Geologic and Hydrologic Data for the Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso County, Texas

By Cynthia G. Abeyta and Peter F. Frenzel

U.S. GEOLOGICAL SURVEY

Open-File Report 99-271

Prepared in cooperation with the

U.S. DEPARTMENT OF THE ARMY,
U.S. ARMY AIR DEFENSE ARTILLERY CENTER AND FORT BLISS

Albuquerque, New Mexico
1999

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
inch	25.40	millimeter
foot	0.3048	meter
mile	1.609	kilometer
acre	4,047	square meter
quart	0.9464	liter
gallon	3.785	liter
foot per mile	0.1894	meter per kilometer
ounce	28.35	gram

Temperature in degrees Celsius (°C) or degrees Fahrenheit (°F) can be converted as follows:

$$°F = 1.8\ (°C) + 32$$

$$°C = 5/9\ (°F - 32)$$

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.

GEOLOGIC AND HYDROLOGIC DATA FOR THE MUNICIPAL SOLID WASTE LANDFILL FACILITY, U.S. ARMY AIR DEFENSE ARTILLERY CENTER AND FORT BLISS, EL PASO COUNTY, TEXAS

By Cynthia G. Abeyta and Peter F. Frenzel

Abstract

Geologic and hydrologic data for the Municipal Solid Waste Landfill Facility on the U.S. Army Air Defense Artillery Center and Fort Bliss in El Paso County, Texas, were collected by the U.S. Geological Survey in cooperation with the U.S. Department of the Army. The 106.03-acre landfill has been in operation since January 1974. The landfill contains household refuse, Post solid wastes, bulky items, grass and tree trimmings from family housing, refuse from litter cans, construction debris, classified waste (dry), dead animals, asbestos, and empty oil cans. The depth of the filled areas is about 30 feet and the cover, consisting of locally derived material, is 2 to 3 feet thick.

Geologic and hydrologic data were collected at or adjacent to the landfill during (1) drilling of 10 30- to 31-foot boreholes that were completed with gas-monitoring probes, (2) drilling of a 59-foot borehole, (3) drilling of a 355-foot borehole that was completed as a ground-water monitoring well, and (4) in situ measurements made on the landfill cover. After completion, the gas-monitoring probes were monitored on a quarterly basis (1 year total) for gases generated by the landfill. Water samples were collected from the ground-water monitoring well for chemical analysis.

Data collection is divided into two elements: geologic data and hydrologic data. Geologic data include lithologic descriptions of cores and cuttings, geophysical logs, soil-gas and ambient-air analyses, and chemical analyses of soil. Hydrologic data include physical properties, total organic carbon, and pH of soil and sediment samples; soil-water chloride and soil-moisture analyses; physical properties of the landfill cover; measurements of depth to ground water; and ground-water chemical analyses. Interpretation of data is not included in this report.

INTRODUCTION

The U.S. Army Air Defense Artillery Center and Fort Bliss (USAADACENFB) Municipal Solid Waste Landfill Facility (MSWLF or "landfill"), established in January 1974, is a 106.03-acre landfill located within El Paso County, Texas, about 10 miles northeast of downtown El Paso, on Federal land administered by the USAADACENFB (fig. 1). The USAADACENFB is evaluating geologic and hydrologic conditions of the MSWLF to implement requirements of Federal and State of Texas regulatory programs. In 1994, the U.S. Geological Survey (USGS), in cooperation with the U.S. Army, initiated a study of the USAADACENFB MSWLF to describe geologic and hydrologic conditions at the facility. Results of this study will be used by the U.S. Army to aid in fulfilling regulatory requirements at the facility, as specified in Title 40 of the Code of Federal Regulations, Parts 257 and 258 (40 CFR 257 and 258), Subtitle D (U.S. Environmental Protection Agency, 1993), and Part 30 of the Texas Administrative Code, Section 330 (30 TAC 330) (Texas Natural Resources Conservation Commission, 1993).

Purpose and Scope

This report presents data collected by the USGS at the MSWLF during 1994 and 1995. This compilation of data will result in a better understanding of the geology and hydrology at the MSWLF. Geologic and hydrologic data presented in this report were collected on and adjacent to the landfill. These data were collected during (1) drilling and installation of 10 gas-monitoring probes (GMPs), (2) drilling of a 59-foot borehole that was plugged and abandoned after completion, (3) drilling of a 355-foot borehole that was completed as a ground-water monitoring well, and (4) in situ measurements made on the landfill cover.

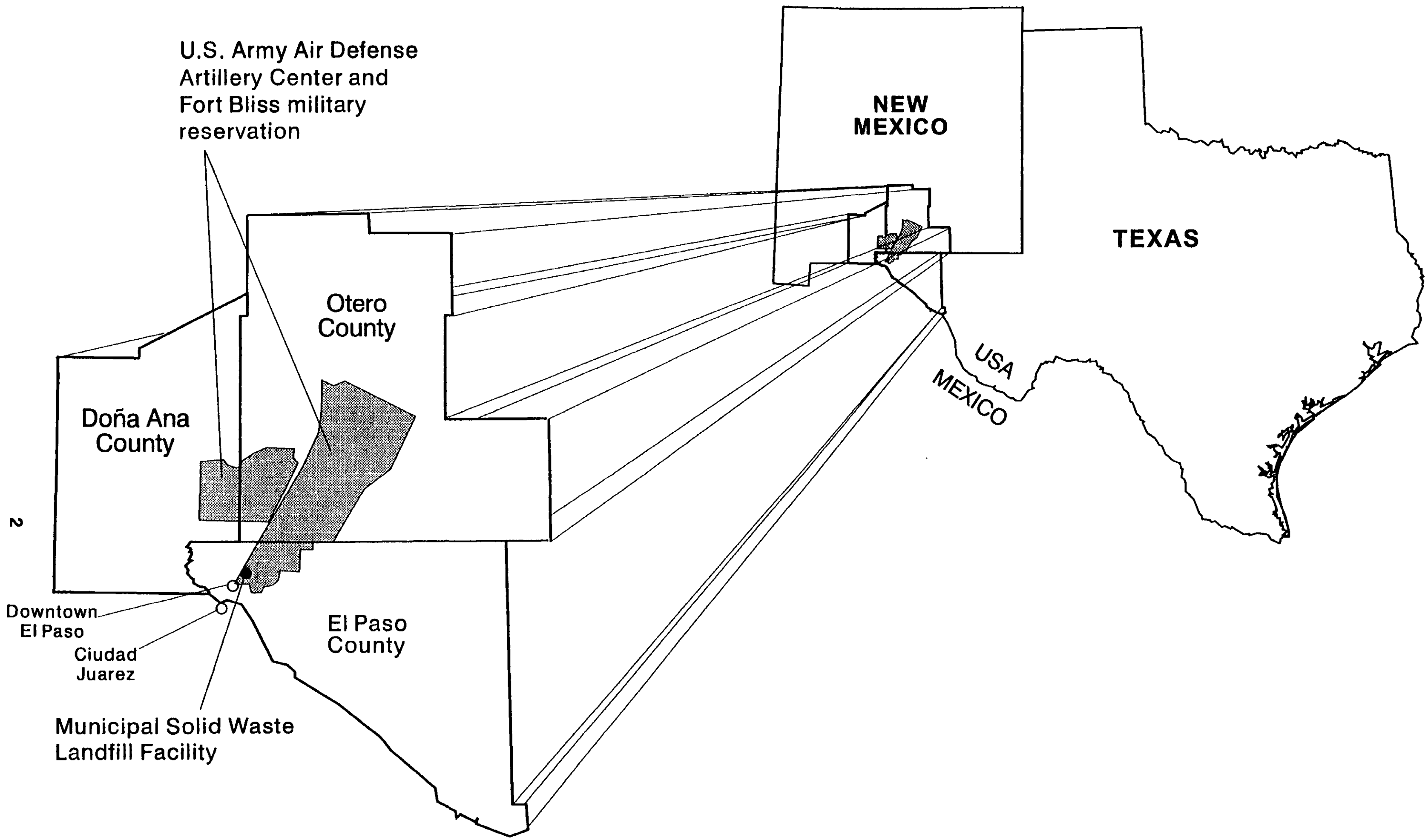

Figure 1.--Location of U.S. Army Air Defense Artillery Center and Fort Bliss military reservation and Municipal Solid Waste Landfill Facility, Texas and New Mexico.

Most of the data were collected in accordance with Texas Natural Resources Conservation Commission (TNRCC)-approved plans and specifications to maintain a consistent data collection program. These plans and specifications are described in the following documents:

(1) Workplan for methane monitoring network at the Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas, Final (U.S. Geological Survey, written commun., November 1994);

(2) Workplan for ground-water monitoring at the Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas, Final (U.S. Geological Survey, written commun., March 1995); and

(3) Sampling and analysis plan for ground-water monitoring at the Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas, Final (U.S. Geological Survey, written commun., March 1995).

In addition to data collected as described above, additional data were collected to evaluate the transport of solutes from the landfill to the water table.

Data collected by the USGS at the MSWLF included lithologic descriptions of cores and cuttings; geophysical logs; soil-gas and ambient-air analyses; chemical analyses of soil; physical-property, total organic carbon, and pH analyses of soil and sediment samples; soil-water chloride and soil-moisture analyses; physical properties of the landfill cover; measurements of depth to ground water; and ground-water chemical analyses. Interpretation of data is not included in this report.

Description of the Municipal Solid Waste Landfill Facility

The MSWLF, established in January 1974, is located northwest of Biggs Army Airfield, 300 feet east of the Southern Pacific Railroad tracks, and about 1,200 feet east of the nearest occupied structure (fig. 2). The landfill fill rate is 1-4 acres per year and at this fill rate the landfill is expected to reach its capacity by 2004 (approximately 15 acres of the permitted area will not be filled). Types of solid wastes disposed of at the MSWLF include household refuse, Post solid wastes, bulky items, grass and tree trimmings from family housing, refuse from litter cans, construction debris, classified waste (dry), dead animals, asbestos, and empty oil cans (1-quart and 5-gallon sizes). The depth of the filled areas is about 30 feet and the cover, consisting of locally derived material, is 2 to 3 feet thick. Since 1994, the filled area (labeled Subtitle D in fig. 3) has been lined with soil and plastic, as required under Subtitle D regulations (40 CFR Part 258) (Abeyta, 1996, p. 16).

An all-weather road is accessible to the MSWLF year round. The MSWLF is surrounded by a fence with an unfilled border area between the fence and the landfill that is about 50 feet wide (fig. 3). An enclosed guard shack is located on the facility near the entrance. Bladed strips on both sides of the landfill fence serve as access roads. The roads are a few inches below the surface of the land surrounding the landfill and are separated by a small berm at the fence line. The land-surface elevation is about 3,920 feet above sea level near the landfill. The landfill rises on a slope of about 3 percent to about 10 feet above the surrounding terrain. The hummocky land surface around the MSWLF generally slopes about 20 feet per mile toward the south-southwest. No utilities are within the perimeter of the MSWLF.

A previous study by Abeyta (1996) presents a geohydrologic site characterization of the USAADACENFB MSWLF that includes information on the (1) boundaries, area, and contents of the MSWLF; (2) environmental setting of the MSWLF and vicinity, including a description of the physiography, climate, and soils; (3) geologic and hydrologic characteristics of the unsaturated zone and shallow aquifer; and (4) ground-water quality in the vicinity of the MSWLF.

GEOLOGIC DATA

Geologic data were collected at or adjacent to the MSWLF during the drilling of 12 boreholes. In November 1994, 10 30- to 31-foot vertical boreholes (GMP-1 through GMP-10) were drilled around the perimeter of the landfill (fig. 3). Drill cuttings from the boreholes were described and compiled into lithologic logs. Permanent gas-monitoring probes were installed in the boreholes in accordance with requirements listed in 30 TAC 330.56(a)(2). The monitoring network was designed to collect representative samples of explosive gases (specifically methane) generated by the facility

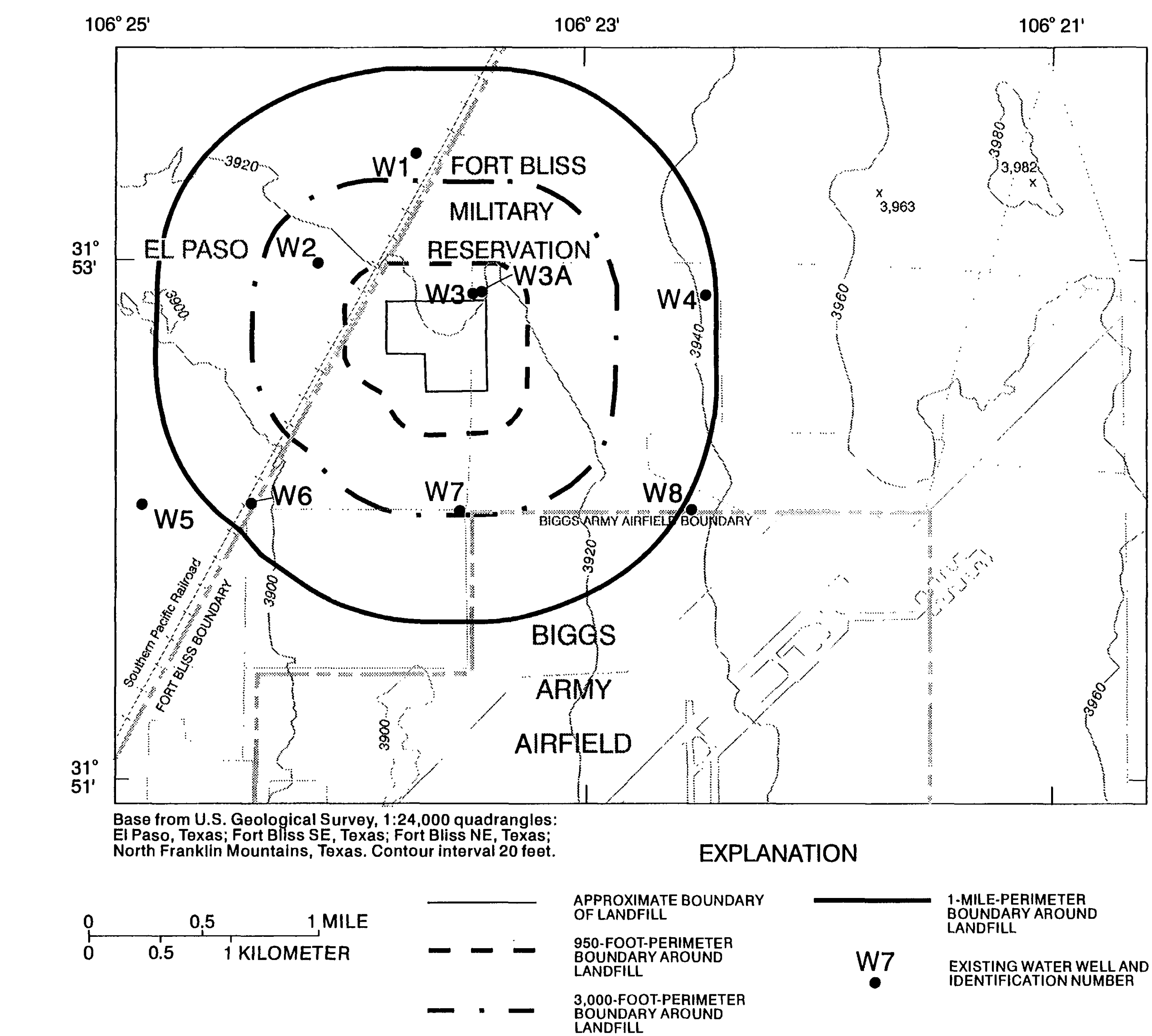

Figure 2.--Location of U.S. Army Air Defense Artillery Center and Fort Bliss Municipal Solid Waste Landfill Facility, El Paso, Texas.

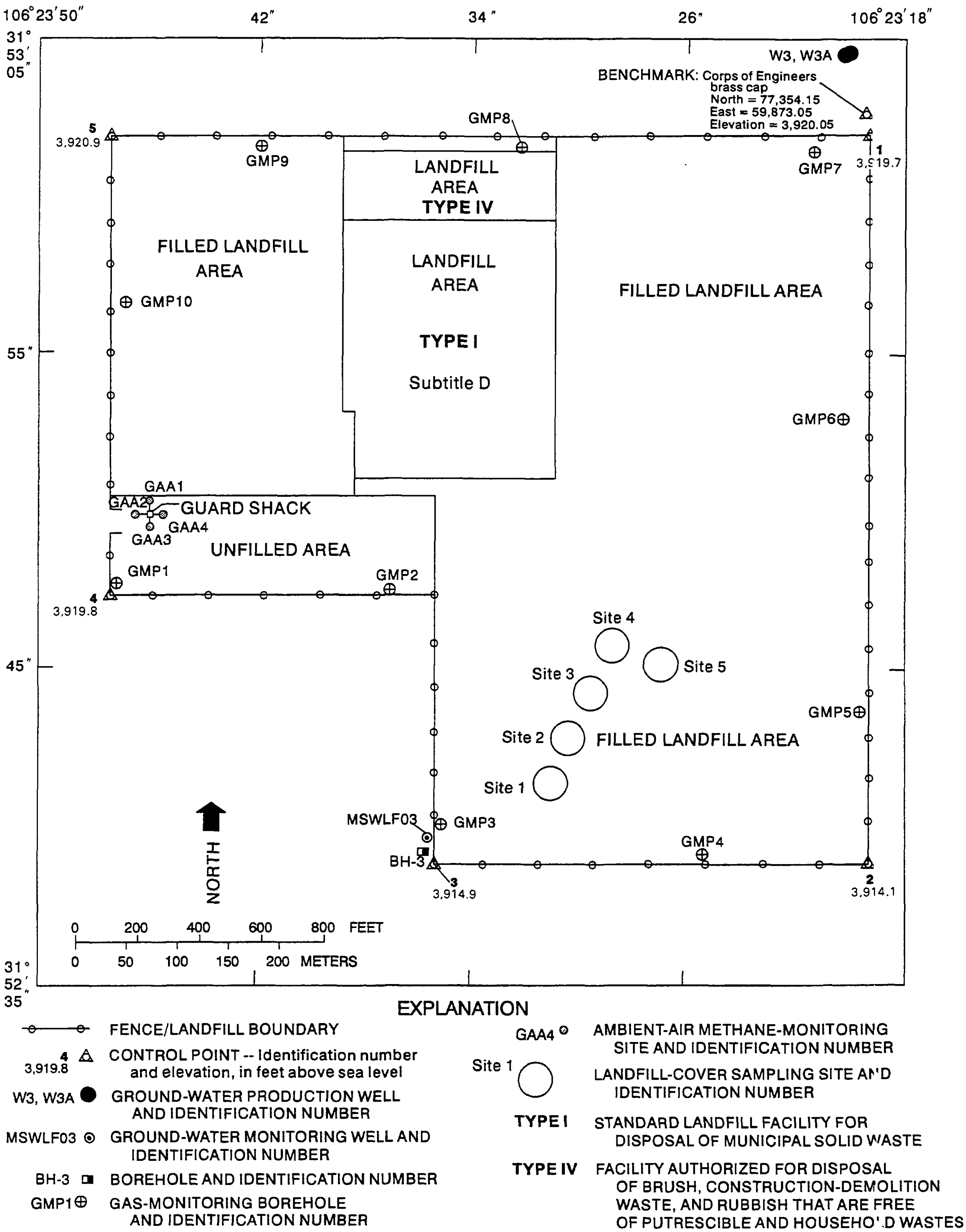

Figure 3.--Municipal Solid Waste Landfill Facility boundary and location of gas-monitoring boreholes, borehole BH-3, ground-water monitoring well MSWLF03, and landfill-cover sampling sites.

and to monitor whether these gases exceed maximum allowable levels as defined in RCRA Subtitle D (40 CFR 258.23(d) and 30 TAC 330.56(n)(2)). During April-May 1995, one 59-foot vertical borehole (BH-3) and one 355-foot vertical borehole (MSWLF03) were drilled near the southwest corner of the landfill (fig. 3). Core samples were collected during drilling of these two boreholes and the lithology of the recovered cores were described. Samples were collected from selected intervals of the recovered cores that were representative of the various lithologic units (such as clay, sand, and silty sand). These samples were sent to various laboratories for physical-property, soil-water chloride, soil-moisture, and chemical analysis. Geophysical logs were obtained from the mud-filled borehole MSWLF03. The 355-foot borehole was completed as a ground-water monitoring well in accordance with requirements listed in 30 TAC 330 Subchapter I. Geologic data collected at the MSWLF are presented in the following sections.

Borehole Drilling and Completion Procedures

Boreholes GMP-1 through GMP-10 and BH-3 were drilled using a hollow-stem auger. Boreholes GMP-1 through GMP-10 were drilled to depths of 30 to 31 feet below land surface; borehole BH-3 was drilled to a depth of 59 feet. Borehole BH-3 was plugged and marked with a cement cap. The boreholes were 8 3/4 inches in diameter. A 4-inch-diameter core was collected at 2- to 5-foot intervals using a 5-foot-long split-spoon sampler and continuous flight auger; at times a stainless steel catcher was placed in the shoe of the split-spoon to achieve better recoveries in unconsolidated geologic formations. The sampler was pushed into the undisturbed material below the auger, withdrawn, and opened. All cores collected were then described; at times, cuttings were described when there was no recovery of the core. The descriptions of cores and cuttings are presented in the "Lithologic description of cores and cuttings" section of this report.

Gas-monitoring probes were installed in boreholes GMP-1 through 10 immediately after each borehole was drilled to total depth; completion diagrams are presented in figures 4-13. A 24.55-foot-long, 1-inch-diameter, threaded polyvinyl chloride (PVC), 0.010-inch slotted screen was inserted into the borehole while the auger flights were still in the ground; the bottom of the screen was capped. A 7.25-foot-long, 1-inch-diameter, threaded PVC riser was placed directly above the screen. The top of the riser was capped with a reducer/coupling, a PVC ball valve, more couplings and reducers, and one-quarter-inch polyethylene tubing. The auger flights were withdrawn as the annular space of the borehole was filled with a three-eighths-inch pea gravel filter pack. The filter pack was placed to about 5 feet below land surface; at times the annular space in the borehole filled with natural backfill when the hole would not remain open without the auger flights. A 3-linear-foot seal of hydrated bentonite pellets was placed above the filter pack. The annular space above the bentonite seal was filled with concrete to the ground surface. A 3-foot-square concrete surface pad surrounds a locking, steel, protective casing that extends 2 to 3 feet above ground level and contains the 1-inch PVC riser and probe. Four 3-inch-diameter steel guard posts were placed at each corner of the surface pad that extend about 3 feet above the land surface.

The borehole for ground-water monitoring well MSWLF03 was drilled using mud-rotary drilling techniques and bentonite mud. A diamond-button core-bit was attached to the bottom of the drill string, which contained a 10-foot-long, 3.5-inch-diameter core barrel; at times a stainless steel catcher was placed in the shoe of the core barrel to achieve better recoveries. The drill string was rotated while coring to expose the core-bit's buttons to the full annular area of the undisturbed material at the bottom of the drill string. An approximately 3.5-inch-diameter core was collected in the stainless steel split-core barrel. The core barrel was withdrawn, opened, and the core collected and described. The descriptions of cores and cuttings are presented in the "Lithologic description of cores and cuttings" section of this report.

Prior to completion as ground-water monitoring well MSWLF03, the borehole was reamed to a total depth of 355 feet. Completion of the well consisted of a 3.826-inch-inside-diameter, 4.5-inch-outside-diameter, flush-joint, threaded, schedule 80 PVC sump, screen, and riser (fig. 14). A 40-foot-long screen with 0.010-inch-wide slotted openings was attached to the 5-foot-long sump; an approximately 307-foot-long riser was attached to the screen. The annular space of the borehole was gravel packed with 10-20 mesh clean silica sand tremmied from the bottom of the hole to about 11 feet above the top of the well screen. A 26-foot bentonite-pellet seal was tremmied into place above the gravel pack, and a 4-foot section of 20-mesh clean silica sand was placed above the bentonite seal. The annular space above the sand was tremmied to approximately 1 foot below land surface with Volclay grout.

NAME AND
NUMBER: Municipal Solid Waste Landfill Facility
gas-monitoring probe GMP-1

LOCATION: U.S. Army Air Defense Artillery Center and Fort Bliss,
Texas State Plane Coordinates 856,225.6589 north
118,820.9904 east

DATE INSTALLATION COMPLETED: 11-NOV-94
DRILL METHOD: Hollow-stem auger
DRILLED BY: U.S. Geological Survey

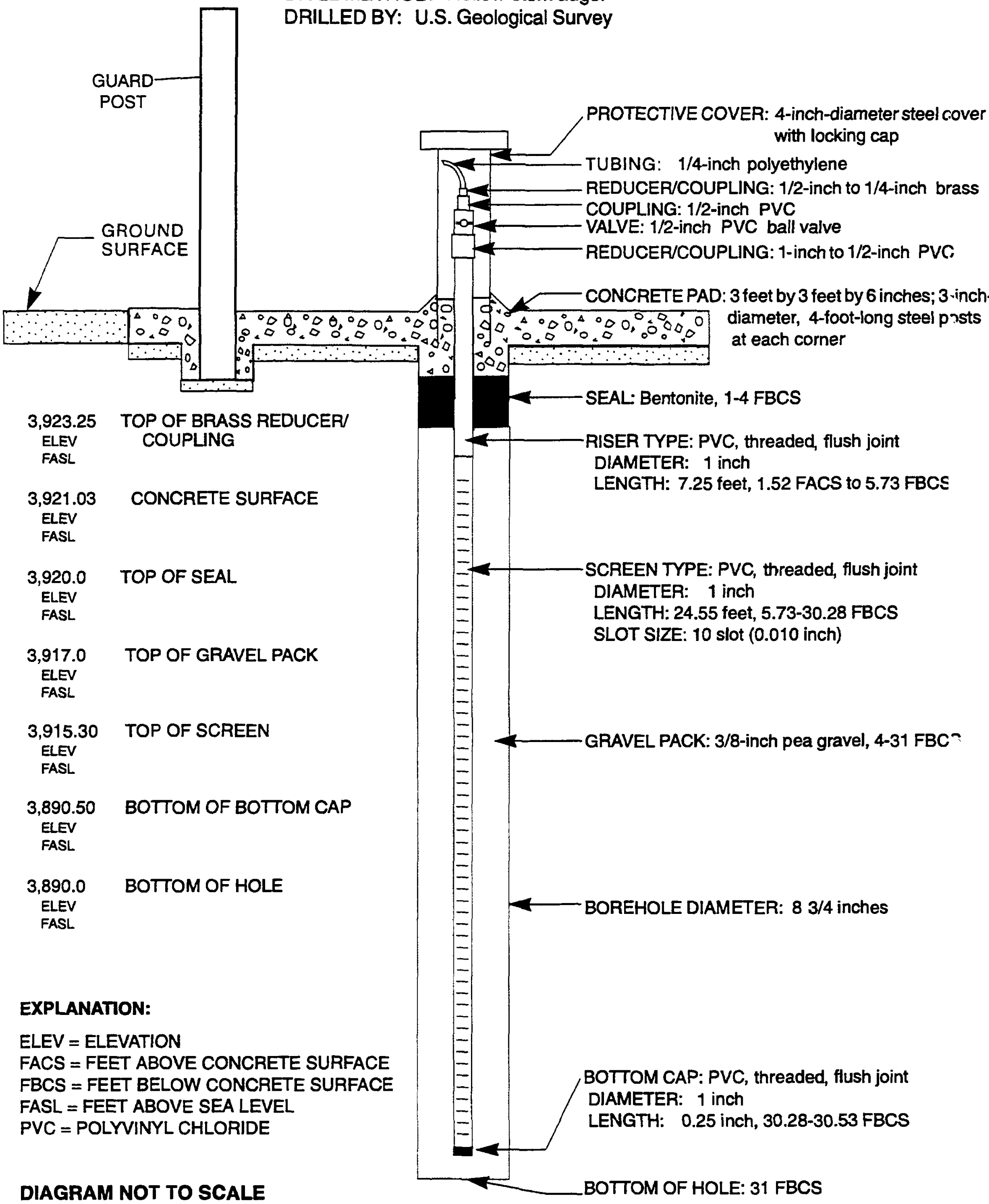

Figure 4.--Completion of gas-monitoring probe GMP-1.

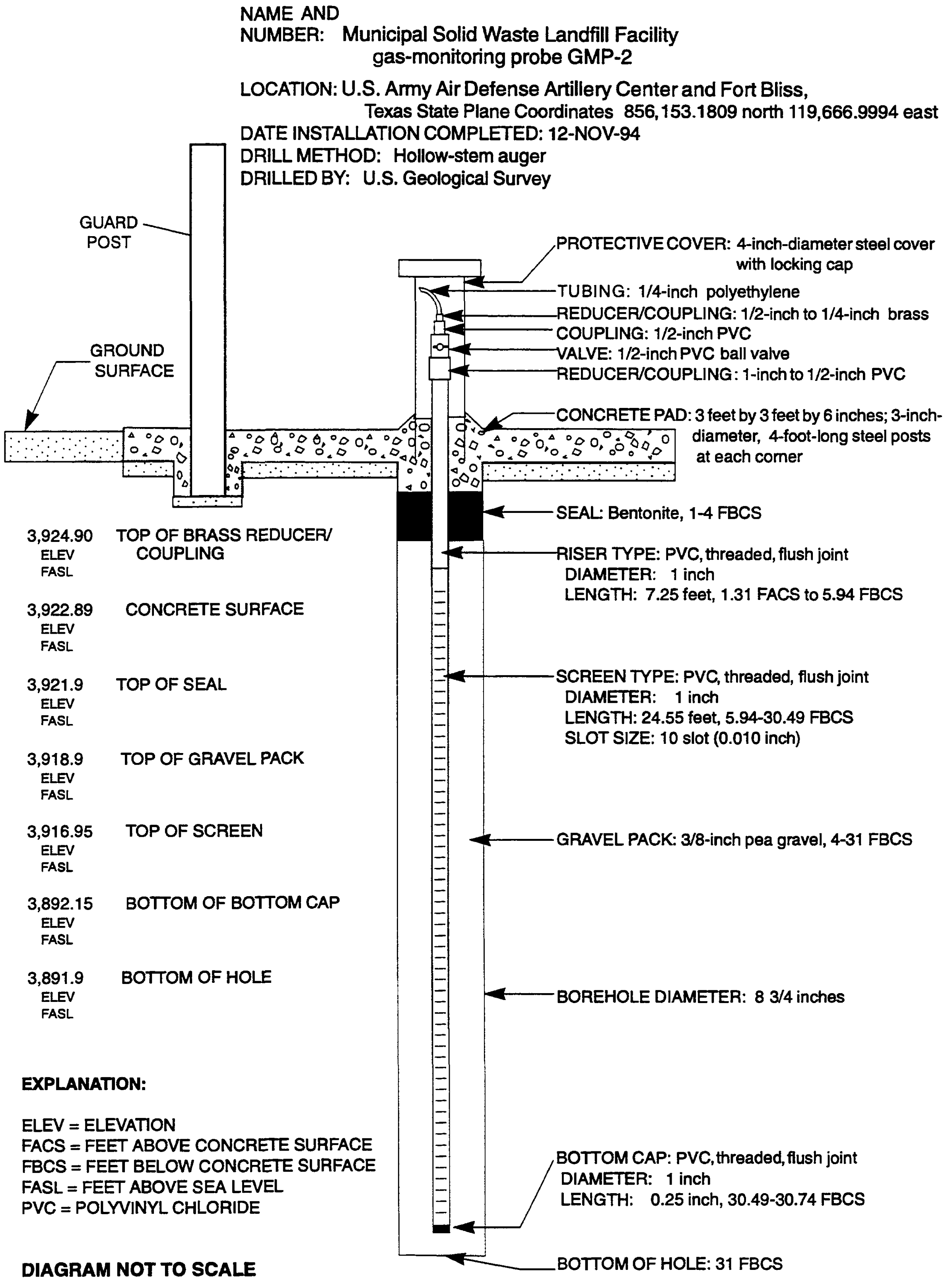

Figure 5.--Completion of gas-monitoring probe GMP-2.

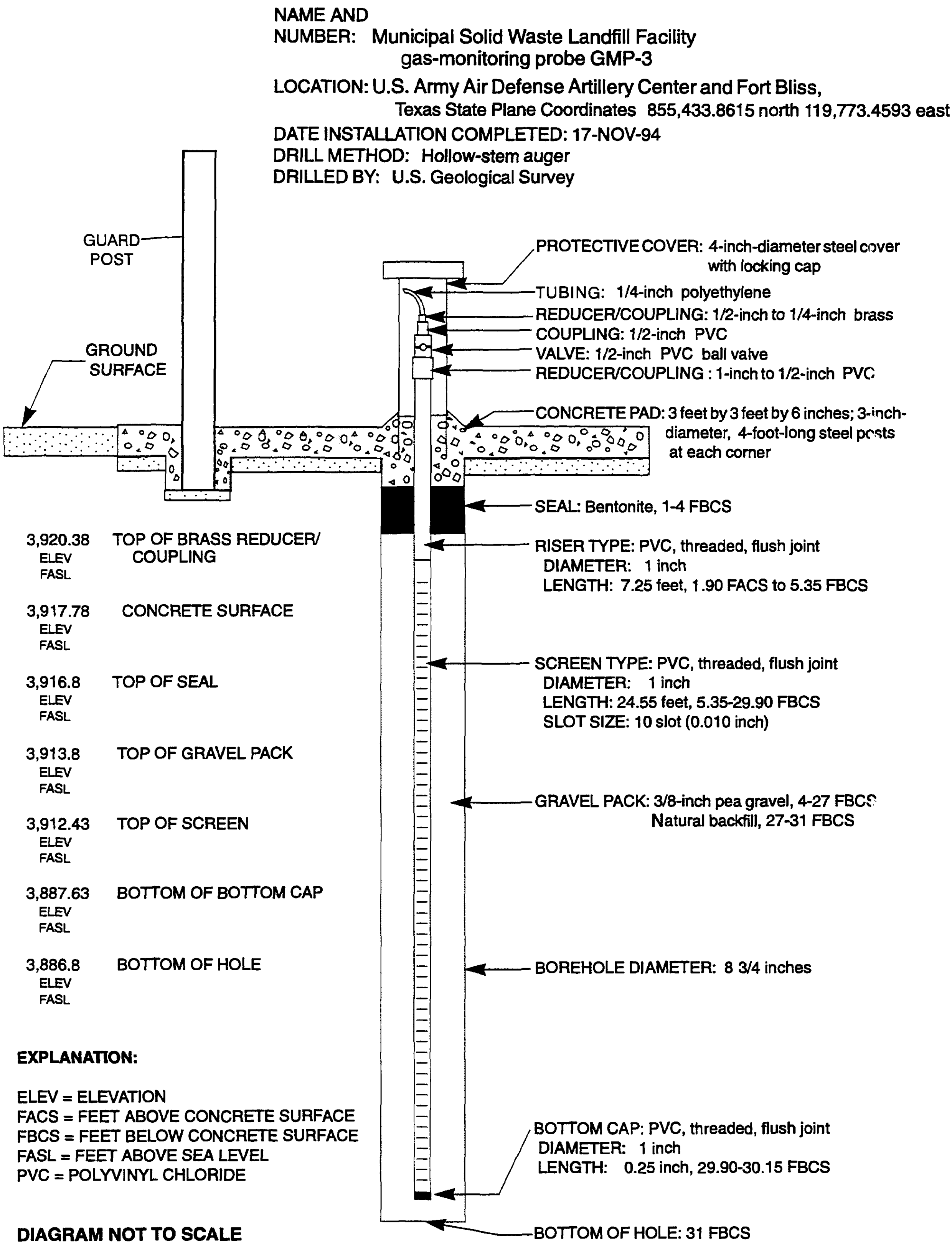

Figure 6.--Completion of gas-monitoring probe GMP-3.

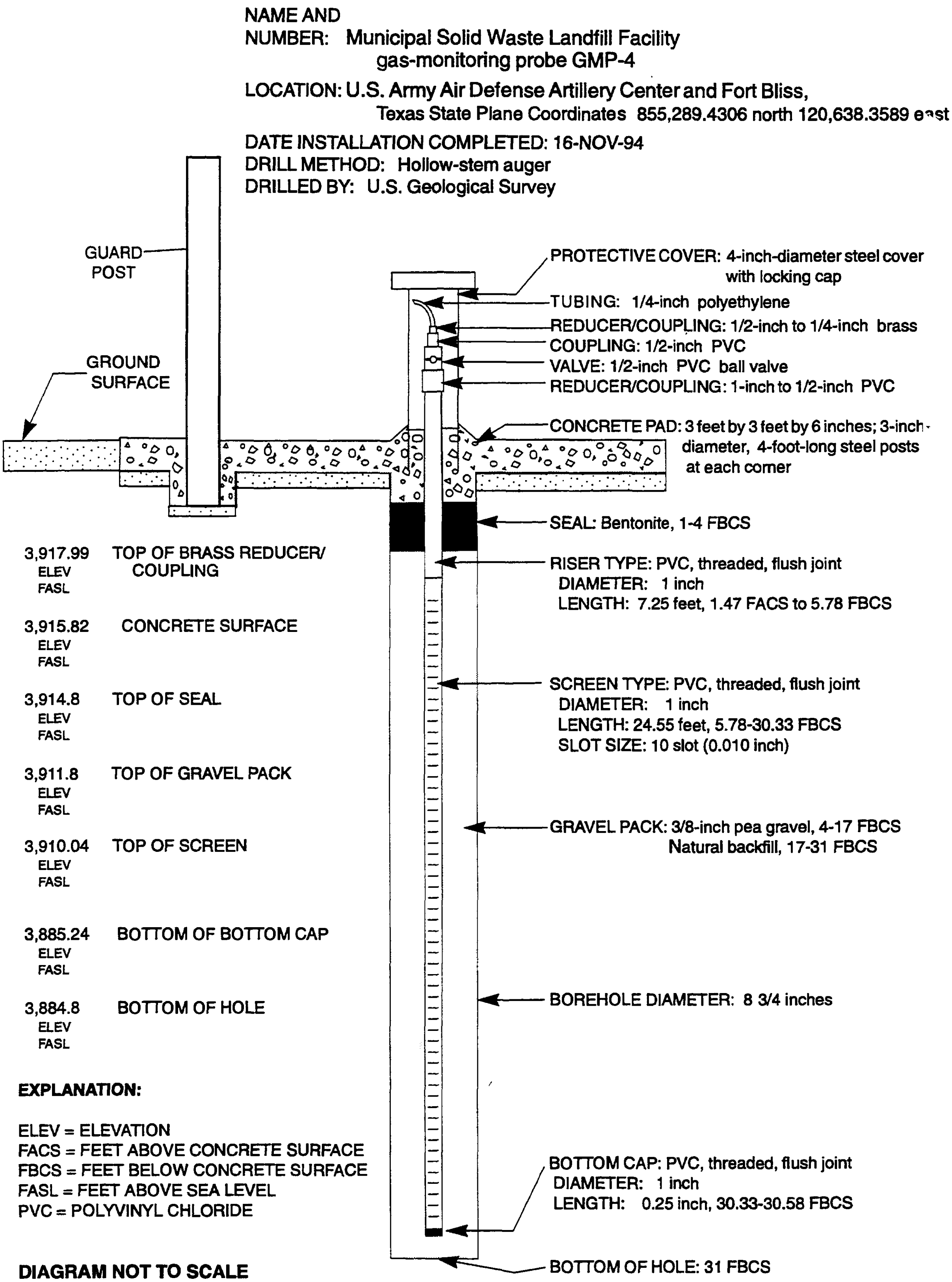

Figure 7.--Completion of gas-monitoring probe GMP-4.

NAME AND
NUMBER: Municipal Solid Waste Landfill Facility
gas-monitoring probe GMP-5

LOCATION: U.S. Army Air Defense Artillery Center and Fort Bliss,
Texas State Plane Coordinates 855,722.2537 north 121,132.8111 east

DATE INSTALLATION COMPLETED: 16-NOV-94
DRILL METHOD: Hollow-stem auger
DRILLED BY: U.S. Geological Survey

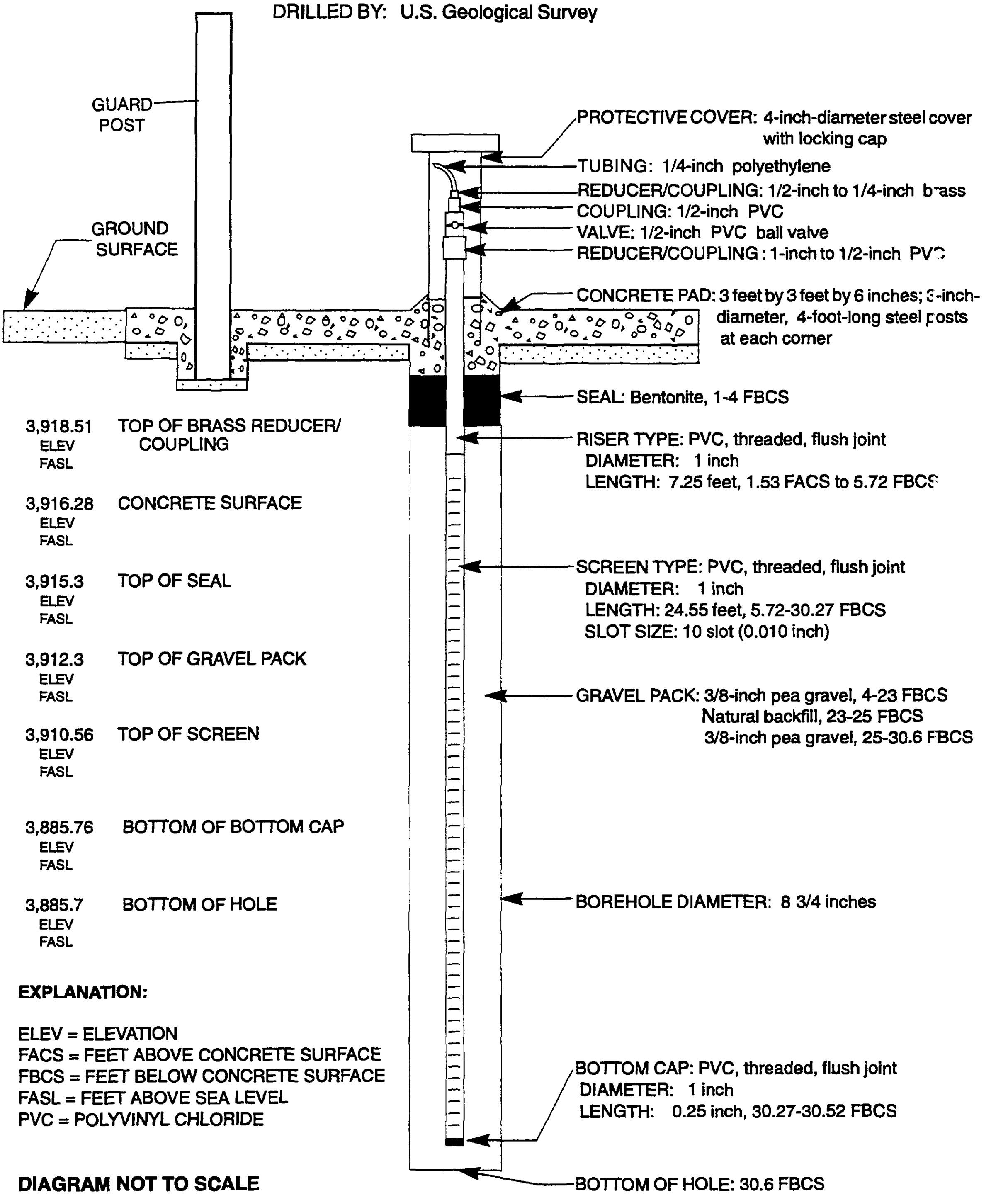

Figure 8.--Completion of gas-monitoring probe GMP-5.

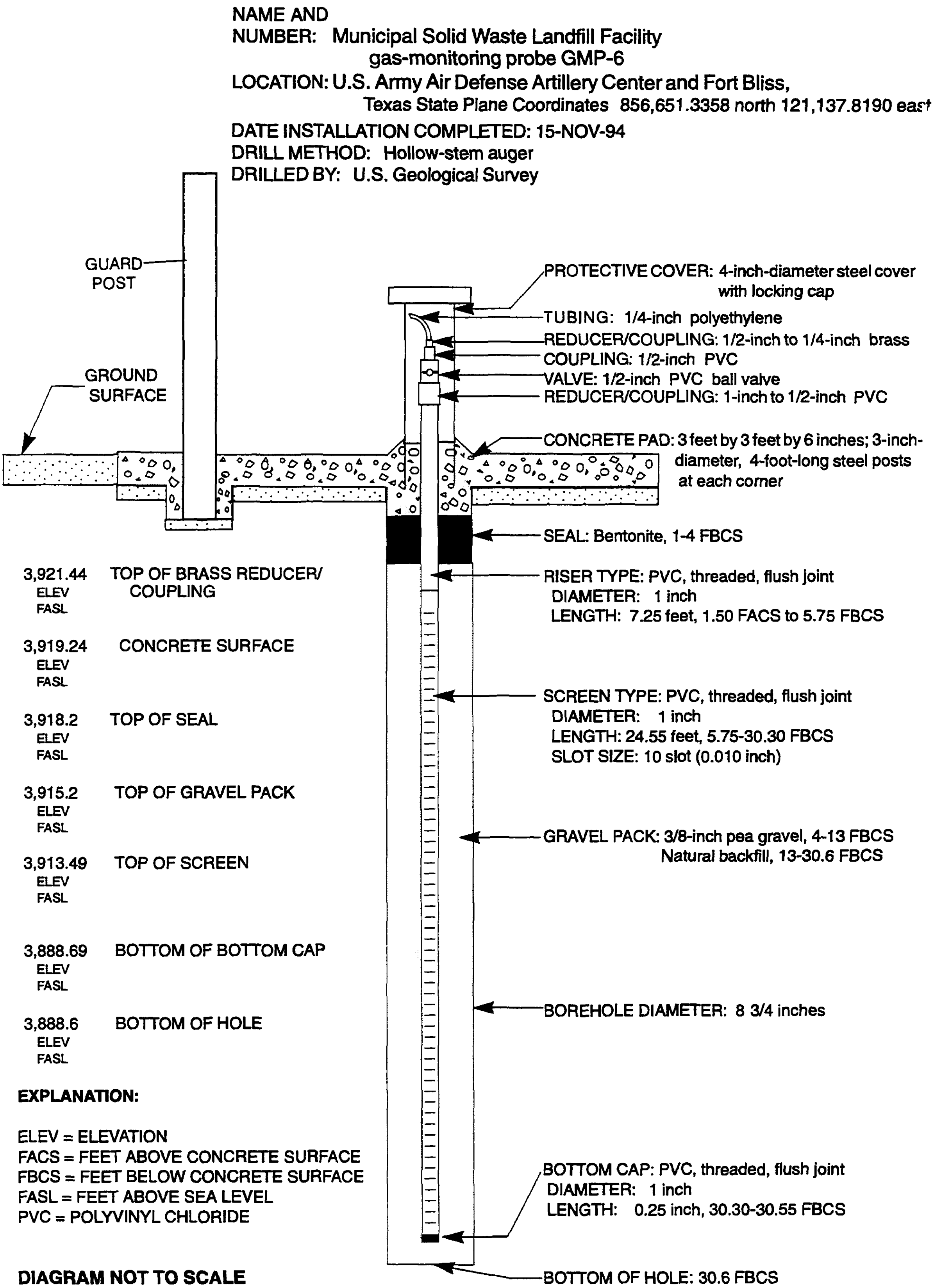

Figure 9.--Completion of gas-monitoring probe GMP-6.

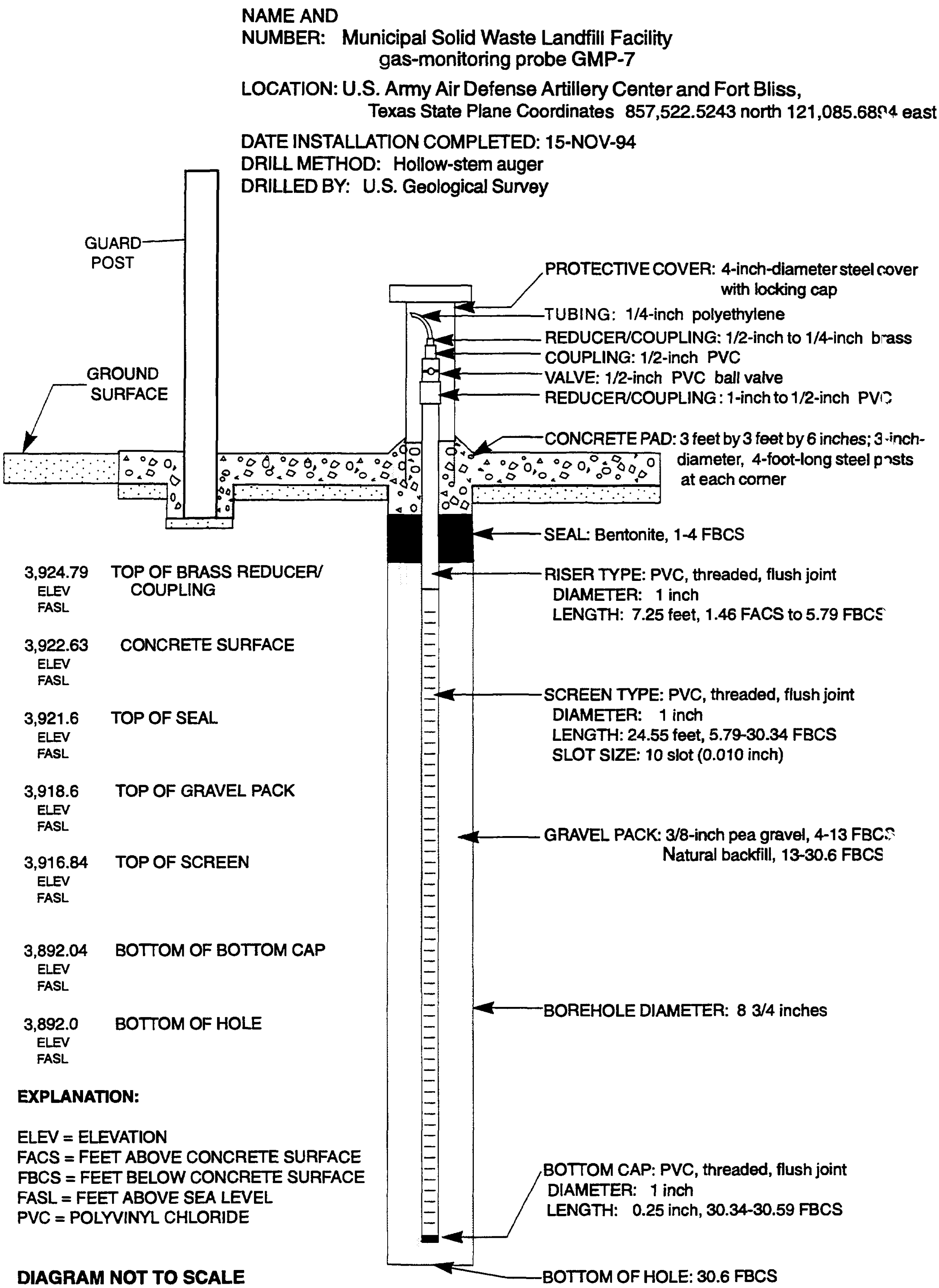

Figure 10.--Completion of gas-monitoring probe GMP-7.

NAME AND
NUMBER: Municipal Solid Waste Landfill Facility
gas-monitoring probe GMP-8

LOCATION: U.S. Army Air Defense Artillery Center and Fort Bliss,
Texas State Plane Coordinates 857,581.6823 north 120,182.0386 east

DATE INSTALLATION COMPLETED: 14-NOV-94
DRILL METHOD: Hollow-stem auger
DRILLED BY: U.S. Geological Survey

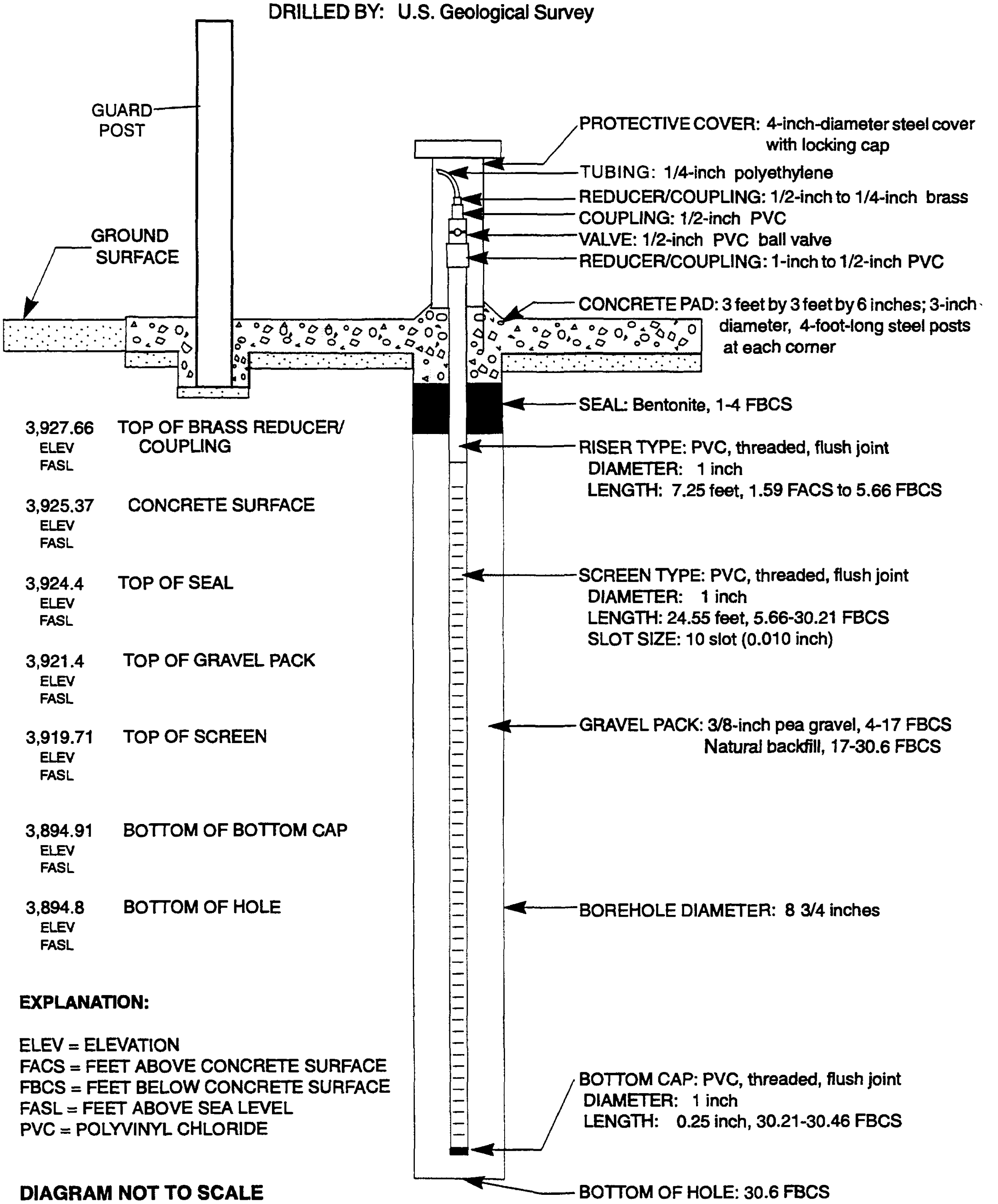

Figure 11.--Completion of gas-monitoring probe GMP-8.

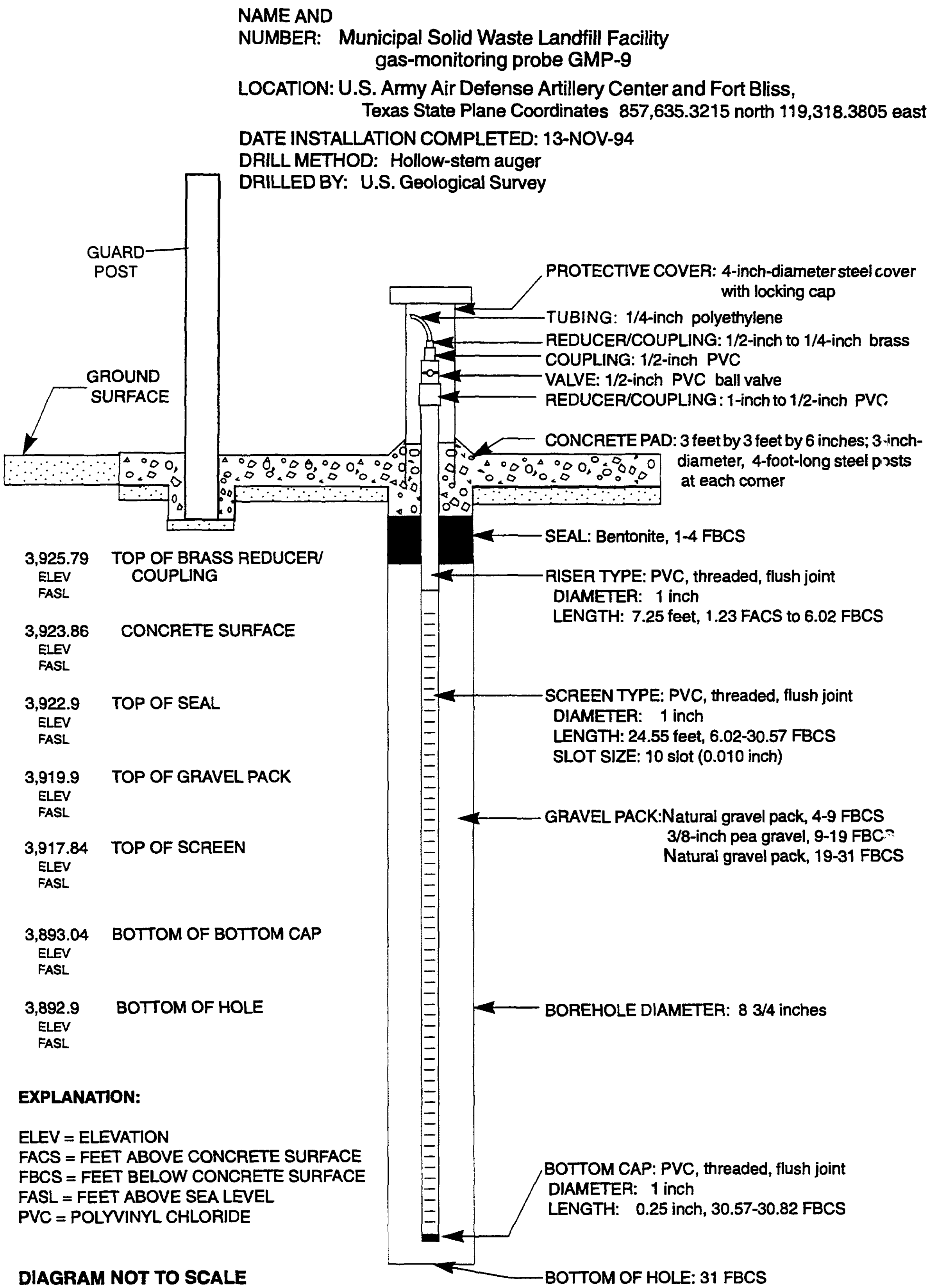

Figure 12.--Completion of gas-monitoring probe GMP-9.

NAME AND
NUMBER: Municipal Solid Waste Landfill Facility
gas-monitoring probe GMP-10
LOCATION: U.S. Army Air Defense Artillery Center and Fort Bliss,
Texas State Plane Coordinates 857,156.4237 north 118,864.2410 eas'
DATE INSTALLATION COMPLETED: 12-NOV-94
DRILL METHOD: Hollow-stem auger
DRILLED BY: U.S. Geological Survey

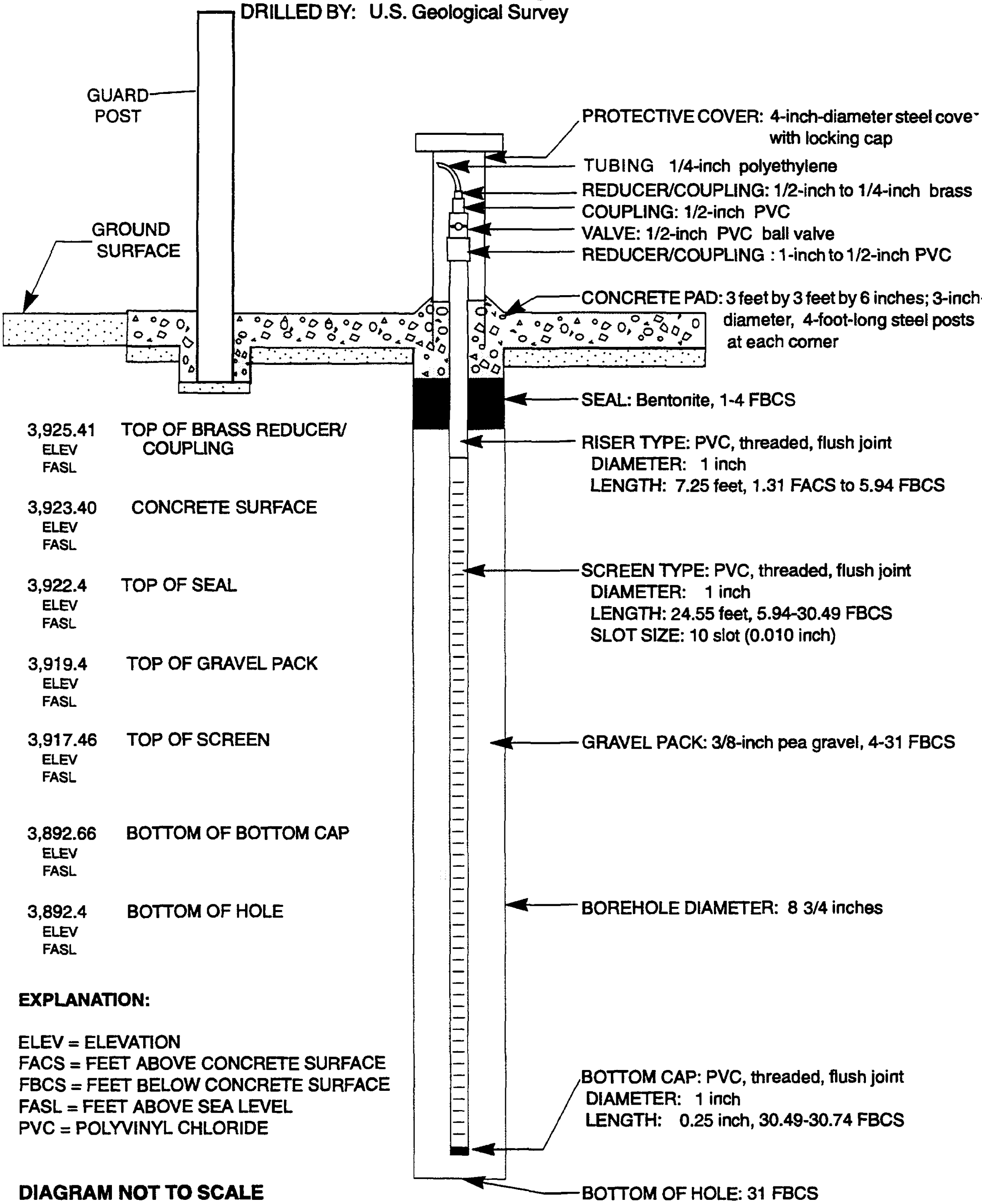

Figure 13.--Completion of gas-monitoring probe GMP-10.

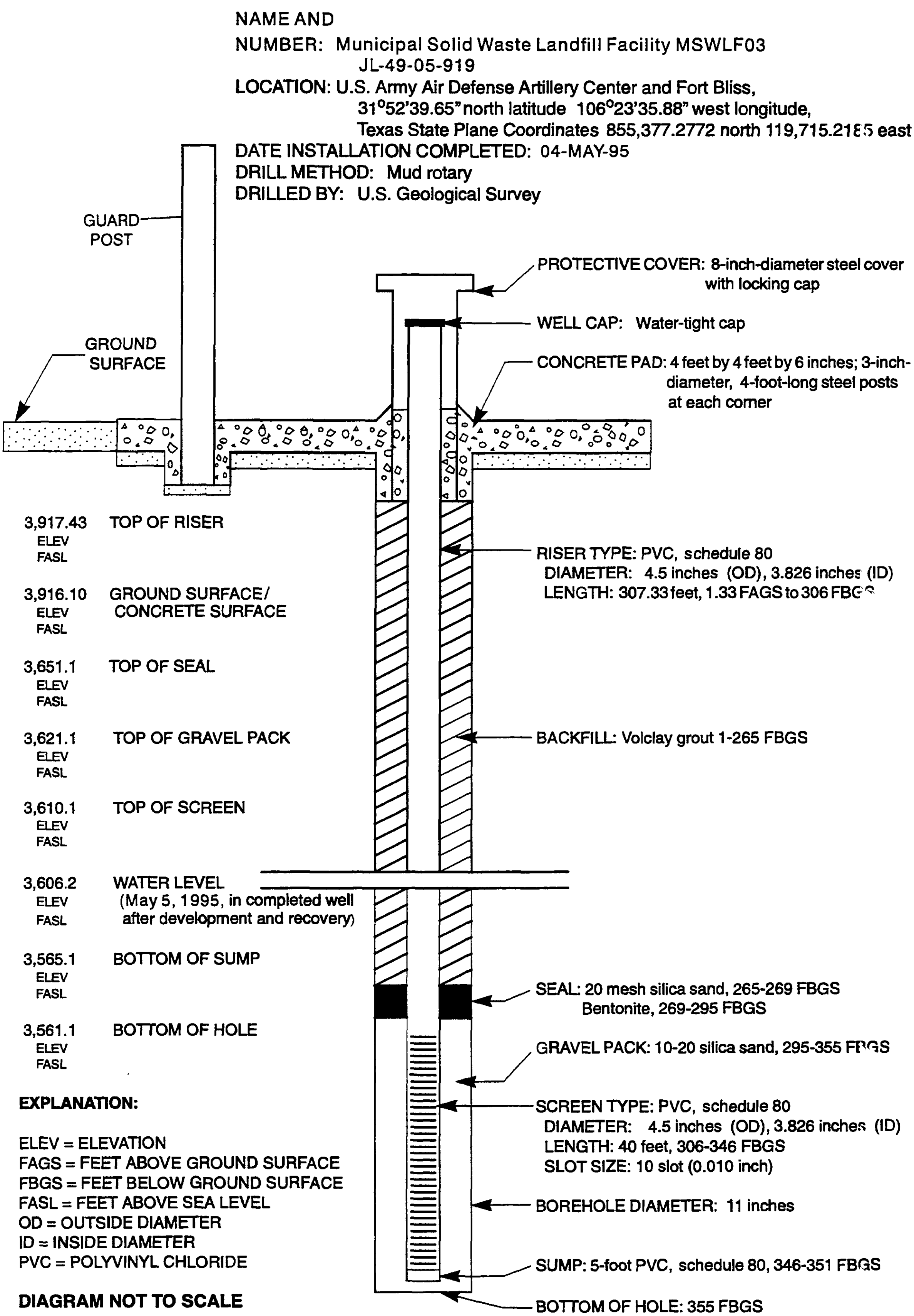

Figure 14.--Completion of ground-water monitoring well MSWLF03.

After the Volclay grout was allowed to settle overnight, the well was developed by surging it with compressed air until the water removed from the well was relatively clear and free of sediment (approximately 5 hours) and water-quality measurements had stabilized. Water samples collected during the surging process were measured for pH, specific conductance, turbidity, and temperature; these measurements are discussed in the "Ground-water chemical data" section of this report. The water level was measured at 309.9 feet below land surface (3,606.2 feet above sea level).

A concrete seal and 4-foot-square by 6-inch-thick concrete surface pad with locking steel protective casing was placed on the Volclay grout and around the riser. Four 3-inch-diameter, cement-filled steel guard posts, which extend about 3 feet above the land surface, were placed at each corner of the concrete surface pad (fig. 14).

Soil-Sampling Procedures

Soil samples collected during drilling of the BH-3 and MSWLF03 boreholes were preserved for laboratory analysis of soil chemistry, physical properties, soil-water chloride concentration, and soil moisture. Soil samples also were collected from the landfill cover in the southern area of the landfill (fig. 3).

Soil samples for soil-chemistry analysis were collected from borehole BH-3 at depths of 5, 20, and 50 feet below land surface. The stainless steel split-spoon sampler was pushed into the undisturbed 2-foot interval bracketing the sampling depth. The sampler was retrieved and opened, and the soil samples were immediately collected. Soil samples for analysis of volatile organic compounds and soil moisture were collected first, followed by collection of soil samples for nonvolatile analysis. The quality-assurance/quality-control (QA/QC) criteria (Sampling and analysis plan for ground-water monitoring at the Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas, U.S. Geological Survey, written commun., March 1995) for the field-sampling and laboratory procedures included collection of (1) one equipment blank; (2) one duplicate soil sample (collected with the soil sample collected at 50 feet); (3) one ambient-conditions blank; (4) one trip blank; (5) one matrix-spike (MS) sample; and (6) one matrix-spike duplicate (MSD) sample. The equipment blank was collected by running American Society of Testing and Materials (ASTM) Type II reagent water through the decontaminated split-sampling barrel and catching it in the appropriate sampling bottles. The duplicate soil sample was collected immediately after collection of the environmental sample. The ambient-conditions blank was prepared on site using ASTM Type II reagent water; a bottle of ASTM Type II water was left open at the sampling location and then poured into a sample bottle after its respective environmental, duplicate, MS, and MSD samples were collected. The trip blank was prepared using ASTM Type II reagent water shipped to the site with the sample bottles and was handled as a sample. The MS/MSD samples were collected at the 50-foot sample interval immediately after the respective environmental and duplicate sample bottles were filled. Collection procedures for MS/MSD samples were identical to those for the environmental and replicate samples. The filled and preserved MS/MSD sample bottles were sent to the laboratory where they were spiked with known concentrations of analytes. Analytical results of these samples are presented in the "Soil-chemical data" section of this report.

Soil samples for analysis of physical properties were collected at various intervals to 55 feet in borehole BH-3 and to 318.5 feet in borehole MSWLF03. A total of 27 soil samples from the recovered cores were collected for laboratory analysis. Twenty-five of the samples were collected from the unsaturated zone (above 306-foot depth); the lower two samples were collected from the saturated zone (below 306-foot depth). With the hollow-stem auger drilling technique, 6-inch-long by 3.5-inch-diameter stainless steel tubes were placed in the split-spoon sampler, and the cores (soil samples) were collected directly into the tubes. When the split-spoon sampler was brought to the surface and opened, the tubes were removed from the sampler and plastic end caps were placed on each end. Electrical tape was wrapped around the cap/tube junction to provide a more secure seal to preserve the moisture content of the samples. With the mud-rotary drilling technique, the core (soil sample) was removed from the split-spoon sampler and placed into split PVC pipe that was about 6 to 8 inches long and approximately the same diameter as the core. The split PVC pipe was capped with plastic end caps, taped with fiberglass filament tape to keep the two split halves together, and sealed with electrical tape at the cap/PVC junction and along split seams to prevent moisture loss.

After each soil sample was collected, it was marked with identifying information and packed with paper or bubble pack in an insulated container to avoid wide temperature fluctuations and mechanical damage. Each insulated container contained a wet sponge to maintain a high humidity and was kept shaded as much as possible until delivered to the laboratory. At the laboratory, the cores stored in PVC were subsampled by pressing smaller brass tubes into the core (Daniel B. Stephens and Assoc., Albuquerque, N. Mex., written commun., 1995). Analytical results of these samples are presented in the "Physical properties, total organic carbon, and pH of soil and sediment samples" section of this report.

Soil samples for analysis of soil-water chloride concentration and soil moisture were collected at approximately 1-foot intervals to 55 feet. At times core recovery was not 100 percent; in these cases, the lost core was assumed to be from the bottom of the interval. Samples were taken from the center of the core using a stainless steel spoon. The outer part of the core was trimmed away to avoid, as much as possible, the effects of moisture migration that might result from heat produced by the auger bit. The samples were placed in 4-ounce glass jars with metal screw-on lids with a composite rubber seal. After the lids were screwed on tightly, plastic electrical tape was wrapped around the jar and lid to help prevent moisture loss from the sample. The samples were then placed in an insulated container with a wet sponge to maintain high humidity and kept in the shade. Analytical results of these samples are presented in the "Soil-water chloride and soil-moisture data" section of this report.

During October 1995, hydraulic conductivity of the landfill cover was determined by an infiltrometer technique (Ankeny, 1992). Hydrologic properties of the landfill cover were measured at five sites (fig. 3). At each site, in situ infiltration was measured at two places about 50 feet apart. After each infiltration measurement was made, a soil core was collected by forcing a brass tube into the moistened soil. The brass tubes filled with soil were capped, taken to the laboratory, and tested for porosity and for percentage of water retained at field capacity and wilting point. Analytical results of these samples are presented in the "Physical properties, total organic carbon, and pH of soil and sediment samples" section of this report.

Lithologic Description of Cores and Cuttings

The lithology for cores and cuttings from boreholes GMP-1 through GMP-10, BH-3, and MSWLF03 were described using a standard format that allowed consistent, comprehensive recording of the data. The format used included:

- Name of unconsolidated sediment (fig. 15)
- Texture
  Grain-size distribution (American Geological Institute, 1989, data sheet 29.1), particle shape (Compton, 1962), sorting (Compton, 1962), grading and packing (American Geological Institute, 1989, data sheets 23.1 and 23.2), and fabric
- Composition of larger grained sediments
  Mineralogy
- Color
  Rock-Color Chart (National Research Council, 1948)
- Sedimentary structures
  Laminations, microfaults, or other discernible structures
- Degree of consolidation and cementation, presence of caliche or calcium carbonate, reaction with 10 percent hydrochloric acid (HCl)
  Loosely, moderately, or strongly compacted; weakly, moderately, or strongly cemented; weak, moderate, or strong reaction with HCl
- Qualitative moisture content
  Dry, moist, wet, or saturated
- Description of basal contact
  Abrupt or gradational basal contact

Lithologic descriptors were limited to those readily visible to the eye or with the use of a 10X hand lens. Made by a USGS hydrologist trained in lithologic description, the descriptions are presented in tables 1-12 and plate 1 (all tables are in the back of the report).

In addition to lithologic descriptions, field observations were made of depth, core recovery, hole collapse and presence of backfill material, field or drilling conditions that affected the collection of cores or cuttings, changes in drilling procedures, and mud weight and viscosity.

Naming of Unconsolidated Sediments

	Main particle			
	Gravel	Sand	Silt	Clay
Greater than 15 percent gravel	Gravel	Gravelly sand	Gravelly silt	Gravelly clay
Greater than 15 percent sand	Sandy gravel	Sand	Sandy silt	Sandy clay
Greater than 15 percent silt	Silty gravel	Silty sand	Silt	Silty clay
Greater than 15 percent clay	Clayey gravel	Clayey sand	Clayey silt	Clay
5-15 percent gravel	Not applicable	Sand with gravel	Silt with gravel	Clay with gravel
5-15 percent sand	Gravel with sand	Not applicable	Silt with sand	Clay with sand
5-15 percent silt	Gravel with silt	Sand with silt	Not applicable	Clay with silt
5-15 percent clay	Gravel with clay	Sand with clay	Silt with clay	Not applicable
Greater than 15 percent gravel plus greater than 15 percent sand	Sandy gravel	Gravelly sand	Gravelly sandy silt	Gravelly sandy clay
Greater than 15 percent gravel plus greater than 15 percent silt	Silty gravel	Gravelly silty sand	Gravelly silt	Gravelly silty clay
Greater than 15 percent gravel plus greater than 15 percent clay	Clayey gravel	Gravelly clayey sand	Gravelly sandy silt	Gravelly clay
Greater than 15 percent sand plus greater than 15 percent silt	Silty sandy gravel	Silty sand	Sandy silt	Sandy silty clay
Greater than 15 percent sand plus greater than 15 percent clay	Sandy clayey gravel	Clayey sand	Sandy clayey silt	Sandy clay
Greater than 15 percent silt plus greater than 15 percent clay	Silty clayey gravel	Silty clayey sand	Clayey silt	Silty clay
NOTE: Other combinations are possible when all particle sizes present are greater than 15 percent--for example, a silty clayey gravelly sand. Other possible combinations exist, such as a gravelly sand with silt.				

Figure 15.--Protocol used in naming of unconsolidated sediments.

Geophysical Logs

Geophysical logs were obtained from the open, mud-filled borehole MSWLF03. Types of logs collected include neutron, gamma ray, resistivity (16-inch and 64-inch normal), and caliper (three arm). Geophysical logs can be used as an exploratory method to help describe the lithology of drill cores and cuttings where there is little or no recovery and may also be useful in identifying the water table. Selected geophysical logs are presented on plate 1.

Soil-Gas and Ambient-Air Data

Soil-gas samples were collected from the 10 GMPs at the MSWLF, and ambient-air samples were collected at four locations inside the MSWLF guard shack (fig. 3). Samples were collected by the USGS on a quarterly basis from December 1994 to September 1995 (four quarters total). The samples were analyzed in the field with a gas-analyzer meter (Landtec model GA-90). Precipitation data, measured at the El Paso International Airport about 4.5 miles southeast of the MSWLF, also were compiled in conjunction with the soil-gas and ambient-air data. Soil-gas and ambient-air sampling and analysis procedures are documented in "Workplan for methane monitoring network at the Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas, Final" (U.S. Geological Survey, written commun., November 1994).

Prior to sampling and analysis, the gas analyzer was calibrated according to manufacturer specifications. After the meter was calibrated, barometric pressure and air temperature were measured. Background ambient-air samples were then collected and analyzed for methane, in percent lower explosive limit; methane, in percent by volume; carbon dioxide, in percent by volume; and oxygen, in percent by volume.

After the background measurements were completed, the GMPs were purged, and soil-gas samples were collected and analyzed directly with the gas-analyzer meter. Procedures for sampling each GMP included measuring the probe pressure before pumping; purging the GMP of three well volumes (approximately 20 minutes pumping time at the pumping rate of about 700 cubic centimeters per minute) or until the gas-analyzer readings stabilized (minimum purge of 1 minute); allowing the GMP to recover; measuring barometric pressure and air temperature; and collecting and analyzing the sample. Each soil-gas sample was analyzed for methane, in percent lower explosive limit; methane, in percent by volume; carbon dioxide, in percent by volume; and oxygen, in percent by volume. Gas temperature also was measured during the sampling process.

After the GMPs were sampled and analyzed, ambient-air samples were collected and analyzed at four locations within the MSWLF guard shack (fig. 3). The ambient-air samples were collected from a linear scan with the gas-analyzer meter within 5 feet of each wall inside the guard shack. These samples were analyzed for methane, in percent lower explosive limit; methane, in percent by volume; carbon dioxide, in percent by volume; and oxygen, in percent by volume. Barometric pressure and air temperature also were measured. Soil-gas and ambient-air data collected from the GMPs and guard shack and precipitation data collected at the El Paso International Airport are presented in tables 13-16.

Soil-Chemical Data

Soil samples collected from borehole BH-3 at depths of 5, 20, and 50 feet below land surface, described in the "Soil-sampling procedures" section of this report, were submitted to Quanterra Environmental Services, Arvada, Colo., for chemical analysis. Soil-chemical data for soil samples collected from borehole BH-3 are presented in table 17; associated data-qualifier codes are presented in table 18. QA/QC and review of analytical data are further discussed in the "Quality assurance/quality control and review of analytical data" section of this report.

HYDROLOGIC DATA

Hydrologic data were compiled from (1) soil and sediment samples collected at or adjacent to the MSWLF during the drilling of boreholes BH-3 and MSWLF03, (2) samples collected from the landfill cover over the older part of the MSWLF, and (3) water samples collected from ground-water monitoring well MSWLF03. These data are presented in the following sections.

Physical Properties, Total Organic Carbon, and pH of Soil and Sediment Samples

Twenty-seven soil and sediment samples representative of the 351-foot cored interval adjacent to the MSWLF were collected from boreholes BH-3 and MSWLF03 and analyzed in the laboratory (Daniel B. Stephens and Associates, Inc., Albuquerque, N. Mex.) for physical properties, total organic carbon, and pH. The 27 samples were analyzed for the following physical properties: initial moisture content, dry bulk density, porosity, saturated hydraulic conductivity, moisture retention percentages at various suction values, calculated parameters for the van Genuchten (van Genuchten, 1980) and Brooks-Corey (Brooks and Corey, 1966) equations relating hydraulic conductivity to saturation, and particle size. Analytical methods used to analyze the samples are presented in table 19; results of the analyses are presented in tables 20-24. The upper 25 samples are representative of the unsaturated zone adjacent to the MSWLF; the lower 2 samples are representative of the saturated zone. Sample numbers (tables 20-24) indicate depth, in feet, for all samples except numbers MSWLF03-81, MSWLF03-318, and MSWLF03-318.5, which were collected from depths of 79, 316, and 316.5 feet, respectively.

Soil samples were collected at five locations on the landfill cover (fig. 3). The area where the samples were collected is representative of the older part of the landfill cover (the filled area outside the Subtitle D area), which consists of locally derived materials. Soil samples collected from the landfill cover were analyzed in the laboratory (Daniel B. Stephens and Associates, Inc., Albuquerque, N. Mex.) for the following physical properties: initial moisture content, dry bulk density, porosity, and moisture retention percentages at various suction values.

In situ infiltration rates were measured in the landfill cover at the same location where the soil samples were collected. Values for saturated and unsaturated hydraulic conductivity were derived from in situ infiltration rate data. Methods used to analyze the landfill-cover samples and in situ measurements are presented in table 25; results of the analyses are presented in tables 26-28.

Soil-Water Chloride and Soil-Moisture Data

Fifty-eight soil samples were collected for soil-water chloride and soil-moisture analysis (table 29). Samples from 2 to 55 feet were collected from core recovered during the drilling of borehole BH-3 using hollow-stem auger drilling techniques. Samples from 92 to 325 feet were collected from core recovered during the drilling of borehole MSWLF03 using mud-rotary drilling techniques. Samples were taken from near the axis of the core using the procedure described in the "Soil-sampling procedures" section of this report.

In the laboratory, the tape was removed from the sample jars, any dirt or adhesive was removed from the exterior, and the jars were weighed (sample weight 1) immediately. Then the lids were removed and the sample, including jar and lid, was oven dried at 105-107 degrees Celsius for 24 hours. Some unused containers were weighed and oven baked to assure that weight loss could not be attributed to changes to the rubber seal that might result from the baking. After oven drying, the samples were weighed again (sample weight 2) and the weight loss was attributed to moisture content. A measured weight of deionized water (about 60 grams) was then added to each jar and the jars were agitated for 8 hours (McGurk and Stone, 1985, p. 15) to redissolve the chloride. The resulting solution was extracted and the chloride concentration was measured by USGS personnel using a chloride electrode (Orion model 95-17B) and the instructions of the electrode manufacturer.

Soil-water chloride concentration was calculated as:

$$C_{sw} = C_{ext} \cdot V_{di}/V_s$$

where C_{sw} = chloride concentration of soil water, in milligrams per liter;
C_{ext} = chloride concentration of extract, in milligrams per liter;
V_{di} = volume of deionized water added to the sample, in milliliters; and
V_{sw} = volume of soil water in the sample, in milliliters.

After the chloride analyses were completed, the jars were emptied and the jars and lids were cleaned and tared; tare weights were subtracted from sample weight 2 to determine dry soil weights. The gravimetric moisture content is equal to the soil-water weight divided by the dry soil weight. The volumetric moisture content is defined by the following equation:

$$SM_v = SM_g \cdot \rho_s/\rho_w$$

where SM_v = volumetric moisture content, in grams per cubic centimeter;
SM_g = gravimetric soil moisture, in grams per gram;
ρ_s = bulk density of sample, in grams per cubic centimeter; and
ρ_w = density of water, in grams per cubic centimeter.

Soil dry bulk density was as reported by Daniel B. Stephens for samples collected at the same depth as those collected for physical-property analysis. For chloride samples collected at intermediate depths, the dry bulk density was estimated by interpolation.

Depth to Ground Water

The primary source of ground water in the vicinity of the MSWLF is the unconsolidated and semiconsolidated sedimentary deposits of the Hueco Bolson. Wells completed in the Hueco Bolson supply water for the City of El Paso, Ciudad Juarez, Fort Bliss Military Reservation (figs. 1-2), private industries, and agricultural areas. Wells discharging large amounts of water generally are drilled at least 200 feet into water-yielding material. City of El Paso and Fort Bliss municipal wells completed in the Hueco Bolson range in depth from about 600 to greater than 1,200 feet. Hydraulic characteristics of the Hueco Bolson vary significantly because of the nonuniform nature of the individual beds (Alvarez and Buckner, 1980). On a regional scale the Hueco Bolson can be considered a single aquifer, but on a local scale the rate and volume of water flowing through individual beds probably vary considerably. Hydraulic characteristics of the Hueco Bolson are presented in Abeyta (1996).

On May 5, 1995, depth to water in well MSWLF03 after drilling, development, and recovery was 309.9 feet. On February 19, 1997, depth to water in well MSWLF03 was 315.0 feet.

Ground-Water Chemical Data

Well MSWLF03 is located hydraulically downgradient from the MSWLF and is assumed to represent the chemistry of ground water moving beneath the MSWLF (Abeyta, 1996, p. 22). A water sample was collected from well MSWLF03 (fig. 3) on February 19, 1997.

Prior to purging and sampling, a water sample from the top of the water column was collected using a translucent Teflon bailer to examine for the presence of floating hydrocarbons. No visible immiscible layer was observed. Prior to sampling, the well was purged with a stainless steel submersible piston pump (Bennett model 1800-7) with a 500-foot Teflon water-discharge line. Prior to purging, the pump and discharge line were decontaminated. The outside of the water-discharge line of the sample pump was washed with a solution of potable water and laboratory-grade detergent. The pump and water-discharge line were rinsed with deionized water, and allowed to dry. The pump and inside of the water-discharge line were decontaminated by pumping approximately 35 gallons of deionized water. After decontamination, approximately 8 gallons of ASTM Type II reagent water were pumped through the water-discharge line, then followed by deionized water to allow collection of the ASTM Type II reagent water for the equipment blank. Compressed nitrogen gas was used to operate the submersible piston pump.

Temperature, turbidity, pH, and specific conductance of the purged ground water were measured periodically during purging until a minimum of 3.5 well volumes of water were removed and the temperature, turbidity, pH, and specific conductance had stabilized.

After purging was completed, the well was sampled. Sample bottles for particular analytes were filled in the following order: (1) volatile organics, (2) metals, (3) nitrates and common ions, and (4) field properties. Sample bottles were filled from the Teflon discharge line and preserved immediately. Duplicate-, MS, and MSD sample bottles were filled immediately after their respective environmental samples were collected.

Chain-of-custody procedures were followed to ensure that samples were collected, protected, stored, handled, analyzed, and disposed of properly by authorized personnel (Sampling and analysis plan for ground-water monitoring at the Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas, Final, U.S. Geological Survey, written commun., March 1995). The USGS team leader who collected the sample in the field had initial custody of the samples. The analytical laboratory, Quanterra Environmental Services, Arvada, Colo., was the ultimate recipient of the samples.

Purged water from the monitoring wells was stored in 55-gallon steel drums next to the well, classified by USGS personnel according to Title 30 TAC 335 Subchapter R, and labeled appropriately. The analytical data for the samples were received and reviewed by USGS staff, and the purged water was determined to be uncontaminated. This determination was based on comparison of analytes identified to U.S. Environmental Protection Agency (EPA)-defined maximum contaminant levels (MCLs) for drinking water (U.S. Environmental Protection Agency, 1994). The purged water was then properly disposed of by USAADACENFB personnel.

Quality Assurance/Quality Control and Review of Analytical Data

The objective of QA/QC is to monitor the overall sampling program and all environmentally related data collection and analysis to ensure that all data produced are suitable for evaluation and interpretation of ground-water quality at the MSWLF site. Detailed QA objectives and goals for accuracy, precision, completeness, representativeness, and comparability and QC objectives and goals for production and documentation of quality data are defined in the Sampling and analysis plan for ground-water monitoring at the Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas, Final (U.S. Geological Survey, written commun., March 1995).

The field QA/QC program was developed to ensure and validate that inconsistencies in protocols did not introduce errors into the data-collection process. Field QC checks were used to (1) identify inconsistencies and (2) minimize the potential for interference or introduction of nonenvironmental contaminants during sample collection, storage, transport, and/or equipment decontamination. Applicable QA/QC samples were collected and analyzed during all field sampling activities at the MSWLF site. The following protocols were followed for collection of QA/QC field samples:

Equipment blanks--One was collected per sampling event (soil and water sample collection) and analyzed for the same parameters as the environmental samples. These samples were collected by pumping ASTM Type II reagent water through the sampling equipment (Bennett pump and tubing) and into the appropriate sample bottles. Equipment blanks for soluble metals were run through a filtering apparatus in the field.

Field duplicates--One was collected per sampling event (soil and water sample collection) and analyzed for the same parameters as the environmental samples. Each field-duplicate bottle was filled immediately after its respective environmental sample bottle was filled. Collection procedures for field duplicates were identical to those for the environmental samples.

Matrix spikes and matrix-spike duplicates--One pair was collected per each sampling event (soil and water sample collection). The MS/MSD sample bottles were filled immediately after their respective field-duplicate sample bottles were filled. Collection procedures for MS/MSD sample bottles were identical to those for the environmental samples. The filled and preserved MS/MSD sample bottles were sent to the laboratory where they were spiked with known concentrations of analytes. Each MS/MSD pair was analyzed for the same parameters as its respective environmental sample.

Trip blanks--One trip blank per sampling event (soil and water sample collection) was prepared for analysis of volatile organic compounds. It was prepared using ASTM Type II reagent water shipped to the site with the sample bottles and handled as a sample.

Ambient-conditions blanks--One ambient-conditions blank per sampling event (soil and water collection) was collected for analysis of volatile organic compounds. It was prepared on site using ASTM Type II reagent water. A bottle of the ASTM Type II water was left open at the sampling location and then poured into its respective sample bottle after its respective environmental sample, sample duplicate, MS, and MSD samples were collected.

The accuracy of laboratory QA/QC program analytical data was evaluated by the following:

Standard methods that, whenever possible, are recognized and considered as standard by the scientific community. EPA methods generally were used.

Calibration standards obtained from the National Institute of Standards and Technology EPA repository or other reliable commercial sources.

Audit samples evaluating laboratory performance on EPA Water Supply and Water Pollution samples to maintain EPA certification.

Surrogate spikes for volatile and semivolatile organic compounds where recovery of organic surrogate analytes should be within three standard deviations of the laboratory-established average recovery of the surrogate analyte.

Known laboratory control samples where recovery of analytes should be within three standard deviations of the laboratory-established average recovery of the analyte. For multiple-analyte samples, 80 percent of the analytes should be within control limits. In-house control limits were used.

Recovery of analytes where recovery should be within three standard deviations of the laboratory-established average recovery of the analyte. For multiple-analyte methods, 95 percent of the analytes should be within control limits.

The precision of analytical data was evaluated by submitting duplicate/environmental, MS, and MSD samples. Analytical results for these samples should be within established control limits as defined in the Sampling and analysis plan for ground-water monitoring at the Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas, Final (U.S. Geological Survey, written commun., March 1995).

Completeness was evaluated by dividing the number of valid data obtained by the total number of samples analyzed and multiplying by 100 to obtain the percentage of analytical data associated with acceptable QC criteria. If 95 percent or greater of the analytical data were in control, then the sample batch was determined to be in control.

Representativeness of field data was evaluated by (1) use of standard methods of measurement and sample collection; (2) collection of sufficient size or amount of sample; (3) documentation of reasons for use of nonstandard techniques; and (4) adherence to chain-of-custody procedures. Representativeness of laboratory analytical data was evaluated by (1) use of preservation techniques to minimize sample degradation that may occur between sample collection and sample analysis; (2) prescribed holding times; (3) field and laboratory blank analyses to determine whether samples have been contaminated; and (4) use of matrix spikes to determine the presence of matrix effects.

Comparability of field and laboratory measurements was evaluated by using standard methods of measurement and analysis of consistent reporting units. Comparability in the laboratory also was evaluated by traceable materials for calibration and QC.

Upon completion of analyses and review of analytical and QA/QC results, the laboratory submitted laboratory analytical results reports to the USGS. The data were reviewed, and data that did not meet the QA/QC criteria were identified. The USGS submitted laboratory analytical results and QA/QC data-validation results to the USAADACENFB. The USAADACENFB reviewed the information and submitted laboratory analytical results reports and QA/QC data-validation reports to the TNRCC. These reports are available to the public at the USAADACENFB, Directorate of Environment, El Paso, Texas, and at the TNRCC Records Center, Austin, Texas.

The QA/QC analytical data collected during sampling at the MSWLF site are not presented in this report; they may be reviewed at the locations mentioned above. Environmental-sample data collected February 19, 1997, from the MSWLF ground-water monitoring well are presented in the following sections of this report. Environmental-sample data that did not meet the QA/QC criteria are still reported in the data table but are qualified. Qualified data are flagged data that may have been noncompliant but were usable.

Results of Analyses

Water-quality data collected February 19, 1997, for MSWLF03 are presented in table 30; associated data-qualifier codes are presented in table 18. Chemical concentrations detected in water for well MSWLF03 were below EPA-identified MCLs (table 31) for public drinking-water supplies.

REFERENCES

Abeyta, C.G., 1996, Geohydrologic site characterization of the Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas: U.S. Geological Survey Water-Resources Investigations Report 95-4217, 36 p.

Alvarez, H.J., and Buckner, A.W., 1980, Ground-water development in the El Paso region, Texas, with emphasis on the resources of the lower El Paso Valley: Texas Department of Water Resources Report 246, 346 p.

American Geological Institute, 1989, Data sheets for geology in the field, laboratory, and office: American Geological Institute.

American Public Health Association and others, 1985, Standard methods for the examination of water and wastewater (16th ed.): Washington, D.C., American Public Health Association, 1,268 p.

Ankeny, M.D., 1992, Methods and theory for unconfined infiltration measurements, *in* Advances in measurement of soil physical properties--Bringing theory into practice: Soil Science Society of America Special Publication 30, p. 123-141.

Ankeny, M.D., Ahmed, M., Kaspar, T.C., and Horton, R., 1991, A simple field method for determining unsaturated hydraulic conductivity: Soil Science Society American Journal, v. 55, p. 467-470.

Ankeny, M.D., Kaspar, T.C., and Horton, R., 1988, Design for an automated tension infiltrometer: Soil Science Society American Journal, v. 52, p. 893-896.

———1989, Design for an automated tension infiltrometer: U.S. Patent #4,884,436.

Brooks, R.H., and Corey, A.T., 1966, Properties of porous media affecting fluid flow, *in* Journal of the Irrigation and Drainage Division: Proceedings of the American Society of Civil Engineers, v. 92, no. IR2, June 1966, p. 61-88.

Compton, R.R., 1962, Manual of field geology: New York, John Wiley and Sons, 378 p.

Elrick, D.E., Reynolds, W.D., Baumgartner, N., Tan, K.A., and Bradshaw, K.L., 1988, In situ measurements of hydraulic properties of soils using the Guelph permeameter and the Guelph infiltrometer, *in* Proceedings of the Third International Workshop on Land Drainage: Columbus, Ohio, December 7-11, 1987.

Klute, A., ed., 1986, Methods of soil analysis, part 1: Madison, Wisc., American Society of Agronomy (2d ed.).

McGurk, B.E., and Stone, W.J., 1985, Evaluation of laboratory procedures for determining soil-water chloride: Socorro, New Mexico Bureau of Mines and Mineral Resources Open-File Report 215, 33 p.

National Research Council, 1948, Rock-Color Chart: Geological Society of America, 16 p.

Perroux, K.M., and White, I., 1988, Designs for disc permeameters: Soil Science Society American Journal, v. 52, p. 1,205-1,215.

Prieksat, M.A., Ankeny, M.D., and Kaspar, T.C., 1991, Design for an automated single-ring ponded infiltrometer: Soil Science Society American Journal, v. 56, p. 1,409-1,411.

Texas Natural Resources Conservation Commission, 1993, 30 TAC 330, Municipal solid waste: Texas Register, Austin, Tex., 194 p. plus updates through December 1993.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service, 1992, Annual summary, Texas: National Oceanic and Atmospheric Administration, v. 97, no. 13, 80 p.

U.S. Environmental Protection Agency, 1983, Methods for chemical analysis of water and wastes: U.S. Environmental Protection Agency Manual 600/4-79-020.

———1986a, Inductively coupled plasma-atomic emission spectrometer method for trace element analysis of water and wastes: Federal Register, 40 CFR 261, app. C, July 1, 1986.

———1986b, Methods for organic chemical analysis of municipal and industrial wastewater: Federal Register, 40 CFR 136, app. A, July 1, 1986.

———1986c, Test methods for evaluating solid waste, physical/chemical methods, SW-846 (3d ed.).

———1991, The RETC code for quantifying the hydraulic functions of unsaturated soils: EPA/600/2-91/065, December 1991.

———1993, Code of Federal Regulations, Title 40, Environment, Parts 257 and 258, Subtitle D, July 1, 1993.

———1994, Summary of EPA finalized national primary drinking water regulations: U.S. Environmental Protection Agency, July 1994, 7 p.

———1996, Drinking water regulations and health advisories: Washington, D.C., U.S. Environmental Protection Agency, Office of Water, 11 p.

van Genuchten, M., 1980, A closed form equation for predicting the hydraulic conductivity of unsaturated soils: Soil Science Society of America Journal, v. 44, p. 892-898.

Wooding, P.A., 1968, Steady infiltration from a shallow circular pond: Water Resources Research, v. 4, p. 1,259-1,273.

Table 1.--Lithology penetrated by borehole GMP-1

[Color codes are from the Rock-Color Chart (National Research Council, 1948). See figure 15 for protocol used in naming unconsolidated sediments. ≤, less than or equal to; <, less than; %, percent; ft, feet; mm, millimeters; HCl, hydrochloric acid]

Lithologic description	Depth interval below land surface (feet)
Sand; fine grained, very well sorted, angular to subangular; arkosic with abundant quartz; light brown (5 YR5/6); loose, slight to moderate reaction with HCl; very slightly moist; abrupt basal contact	0-2
Sandy silt (caliche); sand--very fine to fine grained, pebbles approximately 1% and ≤ 35 mm; sand and pebbles--subangular to subrounded, well sorted; sand--quartz with minor feldspar; grayish orange (10 YR7/4); loose to slightly compacted from 4 to 4.5 ft, slightly to moderately compacted from 4.5 to 6 ft, strong reaction with HCl; dry; gradational basal contact	2-6
Silty sand with caliche; sand--very fine to fine grained, pebbles < 1% at top to 3% at bottom and ≤ 40 mm, well sorted at top to poorly sorted toward bottom; sand--quartz with minor feldspar; pebbles--quartzite, granite; moderately to strongly compacted, caliche abundant as blebs, strong to moderate reaction with HCl; slightly moist to dry	6-7.2
No recovery	7.2-9
Sand; sand--fine to medium grained, pebbles ≤ 3% and ≤ 40 mm; sand--angular, subangular, and subrounded; pebbles--subangular, subrounded, and rounded, moderately well sorted; sand--quartz with minor feldspar; pebbles--sandstone, quartzite, granite; loose, moderate reaction with HCl; slightly moist; abrupt basal contact	9-10.3
Clayey sand; sand--very fine grained, very well sorted; moderate-yellowish-brown (10 YR5/4); moderately compacted, caliche minor and present as blebs, no reaction with HCl, blebs have strong reaction with HCl; slightly moist; abrupt basal contact	10.3-13
Silty sand; sand--very fine grained, very well sorted; dark yellowish orange (10 YR6/6); 1- to 2-mm laminations; moderately to slightly compacted, no reaction with HCl; slightly moist; gradational basal contact	13-15.5
Clayey silty sand with caliche; sand--very fine grained, well sorted; clayey zones--moderate brown (5 YR4/4); silty sand--moderate-yellowish-brown (10 YR5/4); clay as blebs; moderately compacted, caliche as blebs, no to weak reaction with HCl, caliche has strong reaction with HCl; slightly moist; abrupt basal contact	15.5-16.8
Sand; sand--very fine to fine grained, pebbles < 1% and < 45 mm from 18.1 to 18.6 ft; sand--subangular, pebbles--subangular to subrounded, very well to moderately well sorted; sand--arkosic with abundant quartz; pebbles--quartzite, granite; moderate yellowish brown (10 YR5/4); loose, no reaction with HCl; slightly moist; gradational basal contact	16.8-21.4
Sandy clay; sand--very fine to fine grained, well sorted; moderate brown (5 YR4/4); moderately to strongly compacted, friable, caliche present as blebs, very strong reaction with HCl; slightly moist to moist; abrupt basal contact	21.4-22.3
Sand; fine to medium grained, grading to medium to very coarse grained toward bottom, pebbles ≤ 0.5% to < 3% and ≤ 45 mm from 23.5 to 31 ft; sand--angular to subangular, very well sorted from 22.3 to 23.5 ft, well graded from 23.5 to 31 ft; sand--arkosic with abundant quartz; moderate yellowish brown (10 YR5/4); loose, no reaction with HCl; moist to very moist	22.3-31

Table 2.--Lithology penetrated by borehole GMP-2

[Color codes are from the Rock-Color Chart (National Research Council, 1948). See figure 15 for protocol used in naming unconsolidated sediments. $\leq$, less than or equal to; <, less than; %, percent; ft, feet; mm, millimeters; HCl, hydrochloric acid; $CaCO_3$, calcium carbonate]

Lithologic description	Depth interval below land surface (feet)
Silty sand; sand--very fine to fine grained, angular to subangular, well sorted; sand--arkosic with abundant quartz; dark-yellowish-orange (10 YR6/6); loose, strong reaction with HCl; moist (due to current rainshowers); abrupt basal contact	0-4.2
Silty sand (caliche); sand--very fine to fine grained, pebbles < 0.5% and $\leq$ 40 mm; sand--angular to subangular; pebbles--subrounded (fractured by drilling), well sorted; sand--arkosic with very abundant quartz; pebbles--quartzite, granite, andesite(?); dark yellowish orange (10 YR6/6), grayish orange (10 YR7/4) where caliche is very abundant; moderately to strongly compacted, friable, caliche abundant as nodules and as matrix, strong reaction with HCl; dry; gradational basal contact	4.2-8.5
Sand; fine to medium grained with zones of medium to very coarse grains from 8.5 to 10 ft, 10 to 14.3 ft is very fine grained, pebbles < 0.5% at 8.5 ft to $\leq$ 8% at 10 ft, pebbles $\leq$ 35 mm; sand--angular to subangular; pebbles--subangular to subrounded; sand--well graded from 8.5 to 10 ft, very well sorted from 8.5 to 14.3 ft; sand--quartz with minor feldspar; pebbles--quartzite, granite, andesite (?); grayish orange (10 YR7/4) to moderate yellowish brown (10 YR5/4); loose to slightly compacted/cemented toward bottom, friable, no reaction with HCl; very slightly to slightly moist; abrupt grain size contact at 10 ft, abrupt basal contact	8.5-14.3
Sandy clay with caliche; sand--very fine grained; moderate brown (5 YR4/4) with zones of moderate-orange-pink (5 YR8/4) and dusky-yellowish-brown (10 YR2/2) iron stains; moderately to strongly compacted, caliche abundant as blebs, weak reaction with HCl, caliche has strong reaction with HCl; slightly moist; abrupt basal contact	14.3-15.7
Sand; very fine to fine grained, subangular, very well sorted; arkosic with abundant quartz; moderate-yellowish-brown (10 YR5/4); loose to slightly compacted, friable, no to weak reaction with HCl; slightly moist to moist; gradational basal contact	15.7-18
Silty sand; sand--very fine grained, well sorted; sand--arkosic with abundant quartz; moderate yellowish brown (10 YR5/4); 1- to 3-mm laminations; moderately cemented with $CaCO_3$, friable, strong reaction with HCl; slightly moist; abrupt basal contact	18-19.2
Sand; very fine to fine grained at top to medium to coarse grained with pebbles 1% and < 47 mm from approximately 22 ft down; sand--angular to subangular, very well sorted at top to well sorted toward bottom; sand--quartz with minor feldspar; pebbles--quartzite, minor granite, andesite (?); grayish orange (10 YR7/4) to moderate yellowish brown (10 YR5/4); 25.5- to 27.5-ft zone has 1 to 2 mm $CaCO_3$ lens; loose, no reaction with HCl, cemented lens has strong reaction with HCl; moist	19.2-30.4

Table 3.--Lithology penetrated by borehole GMP-3

[Color codes are from the Rock-Color Chart (National Research Council, 1948). See figure 15 for protocol used in naming unconsolidated sediments. ≤, less than or equal to; <, less than; %, percent; ft, feet; mm, millimeters; HCl, hydrochloric acid]

Lithologic description	Depth interval below land surface (feet)
Silty sand; sand--very fine to fine grained, subangular to subrounded, well sorted; sand--arkosic with abundant quartz; dark-yellowish-orange (10 YR6/6); loose, caliche increasing with depth, weak reaction with HCl at top to strong reaction with depth; very slightly moist	0-2
Silty sand (caliche); sand--very fine to fine grained, well sorted; sand--arkosic with abundant quartz; dark yellowish orange (10 YR6/6) at top to moderate yellowish brown (10 YR5/4) toward bottom; caliche--very pale orange (10 YR8/2); loose (cuttings), moderately to strongly compacted, caliche abundant as blebs, nodules, and matrix, strong reaction with HCl; slightly moist to dry; gradational basal contact	2-7.6
Silty sand; sand--very fine to fine grained, subangular to subrounded, well sorted; sand--arkosic with abundant quartz; 7.6-9.9 ft--light brown (5 YR5/6); 9.9-10.4 ft--light brown (5 YR6/4); 9.9-10.4 ft appears to contain part of a clay nodule; weakly compacted, friable, moderate reaction with HCl; slightly moist	7.6-10.4
Sand with silt; sand--very fine grained, well sorted; sand--quartz with minor feldspar and mafics; grayish orange (10 YR7/4); loose, weak to no reaction with HCl; slightly moist; abrupt basal contact	10.4-11.5
Sand; very fine to medium grained, subangular to subrounded, well graded; quartz with minor feldspar and mafics, grayish orange (10 YR7/4) to moderate yellowish brown (10 YR5/4); loose, no reaction with HCl; slightly moist to moist	11.5-14
Sand; very fine to fine grained, subangular to subrounded, very well sorted; quartz with very minor feldspar and mafics; grayish orange (10 YR7/4); loose, no reaction with HCl; slightly moist to moist; gradational basal contact	14-19.7
Silty sand; sand--very fine to very coarse grained, pebbles ≤ 1% and ≤ 25 mm; sand and pebbles--subangular to subrounded, poorly sorted; sand--quartz with minor feldspar and mafics; pebbles--quartzite, granite, obsidian; moderate yellowish brown (10 YR5/4); moderately compacted/cemented, strong to moderate reaction with HCl; slightly moist to moist; gradational basal contact	19.7-21.2
Sand with pebbles; sand--very fine to very coarse grained, pebbles ≤ 2% at top to ≤ 5% toward bottom, ≤ 15% in zones and ≤ 50 mm; sand and pebbles--subangular to subrounded; some pebbles--rounded, well graded, very poorly sorted; sand--quartz with minor feldspar and mafics; pebbles--quartzite, feldspar, basalt, sandstone, andesite(?); pale yellowish brown (10 YR6/2) at top to moderate yellowish brown (10 YR5/4) toward bottom; loose, no reaction with HCl; moist	21.2-30.4

Table 4.--Lithology penetrated by borehole GMP-4

[Color codes are from the Rock-Color Chart (National Research Council, 1948). See figure 15 for protocol used in naming unconsolidated sediments. ≤, less than or equal to; <, less than; %, percent; ft, feet; mm, millimeters; HCl, hydrochloric acid]

Lithologic description	Depth interval below land surface (feet)
Silty sand; sand--very fine to fine grained, subangular to subrounded, well sorted; sand--arkosic with abundant quartz and equal but lesser amounts of feldspar and mafics; moderate yellowish brown (10 YR5/4) to light brown (5 YR5/6); loose, moderate to strong reaction with HCl; slightly moist	0-2
Silty sand (caliche) grading to sandy silt; silt more abundant than at 0 to 2 ft; sand--very fine to fine grained, subangular to subrounded; well sorted sand--arkosic with abundant quartz and equal but lesser amounts of feldspar and mafics; light brown (5 YR6/4); caliche--very pale orange (10 YR8/2), moderate yellowish brown (10 YR5/4) near bottom; loose to powdery, slightly compacted toward bottom, caliche abundant as nodules, moderate to strong reaction with HCl; slightly moist; gradational basal contact	2-4.8
Silty sand; sand--very fine to fine grained, subangular to subrounded, well sorted; sand--arkosic with abundant quartz; light brown (5 YR5/6); caliche--very pale orange (10 YR8/2); moderately compacted, caliche abundant as veins and as blebs in lower 1.3 ft, weak reaction with HCl, caliche has strong reaction with HCl; slightly moist; gradational basal contact	4.8-9.9
Sand; sand--very fine to fine grained to approximately 25 ft, very fine to very coarse grained from 25 to 30.4 ft, 20 to 25 ft has 0.2-ft zone with pebbles < 3% and ≤ 40 mm; sand and pebbles--subangular to subrounded, very well sorted to 25 ft, well graded from 25 to 30.4 ft; sand--quartz, also minor feldspar and mafics from 20 to 30.4 ft; pebbles--quartzite; 9.9 ft to approximately 20 ft--dark yellowish orange (10 YR6/6) to moderate yellowish orange (10 YR5/4); 20-25 ft--pale yellowish brown (10 YR6/2); 25-30.4 ft--grayish orange (10 YR7/4); loose, 11 to 12 ft contains some caliche and has moderate to strong reaction with HCl, otherwise no to weak reaction with HCl; slightly moist at top to slightly moist to moist toward bottom	9.9-30.4

Table 5.--Lithology penetrated by borehole GMP-5

[Color codes are from the Rock-Color Chart (National Research Council, 1948). See figure 15 for protocol used in naming unconsolidated sediments. ≤, less than or equal to; <, less than; %, percent; ft, feet; mm, millimeters; HCl, hydrochloric acid]

Lithologic description	Depth interval below land surface (feet)
Silty sand; sand--very fine to fine grained; subangular to subrounded, very well sorted; sand--arkosic with abundant quartz; moderate yellowish brown (10 YR5/4) to light brown (5 YR5/6); loose, moderate to strong reaction with HCl; slightly moist	0-1.3
Silty sand (caliche); silt more abundant than in previous interval; sand--very fine to fine grained, zone of pebbles < 2% and < 12 mm at 10 ft, subangular to subrounded, very well to well sorted; sand--quartz with minor feldspar; 1.3-4 ft--light brown (5 YR5/6); 4-7 ft--dark yellowish orange (10 YR6/6); 7-10.6 ft--pale-yellowish-orange (10 YR8/6); caliche--very pale orange (10 YR8/2); 1.3-4 ft--loose (cuttings); 4-10.6 ft--moderately compacted, friable, caliche as blebs and matrix, strong to moderate reaction with HCl; slightly moist; gradational basal contact	1.3-10.6
Sand; very fine to very coarse grained from 10.6 to 11.5 ft, fine to medium grained toward bottom, pebbles < 3% and ≤ 45 mm from 10.6 to 14.1 ft; sand--subangular to subrounded; pebbles--subrounded to rounded, well graded from 10.6 to 11.5 ft, well sorted toward bottom; sand--quartz with minor feldspar and mafics; pebbles--quartz, metagranite, minor amounts of basalt; moderate yellowish brown (10 YR5/4); loose, no reaction with HCl; slightly moist from 10.6 to 14.1 ft, moist toward bottom	10.6 - 17.5
No recovery	17.5-20
Sand; fine to medium grained, subangular to subrounded, well sorted; quartz with minor feldspar and mafics; moderate yellowish brown (10 YR5/4); loose, no reaction with HCl, moist, moisture increasing toward basal contact; abrupt basal contact	20-22
Sandy clay; sand--very fine to fine grained, pebbles < 5% and ≤ 18 mm, angular to subrounded; sand--quartz; pebbles--quartz, metagranite, ultramafics; moderate brown (5 YR4/4) to moderate brown (5 YR3/4); moderately compacted, no reaction with HCl; moist	22-22.5
No recovery	22.5-25
Sand with pebbles; sand--very fine to very coarse grained, pebbles < 10% and ≤ 55 mm, very poorly sorted; sand--quartz with minor feldspar and mafics; pebbles--quartz, quartzite, metagranite, and metavolcanics; sand--light brown (5 YR5/6) to dark yellowish brown (10 YR4/2); pebbles--variegated color; loose, no reaction with HCl; moist	25-26.2
No recovery	26.2-30

Table 6.--Lithology penetrated by borehole GMP-6

[Color codes are from the Rock-Color Chart (National Research Council, 1948). See figure 15 for protocol used in naming unconsolidated sediments. ≤, less than or equal to; <, less than; %, percent; ft, feet; mm, millimeters; HCl, hydrochloric acid]

Lithologic description	Depth interval below land surface (feet)
Silty sand; sand--very fine to fine grained with < 2% coarse grains; sand--subangular to subrounded, very well sorted; sand--arkosic with abundant quartz; moderate yellowish brown (10 YR5/4) to light brown (5 YR5/6); loose, moderate to strong reaction with HCl; slightly moist	0-1.5
Silty sand (caliche); silt more abundant than above section; sand--very fine to fine grained, sand--subangular to subrounded, very well to well sorted; sand--arkosic with abundant quartz; light brown (5 YR6/4) to moderate orange pink (5 YR8/4); caliche--very pale orange (10 YR8/2); loose (cuttings) to moderately compacted, friable, caliche as blebs, strong to moderate reaction with HCl; slightly moist; abrupt basal contact	1.5-5.4
(Caliche) silty sand; sand--very fine to fine grained; sand--subangular to subrounded, very well to well sorted; sand--arkosic with abundant quartz; very pale orange (10 YR8/2) to grayish orange (10 YR7/4); moderately compacted, caliche dominant as large blebs, strong reaction with HCl; slightly moist; abrupt basal contact	5.4-7.8
Silty sand; sand--very fine to fine grained, very well sorted; sand--quartz with minor feldspar and mafics; pale yellowish orange (10 YR8/6) to dark yellowish orange (10 YR6/6); loose, moderate to strong reaction with HCl; slightly moist; gradational basal contact	7.8-11.3
Clayey sand; sand--very fine to fine grained; sand--subrounded to rounded, very well sorted; sand--quartz with feldspar; grayish orange (10 YR7/4) to light brown (5 YR6/4); moderately compacted, friable, moderate reaction with HCl; slightly moist; abrupt basal contact	11.3-11.9
Sand; very fine to fine grained, pebbles < 2% and < 40 mm from 14 to 19.5 ft, subangular to subrounded; pebbles--subrounded to rounded; sand--very well sorted; pebbles--poorly sorted; sand--quartz with minor feldspar and mafics, feldspar decreasing toward bottom while mafics increase; pebbles--quartzite, granite, sandstone; grayish orange (10 YR7/4) to dark yellowish orange (10 YR6/6); loose, weak to no reaction with HCl; moist	11.9-30

Table 7.--Lithology penetrated by borehole GMP-7

[Color codes are from the Rock-Color Chart (National Research Council, 1948). See figure 15 for protocol used in naming unconsolidated sediments. ft, feet; HCl, hydrochloric acid]

Lithologic description	Depth interval below land surface (feet)
Silty sand; sand--very fine to fine grained; sand--subrounded to subangular, well sorted; sand--arkosic with abundant quartz; moderate yellowish brown (10 YR5/4) to dark yellowish orange (10 YR6/6); loose (mostly cuttings), strong reaction with HCl; slightly moist (recent rain showers); gradational basal contact	0-5.3
(Caliche) silty sand; sand--very fine to fine grained, subrounded to subangular, moderately well sorted; sand--arkosic with abundant quartz; dark yellowish orange (10 YR6/6), where caliche is abundant--very pal orange (10 YR8/2); caliche is dominant in lower 1.9 ft and sand occurs as veins; moderately compacted to strongly compacted where caliche is more abundant, caliche as blebs, moderate to strong reaction with HCl; slightly moist (recent rain showers)	5.3-7.5
Silty sand; sand--very fine to fine grained, subangular to subrounded, well sorted; sand--quartz with minor feldspar; light brown (5 YR5/6); loose to slightly compacted, friable, caliche minor as blebs, moderate to strong reaction with HCl; slightly moist; gradational basal contact	7.5-9.5
Silty sand (caliche); sand--very fine to fine grained, subangular to subrounded, well sorted; sand--quartz with minor feldspar; grayish orange (10 YR7/4); caliche--very pale orange (10 YR8/2); moderately to strongly compacted, caliche as large and medium blebs, and as matrix, strong reaction with HCl; dry; gradational basal contact	9.5-12.3
Sand with silt; sand--very fine to fine grained, subangular to subrounded, well sorted; sand--quartz with minor feldspar and mafics; pale yellowish orange (10 YR8/6) to dark yellowish orange (10 YR6/6); moderately compacted, friable, no reaction with HCl; slightly moist; fairly abrupt contact	12.3-13
Clayey sand; sand--very fine to fine grained; sand--angular to subangular, moderately well sorted; sand--quartz with minor mafics; light brown (5 YR5/6) to moderate brown (5 YR4/4); iron stains--dusky yellowish brown (10 YR2/2); clay contains iron staining; moderately to strongly compacted, slight reaction with HCl; slightly moist	13-13.4
No recovery	13.4-15
Sand; very fine to very coarse grained, sand becomes fine to medium grained from 25 to 30 ft, subrounded to angular, poorly sorted from 15 to 25 ft, well sorted from 25 to 30 ft; quartz with minor feldspar and mafics; grayish orange (10 YR7/4) to dark yellowish orange (10 YR6/6); loose, weak to moderate reaction with HCl, weak reaction from 25 to 30 ft; slightly moist	15-30

Table 8.--Lithology penetrated by borehole GMP-8

[Color codes are from the Rock-Color Chart (National Research Council, 1948). See figure 15 for protocol used in naming unconsolidated sediments. ≤, less than or equal to; <, less than; %, percent; ft, feet; mm, millimeters; HCl, hydrochloric acid]

Lithologic description	Depth interval below land surface (feet)
Silty sand; sand--very fine to fine grained, subangular to subrounded, moderately well sorted; sand--arkosic with abundant quartz; moderate yellowish brown (10 YR5/4); loose, strong reaction with HCl; dry; abrupt basal contact	0-3.4
Silty sand (caliche); sand--very fine to fine grained, pebbles < 1% and ≤ 10 mm toward bottom; sand--subangular, moderately well sorted; sand--arkosic with abundant quartz; grayish orange (10 YR7/4); caliche--very pale orange (10 YR8/2); strongly to moderately compacted, friable, strong reaction with HCl; dry	3.4-7
Sand; very fine to very coarse grained, pebbles approximately 1% and ≤ 43 mm; sand--subangular to subrounded, well graded, moderately well sorted coarse to very coarse grains in bottom 1.2 ft; sand--quartz with minor feldspar and mafics; pebbles--quartzite, granite, andesite(?), magnetite(?), iron abundant; pale yellowish brown (10 YR6/2) to moderate yellowish brown (10 YR5/4); loose, strong reaction with HCl; dry; abrupt basal contact	7-12.7
Silty sand (caliche); sand--very fine to fine grained, well sorted; sand--quartz with minor feldspar and mafics; grayish orange (10 YR7/4), very pale orange (10 YR8/2) where caliche is more abundant; 1- to 3-mm lamination zones; moderately to very strongly compacted, loose in zones where less caliche, caliche as blebs, veins, and matrix, moderate to strong reaction with HCl; dry where caliche is abundant, slightly moist where more sandy; abrupt basal contact	12.7-15.6
Sandy clay with caliche; sand--very fine grained; moderate brown (5 YR4/4) to moderate brown (5 YR3/4); caliche--very pale orange (10 YR8/2); iron stains/organic matter--dusky yellowish brown (10 YR2/2); organic matter abundant (roots); strongly compacted, caliche as blebs, veins, and matrix, friable, strong reaction with HCl; dry to slightly moist	15.6-16.5
No core recovery; cuttings--**Sand**	16.5-25
No core recovery; cuttings--**Sand**	25-30.4

Table 9.--Lithology penetrated by borehole GMP-9

[Color codes are from the Rock-Color Chart (National Research Council, 1948). See figure 15 for protocol used in naming unconsolidated sediments. ≤, less than or equal to; <, less than; %, percent; ft, feet; mm, millimeters; HCl, hydrochloric acid; $CaCO_3$, calcium carbonate]

Lithologic description	Depth interval below land surface (feet)
Silty sand; sand--very fine to fine grained; sand--subangular, well sorted; sand--arkosic; light brown (5 YR5/6); loose, moderate reaction with HCl; slightly moist (from overnight rain showers); abrupt basal contact	0-2.5
Sandy silt (caliche); sand--very fine grained, minor medium grains, well sorted; sand--arkosic; very pale orange (10 YR8/2); loose, powdery, strong reaction with HCl; dry; gradational basal contact	2.5-4.4
Silty sand (caliche); sand--very fine to fine grained, pebbles < 1% and ≤ 12 mm; sand--subangular; pebbles--subangular to subrounded; sand--quartz with minor feldspar and mafics; pebbles--quartzite, sandstone; grayish orange (10 YR7/4); caliche--very pale orange (10 YR8/2); moderately to strongly compacted, friable, caliche abundant as blebs, becoming less abundant toward bottom, strong reaction with HCl; dry	4.4-9
Sand; fine to medium grained, pebbles < 1% and ≤ 25 mm; sand--subangular; pebbles--subrounded to rounded, well graded; sand--arkosic with abundant quartz; pebbles--sandstone, quartzite; moderate yellowish brown (10 YR5/4); loose, no reaction with HCl; slightly moist; abrupt basal contact	9-12.4
Sandy clay; sand--very fine to fine grained; sand--subangular; sand--arkosic; moderate brown (5 YR4/4); caliche blebs--grayish orange (10 YR7/4); iron stains--dusky yellowish brown (10 YR2/2); moderately to strongly compacted, friable, caliche as blebs; clay--no to weak reaction with HCl; caliche--strong reaction with HCl; slightly moist	12.4-12.8
No recovery	12.8-14.6
Sand; very fine to fine grained, angular to subangular, very well sorted; quartz with minor feldspar and mafics; moderate yellowish brown (10 YR5/4); iron stains--dusky yellowish brown (10 YR2/2); loose, no to weak reaction with HCl; slightly moist to moist; gradational basal contact	14.6-17.3
Clayey sand; sand approximately 85% and very fine to medium grained, subangular, well graded; sand--quartz with minor feldspar and mafics; light brown (5 YR5/6); moderately compacted/cemented, $CaCO_3$ cement, friable, $CaCO_3$ as blebs and cement, moderate to strong reaction with HCl, slightly moist; abrupt basal contact	17.3-17.9
Sand; very fine to very coarse grained, angular, subangular, and subrounded, well graded; quartz with minor feldspar and mafics; pale yellowish brown (10 YR6/2) to moderate yellowish brown (10 YR5/4); loose, moderate reaction with HCl, strong reaction from 29 to 30.4 ft; slightly moist, slightly moist to moist from 29 to 30.4 ft	17.9-30.4

Table 10.--Lithology penetrated by borehole GMP-10

[Color codes are from the Rock-Color Chart (National Research Council, 1948). See figure 15 for protocol used in naming unconsolidated sediments. <, less than; %, percent; ft, feet; mm, millimeters; HCl, hydrochloric acid]

Lithologic description	Depth interval below land surface (feet)
Silty sand; sand--very fine to fine grained, angular to subangular, minor subrounded, well sorted; sand--arkosic with abundant quartz; moderate yellowish brown (10 YR5/4); loose, strong reaction with HCl; moist (due to rain showers)	0-4.3
Silty sand (caliche); sand--very fine to fine grained, angular to subangular, minor subrounded, well sorted; sand--arkosic with abundant quartz; moderate yellowish brown (10 YR5/4); moderately to strongly compacted toward bottom, caliche abundant as nodules, blebs, and matrix, strong reaction with HCl; dry; gradational basal contact	4.3-8
Silty sand; sand--very fine to fine grained in upper 1.6 ft with approximately 5% medium grains; lower 1.5 ft--fine to medium grained, angular to subangular; sand--quartz with minor feldspar; upper 1.6 ft--light brown (5 YR5/6); lower 1.5 ft--moderate yellowish brown (10 YR5/4); loose; upper 1.6 ft--strong reaction with HCl; lower 1.5 ft--no reaction with HCl; slightly moist	8-11.1
No recovery	11.1-12.5
Sand; fine to medium grained, angular to subangular, well sorted; quartz with minor feldspar and mafics; pale yellowish brown (10 YR6/2) to moderate yellowish brown (10 YR5/4); loose, no reaction with HCl; slightly moist; abrupt basal contact	12.5-14
Sandy clay; sand approximately 40% and very fine grained, well sorted; moderate brown (5 YR4/4), dusky-yellowish-brown (10 YR2/2) iron stains; strongly compacted, friable, no reaction with HCl; slightly moist; abrupt basal contact	14-14.7
Sand; very fine to fine grained, angular to subangular, well sorted; quartz with minor feldspar and mafics; moderate yellowish brown (10 YR5/4); loose, no reaction with HCl; slightly moist; abrupt basal contact	14.7-15.5
Clayey sand with caliche; sand--very fine to fine grained, well sorted; moderate brown (5 YR4/4) where clayey to dark yellowish orange (10 YR6/6) where caliche abundant; 1- to 4-mm laminations at bottom of interval; moderately to strongly compacted, caliche as blebs and as matrix toward bottom; weak reaction with HCl where clayey (clay decreases toward bottom), strong reaction where caliche is abundant; slightly moist	15.5-18.6
Sand; very fine to fine grained, grading to fine to medium grained below 22.5 ft, 0.4-ft pebbles zone between 22.5 and 24.2 ft with pebbles 20% and 11 to 49 mm, pebbles < 1% and 10 to 63 mm from 27.5 to 30.4 ft; sand--angular to subangular; pebbles--subrounded to rounded, very well to well sorted; pebbles zone--moderately sorted; sand--quartz with minor feldspar and mafics; pebbles--quartzite, granite; moderate yellowish brown (10 YR5/4) to pale yellowish brown (10 YR6/2); loose, no reaction with HCl; slightly moist to moist from 18.6 to 21.5 ft, moist from 21.5 to 30.4 ft	18.6-30.4

Table 11.--Lithology penetrated by borehole BH-3

[Color codes are from the Rock-Color Chart (National Research Council, 1948). See figure 15 for protocol used in naming unconsolidated sediments. ≤, less than or equal to; <, less than; %, percent; ft, feet; mm, millimeters; HCl, hydrochloric acid; $CaCO_3$, calcium carbonate; SiO_2, silica]

Lithologic description	Depth interval below land surface (feet)
Silty sand; sand--very fine to fine grained, approximately 5% medium grains in upper 3 ft; sand--subangular to subrounded, very well sorted; sand--quartz, minor mafics, and feldspar; moderate yellowish brown (10 YR5/4); loose to slightly compacted, caliche present in minor zones as matrix and blebs from 3 to 8 ft, moderately cemented in caliche zones, moderate reaction with HCl, strong reaction in caliche zones; slightly moist	0-12.3
Silty sand and caliche; sand--very fine to fine grained, subangular to subrounded, very well sorted; sand--quartz, minor feldspar, and mafics; moderate yellowish brown (10 YR5/4), moderately to strongly cemented, $CaCO_3$ cement, caliche abundant as matrix and blebs, strong reaction with HCl; slightly moist; abrupt basal contact	12.3-14.3
Clay and caliche with sand; sand ≤ 15% and very fine to fine grained, very minor medium grains, well sorted; sand--quartz; clay--moderate brown (5 YR4/4) to moderate brown (5 YR3/4); caliche--pinkish gray (5 YR8/1); moderately to strongly compacted, caliche as matrix, blebs, and nodules, clay has weak reaction with HCl, caliche, and some matrix has strong reaction; slightly moist--dried out quickly; organic material (roots) abundant; abrupt basal contact	14.3-16.1
Sand; very fine to fine grained, <3% medium grains, pebbles < 1% and ≤ 38 mm, 0.4-ft zone near 18.4 ft has very fine to very coarse grains with < 10% pebbles, ≤ 38 mm; sand--subangular to subrounded; pebbles--subrounded, well sorted, 0.4-ft zone is well graded; sand--quartz, very minor feldspar and mafics; pebbles--quartzite; pale yellowish brown (10 YR6/2); loose; no reaction with HCl; slightly moist	16.1-20
No recovery	20-23
Sand; very fine to very coarse grained, pebbles < 1% and ≤ 23 mm, 0.5-ft zone with pebbles approximately 10% near 32.5 ft, one 70-mm cobble near top of section; sand--subangular to subrounded, well graded; sand--quartz, minor mafics; pebbles--quartzite, basalt(?); cobble--conglomerate; loose, no reaction with HCl; moist	23-38
Sand; medium to very coarse grained, pebbles < 2% and ≤ 10 mm, subangular to subrounded, well sorted; quartz, moderate feldspar, and mafics; pale yellowish brown (10 YR6/2); loose to slightly compacted; no reaction with HCl; moist; abrupt basal contact	38-39
Sand; very fine to fine grained, subangular to subrounded, very well sorted; quartz, minor feldspar, and mafics; loose to slightly compacted, no reaction with HCl; moist; gradational basal contact	39-40.3

Table 11.--Lithology penetrated by borehole BH-3--Concluded

Lithologic description	Depth interval below land surface (feet)
Sand with pebbles; sand--very fine to very coarse grained, pebbles $\leq$ 8% and $\leq$ 30 mm, subangular to subrounded, well graded; sand--quartz, minor feldspar, and mafics; pebbles--quartzite, andesite(?); pale yellowish brown (10 YR6/2); one approximately 55-mm decomposing(?) pebble, $CaCO_3$ cemented conglomerate, strong reaction with HCl at about 45 ft; loose to slightly compacted, zones of weakly cemented sand from 41 to 48 ft, SiO_2(?) cement, no reaction with HCl; moist	40.3-48
Sand; fine grained, subangular to subrounded, very well sorted; quartz with minor feldspar and mafics; pale yellowish brown (10 YR6/2); loose; no reaction with HCl; moist	48-52
Sand; very fine to very coarse grained, pebbles < 3% and $\leq$ 15 mm, some clay present as blebs, sand--subangular to subrounded; pebbles--subrounded, well graded; sand--quartz with minor feldspar and mafics; pebbles--quartzite; sand--pale yellowish brown (10 YR6/2); clay--moderate yellowish brown (10 YR5/4); loose to slightly compacted, slight to moderate reaction with HCl; moist	52-53.4
Sand; very fine to fine grained, some clay present as blebs; sand--subangular to subrounded, well sorted; sand--quartz with minor feldspar and mafics; sand--pale yellowish brown (10 YR6/2); clay--moderate yellowish brown (10 YR5/4); loose to slightly compacted, no reaction with HCl; moist	53.4-56

Table 12.--Lithology penetrated by borehole MSWLF03

[Color codes are from the Rock-Color Chart (National Research Council, 1948). See figure 15 for protocol used in naming unconsolidated sediments. ≤, less than or equal to; <, less than; %, percent; ft, feet; mm, millimeters; HCl, hydrochloric acid; $CaCO_3$, calcium carbonate]

Lithologic description	Depth interval below land surface (feet)
For description of 0-56 ft see table 11.	0-56
No recovery (few lumps of clay with abundant black organic matter left in barrel from 49- to 59-ft drilling interval)	56-66
Clay; moderate yellowish brown (10 YR5/4); very slick, shinny organic matter visible but not very abundant; very strongly compacted, caliche present as nodules, no to weak reaction with HCl, nodules have strong reaction with HCl; moist	66-67.2
No recovery	67.2-69
Clay; moderate yellowish brown (10 YR5/4); pebbles below clay; moderately compacted, no to weak reaction with HCl; moist	69-70
Sand and pebbles; only pebbles recovered, pebbles ≤ 40 mm, subrounded to rounded; pebbles--quartzite, andesite, and granite	70-72
Clayey silty sand; sand--very fine to fine grained, subangular, very well sorted; sand--quartz with minor feldspar and mafics; clay--moderate brown (5 YR4/4); sand--moderate yellowish brown (10 YR5/4); clay present as matrix, lenses, and blebs, grayish-black (N2) organic matter as veins and blebs abundant in clay; moderately to strongly compacted, sand has weak to moderate reaction with HCl, clay has no reaction; moist	72-79.4
No recovery	79.4-91.4
Silty sand with clay; sand--very fine grained, very well sorted; sand--quartz; pale yellowish brown (10 YR6/2) to moderate yellowish brown (10 YR5/4) where clayey; clay minor and in zones as lenses with grayish-black (N2) organic matter as blebs between laminated clay lenses; loosely compacted, moderately compacted in the presence of clay, caliche present as matrix and minor as veins broken in the presence of clay, moderate to strong reaction with HCl; moist	91.4-92
Sand; upper approximately 4 ft--very fine to fine grained with silt; lower approximately 1.4 ft--fine to medium grained with approximately 3% medium to very coarse grains and < 0.5% pebbles ≤ 35 mm; sand--subangular to subrounded; pebbles--subrounded to rounded; upper approximately 4 ft--very well sorted; lower approximately 1.4 ft--moderately well sorted to moderately well graded; sand--quartz, feldspar, and minor mafics; upper approximately 4 ft--moderate yellowish brown (10 YR5/4); lower approximately 1 ft--pale yellowish brown (10 YR6/2); upper 4 ft--moderately compacted, no reaction with HCl; lower 1.4 ft--slightly compacted/weakly cemented(?), moderately cemented when dried out, $CaCO_3$ cement, weak to moderate reaction with HCl when wet, strong reaction when dried out; upper 4 ft--moist; lower 1 ft--very moist to wet	92-97.4
No recovery	97.4-102

Table 12.--Lithology penetrated by borehole MSWLF03--Continued

Lithologic description	Depth interval below land surface (feet)
Silty sand with clay; sand--very fine to fine grained; sand--subangular, well sorted sand; sand--quartz with minor feldspar and mafics; sand--moderate yellowish brown (10 YR5/4); clay--moderate brown (5 YR4/4); clay present mostly as lenses blebs, pebbles at bottom of recovery ≤ 35 mm, subrounded to rounded, quartzite, andesite, dacite(?); moderately compacted, moderate reaction with HCl, grayish black (N2) organic matter present in some clay zones; moist	102-102.4
No recovery (driller reported 102- to 108-ft interval as approximately 4 ft sand, then approximately 1.5 ft clay(?) and 0.5 ft(?) sand)	102.4-108
Silty sand; sand--very fine to fine grained; sand--subangular, very well sorted; sand--quartz, minor mafics toward bottom; moderate yellowish brown (10 YR5/4); minor clay stringers--moderate brown (5 YR4/4), pale yellowish brown (10 YR6/2) and moderate yellowish brown (10 YR5/4) toward bottom; slightly compacted, friable in lower 0.4 ft, no reaction with HCl, 3-inch $CaCO_3$ cemented sand lens at 118 ft is very strongly cemented and has strong reaction with HCl; moist	108-118.4
Sandstone; $CaCO_3$ cemented sand lens; very strongly cemented, strong reaction with HCl	118.4-118.6
No recovery (driller reported soft drilling from 123 to 133 ft, probably sand, pebbles at top of 133- to 136.6-ft interval ≤ 38 mm; subrounded to rounded; andesite, cross-bedded fine-grained sandstone)	118.6-133
Silty sand; sand--very fine grained, well sorted; sand--quartz; moderate yellowish brown (10 YR5/4) with pale-brown (5 YR5/2) clay zones at top to dark yellowish orange (10 YR6/6) at middle to moderate yellowish brown (10 YR5/4) toward bottom; moderately to strongly compacted, stronger where clay is present, caliche as matrix, nodules, and blebs in clay zones have strong reaction with HCl, otherwise no reaction with HCl; moist	133-136.6
No recovery	136.6-143
Silty clay; moderate yellowish brown (10 YR5/4); organic matter--grayish black (N2); caliche--very pale orange (10 YR8/2); clay laminated around caliche nodules; very strongly compacted caliche present as nodules ≤ 30 mm, clay has no reaction with HCl, nodules have strong reaction; moist; gradational basal contact	143-143.4
Sand with silt; sand--very fine to fine grained, very well sorted; sand--quartz with minor mafics, moderate yellowish brown (10 YR5/4); slightly compacted, moderate reaction with HCl; moist; gradational basal contact	143.4-143.7
Clayey sand; sand--very fine grained, well sorted; moderate yellowish brown (10 YR5/4); moderately to strongly compacted, weak reaction with HCl; moist; gradational basal contact	143.7-144.2
Clay; moderate yellowish brown (10 YR5/4); organic veins--grayish black (N2); 1- to 2-mm laminations, shiny clay; strongly compacted, caliche present as stringers; clay--weak reaction with HCl; caliche--strong reaction; moist; gradational basal contact	144.2-144.9

Table 12.--Lithology penetrated by borehole MSWLF03--Continued

Lithologic description	Depth interval below land surface (feet)
Clayey silty sand; sand--very fine grained, very well sorted; sand--quartz with minor feldspar and mafics; dark yellowish orange (10 YR6/6) to moderate yellowish brown (10 YR5/4); strongly compacted, no reaction with HCl; moist; gradational basal contact	144.9-145.7
Sandy silty clay; sand--very fine grained; moderate brown (5 YR4/4); strongly compacted/cemented, caliche as matrix and nodules ≤ 30 mm, weak to strong reaction with HCl (nodules have strong reaction); moist; gradational basal contact	145.7-147.5
Silty sand; sand--very fine to fine grained, well sorted; sand--quartz with minor mafics; dark yellowish orange (10 YR6/6) to moderate yellowish brown (10 YR5/4); moderately compacted/cemented, $CaCO_3$ cement, friable when dry; moist	147.5-151.2
No recovery (driller reported **sand and gravel** for interval)	151.2-160.5
Clayey silty sand; sand--very fine grained, well sorted; dark yellowish orange (10 YR6/6) to moderate yellowish brown (10 YR5/4); strongly compacted caliche present as matrix and as nodules, moderate to strong reaction with HCl; moist; gradational basal contact	160.5-161.5
Silty clay; moderate brown (5 YR4/4) with grayish-black (N2) organic blebs and stringers; some laminations, shiny in zones; moderately to strongly compacted, no to weak reaction with HCl, moist; abrupt basal contact	161.5-162.3
Sandstone (lens); sand--medium grained, subangular, well sorted; quartz with minor mafics and feldspar; pale yellowish brown (10 YR6/2); very strongly cemented, $CaCO_3$ cement, strong reaction with HCl; moist	162.3-162.7
Clayey silty sand; sand--very fine grained, well sorted; moderate yellowish brown (10 YR5/4); moderately compacted/cemented, $CaCO_3$ cement, somewhat friable when dry, moderate reaction with HCl; moist; gradational basal contact	162.7-164.3
Clay; very fine grained sand stringers; moderate brown (5 YR4/4) with grayish-black (N2) organic blebs and stringers; clay is shiny in zones and somewhat laminated; strongly compacted, caliche present as nodules ≤ 10 mm, clay has no reaction with HCl, caliche has strong reaction; moist; abrupt basal contact	164.3-165.1
Silty sand; sand--very fine grained, very well sorted; sand--quartz with minor feldspar; moderate yellowish brown (10 YR5/4) with zones of light-brown (5 YR5/6) stains(?); no reaction with HCl, slightly compacted; moist, gradational basal contact	165.1-166.3
Silty clay; moderate yellowish brown (10 YR5/4) with stringers of light-brown (5 YR5/6) stains; moderately compacted, $CaCO_3$ present as matrix, moderate reaction with HCl, 1-mm white (N9) veins have no reaction with HCl; moist abrupt basal contact	166.3-166.7
Silty sand; sand--very fine grained, very well sorted; sand--quartz; moderate yellowish brown (10 YR5/4) to dark yellowish orange (10 YR6/6); slightly compacted/cemented, soft and somewhat friable, $CaCO_3$ cement, weak to moderate reaction with HCl; moist; gradational basal contact	166.7-167.3

Table 12.--Lithology penetrated by borehole MSWLF03--Continued

Lithologic description	Depth interval below land surface (feet)
Clay; moderate brown (5 YR4/4); shiny in zones, somewhat laminated; strongly compacted, caliche present as nodules, clay has no reaction with HCl, nodules have strong reaction; moist; abrupt basal contact	167.3-167.5
Silty sand with clay zones; sand--very fine to fine grained, subangular, moderately well sorted; sand--quartz with minor feldspar and mafics; sand--moderate yellowish brown (10 YR5/4); clay--moderate brown (5 YR3/4); clay as 20-mm lens with 3-mm white (N9) vein; weakly to moderately compacted; somewhat friable, minor $CaCO_3$ cementing, clay has no reaction with HCl and is strongly compacted, sand has no, weak, and moderate reaction with HCl; moist	167.5-168
Silty sand; sand--very fine to fine grained, subangular, well sorted; sand--quartz, minor feldspar, and mafics; moderate yellowish brown (10 YR5/4); moderately compacted/cemented, somewhat friable when dried out, $CaCO_3$ cement, moderate reaction with HCl; moist; abrupt basal contact	168-172.9
Sand; very fine to medium grained with <3% coarse to very coarse grains, pebbles < 1% and ≤ 5 mm; sand--subangular, some subrounded; pebbles--subrounded to rounded, well graded; sand--quartz with minor feldspar and mafics; slightly compacted, no to weak reaction with HCl; moist to very moist in bottom 0.5 ft; abrupt basal contact	172.9-178.5
Clay with sand; sand present as stringers, stringers silty, very fine grained sand and very fine to fine-grained sand, well sorted; sand--quartz; clay moderate brown (5 YR4/4); moderately to strongly compacted, caliche present as matrix and nodules ≤ 15 mm, clay has no to weak reaction with HCl, stringers have moderate to strong reaction, caliche nodules have strong reaction; moist; abrupt basal contact	178.5-179.1
Silty sand; sand--very fine grained, very well sorted; moderate yellowish brown (10 YR5/4); moderately compacted, moderate reaction with HCl; moist; abrupt basal contact	179.1-179.8
Silty clay; moderate yellowish brown (10 YR5/4); zones of lamination; moderately compacted, no to weak reaction with HCl; moist	179.8-180.6
No recovery	180.6-187
Silty clay; moderate yellowish brown (10 YR5/4); zones of lamination, grayish-black (N2) organic matter as blebs and veins; moderately compacted, no to weak reaction with HCl; moist; gradational basal contact	187-187.7
Silty sand; very fine grained, well sorted; moderate yellowish brown (10 YR5/4); moderately compacted/cemented, moderate to strong reaction with HCl, friable when dry, moist; gradational basal contact	187.7-188.7
Silty clay; moderate yellowish brown (10 YR5/4) to moderate brown (5 YR4/4); moderately to strongly compacted, no reaction with HCl; moist	188.7-190

Table 12.--Lithology penetrated by borehole MSWLF03--Continued

Lithologic description	Depth interval below land surface (feet)
Silty sand; sand--very fine to fine grained, < 1% coarse to very coarse grains, subangular to subrounded, well sorted; sand quartz with minor feldspar an mafics; light brown (5 YR5/6) to moderate brown (5 YR4/4); loose, no reaction with HCl; very moist; gradational basal contact	190-191.2
Sand; very fine to medium grained, more medium grained toward bottom of interval, subangular to subrounded, moderately graded/moderately sorted; quartz, minor feldspar, and mafics; loose, no reaction with HCl; wet, very wet at approximately 195 ft	191.2-200
No recovery (probably wet sand)	200-205.8
Sand; medium to very coarse grained, pebbles < 1% and $\leq$ 10 mm, subangular to subrounded; pebbles--rounded, moderately sorted/graded; quartz with minor feldspar and mafics; pale yellowish brown (10 YR6/2) to moderate yellowish brown (10 YR5/4); loose, no reaction with HCl; wet to very wet; abrupt basal contact	205.8-206.7
Clay nodule; moderate brown (5 YR4/4); organic material--grayish black (N2); organic matter as blebs, clay shiny; moderately compacted, friable when dry, no reaction with HCl; moist; abrupt basal contact	206.7-206.9
Sand; fine to medium grained, subangular to subrounded, moderately sorted/graded; pale reddish brown (10 YR6/2) to moderate yellowish brown (10 YR5/4); loose, no reaction with HCl; very wet/wet; abrupt basal contact	206.9-208.6
Clay; lens, laminated, organic matter abundant; moderate yellowish brown (10 YR5/4); organic matter--grayish black (N2); strongly compacted, caliche as matrix, moderate reaction with HCl, moist; abrupt basal contact	208.6-208.8
Sand; medium grained, < 2% very coarse grains, subangular to subrounded, well sorted; quartz with minor feldspar and mafics; loose, no to weak reaction with HCl; very wet to wet	208.8-210.5
No recovery	210.5-218.8
Sand; medium grained, < 2% very coarse grains, subangular to subrounded, well sorted; quartz with minor feldspar and mafics; loose, some $CaCO_3$ cementing at bottom, no to weak reaction with HCl, bottom has strong reaction with HCl; very wet to wet	218.8-219.8
Silty clay; moderate brown (5 YR4/4); moderately compacted, friable when dry, moderate reaction with HCl; moist; abrupt basal contact	219.8-220.8
Silty sand; sand--fine grained, very well sorted; sand--quartz with minor feldspar and mafics; light brown (5 YR5/6) to moderate yellowish brown (10 YR5/4); weakly compacted, no reaction with HCl; moist	220.8-222.5
No recovery	222.5-226
Silty sand with clay; sand--very fine grained, sand is well sorted; sand--quartz with minor feldspar and mafics; moderate brown (5 YR4/4) to light brown (5 YR5/6); moderately compacted, no reaction with HCl; moist; abrupt basal contact	226-228.9

Table 12.--Lithology penetrated by borehole MSWLF03--Continued

Lithologic description	Depth interval below land surface (feet)
Sand; fine grained, subangular to subrounded, very well sorted; quartz with minor feldspar and mafics; pale yellowish brown (10 YR6/2) to moderate yellowish brown (10 YR5/4); loose, no reaction with HCl; wet	228.9-237.3
No recovery	237.3-242.5
Silty sandy clay; sand--very fine grained, sand is well sorted; moderate yellowish brown (10 YR5/4) to moderate brown (5 YR4/4); caliche present as matrix and nodules ≤ 30 mm, strongly compacted, some cementing, moderate to strong reaction with HCl; moist; abrupt basal contact	242.5-243.2
Sand; fine grained, subangular to subrounded, very well sorted; quartz with minor feldspar and mafics; pale yellowish brown (10 YR6/2) to moderate yellowish brown (10 YR5/4); iron stringers ≤ 10 mm thick at top and bottom of section (strong magnetic reaction); weakly compacted, no reaction with HCl; very moist; abrupt basal contact	243.2-244.1
Silty sandy clay; sand--very fine grained; sand--well sorted; moderate brown (5 YR4/4) to moderate yellowish brown (10 YR5/4); moderately to strongly compacted moist	244.1-246.5
No recovery	246.5-255.4
Clay; moderate brown (5 YR4/4); very tight, shiny and compacted, very minor zones of caliche nodules ≤ 10 mm and minor organics as blebs, clay has no reaction with HCl; moist	255.4-260
No recovery	260-280
Sand with silt; sand--fine to very fine grained, subangular, well sorted; sand--quartz with minor feldspar and mafics; moderate brown (5 YR4/4); loose, no reaction with HCl; moist	280-286.2
No recovery	286.2-290
Sand; fine to very fine grained, pebbles < 3% and < 35mm; pebbles--subrounded, sand coarser toward bottom of interval, subangular, well sorted; sand--quartz with minor feldspar and mafics; pebbles--quartzite, granite; moderate brown (5 YR4/4); silty clay laminations 3 to 15 mm thick scattered throughout section; loose, no reaction with HCl, moist	290-294.7
Clayey sand; very fine grained, angular, well sorted; quartz with minor feldspar and mafics; light brown (5 YR5/6); compacted, no reaction with HCl; moist; abrupt basal contact	294.7-295.7
Silty clay; moderate brown (5 YR4/4); compacted, moderate reaction with HCl; dry; abrupt basal contact	295.7-297.2
Silty sand; subangular to subrounded, well sorted; quartz with minor feldspar and mafics; moderate yellowish brown (10 YR5/4); loose, no reaction with HCl; wet; abrupt basal contact	297.2-299.8
No recovery (driller reported mostly sand and some clay)	299.8-309.7
Clay with silt; moderate brown (5 YR4/4); strongly compacted, weak reaction with HCl; moist; gradational basal contact	309.7-310

Table 12.--Lithology penetrated by borehole MSWLF03--Concluded

Lithologic description	Depth interval below land surface (feet)
Silty sand; sand--very fine to fine grained, well sorted; quartz with minor mafics; moderate yellowish brown (10 YR5/4); moderately compacted clay laminations 2 mm to 6 mm thick, moderate reaction with HCl; moist to very moist	310-310.4
Sand; very fine to fine grained, subangular to subrounded, well sorted; quartz with mafics and minor feldspar; moderate yellowish brown (10 YR5/4); weakly compacted to loose, no reaction with HCl; very moist/wet	310.4-316.7
No recovery	316.7-321.2
Silty sandy clay; sand--very fine grained; moderate yellowish brown (10 YR5/4) to moderate brown (5 YR4/4); strongly compacted, caliche as matrix and blebs, clay has no to weak reaction with HCl, moderate to strong reaction where sandy and silty; moist; gradational basal contact	321.2-321.7
Silty sand with clay; sand--very fine grained, well sorted, moderate yellowish brown (10 YR5/4), moderate brown (5 YR4/4) where more clayey; moderately to strongly compacted, caliche present as matrix and nodules in upper 4.2 ft, no to weak reaction with HCl, caliche zones (minor) have moderate to strong reaction with HCl; moist in upper 4.2 ft to slightly moist to moist toward bottom; gradational basal contact	321.7-329.6
Silty clay; moderate yellowish brown (10 YR5/4) to moderate brown (5 YR7/4); caliche minor as blebs and stringers; clay has no reaction with HCl, caliche has moderate to strong reaction with HCl; slightly moist	329.6-331
Silty sand; sand--very fine grained; moderate yellowish brown (10 YR5/4); weakly to moderately compacted, two strongly cemented $CaCO_3$ sand zones near base, $CaCO_3$ present as matrix and nodules in zones, no to weak reaction with HCl, strong reaction where caliche; moist	331-333.5
Sand; very fine to fine grained with zones of medium grains < 1% pebbles, subrounded, well sorted; quartz with minor mafics and feldspar; moderate yellowish brown (10 YR5/4); loose, no reaction with HCl; wet	333.5-351
No recovery (hole reamed to a total depth of 355 feet)	351-355

Table 13.--Analytical results of soil-gas and ambient-air samples collected at the Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas, December 1994

[See figure 3 for sampling locations. H_2O, water; Hg, mercury; F, Fahrenheit; %, percent; LEL, lower-explosive limit; CO_2, carbon dioxide; O_2, oxygen; N/A, not applicable]

Site number	Date	Time	Probe pressure (inches H_2O)	Barometric pressure (inches Hg)	Air temperature (degrees F)	Gas temperature (degrees F)	Methane (% by volume)	Methane (% LEL)	CO_2 (% by volume)	O_2 (% by volume)
GMP-1	06DEC94	1045	26.2	26.1	60	60	0.0	0.0	0.0	19.9
GMP-2	06DEC94	1330	26.1	26.1	63	63	0.0	0.0	0.8	19.5
GMP-3	06DEC94	1450	26.1	26.1	68	70	0.0	0.0	1.2	18.8
GMP-4	06DEC94	1520	26.0	26.0	64	66	0.0	0.0	0.6	19.7
GMP-5	06DEC94	1405	26.1	26.1	67	69	0.0	0.0	1.8	18.8
GMP-6	06DEC94	1555	26.0	26.0	65	68	0.0	0.0	0.1	19.9
GMP-7	06DEC94	1625	26.1	26.1	63	66	0.0	0.0	0.4	19.8
GMP-8	06DEC94	1655	26.1	26.1	62	65	0.0	0.0	0.0	20.0
GMP-9	06DEC94	1220	26.1	26.1	64	66	0.0	0.0	8.5	14.1
GMP-10	06DEC94	1130	26.2	26.1	63	63	0.9	18	11.0	12.4
GAA1	06DEC94	1252	N/A	26.1	64	64	0.0	0.0	0.0	20.3
GAA2	06DEC94	1257	N/A	26.1	64	64	0.0	0.0	0.0	20.3
GAA3	06DEC94	1258	N/A	26.1	64	64	0.0	0.0	0.0	20.3
GAA4	06DEC94	1259	N/A	26.1	64	64	0.0	0.0	0.0	20.3

METEOROLOGICAL DATA:
Cumulative precipitation, in inches, 3 months prior to this initial sampling event: 2.54 Location of precipitation measurement site: El Paso International Airport
Date of last measurement: 06SEPT94 Date of current measurement: 06DEC94 Number of cumulative days for cumulative precipitation: 91

COMMENTS: LANDTEC GA-90 meter (serial number GA1.1 975) calibrated on 06DEC94 at 1000. Although carefully calibrated, meter readings of O_2 in ambient air, outside and many feet away from wells, was stable at 20.3% for all sites.

Table 14.--Analytical results of soil-gas and ambient-air samples collected at the Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas, March 1995

[See figure 3 for sampling locations. H_2O, water; Hg, mercury; F, Fahrenheit; %, percent; LEL, lower-explosive limit; CO_2, carbon dioxide; O_2, oxygen; N/A, not applicable]

Site number	Date	Time	Probe pressure (inches H_2O)	Barometric pressure (inches Hg)	Air temperature (degrees F)	Gas temperature (degrees F)	Methane (% by volume)	Methane (% LEL)	CO_2 (% by volume)	O_2 (% by volume)
GMP-1	08MAR95	0856	26.4	26.3	42	56	0	0	0	20.2
GMP-2	08MAR95	0935	26.4	26.4	55	60	0	0	0	19.7
GMP-3	08MAR95	1018	26.4	26.4	53	59	0	0	2.4	17.9
GMP-4	08MAR95	1110	26.3	26.5	56	60	0	0	2.8	17.3
GMP-5	08MAR95	1146	26.3	26.3	67	66	0	0	1.3	18.8
GMP-6	08MAR95	1227	26.3	26.3	60	63	0	0	0.3	19.7
GMP-7	08MAR95	1304	26.3	26.3	69	68	0	0	2.3	17.5
GMP-8	08MAR95	1336	26.3	26.3	62	63	0	0	0.2	20.1
GMP-9	08MAR95	1424	26.3	26.3	71	72	0	0	9.0	13.0
GMP-10	08MAR95	1506	26.3	26.3	66	65	2.4	48	14.4	9.0
GAA1	08MAR95	1520	26.3	26.3	67	N/A	0	0	0	20.2
GAA2	08MAR95	1523	26.3	26.3	67	N/A	0	0	0	20.2
GAA3	08MAR95	1522	26.3	26.3	66	N/A	0	0	0	20.2
GAA4	08MAR95	1521	26.3	26.3	66	N/A	0	0	0	20.2

METEOROLOGICAL DATA:

Cumulative precipitation in inches since last sampling event: 2.5

Location of precipitation measurement site: El Paso International Airport

Date of last measurement: 06DEC94

Date of current measurement: 08MAR95

Number of cumulative days for cumulative precipitation: 92

COMMENTS: LANDTEC GA-90 meter (serial number GA1.1 975) calibrated on 08MAR95 at 0800. Note: meter reading of % O_2 in background air was 20.2% immediately after calibration. This slight discrepancy from the the accepted value of 20.9% is characteristic of the meter. Sunlight appeared to have an effect on gas temperature.

Table 15.--Analytical results of soil-gas and ambient-air samples collected at the Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas, June 1995

[See figure 3 for sampling locations. H_2O, water; Hg, mercury; F, Fahrenheit; %, percent; LEL, lower-explosive limit; CO_2, carbon dioxide; O_2, oxygen; N/A, not applicable]

Site number	Date	Time	Probe pressure (inches H_2O)	Barometric pressure (inches Hg)	Air temperature (degrees F)	Gas temperature (degrees F)	Methane (% by volume)	Methane (% LEL)	CO_2 (% by volume)	O_2 (% by volume)
GMP-1	15JUNE95	1046	26.0	26.0	98	95	0	0	0.4	18.0
GMP-2	15JUNE95	1116	26.0	26.0	101	100	0	0	0.5	17.8
GMP-3	15JUNE95	1130	26.0	26.0	101	98	0	0	2.5	16.5
GMP-4	15JUNE95	1142	26.0	26.0	98	98	0	0	2.2	17.0
GMP-5	15JUNE95	1153	26.0	26.0	100	100	0	0	1.1	18.5
GMP-6	15JUNE95	1202	26.0	26.0	97	98	0	0	0.1	19.1
GMP-7	15JUNE95	1213	26.0	26.0	96	101	0	0	1.6	17.5
GMP-8	15JUNE95	1223	26.0	26.0	101	96	0	0	0.0	19.1
GMP-9	15JUNE95	1234	26.0	26.0	95	96	0	0	6.8	14.4
GMP-10	15JUNE95	1253	26.0	26.0	101	105	1.4	28	14.5	8.3
GAA1	15JUNE95	1101	N/A	26.0	98	N/A	0	0	0	20.2
GAA2	15JUNE95	1102	N/A	26.0	98	N/A	0	0	0	20.2
GAA3	15JUNE95	1103	N/A	26.0	98	N/A	0	0	0	20.2
GAA4	15JUNE95	1104	N/A	26.0	98	N/A	0	0	0	20.2

Cumulative precipitation, in inches, since last sampling event: 0.39 Location of precipitation measurement site: El Paso International Airport
Date of last measurement: 08MAR95 Date of current measurement: 15JUNE95 Number of cumulative days for cumulative precipitation: 99

COMMENTS: LANDTEC GA-90 meter (serial number GA1.1 975) calibrated on 15JUNE95 at 1015. Note: meter reading of % O_2 in background air was 20.2% immediately after calibration. This slight discrepancy from the accepted value of 20.9% is characteristic of the meter. Sunlight appeared to have an effect on gas temperature.

Table 16.--Analytical results of soil-gas and ambient-air samples collected at the Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas, September 1995

[See figure 3 for sampling locations. H_2O, water; Hg, mercury; F, Fahrenheit; %, percent; LEL, lower-explosive limit; CO_2, carbon dioxide; O_2, oxygen; N/A, not applicable]

Site number	Date	Time	Probe pressure (inches H_2O)	Barometric pressure (inches Hg)	Air temper-ature (degrees F)	Gas temper-ature (degrees F)	Methane (% by volume)	Methane (% LEL)	CO_2 (% by volume)	O_2 (% by volume)
GMP-1	21SEPT95	1320	26.1	26.1	87	89	0	0	0.4	17.6
GMP-2	21SEPT95	1333	26.1	26.1	86	92	0	0	0.5	17.6
GMP-3	21SEPT95	1350	26.1	26.1	87	85	0	0	2.2	16.3
GMP-4	21SEPT95	1403	26.1	26.1	86	89	0	0	3.9	14.9
GMP-5	21SEPT95	1415	26.1	26.1	90	88	0	0	1.8	16.6
GMP-6	21SEPT95	1430	26.1	26.1	91	88	0	0	0.3	18.1
GMP-7	21SEPT95	1444	26.1	26.1	88	88	0	0	2.6	15.8
GMP-8	21SEPT95	1455	26.1	26.1	90	88	0	0	0.1	18.6
GMP-9	21SEPT95	1502	26.1	26.1	87	88	0	0	6.7	13.3
GMP-10	21SEPT95	1512	26.1	26.1	86	88	1.3	26	15.1	6.9
GAA1	21SEPT95	1525	N/A	26.1	86	N/A	0	0	0	19.4
GAA2	21SEPT95	1526	N/A	26.1	86	N/A	0	0	0	19.4
GAA3	21SEPT95	1527	N/A	26.1	86	N/A	0	0	0	19.4
GAA4	21SEPT95	1528	N/A	26.1	86	N/A	0	0	0	19.4

METEOROLOGICAL DATA:
Cumulative precipitation in inches since last sampling event: 5.79 Location of precipitation measurement site: El Paso International Airport
Date of last measurement: 15JUNE95 Date of current measurement: 21SEPT95 Number of cumulative days for cumulative precipitation: 98

COMMENTS: LANDTEC GA-90 meter (serial number GA1.1 975) calibrated on 21SEPT95 at 1300 with 15% CO_2, 15% methane calibration gas, and 4% O_2 calibration gas. **Note:** O_2 measurements for background atmospheric O_2 ranged from 18.9% to 19.4%; therefore, reported values for O_2 need to be interpreted with this in mind.

Table 17.--Soil-chemical results[1] of soil samples collected from borehole BH-3, Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas

[Qualifier codes are identified in table 18. --, no data; ASL, above sea level; mg/kg, milligrams per kilogram; ND, not detected]

Parameter and units	Method number[2]	Reporting limit	Soil sample from 5 feet below land surface result/qualifier	Soil sample from 20 feet below land surface result/qualifier	Soil sample from 50 feet below land surface result/qualifier
Date	--	--	25APR95	25APR95	26APR95
Time	--	--	1330	1655	0958
USGS sample number	--	--	MSWLF0302	MSWLF0303	MSWLF0304
Laboratory sample number	--	--	041760-0002-SA	041760-0003-SA	041760-0004-SA
Sample depth, elevation, feet ASL	--	0.1	3,911.1	3,896.1	3,866.1
Volatile organic compounds:					
Acetone, mg/kg	SW8240	0.10	ND	ND	ND
Acrolein, mg/kg	SW8240	0.30	ND	ND	ND
Acrylonitrile, mg/kg	SW8240	0.20	ND	ND	ND
Benzene, mg/kg	SW8240	0.10	ND	ND	ND
Bromodichloromethane, mg/kg	SW8240	0.10	ND	ND	ND
Bromoform, mg/kg	SW8240	0.10	ND	ND	ND
Bromomethane, mg/kg	SW8240	0.10	ND	ND	ND
Carbon disulfide, mg/kg	SW8240	0.10	ND	ND	ND
Carbon tetrachloride, mg/kg	SW8240	0.10	ND	ND	ND
Chlorobenzene, mg/kg	SW8240	0.10	ND	ND	ND
Chloroethane, mg/kg	SW8240	0.10	ND	ND	ND
Chloroform, mg/kg	SW8240	0.10	ND	ND	ND
Chloromethane, mg/kg	SW8240	0.10	ND	ND	ND
Dibromochloromethane, mg/kg	SW8240	0.10	ND	ND	ND
Dibromomethane, mg/kg	SW8240	0.10	ND	ND	ND
Dichlorodifluoromethane, mg/kg	SW8240	0.10	ND	ND	ND
Ethanol, mg/kg	SW8240	--	ND/c	ND/c	ND/c
Ethylbenzene, mg/kg	SW8240	0.10	ND	ND	ND
Ethyl methacrylate, mg/kg	SW8240	0.10	ND	ND	ND
Iodomethane, mg/kg	SW8240	0.10	ND	ND	ND
Methylene chloride, mg/kg	SW8240	0.10	0.0077/j	0.0072/j	0.0078/j
Styrene, mg/kg	SW8240	0.10	ND	ND	ND
Tetrachloroethene, mg/kg	SW8240	0.10	ND	ND	ND
Volatile organic compounds--Continued:					
Toluene, mg/kg	SW8240	0.10	ND	ND	ND
Trichloroethene, mg/kg	SW8240	0.10	ND	ND	ND
Trichlorofluoromethane, mg/kg	SW8240	0.10	ND	ND	ND
Vinyl acetate, mg/kg	SW8240	0.30	ND	ND	ND
Vinyl chloride, mg/kg	SW8240	0.10	ND	ND	ND
Xylenes (total), mg/kg	SW8240	0.10	ND	ND	ND
cis-1,3-Dichloropropene, mg/kg	SW8240	0.10	ND	ND	ND

Table 17.--Soil-chemical results[1] of soil samples collected from borehole BH-3, Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas--Concluded

Parameter and units	Method number[2]	Reporting limit	Soil sample from 5 feet below land surface result/qualifier	Soil sample from 20 feet below land surface result/qualifier	Soil sample from 50 feet below land surface result/qualifier
trans-1,3-Dichloropropene, mg/kg	SW8240	0.10	ND	ND	ND
trans-1,4-Dichloro-2-butene, mg/kg	SW8240	0.10	ND	ND	ND
1,1,1-Trichloroethane, mg/kg	SW8240	0.10	ND	ND	ND
1,1,2,2-Tetrachloroethane,mg/kg	SW8240	0.10	ND	ND	ND
1,1,2-Trichloroethane, mg/kg	SW8240	0.10	ND	ND	ND
1,1-Dichloroethane, mg/kg	SW8240	0.10	ND	ND	ND
1,1-Dichloroethene, mg/kg	SW8240	0.10	ND	ND	ND
1,2,3-Trichloropropane, mg/kg	SW8240	0.10	ND	ND	ND
1,2-Dichloroethane, mg/kg	SW8240	0.10	ND	ND	ND
1,2-Dichloroethene (total), mg/kg	SW8240	0.10	ND	ND	ND
1,2-Dichloropropane, mg/kg	SW8240	0.10	ND	ND	ND
2-Butanone, mg/kg	SW8240	0.20	ND	ND	ND
2-Chloroethyl vinyl ether, mg/kg	SW8240	0.50	ND	ND	ND
2-Hexanone, mg/kg	SW8240	0.10	ND	ND	ND
4-Methyl-2-pentanone, mg/kg	SW8240	0.10	ND	ND	ND
Metals:					
Arsenic, total, mg/kg	SW6010	30	ND	ND	ND
Barium, total, mg/kg	SW6010	10.0	51.3	64.8	31.4
Cadmium, total, mg/kg	SW6010	2.0	ND	ND	ND
Chromium, total, mg/kg	SW7191	4.0	3.2/j	0.87/j	1.1/j
Cobalt, total, mg/kg	SW6010	4.0	2.5/j	1.7/j	1.5/j
Metals--Continued					
Copper, total, mg/kg	SW6010	3.0	3.2	1.2/j	1.3/j
Lead, total, mg/kg	SW6010	20.0	5.9/j	ND	3.6/j
Nickel, total, mg/kg	SW6010	4.0	4.3	2.7/j	3.0/j
Selenium, total, mg/kg	SW6010	40.0	ND/C,J,M	ND/C,J,M	ND/C,J,M
Nitrite as nitrogen, total, mg/kg	E354.1	0.050	ND/M	ND/M	ND/M
Nitrate plus nitrite as nitrogen, total, mg/kg	E353.2 modified	0.50	ND/M	ND/M	ND/M
Soil moisture, percent	D2216	0.10	5.1	3.4	4.2
Total petroleum hydrocarbons, mg/kg	SW3550/ 418.1	20.0	ND	ND	ND

[1]Analyses performed by Quanterra Environmental Services, Arvada, Colorado
[2]Method numbers preceded by SW are from:
U.S. Environmental Protection Agency, 1986c
Method numbers preceded by E are from:
U.S. Environmental Protection Agency, 1983, 1986a, b
Method numbers preceded by D are from:
American Society for Testing and Materials, 1919 Race Street, Philadelphia, PA 19103

Table 18.--Data-qualifier codes used to qualify chemical-analytical data
[TIC, tentatively identified compound]

Data-qualifier code	Definition
A	Reported results may be less than the actual value or possibility of a false non-detect because the sample was extracted or analyzed after the required analytical holding-time limits[1].
B	Associated surrogate-recovery sample results did not meet the frequency or quality-control acceptance criteria.
b	Compound also is detected in the blank (laboratory qualifier code).
C	Reported results did not meet the project-reporting limits[2].
c	Reporting limit was not reported by the laboratory.
D	Associated field-duplicate sample results did not meet the frequency (discussed in the Quality assurance/quality control and review of analytical data section of this report) or quality-control acceptance criteria[3].
E	Associated equipment blank results did not meet the frequency or quality-control acceptance criteria.
F	Associated ambient-conditions blank results did not meet the frequency or quality-control criteria.
G	Associated trip blank results did not meet the frequency or quality-control criteria.
g	Reporting limit raised due to matrix interference (laboratory qualifier code).
H	Reported value may be biased high because the quality-control results are substantially greater than the quality-control limits[4].
I	Reported value may be biased low because the quality-control results are substantially less than the quality-control limits.
J	Associated laboratory duplicate-control sample results did not meet the frequency or quality-control acceptance criteria.
j	Result is detected below the reporting limit or is an estimated concentration (laboratory qualifier code).
K	Associated laboratory single-control sample results did not meet the frequency or quality-control acceptance criteria.
L	Associated method blank results did not meet the frequency or quality-control acceptance criteria.
M	Associated matrix spike or matrix-spike duplicate sample results did not meet the frequency or quality-control acceptance criteria.
N	Instrument tuning, calibration, internal standards, or performance results did not meet the frequency or quality-control acceptance criteria.
O	Problems with inductively coupled plasma analysis such as interelemental interferences or serial dilution. (This qualifier is to be used only with inorganic data.)
P	Reported result was more than the highest calibration of method limits or exceeded the instrument's linear range.
Q	Reported result was less than the lowest calibration, target-detection, reporting, or method limits or was below the instrument's linear range.
R	Problems in the sampling or analysis process such as field or laboratory contamination of a sample.
S	The sample result (positive or not detected) is considered conditionally rejected because of serious deficiencies in the ability to analyze the sample, or the quality-control acceptance criteria were substantially outside the required limits. Resampling or reanalysis may be necessary to verify the presence or absence of the constituent.

Table 18.--Data-qualifier codes used to qualify chemical-analytical data--Concluded

Data-qualifier code	Definition
T	The reported positive sample result is considered not reliable because of substantial contamination in the associated blanks on the basis of the following criteria: (1) concentration of analyte that is a common laboratory organic contaminant has a concentration less than 10 times the concentration in the associated blank or (2) other analytes have concentrations less than 5 times the concentration in the associated blank.
t	Sample diluted because of the concentration of target compounds (laboratory qualifier code).
U	The reported positive sample result is considered an estimated quantity or questionable because: (1) there were analysis problems, (2) the quality-control or confirmation acceptance criteria were not met, or (3) the amount reported is less than or more than the calibration or method-detection limits[5,6].
V	The reported not-detected (ND) sample result is questionable because of analysis problems or unmet quality-control acceptance criteria.
W	The identification of a TIC is questionable and the reported positive result for the TIC is strictly an estimated value because normal analysis and quality-control acceptance criteria do not apply directly for the reported TIC result. (This data-qualifier code is to be used only with TIC data.)
X	The identification of a TIC is questionable and the reported positive result is considered not reliable because this TIC was also detected in an associated quality-control blank. (This data-qualifier code is to be used only with TIC data.)
Y	The identification of a TIC is questionable and the reported positive result is considered as conditionally rejected because this TIC is considered a common laboratory contaminant. (This data-qualifier code is to be used only with TIC data.)
Z	This data qualifier code is used for specific analytical results that have data-quality problems not covered or represented in this list. If this code is used, some explanation is needed to describe the specific data-quality problem.

[1]Holding time - period of time during which a sample can be stored after collection and preservation. Holding-time limits are listed in table 1.5.2.1 of the Sampling and Analysis Plan for Ground-Water Monitoring at the Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas, Final (U.S. Geological Survey, written commun., March 1995)

[2]Project-reporting limit - the minimum signal level required to quantitatively identify a specific analyte by a specific procedure at a confidence level that is greater than 97 percent. Limits are listed in table 1.8.2.1 of the Sampling and Analysis Plan for Ground-Water Monitoring at the Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas, Final (U.S. Geological Survey, written commun., March 1995)

[3]Quality-control acceptance criteria - predefined requirements established to monitor that the data generated are precise and accurate. Criteria are listed in table 1.8.3.1 of the Sampling and Analysis Plan for Ground-Water Monitoring at the Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas, Final (U.S. Geological Survey, written commun., March 1995)

[4]Quality-control limits - limits for assessing accuracy through the use of matrix-spike and matrix-spike duplicate samples. Limits are listed in table 1.13.2.1 of the Sampling and Analysis Plan for Ground-Water Monitoring at the Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas, Final (U.S. Geological Survey, written commun., March 1995)

[5]Calibration limit - the frequency of calibration and calibration verification and the concentration of calibration standards are determined by the manufacturer's guidelines, the analytical method, or the requirements of special contracts

[6]Method-detection limit - minimum concentration of a substance that can be measured and reported using a specific method

Table 19.--Analytical methods used[1] for physical properties, total organic carbon, and pH analysis of soil samples collected from boreholes BH-3 and MSWLF03, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas

Parameter and unit	Method number or reference[2]
Moisture content, percent	ASTM D 2216-90
Bulk density, grams per cubic centimeter	Klute (1986, p. 363-367)
Porosity, percent	Klute (1986, p. 444-445)
Saturated hydraulic conductivity, centimeters per second	
Constant head	ASTM D 2434-68(74)
Falling head	Klute (1986, p. 700-703)
Total organic carbon, milligrams per kilogram	DISC-860 (c-analyzer)
pH, standard units	EPA 600/2-78-054 Method 3.2.17
Moisture retention characteristics,	
Pressure head, per centimeter water	
Moisture content, percent by volume	
Hanging column	Klute (1986, p. 637-639)
Pressure plate extractor	ASTM D 2325-68(81)
Thermocouple psychrometer	Klute (1986, p. 597-618), Operators' manual for the SC-10A thermocouple psychrometer sample chamber (manufactured by Decagon Devices, Inc., Pullman, Wash.)
Saturated salt-equilibration	
Calculated parameters (relating hydraulic conductibity to saturation)	U.S. Environmental Protection Agency (1991)
van Genuchten	van Genuchten (1980)
Brooks and Corey	Brooks and Corey (1966)
Particle-size characteristics	
Sieve	ASTM D 422-63(90)
Hydrometer	ASTM D 422-63(90)

[1]Analyses performed by Daniel B. Stephens & Associates, Inc., Albuquerque, N. Mex.

[2]Method numbers preceded by ASTM D are from:
Annual Book of ASTM Standards, American Society for Testing and Materials (ASTM), 1919 Race Street, Philadelphia, PA 19103

Table 20.--Initial moisture content, dry bulk density, calculated porosity, saturated hydraulic conductivity, total organic carbon, and pH of core samples collected from boreholes BH-3 and MSWLF03, Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas

[g/g, gram per gram; cm^3/cm^3, cubic centimeter per cubic centimeter; g/cm^3, gram per cubic centimeter; cm/sec, centimeter per second; mg/kg, milligram per kilogram]

Sample number	Depth (feet below land surface)	Initial moisture content: Gravimetric (percent, g/g)	Initial moisture content: Volumetric (percent, cm^3/cm^3)	Dry bulk density (g/cm^3)	Calculated porosity (percent)	Saturated hydraulic conductivity[1] (cm/sec)	Total organic carbon (mg/kg)	pH (standard units)
MSWLF03-14	14	8.4	12.1	1.45	45.3	3.7×10^{-5}(a)	874	8.0
MSWLF03-16	16	21.7	33.8	1.55	41.4	1.9×10^{-8}(a)	731	7.8
MSWLF03-29	29	1.5	2.2	1.49	43.7	2.3×10^{-2}(b)	386	8.3
MSWLF03-45	45	2.0	3.3	1.68	36.7	2.5×10^{-2}(b)	245	8.1
MSWLF03-65	65	25.5	39.8	1.56	41.2	8.4×10^{-10}(c)	558	7.9
MSWLF03-72	72	25.1	40.6	1.62	39.0	1.6×10^{-9}(a)	760	7.8
MSWLF03-81	79	14.8	26.8	1.80	31.9	1.6×10^{-7}(a)	716	7.8
MSWLF03-92	92	22.0	34.9	1.59	40.2	2.9×10^{-6}(a)	690	7.9
MSWLF03-93	93	15.2	26.4	1.73	34.6	6.0×10^{-5}(b)	946	8.1
MSWLF03-109	109	14.8	25.9	1.75	33.9	1.9×10^{-6}(a)	817	8.0
MSWLF03-140	140	10.0	18.2	1.83	31.1	2.5×10^{-6}(a)	621	7.9
MSWLF03-147	147	19.8	33.6	1.70	35.9	7.6×10^{-8}(a)	592	8.1
MSWLF03-151	151	11.5	21.4	1.85	30.1	1.6×10^{-6}(b)	541	8.1
MSWLF03-164	164	21.1	34.5	1.63	38.4	2.8×10^{-9}(a)	373	8.2
MSWLF03-180	180	27.5	42.2	1.53	42.1	1.8×10^{-8}(c)	908	8.0

Table 20.--Initial moisture content, dry bulk density, calculated porosity, saturated hydraulic conductivity, total organic carbon, and pH of core samples collected from boreholes BH-3 and MSWLF03, Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas--Concluded

		Initial moisture content						
Sample number	Depth (feet below land surface)	Gravimetric (percent, g/g)	Volumetric (percent, cm^3/cm^3)	Dry bulk density (g/cm^3)	Calculated porosity (percent)	Saturated hydraulic conductivity[1] (cm/sec)	Total organic carbon (mg/kg)	pH (standard units)
MSWLF03-199	199	18.0	28.2	1.56	41.0	4.4×10^{-3}(b)	500	8.3
MSWLF03-220	220	31.2	45.9	1.47	44.5	4.7×10^{-9}(a)	520	7.9
MSWLF03-233	233	38.5	39.8	1.03	61.0	2.0×10^{-4}(b)	289	7.8
MSWLF03-236	236	23.6	36.8	1.56	41.3	5.5×10^{-4}(b)	340	8.7
MSWLF03-245	245	17.5	31.7	1.81	31.7	1.1×10^{-7}(c)	364	7.9
MSWLF03-259	259	27.7	42.5	1.54	42.0	9.5×10^{-10}(c)	840	7.8
MSWLF03-284	284	15.3	25.2	1.65	37.9	6.3×10^{-4}(b)	363	8.5
MSWLF03-289	289	19.0	31.4	1.66	37.5	1.9×10^{-3}(b)	264	7.9
MSWLF03-294	294	26.7	41.1	1.54	41.9	4.2×10^{-7}(a)	536	7.9
MSWLF03-298	298	19.7	29.9	1.52	42.8	2.7×10^{-3}(b)	392	8.5
MSWLF03-318	316	22.1	36.1	1.63	38.5	2.4×10^{-3}(b)	515	8.3
MSWLF03-318.5	316.5	18.1	29.9	1.65	37.7	1.2×10^{-4}(b)	356	8.3

[1]Method of analysis for saturated hydraulic conductivity:
(a) Constant head,
(b) Falling head, or
(c) Modified constant head method with pressure-assisted saturation and flux of water through test specimen

Table 21.--Moisture content, measured at various pressure heads, of core samples collected from boreholes BH-3 and MSWLF03, Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas

Sample number	Depth (feet below land surface)	Pressure head [1] (per centimeter water)	Moisture content (percent by volume, cubic centimeter per cubic centimeter)
MSWLF03-14	14	0(a)	47.3
		34(a)	44.5
		107(a)	41.0
		347(b)	31.4
		1040(b)	21.2
		17449(c)	11.2
		861134(d)	4.0
MSWLF03-16	16	0(a)	49.5
		54(a)	46.6
		108(a)	45.1
		1020(b)	42.1
		3059(b)	40.2
		23731(c)	32.5
		861134(d)	11.4
MSWLF03-29	29	0(a)	35.5
		15(a)	34.8
		35(a)	19.5
		92(a)	7.0
		224(b)	5.8
		1020(b)	4.1
		18540(c)	1.0
		861134(d)	0.4
MSWLF03-45	45	0(a)	26.0
		15(a)	25.1
		32(a)	11.4
		70(a)	4.7
		1020(b)	4.1
		15093(b)(c)	3.4
		861134(d)	1.2
MSWLF03-65	65	0(a)	51.7
		57(a)	50.4
		107(a)	50.1
		861134(d)	12.2
MSWLF03-72	72	0(a)	47.0
		57(a)	46.3
		102(a)	46.2
		846(b)	43.8
		3059(b)	40.4
		28585(c)	29.7
		861134(d)	13.2

Table 21.--Moisture content, measured at various pressure heads, of core samples collected from boreholes BH-3 and MSWLF03, Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas--Continued

Sample number	Depth (feet below land surface)	Pressure head [1] (per centimeter water)	Moisture content (percent by volume, cubic centimeter per cubic centimeter)
MSWLF03-81	79	0(a)	35.2
		28(a)	34.8
		130(a)	33.8
		540(b)	32.1
		979(b)	30.8
		17632(c)	22.1
		853025(d)	7.0
MSWLF03-92	92	0(a)	39.4
		43(a)	38.1
		144(a)	31.4
		530(b)	21.8
		1020(b)	19.9
		15093(b)(c)	15.4
		861134(d)	3.2
MSWLF03-93	93	0(a)	34.9
		23(a)	33.3
		59(a)	30.3
		134(a)	20.3
		551(b)	13.9
		28809(c)	7.8
		853025(d)	2.1
MSWLF03-109	109	0(a)	31.9
		43(a)	30.1
		160(a)	25.7
		347(b)	23.4
		1040(b)	19.4
		27188(c)	11.2
		861134(d)	2.8
MSWLF03-140	140	0(a)	31.9
		28(a)	31.0
		128(a)	29.4
		520(b)	22.7
		846(b)	21.3
		14848(c)	13.7
		853025(d)	5.7
MSWLF03-147	147	0(a)	42.4
		51(a)	38.9
		105(a)	38.3
		1050(b)	36.0
		17071(c)	29.9
		853025(d)	9.8

Table 21.--Moisture content, measured at various pressure heads, of core samples collected from boreholes BH-3 and MSWLF03, Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas--Continued

Sample number	Depth (feet below land surface)	Pressure head [1] (per centimeter water)	Moisture content (percent by volume, cubic centimeter per cubic centimeter)
MSWLF03-151	151	0(a)	34.3
		26(a)	31.4
		130(a)	28.7
		520(b)	24.7
		846(b)	23.8
		14838(c)	14.9
		853025(d)	4.2
MSWLF03-164	164	0(a)	38.7
		55(a)	37.7
		104(a)	37.5
		846(b)	35.1
		3059(b)	31.3
		14685(c)	22.6
		861134(d)	7.0
MSWLF03-180	180	0(a)	49.2
		51(a)	46.1
		106(a)	45.3
		1020(b)	42.1
		3080(b)	40.0
		15103(c)	26.1
		853025(d)	8.1
MSWLF03-199	199	0(a)	34.6
		13(a)	32.3
		45(a)	28.2
		61(a)	19.7
		224(b)	11.5
		1020(b)	8.3
		20661(c)	3.9
		861134(d)	1.7
MSWLF03-220	220	0(a)	50.6
		54(a)	48.2
		105(a)	47.7
		846(b)	46.6
		3059(b)	45.2
		18061(c)	39.8
		861134(d)	12.1
MSWLF03-233	233	0(a)	57.7
		23(a)	56.0
		37(a)	48.4
		131(a)	33.0
		551(b)	20.9
		25536(c)	7.5
		853025(d)	2.6

Table 21.--Moisture content, measured at various pressure heads, of core samples collected from boreholes BH-3 and MSWLF03, Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas--Continued

Sample number	Depth (feet below land surface)	Pressure head [1] (per centimeter water)	Moisture content (percent by volume, cubic centimeter per cubic centimeter)
MSWLF03-236	236	0(a)	39.9
		28(a)	38.3
		48(a)	33.1
		224(b)	27.5
		1020(b)	21.5
		28554(c)	2.8
		861134(d)	1.2
MSWLF03-245	245	0(a)	34.9
		28(a)	33.5
		128(a)	32.0
		510(b)	31.1
		1020(b)	30.4
		17908(c)	17.6
		853025(d)	5.3
MSWLF03-259	259	0(a)	49.4
		53(a)	46.3
		105(a)	45.6
		861134(d)	13.5
MSWLF03-284	284	0(a)	37.3
		24(a)	33.3
		45(a)	21.9
		224(b)	14.8
		1020(b)	11.9
		21732(c)	2.6
		861134(d)	1.5
MSWLF03-289	289	0(a)	37.3
		13(a)	36.1
		38(a)	32.2
		73(a)	10.2
		203(a)	6.6
		21742(c)	2.6
		853025(d)	0.9
MSWLF03-294	294	0(a)	50.1
		22(a)	48.1
		129(a)	45.4
		551(b)	43.7
		1050(b)	42.6
		22619(c)	33.9
		853025(d)	12.1

Table 21.--Moisture content, measured at various pressure heads, of core samples collected from boreholes BH-3 and MSWLF03, Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas--Concluded

Sample number	Depth (feet below land surface)	Pressure head [1] (per centimeter water)	Moisture content (percent by volume, cubic centimeter per cubic centimeter)
MSWLF03-298	298	0(a)	35.3
		12(a)	34.1
		41(a)	30.4
		70(a)	14.6
		204(b)	10.6
		1020(b)	10.0
		22599(c)	1.9
		861134(d)	0.9
MSWLF03-318	316	0(a)	39.7
		15(a)	38.2
		43(a)	35.2
		73(a)	15.4
		1020(b)	8.7
		15093(b)(c)	5.9
		861134(d)	1.3
MSWLF03-318.5	316.5	0(a)	35.4
		22(a)	33.9
		47(a)	27.9
		136(a)	17.1
		530(b)	14.3
		17153(c)	3.5
		853025(d)	1.0

[1]Method of analysis:
(a) Hanging column;
(b) Pressure plate extractor;
(c) Thermocouple psychrometer; or
(d) Saturated salt equilibration

Table 22.--Van Genuchten alpha and beta coefficients calculated using van Genuchten[1] equations with measured values for residual and saturated soil-water content and saturated hydraulic conductivity from core samples collected from boreholes BH3 and MSWLF03, Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas

[θ_r, residual soil-water content; θ_s, saturated soil-water content; K_{sat}, saturated hydraulic conductivity; cm, centimeter; %, percent; cm^3/cm^3, cubic centimeter per cubic centimeter; cm/sec, centimeter per second; --, no data]

Sample number	Depth (feet below land surface)	Alpha (per cm) Calculated value	Alpha 95% confidence limits Lower	Alpha 95% confidence limits Upper	Beta (dimensionless) Calculated value	Beta 95% confidence limits Lower	Beta 95% confidence limits Upper	θ_r (%, cm^3/ cm^3)	θ_s (%, cm^3/ cm^3)	K_{sat} (cm/sec)
MSWLF03-14	14	0.00808	0.0049	0.0112	1.40075	1.3108	1.4908	4.0	47.3	$3.7x10^{-5}$
MSWLF03-16	16	0.00064	-0.0007	0.0020	1.30687	0.9875	1.6263	11.4	49.5	$1.9x10^{-8}$
MSWLF03-29	29	0.03480	0.0199	0.0497	2.28173	1.5134	3.0501	0.4	35.5	$2.3x10^{-2}$
MSWLF03-45	45	0.03827	0.0260	0.0505	3.59149	1.2385	5.9445	1.2	26.0	$2.5x10^{-2}$
MSWLF03-65	65	--	--	--	--	--	--	--	--	--
MSWLF03-72	72	0.00029	-0.0001	0.0006	1.41448	1.1325	1.6965	13.1	47.0	$1.6x10^{-9}$
MSWLF03-81	79	0.0076	-0.0006	0.0021	1.32059	1.0735	1.5677	7.0	35.3	$1.6x10^{-7}$
MSWLF03-92	92	0.01386	-0.0045	0.0323	1.27251	1.1194	1.4257	3.2	39.4	$2.9x10^{-6}$
MSWLF03-93	93	0.02065	-0.0004	0.0417	1.39086	1.1451	1.6367	2.1	34.9	$6.0x10^{-5}$
MSWLF03-109	109	0.00942	0.0004	0.0184	1.25907	1.1493	1.3689	2.8	31.9	$1.9x10^{-6}$
MSWLF03-140	140	0.00584	0.0012	0.0105	1.30876	1.1870	1.4305	5.7	31.9	$2.5x10^{-6}$
MSWLF03-147	147	0.00009	-0.0002	0.0004	1.77791	-1.1650	4.7208	9.8	42.4	$7.6x10^{-8}$
MSWLF03-151	151	0.00828	-0.0035	0.0201	1.24713	1.0999	1.3943	4.2	34.3	$1.6x10^{-6}$
MSWLF03-164	164	0.00039	0.0000	0.0007	1.44875	1.1811	1.71634	7.0	38.7	$2.8x10^{-9}$
MSWLF03-180	180	0.00046	-0.0001	0.0010	1.44497	1.0750	1.8149	8.1	49.2	$1.8x10^{-8}$
MSWLF03-199	199	0.02572	0.0120	0.0395	1.58902	1.3459	1.8322	1.7	34.6	$4.4x10^{-3}$

Table 22.--Van Genuchten alpha and beta coefficients calculated using van Genuchten[1] equations with measured values for residual and saturated soil-water content and saturated hydraulic conductivity from core samples collected from boreholes BH3 and MSWLF03, Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas--Concluded

		Alpha (per cm)			Beta (dimensionless)					
			95% confidence limits			95% confidence limits				
Sample number	Depth (feet below land surface)	Calculated value	Lower	Upper	Calculated value	Lower	Upper	θ_r (%, cm^3/ cm^3)	θ_s (%, cm^3/ cm^3)	K_{sat} (cm/sec)
MSWLF03-220	220	0.00006	0.0000	0.0001	1.79263	0.3316	3.2537	12.1	50.6	4.6×10^{-9}
MSWLF03-233	233	0.02177	0.0106	0.0329	1.45340	1.2997	1.6071	2.6	57.7	2.0×10^{-4}
MSWLF03-236	236	0.01088	-0.0037	0.0254	1.34953	1.1116	1.5874	1.2	39.9	5.5×10^{-4}
MSWLF03-245	245	0.00098	-0.0002	0.0022	1.35407	1.1341	1.5740	5.3	34.9	7.6×10^{-8}
MSWLF03-259	259	--	--	--	--	--	--	--	--	--
MSWLF03-284	284	0.05208	-0.0081	0.1122	1.38087	1.1493	1.6125	1.5	37.3	6.3×10^{-4}
MSWLF03-289	289	0.01914	0.0148	0.0235	4.39817	1.9757	6.8207	0.9	37.3	1.9×10^{-3}
MSWLF03-294	294	0.00167	-0.0024	0.0057	1.24202	1.0042	1.4799	12.1	50.1	4.2×10^{-7}
MSWLF03-298	298	0.02173	0.0063	0.0371	2.04670	1.0181	3.0753	0.9	35.3	2.7×10^{-3}
MSWLF03-318	316	0.01638	0.0119	0.0209	5.07106	-0.0394	10.1815	1.3	39.7	2.4×10^{-3}
MSWLF03-318.5	316.5	0.02634	0.0045	0.0482	1.42609	1.2045	1.6477	1.0	35.4	1.2×10^{-4}

[1] van Genuchten (1980)

Table 23.--Air entry value and Brooks and Corey exponent derived for core samples collected from boreholes BH-3 and MSWLF03, Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas

[--, no data]

Sample number	Depth (feet below land surface)	Air entry value (per centimeter)	Brooks and Corey[1] exponent
MSWLF03-14	14	124	0.40075
MSWLF03-16	16	1,563	0.30687
MSWLF03-29	29	29	1.28173
MSWLF03-45	45	26	2.59149
MSWLF03-65	65	--	--
MSWLF03-72	72	3,448	0.41448
MSWLF03-81	79	1,316	0.32059
MSWLF03-92	92	72	0.27251
MSWLF03-93	93	48	0.39086
MSWLF03-109	109	106	0.25907
MSWLF03-140	140	171	0.30876
MSWLF03-147	147	11,111	0.77791
MSWLF03-151	151	121	0.24713
MSWLF03-164	164	2,564	0.44875
MSWLF03-180	180	2,174	0.44497
MSWLF03-199	199	39	0.58902
MSWLF03-220	220	16,667	0.79263
MSWLF03-233	233	46	0.4534
MSWLF03-236	236	92	0.34953
MSWLF03-245	245	1,020	0.35407
MSWLF03-259	259	--	--
MSWLF03-284	284	19	0.38087
MSWLF03-289	289	52	3.39817
MSWLF03-294	294	599	0.24202
MSWLF03-298	298	46	1.04670
MSWLF03-318	316	61	4.07106
MSWLF03-318.5	316.5	38	0.42609

[1]Brooks and Corey (1966)

Table 24.--Particle-size characteristics of core samples collected from boreholes BH-3 and MSWLF03, Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas

[--, no data; mm, millimeter; d_{10}, 10th percentile; d_{16}, 16th percentile; d_{30}, 30th percentile; d_{50}, 50th percentile and median particle diameter; d_{60}, 60th percentile; d_{84}, 84th percentile; C_u, uniformity coefficient; C_c, coefficient of curvature]

Sample number	Depth (feet below land surface)	Particle diameter (mm)								
		d_{10}	d_{16}	d_{30}	d_{50}	d_{60}	d_{84}	C_u[1]	C_c[2]	Mean particle diameter[3] (mm)
MSWLF03-14	14	0.0078	0.020	0.038	0.096	0.16	0.36	20	1.2	0.16
MSWLF03-16	16	--[4]	--[4]	--[4]	0.0014	0.0022	0.0095	--[5]	--[5]	--[6]
MSWLF03-29	29	0.16	0.20	0.27	0.33	0.36	0.43	2.2	1.3	0.32
MSWLF03-45	45	0.24	0.31	0.46	0.74	0.95	3.0	4.0	0.93	1.4
MSWLF03-65	65	--	--	--	--	--	--	--	--	--
MSWLF03-72	72	--[4]	--[4]	--[4]	--[4]	0.0021	0.044	--[5]	--[5]	--[6]
MSWLF03-81	79	--[4]	--[4]	0.0033	0.10	0.16	0.41	--[5]	--[5]	--[6]
MSWLF03-92	92	0.044	0.057	0.087	0.15	0.19	0.36	4.3	0.92	0.19
MSWLF03-93	93	0.079	0.097	0.14	0.21	0.24	0.41	3.1	1.1	0.24
MSWLF03-109	109	0.058	0.087	0.13	0.19	0.22	0.35	3.7	1.4	0.21
MSWLF03-140	140	0.075	0.088	0.12	0.18	0.21	0.36	2.8	0.94	0.21
MSWLF03-147	147	--[4]	--[4]	--[4]	0.012	0.035	0.073	--[5]	--[5]	--[6]
MSWLF03-151	151	0.042	0.089	0.14	0.21	0.25	0.47	5.9	1.9	0.26
MSWLF03-164	164	--[4]	--[4]	0.0048	0.022	0.045	0.094	--[5]	--[5]	--[6]
MSWLF03-180	180	--[4]	--[4]	--[4]	0.0044	0.0070	0.017	--[5]	--[5]	--[6]
MSWLF03-199	199	0.13	0.15	0.20	0.29	0.34	0.61	2.7	0.96	0.35
MSWLF03-220	220	--[4]	--[4]	--[4]	--[4]	0.0014	0.0036	--[5]	--[5]	--[6]
MSWLF03-233	233	0.014	0.046	0.13	0.22	0.29	0.77	20	4.2	0.34

Table 24.--Particle-size characteristics of core samples collected from boreholes BH-3 and MSWLF03, Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas--Concluded

Sample number	Depth (feet below land surface)	Particle diameter (mm)								
		d_{10}	d_{16}	d_{30}	d_{50}	d_{60}	d_{84}	C_u[1]	C_c[2]	Mean particle diameter[3] (mm)
MSWLF03-236	236	0.13	0.14	0.17	0.22	0.24	0.36	1.9	0.97	0.24
MSWLF03-245	245	--[4]	--[4]	0.0082	0.046	0.073	0.20	--[5]	--[5]	--[6]
MSWLF03-259	259	--	--	--	--	--	--	--	--	--
MSWLF03-284	284	0.15	0.18	0.26	0.34	0.38	0.62	2.6	1.2	0.38
MSWLF03-289	289	0.13	0.15	0.19	0.26	0.31	0.42	2.4	0.95	0.27
MSWLF03-294	294	--[4]	--[4]	--[4]	0.0019	0.0041	0.061	--[5]	--[5]	--[6]
MSWLF03-298	298	0.12	0.13	0.16	0.20	0.22	0.33	1.9	0.98	0.22
MSWLF03-318	316	0.11	0.12	0.15	0.20	0.22	0.33	2.0	0.98	0.22
MSWLF03-318.5	316.5	0.076	0.11	0.15	0.20	0.23	0.36	3.0	1.2	0.22

[1] $C_u = d_{60}/d_{10}$

[2] $C_c = [(d_{30})^2/(d_{10} \times d_{60})]$

[3] Mean particle diameter = $[(d_{16}+d_{50}+d_{84})/3]$

[4] Value not reached with test specified

[5] Value dependent on 10th-percentile particle diameter

[6] Value not calculated because one or two of the dependent particle-diameter values (16th and 50th percentiles) were not reached

Table 25.--Analytical methods used[1] for physical analyses of soil samples collected from the landfill cover, Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas

Parameter and unit	Method number or reference[2]
Moisture content, percent	ASTM D 2216-90
Bulk density, grams per cubic centimeter	Klute (1986, p. 363-367)
Porosity, percent	Klute (1986, p. 444-445)
Moisture retention characteristics,	
Pressure head, per centimeter water	
Moisture content, percent by volume	
Pressure plate extractor	ASTM D 2325-68(81)
Thermocouple psychrometer	Klute (1986, p. 597-618), Operator's manual for the SC-10A thermocouple psychrometer sample chamber (manufactured by Decagon Devices, Inc., Pullman, Wash.)
Infiltration rate, centimeters per second	Perroux and White (1988) Elrick and others (1988) Ankeny and others (1988; 1989) Prieksat and others (1991)
Hydraulic conductivity (calculated from unconfined infiltration data), centimeters per second	Wooding (1968) Ankeny and others (1991) Elrick and others (1988)

[1]Analyses performed by Daniel B. Stephens & Associates, Inc., Albuquerque, N. Mex.

[2]Method numbers preceded by ASTM D are from:
Annual Book of ASTM Standards, American Society for Testing and Materials (ASTM), 1919 Race Street, Philadelphia, PA 19103

Table 26.--Initial moisture content, dry bulk density, and calculated porosity of soil samples collected from the landfill cover, Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas

[g/g, gram per gram; cm^3/cm^3, cubic centimeter per cubic centimeter; g/cm^3, gram per cubic centimeter]

Sample number	Initial moisture content: Gravimetric (percent, g/g)	Initial moisture content: Volumetric (percent, cm^3/cm^3)	Dry bulk density (g/cm^3)	Calculated porosity (percent)
Site 1, Rep 1	14.4	25.1	1.74	34.4
Site 1, Rep 2	12.5	22.3	1.79	32.5
Site 2, Rep 1	11.7	20.5	1.75	34.0
Site 2, Rep 2	8.2	13.8	1.68	36.6
Site 3, Rep 1	16.6	29.4	1.77	33.3
Site 3, Rep 2	10.5	18.0	1.71	35.5
Site 4, Rep 1	17.7	29.7	1.68	36.5
Site 4, Rep 2	17.7	28.9	1.63	38.4
Site 5, Rep 1	13.8	23.2	1.68	36.8
Site 5, Rep 2	12.2	21.4	1.76	33.6

Table 27.--Moisture content, measured at various pressure heads, of soil samples collected from the landfill cover, Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas

[cm, centimeter; cm^3/cm^3, cubic centimeter per cubic centimeter]

Sample number	Pressure head[1] (per cm water)	Moisture content (percent, cm^3/cm^3)
Site 1, Rep 1	0(a)	35.0
	337(a)	20.0
	26617(b)	9.1
Site 1, Rep 2	0(a)	35.2
	337(a)	20.2
	17643(b)	9.8
Site 2, Rep 1	0(a)	33.8
	337(a)	20.3
	24781(b)	9.3
Site 2, Rep 2	0(a)	28.3
	337(a)	12.7
	21092(b)	8.7
Site 3, Rep 1	0(a)	41.7
	337(a)	29.1
	18662(b)	11.0
Site 3, Rep 2	0(a)	31.7
	337(a)	15.8
	21518(b)	8.6
Site 4, Rep 1	0(a)	41.0
	337(a)	27.8
	15195(b)	10.0
Site 4, Rep 2	0(a)	33.5
	337(a)	18.6
	15909(b)	7.7
Site 5, Rep 1	0(a)	25.0
	337(a)	12.0
	19682(b)	8.1
Site 5, Rep 2	0(a)	32.5
	337(a)	16.7
	16725(b)	6.1

[1]Method of analysis:
(a) Pressure plate extractor or
(b) Thermocouple psychrometer

Table 28.--Infiltration rate and hydraulic conductivity of the landfill cover , Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas

[cm/sec, centimeter per second]

	Infiltration rate[1]		Hydraulic conductivity[2]	
Sample number	Saturated[3] (x 10^{-3} cm/sec)	Unsaturated[4] (x 10^{-3} cm/sec)	Saturated[3] (x 10^{-3} cm/sec)	Unsaturated[4] (x 10^{-3} cm/sec)
Site 1, Rep 1	2.63	1.42	1.16	0.63
Site 1, Rep 2	2.73	1.65	1.09	0.65
Site 2, Rep 1	2.25	1.27	0.96	0.54
Site 2, Rep 2	1.98	1.02	0.92	0.47
Site 3, Rep 1	3.38	1.52	1.69	0.76
Site 3, Rep 2	2.61	1.10	1.35	0.57
Site 4, Rep 1	3.5	2.01	1.46	0.84
Site 4, Rep 2	3.56	1.89	1.59	0.85
Site 5, Rep 1	5.00	1.15	3.12	0.72
Site 5, Rep 2	6.75	1.79	4.09	1.09

[1]In situ measurements of the landfill cover

[2]Values derived from in situ infiltration data

[3]Saturated measurements made with 0.5-centimeter ponded water head

[4]Unsaturated measurements made at 3-centimeter tension

Table 29.--Analytical results of soil-moisture and soil-chloride data for soil samples collected from cores from the Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas

[--, not determined]

Depth (feet below land surface)	Soil water in sample[1] (grams)	Dry soil in sample (grams)	Bulk density of soil (grams per cubic centimeter)	Volumetric moisture content (fraction)	Soil-water chloride concentration[2] (milligrams per liter)	Soil chloride content (micrograms per cubic centimeter)
2	3.0	121.8	1.5	0.037	151.5	5.596
4	3.6	82.9	1.5	0.065	54.2	3.532
5	2.3	48.6	1.5	0.071	26.8	1.904
6	1.8	52.7	1.5	0.051	91.5	4.688
7	2.9	41.4	1.5	0.105	33.7	3.542
8	3.3	63.5	1.5	0.078	77.3	6.028
9	2.8	35.1	1.5	0.120	71.8	8.588
10	2.7	45.5	1.5	0.089	135.8	12.086
11	3.0	46.7	1.5	0.096	84.9	8.178
12	4.2	66.0	1.5	0.095	60.5	5.775
13	2.8	51.0	1.5	0.082	77.3	6.362
14	6.9	52.1	1.45	0.192	19.5	3.744
15	7.6	47.4	1.55	0.249	45.7	11.348
16	2.0	117.9	1.5	0.025	42.3	1.076
19	3.2	176.2	1.5	0.027	41.0	1.116
20	1.6	129.5	1.5	0.019	90.8	1.682
24	1.7	141.5	1.5	0.018	1,812.6	32.665
25	2.4	162.5	1.5	0.022	903.0	20.005
26	2.5	146.6	1.5	0.026	1,563.1	39.984
28	1.4	144.4	1.5	0.015	2,605.9	37.897
29	1.4	129.5	1.49	0.016	836.2	13.470
30	1.9	146.6	1.5	0.019	732.6	14.243
33	3.2	141.0	1.5	0.034	642.8	21.883
34	1.7	133.7	1.6	0.020	1,909.4	38.845
35	3.4	157.7	1.6	0.034	1,148.2	39.609
36	3.3	121.8	1.6	0.043	910.6	39.476
37	1.7	128.1	1.6	0.021	388.2	8.244
38	2.2	112.1	1.6	0.031	393.4	12.353
39	2.5	124.2	1.6	0.032	263.0	8.471
40	3.3	140.6	1.6	0.038	366.1	13.747
42	2.1	138.9	1.7	0.026	345.1	8.871

Table 29.--Analytical results of soil-moisture and soil-chloride data for soil samples collected from cores from the Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas--Concluded

Depth (feet below land surface)	Soil water in sample[1] (grams)	Dry soil in sample (grams)	Bulk density of soil (grams per cubic centimeter)	Volumetric moisture content (fraction)	Soil-water chloride concentration[2] (milligrams per liter)	Soil chloride content (micrograms per cubic centimeter)
43	2.5	145.7	1.7	0.029	316.2	9.223
44	2.9	158.4	1.7	0.031	518.1	16.125
45	5.3	172.4	1.68	0.052	471.1	24.332
46	2.7	157.5	1.7	0.029	610.0	17.777
48	3.0	126.5	1.7	0.040	762.5	30.742
49	3.6	111.4	1.7	0.055	732.2	40.225
51	3.0	152.3	1.7	0.033	853.3	28.575
52	3.1	164.7	1.7	0.032	985.5	31.533
55	2.6	135.5	1.7	0.033	1,358.5	44.315
92	15.0	73.0	1.59	0.327	--	14.567
94	15.9	109.3	1.73	0.252	--	19.595
109	14.1	94.6	1.75	0.261	--	21.696
118	8.9	69.8	1.8	0.230	--	4.376
120	12.8	62.8	1.8	0.367	--	29.479
143	8.5	74.5	1.83	0.209	--	71.232
151	10.5	92.5	1.85	0.210	--	3.455
164	14.0	74.7	1.63	0.305	--	8.421
176	7.2	93.0	1.6	0.124	--	10.173
199	18.4	103.4	1.56	0.278	--	31.137
233	13.8	62.7	1.03	0.227	--	11.330
236	14.5	68.5	1.56	0.330	--	30.162
245	10.5	59.8	1.6	0.281	--	10.899
284	20.2	103.2	1.65	0.323	--	25.131
290	15.2	81.4	1.66	0.310	--	20.197
298	13.4	103.6	1.52	0.197	--	26.673
316	21.7	104.1	1.63	0.340	--	32.741
325	11.8	44.7	1.6	0.422	--	5.658

[1]An increase in soil water was observed in samples collected from core recovered using mud-rotary drilling compared with samples collected from core recovered using hollow-stem auger drilling

[2]Soil-water chloride concentration not determined for samples collected from core recovered using mud-rotary drilling because of possible influence of moisture from drilling mud on soil water in soil sample

Table 30.--Analytical results[1] of ground-water sample collected from well MSWLF03, Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas

[Qualifier codes are identified in table 18. --, no data; NTUs, nephelometric turbidity units; mS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; mg/L, micrograms per liter; ND, not detected]

Parameter and unit	Method[2]	Reporting limit	Well MSWLF03 result/qualifier
Date	--	--	19-Feb-97
Time	--	--	1515
USGS sample number	--	--	MSWLF0310
Laboratory sample number	--	--	053820-0001-SA
Water-level elevation, feet above sea level, prior to pumping	--	0.01	3,601.10
Amount purged prior to sampling, gallons	--	1	110
Depth sampled, feet below land surface	--	1	325
Field properties:			
Temperature, degrees Celsius	E170.1	0.1	21.3
Turbidity, NTUs	E180.1	1	4.07
pH	E150.1	0.1	8.10
Specific conductance, µS/cm	E120.1	10.0	521
Alkalinity, total, mg/L	E310.1	5.0	136
Alkalinity, bicarbonate, mg/L	E310.1	5.0	136
Alkalinity, carbonate, mg/L	E310.1	5.0	ND
Alkalinity, hydroxide, mg/L	E310.1	5.0	ND
Dissolved solids, mg/L	E160.1	10.0	327
Common ions:			
Chloride, total, mg/L	E300	0.50	38.6
Fluoride, total, mg/L	E300	0.50	0.79
Nitrate as nitrogen, total, mg/L	E300	0.50	2.0
Ammonia as nitrogen, total, mg/L	E350.1	0.10	ND
Orthophosphate as phosphorus, total, mg/L	E300	0.50	ND
Sulfate, total, mg/L	E300	0.50	48.6
Calcium, dissolved, mg/L	SW6010	5.0	17.4
Magnesium, dissolved, mg/L	SW6010	5.0	5.5
Potassium, dissolved, mg/L	SW6010	5.0	9.0

Table 30.--Analytical results[1] of ground-water sample collected from well MSWLF03, Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas--Continued

Parameter and unit	Method[2]	Reporting limit	Well MSWLF03 result/qualifier
Common ions--Continued:			
Sodium, dissolved, mg/L	SW6010	5.0	77.0
Volatile organic compounds:			
Acetone, mg/L	SW8260	10	ND
Benzene, mg/L	SW8260	1.0	ND
Bromodichloromethane, mg/L	SW8260	1.0	ND
Bromoform, mg/L	SW8260	1.0	ND
Bromomethane, mg/L	SW8260	2.0	ND
Carbon disulfide, mg/L	SW8260	1.0	ND
Carbon tetrachloride, mg/L	SW8260	1.0	ND
Chlorobenzene, mg/L	SW8260	1.0	ND
Chloroethane, mg/L	SW8260	2.0	ND
Chloroform, mg/L	SW8260	1.0	ND
Chloromethane, mg/L	SW8260	2.0	ND
Dibromochloromethane, mg/L	SW8260	1.0	ND
Ethylbenzene, mg/L	SW8260	1.0	ND
Methylene chloride, mg/L	SW8260	1.0	ND
Styrene, mg/L	SW8260	1.0	ND
Tetrachloroethene, mg/L	SW8260	1.0	ND
Toluene, mg/L	SW8260	1.0	ND
Trichloroethene, mg/L	SW8260	1.0	ND
Vinyl chloride, mg/L	SW8260	2.0	ND
Xylenes (total), mg/L	SW8260	1.0	ND
cis-1,3-Dichloropropene, mg/L	SW8260	1.0	ND
trans-1,3-Dichloropropene, mg/L	SW8260	1.0	ND
1,1,1-Trichloroethane, mg/L	SW8260	1.0	ND
1,1,2,2-Tetrachloroethane,mg/L	SW8260	1.0	ND

Table 30.--Analytical results[1] of ground-water sample collected from well MSWLF03, Municipal Solid Waste Landfill Facility, U.S. Army Air Defense Artillery Center and Fort Bliss, El Paso, Texas--Concluded

Parameter and unit	Method[2]	Reporting limit	Well MSWLF03 result/qualifier
Volatile organic compounds--Continued:			
1,1,2-Trichloroethane, mg/L	SW8260	1.0	ND
1,1-Dichloroethane, mg/L	SW8260	1.0	ND
1,1-Dichloroethene, mg/L	SW8260	1.0	ND
1,2-Dichloroethane, mg/L	SW8260	1.0	ND
1,2-Dichloroethene (total), mg/L	SW8260	1.0	ND
1,2-Dichloropropane, mg/L	SW8260	1.0	ND
2-Butanone (MEK), mg/L	SW8260	5.0	ND
2-Hexanone, mg/L	SW8260	5.0	ND
4-Methyl-2-pentanone, mg/L	SW8260	5.0	ND
Metals:			
Arsenic, dissolved, mg/L	SW6010	0.010	ND
Barium, dissolved, mg/L	SW6010	0.10	ND
Cadmium, dissolved, mg/L	SW6010	0.0050	ND
Chromium, dissolved, mg/L	SW6010	0.030	ND
Cobalt, dissolved, mg/L	SW6010	0.040	ND
Copper, dissolved, mg/L	SW6010	0.030	ND
Iron, dissolved, mg/L	SW6010	0.040	ND
Lead, dissolved, mg/L	SW6010	0.0040	ND/g
Nickel, dissolved, mg/L	SW6010	0.040	ND
Selenium, dissolved, mg/L	SW7740	0.010	ND/g

[1]Analyses performed by Quanterra Environmental Services, Arvada, Colorado

[2]Method numbers preceded by E are from:
U.S. Environmental Protection Agency (1983; 1986a,b)
Method numbers preceded by SW are from:
U.S. Environmental Protection Agency (1986c)

Table 31.--Summary of maximum contaminant levels for selected water-quality constituents and properties for public water-supply systems[1]

[--, no data; mg/L, milligrams per liter]

Constituent	Maximum contaminant level[2]	Secondary maximum contaminant level[3]
pH (standard units)	--	6.5-8.5
Dissolved solids	--	500 mg/L
Chloride, total	--	250 mg/L
Fluoride, total	4.0 mg/L	2.0 mg/L
Nitrate as nitrogen, total	10 mg/L	--
Sulfate, total	--	250 mg/L
Arsenic, total	0.05 mg/L	--
Barium, total	2 mg/L	--
Cadmium, total	0.005 mg/L	--
Chromium, total	0.1 mg/L	--
Copper, total	--	1.0 mg/L
Iron, total	--	0.3 mg/L
Nickel, total	0.1 mg/L	--
Selenium, total	0.05 mg/L	--

[1]Public water-supply system--A system for the provision of piped water to the public for human consumption, if such system has at least 15 service connections or regularly serves at least 25 individuals daily at least 60 days of the year

[2]Maximum contaminant level--Maximum permissible level of a contaminant in water that is delivered to the free-flowing outlet of the ultimate user of a public water system. Maximum contaminant levels are those levels set by the U.S. Environmental Protection Agency (1994) in the national primary drinking water regulations. These regulations deal with contaminants that may have a substantial direct impact on the health of the consumer and are enforceable by Federal law

[3]Secondary maximum contaminant level--Advisable maximum level of a contaminant in water that is delivered to a free-flowing outlet of the ultimate user of a public water system. Secondary maximum contaminant levels are those levels proposed by the U.S. Environmental Protection Agency (1996) in the national secondary drinking water regulations--These regulations deal with contaminants that may not have a substantial direct impact on the health of the consumer, but their presence in excessive quantities may affect the aesthetic qualities of the water and may discourage the use of a drinking-water supply by the public