ASSESSMENT OF CONTAMINATION OF GROUND WATER AND SURFACE WATER IN THE AREA OF BUILDING 24, PICATINNY ARSENAL, NEW JERSEY, 1986-87

By B. Pierre Sargent, Thomas V. Fusillo, Donald A. Storck, and
James A. Smith

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CONVERSION FACTORS AND ABBREVIATIONS

Multiply inch-pound unit	by	To obtain SI unit
	Length	
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	0.4047	hectare (ha)
square mile (mi^2)	259.0	hectare (ha)
	Volume	
gallon (gal)	3.785	liter (L)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
	Flow	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
gallon per day (gal/d)	0.003785	cubic meter per day (m^3/d)
	Mass	
pound, avoirdupois (lb)	0.4536	kilogram (k)
	Temperature	
degree Fahrenheit (°F)	°C = 5/9 x (°F-32)	degree Celsius (°C)
	Transmissivity	
foot squared per day (ft^2/d)	0.09290	meter squared per day (m^2/d)

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

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ABSTRACT

A zone of contaminated ground water at Picatinny Arsenal, New Jersey, has resulted from the operation of a metal-plating wastewater-treatment system from 1960 through 1981. Contaminants entered the ground-water system through surface sand filtration beds used in wastewater treatment. In order to define the extent of ground-water contamination, a drive-point reconnaissance survey was conducted in 1986 to determine the optimum locations for wells. Twenty-seven wells were subsequently installed using the hollow-stem-auger method and six wells were installed using the mud-rotary method. These wells and 27 existing wells were sampled in 1987 for analysis of inorganic constituents, trace elements, volatile organic compounds, and nutrients. Eleven of these wells also were sampled for analysis of base/neutral- and acid-extractable compounds and pesticides. Soil gas in the unsaturated zone was sampled for analysis for the presence of volatile organic compounds by using soil-gas probes at six sites. In addition, surface-water samples were collected at three sites in Green Pond Brook to determine whether volatile organic compounds were present.

Trichloroethylene, the primary organic contaminant in the study area, was found in the ground water in concentrations of up to 44,000 micrograms per liter. The contaminated zone originates in the area of building 24 and extends 1,600 feet downgradient in a shallow unconfined aquifer. This zone is approximately 400 to 800 feet wide and extends downward about 50 feet into an unconfined aquifer. Contaminants also were detected in water from an underlying deep, confined aquifer.

Although inorganic constituents were found in elevated concentrations within the trichloroethylene plume, only chloride was detected in concentrations greater than the Federal drinking-water regulation of 250 milligrams per liter. Trace metals and cyanide were present in the building 24 wastewater; however, these compounds have not been detected in elevated concentrations downgradient from the source. Polychlorinated biphenyl 1260 was detected in one ground-water sample from a well in an adjacent area. If contaminants are assumed to move with ground water by advection, the estimated average velocity of contaminant movement is 0.42 to 1.8 feet per day.

Surface water in Green Pond Brook contained trichloroethylene in concentrations that ranged from the detection limit (3.0 micrograms per liter) to 3.8 micrograms per liter. Volatilization is expected to remove volatile organic compounds in the steep, fast-flowing reaches of the brook. Concentrations of trichloroethylene in five soil-gas samples were 1,000 nanograms per liter or greater. Both tetrachoroethylene and dichloroethylene also were detected in some soil-gas samples at maximum concentrations of 130 nanograms per liter.

INTRODUCTION

Picatinny Arsenal is located just north of the Wisconsin terminal moraine in north-central New Jersey (fig. 1). At the installation, officially known since 1986 as the U.S. Army Armament Research Development and Engineering Center, about 5,500 people are employed in research and development of munitions and weapons. (The installation previously was known as the U.S. Army Armament Research and Development Command (1978-83) and the U.S. Army Armament Research and Development Center (1983-86).) The arsenal encompasses more than 1,500 buildings on 6,491 acres.

The site of the arsenal has a long industrial history. Middle Forge, one of the first forges in New Jersey, was established there in 1749. The forge later became part of Mount Hope Iron Works, which provided cannon shot and other iron implements for the Revolutionary War. In 1880, the U.S. War Department established the Picatinny Powder Works at the site, and, since 1907, as a result of expanding activities, the facility has been known as Picatinny Arsenal. During World War I, the arsenal produced many types of ammunition; during World War II production was expanded to include bombs, high explosives, pyrotechnics, and other ordnance items. In recent years, the arsenal's mission has shifted to research and development of large-caliber munitions.

The arsenal is situated in an elongated valley that extends northeast-southwest. The valley is bounded by Green Pond Mountain on the west, Copperas Mountain on the northeast, and an unnamed mountain on the east and southwest (fig. 2). Green Pond and Cooperas Mountains are rugged with steep, rocky slopes and altitudes exceeding 1,200 ft (feet). The slopes on the eastern boundary are less rugged and less steep, with maximum elevations of about 1,100 ft.

Background

In March 1981, during an investigation by the U.S. Army Environmental Hygiene Agency (USAEHA), water samples from two water-supply wells in the area southwest of Picatinny Lake were found to be contaminated with volatile organic compounds (VOCs)--specifically, chlorinated solvents (Foster Wheeler USA Corporation, 1987). Further investigation by USAEHA and Picatinny Arsenal employees identified the metal-plating shop in building 24 as a possible source of the contamination because trichloroethylene (TCE) and other chlorinated solvents had been used in metal-degreasing operations at the shop.

In 1982, the U.S. Geological Survey (USGS), at the request of the U.S. Army, became involved in an assessment of the water resources of the arsenal. Initial USGS efforts included (1) surface-geophysical surveys, (2) supervision of test-drilling and installation of observation wells by the U.S. Army Corps of Engineers, (3) collection of water-level data, (4) aquifer tests, (5) establishment of stream-gaging stations, (6) base-flow seepage measurements, (7) sampling and analysis of surface and ground water, and (8) development of a computerized data base for surface-water and hydrogeologic data.

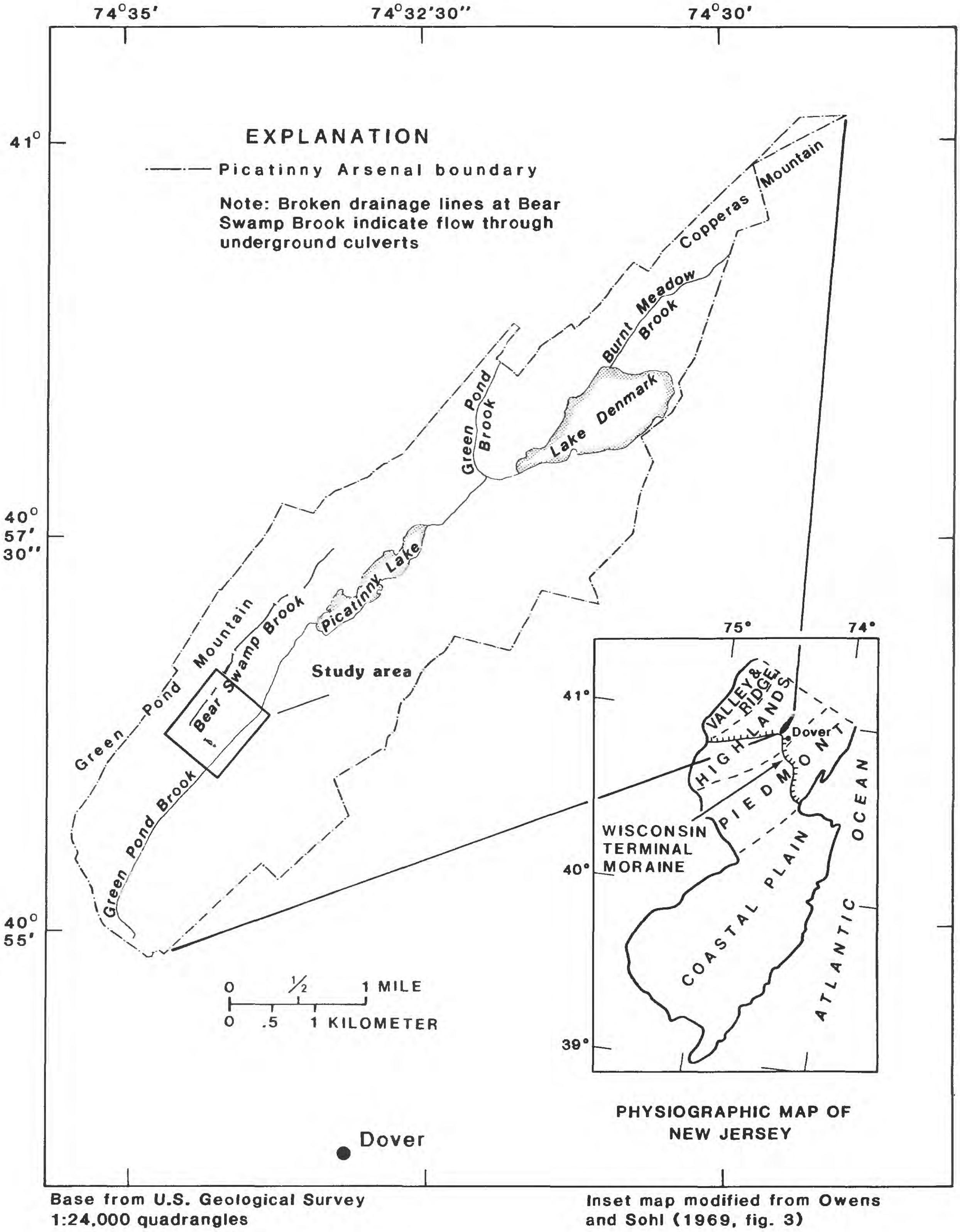
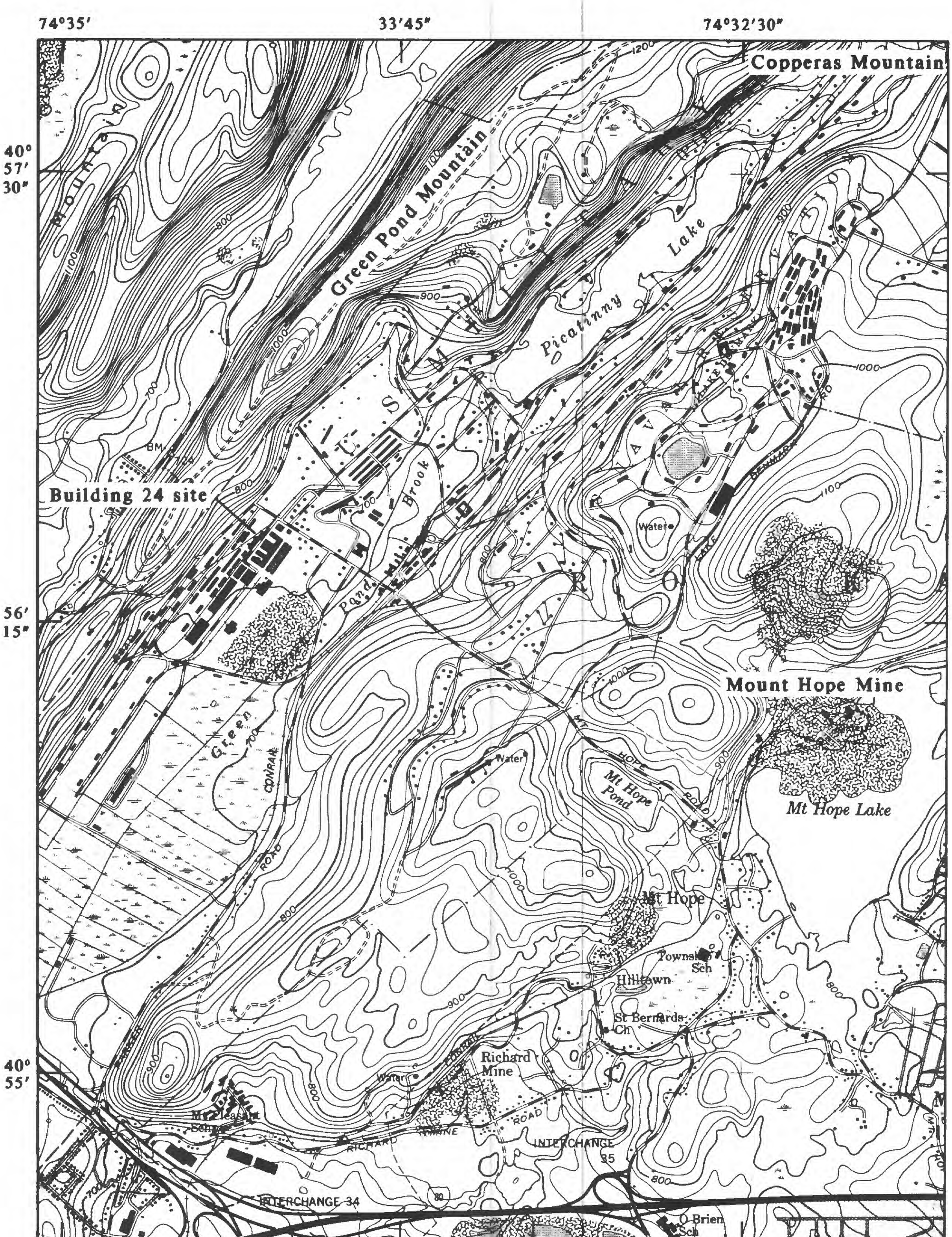


Figure 1.--Location of Picatinny Arsenal, New Jersey.



Base from U.S. Geological Survey
1:24,000, quadrangle, Dover, 1954

EXPLANATION

—800— Topographic contour. Interval 20 feet. Datum is sea level

0 1/2 1 MILE

0 .5 1 KILOMETER

Figure 2.--Physical features in the vicinity of Picatinny Arsenal.

In March 1986, the U.S. Army requested that the USGS assess ground-water quality at Picatinny Arsenal as required under the Resource Conservation and Recovery Act (RCRA--Public Law 94-580, October 21, 1976). This law regulates operations at hazardous-waste-treatment facilities. On the basis of preliminary assessments, contamination caused by the metal-plating operations at building 24 appeared to be a more serious environmental concern than the other RCRA-regulated activities at the arsenal, and the decision was made to focus the investigation in this area (Foster Wheeler USA Corporation, 1987).

The study area extends from building 24 southward to Green Pond Brook. Bear Swamp Brook flows under building 24 and drains into Green Pond Brook, which flows southwest out of the valley. The area is nearly flat and is generally about 700 ft above sea level. Unconsolidated sediments comprise both an unconfined and a confined aquifer, and a second confined aquifer is present in the underlying bedrock.

Purpose and Scope

This report describes the results of a study of ground-water contamination conducted by the Survey at Picatinny Arsenal from 1986 through 1988. The investigation was designed to determine the extent of ground-water contamination and the rate of contaminant movement in the vicinity of the metal-plating shop at building 24. Contamination in the unsaturated zone and in surface water also was investigated.

The report includes results of a ground-penetrating-radar survey, test drilling, observation-well installation, slug tests, and chemical analyses of ground- and surface-water samples. Although results of analyses of ground-water samples from the confined aquifer systems are included, the focus of the study was the shallow, unconfined aquifer. Data collected to define the hydrogeologic framework and ground-water quality in the study area supplements work previously done by both the USGS and USAEHA.

History of Ground-Water Contamination and Previous Studies

From 1960 through 1981, wastewater from a wastewater-treatment system for a metal-plating operation at building 24 was discharged into two lagoons (fig. 3). The lagoons originally were designed with sand bottoms that allowed some of the wastewater to infiltrate into the ground. Residual wastewater also was discharged to Bear Swamp Brook, a tributary to Green Pond Brook (fig. 1). Discharge records are not readily available; however, during 1979, approximately 10,000 gallons per day of wastewater discharged to the brook; the maximum daily discharge was 21,600 gal (gallons) (Michael Ruiz, U.S. Army Research and Development Center, oral commun., 1985).

In May 1979, the USAEHA conducted a study of the geohydrology and the potential effects of wastewater-disposal practices on ground-water quality at Picatinny Arsenal (J.W. Bauer, U.S. Army Environmental Hygiene Agency, written commun., 1979). The two sand-lined lagoons behind building 24 were identified as potential sources of ground-water contamination, and installation of observation wells upgradient and downgradient from the lagoons was recommended. Results of analyses of samples from these wells

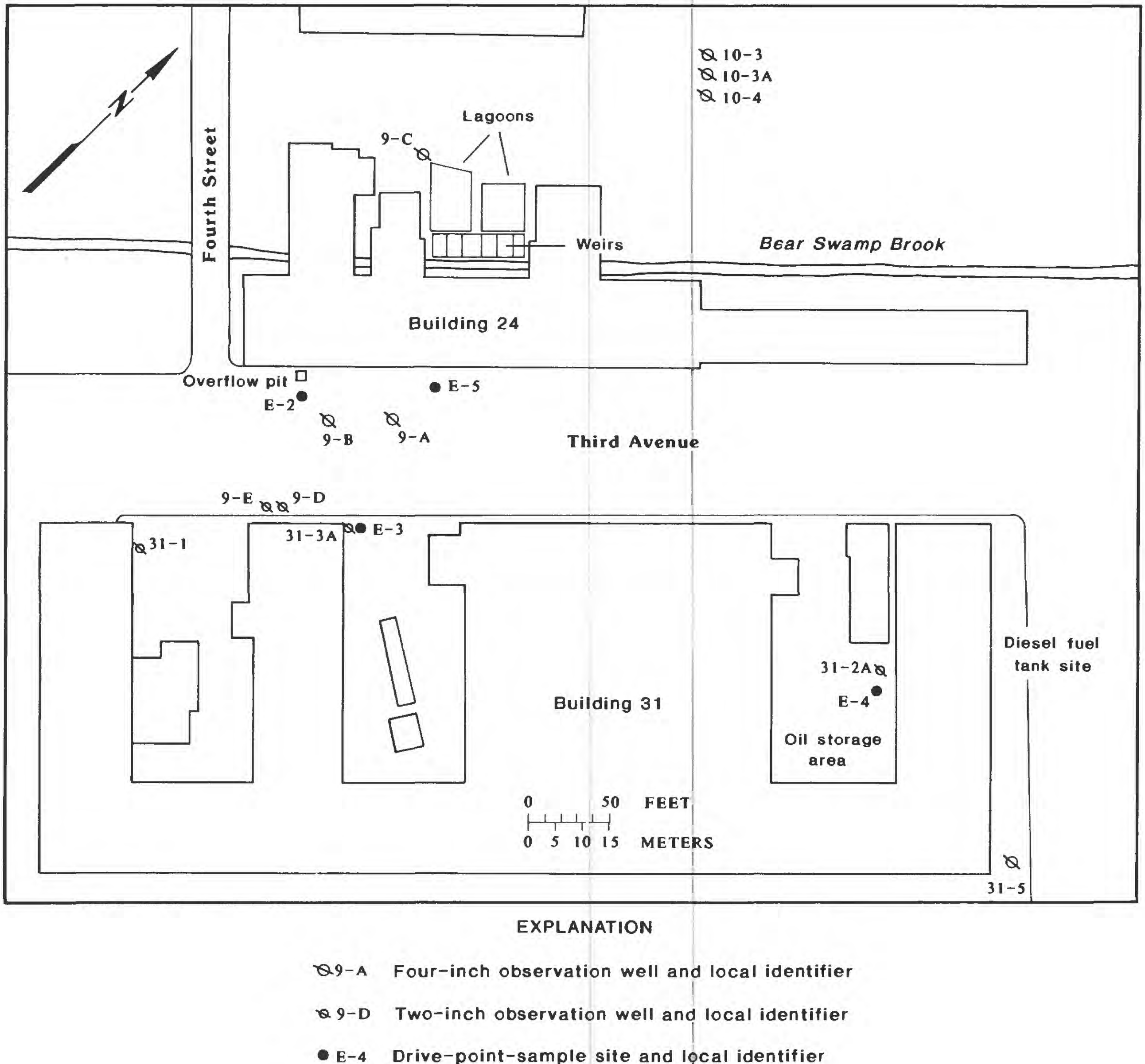


Figure 3.--Location of wastewater-treatment and -disposal facilities at building 24.

showed that chromium was the predominant metal in the wastewater effluent discharged into the lagoons. Aluminum, cadmium, copper, nickel, and zinc also were present in the effluent.

In 1981, the first phase of the recommended ground-water-quality assessment was performed by USAEHA (D.C. Bayha, U.S. Army Environmental Hygiene Agency, written commun., 1981). Four shallow observation wells (less than 25 ft deep) were installed by a private contractor in the vicinity of building 24--one upgradient and three downgradient from the wastewater lagoons. Water samples collected from all four shallow observation wells and from two nearby deep (greater than 100 ft deep) water-supply wells were found to contain VOCs. Cadmium, chromium, and cyanide also were found in water samples from the observation wells. On the basis of these results, USAEHA recommended a detailed study of ground-water contamination. The agency developed a ground-water-quality-assessment plan for Picatinny Arsenal with priority assigned to assessment of contamination in the area of building 24. The plan called for installation of additional shallow and deep observation wells.

During the first phase of the assessment, from December 1981 through February 1982, five additional shallow observation wells were installed in the vicinity of building 24. The second phase of the assessment consisted of installation of two clusters of four wells screened at different depths, with one cluster near the arsenal cafeteria and another near building 65, in November and December 1982. These wells were drilled by the U.S. Army Corps of Engineers under the supervision of USGS. The hydrogeologic data collected during drilling are presented and discussed by Harte and others (1986). Ground-water sampling of the new wells by USAEHA in January 1983 showed that water from all of the shallow observation wells and several of the deep wells contained VOCs.

The final report of the ground-water assessment completed by USAEHA (D.C. Bayha, U.S. Army Environmental Hygiene Agency, written commun., 1984) concluded that (1) concentrations of iron and manganese exceeded the U.S. Environmental Protection Agency (USEPA) secondary drinking-water regulations in water from most wells; (2) concentrations of cadmium exceeded the primary drinking-water regulation in water from two wells; (3) water from more than half the observation wells contained detectable levels of VOCs, with TCE the primary contaminant; and (4) the detection of TCE in water from the deep observation wells near the cafeteria and building 24 indicated downward vertical movement of contaminants in the aquifer, possibly caused by pumping of water-supply wells in the area.

Following the completion of the USAEHA study, ground-water sampling at Picatinny Arsenal was continued by private contract laboratories. The ground-water-quality data collected through January 1985 are presented in Sargent and others (1986). A preliminary evaluation by the Survey of the ground-water contamination at building 24 and at another metal-plating facility at building 95, based on previously collected data, concluded that a contaminant plume emanated from building 24 and followed the general water-table gradient for a distance greater than 1,600 ft (E.F. Vowinkel, U.S. Geological Survey, written commun., 1985). TCE was determined to be the principal ground-water contaminant. Evidence of TCE contamination in one of the deep confined aquifers indicates that pumpage from the water-supply wells apparently has caused contaminants to move around or through a confining unit.

Since 1981, various actions have been taken to eliminate the sources of ground-water contamination at the site--

(1) The seepage lagoons were replaced by concrete-lined settling basins in 1981. During reconstruction, 532 ft^3 (cubic feet) of contaminated soil were removed from the site.

(2) A relief line connected to the degreaser in building 24 and to an overflow pit (dry well) in front of the building was capped in 1985. The relief line had been designed to prevent the accidental overflow of solvent in the degreaser tank. The line directed overflowing solvent out of the building and into the pit. Although there is no direct knowledge of such an overflow event, possible condensation of TCE vapor within the pipe during the operation of the degreaser may have caused the release of a significant quantity of TCE to the overflow pit. The pit drains directly into the subsurface and may have released TCE into the ground water.

(3) In 1983, 1,1,1-trichloroethane replaced TCE as the degreasing agent in the metal-plating process.

(4) In 1985, potentially contaminated top soil was removed from the oil-storage area adjacent to building 31 (fig. 3), about 275 ft from building 24 (P. Riebel, U.S. Army Research Development and Engineering Center, oral commun., 1988). An underground storage tank containing diesel fuel at the northeast corner of building 31 was found to be leaking and was removed in 1986.

(5) Intermittent summer operation of water-supply well no. 130 was halted in 1985. Withdrawals from this well, which is about 500 ft from building 24, may have induced the downward migration of contaminants into the confined glacial aquifer.

(6) In 1986, observation well 130-obs was sealed. This well was adjacent to water-supply well no. 130 and was screened from 17.5 to 125 ft below land surface. Because observation well 130-obs was screened through a confining unit, it may have acted as a conduit for the movement of contaminants from the shallow unconfined aquifer to the confined glacial aquifer, especially during the operation of the adjacent water-supply well.

Ground-water-quality data collected from 1981-84 are listed in Sargent and others (1986). TCE is the organic compound that is present in the highest concentrations in the contaminant plume in the unconfined aquifer; a maximum concentration of 25,200 $\mu g/L$ (micrograms per liter) was found immediately downgradient from building 24. In addition to TCE, tetrachloroethylene (maximum concentration 197 $\mu g/L$), 1,1,1 trichloroethane (165 $\mu g/L$); and trans-1,2-dichloroethylene (542 $\mu g/L$) were detected. The concentrations of trans-1,2-dichloroethylene include both cis-1,2-dichloroethylene and trans-1,2-dichloroethylene, as these compounds are indistinguishable by

USEPA analytical methods 601-602 or 624 (Longbottom and Lichtenbery, 1982). Both isomers of dichloroethylene have been identified as biodegradation products of TCE (Wood and others, 1985, p. 495).

Since 1981, elevated levels of several inorganic constituents also have been detected in ground water. These constituents include cadmium (maximum concentration, 61 μg/L), chromium (150 μg/L), lead (97 μg/L), selenium (20 μg/L), cyanide (430 μg/L), and copper (409 μg/L). By 1985, the concentrations of most inorganic constituents were found to have decreased significantly from the maximum levels (E.F. Vowinkel, U.S. Geological Survey, written commun., 1985).

Acknowledgments

The authors extend their appreciation to personnel of the Environmental Engineering Section of the U.S. Army Armament Research Development and Engineering Center for assistance in the planning and implementation of this investigation, and to Wayne A. Fox of the U.S. Army Environmental Hygiene Agency for providing technical guidance during the initial planning stages. Thanks also is extended to the U.S. Army Toxic and Hazardous Materials Agency (USATHEMA) for performing chemical analyses of ground-water samples. Richard Walker, formerly of the U.S. Geological Survey, is acknowledged for designing the drive-point sampler used in the investigation.

DATA COLLECTION AND ANALYSIS

Data collection was begun in 1986 with a ground-penetrating-radar survey of the study area. In addition, as part of a drive-point reconnaissance survey, water samples were collected at 15 sites at 5-ft intervals from the top of the water table to a depth of approximately 50 ft. Thirty-three observation wells subsequently were installed in or adjacent to areas of known contamination. In October and November 1987, ground-water samples were collected from 62 wells. During December 1987 and February 1988, water levels were measured in all wells in the study area and stream discharge in Bear Swamp Brook and Green Pond Brook was measured.

Drive-Point Sampling

Ground-water-quality data from samples collected in the vicinity of building 24 prior to 1986 indicated that the concentrations of contaminants in wells located near one another are highly variable. It was suspected that some of this variability might be caused by vertical stratification of contaminants in the ground-water system. In order to determine the vertical distribution of contaminant concentrations, a temporary drive-point sampling device was used to collect discrete ground-water samples at various depths. Drive-point sampling allowed for definition of the three-dimensional distribution of contaminants in ground water, and for efficient selection of observation-well locations and screened intervals.

The drive-point sampler was constructed from a 2-ft length of steel AW drill rod. A number of 1/2-in.- (inch) diameter holes were drilled in rows around the drill rod. A stainless-steel screen made of 100-mesh wire cloth on an expanded steel support was inserted inside the drill rod as a filter to prevent sediment from entering the sampler. A hardened-steel drive point was screwed on the bottom of the sampler to facilitate driving the device into the subsurface. At the top of the sampler, a 0.25-in.-outside diameter tubing connector was threaded into the top of the coupling in order to attach the tubing used to collect water samples. Five-foot sections of AW drill rod were added to the drive-point sampler, and a drive plate with a 240-pound drive hammer was secured for driving. A truck-mounted or tripod-mounted cathead was used to drive the sampler into the ground. Samples were collected, generally at 5-ft depth intervals, between the top of the water table, approximately 10 ft below land surface, and 50 or 55 ft below land surface.

Continuous lengths of polyethylene tubing were used to collect the water samples. The polyethylene tubing was sufficiently durable to withstand the force of driving and probably did not have a major effect on the concentrations of volatile organic constituents in the sampled ground water. Barcelona and others (1985) estimated that pumpage of contaminated water through a 15-m (meter) (49.21 ft) length of polyethylene tubing at a rate of 100 mL/min (milliliters per minute) would result in an estimated 10 percent loss of chlorinated hydrocarbons from a 40 $\mu g/L$ mixture of chloroform, TCE, tetrachloroethane, and tetrachloroethylene. The contact time between the ground water and the tubing was less than 5 min (minutes) for most of the drive-point samples collected, so that sorption onto the tubing probably was minimal.

A peristaltic pump was used to collect the water samples. In field tests, the peristaltic pump resulted in a loss from 0 to 40 percent of volatile organic compounds (Imbrigiotta and others, 1988). Other ground-water sampling devices, such as bladder pumps or submersible pumps, result in less loss; however, the peristaltic pump was the only sampling device that could be used in conjunction with the drive-point sampler because of the sampler's construction. The recoveries and results obtained with this system were considered to be satisfactory because the drive-point sampler was intended to be used as a reconnaissance tool. More rigorous ground-water sampling was performed following installation of observation wells.

At each sampling depth, the sampler tubing was attached to the peristaltic pump and ground water pumped for at least 20 min prior to sample collection. In order to reduce the potential for vertical cross-contamination between sampling depths at any one site, the sampler was flushed continuously. This method was more practical than removing the sampler from the borehole between sample collections. Slight cross-contamination between samples will have no effect on data interpretation because of the reconnaissance nature of the survey. Generally 5 to 10 volumes of the sampler and discharge tubing were purged prior to sample collection. Temperature, pH, specific conductance, and dissolved oxygen concentration were measured frequently during pumping. In order to ensure collection of a representative ground-water sample, stability (no observed change in 5 minutes) in the measurements of these four characteristics was required prior to sample collection. Following sample collection at a specific depth, a 5-ft section of drill rod was attached and the sampler was driven an additional 5 ft, at which depth the next sample was collected.

The drive-point sampler and discharge tubing were decontaminated with methanol and deionized water between sampling sites. Analysis of field wash blanks collected after decontamination showed that VOC contaminant concentrations typically did not exceed the detection limit of 1 μg/L.

Well Drilling

After drive-point sampling was completed, twenty-seven 2-in.-I.D. (inside diamter) observation wells ranging in depth from 15.7 to 55.9 ft were installed in clusters in the area between building 24 and Green Pond Brook (fig. 4). The wells were installed with the use of a hollow-stem auger, and were constructed with 5-ft stainless-steel screens and stainless-steel casings to minimize sample contamination.

In order to expand the observation-well network in the deeper aquifers, six 4-in.-I.D. wells were installed at three sites to depths ranging from 95 to 265 ft. The wells were installed using the mud-rotary method, and have stainless-steel screens and black steel casings. Well-construction details for the newly installed wells and the existing wells that were sampled in October and November 1987 are shown in table 1.

In order to reduce the possibility of cross-contamination of wells by TCE, the 2-in.-I.D. observation wells were installed in a sequence that began at the fringes of the presumed contamination area and ended near the contaminant source. All drilling equipment, well casings, and screens were steam-cleaned prior to installation in the borehole. These wells, drilled by auger, were completed by inserting the well screen and casing into the hollow auger stem. A sand pack was placed at least 5 ft above the top of the screen. The auger flights then were removed and the remainder of the borehole was filled with a 100-percent bentonite grout. All of the wells were completed at land surface in flush-mounted locking roadway boxes which were cemented at the top of the borehole to protect the well. The altitude of ground surface at each new well was surveyed to the nearest one-hundredth of a foot. During drilling, a log was recorded and samples of borehole materials were collected. The well logs for the deepest well at each cluster are presented in the Appendix. The wells were developed to remove particles from the screen and sand pack by pumping until relatively clear water was produced.

The six 4-in.-I.D. deep wells were installed using mud-rotary methods. At two of the three sites, two wells were completed in the confined glacial aquifer--one near the bottom of the unit and one near the top. At the third site, one well was completed in the confined glacial aquifer and the second was screened in the bedrock aquifer. Borehole geophysical logging and collection of split-spoon core samples aided in the selection of screened intervals. The well casing and the screen were steam-cleaned prior to installation. The wells were developed by a combination of air lifting, pumping, and surging to remove drilling fluids and other particles from the screened zone.

Gas Sampling in the Unsaturated Zone

Soil-gas samples were collected from the unsaturated zone using probes constructed of 0.25-in.-I.D. stainless-steel tubes cut to the desired probe depth. The bottom 3 in. of each probe was slotted and covered with a fine-mesh stainless-steel screen. The probes were installed at two or three

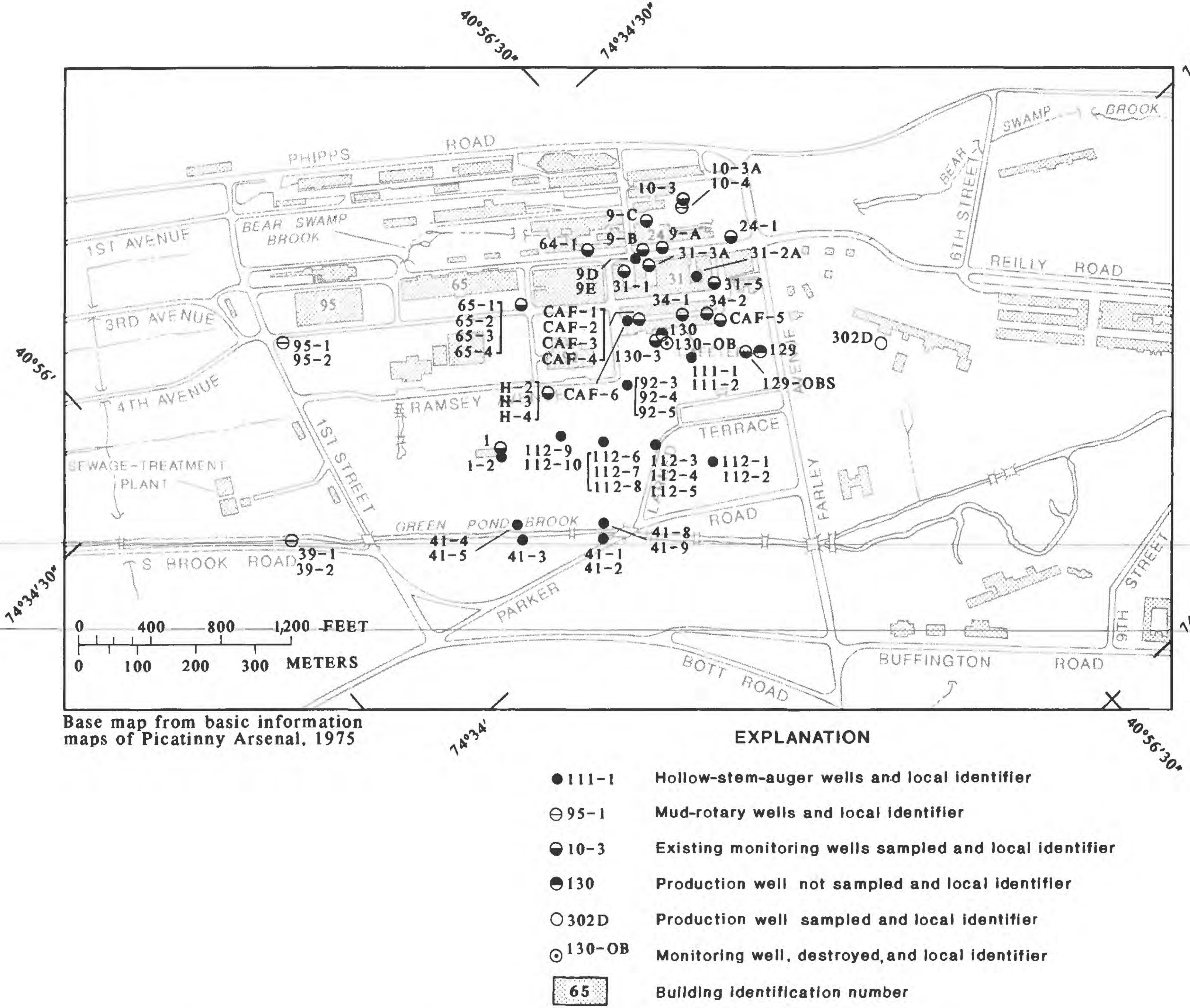


Figure 4.--Location of wells sampled October 19 through November 11, 1987.

Table 1.--Well-construction and specific-capacity data for selected wells in the study area

[ft, feet; LSD, land-surface datum; gal/min, gallons per minute; SFDF, stratified drift; LSVL, Leithsville Formation; HRDS, Hardyston quartsite; --, indicates missing value]

Well number	Local well identifier	Date completed	Altitude of land surface (ft above sea level)	Screen setting (ft below LSD)	Screened diameter (inches)	Static water level (ft below LSD)	Date water level measured	Pumping water level (ft below LSD)	Pumping period (hours)	Yield (gal/min)	Specific capacity (gal/min/ft)	Geologic unit[2]
270974	10-3	10-13-86	702.0	5.0- 15.0	4	5.64	12-17-87	--	--	--	--	112SFDF
270968	[1]10-3A	08-05-87	701.9	249.5-264.5	4	4.00	09-29-87	28.80	--	2.0	0.08	374LSVL
270969	[1]10-4	08-11-87	701.9	85.5- 95.5	4	8.55	09-25-87	25.00	--	6.0	.36	112SFDF
270958	[1]111-1	07-28-87	702.5	36.1- 41.1	2	11.30	08-25-87	17.61	1.0	2.5	.40	112SFDF
270959	[1]111-2	07-27-87	702.4	20.9- 25.9	2	11.19	08-25-87	14.00	.8	16.0	5.69	112SFDF
270944	[1]112-1	07-27-87	697.2	32.0- 37.0	2	7.61	08-24-87	10.32	2.2	2.2	.81	112SFDF
270953	[1]112-10	07-30-87	694.3	10.7- 15.7	2	5.53	08-26-87	12.68	.8	30.0	4.20	112SFDF
270945	[1]112-2	07-27-87	696.9	15.9- 20.9	2	7.27	08-24-87	7.83	.5	20.0	35.71	112SFDF
270946	[1]112-3	08-05-87	698.2	46.1- 51.1	2	8.79	09-03-87	30.05	1.5	5.0	.24	112SFDF
270947	[1]112-4	07-30-87	698.3	37.0- 42.0	2	8.93	09-03-87	30.60	1.0	3.0	.14	112SFDF
270948	[1]112-5	07-30-87	698.2	15.9- 20.9	2	8.82	09-03-87	17.97	.8	15.0	1.64	112SFDF
270949	[1]112-6	07-30-87	695.6	36.1- 41.1	2	6.35	08-27-87	21.88	.8	15.0	.97	112SFDF
270950	[1]112-7	08-05-87	695.7	46.1- 51.1	2	6.67	08-27-87	28.82	1.8	1.0	.05	112SFDF
270951	[1]112-8	07-29-87	695.6	15.9- 20.9	2	6.52	08-26-87	12.96	.3	7.0	1.09	112SFDF
270952	[1]112-9	08-06-87	694.3	31.0- 36.0	2	5.41	08-26-87	11.78	.6	4.5	.71	112SFDF
270267	129-OBS	08-26-83	703.4	19.0- 23.0	2	13.30	03-20-85	16.10	2.0	1.0	.36	112SFDF
270333	130-3	08-01-85	701.8	23.0- 28.0	2	11.20	08-02-85	16.80	.5	12.0	2.14	112SFDF
270327	24-1	07-11-85	701.4	18.0- 23.0	2	7.90	08-02-85	11.80	1.0	6.0	1.54	112SFDF
270083	302D	01-01-21	697.0	110.0-403.0	8	8.00	01-01-21	38.00	--	490.0	16.33	374LSVL
270336	31-1	07-12-85	702.6	19.0- 24.0	2	10.60	08-01-85	13.60	1.5	1.5	.50	112SFDF
270963	[1]31-2A	08-03-87	702.1	25.9- 30.9	2	9.73	08-28-87	--	1.0	18.0	--	112SFDF
270330	31-3A	07-11-85	702.2	13.0- 23.0	2	9.90	08-02-85	12.40	.7	12.0	4.80	112SFDF
270964	31-5	10-15-86	703.0	11.0- 21.0	4	8.43	12-17-87	--	--	--	--	112SFDF
270965	31-6	10-17-86	702.2	8.0- 18.0	4	6.86	12-17-87	--	--	--	--	112SFDF
270966	31-7	10-10-86	702.2	10.0- 20.0	4	7.21	12-17-87	--	--	--	--	112SFDF
270331	34-1	07-11-85	703.2	19.0- 24.0	2	12.6	08-02-85	15.40	1.0	4.0	1.43	112SFDF
270967	34-2	10-23-86	703.3	8.0- 18.0	4	9.89	12-17-87	--	--	--	--	112SFDF
270970	[1]39-1	08-26-87	692.7	195.0-205.0	4	2.17	12-17-87	171.00	--	.5	.01	112SFDF
270971	[1]39-2	08-28-87	692.4	90.0-100.0	4	2.27	12-17-87	70.80	1.5	1.8	.04	112SFDF
270937	[1]41-1	07-22-87	692.6	39.6- 44.6	2	2.91	08-20-87	--	3.0	1.6	--	112SFDF
270938	[1]41-2	07-21-87	692.6	15.6- 20.6	2	5.69	08-20-87	--	4.0	1.1	--	112SFDF
270939	[1]41-3	07-21-87	689.5	17.1- 22.1	2	3.54	08-21-87	--	2.2	1.4	--	112SFDF
270940	[1]41-4	07-23-87	688.6	28.1- 33.1	2	2.16	09-02-87	25.07	1.0	2.5	.11	112SFDF
270941	[1]41-5	07-23-87	688.8	12.2- 17.2	2	2.61	09-02-87	10.85	.7	18.0	2.18	112SFDF
270942	[1]41-8	08-04-87	690.5	30.8- 35.8	2	2.70	09-02-87	27.35	2.0	1.0	.04	112SFDF
270943	[1]41-9	07-30-87	690.4	15.8- 20.8	2	4.39	09-02-87	15.43	1.0	14.0	1.27	112SFDF
270337	64-1	08-01-85	701.5	17.0- 22.0	2	9.2	08-02-85	18.00	.4	8.0	.91	112SFDF
270246	65-1	12-16-82	699.1	267.0-287.0	4	11.50	12-22-82	125.00	3.8	4.5	.04	374LSVL
270247	65-2	12-09-82	699.9	201.0-206.0	4	11.25	01-12-83	25.30	.2	9.0	.64	112SFDF
270248	65-3	12-15-82	700.0	135.0-140.0	4	4.20	01-12-83	123.0	.1	5.5	.05	112SFDF
270249	65-4	12-15-82	699.9	30.0- 35.0	4	9.35	12-21-82	19.12	.2	12.0	1.23	112SFDF
270093	9-A	03-09-81	701.8	2.0- 22.0	4	8.30	03-19-85	9.20	1.0	1.0	1.11	112SFDF
270094	9-B	03-09-81	702.0	3.0- 23.0	4	8.90	09-11-84	--	.5	--	--	112SFDF
270095	9-C	03-09-81	702.1	6.0- 16.0	4	6.00	03-09-81	--	--	2.0	--	112SFDF
270961	9-D	08-04-87	702.2	26.0- 31.0	2	8.51	09-10-87	12.19	2.0	5.0	1.36	112SFDF
270962	[1]9-E	08-04-87	702.2	14.3- 19.3	2	8.64	09-10-87	13.50	.8	6.0	1.23	112SFDF
270955	[1]92-3	08-03-87	700.2	50.2- 55.2	2	9.84	09-04-87	31.78	1.0	6.0	.27	112SFDF
270956	[1]92-4	07-31-87	699.9	38.0- 43.0	2	9.53	09-04-87	23.05	.8	12.0	.89	112SFDF
270957	[1]92-5	07-31-87	699.6	25.9- 30.9	2	9.13	09-03-87	23.33	.7	8.0	.56	112SFDF
270972	[1]95-1	09-09-87	695.2	100.0-120.0	4	3.09	09-30-87	30.00	--	.5	.02	112SFDF
270973	[1]95-2	09-28-87	695.2	190.0-200.0	4	4.52	10-06-87	28.48	--	2.5	.10	112SFDF
270242	CAF-1	11-12-82	702.7	253.0-268.0	4	6.30	12-15-82	146.80	2.7	3.0	.02	377HRDS
270243	CAF-2	11-15-82	702.7	31.0- 36.0	4	10.90	12-08-82	31.00	--	10.0	.50	112SFDF
270244	CAF-3	11-17-82	702.8	123.0-128.0	4	13.70	12-09-82	123.00	.2	4.0	.04	112SFDF
270245	CAF-4	12-10-82	702.9	168.0-173.0	4	11.80	12-17-82	156.80	1.7	4.0	.03	112SFDF
270304	CAF-5	04-25-84	703.2	24.0- 29.0	4	10.88	02-01-88	--	--	--	--	112SFDF
270960	[1]CAF-6	08-06-87	702.7	50.9- 55.9	2	10.98	09-03-87	28.93	.6	4.5	.25	112SFDF
270280	H-2	04-18-84	699.2	203.0-223.0	4	11.33	11-28-84	--	--	5.0	--	374LSVL
270281	H-3	04-20-84	699.2	115.0-125.0	4	9.61	11-28-84	56.77	.8	10.0	.21	112SFDF
270282	H-4	04-23-84	699.0	15.0- 25.0	4	9.70	11-28-84	11.34	5.0	10.0	6.10	112SFDF
270239	I	12-30-81	693.3	9.0- 29.0	4	5.50	12-30-81	9.50	--	10.0	2.50	112SFDF
270954	[1]I-2	07-29-87	693.2	31.9- 36.9	2	3.66	08-26-87	15.50	.5	4.0	.34	112SFDF

[1] Well completed as part of this study

[2] Wells screened in geologic unit SFDF are screened in either the unconfined or confined glacial aquifer. Wells screened in geologic unit LSVL or HRDS are screened in a confined bedrock aquifer

depths, ranging from 1.5 to 9.0 ft, at each of six locations in the study area. The screened intervals of the probes were separated by bentonite in order to minimize vapor transport in the vertical direction during sampling.

Samples were collected by drawing soil gas through the probes and into two 125-mL (milliliter) glass sampling bulbs with Teflon[1] stopcocks at both ends. The sampling bulbs were connected in parallel to the vapor probe by a glass "Y" joint. A peristaltic pump connected on the exhaust side of the bulb was used to pull gas through the bulbs at a rate of approximately 120 mL/min per bulb. After 1,000 mL of gas was removed from the soil, the stopcocks on the sampling bulbs were closed. The bulbs were spiked with a field vapor surrogate, bromochloromethane, and transported to the Survey laboratory in Trenton, New Jersey, for same-day analysis.

Each gas sample was analyzed by purging the organic vapors from the sampling bulb onto an adsorbent trap with 550 mL of helium. The compounds subsequently were desorbed from the trap onto a capillary gas-chromatography column. The concentrations of the organic vapors were quantified by a calibrated Hall[1] electrolytic-conductivity detector. Vapor-calibration standards were prepared by injection of the neat compounds into a 2-L (liter) static dilution bottle. The large sample size (125 mL) discharged to the adsorbent trap, in combination with the sensitivity of the detector for halogenated organic compounds, yielded a method quantitation limit of 40 ng/L (nanograms per liter).

Collection of Ground-Water Samples and Laboratory Methods

Ground-water samples for analysis of cations, anions, nutrients, metals, and VOCs were collected from October through December 1987 at 59 wells in the study area. Samples were collected, filtered, and preserved in accordance with accepted USGS field techniques (Brown and others, 1970; Wood, 1976). Field measurements included temperature, specific conductance, pH, and alkalinity. Two-in.-I.D. wells were purged using a small-diameter, stainless-steel and Teflon submersible pump. Samples for analysis of inorganic constituents were collected with the same pump. Samples for analysis for VOCs or other organic constituents were collected using a Teflon bailer with Teflon-coated support wire. The 4-in.-I.D. wells were purged and sampled for inorganic constituents with a standard 3.875-in.-diameter submersible pump with polyvinylchloride (PVC) discharge pipe. A Teflon bailer also was used to collect water samples from the 4-in.-I.D. wells for analysis for VOCs.

The wells were sampled beginning with those that were expected to contain the lowest contaminant concentrations and progressing to those that were expected to contain the highest contaminant concentrations. In order to reduce the potential for cross-contamination between wells, sampling equipment was rinsed with deionized water between wells and was flushed several times with well water prior to sample collection. Samples were collected after removal of at least three casing volumes of water and after the temperature, pH, and specific-conductance measurements had stabilized

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

(no observable change in measurement). Immediately following collection, samples were preserved and prepared for shipment to the laboratory. In areas of TCE contamination, purge water from each well was treated by filtration through three 55-gal drums containing activated carbon prior to discharge.

Concentrations of inorganic constituents from drive-point and well samples were determined using the methods of Skougstad and others (1979) at the USGS National Water-Quality Laboratory (NWQL) in Denver, Colorado. Organic constituents, including organic carbon, organic nitrogen, and purgeable organic compounds, were analyzed by the methods described in Wershaw and others (1983) at the NWQL in Denver, Colorado. The method for organic analysis is equivalent to USEPA Methods for Organic Chemical Analysis of Municipal and Industrial Wastewater 624 (Longbottom and Lichtenberg, 1982). Quality-assurance checks were conducted based on the methods of Friedman and Erdmann (1982).

Analyses of drive-point and well samples for 30 priority pollutants and VOCs were performed at the Survey laboratory in Trenton, New Jersey. The method used was a modification of USEPA methods 601 and 602 (Longbottom and Lichtenberg, 1982). Modifications included the use of a wide-bore capillary chromatograph column; two selective detectors, a Hall electrolytic conductivity detector, and a photoionization detector connected in series; and subambient cooling.

The USATHEMA contract laboratory used several protocols for analyzing water samples. All metals, except mercury, were determined by inductively coupled argon plasma method and graphite furnace atomic adsorption. Mercury was analyzed by co-vapor atomic adsorption. Base/neutral-, acid-extractable, and other semi-volatile organic compounds were analyzed by gas chromatography-mass spectrometry (GC/MS) with USEPA method-625 protocols for analyses that are not described under the USEPA contract-laboratory protocol. For compounds described by the contract-laboratory protocol, the detection limit specified for that protocol was used. Six VOCs were determined by GC/MS by using USEPA method 624. Sample analysis for pesticides followed USEPA method 608 (Longbottom and Lichtenberg, 1982).

DESCRIPTION OF STUDY AREA

Climate

The climate in the study area is predominantly continental; prevailing winds are from the northwest during October through April and from the southwest during the rest of the year (Gill and Vecchioli, 1965). From 1951-80 mean annual precipitation was 47.85 in.; and monthly average rainfall ranged from 3.08 in. during February to 4.54 in. during August. The mean annual temperature was 50.3 °F (degrees Fahrenheit); the coldest average monthly temperature, 27.4 °F, occurs in January and the warmest, 72.4 °F, in July (U.S. Department of Commerce, 1982).

Geology

Picatinny Arsenal is located within the Green Pond Syncline, a structural region of the New Jersey Highlands physiographic province. The

New Jersey Highlands comprises a northeast-southwest trending system of folded and faulted Proterozoic- to Devonian-age rocks that form a sequence of valleys and ridges. The ridges typically are broad, rounded, or flat-topped; the valleys typically are deep and narrow. Generally, a 400- to 600-ft difference in elevation separates ridge crest from valley floor (Wolf, 1977, p. 226).

Bedrock

Structure

The Green Pond Syncline is a narrow, northeast-trending, faulted syncline containing narrow outliers of Paleozoic rocks. The Paleozoic rocks typically lie unconformably on the Proterozoic rocks, which are exposed on the eastern side of the syncline (fig. 5). However, thrust faults and folds in the Paleozoic rocks have obscured the original contact between the basement and cover rocks (Lyttle and Epstein, 1987).

There are two major faults in the area of Picatinny Arsenal--the Green Pond fault and the Mount Hope fault. The Green Pond fault is a longitudinal fault that runs along the western side of the valley, parallel to the valley trend (Sims, 1953, p. 269). Total throw of this fault is about 1,500 ft, with uplift on the west side. The fault plain dips steeply to the northwest (Kummel and Weller, 1902, p. 28). The Mount Hope fault cuts across the valley trend and strikes north 78 °W, with an average dip of 60 °SW. Uplift is on the northern side of the fault (Sims, 1958, p. 56).

In the Mount Hope Mine (fig. 2), the Mount Hope fault is exposed as a brecciated and shattered zone 20 to 30 ft wide (Sims, 1958, p. 56). Little rotation of the fault is indicated because of the slight difference in its attitude and displacement between the surface and a depth of 2,100 ft. The net vertical movement is about 300 ft. Because no well intersects the fault in the study area, whether the fault has characteristics similar to those observed in the mine shaft is unknown.

Description of Units

The oldest bedrock unit, a hornblende granite and associated alaskite of Middle Proterozoic age, is exposed at the southeastern entrance to the arsenal (Puffer, 1980, p. 50). The granite is pinkish buff to greenish buff in color with a distinct gneissoid structure. The granite is mapped as an alaskite where mafic mineral content is less than five percent by volume. The alaskite facies is closely associated with magnetite-ore deposits that were mined west of the arsenal (table 2).

The Hardyston Quartzite is an Early Cambrian-age, fine- to medium-grained, white to dark gray, thin- to medium-bedded, feldspathic quartzite interbedded with arkose, quartz-pebble conglomerate, and silty shale or phyllite. The contact with the underlying Proterozoic granite is unconformable and abrupt. Thickness of the unit ranges up to 100 ft in New Jersey (Lyttle and Epstein, 1987).

The Leithsville Formation is an Early and Middle Cambrian-age interbedded, light- to medium-gray, coarse-grained dolomite and calcitic

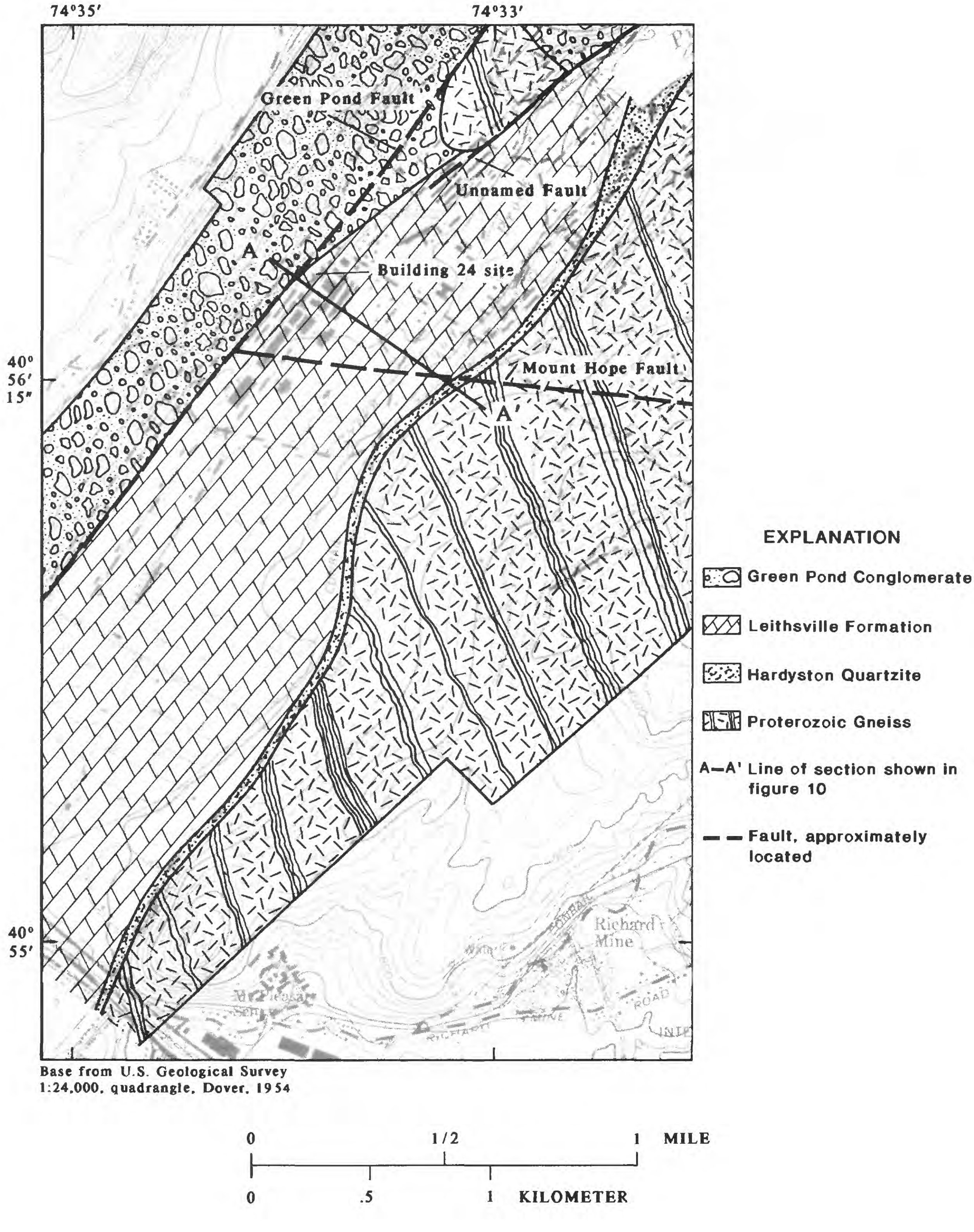


Figure 5.--Generalized bedrock geology in the study area.

Table 2.--Stratigraphic and geohydrologic characteristics of geologic units at Picatinny Arsenal

Time-stratigraphic unit			Geologic unit	Maximum thickness (in feet)	Lithology	Geohydrologic characteristics
Era	System	Series	Formation or lithologic unit			
Cenozoic	Quaternary	Holocene	Alluvium	10	Ranges from a sandy loam in the valley to a stony gravel on hillsides	Too thin to be tapped
			Swamp deposits(muck)	30	Black, brown, and gray organic material	Permeability rapid along organic layers
		Pleistocene	Stratified drift	200+	Present in the form of glaciofluvial and glaciolacustrine deposits, mostly sand- to clay-size sediments; exhibits stratification and in some cases rythmic laminations (varves)	Yield depends on degree of sorting and grain size; the well-sorted and coarse-grained deposits are good aquifers with yields up to 2,200 gallons per minute; clay and silt deposits generally are unsuitable as aquifers
			Unstratified drift	100+	Unstratified drift deposits are present in the form of ground, terminal, and recessional moraine. Deposits generally are tightly packed, poorly sorted, with grain sizes ranging from boulders to clay Unconformity	Yield depends on degree of sorting and packing; generally low yields
Paleozoic	Silurian	Upper	Green Pond Conglomerate	1500+	Coarse quartz conglomerate interbedded with and grading upward into quartzite and sandstone, generally massive and red but may contain white and green beds Unconformity	Generally yields small amount of water from fracture and joints
	Cambrian	Middle	Leithsville Formation	1000+	Predominantly a light-to medium-gray, microcrystalline, locally stylolitic rock to a fissile, siliceous to dolomitic micrite texture rock; often highly weathered to a medium-yellow, silty clay Gradational	Contains water-bearing fractures and solution cavities that generally have moderate yields of up to 380 gallons per minute
		Lower	Hardyston Quartzite	200	Orthoquartzite to conglomeratic; generally well indurated Unconformity	Generally few fractures; yields small amounts of water
Proterzoic			Alaskite		Medium- to coarse-grained, predominantly granitoid gneiss composed principally of microperthite, quartz, and oligoclase; includes local bodies of microantiperthite granite and granite pegmatite; amphibolite inclusions are common	All three lithologic units have similar hydrologic characteristics; ground water occurs in fractures and joints; yields generally are low, ranging from 26 to 75 gallons per minute
			Hornblende granite		Medium- to coarse-grained, predominantly granitoid gneiss composed principally of microperthite, quartz oligoclase, and hornblende; includes local bodies of biotite granite, horneblende granite gneiss, granodiroite, and granite pegmatite; amphibolite inclusions are common	
			Biotite-quartz-feldspar gneiss		Medium-to coarse-grained gneiss of widely varying composition; the predominant facies is composed of biotite, quartz, and oligoclase; minor facies are characterized by abundant garnet and microperthite, and locally by sillimanite and graphite	

Modified from Drake, 1969, table 20; Sims, 1958, pl. 1; Gill and Vecchioli, 1965, table 3 dolomite containing thin layers of quartz and dolomitic sandstone (Wolf, 1977, p. 46). The Leithsville Formation is approximately 800 ft thick. Mud cracks, ripple marks, and graded beds are common in the formation (Wolf, 1977, p. 46). The lower contact typically is gradational. The presence of solution cavities in this unit creates the potential for significant ground-water withdrawals (Gregory Herman, New Jersey Geological Survey, oral commun., 1988).

The Green Pond Conglomerate is a Late Silurian-age, gray to reddish-gray sandstone and conglomerate with predominantly white quartz and minor gray, green, red, and yellow chert, red shale, and red sandstone cobbles (Lyttle and Epstein, 1987). The lower contact is separated from the Leithsville Formation by the Green Pond fault. Thickness ranges from 984 to 1,394 ft (Lyttle and Epstein, 1987).

Glacial Deposits

History of Deposition

Continental ice sheets advanced across the study area at least twice during the Quaternary Period (Stanford, 1989). As a result, the bedrock surface is covered by a mantle of unconsolidated glacial deposits, predominantly till in the upland areas and stratified-drift in the valleys. In the study area, the distribution and characteristics of the stratified-drift reflect the manner in which the area was deglaciated. Deglaciation began approximately 18,000 years ago and progressed in stages. The southernmost extent of glaciation is delineated by a terminal moraine at the southwestern boundary of the arsenal. The initial melting of ice north of the terminal moraine caused the formation of a temporary proglacial lake, Lake Picatinny, in the Green Pond Brook valley. Glacial Lake Picatinny was dammed across the southern end by the moraine, and the glacier blocked northward drainage. The glacier receded to the south end of the present-day Picatinny Lake where a ridge of till was deposited. The lake drained to the southeast through a gap in a bedrock ridge at an elevation of about 700 ft and was filled with a sequence of sediments: sublacustrine sand and gravel was overlain by lake-bottom and deltaic fine sand and silt and capped by deltaic sands and gravels. Following deglaciation, deposits of silt and clay and finally peat formed in floodplains and large ice-blocked depressions along Green Pond Brook (Stanford, 1989).

Description of Deposits

Three distinct sedimentary facies have been distinguished in the study area from sediment samples collected at the cafeteria site (fig. 4). Figure 6 is a plot of percent of sediment sample with particle sizes less than 0.25 millimeter (0.01 in.) against depth, from which the different facies may be distinguished. In order of increasing depth, these facies are (1) deltaic deposits (20 to 62 ft thick), (2) lake-bottom and deltaic deposits (55 to 93 ft thick), and (3) sublacustrine sand and gravel (20 to 90 ft thick).

Variability in the particle-size distributions of the aquifers and confining units reflects the variability in the energy of deposition of meltwater during deglaciation. After formation of Glacial Lake Picatinny, meltwater streams carried sediments into the lake, where they were

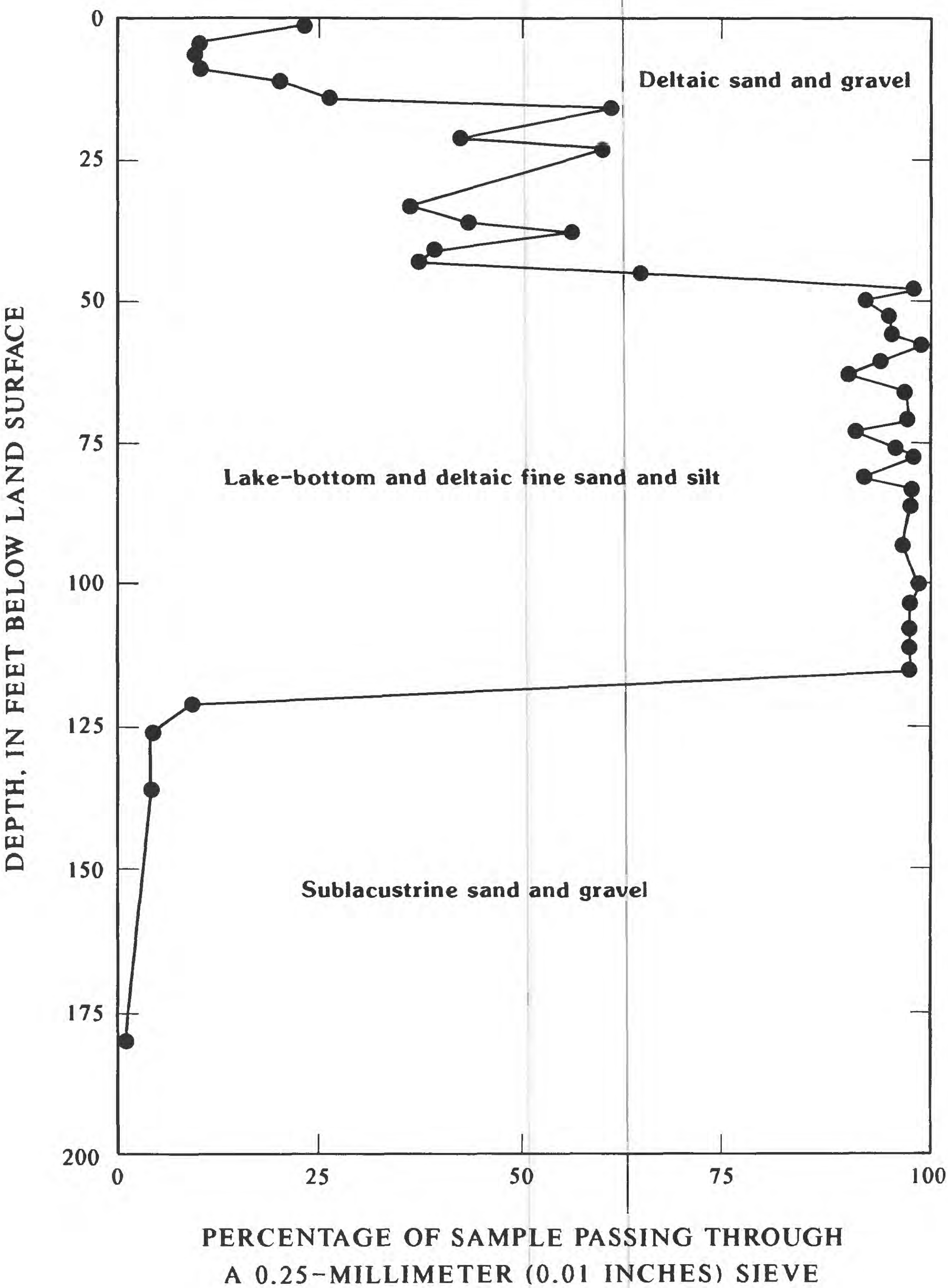


Figure 6.--Percentage of sample less than 0.25 millimeters (0.01 inches) in size against depth below land surface in well CAF-1.

deposited. Where the streams entered the lake, alluvial fans and deltas formed. In the main body of the lake, seasonal changes caused deposition of thin layers of alternating fine- and coarse-grained material. Particle size generally ranges from coarse to fine down-valley and vertically downward from the land surface toward the confining unit (Stanford, 1989).

A ground-penetrating-radar survey of the study area was conducted to define glacial or post-glacial fluvial features that may influence the movement of ground water in the unconfined aquifer. Results of the survey showed an ancestral stream channel or oxbow lake in the vicinity of Green Pond Brook (fig. 7). The depression is 18 to 22 ft below present land surface at its deepest points and 3 ft below land surface at its extremities (fig. 8). Peat deposits and fine sand fill the depression which is in an area mapped as Carlisle Muck Series soil. Because the ground-penetrating-radar survey was conducted only within the study area, the down-valley extent of the channel was not determined.

Soils

The study area contains soils formed on organic deposits, glacial-lake sediments, or glacial outwash (Carlisle-Parsippany-Preakness Soil Association), with a small area of soil formed in glacial till (Rockaway-Hibernia-Urban Land Soil Associations) (Eby, 1976). The individual soil series found in the study area are shown in figure 9. The soil type, drainage, and slope for each soil are listed in table 3.

Hydrology

Water in the region enters the ground from precipitation, flows through various combinations of bedrock, till, and stratified drift, and then discharges into streams and ponds. In the valley, three aquifers have been identified: (1) an unconfined glacial (water-table) aquifer, (2) a confined glacial aquifer, and (3) a confined bedrock aquifer in the Leithsville Formation (fig. 10). The unconfined aquifer is contained in the deltaic sands and gravels that are exposed at land surface. The confined glacial aquifer comprises the sublacustrine sand-and-gravel unit, which is separated from the unconfined aquifer by the lake-bottom fine sand and silt. The lake-bottom fine-sand-and-silt layer is a leaky confining unit, and probably is discontinuous near the valley wall. Ground-water movement in the bedrock aquifer depends on the secondary porosity caused by solution channels and fractures rather than on primary porosity, as is the case for the aquifers in stratified drift.

Aquifer Properties

Slug tests were chosen as the means of estimating horizontal hydraulic conductivity in the unconfined aquifer because (1) slug tests do not require removal and handling of large volumes of contaminated water, as is necessary in aquifer tests, and (2) slug tests can be completed rapidly in comparison with the lengthy sampling period necessary for an in-situ tracer test. In the study area, slug tests were performed on 22 of the 2-in.-I.D. observation wells with the use of a pressure transducer connected to a Hermit data logger. A sealed 1-in.-I.D. PVC pipe was inserted into the well in order to displace well water. When the pipe was removed, the data logger

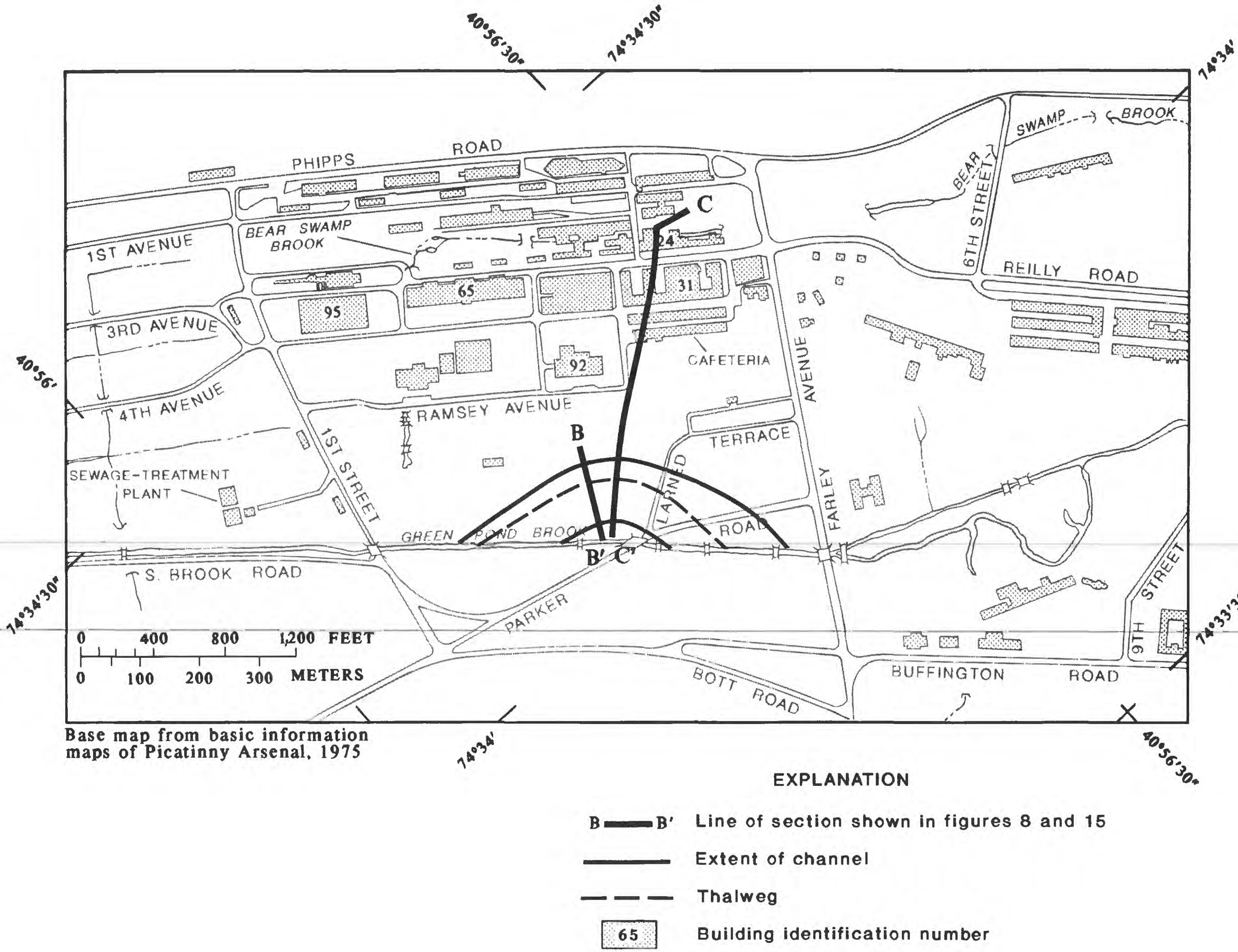


Figure 7.--Location of buried stream channel determined from ground-penetrating-radar survey.

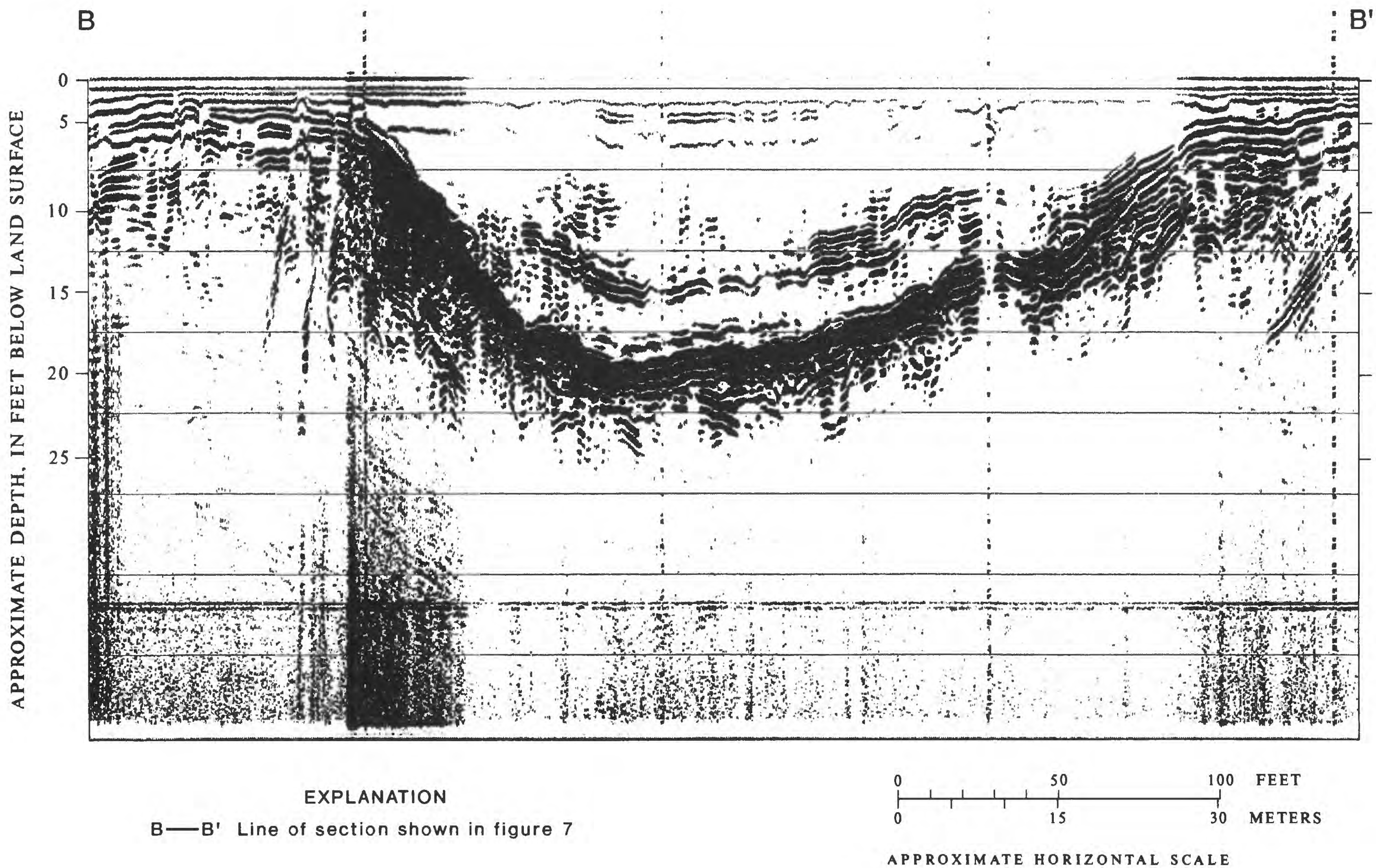
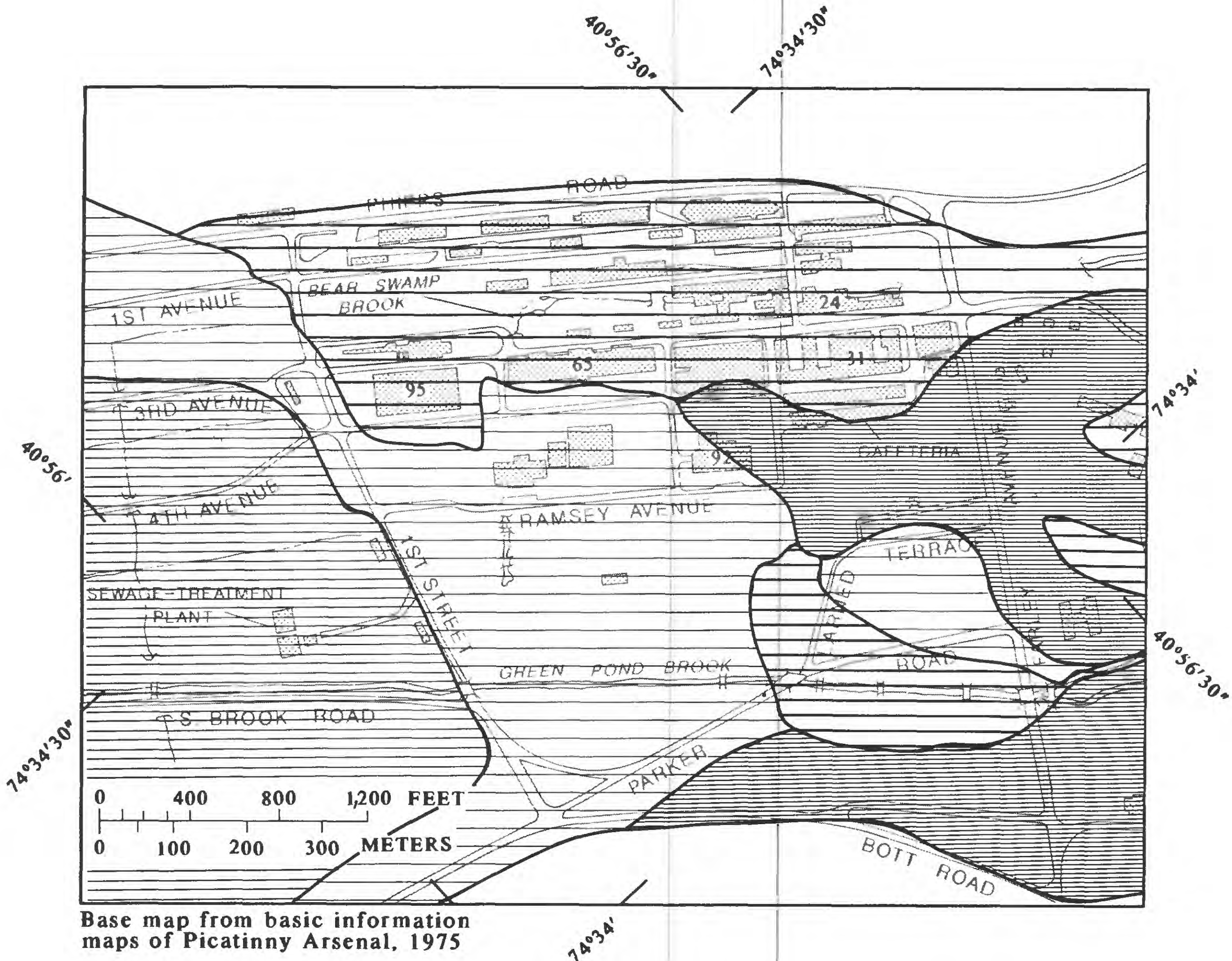


Figure 8.--Ground-penetrating-radar section showing buried stream channel.



Base map from basic information maps of Picatinny Arsenal, 1975

EXPLANATION

Soil Series

- Rockaway
- Urban Land
- Preakness
- Otisville
- Adrian Muck
- Carlisle Muck

65 Building identification number

Figure 9.--Soils in the study area.

Table 3.--Descriptions of soils in the study area

Soil name	Soil type	Drainage	Slope
Rockaway	stony, sandy loam	well	gently sloping to very steep
Urban land	reworked sand and gravel	well	gently sloping
Otisville Series	gravelly loamy sand	excessive	gently sloping to steep
Preakness Series	sandy loam	moderate	nearly level
Carlise Muck Series	organic	poorly	nearly level
Adrain Muck	organic	very poor	nearly level

Source: Eby (1976)

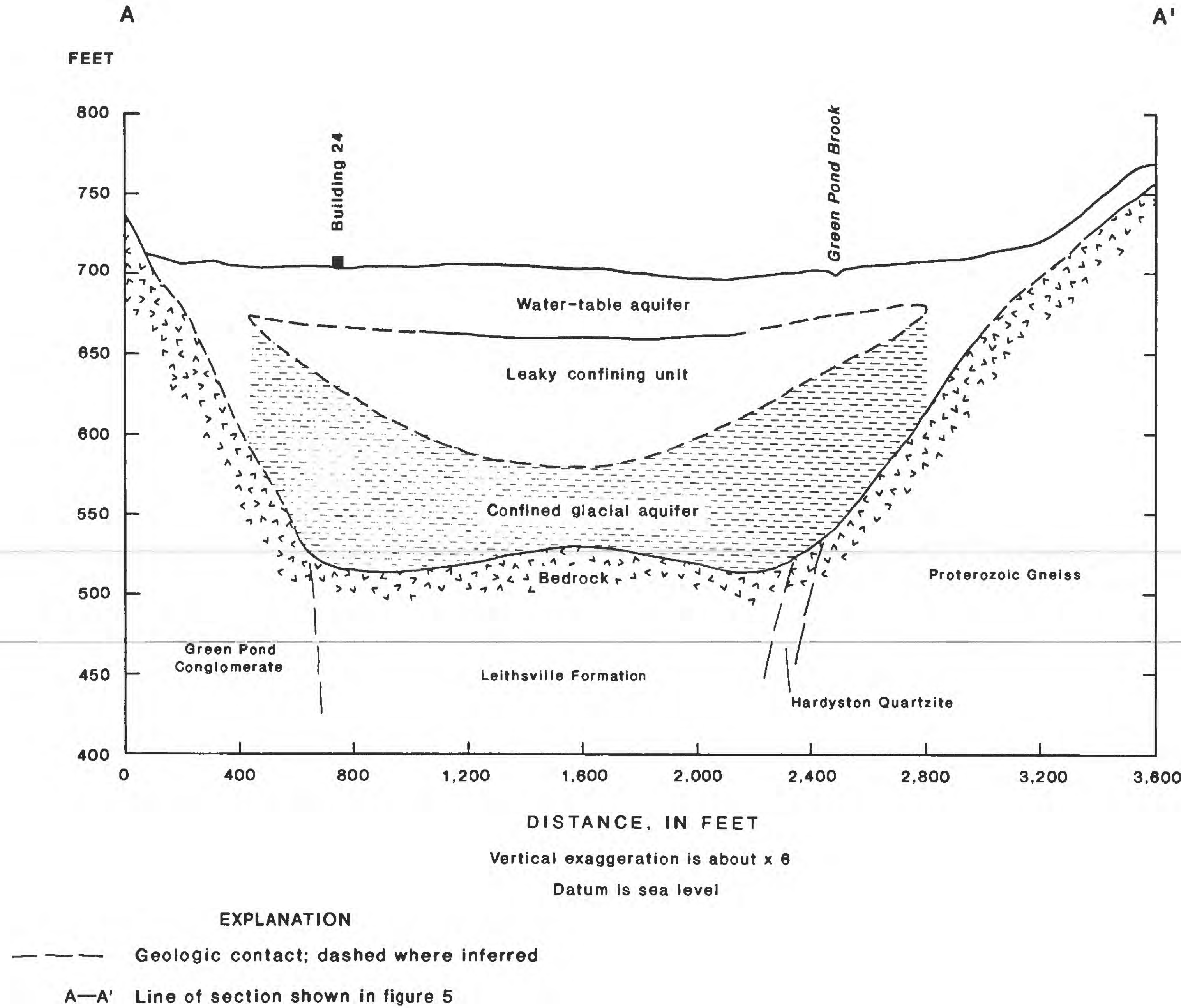


Figure 10.--Generalized hydrogeologic section through the study area showing bedrock and aquifer units.

recorded the water levels as the well recovered. This method used to calculate horizontal hydraulic conductivity is applicable to completely or partly penetrating wells in unconfined aquifers (Bower and Rice, 1976). This technique takes into consideration the borehole size and characteristics of the gravel pack through which water flows into the well.

The results of the slug tests are provided in table 4. Areal and vertical variations in horizontal hydraulic conductivities are evident. The largest values of horizontal hydraulic/conductivity obtained from the slug tests (123 to 195 ft/d (feet per day)) were in well 112-2 (fig. 4), a shallow well located on the upstream end of the study area. In general, trends in hydraulic-conductivity values reflect the general trend in sediment distribution, with coarser material found up-valley, toward Lake Picatinny. Generally, high hydraulic conductivities also were obtained at shallow depths. Hydraulic conductivities of 12 to 195 ft/d were obtained for wells up to 25 ft deep and of 0.5 to 11 ft/d were obtained for wells screened at a depth greater than 40 ft. Specific-capacity data are provided in the table for comparison. As expected, variations in specific-capacity values correlate with variations in values of horizontal hydraulic conductivity.

Another method for estimating horizontal hydraulic conductivities uses the lithologic log for each well (Lohman, 1972, p. 52). Values of horizontal hydraulic conductivity are assigned to each unit of known thickness on the basis of its lithologic characteristics (Harte and others, 1986). The values of hydraulic conductivity for each unit then are added and divided by the total aquifer thickness at that location, yielding an average hydraulic conductivity for the total thickness of the strata. Estimates from four wells calculated by this method are as follows: CAF-2, 50.9 ft/d; 65-4, 60.0 ft/d; 9-A, 65.4 ft/d; and H-4, 58.4 ft/d. These values fall within the range (0.5 to 195 ft/d) of the slug-test results.

The initial estimates of aquifer properties in the confined glacial aquifer are based on aquifer-test data. Tests in 1965 on water-supply wells no. 130 and 129 produced transmissivity values of 5,570 ft^2/d (square feet per day) and 7,424 ft^2/d, respectively. An additional aquifer test of well no. 129 in 1983 produced a transmissivity value of 6,867 ft^2/d, with a storage coefficient of 0.0001. Vertical hydraulic conductivity of the confining unit was calculated to be 0.6 ft/d.

Ground Water

In order to determine the direction of ground-water flow and, potentially, the direction of contaminant movement, the altitude and configuration of the water table must be known. The direction of ground-water flow in the unconfined aquifer in December 1987 is shown on the water-table map constructed from water-level measurements at 49 wells and stream sites (fig. 11). Flow generally is toward Green Pond Brook, except in the southwestern part of the study area, where ground-water flow is toward Bear Swamp Brook. In its upper reaches, near building 24, Bear Swamp Brook loses water to the aquifer.

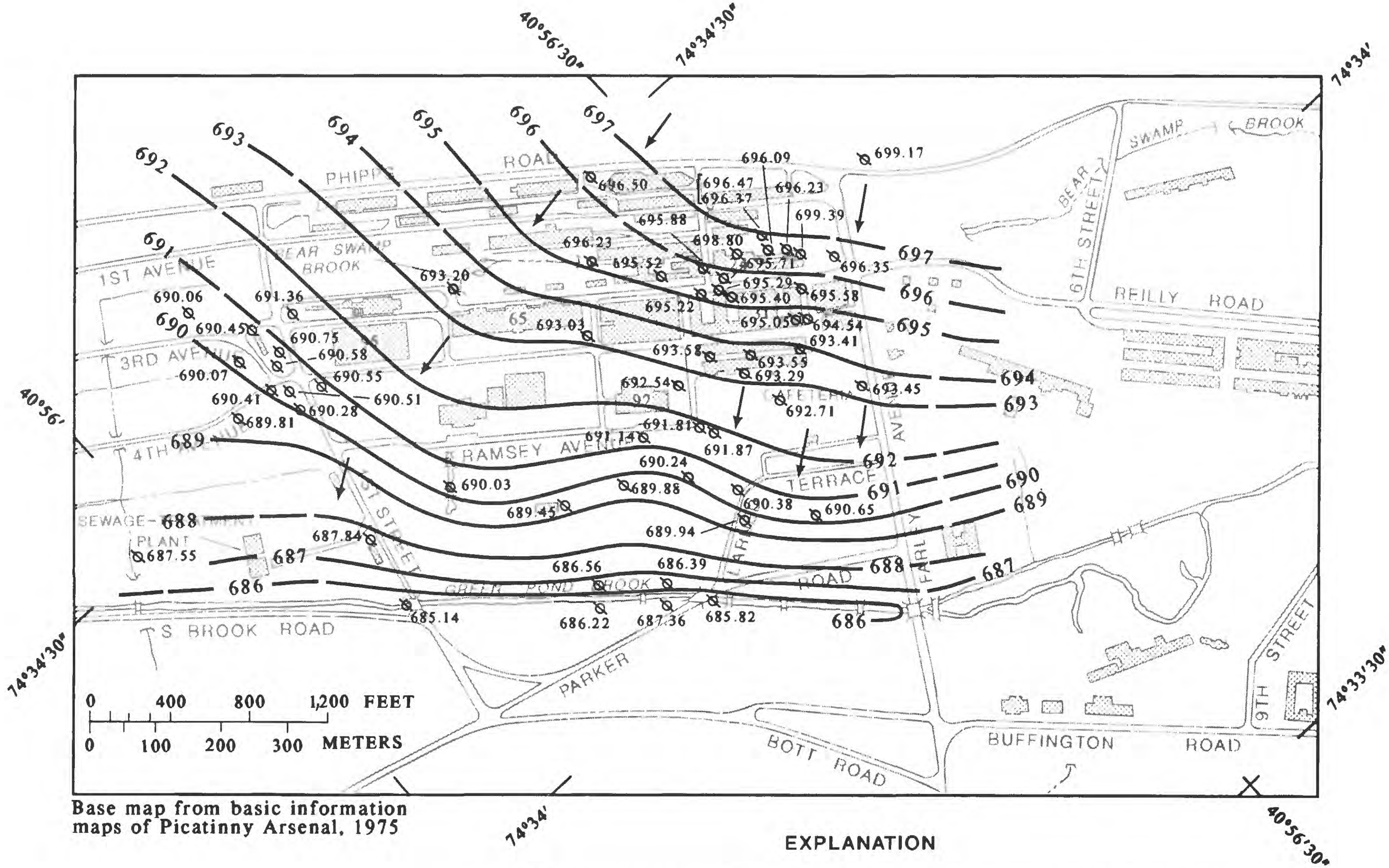
Changes in the water table, indicated by changes in water levels in wells, reflect changes in ground-water storage, which is controlled by

Table 4.--Results of slug tests conducted at Picatinny Arsenal, 1988

[ft/day, feet per day; ft below LSD, feet below land-surface datum; (gal/min)/ft, gallons per minute per foot of drawdown]

Well number	Local well identifier	Hydraulic conductivity[1] (ft/day)	Screen setting (ft below LSD)	Specific capacity (gal/min)/ft
270940	41-4	1.1 - 1.8	28.1-33.1	.11
270941	41-5	59 - --	12.2-17.2	2.18
270942	41-8	.5 - .8	30.8-35.8	.04
270943	41-9	14 - 22	15.8-20.8	1.27
270944	112-1	13 - 21	32.0-37.0	.81
270945	112-2	123 - 195	15.9-20.9	35.71
270946	112-3	5 - 7	46.1-51.1	.24
270947	112-4	2 - 2	37.0-42.0	.14
270948	112-5	19 - 30	15.9-20.9	1.64
270949	112-6	12 - 18	36.1-41.1	.97
270950	112-7	.5 - .8	46.1-51.1	.05
270951	112-8	12 - 19	15.9-20.9	1.09
270952	112-9	12 - 18	31.0-36.0	.71
270953	112-10	36 - 58	10.7-15.7	4.20
270954	I-2	5 - 8	31.9-36.9	.34
270955	92-3	6 - --	50.2-55.2	.27
270956	92-4	13 - 20	38.0-43.0	.89
270957	92-5	9 - 14	25.9-30.9	.56
270958	111-1	8 - 12	36.1-41.1	.40
270959	111-2	98 - 139	20.9-25.9	5.69
270960	Cafeteria 6	8 - 11	50.9-55.9	.25
270961	MW 9D	24 - 37	26.0-31.0	1.36

[1] The first value does not take into account the borehole diameter and properties of the gravel pack. The second value includes the effects of the borehole with a diameter of 8 inches and a gravel-pack porosity of .2



Base map from basic information maps of Picatinny Arsenal, 1975

EXPLANATION

—— 687 — —	POTENTIOMETRIC CONTOUR--Shows altitude at which water would have stood in tightly cased wells. Dashed where approximated. Contour interval 1 foot. Datum is sea level
685.14	LOCATION OF OBSERVATION WELL--Number shown is water level measured in December 17, 1987
←	GENERAL DIRECTION OF GROUND-WATER FLOW
65	Building identification number

Figure 11.--Altitude of the water table and direction of ground-water flow, December 17, 1987.

seasonal variations in precipitation and evapotranspiration and, to a minor extent, by pumpage (fig. 12). This seasonal fluctuation in water levels is typical of that in shallow, unconfined aquifers composed of coarse-grained materials--low in late summer or fall and high by late spring. Between March 1983 and February 1984, water-level fluctuations in well CAF-2 were approximately 6 ft. This amount of fluctuation is thought to be typical for a well at this location (in the middle of the valley, between the valley walls and the discharge area); fluctuations near Green Pond Brook are expected to be smaller.

In the underlying confined aquifer, the potentiometric surface is similar in orientation to the water-table surface. Figures 13 and 14 show the potentiometric surfaces in the confined glacial and bedrock aquifers, respectively. Water levels were measured in February 1988. The confined glacial aquifer shows a 5-ft drop in head across the study area; in the bedrock aquifer, the change in head is 11 ft. The greater head change in the bedrock aquifer probably reflects recharge to bedrock from the adjacent hills. In the center of the valley, head differences between the confined glacial and unconfined water-table aquifers in the same area ranged from 0.37 to 2.23 ft at well clusters. Head differences between the bedrock aquifer and the confined glacial aquifer ranged from 0.17 to 0.98 ft.

Water in the unconfined aquifer moves predominantly toward streams under a cross-valley gradient, with a smaller component of flow down the valley. In the two deeper aquifers, the down-valley component of flow is larger than in the unconfined aquifer (M. Martin, U.S. Geological Survey, written commun., 1988). Both down-valley and cross-valley gradients are controlled primarily by the streambed gradient and local variations in recharge, saturated thickness, aquifer permeability, and pumpage.

Figure 15 delineates the three aquifers and shows the pattern of ground-water flow. Within the unconfined and confined glacial aquifers, ground-water flow generally is horizontal and upward toward Green Pond Brook. Discontinuities in the confining silts and clays and small scale silts and clay lens (not shown in fig. 15) probably modify the general flow path. Vertical gradients in the unconsolidated deposits generally are downward on the sides of the valley and upward in the vicinity of the brook. Zones of highest vertical gradient in the bedrock aquifer are near the valley sides where the vertical component of flow is generally upward, reflecting flow from the underlying bedrock aquifer to the confined glacial aquifer. Ground-water flow in this deep system also includes a down-valley component.

Exposed rock outcrops on the hillsides provide a pathway for recharge to the bedrock aquifer. This flow pattern is consistent with the conceptual view of ground-water movement in a flow system consisting of recharge and discharge areas (Freeze and Cherry, 1979, p. 194).

The rate of flow in the unconfined aquifer, without consideration of porosity, is proportional to the horizontal hydraulic conductivity and the hydraulic gradient, according to Darcy's Law. If horizontal hydraulic conductivities in the range of 25 to 75 ft/d are assumed and an average gradient, of 0.0055 is used, then calculated average velocities of ground-water flow range from 0.46 to 1.4 ft/d. These calculations were made using an effective porosity of 0.3, which is characteristic of sandy aquifer

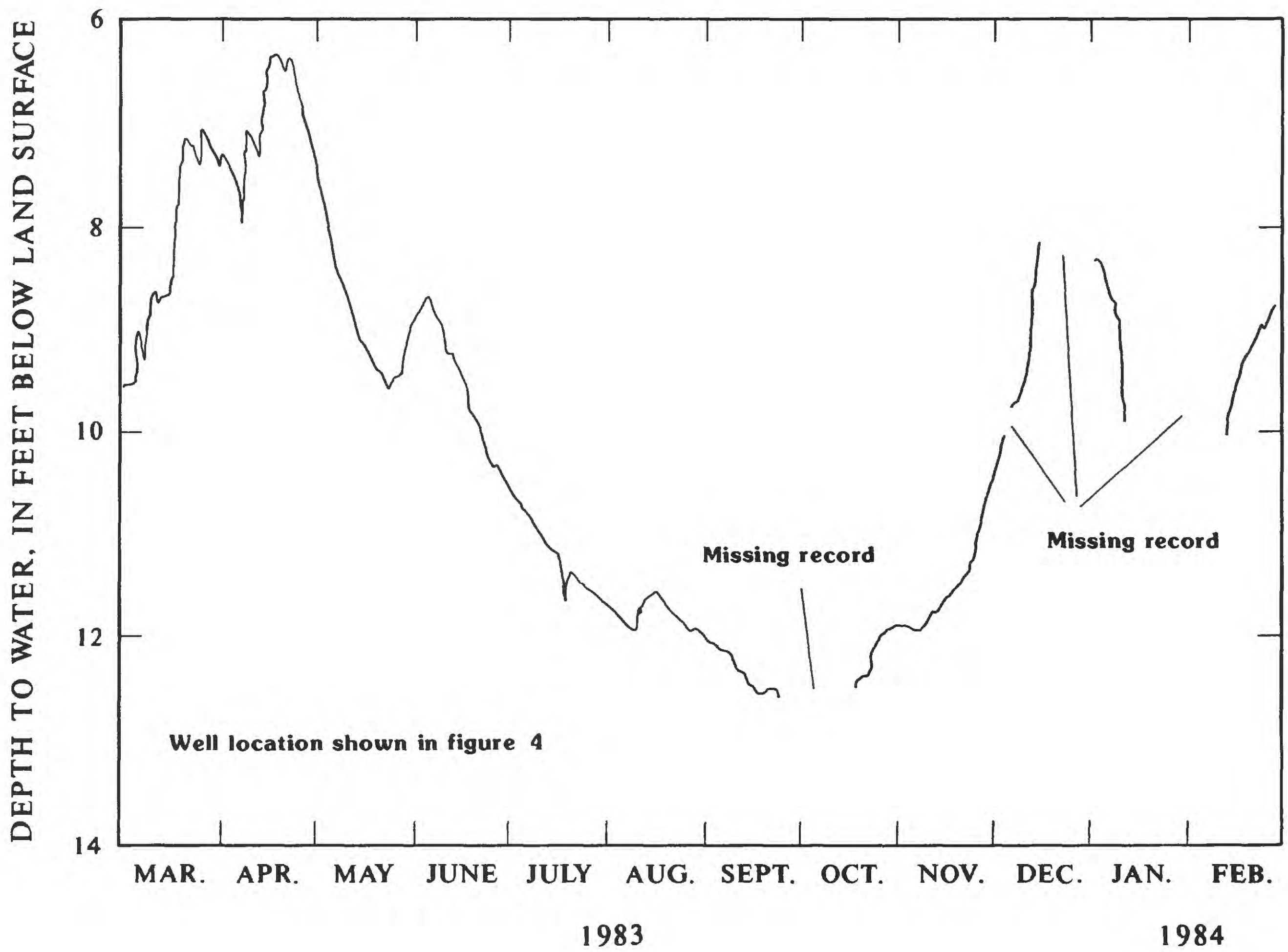
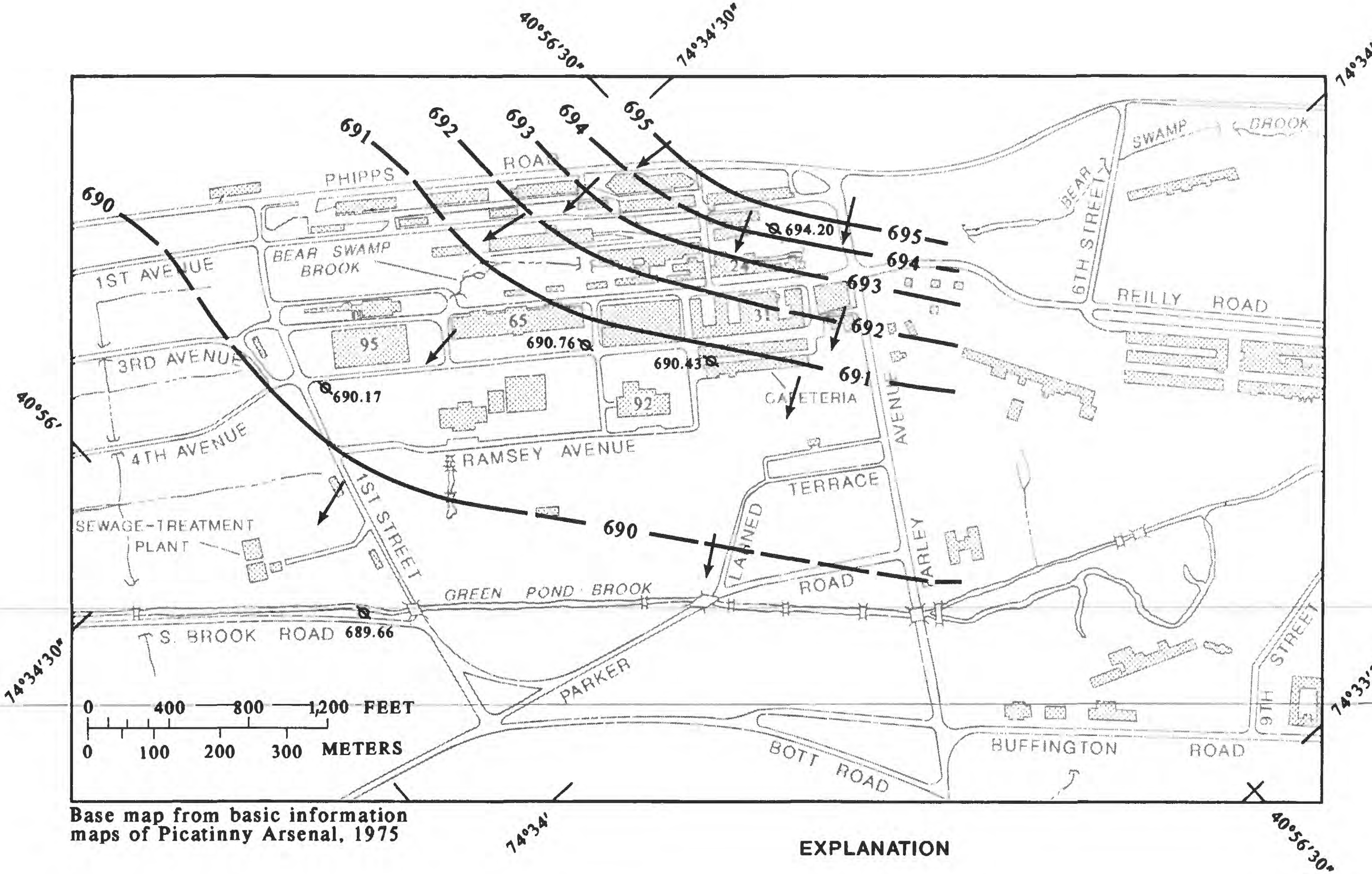


Figure 12.--Hydrograph of well CAF-2, March 1983 through February 1984.



Base map from basic information maps of Picatinny Arsenal, 1975

EXPLANATION

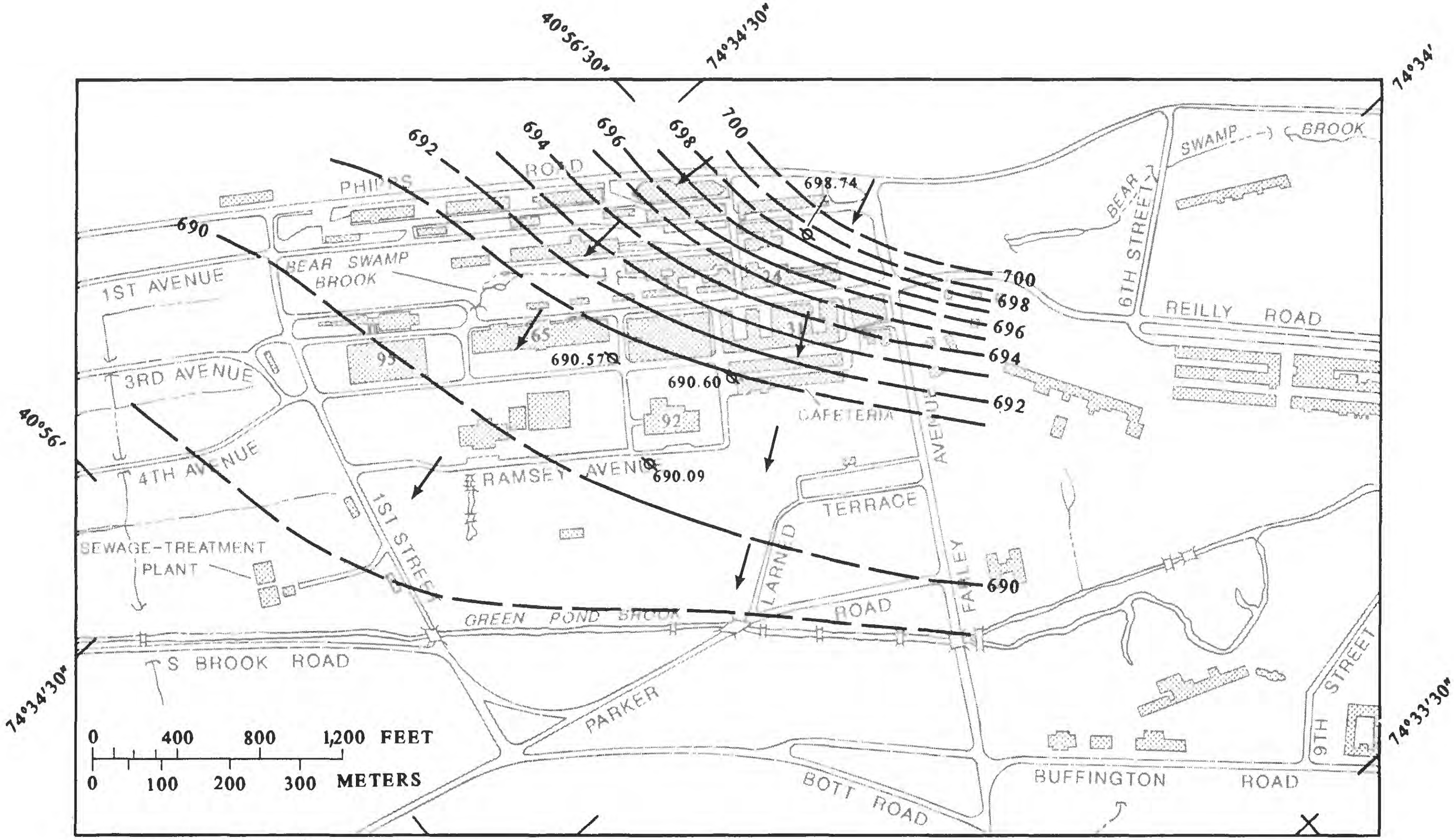
691 — POTENTIOMETRIC CONTOUR--Shows altitude at which water would have stood in tightly cased wells. Dashed where approximated. Contour interval 1 foot. Datum is sea level

689.66 — LOCATION OF OBSERVATION WELL--Number shown is water level measured in February 1988

← GENERAL DIRECTION OF GROUND-WATER FLOW

65 — Building identification number

Figure 13.--Potentiometric surface in the confined glacial aquifer, February 1, 1988.



Base map from basic information maps of Picatinny Arsenal, 1975

EXPLANATION

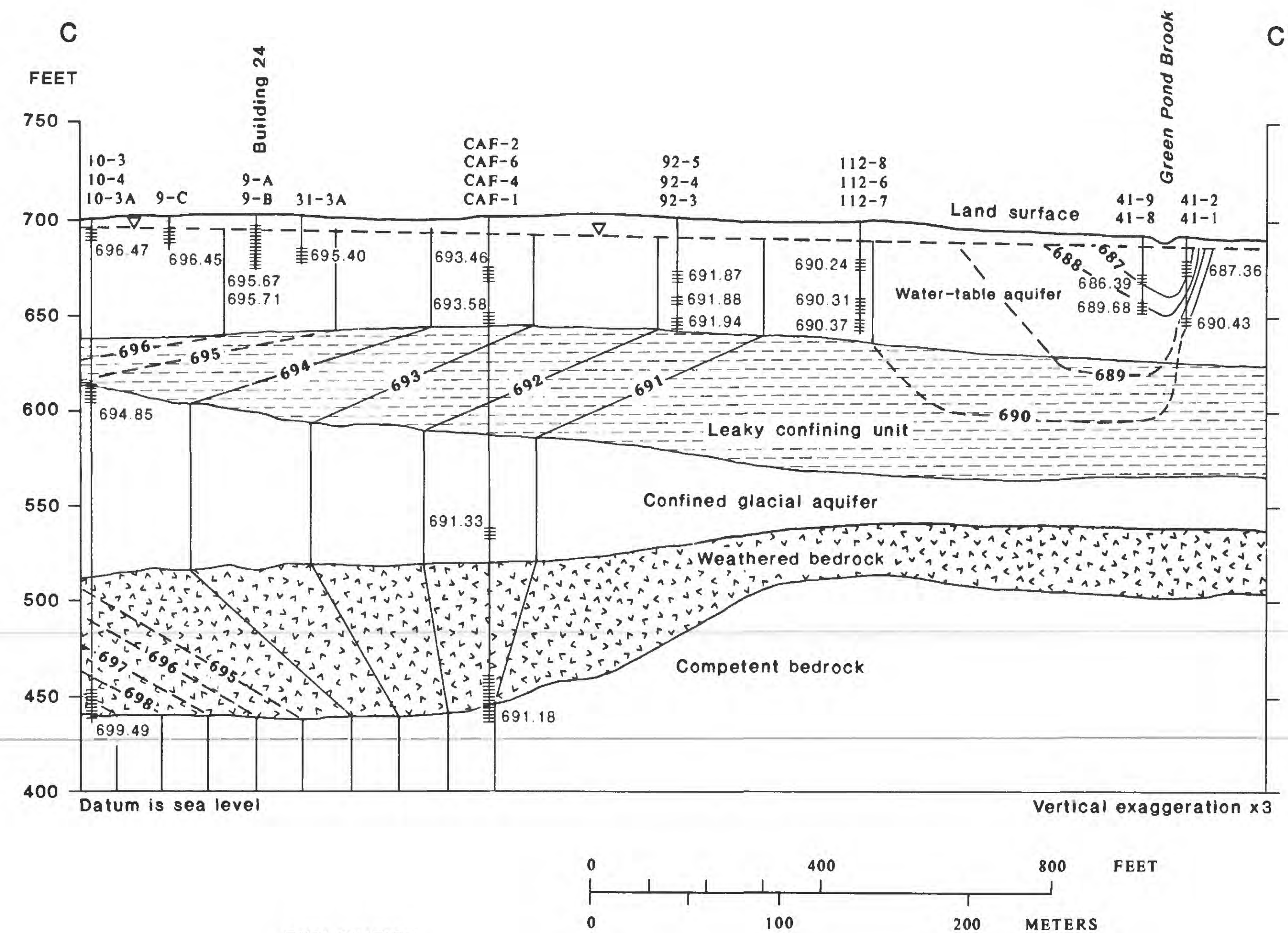
—— 700 — — POTENTIOMETRIC CONTOUR--Shows altitude at which water would have stood in tightly cased wells. Dashed where approximated. Contour interval 1 foot. Datum is sea level

690.57 LOCATION OF OBSERVATION WELL--Number shown is water level measured in February 1, 1988

← GENERAL DIRECTION OF GROUND-WATER FLOW

65 Building identification number

Figure 14.--Potentiometric surface in the bedrock aquifer, February 1, 1988.



EXPLANATION

— —693— POTENTIOMETERIC CONTOUR--Shows altitude at which water would have stood in tightly cased wells. Dashed where approximated. Contour interval 1 foot. Datum is sea level

C—C' Line of section shown in figure 7

690.31 Screened interval and number is water level measured in December 17, 1987

CAF-2 Location of well and local identifier

Figure 15.--Hydrogeologic section showing equipotential lines and approximate water-table surface, December 17, 1987.

materials (Freeze and Cherry, 1979, p. 37). If an effective porosity of 0.25 is assumed, average velocities range from 0.55 to 1.65 ft/d. For the maximum variation, asumming gradients of either 0.005 or 0.006 and the highest and lowest values of the other two parameters, average velocities range from 0.42 to 1.8 ft/d.

Surface Water

The major stream in the study area is Green Pond Brook, a tributary to Rockaway River which flows into the Boonton Reservoir, a water-supply reservoir for Jersey City, New Jersey. Green Pond Brook drains a long, narrow valley between Green Pond Mountain and Copperas Mountain. Three artificial lakes are located in the Green Pond Brook valley: Green Pond, which is upstream of the arsenal, and Lake Denmark and Picatinny Lake, which are within the arsenal boundaries. As shown in figure 16, Burnt Meadow Brook drains Lake Denmark and discharges into Green Pond Brook approximately 0.5 mi upstream from Picatinny Lake.

The Survey maintains three streamflow-gaging stations on Green Pond Brook within the arsenal (fig. 16). Station SW-1, Green Pond Brook at Picatinny Arsenal, is just upstream from Picatinny Lake. Station SW-1 gages a drainage area of 7.65 mi^2 (square miles) and has been active since October 1982. Station SW-2, Green Pond Brook below Picatinny Lake at Picatinny Arsenal, is just downstream from the dam at Picatinny Lake. Station SW-2 gages an area of 9.16 mi^2 and has been active since October 1984. Station SW-3, Green Pond Brook at Wharton, is about 100 ft upstream from the point at which Green Pond Brook flows off the arsenal property. Station SW-3 has a drainage area of 12 mi^2 and has been active since October 1982.

Figure 17 shows discharge hydrographs for the three gaging stations for January 1985 through November 1987. These hydrographs show that Green Pond Brook exhibits a large, sharp response to rainfall because of the rapid runoff from the steep slopes of the valley. The recession of the runoff hydrograph tends to be prolonged as a result of storage in the lakes of the basin. Mean daily discharge during the 1986 water year was 14.7, 16.1, and 26.5 ft^3/s (cubic feet per second) at sites SW-1, SW-2, and SW-3, respectively. Peak discharges of 333 ft^3/s and 572 ft^3/s were recorded at stations SW-1 and SW-3, respectively, on April 5, 1984. Peak discharge at station SW-2 is unavailable because the station was not in operation in April 1984.

Ground-Water/Surface-Water Interactions

The water-level contours in the unconfined aquifer in the study area suggest that Green Pond Brook is the discharge area for the unconfined aquifer in this reach. In order to verify this hypothesis, seepage measurements were made on June 3 and 4, 1987, at Green Pond Brook and Bear Swamp Brook. (Seepage measurements are a series of stream discharge measurements made along a stream reach during a period of stable, low flow to determine whether stream discharge increases downstream along the reach indicating a gaining stream, or decreases downstream along the reach indicating a losing stream.) The results of these measurements are illustrated in figure 18.

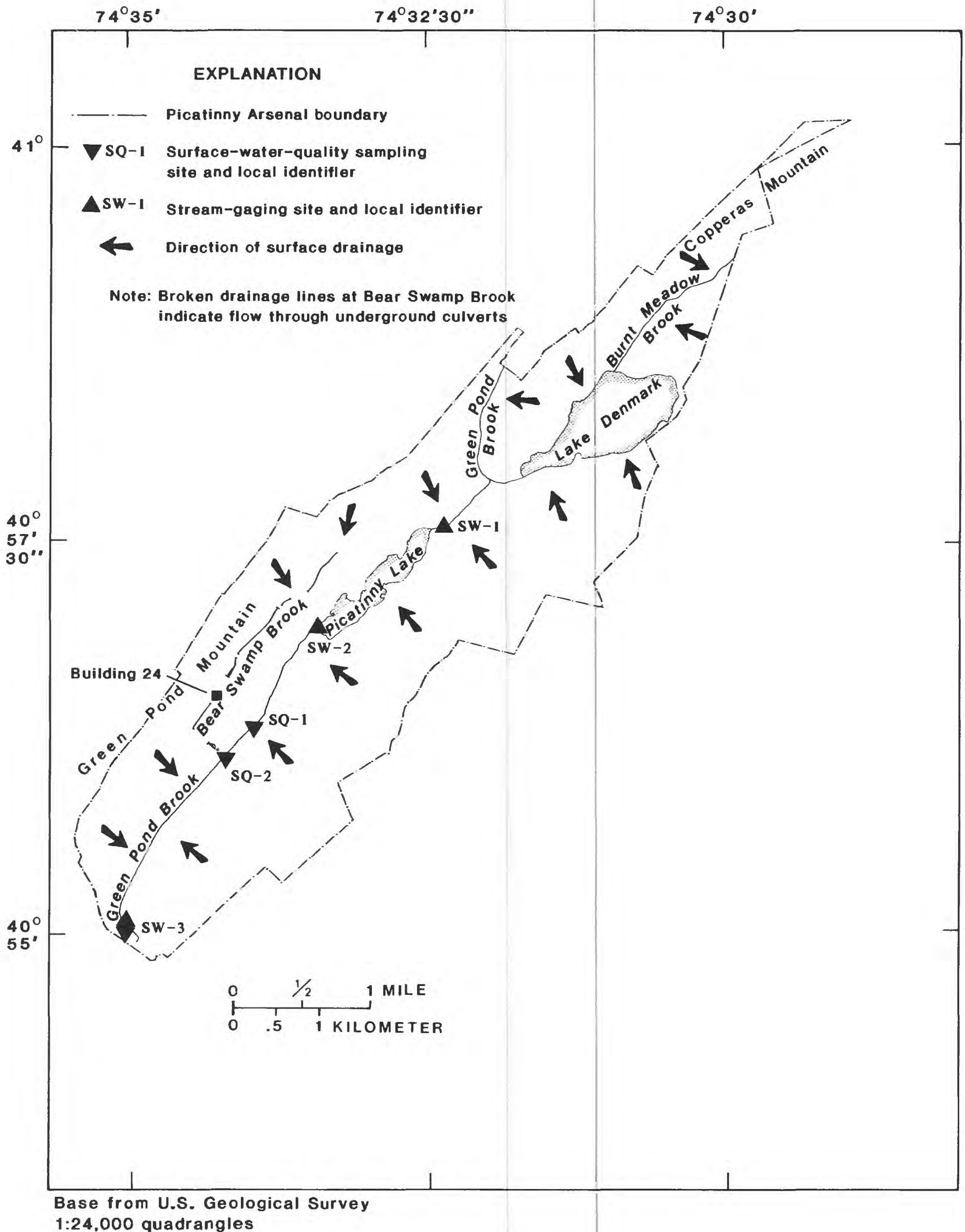


Figure 16.--Surface-water drainage at Picatinny Arsenal and location of surface-water-measurement and sample-collection sites.

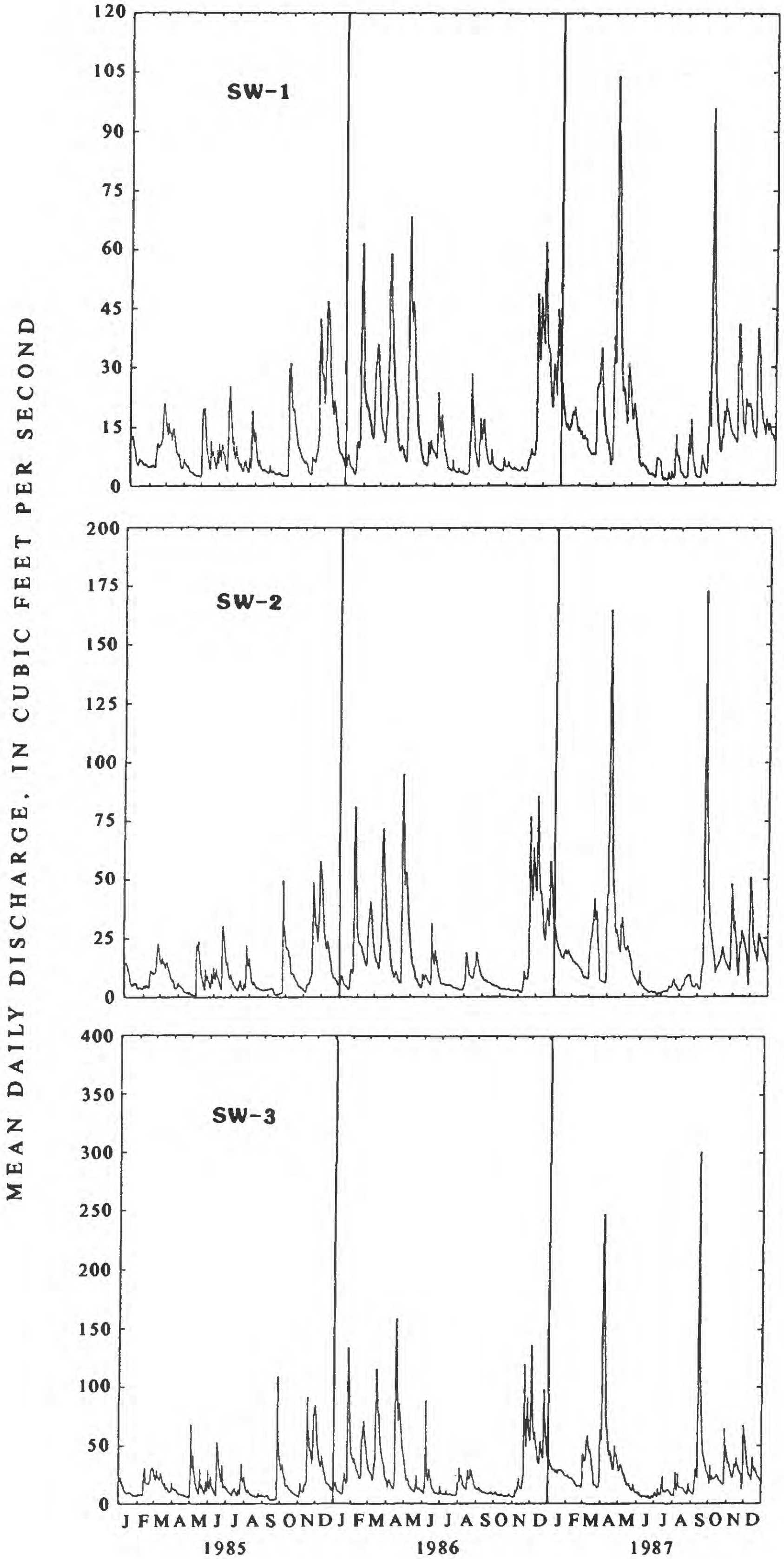
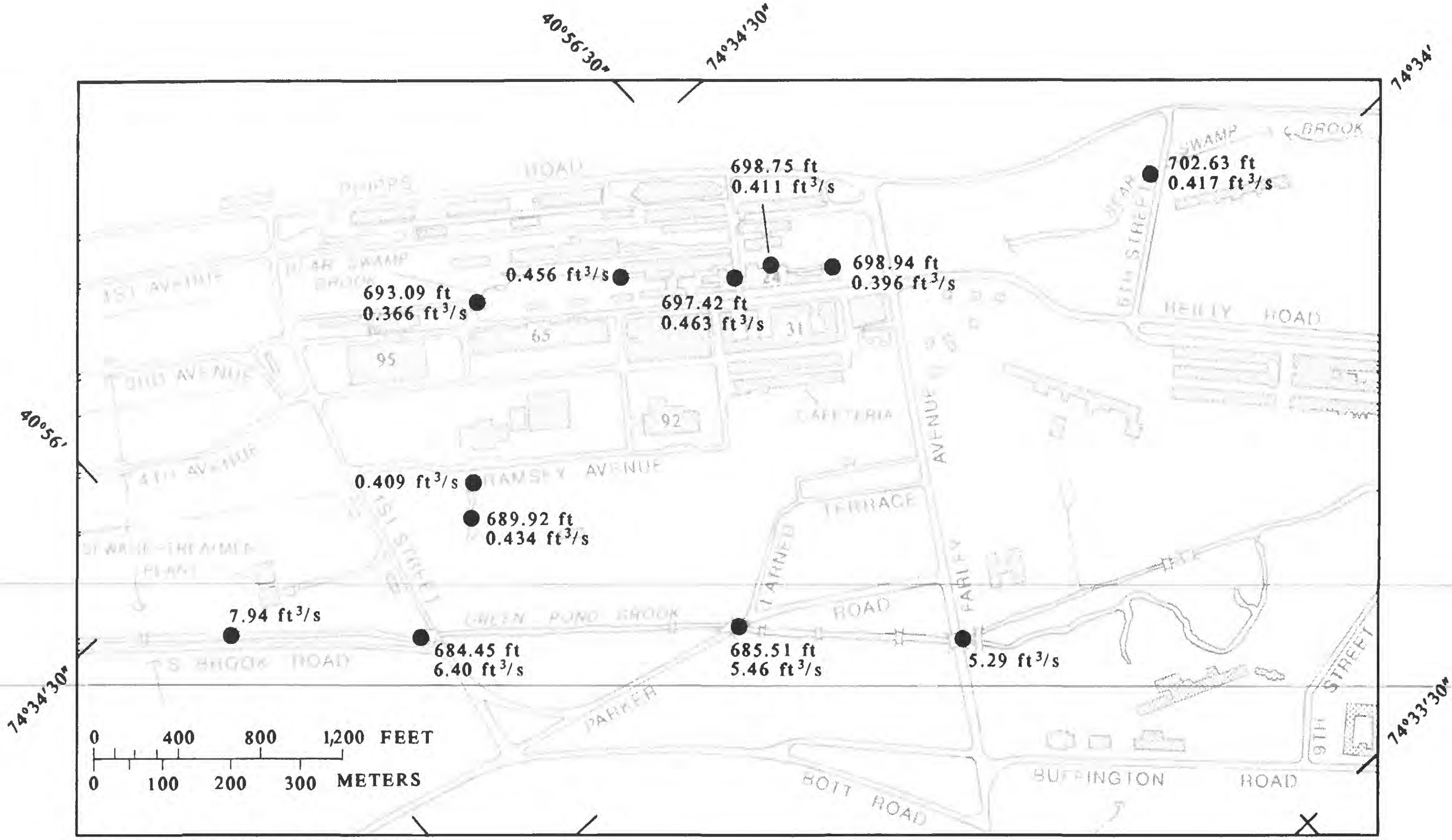


Figure 17.--Streamflow hydrographs for three sites on Green Pond Brook.



Base map from basic information maps of Picatinny Arsenal, 1975

EXPLANATION

● 684.45 ft 6.40 ft³/s — Surface-water-measurement site. Elevation, in feet above sea level. Discharge, in cubic feet per second

65 — Building identification number

Figure 18.--Results of seepage measurements on Green Pond and Bear Swamp Brooks, June 3 and 4, 1987.

The flow in Green Pond Brook increased in the downstream direction, indicating surface- and ground-water inflow to the stream. The discharge of Green Pond Brook appeared to increase from 5.29 ft^3/s at Farley Avenue to 5.46 ft^3/s at Parker Road. No tributaries discharge to Green Pond Brook in this reach, indicating that ground-water inflow was the most likely source of the increased flow. From Parker Avenue to First Street, flow in Green Pond Brook increased from 5.46 ft^3/s to 6.40 ft^3/s. Approximately 0.43 ft^3/s of this increase was the result of inflow from Bear Swamp Brook, which discharges to Green Pond Brook just upstream from First Street. The remainder of the increase (0.5 ft^3/s) in discharge along this reach probably is the result of ground-water inflow. The flow in the brook increased from 6.40 ft^3/s to 7.94 ft^3/s between First Street and the measurement site just downstream from the sewage-treatment plant. Although much of this increase most likely is attributable to effluent discharged from the treatment plant, which was not measured, ground-water inflow probably occurs in this reach as well.

Discharge measurements made on Bear Swamp Brook showed erratic changes in discharge along the channel. These changes probably result from the nature of the Bear Swamp Brook channel, which has been highly modified with culverts and sluice gates. These modifications have caused ponding of water in some areas of the stream channel. Water-level measurements indicate that at least part of the Bear Swamp Brook channel is above the water table. This condition creates the potential for discharge of surface water to the ground-water system.

CONTAMINATION OF GROUND WATER AND SURFACE WATER

Nature and Significance of Trichloroethylene

TCE is a nonflammable organic liquid compound that was used as a degreasing solvent in metal and electronic industries. This compound, along with tetrachloroethylene, 1,1,1-trichloroethane, and 1,2-dichloroethylene, belong to a family of straight-chain molecules known as aliphatic hydrocarbons (Smith and others, 1987, p. 8). TCE has a water solubility of 1,100 mg/L (milligrams per liter) at 25 °C (degrees Celsius), and a density of 1.47. Because of its density TCE tends to sink in water; however, when TCE dissolves in water it is likely to move together with water molecules as a solute (Bradley, 1982, p. 2). TCE has a melting point of -87 °C and a vapor pressure of 60 millimeters at 20 °C, so that it evaporates when exposed to air. TCE evaporates more rapidly than does water.

TCE that is dissolved in ground water can persist for a long time for several reasons. The compound does not adsorb readily on matrix material with low organic-carbon content or degrade easily as a result of microbial action, and it may not evaporate because it has little direct contact with the atmosphere except at the water table. Where the proper conditions exist, however, TCE ultimately is dechlorinated anaerobically into trans-1,2-dichloroethylene and cis-1,2-dichloroethylene and, eventually, into vinyl chloride (Wood and others, 1985, p. 495). Near the water table, TCE can move into the unsaturated zone as a gas by air/water partitioning and gaseous diffusion (Marrin and Thompson, 1987). Water-table fluctuations also can provide a rapid mechanism for moving volatile contaminants across the capillary fringe and into the soil gas (Lappala and Thompson, 1983).

Ground Water

The ground-water-quality data discussed below are divided into two groups. As part of the 1986 drive-point-sampling program, water samples were collected and analyzed for inorganic constituents, trace metals, and VOCs. After the installation of 33 new wells, the well-sampling effort in October 1987 provided water-quality data from the unconfined aquifer as well as the confined glacial and bedrock aquifers. Analysis of selected water samples was expanded to include base/neutral- and acid-extractable compounds, pesticides, and polychlorinated biphenyls (PCBs).

Drive-Point Sampling

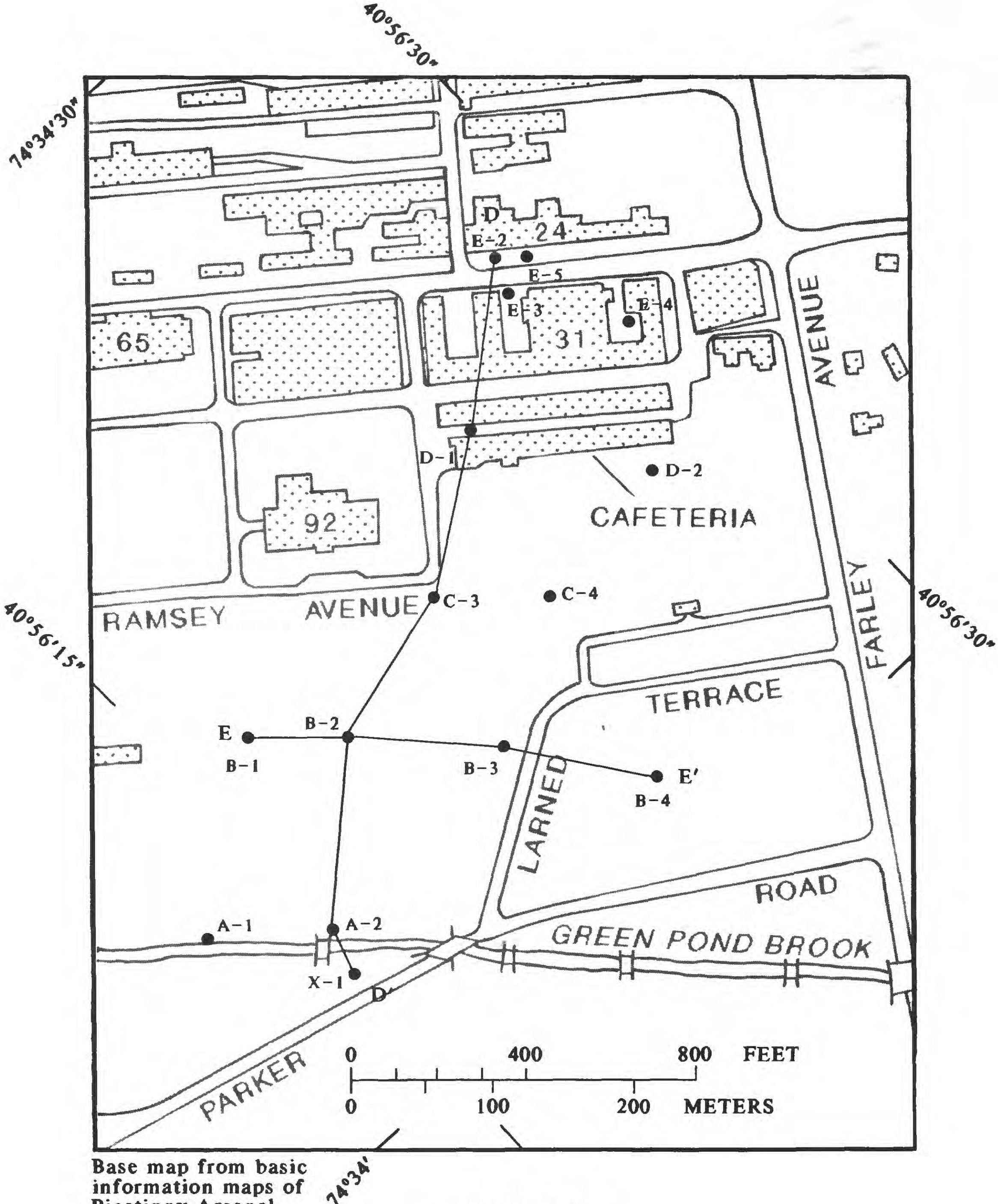
Water samples collected from 15 drive-point sites (fig. 19) were analyzed for chemical characteristics, inorganic constituents, trace metals, and VOCs. At each site, concentrations of chemical constituents and trace metals were determined at 10-ft intervals and concentrations of VOCs were determined at 5-ft intervals. The NWQL performed the analyses for inorganic constituents and trace metals; these results, sorted by local well identifier, are shown in table 5; note that the third number in the local identifier is the sampling depth.

Two of the drive-point sites, X-1 and E-4, were not installed to delineate TCE contamination. Site X-1 is located on the southeastern side of Green Pond Brook where ground water is assumed to move from the southeastern side of the valley toward the brook. The results of chemical analyses of water samples from this site are presumed to be representative of uncontaminated ground water. Site E-4 was selected to investigate possible ground-water contamination from the oil-storage area at building 31.

Inorganic Constituents and Trace Metals

Conservative constituents that are not adsorbed by the aquifer matrix have the potential for defining the farthest extent of a contaminant plume because they commonly move further than organic contaminants through a sandy, unconfined aquifer. In the study area, however, conservative inorganic constituents did not appear to define a contaminant plume. Although their concentrations appeared to be elevated in some areas, results were inconclusive.

Values of pH in ground water (table 5) ranged from 5.8 to 8.6, with a range of 5.8 to 6.2 measured at the site presumed to provide water samples representative of uncontaminated ground water, X-1. Watering of the golf course and application of fertilizers and pesticides could have modified the pH and other physical properties by processes unrelated to TCE contamination. Values of specific conductance and concentrations of dissolved solids showed elevated values in comparison to those found in ground-water samples throughout the arsenal (Sargent and others, 1986). The elevated values of specific conductance reflect the fact that concentrations of inorganic ions are higher in contaminated than in uncontaminated water. The increase in concentration of calcium, magnesium, and sodium can result from ion exchange, weathering of clay lenses, or introduction of water containing these ions into the ground water as a result of activities at



Base map from basic information maps of Picatinny Arsenal, 1975

EXPLANATION

● X-1	Drive-point site and local identifier
D——D'	Line of section shown in figures 23 and 25
65	Building identification number

Figure 19.--Location of drive-point sites in the study area.

Table 5.--Results of analyses of drive-point water samples for selected chemical characteristics, constituents, and trace metals

[All constituents are dissolved; concentrations in milligrams per liter, except as noted; a dash indicates constituent not determined; <, less than; μS/cm, microsiemens per centimeter at 25 degrees Celsius; all samples analyzed at the National Water-Quality Laboratory]

Local identifier[1]	Altitude of land surface (ft above sea level)	Field pH (units) (P00403)	Specific conductance (μS/cm) (P00095)	Lab alkalinity (as $CaCO_3$) (P90410)	Dissolved solids (P70300)	Ammonia (as N) (P00608)	Ammonia + organic N (asn N) (P00623)	Nitrite (as N) (P00613)	NO_2 + NO_3 (as N) (P00630)
A-1-10	689.2	7.4	649	159	347	0.05	0.2	<0.01	<0.1
A-1-20		8.0	636	164	387	.08	.3	<.01	<.1
A-1-30		8.8	160	64	97	.16	.3	<.01	<.1
A-1-40		8.6	174	85	116	.17	.5	<.01	<.1
A-1-50		8.6	176	79	112	.17	.4	<.01	<.1
A-2-10	690.6	7.2	543	169	311	.04	<.2	<.01	<.1
A-2-15		7.3	779	182	447	.05	.2	<.01	<.1
A-2-25		7.9	312	105	171	.1	.3	<.01	<.1
A-2-40		6.5	299	62	164	<.01	<.2	<.01	.9
A-2-50		6.4	330	56	181	<.01	.3	<.01	.83
B-1-10	695.5	6.1	590	[2]34	282	.01	3.8	<.01	2.2
B-1-20		6.1	300	[2]31	173	.02	.4	<.01	1.2
B-1-30		6.8	340	[2]105	228	.01	.4	<.01	.88
B-1-40		7.5	470	[2]137	265	.02	.4	<.01	<.1
B-1-45		7.9	210	[2]77	116	.06	.3	<.01	<.1
B-2-10	695.8	6.2	338	[2]32	171	.02	.4	<.01	2.2
B-2-25		6.4	470	[2]35	248	.03	.5	<.01	2.8
B-2-35		7.2	415	[2]158	300	.04	.3	<.01	<.1
B-3-20	698.0	6.5	156	45	100	.02	.3	<.01	3.1
B-3-25		7.1	646	143	370	.03	<.2	<.01	.14
B-3-35	698.0	7.2	889	154	536	.14	.3	.02	<.1
B-3-45		7.7	845	182	501	.1	.2	<.01	<.1
B-4-15	695.9	6.3	174	21	108	.03	.4	<.01	2.6
B-4-25		6.4	327	40	208	.06	.5	.02	2.4
B-4-35		7.1	553	103	295	.08	<.2	<.01	<.1
B-4-47		7.2	495	125	260	.03	<.2	<.01	<.1
C-3-10	699.1	5.9	834	43	434	.05	.5	<.01	3.7
C-3-20		6.0	360	42	202	.04	.4	.02	1.3
C-3-30		5.8	448	32	263	.05	.3	.05	.19
C-3-40		7.0	645	128	387	.09	.3	<.01	<.1
C-3-50		7.7	423	115	239	.06	.2	<.01	<.1
C-4-15	701.9	6.8	570	[2]98	318	.05	.3	.04	.3
C-4-40		7.3	850	[2]126	427	.1	.4	<.01	<.1
D-1-15	702.8	6.2	333	82	240	.04	.6	.04	2.4
D-1-25		6.3	380	88	232	.05	.3	.07	.19
D-1-35		6.6	606	96	385	.14	.4	.01	.11
D-1-45		6.7	572	56	340	.05	<.2	.01	.79
D-2-15	702.9	6.3	395	60	228	<.01	1.5	<.01	.32
D-2-25		6.1	554	67	295	.68	.9	<.01	.13
D-2-35		6.1	424	42	234	.31	1.1	<.01	<.1
D-2-45		6.3	497	98	287	<.01	.6	<.01	<.1
D-2-50		7.0	675	105	389	.03	.3	<.01	<.1
E-2-10	701.9	7.4	620	202	435	.9	3.2	.31	6.3
E-2-17		6.8	400	109	336	.96	2	.02	<.1
E-2-30		7.7	420	128	272	.13	.4	.02	.47
E-2-40		6.4	501	47	310	.03	.2	.01	2.4
E-3-10	702.2	6.8	141	[2]50	77	.03	.2	.01	.25
E-3-20		6.2	360	[2]54	207	.04	.2	.02	.2
E-3-30		-	7	[2]66	209	.41	.6	<.01	<.1
E-3-40		6.2	820	[2]32	412	.04	.4	.01	1.3
E-3-50		6.8	770	[2]110	398	.04	.2	<.01	<.1
E-4-20	702.4	6.3	732	83	420	1.1	1.4	<.01	<.1
E-4-30		6.3	1107	117	720	.49	.9	<.01	<.1
E-4-35		6.2	561	33	325	.61	.8	<.01	<.1
E-5-15		6.4	411	84	241	<.01	.2	<.01	.33
E-5-25		6.5	435	65	231	.09	.5	<.01	<.1
E-5-35		6.2	664	49	355	<.01	.3	<.01	<.1
E-5-45		7.8	852	191	467	<.01	.2	<.01	.88
X-1-10	692.8	5.8	344	70	198	.02	.3	.01	.83
X-1-20		7.2	295	103	235	.05	.3	.01	.88
X-1-30		6.3	333	64	180	.04	<.2	<.01	.82
X-1-40		6.1	304	49	183	.03	<.2	<.01	.81
X-1-50		6.2	315	49	180	.03	.3	<.01	.94

Table 5.--Results of analyses of drive-point water samples for selected chemical characteristics, constituents, and trace metals--Continued

Local identifier[1]	Phosphorus (P00665)	Ortho-phosphate (P00671)	Organic carbon (P00681)	Calcium (P00915)	Magnesium (P00925)	Sodium (P00930)	Potassium (P00935)	Chloride (P00940)	Sulfate (P00945)	Silica (SiO_2) (P00955)
A-1-10	0.01	<0.01	1.5	46	18	50	3.4	69	42	13
A-1-20	.03	.01	1.0	52	25	32	2.3	82	34	16
A-1-30	.04	.04	1.7	21	1.4	8.5	1.2	2.1	13	9.8
A-1-40	.06	.06	0.9	25	1.5	12	1.2	1.2	9.5	10
A-1-50	.07	.07	.6	27	1.2	11	0.9	1.1	9.2	10
A-2-10	.01	<.01	1.6	35	19	33	4	43	62	12
A-2-15	.01	<.01	1.9	50	23	71	2.9	86	83	16
A-2-25	.04	.04	.8	35	8.7	12	1.2	18	24	12
A-2-40	<.01	<.01	1.7	15	5.8	34	1.1	44	19	11
A-2-50	<.01	<.01	1.0	18	7.7	33	1.3	53	20	12
B-1-10	<.01	<.01	1.5	22	4.4	66	1.9	100	24	6.4
B-1-20	<.01	<.01	2.4	15	5.1	42	1.2	65	15	9.8
B-1-30	.02	.02	1.9	28	15	31	1.5	53	20	17
B-1-40	.02	.02	1.5	40	19	26	1.7	50	20	17
B-1-45	.07	.07	2.6	23	7.8	3.4	.9	11	16	16
B-2-10	<.01	<.01	1.2	10	2.5	47	2.1	60	14	6.2
B-2-25	.01	<.01	1.9	11	2.6	76	2.6	100	14	7.1
B-2-35	.02	<.01	1.7	37	20	37	1.6	69	56	18
B-3-20	<.01	<.01	1.2	11	4.4	8.7	2.5	6.6	24	11
B-3-25	<.01	<.01	1.5	42	24	49	2.5	63	87	13
B-3-35	<.01	<.01	3.4	42	18	110	2.2	92	130	30
B-3-45	.02	.02	1.7	55	19	84	2.0	96	120	22
B-4-15	<.01	<.01	.5	8.9	1.7	17	1.5	14	18	6.4
B-4-25	<.01	<.01	.4	19	4.7	27	3.8	50	21	8.9
B-4-35	.01	<.01	.6	34	19	32	3.7	68	23	15
B-4-47	.01	<.01	.8	35	17	31	1.9	65	21	20
C-3-10	<.01	<.01	2.1	21	4.5	130	2.3	170	56	5
C-3-20	<.01	<.01	2.1	16	4.2	44	3.1	55	32	11
C-3-30	<.01	<.01	1.8	12	3.9	66	2.1	71	64	20
C-3-40	<.01	<.01	2.1	30	16	79	2.4	73	77	23
C-3-50	.04	.04	2.2	39	17	14	1.8	38	41	18
C-4-15	.01	<.01	2.8	9.7	2	100	2.8	99	52	11
C-4-40	.02	<.01	2.1	30	17	84	3.4	98	100	26
D-1-15	<.01	<.01	8.1	21	2.9	38	5.8	36	18	6.7
D-1-25	<.01	<.01	3.2	6.9	1.6	63	2.5	44	36	7.5
D-1-35	.02	.01	8.7	4.4	1.0	120	2.0	86	40	8.7
D-1-45	<.01	.01	18	26	15	55	2.9	120	23	22
D-2-15	<.01	<.01	2.2	21	4.5	45	4.0	61	21	10
D-2-25	<.01	<.01	5.1	19	7.1	64	3.5	120	25	16
D-2-35	.03	<.01	2.0	18	6.1	46	4.1	77	29	18
D-2-45	.02	<.01	.8	27	12	46	2.7	82	38	18
D-2-50	<.01	<.01	.8	42	22	49	3.3	88	44	27
E-2-10	.86	.84	48	6.7	.8	130	2.8	20	48	5.7
E-2-17	.12	.06	33	2.3	.2	88	1.1	29	58	8.5
E-2-30	.28	.27	4.0	9.3	.3	81	1.8	40	36	1.7
E-2-40	.01	<.01	1.1	20	3.3	77	1.7	110	32	7.9
E-3-10	<.01	.02	3.7	13	0.9	6.9	1.6	7.2	7.9	6.4
E-3-20	.01	.01	5.0	16	2.4	50	1.1	51	53	8.3
E-3-30	.02	.02	4.2	3.7	.5	69	1.4	31	58	7.7
E-3-40	<.01	<.01	1.8	41	19	62	2.4	180	21	23
E-3-50	<.01	<.01	1.6	53	28	43	2.8	150	23	18
E-4-20	.03	<.01	8.6	32	6.6	83	3.7	130	29	14
E-4-30	.02	<.01	12	45	12	130	3.4	250	8.7	13
E-4-35	.02	<.01	3.1	17	5.1	61	2.4	91	40	21
E-5-15	<.01	<.01	2.1	26	5.8	47	2.5	73	23	11
E-5-25	<.01	<.01	1	23	3.6	45	4.0	63	31	11
E-5-35	.01	<.01	.8	12	4.9	95	2.7	159	34	17
E-5-45	.01	<.01	.8	55	28	71	2.5	150	35	20
X-1-10	<.01	<.01	.6	19	8.2	34	1.4	56	18	15
X-1-20	<.01	<.01	300	25	11	32	2.1	48	20	13
X-1-30	.01	<.01	32	16	6.3	33	1.9	49	16	10
X-1-40	.01	<.01	74	16	6.5	35	1.4	52	17	11
X-1-50	<.01	<.01	7.9	16	7.1	32	1.4	45	19	13

Table 5.--Results of analyses of drive-point water samples for selected chemical characteristics, constituents, and trace metals--Continued

Concentrations in micrograms per liter

Local identifier[1]	Arsenic (P00100)	Beryllium (P01010)	Cadmium (P01025)	Chromium (P01030)	Cobalt (P01035)	Copper (P01040)	Iron (P01046)	Lead (P01049)	Manganese (P01056)	Molybdenum (P01060)
A-1-10	1	<0.5	2	1	<3	<10	3,000	<10	650	<10
A-1-20	4	<.5	2	<1	<3	<10	1,200	<10	610	<10
A-1-30	4	<.5	<1	<1	<3	<10	38	<10	68	<10
A-1-40	7	<.5	3	<1	<3	<10	28	<10	52	<10
A-1-50	6	<.5	<1	<1	<3	<10	7	10	45	<10
A-2-10	2	<.5	<1	<1	<3	<10	150	<10	49	<10
A-2-15	3	<.5	<1	<1	<3	<10	4,000	<10	730	<10
A-2-25	8	<.5	<1	<1	<3	<10	100	<10	220	<10
A-2-40	<1	<.5	<1	<1	<3	<10	310	<10	55	<10
A-2-50	<1	<.5	<1	<1	<3	<10	420	<10	130	<10
B-1-10	<1	<.5	<1	2	<3	<10	260	190	28	<10
B-1-20	<1	<.5	<1	<1	<3	<10	170	30	95	<10
B-1-30	<1	<.5	<1	2	<3	<10	7	<10	160	<10
B-1-40	2	.6	<1	<1	<3	<10	12	<10	320	<10
B-1-45	6	<.5	<1	<1	<3	<10	47	<10	240	<10
B-2-10	<1	<.5	<1	<1	<3	<10	160	<10	38	<10
B-2-25	<1	1.4	<1	<1	<3	<10	170	<10	110	<10
B-2-35	2	<.5	<1	<1	<3	<10	1300	<10	320	<10
B-3-20	<1	<.5	<1	<1	<3	<10	5	<10	180	<10
B-3-25	<1	<.5	<1	<1	<3	<10	<3	<10	1,300	<10
B-3-35	6	<.5	<1	<1	<3	<10	6,700	<10	2,000	<10
B-3-45	6	<.5	<1	<1	<3	<10	120	<10	360	<10
B-4-15	<1	<.5	<1	<1	<3	<10	340	<10	170	<10
B-4-25	<1	2.5	<1	<1	7	<10	1,200	10	440	<10
B-4-35	2	1.4	<1	<1	<3	<10	4,000	<10	910	<10
B-4-47	<1	1.4	<1	<1	<3	<10	240	<10	290	<10
C-3-10	<1	<.5	2	<1	<3	<10	1,600	<10	610	<10
C-3-20	<1	<.5	<1	<1	<3	<10	1,100	<10	250	<10
C-3-30	<1	<.5	2	<1	<3	<10	2,000	<10	190	<10
C-3-40	<1	<.5	1	<1	<3	<10	4,000	<10	740	<10
C-3-50	4	<.5	<1	<1	<3	<10	370	<10	550	<10
C-4-15	<1	1	1	<1	<3	<10	270	<10	420	<10
C-4-40	1	1	<1	1	<3	<10	6,000	<10	1,200	<10
D-1-15	<1	<.5	2	1	<3	<10	1,300	<10	720	<10
D-1-25	<1	<.5	4	3	<3	10	3,000	<10	810	<10
D-1-35	<1	<.5	<1	2	<3	10	1,300	<10	520	<10
D-1-45	<1	<.5	3	<1	<3	<10	1,100	<10	1,500	<10
D-2-15	<1	<.5	<1	1	<3	<10	1,900	<10	220	<10
D-2-25	<1	<.5	2	3	<3	<10	12,000	<10	650	<10
D-2-35	<1	<.5	<1	2	<3	<10	5,700	<10	520	<10
D-2-45	<1	<.5	<1	2	<3	<10	5,900	10	450	<10
D-2-50	2	1.8	<3	1	<9	<30	590	<10	<10	<10
E-2-10	11	<.5	1	13	<3	70	1,000	<10	23	20
E-2-17	2	<.5	65	48	<3	50	1,600	<10	36	10
E-2-30	2	<.5	2	<1	<3	<10	52	<10	29	10
E-2-40	<1	<.5	<1	1	<3	<10	800	<10	57	<10
E-3-10	<1	<.5	<1	3	<3	<10	240	<10	27	<10
E-3-20	<1	.9	26	1	<3	<10	760	<10	81	<10
E-3-30	<1	<.5	7	<1	<3	10	250	<10	47	<10
E-3-40	<1	1.1	<1	1	<3	<10	1,100	<10	130	<10
E-3-50	<1	1.1	<1	1	<3	<10	1,000	<10	370	<10
E-4-20	5	<.5	<1	2	<3	<10	17,000	<10	500	<10
E-4-30	4	<.5	6	1	<3	<10	20,000	<10	1,400	<10
E-4-35	2	<.5	<1	1	<3	<10	28,000	<10	490	<10
E-5-15	<1	<.5	1	<1	<3	<10	1,700	<10	160	<10
E-5-25	3	<.5	5	<1	<9	<30	5,800	<10	440	<10
E-5-35	<1	<.5	<1	<1	<3	<10	2,099	10	140	<10
E-5-45	<1	<.5	<1	<1	<3	<10	1,200	<10	689	<10
X-1-10	<1	.9	<1	<1	<3	<10	310	<10	42	<10
X-1-20	<1	.7	<1	<1	<3	<10	550	10	400	<10
X-1-30	<1	.9	<1	<1	6	<10	200	10	550	<10
X-1-40	<1	.9	<1	<1	<3	<10	200	<10	37	<10
X-1-50	<1	.9	<1	<1	<3	<10	260	<10	92	<10

Table 5.--Results of analyses of drive-point water samples for selected chemical characteristics, constituents, and trace metals--Continued

Concentrations in micrograms per liter

Local identifier[1]	Strontium (P01080)	Vanadium (P01085)	Zinc (P01090)	Aluminum (P01106)	Lithium (P01130)	Selenium (P01145)
A-1-10	85	<6	7	-	14	-
A-1-20	96	<6	4	-	15	-
A-1-30	110	<6	5	-	9	-
A-1-40	140	<6	31	-	6	-
A-1-50	150	<6	3	-	15	-
A-2-10	76	<6	6	-	7	-
A-2-15	94	<6	4	20	5	<1
A-2-25	130	<6	4	50	<4	<1
A-2-40	52	<6	8	10	<4	<1
A-2-50	57	<6	7	<10	<4	<1
B-1-10	76	<6	11	-	<4	-
B-1-20	48	<6	19	-	<4	-
B-1-30	53	<6	11	-	<4	-
B-1-40	74	<6	<3	-	9	-
B-1-45	29	<6	<3	-	<4	-
B-2-10	42	<6	4	<10	<4	<1
B-2-25	50	<6	<3	10	<4	<1
B-2-35	48	<6	10	10	4	<1
B-3-20	37	<6	<3	-	<4	-
B-3-25	95	<6	5	-	8	-
B-3-35	83	<6	6	-	11	-
B-3-45	130	<6	6	-	11	-
B-4-15	17	<6	7	-	<4	-
B-4-25	56	<6	16	-	8	-
B-4-35	80	<6	3	-	10	-
B-4-47	56	<6	4	-	11	-
C-3-10	91	<6	18	<10	<4	<1
C-3-20	49	<6	32	<10	<4	<1
C-3-30	65	<6	34	20	<4	<1
C-3-40	73	<6	15	10	8	<1
C-3-50	61	<6	7	10	7	<1
C-4-15	47	<6	22	-	<4	-
C-4-40	53	<6	12	-	8	-
D-1-15	160	<6	7	<10	8	<1
D-1-25	43	<6	5	20	12	<1
D-1-35	29	<6	17	30	4	<1
D-1-45	92	<6	31	<10	25	<1
D-2-15	110	<6	17	-	<4	-
D-2-25	83	<6	29	-	<4	-
D-2-35	70	<6	25	-	4	-
D-2-45	120	<6	13	-	7	-
D-2-50	110	<6	21	-	18	-
E-2-10	53	54	17	680	<4	4
E-2-17	15	<6	15	540	<4	<1
E-2-30	19	<6	5	50	<4	<1
E-2-40	140	<6	31	<10	13	<1
E-3-10	85	<6	11	20	<4	<1
E-3-20	100	<6	10	40	<4	<1
E-3-30	20	<6	<3	20	<4	<1
E-3-40	130	<6	6	<10	11	<1
E-3-50	92	<6	<3	10	12	<1
E-4-20	210	<6	12	-	10	-
E-4-30	320	<6	9	-	15	-
E-4-35	92	<6	7	-	9	-
E-5-15	150	<6	11	<10	7	1
E-5-25	180	<6	32	<10	18	<1
E-5-35	73	<6	10	10	8	<1
E-5-45	100	<6	5	<10	23	<1
X-1-10	48	<6	6	-	7	-
X-1-20	66	<6	12	-	9	-
X-1-30	55	<6	5	-	6	-
X-1-40	58	<6	9	-	5	-
X-1-50	50	<6	5	-	5	-

[1] The last two digits in the local identifier represent the depth from which the sample was collected. At sites B1, B2, C4, and E3 water samples collected in April 1986 and at the remaining sampling site August-September, 1986.

[2] Value represents field alkalinity.

building 24 or other buildings. Increases in concentrations of sulfate and chloride can result from the use of sulfuric acid and hydrochloric acid in the plating process. Although chloride concentrations were relatively high (near 250 mg/L), the only water sample with a concentration greater than that of the USEPA secondary regulation, 250 mg/L (USEPA, 1979b), was from building 31 oil-storage site E-4, at a depth of 35 ft. Concentrations of the other inorganic constituents in the zone of contamination did not differ from those found in arsenal ground water (Sargent and others, 1986).

Trace metals in the wastewater from building 24 metal-plating activities generally were not found in elevated concentrations downgradient. Metals may have been removed by the building 24 wastewater-treatment system before the wastewater reached the seepage lagoons. Metals can fail to mobilize in ground water because in the elemental form, the heavy trace metals, including cadmium, chromium, copper, lead, strontium, and zinc, tend to precipitate out and are not readily changed to a mobile soluble state, and they are likely to be adsorbed from solution by organic or clay colloids and by hydrous iron or manganese coatings on sediments (Kimmel and Braids, 1980, p. 19).

Concentrations and frequencies of detection of iron and manganese were highest downgradient from building 24. Concentrations of these metals ranged from <3 to 28,000 µg/L and from <10 to 2,000 µg/L, respectively. The high concentrations of iron in ground water (the USEPA secondary regulations for iron and manganese are 0.3 and 0.05 mg/L, respectively) may not have been from the contamination source, as iron typically is found in similar concentrations throughout the arsenal (Sargent and others, 1986). Aquifer sediments, which may be coated with hydrous oxides of iron, can contribute iron under the reducing conditions that exist in the contaminated water. The same mechanisms also may move manganese into ground water.

A number of trace metals (arsenic, chromium, copper, molybdenum, and vanadium) were detected in concentrations greater than 10 µg/L at site E-2, immediately adjacent to building 24. Although also detected at other sites, the highest concentrations of aluminum in the study area, 680 and 540 µg/L, were found at site E-2 at depths of 10 and 17 ft, respectively. The highest concentration of cadmium found at site E-2, 65 µg/L, exceeds the USEPA primary drinking-water regulation of 10 µg/L (USEPA, 1976). The primary drinking-water regulation for cadmium also was exceeded at site E-3, where a concentration of 26 µg/L was found at a depth of 20 ft. Site E-3 is on the opposite side of Third Avenue from site E-2 (fig. 3). The trace metals strontium, zinc, and lithium were found in concentrations exceeding the detection limit at nearly all of the sites. The concentration of lead exceeded the USEPA primary drinking-water regulation of 50 µg/L (USEPA, 1976) at site B-1, where a concentration of 190 µg/L was found. This isolated high lead concentration may reflect localized past land use rather than contaminant movement from building 24. Beryllium, cobalt, and selenium, although detected, were not found in concentrations greater than the USEPA primary drinking-water regulation for selenium (10 µg/L) in the study area.

Organic Compounds

All water samples collected through drive-point sampling were analyzed for VOCs and methane. Analyses were performed at the Survey laboratory in Trenton, New Jersey. Seventeen duplicate water samples were collected and sent to the NWQL for analyses of VOCs, iodide, bromide, styrene, and methylene-blue active substances (MBAS). MBAS is a measure of the concentration of detergents in water. The results of the analyses of drive-point water samples from both laboratories are shown in table 6. When both laboratories reported measurable concentrations of the same VOC, the range of values was considered to be acceptable.

Of 105 water samples analyzed, 15 samples contained concentrations of organic compounds at or less than the detection limit, 46 samples contained various organic compounds in concentrations up to 50 μg/L, and 44 samples contained organic compounds in concentrations greater than 50 μg/L. The following compounds were found in concentrations greater than 100 μg/L: TCE, methane, tetrachloroethylene, cis-1,2-dichloroethylene, and cis- and trans-1,2-dichloroethylene combined. (The NWQL reported the combined concentration of these two compounds.) TCE was the most frequently detected volatile organic compound and was found in the highest concentrations.

TCE-contaminated ground water forms a plume that follows the flow system in the unconfined aquifer, moving downward from the source and then upward with ground water that discharges to Green Pond Brook. Failure to detect TCE on the opposite side of the brook, at site X-1, indicates that the plume does not extend across the brook.

Lines of equal concentration of TCE at altitudes of 650, 670, and 690 ft, illustrated in figures 20, 21, 22, respectively, delineate the contaminant plume in three dimensions. The 650-ft altitude is near the base of the unconfined aquifer. A zone of contamination (with concentrations greater than 10,000 μg/L) appears to be located just above the confining unit. The axis of this slug appears to be oriented along a line that does not intersect the source at building 24. Although pumping at water-supply well 130 probably caused the plume to move toward the well, the plume may have been moving downgradient away from well 130 after pumping ceased. Well 130 is screened in the confined glacial aquifer, but a formerly adjacent observation well 130-OB was screened through the confining unit and could have caused an increase in the downward component of flow in the unconfined aquifer near the pumped well (see fig. 4 for location).

At the intermediate depth, an altitude of 670 ft, TCE is found in concentrations greater than 1,000 μg/L in the center of the plume and adjacent to Green Pond Brook (fig. 21). The area within the 100-μg/L contour appears to have an axis oriented through the source of contamination at building 24. Adjacent to Green Pond Brook, the elevated concentrations can reflect the effect of peat deposits that slowed the movement of the plume upward toward the brook. At the upper extent of the contaminant plume, which ranges from 680 to 690 ft, TCE concentrations greater than 1,000 μg/L are found at the source adjacent to building 24, in the middle of the plume, and at Green Pond Brook (fig. 22).

Table 6.--Results of analyses of drive-point water samples for selected chemical constituents and organic compounds

[All constituents are dissolved; concentrations in micrograms per liter; NWQL, National Water-Quality Laboratory, Lakewood, Colorado; TRN, Survey Laboratory, Trenton, New Jersey; a dash indicates constituent not determined; <, less than]

Local identifier[1]	Laboratory	Dichlorobromomethane (P32101)	Carbon tetrachloride (P32102)	1,2-Dichloroethane (P32103)	Bromoform (P32104)	Chlorodibromomethane (P32105)	Chloroform (P32106)	Toluene (P34010)	Benzene (P34030)	Chlorobenzene (P34301)	1,3-Dichlorobenzene (P34566)
A-1-10	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
A-1-15	NWQL	<.2	<.2	<.2	<.2	<.2	.2	<.2	<.2	<.2	<.2
	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
A-1-20	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
A-1-25	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
A-1-30	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
A-1-35	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
A-1-40	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
A-1-50	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
A-2-10	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
A-2-15	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
A-2-20	NWQL	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
	TRN	<1	<1	2	<1	<1	<1	<1	<1	<1	-
A-2-25	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
A-2-30	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
A-2-40	TRN	<10	<10	<10	<10	<10	<10	<10	<10	<10	-
A-2-50	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
B-1-10	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
B-1-20	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
B-1-30	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
B-1-40	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
B-1-45	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
B-2-10	NWQL	<3	<3	<3	<3	<3	3.7	<3	<3	<3	<3
	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
B-2-20	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
B-2-25	NWQL	<3	<3	<3	<3	<3	3.9	<3	<3	<3	<3
	TRN	<5	<5	<5	<5	<5	<5	<5	<5	<5	-
B-2-35	NWQL	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
B-2-45	NWQL	<3	<3	7.3	<3	<3	<3	<3	<3	<3	<3
	TRN	<1	<1	5	<1	<1	<1	<1	<1	<1	-
B-3-15	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
B-3-20	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
B-3-25	TRN	<10	<10	<10	<10	<10	<10	<10	<10	<10	-
B-3-30	TRN	<10	<10	<10	<10	<10	<10	<10	<10	<10	-
B-3-35	TRN	<10	<10	<10	<10	<10	<10	<10	<10	<10	-
B-3-40	NWQL	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
	TRN	<10	<10	<10	<10	<10	<10	<10	<10	<10	-
B-3-45	TRN	<10	<10	<10	<10	<10	<10	<10	<10	<10	-
B-3-50	TRN	<10	<10	<10	<10	<10	<10	<10	<10	<10	-
B-4-15	NWQL	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
B-4-20	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
B-4-25	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
B-4-30	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
B-4-35	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
B-4-47	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
C-3-10	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
C-3-15	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
C-3-20	TRN	<10	<10	<10	<10	<10	<10	<10	<10	<10	-
C-3-25	TRN	<10	<10	<10	<10	<10	<10	<10	<10	<10	-
C-3-30	TRN	<10	<10	<10	<10	<10	<10	<10	<10	<10	-
C-3-35	TRN	<10	<10	<10	<10	<10	<10	<10	<10	<10	-
C-3-40	TRN	<10	<10	<10	<10	<10	<10	<10	<10	<10	-
C-3-45	TRN	<10	<10	<10	<10	<10	<10	<10	<10	<10	-
C-3-50	TRN	<10	<10	<10	<10	<10	<10	<10	<10	<10	-
C-4-15	NWQL	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
C-4-30	NWQL	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
	TRN	<10	<10	<10	<10	<10	<10	<10	<10	<10	-
C-4-40	NWQL	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
	TRN	<10	<10	<10	<10	<10	<10	<10	<10	<10	-
D-1-15	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
D-1-20	TRN	<10	<10	<10	<10	<10	<10	<10	<10	<10	-
D-1-25	NWQL	<70	<70	<70	<70	<70	<70	<70	<70	<70	<70

Table 6.--Results of analyses of drive-point water samples for selected chemical constituents and organic compounds--Continued

Local identifier[1]	Lab-ora-tory	Dichloro-bromo-methane (P32101)	Carbon tetra-chloride (P32102)	1,2-Dichloro-ethane (P32103)	Bromo-form (P32104)	Chloro-dibromo-methane (P32105)	Chloro-form (P32106)	Toluene (P34010)	Benzene (P34030)	Chloro-benzene (P34301)	1,3-Di-chloro-benzene (P34566)
D-1-25	TRN	<10	<10	<10	<10	<10	<10	<10	<10	<10	-
D-1-30	TRN	<10	<10	<10	<10	<10	<10	<10	<10	<10	-
D-1-35	TRN	<10	<10	<10	<10	<10	<10	<10	<10	<10	-
D-1-40	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
D-1-45	TRN	<10	<10	<10	<10	<10	<10	<10	<10	<10	-
D-1-50	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
D-2-15	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
D-2-20	TRN	<1	<1	1	<1	<1	<1	<1	<1	<1	-
D-2-25	TRN	<1	<1	1	<1	<1	<1	<1	<1	<1	-
D-2-30	TRN	<1	<1	1	<1	<1	<1	<1	<1	<1	-
D-2-35	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
D-2-40	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
D-2-45	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
D-2-50	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
D-2-55	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
E-2-10	TRN	<100	<100	<100	<100	<100	<100	<100	<100	<100	-
E-2-15	TRN	<10	<10	<10	<10	<10	<10	<10	<10	<10	-
E-2-17	TRN	<10	<10	<10	<10	<10	<10	<10	<10	<10	-
E-2-25	NWQL	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40
	TRN	<10	<10	<10	<10	<10	<10	<10	<10	<10	-
E-2-30	TRN	<10	<10	<10	<10	<10	<10	<10	<10	<10	-
E-2-35	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
E-2-40	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
E-2-45	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
E-3-10	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
E-3-20	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
E-3-30	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
E-3-40	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
E-3-45	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
E-3-50	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
E-3-55	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
E-4-15	NWQL	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
E-4-20	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
E-4-25	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
E-4-30	NWQL	<.2	<.2	<.2	<.2	<.2	.2	<.2	.7	<.2	<.2
	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
E-4-35	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
E-4-40	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
E-5-15	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
E-5-20	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
E-5-25	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
E-5-30	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
E-5-35	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
E-5-40	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
E-5-45	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
X-1-10	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
X-1-15	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
X-1-20	NWQL	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
X-1-25	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
X-1-30	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
X-1-35	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
X-1-40	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
X-1-45	NWQL	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
	TRN	<1	<1	<1	<1	<1	3	<1	<1	<1	-
X-1-50	TRN	<1	<1	<1	<1	<1	2	<1	<1	<1	-

Table 6.--Results of analyses of drive-point water samples for selected chemical constituents and organic compounds--Continued

Local identifier[1]	Laboratory	Ethylbenzene (P34371)	Methyl-bromide (P34413)	Methyl-chloride (P34418)	Methylene-chloride (P34423)	Tetrachloroethylene (P34475)	Trichlorofluoromethane (P34488)	1,1-Dichloroethane (P34496)	1,1-Dichloroethylene (P34501)	1,1,1-Trichloroethane (P34506)	Chloroethane (P34311)
A-1-10	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
A-1-15	NWQL	<.2	<.2	<.2	<.5	<.2	<.2	.2	.9	<.2	<.2
	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
A-1-20	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
A-1-25	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
A-1-30	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
A-1-35	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
A-1-40	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
A-1-50	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
A-2-10	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
A-2-15	TRN	<1	<1	<1	<1	10	<1	<1	<1	<1	-
A-2-20	NWQL	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
	TRN	<1	<1	<1	<1	4	<1	1	3	<1	-
A-2-25	TRN	<1	<1	<1	<1	1	<1	<1	<1	<1	-
A-2-30	TRN	<1	<1	<1	<1	1	<1	<1	<1	<1	-
A-2-40	TRN	<10	<10	<10	<10	<10	<10	<10	<10	<10	-
A-2-50	TRN	<1	<1	<1	<1	1	<1	<1	<1	<1	-
B-1-10	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
B-1-20	TRN	<1	<1	<1	<1	1	<1	<1	<1	<1	-
B-1-30	TRN	<1	<1	<1	<1	3	<1	<1	1	<1	-
B-1-40	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
B-1-45	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
B-2-10	NWQL	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
B-2-20	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
B-2-25	NWQL	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
	TRN	<5	<5	<5	<5	<5	<5	<5	<5	<5	-
B-2-35	NWQL	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
B-2-45	NWQL	<3	<3	<3	<3	<3	<3	<3	22	<3	<3
	TRN	<1	<1	<1	<1	<1	<1	<1	16	<1	-
B-3-15	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
B-3-20	TRN	<1	<1	<1	<1	9	<1	<1	<1	<1	-
B-3-25	TRN	<10	<10	<10	<10	200	<10	<10	<10	<10	-
B-3-30	TRN	<10	<10	<10	<10	70	<10	<10	<10	<10	-
B-3-35	TRN	<10	<10	<10	<10	<10	<10	<10	<10	<10	-
B-3-40	NWQL	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
	TRN	<10	<10	<10	<10	<10	<10	<10	<10	<10	-
B-3-45	TRN	<10	<10	<10	<10	<10	<10	<10	<10	<10	-
B-3-50	TRN	<10	<10	<10	<10	<10	<10	<10	<10	<10	-
B-4-15	NWQL	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
	TRN	<1	<1	<1	<1	1	<1	<1	<1	<1	-
B-4-20	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
B-4-25	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
B-4-30	TRN	<1	<1	<1	<1	<1	<1	<1	<1	1	-
B-4-35	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
B-4-47	TRN	<1	<1	<1	<1	1	<1	<1	<1	1	-
C-3-10	TRN	<1	<1	<1	<1	2	<1	<1	<1	<1	-
C-3-15	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
C-3-20	TRN	<10	<10	<10	<10	19	<10	<10	<10	<10	-
C-3-25	TRN	<10	<10	<10	<10	11	<10	<10	<10	<10	-
C-3-30	TRN	<10	<10	<10	<10	18	<10	<10	<10	<10	-
C-3-35	TRN	<10	<10	<10	<10	11	<10	<10	<10	<10	-
C-3-40	TRN	<10	<10	<10	<10	32	<10	<10	<10	<10	-
C-3-45	TRN	<10	<10	<10	<10	61	<10	<10	<10	<10	-
C-3-50	TRN	<10	<10	<10	<10	12	<10	<10	<10	<10	-
C-4-15	NWQL	<3	<3	<3	<3	28	<3	<3	<3	3.3	<3
	TRN	<1	<1	<1	<1	33	<1	3.4	3	1	-
C-4-30	NWQL	<3	<3	<3	<3	16	<3	<3	<3	<3	<3
	TRN	<10	<10	<10	<10	22	<10	<10	26	<10	-
C-4-40	NWQL	<3	<3	<3	<3	40	<3	<3	<3	<3	<3
	TRN	<10	<10	<10	<10	58	<10	<10	<10	<10	-
D-1-15	TRN	<1	<1	<1	<1	2	<1	<1	<1	2	-
D-1-20	TRN	<10	<10	<10	<10	<10	<10	<10	<10	12	-
D-1-25	NWQL	<70	<70	<70	<70	<70	<70	<70	<70	<70	<70

Table 6.--Results of analyses of drive-point water samples for selected chemical constituents and organic compounds--Continued

Local identifier[1]	Laboratory	Ethylbenzene (P34371)	Methylbromide (P34413)	Methylchloride (P34418)	Methylene chloride (P34423)	Tetrachloroethylene (P34475)	Trichlorofluoromethane (P34488)	1,1-Dichloroethane (P34496)	1,1-Dichloroethylene (P34501)	1,1,1-Trichloroethane (P34506)	Chloroethane (P34311)
D-1-25	TRN	<10	<10	<10	<10	<10	<10	<10	<10	41	-
D-1-30	TRN	<10	<10	<10	<10	<10	<10	<10	<10	45	-
D-1-35	TRN	<10	<10	<10	<10	<10	<10	<10	<10	<10	-
D-1-40	TRN	<1	<1	<1	<1	19	<1	<1	<1	2	-
D-1-45	TRN	<10	<10	<10	<10	51	<10	<10	<10	<10	-
D-1-50	TRN	<1	<1	<1	<1	80	<1	<1	<1	<1	-
D-2-15	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
D-2-20	TRN	<1	<1	<1	<1	<1	<1	1	1	<1	-
D-2-25	TRN	<1	<1	<1	<1	<1	<1	2	1	<1	-
D-2-30	TRN	<1	<1	<1	<1	<1	<1	2	2	<1	-
D-2-35	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
D-2-40	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
D-2-45	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
D-2-50	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
D-2-55	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
E-2-10	TRN	<100	<100	<100	<100	<100	<100	<100	<100	<100	-
E-2-15	TRN	<10	<10	<10	<10	<10	<10	<10	<10	30	-
E-2-17	TRN	<10	<10	<10	<10	<10	<10	<10	<10	50	-
E-2-25	NWQL	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40
	TRN	<10	<10	<10	<10	<10	<10	<10	<10	<10	-
E-2-30	TRN	<10	<10	<10	<10	<10	<10	<10	<10	<10	-
E-2-35	TRN	<1	<1	<1	<1	2	<1	<1	<1	<1	-
E-2-40	TRN	<1	<1	<1	<1	2	<1	<1	<1	<1	-
E-2-45	TRN	<1	<1	<1	<1	3	<1	<1	<1	<1	-
E-3-10	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
E-3-20	TRN	<1	<1	<1	<1	6	<1	1.5	2	5	-
E-3-30	TRN	<1	<1	<1	<1	4	<1	3	3	6	-
E-3-40	TRN	<1	<1	<1	<1	2	<1	<1	<1	<1	-
E-3-45	TRN	<1	<1	<1	<1	6	<1	<1	<1	3	-
E-3-50	TRN	<1	<1	<1	<1	2	<1	<1	<1	3	-
E-3-55	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
E-4-15	NWQL	<3	<3	<3	<3	<3	3.9	<3	<3	<3	<3
	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
E-4-20	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
E-4-25	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
E-4-30	NWQL	<.2	<.2	<.2	<.5	<.2	<.2	.5	.6	<.2	<.2
	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
E-4-35	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
E-4-40	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
E-5-15	TRN	<1	<1	<1	<1	6	<1	<1	<1	<1	-
E-5-20	TRN	<1	<1	<1	<1	5	<1	<1	<1	<1	-
E-5-25	TRN	<1	<1	<1	<1	1.5	<1	<1	<1	<1	-
E-5-30	TRN	<1	<1	<1	<1	1	<1	<1	<1	<1	-
E-5-35	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
E-5-40	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
E-5-45	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
X-1-10	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
X-1-15	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
X-1-20	NWQL	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
X-1-25	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
X-1-30	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
X-1-35	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
X-1-40	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
X-1-45	NWQL	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
X-1-50	TRN	<1	<1	<1	<1	<1	<1	<1	<1	<1	-

Table 6.--Results of analyses of drive-point water samples for selected chemical constituents and organic compounds--Continued

Local identifier[1]	Laboratory	1,1,2-Trichloroethane (P34511)	1,2-Dichlorobenzene (P34536)	1,4-Dichlorobenzene (P34571)	1,2-Dichloropropane (P34541)	1,3-Dichloropropane (P34561)	2-CL-Ethylvinylether (P34576)	Trans-1,2-dichloroethylene[2] (P34546)	Cis-1,2-dichloroethylene	Vinyl chloride (P39175)	Trichloroethylene (P39180)
A-1-10	TRN	<1	<1	-	<1	<1	<1	<1	4	<1	59
A-1-15	NWQL	<.2	<.2	<.2	<.2	<.2	<.2	8.5	-	<.2	46
	TRN	<1	<1	-	<1	<1	<1	<1	10	<1	83
A-1-20	TRN	<1	<1	-	<1	<1	<1	<1	19	<1	10
A-1-25	TRN	<1	<1	-	<1	<1	<1	<1	<1	<1	2
A-1-30	TRN	<1	<1	-	<1	<1	<1	<1	<1	<1	1
A-1-35	TRN	<1	<1	-	<1	<1	<1	<1	<1	<1	1
A-1-40	TRN	<1	<1	-	<1	<1	<1	<1	<1	<1	<1
A-1-50	TRN	<1	<1	-	<1	<1	<1	<1	<1	<1	<1
A-2-10	TRN	<1	<1	-	<1	<1	<1	<1	180	<1	39
A-2-15	TRN	<1	<1	-	<1	<1	<1	<1	27	2	610
A-2-20	NWQL	<50	<50	<50	<50	<50	<50	140	-	<50	3,700
	TRN	<1	<1	-	<1	<1	<1	<1	53	12	2,500
A-2-25	TRN	<1	<1	-	<1	<1	<1	<1	3	<1	180
A-2-30	TRN	<1	<1	-	<1	<1	<1	<1	1.6	<1	74
A-2-40	TRN	<10	<10	-	<10	<10	<10	<10	<10	<10	48
A-2-50	TRN	<1	<1	-	<1	<1	<1	<1	<1	<1	13
B-1-10	TRN	<1	<1	-	<1	<1	<1	<1	3	<1	42
B-1-20	TRN	<1	<1	-	<1	<1	<1	<1	10	<1	76
B-1-30	TRN	<1	<1	-	<1	<1	<1	<1	35	<1	690
B-1-40	TRN	<1	<1	-	<1	<1	<1	<1	<1	<1	11
B-1-45	TRN	<1	<1	-	<1	<1	<1	<1	<1	<1	3
B-2-10	NWQL	<3	<3	<3	<3	<3	<3	<3	-	<3	54
	TRN	<1	<1	-	<1	<1	<1	<1	3	<1	56
B-2-20	TRN	<1	<1	-	<1	<1	<1	<1	3	<1	18
B-2-25	NWQL	<3	<3	<3	<3	<3	<3	<3	-	<3	88
	TRN	<5	<5	-	<5	<5	<5	<5	<5	<5	85
B-2-35	NWQL	<3	<3	<3	<3	<3	<3	15	-	<3	1,500
	TRN	<1	<1	-	<1	<1	<1	<1	14	1	1,900
B-2-45	NWQL	<3	<3	<3	<3	<3	<3	140	-	<3	16,000
	TRN	<1	<1	-	<1	<1	<1	<1	160	9	16,000
B-3-15	TRN	<1	<1	-	<1	<1	<1	<1	<1	<1	2
B-3-20	TRN	<1	<1	-	<1	<1	<1	<1	1	<1	36
B-3-25	TRN	<10	<10	-	<10	<10	<10	<10	75	17	750
B-3-30	TRN	<10	<10	-	<10	<10	<10	<10	120	30	2,000
B-3-35	TRN	<10	<10	-	<10	<10	<10	<10	100	15	6,100
B-3-40	NWQL	<100	<100	<100	<100	<100	<100	380	-	<100	14,000
	TRN	<10	<10	-	<10	<10	<10	<10	70	12	7,000
B-3-45	TRN	<10	<10	-	<10	<10	<10	<10	50	12	2,500
B-3-50	TRN	<10	<10	-	<10	<10	<10	<10	15	<10	800
B-4-15	NWQL	<3	<3	<3	<3	<3	<3	<3	-	<3	<3
	TRN	<1	<1	-	<1	<1	<1	<1	<1	<1	8
B-4-20	TRN	<1	<1	-	<1	<1	<1	<1	<1	<1	14
B-4-25	TRN	<1	<1	-	<1	<1	<1	<1	<1	<1	<1
B-4-30	TRN	<1	<1	-	<1	<1	<1	<1	1	<1	3
B-4-35	TRN	<1	<1	-	<1	<1	<1	<1	<1	<1	2
B-4-47	TRN	<1	<1	-	<1	<1	<1	<1	1	<1	2
C-3-10	TRN	<1	<1	-	<1	<1	<1	<1	<1	<1	17
C-3-15	TRN	<1	<1	-	<1	<1	<1	<1	1	<1	210
C-3-20	TRN	<10	<10	-	<10	<10	<10	<10	<10	<10	1,000
C-3-25	TRN	<10	<10	-	<10	<10	<10	<10	41	<10	2,300
C-3-30	TRN	<10	<10	-	<10	<10	<10	<10	44	<10	3,000
C-3-35	TRN	<10	<10	-	<10	<10	<10	<10	23	<10	330
C-3-40	TRN	<10	<10	-	<10	<10	<10	<10	16	<10	460
C-3-45	TRN	<10	<10	-	<10	<10	<10	<10	18	<10	780
C-3-50	TRN	<10	<10	-	<10	<10	<10	<10	180	<10	20,000
C-4-15	NWQL	<3	<3	<3	<3	<3	<3	54	-	<3	2,200
	TRN	<1	<1	-	<1	<1	<1	3	44	2.8	2,200
C-4-30	NWQL	<3	<3	<3	<3	<3	<3	31	-	<3	440
	TRN	<10	<10	-	<10	<10	<10	13	20	<10	380
C-4-40	NWQL	<3	<3	<3	<3	<3	<3	55	-	<3	1,800
	TRN	<10	<10	-	<10	<10	<10	<10	50	<10	1,200
D-1-15	TRN	<1	<1	-	<1	<1	<1	<1	10	<1	400
D-1-20	TRN	<10	<10	-	<10	<10	<10	<10	12	<10	1,100
D-1-25	NWQL	<70	<70	<70	<70	<70	<70	<70	-	<70	1,900

Table 6.--Results of analyses of drive-point water samples for selected chemical constituents and organic compounds--Continued

Local identifier[1]	Lab-oratory	1,1,2-Trichloro-ethane (P34511)	1,2-Dichloro-benzene (P34536)	1,4-Dichloro-benzene (P34571)	1,2-Dichloro-propane (P34541)	1,3-Dichloro-propane (P34561)	2-CL-Ethyl-vinyl-ether (P34576)	Trans-1,2-dichloro-ethylene[2] (P34546)	Cis-1,2-dichloro-ethylene	Vinyl chloride (P39175)	Tri-chloro-ethylene (P39180)
D-1-25	TRN	<10	<10	-	<10	<10	<10	<10	28	<10	1,500
D-1-30	TRN	<10	<10	-	<10	<10	<10	<10	34	<10	4,000
D-1-35	TRN	<10	<10	-	<10	<10	<10	<10	12	<10	650
D-1-40	TRN	<1	<1	-	<1	<1	<1	<1	4	<1	140
D-1-45	TRN	<10	<10	-	<10	<10	<10	<10	<10	<10	330
D-1-50	TRN	<1	<1	-	<1	<1	<1	<1	8	<1	580
D-2-15	TRN	<1	<1	-	<1	<1	<1	<1	5	<1	7
D-2-20	TRN	<1	<1	-	<1	<1	<1	1	23	9	15
D-2-25	TRN	<1	<1	-	<1	<1	<1	1	34	15	17
D-2-30	TRN	<1	<1	-	<1	<1	<1	<1	30	10	17
D-2-35	TRN	<1	<1	-	<1	<1	<1	<1	10	3	10
D-2-40	TRN	<1	<1	-	<1	<1	<1	<1	2	1	4
D-2-45	TRN	<1	<1	-	<1	<1	<1	<1	1.4	<1	8
D-2-50	TRN	<1	<1	-	<1	<1	<1	<1	1	<1	1
D-2-55	TRN	<1	<1	-	<1	<1	<1	<1	<1	<1	1
E-2-10	TRN	<100	<100	-	<100	<100	<100	<100	<100	<100	44,000
E-2-15	TRN	<10	<10	-	<10	<10	<10	<10	22	<10	4,000
E-2-17	TRN	<10	<10	-	<10	<10	<10	<10	50	<10	1,400
E-2-25	NWQL	<40	<40	<40	<40	<40	<40	<40	-	<40	1,000
	TRN	<10	<10	-	<10	<10	<10	<10	<10	<10	800
E-2-30	TRN	<10	<10	-	<10	<10	<10	<10	<10	<10	500
E-2-35	TRN	<1	<1	-	<1	<1	<1	<1	<1	<1	260
E-2-40	TRN	<1	<1	-	<1	<1	<1	<1	<1	<1	150
E-2-45	TRN	<1	<1	-	<1	<1	<1	<1	<1	<1	150
E-3-10	TRN	<1	<1	-	<1	<1	<1	<1	<1	<1	2
E-3-20	TRN	<1	<1	-	<1	<1	<1	<1	3	3	37
E-3-30	TRN	<1	<1	-	<1	<1	<1	<1	5	3	22
E-3-40	TRN	<1	<1	-	<1	<1	<1	<1	<1	<1	9
E-3-45	TRN	<1	<1	-	<1	<1	<1	<1	<1	<1	15
E-3-50	TRN	<1	<1	-	<1	<1	<1	<1	2	<1	9
E-3-55	TRN	<1	<1	-	<1	<1	<1	<1	<1	<1	28
E-4-15	NWQL	<3	<3	<3	<3	<3	<3	5.7	-	30	<3
	TRN	<1	<1	-	<1	<1	<1	<1	4	8	2
E-4-20	TRN	<1	<1	-	<1	<1	<1	<1	6	9	2
E-4-25	TRN	<1	<1	-	<1	<1	<1	<1	7	2	9
E-4-30	NWQL	<.2	<.2	<.2	<.2	<.2	<.2	6.7	-	8.9	3.6
	TRN	<1	<1	-	<1	<1	<1	<1	6	20	5
E-4-35	TRN	<1	<1	-	<1	<1	<1	<1	11	7	19
E-4-40	TRN	<1	<1	-	<1	<1	<1	<1	<1	<1	2
E-5-15	TRN	<1	<1	-	<1	<1	<1	<1	1	<1	14
E-5-20	TRN	<1	<1	-	<1	<1	<1	<1	1	3	8
E-5-25	TRN	<1	<1	-	<1	<1	<1	<1	1.5	<1	9
E-5-30	TRN	<1	<1	-	<1	<1	<1	<1	<1	<1	2
E-5-35	TRN	<1	<1	-	<1	<1	<1	<1	<1	<1	<1
E-5-40	TRN	<1	<1	-	<1	<1	<1	<1	<1	<1	<1
E-5-45	TRN	<1	<1	-	<1	<1	<1	<1	<1	<1	1.5
X-1-10	TRN	<1	<1	-	<1	<1	<1	<1	<1	<1	<1
X-1-15	TRN	<1	<1	-	<1	<1	<1	<1	<1	<1	<1
X-1-20	NWQL	<3	<3	<3	<3	<3	<3	<3	-	<3	<3
	TRN	<1	<1	-	<1	<1	<1	<1	<1	<1	1
X-1-25	TRN	<1	<1	-	<1	<1	<1	<1	<1	<1	<1
X-1-30	TRN	<1	<1	-	<1	<1	<1	<1	<1	<1	<1
X-1-35	TRN	<1	<1	-	<1	<1	<1	<1	<1	<1	<1
X-1-40	TRN	<1	<1	-	<1	<1	<1	<1	<1	<1	<1
X-1-45	NWQL	<3	<3	<3	<3	<3	<3	<3	-	<3	<3
	TRN	<1	<1	-	<1	<1	<1	<1	<1	<1	<1
X-1-50	TRN	<1	<1	-	<1	<1	<1	<1	<1	<1	<1

Table 6.--Results of analyses of drive-point water samples for selected chemical constituents and organic compounds--Continued

Local identifier[1]	Laboratory	Iodide (P71865)	Bromide (P71870)	Methane (P76994)	Styrene (P77128)	MBAS, total[3] (P38260)	Dichloro-difluoro-methane (P34668)	1,2-Di-bromo-ethylene (P39082)	1,1,2,2-Tetrchloro-ethane (P34516)	Cis 1,3-di-chloro-propene (P34704)	Trans-1,3-di-chloro-propene (P34699)
A-1-10	TRN	-	-	-	-	-	<1	-	<1	-	-
A-1-15	NWQL	-	-	-	<.2	-	<.2	<.2	<.2	<.2	<.2
	TRN	-	-	-	-	-	<1	-	<1	-	-
A-1-20	TRN	-	-	<2	-	-	<1	-	<1	-	-
A-1-25	TRN	-	-	-	-	-	<1	-	<1	-	-
A-1-30	TRN	-	-	<2	-	-	<1	-	<1	-	-
A-1-35	TRN	-	-	-	-	-	<1	-	<1	-	-
A-1-40	TRN	-	-	<2	-	-	<1	-	<1	-	-
A-1-50	TRN	-	-	<2	-	-	<1	-	<1	-	-
A-2-10	TRN	-	-	-	-	-	<1	-	<1	-	-
A-2-15	NWQL	.019	.049	-	-	.04	-	-	-	-	-
	TRN	-	-	-	-	-	<1	-	<1	-	-
A-2-20	NWQL	-	-	-	<50	-	<50	<50	<50	<50	<50
	TRN	-	-	8	-	-	<1	-	<1	-	-
A-2-25	NWQL	.002	.021	-	-	<.01	-	-	-	-	-
	TRN	-	-	<2	-	-	<1	-	<1	-	-
A-2-30	TRN	-	-	-	-	-	<1	-	<1	-	-
A-2-40	NWQL	.001	.024	-	-	.01	-	-	-	-	-
	TRN	-	-	<2	-	-	<10	-	<10	-	-
A-2-50	NWQL	.001	.029	-	-	.02	-	-	-	-	-
	TRN	-	-	<2	-	-	<1	-	<1	-	-
B-1-10	TRN	-	-	-	-	-	<1	-	<1	-	-
B-1-20	TRN	-	-	-	-	-	<1	-	<1	-	-
B-1-30	TRN	-	-	-	-	-	<1	-	<1	-	-
B-1-40	TRN	-	-	-	-	-	<1	-	<1	-	-
B-1-45	TRN	-	-	-	-	-	<1	-	<1	-	-
B-2-10	NWQL	.004	.061	-	<3	.04	<3	<3	<3	<3	<3
	TRN	-	-	<2	-	-	<1	-	<1	-	-
B-2-20	TRN	-	-	-	-	-	<1	-	<1	-	-
B-2-25	NWQL	.004	<.01	-	<3	.06	<3	<3	<3	<3	<3
	TRN	-	-	<2	-	-	<5	-	<5	-	-
B-2-35	NWQL	.007	.16	-	<3	.03	<3	<3	<3	<3	<3
	TRN	-	-	<2	-	-	<1	-	<1	-	-
B-2-45	NWQL	-	-	-	<3	-	<3	<3	<3	<3	<3
	TRN	-	-	-	-	-	<1	-	<1	-	-
B-3-15	TRN	-	-	-	-	-	<1	-	<1	-	-
B-3-20	TRN	-	-	<2	-	-	<1	-	<1	-	-
B-3-25	TRN	-	-	<2	-	-	<10	-	<10	-	-
B-3-30	TRN	-	-	-	-	-	<10	-	<10	-	-
B-3-35	TRN	-	-	24	-	-	<10	-	<10	-	-
B-3-40	NWQL	-	-	-	<100	-	<100	<100	<100	<100	<100
	TRN	-	-	-	-	-	<10	-	<10	-	-
B-3-45	TRN	-	-	6	-	-	<10	-	<10	-	-
B-3-50	TRN	-	-	9	-	-	<10	-	<10	-	-
B-4-15	NWQL	-	-	-	<3	-	<3	<3	<3	<3	<3
	TRN	-	-	<2	-	-	<1	-	<1	-	-
B-4-20	TRN	-	-	<2	-	-	<1	-	<1	-	-
B-4-25	TRN	-	-	<2	-	-	<1	-	<1	-	-
B-4-30	TRN	-	-	<2	-	-	<1	-	<1	-	-
B-4-35	TRN	-	-	<2	-	-	<1	-	<1	-	-
B-4-47	TRN	-	-	<2	-	-	<1	-	<1	-	-
C-3-10	NWQL	.007	.045	-	-	.14	-	-	-	-	-
	TRN	-	-	<2	-	-	<1	-	<1	-	-
C-3-15	TRN	-	-	-	-	-	<1	-	<1	-	-
C-3-20	NWQL	.004	.074	-	-	.06	-	-	-	-	-
	TRN	-	-	18	-	-	<10	-	<10	-	-
C-3-25	TRN	-	-	-	-	-	<10	-	<10	-	-
C-3-30	NWQL	.01	.11	-	-	.04	-	-	-	-	-
	TRN	-	-	18	-	-	<10	-	<10	-	-
C-3-35	TRN	-	-	-	-	-	<10	-	<10	-	-
C-3-40	NWQL	.01	.18	-	-	.04	-	-	-	-	-
	TRN	-	-	12	-	-	<10	-	<10	-	-
C-3-45	TRN	-	-	-	-	-	<10	-	<10	-	-
C-3-50	NWQL	.005	.046	-	-	.02	-	-	-	-	-
	TRN	-	-	<2	-	-	<10	-	<10	-	-

Table 6.--Results of analyses of drive-point water samples for selected chemical constituents and organic compounds--Continued

Local identifier[1]	Laboratory	Iodide (P71865)	Bromide (P71870)	Methane (P76994)	Styrene (P77128)	MBAS, total[3] (P38260)	Dichlorodifluoromethane (P34668)	1,2-di-Bromoethylene (P39082)	1,1,2,2-Tetrchloroethane (P34516)	Cis 1,3-dichloropropene (P34704)	Trans-1,3-dichloropropene (P34699)
C-4-15	NWQL	-	-	-	<3	-	<3	<3	<3	<3	<3
	TRN	-	-	63	-	-	<1	-	<1	-	-
C-4-30	NWQL	-	-	-	<3	-	<3	<3	<3	<3	<3
	TRN	-	-	-	-	-	<10	-	<10	-	-
C-4-40	NWQL	-	-	-	<3	-	<3	<3	<3	<3	<3
	TRN	-	-	8	-	-	<10	-	<10	-	-
D-1-15	NWQL	.014	.029	-	-	.07	-	-	-	-	-
	TRN	-	-	3	-	-	<1	-	<1	-	-
D-1-20	TRN	-	-	15	-	-	<10	-	<10	-	-
D-1-25	NWQL	.022	.011	-	<70	.08	<70	<70	<70	<70	<70
	TRN	-	-	18	-	-	<10	-	<10	-	-
D-1-30	TRN	-	-	30	-	-	<10	-	<10	-	-
D-1-35	NWQL	.019	.044	-	-	.07	-	-	-	-	-
	TRN	-	-	7	-	-	<10	-	<10	-	-
D-1-40	TRN	-	-	<2	-	-	<1	-	<1	-	-
D-1-45	NWQL	.01	.068	-	-	.04	-	-	-	-	-
	TRN	-	-	<2	-	-	<10	-	<10	-	-
D-1-50	TRN	-	-	<2	-	-	<1	-	<1	-	-
D-2-15	TRN	-	-	8	-	-	<1	-	<1	-	-
D-2-20	TRN	-	-	210	-	-	<1	-	<1	-	-
D-2-25	TRN	-	-	670	-	-	<1	-	<1	-	-
D-2-30	TRN	-	-	350	-	-	<1	-	<1	-	-
D-2-35	TRN	-	-	180	-	-	<1	-	<1	-	-
D-2-40	TRN	-	-	40	-	-	<1	-	<1	-	-
D-2-45	TRN	-	-	10	-	-	<1	-	<1	-	-
D-2-50	TRN	-	-	2	-	-	<1	-	<1	-	-
D-2-55	TRN	-	-	4	-	-	<1	-	<1	-	-
E-2-10	NWQL	.017	.14	-	-	.08	-	-	-	-	-
	TRN	-	-	21	-	-	<100	-	<100	-	-
E-2-15	TRN	-	-	150	-	-	<10	-	<10	-	-
E-2-17	NWQL	.01	.14	-	-	.1	-	-	-	-	-
	TRN	-	-	150	-	-	<10	-	<10	-	-
E-2-25	NWQL	-	-	-	<40	-	<40	<40	<40	<40	<40
	TRN	-	-	<2	-	-	<10	-	<10	-	-
E-2-30	NWQL	.015	.041	-	-	.04	-	-	-	-	-
	TRN	-	-	<2	-	-	<10	-	<10	-	-
E-2-35	TRN	-	-	15	-	-	<1	-	<1	-	-
E-2-40	NWQL	.009	.069	-	-	.07	-	-	-	-	-
	TRN	-	-	<2	-	-	<1	-	<1	-	-
E-2-45	TRN	-	-	<2	-	-	<1	-	<1	-	-
E-3-10	NWQL	<.001	<.01	-	-	.04	-	-	-	-	-
	TRN	-	-	-	-	-	<1	-	<1	-	-
E-3-20	NWQL	.011	.054	-	-	.07	-	-	-	-	-
	TRN	-	-	-	-	-	<1	-	<1	-	-
E-3-30	NWQL	.009	.035	-	-	.05	-	-	-	-	-
	TRN	-	-	-	-	-	<1	-	<1	-	-
E-3-40	NWQL	.003	.1	-	-	.06	-	-	-	-	-
	TRN	-	-	-	-	-	<1	-	<1	-	-
E-3-45	TRN	-	-	-	-	-	<1	-	<1	-	-
E-3-50	NWQL	.003	.1	-	-	.05	-	-	-	-	-
	TRN	-	-	-	-	-	<1	-	<1	-	-
E-3-55	TRN	-	-	-	-	-	<1	-	<1	-	-
E-4-15	NWQL	-	-	-	<3	-	<3	<3	<3	<3	<3
	TRN	-	-	-	-	-	<1	-	<1	-	-
E-4-20	TRN	-	-	410	-	-	<1	-	<1	-	-
E-4-25	TRN	-	-	-	-	-	<1	-	<1	-	-
E-4-30	NWQL	-	-	-	<0.2	-	<0.2	<0.2	<0.2	<0.2	<0.2
	TRN	-	-	1,500	-	-	<1	-	<1	-	-
E-4-35	TRN	-	-	110	-	-	<1	-	<1	-	-
E-4-40	TRN	-	-	20	-	-	<1	-	<1	-	-
E-5-15	NWQL	.004	-	-	-	.05	-	-	-	-	-
	TRN	-	-	6	-	-	<1	-	<1	-	-
E-5-20	TRN	-	-	<2	-	-	<1	-	<1	-	-
E-5-25	NWQL	.005	-	-	-	.05	-	-	-	-	-
	TRN	-	-	44	-	-	<1	-	<1	-	-

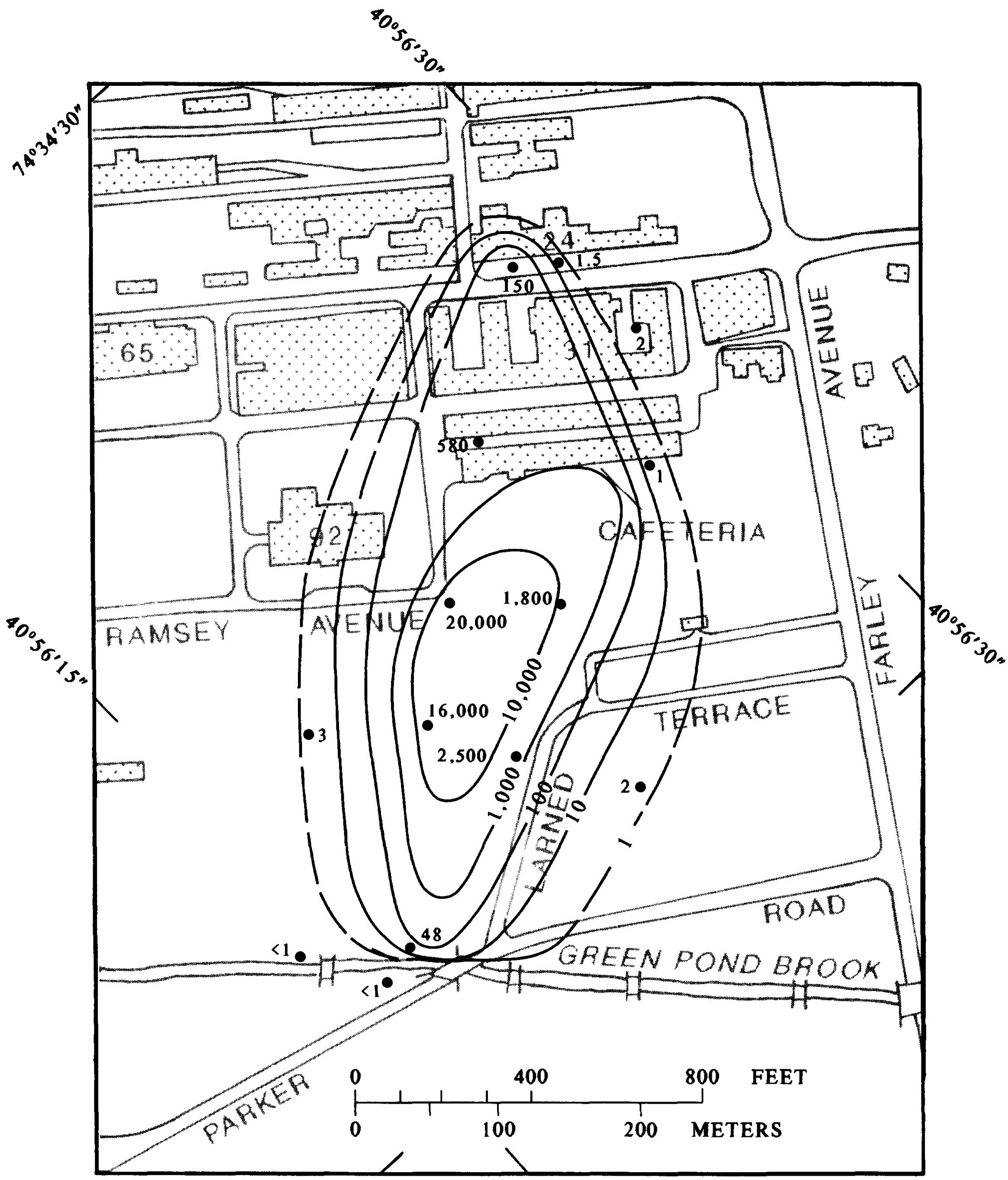
Table 6.--Results of analyses of drive-point water samples for selected chemical constituents and organic compounds--Continued

Local identifier[1]	Lab-ora-tory	Iodide (P71865)	Bromide (P71870)	Methane (P76994)	Styrene (P77128)	MBAS, total[3] (P38260)	Dichloro-difluoro-methane (P34668)	1,2-Di-bromo-ethylene (P39082)	1,1,2,2-Tetrchloro-ethane (P34516)	Cis 1,3-di-chloro-propene (P34704)	Trans-1,3-di-chloro-propene (P34699)
E-5-30	TRN	-	-	<2	-	-	<1	-	<1	-	-
E-5-35	NWQL	.003	-	-	-	.06	-	-	-	-	-
	TRN	-	-	<2	-	-	<1	-	<1	-	-
E-5-40	TRN	-	-	<2	-	-	<1	-	<1	-	-
E-5-45	NWQL	.003	-	-	-	.04	-	-	-	-	-
	TRN	-	-	<2	-	-	<1	-	<1	-	-
X-1-10	TRN	-	-	-	-	-	<1	-	<1	-	-
X-1-15	TRN	-	-	-	-	-	<1	-	<1	-	-
X-1-20	NWQL	-	-	-	<3	-	<3	<3	<3	<3	<3
	TRN	-	-	-	-	-	<1	-	<1	-	-
X-1-25	TRN	-	-	-	-	-	<1	-	<1	-	-
X-1-30	TRN	-	-	-	-	-	<1	-	<1	-	-
X-1-35	TRN	-	-	-	-	-	<1	-	<1	-	-
X-1-40	TRN	-	-	-	-	-	<1	-	<1	-	-
X-1-45	NWQL	-	-	-	<3	-	<3	<3	<3	<3	<3
	TRN	-	-	-	-	-	<1	-	<1	-	-
X-1-50	TRN	-	-	-	-	-	<1	-	<1	-	-

[1] The last two digits in the local identifier represent the depth from which the sample was collected; altitudes of site shown on table five. At sites B1, B2, C4, and E3 water samples collected in April 1986 and at the remaining sampling site August-September, 1986.

[2] The Survey Laboratory in Denver, Colorado, reports both trans- and cis-1,2 dichloroethylene as trans-1,2 dichloroethylene.

[3] MBAS, methylene blue active substance, in milligrams per liter. This substance is an indicator of the detergent concentration

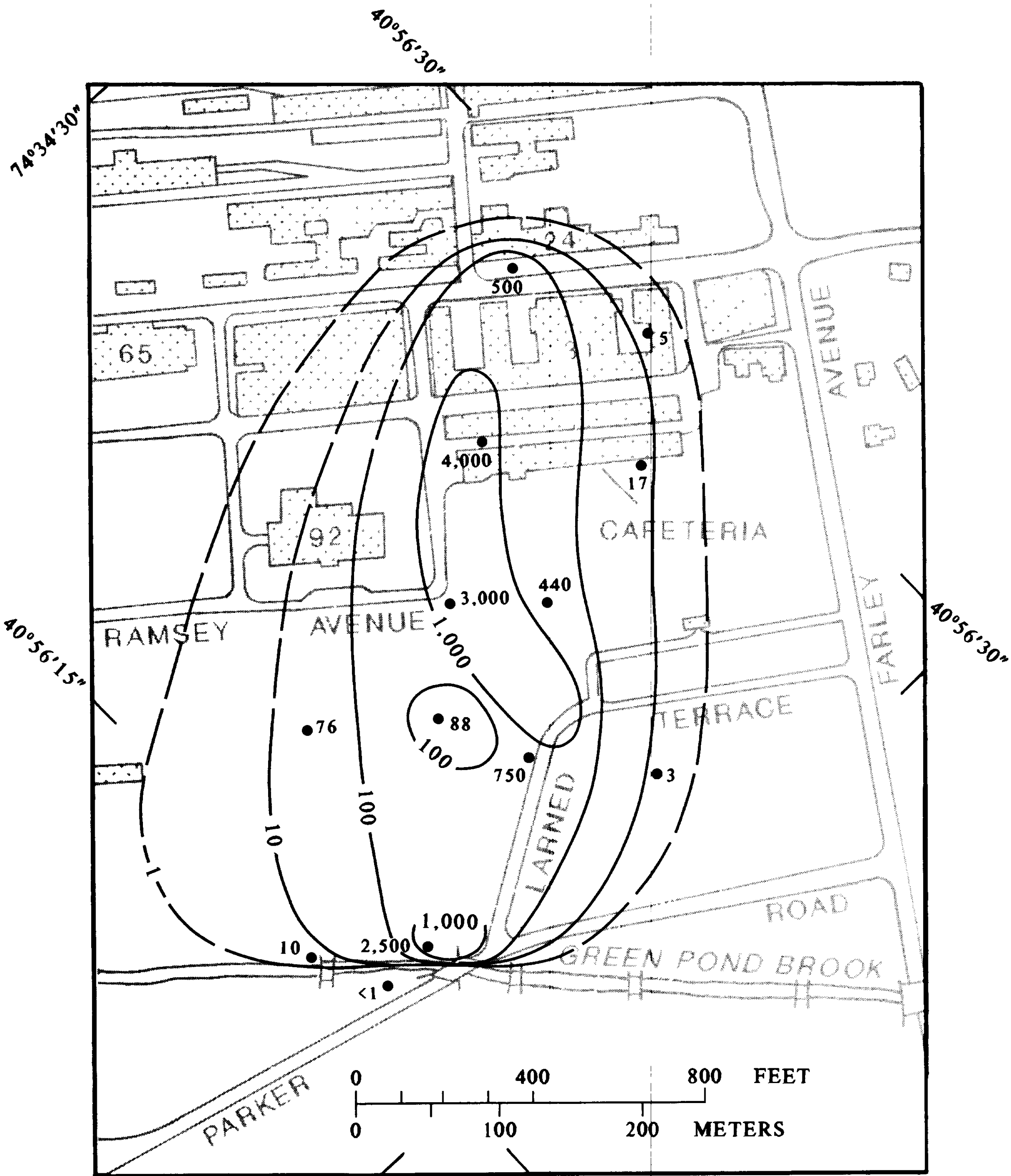


Base map from basic information maps of Picatinny Arsenal, 1975

EXPLANATION

——— 10 — —	LINE OF EQUAL CONCENTRATION OF TRICHLOROETHYLENE--In micrograms per liter. Interval is variable. Dashed where approximate
● 48	LOCATION OF DRIVE-POINT SITE--Number shown is concentration of trichloroethylene, in micrograms per liter
65	Building identification number

Figure 20.--Concentration of trichloroethylene in ground-water samples at the 650-foot altitude, 1986.



Base map from basic information maps of Picatinny Arsenal, 1975

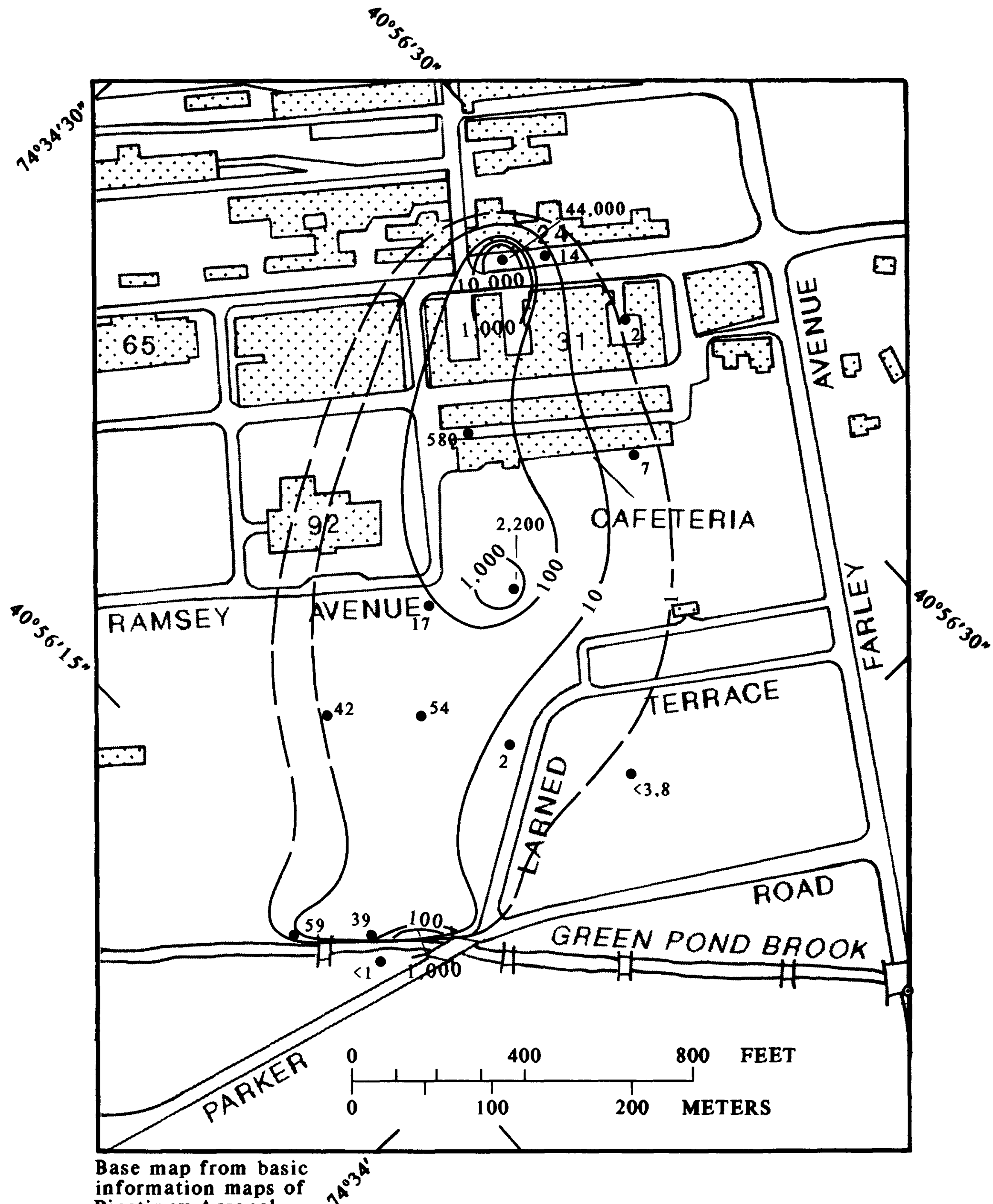
EXPLANATION

—— 10 — — LINE OF EQUAL CONCENTRATION OF TRICHLOROETHYLENE--In micrograms per liter. Interval is variable. Dashed where approximate

● 76 LOCATION OF DRIVE-POINT SITE--Number shown is concentration of trichloroethylene, in micrograms per liter

65 Building identification number

Figure 21.--Concentration of trichloroethylene in ground-water samples at the 670-foot altitude, 1986.



Base map from basic information maps of Picatinny Arsenal, 1975

EXPLANATION

10 — LINE OF EQUAL CONCENTRATION OF TRICHLOROETHYLENE--In micrograms per liter. Interval is variable. Dashed where approximate

● 7 LOCATION OF DRIVE-POINT SITE--Number shown is concentration of trichloroethylene, in micrograms per liter

65 Building identification number

Figure 22.--Concentration of trichloroethylene in ground-water samples at the 680- to 690-foot altitude, 1986.

Several characteristics of the TCE plume are illustrated in the longitudinal and transverse sections shown in figure 23. At section D-D', 1,300 ft from building 24, the plume is approximately 20 ft thick and the zone of TCE concentrations greater than 10,000 μg/L is found 35 ft below the water table. Here the plume is overlain by 15 to 20 ft of relatively uncontaminated ground water. The distribution of TCE does not appear to be affected by the buried stream channel near the brook. The lowermost extent of the plume generally coincides with the boundary between the unconfined aquifer and the lower confining unit, at a depth of approximately 50 ft. Section E-E' is a transverse section through site B-2 that shows the lateral shape of the plume.

The elevated TCE concentrations at the base of the unconfined aquifer can indicate that nonaqueous-phase TCE has "pooled" at the top of the confining unit. Because pure TCE is denser than ground water, TCE may have sunk by gravity through the coarse, unconfined sediments until its downward movement was stopped by the fine-grained sediments of the underlying confining unit.

Cis-1,2-dichloroethylene is the second most abundant VOC in the contaminant area. An areal view of cis-1,2-dichloroethylene concentrations suggests the existence of two plumes--one emanating from building 24 and the other emanating from the building 31 oil-storage area (fig. 24). The values shown represent the highest value at each drive-point site. Drive-point installation and plume delineation were difficult near the contaminant source because the presence of buildings in the area reduced the number of available drilling sites.

Figure 25 shows the distribution of cis-1,2-dichloroethylene in longitudinal section D-D' and transverse section E-E'. (Locations of sections are shown in fig. 19.) The distribution of this compound is similar to that of TCE, although the concentrations are lower. The zone of concentrations that equal or exceed 10 μg/L extends downward from building 24, then moves upward with recharge to Green Pond Brook. The transverse section E-E' shows two zones where concentrations exceed 100 μg/L--one near the base of the aquifer and the other at an altitude of 660 to 670 ft.

The remaining organic compounds detected in concentrations greater than 100 μg/L, methane and tetrachloroethylene, could not be mapped. A tetrachlorethylene concentration greater than 100 μg/L was found in only one water sample, whereas methane concentrations greater than 100 μg/L were found in nine water samples. The presence of methane in an aquifer system is an indicator of methane-producing bacteria (T.A. Ehlke, U.S. Geological Survey, oral commun., 1989). Methane-degrading bacteria can degrade TCE under anaerobic conditions (Little and others, 1988). Both types of bacteria are present in ground water at the arsenal (T.A. Ehlke, U.S. Geological Survey, oral commun., 1989). The distributions of TCE, cis-1,2-dichloroethylene, vinyl chloride, and methane with depth at sites B-3 and D-2 are shown in figures 26 and 27, respectively.

Site B-3 is approximately two-thirds of the distance from building 24 to Green Pond Brook (fig. 19). The highest concentrations of cis-1,2-dichloroethylene, vinyl chloride, and methane determined at the site were

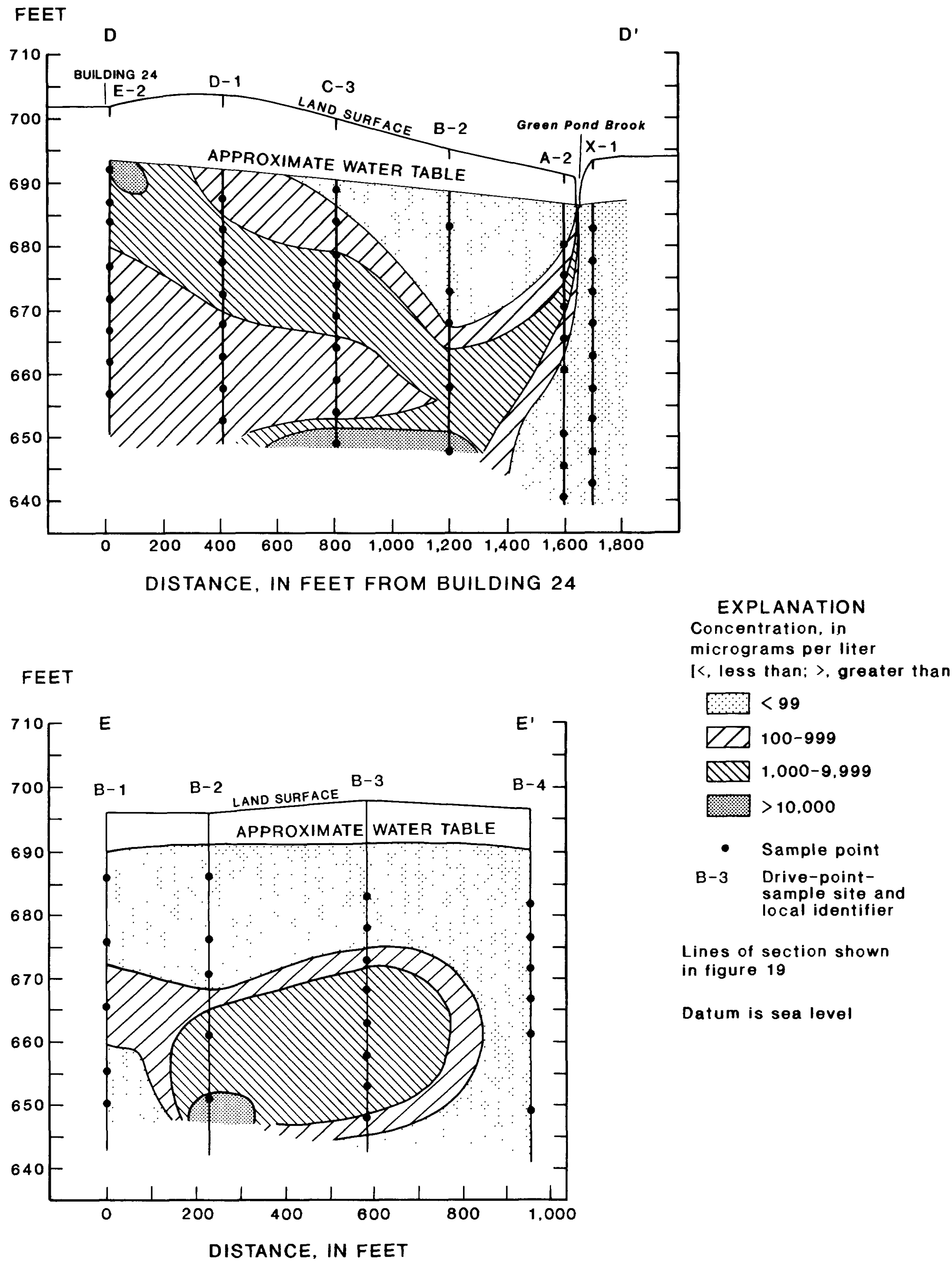
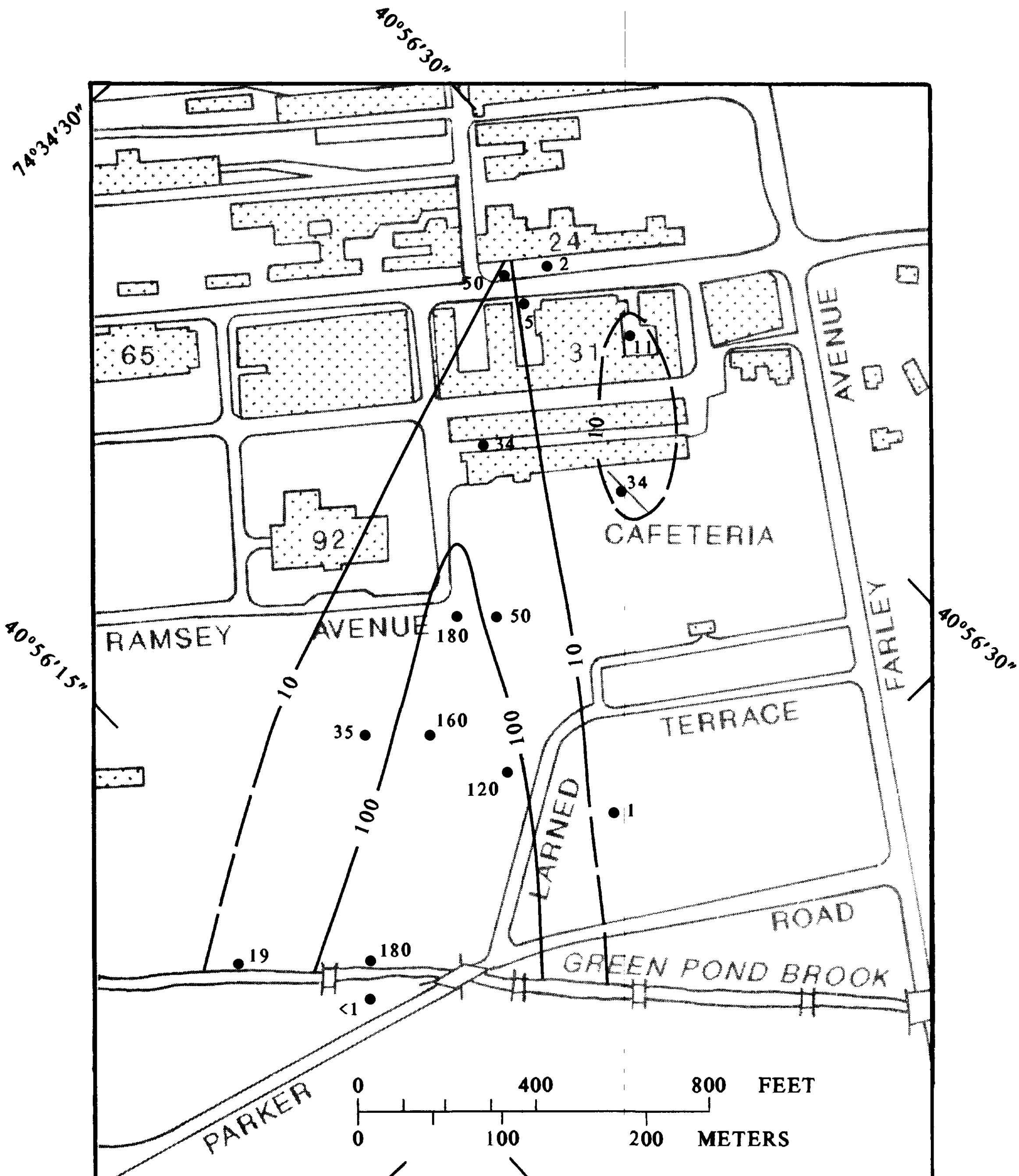


Figure 23.--Logitudinal and transverse sections showing vertical distribution of trichloroethylene in ground-water samples, 1986.



Base map from basic information maps of Picatinny Arsenal, 1975

EXPLANATION

——— 10 — — — LINE OF EQUAL CONCENTRATION OF CIS-1,2-DICHLOROETHYLENE--In micrograms per liter. Interval is variable. Dashed where approximated

●34 LOCATION OF DRIVE-POINT SITE--Number shown is the maximum concentration of cis-1,2-dichloroethylene found at that site, in micrograms per liter

65 Building identification number

Figure 24.--Generalized distribution of cis-1,2-dichloroethylene, 1986.

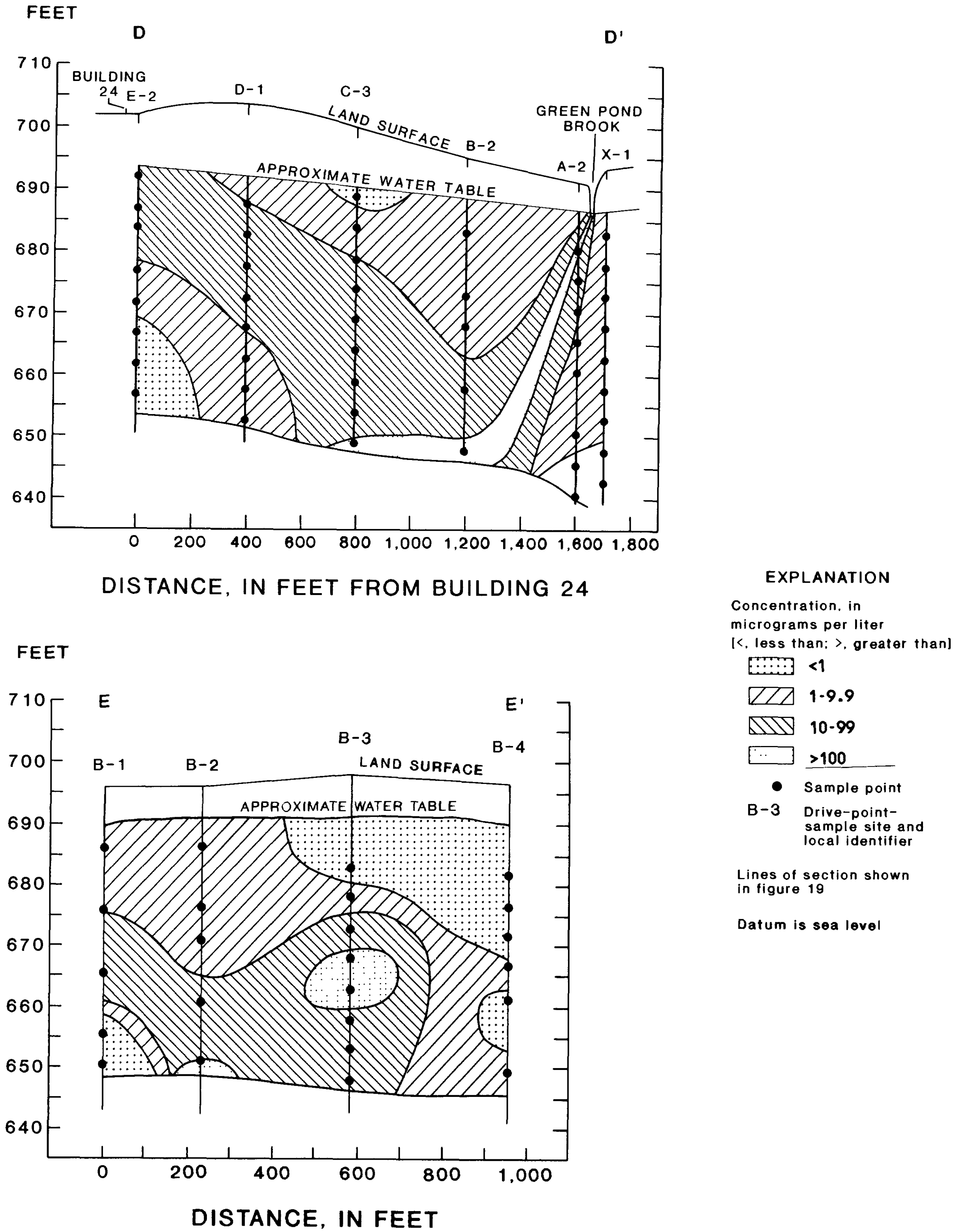


Figure 25.--Logitudinal and transverse sections showing vertical distribution of cis-1,2-dichloroethylene in ground-water samples, 1986.

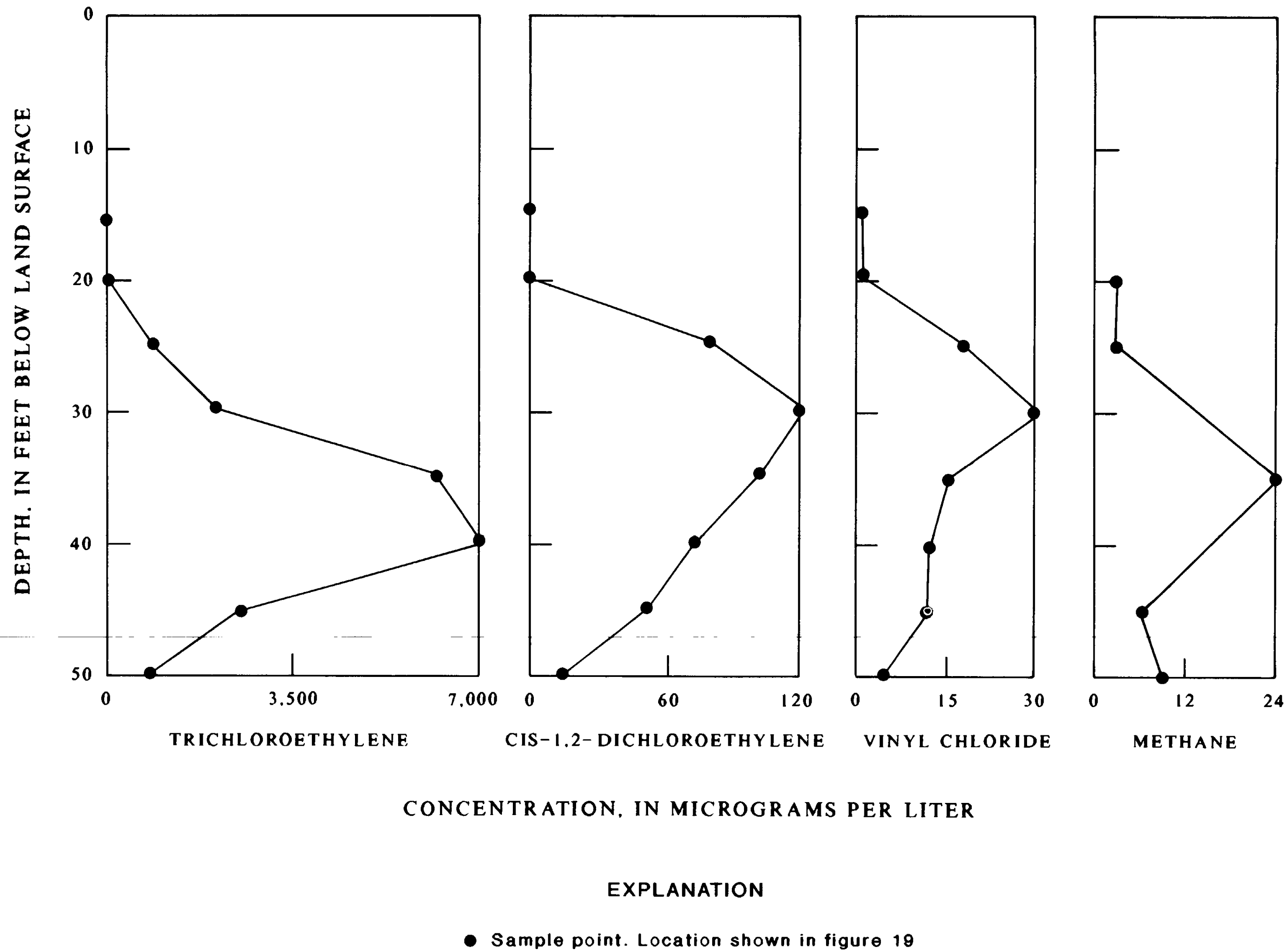
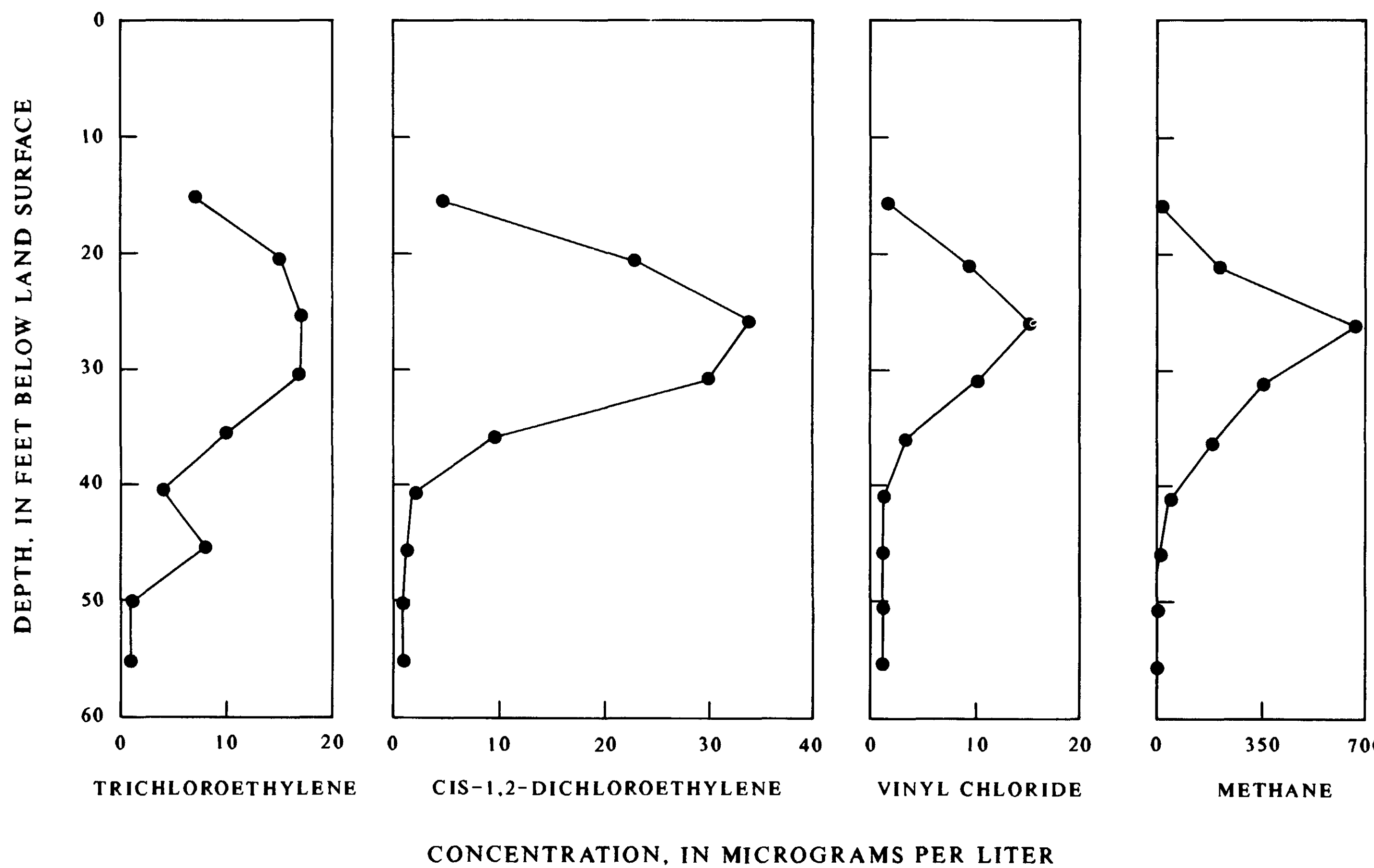


Figure 26.--Vertical distribution of organic constituents at site B-3.



EXPLANATION

● Sample point. Location shown in figure 19

Figure 27.--Vertical distribution of organic constituents at site D-2.

found in shallower ground water than was the highest TCE concentration (7,000 µg/L). High TCE concentrations can be toxic to microbes, preventing degradation of trichloroethylene except at the edges of the TCE plume.

Site D-2 is downgradient from the building 31 oil-storage area and the diesel fuel-tank site. Diesel fuel probably is providing a source of carbon for methane-producing bacteria (T.A. Ehlke, U.S. Geological Survey, oral commun., 1989). The highest methane concentration found in the study area, 1,500 µg/L, was detected at site E-4, which is the site closest to the diesel-fuel tank site. The absence of detectable nitrates at site E-4 is an indicator of reducing conditions. At site D-2 the maximum TCE concentration was less than 20 µg/L; therefore, vertical variation in concentrations of cis-1,2-dichloroethylene or vinyl chloride resulting from TCE toxicity was not expected.

Well Sampling

Water samples were collected from 60 wells during October and November 1987. Five of the sampled wells are screened in the bedrock aquifer, 10 are screened in the confined glacial aquifer, and the remaining 45 wells are screened in the unconfined aquifer. The wells screened in the two deep aquifers are listed below:

Bedrock-aquifer wells	Confined-aquifer wells	
10-3A	10-4	39-1
302-D	39-2	65-3
65-1	95-1	95-2
CAF-1	CAF-3	CAF-4
H-2	H-3	65-2

Well 302D was left uncased from 110 to 403 ft below land surface when it was completed in 1921. Little is known about its present condition; this well may tap a part of the confined glacial aquifer. Wells 10-3A, 10-4, 39-1, 39-2, 95-1, and 95-2 were installed as part of the 1987 drilling program for this study.

Variations in the diameters and screened lengths of wells affect the representative volume of ground water from which the samples are collected. However, all of the 27 new wells screened in the unconfined aquifer have similar 5-ft screened lengths and 2-in. I.D. Most sampled wells had inside diameters of 2 or 4 in., and screened lengths of 5 to 20 ft. Screens in wells 9-A, 9-B, 9-C, and I (fig. 3) are atypical of wells in the area because they extend above the surface of the water table.

As part of the quality-assurance program, four USGS Standard Reference Water Samples (Schroder and others, 1980) were shipped to the USATHEMA contract laboratory for analysis. The results are provided in table 7. USATHEMA sample GB-W contained a lead concentration three times greater than the reference sample mean concentration. Although chromium concentrations

Table 7.--Results of analyses of standard reference samples

[Concentrations in micrograms per liter; dash indicates constituent not determined]

Trace metal	Identifier		Reference water sample T97		
	GB-W	GB-F	Sample mean	Standard deviation	Number of analyses
Silver	[1]<13.5	<13.5	7	1.8	34
Arsenic	11	11	11.3	1.5	37
Barium	84	84	98	12	35
Cadmium	20	22	16.3	2.1	38
Chromium	30	30	26	4.3	49
Copper	10	8.2	16.8	2.5	41
Mercury	.62	.76	.9	.2	34
Nickel	<37.8	<37.8	15.2	5.8	28
Lead	46	<18.6	15.0	3.7	39
Antimony	<23.8	<23.8	15.0	11.3	13
Selenium	<9.6	<9.6	15.9	3.4	36
Thallium	<6.99	<6.99	-	-	-
Zinc	170	160	153	10	49

Trace metal	Identifier		Reference water sample T99		
	BB-4	GB-1	Sample mean	Standard deviation	Number of analyses
Silver	<13.5	<13.5	3	3	34
Arsenic	4.4	4.7	5.8	1.9	35
Barium	14	15	25.1	10.2	30
Cadmium	14	14	4.7	1.5	49
Chromium	45	46	16.3	6.5	51
Copper	19	21	27.9	4.6	51
Mercury	<.243	<.243	-	-	-
Nickel	<37.8	<37.8	5.	-	26
Lead	<18.6	<18.6	4.7	3.4	21
Antimony	<23.8	<23.8	3.4	1.4	8
Selenium	21	20	9.8	3.4	31
Thallium	<6.99	<6.99	3.5	1.7	4
Zinc	<20.1	36	36	7.3	54

[1] "less than" symbol (<) indicates constituent not detected in sample and for which the laboratory has been certified by the U.S. Army Toxic and Hazardous Materials Command; number shown is detection limit

reported by USATHEMA for samples BB-4 and GB-1 were similar to one another, they were high compared to the mean chromium concentration reported for the reference sample. Concentrations of the remaining metals typically were within a standard deviation of the mean concentration.

Inorganic Constituents and Cyanide

The National Water Quality Laboratory analyzed samples of ground water from wells for chemical and physical properties and selected chemical constituents. The results of these analyses are presented in table 8. Neither the bedrock nor the confined glacial aquifer contained unusually high concentrations of any of these inorganic constituents or cyanide. The highest temperature and pH values observed in water from all wells, 20.0 °C and 11.8 units, respectively, were in ground water from well 95-1. The hydration of cement used in the construction of this newly completed well probably affected these and other measurements of the sample.

The results of sample analyses from wells screened in the unconfined aquifer generally were similar to those obtained from the drive-point sampling. Like the drive-point-sampling results, all concentrations of nitrate (as nitrogen) were less than the USEPA primary drinking-water regulation of 10 mg/L (U.S. Environmental Protection Agency, 1976). The highest chloride concentration, 210 mg/L, at well 31-2A was similar to the results of drive-point sampling, where a chloride concentration of 250 mg/L was found at site E-4 (fig. 19).

Cyanide was detected in concentrations less than 1.0 μg/L at four wells: 9-D, 9-E, 92-5, and CAF-2 (fig. 4). Cyanide appears to have been used extensively in plating operations at building 24. Low cyanide concentrations only 1,000 ft downgradient from building 24 could reflect the tendency for cyanide to form strong soluble complexes with metal ions; the relatively large size of such ligands can inhibit their movement in the aquifer (Hem, 1985, p. 124). Cyanide was not detected in any of the deep wells (fig. 19).

Trace Metals and Volatile Organic Compounds

A USATHEMA contract laboratory analyzed samples of ground water from wells for 14 trace metals and six VOCs. Results of these analyses are shown in table 9. Five replicate samples also were sent to the contract laboratory. Results of these analyses compare well with the original analyses. Results of analyses of the replicate samples and USGS samples for TCE are included in the table.

The metals mercury and cadmium were detected in concentrations greater than the USEPA primary drinking-water regulations of 2 μg/L and 10 μg/L, respectively. Mercury was detected in water from all three aquifers in concentrations greater than 2 μg/L. Water from well 65-1, screened in the bedrock aquifer, contained mercury in a concentration of 2.23 μg/L, and water from wells 112-3 and 9-B, screened in the unconfined aquifer, had concentrations of 2.09 μg/L and 2.67 μg/L, respectively. The mercury concentrations found in these three wells could be the result of sampling- or shipment-related cross-contamination from water samples preserved with

Table 8.--Results of analyses of ground-water samples for chemical and physical properties, and selected chemical constituents

[All constituents are dissolved; concentrations in milligrams per liter, except as noted; a dash (-) indicates constituent not determined; <, less than; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 degrees Celsius; all wells sampled October or November 1987]

Well number	Local well identifier	Temperature (°C) (P00010)	Dissolved oxygen (P00300)	Field pH (units) (P00403)	Field alkalinity (as $CaCO_3$) (P00410)	Lab specific conductance (µS/cm) (P90095)	Ammonia (as N) (P00608)	Nitrite (as N) (P00613)	Ammonia + organic N (as N) (P00623)	NO_2 + NO_3 (as N) (P00630)
270974	10-3	19.0	0.5	6.30	63	193	0.07	<0.01	-	<0.10
270968	10-3A	13.0	6.1	7.60	-	235	-	-	-	-
270969	10-4	14.0	12.5	8.60	87	413	.03	<.01	<0.2	.19
270958	111-1	17.0	.4	6.11	58	474	.39	<.01	.8	<.10
270959	111-2	17.0	1.2	6.30	56	287	.01	<.01	<.2	1.70
270944	112-1	13.0	.2	6.50	70	440	<.01	.02	<.2	1.40
270953	112-10	16.0	4.7	6.56	37	494	<.01	<.01	<.2	1.90
270945	112-2	14.0	10.6	6.10	20	217	<.01	<.01	<.2	2.70
270946	112-3	12.5	.6	7.95	155	809	.07	<.01	<.2	<.10
270947	112-4	12.5	.4	7.60	158	886	.10	<.01	.3	<.10
270948	112-5	14.0	5.4	7.76	62	242	<.01	<.01	<.2	4.00
270949	112-6	13.0	.5	7.68	143	686	.02	<.01	.8	<.10
270950	112-7	13.0	.4	7.96	430	437	.05	<.01	<.2	<.10
270951	112-8	14.0	4.5	6.96	42	630	<.01	<.01	.2	2.30
270952	112-9	15.0	.5	8.35	184	557	<.01	.03	<.2	.89
270267	129-OBS	15.0	2.0	6.20	70	681	<.01	<.01	<.2	.97
270333	130-3	18.5	.4	5.90	52	513	1.70	<.10	1.8	.77
270327	24-1	13.5	.03	6.40	88	362	.60	<.01	1.0	<.10
270083	302D	13.5	.6	7.50	158	567	.01	<.01	1.3	<.10
270336	31-1	17.0	.5	6.26	57	408	<.01	.05	<.2	1.20
270963	31-2A	17.0	1.5	6.53	144	861	1.40	<.01	1.8	<.10
270330	31-3A	18.5	.5	6.70	89	401	.36	<.01	.9	.37
270964	31-5	16.0	1.0	6.21	76	687	.01	<.01	.4	1.60
270331	34-1	19.5	.5	6.20	49	321	<.01	<.01	<.2	.38
270967	34-2	19.0	.9	6.20	60	398	<.01	<.01	<.2	.61
270970	39-1	14.0	3.7	8.60	103	288	.04	<.01	<.2	<.10
270971	39-2	12.0	11.6	8.30	92	324	.03	<.01	<.2	<.10
270937	41-1	12.0	9.4	6.40	46	308	<.01	<.01	<.2	1.40
270938	41-2	12.0	8.9	6.60	68	334	.01	<.01	<.2	1.20
270939	41-3	11.0	.1	8.60	72	176	.04	<.01	<.2	<.10
270940	41-4	12.0	.5	8.62	64	166	.12	<.01	.2	<.10
270941	41-5	13.0	.7	7.57	157	746	.02	.02	<.2	.21
270942	41-8	12.0	7.8	7.04	99	421	<.01	<.01	<.2	.99
270943	41-9	12.5	.5	7.64	184	759	.11	<.01	.3	<.10
270337	64-1	18.5	.4	6.80	63	232	.09	<.01	<.2	<.10
270246	65-1	12.5	.1	8.30	148	262	.01	<.01	<.2	<.10
270247	65-2	12.0	4.3	8.60	72	226	.01	<.01	<.2	<.10
270248	65-3	15.5	1.2	8.50	89	154	.08	<.01	<.2	<.10
270249	65-4	14.0	1.9	7.70	204	826	<.01	<.01	<.2	1.40
270093	9-A	19.0	.4	7.70	124	426	.94	<.01	.9	.23
270094	9-B	18.0	.4	7.67	129	460	.41	.01	1.0	.22
270095	9-C	18.0	.4	6.57	166	436	.75	<.01	1.1	<.10
270961	9-D	11.0	.5	7.28	112	436	.90	<.01	1.1	.14
270962	9-E	19.0	.4	7.16	153	739	.26	.02	.7	1.00
270955	92-3	15.5	.4	8.80	106	382	.02	<.01	<.2	.48
270956	92-4	16.0	.4	6.58	73	602	.02	<.01	<.2	.14
270957	92-5	16.0	.4	5.70	31	394	.03	.05	<.2	.14
270972	95-1	20.0	4.1	11.80	302	-	.53	.01	.8	<.10
270973	95-2	13.5	-	8.9	90	281	.06	<.01	.2	<.10
270242	CAF-1	12.5	.2	7.17	266	214	.04	<.01	.3	<.10
270243	CAF-2	16.0	4.8	6.80	115	499	.03	<.01	.4	<.10
270244	CAF-3	14.5	.3	8.00	104	245	.01	<.01	.2	<.10
270245	CAF-4	14.0	.2	7.70	128	306	.04	<.01	<.2	<.10
270304	CAF-5	17.0	1	6.39	120	752	.64	<.01	.6	<.10
270960	CAF-6	16.0	.3	7.60	98	404	.02	<.01	.4	<.10
270280	H-2	16.5	.2	9.20	10	265	<.01	<.01	.2	<.10
270281	H-3	14.0	.1	9.20	66	140	.08	<.01	.3	<.10
270282	H-4	18.5	2.1	6.30	-	362	<.01	<.01	.4	1.3
270239	I	14.0	.6	7.70	169	827	<.01	.03	<.2	.62
270954	I-2	13.0	.5	8.10	84	506	.04	<.01	<.2	.14

Table 8.--Results of analyses of ground-water samples for chemical and physical properties, and selected chemical constituents--Continued

Well number	Local well identifier	Phosphorus (P00665)	Orthophosphate (P00671)	Organic carbon (P00681)	Cyanide (P00723)	Calcium (P00915)	Magnesium (P00925)	Sodium (P00930)	Potassium (P00935)
270974	10-3	0.02	-	-	-	18	12	1.7	0.3
270968	10-3A	-	-	4.0	<0.01	24	4.2	12	2.6
270969	10-4	.03	0.02	0.4	<.01	30	13	29	1.8
270958	111-1	.01	.01	4.9	<.01	20	6.6	60	3.4
270959	111-2	.01	<.01	1.3	<.01	17	3.8	31	2.8
270944	112-1	<.01	<.01	1.1	<.01	24	13	35	3.2
270953	112-10	<.01	<.01	1.1	<.01	24	4.1	59	3.1
270945	112-2	<.01	<.01	.7	<.01	14	3.3	18	1.6
270946	112-3	.04	.04	1.4	<.01	67	21	65	1.3
270947	112-4	.03	.02	2.1	<.01	61	21	86	1.5
270948	112-5	.02	.01	.9	<.01	16	7.3	13	2.6
270949	112-6	.03	.01	1.1	<.01	41	21	67	1.8
270950	112-7	.03	.04	.7	<.01	41	13	23	1.1
270951	112-8	.03	<.01	.8	<.01	20	4.5	89	3.5
270952	112-9	<.01	.02	.9	<.01	44	22	34	1.3
270267	129-OBS	.01	.01	3.2	<.01	32	7.6	74	4.1
270333	130-3	.01	<.01	1.5	<.01	7.6	2.2	83	2.6
270327	24-1	.10	.10	6.9	<.01	28	3.8	36	1.8
270083	302D	<.01	.01	.8	-	50	22	31	1.7
270336	31-1	.03	<.01	2.8	<.01	20	4.4	45	1.1
270963	31-2A	<.01	.01	9.2	<.01	49	9.6	110	4.0
270330	31-3A	.03	.01	12	<.01	11	.79	73	1.5
270964	31-5	<.01	<.01	3.4	<.01	34	5.2	89	4.6
270331	34-1	<.01	<.01	1.6	<.01	16	4.6	36	2.7
270967	34-2	.02	<.01	4.7	<.01	18	2.4	54	3.1
270970	39-1	.08	.05	1.4	<.01	14	3.9	39	2.3
270971	39-2	.04	.04	.5	<.01	36	10	8.5	1.0
270937	41-1	.01	<.01	.4	<.01	15	6.1	33	1.2
270938	41-2	.02	<.01	.8	<.01	17	7.3	34	1.2
270939	41-3	.13	.11	.4	<.01	19	4.2	8.6	.6
270940	41-4	.06	.06	.6	<.01	19	1.3	10	.4
270941	41-5	<.01	<.05	.9	<.01	55	20	60	1.6
270942	41-8	<.01	<.01	.8	<.01	30	12	34	1.3
270943	41-9	.01	.02	1.9	<.01	48	19	80	1.7
270337	64-1	.02	.02	1.9	<.01	18	5.8	15	.8
270246	65-1	.02	.02	.5	<.01	23	12	12	1.6
270247	65-2	.03	.03	.6	<.01	23	7.9	4.7	.8
270248	65-3	.10	.08	.5	<.01	17	2.1	11	.5
270249	65-4	.01	<.01	.7	<.01	56	24	67	1.8
270093	9-A	.01	.02	5.0	<.01	17	2.9	63	3.7
270094	9-B	.55	.52	18	<.01	8.3	1.1	89	1.7
270095	9-C	.06	.07	5.1	<.01	43	5.8	42	5.6
270961	9-D	.03	.03	13	.02	8.5	.99	83	1.5
270962	9-E	.06	.06	16	.04	25	3.6	120	5.0
270955	92-3	.06	.05	.7	<.01	37	16	10	.9
270956	92-4	.01	<.01	1.0	<.01	26	12	71	1.8
270957	92-5	.02	.01	1.8	.06	6.1	1.9	64	1.5
270972	95-1	<.01	<.01	2.3	<.01	80	<.01	61	6.7
270973	95-2	.10	.11	.4	<.01	8.3	1.9	46	1.3
270242	CAF-1	<.01	.03	.5	<.01	23	8.2	3.5	2.6
270243	CAF-2	.04	.04	12	.22	3.2	.7	97	.7
270244	CAF-3	.06	.04	.6	<.01	26	9.7	5.1	.8
270245	CAF-4	<.01	.01	.7	<.01	32	11	13	1.2
270304	CAF-5	<.01	.15	5.4	<.01	30	10	86	2.9
270960	CAF-6	.03	.01	.9	<.01	32	15	22	1.3
270280	H-2	.05	.03	.5	<.01	26	12	6.8	5.1
270281	H-3	.19	.17	.4	<.01	16	.44	12	.9
270282	H-4	<.01	.02	.8	<.01	20	8.2	33	1.4
270239	I	.02	.02	.8	<.01	55	24	73	1.6
270954	I-2	.03	.03	.5	<.01	48	16	20	1.1

Table 8.-- Results of analyses of ground-water samples for chemical and physical properties, and selected chemical constituents--Continued

Well number	Local well identifier	Chloride (P00940)	Sulfate (P00945)	Fluoride (P00950)	Silica (SiO_2) (P00955)
270974	10-3	2.9	5.7	0.1	6.3
270968	10-3A	10	24	.1	11
270969	10-4	52	24	.2	13
270958	111-1	91	27	.1	16
270959	111-2	39	17	.1	9.5
270944	112-1	65	30	.1	12
270953	112-10	110	22	.1	7.4
270945	112-2	35	16	.1	7.7
270946	112-3	91	110	.1	23
270947	112-4	98	110	.2	25
270948	112-5	18	22	.1	11
270949	112-6	91	56	.1	11
270950	112-7	42	49	.2	9.3
270951	112-8	170	12	.1	7.5
270952	112-9	53	27	.1	21
270267	129-OBS	140	27	.1	10
270333	130-3	110	28	.1	14
270327	24-1	46	23	.2	15
270083	302D	66	22	.1	18
270336	31-1	66	22	.1	7.7
270963	31-2A	210	17	.1	12
270330	31-3A	44	31	.4	7.0
270964	31-5	150	17	.1	8.3
270331	34-1	49	21	.1	12
270967	34-2	73	13	.1	8.0
270970	39-1	18	34	.3	11
270971	39-2	34	25	.2	13
270937	41-1	45	18	.2	11
270938	41-2	48	19	.1	12
270939	41-3	4.1	12	.2	10
270940	41-4	3.3	11	.3	9.6
270941	41-5	120	32	.1	12
270942	41-8	55	18	.1	14
270943	41-9	85	78	.1	20
270337	64-1	25	8.1	.2	9.1
270246	65-1	11	15	.1	9.9
270247	65-2	20	24	.2	12
270248	65-3	2.5	9.5	.2	10
270249	65-4	130	28	.1	17
270093	9-A	48	28	.1	8.9
270094	9-B	39	41	.6	6.1
270095	9-C	20	28	.9	11
270961	9-D	40	42	.6	6.4
270962	9-E	120	43	.3	6.5
270955	92-3	36	28	.1	17
270956	92-4	110	50	.2	18
270957	92-5	65	41	.2	17
270972	95-1	7.3	25	.9	22
270973	95-2	5.8	26	.6	6.9
270242	CAF-1	2.0	9.4	.2	15
270243	CAF-2	51	45	.2	7.5
270244	CAF-3	9.7	17	.2	11
270245	CAF-4	15	17	.1	11
270304	CAF-5	160	18	.1	18
270960	CAF-6	46	26	.2	15
270280	H-2	11	15	.1	8.8
270281	H-3	.8	9.9	.2	10
270282	H-4	63	25	.1	16
270239	I	140	35	.1	16
270954	I-2	86	31	.1	15

Table 9.--Results of analyses of ground-water samples for selected metals and volatile organic compounds

[All constituents are dissolved; concentrations in micrograms per liter; dash indicates constituent not determined; all wells sampled October or November 1987]

Local well identifier	Arsenic (P01000)	Barium (P01005)	Beryllium (P01010)	Cadmium (P01025)	Chromium (P01030)	Copper (P01040)	Lead (P01049)	Thallium (P01057)	Nickel (P01065)	Silver (P01075)
10-3	[3]<3.07	37.7	-	<5.16	6.96	<7.93	<18.6	-	<37.8	<13.5
10-3A	<3.07	<10.4	-	<5.16	<5.96	<7.93	<18.6	-	<37.8	<13.5
10-4	<3.07	29.9	-	<5.16	<5.96	<7.93	<18.6	-	<37.8	<13.5
111-1	<3.07	67.8	<10	<5.16	<5.96	12.1	<18.6	<6.99	<37.8	<13.5
111-2	<3.07	33.9	-	<5.16	<5.96	<7.93	<18.6	<6.99	<37.8	<13.5
112-1	<3.07	57.4	-	<5.16	<5.96	<7.93	<18.6	-	<37.8	<13.5
112-10	<3.07	<10.4	-	<5.16	8.13	<7.93	<18.6	<6.99	<37.8	<13.5
112-2	<3.07	26.3	-	<5.16	<5.96	<7.93	<18.6	-	<37.8	<13.5
112-3	6.9	81.5	-	<5.16	10.2	<7.93	<18.6	<6.99	<37.8	<13.5
112-4	5.7	76.1	-	<5.16	14.9	8.49	<18.6	<6.99	<37.8	<13.5
112-5	<3.07	23.7	-	<5.16	8.13	<7.93	<18.6	<6.99	<37.8	<13.5
112-6	<3.07	81.2	-	<5.16	14.2	<7.93	<18.6	<6.99	<37.8	<13.5
112-7	3.1	34.6	-	<5.16	6.1	<7.93	<18.6	<6.99	<37.8	<13.5
112-8	<3.07	25.8	-	<5.16	<5.96	<7.93	<18.6	<6.99	<37.8	<13.5
112-9	<3.07	28.1	<10	<5.16	<5.96	9.34	<18.6	<6.99	<37.8	17.5
129-OBS	<3.07	88.3	-	<5.16	<5.96	10.1	<18.6	<6.99	<37.8	<13.5
130-3	<3.07	27.1	-	<5.16	8.13	<7.93	19.2	<6.99	<37.8	<13.5
24-1	<3.07	43.6	<10	<5.16	<5.96	15.6	<18.6	<6.99	<37.8	<13.5
302-D	<3.07	41.5	-	<5.16	21	<7.93	19.2	<6.99	<37.8	<13.5
31-1	<3.07	47.6	<10	12.7	<5.96	8.17	<18.6	<6.99	<37.8	<13.5
31-2A	<3.07	166	<10	<5.16	<5.96	<7.93	18.8	<6.99	<37.8	<13.5
31-3A	<3.07	27	<10	6.35	<5.96	21.4	<18.6	<6.99	<37.8	<13.5
31-5	<3.07	118	-	<5.16	7.57	<7.93	<18.6	-	<37.8	<13.5
34-1	<3.07	22.6	<10	<5.16	<5.96	9.73	<18.6	<6.99	<37.8	<13.5
34-2	<3.07	30.3	<10	<5.16	<5.96	<7.93	<18.6	<6.99	<37.8	<13.5
39-1	<3.07	13.7	-	<5.16	<5.96	<7.93	<18.6	-	<37.8	<13.5
39-2	<3.07	22.4	-	<5.16	<5.96	<7.93	<18.6	-	<37.8	<13.5
41-1	<3.07	11.7	-	<5.16	8.79	<7.93	<18.6	-	<37.8	<13.5
41-2	<3.07	11.3	-	<5.16	7.3	<7.93	<18.6	-	<37.8	<13.5
41-3	6.5	18.3	-	<5.16	<5.96	<7.93	<18.6	-	<37.8	<13.5
41-4	<3.07	<10.4	<10	<5.16	<5.96	<7.93	<18.6	<6.99	<37.8	<13.5
41-5	<3.07	74.6	<10	<5.16	<5.96	<7.93	<18.6	<6.99	<37.8	<13.5
41-8	<3.07	19.6	-	<5.16	<5.96	<7.93	<18.6	-	<37.8	<13.5
41-9	<3.07	61	-	<5.16	8.13	<7.93	<18.6	<6.99	<37.8	<13.5
64-1	<3.07	<10.4	<10	<5.16	<5.96	<7.93	<18.6	<6.99	<37.8	<13.5
65-1	<3.07	33.9	-	<5.16	8.81	<7.93	36.8	<6.99	<37.8	<13.5
65-2	<3.07	12.5	-	<5.16	<5.96	<7.93	<18.6	-	<37.8	16.9
65-3	4.7	<10.4	-	<5.16	<5.96	<7.93	<18.6	<6.99	<37.8	<13.5
65-4	<3.07	23.6	<10	<5.16	<5.96	<7.93	20.3	<6.99	<37.8	<13.5
9-A	<3.07	25.9	-	<5.16	<5.96	11.3	<18.6	<6.99	<37.8	<13.5
9-B	<3.07	<10.4	-	8.91	15.6	89.3	<18.6	<6.99	<37.8	<13.5
9-C	<3.07	28.8	<10	34.9	<5.96	14.8	<18.6	<6.99	<37.8	18.8
9-D	<3.07	<10.4	-	31.8	6.78	16.6	<18.6	<6.99	<37.8	<13.5
9-E	<3.07	62.8	<10	<5.16	10.5	53.3	<18.6	<6.99	<37.8	<13.5
92-3	3.7	22	-	<5.16	6.1	<7.93	32	<6.99	<37.8	<13.5
92-4	<3.07	79.3	-	<5.16	8.13	<7.93	35.2	<6.99	<37.8	<13.5
92-5	<3.07	51.9	-	<5.16	<5.96	<7.93	<18.6	<6.99	<37.8	<13.5
95-1	4.0	21.5	-	<5.16	<5.96	<7.93	<18.6	-	<37.8	<13.5
95-2	<3.07	<10.4	-	<5.16	<5.96	<7.93	<18.6	-	<37.8	<13.5
CAF-1	<3.07	20.9	<10	<5.16	<5.96	<7.93	<18.6	<6.99	<37.8	<13.5
CAF-2	<3.07	26	<10	<5.16	<5.96	15.2	<18.6	<6.99	<37.8	<13.5
CAF-3	<3.07	15.9	-	<5.16	<5.96	<7.93	<18.6	<6.99	<37.8	<13.5
CAF-4	<3.07	51	<10	<5.16	<5.96	<7.93	<18.6	<6.99	<37.8	<13.5
CAF-5	<3.07	80.8	<10	<5.16	<5.96	<7.93	28.2	<6.99	<37.8	<13.5
CAF-6	<3.07	10.5	-	<5.16	7.46	<7.93	<18.6	<6.99	<37.8	<13.5
H-2	<3.07	40.4	<10	<5.16	<5.96	<7.93	23.5	<6.99	<37.8	17.5
H-3	5.2	12.7	<10	<5.16	<5.96	<7.93	<18.6	<6.99	<37.8	<13.5
H-4	<3.07	29.8	<10	<5.16	<5.96	<7.93	<18.6	<6.99	<37.8	<13.5
I	<3.07	48.3	<10	<5.16	<5.96	20.2	29.7	<6.99	<37.8	17.5
I-2	3.8	31.8	<10	<5.16	<5.96	<7.93	<18.6	<6.99	<37.8	<13.5

Table 9.--Results of analyses of ground-water samples for selected metals and volatile organic compounds--Continued

Local well identifier	Zinc (P01090)	Antimony (P01095)	Mercury (P71890)	Selenium (P01145)	Trichloroethylene[1] (P39180)	Vinyl chloride (P39175)	1,1,1-Trichloroethane (P34506)	Tetrachloroethylene (P34475)	1,1-Dichloroethylene (P34501)	1,2-Dichloroethylene[2] (P34546)
10-3	24.3	<23.8	<0.243	<9.66	1.9	[4]ND1	<1	<1	ND1	<1.2
10-3A	<20.1	<23.8	<.243	<9.66	55	ND1	<1	<1	ND1	<1.2
10-4	<20.1	<23.8	<.243	<9.66	<1	ND1	<1	<1	ND1	<1.2
111-1	<20.1	<23.8	<.243	<9.66	36.6/18	16	<1	<1	1.3	24.2
111-2	<20.1	<23.8	<.243	<9.66	6.83/7.72*	ND1	<1	<1	ND1	2.95
112-1	<20.1	<23.8	<.243	<9.66	<1	ND1	<1	<1	ND1	<1.2
112-10	<20.1	<23.8	1.94	<9.66	14/20.8*	ND1	<1	<1	ND1	1.37
112-2	<20.1	<23.8	<.243	<9.66	<1	ND1	<1	<1	ND1	<1.2
112-3	39.3	<23.8	2.09	<9.66	1760/1980/1980*	ND1	<1	<1	ND1	<1.2
112-4	4149.99	<23.8	1.22	<9.66	4490/4950	ND1	<1	<1	ND1	<1.2
112-5	<20.1	<23.8	<.243	<9.66	65.3	ND1	<1	22.5	ND1	4.3
112-6	<20.1	<23.8	1.8	<9.66	1733/3710	ND1	<1	<1	ND1	52.6
112-7	<20.1	<23.8	<.243	<9.66	6430/[5]>160	3.6	<1	<1	9.4	53.7
112-8	<20.1	<23.8	<.243	<9.66	149/180**	ND1	<1	<1	ND1	3.79
112-9	158	<23.8	1.8	<9.66	163/160	ND1	<1	<1	ND1	29.5
129-OBS	1090	<23.8	.852	<9.66	2.67	ND1	2.6	<1	ND1	<1.2
130-3	<20.1	<23.8	.464	<9.66	19.8	ND1	<1	13.7	ND1	2.63
24-1	<20.1	<23.8	<.243	<9.66	<1	ND1	<1	<1	ND1	<1.2
302-D	<20.1	<23.8	<.243	<9.66	6.83	ND1	<1	<1	ND1	<1.2
31-1	<20.1	<23.8	1.8	<9.66	28.7	ND1	<1	2.65	ND1	1.37
31-2A	<20.1	<23.8	<.243	<9.66	<1	4.4	<1	<1	ND1	<1.2
31-3A	21.7	<23.8	<.243	<9.66	66.3	1.6	<1	3.47	ND1	5.47
31-5	34.5	<23.8	<.243	<9.66	12.9	ND1	<1	49	ND1	6.84
34-1	42.7	<23.8	<.243	<9.66	11.9	1	<1	<1	ND1	3.16
34-2	<20.1	<23.8	<.243	<9.66	4.46	ND1	<1	4.31	ND1	3.26
39-1	<20.1	<23.8	<.243	<9.66	<1	ND1	<1	<1	ND1	<1.2
39-2	24.5	<23.8	<.243	<9.66	<1	ND1	<1	<1	ND1	<1.2
41-1	<20.1	<23.8	<.243	<9.66	<1	ND1	<1	<1	ND1	<1.2
41-2	<20.1	<23.8	<.243	<9.66	<1	ND1	<1	<1	ND1	<1.2
41-3	<20.1	<23.8	<.243	<9.66	<1	ND1	<1	<1	ND1	<1.2
41-4	<20.1	<23.8	.583	<9.66	<1	ND1	<1	<1	ND1	<1.2
41-5	<20.1	<23.8	<.243	<9.66	16.1/4.06	ND1	<1	<1	ND1	2.74
41-8	<20.1	<23.8	<.243	<9.66	<1	ND1	<1	<1	ND1	<1.2
41-9	<20.1	<23.8	<.243	<9.66	1020/1980/2400**	ND1	<1	<1	ND1	316
64-1	<20.1	<23.8	.927	<9.66	2.08	ND1	<1	<1	ND1	<1.2
65-1	<20.1	<23.8	2.23	<9.66	4.55	ND1	4.15	<1	ND1	1.58
65-2	<20.1	<23.8	<.243	<9.66	<1	ND1	<1	<1	ND1	<1.2
65-3	<20.1	<23.8	<.243	<9.66	53.5	ND1	43.6	<1	ND1	4.63
65-4	24.1	<23.8	<.243	<9.66	<1	ND1	<1	<1	ND1	<1.2
9-A	<20.1	<23.8	1.94	<9.66	198	20	<1	78.4	ND1	73.7
9-B	<20.1	<23.8	2.67	<9.66	495/1500**	ND1	<1	4.9	ND1	21.1
9-C	22.5	<23.8	<.243	<9.66	4.85	9.9	<1	<1	ND1	2.11
9-D	<20.1	<23.8	<.243	<9.66	447/396/594*	ND1	<1	<1	ND1	<1.2
9-E	<20.1	<23.8	<.243	<9.66	2300/ >160/1980*	ND1	<1	49	ND1	42.1
92-3	<20.1	<23.8	<.243	<9.66	24,300/139	ND1	<1	<1	ND1	<1.2
92-4	<20.1	<23.8	<.243	<9.66	1680/ >160	ND1	<1	16.7	ND1	4.42
92-5	<20.1	<23.8	-	<9.66	1780/-/4500**	-	-	-	-	-
95-1	<20.1	<23.8	<.243	<9.66	<1	ND1	<1	<1	ND1	<1.2
95-2	<20.1	<23.8	<.243	<9.66	<1	ND1	<1	<1	ND1	<1.2
CAF-1	63.7	<23.8	<.243	<9.66	<1	ND1	<1	<1	ND1	<1.2
CAF-2	141	<23.8	.635	<9.66	>160/580**	3	9.32	2.65	3.1	>160
CAF-3	<20.1	<23.8	<.243	<9.66	396	ND1	<1	24.5	ND1	<1.2
CAF-4	59.8	<23.8	1.07	<9.66	>160	ND1	2.53	<1	ND1	25.3
CAF-5	<20.1	<23.8	<.243	<9.66	4.06	ND1	<1	<1	ND1	4.74
CAF-6	<20.1	<23.8	<.243	<9.66	1070/990	ND1	<1	39.2	ND1	21.1
H-2	71.4	<23.8	<.243	<9.66	<1	ND1	<1	<1	ND1	<1.2
H-3	<20.1	<23.8	<.243	<9.66	<1	ND1	<1	<1	ND1	<1.2
H-4	<20.1	<23.8	1.07	<9.66	19.8	ND1	1.32	<1	ND1	<1.2
I	58.2	<23.8	<.243	<9.66	4.55	ND1	<1	0.98	ND1	<1.2
I-2	<20.1	<23.8	<.243	<9.66	<1	ND1	<1	<1	ND1	<1.2

[1]Values preceeding are results of USGS sampling in August 1987; values following are results of replicate sampling (*) or USGS sampling in March 1988 (**)

[2]Includes both cis- and trans-1,2-dichloroethylene

[3]"less than" symbol (<) indicates constituent not detected in sample and for which the laboratory has been certified by the U.S. Army Toxic and Hazardous Material Command

[4]ND indicates constituent not detected in sample and for which the laboratory has not been certified by the U.S. Army Toxic and Hazardous Materials Command

[5]"greater than" symbol (>) indicates constituent found in sample in concentration greater than the certified upper detection limit

mercuric chloride. Mercury was detected in concentrations near the detection limit in water from the confined glacial aquifer.

Cadmium was detected in concentrations greater than the primary drinking-water regulation of 10 μg/L (U.S. Environmental Protection Agency, 1976) in the unconfined aquifer only. This metal was found in concentrations of 12.7, 34.9, and 31.8 μg/L in water from wells 31-1, 9-C, and 9-D, respectively. Cadmium appears to have moved little from the source of contamination at building 24. Copper concentrations also were high, but only near building 24. Copper was found in concentrations greater than 50 μg/L, the secondary drinking-water standard, at wells 9-B and 9-E. At other wells in the contaminated area, copper was detected in concentrations less than 25 μg/L.

Arsenic, chromium, and silver were detected in concentrations less than 20 μg/L in water from a number of wells screened in the unconfined aquifer. Arsenic and silver were detected in the confined glacial aquifer, whereas chromium and silver were detected in the bedrock aquifer.

Lead was not detected in concentrations greater than 50 μg/L in any of the water samples from wells. In the bedrock aquifer, lead was found in concentrations that ranged from 19.2 to 36.8 μg/L. In the unconfined aquifer, lead was detected in scattered wells with no apparent pattern. Lead concentrations in wells 112-9 and 112-10 did not correspond to the high concentrations found at nearby drive-point site B-1.

Zinc was detected in a number of wells scattered throughout the study area. The high concentration (1,090 μg/L) in well 129-obs probably is a result of the galvanized-steel casing of this well. However, well 112-4 has a stainless-steel casing and contained a zinc concentration of 4,149.9 μg/L. The metals beryllium, thallium, nickel, antimony, and selenium were below the detection limits, which ranged from 6.99 to 37.8 μg/L. Metals may have been adsorbed onto clay particles near building 24 and, therefore, did not move downgradient with the ground-water flow.

VOCs were detected in all three aquifers. In the bedrock aquifer, wells 10-3A and 65-1 contained measurable amounts of TCE. However, the TCE concentration of 55 μg/L in well 10-3A at a depth of 265 ft was unexpected, because this site is assumed to be upgradient from the contamination source at building 24. In addition, the surface casing of well 10-3A is set in bedrock to prevent the movement of contaminants down the borehole and into the well screen. Therefore, the concentration of TCE in this well is considered to be suspect until verified by resampling. A TCE concentration of 4.55 μg/L was determined for the water sample collected from well 65-1. Previously, samples from well 65-1 had contained low concentrations of TCE (13-50 μg/L; Sargent and others, 1986, p. 66); the current result is similar to the earlier data.

In the confined glacial aquifer, water from wells 65-3, CAF-3, and CAF-4 had detectable concentrations of VOCs. Results of 1983 analyses showed TCE concentrations in water from well 65-3 that ranged from 2 to 80 μg/L (Sargent and others, 1986, p. 63). However, the detection of 1,1,1-trichloroethane and cis-1,2-dichloroethylene in these wells differs from results of 1983 sampling, when these compounds were not detected. Water from wells CAF-3 and CAF-4 previously contained TCE concentrations in the range of 51.3 to 180 μg/L. Current results (396 μg/L and greater than 160 μg/L, respectively) show that TCE is still present in these wells. Results of 1987 sampling also showed detectable concentrations of tetrachloroethylene, 1,1,1-trichloroethylene, and cis-1,2-dichloroethylene.

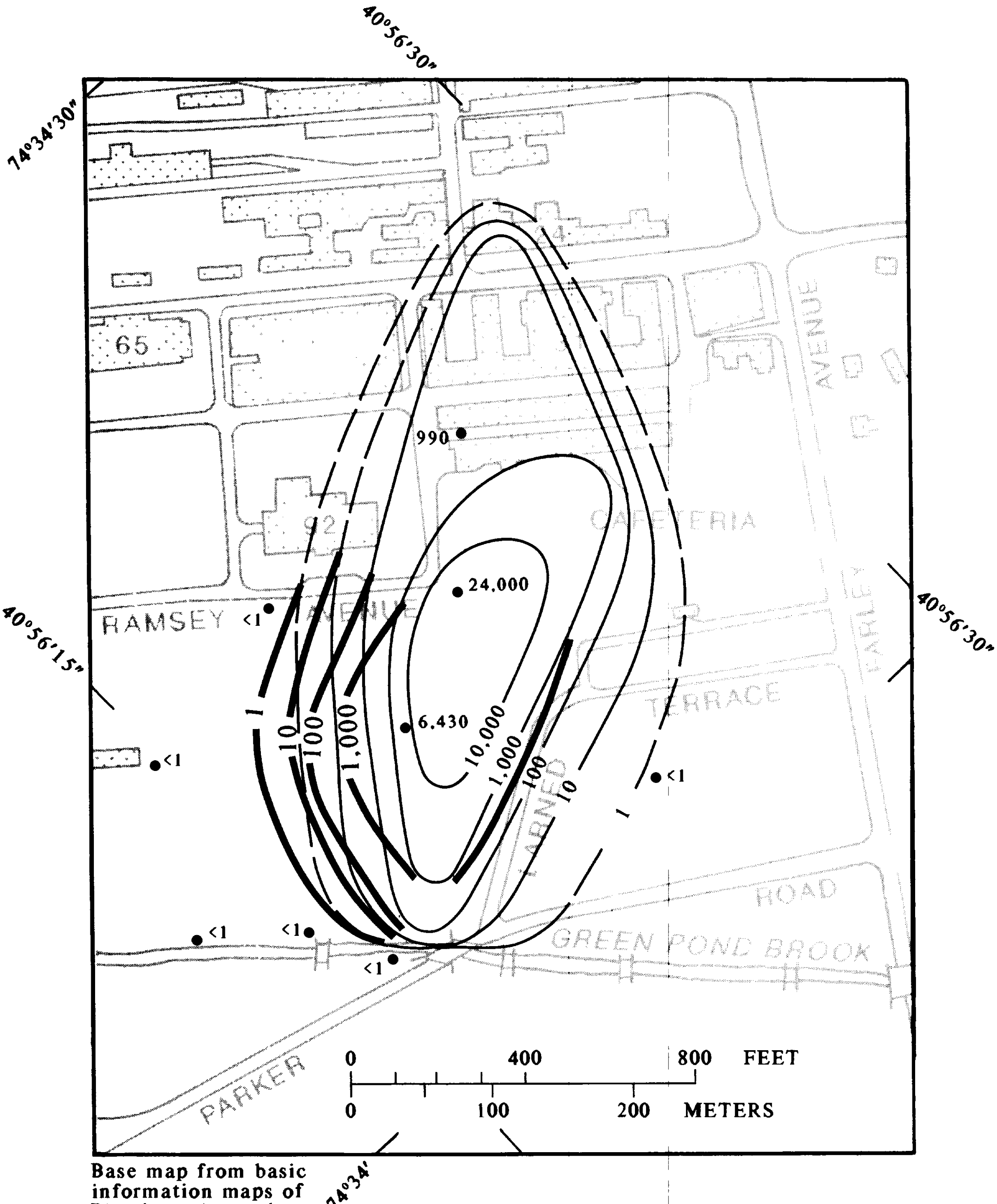
In the unconfined aquifer, concentrations of TCE in observation wells follow the distribution determined from the 1986 drive-point sampling. Drive-point water-quality data and well water-quality data may be compared with caution, because the two sampling plans are not completely comparable. The areal distribution of observation wells is more extensive than the distribution of drive-point-sampling locations, whereas the reverse is true for the vertical distribution of drive-point sites in comparison to the well-screen locations. Figures 28, 29, and 30 show lines of equal TCE concentration determined from results of drive-point and well sampling at altitudes, 650, 670, and 690 ft, respectively.

Results of well sampling in 1987 indicate that, at its base (the 650-ft altitude), the plume appeared to have moved downgradient since the drive-point samples were collected (fig. 29). In August 1987, water samples from well 92-3 (screened from 50.2 to 55.2 ft) contained a TCE concentration of 24,300 μg/L; samples collected during October and November 1987 contained 139 μg/L. Two samples from well 92-4 (screened from 38.0 to 43.0 ft), which is at the same location but is screened 7.2 ft nearer the ground surface than well 92-3, contained TCE concentrations greater than 160 and 1,680 μg/L, respectively. Because concentrations of TCE tend to increase with depth in this area, the value of 24,300 μg/L may be representative of the water quality at the 650-ft altitude.

Figure 29 shows the concentration of TCE in ground water at the 670-ft altitude. The area within the 1-μg/L contour line is larger than the area originally delineated as a result of drive-point sampling. Near Green Pond Brook, the 1,000-μg/L contour line is elongated to include well 41-8. Samples collected during August 1987 to March 1988 showed concentrations of TCE that ranged from 1,020 to 2,400 μg/L. The concentration of 29 μg/L in water from well 31-1 is similar to the low concentrations found at drive-point site E-3. Buried foundations or old drainage lines may have caused contaminants to bypass this area. Water from well 9-D, near well 31-1, exhibited higher concentrations ranging from 396 to 594 μg/L.

At the 680- to 690-ft altitude, near the top of the water table, the 1-μg/L contour line encloses a large area (fig. 30). Because data points are scattered, pockets or separate plumes in the building 31 area may be mapped as part of the building 24 plume. The value of 12.9 μg/L observed in water from well 31-5 may reflect contamination originating from a source other than building 24. The 100-μg/L contour line appears to have been displaced downgradient since the drive-point samples were collected. In contrast to the results of drive-point sampling, no concentrations greater than 10,000 μg/L were found at the building 24 site.

The distribution of the five other VOCs shown in table 8 could not be mapped. 1,2-Dichloroethylene, the most frequently detected VOC other than TCE, was found in concentrations greater than 160 μg/L in water from well

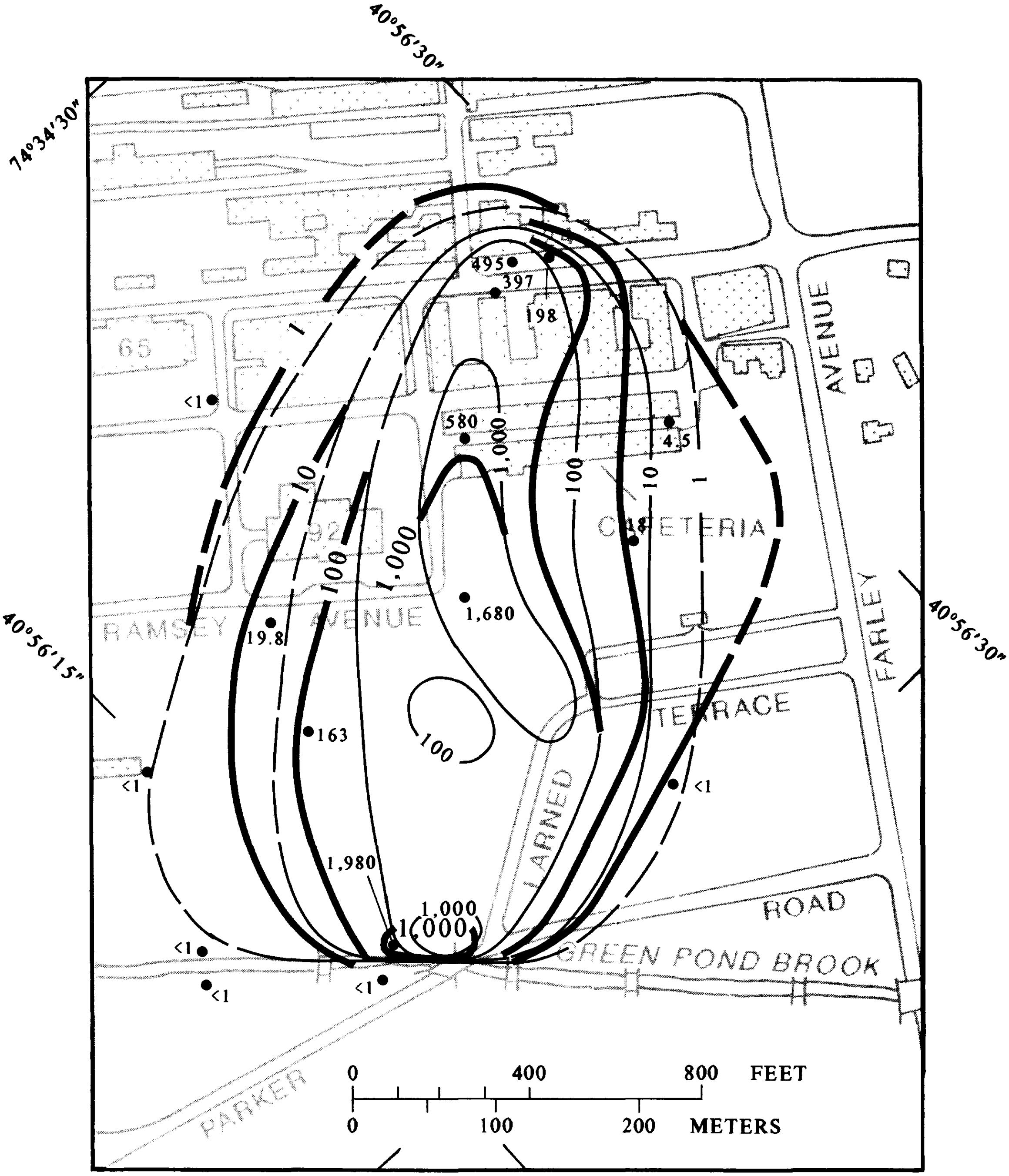


Base map from basic information maps of Picatinny Arsenal, 1975

EXPLANATION

—10— —	LINE OF EQUAL CONCENTRATION OF TRICHLOROETHYLENE, 1986--In micrograms per liter. Interval is variable. Dashed where approximated. Contours based on data from drive-point sites
━10━ ━	LINE OF EQUAL CONCENTRATION OF TRICHLOROETHYLENE, 1987--In micrograms per liter. Interval is variable. Dashed where approximated. Contours based on data from observation wells
• 990	LOCATION OF WELL--Number shown is concentration of trichloroethylene, in micrograms per liter, 1987
65	Building identification number

Figure 28.--Concentration of trichloroethylene in ground-water samples from 1986 drive-point and 1987 well sampling at the 650-foot altitude.



Base map from basic information maps of Picatinny Arsenal, 1975

EXPLANATION

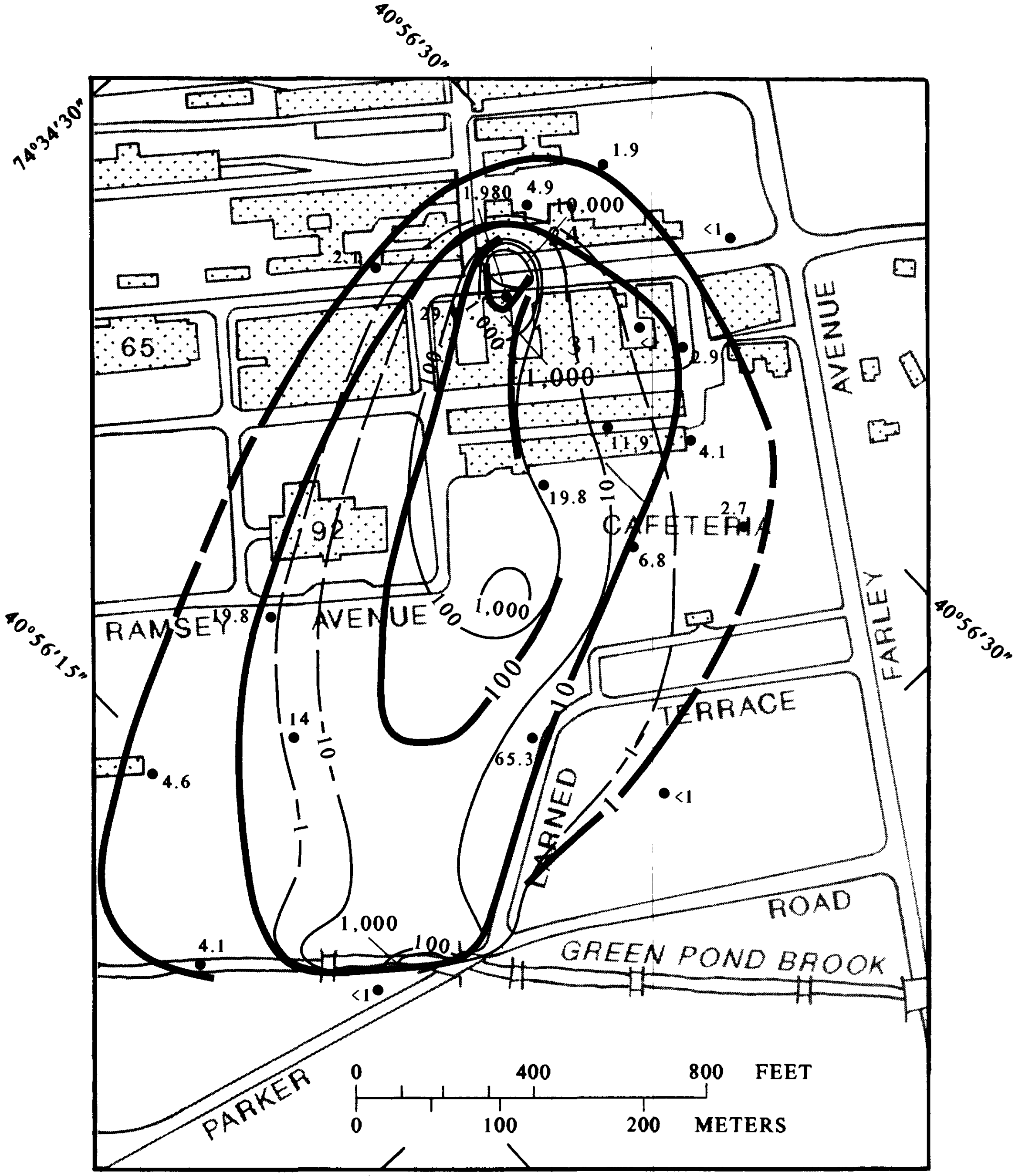
10 — LINE OF EQUAL CONCENTRATION OF TRICHLOROETHYLENE, 1986--In micrograms per liter. Interval is variable. Dashed where approximated. Contours based on data from drive-point sites

10 — LINE OF EQUAL CONCENTRATION OF TRICHLOROETHYLENE, 1987--In micrograms per liter. Interval is variable. Dashed where approximated. Contours based on data from observation wells

● <1 LOCATION OF WELL--Number shown is concentration of trichloroethylene, in micrograms per liter, 1987

65 Building identification number

Figure 29.--Concentration of trichloroethylene in ground-water samples from 1986 drive-point and 1987 well sampling at the 670-foot altitude.



Base map from basic information maps of Picatinny Arsenal, 1975

EXPLANATION

——1,000— — LINE OF EQUAL CONCENTRATION OF TRICHLOROETHYLENE, 1986--In micrograms per liter. Interval is variable. Dashed where approximated. Contours based on data from drive-point sites

▬▬1,000▬ ▬ LINE OF EQUAL CONCENTRATION OF TRICHLOROETHYLENE, 1987--In micrograms per liter. Interval is variable. Dashed where approximated. Contours based on data from observation wells

● 4.6 LOCATION OF WELL--Number shown is concentration of trichloroethylene, in micrograms per liter, 1987

65 Building identification number

Figure 30.--Concentration of trichloroethylene in ground-water samples from 1986 drive-point and 1987 well sampling at the 680- to 690-foot altitude.

CAF-2 and 316 μg/L in water from well 41-9. Vinyl chloride, 1,1,1-trichloroethane, tetrachloroethylene, and 1,1-dichloroethylene were found only in concentrations less than 80 μg/L.

Base/Neutral- and Acid-Extractable Organic Compounds, Pesticides, and Polychlorinated Biphenyls

Eleven wells were sampled for analysis of base/neutral- and acid-extractable compounds, pesticides, and PCBs. The local identifiers of these 11 wells are listed below: 10-3, 111-1, 112-9, 302-D, 31-2A, 41-2, 41-9, 9-E, 92-3, CAF-2, and CAF-3.

Table 10 shows the compounds analyzed for and their corresponding detection limits. Only two of the compounds listed were detected. Bis (2-ethylhexyl) phthalate was detected in six samples in concentrations less than 5 μg/L. This compound is abundant in the environment. At the low concentrations found, its presence probably is an artifact of field or laboratory procedures rather than an indication of ground-water contamination. PCB 1260 was found in the water sample from well 31-2A at a concentration of 530 μg/L. This well is located in the building 31 area, from which suspected contaminated soil had been removed, so that this value likely indicates ground-water contamination.

Surface Water

During 1986 and 1987, water samples were collected at three sites on Green Pond Brook for analysis of VOCs: SQ-1, Green Pond Brook at Farley Avenue; SQ-2, Green Pond Brook at First Street; and SW-3, Green Pond Brook at Wharton. The locations of the sampling sites are shown on figure 16. Site SQ-1 is upstream from the reach affected by the ground-water contamination at building 24 and is indicative of background stream-water quality. Site SQ-2 is just downstream from the reach where contaminated ground water discharges into the stream. Water quality at this site typifies the quality of the stream water at the point where it is most affected by the inflow of contaminated ground water. Water quality at site SW-3, at the lower-stream gaging station, exemplifies the water quality of the stream just before it exits the arsenal. The results of these analyses are shown in table 11.

The data indicate that the concentration of TCE or cis- and trans-1,2-dichloroethylene occassionally increased slightly between sites SQ-1 and SQ-2. At site SQ-1, neither TCE nor dichloroethylene (DCE) was detected above the detection limit of 3.0 μg/L in any of the 10 samples. In one sample collected at site SQ-1 in October 1986, tetrachloroethylene (PCE) was detected at 4.6 μg/L; the source of this PCE is unknown. At site SQ-2, TCE was detected in 5 of 10 samples at concentrations ranging from 2.5 to 3.8 μg/L, and DCE was detected in 6 of 10 samples at concentrations ranging from 2.3 to 11 μg/L. This slight increase in TCE and DCE concentrations probably reflects the inflow of contaminated ground water from the building 24 plume. The concentrations of these contaminants probably are reduced to near detection limits by the processes of dilution and volatilization as the relatively small volume of contaminated ground water discharges into the much larger volume of stream water.

Table 10.--Detection limits of selected priority pollutants and other compounds determined in samples from 11 wells

Compound	Detection limit (micrograms per liter)
Base/Neutral-Extractable Organic Compounds	
Benzo (g,h,i) perylene	[1]ND 1.7
1,2-Dichlorobenzene	ND 1.7
1,3-Dichlorobenzene	ND 1.7
1,4-Dichlorobenzene	ND 1.7
Hexachlorobenzene	ND 1.6
Naphthalene	ND .5
Nitrobenzene	ND 2
2,4-dinitrotoluene	ND 4.5
2,6-dinitrotoluene	ND .79
4-Bromophenyl phenyl ether	ND 4.2
4-Chlorophenyl phenyl ether	ND 5.1
Phenanthrene	ND .5
Pyrene	ND 2.8
Anthracene	ND .5
Benzo (a) anthracene	ND 1.6
Benzo (b) fluoranthene	ND 5.4
Acenphthylene	ND .5
Acenaphthene	ND 1.7
Dimethyl phthalate	ND 1.5
Fluoranthene	ND 3.3
Fluorene	ND 3.7
Hexachlorocyclopentadiene	ND 8.6
Hexachloroethane	ND 1.5
Indeno (1,2,3-c,d) pyrene	ND 8.6
bis (2-Chloroethyl) ether	ND 1.9
bis (2-Ethylhexyl) phthalate	ND 4.8
Isophorone	ND 4.8
N-Nitrosodi-n-propylamine	ND 4.4
N-Nitrosodiphenylamine	ND 3
1,2,4-Trichlorobenzene	ND 1.9
Di-n-octyl-phthalate	ND15
3,3-Dichlorobenzidine	ND12
Di-n-butyl phthalate	ND 3.7
Hexachlorobutadiene	ND 3.4
Dibenzo (a,h) anthracene	ND 6.5

Table 10.--Detection limits of selected priority pollutants and other compounds determined in samples from 11 wells--Continued

Compound	Detection limit (micrograms per liter)
Acid-Extractable Organic Compounds	
Phenol	
2-Nitrophenol	[2]<3.7
4-Nitrophenol	<12
2,4-Dinitrophenol	<21
Pentachlorophenol	<21
2-Chlorophenol	<1.1
2,4-Dichlorophenol	<1
2,4,6-Trichlorophenol	<4.2
2,4-Dimethylphenol	<2.1
Pesticides and Polychlorinated Biphenyls	
Alpha-Endosulfan	ND 5
Beta-Endosulfan	ND 5
Alpha-benzenehexachloride	ND 5
Beta-benzenehexachloride	ND 5
Delta-benzenehexachloride	ND 5
Aldrin	<.07
Dieldrin	<.06
2,2-Bis (Para-chlorophenyl)-1,1-dichloroethene	<.053
2,2-Bis (Para-chlorophenyl) -1,1-dichloroethane	ND 5
2,2-Bis (Para-chlorophenyl)-1,1,1-trichloroethane	<.07
Chlordane	ND100
Endrin aldehyde	ND 5
Heptachlor	ND 5
Heptachlor epoxide	ND 5
Lindane	ND 5
Toxaphene	ND558
Polychlorinated biphenyl 1016	ND370
Polychlorinated biphenyl 1221	ND300
Polychlorinated biphenyl 1232	ND300
Polychlorinated biphenyl 1242	ND300
Polychlorinated biphenyl 1248	ND300
Polychlorinated biphenyl 1254	ND300
Polychlorinated biphenyl 1260	ND410
Endrin	<.052

Table 10.--Detection limits of selected priority pollutants and other compounds determined in samples from 11 wells--Continued

Compound	Detection limit (micrograms per liter)
Other Compounds	
4-Chloroaniline	ND 8
Benzoic acid	<8
Benzyl alcohol	<.72
4-Nitroanaline	ND 5.2
Bis (2-Chloroethoxy) methane	ND 1.5
Bis (2-chloroisopropyl) ether	ND 5.3
4-Methylphenol	<5.2
2-Methyl-napthalene	ND 1.7
2-Nitroanaline	ND 4.3
Dibenzofuran	ND 1.7
2-methyl-4,6 Dinitrophenol	<17
Methylphenol	<.5
3-Nitroaniline	ND 4.9
3-Methyl-4-chlorophenol	<.84
2,4,5-Trichlorophenol	<5.2

[1] ND indicates constituents not detected in sample and for which the laboratory has not been certified by the U.S. Army Toxic and Hazardous Materials Command

[2] "less than" symbol (<) indicates constituents not detected in sample and for which the laboratory has been certified by the U.S. Army Toxic and Hazardous Materials Command

Table 11.--Concentrations of volatile organic compounds detected in samples from Green Pond Brook

[Site locations shown in figure 15; ft^3/s, cubic feet per second; µg/L, micrograms per liter; <, less than; double dash indicates discharge not measured]

Date	Time	Streamflow (ft^3/s)	Trichloro-ethylene (µg/L)	cis+trans-1,2-Dichloroethylene (µg/L)	Tetrachloro-ethylene (µg/L)
		Site SQ-1 Green Pond Brook at Farley Avenue			
08-07-86	1730	--	<3.0	<3.0	<3.0
09-10-86	1805	--	<3.0	<3.0	<3.0
10-29-86	1500	--	<3.0	<3.0	4.6
03-12-87	1220	--	<3.0	<3.0	<3.0
04-30-87	1550	--	<3.0	<3.0	<3.0
05-20-87	1110	--	<3.0	<3.0	<3.0
06-04-87	1313	--	<3.0	<3.0	<3.0
08-25-87	1125	--	<3.0	<3.0	<3.0
09-29-87	1355	--	<3.0	<3.0	<3.0
11-09-87	1150	--	.3	<.20	<.20
		Site SQ-2 Green Pond Brook at First Street			
08-07-86	1850	--	<3.0	<3.0	<3.0
09-10-86	1820	--	3.5	5.7	<3.0
10-29-86	1445	--	3.6	11	<3.0
03-12-87	1425	--	<3.0	<3.0	<3.0
04-30-87	1605	--	<3.0	5.4	<3.0
05-20-87	1055	--	3.8	4.8	<3.0
06-04-87	1337	--	<3.0	<3.0	<3.0
08-25-87	1140	--	3.6	5.8	<3.0
09-29-87	1415	--	<3.3	<4.7	<3.0
11-09-87	1210	--	2.5	2.3	.20
		Site SW-3 Green Pond Brook at Wharton			
08-07-86	1830	22	<3.0	<3.0	<3.0
09-10-86	1835	11	<3.0	<3.0	<3.0
03-12-87	1550	43	<3.0	<3.0	<3.0
04-30-87	1616	35	<3.0	<3.0	<3.0
05-20-87	1030	15	<3.0	4.2	<3.0
06-04-87	0742	7.8	<3.0	<3.0	<3.0
08-25-87	1105	8.9	<3.0	3.0	<3.0
09-29-87	1440	26	<3.0	<3.0	<3.0
11-09-87	1230	27	1.8	1.9	<.20

As Green Pond Brook flows downstream from site SQ-2, further dilution by surface-water and ground-water inflow to the stream and volatilization from the water surface reduce the already low concentrations of TCE and DCE in the stream. At site SW-3, concentrations of TCE were less than 3.0 $\mu g/L$ in all of the nine samples and DCE was detected in only one sample at a concentration of 3.0 $\mu g/L$ and in a second sample at a concentration of 4.2 $\mu g/L$. The reach of Green Pond Brook between sites SQ-2 and SW-3 is deep and slow-moving with few riffles and little aeration. The volatilization of VOCs from this reach probably is low. The reach immediately downstream from site SW-3, however, is steep and fast-moving, and characterized by a rocky channel with many small falls and riffles. Volatilization in this reach would be expected to remove any traces of TCE or DCE remaining in the stream.

Ground Water Discharging to Green Pond Brook

In order to determine the extent of contamination in ground water that discharges to Green Pond Brook, a series of water samples was collected from beneath the bed of Green Pond Brook for VOC analysis. These samples were collected through 0.25-in.-I.D. stainless-steel tubing, which was slotted in the bottom 3 in. The tubing was driven about 2 ft into the streambed, and a peristaltic pump with Teflon and silicone tubing was used to pump a sample from beneath the streambed. These samples were screened in the field by using a photo-ionization detector for headspace analysis in a 40-mL VOC vial half-filled with sample water. Water samples also were analyzed at the USGS laboratory in Trenton, New Jersey, by a method equivalent to USEPA Methods 601 and 602 (Longbottom and Lichtenbery, 1982). Cis-1,2-dichloroethylene and TCE were the only compounds detected in elevated concentrations. The results of these analyses are presented in table 12.

The seven sampling locations are shown in figure 31. At the first few sites, samples were collected near the left edge of the channel, at the center of the channel, and near the right edge of the channel. When it became apparent that only the samples from the right edge of the channel contained elevated concentrations of organic constituents, the channel-center and left-bank samples were discontinued, and subsequent samples were collected at more closely spaced intervals along the right bank.

The streambed-sample results closely agree with estimates of the dimension of the plume based on drive-point and observation-well data. The highest concentrations of TCE and DCE were found at sites GPB-3 to GPB-5 in the area of correspondingly high concentrations of these compounds in the water-table aquifer. Maximum concentrations of TCE were as high as 2,800 $\mu g/L$ and maximum concentrations of DCE were as high as 1,400 $\mu g/L$. The ratio of DCE to TCE was higher in the streambed-water samples than in the ground-water sample. This observation is in agreement with the higher ratio of DCE to TCE found in stream-water samples than in ground-water samples. Further reductive dechlorination may be occurring either just beneath the water table or within the streambed, as the ground water discharges into the stream. The upper 10 to 15 ft of the subsurface in this area contains a large amount of peat, which may be responsible for the reducing conditions necessary for further TCE dechlorination. Organic matter within the streambed also may contribute to this process.

Table 12.--Concentrations of trichloroethylene and cis-1,2-dichloroethylene in ground-water samples from beneath the streambed of Green Pond Brook, July 14, 1987

[All concentrations in micrograms per liter; <, less than]

Site	Part of channel	Cis-1,2-dichloro-ethylene	Trichloro-ethylene
GPB-1	LEFT	<1	<1
	CENTER	2.3	<1
	RIGHT	2.3	12.8
GPB-2	LEFT	<1	<1
	CENTER	2.1	<1
	RIGHT	4.0	70
GPB-3	LEFT	<1	<1
	CENTER	<1	3.0
	RIGHT	803	121
GPB-3A	RIGHT	480	1871
GPB-4	LEFT	3.1	<1
	CENTER	1.9	<1
	RIGHT	113	241
GPB-5	RIGHT	1430	2754
GPB-6	RIGHT	2.3	18.4

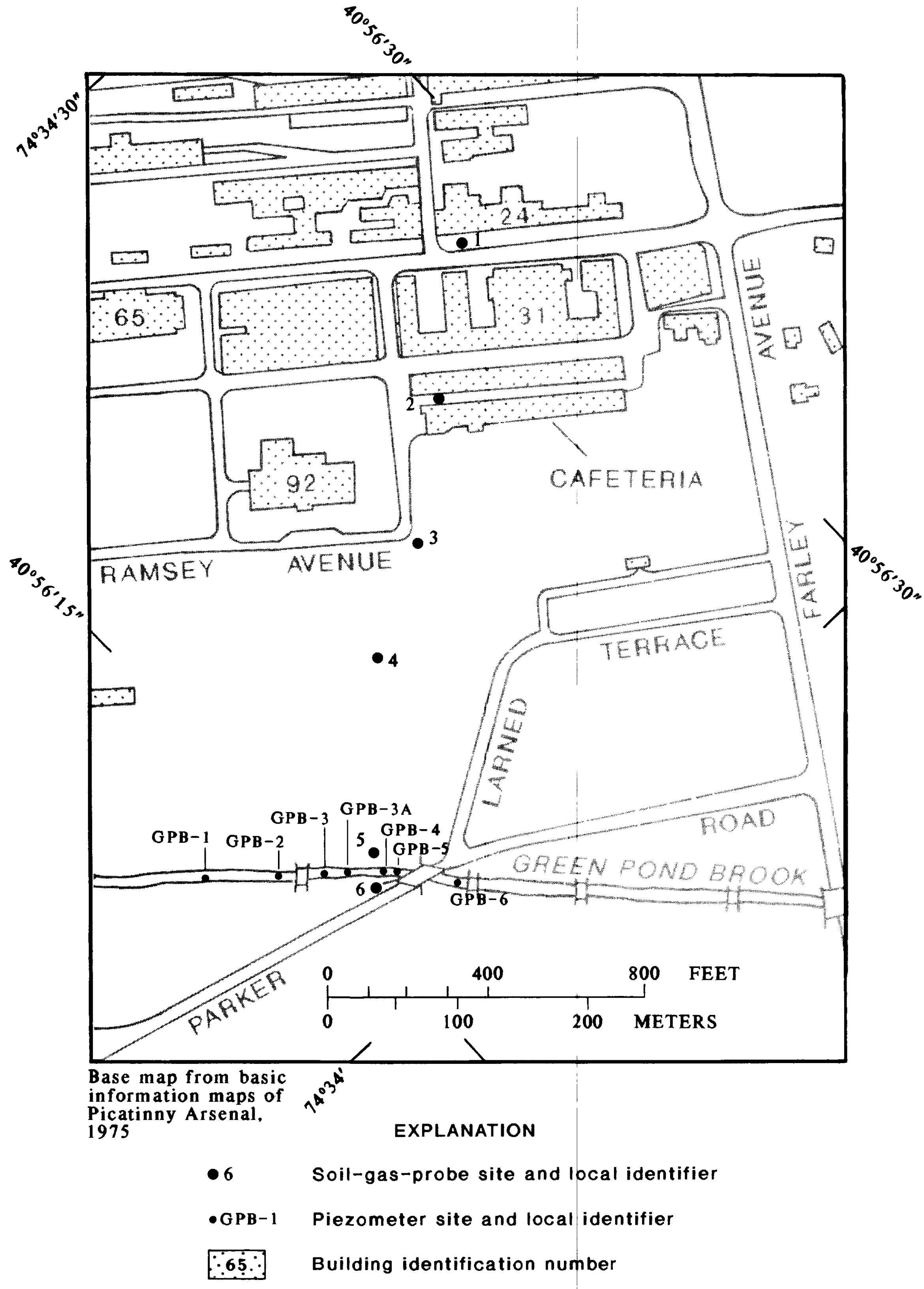


Figure 31.--Location of soil-gas-probe and streambed piezometer sites.

CONTAMINATION IN THE UNSATURATED ZONE

The 16 soil-gas probes were sampled in February 1988, and the 6 deepest probes were resampled in March 1988. The results of these two sampling efforts are presented in table 13. Figure 31 shows the location of the soil-gas-probe sites. As the table shows, TCE is the predominant gas-phase contaminant. The TCE concentration in five gas samples was 1,000 ng/L or greater. The maximum TCE concentration (7,300 ng/L) was found in gas samples collected from approximately 1 ft above the water table near building 24, the source of contamination. Dichloroethylene and tetrachloroethylene also were detected in selected gas samples at maximum concentrations of 130 ng/L.

Areally, the soil-gas data shown in table 13 parallel the near-surface ground-water contamination discussed above. The soil-gas concentration of TCE was highest near the source of contamination (soil-gas site 1; fig. 31) and decreased with downgradient distance from this location. A slight increase in TCE concentration was observed at site 5 relative to site 4. At the site adjacent to drive-point site X-1 (soil-gas site 6), on the southeastern side of Green Pond Brook, TCE was not detected in the unsaturated zone. This result is consistent with the selection of water-quality data from drive-point site X-1 as representative of uncontaminated water.

Vertically, TCE-vapor concentrations at each site decreased with distance above the water table. At site 1, TCE was not detected in soil gas collected from 2 ft below land surface. Unlike other sampling sites, site 1 is covered by asphalt pavement, which presumably prevents any significant mixing of near-surface soil gas with ambient air.

SUMMARY AND CONCLUSIONS

A zone of contaminated ground water was produced by a metal-plating wastewater-treatment system that operated from 1960-81 at building 24, Picatinny Arsenal, New Jersey. Twenty-seven wells subsequently were installed using the hollow-stem auger method and six wells were installed using the mud-rotary method. These wells and 27 existing wells were sampled in 1987 for analysis of inorganic constituents, trace elements, VOCs, and nutrients. Water from 11 of these wells also was sampled for analysis of base/neutral- and acid-extractable compounds, pesticides, and PCBs. Soil-gas probes at six sites were used to sample soil gas in the unsaturated zone to analyze for the presence of VOCs. In addition, surface-water samples were collected at three sites in Green Pond Brook to determine whether VOCs were present.

A plume of VOCs, mainly TCE, was determined to originate in the building 24 area and follow the general water-table gradient about 1,600 ft to Green Pond Brook. The plume is approximately 400 to 800 ft wide and extends downward about 50 ft in the unconfined aquifer. Because of seepage around or through a confining unit, ground water in a confined aquifer, and a bedrock aquifer also contains VOCs. On the basis of the analyses of ground-water, surface-water, and soil-gas samples, the following statements can be made on the nature of contamination at the site:

Table 13.--Concentrations of trichloroethylene and two related compounds in soil-gas samples collected during February and March 1988

[ft, feet; <, less than; concentrations in nanograms per liter]

Sample site	Approximate distance below land surface (ft)	Approximate distance above water table (ft)	Compound[1]		
			cis-1,2-Dichloroethylene	Trichloroethylene	Tetrachloroethylene
1	2.0	6.5	< 40	< 40	< 40
1	4.5	4.0	<400	2900	<400
1	7.5	1.0	<400, <40	7300, <40	<400, <40
2	2.0	8.0	< 40	< 40	< 40
2	5.0	5.0	< 40	480	65
2	9.0	1.0	68, 67	1300, 1100	75, 57
3	2.5	5.0	< 40	230	< 40
3	4.0	3.5	< 40	1000	< 40
3	7.0	.5	< 40, <40	1500, 1300	130, 68
4	1.5	4.0	< 40	< 40	< 40
4	3.0	2.5	< 40	< 40	< 40
4	4.5	1.0	< 40, <40	190, 190	< 40,<40
5	1.5	3.0	< 40	< 40	< 40
5	3.0	1.5	130, 80	270, 120	< 40, <40
6	2.5	2.6	< 40	< 40	< 40
6	5.0	.1	< 40, <40	< 40, <40	< 40, <40

[1]When two values are given, the first is from February sampling and the second is from March sampling; when one number is given, it is from February sampling

1. If contaminants are assumed to move with ground water (by advection), the average velocity of contaminant movement is estimated to be 0.42 to 1.8 ft/d.

2. Although inorganic constituents were found in elevated concentrations within the TCE plume, only chloride was detected above the USEPA secondary drinking-water regulation of 250 mg/L.

3. Although trace metals and cyanide were present in the building 24 wastewater, these compounds have not been detected in elevated concentrations downgradient from the source.

4. Polychlorinated biphenyl 1260 was detected in one ground-water sample. This sample was collected from a well in the building 31 area from which suspected contaminated soil has been removed.

5. Surface water in Green Pond Brook contained TCE in concentrations that ranged from the detection limit (3.0 μg/L) to 3.8 μg/L. Volatilization probably removes VOCs in the steep, fast-moving reaches of the brook.

6. Concentrations of TCE in five soil-gas samples were 1,000 ng/L or greater. Both tetrachoroethylene and dichloroethylene also were detected in selected soil-gas samples, each at a maximum concentration of 130 ng/L.

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APPENDIX

Appendix--Well logs for selected wells installed in 1987
{Altitude in feet above sea level}

WELL NUMBER: 270937 (41-1)
Altitude of land surface: 692.6

Lithology	Depth interval (feet)	
Top soil, organic material, silty clay with granules and pebbles; brownish black (5YR2/1)	0.0	3.0
Sand, coarse-grained with pebbles and cobbles; dark yellowish brown (10YR4/2); poorly sorted	3.0	6.0
Sand, fine- to coarse-grained with some silt; dark yellowish brown (10YR4/2); subangular to angular, poorly sorted	6.0	9.0
Sand, fine- to very fine-grained with small amount of coarse- to very coarse-grained sand and silt; dark yellowish brown (10YR4/2); well sorted	9.0	12.0
No sample	12.0	30.0
Sand, coarse- to very coarse-grained with some gravel and cobbles; moderate brown (5YR3/4)	30.0	33.0
Sand, medium- to very coarse-grained; dark yellowish brown (10YR4/2); moderately sorted	33.0	35.5
Sand, fine- to very coarse-grained with pebbles, cobbles, and boulders; moderate yellowish brown (10YR5/4); subangular to angular, very poorly sorted	35.5	37.0
No sample	37.0	40.0
Sand, coarse- to fine-grained Note: Sample from split-spoon core	40.0	47.0

Note: All samples from hollow-stem-auger cores unless otherwise noted

WELL NUMBER: 270937 (41-3)
Altitude of land surface: 689.5

Lithology	Depth interval (feet)	
Sand, medium- to coarse-grained with some very coarse sand, granules, and pebbles; light brown (5YR5/6); subrounded to rounded, spherical to subelongated, poorly sorted; predominantly quartz	0.0	2.5
Sand, fine- to medium-grained with some very coarse sand, dark yellowish brown (10YR4/2); subangular to angular, subspherical to spherical, moderately sorted; predominantly quartz	2.5	5.0
Sand, fine- to medium-grained with small amount of coarse to very coarse sand; dark yellowish brown (10YR4/2); subangular to angular, subspherical to spherical, moderately to well sorted; predominantly quartz	5.0	10.0
Sand, very fine- to fine-grained with some silt, dark yellowish brown (10YR4/2); subangular to subrounded, spherical to subspherical, well sorted; predominantly quartz	10.0	12.5
No sample	12.5	14.0
Sand, very fine- to fine-grained with some silt, dark yellowish brown (10YR4/2); subangular to subrounded, spherical to subspherical, well sorted; predominantly quartz	14.0	17.5
Sand, very fine- to medium-grained with small amount of coarse to very coarse sand; dark yellowish brown (10YR4/2); subangular to angular, subspherical to spherical, moderately to well sorted; predominantly quartz	17.5	20.0

Note: All samples from hollow-stem-auger cores

WELL NUMBER: 270937 (41-4)
Altitude of land surface: 668.6

Lithology	Depth interval (feet)	
Sand, fine- to very coarse-grained and granules, pebbles, and organic material; pale brown (5YR5/2); subrounded to subangular, subelongated to spherical, very poorly sorted; predominantly quartz and rock fragments	0.0	2.5
Sand, fine- to medium-grained with occasional coarse sand; dark yellowish brown (10YR4/2); spherical to subspherical, subangular to subrounded, well sorted; predominantly quartz	2.5	12.5
Sand, medium- to coarse-grained with some very coarse sand; dark yellowish brown (10YR4/2); subangular to subrounded, subspherical to subelongated, moderately to well sorted; predominantly quartz with some shale fragments	12.5	15.0
Sand, fine- to coarse-grained with occasional very coarse sand; dark yellowish brown (10YR4/2); subangular to subrounded, subspherical to subelongated, moderately to well sorted; predominantly quartz with some shale fragments	15.0	17.5
No sample	17.5	19.0
Sand, fine- to coarse-grained with occasional very coarse sand; dark yellowish brown (10YR4/2); subangular to subrounded, subspherical to subelongated, moderately to well sorted; predominantly quartz with some shale fragments	19.0	22.5
No sample	22.5	26.5
Sand, fine- to very fine-grained; dark yellowish brown (10YR4/2); spherical to subspherical, subangular to subrounded, well sorted; predominantly quartz	26.5	29.0

Note: All samples from hollow-stem-auger cores

WELL NUMBER: 270942 (41-8)
Altitude of land surface: 690.5

Lithology	Depth interval (feet)	
Silty sand, gravel, and topsoil with small amount of organic material; dark yellowish brown (10YR4/3); rounded to subrounded, elongated to subspherical, very poorly sorted; varied lithology	0.0	4.0
Silt and fine- to very fine-grained sand with small amount of medium to very coarse sand and granules; dark yellowish brown (10YR4/2); subangular to subrounded, spherical to subspherical, moderately sorted, predominantly quartz	4.0	14.0
Sand, fine- to very coarse-grained with some granules; moderate brown (5YR3/4); subangular to subrounded, subspherical to subelongated, moderately to poorly sorted, predominantly quartz	14.0	18.0
Sand, fine- to coarse-grained and silty clay and peat; sand is moderate yellowish brown (10YR5/4), clay and peat are brownish black (5yr2/1) Note: Sample from split-spoon core	14.0	16.0
Sand, fine- to medium-grained; moderate yellowish brown (10YR5/4); subangular to subrounded, subspherical to subelongated, well sorted; predominantly quartz Note: Sample from split-spoon core	16.0	18.0
Sand, very fine- to medium-grained; moderate yellowish brown (10YR5/4); subangular to subrounded, spherical to subelongated, well sorted; predominantly quartz	18.0	19.0
Sand, fine- to very coarse-grained with some granules, dark yellowish brown (10YR4/2); subangular to subrounded, subspherical to subelongated, moderately to poorly sorted; predominantly quartz	19.0	24.0
Sand, fine- to medium-grained with some coarse to very coarse sand, granules, and pebbles; dark yellowish brown (10YR4/2); subangular to subrounded, subspherical to spherical, moderately sorted; predominantly quartz Note: Sample from split-spoon core	24.0	27.0

Sand, fine- to medium-grained with some coarse to very coarse sand, granules, and pebbles; dark yellowish brown (10YR4/2); subangular to subrounded, subspherical to spherical, moderately sorted; predominantly quartz	27.0	29.0
Sand, fine- to medium-grained with granules and pebbles, and some coarse to very coarse sand, dark yellowish brown (10YR4/2); subangular to subrounded, subspherical to spherical, poorly sorted; predominantly quartz	29.0	34.0
No sample	34.0	38.0
Clay, silt, and fine- to medium-grained sand with coarse to very coarse sand, granules, and pebbles; moderate yellowish brown (10YR5/4); subangular to rounded, elongated to spherical, very poorly sorted Note: Sample from Waterloo core	38.0	40.5
Clay, silt, and fine- to medium-grained sand with small amount of coarse to very coarse sand, granules, and pebbles; moderate yellowish brown (10YR5/4); subangular to rounded, elongated to spherical, very poorly sorted Note: Sample from Waterloo core	40.5	43.0

Note: Samples from hollow-stem-auger cuttings unless otherwise noted

WELL NUMBER: 270944 (112-1)
Altitude of land surface: 697.2

Lithology	Depth interval (feet)	
Sand, fine- to coarse-grained with some fine sand, granules, pebbles and soil; very pale orange (10YR8/2) to dark yellowish orange (10YR6/6); rounded to subangular, elongated to subspherical, very poorly sorted; predominantly rock fragments with some quartz grains	0.0	2.5
Sand, medium- to very coarse-grained with some granules and pebbles; pale yellowish brown (10YR6/2); angular to subrounded, subspherical to subelongated, moderately sorted; predominantly quartz	2.5	5.0

Sand, medium- to very coarse-grained with some granules and pebbles; moderate yellowish brown (10YR5/4); angular to subrounded, subspherical to subelongated, moderately sorted; predominantly quartz	5.0	10.0
Sand, medium- to coarse-grained with occasional very coarse sand and granules; moderate yellowish brown (10YR5/4); angular to subrounded, spherical to subspherical, moderately to well sorted; predominantly quartz	10.0	12.5
Sand, fine- to medium-grained in a silty matrix with some granules, and pebbles; dusky brown (5YR2/2); poorly sorted	12.5	15.0
Sand, coarse- to very coarse-grained with some fine to medium sand, granules, and pebbles; dusky brown (5YR2/2); iron coating on some grains	15.0	17.5
Sand, medium- to very coarse-grained with some pebbles and fine sand; moderate brown (5YR4/2); poorly sorted; iron coating on some grains	17.5	20.0
Sand, medium- to coarse-grained; poorly sorted	20.0	25.0
No sample	25.0	30.0

Note: All samples from hollow-stem-auger cores

WELL NUMBER: 270946 (112-3)
Altitude of land surface: 698.2

Lithology	Depth interval (feet)	
Sand, coarse-grained and medium to coarse gravel; dark yellowish brown (10YR4/2); subrounded to rounded, spherical to elongated, very poorly sorted; less than 50 percent quartz	0.0	4.0
Sand, medium- to coarse-grained and fine to coarse gravel; two distinct colors, dark yellowish brown (10YR4/2) and moderate brown (5YR3/4); subrounded to rounded, spherical to elongated, very poorly sorted; less than 50 percent quartz	4.0	9.0
Sand, medium- to coarse-grained with very coarse sand, granules, and pebbles; moderate brown (5YR4/4) to dark yellowish brown (10YR4/2); moderately to poorly sorted	9.0	14.0

Sand, fine- to medium-grained with coarse to very coarse sand and some granules; moderate yellowish brown (10YR5/4); subangular to subrounded, subspherical to spherical, well sorted; predominantly quartz	14.0	19.0
Sand, fine- to medium-grained with some coarse sand; moderate yellowish brown (10YR5/4); subangular to subrounded, subspherical to spherical, well sorted; predominantly quartz Note: Sample from split-spoon core	19.0	24.0
Sand, fine- to medium-grained with some coarse sand; dark yellowish brown (10YR4/2); subangular to subrounded, subspherical to spherical, well sorted; predominantly quartz	24.0	29.0
Sand, fine- to coarse-grained; dark yellowish brown (10YR4/2); subangular to subrounded, subspherical to spherical, well sorted; predominantly quartz Note: Sample from split-spoon core	29.0	31.0
Sand, very fine- to medium-grained with some silt; olive gray (5Y4/1); angular to subrounded, subspherical to spherical, moderately sorted; predominantly quartz	31.0	41.0
Sand, very fine- to fine-grained with some silt; olive gray (5Y4/1); subangular to subrounded, spherical to subspherical, well sorted; predominantly quartz Note: Sample from split-spoon core	41.0	43.0
Sand, very fine- to medium-grained with some silt; olive gray (5Y4/1); angular to subrounded, subspherical to spherical, moderately sorted; predominantly quartz	43.0	48.0
Sand, very fine- to fine-grained and silt with traces of clay; olive gray (5Y4/1); subangular to subrounded, spherical to subspherical, moderately sorted; predominantly quartz Note: Sample from split-spoon core	48.0	50.0
Sand, very fine- to medium-grained with some silt; olive gray (5Y4/1); angular to subrounded, subspherical to spherical, moderately sorted; predominantly quartz Note: All samples from hollow-stem-auger cuttings unless otherwise noted	50.0	52.0

WELL NUMBER: 270950 (112-7)
Altitude of land surface: 695.7

Lithology	Depth interval (feet)	
Sand, medium- to coarse-grained with some very coarse sand, granules, and pebbles; dark yellowish brown (10YR4/2); angular to subangular, subspherical, poorly sorted; predominantly quartz	0.0	4.5
Sand, medium- to very coarse-grained with granules and pebbles; dark yellowish brown (10YR4/2); angular to subangular, subspherical, poorly sorted; predominantly quartz	4.5	9.5
Sand, medium- to very coarse-grained with granules and pebbles; moderate yellowish brown (10YR5/4); angular to subangular, subspherical, poorly sorted; predominantly quartz	9.5	14.5
Sand, medium- to very coarse-grained, with granules pebbles, and some fine sand; moderate yellowish brown (10YR5/4); angular to subangular, subspherical, poorly sorted; predominantly quartz	14.5	19.5
Sand, medium- to very coarse-grained with some fine sand; angular to subangular, subspherical, moderately to poorly sorted; predominantly quartz	19.5	24.5
Sand, medium- to very coarse-grained with some fine sand, granules, and pebbles; moderate yellowish brown (10YR5/4); angular to subangular, subspherical, moderately to poorly sorted; predominantly quartz	24.5	29.5
Sand, fine- to medium-grained, with some coarse to very coarse sand and occasional granules; dark yellowish orange (10YR6/6) to moderate yellowish brown (10YR5/4); subangular to subrounded, subspherical, poorly sorted; predominantly quartz Note: Sample from split-spoon core at 29.5 to 31.5	29.5	39.5
Sand, fine- to medium-grained with some very coarse sand, granules, and pebbles; moderate yellowish brown (10YR5/4); subangular to subrounded, subspherical, poorly sorted; predominantly quartz Note: Sample from split-spoon core	39.5	41.0

Sand, fine- to medium-grained with some very coarse sand, granules, and pebbles; moderate yellowish brown (10YR5/4); subangular to subrounded, subspherical, moderately sorted; predominantly quartz Note: Sample from split-spoon core	41.0 44.5
Sand, very fine- to medium-grained with clayey silt; dark yellowish brown (10YR4/2); subangular to subrounded, subspherical to spherical, moderately to poorly sorted; predominantly quartz Note: Sample from split-spoon core	44.5 47.5
Sand, medium-grained with some fine sand; pale yellowish brown (10YR6/2); subangular to subrounded, subspherical, well sorted; predominantly quartz	47.5 49.0
Sand, medium-grained with some fine sand and occasional pebbles; pale yellowish brown (10YR6/2); subangular to subrounded, subspherical, well sorted; predominantly quartz	49.0 52.0

Note: All samples from hollow-stem-auger cuttings unless otherwise noted

WELL NUMBER: 270952 (112-9)
Altitude of land surface: 694.3

Lithology	Depth interval (feet)
Sand, medium- to very coarse-grained with granules and pebbles; dark yellowish brown (10YR4/2); rounded to subangular, subspherical to spherical, poorly sorted; predominantly quartz	0.0 4.5
Sand, fine- to very coarse-grained with granules and pebbles; dark yellowish orange (10YR5/6); rounded to subangular, subspherical to spherical, poorly sorted; predominantly quartz	4.5 9.5
Sand, medium-grained with some coarse to very coarse sand, granules, and pebbles; moderate yellowish brown (10YR5/4); subrounded to subangular, subspherical to spherical, moderately sorted; predominantly quartz Note: Sample from split-spoon core	9.5 11.5

Sand, medium-grained with some coarse to very coarse sand, granules, and pebbles; moderate yellowish brown (10YR5/4); subrounded to subangular, subspherical to spherical, well sorted; predominantly quartz Note: Samples from split-spoon cores at 11.5 to 13.5 and 19.5 to 21.5 feet	11.5	29.5
Sand, very fine- to medium-grained with some coarse to very coarse sand; moderate yellowish brown (10YR5/4); angular to subrounded, subspherical to spherical, well sorted; predominantly quartz Note: Samples from split-spoon cores at 29.5 to 31.5 and 31.5 to 33.5 feet	29.5	37.0

Note: All samples from hollow-stem-auger cuttings unless otherwise noted

WELL NUMBER: 270954 (I-2)
Altitude of land surface: 693.2

Lithology	Depth interval (feet)	
Sand, medium- to very coarse-grained with granules, pebbles, and small amount of fine sand; moderate yellowish brown (10YR5/4); subrounded to subangular, subelongated to subspherical, poorly sorted; predominantly quartz	0.0	5.0
Sand, fine- to medium-grained with some very coarse sand and granules; dark yellowish brown (10YR4/2); subangular to subrounded, spherical to subelongated, well sorted; predominantly quartz	5.0	10.0
Sand, fine- to very coarse-grained with occasional granules; moderate brown (5YR3/4); subangular to angular, subspherical to subelongated, moderately to poorly sorted; varied lithology, 70 to 80 percent quartz	10.0	22.5
Sand, medium- to very coarse-grained with occasional granules; moderate brown (5YR3/4); subangular to angular, subspherical to subelongated, well sorted; varied lithology, 70 to 80 percent quartz	22.5	25.0
Sand, fine- to medium-grained with some coarse sand; dark yellowish brown (10YR4/2); angular to subrounded, spherical to subelongated, well sorted; predominantly quartz	25.0	27.5

No sample	27.5	32.0
Sand, very fine- to medium-grained with some coarse sand; dark yellowish brown (10YR4/2); angular to subrounded, spherical to subelongated, well sorted; predominantly quartz	32.0	37.0
Note: All samples from continuous hollow-stem-auger cores		

WELL NUMBER: 270955 (92-3)
Altitude of land surface: 700.2

Lithology	Depth interval (feet)	
Sand, fine- to very coarse-grained, gravel, and organic material; moderate yellowish brown (10YR5/4); smaller grains are subrounded to rounded, and spherical; granules and pebbles are rounded to elongated; very poorly sorted	0.0	4.0
Sand, coarse- to very coarse-grained with medium sand, granules, and pebbles; moderate yellowish brown (10YR5/4); sand grains are subrounded to rounded, subspherical to spherical; pebbles and cobbles are elongated to subelongated; poorly sorted	4.0	9.0
Sand, fine- to medium-grained with coarse sand and granules; moderate yellowish brown (10YR5/4); subangular to rounded, spherical to subspherical, well sorted; predominantly quartz	9.0	24.0
Sand, very fine- to fine-grained with small amount of silt and medium sand; moderate yellowish brown (10YR5/4); angular to subangular, spherical to subspherical; predominantly quartz Note: Sample from split-spoon core	24.0	26.0
Sand, fine- to medium-grained with coarse sand and granules; moderate yellowish brown (10YR5/4); subangular to rounded, spherical to subspherical, well sorted; predominantly quartz	26.0	34.0
Sand, fine- to medium-grained with small amount of coarse sand; moderate yellowish brown (10YR5/4); subangular to rounded, spherical to subspherical, very well sorted; predominantly quartz Note: Sample from split-spoon core	34.0	36.0

Sand, fine- to medium-grained with coarse sand and granules; moderate yellowish brown (10YR5/4); subangular to rounded, spherical to subspherical, well sorted; predominantly quartz	34.0	39.0
Sand, fine- to medium-grained with small amount of coarse sand and granules; moderate yellowish brown (10YR5/4); subangular to rounded, spherical to subspherical, very well sorted; predominantly quartz	39.0	44.0
Sand, fine- to medium-grained with coarse sand and occasional granules; dark yellowish brown (10YR4/2); angular to subrounded, spherical to subspherical, moderately to well sorted; predominantly quartz	44.0	49.0
Sand, fine- to medium-grained with very fine sand and silt; pale yellowish brown (10YR6/2); subrounded to rounded, spherical, well sorted; predominantly quartz	49.0	54.0
Sand, very fine- to fine-grained with small amount of medium to very coarse sand; olive gray (5Y4/1); angular to subrounded, subspherical to spherical; well sorted; predominantly quartz Note: Sample from Waterloo core	54.0	56.5

Note: All samples from hollow-stem-auger cuttings unless otherwise noted

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WELL NUMBER 270958 (111-1)
Altitude of land surface: 702.5

Lithology	Depth interval (feet)	
Topsoil, organic material	0.0	1.0
Sand, fine- to coarse-grained with granules, pebbles, and small amount of silt; moderate yellowish brown (10YR5/4); subangular to subrounded, subspherical to subrounded, poorly sorted	1.0	5.0
Sand, fine- to very coarse-grained with granules, pebbles, and silt; moderate yellowish brown (10YR5/4); subrounded, poorly sorted	5.0	10.0
Sand, medium- to coarse-grained with small amount of very coarse sand; dark yellowish brown (10YR4/2); subrounded, moderately to well sorted	10.0	15.0

Sand, fine-grained with small amount of medium and very fine sand; dark yellowish brown (10YR4/2); subrounded, well sorted	15.0	20.0
Sand, medium- to coarse-grained with small amount of very coarse sand; dark yellowish brown (10YR4/2); subrounded, moderately to well sorted	20.0	27.5
Sand, medium-grained with fine sand and small amount of coarse sand; dark yellowish brown (10YR4/2); subrounded, well sorted	27.5	30.0
Sand, medium- to coarse-grained with some very coarse sand; dark yellowish brown (10YR4/2); subrounded, moderately to well sorted	30.0	35.0
Sand, fine- to medium-grained with some very fine sand; dark yellowish brown (10YR4/2); subrounded, well sorted	35.0	40.0
Sand, fine- to very fine-grained with some medium sand; dark yellowish brown (10YR4/2) to light olive gray (5Y5/2); subrounded to rounded, well sorted	40.0	46.0

Note: All samples from continuous hollow-stem-auger cores

WELL NUMBER: 270960 (cafeteria 6)
Altitude of land surface: 702.7

Lithology	Depth interval (feet)	
Sand, coarse- to very coarse-grained and gravel with some clayey silt; moderate brown (5YR4/4); rounded to subrounded, subspherical to elongated, very poorly sorted	0.0	4.5
Sand, medium- to coarse-grained with granules and pebbles; moderate yellowish brown (10YR5/4); subrounded to rounded, spherical to elongated, poorly sorted; predominantly quartz	4.5	9.5
Sand, medium- to coarse-grained with granules and occasional pebbles; moderate yellowish brown (10YR5/4); subrounded to rounded, spherical to elongated, poorly sorted; predominantly quartz Note: Sample from split-spoon core at 14.5 to 16.5	9.5	24.5

Sand, medium- to coarse-grained with some very coarse sand and granules; subrounded to rounded, spherical to elongated, moderately to well sorted; predominantly quartz	24.5	29.5
Sand, medium- to coarse-grained with granules and pebbles; moderate yellowish brown (10YR5/4); subrounded to rounded, spherical to elongated, poorly sorted; predominantly quartz Note: Sample from split-spoon core	26.5	28.5
Sand, medium- to coarse-grained with very coarse sand, granules, and pebbles; subrounded to rounded, spherical to elongated; predominantly quartz Note: Sample from split-spoon core at 28.5 to 30.5	29.5	34.5
Sand, medium- to very coarse-grained with granules and pebbles; moderate yellowish brown (10YR5/4); rounded to subangular, subspherical to spherical, poorly sorted; predominantly quartz Note: Sample from split-spoon core at 34.5 to 36.5	34.5	39.5
Sand, medium- to very coarse-grained with granules and occasional pebbles; moderate yellowish brown (10YR5/4); rounded to subangular, subspherical to spherical, poorly sorted; predominantly quartz Note: Sample from split-spoon core at 44.5 to 46.5	39.5	49.5
No sample	49.5	52.0
Sand, very fine- to medium-grained; moderate yellowish brown (10YR5/4); subangular to rounded, subspherical to spherical, well sorted; predominantly quartz Note: Sample from split-spoon core	52.0	54.0
Sand, fine- to medium-grained with very fine sand; olive gray (5Y4/1); subangular to rounded, subspherical to spherical, well sorted; predominantly quartz Note: Sample taken from auger flight after removal	54.0	57.0

Note: All samples from hollow-stem-auger cuttings unless otherwise noted

WELL NUMBER: 270961 (9D)
Altitude of land surface: 702.2

Lithology	Depth interval (feet)	
Sand, fine- to medium-grained, granules to cobbles with some silt to clay and organic material; moderate brown (5YR3/4); subangular to subrounded, very poorly sorted	0.0	4.5
Sand, medium- to very coarse-grained with some silty clay; moderate yellowish brown (10YR5/4); subangular to subrounded, poorly sorted; predominantly quartz	4.5	9.5
Sand, medium- to coarse-grained with some fine to very fine sand, granules, and pebbles; moderate yellowish brown (10YR5/4); subangular to subrounded, very poorly sorted; grains coated with clayey material	9.5	14.5
Sand, fine- to very coarse-grained with some pebbles; dark yellowish brown (10YR4/2); subangular to subrounded, poorly sorted Note: Sample from split-spoon core	9.5	11.5
Sand, very fine-grained to silt with some very coarse sand; moderate yellowish brown (10YR5/4); well sorted Note: Sample from split-spoon core	11.5	13.5
Sand, fine- to very coarse-grained with very fine sand and silt matrix; dark yellowish brown (10YR4/2); subangular to subrounded, poorly sorted; predominantly quartz Note: Sample from split-spoon core	14.5	16.5
Sand, medium-grained with some fine and coarse to very coarse sand; moderate yellowish brown (10YR5/4); subangular to angular, well sorted; predominantly quartz Note: Sample from split-spoon core	16.5	18.5
No sample	18.5	19.5
Sand, very fine- to very coarse-grained; dark yellowish brown (10YR4/2); angular to subrounded, poorly sorted; predominantly quartz Note: Sample from split-spoon core	19.5	21.5

Sand, medium-grained with fine and coarse to very coarse sand; dark yellowish brown (10YR4/2); subangular to subrounded, moderately sorted; predominantly quartz Note: Sample from split-spoon core	21.5	23.5
No sample	23.5	24.5
Sand, medium-grained with fine and coarse to very coarse sand; dark yellowish brown (10YR4/2); subangular to subrounded, moderately sorted; predominantly quartz Note: Sample from split-spoon core	24.5	26.5
Sand, very fine- to medium-grained with some coarse to very coarse sand; dark yellowish brown (10YR4/2); subangular to subrounded, moderately sorted; predominantly quartz Note: Sample from split-spoon core at 26.5 to 30.5	26.5	32.0

Note: All samples from hollow-stem-auger cuttings unless otherwise noted

WELL NUMBER: 270963 (31-2a)
Altitude of land surface: 702.1

Lithology	Depth interval (feet)	
No sample	0.0	4.5
Sand, medium- to very coarse-grained, granules, and pebbles; dark yellowish brown (10YR4/2); poorly sorted	4.5	14.5
Sand, fine- to very coarse-grained; dark yellowish brown (10YR4/2); subangular to subrounded, poorly sorted; varied composition, predominantly quartz	14.5	19.5
Sand, medium- to coarse-grained with some granules and fine sand; dark yellowish brown (10YR4/2); angular to subrounded, moderately sorted; predominantly quartz	19.5	24.5
No sample	24.5	26.5
Sand, very fine- to very coarse-grained; dark yellowish brown (10YR4/2); subangular to rounded, poorly sorted; predominantly quartz with hematitic and limonitic stained grains Note: Sample from split-spoon core	26.5	28.5

Sand, very fine- to coarse-grained; dark yellowish brown (10YR4/2); subangular to subrounded, moderately sorted; predominantly quartz Note: Sample from split-spoon core	28.5	30.5
Sand, fine- to coarse-grained; dark yellowish brown (10YR4/2); subangular to subrounded, moderately sorted; predominantly quartz	30.5	32.0

Note: All samples from hollow-stem-auger cuttings unless otherwise noted

WELL NUMBER: 270972 (95-1)
Altitude of land surface: 695.2

Lithology	Depth interval (feet)	
Sand and gravel	0.0	10.0
No sample	10.0	20.0
Sand, fine- to medium-grained; dark yellowish brown (10YR4/2); subangular to angular, subspherical to spherical, well sorted; predominantly quartz	20.0	22.0
No sample	22.0	28.0
Sand, fine- to medium-grained; dark yellowish brown (10YR4/2); subangular to angular, subspherical to spherical, well sorted; predominantly quartz	28.0	29.0
Silt, with some very fine sand and clay; dark yellowish brown (10YR4/2); moderately to well sorted	29.0	30.0
No sample	30.0	38.0
Sand, medium-grained with fine and coarse to very coarse sand; dark yellowish brown (10YR4/2); angular to subrounded, spherical to subelongated, moderately to poorly sorted; predominantly quartz	38.0	39.0
Sand, fine- to medium-grained; olive gray (5Y4/1); subangular to angular, subspherical to spherical, well sorted; predominantly quartz	39.0	41.0
No sample	41.0	48.0

Sand, medium-grained with fine and coarse to very coarse sand; dark yellowish brown (10YR4/2); angular to subrounded, spherical to subelongated, moderately to poorly sorted; predominantly quartz	48.0	48.5
Sand, fine- to medium-grained; olive gray (5Y4/1); subangular to angular, subspherical to spherical, well sorted; predominantly quartz	48.5	49.5
Silt and clay; olive gray (5Y4/1)	49.5	50.5
No sample	50.5	58.0
Clay and silt; olive gray (5Y4/1)	58.0	60.5
No sample	60.5	68.0
Sand, very fine- to fine-grained; olive gray (5Y4/1); subangular to angular, subspherical to spherical, well sorted; predominantly quartz, 10 to 20 percent Green Pond Formation minerals	68.0	69.0
Sand, very fine-grained with silt and small amount of clay; olive gray (5Y4/1); subspherical to spherical, subangular to angular, moderately to well sorted; predominantly quartz	69.0	70.0
No sample	70.0	78.0
Sand, very fine-grained with silt and small amount of clay; olive gray (5Y4/1); subspherical to spherical, subangular to angular, moderately to well sorted; predominantly quartz	78.0	80.0
No sample	80.0	88.0
Sand, very fine-grained and silt with small amount of clay; olive gray (5Y4/1); subspherical to spherical, subangular to angular, moderately to well sorted; predominantly quartz	88.0	90.5
No sample	90.5	98.0
Sand, very fine-grained with silt and small amount of clay; olive gray (5Y4/1); subspherical to spherical, subangular to angular, moderately to well sorted; predominantly quartz	98.0	99.0
Sand, very fine-grained and silt; olive gray (5Y4/1); subspherical to spherical, subangular to angular, moderately to well sorted; predominantly quartz	99.0	100.5
No sample	100.5	108.0

Sand, coarse-grained to granules with very fine sand and silt; dark yellowish brown (10YR4/2); coarse grains are rounded to subangular, elongated to subspherical; predominantly rock fragments, largest grains 5 millimeters long	108.0 109.5
Silt with some clay; olive gray (5Y4/1); well sorted	109.5 110.5
No sample	110.5 118.0
Clay; brownish gray (5YR4/1)	118.0 118.5
Sand, very fine-grained; dark yellowish brown (10YR4/2); subangular to angular, subspherical to spherical, well sorted; predominantly quartz	118.5 120.5
No sample	120.5 128.0
Sand, very fine- to very coarse-grained with granules; pale yellowish brown (10YR6/2); large grains rounded to subangular, spherical to elongated; smaller grains spherical to subspherical; predominantly quartz and rock fragments	128.0 130.0
Clay and silt, alternating layers; clay is brownish gray (5YR4/1), silt is brownish gray (5YR4/1) to olive gray (5Y4/1)	130.0 130.5
Silt, very fine sand, and clay; light olive gray (5Y 5/2 - 5Y 6/1), laminated	130.5 148.0
Sand, very fine-grained, silt, and clay (predominantly silt and clay); light olive gray (5Y 5/2)	148.0 155.0
Silt and sand	155.0 163.0
Silt, very fine, grading to coarse-grained sand; silt is subangular, light olive gray (5Y 5/2), and well sorted; sand is light olive gray (5Y 6/1) and well sorted	163.0 165.5
Sand, boulders, and cobbles	165.5 178.0
Clay	178.0 183.0
Sand and silt matrix, very fine-grained; light olive gray (5Y 5/2); predominantly quartz; grains rounded and spherical	183.0 185.0
Cobbles and gravel	185.0 193.0

Weathered bedrock, boulders	193.0 195.0
Clay; brown	202.0 204.0
Weathered bedrock, claystone, and clay; color varies with grain; pale olive (10Y 6/2) angular, grayish red purple (5RP 4/2) angular, and medium dark gray (5N5) subangular, predominantly of three bedrock types of granite and arkosic sandstone origins, also quartz, angular dolomite and claystone, dark yellowish orange (10YR 6/6) (sample 223.0-225.0)	204.0 352.0

WELL NUMBER: 270970 (39-1)
Altitude of land surface: 692.7

Lithology	Depth interval (feet)	
Sand, fine- to coarse-grained with some organic material; dark yellowish brown (10YR4/2); subrounded to subangular, poorly sorted Note: Sample from mud-rotary cuttings	0.0	5.0
Sand, medium-grained with clay and some silt; sand is dark yellowish brown (10YR4/2), clay is dusky brown (5YR2/2); moderately sorted Note: Sample from mud-rotary cuttings	5.0	10.0
Sand, very fine- to medium-grained with some coarse sand; dusky yellowish brown (10YR2/2); subrounded, poorly sorted Note: sample from mud-rotary cuttings	10.0	20.0
Silt and very fine- to fine-grained sand; olive gray (5Y4/1); moderately sorted Note: Sample from mud-rotary cuttings	20.0	23.0
Sand, coarse to very coarse; olive gray (5Y 4/1); individual grains grayish dark purple (5RP 4/2), medium dark gray and white (5N5); moderately to well sorted, subangular; minor feldspar and quartz	23.0	34.0
Silt and very fine sand; light olive gray (5Y 6/1); very well sorted	34.0	44.0
Clay, silt, and very fine-grained sand; light olive gray (5Y 5/2); subangular	44.0	56.0
Silt; light olive gray (5Y 6/1 - 5Y 5/2); well sorted; clay 20 percent, dusky yellowish brown (10YR2/2)	56.0	66.0

Silt	66.0	84.0
Sand, predominantly light grayish pink (5R 8/2) with grayish red purple (5RP 4/2) and plagioclase feldspar	84.0	90.0
Sand, fine- to very fine-grained; light olive gray (5Y 6/1); angular, well sorted	90.0	96.0
Quartzite bedrock cobbles (to 2 centimeters), grayish black (2N2), pale to grayish red (5R 5/2) to very light gray (8N8)	96.0	110.0
Silt, gray	110.0	124.0
Sand, medium to very coarse-grained, variety of colors; quartz with pink (5R 8/2), arkose, grayish purple (5P 4/2), feldspar, white (9N9), mica (minor), subangular, moderately sorted	124.0	134.0
Sand, very fine- to very coarse-grained; dark yellowish brown (10YR4/2); well sorted; multi-colored pebbles same as 124.0-126.0 of very coarse grained	134.0	136.0
Sand, fine- to very fine-grained with small amount of silt and medium sand; dark yellowish brown (10YR4/2); moderately to well sorted Note: Sample from mud-rotary cuttings	136.0	149.0
Sand with poorly sorted pebbles; sand grayish orange (10YR 7/4), medium-grained, well sorted; feldspar, quartz and manganese grains, angular	149.0	151.0
Sand and clay	151.0	178.0
Clay	178.0	179.0
Till, clay with gravel and cobbles	179.0	184.0
No sample	184.0	194.0
Sand with poorly sorted pebbles; sand grayish orange (10YR 7/4), medium-grained, well sorted; feldspar, quartz, and manganese grains, angular	194.0	196.0
Quartzite bedrock, grayish black (2N2), with arkosic bedrock cobbles at depth, light brownish/pinkish gray (5YR 7/1)	196.0 204.0	204.0 207.0
Till, gravel, cobbles, and medium sand	207.0	210.0
Boulders	210.0	220.0

Gravel and clay	220.0	225.5
Clay and fine silt with weathered bedrock, arkosic fine-grained sandstone with quartz crystals and veins, pale yellow brown (10YR 6/2), slightly darker with depth (10YR 4/2)	225.5	235.0
Weathered bedrock, mudstone, yellowish gray (5Y 7/2), variable with pale yellow orange (10 YR 8/6)	235.0	244.0
Nodules, large iron, brownish gray (5 YR 4/1) to grayish black (2N2)	244.0	247.0
Clay, pale yellowish orange (10 YR 8/6) variable to yellowish gray (5y 7/2) with iron nodules	247.0	256.0

WELL NUMBER: 270968 (10-3a)
Altitude of land surface: 701.9

Lithology	Depth interval (feet)	
Sand, coarse- to very coarse-grained, granules, and slag; multi-colored; subangular to angular, subelongated, poorly sorted, small grains are subrounded; varied lithology, 50 percent quartz	0.0	9.0
Gravel	9.0	11.0
Sand and some cobbles	11.0	13.0
Sand, coarse- to very coarse-grained, granules, and slag; multi-colored; subangular to angular, subelongated, moderately sorted, small grains are subrounded; varied lithology, 50 percent quartz	13.0	15.0
Sand, medium-grained; dark yellowish brown (10YR4/2); well sorted	15.0	17.0
Sand, medium- to coarse-grained with some gravel and fine sand; dark yellowish brown (10YR4/2)	17.0	21.0
Sand, coarse-grained, granules, and pebbles, subangular to angular, subelongated; some slag, ash, and sandstone also present, dusky red (5R3/4) subspherical to rounded	21.0	30.0
Sand, fine- to coarse-grained and gravel and cobbles dark yellowish brown (10YR4/2); sandy matrix	30.0	45.0

Sand, fine-grained and silt; dark yellowish brown (10YR4/2)	45.0	55.0
Sand, fine- to medium-grained, dark yellowish brown (10YR4/2); subangular to subrounded, subspherical, well sorted; sample contains some dusky red sandstone	55.0	57.0
Sand, very fine-grained	57.0	62.0
Silt and very fine-grained sand; gray	62.0	65.0
Sand, fine- to coarse-grained; light olive gray (5Y5/2)	65.0	65.1
Sand, coarse- to very coarse-grained; some quartz grains	65.1	65.5
Sand, very coarse-grained and gravel	65.5	66.0
Sand, very fine-grained with silt and some clay; pale brown (5YR5/2)	66.0	66.5
Sand, very fine-grained and silt; pale brown (5YR5/2) to pale yellowish brown (10YR6/2)	66.5	67.0
Sand, fine- to very fine-grained with some medium sand; dark yellowish brown (10YR4/2); spherical to subspherical, subangular to subrounded, moderately to well sorted; predominantly quartz	67.0	75.0
Sand, very fine-grained and silt; dark yellowish brown (10YR4/2); very well sorted	75.0	77.0
Sand, fine- to very fine-grained with some medium sand; dark yellowish brown (10YR4/2); spherical to subspherical, subangular to subrounded, moderately to well sorted; predominantly quartz	77.0	87.0
Sand, very fine-grained with some silt and medium sand; dark yellowish brown (10YR4/2) and light brown (5YR5/6); 5 percent opaques	87.0	90.0
Sand, very fine-grained; dark yellowish brown (10YR4/2); very well sorted; predominantly quartz, 3 percent opaques	90.0	95.0
Sand, fine- to very fine-grained with some medium sand; dark yellowish brown (10YR4/2); spherical to subspherical, subangular to subrounded, moderately to well sorted; predominantly quartz	95.0	105.0
Sand, very fine-grained; dark yellowish brown (10YR4/2); well sorted; 3 percent opaques	105.0	107.0

Weathered bedrock, poorly sorted pebbles, variable colors as 201-207, and grayish red purple (5RP 4/2)	114.0	119.0
Sand, fine-grained, silt and clay	119.0	121.0
Sand, fine-grained; dark yellowish brown (10YR4/2); very well sorted; 3 percent opaques, 2 percent light brown (5YR5/6)	121.0	122.0
Sand, fine-grained with small amount of clay; dark yellowish brown (10YR4/2)	122.0	132.0
Clay, dark yellowish brown (10YR4/2)	132.0	137.0
Sand, fine-grained with small amount of clay; dark yellowish brown (10YR4/2)	137.0	148.0
Silt and clay with small amount of fine sand; dark yellowish brown (10YR4/2)	148.0	159.0
Cobbles and boulders	159.0	163.0
Gravel and boulders	163.0	168.0
Till, clayey silt, very fine- to coarse-grained sand and gravel; pale yellowish brown (10YR6/2); predominantly quartz with rock fragments; gravel includes poorly sorted dark yellowish orange (10YR6/6) sandstone and greenish black (5G2/1) igneous rock (basalt)	168.0	179.0
Clay, pale yellowish brown (10YR 7/2), homogeneous, well sorted	179.0	184.0
Till and weathered conglomerate	184.0	184.5
Clay and weathered bedrock, iron-stained bedrock	184.5	187.0
Clay with some rock fragments; yellowish orange	187.0	189.0
Clay and sand, iron-stained bedrock	189.0	190.0
Fractured quartz conglomerate; massive, rust- to maroon-colored, conchoidal fractures, small amount of clay	190.0	195.0
Solid conglomerate; white and yellow clay mixed with rock fragments	195.0	197.0
Clay alternating with rock fragments; very cohesive; clay is white with black nodules 1 to 2 millimeters diameter with some yellow clay; bedrock layers are vertically stratified	197.0	206.0

Clay alternating with rock fragments; increased density and cohesion of rock	206.0	220.0
High concentration of dolomitic rock fragments	220.0	221.0
Clayey silt; very pale orange (10YR8/2) to dark yellowish orange (10YR6/6); with zones of weathered dolomitic bedrock fragments	221.0	232.0
Ferrous rock fragments	232.0	233.0
No sample	233.0	234.0
Clay with occasional iron fragments and weathered bedrock; dark yellowish orange (10YR6/6)	234.0	239.0
Weathered dolomitic bedrock with iron staining and alterations along fractures	239.0	241.0
Sandy silt with some clay, dolomitic rock fragment and ferrous rock fragments; very pale orange (10YR8/2) to dark yellowish orange (10YR6/6)	241.0	250.0
Quartzose fractured rock, unweathered	250.0	251.0
Dolomitic rock, weathered	251.0	253.0
Silt and sand; pale yellowish orange (10YR8/6) to pale olive (10Y6/2)	253.0	254.0
Clay and silt; very pale orange (10YR8/2) to dark yellowish orange (10YR6/6)	254.0	255.0
Quartzose rock fragments	255.0	255.5
Ferrous rock fragments, solid	255.5	256.0
Silt and sand; dark yellowish orange (10YR6/6)	256.0	257.0
Silt and sand with clay and rock fragments; very pale orange (10YR8/2)	257.0	259.0
Dolomitic and ferrous rock fragments and silt; pale orange (10YR8/4)	259.0	260.0
Silt with some rock fragments; pale yellowish orange (10YR8/6)	260.0	264.0
Silt and fine- to coarse-grained sand, alternating layers; pale yellowish orange (10YR8/6); predominantly quartz sand	264.0	265.5
Silt and hematite; reddish black	265.5	266.5

Silt with some rock fragments; pale yellowish orange (10YR8/6); 2-inch hematitic layer at 268	266.5	269.0
Silt with some clay; pale yellowish orange (10YR8/6) to dark yellowish orange (10YR6/6); cleavable layer at 271	269.0	273.0
Silt; dark yellowish orange (10YR6/6); little cohesion, cleavable	273.0	279.0
Hematite layer 45 degrees from vertical	279.0	280.0
Silt; dark yellowish orange (10YR6/6); little cohesion, cleavable	280.0	281.5
Hematite layer	281.5	281.7
Silt and clay; pale yellowish orange (10YR8/6) to dark yellowish orange (10YR6/6)	281.7	284.0
Clay with ferrous rock fragments; clay is moderate reddish brown, ferrous rock is black	284.0	285.0
Silt and clay; dark yellowish orange (10YR6/6)	285.0	286.0
Quartzite; gray; water-stained fractures, cleavage 30 to 45 degrees from vertical	286.0	288.0
Clay associated with quartzite 30 degrees from vertical	288.0	288.5
Quartzite, coarse-grained; gray; 45- and 30-degree cleavage from vertical, numerous old fractures in which quartz has recrystallized, vertical plane of weakness	288.5	297.5
Quartzite, coarse-grained; gray; 45- and 30-degree cleavage from vertical, numerous old fractures in which quartz has recrystallized, vertical plane of weakness, increasing ratio of matrix to coarse quartz grains with depth	297.5	305.0
Quartzite, coarse-grained, with small amount of clay; gray; 45- and 30-degree cleavage from vertical, numerous old fractures in which quartz has recrystallized, vertical plane of weakness	305.0	306.0