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EVALUATION OF GEOPHYSICAL LOGS, PHASE I, FOR CROSSLEY FARMS SUPERFUND SITE, BERKS COUNTY, PENNSYLVANIA

by Randall W. Conger

Open-File Report 98-62

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U.S. DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS, ABBREVIATED WATER-QUALITY UNITS, AND VERTICAL DATUM

	Length	
inch (in.)	25.40	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Volume	
gallon per minute (gal/min)	0.00006309	cubic meter per second

Abbreviated water-quality unit used in report:

μg/L, micrograms per liter

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

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ABSTRACT

Twenty-one wells were drilled at Crossley Farms Superfund Site between December 15, 1987, and May 1, 1988, to define and monitor the horizontal and vertical distribution of ground-water contamination emanating from a suspected contaminant source area (Blackhead Hill). Eight well clusters were drilled on or near the Crossley Site and three well clusters were drilled at locations hydrologically down gradient from the site. Depths of wells range from 21 to 299 feet below land surface. These wells were installed in saprolite in shallow, intermediate, and deep water-producing zones of the fractured bedrock aquifer.

Borehole-geophysical and video logging were conducted between April 24, 1997, and May 8, 1997, to determine the water-producing zones, water-receiving zones, zones of vertical flow, borehole depth, and casing integrity in each well. This data and interpretation will be used to determine the location of the well intake for the existing open-hole wells, which will be retrofitted to isolate and monitor water-producing zones and prevent further cross-contamination within each open borehole, and identify wells that may need rehabilitation or replacement.

Caliper and video logs were used to locate fractures, inflections on fluid-temperature and fluid-resistivity logs indicated possible fluid-bearing fractures, and flowmeter measurements verified these locations. Single-point-resistance and natural-gamma logs provided information on stratigraphy. After interpretation of geophysical logs, video logs, and driller's notes, all wells will be constructed so that water-level fluctuations can be monitored and discrete water samples collected from shallow, intermediate, and deep water-bearing zones in each well.

Geophysical logs were run on seven bedrock and two deep bedrock wells. Gamma logs were run on 10 bedrock wells. Twenty-two wells were inspected visually with the borehole video camera for casing integrity.

INTRODUCTION

The Crossley Farms Superfund Site is about 20 mi northeast of Reading, in the community of Huffs Church in Hereford Township, Berks County, Pa. (fig. 1). The Crossley Site boundaries are not delineated but are assumed to be the extent of the ground-water contamination plume previously documented near Blackhead Hill (Halliburton NUS, 1995).

At the Crossley Farms Superfund Site, illegal wastes were reported to be disposed of at the abandoned quartzite quarry and nearby areas on the top of Blackhead Hill during the mid-1960's to the mid-1970's (Halliburton NUS, 1995). In the early 1980's, nearby residents complained about the quality of their well water. In 1983, ground-water samples collected by the Pennsylvania Department of Environmental Resources and Roy F. Weston, Inc. indicated some residential wells were contaminated with trichloroethylene (TCE) and lesser concentrations of tetrachloroethene (PCE). Additional sampling identified TCE as the principal contaminant at concentrations as great as 22,857 µg/L in residential well water. Nearby affected residential wells are currently (1996) equipped with carbon filters at the point of use.

In 1987-88, a hydrogeologic assessment was conducted at the Crossley Farms Superfund Site by Roy F. Weston, Inc. and IT Corporation (Roy F. Weston/IT, 1988). They conducted soil gas surveys, drilled 21 monitor wells in proximity to the site, and concluded the source of the TCE was from the top of Blackhead Hill, probably near the abandoned quarry and borrow-pit area (Halliburton NUS, 1995). To delineate the extent of ground-water contamination, a Focused Feasibility Study (FFS) and Remedial Investigation/Feasibility Study (RI/FS) currently are being conducted by Brown and Reot Environmental (B&R), formerly Halliburton NUS Inc., to better characterize the nature and extent of hazardous contamination and evaluate remedial options for the contaminated residential wells.

This report evaluates borehole-geophysical and video logs run by the U.S. Geological Survey (USGS) in 21 boreholes at Crossley Farms Superfund Site, 1 private well adjacent to the site, and 1 well in downtown Bally (table 1, fig. 1). This report identifies one or more fluid-bearing zones in each borehole and describes problems with the integrity of the casing on the basis of geophysical and video-log data. Borehole video logs were run in all boreholes. Caliper, natural-gamma, single-point-resistance, fluid-resistivity, fluid-temperature, and borehole-flow (heat-pulse-flowmeter) logs were run in seven boreholes. Caliper, borehole video, natural-gamma, single-point-resistance, fluid-resistivity, and fluid-temperature logs were run in one borehole. A natural-gamma log was run in three boreholes. A cross reference between USGS borehole-identification numbers and B&R borehole-identification numbers and a list of logs run in each borehole are shown in table 1.

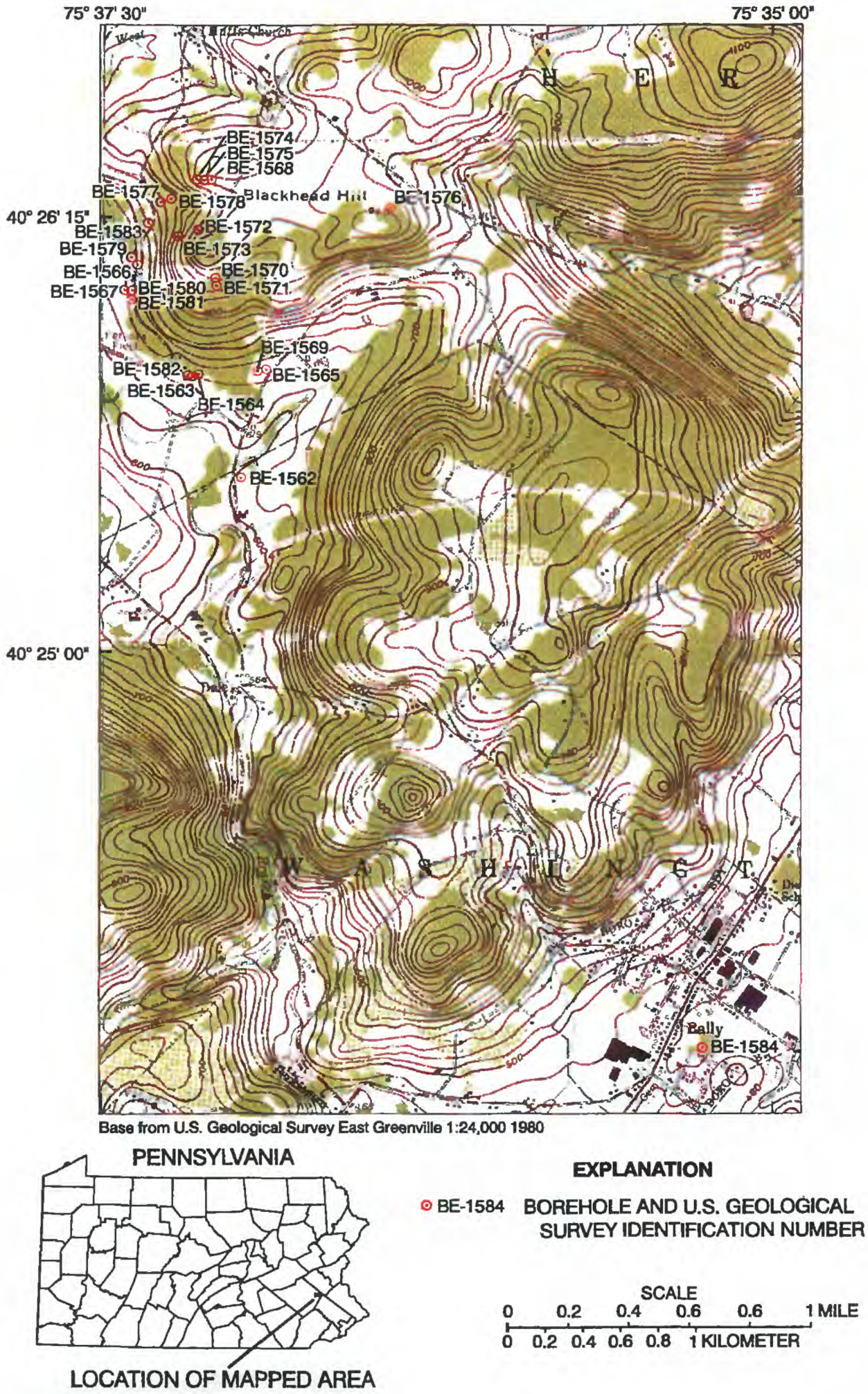

Figure 1. Locations of boreholes logged at the Crossley Farms Superfund Site, Berks County, Pennsylvania.

Table 1. *Boreholes logged at Crossley Farms Superfund Site, Berks County, Pennsylvania*

[B, borehole-video log; C, caliper log; G, natural-gamma log; R, single-point-resistance log; F, fluid-resistivity log; T, fluid-temperature log; V, borehole-flow measurement]

U.S. Geological Survey borehole-identification number	Brown and Root Environmental identification number	Depth logged (feet)	Geophysical logs run
BE-1562	MW-8-R	121	B, C, G, R, F, T, V
BE-1563	MW-7-R	94	B, C, G, R, F, T, V
BE-1564	MW-7-DR	122	B, C, G, R, F, T
BE-1565	MW-6-R	94	B, G
BE-1566	MW-4-R	233	B, G
BE-1567	MW-5-R	299	B, C, G, R, F, T, V
BE-1568	MW-2-DR	302	B, C, G, R, F, T, V
BE-1569	MW-6-OB	37	B
BE-1570	MW-1-OB	56	B
BE-1571	MW-1-R	162	B, G
BE-1572	MW-1.1-OB	41	B
BE-1573	MW-1.2-OB	44	B
BE-1574	MW-2-OB	26	B
BE-1575	MW-2-R	50	B
BE-1576	MW-2.1-OB	60	B
BE-1577	MW-3-OB	23	B
BE-1578	MW-3-DOB	69	B
BE-1579	MW-4-OB	21	B
BE-1580	MW-5-OB	33	B
BE-1581	MW-5-DOB	100	B
BE-1582	MW-7-OB	58	B
BE-1583	Wetzel	278	B, C, G, R, F, T, V
BE-1584	92-17	435	B, C, G, R, F, T, V

Location and Physiography of Site

The Crossley Farms Superfund Site is located in the Reading Prong Section of the New England Physiographic Province. The upland area of Blackhead Hill is underlain by Precambrian gneiss and Cambrian quartzite of the Hardystown Formation. The adjacent valley to the south and west is underlain mainly by Cambro-Ordovician dolomite of the Leithsville Formation. Bedrock is overlain by 30 to 120 ft of unconsolidated regolith (Roy F. Weston/IT, 1988).

Ground water moves through the pore spaces of the regolith and fractures in the bedrock. Within the Leithsville Formation, the fractures have been enlarged because of dissolution and weathering of the dolomite. Maps of the water table in the regolith indicate shallow ground water probably moves radially to the south and west from the summit of Blackhead Hill. Maps of the water table in the bedrock indicate a potential for ground-water movement from the quarry area to the south and west (Roy F. Weston/IT 1988). Within the Leithsville Formation, hydraulic gradients are much less steep than in the crystalline bedrock. Ground water apparently moves from Blackhead Hill toward the valley; however, specific flow paths of ground water are difficult to characterize because they can be affected greatly by the anisotropy of the fractured bedrock and heterogeneity of water-bearing zones.

Borehole-Geophysical Logs

Geophysical logs provide information on location of fractures and water-bearing and water-receiving zones (caliper and video log), intervals of vertical borehole flow (fluid-resistivity and fluid-temperature logs), quantification of borehole flow (heat-pulse flowmeter logs), lithologic correlation (gamma and electric logs), and data on well construction (caliper and electric logs) where unknown.

Caliper logs provide a continuous record of average borehole diameter, which is related to fractures, lithology, and drilling technique. Caliper logs are used to identify fractures and possible water-producing openings and to correct other geophysical logs for changes in borehole diameter. Correlation of caliper logs with fluid-resistivity and fluid-temperature logs is used to identify fractures, water-producing zones, and water-receiving zones and to measure water velocity.

The natural-gamma or gamma log measures the natural-gamma radiation (photons) emitted from all rocks. The most common sources 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. The gamma log can be run in or out of water or casing. However, casing does reduce the gamma response. The gamma log is used to correlate geologic units between wells (Keys, 1988).

The single-point-resistance log measures 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 increasing borehole diameter, water-bearing fractures, and increasing dissolved-solids concentration of borehole fluid. The single-point-resistance log is used to correlate geology between wells and may help identify formation water-bearing zones. (Keys and MacCary, 1971).

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 the well water. 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. Also, zones of salt-water intrusion and some types of contaminant plumes can be identified.

Fluid-temperature logs provide a continuous record of the vertical variation in temperature of the water in a borehole. 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).

The direction and rate of any movement of water in the borehole was determined by the use of a heat-pulse flowmeter. The heat-pulse 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).

All flow measurements were conducted under ambient conditions. The flowmeter can measure flow only if pressure head differences exist between water-producing zones in the borehole.

Some heat-pulse-flowmeter measurements may be influenced by (1) an incomplete seal between the borehole and heat-pulse 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 flow measurements that are less than the actual rate. When flowmeter measurements are conducted under pumping conditions, some measurements of flow rate may be affected if the water level in the borehole has not stabilized. When drawdown has not completely stabilized, a portion of the discharge water is contributed from storage within the borehole rather than from the aquifer. Although the heat-pulse flowmeter is a calibrated probe, the data are used primarily as a relative indicator to identify water-producing and water-receiving zones.

Borehole television logging was conducted by lowering a waterproof video camera down the borehole and recording the image on video tape. The depth indicated on the video log may not correspond exactly to the geophysical logs because of some minor slippage of the television cable.

EVALUATION OF BOREHOLE-GEOPHYSICAL LOGS

The locations of boreholes logged are shown on figure 1. The reference measuring point for all geophysical and video logs is land surface. Depth of wells, casing lengths, and water levels at the time of logging are given in feet below land surface (table 2).

Table 2. *Well depth, casing length, and depth to water for boreholes logged by the U.S. Geological Survey at Crossley Farms Superfund Site, Berks County, Pennsylvania*

[ft, feet]

U.S. Geological Survey borehole-identification number	Depth of well below land surface (ft)	Length of casing and screen below land surface (ft)	Open (O) or screened (S) interval below land surface (ft)	Depth to water below land surface (ft)	Date water level measured
BE-1562	121	76	76-121 (O)	13.07	4/24/97
BE-1563	94	58	58-94 (O)	47.50	4/25/97
BE-1564	122	108	108-122 (O)	47.76	4/25/97
BE-1565	94	94	collapsed	49.33	4/25/97
BE-1566	232	228	228-233 (O)	57.05	4/25/97
BE-1567	299	196	196-299 (O)	33.91	4/25/97
BE-1568	302	56	56-302 (O)	24.07	5/2/97
BE-1569	37	37	29-37 (S)	20.8	5/2/97
BE-1570	56	56	46-56 (S)	20.0	5/8/97
BE-1571	162	undetermined[1]		27.15	5/7/97
BE-1572	41	41	31-41 (S)	31.9	5/8/97
BE-1573	44	44	34-44 (S)	39.3	5/8/97
BE-1574	26	26	16-26 (S)	dry	5/6/97
BE-1575	50	undetermined[1]		26.5	5/6/97
BE-1576	60	60	50-60 (S)	40.3	5/8/97
BE-1577	23	23	13-23 (S)	.5	5/6/97
BE-1578	69	69	49-69 (S)	30.2	5/6/97
BE-1579	21	21	11-21 (S)	1.7	5/6/97
BE-1580	33	33	23-33 (S)	24.1	5/8/97
BE-1581	100	100	82-100 (S)	55.1	5/8/97
BE-1582	58	58	38-58 (S)	49.2	5/6/97
BE-1583	278	[2]56	56-278 (O)	31.98	5/6/97
BE-1584	435	54	54-435 (O)	3.64	5/8/97

[1] Unable to determine visually; water cloudy.
[2] Apparent casing depth.

BE-1562 (MW-8-R)

The caliper log shows the total depth of the borehole is 121 ft and it is cased with 6-in.-diameter casing (fig. 2). The static water level was 13.07 ft bls (below land surface). The single-point-resistance log shows steel casing to 76 ft bls. The caliper log shows major fractures at 98-102 and 118-121 ft bls and several minor fractures throughout the open-hole interval. The fluid-resistivity log shows a change in slope at approximately 76 ft bls that correlates to a minor fracture shown on the caliper log. The video log shows the borehole water becomes slightly cloudy below casing, more cloudy at 91 ft bls, then visibility declines to zero near the bottom of the borehole. Under ambient conditions, the heat-pulse flowmeter measured upward borehole flow at 86, 96, and 108.5 ft bls (table 3). The geophysical logs and the heat-pulse-flowmeter data indicate water enters the borehole through the large fracture at 118-121 ft bls, moves upward, and exits the borehole through a small fracture near the bottom of casing at 76 ft bls. If the water produced at the fracture at 118-121 ft bls is contaminated, leaving this well as an open borehole may cross-contaminate the water-receiving zone. A screen and sand placed at 111-121 ft bls would include the water-producing fractures at 118-121 ft bls.

Table 3. *Summary of heat-pulse-flowmeter measurements for borehole BE-1562 (MW-8-R) at Crossley Farms Superfund Site, Berks County, Pennsylvania*

[ft bls, feet below land surface; gal/min, gallons per minute]

Depth (ft bls)	Flow rate under ambient conditions (gal/min)	Flow direction under ambient conditions
70	no flow	
86	0.20	up
96	.24	up
108.5	.27	up

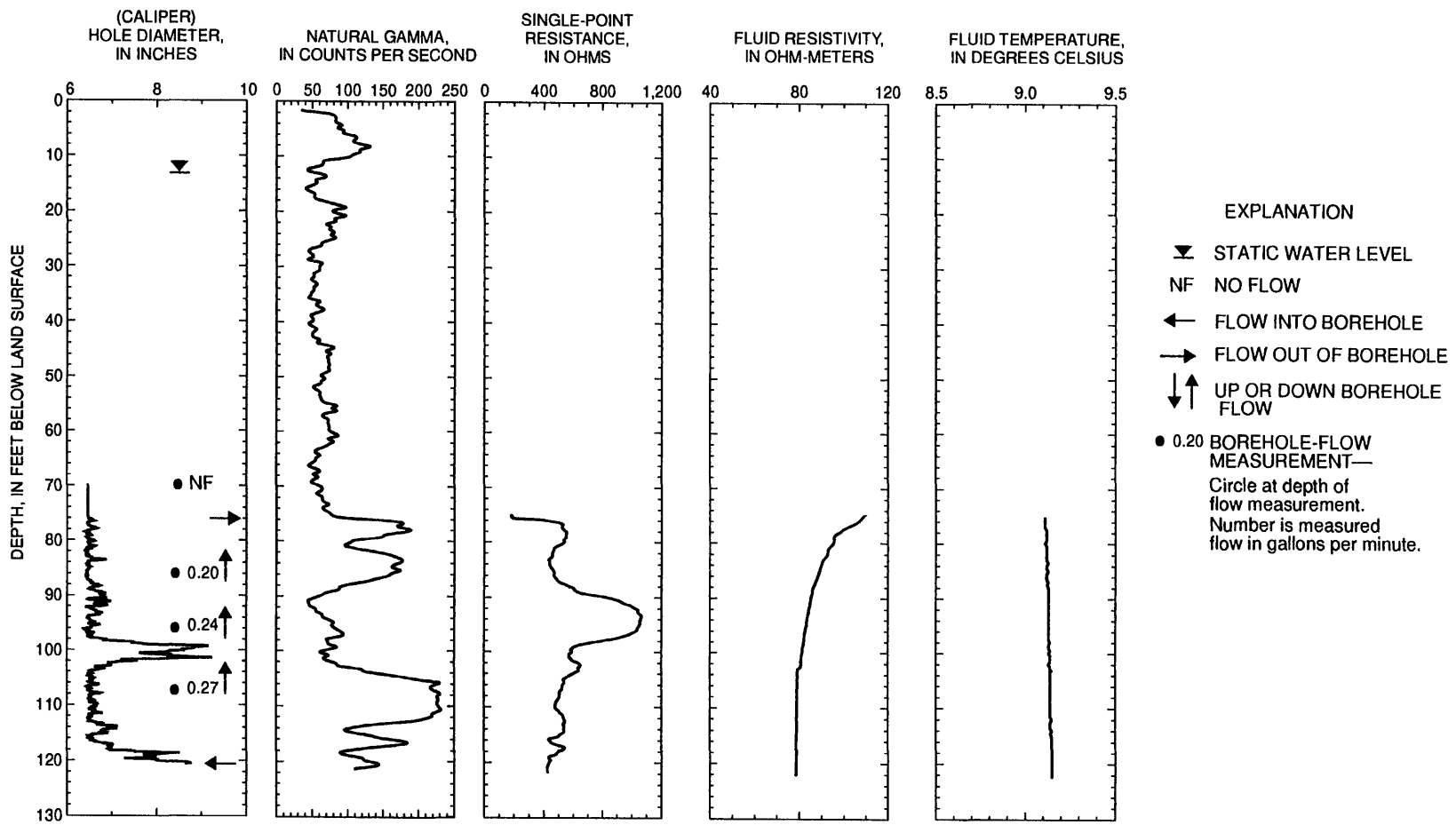

Figure 2. Borehole-geophysical logs for borehole BE-1562 (MW-8-R), collected on April 24, 1997, Crossley Farms Superfund Site, Berks County, Pennsylvania.

BE-1563 (MW-7-R)

The caliper log shows the total depth of the borehole is 94 ft and it is cased with 6.25-in.-diameter casing (fig. 3). The static water level was 47.50 ft bls. The single-point-resistance log shows steel casing to 58 ft bls. The caliper log shows a fracture at 93 ft bls and only minor fractures throughout the open-hole interval. The fluid-resistivity log shows a change in slope at 58-60 ft bls that correlates to minor fractures on the caliper log. The video log shows the borehole water becomes slightly cloudy near the bottom of casing. Under ambient conditions, the heat-pulse-flowmeter data indicated upward borehole flow at 50, 56, 66, 74, and 84 ft bls (table 4). The geophysical logs and the heat-pulse-flowmeter data indicate water enters the borehole through the fracture at 93 ft bls, moves upward, and exits the borehole through a break in casing above 50 ft bls. If the water produced by the fracture at 93 ft bls is contaminated, leaving this well as an unrepaired open borehole may cross-contaminate the shallow water-producing zones. Screen and sand placed at 84-94 ft bls would include the water-producing zone at 93 ft bls.

Table 4. *Summary of heat-pulse-flowmeter measurements for borehole BE-1563 (MW-7-R) at Crossley Farms Superfund Site, Berks County, Pennsylvania*

[ft bls, feet below land surface; gal/min, gallons per minute]

Depth (ft bls)	Flow rate under ambient conditions (gal/min)	Flow direction under ambient conditions
50	0.15	up
56	.13	up
66	.13	up
74	.09	up
84	.11	up

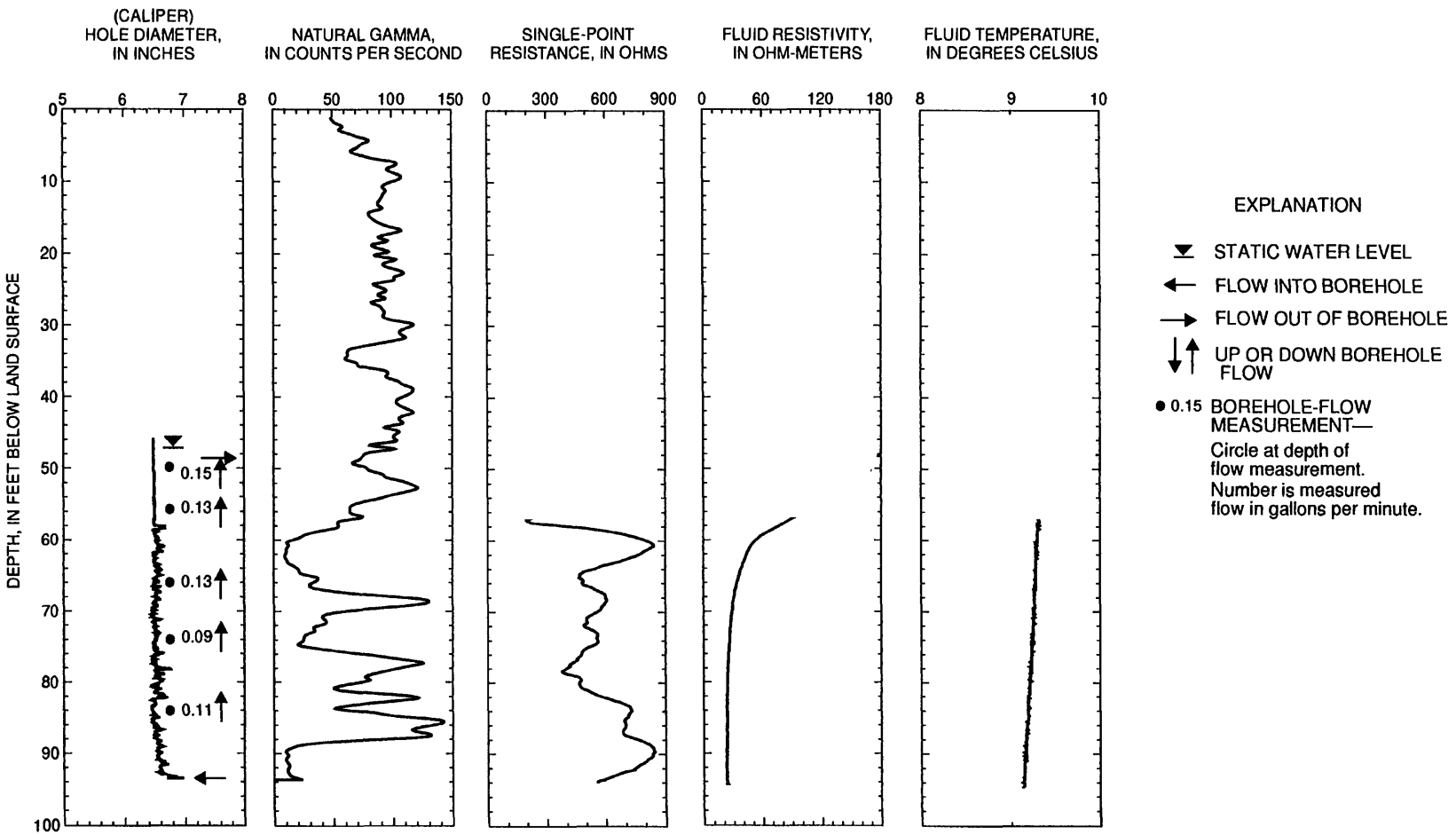

Figure 3. Borehole-geophysical logs for borehole BE-1563 (MW-7-R), collected on April 25, 1997, Crossley Farms Superfund Site, Berks County, Pennsylvania.

BE-1564 (MW-7-DR)

The caliper log shows the total depth of the borehole is 122 ft and it is cased with 6.25-in.-diameter casing (fig. 4). The static water level was 47.76 ft bls. The single-point-resistance log shows steel casing extends to 108 ft bls. The caliper log shows a major fracture at 115 ft bls. The single-point-resistance log shows a spike at 115 ft bls that correlates to a fracture shown on the caliper log, which indicates a water-producing zone. The video log shows the borehole water becoming slightly cloudy in the open hole and a large horizontal fracture at 115 ft bls. A screen placed at 110-120 ft bls would include the apparent water-producing zone at 115 ft bls.

BE-1565 (MW-6-R)

Only the gamma and video logs were run in this borehole. The static water level was 49.33 ft bls. The gamma log shows the total depth of the borehole is 94 ft bls (fig. 5). The borehole video log shows the casing is in good condition and extends to at least 94 ft bls. The borehole has completely collapsed below the casing; no open hole exists.

BE-1566 (MW-4-R)

The gamma and video logs were run in this borehole. The static water level was 57.05 ft bls. The gamma log shows the total depth of the borehole is 232 ft bls and it is cased with steel to 228 ft bls (fig. 6). The borehole-video log shows the casing is broken or cracked above a joint at 46 ft bls. The video log identified fractures at 228-230 ft bls and a large vertical fracture at 232 ft bls. If water is produced by fractures near the break in casing at 46 ft bls and is contaminated, leaving this well unrepaired may cross-contaminate water-receiving zones. A screen placed at 228-232 ft bls would include the current open-hole interval and restrict any vertical flow caused as a result of damaged casing.

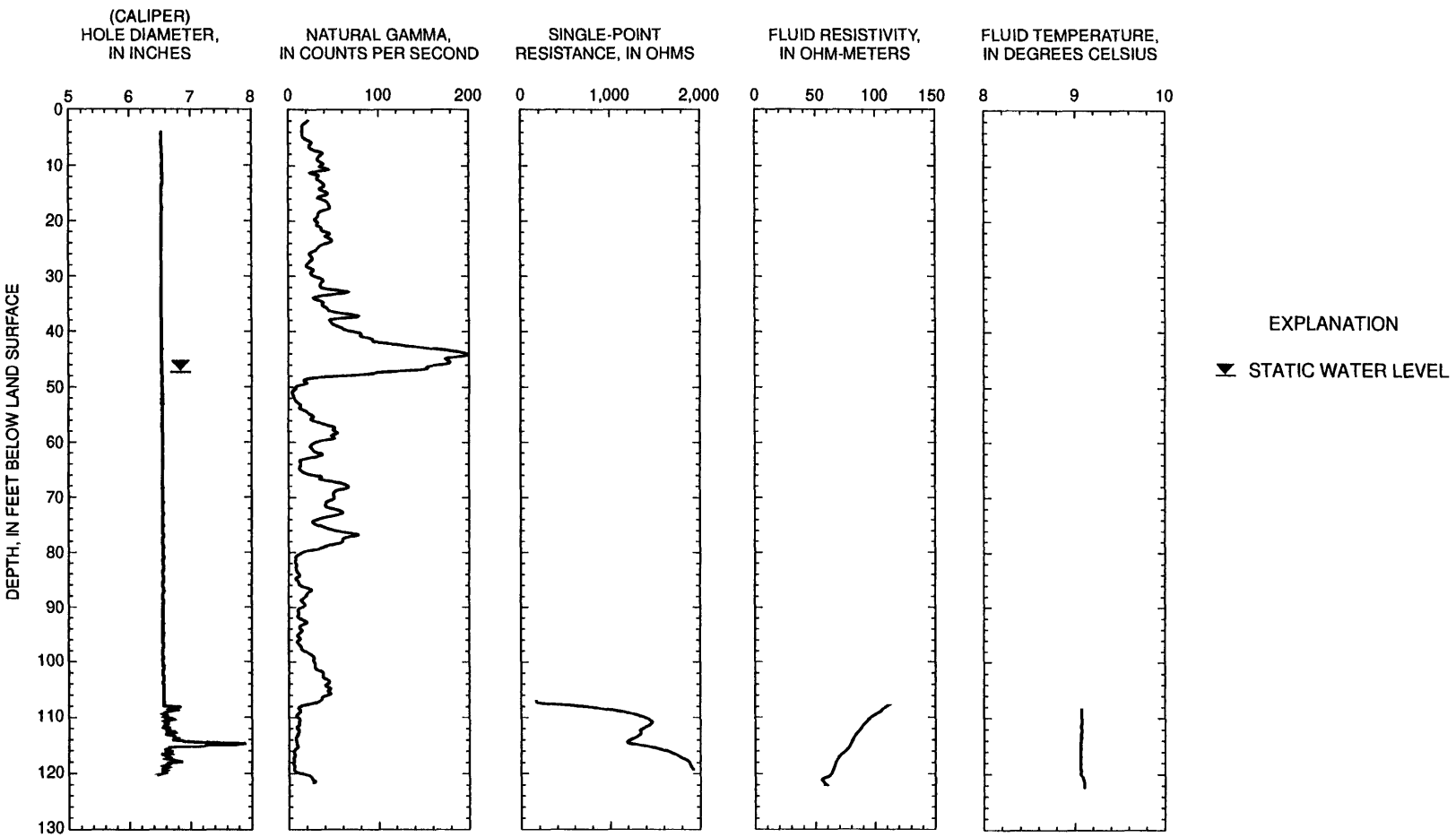

Figure 4. Borehole-geophysical logs for borehole BE-1564 (MW-7-DR), collected on April 25, 1997, Crossley Farms Superfund Site, Berks County, Pennsylvania.

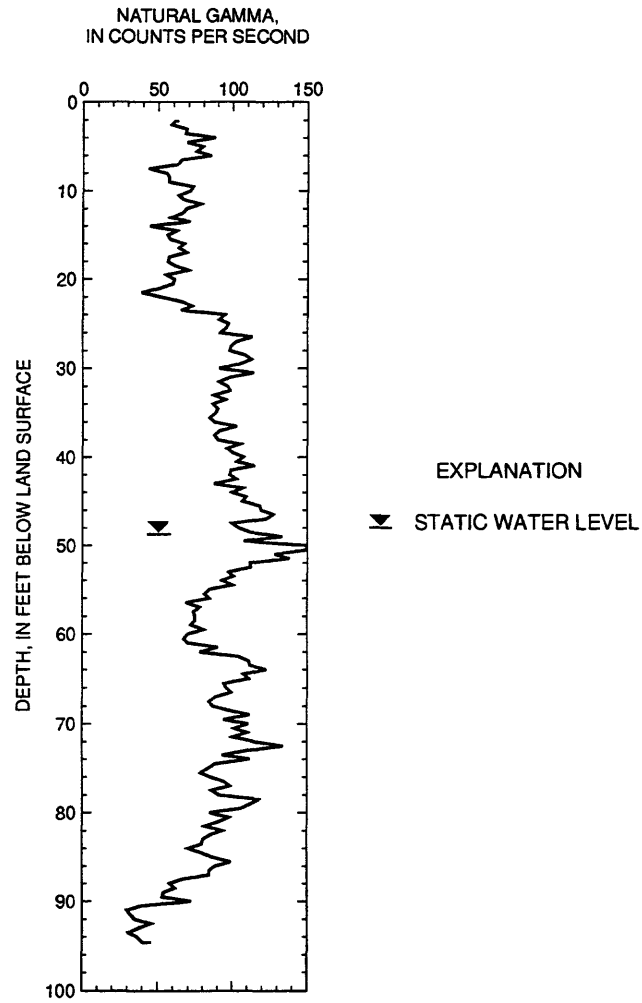

Figure 5. Borehole-geophysical log for borehole BE-1565 (MW-6-R), collected on April 25, 1997, Crossley Farms Superfund Site, Berks County, Pennsylvania.

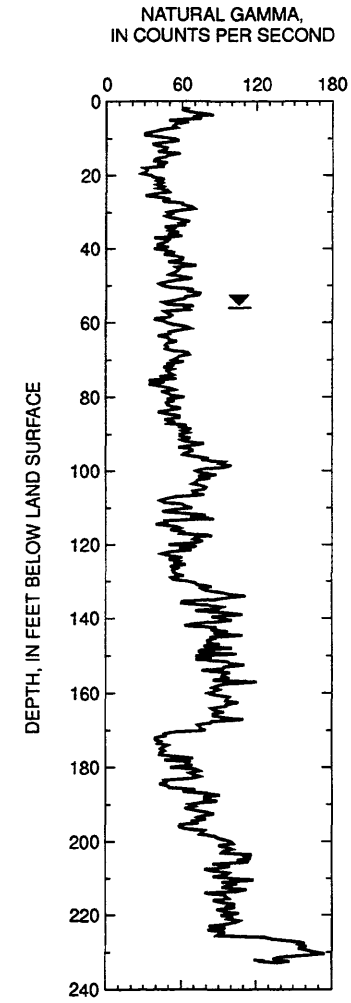

Figure 6. Borehole-geophysical log for borehole BE-1566 (MW-4-R), collected on April 25, 1997, Crossley Farms Superfund Site, Berks County, Pennsylvania.

BE-1567 (MW-5-R)

The caliper log shows the total depth of the borehole is 299 ft and it is cased with 6-in.-diameter casing (fig. 7). The static water level was 33.91 ft bls. The single-point-resistance log shows steel casing to 196 ft bls. The caliper log shows fractures at 206 ft bls and only minor fractures throughout the open-hole interval. The caliper log shows the bottom 9 ft of the borehole is filled with soft sediment. The fluid-resistivity and fluid-temperature logs show a change in slope at 269 ft bls that correlates to a minor fracture on the caliper log and may indicate a water-producing zone. The video log shows the visibility of the borehole water becomes zero below 52 ft bls. Under ambient conditions, the heat-pulse-flowmeter measurements indicated upward borehole flow at 199 and 220 ft bls and no flow at 241 and 258 ft bls (table 5). The geophysical logs and the heat-pulse-flowmeter data indicate water enters the borehole through the fractures between 222 and 238 ft bls moves upward and exits the borehole through fractures at approximately 196 ft bls. If the water produced by the fractures at 222-238 ft bls is contaminated, leaving this well as an open borehole may create cross-contamination of the deeper water-producing zones. A screen placed at 200-210 or 221-241 ft bls would include the water-receiving and water-producing zone at 204 or 222-238 ft bls, respectively.

Table 5. *Summary of heat-pulse-flowmeter measurements for borehole BE-1567 (MW-5-R) at Crossley Farms Superfund Site, Berks County, Pennsylvania*

[ft bls, feet below land surface; gal/min, gallons per minute]

Depth (ft bls)	Flow rate under ambient conditions (gal/min)	Flow direction under ambient conditions
190	no flow	
199	0.10	up
220	.20	up
241	no flow	
258	no flow	

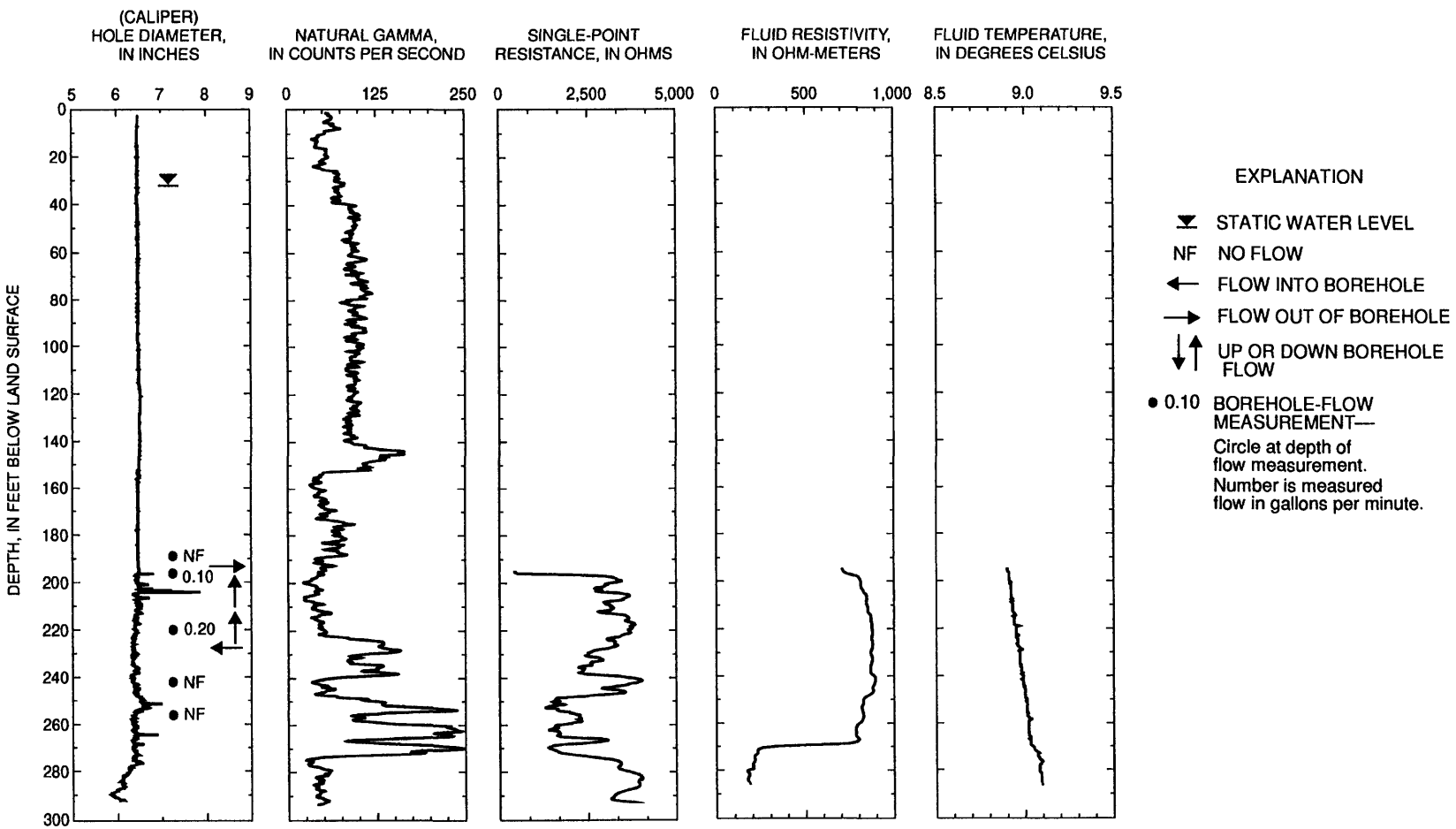

Figure 7. Borehole-geophysical logs for borehole BE-1567 (MW-5-R), collected on April 25, 1997, Crossley Farms Superfund Site, Berks County, Pennsylvania.

BE-1568 (MW-2-DR)

The caliper log shows the total depth of the borehole is 302 ft and it is cased with 6-in.-diameter casing (fig. 8). The static water level was 24.07 ft bls. The single-point-resistance log shows steel casing to 56 ft bls. The caliper log shows numerous minor fractures throughout the open-hole interval. The fluid-resistivity log shows a sudden change in slope at about 70 ft bls that correlates to a minor fracture on the caliper log and may be indicative of lateral borehole flow. Under ambient conditions, the heat-pulse-flowmeter measurements indicate minor upward borehole flow at 250, 264, 282, and 294 ft bls and no flow at 80, 128, and 216 ft bls (table 6). The geophysical logs and the heat-pulse-flowmeter data indicate water enters the borehole through the fractures at 286 and 300 ft bls, moves upward, and exits the borehole through fractures between 220 and 245 ft bls. If the water produced by the fractures at 286 and 300 ft bls is contaminated, leaving this well as an open borehole may create cross-contamination of the deeper water-producing zones. A screen placed at 220-245 ft bls or 250-300 ft bls would include the minor water-receiving and water-producing fractures, respectively, at these intervals.

Table 6. *Summary of heat-pulse-flowmeter measurements for borehole BE-1568 (MW-2-DR) at Crossley Farms Superfund Site, Berks County, Pennsylvania*

[ft bls, feet below land surface; gal/min, gallons per minute]

Depth (ft bls)	Flow rate under ambient conditions (gal/min)	Flow direction under ambient conditions
80	no flow	
128	no flow	
216	no flow	
250	0.06	up
264	.05	up
282	.08	up
294	.05	up

BE-1569 (MW-6-OB)

Only the borehole-video log was run in this well. The log shows the total depth of the borehole is 37 ft bls and it is screened from 29 to at least 37 ft bls. The static water level was 20.8 ft bls. The PVC casing is broken and misaligned at 3 ft bls and leaking below a joint at 19.5 ft bls. The video log shows silt on the bottom of the well.

BE-1570 (MW-1-OB)

Only the borehole-video log was run in this well. The log shows the total depth of the borehole is 56 ft bls and it is screened with PVC from about 47 to 56 ft bls. The static water level was 20.0 ft bls. The video log shows dirty joints at 7.4, 17.4, and 36.7-46.7 ft bls, indicating locations of possible seepage into the well. The video log shows an apparent high water-level mark (stain) at 13.7 ft bls, staining possibly from iron or bacteria at 48 ft bls, and silt on the bottom at 56 ft bls.

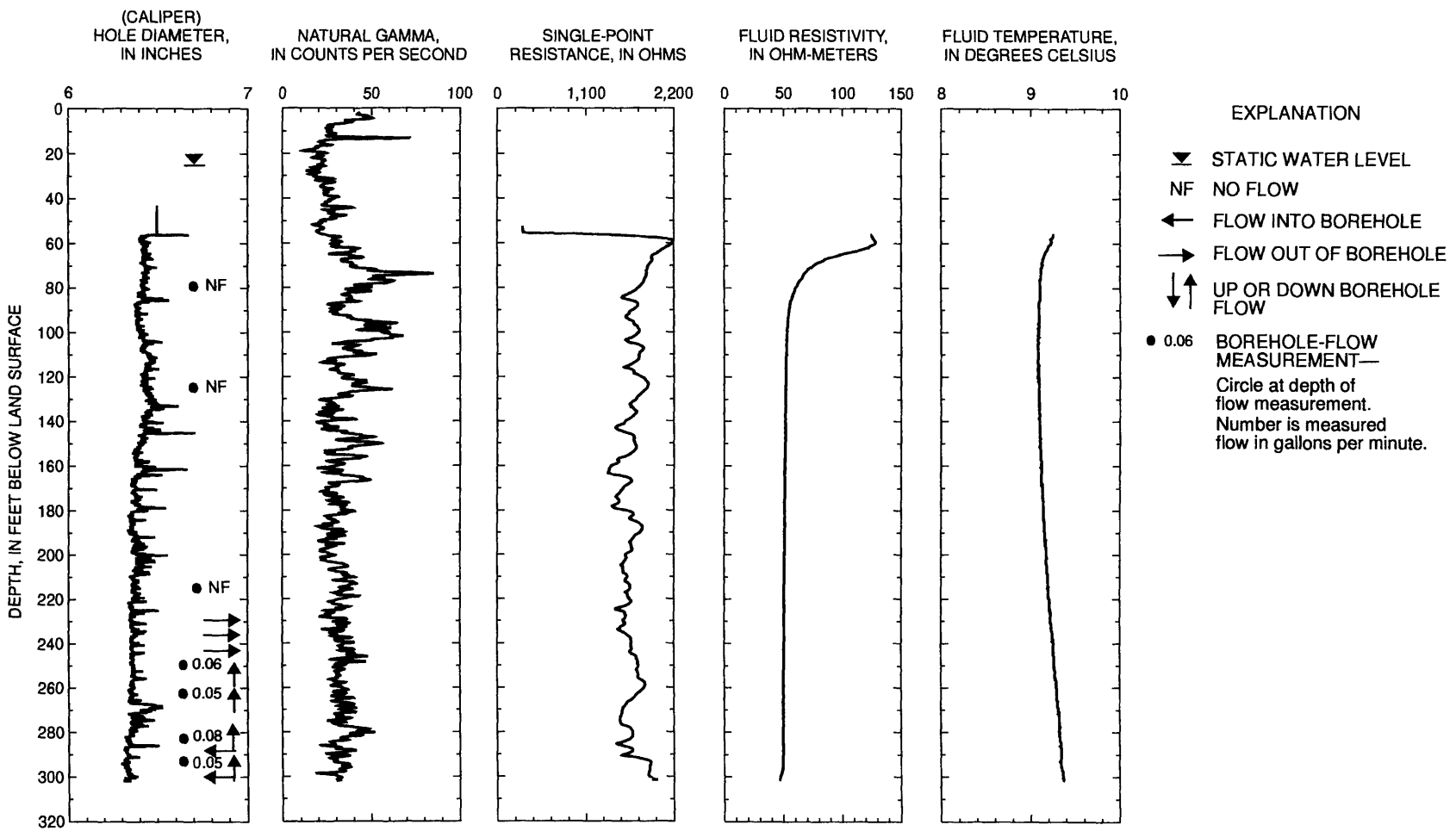

Figure 8. Borehole-geophysical logs for borehole BE-1568 (MW-2-DR), collected on May 2, 1997, Crossley Farms Superfund Site, Berks County, Pennsylvania.

BE-1571(MW-1-R)

The gamma and borehole-video logs were run in this borehole. The gamma log shows the total depth of the borehole is 162 ft bls (fig. 9). The static water level was 27.15 ft bls. The video log could not define depth of casing because of poor visibility. The video log shows the water becomes cloudy below 60 ft bls, the borehole becomes visually out of plumb at 135 ft bls, and visibility becomes very low at 150 ft bls to bottom. This borehole is the most contaminated with volatile organic compounds (Halliburton, NUS, written commun., 1996).

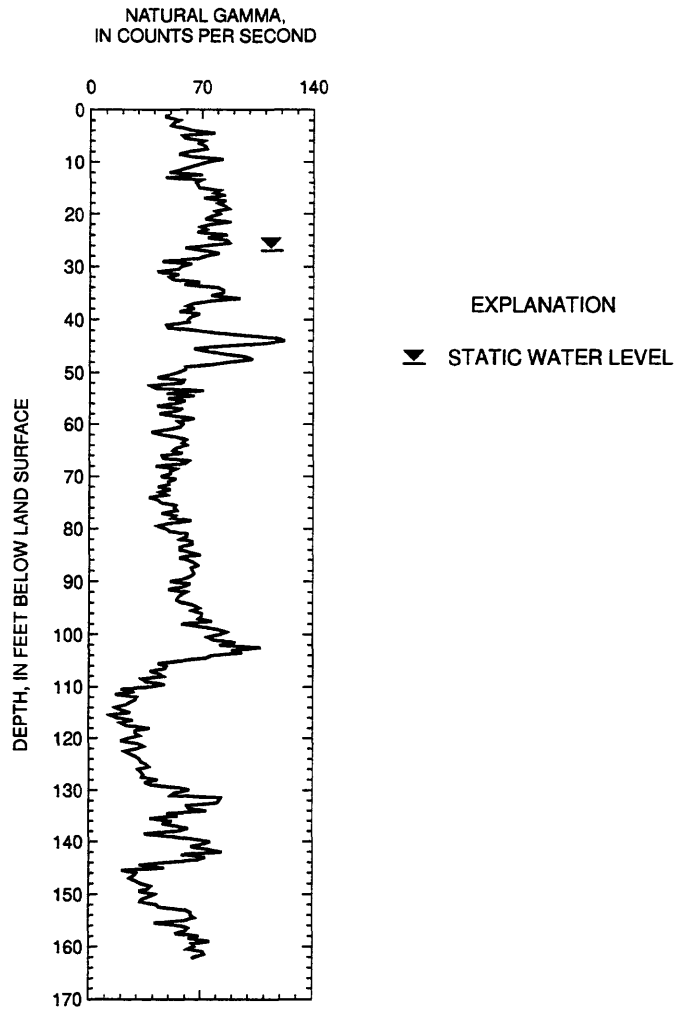

Figure 9. Borehole-geophysical log for borehole BE-1571 (MW-1-R), collected on May 7, 1997, Crossley Farms Superfund Site, Berks County, Pennsylvania.

BE-1572 (MW-1.1-OB)

Only the borehole-video log was run in this well. The log shows the total depth of the well is 41 ft bls and it is screened with PVC from 31 to 41 ft bls. The static water level was 31.9 ft bls. The video log shows light-colored staining at 11.7 and 25-27 ft bls, indicating possible seepage into the well. PVC casing threads are visible at the top of the PVC screen at 30.8 ft bls, indicating incomplete tightening of the casing joint.

BE-1573 (MW-1.2-OB)

Only the borehole-video log was run in this well. The log shows the total depth of the well is 44 ft bls and it is screened from 34 to 44 ft bls. The static water level was 39.3 ft bls. The video log shows an apparent high water mark at 22.6 ft bls and light-colored staining at 32.7 and 36 ft bls, indicating locations of possible seepage into the well. Some type of debris and staining are located just below water level at 39.3 ft bls. PVC casing threads are visible at the top of the screen at 34 ft bls, indicating incomplete tightening of the casing joint.

BE-1574 (MW-2-OB)

Only the borehole-video log was run in this borehole. The log shows the total depth of the well is 26 ft bls and it is screened with PVC from 15.8 to 25.8 ft bls. The borehole-video log shows the well has dry, brown stains at 13.5, 19.8, and 24.5 ft bls (may indicate previous water levels), an undefined semicircle on the PVC screen at 20.5 ft bls, and debris on well bottom.

BE-1575 (MW-2-R)

Only the borehole-video log was run in this well. The log shows the total depth of the borehole is 50 ft bls. The static water level was 26.5 ft bls. The video log could not define the depth of steel casing because of poor visibility. The borehole-video log shows large openings and horizontal fractures at 35 and 42 ft bls. The borehole is partially constricted at 42 ft bls because of shifting of loose formation material.

BE-1576 (MW-2.1-OB)

Only the borehole-video log was run in this well. The log shows the total depth is 60 ft bls and it is screened with PVC casing from approximately 50 to 60 ft bls. The static water level was 40.3 ft bls. The video log shows stains at 33.4, 39.2, and 45 ft bls that may indicate different static water levels. The screen is slightly stained and dirty.

BE-1577 (MW-3-OB)

Only the borehole-video log was run in this well. The log shows the total depth is 23 ft bls and it is screened with PVC casing from 13 to 23 ft bls. The static water level was 0.5 ft bls. An orange paint-can cap had to be removed from the well before logging. The video log shows a very dirty casing, debris at 15.5 ft bls, and sand and silt on the bottom of well.

BE-1578 (MW-3-DOB)

Only the borehole-video log was run in this well. The log shows the total depth is 69 ft bls and it is screened with PVC casing from 49.5 ft bls to the visible bottom. The static water level was 30.2 ft bls. The borehole video log shows debris at 26 ft bls, possibly indicating a high water level. The casing is chipped at 29.7 ft bls, debris is seen at 67.1 ft bls, and sand and silt on the bottom appear to contain PVC shreds.

BE-1579 (MW-4-OB)

Only the borehole-video log was run in this well. The log shows the total depth is 21 ft bls and it is screened with PVC casing from 11 to 21 ft bls. The static water level was 1.7 ft bls. The borehole-video log shows the well is clean with little debris or dirt and only slight sediment on the bottom.

BE-1580 (MW-5-OB)

Only the borehole-video log was run in this well. The log shows the total depth is 33 ft bls and it is screened with PVC casing from 23 to 33 ft bls. The static water level was 24.1 ft bls. The borehole-video log shows organic material growing on joint threads at 4.9 ft bls, moisture and possible bacterial growth at the joint at 13 ft bls, and stain marks at 16.6, 19.8, and 20.9 ft bls that may indicate different static water levels. The PVC screen is stained and coated beginning at 26.2 ft bls to bottom.

BE-1581 (MW-5-DOB)

Only the borehole-video log was run in this well. The log shows the total depth is 100 ft bls and it is screened with PVC casing from approximately 80 to at least 100 ft bls. The static water level was 55.1 ft bls. The borehole video log shows white material that may be the bentonite used to seal the annulus between the borehole and the PVC casing coming from the joint at 52.5 ft bls. The video shows possible bacteria staining below 59 ft bls that increases with depth. The PVC screen is stained and partly coated or clogged for its entire length.

BE-1582 (MW-7-OB)

Only the borehole-video log was run in this well. The log shows the total depth is 58 ft bls and it is screened with PVC casing from 38 to 58 ft bls. The static water level was 49.2 ft bls. The borehole-video log indicates possible seepage from the joint at 28 ft bls. Joint threads are visible at the top of the screen at 38 ft bls, indicating incomplete tightening. The video shows the casing is dirty and stained the entire length, especially below 28 ft bls. The screen is dirty and shows unknown deposits at 41.5 and 44 ft bls; some silt or sand is on the well bottom.

BE-1583 (Wetzel)

The caliper log shows the total depth of the borehole is 278 ft and it is cased with 6-in.-diameter casing (fig. 10). The single-point-resistance log shows steel casing to 56 ft bls. The static water level was 31.98 ft bls. The caliper log shows only minor fractures throughout the open-hole interval and a minor constriction at 269 ft bls. The caliper log shows the bottom 7 ft of the borehole is filled with soft sediment. Under ambient conditions, the heat-pulse-flowmeter measurements indicated upward borehole flow at 60, 80, 100, 150, 200, 250, and 260 ft bls (table 7). The borehole video shows near zero visibility from water level to 82 ft bls, partial clearing near 82 ft bls, and poor visibility below 150 ft bls. The geophysical logs and the heat-pulse-flowmeter data indicate water enters the borehole through the fractures below 260 ft bls, moves upward, and exits the borehole through fractures at 84 and 57 ft bls. If the water produced by the fractures below 260 ft bls is contaminated, leaving this well as an open borehole may create cross-contamination of the shallow aquifer. A screen placed at 250-270 ft bls would include the water-producing fractures below 260 ft bls.

Table 7. *Summary of heat-pulse-flowmeter measurements for borehole BE-1583 (Wetzel) at Crossley Farms Superfund Site, Berks County, Pennsylvania*

[ft bls, feet below land surface; gal/min, gallons per minute]

Depth (ft bls)	Flow rate under ambient conditions (gal/min)	Flow direction under ambient conditions
50	no flow	
60	0.06	up
80	.09	up
100	.26	up
150	.43	up
200	.32	up
250	.32	up
260	.33	up

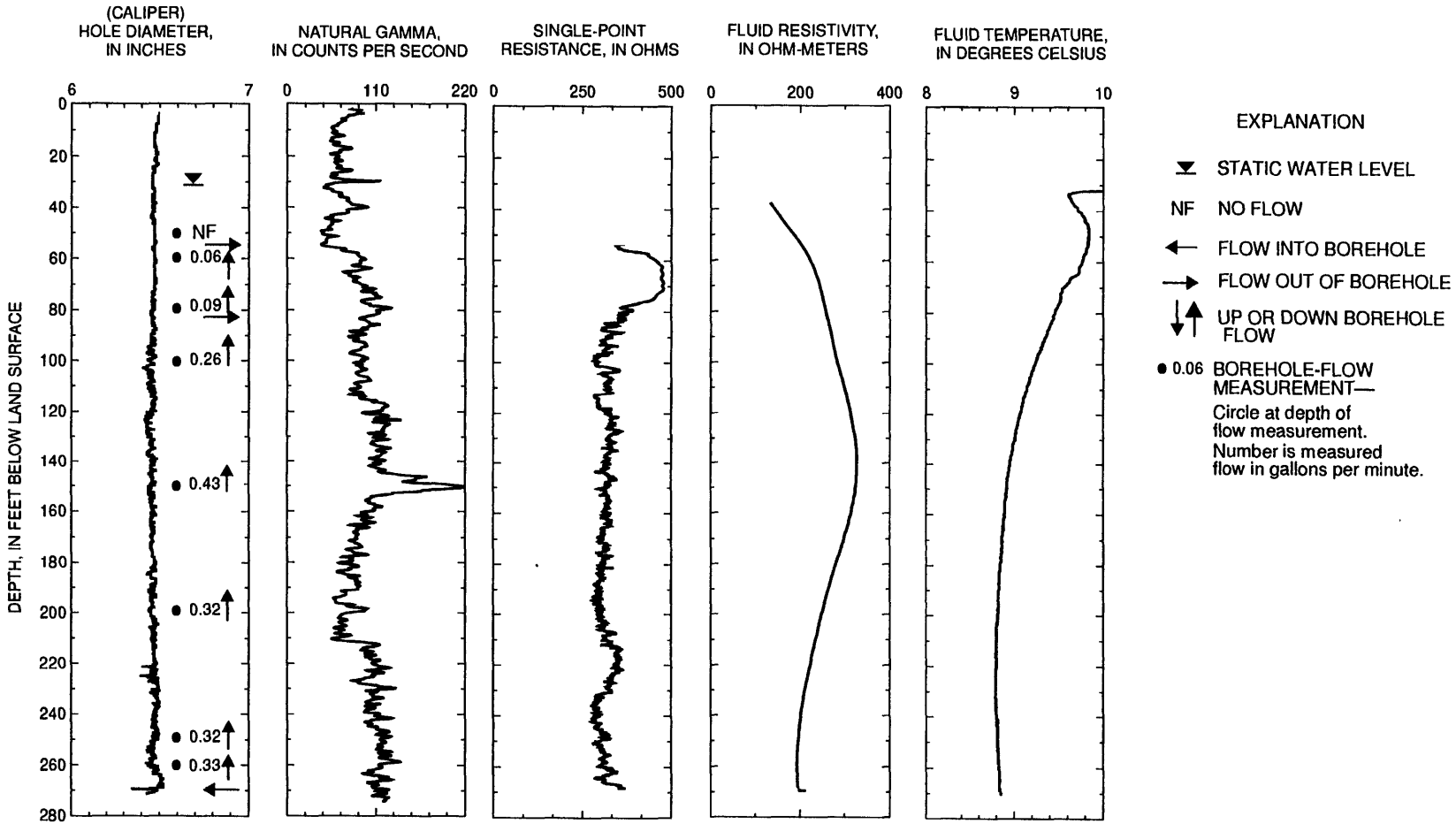

Figure 10. Borehole-geophysical logs for borehole BE-1583 (Wetzel), collected on May 6, 1997, Crossley Farms Superfund Site, Berks County, Pennsylvania.

BE-1584 (92-17)

The caliper log shows the total depth of the borehole is 435 ft and it is cased with 6-in.-diameter casing to approximately 54 ft bls (fig. 11). The static water level was 3.64 ft bls. The caliper log shows major fractures at 54.5-59, 162, and 276-278 ft bls and numerous minor fractures throughout the open-hole interval. The fluid-resistivity and fluid-temperature logs show changes in slope at approximately 60, 110, and 320 ft bls. Under ambient conditions, the heat-pulse-flowmeter measurements indicated upward borehole flow at 64, 70, 80, 124, 150, 200, 264, 302, 350, and 401 ft bls; downward flow at 88 and 100 ft bls, and no flow at 420 ft bls (table 8). The borehole video shows the water column is very cloudy with many suspended particles. Partial clearing does occur at 66-68 ft bls. The geophysical logs and the heat-pulse-flowmeter data indicate water enters the borehole through the fractures below 400 ft bls, at 320, 276-278, and about 130 ft bls, moves upward, and exits the borehole through fractures at 102-117 ft bls. Also, water enters the borehole through fractures at 83 ft bls, moves upward and downward, and exits the borehole through fractures at 59 and 102-117 ft bls, respectively. If the water produced by the fractures below 400 ft bls, at 320, at 276-278, and approximately 130 ft bls is contaminated, leaving this well as an open borehole may create cross-contamination of the intermediate or shallow aquifer.

Table 8. *Summary of heat-pulse-flowmeter measurements for borehole BE-1584 (92-17) at Crossley Farms Superfund Site, Berks County, Pennsylvania*

[ft bls, feet below land surface; gal/min, gallons per minute]

Depth (ft bls)	Flow rate under ambient conditions (gal/min)	Flow direction under ambient conditions
64	0.23	up
70	.07	up
80	.07	up
88	.28	down
100	.68	down
124	.80	up
150	.43	up
200	.38	up
264	.49	up
302	.42	up
350	.06	up
401	.06	up
420	no flow	

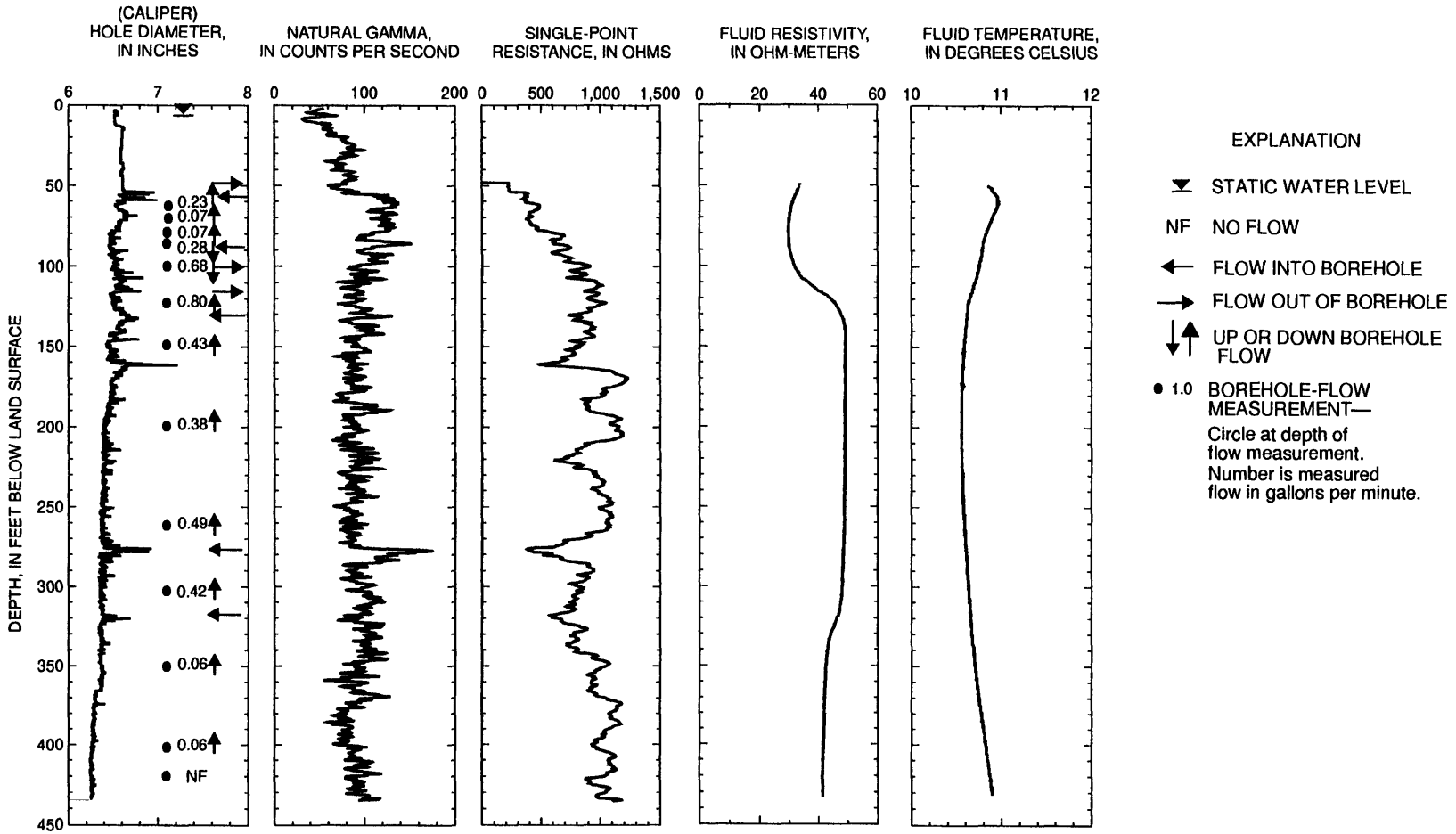

Figure 11. Borehole-geophysical logs for borehole BE-1584 (92-17), collected on May 8, 1997, Crossley Farms Superfund Site, Berks County, Pennsylvania.

CONCLUSIONS

This report identifies water-producing zones, water-receiving zones, and intervals of vertical borehole flow and determines the condition of existing well construction by the use of geophysical logs, heat-pulse-flowmeter data, and video logs. These data will help evaluate horizontal and vertical distribution of any contaminated ground water migrating from known contaminant sources and the integrity of existing wells.

Boreholes located off the Crossley Farms Superfund Site, BE-1562 (MW-8R), BE-1563 (MW-7R), BE-1567 (MW-5R), and BE-1583 (Wetzel), are located down gradient from the Crossley Farms Superfund Site near the base of Blackhead Ridge and show upward ambient borehole flow. In these boreholes, water is produced through fractures between 90-270 ft bls, moves upward, and exits the borehole through fractures between 55-200 ft bls, indicating that these boreholes are located in areas of ground-water discharge.

Borehole BE-1568 (MW-2DR) is deep and shows only minor upward flow near the bottom. BE-1571 (MW-1R), located on-site down gradient from the contaminant source, penetrates a fracture zone, is high yielding, and is the most contaminated borehole.

Flowmetered boreholes BE-1562, BE-1563, BE-1564, BE-1567, BE-1568, and BE-1583 all show minor vertical flow within the borehole. Generally, water is produced near the bottom of the borehole, regardless of depth, moves upward, and exits the borehole through fractures near the bottom of casing. The upper fluid-receiving fractures apparently depend on the depth of casing in each borehole. Heat-pulse-flowmeter data indicate all boreholes penetrate one to three water-bearing zones depending on well depth. Well yield apparently depends on chance interception of interconnected water-producing fractures.

The video logs were useful for casing inspection, especially for PVC-screened wells. Screen intervals were verified and potential construction problems were identified in several wells. The video logs show that most wells were cloudy with poor visibility that may be partially a result of logging activities. Visibility was so poor in wells BE-1571 and BE-1575 that depth of casing could not be determined. The video log shows that BE-1566 (MW4-R) has broken casing at 46 ft bls.

REFERENCES CITED

Conger, R.W., 1996, Borehole geophysical logging for water-resources investigations in Pennsylvania: U.S. Geological Survey Fact Sheet 218-95, 4 p.

Halliburton NUS, 1995, Draft Remedial Investigation/Feasibility Study Project Operations Plan, Crossley Farms Site, Berks County, Pennsylvania: EPA Contract No. 68-W8-0037.

Keys, W.S., 1988, Borehole geophysics applied to ground-water investigations: U.S. Geological Survey Open-File Report 87-539, 305 p.

Keys, W.S., and MacCary, L.M., 1971, Application of borehole geophysics to water-resources investigations: U.S. Geological Survey Techniques of Water-Resources Investigations, book 2, chap. E1, 124 p.

Roy F. Weston/IT, 1988, Regional Hydrogeologic Investigation, Town of Hereford Site, Berks County, Pennsylvania: EPA Contract No. 68-03-3482.

Williams, J.H., and Conger, R.W., 1990, Preliminary delineation of contaminated water-bearing fractures intersected by open-hole bedrock wells: Groundwater Monitoring Review, Fall 1990, p. 118-121.