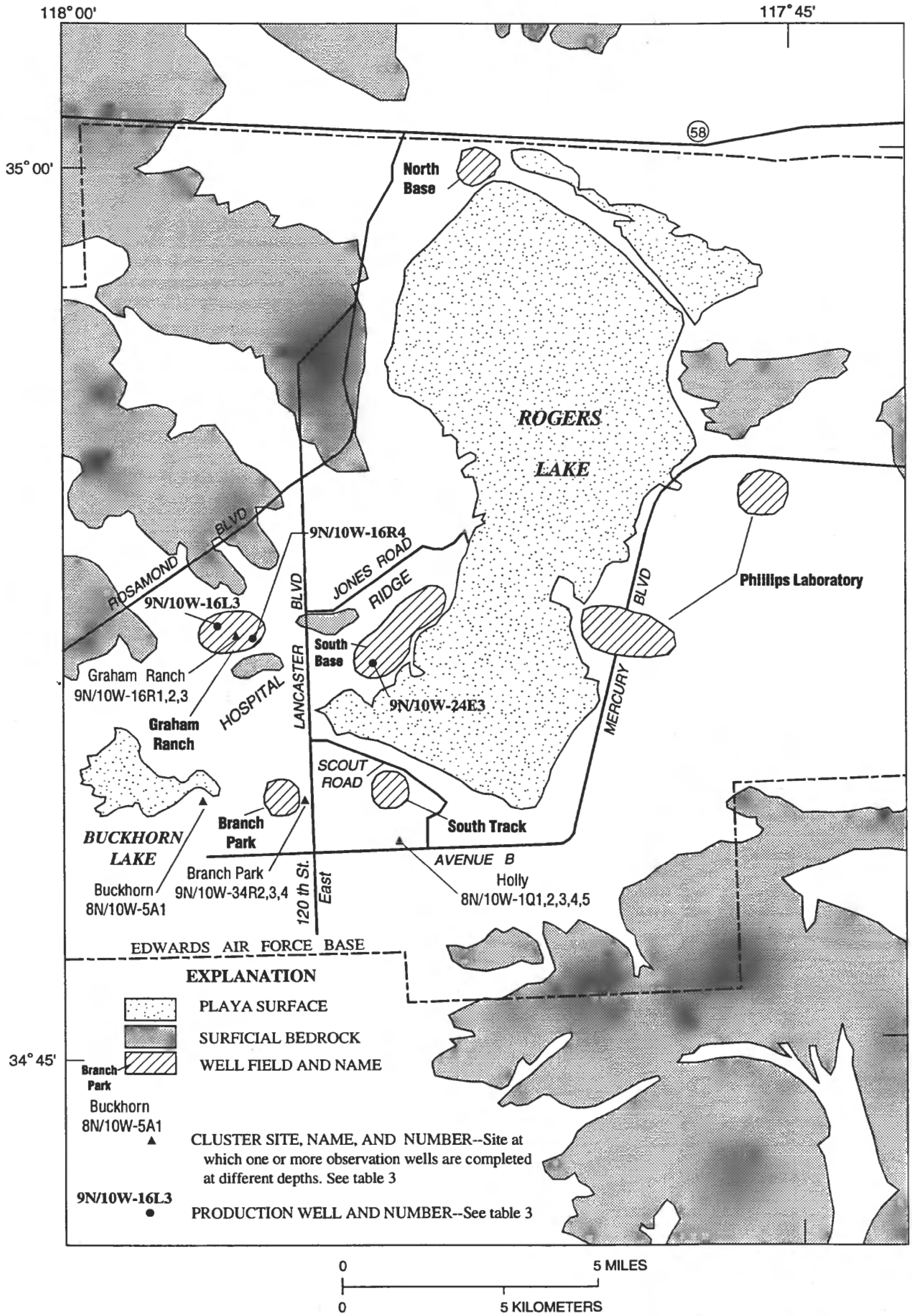

Figure 8. Location of well fields and cluster sites on Edwards Air Force Base.

PWS-0194-0021

Table 3. Construction data for wells completed in 1989 and 1990 on Edwards Air Force Base

[Altitude of land surface in feet above sea level. Primary use of well: Obs, observation well; Wtr, water-supply well. Depth drilled, casing depth, and gravel pack in feet below land surface. Type of finish: Grvl, gravel pack; Open, open hole. Screened interval and initial water level in feet below land surface. in., inch]

Site name and State well No.	Local well name	Altitude of land surface	Primary use of well	Depth drilled	Date of construction	Casing Diameter (in.)	Casing Depth	Gravel pack	Type of finish	Screened interval	Initial water level	Date of measurement
Buckhorn												
8N/10W- 5A1	BH1	2,287.2	Obs	958	10-31-89	2	947	884 - 947	Grvl	897 - 927	129.65	1-31-90
Branch Park												
9N/10W- 34R2	BP1	2,290.3	Obs	953	12-07-89	2	838	782 - 940	Grvl	788 - 808	136.76	2-06-90
34R3[1]	BP2	2,290.4	Obs	550	12-07-89	2	520	475 - 515	Grvl	480 - 510	136.08	2-06-90
34R4[1]	BP3	2,290.4	Obs	550	12-07-89	2	250	205 - 245	Grvl	210 - 240	136.08	2-06-90
Holly												
8N/10W- 1Q1	HO1	2,301.8	Obs	1,075	2-23-90	2	1,023	970 - 1,075	Grvl	980 - 1,010	147.37	5-09-90
1Q2[1]	HO2	2,301.7	Obs	1,107	3-01-90	3	643	600 - 640	Grvl	605 - 635	146.87	5-10-90
1Q3[1]	HO3	2,301.7	Obs	1,107	3-01-90	2	475	425 - 465	Grvl	430 - 460	145.46	5-10-90
1Q4[1]	HO4	2,301.7	Obs	1,107	3-01-90	2	130	80 - 120	Grvl	85 - 115	51.98	5-10-90
1Q5[2]	HO5	2,301.7	Obs	840	3-01-90	6	810	--	Open	--	--	--
Graham Ranch												
9N/10W- 16R1	GR1	2,315	Obs	965	11-12-89	2	840	790 - 840	Grvl	800 - 830	100.67	3-16-90
16R2[1]	GR2	2,315	Obs	650	11-12-89	2	584	485 - 580	Grvl	494 - 564	101.19	3-16-90
16R3[1]	GR3	2,315	Obs	650	11-12-89	2	360	290 - 350	Grvl	300 - 340	101.59	3-16-90
Graham Ranch well field												
9N/10W- 16L3	C-4 exploration well	2,325	Obs	270	8-31-89	16	270	50 - 270	Grvl	130 - 260	111.50	1-05-90
9N/10W- 16R4	C-4 production well	2,308.4	Wtr	709	6-30-90	16	700	0 - 702	Grvl	290 - 690	[3]110	4-15-90
South Base well field												
9N/10W- 24E3	S-7 production well	2,275	Wtr	706	8-03-89	16	700	0 - 700	Grvl	290 - 690	[4]140	8-03-89

[1]Clustered wells.
[2]Extensometer.
[3]Approximated from acoustic log.
[4]From driller's log.

PWS-0194-0022

from vertically adjacent screened intervals by bentonite grout placed in the annular space. At the Buckhorn site, one borehole was drilled and a single well 8N/10W-5A1, screened from 897 to 927 ft, was completed in it. Two boreholes were drilled at Branch Park, a single well 9N/10W-34R2 screened from 788 to 808 ft below land surface was completed in one of the boreholes and two cluster wells, one screened from 480 to 510 ft (9N/10W-34R3) and the other from 210 to 240 ft (9N/10W-34R4) were completed in the second borehole. Three boreholes were drilled at the Holly site. A single well, 8N/10W-1Q1, screened from 980 to 1,010 ft, was completed in one borehole. Three cluster wells, one screened from 605 to 635 ft (8N/10W-1Q2), the second from 430 to 460 ft (8N/10W-1Q3), and the third from 85 to 115 ft (8N/10W-1Q4), were completed in the second borehole. An extensometer was installed in the third borehole, 8N/10W-1Q5. The extensometer measures aquifer-system compaction in the interval from 15 to about 840 ft. Construction and operation of the Holly extensometer are further discussed by Blodgett and Williams (1992). At the Graham Ranch site, two boreholes were drilled. In the first borehole, a single well 9N/10W-16R1 was constructed with a screened interval from 800 to 830 ft. In the other borehole, two cluster wells were completed; one was screened from 494 to 564 ft (9N/10W-16R2) and the other from 300 to 340 ft (9N/10W-16R3). Each of the boreholes drilled by EAFB were completed with large diameter casings, long screen intervals, and gravel packs from the bottom of the hole to near land surface (table 3).

LITHOLOGIC LOGS

Lithologic logs were made of subsurface materials from drill cuttings collected at the surface during the drilling of the deepest borehole at Buckhorn, Branch Park, and Graham Ranch sites and the intermediate borehole at the Holly site (figs. 8 and 9*A*-*D*). Lithologic logs also were made during the drilling of three base boreholes, 9N/10W-16L3, 9N/10W-16R4, and 9N/10W-24E3 (figs. 9*E*-*G*).

The lithologic logs indicate that subsurface materials are largely heterogeneous arkosic alluvium consisting of varying thicknesses of interbedded clay, silt, sand, and gravel (figs. 9*A*-*G*). The only continuous horizons distinguishable from site to site on the basis of the drill cuttings were the brown, green, greenish-gray, and gray clays in the upper sections of the boreholes at the Buckhorn, Branch Park, and Holly sites (fig. 8).

Bottom-hole cores were collected from seven of the boreholes using a 10-foot core barrel. These cores, described in table 4, represent a small part of the stratigraphy of the sediments filling the basin in Antelope Valley, yet they delineate the variability, texture, composition, and degree of consolidation of the sampled horizons in the ground-water basin.

BOREHOLE GEOPHYSICS

Borehole-geophysical surveys were conducted at each of the four cluster sites (figs. 8, 9*A*-9*D*). EAFB supplied geophysical-log data for the three new production wells (figs. 8, 9*E*-9*G*). The surveys consisted of a set of four electric logs: spontaneous potential, 16- and 64-inch normal resistivity, and guard (focused) resistivity, in addition to natural gamma, acoustic, and caliper logs. Borehole-geophysical data were collected from the deepest borehole at each site except where noted. Acoustic surveys were not done at the Holly site, and only a partial acoustic log was done at the Branch Park site due to obstructions in the deepest borehole.

Electric logs measure the electrical properties of the formation around the borehole, the fluid in the formation, and the depth of borehole. Spontaneous potential (SP) and normal resistivity logs are used to distinguish between fine-grained sediments, silts and clays, and coarser grained sand and gravel (figs. 9*A*-*G*). For clays, the SP log had a positive deflection towards the right side of the scale; however, the resistivity log had a relatively negative deflection toward the left side of the scale. Sand and gravel beds have a negative deflection toward the left on the SP log and the resistivity logs have a high resistivity response toward the right side of the scale. A negative SP response with low resistivity generally indicates brackish water with a high dissolved-solids concentration. Guard resistivity is similar to the normal resistivity except the measurement is focused on a smaller interval thickness measuring discrete changes in resistivity, and capable of detecting thin layers in the section. The natural gamma log measures the amount of gamma emission from materials that have relatively high concentrations of potassium-40, uranium-238, uranium-235, and thorium-232. Clays, as well as feldspar-rich gravel, generally have higher concentrations of potassium-40. The acoustic log measures the velocity of an acoustic pulse between a transmitter and a receiver on the probe. The acoustic log gives an indication of the degree of consolidation of the formation, an approximate location of the water table, and is useful in the

A.

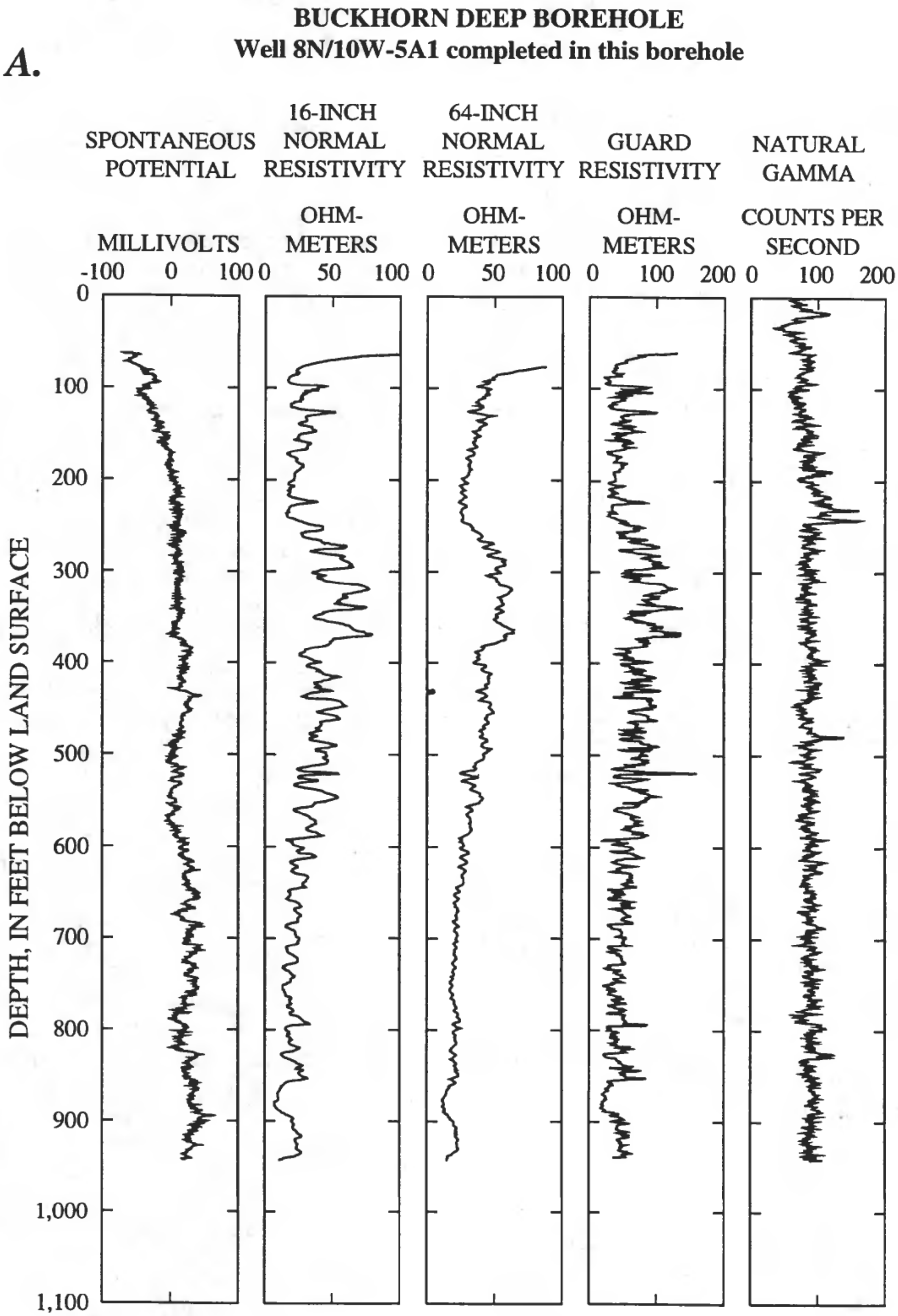

Figure 9. Geophysical and lithologic logs for boreholes drilled on Edwards Air Force Base during 1989 and 1990.

PWS-0194-0024

BUCKHORN DEEP BOREHOLE
Well 8N/10W-5A1 completed in this borehole

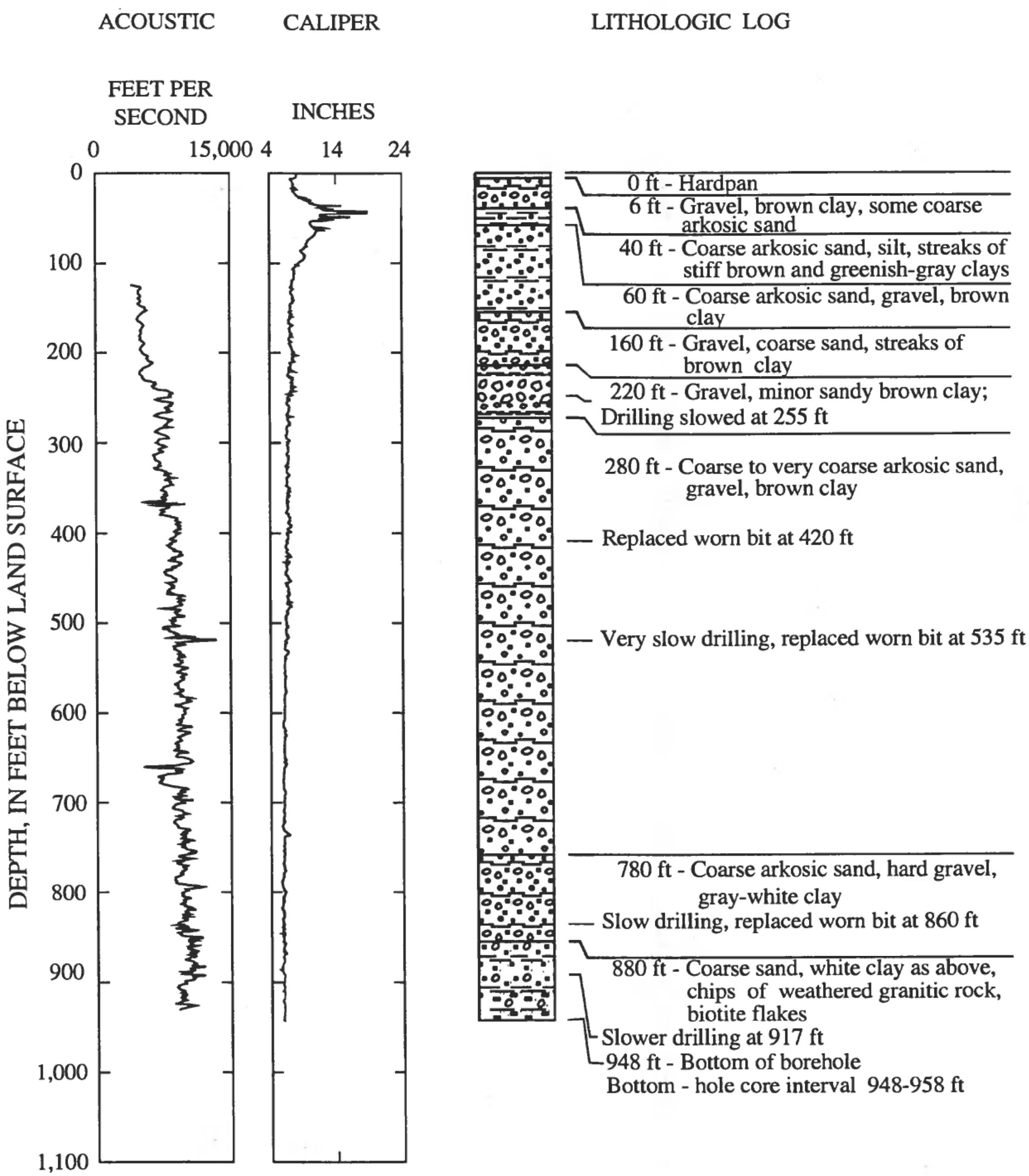

Figure 9. Geophysical and lithologic logs for boreholes drilled on Edwards Air Force Base during 1989 and 1990--*Continued.*

PWS-0194-0025

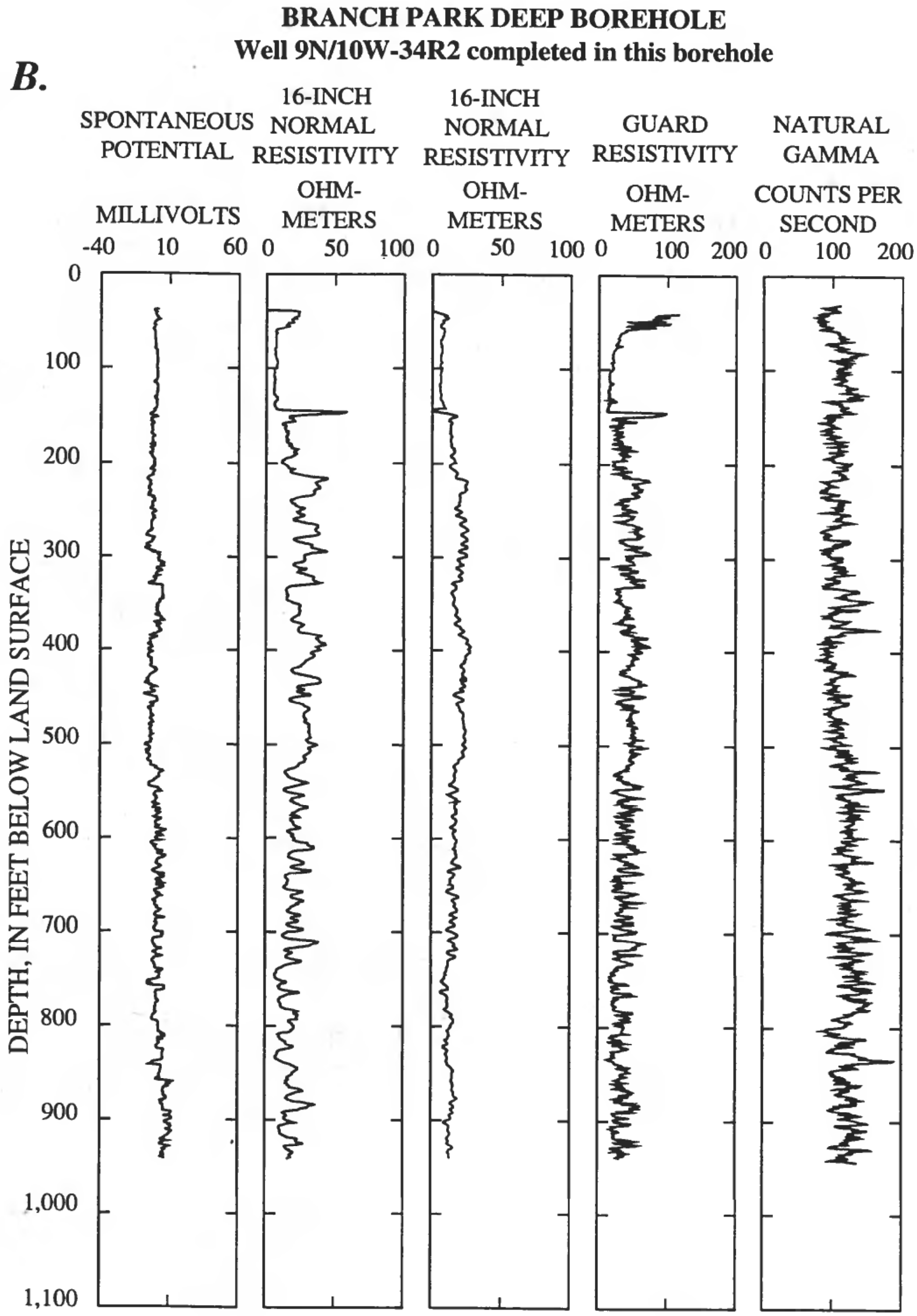

Figure 9. Geophysical and lithologic logs for boreholes drilled on Edwards Air Force Base during 1989 and 1990--*Continued.*

PWS-0194-0026

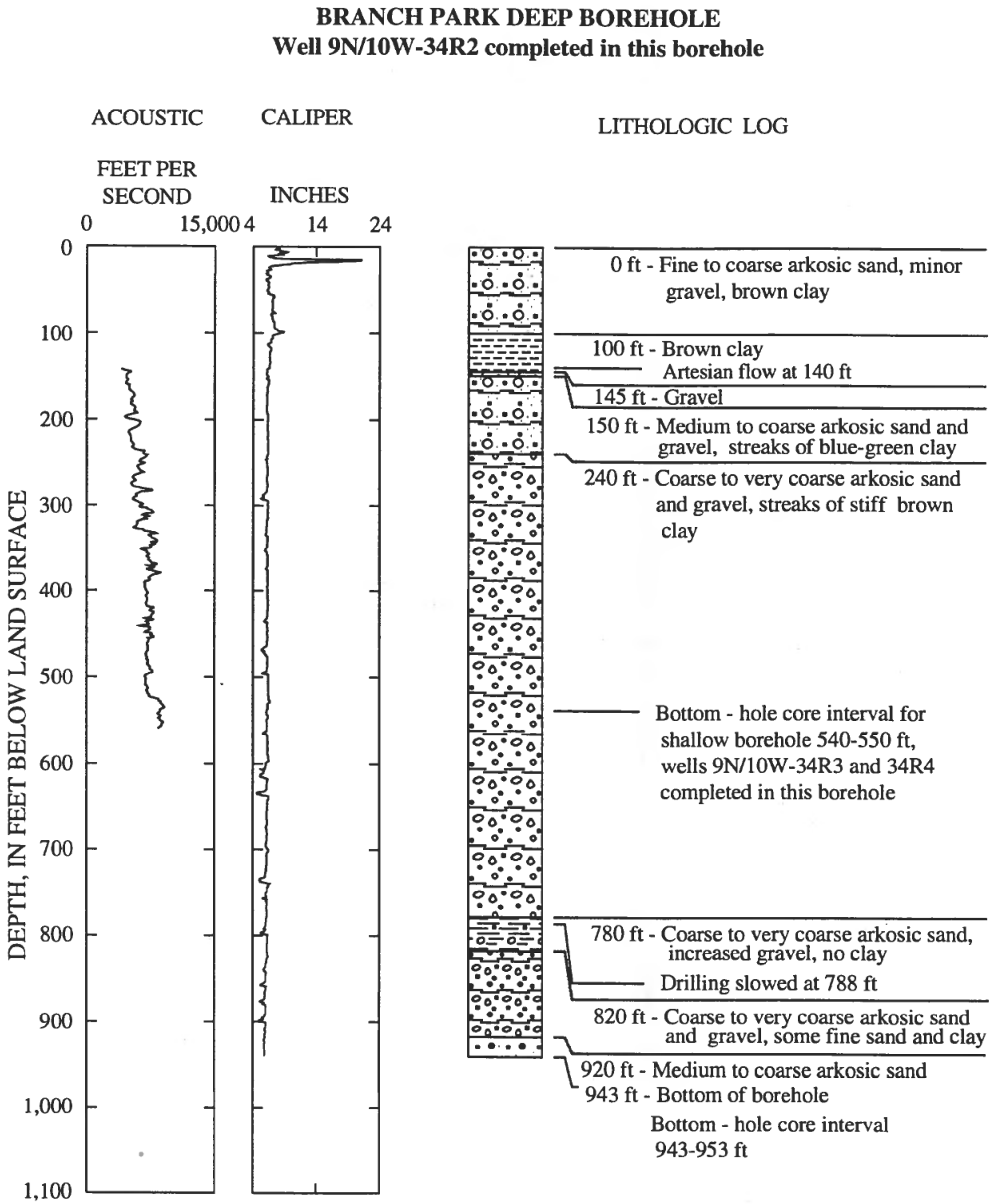

Figure 9. Geophysical and lithologic logs for boreholes drilled on Edwards Air Force Base during 1989 and 1990--*Continued.*

PWS-0194-0027

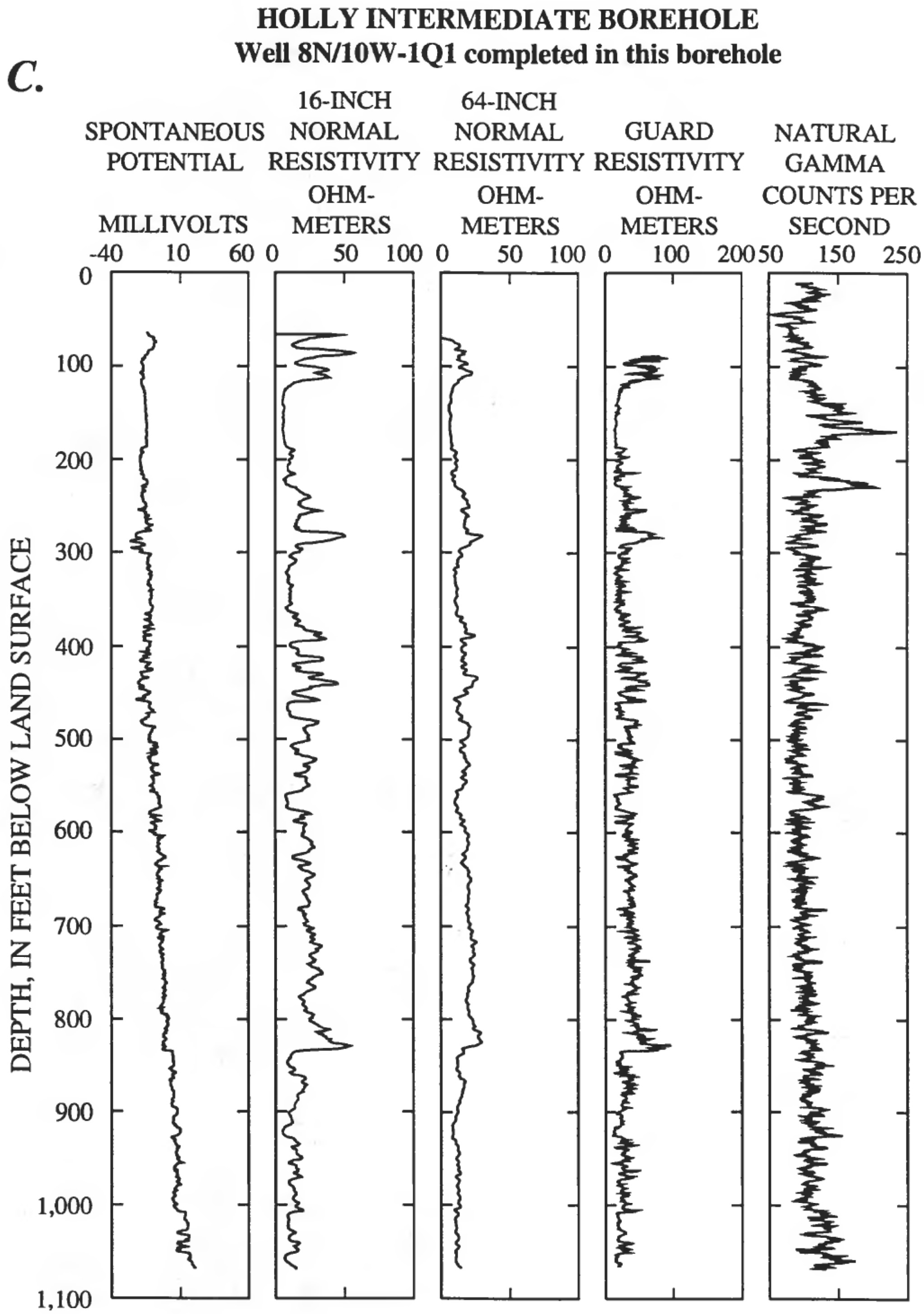

Figure 9. Geophysical and lithologic logs for boreholes drilled on Edwards Air Force Base during 1989 and 1990--*Continued.*

PWS-0194-0028

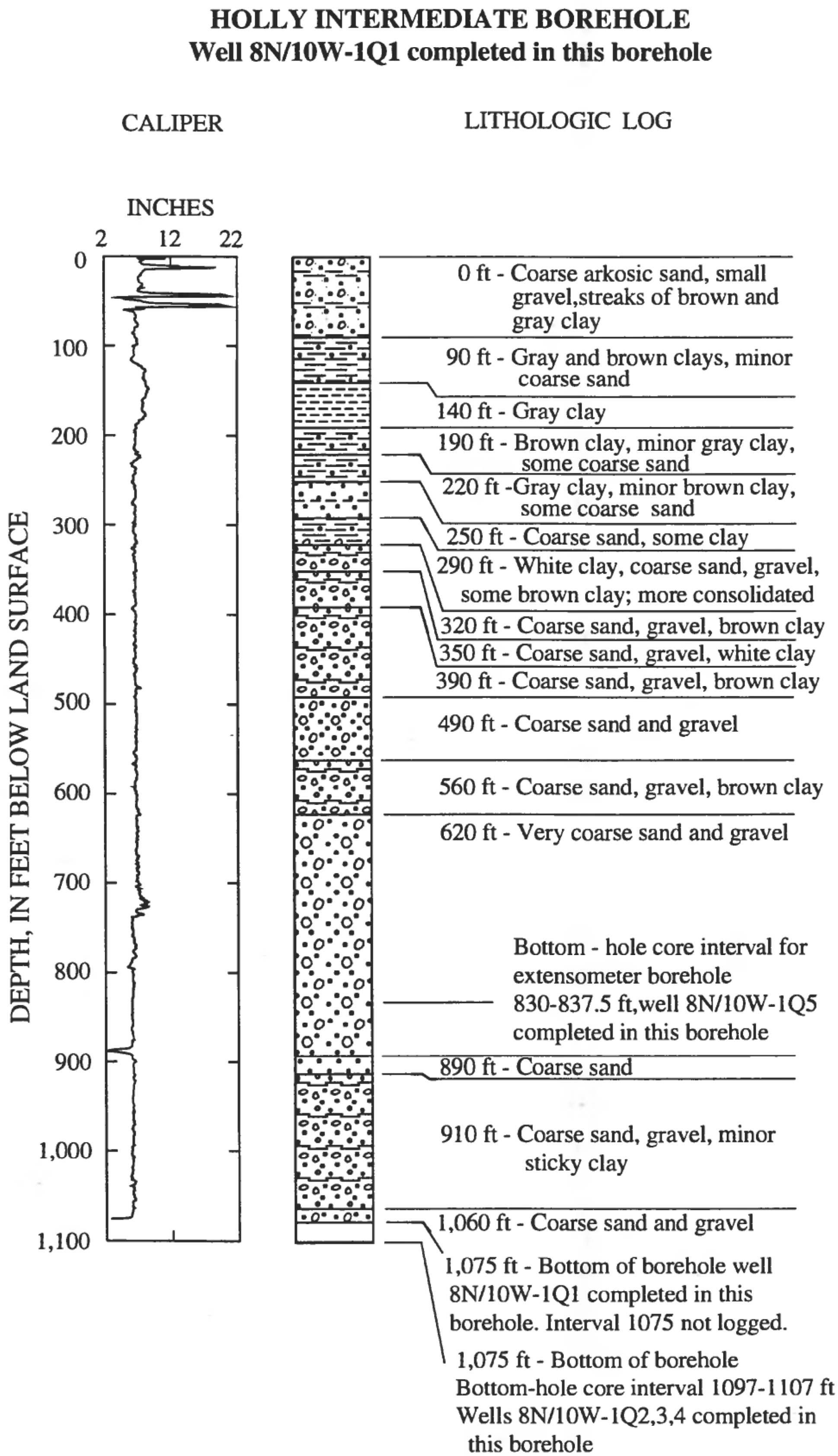

Figure 9. Geophysical and lithologic logs for boreholes drilled on Edwards Air Force Base during 1989 and 1990--*Continued.*

PWS-0194-0029

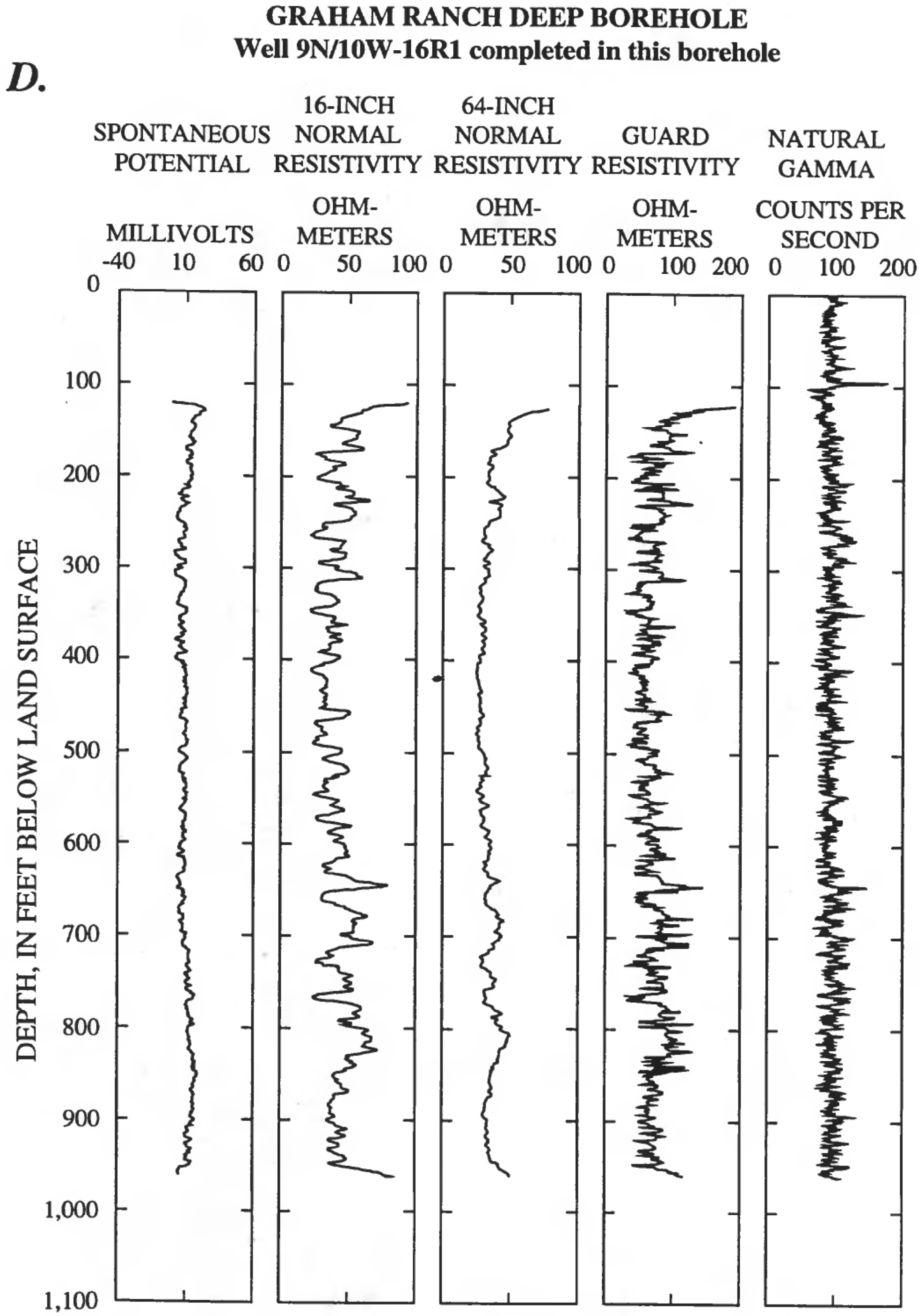

Figure 9. Geophysical and lithologic logs for boreholes drilled on Edwards Air Force Base during 1989 and 1990--*Continued.*

PWS-0194-0030

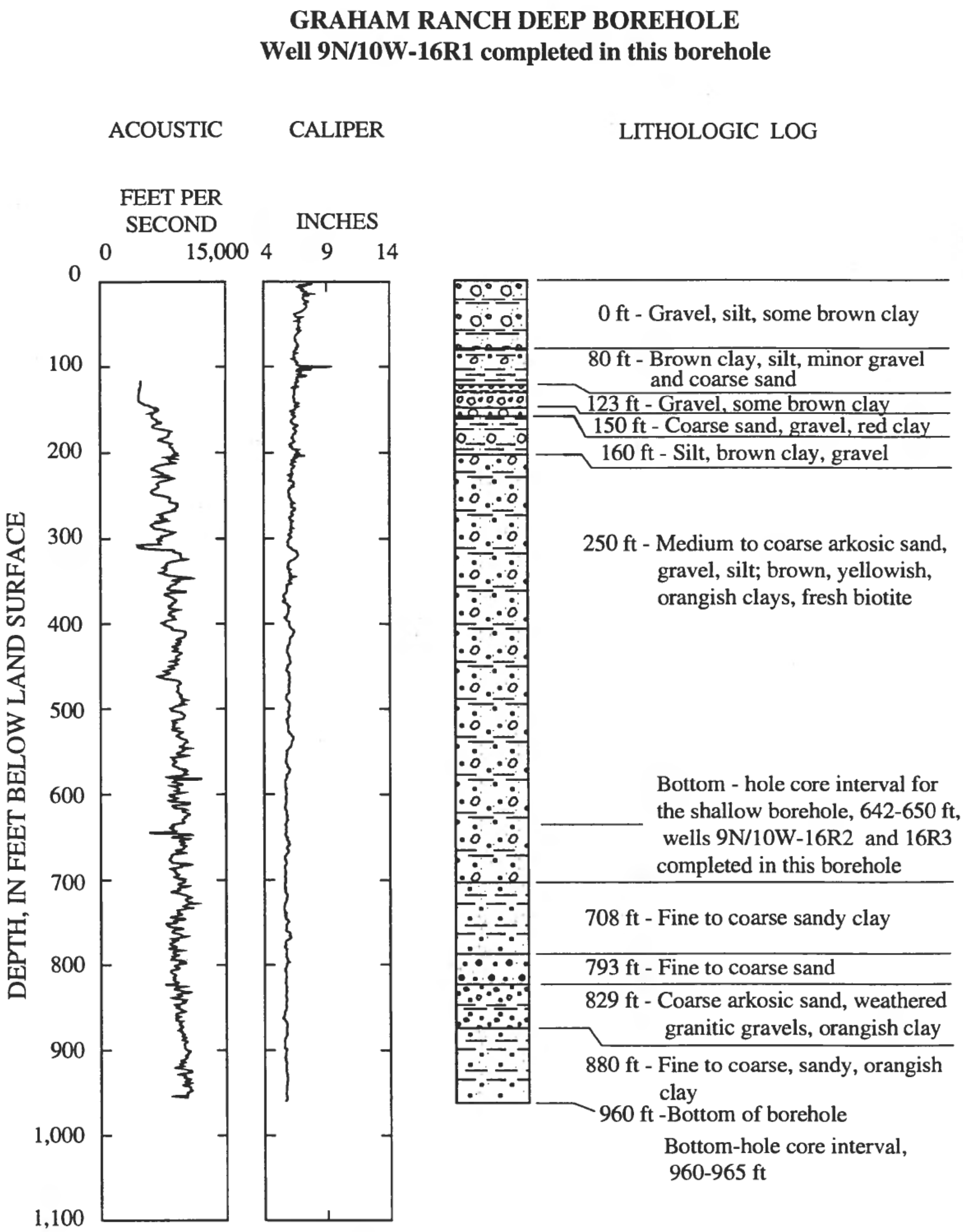

Figure 9. Geophysical and lithologic logs for boreholes drilled on Edwards Air Force Base during 1989 and 1990--*Continued.*

PWS-0194-0031

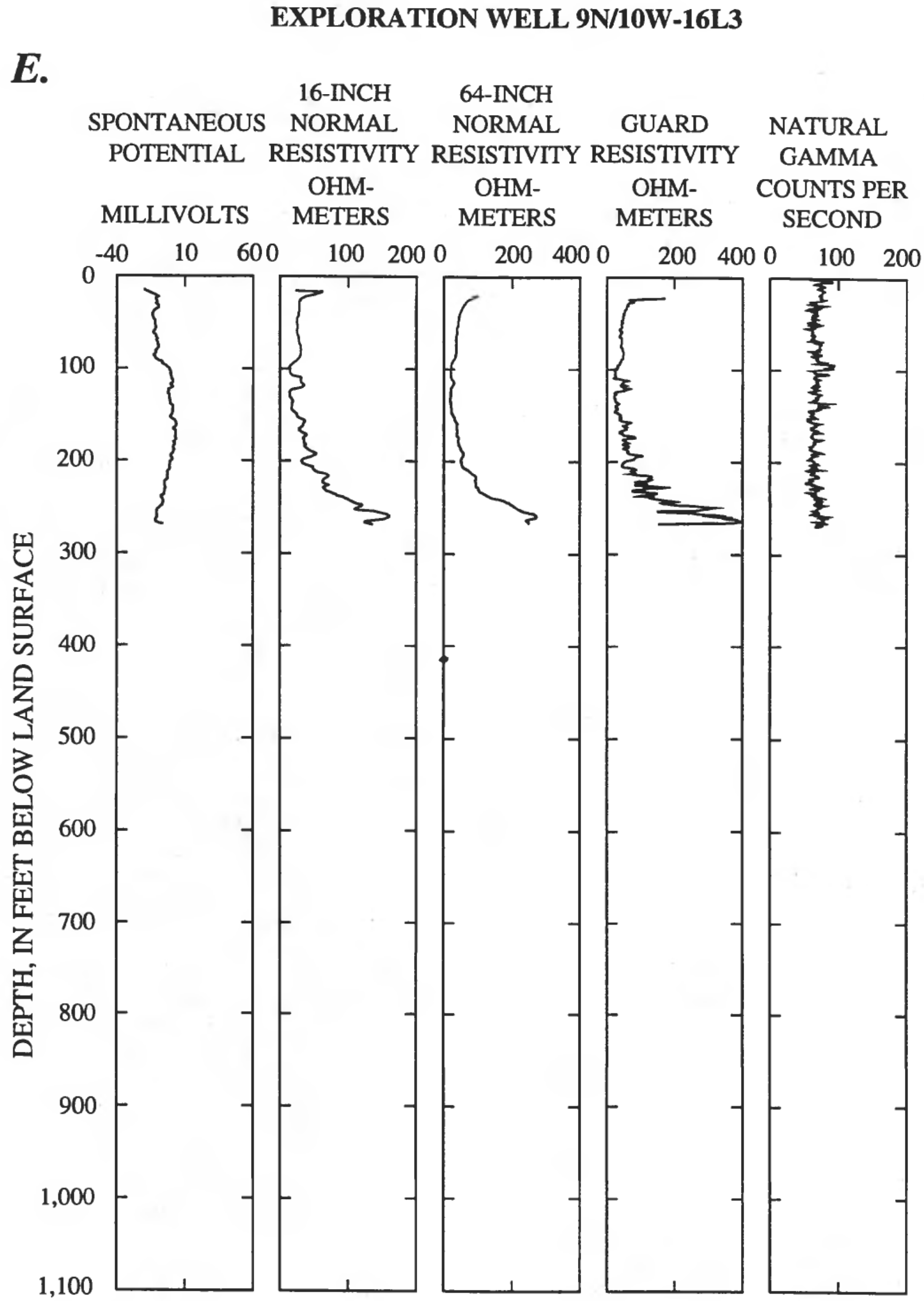

Figure 9. Geophysical and lithologic logs for boreholes drilled on Edwards Air Force Base during 1989 and 1990--*Continued.*

PWS-0194-0032

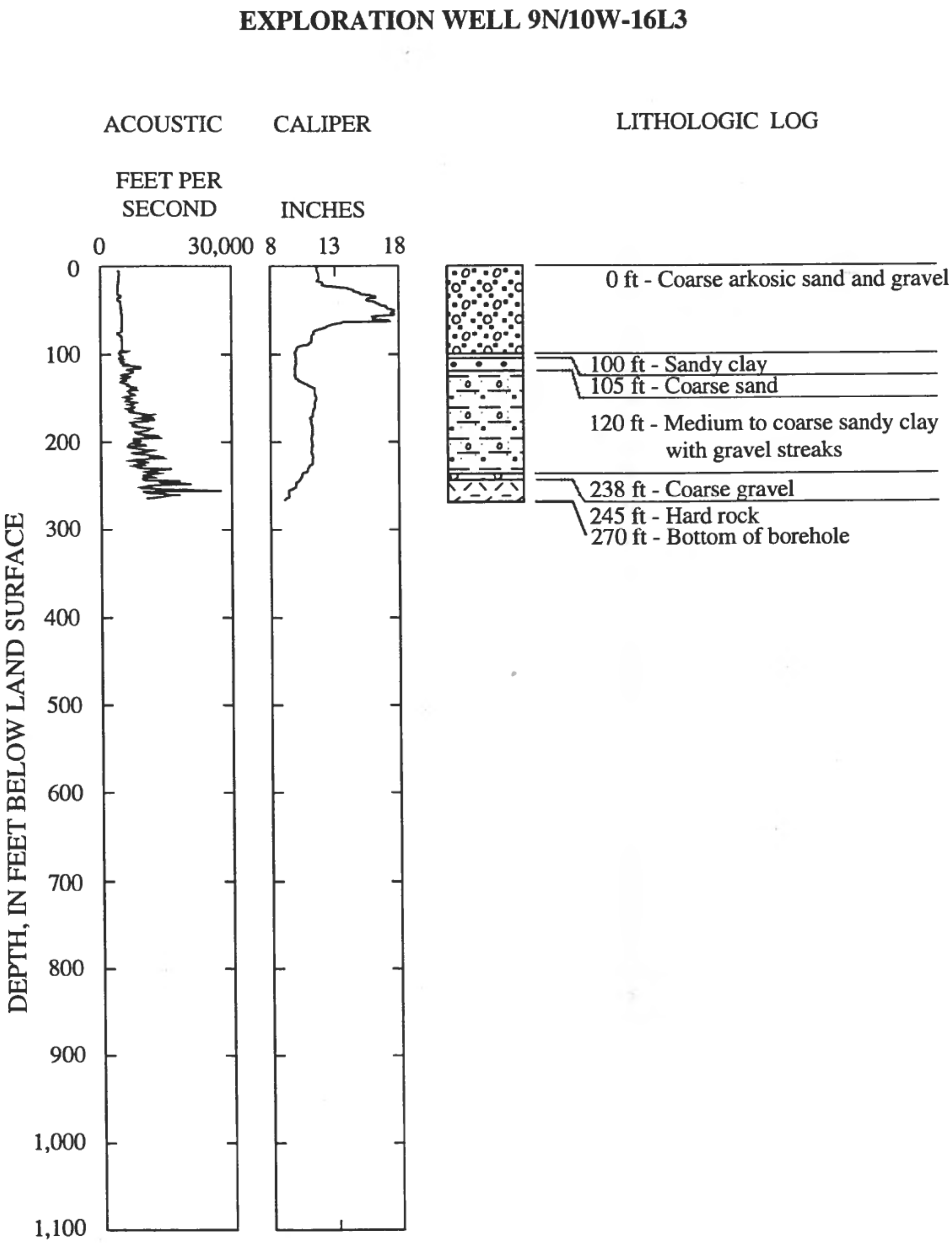

Figure 9. Geophysical and lithologic logs for boreholes drilled on Edwards Air Force Base during 1989 and 1990--*Continued.*

PWS-0194-0033

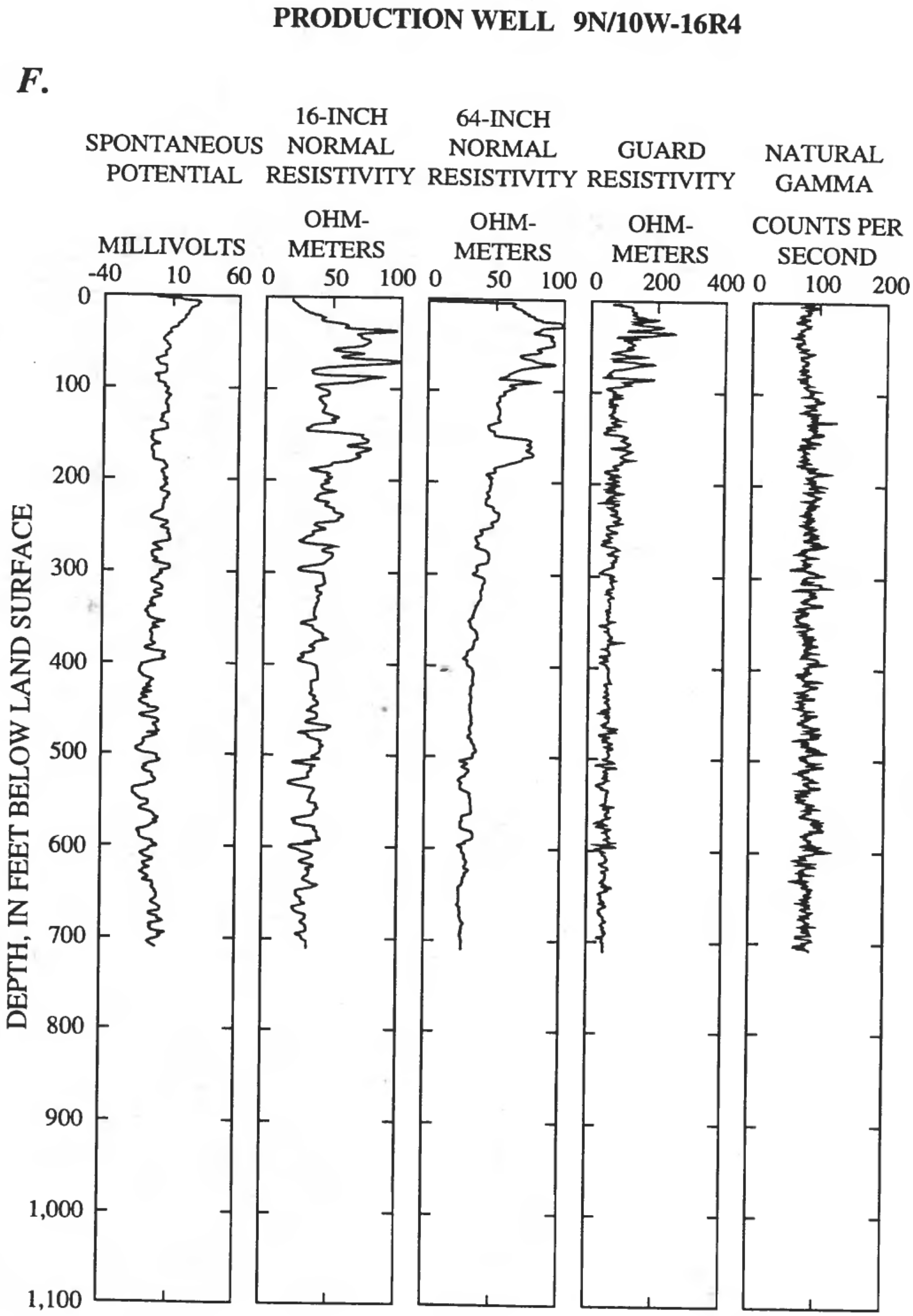

Figure 9. Geophysical and lithologic logs for boreholes drilled on Edwards Air Force Base during 1989 and 1990--*Continued.*

PWS-0194-0034

PRODUCTION WELL 9N/10W-16R4

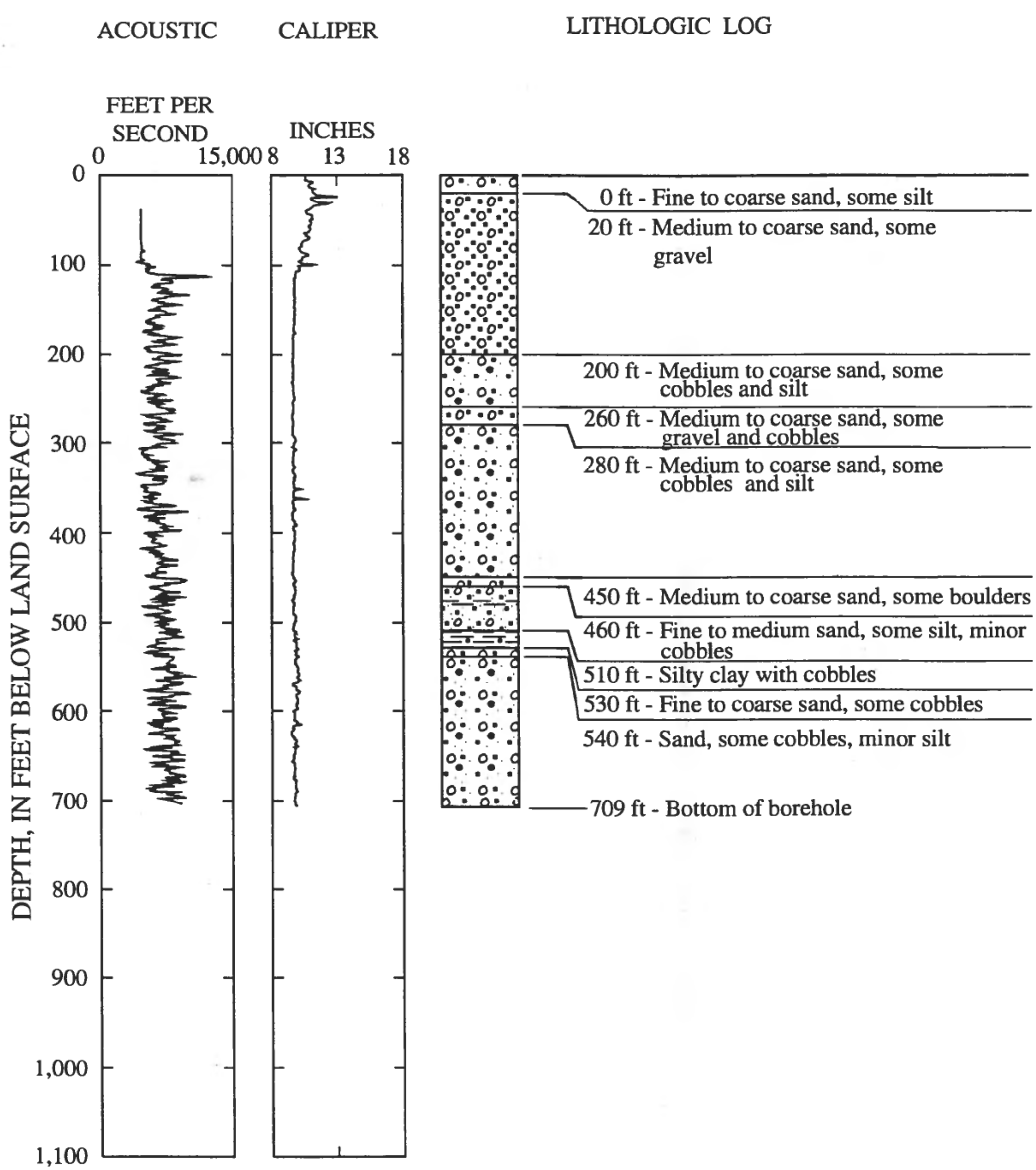

Figure 9. Geophysical and lithologic logs for boreholes drilled on Edwards Air Force Base during 1989 and 1990--*Continued.*

PWS-0194-0035

G.

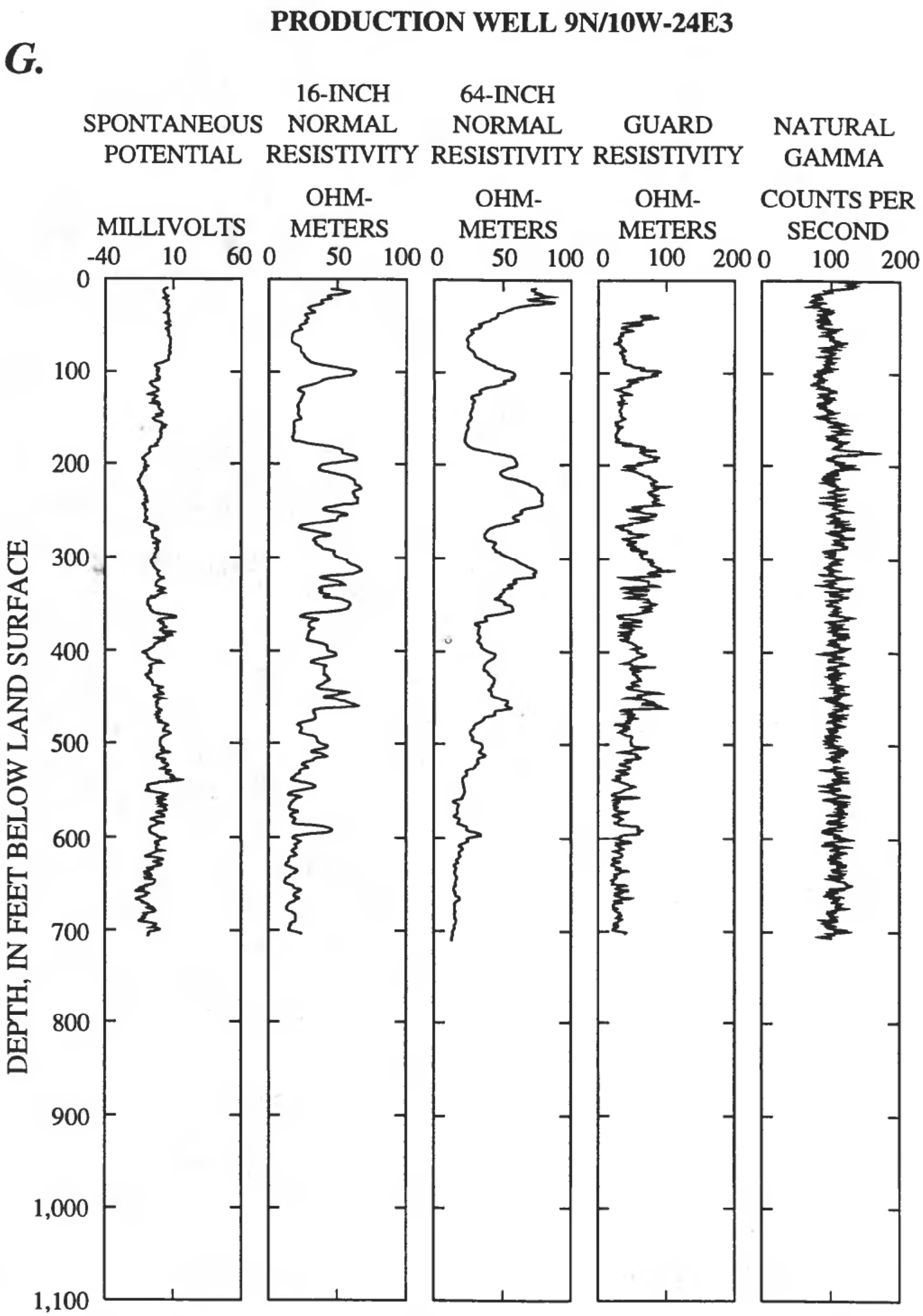

Figure 9. Geophysical and lithologic logs for boreholes drilled on Edwards Air Force Base during 1989 and 1990--*Continued.*

PWS-0194-0036

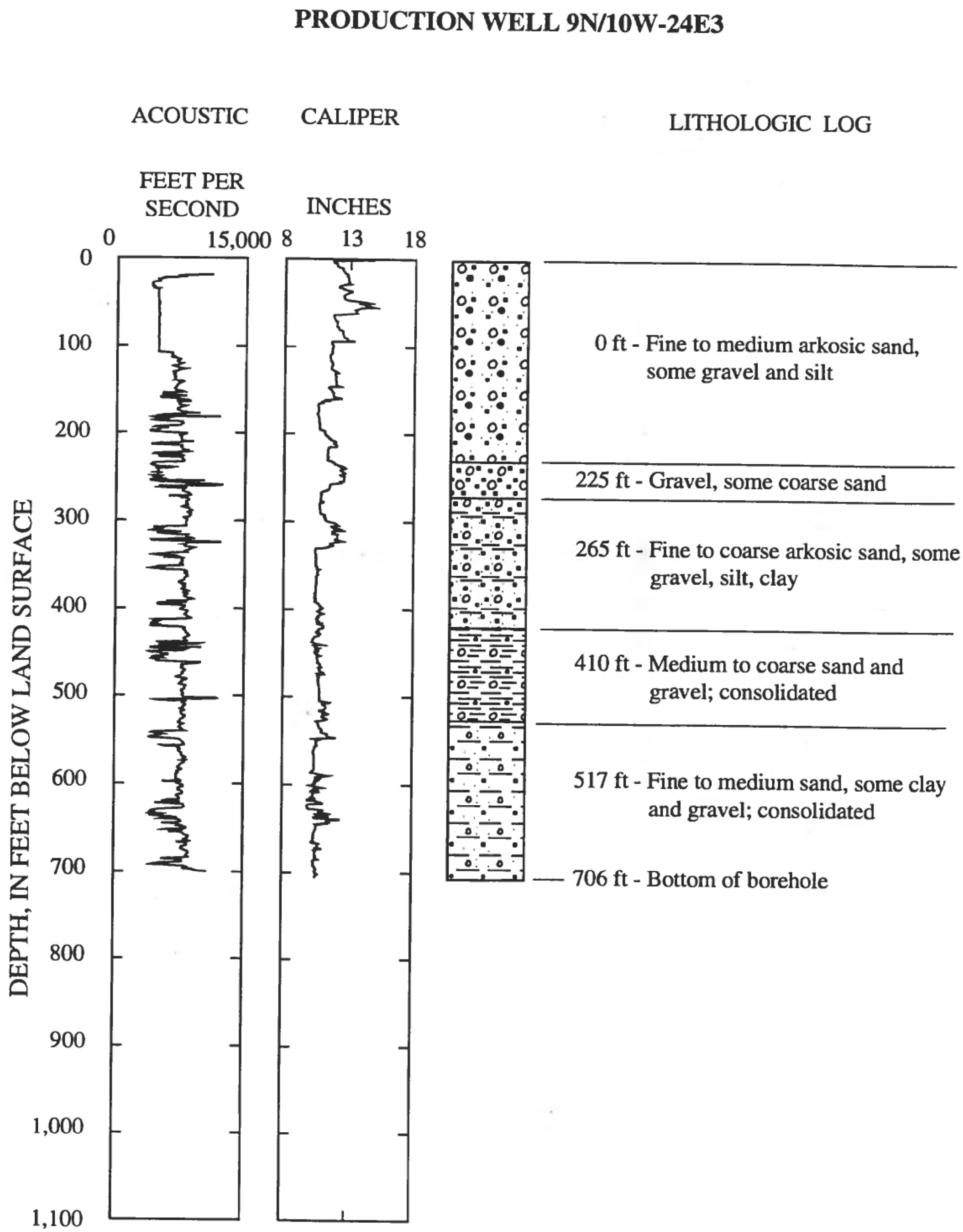

Figure 9. Geophysical and lithologic logs for boreholes drilled on Edwards Air Force Base during 1989 and 1990--*Continued.*

PWS-0194-0037

Table 4. Description of cores from boreholes drilled in 1989 and 1990 on Edwards Air Force Base

[Thickness and depth in feet. ft, foot; in., inch; ohm-m, ohm-meter]

Core description	Thickness	Depth
Buckhorn deep borehole. Core interval depth, 948-958 ft; 100 percent recovery. Core is a pale tan to medium orange brown, poor to well consolidated with siliceous cement, poorly sorted, frosted fine- to very coarse grained, subangular to very angular, granitic alluvium. Subhorizontal, coring-induced fractures occur randomly throughout the core. Resistivity values are unknown for this bottom hole core. Well 8N/10W-5A1 completed in this borehole.		
Alluvium is dark in color, black mica- and clay-rich, very coarse arkosic sand with occasional granitic and aplite pebbles to 0.4 in.	2	948
Upper alluvium grades into gravelly sand with decreased mica and clay, and increased silt. Clasts generally range from 0.1 to 0.2 in. with occasional pebbles from 0.7 to 3.1 in.	6.5	950
Core barrel penetrated a large, highly altered granitic cobble, 15 cm thick. Texture generally is equigranular with anhedral to euhedral grains of gray quartz, pink microcline, white altered orthocase, and black book biotite. Two induced fractures separate the cobble into three pieces.	0.5	956.5
Below the cobble, the alluvium changes into a light colored, sericitic-rich, poorly sorted, poorly consolidated, pebbly sand. The granitic clasts range from 0.6 to 2.0 in.	1	957
Branch Park deep borehole. Core interval depth, 943-953 ft; 50 percent recovery. Core is light grayish brown to medium grayish brown, of fine to medium coarse grained, angular to subrounded, arkosic alluvium that is well consolidated when dry with a siliceous cement, disintegrating when wet. No resistivity values available for this bottom hole core. Well 9N/10W-34R2 completed in this borehole.		
Alternating fine-grained, 6- to 8-inch thick, moderately sorted, pebbly, sandy silt and 1- to 3-inch, fine gravel layers.	4	943
Same as above with a higher clay content.	1	947
Branch Park shallow borehole. Core interval depth, 540-550 ft; 100 percent recovery. Core is medium grayish tan to medium grayish brown, well consolidated, poorly to moderately sorted arkosic alluvium with a siliceous cement. The 16-inch normal resistivity log for this borehole (fig. 9) shows that the 540- to 550-foot interval has resistivity values ranging from 12 to 19 ohm-m. Wells 9N/10W-34R3 and 34R4 were completed in this borehole.		
Alluvium is massive, with fine- to medium-grained, subangular to subrounded, gray quartz, white and pink feldspars, and bronze biotite grains and occasional quartz monzonite gravels 0.4 to 2.4 in. in diameter.	2	540
Gradation into a fine to coarse, subangular to rounded, alternating matrix- and clast-supported sandy conglomerate, ending with a thin 1-inch, thick gravel layer.	2.5	542
Alluvium is massive, finer grained, with few clasts larger than 0.2 in., and an increase in fine, black biotite.	5.5	544.5

Table 4. Description of cores from boreholes drilled in 1989 and 1990 on Edwards Air Force Base--*Continued*

Core description	Thickness	Depth
Holly deep borehole. Core interval depth, 1,097-1,107 ft; 60 percent recovery. Core is highly fractured, highly altered, coarse-grained quartz monzonite bedrock. Wells 8N/10W-1Q2, 1Q3, and 1Q4 completed in this borehole.		
Weathered bedrock fragments to 4.7 in., composed of white, altered feldspars, gray quartz, bronze biotite, and manganese oxide.	2.5	1,097
Decomposed bedrock with mineral composition of white, altered orthoclase, pink microcline, gray quartz, and bronze biotite. Fracture planes in this section show slippage, and limonite staining.	1.5	1,099.5
Pegmatite dike with very angular rock fragments to 1.6 in. of pink microcline and gray quartz.	1	1,101
Same composition and texture as 1,099.5-foot interval.	1	1,102
Holly extensometer borehole. Core interval depth, 830-840 ft; 80 percentage recovery. Core is light tan to light grayish orange, well consolidated when dry with siliceous cement. This core is correlated to the 830- to 837.5-foot interval of the 16-inch normal resistivity log of the Holly intermediate borehole (fig. 9*C*) about 50 ft to the southeast with resistivity values ranging from 14 to 18 ohm-m. This core is similar to the 600-foot zone of the Graham Ranch shallow borehole core. Well 8N/10W-1Q5 completed in this borehole.		
Alternating medium-grained, 6- to 8-inch thick, pebbly, sandy arkosic alluvium and 1- to 4-inch cobble layers. Matrix grains are frosted, angular to rounded, clear quartz, white, altered feldspar, and minor black biotite. Pebbles and cobbles, 5 to 10 percent, are subrounded to rounded, 0.2 to 2.4 in. granitoids with color index of 1-3, dense red, green, and purplish rhyolites, and white, banded rhyolites.	7.5	830
Gradation to a sandy silt with same composition as above.	0.5	837.5
Graham Ranch deep borehole. Core interval depth, 960-965 ft; 80 percent recovery. Well 9N/10W-16R1 completed in this borehole.		
Core is a light tan to light grayish tan, composed of poorly sorted, massive, coarse sandy arkosic alluvium with a fine-grained siliceous cementing matrix and occasional gravels. The mineral composition is subangular to subrounded, coarse sand of gray quartz, pink and white feldspars, and black biotite. Gravels are angular to well rounded, white quartz monzonite, pink granite, and pink and gray pegmatite clasts from 0.8 to 2.4 in. in diameter. Resistivity values are unknown for this bottom hole core. Well 9N/10W-16R1 completed in this borehole.	4	960
Graham Ranch shallow borehole. Core interval depth, 642-650 ft; 100 percent recovery. Core consists of light tan to grayish orange brown, poorly sorted, massive, angular to well rounded, medium- to coarse-grained arkosic alluvium. The material is well consolidated when dry, having a siliceous cement, but disintegrates when saturated. Occasional subangular to rounded, granitoid, aplite, and pegmatite gravels ranging from 0.4 to 1.6 in. throughout the core. Correlating this interval to the 16-inch normal resistivity log of the nearby deep borehole (fig. 9*D*), the resistivity values range from 33 to 38 ohm-m. Wells 9N/10W-16R2 and 16R3 completed in this borehole.		
Alluvium is darker in color and clay-rich.	1	642
Gradation into material lighter in color and rich in white, altered orthoclase.	7	643

identification of contrasting lithologic units that may cause seismic refractions along the contact. The caliper logs show the diameter of the borehole with depth.

The logs for the deep borehole at the Buckhorn site (fig. 9*A*) suggest unsaturated and saturated, unconsolidated, very fine-, fine-, and medium-grained alluvial sediments from the surface to about 240 ft below land surface; poor to moderately consolidated, medium- and coarse-grained beds to 540 ft; and moderate to moderately well-consolidated, clay-rich, fine-, medium-, and coarse-grained beds to the bottom of the borehole. At the Branch Park site, 2 mi to the east of the Buckhorn site (fig. 8), the logs for the deep borehole (fig. 9*B*) indicate unsaturated and saturated, unconsolidated to moderately consolidated, relatively thick sequences of very fine-, fine-, medium-, and coarse-grained sediments from the surface to about 530 ft below land surface, and moderate to moderately well-consolidated, narrower beds of fine-, medium-, and coarse-grained sediments to the bottom of the borehole. The logs for the intermediate borehole at the Holly site (fig. 9*C*) indicate unsaturated and saturated, unconsolidated to moderately well-consolidated, interbedded, very fine-, fine-, medium-, and coarse-grained alluvial sediments from the surface to about 838 ft below land surface. At depths greater than 838 ft to the bottom of the borehole, the logs indicate that the material becomes finer grained and perhaps more consolidated.

The borehole geophysical logs for the deep borehole at the Graham Ranch site (fig. 9*D*) indicate varying thicknesses of interbedded, fine-, medium-, and coarse-grained alluvial sediments that are unconsolidated at the surface, becoming more consolidated with depth. At about 770 ft to the bottom of the hole, the formation becomes moderately well- to well-consolidated. The logs for well 9N/10W-16L3 (fig. 9*E*), which is northwest of the Graham Ranch site (fig. 8), show unsaturated, unconsolidated, medium- to coarse-grained alluvium from the surface to about 95 ft below land surface; unsaturated and saturated moderately consolidated, fine- and coarse-grained beds to about 135 ft; poorly consolidated weathered bedrock to about 245 ft; and competent bedrock to the bottom of the borehole. Figure 9*F* illustrates the logs for well 9N/10W-16R4 and shows electrical, gamma, and acoustic responses for bedding thickness, grain-size distribution, and consolidation of the subsurface sediments similar to those for the deep borehole at the Graham Ranch site located just to the west (figs. 8, 9*D*) as in figure 9*D*. The logs illustrated in figure 9*G* for well 9N/10W-24E3 in the South Base well field (fig. 8) indicate unsaturated and saturated, unconsolidated, very fine-, fine-, medium-, and coarse-grained alluvial sediment from the surface to about 360 ft below land surface; poor to moderately consolidated medium- and coarse-grained beds to about 600 ft; and moderately consolidated fine-, medium-, and coarse-grained beds to the bottom of the borehole.

The Buckhorn, Branch Park, Holly sites and well 9N/10W-24E3 are near the southwestern shores of Rogers Lake (fig. 8). Normal resistivity for the subsurface materials at these locations generally range from about 5 ohm-meters (ohm-m) for very fine-grained clays to about 80 ohm-m for coarse-grained gravel (figs. 9*A*, 9*B*, 9*C*, and 9*G*). The Graham Ranch site and wells 9N/10W-16L3 and 9N/10W-16R4 are northwest of the other sites and topographically separated from the valley by Hospital Ridge (fig. 8). The normal resistivity in this area ranges from 15 ohm-m for fine-grained silts and clays to about 80 ohm-m for coarse-grained gravel to about 260 ohm-m for competent bedrock (figs. 9*D*, 9*E*, and 9*F*). The less consolidated sediments have relatively small acoustic velocity values for very fine- and fine-grained clays and silts, and larger acoustic velocity values for medium- and coarse-grained sands and gravel. The logs also indicate that the acoustic velocities generally increase with depth for fine- and coarser-grained sediments suggesting that the sediments become more consolidated, and perhaps less permeable, with depth (figs. 9*A*, 9*B*, 9*D*, 9*E*, 9*F*, and 9*G*).

The upper sections of the geophysical logs for the Branch Park and Holly sites and production well 9N/10W-24E3 show distinctive unconsolidated, very fine-grained layers that correlate with brown, blue-green, and gray clays, based on lithologic logs, (figs. 9*B*, 9*C*, and 9*G*) at depths of about 100 to 250 ft below land surface. Streaks of brown and greenish-gray clays also are present within the upper 200 ft at the Buckhorn site (fig. 9*A*). These clays may be similar to the thick, deeper, blue and green clays described in logs from wells drilled farther south near Redman and Lancaster (Dutcher and others, 1962) and may be part of the lacustrine sediments that separate the principal aquifer from the deeper aquifer in the Antelope Valley (Durbin, 1978). Another very fine- to fine-grained layer is at the 315- to 365-foot interval at the Holly site. The logs for Branch Park and Buckhorn sites indicate a westward facies change at this interval from very fine- and fine-grained sediments to medium- and coarse-grained sediments. Protrusions into the boreholes shown in the Branch Park and Holly borehole caliper logs (figs. 9*B*-9*C*) correspond to fine- to medium-grained layers that probably have a large percentage of very fine-grained matrix composed of expansive clay minerals, such as montmorillonite.

The geophysical logs for the Graham Ranch site and production well 9N/10W-16R4 show a deep sequence of corresponding fine-grained beds interbedded with varying thicknesses of medium- and coarse-grained beds, suggesting deposition of suspended fine-grained sediments over fan-deposit material eroded from adjacent highlands to the north and northwest. These two sites are in close proximity to the shallow exploration well 9N/10W-16L3 that penetrated competent bedrock at about 230 ft below land surface. This indicates that the bedrock plunges very steeply to the south or southeast between these two sites.

SURFACE GEOPHYSICS

Surface geophysical surveys were conducted and analyzed in the following sequence: (1) gravity surveys, (2) seismic-refraction surveys, and (3) vertical electric soundings. The purpose of the surveys was to define the shape and structure of the pre-Tertiary crystalline basement surface, and map the subsurface distribution of fine-grained and coarse-grained sediments in order to identify potential aquifers, and areas where ground-water withdrawals might further exacerbate land-subsidence problems. Because new sources of ground water are being explored in the Graham Ranch area, the focus is on Graham Ranch.

GRAVITY SURVEYS

Gravity surveys measure differences in the acceleration of gravity at the Earth's surface caused by differences in the mass of the material beneath the surface. The differences can be used to indicate the geologic structure and general shape of the basement complex beneath the sedimentary deposits. Because of density variations between bedrock types, isostatic residual gravity maps should not be directly interpreted as indicating the depth to basement complex. In general, a gravity low corresponds to an area with a thick sedimentary section of unconsolidated, hence low-density sediments. A gravity high corresponds to an area with high-density bedrock, whether igneous, metamorphic, or sedimentary, which crops out at the surface or is buried near the surface and covered only by a thin veneer of lower density unconsolidated sediments.

Gravity data at more than 1,100 new gravity stations (Morin and others, (1990) were used to supplement an existing gravity data base (Snyder and others, 1982) and to produce an isostatic residual gravity map of EAFB and vicinity (fig. 10). The gravity map illustrates the location of EAFB with respect to two of the major structural basins, East Antelope and Kramer, that underlie the eastern parts of Antelope Valley. The closed lines of equal isostatic gravity residuals provide an approximate shape of the basins. The East Antelope structural basin is an elongated northeast to southwest oriented trough, the northeast edge of which is beneath the southwestern end of Rogers Lake. A small, crudely triangular-shaped extension of the basin lies beneath the southern one-half of Rogers Lake. The identification of this structure as a separate trough attached to the East Antelope structural basin is a refinement of detail to previous gravity mapping (Mabey, 1960). The northwestern flank of the East Antelope basin is characterized by a steep gravity gradient extending from the middle of Rogers Lake southwestward to near the city of Lancaster. Mabey (1960) inferred the western segment of this steep gradient to be a fault in the pre-Tertiary basement rock now buried by Cenozoic sediments deposited in the basin. Data presented in this report suggest that this inferred fault extends farther east to near Rogers Lake (fig. 2). The interpreted form of the Kramer structural basin, northeast of Rogers Lake, is little changed from that interpreted by Mabey (1960).

Figure 11 shows a larger scale isostatic residual gravity map of the Graham Ranch area. The Graham Ranch area is a flat alluvial surface of very gentle slope extending from a northwest trending valley between the Rosamond and Bissell Hills to the north, to a low, northeast trending, granitic ridge (Dibblee, 1960b), bordering the area on the south and referred to in this report as Hospital Ridge. Separated from the main part of Antelope Valley by the granitic rocks of Hospital Ridge, the Graham Ranch area lies 30 ft higher than the playa surfaces south of the ridge. The gravity contours (fig. 11) suggest the existence of a small west-to-east oriented basin underlying the Graham Ranch area. The isostatic residual gravity decreases rapidly from -10 mgals (milligals) at the Bissell Hills to -22 mgals at Hospital Ridge, both mapped as quartz monzonite.

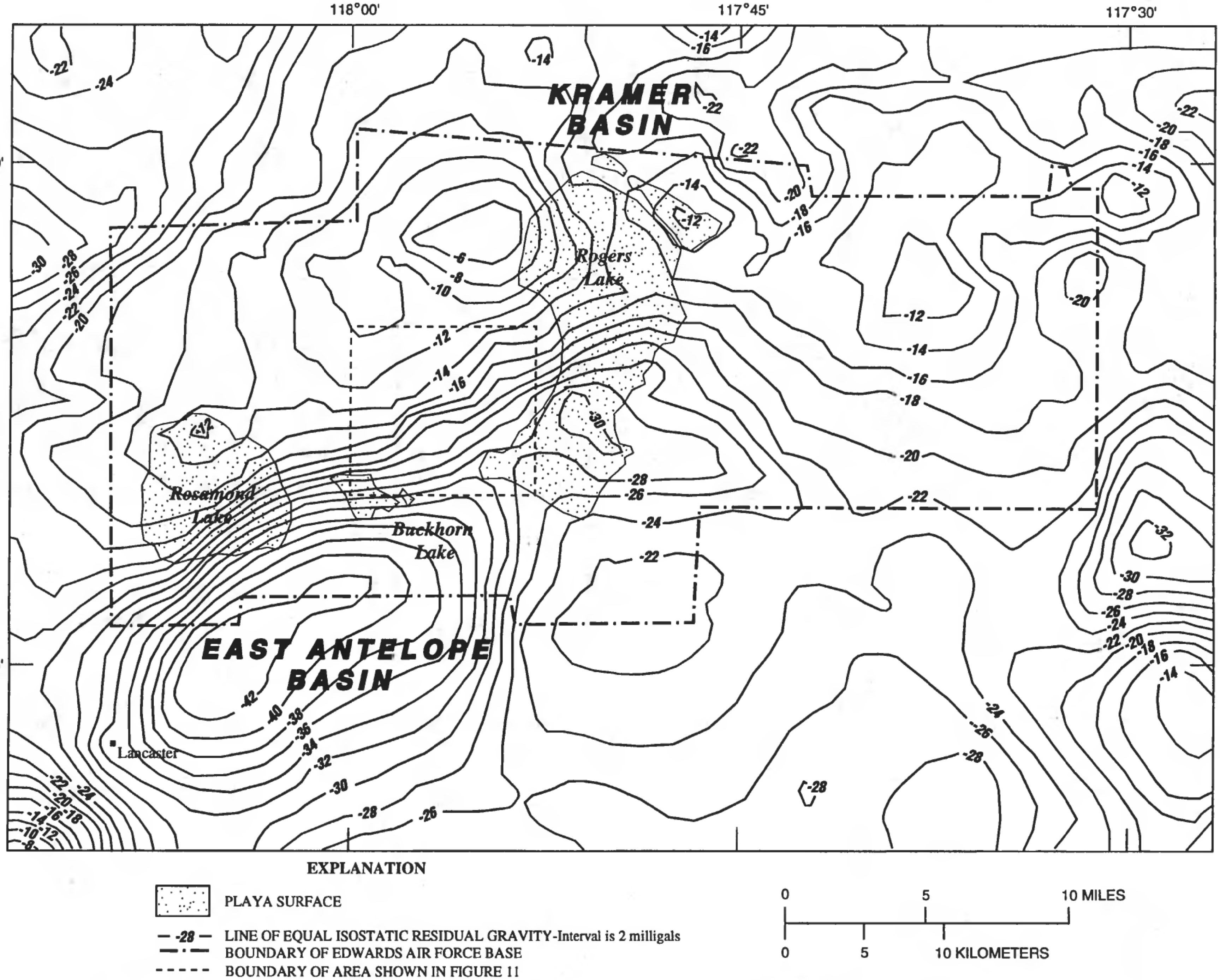

Figure 10. Isostatic residual gravity for Edwards Air Force Base and immediate vicinity. Modified from R.C. Jachens, U.S. Geological Survey, written commun., 1989.

PWS-0194-0042

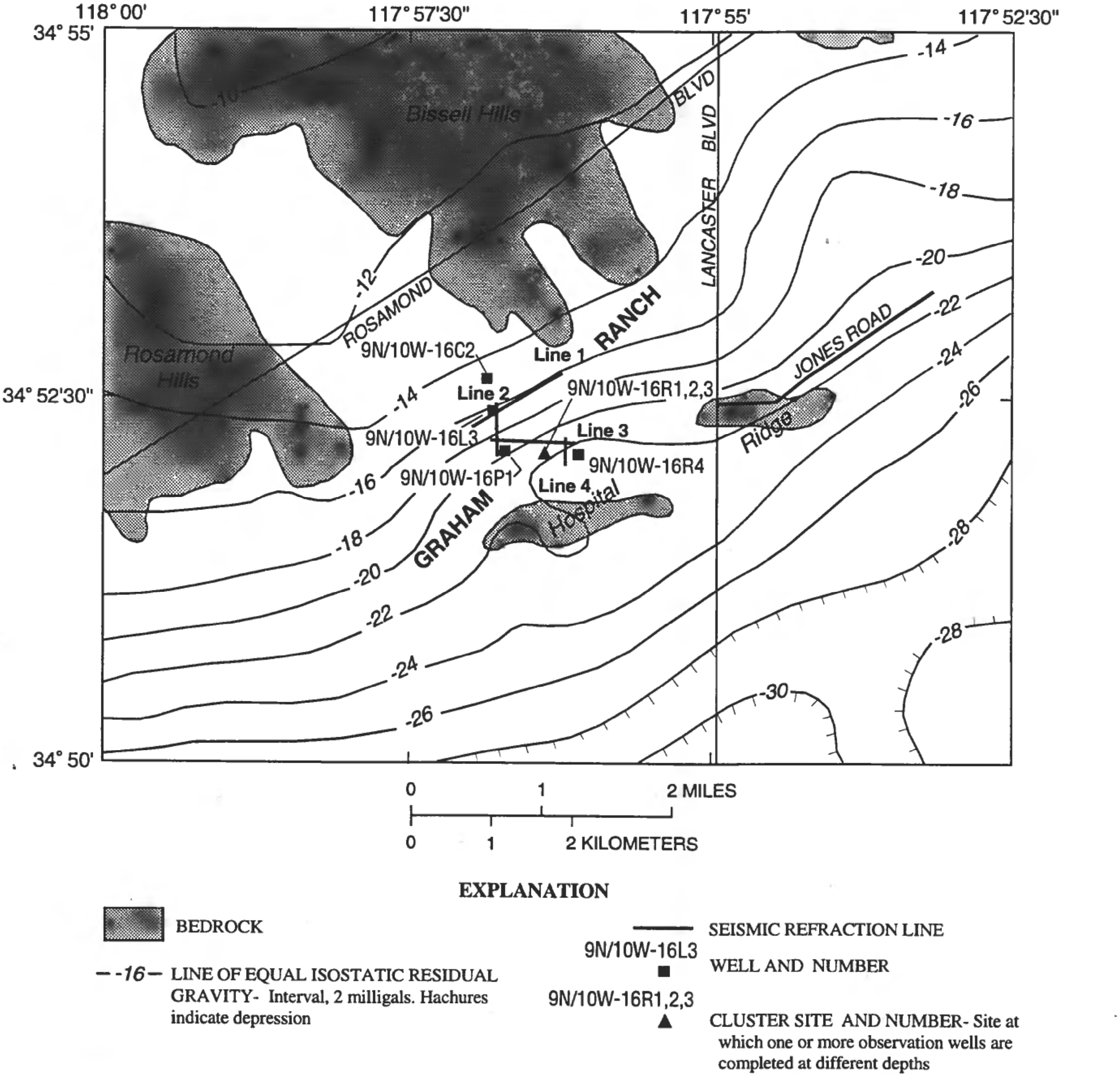

Figure 11. Isostatic residual gravity and seismic refraction lines for the Graham Ranch area on Edwards Air Force Base. Modified from Morin and others (1990).

This suggests that a prominent density variation in the pre-Tertiary basement rocks may occur along a northeast strike between the Bissell Hills and Hospital Ridge (John Mariano, U.S. Geological Survey, written commun., 1991) or that the bedrock outcrops that form Hospital Ridge are not connected to the bedrock basement but rather are isolated blocks of bedrock underlain by alluvium (Zohdy and Bisdorf, 1990).

SEISMIC-REFRACTION SURVEYS

A seismic-refraction survey measures the acoustic velocity of an elastic energy wave that has been imparted into the ground from an energy source. The spectrum of acoustic velocities measured range from several hundred feet per second for very loose unconsolidated sediments, usually found only at the surface, to more than 20,000 ft/s for very competent

PWS-0194-0043

bedrock. In general, unconsolidated sediments have low acoustic velocities of only a few thousand feet per second, whereas consolidated rocks are characterized by acoustic velocities in excess of 15,000 ft/s. Water-saturated unconsolidated sand has an approximate acoustic velocity of 5,000 ft/s (Press, 1966).

In September 1989, seismic-refraction surveys were done in the Graham Ranch area to evaluate a depression in the bedrock surface suggested on the basis of the gravity surveys (fig. 11). Four seismic refraction lines (fig. 11) were implemented, with a total of 10 seismic spreads, each with 12 geophones at 100-foot spacings. To provide continuity between spreads, a two geophone overlap was used between continuous spreads and at each line intersection one geophone remained in place from a preceding spread. An additional spread was used to measure the characteristic acoustic velocity of quartz monzonite assumed to underlie the sedimentary deposits. This spread was laid out on a weathered outcrop of fractured and faulted quartz monzonite on Hospital Ridge, and an apparent velocity of 16,700 ft/s was measured. Traveltime data were collected for both forward and reverse directions along each spread. The seismic source consisted of a buried, two component explosive. The seismic refraction data were processed using an inverse modeling program, SIPT2 (Rimrock Geophysics, Inc., 1987-89).

Four refractors, layers 1 through 4, were identified in the Graham Ranch area (David Berger, U.S. Geological Survey, written commun., 1990). The interpreted seismic section beneath each refraction line is shown in figure 12. Table 5 shows the measured apparent acoustic velocities and the average modeled acoustic velocities for each layer. Layer 1 is a relatively thin, discontinuous layer from 3 to 35 ft thick and has an apparent velocity of about 1,940 ft/s (table 5). Layer 2 is laterally continuous, and ranges in thickness from about 50 to 200 ft (fig. 12) with apparent velocities ranging from 2,060 to 3,450 ft/s (table 5). The interface between layers 1 and 2 is represented by a compositional change indicated in the lithologic logs for the Graham Ranch site and exploration well 9N/10W-16L3 (figs. *9D* and *9E*). The measured apparent velocities in layers 1 and 2 are consistent with the unconsolidated, unsaturated alluvium logged in these wells.

Layer 3 ranges in thickness from about 140 to more than 850 ft (fig. 12) and has apparent velocities ranging from 7,740 to 12,150 ft/s. Velocities in this range are indicative of a fine-grained, semiconsolidated deposits (David Berger, U.S. Geological Survey, written commun., 1990). Water levels measured in well 9N/10W-16R1 at the Graham Ranch site and exploration well 9N/10W-16L3 (table 3) would indicate that the water table in this area is in layer 3. However, it was not discernible because of the high apparent velocities of the formation. The large apparent velocities are consistent with the lithologic and borehole geophysical data collected from the Graham Ranch site and exploration well 9N/10W-16L3, and the borehole geophysical data collected from production well 9N/10W-16R4. The acoustic logs for the Graham Ranch site and wells 9N/10W-16L3 and 16R4 (figs. *9D-9F*) indicate a transitional increase in acoustic velocities from an average 4,500 ft/s for shallower logged intervals, to an average 7,100 ft/s at depths of about 150 ft at the Graham Ranch site, and 110 ft in wells 9N/10W-16L3 and 16R4. Below the transition, average acoustic velocities show a steady increase with increasing depth. Average bottom-hole acoustic velocities at the Graham Ranch site and in well 9N/10W-16R4 were about 10,000 and 8,330 ft/s, respectively. Cores collected from the boreholes at the Graham Ranch site at about 642 and 960 ft consisted of moderately consolidated, semicemented (siliceous cementation), poorly sorted, older alluvium (table 4).

Layer 4 has apparent acoustic velocities in the large range from 16,700 to 41,700 ft/s. The smaller velocities in this range are consistent with the measured characteristic velocity of 16,700 ft/s for weathered quartz monzonite (David Berger, U.S. Geological Survey, written commun., 1990). The anomalously large velocity of 41,700 ft/s most likely

Table 5. Seismic refraction acoustic velocities for layers 1-4 for the Graham Ranch area on Edwards Air Force Base

[Source of data: David Berger, U.S. Geological Survey, written commun., 1990. ft/s, foot per second]

Layer	Measured apparent velocities (ft/s)	Average modeled velocities (ft/s)
1	1,940	1,900
2	2,060 - 3,450	2,800
3	7,740 - 12,150	9,000
4	16,700 - 41,700	17,000

PWS-0194-0044

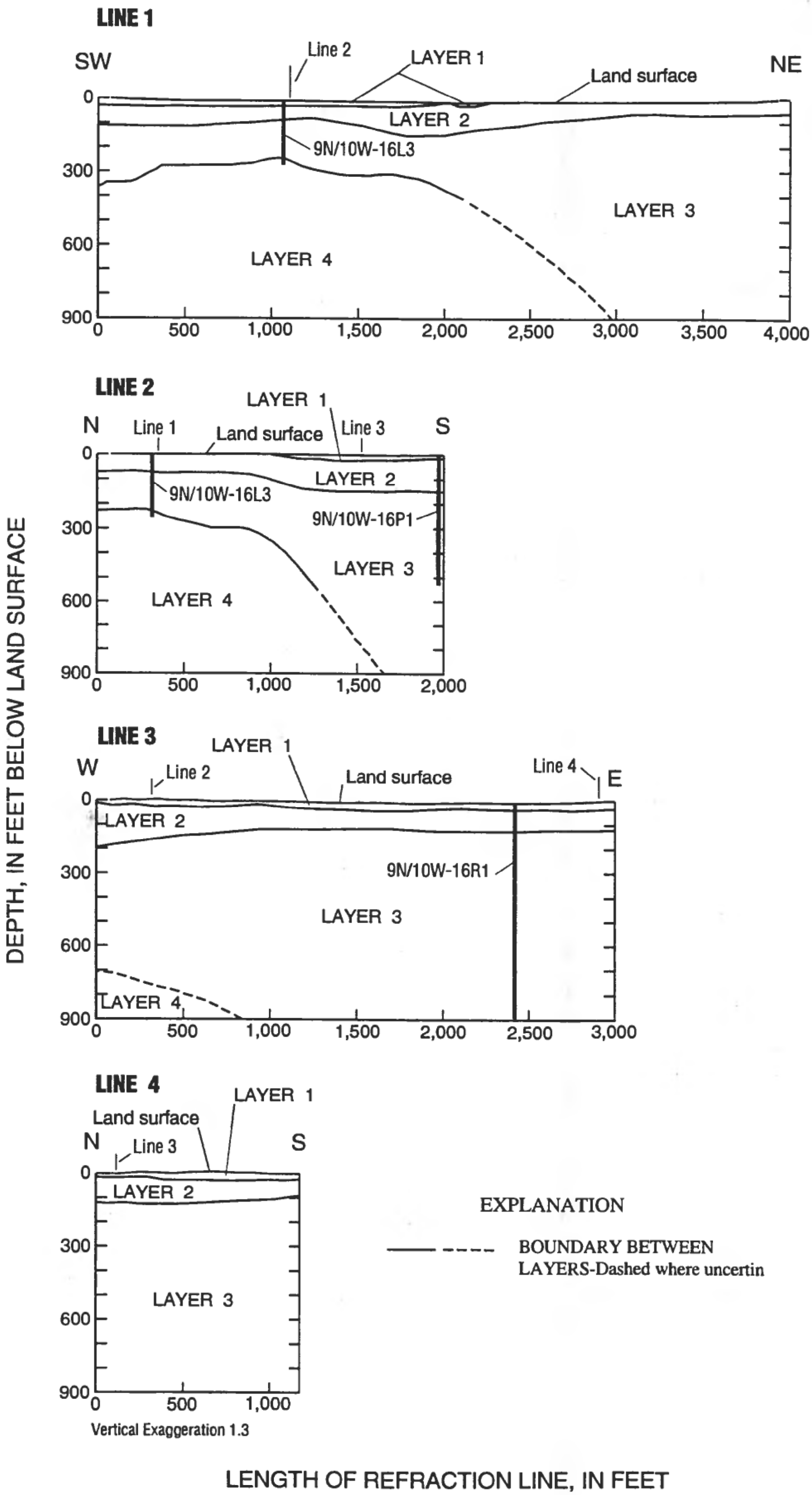

Figure 12. Seismic refraction lines in the Graham Ranch area on Edwards Air Force Base. Location of lines shown on figure 11. (Data from David Berger, U.S. Geological Survey, written commun., 1990).