GEOHYDROLOGY AND VERTICAL DISTRIBUTION OF VOLATILE ORGANIC COMPOUNDS IN GROUND WATER, FISCHER AND PORTER COMPANY SUPERFUND SITE, WARMINSTER, BUCKS COUNTY, PENNSYLVANIA

By Ronald A. Sloto, Paola Macchiaroli, and Randall W. Conger

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CONVERSION FACTORS AND ABBREVIATIONS

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
foot per minute (ft/min)	0.3048	meter per minute
foot per day (ft/d)	0.3048	meter per day
	Area	
acre	0.4047	hectare
	Volume	
gallon (gal)	3.785	liter
	Flow	
gallon per minute (gal/min)	0.06309	liter per second
	Specific Capacity	
gallon per minute per foot [(gal/min)/ft]	0.2070	liter per second per meter
	Temperature	
degree Fahrenheit (°F)	°C=5/9 (°F-32)	degree Celsius

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

Abbreviated water-quality units used in report:

(μg/L) micrograms per liter
(μS/cm) microsiemens per centimeter at 25 degrees Celsius

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ABSTRACT

The Fischer and Porter Company Superfund Site is underlain by sedimentary rocks of the Upper Triassic Stockton Formation, which consists of interbedded siltstone, very-fine grained to coarse-grained sandstone, and conglomerate in crudely defined, upward fining cycles. These rocks form a complex, heterogeneous, leaky, multiaquifer system comprised of a series of gently dipping lithologic units with different hydraulic properties. Ground water is unconfined in the shallower part of the aquifer and confined or semiconfined in the deeper part of the aquifer. Water levels measured in monitor well clusters and borehole-flow measurements made in open boreholes show a downward hydraulic head gradient at the site, caused in part by the pumping of nearby, deep public-supply wells and the Fischer and Porter treatment system extraction wells. Downward borehole flow was measured at rates up to 9 gallons per minute. Aquifer-isolation tests were run in the six boreholes to obtain depth-discrete specific-capacity and water-quality data. On the basis of specific-capacity data for 27 isolated intervals, specific capacity is not related to depth.

Water levels in monitor wells at the Fischer and Porter Site are greatly affected by the pumping of nearby public-supply wells, as well as the pumping of the Fischer and Porter treatment system extraction wells. Pumping of the public-supply wells causes daily water-level fluctuations in wells at the site as great as 5.3 feet. The shutdown of the Fischer and Porter treatment system extraction wells caused a rise in water level in all wells screened in the intermediate and deep zones. The rise in water level was as great as 4.3 feet in the intermediate zone and as great as 5.9 feet in the deep zone. The direction of ground-water flow is toward the north in the shallow and intermediate zones and toward the west and west-southwest in the deep zone. Ground-water discharge probably is to the unnamed tributary to Pennypack Creek north and west of the site.

Volatile organic compounds (VOC's) were detected in most depth-discrete water samples. No general trend of increasing or decreasing concentrations of VOC's with depth were observed, and none of the isolated intervals had highly elevated concentrations of VOC's. Observed fairly constant concentrations of VOC's with depth are the result of the downward head gradient and the former presence of open boreholes on the site. The downward head gradient and pumping of nearby, deep public-supply wells caused the vertical migration and outward movement of VOC's into the aquifer through former supply and monitor wells of open-hole construction in the main area of contamination.

INTRODUCTION

The Fischer and Porter Company Superfund Site (fig. 1) occupies about 41 acres in Warminster Township, Bucks County, Pa., on the boundary between Bucks and Montgomery Counties. In 1979, volatile organic compounds (VOC's) were detected in nearby public-supply wells. VOC's also were detected in Fischer and Porter's onsite supply wells. A suit filed by the U.S. Environmental Protection Agency (USEPA) against the Fischer and Porter Company in October of 1980 was settled in November of 1984. Under the Consent Decree, the Fischer and Porter Company pumps and treats ground water from three onsite wells at a combined rate of 75 gal/min. The Fischer and Porter Site was designated as a Superfund site and placed on the National Priorities List in September of 1983 under the USEPA's Comprehensive Environmental Response, Compensation, and Liability Act program (U.S. Environmental Protection Agency, 1992). A remedial investigation/feasibility study was never done for the site.

This investigation by the USGS was done to (1) provide hydrologic and geologic data for the site, (2) determine the vertical and horizontal extent of ground-water contamination by VOC's along the site boundary, and (3) determine the hydraulic effect of pumping the wells in the Fischer and Porter treatment system. The report will serve as the hydrology and geology background of the USEPA's evaluation of the effectiveness of the Fischer and Porter treatment system.

The investigation was done in six phases: (1) borehole geophysical logging of existing boreholes, (2) drilling exploratory boreholes and coreholes, (3) geophysical logging and borehole television surveys of exploratory boreholes, (4) packer testing and ground-water sampling of exploratory boreholes, (5) construction of exploratory boreholes as monitor wells and drilling and construction of additional monitor wells, and (6) water-level monitoring.

In this report, the term "borehole" is used to describe open-hole construction drilled holes used for the collection of geologic, hydrologic, water-level, and (or) water-quality data. The term "well" is used to describe drilled holes that have been completed as screened monitor wells, public-supply wells, and pumped extraction wells in the Fischer and Porter treatment system.

Purpose and Scope

This report details the hydrogeology of the Fischer and Porter Site. The report describes (1) the geologic framework of the site, (2) vertical and horizontal ground-water-flow directions, (3) the vertical distribution of specific capacity in zones isolated by straddle packers, (4) the response of water levels to pumping stress, and (5) the vertical and horizontal extent of ground-water contamination by VOC's at the site boundaries. The report presents all data collected during the investigation.

Physiography and Climate

The Fischer and Porter Site is underlain by sedimentary rocks of the Triassic Lowlands Section of the Piedmont Physiographic Province. The local topography is flat to rolling. The area surrounding the Fischer and Porter Site is drained by tributaries to Pennypack Creek (fig. 1), which flows southward to the Delaware River.

The area has a humid, modified continental climate characterized by warm summers and moderately cold winters. The normal (1961-90) mean annual temperature at the Neshaminy Falls National Oceanic and Atmospheric Administration station, which is 7 mi to the southeast, is 53.3°F (Owenby and Ezell, 1992). The normal (1961-90) mean temperature for January, the coldest month, is 29.6°F, and the normal mean temperature for July, the warmest month, is 75.4°F.

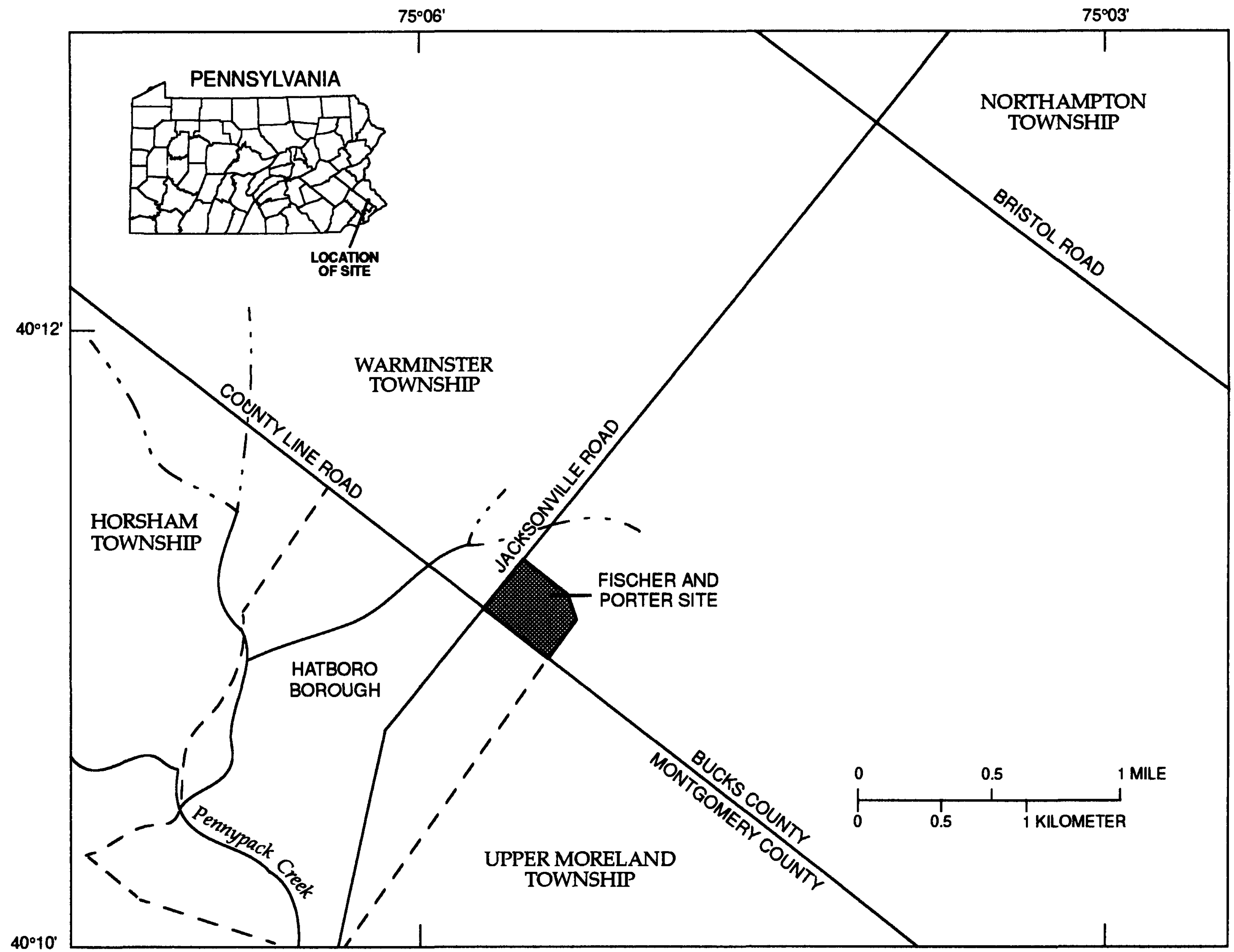


Figure 1. Location of the Fischer and Porter Site, Warminster, Pa.

The normal (1961-90) annual precipitation at the Neshaminy Falls station is 45.43 in. Precipitation is about evenly distributed throughout the year, with slightly more occurring during July and August because of localized thunderstorms.

Previous Ground-Water Investigations

The geology and hydrology of the Stockton Formation in southeastern Pennsylvania was described by Rima and others (1962). Sloto and Davis (1983) described the effect of urbanization on the water resources of Warminster Township. Sloto and others (1992, 1994) and Sloto (1995) described the use of borehole geophysical methods to determine the extent of aquifer cross-contamination by VOC's through open boreholes in Hatboro, Pa. Two site studies (SMC-Martin, Inc., 1980; BCM, Inc., 1986) were done for the Fischer and Porter Company by consulting firms.

Acknowledgments

The authors thank the Fischer and Porter Company for their cooperation, access to existing wells, and permission to drill and test additional wells on their property; William Gross was especially helpful. The authors also thank the Hatboro Water Authority for data, access to their wells, and for pumping well MG-946; Robert Todd and Joseph Gallagher were especially helpful.

METHODS OF STUDY

Borehole Geophysical Logs

Caliper, natural-gamma, single-point-resistance, fluid-resistivity, and fluid-temperature logs were run in 5 existing boreholes onsite, 2 existing boreholes offsite, and 13 boreholes and 3 coreholes drilled for this investigation (fig. 2). Data for wells and boreholes are given in table 1.

Caliper Logs

Caliper logs provide a continuous record of average borehole diameter, which is related to fractures, lithology, and drilling technique. The caliper tool is calibrated at land surface after each log is run. Caliper logs were used to help correlate lithostratigraphy, identify fractures and possible water-bearing openings, and qualitatively correct other geophysical logs for changes in borehole diameter. Correlation of caliper logs with single-point-resistance, fluid-resistance, and fluid-temperature logs was used to identify fractures and water-producing and water-receiving openings.

Natural-Gamma Logs

Natural-gamma logs, also called gamma-ray logs, record the natural-gamma radiation emitted from rocks penetrated by the borehole. Gamma radiation can be measured through casing, but the gamma response is dampened. Uranium-238, thorium-232, and the progeny of their decay series and potassium-40 are the most common emitters of natural-gamma radiation. These radioactive elements may be concentrated in clay by adsorption and ion exchange; therefore, fine-grained sedimentary rocks (siltstone units) usually emit more gamma radiation than do coarse-grained sedimentary rocks (sandstone units). Natural-gamma logs were used to differentiate between sandstone and siltstone units and to correlate lithostratigraphy between boreholes.

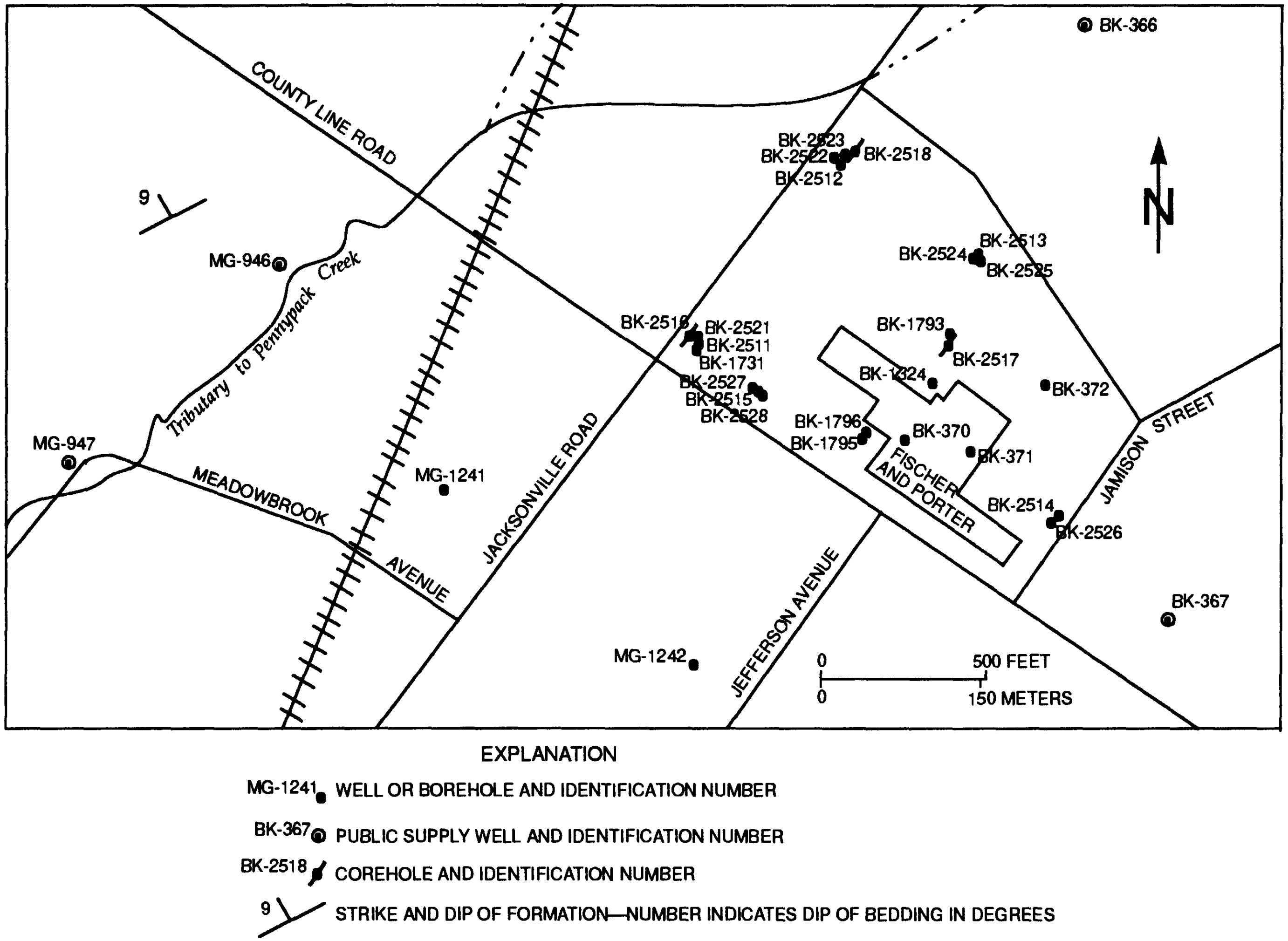


Figure 2. Location of wells and boreholes at the Fischer and Porter Site and vicinity, Warminster, Pa.

Table 1. *Record of wells and boreholes, Fischer and Porter Site, Warminster, Pa.*

[USGS, U.S. Geological Survey; OH, open-hole construction; S, PVC screen; TOC, top of casing; M, monitor well; P, active public-supply well; T, Fischer and Porter treatment system extraction well; X, destroyed; U, unused public- supply well; --, no data]

USGS identi-fication number	Owner and owner identification number	Year drilled	Depth drilled (feet)	Casing length (feet)	Casing diameter (inches)	Open interval (feet below land surface)	Elevation of land surface (feet above sea level)	Use of well
BK-366	Warminster Heights Development Corporation WH-1	--	300	40	8	40-300 OH	280	P
BK-367	Warminster Heights Development Corporation WH-2	1943	300	56	8	56-300 OH	300	P
BK-370	Fischer and Porter Company FP-2	1940	190	15	6	15-190 OH	296.79 TOC	T
BK-371	Fischer and Porter Company FP-1	1948	474	--	8	--	305.39 TOC	T
BK-372	Fischer and Porter Company FP-3	1952	601	49.5	8	--	309.48	X
BK-1324	Fischer and Porter Company FP-7	1980	300	19	6	21.4-300 OH	300.73	T
BK-1731	U.S. Environmental Protection Agency	1991	300	47	6	47-65 OH	282.71	M
BK-1793	Fischer and Porter Company FP-5	1980	40	23.4	6	23.4-40 OH	295.06	M
BK-1795	Fischer and Porter Company FP-8	1980	54	23	6	23-31 OH	302.52	M
BK-1796	Fischer and Porter Company FP-12	1985	146	78	6	78-146 OH	302.82	M
BK-2511	U.S. Environmental Protection Agency	1993	352	146	8 steel 4 PVC	300-325 S	281.38	M
BK-2512	U.S. Environmental Protection Agency	1993	303	5 87	12 steel 8 steel 4 PVC	237-257 S	271.16	M
BK-2513	U.S. Environmental Protection Agency	1993	301	5 126	12 steel 8 steel 4 PVC	255-275 S	285.37	M
BK-2514	U.S. Environmental Protection Agency	1993	292	37	8 steel 4 PVC	217-252 S	314.67	M
BK-2515	U.S. Environmental Protection Agency	1993	310	108	8 steel 4 PVC	285-305 S	291.50	M
BK-2516	U.S. Environmental Protection Agency	1993	262	15	4	--	281.98	X
BK-2517	U.S. Environmental Protection Agency	1993	277	20	4	--	295.48	X
BK-2518	U.S. Environmental Protection Agency	1993	274.5	10	4	--	271.36	X
BK-2521	U.S. Environmental Protection Agency	1993	229	63	8 steel 4 PVC	190-210 S	281.99	M
BK-2522	U.S. Environmental Protection Agency	1993	159	21	8 steel 4 PVC	132-157 S	271.62	M
BK-2523	U.S. Environmental Protection Agency	1993	53	21	8 steel 4 PVC	23.5-43.5 S	271.21	M
BK-2524	U.S. Environmental Protection Agency	1993	158	30	8 steel 4 PVC	115-135 S	285.13	M
BK-2525	U.S. Environmental Protection Agency	1993	80	10 30	12 steel 8 steel 4 PVC	31-51 S	285.41	M
BK-2526	U.S. Environmental Protection Agency	1993	79	21	8 steel 4 PVC	50-70 S	315.40	M
BK-2527	U.S. Environmental Protection Agency	1993	201	21	8 steel 4 PVC	157-187 S	292.26	M
BK-2528	U.S. Environmental Protection Agency	1993	53.5	21	8 steel 4 PVC	25-45 S	292.92	M
MG-946	Hatboro Borough Authority H-16	1969	300	30 40	14 10	40-300 OH	240	U
MG-947	Hatboro Borough Authority H-17	1969	300	31 42	14 10	42-300 OH	245	P
MG-1241	Fischer and Porter Company FP-13	--	174	21	6	21-70.5 OH	270	M
MG-1242	Fischer and Porter Company FP-14	--	177	19	6	19-135 OH	302	M

Single-Point-Resistance Logs

Single-point-resistance logs record the electrical resistance between the borehole and an electrical ground at land surface. In general, resistance increases with grain size and decreases with borehole diameter, density of water-bearing openings, and increasing dissolved-solids concentration of borehole fluid (Keys, 1990). A fluid-filled borehole is required for single-point-resistance logs, and they are run only for the saturated part of the formation below the casing. Single-point-resistance logs were used to correlate lithostratigraphy and sometimes helped to identify the location of water-bearing openings because a fluid-filled fracture is less resistive than solid rock.

Fluid-Resistivity Logs

Fluid-resistivity logs measure the electrical resistance of fluid in the borehole. Resistivity is the reciprocal of fluid conductivity, and fluid-resistivity logs reflect changes in the dissolved-solids concentration of the borehole fluid. Fluid-resistivity logs were used to identify water-producing and water-receiving openings and to determine intervals of vertical-borehole flow. Water-producing and water-receiving openings usually were identified by sharp changes in resistivity, and intervals of borehole flow were identified by a low resistivity gradient between water-producing and water-receiving openings.

Fluid-Temperature Logs

Fluid-temperature logs provide a continuous record of the temperature of the fluid in the borehole. Fluid-temperature logs were used to identify water-producing and water-receiving openings and to determine intervals of vertical borehole flow. Water-producing and water-receiving openings usually were identified by sharp changes in temperature, and intervals of vertical borehole flow were identified by little or no temperature gradient. In the study area, fluid-temperature logs from boreholes with no flow generally show a decrease in fluid temperature with depth caused by surface heating in the upper part of the borehole and an increase in fluid temperature with depth as a function of the geothermal gradient in the lower part of the borehole.

Measurement of Borehole Flow

Upon completion of geophysical logging, the suite of logs was evaluated in the field to choose zones of potential borehole flow. The direction and rate of borehole-fluid movement was determined by injecting a slug of high-conductance fluid at a specific depth in a borehole and monitoring the movement of the slug with the fluid-resistivity tool. This is the brine-tracing method described by Patten and Bennett (1962). The lower limit of flow measurement is about 0.5 gal/min in a 6-in. diameter borehole. Borehole flow was calculated by

$$Q = 7.481\, V \pi r^2, \tag{1}$$

where Q is borehole flow, in gallons per minute;
V is the rate of vertical borehole-fluid movement, in feet per minute; and
r is the borehole radius, in feet.

Figure 3 shows the movement of a slug of high-conductance fluid injected 80 ft below land surface (bls) in borehole BK-2514. The slug moved downward at 3.2 ft/min, which is equal to a flow rate of 8.3 gal/min in an 8-in. diameter borehole.

Borehole Television Surveys

Borehole television surveys were conducted by lowering a waterproof video camera with a very wide angle lens down the borehole and recording the results on videotape. Borehole television surveys were used to aid interpretation of geophysical logs and to locate smooth sections of borehole to set straddle packers for the aquifer-isolation tests.

Location of Deep Exploratory Boreholes and Coreholes

Exploratory boreholes generally were drilled between public-supply wells and the main area of contamination (in the vicinity of well BK-1324). Ground water in the Stockton Formation moves preferentially in response to the pumping of wells. Corehole locations were chosen to provide geological data to aid understanding of the aquifer-system framework.

Borehole BK-2511 was drilled between the main area of contamination and Hatboro public-supply well MG-946 (H-16). Borehole BK-2512 was drilled downdip of the main area of contamination. Borehole BK-2513 was drilled between the main area of contamination and Warminster Heights Development Corporation public-supply well BK-366 (WH-1). Borehole BK-2514 was drilled between the main area of contamination

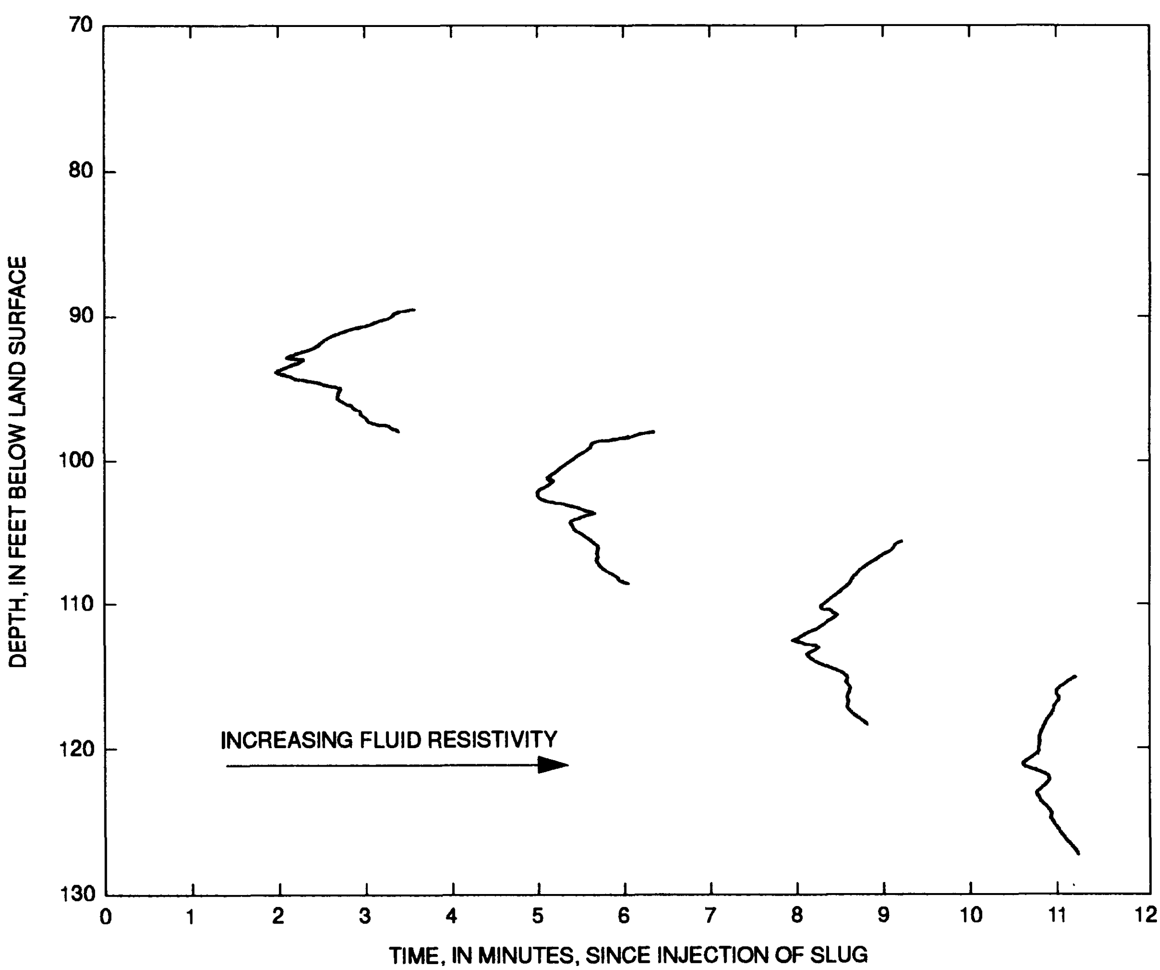


Figure 3. Movement of a high-conductance fluid slug injected in borehole BK-2514 at 80 feet below land surface, Fischer and Porter Site, Warminster, Pa.

and Warminster Heights Development Corporation public-supply well BK-367 (WH-2). Borehole BK-2515 was drilled between the main area of contamination and Hatboro public-supply well MG-947 (H-17).

Three continuous rock cores were collected at the Fischer and Porter Site. Corehole BK-2517 was located in the main contaminant area to provide a continuous record of site geology at that location. Corehole BK-2518 was located downdip from the main contaminant area. Corehole BK-2516 was located along strike from the main contaminant area. The cores provide a continuous record of site geology and reference points to correlate geophysical logs to lithology. Geologic descriptions of the cores are given in appendix 2.

Monitor Well Drilling and Construction

Thirteen 8-in. diameter boreholes were drilled for this investigation by use of an air rotary drilling rig. Five deep exploratory boreholes (BK-2511, BK-2512, BK-2513, BK-2514, and BK-2515) were initially drilled (fig. 2). After geophysical logging and aquifer-isolation tests were completed in these boreholes, four intermediate-depth boreholes (BK-2521, BK-2522, BK-2524, and BK-2527) and four shallow boreholes (BK-2523, BK-2525, BK-2526, and BK-2528) were drilled near the deep boreholes in a cluster arrangement to screen the aquifer at different depths at the same location (fig. 2).

Boreholes were cased with 8-in. diameter steel casing set into competent bedrock. Boreholes BK-2512, BK-2513, and BK-2525 required an outer 12-in. diameter steel casing to prevent hole collapse while setting 8-in. diameter casing. A small quantity of potable water was added during drilling to prevent mudcaking if formation water production was insufficient. The quantity of water produced from each water-bearing zone during drilling was estimated. Water was blown from the borehole by use of compressed air, and the yield was measured by stopwatch and bucket after completion of drilling. Each borehole was developed by pumping with air pressure from the drilling rig for at least 30 minutes following completion of drilling. During drilling of the exploratory boreholes, composite samples of drill cuttings were collected for each 5-ft interval. Geologic logs for the exploratory boreholes are given in appendix 3.

Each borehole was constructed as a screened monitor well in the following manner. An interval to be screened was selected on the basis of drilling data, borehole geophysical logs, borehole television surveys, and aquifer-isolation test hydraulic and chemical data. Screened intervals for each borehole and the reasons why the intervals were chosen are listed in table 2. The borehole was backfilled with bentonite to the bottom of the interval selected for screening. One to 2 ft of coarse sand was placed on top of the bentonite, and a 4-in. diameter Schedule 40 polyvinyl chloride (PVC) flush joint threaded 0.020-in. well screen with an end cap on the lower end and a 4-in. diameter Schedule 40 PVC flush joint threaded inner casing was installed in the center of each borehole. A filter pack consisting of coarse sand was placed from the top of the bentonite backfill to 2 ft above the top of the well screen in the annulus between the 8-in. diameter borehole and the 4-in. diameter PVC well screen. A bentonite seal was installed above the filter pack in the annulus, and the annulus was grouted to land surface with a 90-percent cement grout and 10-percent bentonite mixture pumped down the annulus with a tremie pipe.

Boreholes BK-1731, BK-1793, BK-1795, and BK-1796 were not reconstructed as monitor wells. The bottom of borehole BK-1731 was sealed with a 5-ft thick bentonite plug to prevent downward leakage, making it a 65-ft deep borehole of open-hole construction. Boreholes MG-1241 and MG-1242 were backfilled with bentonite on the basis of borehole geophysical logs and borehole television surveys to eliminate borehole flow and the cross-connection between water-bearing zones. Borehole MG-1241 was backfilled to 70.5 ft bls, and borehole MG-1242 was backfilled to 135 ft bls.

After completion of well construction, the elevation of the top of casing and (or) land surface of all wells installed by the USGS was surveyed. Elevations listed in table 1 are relative to the elevation of the top of casing of borehole BK-1793. The elevation for borehole BK-1793 was taken from table 29 of SMC-Martin, Inc. (1980). The SMC-Martin, Inc. report does not explain what datum was used as the basis for determining elevations. However, by using borehole BK-1793 as a reference point, water-level elevations measured for this study are comparable to those in SMC-Martin, Inc. (1980) and BCM, Inc. (1986).

The three coreholes were drilled by a hydraulic rotary drilling rig equipped with a wireline corebarrel retrieval system. Core was obtained in 10-ft lengths. The orientation was marked on the core, the recovery rate was noted, and the core was placed in marked boxes. After geophysical logging of the coreholes, the casings were removed, and the coreholes were abandoned by filling them with a 90-percent cement grout and 10-percent bentonite mixture to land surface.

Table 2. *Intervals screened in monitor wells, Fischer and Porter Site, Warminster, Pa.*

[USGS, U.S. Geological Survey, <, greater than; >, less than; gal/min, gallons per minute; (gal/min)/ft, gallons per minute per foot; ft bls, feet below land surface]

USGS well number	Depth drilled	Well yield	Screened interval	Reason for selection of screened interval
BK-2511	352	15	300-325	Deep 5 gal/min water-bearing zone
BK-2512	303	>150	237-257	Deep water-bearing zone with yield >70 gal/min and specific capacity of 8.7 (gal/min)/ft. The geophysical logs and borehole-flow measurements indicate that this zone is a water-receiving zone.
BK-2513	301	100	255-275	Deep 20 gal/min water-bearing zone
BK-2514	292	35	217-252	Deep 30 gal/min water-bearing zone. Geophysical logs and borehole-flow measurements indicated that the fractures at 225 and 250 ft bls are water-receiving zones.
BK-2515	310	15	285-305	Deep 12 gal/min water-bearing zone
BK-2521	229	20	190-210	Intermediate-depth water-bearing zone at 198-200 ft bls (see caliper log in appendix 1, fig. 21)
BK-2522	159	60	132-157	Intermediate-depth water-bearing zone at 146 ft bls (see caliper log in appendix 1, fig. 22). The geophysical logs indicate that this fracture probably is a water-receiving zone.
BK-2523	53	10	23.5-43.5	Shallow water-bearing zone from 30 to 42.5 ft bls (see caliper log in appendix 1, fig. 23)
BK-2524	158	>80	115-135	Intermediate-depth water-bearing zone at 123-129.5 ft bls (see caliper log in appendix 1, fig. 24)
BK-2525	80	4	31-51	Shallow water-bearing zone at 34-35 ft bls (see caliper log in appendix 1, fig. 25).
BK-2526	79	4	50-70	Shallow water-bearing zones at 55-57 and 60 ft bls (see caliper log in appendix 1, fig. 26)
BK-2527	201	5	157-187	Intermediate-depth water-bearing zone at 163 ft bls (see caliper log in appendix 1, fig. 27)
BK-2528	53.5	<1	25-45	Shallow water-bearing zone

Aquifer-Isolation Tests

A straddle packer assembly was used to isolate discrete intervals in the five deep exploratory boreholes (BK-2511, BK-2512, BK-2513, BK-2514, BK-2515) and one offsite borehole (MG-1242) to determine depth- discrete specific capacity and to obtain depth-discrete water samples. The packer assembly consisted of two 7.2-ft long inflatable packers separated by 20.8 ft of perforated pipe (fig. 4).

For the onsite boreholes, the distance from the center of the upper packer to the center of the lower packer was 28 ft. For the offsite borehole (MG-1242), the distance from the center of the upper packer to the center of the lower packer was 25 ft. Packer settings given in tables in this report are from the center of the upper packer to the center of the lower packer. The transducer in the isolated zone was 16.25 ft below the center of the upper packer. The transducer below the packer string was 3.88 ft below the center of the lower packer.

The packer assembly was lowered to the selected depth in the borehole with 2-in. diameter drill-stem pipe, and the two packers were inflated against the borehole wall, isolating the selected interval. Inflation of the packers created three zones--an isolated interval between the inflated packers, an interval above the upper packer, and an interval below the lower packer (fig. 4). Two measures were taken to ensure that the isolated interval was hydraulically isolated from the overlying and underlying intervals. First, packer inflation pressures were monitored continuously. They remained constant throughout each test. Second, water levels were monitored in all three intervals.

Generally, the lower packer was inflated first, and the upper packer was inflated after water levels above and below the lower packer had stabilized. After both packers were inflated, water levels in each zone were allowed to reach static levels. Water levels were measured by transducers or electric measuring tape. When water levels stabilized, pumping began. However, water levels in some zones did not stabilize because of interference caused by pumping of nearby public-supply wells.

Ground-Water Sampling

Water samples to be analyzed for VOC's were pumped from each isolated interval with a submersible pump set in the isolated interval through the drill-stem pipe (fig. 4). Before collecting a water sample, each isolated zone was pumped until at least three volumes were purged from the isolated interval or until successive temperature and specific-conductance measurements varied by less than 10 percent. The volume of water pumped from each isolated interval was measured. The samples were analyzed at the USGS New Jersey District laboratory in Trenton with a gas chromatograph using a photoionization detector and an electrolytic conductivity detector in series. The analytical method used is a modification of USEPA methods 601 and 602 and is described by Kammer and Gibbs (1989). The detection level is 0.8 μg/L for samples run by the USGS New Jersey District laboratory. A duplicate sample from each borehole was analyzed by the USGS National Water Quality Laboratory in Arvada, Colo. The detection level for these samples is 0.2 μg/L. Analytical data for each sample are given in appendix 5.

Water-Level Measurements

Water levels in each onsite monitor well or borehole were measured with a continuous water-level recorder utilizing a strip chart. The chart drum was connected by a gear assembly to a float wheel. A float and counter weight assembly on beaded cable in the well rose and fell with the water level. The changes were recorded as a continuous graph on the chart. Hydrographs are presented in appendix 4.

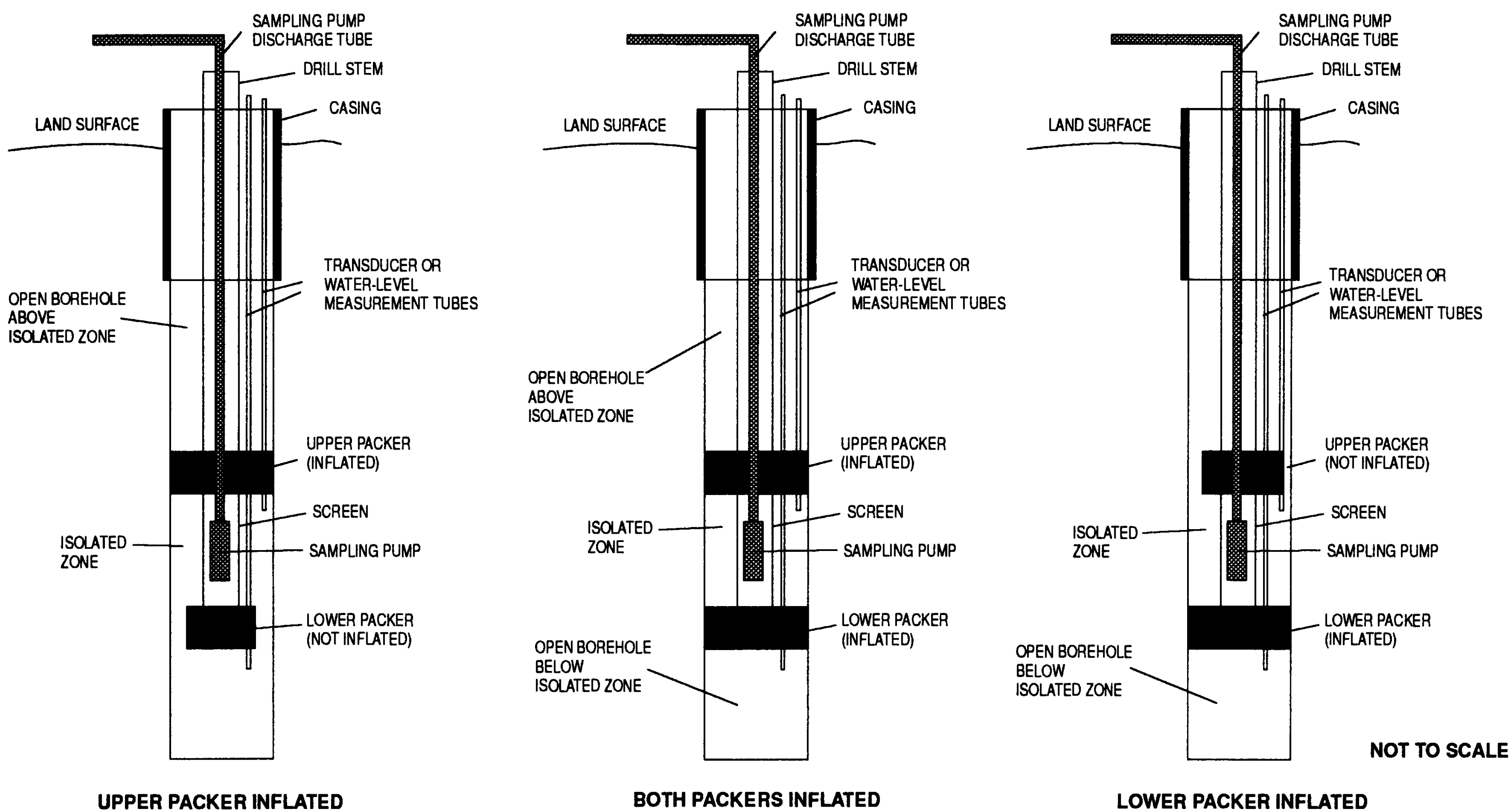


Figure 4. Generalized sketch of straddle-packer assembly and sampling pump in a borehole.

GEOLOGY AND GEOHYDROLOGY

Geology

The Fischer and Porter Site and surrounding area are underlain by sedimentary rocks of the Stockton Formation of Upper Triassic age. The Stockton Formation is the basal unit of the Newark Supergroup rocks in the Triassic-Jurassic Newark Basin. This basin contains 16,000 to 20,000 ft of nonmarine sedimentary rocks. The Newark Basin is approximately 140 mi long and 32 mi wide and is the largest of the 13 major exposed Triassic-Jurassic rift basins stretching from Nova Scotia to South Carolina. Sedimentation was the result of infilling of a rift basin formed during the initial stages of continental breakup (Turner-Peterson and Smoot, 1985, p. 10). Sedimentation in the Newark Basin began with an influx of arkosic detritus from uplifted crystalline rocks to the south not far from the present day southern basin margin (Glaeser, 1966, p. 26). One of the characteristics of the Stockton is the thick-bedded to locally massive arkosic sandstones. The sediments were deposited on folded and deeply eroded Precambrian and Paleozoic rocks. The basin filled with thousands of feet of sediments over a period of about 45 million years.

The Stockton Formation is subdivided into three units called the lower arkose, middle arkose, and upper shale members by Rima and others (1962). The rocks that underlie the site belong to the middle arkose member. The Stockton Formation is 6,000 ft thick near the Bucks and Montgomery County boundary; the middle arkose member accounts for 70 percent of its thickness. In the vicinity of the Fischer and Porter Site, the Stockton Formation strikes approximately N. 65°E. and dips approximately 9°NW. (Sloto and others, 1992). The rocks are chiefly arkosic sandstone and siltstone. Quartz and feldspar are the dominant minerals.

The Stockton Formation includes alluvial fans, fluvial and lacustrine sandstones, and fluvial and near-shore lacustrine siltstones (Turner-Peterson and Smoot, 1985). Near the southern margin, the Stockton contains laterally coalescing alluvial fans deposited by well-established streams. Sediments in thick, poorly defined upward fining cycles possibly were deposited by large, perennial, meandering rivers.

Three continuous rock cores were collected at the Fischer and Porter Site to provide a continuous record of site geology and reference points to correlate geophysical logs to lithology. Rock cores from coreholes BK-2516, BK-2517, and BK-2518 extend from near land surface to a depth of 262, 277, and 274.5 ft bls, respectively. Geologic descriptions of the cores are given in appendix 2. On the basis of visual identification of the cores, eight lithologies were identified. They are:

(1) reddish-brown or dark purple-gray, sometimes micaceous siltstone,

(2) pinkish-gray, silty, fine-grained sandstone,

(3) dark gray, very fine-grained sandstone,

(4) gray, fine-grained sandstone,

(5) gray, poorly sorted, fine- to medium-grained sandstone,

(6) gray, medium-grained sandstone,

(7) light gray, medium- to coarse-grained sandstone, and

(8) light gray or brown conglomerate.

Each lithology has a certain amount of variability of percent silt, percent organic content (lignite), amount of disseminated iron oxides in pore spaces, number of stylolites, and frequency of fractures. Organic material is accompanied by a localized abundance of sulfide minerals. The majority of fractures are either filled or partly lined with calcite or kaolinite (in the siltstone units). Some fractures are coated with a light green, soapy textured mineral identified by X-ray diffraction analysis as muscovite.

The three rock cores show many gradational lithologic units consistent with the fluvial-deltaic depositional environment of the Stockton Formation. A few transitional lithologic units are characterized as a combination of two lithologic units. Transitional lithologic units appear banded or randomly mixed from units above and below. Some portions of the rock cores show bedding structures that dip up to 30° from the horizontal of the core orientation. Stylolites also appear with similar dip angles.

The rock cores were compared to the single-point-resistance, natural-gamma, and caliper logs of each corehole. The labels on plates 1 and 2 and the correlation between lithologic units and the response seen in the geophysical logs (pl. 1 and 2) are:

(S) siltstone—elevated natural-gamma and weak single-point-resistance response

(SS) silty, fine-grained sandstone—fluctuating natural-gamma and moderate single-point-resistance response

(VF) very fine-grained sandstone and (F) fine-grained sandstone—weak natural-gamma and strong single-point-resistance response

(M) poorly sorted, fine- to medium-grained sandstone and medium-grained sandstone—weak natural-gamma and moderate single-point-resistance response (less than that of the fine-grained sandstone)

(C) medium- to coarse-grained sandstone and (CG) conglomerate—weak natural-gamma and moderate to strong single-point-resistance response (weaker than that of the fine-grained sandstone and stronger than that of the medium-grained sandstone)

A few poorly sorted, coarse-grained sandstone and conglomerate units in the rock cores have a moderate natural-gamma response similar to the response of the siltstone units, possibly because of a higher muscovite content.

The difference between some units is not discernible on the geophysical logs when the beds are thin and fall between two units with very different single-point-resistance responses. Thin beds, generally less than 5 ft thick, could not be correlated from the coreholes to adjacent boreholes. These thin units either pinch out or grade into other units.

Geophysical logs are not available for wells BK-366 and BK-367, which are active public-supply wells; therefore, driller's logs from these wells were used for correlation. The driller's logs for wells BK-366 and BK-367 are from USGS files. The entire section penetrated by well MG-946 is stratigraphically above the strata underlying the Fischer and Porter Site.

The number of lithologic units in the three cores was reduced by redefining lithologic boundaries on the basis of single-point-resistance-log response instead of megascopic textural descriptions alone. In addition, the difference between some units is difficult to discern from the geophysical logs, especially for very similar lithologic units, such as medium-grained sandstone and coarse-grained sandstone or when the beds are thin and fall between two units with very different electrical responses. Color variations are not consistently reflected by the geophysical logs, and color is not considered a diagnostic feature. Considering the observations above, some lithostratigraphic correlations across the site may either misidentify or miss a unit.

In the core from corehole BK-2516, 48 lithostratigraphic units were identified (appendix 1, table 1). On the basis of the correlation between the core and the geophysical logs, 25 lithostratigraphic units were easily discernible. In the core from corehole BK-2517, 62 lithostratigraphic units were identified (appendix 1, table 2). On the basis of the correlation between the core and the geophysical logs, 24 lithostratigraphic units were easily discernible. Abundant fractures near the land surface interfere with the geophysical response of a fine-grained sandstone unit. In the core from corehole BK-2518, 61 lithostratigraphic units were identified to a depth of 209 ft bls; and 81 units were identified to a depth of 274.5 ft bls (appendix 1, table 3). The core extends to 274.5 ft bls, but geophysical logs were run only to a depth of 209 ft bls because of collapse of the hole. On the basis of the correlation between the core and the geophysical logs, 21 lithostratigraphic units were easily discernible.

Lithostratigraphy

The lithostratigraphy of the Fischer and Porter Site is shown on plates 1 and 2, which show the correlation of borehole geophysical logs from one rock core and eight boreholes and wells at and near the site. Plate 1 shows the interpreted lithostratigraphic correlation of geophysical logs projected to a line approximately parallel to strike. Section A-A′ extends northeastward from borehole MG-1242 to well BK-366. Plate 2 shows the interpreted lithostratigraphic correlation of geophysical logs projected to a line approximately parallel to dip. Section B-B′ extends eastward from borehole BK-2512 to well BK-367. The upper left corner of the scale to the left of each caliper log is the spatially correct land-surface location of each borehole. Lithostratigraphic interpretations and correlations were based on the relative response of the geophysical logs to lithology. Variations in natural-gamma and single-point-resistance responses correspond to compositional and textural variations within lithologic units. Thin interbeds in each unit also account for some variation in log response.

Because the lithologic units of the Stockton Formation grade, interfinger, and coalesce, none of the units could be used as marker beds within the lithostratigraphic sequence at the site. Therefore, the interpreted lithology of each borehole was initially developed from correlation with rock cores and then extended along strike or dip to the next nearest borehole location to correlate lithostratigraphy. Some lithostratigraphic units correlate above or below the expected projection line, probably because of the lens-like structure characteristic of alluvial-fan environments. Correlations between boreholes generally are consistent with strike and dip but show the thinning and thickening of units across the site. The accuracy of the correlations deteriorate near land surface because of the absence of single-point-resistance measurements and dampened natural-gamma response caused by casing.

Generalized Stratigraphic Model

The site lithostratigraphy presented on plates 1 and 2 was simplified by combining individual lithologic units into generalized sedimentary cycles, which are shown on plate 3. Some siltstone units are continuous under the entire Fischer and Porter Site and can be traced from borehole to borehole. These siltstone units are numbered on plates 1 and 2 (S5, for example). The numbered siltstone units are the top unit of a poorly defined, upward fining sedimentary cycle. These cycles are shown on plate 3 (unit 5, for example). Numbered sedimentary cycles shown on plate 3 correspond to the numbered siltstone units shown on plates 1 and 2; for example, unit 5 is the sedimentary cycle shown on plate 3 capped by siltstone unit S5, which is shown on plate 1. Grouping individual lithologic units into sedimentary cycle units simplifies the geologic framework and more easily permits tracing the lithology from borehole to borehole.

Geohydrology

In the Stockton Formation, the hydrologic system operates within the geologic framework but is somewhat independent of it. Ground water in the weathered zone moves through intergranular openings that have formed as a result of weathering. In some places, permeability of the weathered zone may be poor because of a high percentage of clay derived from weathering of siltstone. Ground water in the unweathered zone mainly moves through a network of interconnecting secondary openings—fractures, bedding planes, and joints. Beds within the Stockton Formation are hydraulically connected by vertical joints that cross each other at various angles. Thus, ground water may move across beds, particularly in the direction of dip, rather than through individual beds.

In general, the sandstone units are the principle water-bearing units, but some of the finer-grained units may contain water-bearing openings. However, because of the softness and fine grain size of the siltstone units, water-bearing openings tend to be clogged. In addition, the soft siltstone beds deform without breaking under stress and, as a result, have lower permeability than the harder sandstone beds, which tend to develop fractures and joints and are more permeable.

Some water-bearing openings may be slightly enlarged by circulating ground water, which has decomposed and disintegrated mineral constituents in the walls of fractures. Primary porosity that may have originally existed has been almost eliminated by compaction and cementation. Some water may move through intergranular openings in the rock below the weathered zone where the cement has been removed and the permeability has increased, but this generally is restricted to a few coarse-grained sandstone and conglomerate beds. Laboratory hydraulic conductivities were run on core sections collected 0.5 mi south of the Fischer and Porter Site. Red siltstone had a hydraulic conductivity of 5.14×10^{-7} ft/d; red, silty, fine-grained sandstone had a hydraulic conductivity of 2.92×10^{-6} ft/d; gray, fine-grained sandstone had a hydraulic conductivity of 1.18×10^{-4} ft/d; and medium- to coarse-grained sandstone (with some cement removed) had a hydraulic conductivity of 0.19 ft/d.

The rocks of the Stockton Formation form a complex, heterogeneous, multiaquifer system. This aquifer system is comprised of a series of gently dipping lithologic units with different hydraulic properties. The ground-water system can be visualized as a series of beds with a relatively high transmissivity separated by beds with a relatively low transmissivity. The beds, a few inches to a few feet thick, act as a series of alternating aquifers and confining or semiconfining units that form a leaky, multiaquifer system. Each bed generally has different hydraulic properties, and permeability commonly differs from one bed to another.

Ground water is unconfined in the shallower part of the aquifer and confined or semiconfined in the deeper part of the aquifer. Under confined conditions, ground water is confined under pressure greater than atmospheric by overlying, less permeable lithologic units and is not free to rise and fall. Differences in the ratio of vertical to horizontal hydraulic conductivity, as well as differences in vertical hydraulic conductivity within and among lithologic units, create confining conditions.

Nearly all deep wells in the Stockton Formation are open to several water-bearing zones and are multiaquifer wells. Each water-bearing zone usually has a different hydraulic head. The hydraulic head in a deep, open-hole well is the composite of the heads in the several water-bearing zones penetrated. This can cause water levels in some wells to be different than water levels in adjacent wells of different depths. Where differences in hydraulic head exist between water-bearing zones, water in the well bore flows under nonpumping conditions in the direction of decreasing head. Water moves downward through the aquifer system in response to this downward head gradient, which is caused in part by the pumping of deep public-supply wells and the Fischer and Porter treatment system extraction wells.

Geohydrology at Existing Boreholes

In September and October of 1992, borehole geophysical logs were run in all existing, nonpumping boreholes, and borehole-flow measurements were made in selected boreholes to (1) locate subsurface fractures; (2) identify, where possible, important water-bearing fractures; (3) identify zones of potential borehole flow; (4) measure direction and rate of natural borehole flow; and (5) aid in characterization of the ground-water-flow system. Figure 2 shows the location of the wells and table 1 provides construction data. Geophysical logs are presented in appendix 1.

BK-372

Borehole BK-372, which was located in a pit inside a quonset hut, was originally drilled to 601 ft bls in 1952 but had collapsed. It was logged to a depth of 442 ft on March 1, 1991, and to a depth of 435 ft on September 8, 1992. The borehole was cased with 10-in. diameter steel casing to 49.5 ft below the quonset hut floor level. The caliper log (appendix 1, figs. 1 and 2) shows major fractures at 56, 65.5, 177, 205, 280, 345.5, 374-388, and 422-436 ft bls and numerous smaller fractures. The fracture zones from 374 to 388 and 422 to 436 ft bls are collapse zones that contributed the material filling the borehole. A partially collapsed zone that reduces the borehole diameter to 4.25 in. is at 63 ft bls. The gamma and single-point- resistance logs show that siltstone units correlate with the collapsed zones shown on the caliper log. Borehole BK-372 was abandoned when it was filled with a cement grout-bentonite mixture by a USEPA contractor in the fall of 1992.

On March 1, 1991, slugs of high-conductance fluid were injected in the borehole at depths of 130, 185, 190, 250, 310, 355, and 400 ft bls. Upward borehole flow of 2.0 gal/min was measured at 400 and 355 ft bls (fig. 5). Upward borehole flow of 0.5 gal/min was measured at 250 ft bls. No flow was measurable at 130, 185, 190, or 310 ft bls. On September 8, 1992, while the Fischer and Porter treatment system wells were shut down, slugs of high-conductance fluid were injected in the borehole at depths of 130, 190, 250, 300, 360, and 400 ft bls. No borehole flow was measurable at any of these depths. The upward flow measured on March 1, 1991, may have been caused by the pumping of the Fischer and Porter treatment system wells.

The suite of geophysical logs run on March 1, 1991, indicates that water enters the borehole from the fracture zone at 422-436 ft bls and moves upward at 2 gal/min to a fracture at 345.5 ft bls where it exits the borehole. Water also enters the borehole from a fracture at 280 ft bls and moves upward at 0.5 gal/min to a fracture at 205 ft bls where it exits the borehole. A zone of no flow is present between the two zones of flow.

BK-1324

Well BK-1324, which is an extraction well for the Fischer and Porter treatment system, was logged to a depth of 299 ft on September 20, 1990, when the pump was removed from the well. The caliper log (appendix 1, fig. 3) shows that the well is cased with 19 ft of 6-in. diameter casing. The caliper log shows minor fractures at 25.5 and 40.5 ft bls. The fluid-resistivity and fluid-temperature logs do not indicate borehole flow. Borehole-flow measurements were not made because of a considerable quantity of free product floating on the water surface.

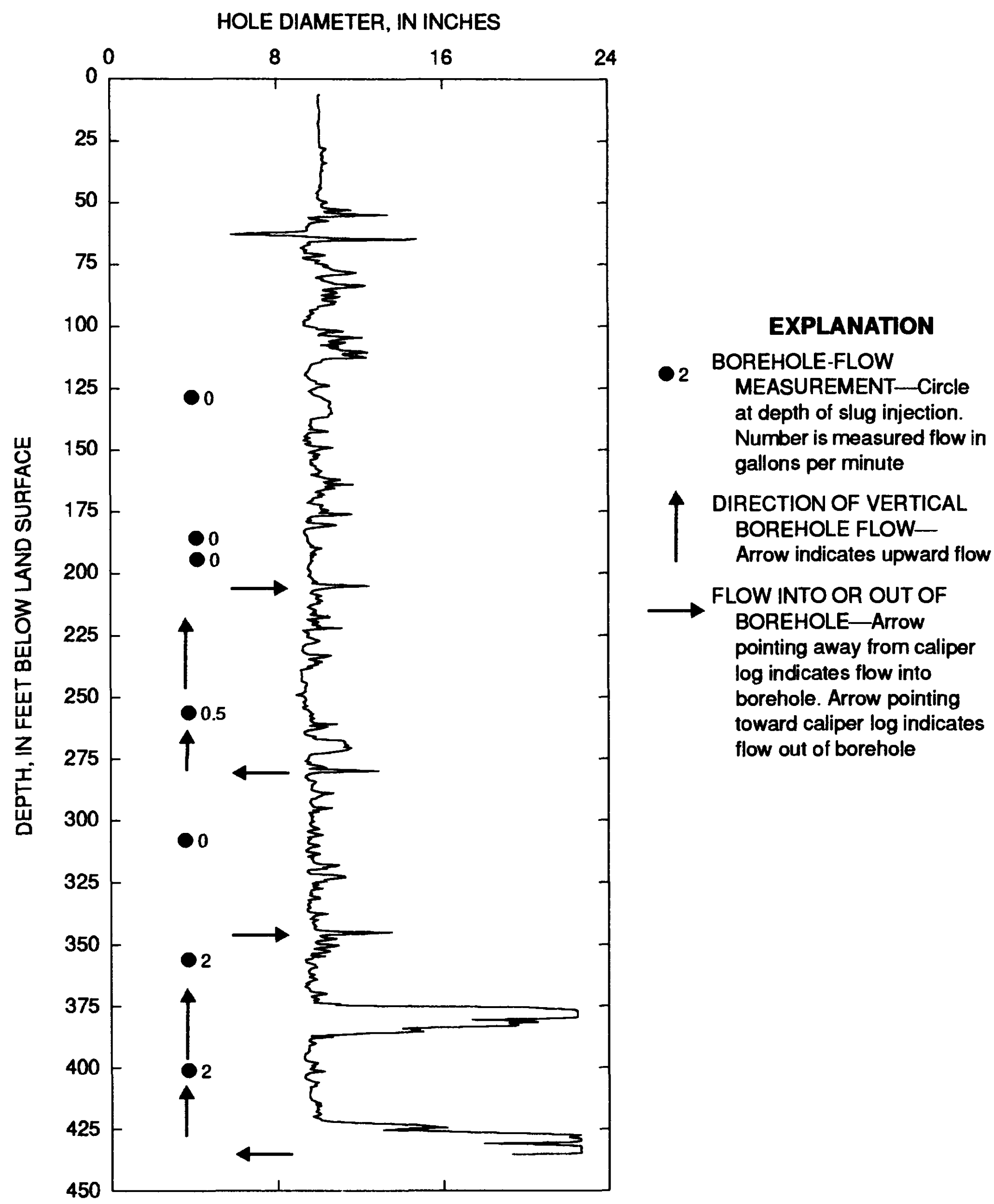


Figure 5. Caliper log from borehole BK-372 showing borehole-flow measurements, Fischer and Porter Site, Warminster, Pa., March 1, 1991.

BK-1731

Borehole BK-1731 was drilled to 300 ft bls on May 22-24, 1991. The borehole collapsed. It was logged to a depth of 140 ft on May 31, 1991, and to a depth of 69 ft on September 14, 1992. The borehole is cased with 6-in. diameter steel casing to 47 ft bls. The caliper log (appendix 1, figs. 4 and 5) shows major fractures at 47.5, 59, 78.5, 88-89, and 139-140 ft bls. The natural-gamma log shows a contact between a sandstone unit (from the bottom of the casing to 59 ft bls) and a siltstone unit (below 59 ft bls) at 59 ft bls that correlates with a fracture shown on the caliper log. On September 14, 1992, a slug of high-conductance fluid was injected in the borehole at 55 ft bls while the Fischer and Porter treatment system wells were shut down; no vertical movement was measurable.

BK-1795

Borehole BK-1795 was originally drilled to 54 ft bls on February 7, 1980. It was logged to a depth of 31 ft on September 14, 1992 (appendix 1, fig. 6). The borehole is cased to 23 ft bls with 6-in. diameter steel casing. The borehole was dry when logged; therefore, only a caliper and natural-gamma log were run.

BK-1796

Borehole BK-1796 was logged to a depth of 146 ft on September 14, 1992, while the Fischer and Porter treatment system wells were shut down and on September 28, 1992, when the Fischer and Porter treatment system wells were pumping (appendix 1, figs. 7 and 8). The borehole is cased with 6-in. diameter steel casing to 78 ft bls. The caliper log shows minor fractures at 89.5, 96, 98, 107-109, 113, 121, and 143-144 ft bls.

The fluid-resistivity and fluid-temperature logs did not indicate borehole flow. On September 28, the water level in borehole BK-1796 was 6.39 ft lower than on September 14 despite heavy rains 2 days prior to logging. The decrease in water level probably was caused by the pumping of the Fischer and Porter treatment system wells. The fluid-resistivity log run on September 28 shows a similar pattern to that run on September 14. However, total dissolved solids of the borehole fluid on September 28 was half of that measured on September 14, indicating recharge to the borehole. On September 28, 1992, a slug of high-conductance fluid was injected in the borehole at a depth of 110 ft bls while the treatment system wells were pumping; no vertical movement was measurable.

MG-1241

Borehole MG-1241 was logged to a depth of 174 ft. The borehole is cased with 6-in. diameter steel casing to 21 ft bls. The caliper log (appendix 1, figs. 9 and 10) shows a major fracture at 91 ft bls and numerous smaller fractures.

The fluid-resistivity log run on December 7, 1990, shows breaks in slope at 54, 155, and 168 ft bls. Fluid resistivity was constant between 54 and 155 ft bls, indicating a potential zone of borehole flow. The fluid-resistivity log run on September 9, 1992, shows breaks in slope at 75 and 160 ft bls. The fluid-temperature log run on December 7, 1990, shows a low gradient between 39 and 137 ft bls and breaks in slope at 137, 148, and 155 ft bls. The fluid-temperature log run on September 9, 1992, shows breaks in slope at 136, 147, and 155 ft bls. The fluid-temperature logs run on December 7, 1990, indicate borehole flow, but the logs are difficult to evaluate because the water level in borehole MG-1241 is greatly affected by the pumping of Hatboro public-supply well MG-947, which is 1,350 ft to the west. Pumping of well MG-947 causes a daily water-level change of approximately 6 to 7 ft in borehole MG-1241 (fig. 6).

On December 7, 1990, slugs of high-conductance fluid were injected in the borehole at 65, 110, 145, and 160 ft bls. At 110 and 145 ft bls, downward flow of less than 0.5 gal/min was observed. No borehole flow was measurable at 65 and 160 ft bls. On September 9, 1992, slugs of high-conductance fluid were injected at the same depths. Measured downward flows were 1.5 gal/min at 110 ft bls, 1.1 gal/min at 145 ft bls, and less than 0.5 gal/min at 65 and 160 ft bls. The differences in flow observed between the measurements made in December of 1990 and September of 1992 may be due, in part, to differences in pumping of well MG-947.

The suite of geophysical logs indicates that a small quantity of water enters the borehole from a fracture at 48 ft bls and moves downward (fig. 7). Additional water enters the borehole from a fracture at 75 ft bls for a total inflow of 1.5 gal/min. The water flows downward and exits the borehole through fractures at 158 and 168 ft bls.

MG-1242

Borehole MG-1242 was logged to a depth of 177 ft. The borehole is cased with 6-in. diameter steel casing to 19 ft bls. The caliper log (appendix 1, figs. 11 and 12) shows major fractures at 24, 70, and 156 ft bls plus numerous smaller fractures.

The fluid-resistivity log run on December 7, 1990, shows changes in slope at 70 and 82 ft bls, which indicate possible fluid-producing zones. The log shows little gradient between 82 and 171 ft bls, which indicates a zone of borehole flow. The fluid-resistivity log run on September 9, 1992, shows changes in slope at 70, 76, and 172 ft bls. The fluid-temperature log run on December 7, 1990, shows little gradient between 44 and 160 ft bls, which indicates a zone of borehole flow. The fluid-temperature log run on September 9, 1992, shows a change in slope at 169 ft bls and little gradient between 55 and 168 ft bls.

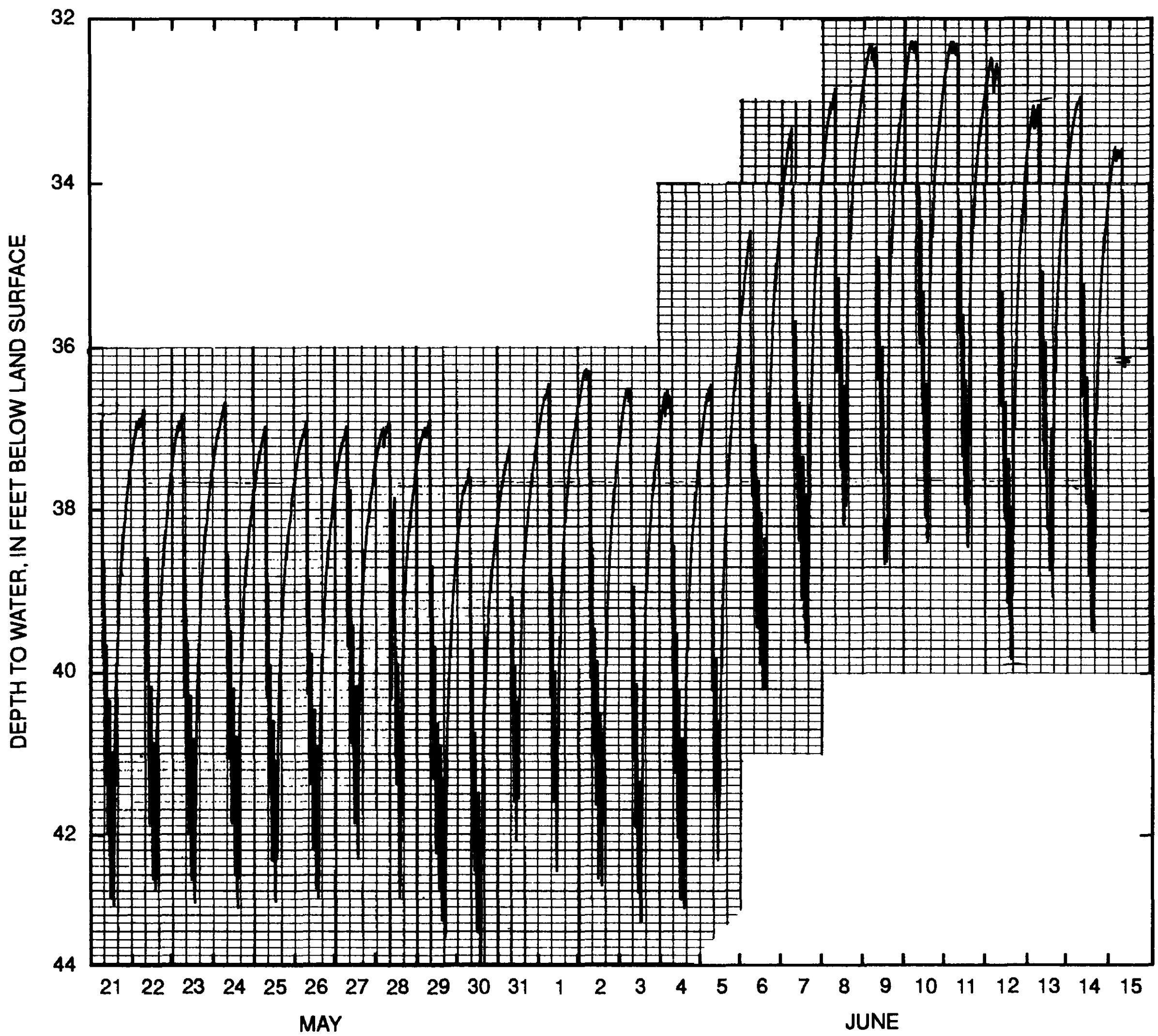


Figure 6. Hydrograph of borehole MG-1241, Hatboro, Pa., May 21 to June 15, 1992.

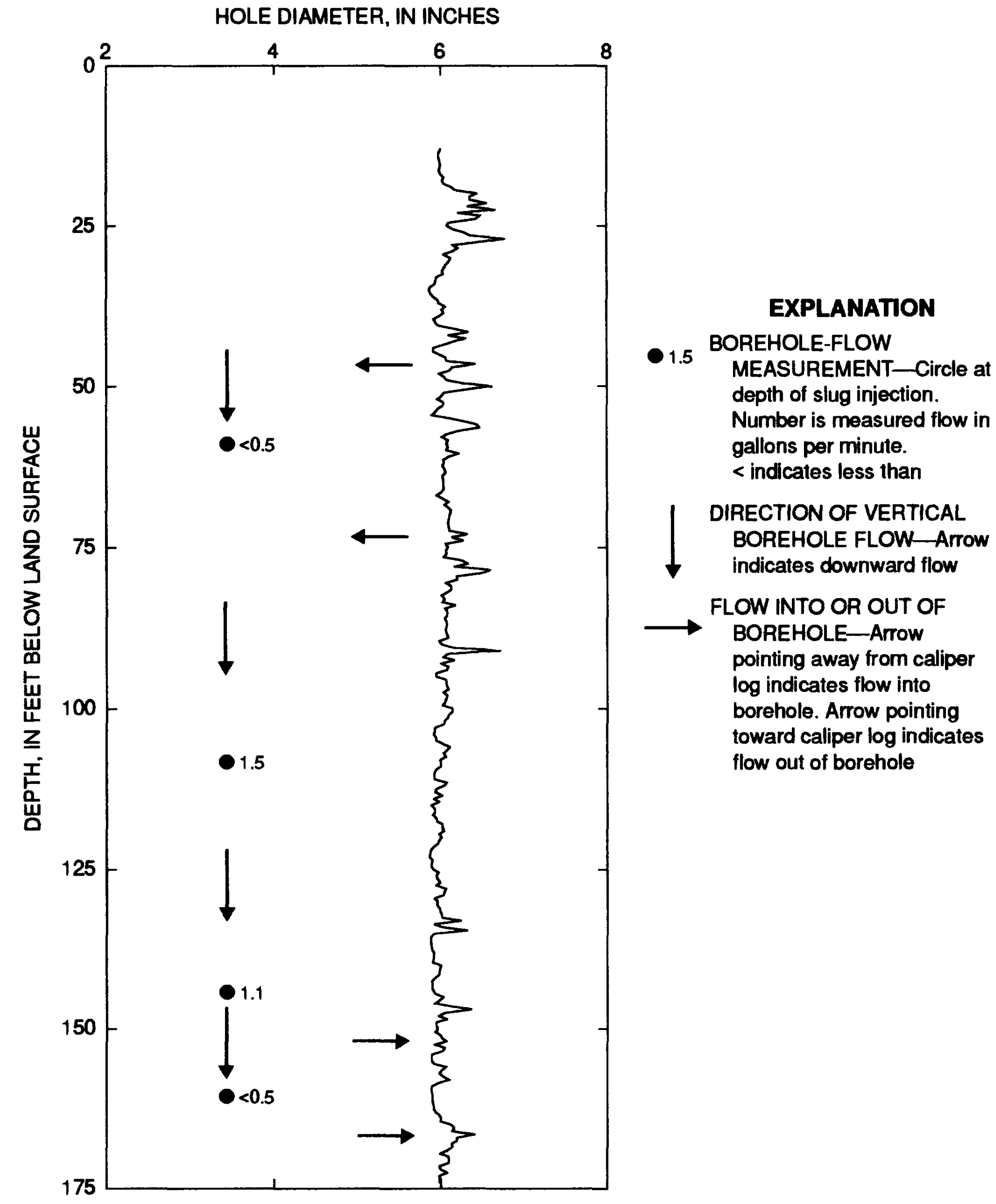


Figure 7. Caliper log from borehole MG-1241 showing borehole-flow measurements, Hatboro, Pa., September 9, 1992.

On December 7, 1990, slugs of high-conductance fluid were injected in the borehole at 60, 90, and 140 ft bls. Downward flow of less than 0.5 gal/min was measured at 90 and 140 ft bls. No borehole flow was measurable at 60 ft bls. On September 9, 1992, slugs of high-conductance fluid were injected in the borehole at 65, 95, and 140 ft bls. Downward flow of less than 0.7 gal/min was measured at 140 ft bls. Slight downward flow was observed, but not quantifiable, at 95 ft bls. No borehole flow was measurable at 65 ft bls.

The suite of geophysical logs indicates that a small quantity of water enters the borehole through fractures at 70, 82, and 129 ft bls and flows downward (fig. 8). Water exits the borehole through a fracture at 156 ft bls.

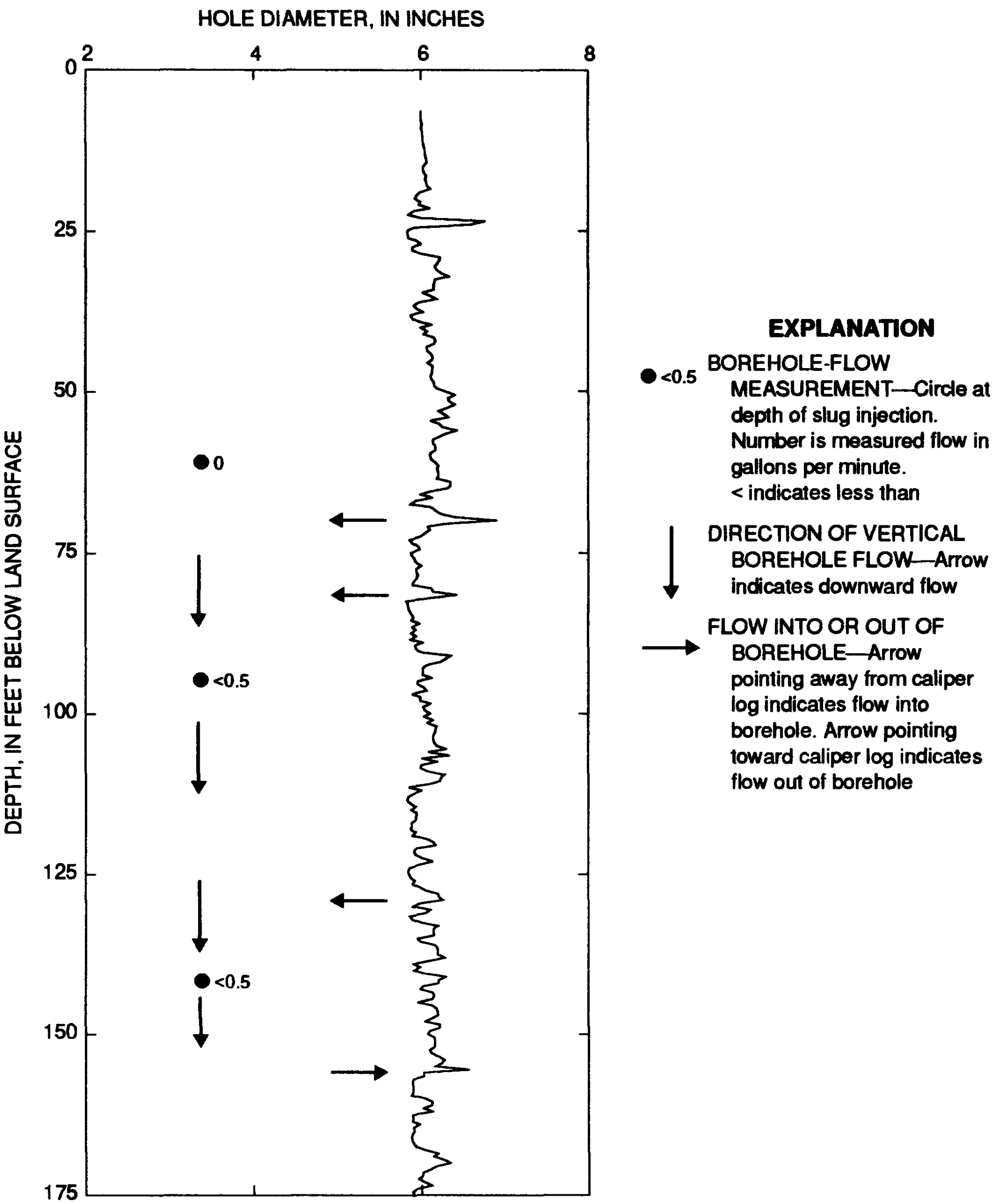


Figure 8. Caliper log from borehole MG-1242 showing borehole-flow measurements, Hatboro, Pa., December 7, 1990.

Geohydrology at Exploratory Boreholes

After completion of drilling, a suite of borehole geophysical logs and a borehole television survey was run in each of the exploratory boreholes.

BK-2511

Borehole BK-2511 was drilled to 352 ft bls and cased with 146 ft of 8-in. diameter steel casing. The yield was 15 gal/min. The driller reported water-bearing zones at 170 ft (5 gal/min), 270 ft (5 gal/min), and 315 ft bls (5 gal/min). A water-bearing zone at 53 ft bls was cased off.

Borehole BK-2511 was logged to a depth of 349 ft. The caliper log (appendix 1, fig. 13) and borehole television survey show numerous minor fractures and several major fractures. Major horizontal fractures are at 253, 312, and 326.5 ft bls. Major vertical fractures are at 147.5 and 278.5-279.5 ft bls. The fluid-resistivity and fluid-temperature logs do not indicate borehole flow.

BK-2512

Borehole BK-2512 was drilled to 303 ft bls and cased with 5 ft of 12-in. diameter steel casing and 87 ft of 8-in. diameter steel casing. The yield was greater than 150 gal/min. The driller reported water-bearing zones at 98 ft (8 gal/min), 106 ft (7 gal/min), 146 ft (20 gal/min), 178 ft (5 gal/min), 189 ft (20 gal/min), 230 ft (20 gal/min), 245 ft (greater than 20 gal/min), and 250 ft bls (greater than 50 gal/min). A water-bearing zone at 54 ft bls was cased off.

The caliper log (appendix 1, fig. 14) and borehole television survey show numerous minor fractures and several major fractures. Minor horizontal fractures are at 96, 101, 148, and 217 ft bls. Major vertical fractures are at 99-101, 242-250, and 259-261 ft bls, and minor vertical fractures are at 105-109, 128-130, 137-142, and 144-146 ft bls. The large vertical fracture at 242-250 ft bls is the dominant feature in the borehole (fig. 9).

The fluid-resistivity log shows a change in slope at 213 and 252 ft bls. These changes in slope coincide with fractures shown on the caliper log at 217 and 242-250 ft bls. The fluid-temperature log shows very little gradient, which indicates borehole flow. Slugs of high-conductance fluid were injected in the borehole at 120, 190, 230, and 270 ft bls. Downward flow at the rate of 1.7 gal/min was measured at 120 ft bls, and downward flow at the rate of 1.3 gal/min was measured at 190 ft bls. No borehole flow was measurable at 230 or 270 ft bls.

The suite of geophysical logs indicates that water enters the borehole through a horizontal fracture at 96 ft bls and moves downward at the rate of 1.7 gal/min (fig. 10). The borehole television survey shows a disruption of downward particle movement at this fracture. About 0.4 gal/min is lost to a fracture at 148 ft bls. Water continues moving down the borehole at 1.3 gal/min to water-receiving fractures at 217 and 242-250 ft bls. The borehole television survey shows a disruption of downward particle movement at the fracture at 217 ft bls.

BK-2513

Borehole BK-2513 was drilled to 301 ft bls and cased with 5 ft of 12-in. diameter steel casing and 126 ft of 8-in. diameter steel casing. The yield was 100 gal/min. The driller reported water-bearing zones at 131 ft (60 gal/min), 160 ft (20 gal/min), and 171 ft bls (20 gal/min). Water-bearing zones at 60 and 120 ft bls were cased off.

Borehole BK-2513 was logged to a depth of 298 ft. The caliper log (appendix 1, fig. 15) and borehole television survey show numerous minor fractures and several major fractures. Major vertical fractures are at 124.5-128, 133.5-136, 146.5-156.5, 187-194, and 267-269 ft bls. The fluid-resistivity and fluid-temperature logs do not indicate borehole flow. Slugs of high-conductance fluid were injected in the borehole at 135, 200, 260, and 270 ft bls. No borehole flow was measurable. The borehole television survey shows a disruption of downward particle movement at the fractures at 245 and 268.5 ft bls; this may be flow across the borehole through these fractures.

BK-2514

Borehole BK-2514 was drilled to 292 ft bls and cased with 37 ft of 8-in. diameter steel casing. The yield was 35 gal/min. The driller reported water-bearing zones at 200 ft (5 gal/min), 215 ft (25 gal/min), and below 215 ft bls (5 gal/min).

The caliper log (appendix 1, fig. 16) and borehole television survey show numerous minor fractures and several major fractures. Major horizontal fractures are at 83.5, 114.5, 133, 151, 225, and 250 ft bls. Major vertical fractures are at 51-60, 95-96, and 211-213 ft bls.

The fluid-resistivity log shows a very large change in slope at 57 ft, which coincides with a large vertical fracture at 51-60 ft bls; the largest opening of this fracture is at 58 ft bls. The fluid-temperature log shows little gradient, which indicates borehole flow. Changes in slope at 225 and 255 ft bls coincide with horizontal fractures. Slugs of high-

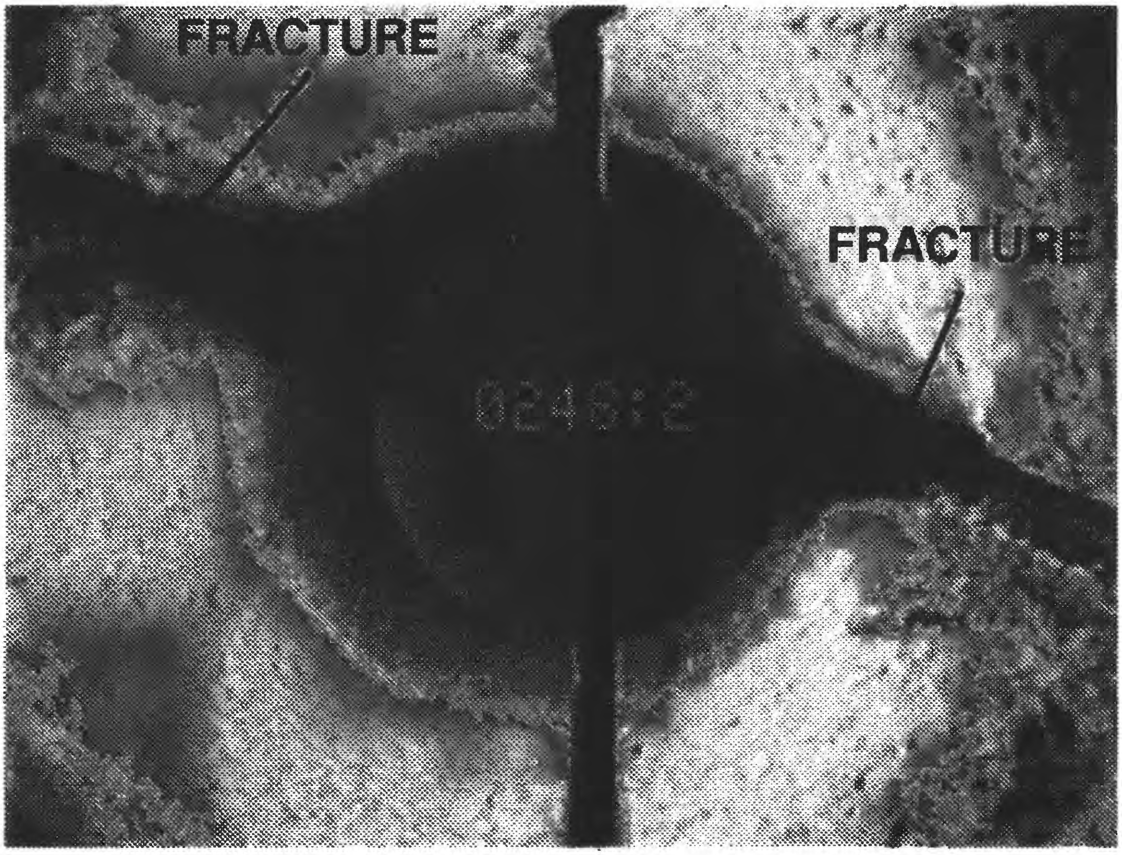


Figure 9. Photograph from borehole television survey of borehole BK-2512 showing fracture at 248.2 feet below land surface, Fischer and Porter Site, Warminster, Pa.

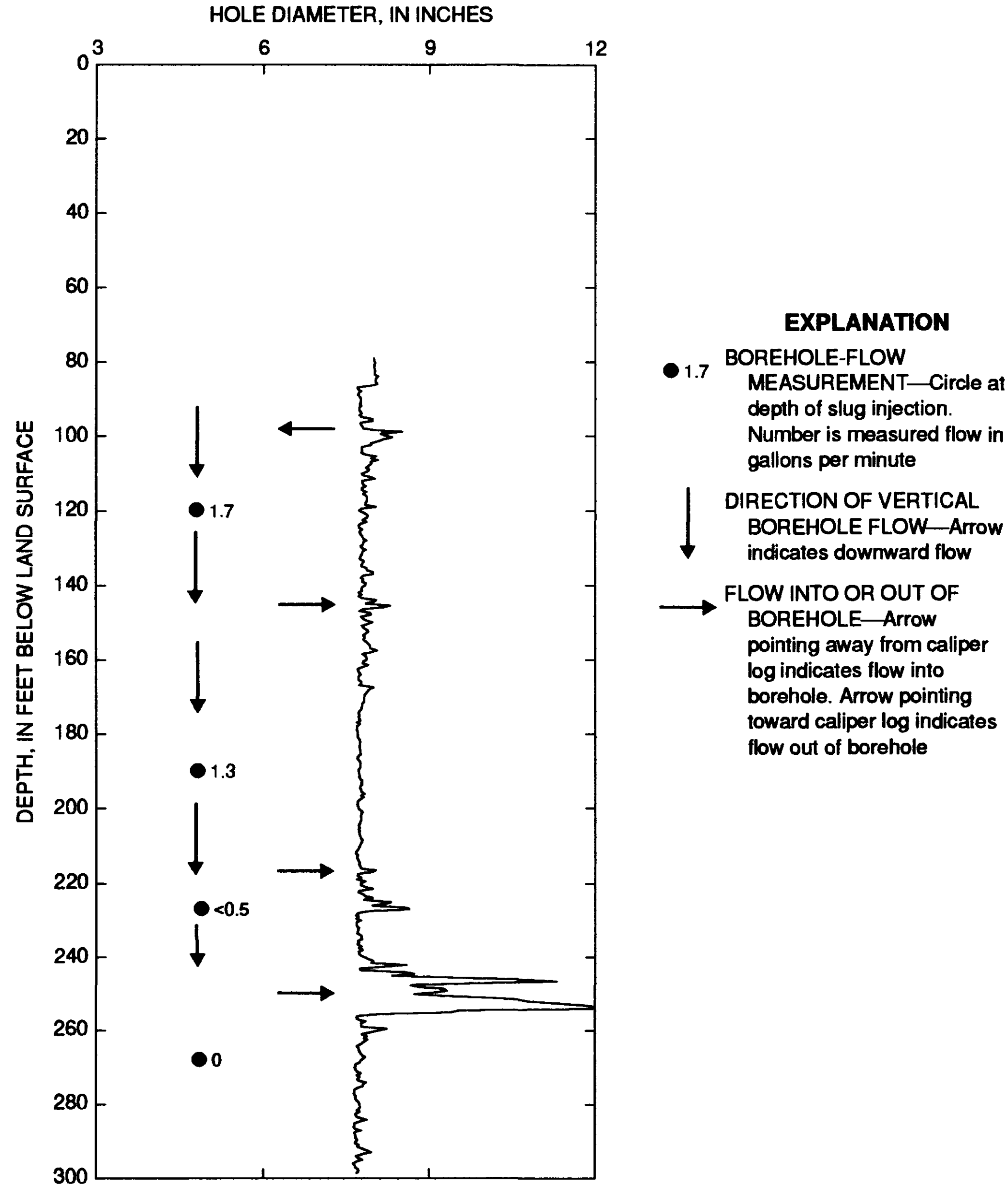


Figure 10. Caliper log from borehole BK-2512 showing borehole-flow measurements, Fischer and Porter Site, Warminster, Pa.

conductance fluid were injected in the borehole at 80 and 170 ft bls. Downward flow at the rate of 8.3 gal/min was measured at 80 ft bls, and downward flow at the rate of 9 gal/min was measured at 170 ft bls.

The suite of geophysical logs indicates that water enters the borehole through a vertical fracture at approximately 58 ft bls and moves downward at the rate of 8.3 gal/min (fig. 11). An additional 0.7 gal/min enters the borehole, probably through fractures at 133 and (or) 151 ft bls. Water continues moving down the borehole at 9 gal/min to water-receiving horizontal fractures at 225 and 250 ft bls.

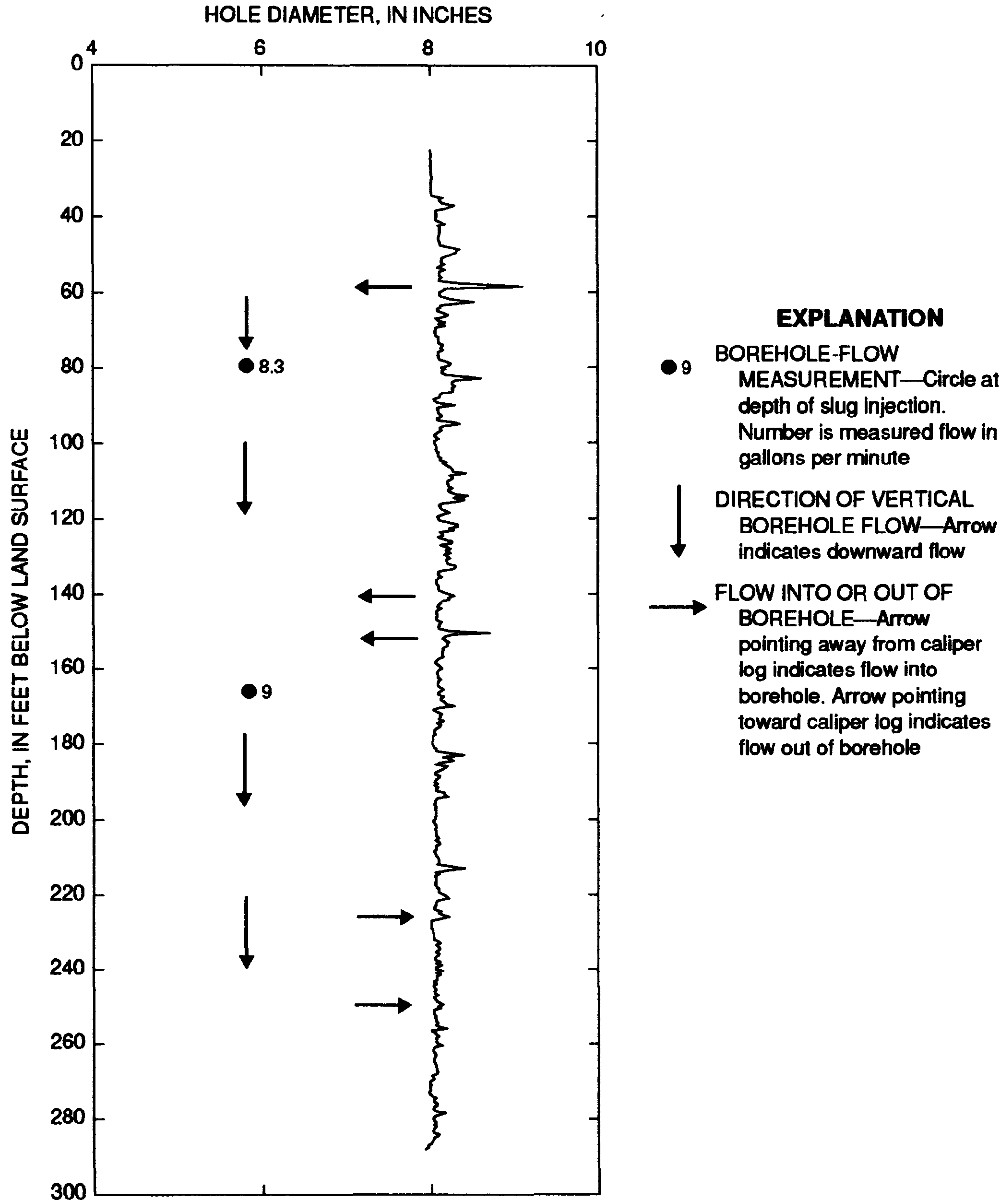


Figure 11. Caliper log from borehole BK-2514 showing borehole-flow measurements, Fischer and Porter Site, Warminster, Pa.

BK-2515

Borehole BK-2515 was drilled to 310 ft bls and cased with 5 ft of 12-in. diameter steel casing and 108 ft of 8-in. diameter steel casing. The yield was 15 gal/min. The driller reported water-bearing zones at 208 ft (3 gal/min), 282-287 ft (3 gal/min), and 302 ft bls (9 gal/min). A water-bearing zone at 31 ft bls was cased off.

The caliper log (appendix 1, fig. 17) and borehole television survey show numerous minor fractures and several major fractures. The major horizontal fracture is at 172.5 ft bls. Major vertical fractures are at 111-123 and 293-304 ft bls. The fluid-resistivity log shows changes in slope at approximately 112, 180, and 275 ft bls, which coincide with fractures. The fluid-temperature log shows a large gradient, which does not indicate borehole flow.

Vertical Distribution of Specific Capacity

A straddle packer system was used to isolate selected intervals in the five exploratory boreholes and one offsite borehole (MG-1242) to obtain water-level, specific-capacity, and water-quality data. A water sample from each isolated interval was analyzed for VOC's. Small changes in water level above the upper packer or below the lower packer are caused by the pumping of nearby public-supply wells.

Tables 3, 5, 7, 9, 11, and 13 present specific-capacity data for 27 intervals isolated in 6 boreholes. Specific capacity is not related to depth. Specific capacities greater than 1 (gal/min)/ft were evenly distributed in intervals isolated between the bottom of casing and 265 ft bls: 87-115 ft bls [8.2 (gal/min)/ft], 126-143 ft bls [>5.7 (gal/min)/ft], 145-177 ft bls [4.7 (gal/min)/ft], 204-235 ft bls [>7.9 (gal/min)/ft], and 237-265 ft bls [8.7 (gal/min)/ft]. Three of the isolated intervals with specific capacities greater than 1 (gal/min)/ft were identified by geophysical logging as water-receiving zones and one was identified as a water-producing zone.

BK-2511

Six intervals were isolated in borehole BK-2511 (table 3). The interval from 187 to 215 ft bls did not produce water. The specific capacity of the other intervals ranged from 0.01 to 0.04 (gal/min)/ft. Data on water levels above the isolated zone, in the isolated zone, and below the isolated zone before the start of pumping and just before pumping stopped are summarized in table 4.

Table 3. *Intervals isolated by straddle packers in borehole BK-2511, Fischer and Porter Site, Warminster, Pa.*

[(gal/min)/ft, gallons per minute per foot of drawdown; µs/cm, microsiemens per centimeter at 25 degrees Celsius; --, no data]

Packer settings (feet below land surface)	Pumping time (minutes)	Volume pumped (gallons)	Specific capacity [(gal/min)/ft]	Specific conductance (µs/cm)	Remarks
[1]187	186	1,260	0.2	500	
187-215	12.5	37.5	--	--	No water; no sample taken
211-239	96	120	.01	480	
241-269	24	110	.04	485	Pumped dry
277-305	32	100	.03	480	Pumped dry
[2]305	22.5	110	.04	480	Pumped dry

[1] The lower packer was inflated, and water was pumped from above the lower packer. The upper packer was not inflated.

[2] The upper packer was inflated, and water was pumped from below the upper packer. The lower packer was not inflated.

Table 4. *Water levels before and at the end of aquifer-isolation tests of borehole BK-2511, Fischer and Porter Site, Warminster, Pa.*

[--, packer not inflated]

Packer settings (feet below land surface)	Depth to water before start of pumping (feet below land surface)			Depth to water at end of pumping (feet below land surface)		
	Above upper packer	In isolated zone	Below lower packer	Above upper packer	In isolated zone	Below lower packer
[1]187	--	30.03	[2]121.65	--	62.93	84.53
187-215	29.16	27.56	30.18	30.31	156.96	30.61
211-239	28.80	28.36	30.84	30.39	151.46	31.73
241-269	29.58	28.06	29.56	29.93	155.41	31.21
277-305	29.16	27.97	27.08	29.20	149.36	29.25
[3]305	27.09	25.89	--	28.27	142.67	--

[1] The lower packer was inflated, and water was pumped from above the lower packer. The upper packer was not inflated.

[2] Water level not fully recovered from test of interval 187-215 feet below land surface.

[3] The upper packer was inflated, and water was pumped from below the upper packer. The lower packer was not inflated.

BK-2512

Six intervals were isolated in borehole BK-2512 (table 5). Isolated intervals that included a water-producing or water-receiving fracture had the highest specific capacities. Specific capacities greater than 7.9 (gal/min)/ft were measured in the intervals above 115, 204-235, and 237-265 ft bls. Fractures in these intervals are in fine-grained sandstone units. The interval above 115 ft bls includes the water-producing fracture at 96 ft bls. The interval 204-235 ft bls includes the water-receiving fracture at 217 ft bls. The interval 237-265 ft bls includes a large, water-receiving, vertical fracture at 242-250 ft bls. The interval 132-160 ft bls includes the fracture at 148 ft bls, which is a minor water-receiving fracture; specific capacity of this interval is 0.81 (gal/min)/ft. The interval below 260 ft bls, which included the highest yielding water-bearing zone in the borehole reported by the driller (greater than 50 gal/min at 280 ft bls) had the second lowest specific capacity of the intervals isolated in borehole BK-2512, 0.03 (gal/min)/ft. The specific conductance of water pumped from the receiving zones was higher than that of the water pumped from the producing zone (table 5), indicating that the water pumped from the receiving zones was not all the same water that flowed down the well bore from the producing zone. Data on water levels above the isolated zone, in the isolated zone, and below the isolated zone before the start of pumping and just before pumping stopped are summarized in table 6.

Table 5. *Intervals isolated by straddle packers in borehole BK-2512, Fischer and Porter Site, Warminster, Pa.*

[(gal/min)/ft, gallon per minute per foot of drawdown; μS/cm, microsiemens per centimeter at 25 degrees Celsius; >, greater than]

Packer settings (feet below land surface)	Pumping time (minutes)	Volume pumped (gallons)	Specific capacity [(gal/min)/ft]	Specific conductance (μS/cm)
[1] 115	94	799	8.2	420
132-160	46	391	.81	625
164-192	75	110	.01	520
204-235	43	1,340	>7.9	475
237-265	49	275	8.7	475
[2] 265	67	268	.03	560

[1] The lower packer was inflated, and water was pumped from above the lower packer. The upper packer was not inflated.

[2] The upper packer was inflated, and water was pumped from below the upper packer. The lower packer was not inflated.

Table 6. *Water levels before and at the end of aquifer-isolation tests of borehole BK-2512, Fischer and Porter Site, Warminster, Pa.*

[--, packer not inflated]

Packer settings (feet below land surface)	Depth to water before start of pumping (feet below land surface)			Depth to water at end of pumping (feet below land surface)		
	Above upper packer	In isolated zone	Below lower packer	Above upper packer	In isolated zone	Below lower packer
[1] 115	--	19.15	20.00	--	20.04	20.34
132-160	18.83	18.49	19.90	19.71	23.78	21.51
162-192	23.27	27.06	26.86	20.97	130.97	24.26
204-235	23.77	24.38	27.69	22.31	27.49	24.54
237-265	23.24	24.00	24.86	23.82	24.47	25.12
[2] 265	23.54	24.75	--	24.49	158.41	--

[1] The lower packer was inflated, and water was pumped from above the lower packer. The upper packer was not inflated.

[2] The upper packer was inflated, and water was pumped from below the upper packer. The lower packer was not inflated.

BK-2513

Six intervals were isolated in borehole BK-2513 (table 7). The interval isolated above 143 ft bls, which included the highest yielding water-bearing zone in the borehole reported by the driller (60 gal/min at 131 ft bls), had the highest specific capacity of the intervals isolated in borehole BK-2513, which was greater than 5.7 (gal/min)/ft. This water-bearing zone is in a very fine-grained sandstone unit. Specific capacities of the other isolated intervals ranged from 0.07 to 0.23 (gal/min)/ft. Data on water levels above the isolated zone, in the isolated zone, and below the isolated zone before the start of pumping and just before pumping stopped are summarized in table 8.

Table 7. *Intervals isolated by straddle packers in borehole BK-2513, Fischer and Porter Site, Warminster, Pa.*

[(gal/min)/ft, gallon per minute per foot of drawdown; µS/cm, microsiemens per centimeter at 25 degrees Celsius; >, greater than]

Packer settings (feet below land surface)	Pumping time (minutes)	Volume pumped (gallons)	Specific capacity [(gal/min)/ft]	Specific conductance (µS/cm)
[1]143	151	860	>5.7	450
143-171	57	275	.14	470
176-204	57	290	.12	450
202-232	74	275	.23	435
232-260	111	275	.07	470
[2]260	46	250	.09	540

[1] The lower packer was inflated, and water was pumped from above the lower packer. The upper packer was not inflated.

[2] The upper packer was inflated, and water was pumped from below the upper packer. The lower packer was not inflated.

Table 8. *Water levels before and at the end of aquifer-isolation tests of borehole BK-2513, Fischer and Porter Site, Warminster, Pa.*

[--, packer not inflated]

Packer settings (feet below land surface)	Depth to water before start of pumping (feet below land surface)			Depth to water at end of pumping (feet below land surface)		
	Above upper packer	In isolated zone	Below lower packer	Above upper packer	In isolated zone	Below lower packer
[1]143	--	38.50	38.32	--	38.55	38.29
143-171	35.58	35.01	35.87	36.88	69.29	36.63
176-204	37.60	37.70	38.06	37.73	78.52	38.43
202-232	36.84	37.09	36.90	35.98	53.18	37.15
232-260	38.01	38.50	38.43	38.11	73.78	38.62
[2]260	38.00	37.89	--	38.88	100.22	--

[1] The lower packer was inflated, and water was pumped from above the lower packer. The upper packer was not inflated.

[2] The upper packer was inflated, and water was pumped from below the upper packer. The lower packer was not inflated.

BK-2514

Seven intervals were isolated in borehole BK-2514 (table 9). Specific capacity ranged from <0.03 to 0.43 (gal/min)/ft. Specific capacity could not be calculated for the interval 209-237 ft bls, which includes the water-receiving fracture at 225 ft bls, because the transducer data were unreliable. The interval below 237 ft bls, which includes the water-receiving fractures at 225 and 250 ft bls, had the highest specific capacity, 0.43 (gal/min)/ft, of the intervals isolated in borehole BK-2514. The interval above 58 ft bls, which includes a water-producing fracture at 58 ft bls that produced 8.3 gal/min during geophysical logging, had the lowest specific capacity of the intervals isolated in borehole BK-2514, <0.03 (gal/min)/ft. At the time of the aquifer-isolation test, the water level in the interval above 72 ft bls was 58.58 ft bls (table 10), indicating that this fracture had been partially or completely dewatered either by the natural seasonal decline in water level or drainage through the open borehole. The specific conductance of water in the receiving zones was higher than that of the water in the producing zone (table 9), indicating that water pumped from the receiving zones was not all the same water that flowed down the well bore from the producing zone.

Data on water levels above the isolated zone, in the isolated zone, and below the isolated zone before the start of pumping and just before pumping stopped are summarized in table 10. During the aquifer-isolation test of this borehole, a thunderstorm produced lightning that struck and destroyed the transducers and data logger. Measurements thereafter were made with electric measuring tapes.

***Table 9.** Intervals isolated by straddle packers in borehole BK-2514, Fischer and Porter Site, Warminster, Pa.*

[(gal/min)/ft, gallon per minute per foot of drawdown; µS/cm, microsiemens per centimeter at 25 degrees Celsius; --, no data; <, less than]

Packer settings (feet below land surface)	Pumping time (minutes)	Volume pumped (gallons)	Specific capacity [(gal/min)/ft]	Specific conductance (µS/cm)	Remarks
[1]72	100	110	<0.3	500	
72-100	--	--	--	--	No water; no sample
100-128	44	26	.03	620	
130-158	29	75	.05	570	
177-205	50	270	.06	580	
209-237	68	350	(2)	590	
[3]237	60	420	.43	620	

[1] The lower packer was inflated, and water was pumped from above the lower packer. The upper packer was not inflated.

[2] Transducer data unreliable.

[3] The upper packer was inflated, and water was pumped from below the upper packer. The lower packer was not inflated.

Table 10. *Water levels before and at the end of aquifer-isolation tests of borehole BK-2514, Fischer and Porter Site, Warminster, Pa.*

[--, packer not inflated]

Packer settings (feet below land surface)	Depth to water before start of pumping (feet below land surface)			Depth to water at end of pumping (feet below land surface)		
	Above upper packer	In isolated zone	Below lower packer	Above upper packer	In isolated zone	Below lower packer
[1]72	--	58.58	58.44	--	62.03	59.15
72-100	([2])	([2])	([2])	([2])	([2])	([2])
100-128	59.41	57.27	65.89	58.68	71.48	65.27
130-158	59.36	59.49	[3]65.67	59.19	111.03	66.37
177-205	59.47	67.27	67.09	58.95	153.57	67.08
209-237	62.10	57.50	60.79	62.07	([4])	([4])
[5]237	64.87	66.53	--	65.56	82.87	--

[1] The lower packer was inflated, and water was pumped from above the lower packer. The upper packer was not inflated.

[2] No water in this interval.

[3] Transducer data unreliable.

[4] Transducers and data logger destroyed by lightning.

[5] The upper packer was inflated, and water was pumped from below the upper packer. The lower packer was not inflated.

BK-2515

Five intervals were isolated in borehole BK-2515 (table 11). Specific capacities ranged from 0.01 to 0.09 (gal/min)/ft. Data on water levels above the isolated zone, in the isolated zone, and below the isolated zone before the start of pumping and just before pumping stopped are summarized in table 12.

Table 11. *Intervals isolated by straddle packers in borehole BK-2515, Fischer and Porter Site, Warminster, Pa.*

[(gal/min)/ft, gallon per minute per foot of drawdown; μS/cm, microsiemens per centimeter at 25 degrees Celsius; --, no data]

Packer settings (feet below land surface)	Pumping time (minutes)	Volume pumped (gallons)	Specific capacity [(gal/min)/ft]	Specific conductance (μS/cm)	Remarks
[1]172	74	495	[2]0.09	650	Pumped dry
172-200	91	220	.03	740	
202-230	52.5	75	--	--	No water; no sample
249-277	10	20	--	--	No water; no sample
[3]277	72	302	.05	620	

[1] The lower packer was inflated, and water was pumped from above the lower packer. The upper packer was not inflated.

[2] Measurement after 48 minutes of pumping. Constriction in measurement tube prevented additional measurements.

[3] The upper packer was inflated, and water was pumped from below the upper packer. The lower packer was not inflated.

Table 12. *Water levels before and at the end of aquifer-isolation tests of borehole BK-2515, Fischer and Porter Site, Warminster, Pa.*

[--, packer not inflated]

Packer settings (feet below land surface)	Depth to water before start of pumping (feet below land surface)			Depth to water at end of pumping (feet below land surface)		
	Above upper packer	In isolated zone	Below lower packer	Above upper packer	In isolated zone	Below lower packer
[1]172	--	35.99	38.03	--	[2]69.72	[1]38.20
172-200	35.33	35.94	([3])	36.90	105.35	([3])
202-230	35.37	34.91	33.83	36.86	163.10	28.37
249-277	36.33	34.33	31.00	36.69	156.42	32.00
[4]277	35.75	40.41	--	36.54	115.49	--

[1] The lower packer was inflated, and water was pumped from above the lower packer. The upper packer was not inflated.

[2] Measurement after 48 minutes of pumping. Constriction in measurement tube prevented additional measurements.

[3] No data.

[4] The upper packer was inflated, and water was pumped from below the upper packer. The lower packer was not inflated.

MG-1242

Four intervals were isolated in borehole MG-1242 (table 13). Specific capacities ranged from 0.02 to 4.7 (gal/min)/ft. The interval below 145 ft bls, which includes the water-receiving fracture at 156 ft bls, had the highest specific capacity, 4.7 (gal/min)/ft, of the intervals isolated in borehole MG-1242. Data on water levels above the isolated zone, in the isolated zone, and below the isolated zone before the start of pumping and just before pumping stopped are summarized in table 14.

Table 13. *Intervals isolated by straddle packers in borehole MG-1242, Hatboro, Pa.*

[(gal/min)/ft, gallon per minute per foot of drawdown; μS/cm, microsiemens per centimeter at 25 degrees Celsius]

Packer settings (feet below land surface)	Pumping time (minutes)	Volume pumped (gallons)	Specific capacity [(gal/min)/ft]	Specific conductance (μS/cm)
[1]90	59	220	0.14	640
90-115	79	90	.02	550
120-145	27	70	.03	700
[2]145	41	141	4.7	740

[1] The lower packer was inflated, and water was pumped from above the lower packer. The upper packer was not inflated.

[2] The upper packer was inflated, and water was pumped from below the upper packer. The lower packer was not inflated.

Table 14. *Water levels before and at the end of aquifer-isolation tests of borehole MG-1242, Hatboro, Pa.*

[--, packer not inflated]

Packer settings (feet below land surface)	Depth to water before start of pumping (feet below land surface)			Depth to water at end of pumping (feet below land surface)		
	Above upper packer	In isolated zone	Below lower packer	Above upper packer	In isolated zone	Below lower packer
[1]90	--	38.17	(2)	--	63.80	(2)
90-115	38.33	43.19	(2)	39.38	110.00	(2)
120-145	38.19	43.17	(2)	38.21	140.00	(2)
[3]145	36.74	43.42	--	36.74	44.15	--

[1] The lower packer was inflated, and water was pumped from above the lower packer. The upper packer was not inflated.

[2] No data.

[3] The upper packer was inflated, and water was pumped from below the upper packer. The lower packer was not inflated.

Water Levels

Water levels at the Fischer and Porter Site were monitored to determine the effects of pumping of extraction wells in the Fischer and Porter treatment system and public-supply wells on water levels at the site. All 17 monitor wells on the Fischer and Porter Site (fig. 2) were equipped with continuous water-level recorders. The graphical charts recorded aquifer response to pumping, precipitation, and seasonal water-level trends. Plate 3 shows the generalized stratigraphy, which was based on analysis of borehole geophysical logs, and the vertical location of the well screens for each monitor well cluster. The wells used for water-level monitoring, the screened intervals, and the effect of pumping of the Fisher and Porter treatment system wells and public-supply wells are listed in table 15. Hydrographs from the monitor wells are in appendix 4.

The Fischer and Porter treatment system uses recovery wells BK-370, BK-371, and BK-1324 (fig. 2), which are continuously pumped at a combined rate of 75 gal/min. To determine the effect of pumping these wells on water levels, the recovery wells were shut down for 3 days and then turned back on. The recovery of water levels during the shutdown was used to assess the effect of pumping the treatment system wells on water levels in the monitor wells. In some cases, no recovery took place, and the slowing or halt in the natural water-level recession was used to estimate the effect of pumping the treatment system wells. Where water levels are greatly influenced by pumping of public-supply wells, the change in the daily peaks or lows was used to determine the effect of pumping the treatment system wells.

To determine the potential effect of pumping unused public-supply well MG-946 (H-16), the Hatboro Municipal Authority pumped well MG-946 at approximately 350 gal/min during January 5-7, 1994. During this time, monitor wells BK-1731, BK-1795, BK-1796, BK-2512, BK-2521, BK-2527, and BK-2528 along the western side of the Fischer and Porter Site were equipped with water-level recorders. The pumping of well MG-946 did not cause a measurable effect on water levels at the Fischer and Porter Site.

In general, water levels fluctuate in response to recharge to the ground-water system from precipitation and discharge from the ground-water system to pumping wells, ground-water evapotranspiration, and streams. Water levels generally rise during the late fall, winter, and early spring when ground-water evapotranspiration and soil-moisture evapotranspiration is at a minimum and recharge is at a maximum. Water levels generally decline during the late spring, summer, and early fall when ground-water evapotranspiration and soil-moisture evapotranspiration are at a maximum and recharge is at a minimum.

Water levels in some wells at the Fischer and Porter Site are greatly affected by the pumping of Warminster Heights Development Corporation supply wells BK-366 and BK-367. Well BK-366 is open from 40 to 300 ft bls and penetrates units 1 to 5 (pl. 3). Well BK-367 is open from 56 to 300 ft bls and penetrates units 5 to 8 (pl. 3).

Hydrographs of the water level in public-supply well MG-947 (H-17) were obtained from the Hatboro Municipal Authority for selected time periods. The pumping pattern of well MG-947 was compared with water-level hydrographs from wells on the Fischer and Porter Site. Water-level fluctuations measured in wells at the Fischer and Porter Site did not match the pumping pattern of well MG-947, indicating no hydraulic connection.

Table 15. *Changes in water level caused by pumping of public-supply wells and the shutdown of the Fischer and Porter treatment system wells, Fischer and Porter Site, Warminster, Pa.*

[e, estimated]

U.S. Geological Survey identification number	Screened or open interval (feet below land surface)	Approximate daily change in water level caused by pumping of public-supply wells (feet)	Date of shutdown of Fischer and Porter treatment system wells	Rise in water level caused by shutdown of the Fischer and Porter treatment system wells (feet)
BK-1731	47-65	0.1	December 13-15, 1993	0.2 e
BK-1793	23-40	[1].3	November 17-19, 1993	[1].5 e
BK-1795	23-31	.0	December 13-15, 1993	.2 e
			May 16-19, 1994	.4 e
BK-1796	78-146	.5	December 13-15, 1993	2.8
BK-2511	300-325	.7	December 13-15, 1993	5.9
BK-2512	237-257	5.3	May 16-19, 1994	2.2
BK-2513	255-275	2.3	November 17-19, 1993	3.1
BK-2514	217-252	2.8	May 16-19, 1994	.8
BK-2515	285-305	.9	December 13-15, 1993	6.3
BK-2521	190-210	3.6	December 13-15, 1993	4.3
BK-2522	132-157	2.0	April 27-29, 1994	.1 e
BK-2523	23.5-43.5	1.7	April 27-29, 1994	.1 e
BK-2524	115-135	5.3	November 17-19, 1993	1.1
BK-2525	31-51	.0	April 27-29, 1994	.0
BK-2526	50-70	.0	May 16-19, 1994	.9 e
			April 27-29, 1994	.0 e
BK-2527	157-187	2.6	December 13-15, 1993	3.3
BK-2528	25-45	.1	December 13-15, 1993	.4 e

[1] Change in fluid level.

Water Levels at Monitor Well Clusters and Boreholes

BK-2511, BK-2521, and BK-1731—Well BK-2511 is screened from 300 to 325 ft bls in unit 6 (pl. 3). Well BK-2511 was monitored during December 3-20, 1993 (appendix 4, fig. 1); the range in water-level fluctuation was 14.9 ft. The water level is affected by the pumping of a public-supply well, probably BK-367; the daily fluctuation caused by pumping is about 0.7 ft. The effect of pumping can be seen in the hydrograph, but the pumping cycle is not discernible. The shutdown of the Fischer and Porter treatment system wells during December 13-15 caused a rise in water level of 5.9 ft.

Well BK-2521 is screened from 190 to 210 ft bls in unit 3 (pl. 3). Well BK-2521 was monitored during December 6, 1993, to January 14, 1994 (appendix 4, figs. 2 and 3). The range in water-level fluctuation during December 6-20 was 8.0 ft, and the range in water-level fluctuation during December 20 to January 14 was 16.5 ft. The water level is affected by the pumping of public-supply well BK-366, which is open to unit 3; the daily fluctuation caused by pumping is about 3.6 ft. The pumping cycle of well BK-366 can be clearly seen in the hydrograph. The shutdown of the Fischer and Porter treatment system wells during December 13-15 caused a rise in water level of 4.3 ft.

Borehole BK-1731 is open from 47 to 65 ft bls in unit 1 (pl. 3). Borehole BK-1731 was monitored during December 3, 1993, to January 13, 1994 (appendix 4, figs. 4 and 5); the range in water-level fluctuation was 5.5 ft. The water level is slightly affected by the pumping of public-supply well BK-366; the daily fluctuation caused by pumping is approximately 0.1 ft. The effect of pumping can be seen in the hydrograph, but the pumping cycle is not discernible. The shutdown of the Fischer and Porter treatment system wells during December 13-15 caused a slowing of the natural water-level recession; it is equivalent to a rise in water level of approximately 0.2 ft.

Water levels measured in this cluster on December 13, 1993 (table 16), indicate a downward head gradient.

Table 16. *Water-level measurements, December 13, 1993, and May 3, 1994, Fischer and Porter Site, Warminster, Pa.*

Well or borehole number	Land surface elevation (feet above sea level)	December 13, 1993		May 3, 1994	
		Depth to water below land surface (feet)	Water level (feet above sea level)	Depth to water below land surface (feet)	Water level (feet above sea level)
BK-1731	282.71	12.08	270.63	13.18	269.53
[1]BK-1793	294.90	20.56	274.34	22.48	272.42
BK-1795	302.52	21.03	281.49	26.47	276.05
BK-1796	302.48	35.24	267.24	37.72	264.76
BK-2511	281.38	22.42	258.96	20.58	260.80
BK-2512	271.16	10.26	260.90	10.00	261.16
BK-2513	285.37	22.92	262.45	22.28	263.09
BK-2514	314.67	52.94	261.73	51.10	263.57
BK-2515	291.50	35.63	255.87	30.92	260.58
BK-2521	281.99	17.22	264.77	19.14	262.85
BK-2522	271.62	10.34	261.28	9.98	261.64
BK-2523	271.21	9.65	261.56	10.13	261.08
BK-2524	285.13	22.70	262.43	22.06	263.07
BK-2525	285.41	11.34	274.07	13.32	272.09
BK-2526	315.40	35.66	279.74	38.32	277.08
BK-2527	292.26	27.84	264.42	29.94	262.32
BK-2528	292.92	20.03	272.89	22.46	270.46

[1] Measurements represent level of top of free product floating on water surface.

BK-2515, BK-2527, and BK-2528—Well BK-2515 is screened from 285 to 305 ft bls in unit 6 (pl. 3). Well BK-2515 was monitored during December 8, 1993, to January 13, 1994 (appendix 4, figs. 6 and 7); the range in water-level fluctuation was 13.5 ft. The water level is affected by the pumping of a public-supply well, probably BK-367, which is open to unit 6; the daily fluctuation caused by pumping is about 0.9 ft. The effect of pumping can be seen in the hydrograph, but the pumping cycle is not discernible. The shutdown of the Fischer and Porter treatment system wells during December 13-15 caused a rise in water level of 6.3 ft.

Well BK-2527 is screened from 157 to 187 ft bls in unit 3 (pl. 3). Well BK-2527 was monitored during December 7, 1993, to January 13, 1994 (appendix 4, figs. 8 and 9); the range in water-level fluctuation was 16.9 ft. The water level is affected by the pumping of public-supply well BK-366; the daily fluctuation caused by pumping is about 2.6 ft. The pumping cycles can be clearly seen in the hydrograph. The shutdown of the Fischer and Porter treatment system wells during December 13-15 caused a rise in water level of 3.3 ft.

Well BK-2528 is screened from 25 to 45 ft bls in unit 1 (pl. 3). Well BK-2528 was monitored during December 7, 1993, to January 13, 1994 (appendix 4, figs. 10 and 11); the range in water-level fluctuation was 7.6 ft. The water level is slightly affected by the pumping of a public-supply well; the daily fluctuation caused by pumping is approximately 0.1 ft. The effect of pumping can be seen in the hydrograph, but the pumping cycle is not discernible. The shutdown of the Fischer and Porter treatment system wells during December 13-15 caused a slowing of the natural water-level recession equivalent to a rise in water level of approximately 0.4 ft.

Water levels measured in this well cluster on December 13, 1993 (table 16), indicate a downward head gradient.

BK-1795 and BK-1796—Borehole BK-1795 is open from 23 to 31 ft bls in unit 2 (pl. 3). Borehole BK-1795 was monitored during December 6, 1993, to January 21, 1994 (appendix 4, figs. 12 and 13); the range in water-level fluctuation was 8.2 ft. The water level in BK-1795 does not appear to be affected by the pumping of public-supply wells. The shutdown of the Fischer and Porter treatment system wells during December 13-15 caused a slowing of the water-level recession equivalent to a rise in water level of approximately 0.2 ft. Borehole BK-1795 also was monitored during May 9-23, 1994 (appendix 4, fig. 14). The shutdown of the Fischer and Porter treatment system wells during May 16-19 caused a rise in water level of 0.4 ft.

Borehole BK-1796 is open from 78 to 146 ft bls in unit 3 (pl. 3). Borehole BK-1796 was monitored during December 8, 1993, to January 13, 1994 (appendix 4, figs. 15 and 16); the range in water-level fluctuation was 14.5 ft. The water level is affected by the pumping of public-supply well BK-366, which is open to unit 3; the daily fluctuation caused by pumping is about 0.5 ft. The effect of pumping can be seen in the hydrograph, but the pumping cycle is not discernible. The shutdown of the Fischer and Porter treatment system wells during December 13-15 caused a rise in water level of 2.8 ft.

Water levels measured in this pair of boreholes on December 13, 1993 (table 16), indicate a downward head gradient.

BK-2514 and BK-2526—Well BK-2514 is screened from 217 to 252 ft bls in unit 8 (pl. 3). Well BK-2514 was monitored during May 9-23, 1994 (appendix 4, fig. 17); the range in water-level fluctuation was 6.7 ft. The spike in the hydrograph on May 12 was caused by surface runoff infiltrating the well. The water level is affected by the pumping of public-supply well BK-367, which is open to unit 8; the daily fluctuation caused by pumping is about 2.8 ft. The pumping cycle of well BK-367 can be clearly seen in the hydrograph. The shutdown of the Fischer and Porter treatment system wells during May 16-19 caused a rise in water level of about 0.8 ft.

Well BK-2526 is screened from 50 to 70 ft bls in unit 4 (pl. 3). Well BK-2526 was monitored during April 12 to May 23, 1994 (appendix 4, figs. 18 and 19). The spikes in the hydrograph were caused by surface runoff infiltrating the well. The range in water-level fluctuation was 7.4 ft during April 12 to May 9, 3.5 ft during May 9-23, and 10.7 ft during April 14 to May 23. The water level is not affected by the pumping of public-supply wells. The shutdown of the Fischer and Porter treatment system wells during April 27-29 did not affect the water level in well BK-2526; however, the shutdown of the Fischer and Porter treatment system wells during May 16-19 caused a halt in the natural water-level recession equivalent to a rise in water level of approximately 0.9 ft.

Water levels measured in this pair of wells on May 3, 1994 (table 16), indicate a downward head gradient.

BK-1793—Borehole BK-1793 is open from 23 to 40 ft bls in unit 3 (pl. 3). Borehole BK-1793 was monitored during November 4 to December 6, 1993 (appendix 4, fig. 20). The depth to the top of free product floating on the water surface was measured. The range in fluid-level fluctuation during that time was 9.3 ft. The fluid level is affected by the pumping of public-supply well BK-366, which is open to unit 3; the daily fluctuation caused by pumping is about 0.3 ft. The effect of pumping can be seen in the hydrograph, but the pumping cycle is not discernible. The shutdown of the Fischer and Porter treatment system wells during November 17-19 caused a halt in the fluid-level recession equivalent to a rise in fluid level of approximately 0.5 ft.

BK-2513, BK-2524, and BK-2525—Well BK-2513 is screened from 255 to 275 ft bls in unit 6 (pl. 3). Well BK-2513 was monitored during November 5 to December 7, 1993 (appendix 4, fig. 21); the range in water-level fluctuation was 10.5 ft. The water level is affected by the pumping of public-supply well BK-366; the daily fluctuation caused by pumping is about 2.3 ft. The pumping cycle of well BK-366 can be clearly seen in the hydrograph. The shutdown of the Fischer and Porter treatment system wells during November 17-19 caused a rise in water level of 3.1 ft.

Well BK-2524 is screened from 115 to 135 ft bls in unit 3 (pl. 3). Well BK-2524 was monitored during November 8 to December 8, 1993 (appendix 4, fig. 22); the range in water-level fluctuation was 14.3 ft. The water level is affected by the pumping of public-supply well BK-366, which is open to unit 3; the daily fluctuation caused by pumping is about 5.3 ft. The pumping cycle of well BK-366 can be clearly seen in the hydrograph. The shutdown of the Fischer and Porter treatment system wells during November 17-19 caused a rise in water level of 1.1 ft.

Well BK-2525 is screened from 31 to 51 ft bls in the top of unit 2 (pl. 3). Well BK-2525 was monitored during April 20 to May 9, 1994 (appendix 4, fig. 23); the range in water-level fluctuation was 3.2 ft. The water level is not affected by the pumping of public-supply wells. The shutdown of the Fischer and Porter treatment system wells during April 27-29 did not cause a measurable effect on the water level in well BK-2525.

Water levels measured in this cluster on December 13, 1993 (table 16), indicate a downward head gradient from the shallow to the intermediate and deep zones.

BK-2512, BK-2522, and BK-2523—Well BK-2512 is screened from 237 to 257 ft bls in unit 5 (pl. 3). Well BK-2512 was monitored during May 3-19, 1994 (appendix 4, fig. 24-26); the range in water-level fluctuation was 8.5 ft. The water level is greatly affected by the pumping of public-supply well BK-366, which is open to unit 5; the daily fluctuation caused by pumping is about 5.3 ft. The pumping cycle of well BK-366 can be clearly seen in the hydrograph. The shutdown of the Fischer and Porter treatment system wells during May 16-19 caused a rise in water level of 2.2 ft.

Well BK-2522 is screened from 132 to 157 ft bls in the bottom of unit 2 and the top of unit 3 (pl. 3). Well BK-2522 was monitored during April 14 to May 9, 1994 (appendix 4, fig. 27); the range in water-level fluctuation was 5.1 ft. The water level is affected by the pumping of public-supply well BK-366, which is open to units 2 and 3; the daily fluctuation caused by pumping is about 2.0 ft. The pumping cycle of well BK-366 can be clearly seen in the hydrograph. It is difficult to determine the effect of the shutdown of the Fischer and Porter treatment system wells during April 27-29; the shutdown appears to have caused a rise in water level of about 0.1 ft.

Well BK-2523 is screened from 23.5 to 43.5 ft bls above unit 1 (pl. 3). Well BK-2523 was monitored during April 11 to May 9, 1994 (appendix 4, fig. 28); the range in water-level fluctuation was 3.7 ft. The water level is affected by the pumping of public-supply well BK-366, which is open to unit 1; the daily fluctuation caused by pumping is approximately 1.7 ft. The pumping cycle of well BK-366 can be clearly seen in the hydrograph. Well BK-2523 is the only shallow well in which a pumping cycle can be seen. The shutdown of the Fischer and Porter treatment system wells during April 27-29 caused a rise in water level of approximately 0.1 ft.

Water levels measured in this cluster on December 13, 1993, and May 3, 1994, were within 0.66 and 0.56 ft, respectively (table 16). The December 13, 1993, measurements indicate a slight downward head gradient.

Effect of Pumping the Fischer and Porter Treatment System Wells on Water Levels

The shutdown of the Fischer and Porter treatment system wells had only a small effect on water levels in the shallow zone. Estimated rises in water level were less than 1 ft. The shutdown did not cause a measurable effect on the water level in shallow well BK-2525. The shutdown of the Fischer and Porter treatment system wells caused a rise in water level in all wells screened in the intermediate and deep zones. These wells are located around the boundary of the Fischer and Porter property. The rise in water level was as great as 4.3 ft (well BK-2521) in the intermediate zone (fig. 12) and as great as 6.9 ft (well BK-2511) in the deep zone (fig. 13).

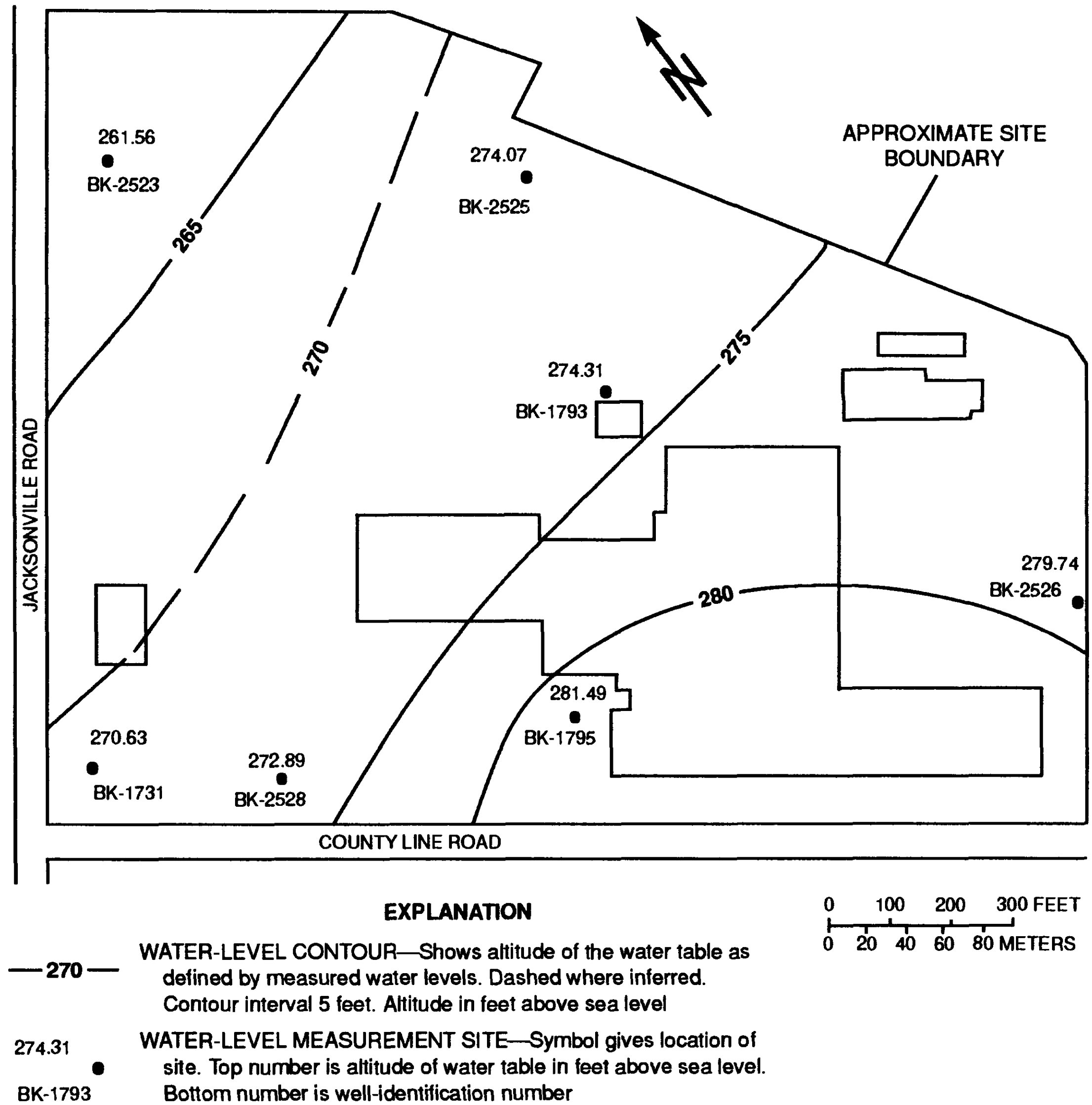
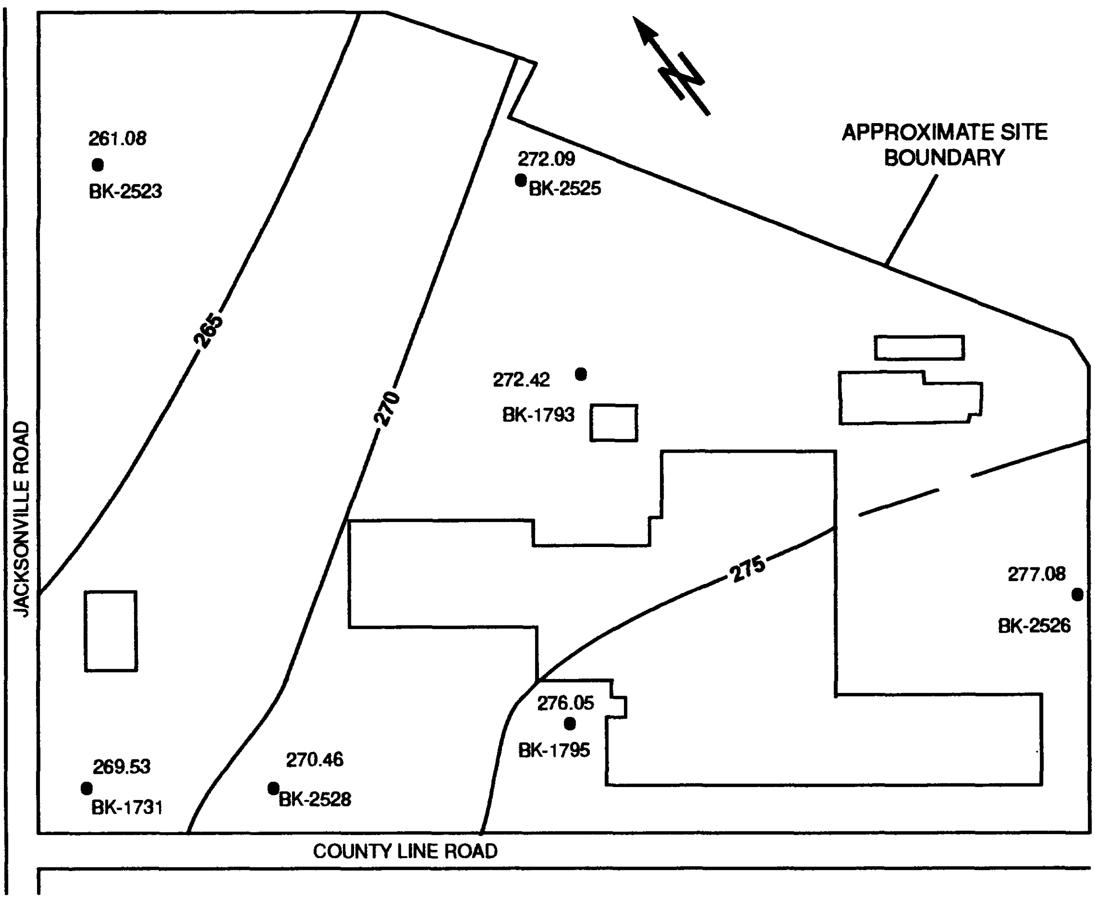


Figure 12. Water-level contour map for wells screened in the shallow zone, Fischer and Porter Site, Warminster, Pa., December 13, 1993.



EXPLANATION

—270— WATER-LEVEL CONTOUR—Shows altitude of the water table as defined by measured water levels. Dashed where inferred. Contour interval 5 feet. Altitude in feet above sea level

272.42 ● BK-1793 WATER-LEVEL MEASUREMENT SITE—Symbol gives location of site. Top number is altitude of water table in feet above sea level. Bottom number is well-identification number

0 100 200 300 FEET
0 20 40 60 80 METERS

Figure 13. Water-level contour map for wells screened in the shallow zone, Fischer and Porter Site, Warminster, Pa., May 3, 1994.

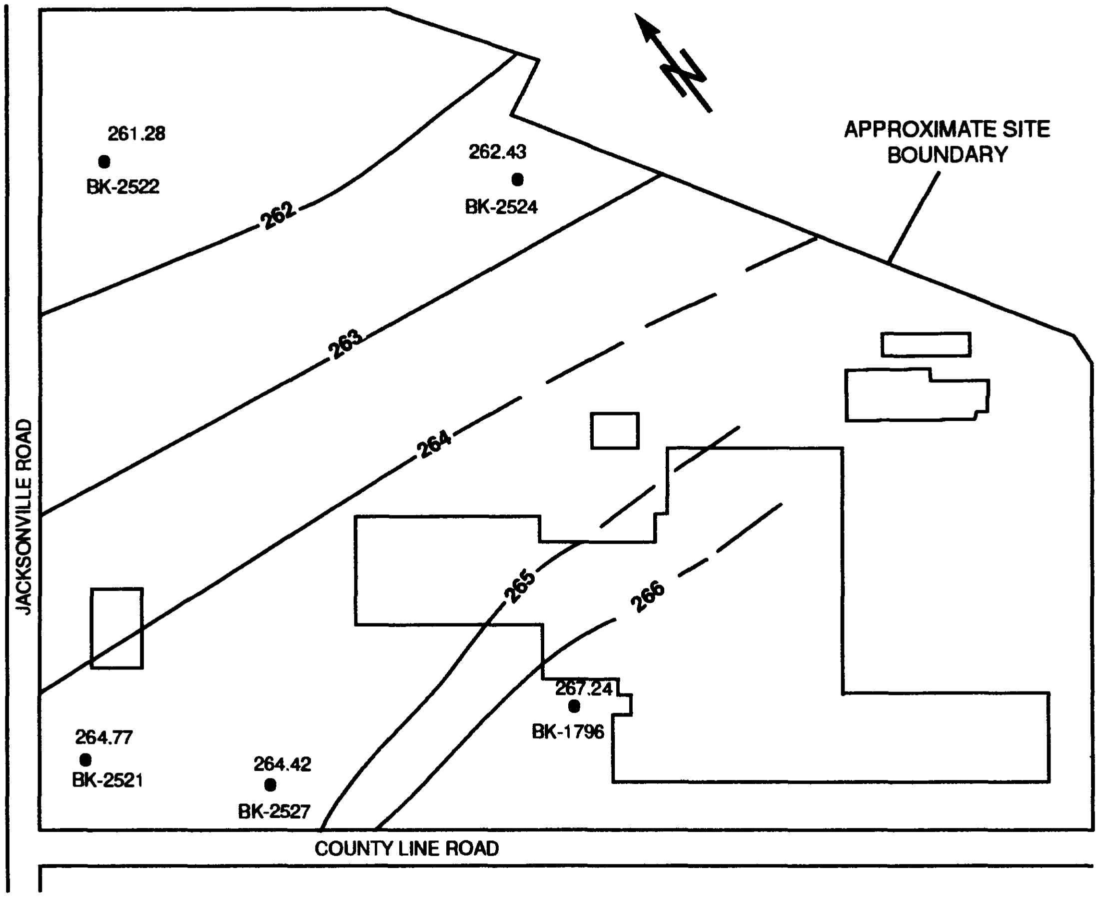
Synoptic Water-Level Measurements

All of the monitor wells at the Fischer and Porter Site were measured on December 13, 1993, and May 3, 1994, while the extraction wells were pumping. Measurements are listed in table 16, and water-level contours are shown on figures 14-17. Water levels were plotted by the depth interval (shallow, intermediate, or deep) at which each well is screened or open. Shallow wells and boreholes (BK-1731, BK-1793, BK-1795, BK-2523, BK-2525, BK-2526, and BK-2528) are those that are screened or open between 23 and 70 ft bls. Intermediate-depth wells and boreholes (BK-1796, BK-2521, BK-2522, BK-2524, and BK-2527) are those that are screened or open between 78 and 210 ft bls. Deep wells (BK-2511, BK-2512, BK-2513, BK-2514, and BK-2515) are those that are screened between 217 and 325 ft bls. Water levels were plotted on the basis of depth of well screen or open interval because the response of water levels to stress generally is more related to the depth of the stratigraphic unit that a well is screened in than to which particular stratigraphic unit the well is screened in. Water levels in wells screened in the same depth interval are contourable. For example, the response of water levels to pumping in wells screened or open to unit 3 depends on the depth of unit 3 at the well location. If unit 3 is near the land surface, the response of water levels in wells screened in it at this depth is similar to the response observed in other shallow wells. If unit 3 is between 217 and 335 ft bls, the response of water levels in wells screened in it at this depth is similar to the response observed in other deep wells. Water levels measured in all wells screened in unit 3 are not contourable. Wells in the Fischer and Porter treatment system were not measured because they are open-hole construction, and water levels measured in these wells represent a composite of all water-bearing zones penetrated by the well. Extraction well BK-1324 is not measurable because of the oil skimming system installed in the well.

Water-level contours for December 13, 1993, and May 3, 1994, for the shallow zone are shown in figures 14 and 15. The maximum water-level-altitude difference was 19.9 ft on December 13 and 16.0 ft on May 3. The direction of ground-water flow, which is perpendicular to the water-level contours, is toward the north. Discharge is to the unnamed tributary to Pennypack Creek north of the Fischer and Porter Site.

Water-level contours for December 13, 1993, and May 3, 1994, for the intermediate-depth zone are shown in figures 16 and 17. The maximum water-level-altitude difference was 5.9 ft on December 13 and 3.2 ft on May 3. The direction of ground-water flow, which is perpendicular to the water-level contours, is toward the north. Discharge probably is to the unnamed tributary to Pennypack Creek north of the Fischer and Porter Site.

Water-level contours for December 13, 1993, and May 3, 1994, for wells screened in the deep zone are shown in figures 18 and 19. The maximum water-level-altitude difference was 6.6 ft on December 13 and 3.0 ft on May 3. The direction of ground-water flow, which is perpendicular to the water-level contours, was toward the west-southwest on December 13 and toward the west on May 3. Discharge probably is to the unnamed tributary to Pennypack Creek west of the Fischer and Porter Site.



EXPLANATION

—270— WATER-LEVEL CONTOUR—Shows altitude of the water table as defined by measured water levels. Dashed where inferred. Contour interval 1 foot. Altitude in feet above sea level

261.28 ● BK-2522 WATER-LEVEL MEASUREMENT SITE—Symbol gives location of site. Top number is altitude of water table in feet above sea level. Bottom number is well-identification number

Figure 14. Water-level contour map for wells screened in the intermediate zone, Fischer and Porter Site, Warminster, Pa., December 13, 1993.

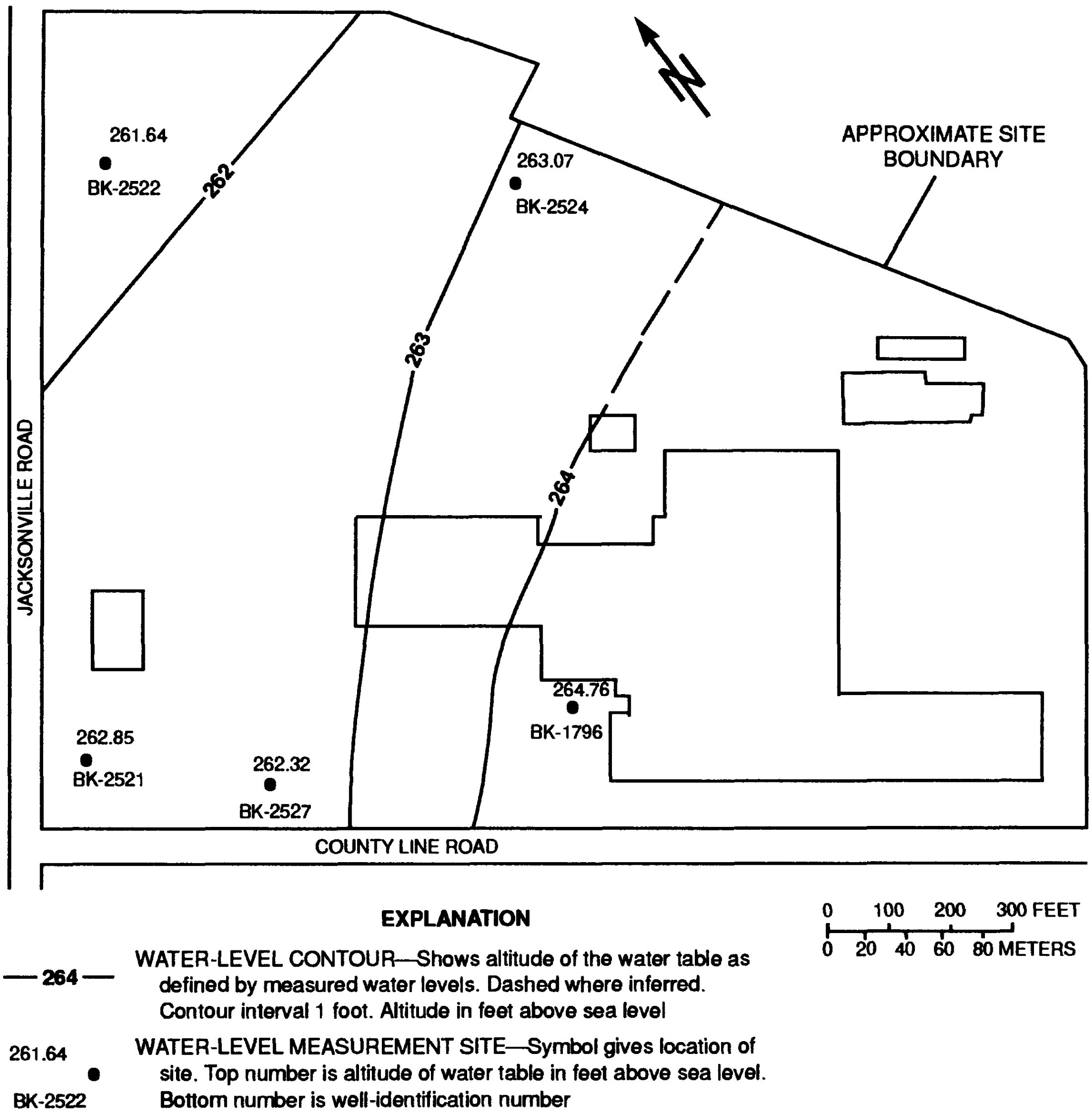
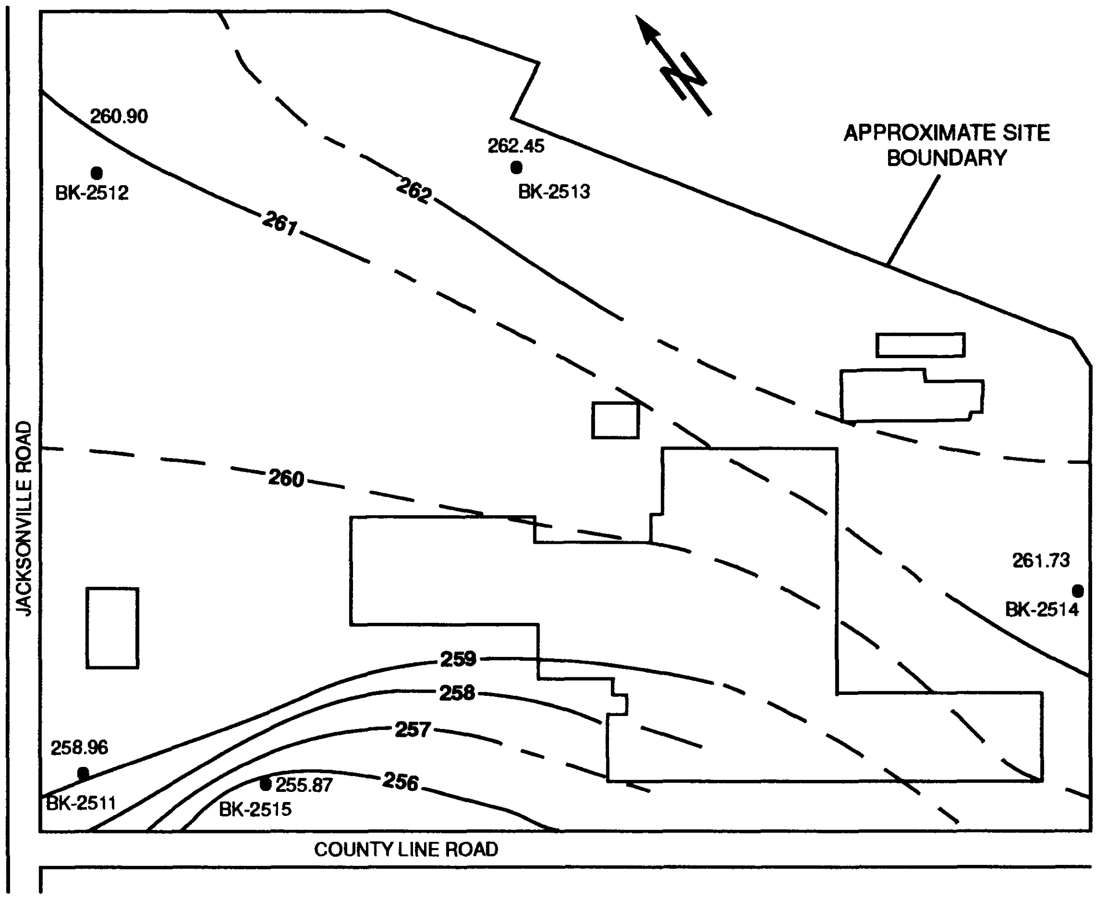


Figure 15. Water-level contour map for wells screened in the intermediate zone, Fischer and Porter Site, Warminster, Pa., May 3, 1994.



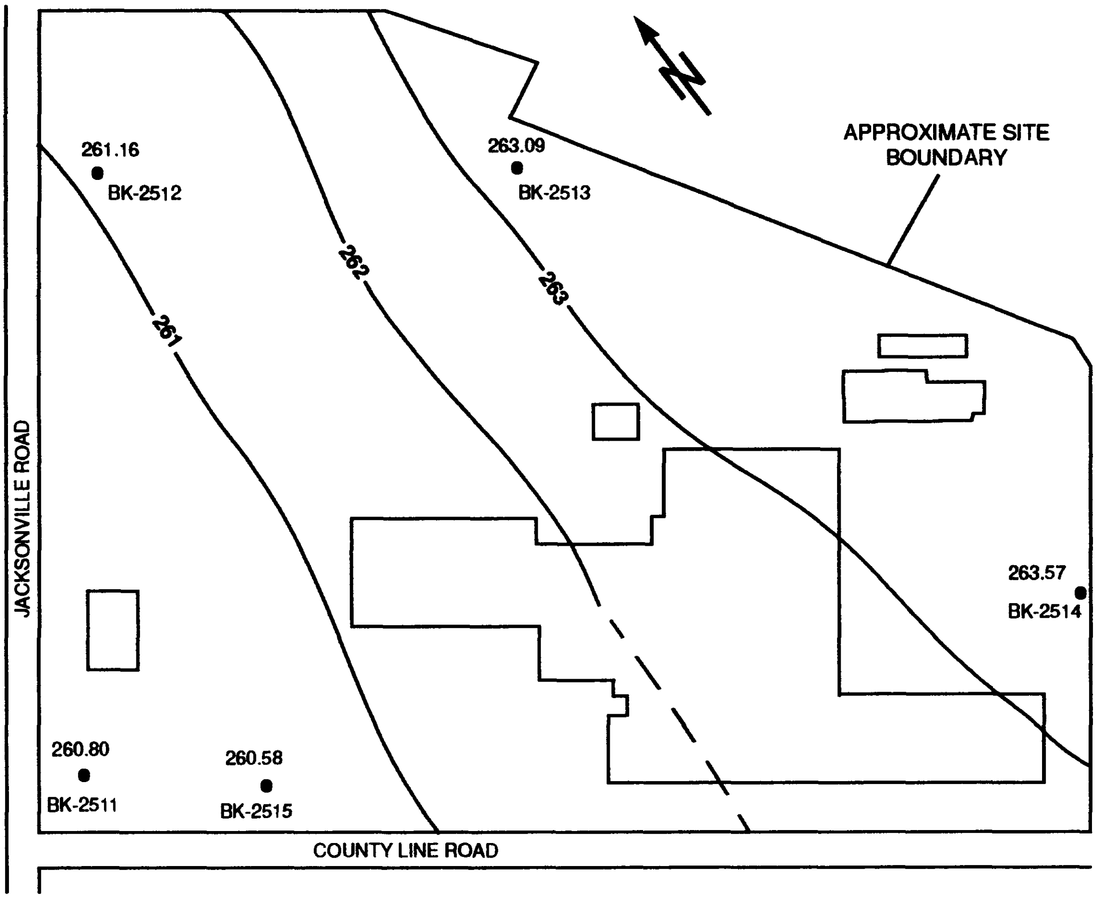
EXPLANATION

—260— WATER-LEVEL CONTOUR—Shows altitude of the water table as defined by measured water levels. Dashed where inferred. Contour interval 1 foot. Altitude in feet above sea level

260.90 ● BK-2512 WATER-LEVEL MEASUREMENT SITE—Symbol gives location of site. Top number is altitude of water table in feet above sea level. Bottom number is well-identification number

0 100 200 300 FEET
0 20 40 60 80 METERS

Figure 16. Water-level contour map for wells screened in the deep zone, Fischer and Porter Site, Warminster, Pa., December 13, 1993.



EXPLANATION

—262— WATER-LEVEL CONTOUR—Shows altitude of the water table as defined by measured water levels. Dashed where inferred. Contour interval 1 foot. Altitude in feet above sea level

261.16 ● BK-2512 WATER-LEVEL MEASUREMENT SITE—Symbol gives location of site. Top number is altitude of water table in feet above sea level. Bottom number is well-identification number

0 100 200 300 FEET
0 20 40 60 80 METERS

Figure 17. Water-level contour map for wells screened in the deep zone, Fischer and Porter Site, Warminster, Pa., May 3, 1994.

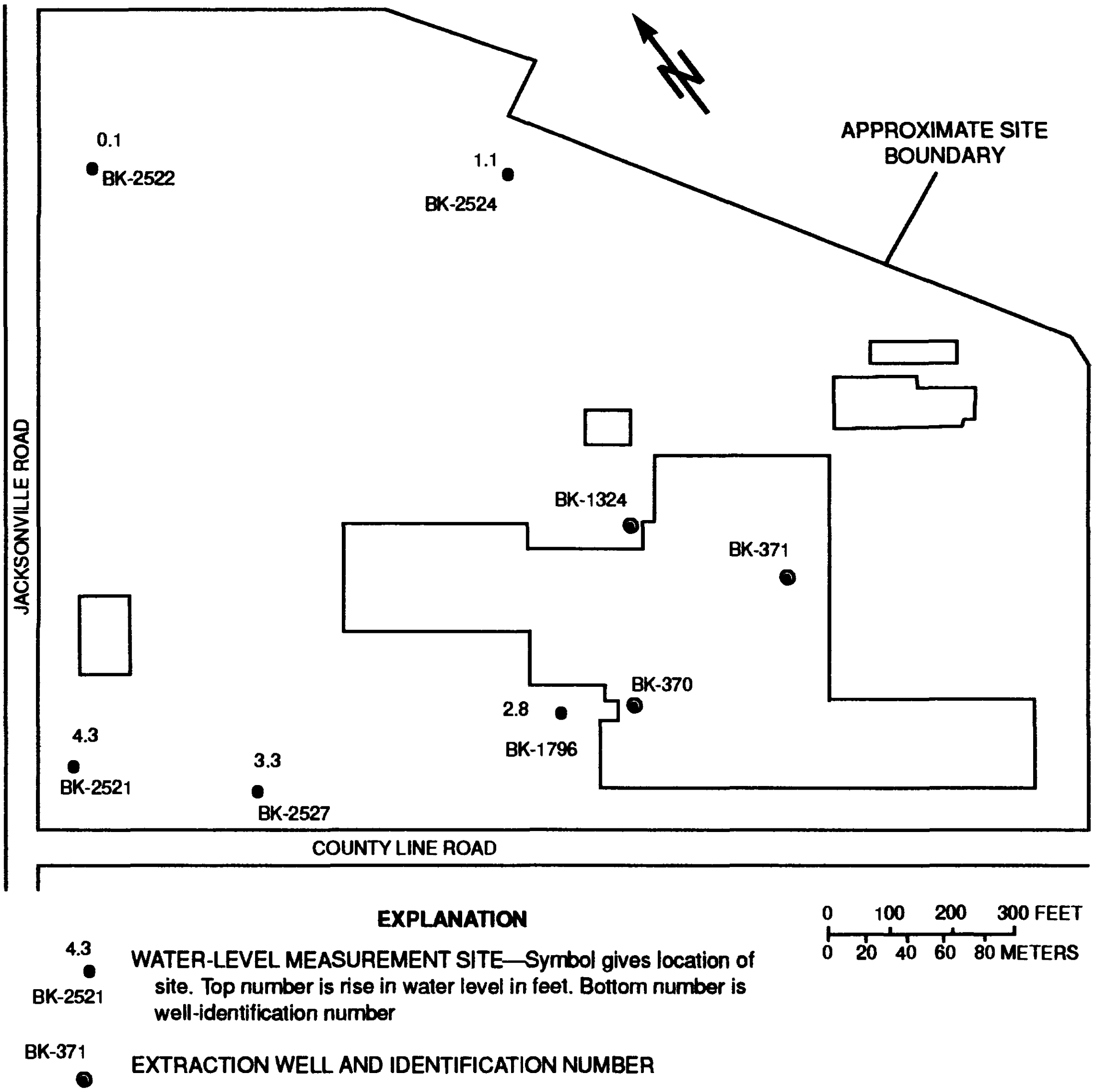


Figure 18. Rise in water level in wells screened in the intermediate zone caused by the shutdown of the treatment system wells, Fischer and Porter Site, Warminster, Pa.

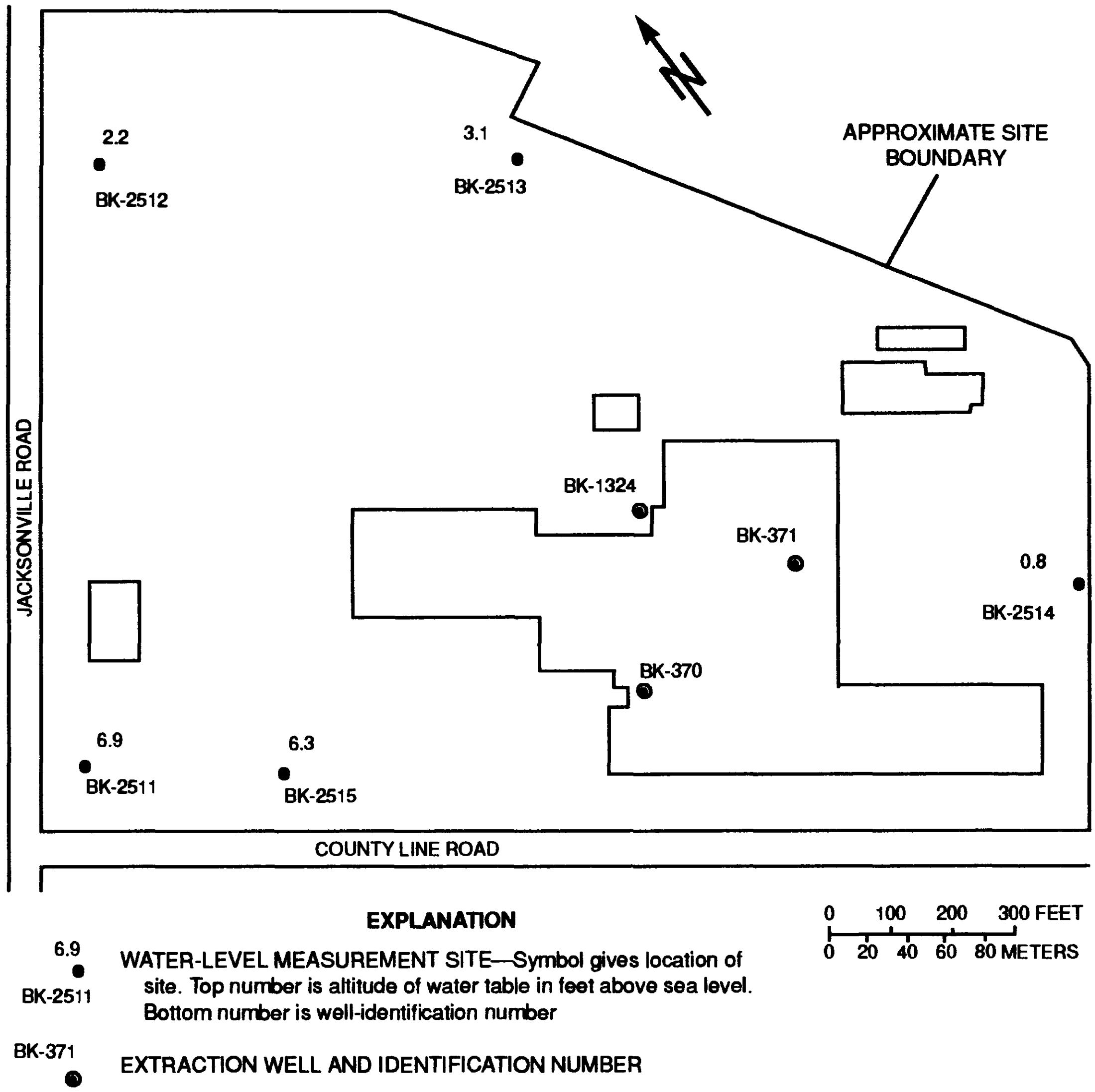


Figure 19. Rise in water level in wells screened in the deep zone caused by the shutdown of the treatment system wells, Fischer and Porter Site, Warminster, Pa.

VERTICAL DISTRIBUTION OF VOLATILE ORGANIC COMPOUNDS

Results of laboratory analysis for VOC's in water samples collected at the end of aquifer-isolation tests from 30 intervals isolated in 6 boreholes are given in appendix 5. A summary of compounds detected in water samples from each onsite borehole are given in tables 17-21. On the basis of laboratory and field blanks, chloroform and benzene are considered laboratory contaminants, and toluene is considered a field contaminant.

Trichloroethylene (TCE), tetrachloroethylene (PCE), 1,1,1-trichloroethane (TCA), cis-1,2-dichloroethylene (cis-1,2-DCE), 1,1-dichloroethylene (1,1-DCE), 1,1-dichloroethane, 1,2-dichloroethane, and vinyl chloride were detected in water samples collected during the aquifer-isolation tests. TCE, PCE, and TCA were detected in 77, 69, and 54 percent, respectively, of onsite water samples. Concentrations of TCE ranged up to 96 μg/L, PCE up to 14 μg/L, and TCA up to 9.1 μg/L. None of the isolated intervals had highly elevated concentrations of VOC's. Concentrations of all VOC's detected in water samples from offsite borehole MG-1242 were less than 2 μg/L (appendix 5, table 6).

Anaerobic degradation products of TCE and PCE (fig. 20) were detected in some water samples. Degradation products cis-1,2-DCE and 1,1-DCE were detected in most water samples where the concentration of TCE was greater than 70 μg/L. Degradation product vinyl chloride was detected in two water samples where the concentration of TCE was greater than 80 μg/L. The water sample (isolated interval 132-160 ft bls in borehole BK-2512) with the greatest concentration of TCE (96 μg/L) also had the greatest concentration of vinyl chloride (5.8 μg/L).

No general trend of increasing or decreasing concentrations of VOC's with depth were observed. VOC's generally were evenly distributed throughout all intervals tested and were present in water samples from the isolated interval closest to land surface (37-72 ft bls in borehole BK-2314) to the deepest isolated interval (305-352 ft bls in borehole BK-25111).

The fairly constant concentrations of VOC's with depth are the result of two factors, the downward head gradient and the presence of open boreholes on the site in the past. The downward head gradient at the site, caused in part by the pumping of nearby public-supply wells BK-366 and BK-367, caused the vertical migration of VOC's into the aquifer through wells BK-370 and BK-371 between the time they were taken out of service as supply wells and the time that they were put into service as extraction wells and through well BK-1324 between the time that it was drilled and the time it was put into service as an extraction well. These three wells are of open-hole construction and are located in the main area of contamination. SMC-Martin, Inc. (1980, tables 1, 3, and 8) reported concentrations of TCE to 66,400 μg/L, PCE to 26,000 μg/L, and TCA to 610 μg/L in water samples from well BK-370; TCE to 7,500 μg/L, PCE to 190 μg/L, and TCA to 97 μg/L in water samples from well BK-371; and TCE to 15,000 μg/L, PCE to 920 μg/L, and TCA to 4,600 μg/L in water samples from well BK-1324. High concentrations of these VOC's migrated downward in the open boreholes in response to the downward head gradient and then moved outward into the aquifer at different depths in response to pumping and natural hydraulic gradients.

Concentrations of TCE detected in water samples from borehole BK-2511 (table 17) ranged from 73 to 88 μg/L, and TCE was about evenly distributed through all isolated intervals. Concentrations of PCE ranged from 8.6 to 14 μg/L. The highest concentrations of TCE, PCE, cis-1,2-DCE, and 1,1-DCE were in the upper two isolated intervals above 187 ft and 211-239 ft bls.

Concentrations of TCE in water samples from borehole BK-2512 (table 18) ranged from 56 to 96 μg/L, and concentrations of PCE ranged from below the minimum reporting level to 37 μg/L. The highest concentrations of VOC's were detected in the interval 132-160 ft bls, which is a water-receiving zone identified by borehole geophysical logging. The concentrations of VOC's in the interval 132-160 ft bls are greater than the concentrations of VOC's in the interval above 115 ft bls, which includes the water-producing zone that contributes borehole flow to the interval 132-160 ft bls.

Concentrations of TCE in water samples from borehole BK-2513 (table 20) ranged from 20 to 43 μg/L, and concentrations of PCE ranged from 2.3 to 11 μg/L. A water sample collected from nearby public-supply well BK-366 by the Fischer and Porter Company on May 26, 1993, had a TCE concentration of 41 μg/L and a PCE concentration of 3.1 μg/L. These concentrations are similar to concentrations in water samples from borehole BK-2513.

TCE in water samples from borehole BK-2514 (table 20) was detected (9.7 μg/L) above the minimum reporting level only in the interval above 72 ft bls. PCE was not detected in any isolated interval. A water sample collected from nearby public-supply well BK-367 by the Fischer and Porter Company on May 26, 1993, had a TCE concentration of less than 1 μg/L and a PCE concentration of 10 μg/L.

Concentrations of TCE in water samples from borehole BK-2515 (table 21) ranged from 71 to 84 μg/L, and concentrations of PCE ranged from 6.3 to 7.3 μg/L. Vinyl chloride was detected at a concentration of 1.7 μg/L in the interval above 172 ft bls.

Table 17. *Volatile organic compounds detected in water samples from borehole BK-2511, Fischer and Porter Site, Warminster, Pa.*

[Concentrations given in micrograms per liter; <, less than]

Compound	Sampled depth interval (feet below land surface)			
	Above 187	211-239	241-269	Below 305
1,1-Dichloroethane	1.5	1.7	1.4	1.1
1,1-Dichloroethylene	4.3	4.5	3.7	2.6
cis-1,2-Dichloroethene	17	19	15	14
1,2-Dichloropropane	2.3	<.8	<.8	<.8
Tetrachloroethylene	14	14	11	8.6
1,1,1-Trichloroethane	2.8	1.9	1.2	<.8
Trichloroethylene	88	87	78	73

Table 18. *Volatile organic compounds detected in water samples from borehole BK-2512, Fischer and Porter Site, Warminster, Pa.*

[Concentrations given in micrograms per liter; <, less than]

Compound	Sampled depth interval (feet below land surface)					
	Above 115	132-160	164-192	204-235	237-265	Below 265
1,1-Dichloroethane	<0.8	<0.8	<0.8	<0.8	<0.8	1.6
1,2-Dichloroethane	<.8	8.3	2.1	1.9	1.8	<.8
1,1-Dichloroethylene	<.8	5.5	1.0	<.8	<.8	2.0
cis-1,2-Dichloroethene	8.2	55	30	25	29	27
Tetrachloroethylene	5.9	37	12	11	<.8	13
1,1,1-Trichloroethane	<.8	1.8	<.8	.9	<.8	1.3
Trichloroethylene	56	96	75	75	76	82
Vinyl chloride	<.8	5.8	<.8	<.8	<.8	<.8

Table 19. *Volatile organic compounds detected in water samples from borehole BK-2513, Fischer and Porter Site, Warminster, Pa.*

[Concentrations given in micrograms per liter; <, less than]

Compound	Sampled depth interval (feet below land surface)					
	Above 143	143-171	176-204	202-232	232-260	Below 260
1,2-Dichloroethane	29	35	23	27	6.5	6.7
Ethylbenzene	<.8	<.8	<.8	>.8	<.8	2.5
Tetrachloroethylene	10	11	4.5	2.3	3.8	4.4
1,1,1-Trichloroethane	1.2	1.4	<.8	1.7	2.5	.8
Trichloroethylene	39	43	34	37	20	20

Table 20. *Volatile organic compounds detected in water samples from borehole BK-2514, Fischer and Porter Site, Warminster, Pa.*

[Concentrations given in micrograms per liter; <, less than]

Compound	Sampled depth interval (feet below land surface)						
	Above 72	72-100	100-128	130-158	177-205	209-237	Below 237
1,1-Dichloroethane	<0.8	<0.8	<0.8	<0.8	<0.8	1.1	<0.8
1,2-Dichloroethane	4.5	<.8	<.8	<.8	<.8	<.8	<.8
1,1,1-Trichloroethane	<.8	.8	<.8	9.1	<.8	<.8	1.1
Trichloroethylene	9.7	<.8	<.8	<.8	<.8	<.8	<.8

Table 21. *Volatile organic compounds detected in water samples from borehole BK-2515, Fischer and Porter Site, Warminster, Pa.*

[Concentrations given in micrograms per liter]

Compound	Sampled depth interval (feet below land surface)		
	Above 172	172-200	Below 277
1,1-Dichloroethane	3.1	1.7	2.0
1,1-Dichloroethylene	6.6	5.6	2.0
cis-1,2-Dichloroethene	17	14	19
Tetrachloroethylene	6.3	7.3	7.3
Trichloroethylene	84	71	76
Vinyl chloride	1.3	<.8	<.8

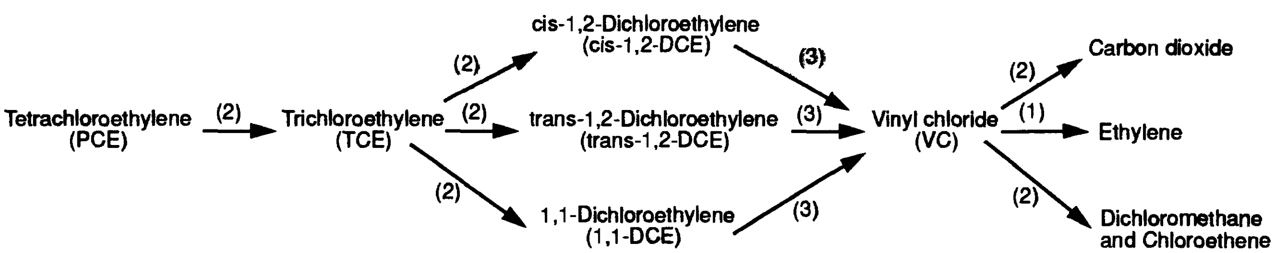


Figure 20. Typical reaction pathways for the anaerobic degradation of tetrachloroethylene and trichloroethylene by reductive dehalogenation. Reactions from: (1) Freedman and Gossett (1989); (2) Parsons and others (1984); and (3) Vogel and McCarty (1985).

SUMMARY AND CONCLUSIONS

The Fischer and Porter Company Superfund Site is underlain by sedimentary rocks of the Upper Triassic Stockton Formation, which consist of interbedded siltstone, very-fine grained to coarse-grained sandstone, and conglomerate in crudely defined, upward fining cycles. The rocks of the Stockton Formation form a complex, heterogeneous, leaky, multiaquifer system comprised of a series of gently dipping lithologic units with different hydraulic properties. In general, the sandstone units are the principle water-bearing units, but some of the finer-grained units may contain water-bearing zones. Ground water is unconfined in the shallower part of the aquifer and confined or semiconfined in the deeper part of the aquifer. Differences in the ratio of vertical to horizontal hydraulic conductivity, as well as differences in vertical hydraulic conductivity within and among lithologic units, create confining conditions.

Water levels measured in monitor well clusters and borehole-flow measurements made in open boreholes show a downward hydraulic head gradient at the site. Water moves downward through the aquifer system in response to this downward head gradient, which is caused in part by the pumping of nearby, deep public-supply wells and the Fischer and Porter treatment system extraction wells. Differences in head in open boreholes cause water in the well bore to flow under nonpumping conditions in the direction of decreasing head. Downward borehole flow was measured at rates up to 0.5, 1.7, and 9 gal/min in boreholes BK-372, BK-2511, and BK-2514, respectively.

Aquifer-isolation tests were run in the five exploratory boreholes and offsite borehole MG-1242. On the basis of specific-capacity data for 27 isolated intervals, specific capacity is not related to depth. Three of the isolated intervals with specific capacities greater than 1 (gal/min)/ft were identified by borehole geophysical logging as water-receiving zones, and one was identified as a water-producing zone.

Water levels in monitor wells at the Fischer and Porter Site are greatly affected by the pumping of public-supply wells BK-366 and BK-367 as well as the pumping of the Fischer and Porter treatment system extraction wells. Pumping of the public-supply wells causes daily water-level fluctuations in wells at the site as great as 5.3 ft. The shutdown of the Fischer and Porter treatment system extraction wells had only a small effect on water levels in the shallow zone. Estimated rises in water level were less than 1 ft. The shutdown of the Fischer and Porter treatment system extraction wells caused a rise in water level in all wells screened in the intermediate and deep zones. The rise in water level was as great as 4.3 ft in the intermediate zone and as great as 5.9 ft in the deep zone.

The response of water levels to stress generally is more related to the depth of the stratigraphic unit that a well is screened in than to the particular stratigraphic unit the well is screened in. Water levels in wells screened in the same depth interval respond to stress in a similar manner and are contourable. Water levels measured in all wells screened in a particular stratigraphic unit are not contourable.

On the basis of water levels measured on December 13, 1993, and May 3, 1994, the direction of ground-water flow in the shallow and intermediate zones is toward the north; discharge is to the unnamed tributary to Pennypack Creek north of the site. The direction of ground-water flow in the deep zone was toward the west-southwest on December 13 and toward the west on May 3; discharge probably is to the unnamed tributary to Pennypack Creek west of the site.

TCE, PCE, TCA, cis-1,2-DCE, 1,1-DCE, 1,1-dichloroethane, 1,2-dichloroethane, and vinyl chloride were detected in water samples collected during the aquifer-isolation tests. TCE, PCE, and TCA were detected in 77, 69, and 54 percent, respectively, of onsite water samples. Concentrations of TCE ranged up to 96 μg/L, PCE up to 14 μg/L, and TCA up to 9.1 μg/L. Anaerobic degradation products cis-1,2-DCE and 1,1-DCE were detected in most water samples where the concentration of TCE was greater than 70 μg/L, and vinyl chloride was detected in two water samples where the concentration of TCE was greater than 80 µg/L. No general trend of increasing or decreasing concentrations of VOC's with depth were observed. None of the isolated intervals had highly elevated concentrations of VOC's.

The fairly constant concentrations of VOC's with depth are the result of the downward head gradient and the presence of open boreholes on the site. The downward head gradient at the site, caused in part by the pumping of nearby public-supply wells caused the vertical migration of VOC's into the aquifer through wells BK-370 and BK-371 between the time they were taken out of service as supply wells and the time that they were put into service as extraction wells and through well BK-1324 between the time that it was drilled and the time it was put into service as an extraction well. These three wells are of open-hole construction and are located in the main area of contamination. VOC's migrated downward in the open boreholes in response to the downward head gradient and then moved outward into the aquifer at different depths in response to the pumping of nearby wells and natural hydraulic gradients.

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APPENDIX 1. BOREHOLE GEOPHYSICAL LOGS

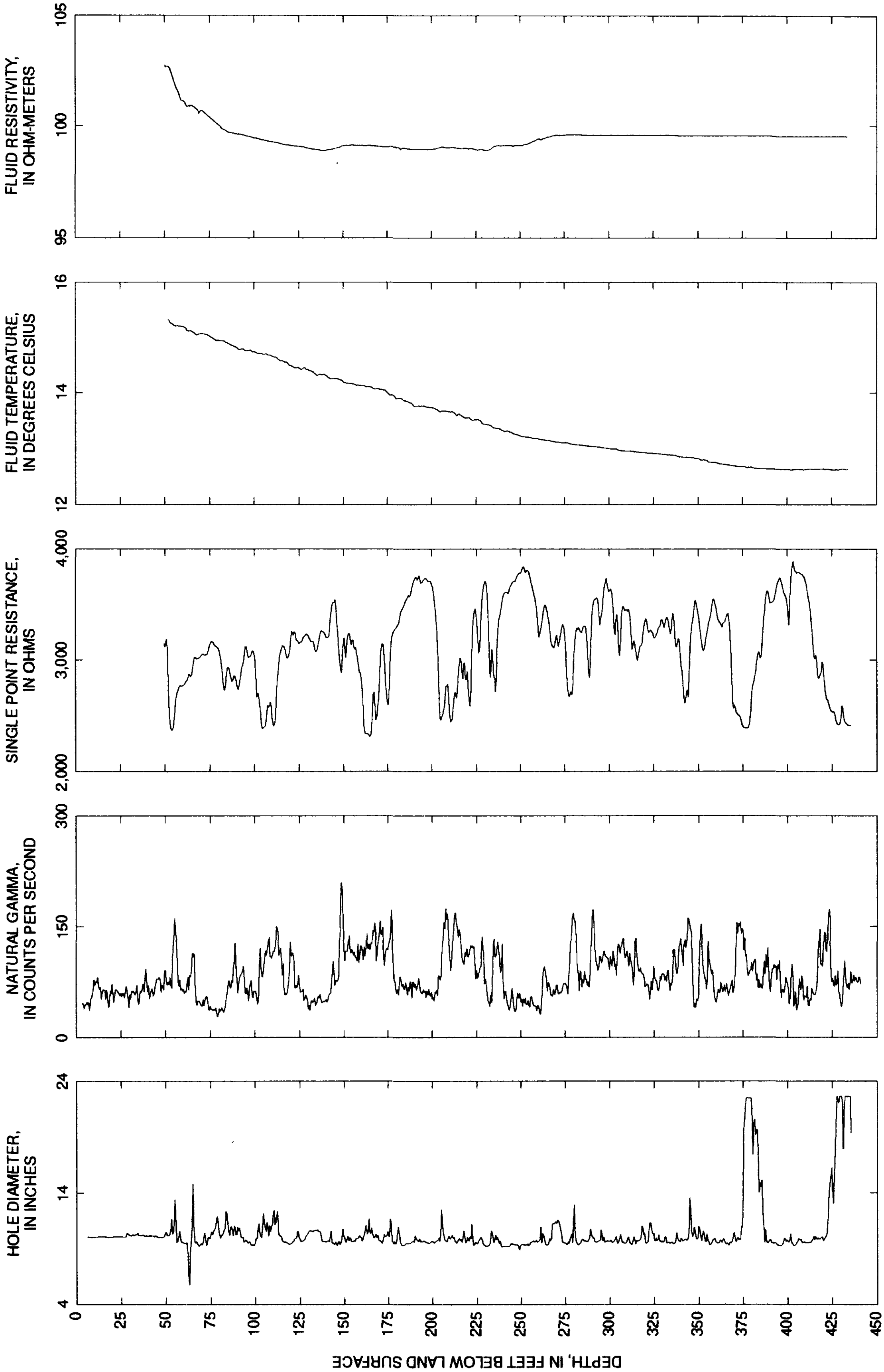

Figure 1. Borehole geophysical logs for borehole BK-372, Fischer and Porter Site, Warminster, Pa., March 1, 1991.

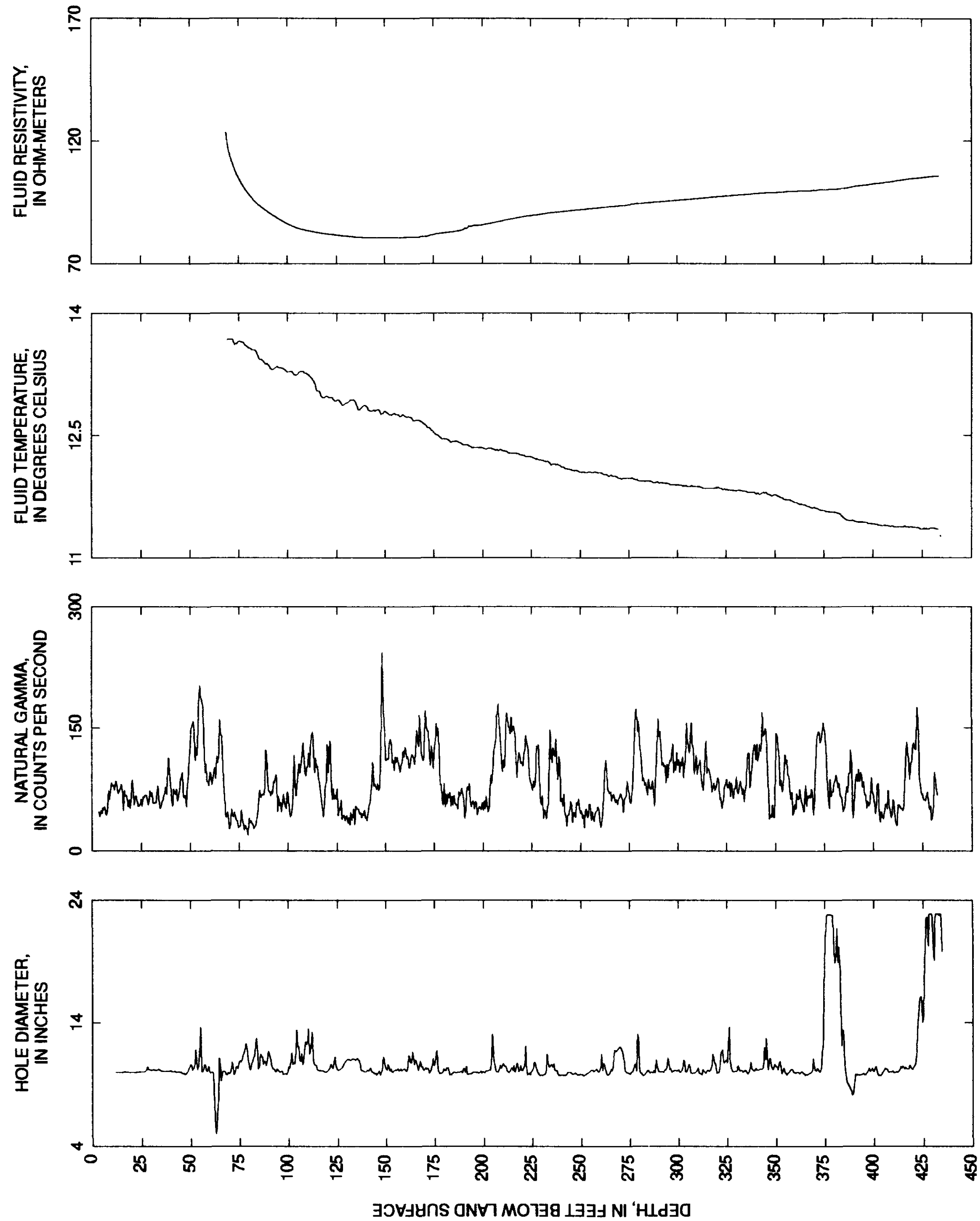

Figure 2. Borehole geophysical logs for borehole BK-372, Fischer and Porter Site, Warminster, Pa., September 8, 1992.

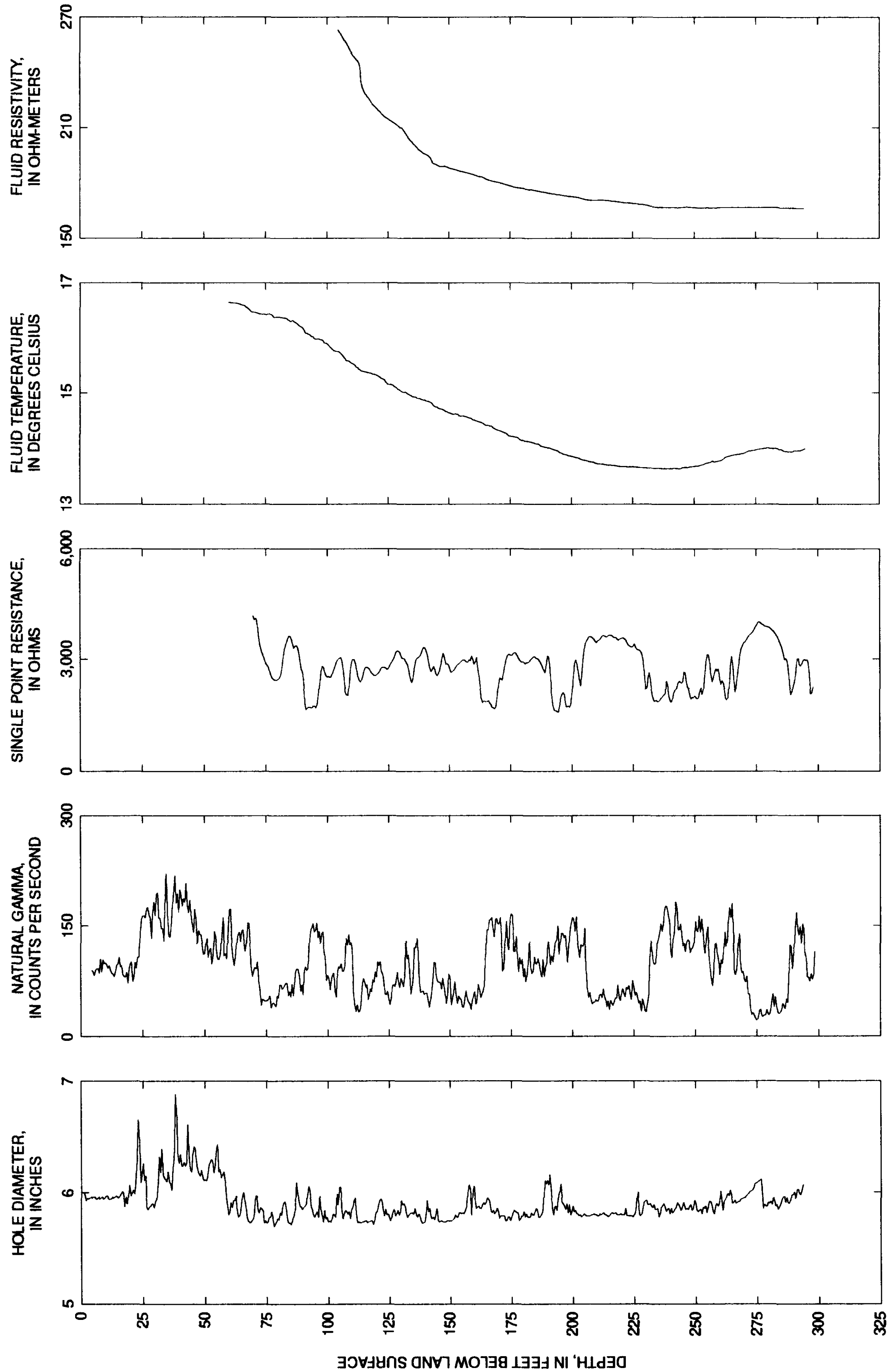

Figure 3. Borehole geophysical logs for borehole BK-1324, Fischer and Porter Site, Warminster, Pa.

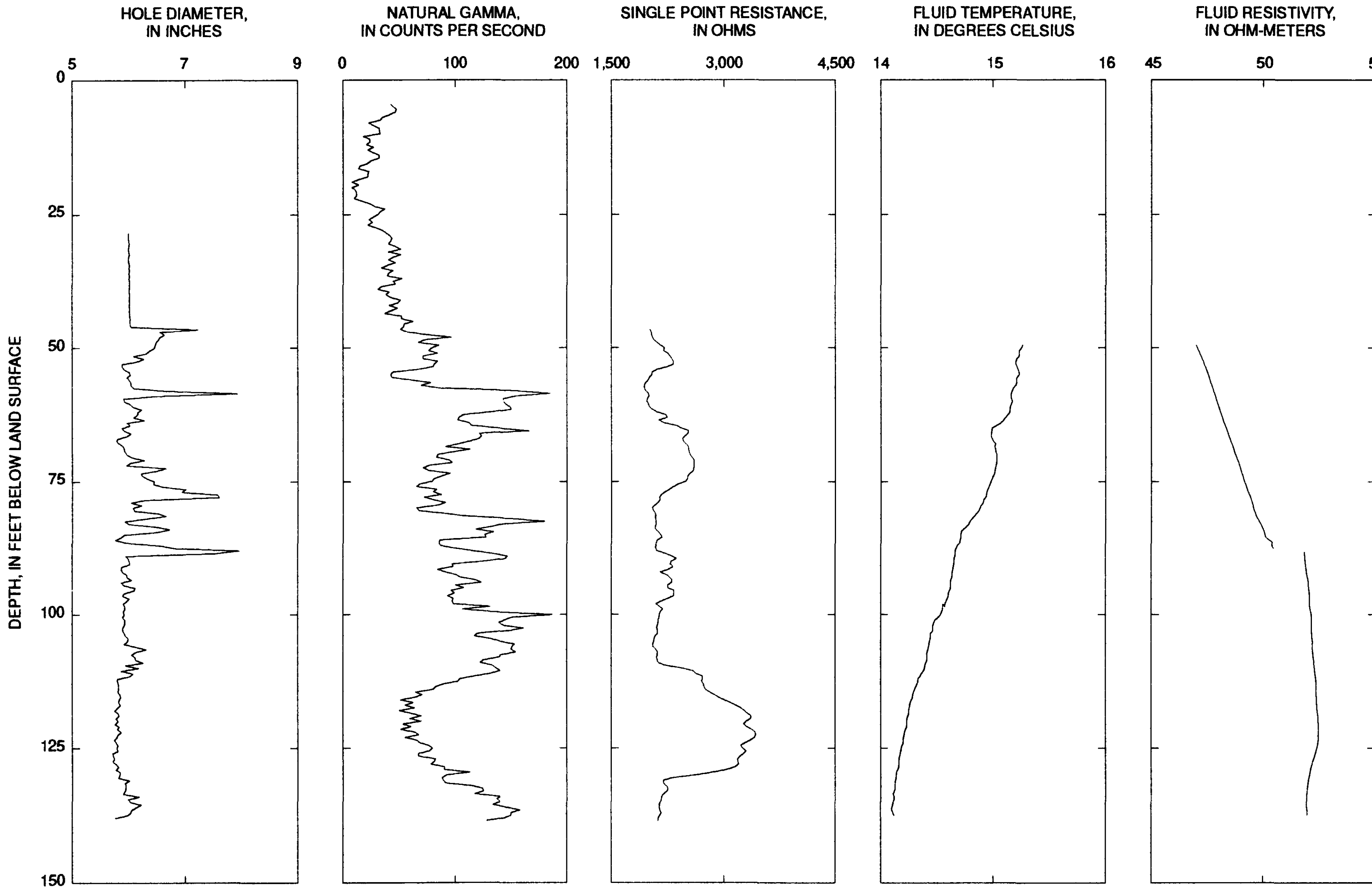

Figure 4. Borehole geophysical logs for borehole BK-1731, Fischer and Porter Site, Warminster, Pa., May 31, 1991.

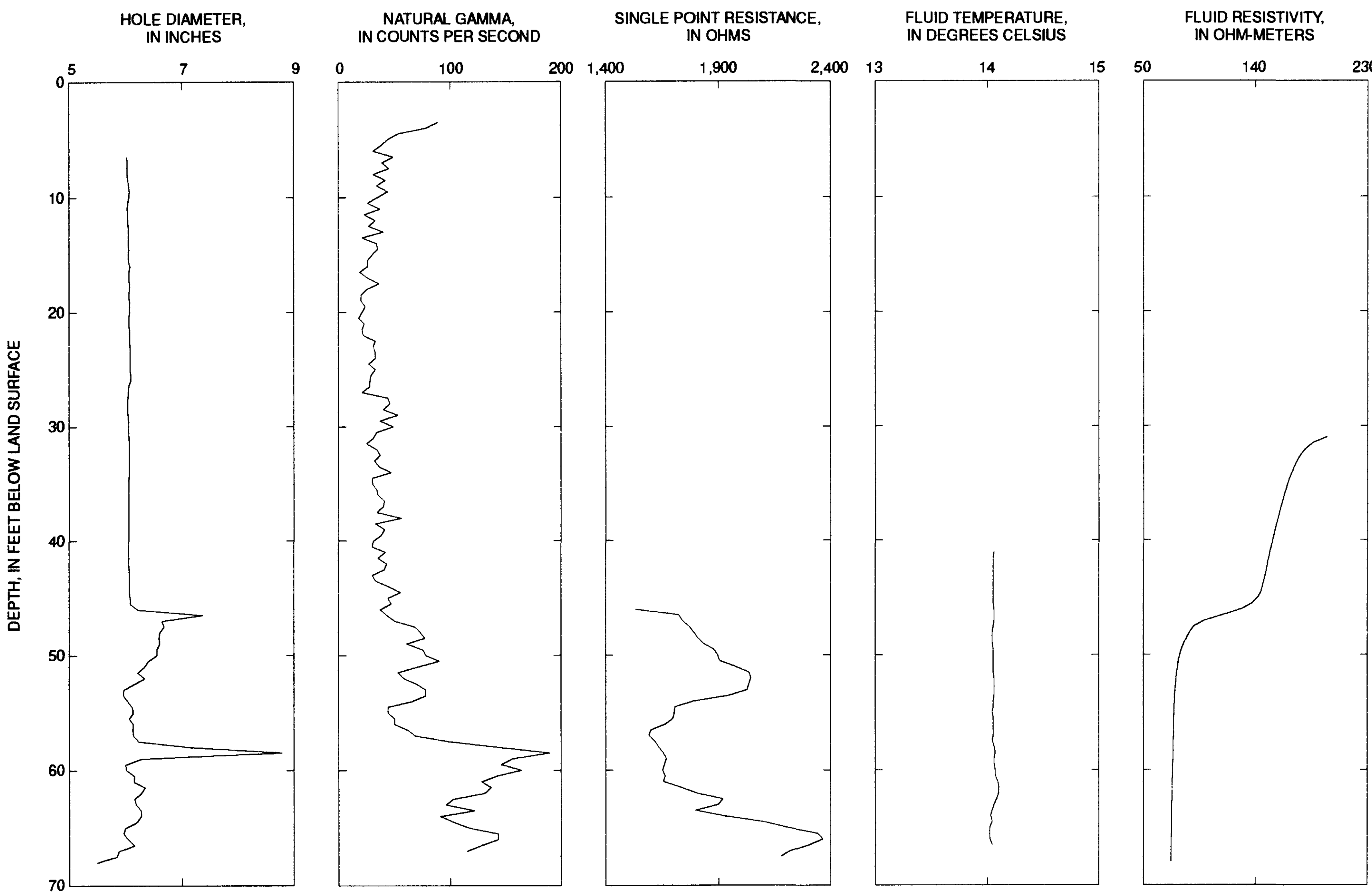

Figure 5. Borehole geophysical logs for borehole BK-1731, Fischer and Porter Site, Warminster, Pa., September 14, 1992.

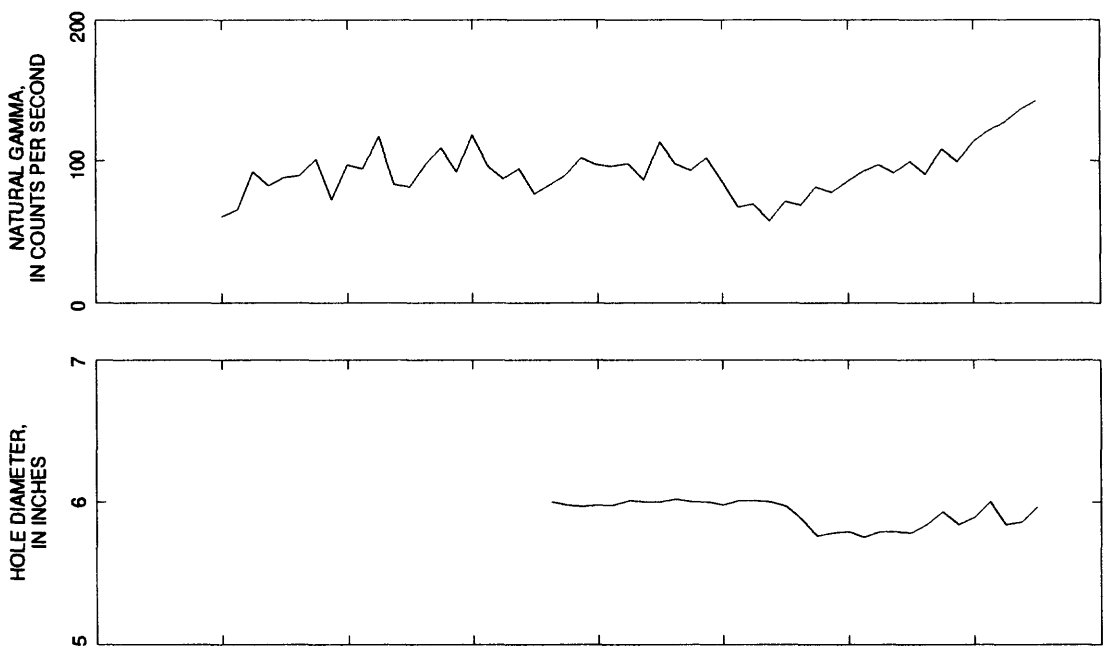

Figure 6. Borehole geophysical logs for borehole BK-1795, Fischer and Porter Site, Warminster, Pa.

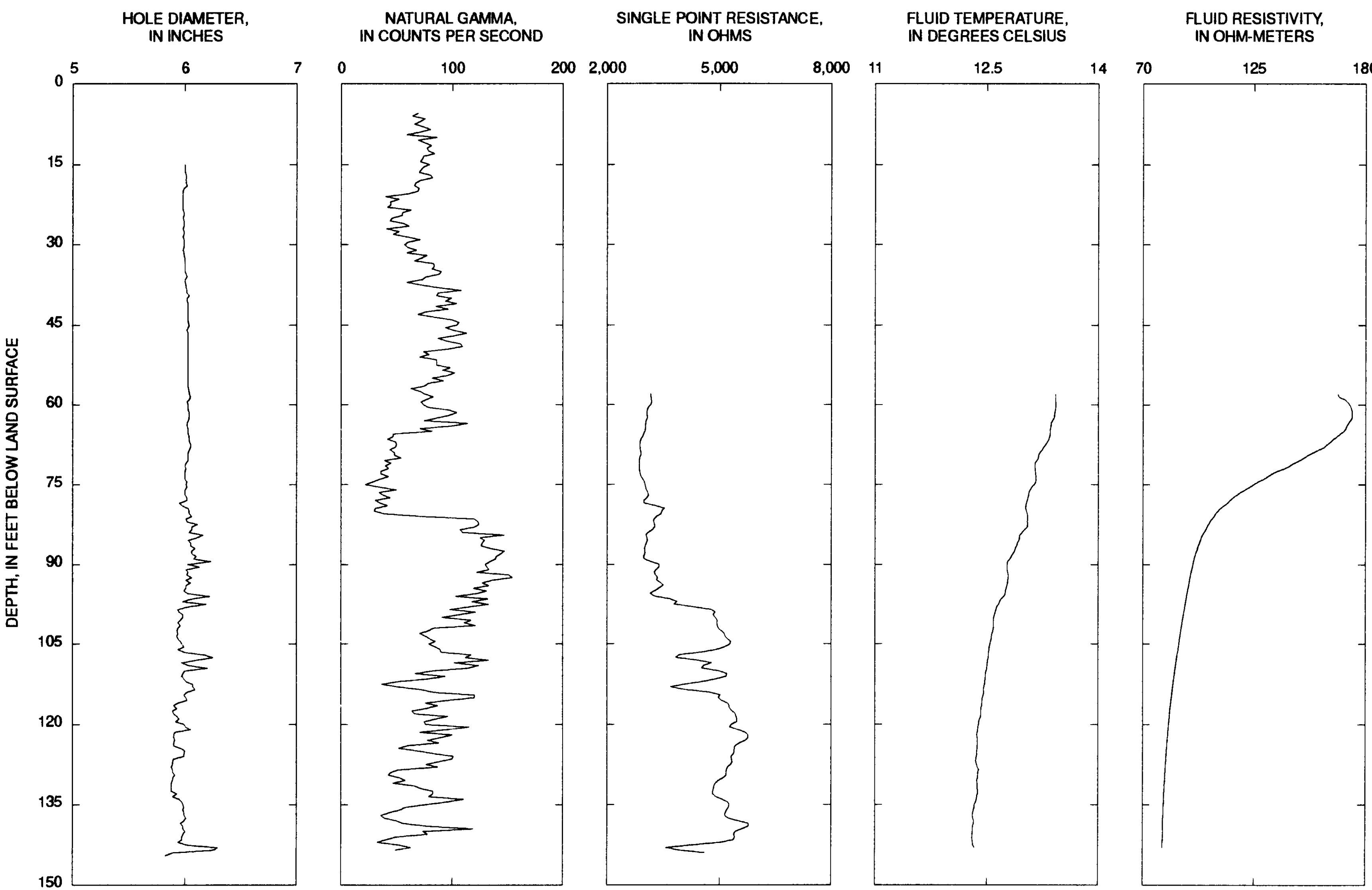

Figure 7. Borehole geophysical logs for borehole BK-1796, Fischer and Porter Site, Warminster, Pa., September 14, 1992.

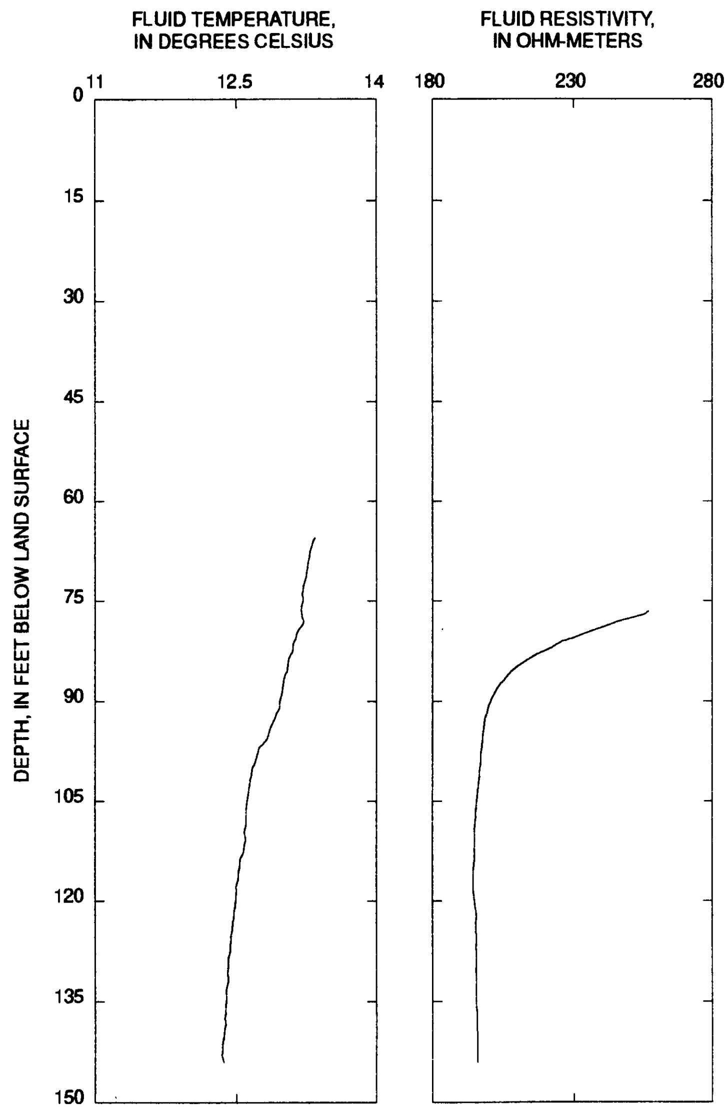

Figure 8. Borehole geophysical logs for borehole BK-1796, Fischer and Porter Site, Warminster, Pa., September 28, 1992.

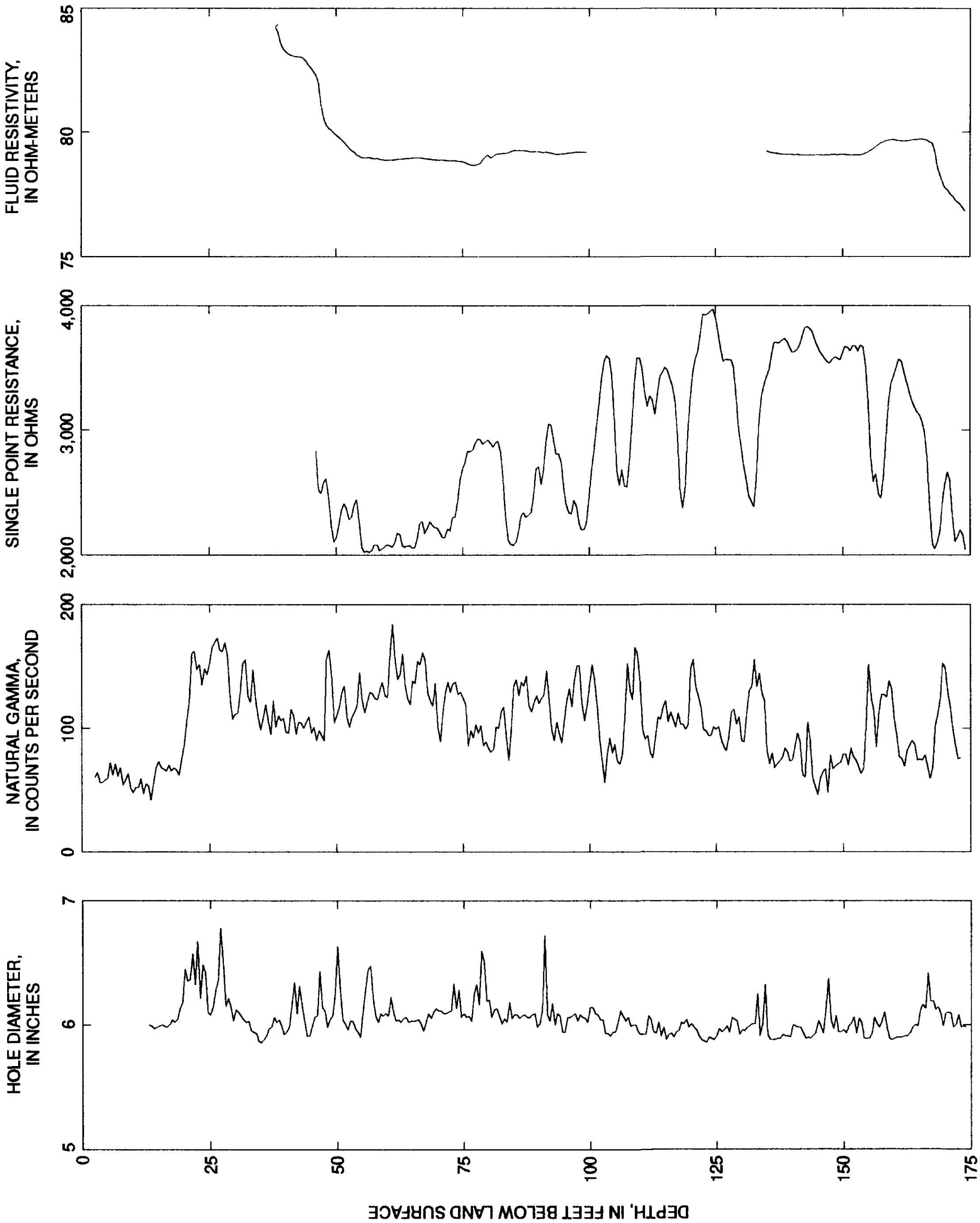

Figure 9. Borehole geophysical logs for borehole MG-1241, Hatboro, Pa., November 26 and December 7, 1990.

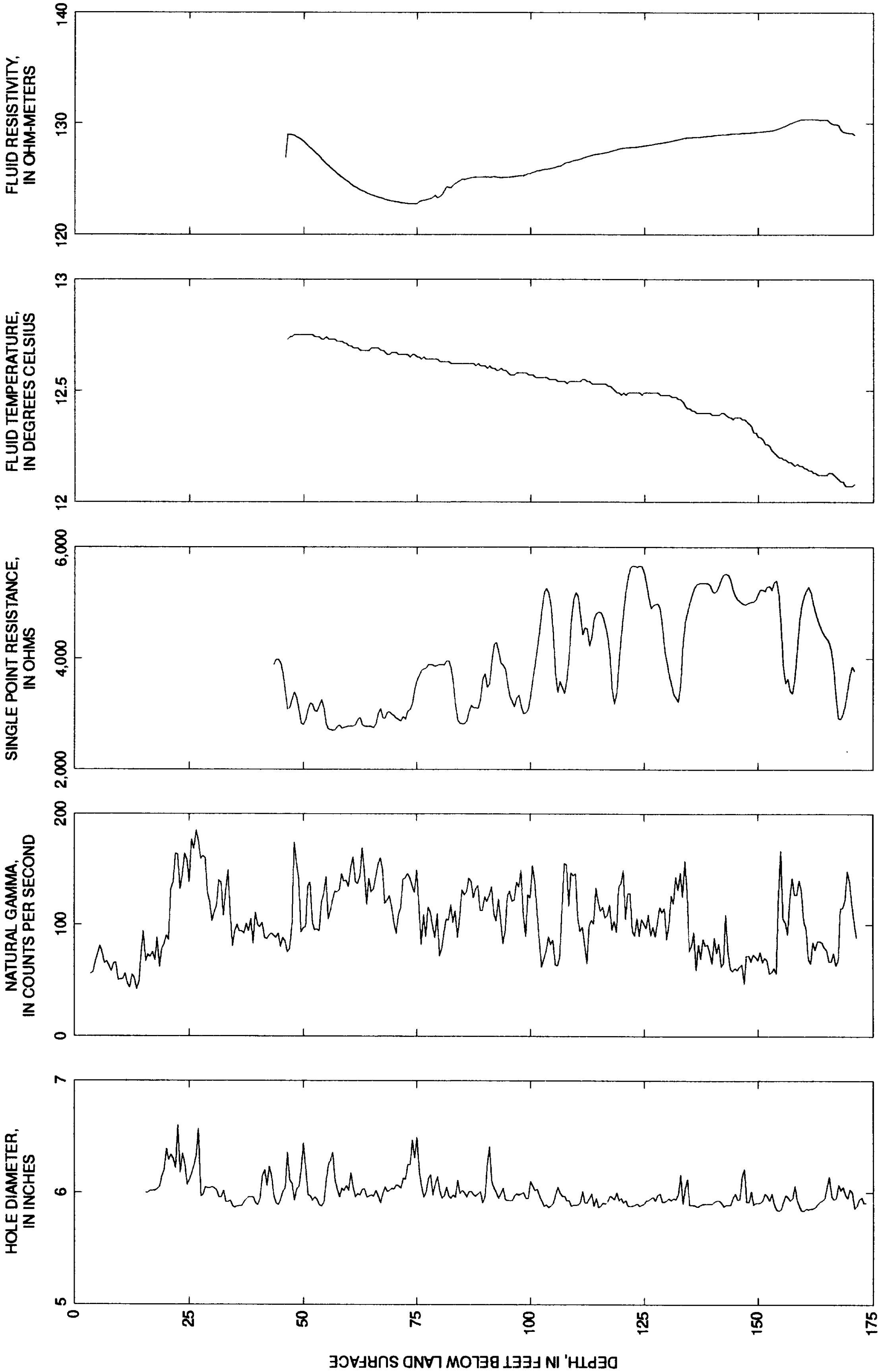

Figure 10. Borehole geophysical logs for borehole MG-1241, Hatboro, Pa., September 9, 1992.

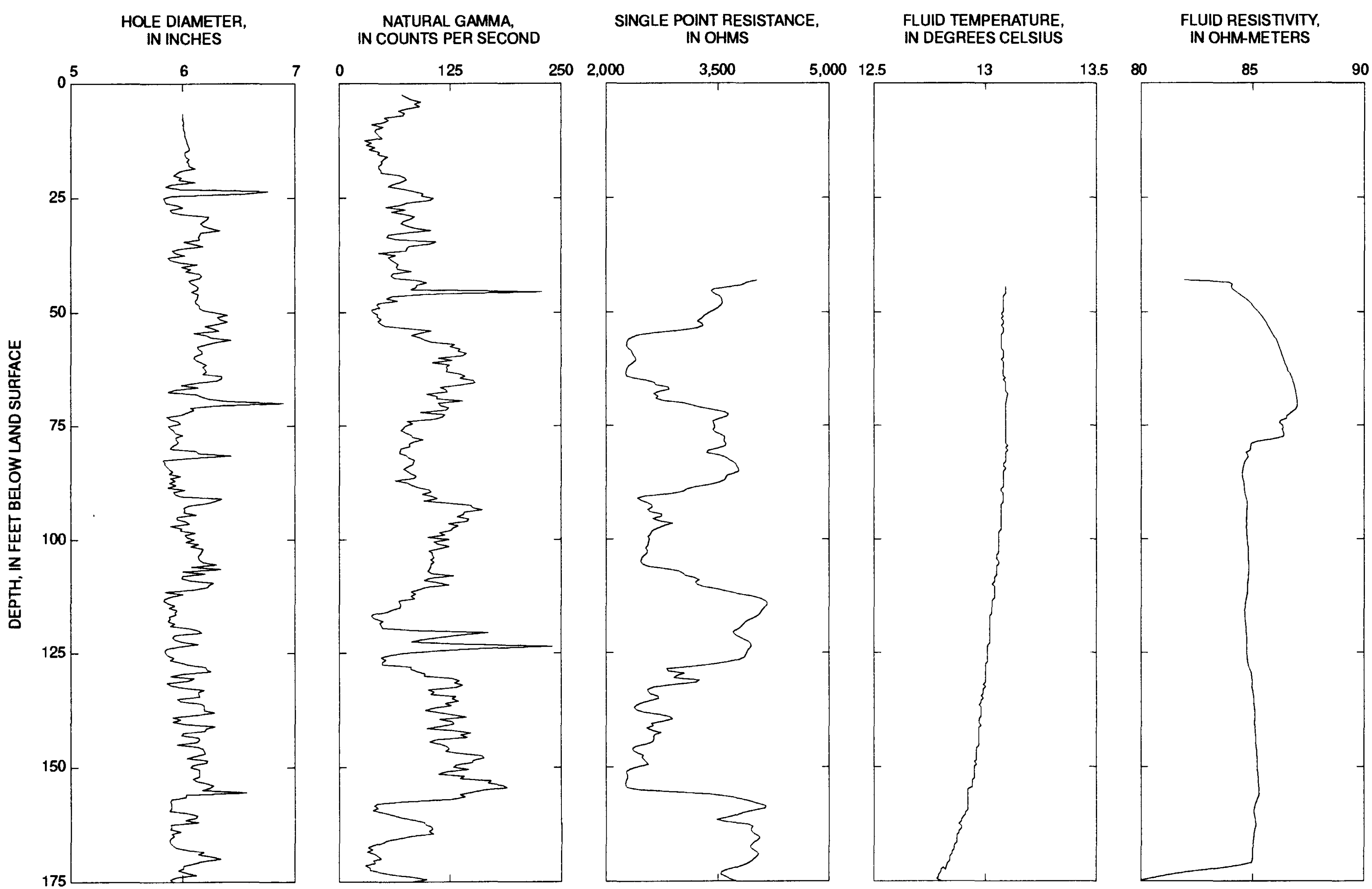

Figure 11. Borehole geophysical logs for borehole MG-1242, Hatboro, Pa., December 7, 1990.

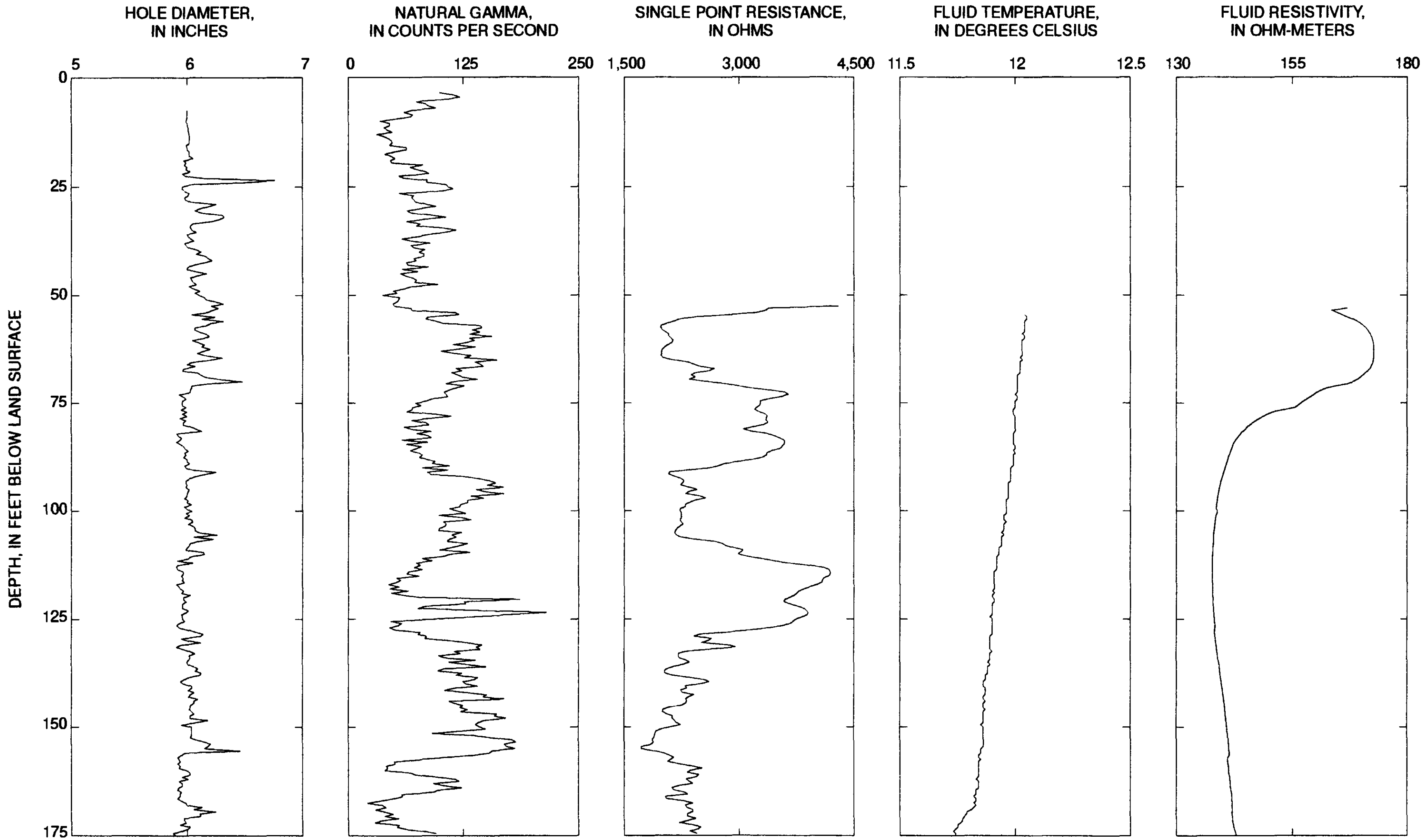

Figure 12. Borehole geophysical logs for borehole MG-1242, Hatboro, Pa., September 9, 1992.

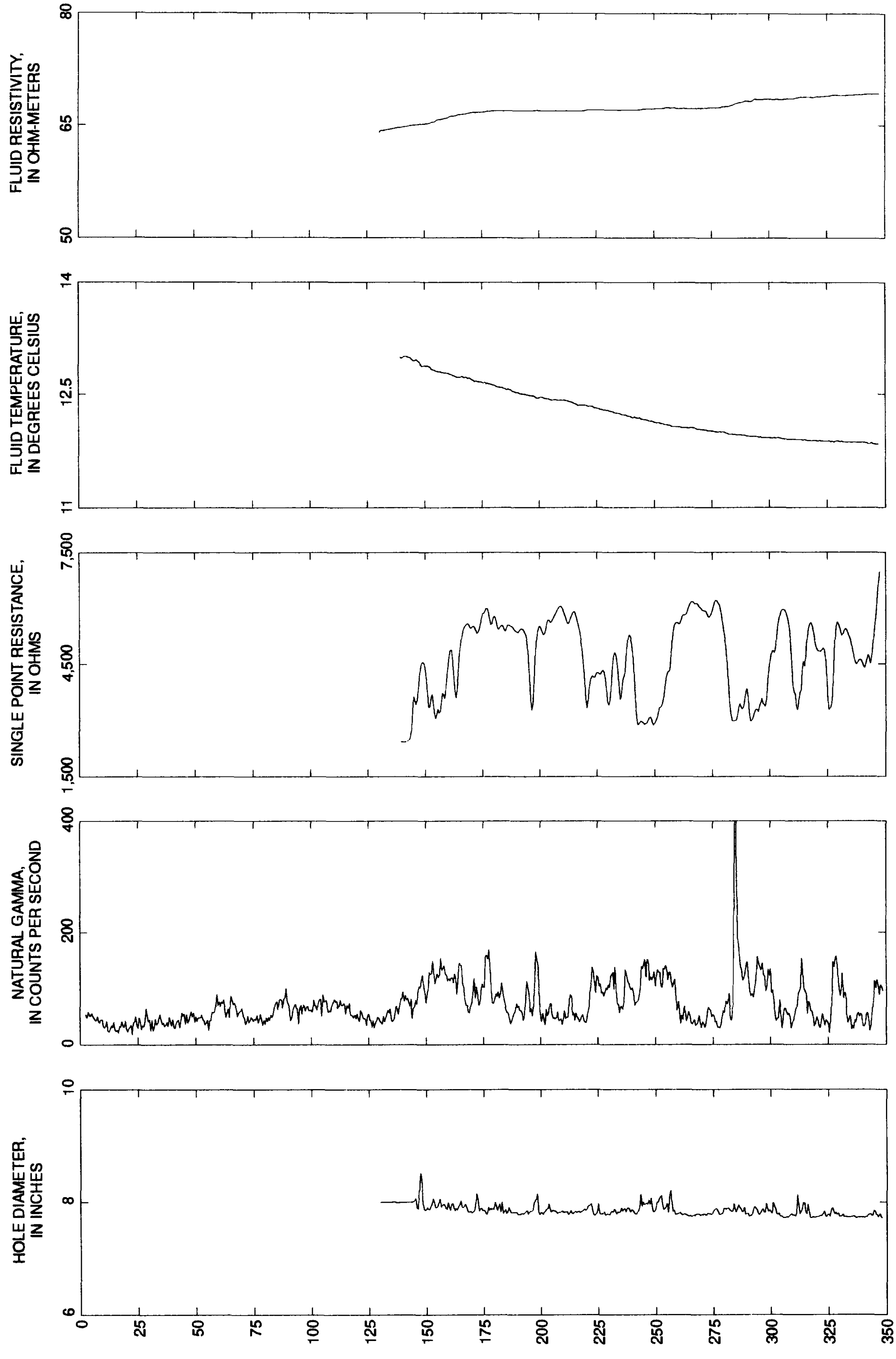

Figure 13. Borehole geophysical logs for borehole BK-2511, Fischer and Porter Site, Warminster, Pa.

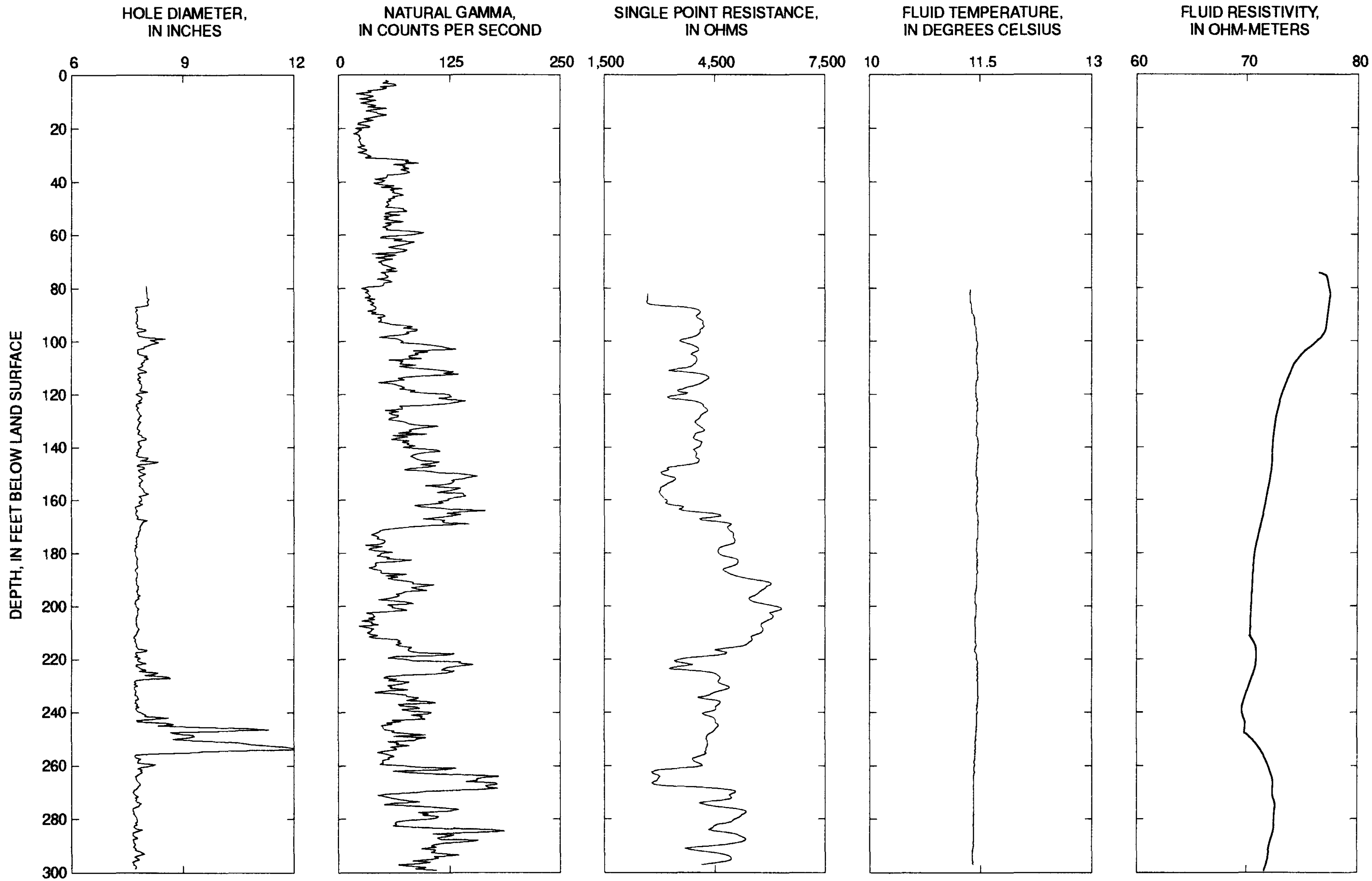

Figure 14. Borehole geophysical logs for borehole BK-2512, Fischer and Porter Site, Warminster, Pa.

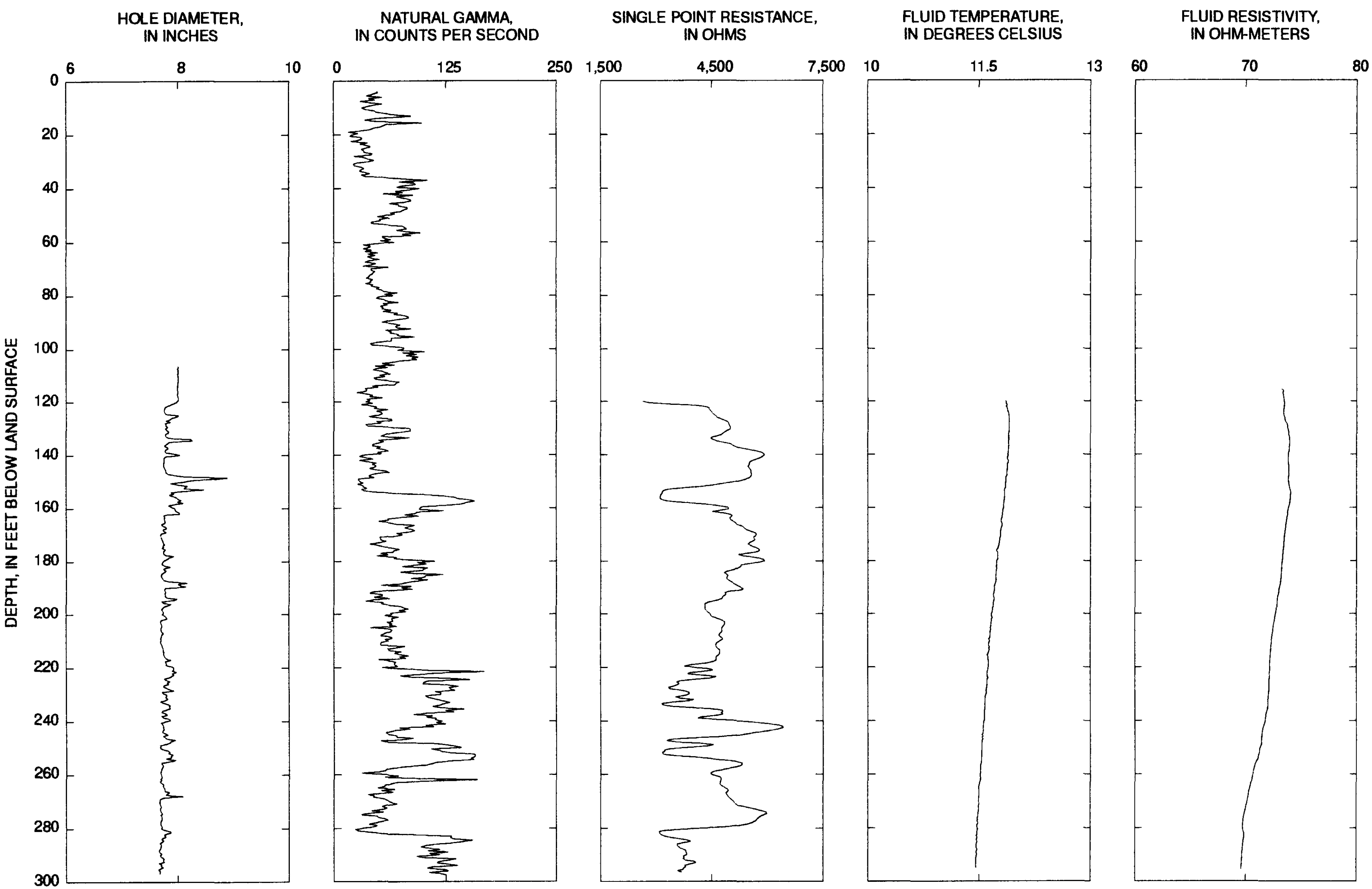

Figure 15. Borehole geophysical logs for borehole BK-2513, Fischer and Porter Site, Warminster, Pa.

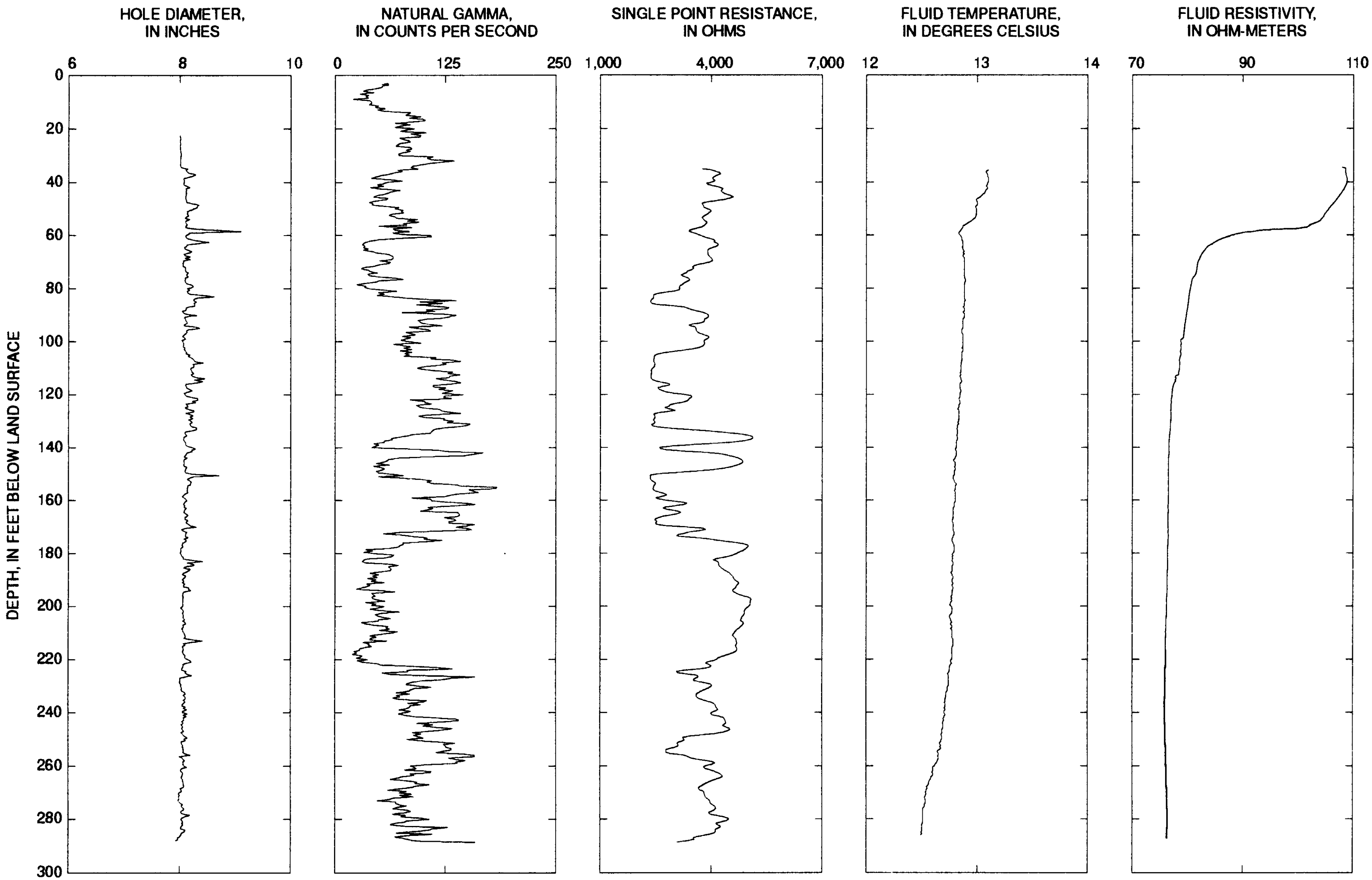

Figure 16. Borehole geophysical logs for borehole BK-2514, Fischer and Porter Site, Warminster, Pa.

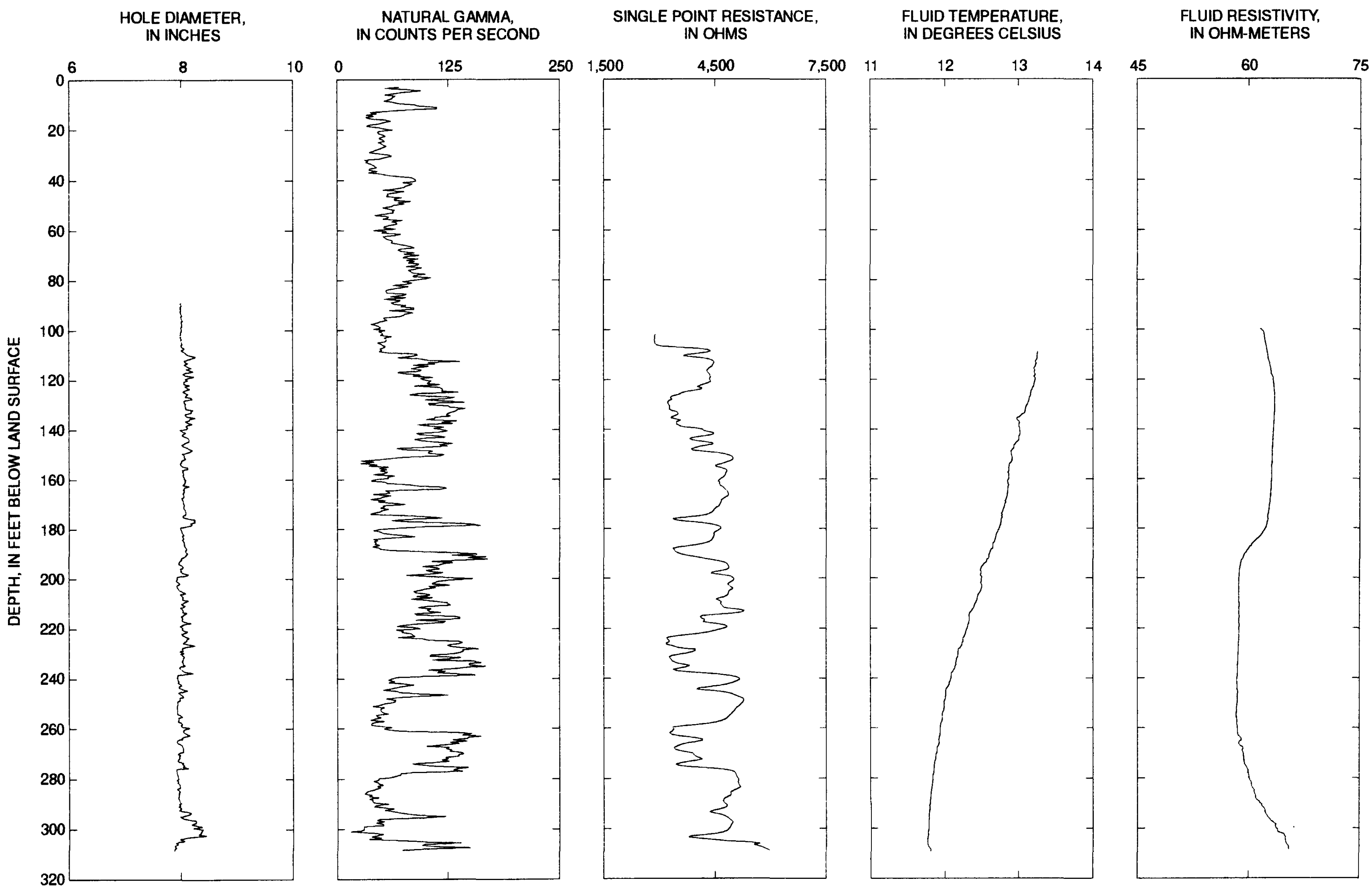

Figure 17. Borehole geophysical logs for borehole BK-2515, Fischer and Porter Site, Warminster, Pa.

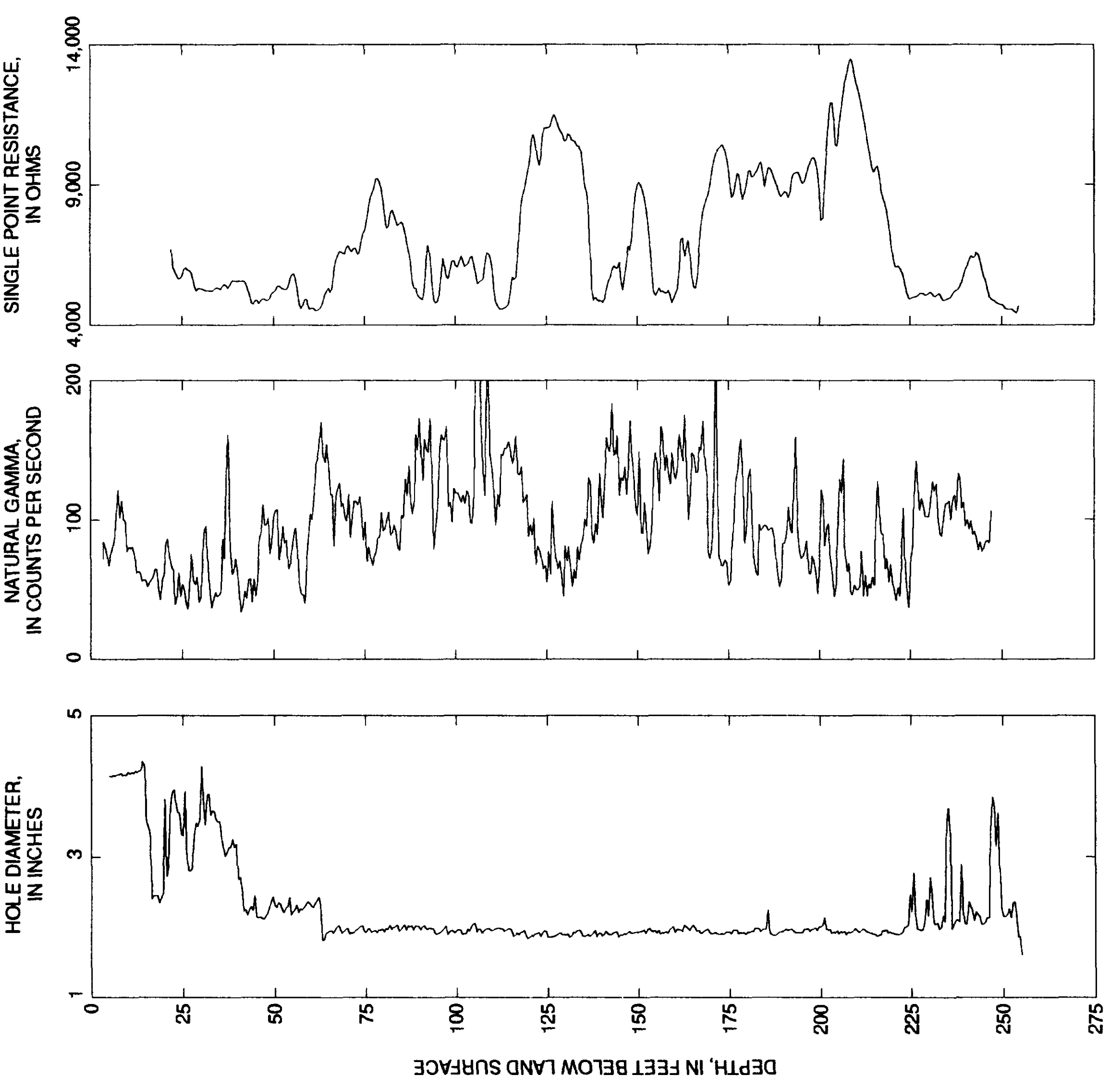

Figure 18. Borehole geophysical logs for borehole BK-2516, Fischer and Porter Site, Warminster, Pa.

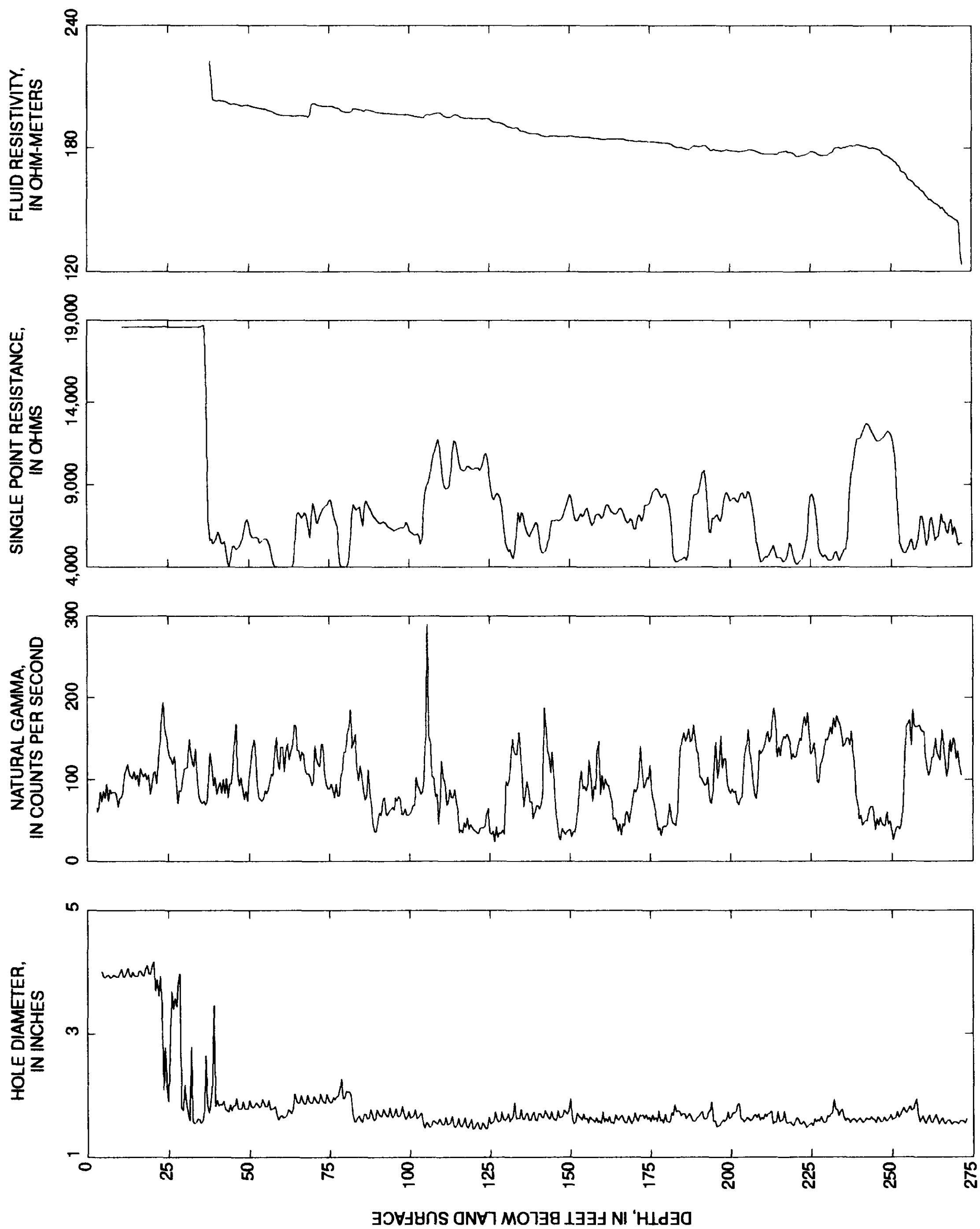

Figure 19. Borehole geophysical logs for borehole BK-2517, Fischer and Porter Site, Warminster, Pa.

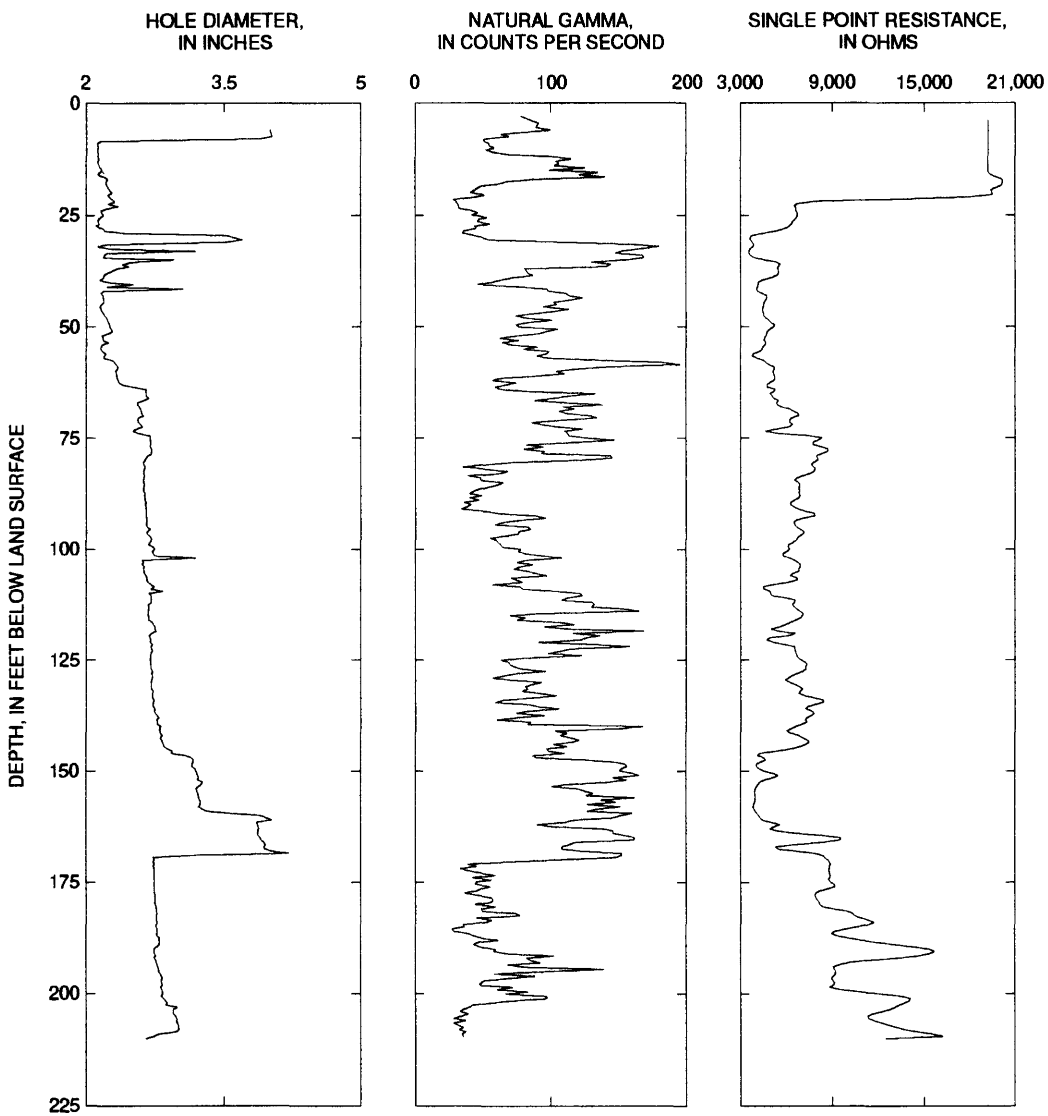

Figure 20. Borehole geophysical logs for borehole BK-2518, Fischer and Porter Site, Warminster, Pa.

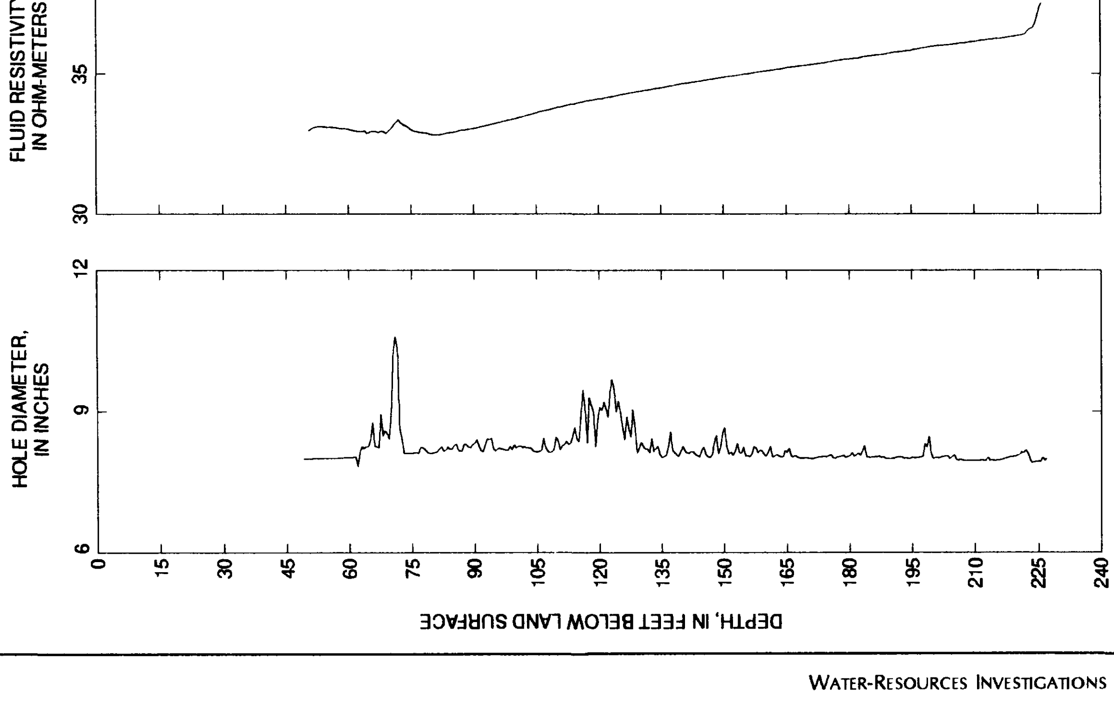

Figure 21. Borehole geophysical logs for borehole BK-2521, Fischer and Porter Site, Warminster, Pa.

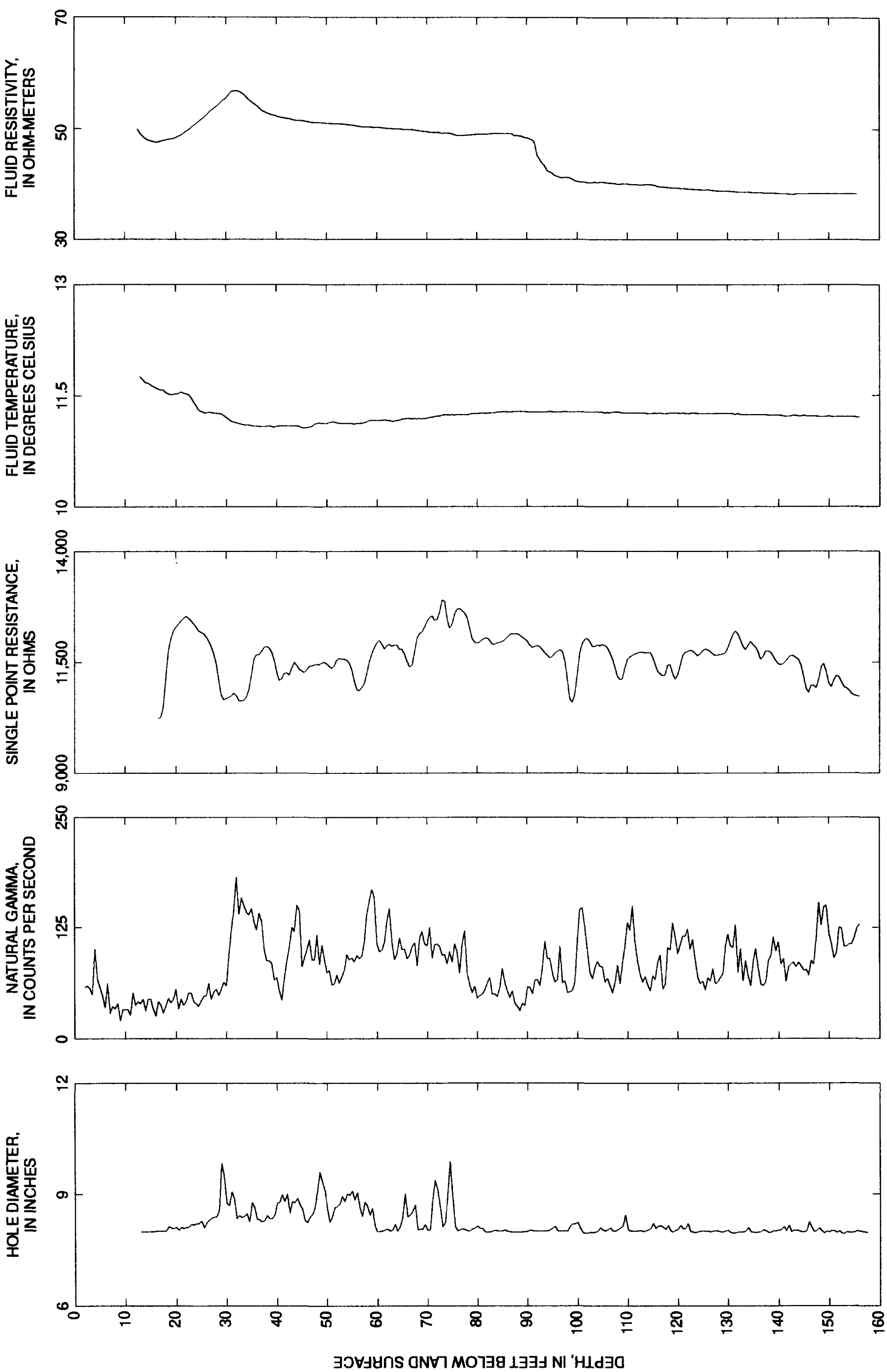

Figure 22. Borehole geophysical logs for borehole BK-2522, Fischer and Porter Site, Warminster, Pa.

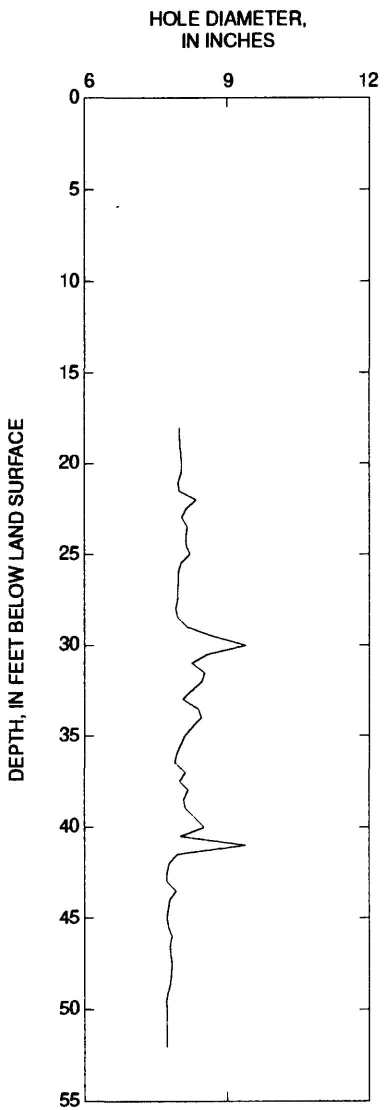

Figure 23. Borehole geophysical logs for borehole BK-2523, Fischer and Porter Site, Warminster, Pa.

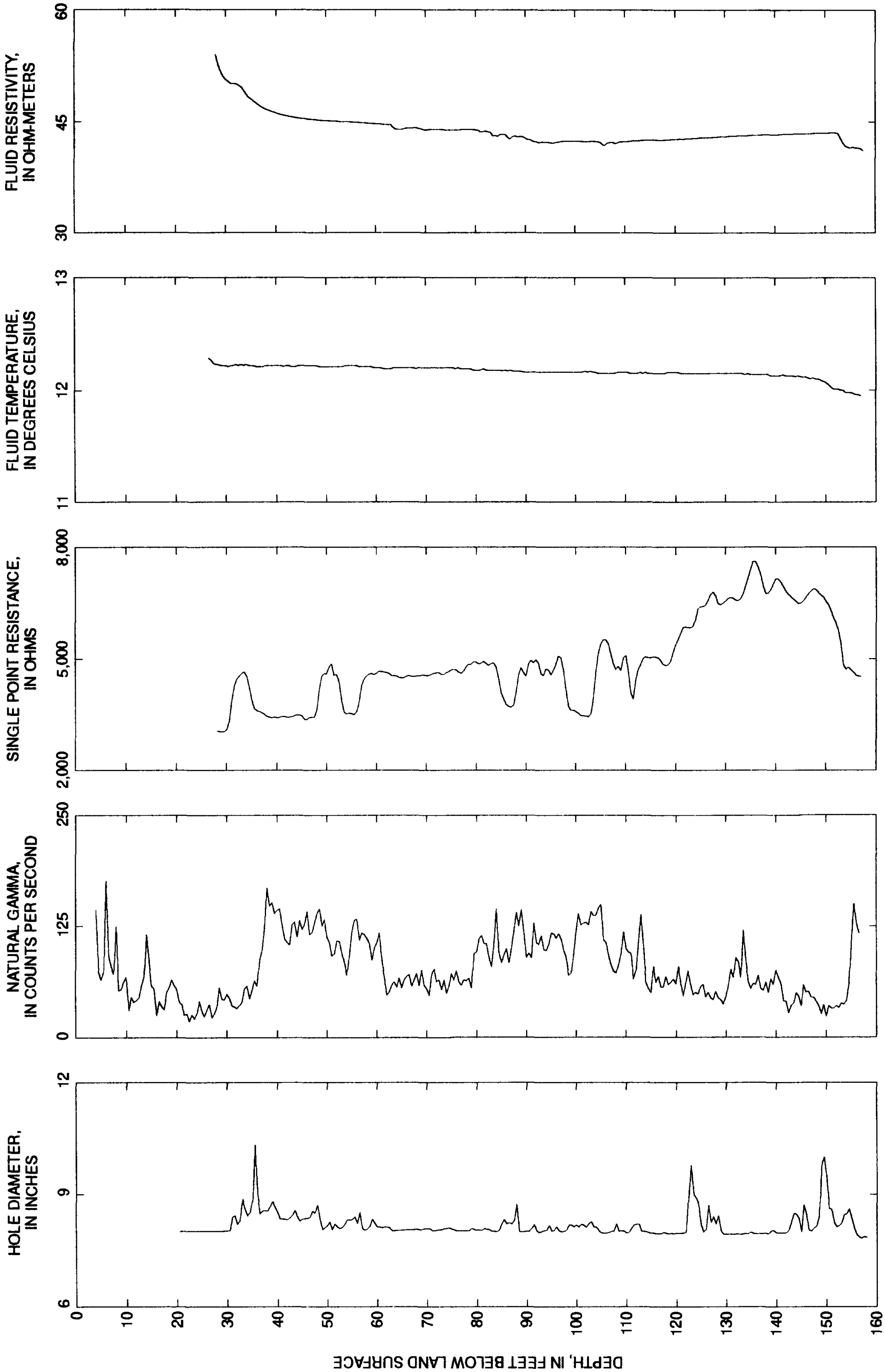

Figure 24. Borehole geophysical logs for borehole BK-2524, Fischer and Porter Site, Warminster, Pa.

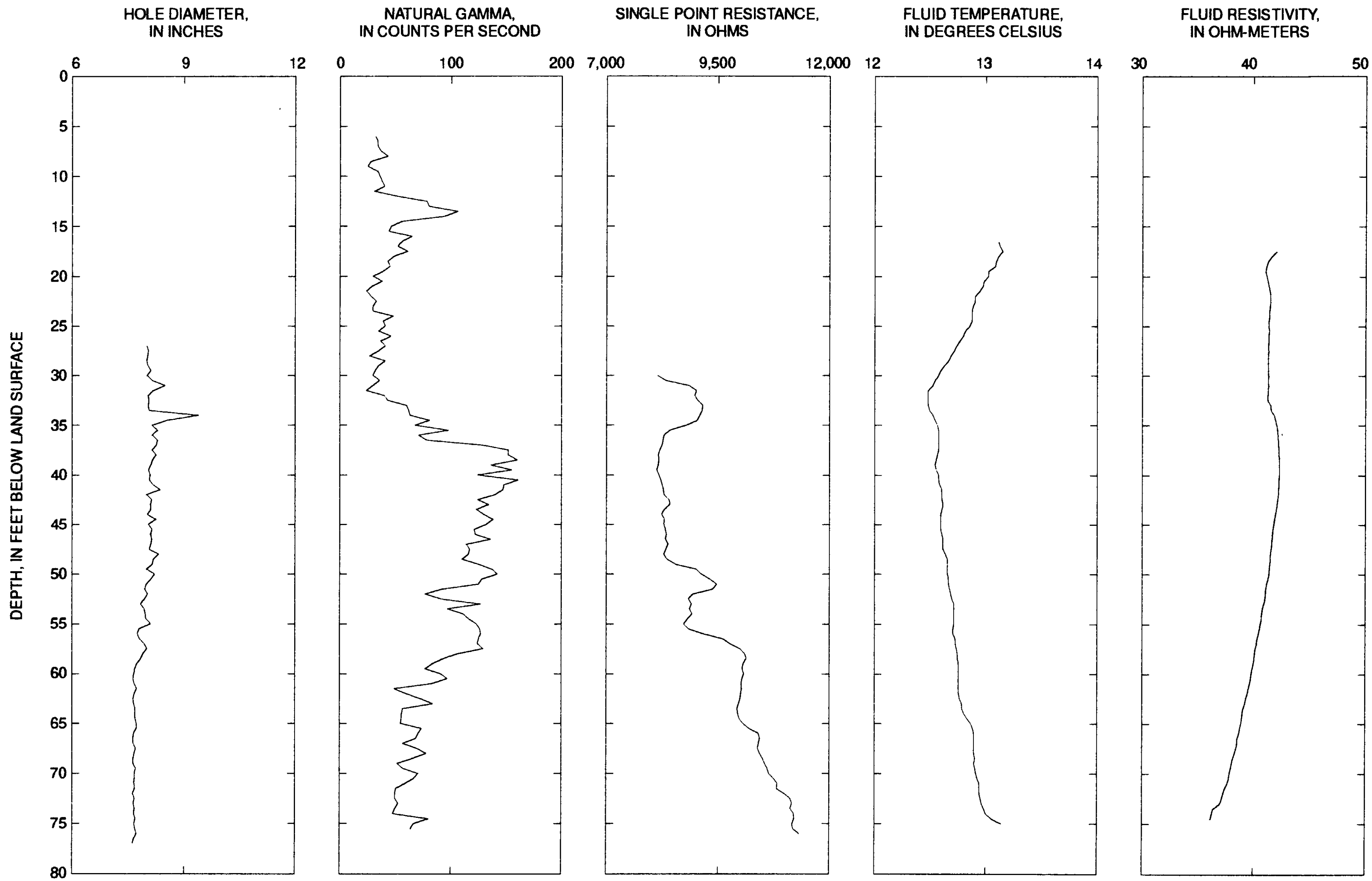

Figure 25. Borehole geophysical logs for borehole BK-2525, Fischer and Porter Site, Warminster, Pa.

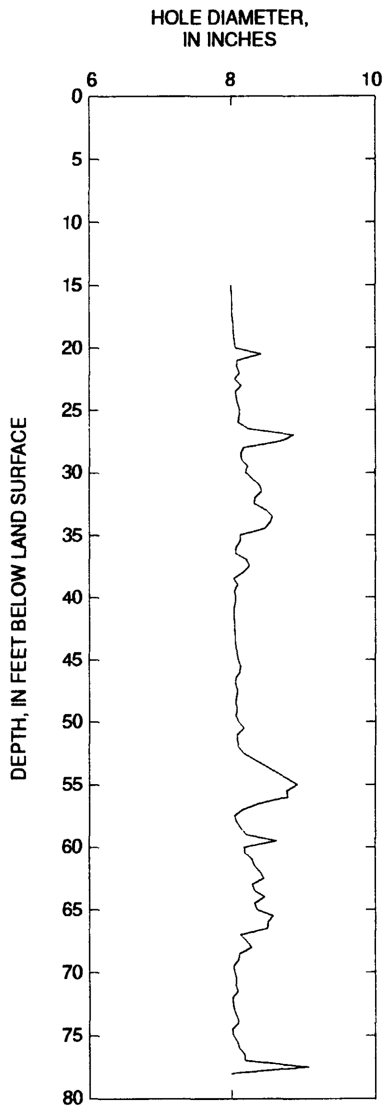

Figure 26. Borehole geophysical logs for borehole BK-2526, Fischer and Porter Site, Warminster, Pa.

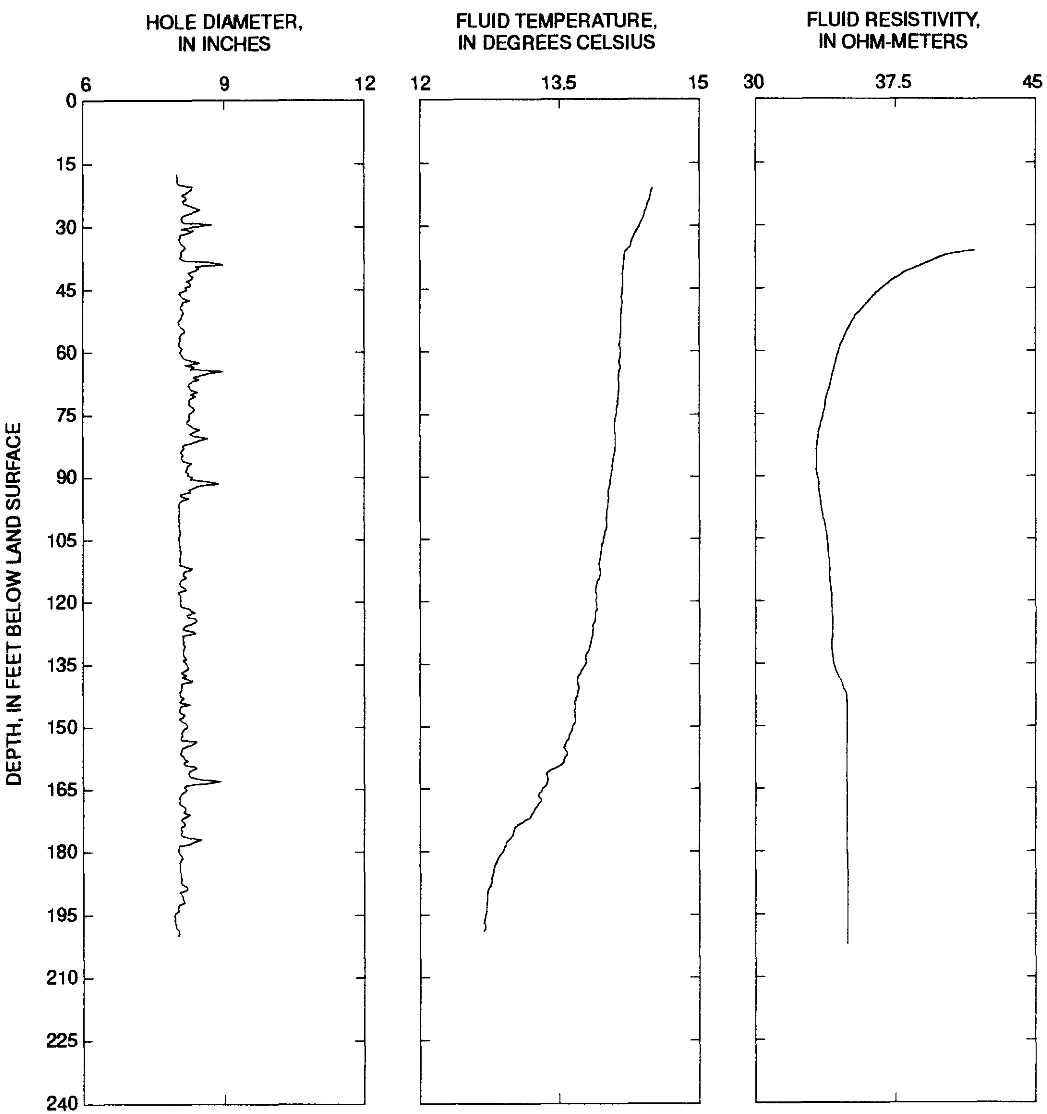

Figure 27. Borehole geophysical logs for borehole BK-2527, Fischer and Porter Site, Warminster, Pa.

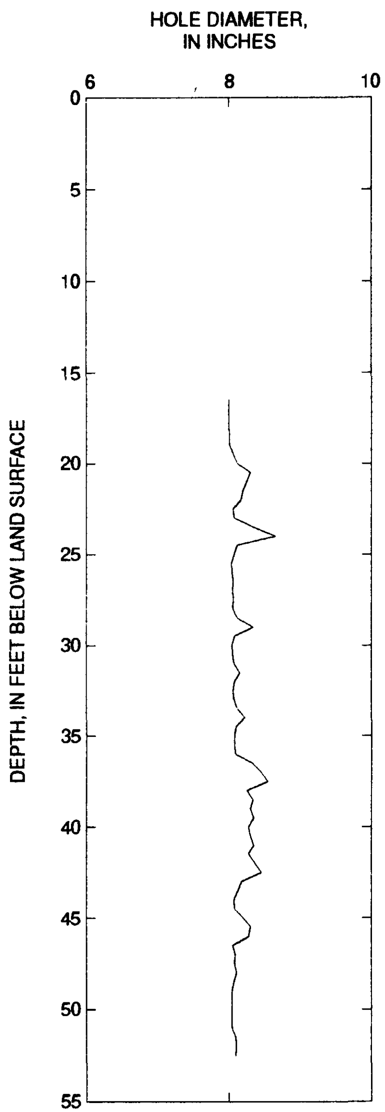

Figure 28. Borehole geophysical logs for borehole BK-2528, Fischer and Porter Site, Warminster, Pa.

APPENDIX 2.—GEOLOGIC LOGS OF ROCK CORES

***Table 1.** Geologic log of rock core from corehole BK-2516, Fischer and Porter Site, Warminster, Pa.*

Depth, in feet below land surface	Description
15.46-29.7	Light gray-white, fine-grained sandstone
29.7-30.9	Gray, poorly sorted, medium- to fine-grained sandstone
30.9-42.0	Light gray, fine-grained sandstone
Gradational contact	
42.0-44.0	Light gray, poorly sorted, medium-grained sandstone with silt blebs
44.0-44.5	Light gray, fine-grained sandstone
44.5-55.3	Light purple-gray, silty, fine-grained sandstone
Gradational contact	
55.3-60.1	Light gray, fine-grained sandstone
60.1-66.43	Red-brown siltstone
66.43-72.43	Light purple, silty, fine-grained sandstone
Gradational contact	
74.43-80.75	Light gray, fine-grained, micaceous sandstone
80.75-82.0	Light gray, fine-grained sandstone
82.0-86.6	Light gray, poorly sorted, medium- to fine-grained sandstone
86.6-88.85	Transitional unit - mix of thin siltstone beds with light gray, medium- to fine-grained, poorly sorted sandstone with silt blebs
88.85-92.6	Red-brown siltstone
92.6-94.68	Light purple-gray, silty, fine-grained sandstone
94.68-95.75	Red-brown siltstone
95.75-96.0	Light gray, fine-grained sandstone
96.0-97.08	Red-brown siltstone
97.08-100.08	Light purple-gray, silty, fine-grained siltstone
100.08-104.08	Dark gray, banded, silty, fine-grained, micaceous sandstone
104.08-106.08	Green and light gray, banded, fine-grained sandstone
106.08-108.4	Light gray, fine-grained sandstone
108.4-117.88	Red-brown siltstone
117.88-119.04	Light purple-gray, silty, fine-grained sandstone
119.04-139.05	Light gray, fine-grained sandstone
139.05-144.28	Red-brown siltstone
Gradational contact	
144.28-149.28	Light red-brown, micaceous siltstone
149.28-155.12	Purple-gray, silty, fine-grained sandstone
155.12-161.61	Red-brown siltstone
Gradational contact	
161.61-162.0	"Banded" bed
Gradational contact	
162.0-163.0	Red-brown siltstone
163.0-164.33	"Banded" bed

Table 1. *Geologic log of rock core from corehole BK-2516, Fischer and Porter Site, Warminster, Pa.—Continued*

Depth, in feet below land surface	Description
164.33-164.52	Dark red-brown siltstone
164.52-165.6	"Banded" bed
165.6-165.85	Light brown, coarse-grained, poorly sorted conglomerate
165.85-166.2	"Banded" unit (sandier than above)
166.2-168.2	Dark red-brown siltstone
Gradational contact	
168.2-176.5	Light gray, fine-grained sandstone
Gradational contact	
176.5-178.5	Light gray, medium- to very fine-grained, poorly sorted sandstone with siltstone inclusions
178.5-180.0	Dark gray, very fine-grained sandstone to silty, very fine-grained sandstone
180.0-182.58	Light gray, course- to very fine-grained, poorly sorted sandstone with siltstone inclusions
182.58-187.25	Purple-gray, silty, fine-grained sandstone
Gradational contact	
187.25-188.0	Light gray, fine-grained sandstone, weathered
188.0-225.5	Light gray, fine-grained sandstone
225.5-239.9	Dark red-brown siltstone
239.9-246.44	Purple-gray, fine-grained sandstone
246.44-247.6	Light red-brown "banded" bed
247.6-261.70	Red-brown siltstone

***Table 2.** Geologic log of rock core from corehole BK-2517, Fischer and Porter Site, Warminster, Pa.*

Depth, in feet below land surface	Description
19.0-24.0	Red-brown siltstone
24.0-27.4	Dark purple-brown, micaceous siltstone
29.0-29.5	Red-brown siltstone
29.5-37.5	Light brownish-gray, fine-grained sandstone
37.5-39.0	No recovery
39.0-43.0	Light gray, very fine- to fine-grained sandstone
43.0-44.0	No recovery
44.0-45.8	Light pinkish-gray, fine-grained sandstone
45.8-45.9	Dark purple-gray, micaceous siltstone
45.9-46.0	Red-brown siltstone
46.0-46.8	No recovery
46.8-61.3	Dark purple-gray, micaceous siltstone
61.3-62.5	Light gray, medium- to coarse-grained sandstone and conglomerate
62.5-69.0	Red-brown siltstone, abundant caliche
69.0-73.0	Dark purplish red-brown, micaceous siltstone
73.0-73.1	Red-brown siltstone
73.1-75.5	Dark purplish red-brown, micaceous siltstone
Gradational contact	
75.5-76.5	Purple-gray, very fine-grained sandstone (some micaceous)
76.5-77.0	Light gray, fine-grained sandstone
77.0-79.0	Dark purple-gray, very fine-grained sandstone, weathered
79.0-83.6	Red-brown siltstone
83.6-85.6	Dark purple-gray siltstone
85.6-87.5	Dark purple-gray, micaceous siltstone
87.5-90.0	Dark gray, very fine-grained sandstone, weathered
90.0-94.9	Light gray, very fine-grained sandstone
94.9-101.0	Light gray, fine-grained sandstone
Gradational contact	
101.0-108.2	Light gray, medium-grained sandstone, poorly sorted
108.2-109.7	Light gray, medium- to fine-grained sandstone
109.7-109.8	Light gray, poorly sorted, coarse- to fine-grained sandstone
109.8-114.5	Light gray, fine-grained sandstone
114.5-115.0	Light gray, fine-grained sandstone grading to medium-grained sandstone, weathered
Gradational contact	
115.0-123.0	Light gray conglomerate
123.0-124.5	Light gray, fine-grained sandstone
124.5-127.9	Conglomerate and coarse-grained sandstone
127.9-129.2	Light gray, medium-grained sandstone, weathered

Table 2. *Geologic log of rock core from corehole BK-2517, Fischer and Porter Site, Warminster, Pa.—Continued*

Depth, in feet below land surface	Description
129.2-130.8	Dark charcoal-gray to dark gray, micaceous siltstone
Gradational contact	
130.8-134.5	Red-brown siltstone
134.5-135.7	Light purple-gray, silty, very fine-grained sandstone
Gradational contact	
135.7-136.6	Dark purple-gray siltstone
136.6-140.0	Light purple-gray, silty, very fine-grained sandstone
Gradational contact	
140.0-141.9	Light gray, fine-grained sandstone
141.9-144.0	Light purple-gray, silty, fine-grained sandstone
144.0-144.3	Red- brown siltstone
144.3-145.0	Light purple-gray, silty, fine-grained sandstone
145.0-152.3	Light gray, medium- to fine-grained sandstone
Gradational contact	
152.3-152.8	Light gray, poorly sorted, coarse-grained sandstone
Gradational contact	
152.8-155.2	Light gray, fine-grained sandstone with some thin beds of light gray, medium-grained sandstone
155.2-158.8	Light gray, poorly sorted, coarse- to medium-grained sandstone
158.8-170.75	Light gray, fine-grained sandstone
170.75-172.1	Dark red-brown siltstone
172.1-173.7	Purple-gray, silty, fine-grained sandstone
173.7-175.0	Gray, poorly sorted, coarse-grained sandstone
Gradational contact	
175.0-183.5	Light gray, fine-grained sandstone
183.5-188.6	Red-brown siltstone
188.6-189.3	Light gray, very fine-grained sandstone
189.3-189.8	Dark gray, fine-grained sandstone
189.8-195.4	Light gray, fine-grained sandstone
195.4-195.6	Dark green siltstone
195.6-197.8	Light gray, fine-grained sandstone
Gradational contact	
197.8-205.0	Purple-gray, silty, fine-grained sandstone
Gradational contact	
205.0-209.8	Light purple-gray, fine-grained sandstone
209.8-235.92	Red-brown siltstone
235.92-238	Dark brown, micaceous siltstone
238-253.25	Light gray, fine-grained sandstone
253.25-277.2	Red-brown siltstone

Table 3. *Geologic log of rock core from corehole BK-2518, Fischer and Porter Site, Warminster, Pa.*

Depth, in feet below land surface	Description
9.8-10.7	Light gray, fine-grained sandstone
10.7-15.0	Light gray, very fine-grained sandstone
15.0-15.33	Light gray, poorly sorted, medium- to coarse-grained sandstone and conglomerate
15.33-16.40	Light gray, fine-grained sandstone
16.40-17.92	Gray, poorly sorted, coarse-grained sandstone and conglomerate
17.92-18.9	Light gray, fine-grained sandstone
18.9-25.43	Light gray, poorly sorted, coarse-grained sandstone and conglomerate
25.43-27.18	Light gray, medium to coarse-grained sandstone
Gradational contact	
27.18-30.1	Light gray, fine-grained sandstone
30.1-36.4	Red-brown siltstone
36.4-37.73	Light purple-gray, silty, fine-grained sandstone
37.73-40.9	Light gray, fine-grained sandstone
40.9-50.17	Red-brown siltstone grading into dark purple-brown, silty, fine-grained sandstone
50.17-51.3	Dark gray, micaceous, very fine-grained sandstone and siltstone
51.3-53.3	Light gray, very fine-grained sandstone
53.3-53.63	Dark gray, micaceous, very fine-grained sandstone and siltstone
53.63-55.5	Light purple-gray, silty, fine-grained sandstone
Gradational contact	
55.5-61.88	Light gray, fine-grained sandstone
61.88-62.88	Red-brown siltstone
62.88-65.8	Dark gray, very fine-grained sandstone
65.8-69.55	Light gray, fine-grained sandstone
Gradational contact	
69.55-70.63	Dark purple-brown siltstone
70.63-72.13	Purple gray, silty, fine-grained sandstone
Gradational contact	
72.13-72.88	Dark gray, micaceous, very fine-grained sandstone and siltstone
Gradational contact	
72.88-76.49	Gray, very fine-grained sandstone
76.49-77.0	Light gray, fine-grained sandstone
77.0-77.66	Light gray, poorly sorted, medium- to coarse-grained sandstone and conglomerate
77.66-80.0	Light gray, fine- to very fine-grained sandstone
Gradational contact	
80.0-80.6	Dark red-brown, micaceous siltstone
80.6-81.1	Dark gray, micaceous, very fine-grained sandstone

Table 3. *Geologic log of rock core from corehole BK-2518, Fischer and Porter Site, Warminster, Pa.—Continued*

Depth, in feet below land surface	Description
Well-defined contact	
81.1-83.5	Light gray, fine-grained sandstone
83.5-84.75	Light gray, medium-grained, poorly sorted sandstone and conglomerate
84.75-108.2	White to light gray, fine-grained sandstone, weathered
108.2-112.36	Purple-gray, silty, fine-grained sandstone
112.36-113.66	Gray, very fine-grained sandstone, weathered
113.66-114.5	Dark purple-gray, silty, fine-grained sandstone
114.5-116.16	Gray, fine-grained sandstone and conglomerate, heavily weathered
116.16-119.24	Dark purple-gray, silty, very fine-grained sandstone
119.24-123.9	Light gray, fine-grained sandstone, weathered
123.9-129.23	Dark red-brown siltstone
129.23-140.5	Light purple-gray, fine-grained sandstone
Gradational contact	
140.5-141.5	Dark purple-gray, micaceous, very fine-grained sandstone and siltstone
Gradational contact	
141.5-144.0	Light purple-gray, very fine-grained sandstone
Gradational contact	
144.0-145.2	Light gray, fine-grained sandstone, weathered
145.2-145.62	Light gray, medium-grained sandstone and conglomerate
145.62-146.62	Dark purple-gray, micaceous, very fine-grained sandstone and siltstone
Gradational contact	
146.62-148.3	Light purple-gray silty, fine-grained sandstone
148.3-148.8	Red-brown siltstone
Gradational contact	
148.8-151.55	Light purple-gray, silty, fine-grained sandstone
151.55-152.5	Dark purple-gray, micaceous, very fine-grained sandstone and siltstone
Gradational contact	
152.5-153.25	Purple gray, silty, fine-grained sandstone
153.25-172.25	Red-brown siltstone
172.25-174.25	Dark brown, micaceous, very fine-grained sandstone and siltstone
174.25-176.58	Red-brown siltstone
Gradational contact	
176.58-187.16	White to light gray, fine-grained sandstone
187.16-189.58	Light gray, very fine-grained sandstone
Gradational contact	
189.58-194.5	Light gray, poorly sorted sandstone
Gradational contact	
194.5-197.25	Light gray, very fine-grained sandstone
Gradational contact	

Table 3. *Geologic log of rock core from corehole BK-2518, Fischer and Porter Site, Warminster, Pa.—Continued*

Depth, in feet below land surface	Description
197.25-200.9	White-gray, fine-grained sandstone with abundant clasts (conglomerate)
Gradational contact	
200.9-201.32	Conglomerate with thin, dark gray siltstone beds
201.32-209.0	Light gray, fine-grained sandstone
209.0-211.5	Light gray, coarse-grained conglomerate
Gradational contact	
211.5-214.5	Light gray, fine-grained sandstone
Gradational contact	
214.5-217.25	Light gray, medium-grained sandstone, weathered
Gradational contact	
217.25-219.0	Light gray, fine-grained sandstone
219.0-224.75	Dark gray, very fine-grained sandstone
Gradational contact	
224.75-225.25	Red-brown and gray conglomerate
225.25-226.95	Dark purple-brown, silty, micaceous, fine-grained sandstone
Gradational contact	
226.95-234.0	Red-brown siltstone
Gradational contact	
234.0-239.75	Dark gray, very fine-grained sandstone
239.75-240.9	Light gray, fine-grained sandstone
240.9-243.85	Light gray, fine-grained sandstone
243.85-244.35	Conglomerate
244.35-245.0	Light gray, fine-grained sandstone
245.0-245.66	Conglomerate with thin beds of red-brown siltstone
245.66-262.1	Light gray, fine-grained sandstone, weathered
262.1-262.52	Dark gray, very fine-grained sandstone
262.52-265.6	Light gray, fine-grained sandstone
265.6-265.9	Red-brown siltstone
265.9-271.25	Light gray, fine-grained sandstone
271.25-274.5	Red-brown siltstone

APPENDIX 3.—GEOLOGIC LOGS FROM EXPLORATORY BOREHOLES

Table 1. *Geologic log for borehole BK-2511, Fischer and Porter Site, Warminister, Pa.*
[gal/min, gallons per minute]

Depth, in feet below land surface	Description
0-50	Overburden
50-55	Purple-gray siltstone
55-62	Purple-gray, very fine-grained sandstone
62-69	Red-brown siltstone
69-75	Purple-gray siltstone
75-90	Purple-gray, very fine-grained sandstone/siltstone
90-96	Purple-gray siltstone
96-100	Red-brown siltstone
100-104	Purple-gray siltstone
104-108	Light gray, medium-grained sandstone
108-121	Red-brown siltstone with interbedded green siltstone/shale
121-135	Purple-gray, very fine-grained sandstone with interbeded green siltstone/shale
135-142	Light gray, medium-grained sandstone
142-148	Purple-gray, fine-grained sandstone
148-168	Purple-gray siltstone
168-173	Purple-gray, very fine-grained sandstone; 5 gal/min at 170
173-178	Purple-gray, fine-grained sandstone
178-228	Light gray, fine-grained sandstone with interbedded green siltstone/shale
228-237	Red-brown siltstone
237-242	Red-brown, very fine-grained silty sandstone
242-249	Dark-gray siltstone
249-264	Red-brown siltstone
264-270	Light gray, very fine-grained sandstone; 5 gal/min at 270
270-289	Light gray, fine-grained sandstone
289-305	Red-brown siltstone
305-316	Light purple-gray, very fine-grained sandstone; 5 gal/min at 315
316-321	Red-gray siltstone
321-332	Light gray, fine-grained sandstone
332-349	Light gray, very fine-grained sandstone
349-352	Red-brown siltstone

Table 2. *Geologic log for borehole BK-2512, Fischer and Porter Site, Warminster, Pa.*

[gal/min, gallons per minute; >, greater than]

Depth, in feet below land surface	Description
0-20	Overburden
20-30	Light gray, fine-grained sandstone
30-51	Red-brown siltstone
51-76	Dark brown siltstone; 10 gal/min at 54
76-106	Light gray, fine-grained sandstone; 8 gal/min at 98; 7 gal/min at 106
106-111	Purple-gray, silty, very fine-grained sandstone
111-126	Transition zone with interbedded red-brown siltstone
126-131	Light gray, fine-grained sandstone
131-152	Purple-gray, silty, very fine-grained sandstone; 20 gal/min at 146
152-168	Red-brown siltstone
168-204	Light gray, fine-grained sandstone with interbedded dark gray, silty, very fine-grained sandstone; 5 gal/min at 178; 20 gal/min at 189
204-214	White-gray, medium-grained sandstone
214-235	Dark purple-gray, silty, very fine-grained sandstone; 20 gal/min at 230
235-263	Light gray, fine-grained sandstone; > 20 gal/min at 245; >50 gal/min at 250
263-271	Red-brown siltstone
271-276	Light gray, fine-grained sandstone
276-281	Purple-gray siltstone
281-286	Light gray, fine-grained sandstone
286-302	Purple-gray siltstone
302-303	Red-brown siltstone

***Table 3.** Geologic log for borehole BK-2513, Fischer and Porter Site, Warminster, Pa.*

[gal/min; gallons per minute]

Depth, in feet below land surface	Description
0-35	Overburden
35-50	Red-brown siltstone
50-61	Purple-brown, silty, very fine-grained sandstone; 5 gal/min at 60
61-86	Light purple-gray, very fine-grained sandstone
86-96	Dark red-brown siltstone
96-102	Purple-gray, very fine-grained, silty sandstone
102-112	Dark purple-gray siltstone
112-138	Gray, very fine-grained sandstone; 15 gal/min at 120; 60 gal/min at 131
138-149	White-gray, medium-grained sandstone
149-158	White-gray, fine-grained sandstone
158-165	Dark gray siltstone; 20 gal/min at 160
165-185	Light gray, fine-grained sandstone; 20 gal/min at 171
185-190	Dark gray, very fine-grained sandstone
190-220	Light gray, very fine-grained to fine-grained sandstone
220-225	Dark gray, siltstone/silty sandstone
225-245	Red-brown siltstone
245-251	Gray, very fine-grained sandstone
251-256	Red-brown siltstone
256-261	Dark gray, very fine-grained to fine-grained sandstone
261-276	Light gray, fine-grained sandstone
276-281	White-gray, medium-grained sandstone
281-300	Red-brown siltstone

Table 4. *Geologic log for borehole BK-2514, Fischer and Porter Site, Warminster, Pa.*

[gal/min; gallons per minute]

Depth, in feet below land surface	Description
0-22	Overburden
22-36	Red-brown siltstone, weathered
36-70	Light-gray, very fine-grained to fine-grained sandstone
70-75	Dark gray, fine-grained sandstone
75-86	Light gray, fine-grained sandstone
86-101	Red-brown siltstone
101-112	Gray, very fine-grained sandstone
112-138	Red-brown siltstone
138-159	Gray, very fine-grained to fine-grained sandstone
159-180	Red-brown siltstone
180-191	Purple-gray, very fine-grained sandstone
191-226	White-gray, fine-grained sandstone; 5 gal/min at 200; 5 gal/min at 215
226-258	Dark purple-gray, very fine-grained sandstone/silty sandstone
258-263	Red-brown siltstone
263-267	Dark gray, silty, fine-grained sandstone and siltstone; 5 gal/min
267-292	Light gray, very fine-grained sandstone

Table 5. *Geologic log for borehole BK-2515, Fischer and Porter Site, Warminster, Pa.*

[gal/min; gallons per minute]

Depth, in feet below land surface	Description
0-25	Overburden
25-30	Dark gray, silty fine-grained sandstone
30-40	Dark-gray, very fine-grained sandstone; 20 gal/min at 31
40-46	Red-brown siltstone
46-57	Dark gray, silty, fine-grained sandstone
57-66	Dark gray, very fine-grained sandstone
66-82	Red-brown siltstone
82-87	Purple-gray, silty, fine-grained sandstone
87-97	Red-brown siltstone
97-102	Dark gray, silty, fine-grained sandstone
102-112	Light gray, very fine-grained to fine-grained sandstone
112-124	Dark gray siltstone
124-132	Dark gray silty, fine-grained sandstone
132-148	Red-brown siltstone
148-158	Dark gray siltstone
158-193	Light gray, very fine-grained to fine-grained sandstone
193-209	Red-brown siltstone; 3 gal/min at 208
209-225	Red-brown siltstone to silty, fine-grained sandstone
225-232	Purple-gray, silty, fine-grained sandstone
232-240	Red-brown siltstone
240-245	Purple-gray, silty, fine-grained sandstone
245-267	Light gray, very fine-grained to fine-grained sandstone
267-282	Red-brown siltstone
282-307	Light gray, very fine-grained to fine-grained sandstone with interbedded dark gray, silty, fine-grained sandstone; 3 gal/min at 282-287; 9 gal/min at 302
307-313	Purple-gray, silty, fine-grained sandstone

APPENDIX 4.—WATER LEVEL HYDROGRAPHS

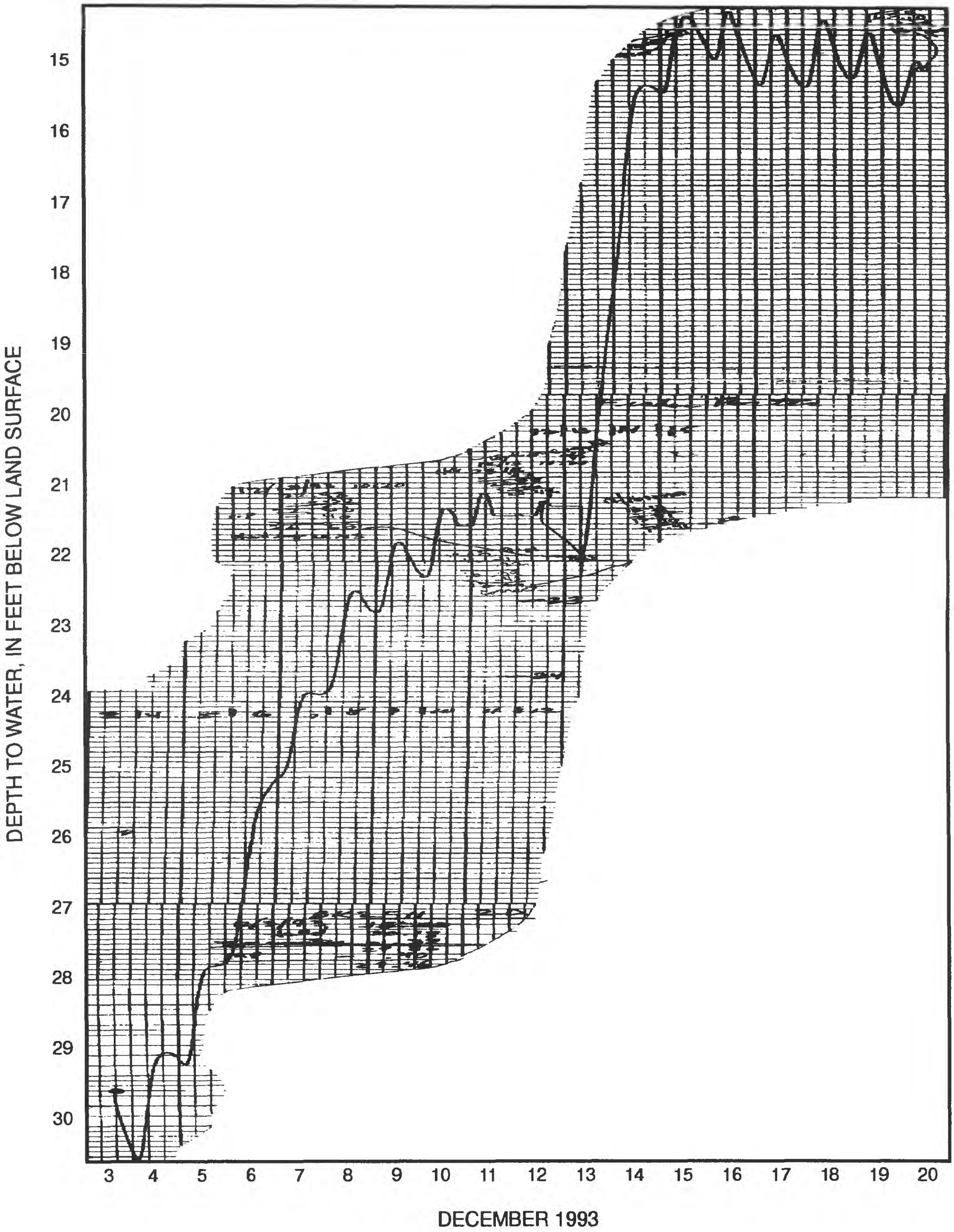

Figure 1. Hydrograph of well BK-2511, Fischer and Porter Site, Warminster, Pa., December 3-20, 1993.

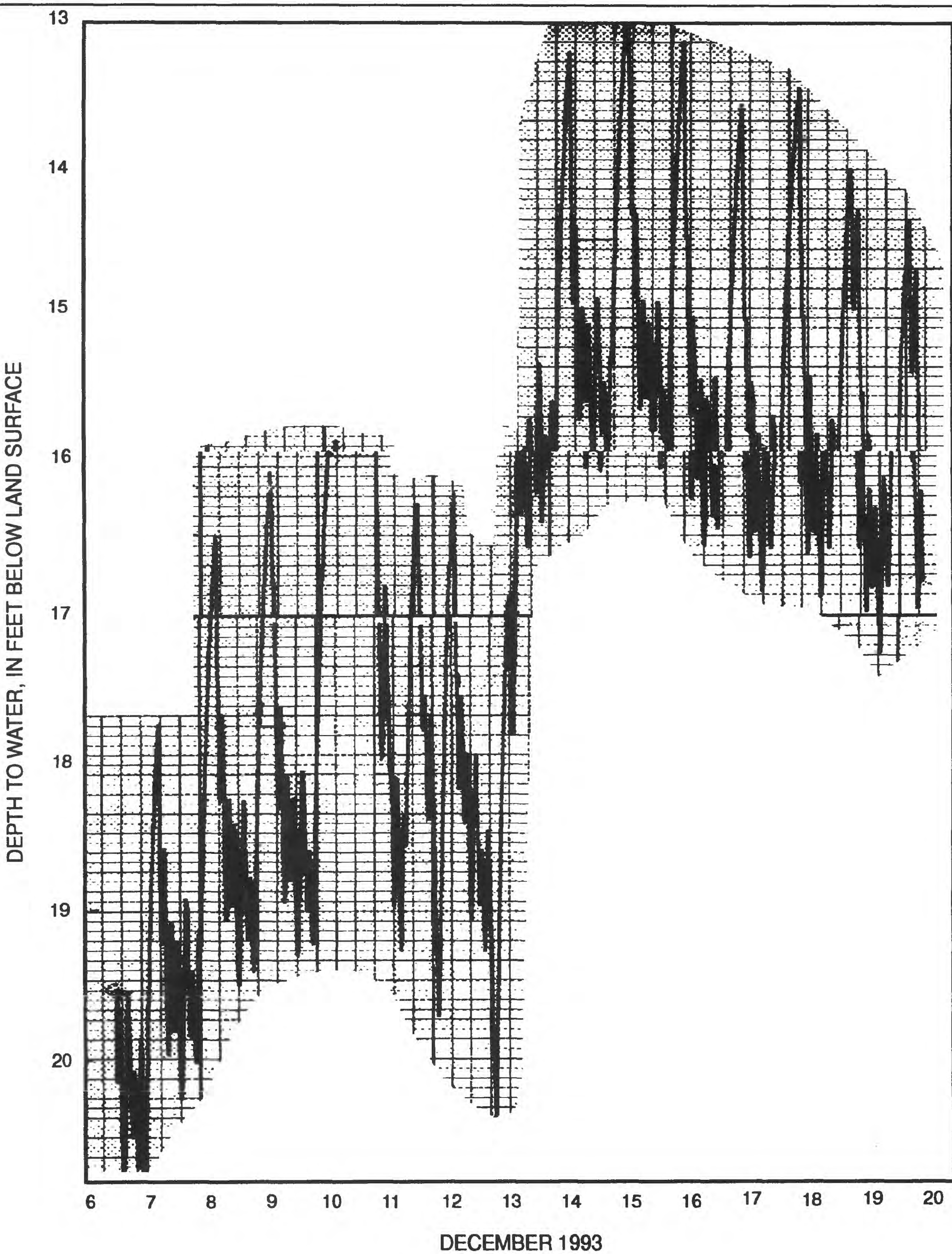

Figure 2. Hydrograph of well BK-2521, Fischer and Porter Site, Warminster, Pa., December 6-20, 1993.

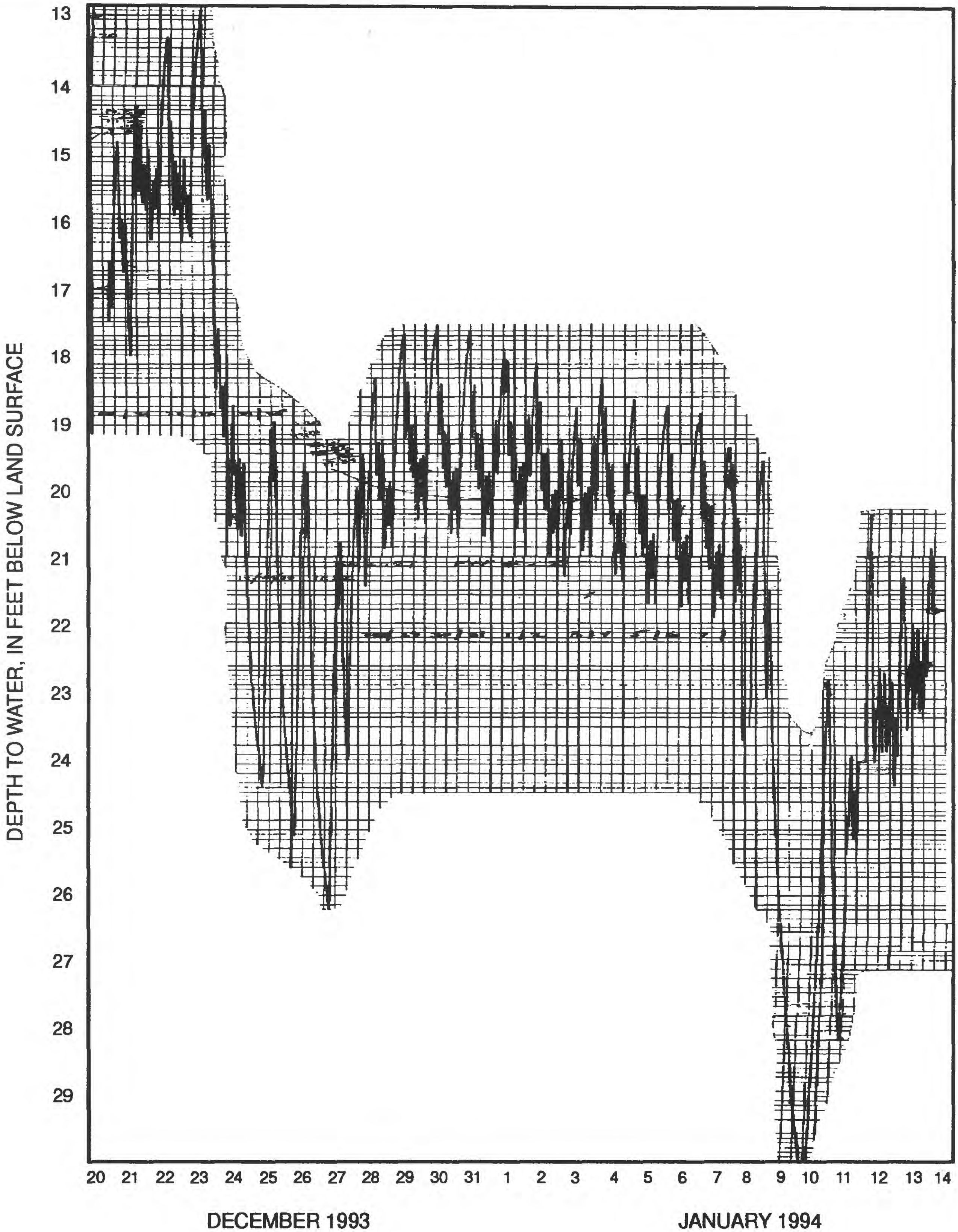

Figure 3. Hydrograph of well BK-2521, Fischer and Porter Site, Warminster, Pa., December 20, 1993, to January 14, 1994.

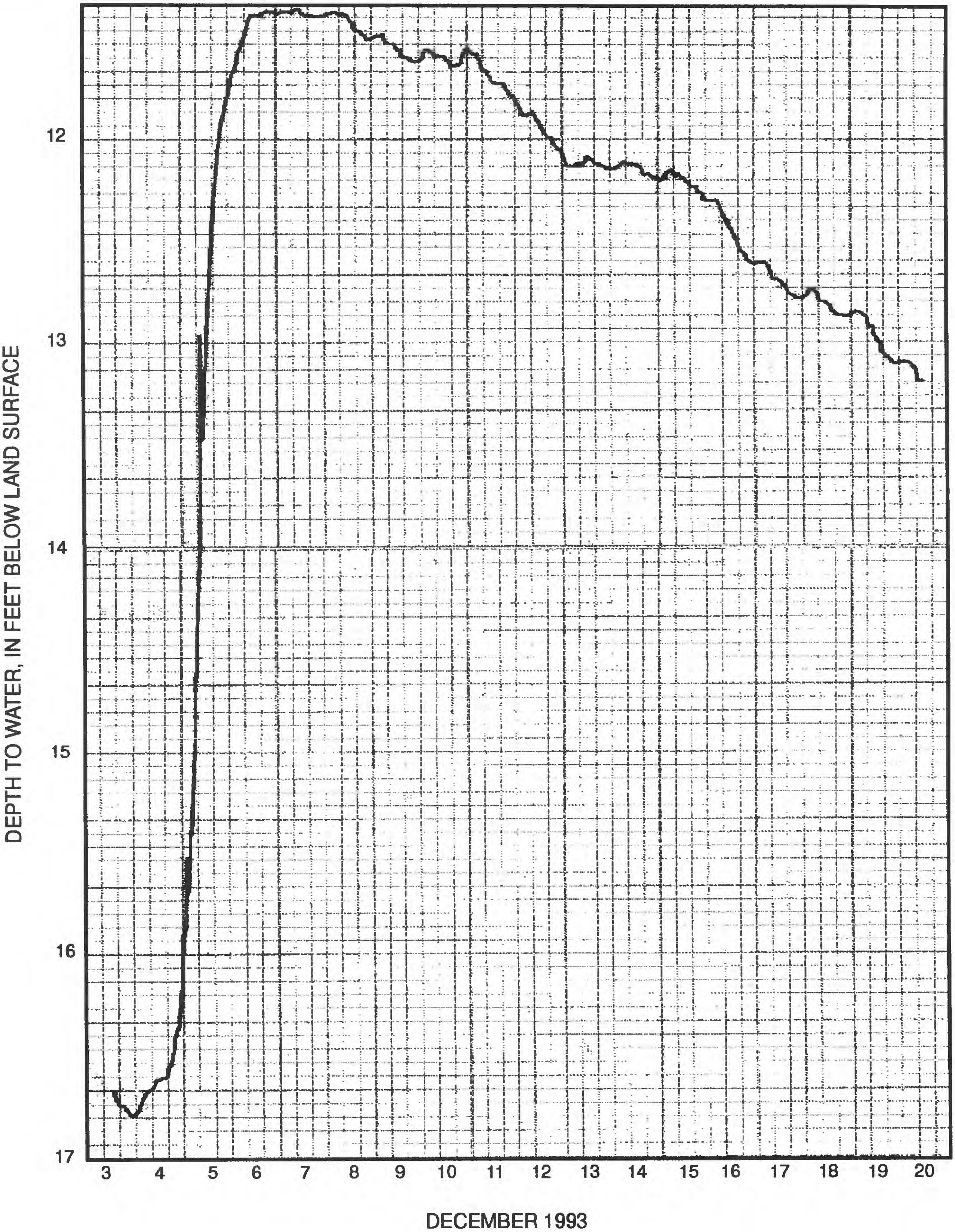

Figure 4. Hydrograph of well BK-1731, Fischer and Porter Site, Warminster, Pa., December 3-20, 1993.

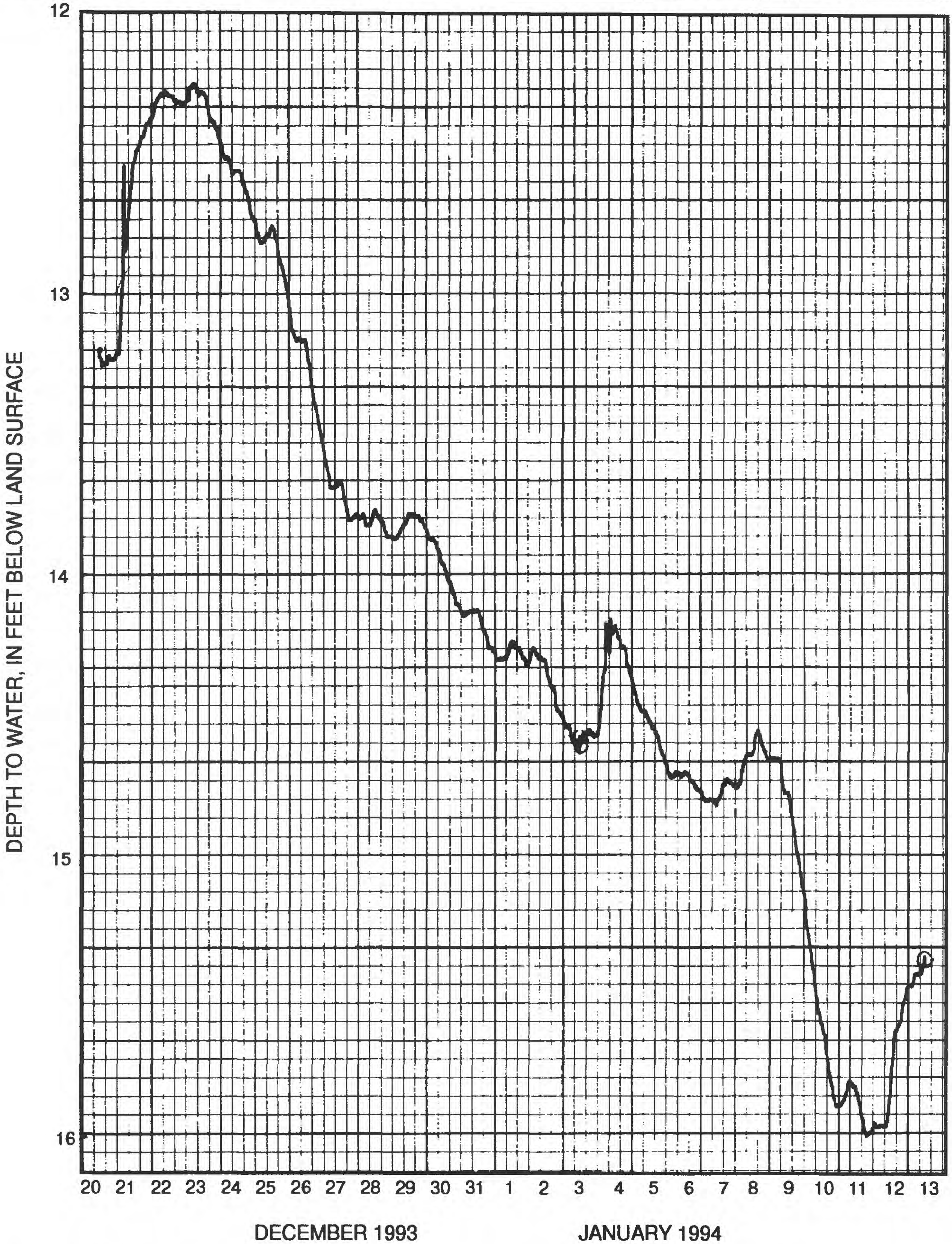

Figure 5. Hydrograph of well BK-1731, Fischer and Porter Site, Warminster, Pa., December 20, 1993, to January 13, 1994.

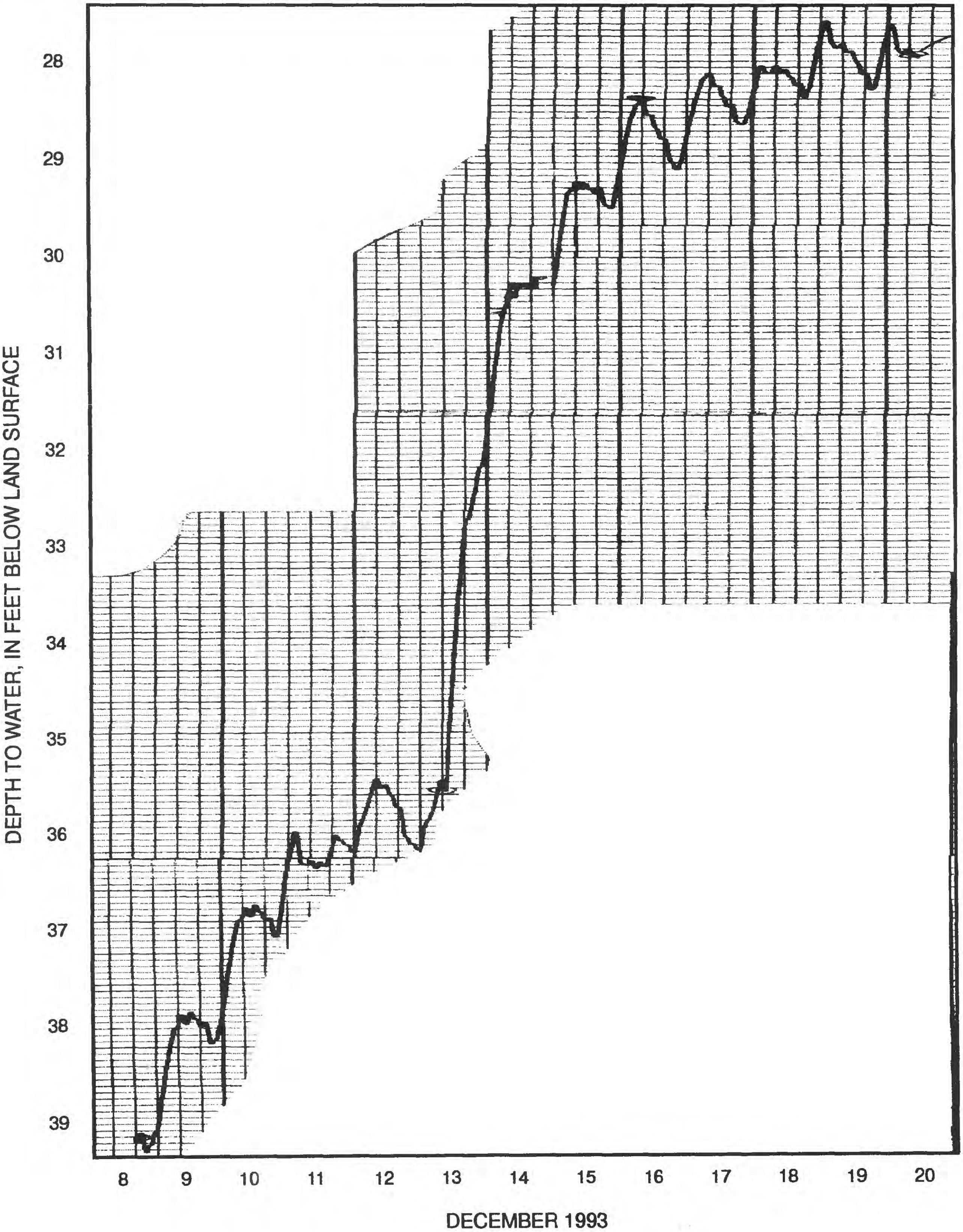

Figure 6. Hydrograph of well BK-2515, Fischer and Porter Site, Warminster, Pa., December 8-20, 1993.

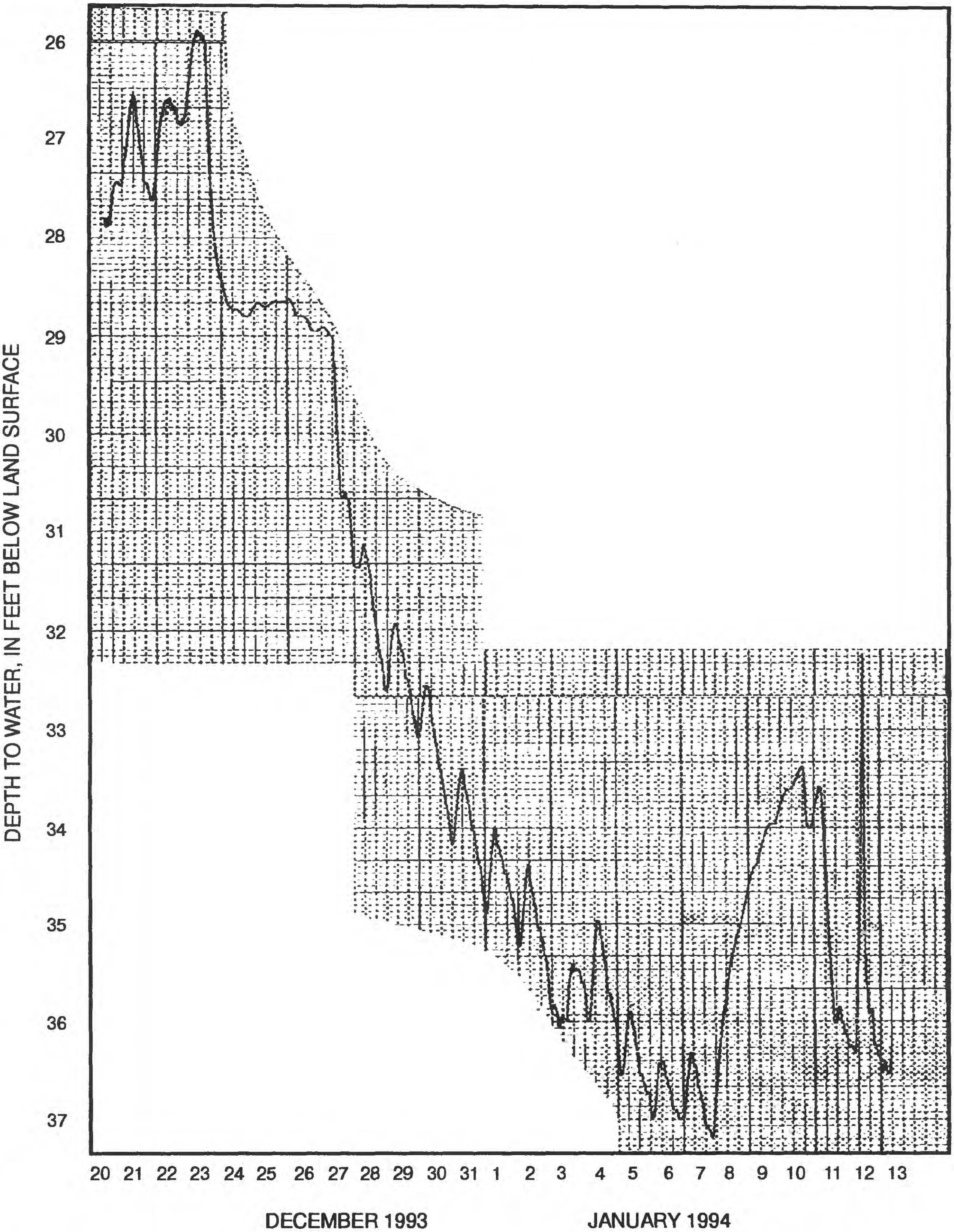

Figure 7. Hydrograph of well BK-2515, Fischer and Porter Site, Warminster, Pa., December 20, 1993, to January 13, 1994.

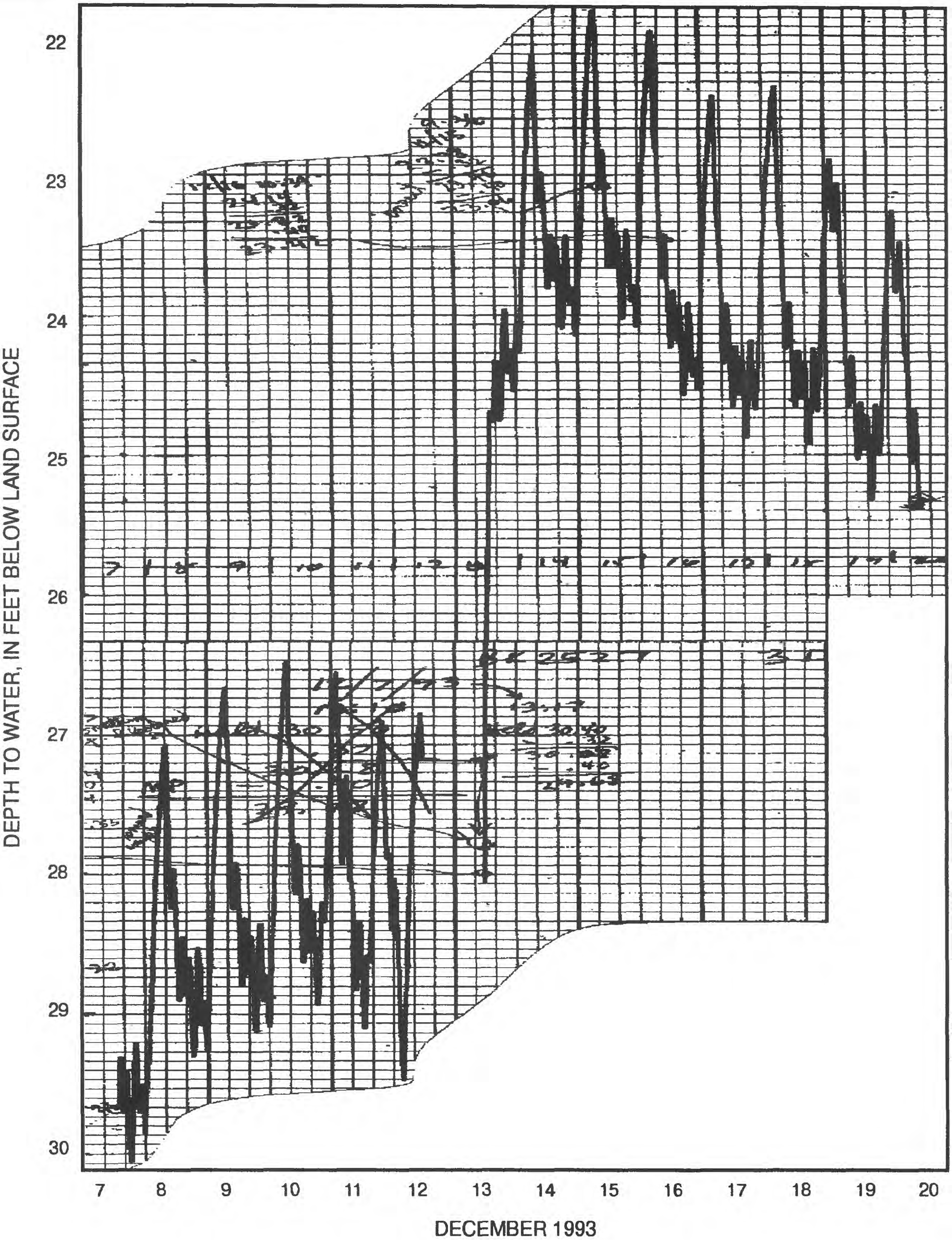

Figure 8. Hydrograph of well BK-2527, Fischer and Porter Site, Warminster, Pa., December 7-20, 1993.

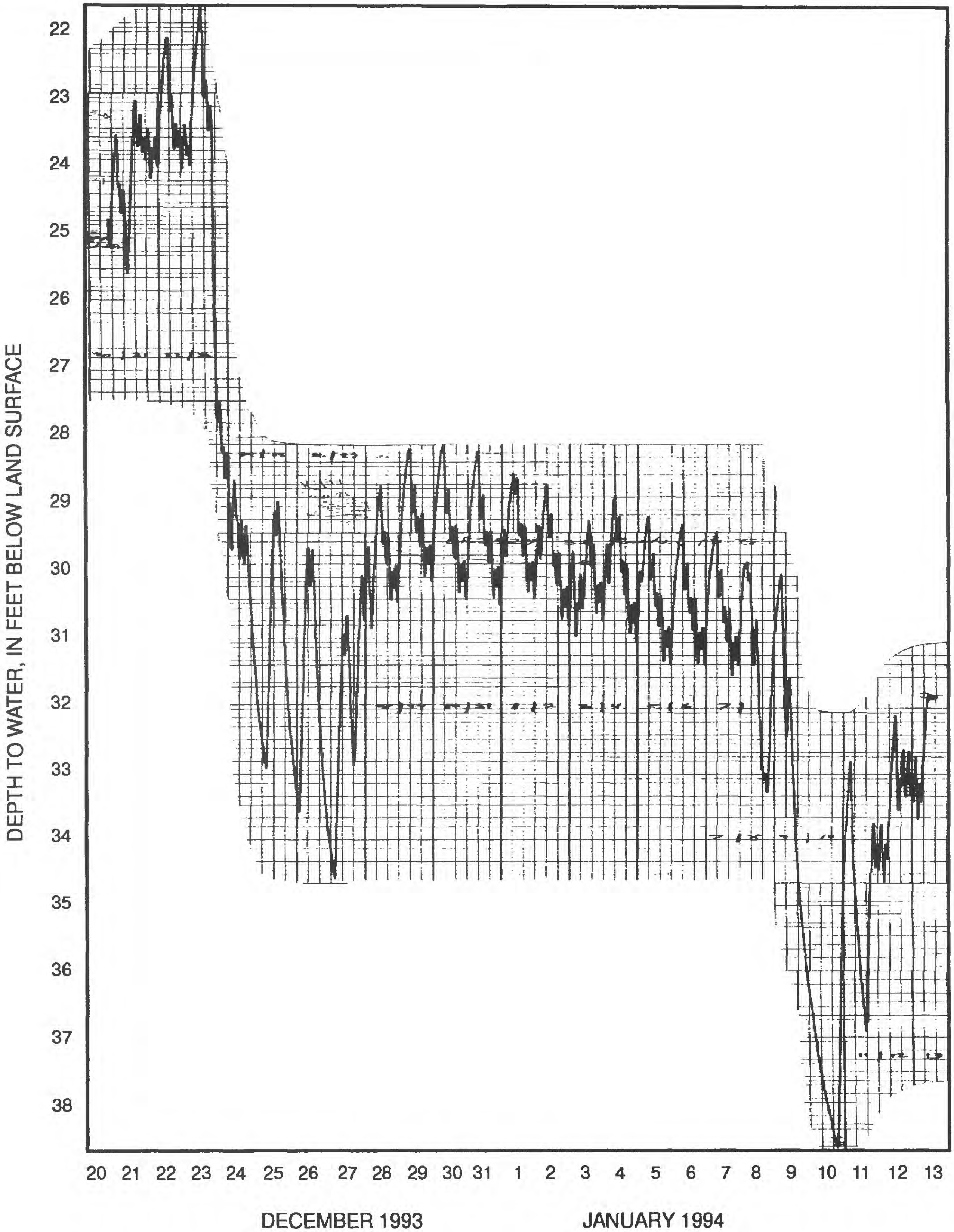

Figure 9. Hydrograph of well BK-2527, Fischer and Porter Site, Warminster, Pa., December 20, 1993, to January 13, 1994.

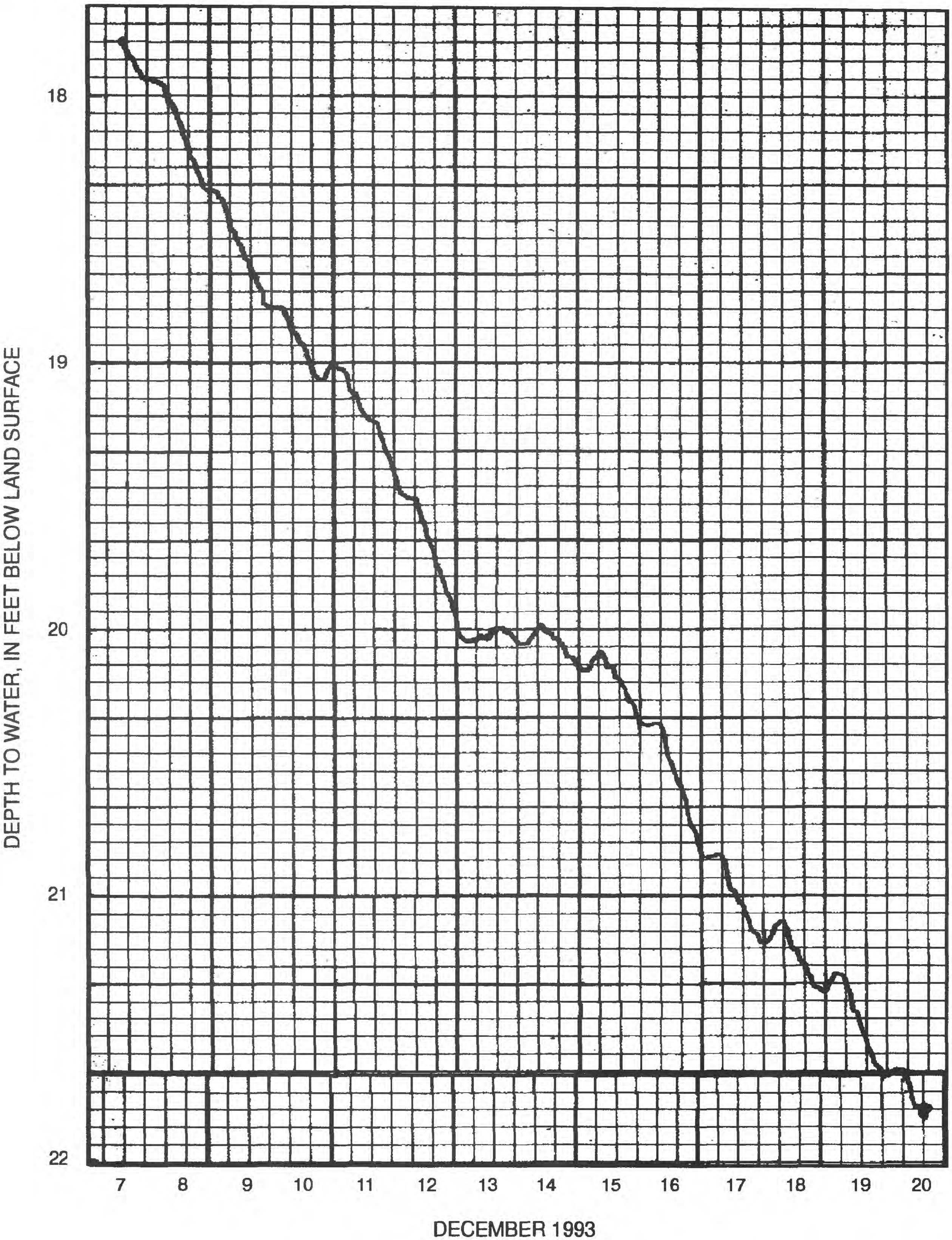

Figure 10. Hydrograph of well BK-2528, Fischer and Porter Site, Warminster, Pa., December 7- 20, 1993.

Figure 11. Hydrograph of well BK-2528, Fischer and Porter Site, Warminster, Pa., December 20, 1993, to January 13, 1994.

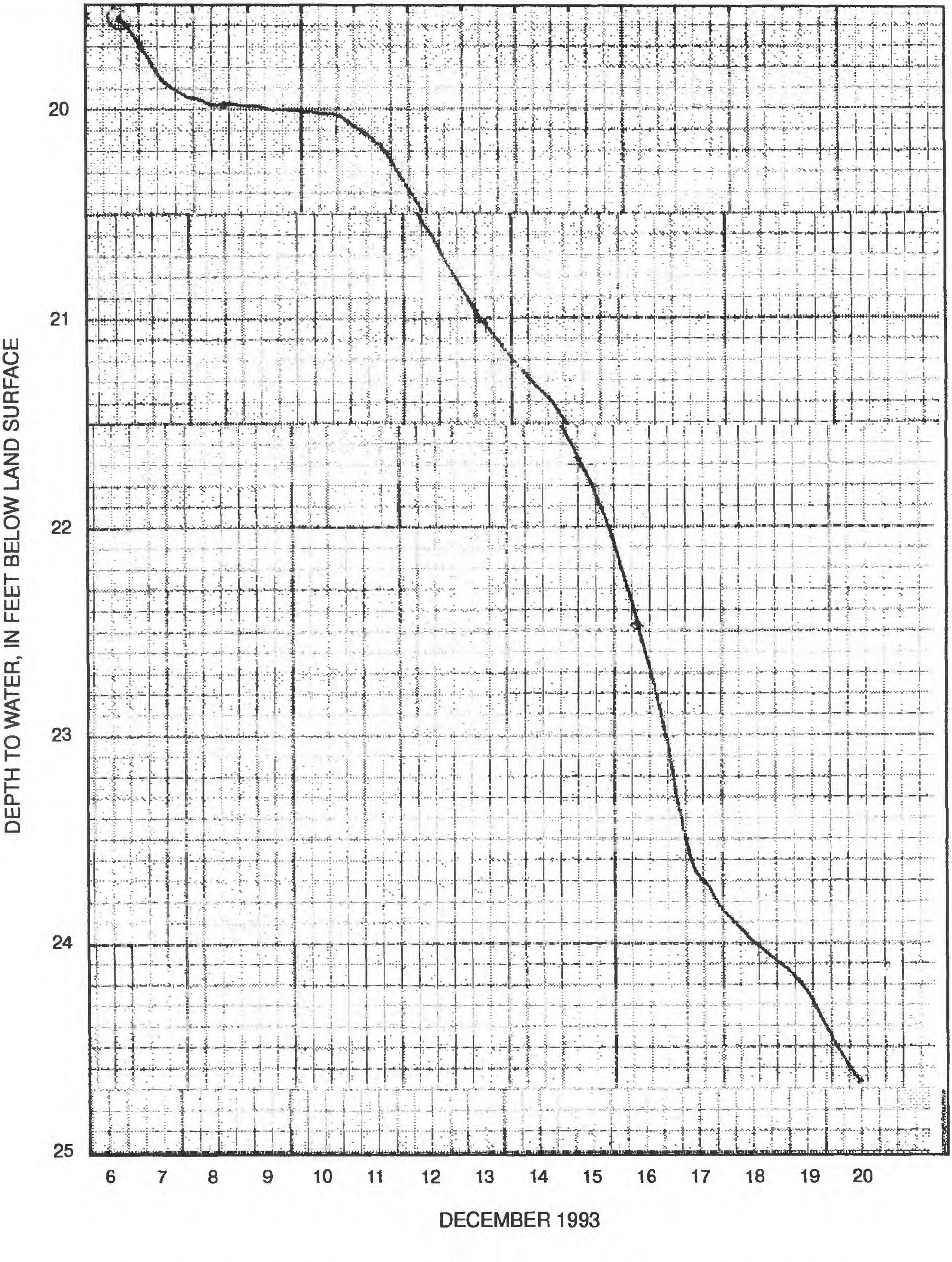

Figure 12. Hydrograph of well BK-1795, Fischer and Porter Site, Warminster, Pa., December 6-20, 1993.

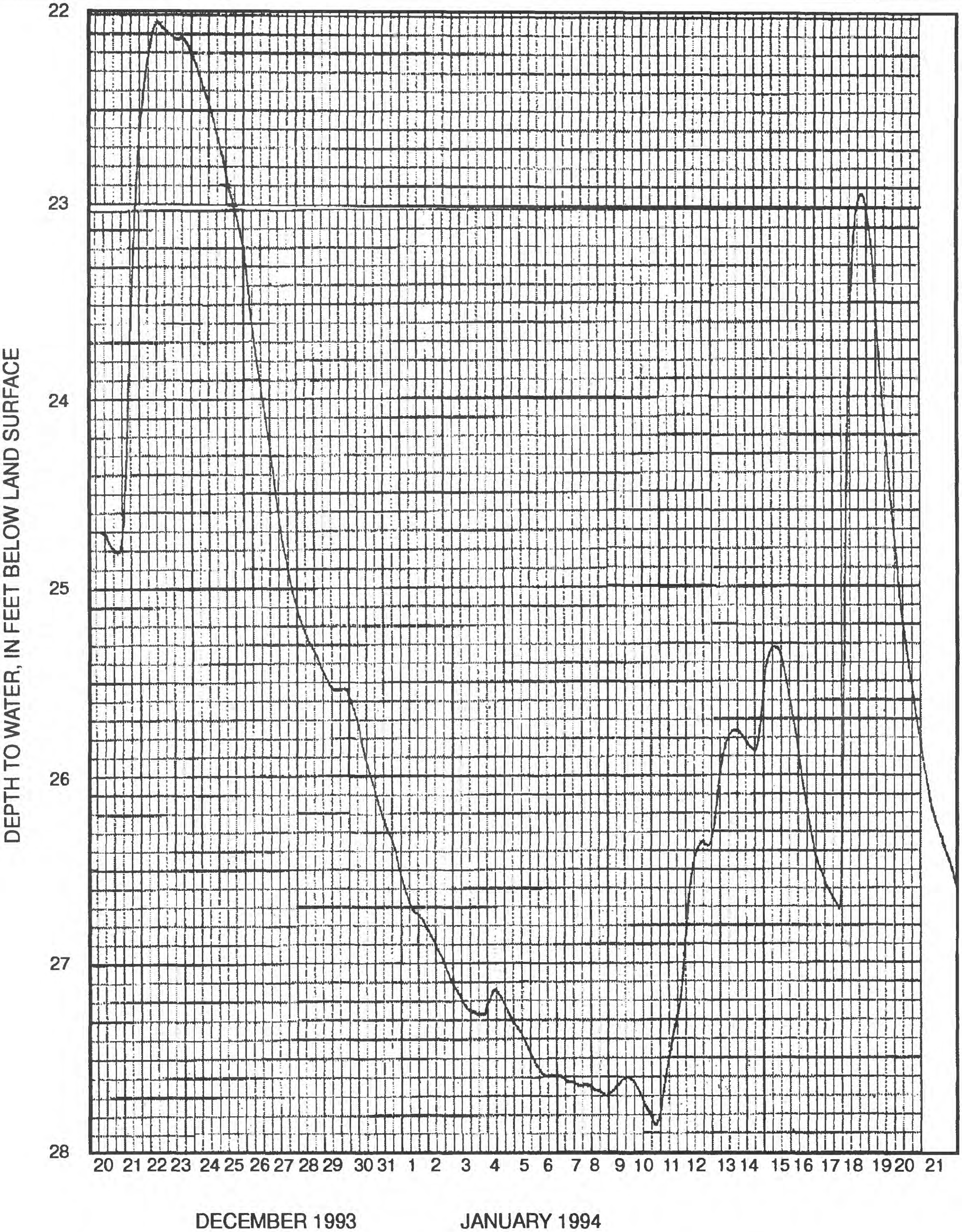

Figure 13. Hydrograph of well BK-1795, Fischer and Porter Site, Warminster, Pa., December 20, 1993, to January 21, 1994.

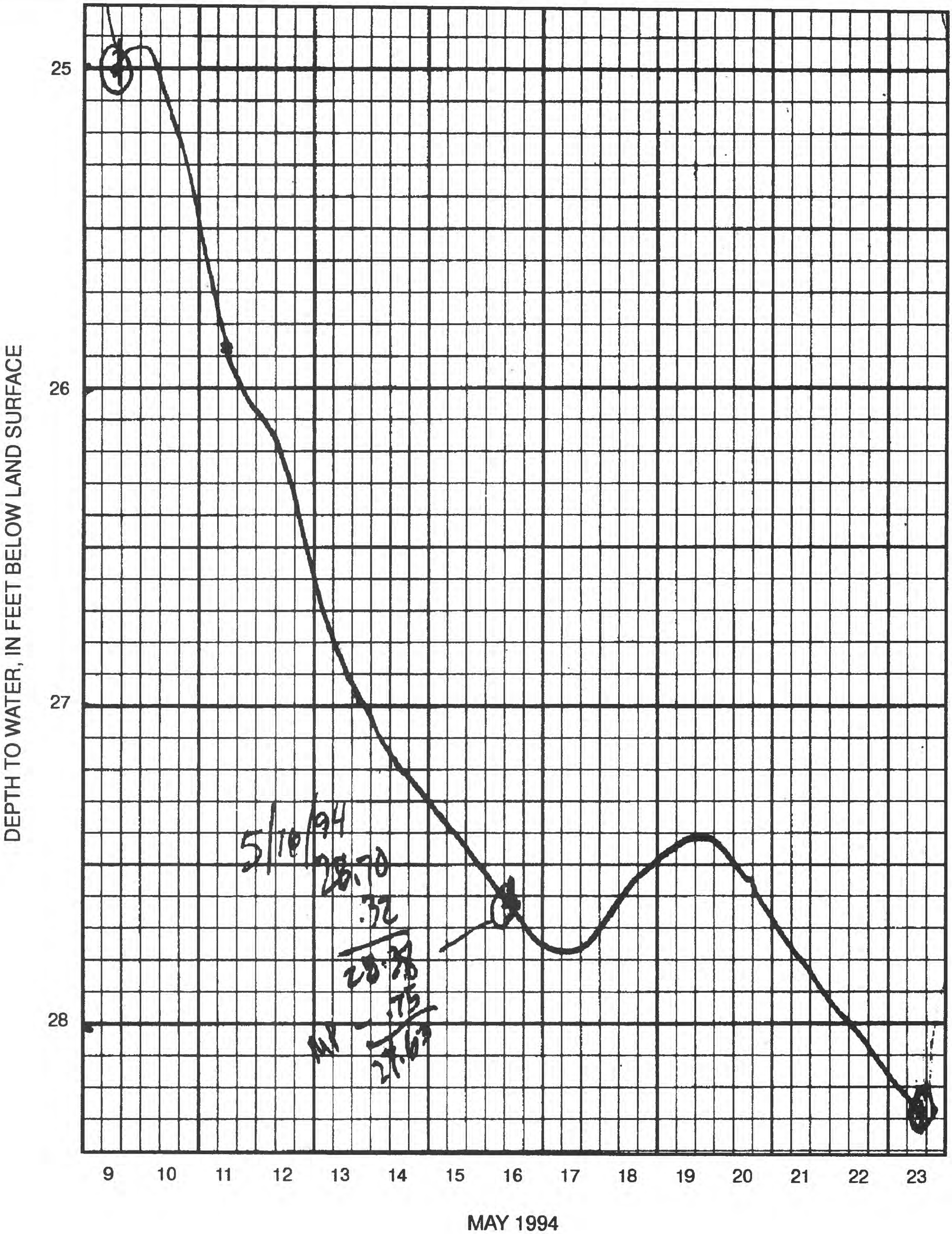

Figure 14. Hydrograph of well BK-1795, Fischer and Porter Site, Warminster, Pa., May 9-23, 1994.

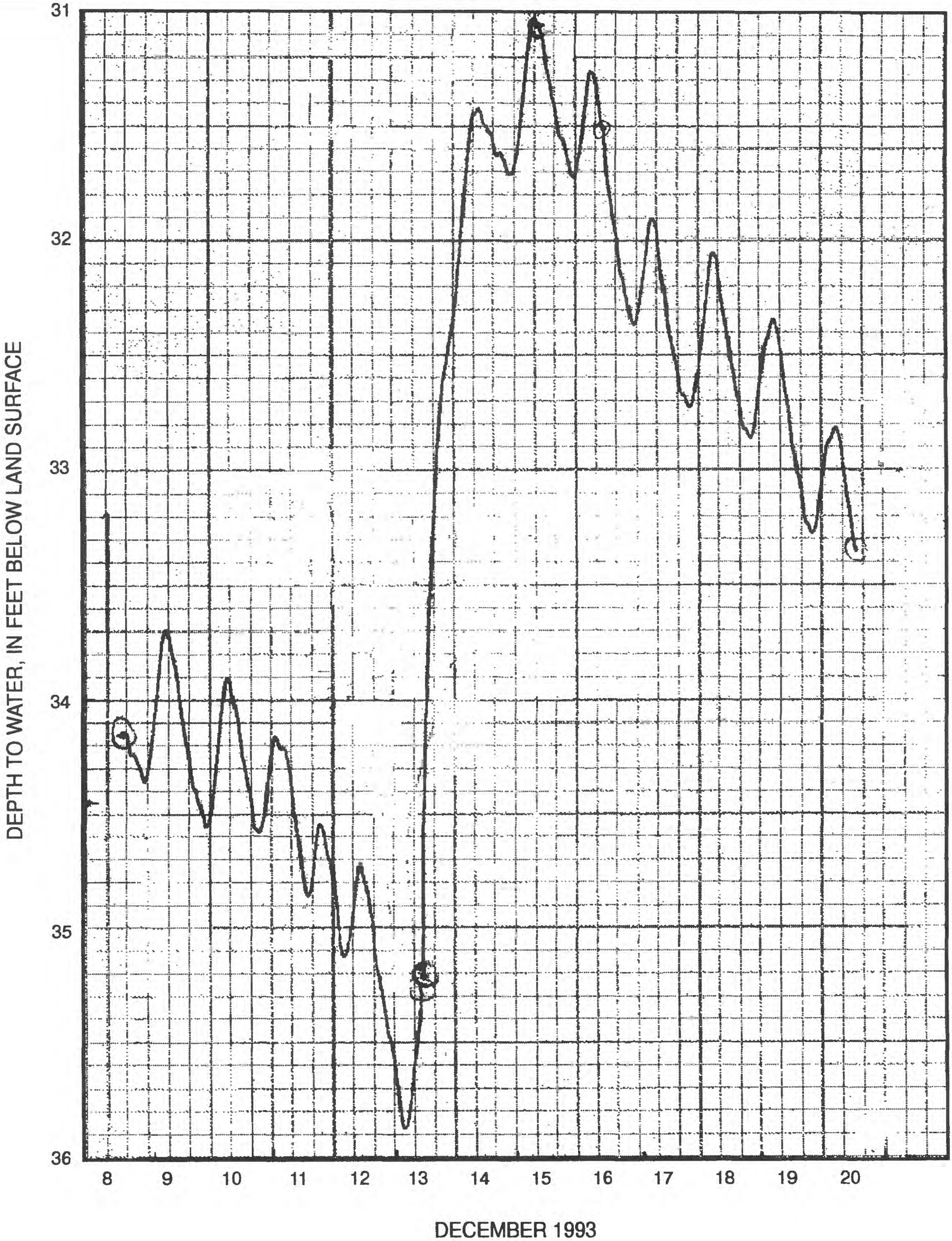

Figure 15. Hydrograph of well BK-1796, Fischer and Porter Site, Warminster, Pa., December 8- 20, 1993.

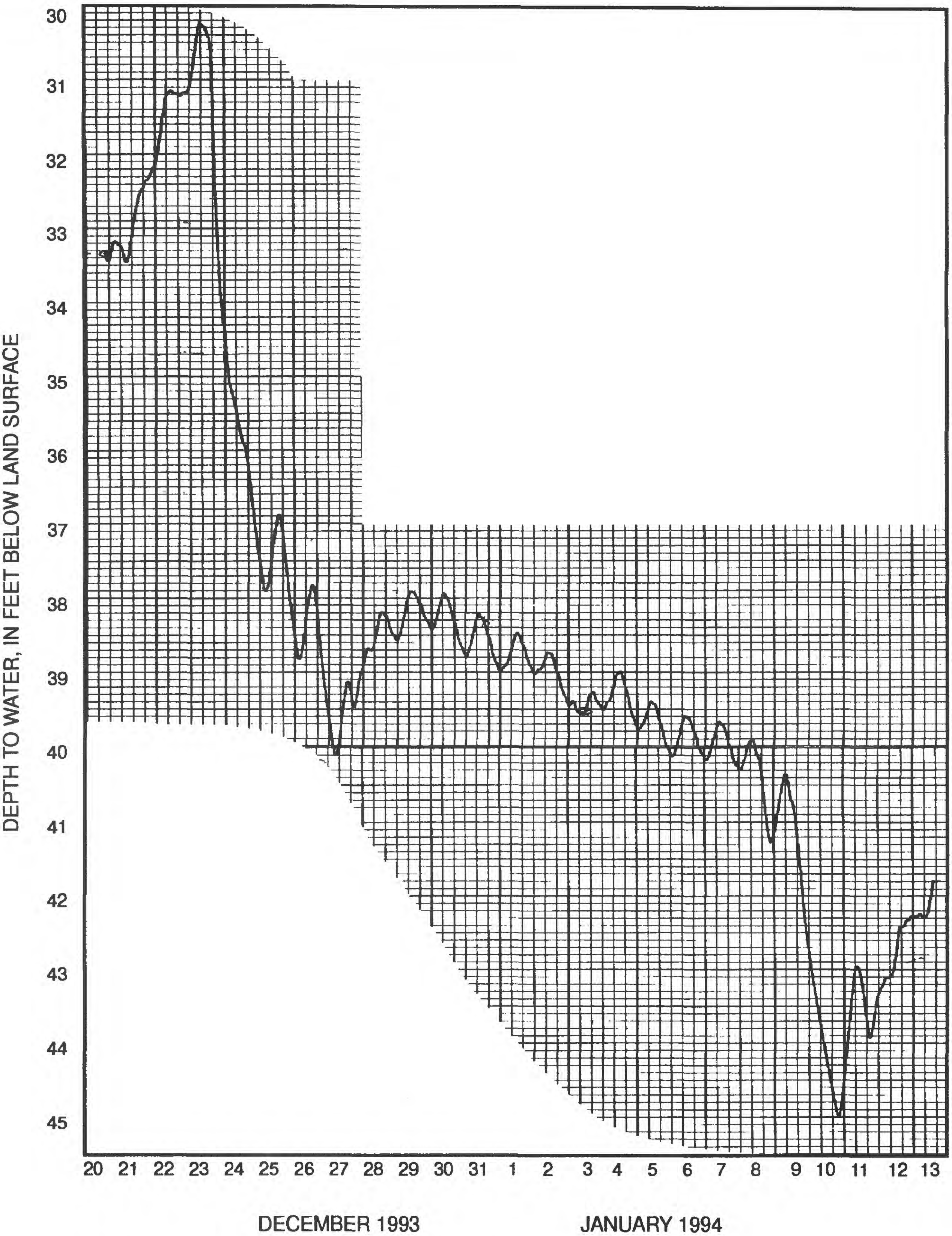

Figure 16. Hydrograph of well BK-1796, Fischer and Porter Site, Warminster, Pa., December 20, 1993, to January 13, 1994.

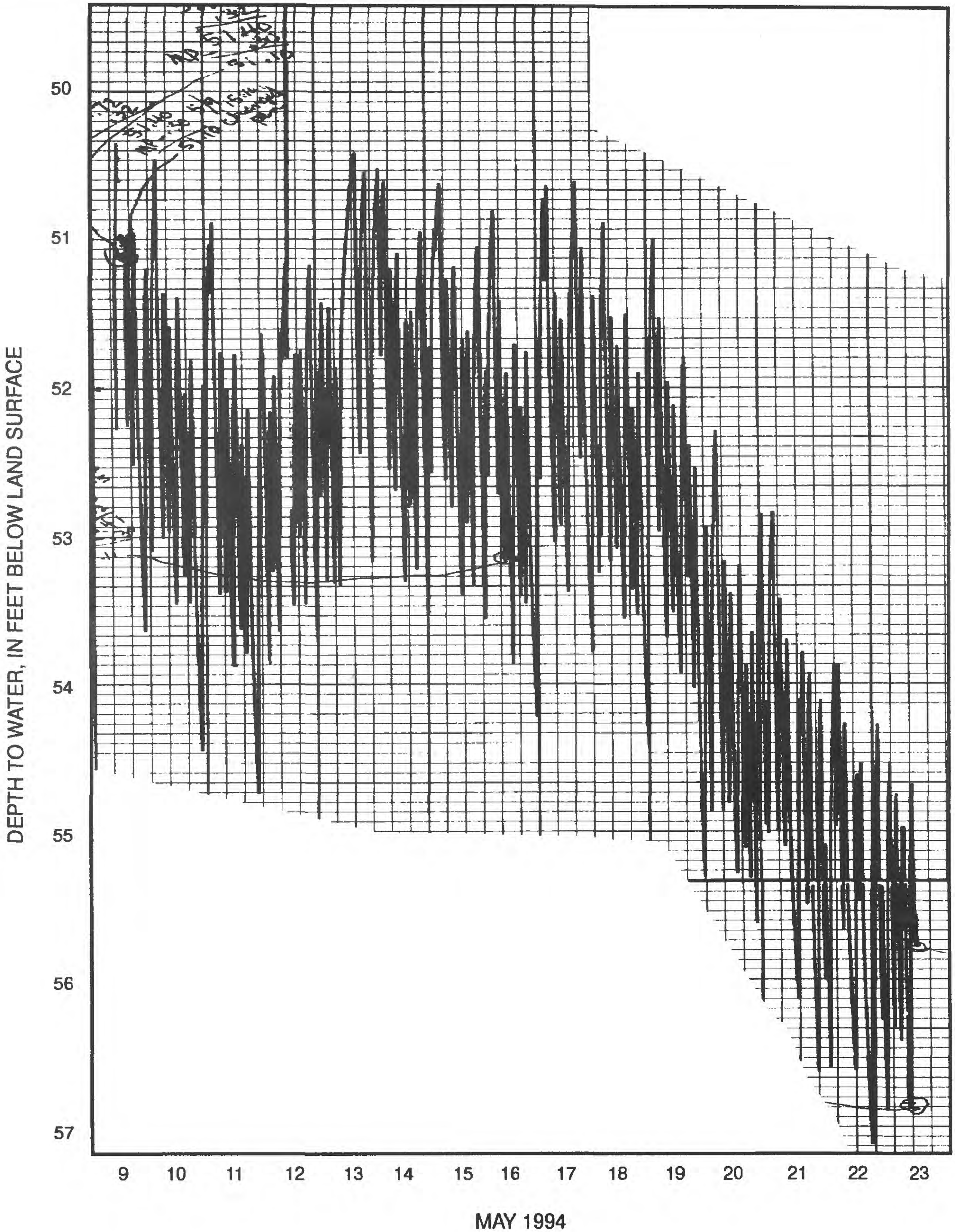

Figure 17. Hydrograph of well BK-2514, Fischer and Porter Site, Warminster, Pa., May 9-23, 1994.

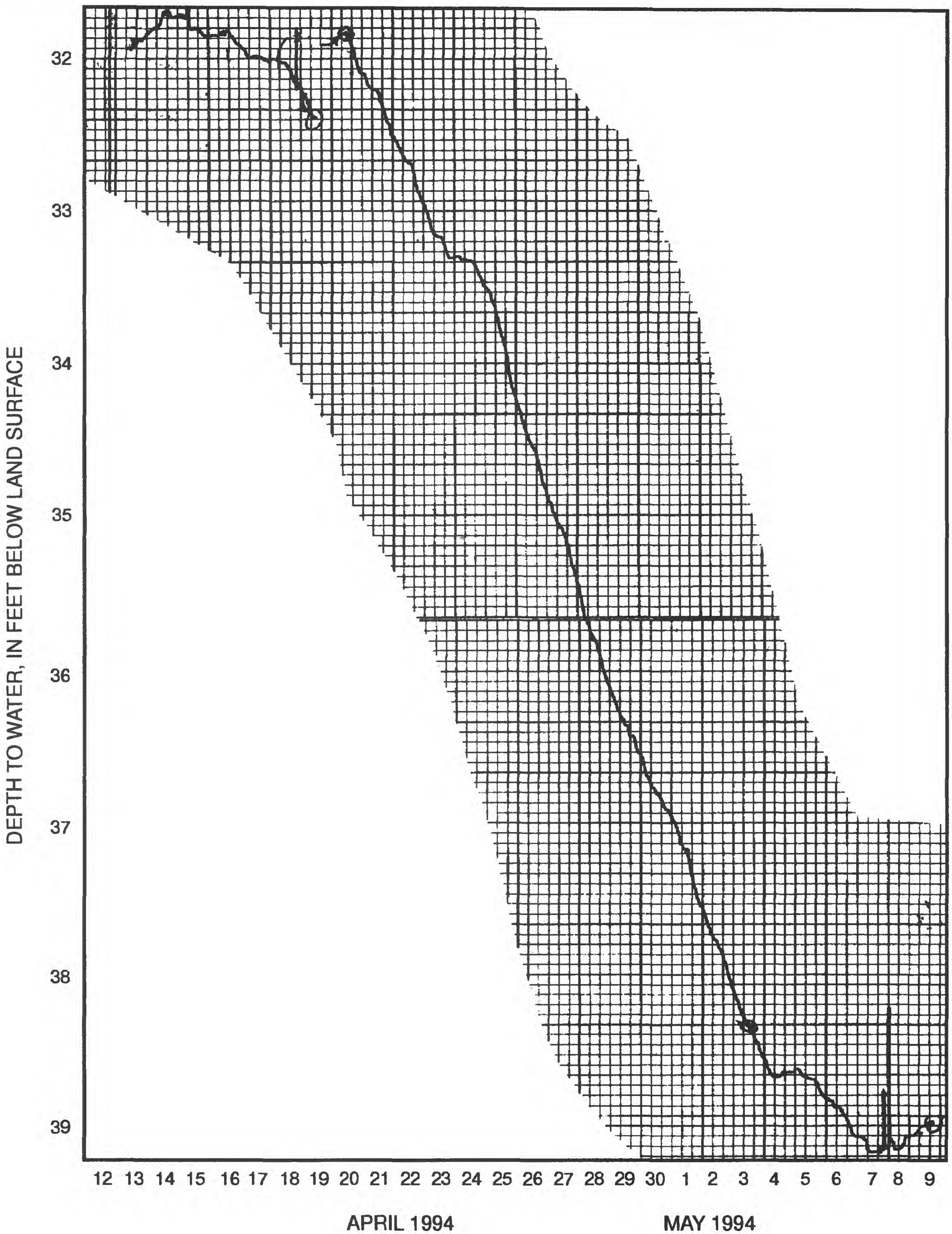

Figure 18. Hydrograph of well BK-2526, Fischer and Porter Site, Warminster, Pa., April 12 to May 9, 1994.

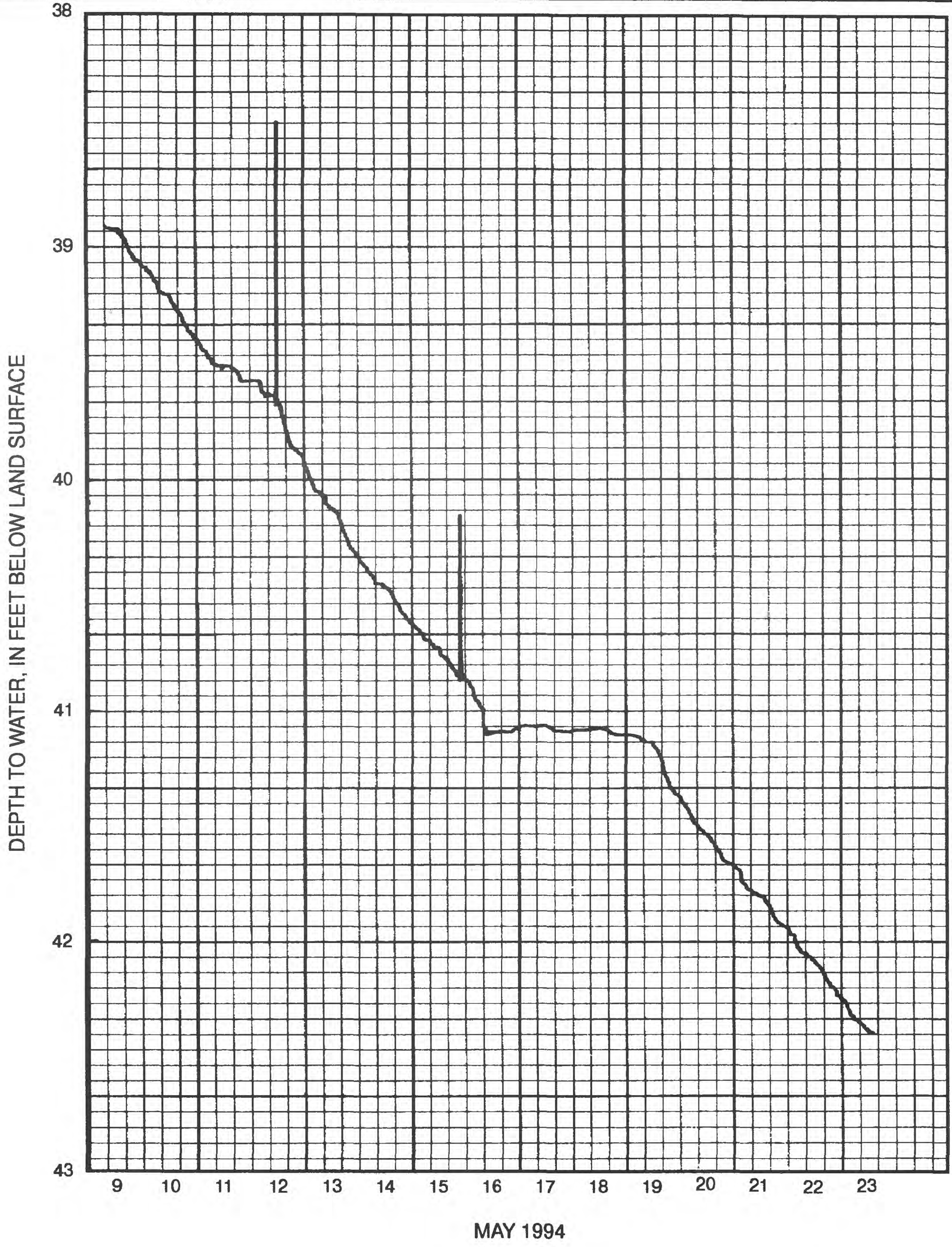

Figure 19. Hydrograph of well BK-2526, Fischer and Porter Site, Warminster, Pa., May 9-23, 1994

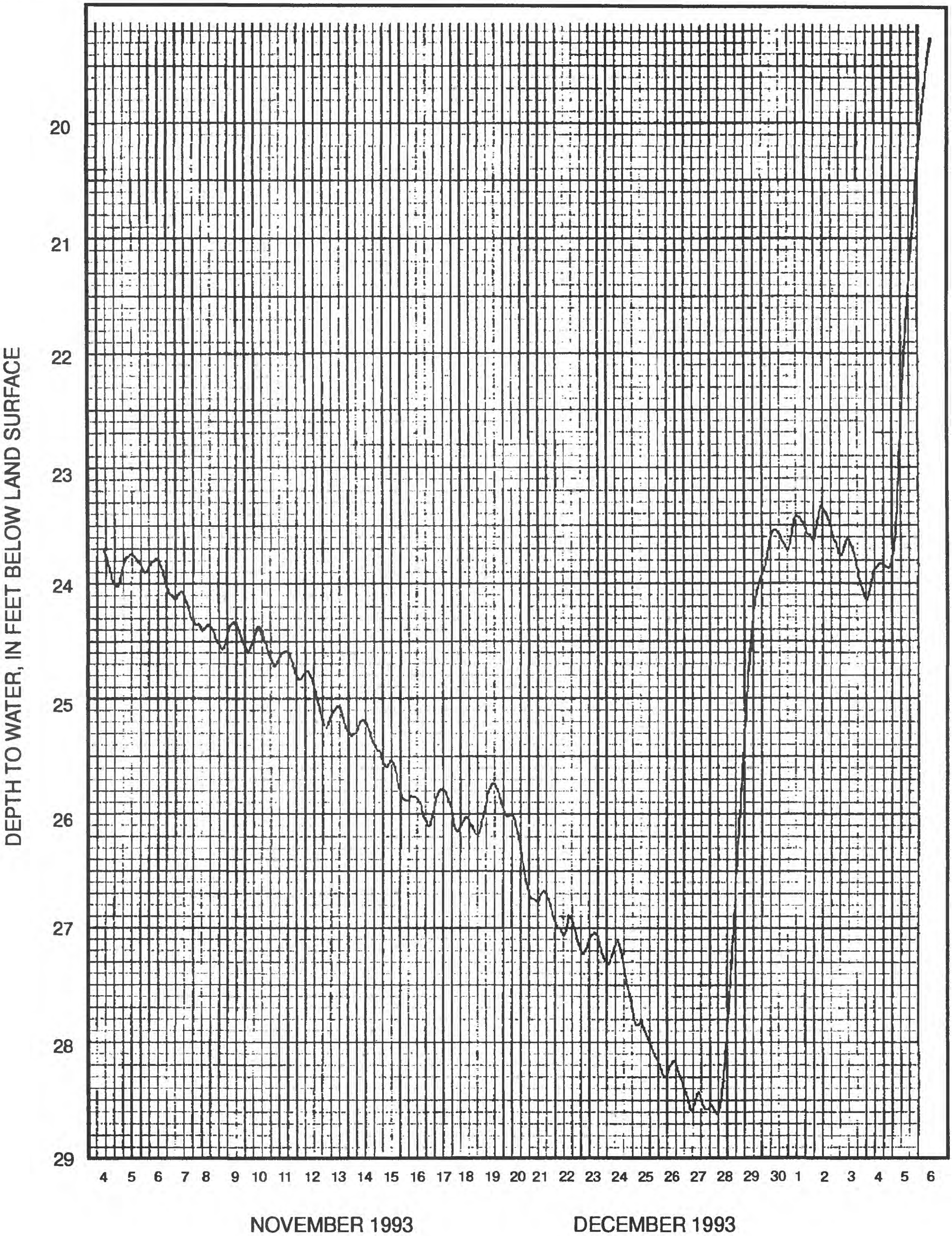

Figure 20. Hydrograph of well BK-1793, Fischer and Porter Site, Warminster, Pa., November 4 to December 6, 1993.

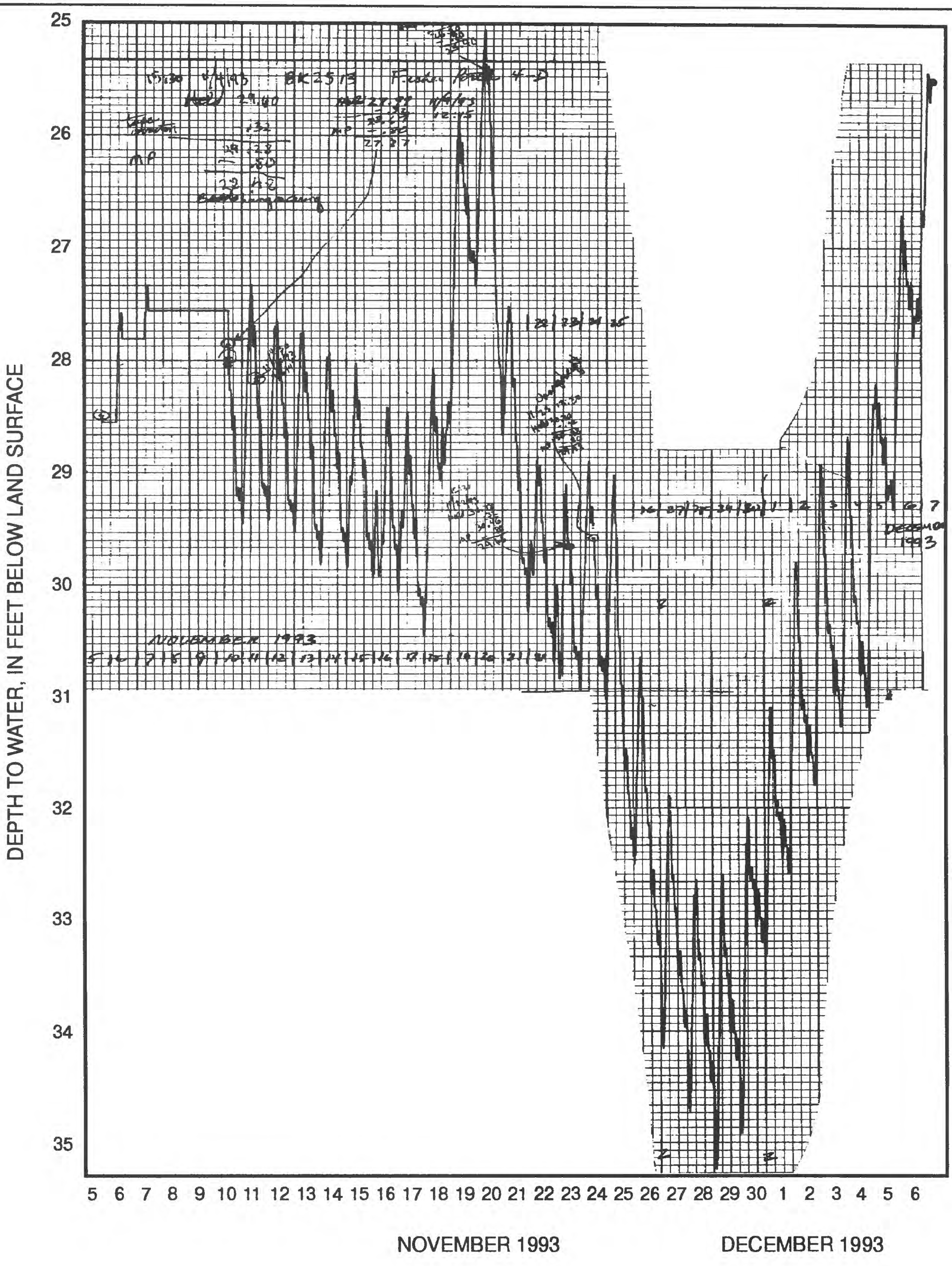

Figure 21. Hydrograph of well BK-2513, Fischer and Porter Site, Warminster, Pa., November 5 to December 6, 1993

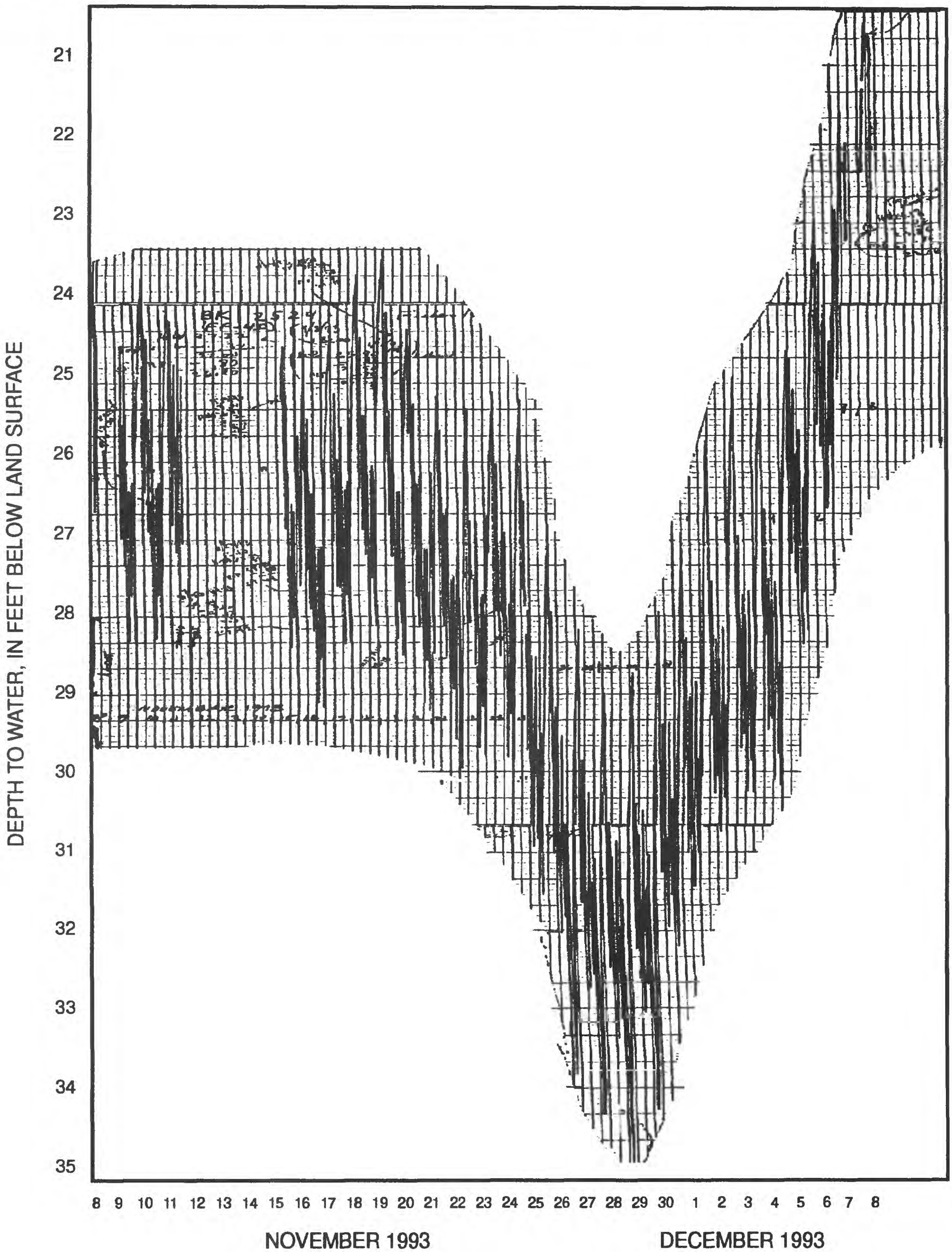

Figure 22. Hydrograph of well BK-2524, Fischer and Porter Site, Warminster, Pa., November 8 to December 8, 1993

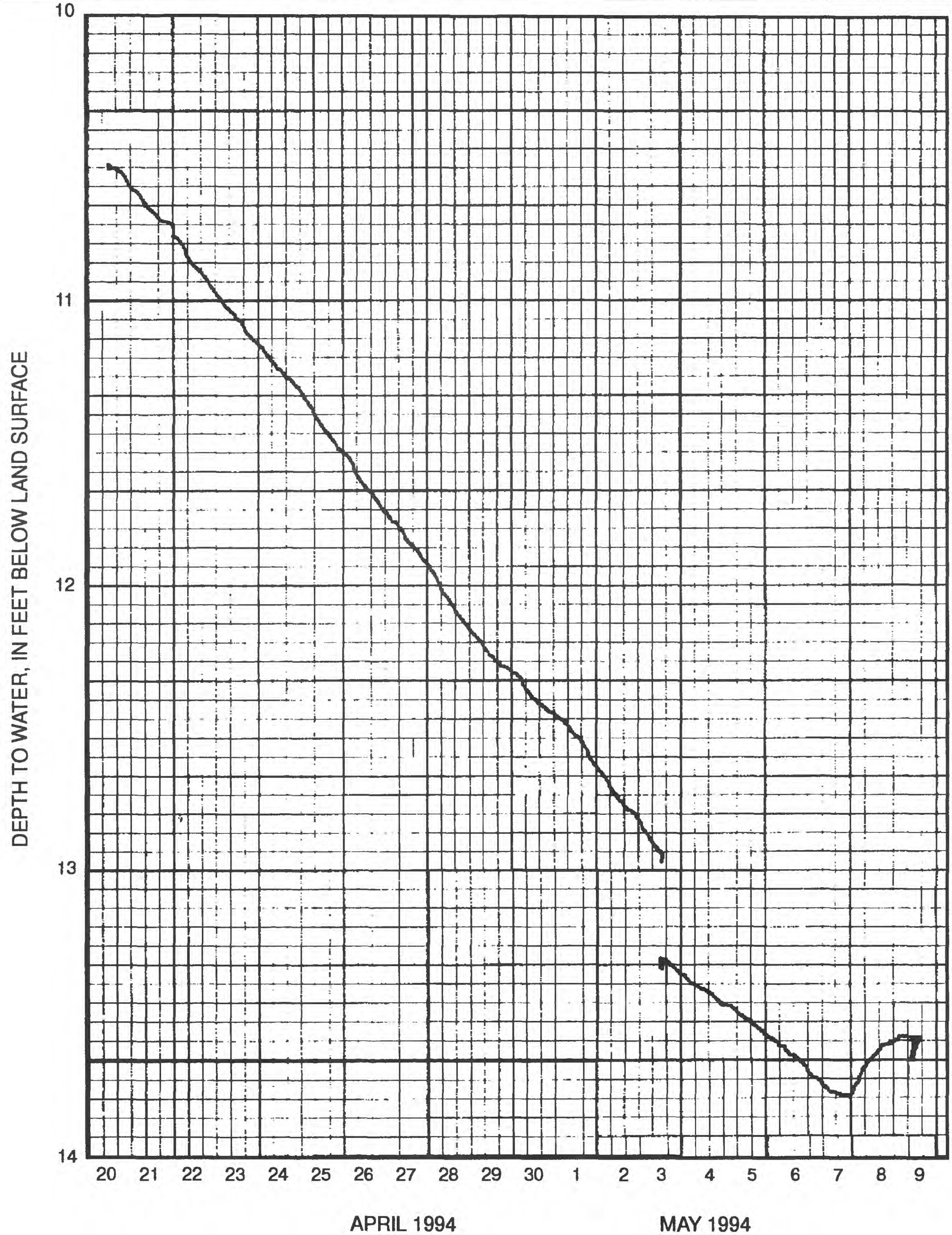

Figure 23. Hydrograph of well BK-2525, Fischer and Porter Site, Warminster, Pa., April 20 to May 9, 1994

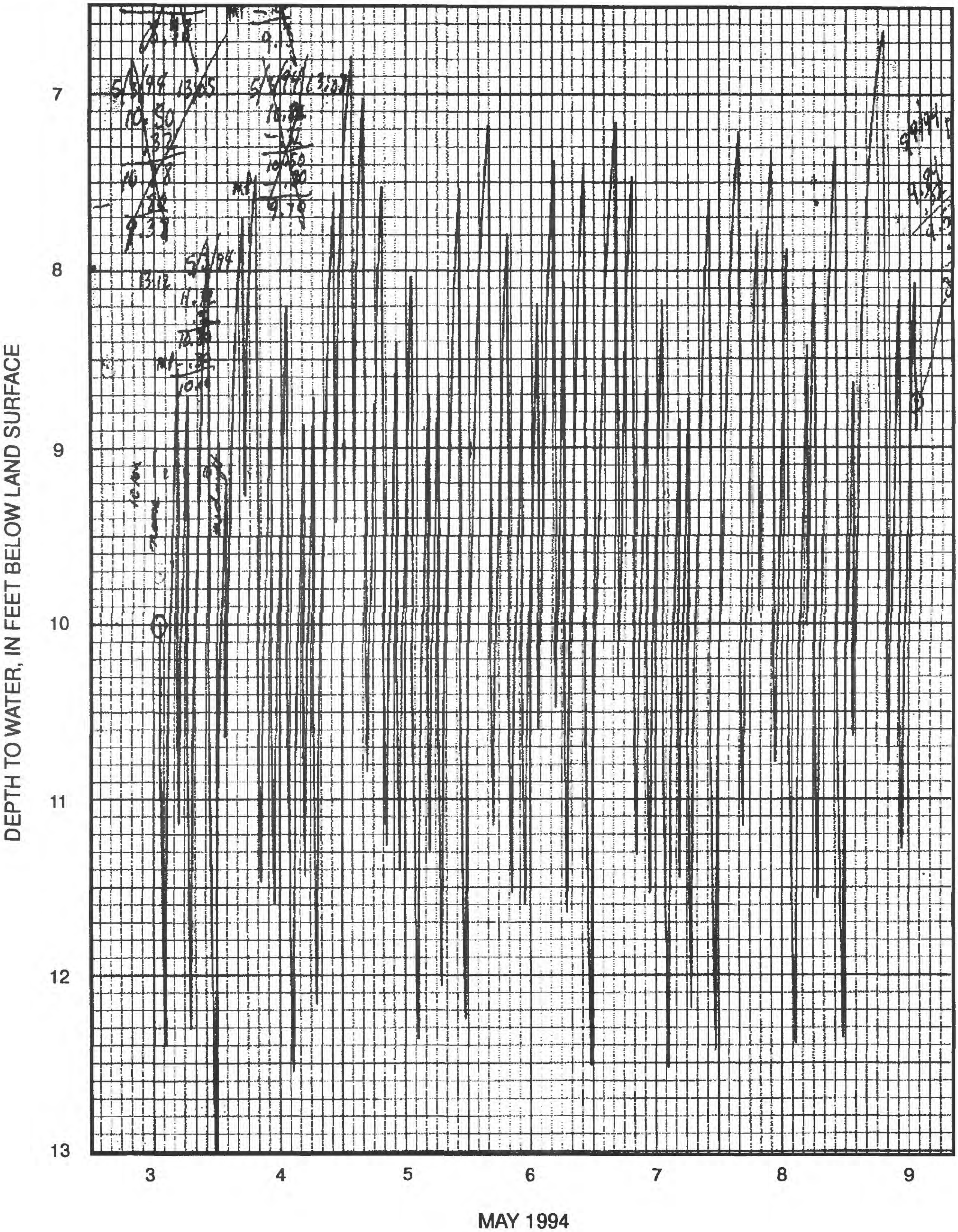

Figure 24. Hydrograph of well BK-2512, Fischer and Porter Site, Warminster, Pa., May 3-9, 1994.

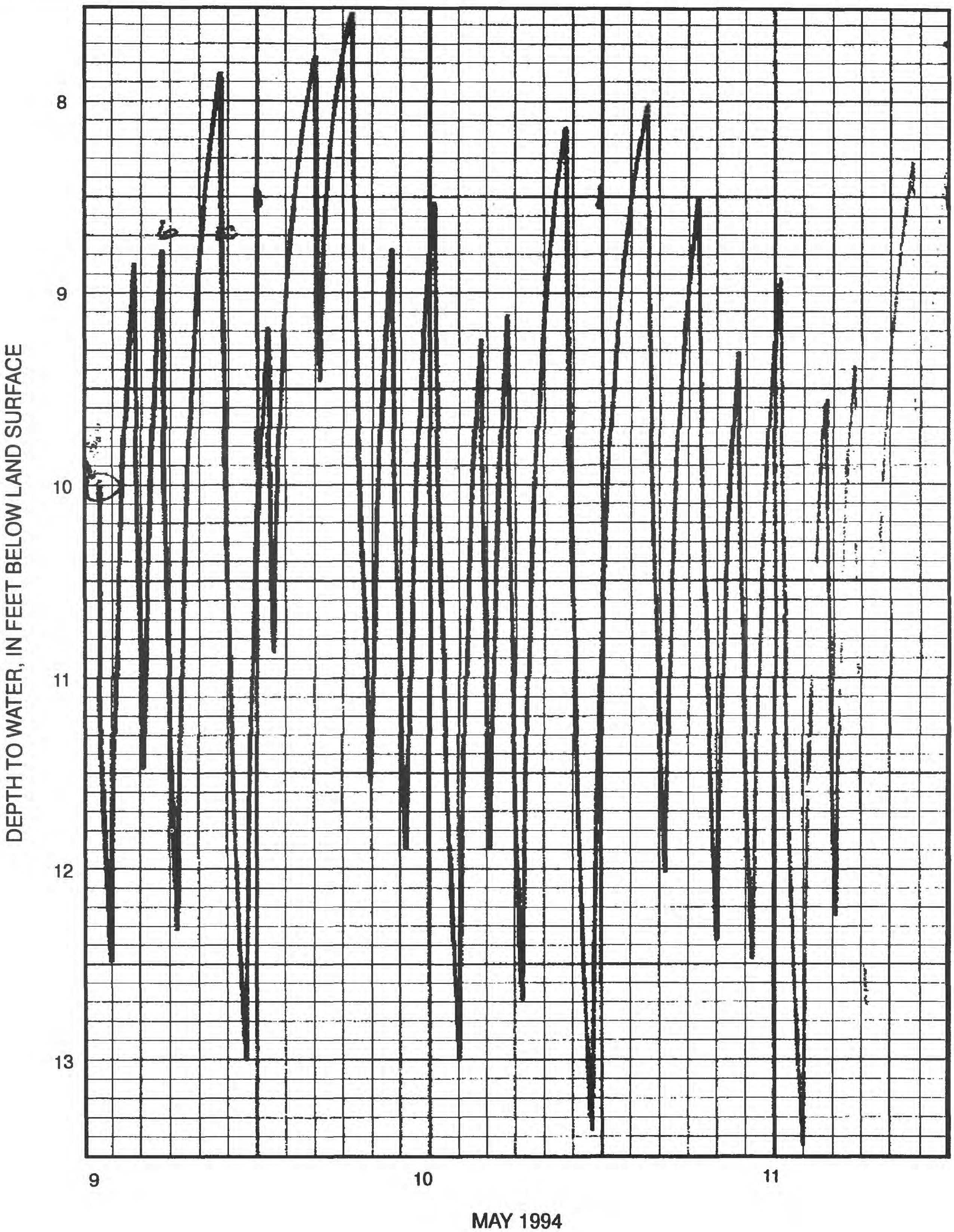

Figure 25. Hydrograph of well BK-2512, Fischer and Porter Site, Warminster, Pa., May 9-11, 1994.

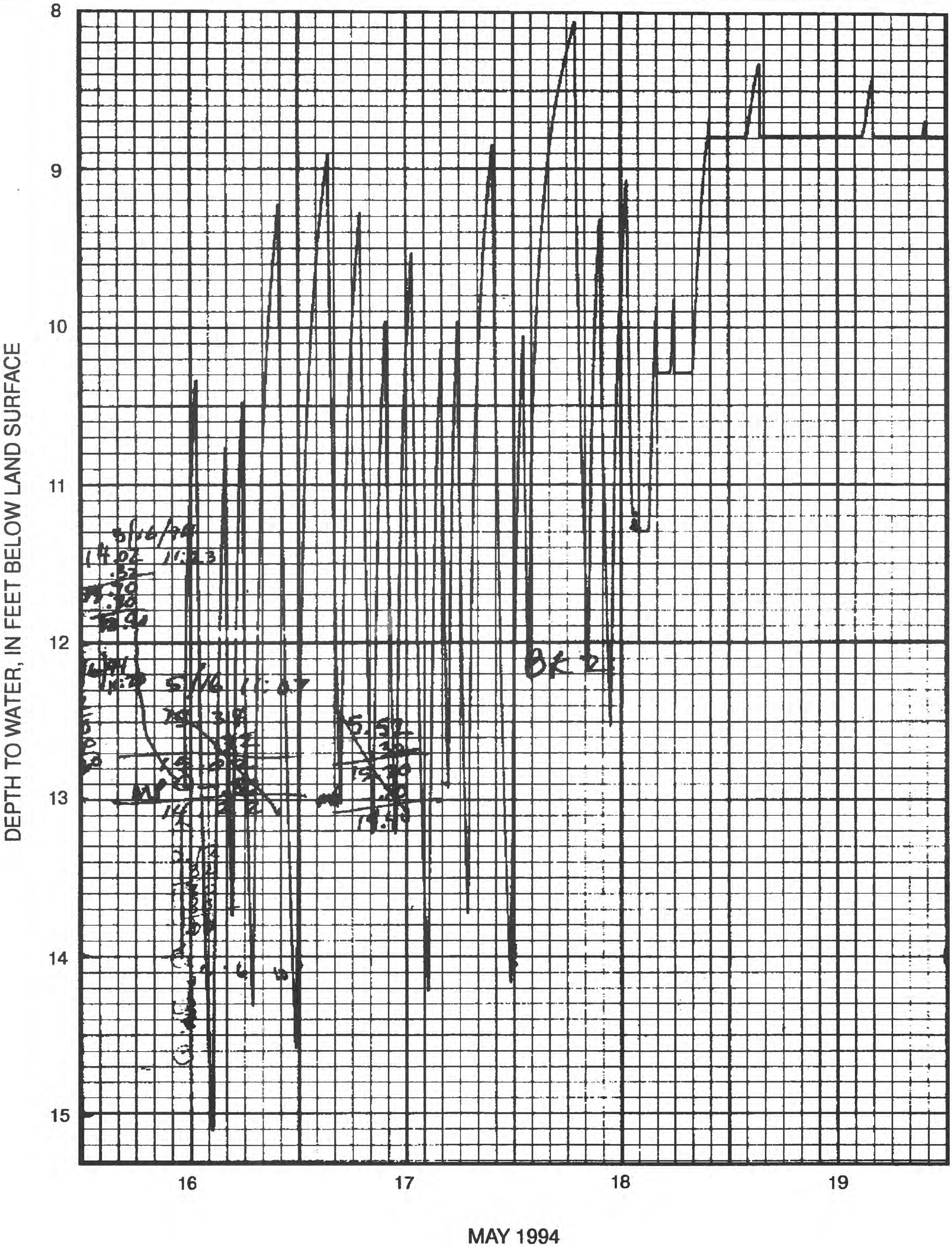

Figure 1. Hydrograph of well BK-2512, Fischer and Porter Site, Warminster, Pa., May 16-19, 1994.

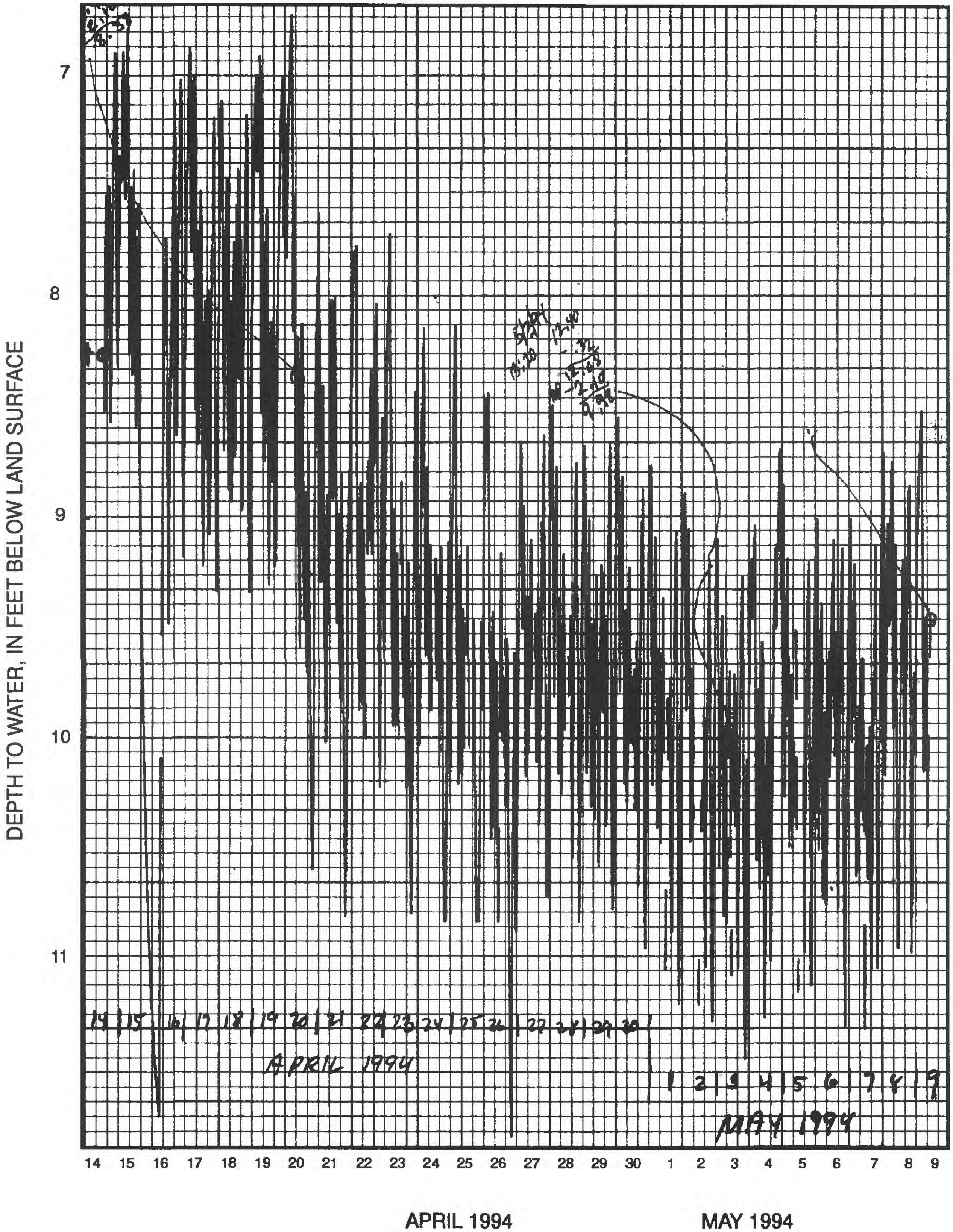

Figure 27. Hydrograph of well BK-2522, Fischer and Porter Site, Warminster, Pa., April 14 to May 9, 1994.

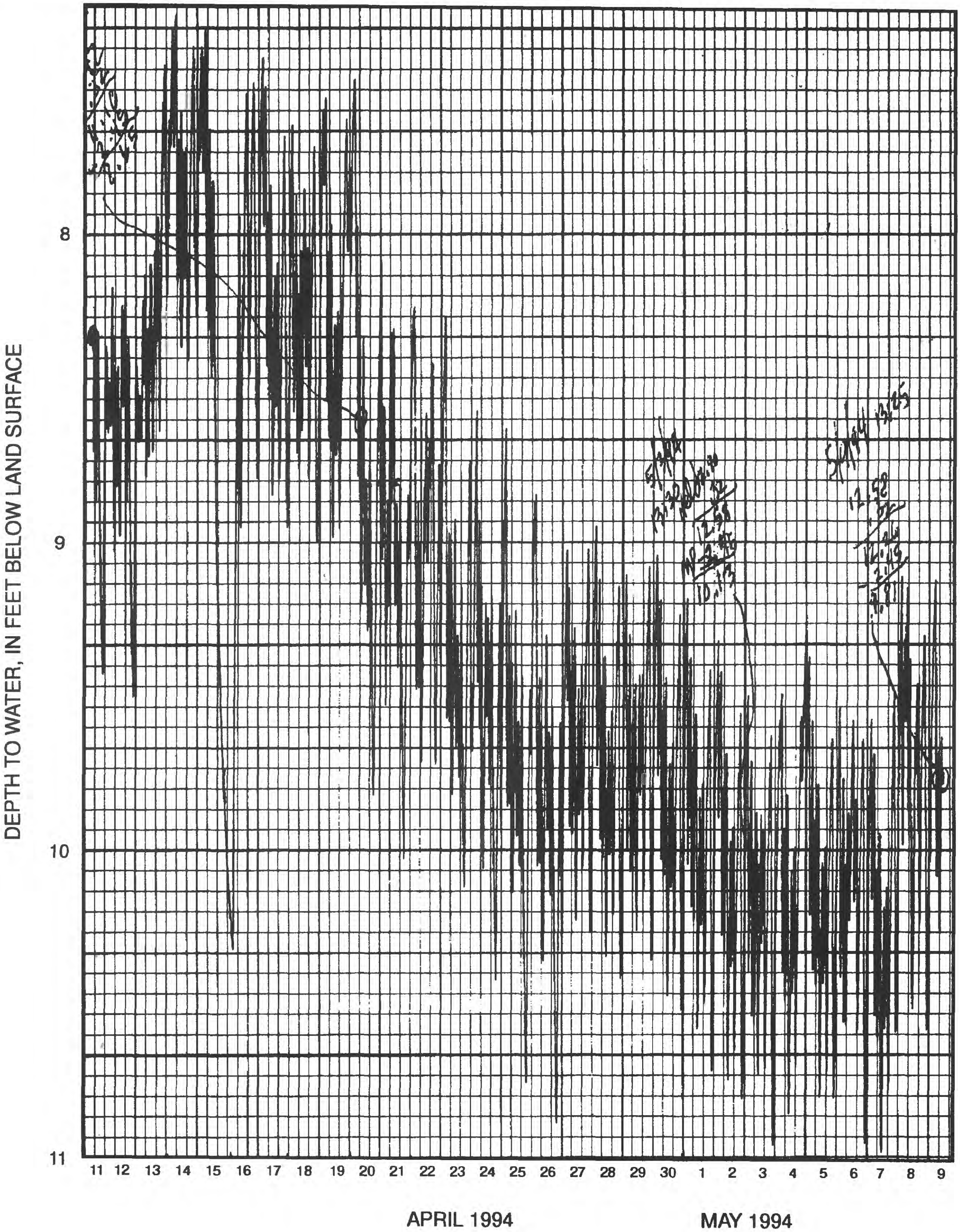

Figure 28. Hydrograph of well BK-2523, Fischer and Porter Site, Warminster, Pa., April 11 to May 9, 1994.

APPENDIX 5.—RESULTS OF CHEMICAL ANALYSES FOR VOLATILE ORGANIC COMPOUNDS

Table 1. *Results of chemical analyses for volatile organic compounds in water samples from borehole BK-2511, Fischer and Porter Site, Warminster, Pa.*

[Concentrations given in micrograms per liter; sample from interval 277-305 feet below land surface ruined by lab; <, less than; --, no data]

Compound	Sampled depth interval (feet below land surface)							
	Above 187[1]	Above 187[2]	211-239	241-269	241-269 replicate	Below 305	Field blank	Lab blank[1]
Benzene	--	0.3	--	--	--	--	--	--
Bromoform	<0.8	<.2	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8
1,2-Dibromomethane	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8
Carbon tetrachloride	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8
Chlorobenzene	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8
Dichlorobenzene	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8
1,3-Dichlorobenzene	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8
1,4-Dichlorobenzene	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8
Chlorodibromomethane	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8
Chloroethane	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8
2-Chloroethylvinylether	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8
Chloroform	<.8	.2	<.8	<.8	<.8	<.8	<.8	1.8
Dichlorobromomethane	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8
Dichlorodifluoromethane	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8
1,1-Dichloroethane	1.5	1.3	1.7	1.4	.9	1.1	<.8	<.8
1,2-Dichloroethane	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8
1,1-Dichloroethylene	4.3	2.4	4.5	3.7	2.9	2.6	<.8	<.8
cis-1,2-Dichloroethene	17	14	19	15	12	14	<.8	<.8
trans-1,2-Dichloroethene	<.8	--	<.8	<.8	<.8	<.8	<.8	<.8
1,2-Dichloropropane	2.3	<.4	<.8	<.8	<.8	<.8	<.8	<.8
1,3-Dichloropropene	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8
cis-1,3-Dichloropropene	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8
trans-1,3-Dichloropropene	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8
Ethylbenzene	--	<.2	--	--	--	--	--	--
Methylbromide	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8
Methylchloride	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8
Methylene chloride	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8
Styrene	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8
1,1,2,2-Tetrachloroethane	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8
Tetrachloroethylene	14	5.7	14	11	7.9	8.6	<.8	<.8
Toluene	--	<.2	--	--	--	--	--	--
1,1,1-Trichloroethane	2.8	<.6	1.9	1.2	<.8	<.8	<.8	<.8
1,1,2-Trichloroethane	<.8	<.3	<.8	<.8	<.8	<.8	<.8	<.8
Trichloroethylene	88	130	87	78	74	73	<.8	1.6
Trichlorofluoromethane	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8
Vinyl chloride	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8
Xylene	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8

[1] U.S. Geological Survey New Jersey District Laboratory.

[2] U.S. Geological Survey National Water Quality Laboratory, Arvada, Colorado.

Table 2. *Results of chemical analyses for volatile organic compounds in water samples from borehole BK-2512, Fischer and Porter Site, Warminster, Pa.*

[Concentrations given in micrograms per liter; <, less than; --, no data]

Compound	Sampled depth interval (feet below land surface)										
	Above 115[1]	Above 115[2]	132-160	132-160 replicate	164-192	204-235	204-235	237-265	Below 265	Field blank	Lab blank
Benzene	--	<0.2	--	--	--	--	--	--	--	--	--
Bromoform	<0.8	<.2	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8
1,2-Dibromomethane	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Carbon tetrachloride	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Chlorobenzene	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Dichlorobenzene	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
1,3-Dichlorobenzene	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
1,4-Dichlorobenzene	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Chlorodibromomethane	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Chloroethane	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
2-Chloroethylvinylether	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Chloroform	<.8	.6	3.8	3.9	<.8	<.8	<.8	<.8	<.8	<.8	1.5
Dichlorobromomethane	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Dichlorodifluoromethane	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
1,1-Dichloroethane	<.8	1.2	<.8	<.8	<.8	<.8	<.8	<.8	1.6	<.8	<.8
1,2-Dichloroethane	<.8	<.2	8.3	7.7	2.1	1.9	2.2	1.8	<.8	<.8	<.8
1,1-Dichloroethylene	<.8	.8	5.5	5.2	1.0	<.8	<.8	<.8	2.0	<.8	<.8
cis-1,2-Dichloroethene	8.2	13	55	56	30	25	29	29	27	<.8	<.8
trans-1,2-Dichloroethene	<.8	--	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
1,2-Dichloropropane	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
1,3-Dichloropropene	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
cis-1,3-Dichloropropene	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
trans-1,3-Dichloropropene	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Ethylbenzene	--	<.2	--	--	--	--	--	--	--	--	--
Methylbromide	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Methylchloride	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Methylene chloride	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	15	<.8
Styrene	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
1,1,2,2-Tetrachloroethane	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Tetrachloroethylene	5.9	5.6	37	37	12	11	11	<.8	13	<.8	<.8
Toluene	--	<.2	--	--	--	--	--	--	--	--	--
1,1,1-Trichloroethane	<.8	.6	1.8	1.8	<.8	.9	<.8	<.8	1.3	6.8	<.8
1,1,2-Trichloroethane	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Trichloroethylene	56	73	96	110	75	75	74	76	82	<.8	<.8
Trichlorofluoromethane	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Vinyl chloride	<.8	<.2	5.8	5.6	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Xylene	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8

[1] U.S. Geological Survey New Jersey District Laboratory.

[2] U.S. Geological Survey National Water Quality Laboratory, Arvada, Colorado.

Table 3. *Results of chemical analyses for volatile organic compounds in water samples from borehole BK-2513, Fischer and Porter Site, Warminster, Pa.*

[Concentrations given in micrograms per liter; <, less than; --, no data]

Compound	Sampled depth interval (feet below land surface)										
	Above 143	143-171[1]	143-171[2]	176-204	176-204 replicate	202-232	202-232 replicate	232-260	Below 260	Field blank	Lab blank
Benzene	<0.8	<0.8	<0.2	<0.8	<0.8	1.4	12	1.8	<0.8	<0.8	3.2
Bromoform	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
1,2-Dibromomethane	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Carbon tetrachloride	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Chlorobenzene	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Dichlorobenzene	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
1,3-Dichlorobenzene	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
1,4-Dichlorobenzene	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Chlorodibromomethane	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Chloroethane	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
2-Chloroethylvinylether	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Chloroform	<.8	<.8	1.0	<.8	<.8	<.8	<.8	<.8	<.8	<.8	1.8
Dichlorobromomethane	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Dichlorodifluoromethane	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
1,1-Dichloroethane	<.8	<.8	.3	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
1,2-Dichloroethane	29	35	<.2	23	23	27	24	6.5	6.7	<.8	<.8
1,1-Dichloroethylene	<.8	<.8	1.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
cis-1,2-Dichloroethene	<.8	<.8	1.5	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
trans-1,2-Dichloroethene	<.8	<.8	--	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
1,2-Dichloropropane	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
1,3-Dichloropropene	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
cis-1,3-Dichloropropene	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
trans-1,3-Dichloropropene	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Ethylbenzene	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8	2.5	<.8	<.8
Methylbromide	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Methylchloride	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Methylene chloride	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Styrene	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
1,1,2,2-Tetrachloroethane	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Tetrachloroethylene	10	11	10	4.5	4.4	2.3	2.2	3.8	4.4	<.8	<.8
Toluene	<.8	3.6	.2	3.1	3.4	<.8	<.8	11	2.5	20	1.3
1,1,1-Trichloroethane	1.2	1.4	1.9	<.8	<.8	1.7	<.8	2.5	.8	<.8	<.8
1,1,2-Trichloroethane	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Trichloroethylene	39	43	28	34	33	37	34	20	20	<.8	1.6
Trichlorofluoromethane	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Vinyl chloride	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Xylene	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8

[1] U.S. Geological Survey New Jersey District Laboratory.
[2] U.S. Geological Survey National Water Quality Laboratory, Arvada, Colorado.

***Table 4.** Results of chemical analyses for volatile organic compounds in water samples from borehole BK-2514, Fischer and Porter Site, Warminster, Pa.*

[Concentrations given in micrograms per liter; <, less than; --, no data]

Compound	Sampled depth interval (feet below land surface)										
	Above 72[1]	Above 72[2]	72-100	100-128	130-158	177-205	209-237	209-237 replicate	Below 237	Below 237 replicate	Field blank	Lab blank
Benzene	--	<0.2	--	--	--	--	--	--	--	--	--	--
Bromoform	<0.8	<.2	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8
1,2-Dibromomethane	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Carbon tetrachloride	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Chlorobenzene	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Dichlorobenzene	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
1,3-Dichlorobenzene	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
1,4-Dichlorobenzene	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Chlorodibromomethane	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Chloroethane	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
2-Chloroethylvinylether	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Chloroform	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	1.4
Dichlorobromomethane	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Dichlorodifluoromethane	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
1,1-Dichloroethane	<.8	<.2	<.8	<.8	<.8	<.8	1.1	<.8	<.8	<.8	<.8	<.8
1,2-Dichloroethane	4.5	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
1,1-Dichloroethylene	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
cis-1,2-Dichloroethene	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
trans-1,2-Dichloroethene	<.8	--	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
1,2-Dichloropropane	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
1,3-Dichloropropene	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
cis-1,3-Dichloropropene	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
trans-1,3-Dichloropropene	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Ethylbenzene	--	<.2	--	--	--	--	--	--	--	--	--	--
Methylbromide	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Methylchloride	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Methylene chloride	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	19	<.8
Styrene	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
1,1,2,2-Tetrachloroethane	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Tetrachloroethylene	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Toluene	--	.4	--	--	--	--	--	--	--	--	--	--
1,1,1-Trichloroethane	<.8	<.2	.8	<.8	9.1	<.8	<.8	<.8	1.1	1.1	<.8	<.8
1,1,2-Trichloroethane	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Trichloroethylene	9.7	.5	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Trichlorofluoromethane	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Vinyl chloride	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8
Xylene	<.8	<.2	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8	<.8

[1] U.S. Geological Survey New Jersey District Laboratory.
[2] U.S. Geological Survey National Water Quality Laboratory, Arvada, Colorado.

Table 5. *Results of chemical analyses for volatile organic compounds in water samples from borehole BK-2515, Fischer and Porter Site, Warminster, Pa.*

[Concentrations given in micrograms per liter; <, less than; --, no data]

Compound	Sampled depth interval (feet below land surface)						
	Above 172	172-200[1]	172-200[2]	Below 277	Below 277 replicate	Field blank	Lab blank
Benzene	--	--	<0.2	--	--	--	--
Bromoform	<0.8	<0.8	<.2	<0.8	<0.8	<0.8	<0.8
1,2-Dibromomethane	<.8	<.8	<.2	<.8	<.8	<.8	<.8
Carbon tetrachloride	<.8	<.8	<.2	<.8	<.8	<.8	<.8
Chlorobenzene	<.8	<.8	<.2	<.8	<.8	<.8	<.8
Dichlorobenzene	<.8	<.8	<.2	<.8	<.8	<.8	<.8
1,3-Dichlorobenzene	<.8	<.8	<.2	<.8	<.8	<.8	<.8
1,4-Dichlorobenzene	<.8	<.8	<.2	<.8	<.8	<.8	<.8
Chlorodibromomethane	<.8	<.8	.3	<.8	<.8	<.8	<.8
Chloroethane	<.8	<.8	<.2	<.8	<.8	<.8	<.8
2-Chloroethylvinylether	<.8	<.8	<.2	<.8	<.8	<.8	<.8
Chloroform	<.8	<.8	.3	<.8	<.8	<.8	1.4
Dichlorobromomethane	<.8	<.8	<.2	<.8	<.8	<.8	<.8
Dichlorodifluoromethane	<.8	<.8	<.2	<.8	<.8	<.8	<.8
1,1-Dichloroethane	3.1	1.7	2.1	2.0	2.0	<.8	<.8
1,2-Dichloroethane	<.8	<.8	.3	<.8	<.8	<.8	<.8
1,1-Dichloroethylene	6.6	5.6	5.2	2.0	5.3	<.8	<.8
cis-1,2-Dichloroethene	17	14	19	19	16	<.8	<.8
1,2-Dichloropropane	<.8	<.8	.3	<.8	<.8	<.8	<.8
1,3-Dichloropropene	<.8	<.8	<.2	<.8	<.8	<.8	<.8
cis-1,3-Dichloropropene	<.8	<.8	<.2	<.8	<.8	<.8	<.8
trans-1,3-Dichloropropene	<.8	<.8	<.2	<.8	<.8	<.8	<.8
Ethylbenzene	--	--	<.2	--	--	--	--
Methylbromide	<.8	<.8	<.2	<.8	<.8	<.8	<.8
Methylchloride	<.8	<.8	<.2	<.8	<.8	<.8	<.8
Methylene chloride	<.8	<.8	<.2	<.8	<.8	<.8	<.8
Styrene	<.8	<.8	<.2	<.8	<.8	<.8	<.8
1,1,2,2-Tetrachloroethane	<.8	<.8	<.2	<.8	<.8	<.8	<.8
Tetrachloroethylene	6.3	7.3	6.4	7.3	5.6	<.8	<.8
Toluene	--	--	.3	--	--	--	--
1,1,1-Trichloroethane	<.8	<.8	.8	<.8	<.8	<.8	<.8
1,1,2-Trichloroethane	<.8	<.8	<.2	<.8	<.8	<.8	<.8
Trichloroethylene	84	71	150	76	75	<.8	<.8
Trichlorofluoromethane	<.8	<.8	<.2	<.8	<.8	<.8	<.8
Vinyl chloride	1.3	<.8	1.4	<.8	.8	<.8	<.8
Xylene	<.8	<.8	<.2	<.8	<.8	<.8	<.8

[1] U.S. Geological Survey New Jersey District Laboratory.
[2] U.S. Geological Survey National Water Quality Laboratory, Arvada, Colorado.

Table 6. *Results of chemical analyses for volatile organic compounds in water samples from borehole MG-1242, Hatboro, Pa.*

[Concentrations given in micrograms per liter; <, less than; --, no data]

Compound	Sampled depth interval (feet below land surface)							
	Above 90	90-115[1]	90-115[2]	120-145	120-145 replicate	Below 145	Field blank	Lab blank
Benzene	<0.8	<0.8	<0.2	<0.8	<0.8	<0.8	<0.8	<0.8
Bromoform	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8
1,2-Dibromomethane	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8
Carbon tetrachloride	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8
Chlorobenzene	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8
Dichlorobenzene	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8
1,3-Dichlorobenzene	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8
1,4-Dichlorobenzene	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8
Chlorodibromomethane	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8
Chloroethane	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8
2-Chloroethylvinylether	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8
Chloroform	<.8	<.8	.2	<.8	<.8	<.8	<.8	<.8
Dichlorobromomethane	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8
Dichlorodifluoromethane	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8
1,1-Dichloroethane	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8
1,2-Dichloroethane	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8
1,1-Dichloroethylene	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8
trans-1,2-Dichloroethene	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8
1,2-Dichloropropane	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8
1,3-Dichloropropene	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8
cis-1,3-Dichloropropene	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8
trans-1,3-Dichloropropene	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8
Ethylbenzene	<.8	<.8	<.2	<.8	<.8	<.8	<.8	.8
Methylbromide	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8
Methylchloride	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8
Methylene chloride	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8
Styrene	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8
1,1,2,2-Tetrachloroethane	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8
Tetrachloroethylene	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8
Toluene	<.8	<.8	<.2	<.8	<.8	<.8	<.8	11.8
1,1,1-Trichloroethane	<.8	<.8	.3	<.8	<.8	<.8	<.8	<.8
1,1,2-Trichloroethane	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8
Trichloroethylene	<.8	1.0	1.3	1.2	.8	<.8	<.8	<.8
Trichlorofluoromethane	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8
Vinyl chloride	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8
Xylene	<.8	<.8	<.2	<.8	<.8	<.8	<.8	<.8

[1] U.S. Geological Survey New Jersey District Laboratory.
[2] U.S. Geological Survey National Water Quality Laboratory, Arvada, Colorado.