# EVALUATION OF THE HYDROGEOLOGY AND CONTAMINATION IN THE VICINITY OF AN ABANDONED MANUFACTURED GAS PLANT IN ALBANY, GEORGIA

By Melinda J. Chapman

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U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 91-4178

Prepared in cooperation with the

**CITY OF ALBANY**
**WATER, GAS, AND LIGHT COMMISSION**

U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849

Doraville, Georgia

1991

U.S. DEPARTMENT OF THE INTERIOR

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## CONVERSION FACTORS, VERTICAL DATUM, AND ACRONYMNS

| *Multiply* | *by* | *to obtain* |
|---|---|---|
| | **Length** | |
| inch (in.) | 25.4 | millimeter |
| foot (ft) | 0.3048 | meter |
| mile (mi) | 1.609 | kilometer |
| | **Area** | |
| acre | 0.4047 | hectare |
| | **Hydraulic conductivity** | |
| foot per day (ft/d) | 0.3048 | meter per day |
| | **Mass** | |
| ounce (oz) | 0.02835 | kilogram |
| pound (lb) | 0.4536 | kilogram |
| | **Concentration** | |
| part per billion (ppb) | 1 | microgram per liter |
| part per billion (ppb) | 1 | microgram per kilogram |
| part per million (ppm) | 1 | milligram per liter |
| part per million (ppm) | 1 | milligram per kilogram |
| | **Volume** | |
| gallons (gal) | 0.003785 | meter$^3$ |

## CONVERSION FACTORS, VERTICAL DATUM, AND ACRONYMNS--Continued

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

## ACRONYMNS

| | |
|---|---|
| ARS | U.S. Department of Agriculture, Agricultural Research Service |
| AWGLC | Albany Water, Gas, and Light Commission |
| EP | Extraction procedure |
| MGP | Manufactured gas plant(s) |
| NPAL | Nonaqueous-phase liquid |
| PVC | Polyvinylchloride |
| RCRA | Resource Conservation and Recovery Act |
| SVOC | Semivolatile organic compound(s) |
| VOC | Volatile organic compound(s) |

# EVALUATION OF THE HYDROGEOLOGY AND CONTAMINATION IN THE VICINITY OF AN ABANDONED MANUFACTURED GAS PLANT IN ALBANY, GEORGIA

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## ABSTRACT

An investigation was conducted in the area of an abandoned manufactured gas plant in Albany, Georgia, to evaluate the extent and movement of wastes resulting from past manufacturing operations in hydrogeologic systems such as those present in the area. A preliminary investigation (1990) delineated areas of hydrocarbon contamination near the former gas-holding tanks at the abandoned gas-plant site. Maximum concentrations of hydrocarbons in ground water from the shallow water-bearing zone included 18,000 micrograms per liter (μg/L) naphthalene, 17,000 μg/L benzene, and 5,300 μg/L phenanthrene. Unconsolidated sediment samples also contained high concentrations of hydrocarbons, including 560,000 micrograms per kilogram (μg/kg) naphthalene, 73,000 μg/kg ethylbenzene, and 28,000 μg/kg benzene. Various metals and cyanide also were detected in the sediment samples. In some of these areas, the contamination extended downward to the top of the Ocala Limestone, the principal formation of the Upper Floridan aquifer in the Albany area. In general, shallow contamination (less than 30 feet below land surface) in the unconsolidated sediments decreased areally away from the former gas-holding tank area.

This investigation (1991) expands the scope of the preliminary study (1990) to include the evaluation of possible ground-water contamination in the Upper Floridan aquifer. Results from the chemical analyses of ground water collected as part of this investigation indicate the presence of hydrocarbons in the upper water-bearing zone of the Upper Floridan aquifer in the study area. Many of the same organic compounds detected in samples from the shallow water-bearing zone during the preliminary investigation also were detected in water samples from the Upper Floridan aquifer. Maximum concentrations of selected contaminants included 200 μg/L naphthalene, 150 μg/L benzene, and 130 μg/L ethylbenzene. These results indicate that downward migration of contaminants occurs in the vicinity of the former gas-holding tanks in the study area, and may be occurring at other abandoned manufactured gas plant sites where hydrogeologic conditions are similar.

Water samples from the shallow water-bearing zone and from the Upper Floridan aquifer were found to contain iron, manganese, lead, and cadmium concentrations greater than recommended limits in Federal drinking-water standards. The spatial distribution of the metals does not correlate with the distribution of organic compounds; and thus, may not be related to past gas-plant operations. Various metal, brick, concrete, and wood debris have been deposited in surficial fill in the study area.

# INTRODUCTION

Prior to World War II, much of the gas used for lighting and heating in the United States was produced from coal or oil, or a combination of both, at manufactured gas plants. By 1942, there were more than 1,000 such plants throughout the United States (Edison Electric Institute, 1984). Following the introduction of interstate pipelines for natural gas distribution in the late 1940's and early 1950's, manufactured gas plants began to cease operations because of the lower heating value of manufactured gas (measured in British Thermal Units) compared to that of less expensive natural gas.

Gas plant by-products and wastes commonly were disposed of on site and may still be present in the environment. These primary wastes include condensed tar, residues and sludges, spent oxides, and ash materials. These wastes also may include a complex mixture of hundreds of aromatic organic compounds, as well as cyanides and metals, many of which are recognized by the U.S. Environmental Protection Agency (EPA) (1986, 1989) as carcinogenic or priority pollutants, or both.

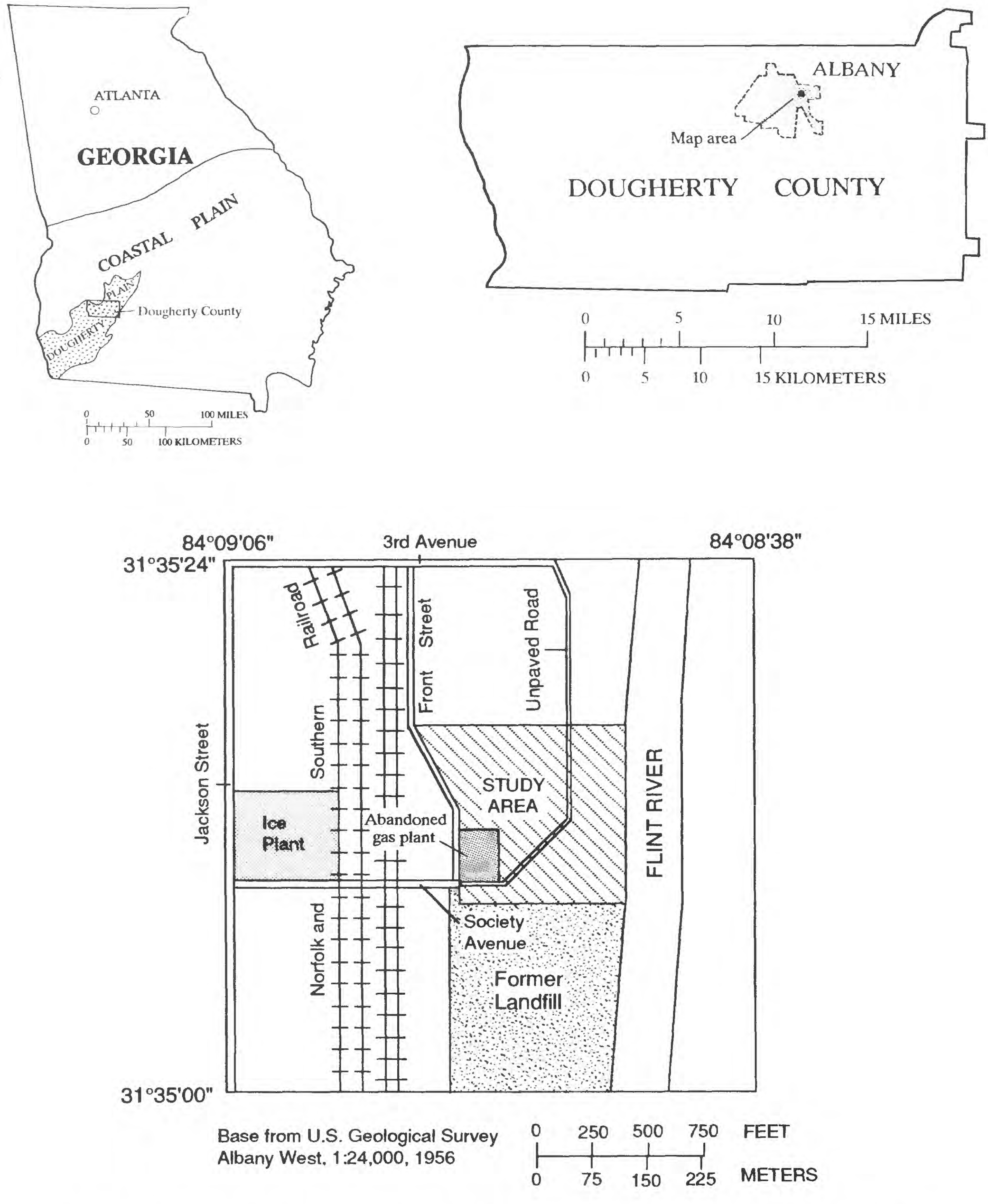
Although it has been decades since manufactured gas plants ceased operations, the presence of their generated wastes in the environment and the possible migration of waste condtituents into surface- or ground-water supplies have resulted in concern about public health and environmental contamination. Despite the widespread distribution of gas plants and the potentially harmful nature of the associated wastes, few of these sites have been investigated (Chapman and others, 1990).

In January 1989, the U.S. Geological Survey, in cooperation with the Albany Water, Gas, and Light Commission (AWGLC), began an investigation in the area of an abandoned manufactured gas plant (MGP) to evaluate the extent and movement of those waste products in hydrogeologic systems, such as those present in the study area (fig. 1). A preliminary investigation delineated areas of hydrocarbon contamination near the former gas-holding tank areas (Chapman and others, 1990). Because contamination was detected to the depth of the top of the Upper Floridan aquifer, further study of possible ground-water contamination and the movement of contaminants in aquifer systems, such as the Upper Floridan, was initiated. The results of this study can be used to guide management and remediation decisions related to this and other abandoned manufactured gas plants in similar hydrogeologic environments.

## Purpose and Scope

The objectives of the investigation were to (1) describe the hydrogeologic framework of the uppermost major aquifer system (Upper Floridan aquifer) and its relation to the overlying unconsolidated sediments, (2) chemically characterize wastes and evaluate the distribution of selected contaminants in water within the Upper Floridan aquifer, (3) further characterize contaminants in the overlying unconsolidated sediments and water from the shallow water-bearing zone, and (4) identify potential pathways of contaminant migration in the unconsolidated sediments and in the Upper Floridan aquifer in the area of the abandoned Albany MGP.

This report describes the hydrogeologic characteristics of the upper water-bearing zone of the Upper Floridan aquifer based on data from geologic logs recorded during drilling of four monitoring wells and from borehole geophysical logs. The hydrogeologic characteristics of the unconsolidated sediments are described from the hydraulic-conductivity analyses of clay samples. Additional information is provided on the characteristics of wastes from the Albany MGP operations and water quality in the shallow water-bearing zone of the unconsolidated sediments. Discussions also include water-level fluctuations, ground-water quality, and potential sources and migration pathways of contaminants in the Upper Floridan aquifer.



Base from U.S. Geological Survey
Albany West, 1:24,000, 1956

Figure 1.--Study area, ice plant, abandoned gas plant, and former landfill in the Albany area. From Chapman and others (1990).

## Description of the Area

The study area lies in the Dougherty Plain district of the Coastal Plain physiographic province in southwestern Georgia, in the city of Albany (fig. 1). The area encompasses about 12 acres and is characterized by relatively level topography ranging in altitude from 150 to 187 ft above sea level (Chapman and others, 1990). The Albany MGP was located on approximately 3 acres of the study area. The operational layout of the Albany MGP is shown on figure 2.

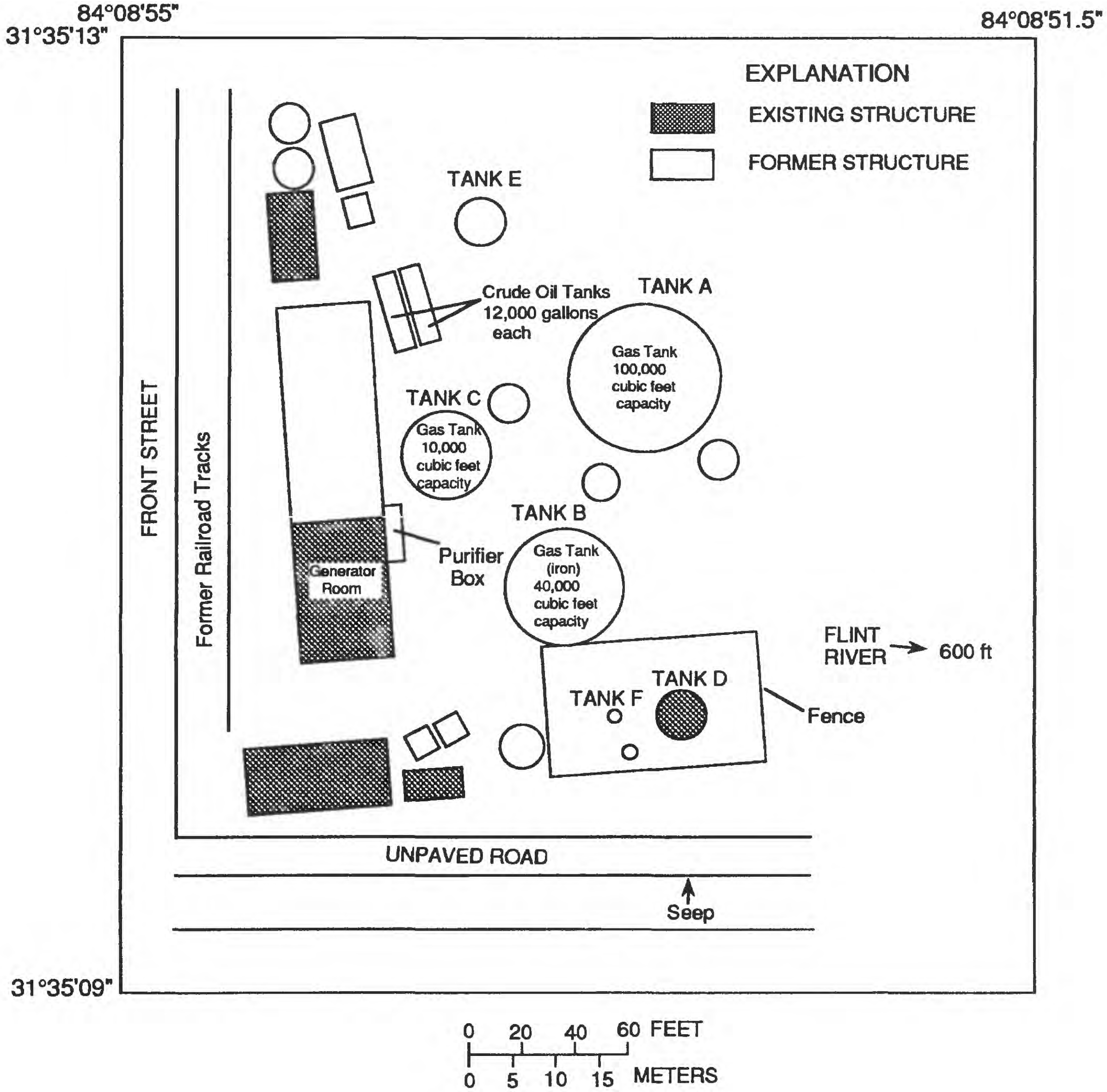


Figure 2.--General operational layout of the Albany gas plant. Modified from Chapman and others (1990).

The Flint River flows within 600 ft of the abandoned MGP and is the eastern boundary of the study area (fig. 1). An unpaved road near the southern and eastern boundaries provides access to the river. The Flint River, originating near Atlanta, Ga., and flowing toward the southwestern corner of the State, is the principal surface-water drain for the Dougherty Plain.

Land use within a 3-mi radius of the study area is designated as residential (single-family), commercial, and industrial. Residential housing is dominant (Chapman and others, 1990). About 85,000 people live in the city limits of Albany within an 8-mi radius of the study area. The total population of Metropolitan Albany is about 117,000 (University of Georgia, 1989).

Most of the 116 wells within a 3-mi radius of the study area (table 1), tap the Upper Floridan aquifer; however, some of the wells are completed in the deeper Claiborne, Clayton, and Cretaceous aquifers (Hicks and others, 1981). Well use includes domestic supply (50 percent), commercial and industrial supply (25 percent), and public supply (11 percent) (Dougherty County Health Department, written commun., 1990). Some wells (14 percent) are used as observation wells. Many of the domestic wells are used for nonpotable purposes, such as irrigation and in cooling systems (Dougherty County Health Department, written commun., 1990).

## Methods of Investigation

This investigation includes several methods of data collection and analyses

- drilling monitoring wells completed in the upper unit of the Ocala Limestone (upper water-bearing zone of the Upper Floridan aquifer),
- collecting split-spoon samples of the unconsolidated sediments,
- collecting core samples from the Ocala Limestone,
- collecting clay samples in the unconsolidated sediments,
- collecting samples in the unconsolidated sediments that contain wastes from MGP operations,
- conducting a soil-gas survey in the unconsolidated sediments,
- collecting borehole geophysical logs,
- collecting water samples from wells tapping the upper water-bearing zone of the Upper Floridan aquifer and the shallow water-bearing zone of the unconsolidated sediments, and
- chemically analyzing waste samples from the unconsolidated sediments and ground-water samples from the shallow water-bearing zone of of the unconsolidated sediments and the Upper Floridan aquifer.

Four wells were drilled into the Upper Floridan aquifer, using a combination of hollow-stem augering and rotary drilling methods. Split-spoon samples were collected in the overlying unconsolidated sediments at designated intervals. An outer, 4-in. polyvinylchloride (PVC) casing was sealed by pressure grouting in the annulus of the borehole using neat cement through the unconsolidated sediments. The borehole was advanced into the Upper Floridan aquifer (Ocala Limestone) by rotary drilling methods. Core samples of aquifer material (Ocala Limestone) were collected using a 3-in. coring bit. Borehole stability was increased by adding natural, water-soluble polymer (Variflow[1/]) to the drilling mud that chemically degrades in 72 hours.

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[1/] The use of brand names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

## Table 1.--*Inventory of wells within a 3-mile radius of the study area*

[UFA, Upper Floridan aquifer; CLBR, Claiborne aquifer; CLTN, Clayton aquifer; K, Cretaceous aquifer system; M/A, multi-aquifer well; M/S, multi-screened well; US, unconsolidated sediments; obs., observation well; ps, public-supply well; do., ditto; comm, commercial well; dom, domestic well; ind, industrial well; TW, test well; open, open-hole well (no screens); --, no data]

| Well grid number | Well owner | Year well constructed | Well depth (feet) | Well diameter (inches) | Depth of casing (feet) | Well completion interval | Principal aquifer | Water use | Latitude | Longitude | Land surface altitude (feet) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 12L001 | City of Albany 6 | 1937 | 955 | 18 | 365 | M/S | M/A | ps | 31°34'54" | 84°08'38" | 206 |
| 12L002 | City of Albany 7 | 1939 | 1,027 | 12 | 430 | do. | do. | do. | 31°34'46" | 84°08'55" | 188 |
| 12L003 | City of Albany 8 | 1941 | 653 | 12 | 319 | do. | do. | do. | 31°34'44" | 84°09'56" | 205 |
| 12L004 | City of Albany 9 | 1947 | 795 | 10 | 695 | do. | CLTN | do. | 31°34'48" | 84°08'32" | 195 |
| 12L005 | City of Albany 10 | 1949 | 868 | 10 | 260 | do. | M/A | do. | 31°34'52" | 84°09'33" | 202 |
| 12L006 | City of Albany 11 | 1950 | 921 | 10 | 245 | do. | do. | do. | 31°34'55" | 84°10'25" | 217 |
| 12L007 | City of Albany 12 | 1952 | 725 | 10 | 230 | do. | do. | do. | 31°35'27" | 84°11'14" | 209 |
| 12L008 | City of Albany 13 | 1952 | 800 | 10 | 270 | do. | do. | do. | 31°34'52" | 84°09'16" | 200 |
| 12L009 | City of Albany 14 | 1954 | 885 | 10 | 275 | do. | do. | do. | 31°34'26" | 84°11'25" | 212 |
| 12L010 | City of Albany 15 | 1954 | 975 | 10 | 270 | do. | do. | do. | 31°36'04" | 84°10"50" | 212 |
| 12L011 | City of Albany 16 | 1955 | 928 | 10 | 280 | do. | do. | do. | 31°35'50" | 84°09'29" | 193 |
| 12L013 | City of Albany 20 | 1963 | 900 | 10 | 289 | do. | do. | do. | 31°32'55" | 84°09'51" | 182 |
| 12L019 | U.S. Geological Survey TW-5 | 1978 | 257 | 4 | 241 | do. | CLBR | obs | 31°35'34" | 84°10'30" | 198 |
| 12L020 | U.S. Geological Survey TW-6 | 1977 | 690 | 6 | 619 | open | CLTN | do. | 31°35'34" | 84°10'30" | 198 |
| 12L021 | U.S. Geological Survey TW-10 | 1978 | 846 | 6 | 810 | do. | K | do. | 31°35'34" | 84°10'30" | 198 |
| 12L022 | Chehaw State Park 1 | 1937 | 800 | -- | -- | do. | -- | comm | 31°37'27" | 84°08'21" | 220 |
| 12L025 | Swift and Company | -- | 594 | 4 | -- | do. | CLTN | ind | 31°33'49" | 84°10'06" | 193 |
| 12L026 | Albany Ice Plant | 1885 | 710 | 5 | 660 | do. | K | do. | 31°35'11" | 84°09'12" | 196 |
| 12L029 | U.S. Geological Survey TW-13 | 1982 | 178 | 6 | 35 | do. | UFA | obs | 31°34'50" | 84°09'18" | 200 |
| 12L031 | Watkins Lumber Company | 1951 | 113 | 6 | 72 | do. | do. | ind | 31°36'02" | 84°09'05" | 187 |
| 12L032 | Estech, Inc. (Swift and Co.) | 1966 | 170 | 10 | 60 | do. | do. | do. | 31°36'10" | 84°09'15" | 196 |
| 12L041 | Bob Fowler | 1959 | 87 | 3 | 42 | do. | do. | dom | 31°36'54" | 84°09'30" | 186 |
| 12L042 | Estech, Inc. 2 | 1953 | 115 | 6 | 58 | do. | do. | ind | 31°35'56" | 84°09'19" | 195 |
| 12L043 | B.L. Pressley | -- | -- | -- | -- | do. | do. | dom | 31°37'21" | 84°08'54" | 189 |
| 12L044 | Estech, Inc. 1 | -- | 91 | -- | 26 | do. | -- | ind | 31°35'56" | 84°09'19" | 195 |
| 12L045 | Scottish Rite Temple | 1974 | 105 | 4 | 63 | do. | UFA | comm | 31°36'58" | 84°09'32" | 192 |
| 12L052 | Albany Yacht Club | 1939 | 84 | 3 | 75 | do. | do. | do. | 31°36'56" | 84°09'20" | 190 |
| 12L055 | Morningside Subdivision | 1953 | 135 | 8 | 65 | do. | do. | dom | 31°33'21" | 84°08'09" | 195 |
| 12L057 | J.P. Watkins | 1956 | 100 | 6 | 48 | do. | do. | do. | 31°32'31" | 84°09'10" | 185 |
| 12L062 | Oglethorpe Motel | 1954 | 170 | 6 | 85 | do. | do. | comm | 31°34'31" | 84°10'19" | 192 |

## Table 1.--*Inventory of wells within a 3-mile radius of the study area*--Continued

[UFA, Upper Floridan aquifer; CLBR, Claiborne aquifer; CLTN, Clayton aquifer; K, Cretaceous aquifer system;
M/A, multi-aquifer well; M/S, multi-screened well; US, unconsolidated sediments; obs., observation well;
ps, public-supply well; do., ditto; comm, commercial well; dom, domestic well; ind, industrial well;
TW, test well; open, open-hole well (no screens); --, no data]

| Well grid number | Well owner | Year well constructed | Well depth (feet) | Well diameter (inches) | Depth of casing (feet) | Well completion interval | Principal aquifer | Water use | Latitude | Longitude | Land surface altitude (feet) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 12L062 | Colonial Dairies | 1958 | 160 | 8 | 87 | do. | do. | do. | 31°34'32" | 84°09'56" | 190 |
| 12L063 | First Methodist Church | 1962 | 243 | 8 | 95 | do. | do. | do. | 31°34'48" | 84°09'15" | 200 |
| 12L065 | Albany Yacht Club | 1939 | 78 | 3 | 75 | do. | do. | do. | 31°36'48" | 84°08'58" | 190 |
| 12L067 | American Legion Club | 1940 | 105 | 3 | 52 | do. | do. | do. | 31°36'42" | 84°09'12" | 200 |
| 12L068 | Albany Electric Supply | 1960 | 180 | 4 | 101 | do. | do. | do. | 31°34'52" | 84°09'42" | 196 |
| 12L069 | Boy Scouts of Albany | 1943 | 80 | 3 | 44 | do. | do. | do. | 31°36'49" | 84°09'02" | 194 |
| 12L070 | Viola Bland | 1942 | 140 | 3 | 84 | do. | do. | dom | 31°35'25" | 84°10'25" | 215 |
| 12L071 | Dan Barfield | 1947 | 112 | 3 | 63 | do. | do. | do. | 31°33'42" | 84°08'16" | 195 |
| 12L072 | Roy Parks | 1947 | 127 | 3 | 107 | do. | do. | do. | 31°33'07" | 84°08'13" | 192 |
| 12L074 | Carl Smith | 1949 | 128 | 3 | 63 | do. | do. | do. | 31°33'35" | 84°08'24" | 195 |
| 12L075 | Walker Chemical Company | 1951 | 108 | 3 | 90 | do. | do. | ind | 31°36'29" | 84°10'29" | 198 |
| 12L076 | D.C. Green | 1952 | 84 | 3 | 74 | do. | do. | dom | 31°34'00" | 84°09'33" | 192 |
| 12L077 | WJAZ Radio | 1952 | 96 | 4 | 86 | do. | do. | comm | 31°37'03" | 84°10'33" | 210 |
| 12L078 | Optimist Club | 1953 | 100 | 3 | 53 | do. | do. | do. | 31°36'46" | 84°08'39" | 190 |
| 12L079 | Ace Adams | 1954 | 108 | 4 | 53 | do. | do. | dom | 31°36'36" | 84°10'32" | 195 |
| 12L080 | G.M. Blakey | 1954 | 112 | 3 | 93 | do. | do. | do. | 31°36'46" | 84°10'45" | 200 |
| 12L082 | Dr. I.M. Lucas | 1954 | 123 | 4 | 71 | do. | do. | do. | 31°34'24" | 84°08'27" | 220 |
| 12L083 | G.L. Kysler | 1955 | 76 | 3 | 53 | do. | do. | do. | 31°33'10" | 84°07'36" | 195 |
| 12L085 | Golden Glow Dairies | 1955 | 162 | 6 | 116 | do. | do. | ind | 31°34'18" | 84°10'33" | 201 |
| 12L087 | Soloman Johnson | 1955 | 98 | 3 | 77 | do. | do. | dom | 31°35'00" | 84°07'55" | 210 |
| 12L088 | Lee Riggins | 1956 | 84 | 4 | 55 | open | UFA | dom | 31°32'58" | 84°09'33" | 180 |
| 12L089 | Gospel Tabernacle | 1956 | 99 | 4 | 63 | do. | do. | comm | 31°36'45" | 84°10'34" | 210 |
| 12L090 | Harry Dervan | 1956 | 111 | 4 | 63 | do. | do. | dom | 31°37'19" | 84°10'54" | 225 |
| 12L092 | Frank Huggins | 1956 | 128 | 4 | 80 | do. | do. | do. | 31°33'35" | 84°08'24" | 185 |
| 12L095 | F.W. Pearson | 1956 | 130 | 4 | 98 | do. | do. | do. | 31°35'13" | 84°10'50" | 215 |
| 12L096 | George Bullington | 1956 | 147 | 3 | 57 | do. | do. | do. | 31°33'30" | 84°07'50" | 195 |
| 12L097 | Mrs. J.B. Casey | 1956 | 100 | 3 | 44 | do. | do. | do. | 31°36'26" | 84°09'42" | 195 |
| 12L098 | Agnes Fenney | 1956 | 147 | 3 | 131 | do. | do. | do. | 31°34'18" | 84°07'18" | 193 |
| 12L099 | W.K. Huff | 1956 | 108 | 4 | 89 | do. | do. | do. | 31°36'42" | 84°10'48" | 210 |
| 12L101 | C.D. Campbell, Jr. | 1957 | 115 | 4 | 69 | do. | do. | do. | 31°35'48" | 84°10'18" | 210 |

Table 1.--*Inventory of wells within a 3-mile radius of the study area*--Continued

[UFA, Upper Floridan aquifer; CLBR, Claiborne aquifer; CLTN, Clayton aquifer; K, Cretaceous aquifer system; M/A, multi-aquifer well; M/S, multi-screened well; US, unconsolidated sediments; obs., observation well; ps, public-supply well; do., ditto; comm, commercial well; dom, domestic well; ind, industrial well; TW, test well; open, open-hole well (no screens); --, no data]

| Well grid number | Well owner | Year well constructed | Well depth (feet) | Well diameter (inches) | Depth of casing (feet) | Well completion interval | Principal aquifer | Water use | Latitude | Longitude | Land surface altitude (feet) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 12L102 | J.T. Spratling | 1957 | 102 | 4 | 50 | do. | do. | do. | 31°36’30" | 84°10’20" | 195 |
| 12L104 | R.E. McCormack | 1957 | 204 | 6 | 181 | do. | CLBR | do. | 31°35’08" | 84°10’59" | 220 |
| 12L105 | Dr. William Fields | 1957 | 115 | 4 | 66 | do. | UFA | do. | 31°35’29" | 84°09’34" | 200 |
| 12L106 | T.J. Danford | 1957 | 100 | 3 | 73 | do. | do. | do. | 31°36’48" | 84°10’46" | 200 |
| 12L108 | E.R. Ross | 1958 | 125 | 3 | 105 | do. | do. | do. | 31°33’29" | 84°07’41" | 190 |
| 12L109 | Willard Davis | 1957 | 126 | 3 | 95 | do. | do. | do. | 31°33’37" | 84°09’43" | 190 |
| 12L111 | George Bargham | 1959 | 107 | 4 | 42 | do. | do. | do. | 31°33’46" | 84°08’01" | 190 |
| 12L112 | Wallace Hawk | 1959 | 105 | 4 | 70 | do. | do. | do. | 31°35’48" | 84°09’59" | 190 |
| 12L113 | Don Sanders | 1959 | 134 | 3 | 131 | do. | do. | do. | 31°33’37" | 84°07’43" | 185 |
| 12L115 | Dr. Glen Seymour | 1959 | 103 | 4 | 82 | do. | do. | do. | 31°36’16" | 84°11’22" | 205 |
| 12L116 | J. Sagendorph | 1959 | 107 | 4 | 66 | do. | do. | do. | 31°34’19" | 84°11’01" | 207 |
| 12L118 | Henry Reese | 1959 | 80 | 3 | 48 | do. | do. | do. | 31°33’35" | 84°07’52" | 192 |
| 12L120 | Ralph Griffith | 1960 | 118 | 4 | 63 | do. | do. | do. | 31°33’50" | 84°07’43" | 196 |
| 12L123 | Rufus Grant | 1960 | 127 | 3 | 124 | do. | do. | do. | 31°32’36" | 84°09’44" | 180 |
| 12L126 | H. E. Allen | 1961 | 90 | 3 | 77 | do. | do. | do. | 31°37’02" | 84°09’14" | 190 |
| 12L131 | Harry Stanberry | 1962 | 155 | 4 | 142 | do. | do. | do. | 31°35’43" | 84°09’55" | 210 |
| 12L132 | J.B. Morton | 1962 | 88 | 3 | 64 | do. | do. | do. | 31°36’56" | 84°10’17" | 206 |
| 12L135 | W.C. Bell | 1963 | 95 | 3 | 94 | do. | do. | do. | 31°37’00" | 84°09’18" | 190 |
| 12L145 | Charles Nobles | 1966 | 104 | 3 | 50 | do. | do. | do. | 31°36’32" | 84°09’48" | 192 |
| 12L146 | John C. Davis | 1966 | 111 | 4 | 84 | do. | do. | do. | 31°36’43" | 84°11’08" | 215 |
| 12L153 | Lakeside Baptist Church | 1967 | 96 | 4 | 72 | do. | do. | comm | 31°37’05" | 84°09’36" | 190 |
| 12L156 | Latham Construction Company | 1968 | 81 | 4 | 48 | do. | do. | do. | 31°37’02" | 84°09’03" | 185 |
| 12L158 | Monroe Latham | 1968 | 80 | 4 | 42 | do. | do. | dom | 31°37’08" | 84°08’56" | 190 |
| 12L171 | Albany Tallow Plant | 1969 | 140 | 4 | 98 | do. | do. | ind | 31°32’40" | 84°08’38" | 175 |
| 12L175 | WALG Radio | 1970 | 100 | 4 | 78 | do. | do. | comm | 31°37’18" | 84°09’10" | 195 |
| 12L186 | Bill Haire | 1971 | 90 | 4 | 42 | do. | do. | dom | 31°37’07" | 84°09’00" | 190 |
| 12L187 | Latham Brothers Construction | 1971 | 95 | 4 | 63 | do. | do. | comm | 31°37’05" | 84°09’07" | 190 |
| 12L190 | Ozell Wright | 1971 | 125 | 4 | 63 | do. | do. | dom | 31°36’39" | 84°09’25" | 190 |
| 12L210 | Buddy Clark | 1976 | 95 | 4 | 63 | do. | do. | do. | 31°37’03" | 84°09’11" | 190 |
| 12L217 | Edwin Brown | 1978 | 145 | 6 | 84 | do. | do. | do. | 31°34’37" | 84°11’11" | 210 |

Table 1.--*Inventory of wells within a 3-mile radius of the study area*--Continued

[UFA, Upper Floridan aquifer; CLBR, Claiborne aquifer; CLTN, Clayton aquifer; K, Cretaceous aquifer system;
M/A, multi-aquifer well; M/S, multi-screened well; US, unconsolidated sediments; obs., observation well;
ps, public-supply well; do., ditto; comm, commercial well; dom, domestic well; ind, industrial well;
TW, test well; open, open-hole well (no screens); --, no data]

| Well grid number | Well owner | Year well constructed | Well depth (feet) | Well diameter (inches) | Depth of casing (feet) | Well completion interval | Principal aquifer | Water use | Latitude | Longitude | Land surface altitude (feet) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 12L230 | W.C. Holman, Jr. | 1980 | 155 | 4 | 84 | do. | do. | do. | 31°35'40" | 84°10'07" | 210 |
| 12L238 | Dewey Booth | 1981 | 140 | 4 | 63 | do. | do. | do. | 31°37'15" | 84°09'39" | 192 |
| 12L242 | Mary B. McCormack | 1982 | 153 | 6 | 82 | do. | do. | do. | 31°35'10" | 84°11'03" | 217 |
| 12L244 | Royal American, Inc. | 1983 | 200 | 6 | 90 | do. | do. | ind | 31°34'00" | 84°08'10" | 210 |
| 12L245 | William C. Holman, III | 1983 | 125 | 4 | 63 | do. | do. | dom | 31°35'25" | 84°10'25" | 220 |
| 12L246 | Jim Reid | 1983 | 125 | 4 | 67 | do. | do. | do. | 31°37'14" | 84°09'03" | 190 |
| 12L249 | Debra Ferguson | 1984 | 120 | 4 | 42 | do. | do. | do. | 31°36'39" | 84°08'48" | 185 |
| 12L250 | Georgia-Pacific Corp. | 1984 | 150 | 6 | 83 | do. | do. | ind | 31°36'19" | 84°09'24" | 195 |
| 12L253 | Andy Barfield | 1985 | 120 | 4 | 42 | do. | do. | dom | 31°37'20" | 84°09'00" | 192 |
| 12L255 | Clyde W. Butler | 1979 | 115 | 4 | 42 | do. | do. | do. | 31°36'31" | 84°09'51" | 195 |
| 12L256 | Roy Parrish | 1985 | 120 | 4 | 44 | do. | do. | do. | 31°37'17" | 84°09'26" | 195 |
| 12L258 | Jim Pace | 1985 | 130 | 4 | 65 | do. | do. | do. | 31°36'41" | 84°09'26" | 190 |
| 12L261 | Agnes Harsett | -- | 110 | -- | -- | do. | do. | do. | 31°36'54" | 84°09'30" | 190 |
| 12L263 | Covenant Presbyterian Church | 1957 | 155 | 8 | 83 | do. | do. | comm | 31°36'23" | 84°12'29" | 233 |
| 12L264 | Dawes Silica Mining Company 3 | 1964 | 175 | 12 | 78 | do. | do. | ind | 31°33'31" | 84°08'09" | 153 |
| 12L265 | Central Baptist Church | 1961 | 140 | 8 | 91 | do. | do. | comm | 31°35'27" | 84°11'25" | 200 |
| 12L266 | McGregor Corporation | 1958 | 168 | 16 | 80 | do. | do. | ind | 31°33'04" | 84°10'41" | 212 |
| 12L267 | Wetherbee Planetarium | 1984 | 187 | 6 | 90 | do. | do. | comm | 31°34'57" | 84°09'01" | 192 |
| 12M022 | Chehaw State Park | 1956 | 164 | -- | 88 | open | UFA | comm | 31°37'46" | 84°08'07" | 192 |
| 13L002 | Turner City | 1951 | 760 | 12 | 713 | M/S | CLTN | obs. | 31°35'51" | 84°06'24" | 213 |
| 13L005 | City of Albany 19 | 1962 | 965 | 10 | 265 | do. | ps | do. | 31°34'13" | 84°06'03" | 199 |
| 13L009 | City of Albany 30 | 1978 | 940 | 12 | 300 | do. | ps | do. | 31°34'45" | 84°06'40" | 215 |
| 13L060 | A. Stanley | 1947 | 120 | 3 | 67 | open | UFA | dom | 31°36'10" | 84°06'52" | 205 |
| 13L061 | Cecil Sheffield | 1947 | 140 | 2 | 74 | do. | do. | do. | 31°36'23" | 84°07'15" | 220 |
| 13L062 | D.C. Tarts | 1949 | 139 | 3 | 72 | do. | do. | do. | 31°36'23" | 84°06'30" | 195 |
| 13L168 | Layne-Atlantic, Inc. | 1946 | 104 | 6 | 67 | do. | do. | comm | 31°34'32" | 84°06'20" | 205 |

The wells were completed open-hole through the aquifer material; however, the open-hole section of the wells collapsed shortly after completion. After the open borehole collapsed, the sediment was cleaned from the borehole. High-viscosity bentonite drilling additive was used during the cleaning process to maintain borehole stabililty. Subsequently, 2-in. PVC casing and screen were inserted through the existing 4-in. (grouted) casing, from land surface to the bottom of the borehole. The screened interval consisted of the length of the previously open borehole. After completion, the wells were developed using compressed air. Throughout well installation and modification processes, the drilling rig was steam-cleaned between boreholes and wells to prevent cross contamination. A continuous recorder was installed in one of the wells to observe ground-water-level fluctuations in the Upper Floridan aquifer.

Clay samples were collected in the unconsolidated sediments to obtain vertical hydraulic-conductivity data, and to provide samples for Resource Conservation and Recovery Act (RCRA) analyses (U.S. Environmental Protection Agency, 1988a). Boreholes were drilled using a hollow-stem auger rig and continuous cores were collected using a Central Mining and Equipment Company (CME) soil-sampler lined with 6-in. long brass tubes for the organics analyses, or acrylic tubes for the metals analyses. After the cores were collected, the boreholes were backfilled with native sediments and bentonite.

During drilling activities, organic vapor and combustible gas concentrations were monitored in the breathing zone and in the borehole to ensure personnel safety (U.S. Department of Labor, 1989). The personnel safety-monitoring instruments included organic vapor analyzers (both flame-ionization and photoionization detectors), and a combustible gas indicator. Personnel were initially dressed to meet protective safety requirements of Level D, as defined by the U.S. Department of Labor (1989), and specified in the personal protection safety guidelines (Geraghty and Miller, Inc., 1990); however, when the safety-monitoring instruments indicated the presence of organic vapors or combustible gases, an upgrade to Level C (U.S. Department of Labor, 1989) protection was implemented.

A soil-gas survey was conducted in the unconsolidated sediments overlying the shallow water-bearing zone using a portable gas chromatograph equipped with a photoionization detector. Soil-gas samples were collected at 26 stations to delineate areas where organic vapors were present near land surface. An access hole, about 0.5-in. diameter, was hammered to a depth of about 4 ft using the driving rod of a plunger bar. A copper tube having slots near the bottom was inserted into the hole, and the annular space was sealed with native sediments. Soil gas was withdrawn from the subsurface using a peristaltic pump. The hole was evacuated for approximately 5 minutes prior to the soil-gas collection. As pumping continued, the gas sample was collected from the septum joint at the top of the copper tube using a syringe. The soil-gas sample was injected from the syringe directly into a portable gas chromatograph to identify organic vapor peaks and determine relative concentrations. The copper tube was removed, and the hole was backfilled. To ensure proper decontamination between holes, gas samples were withdrawn from the tube (after the tube was removed from the hole), and analyzed to determine if residual organic vapors were present in the copper tube. Field procedures and analytical techniques used in the soil-gas surveys are discussed in detail by Brock (1990).

Natural gamma-ray and neutron geophysical logs were run in eight wells in the study area to provide data on lithologic boundaries and correlation of clay layers. In addition, the neutron logs were used to obtain data on total porosity below the water table.

Ground-water samples were collected from seven wells completed in the Upper Floridan aquifer and from one additional well completed in the shallow water-bearing zone. Wells were purged prior to sampling using a small-diameter submersible pump. The wells were purged until three to five well volumes of water were evacuated, the water became clear, and the pH and specific conductance of the water had stabilized. Ground-water samples were collected using a stainless steel, submersible pump equipped with Teflon delivery lines. In some cases, preservatives, including $NaOH$, $HgCl_2$, $HNO_3$, and $HNO_3/K_2CrO_7$, were added to the samples for certain analyses. Evacuated ground water from the wells and rinsewater were stored in 55-gal drums for transportation to a regulated disposal facility. After each well was sampled, the pump was decontaminated using hexane, methanol, and acetone, as needed, along with soap and deionized water. Rinsewater and trip-blank samples were collected to ensure proper quality control of the ground-water samples.

The ground-water samples were submitted to the U.S. Geological Survey laboratory for analyses of organic and inorganic constituents. The samples were analyzed for more than 30 volatile (purgeable) organic compounds (U.S. Environmental Protection Agency (1988b), and 50 semivolatile (methylene chloride-extractable) organic compounds. The specific target compounds were identified by gas chromotography and electron impact mass spectrometry (GC/MS), and confirmed by comparison with standard samples. The waste samples (containing hydrocarbon) collected for the RCRA analyses were analyzed by a contract laboratory of the U.S. Geological Survey.

## Previous Investigations

The Upper Floridan aquifer has been the subject of several investigations in the Albany area. Hicks and others (1981) discussed the hydrogeology of major aquifers of the Albany area and included previously unpublished data on aquifer characteristics as well as the potentiometric surface of the Upper Floridan aquifer (formerly Ocala aquifer). Hayes and others (1983) developed a ground-water-flow model of the Upper Floridan aquifer (formerly principal artesian aquifer) in the Dougherty Plain physiographic district. The ground-water-flow model simulated regional water-level changes in the Upper Floridan aquifer that may result from real or hypothetical pumping increases. Hayes and others (1983) also included data on the hydrogeology and hydraulic characteristics of the Upper Floridan aquifer.

Hicks and others (1987) conducted the most recent investigation in the Albany area to evaluate (1) the development potential of the Upper Floridan aquifer as an alternative source of ground water for public supply, and (2) the chemical quality of water in the Upper Floridan aquifer. Torak and others (1991) assessed the effects of increased ground-water withdrawal from the Upper Floridan aquifer, and improved the understanding of aquifer characteristics and ground-water-flow paths in the Albany area.

Most pertinent to this investigation (1991) were data and interpretations discussed by Chapman and others (1990). Chapman and others (1990) presented detailed, on-site data collected in the area of the abandoned Albany MGP, such as concentrations and distribution of contaminants in the shallow subsurface and hydrogeologic characteristics of the unconsolidated sediments that overlie the Upper Floridan aquifer. Areas of hydrocarbon contamination are identified to at least the top of the Ocala Limestone (Upper Floridan aquifer) in the vicinity of the former gas-holding tanks (Chapman and others, 1990).

During the preliminary investigation, Chapman and others (1990) attempted to collect stream-sediment samples. However, because of the high velocity of the Flint River, sediment deposits are rare in the vicinity of the study area. The streambed is an erosional surface in the Ocala Limestone. Surface-water in the Flint River was not sampled because the probable volume of contaminant release could easily be masked by dilution.

## Acknowledgments

Many individuals assisted in the successful completion of this study. The author extends special thanks to U. Walter Rodemann, General Manager, AWGLC, for his support and assistance. Other members of the AWGLC staff who were very helpful include James K. Goodin, Harold A. Bryan, and Thomas B. Pittman.

Special appreciation is extended to the U.S. Department of Agriculture, Agricultural Research Service (ARS), Tifton, Ga., for the use of soil-sampling equipment and their assistance. Thanks also are extended to Herman E. Henry, ARS, for assistance in obtaining borehole geophysical logs, and Robert K. Hubbard, ARS, for providing laboratory hydraulic-conductivity analyses.

Appreciation also is extended to Douglas B. Manigold, Robert D. Brock, and Jana L. Zamboni, U.S. Geological Survey, Organics Section, National Water Quality Laboratory, who conducted the soil-gas survey in the study area.

# HYDROGEOLOGY

The study area is underlain, in descending order, by surficial fill, unconsolidated sediments (sand and clay layers), and the Ocala Limestone (fig. 3) (Chapman and others, 1990). A shallow water-bearing zone is present in the upper sand layer of the unconsolidated sediments. The Upper Floridan aquifer is comprised chiefly of the Ocala Limestone in the Albany area, and includes an overlying sand layer (lower sand layer) of the unconsolidated sediments in the study area.

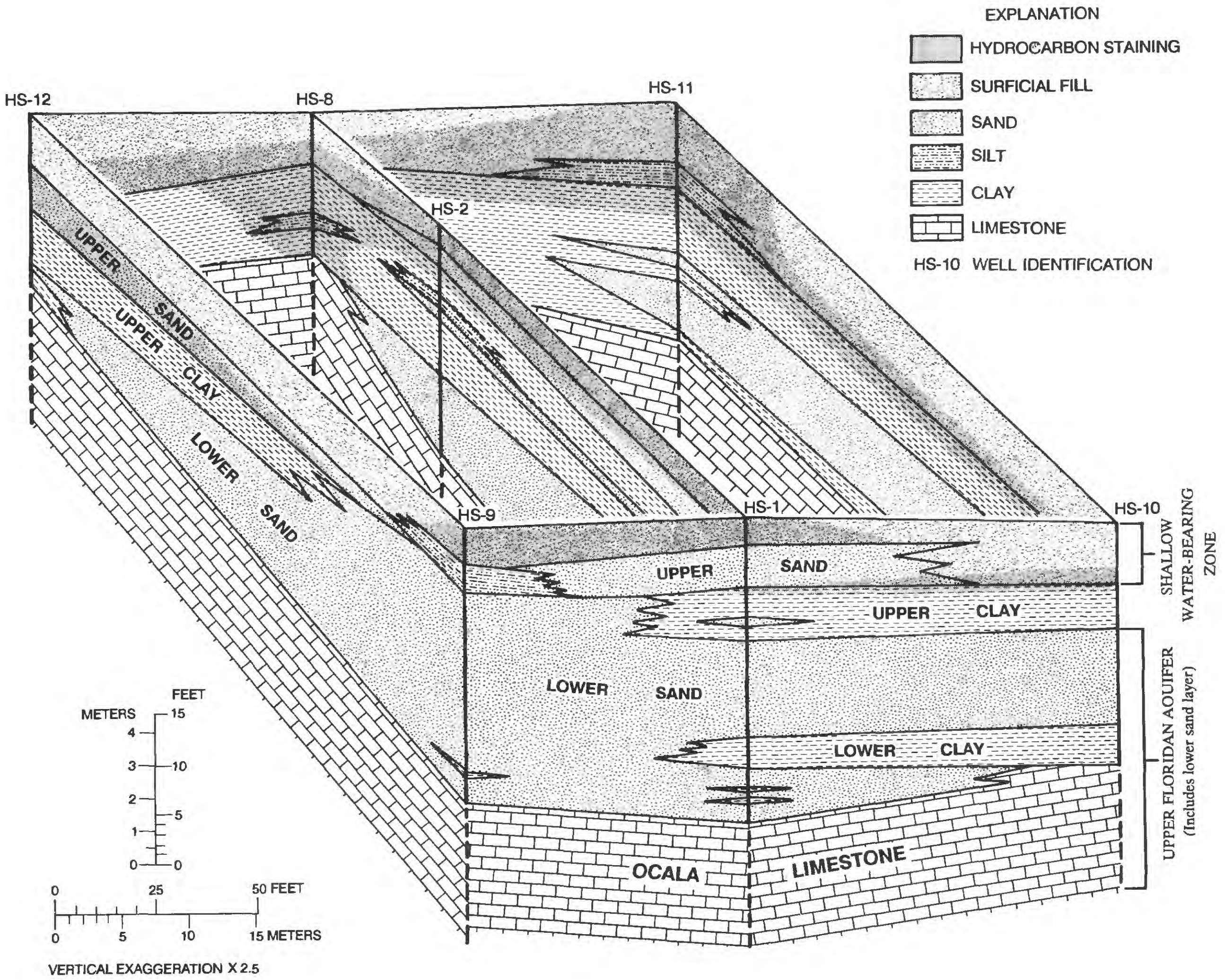

Figure 3.--Generalized fence diagram showing lithology of the area adjacent to the abandoned gas plant (trace of fence diagram shown in figure 4). Modified from Chapman and others (1990).

## Shallow Water-Bearing Zone

The upper sand layer in the unconsolidated sediments (fig. 3) forms a seasonally-saturated, perched, shallow water-bearing zone. The shallow water-bearing zone is not areally extensive, and appears to be confined to the former gas-holding tank area. The upper sand layer is overlain by about 2 to 10 ft of surficial fill material. The shallow water-bearing zone is unconfined, and receives recharge directly from infiltration of rainfall. An underlying clay layer in the unconsolidated sediments (upper clay layer, fig. 3) restricts vertical movement of ground water in the shallow water-bearing zone. The clay layer ranges in depth from about 4.5 to 10.0 ft below land surface. Wells B-5, HS-3, HS-7, and TP-5 (table 2 and fig. 4) are completed in the shallow water-bearing zone.

Table 2.--*Inventory of wells tapping the shallow water-bearing zone and the Upper Floridan aquifer in the study area*

[B, solid-stem auger boring; SZ, shallow water-bearing zone; HS, hollow-stem auger boring; TP, test pit; UFA, Upper Floridan aquifer; Do., ditto; OC, Ocala Limestone well. Modified from Chapman and others, 1990]

| Well number | Date drilled/ excavated | Depth (feet) | Depth of casing (feet) | Screen length (feet) | Land surface altitude (feet) | Water-bearing zone |
|---|---|---|---|---|---|---|
| B-5 | 03-07-89 | 10 | 5 | 5 | 185.92 | SZ |
| HS-1 | 04-04-89 | 30.5 | 20.5 | 10 | 184.42 | UFA |
| HS-2 | 04-04-89 | 23 | 18 | 5 | 184.99 | Do. |
| HS-3 | 04-05-89 | 8 | 3 | 5 | 185.90 | SZ |
| HS-7 | 04-05-89 | 6 | 3.5 | 2.5 | 185.20 | Do. |
| TP-5 | 05-03-89 | 7 | 2 | 5 | 184.84 | Do. |
| HS-9 | 07-11-89 | 27.5 | 17.5 | 10 | 183.62 | UFA |
| HS-10 | 07-12-89 | 24 | 14 | 10 | 183.64 | Do. |
| HS-11 | 07-13-89 | 23.5 | 18.5 | 5 | 185.09 | Do. |
| HS-12 | 07-13-89 | 17 | 12 | 5 | 184.13 | Do. |
| OC-1 | 01-30-90 | 66 | 16 | 50 | 185.90 | Do. |
| OC-2 | 01-30-90 | 75.5 | 35.5 | 40 | 184.55 | Do. |
| OC-3 | 02-01-90 | 73 | 43 | 30 | 183.50 | Do. |
| OC-4 | 02-04-90 | 30 | 20 | 10 | 182.21 | Do. |

The composition of the surficial fill material and the shallow unconsolidated sediments (upper sand and clay layers) varies across the study area; hence, hydrogeologic characteristics of the materials may be variable. Material in the fill includes brick, concrete, metal, ash, and various other debris intermixed with sand and clay. Material comprising the upper sand layer varies from a very clean, coarse sand to a clayey, fine sand. Although the upper clay layer contains some sand, overall, this layer has low permeability.

In addition to geologic logs recorded during drilling activities, natural gamma-ray and neutron borehole geophysical logs were used to define lithologic boundaries in the study area. In the natural gamma-ray logs, the clay layers result in positive deflections; whereas, the sand layers produce negative responses (fig. 5). Conversely, clay layers result in negative responses in the neutron logs, and the sand layers produce positive deflections.

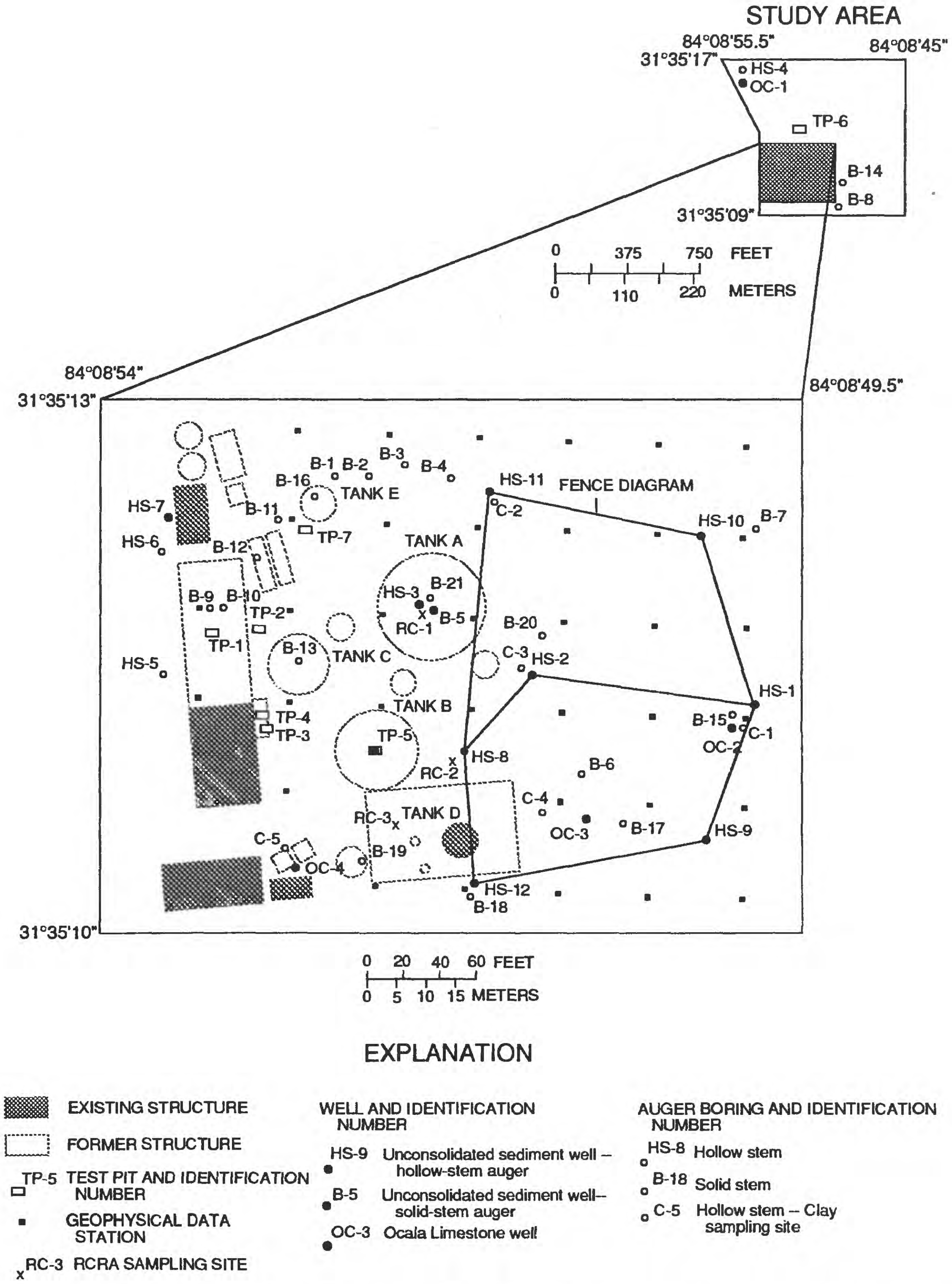

Figure 4.--Auger borings, test pits, wells, and sampling sites in part of the study area. Modified from Chapman and others (1990).

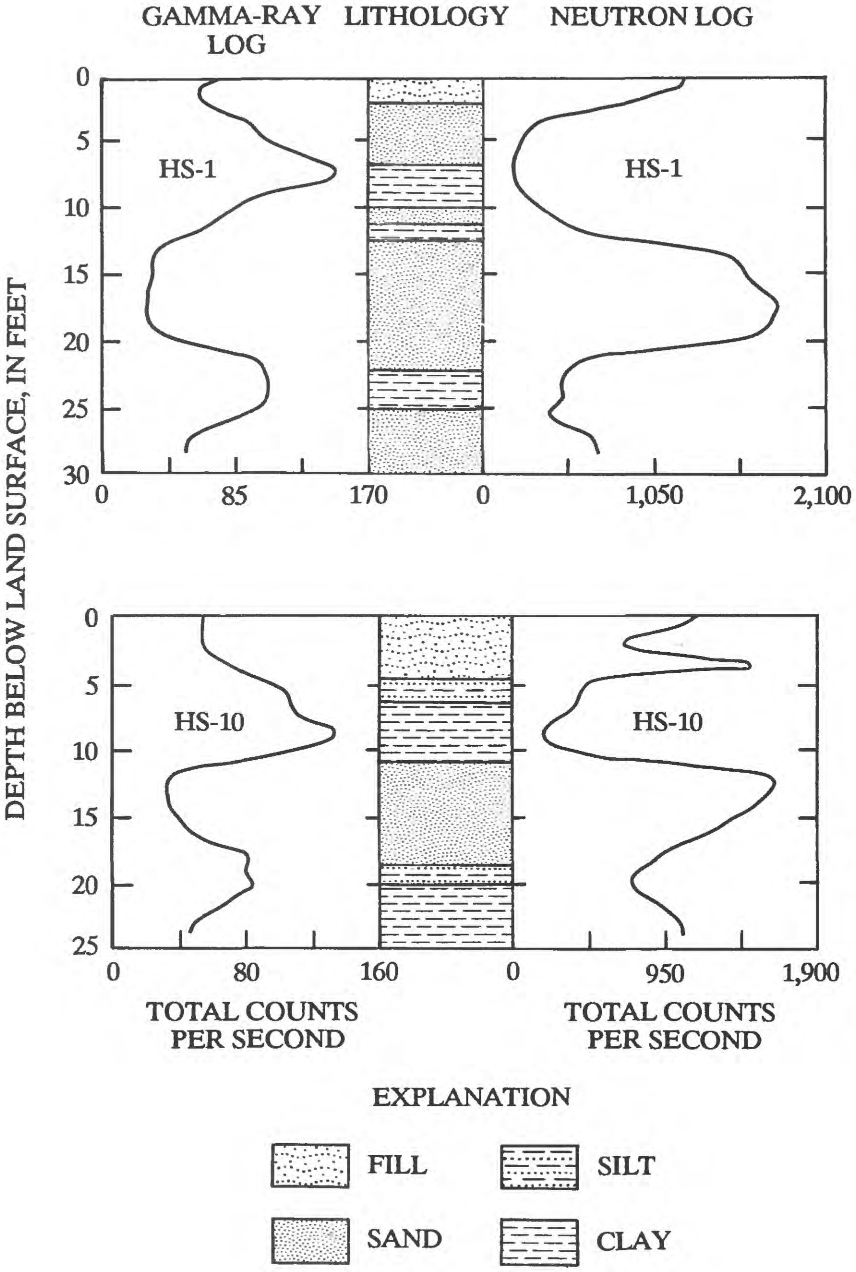

Figure 5.--Response of natural gamma ray and neutron geophysical logs to sand and clay layers, in wells HS-1 and HS-10.

The upper clay layer (fig. 3) restricts vertical ground-water flow in the shallow water-bearing zone and ranges in thickness from 0.5 to 6.5 ft. Structural contours of the top of the upper clay layer are shown in figure 6. The upper clay layer is present throughout most of the study area, except at well HS-9 (Chapman and others, 1990). Clay samples from five sites (fig. 4) were tested in the laboratory for vertical hydraulic conductivity. Hydraulic conductivity of the upper clay layer ranged from $1.88 \times 10^{-1}$ to $3.15 \times 10^{-4}$ ft/d; and averaged $2.39 \times 10^{-3}$ ft/d. Because of the low vertical hydraulic conductivity of the upper clay layer, ground water in the shallow water-bearing zone moves laterally in the upper sand layer and fill material.

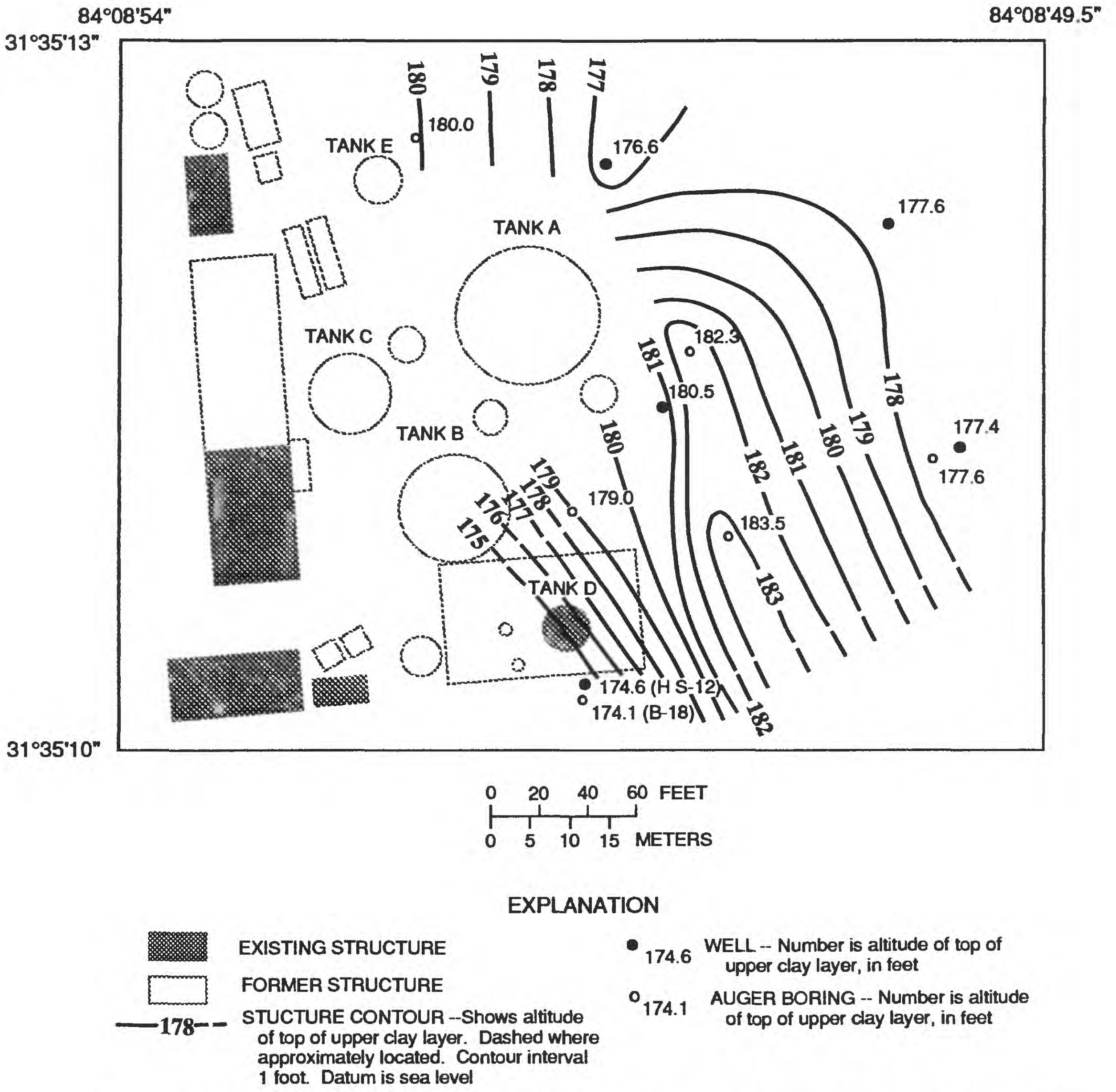

Figure 6.--Altitude of the top of the upper clay layer. Modified from Chapman and others (1990).

When the upper sand layer is saturated, the altitude of water levels in the shallow water-bearing zone are relatively stable and average 178 to 179 ft. Except during higher stages of the Flint River, water levels in this zone generally are 14 to 26 ft higher than those in the Upper Floridan aquifer. Water levels recorded before, during, and after the flood of the Flint River on March 23, 1990 (Roger D. McFarlane, U.S. Geological Survey, oral commun., 1990), are listed in table 3.

Table 3.--*Water-level measurements in wells in the study area during March-April 1990*

[Measurements are altitude in feet above sea level; OC, Ocala Limestone well; HS, hollow-stem auger boring; B, solid-stem auger boring; TP, test pit; --, no measurement]

| Well number | Date of measurement | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | March 1 | March 20 | March 22 | March 23 | March 26 | March 27 | April 2 | April 11 | April 25 |
| Upper Floridan aquifer | | | | | | | | | |
| OC-1 | 161.71 | 166.14 | 172.04 | 174.26 | 173.10 | 171.63 | -- | 162.75 | 162.35 |
| OC-2 | 162.08 | 165.06 | 175.89 | 179.29 | 171.20 | 168.60 | 159.95 | 160.70 | 159.03 |
| OC-3 | 161.11 | 165.15 | 175.89 | 178.99 | 170.79 | 168.07 | 160.25 | 158.35 | 155.95 |
| OC-4 | 165.49 | 164.84 | 172.27 | 176.68 | 173.99 | 172.27 | 165.66 | 162.46 | 159.76 |
| HS-1 | 162.68 | -- | 175.17 | 179.17 | 171.82 | 167.42 | 159.71 | 160.62 | 159.06 |
| HS-2 | 164.33 | -- | 173.72 | 178.80 | 172.64 | 170.57 | -- | -- | -- |
| HS-9 | 161.47 | -- | 176.60 | 179.84 | 172.08 | -- | 159.91 | 157.91 | -- |
| HS-10 | 162.30 | -- | 174.27 | 178.83 | 171.96 | -- | 160.51 | -- | -- |
| HS-11 | 163.53 | -- | 171.17 | 177.19 | 172.56 | -- | -- | -- | -- |
| HS-12 | 167.06 | -- | 174.42 | 178.91 | 174.51 | 172.62 | -- | -- | -- |
| Shallow water-bearing zone | | | | | | | | | |
| B-5 | 178.93 | -- | 179.04 | 179.00 | 179.03 | 179.06 | -- | -- | -- |
| TP-5 | 179.93 | -- | 179.95 | 179.93 | 179.92 | -- | 179.57 | -- | -- |
| HS-3 | 178.69 | -- | 178.98 | 178.78 | 178.97 | -- | -- | -- | -- |

## Upper Floridan Aquifer

In the study area, the Upper Floridan aquifer consists of the Ocala Limestone and the overlying lower sand layer of the unconsolidated sediments. Regionally, the Upper Floridan aquifer generally is semiconfined by overlying, low permeability clay layers of the unconsolidated sediments (Torak and others, 1991). Even though overlying clay layers are present in the study area, water levels generally are below the top of the aquifer, resulting in a more unconfined system. The aquifer is considered to be unconfined in the area of well HS-9 (figs. 3 and 4) where overlying clay layers are absent. In the study area, water levels in the Upper Floridan aquifer primarily are affected by the stage of the nearby Flint River, which has incised the Ocala Limestone. As a result the aquifer is unconfined near the river, and during higher stages of the river, water levels approach the top of the aquifer (table 3).

The lower sand layer of the unconsolidated sediments forms the upper part of the Upper Floridan aquifer in the study area, and has a composition similar to the upper sand layer (shallow water-bearing zone), and varies from a very clean, coarse sand to a clayey, fine sand. Chapman and others (1990) established the relation of water levels in the lower sand layer to the stage of the Flint River. Water levels in well HS-1 (fig. 4) respond nearly instantaneously to changes in the river stage.

The Ocala Limestone forms the major part of the Upper Floridan aquifer in the Albany area. The Ocala Limestone generally is defined as having upper, middle, and lower lithologic units (Hicks and others, 1987). The upper unit of the Ocala is a white, chalky, sugary-textured, fossiliferous limestone that has variable degrees of weathering and solutioning both areally and with depth. The middle unit consists of a white to brown, dense, chalky limestone interlayered with clay and silt. The lower unit consists of highly-fractured alternating layers of sandy limestone and dolomitic limestone (Hicks and others, 1987).

In the study area, the depth of auger refusal was interpreted to be near the contact between the unconsolidated sediments and the Ocala Limestone. As a result of solutioning in the Ocala Limestone, auger refusal did not occur along this contact in parts of the study area. The altitude of auger refusal ranged from 171.4 to 140.0 ft (fig. 7). The deepest auger refusal occurred at well OC-3 where about 18.5 ft of calcareous sand and clay was encountered above refusal depth. Solutioning along the top or within the Ocala Limestone may have resulted in deeper weathering of the limestone at well OC-3. This feature may be a sinkhole-collapse structure that may provide a connection to deeper water-bearing zones in the Upper Floridan aquifer and a potentially direct contaminant pathway.

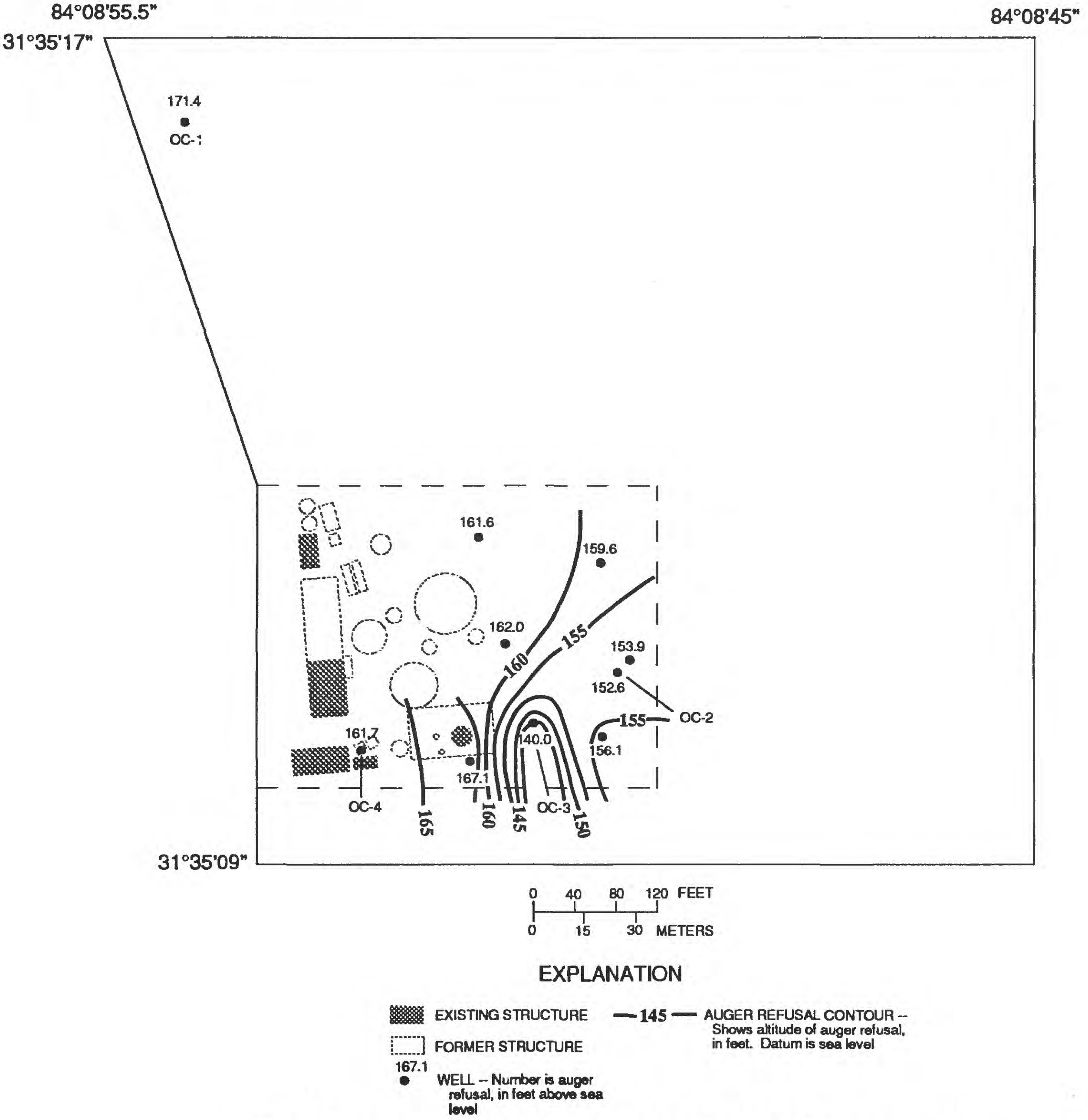

Figure 7.--Altitude of auger refusal near the top of the Ocala Limestone.

Because the geology of the Ocala Limestone varies with depth and lithologic unit, permeabilities of the units also vary. The upper unit of the Ocala Limestone generally has higher primary porosity and secondary permeability than the middle unit. In the Albany area, the middle unit of the Ocala generally is considered to be less permeable and confines the lower unit. The lower unit has well-developed secondary permeability along solution features, such as joints, bedding planes, and other fractures (Hicks and others, 1987). Wells were completed in the upper unit of the Ocala Limestone as a part of this investigation.

The permeability of the upper unit of the Ocala Limestone (upper water-bearing zone of the Upper Floridan aquifer) is variable in the study area. The core descriptions (see Appendix at the end of this report), indicate that the texture varies from a fine-grained dense limestone having relatively lower permeability, to a very coarse-grained, vuggy limestone having higher permeability. Degrees of weathering and solutioning in the limestone also vary areally and with depth. Secondary features that enhance permeability include horizontal fractures parallel to bedding planes, and fractures oblique to bedding. Iron staining along fractures indicates ground-water movement along these secondary features.

Clay layers in the Upper Floridan aquifer at well OC-1 at depths of about 14.5 ft to 28 ft (fig. 8) were identified from peaks on the gamma-ray log of the well. Geologic logs confirmed the presence of clay layers at sampling intervals of 9.0 to 10.5, 12.0 to 13.5, and 14.0 to 14.5 ft (see Appendix). In the Ocala Limestone, positive deflections on the gamma-ray log are most likely the result of the presence of glauconite or clay layers. Geologic samples, when recoverable, are used to determine whether glauconite or clay is producing the observed response. Reduced concentration of glauconite or the absence of clay layers most likely resulted in the absence of pronounced peaks and general uniformity of the gamma-ray log below a depth of about 20 ft in well OC-1.

The lithologic and hydrologic character of the Ocala Limestone in wells OC-2 and OC-3 vary from that in well OC-1. During the drilling of well OC-3, auger refusal occurred at an altitude of about 140.0 ft, which is about 31.4 ft deeper than the refusal at well OC-1 (fig. 7). The Ocala Limestone at wells OC-2 and OC-3 is more weathered and contains higher concentrations of glauconite, than the limestone at well OC-1. The presence of increased glauconite and clay layering in the limestone most likely resulted in positive deflections on the natural gamma-ray log of well OC-2 (fig. 8). However, the lithology could not be verified because of the reduced core recoveries.

In well OC-2, areas having greater total porosity or secondary solutioning were identified below the water table using neutron logs. These areas were confirmed during drilling by reduced core recoveries. In well OC-1, the water level was 29 ft below land surface when the borehole geophysical logs were run. At the same time, well OC-2 had a water level 30.5 ft below land surface. The water level of wells OC-1 and OC-2 are marked by sharp, negative deflections on the neutron logs (fig. 8). Below the water level in well OC-1, the total porosity is more uniform than the total porosity in well OC-2. Solution openings that enhance the porosity or permeability were identified in well OC-2 based on negative deflections on the neutron log, an overall decrease in core recovery, and drilling problems encountered during well installation. Core recoveries below the water table at well OC-1 were greater than 94 percent; whereas, core recoveries below the water table at well OC-2 ranged from 15 to 82 percent.

### *Ground-water levels and flow characteristics*

Water-level data from the lower sand layer in the unconsolidated sediments and from the upper unit of the Ocala Limestone indicate that these two water-bearing units are hydraulically connected. Water-levels in well OC-2, screened in the upper unit of the Ocala Limestone, and well HS-1, screened in the lower sand layer, were similar throughout this investigation (fig. 9). In well OC-2, casing was extended through the entire thickness of the lower sand layer; thus, the Ocala Limestone is the source of water in the well. Apparently, a hydraulic barrier does not exist between the lower sand layer and the Ocala Limestone at well OC-2. Water levels in wells tapping either of the two water-bearing units are representative of the same ground-water reservoir--the upper water-bearing zone of the Upper Floridan aquifer. Water-levels in the Upper Floridan aquifer ranged from about 153 to 180 ft above sea level during this investigation; water levels rose only during elevated stages of the Flint River.

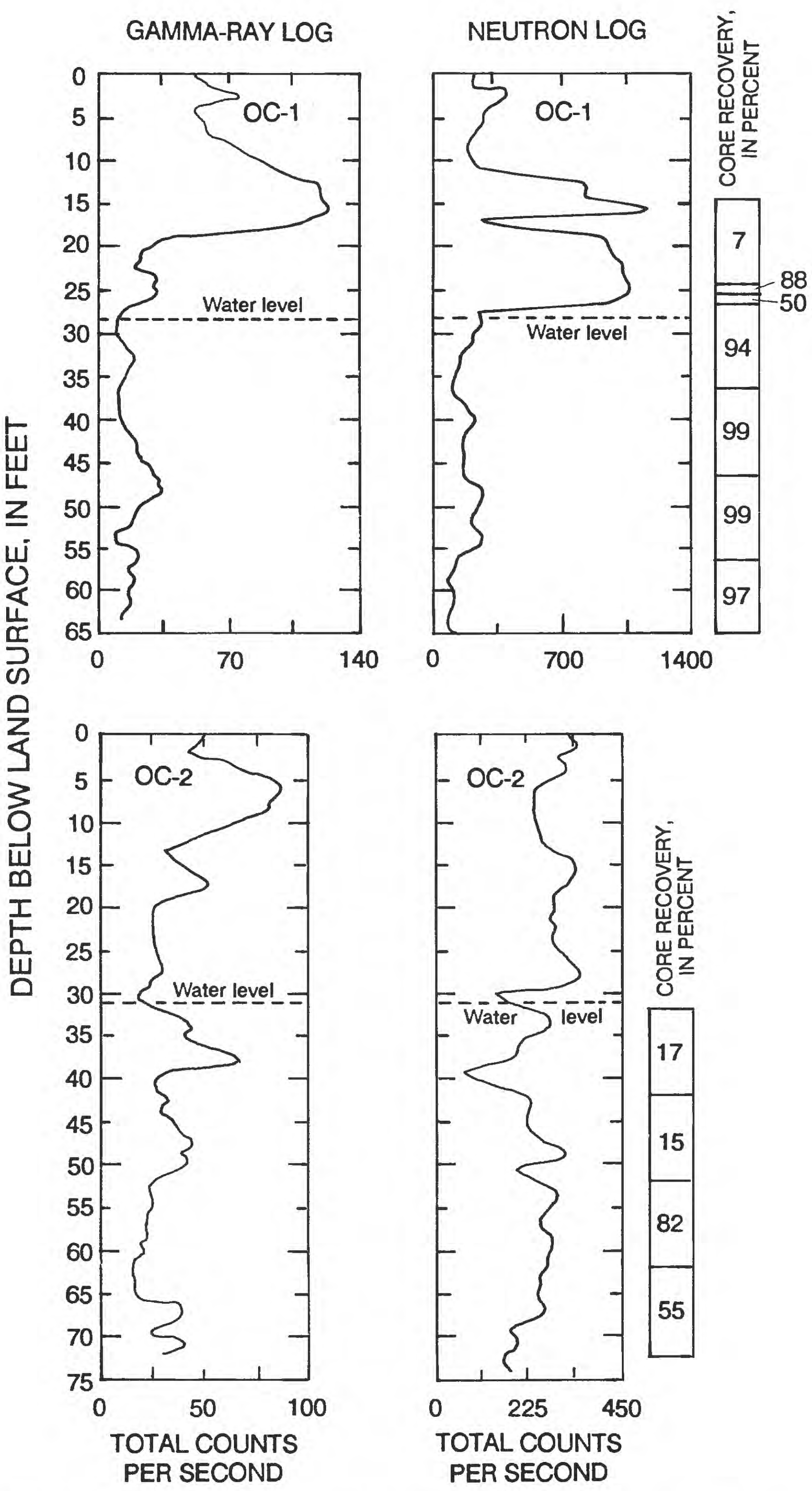

Figure 8.--Gamma-ray logs and correlation of neutron logs with core recoveries in the Ocala Limestone.

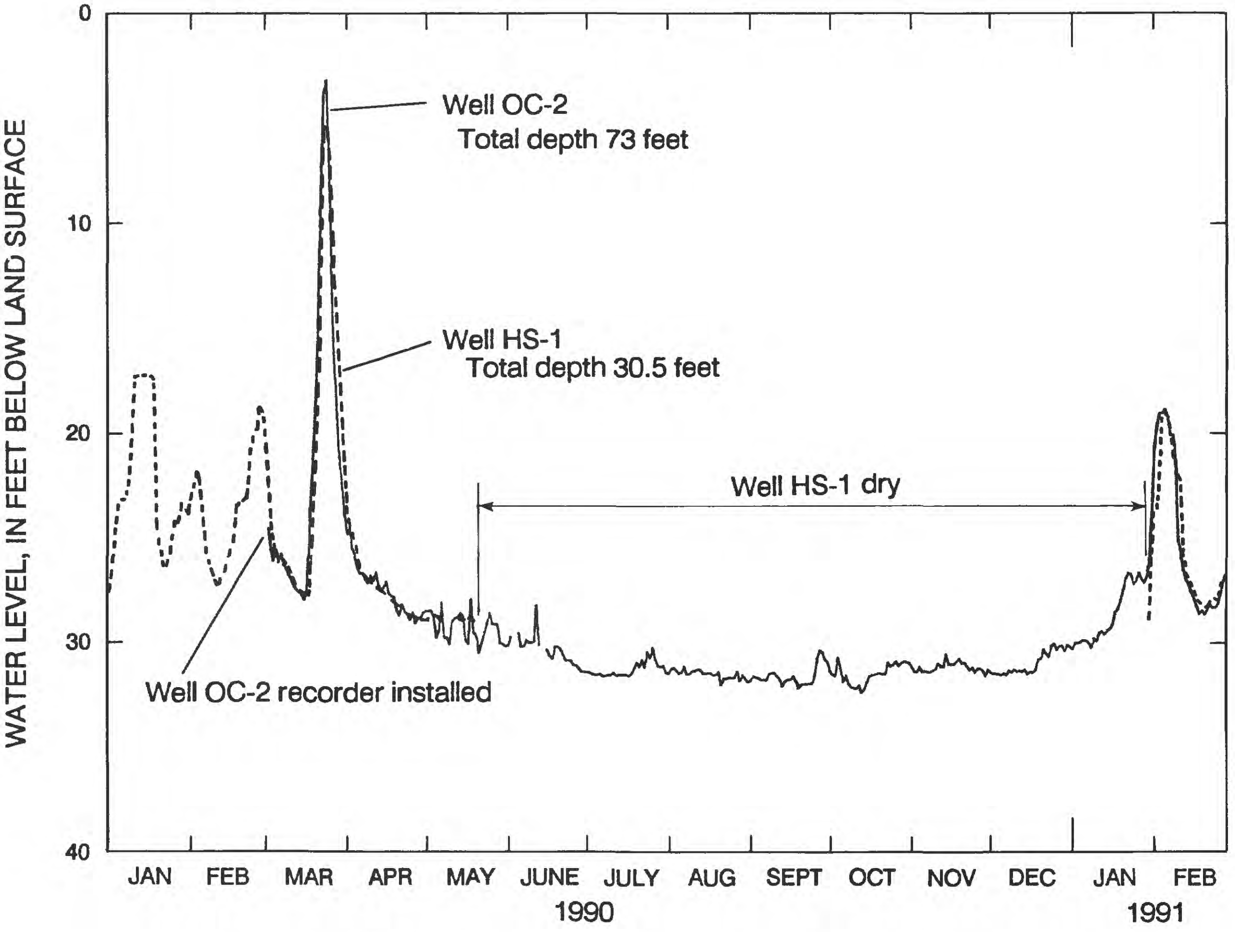

Figure 9.--Daily mean water levels in recorder wells HS-1 and OC-2, January 1990-February 1991.

Regionally, ground water in the Upper Floridan aquifer flows toward the southeast (about 10 degrees east of south), through the study area (Hicks and others, 1987). However, local variations in ground-water-flow paths are expected in karst terrains, and solutioning in the Ocala Limestone has resulted in variations in local ground-water flow. Ground-water-flow paths in the Upper Floridan aquifer were variable during this investigation. Well OC-3, which taps the upper unit of the Ocala Limestone, often had the lowest hydraulic head in the study area during the spring, and acted as a "sink" for ground water (figs. 10 and 11). In the spring, the gradient from well OC-2 to well OC-3 ranged from about 1 to 3 ft over a lateral distance of 100 ft. This high gradient may be due to solution features in the Ocala Limestone at well OC-3. However, well OC-3 had a higher head than well OC-2 at times, which resulted in a reversal of the ground-water-flow direction. In general, during higher ground-water levels in the winter and spring 1990, well OC-3 had a lower head than in the surrounding wells. During the summer and fall 1990, wells OC-2 and OC-3 had similar water levels. Heterogeneities, possibly resulting from the dissolution of the Ocala Limestone, may be present in the aquifer at shallower depths, resulting in a greater degree of head variation during periods of higher water levels.

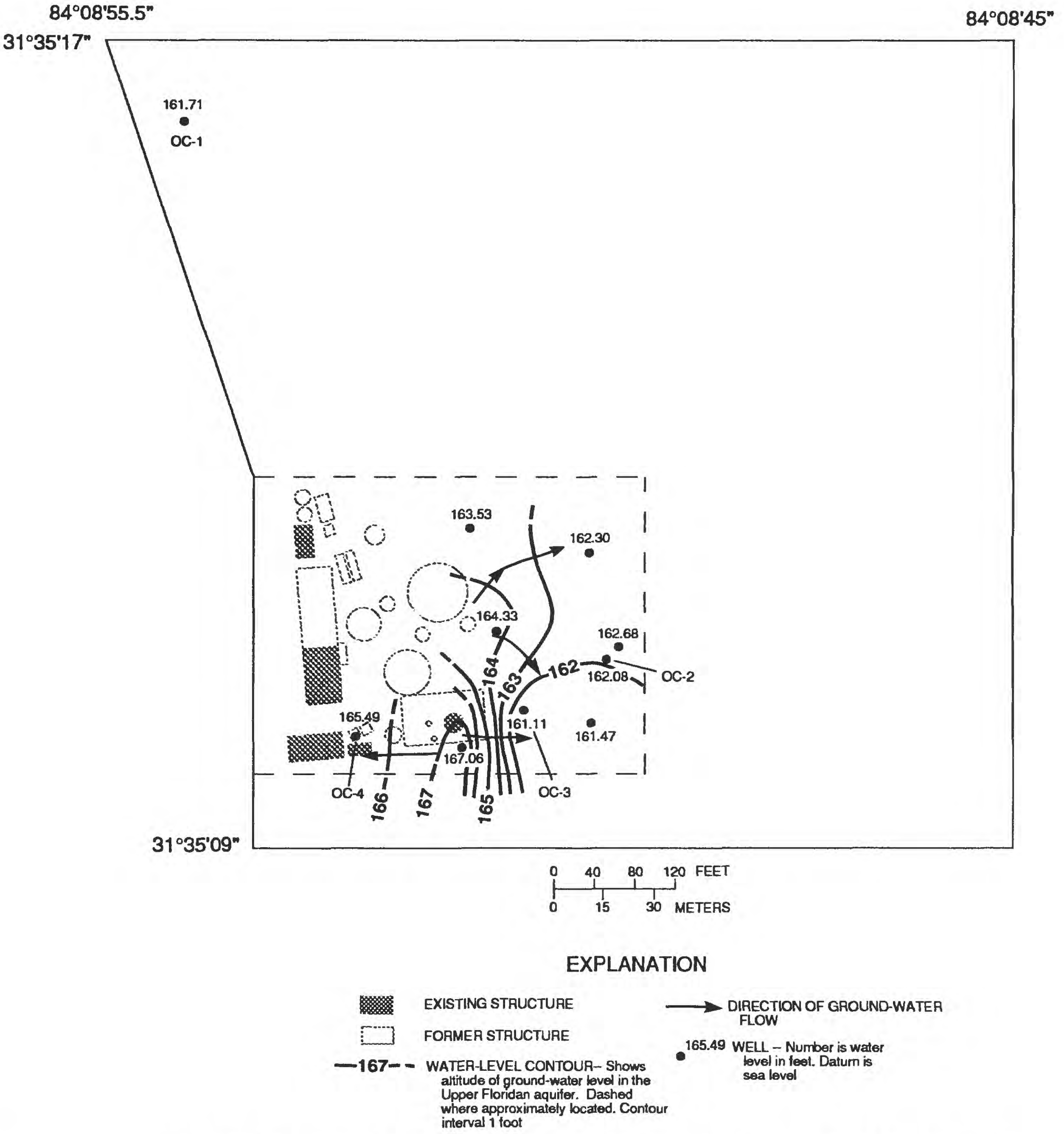

Figure 10.--Directions of ground-water flow in the Upper Floridan aquifer, March 1, 1990.

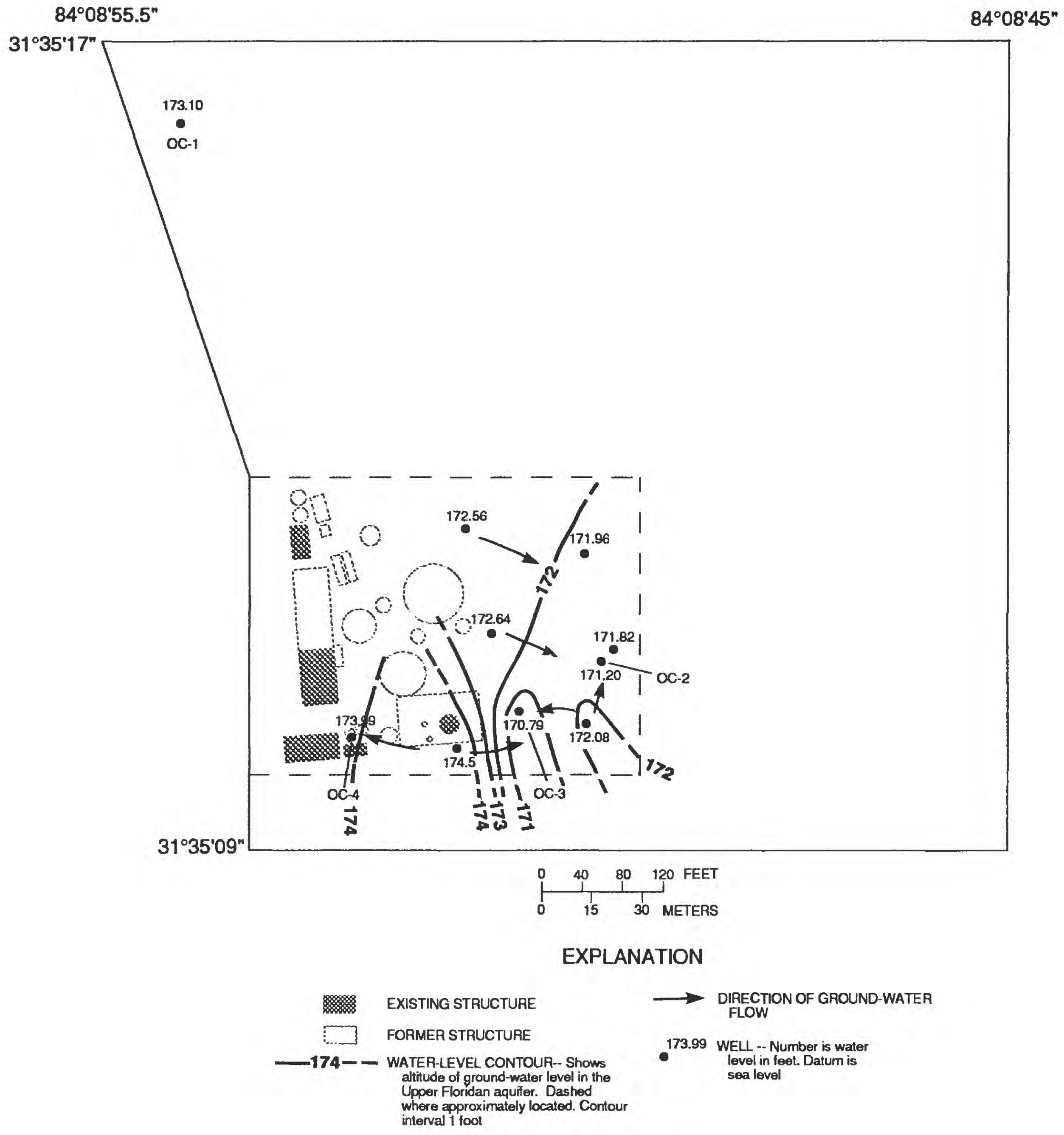

Figure 11.--Directions of ground-water flow in the Upper Floridan aquifer, March 26, 1990.

*Ground-water and surface-water relations*

A direct relation between water levels in the Upper Floridan aquifer and the stage of the Flint River in the study area was established by Chapman and others (1990). Water-level data from wells HS-1 (lower sand layer) and OC-2 (Ocala Limestone) indicate a direct relation between the Upper Floridan aquifer and the stage of the Flint River (figs. 9 and 12). (The gaging station used for comparison is about 0.6 mi upstream from the study area.) In March 1990, the Flint River had the highest stage since March 1966 (Stokes and others, 1989; Roger D. McFarlane, U.S. Geological Survey, oral commun., 1990). Water-level fluctuations in recorder wells HS-1 and OC-2 correlated closely with the stage of the river (figs. 9 and 12). The peak water level for well HS-1 coincided with the highest stage of the river. The water level in well OC-2 responded simultaneously to the river and continued to rise for a 24-hour period after the flood wave had moved through the study area.

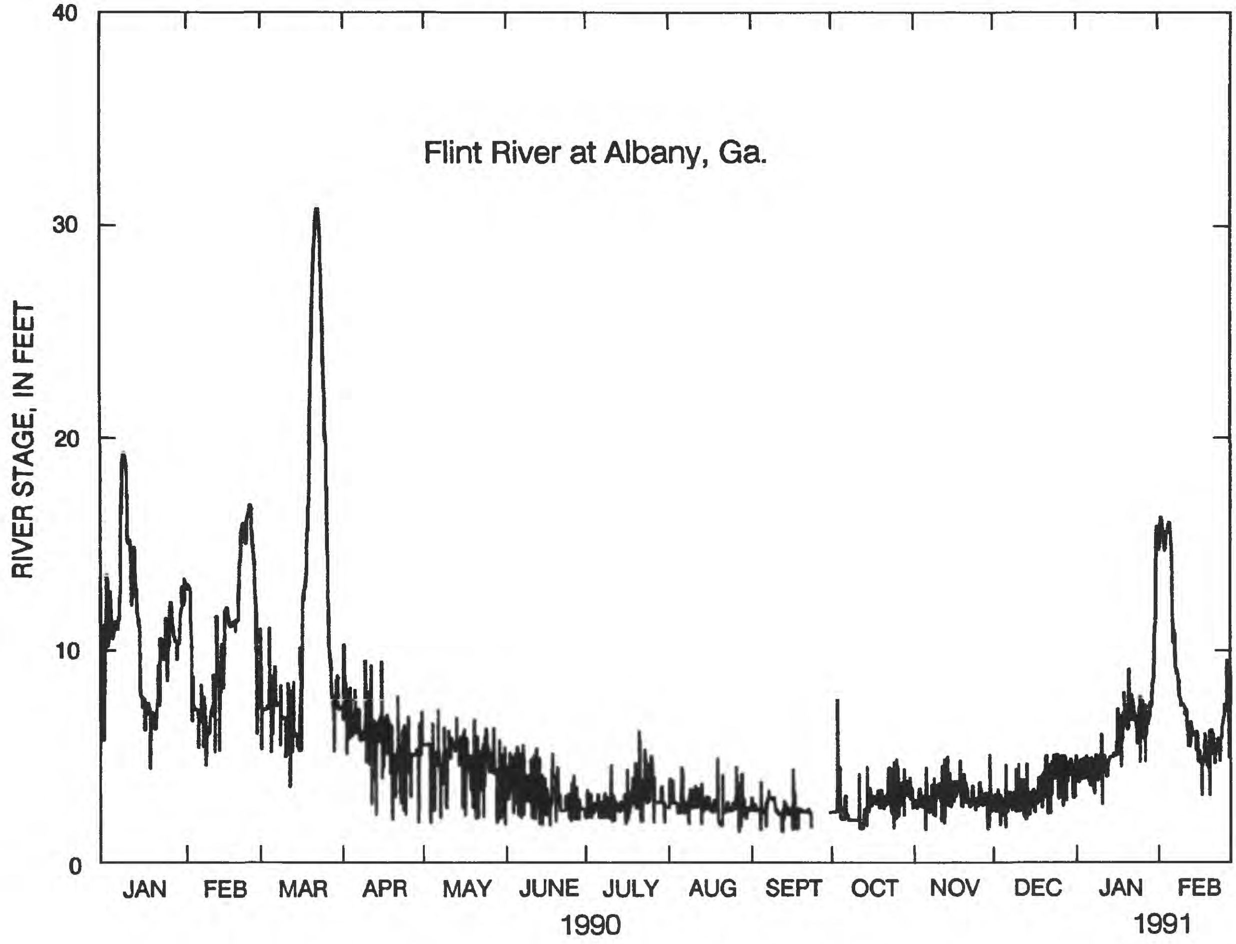

Figure 12.--Stage of the Flint River, near the study area, 1990.

Water levels were measured in all wells in the study area that tap the Upper Floridan aquifer prior to, during, and subsequent to the flooding of the Flint River in March 1990. Prior to the flood, ground-water flow generally was toward well OC-3 (figs. 10 and 11). Ground-water levels measured on March 23 indicated that the ground-water-flow paths were reversed, and directed toward the northwest during the peak stage of the Flint River (fig. 13). Well HS-9 had the highest head during the period of peak stage. This southeast-northwest flow path may represent a conduit connection with the river. As the flood waters receded, ground-water-flow paths in the Upper Floridan aquifer were again reversed, returning to pre-flood directions toward the south-southeast and well OC-3.

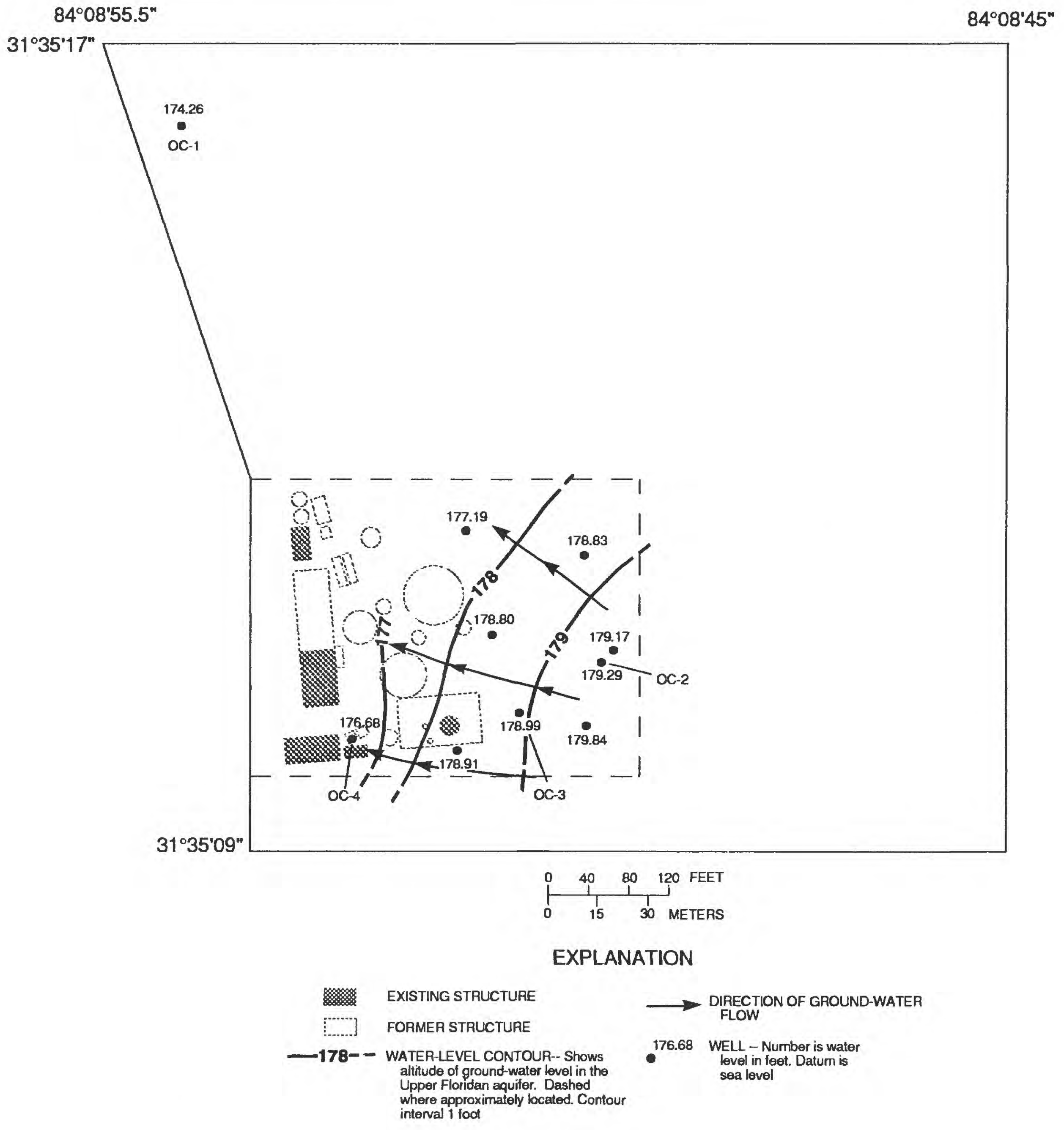

Figure 13.--Directions of ground-water flow in the Upper Floridan aquifer during the flood of March 23, 1990.

# CHARACTERIZATION OF CONTAMINATION

## Occurrence and Distribution of Contaminants

Organic compounds, as well as various metals and other inorganic constituents, were detected in substantial concentrations in the study area (Chapman and others, 1990). Samples of the unconsolidated sediments and ground water from the shallow water-bearing zone were analyzed for volatile and semivolatile organic compounds, metals, cyanide, and various other inorganic constituents (Chapman and others, 1990). Although not chemically analyzed, substantial amounts of solidified tar are present in the drainage ditch (fig. 1). The tar possibly was released to the drainage ditch as a liquid substance and may have contributed to ground-water contamination. This investigation includes the collection and analyses of ground-water samples from the Upper Floridan aquifer, and additional inorganic analyses of a ground-water sample from the shallow water-bearing zone. Similar organic contaminants were detected in both the shallow water-bearing zone and the Upper Floridan aquifer.

### *Soil gas*

Vapor-phase organic compounds were detected in the unsaturated zone at various depths during drilling and trenching operations. During this investigation, an organic-vapor analyzer was used to monitor concentrations of organic vapors in the borehole, the breathing zone, and near sediment and waste samples. The areas of former tank A and boring HS-8 were found to contain the highest organic vapor concentrations in the unconsolidated sediments (Chapman and others, 1990) (table 4). Data obtained from headspace analyses of split-spoon sediment samples indicate the presence of vapor-phase compounds at wells OC-3 and OC-4 (fig. 4 and table 5).

Areas of organic-vapor concentration near the former gas-holding tanks and the present-day (1991) surface-storage tank (also a former gas-holding tank, see fig. 2, tank D) were delineated by Chapman and others (1990). As part of this investigation, a soil-gas survey was conducted in areas of known, near-surface, organic-vapor concentrations to define the presence of contaminants and to determine the relative concentration of organic compounds in the vapor phase in the unsaturated zone. Although contaminants occurred at various depths, a shallow depth of investigation (4 ft) was selected to provide data on sources of near-surface contamination that may migrate or diffuse upward toward land surface. All soil-gas samples having detectable concentrations of organic vapors contained the same four organic compounds---benzene, toluene, ethylbenzene, and xylene (collectively known as BTEX)---in similar, relative concentrations. Because benzene was the strongest and earliest peak on the gas chromatograph, all samples were compared based on their relative benzene concentration.

In general, the areas surrounding boring HS-8 and tank D had detectable concentrations of benzene in soil gas near the surface. The sample containing the highest concentration of benzene (3,500 parts per billion (ppb)) detected in the soil-gas survey was collected about 10 ft southeast of boring HS-8 (fig. 14). The sample at boring HS-8 had the second highest concentration of benzene (980 ppb). The area near boring HS-8 was delineated as having the highest concentrations of hydrocarbons during the preliminary study (Chapman and others, 1990). A benzene concentration of 230 ppb was detected inside the fenced area that secures tank D, which is currently used to store road-primer oil (fig. 2). A smaller, surface-storage tank (tank F, fig. 2) located inside the fenced area also was used to store road-primer oil. A sample of the road-primer oil contained a wide variety of hydrocarbons, including various benzene derivatives.

Table 4.--*Volatile-phase hydrocarbons detected in boreholes during drilling operations*

[HNU, HNU Systems, Inc.; OVA, Century Organic Vapor Analyzer; ppm, parts per million; degree of intensity is a subjective evaluation of odor during drilling; --, no data; >, greater than. Modified from Chapman and others, 1990]

| Well/ boring number | Sampling interval (feet) | Geologic unit | Type of material | HNU or OVA reading(s) (ppm) | Degree of intensity of odor |
|---|---|---|---|---|---|
| B-3 | 1.0- 2.0 | fill | dry, blocky, stained fill | 30,50 | moderate |
| B-5 | 8.0-10.0 | upper sand | hydrocarbon-saturated, loamy sand | 70<br>>1,000 | strong<br>very strong (when cased) |
| B-6 | 4.0- 6.0 | upper sand | hydrocarbon-saturated clayey sand | 3.0 | weak |
| B-7 | 4.0- 6.0 | upper clay | clay | -- | weak |
| B-16 | 3.5 | fill | sandy clay | 8.5 | moderate |
| B-20 | 2.5- 7.0 | fill | clay | -- | moderate |
| B-21 | 5.5- 7.5 | upper clay | clay | -- | strong |
| HS-2 | 3.0- 4.5<br>18.0-22.5 | fill<br>lower sand | silty sand<br>coarse sand | 300<br>>1,000 | strong<br>strong |
| HS-3 | 6.5- 8.0 | upper sand | sand | -- | strong |
| HS-8 | 2.5-14.0 | lower clay | loamy sand and gravelly, clay fill, sandy clay, clayey silt | >1,000 | very strong |
| HS-10 | 4.5- 6.0 | fill | dry, ashy hydrocarbon-stained sandy silt | -- | weak |
| HS-11 | 2.0- 5.5 | fill | gravelly, clay fill | -- | weak |
| HS-12 | 5.5- 9.5 | upper sand | silty sand, clay | -- | moderate |

Table 5.--*Volatile-phase organic compounds detected in head-space analyses of split-spoon sediment samples*

[HNU, HNU Systems, Inc.; OVA, Century Organic Vapor Analyzer; ppm, parts per million; <less than]

| Well number | Sample interval (feet) | Geologic unit | HNU or OVA reading(s) (ppm) |
|---|---|---|---|
| OC-1 | 4.0-5.5 | fill | <1 |
| | 6.0-7.5 | upper sand | 3 |
| | 9.0-10.5 | upper clay | <1 |
| | 12.0-13.5 | lower clay | <1 |
| | 14.0-14.5 | lower clay | <1 |
| OC-2 | 6.0-7.5 | fill | <1 |
| | 9.0-10.5 | upper clay | 3 |
| | 14.0-15.5 | lower sand | <1 |
| | 17.0-19.5 | lower sand | <1 |
| | 21.0-23.5 | lower clay | <1 |
| | 29.0-30.5 | sand | <1 |
| OC-3 | 1.5-2.5 | fill | 3 |
| | 4.0-5.5 | fill | <1 |
| | 6.0-7.5 | fill | <1 |
| | 9.0-10.5 | upper clay | <1 |
| | 13.5-14.5 | upper clay/lower sand | <1 |
| | 25.0-26.5 | lower sand | <1 |
| | 28.0-29.5 | lower sand | 11,12 |
| | 32.0-32.5 | lower clay | 5 |
| | 35.0-36.5 | sand | 9,8 |
| | 38.0-39.5 | sand | 6,8 |
| | 42.0-43.5 | clay | 5 |
| OC-4 | 1.5-2.5 | fill | <1 |
| | 2.5-4.0 | fill | 6,8 |
| | 4.0-5.5 | fill | 3 |
| | 6.0-7.5 | upper clay | 5,4 |
| | 9.0-10.5 | lower sand | 14,13 |
| | 13.0-14.5 | lower sand | 15,12 |
| | 15.0-16.5 | lower clay | 30,38 |
| | 17.0-17.5 | lower clay | 25,30 |
| | 17.5-18.5 | lower clay | 13,13 |
| | 19.0-20.5 | limestone | 12,6 |

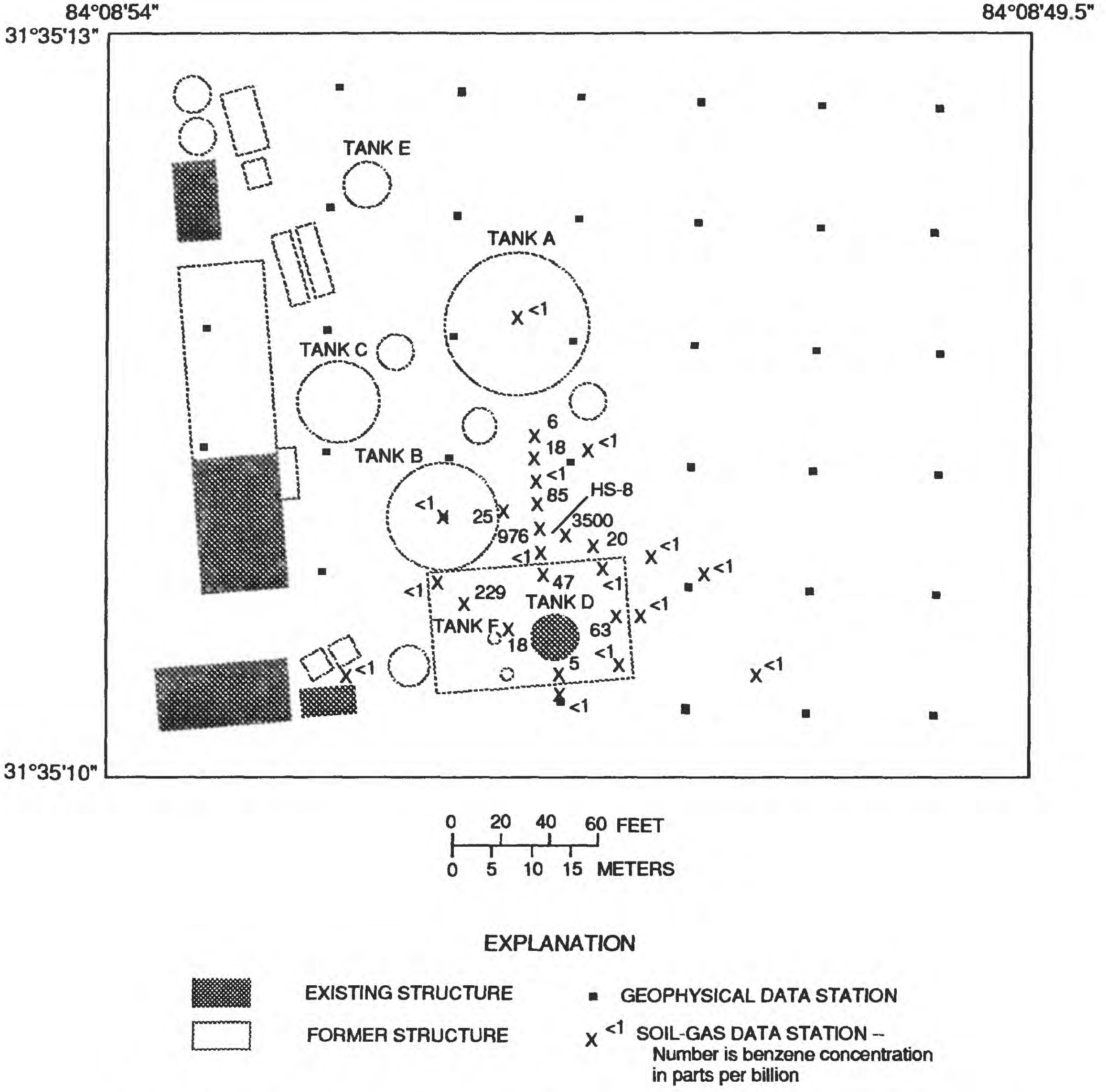

Figure 14.--Distribution of benzene in the shallow subsurface ( 4 feet below land surface) detected during the soil gas survey, April 1990.

The areas of shallow contamination delineated during the soil-gas survey may be the result of both past and present waste disposal. Shallow contamination near tank D may be the result of accidental road-primer oil spills that occurred while the oil was being pumped into tanker trucks during the study period. A sediment sample from the area near tank D (RCRA sample RC-3, fig. 4) was saturated with road-primer oil. The road-primer oil contains a variety of hydrocarbon compounds, many of which also were detected in waste samples considered to be associated with past MGP operations. Contamination in the vicinity of boring HS-8 seems to be related to past MGP operations, possibly from past on-site waste disposal in that area and weathering of tar and other hydrocarbon products in place, or from redistribution of the fill and sediments during decommissioning of the Albany MGP. Hydrocarbon compounds are present in a solid, weathered phase near boring HS-8, but are present as fresh liquid oil near tank D.

## *Unconsolidated sediments*

### *Organic Compounds*

Substantial concentrations of both the solid and liquid phases of organic compounds (primarily hydrocarbons) were detected in the unconsolidated sediments by Chapman and others (1990). The highest concentrations of volatile organic compounds (VOC) in the study area were detected in sediment samples from boring HS-8 (hydrocarbon solid phase), and well HS-3 (hydrocarbon solid and liquid phases) (fig. 4 and table 6). Naphthalene was the VOC having the highest concentration in unconsolidated sediments (560,000 μg/kg), in sample HS-8 and 450,000 μg/kg in sample HS-3. Other prominent VOC detected in the sediments were benzene, xylenes, and toluene. The highly contaminated samples were collected from the upper sand layer (shallow water-bearing zone) of the unconsolidated sediments. Well HS-3 is near the center of the location of former tank A (figs. 2 and 4). Boring HS-8 is in the vicinity of the former location of tank B and near present-day surface-storage tank D.

Table 6.--*Volatile organic-compound concentrations in sediment cores*

[Concentrations in micrograms per kilogram, μg/kg; estimated detection level ranges from 10 to 20 μg/kg; nd, none detected. Modified from Chapman and others, 1990]

| | Concentration, in micrograms per kilogram, at indicated well or boring (and depth, in feet | | | | |
|---|---|---|---|---|---|
| Volatile organic compound | [1]HS-8 (8 feet) | [2]HS-3 (7 feet) | [3]HS-2 (21 feet) | [3]HS-1 (19 feet) | [2]HS-4 (10 feet) |
| Naphthalene | 560,000 | 450,000 | 860 | nd | nd |
| Benzene | 14,000 | 28,000 | 89 | nd | nd |
| Ethylbenzene | 65,000 | 73,000 | 120 | nd | nd |
| 1,2,4-Trimethylbenzene | 21,000 | 18,000 | 110 | nd | nd |
| 1,3,5-Trimethylbenzene | 9,900 | 6,400 | 98 | nd | nd |
| N-Propylbenzene | 940 | 860 | 90 | nd | nd |
| N-Butylbenzene | 1,300 | nd | 270 | nd | nd |
| Dimethylbenzene (total) | 61,000 | 41,000 | 160 | nd | nd |
| Isopropylbenzene | 3,700 | 3,300 | 140 | nd | nd |
| Toluene | 24,000 | 5,900 | 110 | nd | nd |
| p-Isopropyltoluene | 3,400 | 1,600 | 190 | nd | nd |
| Styrene | 1,500 | 1,200 | 59 | nd | nd |
| m and p - xylene | 40,000 | 33,000 | 110 | nd | nd |
| o-xylene | 28,000 | 8,000 | 49 | nd | nd |
| Tert-butylbenzene | nd | nd | 33 | nd | nd |
| Sec-butylbenzene | nd | nd | 85 | nd | nd |

[1] Collected on 04-06-89.
[2] Collected on 04-05-89.
[3] Collected on 04-04-89.

Three waste samples, consisting of a combination of hydrocarbons in the solid and liquid phases, were collected to further characterize MGP wastes. The samples from sites RC-1, RC-2, and RC-3 (fig. 4) were analyzed for RCRA hazardous-waste characteristics (U.S. Environmental Protection Agency, 1988a). The samples were collected in the fill/upper sand layer of the unconsolidated sediments within a few feet of land surface near wells B-5 and HS-3 (RC-1), boring HS-8 (RC-2), and near the surface-storage tank F (RC-3) (fig. 2), which was recently removed from the area. The samples passed the RCRA tests of ignitability, corrosivity, and extraction procedure (EP) toxicity (table 7). Two of the samples passed the reactivity test (cyanide and sulfide reactions); the third sample, RC-3, was somewhat reactive with sulfide. [The defininitions of these properties pertaining to a hazardous waste are stated in Code of Federal Regulations 40 part 261, subpart C (U.S. Environmental Protection Agency, 1988a)].

Table 7.--*Results of Resource Conservation and Recovery Act hazardous-waste characteristics analyses of hydrocarbon-waste samples*

[EP, extraction procedure; nd, none detected; >, greater than; RCRA, Resource Conservation and Recovery Act]

| Analysis | Sample number | | |
|---|---|---|---|
| | RC-1 | RC-2 | RC-3 |
| **EP toxicity** (milligram per liter) | | | |
| Arsenic | nd | nd | nd |
| Barium | 0.68 | 0.10 | 0.33 |
| Cadmium | nd | nd | nd |
| Chromium | nd | nd | nd |
| Lead | nd | nd | nd |
| Silver | nd | nd | nd |
| Mercury | nd | nd | nd |
| Selenium | nd | nd | nd |
| **Corrosivity** (millimeter per year) | 1.6 | 0.7 | 0.63 |
| **Ignitability** (degree Fahrenheit) | >160 ° | >160 ° | >158 ° |
| **Reactivity** (milligram per kilogram) | | | |
| Cyanide | nd | nd | nd |
| Sulfide | nd | nd | 0.70 |
| **Oil and grease** (milligram per kilogram) | 2,080 | 294 | 1,750 |
| **Total petroleum hydrocarbons** (milligram per kilogram) | 1,350 | 247 | 75.5 |
| **Total solids** (percent) | 83.1 | 82.5 | 76.3 |

Moderate concentrations of organic compounds (generally less than 1,000 µg/kg) also were detected in one sediment sample from the lower sand layer (Upper Floridan aquifer) (fig. 3) at well HS-2. Naphthalene, various benzene derivatives, xylene, and toluene again were the dominant contaminants in the sample collected at this location (table 6). However, one sediment sample at well HS-1, about 125 ft east of well HS-2 (lower sand layer, Upper Floridan aquifer), did not contain detectable concentrations of VOC.

### *Inorganic Constituents*

During the previous investigation by Chapman and others (1990), various metals and cyanide were detected in unconsolidated sediment samples (tables 8 and 9). Concentrations of metals and cyanide in sediment samples were highly variable in the study area. Maximum concentrations of metals detected in the unconsolidated sediments were 94 milligrams per kilogram (mg/kg) lead, 500 mg/kg zinc, 19 mg/kg arsenic, 1.9 mg/kg antimony, 0.9 mg/kg selenuium, and 0.11 mg/kg manganese. Samples collected in areas considered to be areally removed from past MGP operations, such as near boring HS-4 and well HS-1, contained substantial levels of several metals (table 8). Only the higher concentrations of metals in the sample at trench TP-4 could be related to past MGP operations. This sample was collected at the location of the only known purifier box. Purifier boxes contained lime and iron oxide that were used as solid reactants for the removal of sulfur from the gas. Areas near former purifier boxes commonly contain elevated concentrations of metals and other inorganic constituents (Edison Electric Institute, 1984; Gas Research Institute, 1987).

Table 8.--*Metal concentrations in sediment samples*

[Results in milligrams per kilogram; Cu, copper; Pb, lead; Zn, zinc; Ni, nickel; Co, cobalt; Cd, cadmium; Cr, chromium; As, arsenic; Sb, antimony; Se, selenium; Fe, iron; Mn, manganese; Al, aluminum; Ti, titanium; *, duplicate sample; <, less than; Do., ditto. Modified from Chapman and others, 1990]

| Site number | Depth (feet) | Cu | Pb | Zn | Ni | Co | Cd | Cr | As | Sb | Se | Fe | Mn | Al | Ti | Geologic unit |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| [1]HS-1 | 7.0-7.5 | 31 | 94 | 190 | 15 | 8 | 0.6 | 35 | 2.9 | 2.5 | 0.4 | 1.70 | 0.11 | 2.9 | 0.28 | Upper clay |
|  | * | 31 | 85 | 180 | 15 | 6 | .5 | 35 | 2.8 | 4.5 | .4 | 1.60 | .18 | 2.8 | .27 | Do. |
|  | 9.0 | 21 | 29 | 78 | 22 | 10 | < .5 | 66 | 4.1 | 0.4 | .6 | 4.00 | .04 | 11.2 | .59 | Do. |
|  | 14.0 | 5 | 2 | 38 | 5 | 6 | < .5 | 52 | 17.0 | .1 | .2 | 6.50 | .01 | 1.6 | .06 | Lower sand |
|  | * | 5 | 1 | 40 | 5 | 4 | < .5 | 38 | 19.0 | .1 | .2 | 7.30 | .01 | 0.7 | .04 | Do. |
|  | 18.0-18.5 | 1 | 1 | 13 | 2 | 3 | < .5 | 10 | 1.0 | < .1 | .1 | 0.60 | < .01 | 0.7 | .04 | Do. |
| [2]HS-3 | 7.0-8.0 | 23 | 73 | 47 | 6 | 2 | < .5 | 18 | 3.5 | 1.6 | .9 | .80 | .08 | 2.6 | .16 | Upper sand |
| [2,5]HS-4 | 10.0-10.5 | 23 | 19 | 55 | 19 | 19 | < .5 | 55 | 3.3 | .3 | .1 | 3.00 | .01 | 9.0 | .46 | Upper clay |
|  | 14.0 | 16 | 22 | 67 | 24 | 19 | < .5 | 70 | 1.6 | .3 | .1 | 2.80 | .01 | 8.1 | .44 | Lower clay |
|  | * | 17 | 22 | 68 | 25 | 20 | < .5 | 69 | 1.7 | .4 | .2 | 2.80 | .01 | 8.1 | .44 | Do. |
| [2]HS-5 | 2.0 | 5 | 2 | 8 | 2 | 2 | < .5 | 3 | 1.4 | .3 | .4 | .20 | < .01 | .3 | .02 | Fill |
|  | * | 7 | < 1 | 14 | 5 | 2 | < .5 | 3 | 2.7 | .4 | .6 | .20 | < .01 | .3 | .02 | Do. |
| [3]HS-8 | 4.0-4.5 | 11 | 40 | 36 | 10 | 5 | < .5 | 33 | 3.7 | 1.2 | .4 | 1.80 | .02 | 3.6 | .49 | Do. |
| [4]TP-4 | 2.0-4.0 | 45 | 70 | 500 | 14 | 9 | .9 | 48 | 8.5 | 1.1 | .6 | 2.20 | .01 | 4.4 | .33 | Do. |
| [4]TP-6 | 4.0 | 34 | 37 | 92 | 15 | 10 | < .5 | 32 | 5.1 | 1.9 | .4 | 1.60 | .08 | 2.9 | .28 | Do. |

[1] Collected on 04-04-89.
[2] Collected on 04-05-89.
[3] Collected on 04-06-89.
[4] Collected on 05-03-89.
[5] Sampling site areally removed from past gas-plant operations.

Table 9.--*Cyanide concentrations in sediment samples*

[µg/kg, micrograms per kilogram; <, less than. Modified from Chapman and others, 1990]

| Well/ boring number | Sample collection date | Depth (feet) | Concentration (µg/kg) |
|---|---|---|---|
| HS-1 | 04-04-89 | 19 | < 200 |
| HS-2 | 04-04-89 | 21 | < 200 |
| HS-3 | 04-05-89 | 7 | 1,500 |
| HS-4 | 04-05-89 | 10 | < 200 |
| HS-5 | 04-05-89 | 1 | < 400 |
| HS-8 | 04-06-89 | 8 | 1,600 |

Cyanide also was detected in sediment samples during the preliminary investigation (Chapman and others, 1990). Concentrations of cyanide detected in sediment samples ranged from less than 200 to about 1,600 µg/kg (table 9). The highest concentrations, 1,500 and 1,600 µg/kg, were detected at well HS-3 and boring HS-8, respectively. Greater concentrations of cyanide detected at well HS-3 and boring HS-8 seem to be related to the organic contamination; and thus, past MGP operations in those areas.

### *Ground water*

#### *Organic Compounds*

Solid- and liquid-phase hydrocarbons, as well as a combination of the phases in the unconsolidated sediments, are potential sources of ground-water contamination by organic compounds in the study area. Organic compounds were detected in ground-water samples from the shallow water-bearing zone and from the Upper Floridan aquifer. Results of analyses for organic compounds in ground-water samples from nine wells and in one sample from a drainage-ditch seep are listed in tables 10 and 11. (A semivolatile seep sample was not collected because of low-flow conditions.) The principal source areas for organic contamination probably are locations near the former gas-holding tanks and the present-day surface-storage tank (fig. 2).

Analyses of ground-water samples indicated that well B-5, completed in the shallow water-bearing zone near the center of the former location of gas-holding tank A (fig. 2), contained water having the highest concentrations of organic compounds in the study area (tables 10 and 11). Volatile organic compounds detected in a water sample from well B-5 include benzene (17,000 micrograms per liter (µg/L)), ethylbenzene (3,300 µg/L), and total xylenes (3,000 µg/L). Concentrations of naphthalene were measured as both volatile (18,000 µg/L) and semivolatile (7,200 µg/L) compounds. VOC include compounds that can be extracted by "purge and trap" methodology, and generally have higher vapor pressures than the semivolatile-organic compounds (SVOC). SVOC generally are extracted using methylene chloride. Well B-5 also contained high concentrations of the SVOC phenanthrene (5,300 µg/L), acenaphthene (2,700 µg/L), and fluorene (1,900 µg/L).

Table 10.--*Concentrations of organic compounds in ground water in the study area*

[Concentrations in micrograms per liter (µg/L); EPA, U.S. Environmental Protection Agency; nd, none detected; na, not applicable; <, less than; p, proposed]

| Organic compound | Shallow water-bearing zone | | Upper Floridan aquifer | | | | | | | | EPA recommended limit for drinking water (µg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | [1,7]/B-5 | [2,7]/SEEP | [3]/OC-1 | [4]/OC-2 | [3]/OC-3 | [4]/OC-4 | [1,7]/HS-1 | [5,7]/HS-2 | [6]/HS-9 | [5]/HS-12 | |
| **Volatile organic compounds** | | | | | | | | | | | |
| *Note:* Reporting limit is 0.2 µg/L | | | | | | | | | | | |
| Benzene | 17,000 | 750 | nd | nd | 150 | 77 | nd | 7.7 | nd | nd | 0.005 |
| Toluene | 88 | 25 | nd | nd | 3.0 | 3.7 | nd | 0.6 | nd | nd | 2.0p |
| Xylenes (total) | 3,000 | 290 | nd | nd | 37 | 13 | nd | 1.2 | nd | nd | 10.0p |
| Ethylbenzene | 3,300 | 130 | nd | nd | 130 | nd | nd | 4.0 | nd | nd | 0.7p |
| Naphthalene | 18,000 | 1,500 | nd | nd | nd | nd | nd | nd | nd | nd | na |
| Isopropylbenzene | 48 | 4.1 | nd | nd | 13 | nd | nd | nd | nd | nd | na |
| N-propylbenzene | 840 | nd | nd | nd | 2.3 | nd | nd | nd | nd | nd | na |
| 1,3,5 Trimethylbenzene | 140 | 31 | nd | nd | 14 | nd | nd | nd | nd | nd | na |
| N-butylbenzene | nd | nd | nd | nd | < 2.5 | nd | nd | nd | nd | nd | na |
| 1,4-Dimethyl-2-ethylbenzene | nd | nd | nd | nd | 4.8 | nd | nd | nd | nd | nd | na |
| 1,3-Dimethyl-2-ethylbenzene | nd | nd | nd | nd | 0.8 | nd | nd | nd | nd | nd | na |
| 1,2,3,5-Tetramethylbenzene | nd | nd | nd | nd | 13 | nd | nd | nd | nd | nd | na |
| 1,2,4-Trimethylbenzene | 300 | 61 | nd | nd | 28 | nd | nd | nd | nd | nd | na |
| 1,2,3-Trimethylbenzene | nd | nd | nd | nd | 41 | nd | nd | nd | nd | nd | na |
| 2-Ethyltoluene | nd | nd | nd | nd | 37 | nd | nd | nd | nd | nd | na |
| Trichloroethane | nd | nd | nd | nd | nd | nd | nd | nd | nd | 1.5 | na |
| Transdichloroethene | nd | nd | nd | nd | nd | 0.9 | nd | nd | nd | nd | na |
| Vinylchloride | nd | nd | nd | nd | nd | 1.3 | nd | nd | nd | nd | 0.002 |
| P-Isopropyltoluene | nd | 16 | nd | nd | nd | nd | nd | nd | nd | nd | na |
| Styrene | nd | 4.1 | nd | nd | nd | nd | nd | nd | nd | nd | 0.1p |
| Chloroform | nd | nd | 0.8 | nd | nd | nd | nd | nd | nd | nd | na |

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[1]/Sampled on 07-14-89.
[2]/Sampled on 06-01-89.
[3]/Sampled on 04-27-90.
[4]/Sampled on 03-28-90.
[5]/Sampled on 03-27-90.
[6]/Sampled on 04-21-89.
[7]/From Chapman and others, 1990.

Table 11.--*Concentrations of semivolatile organic compounds in ground water in the study area*

[Concentrations in micrograms per liter (µg/L); EPA, U.S. Environmental Protection Agency; nd, none detected; na, not applicable; <, less than; p, proposed

| Organic compound | Shallow water-bearing zone | | Upper Floridan aquifer | | | | | | | | Reporting limits (µg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | [1,7]/B-5 | [2,7]/SEEP | [3]/OC-1 | [4]/OC-2 | [3]/OC-3 | [4]/OC-4 | [1,7]/HS-1 | [5,7]/HS-2 | [6]/HS-9 | [5]/HS-12 | |
| **Semivolatile organic compounds** | | | | | | | | | | | |
| Naphthalene | 7,200 | na | nd | nd | 9.0 | 200 | nd | nd | nd | nd | na |
| Acenaphthylene | 340 | na | nd | nd | 110 | 30 | nd | nd | nd | nd | na |
| Acenaphthene | 2,700 | na | nd | 9.0 | 130 | 250 | nd | 23 | nd | nd | na |
| Anthracene | 1,200 | na | nd | nd | 19 | 96 | nd | nd | nd | nd | na |
| Fluoranthene | 900 | na | nd | nd | 11 | 110 | nd | nd | nd | nd | na |
| Fluorene | 1,900 | na | nd | nd | 240 | 87 | nd | nd | nd | nd | na |
| Phenanthrene | 5,300 | na | nd | nd | 130 | 240 | nd | nd | nd | nd | na |
| Pyrene | 1,200 | na | nd | nd | 13 | 140 | [8]/2.75 | nd | nd | nd | na |
| Benzo(k)fluoranthene | 710 | na | nd | nd | nd | 13 | nd | nd | nd | nd | na |
| Benzo(a)pyrene | nd | na | nd | nd | nd | 20 | nd | nd | nd | nd | na |
| Chrysene | 840 | na | nd | nd | nd | 22 | nd | nd | nd | nd | na |
| Benzo(a)anthracene | 950 | na | nd | nd | nd | 21 | nd | nd | nd | nd | na |
| Phenol | 680 | na | nd | nd | nd | nd | [8]/3.16 | nd | nd | nd | na |
| Bis(2-ethylhexyl) phthalate | 37 | na | nd | nd | nd | nd | 10.60 | nd | nd | nd | na |
| Di-N-butylphthalate | 27 | na | nd | nd | nd | nd | 3.25 | nd | nd | nd | na |
| Diethyl-phthalate | nd | na | nd | nd | nd | nd | 2.03 | nd | nd | nd | na |

[1]/Sampled on 07-14-89.
[2]/Sampled on 06-01-89.
[3]/Sampled on 04-27-90.
[4]/Sampled on 03-28-90.
[5]/Sampled on 03-27-90.
[6]/Sampled on 04-21-89.
[7]/From Chapman and others, 1990.
[8]/Concentration determined by mass-spectrometry scan.

Water from well B-5 had visible organic contamination during the study period. This well is near the location of former tank A, where a larger hydrocarbon pool was observed and photographed (fig. 15). The dispersion of the hydrocarbon wastes in the ground water at this site has resulted in a distinctive hydrocarbon odor and a black appearance to sediment and water samples from the shallow water-bearing zone. A viscous tar having a "fresh" appearance, was encountered near the bottom of well B-5 during drilling. Nonaqueous-phase liquid (NAPL) hydrocarbon, visibly phase-separated tars and oils observed in ground water, are considered "sinking" contaminants in well B-5; and thus, tend to concentrate at the bottom of the water column.

Figure 15.--A large, open pool of hydrocarbon liquid at the abandoned gas plant, January 12, 1962. (Photography by Air Photography and Cartographic Service, Military Affairs Transportation Service. Photograph on file with the Albany Chamber of Commerce.)

The ground-water sample from the drainage-ditch seep (table 10) contained many of the same VOC as detected in the sample from well B-5. This sample was collected subsequent to an accidental spill of road-primer oil during the removal of tank F (the smaller surface-storage tank) (fig. 2). A sample of the road-primer oil contained a variety of both aromatic and polyaromatic hydrocarbons. Ground water flowing from this seep along the contact between the upper sand layer and the underlying upper clay layer (the base of the shallow water-bearing zone) normally has a hydrocarbon sheen or floating contaminants on the surface of the water. However, following the spill, the water was black, having the appearance of oil. Because of the observed oil substance at the seep shortly after the spill, a short flow path most likely exists between the spill area and the seep in the shallow water-bearing zone. A water sample collected from the seep contained moderate concentrations of BTEX and naphthalene.

Ground-water samples from wells HS-2, OC-3, and OC-4 tapping the Upper Floridan aquifer contained detectable concentrations of many of the same VOC and SVOC as detected in well B-5 (shallow water-bearing zone), but in lower concentrations. NAPL hydrocarbons also were detected in ground water in wells OC-3 and OC-4 (Upper Floridan aquifer); however, the appearance of water samples from these wells was quite different. Water from well OC-3 was black and contained mainly "sinking" (heavier than water) contaminants, as did water from well B-5. However, water from well OC-4 had "floating" contaminants having the appearance of reddish-brown oil. Water from wells OC-3 and OC-4 both had detectable hydrocarbon odors, and contained moderate concentrations of many of the same VOC and SVOC as those detected in the sample from well B-5 (tables 10 and 11). Wells OC-3 and OC-4 are near the former gas-holding tank area and the present-day surface-storage tank (tank D, fig. 2).

The ground-water sample from well HS-2 contained low concentrations of VOC and SVOC (tables 10 and 11). Well HS-2 taps the lower sand layer (Upper Floridan aquifer) and is dry throughout most of the year, except during periods of high stages in the Flint River. [A sediment samples from the lower sand layer (Upper Floridan aquifer) at this location also contained the same VOC as detected in sediments from the area of former tank A (fig. 2, table 6)].

Water from well HS-12, also in the vicinity of the present-day surface-storage tank (tank D, fig. 2), did not contain detectable concentrations of BTEX (table 10). Well HS-12 was completed in the lower sand layer (Upper Floridan aquifer), and VOC concentrations seem to be confined to the shallow water-bearing zone in this area.

### *Inorganic Constituents*

The specific conductance and pH of ground water in the study area were highly variable. Specific conductance of water from the Upper Floridan aquifer ranged from about 250 to 2,240 microsiemens per centimeter (μs/cm). Water from well HS-2 had the highest conductance of any sample collected during this investigation. Water from well B-5 in the shallow water-bearing zone had a specific conductance of 1,590 μs/cm and a pH of 7.2. Water from the Upper Floridan aquifer had a pH that ranged from 4.7 at well HS-2, to 6.9 at well OC-4.

Ground-water samples from the shallow water-bearing zone and Upper Floridan aquifer contained substantial concentrations of inorganic constituents. Inorganic constituents detected in concentrations that exceeded the U.S. Environmental Protection Agency (1990) drinking-water standards included iron (140,000 μg/L), manganese (38,000 μg/L), aluminum (3,700 μg/L), lead (90 μg/L), and cadmium (28 μg/L) (table 12). In the shallow water-bearing zone, the sample from well B-5 contained elevated concentrations of iron, manganese, and cyanide (table 12). Noteable concentrations of iron and manganese were detected in samples from wells HS-2, OC-2, OC-3, and OC-4 tapping the Upper Floridan aquifer. Concentrations of aluminum were elevated in wells HS-1, HS-2, HS-12, and OC-1 (Upper Floridan aquifer).

Table 12.--*Inorganic constituent concentrations in ground water in the study area*

[µg/L, micrograms per liter; na, not analyzed, nd, none detected; EPA, U.S. Environmental Protection Agency; p, proposed; mg/L, milligrams per liter; --, not applicable; µs/cm, micromsiemens per centimeter]

| Property or constituent | Shallow water-bearing zone | Upper Floridan aquifer | | | | | | | EPA recommended limit for drinking water | Reporting limit |
|---|---|---|---|---|---|---|---|---|---|---|
| | [1]B-5 | [2]OC-1 | [1]OC-2 | [2]OC-3 | [1]OC-4 | [1]HS-1 | [3]HS-2 | [3]HS-12 | | |
| | | | | | *Trace Elements* | | | | | |
| Arsenic[4] (µg/L) | na | nd | nd | nd | nd | nd | 3.0 | nd | 50 | 1.0 |
| Barium[4] (µg/L) | 220 | 130 | 120 | 230 | 430 | 190 | 23 | 120 | 5,000p | 2.0 |
| Beryllium (µg/L) | nd | nd | nd | nd | nd | nd | 7 | nd | -- | 0.5 |
| Boron (µg/L) | na | 40 | 60 | 90 | 70 | 140 | 100 | 40 | -- | 10 |
| Cadmium[4] (µg/L) | nd | nd | 2.0 | 5.0 | 2.0 | nd | 28 | nd | 5.0p | 1.0 |
| Chromium[4] (µg/L) | nd | nd | nd | nd | nd | 20 | nd | nd | 100p | 5.0 |
| Cobalt (µg/L) | nd | 5.0 | nd | nd | nd | 240 | nd | 4.0 | -- | 3.0 |
| Copper[5] (µg/L) | nd | 20 | nd | nd | nd | nd | 30 | nd | 1,300p | 10.0 |
| Cyanide (mg/L) | 0.68 | nd | 0.11 | 1.1 | nd | 0.03 | 1.7 | nd | -- | 0.01 |
| Calcium (mg/L) | 140 | 120 | 130 | 200 | 110 | 200 | 160 | 46 | -- | 0.02 |
| Iron[5] (µg/L) | 14,000 | 140 | 480 | 6,900 | 6,300 | 55 | 140,000 | 120 | 300 | 3.0 |
| Lead[4] (µg/L) | nd | nd | nd | nd | nd | nd | 90 | nd | 5.0p | 10.0 |
| Manganese[5] (µg/L) | 470 | 180 | 4,000 | 3,400 | 1,400 | 5.0 | 38,000 | 8.0 | 50 | 1.0 |
| Molybdenum (µg/L) | 20 | nd | nd | 20 | nd | 20 | 30 | nd | -- | 10.0 |
| Nickel (µg/L) | nd | nd | nd | 20 | nd | nd | 30 | nd | -- | 10.0 |
| Silver[4] (µg/L) | nd | nd | 2.0 | 4.0 | 2.0 | nd | 11 | nd | 50 | 1.0 |
| Strontium (µg/L) | 1,300 | 68 | 270 | 320 | 200 | 460 | 830 | 180 | -- | 5.0 |
| Vanadium (µg/L) | nd | nd | nd | nd | nd | nd | 50 | nd | -- | 6.0 |
| Zinc[5] (µg/L) | nd | 16 | 5.0 | 11 | 5.0 | 10 | 460 | 18 | 5,000 | 3.0 |
| Antimony (µg/L) | nd | nd | 3.0 | nd | 2.0 | 2.0 | 3.0 | 4.0 | -- | 1.0 |
| Aluminum (µg/L) | na | 230 | 10 | nd | 20 | 70 | 3,700 | 630 | -- | 10.0 |
| Lithium (µg/L) | 4.0 | 6 | 5.0 | 7 | 5.0 | 6.0 | 15 | 4.0 | -- | 4.0 |
| Selenium[4] (µg/L) | nd | nd | nd | nd | nd | 2.0 | nd | nd | 50p | 1.0 |
| Mercury[4] (µg/L) | nd | nd | nd | nd | nd | nd | nd | nd | 2.0 | 0.01 |
| | | | | | *Major Constituents* | | | | | |
| Magnesium (mg/L) | 30 | 1.3 | 11 | 11 | 6.1 | 22 | 18 | 6.8 | -- | 0.01 |
| Sodium (mg/L) | 45 | 6.0 | 13 | 19 | 19 | 13 | 30 | 3.1 | -- | 0.2 |
| Silica (mg/L) | 24 | 15 | 12 | 18 | 14 | 6.2 | 11 | 21 | -- | 0.01 |
| Phosphorus (mg/L) | na | 0.03 | nd | nd | nd | 0.03 | nd | nd | -- | 0.01 |
| Potassium (mg/L) | na | 0.6 | 11 | 2.7 | 3.8 | 33 | 7.0 | 1.1 | -- | 0.1 |
| Chloride[5] (mg/L) | na | 6.6 | 11 | 13 | 8.4 | 7.6 | 0.10 | 2.4 | 250 | 0.1 |
| Sulfate[5] (mg/L) | na | 13 | 58 | 90 | 42 | 120 | 160 | 44 | 250 | 0.2 |
| Fluoride[4,5] (mg/L) | na | nd | 0.20 | 0.10 | 0.10 | 0.10 | 0.30 | 0.10 | 4.0, 2.0 | 0.01 |
| | | | | | *Physical Properties* | | | | | |
| pH[6] (units) | 7.2 | 7.0 | 6.7 | 6.6 | 7.0 | 6.6 | 4.8 | 6.2 | -- | -- |
| Conductance[6] (µS/cm) | 1,590 | 552 | 770 | 970 | 655 | 1,200 | 1,220 | 277 | -- | -- |

[1] Collected on 03-28-90.

[2] Collected on 04-27-90.

[3] Collected on 03-27-90.

[4] Regulated by primary drinking water standards (U.S. Environmental Protection Agency, 1988a and 1990).

[5] Regulated by secondary drinking water standards (U.S. Environmental Protection Agency, 1988a and 1990).

[6] Field readings recorded on date of sampling.

The ground-water sample from well HS-2, tapping the Upper Floridan aquifer, had a lower pH (4.8) and a higher specific conductance (1,220 μs/cm) than samples from other wells in the area. This ground-water sample also contained anomalously high concentrations of various metals. The source of inorganic contamination at well HS-2 was not determined. The fill material contains various metallic debris. However, concentrations of metals in other areas of substantial organic contamination are not comparable to those detected in well HS-2.

Ground-water samples from wells HS-2 and OC-3 contained relatively high concentrations of cyanide, 1,700 and 1,100 μg/L, respectively (table 12). Concentrations of cyanide in ground-water are comparable to those in sediment samples from boring HS-8 and well HS-3 (1,600 and 1,500 μg/kg, respectively. Concentrations of cyanide in ground water seem to be related to organic contamination and; therefore, may be related to past MGP operations.

### Migration of Contaminants

In the study area, contaminants have migrated downward from the source areas in the unsaturated zone of surficial fill and upper sand layer (fig. 16) into ground water in the shallow water-bearing zone. Organic compounds associated with past MGP operations were detected in ground-water samples from well B-5 and the drainage-ditch seep. Primarily, lateral downgradient contaminant movement within the shallow water-bearing zone most likely has occurred.

Contaminants were detected in the upper water-bearing zone of the Upper Floridan aquifer (fig. 3, tables 10, 11, and 12). Downward movement of contaminants into the Upper Floridan aquifer has occurred by leakage through the upper clay layer. Data indicate that hydrocarbon saturation in the upper clay layer may have occurred in the vicinity of boring HS-8. However, laboratory-determined vertical hydraulic conductivity of the clay indicates that ground-water movement through the clay layer probably would be relatively slow. Another possibile explanation for downward contaminant movement is that the contaminants have migrated into the Upper Floridan aquifer through breaches in the clay layer that may have developed during excavation for the installation of the former gas-holding tanks. If this were the case, any leakage of hydrocarbons from the tanks or spillage during tank removal may have migrated directly into the Upper Floridan aquifer. Contaminant migration into the Upper Floridan aquifer also may have occurred as a result of downgradient movement along the upper sand layer and upper clay layer boundary (base of the shallow water-bearing zone) toward the southeastern part of the study area, where the upper clay layer is absent. However, evidence of contamination has not been detected in the southeastern part of the study area (near well HS-9).

Because contaminants were detected in the upper water-bearing zone of the Upper Floridan aquifer, the potential exists for further migration downgradient or vertically. Contaminants may migrate downgradient toward the Flint River. Well OC-4, a contaminated well (tables 10 and 11), consistently had a higher head than wells OC-3 and OC-2. Ground water in the vicinity of well OC-4 may be a contributing source of contamination in well OC-3. In areas where the semiconfining middle unit of the Ocala Limestone is more permeable or absent, contaminants that have reached the upper unit of the Upper Floridan aquifer could conceivably move downward into the lower water-bearing zone of the Upper Floridan aquifer.

## COMPARISON WITH OTHER MANUFACTURED GAS PLANT SITES

The organic compounds and inorganic constituents detected at the abandoned Albany MGP site have been found at other abandoned manufactured gas plant sites (Gas Research Institute, 1987). Samples from the Albany MGP study area generally had concentrations of organic and inorganic constituents within the range of concentrations reported at other sites. Only a few contaminants were detected in concentrations higher than maximum concentrations found at other MGP sites. Trimethylbenzenes (1,3,5 and 1,2,4) were detected in sediment samples and in one ground-water sample in concentrations that were higher than the reported concentrations at other sites. Of the inorganic constituents, cobalt and chromium concentrations in sediment samples were higher than those reported from other sites. In ground-water samples, cobalt, iron, and manganese were detected in concentrations higher than those reported from other similar sites.

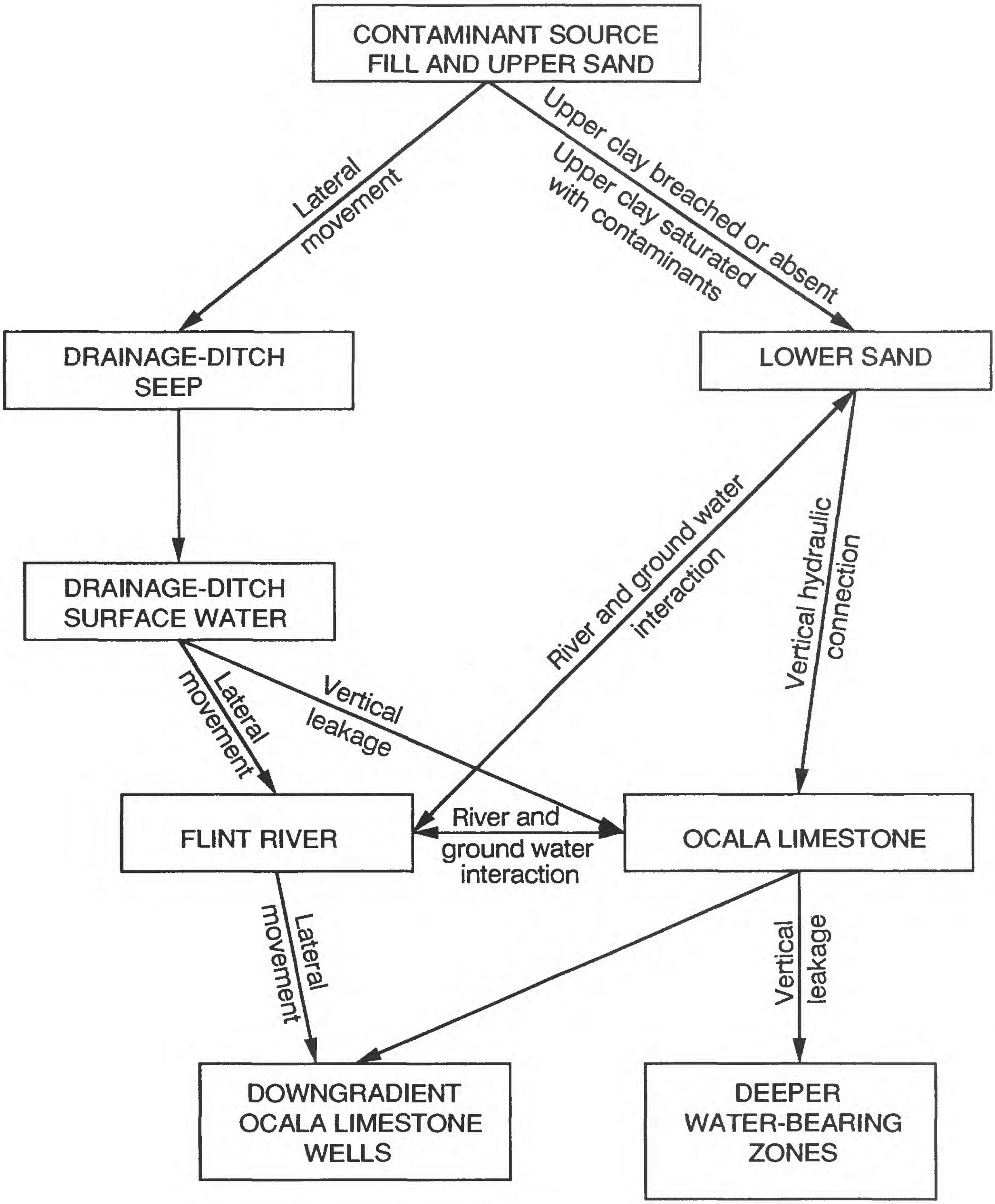

Figure 16.--Possible contaminant migration pathways in the study area.

# SUMMARY AND CONCLUSIONS

In January 1989, an investigation was initiated by the U.S. Geological Survey, in cooperation with the Albany Water, Gas, and Light Commission, in the area of an abandoned MGP in Albany, Ga., to assess the extent and movement of contaminants associated with past gas-plant operations, in hydrogeologic environments similar to those in the study area. Results from this investigation may be used to guide investigations and management decisions involving this and other abandoned MGP located in similar hydrogeologic settings.

Hydrocarbon compounds present in the study area were observed in four phases (1) the liquid hydrocarbon phase; (2) the solid hydrocarbon phase; (3) the aqueous phase; and (4) the vapor phase. The liquid and solid hydrocarbon phases generally were confined to areas near the former gas-holding tanks and present-day surface-storage tank. The vapor and aqueous phases of contaminants also were prevalent in this area, and locally were detected in other parts of the study area, although in relatively lower concentrations.

Substantial concentrations of volatile organic compounds (VOC) were detected in unconsolidated sediment samples (Chapman and others, 1990) and ground-water samples from the shallow water-bearing zone and the Upper Floridan aquifer in the area of the abandoned Albany MGP. Benzene (maximum concentration 17,000 micrograms per liter (μg/L), ethylbenzene (3,300 μg/L), and xylenes (3,000 μg/L) were the dominant VOC detected in the ground-water samples. Semivolatile organic compounds (SVOC) also were detected in the ground-water samples. Naphthalene was detected as both a volatile (18,000 μg/L) and a semivolatile (7,200 μg/L) organic compound. Phenanthrene (5,300 μg/L), acenaphthene (2,700 μg/L), amd fluorene (1,900 μg/L), were among the SVOC detected.

Inorganic constituents also were detected in substantial concentrations in the unconsolidated sediment and ground-water samples from the shallow water-bearing zone and the Upper Floridan aquifer. The most notable concentrations of metals and inorganic constituents detected in the sediment samples were lead (94 micrograms per kilogram (μg/kg), zinc (500 μg/kg), arsenic (19 μg/kg), and cyanide (1,600 μg/kg). In the ground-water samples, inorganic constituents detected in concentrations that exceed Federally regulated (primary) and recommended (secondary and proposed secondary) drinking-water standards included iron (140,000 μg/L), manganese (38,000 μg/L), lead (90 μg/L), and cadmium (28 μg/L). Cyanide also was detected in ground-water samples at a maximum concentration of 1,700 μg/L.

Several contaminants detected in substantial concentrations in ground water in the study area are listed as priority pollutants or carcinogens, or both, by the U.S. Environmental Protection Agency. Priority pollutants detected include benzene, toluene, ethylbenzene, naphthalene, other polycyclic aromatic hydrocarbons, cyanide, and various metals such as cadmium, chromium, copper, lead, and zinc. Of the detected priority pollutants, those listed as carcinogens include benzene and polycyclic aromatic hydrocarbons.

The Upper Floridan aquifer is the shallowest, major water-bearing zone in the study area. The seasonally perched, shallow water-bearing zone in the fill and upper sand layer of the unconsolidated sediments, is not areally extensive and seems to be confined to the former gas-holding-tank area. Water levels in the Upper Floridan aquifer respond to changes in the stage of the Flint River, and water levels in the shallow water-bearing zone respond to infiltration from local precipitation. Hydraulic heads in the shallow water-bearing zone generally are 10 to 20 ft higher than those in the Upper Floridan aquifer. Also, the Upper Floridan aquifer has a relatively thick unsaturated zone during most of the year and is considered to be unconfined in the study area.

Two probable contaminant migration pathways can be interpreted from field observations: (1) migration of contaminants in ground water in the shallow water-bearing zone toward the drainage ditch seep, and (2) migration of contaminants in the Upper Floridan aquifer toward well OC-3. Well OC-3 had a lower hydraulic head than surrounding wells during much of this investigation, and may be in a sink collapse feature in the Ocala Limestone. Because little organic contamination was detected east of well OC-3 at wells OC-2, HS-1, and HS-9, contaminants at well OC-3 may be migrating laterally within the upper water-bearing zone of the Upper Floridan aquifer, offsite, or vertically into other hydrogeologic units. Another possible pathway for contaminants from the abandoned Albany MGP may be interaction of ground water in the study area with surface water during higher stages of the Flint River. A "flushing" of contaminants may occur when head gradients are reversed. Ground water in well OC-3 was observed to have a much greater concentration of nonaqueous-phase liquid hydrocarbons subsequent to the flood in March 1990.

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# APPENDIX

## Geologic Logs

[--, not applicable; ft, feet; ppm, parts per million; OVA, Century Organic Vapor Analyzer[1]/.
*Note:* Samples collected at selected intervals]

| Well number | Depth (feet) | Core recovery (percent) | Core recovery (feet) | Description |
|---|---|---|---|---|
| **OC-1** | | | | **Unconsolidated Sediments:** |
| | 1.5-2.5 | -- | -- | fill, dark brown, gravelly; pieces of brick; some stained ashy material. |
| | 4.0-5.5 | -- | -- | fill, dark reddish-brown, clayey, sandy, dry, firm; increase in clay percentage compared to above interval. |
| | 6.0-7.5 | -- | -- | sand, dark reddish-brown, clayey. |
| | 9.0-10.5 | -- | -- | clay, reddish-brown, sandy; somewhat mottled bluish-gray; tight. |
| | 12.0-13.5 | -- | -- | clay, dark reddish-brown, sandy, gravelly, tight; limestone gravel in matrix at 13.5 ft. |
| | 14.0-14.5 | -- | -- | clay, reddish-brown, sandy, gravelly; somewhat mottled bluish-gray; limestone gravel in matix; auger refusal at 14.5 ft. |
| | 14.5-24.5 | 7 | 0.5 | chert, brown, hard; softer white, silty sand (noncalcareous) inbedded in chert. |
| | | | | **Ocala Limestone:** |
| | | | 0.2 | limestone, white, sandy; slightly weathered; no visible fossils; lost circulation at 18 ft. |
| | 24.5-25.5 | 90 | 0.6 | clay, white, sandy, calcareous. |
| | | | 0.3 | limestone, white, sandy, clayey, fossiliferous; low porosity. |
| | 25.5-26.5 | 50 | 0.5 | limestone, white, sandy, fossiliferous; slighty weathered; low porosity. |
| | 26.5-36.5 | 94 | 7.4 | limestone, white, sandy, chalky, fine to very coarse-grained; fossils are present in layers; alternating layers of resistant and weathered limestone, 0.2 to 1.9 ft thick; fewer weathered out fossils interval above; increase in fractures and glauconite staining at 1.4 ft; iron staining along fractures; greater permeability than interval above. |
| | | | 2.0 | limestone, white, coarse-grained, very fossiliferous; greater permeability than layer above; iron stains along fractures; few glauconitic zones. |

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[1]/The use of brand names in this report is for identification purposes only, and does not consitute endorsement by the U.S. Geological Survey.

# APPENDIX--Continued

## Geologic Logs

[--, not applicable; ft, feet; ppm, parts per million; OVA, Century Organic Vapor Analyzer[1/].
*Note:* Samples collected at selected intervals]

| Well number | Depth (feet) | Core recovery | | Description |
|---|---|---|---|---|
| | | (percent) | (feet) | |
| **OC-1--Continued** | | | | |
| | 36.5-46.5 | 97 | 3.9 | limestone, white, sandy, chalky, fine to coarse-grained; few fractures; layer of fossils; little weathering; low permeability. |
| | | | 5.8 | limestone, white sandy, chalky, medium to coarse-grained; greater chalk percentage than interval above; highly fractured; greater permeability and grain size than interval above; iron stains along fractures; some glauconite staining; rubbly recovery zones. |
| | 46.5-56.5 | 99 | 7.9 | limestone, white to stained brown (iron), coarse-grained, very fossiliferous; fractured; clay is present in fractures; greater iron staining than interval above; fossils present in layers and more abundant than above interval; weathered zones; low porosity. |
| | | | 2.0 | limestone, white to stained brown (iron); increase in fossils than interval above; less weathered than interval above; clay present in fractures; few weathered out fossils; lower permeability than interval above. |
| | 56.5-66.5 | 97 | 6.0 | limestone, white to stained brown (iron), sandy, chalky, coarse-grained, very fossiliferous; greater weathered zones and iron staining than interval above; very permeable where fossils are weathered out; increase in fractures from above interval; high primary and secondary porosity; clay accumulation along fractures. |
| | | | 3.7 | limestone, white to stained brown (iron), sandy, chalky, very coarse-grained; increase in vugs where fossils have weathered out; increase and fractures and overall porosity than interval above. |
| **OC-2** | | | | **Unconsolidated Sediments:** |
| | 0.0-6.0 | -- | -- | fill; drilling problems encountered due to near-surface debris. |
| | 6.0-7.5 | -- | -- | fill, dark brown, clayey, gravelly, stained. |
| | 9.0-10.5 | -- | -- | clay, mottled yellowish-brown and bluish-gray, tight, but not firm; sand stringers in matrix. |
| | 14.0-15.5 | -- | -- | sand, yellowish-brown, medium to coarse-grained, damp; sand/clay contact at about 14.5 ft. |
| | 17.0-18.5 | -- | -- | sand, yellowish-brown, medium to coarse-grained, very loose. |
| | 21.0-23.5 | -- | -- | clay, mottled reddish-brown and bluish-gray, gravelly, sandy; limestone gravel in matrix; possibly weathered/solutioned Ocala Limestone contact at 22 ft. |

## APPENDIX--Continued

### Geologic Logs

[--, not applicable; ft, feet; ppm, parts per million; OVA, Century Organic Vapor Analyzer[1/].
*Note:* Samples collected at selected intervals]

| Well number | Depth (feet) | Core recovery | | Description |
|---|---|---|---|---|
| | | (percent) | (feet) | |
| **OC-1--Continued** | | | | |
| | 27.0-28.5 | -- | -- | sand, white, very gravelly, clayey, calcareous, limestone gravel; wet. |
| | 29.0-30.5 | -- | -- | sand, white, clayey, calcareous; auger refusal at 32 ft. |
| | | | | **Ocala Limestone:** |
| | 32.0-42.0 | 17 | 1.7 | limestone, white to stained brown (iron), sandy, chalky, fine to medium-grained, fossiliferous; iron and manganese-oxide stains; low porosity; lost circulation at 34 ft. |
| | 42.0-52.0 | 17 | 1.7 | limestone, white with greenish-black stains, coarse-grained; greater weathering and iron staining than interval above; greenish-black staining is glauconite; increase in fractures than interval above; gravelly recovery zones. |
| | 52.0-62.0 | 81 | 4.3 | limestone, white with greenish stains, sandy, chalky, medium to coarse-grained, very fossiliferous, fractured; greater weathered out fossils and permeability than interval above; less iron and glauconite staining than interval above. |
| | | | 3.8 | limestone, white with greenish stains, sandy, chalky, coarse-grained; increase in grain size, weathering, glauconite staining, and permeability than interval above. |
| | 62.0-72.0 | 55 | 5.5 | limestone, white, sandy; less weathering and glauconite staining than interval above; highly fractured zones; high permeability; vuggy where fossils have weathered out; possible void noted at 68 ft. |
| | 72.0-82.0 | 33 | 3.3 | limestone, white, sandy, chalky, medium to coarse-grained, fossiliferous; very weathered; clayey sand zones; greater clay content than interval above; high permeability; rubbly recovery zones; possible borehole collapse. |
| **OC-3** | | | | **Unconsolidated Sediments:** |
| | 0.0-2.5 | -- | -- | fill, black (stained), gravelly, sandy; drilling problems encounterd due to near-surface concrete debris. |
| | 4.0-5.5 | -- | -- | fill, reddish-brown, gravelly, sandy; organic matter present. |
| | 6.0-7.5 | -- | -- | fill, dark brown, sandy, clayey; somewhat mottled bluish-gray; tight, damp. |
| | 9.0-10.5 | -- | -- | clay, reddish-brown, sandy; somewhat mottled bluish-gray; few pebbles in matrix; tight; natural organic stains in matrix. |

# APPENDIX--Continued

## Geologic Logs

[--, not applicable; ft, feet; ppm, parts per million; OVA, Century Organic Vapor Analyzer1/.
*Note:* Samples collected at selected intervals]

| Well number | Depth (feet) | Core recovery (percent) | Core recovery (feet) | Description |
|---|---|---|---|---|
| **OC-3--Continued** | | | | |
| | 13.0-14.5 | -- | -- | clay/sand contact at about 14 ft. sand, dark reddish-brown, clayey, coarse-grained, wet. |
| | 17.0-18.5 | -- | -- | sand, dark reddish-brown, clayey, coarse-grained, wet. |
| | 21.0-22.5 | -- | -- | sand, reddish-brown, clayey, medium to coarse-grained; water level at about 24 ft. |
| | | | | **Ocala Limestone:** |
| | 25.0-26.5 | -- | -- | sand, white to light brown, clayey, calcareous; limestone gravel; possible weathered/solutioned Ocala Limestone contact at about 25 ft. |
| | 28.0-29.5 | -- | -- | sand, bluish-gray (stained) to light brown, clayey; limestone gravel; wet, calcareous; hydrocarbon odor noted; sand/clay contact at about 29 ft. clay, dark brown, gravelly, calcareous; hydrocarbon odor noted. |
| | 31.0-32.5 | -- | -- | clay, light brown, sandy, calcareous, wet. |
| | 35.0-36.5 | -- | -- | sand, brown, clayey, calcareous; hydrocarbon odor noted; possible void noted. |
| | 38.0-39.5 | -- | -- | sand, white to light brown, gravelly, clayey, calcareous; hydrocarbon odor noted; possible glauconite staining. |
| | 42.0-43.5 | -- | -- | clay, white to light brown, very gravelly, calcareous; limestone gravel; somewhat dry; no apparent hydrocarbon odor; auger refusal at about 43.5 ft. |
| | 43.5-54.0 | -- | -- | roller bit used. |
| | 54.0-59.0 | 72 | 3.6 | limestone, white to stained greenish-brown, sandy, chalky, medium-grained, fossiliferous, fractured; glauconite and iron stains; weathered; greater permeability from 58.0 - 59.0 ft. |
| | 59.0-69.0 | 21 | 1.8 | limestone, white, sandy, coarse-grained, fractured; weathered out fossils; iron stains; greater permeability than interval above; very weathered; high permeability; possible void noted; hydrocarbon odor noted; hydrocarbon sheen on bottom of sample; floating oil noted on ground water. |
| | 69.0-73.0 | -- | -- | interval not cored. |

# APPENDIX--Continued

## Geologic Logs

[--, not applicable; ft, feet; ppm, parts per million; OVA, Century Organic Vapor Analyzer1/.
*Note:* Samples collected at selected intervals]

| Well number | Depth (feet) | Core recovery | | Description |
|---|---|---|---|---|
| | | (percent) | (feet) | |
| OC-4 | | | | **Unconsolidated Sediments:** |
| | 0.0-4.0 | -- | -- | fill, black (stained), gravelly, clayey, sandy. |
| | 4.0-5.5 | -- | -- | fill, reddish-brown, gravelly, clayey, sandy. |
| | 6.0-7.5 | -- | -- | clay, reddish-brown, gravelly, sandy; weak hydrocarbon odor noted. |
| | 9.0-10.5 | -- | -- | sand, reddish-brown, clayey; hydrocarbon odor noted. |
| | 13.0-14.5 | -- | -- | sand, dark brown, clayey; limestone gravel; strong hydrocarbon odor detected; OVA reading of 200-250 ppm; upgrade to Level C personal protection. |
| | 15.0-16.5 | -- | -- | clay, mottled reddish-brown and bluish-gray, sandy; few pebbles; weak hydrocarbon odor noted. |
| | 17.0-18.5 | -- | -- | clay, dark to light brown, gravelly, sandy; limestone gravel in matrix; calcareous; moderate hydrocarbon noted. |
| | | | | **Ocala Limestone:** |
| | 19.0-20.5 | -- | -- | limestone, white, chalky, sandy; very weathered; hydrocarbon odor detected; auger refusal at about 20.5 ft. |
| | 20.5-30.0 | 97 | 7.5 | limestone, white, chalky, fine to coarse-grained; strong hydrocarbon odor noted; hydrocarbon staining along fractures and in vugs from 2.0 to 2.5 ft; few glauconite stains; hydrocarbon staining is isolated; no loss of circulation; floating oil on white, chalky return water; OVA reading of 14 ppm; upgrade to Level C personal protection. |
| | | | 2.2 | limestone, white, chalky, coarse-grained; increase in grain size, weathering, iron and glauconite staining, and fractures compared to above interval. |