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EVALUATION OF BOREHOLE GEOPHYSICAL LOGGING, AQUIFER-ISOLATION TESTS, DISTRIBUTION OF CONTAMINANTS, AND WATER-LEVEL MEASUREMENTS AT THE NORTH PENN AREA 5 SUPERFUND SITE, BUCKS AND MONTGOMERY COUNTIES, PENNSYLVANIA

Water-Resources Investigations Report 01-4261

In cooperation with the

U.S. ENVIRONMENTAL PROTECTION AGENCY

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by Philip H. Bird and Randall W. Conger

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New Cumberland, Pennsylvania
2002

U.S. DEPARTMENT OF THE INTERIOR
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CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATIONS

	Length	
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	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
(pCi/L) picocuries per liter

Evaluation of Borehole Geophysical Logging, Aquifer-Isolation Tests, Distribution of Contaminants, and Water-Level Measurements at the North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania

by Philip H. Bird and Randall W. Conger

ABSTRACT

Borehole geophysical logging and aquifer-isolation (packer) tests were conducted at the North Penn Area 5 Superfund site in Bucks and Montgomery Counties, Pa. Caliper, natural-gamma, single-point-resistance, fluid-temperature, fluid-resistivity, heatpulse-flowmeter, and digital acoustic-televiewer logs and borehole television surveys were collected in 32 new and previously drilled wells that ranged in depth from 68 to 302 feet. Vertical borehole-fluid movement direction and rate were measured with a high-resolution heatpulse flowmeter under nonpumping conditions. The suite of logs was used to locate water-bearing fractures, determine zones of vertical borehole-fluid movement, select depths to set packers, and locate appropriate screen intervals for reconstructing new wells as monitoring wells. Aquifer-isolation tests were conducted in four wells to sample discrete intervals and to determine specific capacities of discrete water-bearing zones. Specific capacities of isolated zones during packer testing ranged from 0.12 to 15.30 gallons per minute per foot. Most fractures identified by borehole geophysical methods as water-producing or water-receiving zones produced water when isolated and pumped. The acoustic-televiewer logs define two basic fracture sets, bedding-plane partings with a mean strike of N. 62° E. and a mean dip of 27° NW., and high-angle fractures with a mean strike of N. 58° E. and a mean dip of 72° SE. Correlation of heatpulse-flowmeter data and acoustic-televiewer logs showed 83 percent of identified water-bearing fractures were high-angle fractures.

INTRODUCTION

The North Penn Area 5 Superfund Site is in Montgomery and Hatfield Townships, Montgomery County, and New Britain Township, Bucks County, Pa. (fig. 1). In August 1979, the North Penn Water Authority (NPWA) detected trichloroethene (TCE) in water samples collected from municipal-supply well MG–924 (NP–21); this well was then removed from service (Earth Technology Corporation, 1993). Subsequently, American Electronics Laboratory (AEL), at 305 Richardson Road, discovered leakage from its underground spent solvent tank, which contained, in part, TCE. AEL removed the underground tank in June 1980, aerated the associated contaminated soil, and returned it to the excavated hole. In April 1981, AEL signed a Consent Order and Agreement with the Pennsylvania Department of Environmental Resources (PaDER), now known as the Pennsylvania Department of Environmental Protection (PaDEP). As part of the agreement, AEL installed monitor and recovery wells and a ground-water treatment system. In 1985, TCE and similar compounds were detected in several NPWA wells on the North Penn Area 5 Superfund Site, and, as a result, the site was proposed for the National Priorities List (NPL) in January 1987 (Earth Technology Corporation, 1993). The site was added to the NPL in March 1989.

Subsequent ground-water sampling indicated the contaminant plume was migrating away from the original spill area at AEL (Earth Technology Corporation, 1993). The highest concentrations in ground-water samples were detected at the northern boundary of the AEL property, suggesting sources outside the AEL property also may be contributing to ground-water contamination. From February through May 1990, KEMA-Powertest conducted ground-water sampling at the property on County Line Road that it later purchased in

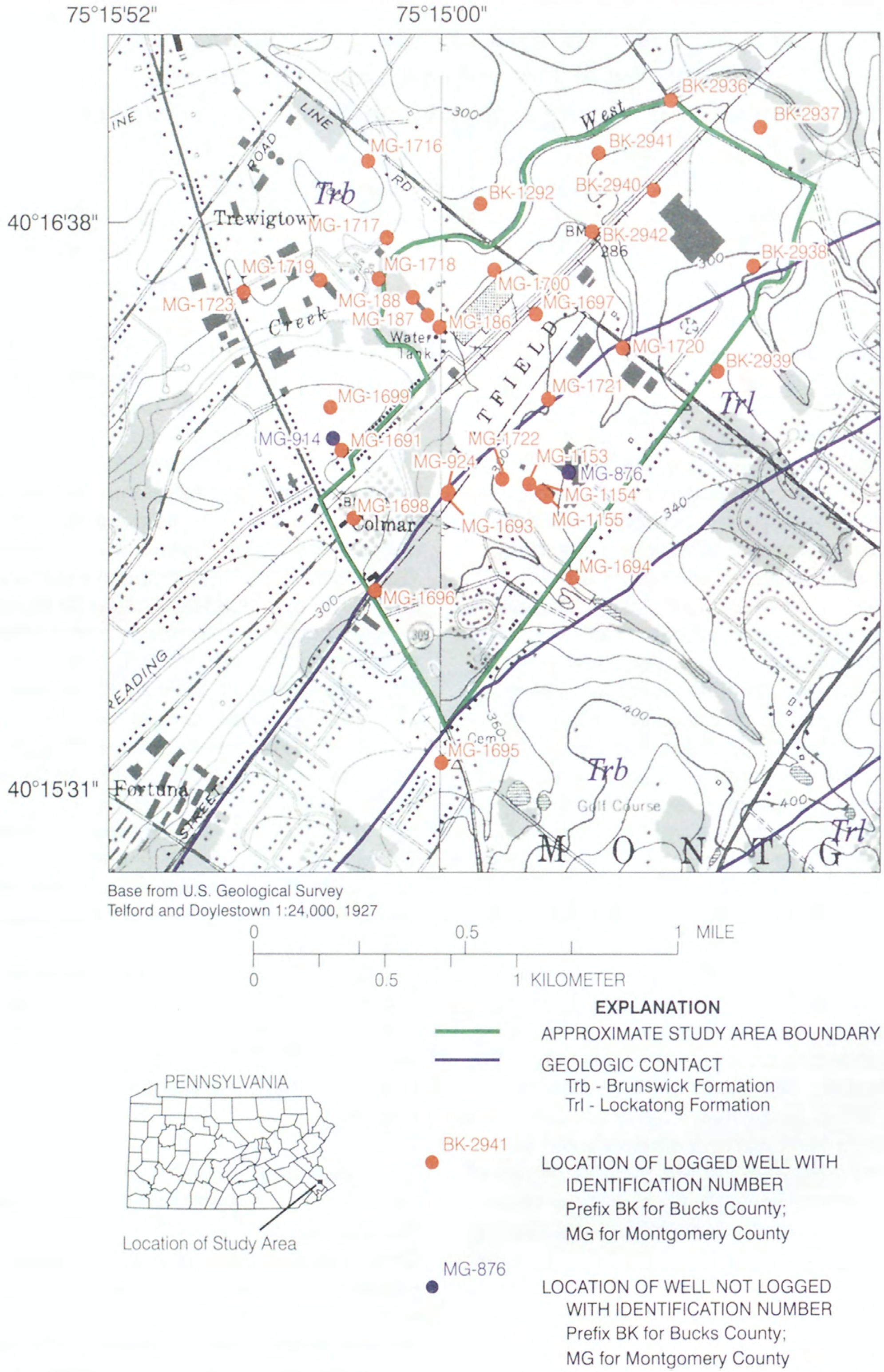


Figure 1. Geology and location of wells at the North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

June 1990. Elevated concentrations (above background) of 1,1,1-trichloroethane (TCA) were detected in one shallow monitoring well (Earth Technology Corporation, 1993). TCA is not a breakdown product of TCE. This result suggested additional sources of ground-water contamination. The North Penn Area 5 Superfund Site now includes the properties where contamination was detected and surrounding areas (fig. 1).

Contaminants of concern detected at the site include TCE, TCA, and tetrachloroethene (PCE). Affected environmental media include soil and ground water. Primary exposure routes to contaminants include ingestion of ground water through drinking, inhalation of ground water used for sanitary purposes, and contact during recreational activities with ground water that has discharged to the West Branch Neshaminy Creek.

Purpose and Scope

This report describes the results of borehole geophysical logging and aquifer-isolation (packer) tests at the North Penn Area 5 Superfund Site. Caliper, natural-gamma, single-point-resistance, fluid-resistivity, fluid-temperature, and heatpulse-flowmeter logs were run in 32 boreholes. Digital acoustic-televiewer logs were run in 31 boreholes. Borehole television surveys were run in 32 boreholes. The report identifies water-bearing zones and intervals of vertical borehole flow. Aquifer-isolation tests were performed in four boreholes. Samples for water-quality analyses for volatile organic compounds (VOC's) were collected from discrete zones in four boreholes to determine the distribution of contamination. This report also presents a potentiometric-surface map of the site on July 13, 1998.

Geologic Setting

The North Penn Area 5 Superfund Site is in the Piedmont Physiographic Province and is underlain by Triassic-age sediments of the Newark Supergroup. The terrain varies from flat to low rolling hills and is drained by the West Branch Neshaminy Creek and two unnamed tributaries to the West Branch Neshaminy Creek.

Brunswick Formation

The Brunswick Formation underlies the northwestern part of the study area. The Brunswick interfingers laterally with the Lockatong Formation. The contact between the Brunswick and the Lockatong generally is placed where the thickness of red beds of the Brunswick equals the thickness of gray and black beds of the Lockatong. The lower part of the Brunswick Formation consists of homogeneous, soft, red to reddish-brown and gray to greenish-gray mudstones and shales that crumble easily. The bedding is irregular, wavy, and sometimes micaceous. Interbedded shales and siltstones are fairly well sorted. Conglomerate and fine-grained sandstone are found in the upper part of the formation. Mudcracks, ripple marks, cross-beds, and burrows are found in all the beds (Drake and others, 1967). The Brunswick Formation contains detrital cycles of medium to dark gray and olive to greenish-gray, thin-bedded and evenly bedded shale and siltstone; these are similar to the rocks of the underlying Lockatong Formation (Lyttle and Epstein, 1987). These units are not as continuous as those in the Lockatong Formation. Higher parts of the formation have gray beds that are softer and are largely mud- and silt-shale and siltstone. The interfingered thin beds that underlie the southeastern part of the site were mapped as the Lockatong Formation by Willard and others (1959) but are considered the lower beds of the Brunswick Formation by Lyttle and Epstein (1987). The contact of the Brunswick Formation with the Lockatong Formation is gradational over about 1,640 ft (Lyttle and Epstein, 1987). The lower contact of the Brunswick can be either conformable and gradational to older rocks of the Newark Supergroup or unconformable on basement rocks. The thickness of the formation is estimated to be 3,420 ft (Drake and others, 1967). The mean strike of the Brunswick Formation determined from the acoustic-televiewer logs at the North Penn Area 5 Superfund Site is N. 62° E. (dip azimuth 332°), and the dip is 31° NW.

Lockatong Formation

The Lockatong Formation underlies the southeastern area of the site. It underlies and interfingers laterally with the Brunswick Formation. The lithology of the Lockatong Formation is fairly homogeneous and includes detrital and chemical-lacustrine sediments. The detrital rocks are dark gray to black, calcareous, pyritic siltstone and shale in the lower part overlain by dark gray, calcareous siltstone and fine-grained sandstone (Van Houten, 1962). The chemical-lacustrine rocks are dark gray to black, dolomitic siltstone and marlstone with lenses of pyritic limestone in the lower part, overlain by red or gray analcime- and carbonate-rich siltstone. These rocks are non-fissile and are very resistant to weathering. Willard and others (1959) refer to these rocks as argillite, a term meaning a tough, firmly cemented, non-fissile, argillaceous (composed of clay or clay-sized particles) rock. Dark red shale, siltstone, and marlstone interfinger with gray beds, especially in the upper and western parts, but differ from the gray beds mainly in color. Pyrite and calcite crystals up to 1/4-in. long are scattered throughout the beds. Rock containing sufficient calcite to be considered an argillaceous limestone occurs in beds up to a few feet thick (Willard and others, 1959). The rocks contain shrinkage cracks, mudcracks, ripple marks, root disruptions, and burrows. Bedding generally is even and commonly about 1 ft thick, although some beds may be massive. In some places, the contact between red and gray beds is sharp; in most others, there is a brownish- to purplish-gray transition rock, which is a few inches to a few feet thick. Where the contact is sharp, the gray commonly is suncracked, and the cracks are filled with red sediment (Willard and others, 1959). The maximum thickness of the formation is estimated to be 3,900 ft (Lyttle and Epstein, 1987). The mean strike of the Lockatong Formation determined from the acoustic-televiewer logs at the North Penn Area 5 Superfund Site is N. 67° E. (dip azimuth 337°), and the dip is 19° NW.

Hydrologic Setting

Ground water at the North Penn Area 5 Superfund Site originates from infiltration of local precipitation and discharges to streams and pumping wells. After infiltrating through soil and saprolite, ground water moves through vertical and horizontal fractures in the shale and siltstones. Primary porosity is very low or nonexistent. Permeability and storage are very low. Ground water in rocks of the Brunswick Formation and Lockatong Formation may be under confined, unconfined, or perched conditions. Ground water in the upper part of the aquifer generally is under unconfined (water-table) conditions; ground water in the deeper part of the aquifer may be confined or partially confined, resulting in local artesian conditions.

Shallow and deep ground-water-flow systems are present at the site. Ground-water levels fluctuate with pumping and seasonal variations in recharge. Water from the upper system drains locally to streams and also leaks downward to a deeper ground-water-flow system. Wells constructed as open-hole boreholes may penetrate both systems, and water levels measured in these wells represent composite heads. Where differences in potentiometric head are present, water in the borehole flows from zones of higher head to zones of lower head. Shallow ground water generally flows in a direction similar to the topographic gradient. The natural direction of flow can be altered by pumping. In the rocks of the Brunswick and Lockatong Formations, cones of depression caused by pumping tend to extend along strike or fracture orientation (Longwill and Wood, 1965).

The configuration of the water table commonly is similar to topography, and depth to water commonly is greater beneath ridge tops than hillsides or valleys. Available data indicate the depth to water in wells in the vicinity of the site ranges from above land surface (flowing) to 35 ft below land surface.

Previous Investigations

A study of ground water in the Brunswick Formation was conducted by Longwill and Wood (1965). Regional geologic mapping was compiled by Lyttle and Epstein (1987), Rima (1955), Williard and others (1959), and Longwill and Wood (1965). Newport (1971) provided well and ground-water-quality data and a description of the ground-water resources in Montgomery County, Pa., including the Lansdale area, which is approximately 1 mi west of the North Penn Area 5 Superfund Site. Longwill and Wood (1965) compiled a geologic map, which in the Lansdale area was based almost entirely on unpublished manuscripts by Dean B. McLaughlin. Lyttle and Epstein (1987) compiled a geologic map of the Newark 1° × 2° Quadrangle that updated and revised the geologic nomenclature for the area. Biesecker and others (1968) described the water resources of the Schuylkill River Basin, which drains part of the Lansdale area. Senior and Goode (1999) described the ground-water system and effect of pumping on ground-water flow in the Lansdale area.

Well-Numbering System

Well-identification numbers used in this report consist of a county-abbreviation prefix preceding a sequentially assigned well number. The prefix BK denotes a well in Bucks County; the prefix MG denotes a well in Montgomery County. Site-identification numbers have prefixes of RI, NP, RW, R&B,

and AV and are cross-referenced in table 1. Well locations are shown in figure 1. A record of wells is in table 1.

Acknowledgments

The authors gratefully acknowledge the individuals and companies that allowed access to their wells for geophysical logging and packer testing. Thanks to Kim Moyer, Kevin Grazul, Kylie McDaniel, Debra Town, Carrie Stevenson, and Rob Rosman of the USGS for their help. Thanks also to Tad Yancheski, Robin Spiller, and Dave Neideigh of TetraTech for their assistance.

Table 1. *Well depth, casing length, depth to water, and logs collected for boreholes logged by the U.S. Geological Survey at North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania*

[P, borehole television survey; C, caliper log; G, natural-gamma log; R, single-point-resistance log; F, fluid-resistivity log; T, fluid-temperature log; V, heatpulse-flowmeter measurement; S, acoustic-televiewer log]

U.S. Geological Survey borehole-identification number	Site identification number	Depth of well below land surface (feet)	Length of casing below land surface (feet)	Depth to water below land surface (feet)	Date water level measured	Geophysical logs collected
MG–1723	AV–1	153	10	13.02	8/6/98	P, C, G, R, F, T, V
BK–2938	RI–1	118	18	30.01	6/5/98	P, C, G, R, F, T, V, S
BK–2939	RI–2	155	29.5	11.53	6/29/98	P, C, G, R, F, T, V, S
MG–1694	RI–3	72	29	flowing	5/19/98	P, C, G, R, F, T, V, S
MG–1695	RI–4	209	22	10.15	6/15/98	P, C, G, R, F, T, V, S
MG–1696	RI–5	120	20	.7	6/30/98	P, C, G, R, F, T, V, S
MG–1697	RI–6	119	20	4.71	5/21/98	P, C, G, R, F, T, V, S
MG–1698	RI–7	140	20	19.77	6/30/98	P, C, G, R, F, T, V, S
MG–1699	RI–8	149	19	33.03	6/30/98	P, C, G, R, F, T, V, S
MG–1700	RI–9	149	19	4.10	5/21/98	P, C, G, R, F, T, V, S
BK–2936	RI–10	101	19	10.65	5/1/98	P, C, G, R, F, T, V, S
MG–1716	RI–11	152	30	34.65	5/21/98	P, C, G, R, F, T, V, S
MG–1717	RI–12	149	20	4.34	6/16/98	P, C, G, R, F, T, V, S
MG–1718	RI–13	147	20	5.55	6/16/98	P, C, G, R, F, T, V, S
MG–1719	RI–14	287	41	26.29	6/25/98	P, C, G, R, F, T, V, S
BK–2940	RI–15	149	19	31.77	6/29/98	P, C, G, R, F, T, V, S
BK–2941	RI–16	151	9	12.15	7/14/98	P, C, G, R, F, T, V, S
BK–2942	RI–17	259	18	13.32	6/11/98	P, C, G, R, F, T, V, S
MG–1720	RI–18	101	50	5.67	5/19/98	P, C, G, R, F, T, V, S
MG–1721	RI–19	81	20	5.06	6/30/98	P, C, G, R, F, T, V, S
MG–1722	RI–20	147	19	11.46	6/26/98	P, C, G, R, F, T, V, S
BK–2937	W. Br. Park	312	24	3.02	5/1/98	P, C, G, R, F, T, V, S
MG–186	R&B #1	286	44	11.61	6/11/98	P, C, G, R, F, T, V, S
MG–187	R&B #2	291	32	10.60	6/12/98	P, C, G, R, F, T, V, S
MG–188	R&B #3	300	38	8.9	6/15/98	P, C, G, R, F, T, V, S
MG–924	NP–21	253	51	2.02	6/25/98	P, C, G, R, F, T, V, S
MG–1153	RW–1	69.5	23	17.05	6/26/98	P, C, G, R, F, T, V, S
MG–1154	RW–2	149	75	12.24	6/26/98	P, C, G, R, F, T, V, S
MG–1155	RW–3	211	150	7.49	6/29/98	P, C, G, R, F, T, V, S
MG–1691	NP–12B	115	22	46.94	4/22/98	P, C, G, R, F, T, V, S
BK–1292	NP–75	67	20	17.27	4/22/98	P, C, G, R, F, T, V, S
MG–1693	NP–87	476	103	flowing	4/24/98	P, C, G, R, F, T, V, S

METHODS OF INVESTIGATION

Geophysical logs, borehole television surveys, heatpulse-flowmeter measurements, and acoustic-televiewer data were used in the investigation to characterize the geohydrologic framework of the North Penn Area 5 Superfund Site. Interpretive results from the geophysical logs and borehole television surveys were used to select borehole intervals to perform aquifer-isolation tests. Aquifer-isolation tests were done to determine hydraulic properties of discrete fractures in boreholes and to collect water-quality samples for VOC analyses to aid in characterizing the vertical distribution of VOC's.

Borehole Geophysical Logs

Geophysical logs provide information on the location of fractures (caliper logs and borehole television surveys), water-producing and water-receiving zones, intervals of vertical borehole flow (fluid-resistivity and fluid-temperature logs), quantification of borehole flow (heatpulse-flowmeter measurements), lithologic correlation (natural-gamma and single-point-resistance logs), and well construction (caliper and single-point-resistance logs) where unknown.

Caliper logs record the average borehole diameter, which may be related to fractures, lithology, or drilling methods. Caliper logs can be used to identify fractures and possible water-bearing openings and correct other geophysical logs for changes in borehole diameter. They also can be correlated with fluid-resistivity and fluid-temperature logs to identify fractures, water-producing zones, and water-receiving zones. The term fracture used in association with the caliper-log interpretations might identify a change in borehole diameter that may not necessarily indicate a bedding-plane separation, lithologic contact, or water-producing or water-receiving zones but may simply indicate an enlargement of the borehole.

The natural-gamma or gamma log measures the intensity of natural-gamma radiation (photons) emitted from all rocks. The most common emitters of gamma radiation are uranium-238, thorium-232, their daughter elements, and potassium-40. These radioactive elements are concentrated in clays by adsorption, precipitation, and ion exchange. Fine-grained sediments, such as shale or siltstone, usually emit more gamma radiation than sandstone, limestone, or dolomite. Geophysical logging with a gamma probe can be conducted in the fluid-filled, dry, cased, or uncased parts of a borehole. However, casing reduces the gamma response. The gamma log is used to correlate geologic units between wells (Keys, 1990).

The single-point-resistance log records the electrical resistance of a formation between the probe in a water-filled borehole below casing and an electrical ground at land surface. Generally, electrical resistance increases with formation grain size and decreases with borehole diameter, water-bearing fractures, and increasing dissolved-solids concentration of borehole water. The single-point-resistance log is used to correlate geology and lithology between wells and may help identify formation water-bearing zones (Keys, 1990).

Fluid resistivity is the inverse of fluid conductivity. The fluid-resistivity log measures the electrical resistivity of the water column in the well. The fluid-resistivity probe measures the resistivity of borehole water between electrodes in the probe. Fluid-resistivity logs reflect changes in the dissolved-solids concentration of water in the borehole. Fluid-resistivity logs are used to identify water-producing and water-receiving zones and to determine intervals of vertical borehole flow. Water-producing and water-receiving zones are usually identified by distinct changes in resistivity. Intervals of vertical borehole flow are usually identified by a low-resistivity gradient between a water-producing and a water-receiving zone.

Fluid-temperature logs provide a continuous record of the temperature of water in a borehole. Fluid-temperature logs are used to identify water-producing and water-receiving zones and to determine zones of vertical borehole flow. Intervals of vertical borehole flow are characterized by little or no temperature gradient (Williams and Conger, 1990).

Borehole Television Surveys

Borehole television surveys were conducted by lowering a waterproof camera down the borehole and recording the image on both VHS and 8-mm (millimeter) video tape. The depth indicated on the borehole television surveys may not correspond precisely to the geophysical logs because of minor slippage of the television cable.

Heatpulse Flowmeter

The direction and rate of borehole-water movement was determined by the use of a heatpulse flowmeter. The heatpulse flowmeter operates by heating a small sheet of water between two sensitive thermistors (heat sensors). A measurement of direction and rate is computed when a peak temperature is recorded by one of the thermistors. The range of flow measurement is about 0.01–1.5 gal/min in a 2- to 10-in. diameter borehole (Conger, 1996).

Some heatpulse-flowmeter measurements may be affected by (1) poor seal integrity between the borehole and heatpulse flowmeter and (2) contributions of water from storage within the borehole. If the seal between the borehole and flowmeter is not complete, some water can bypass the flowmeter, resulting in measurements of flow that are less than the actual rate. Although the heatpulse flowmeter is a calibrated probe, the data are used primarily as a relative indicator to identify water-bearing zones.

Acoustic Televiewer

The acoustic televiewer is a sonic imaging tool that scans the borehole wall with an acoustic beam. The reflected acoustic waves are recorded digitally on a portable computer, and images of the wave's transit time and amplitude are produced. The logs are corrected for magnetic orientation, magnetic declination (true north), and borehole deviation from vertical by the logging software. Fractures are detected by longer transit times and decreased signal amplitudes. Because the returned data is oriented to true north and corrected for borehole deviation from vertical, strike and dip for each fracture or bedding plane can be determined. The acoustic televiewer can be used in 6 to 9-in. boreholes. Because of magnetic interference, the acoustic televiewer cannot determine fracture orientation within 6 ft of the bottom of steel casing.

Aquifer-Isolation Tests

Aquifer-isolation tests, commonly called packer tests, were conducted in boreholes MG–1697, MG–1699, MG–1722, and BK–2942. Because ground water moves though discrete fractures or fracture zones, the hydraulic properties and water quality of individual fractures or fracture zones can differ. The properties of individual fractures and zones can be obtained by isolating them with a straddle-packer assembly. The straddle-packer assembly consists of two inflatable bladders (packers) separated by a length of perforated pipe in which a pump is set (fig. 2). The perforated pipe length is adjusted to cover the vertical length of the fracture or fracture zone to be tested. Installed transducers allow the water level below the bottom packer and above the upper packer to be recorded concurrently with the water level in the isolated fracture or fracture zone.

EVALUATION OF BOREHOLE GEOPHYSICAL LOGS

Borehole geophysical logs were run in 32 boreholes (table 1). The reference measuring point for all logs is land surface. Depth of wells, casing lengths, and water levels at the time of logging are given in feet below land surface (bls).

MG–1723 (AV–1)

The caliper log shows the total depth of the borehole is 153 ft and it is cased with 6-in.-diameter casing to 10 ft bls (fig. 1a, app.). The caliper log shows a major fracture at 49–51 ft bls. The static water level was 13.02 ft bls at the time of logging. The borehole television survey showed murky water, indicating no substantial vertical flow at the time the survey was made. The fluid-resistivity log shows changes in slope at 48, 66, and 92 ft bls that generally correlate to fractures shown on the caliper log. The fluid-temperature log shows changes in slope at 48 and 88 ft bls that correlate to water-bearing zones. Under nonpumping conditions, the heatpulse flowmeter measured downward flow at 56, 68, 94, 116, 137, and 144 ft bls (table 2). The geophysical logs and the heatpulse-flowmeter data

Table 2. *Summary of heatpulse-flowmeter measurements for borehole MG–1723 (AV–1) at the North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania*

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallon per minute)	Flow direction under nonpumping conditions
56	0.6	down
68	.8	down
94	.4	down
116	.3	down
137	.2	down
144	.2	down

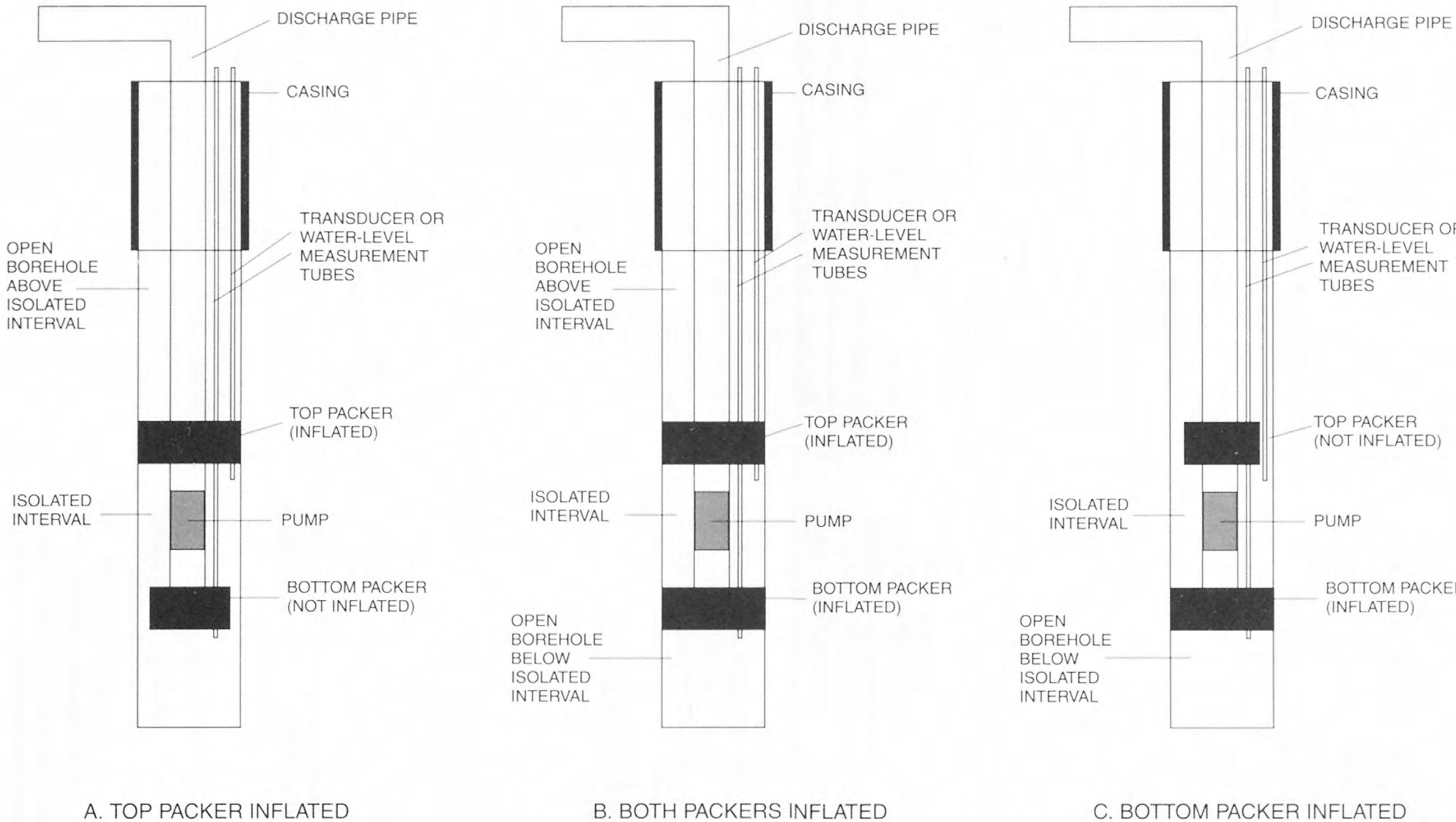


Figure 2. Generalized sketch of packer assembly and pump used in aquifer-isolation tests.

indicate water enters the borehole through fractures at 49–51 and 64 ft bls and moves downward. A minor quantity of the water exits the borehole through fractures at 106–107, 131–134, and 148 ft bls; most water exits the borehole through fractures at 72–92 ft bls. This borehole remains as an open borehole.

BK–2938 (RI–1)

The caliper log shows the total depth of the borehole is 118 ft and it is cased with 6-in.-diameter casing to about 18 ft bls (fig. 2a, app.). The static water level was 30.01 ft bls at the time of logging. The caliper log shows major fractures at 60–63 and 101–104 ft bls. The borehole television survey shows major high-angle fractures at 62 and 102 ft bls. The fluid-resistivity and fluid-temperature logs show a change in slope at 62 ft bls that correlates to a large fracture shown on the caliper and acoustic-televiewer logs. Under nonpumping conditions, the heatpulse flowmeter measured upward borehole flow at 44, 59, 70, 77, 88, and 98 ft bls and no flow at 110 ft bls (table 3). The geophysical logs and the heatpulse-flowmeter data indicate water enters the borehole through a high-angle fracture (dip of 71° NW. and strike of N. 3° E.) at 101–104 ft bls and moves upward. The largest quantity of water exits the borehole through a high-angle fracture (dip of 74° NE. and strike of N. 1° E.) at 60–63 ft bls; the remaining water exits the borehole at 32 ft bls. Screens were placed at 56–66 and 98–108 ft bls to include the water-bearing fractures at 60–63 and 101–104 ft bls (Robin Spiller, TetraTech NUS, written commun., 1999).

Table 3. *Summary of heatpulse-flowmeter measurements for borehole BK–2938 (RI–1) at the North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania*

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallons per minute)	Flow direction under nonpumping conditions
44	0.1	up
59	.1	up
70	1.2	up
77	1.0	up
88	1.1	up
98	.9	up
110	no flow	no flow

BK–2939 (RI–2)

The caliper log shows the total depth of the borehole is 155 ft and it is cased with 6-in.-diameter casing to 29.5 ft bls (fig. 3a, app.). The static water level was 11.53 ft bls at the time of logging. The caliper log shows numerous fractures throughout the open-hole interval. The borehole television survey shows major high-angle fractures at 44, 134, and 142 ft bls. Turbulence was seen on the borehole television survey at 44, 134, and 142 ft bls, indicating possible water-bearing zones. The fluid-resistivity and fluid-temperature logs show a change in slope at 134 ft bls that correlates to a fracture shown on the caliper log. The natural-gamma log shows a shale unit with elevated gamma counts at 61–65 ft bls. Under nonpumping conditions, the heatpulse flowmeter measured upward borehole flow at 35, 41, 49, 56, 70, 83, 105, 130, and 138 ft bls and no flow at 144 ft bls (table 4). The geophysical logs and the borehole television survey indicate water enters the borehole through high-angle fractures at 134 ft bls (dip of 60° SE. and strike of N. 78° E.) and 142 ft bls (dip of 61° SW. and strike of N. 87° W.), moves upward, and exits the borehole through fractures at 32 and 43 ft bls (dip of 73° SE. and strike of N. 79° E.). Screens were placed at 38–48 and 129–139 ft bls to include water-bearing fractures at 43–45 and 133–136 ft bls (Robin Spiller, TetraTech NUS, written commun., 1999).

Table 4. *Summary of heatpulse-flowmeter measurements for borehole BK–2939 (RI–2) at the North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania*

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallons per minute)	Flow direction under nonpumping conditions
35	0.3	up
41	.3	up
49	1.2	up
56	1.2	up
70	1.2	up
83	1.2	up
105	1.2	up
130	1.2	up
138	.5	up
144	no flow	no flow

MG–1694 (RI–3)

The caliper log shows the total depth of the borehole is 72 ft and it is cased with 6-in.-diameter casing to 29 ft bls (fig. 4a, app.). The well was flowing approximately 1.0 gal/min at the time of logging. The caliper log shows a major fracture at 64 ft bls. The borehole television survey shows major high-angle fractures at 41 and 64 ft bls; turbulence is visible in the borehole fluid at both fractures, indicating possible water-bearing zones. The fluid-resistivity log shows changes in slope at 32 and 67 ft bls; the deeper change in slope correlates to a major fracture shown on the caliper log. Under nonpumping conditions, the heatpulse flowmeter measured upward borehole flow at 20, 32, 40, 44, and 57 ft bls and no flow at 71 ft bls (table 5). The geophysical logs and the heatpulse-flowmeter data indicate water enters the borehole through a high-angle fracture at 64 ft bls (dip of 77° NE. and strike of N. 72° W.), moves upward, and discharges out of the top of casing. Screens were placed at 27–47 and 60–70 ft bls to include water-bearing fractures at 29–44 and 64–66 ft bls (Robin Spiller, TetraTech NUS, written commun., 1999).

Table 5. *Summary of heatpulse-flowmeter measurements for borehole MG–1694 (RI–3) at the North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania*

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallons per minute)	Flow direction under nonpumping conditions
20	1.1	up
32	1.2	up
40	1.2	up
44	1.2	up
57	1.2	up
71	no flow	no flow

MG–1695 (RI–4)

The caliper log shows the total depth of the borehole is 209 ft and it is cased with 6-in.-diameter casing to 22 ft bls (fig. 5a, app.). The static water level was 10.15 ft bls at the time of logging. The caliper log shows major fractures at 24, 51–54, 70, 90, 140, and 208 ft bls. The natural-gamma log shows shale units with elevated gamma readings at 28–31 and 56.5–61 ft bls that correlate with other borehole logs from wells in the immediate area. The borehole television survey shows major high-angle fractures at 24, 51, 133, and 177 ft bls. The fluid-resistivity log shows changes in slope at 54 and 104 ft bls that correlate to a major and a minor fracture shown on the caliper log. Under nonpumping conditions, the heatpulse flowmeter measured downward borehole flow at 35, 63, 84, 110, 125, and 160 ft bls (table 6). The geophysical logs and the heatpulse-flowmeter data indicate water enters the borehole through fractures at 24 and 50–54 ft bls (dip of 76° SE. and strike of N. 77° E.) and moves downward. The largest quantity of water exits the borehole through a high-angle fracture at 144 ft bls (dip of 80° SW. and strike of N. 17° W.); a minor quantity exits through a fracture at 202 ft bls. A screen was placed at 20–40 and 126–146 ft bls to include water-bearing fractures at 24 and 138–142 ft bls (Robin Spiller, TetraTech NUS, written commun., 1999).

Table 6. *Summary of heatpulse-flowmeter measurements for borehole MG–1695 (RI–4) at the North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania*

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallon per minute)	Flow direction under nonpumping conditions
35	0.6	down
63	1.0	down
84	.9	down
110	.9	down
125	1.0	down
160	.1	down

MG–1696 (RI–5)

The caliper log shows the total depth of the borehole is 120 ft and it is cased with 6-in.-diameter casing to 20 ft bls (fig. 6a, app.). The static water level was 0.7 ft bls at the time of logging. The caliper log shows major fractures at 20, 24–26, and 49–50 ft bls. The borehole television survey shows major high-angle fractures at 21, 25, 37, and 50 ft bls. Turbulence was visible in the borehole fluid at the fracture at 37 ft bls, indicating a water-bearing zone, and some haze in the borehole fluid above 25 ft bls, possibly indicating no vertical flow in this zone. The fluid-temperature and fluid-resistivity logs show changes in slope at 37 and 50 ft bls that correlate to a major fracture shown on the caliper log. Under nonpumping conditions, the heatpulse flowmeter measured upward borehole flow at 34, 44, 60, 84, and 104 ft bls and no flow at 112 ft bls (table 7). The geophysical logs and the heatpulse-flowmeter data indicate water enters the borehole through fractures at 104, 50 (dip of 83° SE. and strike of N. 45° E.), and 37 ft bls (dip of 80° SE. and strike of N. 41° E.), moves upward, and exits the borehole through the fracture at 25 ft bls. Screens were placed at 20–30 and 45–55 ft bls to include water-bearing fractures at 21 and 48–52 ft bls (Robin Spiller, TetraTech NUS, written commun., 1999).

Table 7. *Summary of heatpulse-flowmeter measurements for borehole MG–1696 (RI–5) at the North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania*

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallon per minute)	Flow direction under nonpumping conditions
34	1.0	up
44	.4	up
60	.1	up
84	.1	up
104	.2	up
112	no flow	no flow

MG–1697 (RI–6)

The caliper log shows the total depth of the borehole is 119 ft and it is cased with 6-in.-diameter casing to 20 ft bls (fig. 7a, app.). The static water level was 4.71 ft bls at the time of logging. The caliper log shows a major fracture zone at 20–23 ft bls. The borehole television survey shows a fracture zone from 20 to 23.5 ft bls and visibility decreasing below 84 ft bls to near-zero at 110 ft bls, indicating no vertical flow in this zone. The fluid-temperature log shows a change in slope at 21 ft bls that correlates to the major fractures shown on the caliper log. Under nonpumping conditions, the heatpulse flowmeter measured downward borehole flow at 32, 47, and 65 ft bls and no flow at 86 and 103 ft bls (table 8). The geophysical logs and the heatpulse-flowmeter data indicate water enters the borehole through fractures at 21 and 50–60 ft bls (dip of 76° NE. and strike of N. 36° W.), moves downward, and exits the borehole through a high-angle fracture at 84 ft bls (dip of 56° SE. and strike of N. 54° E.). Screens were placed at 13–28 and 64–84 ft bls to include water-bearing fractures at 21 and 70–84 ft bls (Robin Spiller, TetraTech NUS, written commun., 1999).

Table 8. *Summary of heatpulse-flowmeter measurements for borehole MG–1697 (RI–6) at the North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania*

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallon per minute)	Flow direction under nonpumping conditions
32	0.2	down
47	.2	down
65	.3	down
86	no flow	no flow
103	no flow	no flow

MG–1698 (RI–7)

The caliper log shows the total depth of the borehole is 140 ft and it is cased with 6-in.-diameter casing to 20 ft bls (fig. 8a, app.). The static water level was 19.77 ft bls at the time of logging. The caliper log shows major fractures at 21, 89, and 93 ft bls. The borehole television survey shows major high-angle fractures at 85, 88, and 91 ft bls. The fluid-resistivity log shows changes in slope at 40 and 60 ft bls that correlate to fractures shown on the caliper log. The fluid-temperature log shows changes in slope at 42 and 124 ft bls that correlate to fractures shown on the caliper log. Under nonpumping conditions, the heatpulse flowmeter measured downward borehole flow at 44, 54, 70, 78, 90, and 110 ft bls and no flow at 30 and 130 ft bls (table 9). Low-visibility conditions were observed during the borehole television survey above 58 ft bls and below 124 ft bls, indicating little vertical flow in these zones. The geophysical logs and the heatpulse-flowmeter data indicate water enters the borehole through a high-angle fracture at 40 ft bls (dip of 75° SE. and strike of N. 58° E.) and a bedding-plane parting at 60 ft bls (dip of 21° NW. and strike of N. 63° E.), moves downward, and exits the borehole through fractures at 89, 93, and 124 ft bls (dip of 64° NW. and strike of N. 32° E.). Screens were placed at 56–66 and 86–96 ft bls to include water-bearing fractures at 60, 89, and 93 ft bls (Robin Spiller, TetraTech NUS, written commun., 1999).

Table 9. *Summary of heatpulse-flowmeter measurements for borehole MG–1698 (RI–7) at the North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania*

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallons per minute)	Flow direction under nonpumping conditions
30	no flow	no flow
44	0.5	down
54	.5	down
70	1.4	down
78	1.4	down
90	.9	down
110	.5	down
130	no flow	no flow

MG–1699 (RI–8)

The caliper log shows the total depth of the borehole is 149 ft and it is cased with 6-in.-diameter casing to 19 ft bls (fig. 9a, app.). The static water level was 33.03 ft bls at the time of logging. The caliper log shows major fractures at 20 and 120 ft bls. The borehole television survey shows a low-angle fracture at 20 ft bls and high-angle fractures at 83 and 119 ft bls. The fluid-resistivity and fluid-temperature logs show changes in slope at 46 and 86 ft bls that may be caused by lateral borehole flow. Under nonpumping conditions, the heatpulse flowmeter measured downward borehole flow at 133 ft bls and no flow at 42, 66, and 96 ft bls (table 10). Visibility on the borehole television survey improved below 83 ft bls, possibly indicating some borehole flow at the time the survey was run. The geophysical logs and the heatpulse-flowmeter data indicate water enters the borehole through a high-angle fracture at 120 ft bls (dip of 77° SE. and strike of N. 54° E.), moves downward, and exits the borehole through a fracture near 142 ft bls (dip of 30° NE. and strike of N. 83° W.). Screens were placed at 80–90 and 115–125 ft bls to include a possible water-bearing fracture at 83 ft bls and a water-bearing fracture at 120 ft bls (Robin Spiller, TetraTech NUS, written commun., 1999).

Table 10. *Summary of heatpulse-flowmeter measurements for borehole MG–1699 (RI–8) at the North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania*

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallon per minute)	Flow direction under nonpumping conditions
42	no flow	no flow
66	no flow	no flow
96	no flow	no flow
133	0.2	down

MG–1700 (RI–9)

The caliper log shows the total depth of the borehole is 149 ft and it is cased with 6-in.-diameter casing to 19 ft bls (fig. 10a, app.). The static water level was 4.10 ft bls at the time of logging. The caliper log shows a major fracture at 19.5 ft bls. The borehole television survey shows a major fracture at 20 ft bls. The fluid-resistivity log shows a change in slope at 120 ft bls that correlates to a fracture on the caliper log and is an apparent water-bearing zone. Under nonpumping conditions, the heatpulse flowmeter measured upward borehole flow at 26, 50, 87, 110, and 124 ft bls and no flow at 139 ft bls (table 11). The geophysical logs and the heatpulse-flowmeter data indicate water enters the borehole through high-angle fractures at 131 ft bls (dip of 82° SE. and strike of N. 49° E.), 120 ft bls (dip of 79° SE. and strike of N. 54° E.), and 92 ft bls (dip of 61° NE. and strike of N. 22° W.), and a bedding-plane parting at 53 ft bls (dip of 25° NW. and strike of N. 64° E.); moves upward; and exits the borehole through fractures at 30 ft bls (dip of 29° NW. and strike of N. 78° E.) and 19.5 ft bls. Screens were placed at 18–48 and 126–136 ft bls to include water-bearing fractures at 30 and 131 ft bls (Robin Spiller, TetraTech NUS, written commun., 1999).

Table 11. *Summary of heatpulse-flowmeter measurements for borehole MG–1700 (RI–9) at the North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania*

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallons per minute)	Flow direction under nonpumping conditions
26	0.7	up
50	1.2	up
87	1.0	up
110	.8	up
124	.6	up
139	no flow	no flow

BK–2936 (RI–10)

The caliper log shows the total depth of the borehole is 101 ft and it is cased with 10-in.-diameter casing to 19 ft bls (fig. 11a, app.). The static water level was 10.65 ft bls at the time of logging. The caliper log shows major fractures at 19.5–23 and 51 ft bls. The borehole television survey shows major fractures at 21 and 51 ft bls and low-visibility conditions above 20 ft bls and below 51 ft bls, possibly indicating vertical flow between 20 and 51 ft bls. The fluid-resistivity log shows changes in slope at 60 and 80 ft bls that correlate to fractures on the caliper log and are water-bearing zones. Under nonpumping conditions, the heatpulse flowmeter measured upward borehole flow at 30, 43, 64, and 90 ft bls (table 12). The geophysical logs and the heatpulse-flowmeter data indicate water enters the borehole through fractures below 90 and at 51 and 60 ft bls, moves upward, and exits the borehole through fractures at 80 and 19.5 ft bls. Screens were placed at 18–28 and 46–61 ft bls to include water-bearing fractures at 21 and 51 ft bls (Robin Spiller, TetraTech NUS, written commun., 1999).

Table 12. *Summary of heatpulse-flowmeter measurements for borehole BK–2936 (RI–10) at the North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania*

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallon per minute)	Flow direction under nonpumping conditions
30	0.2	up
43	.2	up
64	.1	up
90	.1	up

MG–1716 (RI–11)

The caliper log shows the total depth of the borehole is 152 ft and it is cased with 6-in.-diameter casing to 30 ft bls (fig. 12a, app.). The static water level was 34.65 ft bls at the time of logging. The caliper log shows a major fracture zone at 82–84.5 ft bls. The borehole television survey shows major high-angle fractures at 67, 69, 82, 93, 100, 110, 117, 120, and 145 ft bls. The fluid-resistivity and fluid-temperature logs show changes in slope at 46, 67, and 84 ft bls. Under nonpumping conditions, the heatpulse flowmeter measured downward borehole flow at 90, 105, 114, and 132 ft bls and no flow at 54 and 74 ft bls (table 13). The geophysical logs and the heatpulse-flowmeter data indicate water enters the borehole through high-angle fractures at 82–84.5 ft bls (dip of 77° NE. and strike of N. 18° W.) and 93–103 ft bls (dip of 79° SE. and strike of N. 20° E.), moves downward, and exits the borehole through fractures at 112 ft bls (dip of 63° SE. and strike of N. 15° E.) and 144–147 ft bls (dip of 78° NE. and strike of N. 18° W.). Screens were placed at 80–105 and 138–148 ft bls to include water-bearing fractures at 82–85 and 144–147 ft bls (Robin Spiller, TetraTech NUS, written commun., 1999).

Table 13. *Summary of heatpulse-flowmeter measurements for borehole MG–1716 (RI–11) at the North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania*

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallon per minute)	Flow direction under nonpumping conditions
54	no flow	no flow
74	no flow	no flow
90	0.2	down
105	1.0	down
114	.4	down
132	.4	down

MG–1717 (RI–12)

The caliper log shows the total depth of the borehole is 149 ft and it is cased with 6-in.-diameter casing to 20 ft bls (fig. 13a, app.). The static water level was 4.34 ft bls at the time of logging. The caliper log shows major fractures at 20–24, 67–69, 80–85, and 115–118 ft bls. The borehole television survey shows high-angle fractures at 21, 68, and 80 ft bls and water visibly entering the borehole at 68 ft bls, indicating a water-bearing zone. The fluid-temperature log shows a change in slope at about 69 ft bls that correlates to a major fracture shown on the caliper log. Under nonpumping conditions, the heatpulse flowmeter measured downward borehole flow at 28, 40, 64, 75, 98, and 120 ft bls and no flow at 140 ft bls (table 14). The geophysical logs and the heatpulse-flowmeter data indicate water enters the borehole through the fracture at 21 ft bls, moves downward, and exits the borehole through high-angle fractures at 83 and 133 ft bls (dip of 82° SE. and strike of N. 69° E.). Screens were placed at 20–30 and 120–140 ft bls to include water-bearing fractures at 21 and 133 ft bls (Robin Spiller, TetraTech NUS, written commun., 1999).

Table 14. *Summary of heatpulse-flowmeter measurements for borehole MG–1717 (RI–12) at the North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania*

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallons per minute)	Flow direction under nonpumping conditions
28	1.5	down
40	1.5	down
64	1.5	down
75	1.5	down
98	1.4	down
120	1.4	down
140	no flow	no flow

MG–1718 (RI–13)

The caliper log shows the total depth of the borehole is 147 ft and it is cased with 6-in. diameter casing to 20 ft bls (fig. 14a, app.). The static water level was 5.55 ft bls at the time of logging. The caliper log shows major fractures at 34–35 and 119–121 ft bls. The borehole television survey shows a major high-angle fracture at 34 ft bls and a major fracture at 119 ft bls. The fluid-temperature log shows changes in slope at 34 and 121 ft bls that correlate to fractures shown on the caliper log and are water-bearing zones. Under nonpumping conditions, the heatpulse flowmeter measured downward borehole flow at 23, 30, 38, 50, and 81 ft bls and upward flow at 126 ft bls (table 15). The geophysical logs and the heatpulse-flowmeter data indicate water enters the borehole through high-angle fractures at 25 ft bls (dip of 59° SW. and strike of N. 89° W.) and 34–35 ft bls (dip of 76° SE. and strike of N. 57° E.), moves downward, and exits the borehole through high-angle fractures at 43 ft bls (dip of 81° SE. and strike of N. 33° E.), 60 ft bls (dip of 69° NW. and strike of N. 11° E.), and 123 ft bls (dip of 86° SE. and strike of N. 64° E.). Some water also enters the borehole below 126 ft bls, moves upward, and exits the borehole through the fracture at 120 ft bls. Screens were placed at 40–50 and 115–125 ft bls to include water-bearing fractures at 40–45 and 119–121 ft bls (Robin Spiller, TetraTech NUS, written commun., 1999).

Table 15. *Summary of heatpulse-flowmeter measurements for borehole MG–1718 (RI–13) at the North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania*

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallon per minute)	Flow direction under nonpumping conditions
23	0.1	down
30	.4	down
38	1.0	down
50	.4	down
81	.2	down
126	.1	up

MG–1719 (RI–14)

The caliper log shows the total depth of the borehole is 287 ft, the borehole diameter is 6 in., and it is cased with 4-in.-diameter casing to 41 ft bls (fig. 15a, app.). The static water level was 26.29 ft bls at the time of logging. The caliper log shows major fractures at 50–55 and 275–277 ft bls. The borehole television survey shows high-angle fractures at 50, 133, and 155 ft bls. The fluid-temperature log shows changes in slope at 52 and 133 ft bls that correlate to fractures shown on the caliper log and are apparent water-bearing zones. The fluid-resistivity log shows changes in slope at 52, 90, 110, 124, 133, 157, 231, and 275 ft bls. The natural-gamma log shows shale units with elevated gamma counts at 196–204 and 234–241 ft bls. Under nonpumping conditions, the heatpulse flowmeter measured downward borehole flow at 61, 72, 130, 142, 160, 165, 168, 180, 190, 200, 216, and 264 ft bls (table 16). Visibility decreased below 155 ft bls, indicating no significant vertical flow in this zone. The geophysical logs and the heatpulse-flowmeter data indicate water enters the borehole through high-angle fractures at 50–55 ft bls (dip of 80° SW. and strike of N. 79° W.), 134 ft bls (dip of 80° SW. and strike of N. 52° W.), and 156 ft bls (dip of 67° SE. and strike of N. 22° E.). Water exits the borehole through high-angle fractures at 95 ft bls (dip of 81° SW. and strike of N. 60° W.), 110 ft bls (dip of 70° SE. and

Table 16. *Summary of heatpulse-flowmeter measurements for borehole MG–1719 (RI–14) at the North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania*

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallons per minute)	Flow direction under nonpumping conditions
61	0.4	down
72	.3	down
130	.1	down
142	.6	down
160	1.0	down
165	1.2	down
168	.3	down
180	.3	down
190	.2	down
200	.1	down
216	.2	down
264	.1	down

strike of N. 42° E.), and 275–277 ft bls (dip of 84° NE. and strike of N. 53° W.) and bedding-plane partings at 66 ft bls (dip of 36° NW. and strike of N. 73° E.) and 165 ft bls (dip of 30° NW. and strike of N. 60° E.). Fluid movement is downward throughout the well. Screens were placed at 48–58 and 125.5–135.5 ft bls to include water-bearing fractures at 50–55 and 132 ft bls (Robin Spiller, TetraTech NUS, written commun., 1999).

BK–2940 (RI–15)

The caliper log shows the total depth of the borehole is 149 ft and it is cased with 6-in.-diameter casing to 19 ft bls (fig. 16a, app.). The static water level was 31.77 ft bls at the time of logging. The caliper log shows major fractures at 20, 48, 76, 102, 112, and 148 ft bls. The borehole television survey shows rough zones with numerous small fractures at 40–50, 57, 74–77, 102, 110, 126, 134, and 142–146 ft bls. The fluid-resistivity and fluid-temperature logs show minor changes in slope at 46 ft bls that correlate to fractures shown on the caliper log and are water-bearing zones. Under nonpumping conditions, the heatpulse flowmeter measured downward borehole flow at 52, 64, 92, 119, and 140 ft bls and no flow at 36 ft bls (table 17). The geophysical logs and the heatpulse-flowmeter data indicate water enters the borehole through fractures at 48 and 58 ft bls (dip of 49° SW. and strike of N. 17° W.), moves downward, and exits the borehole through fractures at 120 ft bls (dip of 67° NW. and strike of N. 86° E.) and 142–148 ft bls. Screens were placed at 55–65 and 120–145 ft bls to include water-bearing fractures at 58 and 125–143 ft bls (Robin Spiller, TetraTech NUS, written commun., 1999).

Table 17. *Summary of heatpulse-flowmeter measurements for borehole BK–2940 (RI–15) at the North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania*

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallon per minute)	Flow direction under nonpumping conditions
36	no flow	no flow
52	0.1	down
64	.9	down
92	1.0	down
119	.9	down
140	.4	down

BK–2941 (RI–16)

The caliper log shows the total depth of the borehole is 151 ft and it is cased with 10-in.-diameter casing to 9 ft bls (fig. 17a, app.). The static water level was 12.15 ft bls at the time of logging. The caliper log shows major fractures at 20–21 and 33 ft bls. The borehole television survey shows low-visibility conditions throughout the borehole, but slightly higher visibility conditions between 35 and 66 ft bls, possibly indicating slight vertical flow in this interval. The fluid-resistivity and fluid-temperature logs show minor changes in slope only. The natural-gamma log shows shale units with elevated gamma counts at 32–35, 55–63, and 91–93 ft bls. Under nonpumping conditions, the heatpulse flowmeter measured upward borehole flow at 62, 100, 120, and 140 ft bls (table 18). The geophysical logs and the heatpulse-flowmeter data indicate water enters the borehole through fractures at 144–150 ft bls, moves upward, and exits the borehole through fractures at approximately 20–35 and 70 ft bls. Screens were placed at 13–38 and 64–79 ft bls to include water-bearing fractures at 20–35 and 70 ft bls (Robin Spiller, TetraTech NUS, written commun., 1999).

Table 18. *Summary of heatpulse-flowmeter measurements for borehole BK–2941 (RI–16) at the North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania*

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallon per minute)	Flow direction under nonpumping conditions
62	0.1	up
100	.2	up
120	.2	up
140	.2	up

BK–2942 (RI–17)

The caliper log shows the total depth of the borehole is 259 ft and it is cased with 6-in.-diameter casing to 18 ft bls (fig. 18a, app.). The static water level was 13.32 ft bls at the time of logging. The caliper log shows major fractures at 19.5, 47–58, and 230 ft bls. The borehole television survey shows major high-angle fractures at 52, 121, 185, and 227 ft bls. The borehole television survey also shows turbulence in the borehole fluid at 121, 185, and 227 ft bls, indicating possible water-bearing zones. The borehole fluid was slightly cloudy above 52 ft bls, indicating little vertical flow in this zone. The fluid-resistivity and fluid-temperature logs show changes in slope at 25, 45, 186, and 193 ft bls. Under nonpumping conditions, the heatpulse flowmeter measured upward borehole flow at 40, 83, 140, 176, 188, and 216 ft bls and no flow at 244 ft bls (table 19). The geophysical logs and the heatpulse-flowmeter data indicate water enters the borehole through fractures at 230 ft bls (dip of 65° SE. and strike of N. 13° E.), 193 ft bls (dip of 47° NW. and strike of N. 64° E.), 186 ft bls (dip of 55° SE. and strike of N. 79° E.), and 123 ft bls (dip of 62° SE. and strike of N. 56° E.) and moves upward. Most water exits the borehole through fractures from 47–58 ft bls; about 0.1 gal/min exits the borehole through fractures from 19.5–36 ft bls. Screens were placed at 43–63 and 180–190 ft bls to include water-bearing fractures at 47–58 and 186 ft bls (Robin Spiller, TetraTech NUS, written commun., 1999).

Table 19. *Summary of heatpulse-flowmeter measurements for borehole BK–2942 (RI–17) at the North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania*

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallons per minute)	Flow direction under nonpumping conditions
40	0.1	up
83	1.1	up
140	1.1	up
176	1.1	up
188	.5	up
216	.3	up
244	no flow	no flow

MG–1720 (RI–18)

The caliper log shows the total depth of the borehole is 101 ft and it is cased with 10-in.-diameter casing to 50 ft bls (fig. 19a, app.). The static water level was 5.67 ft bls at the time of logging. The caliper log shows a major fracture at 50–55 ft bls. The borehole television survey shows major high-angle fractures at 58 and 71 ft bls and a major fracture at 51 ft bls. The fluid-resistivity and fluid-temperature logs show a change in slope at 55 ft bls. Under nonpumping conditions, the heatpulse flowmeter measured downward borehole flow at 64, 78, and 86 ft bls, upward flow at 40 ft bls, and no flow at 20 and 94 ft bls (table 20). The geophysical logs and the heatpulse-flowmeter data indicate water enters the borehole through fractures at 50–55 ft bls and moves both upward and downward. Water moving downward exits the borehole through fractures below 85 ft bls. Water moving upward exits through an incomplete casing joint weld at 30 ft bls. Screens were placed at 44–64 and 85–95 ft bls to include water-bearing fractures at 50–55 and 90 ft bls (Robin Spiller, TetraTech NUS, written commun., 1999).

Table 20. *Summary of heatpulse-flowmeter measurements for borehole MG–1720 (RI–18) at the North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania*

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallon per minute)	Flow direction under nonpumping conditions
20	no flow	no flow
40	0.2	up
64	.4	down
78	.4	down
86	.3	down
94	no flow	no flow

MG–1721 (RI–19)

The caliper log shows the total depth of the borehole is 81 ft and it is cased with 6-in.-diameter casing to 20 ft bls (fig. 20a, app.). The static water level was 5.06 ft bls at the time of logging. The caliper log shows the borehole is highly fractured. The fluid-resistivity and fluid-temperature logs show changes in slope at 40 and 54 ft bls. Under nonpumping conditions, the heatpulse flowmeter measured downward borehole flow at 48 and 60 ft bls and no flow at 24 and 36 ft bls (table 21). The borehole television survey shows major high-angle fractures at 65, 68, 78, and 81 ft bls. The geophysical logs and the heatpulse-flowmeter data indicate water enters the borehole through fractures from 38–46 ft bls and at 54 ft bls (dip of 80° SE. and strike of N. 85° E.), moves downward, and exits the borehole through fractures below 70 ft bls. Screens were placed at 46–56 and 70–80 ft bls to include water-bearing fractures at 54 and 70–80 ft bls (Robin Spiller, TetraTech NUS, written commun., 1999).

Table 21. *Summary of heatpulse-flowmeter measurements for borehole MG–1721 (RI–19) at the North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania*

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallon per minute)	Flow direction under nonpumping conditions
24	no flow	no flow
36	no flow	no flow
48	0.2	down
60	.8	down

MG–1722 (RI–20)

The caliper log shows the total depth of the borehole is 147 ft and it is cased with 6-in.-diameter casing to 19 ft bls (fig. 21a, app.). The static water level was 11.46 ft bls at the time of logging. The caliper log shows major fractures at 19–21 and 75 ft bls. The fluid-resistivity log shows a change in slope at 105 ft bls that correlates to a fracture zone shown on the caliper log. The borehole television survey shows major low-angle fractures at 20 and 75 ft bls and major high-angle fractures at 32 and 105 ft bls. Water was visible entering into the borehole at 105 ft bls, indicating a water-bearing zone. Visibility decreased below 107 ft bls, indicating little vertical flow in this interval. Under nonpumping conditions, the heatpulse flowmeter measured upward borehole flow at 28, 38, 50, 70, and 90 ft bls and no flow at 130 ft bls (table 22). The geophysical logs, borehole television survey, and the heatpulse-flowmeter data indicate water enters the borehole through a high-angle fracture at 107 ft bls (dip of 85° SW. and strike of N. 36° W.), moves upward, and exits the borehole through fractures between 20 and 50 ft bls and at 75 ft bls (dip of 17° NW. and strike of N. 82° E.). Screens were placed at 70–80 and 100–110 ft bls to include water-bearing fractures at 75 and 105 ft bls (Robin Spiller, TetraTech NUS, written commun., 1999).

Table 22. *Summary of heatpulse-flowmeter measurements for borehole MG–1722 (RI–20) at the North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania*

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallon per minute)	Flow direction under nonpumping conditions
28	0.4	up
38	.6	up
50	.9	up
70	.9	up
90	[1]1.0	up
130	no flow	no flow

[1] Estimated because of turbulence.

MG–1153 (RW–1)

The caliper log shows the total depth of the borehole is 69.5 ft and it is cased with 6-in.-diameter casing to 23 ft bls (fig. 22a, app.). The static water level was 17.05 ft bls at the time of logging. The caliper log shows major fractures at 34, 36–40, and 58–61 ft bls. The fluid-resistivity and fluid-temperature logs show changes in slope at 33–27 and 63 ft bls that correlate to water-bearing fractures shown on the caliper log. Under nonpumping conditions, the heatpulse flowmeter measured downward borehole flow at 49 ft bls, upward flow at 56 and 63 ft bls, and no flow at 32 ft bls (table 23). The borehole television survey shows major high-angle fractures at 33 and 58 ft bls. The geophysical logs and the heatpulse-flowmeter data indicate water enters the borehole through a high-angle fracture at 37 ft bls (dip of 84° NW. and strike of N. 73° E.), a high-angle fracture at 64 ft bls (dip of 87° SE. and strike of N. 82° E.), and at 61 ft bls and exits the borehole through fractures at 51 ft bls. This well remains an open borehole.

Table 23. *Summary of heatpulse-flowmeter measurements for borehole MG–1153 (RW–1) at the North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania*

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallon per minute)	Flow direction under nonpumping conditions
32	no flow	no flow
49	0.2	down
56	.1	up
63	.1	up

MG–1154 (RW–2)

The caliper log shows the total depth of the borehole is 149 ft and it is cased with 6-in.-diameter casing to 75 ft bls (fig. 23a, app.). The static water level was 12.24 ft bls at the time of logging. The caliper log shows minor fractures throughout the open-hole interval. The borehole television survey shows high-angle fractures at 87, 106, 116, and 135–138 ft bls. The fluid-resistivity and fluid-temperature logs do not indicate any major water-bearing zones. Under nonpumping conditions, the heatpulse flowmeter measured upward borehole flow at 125 ft bls and no flow at 87 and 110 ft bls (table 24). The geophysical logs and the heatpulse-flowmeter data indicate water enters the borehole through a bedding-plane parting at 132–134 ft bls (dip of 27° NW. and strike of N. 26° E.), moves upward, and exits the borehole through fractures below 110 ft bls. This well remains an open borehole.

Table 24. *Summary of heatpulse-flowmeter measurements for borehole MG–1154 (RW–2) at the North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania*

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallon per minute)	Flow direction under nonpumping conditions
87	no flow	no flow
110	no flow	no flow
125	0.1	up

MG–1155 (RW–3)

The caliper log shows the total depth of the borehole is 211 ft and it is cased with 6-in.-diameter casing to 150 ft bls (fig. 24a, app.). The static water level was 7.49 ft bls at the time of logging. The caliper log shows minor fractures throughout the open-hole interval. The borehole television survey shows a major high-angle fracture at 208 ft bls. The fluid-resistivity and fluid-temperature logs show no sudden changes in slope. Under nonpumping conditions, the heatpulse flowmeter measured borehole flow at 80, 140, 160, 180, 190, and 201 ft bls (table 25). All heatpulse-flowmeter measurements were highly variable, and some measurements showed flow periodically reversing direction, even within the casing at 80 and 140 ft bls. A pressure transducer in this well showed a strong influence from pumping in AEL production well No. 1 (MG–876). The geophysical logs and heatpulse-flowmeter data indicate water enters the borehole through a fracture at 164 ft bls (dip of 79° SW. and strike of N. 59° W.), moves downward, and exits the borehole through a fracture at 208 ft bls (dip of 72° SE. and strike of N. 44° E.). Water moves upward when the pump in AEL production well No. 1 (MG–876) shuts off. This well remains an open borehole.

Table 25. *Summary of heatpulse-flowmeter measurements for borehole MG–1155 (RW–3) at the North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania*

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallons per minute)	Flow direction under nonpumping conditions
80	0.6–1.5	up and down
140	.8–1.5	up and down
160	.4	up
180	1.1	down
190	1.4	down
201	.6–1.5	down

BK–2937 (West Branch Park)

The caliper log shows the total depth of the borehole is 312 ft and it is cased with 8-in.-diameter casing to 24 ft bls (fig. 25a, app.). The top of casing is at land surface. The static water level varied from 0 to 3.02 ft bls at the time of logging because of inflow at the surface from heavy rainfall. The caliper log shows major fractures at 28, 29, and 76 ft bls. The borehole television survey shows a major fracture at 76 ft bls. At 300 ft bls, the borehole is partially obstructed. During the borehole television survey, low-visibility conditions were observed to 76 ft bls, indicating little vertical flow. The water was clear from 76 to 300 ft bls, indicating vertical flow in this zone. It was not raining during the borehole television survey. The fluid-resistivity log shows changes in slope at approximately 70 and 280 ft bls. The natural-gamma log shows shale units with elevated gamma counts at 151–156, 176–178, 187–190, 210–212, and 296–299 ft bls that may correlate with other borehole logs in the immediate area. Under nonpumping conditions, the heatpulse flowmeter measured downward borehole flow at 20, 38, and 67 ft bls, upward flow at 180, 230, and 270 ft bls, and no flow at 290 ft bls (table 26). The geophysical logs and the heatpulse-flowmeter data indicate water enters the borehole through fractures at 285 and 190–214 ft bls, moves upward, and exits the borehole through a fracture at approximately 76 ft bls (dip of 50° NW. and strike of N. 82° E.). Downward flow of 1.3 to 1.5 gal/min, measured at 20, 38, and 67 ft bls, was caused by heavy rain during flowmetering. During geophysical logging, surface runoff entered at the top of the casing, moved downward, and existed the borehole through the fracture at 76 ft bls. This well remains an open borehole.

Table 26. *Summary of heatpulse-flowmeter measurements for borehole BK–2937 (West Branch Park) at the North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania*

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallons per minute)	Flow direction under nonpumping conditions
20	1.5	down
38	1.5	down
67	1.3	down
180	1.1	up
230	.2–.3	up
270	.2	up
290	no flow	no flow

MG–186 (R&B Industries #1)

The caliper log shows the total depth of the borehole is 286 ft and it is cased with 10-in.-diameter casing to 44 ft bls (fig. 26a, app.). The static water level was 11.61 ft bls at the time of logging. The caliper log shows major fractures at 61, 136–139, 141–142, 144–148, 179–186, and 275 ft bls. The borehole television survey shows major fractures at 135–151 and 176–189 ft bls. The fluid-resistivity and fluid-temperature logs show changes in slope at 60, 150, and 180 ft bls that correlate to fractures on the caliper log. Under nonpumping conditions, the heatpulse flowmeter measured upward borehole flow at 56, 78, 120, 158, 200, 244, 264, and 280 ft bls (table 27). The geophysical logs and the heatpulse-flowmeter data indicate water enters the borehole through fractures below 280 ft bls and at 180 ft bls, moves upward, and exits the borehole through fractures at 61 and 49 ft bls. This well remains an open borehole.

Table 27. *Summary of heatpulse-flowmeter measurements for borehole MG–186 (R&B Industries #1) at the North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania*

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallon per minute)	Flow direction under nonpumping conditions
56	0.2	up
78	.3	up
120	.3	up
158	.2	up
200	.2	up
244	.2	up
264	.2	up
280	.2	up

MG–187 (R&B Industries #2)

The caliper log shows the total depth of the borehole is 291 ft and it is cased with 10-in-diameter casing to 32 ft bls (fig. 27a, app.). The static water level was 10.60 ft bls at the time of logging. The caliper log shows major fractures at 32–33.5, 75, 79, 94–101, 107, 124, 127–130, and 165–176 ft bls. The borehole television survey shows major fractures at 95–100, 124–128, and 164–175 ft bls. The fluid-resistivity and fluid-temperature logs show changes in slope at approximately 60 and 125 ft bls that correlate to fractures shown on the caliper log. The natural-gamma log shows shale units with elevated gamma counts at 105–108 and 111–103 ft bls that may correlate with other borehole logs in the immediate area. Under nonpumping conditions, the heatpulse flowmeter measured upward borehole flow at 38, 48, 72, 84, 110, 146, 160, 214, 238, and 270 ft bls (table 28). Variability in the low-flow rates measured is probably because of turbulence caused by borehole roughness and leakage around the flowmeter seal from the numerous minor fractures throughout the borehole. The geophysical logs and the heatpulse-flowmeter data indicate water enters the borehole through fractures below 270 ft bls and through fracture zones at 118–130 and 75–79 ft bls, moves upward, and exits the borehole through fractures above 38 ft bls. This well remains an open borehole.

Table 28. *Summary of heatpulse-flowmeter measurements for borehole MG–187 (R&B Industries #2) at the North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania*

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallon per minute)	Flow direction under nonpumping conditions
38	0.3	up
48	.2	up
72	.2	up
84	.1	up
110	.4	up
146	.1–.3	up
160	.1	up
214	.2	up
238	.2–.3	up
270	.2	up

MG–188 (R&B Industries #3)

The caliper log shows the total depth of the borehole is 300 ft and it is cased with 10-in.-diameter casing to 38 ft bls (fig. 28a, app.). The static water level was 8.90 ft bls at the time of logging. The caliper log shows major fractures at 46–58, 71–75, and 298–300 ft bls. The borehole television survey shows major fractures at 39–56, 69–75, 160, and 185–188 ft bls.The fluid-resistivity and fluid-temperature logs show changes in slope at approximately 70 and 88 ft bls that correlate to fractures shown on the caliper log. The natural-gamma log shows shale units with elevated gamma readings at 252–255 ft bls that may correlate with other borehole logs in the immediate area. Under nonpumping conditions, the heatpulse flowmeter measured upward borehole flow at 69, 90, 133, 154, 186, 212, 260, and 286 ft bls (table 29). The geophysical logs and the heatpulse-flowmeter data indicate water enters the borehole through fractures below 290 ft bls, moves upward, and exits the borehole through fracture zones at 185–189, 93–114, 71–74, and 46–58 ft bls. This well remains an open borehole.

Table 29. *Summary of heatpulse-flowmeter measurements for borehole MG–188 (R&B Industries #3) at the North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania*

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallon per minute)	Flow direction under nonpumping conditions
69	0.2	up
90	.3	up
133	.3	up
154	.3	up
186	.3	up
212	.9	up
260	.9	up
286	.9	up

MG–924 (NP–21)

The caliper, natural-gamma, single-point-resistance, fluid-resistivity, and fluid-temperature logs were collected, and heatpulse-flowmeter measurements were made in the borehole to 253 ft bls, where the borehole diameter decreases and a riser-pipe sticks up into the borehole. The caliper log shows the borehole is cased with 12-in.-diameter casing to 51 ft bls (fig. 29a, app.). The static water level was 2.02 ft bls at the time of logging. The caliper log shows major fractures at 90, 112, 124–130, and 180 ft bls. The borehole television survey shows a reduction in borehole diameter from 12 in. at 252 ft bls, a riser-pipe sticking up into the borehole at 252 ft bls, and a tangle of pipes and cables at 332 ft bls, which prevented camera advance. The PVC riser pipe has an approximate stick-up of 1 ft. The borehole television survey shows major high-angle fractures at 87, 96, 124, 178, 306, and 315 ft bls. The fluid-resistivity log shows changes in slope at 180, 220, and 234 ft bls. The fluid-temperature log shows changes in slope at 82, 180, and 235 ft bls. Sharp inflections ("spikes") in the fluid-temperature and fluid-resistivity logs at 178 and 234 ft bls correspond to fractures and may be caused by lateral flow or mechanical problems; the spike at 225 ft bls is spurious data. The natural-gamma log shows shale units with elevated gamma counts at 42–44, 105–111, and 235–238 ft bls that may correlate with other gamma logs in the immediate area. Under nonpumping conditions, the heatpulse flowmeter measured upward borehole flow at 66, 123, 176, 230, and 242 ft bls and no flow at 40 ft bls (table 30). The geophysical logs and the heatpulse-flowmeter data indicate water enters the borehole through fractures below 242 ft bls and at 124–130 ft bls, moves upward, and exits the borehole through fractures above 66 ft bls. This well remains an open-borehole production well but currently is inactive.

Table 30. *Summary of heatpulse-flowmeter measurements for borehole MG–924 (NP–21) at the North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania*

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallon per minute)	Flow direction under nonpumping conditions
40	no flow	no flow
66	0.2	up
123	.2	up
176	.1	up
230	.2	up
242	.1	up

MG–1691 (NP–12B)

The caliper log shows the total depth of the borehole is 115 ft and it is cased with 6-in.-diameter casing to 22 ft bls (fig. 30a, app.). The static water level was 46.94 ft bls at the time of logging. The caliper log shows major fractures at 50, 64, and 75 ft bls. The fluid-resistivity log shows changes in slope at 52 and 70 ft bls, and the fluid-temperature log shows changes in slope at 52, 64–66, and 90 ft bls; these may indicate water-bearing intervals affected by the pumping of nearby production well MG–914 (NP–12C). Under nonpumping conditions, the heatpulse flowmeter measured upward borehole flow at 53 and 60 ft bls and was not able to determine flow rates at 70, 82, and 104 ft bls because of borehole turbulence induced by pumping in nearby production well MG–914 (NP–12C) (table 31). The borehole television survey shows major high-angle fractures at 37, 50, 64, and 75 ft bls that are nearly vertical. Low-visibility conditions were encountered above 51 and below 74 ft bls, indicating no vertical flow, and clearer conditions were encountered from 51 to 74 ft bls, indicating a zone of increased vertical flow. The geophysical logs and heatpulse-flowmeter data indicate water enters the borehole through fractures below 60 ft bls, moves upward, and exits the borehole through a fracture at 50 ft bls. The fluid-temperature log suggests considerable lateral flow in the borehole from 68 to 90 ft bls because of pumping of nearby well MG–914. This well remains an open borehole.

Table 31. *Summary of heatpulse-flowmeter measurements for borehole MG–1691 (NP–12B) at the North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania*

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallon per minute)	Flow direction under nonpumping conditions
53	0.1	up
60	.1	up
70	not determined[1]	
82	not determined[1]	
104	not determined[1]	

[1] Flow rate could not be determined because of borehole turbulence.

BK–1292 (NP–75)

The caliper log shows the total depth of the borehole is 67 ft and it is cased with 8-in.-diameter casing to 20 ft bls (fig. 31a, app.). The static water level was 17.27 ft bls at the time of logging. The caliper log shows a major fracture at 65–67 ft bls. The borehole television survey shows rough borehole walls from 20 to 40 ft bls and a major fracture from 65 to 67 ft bls. Reduced visibility above 27 ft bls indicates an interval of little vertical flow. The fluid-temperature log shows changes in slope at 28 and 42 ft bls that correlate to fractures shown on the caliper log. Under nonpumping conditions, the heatpulse flowmeter measured upward and downward borehole flow at 27 ft bls and downward flow at 43 and 59 ft bls (table 32). Flow in the upper part of the borehole probably is affected by pumping from wells at a nearby nursery. The geophysical logs and the heatpulse-flowmeter data indicate water enters the borehole through fractures at 20–40 ft bls, moves upward or downward, depending on local ground-water pumping, and exits the borehole through a fracture at 65–67 ft bls (dip of 66° NE. and strike of N. 16° W.). This well remains as an unused open borehole.

Table 32. *Summary of heatpulse-flowmeter measurements for borehole BK–1292 (NP–75) at the North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania*

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallons per minute)	Flow direction under nonpumping conditions
27	0.2–.3	up/down
43	.5–1.0	down
59	.8–1.3	down

MG-1693 (NP-87)

The caliper log shows the total depth of the borehole is 476 ft and it is cased with 12-in.-diameter casing to 103 ft bls (fig. 32a, app.). The caliper log shows major fractures at 103, 116, 130–136, 263, 268, 307, 418, and 458 ft bls. The borehole television survey shows major high-angle fractures at 105, 129, 260, 390, 420, and 457 ft bls. Water was visibly entering the borehole at 420 ft bls, indicating a water-bearing zone. The fluid-resistivity and fluid-temperature logs show changes in slope at 282, 286, 313, 315, 317, 350–367, 375, 386–398, 430–440, and 445–474 ft bls that suggest water-bearing zones. The natural-gamma log shows shale units with elevated gamma readings at 110–114, 350–352, 441–444, 462–464, and 467–470 ft bls that may correlate with other borehole logs in the immediate area. Under nonpumping conditions, the heatpulse flowmeter measured upward flow at 90, 113, 123, 143, 220, 320, 380, 400, and 443 ft bls (table 33). The geophysical logs indicate water probably enters the borehole through fractures at 130, 390, 426, and 457 ft bls and moves upward. Some water exits the borehole through a fracture at 104 ft bls, but most water exits the borehole through a broken casing joint weld at 82 ft bls. This well remains an unused open borehole.

Table 33. *Summary of heatpulse-flowmeter measurements for borehole MG–1693 (NP–87) at the North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania*

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallons per minute)	Flow direction under nonpumping conditions
20	no flow	no flow
60	no flow	no flow
90	1.2	up
113	1.5	up
123	1.5	up
143	1.5	up
220	1.5	up
320	1.5	up
380	1.5	up
400	1.2	up
443	.1	up
464	no flow	no flow

Fracture Orientation

Acoustic-televiewer logs were run in 31 boreholes in the North Penn Area 5 Superfund Site area. The analytical software identified 353 fractures from the logs; 64 of these fractures were determined to be water bearing with the aid of the geophysical logs, television surveys, and heat-pulse-flowmeter data.

Fracture orientation falls into two populations: bedding-plane partings and high-angle fractures (fig. 3). The acoustic-televiewer logs, supported by borehole television surveys, showed 157 bedding-plane partings with a mean strike of N. 62° E. (mean dip azimuth, or direction of maximum dip angle, of 332°) and a mean dip of 27° NW. The mean strike of the Brunswick Formation determined from the acoustic-televiewer data on 128 bedding-plane partings at the North Penn Area 5 Superfund Site is N. 62° E. (mean dip azimuth of 332°) and the mean dip is 31° NW. The mean strike of the Lockatong Formation determined from the acoustic-televiewer data on 29 bedding-plane partings is N. 67° E. (mean dip azimuth of 337°) and the mean dip is 19° NW. Eleven total bedding-plane partings were water bearing (7 percent of all bedding-plane partings and 3 percent of all detected fractures) (fig. 4). The acoustic-televiewer logs showed 196 high-angle fractures with a mean strike of N. 58° E. (mean dip azimuth of 148°) and a mean dip of 72° SE. Fifty-three total high-angle fractures were water bearing (27 percent of all high-angle fractures and 15 percent of all detected fractures). The relative strike difference of the two fracture populations was 4° (relative dip azimuth difference of 184°), and the relative dip angle difference of the two fracture populations was 81°. Therefore, strike of the two fracture populations was nearly identical, with a 4° difference, but the relative dip angles were within 9° of normal to each other, or nearly perpendicular.

The acoustic-televiewer logs and heatpulse-flowmeter data identified 64 water-bearing fractures. Fifty-three were high-angle fractures, which is 83 percent of all water-bearing fractures. The water-bearing, bedding-plane partings had a mean strike of N. 58° E. (mean dip azimuth of 328°) and a mean dip angle of 30° NW. The water-bearing, high-angle fractures had a mean strike of N. 58° E. (mean dip azimuth of 148°) and a mean dip angle of 77° SE. Mean strike of the two fracture populations was nearly identical, less than 1° difference, and the relative dip angles were within 17° of nor-

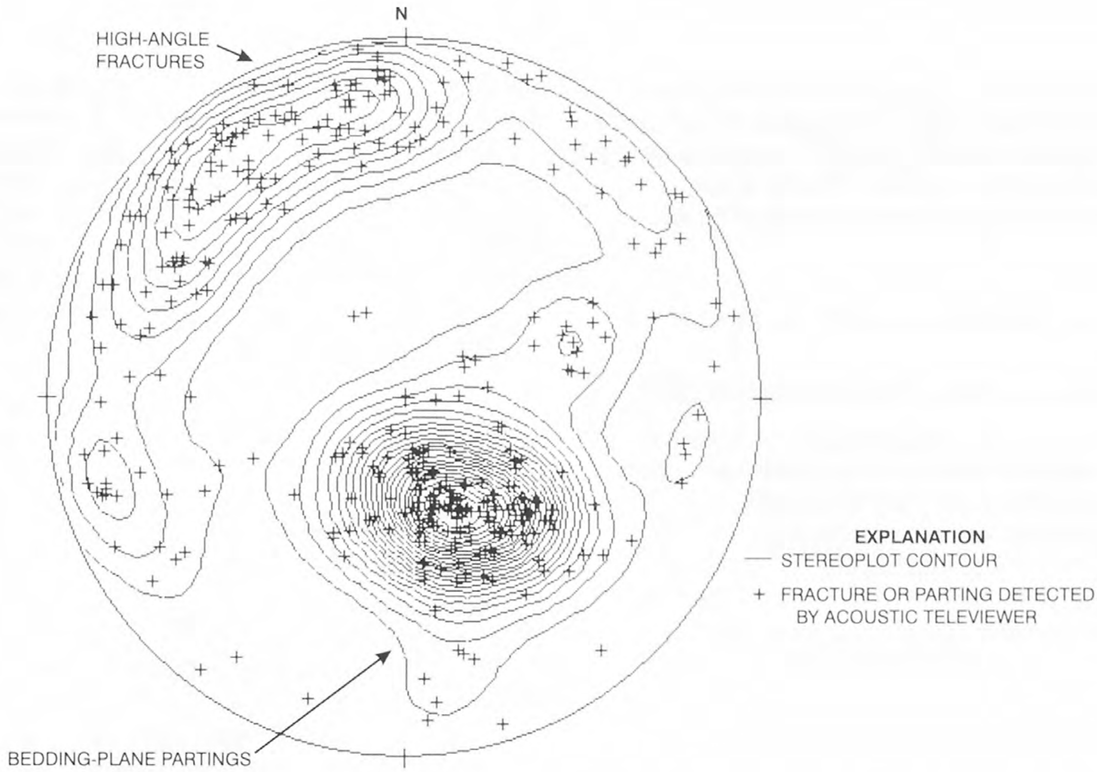


Figure 3. Contour stereoplot showing two main fracture sets, North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

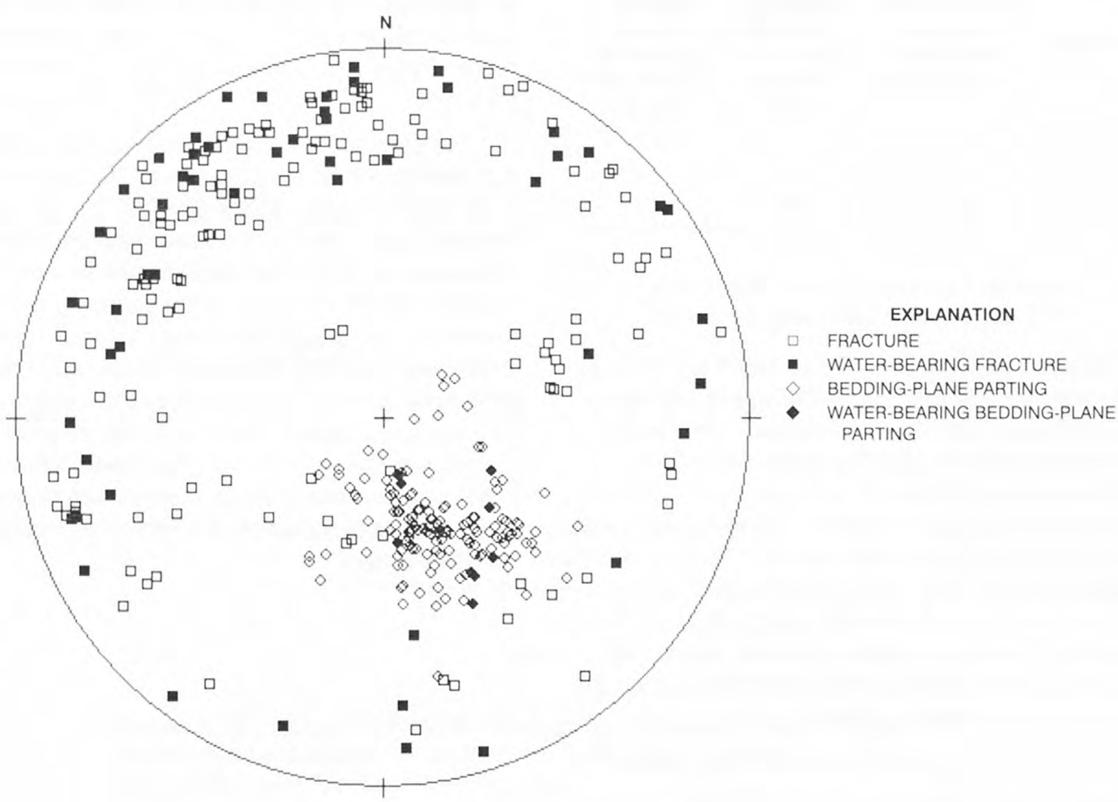


Figure 4. Stereoplot of fractures detected by acoustic televiewer, North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania. (Water-bearing status determined by analysis of heatpulse-flowmeter data.)

mal to each other. Thus, the predominant water-bearing fracture system is composed of high-angle fractures with a strike of N. 58° E., which is nearly identical to formation strike. The dip angle approaches perpendicular to the bedding dip.

AQUIFER-ISOLATION TESTS

Aquifer-Isolation Tests of MG–1697 (RI–6)

On the basis of geophysical logs and heat-pulse-flowmeter data, three intervals were selected for an aquifer-isolation test in well MG–1697 (RI–6) (table 34). For the tests of intervals 1 and 3, only the top packer was inflated (fig. 2). For the test of interval 2, both packers were inflated. The isolated intervals, quantity of water pumped, and specific capacity of each interval are summarized in table 34.

Table 34. *Intervals isolated and specific capacities for well MG–1697 (RI–6) at the North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania*

Interval	Isolated depth interval (feet below land surface)	Step 1, specific capacity (gallons per minute per foot)	Step 2, specific capacity gallons per minute per foot)
1	73–119	0.3	0.2
2	48–71	.6	.4
3	20–46	1.4	1.1

Aquifer-Isolation Test of Interval 1 (73–119 Feet Below Land Surface)

Isolated interval 1 was 73 to 119 ft bls. In order to isolate this interval, the center of the top packer was placed at 72 ft bls and inflated. The bottom packer was not inflated. The static water level in the open borehole prior to inflation was 7.78 ft bls. Fifty-five minutes after inflation, the water level was 7.71 ft bls in the upper interval and 7.79 ft bls in the isolated interval. This result is consistent with the interpretation of the borehole geophysical logs and heatpulse-flowmeter measurements, which indicate the isolated interval has a lower head than the water-bearing fractures above it.

For step 1, the isolated interval was pumped at 4.0 gal/min for 31 minutes (fig. 5). Drawdown was 14.4 ft in the isolated interval and 1.9 ft in the upper interval. The specific capacity of the isolated interval for step 1 was 0.3 (gal/min)/ft. For step 2, the pumping rate was increased to 6.3 gal/min for 37 minutes and then was terminated prematurely because of a thunderstorm. The specific capacity of the isolated interval for step 2 was 0.2 (gal/min)/ft. Surface runoff during the thunderstorm drained into the flush-mounted well, causing a rise in water level to land surface in the upper interval. Drawdown was 21.1 ft in the isolated interval and 0.8 ft in the upper interval prior to the thunderstorm. Drawdown in the upper interval indicates a slight hydraulic connection between the upper and isolated interval.

Aquifer-Isolation Test of Interval 2 (48–71 Feet Below Land Surface)

Isolated interval 2 was 48 to 71 ft bls. In order to isolate this interval, the center of the top packer was placed at 47 ft bls and inflated; the center of the bottom packer was placed at 72 ft bls and inflated. The static water level in the open borehole prior to inflation was 6.96 ft bls. Nineteen minutes after inflation, the water level was 6.91 ft bls in the upper interval, 6.96 ft bls in the isolated interval, and 6.98 ft bls in the lower interval. This result is consistent with the interpretation of the borehole geophysical logs and heatpulse-flowmeter measurements, which indicate the upper interval has a higher hydraulic head than the isolated and lower intervals.

For step 1, the isolated interval was pumped at 4.2 gal/min for 46 minutes (fig. 6). Drawdown was 7.49 ft in the isolated interval, 2.23 ft in the upper interval, and 4.38 ft in the lower interval. The specific capacity of the isolated interval for step 1 was 0.6 (gal/min)/ft. For step 2, the pumping rate was increased to 6.5 gal/min for 50 minutes. Total drawdown was 16.5 ft in the isolated interval, 3.82 ft in the upper interval, and 8.63 ft in the lower interval. The specific capacity of the isolated interval for step 2 was 0.4 (gal/min)/ft. The drawdowns indicate considerable hydraulic connection between all three intervals, especially between the isolated and lower intervals.

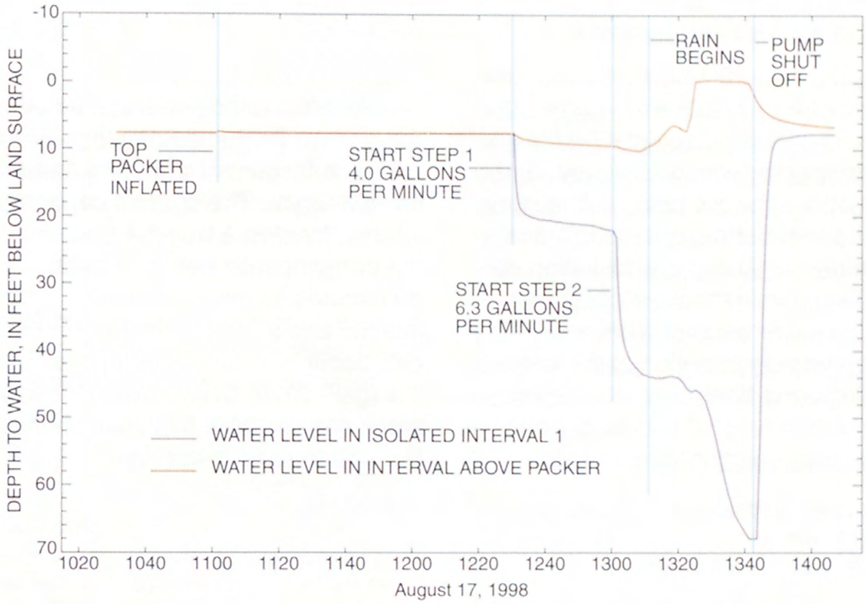


Figure 5. Hydrograph from aquifer-isolation test of interval 1 (73 to 119 feet below land surface) in well MG–1697 (RI–6), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

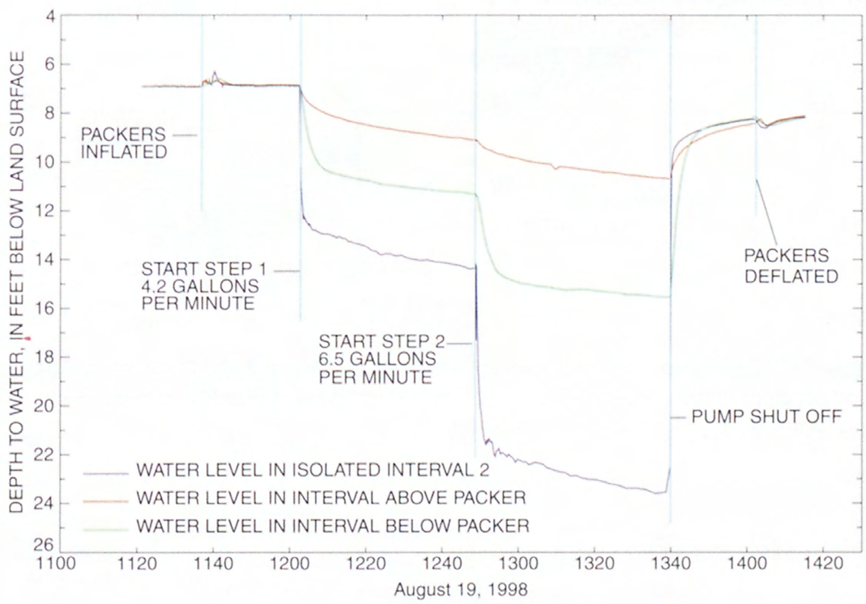


Figure 6. Hydrograph from aquifer-isolation test of interval 2 (48 to 71 feet below land surface) in well MG–1697 (RI–6), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

Aquifer-Isolation Test of Interval 3 (20–46 Feet Below Land Surface)

Isolated interval 3 was 20 ft bls (bottom of casing) to 46 ft bls. In order to isolate this interval, the center of the top packer was placed at 47 ft bls and inflated. The bottom packer was not inflated, and the pump was set above the top packer. The static water level in the open borehole prior to inflation was 8.15 ft bls. Thirteen minutes after inflation, the water level was 7.94 ft bls in the isolated interval and 7.88 ft bls in the lower interval. This result is not consistent with the interpretation of the borehole geophysical logs and heatpulse-flowmeter measurements, which indicate the fracture zone from 20 to 25 ft bls has a higher head than the water-receiving fractures below it, and is probably because of a hydraulic connection between the isolated and lower intervals.

For step 1, the isolated interval was pumped at 3.3 gal/min for 30 minutes (fig. 7). Drawdown was 2.36 ft in the isolated interval and 1.26 ft in the lower interval. The specific capacity of the isolated interval for step 1 was 1.4 (gal/min)/ft. For step 2, the pumping rate was increased to 6.5 gal/min for 30 minutes. Drawdown was 5.77 ft in the isolated interval and 2.79 ft in the lower interval. The specific capacity of the isolated interval for step 2 was 1.1 (gal/min)/ft. Drawdown in the lower interval indicates considerable hydraulic connection between the isolated and lower intervals.

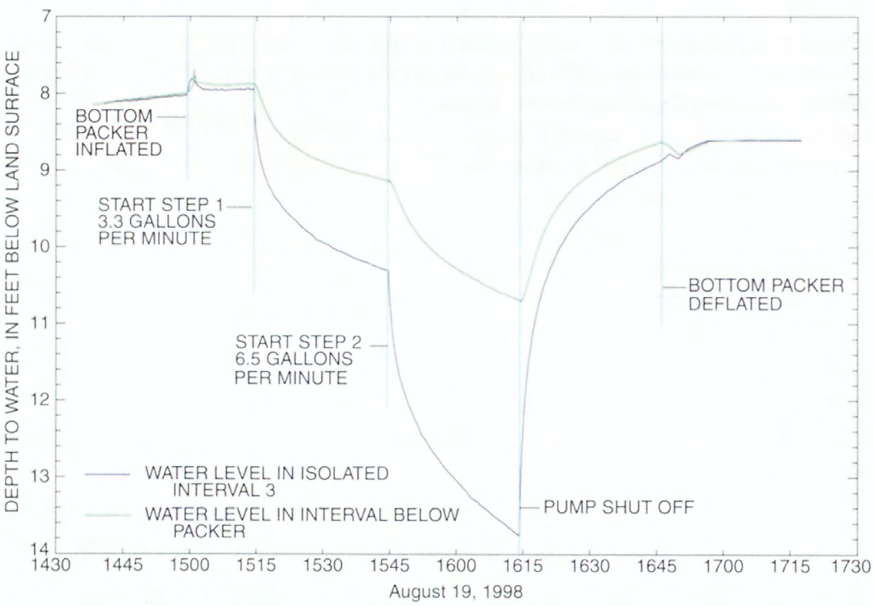


Figure 7. Hydrograph from aquifer-isolation test of interval 3 (20 to 46 feet below land surface) in well MG–1697 (RI–6), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

Aquifer-Isolation Tests of MG–1699 (RI–8)

On the basis of geophysical logs and heat-pulse-flowmeter data, three intervals were selected for an aquifer-isolation test in well MG–1699 (RI–8) (table 35). For the test of interval 3, only the bottom packer was inflated (fig. 2). For tests of interval 1 and 2, both packers were inflated. The isolated intervals and specific capacity of each interval are summarized in table 35.

Table 35. *Intervals isolated and specific capacities for well MG–1699 (RI–8) borehole at North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania*

[N/A, not applicable]

Interval	Isolated depth interval (feet below land surface)	Step 1, specific capacity (gallons per minute per foot)	Step 2, specific capacity (gallons per minute per foot)
1	112–123	6.5	3.7
2	73–96	.1	N/A
3	19–71	.1	N/A

Aquifer-Isolation Test of Interval 1 (112–123 Feet Below Land Surface)

Isolated interval 1 was 112 to 123 ft bls. In order to isolate this interval, the center of the top packer was placed at 111 ft bls and inflated; the bottom packer was placed at 124 ft bls and inflated. The static water level in the open borehole prior to inflation was 36.41 ft bls. Twenty-five minutes after inflation, the water level was 36.37 ft bls in the upper interval, 36.44 ft bls in the isolated interval, and 36.41 ft bls in the lower interval. This result is consistent with the interpretation of the borehole geophysical logs and heatpulse-flowmeter measurements, which indicate little difference in hydraulic head throughout the borehole.

For step 1, the isolated interval was pumped at 3.2 gal/min for 10 minutes (fig. 8). Drawdown was 0.49 ft in the isolated interval, 0.11 ft in the upper interval, and 0.09 ft in the lower interval. The specific capacity of the isolated interval for step 1 was 6.5 (gal/min)/ft. For step 2, the pumping rate was increased to 6.7 gal/min for 60 minutes. Drawdown was 1.8 ft in the isolated interval, 0.59 ft in the upper interval, and 0.50 ft in the lower interval. The specific capacity of the isolated interval for step 2 was 3.7 (gal/min)/ft. The drawdowns indicate a hydraulic connection among all three intervals. The calculated specific capacities of the isolated interval probably are high because of the incomplete isolation of the interval.

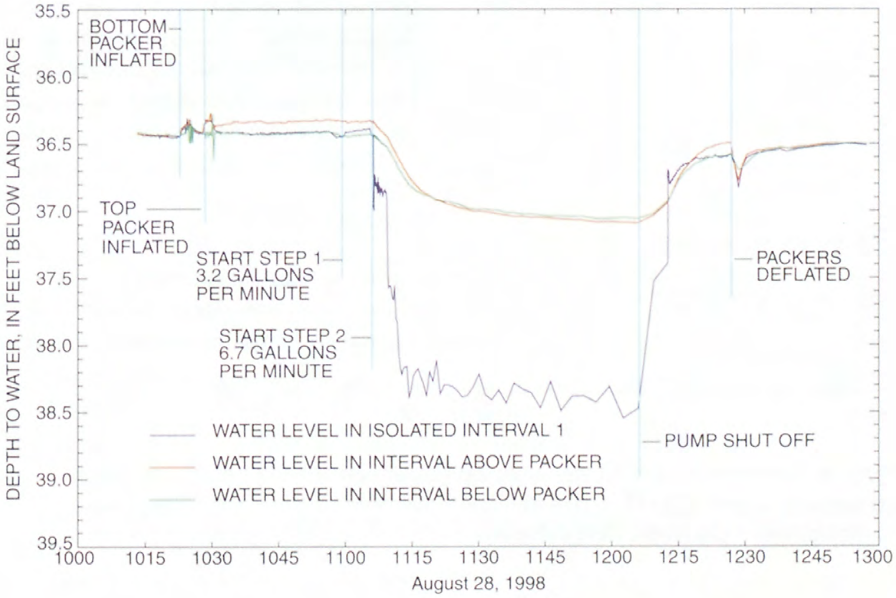


Figure 8. Hydrograph from aquifer-isolation test of interval 1 (112 to 123 feet below land surface) in well MG–1699 (RI–8), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

Aquifer-Isolation Test of Interval 2 (73–96 Feet Below Land Surface)

Isolated interval 2 was 73 to 96 ft bls. In order to isolate this interval, the center of the top packer was placed at 72 ft bls and inflated; the center of the bottom packer was placed at 97 ft bls and inflated. The static water level in the open borehole prior to inflation was 36.8 ft bls. Twenty-seven minutes after inflation, the water level was 36.26 ft bls in the upper interval, 36.33 ft bls in the isolated interval, and 36.39 ft bls in the lower interval. This result is consistent with the interpretation of the borehole geophysical logs and heatpulse-flowmeter measurements, which indicate little difference in hydraulic head throughout the borehole.

The isolated interval was pumped at 1.7 to 3.5 gal/min for 60 minutes (fig. 9). Drawdown was 18 ft in the isolated interval, 12 ft in the upper interval, and 0.3 ft in the lower interval. Drawdowns indicate a strong hydraulic connection between the isolated and upper intervals. The specific capacity of the isolated interval was 0.1 (gal/min)/ft.

Aquifer-Isolation Test of Interval 3 (19–71 Feet Below Land Surface)

Isolated interval 3 was 19 ft bls (bottom of casing) to 71 ft bls. In order to isolate this interval, the center of the top packer was placed at 72 ft bls and inflated. The bottom packer was not inflated, and the pump was set above the top packer. The static water level in the open borehole prior to inflation was 36.44 ft bls. Twenty-five minutes after inflation, the water level was 36.37 ft bls in the isolated interval and 36.44 ft bls in the lower interval. This result is consistent with the interpretation of the borehole geophysical logs and heatpulse-flowmeter measurements, which indicate little difference in hydraulic head throughout the borehole.

The isolated interval was pumped at 1.3 gal/min for 60 minutes (fig. 10). Drawdown was 19 ft in the isolated interval and 0.4 ft in the lower interval. The drawdown in the lower interval indicates little hydraulic connection between the isolated interval and the lower interval. The specific capacity of the isolated interval was 0.1 (gal/min)/ft.

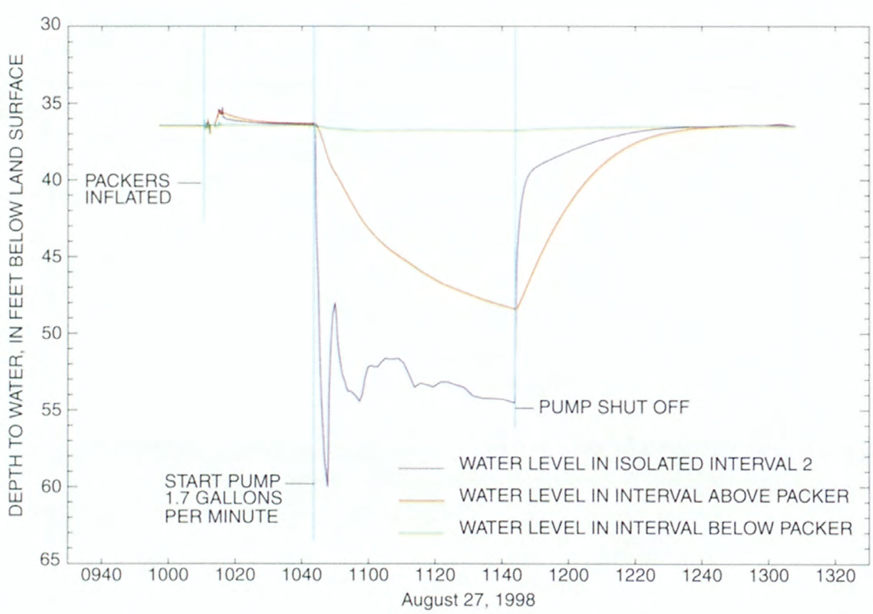


Figure 9. Hydrograph from aquifer-isolation test of interval 2 (73 to 96 feet below land surface) in well MG–1699 (RI–8), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

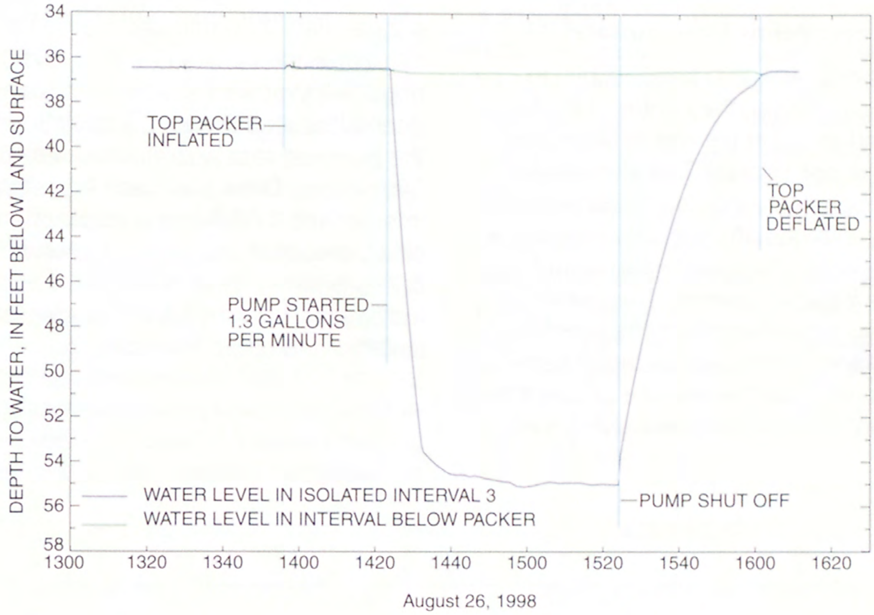


Figure 10. Hydrograph from aquifer-isolation test of interval 3 (19 to 71 feet below land surface) in well MG–1699 (RI–8), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

Aquifer-Isolation Tests of BK–2942 (RI–17)

On the basis of geophysical logs and heat-pulse-flowmeter data, six intervals were selected for an aquifer-isolation test of well BK–2942 (RI–17) (table 36). For the test of interval 1, only the top packer was inflated (fig. 2). For the test of interval 6, only the bottom packer was inflated. For tests of intervals 2, 3, 4, and 5, both packers were inflated. The isolated intervals and specific capacity of each interval are summarized in table 36.

Table 36. *Intervals isolated and specific capacities for well BK–2942 (RI–17) borehole at North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania*

[N/A, not applicable]

Interval	Isolated depth interval (feet below land surface)	Step 1, specific capacity (gallons per minute per foot)	Step 2, specific capacity (gallons per minute per foot)
1	202–259	0.3	0.7
2	178–201	1.0	1.2
3	117–140	.6	.8
4	86–109	.2	N/A
5	42–65	2.3	4.1
6	18-40	4.0	7.5

Aquifer-Isolation Test of Interval 1 (202–259 Feet Below Land Surface)

Isolated interval 1 was 202 to 259 ft bls. In order to isolate this interval, the center of the top packer was placed at 201 ft bls and inflated; the bottom packer was not inflated. The static water level in the open borehole prior to inflation was 14.76 ft bls. Sixty minutes after inflation, the water level was 14.80 ft bls in the upper interval and 13.84 ft bls in the isolated interval. This result is consistent with the interpretation of the borehole geophysical logs and heatpulse-flowmeter measurements, which indicate the fracture at 230 ft bls has a higher head than the water-receiving fractures above it.

For step 1, the isolated interval was pumped at 4.2 gal/min for 30 minutes (fig. 11). Drawdown was 14.02 ft in the isolated interval and 0.32 ft in the upper interval. The specific capacity of the isolated interval for step 1 was 0.3 (gal/min)/ft. For step 2, the pumping rate was increased to 6.3 gal/min for 30 minutes. Drawdown was 9.51 ft in the isolated interval and 0.33 ft in the upper interval. The specific capacity of the isolated interval for step 2 was 0.7 (gal/min)/ft. Drawdown in the upper interval indicates a slight hydraulic connection between the isolated and upper intervals.

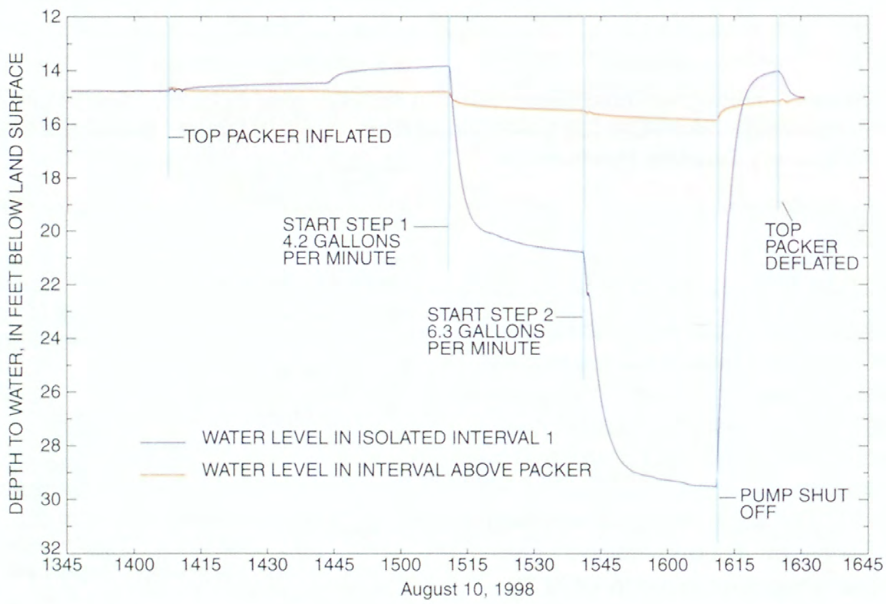


Figure 11. Hydrograph from aquifer-isolation test of interval 1 (202 to 259 feet below land surface) in well BK–2942 (RI–17), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

Aquifer-Isolation Test of Interval 2 (178–201 Feet Below Land Surface)

Isolated interval 2 was 178 to 201 ft bls. In order to isolate this interval, the center of the top packer was placed at 177 ft bls and inflated; the center of the bottom packer was placed at 202 ft bls and inflated. The static water level in the open borehole prior to inflation was 14.84 ft bls. Thirty-seven minutes after inflation, the water level was 15.77 ft bls in the upper interval, 11.68 ft bls in the isolated interval, and 11.52 ft bls in the lower interval. This result is consistent with the interpretation of the borehole geophysical logs and heat-pulse-flowmeter measurements, which indicate the fractures in the lower and isolated intervals have a higher head than the water-receiving fractures above them.

For step 1, the isolated interval was pumped at 3.3 gal/min for 45 minutes (fig. 12). Drawdown was 3.33 ft in the isolated interval, 0.26 ft in the upper interval, and 0.96 ft in the lower interval. The specific capacity of the isolated interval for step 1 was 1.0 (gal/min)/ft. For step 2, the pumping rate was increased to 6.7 gal/min for 60 minutes. Drawdown was 5.65 ft in the isolated interval, 0.31 in the upper interval, and 1.49 ft in the lower interval. The specific capacity of the isolated interval for step 2 was 1.2 (gal/min)/ft. The drawdown in the lower interval indicates a slight hydraulic connection between the isolated and lower intervals.

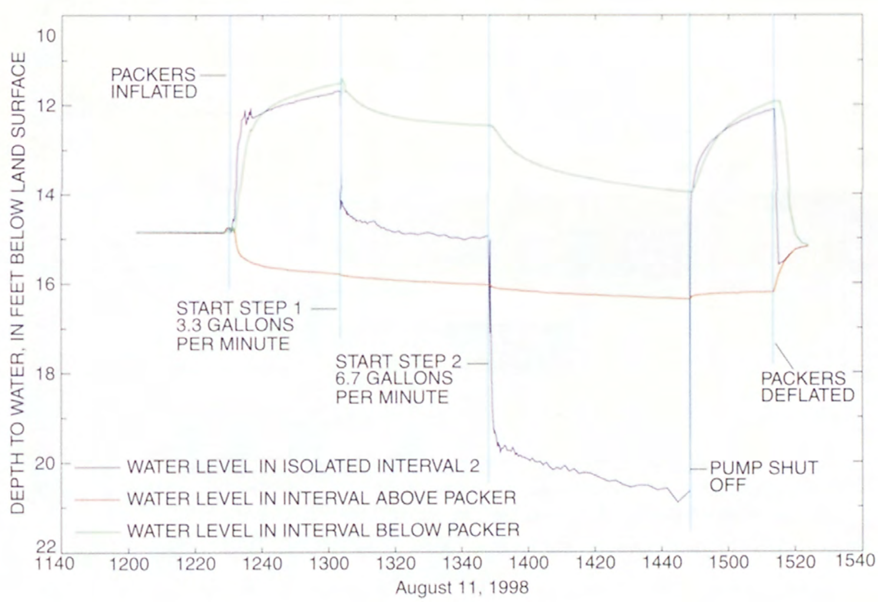


Figure 12. Hydrograph from aquifer-isolation test of interval 2 (178 to 201 feet below land surface) in well BK–2942 (RI–17), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

Aquifer-Isolation Test of Interval 3 (117–140 Feet Below Land Surface)

Isolated interval 3 was 117 to 140 ft bls. In order to isolate this interval, the center of the top packer was placed at 116 ft bls and inflated; the center of the bottom packer was placed at 141 ft bls and inflated. The static water level in the open borehole prior to inflation was 14.93 ft bls. Thirty-seven minutes after inflation, the water level was 16.13 ft bls in the upper interval, 13.57 ft bls in the isolated interval, and 11.81 ft bls in the lower interval. This result is consistent with the interpretation of the borehole geophysical logs and heat-pulse-flowmeter measurements, which indicate the fractures in the lower and isolated intervals have a higher head than the water-receiving fractures above them.

For step 1, the isolated interval was pumped at 3.5 gal/min for 28 minutes (fig. 13). Drawdown was 6.19 ft in the isolated interval, 0.29 ft in the upper interval, and 0.08 ft in the lower interval. The specific capacity of the isolated interval for step 1 was 0.6 (gal/min)/ft. For step 2, the pumping rate was increased to 7.0 gal/min for 32 minutes. Drawdown was 8.57 ft in the isolated interval, 0.35 ft in the upper interval, and 0.29 in the lower interval. The specific capacity of the isolated interval for step 2 was 0.8 (gal/min)/ft. The drawdown in the upper and lower intervals indicates a slight hydraulic connection between the isolated, upper, and lower intervals.

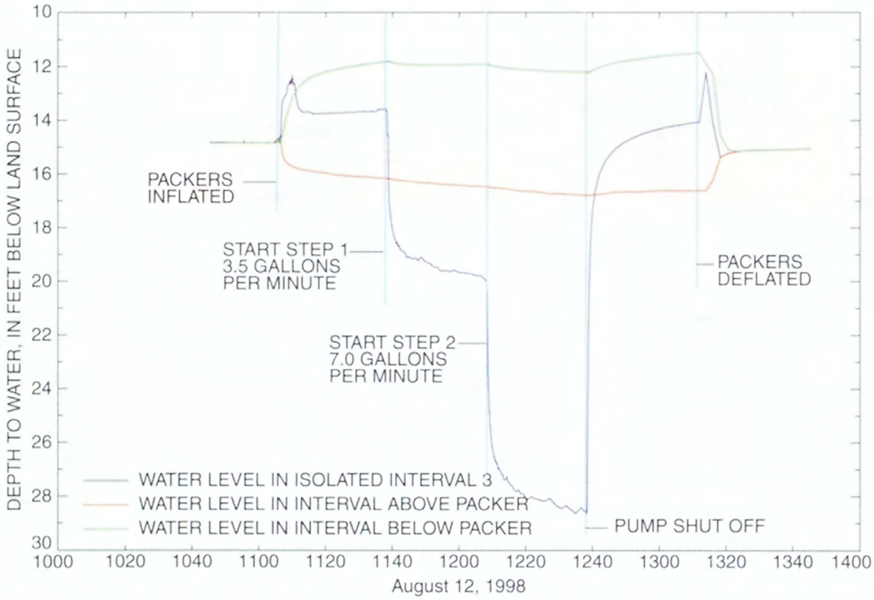


Figure 13. Hydrograph from aquifer-isolation test of interval 3 (117 to 140 feet below land surface) in well BK–2942 (RI–17), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

Aquifer-Isolation Test of Interval 4 (86–109 Feet Below Land Surface)

Isolated interval 4 was 86 to 109 ft bls. In order to isolate this interval, the center of the top packer was placed at 85 ft bls and inflated; the center of the bottom packer was placed at 110 ft bls and inflated. The static water level in the open borehole prior to inflation was 14.93 ft bls. Approximately 65 minutes after inflation, the water level was 16.21 ft bls in the upper interval, 15.95 ft bls in the isolated interval, and 12.43 ft bls in the lower interval. This result is consistent with the interpretation of the borehole geophysical logs and heatpulse-flowmeter measurements, which indicate the fractures in the lower interval have a higher head than the water-receiving fractures in the isolated and upper intervals.

The isolated interval was pumped at 3.9 gal/min for 62 minutes (fig. 14). Drawdown was 16.83 ft in the isolated interval and 1.08 ft in the upper interval. The water level in the lower interval continued to rise throughout the test until the packers were deflated. The specific capacity of the isolated interval was 0.2 (gal/min)/ft. The small drawdown in the upper interval indicates only slight hydraulic connection between the isolated interval and upper interval. The water-level increase in the lower interval indicates no hydraulic connection between the lower and isolated interval.

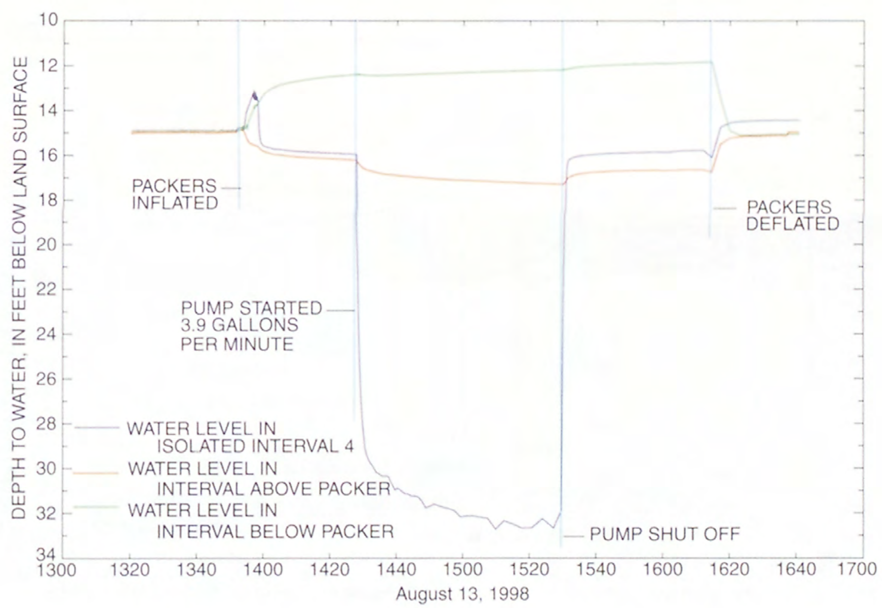


Figure 14. Hydrograph from aquifer-isolation test of interval 4 (86 to 109 feet below land surface) in well BK–2942 (RI–17), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

Aquifer-Isolation Test of Interval 5 (42–65 Feet Below Land Surface)

Isolated interval 5 was 42 to 65 ft bls. In order to isolate this interval, the center of the top packer was placed at 41 ft bls and inflated; the center of the bottom packer was placed at 66 ft bls and inflated. The static water level in the open borehole prior to inflation was 14.95 ft bls. Approximately 40 minutes after inflation, the water level was 15.23 ft bls in the upper interval, 15.23 ft bls in the isolated interval, and 14.74 ft bls in the lower interval. This result is consistent with the interpretation of the borehole geophysical logs and heatpulse-flowmeter measurements, which indicate the fractures in the lower interval have a higher head than the water-receiving fractures in the isolated and upper intervals.

For step 1, the isolated interval was pumped at 4.3 gal/min for 37 minutes (fig. 15). Drawdown was 1.90 ft in the isolated interval, 1.63 ft in the upper interval, and 0.73 ft in the lower interval. The specific capacity of the isolated interval for step 1 was 2.3 (gal/min)/ft. For step 2, the pumping rate was increased to 7.7 gal/min for 58 minutes. Drawdown was 2.43 ft in the isolated interval, 1.89 ft in the upper interval, and 0.79 ft in the lower interval. The specific capacity of the isolated interval for step 2 was 4.1 (gal/min)/ft. The drawdown in the upper interval indicates a strong hydraulic connection between the isolated interval and upper interval. The water-level increase in the lower interval indicates a slight hydraulic connection between the lower and isolated interval.

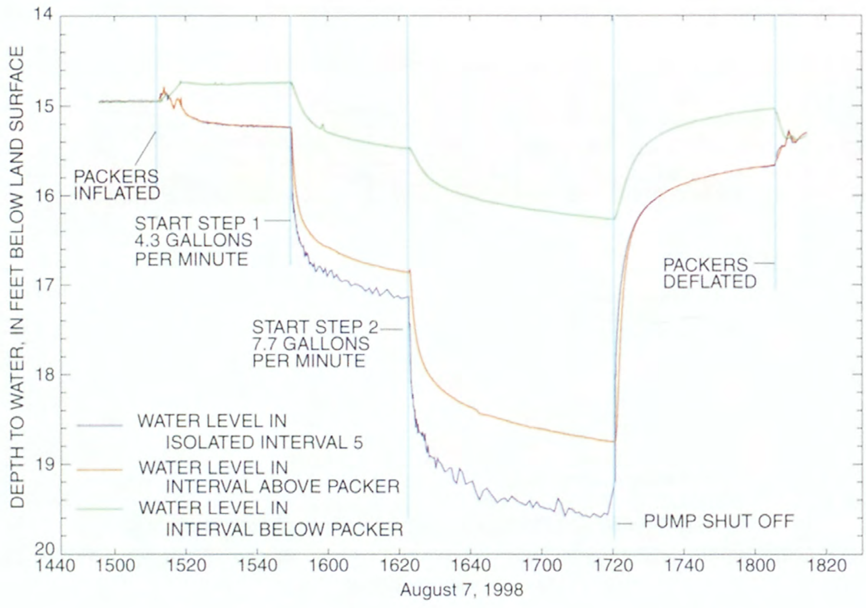


Figure 15. Hydrograph from aquifer-isolation test of interval 5 (42 to 65 feet below land surface) in well BK–2942 (RI–17), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

Aquifer-Isolation Test of Interval 6 (18–40 Feet Below Land Surface)

Isolated interval 6 was 18 ft bls (bottom of casing) to 40 ft bls. In order to isolate this interval, the center of the bottom packer was placed at 41 ft bls and inflated. The top packer was not inflated. The static water level in the open borehole prior to inflation was 14.69 ft bls. Forty minutes after inflation, the water level was 14.68 ft bls in both the isolated and lower intervals. This result is not consistent with the interpretation of the borehole geophysical logs and heatpulse-flowmeter measurements, which indicate the isolated interval has a lower head than the water-bearing fractures below it, and is probably because of the strong hydraulic connection between the isolated and lower intervals.

For step 1, the isolated interval was pumped at 2.7 gal/min for 22 minutes (fig. 16). Drawdown was 0.68 ft in both the isolated and lower intervals. The specific capacity of the isolated interval for step 1 was 4.0 (gal/min)/ft. For step 2, the pumping rate was increased to 4.6 gal/min for 45 minutes. Drawdown was 0.61 ft in both the isolated and lower intervals. The specific capacity of the isolated interval for step 2 was 7.5 (gal/min)/ft. The identical drawdown in the isolated and lower intervals indicates the packer did not seal the borehole completely or there was full hydraulic connection between the intervals outside the borehole. Therefore, the specific capacity is representative of the entire borehole.

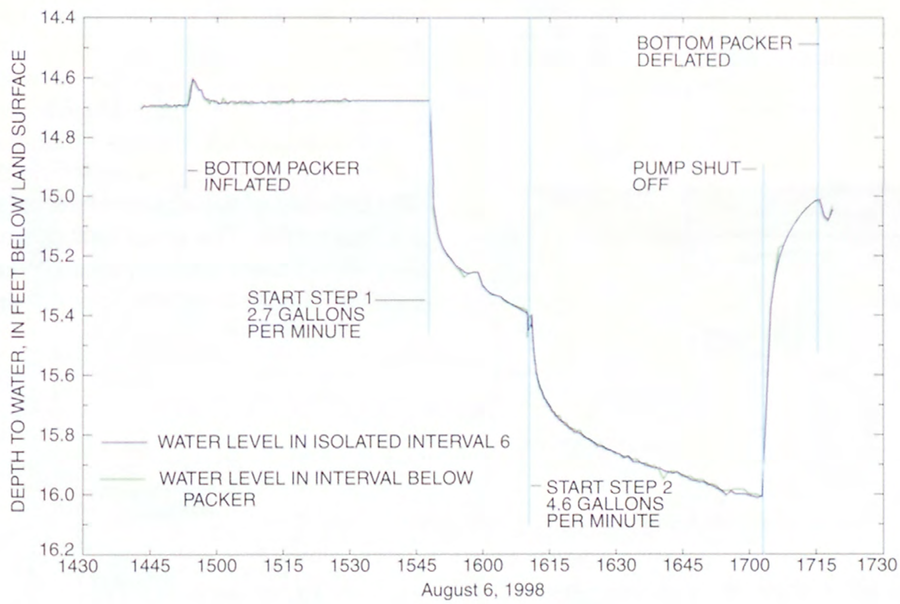


Figure 16. Hydrograph from aquifer-isolation test of interval 6 (18 to 40 feet below land surface) in well BK–2942 (RI–17), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

Aquifer-Isolation Tests of MG–1722 (RI–20)

On the basis of geophysical logs and heat-pulse-flowmeter data, four intervals were selected for an aquifer-isolation test in well MG–1722 (RI–20) (table 37). For the test of interval 1, only the top packer was inflated (fig. 2). For the test of interval 4, only the bottom packer was inflated. For tests of intervals 2 and 3, both packers were inflated. The isolated intervals and specific capacity of each interval are summarized in table 37.

Table 37. *Intervals isolated and specific capacities for well MG–1722 (RI–20) borehole at North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania*

[N/A, not applicable]

Interval	Isolated depth interval (feet below land surface)	Step1, specific capacity (gallons per minute per foot)	Step 2, specific capacity (gallon per minute per foot)
1	119–147	0.1	0.1
2	99–117	1.1	N/A
3	65–83	.3	.4
4	19–49	.4	.3

Aquifer-Isolation Test of Interval 1 (119–147 Feet Below Land Surface)

Isolated interval 1 was 119 to 147 ft bls. In order to isolate this interval, the center of the top packer was placed at 118 ft bls and inflated. The bottom packer was not inflated. The static water level in the open borehole prior to inflation was 14.36 ft bls. Approximately 20 minutes after inflation, the water level was 14.36 ft bls in the upper interval and 14.35 ft bls in the isolated interval. This result is consistent with the interpretation of the borehole geophysical logs and heatpulse-flowmeter measurements, which indicate slight difference in hydraulic head between the upper and isolated intervals.

For step 1, the isolated interval was pumped at 3.7 gal/min for 31 minutes (fig. 17). Drawdown was 30.75 ft in the isolated interval and 0.63 ft in the upper interval. The specific capacity of the isolated interval for step 1 was 0.1 (gal/min)/ft. For step 2, the pumping rate was increased to 4.6 gal/min for 3 minutes, then decreased to 2.3 gal/min for 27 minutes. Drawdown was 48.38 ft in the isolated interval and 0.70 ft in the upper interval. The specific capacity of the isolated interval for step 2 was 0.1 (gal/min)/ft. The small drawdown in the upper interval indicates slight hydraulic connection between the isolated and upper intervals.

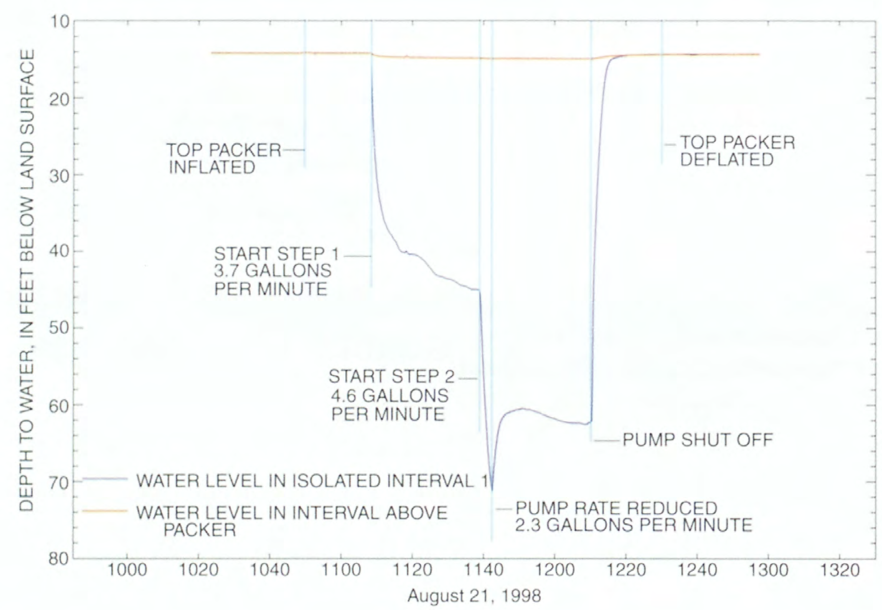


Figure 17. Hydrograph from aquifer-isolation test of interval 1 (119 to 147 feet below land surface) in well MG–1722 (RI–20), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

Aquifer-Isolation Test of Interval 2 (99–117 Feet Below Land Surface)

Isolated interval 2 was 99 to 117 ft bls. In order to isolate this interval, the center of the top packer was placed at 98 ft bls and inflated; the center of the bottom packer was placed at 118 ft bls and inflated. The packers were inflated on August 21, 1998, and remained inflated until the start of the test on August 24. The static water levels were 15.67 ft bls in the upper interval, 14.02 ft bls in the isolated interval, and 14.10 ft bls in the lower interval prior to the start of the test. This result is not consistent with the interpretation of the borehole geophysical logs and heatpulse-flowmeter measurements, which indicate the fracture zone from 101 to 116 ft bls has a higher head than the water-receiving fractures below it, and probably is because of a hydraulic connection between the isolated and lower intervals.

The isolated interval was pumped at 5.7 gal/min for 36 minutes (fig. 18). Drawdown was 5.20 ft in the isolated interval, 0.10 ft in the upper interval, and 4.22 ft in the lower interval. The specific capacity of the isolated interval was 1.1 (gal/min)/ft. The small drawdown in the upper interval indicates little hydraulic connection between the upper and isolated intervals. The large drawdown in the lower interval indicates a good hydraulic connection between the isolated and lower interval.

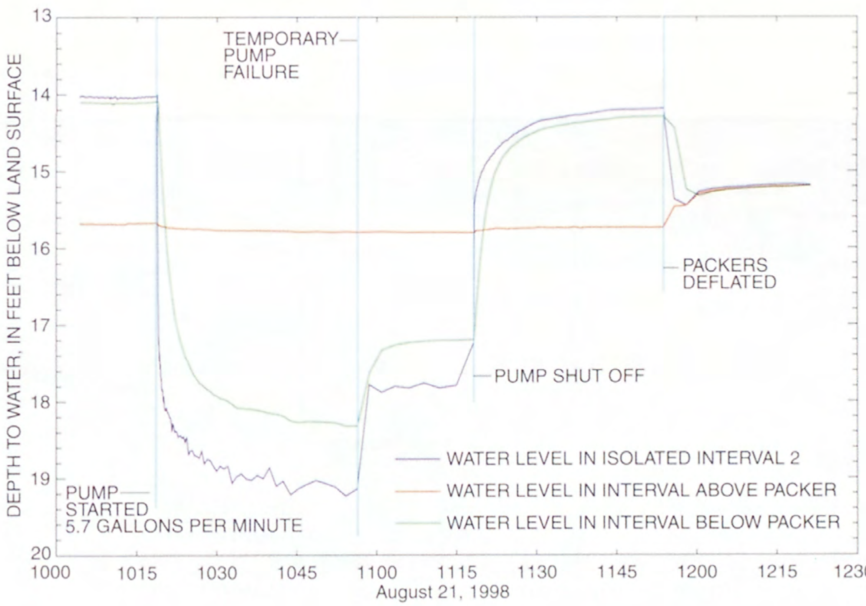


Figure 18. Hydrograph from aquifer-isolation test of interval 2 (99 to 117 feet below land surface) in well MG–1722 (RI–20), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

Aquifer-Isolation Test of Interval 3 (65–83 Feet Below Land Surface)

Isolated interval 3 was 65 to 83 ft bls. In order to isolate this interval, the center of the top packer was placed at 64 ft bls and inflated; the center of the bottom packer was placed at 84 ft bls and inflated. The static water level in the open borehole prior to inflation was 15.10 ft bls. Twenty-four minutes after inflation, the water level was 15.52 ft bls in the upper interval, 15.38 ft bls in the isolated interval, and 14.42 ft bls in the lower interval. This result is consistent with the interpretation of the borehole geophysical logs and heatpulse-flowmeter measurements, which indicate the fractures in the lower interval have a higher head than the water-receiving fractures in the isolated and upper intervals.

For step 1, the isolated interval was pumped at 3.8 gal/min for 30 minutes (fig. 19). Drawdown was 12.42 ft in the isolated interval, 0.82 ft in the upper interval, and 0.06 ft in the lower interval. The specific capacity of the isolated interval for step 1 was 0.3 (gal/min)/ft. For step 2, the pumping rate was increased to 6.4 gal/min for 31 minutes. Drawdown was 14.47 ft in the isolated interval, 1.44 ft in the upper interval, and 0.17 ft in the lower interval. After the initial drawdown, the water level in the isolated interval rose during both steps, possibly indicating hydraulic development by pumping of the fracture at 75 ft bls. The specific capacity of the isolated interval for step 2 was 0.4 (gal/min)/ft. The small drawdown in the upper interval indicates a slight hydraulic connection between the isolated interval and upper interval. The water level increase during the test in the lower interval indicates no hydraulic connection between the lower and isolated interval.

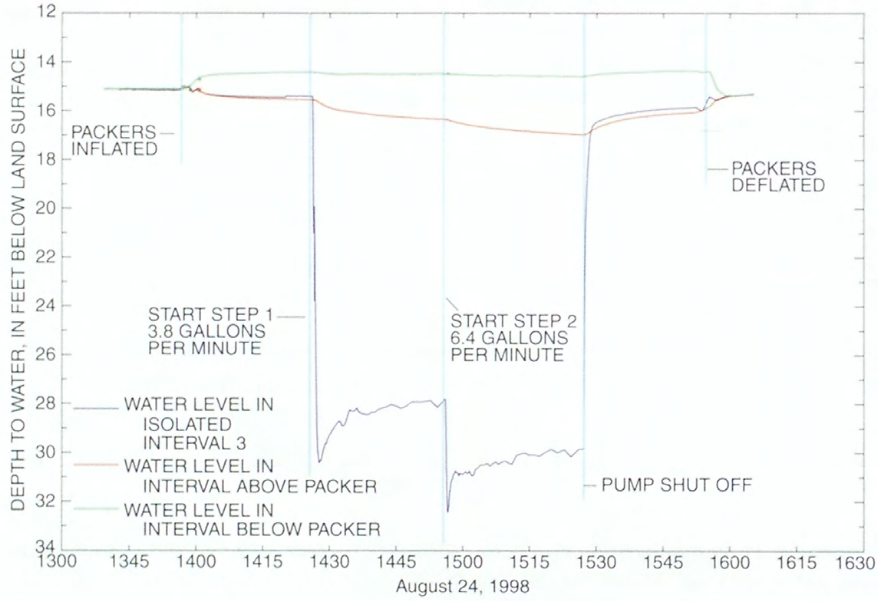


Figure 19. Hydrograph from aquifer-isolation test of interval 3 (65 to 83 feet below land surface) in well MG–1722 (RI–20), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

Aquifer-Isolation Test of Interval 4 (19–49 Feet Below Land Surface)

Isolated interval 4 was 19 ft bls (bottom of casing) to 49 ft bls. In order to isolate this interval, the center of the top packer was placed at 50 ft bls and inflated. The bottom packer was not inflated, and the pump was set above the top packer. The static water level in the open borehole prior to inflation was 15.32 ft bls. Thirty-four minutes after inflation, the water level was 15.42 ft bls in the isolated interval and 15.31 ft bls in the lower interval. This result is consistent with the interpretation of the borehole geophysical logs and heatpulse-flowmeter measurements, which indicate the fractures in the lower interval have a higher head than the water-receiving fractures in the isolated interval.

For step 1, the isolated interval was pumped at 4.0 gal/min for 38 minutes (fig. 20). Drawdown was 10.53 ft in the isolated interval and 0.48 ft in the lower interval. The specific capacity of the isolated interval for step 1 was 0.4 (gal/min)/ft. For step 2, the pumping rate was increased to 4.6 gal/min for 27 minutes. Drawdown was 13.81 ft in the isolated interval and 0.56 ft in the lower interval. The specific capacity of the isolated interval for step 2 was 0.3 (gal/min)/ft. The small drawdown in the lower interval indicates only a slight hydraulic connection between the isolated interval and lower interval.

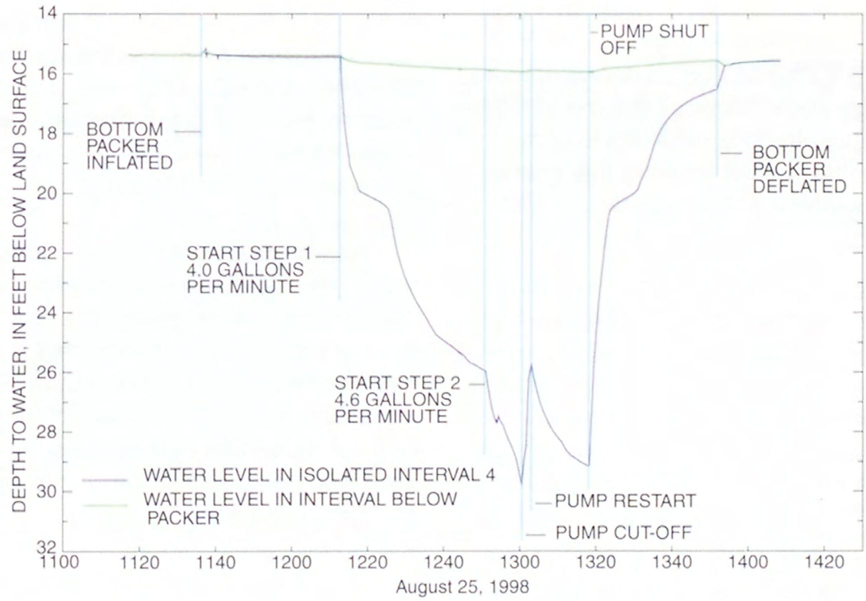


Figure 20. Hydrograph from aquifer-isolation test of interval 4 (19 to 49 feet below land surface) in well MG–1722 (RI–20), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

DISTRIBUTION OF CONTAMINANTS

Fifteen intervals in four wells were sampled for VOC's during aquifer-isolation (packer) testing in August 1998. Ten compounds were detected, and three compounds—TCE, methylene chloride, and toluene—were detected in all four wells. A summary of compounds detected is given in table 38.

Water samples from well MG–1697 had the lowest total concentrations of VOC's. Three compounds were detected; the compound with the highest concentration was toluene (7.2 μg/L). The highest concentrations of most compounds were measured in a water sample from interval 1 (72 to 119 ft bls) and are probably associated with a high-angle fracture at 84 ft bls that strikes N. 54° E. and dips 56° SE. Concentrations of detected compounds increased with depth.

Water samples from well MG–1699 had low concentrations of VOC's. Three compounds were detected, and the compound with the highest concentration was toluene (65 μg/L). The highest concentrations of all compounds were measured in a water sample from interval 2 (72 ft bls to 97 ft bls) and possibly are associated with a rough area of the borehole at 85 ft bls that may have one or more partially filled, high-angle fractures dipping to different azimuths. Concentrations of detected compounds were highest in samples from this interval and were not associated with any particular fracture.

Water samples from well BK–2942 had the highest total concentrations of VOC's and the highest concentrations of TCE, ranging from 270 to 760 μg/L. The highest concentrations of most compounds were measured in a water sample from interval 2 (177 ft bls to 202 ft bls) and probably are associated with a water-bearing, high-angle fracture at 186 ft bls that strikes N. 79° E. and dips 55° SE. This corresponds to the high-angle set of fractures at the site that dip almost 90° to the bedding plane. Concentrations of detected compounds were lower above and below this fracture.

Water samples from well MG–1722 has the highest number of VOC's detected. Ten compounds were detected; the compound with the highest concentration was 1,1-dichloroethene (46 μg/L). The highest concentrations of almost all these compounds were measured in a water sample from interval 3 (64 ft bls to 84 ft bls) and probably are associated with a low-angle fracture at 75 ft bls that strikes N. 82° E. and dips 17° NW. This corresponds to the bedding-plane set of fractures at the site. Concentrations of detected compounds were lower above and below this fracture.

Detected VOC compounds were not distributed evenly throughout the wells. Concentrations increased with depth in well MG–1697 and probably were associated with a high-angle fracture. Concentrations in water samples from well MG–1699 were highest at an intermediate depth but were not associated with a particular fracture. Concentrations in water samples from wells BK–2942 and MG–1722 were associated with discrete fractures at intermediate depths—a high-angle fracture in well BK–2942 and a bedding-plane parting in well MG–1722.

All samples were analyzed for radon-222 activity by the USGS-New Jersey District as part of their ongoing radon study. The highest concentrations of radon-222 were detected in a water sample from well MG–1699 (4,600 pCi/L). Radon-222 was not distributed evenly throughout the wells. The highest radon-222 activity in each well was associated with fractures that produced water under nonpumping conditions.

Table 38. *Summary of concentrations of selected volatile organic compounds and radon in ground water at the North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania*

[ft, feet; µg/L, micrograms per liter; pCi/L, picocuries per liter; <, less than]

U.S. Geological Survey borehole-identification number	Site identification number	Interval	Isolated depth interval (ft below land surface)	Chloroform (µg/L)	1,1-Dichloro-ethane (µg/L)	1, 1-Dichloro-ethene (µg/L)	1,2-Dichloro-ethene (total) (µg/L)	Methylene chloride (µg/L)	4-Methyl-2-pentanone (µg/L)	Tetra-chloro-ethene (µg/L)	Toluene (µg/L)	1,1,1-Trichloro-ethane (µg/L)	Trichloro-ethene (µg/L)	Radon-222 (pCi/L)
MG-1697	RI-6	1	73-119	<25	<25	<25	<25	[1]0.48	<120	<25	[1]7.2	<25	[1]0.68	460
MG-1697	RI-6	2	48-71	<25	<25	<25	<25	[1].31	<120	<25	[1].91	<25	[1].54	420
MG-1697	RI-6	3	20-46	<25	<25	<25	<25	[1].18	<120	<25	[1].70	<25	[1].21	830
MG-1699	RI-8	1	112-123	<25	<25	<25	<25	<25	<120	<25	[1]4.0	<25	<25	4,600
MG-1699	RI-8	2	73-96	<25	<25	<25	<25	[1].49	<120	<25	65	<25	[1].30	2,700
MG-1699	RI-8	3	19-71	<25	<25	<25	<25	<25	<120	<25	27	<25	<25	2,230
BK-2942	RI-17	1	202-259	<25	<25	<25	[1]5.1	[1]19	<120	<25	[1]2.7	<25	270	2,580
BK-2942	RI-17	2	178-201	<25	<25	<25	[1]15	[1]23	<120	<25	<25	<25	760	3,180
BK-2942	RI-17	3	117-140	<25	<25	<25	[1]11	[1]8.1	<120	<25	<25	<25	550	2,600
BK-2942	RI-17	4	86-109	<25	<25	[1]3.0	[1]11	[1]4.2	<120	<25	[1]3.0	<25	570	2,670
BK-2942	RI-17	5	42-65	<25	<25	[1]3.1	[1]11	[1]14	<120	<25	[1]5.9	<25	640	140
MG-1722	RI-20	1	119-147	<25	[1].45	[1]1.9	[1].42	[1].17	<120	<25	[1]1.7	[1]1.2	[1]7.4	1,850
MG-1722	RI-20	2	99-117	<25	[1].44	[1]1.9	[1].40	[1].22	<120	<25	[1].57	[1]1.3	[1]6.8	1,860
MG-1722	RI-20	3	65-83	[1].18	[1]2.2	46	[1]1.3	[1].34	<120	[1].63	[1]1.4	[1]22	61	1,630
MG-1722	RI-20	4	19-49	<25	[1].46	[1]2.3	[1].41	[1].16	[1]1.2	<25	[1]1.8	[1]1.8	[1]7.4	1,610

[1] Denotes detected value below reporting limits (120 µg/L for 4-Methyl-2-pentanone, 25 µg/L for all other listed volatile organic compounds).

SYNOPTIC WATER-LEVEL MEASUREMENTS

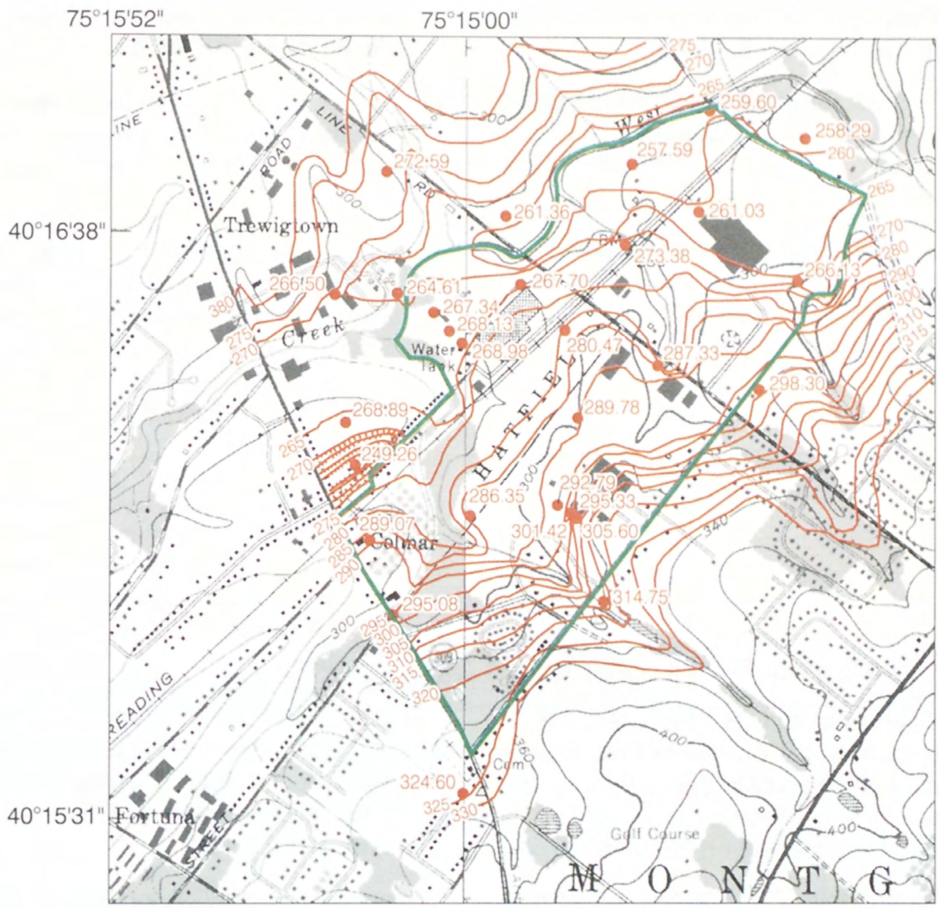
Water levels were measured in 30 open boreholes on July 13, 1998. Because all water levels were measured in open boreholes, they represent composite hydraulic heads. The data were used to prepare a potentiometric-surface map (fig. 21). Ground water at the site generally flows northwest to the West Branch Neshaminy Creek, which forms the northwest boundary of the site, where it discharges to the creek. The creek drains the area at the northeastern edge of the site. Ground water from the area northwest of the West Branch Neshaminy Creek flows generally southeast, where it discharges to the creek. Water levels are depressed in the vicinity of well MG–1691 because of pumping of nearby public-supply well MG–914 (NP–12C). Vertical hydraulic gradients were found in most open boreholes during geophysical logging, but there was no predominant direction of vertical flow at the site.

SUMMARY

Borehole geophysical logs were run in 32 wells at the North Penn Area 5 Superfund Site in Bucks and Montgomery Counties, Pa. The logging results were used to determine locations for screens in the reconstruction of 21 monitor wells. Digital acoustic-televiewer logs were correlated with borehole television surveys and heatpulse-flowmeter data to define bedding-plane, fracture, and water-bearing interval orientations. Bedding-plane features selected from the acoustic-televiewer logs had a mean dip azimuth (direction of maximum dip angle) of 332° (strike of N. 62° E.) and a dip angle of 27° NW. The largest group of water-bearing fractures were high-angle fractures that had a dip azimuth of 136° (strike of N. 46° E.) and a dip angle of 72° SE. Mean strike for the high-angle water-bearing fractures was N. 58° E., which almost exactly matched the formation strike. The mean dip angle of the high-angle fractures was 81° SE. off the mean dip angle of the bedding planes (27° NW.), which is nearly perpendicular to them. Eighty-three percent of all detected water-bearing fractures were high-angle fractures.

Aquifer-isolation tests were run in four wells. Specific capacities were calculated for each pumping step in each of 16 intervals tested. Samples for VOC's were collected in each isolated interval. Ten compounds were detected, and three compounds—TCE, methylene chloride, and toluene—were detected in all four wells. Water samples from well BK–2942 had the highest total concentration of VOC's, water samples from well MG–1722 had the highest number of compounds detected, water samples from well MG–1697 had the lowest total concentrations of VOC's, and water samples from well MG–1699 had the least number of VOC's detected. VOC's were detected in water samples from both high-angle water-bearing fractures and bedding-plane water-bearing fractures. Detected compounds were not distributed evenly throughout the wells. Contaminants were detected in water samples from shallow, intermediate, and deep intervals and were associated with high-angle fractures, bedding-plane partings, and rough areas of the borehole that showed no distinct fractures. All samples were analyzed for radon-222 content by the USGS-New Jersey District. Radon-222 was not distributed evenly throughout the wells, but higher activities were associated in all wells with water samples from fractures that were water-producing under nonpumping conditions.

Water levels were measured in 30 open boreholes prior to reconstruction/screening on July 13, 1998. These levels were used to prepare a potentiometric-surface map. Ground water flows across the site from higher elevations in the southeast to the West Branch Neshaminy Creek, where it discharges to the creek. Most boreholes had measurable vertical flow during geophysical logging, but there was no predominant direction to that flow.



Base from U.S. Geological Survey
Telford and Doylestown 1:24,000, 1927

0 0.25 0.5 0.75 1 MILE

0 0.25 0.5 0.75 1 KILOMETER

EXPLANATION

APPROXIMATE STUDY AREA BOUNDARY

—325— POTENTIOMETRIC CONTOUR.
Contour interval 5 feet, hachured where decreasing.

● 266.50 ALTITUDE OF STATIC WATER LEVEL MEASURED IN DRILLED WELL

Figure 21. Altitude and configuration of the potentiometric surface, July 13, 1998, at the North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

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APPENDIX

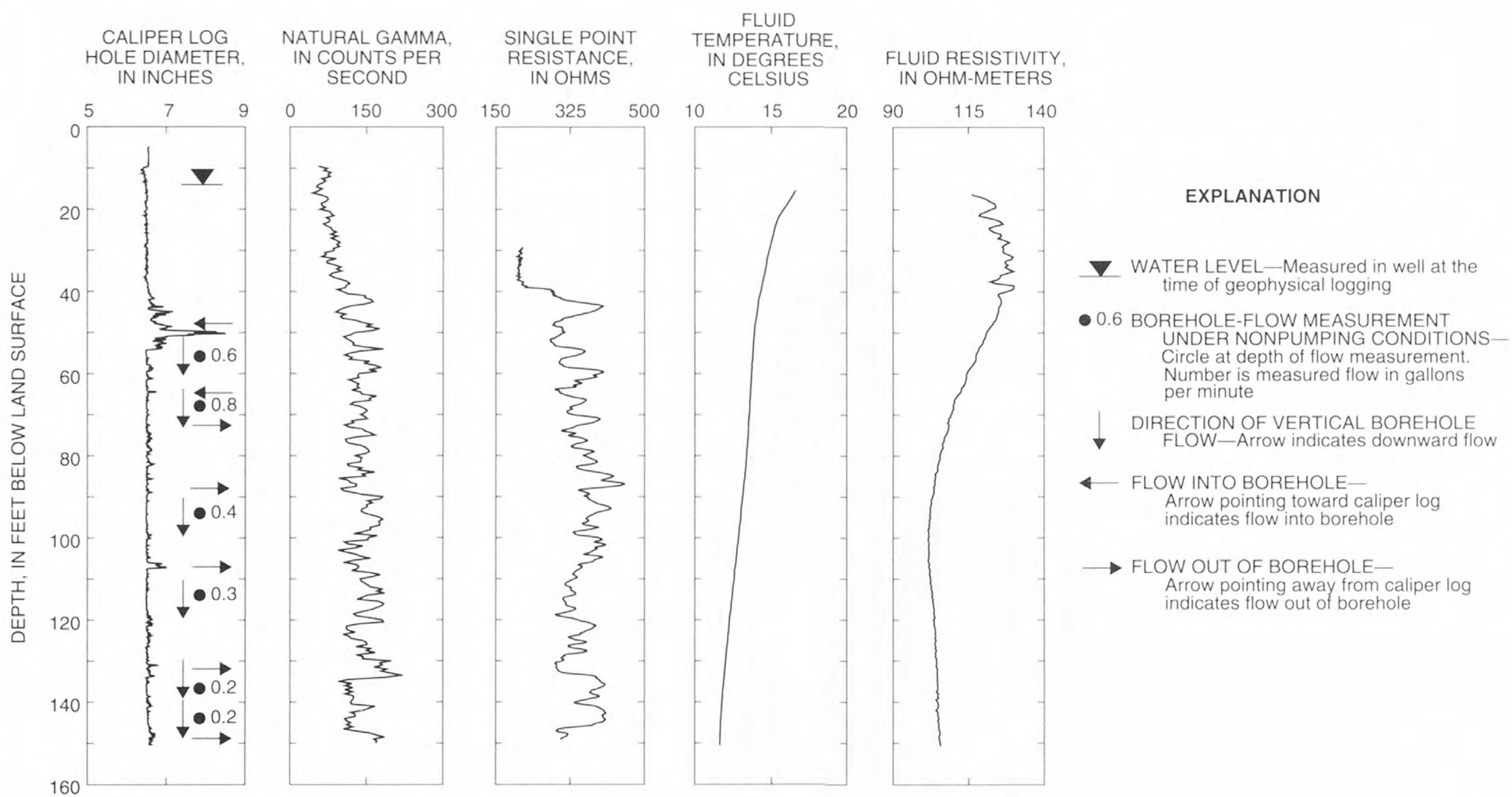

Figure 1a. Borehole geophysical logs from well MG-1723 (AV-1), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

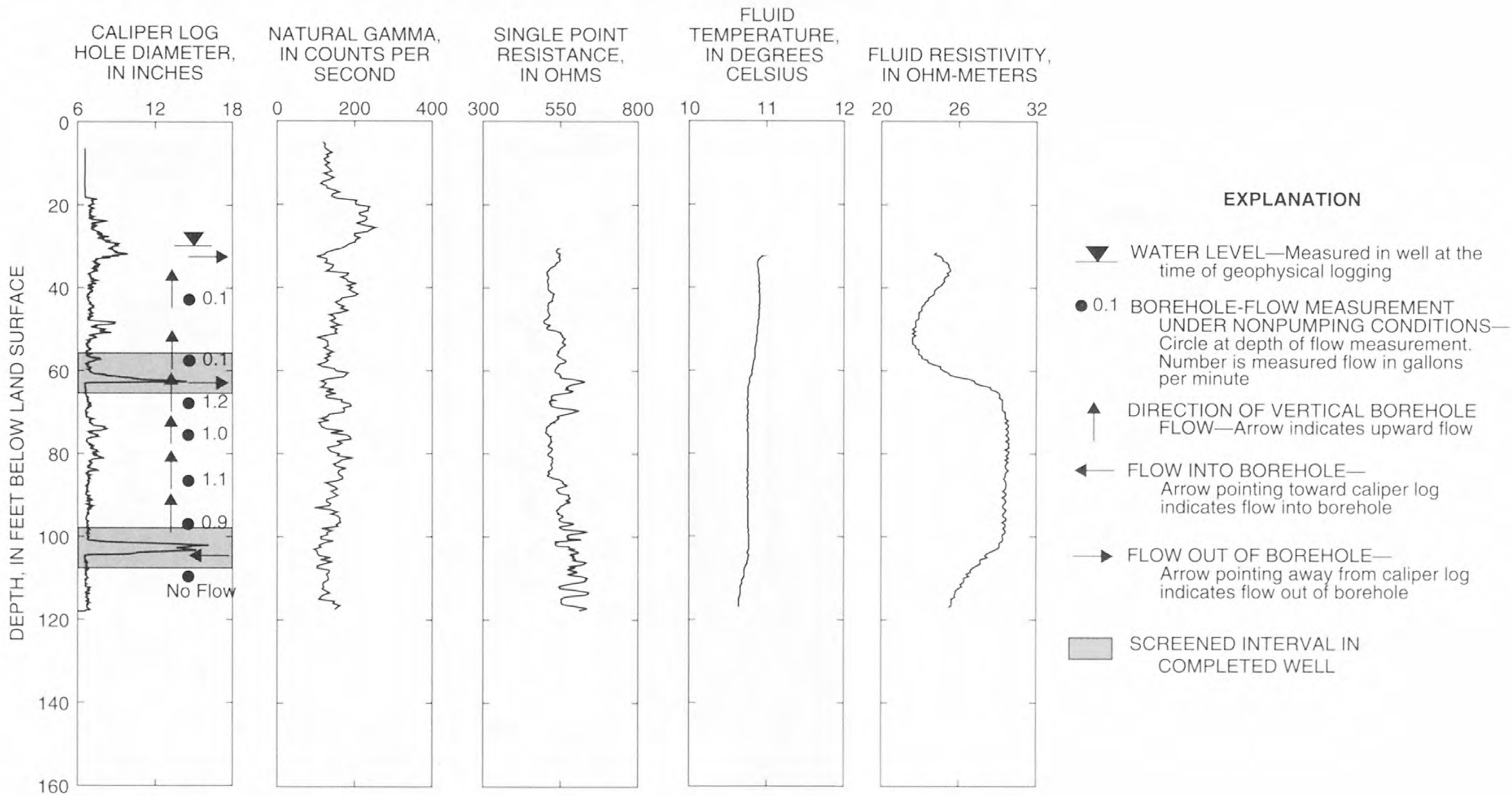

Figure 2a. Borehole geophysical logs from well BK-2938 (RI-1), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

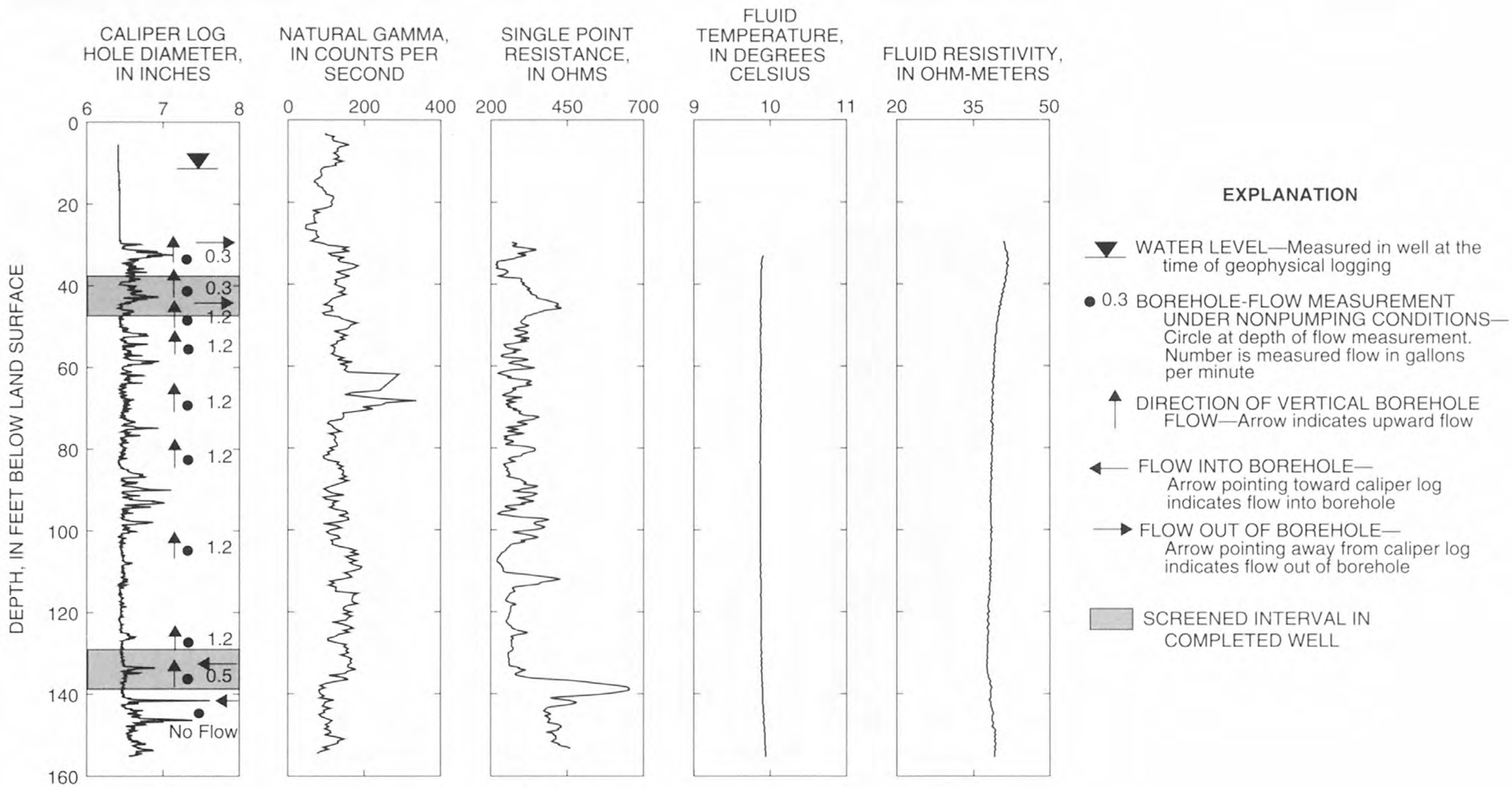

Figure 3a. Borehole geophysical logs from well BK-2939 (RI-2), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

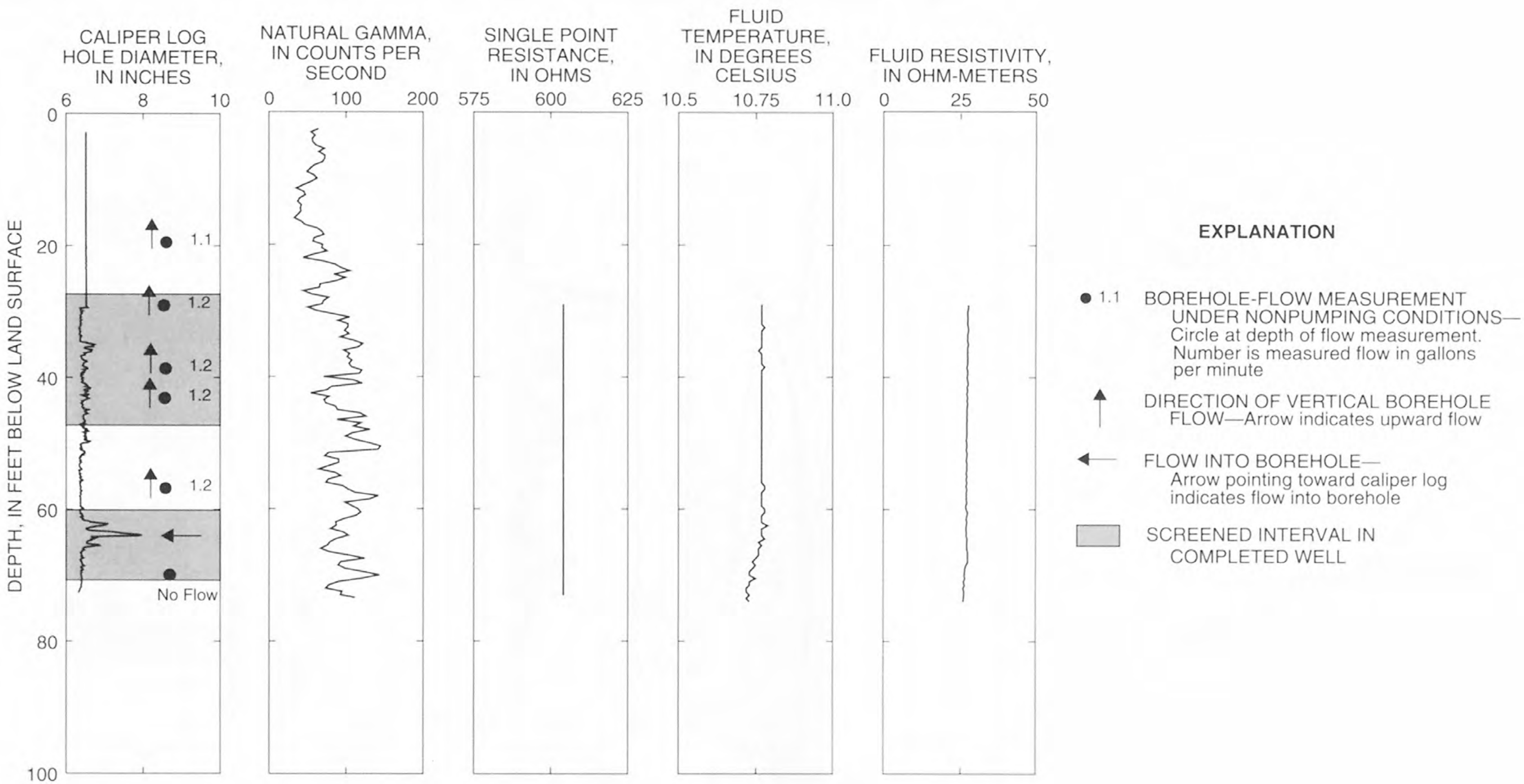

Figure 4a. Borehole geophysical logs from well MG-1694 (RI-3), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

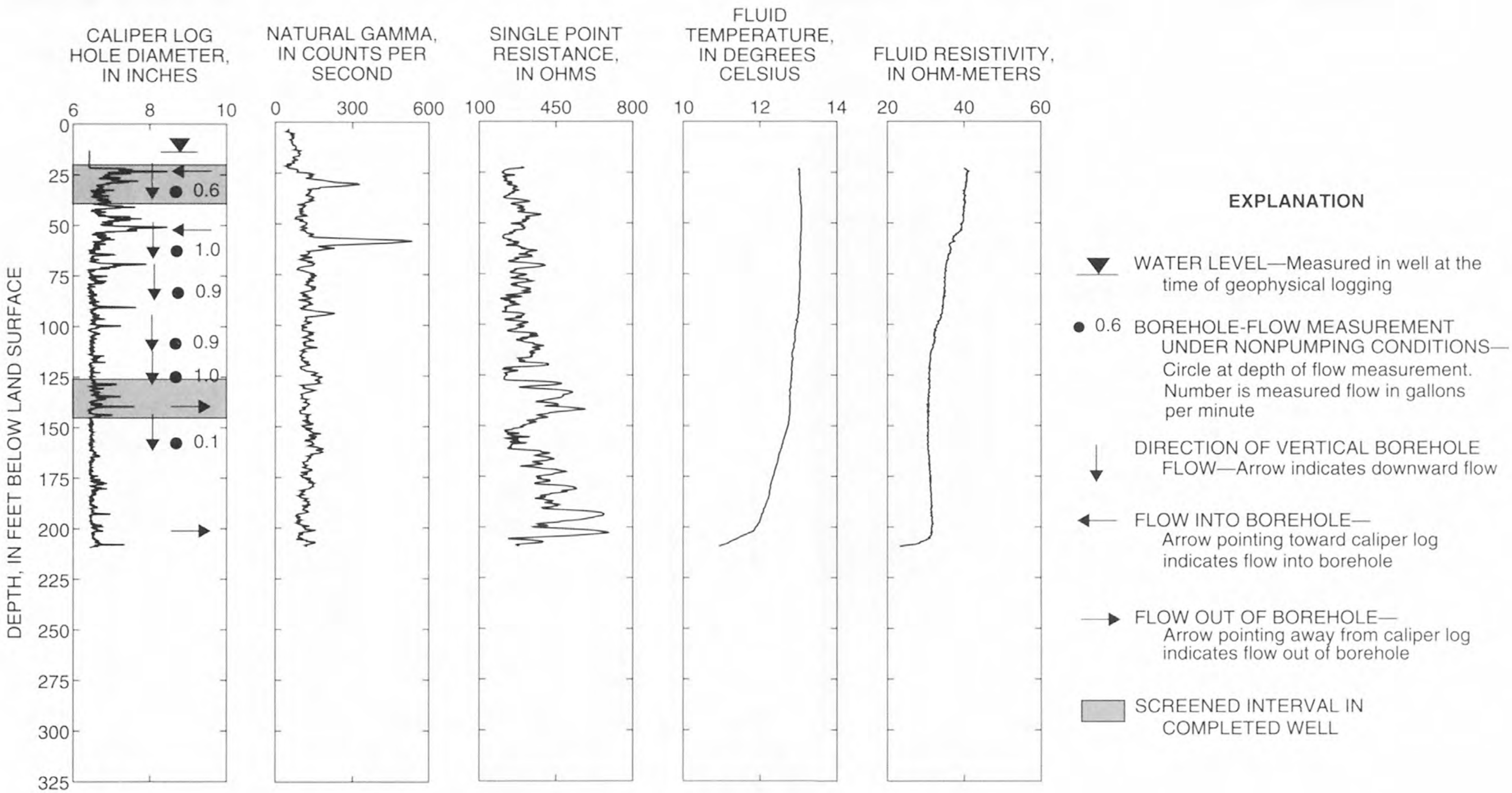

Figure 5a. Borehole geophysical logs from well MG-1695 (RI-4), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

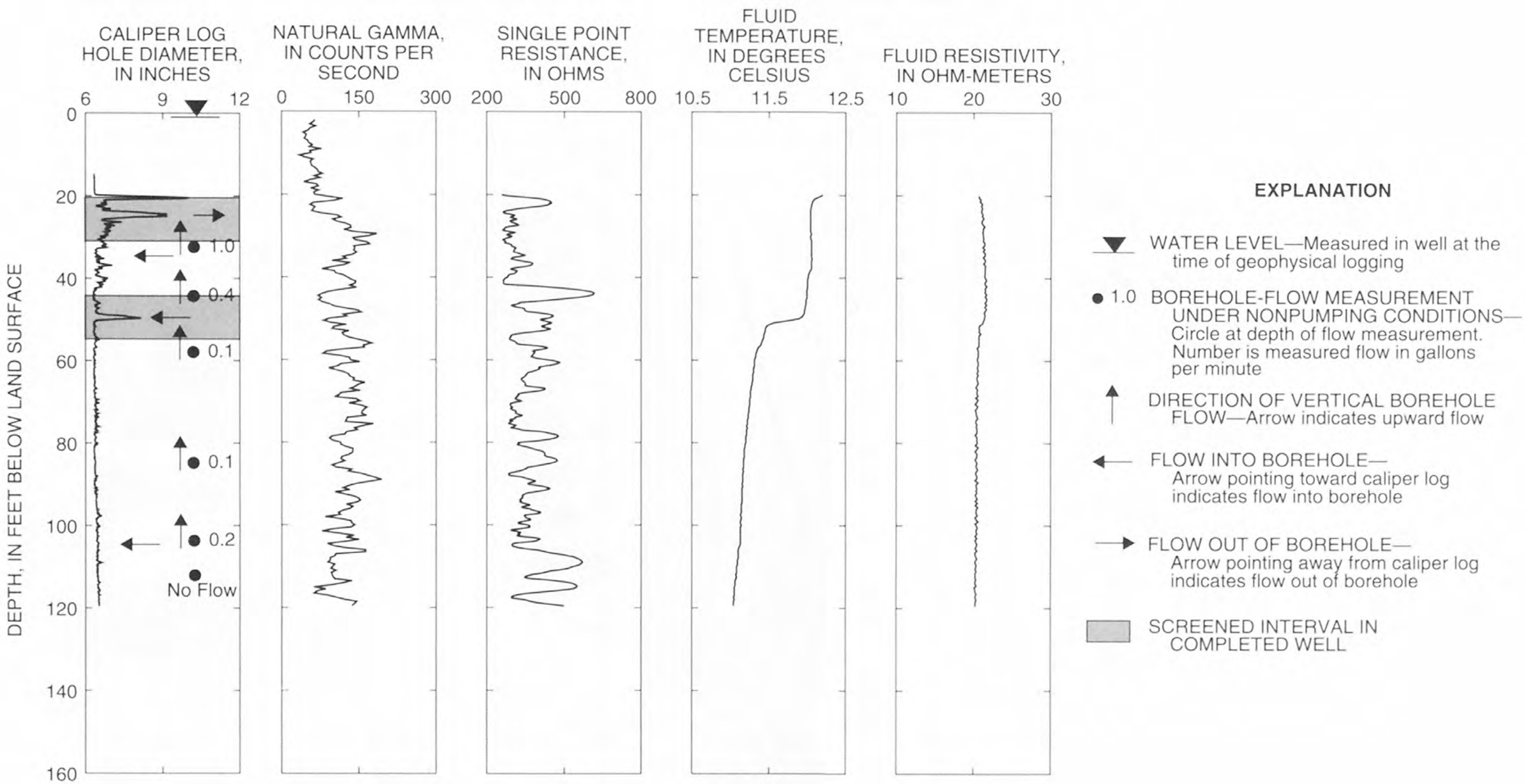

Figure 6a. Borehole geophysical logs from well MG-1696 (RI-5), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

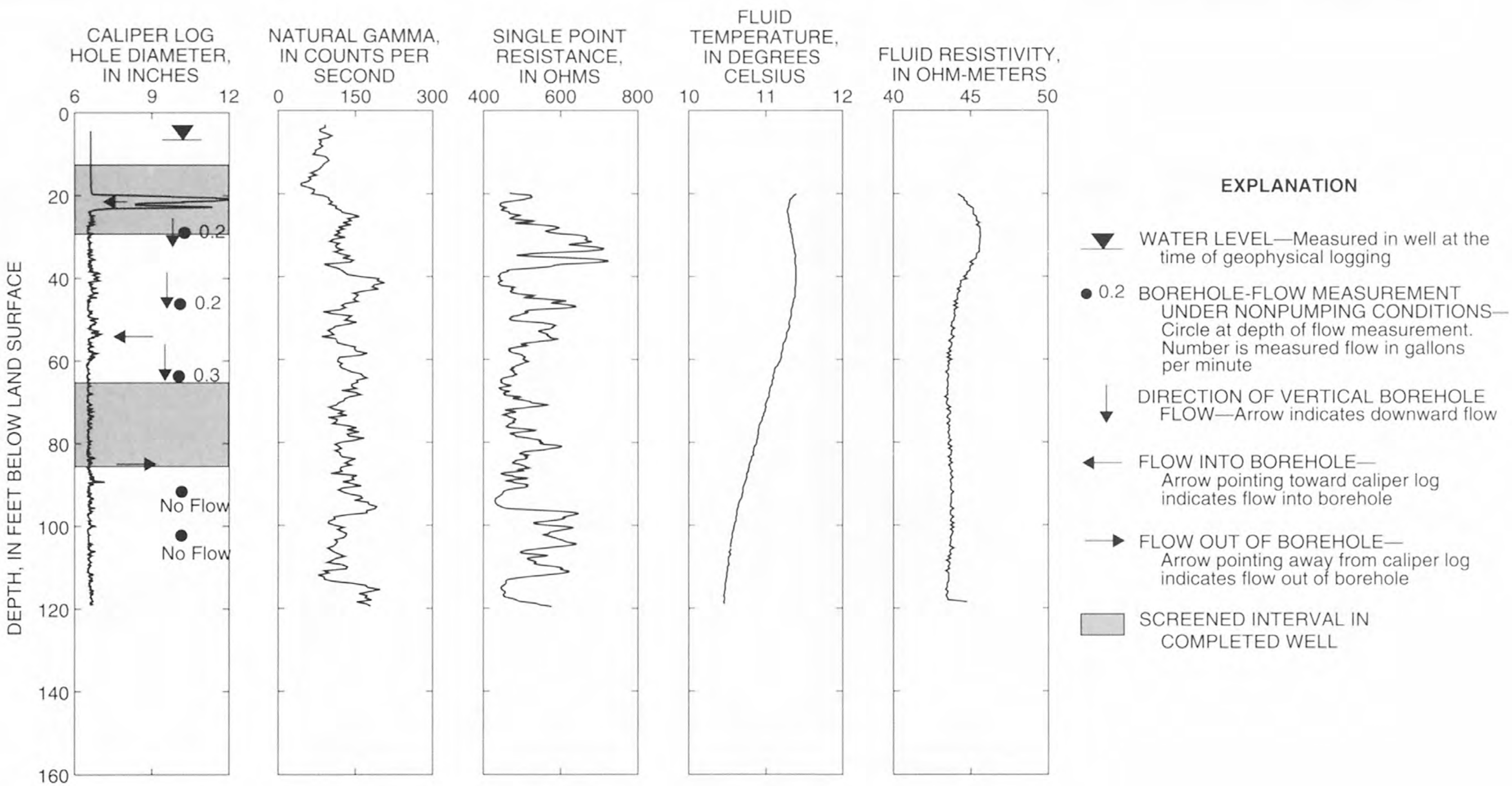

Figure 7a. Borehole geophysical logs from well MG-1697 (RI-6), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

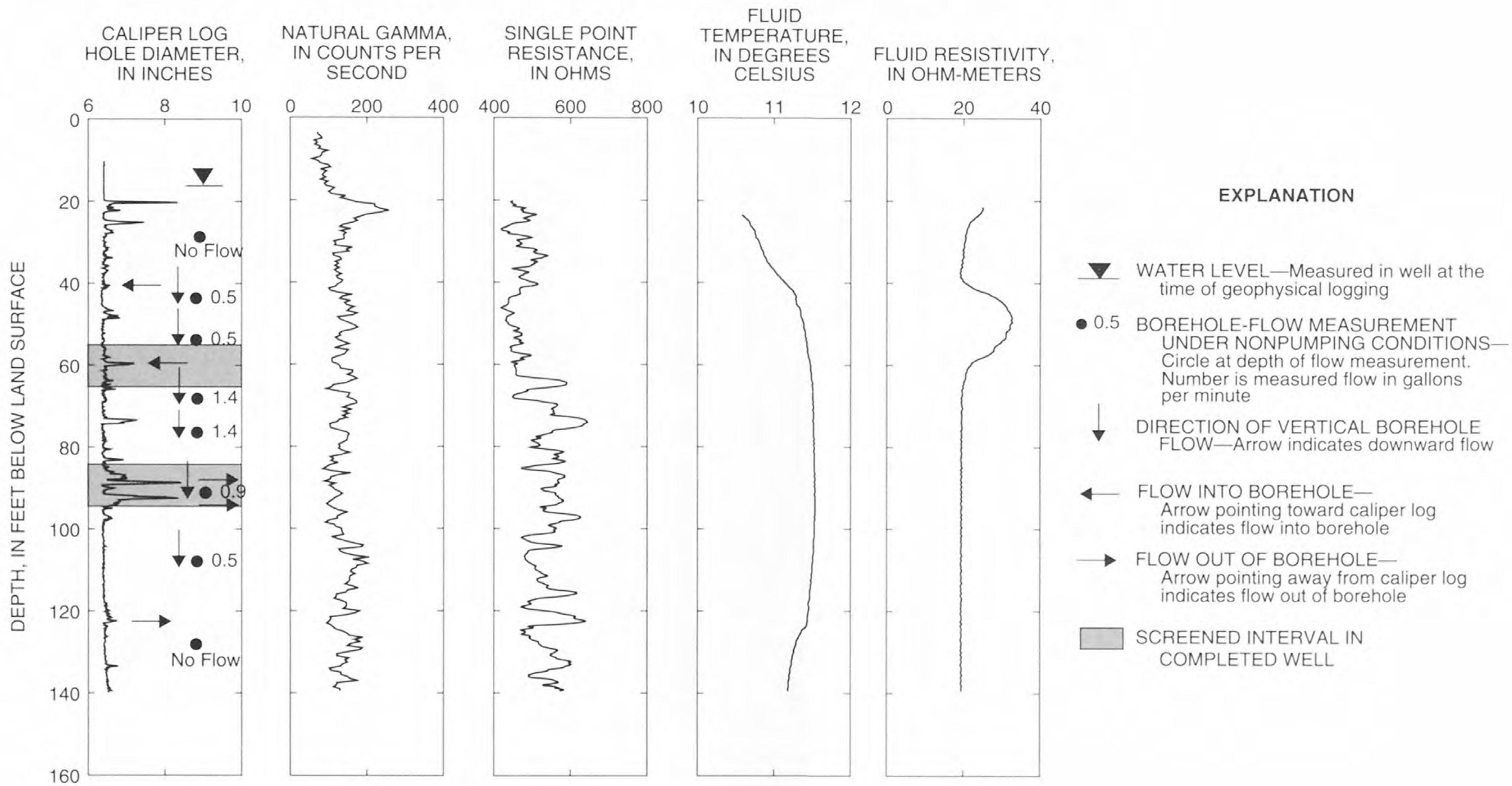

Figure 8a. Borehole geophysical logs from well MG-1698 (RI-7), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

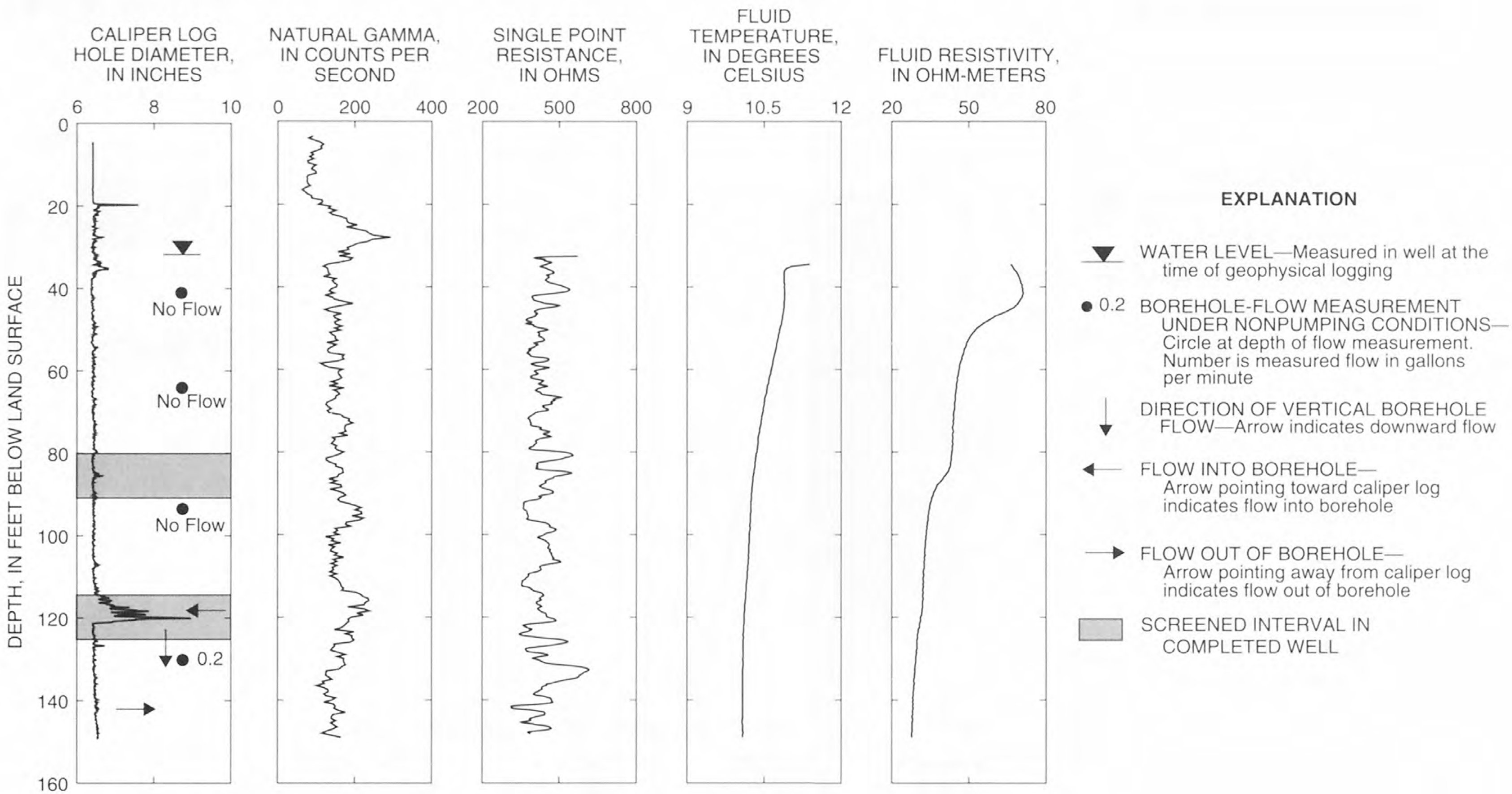

Figure 9a. Borehole geophysical logs from well MG-1699 (RI-8), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

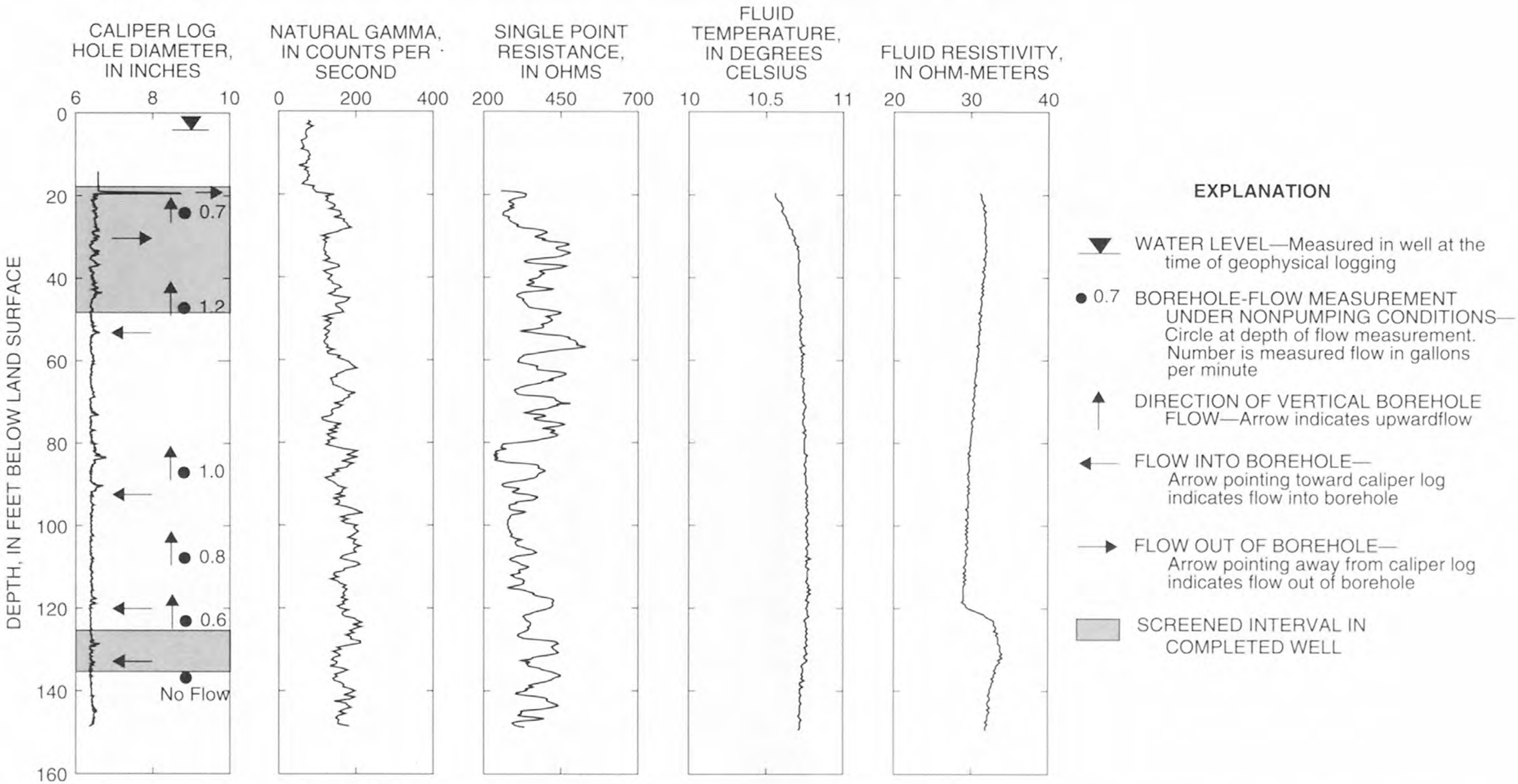

Figure 10a. Borehole geophysical logs from well MG-1700 (RI-9), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

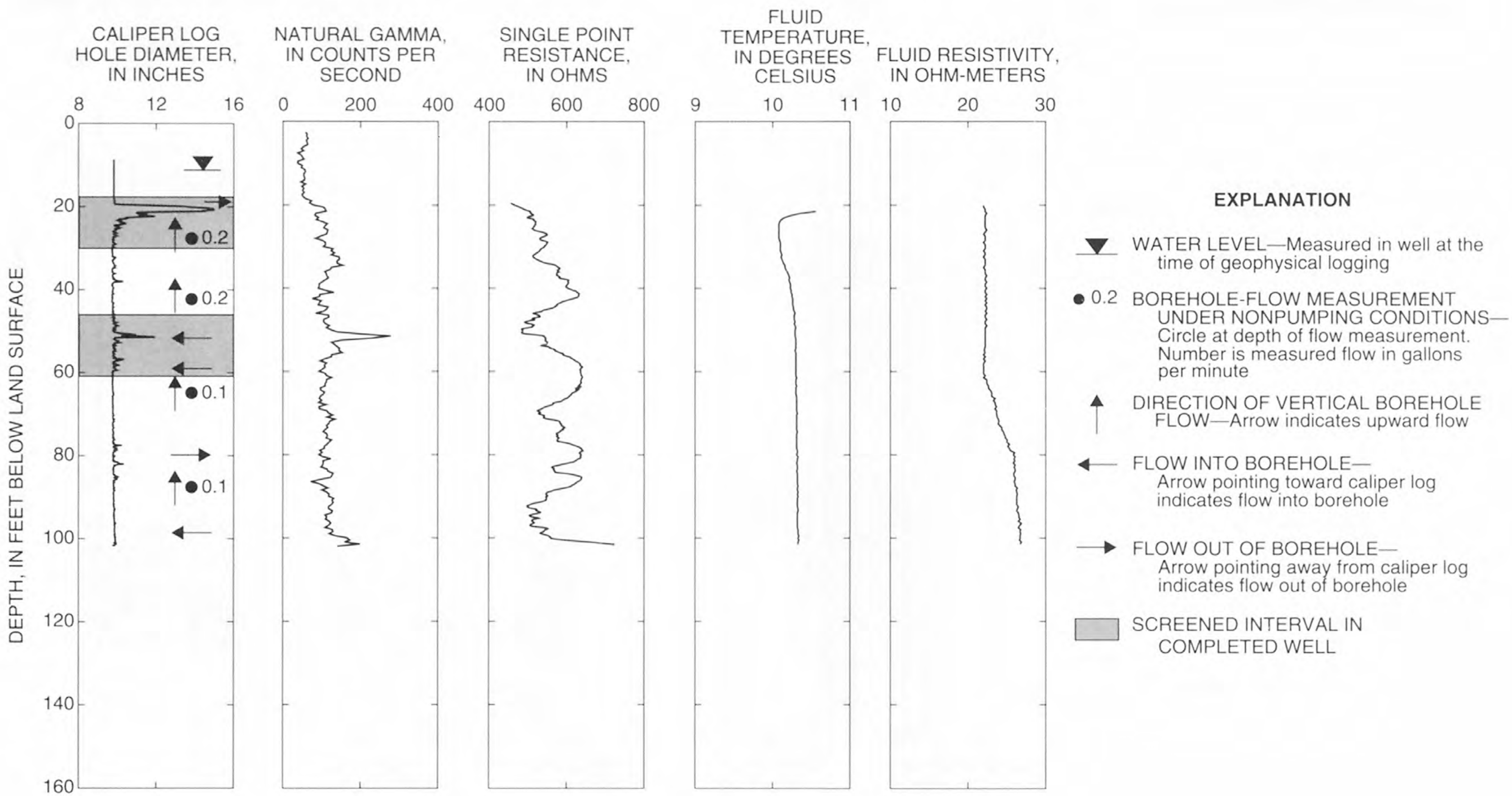

Figure 11a. Borehole geophysical logs from well BK-2936 (RI-10), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

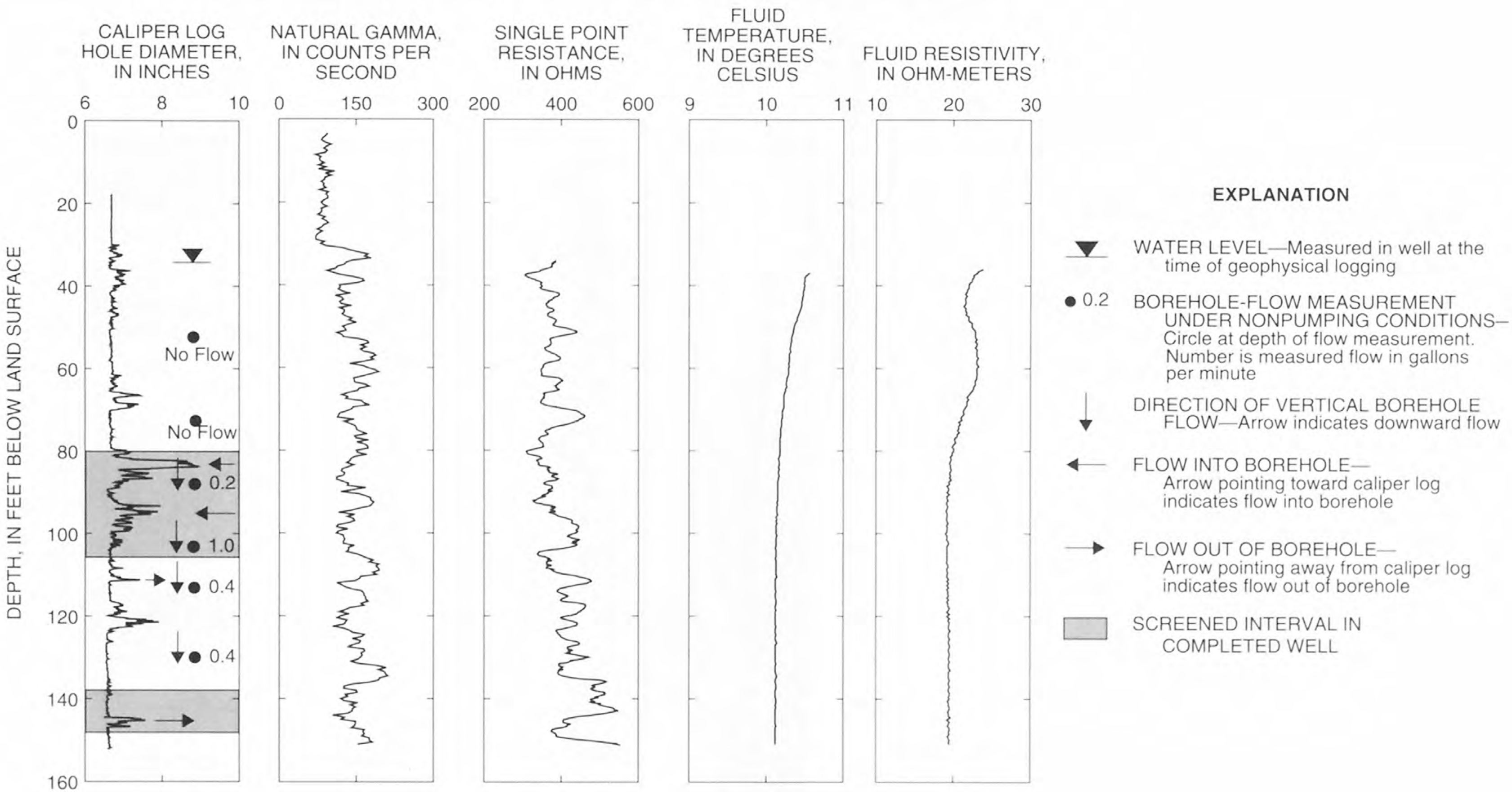

Figure 12a. Borehole geophysical logs from well MG-1716 (RI-11), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

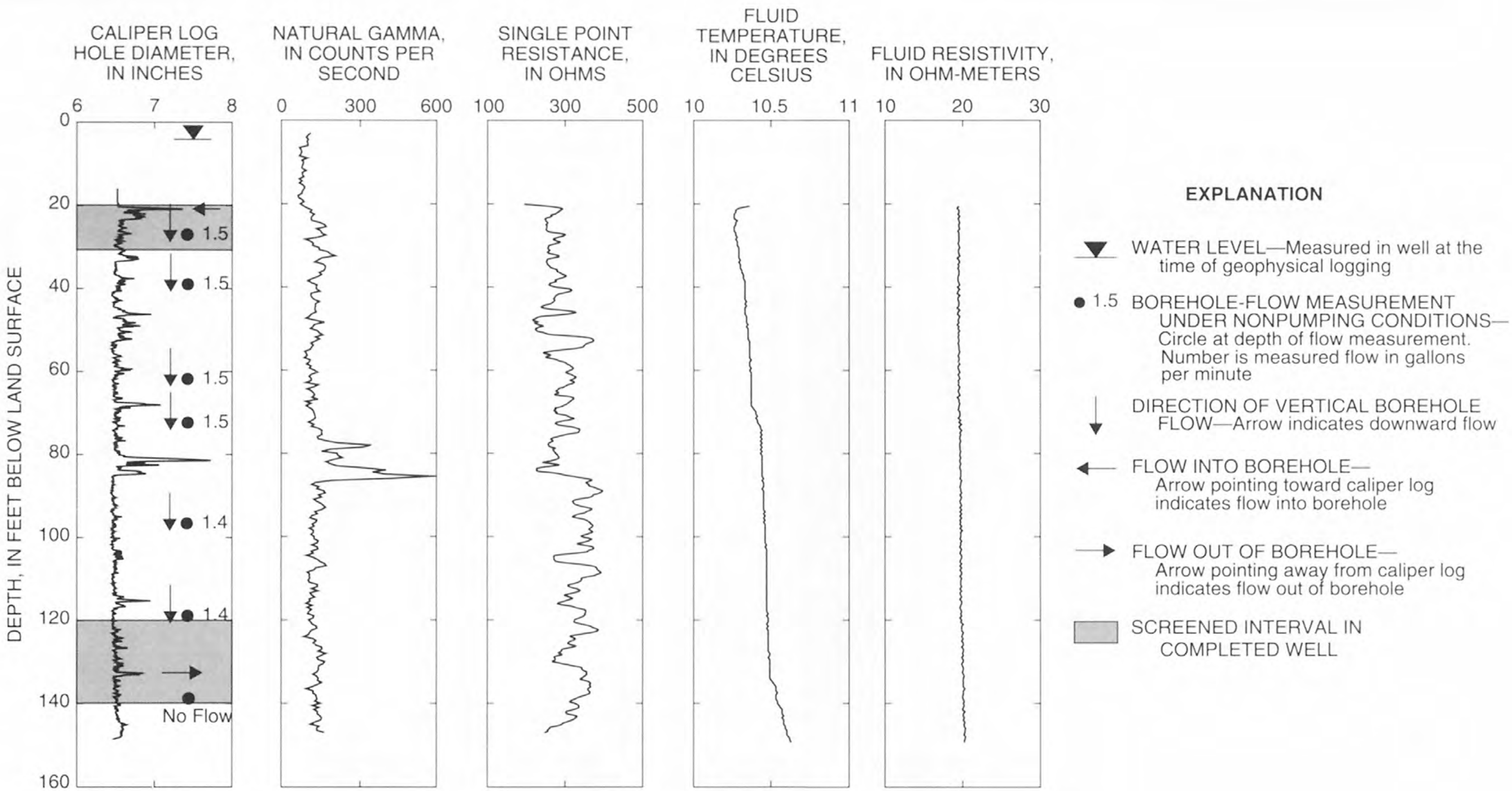

Figure 13a. Borehole geophysical logs from well MG-1717 (RI-12), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

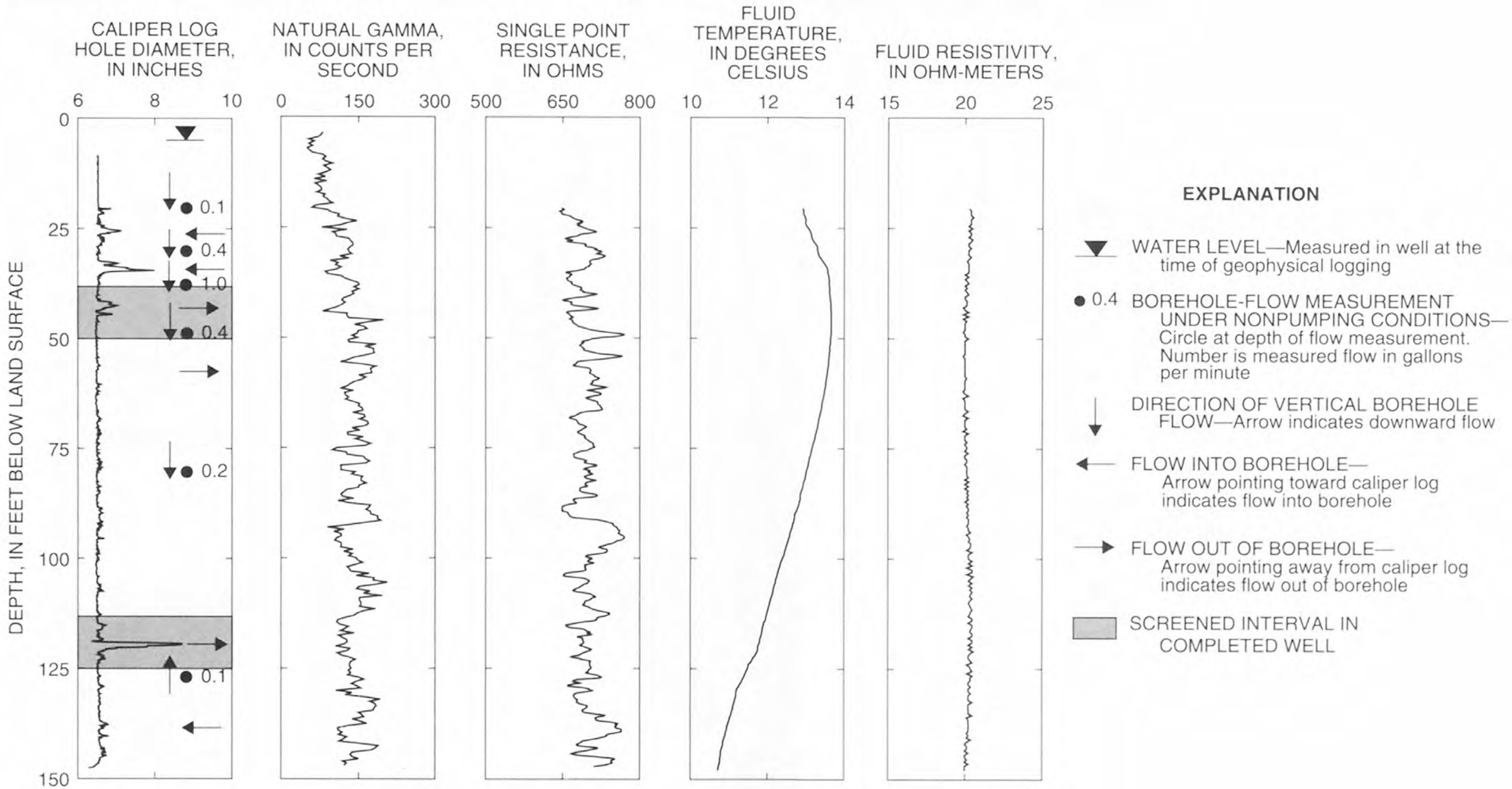

Figure 14a. Borehole geophysical logs from well MG-1718 (RI-13), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

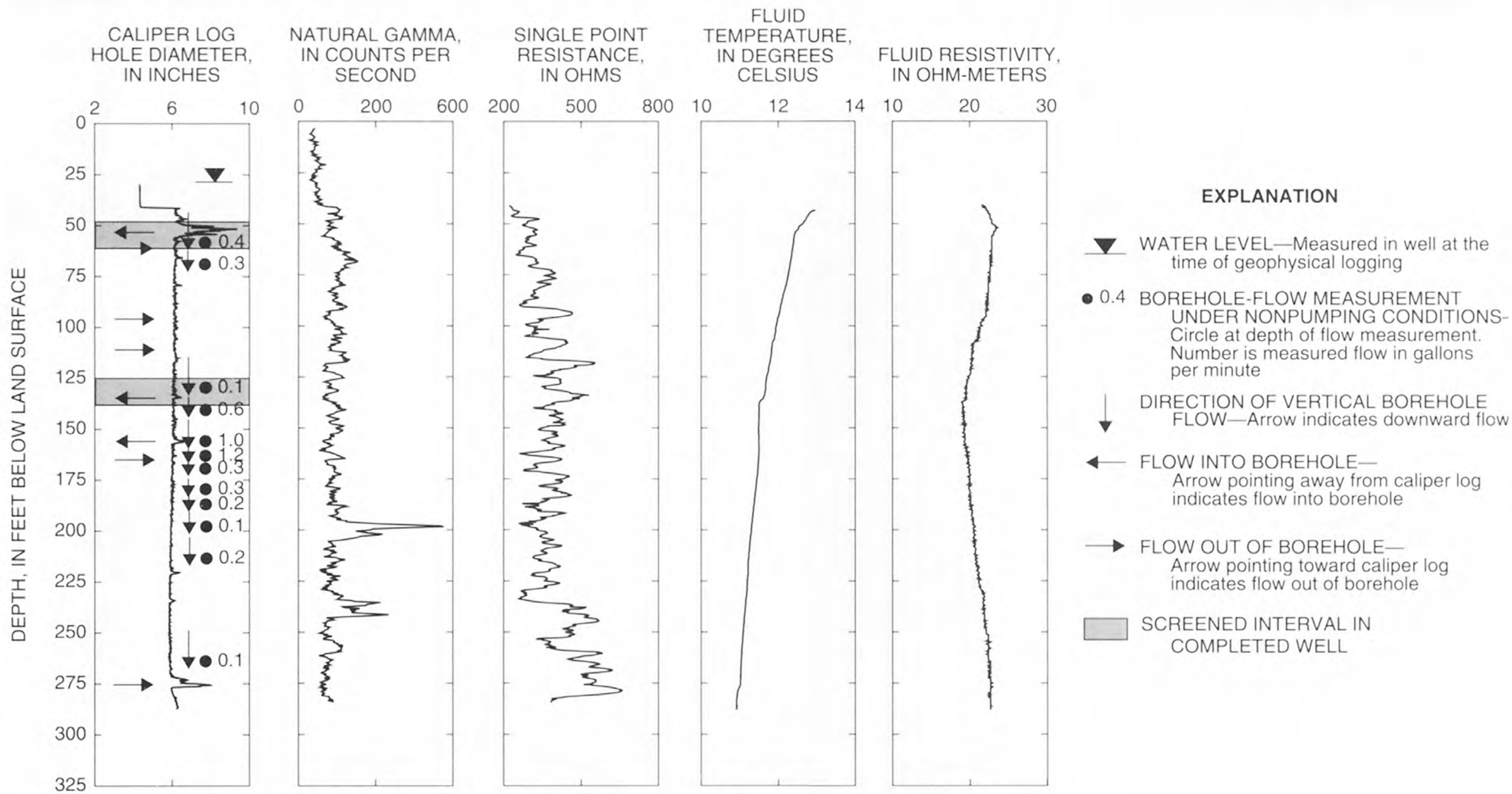

Figure 15a. Borehole geophysical logs from well MG-1719 (RI-14), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

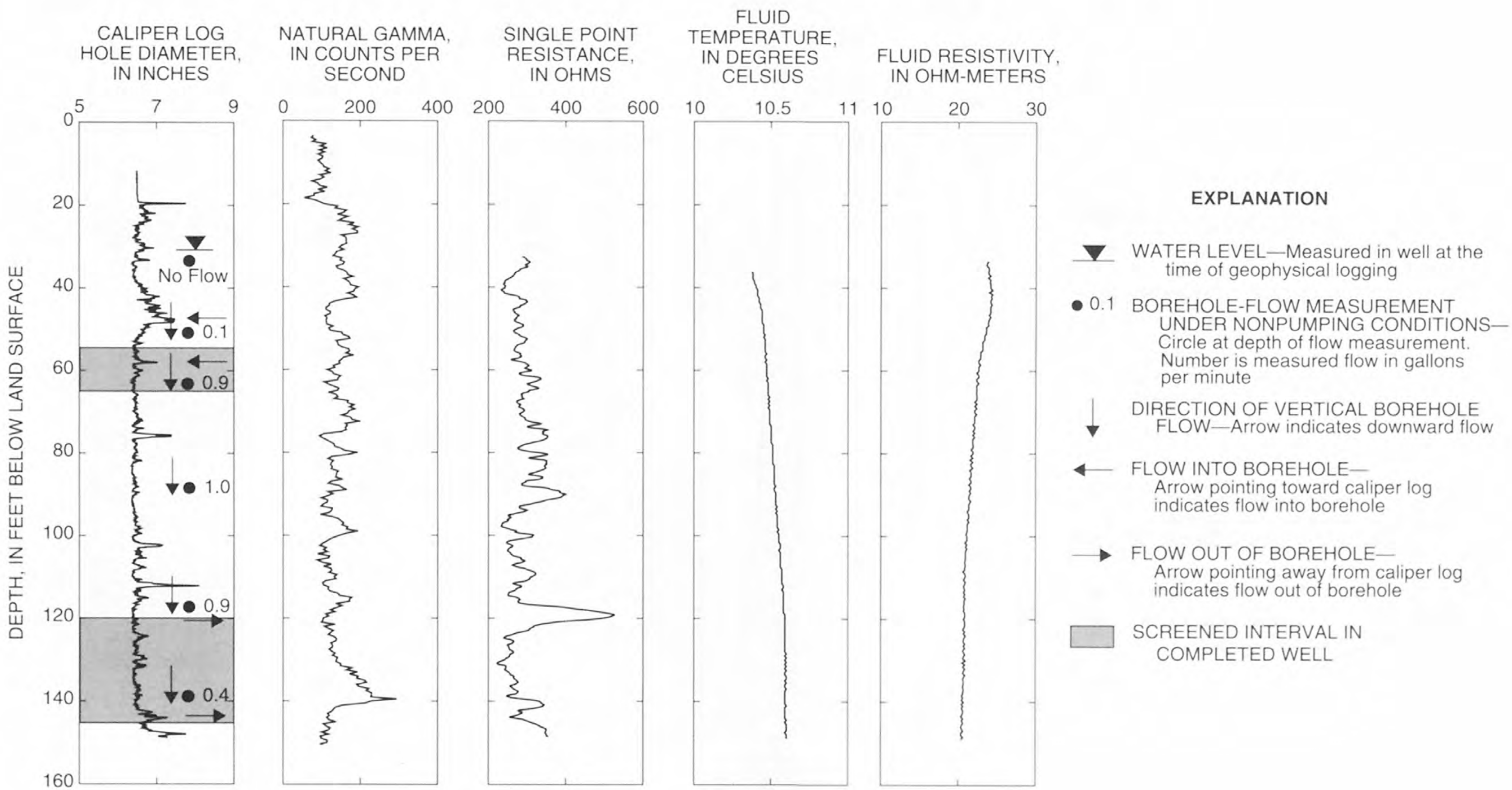

Figure 16a. Borehole geophysical logs from well BK-2940 (RI-15), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

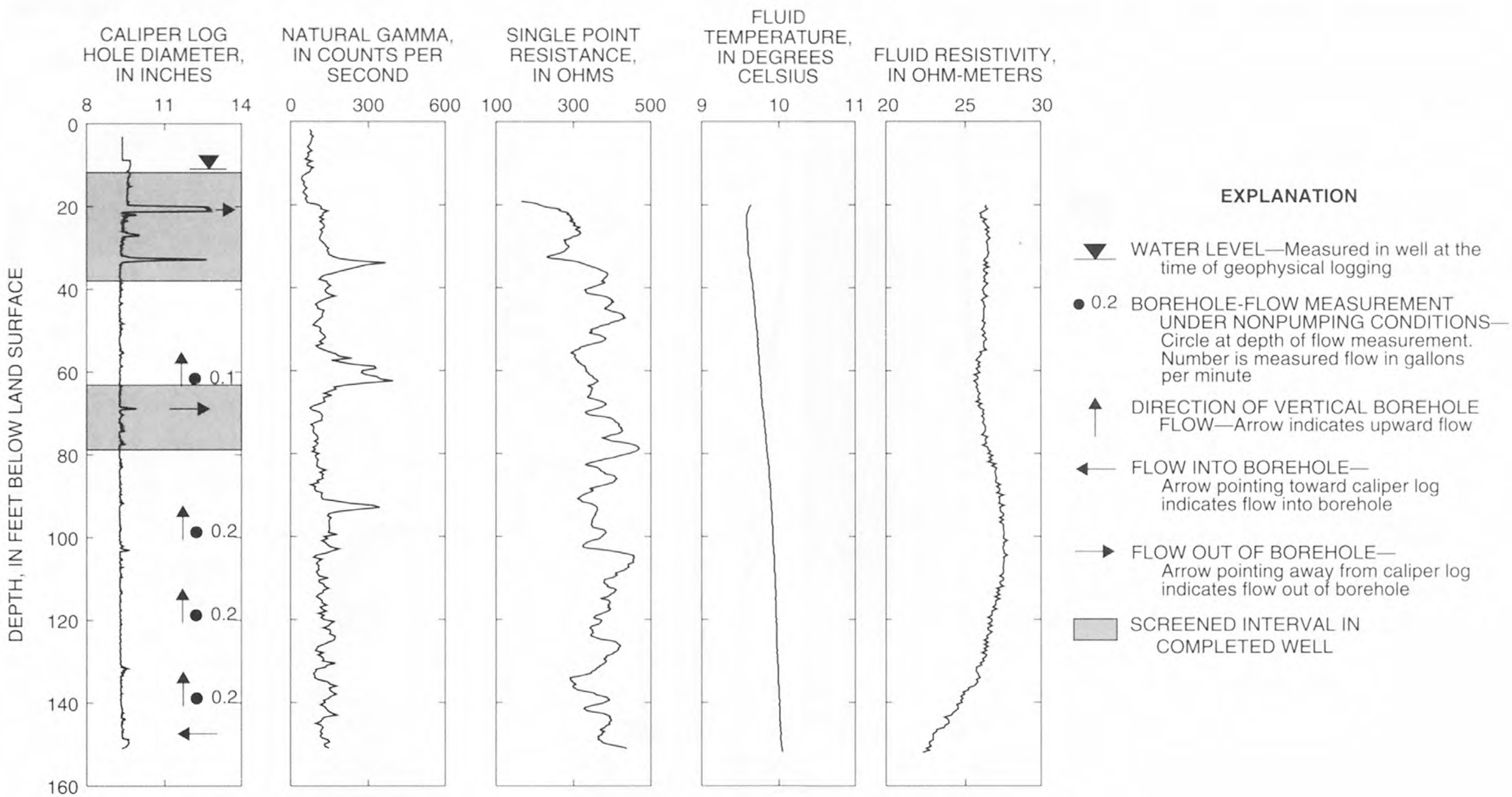

Figure 17a. Borehole geophysical logs from well BK-2941 (RI-16), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

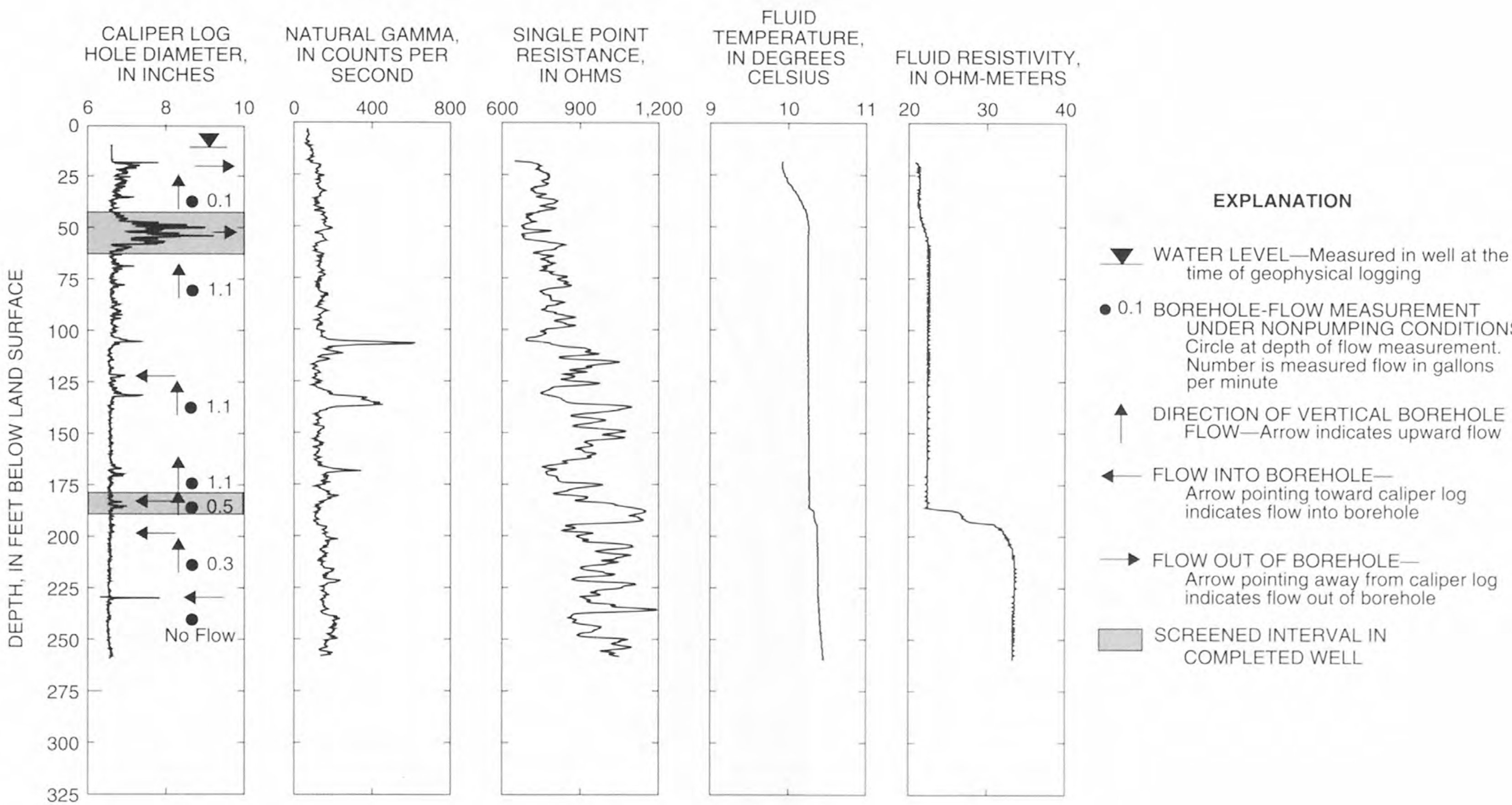

Figure 18a. Borehole geophysical logs from well BK-2942 (RI-17), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

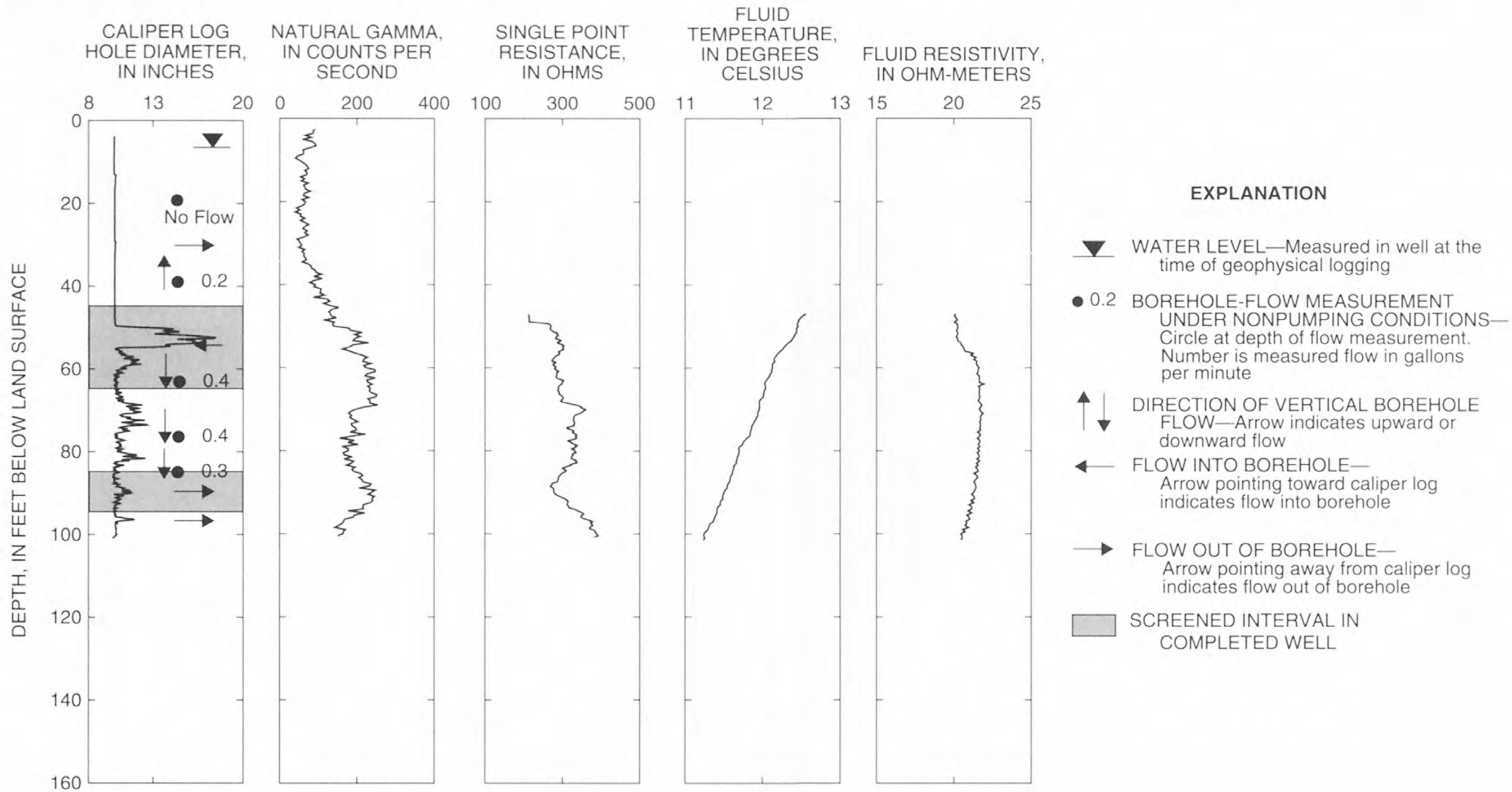

Figure 19a. Borehole geophysical logs from well MG-1720 (RI-18), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

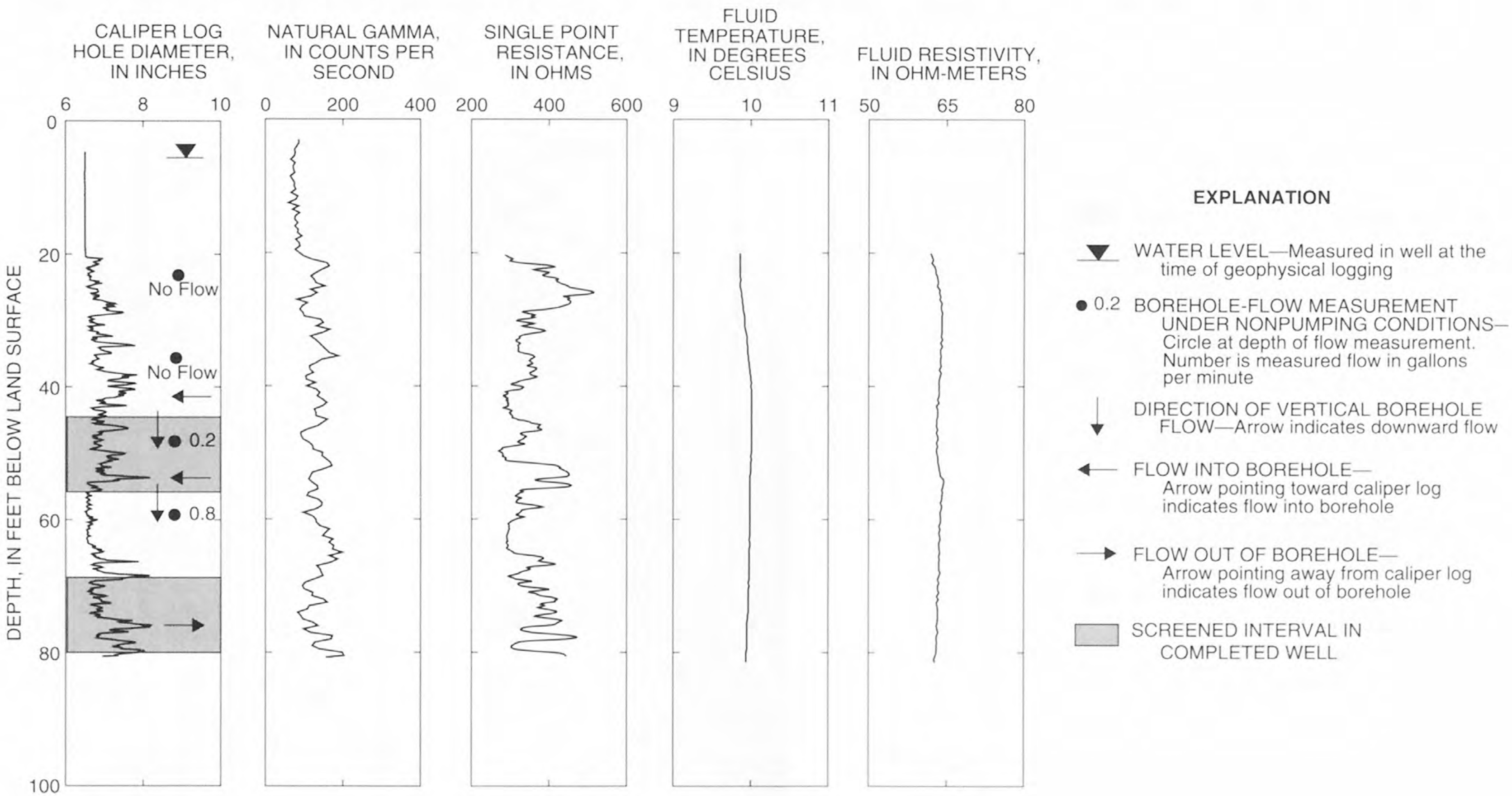

Figure 20a. Borehole geophysical logs from well MG-1721 (RI-19), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

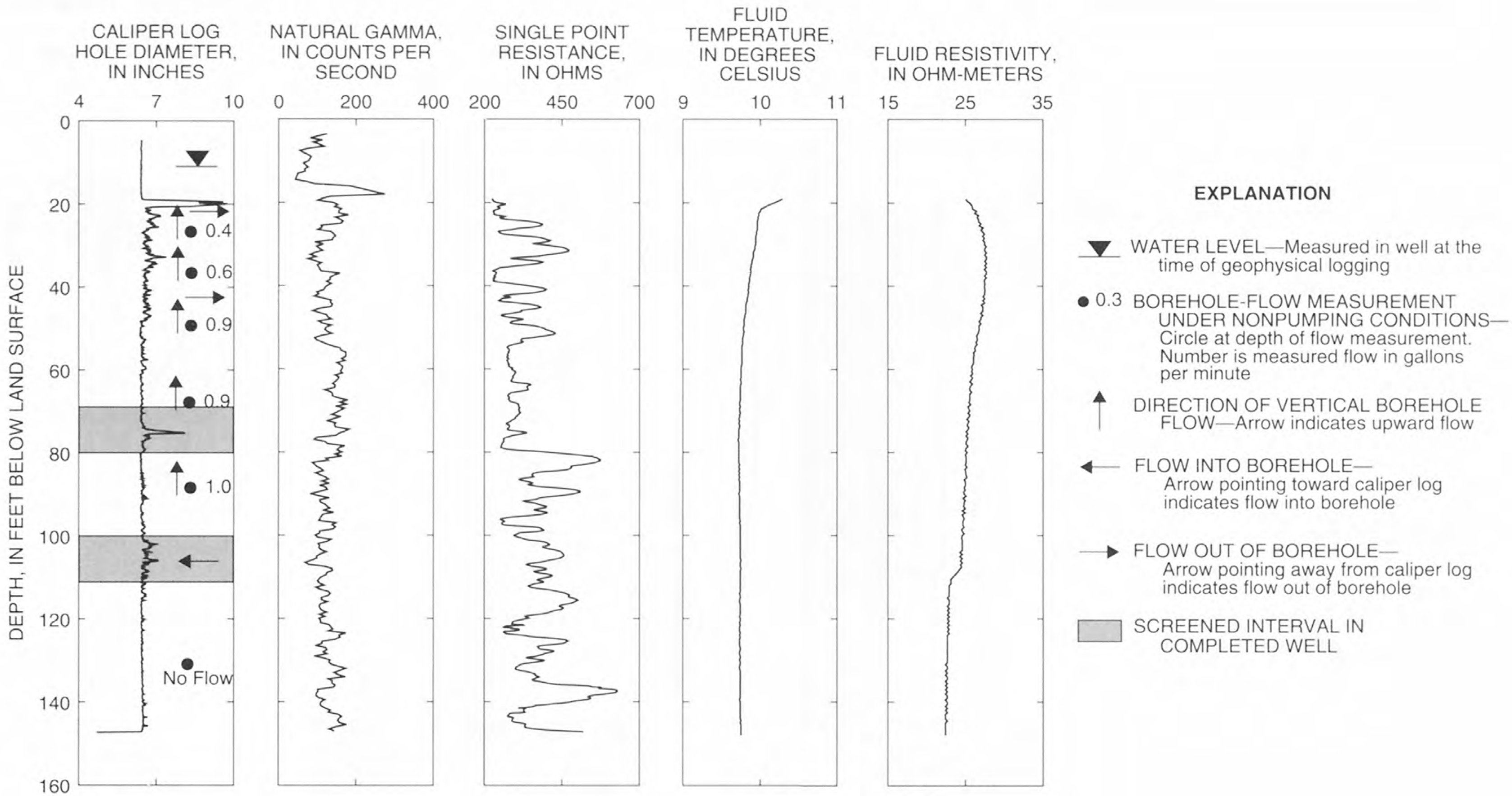

Figure 21a. Borehole geophysical logs from well MG-1722 (RI-20), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

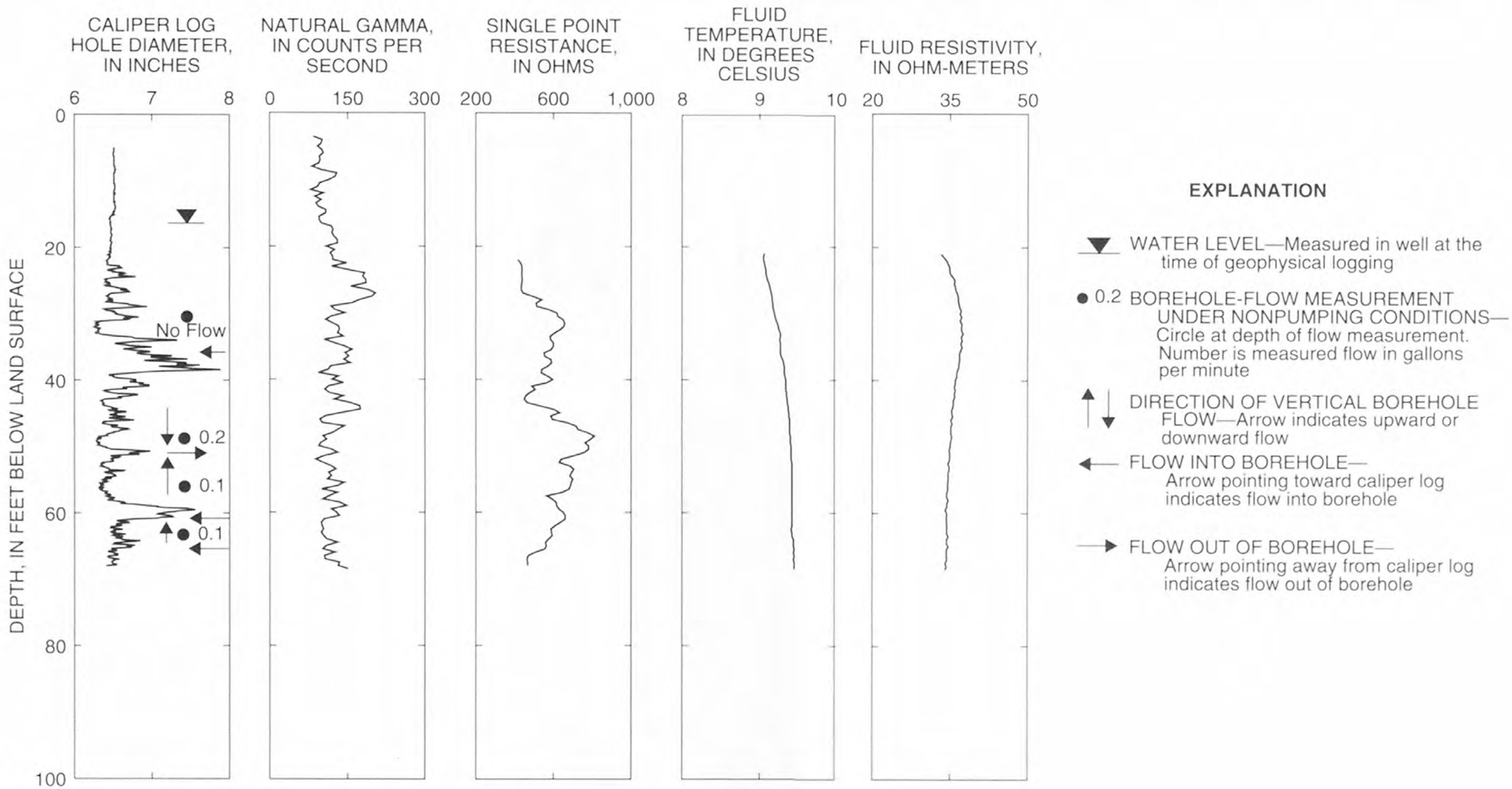

Figure 22a. Borehole geophysical logs from well MG-1153 (RW-1), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

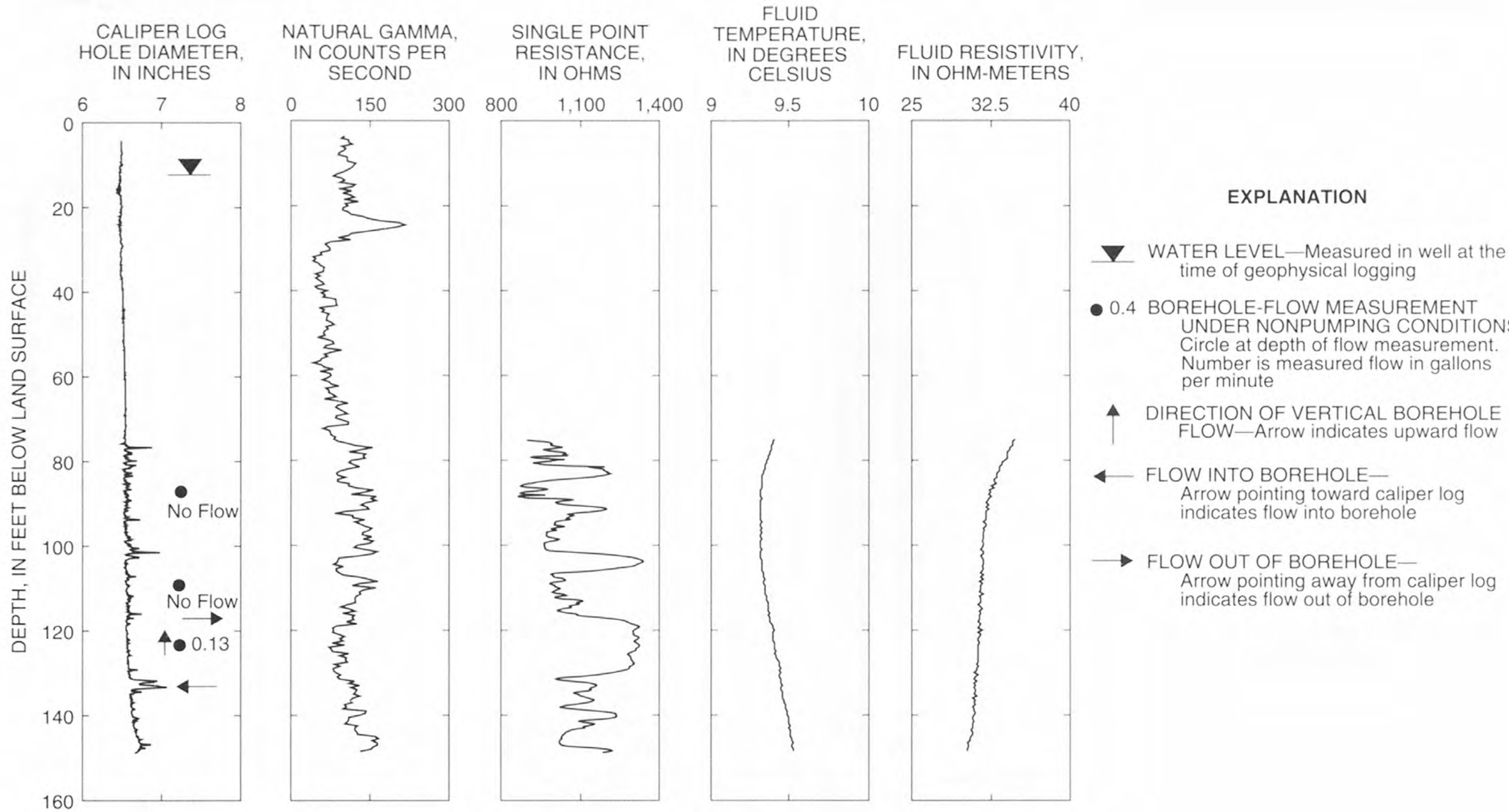

Figure 23a. Borehole geophysical logs from well MG-1154 (RW-2), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

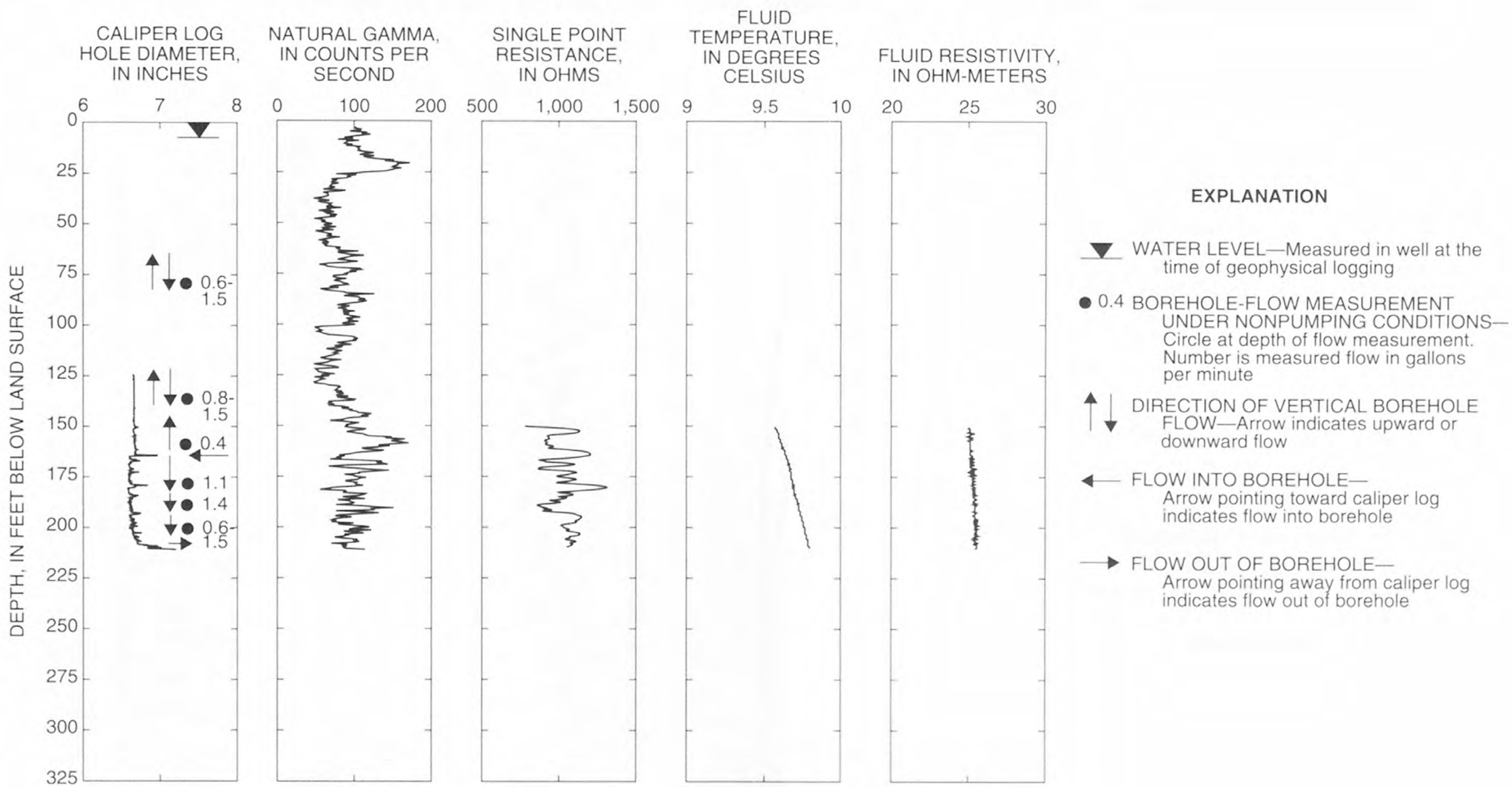

Figure 24a. Borehole geophysical logs from well MG-1155 (RW-3), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

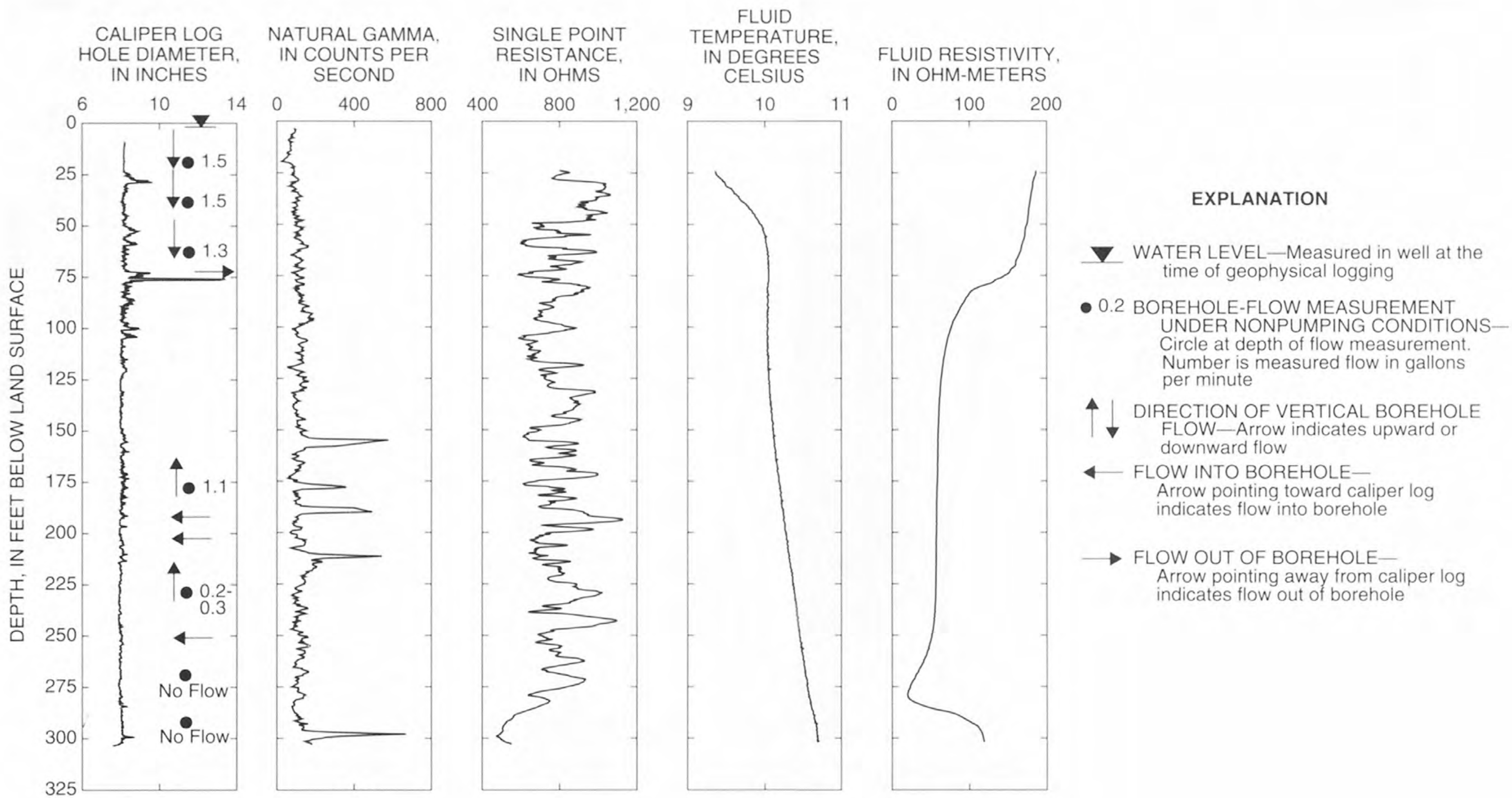

Figure 25a. Borehole geophysical logs from well BK-2937 (West Branch Park), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

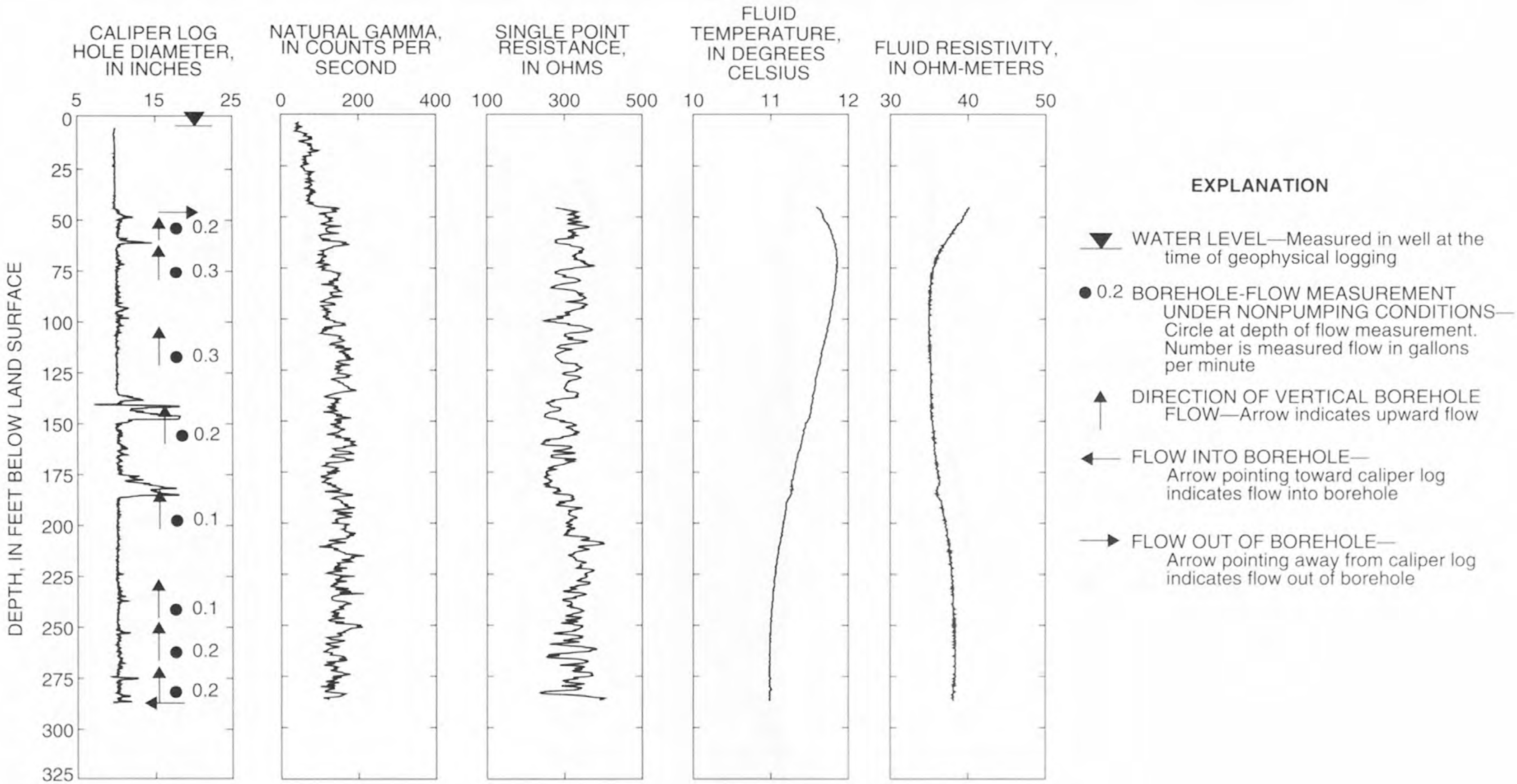

Figure 26a. Borehole geophysical logs from well MG-186 (R&B Industries #1), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

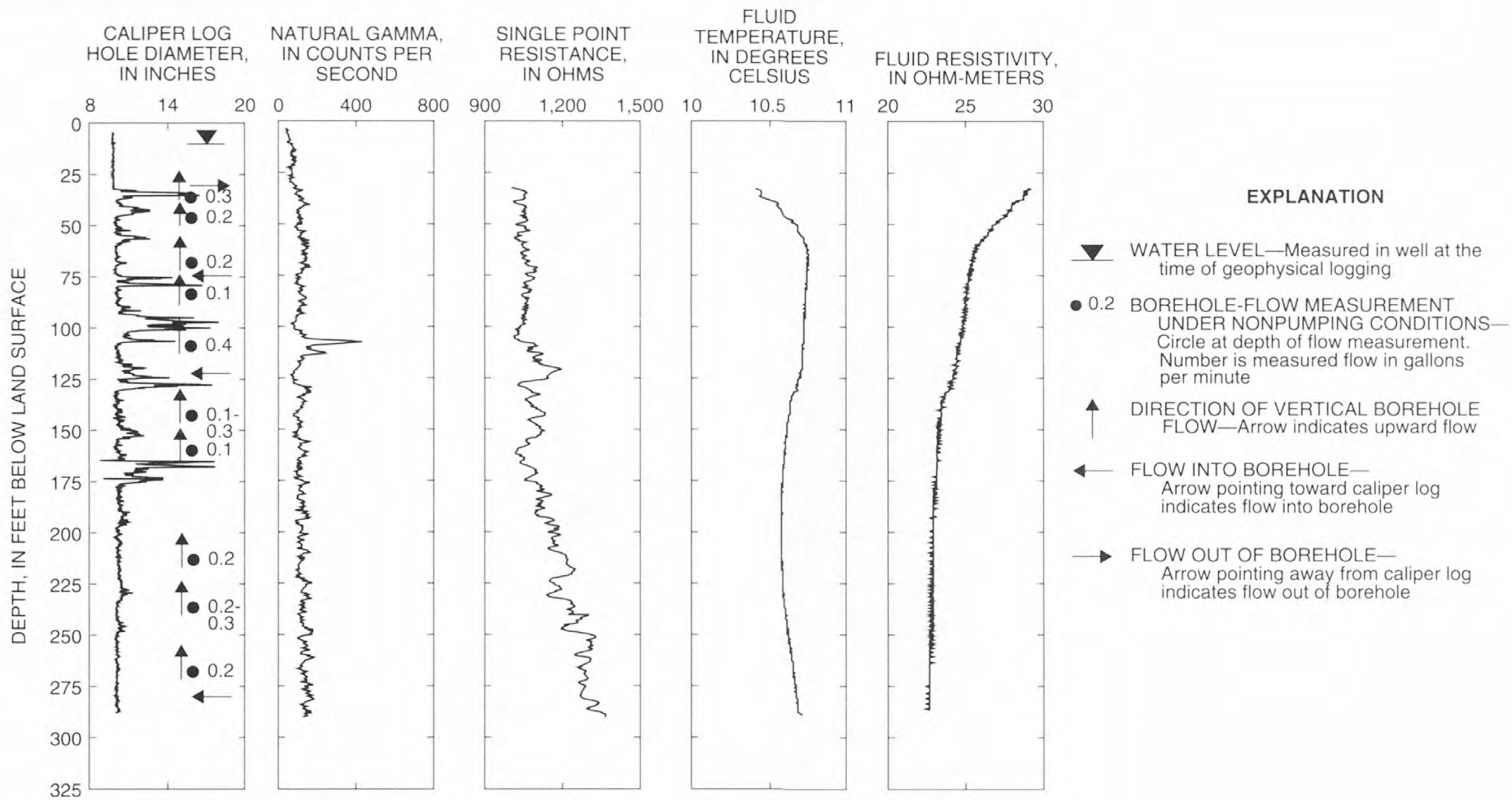

Figure 27a. Borehole geophysical logs from well MG-187 (R&B Industries #2), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

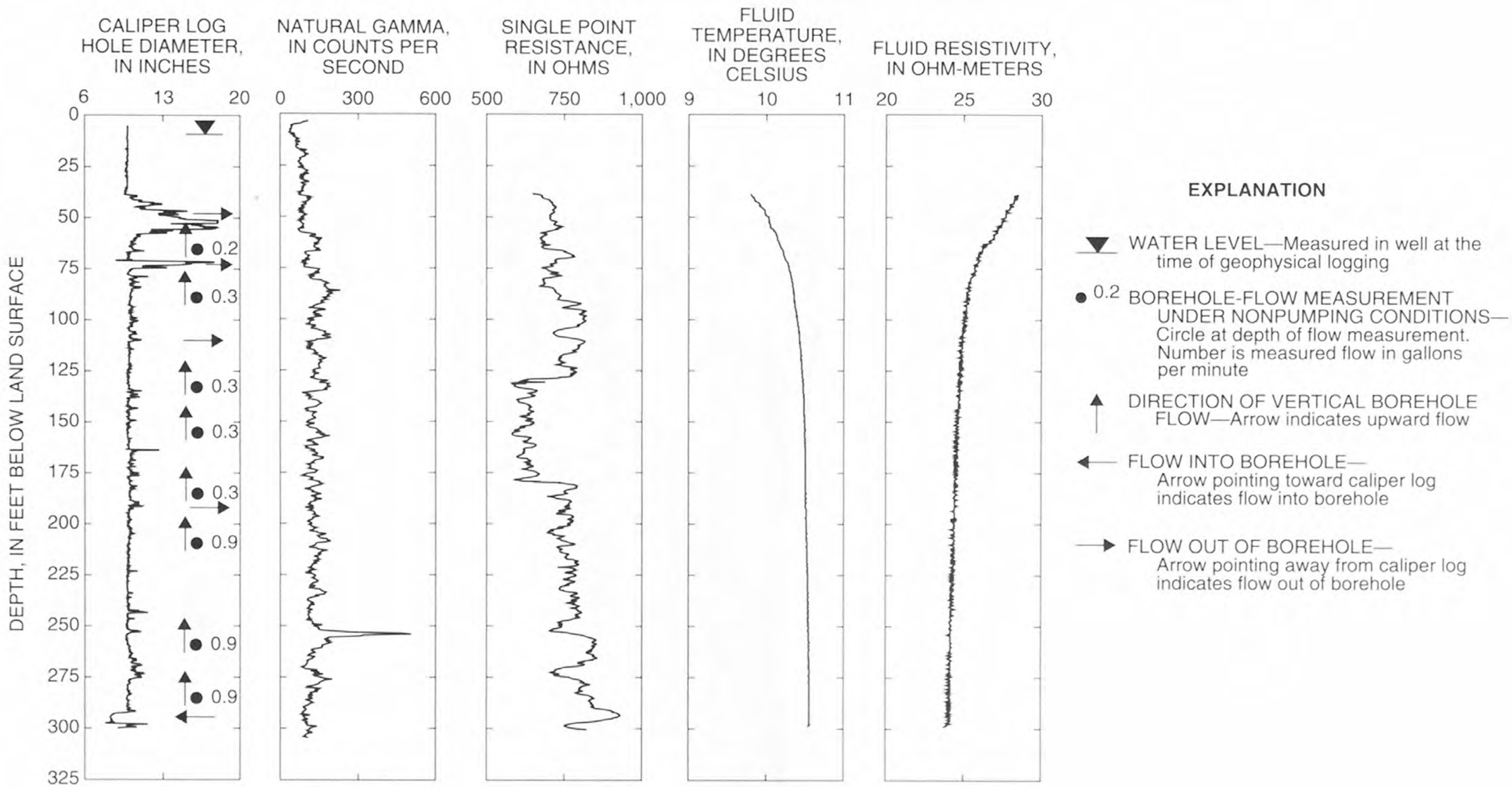

Figure 28a. Borehole geophysical logs from well MG-188 (R&B Industries #3), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

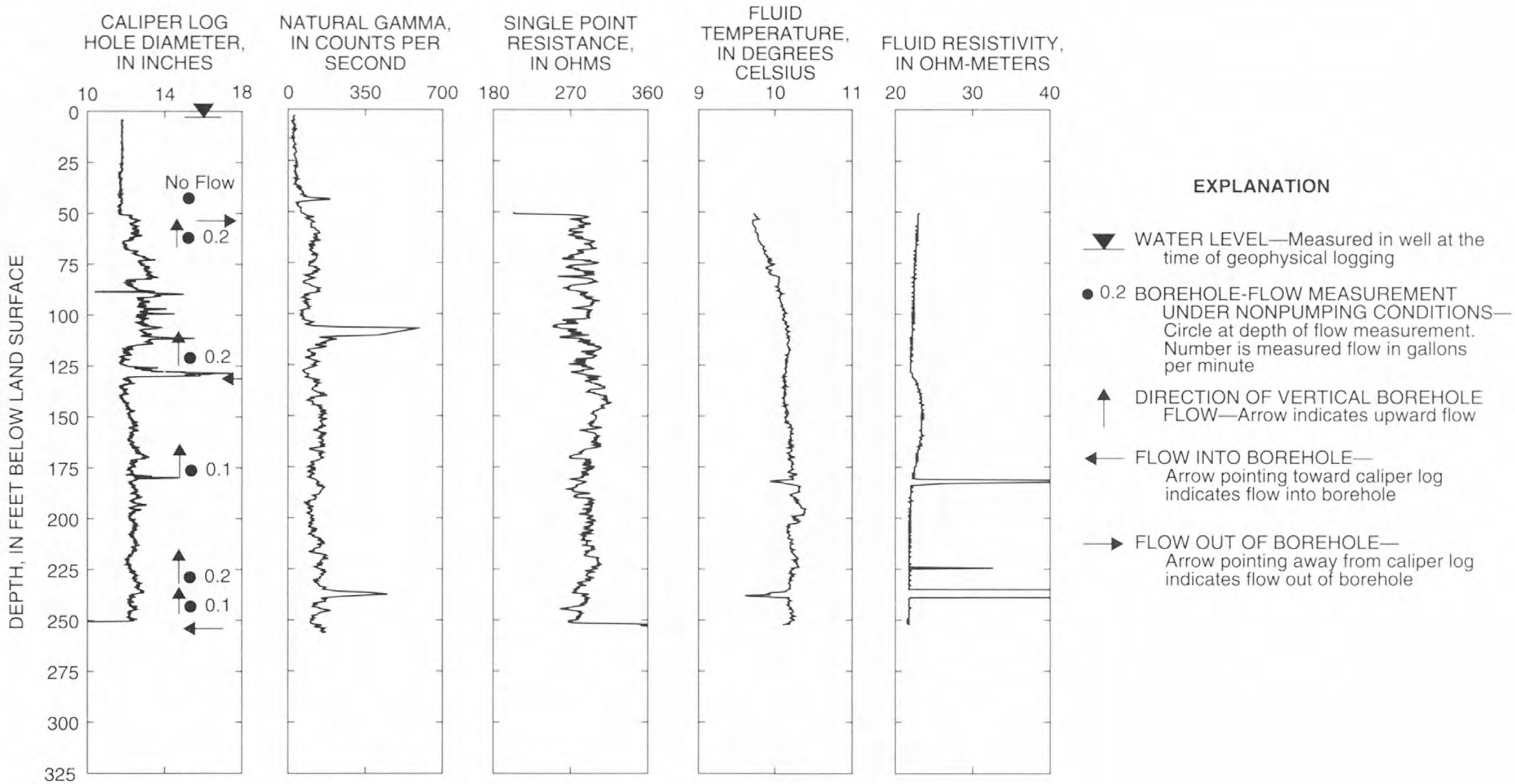

Figure 29a. Borehole geophysical logs from well MG-924 (NP-21), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

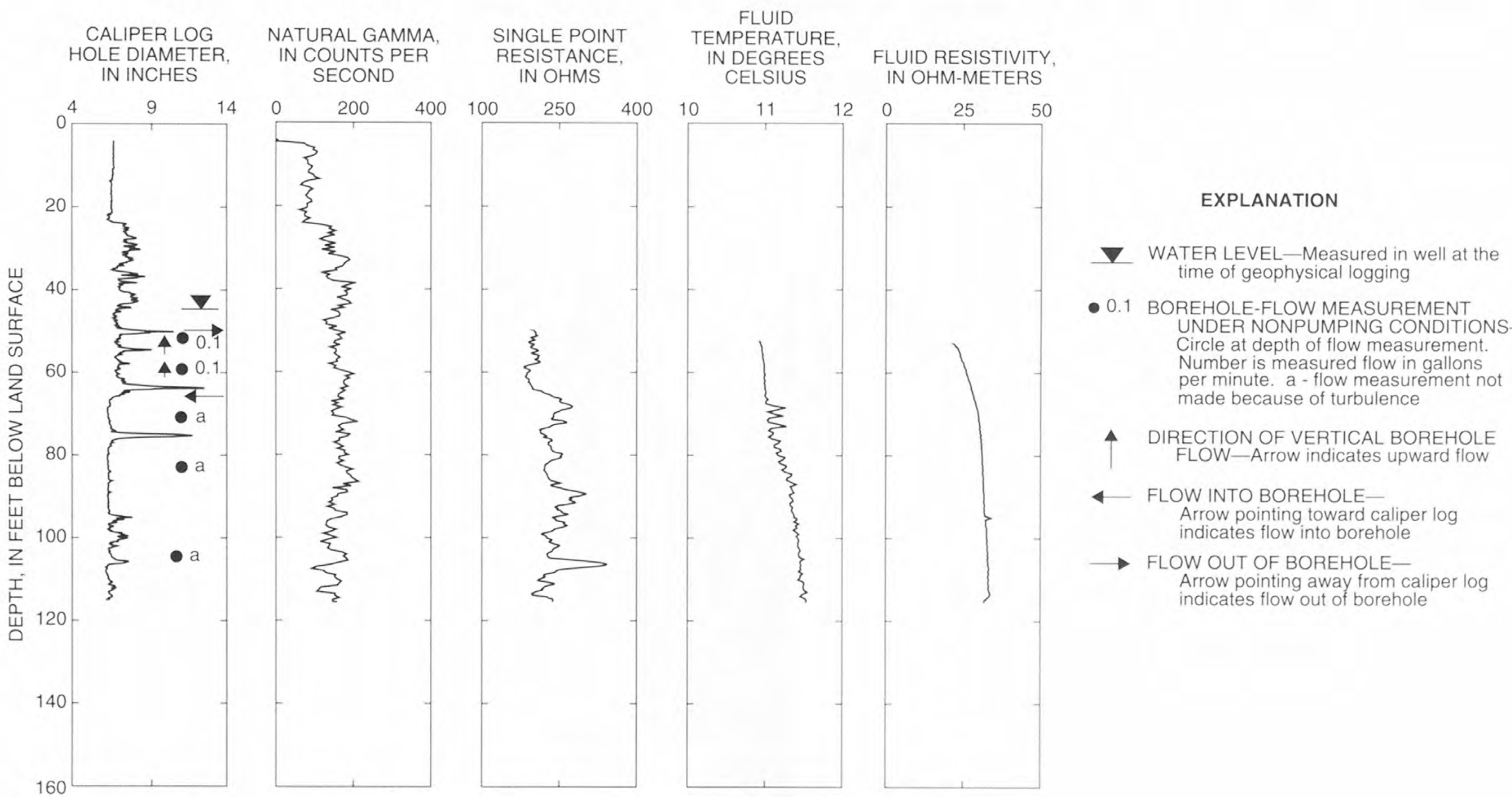

Figure 30a. Borehole geophysical logs from well MG-1691 (NP-12B), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

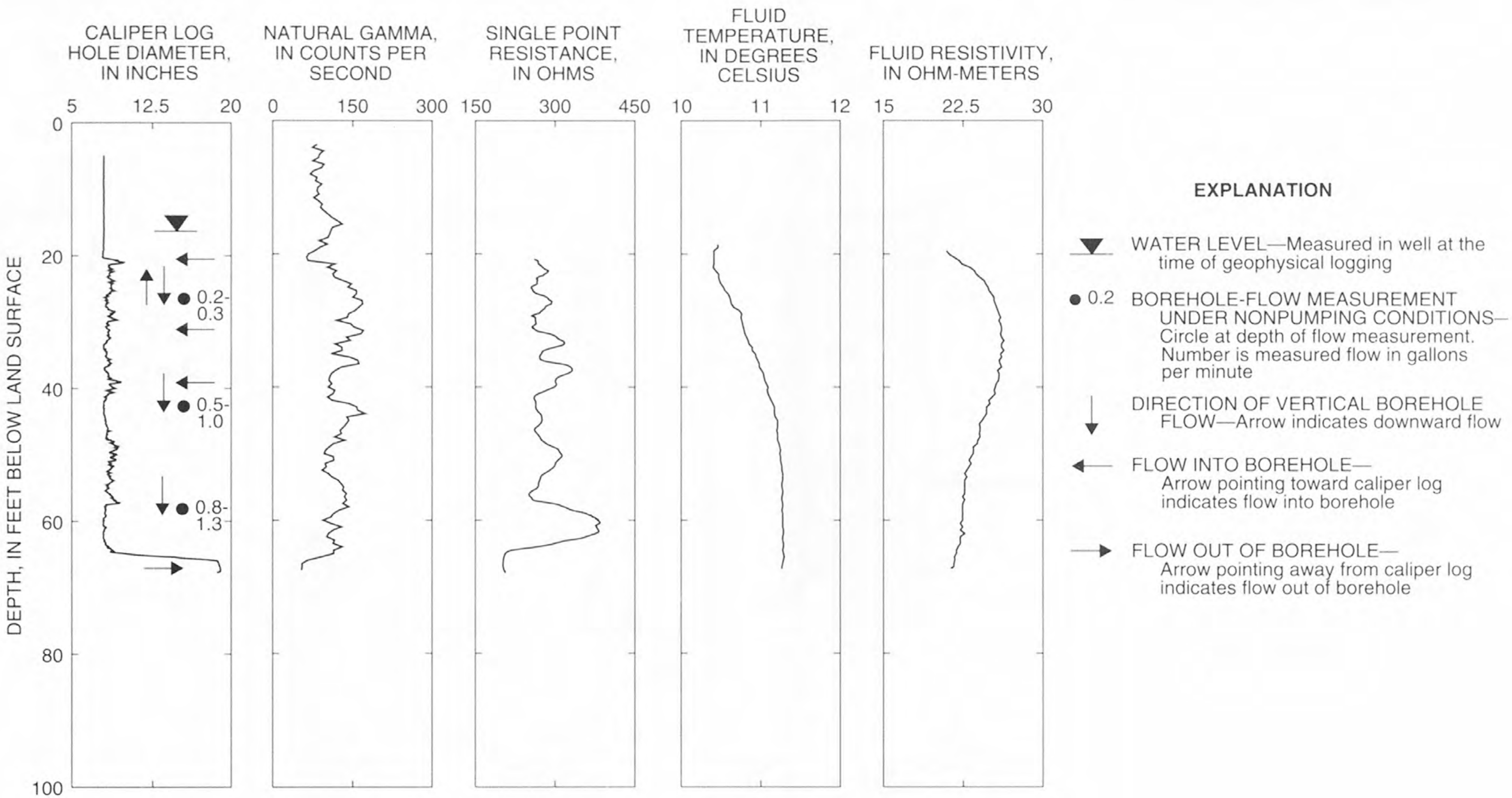

Figure 31a. Borehole geophysical logs from well BK-1292 (NP-75), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

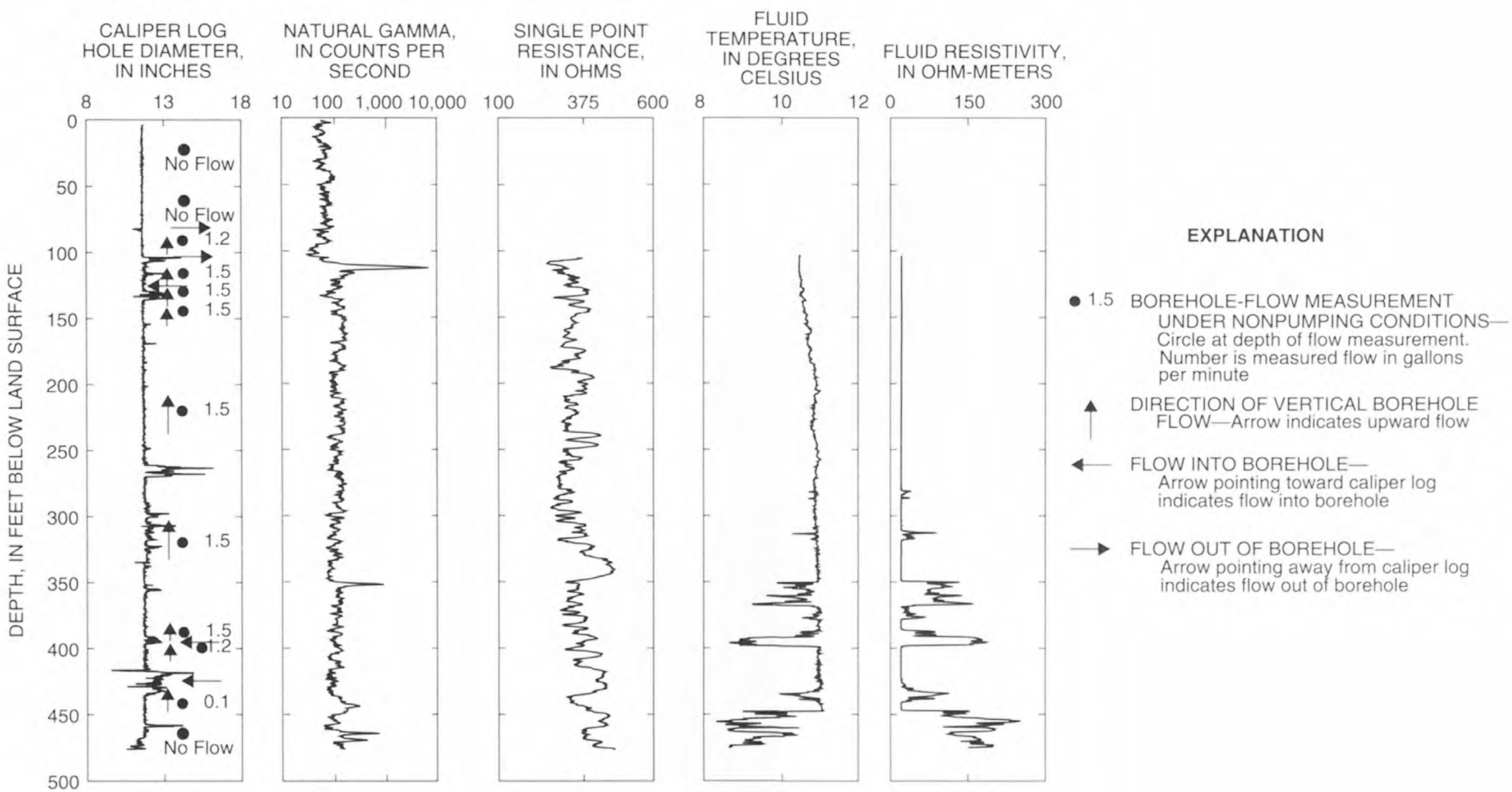

Figure 32a. Borehole geophysical logs from well MG-1693 (NP-87), North Penn Area 5 Superfund Site, Bucks and Montgomery Counties, Pennsylvania.

BIRD, P.H.,
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EVALUATION OF BOREHOLE GEOPHYSICAL LOGGING, AQUIFER-ISOLATION TESTS, DISTRIBUTION OF CONTAMINANTS, AND WATER-LEVEL MEASUREMENTS AT THE NORTH PENN AREA 5 SUPERFUND SITE, BUCKS AND MONTGOMERY COUNTIES, PENNSYLVANIA

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