1.58	1.6	1.20	1.00

Bacteria and Nutrient Concentrations

Bacteria counts, nutrient concentrations, and biochemical oxygen demand for selected surface waters are shown in table 8. All of the sites had bacteria counts greater than the recommended limit for drinking water of 1 col/100 mL. Bacteria counts of greater than 1 col/100 mL are not unusual for surface waters. At some sites, the concentrations of these constituents showed a wider range of variation than the major ions and trace elements concentrations (figs. 21 and 22). This variation may be related to variations in rainfall (fig. 20). The sample from Alachua Sink on August 3, 1982 (which had a fluoride concentration of 10 mg/L), also had the highest bacteria counts of the sites sampled. Total nitrogen in Alachua Sink shows a large fluctuation (0.83 mg/L to 9.6 mg/L), as does nitrate as nitrogen (0.01 mg/L to 3.1 mg/L).

The highest nitrate as nitrogen concentrations were found in Sweetwater Branch (4.6 and 5.6 mg/L). Mean nitrate concentration in the injection water at Kanapaha was 2.3 mg/L (table 6). Nitrate as nitrogen concentrations at Haile Sink, Paynes Prairie, and Lake Alice were always less than or equal to 0.05 mg/L.

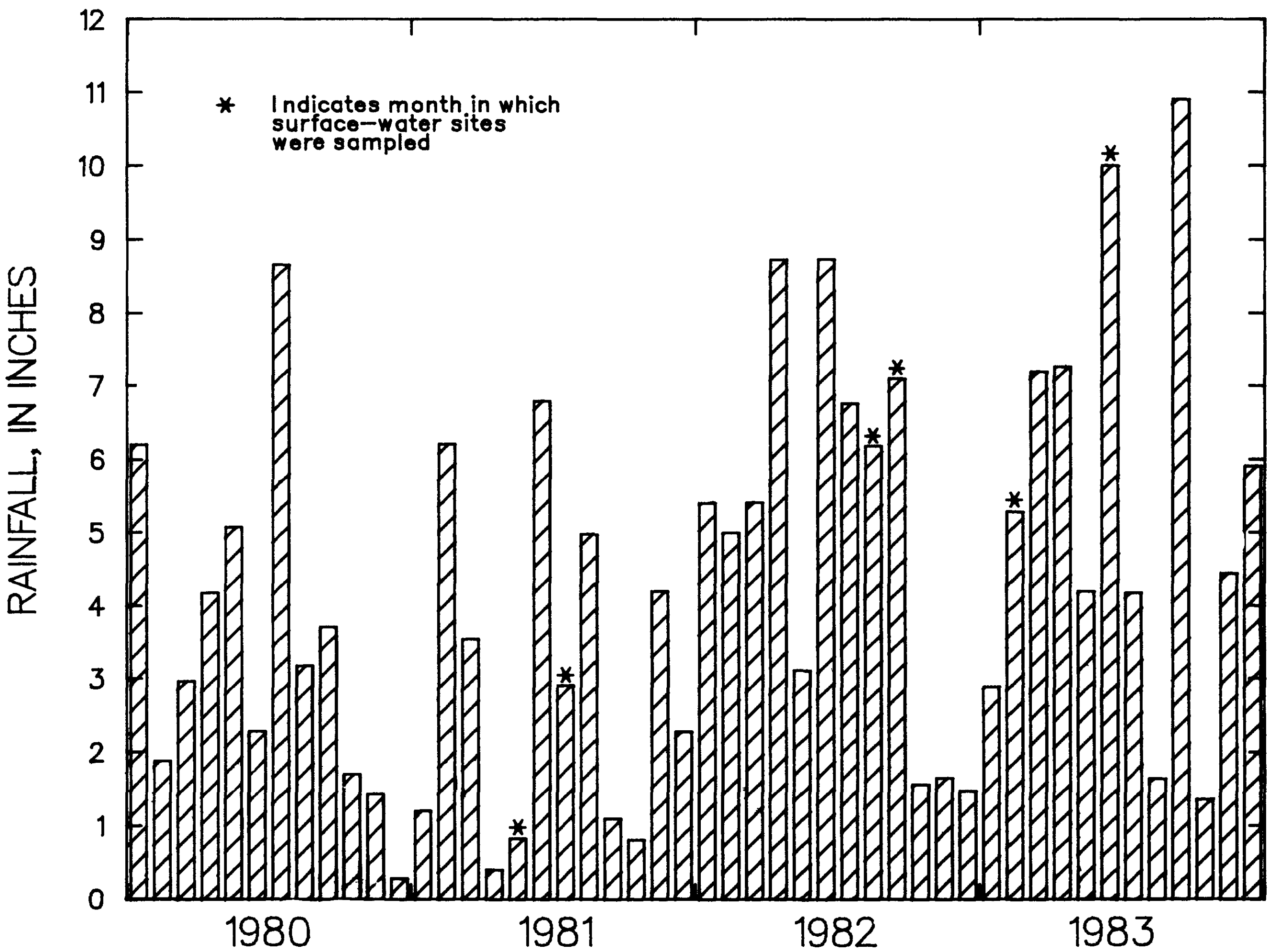

Figure 20.--Monthly rainfall at Gainesville, 1980-83.

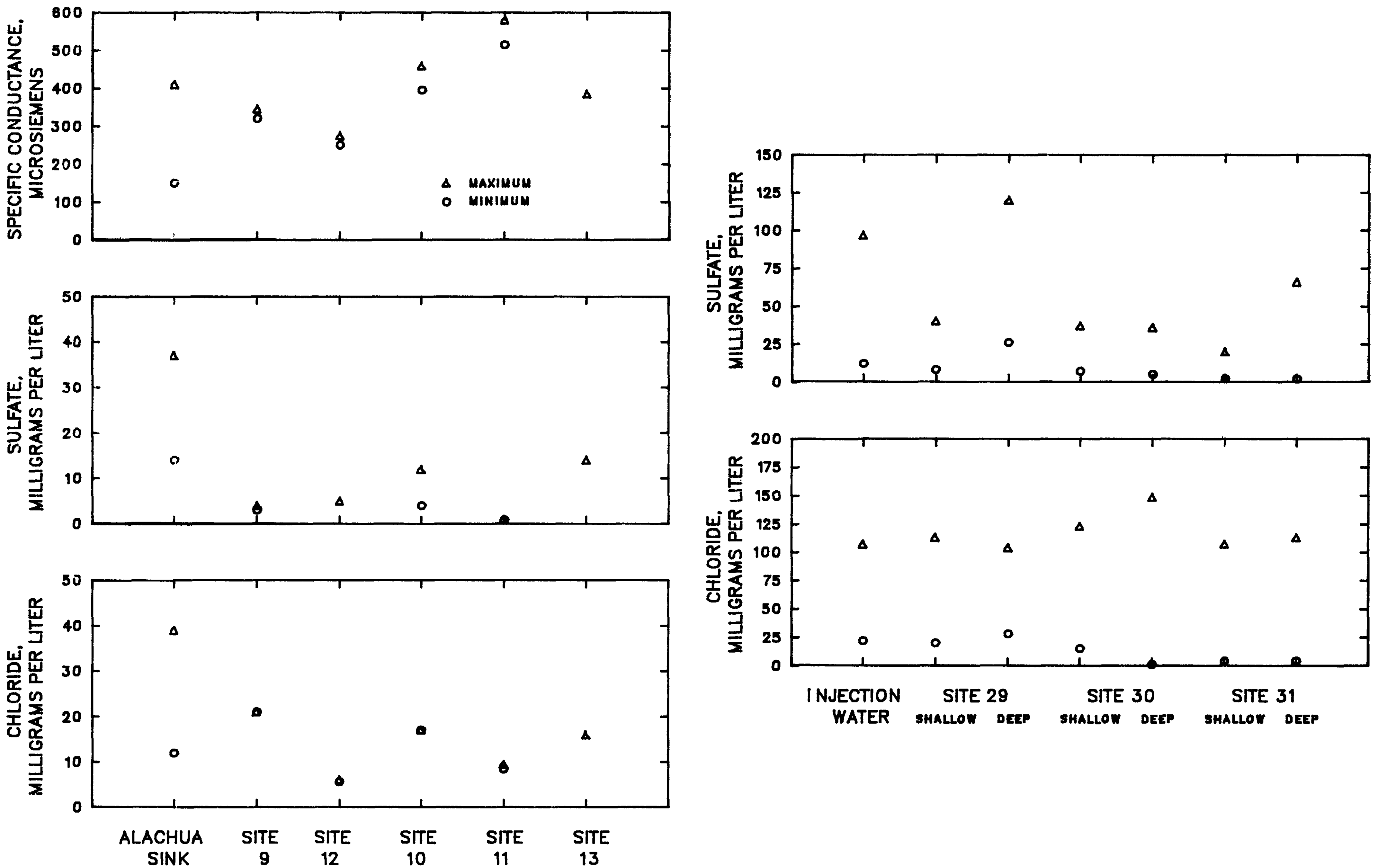

Figure 21.--Maximum and minimum concentrations of chloride, sulfate, and specific conductance of recharge water and water from wells.

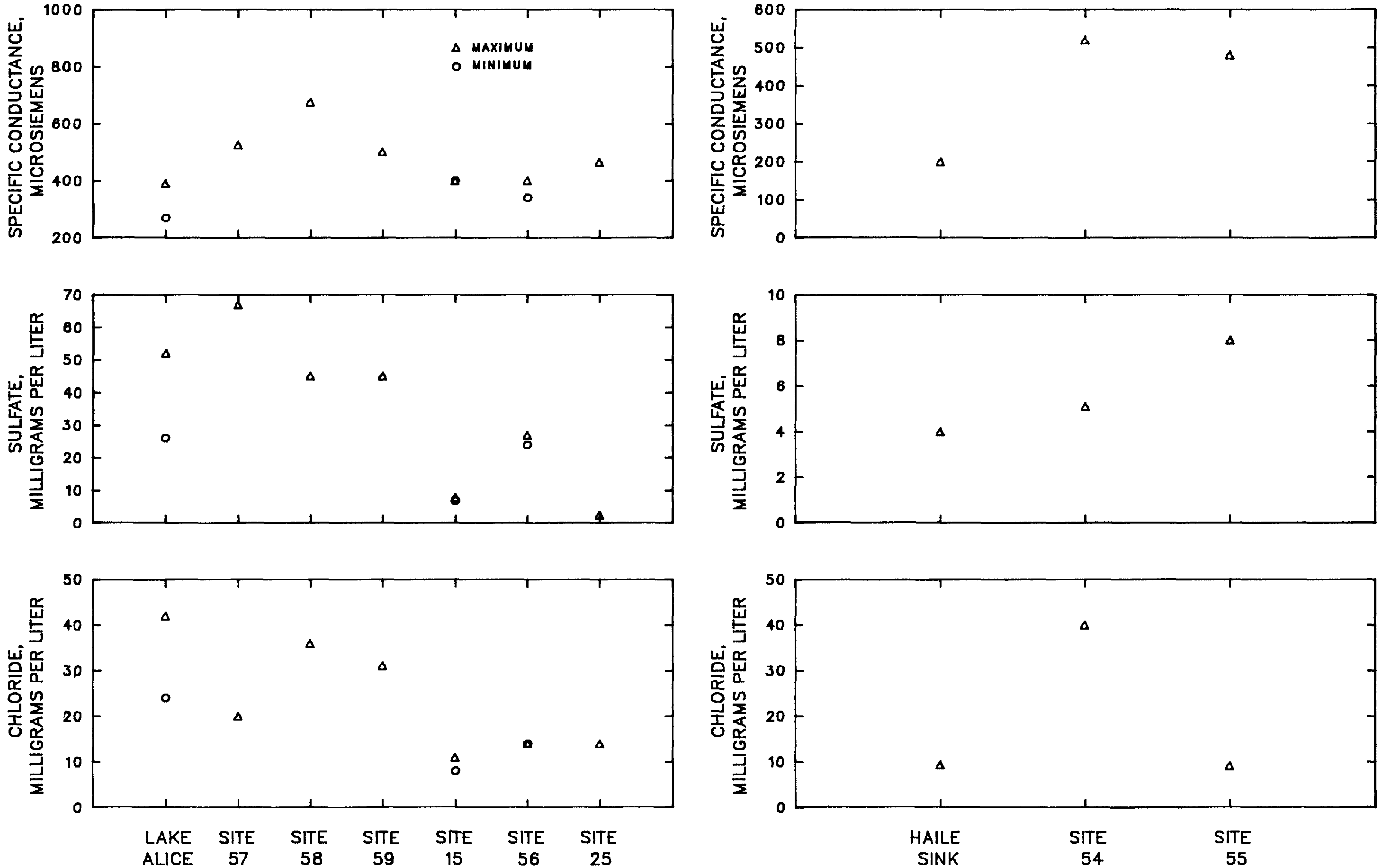

Figure 21.--Maximum and minimum concentrations of chloride, sulfate, and specific conductance of recharge water and water from wells.--Continued

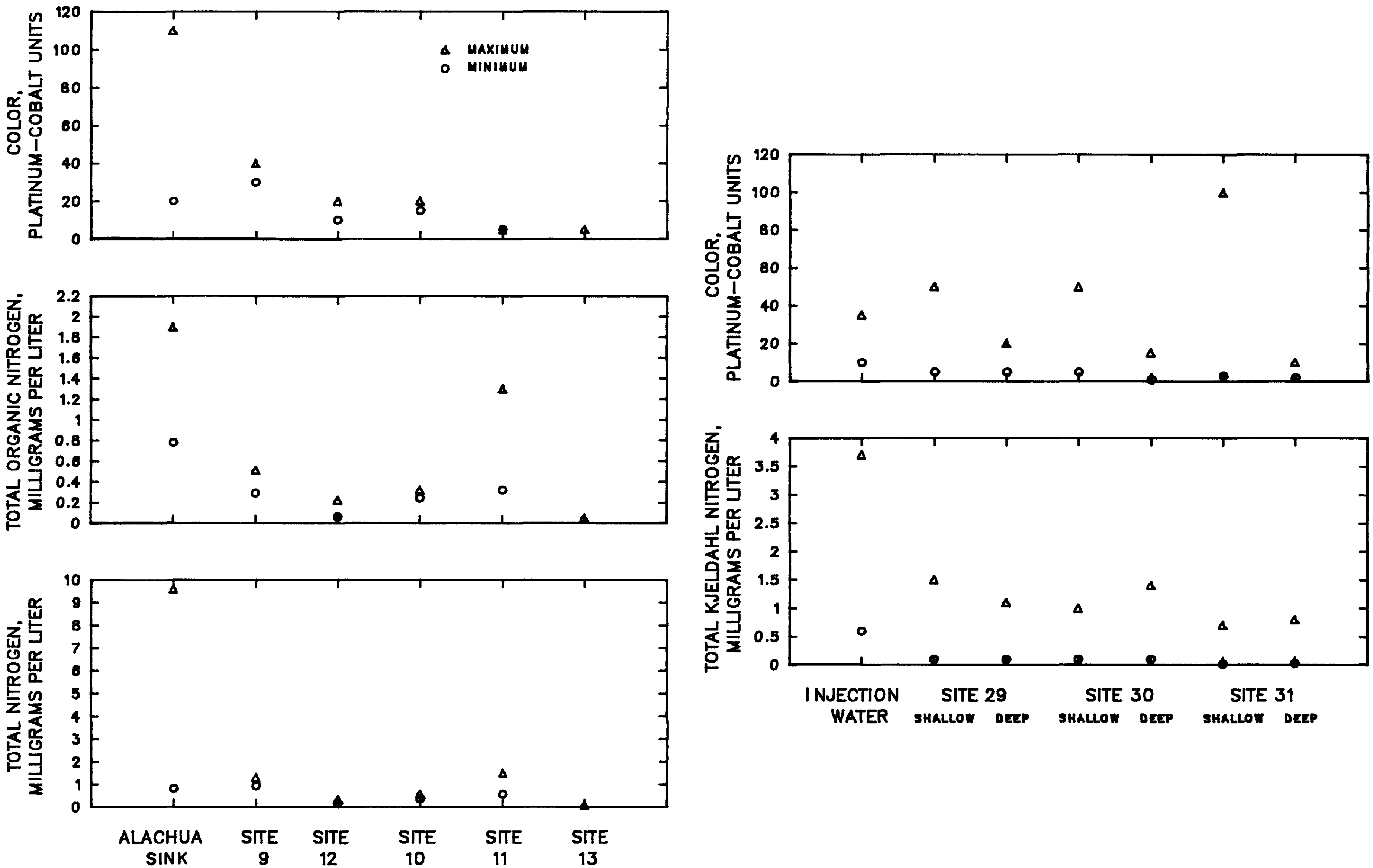

Figure 22.--Maximum and minimum concentrations of nutrients and color of recharge water and water from wells.

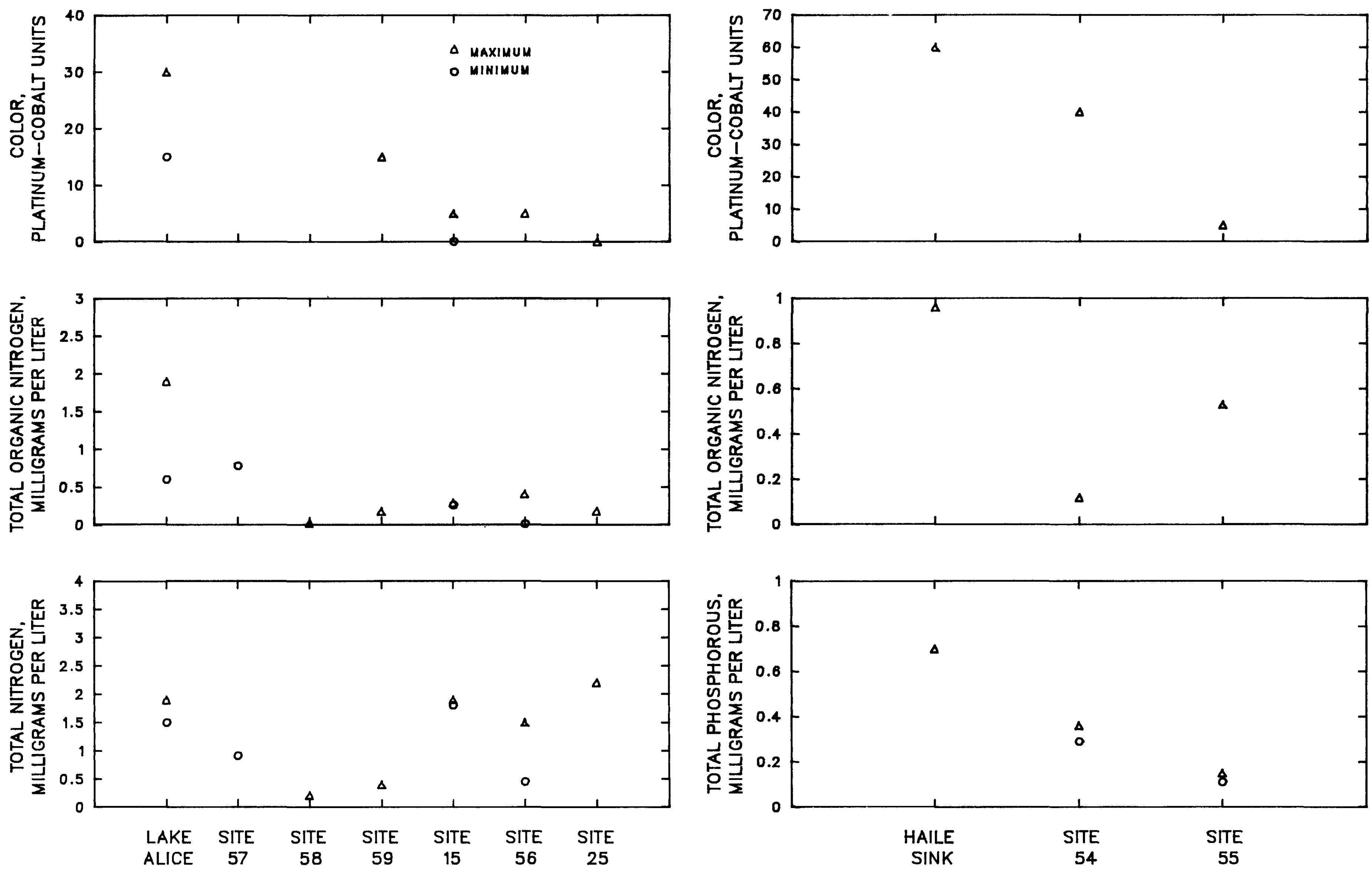

Figure 22.--Maximum and minimum concentrations of nutrients and color of recharge water and water from wells--Continued.

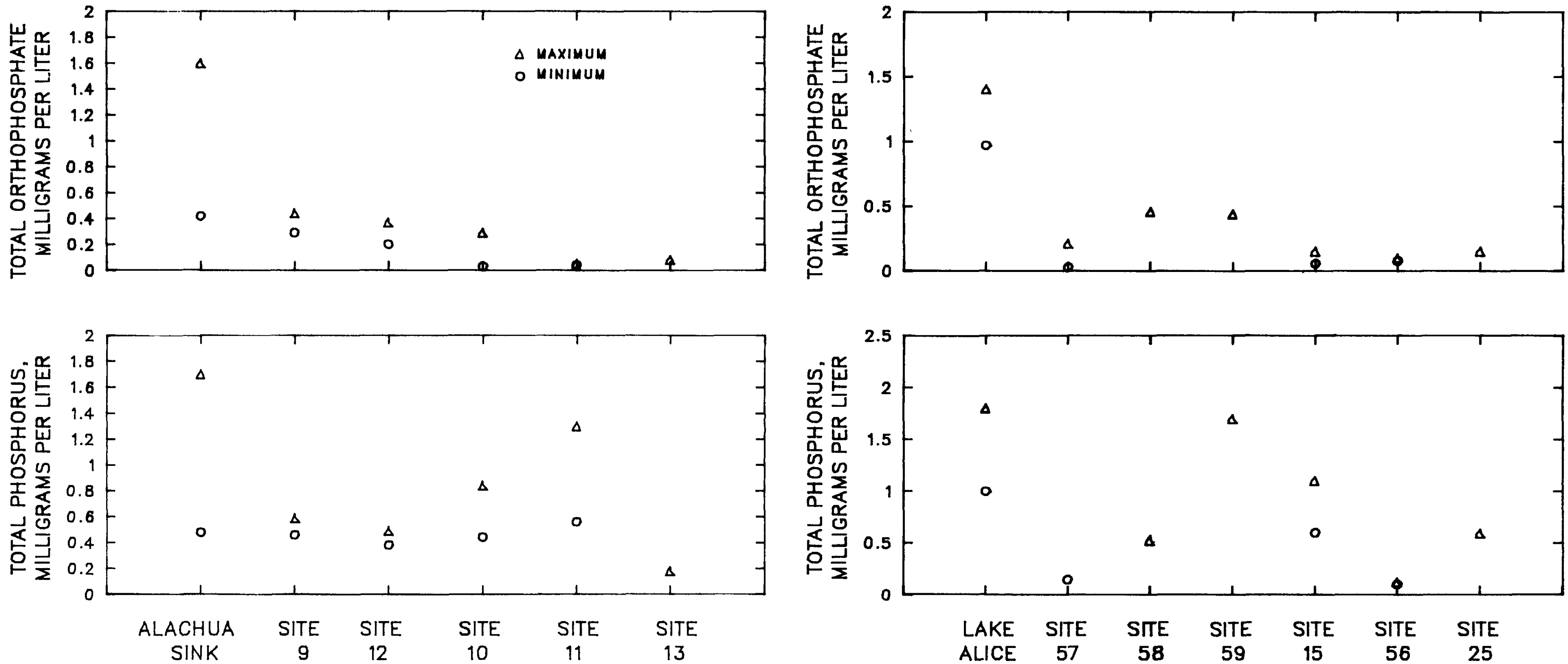

Figure 22.--Maximum and minimum concentrations of nutrients and color of recharge water and water from wells--Continued.

Table 9.--Revised national primary drinking water standards (U.S. Environmental Protection Agency, 1983)

[All constituents are in milligrams per liter, unless otherwise noted]

Constituent	Recommended limit	
Arsenic	0.05	
Barium	1.0	
Cadmium	.01	
Chromium	.05	
Lead	.05	
Mercury	.002	
Nitrate	10	
Selenium	.01	
Silver	.05	
Sodium	160	
Fluoride	1.6	
Turbidity	1	Turbidity unit
Total coliform	1	col/100 mL
Endrin	.0002	
Lindane	.004	
Methoxychlor	.1	
Toxaphene	.005	
2,4-D	.1	
2,4,5-TP (Silvex)	.01	
Trihalomethanes	.10	
Chloride	250	
Color	15	Platinum-cobalt units
Copper	1	
Langlier index	+.2	
Foaming agents	.5	
Iron	.3	
Managnese	.05	
Odor	3	(Threshold odor no.)
pH	6.5	(Standard units) minimum
Sulfate	250	
Dissolved solids	500	
Zinc	5	

Low concentrations of nitrite were expected because it is an intermediate product of the nitrification process and in oxygenated natural water is rapidly oxidized to nitrate (U.S. Environmental Protection Agency, 1976, p. 107). However, the nitrite concentrations in Alachua Sink on February 9, 1983 (1.0 and 1.9 mg/L) were unusually high, but these concentrations correspond to a relatively low stage of the sink (fig. 18) and may be indicative of anaerobic conditions in the sink. Flow to the sink on February 9, 1983, was 15.3 ft^3/s (table 3).

The U.S. Environmental Protection Agency does not set recommended limits for nutrients other than nitrate.

Bacteria were found in most samples. The highest bacteria counts were from a sample taken at Alachua Sink on August 3, 1982. The ratio of fecal coliforms to fecal streptococci may indicate the source of bacteria (Geldreich, 1966, table 35). High ratios of fecal coliforms to streptococci are usually associated with human feces, while low ratios are found in bird and animal feces. Thus, the low ratio found in the Alachua Sink sample on August 3, 1982, may indicate that a large part of the water sampled came from the Paynes Prairie wildlife preserve. Outflow from Paynes Prairie was not sampled on that date. Bacteria are not found in the injection water at the Kanapaha site because the water is treated with chlorine to kill bacteria.

Organic Compounds

Water samples were analyzed to determine if organic compounds are entering the Floridan aquifer system at any of the study sites. Seven organic compounds are included in the list of primary drinking water standards recommended by the U.S. Environmental Protection Agency: endrin, lindane, methoxychlor, toxaphene, 2,4,-D, silvex, and trihalomethanes.

Samples from Alachua Sink, Haile Sink, Lake Alice, and Lake Kanapaha analyzed for the primary drinking water standards by Black, Crow, and Eidsness (1977, table 3-3), yielded detections of 0.06 μg/L lindane at Alachua Sink and 0.11 μg/L 2,4-D at Lake Alice. A detailed analysis for organic compounds by GRU on November 20, 1981, detected chloroform (44 μg/L) and bromodichloromethane (6 μg/L) (R. Ferland, Gainesville Regional Utilities, written commun., 1982).

GRU continues to analyze samples of the injected water quarterly for six of the seven so-called "primary" organic compounds.

Summary results, in micrograms per liter, of that sampling are as follows:

Lindane range	0.02-0.8
Toxaphene	<2.0
Endrin	< .1
Methoxychlor	<1
2,4-D	<10
Silvex range	.1-10

In August 1982, the U.S. Geological Survey sampled Alachua Sink, Haile Sink, Sweetwater Branch, and Lake Alice for the organic compounds listed in table 10. The following compounds, in micrograms per liter, were detected:

Alachua Sink	diazinon	0.06
Lake Alice	diazinon	.03
	malathion	.02
Sweetwater Branch	diazinon	.05

None of the organic compounds shown in table 10 was detected in Haile Sink.

Table 10.--List of organic compounds determined

Volatiles	Base-neutral extractables	Pesticides and herbicides
Benzene	Acenaphthene	Aldrin
Bromoform	Acenaphthylene	Chlordane
Carbon tetrachloride	Anthracene	DDD
Chlorobenzene	Benzidine	DDE
Chlorodibromomethane	Benz(a)anthracene	DDT
Chloroethane	Benzo(a)pyrene	Diazinon
2-Chloroethylvinyl ether	Benzo(g,hi,i)perylene	Dieldrin
Chloroform	Benzo(k)fluoranthene	Endosulfan
Dichlorobromomethane	Benzo(b)fluoranthene	Endrin
Dichlorodifluoromethane	4-Bromophenyl phenyl ether	Ethion
1,1-Dichloroethane	Butylbenzyl phthalate	Heptachlor
1,2-Dichloroethane	Bis(2-chloroethoxy)methane	Heptachlor epoxide
1,1-Dichloroethylene	Bix(2-chloroethyl)ether	Lindane
Chloroethylene	Bis(2-chloroisopropyl)ether	Malathion
1,2-Dichloropropane	2-Chloronaphthalene	Methyl parathion
1,3-Dichloropropene	4-chlorophenyl phenyl ether	Methyl trithion
Ethylbenzene	Chrysene	Methoxychlor
Methyl bromide	Dibenzo(a,h)anthracene	Mirex
Methylene chloride	Dibutyl phthalate	Parathion
1,1,2,2-Tetrachloroethane	1,3-Dichlorobenzene	Perthane
Tetrachloroethylene	1,4-Dichlorobenzene	Silvex
Toluene	1,2-Dichlorobenzene	Toxaphene
1,1,1-Trichloroethane	3,3' dichlorobenzidine	Trithion
1,1,2-Trichloroethane	Diethyl phthalate	2,4-D
Trichloroethylene	Dimethyl phthalate	2,4-DP
Trichlorofluoromethane	2,6-Dinitrotoluene	2,4,5-T
Vinyl chloride	2,4-Dinitrotuluene	
	Dictylphthalate	
	bis(2-Ethylhexyl)phthalate	
Acid extractables	Fluoranthene	
	Fluorene	
P-Chloro-M-cresol	Hexachlorobenzene	
2-Chlorophenol	Hexachlorobutadiene	
2,4-Dichlorophenol	Hexachlorocyclopentadiene	
2,4-Dimethylphenol	Hexachloroethane	
4,6-Dinitro-O-cresol	Indeno(1,2,3)pyrene	
2,4-Dinitrophenol	Isophorone	
2-Nitrophenol	Naphthalene	
4-Nitrophenol	Naphthalenes, poly-chlor	
Pentachlorophenol	Nitrobenzene	
Phenol	N-Nitrosodi-N-propylamine	
2,4,6-Trichlorophenol	N-Nitrosodimethylamine	
	N-Nitrosodiphenylamine	
	PCB	
	Phenanthrene	
	Pyrene	
	1,2,4-Trichlorobenzene	
	2,3,7,8-tetrachlorodibenzo-P-dioxin	

It should be noted that detection limits can not only vary between laboratories because of the type of analytical equipment used, but also can vary in the same laboratory because of the condition of the sample. For example, the presence of a large amount of total organic carbon in a sample can mask organic compounds and, thus, change the detection limits for some constituents.

QUALITY OF WATER FROM MONITOR WELLS

In addition to the regular sampling of monitor wells near the Kanapaha treatment plant by GRU, the U.S. Geological Survey periodically sampled 13 wells, including 3 test wells drilled during this study. Concentrations of major ions, trace elements, bacteria, and nutrients were determined. Data from the Kanapaha monitor wells are shown in table 7 and data collected by the U.S. Geological Survey in 1981-83 are shown in tables 11 and 12.

In general, the chemical quality of the water in the Floridan aquifer system and the recharge waters are similar, though the recharge waters tend to be somewhat lower in calcium and iron than water from the Floridan aquifer system. However, attempts to generalize the quality of water in the Floridan and establish "background" conditions in a karst area is usually difficult; wells that are considered "background" for one particular site may be down-gradient of a nearby unidentified recharge site. Also, the data base of ground-water quality samples in the area is insufficient to characterize "background" water quality statistically. Therefore, no attempt was made to compare the quality of water from wells sampled near the recharge sites to "background" water quality of the Floridan aquifer system in the Gainesville area.

Although statistical comparisons cannot be made because of an insufficient number of samples in the Gainesville area, some general comparisons can be made with the results of sampling done by Schiner and German (1983, tables 6, 7, and 8) for a study of the effects of drainage wells on public-supply wells in the Orlando area. Between September 1977 and June 1979, Schiner and German sampled 21 drainage wells and 52 public-supply wells. The drainage wells recharge the upper part of the Floridan. About 75 percent of the supply wells withdraw from the upper zone and about 25 percent from the lower zone of the Floridan. The upper zone supply wells sampled were chosen carefully to reduce the possible effects on nearby drainage wells near supply wells, thus providing an indication of background water quality in the Floridan.

Recharge water in the Gainesville area generally shows a wider range in concentrations of most constituents than the water from wells, probably because concentrations carried by surface waters are affected by variations in rainfall, but once the water enters the aquifer, the concentrations are quickly diluted and stabilized by the large volume of water in the aquifer. The recharge water has characteristics generally associated with surface water in Florida--low specific conductance and higher nutrient concentrations than ground water. Lake Alice, Alachua Sink, and Kanapaha all receive treated wastewater, and thus, the recharge water at those sites has a somewhat higher chloride concentration than is found in water in the Floridan aquifer system in the Gainesville area.

Table 11.--Major inorganic chemical constituents, physical properties, and trace element concentrations of water from wells near Alachua Sink, Haile Sink, and Lake Alice

Station No.	Site No.	Date of sample	Specific conductance (µS)	pH (standard units)	Color (platinum-cobalt units)	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Alkalinity, Lab (mg/L as $CaCO_3$)
					Wells near Alachua Sink							
293544082165101	13	05-08-81	385	6.6	5	211	26	74	6.4	9.3	0.9	--
293604082180101	11	06-01-81	515	--	--	329	14	120	7.1	6.3	.4	--
		07-31-81	580	7.0	5	355	36	130	7.4	5.5	.4	--
293623082181201	12	07-28-82	250	6.8	20	123	0	47	1.3	3.4	<.1	124
		09-27-82	275	6.5	10	133	12	51	1.3	3.0	.5	120
293625082181001	9	07-28-82	320	7.0	30	134	0	49	2.8	16	1.9	136
		09-27-82	345	6.3	40	132	12	48	2.9	14	2.2	120
		06-28-83	345	7.3	--	--	--	--	--	--	--	--
293631082180501	10	06-01-81	395	--	--	212	12	77	4.8	12	1.4	--
		07-31-81	418	7.2	15	214	9	77	5.3	12	1.7	--
		07-28-82	460	6.7	20	199	0	72	4.7	13	1.5	214
					Wells near Haile Sink							
293744082244401	54	12-14-82	520	--	40	290	11	110	3.6	22	.4	279
293744082245501	55	12-14-82	480	--	5	339	0	130	3.4	9.0	.1	350
					Wells near Lake Alice							
293816082220101	15	05-07-81	400	6.6	5	202	14	76	3.0	5.7	.6	--
		07-30-81	400	7.2	0	227	16	82	5.3	5.5	.8	--
293737082212501	25	02-15-83	465	6.8	0	206	0	75	4.6	10	3.1	215
293833082215201	57	06-28-83	525	7.2	--	--	--	--	--	--	--	--
		06-30-83	--	--	--	264	93	94	7.0	13	1.7	171
293836082214801	58	05-10-83	675	6.5	--	291	20	100	10	24	1.8	271
293837082214901	59	03-03-83	500	6.2	15	205	36	69	7.8	21	2.3	169
293854082221001	56	05-07-81	340	6.6	5	193	33	68	5.7	9.9	1.2	--
		07-30-81	400	7.7	--	196	38	70	5.1	8.6	1.0	--

The mean chloride concentrations of water from wells sampled near Alachua Sink was 14 mg/L and from wells near Lake Alice was 19 mg/L. Near Haile Sink, one well had water with 9.1 mg/L chloride, and one well had 40 mg/L. Thus, these wells do not differ significantly from either the drainage or supply wells in Orlando (table 13). Monitor wells downgradient of Kanapaha show mean chloride concentrations ranging from 35 to 54 mg/L, which are similar to the chloride concentration of the injected water. At monitor well site 29, which is upgradient of Kanapaha, both the deep and shallow wells had mean chloride concentrations of 10 mg/L.

The color of water from the monitor wells in the upper zone of the Floridan near the Kanapaha plant often exceeds the recommended color limit of 15 platinum-cobalt units, but the injected water and water from the deep monitor wells generally do not exceed the limit. The high color may be related to iron concentrations in the upper zone of the Floridan which frequently exceed the recommended limits or possibly to surface water with high color recharging the aquifer through sinkholes.

Table 11.--Major inorganic chemical constituents, physical properties, and trace element concentrations of water from wells near Alachua Sink, Haile Sink, and Lake Alice--Continued

Station No.	Site No.	Date of sample	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Solids, residue at 180°C dissolved (mg/L)	Arsenic, dissolved (µg/L as As)	Barium, dissolved (µg/L as Ba)	Cadmium, dissolved (µg/L as Cd)	Chromium, dissolved (µg/L as Cr)	Copper, dissolved (µg/L as Cu)
					Wells near Alachua Sink							
293544082165101	13	05-08-81	14	16	0.40	28	--	--	--	--	--	--
293604082180101	11	06-01-81	.8	9.4	--	--	--	--	--	--	--	--
		07-31-81	1.0	8.4	.40	--	--	--	--	--	--	--
293623082181201	12	07-28-82	5.0	5.6	.30	9.4	161	2	2	<1	10	2
		09-27-82	5.0	6.1	.40	8.2	175	1	<2	<1	10	1
293625082181001	9	07-28-82	3.0	20	.20	9.6	209	1	3	<1	20	3
		09-27-82	4.0	21	.20	8.3	208	1	3	<1	10	1
		06-28-83	--	--	--	--	--	--	--	--	--	--
293631082180501	10	06-01-81	4.0	17	--	--	--	--	--	--	--	--
		07-31-81	5.8	17	.20	--	--	--	--	--	--	--
		07-28-82	12	15	.20	9.1	273	1	11	1	10	6
					Wells near Haile Sink							
293744082244401	54	12-14-82	<5.0	40	.10	9.0	377	1	15	<1	10	3
293744082245501	55	12-14-82	8.0	9.1	<.10	9.4	417	1	9	<1	10	4
					Wells near Lake Alice							
293816052220101	15	05-07-81	6.8	8.0	.20	16	--	--	--	--	--	--
		07-30-81	7.7	11	--	--	--	--	--	--	--	--
293737082212501	25	02-15-83	2.4	14	.30	5.1	269	2	14	<1	10	2
293833082215201	57	06-28-83	--	--	--	--	--	--	--	--	--	--
		06-30-83	67	20	.40	9.6	382	31	<100	2	10	8
293836082214801	58	05-10-83	45	36	.30	14	366	1	17	2	<10	5
293837082214901	59	03-03-83	45	31	.40	9.5	312	3	11	<1	<10	2
293854082221001	56	05-07-81	27	14	.30	9.8	--	--	--	--	--	--
		07-30-81	24	14	--	--	--	--	--	--	--	--

Dissolved lead concentrations of water from wells near Alachua and Haile Sinks are similar to the mean concentrations from both drainage and supply wells in Orlando. Wells near Lake Alice and Kanapaha are slightly higher. The mean lead concentration of the injected water at Kanahapa is lower than the mean concentrations of water from the monitor wells, and there is no difference between concentrations in the upgradient and downgradient monitor wells.

The hardness of water from wells near Alachua Sink is lower than most of the other wells and thus, more similar to surface water. Also, bacteria counts in wells at sites 9 and 12 (closest to the sink) were the highest observed on September 27, 1982, which corresponds to the highest measured stage of Alachua Sink. These facts are indicative of the recharge that takes place in the sink because those constituents are generally low in native ground water.

Schiner and German (1983, p. 26-34) made the following generalizations about nutrient concentrations in wells in Orlando: (1) total nitrogen and total organic nitrogen of water from the drainage wells were noticeably higher than that of the supply wells; (2) total ammonia was about the same for drainage and supply wells as were total nitrite and total nitrate; and

Table 11.--Major inorganic chemical constituents, physical properties, and trace element concentrations of water from wells near Alachua Sink, Haile Sink, and Lake Alice--Continued

Station No.	Site No.	Date of sample	Iron, dis- solved (μg/L as Fe)	Lead, dis- solved (μg/L as Pb)	Manga- nese, dis- solved (μg/L as Mn)	Mer- cury, dis- solved (μg/L as Hg)	Sele- nium, dis- solved (μg/L as Se)	Silver, dis- solved (μg/L as Ag)	Stron- tium, dis- solved (μg/L as Sr)	Zinc, dis- solved (μg/L as Zn)
					Wells near Alachua Sink					
293544082165101	13	05-08-81	--	--	--	--	--	--	--	--
293604082180101	11	06-01-81	--	--	--	--	--	--	--	--
		07-31-81	--	--	--	--	--	--	--	--
293623082181201	12	07-28-82	310	3	11	.1	<1	<1	30	6
		09-27-82	260	<1	11	.1	<1	<1	30	8
293625082181001	9	07-28-82	400	2	35	.1	<1	<1	36	30
		09-27-82	1,300	1	43	.3	<1	<1	32	14
		06-28-83	--	--	--	--	--	--	--	--
293631082180501	10	06-01-81	--	--	--	--	--	--	--	--
		07-31-81	--	--	--	--	--	--	--	--
		07-28-82	1,300	8	40	.3	<1	<1	89	15
					Wells near Haile Sink					
293744082244401	54	12-14-82	1,900	3	66	<.1	<1	<1	110	8
293744082245501	55	12-14-82	450	3	6	<.1	<1	<1	120	17
					Wells near Lake Alice					
293816082220101	15	05-07-81	--	--	--	--	--	--	--	--
		07-30-81	--	--	--	--	--	--	--	--
293737082212501	25	02-15-83	2,300	12	59	.2	<1	<1	90	38
293833082215201	57	06-28-83	--	--	--	--	--	--	--	--
		06-30-83	2,000	17	10	.1	3	1	150	20
293836082214801	58	05-10-83	100	13	42	.3	<1	<1	320	16
293837082214901	59	03-03-83	370	10	47	.2	<1	<1	480	11
293854082221001	56	05-07-81	--	--	--	--	--	--	--	--
		07-30-81	--	--	--	--	--	--	--	--

(3) total phosphorus was generally higher in drainage wells than in supply wells and total orthophosphate concentrations also tended to be higher in the drainage wells. (Schiner and German's results are summarized in table 13.) Median concentrations of nutrients from wells sampled near the Gainesville recharge sites are more similar to median nutrient concentrations from the Orlando drainage wells and less similar to concentrations from Orlando supply wells:

	Gainesville area	Orlando area	
	Monitor wells (mg/L)	Drainage wells (mg/L)	Supply wells (mg/L)
Total organic nitrogen	0.28	0.24	0.02
Total nitrogen	.74	1.0	.29
Total phosphorus	.50	.23	.07
Total orthophosphate	.15	.11	.07

Data from the sample of June 30, 1983, at site 57 near Gainesville, were omitted from the mean calculations because of abnormally high nutrient concentrations. The anomaly is discussed in a later section.

Table 12.--Biochemical oxygen demand, bacteria counts, and nutrient concentrations of water from wells near Alachua Sink, Haile Sink, and Lake Alice

Station No.	Site No.	Date of sample	Oxygen demand, biochemical, 5 day (mg/L)	Coliform, total, immed. (cols/100 mL)	Coliform, fecal, 0.7 µm-Mf (cols/100 mL)	Streptococci fecal, KF agar (cols/100 mL)	Nitrogen, nitrate total (mg/L as N)	Nitrogen, nitrite total (mg/L as N)	Nitrogen, NO_2 + NO_3 total (mg/L as N)	Nitrogen, ammonia, total (mg/L as N)	Nitrogen, organic total (mg/L as N)	Nitrogen, ammonia + organic total (mg/L as N)	Nitrogen, total (mg/L as N)	Nitrogen, total (mg/L as NO_3)	Phosphorus, total (mg/L as P)	Phosphorus, ortho, total (mg/L as P)
							Wells near Alachua Sink									
293544082165101	13	81-05-08	0.4	21	0	--	0.02	0.000	0.02	0.020	0.05	0.07	0.09	0.39	0.180	0.080
293604082180101	11	81-06-01	--	200	0	0	--	--	--	--	--	--	--	--	--	--
		81-06-01	--	100	0	0	.01	.000	.01	.270	1.3	1.57	1.5	6.9	1.30	.050
		81-07-31	.2	0	0	--	.00	.000	.00	.250	.32	.57	.57	2.5	.560	.040
293623082181201	12	82-07-28	.6	[1]90	<1	<1	.06	.000	.06	.050	.22	.27	.33	1.4	.380	.200
		82-09-27	.4	260	<1	<1	.01	.000	.01	.080	.06	.14	.15	.66	.490	.370
293625082181001	9	82-07-28	.5	<1	<1	<1	.18	.000	.18	.630	.51	1.14	1.3	5.8	.460	.320
		82-09-27	.4	790	[1]100	<1	.00	.000	.00	.870	.29	1.16	1.1	5.1	.460	.440
		83-06-28	--	--	<1	<1	.01	.010	.02	.620	.30	.92	.94	4.1	.590	.290
		83-06-28	--	--	<1	<1	.01	.010	.02	.620	.30	.92	.94	4.1	.500	.290
293631082180501	10	81-06-01	--	0	0	0	--	--	--	--	--	--	--	--	--	--
		81-06-01	.2	0	0	0	.01	.000	.01	.230	.24	.47	.48	2.1	.840	.080
		81-07-31	1.0	30	0	--	.00	.000	.00	.260	.32	.58	.58	2.5	.440	.290
		82-07-28	.5	[1]160	<1	<1	.05	.000	.05	.060	.25	.31	.36	1.5	.620	.030
							Wells near Haile Sink									
293744082244401	54	82-12-14	--	--	--	--	--	--	.00	--	--	--	--	--	--	--
		82-12-14	--	<1	<1	<1	.00	.000	.00	.400	.12	--	--	--	.360	.290
293744082245501	55	82-12-14	--	--	--	--	--	--	.12	--	--	--	--	--	--	--
		82-12-14	--	<1	<1	<1	.12	.000	.12	.020	.53	--	--	--	.150	.110
							Wells near Lake Alice									
293737082212501	25	83-02-15	--	<1	<1	<1	.01	.010	.02	2.00	.18	2.18	2.2	9.7	.590	.150
293816082220101	15	81-05-07	.3	0	0	--	1.7	.000	1.7	.010	.26	.27	1.9	8.7	.600	.060
		81-07-30	.2	0	0	--	1.5	.010	1.5	.020	.29	.31	1.8	8.0	1.10	.150
293833082215201	57	83-06-28	--	--	<1	<1	.02	.010	.03	.100	.78	.88	.91	4.0	.150	.030
		83-06-30	--	--	<1	<1	.01	.010	.02	.010	12	13.0	13	57	[2]75.0	.210
293836082214801	58	83-05-10	--	<1	<1	<1	.10	>.000	.10	.090	.02	.11	.21	.93	.520	.460
293837082214901	59	83-03-03	--	<1	<1	[1]5	.01	.010	.02	.200	.18	.38	.40	1.7	1.70	.440
293854082221001	56	81-05-07	.4	33	0	--	1.5	.000	1.5	.010	.01	.02	1.5	6.7	.100	.100
		81-07-30	.4	7	15	--	.02	.000	.02	.020	.41	.43	.45	1.9	.120	.080

[1]Non-ideal count.
[2]Non-ideal sample.

Table 13.--Concentrations of nutrients and bacteria counts from drainage wells and public-supply wells in the Orlando area, 1977-79

[D indicates drainage well, S indicates supply well; all concentrations in milligrams per liter except as noted. Modified from Schiner and German, 1983, tables 6, 7, and 8]

Constituent	Type well	Mean	Median	Maximum	Minimum
Total organic nitrogen	D	0.40	0.24	1.5	0.07
(as N)	S	.04	.02	.22	.00
Total ammonia nitrogen	D	.42	.30	2.0	.03
(as N)	S	.27	.25	1.1	.00
Total nitrite	D	.01	.00	.14	.00
(as N)	S	.00	.00	.06	.00
Total nitrate	D	.28	.01	2.4	.00
(as N)	S	.18	.00	3.6	.00
Total nitrogen	D	1.1	1.0	2.7	.37
(as N)	S	.48	.29	3.7	.05
Total orthophosphate	D	.17	.11	.55	.02
(as P)	S	.09	.07	.29	.01
Total phosphorus	D	.25	.23	.66	.04
(as P)	S	.09	.07	.30	.01
Total coliform	D	1,200	150	>10,000	0
(cols/100 mL)	S	6	0	80	0
Fecal coliform	D	440	10	4,400	0
(cols/100 mL)	S	1	0	5	0
Lead, dissolved	D	3.0	1.0	38.0	0
(μg/L)	S	2.0	0	10	0
Chloride, dissolved	D	14	15	22	4.9
	S	12	9.6	60	4

Schiner and German (1983, p. 26-31) found no appreciable difference between the ammonia, nitrate, and nitrite concentrations of the drainage and supply wells. In the wells sampled near the Gainesville recharge sites, ammonia was noticeably higher at site 9 (near Alachua Sink) and site 25 (near Bivens Arm) than at any of the other sites. Nitrate concentrations were highest at sites 15 and 56, which are both near Lake Alice. The higher nitrate concentrations are probably due to application of fertilizers near the sampling sites rather than to any effects of the Lake Alice drainage wells (site 15 is in an experimental agricultural area and site 56 is an irrigation well on a golf course).

Although the number of bacteria colonies per milliliter of water (bacteria count) is not necessarily a quantitative indicator of the amount of bacteria present, some trends relating to bacteria in drainage and supply wells in the Orlando area were noted by Schiner and German (1983, p. 33-34). Eighteen of 21 drainage wells had total coliform counts of more than 1 col/100 mL, but supply wells were generally free of total coliform (73 percent of the 52 wells had less than 1 col/100 mL). Fecal coliform were present in fewer wells than total coliform: 6 of 21 drainage wells had detectable fecal coliform, all were less than 1 col/100 mL; 5 of 51 supply wells sampled had detectable fecal coliform.

Bacteria were detected at all sites sampled by the U.S. Geological Survey in the Gainesville area except site 15. At some sites, bacteria were detected only periodically (site 10, for example). Most high bacteria counts were found in wells near Alachua Sink. Many wells in the upper part of the Floridan in the Gainesville area probably contain bacteria because of widespread local recharge through sinkholes.

The samples from the site 57 test well on June 28 and 30, 1983, show the most striking effect of recharge of all the sites studied. The test well is about 140 feet deep and is cased to 104 feet. It is about 150 feet west of the Lake Alice drainage well R1, which is cased to 83 feet. Thus, the well at site 57 samples the zone of injection of well R1. On June 28, site 57 was pumped for about 15 minutes at 2 gal/min before the submersible pump malfunctioned. A sample was bailed from the well and tested for pH, specific conductance, and bacteria and nutrients. The nutrient concentrations of that sample are not very different from samples collected from other wells during the study (table 12). On June 30, the well was pumped at a rate of about 5 gal/min. Based on the well diameter and pumping rate, about 24 minutes of pumping were needed to clear the well casing and obtain a sample of formation water. After 22 minutes of pumping, the water, which had been clear and had a slight hydrogen sulfide odor, suddenly became muddy and did not clear with continued pumping. A sample was taken after about 50 minutes of pumping. The extremely high total nutrient concentrations found in the sample result from fine nutrient-rich suspended sediment. Organic-rich suspended sediment in inflow to drainage well R1 probably settles out of the water and accumulates in cavities in the limestone. Test well 57 probably intersects such a cavity. Thus, the high amount of suspended material in the sample (and resulting total nutrient concentrations higher than the recharge water from Lake Alice) are the result of accumulated sediment which have settled out of recharge water after it enters the aquifer.

CHEMICAL LOADS ENTERING THE FLORIDAN AQUIFER SYSTEM

The amount of chemical constituents entering the aquifer depends on both the concentration of the constituent in the source water and on the rate of recharge. Loads of selected constituents for the four recharge sites near Gainesville were calculated by multiplying the mean flow into each site by the mean concentration of each constituent (table 14). Loads for Alachua Sink and Lake Alice should be considered estimates because calculations of the mean recharge rates were based on only a few measurements. Still, the relation between load and recharge rate is apparent from the table. For example, total nitrogen and phosphorus concentrations and loads are greatest for Alachua Sink. The nitrogen load for Haile Sink is greater than for Kanapaha because the recharge rate at the sink is greater even though the concentration at the sink is lower.

The effects of the loads entering the Floridan were not detected in the monitor wells, based on comparisons with wells in the Orlando area with the exception of chloride concentration near Kanapaha. As apparently happens near Lake Alice, suspended constituents may settle out when the velocity of recharge water decreases after it enters the aquifer. Some constituents, such as lead, may be adsorbed by aquifer materials. Finally, the large volume of water present in the aquifer dilutes and disperses the remaining constituents.

Table 14.--Loads of selected chemical constituents entering the Floridan aquifer system at four recharge sites near Gainesville

Mean flow (Mgal/d)	Mean flow (L/s)	Chloride Concentration (mg/L)	Chloride Load (kg/d)	Lead (dissolved) Concentration (µg/L)	Lead (dissolved) Load (kg/d)	Total nitrogen Concentration (mg/L)	Total nitrogen Load (kg/d)	Total phosphorus Concentration (mg/L)	Total phosphorus Load (kg/d)
				Hogtown Creek/Haile Sink					
12.4	543	9.4	441	<1	<.047	1.0	47	0.7	33
				Lake Alice well R1					
1.88	82	31	220	2	.014	1.6	11	1.1	8
				Lake Alice well R2					
2.33	102	31	273	2	.018	1.6	14	1.2	11
				Alachua Sink					
16.6	727	20	1,256	3	.188	3.4	214	1.5	94
				Kalapaha injection wells					
6.1	267	58	1,338	<7	≤.161	1.23	28	--	--
Total[1]			3,500		<.4		310		150

[1]Because of uncertainties in the load estimates, the total loads are reported only to two significant figures.

SUMMARY AND CONCLUSIONS

Rates of recharge to the Floridan aquifer system at four sites in Alachua County were estimated and water samples analyzed to determine if the recharge water affects the water quality of the aquifer. Two sites, Haile and Alachua Sinks, are sites of naturally occurring recharge. The drainage wells at Lake Alice and the Kanapaha treatment plant wells were specifically designed to inject water into the aquifer. A total of about 33 Mgal/d recharges the upper part of the aquifer system at Haile Sink, Alachua Sink, and the Lake Alice drainage wells. At the Kanapaha site, wells recharge an average of 6.1 Mgal/d into the lower zone of the system.

The samples of water entering the aquifer system collected at the four sites conformed to the drinking water standards recommended by the U.S. Environmental Protection Agency (1983) with the following exceptions: (1) Bacteria were found in all the surface water that enters the aquifer at Haile Sink, Alachua Sink, and Lake Alice, (2) a sample from Alachua Sink on August 3, 1982, exceeded the recommended fluoride concentration, and (3) the maximum reported values of color, nitrate, cadmium, and iron at the Kanapaha injection wells exceeded the standard, although the mean values do not.

Bacteria and nutrient concentrations were more variable in the recharge water than were other constituents. Bacteria were found in recharge water at all sites, except at Kanapaha. The highest bacteria count (8,500 col/100 mL total coliform and 92,200 col/100 mL fecal streptococci) were found at Alachua Sink on August 3, 1982, after a summer of abundant rainfall.

Organic compounds such as diazinon, lindane, and malathion, were occasionally detected in all recharge water, but concentrations never exceeded recommended limits. Organic compounds were not detected at Haile Sink, Alachua Sink, or Lake Alice. Analysis for organic compounds are periodically made by Gainesville Regional Utilities at Kanapaha. Organic compound contamination does not seem to be a problem at the sites sampled.

With one exception, described below, no significant differences were found between the quality of the recharge waters and water from the wells sampled, although the recharge water tended to be lower in calcium and iron than water from the Floridan aquifer system. Definition of "background" water quality in the aquifer is difficult because the karstic geology facilitates influence from other recharge sites.

The water from one well near Lake Alice had high total nutrient concentrations caused by nutrient-rich suspended sediment. Apparently, the nutrient-rich suspended sediment accumulates in cavities in the limestone after recharge water enters the aquifer. The well at site 57 probably intersects such a cavity.

Water samples collected in 1981-83 from wells near Lake Alice, and Haile and Alachua Sinks, were compared to samples collected by Schiner and German (1983) from drainage wells and public-supply wells in the Orlando area because there are insufficient data to determine background water quality in the Gainesville area. Concentrations of nutrients and bacteria in wells near the three recharge sites were more similar to drainage wells than to public-supply wells. The drainage wells had higher levels of total nitrogen, total organic nitrogen, and total phosphorus than the public-supply wells. Bacteria were detected in more drainage wells than public-supply wells in the Orlando study. Bacteria were detected in most wells sampled near the Gainesville recharge sites. The highest counts were from wells near Alachua Sink. Chloride concentrations of water from most wells near Lake Alice, Haile Sink, and Alachua Sink were similar to chloride concentrations of water from both drainage and supply wells in the Orlando area. Wells downgradient of Kanahapa had water with chloride concentrations similar to the injected water. Dissolved lead concentrations in water from all wells did not differ significantly from water from drainage and supply wells in Orlando.

Estimated chemical loads that enter the aquifer include 3,500 kg/d of chloride, less than 0.4 kg/d of lead, 310 kg/d of nitrogen, and 150 kg/d of phosphorus, but the effects of most could not be detected in the monitor wells compared to wells in the Orlando area. Apparently, some of the constituents may settle out, some are adsorbed by aquifer materials, and the remainder diluted and dispersed by the extremely large volume of water in the aquifer.

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