

EFFLUENT MIGRATION FROM SEPTIC TANK SYSTEMS IN
TWO DIFFERENT LITHOLOGIES, BROWARD COUNTY, FLORIDA

By Bradley G. Waller, Barbara Howie, and Carmen R. Causarás

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ABSTRACT

Two septic tank test sites, one in sand and one in limestone, in Broward County, Florida, were analyzed for effluent migration. Ground water from shallow wells, both in background areas and hydraulically downgradient of the septic tank system, was sampled during a 16-month period from April 1983 through August 1984. Water-quality indicators were used to determine the effluent affected zone near the septic tank systems.

Specific conductance levels and concentrations of chloride, sulfate, ammonium, and nitrate indicated effluent movement primarily in a vertical direction with abrupt dilution as it moved downgradient. Effluent was detected in the sand to a depth more than 20 feet below the septic tank outlet, but was diluted to near background conditions 50 feet downgradient from the tank. Effluent in the limestone was detected in all three observation wells to depths exceeding 25 feet below the septic tank outlet and was diluted, but still detectable, 40 feet downgradient.

The primary controls on effluent movement from septic tank systems in Broward County are the lithology and layering of the geologic materials, hydraulic gradients, and the volume and type of use the system receives.

INTRODUCTION

Broward County, on the southeast coast of Florida (fig. 1), is a rapidly growing metropolitan area encompassing numerous cities including Fort Lauderdale, Hollywood, and Pompano Beach. Population estimates for 1985 (Broward County Planning Council, written commun., 1985) show about 1.5 million residents living within the county, an increase of about 400,000 since 1980. Projections by Broward County planners indicate that all inhabitable areas of the county will be completely developed in the next 20 to 30 years. Since 1972, with the impetus of the Clean Water Act, Broward County has upgraded sewage treatment by closing inefficient and small package treatment plants. However, about 80,000 septic tank systems are still used for treatment and disposal of sewage within the county. Future low density development in Broward County will also rely in part on septic tank systems (fig. 2) for sewage disposal (Broward County, 1983).

Concern over the effects of septic tank effluent on the quality of ground water in the Biscayne aquifer, the only source of drinking water in the county, became the impetus for Broward County to enter into a cooperative program with the U.S. Geological Survey to investigate the effects of septic tank effluent on ground water in the county.

Purpose and Scope

This report describes the results of an investigation to determine the horizontal and vertical migration of septic tank effluent from individual tank systems in two different lithologies within the Biscayne aquifer.

The following criteria were used in selecting the study sites:

- Surficial material had to be sand or limestone, the major lithologic types in the county;
- A daily input of domestic waste to the septic tank system for at least 10 years was preferred;
- Septic tank system had to be isolated to avoid any interference from surrounding systems;
- Drilling access was available on the downgradient side of the drainfield;
- Construction of the septic tank system had to be similar to that currently permitted in the county.

The scope included the periodic collection of ground water and septic tank effluent for determination of the concentration of water-quality indicators. Monitor wells at various depths were installed hydraulically downgradient of the septic tank outlet, and wells for background monitoring were installed at various depths upgradient of the test sites. Samples were collected during a 16-month period, April 1983 through August 1984, to determine the range in concentrations caused by seasonal variation. Water samples were analyzed for total nitrogen and phosphorus species, total organic carbon

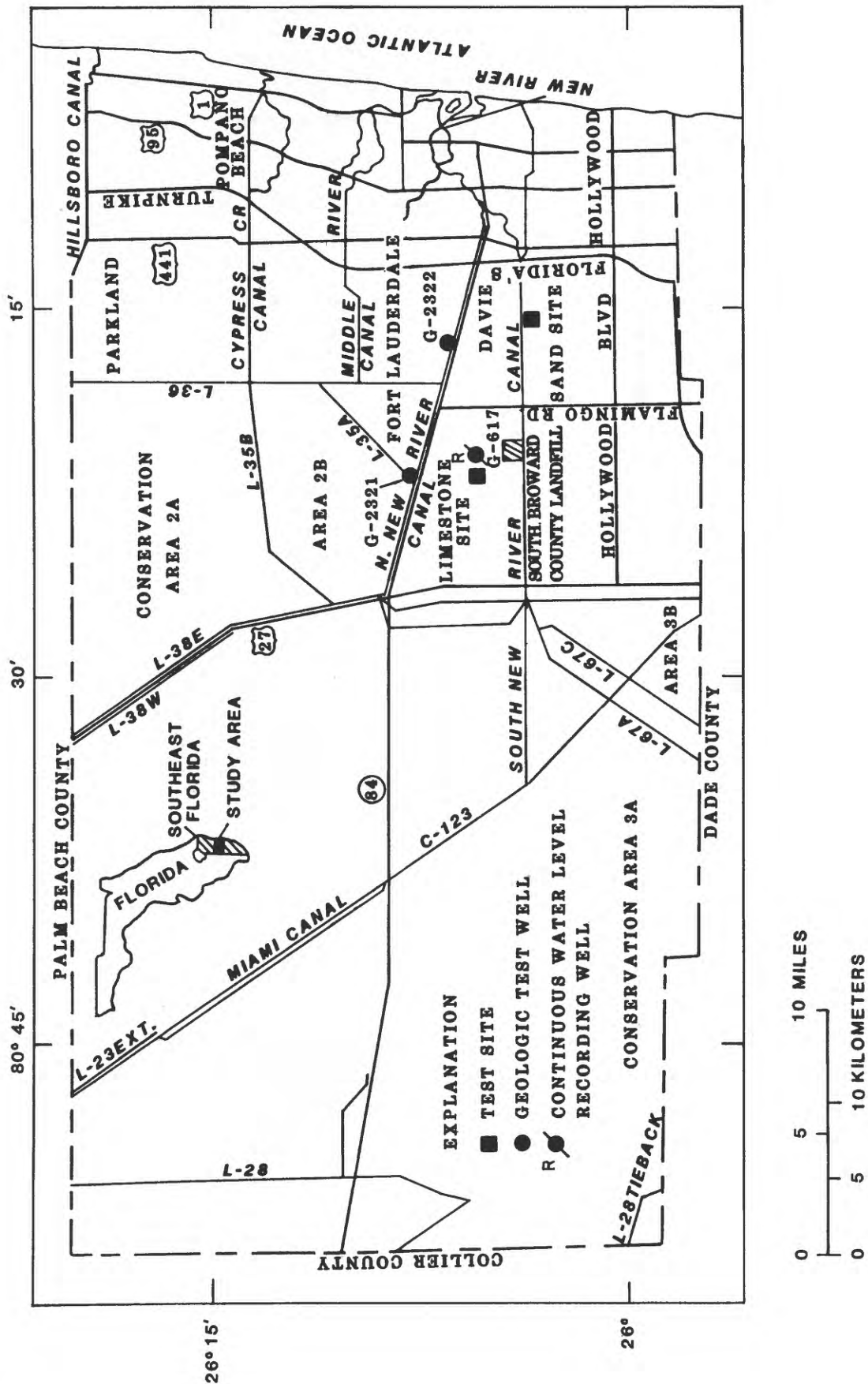


Figure 1.--Broward County septic tank test site locations.

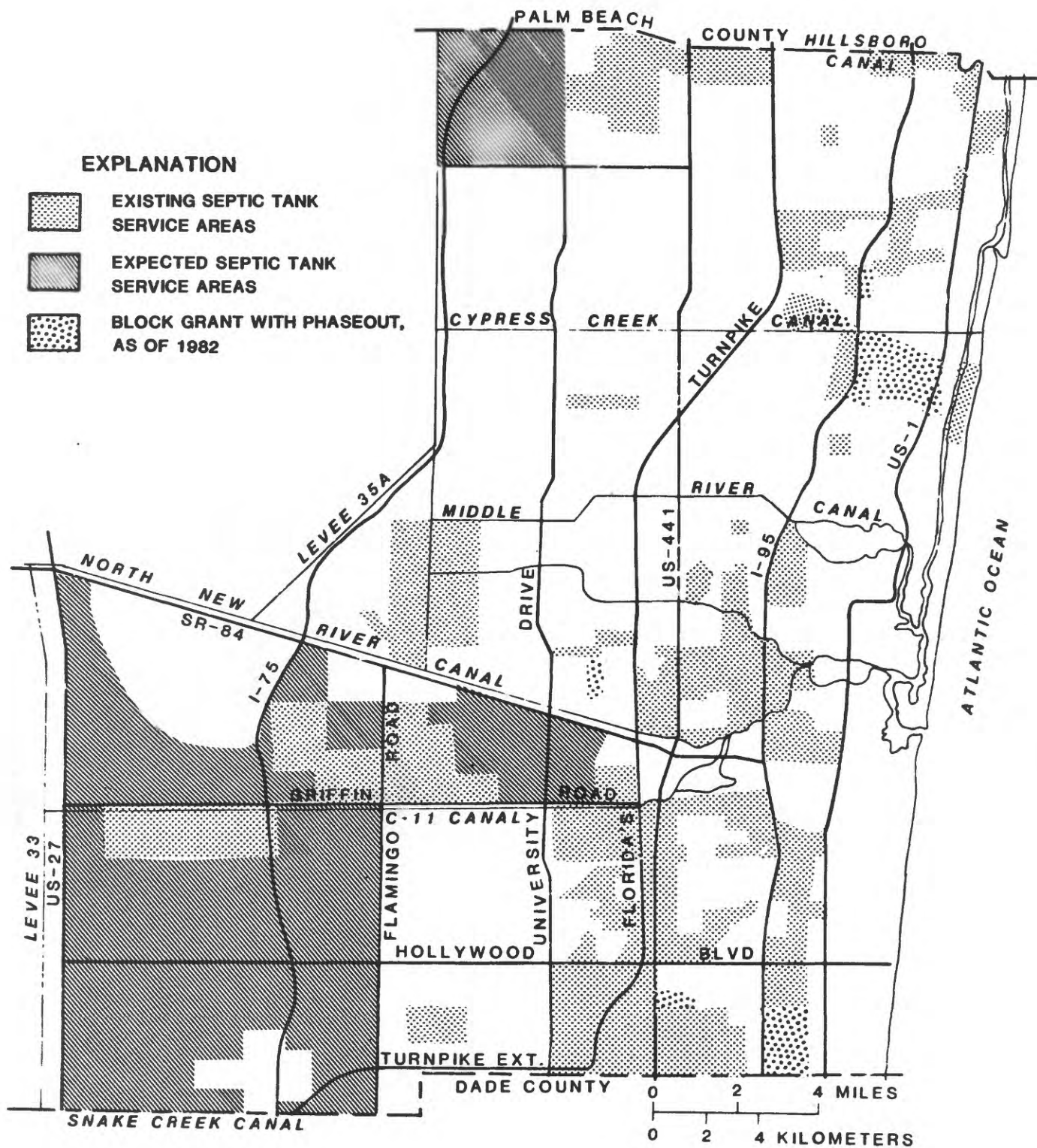


Figure 2.--Broward County areas serviced by septic tanks.

(TOC), dissolved sulfate, chloride, and chemical oxygen demand (COD), and levels of turbidity, color, and specific conductance.

Acknowledgments

The authors thank the staff of the South Florida Water Management District field office in Davie, Fla., and Tony Martin of Calamity Acres farm for allowing the U.S. Geological Survey to install and sample wells on their properties. Thomas D. Walker and his staff at the Broward County Water Resources Management Division provided valuable information on areas serviced by septic tanks within the county.

SITE DESCRIPTIONS AND GEOHYDROLOGY

The two major types of surficial lithologies in Broward County are sand and limestone. Fine- to medium-grained quartz sand of either the Pamlico Sand or the Anastasia Formation covers the eastern part of the county (Causaras, 1985). Limestone units of the Fort Thompson Formation are exposed at the surface in two areas, north-central Broward County (Parkland area) and south-east Broward County (west of Flamingo Road). A septic tank test site was selected, based on the criteria mentioned earlier, in each of these two lithologies.

Sand Test Site

The sand septic tank test site is located at the South Florida Water Management District (SFWMD) field station in Davie (fig. 1). Nine wells in three clusters were completed to various depths at this site (table 1). Three wells were installed at the septic tank outlet, three wells were drilled 25 feet downgradient from the outlet, and three wells were drilled 50 feet downgradient (fig. 3). Two wells, located 500 feet upgradient, were used to determine background water-quality conditions.

The shallowest wells were drilled to a depth about 3 feet below the average water-table level. The mid-depth wells were finished 5 feet below the shallowest well, and the deepest wells were finished 10 feet below the shallowest well.

Lateral ground-water gradients at the sand test site vary greatly, depending on local water-management practices. When water is released seaward from the South New River Canal (fig. 1) 300 feet to the north, the ground-water flow direction is toward the north, and the gradient can vary from 1.0 to 2.0 ft/mi. When water is not being released in the canal, the ground-water flow direction is to the northeast, and the gradient is about 0.2 ft/mi.

Ground-water levels throughout most of the year range from 2 to 3 feet above sea level. The invert level of the septic tank outflow point and the drainfield pipes is about 6 feet above sea level; therefore, the unsaturated zone is about 3 to 4 feet thick.

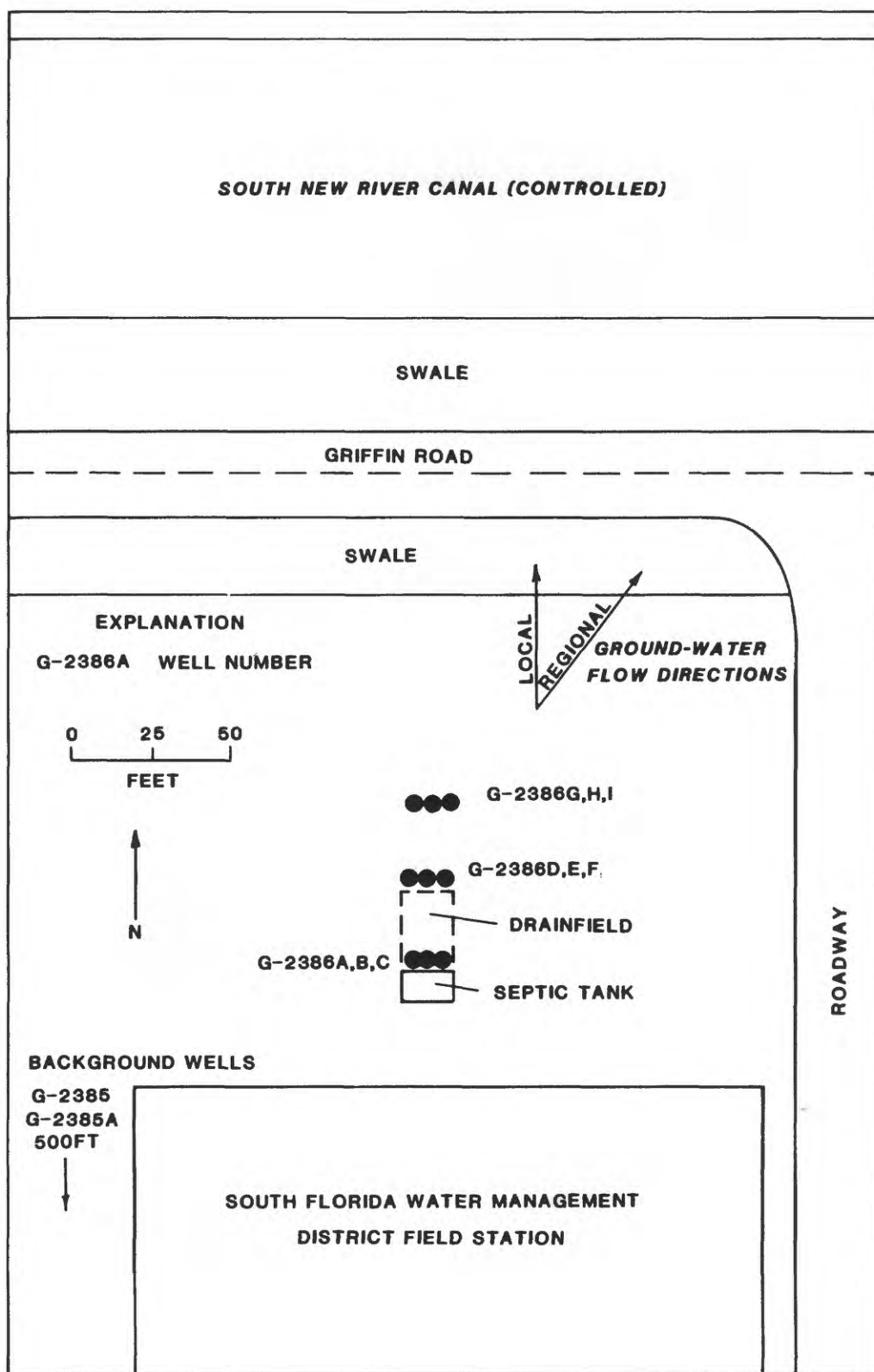


Figure 3.--Septic tank test site in sand showing well placements, well numbers, and regional ground-water flow direction.

Table 1.--Identification numbers and depths of wells at the septic tank test sites

Local Well No.	Identification No.	Depth (ft)
<u>Sand site</u>		
Background (500 feet upgradient)		
G-2385	260340080154003	35.0
G-2385A	260340080154002	14.0
At septic tank outlets		
G-2386A	260350080154301	7.1
G-2386B	260350080154302	11.6
G-2386C	260350080154303	17.4
25 feet downgradient		
G-2386D	260350080154304	7.8
G-2386E	260350080154305	12.8
G-2386F	260350080154306	18.8
50 feet downgradient		
G-2386G	260350080154307	7.9
G-2386H	260350080154308	12.7
G-2386I	260350080154309	18.3

<u>Limestone site</u>		
Background (300 feet upgradient)		
G-2365	260505080204701	74.2
G-2365A	260505080204702	25.0
G-2365B	260505080204703	10.0
At septic tank outlets		
G-2387A	260504080204501	10.8
G-2387B	260504080204502	15.0
G-2387C	260504080204503	27.6
40 feet downgradient		
G-2387D	260504080204504	9.5
G-2387E	260504080204505	14.4
G-2387F	260504080204506	26.0

The SFWMD field station is in operation fulltime during weekdays and intermittently on weekends and at night. Loading to the septic tank system is continuous on a weekly basis, but on certain days there may not be input to the system. The average weekly flow is about 3,000 gallons or about 430 gal/d.

Limestone Test Site

The limestone septic tank test site is about 1 mile northwest of the south Broward County landfill (fig. 1). Six wells at two sites were completed to various depths at this site (table 1). Three wells were drilled at the septic tank outlets, and three wells were drilled 40 feet downgradient (fig. 4). Three wells were drilled about 300 feet upgradient to determine background water-quality conditions. Water-level gradients and flow direction were determined from water-table contour maps on file at the U.S. Geological Survey office in Miami.

Three layers of dense limestone were identified during drilling, at about 10 feet, 15 feet, and 25 feet below land surface. These layers may locally impede the vertical flow of ground water or effluent. The wells at this test site were finished, respectively, just above the three layers of dense limestone.

Lateral ground-water gradients at the limestone test site are relatively uniform throughout the year, varying between about 0.15 and 0.20 ft/mi. Ground-water flow directions are east to southeast, depending on rainfall conditions and water-management practices. Ground-water levels are controlled throughout this part of Broward County and generally range from 2.5 to 4.5 feet above sea level based on data from a nearby well (G-617, see fig. 1 for location). The septic tank system and the house it serves are built on an elevated pad, which is about 10 feet above sea level. The invert level of the septic tank outflow point and drainfield pipes is 8 to 9 feet above sea level; therefore, about 3.5 to 6.5 feet of unsaturated zone occurs between the drainfield and water table.

A single-family residence provides the input to this septic tank system. Two people live in the house fulltime, and there are frequent intermittent guests. Based on average water use for sanitary purposes of 75 gal/d for each person, the volume of flow into the tank is about 200 gal/d.

Geohydrology of Test Sites

The following geologic description of the lithology at the two test sites is based on a report describing the geologic framework of Broward County (Causaras, 1985). Two geologic test wells are located near the corresponding septic tank test sites. Well G-2322 (fig. 1) is about 1.5 miles north of the sand test site, and well G-2321 is about 1.5 miles north of the limestone test site. Geologic sections prepared from these wells (fig. 5) are representative of the lithologies found at the two test sites.

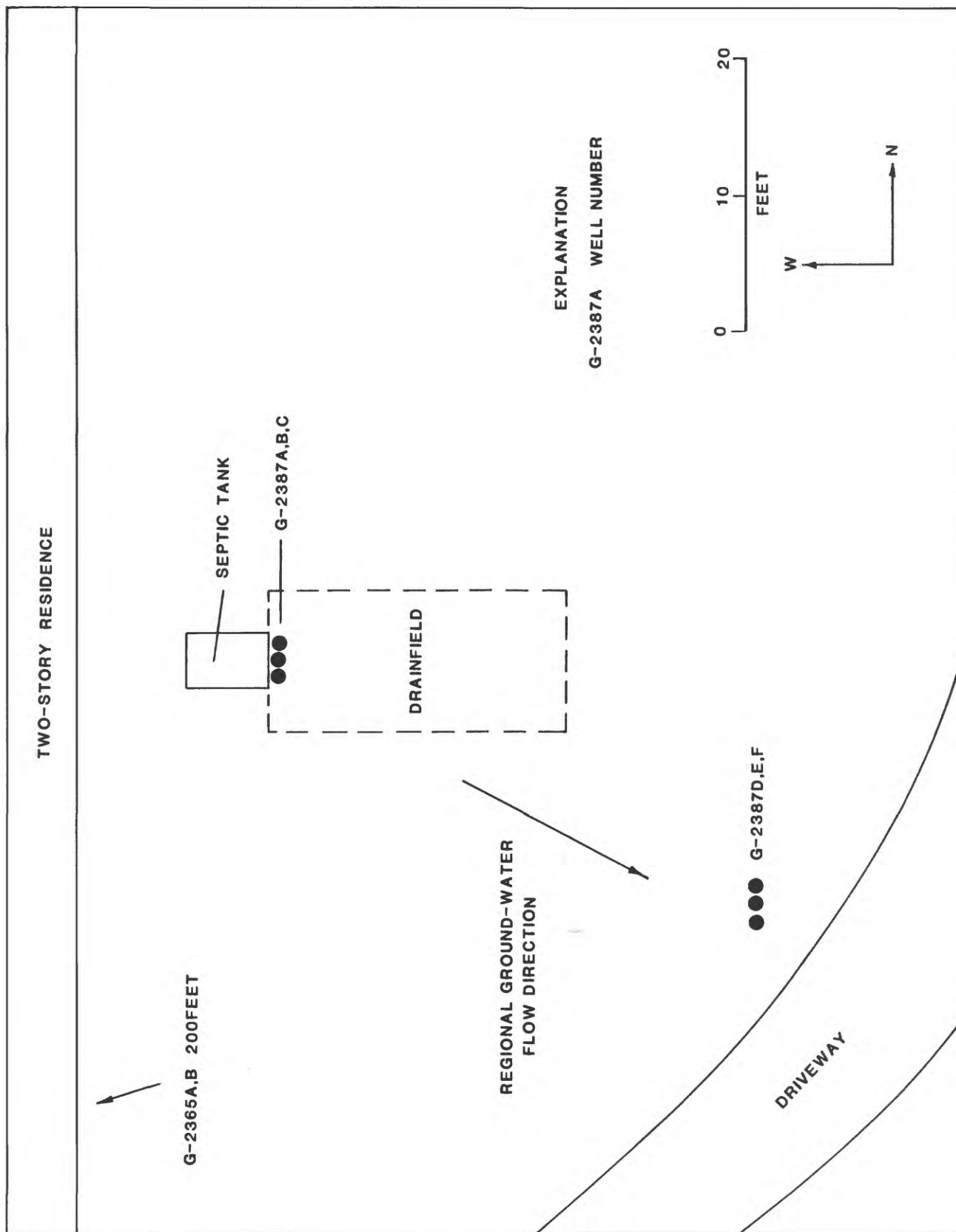


Figure 4.--Septic tank test site in limestone showing well placements, well numbers, and regional ground-water flow direction.

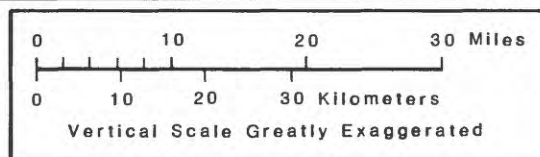
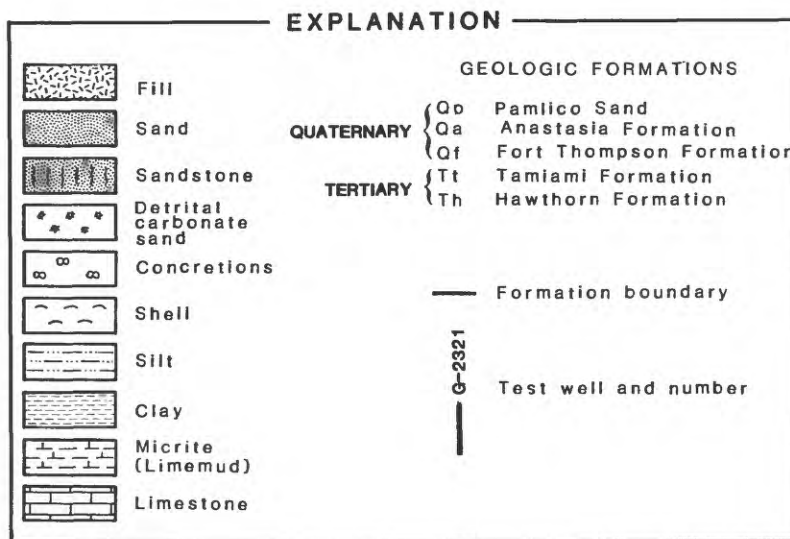
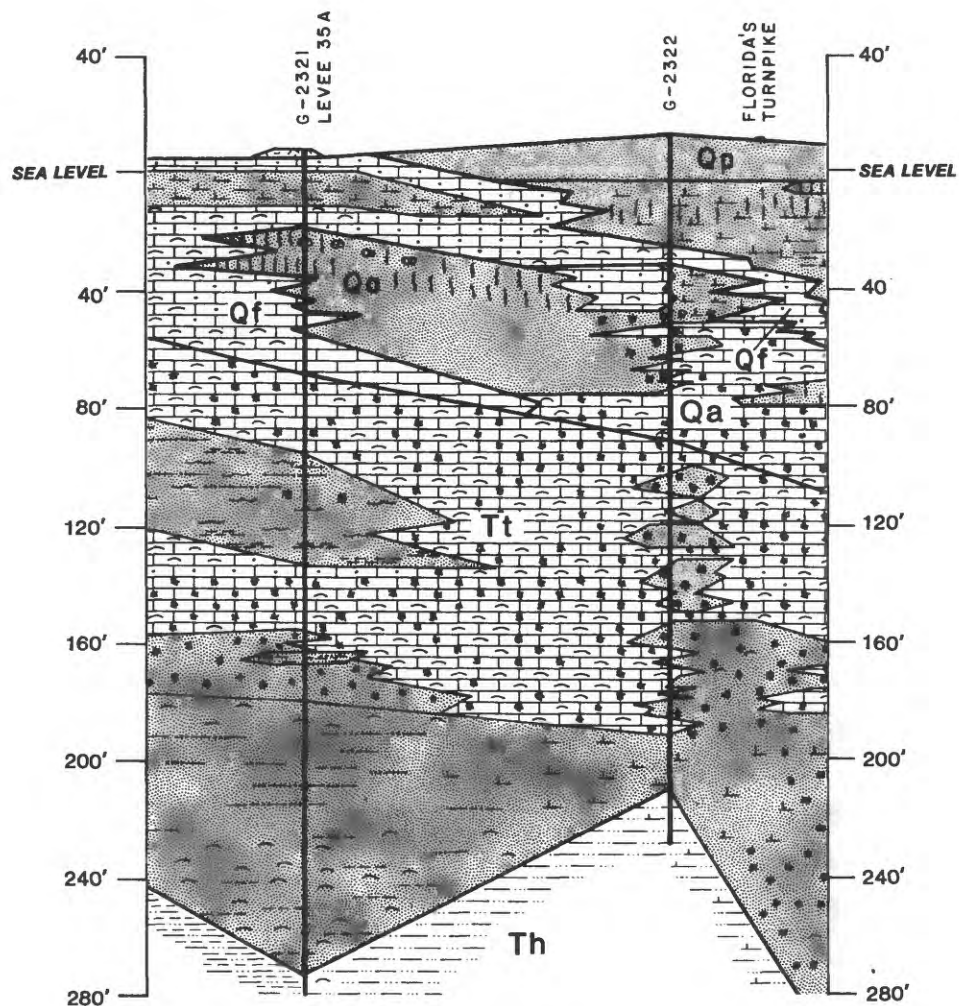


Figure 5.--Geologic sections north of septic tank test sites showing test wells G-2322 and G-2321.

Sand thickness at the sand test site was about 30 feet. The sand was primarily medium to fine grained, well sorted, and quartzose. The sand was tan to brown, indicating the presence of organic material and iron. Deeper drilling at the test site revealed a thin sandstone layer at 32 feet and a thicker sandstone layer at 44 feet below land surface. These layers correspond to those at well G-2322 (fig. 5). Hydraulic conductivities of this sand deposit range from 10 to 100 ft/d (J.E. Fish, U.S. Geological Survey, written commun., 1987). Because no layering was found in the upper 30 feet of material, it is assumed that the horizontal and vertical hydraulic conductivities are nearly equal in this part of the Biscayne aquifer.

In contrast to the uniformity of geologic materials found at the sand test site, the limestone test site is underlain by distinctly layered materials. A dense limestone (defined locally as the cap rock) is present from land surface to 2.5 feet below land surface. From this layer to a depth of about 10 feet is a fine-grained sand and lime mud mixture. This sand corresponds to the thicker sand unit shown at well G-2322 (fig. 5). Limestone of the Fort Thompson Formation lies below the 10-foot level. Hard, dense layers are found at the 10-foot, 15-foot, and 26-foot levels below land surface. Where the septic tank and drainfield were constructed, most of the cap rock and sand had been removed, and crushed limestone fill replaced those layers. Hydraulic conductivity of the sand at this site ranges from 10 to 100 ft/d, and that of the limestone from 1,000 to greater than 1,000 ft/d (J.E. Fish, U.S. Geological Survey, written commun., 1986).

The naturally occurring water type at both of these septic tank test sites is mixed calcium bicarbonate and sodium chloride. Calcium bicarbonate is derived primarily from the dissolution of the limestone and shell fragments present in sand. Sodium chloride is derived primarily from the transport by canals of residual saltwater from the northwest into the area of the test sites (South Florida Water Management District, 1982). Organic soils are common in the vicinity of both test sites, and the decomposition products of these soils cause higher color levels and concentrations of TOC, organic nitrogen, COD, and ammonium than in areas where there is no organic soil cover.

METHODS AND MATERIALS

Two different drilling methods were used during this investigation. At the sand test site, wells were installed by driving a casing to the desired depth, washing out the sand with uncontaminated ground water, and setting the polyvinyl chloride (PVC) casing and 2-foot well screen. At the limestone test site, wells were drilled using the rotary method to the desired depth, and the PVC casing and 2-foot screen were set in the drilled hole and grouted to the surface.

Ground-water samples were collected using two different methods. In wells that would yield more than 3 gal/min, a centrifugal pump was used in each sampling to purge the well and withdraw water for chemical analysis. In wells yielding lesser volumes, a centrifugal pump was used to purge the well, and a peristaltic pump was used to withdraw samples for chemical analysis. Each well was purged at least three casing volumes. Effluent from

the septic tank was withdrawn with a 0.50-inch polyethylene tube inserted through a small-diameter hole in the center of the tank top with a low volume (0.25 gal/min) peristaltic pump.

Specific conductance was determined in the field, and all other water quality indicators were analyzed from unfiltered samples at the U.S. Geological Survey Laboratory in Ocala.

SEPTIC TANK EFFLUENT CHARACTERISTICS

The concentrations of certain water-quality indicators differ in the two effluents sampled (table 2). At the limestone test site, the septic tank system receives inflow of domestic waste, whereas at the sand test site the inflow is more of a commercial type.

Higher concentrations of most of the water-quality indicators were determined in the effluent at the sand site. Ammonium, organic nitrogen, total phosphorus, orthophosphate, COD, and TOC concentrations were much higher at this site than in the effluent at the limestone site; specific conductance and color levels and chloride and sulfate concentrations were only slightly higher. These higher concentrations or levels are attributable to less water use in the laundry, bathtub, and shower and more use of toilets and washrooms at the sand site. Also, there is twice the volume of effluent at the sand site which results in greater loading and, thus, higher concentrations.

EFFLUENT MIGRATION

Patterns of effluent migration from the outlet and drainfield were determined by physical and chemical analyses of ground water in the field and laboratory. Both vertical and horizontal patterns of movement of the effluent were determined at the two test sites. Vertical hydraulic gradients among the wells were too small to measure accurately, but vertical movement of the effluent is inferred from concentrations of water-quality indicators. Physical processes and chemical and biological reactions attenuate the effluent contaminants until they reach background concentrations. Physical processes include filtering, dilution, and dispersion. Chemical and biological reactions include absorption, adsorption, chemical bonding, microbial reactions, and precipitation.

Sewage indicators were used to show effluent migration in ground water (table 3). The best indicators determined in this study are inorganic nitrogen (the sum of nitrate, nitrite, and ammonium), chloride, specific conductance, and sulfate. Other constituents such as organic fractions of nitrogen, phosphorus, and carbon and the effluent components which cause turbidity are readily filtered and do not move with the effluent plume. Also, COD concentrations and color levels had a wide range between samples and are considered poor indicators of effluent migration at the two test sites. Organic nitrogen and orthophosphate are used as auxiliary indicators of sewage effluent but are probably not good tracers because of biochemical reactions.

Table 2.--Chemical and physical characteristics of septic tank effluent from sand and limestone test sites

[All samples are unfiltered, and all concentrations shown in milligrams per liter, except for specific conductance (in microsiemens per centimeter at 25 °C), turbidity (in nephelometric turbidity units), and color (in platinum-cobalt units); NS, not sampled; --, data not available]

Characteristic	Aug 23, 1983	Sept 8, 1983	Nov 1, 1983	Jan 11, 1984	Mar 22, 1984	Aug 29, 1984	Mean	Range
<u>Sand test site</u>								
Specific conductance	1,480	1,250	1,460	1,420	1,700	1,010	1,387	1,010-1,700
Chloride (as Cl)	100	79	105	130	130	71	102	71-130
Sulfate (as SO ₄)	4.6	23	28	30	.1	6.4	15.4	0.1-30
Turbidity	18	23	32	20	23	--	--	18-32
Color	200	200	120	140	140	--	160	120-200
Nitrite (as NO ₂)	.05	.04	.04	.04	.04	.02	.04	0.02-0.05
Nitrate (as NO ₃)	.00	.04	--	--	--	--	--	0.00-0.04
Ammonium (as NH ₄)	110	101	106	124	150	72	110	72-150
Organic nitrogen (as N)	52	32	8	22	20	6	23.3	6-52
Total nitrogen (as N)	162	133	114	146	170	78	133	78-162
Total phosphorus (as P)	13	13	10	11	14	8.1	11.5	8.1-14
Orthophosphate (as P)	12	12	9.4	11	14	7.2	10.9	7.2-14
Chemical oxygen demand	300	340	--	--	--	--	--	300-340
Total organic carbon	100	97	--	--	--	--	--	97-100
<u>Limestone test site</u>								
Specific conductance	960	1,230	1,050	NS	950	1,050	1,048	950-1,230
Chloride (as Cl)	80	130	89	NS	65	71	87	65-130
Sulfate (as SO ₄)	5.1	40	.01	NS	10	6.4	12.3	0.01-40
Turbidity	--	3.1	34	NS	4.7	--	--	3.1-34
Color	60	120	80	NS	240	--	125	60-240
Nitrite (as NO ₂)	.01	.02	.02	NS	.03	.02	.02	0.01-0.03
Nitrate (as NO ₃)	.01	.02	.00	NS	--	--	.01	0.00-0.02
Ammonium (as NH ₄)	24	33	30	NS	24	20	26.2	24-30
Organic nitrogen (as N)	12	27	13	NS	6	6	12.8	6-27
Total nitrogen (as N)	36	60	43	NS	30	26	39	26-60
Total phosphorus (as P)	3	5	4.3	NS	4.8	3.3	4.1	3-5
Orthophosphate (as P)	2.9	4.4	4	NS	4.2	2.5	3.6	2.5-4.4
Chemical oxygen demand	125	220	--	NS	--	--	--	125-220
Total organic carbon	39	64	--	NS	--	--	--	39-64

Table 3.--Summary of water-quality indicators in background and downgradient wells
at both septic tank test sites

[All concentrations shown in milligrams per liter, except for specific conductance which is in
microsiemens per centimeter at 25 °C; BG, background]

Well No.	Loca- tion	Depth (ft)	Specific conductance		Chloride		Ammonium		Nitrate		Sulfate	
			Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
G-2385	BG	35.0	695	690-700	43	41-45	1.6	1.2-2.1	0.01	0.01-0.01	20	18-21
G-2385A	BG	14.0	708	700-720	42	41-43	1.8	1.5-2.2	.01	0.01-0.01	18	17-18
G-2386A	0 feet	7.1	1,254	660-1,530	102	15-136	48	2.8-100	21.4	0.01-73	48	16-120
G-2386B	0 feet	11.6	1,333	1,170-1,480	103	93-130	78	71-92	.07	0.01-0.41	25	8.8-55
G-2386C	0 feet	17.4	1,426	1,310-1,520	109	95-130	93	87-103	.01	0.01-0.03	18	0.3-39
G-2386D	25 feet	7.8	564	530-610	12	7.8-15	2.1	0.4-3.8	5.38	0.01-14.9	18	1.6-25
G-2386E	25 feet	12.8	722	663-770	38	16-52	1.8	1.5-2.0	.03	0.01-0.08	62	46-76
G-2386F	25 feet	18.8	920	727-1,000	67	26-95	1.8	0.46-4.8	.01	0.01-0.01	35	24-47
G-2386G	50 feet	7.9	628	575-740	12	6.0-17	2.7	0.15-9.0	4.8	0.01-12.6	17	1.2-25
G-2386H	50 feet	12.7	615	535-680	25	7.6-33	1.6	1.4-1.8	.01	0.01-0.01	41	23-57
G-2386I	50 feet	18.3	683	637-760	37	32-41	1.9	1.6-2.2	.01	0.01-0.02	54	26-82
G-2365	BG	74.2	698	630-730	58	57-59	.88	0.30-1.2	.01	0.01-0.01	12	8.8-14
G-2365A	BG	25.0	645	630-650	27	24-29	.30	0.29-0.31	.01	0.01-0.01	86	83-26
G-2365B	BG	10.0	548	530-570	15	10-20	.07	0.03-0.13	7.15	5.5-9.4	20	18-26
G-2387A	0 feet	10.8	944	750-1,060	79	56-95	8.6	3.5-17	2.4	0.31-4.5	22	6-58
G-2387B	0 feet	15.0	972	850-1,110	85	72-100	11	4.8-20	.59	0.01-1.4	21	1.2-54
G-2387C	0 feet	27.6	1,011	950-1,040	100	94-110	4.6	3.8-4.7	.01	0.01-0.01	35	34-35
G-2387D	40 feet	9.5	908	850-970	92	80-110	.46	0.23-0.60	1.5	0.43-2.8	22	19-27
G-2387E	40 feet	14.4	935	870-1,020	87	73-110	.36	0.02-0.89	3.35	0.66-7.3	26	20-44
G-2387F	40 feet	26.0	1,433	1,180-1,600	228	140-280	.60	0.42-0.69	.02	0.02-0.07	36	0.9-46

The ground water affected by septic tank effluent is shown by concentrations of water-quality indicators (figs. 6-9), which include specific conductance, chloride, sulfate, ammonium, nitrate, and inorganic nitrogen. Each indicator responds to the ground-water flow direction, the physical composition of the aquifer, dispersion, and dilution to form the pattern of flow away from the septic tank and drainfield. In addition, nitrogen and sulfur compounds are biologically changed in ground water as bacteria act on them and redox conditions change.

At the sand site (figs. 6 and 7), the effluent movement is primarily downward from the tank and drainfield as indicated by ammonium and chloride concentrations and specific conductance levels. An abrupt decrease in concentration occurs as the effluent plume travels downgradient. Concentrations of chloride and sulfate ions (fig. 6) show a migration of effluent at the 15- to 20-foot level below land surface. Movement of this shallow level is strongly affected by the changes in water levels in the nearby canal. Initially, the ammonium concentrations are very high under the septic tank, but two different rates of ground-water flow cause changes in the ammonium concentrations in the ground water. Above the 10-foot level, the effluent is diluted by laminar ground-water flow which is more rapid because of the influence of the nearby primary canal. Below the 10-foot level, concentrations begin to increase because of the lower rate of ground-water flow and, thus, less dilution with time, and also by possible reduction of nitrate and further breakdown of organic nitrogen to ammonia.

Nitrate concentrations increase greatly in the upper part of the aquifer downgradient of the septic tank and drainfield. Because fertilizers are not used at this site, the increased nitrate concentrations are attributed to the nitrification of the ammonium beneath the drainfield. The nitrate concentrations show a strong lateral movement toward the canal, again indicating a higher rate of ground-water flow. Lack of nitrate downgradient at depths below 10 feet may be due to lack of oxygen for nitrification or conversion of ammonium to nitrogen gas.

Concentrations of water-quality indicators shown in figures 6 and 7 portray a definite movement of effluent vertically and downgradient of the septic tank at the sand test site. The highest concentrations of indicator parameters are directly below the outlet, extending downward to at least 20 feet. Diluted effluent, indicated by chloride concentrations, was detected about 40 feet downgradient at 20 feet below land surface. High nitrate concentrations at the 10-foot level are a secondary effect of effluent migration caused by biochemical reactions (nitrification). Chloride ion concentrations indicate dilution of effluent at this 10-foot level.

Effluent migration at the limestone test site (figs. 8 and 9) shows similar patterns evident at the sand test site, but not as sharply defined. This lack of definition is attributed to lower concentrations of effluent indicators in the septic tank in comparison to those occurring naturally in the aquifer and higher hydraulic conductivities in the limestone.

Specific conductance levels and chloride ion concentrations show a decrease downward to the 10-foot level and a slight increase at the deep wells

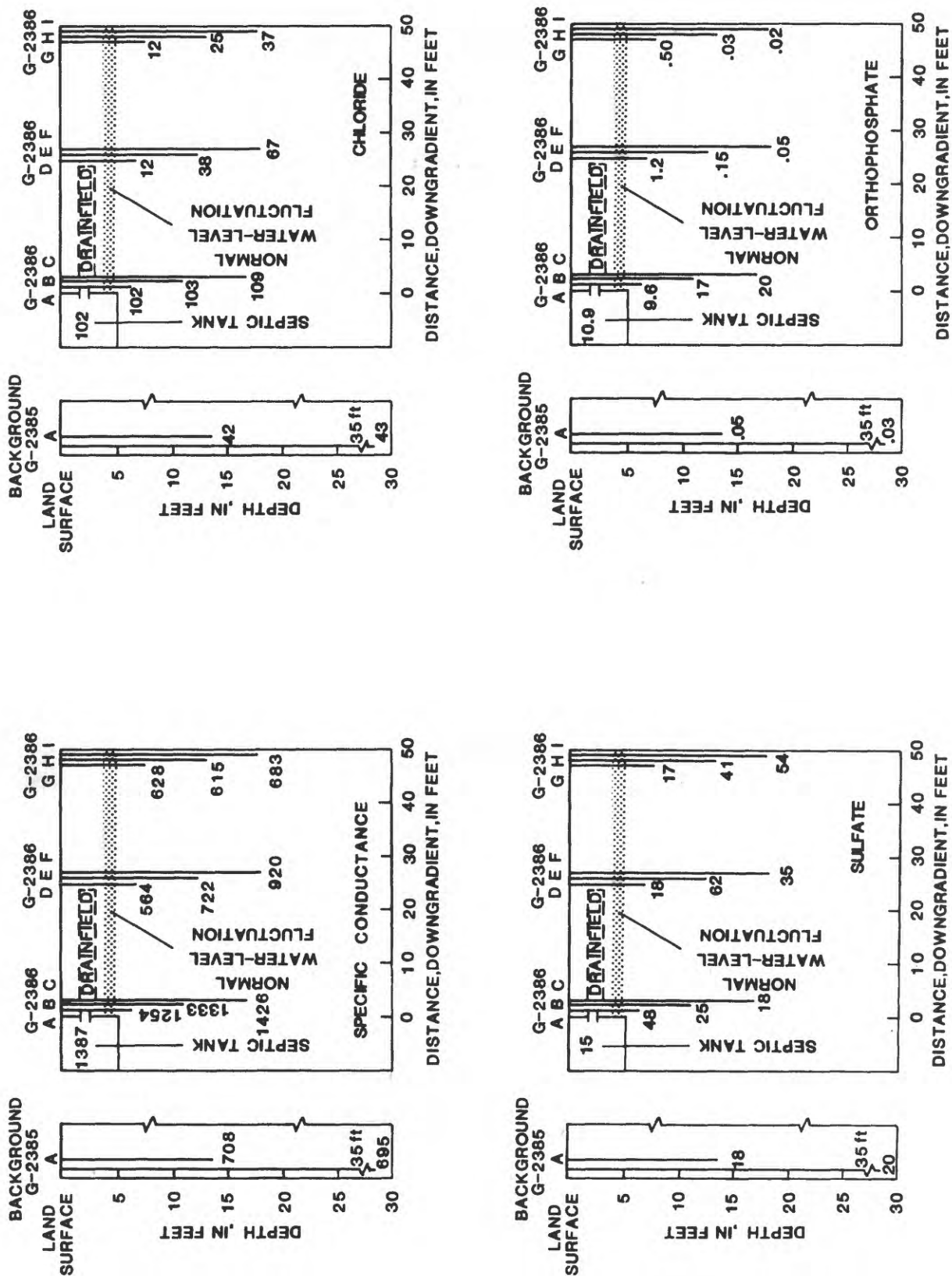


Figure 6.--Sand test site showing mean specific conductance levels and chloride, sulfate, and orthophosphate concentrations.

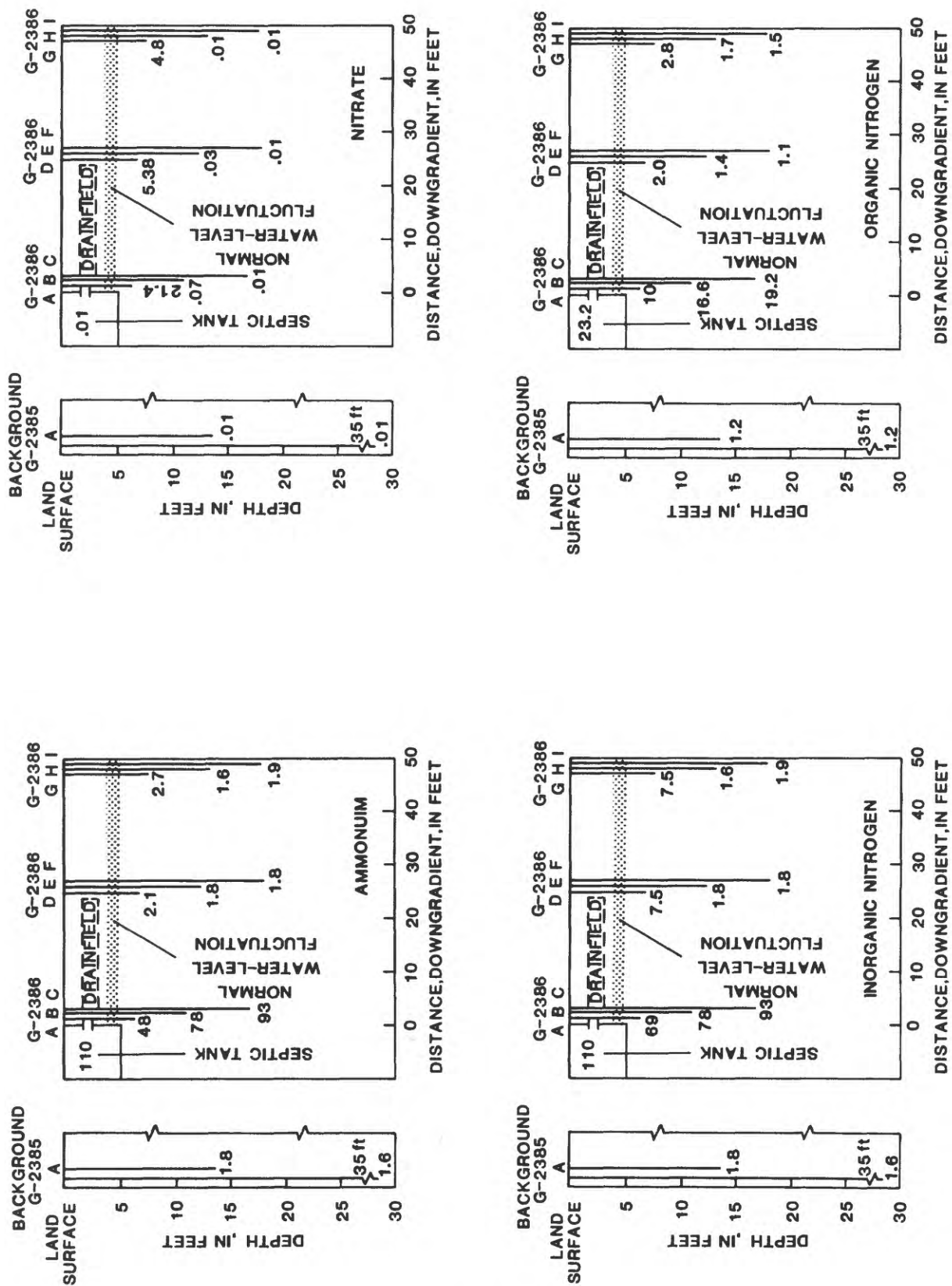


Figure 7.--Sand test site showing mean concentrations of ammonium, nitrate, inorganic nitrogen, and organic nitrogen.

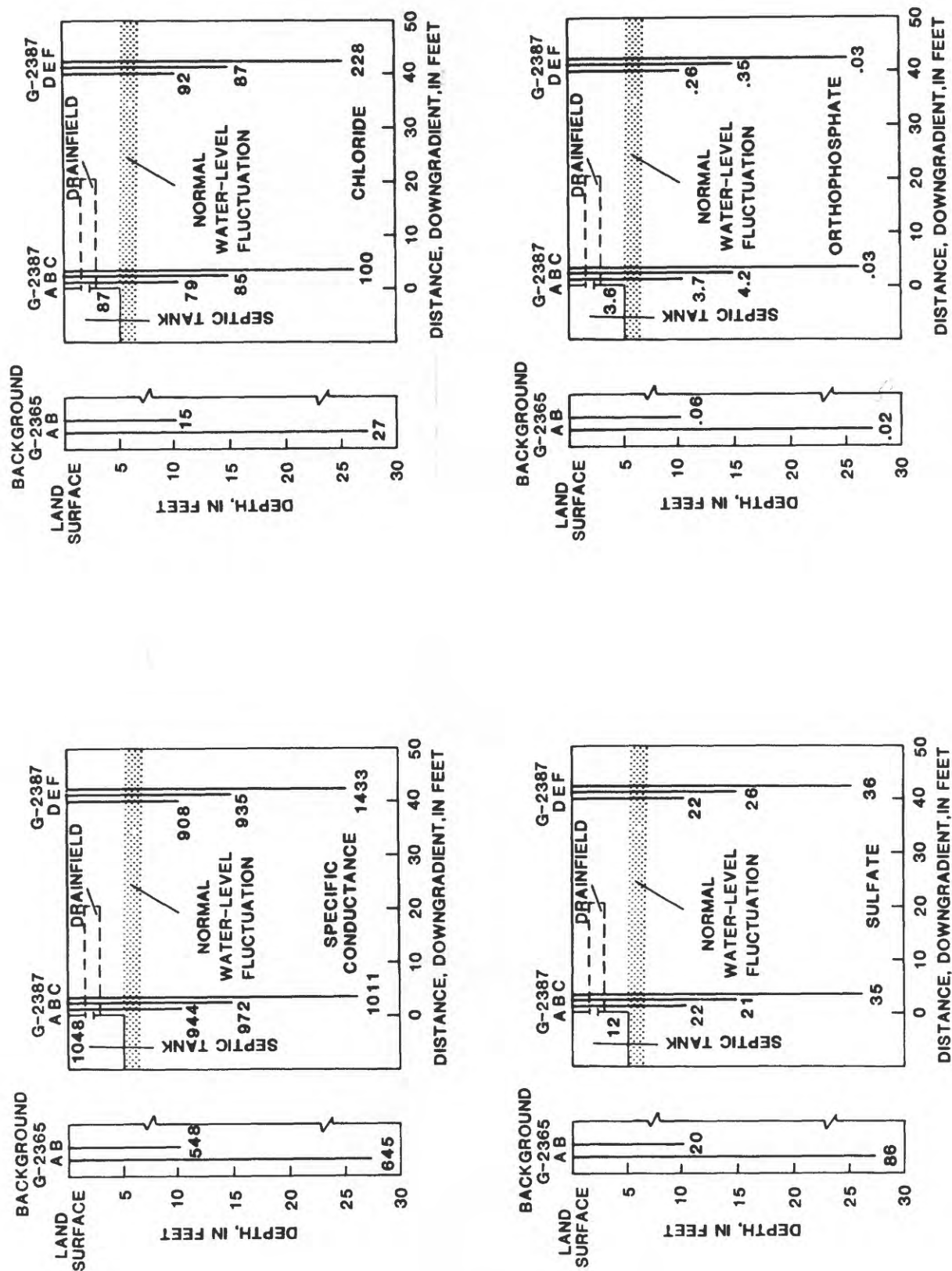


Figure 8.--Limestone test site showing mean specific conductance levels and chloride, sulfate, and orthophosphate concentrations.

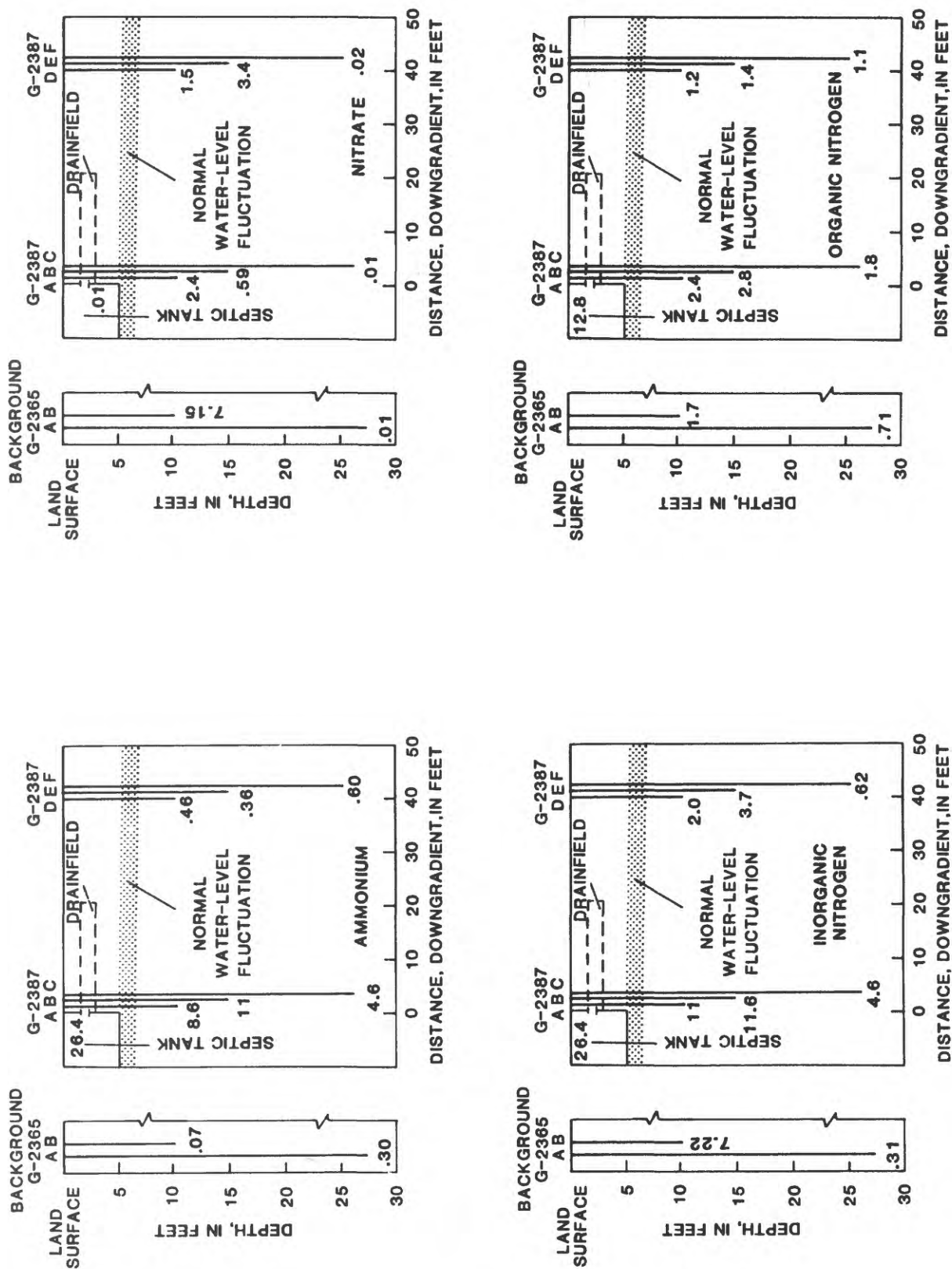


Figure 9.--Limestone test site showing mean concentrations of ammonium, nitrate, inorganic nitrogen, and organic nitrogen.

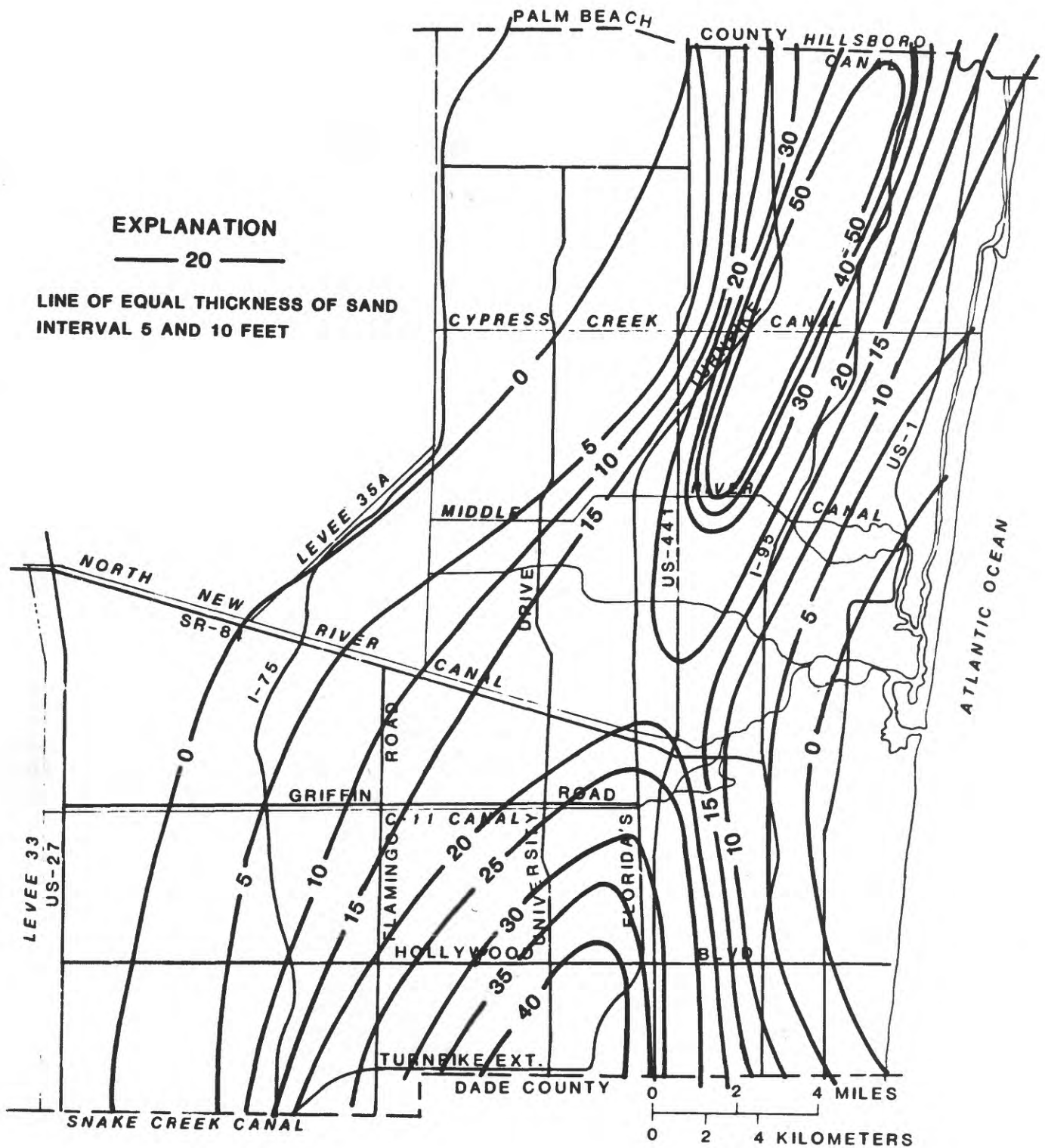


Figure 10.--Eastern Broward County showing thickness of surficial sand deposits.

(25 feet). Anomalous chloride and sulfate concentrations and specific conductance levels occur at the deep downgradient well (G-2387F) because of isolated pockets of dilute residual seawater that is found in this area (South Florida Water Management District, 1982).

Ammonium and nitrate concentrations (fig. 9) show downward movement vertically below the septic tank outlet and horizontally downgradient at the 15- to 20-foot level. Ammonium concentrations are diluted or oxidated to nitrate below the outlet, down to about the 10-foot level, then some increases are indicated which are probably caused by ammonification of the filtered organic nitrogen compounds. As at the sand site, a nitrification zone is apparent beneath the drainfield. Movement of inorganic nitrogen is controlled by oxygenated zones in the ground water and possibly by the dense layers of limestone noted at the 9- to 10-foot level and the 15- to 16-foot level. The movement of nitrate is a secondary effect caused by nitrification of the ammonium.

Specific conductance, chloride, orthophosphate, and sulfate proved to be poor indicators of effluent migration at this site, and the nonconservative inorganic nitrogen specie was used as the best indicator of effluent movement at the limestone test site. Effluent movement at the limestone test site is primarily in the vertical direction with horizontal (downgradient) movement detectable at the 10- to 15-foot zone, 40 feet downgradient. Effluent was detectable 26 feet below the tank outlet. At 40 feet downgradient of the outlet, the effect of the effluent on the ground water was minimal.

The surficial lithology is the primary control on the movement and eventual fate of constituents in septic tank effluent. In areas of surficial sands (fig. 10), the effluent does not disperse and dilute as rapidly as in areas underlain by more highly transmissive limestones. Sands seem to be more effective than limestone in filtering the organic materials by providing a more uniform medium for dispersion of the effluent. Localized layers of impermeable geologic materials will cause uneven dispersion of effluent and nonuniform patterns of migration.

SUMMARY

Two sites in Broward County, Fla., were selected to study the effects of effluent migration from septic tank systems. One site was in sand and the other in limestone, the two major surface lithologies in the county. The sites selected had received a daily input of domestic waste for more than 10 years and were isolated from any surrounding systems. The study was done during 1983-84.

The path and rate of effluent migration were determined by sampling ground water from multidepth wells located hydraulically downgradient from the two septic tank outlets and analyzing those samples for selected chemical constituents and physical parameters. The best indicators of effluent migration were concentrations of chloride, sulfate, nitrate, and ammonium.

Effluent moved primarily in the vertical direction because of low hydraulic gradients and was diluted or attenuated as it moved downgradient.

Effluent was detected more than 20 feet below the septic tank outlet at the sand site and more than 25 feet below the outlet at the limestone site. At the sand site, dissolved constituents in effluent were near background concentrations about 50 feet downgradient. Inorganic indicators of effluent were detected at the limestone site 40 feet downgradient but were near background concentrations.

The primary controls on effluent movement from septic tank systems in Broward County are the lithology and layering of the geologic materials, hydraulic gradients, and volume and type of use the system receives.

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