Water Quality in the Upper Floridan Aquifer in the Vicinity of Drainage Wells, Orlando, Florida

By L.A. Bradner

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CONVERSION FACTORS AND ABBREVIATIONS

The inch-pound units used in this report may be converted to metric (International System) units by the following factors.

Multiply inch-pound unit	By	To obtain metric unit
Length		
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
Area		
acre		0.4047hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
square foot (ft^2)	0.0929	square meter (m^2)
Volume		
million gallons (Mgal)	3,785	cubic meter (m^3)
gallon (gal)	3.785	liter (L)
Mass		
pound (lb)	.4536	kilogram (kg)
Flow		
foot per day (ft/d)	0.3048	meter per day (m/d)
foot per second squared (ft^2/s)	0.3048	meter per second squared (m/s^2)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
inch per year (in/yr)	25.4	millimeter per year (mm/yr)
Transmissivity		
foot squared per day (ft^2/d)	0.0929	meter squared per day (m^2/d)

Equations

For temperature conversion between degrees Celsius (°C) and degrees Fahrenheit (°F):

$$°C = 5/9\ (°F - 32)$$
$$°F = (9/5\ °C) + 32$$

For conversion from million gallons per day (Mgal/d) to inch per year (in/yr) in a square mile (mi^2):

$$\text{Mgal/d} = (0.04761\ \text{in/yr}) \times \text{mi}^2$$

Chemical concentrations are given in micrograms per liter (µg/L) and milligrams per liter (mg/L).

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Sea Level Datum of 1929."

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ABSTRACT

The city of Orlando, Florida, and surrounding areas have used drainage wells to alleviate flooding and to control lake levels since 1904. In the greater Orlando area of about 75 square miles, about 310 drainage wells are presently injecting an average of approximately 23 million gallons a day of surface water into the Upper Floridan aquifer, a zone of high transmissivity approximately 350-feet thick.

A 3-year study, from 1987 through 1989, encompassed about 6 square miles in the downtown urban area of Orlando and included water-quality analyses from wells influenced by inflow from one or more drainage wells. The water- quality data from the urban area were summarized and compared to water- quality data from wells in the Orlando area but upgradient from the urban study area and in the Ocala National Forest area about 50 miles north of Orlando.

Data from continuous monitoring of water quality in the vicinity of specific-use drainage wells (wells receiving lake overflow and stormwater runoff) were included in the study. Estimates of maximum inflow quantities ranged from 240,000 gallons per day to the stormwater-runoff well to more than 12 million gallons per day to the lake-overflow well. Average daily inflow for 1988 was about 9,000 gallons per day to the stormwater-runoff well and about 2.1 million gallons per day to the lake-overflow well.

Samples of water from the Upper Floridan aquifer in the urban Orlando area had tritium values ranging from 3 to 9.4 tritium units, indicating recent (1953 or later) recharge. Calcium, potassium, sodium, chloride, and ammonia are present in substantially higher concentrations in ground water in Orlando than in ground water from the background areas. The pH is substantially lower and the concentration of total organic carbon is substantially higher in ground water upgradient from Orlando and in the urban Orlando area than in ground water from the Ocala National Forest.

Organic compounds were detected in samples from 8 of the 11 wells in the urban Orlando area. Fluorocarbons were detected in samples from two wells. Most sources of the organic compounds are unknown; however, five of the wells sampled were within a hydrocarbon plume that probably originated as effluent from a former manufactured-gas plant.

One lake-overflow drainage well injected an estimated 6,900 pounds of nitrogen and 450 pounds of phosphorus into the aquifer in 1988. Increasing calcium concentrations in ground water downgradient from the drainage well indicate that dissolution of the limestone may be occurring. Higher sulfate concentrations in the ground water were associated with the wet season and higher inflows to the drainage well, indicating that oxygenated inflow water may be converting hydrogen sulfide gas contained within the ground water to sulfate. Specific conductance in the ground water is lowered by incoming stormwater, but rises sharply to background values when inflow to the drainage well ceases.

INTRODUCTION

A large part of the Orlando area contains closed drainage-basin lakes and has little topographic relief. To alleviate flooding and control lake levels, drainage wells have been used in the area since 1904. Some of the drainage wells were also used to drain effluent from large community septic tanks and various industrial wastes from processing plants until the 1950's (Unklesbay, 1944; Telfair, 1948; and Lichtler and others, 1968). Drainage wells have been closely regulated since the mid-1970's and few new wells have been permitted. Most of the newly permitted wells either receive air-conditioning return water or are replacement wells for drainage wells that have been plugged or otherwise destroyed. Most of these wells inject water into the Floridan aquifer system.

The Floridan aquifer system is used as the sole source of public water supply for the Orlando area. It consists of two definable layers of high transmissivity--Upper Floridan aquifer and Lower Floridan aquifer--separated by a less permeable, middle semiconfining unit (Tibbals, 1990). The Upper Floridan aquifer receives most of the inflow from drainage wells. Both the Upper and Lower Floridan are used for public supply; the Lower Floridan is used by the large municipalities for high-volume withdrawal in areas where drainage wells are most prevalent, and the Upper Floridan is used by utilities in outlying areas (fig. 2).

Because of increasing urbanization, the potential for hydrocarbons or other contaminants to enter the Upper Floridan aquifer through drainage wells is increasing. Previous studies involving drainage wells have not shown elevated concentrations of inorganic constituents in water from supply wells in the study area. However, these studies have indicated that the water near drainage wells has elevated concentrations of nitrates, total iron, and coliform bacteria (Schiner and German, 1983). Little data are available on organic constituents in ground water near these wells.

In order to expand the data base and knowledge of the long-term effects of the use of drainage wells on the Upper Floridan aquifer in the Orlando area, the U.S. Geological Survey, in cooperation with the Florida Department of Environmental Regulation, began a study in 1987 to analyze the water quality of the aquifer in and downgradient from an area having a high density of drainage wells.

Purpose and Scope

This report assesses the effects of drainage wells on the quality of water in the Upper Floridan aquifer in the urban Orlando area. The greater Orlando study area of about 75 mi^2 (square miles) was used for information on water levels and water quantity, within which an area of about 6 mi^2 in downtown urban Orlando was chosen for intensive study. Two background areas that are similar hydrologically were also studied for comparison of effects of natural recharge and man-induced drainage-well recharge (figs. 1 and 2).

The urban area is highly developed and contains a high density of drainage wells. The two background areas include one that is adjacent and upgradient to the urban area (low density of drainage wells) and one that is a rural forest area (no drainage wells). The comparison included organic constituents that have not been thoroughly studied in the area as well as conservative inorganic constituents that may show general long-term increases in concentration.

During the 3-year study, from 1987 through 1989, water-quality samples were collected and analyzed from wells affected by inflow from one or more drainage wells. Estimates of inflow to two selected drainage wells were made and continuous data were collected for water levels, specific conductance, and temperature in nearby observation wells. Geophysical logs of the two drainage wells were run to physically describe the wells. Attempts were made to sample bottom sediments in two drainage wells, but the meager deposits recovered from the wells were insufficient for analysis.

Previous Studies

The first mention of drainage wells in the Orlando area was in a report by Sellards and Gunter (1910) on the artesian water supply of eastern Florida. The first use of a drainage well was for relief from surface flooding caused when a sinkhole became plugged in 1904 and water began to flood downtown Orlando.

Several other reports by Stringfield (1933), Unklesbay (1944), and Telfair (1948) documented the presence of more than 200 drainage wells drilled in the Orlando area. Included in these studies were data concerning water levels, inflow to drainage wells, and analyses of bacterial samples from nearby wells. Telfair's study concentrated on wells receiving septic-tank effluent. Until the late 1940's, nearly all of the primary-treated sewage in Orlando was put into drainage wells. Of 102 wells sampled in Orlando in 1948 by Telfair, 38 had high bacteria levels, with some samples possibly indicating the influence of sewage.

Telfair (1948) also reported the occurrence of methane in several water- supply wells in the Orlando area. These wells included a dairy supply well near a drainage well receiving unknown effluent, a domestic well near a drainage well receiving effluent from a citrus-processing plant, a bakery supply well near drainage wells receiving brewery and septic-tank effluent near Lake Ivanhoe, and a drainage well receiving street runoff and located near the aforementioned dairy and citrus-processing plant.

Lichtler and others (1968) added to the data base with data collected in 1960. In 1959 and 1960, above-normal rainfall caused persistent flooding in the Orlando area which resulted in increased drilling of drainage wells. By 1965, there were about 400 drainage wells in Orange County.

A publication by Black, Crow, and Eidsness, Inc., (1968) was fairly definitive in tracing movement of wastes within ground water. That report indicated that effluent from a citrus-processing plant was flowing into a drainage well and being pumped out of the aquifer by a production well 2,500 feet from the inflow point. Although the drainage well was 1,070 feet deep, most of the effluent was moving into the upper transmissive zones just below the casing, 218 feet below land surface. Several studies evolved out of the growing concern for water quality during the late 1970's and early 1980's. Reports by Kimrey (1978), Schiner and German (1983), and Kimrey and Fayard (1984), indicated that there was very little effect on the quality of water in the Upper Floridan aquifer caused by drainage wells, except for bacteria, iron, and nitrate. German (1989b) documented the presence of volatile and polycyclic organic hydrocarbons in inflow to drainage wells and in ground water within the immediate vicinity of the drainage wells; however, the appearance of these compounds was sporadic and concentrations were fairly low.

Rutledge (1987) detected trace elements in water from wells in the Orlando area that exceeded water-quality standards set by the Florida Department of Environmental Regulation. Also detected were several organic compounds for which there are no limits established for potable water.

German (1989a) used a simple, conceptual model to evaluate the buildup of a conservative constituent in the Upper Floridan aquifer as might be caused by inflow through drainage wells. This model indicated that, although effects of drainage-well inflow should now be apparent, concentrations would increase for several more decades before equilibrium would be reached. Because the model simulated a conservative constituent, the results could not be used to predict the fate of organic constituents or metals.

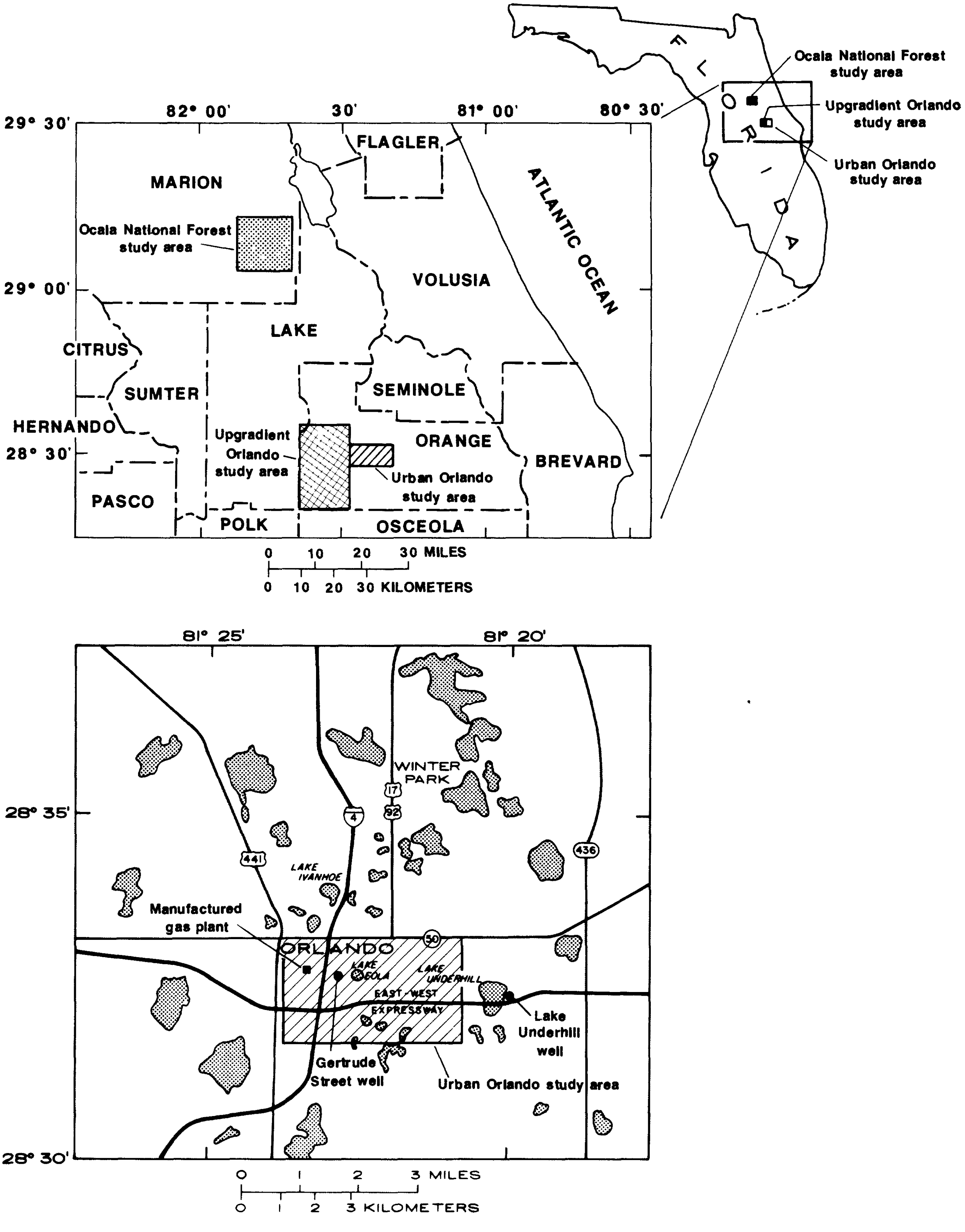


Figure 1. Study areas.

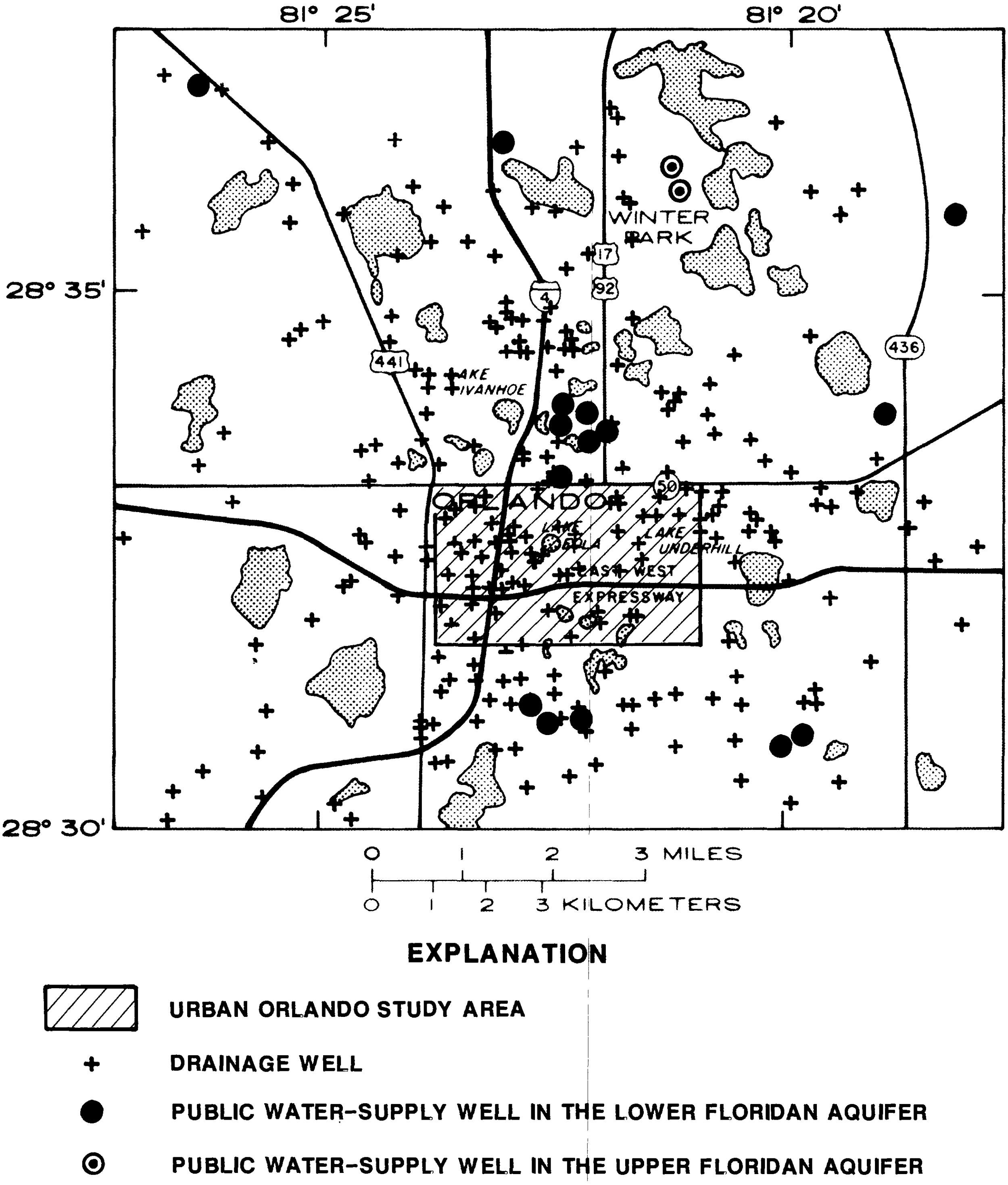


Figure 2. Location of drainage wells and public-supply wells within the study area.

Climate and Land Use

The Orlando area has a subtropical climate and receives an average of 47.82 inches of rain annually (National Oceanic and Atmospheric Administration, 1989). The total rainfall in Orlando in 1988 was 52.49 inches, almost 5 inches above the average. The typical rainy season begins in about mid-May and ends in mid-October. Most rainfall is of high intensity and short duration. Rainfall intensities commonly can be more than 1 inch per hour.

Land use in downtown Orlando is urban, with large commercial areas and accompanying streets and highways. Other land uses in the city include light industrial, residential, and recreational (parks).

Acknowledgments

Appreciation is expressed to the many well owners that provided access to their wells. Special thanks are due to David Pierce, Kenneth Hassel, Hollis Hair, and David Zeno of the City of Orlando and Carla Palmer of Dyer, Riddle, Mills, and Precourt, Inc., for data and assistance in field work. Appreciation is also expressed to the staff of the Greater Orlando Aviation Authority for allowing access to and providing security for the Lake Underhill site. Special thanks are also expressed to Clyde Grant of Orlando, a former employee of the Florida Public Service Company, for information on the physical operation of the manufactured-gas plant.

STUDY APPROACH

This study examines the effects of drainage wells in the Orlando area on water quality in the receiving aquifer. The study was divided into two parts--a general areal water-quality assessment to determine the combined effect of multiple drainage wells and a specific analysis of the individual effects of two drainage wells with different types of inflow (one at Lake Underhill and one at Gertrude Street). As an off-shoot of the assessment of ground-water quality near the Gertrude Street drainage well, a hydrocarbon contaminant plume in the ground water at this site was sampled and delineated. The number of wells sampled in this and in other facets of the investigation are present in the following table.

Study sites (see fig. 1)	Number of wells	Objective for sampling
Ocala National Forest	9	Test background water quality in a pristine area
Upgradient Orlando	18	Test background water quality in an area upgradient from Orlando with low density ofdrainage wells
Urban Orlando area	14	Test water quality in an area of high density of drainage wells
Lake Underhill	3	Test water quality at a lake-overflow site
Gertrude Street	2	Test water quality at a direct stormwater runoff site
Manufactured-gas plant	8	Define hydrocarbon plume

A set of 18 wells directly west and upgradient from the urban Orlando area was chosen for determining background water quality in the Upper Floridan aquifer. Most of the wells in this upgradient area are in an area where the Upper Floridan is confined, there is a low density of drainage wells, and wells are in a hydrologic setting similar to that in the urban area. A second set of 9 wells was selected from the Ocala National Forest, 50 miles north of Orlando (fig. 1) for additional background water-quality information. This background area has a similar hydrogeologic setting and is considered to be unaffected by urbanization.

A set of 14 wells consisting of 11 production and observation wells, 2 drainage wells, and a pressure relief well in downtown Orlando was chosen to represent water quality of the urban area. The locations of these wells are shown in figure 3. Concentrations of tritium and organic compounds in samples from these wells were compared to the Ocala National Forest and in the Orlando area upgradient from the urban area. A nonparametric statistical analysis of major chemical constituent and nutrient concentrations was used to compare the data from the three areas. Data from the two background areas were compared with each other and to data in the downtown urban area. All tests were run at a significance level of 0.05.

Two drainage wells, the Gertrude Street well and the Lake Underhill well, were chosen for intensive study (fig. 1). The Gertrude Street well receives low volumes of direct stormwater runoff mostly from streets and parking lots, and the Lake Underhill well receives lake overflow. Lake Underhill receives stormwater runoff from various land-use types and basically acts as a large detention basin for the overflow that enters the adjacent drainage well. Monitoring wells were drilled downgradient from the Gertrude Street well (site 5) and Lake Underhill drainage well (sites 15 and 16).

The locations of the 14 wells in the urban study area are shown in figure 3. Table 1 lists wells in the urban area and near Lake Underhill that were sampled for the study. Sites 9 and 10 (drainage wells) and site 6 (a pressure-relief well for a drainage well) were sampled only for organic compounds. The 11 wells used for sampling and comparison to the background wells included irrigation wells and wells used for supply to water-cooled air conditioners and generators. There are no Upper Floridan aquifer public water-supply wells within this area.

Various water-quality constituents including hydrocarbons, pesticides, and volatile organic compounds were analyzed to supplement the existing data base. These compounds are indicative of anthropogenic activities that could cause a water supply to become unusable. Volatile organic compounds, such as fluorocarbons, were not used widely until the 1940's and detection of these in sampled water would indicate the presence of recent recharge water in the aquifer.

Nitrogen and phosphorus species and total organic carbon analyses were also selected as an indication of organic matter or the breakdown products of organic matter.

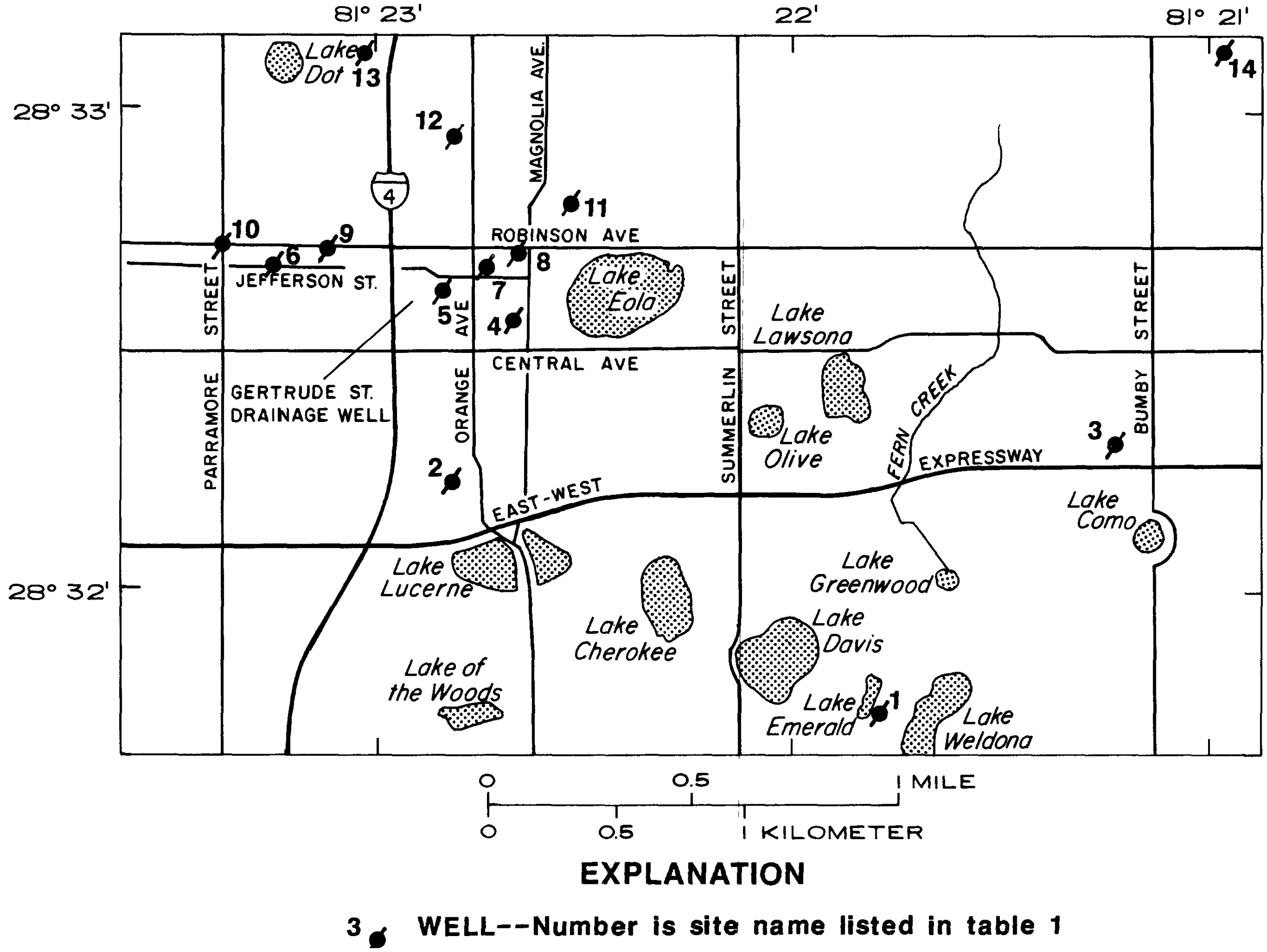


Figure 3. Location of wells sampled within the urban Orlando area.

Table 1. *Upper Floridan aquifer wells in the Orlando area sampled as part of the study*

Site number	Site identification number	Current use of well	Depth (feet)	Diameter (inches)
Urban Orlando sites				
1	283147081214701	Lake augmentation	428	12
2	283218081224801	Air conditioning	Unknown	6
3	283223081211501	Irrigation	214	4
4	283235081223801	Engine cooling	Unknown	6
[1]5	283240081225001	Observation	247	4
6	283241081231501	Pressure relief	275	12
7	283242081224201	Irrigation	Unknown	6
8	283243081224101	do.	290	6
9	283243081230701	Drainage	199	6
10	283244081232001	do.	376	12
11	283252081223101	Irrigation	260	4
12	283300081224701	do.	231	4
13	283309081230001	do.	Unknown	4
14	283310081205901	do.	257	6
Lake Underhill sites				
[2]15	283219081195501	Observation	375	4
[3]16	283219081195601	do.	375	4
[4]17	283219081195701	Drainage	375	20

[1]Gertrude Street monitoring well.
[2]Lake Underhill monitoring well 1.
[3]Lake Underhill monitoring well 2.
[4]Lake Underhill monitoring well 3.

Previous studies had indicated that higher concentrations of these constituents exist in water sampled from drainage wells in the Orlando area than in water from public water-supply wells in the area (Schiner and German, 1983, and Kimrey and Fayard, 1984). Metals are traffic-related elements that have been detected in stormwater runoff in the area, as well as in water from drainage wells. Metals selected for analysis included iron, manganese, lead, chromium, and zinc.

Tritium concentrations were also determined in order to identify recharge water that may be less than 35 years old. Tritium is the radioactive isotope of hydrogen (3H) with a half-life of 12.43 years (Ostlund and Dorsey, 1977). High concentrations of tritium began to appear in precipitation after the detonation of hydrogen bombs during tests in the early to mid-1950's, peaking in concentration in 1963. Tritium in rainfall at Ocala, Fla., (75 miles northwest of Orlando) varies seasonally and now ranges between 3 and 15 tritium units (TU) (unpublished data in the files of the U.S. Geological Survey, Ocala, Fla.). Tritium concentrations in ground water that has not received recent recharge (wells located in the discharge areas of the State) are generally less than 0.5 TU (unpublished data in the files of the U.S. Geological Survey, Altamonte Springs, Fla.). Ground water in Florida rarely has tritium concentrations higher than 10 or 11 TU.

Water samples were collected at the outlet nearest to the well or with a thief sampler where discrete samples were obtained from the uncased part of the well. Pumped samples were taken after clearing at least three well casing volumes of water. Standard collection methods of the U.S. Geological Survey were used (Brown and others, 1970). Water samples were analyzed using standard U.S. Geological Survey methods as described by Thatcher and others (1977), Wershaw and others (1983), and Fishman and Friedman (1985). Trace elements were analyzed by atomic absorption flame spectrometry and organic compounds were extracted from the samples with an organic solvent and analyzed by gas chromatography. Most compounds were identified using laboratory reference standards. Some organic compounds not having laboratory reference standards were tentatively identified using a National Bureau of Standards library of mass spectra. Quality assurance included collection of split samples, duplicate samples, and the use of field blanks.

Data were collected using a tipping-bucket rain gage for rainfall, recorders for water-level data, and a U.S. Geological Survey minimonitor for temperature and specific conductance. All data collected are stored and available in files of the U.S. Geological Survey office, Altamonte Springs, Fla.

Temperature and conductance sensors within the monitoring wells were suspended approximately 30 feet below the bottom of the casing. Because of the small well diameters, float-operated water-level recorders could not be used in the monitoring wells. In these wells, water-level pressure transducers (with an accuracy of 0.05 foot) were connected to the minimonitors, and used to collect water-level data.

Monitoring wells located downgradient from the Gertrude Street and Lake Underhill drainage wells were placed within short distances (85 feet, well 5; 85 feet, well 15; and 170 feet, well 16) of the drainage wells, because the high transmissivity of the aquifer and large volume of water in storage could dilute any effects caused by inflow. Monitoring wells were constructed with the same length of casing and to the same depth as the drainage wells whenever possible. Wells were drilled by cable-tool and mud-rotary methods.

HYDROGEOLOGIC FRAMEWORK

Hydrogeologic Units

The study area is underlain by about 50 feet of surficial sand and silt (surficial aquifer) which are in turn underlain by about 150 feet of sandy clay, silt, and shell (intermediate confining unit). The lower part of the intermediate confining unit is in some places sufficiently transmissive to yield enough water for small irrigation systems.

The intermediate confining unit overlies about 2,500 feet of limestone and dolomite that comprise the Floridan aquifer system (table 2). The upper 1,500 feet contains freshwater and consists of two very transmissive layers, the Upper and Lower Floridan aquifers, separated by a middle semiconfining unit of less permeable limestone (fig. 4). Transmissivities of those units in the study area range from 50,000 to 400,000 ft^2/d (feet squared per day) for the Upper Floridan aquifer and from 100,000 to 600,000 ft^2/d for the Lower Floridan aquifer (Tibbals, 1990).

Ground-Water Movement

The potentiometric surface of the Upper Floridan aquifer for September 1988 is shown in figure 5. A regional west-to-east slope of the potentiometric surface indicates general ground-water movement to the east. Potentiometric surface maps for 1930 and 1943 by Unklesbay (1944) and for 1961 and 1962 by Lichtler and others (1968), showed a mound in the southern part of the city that has persisted as of 1988. However, data collected as part of this study indicate that mounds occur only during the rainy season in areas where lake-overflow wells are located. The depression shown in the potentiometric surface east of Lake Ivanhoe (fig. 5) is probably due to pumping of water from the Lower Floridan aquifer with resultant induced leakage of water from the Upper Floridan aquifer through the semiconfining unit.

Table 2. *Summary of geologic and hydrogeologic units and their water-bearing characteristics In and description of the geologic*

[>, greater than]

Series	Geologic unit	Thickness (feet)	Lithology	Water-bearing characteristics	Hydrogeologic unit
Holocene to Pliocene	Undifferentiated; may include Caloosahatchee Marl	0-100	Quartz sand with varying amounts of clay and shell.	Varies widely in quantity and quality of water produced.	SURFICIAL AQUIFER SYSTEM
Miocene	Hawthorn Formation	100-150	Gray-green, clayey, quartz sand and silt; phosphatic sand; and buff, impure, phosphatic limestone.	Generally low permeablility except for limestone, shell, or gravel beds. Lower limestone beds may be part of Upper Floridan aquifer.	INTERMEDIATE CONFINING UNIT
					FLORIDAN AQUIFER SYSTEM
Eocene	Ocala Limestone	0-125	Cream to tan, fine, soft to medium hard, granular, porous, sometimes dolomitic limestone.	Moderately high transmissivity. Most wells also penetrate underlying formations.	Upper Floridan aquifer
	Avon Park Formation	>1,500	Upper section mostly cream to tan, granular, porous limestone. Lower section mostly dense, hard, brown, crystalline, fractured dolomite alternating with chalky fossiliferous layers of limestone.	Overall transmissivity very high. Contains many interconnected solution cavities. Many large capacity wells draw water from this formation.	Upper Floridan aquifer Middle semi-confining unit Lower Floridan aquifer

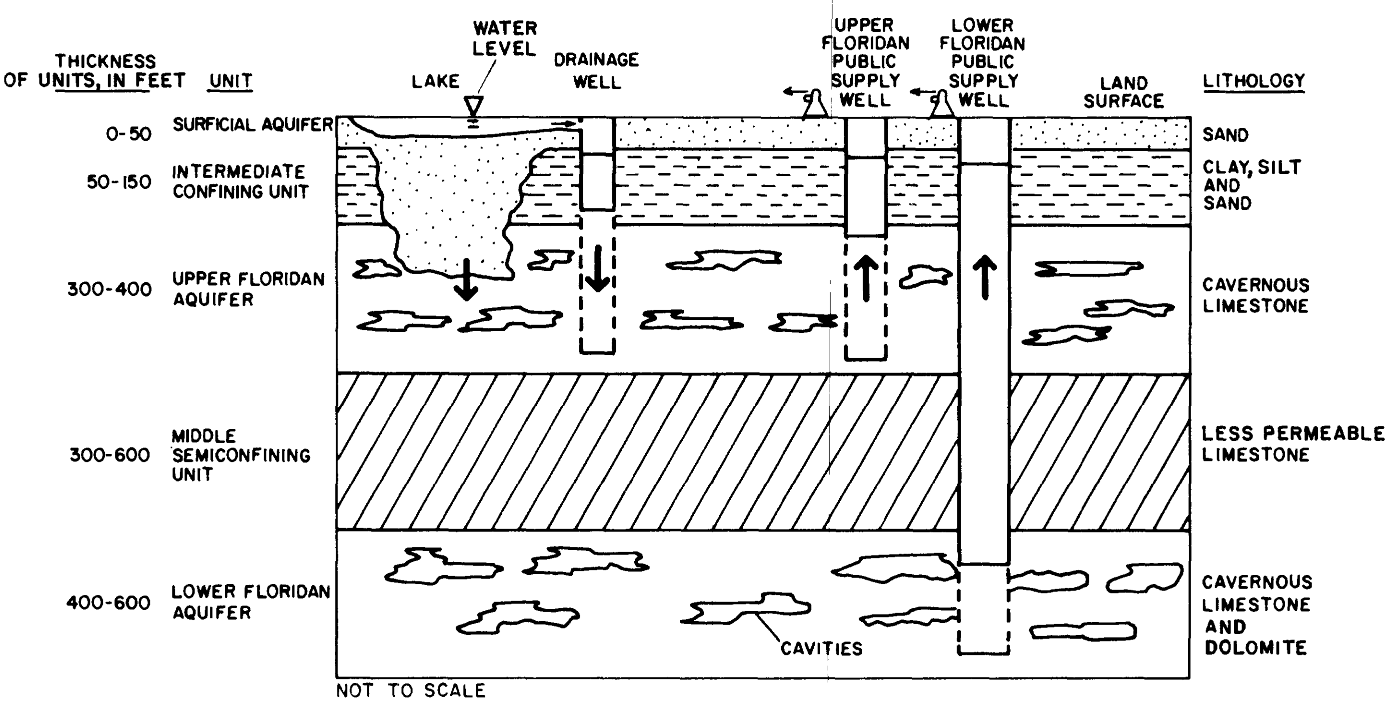
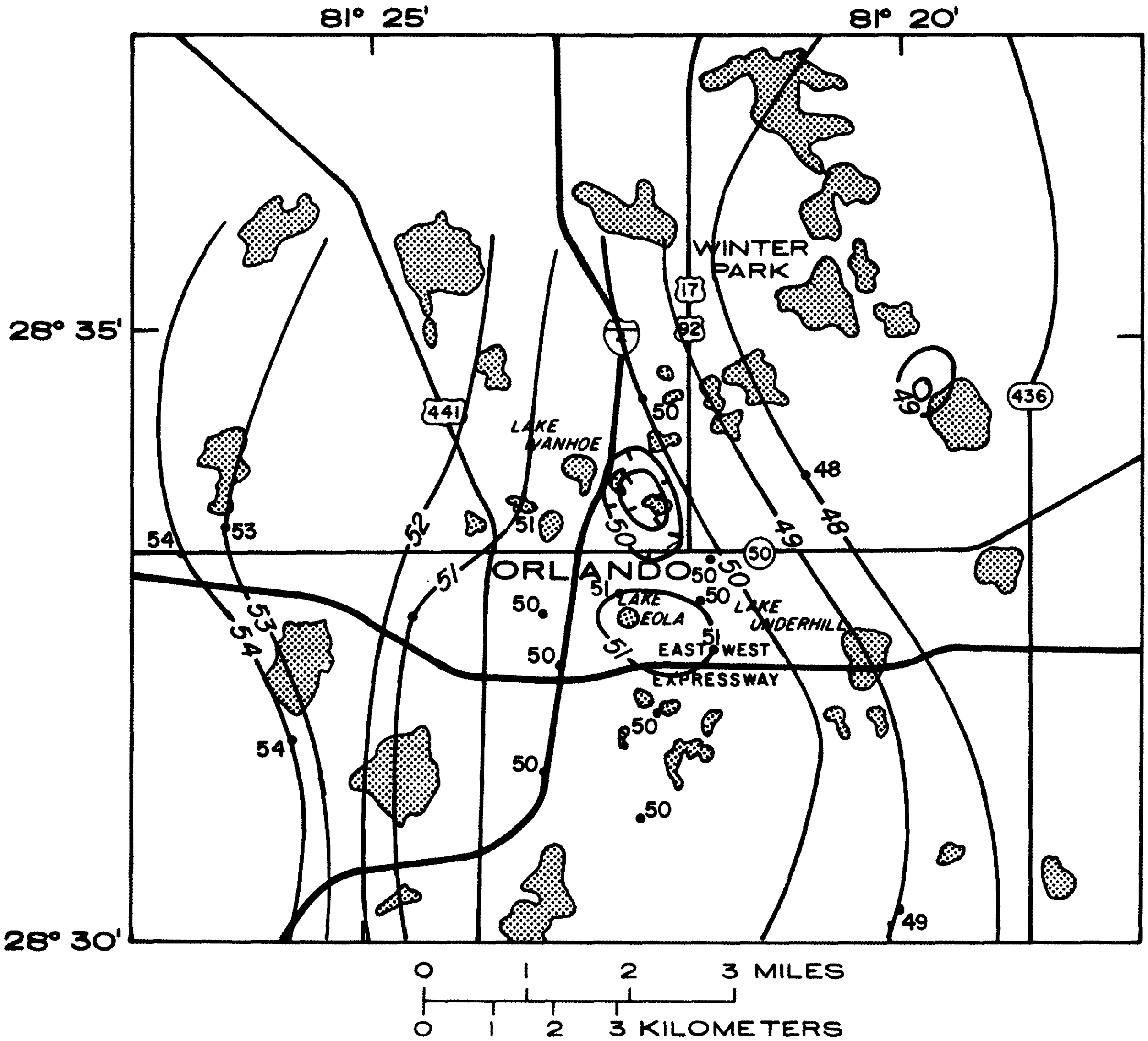


Figure 4. Generalized hydrogeologic section in the Orlando area.



EXPLANATION

——50—— **POTENTIOMETRIC CONTOUR--Shows altitude at which water level would have stood in tightly cased wells, September 1988. Contour interval 1 foot. Datum is sea level**

•51 **WELL--Number is altitude of water level in well, in feet above sea level**

Figure 5. Potentiometric surface of the Upper Floridan aquifer, September 1988.

Ground-Water Withdrawals and Recharge

Ground-water withdrawals from public water-supply wells shown in figure 2 were mostly from the Lower Floridan aquifer and totaled about 51 Mgal/d (million gallons per day) in 1985 (Marella, 1988). The amount of water withdrawn for other uses, such as landscape irrigation, industry, and agriculture, is not known, but withdrawals for these uses are believed to occur from both Upper and Lower Floridan aquifers.

Total recharge to the Floridan aquifer system in the greater Orlando area shown in figure 2 is estimated at about 22 in/yr (inches per year) (German, 1989a). This consists of 20 percent lateral flow from areas to the west, 50 percent diffuse leakage, and 30 percent recharge from drainage wells.

DRAINAGE WELLS

Locations and Design Characteristics

By the 1960's, there were about 175 drainage wells in Orlando, with densities averaging about 5 wells per square mile in the outer areas and 15 wells per square mile in the urban Orlando area (fig. 2). Currently, there are approximately 310 drainage wells within the greater Orlando area shown in figure 2. Diameters of drainage wells range from 4 to 24 inches; more than half are 12 inches or larger. About 50 percent of the drainage wells receive stormwater runoff directly, either from streets or other impervious areas; 30 percent receive lake overflow; 15 percent receive wetland outflow; and the remaining 5 percent either receive water returned from air-conditioning units or are unused wells that historically received industrial effluent or sewage.

Direct stormwater drainage wells generally are 12 inches or less in diameter, are cased to the top, or just short of the top of the Upper Floridan aquifer, and commonly have less than 100 feet of open hole in the Upper Floridan aquifer. These wells are designed to receive stormwater runoff through culverts and overflow pipes. There are usually no controls for inflow except casing elevation. Most lake-overflow wells are 12 or more inches in diameter and have about 200 to 400 feet of open hole in the Upper Floridan aquifer. These wells are designed to maintain lake levels and receive excess water after storms. Some receive lake overflow nearly year round. The inflow is usually controlled by stop-log weirs, intake pipe invert elevation, or elevation of top of casing.

Wetland-outflow wells are usually of the same design as lake-overflow wells, except the inflow comes from a drainage canal, a detention pond, or seeps slowly through low areas in a swamp to the intake. Most of these wells receive inflow nearly year-round.

Less than 5 percent of drainage wells receive water from water-to-air cooling and heating systems. These wells are part of closed systems, are usually small in diameter (less than 8 inches), and receive water nearly year-round.

In the past, effluents from breweries, dairies, septic tanks, industry, and citrus-processing plants have been placed into drainage wells. Most of these wells have been plugged, abandoned, or used to receive stormwater runoff or lake overflow. Data from these historic effluent wells remain in the data base on drainage wells because their effect on current water quality is unknown.

Sources of Inflow

Water entering drainage wells can be classified into six groups (Dyer, Riddle, Mills, and Precourt, Inc., 1982), based on land use of the area. These groups are lake pretreatment, residential runoff, commercial runoff, industrial runoff, high-density combination runoff, and other runoff from vacant land and parks. The urban Orlando study area includes wells that receive all types of stormwater runoff except direct industrial runoff. Also in the study area are lakes that receive drainage from large areas of mixed land use. The sizes of the drainage areas contributing flow to the wells span a large range--from 2 acres to 1,100 acres.

The total drainage area to the Gertrude Street drainage well, a direct stormwater-runoff well, is probably less than 100,000 ft^2 (square feet) or about 2 acres (figs. 6 and 7) of commercial property. In contrast, the drainage area to Lake Underhill, and ultimately its drainage well (fig. 6), consists of 1,118 acres (Dyer, Riddle, Mills, and Precourt, Inc., 1982) and contains four types of land use. These are: citrus, 9 acres; open grassland, 12 acres; residential, 205 acres; and commercial-industrial, 892 acres.

Quantity of Inflow

Total recharge through drainage wells to the Upper Floridan aquifer in central Florida has been estimated to average about 30 Mgal/d (Tibbals, 1990). The greater Orlando study area shown in figure 2 contains 310 drainage wells, or 78 percent of the approximately 400 wells used to estimate the recharge. Based on this percentage, recharge in the area shown in figure 2 probably is at least 23 Mgal/d. Most of the large-volume lake- overflow wells are located in Orlando and the 23 Mgal/d estimate may be low. A long-term mounding effect, causing a maximum head buildup of 4 feet in the area with the highest density of drainage wells (fig. 8), was also estimated from simulation studies by Tibbals (1990). The buildup gradually decreases in outlying areas where there are fewer drainage wells per square mile. The mounding effect is not evident in some areas because of the ground-water withdrawals that mask the recharge.

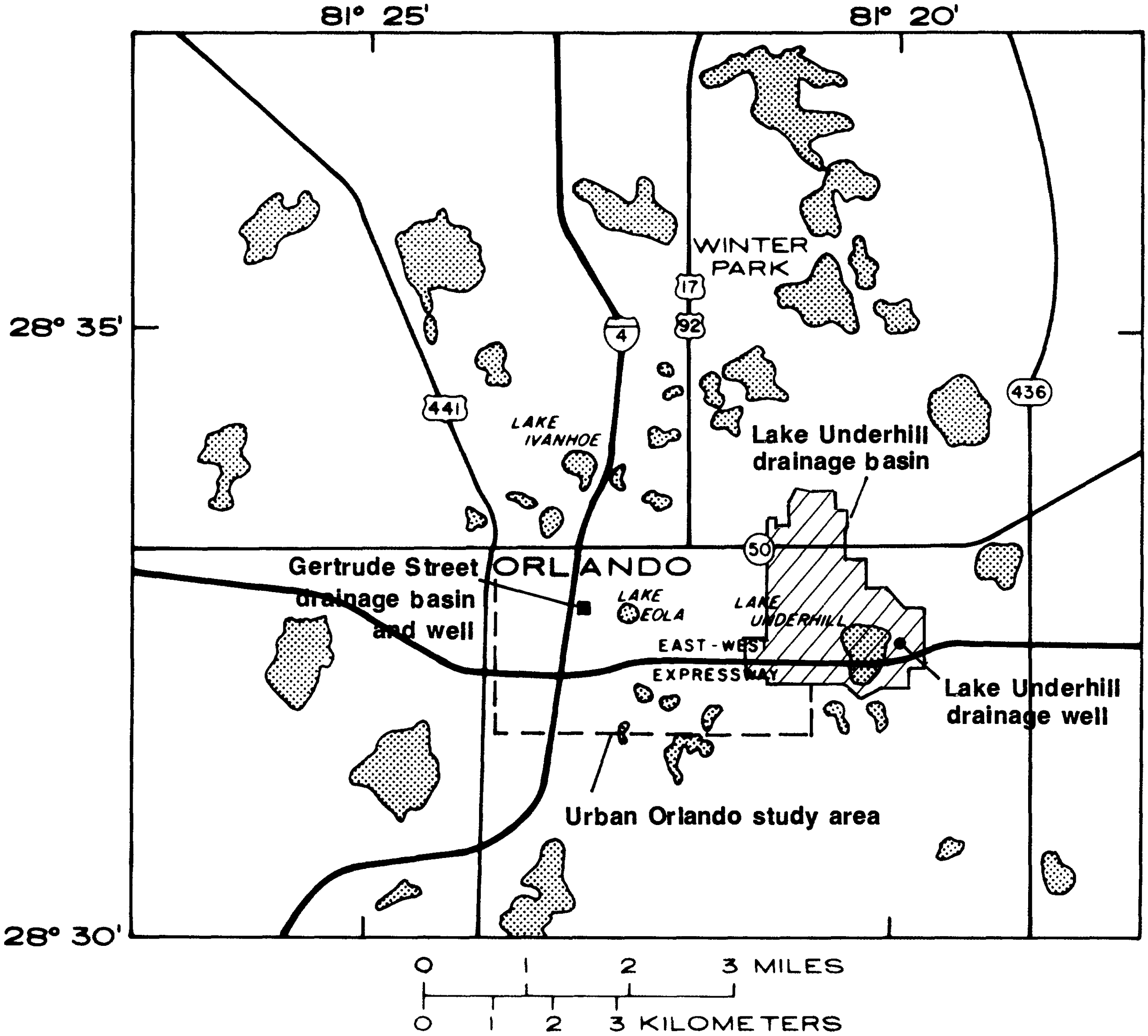


Figure 6. Drainage basins of the Lake Underhill and Gertrude Street drainage wells.

Inflow to individual drainage wells varies with the size of the drainage basins and percentage of impervious areas within the basin. Inflows to the Gertrude Street and Lake Underhill drainage wells are examples of this.

Inflow through the Gertrude Street drainage well is primarily stormwater runoff from impervious surfaces (fig. 7). All runoff in the drainage basin is curb and gutter flow into the stormwater collection system connected to the drainage well. There should not be any backwater in the system due to the small drainage area and large collection basins. For a 1-inch rainfall, this small drainage area would probably contribute about 60,000 gal (gallons) of water. Total inflow for 1988, on the basis of 53 inches of rain, would be 3.3 Mgal (million gallons) or a daily average of about 9,000 gal. Maximum inflow during 1988 was about 240,000 gal during a 4-inch rain in November 1988. There is probably no ground-water seepage from the surficial aquifer into the storm sewer in this area because the water table is approximately 15 feet below land surface and, thus, inflow would only enter the well during storms.

The Lake Underhill site (fig. 9a) is fairly representative of lake-overflow well sites in the area, with stop-log weirs and controlled lake levels. Inflow to the drainage well continues even when the lake level is lowered because of ground-water seepage to the lake. The lake surface area is approximately 141 acres (Dyer, Riddle, Mills, and Precourt, Inc., 1982).

A schematic diagram of the Lake Underhill site in figure 9a shows the location of the monitoring wells and intake to the drainage well. The inflow to the drainage well is controlled by an 8-foot wide stop-log weir, which allows water to free fall into a corrugated metal pipe leading to the drainage well. The drainage well is 20 inches in diameter, with 270 feet of casing and 95 feet of open hole for a total depth of 365 feet. Caliper logs for the well indicate a large cavity in the bottom 45 feet of the well.

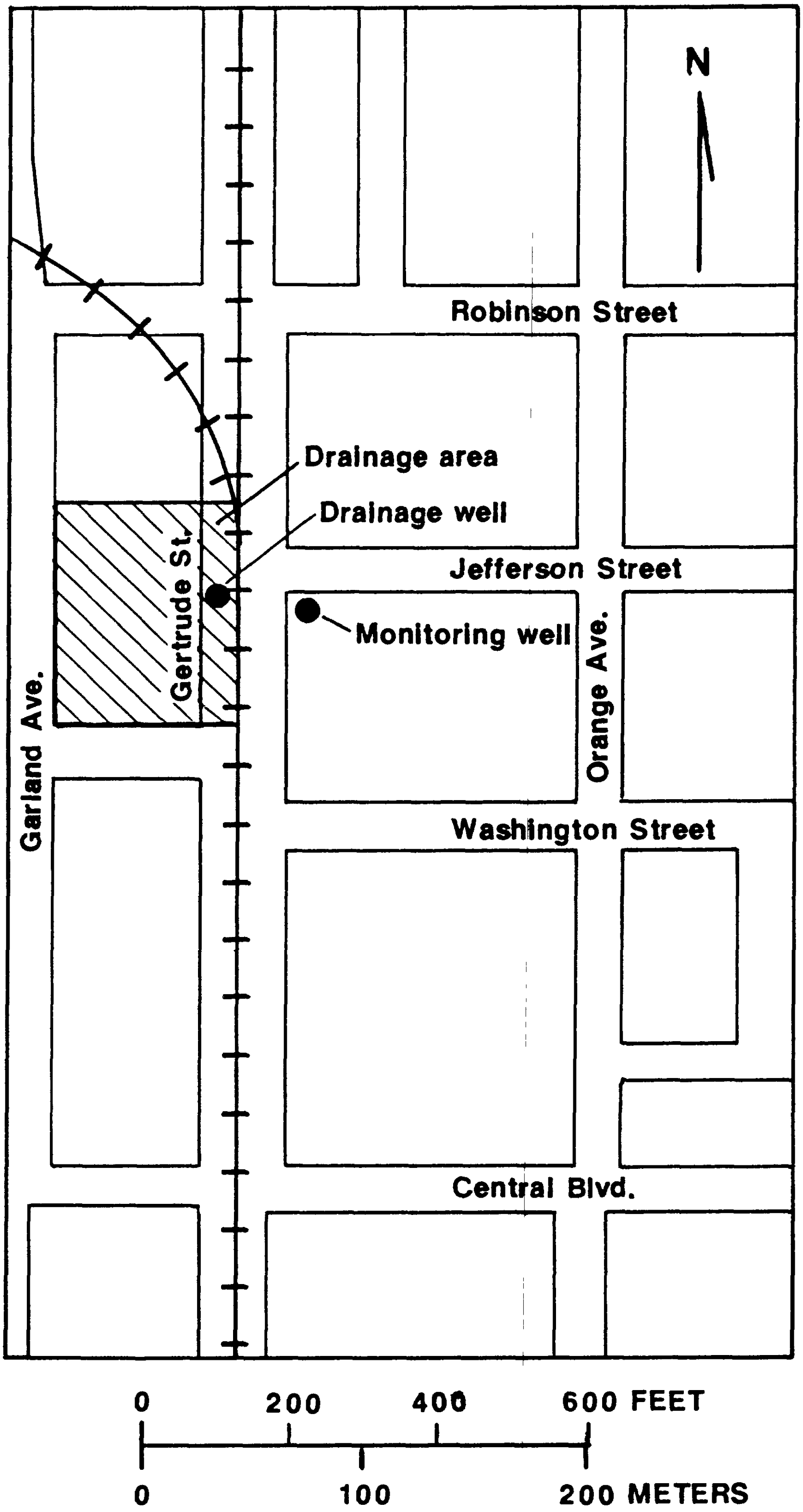
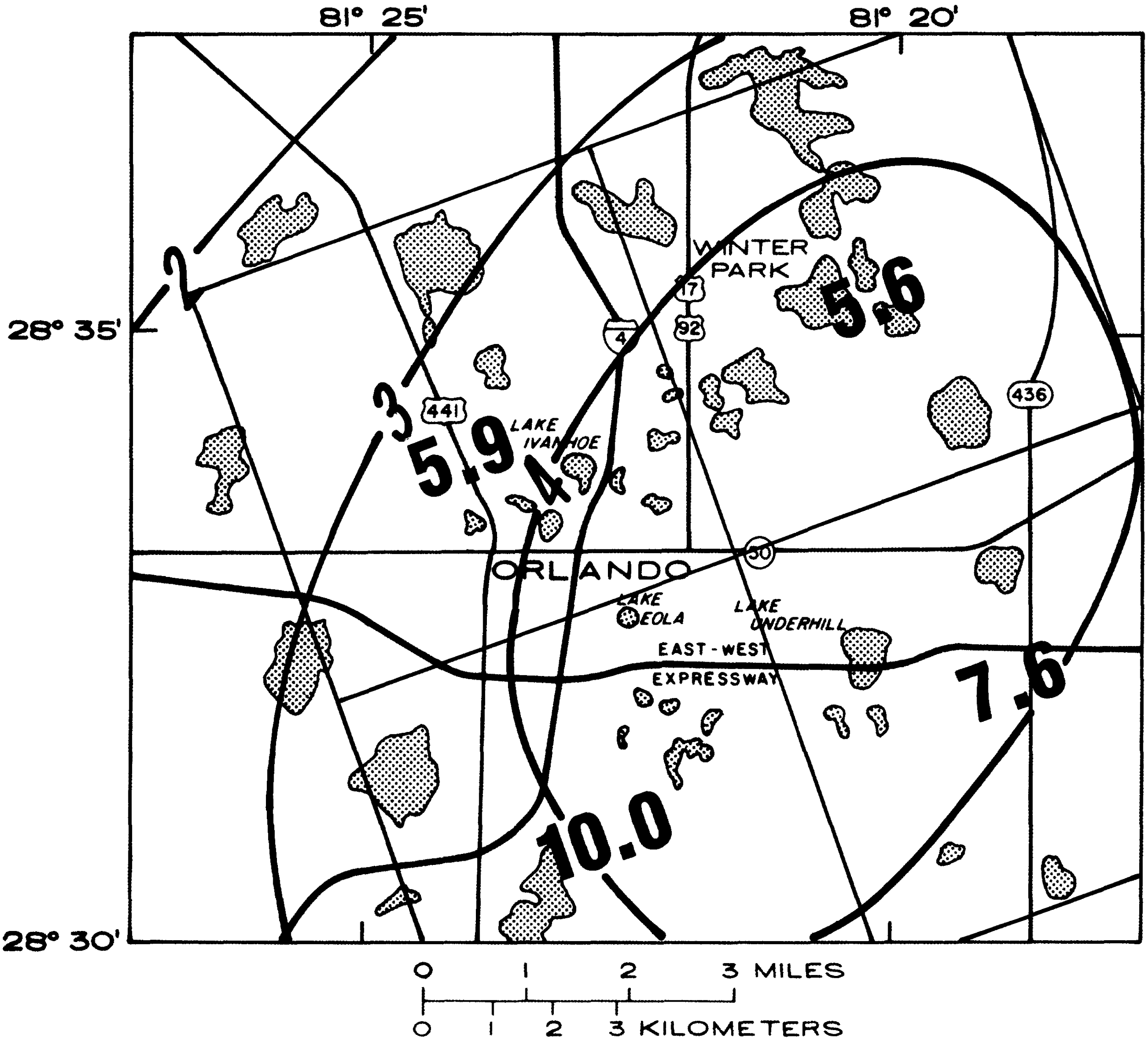


Figure 7. Schematic diagram of Gertrude Street monitoring site.



EXPLANATION

—— 4 —— LINE OF EQUAL SIMULATED BUILDUP IN THE UPPER FLORIDAN AQUIFER--Interval 1 foot

10.0 AREA WHERE RECHARGE OCCURS THROUGH DRAINAGE WELLS--Number is average recharge rate within area, in million gallons per day

Figure 8. Map showing simulated buildup of potentiometric surface of the Upper Floridan aquifer caused by recharge through drainage wells, 1978.

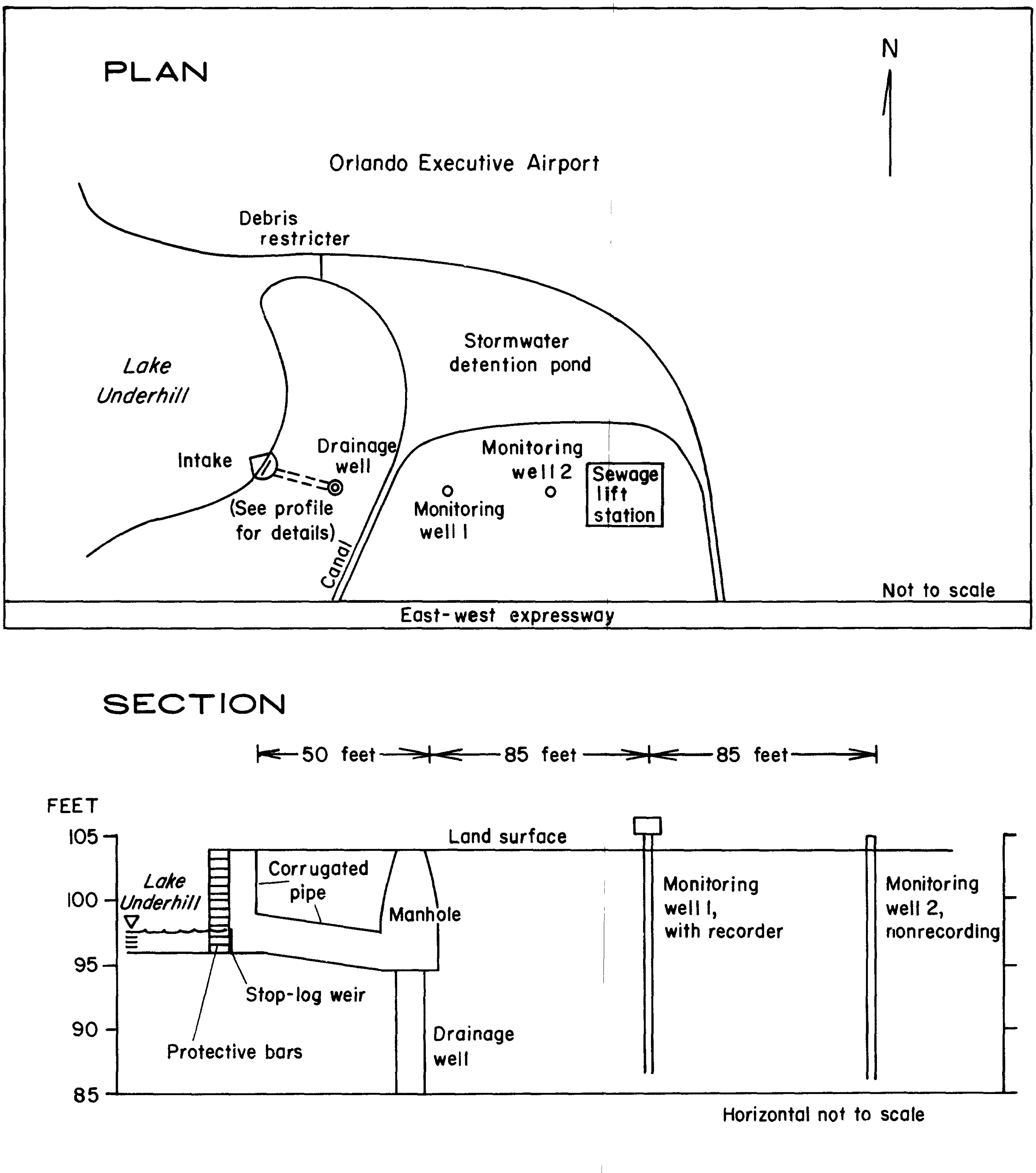


Figure 9a. Lake Underhill monitoring site.

Outflow from Lake Underhill is controlled by three factors. These are: the stop-log weir, hydraulics of the well casing, and the transmissivity of the aquifer (fig. 9b). During normal operation of the system during the study period, most of the flow was controlled by the weir, with some backwater effects caused by turbulence and pipe hydraulics during extreme high flows.

Outflow from Lake Underhill was calculated using the sharp-crested weir formula (Brater and King, 1976, chap 5);

$$Q = CLH^{3/2}$$

where

Q is the discharge, in cubic feet per second;
C is a coefficient, 3.22 for sharp-crested weirs,
L is length of weir in feet, and
H is the height above the weir, in feet.

Flow over the weir is usually not affected by backwater until a depth of about 3 feet is reached in the manhole (fig. 9a, 9b). The depth of 3 feet is an approximate depth based on the 2-foot drop in the slope of the culvert and about 1 foot depth of water over the weir. Until this depth is reached in the manhole, the weir formula is used for calculating the flow. These backwater effects cannot be separated from the effects caused by pipe hydraulics because of the short duration of high flow and the varying heads above the well casing during these periods.

During extreme high flows, backwater forms at the weir because the 20-inch casing cannot hydraulically accept all the water that can flow through the intake. At these higher flows, discharge was calculated using the submerged orifice formula (Brater and King, 1976, chap. 4);

$$Q = CA\sqrt{2gh},$$

where

Q is discharge in cubic feet per second,
C is the coefficient of discharge for sharp-edged circular orifices, 0.602,
A is area of opening in feet squared,
g is acceleration due to gravity (32.17 feet per second squared), and
h is head above the orifice in feet.

Because the water level above the pipe could only be estimated, flows calculated from the submerged orifice formula were verified as reasonable values by calculations of loss in storage volume from the lake during the same period. The maximum calculated discharge using this method was about 20 ft^3/s (cubic feet per second) or 9,200 gal/min (gallons per minute) in November 1988 after a 4-inch rain. Flows may have been higher, but probably were not lower than these estimates.

Vortex action of the water above the casing reduces the effective head above the pipe orifice; however, that reduction in pipe flow is not a factor until the head over the pipe is such that the weir is submerged. The decrease in discharge due to friction losses in the pipe is probably low because of the large diameter of the casing.

The transmissivity of the aquifer is apparently high enough in the vicinity of Lake Underhill to accept at least the 9,200 gal/min in November 1988 by gravity flow. The flow calculations may be reasonably accurate for as much as about 5 feet of head over the submerged orifice of the well, or the maximum depth estimated during the study. Any higher flows may be reduced by the aquifer transmissivity and level of the potentiometric surface at the time of inflow.

The stage and discharge hydrographs shown in figure 10 generally follow rainfall patterns, except during periods when the boards in the weir are manipulated. There were periods of no flow to the drainage well during the year, short periods of extreme high flow, and long periods of low, stable flow to the drainage well due to ground-water seepage into the lake. The periods of high flow did not last long because the well can accept high volumes of water, causing the lake level to decrease rapidly. However, these periods of high flow contribute large volumes of inflow to the Upper Floridan aquifer. Flow for the period November 1987 through December 1988 averaged 3.3 ft^3/s or 2.1 Mgal/d. This inflow is a significant part of the total estimated recharge of 23 Mgal/d through drainage wells in the greater Orlando study area. Inflow during 1988 totaled 766.5 Mgal at the site.

Quality of Inflow

Stormwater runoff contains high concentrations of total organic carbon, organic nitrogen, iron, lead, sulfate, and zinc; but concentrations of most anions and cations are lower in stormwater runoff than in water from the Upper Floridan aquifer (Wanielista and others, 1981; and German, 1989b). Wanielista and others (1981, p. 37) reported concentrations of total organic carbon ranging from 18 to 284 mg/L (milligrams per liter) in runoff to Lake Eola in downtown Orlando. German (1989b) found that inflow to the drainage wells frequently had detectable concentrations of many pesticides, with diazinon being detected in 77 percent of the samples collected and malathion being detected in 50 percent of the samples.

German (1989b) estimated loads of nutrients entering the Upper Floridan aquifer, and analyzed organic compounds in inflow waters at nine drainage well sites. He estimated that 100,000 lb (pounds) of total nitrogen enters the Upper Floridan aquifer each year through drainage wells in central Florida.

Wanielista and others (1981) and German (1989b) also reported sporadic detections in stormwater runoff of phthalates, widely used compounds in the plastics industries, and polycyclic aromatic hydrocarbons, such as fluoranthene, pyrene, anthracene, chrysene, and benzo-a-pyrene, commonly associated with petroleum products. Wanielista sampled runoff at two sites in downtown Orlando for

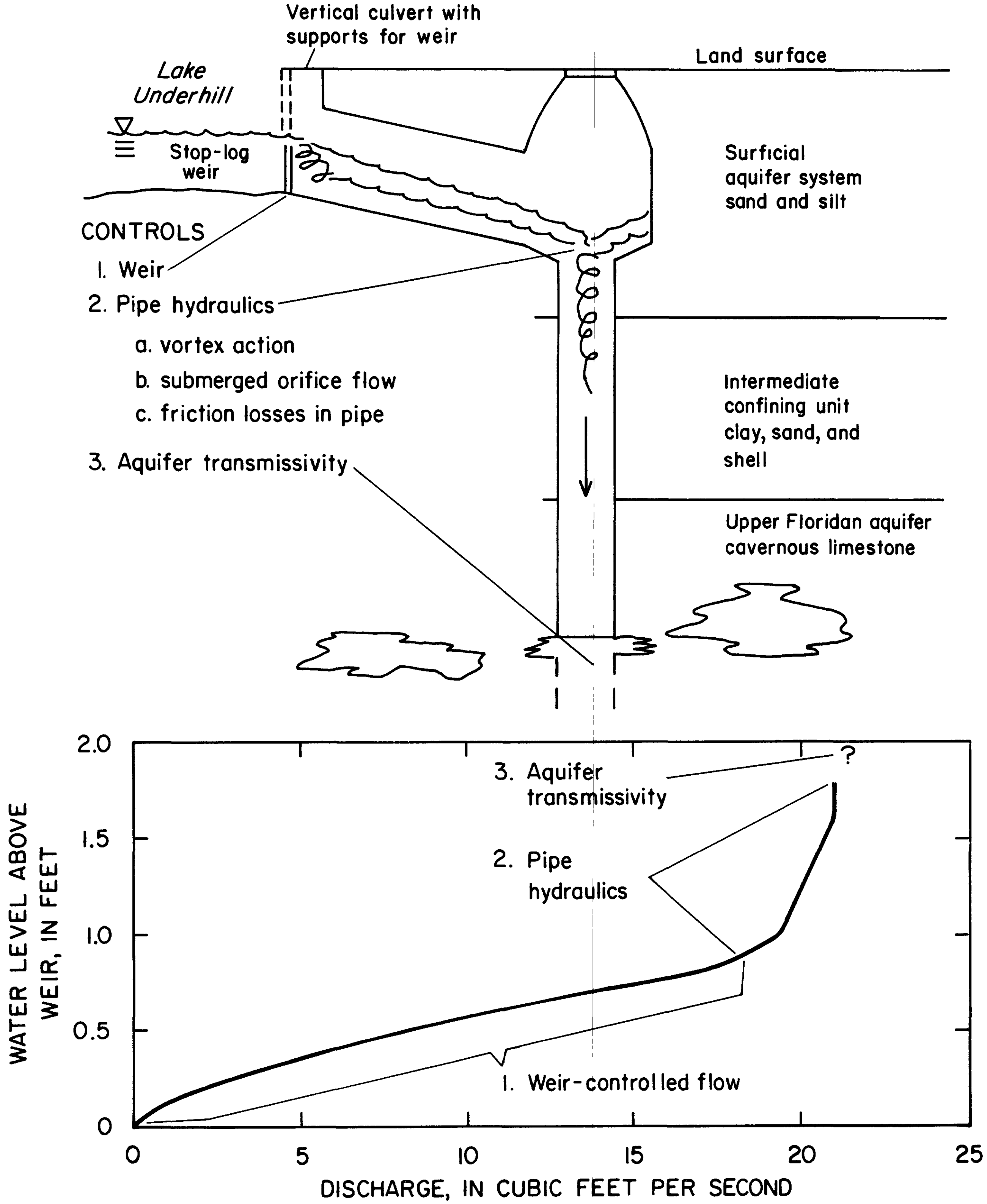


Figure 9b. Factors that affect flow into the Lake Underhill drainage well.

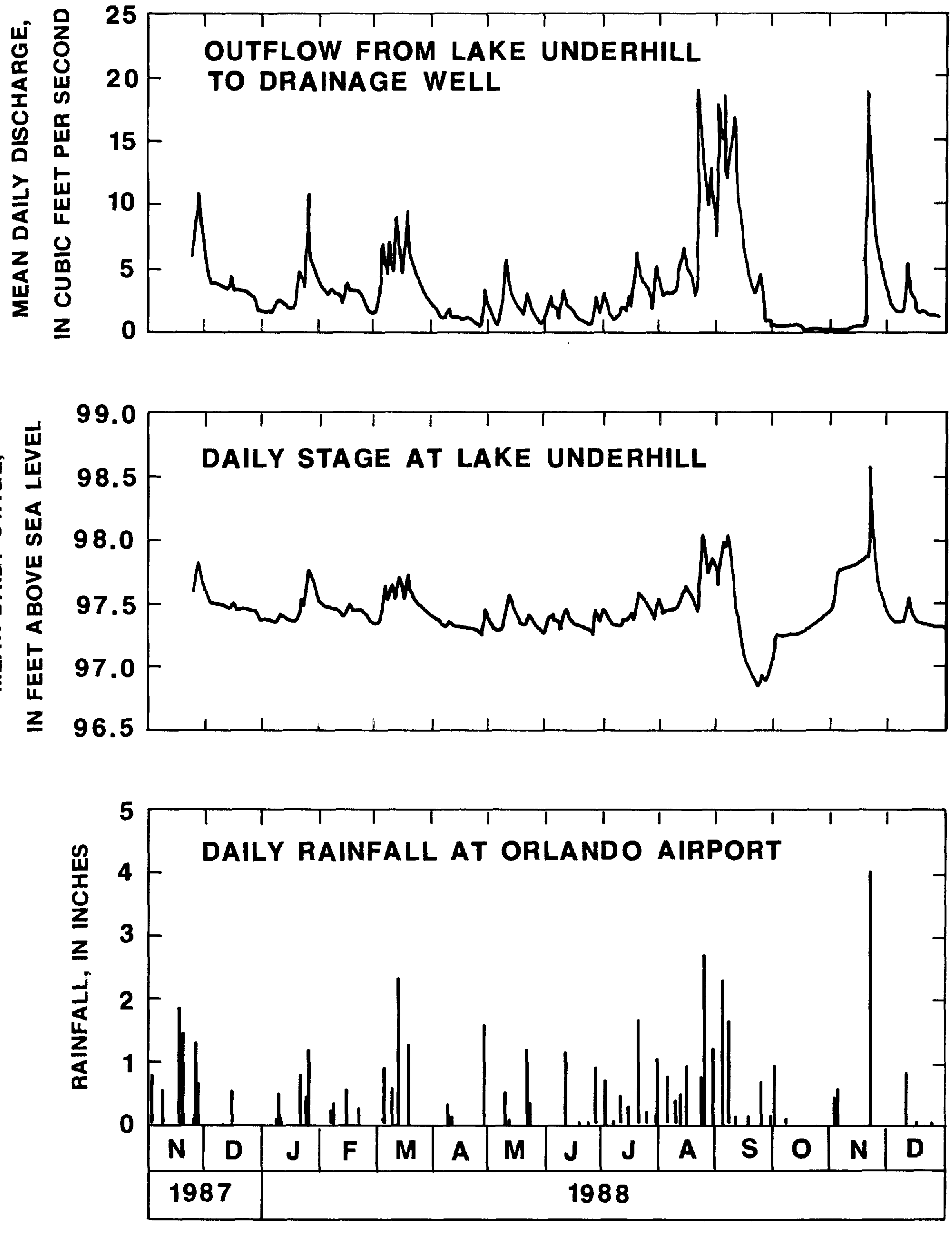


Figure 10. Hydrograph showing stage and outflow at Lake Underhill and rainfall at Orlando, November 1987 through December 1988.

organic compounds and detected hydrocarbons at both sites. One site was in the flow path of runoff from a gasoline station. German detected organic compounds at five of nine sites sampled in his study.

Inflow to the Gertrude Street drainage well was not sampled during the study because of the complexity and cost that would have been involved; but inflow to the drainage well at Lake Underhill was sampled. The inflow, characterized as lake water, did not have elevated concentrations of cations and anions, trace elements, or total organic carbon (see appendixes). Trace amounts of diazinon and 2,4-D were found in one sample, but no other pesticides were detected in the inflow. No volatile organic hydrocarbons were found in the inflow water. Retention time in Lake Underhill may be a factor in reducing organic compound concentrations in stormwater runoff.

WATER QUALITY IN THE UPPER FLORIDAN AQUIFER

Background Areas

A comparison of data from 9 wells in the Ocala National Forest (appendix I) with the data from 18 wells upgradient from Orlando (appendix II) indicated that the general chemistries of water from the Upper Floridan aquifer in the two background areas are similar. Slightly higher concentrations of some constituents, such as total organic carbon, were present in ground water upgradient from Orlando (table 3). Little or no data were available on concentrations of pesticide and organic hydrocarbons in water from the set of wells upgradient from Orlando, so data from wells in the Ocala National Forest were used for comparisons of concentrations of these compounds to data from the urban Orlando area.

Nutrients, Inorganic Constituents, and Age Dating of Water

In comparing concentrations of nutrients, anions, cations, and trace elements between background areas, sulfate was the only constituent substantially higher in ground water from the upgradient site than in ground water from the Ocala National Forest. Concentrations of metals generally were at or below detection limits.

Tritium samples were collected from five wells in the Ocala National Forest area. Tritium concentrations were less than 1.5 TU in three wells and within a range of 3 to 5 TU for two wells. All of these samples indicate that some water of recent origin (since 1953) is included in the sample.

Organic Constituents

The presence of organic constituents in ground water can be indicative of anthropogenic activities, although low concentrations of some organic compounds may be naturally occurring. The median value of 4 mg/L (milligrams per liter) total organic carbon in the upgradient Orlando area was higher than the median value of 1 mg/L in the Ocala National Forest.

In previous studies, some pesticides were detected in water from drainage wells (Schiner and German; 1983, Rutledge, 1987); but the concentrations were at or near

Table 3. *Statistical summary of chemical analyses of water from 18 wells upgradient from Orlando and 9 wells from the Ocala National Forest area*

[N is number of wells. (n) is number of samples. For wells having more than one sample, a median value for all samples from the well was determined and placed into a data set. From this data set, another median was determined, and is the median listed in the table. Range is the maximum and minimum values from the data set. Concentrations are in milligrams per liter, unless otherwise noted. µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, micrograms per liter]

Constituent	Upgradient from Orlando				Ocala National Forest			
	N	(n)	Median	Range	N	(n)	Median	Range
Specific conductance, µS/cm, field	18	(28)	251	198 - 373	8	(8)	233	151 - 322
pH, in standard units	15	(23)	7.5	6.6 - 8.3	8	(17)	8.0	7.9 - 8.1
Total organic nitrogen as N	7	(8)	.03	.0 - .07	8	(8)	<.20	<.20 - .50
Total ammonia as N	7	(8)	.02	.0 - .14	9	(17)	.04	.01 - .52
Total phosphorus as P	7	(8)	.11	.05 - .30	9	(9)	.05	.03 - .31
Total organic carbon	6	(7)	4.0	.0 - 6.0	8	(8)	1.0	.0 - 2.5
Dissolved calcium	13	(20)	33	28 - 38	9	(17)	32	17 - 52
Dissolved magnesium	13	(20)	8.4	3.8 - 17	9	(17)	7.4	4.0 - 9.3
Dissolved sodium	13	(20)	6.6	4.1 - 11	9	(17)	4.3	3.2 - 7.1
Dissolved potassium	13	(20)	.9	.6 - 1.9	9	(17)	0.7	.4 - 1.4
Dissolved chloride	18	(28)	8.9	2.0 - 14	9	(14)	8.4	4.5 - 11.0
Dissolved sulfate	13	(20)	5.7	0.4 - 18	9	(17)	2.6	<.10 - 17
Dissolved iron, mg/L	7	(7)	40	<10 - 60	8	(8)	20	<10 - 520
Total recoverable manganese, mg/L	7	(7)	<10	<10 - 20	9	(13)	<10	<10 - 20

detection limits. Samples for analyses of pesticides in ground water were collected from 5 wells in the area upgradient from Orlando and 9 wells in the Ocala National Forest area. No pesticides were detected in water from either area.

No organic hydrocarbons were detected in samples from the two wells sampled for these specific compounds in the area upgradient from Orlando or in six of the eight samples from wells in the Ocala National Forest area. Of the two remaining wells in the Ocala National Forest area, 0.4 mg/L (micrograms per liter) toluene was detected in water from one well, and 0.3 mg/L chloroform was detected in water from the other well. These concentrations are below the limits set by the Florida Department of Environmental Regulation for public water supply (Florida Department of State, 1989). The detection of these compounds at these low levels may indicate their presence in ground water in the area, but may also be due to sample contamination.

Urban Orlando Area

In the urban Orlando area set, chemical data from 11 wells were compared (appendix III). Because most of the wells had more than one analysis, the median value of each constituent from each well was used for comparison of general water quality (table 4). Sites 9 and 10 which are drainage wells, and site 6, which is near a drainage well, were not used in the statistical analysis because of the possible effects of industrial effluent on the quality of water in these wells. All but four wells in the downtown Orlando area ranged from 200 to 450 feet deep; the depths of the remaining four wells are unknown.

Table 4. Statistical summary of chemical analyses of water from 11 wells within the urban Orlando area

[N is number of wells; (n) is number of samples. For wells having more than one sample, a median value for all samples from the well was determined and placed into a data set. From this data set another median was determined, and is the median listed in the table. Range is the maximum and minimum values from the data set. Concentrations are in milligrams per liter, unless otherwise noted; mS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, micrograms per liter; <, less than]

Constituent	N	(n)	Median	Range
Specific conductance, in μS/cm (field)	8	(22)	357	255 - 390
pH, in standard units	8	(20)	7.6	7.4 – 8.0
Total organic nitrogen as N	11	(33)	.24	.04 - .40
Total ammonia as N	11	(33)	.97	.26 - 6.6
Total phosphorus as P	11	(33)	.16	.03 - .31
Total organic carbon	11	(33)	3.0	1.8 - 5.1
Dissolved calcium	11	(34)	44	30 - 55
Dissolved magnesium	11	(34)	8.6	5.5 - 10
Dissolved sodium	11	(34)	11	8.4 - 17
Dissolved potassium	11	(34)	1.9	.8 - 3.8
Dissolved chloride	11	(28)	14	11 - 21
Dissolved sulfate	11	(34)	7.8	1.7 - 13
Dissolved iron, in mg/L	8	(21)	65	35 - 190
Total recoverable manganese, in mg/L	8	(29)	10	- 30

Nutrients, Inorganic Constituents, and Tritium

The median concentration of organic nitrogen in ground water from the urban Orlando area was 0.24 mg/L as N and the median concentration for ammonia nitrogen was 0.97 mg/L as N. The total phosphorous median concentration was 0.16 mg/L (table 4).

Water from site 3 (fig. 3) had very high concentrations of ammonia nitrogen (maximum value of 10 mg/L as N) and nitrate nitrogen (6.3 mg/L as N). This site has the largest number of upgradient drainage wells of all wells sampled in the downtown study area and is about 2,000 feet downgradient from several groups of drainage wells that historically received primary-treated drainage from community septic tanks. The septic-tank system was discontinued in the late 1940's and the wells now receive stormwater runoff.

Calcium, chloride, sodium and sulfate concentrations varied widely, but did not exceed public water-supply standards (table 4). Compared to the median values for the urban area, water from site 3 contained elevated concentrations of sodium, potassium, and chloride, and water from site 1 had a slightly higher concentration of calcium (Appendix III). Concentrations of iron, manganese, and other metals, such as zinc and chromium in the urban Orlando area, were equal to or slightly greater than detection limits.

Repeated sampling at sites 2, 7, 8, and 13 showed no major changes in water quality due to seasonal inflow to drainage wells in the vicinity, with the exception of the sulfate concentration, which appears to be lower during dry periods than during wet periods.

Samples of ground water from seven wells in the urban Orlando area were collected for tritium analyses. Concentrations ranged from 3 to 9.4 TU, indicating that all wells sampled in Orlando yield water that has been recharged more recently than 1953. However, it cannot be determined if the water is primarily from recent rainfall with low concentrations of tritium, or whether the water is from rainfall of 15 to 30 years ago that has been diluted to these concentrations.

Organic Constituents

Median concentrations of total organic carbon in water from the wells sampled ranged from 1.8 and 5.1 mg/L with a median of the median concentration of 3.0 mg/L. This indicates that the high concentrations of organic carbon entering the aquifer in stormwater are being attenuated quickly. Wanielista and others (1981, p. 37) reported concentrations ranging from 18 to 284 mg/L of total organic carbon in runoff to Lake Eola in downtown Orlando.

Concentrations of total organic carbon never exceeded 10 mg/L in the inflow to the Lake Underhill drainage well.

Samples for pesticide analyses were collected from eight wells in the urban study area (appendix III). Pesticides concentrations were less than detection limits for all of these wells, as was the case for the two background areas.

Organic compounds were detected in water from 8 of the 11 wells that were sampled in the downtown area. The high number of detections is biased, however, because more extensive sampling was performed in an area where high levels of hydrocarbons were detected. Detection limits in some of the analyses were higher than others because of dilution of samples or because of the analytical method used. The eight wells where hydrocarbons were detected in water from the Upper Floridan aquifer are shown in figure 11. Sites 5, 7, 8, and 11 were in an area of a hydrocarbon plume; these and three other wells (sites 6, 9, and 10) are discussed in detail in a later section.

Water from site 1 (fig. 11) contained dichlorodifluoromethane (0.50 μg/L), indicating a source of recent recharge. Fluorocarbons have only been used in abundance since the 1940's. This well is downgradient from many drainage wells that drain urban runoff as well as some abandoned wells that received sewage. The well at site 1 was used as a drainage well until 1960, and during the period 1981-89 has been used for lake augmentation.

One water sample from site 2 also contained hydrocarbons. Five samples were collected from the supply well, but only one showed traces of benzene and toluene (0.3 and 0.2 μg/L, respectively). This well is pumped almost continuously for a water-cooled air-conditioning unit. The low concentrations detected may have been from sample contamination from ambient air concentrations. No fluorocarbons were detected in the samples. Fluorocarbons were detected in wells 6, 9, and 10, but these were drainage wells and a pressure-relief well for a drainage well. These

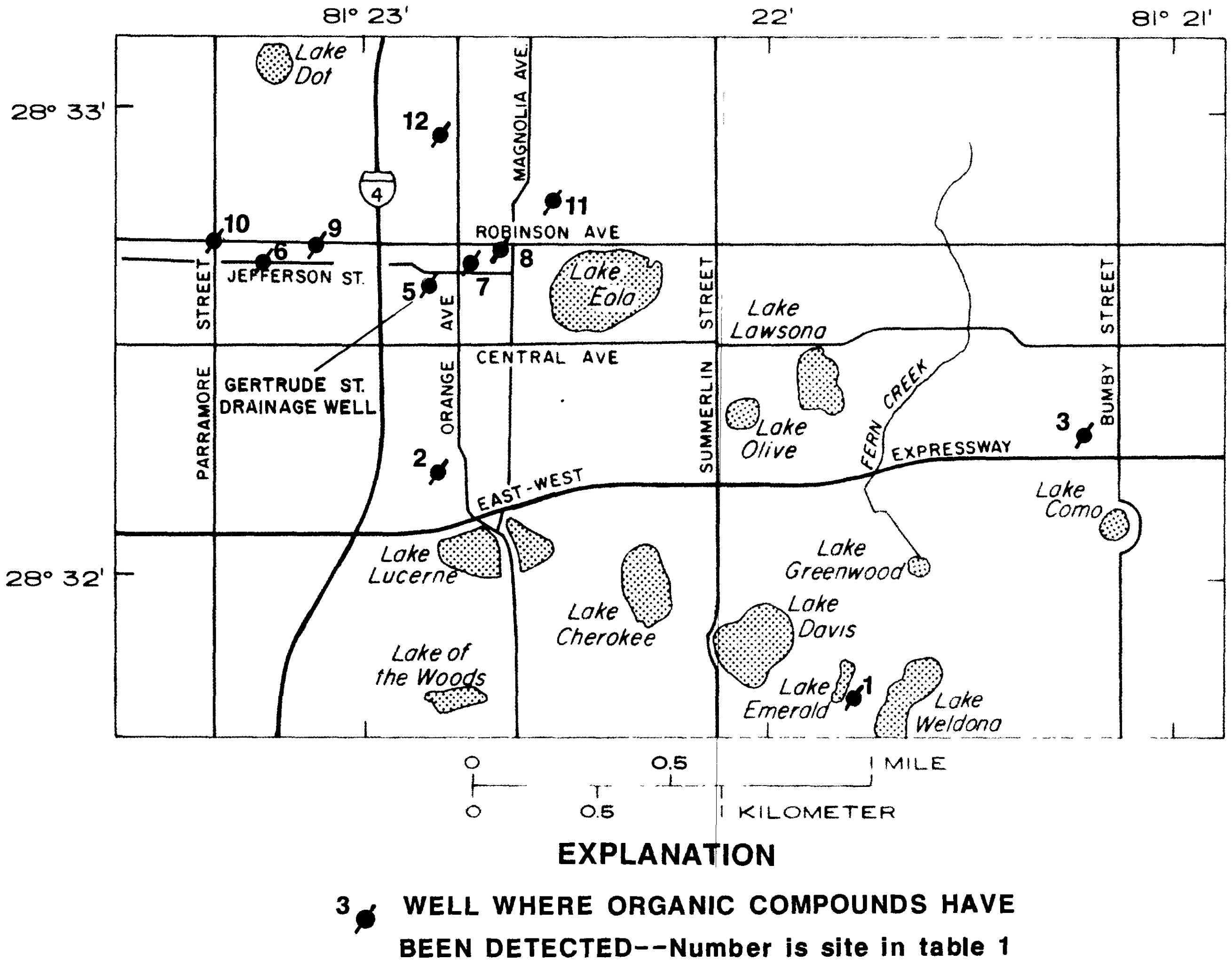


Figure 11. Map showing sites where organic compounds have been detected in ground water.

were not used in the main analyses because they are in the hydrocarbon plume. Water from site 3 contained several organic compounds, including low concentrations of benzene (0.3 µg/L), chlorobenzene (0.7 µg/L), paradichlorobenzene (5.7 µg/L), trichloroethane (0.2 µg/L), transdichloroethylene (1.0 µg/L), and a trace of trichlorofluoromethane. These compounds are used in many different industrial processes and are contained in many solvents. No single source can be specifically identified for the compounds found at this site; however, the high concentrations of other constituents such as sodium, chloride, ammonia, and nitrate suggest a highly concentrated source for those constituents. Chlorobenzene and para-dichlorobenzene have a high affinity to fats that are abundant in sewage.

Water from site 12 contained tetrachloroethylene (0.7 µg/L), a constituent in solvents and dry-cleaning fluids. Only one of three samples at this site contained any organic compound in excess of the detection limit of 0.2 µg/L.

Comparison Between Areas

Samples from selected wells in the urban Orlando area contained tritium concentrations that were equal to or higher than those in samples from the Ocala National Forest. These higher concentrations in the urban area indicate a source of recent recharge and probably reflect inflow from drainage wells.

Box plots showing percentiles of selected constituents for sites in the Ocala National Forest, the area upgradient from Orlando, and the urban study area are shown in figures 12 and 13. The percentiles shown in these box plots are derived from median concentration for each well in the study area. These figures show that concentrations are elevated in the urban area for most of the constituents shown. However, none of the constituents is elevated above the limits for public water supply. Higher concentrations of some major inorganic constituents in the urban area, as compared to the upgradient area, may be a result of natural dissolution as the water moves downgradient through the ground-water system.

The Wilcoxon rank-sum test (Conover, 1971) was used to make a nonparametric statistical analysis of major constituent and nutrient concentrations from the three selected areas to determine if median concentrations of the various constituents differ significantly among the three areas. The rank-sum test is calculated by performing the two-sample t-test on rank transformed data. Average ranks are used in case of ties. The two background sites were compared with each other as well as with the downtown site. A significance level of 0.05 was used for all statistical tests.

The comparison indicates that calcium, potassium, sodium, chloride, and ammonia are significantly higher in the urban Orlando area than in the background areas. Concentrations of these five ions may be higher because of geochemical factors, including a longer retention time of water in the aquifer allowing more mineral dissolution. The higher concentrations of calcium may also be a result of the inflow from drainage wells of different water chemistry mixing with the native ground water as it moves through the aquifer and dissolving aquifer materials. The higher concentrations of chloride, potassium, and sodium are more likely due to drainage-well inflow containing waste salts from water softeners, effluent from abandoned city septic tanks, fertilizers, or byproducts from other processes, than to stormwater runoff, which has lower concentrations of these constituents than the water in the aquifer.

The elevated ammonia concentrations in the urban Orlando area are likely due to drainage-well water because ammonia is not derived directly from aquifer material. Anaerobic conditions present in the Floridan aquifer system, indicated by the presence of hydrogen sulfide gas, provide an environment suitable for the existence of ammonia resulting from the decomposition of organic nitrogen. Most stormwater-runoff samples have not shown high concentrations of ammonia; therefore, the bacterial breakdown of organic matter is probably the source of the ammonia in the aquifer (Wetzel, 1975).

The Wilcoxon test comparison also indicated that the median total organic carbon concentrations in both the upgradient and urban Orlando areas were significantly greater than those in the Ocala National Forest area. Concentrations of total organic carbon were low in all three areas (usually less than 6 mg/L) compared to stormwater runoff in Orlando. Wanielista and others (1981) reported an average of 99 mg/L total organic carbon in composite and single samples in runoff from 13 storms in the Orlando area.

The median pH values of ground water in the upgradient area (7.5 pH units) and urban area (7.6 pH units) are significantly lower than those in the Ocala National Forest area (8.0 pH units). This may be due to the nature of the aquifer materials and residence time of the water in the aquifer rather than any significant changes from man's activities.

Other constituents, including the remainder of the major ions, and trace metals such as dissolved iron, manganese, lead, zinc, and chromium either were not significantly different or data were not sufficient to accurately compare the sites. The metal concentrations were frequently near or below the detection limits.

Concentrations of organic hydrocarbons were detected at 8 of 11 wells in the urban Orlando study area, and some of the concentrations were relatively high (470 µg/L benzene in one sample). Only minor amounts of two volatile organics were detected in ground water in the Ocala National Forest and none were detected in ground water from two wells in the upgradient area. No pesticides were detected in ground water from any of the three areas.

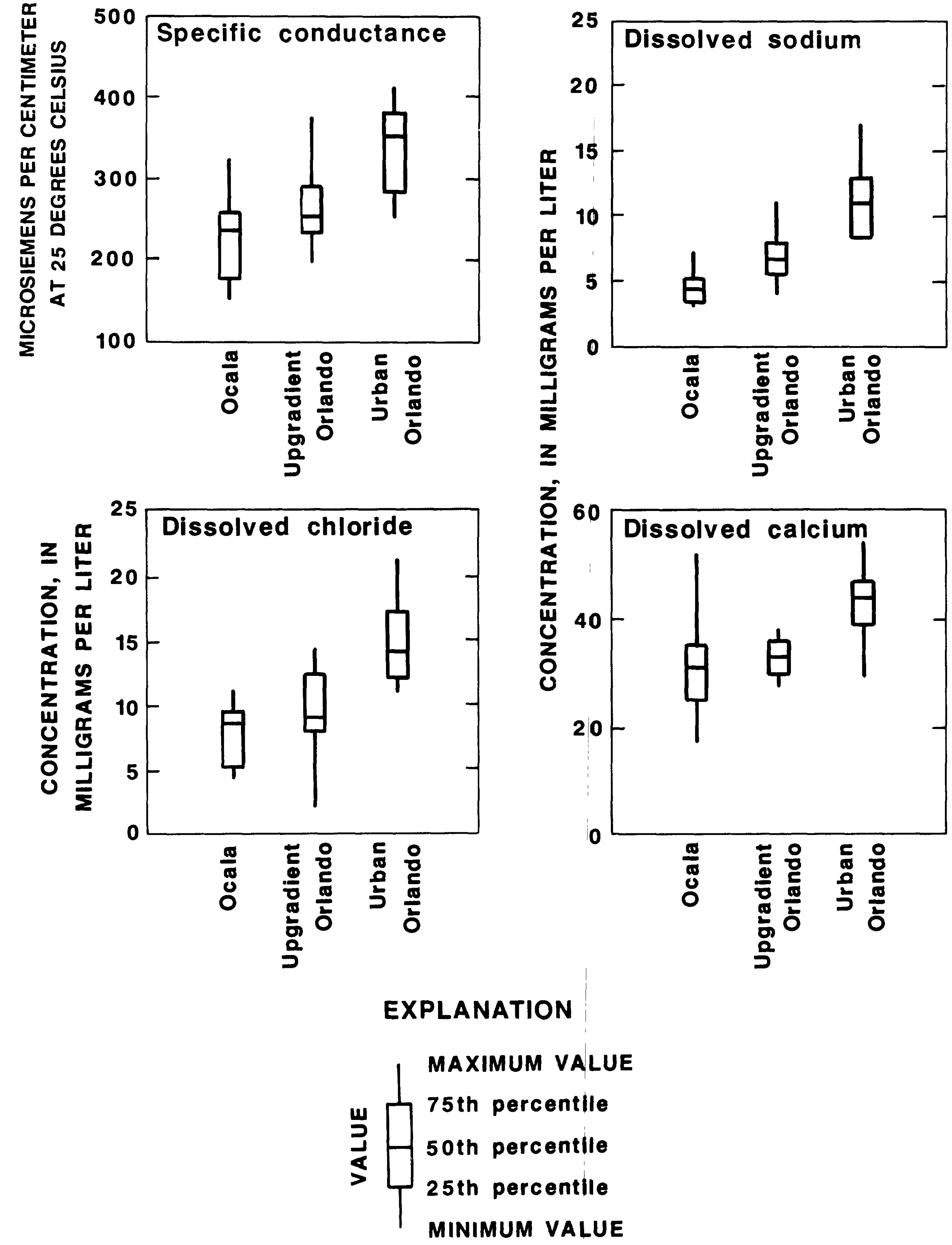


Figure 12. Box plots of specific conductance, sodium, chloride, and calcium in water from wells in the Ocala National Forest, upgradient from Orlando and the urban study area.

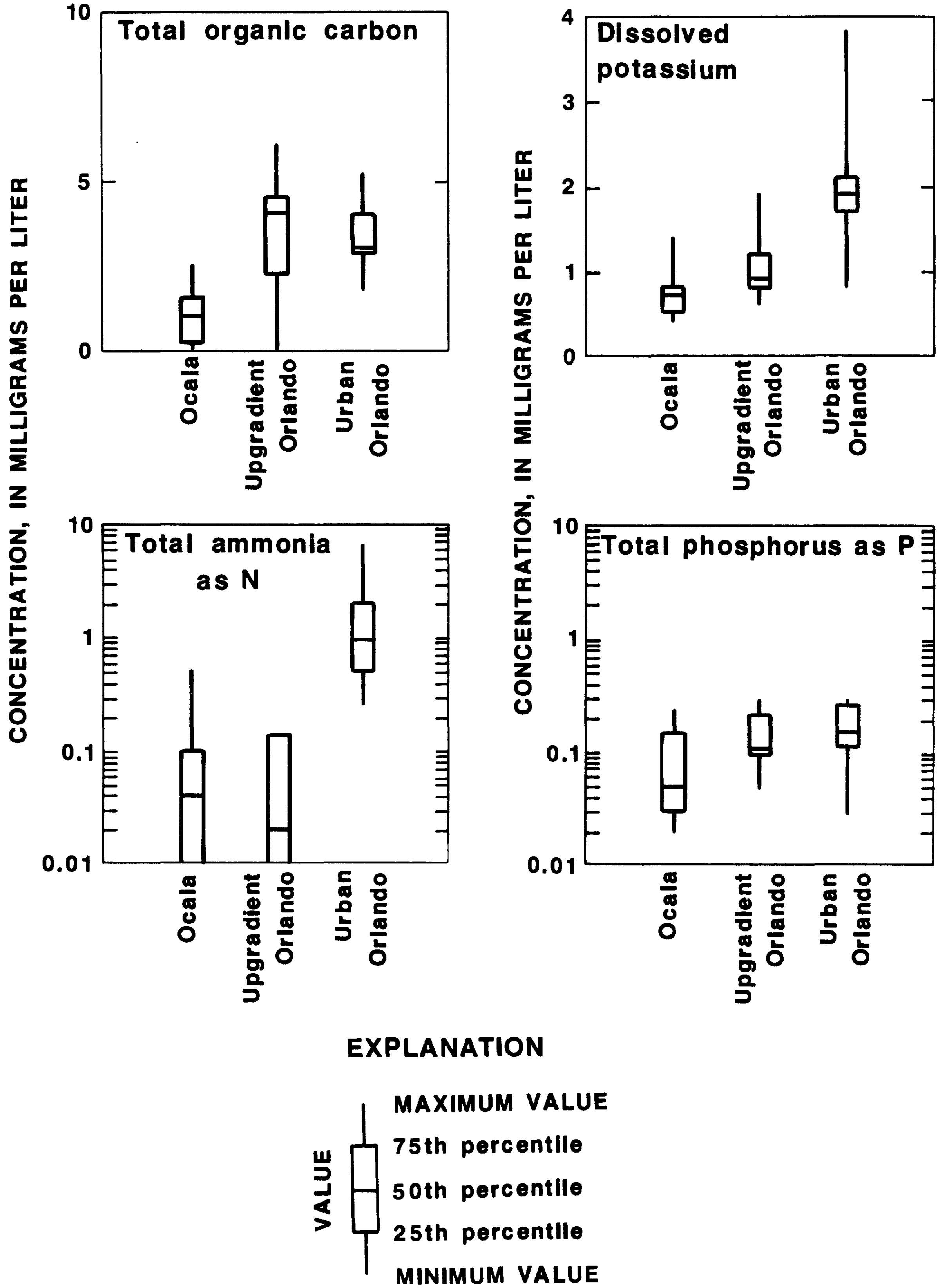


Figure 13. Box plots of total organic carbon, potassium, ammonia, and phosphorus in water from wells in the Ocala National Forest upgradient from Orlando and the urban study area.

INTENSIVELY STUDIED SITES

Lake Overflow

Lake-overflow drainage wells introduce large volumes of water into the Upper Floridan aquifer, possibly affecting the water chemistry of the receiving ground water and increasing dissolution of the limestone. Water-quality changes can be dramatic over short distances from drainage wells. To evaluate these water-quality changes, the lake-overflow drainage well at Lake Underhill was selected for monitoring.

As most of the drainage-well recharge volume probably enters the aquifer through lake-overflow drainage wells, most of the constituent loads probably also enter through these wells. German (1989b) estimated that drainage wells annually inject about 100,000 lb of nitrogen and 13,000 lb of phosphorus into the Upper Floridan aquifer in central Florida.

The nitrogen load introduced into the aquifer at the Lake Underhill drainage well during 1988 can be estimated using a mean concentration of 1.08 mg/L (from four samples) and an average inflow rate of 2.1 Mgal/d in 1988. The estimate of 6,900 lb is approximately 7 percent of the total load estimated by German (1989b) to be entering the Floridan aquifer system through drainage wells in the greater Orlando area. Nearly all the nitrogen in the inflow was organic nitrogen which, under anoxic conditions within the aquifer, can be converted to ammonia nitrogen.

The total phosphorus load to the Lake Underhill drainage well was about 450 lb for 1988, based on a mean concentration of 0.07 mg/L from four samples of inflow. This represents less than 4 percent of the total phosphorus load calculated by German (1989b).

Water samples were collected from Lake Underhill and the monitoring wells (fig. 9a) during two high-flow and two low-flow periods (see table 5, drainage well inflow). All samples were taken when there was inflow to the drainage well. Entrapped air and excessive turbulence in the inflow water caused problems in pumping monitoring wells 1 and 2 with a submersible pump, therefore, a thief sampler was used to collect samples 300 feet below land surface from these monitoring wells during low flow. During high inflow throughout the study period, monitoring well 2 would expel air entrained by the turbulent water flowing into the aquifer through the drainage well. The water level in monitoring well 1 would sometimes rise near land surface, but expulsion of entrained air was not observed.

A comparison of analytical results for water samples from drainage well inflow and monitoring wells 1 and 2 at the Lake Underhill site can be made from the data in table 5. Differences in water chemistry between the drainage well inflow and monitoring well 2 are most evident in the data for pH, specific conductance, ammonia, calcium, and sulfate. The higher concentration of sulfate in the monitoring well may be a result of oxidation of hydrogen sulfide gas present

Table 5. Water quality in drainage well inflow and monitoring wells at the Lake Underhill site

[Concentrations are in milligrams per liter, unless otherwise noted; Mgal/d, million gallons per day; --, no sample]

Date	Rate of well inflow (Mgal/d)	Drainage well inflow	Monitoring well No. 1	Monitoring well No. 2
		pH, in standard units, field		
11-20-87	6.3	[1]8.1	--	[1]8.2
05-24-88	.9	9.1	8.0	7.8
09-08-88	8.3	7.4	7.6	8.0
11-17-88	.3	8.6	7.5	7.5
		Specific conductance, in microsiemens per centimeter at 25 degrees Celsius, lab		
11-20-87	6.3	163	--	358
05-24-88	.9	170	245	400
09-08-88	8.3	149	167	351
11-17-88	.3	157	295	406
		Total organic carbon		
11-20-87	6.3	9.2	--	3.5
05-24-88	.9	6.7	5.2	--
09-08-88	8.3	6.9	8.2	3.7
11-17-88	.3	4.7	4.5	5.9
		Total organic nitrogen		
11-20-87	6.3	0.8	--	0.34
05-24-88	.9	1.6	0.93	.22
09-08-88	8.3	.9	.69	.33
11-17-88	.3	1.1	.62	.76
		Total ammonia nitrogen		
11-20-87	6.3	0.02	--	0.26
05-24-88	.9	.02	0.07	.10
09-08-88	8.3	.04	.11	.17
11-17-88	.3	.01	.38	.11
		Dissolved sulfate		
11-20-87	6.3	16	--	41
05-24-88	.9	16	17	62
09-08-88	8.3	14	16	45
11-17-88	.3	15	26	51
		Dissolved calcium		
11-20-87	6.3	20	--	58
05-24-88	.9	21	26	72
09-08-88	8.3	19	21	57
11-17-88	.3	20	38	67

[1]Laboratory measurement.

in the aquifer by oxygenated inflow water. Concentrations of sulfate in the aquifer water in the urban Orlando area (median value of 7.8 mg/L) are lower than those in the inflow from Lake Underhill. The sulfate produced at the Lake Underhill site is probably not due to the dissolution of gypsum in the aquifer materials, otherwise, a general increase would probably be observed in the entire urban area.

Smaller differences were observed between data for monitoring well 1 and data from the drainage well inflow; however, monitoring well 1 probably is either directly connected to the drainage well by solution channels or it is relatively close to a large cavern, detected by geophysical logs, at the bottom of the drainage well. During the periods of high inflow in November 1987 and September 1988, smaller differences were observed (for most constituents) than during the two periods of low inflow. This probably was due to shorter residence time of the inflow water in the aquifer and higher velocities moving the water through the system. During low flow, there may be more blending with ambient aquifer water.

Concentrations of organic nitrogen and total organic carbon generally were larger in the inflow to the drainage well than in the monitoring wells. The decrease in total organic carbon concentrations between the drainage well and the monitoring well may be due to the adsorptive capacity of the aquifer. The decrease in organic nitrogen is also accompanied by a slight increase in ammonia nitrogen, indicating breakdown of organic matter by bacterial action. The increase in ammonia could also be caused by blending with water that is higher in ammonia, as upgradient concentrations from the urban Orlando area were higher (table 6).

Median concentrations of constituents and physical properties in ground water in the urban Orlando area and at Lake Underhill monitoring well 2 are presented in table 6 for comparison. Median calcium and sulfate concentrations are significantly different for the two data sets as are median concentrations of dissolved iron, total ammonia, sodium, and specific conductance. Variations in the volume of inflow may be the major reason for the difference in concentrations (table 5). Sodium and magnesium concentrations are lowest in ground water from the Lake Underhill monitoring well and probably are affected by recharge water rather than by the aquifer materials.

Other constituent concentrations were measured at the same time, but these could not be related to major changes in chemistry of the water in the aquifer caused by inflow to the drainage well. During the study, inflow water to the drainage well was always within drinking-water standards set by the U.S. Environmental Protection Agency or the Florida Department of Environmental Regulation.

A continuous water-quality monitor was installed in monitoring well 1 with the sensors set at 300 feet below land surface (30 feet below the bottom of the casing). Temperature and conductance were recorded hourly. Effects from drainage-well inflow were noticeable in the specific conductance measurement for nearly every storm (fig. 14). The specific conductance of water in monitoring well 1 had a mean of 159 μS/cm (microsiemens per centimeter) during high-inflow events (nearly the same as inflow water), but increased to about 380 μS/cm during periods of little or no inflow.

Direct Stormwater Runoff

Direct stormwater inflow to drainage wells is relatively small as compared to lake overflow; however, constituent concentrations in stormwater runoff may be high and may have a substantial effect on the quality of water in the Upper Floridan aquifer. Water downgradient from the Gertrude Street drainage well was monitored to evaluate water-quality changes caused by direct stormwater inflow. These changes were then contrasted with water- quality changes caused by lake-overflow drainage wells.

Constituent concentrations for ground water from the monitoring well at the Gertrude Street site (site 5) were within the range observed for other wells in the urban Orlando area (table 6 and appendix III). The median sulfate concentration was much lower for samples from site 5 (7.2 mg/l) than for samples from Lake Underhill monitoring well 2 (48 mg/L). A continuous water-quality monitor was

Table 6. *Median values of selected constituents and physical properties of water from 11 wells in the urban Orlando area, well 16*

[Concentrations are median values, in milligrams per liter, unless otherwise stated. N, number of samples; μS/cm, microsiemens per centimeter at 25 degrees Celsius] mg/L, micrograms per liter]

Constituent	Urban Orlando area		Lake Underhill monitoring well 2		Gertrude Street monitoring well	
	N	Median	N	Median	N	Median
Specific conductance μS/cm, field	19	357	3	430	3	381
pH, in standard units	17	7.6	3	7.8	3	7.6
Total organic nitrogen as N	30	.24	4	.33	3	.20
Total ammonia as N	30	.97	4	.14	3	1.30
Total phosphorus as P	30	.16	3	.13	3	.16
Total organic carbon	30	3.0	4	3.7	3	2.9
Dissolved calcium	31	44	4	62	3	47
Dissolved magnesium	31	8.6	4	6.2	3	10
Dissolved sodium	31	11	4	5.8	3	13
Dissolved potassium	31	1.9	4	2.4	3	1.9
Dissolved chloride	25	14	4	9.7	3	14.0
Dissolved sulfate	31	7.8	4	48	3	7.2
Dissolved iron, in μg/L	18	65	3	18	3	70
Total recoverable manganese, in μg/L	26	10	3	30	3	10

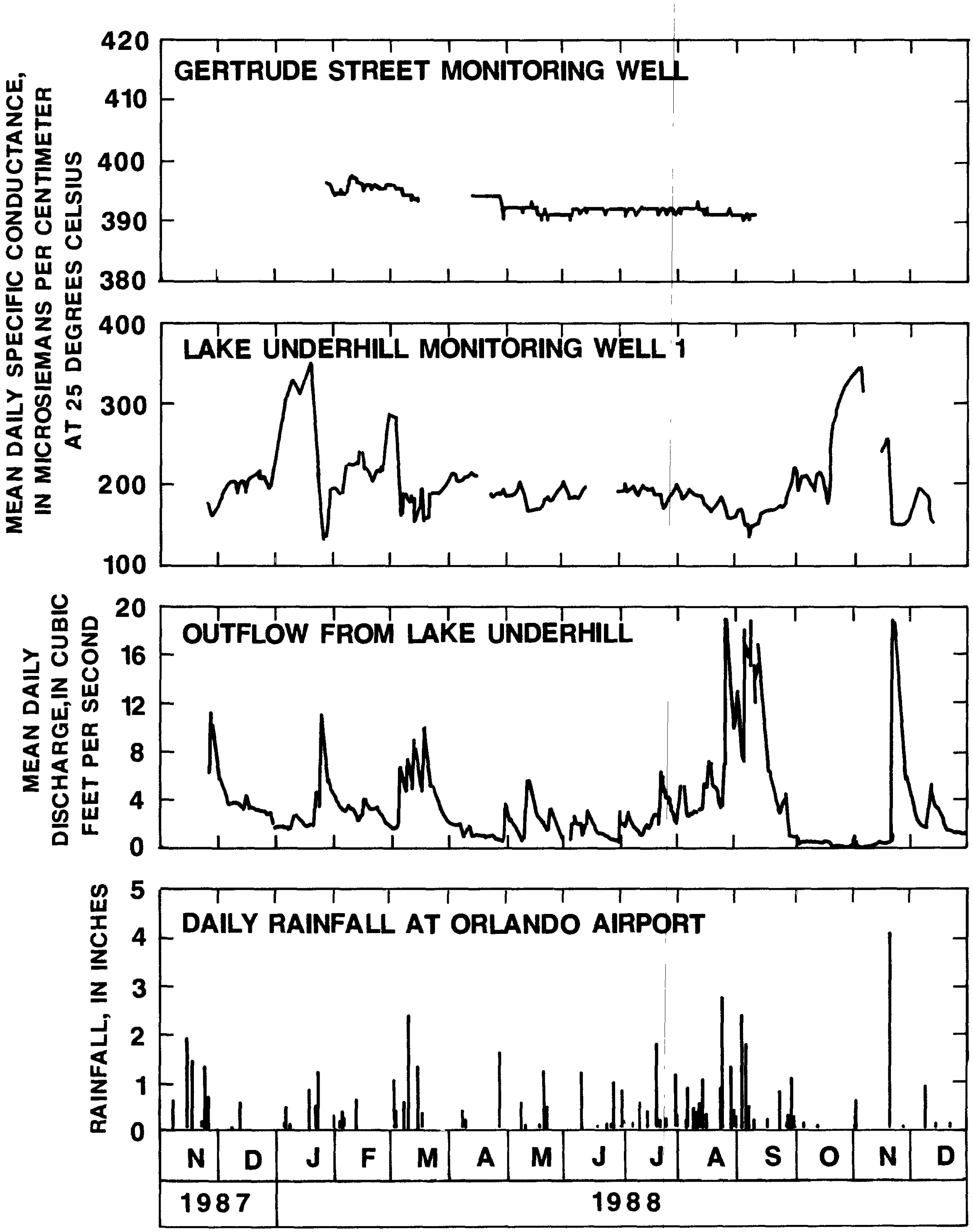


Figure 14. Hydrograph showing specific conductance of water in the Gertrude Street monitoring well and Lake Underhill monitoring well 1, outflow from Lake Underhill, and rainfall at Orlando.

installed in the monitoring well at Gertrude Street with the sensors suspended 40 feet below the bottom of the casing (240 feet below land surface). Temperature and specific conductance were recorded hourly. Specific conductance did not vary significantly (fig. 14) with inflow to the drainage well, but small decreases of 1 to 5 μS/cm were noticeable after periods of heavy rainfall.

Hydrocarbon Plume

Rutledge (1987) sampled the Gertrude Street drainage well and site 8, an irrigation well, in 1985. These sample analyses indicated the presence of benzene and polycyclic aromatic hydrocarbons in ground water. In the initial sampling for this study, site 8 was resampled in 1987 to verify the presence of these compounds. Benzene and polycyclic aromatic hydrocarbons, such as acenaphthene, were detected in these and in subsequent samples in concentrations as high as 93 and 10.3 μg/L, respectively. A nearby irrigation well, site 7, was then sampled and concentrations of benzene in the water from this well were as high as 470 μg/L. Site 7 is upgradient from site 8 and the higher concentration of several hydrocarbon compounds indicated that this well probably was closer to the source of the organic compounds.

The areal distribution of organic compounds in the ground water was difficult to determine because of the paucity of supply wells in the area and the difficulty in installing observation wells in the intensely developed downtown Orlando area. Two drainage wells and one pressure-relief well for a drainage well (sites 9, 10, and 6, respectively) were used to sample ground water upgradient from sites 7 and 8. Other wells eventually used for additional sampling were the Gertrude Street monitoring well (site 5), slightly south and upgradient from sites 7 and 8, and site 11, an irrigation well located northeast and downgradient from sites 7 and 8.

In order to define the extent and distribution of the organic compounds in the aquifer, more advanced analytical techniques were used. Analytical methods described by Wershaw and others (1983) were used so that lower detection limits could be achieved. These included gas chromatography (GC) and mass spectography (MS) techniques which were used to tentatively identify some organic compounds. These data, referred to as tentatively identified organic compounds (TIOC), are based on comparison of sample spectra with library spectra. TIOC data have not been confirmed by direct comparison with reference standards. Therefore, TIOC identification is tentative, and reported concentrations are semiquantitative.

Additional sampling of the wells upgradient from sites 7 and 8 and further search through well records eventually located a probable source of the hydrocarbons, a former manufactured-gas plant on Robinson Avenue (fig. 15). Well records indicated that one drainage well was permitted for disposal of condenser water at the site of the former gas plant. Other direct stormwater runoff drainage wells were also located near the plant. The process wastes could have been introduced into the Upper Floridan aquifer by the drainage well at the plant or perhaps by other drainage wells in the area. This could explain the plume of organic compounds that presently exists in the aquifer.

Analyses listed in table 7 are from samples collected from five selected wells in or near the plume--site 10 is upgradient and sites 7, 8, 9, and 11 are downgradient from the former gas-plant site. Sample analyses indicate that 1 or more of 5 volatile organic compounds and 12 to 22 polycyclic organic compounds, some of which were only tentatively identified, were detected downgradient from the former gas plant. The highest concentrations (94 μg/L benzene and 258 μg/L naphthalene) were detected at site 9, the drainage well nearest the former site of the gas plant. The sample from site 10, the well upgradient from the former gas plant, contained three polycyclic organic compounds, but concentrations of these compounds were less than 0.3 μg/L.

The chemical characteristics of the hydrocarbon compounds found at the plume site result in markedly different potentials for movement through the ground-water system. Among the significant factors most influencing the movement of these hydrocarbon compounds in ground water are hydraulic gradient, solubility, and specific gravity. Soluble compounds would generally be expected to disperse into and be transported with the ground water. Many coal-tar aggregates are nonionic and exist in an immiscible phase as microscopic aggregates known as micelles (Hult and Schoenberg, 1984). As these micelles migrate downgradient, the more soluble compounds, such as naphthalene and benzene, can diffuse into and equilibrate with the water phase. Micelles containing mostly heavy hydrocarbons (with high specific gravity and molecular weight) would tend to deposit in the aquifer pores or sorb onto the aquifer matrix near the source.

Profiles of naphthalene, benzene, and acenaphthene in figure 16 show the variability in concentration of these organic compounds in the hydrocarbon plume. Benzene is apparently one of the most mobile of the compounds, as indicated by the high concentrations downgradient at sites 7 and 8--86 and 53 μg/L, respectively (fig. 16). Benzene is highly soluble in water (1,780 mg/L (Smith and others, 1987)) and has a low specific gravity as well. The relatively constant concentrations of benzene shown in figure 16, sites 9, 7, and 8, may be due to hydraulic effects from inflow through the Lake Eola drainage wells. The inflow could cause increased water levels and a resistance to the natural eastward movement of water at this location, which in turn could allow the buildup of concentrations of organic compounds in the ground water. Repeated sampling at sites 7 and 8 showed large fluctuations in benzene concentrations. This probably was due to pumping rate variations and movement of upgradient water containing higher concentrations of benzene into the area around the wells.

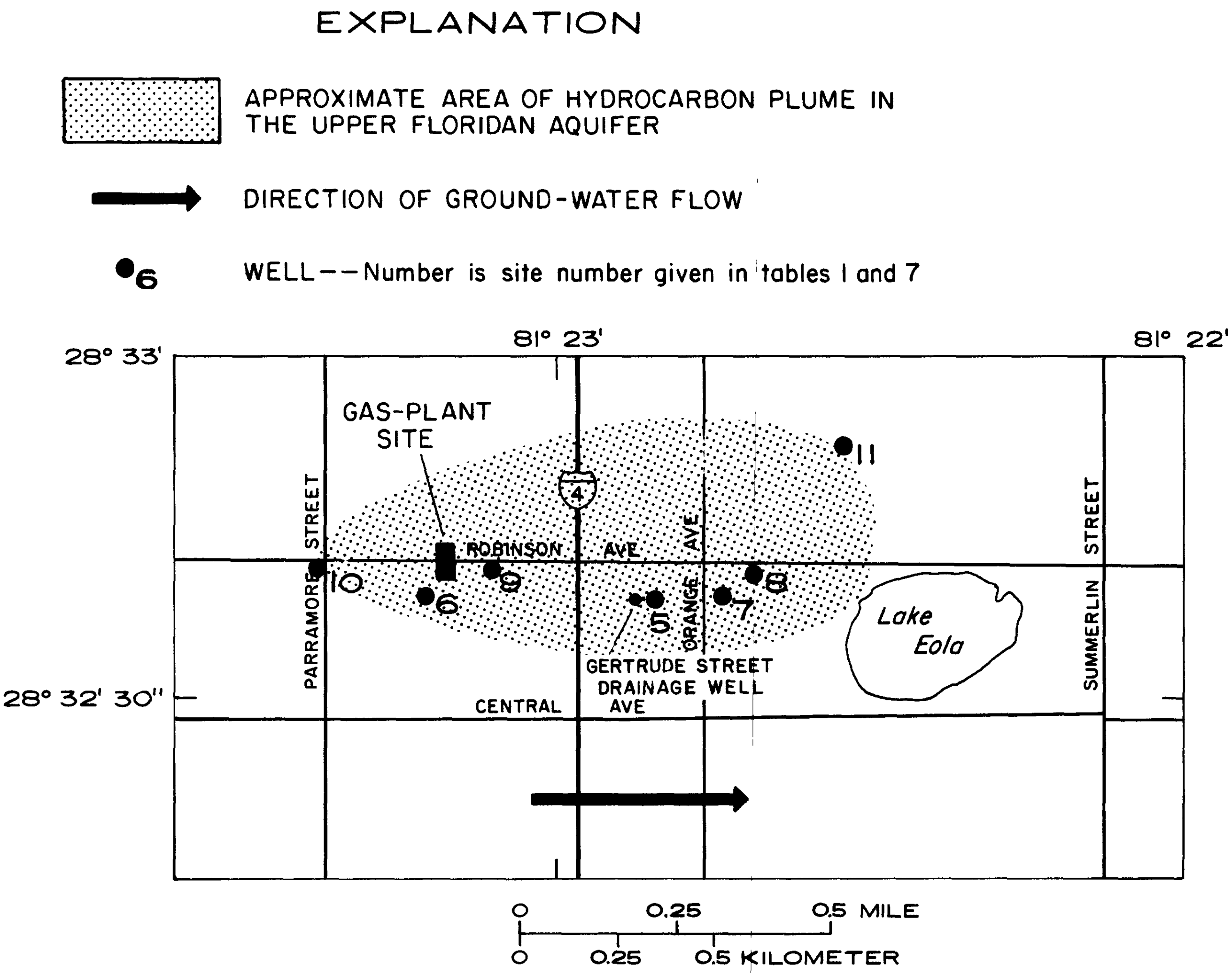


Figure 15. Map shown approximate extent of the hydrocarbon plume in the urban Orlando area.

Table 7. *Organic compounds detected in water from wells within the hydrocarbon plume*

[Number is concentration in micrograms per liter. An asterisk (*) indicates compound was not detected. Compounds with (total) include all isomers added together. TIOC values are semiquantitative]

Compound Name	Site 10	Site 9	Site 7	Site 8	Site 11
		Compounds with authentic reference standards			
Volatiles					
Benzene	*	94	86	53	0.2
Ethylbenzene	*	7.6	.30	*	*
Toluene	*	1.2	*	*	*
Xylene	*	15	.60	.20	*
Polycyclics					
Acenaphthene	0.14	32.73	18.79	10.32	4.04
Acenaphthylene*		.92	.10	*	*
Anthracene	*	2.81	.38	.09	*
Fluoranthene	*	3.94	1.12	.38	.09
Fluorene	*	15.28	1.94	.30	.06
Naphthalene	.04	257.82	7.51	.32	*
Phenanthrene	*	17.21	1.68	.16	*
Phenol,2,4,-dimethyl	.24	.27	.56	*	*
Phenol	*	1.84	2.02	*	*
Pyrene	*	6.94	2.46	.62	.63

Table 7. *Organic compounds detected in water from wells within the hydrocarbon plume--Continued*

[Number is concentration in micrograms per liter. An asterisk (*) indicates compound was not detected. Compounds with (total) include all isomers added together. TIOC values are semiquantitative.]

Compound Name	Site 10	Site 9	Site 7	Site 8	Site 11
	Tentatively identified organic compounds from automated library search				
Volatiles					
Thiophene	*	1.43	3.00	2.33	0.26
Polycyclics					
Benzene, propyl	*	1.81	40	.86	*
Benzo[b]thiophene methyl isomers (total)	*	10.00	1.60	1.70	1.30
Benzo[b]thiophene dimethyl isomers (total)	*	5.00	*	.40	.30
1H-Indene, 2,3-dihydro-	*	68.22	19.70	1.88	*
1H-Indene, 2,3-dihydro-1-methyl	*	3.05	1.67	.84	*
Naphthalene, ethyl isomers (total)	*	14.00	1.80	1.00	.40
Naphthalene, methyl isomers (total)	x	140.00	17.00	4.00	*
Naphthalene, dimethyl isomers (total)	*	90.00	10.50	7.00	2.30
Naphthalene, trimethyl isomers (total)	*	12.70	.80	1.70	.50
9H-Fluorene, methyl isomers (total)	*	12.00	1.60	*	1.10
4H-Cyclopenta [def] phenanthrene	*	4.00	.60	.81	.40
1,1'-Biphenyl, methyl isomers (total)	*	14.00	1.00	3.2	.70

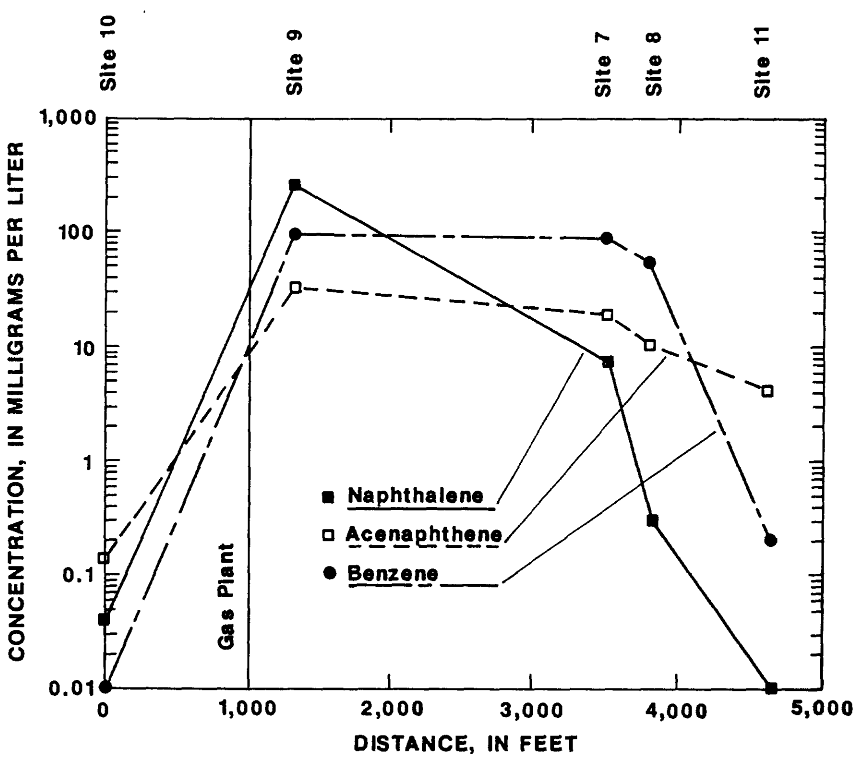


Figure 16. Profiles of acenaphthene, naphthalene, and benzene in water from wells within the hydrocarbon plume.

Although naphthalene was detected at a higher concentration (257 µg/L) than the other compounds at site 9, concentrations of naphthalene were substantially lower at sites 7 and 8. Naphthalene is denser than water (specific gravity is approximately 1.15) and may not travel as fast as the ambient ground water. It is also less soluble in water than benzene.

Acenaphthene was detected in higher concentrations at site 11 farthest removed from the former site of the gas plant than the other two hydrocarbons. Perhaps the hydrocarbons with lower solubilities such as acenaphthene may be moving as micelles and have not dispersed into the water in the same way as the more soluble compounds would have.

Sulphur heterocyclic compounds, such as thiophene and benzo(b)thiophene, were detected in nearly all samples, however, no significant decline in concentrations of these compounds occurred between site 7 and site 11. Not much is known about the solubilities of these compounds.

The highest concentrations of organic compounds occurred at site 9, the well closest to the former site of the gas plant, indicating that these compounds may still be mobilizing 30 years after the plant was closed. The mechanism for addition of these constituents to the ground water is not known but may be continual dissolution or leaching of a pool of viscous material contained in cavities within the aquifer.

At least two other explanations are plausible for the retention of the hydrocarbon plume in the area. If the mobilization of the compounds had terminated when the plant was closed in 1958, the regional ground-water flow rate of about 0.6 ft/d (foot per day) (Rutledge, 1987) probably would have caused the upgradient edge of the plume to migrate more than a mile downgradient by 1988, assuming no dispersion and assuming that the compounds are moving at the same rate as the ground water. A product such as coal tar that enters the aquifer can accumulate in the pores of the limestone, effectively reducing the local transmissivity. Thus, the movement of associated organic compounds could be restrained.

A third plausible explanation is a change in the direction of the natural ground-water flow in the area. The mounding of the potentiometric surface created by the Lake Eola drainage wells tends to reverse the direction of flow seasonally (fig. 5). As the downtown area has continued to become more urbanized, the wells draining Lake Eola probably have received increased runoff thus increasing the mounding effect and further altering the natural ground-water flow regime. An indication of this is the relatively flat gradient of the potentiometric surface in the urban Orlando area.

The vertical movement of the hydrocarbon plume, from the Upper Floridan aquifer to the Lower Floridan aquifer, could be facilitated by the presence of a well tapping the Lower Floridan aquifer at the former gas-plant site. This well was drilled in 1940 for water supply at the plant (Unklesbay, 1944) and was 1,050 feet deep with 486 feet of casing. The potential exists for water from the Upper Floridan aquifer to move downward through the open hole of the well because of the short casing and downward head gradient. It is not known whether this well was plugged in 1958 when the plant was dismantled or whether the well is buried under concrete and could still be open to both aquifers.

The most efficient mechanisms for the degradation of organic hydrocarbons are through oxidation or photolysis. Benzene and polynuclear aromatic hydrocarbons are difficult to break down without the presence of light and oxygen (Versar, Inc., 1979). Nearly all the water in the confined Upper Floridan aquifer is anoxic, therefore, oxidation of these compounds is unlikely. It is not known whether these compounds are being degraded by biological activity.

SUMMARY AND CONCLUSIONS

The city of Orlando and surrounding areas have used drainage wells to alleviate flooding and control lake levels since 1904. Approximately 310 wells in the greater Orlando study area have been used to receive lake overflow, direct stormwater runoff, wetland outflow, and effluent from septic tanks and industrial processes.

A comparison of chemical analyses of water from 11 wells within the urban Orlando area (where the highest density of drainage wells exist) with chemical analyses of water from two background areas was used to determine areal effects of inflow. Two drainage wells, one receiving lake overflow and one receiving direct stormwater runoff, were chosen for continuous monitoring to evaluate water-quality effects from specific inflows.

General ground-water movement in the area is toward the east, but mounding of the potentiometric surface of the Upper Floridan aquifer occurs around the high volume, lake-overflow wells. These ground-water mounds can change the direction of ground-water flow locally for short periods of time. An area of drawdown in the Upper Floridan aquifer near Lake Ivanhoe just north of the Orlando urban area is probably caused by pumping from the Lower Floridan aquifer for public supply.

Total recharge through drainage wells to the Upper Floridan aquifer in the greater Orlando area is estimated to be 23 Mgal/d or greater. Recharge through these wells is estimated to create a maximum head buildup of about 4 feet in the greater Orlando area.

Inflow quantities through individual drainage wells differ greatly. The drainage area of the Gertrude Street drainage well is about 2 acres and total inflow through this well in 1988 was about 3.3 Mgal. The drainage area of the Lake Underhill well is about 1,118 acres and total inflow to this well during 1988 was about 766.5 Mgal and averaged 2.1 Mgal/d. Inflow to the Lake Underhill well during this study probably peaked at 9,200 gal/min in November 1988 after a 4-inch rainfall.

The quality of inflow to drainage wells depends on land use in the contributing drainage area. Urban street runoff has been shown to contain high concentrations of organic nitrogen, iron, lead, zinc, and total organic carbon. Runoff also commonly contains detectable concentrations of pesticides, phthalates, and polynuclear hydrocarbons. Lake overflow drainage wells generally receive better quality water except for elevated concentrations of organic nitrogen. Trace amounts of the pesticides diazinon and 2,4-D were found in samples of inflow at Lake Underhill.

Tritium concentrations in ground water indicate that the Upper Floridan aquifer in the urban Orlando area contains recharge water more recent in age than 1953, when atmospheric atomic tests began. Tritium values ranged from 3 to 9.4 TU in samples from seven wells in the area. Tritium values ranged from 0.35 to 5 TU in samples from five wells in the Ocala National Forest, indicating that tritium is present in ground water in most high-rate recharge areas in Florida.

Water-quality data from wells located upgradient from the urban Orlando area, in the Ocala National Forest, and in the urban area were compared statistically using the Wilcoxon rank-sum test at a significance level of 0.05. The test results indicate that calcium, potassium, sodium, chloride, and ammonia are present in significantly higher concentrations in the urban Orlando area than in either of the two background areas.

Results from the Wilcoxon test also indicate that total organic carbon is present in significantly greater amounts in ground water from both the upgradient and urban Orlando areas than in ground water from the Ocala National Forest. The median pH is lower in the upgradient and urban Orlando areas than in the Ocala National Forest.

For other constituents, significant differences were not indicated or there were insufficient data available to accurately compare the sites. Pesticides were not detected in any of the ground-water samples collected.

Organic hydrocarbons were detected in ground water from 8 of 11 wells in the urban Orlando area. However, most of these wells were in the vicinity of a contaminant plume. Minor amounts of two volatile organics were found in ground water in the Ocala National Forest, but volatile organics were not detected in ground water upgradient from Orlando.

Most of the drainage-well inflow in the urban Orlando area can be classified as either large volume lake overflow which generally has low concentrations of most constituents or small volume stormwater runoff which generally has higher concentration of most constituents. Lake-overflow drainage wells, such as the Lake Underhill drainage well, can increase concentrations of constituents, such as nutrients, in ground water because they inject large volumes of inflow. Small volumes of direct stormwater runoff entering drainage wells also can have a substantial effect on ground-water quality.

Lake Underhill drainage well injected an estimated 6,900 lb of total nitrogen and 450 lb of phosphorus into the Upper Floridan aquifer in 1988. Nearly all the nitrogen in the inflow was organic nitrogen which may be chemically reduced to ammonia in the aquifer. Calcium and sulfate concentrations were much higher in ground water near the Lake Underhill drainage well, indicating dissolution of the limestone in the aquifer, and that oxygenated inflow water may be converting hydrogen sulfide gas in the ground water to sulfate. Increases in specific conductance and decreases in other constituent concentrations during periods of low flow may be caused by blending of inflow and aquifer waters.

Results of long-term monitoring indicated that specific conductance of ground water is high near direct stormwater runoff wells, and decreases slightly only during periods of heavy rainfall. Specific conductance of ground water near the lake-overflow drainage well varied greatly in response to amounts of inflow. Specific conductance decreased to values near those of lake inflow (159 μS/cm) during periods of extremely high inflow and increased to about 380 μS/cm during periods of no inflow.

Ground water near the Gertrude Street drainage well has been affected by organic material in effluent, probably from a former manufactured-gas plant. High concentrations of organic compounds associated with coal tar were detected about 200 feet east of the site of the former gas plant, and persist at lesser concentrations to almost three-quarters of a mile downgradient.

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APPENDIX 1

APPENDIX I. Quality of water analyses from wells in the Ocala National Forest

[μS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; --, no data; <, less than; μg/L, micrograms per liter; TU, tritium units]

Site identification number	Date	Specific conductance, lab (μS/cm)	pH, lab (standard units)	Nitrogen, organic, total (mg/L as N)	Nitrogen, ammonia, total (mg/L as N)	Nitrogen, NO_2+ NO_3 total (mg/L as N)	Phosphorus, total (mg/L as P)	Carbon, organic, total (mg/L as C)
285907081451701	03-11-86	185	8.1	--	0.06	0.01	--	--
285908081470101	03-06-86	290	7.9	--	.02	.01	--	--
	08-19-87	--	8.1	<.20	.04	<.02	.05	.2
290000081380001	03-11-86	225	8.0	--	.02	.35	--	--
	08-20-87	--	8.2	<.20	.02	.39	.05	.5
290228081382301	08-27-87	--	7.9	<.20	.01	<.02	.02	<.1
290300081452001	03-06-86	150	8.1	--	.02	.05	--	--
	08-19-87	--	8.5	<.20	.01	.05	.02	1.0
	03-27-89	--	8.1	--	.01	.05	.02	--
290550081393001	03-05-86	215	8.0	--	.07	<.01	--	--
	08-20-87	--	8.1	<.20	.07	<.02	.06	1.1
290612081402901	03-05-86	176	8.0	--	.05	<.01	--	--
	08-19-87	--	8.2	<.20	.03	<.02	.04	1.1
290633081375201	03-05-86	265	7.8	--	.52	<.01	--	--
	08-27-87	--	7.8	.38	.51	<.02	.23	2.0
290647081342101	03-06-86	320	7.9	--	.19	<.01	--	--
	08-27-87	--	7.8	.50	.18	<.02	.23	2.5

Site identification number	Date	Calcium dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)	Hardness total (mg/L as $CaCO_3$)
285907081451701	03-11-86	26	6.7	3.2	0.70	4.5	0.08	0.10	93
285908081470101	03-06-86	37	9.3	11	.63	17	<1.0	.10	130
	08-19-87	37	9.5	5.2	.90	13	5.7	--	130
290000081380001	03-11-86	29	9.3	4.8	.80	7.0	16	.20	110
	08-20-87	29	9.1	5.3	.60	10	18	--	110
290228081382301	08-27-87	24	4.0	3.2	.80	--	2.0	--	76
290300081452001	03-06-86	17	6.4	4.3	.40	6.5	4.8	.10	69
	08-19-87	17	6.9	4.3	.20	6.2	6.7	--	71
	03-27-89	16	6.6	2.3	.40	4.9	7.4	--	67
290550081393001	03-05-86	33	4.3	5.0	1.5	4.3	<.10	.10	100
	08-20-87	35	4.5	5.3	1.3	4.8	5.3	--	110
290612081402901	03-05-86	26	5.2	3.1	.60	6.1	<.10	.10	86
	08-19-87	29	5.5	3.2	.60	5.1	5.4	--	95
290633081375201	03-05-86	37	9.3	5.2	.60	8.3	<.10	.10	130
	08-27-87	37	9.3	4.8	.60	--	<.10	--	130
290647081342101	03-06-86	53	8.3	3.7	.50	8.4	<1.0	.10	170
	08-27-87	51	8.2	3.4	.40	--	.40	--	160

Site identification number	Date	Chromium, total recoverable (μg/L as Cr)	Iron, total recoverable (μg/L as Fe)	Iron, dissolved (μg/L as Fe)	Lead, total recoverable (μg/L as Pb)	Manganese, total recoverable (μg/L as Mn)	Zinc, total recoverable (μg/L as Zn)	Tritium, total (TU)
285907081451701	03-11-86	4	1,300	140	10	20	2,100	--
285908081470101	03-06-86	2	100	<10	1	<10	640	--
	08-19-87	<10	320	--	<5	10	20	0.4
290000081380001	03-11-86	2	20	<10	<1	<10	80	--
	08-20-87	<10	180	--	<5	<10	40	--
290228081382301	08-27-87	--	--	--	<100	--	20	1.3
290300081452001	03-06-86	8	<10	<10	6	<10	20	--
	08-19-87	20	30	--	<5	<10	30	3.2
290550081393001	03-05-86	1	50	40	<1	20	130	--
	08-20-87	<10	120	--	<5	20	260	--
290612081402901	03-05-86	3	640	520	<1	20	10	--
	08-19-87	<10	640	--	<5	10	<10	--
290633081375201	03-05-86	<1	160	140	<1	10	70	--
	08-27-87	--	--	--	<100	--	20	0.5
290647081342101	03-06-86	5	500	<10	<1	10	10	--
	08-27-87	--	--	--	<100	--	<10	4.9

Site identification number	Date	Ethion, total (μg/L)	Malathion, total (μg/L)	Parathion, total (μg/L)	Diazinon, total (μg/L)	Methyl-Parathion, total (μg/L)	2,4-D, total (μg/L)	2,4,5-T total (μg/L)	Silvex, total (μg/L)
285908081470101	08-19-87	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
290000081380001	08-20-87	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
290228081382301	08-27-87	<.01	<.01	<.01	<.01	<.01	<.02	<.01	<.01
	08-27-87	<.01	<.01	<.01	<.01	<.01	--	<.01	<.01
290300081452001	08-19-87	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
290550081393001	08-20-87	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
290612081402901	08-19-87	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
290633081375201	08-27-87	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
290647081342101	08-27-87	<.01	<.01	<.01	<.01	<.01	<.02	<.01	<.01

APPENDIX I.--Quality of water analyses from wells in the Ocala National Forest--Continued

Site identification number	Date	Dichlorobromomethane total (μg/L)	Carbontetrachloride total (μg/L)	1,2-Dichloroethane total (μg/L)	Bromoform total (μg/L)	Chlorodibromomethane total (μg/L)	Chloroform total (μg/L)	Trichlorofluoromethana total (μg/L)	Dichlorodifluoromethane total (μg/L)
285908081470101	08-19-87	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
290000081380001	08-20-87	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
290228081382301	08-27-87	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
	08-27-87	<.20	<.20	<.20	<.20	<.20	<.20	.20	<.20
290300081452001	08-19-87	1.1	<.20	<.20	<.20	1.9	.90	<.20	<.20
	03-27-89	<.20	<.20	<.20	<.20	<.20	.30	<.20	<.20
290550081393001	08-20-87	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
290612081402901	08-19-87	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
290633081375201	08-27-87	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
290647081342101	08-27-87	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20

Site identification number	Date	Benzene total (μg/L)	Toluene total (μg/L)	Ethylbenzene total (μg/L)	Xylene, total, total recoverable (μg/L)	Chlorobenzene total (μg/L)	1,2-Di-Chlorobenzene total (μg/L)	1,3-Dichlorobenzene total (μg/L)	1,4-Dichlorobenzene total (μg/L)
285908081470101	08-19-87	<0.20	<0.20	<0.20	<0.2	<0.20	<0.20	<0.20	<0.20
290000081380001	08-20-87	<.20	<.20	<.20	<.2	<.20	<.20	<0.20	<0.20
290228081382301	08-27-87	<.20	<.20	<.20	<.2	<.20	<.20	<0.20	<0.20
	08-27-87	<.20	1.0	<.20	<.2	<.20	<.20	<0.20	<0.20
290300081452001	08-19-87	<.20	<.20	<.20	<.2	<.20	<.20	<0.20	<0.20
	03-27-89	<.20	<.20	<.20	<.2	<.20	<.20	<0.20	<0.20
290550081393001	08-20-87	<.20	<.20	<.20	<.2	<.20	<.20	<0.20	<0.20
290612081402901	08-19-87	<.20	<.20	<.20	<.2	<.20	<.20	<0.20	<0.20
290633081375201	08-27-87	<.20	<.20	<.20	<.2	<.20	<.20	<0.20	<0.20
290647081342101	08-27-87	<.20	.40	<.20	<.2	<.20	<.20	<0.20	<0.20

APPENDIX I.--Quality of water analyses from wells in the Ocala National Forest--Continued

Site identification number	Date	Chloro- ethane total (μg/L)	1,1-Di- chloro- ethane total (μg/L)	1,1,1- Tri- chloro- ethane total (μg/L)	1,1,2- Tri- chloro- ethane total (μg/L)	1,1,2,2 Tetra- chloro- ethane total (μg/L)	Methyl- bromide total (μg/L)	Methyl- chlo- ride total (μg/L)	Methyl ene chlo- ride total (μg/L)
285908081470101	08-19-87	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
290000081380001	08-20-87	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
290228081382301	08-27-87	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
	08-27-87	<.20	<.20	<.20	<.20	<.20	<.20	<.20	2.2
290300081452001	08-19-87	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
	03-27-89	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
290550081393001	08-20-87	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
290612081402901	08-19-87	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
290633081375201	08-27-87	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
290647081342101	08-27-87	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20

Site identification number	Date	Tetra- chloro- ethyl- ene total (μg/L)	1,1-Di- chloro- ethyl- ene total (μg/L)	1,2- Transdi chloro- ethene total (μg/L)	Vinyl chlo- ride total (μg/L)	Tri- chloro- ethyl- ene total (μg/L)	2- Chloro- ethyl- vinyl- ether total (μg/L)	1,2- Dibromo ethyl- ene total (μg/L)	1,2- Di- chloro- propane total (μg/L)
285908081470101	08-19-87	<0.20	<0.20	<0.20	<0.20	<0.2	<0.20	<0.2	<0.20
290000081380001	08-20-87	<.20	<.20	<.20	<.20	<.2	<.20	<.2	<.20
290228081382301	08-27-87	<.20	<.20	<.20	<.20	<.2	<.20	<.2	<.20
	08-27-87	<.20	<.20	<.20	<.20	<.2	<.20	<.2	<.20
290300081452001	08-19-87	<.20	<.20	<.20	<.20	<.2	<.20	<.2	<.20
	03-27-89	<.20	<.20	<.20	<.20	<.2	<.20	--	<.20
290550081393001	08-20-87	<.20	<.20	<.20	<.20	<.2	<.20	<.2	<.20
290612081402901	08-19-87	<.20	<.20	<.20	<.20	<.2	<.20	<.2	<.20
290633081375201	08-27-87	<.20	<.20	<.20	<.20	<.2	<.20	<.2	<.20
290647081342101	08-27-87	<.20	<.20	<.20	<.20	<.2	<.20	<.2	<.20

Appendix II

APPENDIX II. Quality of water analyses for upgradient Orlando area wells

[μS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; --, no data; <, less than; μg/L, micrograms per liter; ND, not detected]

Site identification number	Date	Specific conductance, lab (μS/cm)	pH, lab (standard units)	Nitrogen, organic, total (mg/L as N)	Nitrogen, total (mg/L as N)	Nitrogen, ammonia, total (mg/L as N)	Nitrogen, NO_2+NO_2, total (mg/L as N)	Phosphorus, total (mg/L as P)	Carbon, organic, total (mg/L as C)
283005081350801	07-22-60	251	--	--	--	--	--	--	--
	05-20-65	265	7.50	--	--	--	--	--	--
	06-16-66	255	7.40	--	--	--	--	--	--
	05-08-67	249	8.20	--	--	--	--	--	--
	05-20-68	253	7.30	--	--	--	--	--	--
	05-13-69	250	8.00	--	--	--	--	--	--
	04-24-70	255	7.10	--	--	--	--	--	--
	05-25-71	245	8.20	--	--	--	--	--	--
	05-09-72	278	--	--	--	--	--	--	--
283008081343901	07-22-60	279	7.30	--	--	--	--	--	--
283054081295901	09-04-77	236	7.30	.00	.14	.140	<.100	.130	4.0
283217081275701	01-23-61	198	7.50	--	--	--	--	--	--
283225081271001	02-27-62	211	8.00	--	--	--	--	--	--
	06-26-62	215	7.10	--	--	--	--	--	--
283309081293601	07-18-66	315	7.50	--	--	--	--	--	--
283325081374001	02-24-64	278	7.90	--	--	--	--	--	--
283331081255701	09-03-77	235	8.00	.00	.14	.140	<.100	.110	--
283348081351201	05-19-75	243	8.20	.06	.08	.010	--	.050	.00
	09-02-77	244	8.00	.07	.09	.020	<.100	.050	.00
283403081324901	08-24-60	310	--	--	--	--	--	--	--
283414081283301	02-26-62	373	8.10	--	--	--	--	--	--
283446081321101	08-24-60	300	--	--	--	--	--	--	--
283506081313801	08-24-60	198	--	--	--	--	--	--	--
283524081344701	10-07-70	283	8.30	--	--	--	--	--	--
283656081264501	09-03-77	249	6.60	.05	3.7	<.010	3.61	.300	3.0
283658081254801	09-03-77	241	7.00	.03	.97	<.010	.940	.220	4.0
283702081265801	09-03-77	276	7.10	.03	.95	.020	.900	.100	6.0
283707081250901	09-03-77	219	7.30	.05	.12	.070	<.100	.100	4.0

APPENDIX II.--Quality of water analyses for upgradient Orlando area wells--Continued

Site identification number	Date	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)	Hardness total (mg/L as $CaCO_3$)
283005081350801	07-22-60	--	--	--	--	3.0	--	--	--
	05-20-65	34	10	5.3	1.0	9.0	2.4	.20	130
	06-16-66	32	8.9	5.9	1.1	9.0	2.8	.20	120
	05-08-67	33	8.1	5.8	1.1	9.0	.40	.30	120
	05-20-68	34	8.4	5.7	1.1	11	2.4	.20	120
	05-13-69	33	8.3	5.1	1.1	9.0	2.8	.30	120
	04-24-70	34	8.4	5.9	1.2	9.0	2.4	.20	120
	05-25-71	34	8.8	6.4	1.0	10	4.4	.30	120
	05-09-72	--	--	--	--	--	--	--	--
283008081343901	07-22-60	29	17	7.2	1.9	10	.40	.30	140
283054081295901	09-04-77	36	5.2	6.8	.80	12	16	.10	110
283217081275701	01-23-61	--	--	--	--	2.0	--	--	100
283225081271001	02-27-62	--	--	--	--	8.5	--	--	100
	06-26-62	33	3.8	6.0	.80	9.5	6.4	.30	98
283309081293601	07-18-66	36	9.9	7.6	1.8	12	18	.30	130
283325081374001	02-24-64	38	8.5	8.1	1.2	13	15	.20	130
283331081255701	09-03-77	35	6.9	4.1	.80	6.5	2.3	.10	120
283348081351201	05-19-75	32	7.5	5.1	1.5	8.0	13	.10	110
	09-02-77	33	7.0	5.4	.90	8.2	14	.10	110
283403081324901	08-16-31	--	--	--	--	10	--	--	130
	08-24-60	--	--	--	--	7.0	--	--	--
283414081283301	02-26-62	--	--	--	--	14	--	--	170
283446081321101	08-24-60	--	--	--	--	7.0	--	--	--
283506081313801	08-24-60	--	--	--	--	7.0	--	--	--
283524081344701	10-07-70	35	11	6.6	1.0	8.0	.40	.30	130
283656081264501	09-03-77	28	7.2	11	.80	14	5.7	.10	100
283658081254801	09-03-77	29	10	9.8	.90	14	12	.20	110
283702081265801	09-03-77	32	11	6.4	.60	8.8	4.3	.10	130
283707081250901	09-03-77	31	6.5	5.1	.60	8.1	3.8	.10	100

Site identification number	Date	Chromium, total recoverable (µg/L as Cr)	Iron, total recoverable (µg/L as Fe)	Iron, dissolved (µg/L as Fe)	Lead, total recoverable (µg/L as Pb)	Lead, dissolved (µg/L as Pb)	Manganese, total recoverable (µg/L as Mn)	Zinc, total recoverable (µg/L as Zn)	Zinc, dissolved (µg/L as Zn)
283054081295901	09-04-77	<20	<10	40	2	ND	<10	ND	ND
283331081255701	09-03-77	<20	20	40	12	ND	<10	<20	<20
283348081351201	09-02-77	<20	<10	<10	3	ND	<10	<20	<20
283656081264501	09-03-77	<20	760	20	10	4	<10	<20	<20
283658081254801	09-03-77	<20	280	<10	ND	ND	<10	<20	ND
283702081265801	09-03-77	<20	90	60	9	ND	<10	20	ND
283707081250901	09-03-77	<20	20	50	7	ND	<10	ND	ND

Appendix III

APPENDIX III. Quality of water analyses for urban Orlando area wells

[µS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; TU, tritium units; <, less than; --, no data; µg/L, micrograms per liter]

Site No.	Site identification number	Date	Specific conductance, lab (µS/cm)	pH, lab (standard units)	Nitrogen, organic, total (mg/L as N)	Nitrogen, ammonia, total (mg/L as N)	Nitrogen, NO_2+NO_3, total (mg/L as N)	Phosphorus, total (mg/L as P)	Carbon, organic, total (mg/L as C)	Tritium, total (TU)
1	283147081214701	06-10-87	351	7.60	0.20	2.00	<0.10	0.12	5.1	6.3
2	283218081224801	06-09-87	369	7.40	.40	1.00	<.10	.16	5.1	--
		08-31-87	369	7.60	.44	.96	<.02	.17	3.5	6.2
		05-03-88	371	7.60	.23	.97	<.02	.22	2.8	--
		09-13-88	374	7.80	.00	1.60	<.10	.21	3.1	--
		11-02-88	364	7.69	.28	.92	<.02	.22	2.8	--
3	283223081211501	06-11-87	364	7.40	.30	3.30	<.02	.35	2.8	9.4
		08-31-87	450	7.00	.00	10.0	6.30	.25	3.1	4.3
4	283235081223801	08-18-88	248	7.50	.22	.88	<.02	.09	2.5	--
		11-01-88	250	7.83	.57	.93	<.02	.07	1.2	--
*5	283240081225001	04-28-88	378	7.40	.20	1.30	<.02	.21	2.3	--
		09-13-88	372	7.70	.03	.97	<.10	.15	3.7	--
		10-31-88	361	--	.30	1.30	<.02	.16	2.9	--
7	283242081224201	06-17-87	389	7.50	.40	1.40	<.02	.31	5.0	4.7
		09-01-87	379	7.20	.70	2.20	<.02	.24	4.0	4.6
		09-01-87	379	7.20	.70	2.20	<.02	.24	4.5	4.5
		04-28-88	383	7.40	.20	2.00	<.02	.28	2.7	--
		10-26-88	352	7.56	.40	1.10	<.02	.47	3.2	--
8	283243081224101	06-11-87	376	7.50	.30	1.40	<.02	.31	5.0	4.7
		08-28-87	345	7.50	.70	1.30	<.02	.24	4.0	4.8
		04-27-88	353	7.30	.20	1.70	<.02	.33	2.6	--
		09-16-88	347	7.70	.00	1.30	<.10	.23	4.7	--
		10-26-88	344	7.54	.40	1.20	<.02	.32	3.1	--
11	283252081223101	11-02-88	327	7.58	.26	.84	<.02	.21	2.8	--
12	283300081224701	04-27-88	300	7.70	.03	.47	<.02	.20	2.4	--
		08-18-88	268	7.80	.04	.39	<.02	.13	5.3	--
		11-02-88	280	8.19	.16	.35	<.02	.10	3.0	--
13	283309081230001	06-16-87	299	7.50	.29	.67	<.02	.16	4.8	--
		08-31-87	249	7.50	.39	.61	<.02	.12	6.0	6.8
		05-03-88	289	7.50	.19	.49	<.02	.13	4.9	--
		09-16-88	248	7.60	.09	.31	<.10	.08	4.0	--
		11-01-88	281	7.65	.29	.53	<.02	.15	4.0	--
14	283310081205901	06-12-87	310	8.10	.11	.26	<.02	.03	3.0	3.2

*Gertrude Street monitoring well.

APPENDIX III.--Quality of water analyses for urban Orlando area wells--Continued

Site No.	Site identificaiton number	Date	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)	Hardness, total (mg/L as $CaCO_3$)
1	283147081214701	06-10-87	55	8.6	11	2.1	18	10	--	170
2	283218081224801	06-09-87	48	10	12	1.7	17	7.0	--	160
		08-31-87	47	10	12	1.7	--	4.0	--	160
		05-03-88	48	10	11	1.7	15	3.3	.20	160
		09-13-88	49	11	12	1.6	15	7.0	.20	170
		11-02-88	47	10	11	1.7	15	4.9	.20	160
3	283223081211501	06-11-87	42	5.8	14	2.7	21	13	--	130
		08-31-87	50	7.3	20	4.8	--	6.0	--	150
4	283235081223801	08-18-88	30	7.1	8.6	0.80	12	1.5	.20	100
		11-01-88	29	6.6	8.1	0.70	12	1.9	.20	100
5	283240081225001	04-28-88	47	9.8	13	2.3	14	7.2	.30	160
		09-13-88	47	11	13	1.9	14	7.3	.30	160
		10-31-88	45	10	12	1.9	14	5.5	.40	150
7	283242081224201	06-17-87	48	10	13	2.0	17	13	--	160
		09-01-87	46	9.6	15	1.9	--	13	--	150
		09-01-87	47	9.6	15	1.9	--	13	--	160
		04-28-88	47	10	14	1.8	17	6.1	.40	160
		10-26-88	45	9.7	11	1.8	15	5.6	.30	150
8	283243081224101	04-24-86	44	9.1	11	1.9	14	2.8	.30	150
		06-11-87	48	10	11	1.9	14	9.5	--	160
		08-28-87	44	9.2	11	1.9	--	9.7	--	150
		04-27-88	44	10	11	1.9	13	3.2	.30	150
		09-16-88	46	10	12	1.7	13	10	.30	160
		10-26-88	44	9.7	10	1.8	13	5.0	.30	150
11	283252081223101	11-02-88	43	8.6	8.4	1.9	14	7.8	.30	140
12	283300081224701	04-27-88	39	7.3	8.5	1.9	11	7.8	.20	130
		08-18-88	36	5.5	8.6	2.1	12	8.9	.30	110
		11-02-88	40	3.0	12	1.9	8.0	1.9	.50	110
13	283309081230001	06-16-87	37	7.1	9.0	2.3	16	10	--	120
		08-31-87	31	5.5	7.8	2.2	--	11	--	100
		05-03-88	36	6.9	8.6	2.6	16	14	.30	120
		09-16-88	32	5.9	8.4	2.6	13	20	.20	100
		11-01-88	36	6.4	7.9	3.0	15	10	.20	120
14	283310081205901	06-12-87	42	7.0	10	1.0	12	5.0	--	130

APPENDIX III.--Quality of water analyses for urban Orlando area wells--Continued

Site No.	Site identification number	Date	Chromium, total recoverable (µg/L as Cr)	Iron, total recoverable (µg/L as Fe)	Iron, dissolved (µg/L as Fe)	Lead, dissolved (µg/L as Pb)	Lead, total recoverable (µg/L as Pb)	Manganese, total recoverable (µg/L as Mn)	Zinc, dissolved (µg/L as Zn)	Zinc, total recoverable (µg/L as Zn)
1	283147081214701	06-10-87	20	110	--	--	14	30	--	170
2	283218081224801	06-09-87	<10	920	--	--	18	<10	--	260
		08-31-87	--	--	--	--	<100	--	--	20
		05-03-88	<10	580	100	<5	5	10	10	30
		09-13-88	1	130	77	<5	<5	<10	62	150
		11-02-88	<10	340	50	<5	<5	<10	50	70
3	283223081211501	06-11-87	30	280	--	--	<5	10	--	<10
		08-31-87	--	--	--	--	<100	--	--	<10
4	283235081223801	08-18-88	<10	80	50	<5	<5	<10	<10	20
		11-01-88	<10	40	20	<5	<5	<10	<10	<10
5	283240081225001	04-28-88	<10	70	40	<5	<5	10	<10	<10
		09-13-88	1	120	93	<5	<5	<10	6	<10
		10-31-88	<10	100	70	<5	<5	10	<10	<10
7	283242081224201	06-17-87	40	70	--	--	<5	<10	--	<10
		09-01-87	--	--	--	--	<100	--	--	<10
		09-01-87	--	--	--	--	<100	--	--	<10
		04-28-88	<10	60	30	<5	<5	20	<10	10
		10-26-88	<10	100	80	<5	<5	10	<10	10
8	283243081224101	01-18-85	10	180	--	--	<1	50	--	20
		04-24-86	1	100	60	--	14	20	--	20
		06-11-87	<10	90	--	--	<5	<10	--	<10
		08-28-87	--	--	--	--	<100	--	--	<10
		04-27-88	<10	100	60	<5	<5	20	10	40
		09-16-88	1	150	110	<5	<5	<10	12	90
		10-26-88	<10	80	50	<5	<5	10	80	90
11	283252081223101	11-02-88	<10	70	40	<5	<5	10	<10	<10
12	283300081224701	04-27-88	<10	330	260	<5	<5	20	<10	60
		08-18-88	<10	380	110	<5	<5	20	<10	10
		11-02-88	<10	410	170	<5	<5	20	<10	<10
13	283309081230001	06-16-87	20	200	--	--	<5	20	--	<10
		08-31-87	--	--	--	--	<100	--	--	<10
		05-03-88	<10	180	130	<5	<5	20	<10	<10
		09-16-88	1	670	190	<5	<5	20	6	20
		11-01-88	40	1200	610	<5	<5	40	<10	70
14	283310081205901	06-12-87	<10	<10	--	--	<5	<10	--	<10

Site No.	Site identification number	Date	Ace-naph-thylene, total (µg/L)	Ace-naph-thene, total (µg/L)	Anthra-cene, total (µg/L)	Fluor-anthene, total (µg/L)	Fluor-ene, total (µg/L)	Py-rene, total (µg/L)	Phenan-threne, total (µg/L)	Naph-tha-lene, total (µg/L)
7	283242081224201	06-17-87	<5.0	18.9	0.35	0.50	2.2	0.61	1.7	15.3
		10-26-88	.10	18.8	.38	1.1	1.9	2.5	1.7	7.5
8	283243081224101	01-18-85	<1.0	9.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
		06-11-87	<5.0	10.3	.09	.38	.30	.62	.16	.32
9	283243081230701	10-28-88	.92	32.7	2.8	3.9	15.3	6.9	17.2	258
10	283244081232001	10-26-88	<5.0	.14	<5.0	<5.0	<5.0	<5.0	<5.0	.04
11	283252081223101	11-02-88	<5.0	4.0	<5.0	.09	.06	.63	<5.0	<5.0

Site No.	Site identification number	Date	Ethion, total (µg/L)	Mala-thion, total (µg/L)	Para-thion, total (µg/L)	Di-azinon, total (µg/L)	Methyl para-thion, total (µg/L)	2,4-D, total (µg/L)	2,4,5-T total (µg/L)	Silvex, total (µg/L)
1	283147081214701	06-10-87	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
2	283218081224801	06-09-87	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
		08-31-87	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
3	283223081211501	06-11-87	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
		08-31-87	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
7	283242081224201	06-17-87	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
		09-01-87	<.01	<.01	<.01	<.03	<.03	<.01	<.01	<.01
		09-01-87	<.01	<.01	<.01	<.03	<.03	<.01	<.01	<.01
8	283243081224101	01-18-85	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
		06-11-87	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
		08-28-87	<.01	<.01	<.01	.01	<.01	<.01	<.01	<.01
13	283309081230001	06-16-87	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
		08-31-87	<.01	<.01	<.01	.01	<.01	<.01	<.01	<.01
14	283310081205901	06-12-87	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01

Site No.	Site identification number	Date	Dichlorobromomethane, total (μg/L)	Carbontetrachloride, total (μg/L)	1,2-Dichloroethane, total (μg/L)	Bromoform, total (μg/L)	Chlorodibromomethane, total (μg/L)	Chloroform, total (μg/L)	Trichlorofluoromethane, total (μg/L)	Dichlorodifluoromethane, total (μg/L)
1	283147081214701	06-10-87	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	0.50
2	283218081224801	06-09-87	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
		08-31-87	<.20	<.20	<.20	<.20	<.20	<.20	<.20	--
		05-03-88	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
		09-13-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
		11-02-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
3	283223081211501	06-11-87	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
		08-31-87	<.20	<.20	<.20	<.20	<.20	<.20	<.20	--
4	283235081223801	08-18-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
		11-01-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
5	283240081225001	04-28-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
		09-13-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
		10-31-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
6	283241081231501	05-23-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
		05-23-88	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
		10-25-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	.40
		10-25-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	.30
7	283242081224201	06-17-87	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
		09-01-87	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	--
		09-01-87	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	--
		04-28-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
		10-26-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
8	283243081224101	06-11-87	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
		08-28-87	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
		04-27-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
		09-16-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
		10-26-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
9	283243081230701	05-25-88	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
		05-25-88	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
		10-28-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	1.2
		10-28-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	.40
		10-28-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	.40
10	283244081232001	10-26-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	.30
11	283252081223101	11-02-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
		11-02-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
12	283300081224701	04-27-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
		08-18-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
		11-02-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
13	283309081230001	06-16-87	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
		08-31-87	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
		05-03-88	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
		09-16-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
14	283310081205901	06-12-87	<.20	<.20	<.20	<0.20	<.20	<.20	<.20	<.20

APPENDIX III.--Quality of water analyses for urban Orlando area wells--Continued

Site No.	Site identification number	Date	Ben- zene, total (µg/L)	Tol- uene, total (µg/L)	Ethyl- benzene, total (µg/L)	Xylene, total water whole tot rec (µg/L)	Chloro- benzene total (µg/L)	1,2- Di- Chloro- benzene, total (µg/L)	1,3- Di- Chloro- benzene, total (µg/L)	1,4- Di- Chloro- benzene, total (µg/L)
1	283147081214701	06-10-87	<0.20	<0.20	<0.20	<0.2	<0.20	<0.20	<0.20	<0.20
2	283218081224801	06-09-87	<.20	<.20	<.20	<.2	<.20	<.20	<.20	<.20
		08-31-87	<.20	<.20	<.20	<.2	<.20	<.20	<.20	<.20
		05-03-88	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
		09-13-88	<.20	<.20	<.20	<.2	<.20	<.20	<.20	<.20
		11-02-88	.30	.20	<.20	<.2	<.20	<.20	<.20	<.20
3	283223081211501	06-11-87	<.20	<.20	<.20	<.2	<.20	<.20	<.20	<.20
		08-31-87	.30	<.20	<.20	--	.70	<.20	<.20	5.7
4	283235081223801	08-18-88	<.20	<.20	<.20	<.2	<.20	<.20	<.20	<.20
		11-01-88	<.20	<.20	<.20	<.2	<.20	<.20	<.20	<.20
5	283240081225001	04-28-88	87	<.20	<.20	<.2	<.20	<.20	<.20	<.20
		09-13-88	34	<.20	<.20	<.2	<.20	<.20	<.20	<.20
		10-31-88	64	.20	.20	.2	<.20	<.20	<.20	<.20
6	283241081231501	05-23-88	8.2	2.7	<.20	.8	<.20	<.20	<.20	<.20
		05-23-88	3.5	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
		10-25-88	12	.20	<.20	.7	<.20	<.20	<.20	<.20
		10-25-88	12	.20	.20	.7	<.20	<.20	<.20	<.20
7	283242081224201	06-17-87	210	.30	.60	1.2	<.20	<5.0	<5.0	<5.0
		09-01-87	440	1.0	<1.0	1.5	<1.0	<1.0	<1.0	<1.0
		09-01-87	470	1.0	<1.0	1.9	<1.0	<1.0	<1.0	<1.0
		04-28-88	160	.50	.90	1.9	<.20	<.20	<.20	<.20
		10-26-88	86	<.20	.30	.6	<.20	<5.0	<5.0	<5.0
8	283243081224101	06-11-87	>40	.20	.30	<.2	<.20	<5.0	<5.0	<5.0
		08-28-87	65	<.20	<.20	<.2	<.20	<.20	<.20	<.20
		04-27-88	81	<.20	<.20	<.2	<.20	<.20	<.20	<.20
		09-16-88	93	<.20	<.20	<.2	<.20	<.20	<.20	<.20
		10-26-88	53	<.20	<.20	.2	.20	<.20	<.20	<.20
9	283243081230701	05-25-88	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
		05-25-88	100	1.3	5.9	14	<1.0	<1.0	<1.0	<1.0
		10-28-88	32	.70	3.3	6.4	<.20	<.20	<.20	<.20
		10-28-88	90	1.2	7.6	15	<.20	<.20	<.20	<.20
		10-28-88	94	1.2	7.6	15	<.20	<5.0	<5.0	<5.0
10	283244081232001	10-26-88	<.20	<.20	<.20	<.2	<.20	<5.0	<5.0	<5.0
11	283252081223101	11-02-88	<.20	<.20	<.20	<.2	.30	<5.0	<5.0	<5.0
		11-02-88	.20	<.20	<.20	<.2	<.20	<.20	<.20	<.20
12	283300081224701	04-27-88	<.20	<.20	<.20	<.2	<.20	<.20	<.20	<.20
		08-18-88	<.20	<.20	<.20	<.2	<.20	<.20	<.20	<.20
		11-02-88	<.20	<.20	<.20	<.2	<.20	<.20	<.20	<.20
13	283309081230001	06-16-87	<.20	<.20	<.20	<.2	<.20	<.20	<.20	<.20
		08-31-87	<.20	<.20	<.20	<.2	<.20	<.20	<.20	<.20
		05-03-88	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
		09-16-88	<.20	<.20	<.20	<.2	<.20	<.20	<.20	<.20
14	283310081205901	06-12-87	<.20	<.20	<.20	<.2	<.20	<.20	<.20	<.20

APPENDIX III.--Quality of water analyses for urban Orlando area wells--Continued

Site No.	Site identification number	Date	Chloro-ethane, total (μg/L)	1,1-Di-chloro-ethane, total (μg/L)	1,1,1-Tri-chloro-ethane, total (μg/L)	1,1,2-Tri-chloro-ethane, total (μg/L)	1,1,2,2 Tetra-chloro-ethane, total (μg/L)	Methyl-bromide, total (μg/L)	Methyl-chlo-ride, total (μg/L)	Methyl-ene chlo-ride, total (μg/L)
1	283147081214701	06-10-87	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
2	283218081224801	06-09-87	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
		08-31-87	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
		05-03-88	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
		09-13-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
		11-02-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
3	283223081211501	06-11-87	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
		08-31-87	<.20	<.20	.20	<.20	<.20	<.20	<.20	<.20
4	283235081223801	08-18-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
		11-01-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
5	283240081225001	04-28-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
		09-13-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
		10-31-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
6	283241081231501	05-23-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
		05-23-88	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
		10-25-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
		10-25-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
7	283242081224201	06-17-87	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
		09-01-87	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
		09-01-87	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
		04-28-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
		10-26-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
8	283243081224101	06-11-87	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
		08-28-87	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
		04-27-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
		09-16-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
		10-26-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
9	283243081230701	05-25-88	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
		05-25-88	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
		10-28-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
		10-28-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
		10-28-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
10	283244081232001	10-26-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
11	283252081223101	11-02-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
		11-02-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
12	283300081224701	04-27-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
		08-18-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
		11-02-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
13	283309081230001	06-16-87	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
		08-31-87	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
		05-03-88	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
		09-16-88	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
14	283310081205901	06-12-87	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20

APPENDIX III.--Quality of water analyses for urban Orlando area wells--Continued

Site No.	Site identification number	Date	Tetra-chloro-ethyl-ene, total (µg/L)	1,1-Di-chloro-ethyl-ene, total (µg/L)	1,2-Transdi-chloro-ethylene, total (µg/L)	Vinyl chlo-ride, total (µg/L)	Tri-chloro-ethyl-ene, total (µg/L)	2-Chloro-ethyl-vinyl-ether, total (µg/L)	1,2-Dibromo-ethyl-ene, total (µg/L)	1,2-Di-chloro-propane, total (µg/L)
1	283147081214701	06-10-87	<0.20	<0.20	<0.20	<0.20	<0.2	<0.20	<0.2	<0.20
2	283218081224801	06-09-87	<.20	<.20	<.20	<.20	<.2	<.20	<.2	<.20
		08-31-87	<.20	<.20	<.20	<.20	<.2	--	<.2	<.20
		05-03-88	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
		09-13-88	<.20	<.20	<.20	<.20	<.2	<.20	--	<.20
		11-02-88	<.20	<.20	<.20	<.20	<.2	<.20	--	<.20
3	283223081211501	06-11-87	<.20	<.20	<.20	<.20	<.2	<.20	<.2	<.20
		08-31-87	<.20	<.20	1.0	<.50	<.2	--	<.2	<.20
4	283235081223801	08-18-88	<.20	<.20	<.20	<.20	<.2	<.20	<.2	<.20
		11-01-88	<.20	<.20	<.20	<.20	<.2	<.20	--	<.20
5	283240081225001	04-28-88	<.20	<.20	<.20	<.20	2.3	<.20	<.2	<.20
		09-13-88	<.20	<.20	8.9	<.20	1.1	<.20	--	<.20
		10-31-88	<.20	<.20	.20	<.20	.2	<.20	--	<.20
6	283241081231501	05-23-88	<.20	<.20	.30	<.20	<.2	<.20	--	<.20
		05-23-88	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
		10-25-88	<.20	<.20	<.20	<.20	<.2	<.20	--	<.20
		10-25-88	<.20	<.20	<.20	<.20	<.2	<.20	--	<.20
7	283242081224201	06-17-87	<.20	<.20	<.20	<.20	<.2	<.20	<.2	<.20
		09-01-87	<1.0	<1.0	<1.0	<1.0	<1.0	--	<1.0	<1.0
		09-01-87	<1.0	<1.0	<1.0	<1.0	<1.0	--	<1.0	<1.0
		04-28-88	<.20	<.20	<.20	<.20	<.2	<.20	<.2	<.20
		10-26-88	<.20	<.20	<.20	<.20	<.2	<.20	--	<.20
8	283243081224101	06-11-87	<.20	<.20	<.20	<.20	<.2	<.20	<.2	<.20
		08-28-87	<.20	<.20	<.20	<.20	<.2	<.20	<.2	<.20
		04-27-88	<.20	<.20	<.20	<.20	<.2	<.20	<.2	<.20
		09-16-88	<.20	<.20	.20	<.20	<.2	<.20	--	<.20
		10-26-88	<.20	<.20	<.20	<.20	<.2	<.20	--	<.20
9	283243081230701	05-25-88	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
		05-25-88	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	--	<1.0
		10-28-88	<.20	<.20	<.20	<.20	<.2	<.20	--	<.20
		10-28-88	<.20	<.20	<.20	<.20	<.2	<.20	--	<.20
		10-28-88	<.20	<.20	<.20	<.20	<.2	<.20	--	<.20
10	283244081232001	10-26-88	<.20	<.20	<.20	<.20	<.2	<.20	<.20	--
11	283252081223101	11-02-88	<.20	<.20	<.20	<.20	<.2	<.20	--	<.20
		11-02-88	<.20	<.20	<.20	<.20	<.2	<.20	--	<.20
12	283300081224701	04-27-88	.70	<.20	<.20	<.20	<.2	<.20	<.2	<.20
		08-18-88	<.20	<.20	<.20	<.20	<.2	<.20	<.2	<.20
		11-02-88	<.20	<.20	<.20	<.20	<.2	<.20	--	<.20
13	283309081230001	06-16-87	<.20	<.20	<.20	<.20	<.2	<.20	<.2	<.20
		08-31-87	<.20	<.20	<.20	<.20	<.2	<.20	<.2	<.20
		05-03-88	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
		09-16-88	<.20	<.20	<.20	<.20	<.2	<.20	--	<.20
14	283310081205901	06-12-87	<.20	<.20	<.20	<.20	<.2	<.20	<.2	<.20

Appendix IV

APPENDIX IV. Quality of water analyses for Lake Underhill site

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; --, no data; mg/L, milligrams per liter; <, less than; >, greater than; µg/L, micrograms per liter]

Site name	Site identification number	Date	Specific conductance, lab (µS/cm)	pH lab, (standard units)	pH field, (standard units)	Nitrogen, organic, total (mg/L as N)	Nitrogen, ammonia, total (mg/L as N)	Nitrogen, NO_2+NO_3, total (mg/L as N)	Phosphorus, total (mg/L as P)	Carbon, organic, total (mg/L as C)
Lake Underhill	02262550	11-20-87	163	8.1	--	0.78	0.02	<0.01	0.10	9.2
		05-24-88	170	6.9	9.1	1.60	.02	<.02	.07	6.7
		09-08-88	149	7.6	7.4	.86	.04	<.10	.04	6.9
		11-17-88	157	7.3	8.6	1.10	.01	>.02	.08	4.7
Monitoring well 1	283219081195601	05-24-88	245	7.7	8.0	.93	.07	.18	.21	5.2
		09-08-88	167	7.7	7.6	.69	.11	<.10	.04	8.2
		11-17-88	295	7.7	7.5	.62	.38	<.02	.16	4.5
Monitoring well 2	283219081195501	11-20-87	358	8.2	--	.34	.26	<.10	.07	3.5
		05-24-88	400	8.0	7.8	.22	.10	.03	.20	--
		09-08-88	351	8.4	8.0	.33	.17	.10	.07	3.7
		11-17-88	406	7.7	7.5	.76	.11	.03	.25	5.9

Site name	Site identification number	Date	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)	Hardness, total (mg/L as $CaCO_3$)
Lake Underhill	02262550	11-20-87	20	2.2	5.4	2.0	12	16	--	59
		05-24-88	21	2.3	5.5	1.9	9.4	16	.10	62
		09-08-88	19	2.3	5.5	1.8	9.0	14	.10	57
		11-17-88	20	2.2	4.8	2.1	9.3	15	.20	59
Monitoring well 1	283219081195601	05-24-88	26	2.7	5.8	1.9	10	17	.20	76
		09-08-88	21	2.6	5.7	1.8	9.1	16	.10	63
		11-17-88	38	7.7	5.3	2.2	9.8	26	.20	130
Monitoring well 2	283219081195501	11-20-87	58	6.6	5.8	2.3	11	41	--	170
		05-24-88	72	5.6	5.4	2.4	9.2	62	.20	200
		09-08-88	57	6.6	6.0	1.9	9.4	45	.10	170
		11-17-88	67	5.8	5.7	2.5	10	51	.20	190

Site name	Site identification number	Date	Chromium, total recoverable (µg/L as Cr)	Iron, total recoverable (µg/L as Fe)	Iron, dissolved (µg/L as Fe)	Lead, dissolved (µg/L as Pb)	Lead, total recoverable (µg/L as Pb)	Manganese, total recoverable (µg/L as Mn)	Zinc, dissolved (µg/L as Zn)	Zinc, total recoverable (µg/L as Zn)
Lake Underhill	02262550	11-20-87	1	40	--	--	<5	20	--	10
		05-24-88	<10	110	10	<5	<5	20	10	20
		09-08-88	<1	40	4	<5	<5	20	6	10
		11-17-88	<10	120	10	<5	<5	30	<10	20
Monitoring well 1	283219081195601	05-24-88	<10	11,000	70	<5	<5	90	10	30
		09-08-88	<1	510	34	<5	<5	30	35	50
		11-17-88	<10	17,000	10	<5	<5	160	10	40
Monitoring well 2	283219081195501	11-20-87	<1	70	--	--	<5	10	--	<10
		05-24-88	<10	1,100	10	<5	<5	30	20	40
		09-08-88	<1	3,300	18	<5	<5	100	9	10
		11-17-88	<10	1,200	40	<5	<5	30	30	50

APPENDIX IV.--Quality of water analyses for Lake Underhill site--Continued

Site name	Site identification number	Date	Ethion, total (μg/L)	Mala-thion, total (μg/L)	Para-thion, total (μg/L)	Dia-zinon, total (μg/L)	Methyl para-thion, total (μg/L)	2,4-D, total (μg/L)	2,4,5-T total (μg/L)	Silvex, total (μg/L)
Lake Underhill	02262550	11-20-87	<0.01	<0.01	<0.01	0.01	<0.01	0.01	<0.01	<0.01
Monitoring well 2	283219081195501	11-20-87	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01

Site name	Site identification number	Date	Benzene, total (μg/L)	Toluene, total (μg/L)	Ethyl-benzene, total (μg/L)	Xylene, total recov-erable (μg/L)	Chloro-benzene, total (μg/L)	1,2-Di-chloro-benzene, total (μg/L)	1,3-Di-chloro-benzene, total (μg/L)	1,4-Di-chloro-benzene, total (μg/L)
Lake Underhill	02262550	11-20-87	<0.20	0.20	<0.20	<0.2	<0.20	<0.20	<0.20	<0.20
Monitoring well 2	283219081195501	11-20-87	<.20	<.20	--	<.2	<.20	<.20	<.20	<.20

Site name	Site identification number	Date	Di-chloro-bromo-methane, total (μg/L)	Carbon-tetra-chlo-ride, total (μg/L)	1,2-Di-chloro-ethane, total (μg/L)	Bromo-form, total (μg/L)	Chloro-di-bromo-methane, total (μg/L)	Chloro-form, total (μg/L)	Tri-chloro-fluoro-methane, total (μg/L)	Di-chloro-di-fluoro-methane, total (μg/L)
Lake Underhill	02262550	11-20-87	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	0.50
Monitoring well 2	283219081195501	11-20-87	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20

Site name	Site identification number	Date	Chloro-ethane, total (μg/L)	1,1-Di-chloro-ethane, total (μg/L)	1,1,1-Tri-chloro-ethane, total (μg/L)	1,1,2-Tri-chloro-ethane, total (μg/L)	1,1,2,2 Tetra-chloro-ethane, total (μg/L)	Methyl-bromide, total (μg/L)	Methyl-chlo-ride, total (μg/L)	Methyl-ene chlo-ride, total (μg/L)
Lake Underhill	02262550	11-20-87	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Monitoring well 2	283219081195501	11-20-87	--	<.20	<.20	<.20	<.20	<.20	<.20	<.20

Site name	Site identification number	Date	Tetra-chloro-ethyl-ene, total (μg/L)	1,1-Di-chloro-ethyl-ene, total (μg/L)	1,2-Transdi chloro-ethene, total (μg/L)	Vinyl chlo-ride, total (μg/L)	Tri-chloro-ethyl-ene, total (μg/L)	2-Chloro-ethyl-vinyl-ether, total (μg/L)	1,2-Di-bromo-ethyl-ene, total (μg/L)	1,2-Di-chloro-propane, total (μg/L)
Lake Underhill	02262550	11-20-87	<0.20	<0.20	<0.20	<0.20	<0.2	<0.20	<0.2	<0.20
Monitoring well 2	283219081195501	11-20-87	<.20	<.20	<.20	<.20	<.2	<.20	<.2	<.20

*U.S. Government Printing Office: 1991 — 531-124/40004