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

Prepared in cooperation with the
U.S. Environmental Protection Agency

Geohydrology and Ground-Water Quality, Eastern Surplus Superfund Site, Meddybemps, Maine

Water-Resources Investigations Report 98-4174

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

Geohydrology and Ground-Water Quality, Eastern Surplus Superfund Site, Meddybemps, Maine

By FOREST P. LYFORD, JANET RADWAY STONE,
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Marlborough, Massachusetts
1998

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

CONVERSION FACTORS

Multiply	By	To Obtain
acre	0.4047	hectare
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
foot per day (ft/d)	0.3048	meter per day
foot squared per day (ft^2/d)	0.09290	meter squared per day
gallon per day (gal/d)	0.003785	cubic meter per day
gallon per minute (gal/min)	0.06309	liter per second
inch (in)	25.40	millimeter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer

VERTICAL DATUM

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

ABBREVIATIONS

mg/L	milligram per liter
µg/L	microgram per liter
µS/cm	microsiemen per centimeter at 25° centigrade
mm	millimeter

GEOHYDROLOGY AND GROUND-WATER QUALITY, EASTERN SURPLUS SUPERFUND SITE, MEDDYBEMPS, MAINE

By Forest P. Lyford, Janet Radway Stone, Joseph P. Nielsen, *and* Bruce P. Hansen

Abstract

The geohydrology and ground-water quality at the Eastern Surplus Superfund Site in Meddybemps, Maine, was studied from September 1996 through June 1997 to provide information needed to address concerns about the distribution and fate of contaminants in ground water.

Geohydrologic units in the study area include glacial till, coarse-grained glaciomarine deposits, fine-grained glaciomarine deposits, and crystalline bedrock. Till thickness generally ranges from less than 5 feet on the west side of the Dennys River to more than 40 feet east of the river. Coarse-grained glaciomarine deposits in the western part of the study area are more than 30 feet thick in places. Surficial materials under much of the northern and western sides are unsaturated much of the time. The thickness of fine-grained glaciomarine deposits in the central and southern parts of the study area ranges from 0 to about 20 feet. The silt-clay facies of this unit serves as a confining layer for ground water in underlying till and coarse glaciomarine deposits. The yield of wells completed in fractured bedrock varies widely from less than 0.01 to more than 15 gallons per minute. The high-yielding wells are at the southern end of the study area and south of the Site. In some wells, only one or two fractures yield measurable water flow (more than 0.02 gallon per minute).

Ground water in surficial materials and bedrock flows towards the Dennys River. Water-level data for bedrock indicate a potential for flow under the river from the west side to a local cone of depression near a residential well on the east side.

Tetrachloroethylene (PCE), the principal contaminant in ground water at the site, was measured at a concentration of 3,700 micrograms per liter in a northern plume and at a concentration of 1,100 micrograms per liter in a southern plume. Contaminants in both plumes are moving through surficial materials and shallow bedrock towards the Dennys River. Contaminants in the southern plume could move through fractured bedrock to the cone of depression east of the river.

INTRODUCTION

The Eastern Surplus Company in Meddybemps, Maine (fig. 1), was a retailer of surplus and salvage items from 1946 until 1985 (Edward Hathaway, U.S. Environmental Protection Agency, written commun., 1996). Activities included the storage of chemicals in containers, and electrical transformers containing PCBs. During the mid-1980's, the U.S. Environmental Protection Agency (USEPA), U.S. Department of Defense, and Maine Department of Environmental Protection removed the contaminated surficial material that presented an immediate hazard to human health (Edward Hathaway, U.S. Environmental Protection Agency, written commun., 1996). Activities at the Eastern Surplus Site affected ground-water quality, and contaminated ground water may be moving to local surface-water bodies. Residential wells in the area also may be threatened by ground-water contamination. The Eastern Surplus Company property has been designated by the USEPA as a Superfund site under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). This report refers to the Superfund site as the Eastern Surplus Site or simply the Site.

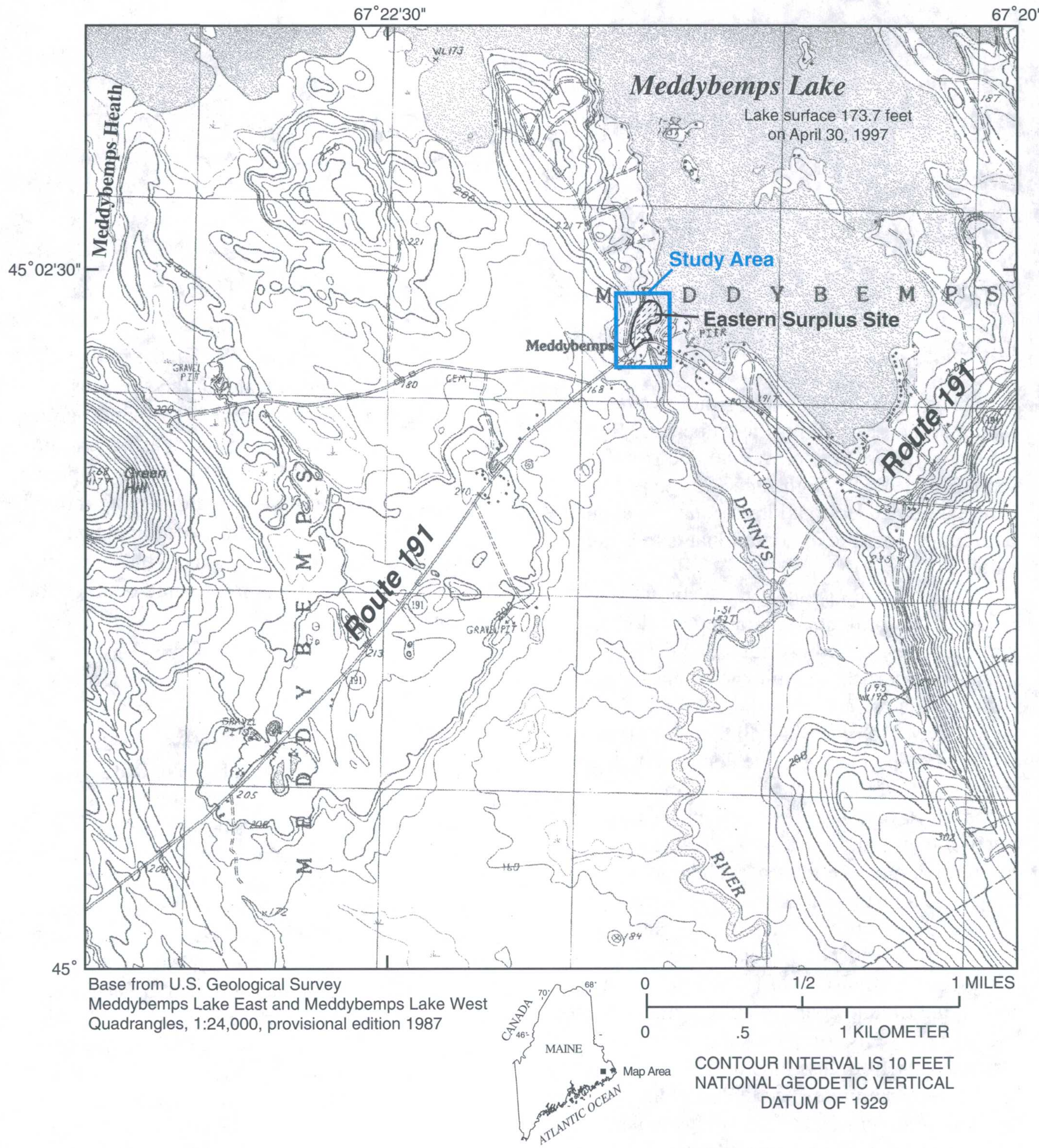

Figure 1. Location of the Eastern Surplus Superfund Site, Meddybemps, Maine.

As a basis for designing appropriate remedial actions and supporting studies at the Site, an evaluation of the extent of ground-water contamination and directions of ground-water flow was needed. To provide that evaluation, the U.S. Geological Survey (USGS), in cooperation with the USEPA, designed and conducted a study to describe the geohydrology and water quality of the ground-water-flow system in and near the Site.

Mr. Edward Hathaway, USEPA Project Manager, provided logistical support for many Site activities. Appreciation is extended to Terry Lord, Madge Orchard, Greg Smith, Harry Smith, and Mona Van Wart, who allowed access to their property for geologic mapping, geophysical surveys, drilling, and hydrologic monitoring.

Purpose and Scope

This report describes the geohydrology and water quality of the ground-water-flow system at the Eastern Surplus Site on the basis of information collected during field investigations from September 1996 to June 1997. The water-quality data presented in this report were collected by employees of Roy F. Weston, Inc. (Timothy Jones, written commun., 1997; 1998a; 1998b) during December 1996 and June 1997. A companion study begun in the spring of 1997 is evaluating the hydrology of fractured bedrock at the Site (Bruce Hansen, U.S. Geological Survey, written commun., 1997). Results of the bedrock study will be reported separately.

Description of Study Area

The Eastern Surplus Site covers about 4 acres adjacent to Route 191, Meddybemps Lake, and the Dennys River in Meddybemps, Maine. The study area extends beyond the boundaries of the site and encompasses an area of about 30 acres (fig. 1). The Dennys River and Meddybemps Lake receive ground-water and surface-water runoff from the site. Both water bodies support active fisheries and spawning areas. The Dennys River is classified by the State of Maine as a Class A waterway, meaning the water is suitable for all potential uses, including drinking. It is one of the few rivers in the United States with a wild Atlantic salmon run. Analyses of soil, ground water, and sediment samples collected from 1985 to 1990 and 1996 to 1997 have shown that some of the chemicals stored on site were released into the environment. As many as 28 residences within half a mile of the site obtain their water from wells completed in fractured bedrock. However, sampling during 1996 and 1997 did not detect site-related contaminants in these residential wells (Roy F. Weston, Inc., 1998b).

The Site borders a former mill pond on the Dennys River that supplied water to a grist mill and saw mill during the 1800's. From the mid-1950's into the early 1970's, a hydroelectric plant at lake level near Route 191 was powered by flow from Meddybemps Lake (Harry Smith, local land owner, oral commun., 1996). Flow to the Dennys River is currently regulated by a bottom discharge gate in a dam at the outlet from Meddybemps Lake. The dam was built by the Maine Atlantic Salmon Authority in 1974 and is used primarily to support Atlantic salmon habitat in the Dennys River. The lake is typically drawn down about 27 in. from mid-June through September to augment streamflow. A fishway at the dam is used primarily for passage of Alewife fish between the lake and river. According to records of the Maine Atlantic Salmon Authority (K. Beland, written commun., 1997), the gate was adjusted occasionally during the study period. On October 2, 1996, the gate was closed for about 8 hours to facilitate sampling of streambed sediments near the site.

The Dennys River flows southward from Meddybemps Lake to the Atlantic Ocean at Dennys Bay. The drainage area at the outlet from the lake is 44.7 mi^2, which is 34 percent of the total drainage area of the Dennys River Basin upstream of Dennys Bay. The mean annual flow at the outlet of Meddybemps Lake is estimated to be 93 ft^3/s on the basis of streamflow data at the USGS gaging station on the Dennys River near Dennysville, Maine, about 12 mi southeast of the study area.

STUDY METHODS

Study methods included installation of wells, collection of geologic data, ground-penetrating-radar surveys, borehole logging, measurements of water levels in wells, measurements of stream and lake-stage, and ground-water sampling using vapor-diffusion samplers.

Well Installation and Completion

Wells were drilled at 16 locations in surficial deposits and at 8 locations in bedrock to provide information about the character of geologic materials, to serve as monitoring points for ground-water levels, and for water-quality sampling. Wells in surficial deposits at locations MW–5S, MW–6S, MW–8S, MW–9S, MW–11S, MW–12S, and MW–13S (fig. 2) were drilled using a 6-inch truck-mounted hollow-stem auger. Augering was continued to a depth where drilling could no longer progress (refusal). Split-spoon samples were collected at selected horizons to determine the character of surficial materials.

Wells at locations MW–7S, MW–17S, MW–18S, and MW–19S, MW–20S, and TB–21S were installed using the spin-casing method to penetrate cobbles and boulders at these locations. Spin casing consisted of a length of steel pipe about 4.5 in. in outside diameter with a diamond bit attached at the bottom. Water was circulated to remove cuttings as the pipe advanced through surficial materials. The bedrock was cored at each of these wells for confirmation of the bedrock surface.

Wells at locations MW–10S, MW–15S, and MW–16S were installed using the air-percussion rotary method and an 8-inch bit. Temporary steel casing was installed to maintain an open borehole prior to completion as a monitoring well. Depth to bedrock was confirmed by drilling about 1 ft after encountering competent rock.

Monitoring wells were constructed by placing a 2-inch polyvinylchloride (PVC) well screen and casing through the auger, spin casing, or temporary surface casing. A sand pack was placed around each well screen from 1 to 3 ft above the screen, a bentonite seal about 2 ft thick was placed in the annulus above the well screen and sandpack, and, for most wells, the annulus above the bentonite seal was filled with native materials removed during drilling. The annulus was filled with neat cement grout in wells MW–17S, MW–18S, MW–19S, and MW–20S. A protective steel casing with a locking cover was cemented in the annulus around each PVC pipe. Well screens varied in length depending on the thickness of saturated materials. Although boreholes at MW–6S, MW–9S, MW–12S, and MW–19S encountered no water during drilling, a monitoring well with a 2.5-foot long screen and holes drilled in the point at the bottom of the screen was completed to allow for water-level monitoring and sampling if surficial materials became saturated during the study. No well was completed at the location of borehole TB–21S because surficial materials at this location are unsaturated above shallow bedrock. Screened intervals and other information relating to the monitoring wells are presented in table 1. Lithologic logs are presented in table 2. Small discrepancies between the land-surface elevations at wells MW–12B, MW–14B, and TB–21S and the contour-line elevation shown on figure 2 can be attributed to subtle variations in the land surface that were not mapped or slight alteration of the land surface during construction of the wells.

The wells completed in surficial deposits were developed by bailing water manually until turbidity was substantially reduced. Approximate yield was determined by monitoring the volume of water removed (table 1). The maximum bailing rate was about 0.5 gal/min.

Bedrock wells were installed using coring and air-percussion rotary methods. Well MW–7B was drilled by first advancing spin casing through overburden and 2 ft into bedrock. A 3.2-inch inside-diameter surface casing was placed through the spin casing and cement was placed in the annulus to several feet above the bedrock surface. The spin casing was removed and the cement was allowed to cure before coring began. A 2-inch-diameter core was removed in 5-foot lengths using a 2.5-inch diameter diamond-bit core and core barrel. About 97 ft of core was retrieved.

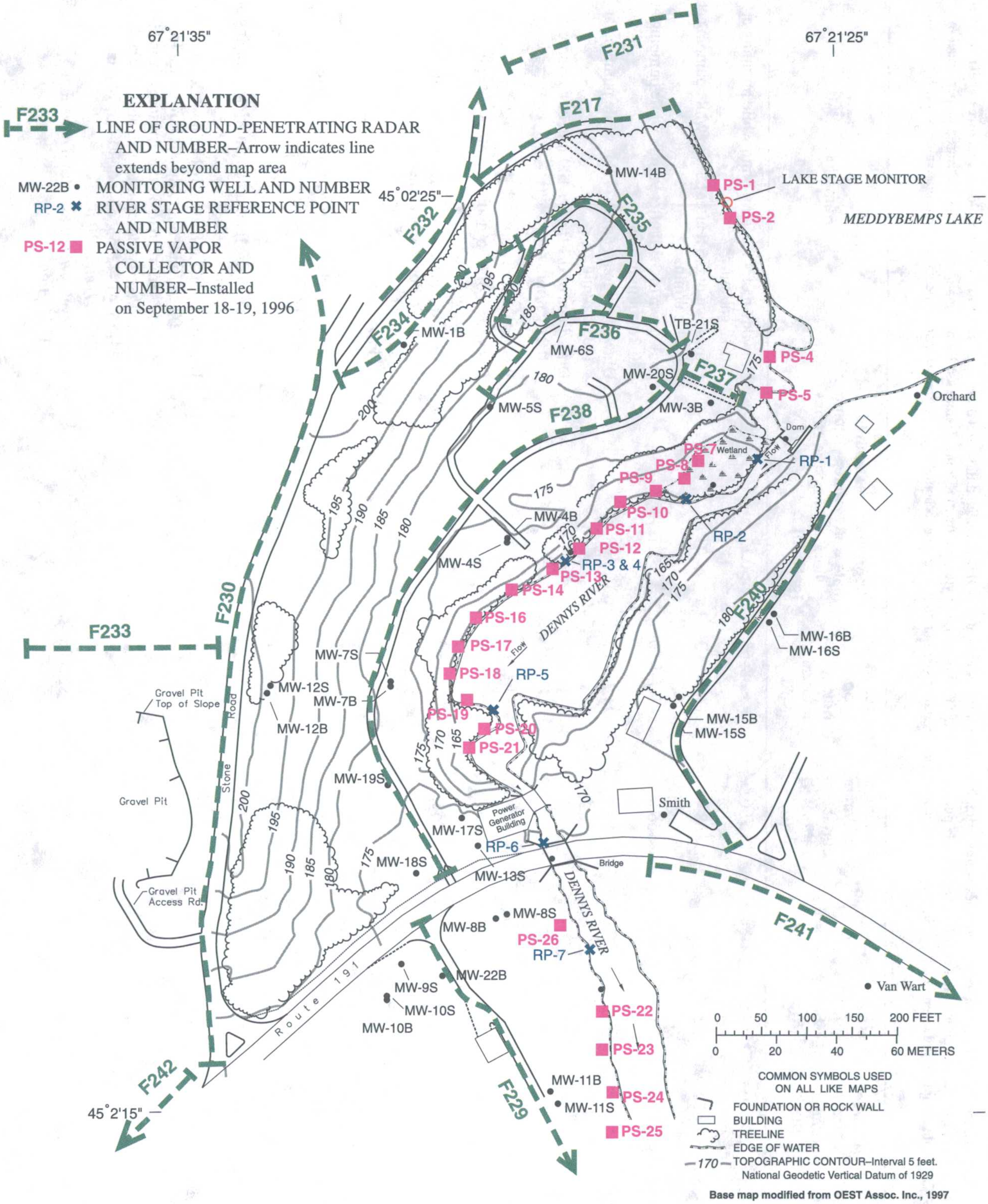

Figure 2. Locations of wells, survey lines for ground-penetrating radar, reference points for measuring river stage, and temporary passive vapor samplers at the Eastern Surplus Superfund Site, Meddybemps, Maine.

Table 1. Records of wells in and near the Eastern Surplus Superfund Site, Meddybemps, Maine

[All depths in feet below land surface. **Well No. or name:** B indicates well is completed in bedrock, S indicates well is completed in surficial material. **Depth to water-yielding fracture zones:** Number in parentheses next to fracture zone indicates relative magnitude of yield while pumping, where (1) is the highest yielding fracture zone. **Remarks:** Pumping and drawdown measured by personnel of Roy F. Weston, Inc. (1997a) while sampling in December 1996. ft, foot; min, minute; gal/min, gallon per minute; -- no data; > actual value is greater than value shown; < actual value is less than value shown]

Well No. or name	Date drilled	Altitude of land surface (ft)	Total depth of borehole (ft)	Depth to bedrock or refusal (r) (ft)	Altitude of bedrock surface or refusal (r) (ft)	Screened (s) or open-hole (o) interval (ft)	Approximate well yield (gal/min)	Depth to water-yielding fracture zones (ft)	Remarks
MW–1B	4-17-88	201.60	57.8	34.6	167.0	s38–53	>0.12	--	Drawdown of 9 ft after 67 min while pumping at 0.12 gal/min.
MW–3B	4-17-88	177.37	23.3	9	168.4	s13.3–23.3	>.21	--	Drawdown of 0.6 ft after 65 min while pumping at 0.21 gal/min.
MW–4S	4-15-88	174.84	18	r18	156.8	s13.0–18.0	>.21	--	Drawdown of 3.3 ft after 95 min while pumping at 0.21 gal/min.
MW–4B	4-14-88	174.75	39.7	19.5	155.3	s24.7–39.7	<.03	--	Drawdown greater than 17.9 ft while pumping at 0.03 gal/min.
MW–5S	10-23-96	179.86	13	r13	r166.9	s10–13	>.5	--	Drawdown of 0.2 ft after 100 min of pumping at 0.21 gal/min.
MW–6S	10-23-96	182.34	7.0	r7.0	r175.3	s4.5–7.0	--	--	Well is generally dry.
MW–7S	10-28-96	177.79	17.2	17	160.8	s12–17	>.26	--	Drawdown of 0.35 ft after 70 min while pumping at 0.26 gal/min.
MW–7B	10-28-96	177.81	117.8	18	159.8	o21–117.8	>.004	89	No measurable flow in borehole for static condition. No flow measurements above depth of 48.6 ft during pumping because of drawdown.
MW–8S	10-25-96	167.30	16.5	r16.5	r150.8	s14–16.5	<.1	--	--
MW–8B	11-04-96	169.04	124	20.5	148.5	o25.7–124	.06	27–34 (2) 55–65 (1)	No measurable flow in borehole for static conditions.
MW–9S	10-25-96	174.03	16.5	r16.5	r157.5	s14–16.5	--	--	--
MW–10S	11-06-96	174.42	23	22	152.4	s18–23	>.5	--	Drawdown of 0.2 ft after 70 min while pumping at 0.2 gal/min.
MW–10B	11-04-96	174.24	120	20	154.2	o26.4–120	1.2	30–31 (1) 37 (3) 72–76 (2)	Drawdown of 1.6 ft after 161 min while pumping at 0.07 gal/min. Static flow is downward from fractures from 26 to 60 ft to fractures from 60 to 85 ft. Water-yielding fractures also observed at 33–35, 41–42, 55, 63–66, 80–83, 94–96, 101–107, and 110 ft.
MW–11S	10-26-96	169.34	26	r26	r143.3	s21–26	<.1	--	Water level lowered to bottom of well at 0.17 gal/min.

Table 1. Records of wells and borings in and near the Eastern Surplus Superfund Site, Meddybemps, Maine—*Continued*

Well No. or name	Date drilled	Altitude of land surface (ft)	Total depth of borehole (ft)	Depth to bedrock or refusal (r) (ft)	Altitude of bedrock surface or refusal (r) (ft)	Screened (s) or open-hole (o) interval (ft)	Approximate well yield (gal/min)	Depth to water-yielding fracture zones (ft)	Remarks
MW–11B	11-04-96	169.69	132	29	140.7	o34–132	15	34–41 (2) 71–74 (3) 77–80 (1)	Drawdown of 1.4 ft after 90 min while pumping at 0.42 gal/min. No measurable flow in borehole for static conditions. Water-yielding fractures also at 88 and 128 to 130 ft.
MW–12S	10-26-96	199.11	22	r22	r177.1	s19–21.5	--	--	Well generally is dry.
MW–12B	11-04-96	200.13	138	22.5	177.6	o27.7–138	.03	34–37	No measurable flow in borehole for static conditions.
MW–13S	10-29-96	171.36	14	r14	r157.4	s11–13.5	<.1	--	
MW–14B	11-05-96	185.70	120	3.5	182.2	o9.4–120	.5	25–27	Drawdown of 1.45 ft after 105 min while pumping at 0.21 gal/min. No measurable flow in borehole for static conditions. No flow measurements above 24 ft during pumping because of drawdown.
MW–15S	11-06-96	178.46	38	36	142.5	s26–36	>.5	--	Drawdown of 2.15 ft after 119 min while pumping at 0.11 gal/min.
MW–15B	11-05-96	178.97	240	39	140.0	o46.9–240	.06	73–78 (1) 92–95 (1)	No measurable flow in borehole for static conditions. Flow from two zones approximately equal.
MW–16S	11-06-96	182.88	38	36	146.9	s28–38	.5	--	Drawdown of 4.9 ft after 165 min while pumping at 0.21 gal/min.
MW–16B	11-05-96	182.18	138	38	144.2	o42.3–140	.09	45–46 (1) 68–68.5 (3) 108–118 (2)	No measurable flow in borehole for static conditions.
MW–17S	4-22-97	172.42	23	18.0	154.4	15–17.5	.5	--	
MW–18S	4-23-97	172.90	19.5	18.0	154.9	16–18.5	.5	--	Perched water observed at 9.0 to 10.0 ft.
MW–19S	4-23-97	177.08	13.5	11.8	165.1	9.3–11.8	Dry	--	--
MW–20S	4-24-97	178.57	8.0	6.0	172.6	3.5–6.0	<.01	--	--
TB–21S	4-24-97	180.90	7.0	5.0	175.9	Not completed	Dry	--	--
MW–22B	1950s	172.35	49	18	154.4	o25–49	25	25.5–30	Former residential well. Yield reported by former owner (E. Gillespie, oral commun., 1996). No measurable flow in borehole for static conditions. Depths estimated from geophysical logs.
Van Wart	--	171.78	142	29	142.8	o39–142	5	--	Residential well. Yield reported by driller (T. Lord, oral commun., 1996).
Orchard	--	--	--	--	--	--	--	--	Residential dug well.
Smith	--	173.35	420	--	--	--	<.3	--	Residential well. Yield reported by driller (T. Lord, oral commun., 1996)

Table 2. Lithologic logs of wells, Eastern Surplus Superfund Site, Meddybemps, Maine

[Descriptions for wells MW–1B, MW–3B, and MW–4B by NUS Corporation (written commun., 1988)]

Description of material	Depth (feet below land surface)
MW–1B	39.8 – 240.8
Sand, medium, brown; some gravel; trace of silt	0 – 5
Sand, coarse, gray; cobbles at 7.5, 10.8, 13.4 to 14.8 ft	5 – 14.8
Gravel; coarse sand; some silt and clay	14.8 – 21
Sand, medium, gray; fine sand with clay layers	21 – 25
Sand, fine; silt; clay (described as till)	25 – 29
Boulders, to 2-foot diameter, diorite, granite	29 – 34.6
Diorite, open and closed fractures	34.6 – 40
Bedrock, competent	40 – 57.8
MW–3B	
Soil, black	0 – 3
Sand, fine to medium, brown	3 – 5
Boulders; sand, fine to medium; clay	5 – 9
Diorite	9 – 23.3
MW–4S	
No description. See description for MW–4B	0 – 18
MW–4B	
Soil, brown; some sand, light brown	0 – 5
Sand, fine, light brown; some interbedded brown clay; trace of silt	5 – 10
Sand, fine, gray and some brown; minor cobbles	10 – 15
Clay, silty, gray; some coarse sand and cobbles	15 – 19.5
Granodiorite	19.5 – 39.7
MW–5S	
Soil, organic; cobbles and pebbles	0 – 1
Silt, light brown	1 – 6
Silt, pebbly and cobbly, medium brown (probably till); refusal at 13 ft	6 – 13
MW–6S	
Clay, silty	0 – 3
Silt; layers of sand, fine to medium	3 – 6
Cobbles (probably till); refusal at 7 ft	6 – 7.0
MW–7S	
Soil; sand, fine	0 – 6
Cobbles, layers of sand	6 – 12
Gravel, granule and pebble, very silty	12 – 17
Gabbro-diorite	17 – 17.2
MW–7B	
Sand, fine	0 – 5
Cobbles and boulders	5 – 13
Gravel, silty	13 – 18
Gabbro-diorite; granite vein at 78.2 to 78.4 ft	18 – 117.8
MW–8S	
Clay, medium brown and light brown	0 – 3
Clay, silty	3 – 7
Silt, sandy	7 – 9
Sand, fine to medium, well sorted, silty layers	9 – 13.5
Cobbles and boulders; possibly weathered rock; refusal at 16.5 ft	13.5 – 16.5
MW–8B	
Surficial materials, see description for MW–8S	0 – 20.5
Gabbro-diorite	20.5 – 122
Granite	122 – 124
MW–9S	
Soil, silty, clayey, light brown, friable	0 – 4
Clay, ductile	4 – 13
Gravel, silty; refusal at 16.5 ft	13 – 16.5
MW–10S	
Silt and clay, light brown	0 – 6
Silt and fine sand	6 – 19
Cobbles	19 – 22
Gabbro-diorite	22 – 23
MW–10B	
Surficial materials (see MW–10S and MW–9S)	0 – 20
Gabbro-diorite	20 – 120
MW–11S	
Fill	0 – 5
Clay, dense, medium gray, fractured evident as iron-stained films	5 – 10.5
Clay, dense, medium gray	10.5 – 13.5
Clay, silty, less dense, medium gray	13.5 – 15.5
Clay	15.5 – 18.5
Clay; thin (less than 1/4 inch) silt layers	18.5 – 20.5
Clay, silty	20.5 – 22
Cobbles	22 – 23.5
Gravel, light gray, silty (probably till); refusal at 26 ft	23.5 – 26

Table 2. Lithologic logs of wells, Eastern Surplus Superfund Site, Meddybemps, Maine—*Continued*

Description of material	Depth (feet below land surface)
MW–11B	
Surficial materials (see MW–11S)	0 – 29
Gabbro-diorite	29 – 132
MW–12S	
Gravel, light brown, sandy	0 – 5
Sand, fine to coarse, silty	5 – 9.5
Sand, medium to coarse	9.5 – 13
Gravel, pebbly, cobbly; refusal at 22 ft	13 – 22
MW–12B	
Surficial materials	0 – 22.5
Gabbro-diorite; driller reports easier drilling from 128–138 ft	22.5 – 138
MW–13S	
Gravel, silty; possibly fill	0 – 4
Gravel	4 – 5
Silt, light brown, clayey	5 – 9
Clay, wet	9 – 10
Cobbles	10 – 11
Gravel; refusal at 14 ft	11 – 14
MW–14B	
Surficial material, probably till	0 – 3.5
Gabbro-diorite and granite	3.5 – 120
MW–15S	
Till, light brown	0 – 9
Till, light gray	9 – 33
Boulders	33 – 36
Gabbro-diorite	36 – 38
MW–15B	
Till (see log for MW–15S) (Driller reports top of rock at 42 ft. Natural gamma-ray log indicates top of rock at 39 ft)	0 – 39
Gabbro-diorite; lighter color at a depth of about 170 ft	39 – 240
MW–16S	
Till, light brown, cobbles	0 – 15
Till, gray, hard spots, probably cobbles	15 – 33
Boulders or "broken ledge"	33 – 36
Gabbro-diorite	36 – 38
MW–16B	
Till (see MW–16S)	0 – 38
Gabbro-diorite	38 – 85
Granite (note: gamma-ray log indicates granite starts at about 85 ft)	85 – 138
MW–17S	
Clay, light brown and yellow orange; silt; sand medium to coarse; gravel, coarse; some roots	0 – 2.5
Clay, gravelly, light gray	2.5 – 7.5
Sand and clay, yellow orange	7.5 – 10
Sand, medium, well sorted, yellow orange	10 – 12.5
Sand, fine to coarse, silty, clayey, gravelly, yellow orange	12.5 – 15
Boulders	15 – 18
Gabbro-diorite	18 – 23
MW–18S	
Clay, silty, light brown	0 – 7.5
Silt, yellow orange; sand, fine	7.5 – 10
Sand, fine to coarse, silty, yellow orange	10 – 12.5
Sand, fine, silty, light brown	12.5 – 15
Sand, fine to coarse, gravelly, yellow orange	15 – 17
Sand, silty, gravelly, yellow orange	17 – 18
Gabbro-diorite	18.0 – 19.5
MW–19S	
Clay, gravelly, yellow orange	0 – 2.5
Sand, fine to medium, silty, yellow orange	2.5 – 11.8
Gabbro-diorite	11.8 – 13.5
MW–20S	
Clay, organic, some gravel, light brown	0 – 2.5
Sand, fine to coarse, clayey, silty, some gravel, light brown and light orange	2.5 – 6.0
Gabbro-diorite	6.0 – 8.0
TB–21S	
Clay, organic, silty, roots, fine gravel, light brown and yellow orange	0 – 2.5
Silt; sand, fine to coarse; gravel, light brown	2.5 – 5
Gabbro-diorite	5 – 7

Bedrock wells MW–8B, MW–10B, MW–11B, MW–12B, MW–14B, MW–15B, and MW–16B were installed using the air-percussion rotary method. An 8-inch hole was first drilled through surficial materials and 5 to 7 ft into bedrock. Steel casing was set in cement placed in the bored bedrock and the cement was allowed to cure. Drilling advanced using a 6-inch bit, and cuttings were collected about every 20 ft. Obvious changes in drill action that might indicate fractures or fracture zones were recorded. Wells were drilled 100 to 120 ft into bedrock except for well MW–15B, which was drilled about 200 ft into bedrock. The deeper well was installed at this location to provide water samples from a greater depth in bedrock near a residential well (the Smith well) that is reportedly 420 ft deep (Terry Lord, driller, oral commun., October 1996). Where possible, well yield was estimated by evacuating the well continuously with air and measuring flow volumetrically. Because yields from wells MW–8B, MW–12B, MW–15B and MW–16B were too small to measure by this method, yield was estimated by monitoring the rate of water-level recovery for 2 to 3 days after the well was drilled and evacuated. The yield for well MW–7B (the cored well) also was estimated by monitoring recovery after the water level in the well was lowered by removal of the drill stem. The estimated yield for this well is considered to be lower than the potential yield because drawdown was limited to about 30 ft.

Data Collection

Data collected for this report includes geologic data, water levels in wells, stage in Meddybemps Lake and the Dennys River, ground-penetrating-radar surveys, borehole logs, and ground-water quality.

Geologic Data

Geologic data were collected by field reconnaissance, aerial-photo interpretation, drilling, ground-penetrating-radar surveys, borehole logging, and review of available geologic reports. Field reconnaissance included inspection of outcrops and gravel pits within a 1-mile radius of the site. Geologic interpretation was partly based on stereoscopic examination of aerial photographs from the Maine Geological Survey. Core and cuttings from boreholes were examined for lithologic characteristics. Available geologic reports for southeastern Maine were reviewed.

Ground-Penetrating Radar

Ground-penetrating radar (GPR) was used to determine the depth to bedrock and the nature of unconsolidated materials in the subsurface. Ground-penetrating radar transmits radio-frequency electromagnetic pulses into the ground to identify subsurface features that have contrasting electrical properties. The energy reflected from subsurface interfaces and received by antennas pulled along the ground surface is recorded, processed, and displayed as a graphic image. The traveltime for an energy pulse is converted to depth using estimates of the electrical properties of geologic materials (Wright and others, 1984; Olhoeft, 1984, 1986; Haeni and others, 1987; and Beres and Haeni, 1991).

For this study, a transmission frequency of 100 megahertz (Mhz) was selected. Lines for the ground-penetrating radar survey are shown in figures 2 and 3. The GPR records supplemented the borehole data for geologic characteristics of the study area. GPR data are not included in this report because the difficulties in presenting several hundred feet of graphic records outweighed the usefulness of the data. Digital and graphic records are kept on file at the USGS office in Augusta, Maine.

Borehole Logging

Borehole logs were collected at most surficial (S) and bedrock (B) wells drilled during 1996 and at MW–3B and MW–4B to supplement subsurface geologic information obtained during drilling and to identify potential water-yielding fractures or fracture zones (appendix 1). Gamma and electromagnetic-induction (EM) logs were collected in the shallow surficial monitoring wells, and gamma, EM, single-point resistivity, spontaneous potential (SP), caliper, and heat-pulse flowmeter logs were collected in most of the bedrock monitoring wells. The logs were collected using a single-conductor logging system that recorded digital data from each 0.1 ft interval. Paillet (1994) describes methods for collecting borehole flow data in fractured rock using the heat-pulse flowmeter. Methods used for other logging techniques are described by Keys (1990). Digital logging data are on file at the USGS office in Augusta, Maine.

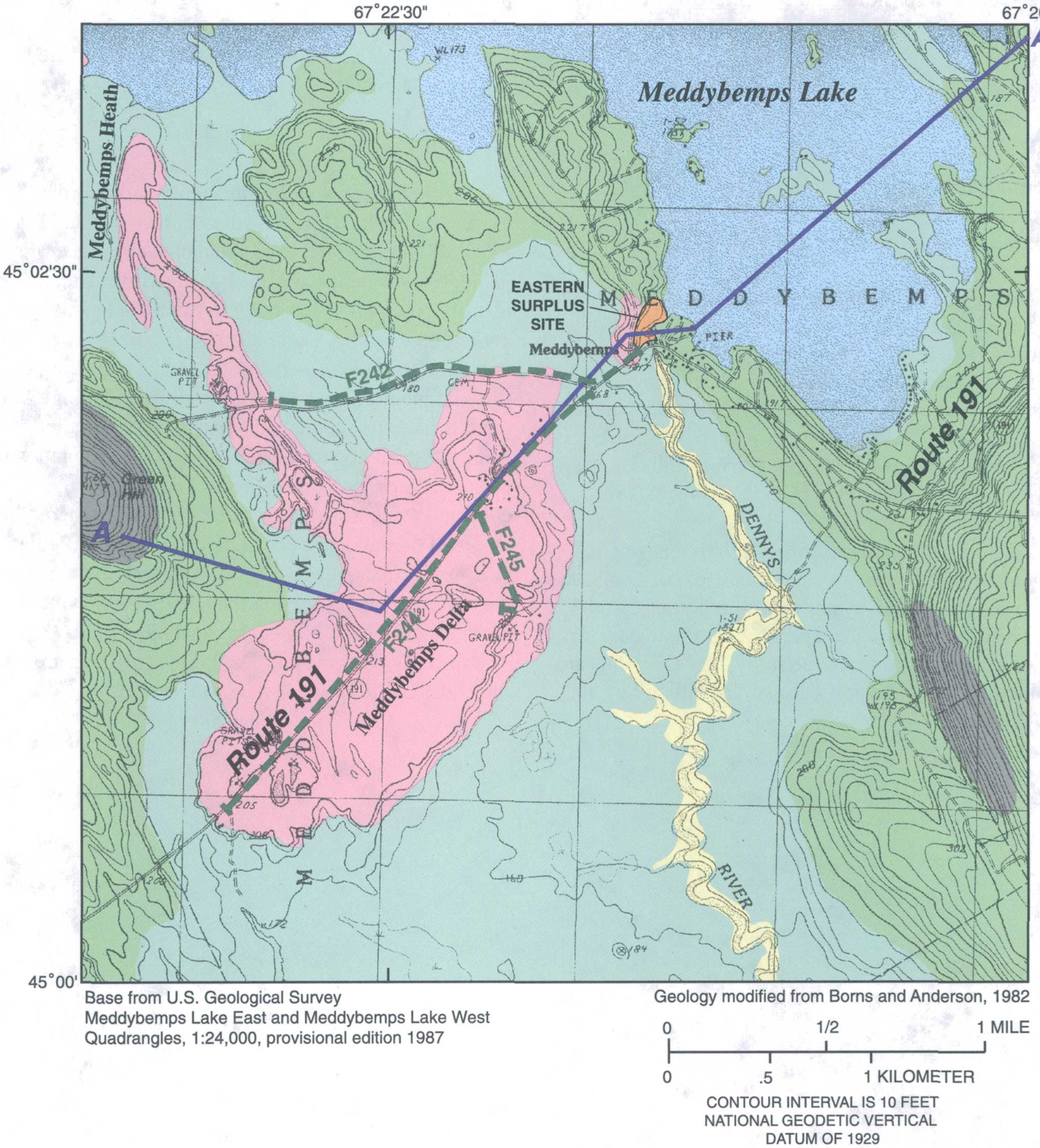

Figure 3. Surficial geology of the area near the Eastern Surplus Superfund Site and the locations of survey lines for ground-penetrating radar beyond the study area, Meddybemps, Maine.

EXPLANATION

POSTGLACIAL DEPOSITS

Floodplain Alluvium—Sand, gravel, and silt with minor amounts of organic material on the modern floodplain of the Dennys River; generally less than 5 ft in thickness and overlies thicker glacial materials in most places

GLACIAL DEPOSITS

Glaciomarine Deposits, fine-grained—Lower part of unit is massive to finely laminated gray silty clay with minor amounts of fine sand and sparse fossil marine mollusk shells and ice-rafted dropstones; deposited in the deeper water glaciomarine environment, distal from the ice margin. Where sediment has been oxidized in the upper part of the section, its color becomes dark olive gray. This unit is the Presumpscot Formation of Bloom (1960, 1963). Upper part of unit (5 to 10 ft) is finely laminated to massive, silty fine to medium sand; deposited in the shallow glaciomarine environment during regression of the sea. Unit is overlain locally by organic wetland deposits (not mapped)

Glaciomarine Deposits, coarse-grained—Well to poorly sorted gravel, sand and gravel, sand, and local diamict sediment deposited as eskers, deltas and subaqueous fans in contact with the glacier margin during retreat of the ice sheet in the glacial sea. Deposits are coarse-grained, poorly sorted, and bedding is collapsed in ice-proximal (northerly) parts; sediments are fine-grained, well-sorted, and beds generally dip southerly far from (distal to) the ice-margin position; fan and delta sediments interfinger with fine-grained glaciomarine sediments in distal parts of the deposits

Glacial Till—Nonsorted and nonstratified, compact mixture of grain sizes ranging from clay to large boulders; matrix is largely fine sand containing as much as 25 percent silt and clay; deposited beneath glacial ice. Locally, a less compact, sandy, stony facies of till may overlie the more compact facies. Till forms a thin blanket over bedrock in most places. Areas where numerous bedrock outcrops are present and till is locally absent are shown in grey color

MAP SYMBOLS

A—A′ LINE OF GEOLOGIC SECTION—See figure 4

F244 GROUND-PENETRATING RADAR LINE AND NUMBER

Figure 3. Surficial geology of the area near the Eastern Surplus Superfund Site and the locations of survey lines for ground-penetrating radar beyond the study area, Meddybemps, Maine—*Continued.*

Water-Level, Stream-Stage, and Lake-Stage Data

The stage of Meddybemps Lake and water levels in several wells were monitored continuously for responses to stresses such as pumping and recharge. Also, stage in the Dennys River at six reference points (RPs), shown in figure 2, and water levels in other wells in and near the site were measured periodically for use in defining ground-water-flow directions and variations with climatic conditions. RP–4 was placed near RP–3 for use during periods of high water in the river. Because river stage was relatively stable during the study period, measurements were not made at RP–4. Periodic measurements of water levels, lake levels, and stream stage are reported in table 3.

Water-level recorders were installed in wells MW–1B, MW–3B, MW–4S, and MW–4B, and Meddybemps Lake (fig. 2) on September 17, 1996. Monitoring continued until December 9, 1996, when the recorders were removed to allow access for water-quality sampling. Recorders were reinstalled on wells MW–1B, MW–3B, MW–4S, and MW–4B on January 14, 1997. Additional recorders were installed in wells MW–7S and MW–7B on January 14, 1997 and in wells MW–10B, MW–11B, MW–14B, and MW–15B on February 27, 1997. On April 30, 1997, recorders were removed from wells MW–10B and MW–15B and reinstalled in wells MW–1B and MW–4B to check the operation of recorders previously installed in those wells. Water-level recorders were serviced about once a month. Water-level monitoring was discontinued in all wells on June 5, 1997 prior to water-quality sampling.

Water-level data collected from well MW–1B from September 17, 1996, to April 30, 1997, reflected general water-level trends. Daily cycles that initially appeared to be a response to pumping, however, were later found to result from instrumentation problems. Average daily water levels for this well reflect general trends and are included in the report, although short-term fluctuations are questionable. Similarly, the water-level record for wells MW–4S and MW–4B from January 14 to April 30, 1997, included spurious readings. Because of questionable quality, data for that period of record from wells MW–4S and MW–4B have not been included in this report.

Ground-Water Sampling

Monitoring wells in the study area were sampled by Roy F. Weston, Inc. (1998a) in December 1996 and again in June 1997 for volatile organic compounds (VOCs), semivolatile organic compounds, pesticides and polychlorinated biphenyls, metals, and total cyanides. Additional samples were collected for analysis of selected anions during the June 1997 sampling period to provide data that may be useful for determining sources of ground water. Sampling in December 1996 and June 1997 was part of a long-term sampling program supported by USEPA to define water-quality conditions including seasonal variation and long-term trends. Low-stress purging techniques were used in accordance with procedures described by USEPA, Region I (Roy F. Weston, Inc., 1998a). Monitoring wells that could not be stabilized using the low-stress technique were pumped dry and sampled after the well recovered. Wells in this category included MW–4B, MW–8S, MW–8B, MW–11S, MW–12B, MW–15B, and MW–16B. Water samples were analyzed using standard USEPA methods (Roy F. Weston, Inc., 1998a).

Passive vapor diffusion samplers were installed along the shore of Meddybemps Lake and near the western edge of the Dennys River, either in the river or in wet areas near the edge of the river channel (fig. 2), using procedures described by Vroblesky and others (1996). The vapor samplers were used to define areas where VOCs in ground water discharge into the river. The samplers were installed on September 18–19, 1996, and retrieved on October 23, 1996. Vapor from the samplers was analyzed at the site on October 23, 1996, using a gas chromatograph (Sharon Gary, analyst, Roy F. Weston, Inc., written commun., October 1996). Two of the samplers (PS–3 and PS–6) were dislodged during the sampling period and their vapors were not processed. The PS–15 number was inadvertently omitted during placement of the samplers.

Table 3. Measurements of water levels in wells, lake level in Meddybemps Lake, and stream stage in the Dennys River, Eastern Surplus Superfund Site, Meddybemps, Maine

[--, no data; <, actual value is less than value shown and well was dry when measured]

Well No. or reference point	Altitude, in feet above sea level								
	9-19-96	10-8-96	10-29-96	11-6-7-96	11-19-96	12-10-96	3-25-97	4-30-97	6-5-97
Water Levels									
MW–1B	167.54	167.35	167.30	167.31	167.51	170.39	167.28	169.57	170.77
MW–3B	172.45	171.53	171.79	171.83	172.18	173.58	171.90	173.63	173.18
MW–4S	164.70	164.22	164.57	165.02	165.42	166.07	164.93	165.93	166.11
MW–4B	162.59	162.26	162.24	162.02	162.60	162.97	162.30	162.76	163.18
MW–5S	--	--	170.26	171.12	172.39	175.20	--	174.41	173.33
MW–6S	--	--	<175.3	--	<175.3	177.01	<175.3	175.40	<175.3
MW–7S	--	--	163.11	162.88	163.50	--	--	163.61	164.68
MW–7B	--	--	154.88	155.59	157.53	--	158.13	158.79	159.07
MW–8S	--	--	157.44	157.39	157.82	158.42	157.41	157.93	158.41
MW–8B	--	--	--	--	156.66	--	156.63	157.01	157.35
MW–9S	--	--	<157.51	--	158.28	158.79	157.84	158.43	159.00
MW–10S	--	--	--	158.31	158.73	--	158.33	158.90	159.50
MW–10B	--	--	--	157.09	157.50	--	157.42	157.90	--
MW–11S	--	--	154.70	154.92	155.07	155.39	154.41	154.99	155.06
MW–11B	--	--	--	155.35	155.56	156.01	155.19	155.49	155.76
MW–12S	--	--	<177.1	--	<177.1	<177.1	177.52	177.60	177.54
MW–12B	--	--	--	--	175.17	175.62	174.55	174.22	175.71
MW–13S	--	--	158.99	158.87	159.48	--	158.93	159.71	160.31
MW–14B	--	--	--	174.03	175.90	179.05	174.54	178.13	175.82
MW–15S	--	--	--	164.26	165.36	166.63	163.55	166.07	165.13
MW–15B	--	--	--	--	155.16	155.51	154.99	155.62	155.58
MW–16S	--	--	--	175.88	176.99	178.63	173.90	178.16	176.17
MW–16B	--	--	--	--	174.99	177.06	173.29	176.54	175.02
MW–17S	--	--	--	--	--	--	--	160.57	161.40
MW–18S	--	--	--	--	--	--	--	160.02	160.90
MW–19S	--	--	--	--	--	--	--	<165.1	<165.1
MW–20S	--	--	--	--	--	--	--	175.44	173.74
MW–22B	--	--	--	--	--	--	--	158.36	158.85
VanWart	--	--	--	--	--	--	167.17	168.54	167.73
Lake Levels									
Meddybemps Lake	172.92	172.42	172.39	172.31	172.59	173.55	172.72	173.71	174.09
Stream stage									
RP–1	167.79	167.38	167.36	167.36	167.27	167.39	167.41	167.25	167.74
RP–2	164.55	164.36	164.36	164.36	164.33	164.36	164.32	164.28	164.47
RP–3	162.92	162.56	162.56	162.54	162.49	162.58	162.46	162.35	162.71
RP–5	162.83	162.44	--	162.45	162.36	162.47	162.48	162.39	162.75
RP–6	154.19	153.74	153.84	153.74	--	153.74	153.74	153.67	153.99
RP–7	153.76	152.78	152.74	152.75	152.63	152.79	152.72	152.67	152.90

GEOHYDROLOGY

Geology

The physiography of the region surrounding the Eastern Surplus Site is a result of the lithology and structure of crystalline bedrock, the distribution of unconsolidated glacial sediments, and postglacial erosional and depositional processes. The hills surrounding Meddybemps Lake are composed of resistant igneous bedrock, which is close to the land surface; altitudes of these hills range from 300 to 500 ft above sea level. In most places, the bedrock is blanketed by thin deposits of glacial till laid down beneath the Late Wisconsinan ice sheet. Similar to many lake basins in Maine (Caldwell and others, 1989; Hanson and Caldwell, 1989), Meddybemps Lake occupies a basin developed by differential fluvial and glacial erosion along fractures and joints in the plutonic bedrock. The low-lying areas around the lake, where altitudes are at or below about 215 ft, are underlain by glaciomarine deposits, which are as thick as 100 ft and completely mantle lows in the bedrock surface. The Dennys River Valley and other stream valleys in southeastern Maine have been incised into the surface of glacial deposits by postglacial stream erosion and are overlain by thin postglacial alluvial deposits on flood-plain surfaces. Also, in postglacial time, organic material has accumulated in low-lying swampy areas such as Meddybemps Heath (fig. 3) (Cameron, 1989). The distribution of geologic units in the area surrounding the site is illustrated in figure 3 and geologic section *A–A′* (fig. 4). The following grain-size classification used in this report is modified from Wentworth (1922).

Bedrock Geology

Regional bedrock geology is shown on published geologic maps (Ludman, 1982; Osberg and others, 1985). More detailed bedrock geology of the Calais 15-minute quadrangle has been mapped by Ludman and Hill (1990). Two different types of intrusive igneous bedrock, underlie the area surrounding the site. Most of the area is underlain by Meddybemps Granite (unit Dgm, fig. 4), which is a light-colored, medium-grained, massive, biotite-hornblende granite. Fresh surface color ranges from gray to salmon pink; weathered surfaces are chalky white, and pervasively altered zones are pink. The principal mineral components of Meddybemps Granite are quartz, plagioclase, and K-feldspar with lesser amounts of biotite, hornblende, and amphibole; trace minerals include apatite, zircon, allanite, and opaque minerals. Also present below the site area is a rock unit referred to by Ludman and Hill (1990) as a "gabbro-diorite intrusive complex" (unit Dic, fig. 4). Rock types within this unit range in composition from gabbro to diorite and locally contain veins and irregular patches of granite. The gabbro-diorite rock units are dark gray in color, fine- to medium-grained, and generally equigranular in texture. The principal mineral components of these rocks are plagioclase and hornblende with lesser amounts of biotite, augite, and quartz; trace minerals include olivine, apatite, zircon, sphene, epidote, and opaque minerals. The presence of K-feldspar in the granite (generally 15 to 30 percent) and not in the gabbro-diorite makes the two rock types easily distinguishable on the borehole gamma logs. Gamma values in the gabbro-diorite are low [less than 20 counts per second (cps)]; gamma values in the granite are high (200 to 300 cps).

<table>
<tr><td colspan="12">Particle Diameter</td></tr>
<tr><td></td><td>10</td><td>2.5</td><td>0.16</td><td>0.08</td><td>0.04</td><td>0.02</td><td>0.01</td><td>0.005</td><td>0.0025</td><td>0.00015</td><td>in.</td></tr>
<tr><td></td><td>256</td><td>64</td><td>4</td><td>2</td><td>1</td><td>0.5</td><td>0.25</td><td>0.125</td><td>0.068</td><td>0.004</td><td>mm</td></tr>
<tr><td>Boulders</td><td>Cobbles</td><td>Pebbles</td><td>Granules</td><td>Very coarse sand</td><td>Coarse sand</td><td>Medium sand</td><td>Fine sand</td><td>Very fine sand</td><td>Silt</td><td colspan="2">Clay</td></tr>
<tr><td colspan="4">GRAVEL PARTICLES</td><td colspan="4">SAND PARTICLES</td><td colspan="4">FINE PARTICLES</td></tr>
</table>

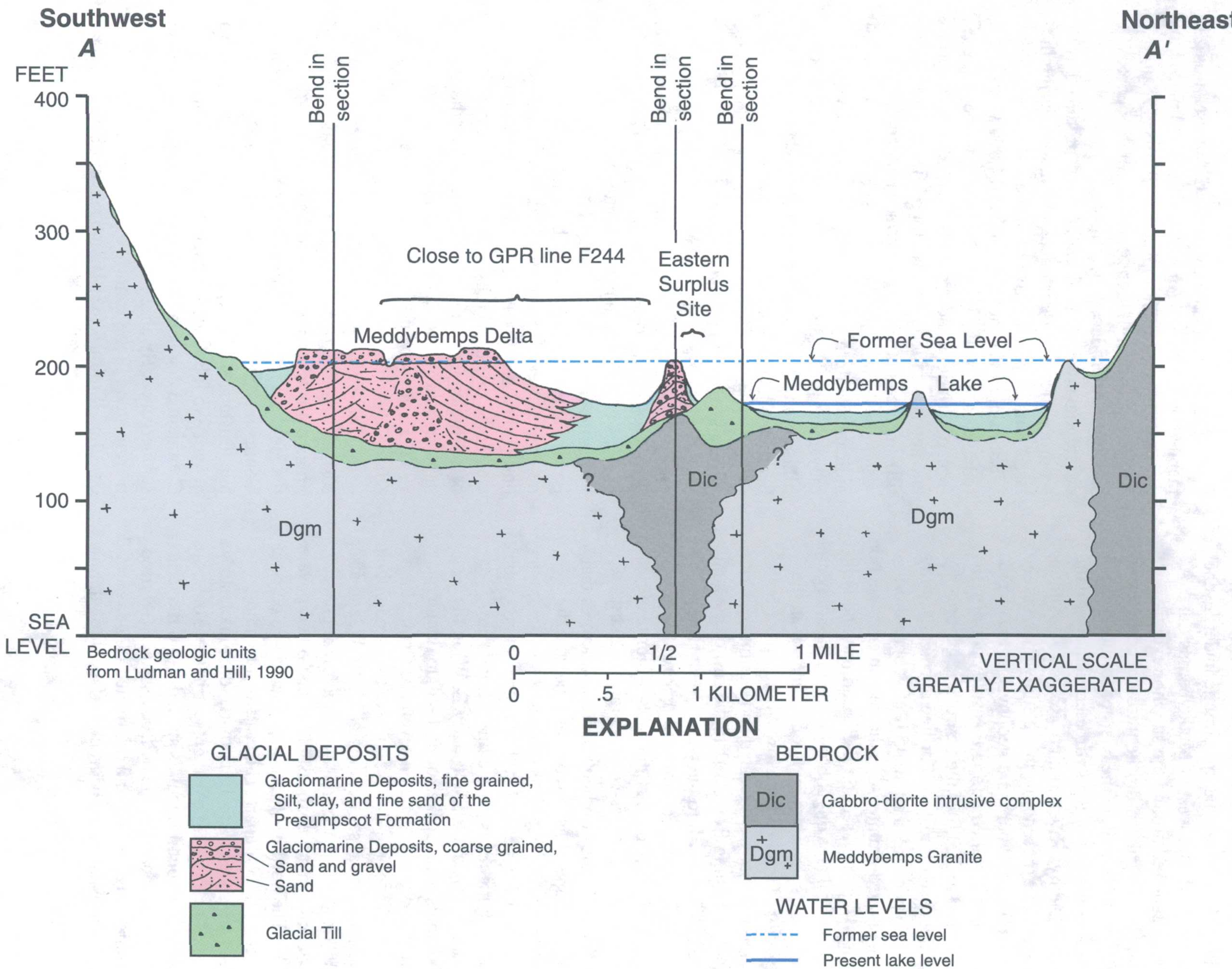

Figure 4. Geologic section A-A′ for the area near the Eastern Surplus Superfund Site, Meddybemps, Maine.

As indicated on the geologic map by Ludman and Hill (1990), Meddybemps Granite underlies the area to the south and west of Meddybemps Lake. A small area centered around the site, however, is underlain by the gabbro-diorite intrusive complex and probably was mapped on the basis of former bedrock exposures at the site of the hydroelectric power dam and on the Dennys River south of Route 191. Although bedrock is not exposed now in the study area, borehole cores, cuttings, and borehole-geophysical logs from bedrock wells installed during this study confirm that the upper 100 to 200 ft of the bedrock is gabbro-diorite; the easternmost well drilled during the study (MW–16B) penetrated about 45 ft of gabbro-diorite and then entered granite. As indicated on cross section *A–A′* (fig. 4) (and on section *B-B′*, Ludman and Hill, 1990), the small area of gabbro-diorite in the study area is most likely a detached body of mafic rock in the Meddybemps Granite. The closest outcrops of both bedrock types that were located and examined during this study are along Route 191 to the east of the study site and on Green Hill to the west. Green Hill is composed of granite; several outcrops examined along Route 191 are composed of the gabbro-diorite intrusive complex with local cross-cutting granitic dikes.

Trends of the dominant bedrock fractures that control the shape of Meddybemps Lake and the surrounding low-lying areas can be seen in the grain of the topography in bedrock hills on aerial photographs and topographic maps. These linear trends are dominantly NW and WSW (nearly E–W) in the Meddybemps area. Strikes of high-angle fractures measured at outcrop scale on several roadcuts along Route 191 east of the study area have two predominant sets: a near-vertical set trending N 25-30° W, and a set dipping steeply S that trends within a few degrees of E–W. Several fractures measured at one outcrop were N 60° W. The northwest-trending fractures in outcrop are spaced 1 to 3 ft apart. The east-west trending fractures are spaced 2 to 10 ft apart, some in clusters a few inches to 1 ft apart. Also present in these outcrops are nearly horizontal fractures spaced 1 to 6 ft apart, which typically parallel the bedrock surface (referred to as "unroofing joints") and are related to the removal of rock by erosion of the bedrock surface through time.

Surficial Geology

The surficial geology of the Calais area was mapped by Borns and Andersen (1982) and placed in a regional context by Thompson and Borns (1985a). Although the overall highs and lows in the bedrock surface were produced by millions of years of differential erosion, the final form was produced by the scouring effects of Pleistocene glaciations during the last 2 million years. A record of the last (Late Wisconsinan) glaciation 25,000 to 14,000 years ago is found locally on the present bedrock surface in the form of striations and grooves cut into the rock surface and deposits of lodgment till (hereafter referred to as till) smeared onto the rock surface beneath the great weight of the ice sheet. Thompson and Borns (1985a) indicate that during maximum glaciation, ice movement in this area was southeasterly; as a result, till is commonly thicker on the northwest sides of bedrock hills than on the southern and eastern sides.

Till deposits in the region are commonly thin (less than 10 to 20 ft) and consist of a compact, unsorted mixture of stones in a fine-grained matrix of sand, silt, and clay. The color and texture of particular till deposits differ from place to place and are related to the type of bedrock in northerly adjacent areas from which the till was derived. Most of the till sheet that is present at the land surface or beneath glaciomarine deposits is fresh, unweathered, and was deposited during the Late Wisconsinan glaciation. A more weathered till also is present in some localities at depth below the upper till and is believed to have been deposited during an earlier glaciation (Thompson, 1982; Thompson and Borns, 1985b; Weddle and others, 1989).

The glacially scoured and till-draped bedrock surface in this region is overlain by extensive coarse-grained glaciomarine deposits that were laid down as the ice sheet retreated from its terminal position on the Continental Shelf between 17,000 and 15,000 years ago. Eustatic sea level during the time of glaciation was at least 395 ft below its present level (Fairbanks, 1990). Continental deglaciation was accompanied by marine submergence. By about 14,000 years ago, the glacier margin stood in the vicinity of the present-day coastline (Smith, 1985; Thompson and Borns, 1985a), and because the land was depressed about 650 ft by the weight of the glacier, the region was inundated by the seawater to depths of 100 to 300 ft. During glacial retreat, substantial deposits of coarse-grained stratified meltwater sediment and local non-stratified diamict (till-like) sediment were laid down on the sea floor as subaqueous fans and fan complexes. In many places along ice-margin positions, glaciomarine deltas consisting of gravel and sand were built into the sea and record its level at that time. The altitude of the marine limit in the Meddybemps region is marked by a striking example of such a delta (figs. 3 and 4). The Meddybemps delta is located about 0.5 mi west of the Eastern Surplus Site and has a surface altitude of 200 to 210 ft and a topset-forset contact recording sea level at 204 ft (Thompson and others, 1989) (figs. 3 and 4). The narrow sinuous ridge extending northward from the delta is an esker marking the position of the ice-walled channel or tunnel through which meltwater supplied sediment to the delta. These coarse-grained glaciomarine deposits constitute a significant sand and gravel aquifer in the Meddybemps area (Weddle and others, 1988). A small area of coarse-grained glaciomarine deposits on the west side of the Eastern Surplus Site area is composed of northwest-dipping beds of gravel, sand, and diamict sediment. This deposit likely accumulated along the same ice-margin position as the Meddybemps delta, probably as a subaqueous fan deposit, although its surface altitude reaches the paleo-sea level recorded by the delta. Both delta and fan deposits consist of coarse gravel and sand with local diamict sediment in ice-proximal (northerly) parts, and grade to fine gravel and sand within short distances in distal (southerly) directions. The distal sandy beds interfinger with fine-grained marine silt and clay. These glaciomarine deposits are more than 100 ft thick in places. Detailed descriptions of various sedimentary facies that comprise the coarse-grained glaciomarine deposits in the Meddybemps region are given in Thompson (1982), Retelle and Bither (1989), and Smith and Hunter (1989).

Fine-grained glaciomarine deposits consisting of massive to finely laminated, gray to dark-bluish gray silt, clay and minor fine sand also are present in the Meddybemps region; thickness of these deposits ranges from a few feet to as much as 150 ft. This material locally interfingers with the coarse-grained facies, but mostly overlies it. Glaciomarine silty clay deposits in coastal Maine are named the Presumpscot Formation (Bloom, 1960; 1963). The marine silty clay settled out in quiet, deep water as the ice margin retreated to the north. Deposition of the Presumpscot Formation in the deep-water glaciomarine environment in the Meddybemps region probably continued until about 13,000 years ago (Belknap and others, 1989). Because the rate of glacio-isostatic rebound of the earth's crust exceeded the rate of eustatic sea-level rise, the relative sea level in the area began to decline.

A sandy facies of the Presumpscot Formation was formed in the shallow marine environment as the shoreline moved southeasterly through the area. These deposits consist of massive to stratified, generally well-sorted, brown to gray-brown fine- to medium-grained sand that locally grades downward to finely laminated fine-grained sand and silt. This facies is typically 5 to 20 ft thick and gradationally overlies the finer grained silt-clay facies. Particular sea-level stands were brief as sea level fell rapidly, resulting in a completely emergent coastal zone by 11,500 years ago (Smith, 1985). Sea level continued to fall to levels below the present-day shoreline and, by about 9,500 years ago, the rates of uplift and sea-level rise equilibrated at a low stand depth of 180 to 197 ft below present sea level (Belknap and others, 1989; Shipp and others, 1989). During the time that the sea was below the present-day level, on-land streams incised deeply into the surface of glaciomarine deposits. Following the low stand, sea level slowly rose to its present position.

Postglacial deposits in the Meddybemps region include flood-plain alluvial and swamp deposits. Alluvial deposits are thin (commonly less than 5 ft thick), and are present on erosional surfaces such as the flood plain of the Dennys River, where postglacial streams have incised glacial deposits. Low-lying areas such as the Meddybemps Heath accumulated deposits of organic muck and peat after the sea retreated.

Geohydrologic Units

Four geohydrologic units are identified in the study area. Surficial materials have been subdivided into three geohydrologic units on the basis of their lithologic character, depositional environment, and hydraulic properties. The units are glacial till, coarse-grained glaciomarine deposits, and fine-grained glaciomarine deposits. Bedrock comprises a fourth geohydrologic unit. Although aquifer testing was beyond the scope of this study, descriptions of the surficial geohydrologic units in the following sections include discussions of hydraulic properties estimated from values for similar materials reported in the literature and from interpretation of limited discharge and drawdown data collected during water-quality sampling.

The distribution and thickness of the geohydrologic units are shown in figures 5–7. Geologic materials were mapped using all available information from well logs, borehole-geophysical logs, ground-penetrating radar lines, and exposures in the sand and gravel excavation on the west side of the site. Map units (fig. 5) are defined on the basis of the texture of surficial deposits through their entire thickness. Contour lines showing the altitude of the bedrock surface below the surficial deposits also are shown in figure 5. The thickness of surficial deposits shown in figure 6 was determined from well logs and the interpreted bedrock surface shown in figure 5. Geohydrologic sections shown in figure 7*A–D* illustrate vertical relations among various sedimentary facies within the glacial deposits that overlie bedrock. The orange map unit on figure 5, fine-grained glaciomarine deposits over coarse-grained glaciomarine deposits, does not appear on geohydrologic sections because the two units that compose the map unit can be portrayed separately on sections.

Surficial Units

Glacial till consists of a nonlayered, unsorted, generally compact mixture of sand and stones in a fine-grained matrix containing as much as 25 percent silt and clay. Till is present at the surface and comprises the entire thickness of surficial material in most of the eastern part of the study area (figs. 5 and 6). Thickness of till in the study area ranges from 0 to at least 40 ft. Till was inferred to lie beneath glaciomarine deposits and on top of bedrock in several boreholes in the study area on the basis of difficult drilling through the material. Till is inferred to be present beneath glaciomarine deposits in many places in the study area at thicknesses generally less than 10 ft.

The hydraulic conductivity of the thick section of till east of the Dennys River, was estimated from yield and drawdown data for wells MW–15S and MW–16S (table 1). The estimation was based on the following formula presented by Cooper and Jacob (1946):

$$T = \frac{2.30Q}{4\pi s}\log\frac{2.25Tt}{r^2S}$$

where:

- T = transmissivity (L^2/T) = hydraulic conductivity multiplied by aquifer thickness;
- s = drawdown (L);
- Q = pumping rate (L^3/T);
- S = storativity (dimensionless);
- t = time since pumping began (T); and
- r = well radius or distance from the pumping well (L).

The formula was applied by first estimating a transmissivity value and using the value computed by the formula to arrive at a final estimate through a series of iterations. A computer program prepared by Earl Greene (U.S. Geological Survey, written commun., 1997) facilitated the computations. A hydraulic conductivity of about 0.3 ft/d was calculated, assuming a storage coefficient of 0.10, a thickness that is the length of the well screen (10 ft), and a radius equivalent to the borehole radius (4 in.). This value must be considered a rough estimate because of uncertainties about the storage coefficient and well efficiency (Fetter, 1994, p. 256). Also, the pumping duration is marginal for application of the Cooper and Jacob formula. Nevertheless, it is within the range of values for tills derived from crystalline rocks in southern New England and northern New Hampshire (Torak, 1979; Pietras, 1981; Melvin and others, 1992, table 3; Tiedeman and others, 1997, p. 8). Melvin and others (1992, table 3) report porosities for till derived from crystalline rock in southern New England ranging from 22.1 to 40.6 percent and specific yields ranging from 3.9 to 31 percent.

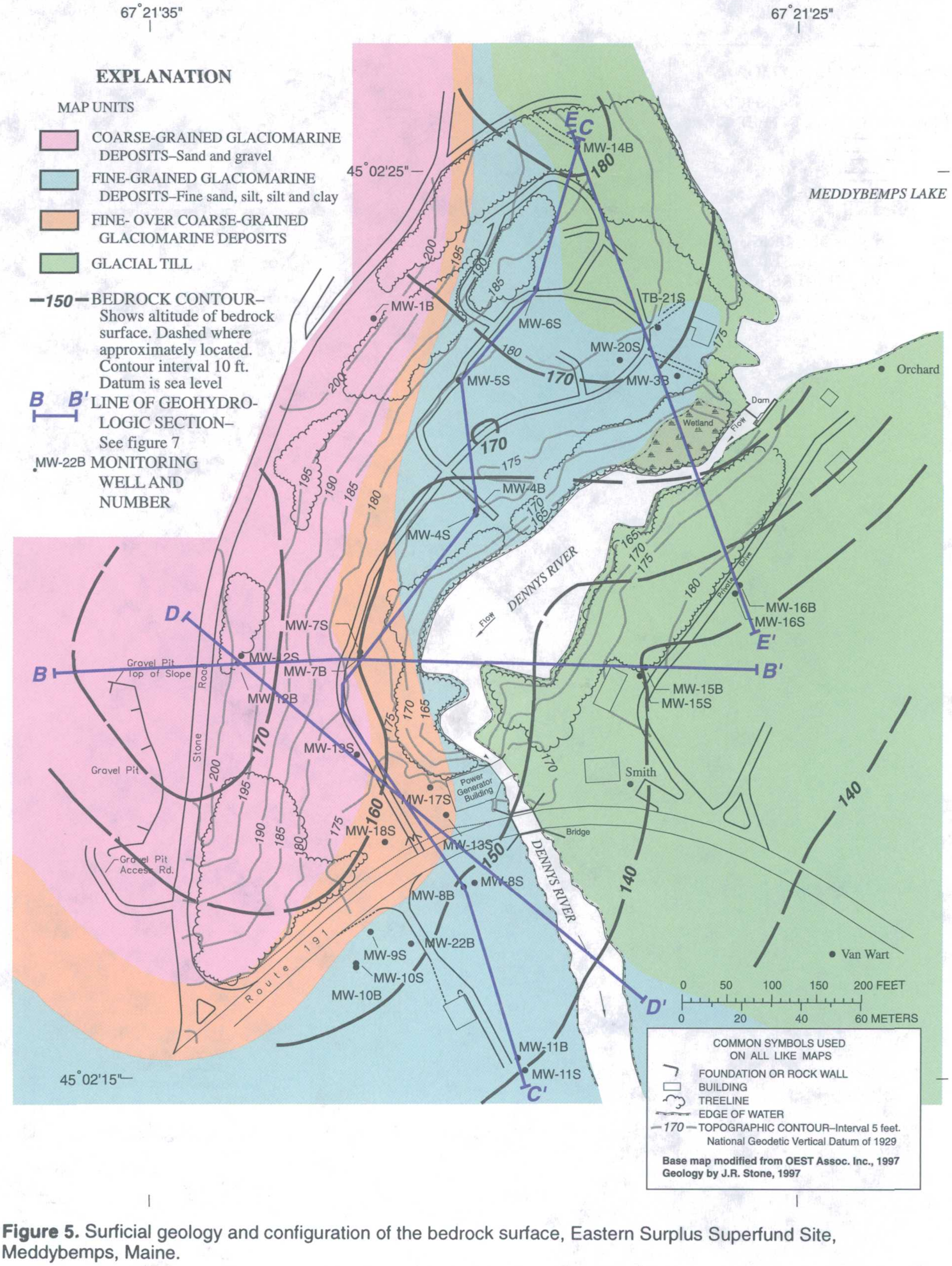

Figure 5. Surficial geology and configuration of the bedrock surface, Eastern Surplus Superfund Site, Meddybemps, Maine.

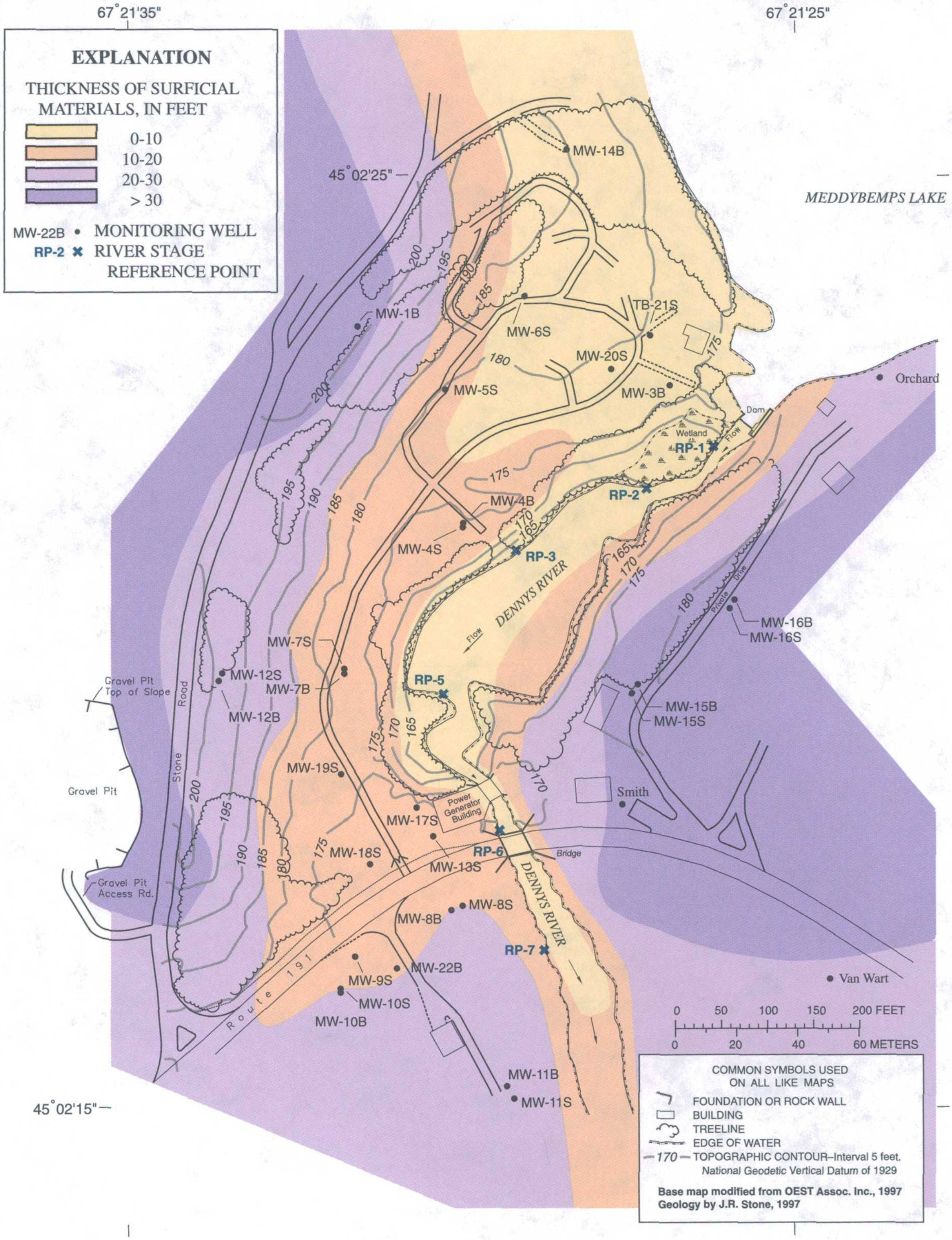

Figure 6. Thickness of surficial materials, Eastern Surplus Superfund Site, Meddybemps, Maine.

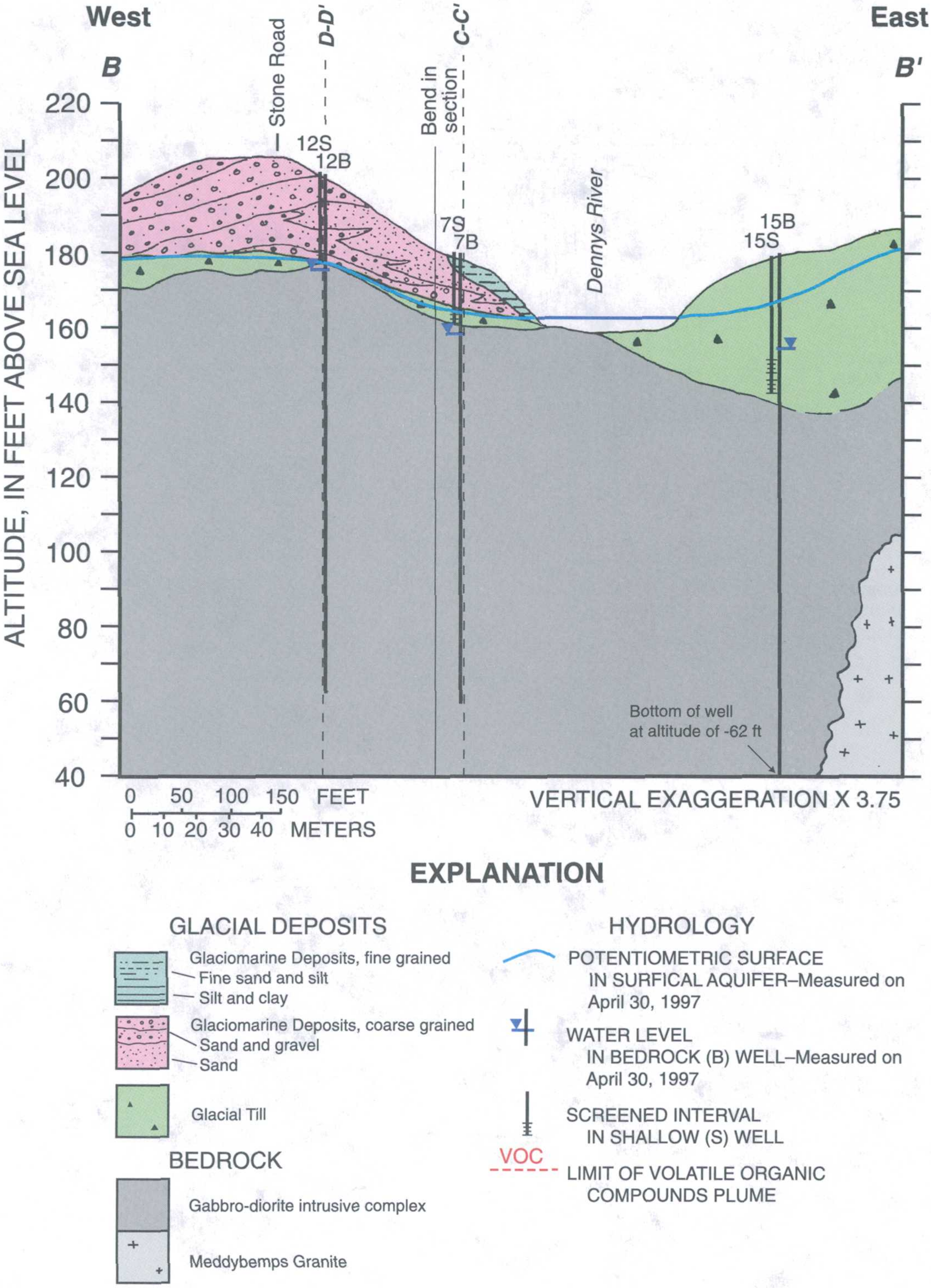

Figure 7. Geohydrologic sections *B-B'* through *E-E'*, Eastern Surplus Superfund Site, Meddybemps, Maine. (Locations of section lines shown on fig. 5.)

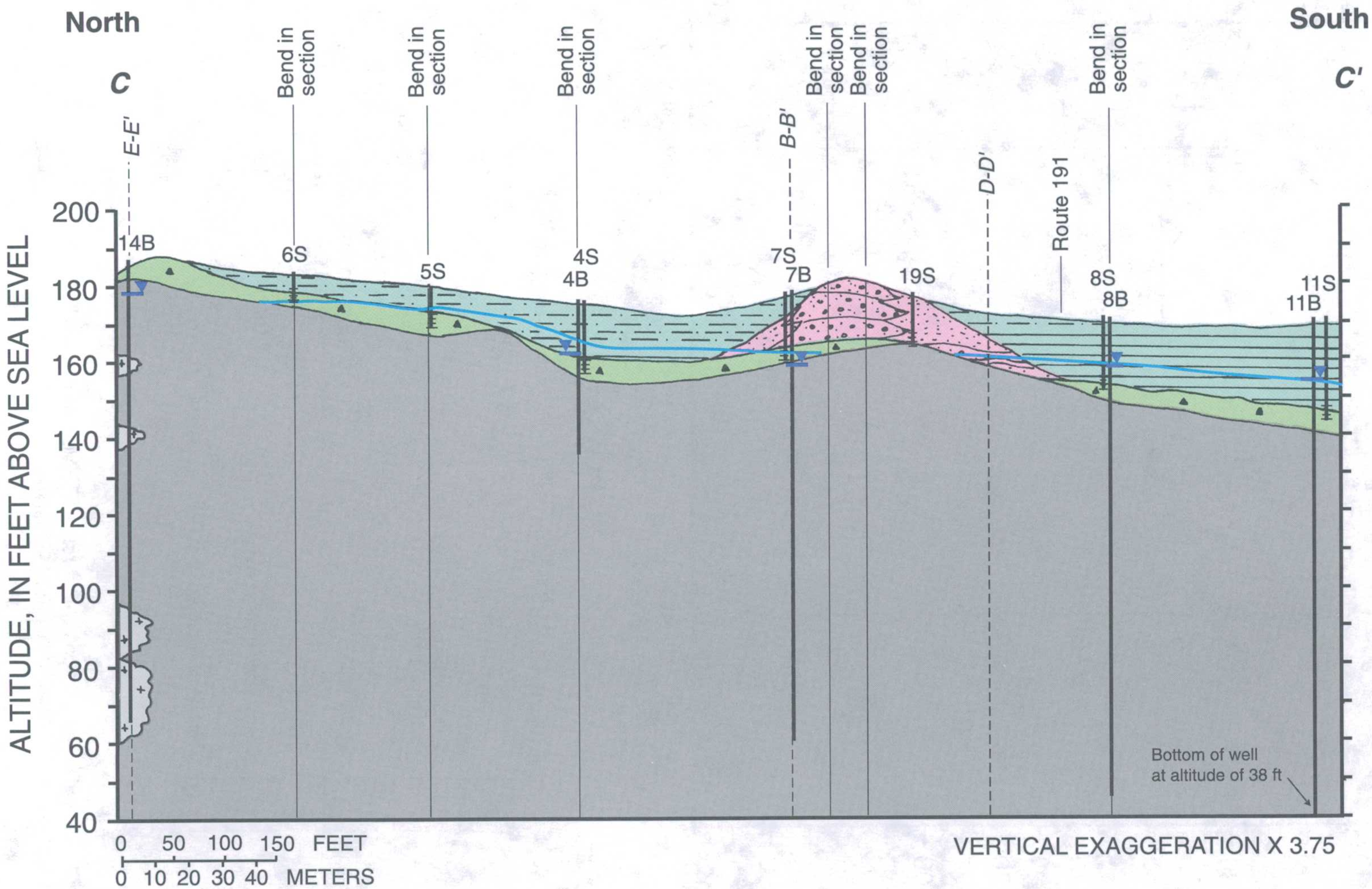

Figure 7. Geohydrologic sections *B-B'* through *E-E'*, Eastern Surplus Superfund Site, Meddybemps, Maine. (Locations of section lines shown on fig. 5)—*Continued.*

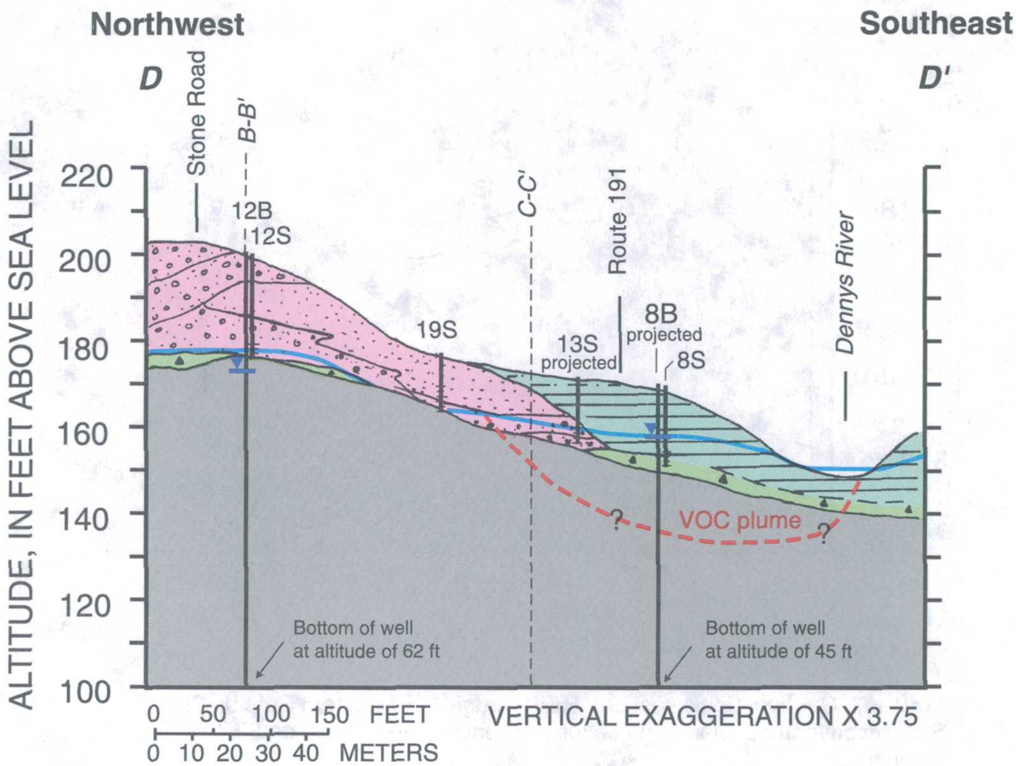

Figure 7. Geohydrologic sections *B-B'* through *E-E'* Eastern Surplus Superfund Site, Meddybemps, Maine. (Locations of section lines shown on fig. 5)—*Continued*.

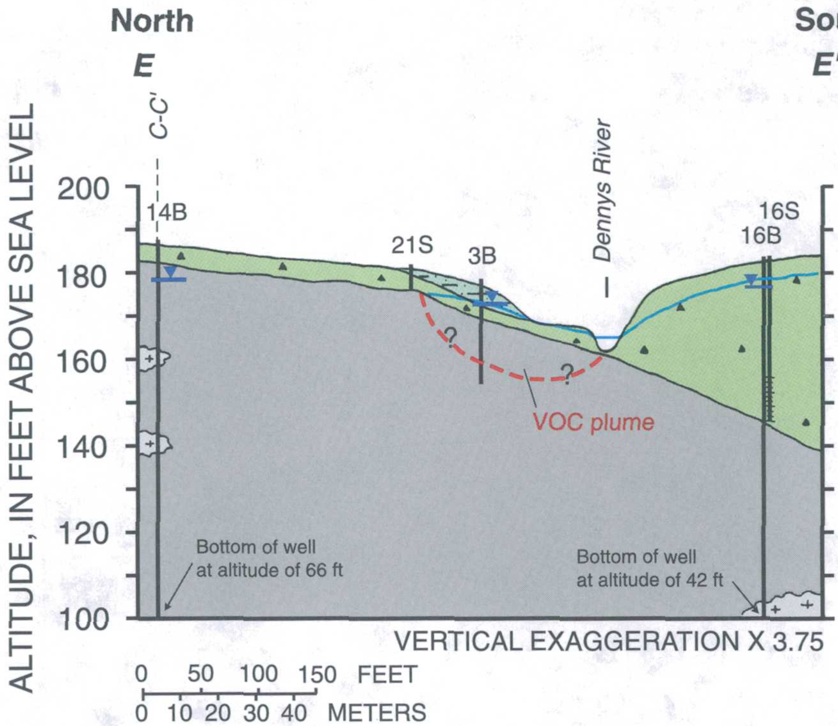

Figure 7. Geohydrologic sections *B-B'* through *E-E'*, Eastern Surplus Superfund Site, Meddybemps, Maine. (Locations of section lines shown on fig. 5)—*Continued.*

Coarse-grained glaciomarine deposits include beds of gravel, mixed sand and gravel, sand and lenses or layers of diamict sediment. Two sedimentary facies of these deposits have been delineated on cross sections (fig. 7*A–D*): a coarse-grained sand and gravel facies, and a fine-grained sand and silt facies. These materials are present at or near the land surface in the western part of the study area (fig. 5), range from 0 to about 30 ft in thickness, and comprise most of the surficial materials in this area (fig. 6). Samples from several monitoring wells (MW–7S, MW–13S, MW–17S and MW–18S) and GPR data indicate that thin, coarse-grained material extends beneath fine-grained glaciomarine deposits in a narrow zone east of the area in which sand and gravel are present at the surface. Northwest-dipping beds of coarse-grained glaciomarine deposits consisting of interlayered cobble gravel, diamict sediment, and medium- to coarse-grained beds, were observed in a gravel pit on the west side of Stone Road.

The thick sections of coarse-grained deposits are largely unsaturated. High yields from wells MW–5S, MW–7S, MW–10S, MW–17S, and MW–18S indicate that these wells may be completed in coarse-grained deposits, but such deposits do not appear on logs for wells MW–5S and MW–10S. The hydraulic conductivities for wells MW–5S, MW–7S, and MW–10S were estimated from yield and drawdown data given in table 1, using the Cooper and Jacob (1946) formula. Hydraulic conductivity for the three wells ranges from about 20 to 40 ft/d, with an assumed storage coefficient of 0.1, a thickness that is the length of the well screen, and a radius equivalent to the borehole radius. Well MW–13S yielded less than 0.1 gal/min during well development, indicating that, at this location, the hydraulic conductivity is not appreciably different than that of till. The porosity and specific yield of these sediments probably are in the same ranges as values for till.

Fine-grained glaciomarine deposits include thinly laminated to massive, fine- to very fine-grained sand, silt, and clay. These deposits are present in the central and southern parts of the study area (fig. 5), where they are as thick as 20 ft. Fine-grained deposits comprise most of the surficial materials south of Highway 191 and west of the Dennys River (fig. 5). Two sedimentary facies are delineated by patterns on the cross sections (fig. 7*A*–*D*). An upper sandy facies in the study area consists of fine-grained sand and silt present in the upper 5 to 10 ft of the fine-grained glaciomarine deposits. The lower silt-clay facies is massive to thinly laminated silt, clay, and minor fine-grained sand. Fine-grained glaciomarine sediments are dark-bluish gray except in their upper sections, where they lie above the water table and have been oxidized. Here the sediments are brownish gray and have numerous dark brown, iron/manganese-stained joints and desiccation cracks that result in a blocky structure. A small section of the unsaturated, fine-grained glaciomarine sediment overlying gravel is exposed on the west side of the Stone Road gravel pit.

The hydraulic conductivity of fine-grained sand and silty sand is typically less than 3 ft/d (Fetter, 1994, p. 98, table 4.6). The hydraulic conductivity of glaciomarine clay of the Presumpscot Formation is typically very low, in the range of 2.7×10^{-5} to 1.0×10^{-3} ft/d (Nielsen and others, 1995, p. 19 and 27). Interbedded fine sands and silts may cause a significantly higher horizontal than vertical hydraulic conductivity. The porosity of silt typically ranges from 35 to 50 percent; the porosity of clay may exceed 50 percent (Fetter, 1994, p. 86, table 4.3).

Bedrock

Although bedrock is not exposed in the Site area, cores and cuttings from wells indicate that the bedrock beneath the Site is dark, fine- to medium-grained igneous rock ranging in composition from gabbro to diorite. Meddybemps Granite was penetrated at depth in the easternmost (MW–16B) and northernmost (MW–14B) wells in the study area. In crystalline bedrock, water is present largely within fractures that provide the pathways for ground-water flow. Water-bearing fractures were detected by borehole-flowmeter measurements in most of the bedrock wells in the study area. Only one or two fractures typically contribute most of the water to each well during pumping. The depth ranges of water-bearing fractures identified by borehole flowmeter within the bedrock are summarized in table 1. The results of a study of the orientation of fractures, their interconnectivity (if any) between wells, and their hydraulic properties will be reported separately.

Well yields determined from tests during drilling and water-level recovery measurements after drilling range widely from less than 0.1 to 25 gal/min (table 1). Three high-yielding wells (MW–10B, MW–11B, and MW–22B) are south of Highway 191. Wells MW–3B and MW–14B at the north end of the study area also have high potential yields. The porosity of fractured crystalline bedrock is generally less than 0.05 percent and storativity can range from 5×10^{-7} to 1×10^{-4} (Earl Greene, written commun., 1997).

Ground-Water-Level Fluctuations and Recharge

Water levels in wells in the study area responded to stresses, including recharge from precipitation, installation of bedrock wells, and lake-stage changes. The nature and magnitude of the responses provide insights about aquifer hydraulic properties, recharge, and discharge. Short-term responses to pumping from residential wells were not apparent in the wells monitored.

Trends in ground-water levels during the study period followed water-level trends in Meddybemps Lake (fig. 8). Highest lake levels and ground-water levels were in late December and early January after a characteristic fall recharge and runoff period. Water levels declined during January to March when most of the precipitation fell as snow; levels rose again during the spring thaw in April.

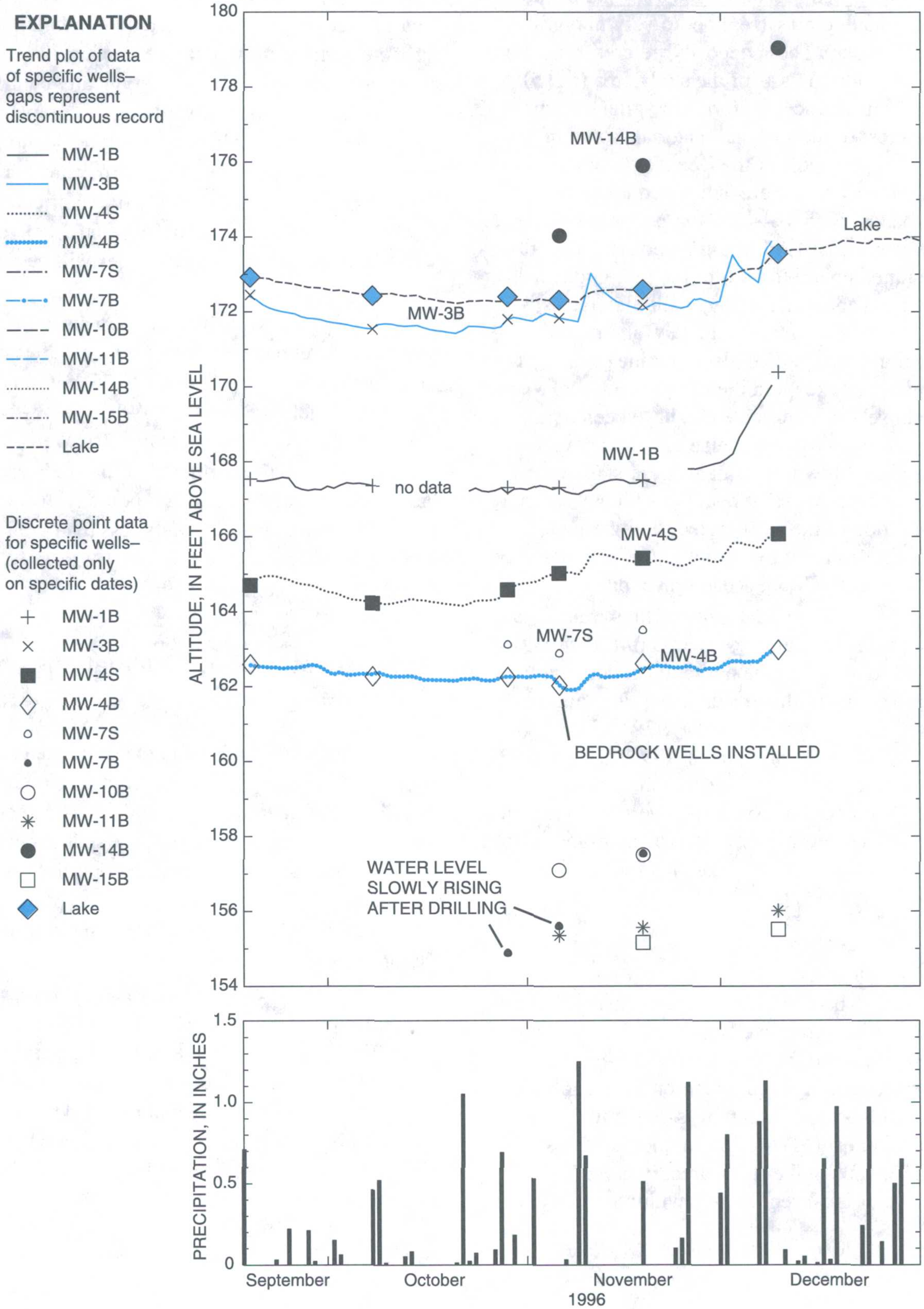

Figure 8. Precipitation, lake level, and water-level fluctuations in selected wells, Eastern Surplus Superfund Site, Meddybemps, Maine.

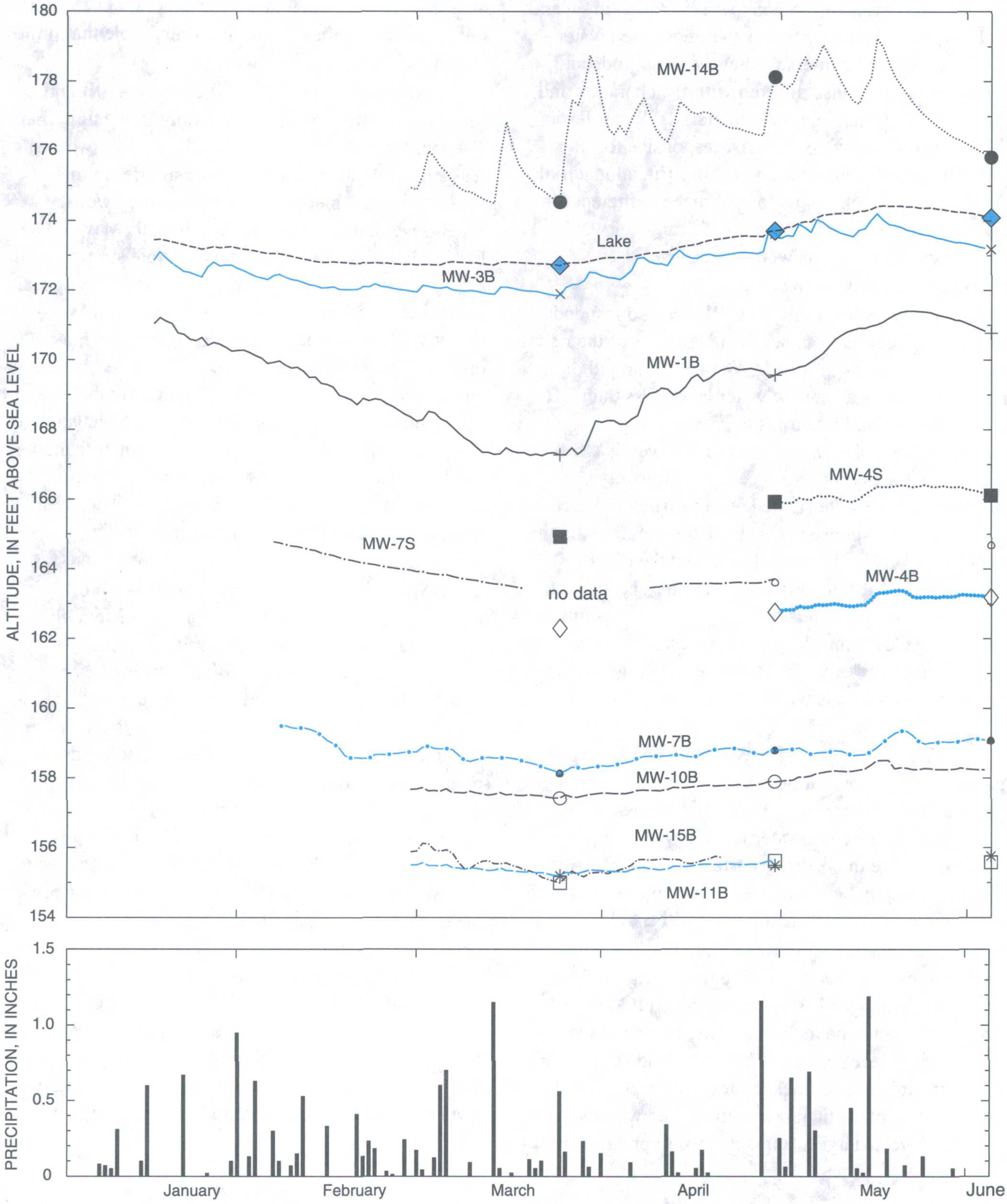

Figure 8. Precipitation, lake level, and water-level fluctuations in selected wells, Eastern Surplus Superfund Site, Meddybemps, Maine—*Continued.*

Water levels responded to precipitation in several wells equipped with recorders that monitored water levels at 15-minute intervals, but the magnitude and timing of the response differed with the character and thickness of surficial geologic materials. Water levels in well MW–14B were the most responsive to precipitation. A combination of thin surficial materials (less than 5 ft thick) and a low storage coefficient for fractured bedrock resulted in a wide range of water-level fluctuations at this well. Water-level rises exceeded 2 ft after some storms.

The water level in well MW–3B also responded quickly to precipitation, but the magnitude of the rise was not as large as in well MW–14B. The rapid response reflects a shallow water level (less than 7 ft deep) and surficial materials that have a high infiltration rate. The water level in this well is a few feet above the bedrock surface and is probably indicative of the water-table level in surficial materials. The subdued response in this well compared to that in well MW–14B is interpreted to reflect the higher storage properties of surficial materials. The average water level in this well is typically 0.5 to 1 ft below the stage in Meddybemps Lake. On at least three occasions after storms, however, ground-water recharge caused the water level in this well to rise temporarily above lake level (fig. 8).

Water levels in well MW–1B respond sluggishly to precipitation, probably indicating a long recharge-pulse transit time through thick, unsaturated surficial materials. Because the water level in this well is typically above the bedrock surface, the short-term fluctuations may be indicative of fluctuations of the water table in surficial materials near the well.

The surficial aquifer at well MW–4S responds to recharge from precipitation, but the magnitude of water-level changes is smaller than at well MW–3B. This smaller change may be a consequence of the deeper water level (about 10 ft below land surface) and the finer-grained and thicker surficial materials that limit the rate of vertical percolation. The water level in well MW–7S is largely unresponsive to precipitation, also reflecting a greater depth to water (about 15 ft) and fine-grained materials above the water table that limit the rate of vertical percolation.

Water levels in bedrock wells MW–10B and MW–11B do not respond perceptibly to precipitation. The similarity of water-level trends in these two wells may reflect a transmissive bedrock aquifer in this area and interconnected fractures between wells. Water-level fluctuations in bedrock wells MW–4B, MW–7B, and MW–15B do not correlate strongly with precipitation, but water levels in well MW–7B appear to respond similarly to water levels in wells MW–4B and MW–15B over their respective common intervals of time. The water level in well MW–4B fell by a few tenths of a foot from November 4 to November 9, 1996, during installation of other bedrock wells in the study area. Apparently, the removal of water from the newly drilled wells and slow recovery of water levels in one or more of these wells caused the water-level decline at MW–4B that persisted after drilling was completed.

Water-level fluctuations in wells north of Highway 191 indicate that ground water is readily recharged by infiltration of precipitation. Surface runoff was not apparent in this area during heavy rainstorms in the autumn of 1996, indicating that surficial soils are sufficiently permeable to allow the infiltration of precipitation for most storms. Annual recharge rates to the surficial aquifer are probably on the order of 24 to 26 in., which is the amount of precipitation not lost to evapotranspiration in this region (Lyford and Cohen, 1988). South of Highway 191, where clays of the Presumpscot Formation are at the surface, water-logged soils were observed after periods of precipitation. In this area, recharge may be limited by the relatively low vertical hydraulic conductivity of the marine clays, and most of the precipitation may reach the Dennys River as overland flow or as shallow subsurface flow through soils. Recharge to bedrock, although apparent from water-level responses to rainfall, cannot be quantified with available information.

Ground-Water Flow

Water levels in wells and stream stages measured on April 30, 1997, were used to construct potentiometric-surface maps for the surficial and bedrock aquifers. Because ground water flows from areas of high potential (relatively high water level in wells) to areas of low potential (lower water levels in wells), the potentiometric surface maps can be used to estimate horizontal and vertical directions of ground-water flow. The water levels and stream stages on April 30, 1997, were somewhat higher than average because of recent snowmelt and minimal evapotranspiration for that time of year. However, periodic water-level measurements (table 3) indicate that the configuration of the potentiometric surfaces does not change appreciably with time, nor do vertical gradients between the surficial aquifer and bedrock.

Surficial Aquifer

Ground-water flow directions in the surficial aquifer are estimated using the potentiometric surface map shown in figure 9. Water levels in shallow bedrock wells MW–1B and MW–3B are above the bedrock surface and presumably reflect water levels in surficial materials because of the observed responses to precipitation. These water levels were used as data points to construct the potentiometric surface map in figure 9, although heads in the surficial materials may be somewhat different, and probably higher, than water levels in bedrock. Water-level contours on the map extend to areas where the saturated thickness of surficial materials was 2 ft or less. In some areas, surficial materials are usually unsaturated. These materials might become saturated temporarily after recharge periods when ground water flows through these materials over the bedrock surface. Surficial materials in some areas contoured in figure 9 are dry during periods of limited infiltration, particularly during the summer months. Many of the wells completed in surficial materials, where saturated thickness was less than 5 ft on April 30, 1997 (fig. 10), were dry or nearly dry when measured by USGS personnel in September 1997. Ground-water flow through surficial material in this area is probably episodic.

Ground water in the surficial aquifer under the northern two thirds of the study area west of the Dennys River flows from north to south or northwest to southeast towards the river. Flow may be northwestward near well MW–1B from a presumed ground-water divide near well MW–5S (fig. 9). Water levels at well MW–3B are generally below lake level, as shown on the hydrographs of figure 8, but flow directions may be altered for a few days when recharge causes ground-water levels to rise temporarily above lake level. At the far northern end of the site, infiltrated precipitation presumably flows periodically over the bedrock surface through shallow till northeastward towards Meddybemps Lake, and on the opposite side of a bedrock ridge near MW–14B (fig. 5) flows southwestward into the area where surficial materials are normally saturated. Some of this water recharges bedrock through fractures at the bedrock surface, as indicated by the response to precipitation in well MW–14B.

Ground water in the southern third of the study area, west of the Dennys River, flows southeastward under Highway 191 and toward the river (fig. 9). Ground water in till and coarse-grained deposits at the bottom of the surficial aquifer in this area is confined by silts and clays of the Presumpscot Formation. As discussed above, direct infiltration of precipitation probably is limited in this area. Perched water above a clay layer, like that found by USGS personnel while drilling well MW–18S during April 1997, may be common above clays of the Presumpscot Formation. The surficial aquifer probably receives water that periodically flows over the bedrock surface in the area to the west and northwest where surficial materials are normally unsaturated. The saturated thickness shown in figure 10 was determined from water levels in wells. The actual saturated thickness may be greater where clays of the Presumpscot Formation confine ground water in surficial materials and restrict gravity drainage of infiltrated precipitation.

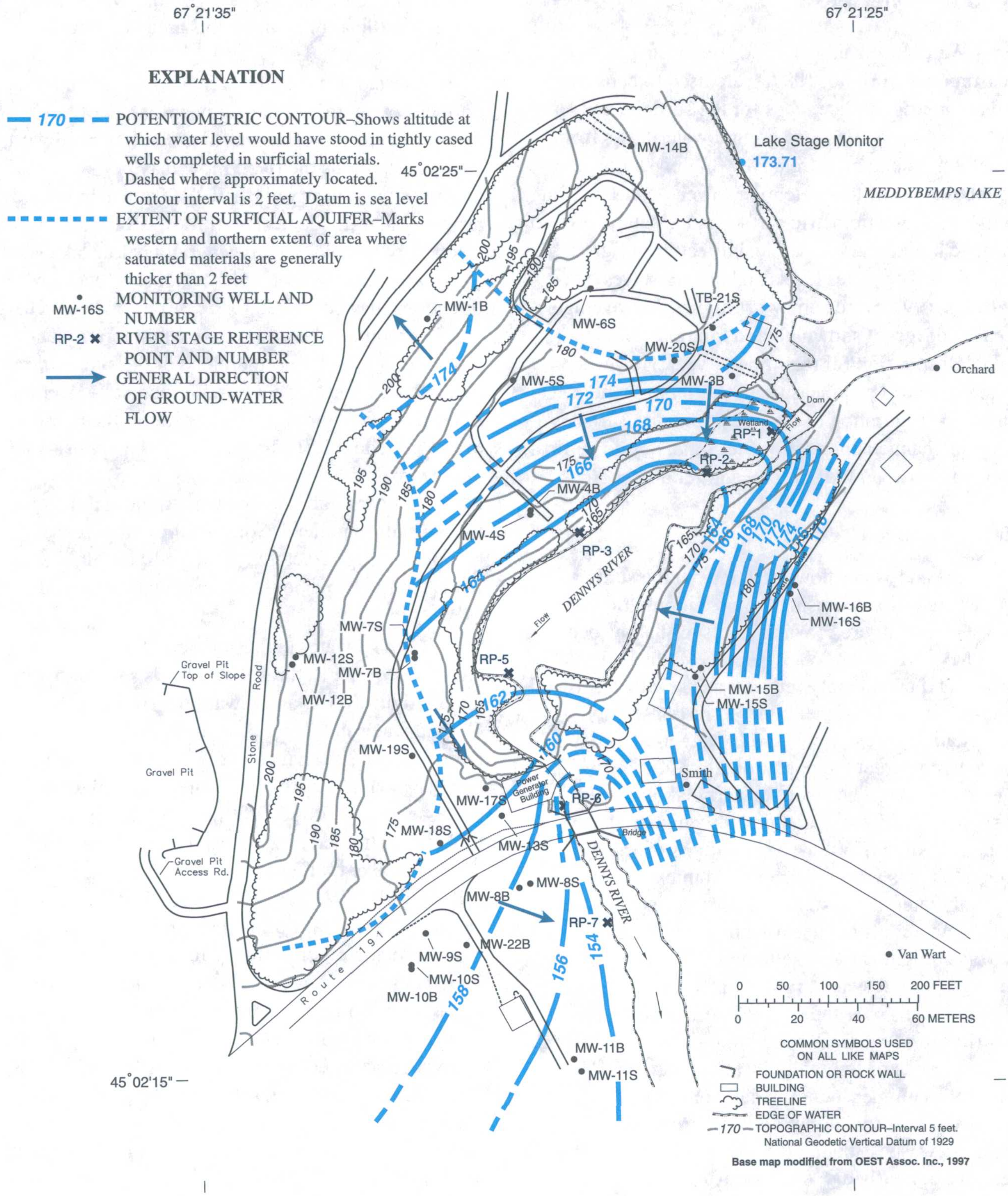

Figure 9. Potentiometric surface and generalized ground-water flow directions for the surficial aquifer on April 30, 1997, Eastern Surplus Superfund Site, Meddybemps, Maine.

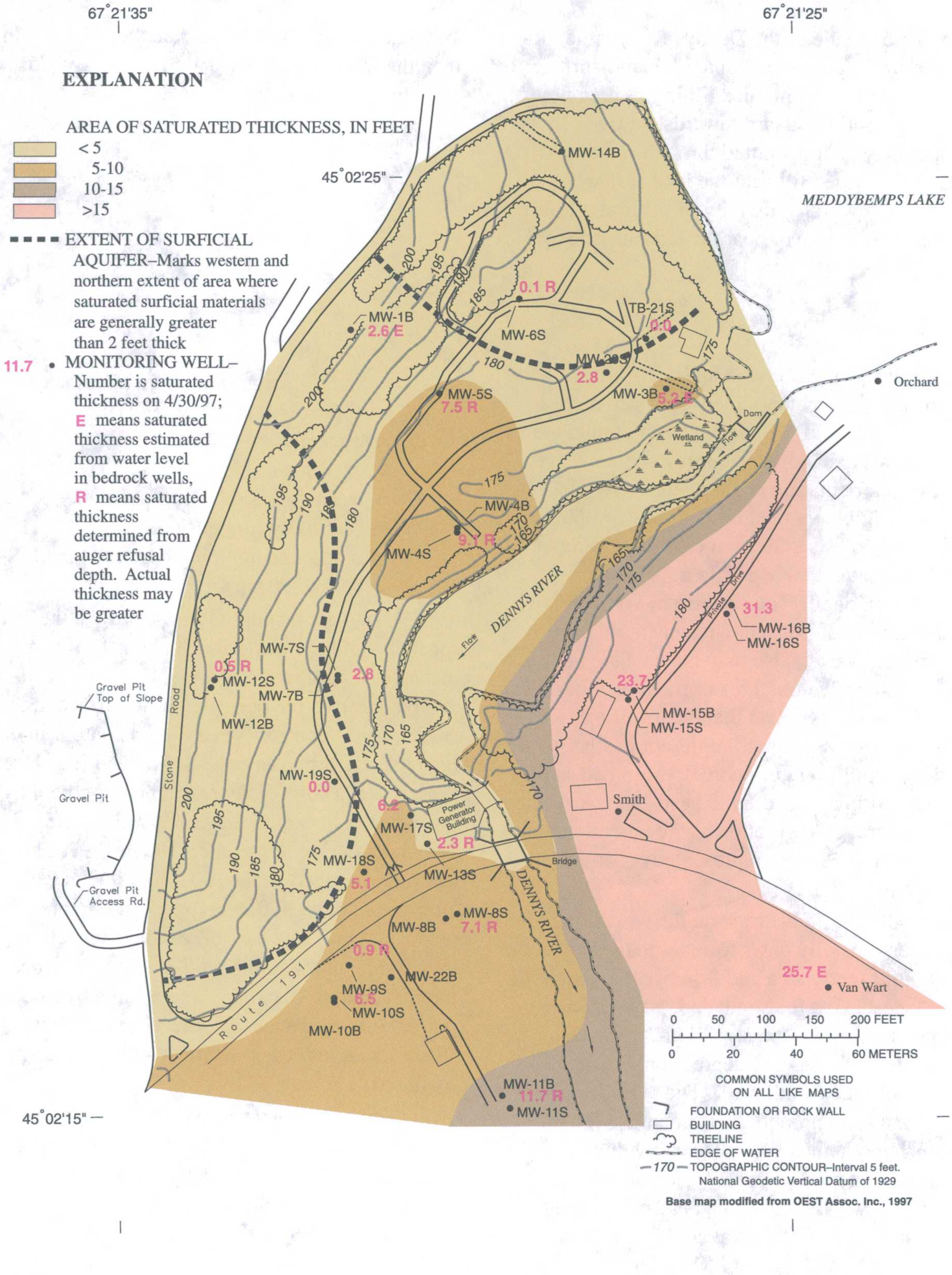

Figure 10. Saturated thickness of surficial materials on April 30, 1997, Eastern Surplus Superfund Site, Meddybemps, Maine.

On the east side of the Dennys River, potentiometric contours approximately parallel land-surface contours. Ground water in thick till in this area flows westward and southwestward towards the river. Much of the water may be transmitted through weathered and possibly fractured till near the land surface. Because of the low transmissivity of till, water levels may periodically rise to or near the land surface in this area.

Bedrock Aquifer

Water levels measured in all bedrock wells were used to construct the potentiometric surface map shown in figure 11 and to define general ground-water-flow directions. Actual flow patterns in bedrock are affected by the orientation and transmissivity of fractures. Negligible vertical flow in most well bores during flowmeter tests under static (nonpumping) conditions indicated that heads do not change appreciably with depth. The absence of vertical flow measurable by a heat-pulse flowmeter (more than 0.02 gal/min), however, also may indicate the presence of poorly transmissive fractures or fracture zones. For this analysis, it was assumed that the heads measured in wells completed in bedrock represent heads throughout the thickness of bedrock examined as part of this study. Although hydraulic heads may vary with depth, the general configuration of the potentiometric surface is considered to be representative for the bedrock aquifer.

Ground water in bedrock on the west side of the Dennys River generally flows from north to south at the north end of the study area and from west to east at the south end (fig. 11). At the south end, ground water in bedrock potentially flows eastward under the Dennys River toward a local cone of depression near a residential well (the Smith well). The closed water-level contour shown around the residential well on figure 11 is hypothetical but consistent with the configuration of a cone in poorly transmissive rocks. For example, if we assume that a head difference of about 10 ft between the surficial aquifer and bedrock aquifer at wells MW–15S and MW–15B results from pumping of the Smith well 120 ft away, that the storage coefficient of bedrock is 1×10^{-4}, that the well has been pumping at an average rate of 100 gal/d for 365 days, and that leakage from the surficial aquifer is minimal, then the following Theis (1935) formula yields a transmissivity of about 0.6 ft^2/d:

$$T = \frac{Q}{4\pi s}W(u) ,$$

and

$$u = \frac{r^2 S}{4Tt} ,$$

where:

$W(u)$ = well function of u (from tables such as appendix 1 in Fetter, 1994);
T = transmissivity (L^2/T)
s = drawdown (L);
Q = pumping rate (L^3/T);
S = storativity (dimensionless);
t = time since pumping began (T); and
r = distance from the pumping well (L).

Using a transmissivity of 0.6 ft^2/d, the Theis formula yields a drawdown of about 13 ft at a distance of 50 ft from the well. This drawdown, when subtracted from the potentiometric surface in the surficial aquifer, results in a closed contour in the bedrock aquifer around the Smith well (fig. 11). The presence of a cone of depression is supported by water-level data collected in the Smith well by USGS personnel during September 10–14, 1997. The depth to water averaged about 100 ft, but fluctuated over a range of about 30 ft in response to pumping for residential use. The lack of response in well MW–15B to pumping at the Smith well may indicate that interconnecting fractures (between the two wells), if present, are above the water level in the Smith well. Water levels in these fractures would not be affected by fluctuations caused by pumping.

The potentiometric surface indicates that hydraulic head in the bedrock may be somewhat below the river through most of the pond area between Meddybemps Lake and Highway 191. Flow south of Highway 191 and on the west side of the river appears to be largely southeastward towards the river. Ground-water flow in bedrock on the east side of the river approximately parallels flow in the surficial aquifer except near the local cone of depression.

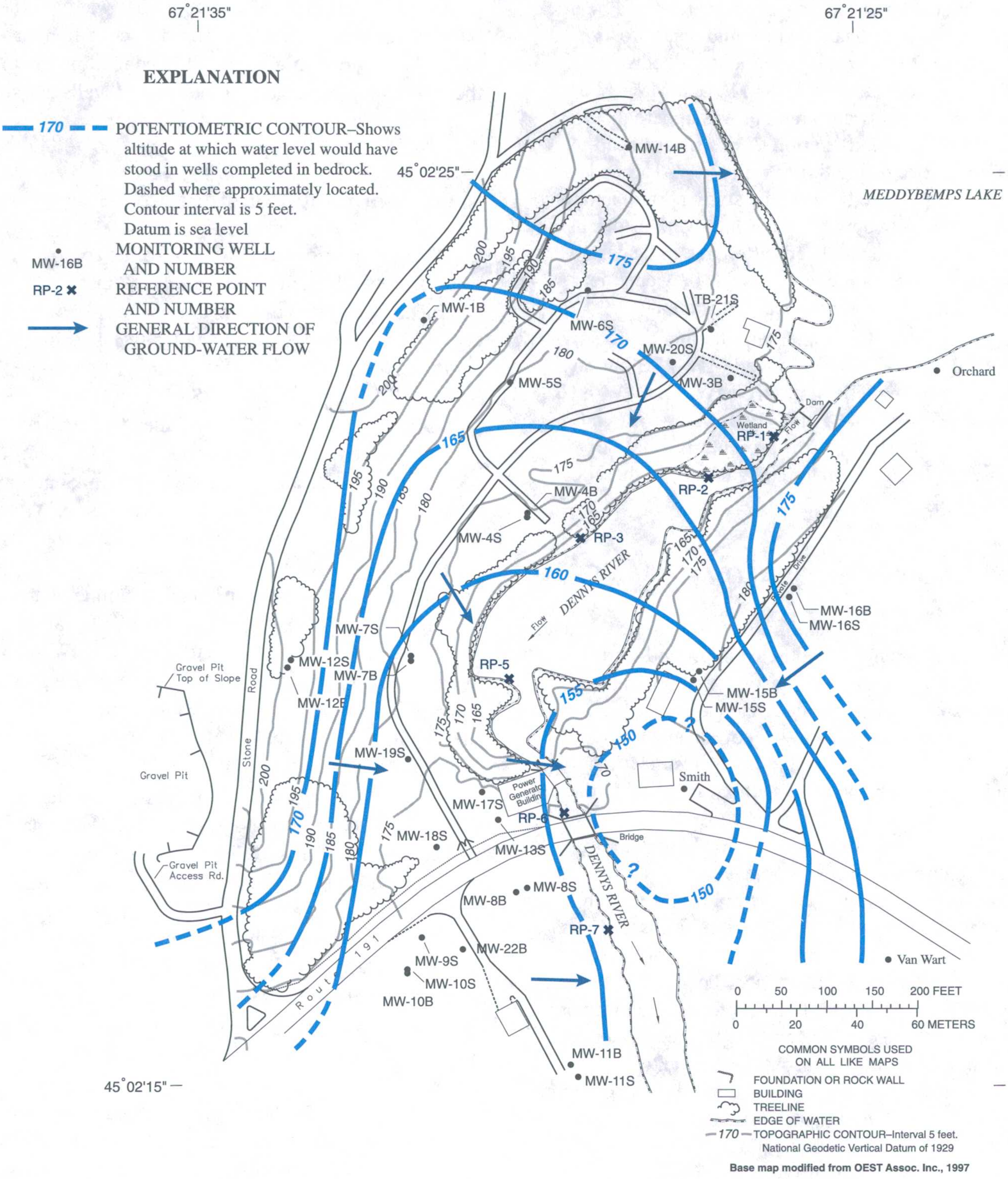

Figure 11. Potentiometric surface and generalized ground-water flow directions for the bedrock aquifer on April 30, 1997, Eastern Surplus Superfund Site, Meddybemps, Maine.

Water-level data in paired surficial and bedrock wells (table 3) indicate that ground water flows downward from surficial sediments to bedrock everywhere but at wells MW–11S and MW–11B, where a slight upward gradient was apparent throughout the study period. A downward head difference exceeding 8 ft at wells MW–15S and MW–15B persisted during the study period, and may result from drawdown in the Smith well, as discussed above. The persistent head difference indicates a very low vertical hydraulic conductivity between the surficial aquifer and bedrock in this area.

Borehole flow-meter tests in nine bedrock wells detected downward flow in well MW–10B but no vertical flow in wells MW–7B, MW–8B, MW–11B, MW–12B, MW–14B, MW–15B, MW–16B, and MW–22B. Vertical flow, if present, may not be measurable (greater than 0.02 gal/min) in these low-yielding wells.

GROUND-WATER QUALITY

Concentrations and milliequivalent percentages of major inorganic constituents in ground water, specifically calcium, magnesium, sodium plus potassium, chloride, sulfate, and carbonate plus bicarbonate, were used to support concepts about sources of ground water and pathways for ground-water flow. Interpretations of the water-quality data are based on two sets of samples (December 1996 and June 1998), some of which included uncertain analytical results. For example, concentrations of potassium for several water samples collected in June 1997 were at or below the detection limits. Because potassium concentrations expressed as milliequivalents per liter are generally less than 10 percent of the sodium concentrations, the reported concentrations of potassium were used to compute milliequivalent percentages. For this reason, the resultant milliequivalent percentages of sodium plus potassium may be somewhat higher than actual. Because of uncertainties in the analytical data and seasonal variations in water quality, the interpretations presented here may be altered as additional data are collected.

A map showing the distribution of tetrachloroethylene (PCE), a major volatile organic compound (VOC) detected in ground water in the study area, is presented to provide a preliminary picture of the extent of VOCs in ground water on the basis of conceptual flow patterns. The contaminant-plume boundaries shown here may be modified with the installation of additional monitoring wells and the collection of additional water-quality data.

Major Inorganic Constituents

Concentrations of dissolved solids are low in water from wells in the study area. The specific conductance of ground water in microsiemens per centimeter (μS/cm), which is typically 1.1 to 1.6 times the dissolved-solids concentration in milligrams per liter (mg/L), ranged from 43 μS/cm in well MW–7S to 506 μS/cm in well MW–22B in June 1997 (table 4). For comparison, the specific conductance of water in Meddybemps Lake and the Dennys River in September and October 1996 was about 20 μS/cm (Roy F. Weston, Inc., 1997b). The range of specific conductance measured in ground water is typical for wells completed in glacial deposits and crystalline bedrock in Maine (Maloney, 1988, p. 280). High pH values in some bedrock wells—MW–7B, MW–8B, MW–11B, and MW–15B—may indicate incomplete curing of cement used to grout surface casing. Concentrations of major ions discussed below also may be affected by incomplete curing of cement.

The percentages of major cations in water from surficial wells (tables 5 and 6) lie within a fairly narrow range, and no patterns of distribution are apparent. Calcium is the principal cation. Analytical results for water collected from wells MW–4S and MW–11S in June 1997 are considerably different than for water samples collected in December 1996 and may reflect seasonal variations in water quality at these wells.

Wells completed in bedrock can be grouped on the basis of cation percentages calculated for the two sets of samples. Water from wells MW–10B, MW–11B, and MW–22B is enriched in magnesium relative to water from other wells completed in bedrock. Common features of these wells are relatively high yields in an area overlain by marine clays of the Presumpscot Formation. Leaching of minerals from the marine clays and rapid flow through interconnected fractures may explain the similarity of water types in these wells.

Table 4. Specific conductance, pH, and concentrations of volatile organic compounds in ground water, December 1996 and June 1997, Eastern Surplus Superfund Site, Meddybemps, Maine

[Data from Roy F. Weston, Inc., (1998a; 1998b; µS/cm, microsiemen per centimeter at 25° centigrade; µg/L, microgram per liter; nd, not detected; --, not analyzed; J, concentration estimated]

Well No. or name	Specific conductance (µS/cm)		pH (standard units)		Tetrachloroethylene (µg/L)		Trichloroethylene (µg/L)		Other volatile organic compounds
	Dec. 1996	June 1997	Dec. 1996	June 1997	Dec. 1996	June 1997	Dec. 1996	June 1997	
MW-1B	55	68	6.6	6.3	nd	nd	nd	nd	2-Butanone, 130 µg/L; benzene, 2J µg/L; toluene, 2J µg/L, Dec. 1996
MW-3B	83	135	6.1	6.1	3,700	620	82	nd	1,2,-dichloroethylene, 32 µg/L, Dec. 1996.
MW-4S	61	82	6.0	5.4	nd	4.5J	nd	nd	none
MW-4B	143	229	7.6	6.7	nd	nd	nd	nd	none
MW-5S	38	87	6.3	6.4	2J	nd	nd	nd	none
MW-7S	62	43	6.4	5.7	nd	nd	nd	nd	none
MW-7B	209	346	11.1	10.7	nd	nd	nd	nd	Acetone, 2.7J µg/L; tetrahydrofuran, 5.3 µg/L, June 1997.
MW-8S	144	193	6.0	5.3	760	1,100	nd	nd	none
MW-8B	199	170	10.5	8.8	180	270	5J	5J	1,1,1-Trichloroethane, 8J µg/L, Dec. 1996 and 5 µg/L, June 1997. Three depth intervals sampled in June 1997; values approximately the same for all depths.
MW-10S	130	138	6.5	6.5	nd	.65	nd	nd	none
MW-10B	137	169	7.8	7.8	nd	.65	nd	0.8J	1,1,1-Trichloroethane, 2J µg/L, Dec. 1996, and 0.5J µg/L, June 1997
MW-11S	281	446	7.4	7.3	nd	nd	nd	nd	none
MW-11B	103	214	8.0	9.0	nd	nd	nd	0.6	1,1,1-trichloroethane, 4J µg/L; chloromethane, 2J µg/L; 2-butanone, 110 µg/L; benzene, 1J µg/L; toluene, 2J µg/L, Dec. 1996. 1,1,1-trichloroethane, 4.6J µg/L, June 1997.
MW-12B	57	55	8.6	6.4	nd	nd	nd	nd	none
MW-13S	82	88	5.8	5.6	110	200	nd	nd	none
MW-14B	63	162	6.5	6.9	nd	1.7	nd	nd	none
MW-15S	206	298	6.8	7.6	nd	nd	nd	nd	none
MW-15B	219	314	10.5	10.0	nd	nd	nd	nd	Tetrahydrofuran, 4.1J µg/L; 2-butanone, 4.3J µg/L, June 1997.
MW-16S	156	177	8.2	8.0	nd	nd	nd	nd	2-Butanone, 140 µg/L; benzene, 2J µg/L; toluene, 3J µg/L, Dec. 1996.
MW-16B	145	167	8.4	8.6	nd	nd	nd	nd	none.
MW-17S	--	137	--	6.1	--	420	--	nd	none
MW-18S	--	103	--	5.9	--	680	--	nd	none
MW-20S	--	71	--	6.0	--	29	--	2J	none
MW-22B	--	506	--	7.1	--	8.6	--	nd	none
Smith	--	180	--	--	nd	nd	nd	nd	none
VanWart	--	140	--	--	nd	nd	nd	nd	none
Orchard	--	90	--	--	nd	nd	nd	nd	none

Table 5. Concentrations of major cations and milliequivalent percentages in ground water from surficial and bedrock wells, December 1996, Eastern Surplus Superfund Site, Meddybemps, Maine

[Data from Roy F. Weston, Inc., (1998a; 1998b). mg/L, milligram per liter; percent, percent of major cations as milliequivalents; nc, not calculated because analytical results are uncertain; u, value reported is detection limit determined during validation of data; J, concentration near detection limit]

Well No.	Calcium		Magnesium		Sodium mg/L	Potassium mg/L	Sodium + potassium (percent)
	mg/L	percent	mg/L	percent			
Surficial							
MW–4S	10.7	66	1.5	15	3.1	0.44	18
MW–5S	5.7	60	1.0	17	2.2	.43	23
MW–7S	6.5u	nc	1.9u	nc	2.2u	.60u	nc
MW–8S	15.8u	nc	5.2	nc	8.2	2.8	nc
MW–10S	11.2	47	3.4	23	7.5	1.3	30
MW–11S	37.6	43	20.8	39	15.4	4.9J	18
MW–13S	7.2u	nc	2.0u	nc	4.8u	.80u	nc
MW–15S	33.7	59	5.8	17	14.4	1.7	24
MW–16S	22.3	59	4.9	21	7.3	2.0J	20
Orchard	14.2	62	.9	6	7.8	.71	31
Bedrock							
MW–1B	6.8	48	1.2	14	6.0	0.53	38
MW–3B	10.4	51	2.7	22	5.9	.77	27
MW–4B	12.0	37	1.8	9	19.7	1.3	54
MW–7B	9.4u	nc	.78u	nc	16.3	2.0	nc
MW–8B	11.6	22	5.2	16	36.8	1.8	62
MW–10B	16.1	47	7.1	34	6.4	1.4	18
MW–11B	7.7u	nc	4.1	nc	5.8u	1.5	nc
MW–12B	6.7	45	2.3	25	3.6	2.6J	30
MW–14B	7.9	62	1.1	14	3.3J	.52J	24
MW–15B	14.2	30	1.5	5	34.8	2.1	65
MW–16B	13.2	40	4.5	22	13.3	1.7J	38
Smith	9.0	23	.08	0	33.6	1.2	77
Van Wart	9.8	25	3.3	14	25.3	2.4	60

Table 6. Concentrations of major cations and anions and milliequivalent percentages in ground water from surficial and bedrock wells, June 1997, Eastern Surplus Superfund Site, Meddybemps, Maine

[Data from Roy F. Weston, Inc., (1998a; 1998b; Timothy Jones, written commun., 1997). --, not analyzed; u, value reported is detection limit determined during validation of data; nc, not calculated because analytical results are uncertain; mg/L, milligram per liter; percent, percent of major cations or major anions as milliequivalents]

Well No.	Calcium		Magnesium		Sodium (mg/L)	Potassium (mg/L)	Sodium + potassium (percent)	Chloride		Sulfate		Carbonate + bicarbonate	
	mg/L	percent	mg/L	percent				mg/L	percent	mg/L	percent	mg/L	percent
Surficial													
MW-4S	12	48	5.3	35	3.3	2.3	17	2.5	6	6.1	10	63	84
MW-5S	7.0	60	1.3	18	2.4	.76u	21	3.4	17	4	14	24	69
MW-7S	5.2	39	3.7	45	2.1	.77u	16	2.1	9	2.8	9	34	82
MW-8S	14	50	4.0	24	7.1	1.9	26	16	33	18	28	33	39
MW-10S	10	42	2.9	20	9.5	1.4	37	15	35	5.5	10	41	55
MW-11S	69	53	23	29	24	3.1	17	17	7	38	12	320	80
MW-13S	8.1	52	2.3	24	3.8	.82u	24	4.1	15	12	33	25	52
MW-15S	38	54	11	26	15	2.4	20	6.9	6	21	13	180	82
MW-16S	22	58	5.6	24	7.0	2.1	19	1.8	3	11	12	100	86
MW-17S	10	56	2.8	26	2.9	1.2	18	2.7	9	12	28	35	64
MW-18S	9.9	53	2.2	20	5.2	.91u	27	2.6	8	11	25	38	67
MW-20S	4.6	51	.97	18	2.8	.66u	31	2	13	5	23	18	64
Orchard	14	60	1.1	8	7.8	.58	32	--	--	--	--	--	--
Bedrock													
MW-1B	8.2	51	2.0	20	4.6	0.69u	29	5.2	18	3.2	8	36	73
MW-3B	9.8	51	2.6	23	5.2	.72u	26	7.2	21	6.1	13	38	65
MW-4B	31	65	5.2	18	8.2	1.5u	17	2.9	3	10	9	130	88
MW-7B	20	60	.30	1	14	2.3	38	3.5	6	6.9	8	89	86
MW-8B	6.4	22	2.9	17	19	1.4u	61	11	22	12	18	52	60
MW-10B	13	46	6.3	36	5.5	1.1	18	14	27	4.7	7	58	66
MW-11B	9.3	36	6.2	39	6.3	1.9	25	5.8	13	4.9	8	63	79
MW-12B	.004u	nc	.09u	nc	2.3	2.7	nc	3.6	nc	2.6	nc	nc	nc
MW-14B	23	74	2.1	11	4.7	1.1	15	7.4	13	7.6	10	74	77
MW-15B	13	25	.38	1	41	1.9	73	26	29	52	43	43	28
MW-16B	15	44	5.2	25	11	1.9	31	2.5	4	14	17	83	79
MW-22B	19	38	11	38	12	2.0	24	--	--	--	--	--	--
Smith	8.1	21	.14	1	34	.99	79	--	--	--	--	--	--
Van Wart	9.7	25	3.5	15	26	2.6	61	--	--	--	--	--	--

Water in wells MW–4B, MW–7B, MW–8B, MW–15B, and the Van Wart and Smith wells is enriched in sodium relative to water in other bedrock wells, although percentages varied somewhat for the two sampling periods. All except the Van Wart well have very low yields—0.3 gal/min or less. The high concentrations of sodium may be caused by long residence times and dissolution of sodium feldspar in the gabbro-diorite bedrock. The high sodium concentrations may indicate minimal leakage from the surficial aquifer where sodium concentrations in water are characteristically low. Road salt, however, cannot be excluded as a possible source of sodium at MW–8B, Van Wart, and Smith wells, which are downgradient from Highway 191. Although well MW–15B is near a driveway that may receive road salt, a lower concentration of sodium in well MW–15S indicates another source of sodium in well MW–15B.

For the rest of the bedrock wells sampled (MW–1B, MW–3B, MW–12B, MW–14B, and MW–16B) percentages of cations are similar to percentages in the surficial aquifer and may indicate a close hydraulic connection and leakage between the two aquifers. Water levels at wells MW–1B, MW–3B, MW–14B, and MW–16B appear to respond readily to precipitation (table 3, fig. 8). This response supports the concept of a close hydraulic connection between the aquifers at these wells.

Analyses for major anions in water samples collected in June 1997 (table 6) (Timothy Jones, written commun., 1997) indicated that carbonate and bicarbonate were the principal anions in water from surficial and bedrock aquifers, except at monitoring well MW–15B where sulfate was the principal anion. Water from the surficial aquifer typically had somewhat higher percentages of sulfate than water from bedrock for unknown reasons. The relatively high percentages of chloride (greater than 25 percent) in wells MW–8S, MW–10S, and MW–10B located near Highway 191 may be attributable to road salt. The percentages of chloride and sulfate were higher in well MW–15B than in other wells for unknown reasons. As discussed above, road salt is an unlikely source because chloride concentrations, like sodium concentrations, are low in well MW–15S.

Volatile Organic Compounds

Water samples collected in wells MW–3B, MW–8S, MW–8B, and MW–13S (table 4) during December 1996 contained high concentrations of VOCs, principally PCE. Trichloroethylene (TCE) also was detected in water samples from wells MW–3B and MW–8B (table 4). Analysis of samples collected in June 1997 confirmed results from December 1996 and also showed elevated concentrations of PCE in wells MW–17S, MW–18S, and MW–20S, which were installed in April 1997. A low concentration of PCE (8.6 µg/L) also was detected in water from well MW–22B. Other VOCs were detected at low concentrations in water from some wells, but results were not consistent for the two sampling periods and may reflect sampling or analytical errors.

Two plumes of PCE-contaminated ground water have been delineated on the basis of analysis of water samples from wells, analyses for VOCs in soils (Roy F. Weston, Inc., 1998c), results from passive vapor samplers, and ground-water-flow patterns (fig. 12). The vertical extent of the plumes is not known but is shown conceptually on figures 7*C* and 7*D* to be at shallow depth in bedrock and to discharge to the Dennys River. The maximum concentration of PCE measured in the northern plume was 3,700 µg/L in a sample collected from well MW–3B in December 1996. The concentration had decreased to 620 µg/L when well MW–3B was sampled in June 1997. The maximum concentration of PCE measured in the southern plume was 1,100 µg/L, in a water sample collected from well MW–8S in June 1997. For comparison, the maximum contaminant levels (MCLs) for PCE and TCE established by USEPA for drinking water is 5 µg/L (Fetter, 1994, table 11.2). PCE, TCE, or both were detected in passive vapor samplers PS–5, PS–7, PS–8, PS–9, and PS–26 (table 7).

Toluene was detected in two passive vapor samplers placed along the shore of Meddybemps Lake and in several samplers along the pool area of the former millpond on the Dennys River (table 7). Toluene was also detected in soil samples at several locations on the site (Roy F. Weston, Inc., 1998c) but not in wells, indicating that toluene persists in some geochemical environments at the site. Alternatively, toluene detected in passive samplers may have been derived from adhesive tapes used to construct the samplers, but this hypothesis could not be confirmed with the available data.

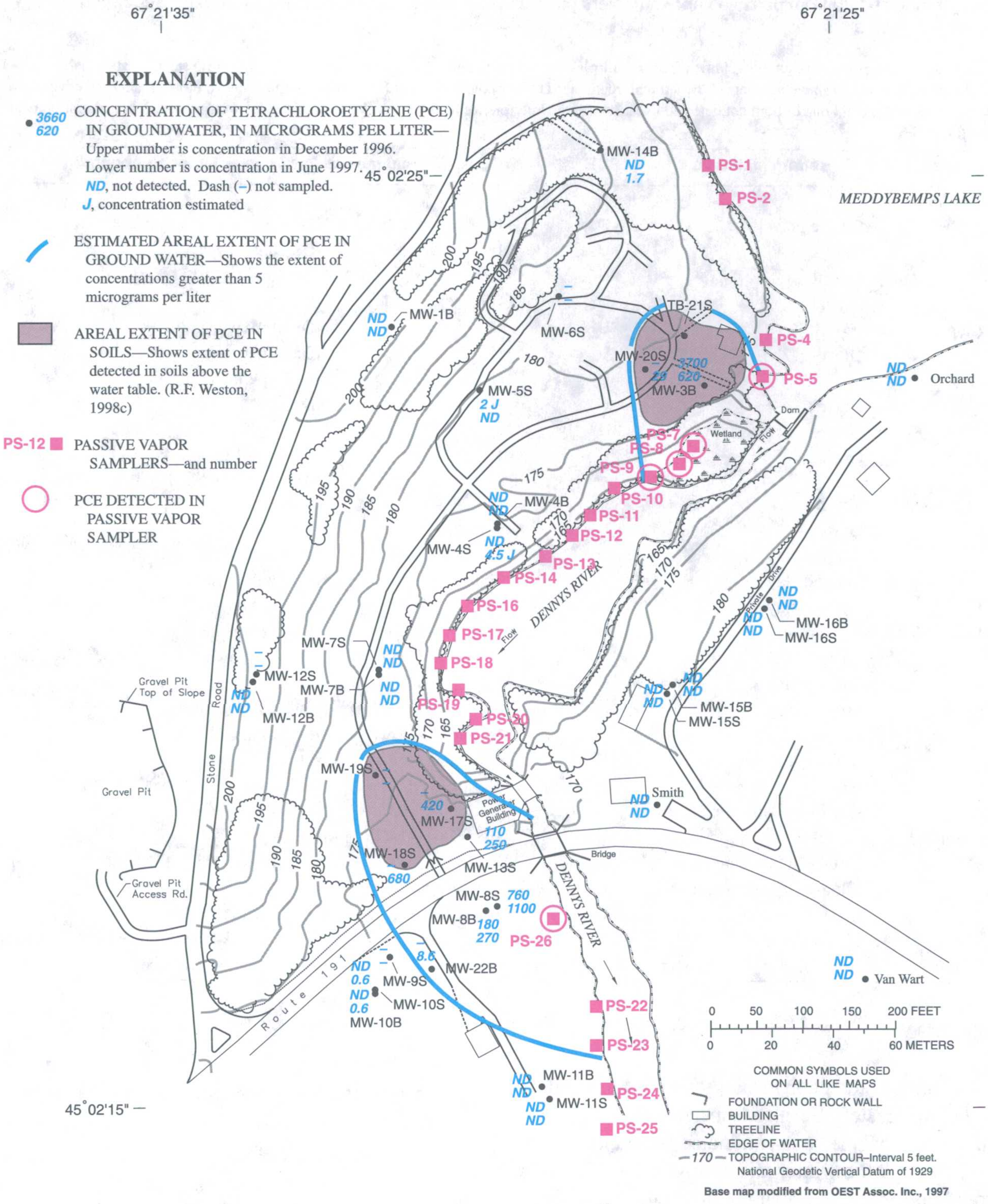

Figure 12. Distribution of tetrachloroethylene (PCE) in ground water, Eastern Surplus Superfund Site, Meddybemps, Maine.

Table 7. Chemical data from passive vapor samplers placed in streambed materials, Eastern Surplus Superfund Site, Meddybemps, Maine

[All concentrations in parts per billion by volume (ppb/v). **Sampler No.:** dup., duplicate sample in separate container from same location; lab. dup., duplicate sample from same container. **PCE:** tetrachloroethene. **TCE:** trichloroethene. **Other:** ND, sample analyzed for 1,1-Dichloroethene and *trans*-1,2-Dichloroethene but one or both not detected because of large interference peak on gas chromatograph. U, not detected; J, concentration near detection limit]

Sampler No.	Bottom materials	PCE	TCE	Toluene	Other compounds
Detection limit	--	40	28	31	--
PS–1	Coarse gravel	U	U	130	ND
PS–2	Gravel	U	U	48	ND; 2 unknowns
PS–4	Gravel	U	U	U	3 unknowns
PS–5	Gravel	U	14J	20J	ND
PS–5 (dup.)	do.	U	6J	22J	ND; orthoxylene, 26J
PS–7	Gravel	U	16J	U	ND; 4 unknowns
PS–7 (lab.dup.)	do.	U	18J	U	ND; 4 unknowns
PS–8	Gravel	U	9J	U	ND
PS–9	Gravel	21J	20J	140	ND
PS–10	Gravel	U	U	U	Toluene less than detection limit—may be lab contaminant
PS–10 (lab. dup.)	do.	U	U	U	do.
PS–11	Gravel	U	U	U	5 unknowns
PS–12	Silt and clay	U	U	53	ND; 3 unknowns
PS–13	Silt and clay	U	U	2,500	ND; 3 unknowns
PS–14	Silt and clay	U	U	89	ND; 5 unknowns
PS–14 (dup.)	do.	U	U	170	ND; 4 unknowns
PS–16	Silt and clay	U	U	360	ND; 5 unknowns
PS–17	Silt and clay	U	U	38	ND
PS–18	Silt and clay	U	U	290	3 unknowns; orthoxylene, 28J
PS–19	Silt and clay	U	U	590	ND; 2 unknowns
PS–20	Silt and gravel	U	U	U	ND; 4 unknowns
PS–21	Gravel	U	U	U	5 unknowns
PS–22	Gravel and organic matter	U	U	22J	ND
PS–22 (dup.)	do.	U	U	24J	ND
PS–23	Gravel and organic matter	U	U	U	ND; 3 unknowns
PS–24	Silt and organic matter	U	U	U	2 unknowns
PS–25	Organic matter	U	U	U	1 unknown
PS–26	Organic matter	240	70	160	ND; trans 1,2-Dichloroethene, 1.1J; 3 unknowns
PS–26 (dup.)	do.	150	50	150	ND; trans 1,2-Dichloroethene, 1.4J; 3 unknowns

SUMMARY

A study of the geohydrology and ground-water quality at the Eastern Surplus Superfund Site in Meddybemps, Maine, was conducted from the autumn of 1996 through the winter and spring of 1997 in order to provide information about the distribution and fate of contaminants in ground water. The study area covers about 30 acres in and around the 4-acre Eastern Surplus Site. Activities included drilling, geologic mapping, water-level and lake-stage monitoring, ground-penetrating radar surveys, borehole logging, and ground-water sampling.

The Eastern Surplus study area is underlain mainly by the Meddybemps Granite. A small area centered on the Site is underlain by a gabbro-diorite intrusive, which is most likely a detached body of mafic rock in the Meddybemps Granite. Surficial materials include till, generally less than 10 to 20 ft thick, and extensive glaciomarine deposits, including coarse- and fine-grained sediments deposited during deglaciation of the region. A nearby subaqueous fan deposit consisting mainly of coarse gravel and sand was deposited in an ancestral sea at the ice margin during retreat of the glacier. Glaciomarine silty clay of

the Presumpscot Formation underlies much of the lowland area in the region. A sandy facies of the Presumpscot Formation was deposited as the land rose relative to sea level and the shoreline moved southeasterly through the area.

Geohydrologic units in the study area include till, coarse- and fine-grained glaciomarine deposits, fine-grained glaciomarine deposits, and bedrock. Till thickness ranges generally from less than 5 ft on the west side of the Dennys River to more than 40 ft on the east side. The coarse-grained glaciomarine deposits at or near the surface in the western part of the study area range in thickness from 0 to more than 30 ft. The thicker sections are largely above the water table. Fine-grained glaciomarine deposits are present in the central and southern parts of the study area where thickness ranges from 0 to about 20 ft. The silt-clay facies of the fine-grained glaciomoraine deposits is poorly permeable and serves as a confining layer for ground water in underlying till and coarse glaciomarine deposits. The occurrence of water-yielding bedrock fractures varies widely; in most wells only 1 or 2 fractures supply measurable quantities of water (more than 0.02 gal/min). The highest yielding wells are at the southern end of the study area.

Water levels in bedrock wells on the north side of the study area respond rapidly to rainfall. Responses to precipitation in surficial materials and bedrock are subdued or are not apparent where silt and clays of the Presumpscot Formation are present. The annual recharge rate (the amount of recharge not lost to evapotranspiration) may approach a potential rate of 24 to 26 in. where till, sand, and sand and gravel are at the surface, but is probably much less where silts and clays are at the surface.

Ground water in surficial materials flows south to eastward toward the Dennys River on the west side of the study area and westward towards the river on the east side of the study area. The saturated thickness of sediments under the Eastern Surplus Site is generally less than 10 ft. Surficial sediments under much of the northern and western sides of the study area are unsaturated for most or all of the year. Water in bedrock flows towards the Dennys River from the east and west sides of the study area. Water-level data indicate a potential for flow under the river from the west side to a hypothesized cone of depression near a residential well on the east side. Actual flow of ground water in fractured bedrock is controlled by the orientation and hydraulic conductivity of individual fractures or fracture zones.

The specific conductance of ground water in the study area ranges from less than 50 to about 500 µS/cm. Percentages of major cations and anions in surficial wells are generally uniform except in samples from three wells near Highway 191, where higher percentages of chloride may result from road salting. Bedrock wells can be grouped on the basis of percentages of major cations. High percentages of magnesium in water samples from three wells south of Highway 191 indicates a close hydraulic connection between the wells, a short residence time, and possibly leakage from overlying marine clays in the Presumpscot Formation. Higher percentages of sodium in low-yielding wells in the central and eastern part of the study area may indicate a long residence time and limited leakage from the surficial aquifer. Similar cation percentages in water from some wells in bedrock and water from wells in the surficial aquifer may indicate leakage between the two aquifers.

Volatile organic compounds (VOCs), including tetrachloroethylene (PCE) and trichloroethylene (TCE), have been detected in ground water in two areas. PCE, the principal contaminant in ground water, has been detected at a concentration of 3,700 µg/L in a northern plume and at 1,100 µg/L in a southern plume. Both plumes move through surficial materials and shallow bedrock towards the Dennys River. Contaminants in the southern plume can potentially move through fractures in bedrock to the hypothesized local cone of depression east of the Dennys River.

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APPENDIX 1

Appendix 1. Borehole geophysical logs at the Eastern Surplus Site in Meddybemps, Maine:

A. Well MW–03B 51
B. Well MW–04B 52
C. Well MW–07B 53
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K. Well MW–12B 61
L. Well MW–12S 62
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N. Well MW–15B 64
O. Well MW–15S 65
P. Well MW–16B 66
Q. Well MW–16S 67
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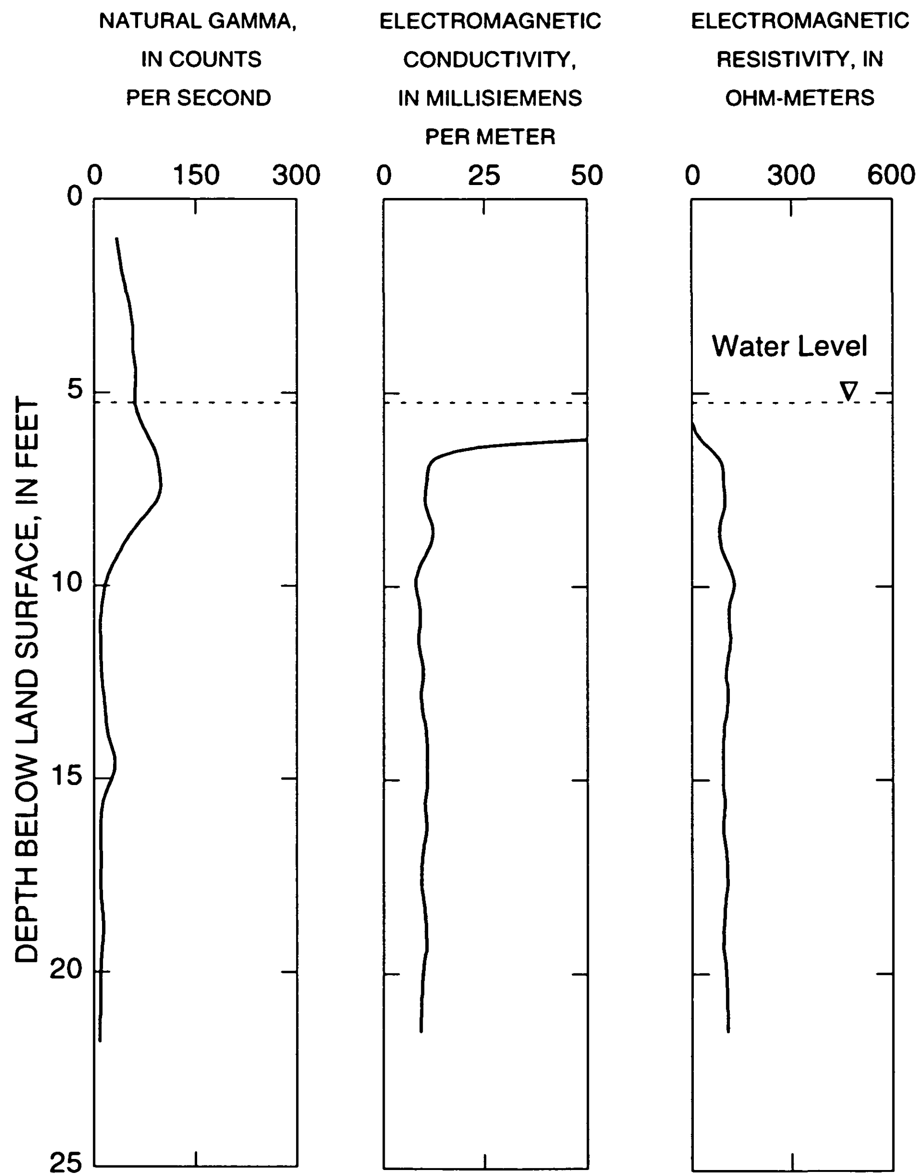
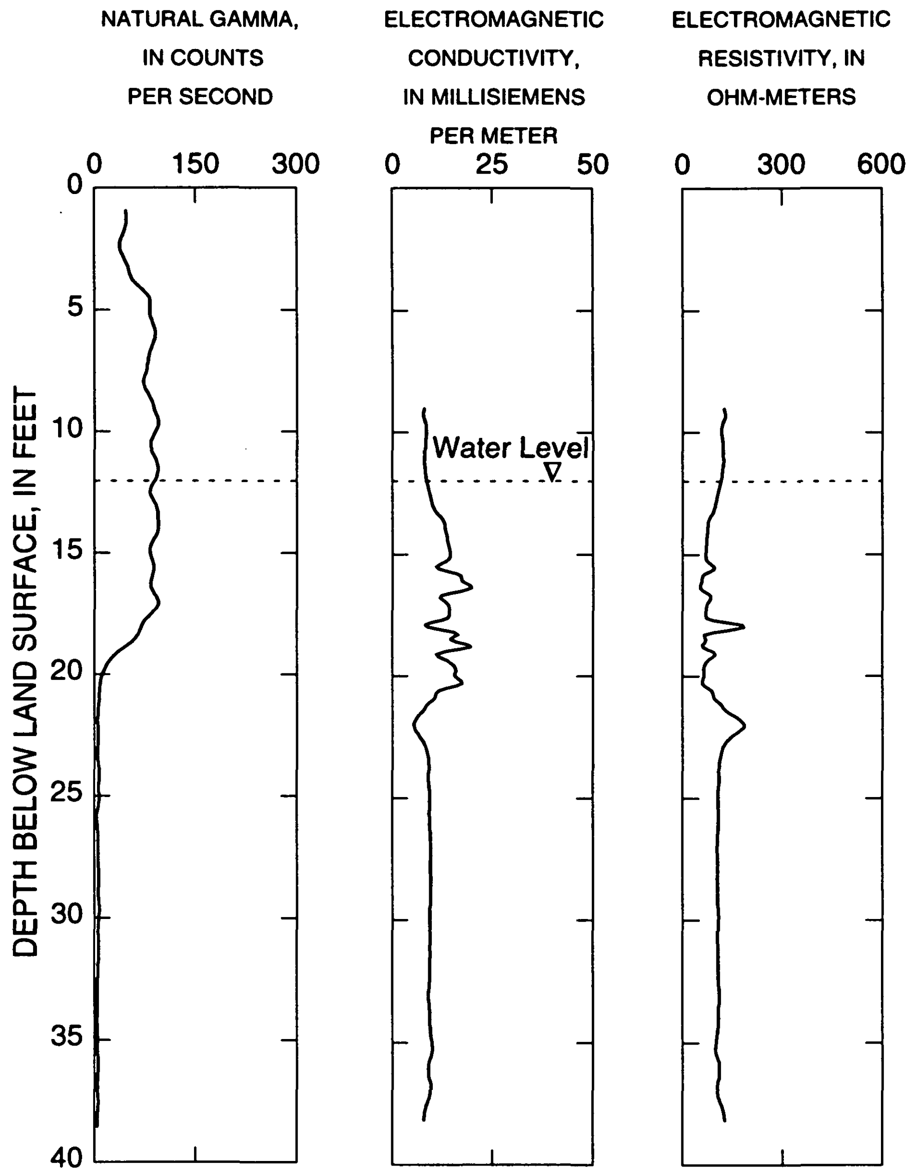
A.--Borehole geophysical logs for well MW-03B



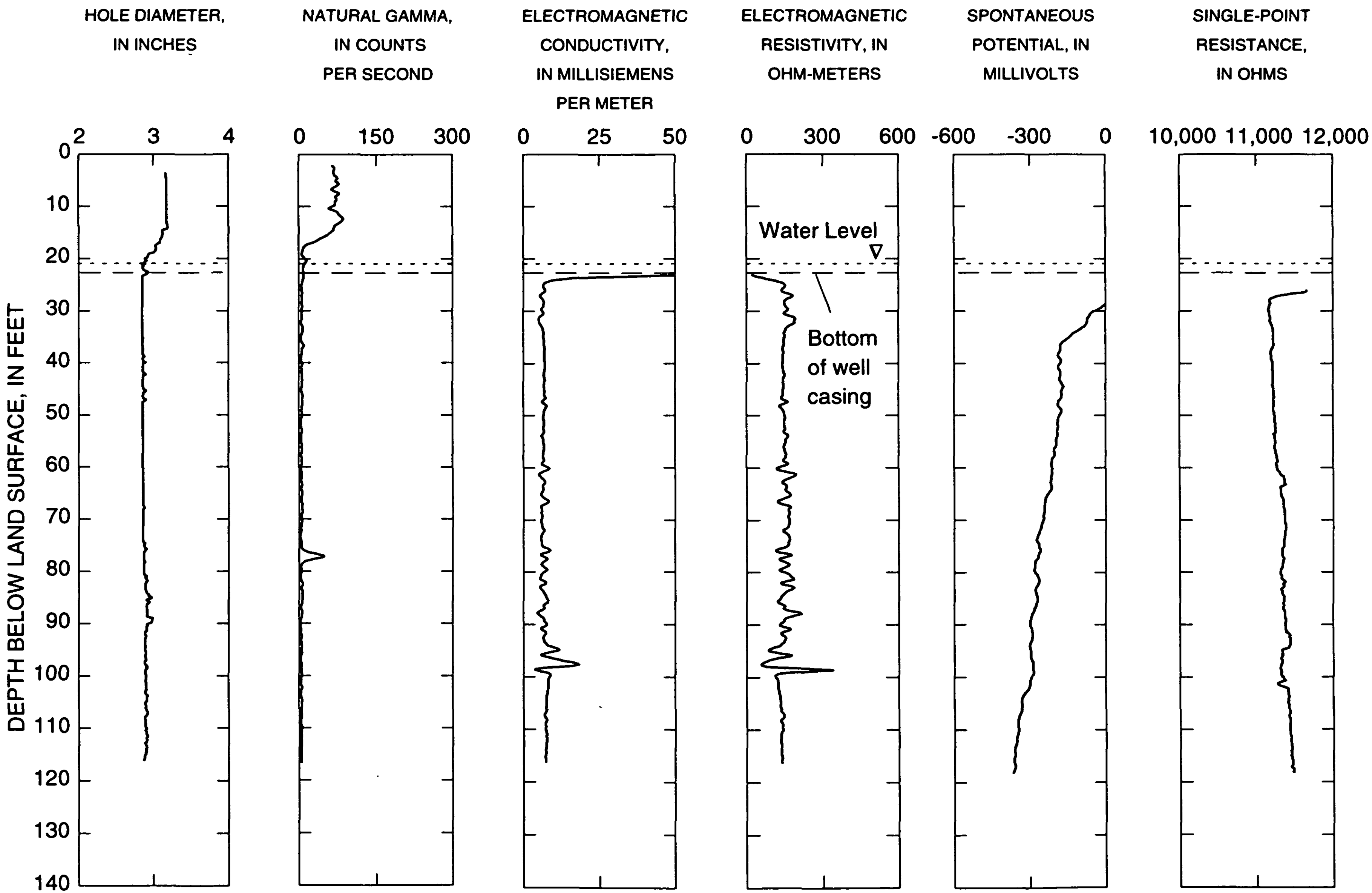
Appendix 1. Borehole geophysical logs at the Eastern Surplus Site in Meddybemps, Maine.

B.--Borehole geophysical logs for well MW-04B



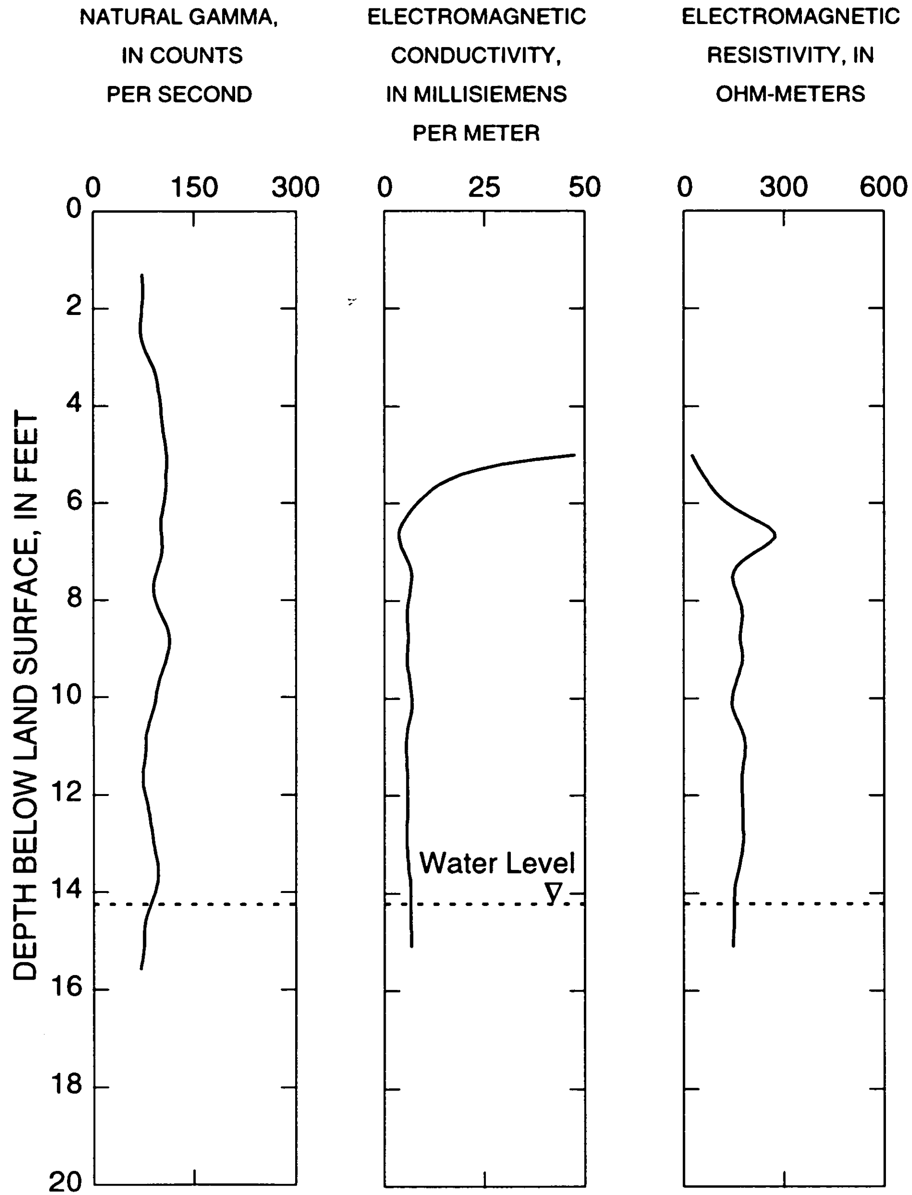
Appendix 1. Borehole geophysical logs at the Eastern Surplus Site in Meddybemps, Maine—*Continued.*

C.--Borehole geophysical logs for well MW-07B



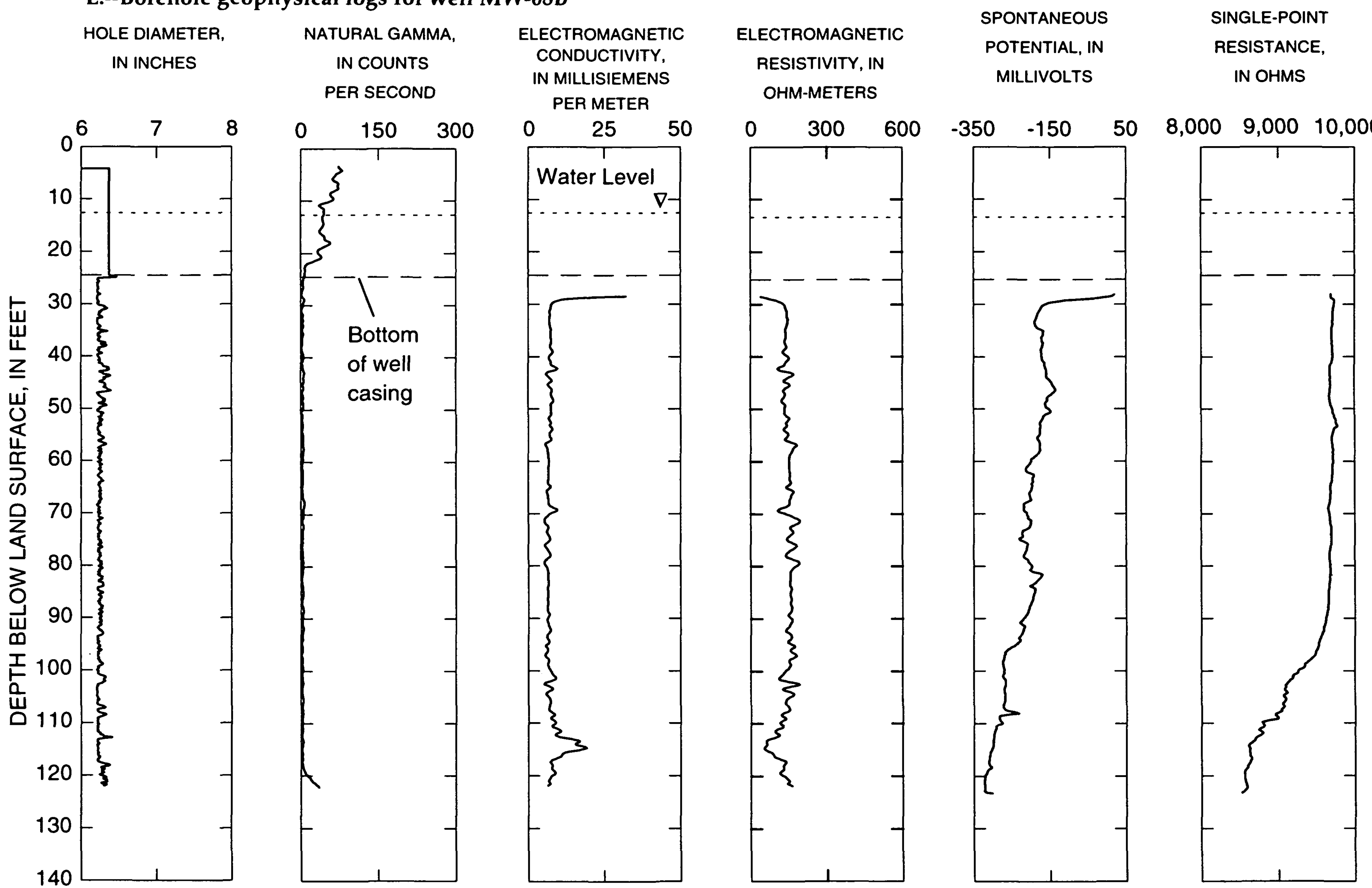
Appendix 1. Borehole geophysical logs at the Eastern Surplus Site in Meddybemps, Maine—*Continued.*

D.--Borehole geophysical logs for well MW-07S



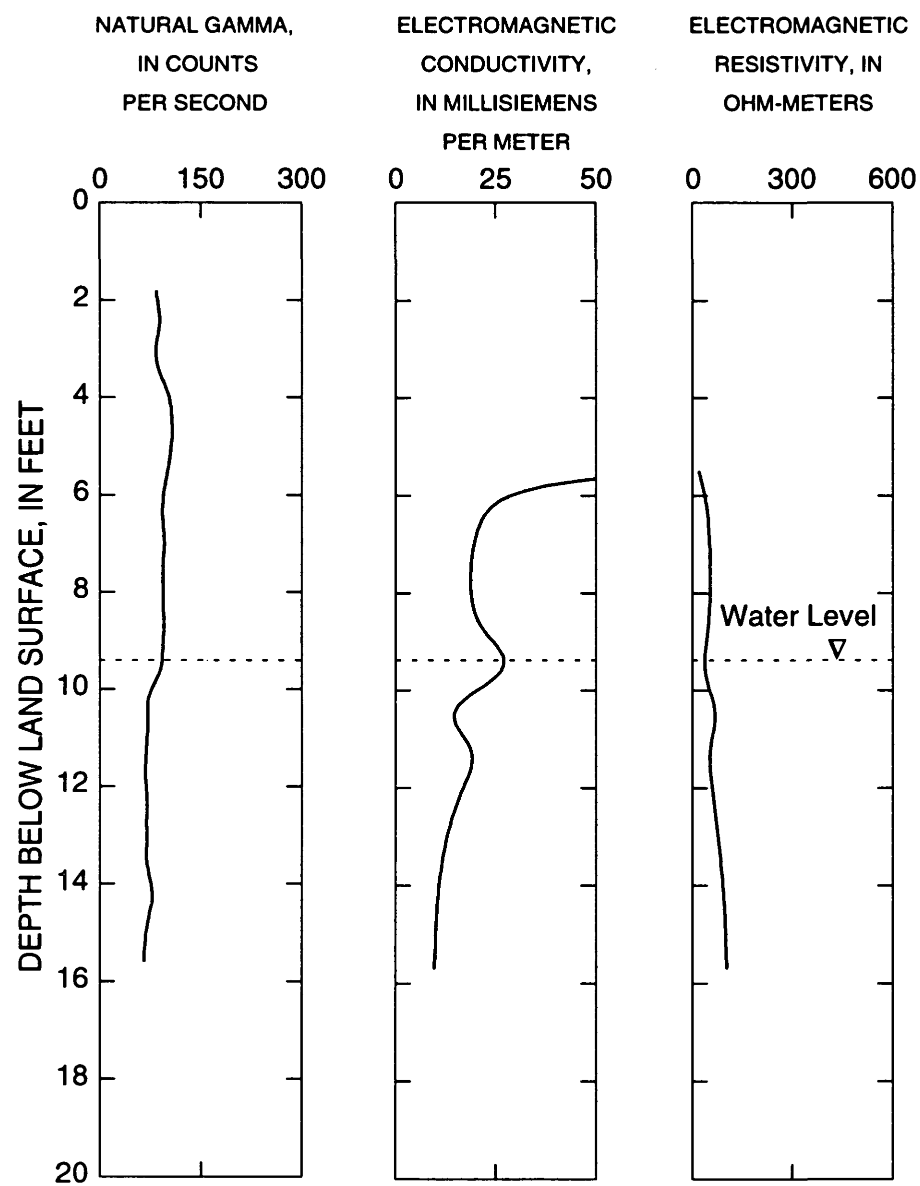
Appendix 1. Borehole geophysical logs at the Eastern Surplus Site in Meddybemps, Maine—*Continued.*

E.--Borehole geophysical logs for well MW-08B



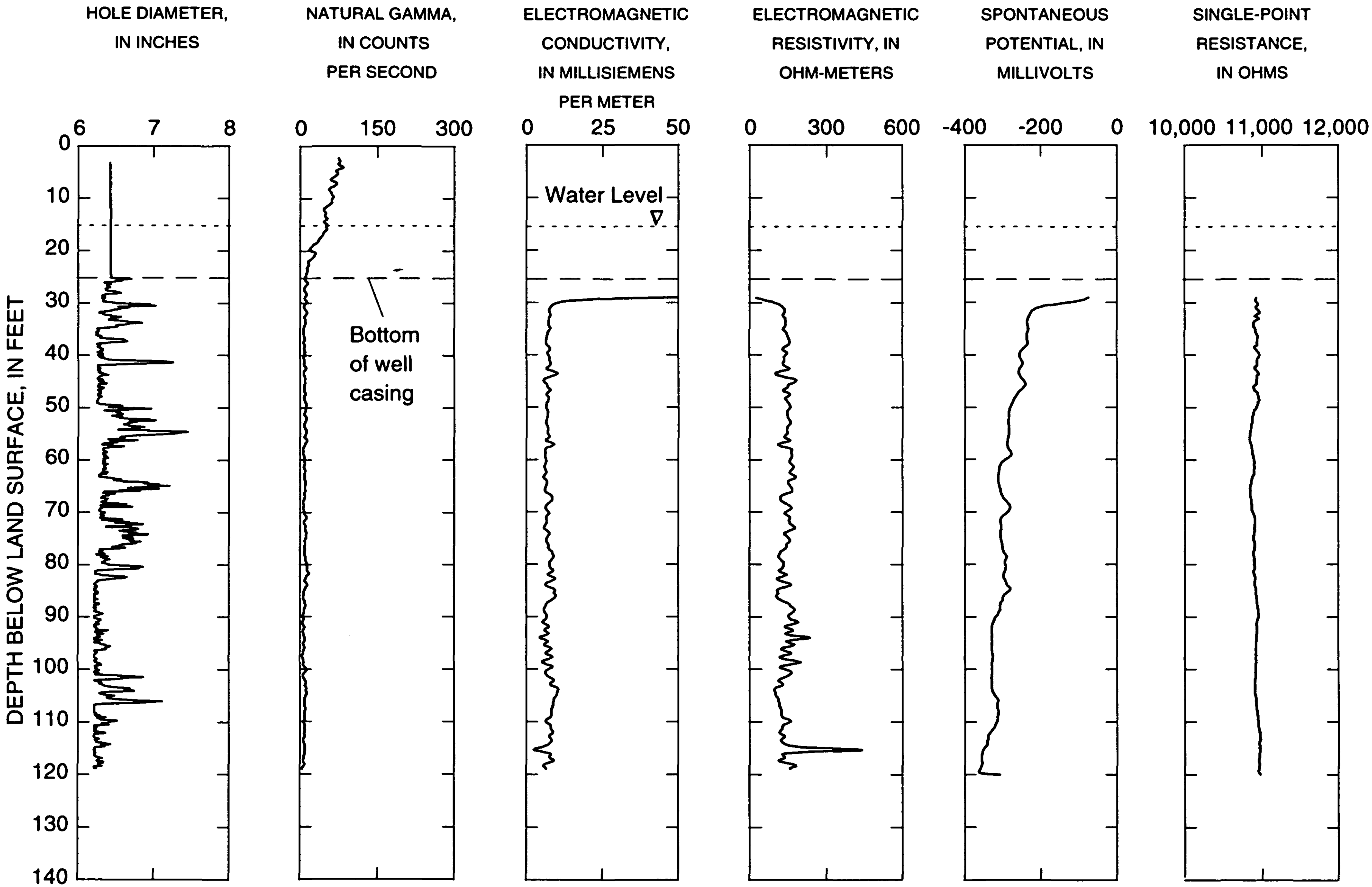
Appendix 1. Borehole geophysical logs at the Eastern Surplus Site in Meddybemps, Maine—*Continued.*

F.--Borehole geophysical logs for well MW-08S



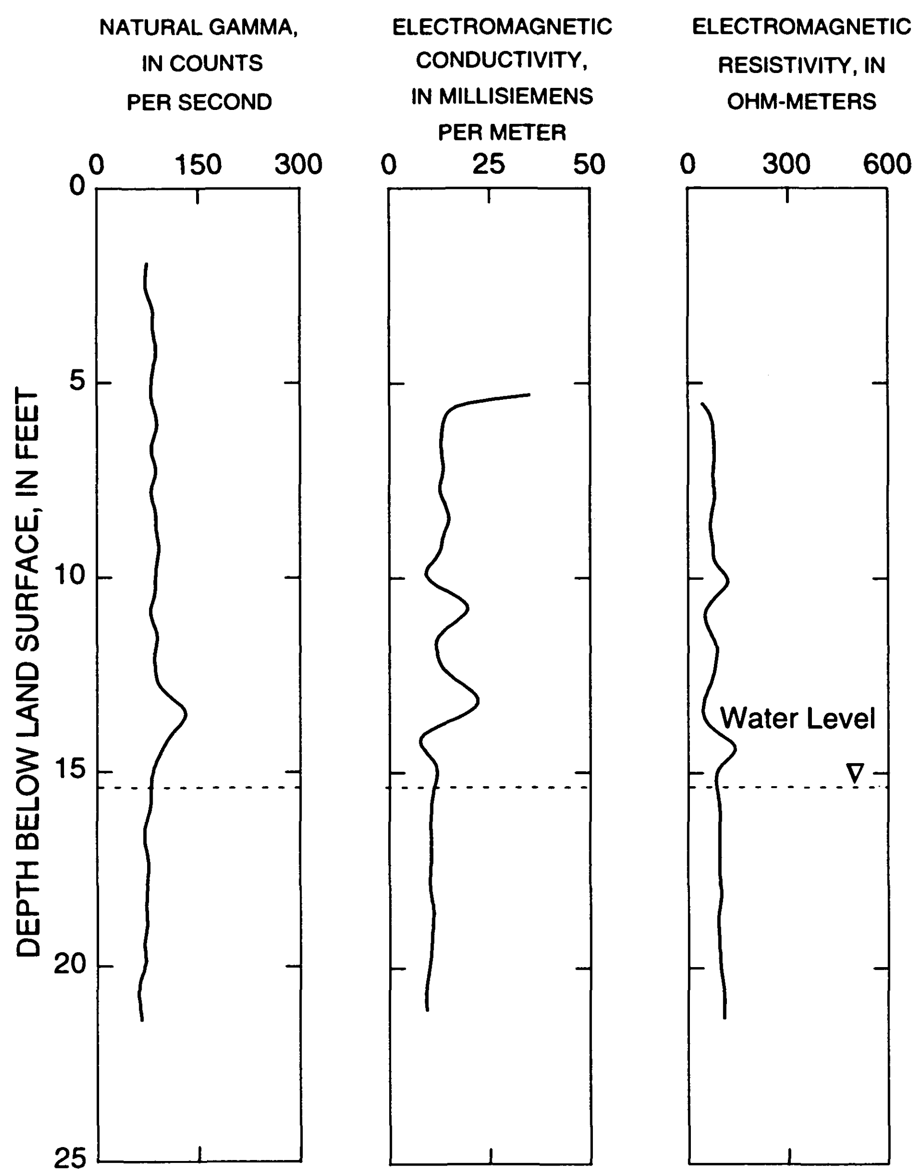
Appendix 1. Borehole geophysical logs at the Eastern Surplus Site in Meddybemps, Maine—*Continued.*

G.--Borehole geophysical logs for well MW-10B



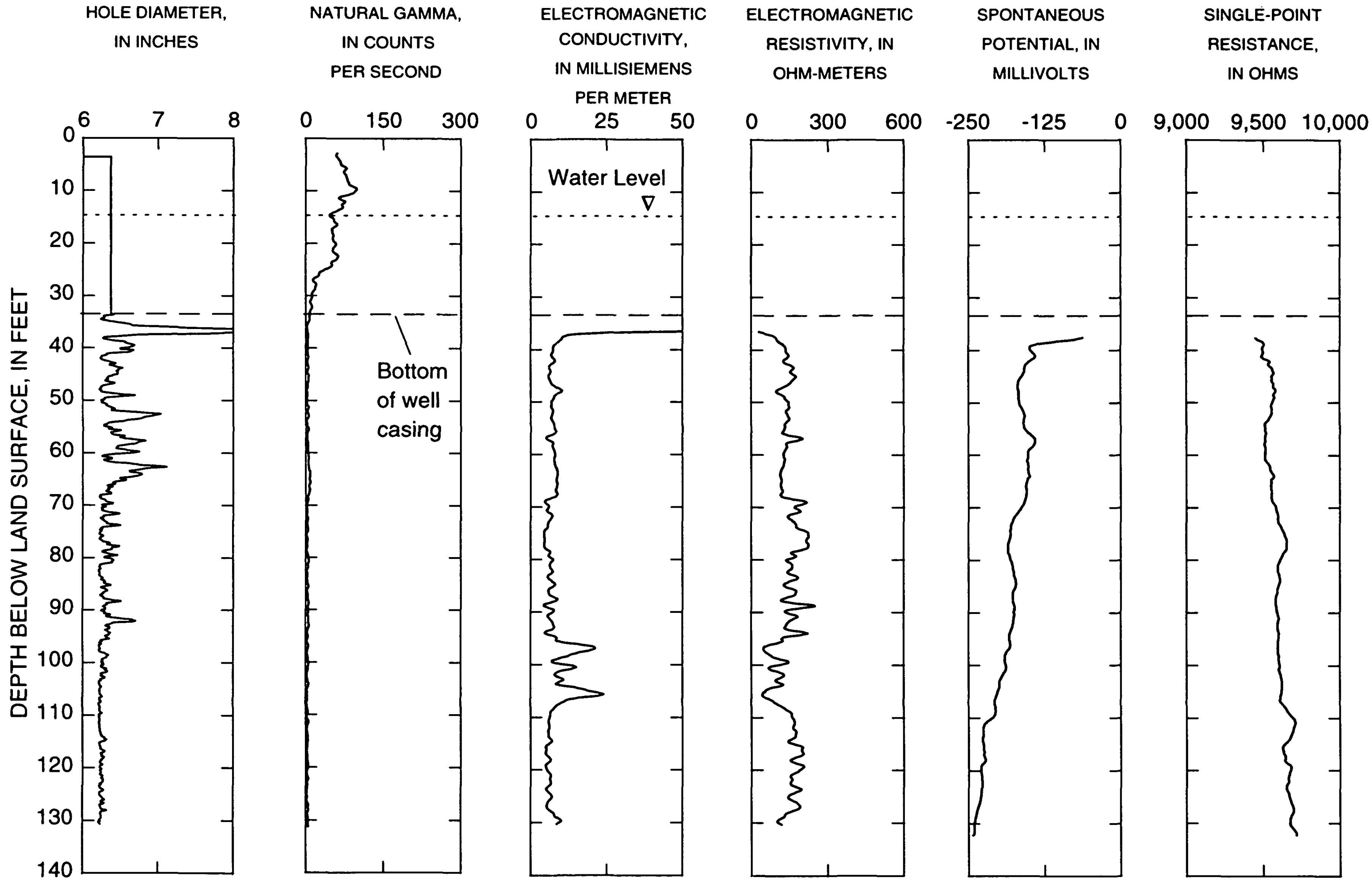
Appendix 1. Borehole geophysical logs at the Eastern Surplus Site in Meddybemps, Maine—*Continued.*

H.--Borehole geophysical logs for well MW-10S



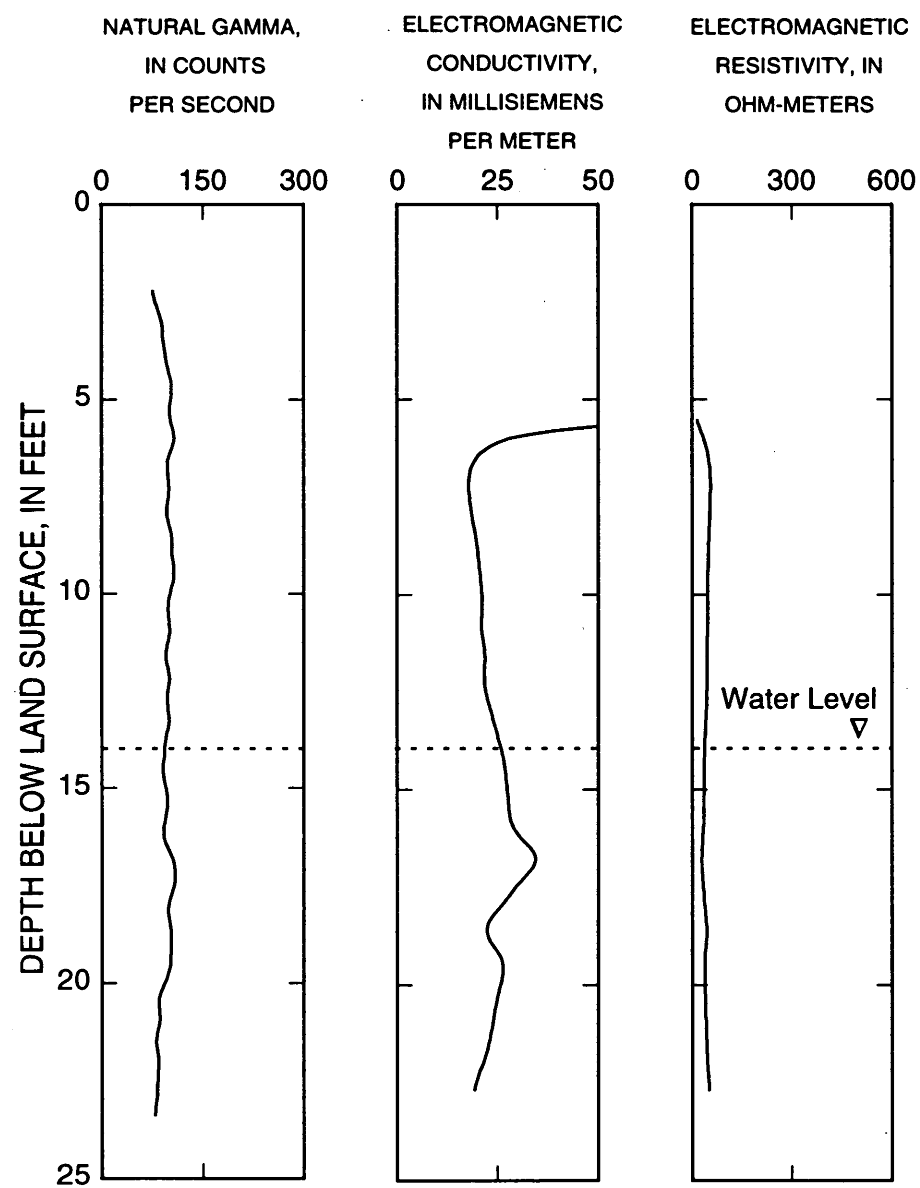
Appendix 1. Borehole geophysical logs at the Eastern Surplus Site in Meddybemps, Maine—*Continued.*

I.--Borehole geophysical logs for well MW-11B



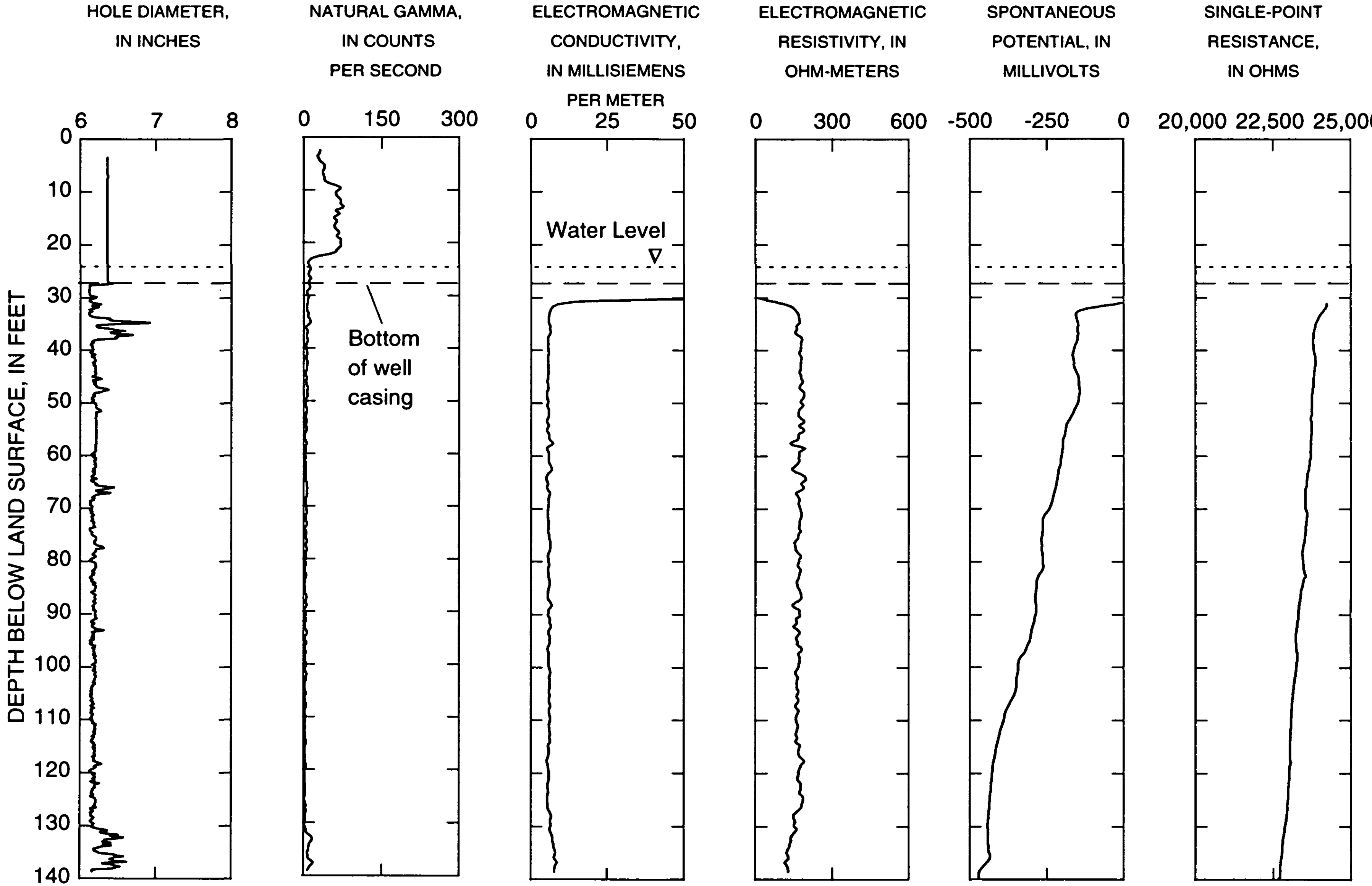
Appendix 1. Borehole geophysical logs at the Eastern Surplus Site in Meddybemps, Maine—*Continued.*

J.--Borehole geophysical logs for well MW-11S

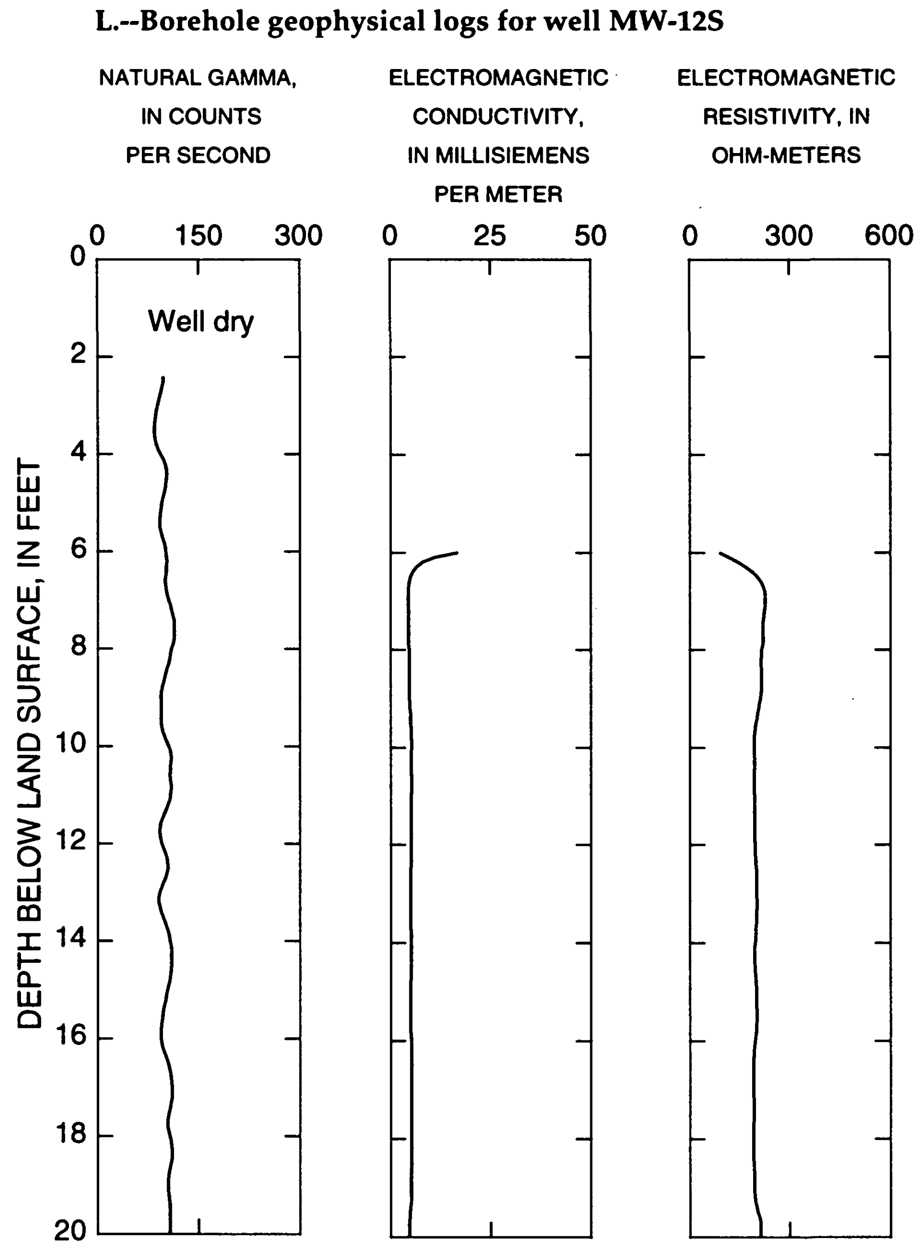


Appendix 1. Borehole geophysical logs at the Eastern Surplus Site in Meddybemps, Maine—*Continued.*

K.--Borehole geophysical logs for well MW-12B

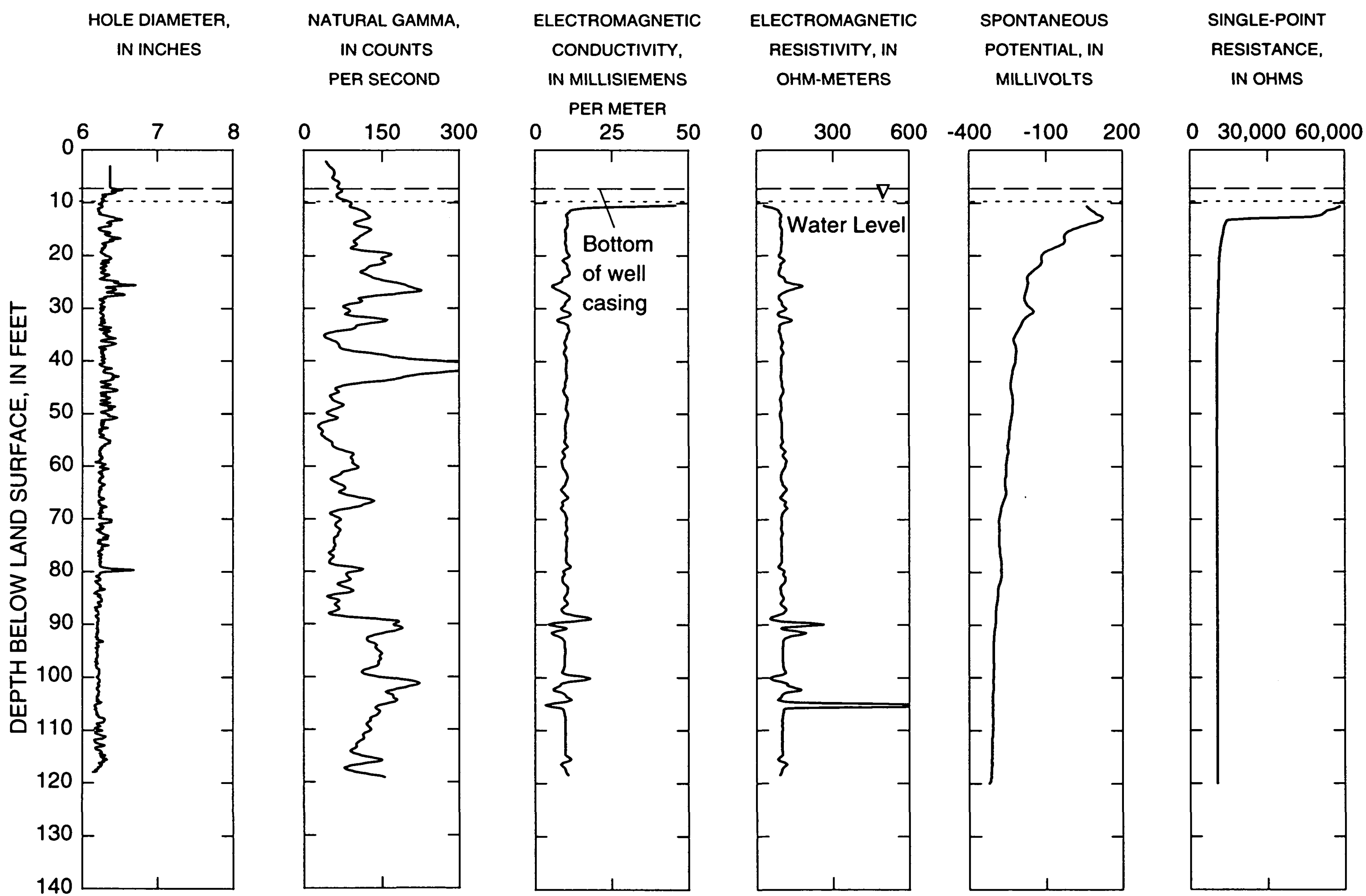


Appendix 1. Borehole geophysical logs at the Eastern Surplus Site in Meddybemps, Maine—*Continued.*



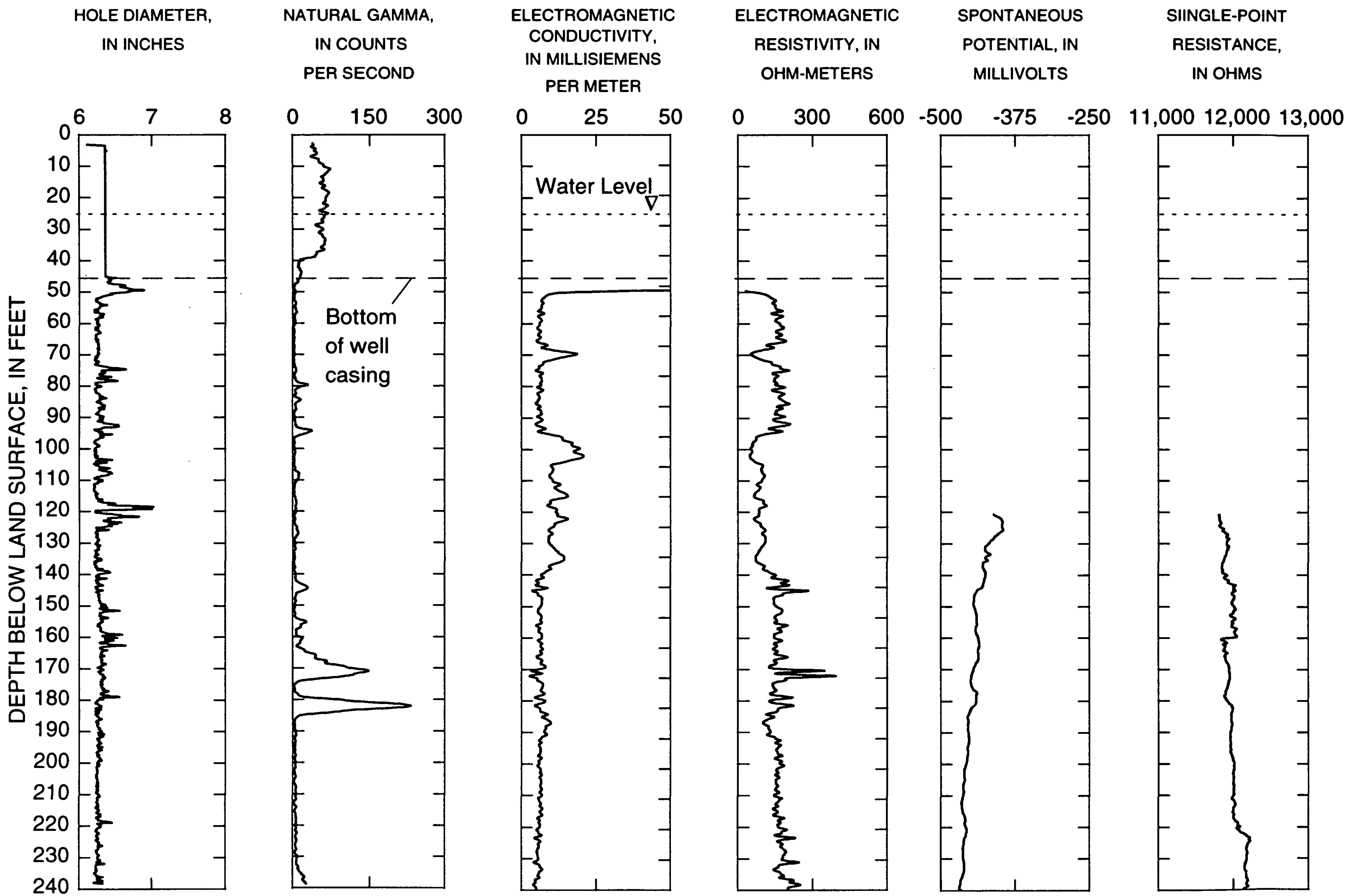
Appendix 1. Borehole geophysical logs at the Eastern Surplus Site in Meddybemps, Maine—*Continued.*

M.--Borehole geophysical logs for well MW-14B



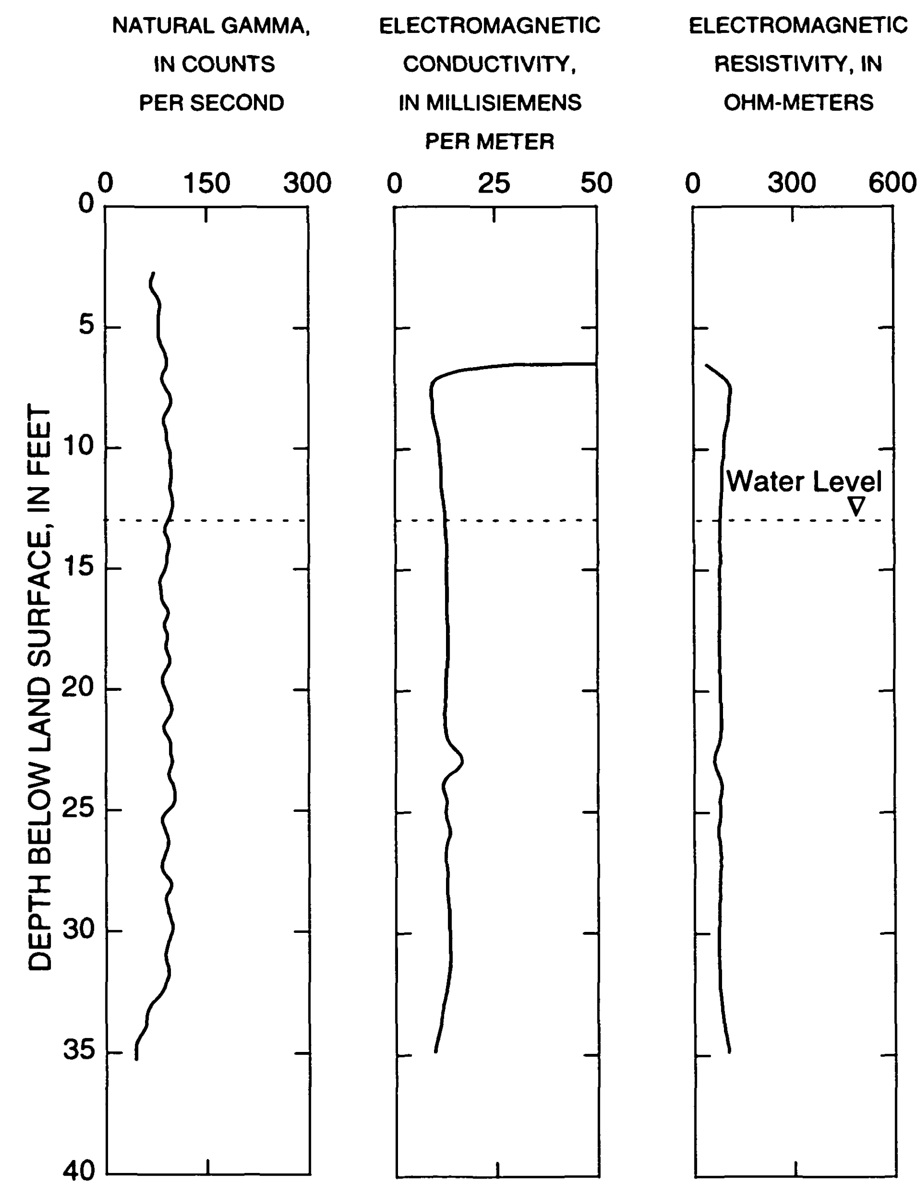
Appendix 1. Borehole geophysical logs at the Eastern Surplus Site in Meddybemps, Maine—*Continued.*

N.--Borehole geophysical logs for well MW-15B



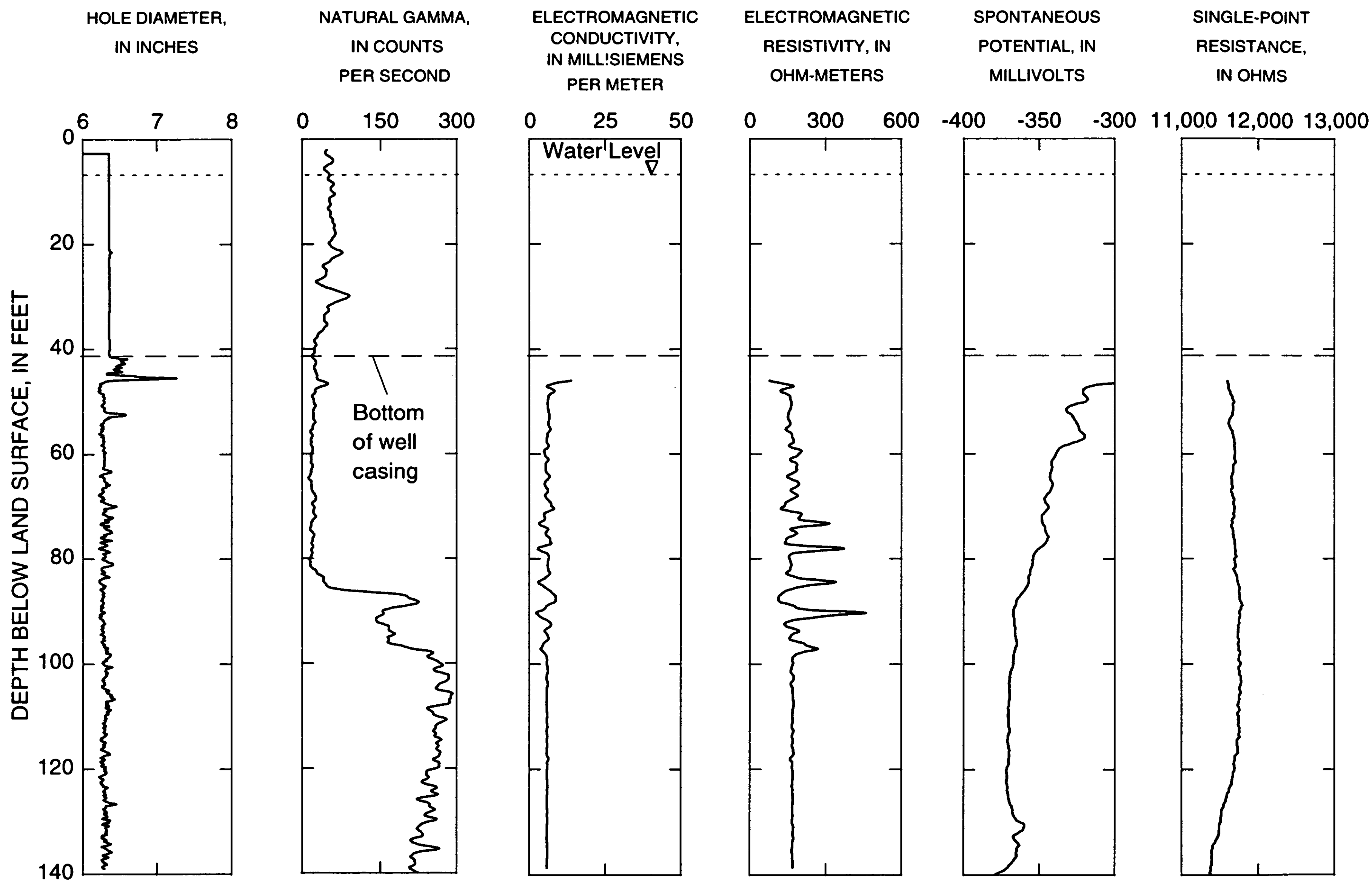
Appendix 1. Borehole geophysical logs at the Eastern Surplus Site in Meddybemps, Maine—*Continued.*

O.--Borehole geophysical logs for well MW-15S



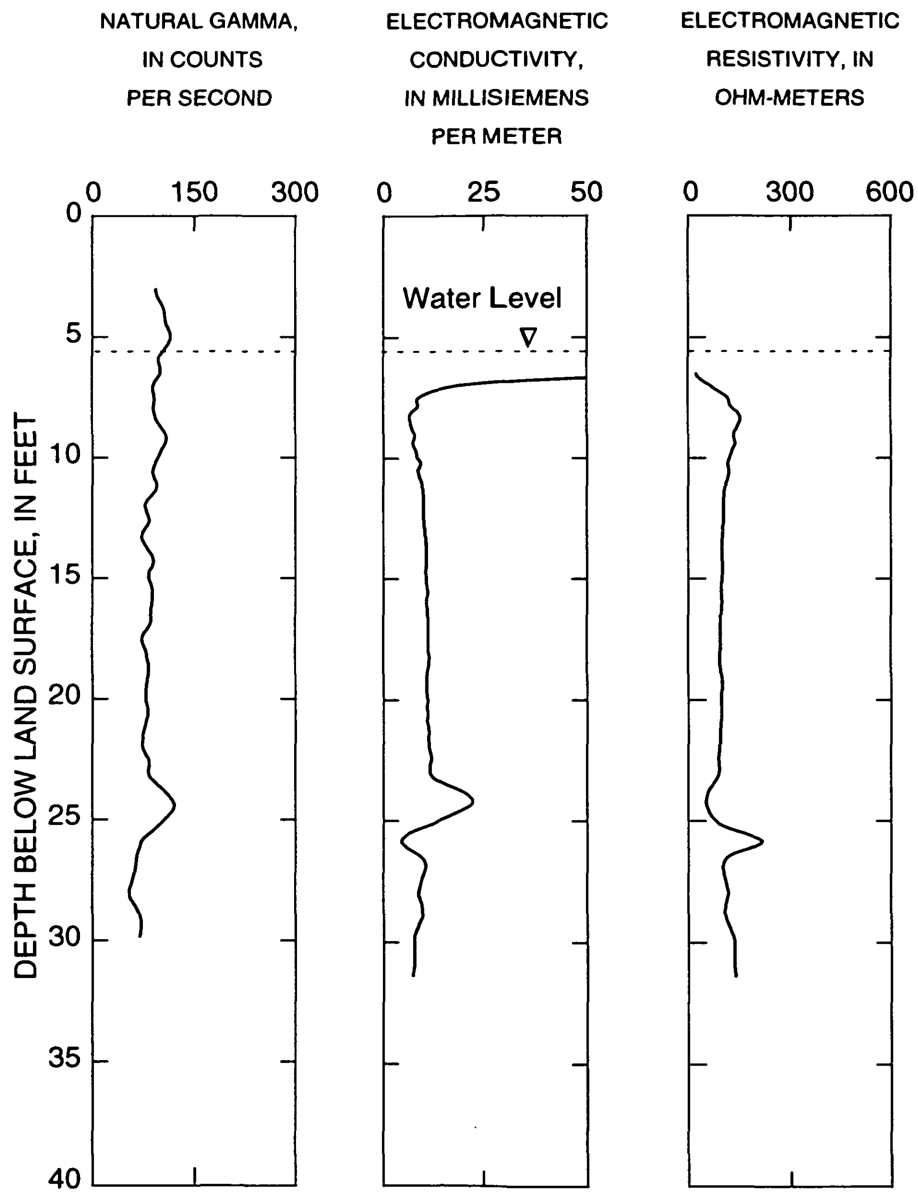
Appendix 1. Borehole geophysical logs at the Eastern Surplus Site in Meddybemps, Maine—*Continued.*

P.--Borehole geophysical logs for well MW-16B



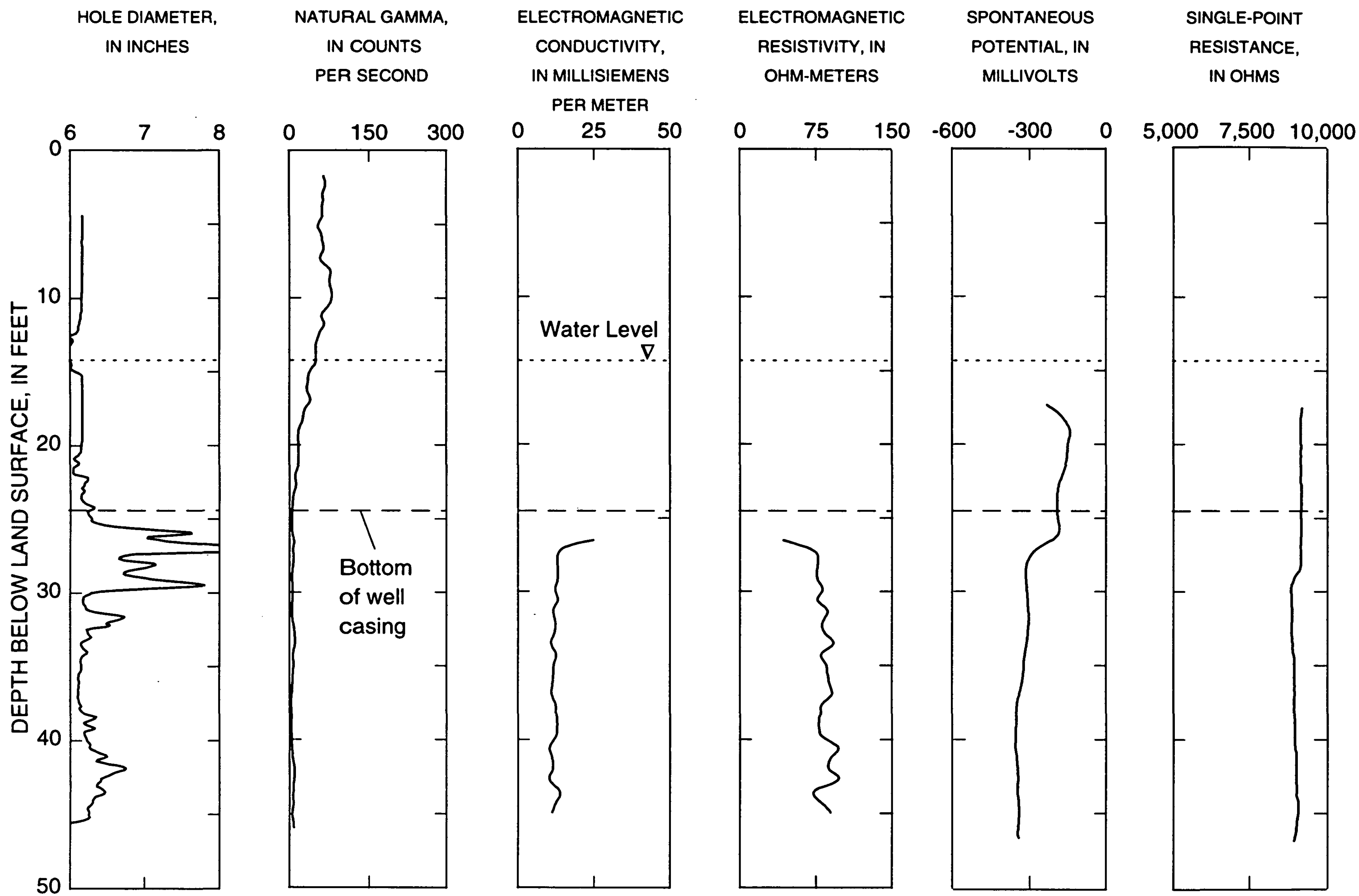
Appendix 1. Borehole geophysical logs at the Eastern Surplus Site in Meddybemps, Maine—*Continued.*

Q.--Borehole geophysical logs for well MW-16S



Appendix 1. Borehole geophysical logs at the Eastern Surplus Site in Meddybemps, Maine—*Continued.*

R.--Borehole geophysical logs for well MW-22B



Appendix 1. Borehole geophysical logs at the Eastern Surplus Site in Meddybemps, Maine—*Continued.*

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