

U.S. Department of the Interior  
U.S. Geological Survey

# Evaluation of Borehole Geophysical and Video Logs, at Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania

*by Dennis J. Low and Randall W. Conger*

Water-Resources Investigations Report 01-4173

*In cooperation with the*  
**U.S. ENVIRONMENTAL PROTECTION AGENCY**

New Cumberland, Pennsylvania  
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**U.S. DEPARTMENT OF THE INTERIOR**

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### CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

Multiply	By	To obtain
	<u>Length</u>	
inch (in)	2.54	centimeter
foot (ft)	0.3048	meter
	<u>Area</u>	
acre	4,047	square meter
	<u>Flow rate</u>	
gallon per minute (gal/min)	0.06309	liter per second
	<u>Temperature</u>	
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, formerly called Sea Level Datum of 1929.

# **Evaluation of Borehole Geophysical and Video Logs, at Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania**

*by Dennis J. Low and Randall W. Conger*

## **ABSTRACT**

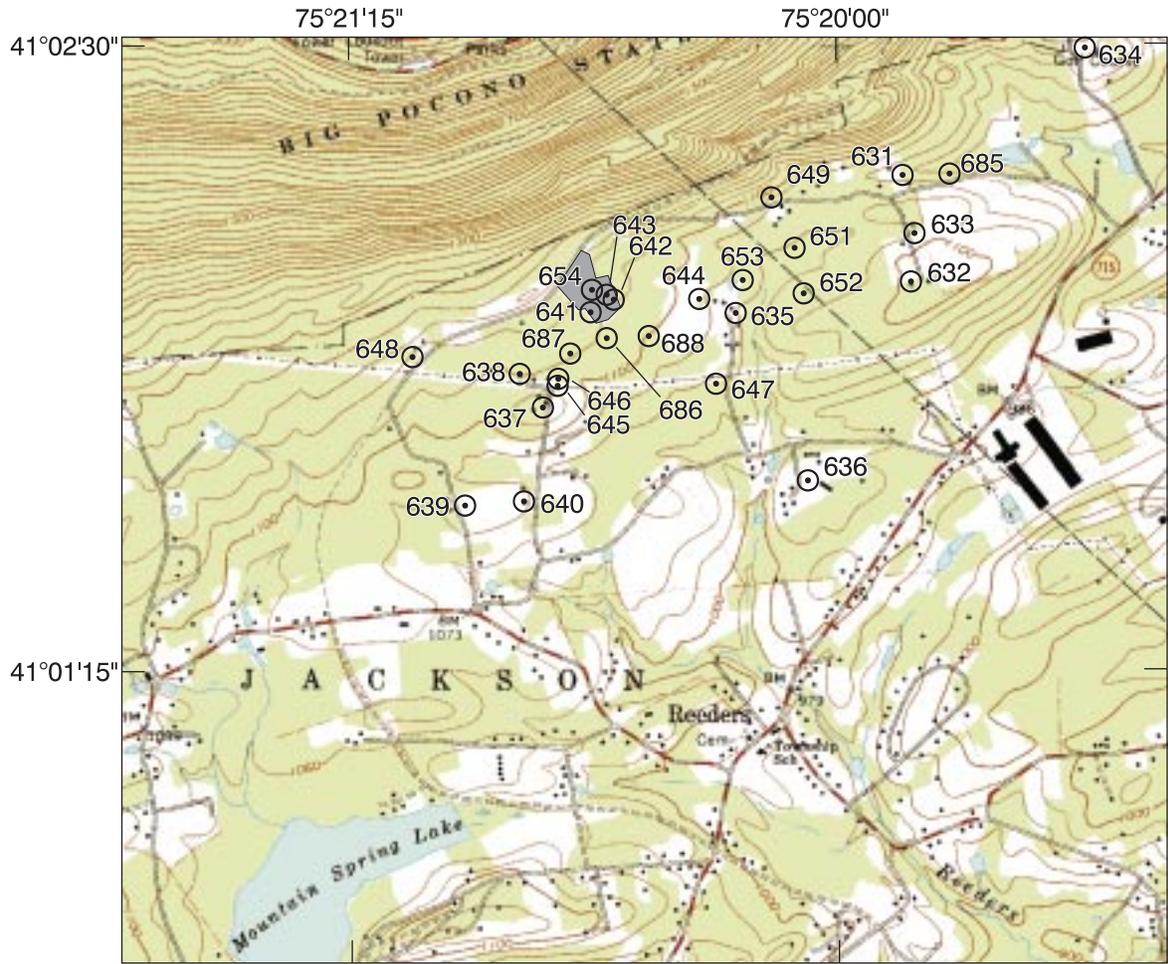
Between February 1996 and November 2000, geophysical logging was conducted in 27 open-borehole wells in and adjacent to the Butz Landfill Superfund Site, Jackson Township, Monroe County, Pa., to determine casing depth and depths of water-producing zones, water-receiving zones, and zones of vertical borehole flow. The wells range in depth from 57 to 319 feet below land surface. The geophysical logging determined the placement of well screens and packers, which allow monitoring and sampling of water-bearing zones in the fractured bedrock so that the horizontal and vertical distribution of contaminated ground water migrating from known sources could be determined. Geophysical logging included collection of caliper, natural-gamma, single-point-resistance, fluid-resistivity, fluid-temperature, and video logs. Caliper and video logs were used to locate fractures, joints, and weathered zones. Inflections on single-point-resistance, fluid-temperature, and fluid-resistivity logs indicated possible water-bearing fractures, and heatpulse-flowmeter measurements verified these locations. Natural-gamma logs provided information on stratigraphy.

## **INTRODUCTION**

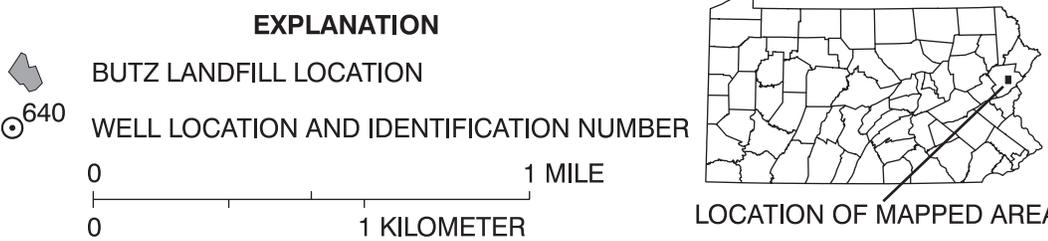
The Butz Landfill Superfund Site (Butz Landfill) covers approximately 13.4 acres; the landfill area and monitor wells are shown on the U.S. Geological Survey (USGS) Mount Pocono 7.5-minute topographic quadrangle map (fig. 1). The Butz Landfill was used as a municipal-waste dump from approximately 1963 until at least 1969; some landfill activities probably continued until 1984 (Bureau of Reclamation, 1994).

In early 1973, the Pennsylvania Department of Environmental Protection (PADEP) ordered the landfill closed. In 1986, PADEP conducted a site inspection and sampling program of domestic wells in close proximity to the site and detected volatile organic compounds (VOC's) in the ground water. A Remedial Investigation/Feasibility Study (RI/FS) was initiated by the U.S. Environmental Protection Agency (USEPA) and its consultants in December 1988 and completed in September 1991. The RI/FS identified trichloroethylene (TCE), 1,2-dichloroethene (1,2-DCE), and vinyl chloride (VC) as the principal contaminants. In June 1992, the Record of Decision (ROD) was signed stating that no remedial actions were necessary for surface water, sediments, or the landfill. The selected remedy for contaminated ground water was to design and install a well-extraction system that would reduce TCE concentrations to background levels prior to discharge to local surface waters. On the basis of the remedial actions in the ROD, USEPA requested the Bureau of Reclamation (BOR) to install a permanent water-supply system and design and install an extraction-well system for cleanup of contaminated ground water.

In 1996, BOR asked USGS to assist with hydrologic investigations for the Remedial Design (RD) study at the Butz Landfill. USGS involvement was directed toward identification of water-bearing zones in the contaminated fractured-bedrock aquifer to help ensure monitor wells were completed at appropriate depth horizons. This work is part of the support provided by USGS to USEPA on hydrogeologic investigations at Superfund sites in Pennsylvania.



Base from U.S. Geological Survey Mount Pocono 1:24,000, 1992



**Figure 1.** Locations of landfill and boreholes logged in and adjacent to the Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania (prefix "MO" is omitted for visual clarity).

## Purpose and Scope

This report evaluates borehole geophysical and video logs collected by the USGS in 27 open boreholes in and adjacent to the Butz Landfill Superfund Site, Jackson Township, Monroe County, Pa., (table 1 and fig. 1) from February 28, 1996, to November 6, 2000. This report (1) identifies the location of subsurface fractures; (2) identifies, where possible, important water-bearing fractures; (3) identifies zones of potential borehole flow; and (4) describes the direction and rate of vertical borehole flow. These data provided hydrogeologic information in and adjacent to the Butz Landfill to select the most appropriate depth to screen and set permanent borehole packers for sampling discrete intervals in each borehole.

**Table 1.** Boreholes logged at the Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania

(B, borehole video; C, caliper log; G, natural-gamma; R, single-point resistance, F, fluid-resistivity log; T, fluid-temperature log; V, heatpulse flowmeter)

U.S.Geological Survey borehole-identification number	Bureau of Reclamation borehole-identification number	Date logged	Depth logged (feet)	Depth to water below land surface (feet)	Length of casing below land surface (feet)	Geophysical logs collected
MO-631	RW8	04/03/1996	118	1.38	28	C, F, T, V
MO-632	RW10	03/29/1996 07/21/1999	167	27.56 42.94	28	C, F, T, V B, C, F, T, V
MO-633	RW12	04/02/1996 07/22/1999	319	35.55 43.54	37	C, F, T, V B, C, F, T, V
MO-634	RW14	04/04/1996	293.6	73.22	8	C, F, T, V
MO-635	RW18	03/13/1996	138	10.72	95	C, F, T, V
MO-636	RW23	04/03/1996	95	24.39	21	C, F, T, V
MO-637	RW39	04/04/1996 07/22/1999	221	40.13 44.40	59	C, F, T, V B, C, F, T, V
MO-638	RW43	03/28/1996	56	6.99	14	C, F, T, V
MO-639	RW50	04/03/1996	88	12.21	66	C, F, T, V
MO-640	RW52	04/02/1996 07/21/1999	122	13.89 19.26	50	C, F, T, V B, C, F, T, V
MO-641	R1_1A	03/07/1996	201	15.75	18	C, F, T, V
MO-642	R1S	04/05/1996	98.7	4.07	25	C, F, T, V
MO-643	R1D	03/14/1996	241	16.56	103	C, F, T, V
MO-644	R2	03/13/1996	132.5	7.12	19	C, F, T, V
MO-645	R3S	03/28/1996	101	25.70	40	C, F, T, V
MO-646	R3D	03/06/1996	239.5	44.29	104	C, F, T, V
MO-647	R4	03/06/1996	147	14.55	18	C, F, T, V
MO-648	R5	02/28/1996	240	5.32	19	C, F, T, V
MO-649	R6	03/05/1996	241	9.19	18	C, F, T, V
MO-651	PW-A	07/08/1996	158.5	12.63	34	C, G, R, F, T, V
MO-652	PW-B	07/09/1996	149	12.17	37	C, G, R, F, T, V
MO-653	PW-C	08/20/1996	185.5	23.40	29	C, G, R, F, T, V
MO-654	PW-D	07/01/1996	248	20.55	30	C, G, R, F, T, V
MO-685	R7	11/06/2000	248	10.39	37	C, G, R, F, T, V
MO-686	R8	10/24/2000	249	28.07	38	C, G, R, F, T, V
MO-687	R9	11/06/2000	249	22.65	37	B, C, G, R, F, T, V
MO-688	R11B	10/24/2000	140.2	18.07	19	B, C, G, R, F, T, V

Caliper, fluid-resistivity, and fluid-temperature logs and heatpulse-flowmeter measurements were collected in all 27 wells. Natural-gamma and single-point-resistance logs were collected in 8 of the 27 wells. Borehole-video logs were run in 6 of the 27 boreholes (table 1). A cross-reference between USGS borehole-identification numbers and BOR borehole-identification numbers is presented in table 1.

### **Location and Physiography**

The Butz Landfill is in the Glaciated Low Plateau Section of the Appalachian Plateaus Physiographic Province (Fenneman, 1938; Berg and others, 1989) and is on the southern flank of east-west trending Camelback Mountain. The topography of the area has been affected greatly by continental glaciation and is characterized by scattered mountains separated by rounded hills and valleys; altitudes range between 700 and 2,133 ft above sea level. Altitude on site averages about 1,140 ft above sea level (fig. 1). The region lacks well-developed drainage; many streams drain into small lakes, ponds, and swamps.

### **HYDROGEOLOGY**

Butz Landfill and surrounding area are overlain by unconsolidated surficial deposits of the Woodfordian Ground Moraine (Berg and others, 1977). The surficial deposits consist mainly of till and nonstratified clay, silt, sand, pebbles, cobbles, and boulders. Seismic refraction surveys done at Butz Landfill indicates that the thickness of surficial deposits range from 25 to 40 ft; the thickness may be as great as 100 ft in areas of local bedrock depressions.

Butz Landfill and surrounding area are underlain by sedimentary rocks of the Upper Devonian age Long Run Member of the Catskill Formation. The Long Run Member consists predominantly of alternating gray to grayish-red, crossbedded to planar-bedded sandstone and red to gray siltstone and shale, arranged in fining-upward fluvial cycles. The fluvial cycles vary from about 20 to 100 ft in thickness (Berg and others, 1977). Butz Landfill lies stratigraphically within the upper cycle facies, which is dominated by siltstone but also contains shale and very fine sandstone. Estimated maximum thickness of the Long Run Member is 3,175 ft. The regional bedding trend strikes N. 65°E. and dips from 5 to 15° to the northwest.

Ground water at Butz Landfill originates from infiltration of local precipitation and discharges to local intermittent streams, pumping wells, and underlying bedrock aquifers. After infiltrating through void spaces in the glaciated surficial glacial deposits and weathered bedrock, ground water moves through vertical and horizontal fractures and joints in the sandstones and shales. The sandstone aquifers are enveloped by shale aquitards.

Three types of flow systems have been recognized in the bedrock aquifers of Monroe County—local, intermediate, and regional (Carswell and Lloyd, 1979). The local flow or shallow ground-water system moves through the glaciated surficial deposits and weathered bedrock. The intermediate and regional or deep ground-water system moves through fractures and joints of the more competent bedrock. Ground-water levels fluctuate with pumping and seasonal variations in recharge. Water from the shallow system may drain locally to the intermittent streams and also leak downward to a deeper ground-water-flow system. Wells constructed as open boreholes 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. Ground water generally flows in a direction similar to the topographic gradient. However, the natural direction of flow can be altered by pumping. Pumping from deep zones may induce downward flow from shallow zones.

## **BOREHOLE GEOPHYSICAL AND VIDEO LOGS**

Geophysical logs provide information on location of fractures (caliper and video logs), 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 data on well construction (caliper and single-point-resistance logs).

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 and water-receiving zones and 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, water-receiving zones, and zones of vertical borehole flow.

The natural-gamma or gamma log measures the natural-gamma radiation (photons) emitted from rocks penetrated by the borehole. 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. Geophysical logging with a gamma probe can be conducted in the fluid-filled, dry, cased, or uncased parts of a borehole. However, casing does reduce the gamma response. The gamma log is used to correlate geologic units between wells or boreholes (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 increasing 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 or boreholes 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 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 usually are 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, some types of contaminant plumes can be identified with fluid-resistivity logs.

Fluid-temperature logs provide a continuous record of the temperature of vertical variation in 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 borehole-water movement was determined by the use of a heatpulse flowmeter. The heatpulse flowmeter operates by heating a small volume 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 measurements is about 0.01 to 1.2 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 primarily are used as a relative indicator to identify water-producing or water-receiving zones.

Borehole-video logging was conducted by lowering a waterproof camera down the borehole and recording the image on video tape. The depth indicated on the video log typically is within plus or minus 1.0 ft of the geophysical logs because of some minor slippage of the television cable and is corrected by comparison with other geophysical logs.

## EVALUATION OF BOREHOLE GEOPHYSICAL AND VIDEO LOGS

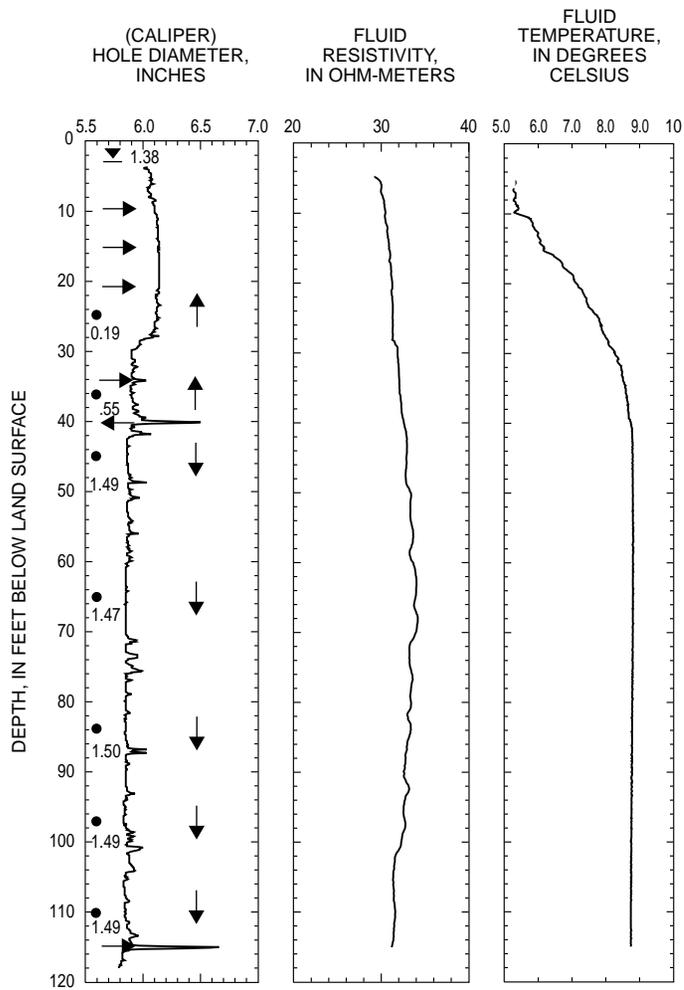
The locations of boreholes logged are shown on figure 1. The reference measuring point for all geophysical logs and video logs is in feet below land surface. For each borehole, the date(s) logged, depth logged, water level at the time of logging, and list of logs run in each borehole are presented in table 1.

### MO-631 (RW8)

Monitor well MO-631 was logged April 3, 1996. The caliper log shows the borehole is drilled to a depth of 118 ft bls (below land surface) and is cased with 6-in.-diameter casing to 28 ft bls (fig. 2). There is, however, 4 ft of muck (soft mud and silt) from 118 to 122 ft bls in the borehole. The caliper log shows major fractures at 40 and 115 ft bls plus numerous minor fractures throughout the openhole interval. The fluid-resistivity log shows numerous minor changes in slope that correlate closely with major and minor fractures on the caliper log, indicating possible lateral flow. The fluid-temperature log shows a change in slope at approximately 40 ft bls that correlates to a major fracture shown on the caliper log. Under nonpumping conditions, the heatpulse flowmeter measured upward borehole flow at 25 and 36 ft bls and downward flow at 45, 65, 84, 97, and 110 ft bls (table 2). The geophysical logs and the heatpulse-flowmeter data indicate water enters the borehole through the major fracture at 40 ft bls, moves upward and downward, and exits the borehole through a minor fracture at 34 ft bls, breaks in casing at about 10, 15, and 21 ft bls, and the fracture at 115 ft bls. The fracture at 40 ft bls produces about 2 gal/min of water under nonpumping conditions.

**Table 2.** Summary of heatpulse-flowmeter measurements for borehole MO-631 (RW8) on April 3, 1996, at the Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallons per minute)	Flow direction under nonpumping conditions
25	0.19	Up
36	.55	Up
45	1.49	Down
65	1.47	Down
84	1.50	Down
97	1.49	Down
110	1.49	Down



### EXPLANATION

- ▼ 1.38 STATIC WATER LEVEL—Measured in well at the time of geophysical logging
- 0.19 BOREHOLE-FLOW MEASUREMENT UNDER NONPUMPING CONDITIONS—  
Circle at depth of flow measurement. Number is measured flow in gallon per minute.
- ↑ ↓ DIRECTION OF BOREHOLE FLOW UNDER NONPUMPING CONDITIONS
- ← KNOWN (OR INFERRED) WATER-PRODUCING ZONE UNDER NONPUMPING CONDITIONS
- KNOWN (OR INFERRED) WATER-RECEIVING ZONE UNDER NONPUMPING CONDITIONS

**Figure 2.** Borehole geophysical logs and direction of borehole flow under nonpumping conditions within MO-631 (RW8), collected on April 3, 1996, Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania.

**MO-632 (RW10)**

Monitor well MO-632 was logged March 29, 1996 (fig. 3), and on July 21, 1999. The caliper log shows the borehole is drilled to a depth of 167 ft and is cased with 6-in.-diameter casing to 28 ft bls. The caliper log shows major fractures at 47 to 49, 72 to 73, and 82 to 86 ft bls plus numerous minor fractures throughout the openhole interval. The fluid-resistivity log shows major changes in slope at 72 and 114 to 132 ft bls plus minor deflections at 33, 40, 48, 54, 60, 87, 95, and 104 ft bls. The decrease in slope of the fluid-resistivity log from 114 to 132 ft bls probably is a product of change in water chemistry (increase in total dissolved solids) as a result of the absence of borehole flow. The fluid-temperature log shows minor changes in slope at 33, 40, and 87 ft bls that correlate with fractures on the caliper log. Under nonpumping conditions, the heatpulse flowmeter measured downward flow at 44, 67, and 77 ft bls, and no flow at 36, 90, and 98 ft bls (table 3). This suite of borehole geophysical logs indicates, under nonpumping conditions, water enters the borehole through the fractures at 38 to 41, 48, and possibly 63 ft bls and moves downward; a small quantity exits the borehole through the fractures at 73 ft bls and 80 to 85 ft bls.

**Table 3.** Summary of heatpulse-flowmeter measurements for borehole MO-632 (RW10) on March 29, 1996, at the Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania

[—, not determined]

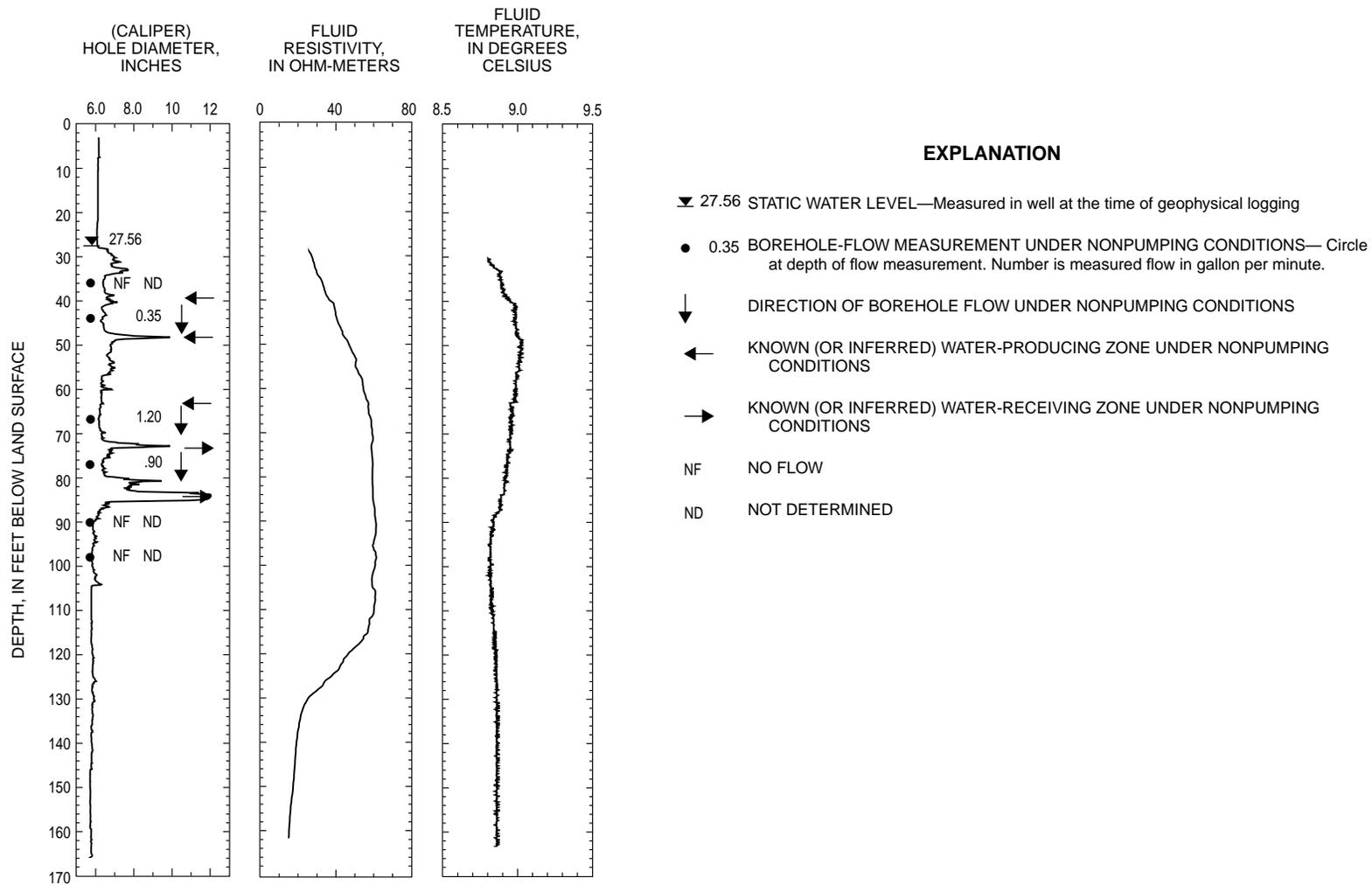
Depth (feet below land surface)	Flow rate under nonpumping conditions (gallons per minute)	Flow direction under nonpumping conditions
36	No flow	—
44	0.35	Down
67	1.20	Down
77	.90	Down
90	No flow	—
98	No flow	—

The caliper log collected on July 21, 1999, is similar to that collected on March 29, 1996. The fluid-resistivity log shows changes in slope at 53, 55, 58, 71, 84, 95, and 102 to 104 ft bls that correlate closely to fractures on the caliper log. Under nonpumping conditions, the heatpulse-flowmeter measurements indicated possible downward flow at 68 ft bls, upward flow at 78 ft bls, and no flow at 99, 120, and 146 ft bls (table 4). The decrease in slope of the fluid-resistivity log from 116 to 132 ft bls probably is a product of change in water chemistry (increase in total dissolved solids) as a result of the absence of borehole flow. The suite of borehole geophysical logs and heatpulse-flowmeter data indicate, under nonpumping conditions, the fractures at 61 and 81 to 86 ft bls are water-producing zones, and the fracture at 73 to 75 ft bls is a water-receiving zone.

**Table 4.** Summary of heatpulse-flowmeter measurements for borehole MO-632 (RW10) on July 21, 1999, at the Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania

[—, not determined]

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallon per minute)	Flow direction under nonpumping conditions	Flow rate under pumping conditions (gallon per minute)	Flow direction under pumping conditions
68	—	Down (?)	0.57	Up
78	0.05	Up	.36	Up
99	No flow	—	No flow	—
120	No flow	—	No flow	—
146	No flow	—	No flow	—



**Figure 3.** Borehole geophysical logs and direction of borehole flow under nonpumping conditions within MO-632 (RW10), collected on March 29, 1996, Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania.

No borehole flow was observed on the video log under nonpumping conditions. The video log does show, however, the borehole is extensively fractured from a depth of about 34 to 88 ft bls; fracturing generally is absent from a depth of about 106 ft bls to the bottom of the borehole. Most of the fractures appear to be low-angle with secondary mineralization of the fractures very common at a depth of about 86 ft bls.

A submersible pump was placed at 60 ft bls, and the borehole was pumped at a rate of approximately 1 gal/min. The water level in the borehole declined 0.21 ft after 42 minutes of pumping. Under pumping conditions, the heatpulse flowmeter measured upward flow at 68 and 78 ft bls and no flow at 99, 120, and 146 ft bls. The suite of geophysical logs and heatpulse-flowmeter data indicate, under pumping conditions, water enters the borehole through the fractures at 73 to 75 and 81 to 86 ft bls, moves upward, and exits the borehole through the fracture at 49 ft bls (table 4).

### **MO-633 (RW12)**

Monitor well MO-633 was logged April 2, 1996, and July 22, 1999. The caliper log shows the borehole is drilled to a depth of 319 ft and is cased with 6-in.-diameter casing to 37 ft bls (fig. 4). The caliper log shows major fractures at 47 to 49, 76 to 78, 95, 156, and 190 ft bls plus numerous minor fractures throughout the openhole interval. The fluid-resistivity log shows changes in slope at 49, 64, and 70 to 78 ft bls that correlate to fractures on the caliper log. The fluid-temperature log shows a minor change in slope at 65 ft bls and a constant gradient change of about 0.2°C per 100 ft of openhole interval from 95 to 319 ft bls. Under nonpumping conditions, the heatpulse flowmeter measured downward borehole flow at 86 ft bls and no flow at 42, 58, 68, 100, 110, 142, 160, and 200 ft bls (table 5). The suite of borehole geophysical logs and heatpulse-flowmeter data indicate that under nonpumping conditions water enters the borehole through the fractures at 70 to 78 ft bls, moves downward, and exits the borehole through the large fracture at 95 ft bls.

**Table 5.** Summary of heatpulse-flowmeter measurements for borehole MO-633 (RW12) on April 2, 1996, at the Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania

[—, not determined]

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallon per minute)	Flow direction under nonpumping conditions	Flow rate under pumping conditions (gallon per minute)	Flow direction under pumping conditions
42	No flow	—	—	—
58	No flow	—	—	—
68	No flow	—	—	—
86	0.11	Down	0.59	Up
100	No flow	—	.47	Up
110	No flow	—	.35	Up
142	No flow	—	.33	Up
160	No flow	—	.22	Up
174	—	—	.17	Up
194	—	—	No flow	—
200	No flow	—	—	—



A submersible pump was placed at 70 ft bls, and the borehole was pumped at a rate less than 0.5 gal/min. The water level in the borehole declined 10.44 ft after 1 hour and 21 minutes of pumping before stabilizing. Under pumping conditions, the heatpulse flowmeter measured upward borehole flow at 86, 100, 110, 142, 160, and 174 ft bls and no flow at 194 ft bls (table 5). The suite of borehole geophysical logs and heatpulse-flowmeter data indicate, under pumping conditions, water enters the borehole through the fractures at 94, 156, and 190 ft bls and moves upward.

The caliper log collected on July 22, 1999, is similar to that collected on April 2, 1996. The fluid-resistivity log shows a change in slope at 71 and 78 ft bls that correlates to fractures on the caliper log. The fluid-temperature log shows a constant temperature gradient increase of about 0.2°C per 100 ft of openhole interval from 95 to 310 ft bls. Under nonpumping conditions, the heatpulse-flowmeter measurements indicated no flow at 44, 74, 84, 148, 184, 250, and 290 ft bls (table 6). This result differs slightly from the data collected on April 2, 1996, in that downward flow of 0.11 gal/min was measured at a depth of 86 ft bls. Apparently, under less dry conditions, the fracture at 76 to 78 ft bls is a water-producing zone, and the fracture at 94 ft bls is a water-receiving zone.

No borehole flow was observed on the video log under nonpumping conditions. The video log does show, however, most fractures appear to be low-angle and are more common in the upper 154 ft of the borehole.

A submersible pump was placed at 65 ft bls, and the borehole was pumped at a rate that ranged from about 0.1 to 1.0 gal/min. The water level in the borehole declined 6.00 ft after 1 hour and 13 minutes of pumping. Under pumping conditions, the heatpulse flowmeter measured upward borehole flow at 74, 84, 100, 120, 150, and 184 ft bls and no flow at 200, 220 and 250 ft bls (table 6). The suite of borehole geophysical logs and heatpulse-flowmeter data indicate, under pumping conditions, the fracture at 190 ft bls is the major water-producing zone.

**Table 6.** Summary of heatpulse-flowmeter measurements for borehole MO-633 (RW12) on July 22, 1999, at the Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania

[—, not determined]

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallons per minute)	Flow direction under nonpumping conditions	Flow rate under pumping conditions (gallon per minute)	Flow direction under pumping conditions
44	No flow	—	—	—
74	No flow	—	0.12	Up
84	No flow	—	.13	Up
100	—	—	.14	Up
120	—	—	.13	Up
148	No flow	—	—	—
150	—	—	.12	Up
184	No flow	—	.07	Up
200	—	—	No flow	—
220	—	—	No flow	—
250	No flow	—	No flow	—
290	No flow	—	—	—

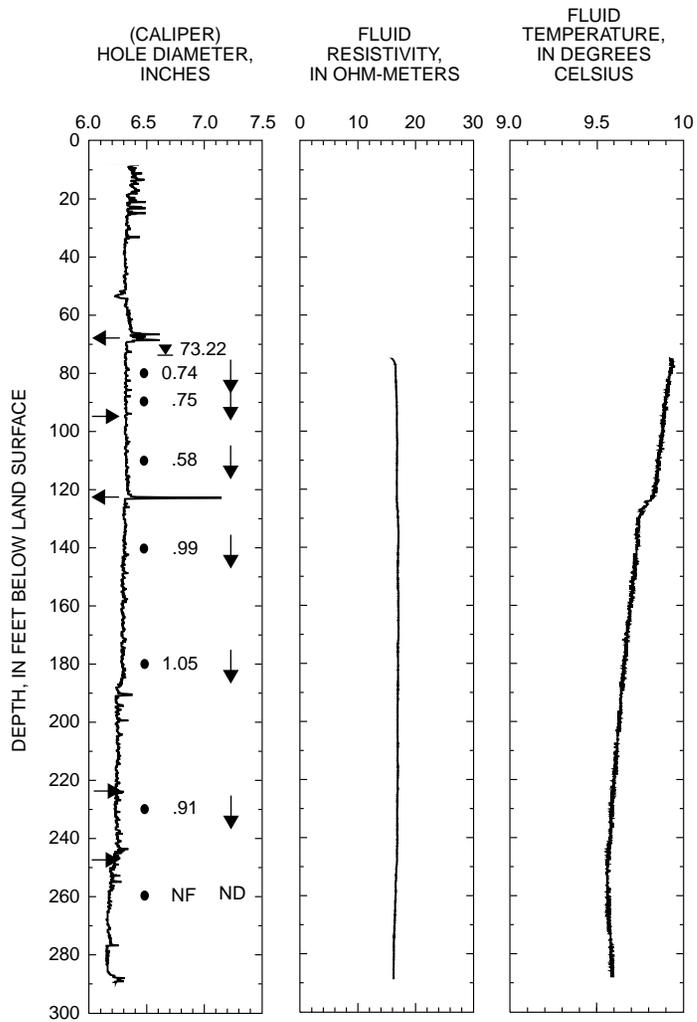
**MO-634 (RW14)**

Monitor well MO-634 was logged April 4, 1996. The caliper log shows the borehole is drilled to a depth of 293.6 ft bls and is cased with 6-in.-diameter casing to 8 ft bls (fig. 5). The caliper log shows major fractures at 66 to 69 and 123 ft bls plus numerous minor fractures throughout the openhole interval. The fluid-resistivity log shows minor changes in slope at 124, 224, 248, 253, 255, and 277 ft bls that correlate with fractures shown on the caliper log. The fluid-temperature log shows changes in slope at 124 and 248 ft bls that correlate with fractures shown on the caliper log. Under nonpumping conditions, the heatpulse flowmeter measured downward borehole flow at 80, 90, 110, 141, 180, and 230 ft bls and no flow at 260 ft bls (table 7). The suite of geophysical logs and the heatpulse-flowmeter data indicate water enters the borehole through the fractures at 66 to 69 and 123 ft bls and moves downward. Most water exits the borehole through the small fracture at 248 ft bls. Additional, but smaller amounts of water exit the borehole through minor fractures at approximately 94 and 224 ft bls.

**Table 7.** Summary of heatpulse-flowmeter measurements for borehole MO-634 (RW14) on April 4, 1996, at the Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania

[—, not determined]

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallon per minute)	Flow direction under nonpumping conditions
80	0.74	Down
90	.75	Down
110	.58	Down
141	.99	Down
180	1.05	Down
230	.91	Down
260	No flow	—



### EXPLANATION

- ▼ 73.22 STATIC WATER LEVEL—Measured in well at the time of geophysical logging
- 0.74 BOREHOLE-FLOW MEASUREMENT UNDER NONPUMPING CONDITIONS— Circle at depth of flow measurement. Number is measured flow in gallon per minute.
- ↓ DIRECTION OF BOREHOLE FLOW UNDER NONPUMPING CONDITIONS
- ← KNOWN (OR INFERRED) WATER-PRODUCING ZONE UNDER NONPUMPING CONDITIONS
- KNOWN (OR INFERRED) WATER-RECEIVING ZONE UNDER NONPUMPING CONDITIONS
- NF NO FLOW
- ND NOT DETERMINED

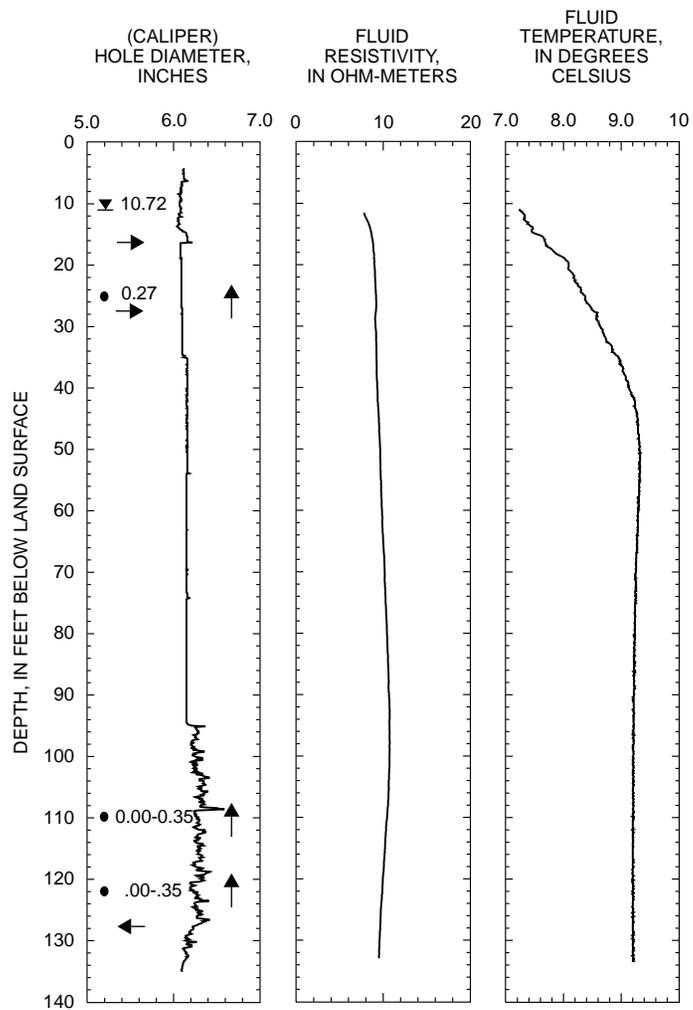
**Figure 5.** Borehole geophysical logs and direction of borehole flow under nonpumping conditions within MO-634 (RW14), collected on April 4, 1996, Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania.

### **MO-635 (RW18)**

Monitor well MO-635 was logged March 13, 1996. The caliper log shows the borehole is drilled to a depth of 138 ft bls and is cased with 6-in.-diameter casing to 95 ft bls (fig. 6). The caliper log shows numerous small fractures throughout the openhole interval and a break in casing at 16 ft bls. The fluid-resistivity log shows a change in slope at approximately 110 ft bls that correlates to a fracture on the caliper log. Under nonpumping conditions, the heatpulse flowmeter measured upward borehole flow at 25, 110, and 122 ft bls (table 8). The large variation in flow measured at the lower two fractures indicate this well is affected by pumping, probably from domestic wells at the adjacent houses. The suite of geophysical logs and heatpulse-flowmeter data indicate water enters the borehole through fractures near the bottom of the borehole (below 122 ft bls), moves upward, and exits the borehole through a break in the casing at 16 ft bls and possibly at 28 ft bls.

**Table 8.** Summary of heatpulse-flowmeter measurements for borehole MO-635 (RW18) on March 13, 1996, at the Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallon per minute)	Flow direction under nonpumping conditions
25	0.27	Up
110	0.00 to 0.35	Up
122	.00 to .35	Up



**EXPLANATION**

- ▼ 10.72 STATIC WATER LEVEL—Measured in well at the time of geophysical logging
- 0.27 BOREHOLE-FLOW MEASUREMENT UNDER NONPUMPING CONDITIONS— Circle at depth of flow measurement. Number is measured flow in gallon per minute.
- ↑ DIRECTION OF BOREHOLE FLOW UNDER NONPUMPING CONDITIONS
- ← KNOWN (OR INFERRED) WATER-PRODUCING ZONE UNDER NONPUMPING CONDITIONS
- KNOWN (OR INFERRED) WATER-RECEIVING ZONE UNDER NONPUMPING CONDITIONS

**Figure 6.** Borehole geophysical logs and direction of borehole flow under nonpumping conditions within MO-635 (RW18), collected on March 13, 1996, Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania.

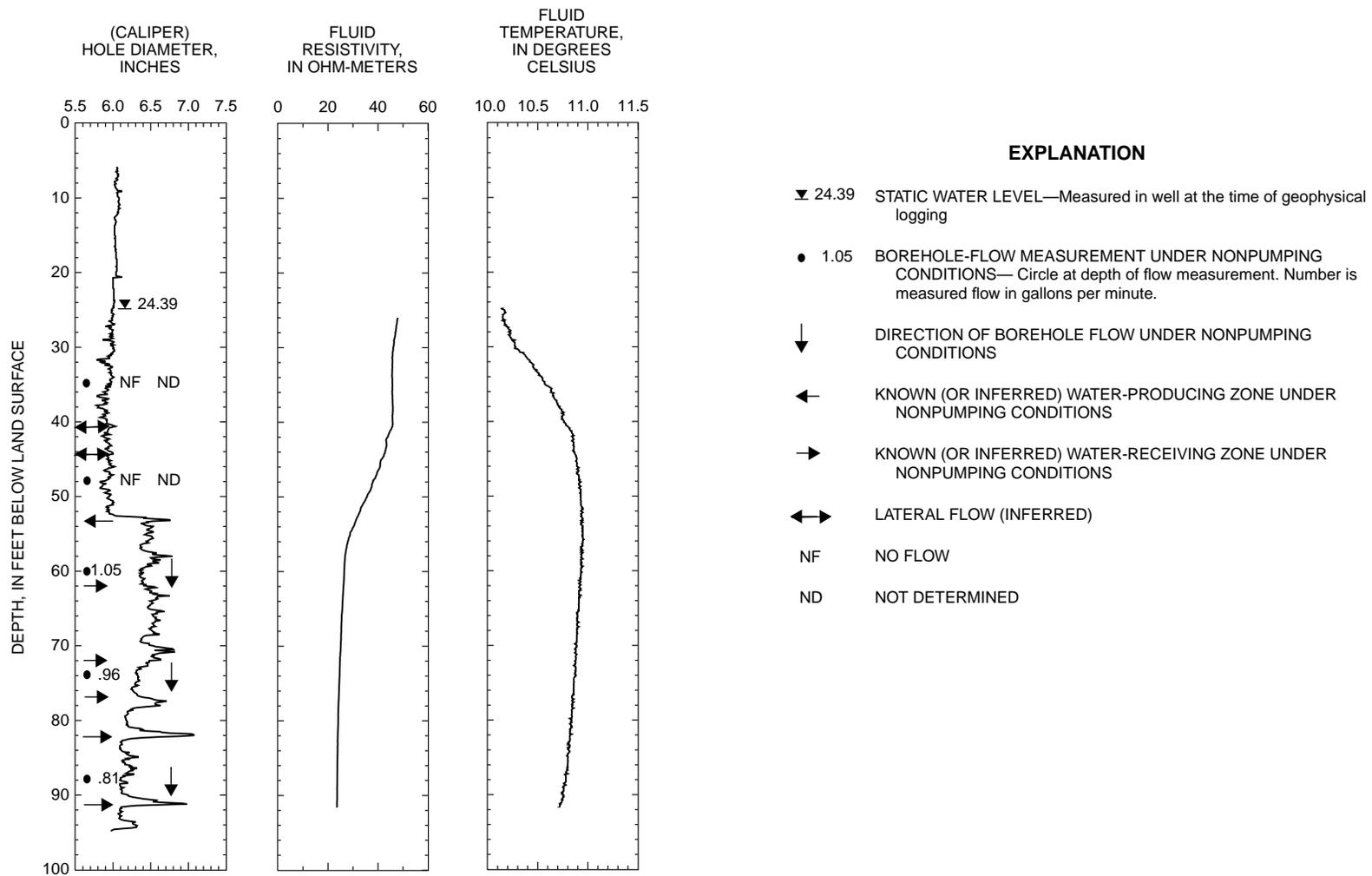
### MO-636 (RW23)

Monitor well MO-636 was logged April 3, 1996. The caliper log shows the borehole is drilled to a depth of 95 ft bls and is cased with 6-in.-diameter casing to 21 ft bls (fig. 7). The caliper log shows numerous fractures throughout the openhole interval. The fluid-resistivity log shows changes in slope from 40 to 56 ft bls. The fluid-temperature log shows minor changes in slope at 40 and 44 ft bls. These changes in slope in the fluid-resistivity and fluid-temperature logs may be caused by lateral borehole flow. Under nonpumping conditions, the heatpulse flowmeter measured downward borehole flow at 60, 74, and 88 ft bls and no vertical flow at 35 and 48 ft bls (table 9). The suite of geophysical logs and heatpulse-flowmeter data indicate water enters the borehole through the fractures at approximately 53 ft bls and moves downward. Minor amounts of water exit the borehole through fractures at 62 to 72, 77, and 82 ft bls; the greatest amount of water leaves the borehole through fractures at 90 to 94 ft bls.

**Table 9.** Summary of heatpulse-flowmeter measurements for borehole MO-636 (RW23) on April 3, 1996, at the Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania

[—, not determined]

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallons per minute)	Flow direction under nonpumping conditions
35	No flow	—
48	Lateral flow	—
60	1.05	Down
74	.96	Down
88	.81	Down



**Figure 7.** Borehole geophysical logs and direction of borehole flow under nonpumping conditions within MO-636 (RW23), collected on April 3, 1996, Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania.

**MO-637 (RW39)**

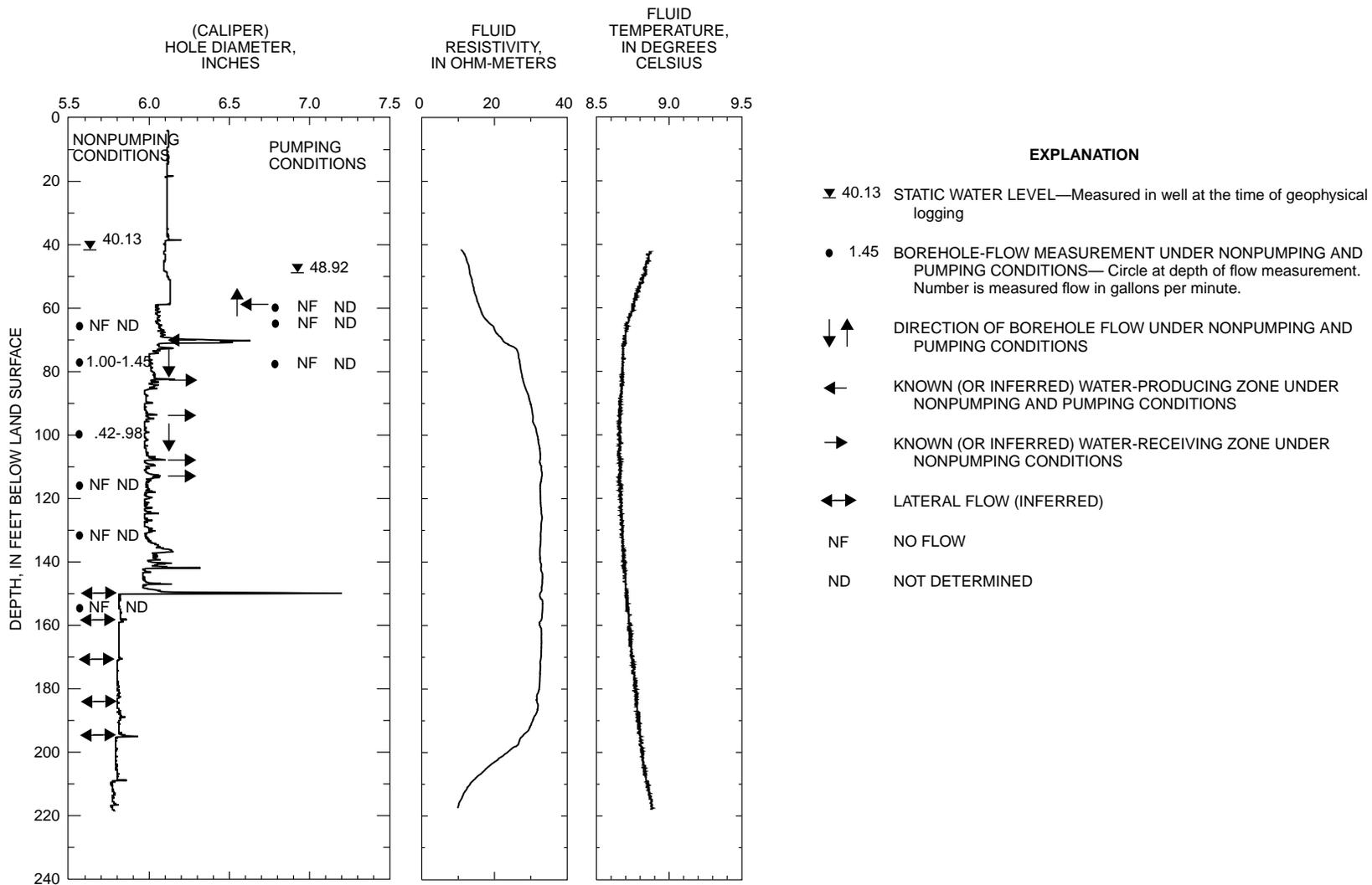
Monitor well MO-637 was logged April 4, 1996, and July 22, 1999. The caliper log shows the borehole is drilled to a depth of 221 ft and is cased with 6-in.-diameter casing to 59 ft bls (fig. 8). The caliper log shows major fractures at 69 to 71 and 149 to 150 ft bls plus numerous minor fractures throughout the openhole interval. The caliper log also shows the driller changed bit size at 150 ft bls. The fluid-resistivity and fluid-temperature logs show a major change in slope at 72 ft bls. The fluid-resistivity log also shows several smaller slope changes at 82, 95, 108, 150, 159, 184, and 195 ft bls that correlate with fractures shown on the caliper log; these small changes in the slope of the fluid-resistivity log indicate possible lateral flow. Under nonpumping conditions, the heatpulse flowmeter measured variable downward borehole flow at 77 and 100 ft bls and no flow at 65, 116, 132, and 155 ft bls (table 10). The suite of borehole geophysical logs and heatpulse-flowmeter data indicate, under nonpumping conditions, water enters the borehole through the fracture at 69 to 71 ft bls, moves downward, and exits the borehole through minor fractures from 82 to 108 ft bls. The variable flow rates measured by the heatpulse flowmeter indicate nearby transient pumpage.

**Table 10.** Summary of heatpulse-flowmeter measurements for borehole MO-637 (RW39) on April 4, 1996, at the Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania

[—, not determined]

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallons per minute)	Flow direction under nonpumping conditions	Flow rate under pumping conditions (gallons per minute)	Flow direction under pumping conditions
60	—	—	No flow	—
65	No flow	—	No flow	—
77	1.00 to 1.45	Down	No flow	—
100	.42 to .98	Down	—	—
116	No flow	—	—	—
132	No flow	—	—	—
155	No flow	—	—	—

A submersible pump was placed at 55 ft bls, and the borehole was pumped at approximately 3 gal/min. The water level in the borehole declined 8.79 ft after 45 minutes of pumping before beginning to stabilize. Under pumping conditions, the heatpulse flowmeter measured no borehole flow at 60, 65, and 77 ft bls (table 10). The suite of geophysical logs and heatpulse-flowmeter data indicate, under pumping conditions, additional water is available to the borehole through a fracture above 60 ft bls, probably at the bottom of the casing.



**Figure 8.** Borehole geophysical logs and direction of borehole flow under nonpumping and pumping conditions within MO-637 (RW39), collected on April 4, 1996, Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania.

The caliper log collected on July 22, 1999, is similar to that collected on April 4, 1996. The fluid resistivity log shows several minor deflections at 55, 59, 82, 95, 108, 113 to 121, 136 to 142, 150, 159, 171, 182, and 189 ft bls. The temperature log shows abrupt changes in slope from 109 to 121 and 137 ft bls that correlate to a series of minor fractures identified on the caliper log. Under nonpumping conditions, the heatpulse-flowmeter measurements indicated turbulent flow at 65 ft bls, downward flow at 78, 100, 122, 145, and 164 ft bls, and no flow at 202 ft bls (table 11). The suite of borehole geophysical logs and heatpulse-flowmeter data indicate, under nonpumping conditions, most water enters the borehole from the major fracture at 70 to 72 ft bls. The remaining fractures appear to be water-receiving zones as vertical borehole flow decreases with increasing depth.

**Table 11.** Summary of heatpulse-flowmeter measurements for borehole MO-637 (RW39) on July 22, 1999, at the Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania

[—, not determined]

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallon per minute)	Flow direction under nonpumping conditions	Flow rate under pumping conditions (gallons per minute)	Flow direction under pumping conditions
65	Turbulent	—	0.80	Up
78	0.50	Down	.24	Up
100	.15	Down	.10	Up
122	.05	Down	.07	Up
145	.03	Down	.09	Up
164	.02	Down	.11	Up
184	—	—	.10	Up
202	No flow	—	.14	Up
212	—	—	.15	Up
218	—	—	.12	Up

Under nonpumping conditions, the video log shows water entering the borehole through horizontal to low-angle fractures at 70 to 72 ft bls, no visible flow at 110 ft bls, and a possible water-receiving zone at about 134 ft bls. Low-angle fractures appear to be relatively common, most near vertical fractures appear to be filled (calcite or gypsum?).

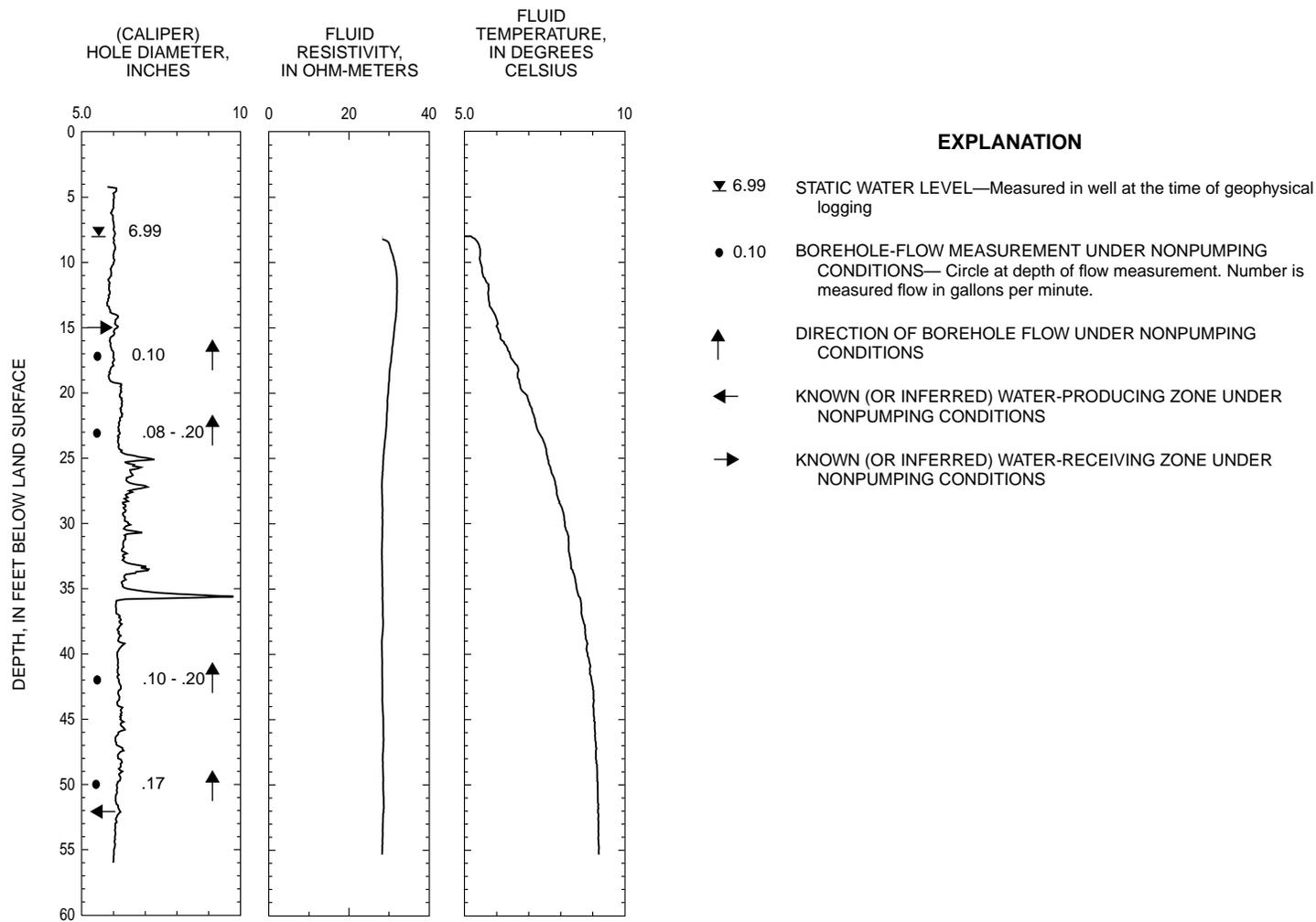
A submersible pump was placed at 55 ft bls, and the borehole was pumped at a rate that ranged from about 0.9 to 1.5 gal/min. The water level in the borehole declined 5.75 ft after 1 hour and 41 minutes of pumping. Under pumping conditions, the heatpulse flowmeter measured upward flow at 65, 78, 100, 122, 145, 164, 184, 202, 212, and 218 ft bls. The suite of borehole geophysical logs and heatpulse-flowmeter data indicate, under pumping conditions, water enters the borehole below a depth of 218 ft and flows upward. Minor water-receiving zones are present from a depth of about 110 to 200 ft bls. Additional water enters the borehole through the minor fractures at 60 to 73, 83 to 86, and 95 ft bls.

**MO-638 (RW43)**

Monitor well MO-638 was logged March 28, 1996. The caliper log shows the borehole is drilled to a depth of 56 ft bls and is cased with 6-in.-diameter casing to 14 ft bls (fig. 9). The caliper log shows a major fracture from 35 to 36 ft bls plus minor fractures throughout the openhole interval. The fluid-resistivity and fluid-temperature logs show only minor changes in slope. Under nonpumping conditions, the heatpulse flowmeter measured variable, upward borehole flow at 17, 23, 42, and 50 ft bls (table 12). Variations in measurements probably are caused by nearby pumping wells. The suite of geophysical logs and heatpulse-flowmeter data indicate most water enters the borehole through the fracture at 52 ft bls, moves upward, and exits the borehole through fractures at 14 to 16 ft bls.

**Table 12.** Summary of heatpulse-flowmeter measurements for borehole MO-638 (RW43) on March 28, 1996, at the Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallon per minute)	Flow direction under nonpumping conditions
17	0.10	Up
23	.08 to .20	Up
42	.10 to .20	Up
50	.17	Up



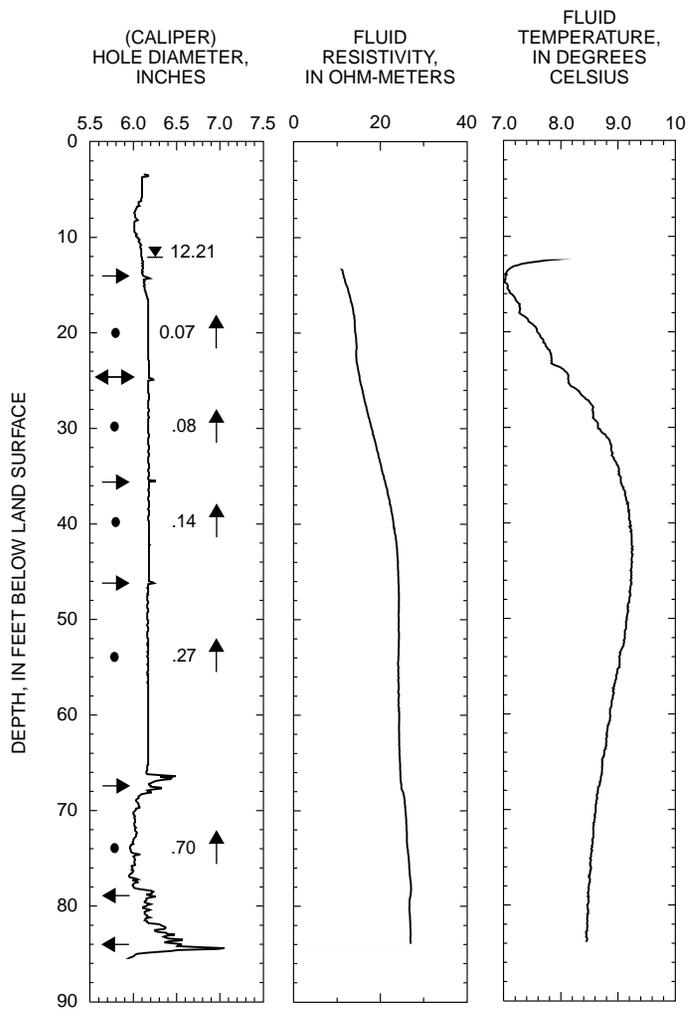
**Figure 9.** Borehole geophysical logs and direction of borehole flow under nonpumping conditions within MO-638 (RW43), collected on March 28, 1996, Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania.

**MO-639 (RW50)**

Monitor well MO-639 was logged April 3, 1996. The caliper log shows this borehole is drilled to a depth of 88 ft bls and is cased with 6-in.-diameter casing to 66 ft bls (fig. 10). The caliper log shows a major fracture at 84 ft bls plus numerous minor fractures below the bottom of the casing. The fluid-resistivity log shows minor changes in slope at 68 and 78 ft bls that correlate to minor fractures on the caliper log. Under nonpumping conditions, the heatpulse flowmeter measured upward borehole flow at 20, 30, 40, 54, and 74 ft bls (table 13). The suite of geophysical logs and heatpulse-flowmeter data indicate water enters the borehole through fractures at 78 to 87 ft bls and moves upward. Some water exits the borehole through the fracture at 66 to 68 ft bls. The remaining water moves up the borehole and exits through breaks in casing at 14, 35, and 46 ft bls with possible lateral flow at 25 ft bls.

**Table 13.** Summary of heatpulse-flowmeter measurements for borehole MO-639 (RW50) on April 3, 1996, at the Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallons per minute)	Flow direction under nonpumping conditions
20	0.07	Up
30	.08	Up
40	.14	Up
54	.27	Up
74	.70	Up



**EXPLANATION**

- ▼ 12.21 STATIC WATER LEVEL—Measured in well at the time of geophysical logging
- 0.07 BOREHOLE-FLOW MEASUREMENT UNDER NONPUMPING CONDITIONS— Circle at depth of flow measurement. Number is measured flow in gallons per minute.
- ↑ DIRECTION OF BOREHOLE FLOW UNDER NONPUMPING CONDITIONS
- ← KNOWN (OR INFERRED) WATER-PRODUCING ZONE UNDER NONPUMPING CONDITIONS
- KNOWN (OR INFERRED) WATER-RECEIVING ZONE UNDER NONPUMPING CONDITIONS
- ↔ LATERAL FLOW (INFERRED)

**Figure 10.** Borehole geophysical logs and direction of borehole flow under nonpumping conditions within MO-639 (RW50), collected on April 3, 1996, Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania.

**MO-640 (RW52)**

Monitor well MO-640 was logged April 2, 1996, and July 21, 1999. The caliper log shows the borehole is drilled to a depth of 122 ft bls and is cased with 6-in.-diameter casing to 50 ft bls (fig. 11). The caliper log shows encrustation on the casing from 10 to 17 ft bls, possible cracks or seams in the casing at 10 and 30 ft bls, and major fractures at 51, 64 to 66, 86, 98, and 106 to 108 ft bls plus numerous minor fractures throughout the openhole interval. The fluid-resistivity log shows changes in slope at 52, 66, 75, and 98 ft bls that correlate closely with fractures identified on the caliper log. The fluid-temperature log shows major changes in slope at 18 and 40 ft bls. Under nonpumping conditions, the heatpulse flowmeter measured downward borehole flow at 80 and 94 ft bls and no flow at 60 and 110 ft bls (table 14). The suite of borehole geophysical logs and heatpulse-flowmeter data indicate, under nonpumping conditions, possible flow within the casing from about 18 to 30 ft bls and possible lateral flow at 50 ft bls. Water enters the borehole through the fractures at 64 to 66, 75, and possibly at 90 ft bls, moves downward, and exits the borehole through the fractures from 98 to 108 ft bls.

**Table 14.** Summary of heatpulse-flowmeter measurements for borehole MO-640 (RW52) on April 2, 1996, at the Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania

[—, not determined]

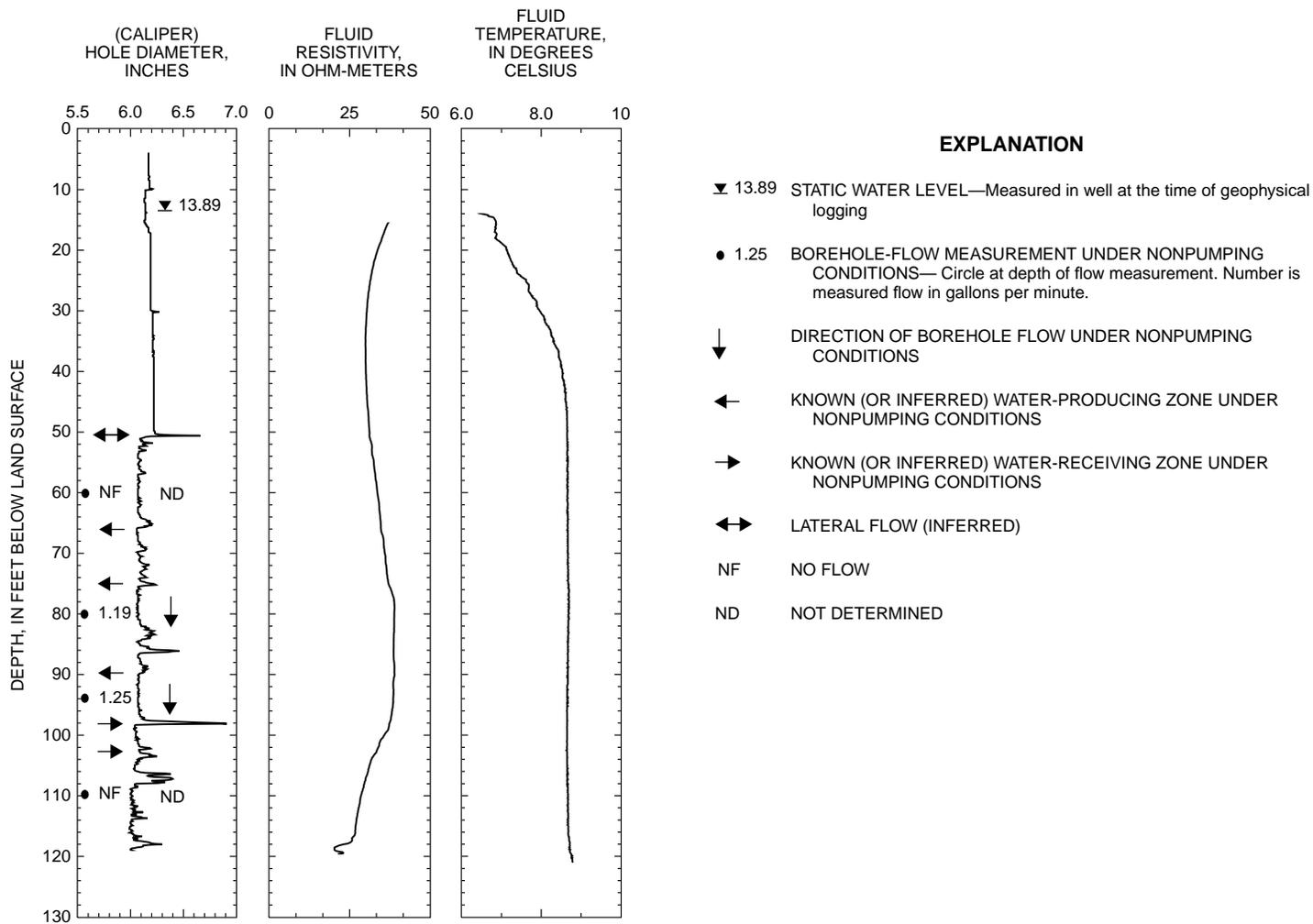
Depth (feet below land surface)	Flow rate under nonpumping conditions (gallons per minute)	Flow direction under nonpumping conditions
60	No flow	—
80	1.19	Down
94	1.25	Down
110	No flow	—

The caliper log of July 21, 1999, is similar to that collected on April 2, 1996. The fluid-resistivity log shows several minor deflections at 52, 65, 76, 86, 91, 99, and 102 to 119 ft bls that correlate closely with fractures identified on the caliper log. The fluid-temperature log shows minor deflections at 112 and 118 ft bls. Under nonpumping conditions, the heatpulse-flowmeter measured upward flow at 55, 61, and 102 ft bls, downward flow at 80 and 95 ft bls, and no flow at 114 ft bls (table 15). The suite of borehole geophysical logs and heatpulse-flowmeter data indicate, under nonpumping conditions, water enters the borehole through fractures at 65 to 66, 76, and 109 to 110 ft bls, moves up, and exits the borehole through the fractures at 57 and 98 ft bls.

**Table 15.** Summary of heatpulse-flowmeter measurements for borehole MO-640 (RW52) on July 21, 1999, at the Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania

[—, not determined]

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallons per minute)	Flow direction under nonpumping conditions	Flow rate under pumping conditions (gallons per minute)	Flow direction under pumping conditions
55	0.20	Up	0.50	Up
61	.30	Up	.60	Up
80	.07	Down	.20	Up
95	.07	Down	.15	Up
102	.20	Up	No flow	—
114	No flow	—	No flow	—



**Figure 11.** Borehole geophysical logs and direction of borehole flow under nonpumping conditions within MO-640 (RW52), collected on April 2, 1996, Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania.

Under nonpumping conditions, the video log shows the water is very cloudy (low visibility of the casing and borehole) from the water surface to a depth of about 65 ft bls but clears considerably by a depth of 70 ft bls. Water was observed entering the borehole from the water-producing fracture at a depth of about 74 ft bls and leaving the borehole at a depth of about 98 ft bls. Horizontal to low-angle fractures are common throughout the borehole. Near vertical fractures are less common and were observed to a depth of about 97 ft bls.

A submersible pump was placed at 42 ft bls, and the borehole was pumped at a rate of about 1.0 gal/min. The water level in the borehole declined 0.28 ft after 53 minutes of pumping. Under pumping conditions, the heatpulse flowmeter measured upward flow at 55, 61, 80, and 95 ft bls and no flow at 102 and 114 ft bls (table 15). The suite of borehole geophysical logs and heatpulse-flowmeter data indicate, under pumping conditions, water enters the borehole at 65 to 66, 76, and 98 ft bls, moves up, and exits the borehole at 57 ft bls.

### **MO-641 (R1\_1A)**

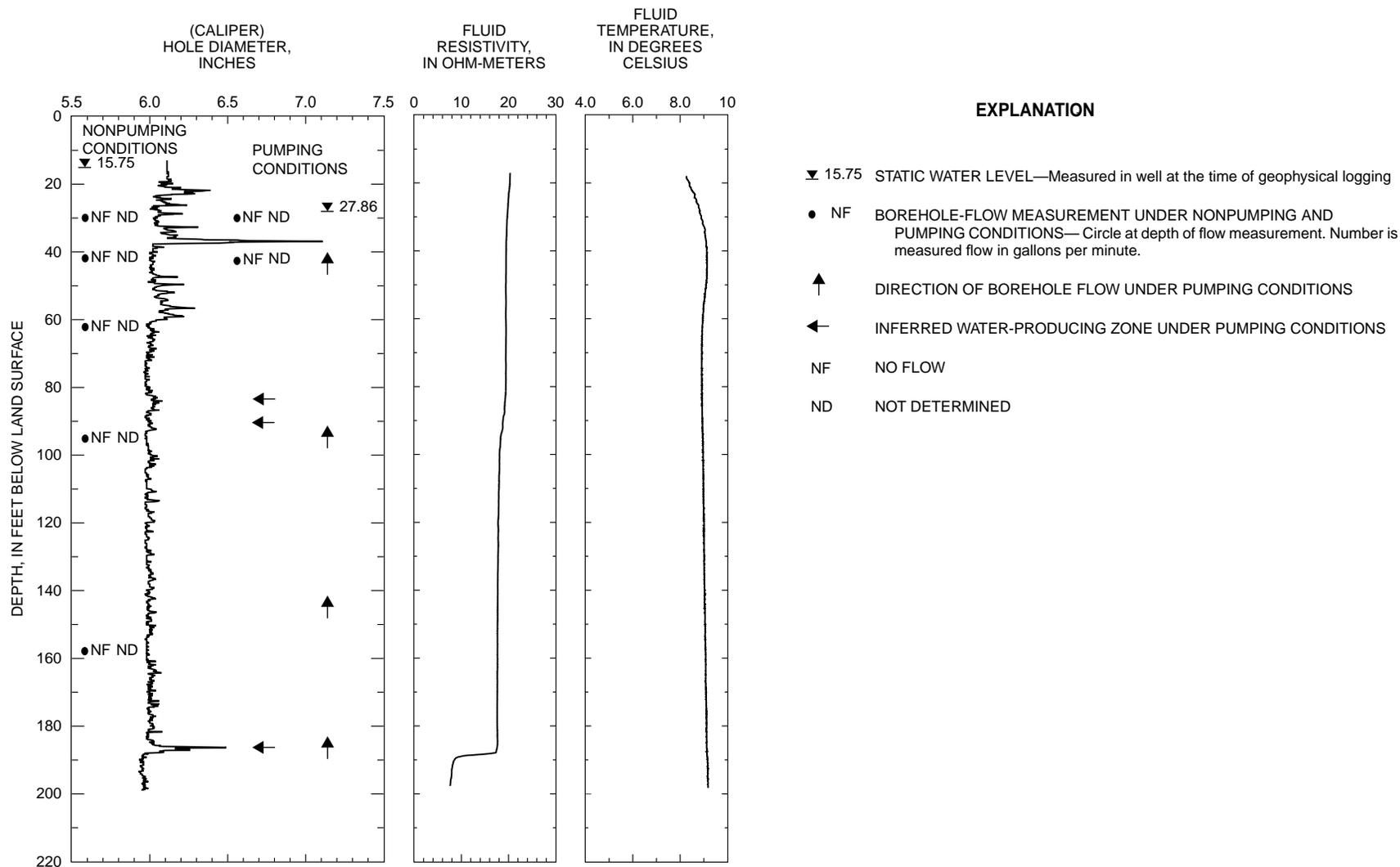
Monitor well MO-641 was logged March 7, 1996. The caliper log shows this borehole is drilled to a depth of 201 ft bls and is cased with 6-in.-diameter casing to 18 ft bls (fig. 12). The caliper log shows major fractures at 36 to 38 and 186 to 188 ft bls plus numerous minor and smaller fractures throughout the openhole interval. The fluid-resistivity log shows changes in slope at 90 and 188 ft bls that correlate to fractures shown on the caliper log. The fluid-temperature log shows a consistent fluid-temperature increase from approximately 70 to 188 ft bls, indicating no vertical borehole flow. Under nonpumping conditions, the heatpulse-flowmeter measurements indicate no borehole flow at 30, 42, 62, 96, and 158 ft bls (table 16).

A submersible pump was placed at 25 ft bls and the borehole was pumped at a rate less than 1.0 gal/min. Because of low borehole yield, the pump was then lowered to 37 ft bls and pumped at a rate less than 0.5 gal/min. The water level in the borehole declined 12.11 ft after 1 hour and 47 minutes of pumping and never stabilized, even when discharge was decreased to 0.2 gal/min. Because of the low yield of the borehole, no water-producing zones within the borehole could be defined with the heatpulse flowmeter. The fluid-resistivity log, however, indicates possible water-producing zones at 83 to 92 and 186 to 188 ft bls. The fluid-temperature log indicates possible water production from the formation above 60 ft bls.

**Table 16.** Summary of heatpulse-flowmeter measurements for borehole MO-641 (R1\_1A) on March 7, 1996, at the Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania

[—, not determined]

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallons per minute)	Flow direction under nonpumping conditions
30	No flow	—
42	No flow	—
62	No flow	—
96	No flow	—
158	No flow	—



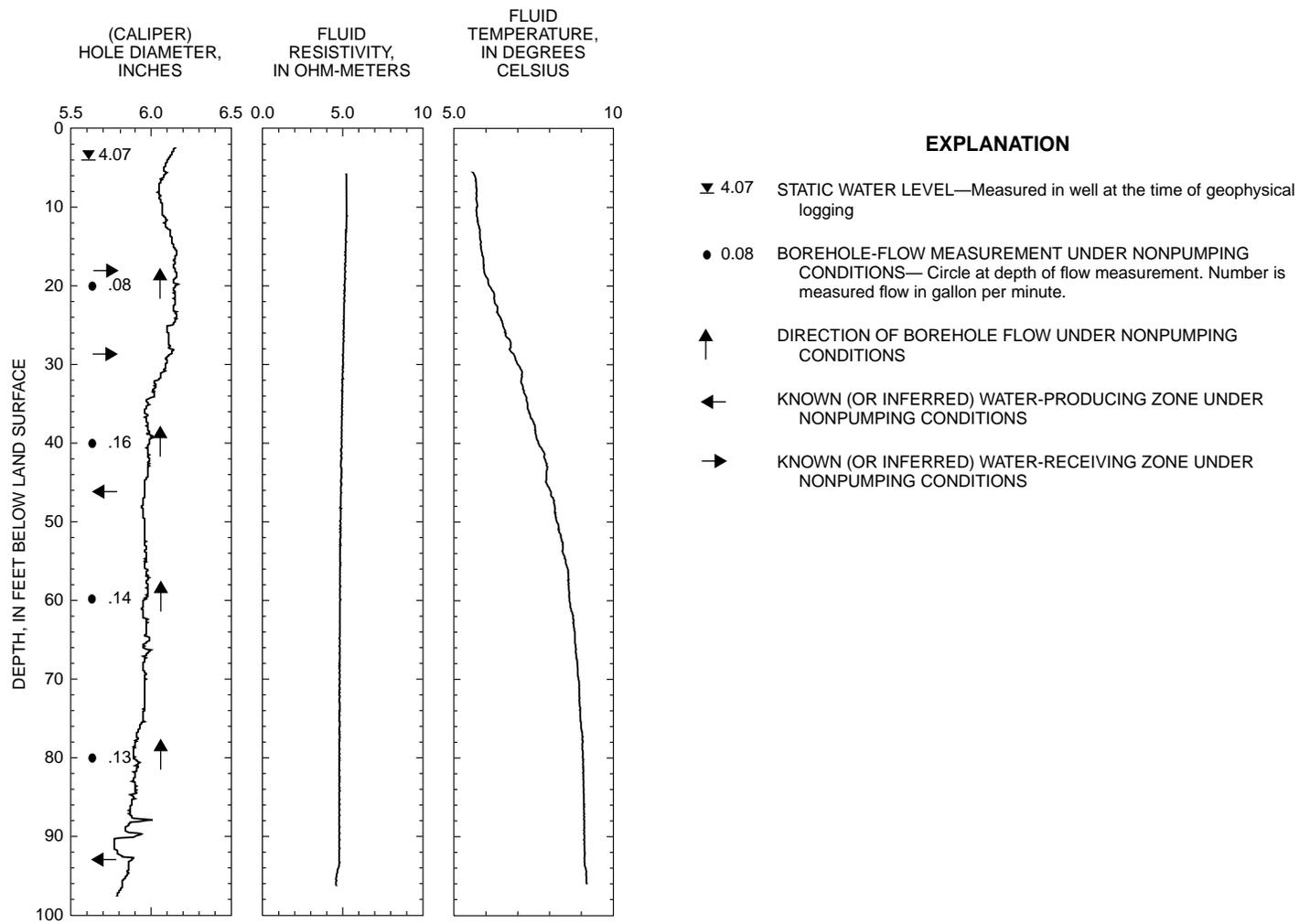
**Figure 12.** Borehole geophysical logs and direction of borehole flow under nonpumping and pumping conditions within MO-641 (R1\_1A), collected on March 7, 1996, Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania.

**MO-642 (R1S)**

Monitor well MO-642 was logged April 5, 1996. The caliper log shows this borehole is drilled to a depth of 98.7 ft bls, is cased with 6-in.-diameter casing to 25 ft bls, and is heavily encrusted to the bottom of casing (fig. 13). The caliper log shows only minor fractures at 88, 90, and 93 ft bls. The fluid-resistivity log shows a minor change in slope at 94 ft bls that correlates to a fracture shown on the caliper log. The fluid-temperature log shows minor deflections in slope at 18, 32, and 45 ft bls that indicate possible water-producing and water-receiving zones. Under nonpumping conditions, the heatpulse flowmeter measured upward borehole flow at 20, 40, 60, and 80 ft bls (table 17). The suite of geophysical logs and heatpulse-flowmeter data indicate most water enters the borehole through the fracture at approximately 93 ft bls and moves upward. About half of the water exits the borehole through fractures between 25 and 40 ft bls, and the remainder exits the borehole through a break in casing above 20 ft bls.

**Table 17.** Summary of heatpulse-flowmeter measurements for borehole MO-642 (R1S) on April 5, 1996, at the Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallon per minute)	Flow direction under nonpumping conditions
20	0.08	Up
40	.16	Up
60	.14	Up
80	.13	Up



**Figure 13.** Borehole geophysical logs and direction of borehole flow under nonpumping conditions within MO-642 (R1S), collected on April 5, 1996, Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania.

### **MO-643 (R1D)**

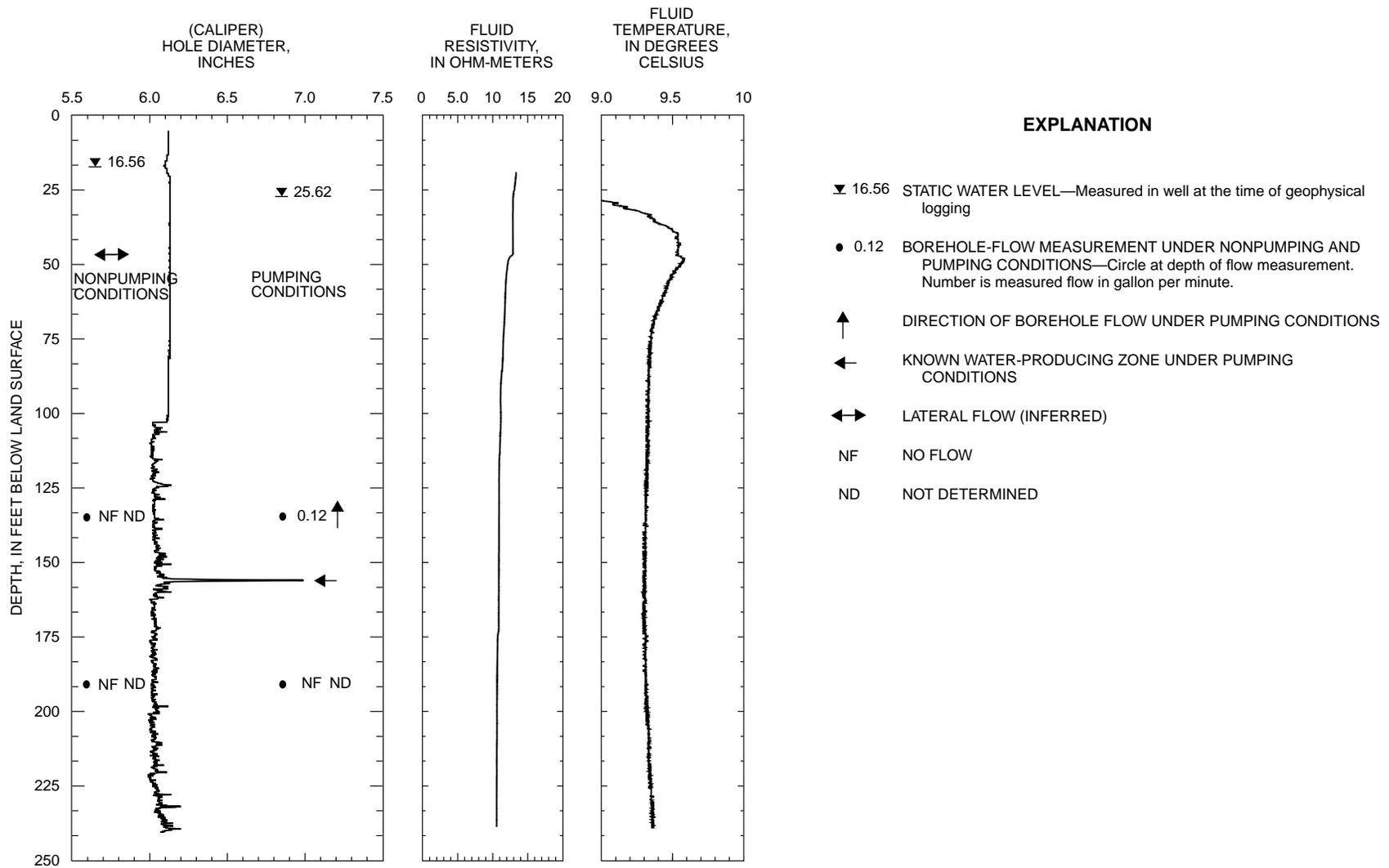
Monitor well MO-643 was logged March 14, 1996. The caliper log shows this borehole is drilled to a depth of 241 ft bls and is cased with 6-in.-diameter casing to 103 ft bls (fig. 14). The caliper log shows a major fracture at 155 to 157 ft bls plus numerous minor fractures throughout the openhole interval. The fluid-resistivity and fluid-temperature logs show a change in slope at 47 ft bls that may indicate water flowing within the casing. Under nonpumping conditions, the heatpulse flowmeter measurements indicate no borehole flow at 132 and 190 ft bls (table 18).

A submersible pump was placed at 50 ft bls, and the borehole was pumped at a rate less than 1.0 gal/min. The water level in the borehole declined 9.60 ft after 51 minutes of pumping before stabilizing. Under pumping conditions, the heatpulse flowmeter measured upward borehole flow at 132 ft bls and no flow at 190 ft bls (table 18). The suite of geophysical logs and heatpulse-flowmeter data indicate the fracture at 155 to 157 ft bls is the major water-producing zone in the borehole.

**Table 18.** Summary of heatpulse-flowmeter measurements for borehole MO-643 (R1D) on March 14, 1996, at the Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania

[—, not determined]

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallons per minute)	Flow direction under nonpumping conditions	Flow rate under pumping conditions (gallons per minute)	Flow direction under pumping conditions
132	No flow	—	0.12	Up
190	No flow	—	No flow	—



**Figure 14.** Borehole geophysical logs and direction of borehole flow under nonpumping and pumping conditions within MO-643 (R1D), collected on March 14, 1996, Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania.

**MO-644 (R2)**

Monitor well MO-644 was logged March 13, 1996. The caliper log shows this borehole is drilled to a depth of 132.5 ft bls and is cased with 6-in.-diameter casing to 19 ft bls (fig. 15). The caliper log shows major fractures at 26 to 28, 44 to 45, 83, 95, 101, and 109 ft bls plus numerous minor fractures throughout the openhole interval. The fluid-resistivity log shows changes in slope at 20 to 40 and 97 ft bls that correlate with fractures on the caliper log, indicating possible water-producing fractures. The fluid-temperature log shows minor changes in slope at 20 to 28 and 97 ft bls that correlate with fractures on the caliper log and indicate water-producing zones. Under nonpumping conditions, the heatpulse-flowmeter measurements indicate no borehole flow at 42, 78, 92, 106, and 114 ft bls (table 19).

A submersible pump was placed at 50 ft bls, and the borehole was pumped at approximately 0.6 gal/min. The water level in the borehole declined 1.9 ft after 1 hour of pumping and never completely stabilized. Under pumping conditions, the heatpulse flowmeter measured upward borehole flow at 42, 50, 78, 92, 106, and 114 ft bls. The fractures at 95 to 101 ft bls produce about 75 percent of the flow, and the fracture at 109 to 111 ft bls produced about 25 percent of the flow. The suite of geophysical logs and heatpulse-flowmeter data indicate the fracture zone at 95 to 101 ft bls is the major water-producing zone in the borehole and lesser quantities of water are produced at 109 to 111 ft bls and below 114 ft bls.

**Table 19.** Summary of heatpulse-flowmeter measurements for borehole MO-644 (R2) on March 13, 1996, at the Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania

[—, not determined]

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallons per minute)	Flow direction under nonpumping conditions	Flow rate under pumping conditions (gallons per minute)	Flow direction under pumping conditions
42	No flow	—	1.1	Up
50	—	—	1.1	Up
78	No flow	—	1.1	Up
92	No flow	—	1.1	Up
106	No flow	—	.30	Up
114	No flow	—	.09	Up

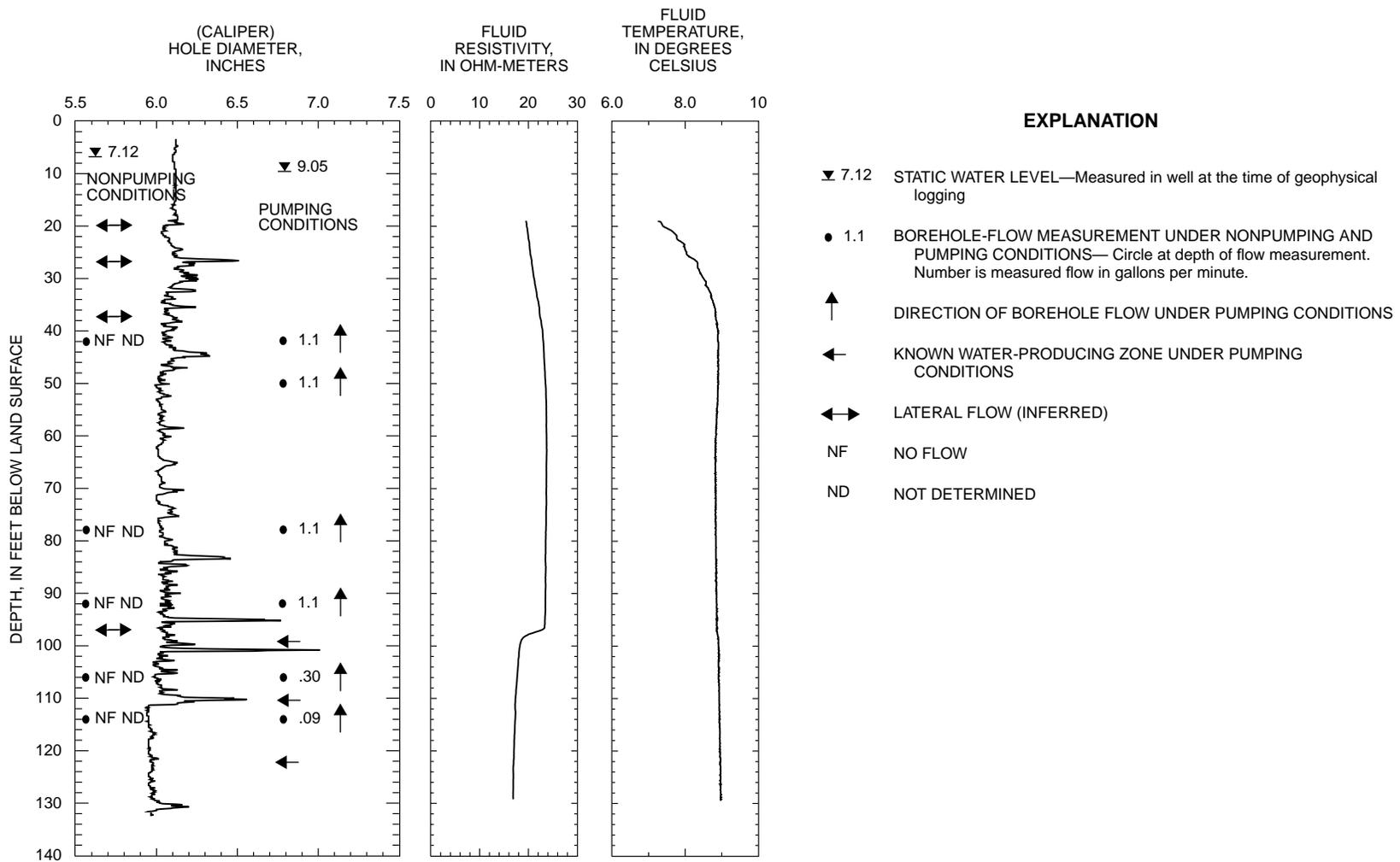


Figure 15. Borehole geophysical logs and direction of borehole flow under nonpumping and pumping conditions within MO-644 (R2), collected on March 13, 1996, Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania.

### **MO-645 (R3S)**

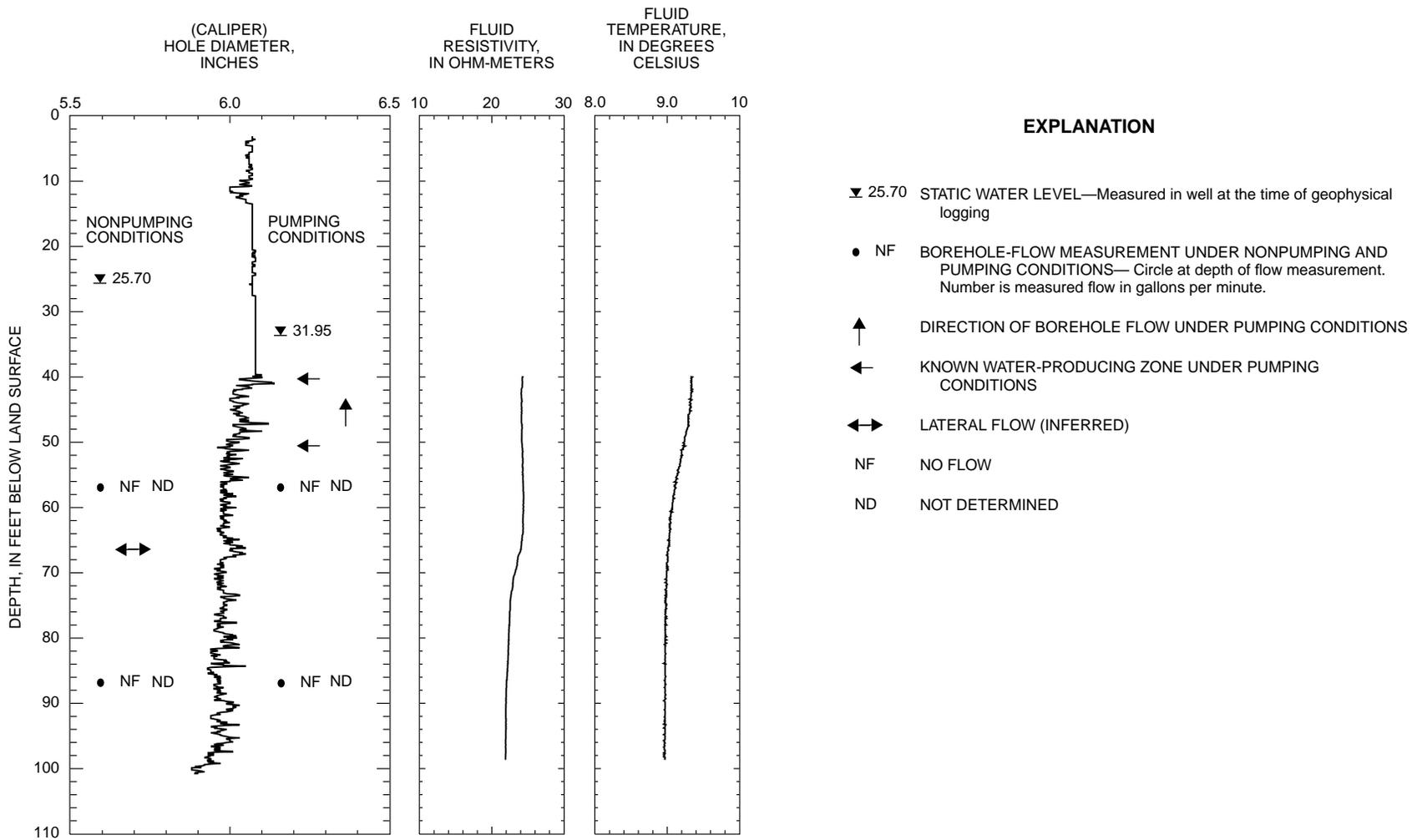
Monitor well MO-645 was logged March 28, 1996. The caliper log shows this borehole is drilled to a depth of 101 ft bls and is cased with 6-in.-diameter casing to 40 ft bls (fig. 16). The caliper log shows only minor fractures throughout the length of the openhole interval. The fluid-resistivity log shows a minor change in slope at 66 ft bls that correlates to small fractures from 65 to 67 shown on the caliper log. Under nonpumping conditions, the heatpulse flowmeter measured no borehole flow at 57 and 87 ft bls (table 20).

A submersible pump was placed at 38 ft bls, and the borehole was pumped at a rate less than 0.25 gal/min. The water level in the borehole declined 6.64 ft after 32 minutes of pumping before beginning to stabilize. Under pumping conditions, the heatpulse-flowmeter measurements also show no borehole flow at 57 and 87 ft bls (table 20). The suite of geophysical logs and heatpulse-flowmeter data indicate the fractures below casing at 40 to 56 ft bls probably are the major water-producing zones in the borehole.

**Table 20.** Summary of heatpulse-flowmeter measurements for borehole MO-645 (R3S) on March 28, 1996, at the Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania

[—, not determined]

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallons per minute)	Flow direction under nonpumping conditions	Flow rate under pumping conditions (gallons per minute)	Flow direction under pumping conditions
57	No flow	—	No flow	—
87	No flow	—	No flow	—



**Figure 16.** Borehole geophysical logs and direction of borehole flow under nonpumping and pumping conditions within MO-645 (R3S), collected on March 28, 1996, Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania.

**MO-646 (R3D)**

Monitor well MO-646 was logged March 6, 1996. The caliper log shows this borehole is drilled to a depth of 239.5 ft bls and is cased with 6-in.-diameter casing to 104 ft bls (fig. 17). The caliper log shows major fractures at 120 and 148 to 151 ft bls plus numerous minor fractures throughout the length of the openhole interval. The fluid-resistivity log shows changes in slope at 104 and 152 ft bls that correlate to fractures shown on the caliper log. The fluid-temperature log shows a consistent fluid-temperature increase from approximately 150 ft bls to the bottom of the borehole, indicating no vertical borehole flow. Under nonpumping conditions, the heatpulse flowmeter measured no borehole flow at 90, 126, 140, and 180 ft bls (table 21).

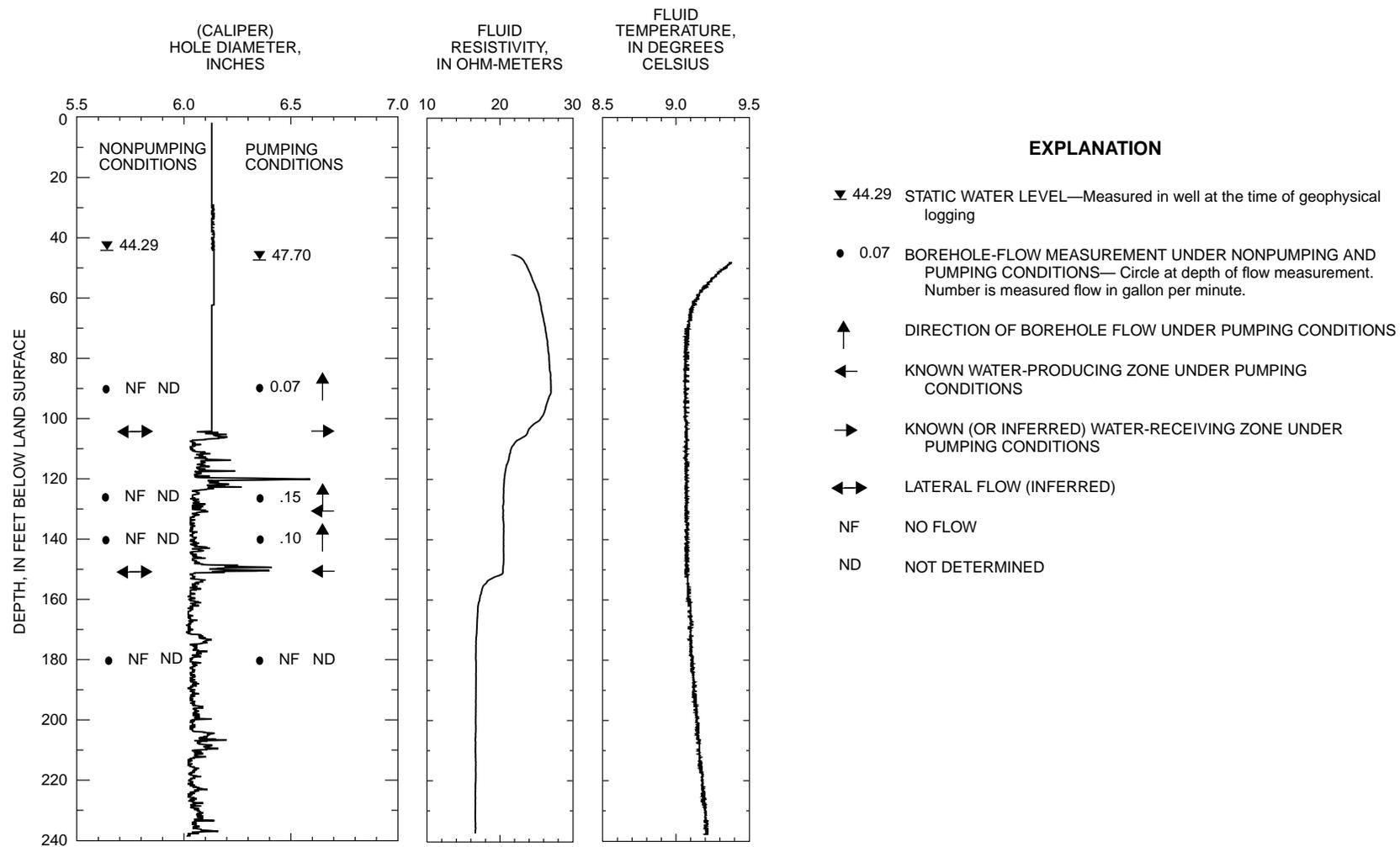
A submersible pump was placed at 78 ft bls, and the borehole was pumped at a rate less than 1.0 gal/min. The water level in the borehole declined 3.75 ft after 42 minutes of pumping and never completely stabilized. Under pumping conditions, the heatpulse flowmeter measured upward borehole flow at 90, 126, and 140 ft bls and no flow at 180 ft bls (table 21). The suite of geophysical logs and heatpulse-flowmeter data indicate the greatest quantity of water enters the borehole through the major fracture at 148 to 151 ft bls; a smaller amount of water is produced by a minor fracture at 130 ft bls. Some water appears to be leaving the borehole at the minor fracture at the base of the casing.

**Table 21.** Summary of heatpulse-flowmeter measurements for borehole MO-646 (R3D) on March 6, 1996, at the Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania

[—, not determined]

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallons per minute)	Flow direction under nonpumping conditions	Flow rate under pumping conditions <sup>1</sup> (gallon per minute)	Flow direction under pumping conditions
90	No flow	—	0.07	Up
126	No flow	—	.15	Up
140	No flow	—	.10	Up
180	No flow	—	No flow	—

<sup>1</sup> Measurements affected by questionable integrity of seal between borehole and heatpulse flowmeter.



**Figure 17.** Borehole geophysical logs and direction of borehole flow under nonpumping and pumping conditions within MO-646 (R3D), collected on March 6, 1996, Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania.

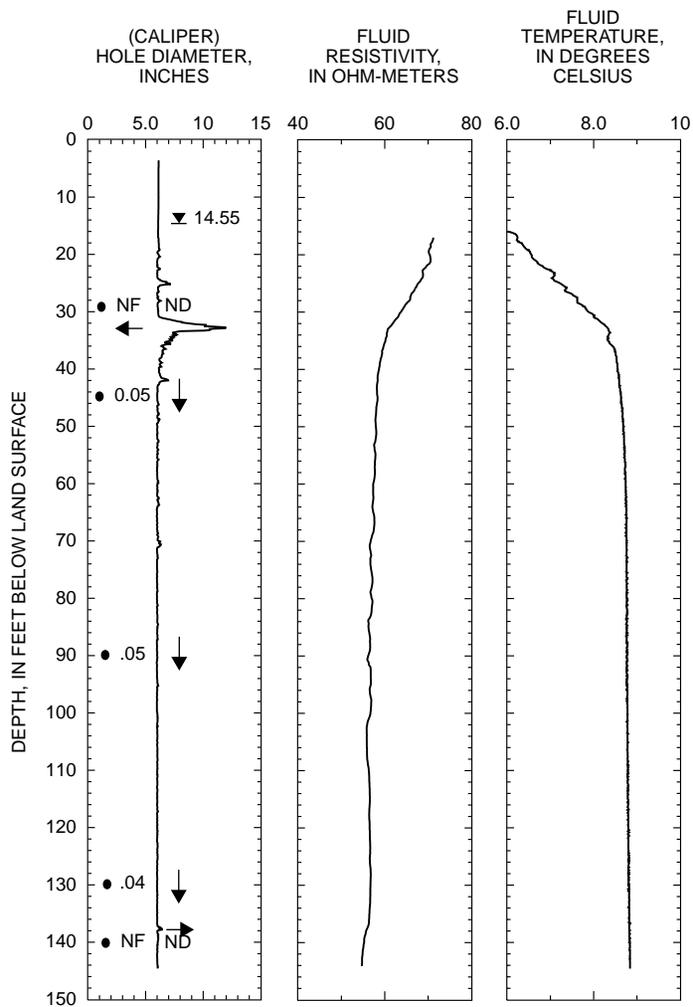
**MO-647 (R4)**

Monitor well MO-647 was logged March 6, 1996. The caliper log shows this borehole is drilled to a depth of 147 ft bls and is cased with 6-in.-diameter casing to 18 ft bls (fig. 18). The caliper log shows a major fracture at 31 to 36 ft bls and minor fractures at 24 to 26, 42, 70 to 71, and 137 to 138 ft bls. The fluid-resistivity and fluid-temperature logs show changes in slope at 31 and 33 ft bls, respectively, that correlate with the major fracture shown on the caliper log, indicating a water-producing fracture. Under nonpumping conditions, the heatpulse flowmeter measured downward borehole flow at 45, 90, and 130 ft bls and no borehole flow at 29 and 140 ft bls (table 22). The suite of geophysical logs and heatpulse-flowmeter data indicate the fracture at 31 to 36 ft bls is the major water-producing fracture in the borehole. Water enters the borehole through fractures at 31 to 36 ft bls, moves vertically downward, and exits the borehole through the fracture at 137 to 138 ft bls.

**Table 22.** Summary of heatpulse-flowmeter measurements for borehole MO-647 (R4) on March 6, 1996, at the Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania

[—, not determined]

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallon per minute)	Flow direction under nonpumping conditions (gallons per minute)
29	No flow	—
45	0.05	Down
90	.05	Down
130	.04	Down
140	No flow	—



**EXPLANATION**

- ▼ 14.55 STATIC WATER LEVEL—Measured in well at the time of geophysical logging
- 0.05 BOREHOLE-FLOW MEASUREMENT UNDER NONPUMPING CONDITIONS— Circle at depth of flow measurement. Number is measured flow in gallon per minute.
- ↓ DIRECTION OF BOREHOLE FLOW UNDER NONPUMPING CONDITIONS
- ← KNOWN (OR INFERRED) WATER-PRODUCING ZONE UNDER NONPUMPING CONDITIONS
- KNOWN (OR INFERRED) WATER-RECEIVING ZONE UNDER NONPUMPING CONDITIONS
- NF NO FLOW
- ND NOT DETERMINED

**Figure 18.** Borehole geophysical logs and direction of borehole flow under nonpumping conditions within MO-647 (R4), collected on March 6, 1996, Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania.

**MO-648 (R5)**

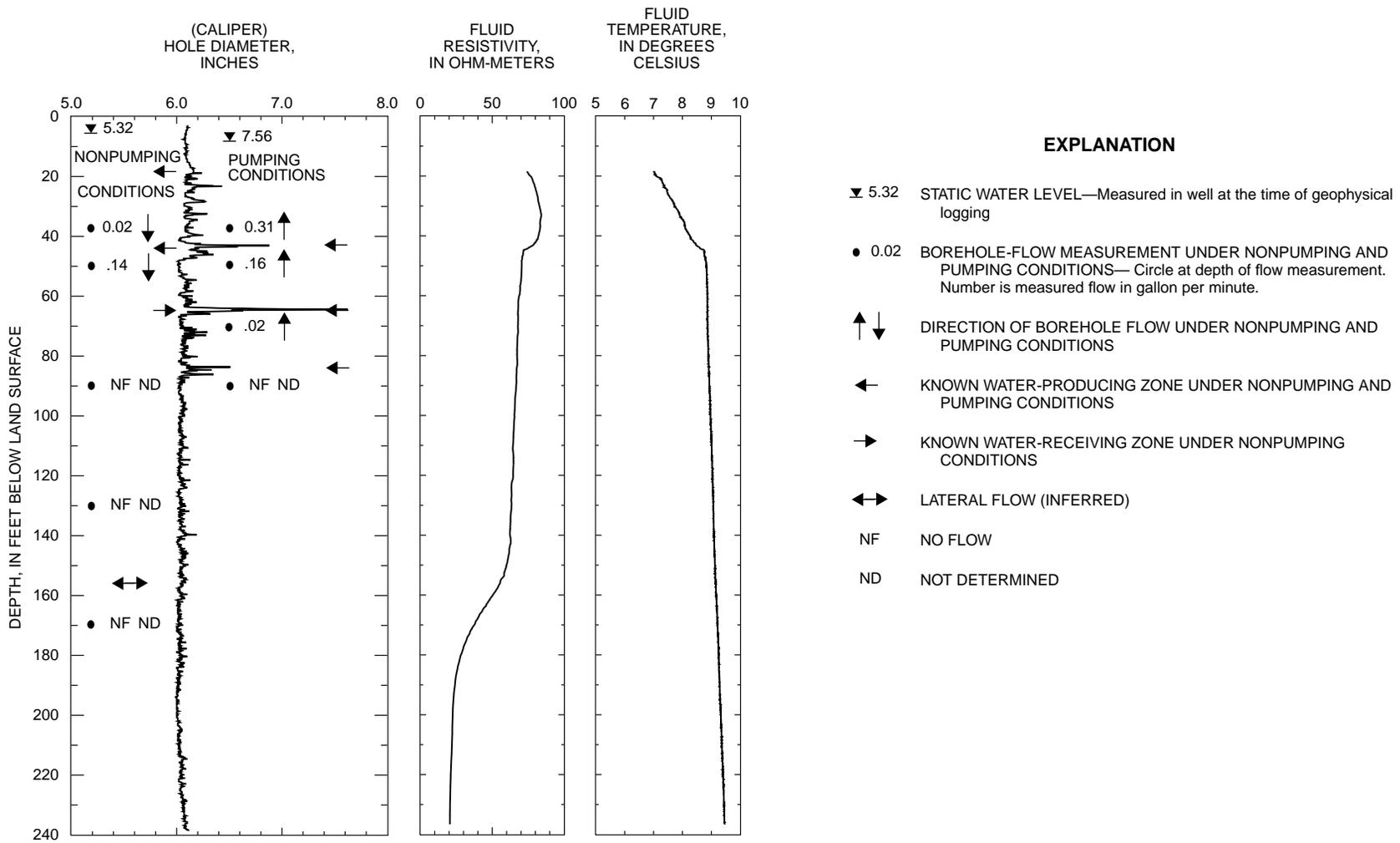
Monitor well MO-648 was logged February 28, 1996. The caliper log shows this borehole is drilled to a depth of 240 ft bls and is cased with 6-in.-diameter casing to 19 ft bls (fig. 19). The caliper log shows major fractures at 42 to 44 and 64 to 66 ft bls plus numerous minor fractures throughout the openhole interval. The fluid-resistivity log shows changes in slope at 44 and 154 ft bls that indicate possible water-producing fractures. The fluid-temperature log also shows a change in slope at 44 ft bls. Under nonpumping conditions, the heatpulse flowmeter measured downward borehole flow at 38 and 50 ft bls and no borehole flow at 90, 130, and 170 ft bls (table 23).

A submersible pump was placed at 14 ft bls and the borehole was pumped at approximately 2.7 gal/min. The water level in the borehole declined 2.35 ft after approximately 1 hour of pumping. Under pumping conditions, the heatpulse-flowmeter data show upward borehole flow at 38 and 50 ft bls, minor upward flow at 70 ft bls, and no flow at 90 ft bls (table 23). The suite of geophysical logs and heatpulse-flowmeter data indicate the fractures at 43 to 45 and 64 to 66 ft bls are the major water-producing fractures in the borehole; a minor amount of water is produced from the fractures at about 18 and 83 to 86 ft bls.

**Table 23.** Summary of heatpulse-flowmeter measurements for borehole MO-648 (R5) on February 28, 1996, at the Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania

[—, not determined]

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallon per minute)	Flow direction under nonpumping conditions	Flow rate under pumping conditions (gallon per minute)	Flow direction under pumping conditions
38	0.02	Down	0.31	Up
50	.14	Down	.16	Up
70	—	—	.02	Up
90	No flow	—	No flow	—
130	No flow	—	—	—
170	No flow	—	—	—



**Figure 19.** Borehole geophysical logs and direction of borehole flow under nonpumping and pumping conditions within MO-648 (R5), collected on February 28, 1996, Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania.

**MO-649 (R6)**

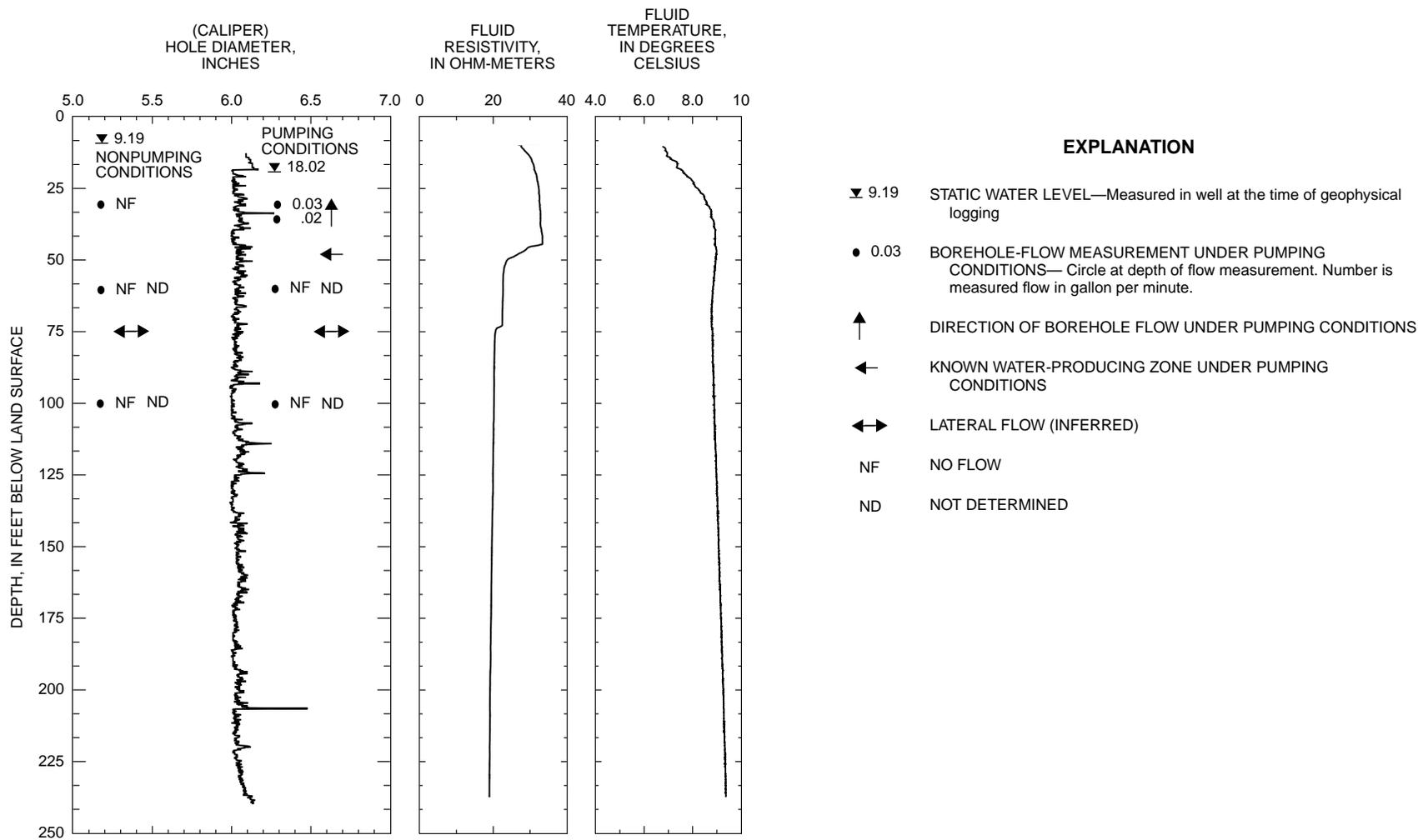
Monitor well MO-649 was logged March 5, 1996. The caliper log shows this borehole is drilled to a depth of 241 ft bls and is cased with 6-in.-diameter casing to 18 ft bls (fig. 20). The caliper log shows minor fractures at 34, 89 to 93, 114, 124, and 207 ft bls plus numerous smaller fractures throughout the openhole interval. The fluid-resistivity log shows changes in slope at 39 to 44, 52, and 73 ft bls that indicate possible water-producing fractures. The fluid-temperature log and the fluid-resistivity log below 76 ft bls show a constant change with depth, indicating no borehole flow. Under nonpumping conditions, the heatpulse flowmeter measured no borehole flow at 30, 60, and 100 ft bls (table 24).

A submersible pump was placed at 21 ft bls, and the borehole was pumped at a rate less than 0.5 gal/min. The water level in the borehole declined 8.83 ft after 52 minutes of pumping and never completely stabilized. Under pumping conditions, the heatpulse-flowmeter data show upward borehole flow at 30 and 35 ft bls and no flow at 60 and 100 ft bls (table 24). The suite of geophysical logs and heatpulse-flowmeter data indicate the fractures at 39 to 58 ft bls probably are the major water-producing fractures in the borehole.

**Table 24.** Summary of heatpulse-flowmeter measurements for borehole MO-649 (R6) on March 5, 1996, at the Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania

[—, not determined]

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallons per minute)	Flow direction under nonpumping conditions	Flow rate under pumping conditions (gallon per minute)	Flow direction under pumping conditions
30	No flow	—	0.03	Up
35	—	—	.02	Up
60	No flow	—	No flow	—
100	No flow	—	No flow	—



**Figure 20.** Borehole geophysical logs and direction of borehole flow under nonpumping and pumping conditions within MO-649 (R6), collected on March 5, 1996, Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania.

### MO-651 (PW-A)

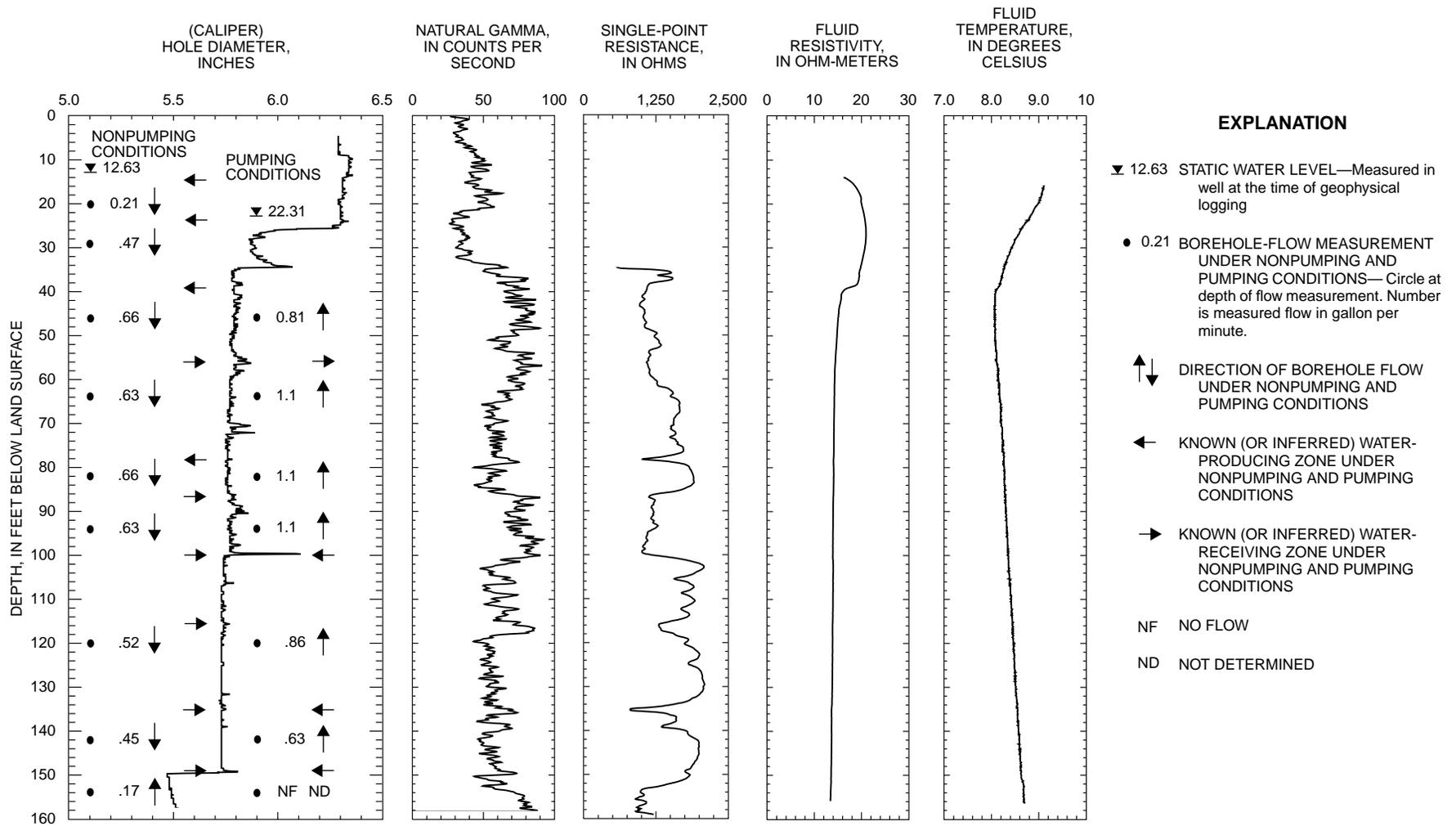
Monitor well MO-651 was logged July 8, 1996. The caliper log shows this borehole is drilled to a depth of 158.5 ft bls and is cased with 6-in.-diameter casing to 34 ft bls (fig. 21). The caliper log shows encrustation on the casing from 26 to 34 ft bls and a minor fracture at 100 ft bls plus numerous smaller fractures throughout the openhole interval. The natural-gamma log shows minor changes in lithology. The single-point resistance log indicates a water-producing zone at 78 ft bls that correlates to a high-angle fracture and possible water-receiving zones at 55, 87, 100, 116, and 135 ft bls that correlate to changes in lithology and may represent bedding-plane fractures. The fluid-resistivity and fluid-temperature logs show a change in slope at approximately 38 ft bls that correlates to a small fracture on the caliper log. The fluid-temperature log also shows a change in slope at 151 ft bls. Under nonpumping conditions, the heatpulse flowmeter measured downward borehole flow at 20, 29, 46, 64, 82, 94, 120, and 142 ft bls and upward flow at 154 ft bls (table 25). The downward flow measured inside casing at 20 and 29 ft bls is derived from water in the overburden leaking through poorly connected, threaded-casing joints. The suite of geophysical logs and heatpulse-flowmeter data indicate, under nonpumping conditions, most water enters the borehole through a break in the casing, a small fracture at 38 ft bls, and below 154 ft bls. Most water exits the borehole through the small fracture at 150 ft bls.

A submersible pump was placed at 24 ft bls, and the borehole was pumped at approximately 1.1 gal/min. The water level in the borehole declined 9.60 ft after 35 minutes before stabilizing. Under pumping conditions, the heatpulse flowmeter measured upward borehole flow at 46, 64, 82, 94, 120, and 142 ft bls and no flow at 154 ft bls (table 25). The fractures at 100 and 150 ft bls produce the greatest amount of water.

**Table 25.** Summary of heatpulse-flowmeter measurements for borehole MO-651 (PW-A) on July 8, 1996, at the Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania

[—, not determined]

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallon per minute)	Flow direction under nonpumping conditions	Flow rate under pumping conditions (gallons per minute)	Flow direction under pumping conditions
20	0.21	Down	—	—
29	.47	Down	—	—
46	.66	Down	0.81	Up
64	.63	Down	1.1	Up
82	.66	Down	1.1	Up
94	.63	Down	1.1	Up
120	.52	Down	.86	Up
142	.45	Down	.63	Up
154	.17	Up	No flow	—



**Figure 21.** Borehole geophysical logs and direction of borehole flow under nonpumping and pumping conditions within MO-651 (PW-A), collected on July 8, 1996, Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania.

**MO-652 (PW-B)**

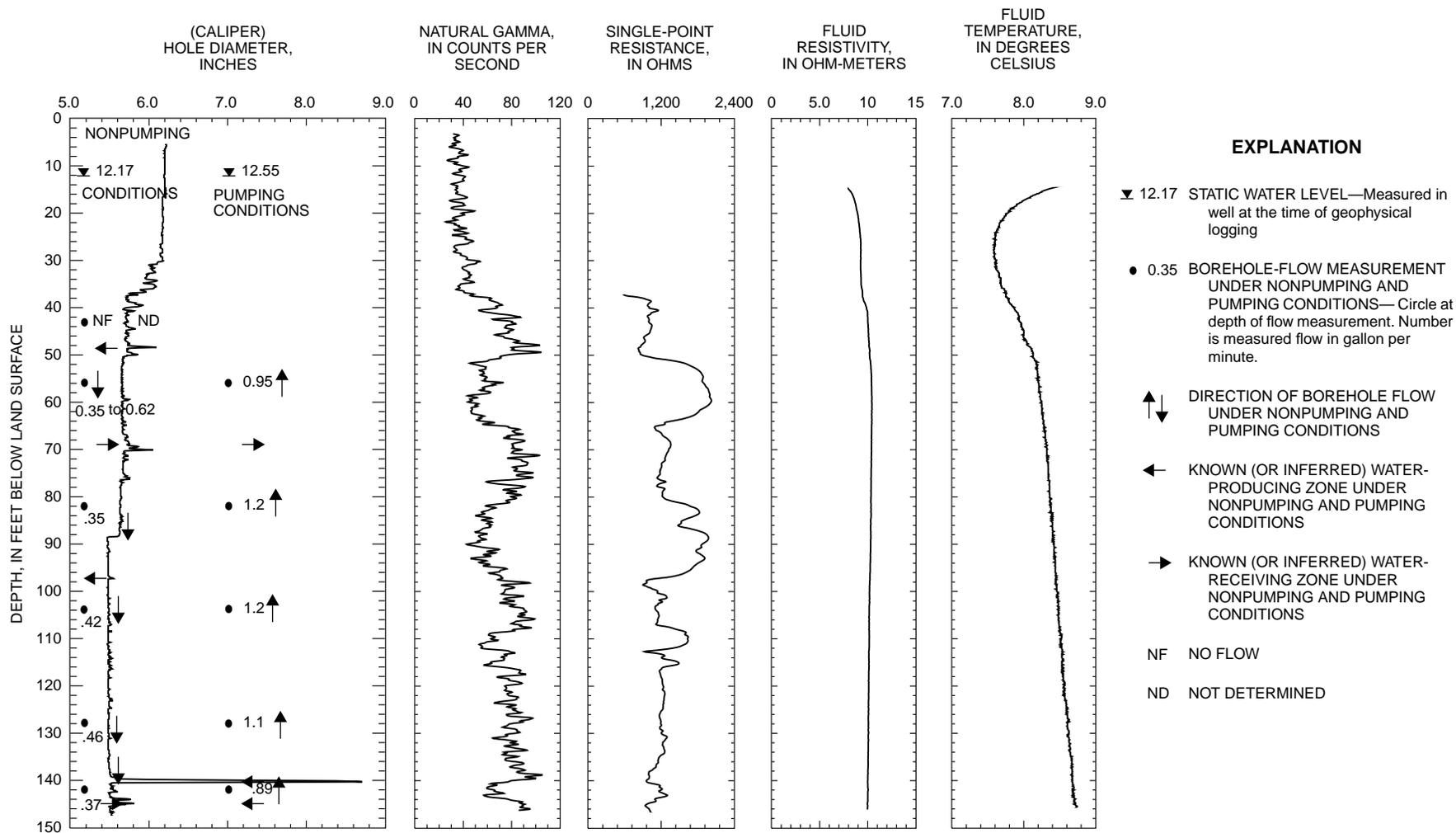
Monitor well MO-652 was logged July 9, 1996. The caliper log shows this borehole is drilled to a depth of 149 ft bls and is cased with 6-in.-diameter casing to 37 ft bls (fig. 22). The caliper log shows encrustation on the casing from 30 to 37 ft bls, a major fracture at 140 ft bls plus numerous minor fractures throughout the openhole interval, and a change in drill bit diameter at 88 ft bls. The natural-gamma log shows minor variations in lithology. The single-point resistance log indicates possible water-producing or water-receiving zones at 48, 65, 85, 97, and 112 ft bls that correlate to minor fractures on the caliper log and at 140 ft bls that correlates to a major fracture. The fluid-resistivity and fluid-temperature logs show a change in slope at approximately 50 ft bls that correlates to a minor fracture on the caliper log. Under nonpumping conditions, the heatpulse flowmeter measured downward borehole flow at 56, 82, 104, 128, and 142 ft bls and no flow at 43 ft bls (table 26). The suite of geophysical logs and heatpulse-flowmeter data indicate water enters the borehole through fractures at 48 to 50 and 98 ft bls and moves downward. Water exits the borehole through fractures at 144 to 145 ft bls.

A submersible pump was placed at 40 ft bls, and the borehole was pumped at approximately 0.75 gal/min. The water level in the borehole declined 0.40 ft after 42 minutes before stabilizing. Under pumping conditions, the heatpulse flowmeter measured upward borehole flow at 56, 82, 104, 128, and 142 ft bls (table 26). The fracture at 144 to 145 ft bls produce the greatest amount of water.

**Table 26.** Summary of heatpulse-flowmeter measurements for borehole MO-652 (PW-B) on July 9, 1996, at the Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania

[—, not determined]

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallon per minute)	Flow direction under nonpumping conditions	Flow rate under pumping conditions (gallons per minute)	Flow direction under pumping conditions
43	No flow	—	—	—
56	0.35 to 0.62	Down	0.95	Up
82	.35	Down	1.2	Up
104	.42	Down	1.2	Up
128	.46	Down	1.1	Up
142	.37	Down	.89	Up



**Figure 22.** Borehole geophysical logs and direction of borehole flow under nonpumping and pumping conditions within MO-652 (PW-B), collected on July 9, 1996, Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania.

### MO-653 (PW-C)

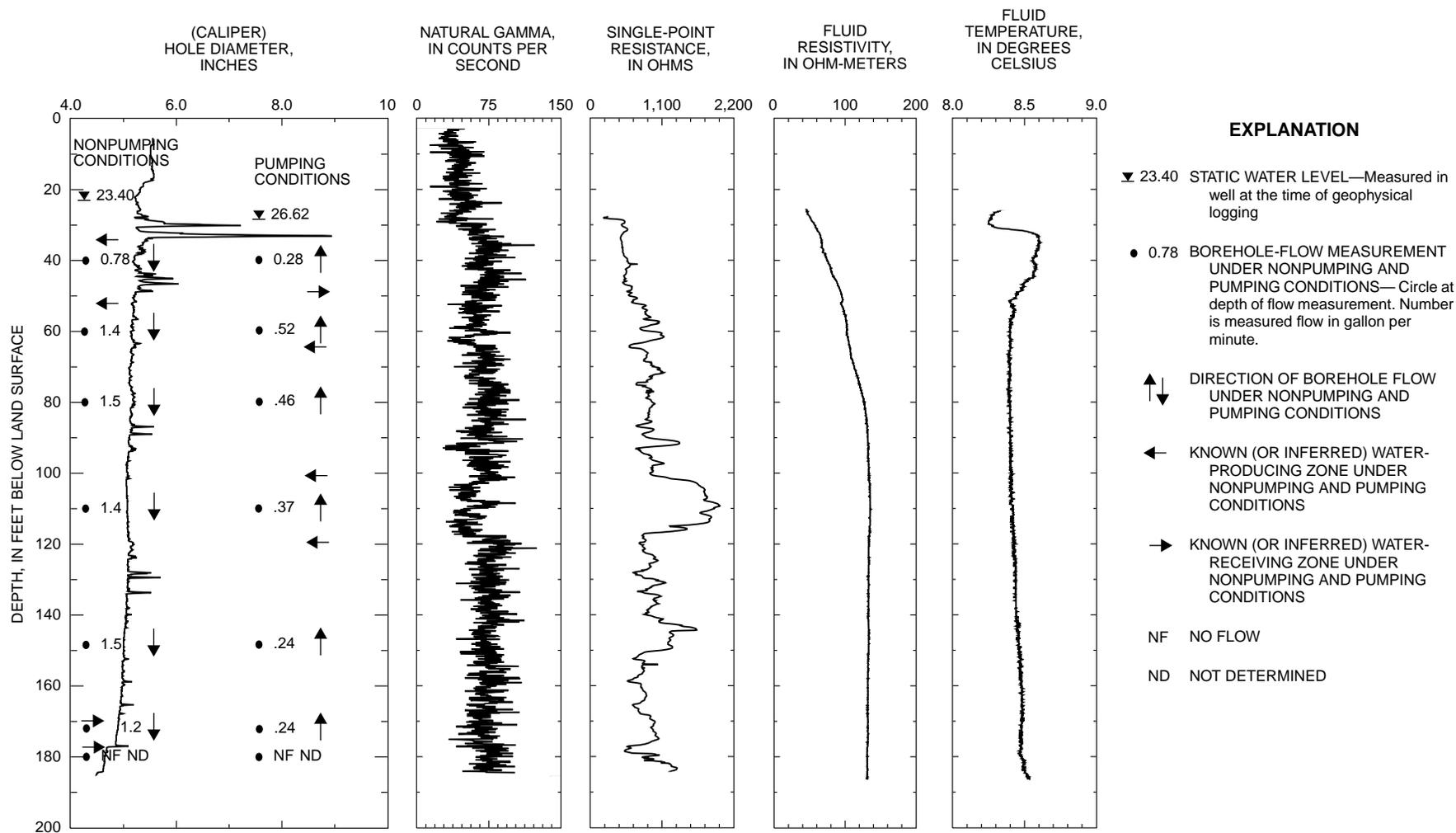
Monitor well MO-653 was logged August 20, 1996. The caliper log shows this borehole is drilled to a depth of 185.5 ft bls and is cased with 6-in.-diameter casing to 29 ft bls (fig. 23). The caliper log shows encrustation on the casing from 17 to 29 ft bls, major fractures at 30 and 32 to 34, and minor fractures from 44 to 49, 87, 89, 128, 134, and 177 ft bls plus numerous smaller fractures throughout the openhole interval. The caliper, natural-gamma, and single-point resistance logs indicate possible water-producing zones at 100 and 120 ft bls that probably are bedding-plane fractures. The fluid-resistivity log shows a change in slope at 34, 52, 68, 80, and 110 ft bls. The fluid-temperature log shows a change in slope at 31, 45, 52, and 178 ft bls. Under nonpumping conditions, the heatpulse-flowmeter measured downward borehole flow at 40, 60, 80, 110, 148, and 172 ft bls and no flow at 180 ft bls (table 27). The suite of geophysical logs and heatpulse-flowmeter data indicate, under nonpumping conditions, water enters the borehole through fractures at 30 to 34 and 40 to 52 ft bls and moves downward; most of the water exits the borehole through the fracture at 178 ft bls.

A submersible pump was placed at 35 ft bls, and the borehole was pumped at approximately 2 gal/min. The water level in the borehole declined 3.22 ft after 49 minutes and never completely stabilized. Under pumping conditions, the heatpulse-flowmeter measured upward borehole flow at 40, 60, 80, 110, 148, and 172 ft bls and no flow at 180 ft bls (table 27). The suite of geophysical logs and heatpulse-flowmeter data indicate, under pumping conditions, the fractures at 64, 100, 120, and 178 ft bls become water-producing zones. The fractures from 40 to 52 ft bls become water-receiving zones.

**Table 27.** Summary of heatpulse-flowmeter measurements for borehole MO-653 (PW-C) on August 20, 1996, at the Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania

[—, not determined]

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallons per minute)	Flow direction under nonpumping conditions	Flow rate under pumping conditions (gallon per minute)	Flow direction under pumping conditions
40	0.78	Down	0.28	Up
60	1.4	Down	.52	Up
80	1.5	Down	.46	Up
110	1.4	Down	.37	Up
148	1.5	Down	.24	Up
172	1.2	Down	.24	Up
180	No flow	—	No flow	—



**Figure 23.** Borehole geophysical logs and direction of borehole flow under nonpumping and pumping conditions within MO-653 (PW-C), collected on August 20, 1996, Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania.

### MO-654 (PW-D)

Monitor well MO-654 was logged July 1, 1996. The caliper log shows this borehole is drilled to a depth of 248 ft bls and is cased with 6-in.-diameter casing to 30 ft bls (fig. 24). The caliper log shows a major fracture at 42 ft bls plus numerous minor fractures throughout the openhole interval. The natural-gamma log shows only minor variation in lithology except at 68 to 70, 203 to 205, and 206 to 208 ft bls where more silty or shaley lenses are present. The fluid-resistivity and fluid-temperature logs show changes in slope at 48 and 100 ft bls. Under nonpumping conditions, the heatpulse flowmeter measured upward borehole flow at 38, 200, 215, and 238 ft bls and no flow at 50, 81, 116, 150, and 170 ft bls (table 28). Flow rates, however, varied during logging and probably were affected by the drilling of monitor well MO-651, indicating the two wells are hydraulically connected. The suite of geophysical logs and heatpulse-flowmeter data indicate, under nonpumping conditions, a small quantity of water enters the borehole at about 44 ft bls, moves upward, and exits the borehole at the fracture just below the casing. The greatest amount of water enters the borehole below 238 ft bls, moves upward, and exits the borehole through the fractures between 170 and 200 ft bls. There may be some lateral flow at about 95 ft bls.

A submersible pump was placed at 40 ft bls, and the borehole was pumped at a rate of less than 0.5 gal/min. The pumping rate was periodically decreased in an effort to stabilize drawdown. The water level in the borehole declined 9.24 ft after 48 minutes of pumping before stabilizing. Under pumping conditions, the heatpulse flowmeter measured upward borehole flow at 52, 81, 116, 150, and 225 ft bls and no borehole flow at 200 and 238 ft bls (table 28). The suite of geophysical logs and heatpulse-flowmeter data indicate, under pumping conditions, the fractures at 161 to 163, 238, and possibly 95 ft bls are water-producing zones.

**Table 28.** Summary of heatpulse-flowmeter measurements for borehole MO-654 (PW-D), July 1, 1996, at the Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania

[—, not determined]

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallon per minute)	Flow direction under nonpumping conditions	Flow rate under pumping conditions (gallon per minute)	Flow direction under pumping conditions
38	0.07	Up	—	—
50	No flow	—	—	—
52	—	—	0.16	Up
81	No flow	—	.23	Up
116	No flow	—	.18	Up
150	No flow	—	.22	Up
170	No flow	—	—	—
200	.07	Up	No flow	—
215	.16	Up	—	—
225	—	—	.06	Up
238	.18	Up	No flow	—



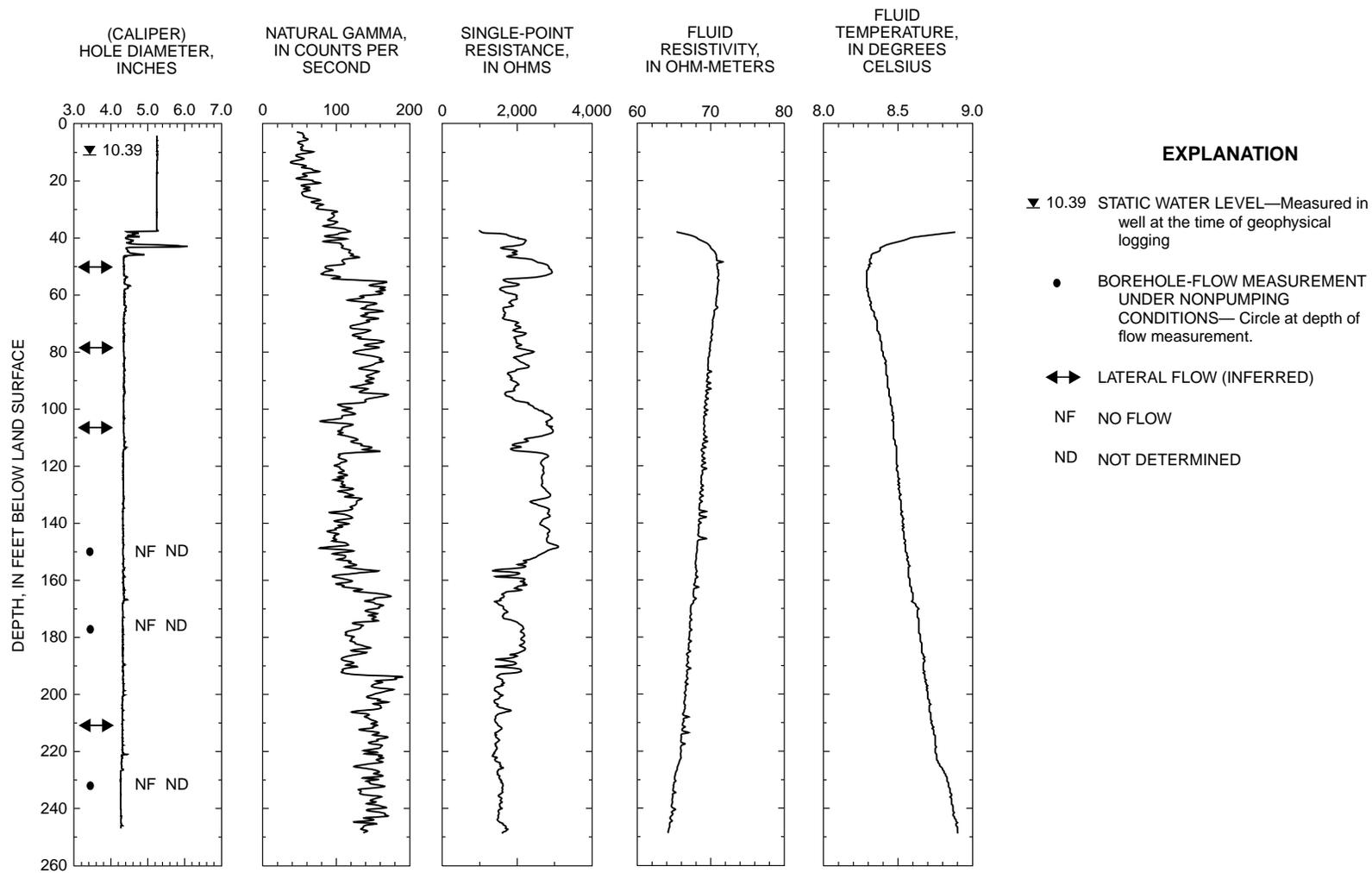
**MO-685 (R7)**

Monitor well MO-685 was logged November 6, 2000. The caliper log shows this borehole is drilled to a depth of 248 ft bls and is cased with 5.25-in.-diameter casing to 37 ft bls (fig. 25). The caliper log shows major fractures at 42 to 46 ft bls plus numerous small and minor fractures throughout the open-borehole interval. The natural-gamma log shows only minor variation in lithology. The single-point resistance log indicates possible water-producing zones at 44, 46, 105, 112 to 114, 188, and 190 ft bls. The fluid-resistivity log shows minor deflections in slope at 48, 145, 163, and 213 ft bls. The fluid-temperature log shows minor deflections in slope at 167, 214, and 226 ft bls. Under nonpumping conditions, the heatpulse flowmeter indicated turbulent flow at 50, 78, and 212 ft bls, no flow at 150, 178, and 232 ft bls, and inconsistent flow measurements at 106 ft bls (table 29). The suite of geophysical logs and heatpulse-flowmeter data indicate, under nonpumping conditions, lateral flow is dominant and no flow below the minor fracture at 227 ft bls.

**Table 29.** Summary of heatpulse-flowmeter measurements for borehole MO-685 (R7) on November 6, 2000, at the Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania

[—, not determined]

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallons per minute)	Flow direction under nonpumping conditions (gallons per minute)
50	Turbulent	—
78	Turbulent	—
106	Inconsistent	—
150	No flow	—
178	No flow	—
212	Turbulent	—
232	No flow	—



**Figure 25.** Borehole geophysical logs and direction of borehole flow under nonpumping conditions within MO- 685 (R7), collected on November 6, 2000, Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania.

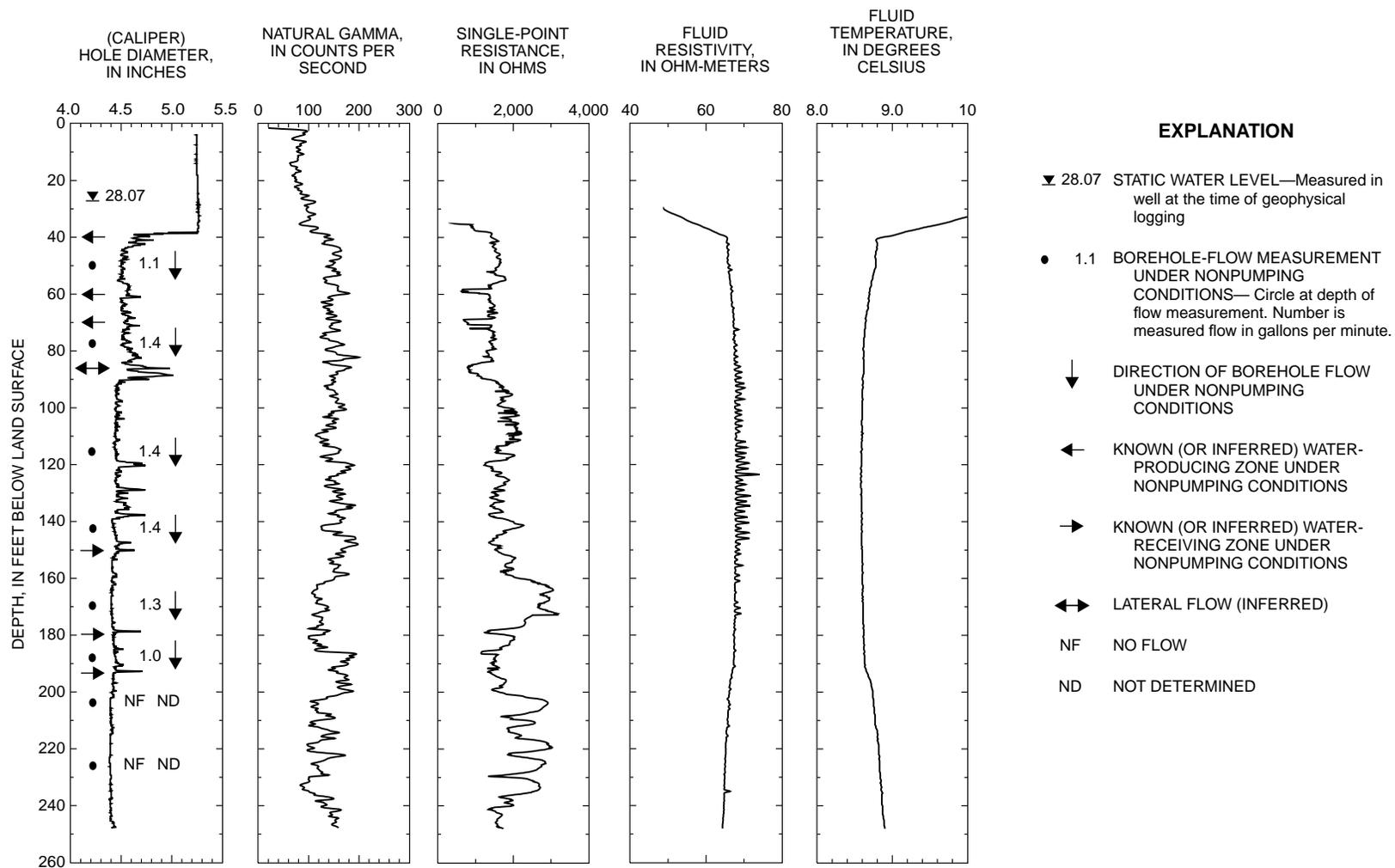
**MO-686 (R8)**

Monitor well MO-686 was logged October 24, 2000. The caliper log shows this borehole is drilled to a depth of 249 ft bls and is cased with 5.25-in.-diameter casing to 38 ft bls (fig. 26). The caliper log shows several minor fractures at 85 to 90, 119 to 121, 129 to 130, 137 to 139, 179, and 193 ft bls plus numerous smaller fractures throughout the open-borehole interval. The natural-gamma log shows only minor variation in lithology. The single-point resistance log indicates possible water-producing or water-receiving zones at 59, 70, 85 to 87, 179, 188, 222, and 229 ft bls. The fluid-resistivity log shows a major deflection in slope at 40 ft bls and numerous minor deflections from 72 to 172 ft bls and again at 235 ft bls. The fluid-temperature log shows major changes in slope at 40 and 194 ft bls that correlate to minor fractures on the caliper log. Under nonpumping conditions, the heatpulse flowmeter measured downward flow at 50, 78, 114, 142, 170, and 188 ft bls and no flow at 204 and 226 ft bls (table 30). The suite of geophysical logs and heatpulse-flowmeter data indicate, under nonpumping conditions, most of the water enters the borehole at 40 ft bls; additional water enters the borehole at about 59 and 70 ft bls. The water moves downward with most of the water exiting the borehole through fractures at 179 and 193 ft bls. Some lateral flow may be present from 85 to 87 ft bls.

**Table 30.** Summary of heatpulse-flowmeter measurements for borehole MO-686 (R8) on October 24, 2000, at the Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania

[—, not determined]

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallons per minute)	Flow direction under nonpumping conditions
50	1.1	Down
78	1.4	Down
114	1.4	Down
142	1.4	Down
170	1.3	Down
188	1.0	Down
204	No flow	—
226	No flow	—



**Figure 26.** Borehole geophysical logs and direction of borehole flow under nonpumping conditions within MO-686 (R8), collected on October 24, 2000, Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania.

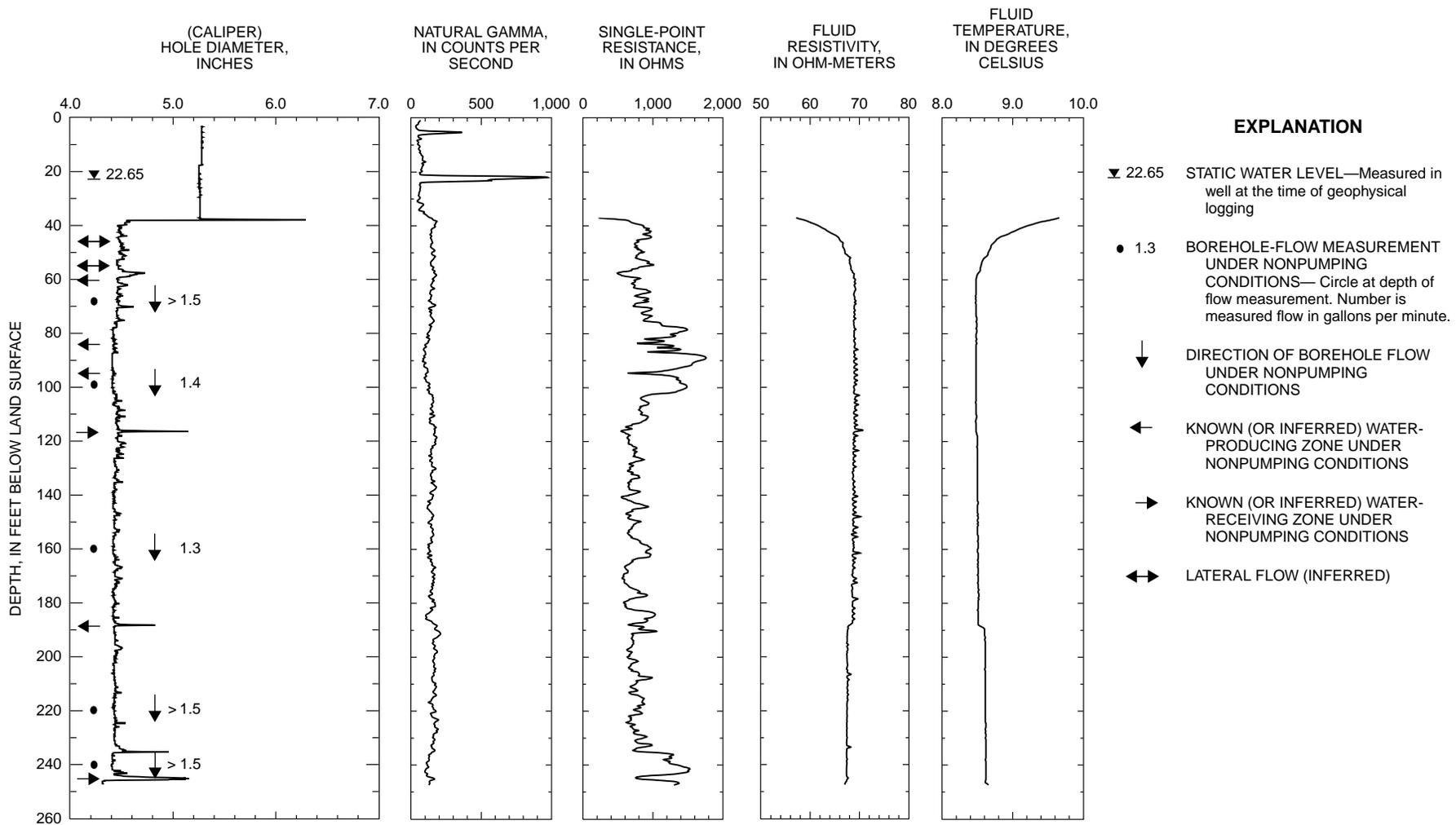
**MO-687 (R9)**

Monitor well MO-687 was logged November 6, 2000. The caliper log shows this borehole is drilled to a depth of 249 ft bls and is cased with 5.25-in.-diameter casing to 37 ft bls (fig. 27). The caliper log shows a major fracture at 37 ft bls and minor fractures at 116 to 117, 188, 235, and 244 to 246 ft bls plus smaller fractures throughout the open-borehole interval. The natural-gamma log shows only minor variation in lithology except at 4 to 6 and 21 to 24 ft bls where more silty or shaley lenses are present. The single-point resistance log indicates possible water-bearing fractures at 58, 82 to 87, 95, 188, and 244 to 246 ft bls. The fluid-resistivity log shows a major deflection in slope at 189 ft bls, plus numerous minor deflections from 43, 51, 57, and 70 to 189 ft bls. The fluid-temperature log shows a major deflection at 189 ft bls, plus minor deflections at 44, 51, 57, 74 to 82, 116, and 140 to 172 ft bls. The borehole video camera proved useful from 38 to 56 ft bls where the water was less cloudy. Possible high-angle fractures were seen at 39 and 41 ft bls. Possible low-angle fractures were seen at 43 and 46 ft bls. A lithologic contact was seen at 56 ft bls; the contact dips to the southeast. The interval from 166 to 170 ft bls was somewhat clearer, possibly indicating a water-producing zone. Possible low-angle fractures were seen at 166 and 170 ft bls. Under nonpumping conditions, the heatpulse flowmeter measured downward flow at 68, 99, 160, 220, and 240 ft bls and turbulent flow at 46 and 55 ft bls (table 31). The suite of geophysical logs and heatpulse-flowmeter data indicate, under nonpumping conditions, most water enters the borehole through fractures from 37 to 59 and 189 ft bls, moves downward, and exits the borehole through the major fracture at 244 to 246 ft bls. Additional water enters the borehole through minor fractures at 82 to 87 and 95 ft bls.

**Table 31.** Summary of heatpulse-flowmeter measurements for borehole MO-687 (R9) on November 6, 2000, at the Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania

[>, greater than; —, not determined]

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallons per minute)	Flow direction under nonpumping conditions
46	Turbulent	—
55	Turbulent	—
68	> 1.5	Down
99	1.4	Down
160	1.3	Down
220	> 1.5	Down
240	> 1.5	Down



**Figure 27.** Borehole geophysical logs and direction of borehole flow under nonpumping conditions within MO-687 (R9), collected on November 6, 2000, Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania.

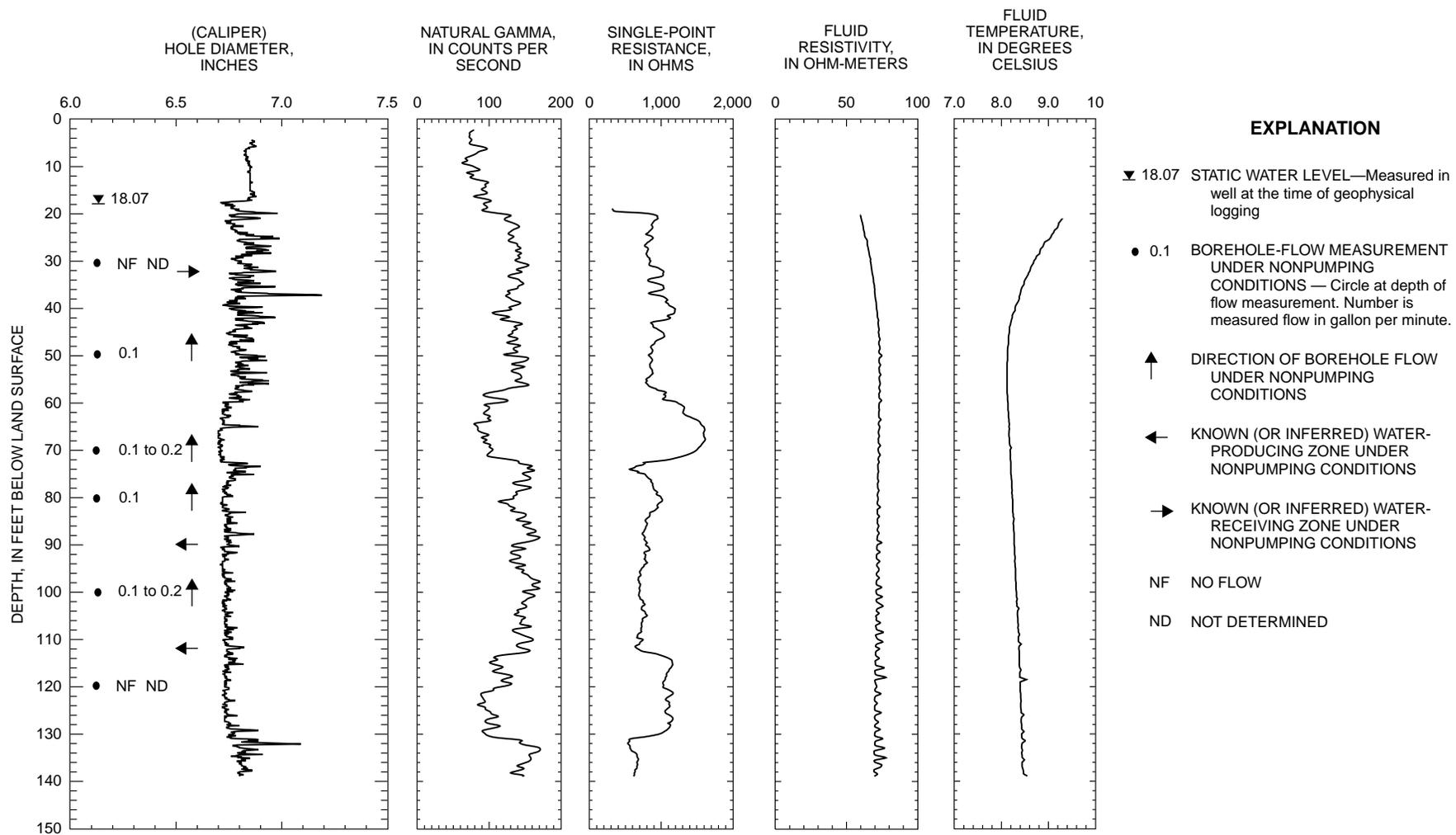
### MO-688 (R11B)

Monitor well MO-688 was logged October 24, 2000. The caliper log shows this borehole is drilled to a depth of 140.2 ft bls and is cased with 6.75-in.-diameter casing to 19 ft bls (fig. 28). The caliper log shows minor fractures at 37 and 132 ft bls plus numerous smaller fractures throughout the open-borehole interval. The natural-gamma log shows only minor variation in lithology with less silty layers at 58 to 72 and 113 to 131 ft bls. The single-point resistance log indicates possible water-bearing fractures at 34, 37, and 74 ft bls. The fluid-resistivity log shows scattered but minor deflections in slope from 25 to 82 ft bls and continuous but minor deflections from 84 to 139 ft bls. The fluid-temperature log shows minor deflections in slope at 69 ft bls and from 113 to 139 ft bls. Under nonpumping conditions, the heatpulse flowmeter measured upward flow at 50, 70, 80, and 100 ft bls and no flow at 30 and 120 ft bls (table 32). The borehole video camera did not prove useful in well MO-688 because the water was too cloudy for visual identification of borehole flow or other borehole features such as fractures. The suite of geophysical logs and heatpulse-flowmeter data indicate, under nonpumping conditions, most water enters the borehole through a series of small fractures from about 82 to 120 ft bls, moves upward, and exits the borehole through small or minor fractures between 30 and 50 ft bls.

**Table 32.** Summary of heatpulse-flowmeter measurements for borehole MO-688 (R11B) on October 24, 2000, at the Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania

[—, not determined]

Depth (feet below land surface)	Flow rate under nonpumping conditions (gallon per minute)	Flow direction under nonpumping conditions
30	No flow	—
50	0.1	Up
70	0.1 to 0.2	Up
80	.1	Up
100	.1 to .2	Up
120	No flow	—



**Figure 28.** Borehole geophysical logs and direction of borehole flow under nonpumping conditions within MO-688 (R11B), collected on October 24, 2000, Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania.

## SUMMARY

Between February 1996 and November 2000, the USGS, in cooperation with USEPA and BOR, collected geophysical logs in 27 open-borehole wells at the Butz Landfill Superfund Site, Jackson Township, Monroe County, Pa., to determine casing depth and depths of water-producing zones, water-receiving zones, and zones of vertical borehole flow. The site was used as a municipal-waste dump from approximately 1963 to 1969. Video logs also were conducted in 6 of the 27 open-borehole wells to locate fractures, joints, and weathered zones. The wells range in depth from 57 to 319 ft bls and penetrate the Long Run Member of the Catskill Formation, which consists of series of fluvial fining upward cycles of siltstone, shale, and sandstone units. Water-producing or water-receiving zones were penetrated as shallow as 16 ft bls and as deep as 255 ft bls. Vertical borehole flow was measured in 20 boreholes.

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