ASSESSMENT OF PETROLEUM-HYDROCARBON CONTAMINATION IN THE SURFICIAL SEDIMENTS AND GROUND WATER AT THREE FORMER UNDERGROUND STORAGE TANK LOCATIONS, FORT JACKSON, SOUTH CAROLINA, 1995

By J. Frederick Robertson

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CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATIONS

Multiply	By	To obtain
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
foot per day (ft/d)	0.3048	meter per day
foot per foot (ft/ft)	0.3048	meter per meter
mile (mi)	1.609	kilometer
gallon (gal)	3.785	liter
pounds per square inch (lb/in^2)	6.895	kilopascal

Temperature in degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) as follows: °F = 9/5 x (°C) + 32

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.

Chemical concentration in water is expressed in micrograms per liter (μg/L) or milligrams per liter (mg/L). Chemical concentration in sediment is expressed in micrograms per kilogram (μg/kg) or milligrams per kilogram (mg/kg). Chemical concentration in air is expressed in microliters per liter (μL/L).

Acronyms and abbreviations used in this report:

bls	below land surface
BTEX	benzene, toluene, ethylbenzene, and total xylenes
ID	inside diameter
MCL	maximum contaminant level
mm	millimeter
MTBE	methyl tertiary butyl ether
OD	outside diameter
OVA	organic vapor analyzer
PID	photoionization detector
PVC	polyvinyl chloride
SCDHEC	South Carolina Department of Health and Environmental Control
TPH	Total Petroleum Hydrocarbons
TPH-DRO	Total Petroleum Hydrocarbons - Diesel Range Organics
TPH-GRO	Total Petroleum Hydrocarbons - Gasoline Range Organics
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
UST	underground storage tank
VOC	volatile organic compound

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ABSTRACT

Ground-water and sediment contamination by petroleum hydrocarbons resulting from leaks and overfills was detected during tank removal activities at three former underground storage tank locations at Fort Jackson, near Columbia, South Carolina. Investigations were initiated to assess the effect of contamination to the surficial aquifer at Sites 1062, 2438, and 2444. These investigations involved the installation of permanent monitoring wells and the collection and analysis of sediment and ground-water samples at the three sites. Water-level data were collected at all sites to determine hydraulic gradients and the direction of ground-water flow. In addition, aquifer tests were made at Site 1062 to determine the hydraulic conductivity of the surficial aquifer at that site.

Sediment borings were made at the three sites to collect subsurface-sediment samples for lithologic description and laboratory analyses, and for the installation of ground-water monitoring wells. Laboratory analyses of sediment samples collected from boreholes at Site 1062 indicated elevated concentrations of petroleum hydrocarbons at three locations. Total Petroleum Hydrocarbons - Diesel Range Organics were detected at one borehole at a concentration of 388,000 micrograms per kilogram. Total benzene, toluene, ethylbenzene, and xylene concentrations in sediment from the site ranged from less than 350 to over 100,000 micrograms per kilogram. Total lead was detected at concentrations ranging from 2,900 to 5,900 micrograms per kilogram. Petroleum hydrocarbons were detected at Site 2438 in one borehole at a trace concentration of 112 micrograms per kilogram of para- and meta-xylenes. No concentrations exceeding the detection limits were reported for petroleum hydrocarbons in sediment samples collected from Site 2444; however, total lead was detected in sediment samples from two boreholes, each at concentrations of 600 micrograms per kilogram.

Ground-water samples were collected from each site for laboratory analysis and field-property determinations. Petroleum hydrocarbons and lead were detected at concentrations exceeding regulatory limits for drinking water in ground water from Site 1062 only. Petroleum hydrocarbons were detected in ground water from three wells at Site 1062, with the highest concentrations occurring in the area of the former underground storage tanks. Benzene was detected at concentrations as much as 28 micrograms per liter; toluene as much as 558 micrograms per liter; para- and meta-xylenes as much as 993 micrograms per liter; and naphthalene as much as 236 micrograms per liter. Ethylbenzene and ortho-xylene were detected in one well at concentrations of 70 and 6 micrograms per liter, respectively. Dissolved lead was detected in ground water from four wells at concentrations from 5 to 152 micrograms per liter.

Analysis of ground-water samples collected from Sites 2438 and 2444 showed little evidence of petroleum-hydrocarbon contamination. Petroleum hydrocarbons were not detected in any of the ground-water samples collected from Site 2438. With the exception of a low concentration of naphthalene (11 micrograms per liter) detected in ground water from one well, petroleum hydrocarbons and lead were not detected in ground water collected from Site 2444.

INTRODUCTION

During the past 6 years, the U.S. Department of the Army has located and removed numerous underground storage tanks (UST's) from various locations at Fort Jackson, near Columbia, S.C. Ground-water and sediment contamination by petroleum hydrocarbons resulting from leaks and overfills was detected during tank removal activities at three of the former UST sites. To assess the effect of contamination on the surficial aquifer at these three sites, investigations were initiated by the U.S. Geological Survey (USGS) in cooperation with the U.S. Army Corps of Engineers, Charleston District. The results of these investigations are presented in two reports, Phase One (Robertson and others, 1994) and Phase Two, this report.

Purpose and Scope

The purpose of this report is to present the results of investigations designed to provide data on the concentrations of petroleum-related contaminants in the surficial sediment and ground water, and to address the horizontal and, to a lesser degree, vertical extent of contamination in the surficial aquifer at study Sites 1062, and 2438 and 2444 at Fort Jackson, S.C. (fig. 1). These tasks were completed during January, February, March, October, and November 1995.

The report describing Phase One of these investigations (Robertson and others, 1994) provided an initial qualitative delineation of petroleum-hydrocarbon contamination. The results from the Phase One investigations were used to direct the Phase Two investigations, which were more quantitative in nature.

This report presents data collected during the Phase Two investigations, which involved the installation of permanent monitoring wells and the collection and analysis of sediment and ground-water samples at three former UST locations (Sites 1062, 2438, and 2444). Ground-water and sediment samples were collected for laboratory analysis of various petroleum constituents. Water-level data were collected at all sites to determine hydraulic gradients and the direction of ground-water flow. In addition, aquifer tests were made at Site 1062 to determine the hydraulic conductivity of the surficial aquifer at that site.

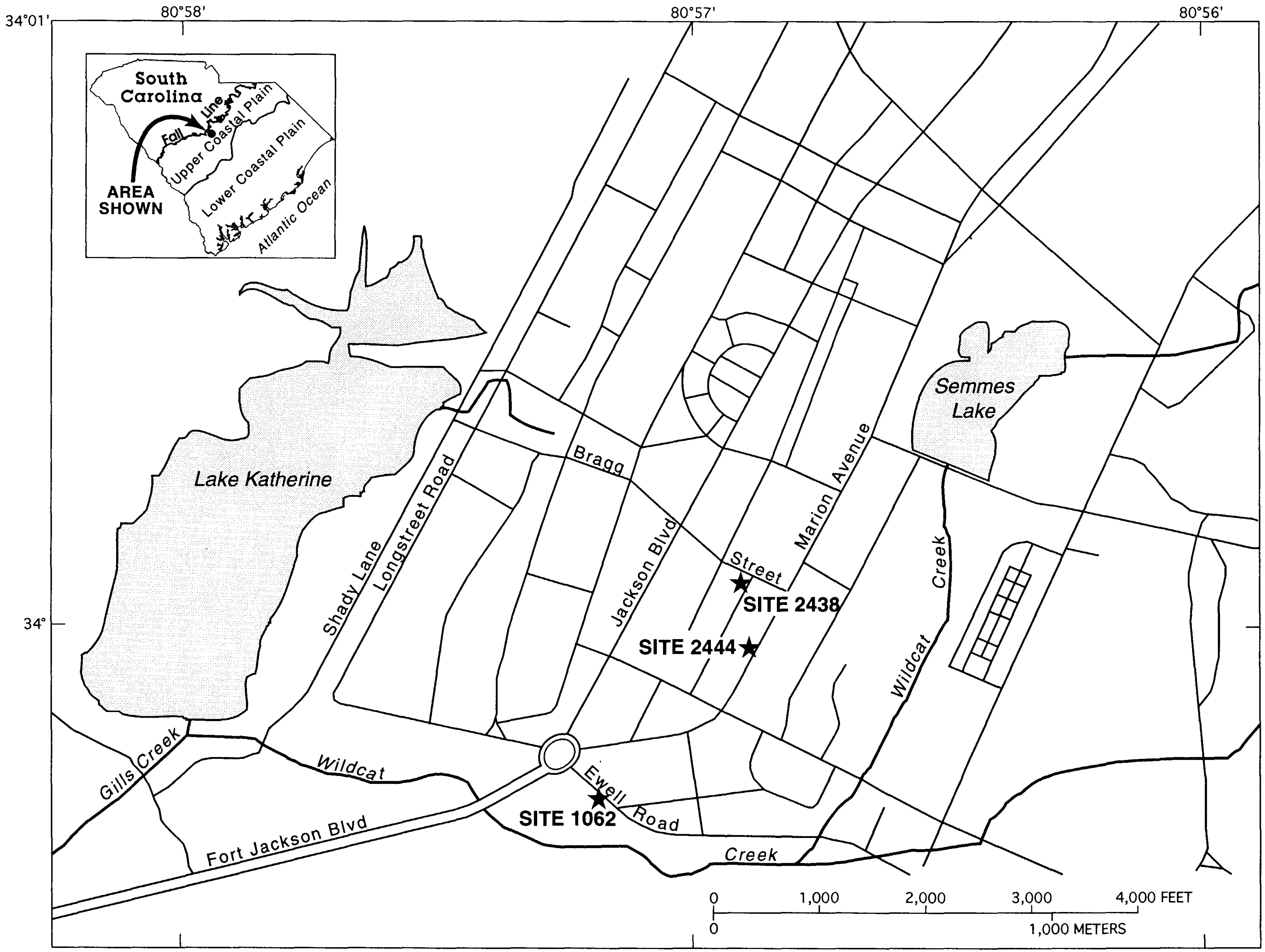

Figure 1. General locations of Site 1062, Site 2438, and Site 2444, Fort Jackson, S.C.

Description of Study Area

Study area Sites 1062, 2438, and 2444 are located in the upper Coastal Plain (fig. 1) and are underlain by unconsolidated, kaolinitic sands, clay, and gravel of Late Cretaceous age which unconformably overlies crystalline rock of pre-Cretaceous age. Previous studies (Ebasco Services Inc., 1992; Robertson and others, 1994) have indicated that the sediments comprising the surficial aquifer beneath Site 1062 are generally sands with appreciable quantities of silt and clay. These sediments have a low permeability and yield relatively small amounts of water. Continuous cores collected at Site 2438 (Robertson and others, 1994) indicated the presence of a dense kaolin layer at a depth of about 6 ft bls. The clay layer was approximately 7-ft thick and appeared to be laterally extensive beneath the study area.

The primary surface-water feature in the vicinity of Site 1062 is Wildcat Creek, which is approximately 450 ft south (downgradient) of the site (fig. 1). From a point south of Site 1062, Wildcat Creek flows westwardly for approximately 0.75 mi to Lake Katherine. A north-south oriented reach of Wildcat Creek, located upstream from Site 1062, is also the primary surface-water feature in the vicinity of Sites 2438 and 2444, and is located approximately 2,000 ft and 1,700 ft southeast (downgradient) of these sites, respectively.

History of Sites

Hydrogeologic investigations made at several of the former UST sites, including Site 1062, indicated that petroleum-hydrocarbon contamination was present in ground water (Ebasco Services Inc., 1992); however, the extent of contamination was not determined. Additionally, preliminary testing of ground water and sediments collected during UST removal activities at Sites 2438 and 2444 suggested the possibility of hydrocarbon contamination.

Reconnaissance investigations of Sites 1062, 2438, and 2444 (Robertson and others, 1994) were made during March 1994. These investigations involved the collection of ground-water or sediment samples, or both, by using a hydraulically driven coring device or temporary well point. Samples were analyzed on-site for benzene, toluene, ethylbenzene, and total xylenes (collectively termed BTEX), Total Petroleum Hydrocarbons-Gasoline Range Organics (TPH-GRO), and Total Petroleum Hydrocarbons-Diesel Range Organics (TPH-DRO) using gas chromatography. Additional samples were collected for laboratory analysis of BTEX compounds as a confirmation of on-site analytical results.

Site 1062

Site 1062 was used as the main Base gas station during the 1980's. When the site was abandoned, Building 1062 was demolished, but the concrete pad was left intact. In December 1990, the three abandoned 10,000-gal storage tanks at this site were removed. One of the three tanks contained less than 6 in. of gasoline product, and the other two tanks each contained less than 6 in. of #2 fuel oil or diesel fuel. Plastic sheeting was placed in the bottom of the excavation, and the hole was reportedly backfilled with the excavated sediment (Ebasco Services Inc., 1992). Samples collected after the tank removal contained BTEX compounds in concentrations ranging from 360 to 3,500 μg/L in ground water and from 1 to 570 μg/kg in sediment (Ebasco Services Inc., 1992). To evaluate the spatial distribution of contamination, sediment borings were made at four locations, and monitoring wells MW-01, MW-02, MW-03, and MW-04 were installed. Analyses of ground-water and sediment samples indicated that BTEX contamination was present; however, the extent of contamination was not determined (Ebasco Services Inc., 1992). Ground-water levels during the time of sample collection (1992) were above the screened interval in three of the monitoring wells. If the ground-water level is above the screened interval of a well during sampling, the existence of floating product on the water table could be undeterminable.

Data collected by Robertson and others (1994) suggested the presence of a contaminant plume at Site 1062 (fig. 1). Thirty-three ground-water samples were collected from 24 locations. On-site analysis detected BTEX compounds in ground water from nine locations, with total BTEX concentrations ranging from 53 to 55,997 μg/L. Concentrations generally decreased rapidly with increasing lateral distance from the former UST area. At three of the locations where BTEX compounds were detected, TPH-GRO also were detected in concentrations ranging from 323 to 3,364 μg/L. Analytical results show that TPH-DRO were not detected in ground water from these same three locations. Three additional samples were collected for laboratory analysis of BTEX as a confirmation of on-site analytical results. These analyses indicated similar qualitative results; however, concentrations determined by laboratory analyses were consistently higher, ranging from less than the detection limit of 5 μg/L to 1,070 μg/L for benzene; to 7,930 μg/L for toluene; to 6,890 μg/L for ethylbenzene; and to 1,524 μg/L for total xylenes.

Site 2438

A 1,000-gal UST was removed from Site 2438 in February 1993. Building 2438 was demolished and removed from this site in January 1994. Little historical information concerning this UST site is available. At the time of excavation, the tank was full of a #2 fuel oil and water emulsion. No apparent holes were discovered in the tank, and piping was not present. The dimensions of the excavation were 16 ft (length) by 12 ft (width) by 6 ft (depth). Ground water was encountered at a depth of approximately 3.5 ft below land surface (bls). The tank, contents of the tank, and the excavated sediments were removed, and the hole was reportedly backfilled with clean sediment.

During excavation, petroleum contamination of the sediment was noted by visual inspection, odor, and organic vapor analyzer (OVA) readings (Mike Lamore, ETI Inc., written commun., 1993). Laboratory analysis of tank contents confirmed the presence of #2 fuel oil. Sediment samples and a single ground-water sample were collected from the excavation pit for laboratory analysis. Analytical results of sediment samples indicated naphthalene concentrations as much as 1,290 μg/kg, TPH-DRO concentrations as much as 727 mg/kg, and total xylene concentrations as much as 412 mg/kg. The ground-water sample contained a naphthalene concentration of 363 μg/L, a TPH-DRO concentration of 15,500 mg/L, a toluene concentration of 70 μg/L, an ethylbenzene concentration of 56 μg/L, and a total xylene concentration of 190 μg/L.

During the reconnaissance investigation of Site 2438 (Robertson and others, 1994), petroleum hydrocarbons were detected in the sediment at one location. Specifically, TPH-DRO was detected (131 mg/kg) by on-site analysis of a sediment sample from beneath the former UST location at a depth of 13.5 ft bls, which was immediately below the bottom of a clay layer that appears to act as a confining layer. However, a split-sample from this interval analyzed for TPH-DRO at a laboratory showed a concentration of less than the detection limit of 10 mg/kg. Petroleum hydrocarbons were not detected in any of the ground-water samples collected from Site 2438.

Site 2444

Two 6,000-gal UST's were removed from Site 2444 in April 1992. Building 2444 remains at this site but is unused. Little historical information regarding the UST's at this site is available. The tanks were situated adjacently, and a single pit measuring 27 ft (length) by 23 ft (width) by 12 ft (depth) was excavated. At the time of removal, both tanks were found to be nearly full of a petroleum and water emulsion and were in good condition (Mike Lamore, ETI Inc., written commun., 1992). Following tank removal, the hole was backfilled with the excavated sediment, and the surface was repaved with asphalt. Ground water was encountered in the excavation; however, the depth below land surface was not noted.

Analysis of the tank contents confirmed the presence of gasoline and diesel fuel (Mike Lamore, ETI Inc., written commun., 1992). It was believed that one tank contained gasoline, and the other tank contained diesel fuel. Visual inspection and OVA screening indicated petroleum-hydrocarbon contamination of the excavated sediment. Laboratory analysis of sediment samples collected from the excavation and the excavated sediment detected concentrations of naphthalene as much as 5,700 μg/kg; TPH-GRO as much as 1,580 mg/kg; TPH-DRO as much as 11,132 mg/kg; toluene as much as 40.5 μg/kg; ethylbenzene as much as 2,020 μg/kg; and total xylenes as much as 5,170 μg/kg. A single ground-water sample collected from the center of the pit contained naphthalene (570 μg/L), TPH-GRO (126 mg/L), ethylbenzene (81.5 μg/L), and total xylenes (292 μg/L). Benzene, toluene, TPH-DRO, and methyl tertiary butyl ether (MTBE) were not detected in the ground-water sample.

During the reconnaissance investigation of Site 2444 (Robertson and others, 1994), 16 ground-water samples were collected from eight locations. Petroleum-hydrocarbon concentrations were detected in ground water from one location only. Specifically, TPH-GRO was detected at a concentration of 3,145 μg/L by on-site analysis of a ground-water sample from the center of the former UST location. Concentrations of BTEX compounds and TPH-DRO were not detected by on-site analysis of ground water from Site 2444, including the location at which TPH-GRO was detected. Three additional samples were collected for laboratory analysis of BTEX as a confirmation of on-site analytical results. Of these analyses, a toluene concentration of 11 μg/L was detected in a sample collected from the center of the former UST location. Sediment samples were not collected for analysis at Site 2444.

Well Inventory

An inventory within a 0.5 mi radius of Sites 1062, 2438, and 2444 was made of all public and domestic water-supply wells. The search was made of the USGS and the South Carolina Department of Natural Resources, Water Resources Division ground-water databases. No potable-water supply wells were identified within the search area. The public water supply for Fort Jackson is currently provided by the City of Columbia, S.C.

DATA COLLECTION AND ANALYSIS

This section describes the various methods used to collect and analyze the data presented in this report. Discussions include (1) the collection of sediment samples for lithologic description and chemical analysis, (2) the installation of monitoring wells for the collection of ground-water samples and the measurement of water levels, (3) the collection of ground-water samples for chemical analysis, (4) the measurement of ground-water elevations to determine flow directions and hydraulic gradients, and (5) the aquifer tests to determine the hydraulic conductivity of the sediments.

Sediment Samples

Sediment borings were made at Sites 1062, 2438, and 2444 to collect subsurface-sediment samples for lithologic description and laboratory analyses, and for the installation of monitoring wells (figs. 2-4). A total of 17 sediment borings were made during January 1995; 6 at Site 1062, 6 at Site 2438, and 5 at Site 2444. All borings were made using 8.25-in. outside-diameter (OD) hollow-stem augers, and sediment samples were collected with a 1.38-in. inside-diameter (ID) split spoon following standard methods (American Society for Testing and Materials, 1994).

All downhole equipment was steam cleaned before setting up at each drilling location to reduce the possibility of cross-contamination. Auger cuttings and water used for decontamination were contained in 55-gal, steel drums, and were stored at their respective sites until disposed of by the USGS in accordance with South Carolina Department of Health and Environmental Control (SCDHEC) regulations.

Subsurface-sediment samples were collected continuously in all boreholes using a split-spoon sampler that was steam cleaned prior to each use. Collection of sediment samples began 2 ft bls. All sediment samples were immediately screened using an HNU DL-101 photoionization detector (PID) equipped with a 10.2 electron volt lamp to qualitatively estimate relative concentrations of volatile organic compounds (VOC's) with depth. The PID was electronically zeroed and calibrated daily to a 100 μL/L isobutylene standard, corrected to a benzene detector response. Background PID response was 0.2 to 0.3 μL/L relative to benzene.

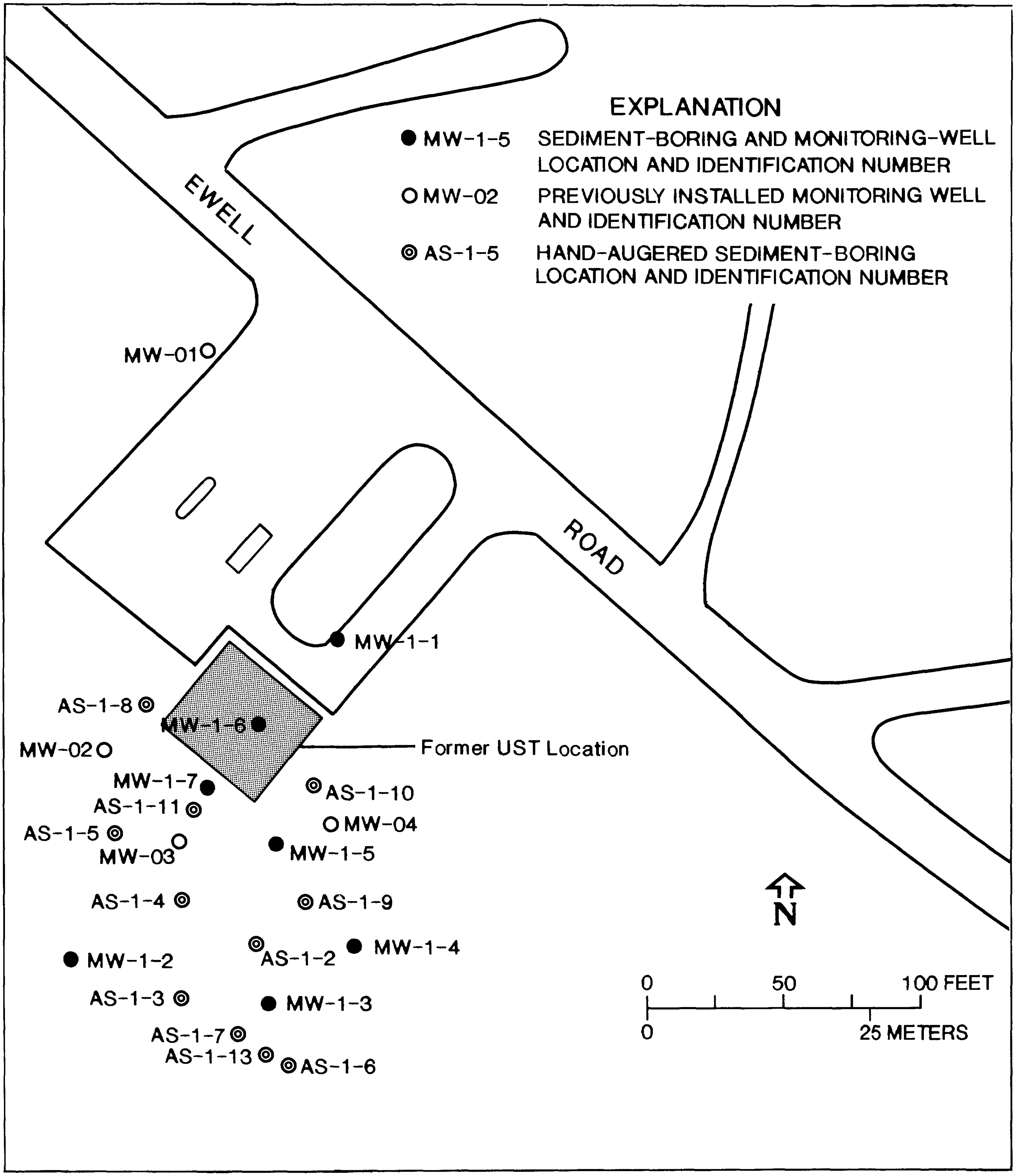

Figure 2. Locations of sediment borings and monitoring wells, Site 1062, Ft. Jackson, S.C.

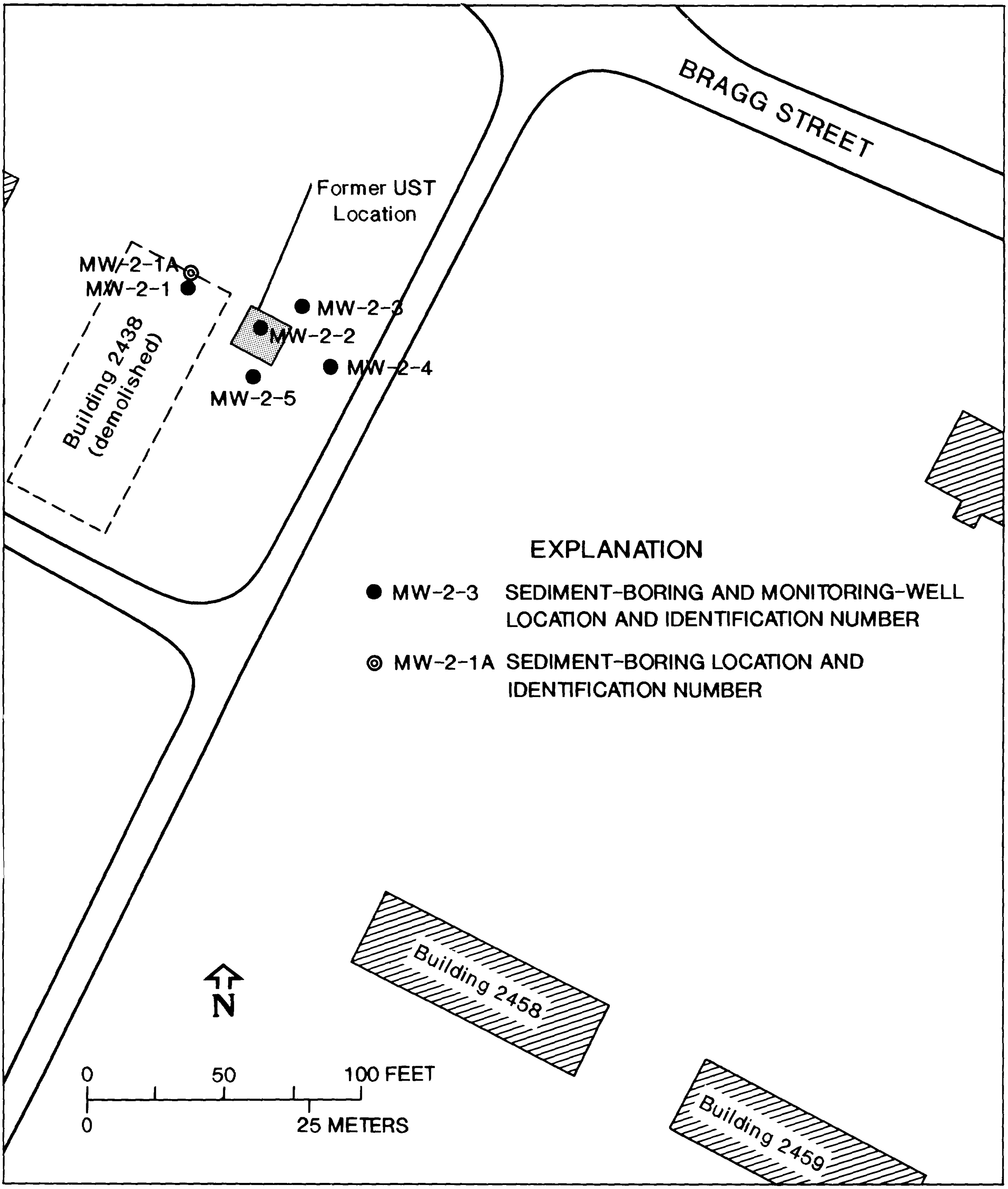

Figure 3. Locations of sediment borings and monitoring wells, Site 2438, Ft. Jackson, S.C.

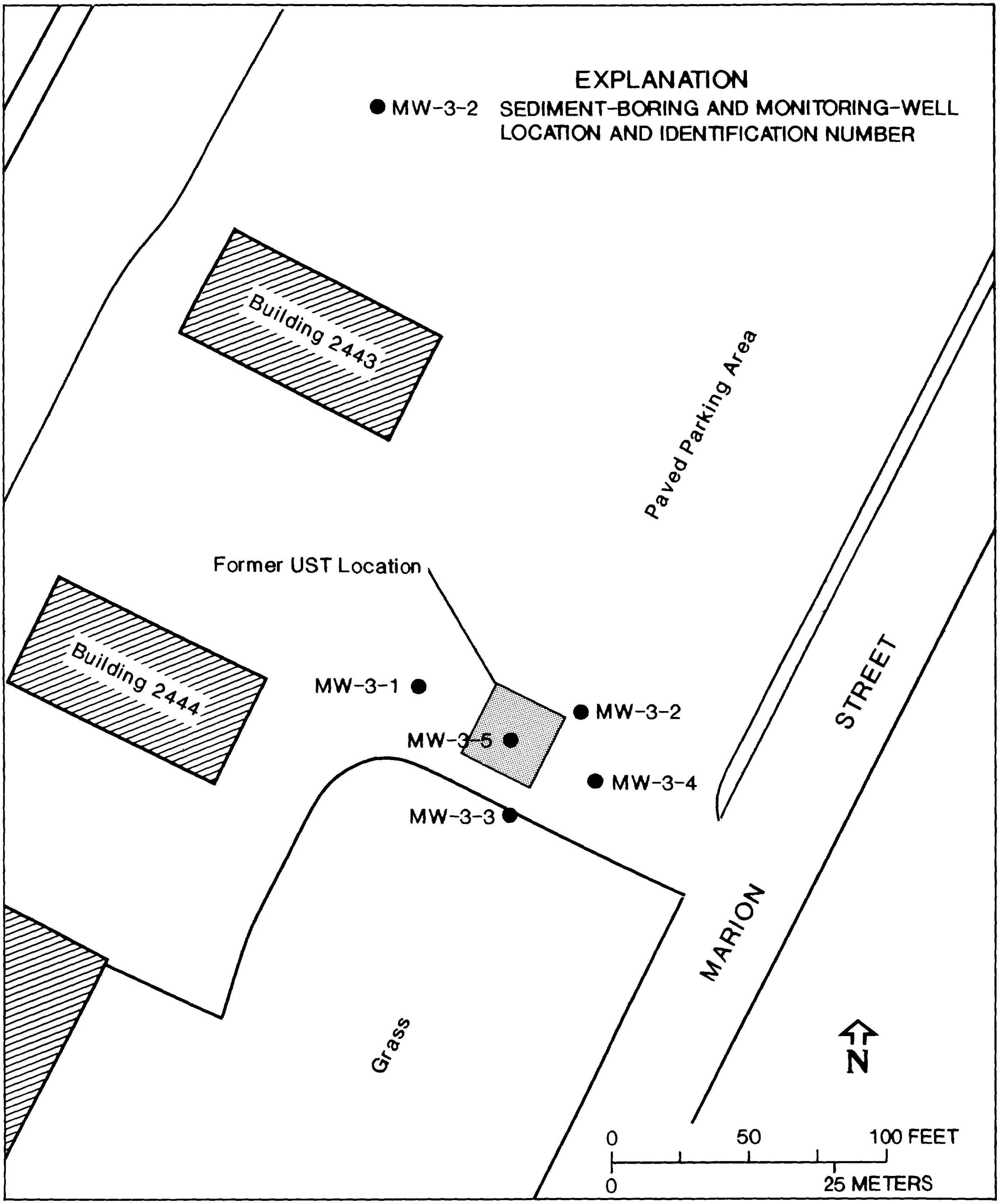

Figure 4. Locations of sediment borings and monitoring wells, Site 2444, Ft. Jackson, S.C.

Each borehole and corresponding monitoring well (figs. 2-4) was designated by assigning them a sequential number following the prefixes MW-1-, MW-2-, or MW-3- for Sites 1062, 2438, and 2444, respectively. Because of poor recovery of the first two split-spoon samples at MW-2-1 (Site 2438), another shallow boring (designated MW-2-1A) was made at a location 5 ft northeast of MW-2-1. A monitoring well was not installed at borehole MW-2-1A. All sediment borings were completed, and corresponding monitoring wells were installed on January 6, 10, 11, and 12, 1995.

Lithologic descriptions, based on the Unified Soil Classification System (American Society for Testing and Materials, 1994), were visually made in the field (tables 1-3, at end of report). Grain-size classifications are based on the Wentworth (1922) Scale. Sediment colors were determined by the comparison of wet sediments to the Geological Society of America Rock Color Chart (1991). The standard penetration number, or blow count, (American Society for Testing and Materials, 1994) was recorded every 0.5 ft of each 2-ft interval as the split-spoon sampler was advanced to provide information regarding the relative density of the sediments (tables 1-3).

Generally, the sediments beneath Site 1062 are composed of clayey or silty sand and clayey silt with some discontinuous sandy clay lenses and yield relatively small amounts of water. Sediments from borehole MW-1-6, however, were composed of relatively loose, very fine- to coarse-grained sands, with a slight clay content. Borehole MW-1-6 is located in the former UST location (fig. 2). It was previously reported that during tank removal activities, the excavation was backfilled with the excavated sediments; however, the sediments at MW-1-6 are not similar to those at other boring locations at Site 1062. Therefore, it appears that the natural sediments in the former UST location were replaced by fill material, either during UST installation or removal.

A definitive water table was not apparent during sediment-sampling activities at all borings except MW-1-6; however, when the augers were lifted out of the boreholes, water began to seep slowly into the hole. Sediments at borehole MW-1-6 were saturated below a depth of about 3 ft bls. Weathered saprolite occurred at boreholes MW-1-2 and MW-1-3 at depths of approximately 11 ft and 17 ft bls, respectively.

At Site 2438, auger cuttings from the first 2 ft in each borehole showed grayish-brown sand, very fine- to coarse-grained, with some clay content. Split-spoon sediment samples collected from depths of approximately 2 to 6 ft bls appeared to be relatively dense, with density increasing with depth, and were either a clayey sand, with grain sizes ranging from very fine to very coarse, or a sandy clay, with a fairly abundant sand content. The dense kaolin layer was encountered at each boring location (excluding MW-2-1A, which was not sampled to a depth greater than 6 ft bls) at approximate depths ranging from 6.2 to 6.8 ft bls.

Borings MW-2-1, MW-2-1A, and MW-2-2 at Site 2438 (fig. 3) were completed and monitoring wells were installed (excluding MW-2-1A) on January 6, 1995. On this date, it appeared that sediments above the kaolin layer were generally moist but not saturated. On January 10, following heavy rains on the night of January 6, monitoring well MW-2-1 contained about 6 ft of water and MW-2-2 contained about 1.5 ft of water. Borings MW-2-3, MW-2-4, and MW-2-5 were completed and monitoring wells were installed on January 10, 1995. On this date, auger cuttings from a depth of about 2 ft bls appeared saturated.

However, split-spoon samples collected from deeper intervals above the kaolin appeared to be moist, but not saturated. All samples collected from the upper part of the kaolin layer were dry and brittle.

Generally, the sediments beneath Site 2444 are composed of very fine- to coarse-grained, clayey or silty sands and sandy clay with some cleaner sands at deeper horizons. The water table was approximately 13 ft bls in each borehole. Backfilled sediments at boring MW-3-5, located at the approximate center of the former UST location, were generally loosely packed; therefore, split-spoon samples were difficult to recover.

Sediment samples for laboratory analyses were collected immediately following a rapid screening with the PID. Sediment-sample containers were filled to capacity as quickly as possible. Samples were immediately packed in ice and sent for analysis at a commercial laboratory possessing SCDHEC certification.

At least four sediment samples were collected for laboratory analysis from each borehole at Site 1062. The PID responses indicated no concentrations of VOC's above background levels in sediments from MW-1-1, MW-1-2, and MW-1-4 (table 1). PID responses were as much as 21.1 μL/L at MW-1-3, 19.0 μL/L at MW-1-5, and 250 μL/L at MW-1-6. Sediment samples for laboratory analyses were collected from the intervals exhibiting the maximum PID responses at MW-1-3, MW-1-5, and MW-1-6. Ideally, at boreholes that did not have PID responses exceeding background levels, sediment samples were collected at and just above the water table. However, in some instances, this approach was difficult to accomplish, because the water table was not apparent during sediment sampling. Intervals from which samples were collected for laboratory analyses and PID responses are noted in table 1.

At least two sediment samples were collected for laboratory analysis from each borehole at Site 2438. Typically, sediment samples were collected from the two split-spoon sample intervals (4 ft to 6 ft, and 6 ft to 8 ft) at and just above the kaolin layer. The PID screening generally indicated no concentrations of VOC's above background levels (table 2). However, a sample from MW-2-2 exhibiting a PID response of 2.5 μL/L was collected from a depth of about 8 ft bls (about 1.2 ft below the top of the kaolin).

At least four sediment samples were collected for laboratory analysis from each borehole at Site 2444 (fig. 4). Typically, sediment samples were collected at and just above the water table, from depth intervals of 10 to 12 ft and 12 to 14 ft bls. The PID responses generally did not indicate concentrations of VOC's above background levels, except for split-spoon samples from MW-3-5 located at the approximate center of the former UST location (table 3). At MW-3-5, a PID response of 8.0 μL/L was detected in a sample from the 12- to 14-ft bls depth interval. However, the split spoon from MW-3-5 at the 12- to 14-ft depth interval did not contain a sufficient sediment volume for laboratory analyses. Similarly, there was no recovery from the previous interval (10 to 12 ft); therefore, samples for laboratory analyses were collected from the 14- to 16-ft and 16- to 18-ft bls depth intervals at borehole MW-3-5.

Sediment samples from all boreholes were collected and analyzed for BTEX compounds using EPA methods 624 or 8260 (U.S. Environmental Protection Agency, 1983 and 1986) and TPH-DRO using the California method equivalent (State of California, 1988). At Sites 1062 and 2444, additional sediment samples were collected for lead analysis using EPA method 239.1 (U.S. Environmental Protection Agency, 1983). Samples for lead analysis were collected from boreholes MW-1-4, MW-1-5, and MW-1-6 at Site 1062, and from boreholes MW-3-3, MW-3-4, and MW-3-5 at Site 2444 only.

Replicate analyses for BTEX and TPH-DRO were run on samples collected from boreholes MW-1-5 and MW-1-6 at Site 1062, MW-2-2 at Site 2438, and MW-3-5 at Site 2444. Replicate analyses for lead were made only on samples collected from boreholes MW-1-6 and MW-3-5.

Additional sediment samples were collected at Site 1062 with a hand auger to further address the extent of soil contamination (fig. 2). These samples were collected to compliment the split-spoon sampling at the six boreholes drilled for monitoring-well installation. Sediment samples from hand-augered holes were collected during March 14 through 16, 1995. Hand-augered sediment samples were collected continuously from a depth of 2 ft bls to slightly below the water table. The hand auger was decontaminated by scrubbing with a detergent solution followed by a deionized water rinse prior to starting each auger hole. All sediment samples from hand-augered holes were immediately screened with the PID upon retrieval (table 4). The PID was calibrated as previously described, and background PID response was 0.2 to 0.4 μL/L relative to benzene. Waste sediments from hand-augered holes were contained in 55-gal steel drums, and the boreholes were backfilled with bentonite to impede the vertical migration of water.

Hand-augered boreholes were designated by number (2 through 11 and 13) following the prefix AS-1, where the number 1 denotes Site 1062. Sediment samples from hand-augered boreholes were analyzed for BTEX using EPA methods 624 or 8260 (U.S. Environmental Protection Agency, 1983 or 1986), except for the sample from AS-1-13, which was analyzed for TPH-DRO using the California method equivalent (State of California, 1988).

Following the investigation of the lateral distribution of petroleum hydrocarbons at Site 1062, another borehole, designated MW-1-7, was made during October 1995 to assess the effect of contamination on the ground water at a deeper horizon, beneath the former UST location. Originally, it was proposed that this borehole and associated monitoring well was to be paired with the existing well MW-1-6 and identified as MW-1-6A. However, problems were encountered that would not permit placement of the well at the proposed location. Two unsuccessful attempts were made to place a surface casing adjacent to MW-1-6. These holes were abandoned and grouted. It became evident that a concrete pad, placed underneath the UST's at 12.5 ft bls, was left intact and unreported during tank removal activities. In an effort to find the downgradient extent of this subsurface pad, two test holes, also abandoned, located the top of the pad at the same depth of 12.5 ft. Borehole MW-1-7 was completed at the location shown on figure 2. The approximate downgradient extent of the subsurface concrete pad was about 24 ft southwest of well MW-1-6, as depicted by the southwestern boundary of the area denoted "former UST location" on figure 2. The extent of the concrete pad was not determined in other directions.

Table 4. Photoionization detector responses from borehole sediment samples collected with hand augers, Site 1062, Fort Jackson, S.C., March 14-16, 1995

[ft, feet; PID, photoionization detector; μL/L, microliters per liter; BG, background; +, denotes depth of BTEX sample; w.t., approximate depth of water table; *, denotes depth of TPH-DRO sample]

Borehole number (fig. 2)	Depth (ft)	PID response (μL/L)	Borehole number	Depth (ft)	PID response (μL/L)	Borehole number	Depth (ft)	PID response (μL/L)	Borehole number	Depth (ft)	PID response (μL/L)
AS-1-2	2.5	BG	AS-1-3	2.0	BG	AS-1-4	2.0	BG	AS-1-5	2.0	BG
	3.0	BG		3.0	BG		2.5	0.7		2.5	BG
	3.5	BG		4.0	BG		3.0	0.5		3.0	BG
	4.0	BG		4.5	BG		3.5	11.7		3.5	BG
	4.5	BG		5.0	BG		4.0	1.9		4.0	BG
	5.0	BG		5.5	BG		5.0	BG		4.5	1.0
	5.5	BG		6.0	BG		5.5	BG		5.0	0.5
	6.0	BG		6.5	BG		6.0	BG		5.5	BG
	6.5	BG		7.0	BG		6.5	0.8		6.0	BG
	7.0	1.1		7.5	BG		7.0	BG		6.5	BG
	7.5	2.1		8.0	BG		7.5^{+}	1.1		7.0	1.3
	8.0	28.8		8.5	BG		8.0 w.t.	0.7		7.5	3.0
	8.25	0.7		9.0	BG					8.0	2.6
	8.5	1.3		9.5 w.t.	BG					8.5	8.0
	9.0^{+} w.t.	30.3								9.0^{+} w.t.	9.0
	9.5	10.7								9.5	3.2
	10.0	19.7									
AS-1-6	3.0	BG	AS-1-7	2.5	BG	AS-1-8	1.0	BG	AS-1-9	2.0	1.2
	3.5	BG		3.0	BG		1.5	0.7		2.5	1.2
	4.0	BG		4.0	BG		2.0	0.5		3.0	BG
	4.5	0.5		4.5	BG		2.2	11.7		3.5	2.2
	5.0	0.5		5.5	BG		2.5	1.9		4.0	1.8
	5.5	BG		6.0	BG		3.0	BG		4.5^{+}	6.8
	6.0	BG		6.5	BG		3.5 w.t.	BG		5.0	1.5
	6.5	BG		7.0	BG		4.5	BG		5.5	BG
	7.0	BG		7.5	BG		5.0	0.8		6.0	1.4
	7.5	BG		8.0	BG					6.5	BG
	8.0	BG		8.5	BG					7.0	0.7
	8.5	0.5		9.0 w.t.	BG					7.5	BG
	9.0 w.t.	BG		9.5	BG					8.0	BG
	9.5	BG		10.0	BG					8.5	BG
	10.0	BG								9.0 w.t.	BG
										9.5	BG

Table 4. Photoionization detector responses from borehole sediment samples collected with hand augers, Site 1062, Fort Jackson, S.C., March 14-16, 1995--Continued

[ft, feet; PID, photoionization detector; µL/L, microliters per liter; BG, background; +, denotes depth of BTEX sample; w.t., approximate depth of water table; *, denotes depth of TPH-DRO sample]

Borehole number (fig. 2)	Depth (ft)	PID response (µL/L)	Borehole number	Depth (ft)	PID response (µL/L)	Borehole number	Depth (ft)	PID response (µL/L)
AS-1-10	2.0	BG	AS-1-11	2.0	BG	AS-1-13	2.0	BG
	2.5	BG		2.5	5.4		3.0	BG
	3.0	1.7		3.0	4.0		3.5	BG
	3.5	1.5		3.5	1.8		4.0	BG
	4.0	1.9		4.0	11.0		5.0	BG
	4.5	3.1		4.5	15.2		5.5	BG
	5.0	3.0		5.0	11.2		6.0	BG
	5.5	1.5		5.5	31.2		6.5	BG
	6.0	2.9		6.0	83.1		7.0	BG
	6.5$^+$w.t.	8.3		6.5	202		7.5	BG
	7.0	6.5		7.0	352		8.0	BG
				7.5$^+$w.t.	353		8.5	BG
				8.0	349		9.0* w.t.	BG
				8.5	340		9.5	BG

Although borehole MW-1-7 was placed immediately downgradient from the former tank area, it was apparent from odor indications that sediments above the bottom of the surface casing had been affected by petroleum hydrocarbons. Furthermore, chemical analysis of auger cuttings from the upper portion of the borehole indicated that this horizon had been affected (ethylbenzene detected at a concentration of 2,480 μg/kg and total xylenes detected at a concentration of 7,010 μg/kg). This sediment sample was collected for the purpose of characterizing investigative-derived waste, and the analytical results are intended to be used in a qualitative nature only. Borehole MW-1-7 was advanced to a depth of 15.5 ft bls with 13.5-in. OD hollow-stem augers, and a 6-in. ID polyvinyl chloride (PVC) surface casing was installed to inhibit the vertical migration of contaminants when advancing the borehole to depths greater than 15.5 ft. The grout surrounding the surface casing was allowed to set for 5 days before the borehole was advanced with 4-in. diameter solid-stem augers, through the inside of the surface casing, to a total depth of 25.8 ft bls.

Auger cuttings and split-spoon samples were collected from MW-1-7 for lithologic description only. Sediments from land surface to a depth of approximately 13 ft bls appeared to be characteristic of the fill material in the former UST area. These sediments were saturated from a depth of about 3.5 ft bls. Sediments below 13 ft were composed of dense, clayey sand, similar to the sediments at most other boring locations at Site 1062. Sediments below 13 ft appeared moist but not saturated as were the sediments above the 13 ft depth.

Monitoring-Well Installation and Development

Monitoring wells installed during these investigations were constructed with 2-in. ID, Schedule-40 PVC casing and slotted screen (0.01 in. slot size). All wells were developed by bailing with clean Teflon bailers until the withdrawn water was clear, or to the maximum extent practical. Before and after use at each monitoring well, the bailers were decontaminated by scrubbing with a detergent solution followed by a deionized water rinse. All water withdrawn during development and subsequent purging was contained in 55-gal, steel drums and later disposed of by the USGS in accordance with SCDHEC regulations. Monitoring-well construction details for all wells installed during these investigations, as well as those installed by Ebasco Services Incorporated at Site 1062, are listed in table 5. As-built construction diagrams for all monitoring wells installed during these investigations are shown in the appendices of this report.

A total of seven monitoring wells were installed at Site 1062 (fig. 2). Six of these wells, MW-1-1 through MW-1-6, were installed during January 1995. These six wells were completed at depths ranging from 12 to 18.5 ft bls and were installed with a 10-ft screened section placed to bracket the water table, unless the depth to the water table was too shallow to allow for such placement. Monitoring wells installed at Site 1062 during January 1995 (excluding MW-1-6) were developed on March 2 and 3, 1995. Each well was bailed dry at least twice. A total of about 29 gal of water was removed from well MW-1-1, 27 gal from MW-1-2, 26 gal from MW-1-3, 8 gal from MW-1-4, and 14.5 gal from MW-1-5. Recovery was very slow in these wells. Monitoring well MW-1-6 was developed by bailing on March 10, 1995. MW-1-6 recovered much more rapidly than other wells installed at Site 1062 during this investigation. A total of 35 gal of water was removed from MW-1-6.

Table 5. Monitoring-well construction details, Sites 1062, 2438, and 2444, Fort Jackson, S.C.

[All depths are relative to land surface. Wells MW-01, MW-02, MW-03, and MW-04 were installed by Ebasco Services, Inc.]

Well number	Site number	Date completed	Borehole diameter (inches)	Casing diameter (inches)	Total depth of borehole (feet)	Total casing depth (feet)	Screened interval (depth in feet)	Gravel-pack interval (depth in feet)	Bentonite interval (depth in feet)
MW-1-1	1062	1/12/95	8.25	2	18.0	13.5	3.5 - 12.8	2.0 - 18.0	1.0 - 2.0
MW-1-2	1062	1/12/95	8.25	2	18.0	16.8	6.8 - 16.1	6.0 - 18.0	4.0 - 6.0
MW-1-3	1062	1/12/95	8.25	2	18.4	18.4	8.4 - 17.7	6.0 - 18.4	4.0 - 6.0
MW-1-4	1062	1/12/95	8.25	2	14.0	14.0	4.0 - 13.3	2.5 - 14.0	1.5 - 2.5
MW-1-5	1062	1/12/95	8.25	2	13.9	13.9	3.9 - 13.2	2.5 - 13.9	1.5 - 2.5
MW-1-6	1062	1/12/95	8.25	2	12.0	11.8	1.8 - 11.1	1.5 - 12.0	1.0 - 1.5
MW-1-7	1062	10/18/95	13.5 to 15.5′ 4.5 to 25.8′	6 (surface) 2 (inner)	25.8	25.8	20.7 - 24.8	19.2 - 25.8	16.2 - 19.2
MW-01	1062	1/28/92	6.75	2	17.0	16.0	6.0 - 16.0	5.0 - 17.0	3.0 - 5.0
MW-02	1062	1/28/92	6.75	2	20.0	20.0	10.0 - 20.0	7.2 - 20.0	5.0 - 7.2
MW-03	1062	1/29/92	6.75	2	19.0	18.0	8.0 - 18.0	6.1 - 19.0	4.0 - 6.1
MW-04	1062	1/29/92	6.75	2	25.0	23.0	13.0 - 23.0	9.5 - 25.0	7.4 - 9.5
MW-2-1	2438	1/6/95	8.25	2	8.2	8.2	3.2 - 7.5	2.0 - 8.2	1.0 - 2.0
MW-2-2	2438	1/6/95	8.25	2	7.5	7.5	2.5 - 6.8	2.0 - 7.5	1.0 - 2.0
MW-2-3	2438	1/10/95	8.25	2	7.6	7.6	2.6 - 6.9	1.5 - 7.6	0.5 - 1.5
MW-2-4	2438	1/10/95	8.25	2	7.4	7.4	2.4 - 6.7	1.1 - 7.4	0.6 - 1.1
MW-2-5	2438	1/10/95	8.25	2	8.0	8.0	3.0 - 7.3	1.5 - 8.0	0.5 - 1.5

Table 5. Monitoring-well construction details, Sites 1062, 2438, and 2444, Fort Jackson, S.C.--Continued

[All depths are relative to land surface. Wells MW-01, MW-02, MW-03, and MW-04 were installed by Ebasco Services, Inc.]

Well number	Site number	Date completed	Borehole diameter (inches)	Casing diameter (inches)	Total depth of borehole (feet)	Total casing depth (feet)	Screened interval (depth in feet)	Gravel-pack interval (depth in feet)	Bentonite interval (depth in feet)
MW-3-1	2444	1/10/95	8.25	2	18.2	18.2	8.2 - 17.5	6.0 - 18.2	2.0 - 6.0
MW-3-2	2444	1/11/95	8.25	2	18.8	18.8	8.8 - 18.1	6.5 - 18.8	4.5 - 6.5
MW-3-3	2444	1/11/95	8.25	2	18.6	18.6	8.6 - 17.9	6.0 - 18.6	4.0 - 6.0
MW-3-4	2444	1/11/95	8.25	2	18.3	18.3	8.3 - 17.6	6.0 - 18.3	4.0 - 6.0
MW-3-5	2444	1/11/95	8.25	2	18.6	18.6	8.6 - 17.9	6.5 - 18.6	4.5 - 6.5

Well MW-1-7 was installed at Site 1062 on October 13, 1995. This well was installed with double casings in a telescoping borehole. A 2-in. ID PVC casing and screen section (5-ft length) was installed through the 6-in. ID PVC surface casing to the total depth of the completed borehole. The screened section was placed at the bottom of the 4.5-in. diameter borehole, which extended from the bottom of the surface casing to total depth. Well MW-1-7 was developed on October 20 and 23, 1995. Water-level recovery in the well was extremely slow. The well was bailed dry twice, with a total of 12 gal, or about 4 casing volumes, removed.

Monitoring wells were installed at five of the six boring locations at Site 2438 (fig. 3). To determine the presence of a water table above the kaolin layer, the wells were installed with 5-ft screened sections, the bottoms of which were situated slightly below the top of the clay layer. Monitoring wells at Site 2438 were developed on January 19, 1995. All wells were bailed dry several times. A total of about 5.5 gal of water was removed from well MW-2-1, 16 gal from MW-2-3, and 20 gal from MW-2-5. Recovery was fairly rapid in MW-2-3 and MW-2-5, somewhat slower in MW-2-1, and extremely slow in wells MW-2-2 and MW-2-4. Consequently, only 1.5 gal were removed from MW-2-2, and only 2 gal were removed from MW-2-4.

Monitoring wells were installed at all five boring locations at Site 2444 (fig. 4). All wells were completed at a depth of approximately 18 ft bls and were installed with a 10-ft screened section placed to bracket the water table. Monitoring wells at Site 2444 were developed on March 10, 1995. Thirty gal of water (approximately 23 casing volumes) were removed from wells MW-3-1, MW-3-2, MW-3-3, and MW-3-5. Thirty-five gal of water were removed from MW-3-4. All wells at Site 2444 recovered rapidly.

Ground-Water Samples

Ground-water samples were collected for laboratory analysis and field-property determinations from all monitoring wells installed during these investigations, including wells MW-01, MW-02, MW-03, and MW-04 (fig. 2). Ground-water samples were collected from Site 1062 on March 23 (all existing wells) and November 3, 1995 (wells MW-1-6 and MW-1-7 only); from Site 2438 on January 20, 1995; and from Site 2444 on March 20, 1995.

Prior to collecting ground-water samples on March 23 at Site 1062, at least three casing volumes were purged from all existing wells. Because of the very slow recovery exhibited in many of the wells during development, MW-1-1, MW-1-2, MW-1-3, MW-1-4, MW-1-5, MW-02, MW-03, and MW-04 were purged on March 22, 1995 (day prior to sampling). These wells were purged dry, with the volume removed approximately equivalent to 3 casing volumes. Wells MW-1-6 and MW-01 recovered relatively fast and were purged of at least 3 casing volumes immediately prior to sampling. At Site 2438, at least three casing volumes were purged from wells MW-2-1, MW-2-3, and MW-2-5 immediately prior to collecting ground-water samples. Because of the very slow recovery exhibited in wells MW-2-2 and MW-2-4 during development, these wells were not purged immediately prior to sampling; however, they had been purged dry on the previous day. Upon arrival at the site on January 20, the water column in both of these wells was only about 1.5 ft. At Site 2444, a minimum of three casing volumes were purged from each well immediately prior to collecting ground-water samples.

Additional ground-water samples were collected from Site 1062 on November 3, 1995, following the installation and development of well MW-1-7. Ground-water samples were collected from MW-1-7 to assess the effect of contamination on the deeper horizons of the surficial aquifer immediately downgradient from the former UST location, an area of known contamination, and from well MW-1-6 to confirm the presence of elevated concentrations of petroleum hydrocarbons as detected at this well during the March 1995 sampling event. Because of the very slow recovery exhibited during the development of well MW-1-7, this well was purged dry on November 2, the day prior to sampling. MW-1-6 was purged of 3 casing volumes immediately prior to sampling.

Ground-water samples were collected and analyzed for BTEX, MTBE (excluding Site 2438), and naphthalene using EPA methods 624 or 8260 (U.S. Environmental Protection Agency, 1983 or 1986), TPH-DRO using the California method equivalent (State of California, 1988), and dissolved lead (excluding Site 2438) using EPA method 239.2 (U.S. Environmental Protection Agency, 1983) at a commercial laboratory possessing SCDHEC certification. Samples were not collected for MTBE and lead analysis from wells at Site 2438, because historical information did not indicate any previous storage of gasoline at this site. Ground-water samples for organics analyses were collected with Teflon bailers equipped with a bottom-discharge valve. Sample bottles for organic analyses were filled slowly with minimal agitation to minimize potential loss of volatile compounds and were checked after sealing to insure the absence of trapped air. Samples collected for BTEX, MTBE, and naphthalene analysis were preserved with hydrochloric acid. Samples for lead analysis were collected using a peristaltic pump with silicon tubing and filtered through a 0.45-micrometer porosity filter membrane. Lead samples were preserved with nitric acid. All samples were packed in ice for transport to the laboratory and were tracked using the chain-of-custody procedures of the laboratory.

Duplicate samples representing greater than 10 percent of the total number of samples per site were collected from wells MW-1-3, MW-3-5, and MW-1-7 (November sampling event) for BTEX, MTBE, naphthalene, TPH-DRO, and lead analyses. A duplicate sample was collected from well MW-2-3 for BTEX, naphthalene, and TPH-DRO analysis. The analyses of trip blanks, which accompanied sample bottles during transport to the field and the return to the laboratory indicated no concentrations of BTEX compounds, MTBE, or naphthalene above the detection limits. However, the detection limits for one of the trip blanks (TB-1-1) were elevated (100 μg/L each) for benzene, toluene, and MTBE. An explanation provided by the laboratory indicated the elevated detection limits were a result of dilution and that these compounds did not appear to be present at elevated concentrations (> 1.25 μg/L) in the trip blank (Bruce E. Watt, Columbia Analytical Laboratories, Inc., written commun., 1995).

Additional samples were collected from all wells to determine field properties. Ground-water temperature and pH were determined on-site by USGS personnel using standard procedures (Wood, 1976). Dissolved-oxygen concentrations were determined in the field using the azide modification iodometric method (American Public Health Association and others, 1989, p. 4-152). Dissolved-ferrous-iron concentrations were determined in the field using the Hach colorimeter/phenanthroline method (Hach Company, 1993, p. 50-9 to 50-14). Because of the minimal amount of water available from wells MW-2-2 and MW-2-4 at Site 2438, dissolved-oxygen concentrations were not determined at these two wells. Temperature and pH could not be determined on January 20 because of meter malfunctions; however, these properties were determined on February 1, 1995. The dissolved-iron concentration at well MW-2-2 was not determined until February 1 because of the lack of water after organics sampling on January 20. Prior to sampling on February 1, monitoring wells MW-2-1, MW-2-2, and MW-2-4 were bailed dry and allowed to recover for about 2 hours. Three casing volumes were purged from wells MW-2-3 and MW-2-5.

Water-Level Elevations

Elevations, relative to sea level, were established at the measuring points (top of casing) of all monitoring wells, including those previously installed (Ebasco Services Inc., 1992) at Site 1062 to provide a common datum to correlate water levels. All measuring-point elevations are approximately equal to land surface. Water levels were measured in all wells by using a steel tape, and the measurements were recorded to the nearest 0.01 ft.

Water-level elevations at Site 1062 were measured in all existing wells on three dates: March 2, 1995, prior to well development; March 22, 1995, prior to ground-water sampling activities; and March 28, 1995. Water-level data are listed in table 6, and water-table contours based on measurements taken March 22, 1995, are shown in figure 5. Water-table contours indicate a general direction of ground-water flow towards the south at Site 1062. The hydraulic gradient along a flow path between wells MW-1-6 and MW-1-3 on March 22, 1995, was determined to be 0.12 ft/ft. Water levels were also measured in wells MW-1-7 and MW-1-6 on November 3, 1995, prior to ground-water sampling.

Water-level elevations at Site 2438 were determined on four dates: January 19, 1995, prior to development; January 20 and February 1, 1995, immediately prior to collecting ground-water samples; and February 9, 1995. Water-level data are listed in table 7, and water-table contours based on measurements taken February 1, 1995, are shown in figure 6. Water-table contours indicate a general direction of ground-water flow trending towards the southeast at Site 2438. The hydraulic gradient along the general flow direction between wells MW-2-1 and MW-2-2 on February 1, 1995 was determined to be 0.08 ft/ft.

At Site 2444, water-level elevations were determined on three dates: February 24, 1995, prior to development; March 20, 1995, immediately prior to ground-water sampling activities; and March 28, 1995. Water-level data are listed in table 8, and water-table contours based on measurements taken March 20, 1995, are shown in figure 7. Water-table contours indicate that the direction of ground-water flow at Site 2444 is towards the southeast. The hydraulic gradient along the flow path between wells MW-3-1 and MW-3-4 on March 20, 1995, was determined to be 0.02 ft/ft.

Aquifer Tests

On November 8 and 13, 1995, positive-displacement slug tests were made on monitoring wells MW-1-7, MW-02, and MW-04 at Site 1062, for the purpose of determining the hydraulic conductivity at various locations in the surficial aquifer. Wells MW-1-7, MW-02, and MW-04 were chosen, because the well screens and gravel packs of these wells were fully saturated at the time the tests were made. These wells are screened in the dense, low-yielding sediments comprising the surficial aquifer.

Table 6. Water-level elevations, Site 1062, Fort Jackson, S.C., March and November 1995

Well number	Date	Depth to water (feet below measuring point)	Measuring point elevation (feet above sea level)	Water-level elevation (feet above sea level)
MW-1-1	03/02/95	1.09	198.73	197.64
	03/22/95	2.46	198.73	196.27
	03/28/95	3.07	198.73	195.66
MW-1-2	03/02/95	7.60	191.26	183.66
	03/22/95	6.80	191.26	184.46
	03/28/95	7.59	191.26	183.67
MW-1-3	03/02/95	9.74	192.01	182.27
	03/22/95	11.24	192.01	180.77
	03/28/95	11.84	192.01	180.17
MW-1-4	03/02/95	8.71	192.43	183.72
	03/22/95	9.58	192.43	182.85
	03/28/95	10.30	192.43	182.13
MW-1-5	03/02/95	6.20	195.21	189.01
	03/22/95	8.23	195.21	186.98
	03/28/95	8.82	195.21	186.39
MW-1-6	03/02/95	1.40	197.63	196.23
	03/22/95	3.43	197.63	194.20
	03/28/95	3.88	197.63	193.75
	11/03/95	2.49	197.63	195.14
MW-1-7	11/03/95	6.24	196.12	189.88
MW-01	03/02/95	1.60	199.96	198.36
	03/22/95	3.00	199.96	196.96
	03/28/95	3.41	199.96	196.55
MW-02	03/02/95	1.72	196.62	194.90
	03/22/95	3.22	196.62	193.40
	03/28/95	3.83	196.62	192.79
MW-03	03/02/95	5.75	194.75	189.00
	03/22/95	9.21	194.75	185.54
	03/28/95	9.72	194.75	185.03
MW-04	03/02/95	5.27	194.46	189.19
	03/22/95	7.22	194.46	187.24
	03/28/95	7.61	194.46	186.85

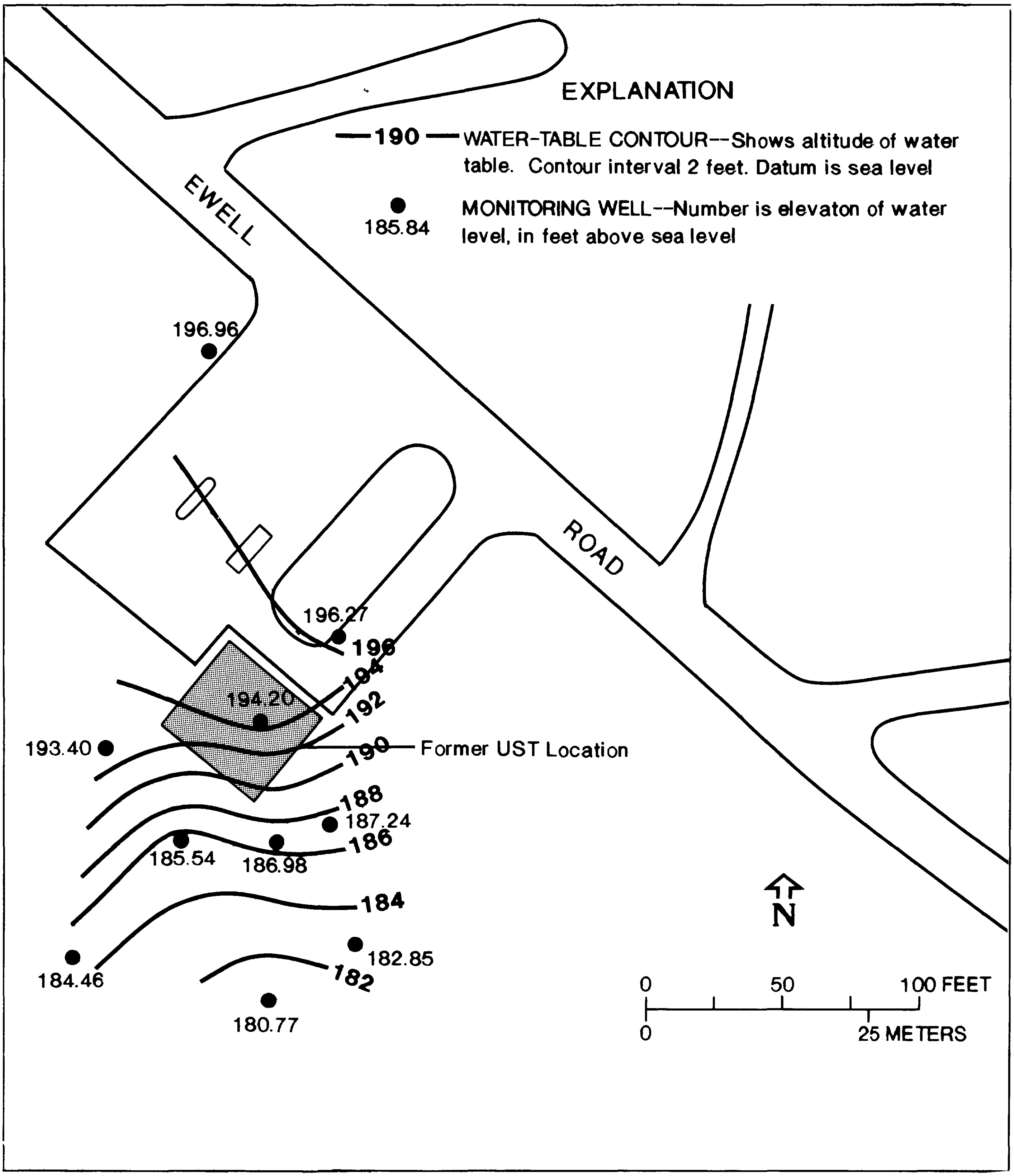

Figure 5. Water-table elevations and contours, Site 1062, Ft. Jackson, S.C., March 22, 1995.

Table 7. Water-level elevations, Site 2438, Fort Jackson, S.C., January and February 1995

Well number	Date	Depth to water (feet below measuring point)	Measuring point elevation (feet above sea level)	Water-level elevation (feet above sea level)
MW-2-1	01/19/95	1.29	226.42	225.13
	01/20/95	1.47	226.42	224.95
	02/01/95	1.67	226.42	224.75
	02/09/95	2.28	226.42	224.14
MW-2-2	01/19/95	4.57	226.10	221.53
	01/20/95	6.17	226.10	219.93
	02/01/95	3.81	226.10	222.29
	02/09/95	4.16	226.10	221.94
MW-2-3	01/19/95	1.46	225.15	223.69
	01/20/95	1.40	225.15	223.75
	02/01/95	1.47	225.15	223.68
	02/09/95	1.77	225.15	223.38
MW-2-4	01/19/95	4.83	225.04	220.21
	01/20/95	5.68	225.04	219.36
	02/01/95	2.74	225.04	222.30
	02/09/95	3.10	225.04	221.94
MW-2-5	01/19/95	2.58	225.35	222.77
	01/20/95	2.60	225.35	222.75
	02/01/95	2.64	225.35	222.71
	02/09/95	2.96	225.35	222.39

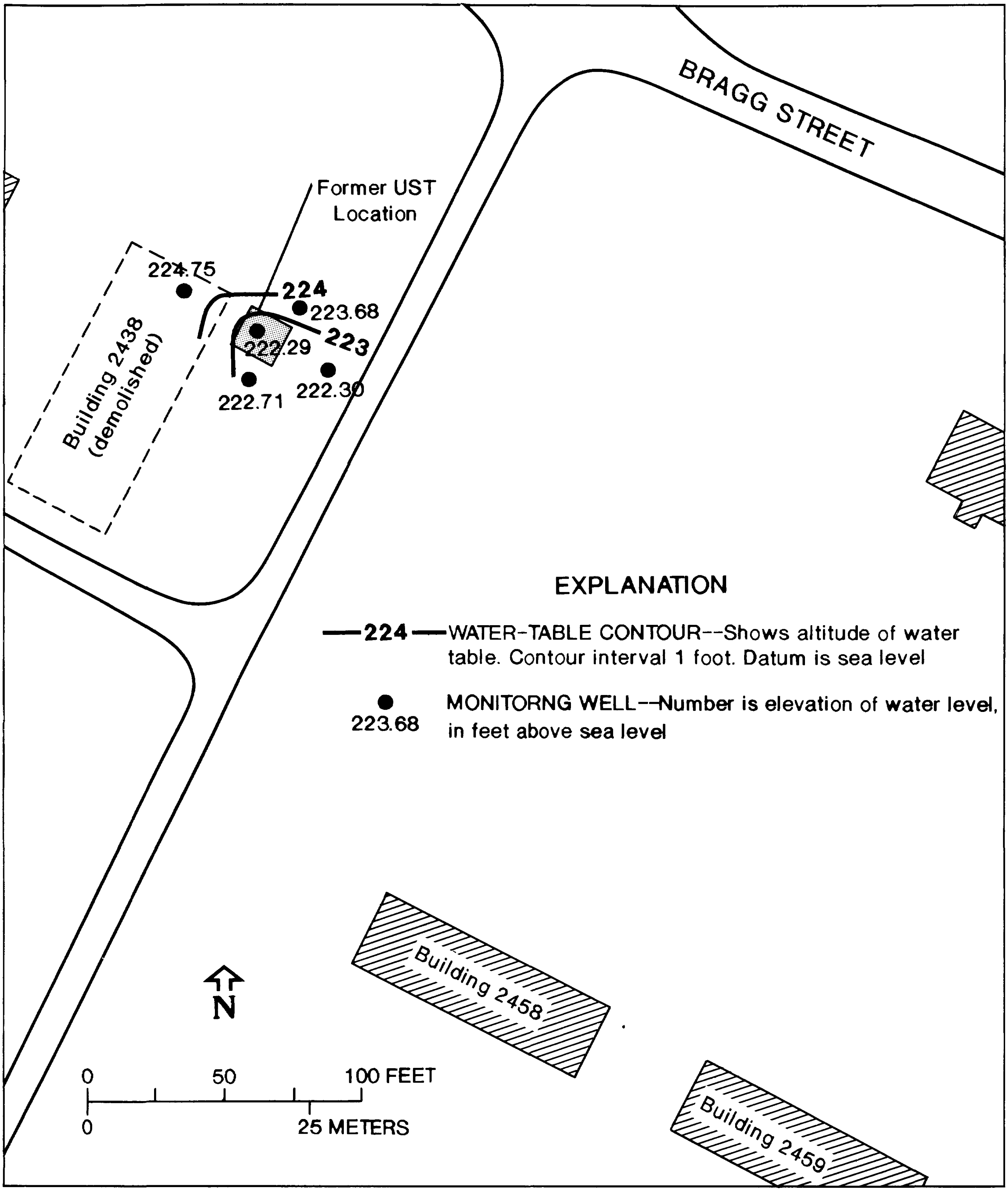

Figure 6. Water-table elevations and contours, Site 2438, Ft. Jackson, S.C., February 1, 1995.

Table 8. Water-level elevations, Site 2444, Fort Jackson, S.C., February and March 1995

Well number	Date	Depth to water (feet below measuring point)	Measuring point elevation (feet above sea level)	Water-level elevation (feet above sea level)
MW-3-1	02/24/95	9.95	220.32	210.37
	03/20/95	10.09	220.32	210.23
	03/28/95	10.27	220.32	210.05
MW-3-2	02/24/95	10.70	220.28	209.58
	03/20/95	10.83	220.28	209.45
	03/28/95	11.00	220.28	209.28
MW-3-3	02/24/95	10.61	220.34	209.73
	03/20/95	10.78	220.34	209.56
	03/28/95	10.96	220.34	209.38
MW-3-4	02/24/95	10.43	219.71	209.28
	03/20/95	10.55	219.71	209.16
	03/28/95	10.73	219.71	208.98
MW-3-5	02/24/95	10.49	220.43	209.94
	03/20/95	10.64	220.43	209.79
	03/28/95	10.81	220.43	209.62

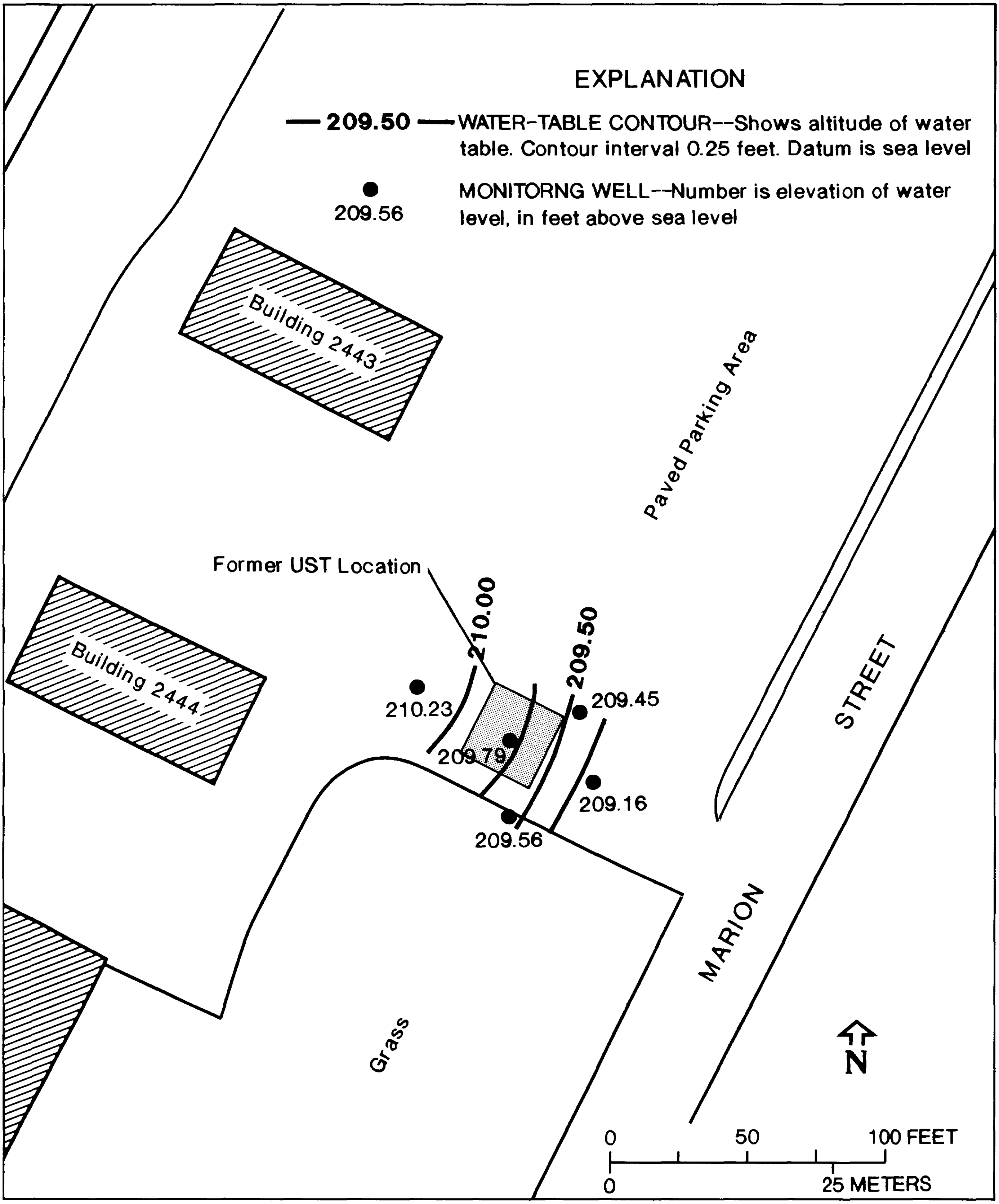

Figure 7. Water-table elevations and contours, Site 2444, Ft. Jackson, S.C., March 20, 1995.

During the slug tests, head changes were monitored using a Hermit 2000 data logger with a 10 lb/in^2 pressure transducer. Water-level measurements were also obtained at various times throughout each test with a steel tape to insure correct readings from the pressure transducer. The data were analyzed using the Hvorslev method (1951) for partially penetrating wells in an unconfined aquifer. The values used for screen length and diameter (L and R, respectively, in Hvorslev's equation) were those of the gravel-pack length and diameter, as suggested by Fetter (1988) for piezometers installed in low-permeability units. The values obtained for hydraulic conductivity were 0.02 ft/d at well MW-1-7; 0.11 ft/d at MW-02; and 0.26 ft/d at MW-04.

ASSESSMENT OF PETROLEUM-HYDROCARBON CONTAMINATION

Petroleum hydrocarbons and lead were detected at concentrations exceeding drinking water standards for ground water at Site 1062 only. Based on the findings of this investigation, the distribution of petroleum-hydrocarbon contamination at Site 1062 appeared to be disperse, with the majority of contaminants detected in the general area of the former UST location, or source area. At Site 2438, petroleum hydrocarbons were detected at trace levels in sediment from one borehole only, and were not detected in any of the ground-water samples collected from this site. With the exception of a low concentration of naphthalene detected in ground water from one well only at Site 2444, petroleum hydrocarbons were not detected in sediments or ground water collected from this site. For these reasons, the distribution of contaminants is not graphically illustrated. Information obtained during these investigations regarding the vertical distribution of contaminants is limited.

Site 1062

A TPH-DRO concentration of 388,000 μg/kg was detected in a sediment sample from MW-1-3 (table 9). Total BTEX concentrations exceeding 100,000 μg/kg were detected in sediment samples from MW-1-6. Total lead was detected at concentrations ranging from 2,900 to 5,900 μg/kg. Petroleum-hydrocarbon concentrations in sediment samples collected from MW-1-1, MW-1-2, MW-1-4, and MW-1-5 were less than the detection limits. The detection limits were 25 or 100 μg/kg for benzene and para- and meta-xylenes; 100 μg/kg for toluene, ethylbenzene, ortho-xylene; and 10,000 μg/kg for TPH-DRO.

Sediment samples for laboratory analysis were collected from 7 of the 11 hand-augered holes. Unless field screening with the PID indicated that there were no concentrations of VOC's above background levels, at least one sample from the interval exhibiting the highest relative concentration of VOC's was collected for BTEX analysis. If PID responses indicated no VOC concentrations above background levels, then the borehole was considered uncontaminated, and samples were not collected for laboratory analysis. Generally, the highest PID responses were for samples just above the water table. Because the sediments at Site 1062 typically have a high clay content, the depth to the water table was determined after sample collection by leaving the holes open overnight. Though sediments from AS-1-8 showed PID responses exceeding background levels, the occurrence of quartz cobbles made representative sediment samples unattainable.

Table 9. Petroleum-hydrocarbon and lead concentrations detected in sediment samples from Site 1062, Fort Jackson, S.C., January 12, 1995

[Depths relative to land surface; All concentrations reported in micrograms per kilogram; TPH-DRO, Total Petroleum Hydrocarbons - Diesel Range Organics; <, less than; --, not analyzed; D, duplicate sample]

Borehole number	Sample depth (feet)	Benzene	Toluene	Ethyl-benzene	Ortho-xylene	Para- and meta-xylenes	TPH-DRO	Lead
MW-1-1	10	<100	<100	<100	<100	<100	<10,000	--
MW-1-1	14	<100	<100	<100	<100	<100	<10,000	--
MW-1-2	8	<100	<100	<100	<100	<100	<10,000	--
MW-1-2	11	<100	<100	<100	<100	<100	<10,000	--
MW-1-3	9	<100	<100	<100	<100	<100	388,000	--
MW-1-3	11	<100	<100	<100	<100	<100	<10,000	--
MW-1-4	6	<100	<100	<100	<100	<100	<10,000	--
MW-1-4	7	--	--	--	--	--	--	4,400
MW-1-4	8	<100	<100	<100	<100	<100	<10,000	--
MW-1-5	2	<100	<100	<100	<100	<100	<10,000	--
MW-1-5	2D	<25	<100	<100	<100	<25	<10,000	--
MW-1-5	7	<25	<100	<100	<100	<25	<10,000	2,900
MW-1-6	6	<25	273	495	344	736	<10,000	--
MW-1-6	8	363	22,800	20,000	27,500	31,500	<10,000	--
MW-1-6	8D	264	19,900	17,800	26,900	30,000	<10,000	--
MW-1-6	10	--	--	--	--	--	--	5,900
MW-1-6	10D	--	--	--	--	--	--	5,400

Concentrations of BTEX compounds were detected in sediment samples from auger hole AS-1-11 only (table 10). Benzene was detected at a concentration of 115 μg/kg, toluene as much as 6,890 μg/kg, ethylbenzene as much as 3,880 μg/kg, ortho-xylene as much as 5,140 μg/kg, and para- and meta-xylenes as much as 8,900 μg/kg. A duplicate sample was collected from AS-1-11 and was analyzed for BTEX. Though samples collected for BTEX analysis from other boreholes exhibited PID responses ranging from 1.1 to 30.3 μL/L, BTEX compounds were not detected at concentrations exceeding the detection limit of 100 μg/kg. A trip blank (TB-1-AS) accompanied the sample bottles during transport to the field and the return to the laboratory. Analysis of the trip blank using EPA method 624 (U.S. Environmental Protection Agency, 1983) indicated no concentrations of BTEX compounds above the detection limit of 5 μg/L for each compound. Because TPH-DRO was detected at a concentration of 388,000 μg/kg in sediment from MW-1-3, three hand-augered boreholes were made downgradient of this monitoring well to aid in determining the lateral extent of petroleum-hydrocarbon contamination in this area. Sediments from these boreholes did not exhibit significant PID responses. A sediment sample from AS-1-13 was collected for TPH-DRO analysis from the same depth that TPH-DRO was detected at MW-1-3. However, TPH-DRO was not detected at concentrations exceeding the detection limit of 10,000 μg/kg.

The results of laboratory analyses and field-property determinations of ground water collected during March 1995 from monitoring wells at Site 1062 (fig. 2) showed that only benzene was detected in ground water from MW-1-3 at concentrations (10 and 11 μg/L) exceeding the detection limit (table 11). In ground water from MW-1-6, benzene was detected at a concentration of 28 μg/L; toluene at 558 μg/L; para- and meta-xylenes at 993 μg/L; and naphthalene at 236 μg/L. Naphthalene was also detected in ground water from MW-02 at a concentration of 160 μg/L. Lead was detected in ground water from MW-1-3 and MW-04 at a concentration of 6 μg/L. The Maximum Contaminant Levels (MCL) established by the U.S. Environmental Protection Agency (1995) for primary drinking water for benzene, toluene, and total xylenes are 5, 1,000, and 10,000 μg/L, respectively. A MCL has not been established for naphthalene; however, an Action Level for naphthalene in drinking water of 25 μg/L has been recommended by the South Carolina State Toxicologist and is used as a criterion by some sections of SCDHEC (Timothy A. Mettlen, SCDHEC, oral commun., 1996). An Action Level of 15 μg/L has been established for total lead in drinking water (U.S. Environmental Protection Agency, 1995).

Ethylbenzene, MTBE, and TPH-DRO were not detected at concentrations exceeding the detection limits in ground-water samples collected from monitoring wells at Site 1062. Ortho-xylene was not detected; however, the detection limit for this compound was elevated (<500 μg/L) for the MW-1-6 sample analysis only. The detection limits for benzene, toluene, ethylbenzene, ortho-xylene, para- and meta-xylenes, MTBE, naphthalene, and lead were 5 μg/L; the detection limit for TPH-DRO was 1,000 μg/L. Values determined for pH ranged from acidic at 3.99 to slightly acidic at 6.09 standard units.

Ground-water temperatures ranged from 15.1 to 19.5 °C. Dissolved-oxygen concentrations ranged from 0.49 to 7.52 mg/L, and dissolved-ferrous-iron concentrations ranged from 0.00 to 3.21 mg/L.

Table 10. Petroleum-hydrocarbon concentrations detected in sediment samples collected with hand augers from Site 1062, Fort Jackson, S.C., March 14-16, 1995

[Depths relative to land surface; All concentrations reported in micrograms per kilogram; TPH-DRO, Total Petroleum Hydrocarbons - Diesel Range Organics; <, less than; --, not analyzed; D, duplicate sample; TB, trip blank; NA, not applicable]

Borehole number	Sample depth (feet)	Benzene	Toluene	Ethyl-benzene	Ortho-xylene	Para- and meta-xylenes	TPH-DRO
AS-1-2	9	<100	<100	<100	<100	<100	--
AS-1-4	7.5	<100	<100	<100	<100	<100	--
AS-1-5	9	<100	<100	<100	<100	<100	--
AS-1-9	4.5	<100	<100	<100	<100	<100	--
AS-1-10	6.5	<100	<100	<100	<100	<100	--
AS-1-11	7.5	<200	6,890	3,880	4,720	8,900	--
AS-1-11	7.5D	115	5,100	2,970	5,140	6,130	--
AS-1-13	9	--	--	--	--	--	<10,000
TB-1-AS	NA	<5	<5	<5	<5	<5	--

Table 11. Field-property determinations, and petroleum-hydrocarbon and dissolved-lead concentrations detected in ground-water samples from Site 1062, Fort Jackson, S.C., March 23 and 24, 1995

[pH reported in standard units; °C, degrees Celsius; DO, dissolved oxygen; mg/L, milligrams per liter; µg/L, micrograms per liter; MTBE, Methyl Tertiary Butyl Ether; TPH-DRO, Total Petroleum Hydrocarbons - Diesel Range Organics; <, less than; --, not analyzed; TB, trip blank]

Well number	pH	Temperature (°C)	DO (mg/L)	Dissolved iron (mg/L)	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	Ortho-xylene (µg/L)	Para- and meta-xylenes (µg/L)	MTBE (µg/L)	Naphthalene (µg/L)	TPH-DRO (µg/L)	Dissolved lead (µg/L)
MW-1-1	5.23	17.6	5.52	.01	<5	<5	<5	<5	<5	<5	<5	<1,000	<5
MW-1-2	5.21	18.5	7.52	.03	<5	<5	<5	<5	<5	<5	<5	<1,000	<5
MW-1-3	4.92	17.8	6.65	.12	10	<5	<5	<5	<5	<5	<5	<1,000	5
MW-1-3R	--	--	--	--	11	<5	<5	<5	<5	<5	<5	<1,000	6
MW-1-4	4.61	19.2	6.85	.03	<5	<5	<5	<5	<5	<5	<5	<1,000	<5
MW-1-5	4.47	15.2	6.37	.00	<5	<5	<5	<5	<5	<5	<5	<1,000	<5
MW-1-6	6.09	15.1	.49	3.21	28	558	<5	<500	993	<5	236	<1,000	<5
MW-01	3.99	19.5	7.00	.00	<5	<5	<5	<5	<5	<5	<5	<1,000	<5
MW-02	5.41	17.5	5.45	.25	<5	<5	<5	<5	<5	<5	160	<1,000	<5
MW-03	5.84	15.9	6.57	.02	<5	<5	<5	<5	<5	<5	<5	<1,000	<5
MW-04	4.83	18.9	4.71	2.08	<5	<5	<5	<5	<5	<5	<5	<1,000	6
TB-1-1	--	--	--	--	<100	<100	<1.25	<1.25	<1.25	<100	<1.25	--	--

The results of laboratory analyses and field-property determinations of ground water collected on November 3, 1995, from monitoring wells MW-1-6 and MW-1-7 at Site 1062 (fig. 2) are presented in table 12. In ground water collected on this date from MW-1-6, benzene was detected at a concentration of 9 μg/L; toluene at 18 μg/L; ethylbenzene at 70 μg/L; ortho-xylene at 6 μg/L; para- and meta-xylenes at 49 μg/L; and naphthalene at 25 μg/L. Detectable concentrations of MTBE and TPH-DRO were not present. Dissolved lead was detected at a concentration of 50 μg/L. Petroleum hydrocarbons were not detected in ground water from MW-1-7; however, dissolved lead was detected in duplicate samples from MW-1-7 at concentrations of 35 and 152 μg/L.

Concentrations of petroleum hydrocarbons detected in well MW-1-6 on November 3, 1995, were generally lower than those detected during the previous sampling event. Dissolved-lead concentrations, however, were higher. Despite the differences in analytical results between the two sampling events, both analytical sets indicate elevated concentrations of petroleum constituents in the area of the former UST's.

Free product was not observed in any of the monitoring wells installed at Site 1062. However, a petroleum sheen was observed during drilling activities on sediments from borehole MW-1-6 and adjacent abandoned boreholes.

Analytical results of sediment and ground-water samples collected during this investigation at Site 1062 suggest that the majority of the petroleum hydrocarbons have not migrated from the source area. The soils used to backfill the excavation are loosely packed and permeable relative to the surrounding natural sediments. The natural sediments comprising the surficial aquifer are generally dense clayey sands and sandy clays with measured hydraulic conductivities ranging from 0.02 to 0.26 ft/d. The dense sediments surrounding the source area may have the effect of impeding the migration of contaminants. Furthermore, if the concrete pad is laterally extensive beneath the former tank location, it would act as an impediment to the vertical migration of contaminants from the source area. Analysis of ground-water samples from well MW-1-7 imply that petroleum hydrocarbons have not affected deeper horizons of the surficial aquifer immediately downgradient from the former UST location; however, dissolved-lead concentrations were as high as 152 μg/L, perhaps the result of leaching from sediments above.

The detection of elevated concentrations of benzene in ground water and TPH-DRO in sediments from well MW-1-3 may be the result of an isolated spill, unrelated to the UST's formerly associated with this site. Considering the past utilization of this site as a gas station, it is not improbable that isolated, unreported releases of petroleum products may have occurred. Evidence that would support this conclusion can be found by examining data collected at locations between well MW-1-3 and the upgradient UST location. Petroleum hydrocarbons were not detected in ground water from wells MW-03, MW-04, MW-1-4, or MW-1-5. Sediment samples from hand-augered boreholes exhibited no BTEX compound concentrations above detection limits except for AS-1-11, which is directly adjacent to the UST area. In an effort to determine the extent of contamination downgradient of MW-1-3, three boreholes (AS-1-6, AS-1-7, and AS-1-13) were hand-augered. Evaluation of these sediments with the PID indicated no concentrations above background levels. Although no BTEX samples were collected from these holes, the sample collected from AS-1-13 exhibited no detectable TPH-DRO concentration.

Table 12. Field-property determinations, and petroleum-hydrocarbon and dissolved-lead concentrations detected in ground-water samples from Site 1062, Fort Jackson, S.C., November 3, 1995

[pH reported in standard units; °C, degrees Celsius; DO, dissolved oxygen; mg/L, milligrams per liter; μg/L, micrograms per liter; MTBE, Methyl Tertiary Butyl Ether; TPH-DRO, Total Petroleum Hydrocarbons - Diesel Range Organics; <, less than; --, not analyzed]

Well number	pH	Temperature (°C)	DO (mg/L)	Dissolved iron (mg/L)	Benzene (μg/L)	Toluene (μg/L)	Ethylbenzene (μg/L)	Ortho-xylene (μg/L)	Para- and meta-xylenes (μg/L)	MTBE (μg/L)	Naphthalene (μg/L)	TPH-DRO (μg/L)	Dissolved lead (μg/L)
MW-1-6	6.18	21.1	0.44	2.08	9	18	70	6	49	<5	25	<1,000	50
MW-1-7	7.55	22.2	3.73	0.01	<5	<5	<5	<5	<5	<5	<5	<1,000	35
MW-1-7R	--	--	--	--	<5	<5	<5	<5	<5	<5	<5	<1,000	152

Site 2438

The results of laboratory analyses of sediment samples collected from boreholes at Site 2438 (fig. 3) are listed in table 13. A para- and meta-xylene concentration of 112 μg/kg was detected in a sample from MW-2-3. Petroleum-hydrocarbon concentrations in all other sediment samples collected from Site 2438, including sample from MW-2-2, taken from the interval exhibiting a 2.5 μL/L PID response, were reported to be less than the detection limits. The detection limits were 25 or 100 μg/kg for benzene; 100 μg/kg for toluene, ethylbenzene, ortho-xylene, and para- and meta-xylenes; and 10,000 μg/kg for TPH-DRO.

The results of laboratory analyses and field-property determinations of ground water collected from monitoring wells installed at Site 2438 (fig. 3) are presented in table 14. Benzene, toluene, ethylbenzene, total xylene, naphthalene, and TPH-DRO concentrations from all ground-water samples collected at Site 2438 were reported to be less than the detection limits. The detection limits were 1.25 μg/L for benzene and para- and meta-xylene; 5 μg/L for toluene, ethylbenzene, ortho-xylene and naphthalene; and 1,000 μg/L for TPH-DRO. Values determined for pH were somewhat acidic, ranging from 5.22 to 5.95 standard units. Ground-water temperatures ranged from 12.5 to 14.0 °C. Dissolved-oxygen concentrations ranged from 5.16 to 9.15 mg/L, and dissolved-ferrous-iron concentrations ranged from 0.02 to 8.28 mg/L.

Based on the results of this investigation, it appears that the sediments of the unconfined, surficial aquifer (above the kaolin layer) have been only minimally affected by petroleum-hydrocarbon contamination (112 μg/kg para- and meta-xylenes at one location only). Furthermore, analytical results obtained during this investigation provide no evidence suggesting any effect on surficial ground-water quality.

Site 2444

The results of laboratory analyses of sediment samples collected from boreholes at Site 2444 (fig. 4) are listed in table 15. No concentrations exceeding the detection limits were reported for BTEX compounds or TPH-DRO in sediment samples collected from Site 2444. The detection limits were 25 or 100 μg/kg for benzene and para- and meta-xylenes; 100 μg/kg for toluene, ethylbenzene, and ortho-xylene; and 10,000 μg/kg for TPH-DRO. Lead (total) was detected in sediment samples from MW-3-3 and MW-3-4 (both from a depth of about 14 ft bls) at concentrations of 600 μg/kg. The detection limit for total lead analysis was 500 μg/kg.

The results of laboratory analyses and field-property determinations of ground water collected from monitoring wells installed at Site 2444 (fig. 4) are presented in table 16. Lead, BTEX compounds, MTBE, and TPH-DRO concentrations from all ground-water samples collected at Site 2444 were reported to be less than the detection limits. Naphthalene was detected in ground water from MW-3-4 at a concentration of 11 μg/L. The detection limits for benzene, toluene, ethylbenzene, ortho-xylene, para- and meta-xylenes, MTBE, naphthalene, and lead were 5 μg/L; the detection limit for TPH-DRO was 1,000 μg/L. Values determined for pH were acidic, ranging from 4.62 to 5.39 standard units. Ground-water temperatures ranged from 19.5 to 21.3 °C. Dissolved-oxygen concentrations ranged from 1.54 to 4.99 mg/L, and dissolved-ferrous-iron concentrations ranged from 0.00 to 0.19 mg/L.

Table 13. Petroleum-hydrocarbon concentrations detected in sediment samples from Site 2438, Fort Jackson, S.C., January 6 and 10, 1995

[Depths relative to land surface; All concentrations reported in micrograms per kilogram; TPH-DRO, Total Petroleum Hydrocarbons - Diesel Range Organics; --, not analyzed; <, less than; D, duplicate sample]

Borehole number	Sample depth (feet)	Benzene	Toluene	Ethyl-benzene	Ortho-xylene	Para- and meta-xylenes	TPH-DRO
MW-2-1A	5	--	--	--	--	--	<10,000
MW-2-1	9	--	--	--	--	--	<10,000
MW-2-2	6	<25	<100	<100	<100	<100	<10,000
MW-2-2	7	<25	<100	<100	<100	<100	<10,000
MW-2-2	8	<25	<100	<100	<100	<100	<10,000
MW-2-2	8D	<25	<100	<100	<100	<100	<10,000
MW-2-3	5	--	--	--	--	--	<10,000
MW-2-3	6	<100	<100	<100	<100	112	<10,000
MW-2-3	8	<100	<100	<100	<100	<100	--
MW-2-4	5	<100	<100	<100	<100	<100	<10,000
MW-2-4	7	<100	<100	<100	<100	<100	<10,000
MW-2-5	6	<100	<100	<100	<100	<100	<10,000
MW-2-5	7	<100	<100	<100	<100	<100	<10,000

Table 14. Field-property determinations and petroleum-hydrocarbon concentrations detected in ground-water samples from Site 2438, Fort Jackson, S.C., January 20, 1995

[pH reported in standard units; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; TPH-DRO, Total Petroleum Hydrocarbons - Diesel Range Organics; <, less than; --, not analyzed]

Well number	pH	Temperature (°C)	Dissolved oxygen (mg/L)	Dissolved iron (mg/L)	Benzene (µg/L)	Toluene (µg/L)	Ethyl-benzene (µg/L)	Ortho-xylene (µg/L)	Para- and meta-xylenes (µg/L)	Naphthalene (µg/L)	TPH-DRO (µg/L)
MW-2-1	5.95	13.6	5.16	8.28	<1.25	<5.00	<5.00	<5.00	<1.25	<5.00	<1,000
MW-2-2	5.48	13.9	--	.43	<1.25	<5.00	<5.00	<5.00	<1.25	<5.00	<1,000
MW-2-3	5.71	12.5	9.15	.02	<1.25	<5.00	<5.00	<5.00	<1.25	<5.00	<1,000
MW-2-3R	--	--	--	--	<1.25	<5.00	<5.00	<5.00	<1.25	<5.00	<1,000
MW-2-4	5.30	13.9	--	.10	<1.25	<5.00	<5.00	<5.00	<1.25	<5.00	<1,000
MW-2-5	5.22	14.0	6.42	.06	<1.25	<5.00	<5.00	<5.00	<1.25	<5.00	<1,000

Note: Ground-water samples for the determination of pH and temperature (all wells) and dissolved iron (MW-2-2 only) collected on February 1, 1995.

Table 15. Petroleum-hydrocarbon and lead concentrations detected in sediment samples from Site 2444, Fort Jackson, S.C., January 10 and 11, 1995

[Depths relative to land surface; All concentrations reported in micrograms per kilogram; TPH-DRO, Total Petroleum Hydrocarbons - Diesel Range Organics; <, less than; --, not analyzed; D, duplicate sample]

Borehole number	Sample depth (feet)	Benzene	Toluene	Ethyl-benzene	Ortho-xylene	Para- and meta-xylenes	TPH-DRO	Lead
MW-3-1	12	<100	<100	<100	<100	<100	<10,000	--
MW-3-1	13	<100	<100	<100	<100	<100	<10,000	--
MW-3-2	12	<25	<100	<100	<100	<25	<10,000	--
MW-3-2	13	<25	<100	<100	<100	<25	<10,000	--
MW-3-3	12	<25	<100	<100	<100	<25	<10,000	--
MW-3-3	13	<25	<100	<100	<100	<25	<10,000	--
MW-3-3	14	--	--	--	--	--	--	600
MW-3-4	12	<25	<100	<100	<100	<25	<10,000	--
MW-3-4	13	<25	<100	<100	<100	<25	<10,000	--
MW-3-4	14	--	--	--	--	--	--	600
MW-3-5	14	<25	<100	<100	<100	<25	<10,000	--
MW-3-5	14D	<25	<100	<100	<100	<25	<10,000	--
MW-3-5	16	<25	<100	<100	<100	<25	<10,000	--
MW-3-5	17	--	--	--	--	--	--	<500
MW-3-5	17D	--	--	--	--	--	--	<500

Based on the analytical results of sediment and ground-water samples collected from Site 2444, it appears that the effect of petroleum-hydrocarbon contamination on sediments and surficial ground water at this site is minimal. Although naphthalene was detected in a ground-water sample from a well (MW-3-4) downgradient of the former UST location, the detected concentration of 11 μg/L is below the recommended Action Level for naphthalene in drinking water of 25 μg/L. Additionally, laboratory analysis of a ground-water sample collected during reconnaissance investigations (Robertson and others, 1994) from a location approximately 45 ft downgradient from well MW-3-4 indicated no detectable concentrations of BTEX compounds. Although this sample was not analyzed for naphthalene, the absence of detectable BTEX compounds may suggest minimal effects from petroleum hydrocarbons on ground water downgradient from the former UST location.

SUMMARY

Ground-water and sediment contamination by petroleum hydrocarbons resulting from leaks and overfills was detected during tank removal activities at three former UST sites at Fort Jackson, near Columbia, S.C. To assess the effect of contamination on the surficial aquifer at Sites 1062, 2438, and 2444, investigations were initiated to provide data on the concentrations of petroleum-related contaminants in the surficial ground water and sediment, and to address the horizontal and, to a lesser degree, vertical extent of contamination. To obtain the necessary information, these investigations involved the installation of permanent monitoring wells and the collection and analysis of sediment and ground-water samples at the three former UST locations. Ground-water and sediment samples were collected for laboratory analysis of various petroleum constituents. Water-level data were collected at all sites to determine the direction of ground-water flow. In addition, aquifer tests were made at Site 1062 to determine the hydraulic conductivity of the surficial aquifer at that site. The values ranged from 0.02 to 0.26 ft/d.

Sediment borings were made at the three sites to collect subsurface-sediment samples for lithologic description and laboratory analyses, and for the installation of monitoring wells. Additional sediment samples were collected at Site 1062 with a hand auger to further address the extent of soil contamination at that site. Laboratory analyses of sediment samples collected from boreholes at Sites 2438 and 2444 did not indicate elevated concentrations of petroleum hydrocarbons; however, elevated concentrations of petroleum hydrocarbons were detected in sediment samples from three boreholes at Site 1062. A TPH-DRO concentration of 388,000 μg/kg was detected in a sediment sample from MW-1-3. Total BTEX concentrations exceeding 100,000 μg/kg were detected in samples from MW-1-6. Total lead was detected at concentrations ranging from 2,900 to 5,900 μg/kg. Concentrations of BTEX compounds were detected in sediment samples from auger hole AS-1-11. Benzene was detected at a concentration of 115 μg/kg; toluene as much as 6,890 μg/kg; ethylbenzene as much as 3,880 μg/kg; ortho-xylene as much as 5,140 μg/kg; and para- and meta-xylenes as much as 8,900 μg/kg. Petroleum hydrocarbons were detected at Site 2438 in one borehole at a trace concentration of 112 micrograms per kilogram of para- and meta-xylenes. No concentrations exceeding the detection limits were reported for BTEX compounds or TPH-DRO in sediment samples collected from Site 2444; however, total lead was detected in sediment samples from two boreholes, each at a concentration of 600 μg/kg.

Table 16. Field-property determinations, and petroleum-hydrocarbon and dissolved-lead concentrations detected in ground-water samples from Site 2444, Fort Jackson, S.C., March 20, 1995

[pH reported in standard units; °C, degrees Celsius; DO, dissolved oxygen; mg/L, milligrams per liter; µg/L, micrograms per liter; MTBE, Methyl Tertiary Butyl Ether; TPH-DRO, Total Petroleum Hydrocarbons - Diesel Range Organics; <, less than; --, not analyzed; TB, trip blank]

Well number	pH	Temperature (°C)	DO (mg/L)	Dissolved iron (mg/L)	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	Ortho-xylene (µg/L)	Para- and meta-xylenes (µg/L)	MTBE (µg/L)	Naphthalene (µg/L)	TPH-DRO (µg/L)	Dissolved lead (µg/L)
MW-3-1	4.63	20.0	4.99	.00	<5	<5	<5	<5	<5	<5	<5	<1,000	<5
MW-3-2	4.62	20.3	4.84	.03	<5	<5	<5	<5	<5	<5	<5	<1,000	<5
MW-3-3	4.93	19.5	1.78	.01	<5	<5	<5	<5	<5	<5	<5	<1,000	<5
MW-3-4	4.87	20.4	1.54	.01	<5	<5	<5	<5	<5	<5	11	<1,000	<5
MW-3-5	5.39	21.3	2.42	.19	<5	<5	<5	<5	<5	<5	<5	<1,000	<5
MW-3-5R	--	--	2.51	--	<5	<5	<5	<5	<5	<5	<5	<1,000	<5
TB-3-1	--	--	--	--	<5	<5	<5	<5	<5	--	--	--	--

Ground-water samples were collected for laboratory analysis and field-property determinations from all monitoring wells installed during these investigations, including four wells at Site 1062 that were installed during a previous investigation. Ground-water samples were collected and analyzed for BTEX, MTBE, naphthalene, TPH-DRO, and dissolved lead. Samples were not collected for MTBE and lead analysis from wells at Site 2438, because historical information did not indicate any previous storage of gasoline at this site.

Petroleum hydrocarbon and lead were detected at concentrations exceeding regulatory limits for drinking water in ground water from Site 1062 only. Benzene only was detected in ground water from MW-1-3 at concentrations (10 and 11 μg/L) exceeding the detection limit. In ground water from MW-1-6, benzene was detected at concentrations as much as 28 μg/L; toluene as much as 558 μg/L; ethylbenzene as much as 70 μg/L; ortho-xylene as much as 6 μg/L; para- and meta-xylenes as much as 993 μg/L; and naphthalene as much as 236 μg/L. Naphthalene also was detected in ground water from MW-02 at a concentration of 160 μg/L. Lead was detected in ground water from MW-1-3, MW-04, and MW-1-6 at concentrations of 6, 6, and 50 μg/L, respectively. Petroleum hydrocarbons were not detected in ground water from MW-1-7, located immediately downgradient from the former UST location and screened at a deeper horizon. However, dissolved lead was detected in duplicate samples from MW-1-7 at concentrations of 35 and 152 μg/L. Methyl tertiary butyl ether and TPH-DRO were not detected at concentrations exceeding the detection limits in ground-water samples collected from monitoring wells at Site 1062. At Site 2438, petroleum hydrocarbons were not detected in any of the ground-water samples collected from this site. With the exception of a low concentration of naphthalene (11 μg/L) detected in ground water from only one well at Site 2444, petroleum hydrocarbons and lead were not detected in ground water collected from this site.

With the exception of one downgradient area of contamination believed to be an isolated incident, analytical results obtained during this investigation at Site 1062 suggest that the majority of the petroleum hydrocarbons have not migrated from the source area. Based on the results of this investigation, it appears that the sediments of the unconfined, surficial aquifer at Site 2438 have been only minimally affected by petroleum-hydrocarbon contamination. Furthermore, analytical results obtained during this investigation provide no evidence suggesting any effect on surficial ground water at Site 2438. Similarly, it appears that the effect of petroleum-hydrocarbon contamination on sediments and surficial ground water at Site 2444 is minimal.

REFERENCES

American Public Health Association and others, 1989, Standard methods for the examination of water and wastewater: Franson, M.A.H. (ed.), American Public Health Association, 1391 p.

American Society for Testing and Materials, 1994, Annual Book of Standards, Section 4, v. 04.08, Philadelphia, Pa.

Ebasco Services Inc., 1992, Final engineering report, Soil and groundwater testing at three underground storage tank locations at Fort Jackson, South Carolina, 33 p.

Fetter, C.W., 1988, Applied hydrogeology (2d ed.): Columbus, Ohio, Merrill Publishing Company, 592 p.

Geological Society of America, 1991, Rock color chart, 7th printing, 6 p.

Hach Company, 1993, DR/700 Colorimeter Procedures Manual, Loveland, Colorado, 600 p.

Hvorslev, M.J., 1951, Time lag and soil permeability in ground-water observations, U.S. Army Corps of Engineers Waterways Experimentation Station, Vicksburg, Mississippi, Bulletin 36, 50 p.

Robertson, J.F., Nagle, D.D., and Rhodes, L.C., 1994, Reconnaissance investigations of potential ground-water and sediment contamination at three former underground storage tank locations, Fort Jackson, South Carolina, 1994: U.S. Geological Survey Open-File Report 94-486, 20 p.

State of California, May 1988, Leaking underground fuel tank field manual, State Water Resources Control Board, Sacramento, California.

U.S. Environmental Protection Agency, Revised March 1983, Methods for chemical analysis of water and waste, EPA-60014-79-020.

----- November 1986, Test methods for evaluating solid waste, SW-846, 3rd Ed.

----- May 1995, Drinking Water Regulations and Health Advisories, Office of Water, Washington, D.C., 14 p.

Wentworth, C.K., 1922, A scale of grade and class terms for clastic sediment: Journal of Geology, v. 30, p. 377-392.

Wood, W.W., 1976, Guidelines for collection and field analysis of ground-water samples for selected unstable constituents: U.S. Geological Survey Techniques of Water-Resources Investigations, book 1, chap. D2, 24 p.

Table 1. Lithologic descriptions, photoionization detector responses, and blow counts from sediment borings made at Site 1062, Fort Jackson, S.C., January 12 and October 13 and 18, 1995

[bls, below land surface; ft, feet; PID, photoionization detector; USCS, Unified Soil Classification System; µL/L, microliters per liter; BG, background; ML, inorganic silt or clayey silt; --, not determined; *, denotes interval of TPH-DRO sample; +, denotes interval of BTEX sample; SM, silty sand; SC, clayey sand; CL, inorganic sandy clay or lean clay; #, denotes interval of lead sample; SW, well-graded sand; <, less than; >, greater than; NR, not recorded; mm, millimeter]

Boring number (fig. 2)	Split-spoon interval (depth bls in ft)	Recovery (ft)	Blow counts (per 0.5 ft)	PID response (µL/L)	USCS group symbol	Lithologic descriptions and other notes
MW-1-1	2 - 4	1.5	4-6-15-24	BG	ML	Very pale orange and pale yellowish-orange clayey silt, some very fine- to fine-grained sand
	4 - 6	0	7-7-5-7	--	--	No recovery
	6 - 8	0.4	4-7-7-7	BG	ML	Very pale orange and pale yellowish-orange clayey silt, some very fine- to coarse-grained sand
	8 - 10^{*+}	1.6	3-3-5-8	BG	ML	Very pale orange and pale yellowish-orange clayey silt, some very fine- to coarse-grained sand
	10 - 12	0	7-5-4-6	--	--	No recovery
	12 - 14^{*+}	1.5	3-5-6-7	BG	SM	Very pale orange and pale yellowish-orange silty sand, very fine- to coarse-grained, trace clay
	14 - 16	2.0	4-5-9-12	BG	ML	Pale yellowish-orange to dark yellowish-orange clayey silt, slight sand content, less clay content in bottom foot of interval
	16 - 18	1.8	3-8-8-11	BG	SM	Dark yellowish-orange silty sand, very fine-grained with some coarse-grained
	18 - 20	1.7	11-12-14-18	BG	SM	Dark yellowish-orange silty sand, very fine-grained with some coarse-grained
MW-1-2	2 - 4	1.7	2-5-8-11	BG	SC	Grayish-orange clayey sand, very fine- to coarse-grained sand, slight silt content
	4 - 6	1.7	6-9-14-20	BG	SC	Dark yellowish-orange clayey sand, very fine- to coarse-grained sand, slight silt content
	6 - 8^{*+}	1.5	3-7-11-11	BG	SC	Dark yellowish-orange clayey sand, very fine- to very coarse-grained sand, coarse pebble gravel at 6.5 ft, slight silt content
	8 - 10	0	7-11-15-25	--	--	No recovery
	10 - 12^{*+}	1.6	4-8-11-11	BG	SC	Very pale orange to grayish-orange clayey sand, very fine- to very coarse-grained sand; bottom foot - weathered saprolite below about 11 ft, moderate reddish-brown and grayish-orange clayey sand, medium- to very coarse-grained sand

Table 1. Lithologic descriptions, photoionization detector responses, and blow counts from sediment borings made at Site 1062, Fort Jackson, S.C., January 12 and October 13 and 18, 1995--Continued

[bls, below land surface; ft, feet; PID, photoionization detector; USCS, Unified Soil Classification System; µL/L, microliters per liter; BG, background; ML, inorganic silt or clayey silt; --, not determined; *, denotes interval of TPH-DRO sample; +, denotes interval of BTEX sample; SM, silty sand; SC, clayey sand; CL, inorganic sandy clay or lean clay; #, denotes interval of lead sample; SW, well-graded sand; <, less than; >, greater than; NR, not recorded; mm, millimeter]

Boring number (fig. 2)	Split-spoon interval (depth bls in ft)	Recovery (ft)	Blow counts (per 0.5 ft)	PID response (µL/L)	USCS group symbol	Lithologic descriptions and other notes
MW-1-2	12 - 14	0	6-9-11-14	--	--	No recovery
	14 - 16	1.5	5-8-15-15	BG	SC	Moderate orange-pink clayey sand, very fine- to very coarse-grained sand
	16 - 18	1.7	10-12-19-20	BG	SC	Moderate orange-pink clayey sand grading to yellowish-gray clayey sand, very fine- to very coarse-grained sand
	18 - 20	1.3	9-14-18-17	BG	SC	Yellowish-gray clayey sand, very fine- to very coarse-grained sand
MW-1-3	2 - 4	1.9	2-2-2-1	BG	SM	Moderate yellowish-brown silty sand, very fine- to coarse-grained sand
	4 - 6	1.9	1-5-6-7	BG	SC/ML	Grayish-orange clayey sand, very fine- to coarse-grained sand, grading to grayish-orange and pinkish-gray clayey silt with slight sand content
	6 - 8	1.6	3-6-11-11	1.9	ML	Grayish-orange and pinkish-gray clayey silt with slight sand content
	8 - 10^{*+}	1.8	4-8-10-16	21.1	ML	Grayish-orange and pinkish-gray to yellowish-gray clayey silt with slight sand content, petroleum odor at about 9 ft
	10 - 12^{*+}	1.5	8-24-24-17	1.1	CL/SM	Very pale orange and yellowish-gray sandy clay grading to pinkish-gray silty sand with slight clay content, very fine- to coarse-grained sand
	12 - 14	1.7	6-8-12-14	0.5	SC/CL	White clayey sand, very fine- to very coarse-grained, grading to white silty clay with a slight sand content
	14 - 16	1.6	8-9-6-7	0.6	SM	White silty sand with coarse pebble gravel to very pale orange and dark yellowish-orange silty sand, very fine- to very coarse-grained sand
	16 - 18	1.7	7-10-14-26	BG	SM	Dark yellowish-orange silty sand, very fine- to very coarse-grained sand; weathered saprolite below about 17 ft
	18 - 20	1.8	5-11-21-28	BG	SM	Dark yellowish-orange silty sand, very fine- to very coarse-grained sand grading to yellowish-gray silty sand with trace clay

Table 1. Lithologic descriptions, photoionization detector responses, and blow counts from sediment borings made at Site 1062, Fort Jackson, S.C., January 12 and October 13 and 18, 1995--Continued

[bls, below land surface; ft, feet; PID, photoionization detector; USCS, Unified Soil Classification System; µL/L, microliters per liter; BG, background; ML, inorganic silt or clayey silt; --, not determined; *, denotes interval of TPH-DRO sample; +, denotes interval of BTEX sample; SM, silty sand; SC, clayey sand; CL, inorganic sandy clay or lean clay; #, denotes interval of lead sample; SW, well-graded sand; <, less than; >, greater than; NR, not recorded; mm, millimeter]

Boring number (fig. 2)	Split-spoon interval (depth bls in ft)	Recovery (ft)	Blow counts (per 0.5 ft)	PID response (µL/L)	USCS group symbol	Lithologic descriptions and other notes
MW-1-4	2 - 4	1.5	11-5-9-5	BG	SM	Yellowish-gray silty sand, very fine- to coarse-grained sand
	4 - 6	0	2-5-7-9	--	--	No recovery
	6 - 8$^{*+\#}$	1.8	4-9-12-30	BG	SM	Pinkish-gray and yellowish-gray silty sand with coarse pebble gravel, very fine- to very coarse-grained sand, trace clay
	8 - 10*	1.2	21-23-26-18	BG	SM	Grayish-orange silty sand with fine pebble gravel, very fine- to very coarse-grained sand
	10 - 12	1.0	6-9-12-11	BG	SM	Very pale orange silty sand with coarse pebble gravel, very fine- to very coarse-grained sand
	12 - 14	1.5	6-6-9-11	BG	SM	White and dark yellowish-orange silty sand, very fine- to coarse-grained sand, slight clay content
MW-1-5	2 - 4^{*+}	1.7	5-6-9-9	19.0	SC	Very pale orange and pale yellowish-orange clayey sand, very fine- to very coarse-grained sand, black stained band (0.1 ft thickness) at top of interval, slight petroleum odor
	4 - 6	1.2	4-7-7-7	BG	SC	Very pale orange and pale yellowish-orange clayey sand, very fine- to very coarse-grained sand
	6 - 8$^{*+\#}$	1.7	3-7-6-7	1.1	SC	Very pale orange and pale yellowish-orange clayey sand, very fine- to very coarse-grained sand
	8 - 10	1.6	4-7-10-10	0.6	SM	Dark yellowish-orange silty sand, very fine- to very coarse-grained sand, slight clay content
	10 - 12	1.6	2-7-10-11	4.1	SM	Dark yellowish-orange silty sand, very fine- to very coarse-grained sand, slight clay content
MW-1-6	2 - 4	1.6	4-4-3-2	BG	SW	Moderate brown sand, very fine- to coarse-grained, saturated at about 3 ft
	4 - 6^{*+}	1.7	3-3-2-3	250	SW	Top of interval like above; plastic sheeting at middle of interval; bottom of interval - moderate yellowish-brown sand, very fine- to coarse-grained, slight clay content, strong petroleum odor, saturated
	6 - 8^{*+}	0.8	1-1-1-1	250	SW	Moderate yellowish-brown sand, very fine- to coarse-grained, slight clay content, strong petroleum odor, slight sheen on sediments, saturated

Table 1. Lithologic descriptions, photoionization detector responses, and blow counts from sediment borings made at Site 1062, Fort Jackson, S.C., January 12 and October 13 and 18, 1995--Continued

[bls, below land surface; ft, feet; PID, photoionization detector; USCS, Unified Soil Classification System; μL/L, microliters per liter; BG, background; ML, inorganic silt or clayey silt; --, not determined; *, denotes interval of TPH-DRO sample; +, denotes interval of BTEX sample; SM, silty sand; SC, clayey sand; CL, inorganic sandy clay or lean clay; #, denotes interval of lead sample; SW, well-graded sand; <, less than; >, greater than; NR, not recorded; mm, millimeter]

Boring number (fig. 2)	Split-spoon interval (depth bls in ft)	Recovery (ft)	Blow counts (per 0.5 ft)	PID response (μL/L)	USCS group symbol	Lithologic descriptions and other notes
MW-1-6	8 - 10$^{\#}$	0.4	1-<1-1-1	202	SW	Moderate yellowish-brown sand, very fine- to coarse-grained, slight clay content, strong petroleum odor, slight sheen on sediments, saturated
	10 - 12	0.5	1->100	91.0	SW	Moderate yellowish-brown sand, very fine- to coarse-grained, slight clay content, strong petroleum odor, slight sheen on sediments, saturated, split-spoon refusal (>100) apparently caused by contact with wood
	12 - 14	0	>100	--	--	No recovery, split-spoon refusal (>100) apparently caused by contact with wood
[1]MW-1-7	0 - 3	--	--	--	SW	Moderate yellowish-brown to light brown sand, very fine- to coarse-grained, slight clay content
	3 - 13	--	--	--	SW	Pale yellowish-brown sand, very fine- to coarse-grained, slight clay content, saturated at about 3.5 ft, heavy petroleum odor
	13 - 16	--	--	--	SC	Pale yellowish-orange clayey sand, very fine- to coarse-grained, moist but not saturated as 10 ft interval above
	16 - 18	1.6	NR	--	SC	Dark yellowish-orange and pale yellowish-orange clayey sand, very fine- to very coarse-grained with some 3 - 6 mm quartz grains; to white and very pale orange clayey sand
	18 - 20	--	--	--	--	Interval not sampled
	20 - 22	1.4	NR	--	SC	Very pale orange and pale yellowish-orange clayey sand, very fine- to very coarse-grained
	22 - 24	0.6	NR	--	SC	Pale yellowish-orange, dark yellowish-orange, and very pale orange clayey sand, very fine- to very coarse-grained with some 3 mm quartz grains
	24 - 26	0.9	NR	--	SC	Same as interval above (22 - 24)

[1] NOTE: Lithologic descriptions of the intervals including 0 to 16 ft depths at borehole MW-1-7 are based on auger cuttings. The blow counts for split-spoon samples at this borehole were not recorded. Sediments from MW-1-7 were not screened with a photoionization detector (PID), and no sediment samples were collected from borehole MW-1-7 for laboratory analyses.

Table 2. Lithologic descriptions, photoionization detector responses, and blow counts from sediment borings made at Site 2438, Fort Jackson, S.C., January 6 and 10, 1995

[bls, below land surface; ft, feet; PID, photoionization detector; USCS, Unified Soil Classification System; NR, not recorded; --, not determined; µL/L, microliters per liter; BG, background; CL, inorganic sandy clay or lean clay; *, denotes interval of TPH-DRO sample; +, denotes interval of BTEX sample; SC, clayey sand]

Boring number (fig. 3)	Split-spoon interval (depth bls in ft)	Recovery (ft)	Blow counts (per 0.5 ft)	PID response (µL/L)	USCS group symbol	Lithologic descriptions
MW-2-1	2 - 4	0	NR-2-2-4	--	--	
	4 - 6	0	NR-3-5-7	--	--	
	6 - 8	1.2	NR-6-7-9	BG	CL	Moist pinkish-gray clay with a little sand content grading to very light gray kaolin at about 6.2 ft, dry, brittle
	8 - 10*	1.5	NR-14-25-26	BG	CL	Grayish-pink kaolin
MW-2-1A	2 - 4	1.3	NR	BG	CL	Light gray, sandy clay
	4 - 6*	1.0	NR	BG	CL	Grayish-orange and very light gray, sandy clay, less sand content than previous interval
MW-2-2	2 - 4	1.3	NR-2-2-2	BG	CL	Grayish-orange sandy clay grading to dark yellowish-orange and light gray mottled sandy clay
	4 - 6*+	1.6	NR-2-3-5	BG	CL	Dark yellowish-orange and light gray mottled sandy clay, greater sand content than previous interval
	6 - 8*+	2.0	NR-8-10-15	BG	CL	Dark yellowish-orange, sandy clay, moderately moist, to sharp contact with kaolin at about 6.8 ft
	8 - 10*+	1.5	NR-10-16-20	2.5	CL	White kaolin
MW-2-3	2 - 4	1.3	8-8-8-8	BG	SC	Dark yellowish-orange and light gray mottled clayey sand, very fine- to coarse-grained, grading to light gray clayey sand, fine- to very coarse-grained, moist
	4 - 6*	1.6	4-14-13-12	BG	SC/CL	Dark yellowish-orange and light gray mottled clayey sand, very fine- to coarse-grained, grading to very light gray sandy clay, moist
	6 - 8*+	1.9	8-17-27-40	BG	CL	Dark yellowish-orange and light gray mottled sandy clay changing to clean, white kaolin at about 6.3 ft
MW-2-4	2 - 4	1.2	2-4-7-10	BG	SC	Dark yellowish-orange and light gray mottled clayey sand, very fine- to coarse-grained, moist
	4 - 6*+	1.4	5-10-15-11	BG	SC	Dark yellowish-orange and very light gray mottled clayey sand, very fine- to coarse-grained, moist
	6 - 8*+	1.6	10-17-22-27	BG	CL	Dark yellowish-orange and light gray mottled sandy clay changing to white kaolin at about 6.3 ft

Table 2. Lithologic descriptions, photoionization detector responses, and blow counts from sediment borings made at Site 2438, Fort Jackson, S.C., January 6 and 10, 1995--Continued

[bls, below land surface; ft, feet; PID, photoionization detector; USCS, Unified Soil Classification System; NR, not recorded; --, not determined; μL/L, microliters per liter; BG, background; CL, inorganic sandy clay or lean clay; *, denotes interval of TPH-DRO sample; +, denotes interval of BTEX sample; SC, clayey sand]

Boring number (fig. 3)	Split-spoon interval (depth bls in ft)	Recovery (ft)	Blow counts (per 0.5 ft)	PID response (μL/L)	USCS group symbol	Lithologic descriptions
MW-2-5	2 - 4	1.8	1-1-1-3	BG	SC	Grayish-brown, very fine- to coarse-grained sand with some clay content, wet, grading to light gray, clayey sand, very fine- to very coarse-grained, moist
	4 - 6*+	1.3	3-4-5-7	BG	SC	Light gray, clayey sand, very fine- to very coarse-grained, moist
	6 - 8*+	1.3	11-17-27-37	BG	CL	Light gray, clayey sand changing to white and pale yellowish-orange kaolin at about 6.2 ft

Table 3. Lithologic descriptions, photoionization detector responses, and blow counts from sediment borings made at Site 2444, Fort Jackson, S.C., January 10 and 11, 1995

[bls, below land surface; ft, feet; PID, photoionization detector; USCS, Unified Soil Classification System; µL/L, microliters per liter; BG, background; SC, clayey sand; --, not determined; CL, inorganic sandy clay or lean clay; ML, inorganic silt or clayey silt; SM, silty sand; *, denotes interval of TPH-DRO sample; +, denotes interval of BTEX sample; SP, poorly graded sand; SW, well-graded sand; #, denotes interval of lead sample; NR, not recorded]

Boring number (fig. 4)	Split-spoon interval (depth bls in ft)	Recovery (ft)	Blow counts (per 0.5 ft)	PID response (µL/L)	USCS group symbol	Lithologic descriptions and other notes
MW-3-1	2 - 4	0.7	6-2-3-4	BG	SC	Dark yellowish-orange clayey sand, very fine- to medium-grained sand
	4 - 6	0	10-4-10-16	--	--	No recovery
	6 - 8	1.9	9-5-20-20	BG	CL/SC/CL	Pale yellowish-orange and very light gray sandy clay to clayey sand, very fine- to coarse-grained sand, grading to medium light gray and pinkish-gray silty clay
	8 - 10	1.6	7-16-32-33	BG	ML/SM/SC/SM	Pale yellowish-orange and very light gray clayey silt with slight very fine-grained sand content grading to dark yellowish-orange, pinkish-gray, and very light gray silty sand and clayey sand, very fine- to very coarse-grained sand
	10 - 12^{*+}	1.3	7-12-12-15	BG	SC/SM	Dark yellowish-orange and very light gray clayey sand to dark yellowish-orange silty sand, very fine- to coarse-grained sand, very moist at about 11 ft
	12 - 14^{*+}	1.1	7-19-21-40	BG	CL/SP/CL	0.1 ft pale red-purple and white sandy clay at top of interval to very pale orange and grayish-orange sand, predominantly coarse-grained with slight clay content to pale red-purple and white sandy clay, saturated at about 13 ft
	14 - 16	1.9	7-10-18-31	BG	CL/SM	Grayish-orange-pink sandy clay to pale red-purple and white clay (no sand) to dark yellowish-orange, pinkish-gray, and moderate orange-pink silty sand, very fine- to medium-grained sand, saturated
	16 - 18	1.7	14-27-23-18	BG	CL/SM	Greyish-orange-pink and white sandy clay to very pale orange and moderate orange-pink silty sand, very fine- to very coarse-grained sand, saturated

Table 3. Lithologic descriptions, photoionization detector responses, and blow counts from sediment borings made at Site 2444, Fort Jackson, S.C., January 10 and 11, 1995--Continued

[bls, below land surface; ft, feet; PID, photoionization detector; USCS, Unified Soil Classification System; µL/L, microliters per liter; BG, background; SC, clayey sand; --, not determined; CL, inorganic sandy clay or lean clay; ML, inorganic silt or clayey silt; SM, silty sand; *, denotes interval of TPH-DRO sample; +, denotes interval of BTEX sample; SP, poorly graded sand; SW, well-graded sand; #, denotes interval of lead sample; NR, not recorded]

Boring number (fig. 4)	Split-spoon interval (depth bls in ft)	Recovery (ft)	Blow counts (per 0.5 ft)	PID response (µL/L)	USCS group symbol	Lithologic descriptions and other notes
MW-3-2	2 - 4	1.3	1-2-4-14	BG	SC	Dark yellowish-orange clayey sand, very fine- to medium-grained sand
	4 - 6	1.6	8-36-50-52	BG	SC/ML	Dark yellowish-orange to moderate reddish-orange clayey sand, very fine- to very coarse-grained sand, grading to pale yellowish-orange and very light gray clayey silt with slight very fine-grained sand content
	6 - 8	1.6	25-39-38-30	BG	ML	Dark yellowish-orange, very pale orange, and white silt grading to moderate orange-pink, pinkish-gray, and grayish-orange silt with very fine-grained sand
	8 - 10	1.7	7-36-36-44	BG	SM	Dark yellowish-orange silty sand, very fine- to very coarse-grained sand
	10 - 12*+	1.6	15-30-17-15	BG	SM	Dark yellowish-orange and grayish-orange silty sand, very fine- to very coarse-grained sand
	12 - 14*+	1.6	3-16-22-21	BG	SC/SW/SC	Dark yellowish-orange and very pale orange clayey sand, very fine- to coarse-grained sand, to pinkish-gray sand, very fine- to coarse-grained sand with slight clay content to very light gray and dark yellowish-orange clayey sand, very fine- to very coarse-grained sand with fine pebble gravel, very moist
	14 - 16	1.8	14-19-27-26	BG	SW/SC	Dark yellowish-orange and white sand, very fine- to very coarse-grained sand with slight clay content grading to moderate orange-pink, grayish-orange, and white layered clayey sand, very fine- to coarse-grained sand, saturated
	16 - 18	1.9	6-16-21-23	BG	SC	Moderate orange-pink and very pale orange clayey sand, very fine- to coarse-grained sand, saturated
MW-3-3	2 - 4	1.5	4-4-4-5	BG	CL	Dark yellowish-orange sandy clay
	4 - 6	1.7	3-7-9-14	BG	CL	Dark yellowish-orange and yellowish-gray sandy clay
	6 - 8	1.3	6-19-33-27	BG	SM/CL/SM	Dark yellowish-orange, very pale orange, and moderate reddish-orange silty sand, very fine- to medium-grained sand, 0.1 ft clay band at middle of interval

Table 3. Lithologic descriptions, photoionization detector responses, and blow counts from sediment borings made at Site 2444, Fort Jackson, S.C., January 10 and 11, 1995--Continued

[bls, below land surface; ft, feet; PID, photoionization detector; USCS, Unified Soil Classification System; µL/L, microliters per liter; BG, background; SC, clayey sand; --, not determined; CL, inorganic sandy clay or lean clay; ML, inorganic silt or clayey silt; SM, silty sand; *, denotes interval of TPH-DRO sample; +, denotes interval of BTEX sample; SP, poorly graded sand; SW, well-graded sand; #, denotes interval of lead sample; NR, not recorded]

Boring number (fig. 4)	Split-spoon interval (depth bls in ft)	Recovery (ft)	Blow counts (per 0.5 ft)	PID response (µL/L)	USCS group symbol	Lithologic descriptions and other notes
MW-3-3	8 - 10	1.8	7-23-34-26	BG	SC/SP/SW	Dark yellowish-orange clayey sand with clay nodules, very fine- to medium-grained sand, grading to dark yellowish-orange sand, fine- to medium-grained, trace clay, grading to dark yellowish-orange sand, very fine- to coarse-grained with trace clay
	10 - 12^{*+}	1.4	7-23-28-27	BG	SC/SW	Dark yellowish-orange, very pale orange, and grayish-orange clayey sand, very fine- to coarse-grained, grading to grayish-orange sand, very fine- to very coarse-grained with trace clay, very moist at about 11 ft
	12 - 14^{*+}	0.9	9-22-23-21	BG	SW/CL	Grayish-orange sand, very fine- to very coarse-grained with trace clay, bottom 0.2 ft pinkish-gray and moderate orange-pink sandy clay, saturated
	14 - 16$^{\#}$	1.6	4-12-22-24	BG	SC/CL/SW/SC	Pinkish-gray and moderate orange-pink clayey sand to sandy clay to dark yellowish-orange sand, very fine- to very coarse-grained with very fine pebble gravel, trace clay, abundant mica, grading to yellowish-gray clayey sand with less mica and gravel than above, saturated
	16 - 18	1.8	21-27-40-57	BG	SC	Very pale orange to pinkish-gray clayey sand, very fine- to very coarse-grained, saturated
MW-3-4	2 - 4	0	4-4-6-7	--	--	No recovery
	4 - 6	1.6	5-10-17-31	BG	SC/CL	Dark yellowish-orange clayey sand, very fine- to coarse-grained sand, grading to dark yellowish-orange, very light gray, and moderate reddish-brown clay with very fine-grained sand
	6 - 8	1.9	19-32-45-60	BG	CL/SC	Dark yellowish-orange, very light gray, and moderate reddish-brown clay with very fine-grained sand, to dark yellowish-orange and moderate reddish-brown clayey sand with very fine pebble gravel, very fine- to very coarse-grained sand

Table 3. Lithologic descriptions, photoionization detector responses, and blow counts from sediment borings made at Site 2444, Fort Jackson, S.C., January 10 and 11, 1995--Continued

[bls, below land surface; ft, feet; PID, photoionization detector; USCS, Unified Soil Classification System; µL/L, microliters per liter; BG, background; SC, clayey sand; --, not determined; CL, inorganic sandy clay or lean clay; ML, inorganic silt or clayey silt; SM, silty sand; *, denotes interval of TPH-DRO sample; +, denotes interval of BTEX sample; SP, poorly graded sand; SW, well-graded sand; #, denotes interval of lead sample; NR, not recorded]

Boring number (fig. 4)	Split-spoon interval (depth bls in ft)	Recovery (ft)	Blow counts (per 0.5 ft)	PID response (µL/L)	USCS group symbol	Lithologic descriptions and other notes
MW-3-4	8 - 10	1.4	17-35-68-NR	BG	SC/CL	Dark yellowish-orange to grayish-orange, very pale orange, and moderate red clayey sand, very fine- to very coarse-grained sand, to pinkish-gray, grayish-orange-pink, and moderate red clay with slight sand content
	10 - 12^{*+}	1.5	9-35-23-18	BG	SC/SW	Dark yellowish-orange clayey sand, very fine- to very coarse-grained sand, grading to dark yellowish-orange, very light gray, grayish-orange, and white layered sand, very fine- to very coarse-grained with trace clay, very moist
	12 - 14$^{*+\#}$	1.7	6-16-23-21	BG	SW	Dark yellowish-orange and grayish-orange sand, very fine- to coarse-grained with trace clay, saturated at about 13 ft
	14 - 16	0	2-7-12-19	--	--	No recovery
	16 - 18	1.9	16-27-52-60	BG	SW	Grayish-orange sand, very fine- to very coarse-grained with trace clay, saturated
MW-3-5	2 - 4	1.2	2-3-5-2	BG	SC	Dark yellowish-orange clayey sand, very fine- to coarse-grained sand
	4 - 6	0.3	2-2-2-2	BG	SC	Dark yellowish-orange clayey sand, very fine- to coarse-grained sand, plastic sheeting at bottom of interval
	6 - 8	0	4-2-2-2	--	--	No recovery
	8 - 10	0.6	4-2-2-2	BG	SC	Dark yellowish-orange clayey sand, very fine- to coarse-grained sand
	10 - 12	0	6-3-1-1	--	--	No recovery
	12 - 14	0.2	3-1-2-3	8.0	--	Very poor recovery, petroleum odor, unable to collect chemical sample
	14 - 16^{*+}	1.4	15-14-22-26	BG	SW/CL	Grayish-orange sand, very fine- to coarse-grained with trace clay, to white and moderate orange-pink clay with slight sand content, saturated, petroleum odor
	16 - 18$^{*+\#}$	1.9	17-20-20-40	2.0	SW/SC	White and very pale orange sand, very fine- to very coarse-grained with trace clay, to dark yellowish-orange to very pale orange clayey sand, very fine- to very coarse-grained sand, saturated, slight petroleum odor

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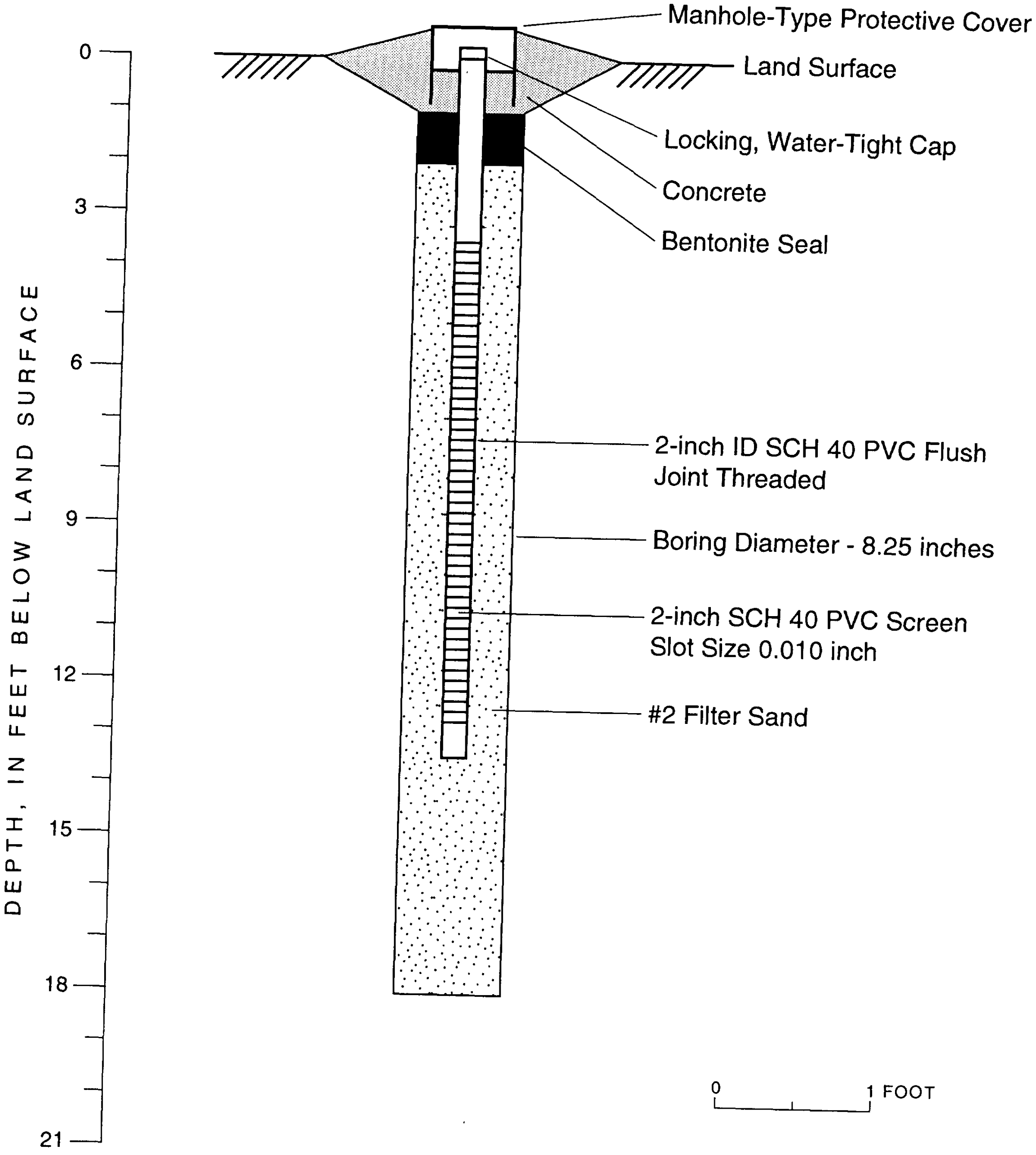
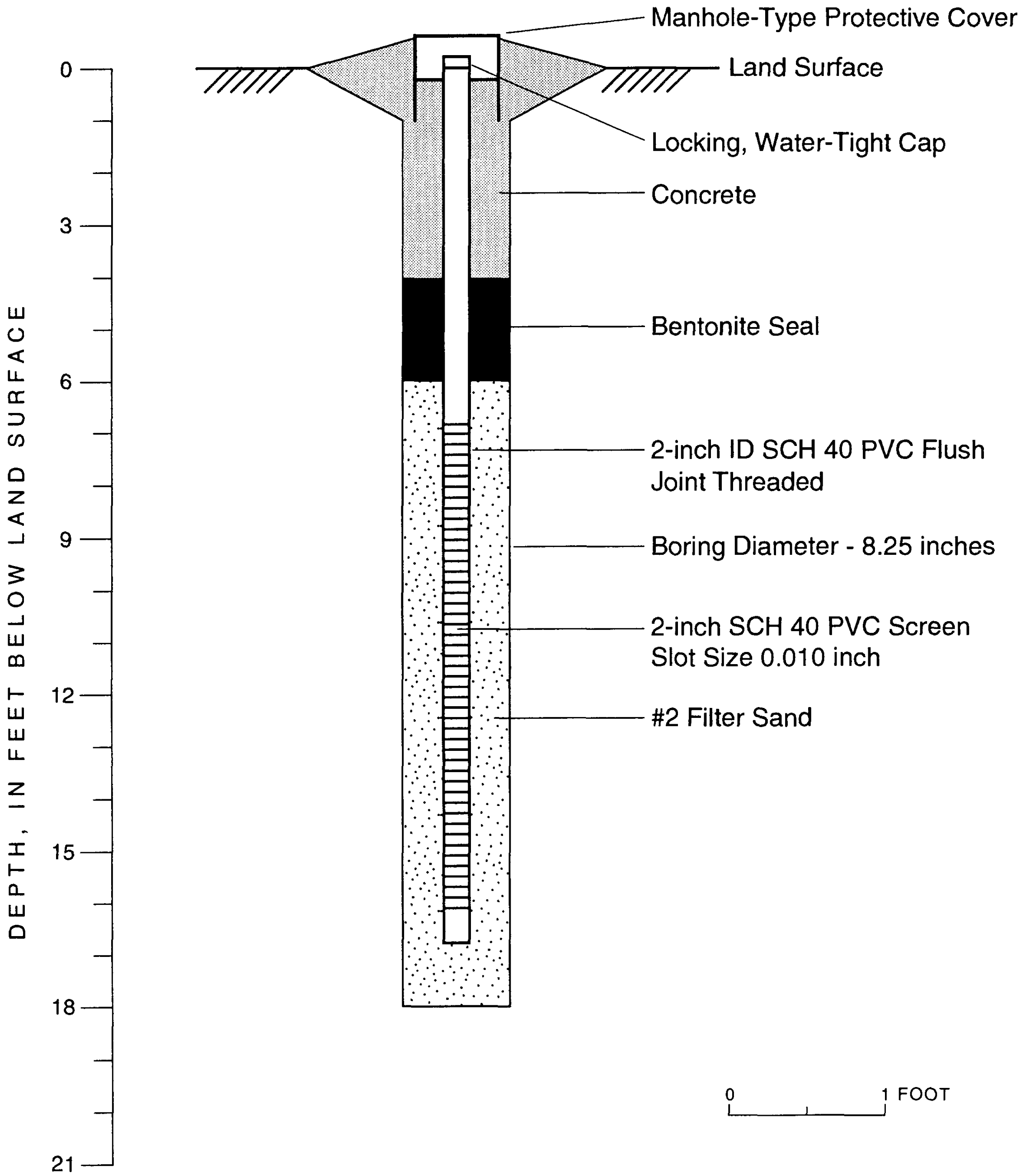
APPENDIX I

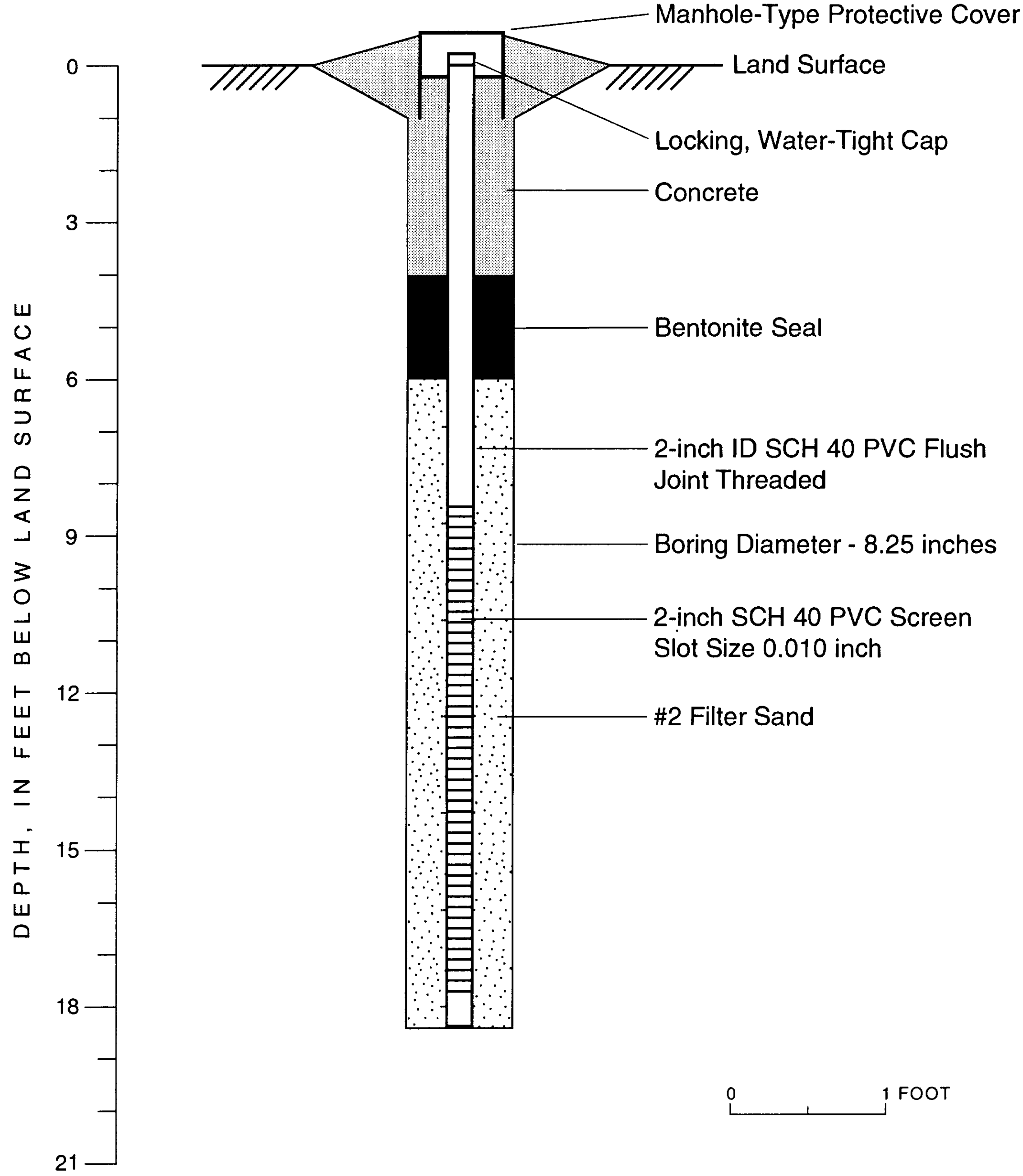
Diagrams showing well construction, Site 1062, Fort Jackson, S.C.



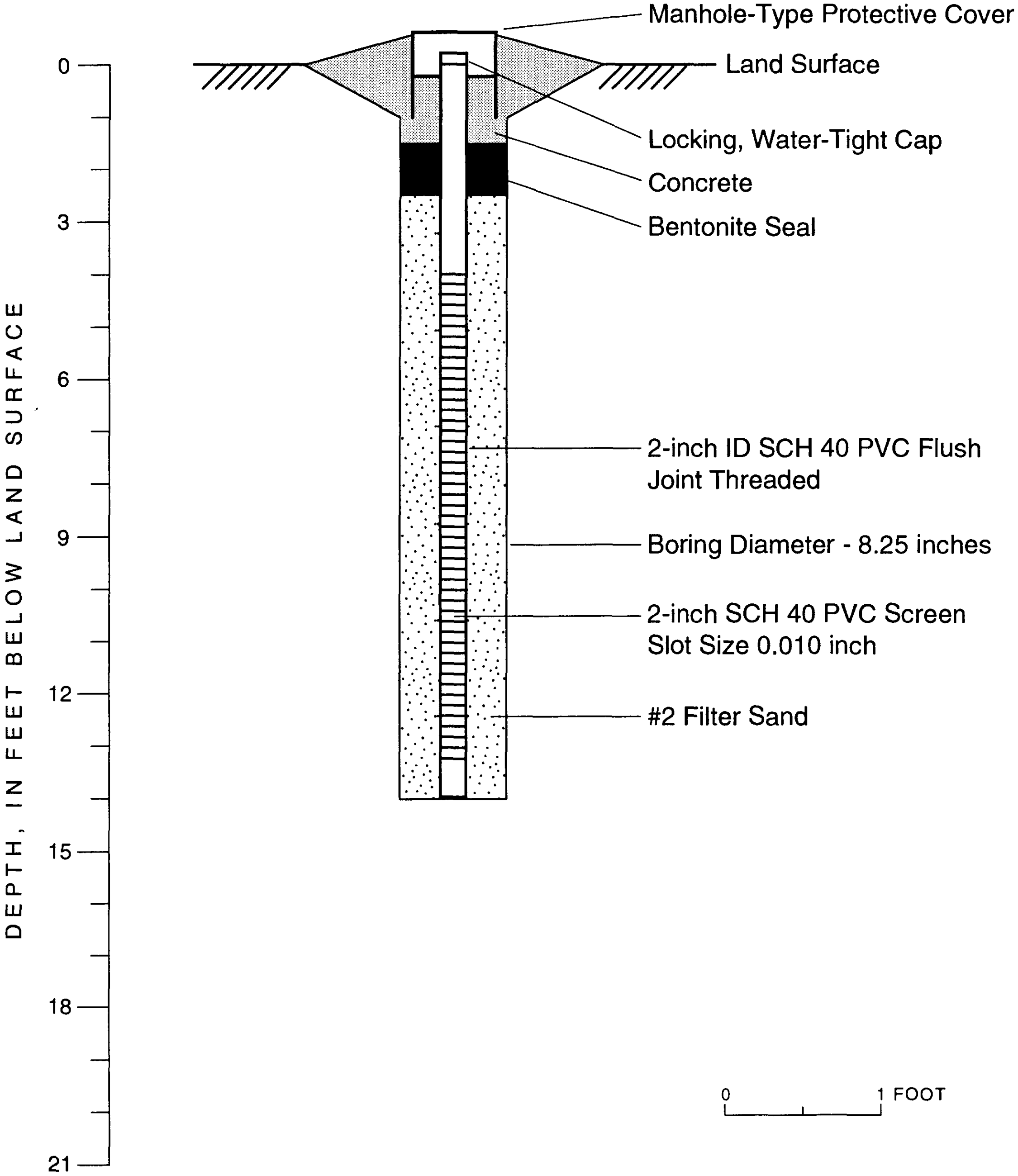
Well construction, MW-1-1, Site 1062, Fort Jackson, S.C.



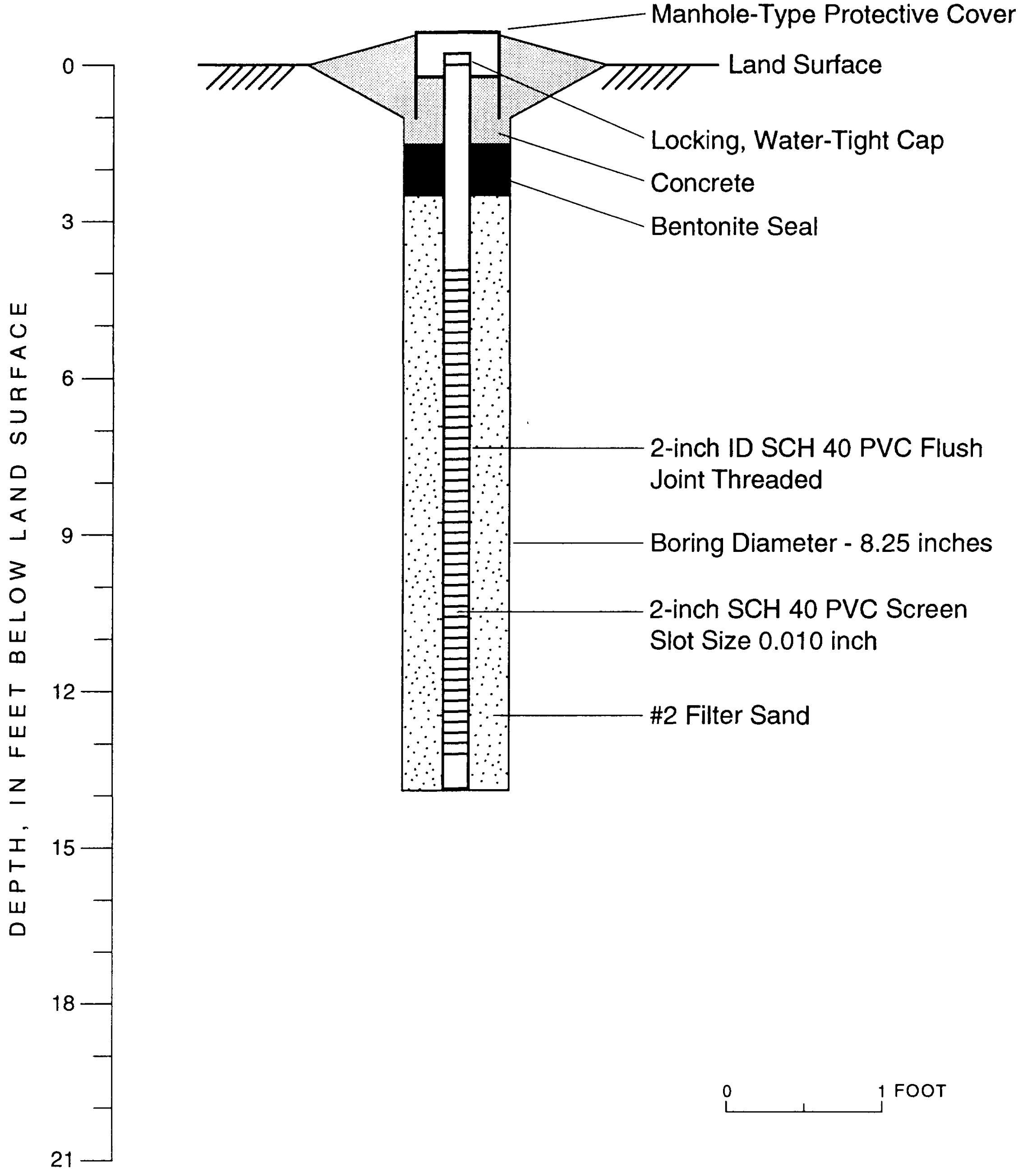
Well construction, MW-1-2, Site 1062, Fort Jackson, S.C.



Well construction, MW-1-3, Site 1062, Fort Jackson, S.C.



Well construction, MW-1-4, Site 1062, Fort Jackson, S.C.



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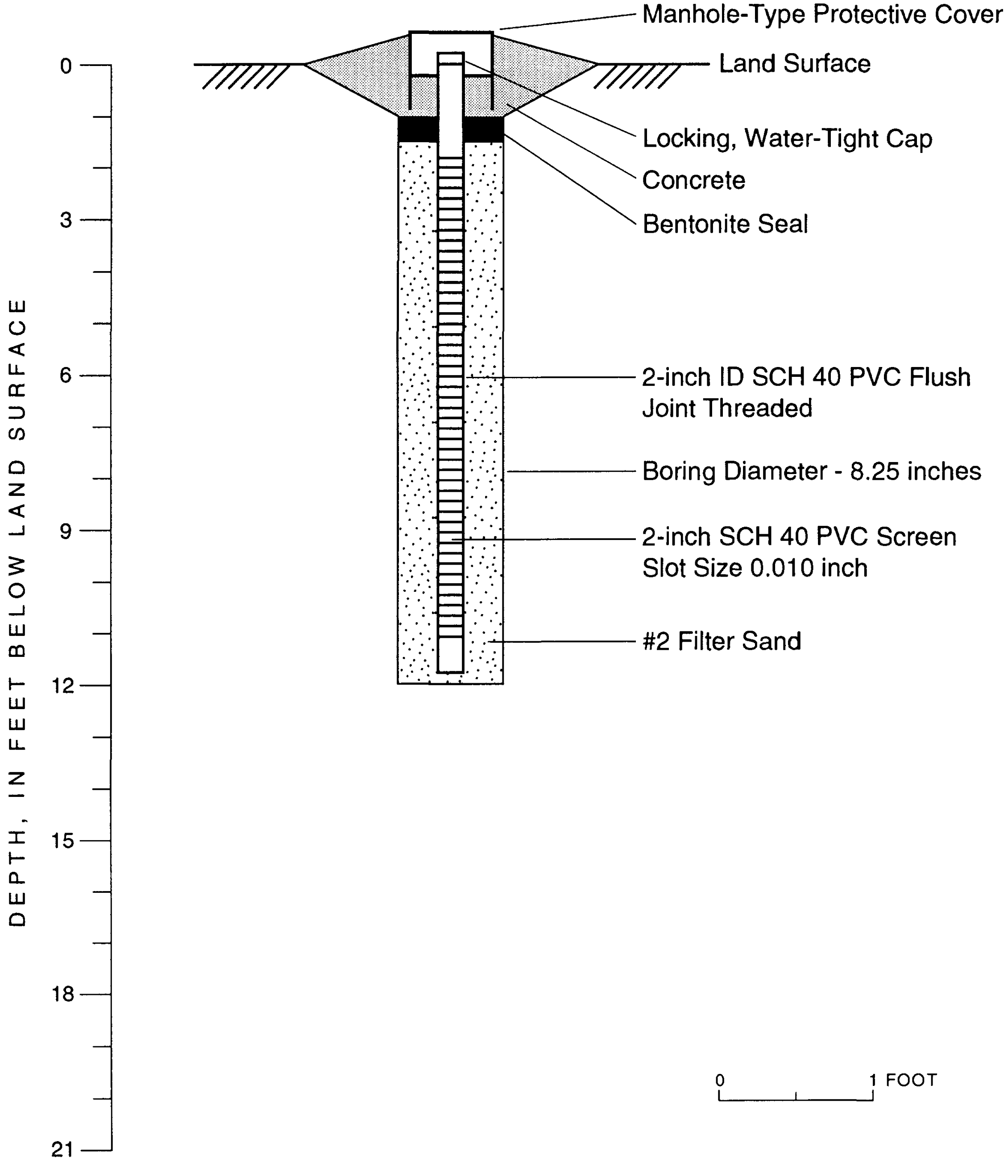

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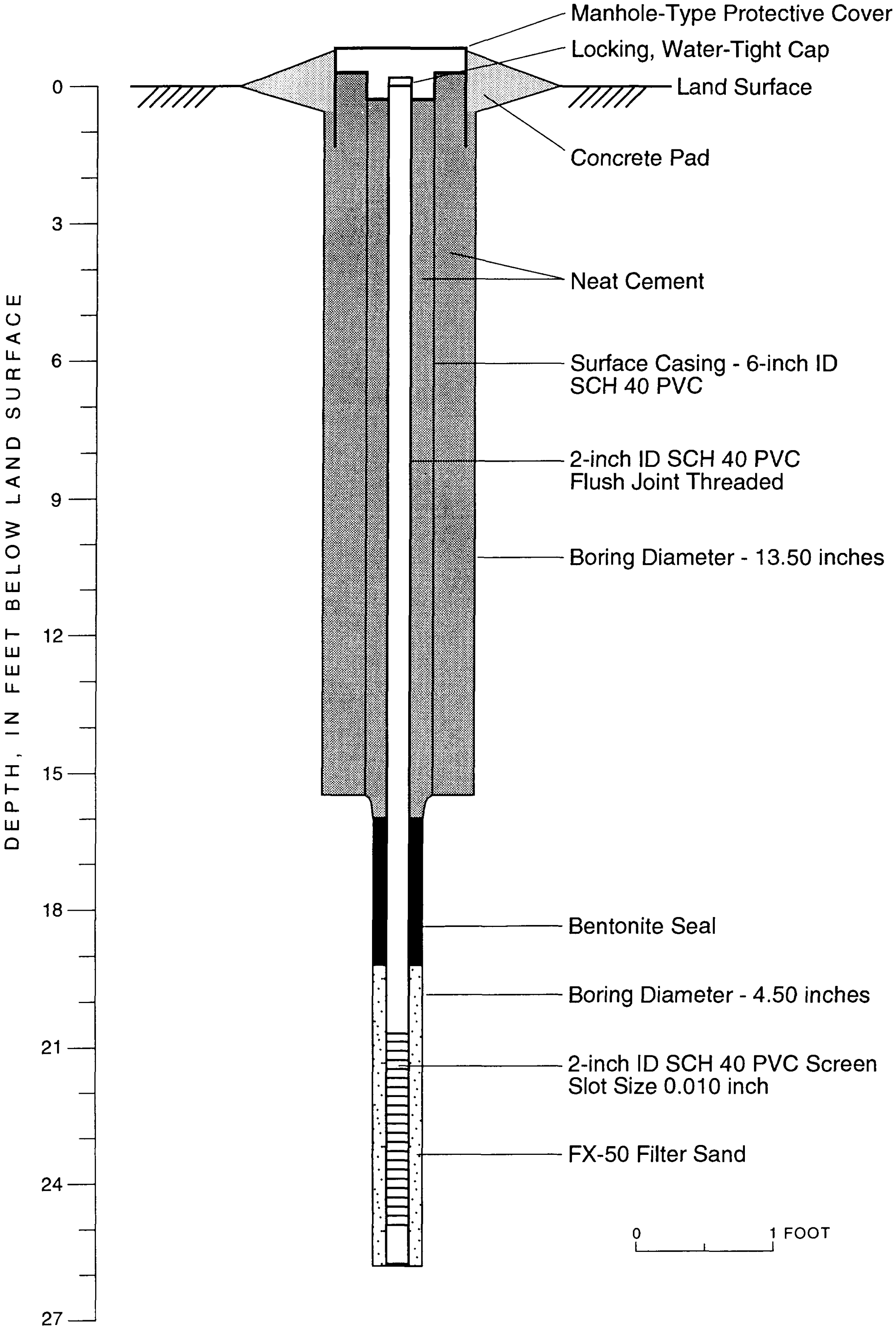
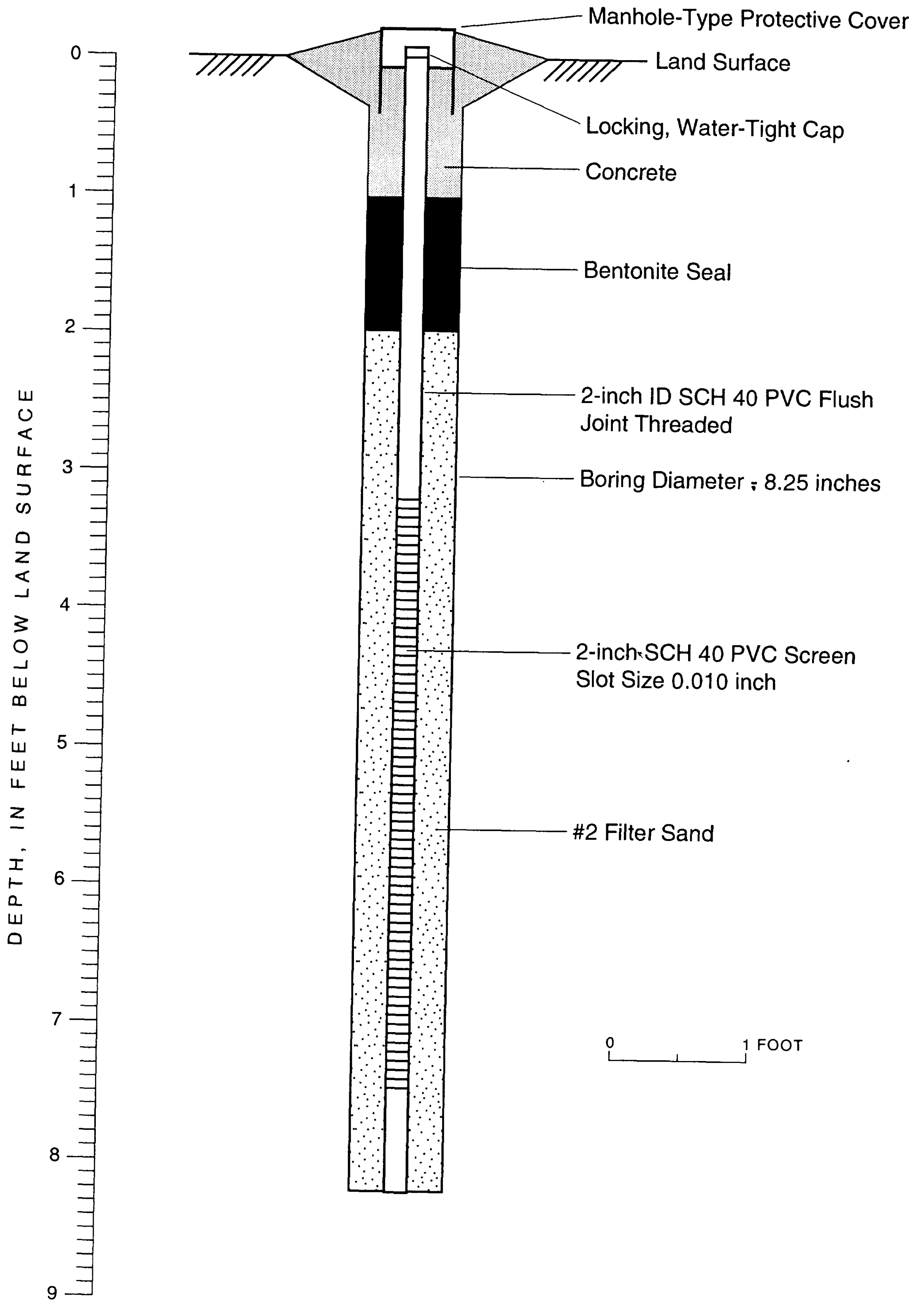


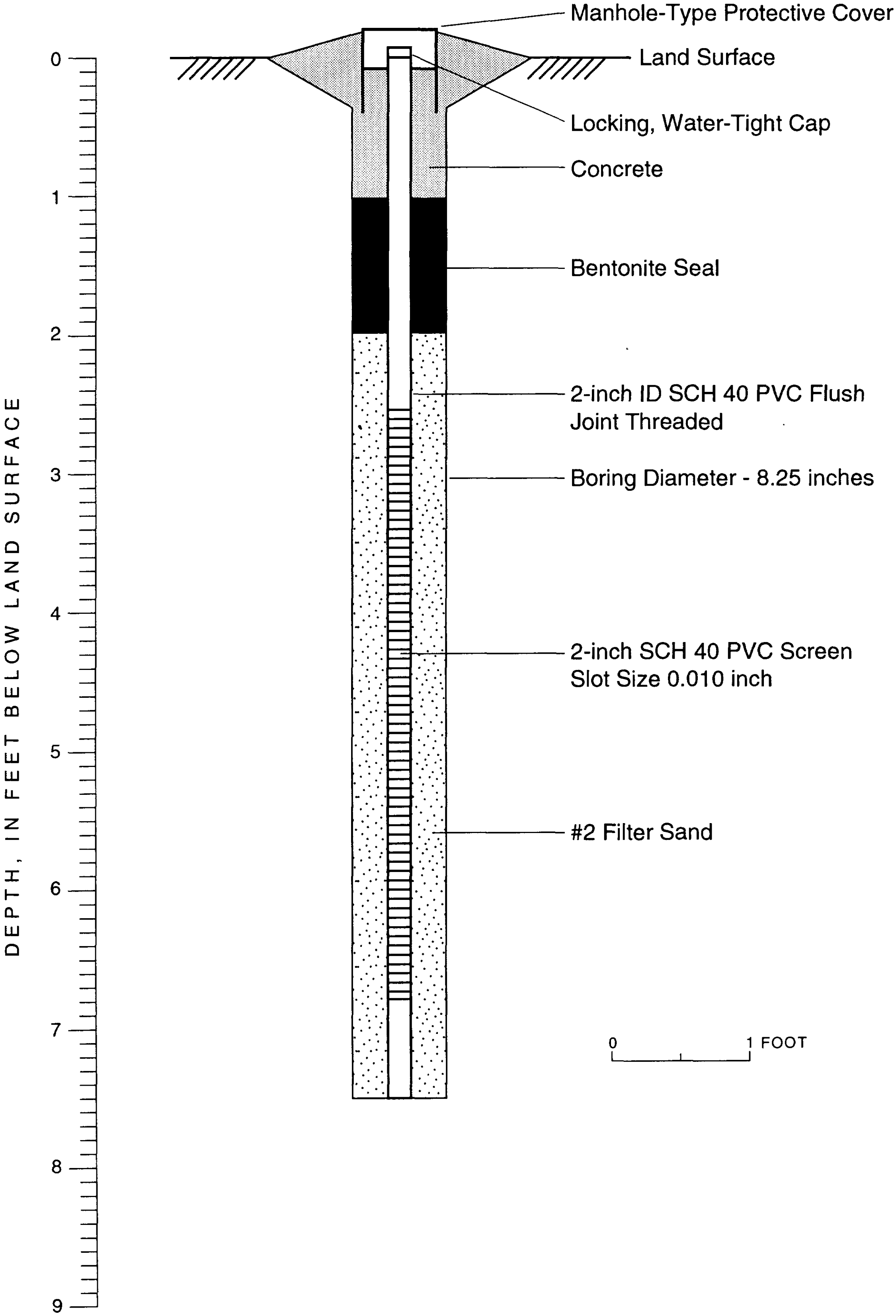
Well construction, MW-1-7, Site 1062, Fort Jackson, S.C.

APPENDIX II

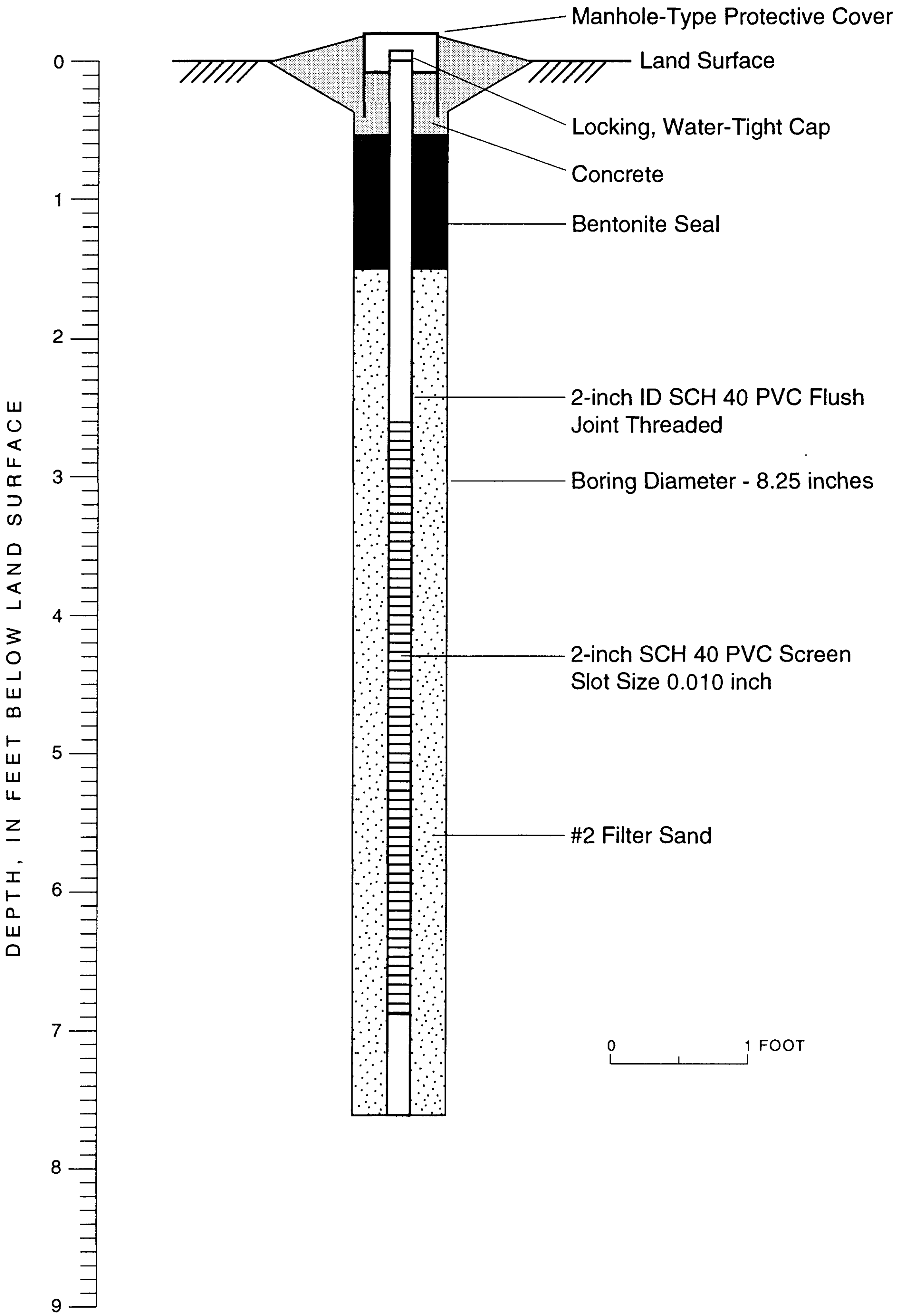
Diagrams showing well construction, Site 2438, Fort Jackson, S.C.



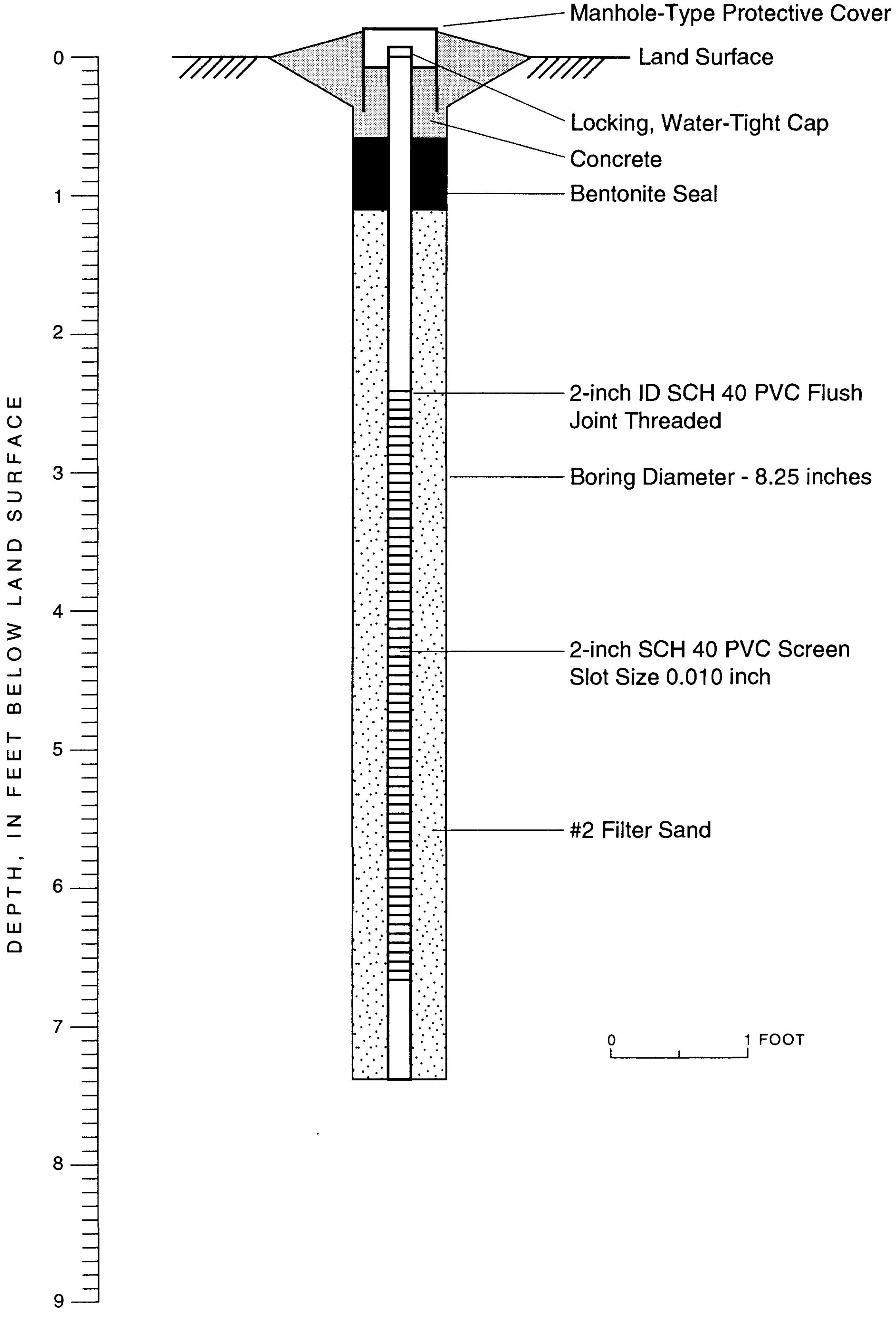
Well construction, MW-2-1, Site 2438, Fort Jackson, S.C.



Well construction, MW-2-2, Site 2438, Fort Jackson, S.C.



Well construction, MW-2-3, Site 2438, Fort Jackson, S.C.



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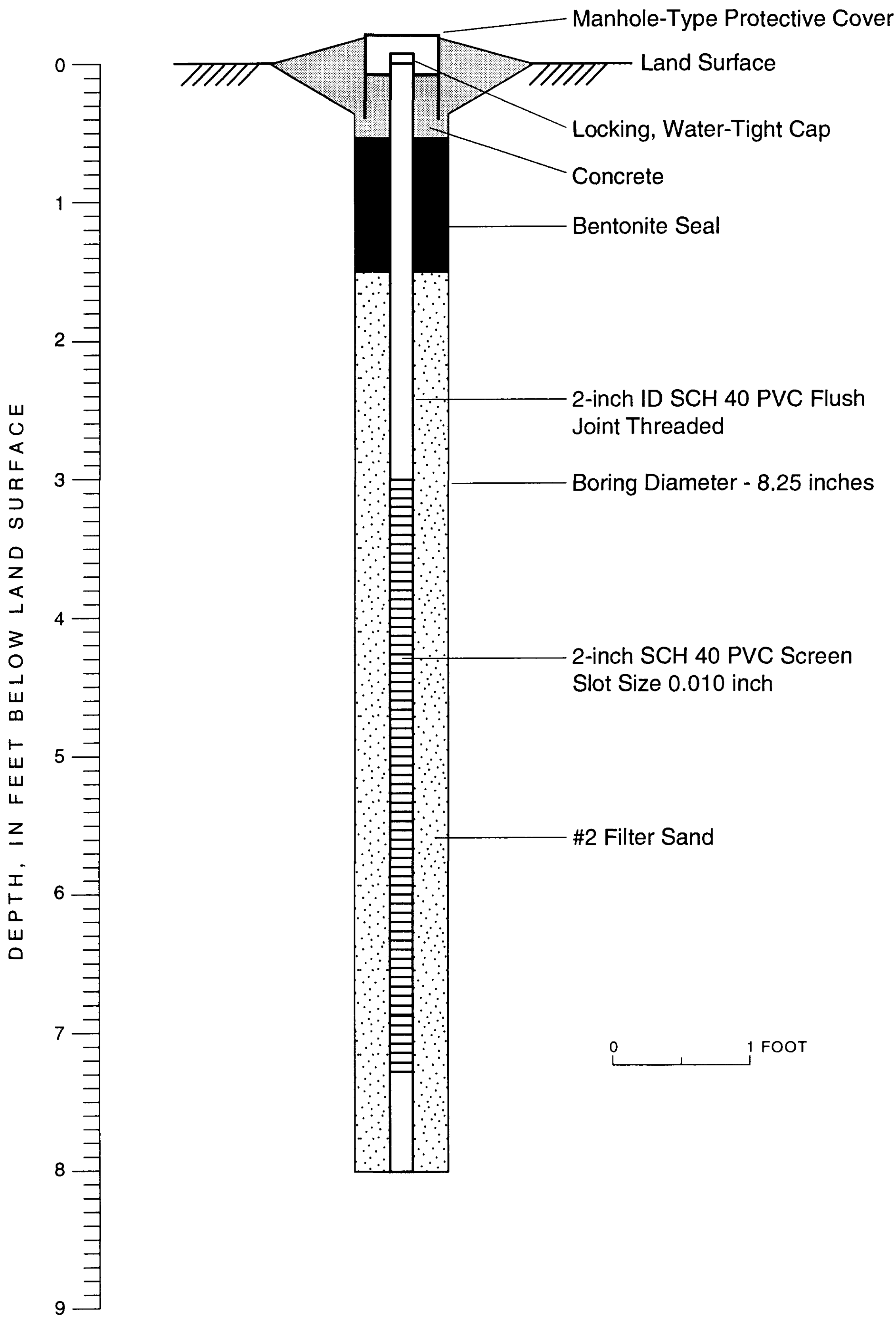
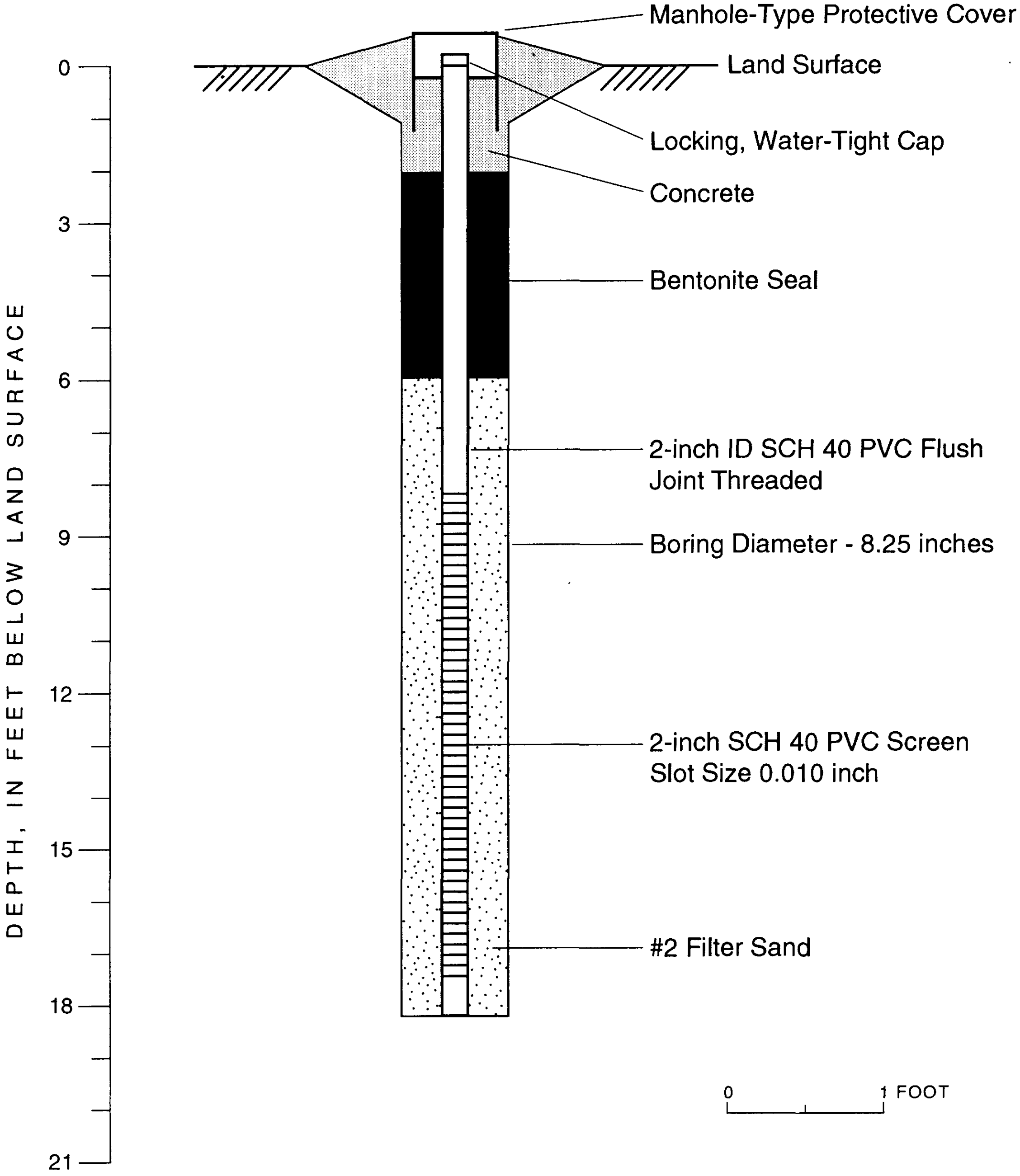


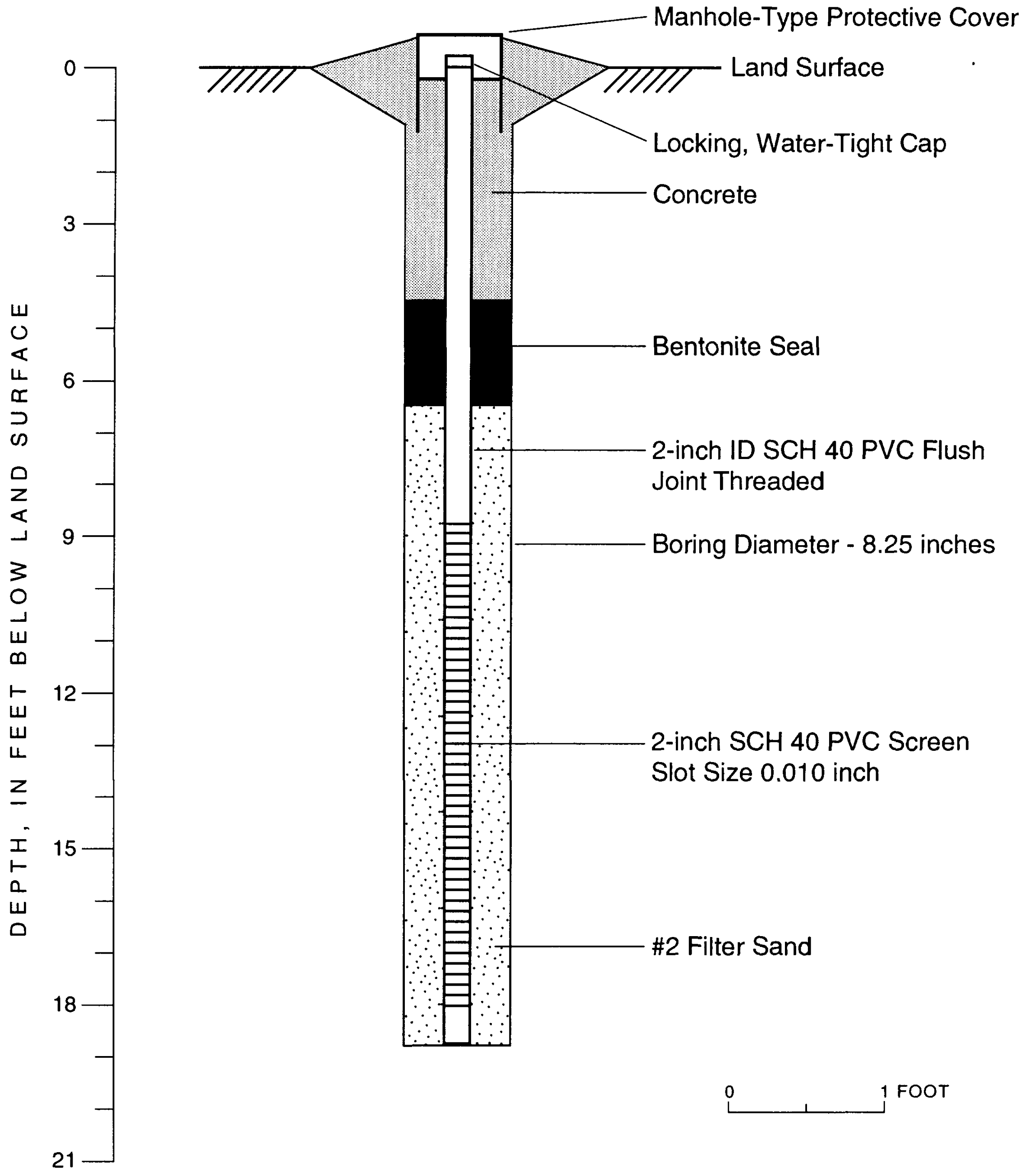
Well construction, MW-2-5, Site 2438, Fort Jackson, S.C.

APPENDIX III

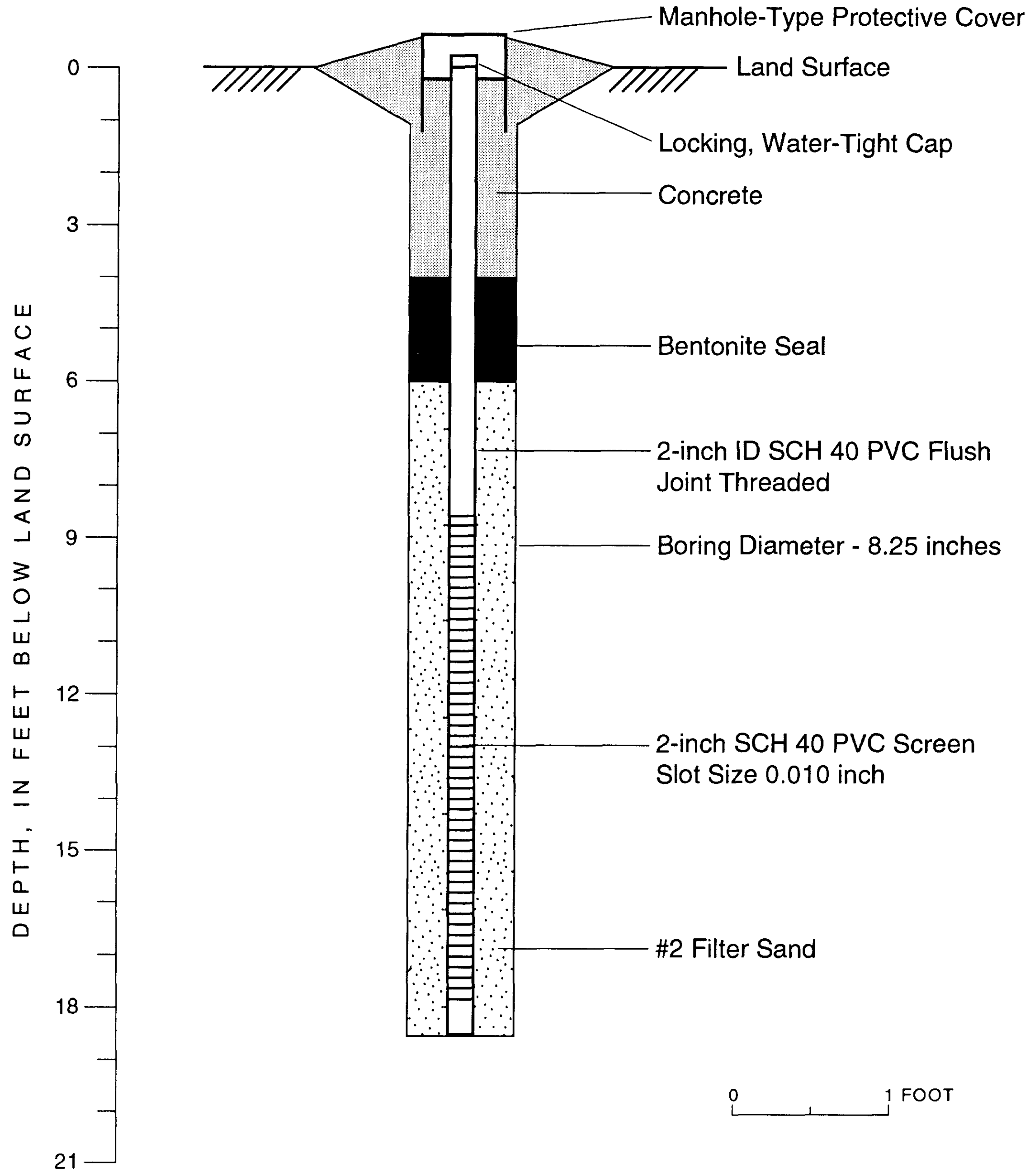
Diagrams showing well construction, Site 2444, Fort Jackson, S.C.



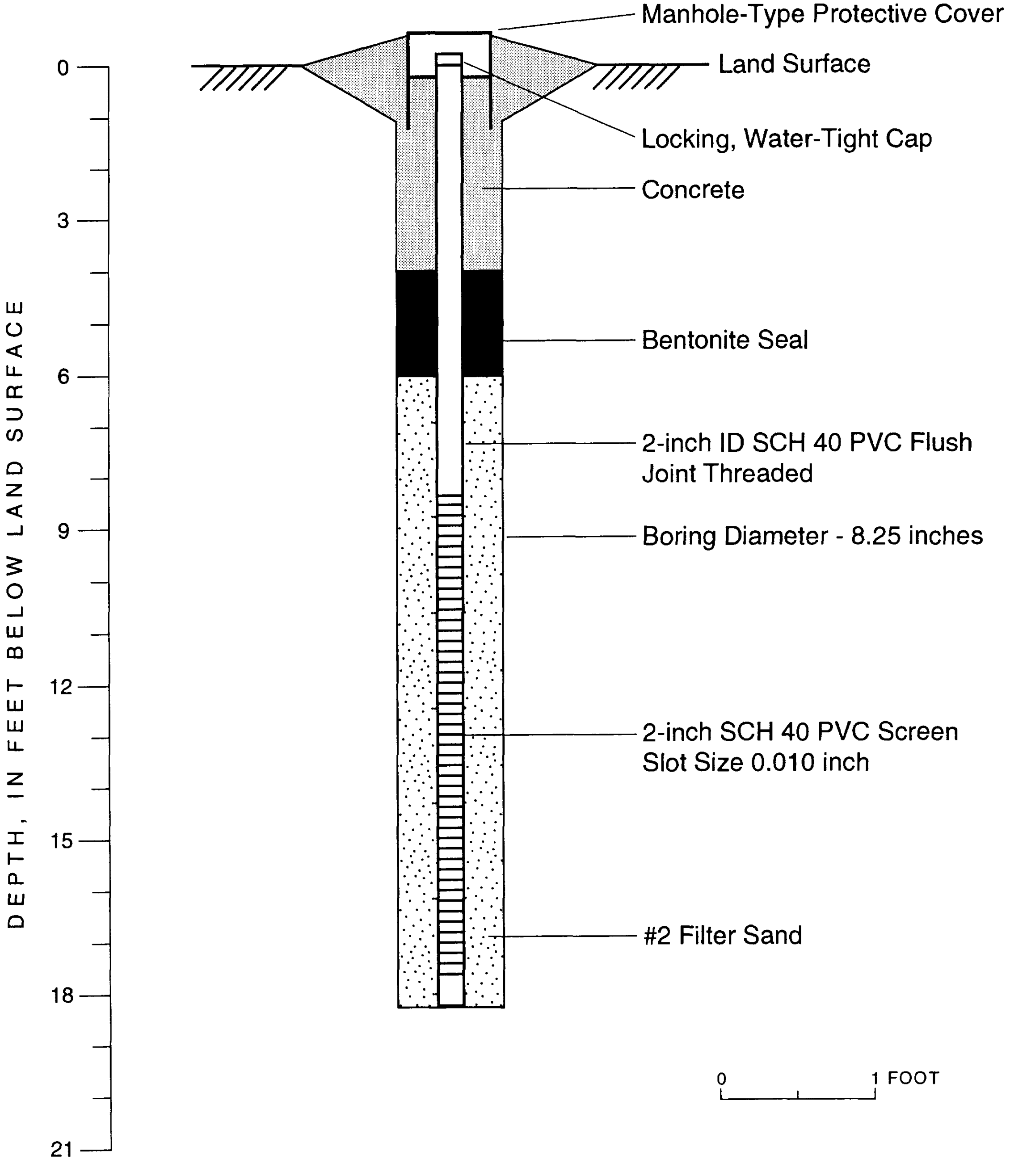
Well construction, MW-3-1, Site 2444, Fort Jackson, S.C.



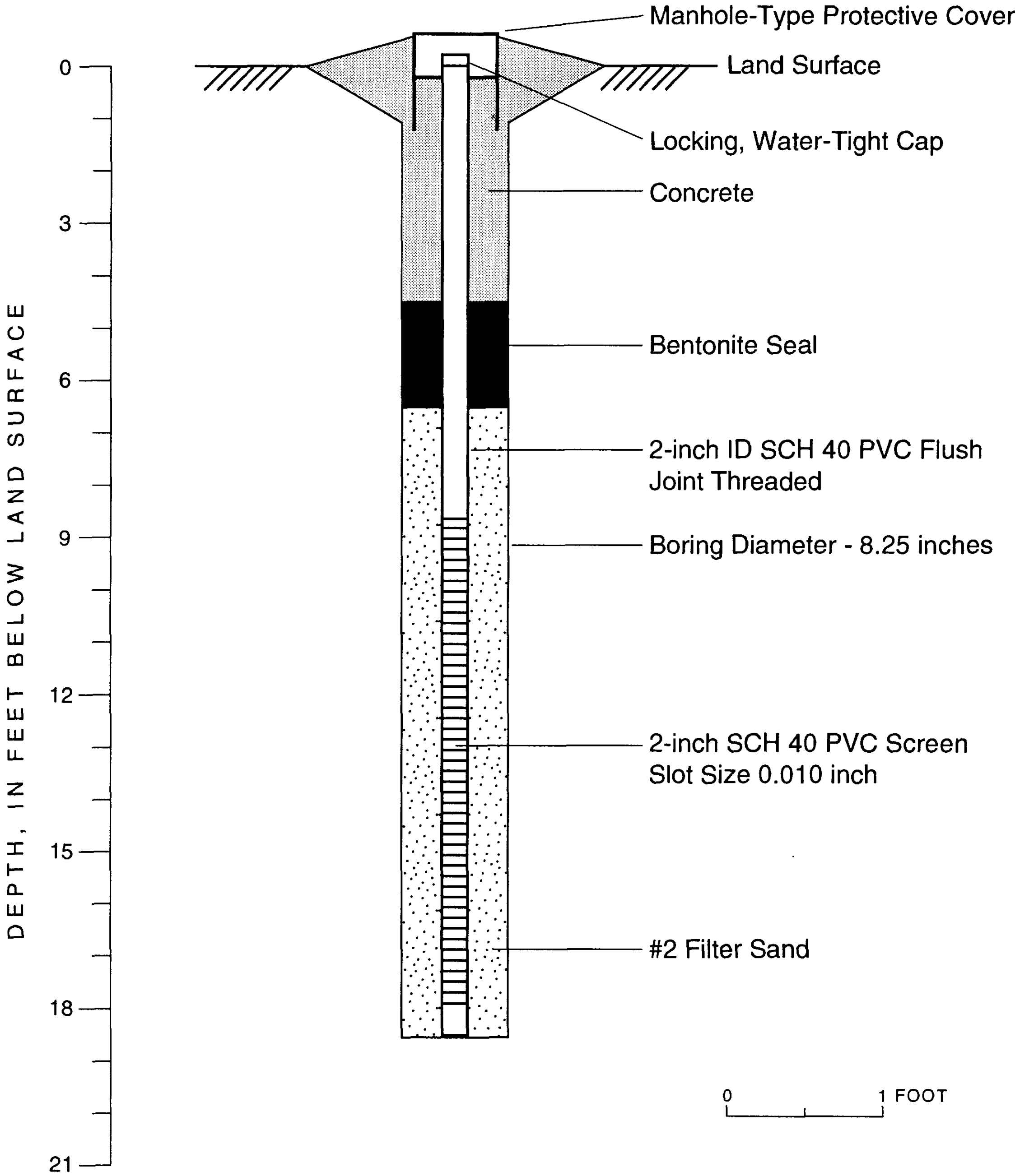
Well construction, MW-3-2, Site 2444, Fort Jackson, S.C.



Well construction, MW-3-3, Site 2444, Fort Jackson, S.C.



Well construction, MW-3-4, Site 2444, Fort Jackson, S.C.



Well construction, MW-3-5, Site 2444, Fort Jackson, S.C.