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U.S. Environmental Protection Agency

Distribution of Salinity in Ground Water from the Interpretation of Borehole-Geophysical Logs and Salinity Data, Calf Pasture Point, Davisville, Rhode Island

Water-Resources Investigations Report 99-4153

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

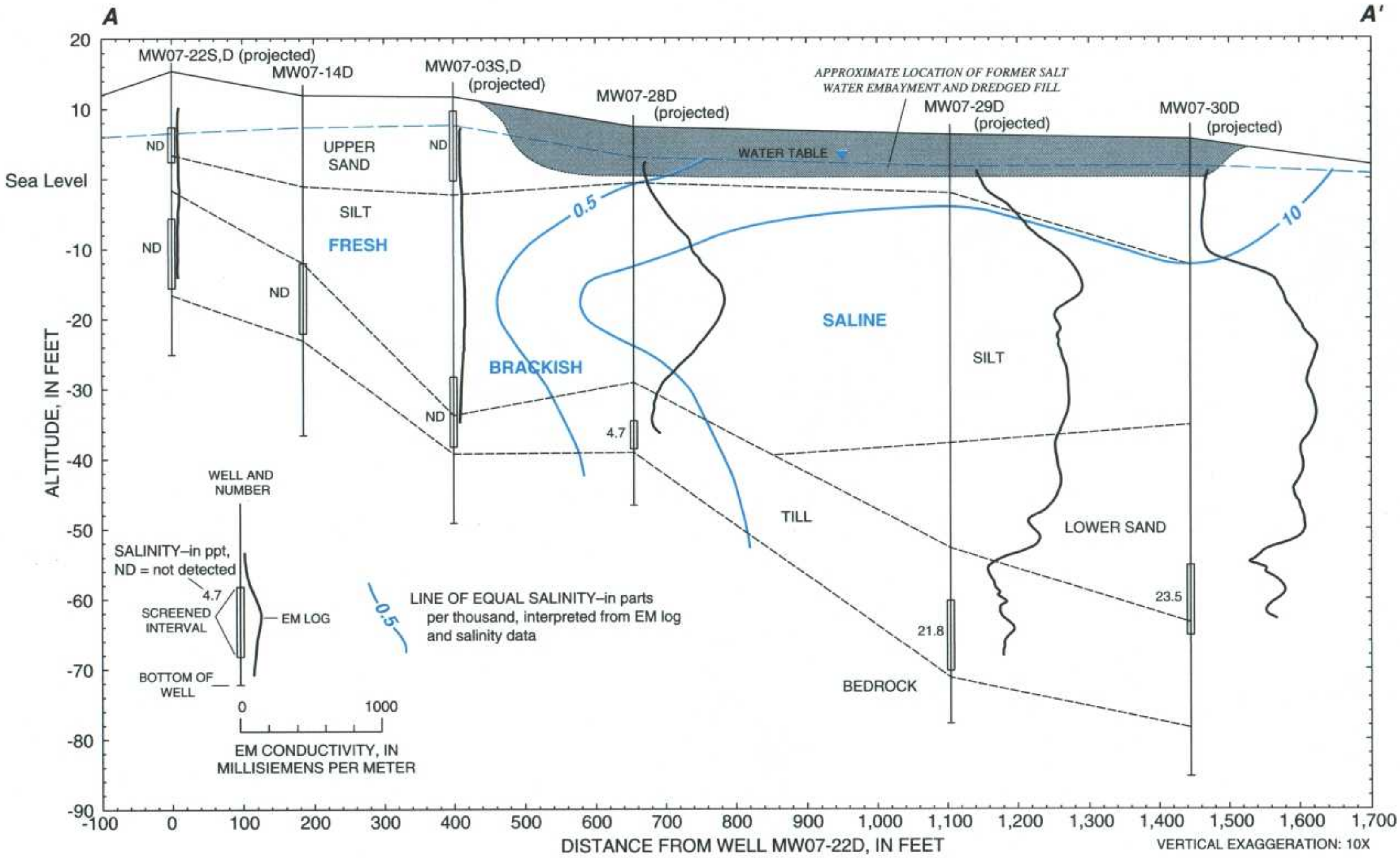


Figure 4. Geohydrologic section along line A-A', Calf Pasture Point, Davisville, Rhode Island.

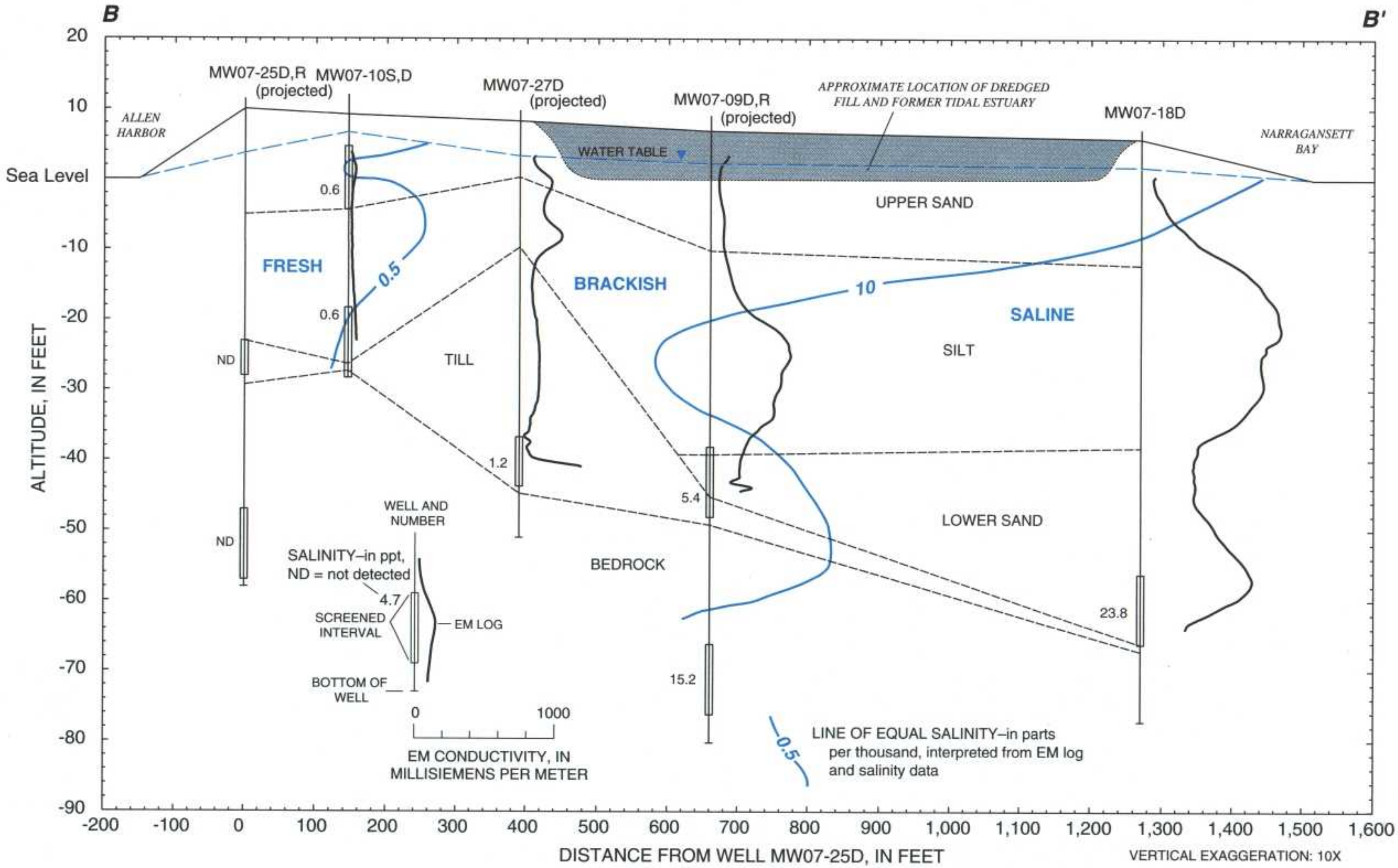


Figure 5. Geohydrologic section along line B-B', Calf Pasture Point, Davisville, Rhode Island.

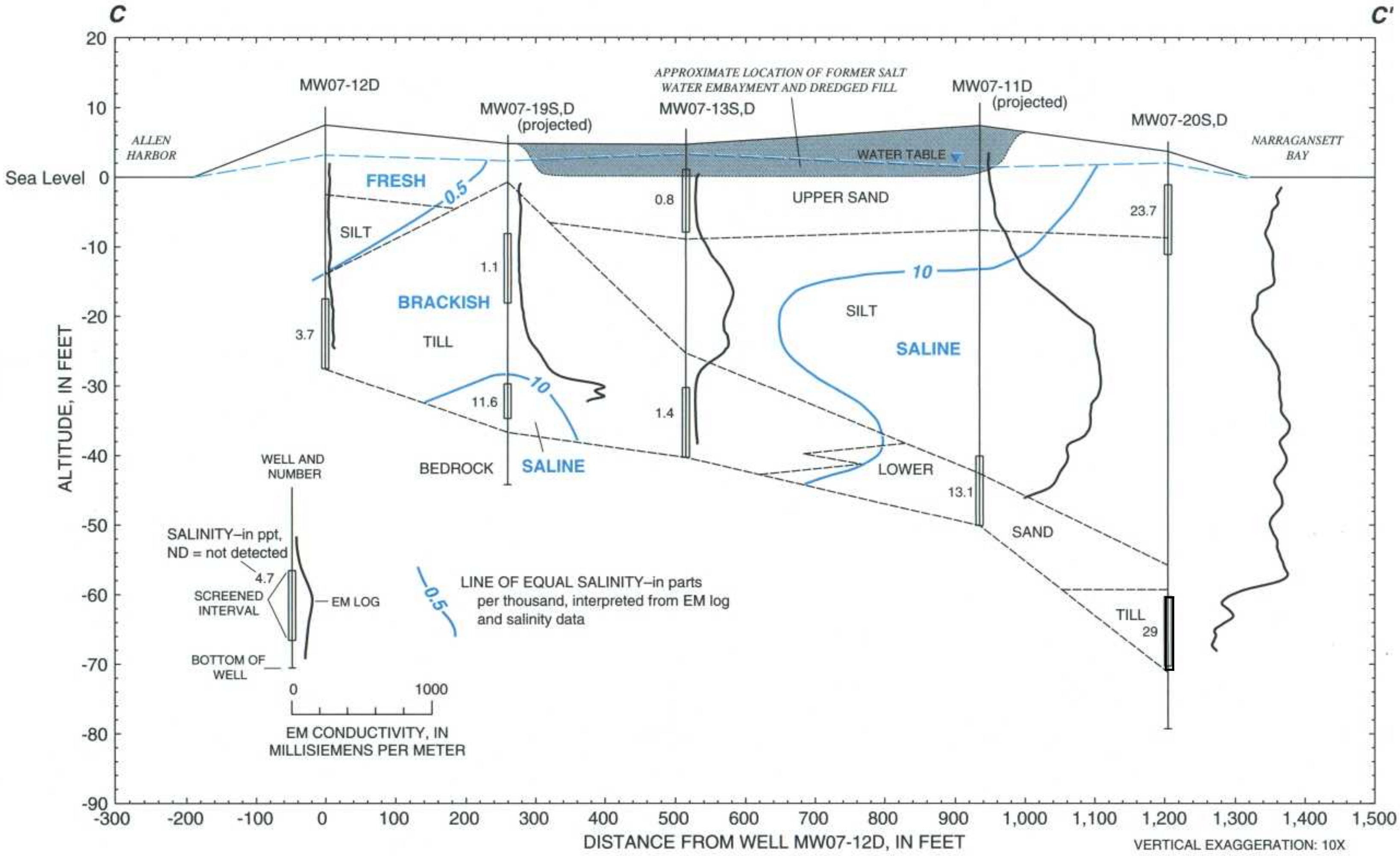


Figure 6. Geohydrologic section along line C-C', Calf Pasture Point, Davisville, Rhode Island.

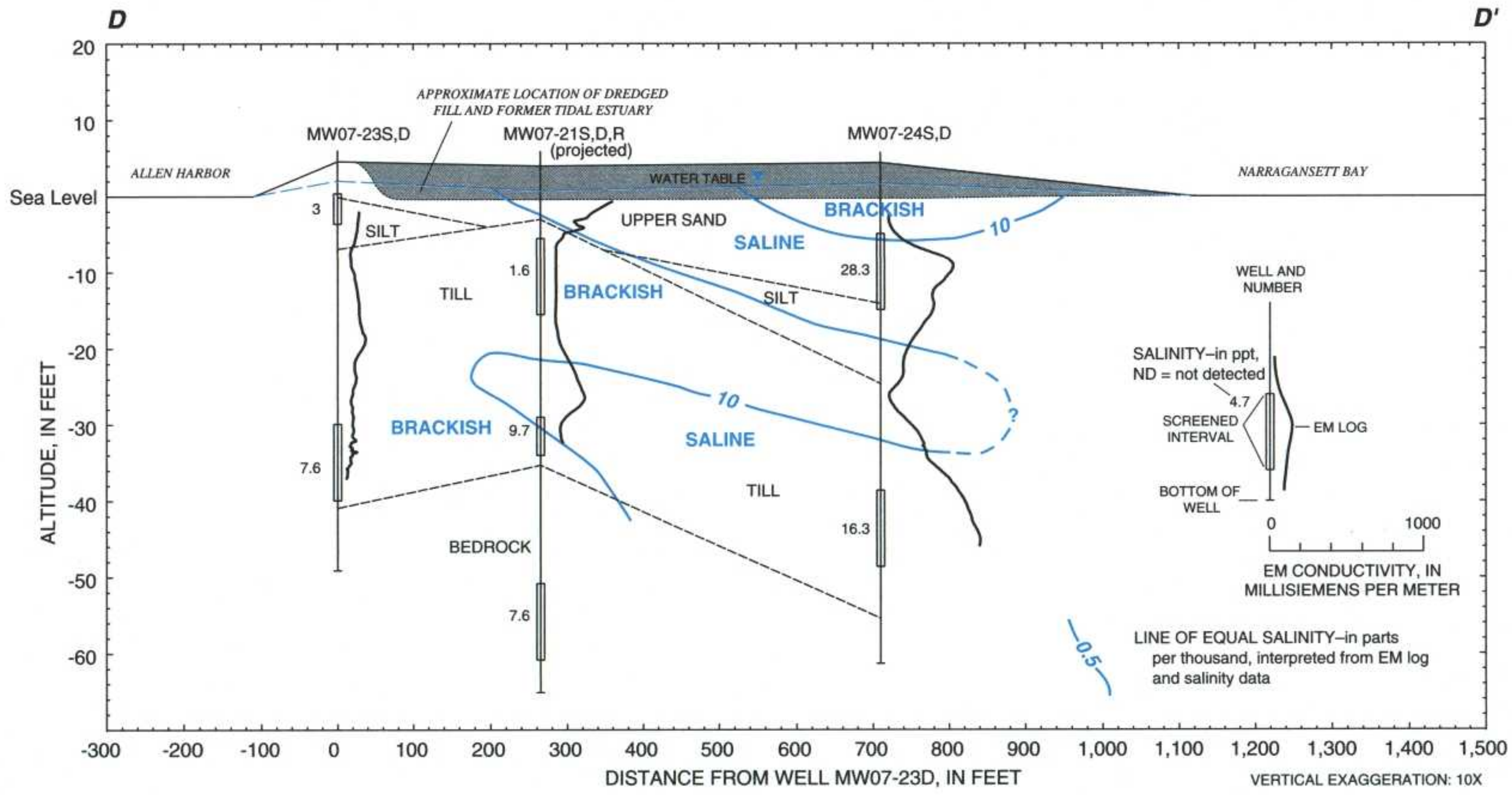


Figure 7. Geohydrologic section along line D-D', Calf Pasture Point, Davisville, Rhode Island.

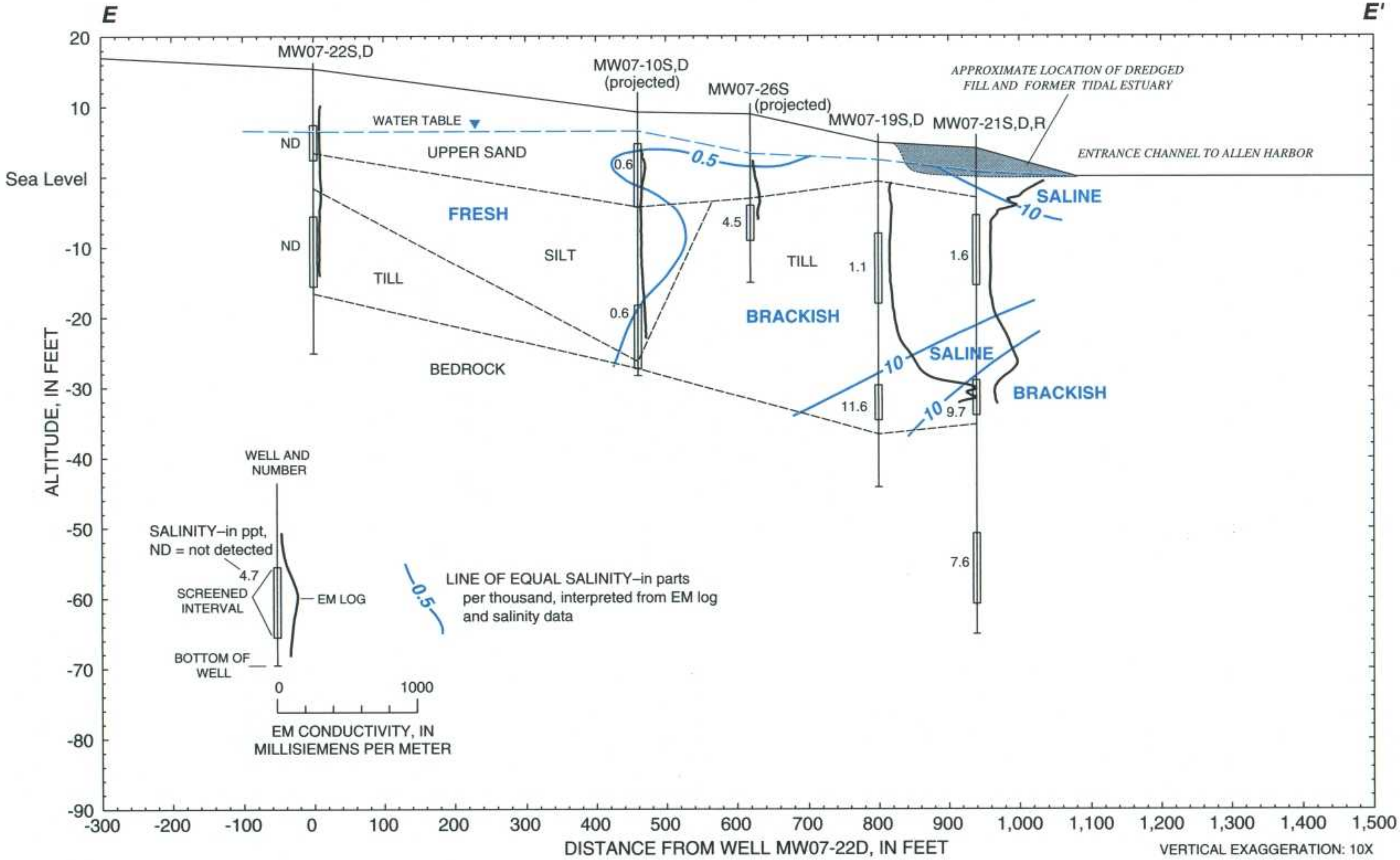


Figure 8. Geohydrologic section along line E-E', Calf Pasture Point, Davisville, Rhode Island.

Brackish water is present in the thick till unit and in the overlying silt and upper sand units at well MW07-27D. At well MW07-09D, brackish water is present in the upper sand unit, upper and lower parts of the silt unit, and the lower sand and till units. Saline water is present in the central part of the silt unit and was also measured in bedrock at this well. At well MW07-18D, which is near Narragansett Bay, brackish and saline water are present in the upper sand unit, and saline water is present in the silt, lower sand, and till units. Although EM conductivity in the upper part of the lower sand unit is considerably less than in the lower part, it is sufficiently high to characterize the water as saline.

As in section A-A', section B-B' also crosses the former saltwater embayment (fig. 1). The EM-conductivity profile at well MW07-09D is similar to that of well MW07-28D, indicating that fresh ground water from upgradient and recharge from precipitation has been diluting the saline water during the nearly 60-year period since the embayment was filled with dredged sediment from the Narragansett Bay.

Section C-C'

Section C-C' (fig. 6) is about 300 ft southwest of section B-B' (fig. 1). The lithology is dominated by the thick till unit in the northwestern part of the section and the thick silt unit in the central and southeastern part of the section. The till unit is directly overlain by the upper sand unit at well MW07-19D; the silt unit is locally absent in this area. EM conductivities at well MW07-12D are low but increase slightly in the till unit; this is consistent with the measured salinity. Freshwater is present in the upper sand and silt units at this well. The EM data from well MW07-19D displays a relatively low EM conductivity in the upper two-thirds of the till unit and a significant increase in EM conductivity in the lower one-third of this unit, consistent with the measured salinities of about 1.1 ppt in well MW07-19S and 11.6 ppt in well MW07-19D. Relatively low EM conductivities correspond with low salinity measurements in both the upper sand unit at well MW07-13S and till unit at well MW07-13D, indicating brackish water. The higher conductivities in the silt unit that separates the sand unit from the till unit can be interpreted as the presence of saline water. However, the higher conductivity also could be the result of a higher porosity and is therefore interpreted as a zone of highly brackish water. The EM-conductivity data from well MW07-11D is consistent with the measured salinity in the lower sand unit. The EM data from this well also indicate brackish water in the upper sand unit and in the upper part of the silt unit, and saline water in the remaining thick silt deposit. EM conductivities at well MW07-20D are very high in the upper sand and in the approximate 47-ft thick layer of silt because of the well's proximity to the shoreline. Thin zones of sand and till separate the silt unit from bedrock. The EM conductivity decreases rapidly from more than 800 mS/m in the silt unit to about 200 mS/m in the till unit. The salinity measured in the till was 29 ppt, equivalent to the salinity of sea water. The abrupt fall in EM conductivity from the silt unit to the till unit could be the result of a significantly lower porosity in the till unit than in the overlying silt and upper sand units.

Wells MW07-13D and MW07-11D are in the area of the former saltwater embayment. EM data from these wells show similar characteristics of high salinity in the silt unit that decreases upward and lower salinity in the upper sand and till units. This salinity pattern is the same as observed at wells MW07-09D, MW07-28D, and MW07-29D, which also are in the filled embayment. Wells MW07-12D and MW07-19D are west of the former saltwater embayment. Freshwater in the upper sand and silt units at well MW07-12D, slightly brackish water in the upper sand unit and in most of the till unit, and saline water in the lower part of the till unit at well MW07-19D are consistent with fresh and brackish water discharge zones near the shoreline of Allen Harbor and the former embayment.

Because these wells are hydraulically upgradient from the fill area, the current salinity distribution shown may also represent the pre-fill conditions.

Section D-D'

Section D-D' (fig. 7) crosses the southern tip of Calf Pasture Point very close to the entrance channel to Allen Harbor (fig. 1). It is underlain primarily by the upper sand unit and a thick till unit over bedrock. Thin zones of silt are present between the upper sand and till units at wells MW07-23D and MW07-24D. Salinity measurements at well MW07-23D indicate the presence of brackish water in the silt unit and in the lower part of the till unit. The small increase in EM conductivity in the middle of the till unit could represent a thin zone of saline water or an increase in porosity, and is therefore interpreted as a zone of highly brackish water. Salinity measurements from wells MW07-21D and MW07-21R indicate the presence of brackish water in the upper and lower parts of the till unit and in bedrock. The EM data from well MW07-21D indicate saline water in the upper sand unit and in a thin zone just above the well screen placed at the bottom of the till unit. At well MW07-24D, saline water was measured in the lower part of the upper sand unit and in the lower part of the till unit. The EM data are consistent with the presence of zones of saline water within these units and also indicate saline water in the upper part of the silt unit. Zones of brackish water were observed in the upper part of the upper sand unit, in the lower part of the silt unit, and in the upper part of the till unit.

Well MW07-23D is in an area that appears to have been stable since the early 1700's (EA Engineering, Science, and Technology, 1997). The brackish water observed in this backshore setting indicates the presence of a mixing zone where freshwater discharges into saline water. Well MW07-21D is in an area that was the mouth of the former saltwater embayment, and well MW07-24D is in a former offshore position on the eastern side of the spit that enclosed the embayment (fig. 1). The current land area in which wells MW07-21D and MW07-24D are located was formed by natural deposition of coastal sediments since 1966 (fig. 1) (EA Engineering, Science, and Technology, 1997). The saline zone in the upper sand unit at these wells is consistent with their former shoreline and offshore environments. The brackish zones in the till unit at wells MW07-23D, MW07-21D, and MW07-24D indicate movement of upgradient freshwater into zones of saline water. The thin saline zone in the till unit at well MW07-21D is considerably thicker at well MW07-24D, consistent with its former offshore position. Because this area remained offshore until at least 1966, the brackish water in the upper part of the upper sand unit at well MW07-24D indicates that saline ground water was diluted by flow of fresh ground water or infiltration of fresh surface water, or both, in the past 30 years.

Section E-E'

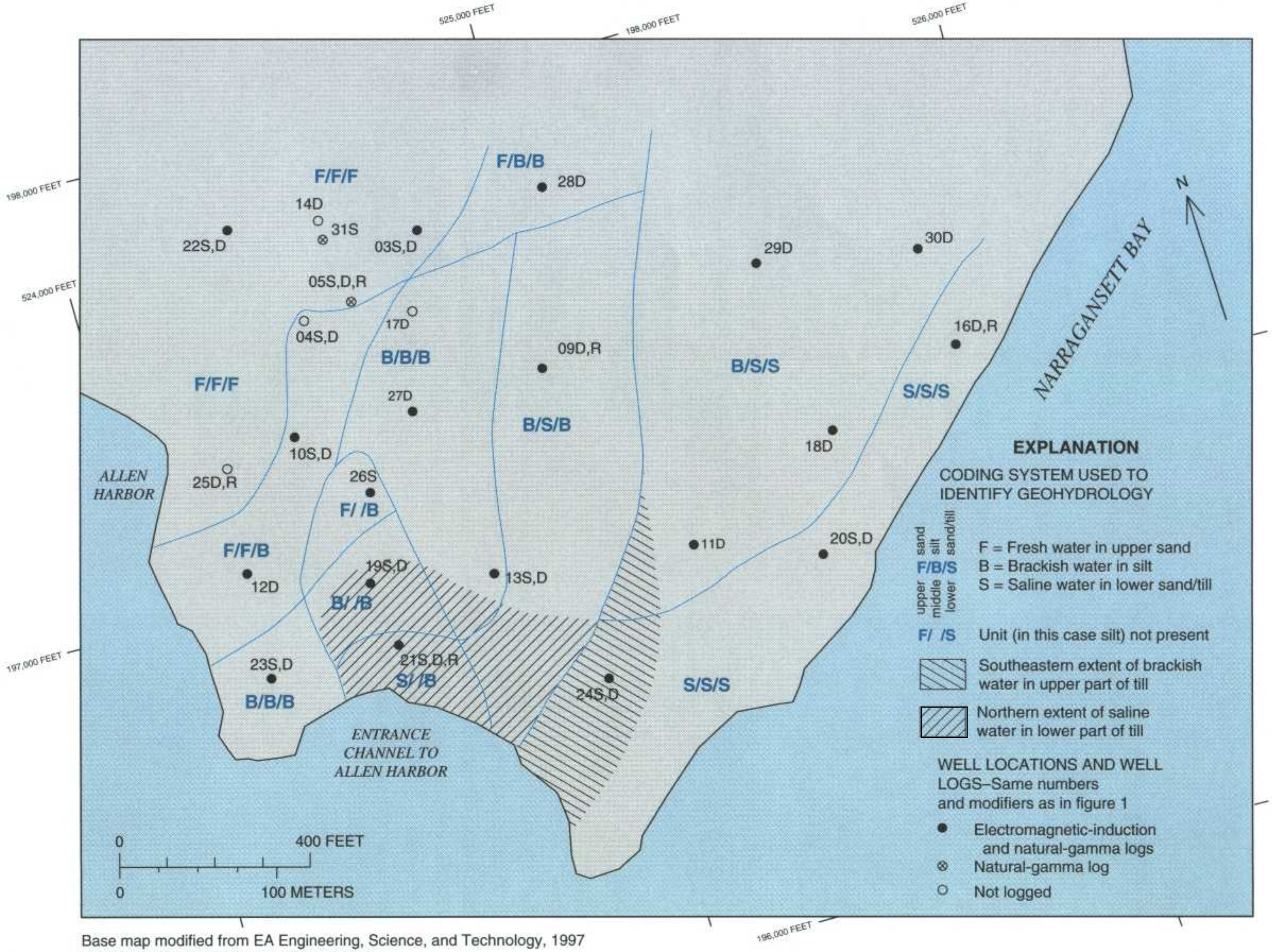
Section E-E' (fig. 8) is oriented approximately north-south and is nearly parallel to the eastern shoreline of Allen Harbor (fig. 1) and perpendicular to the ground-water-flow direction measured from the deep wells screened in the till unit (fig. 2). A thick layer of silt separates the upper sand unit from the till unit in the northern part of this section but is absent in the southern part. Salinity measurements from well MW07-22D indicate the presence of freshwater in the upper sand and till units. EM data indicate freshwater in the silt unit at this well. At well MW07-10D, salinity measurements indicate the presence of slightly brackish water in the upper sand, in the lower part of the silt, and in the till units, which correspond to small increases in EM conductivity. With the exception of these two thin zones, the EM data indicate freshwater at this well. Salinity measurements from well MW07-26S indicate the presence of brackish water in the upper part of the till unit. The EM data are consistent with the presence of brackish water in the upper part of the till unit and also indicate the presence of freshwater in the upper part of the upper sand unit and brackish water in the lower part. Salinity measurements and EM data indicate the presence of brackish water in the upper part of the till unit and saline water in the lower part at well MW07-19D. Although salinity was not measured, nor were EM data obtained from the upper sand unit at this well, the water is considered brackish because of its proximity to saline water in the upper sand unit as indicated by EM data at well MW07-21D. Salinity measurements and EM data at well MW07-21D also indicate the presence of a zone of saline water, with brackish water above and below, within the till unit and brackish water in bedrock.

Wells MW07-26D, MW07-19D are near the western shoreline and well MW07-21D is at the mouth of the former saltwater embayment. Brackish water in these wells indicates a transition from upgradient freshwater to saline water beneath the entrance channel to Allen Harbor. The saline zone in the lower part of the till unit at wells MW07-19D and MW07-21D appears to be continuous with the thicker saline zone in the till unit at well MW07-24D (section D-D', fig. 6). This saline zone also appears to extend into bedrock at wells MW07-19D and MW07-24D but is underlain by brackish water at well MW07-21D.

Horizontal Distribution of Salinity

Horizontal distribution of fresh, brackish, and saline water in the upper sand, silt, and till units (lower sand and till combined) was determined from the interpreted salinity contours shown on the geohydrologic-sections. A composite map was then made to divide the study site into areas of similar salinity and lithologic characteristics (fig. 9). Although at some wells, fresh and brackish water, or brackish and saline water, are present in the same lithologic unit, the type of water most represented in the lithologic unit was selected for this composite map. Ten distinct area types were identified, ranging from freshwater in all lithologic units to saline water in all lithologic units. Some of these area types are represented by only one well whereas others are represented by several wells.

Freshwater in the upper sand, silt, and till units was identified in the northern and northwestern parts of the site which includes wells MW07-03D, MW07-14D, MW07-22D, and MW07-25D. Two areas were characterized by brackish water in the upper sand, silt, and till units. One of these areas is in the central part of the site and includes wells MW07-13D, MW07-17D and MW07-27D. The other area is in the southwestern part of the site near Allen Harbor, represented by well MW07-23D. The southeastern area along Narragansett Bay and the beginning of the entrance channel to Allen Harbor, which includes wells MW07-16D, MW07-20D, and MW07-24D, contains saline water in all lithologic zones. Although water is primarily saline in the till unit at well MW07-24D, a thin zone of brackish water is present in the upper part of the till unit. This brackish zone appears to extend to near the entrance channel to Allen Harbor. Well MW07-09D is in a large central area where brackish water is present in the upper sand and till units, and saline water is present in the intervening silt unit. Wells MW07-11D, MW07-18D, MW07-29D, and MW07-30D are in an area characterized by brackish water in the upper sand unit and saline water in the underlying silt and till units. In the area defined by wells MW07-26S, MW07-19D, and MW07-21D, where the silt unit is absent and the till unit slopes upward towards the entrance channel to Allen Harbor, freshwater in the upper sand unit overlies brackish water in the till unit at MW07-26S, brackish water in the upper sand unit overlies predominately brackish water in the till unit at well MW07-19D, and saline water in the upper sand unit overlies predominately brackish water in the till unit at well MW07-21D. A thin zone of saline water in the lower part of the till unit appears to extend from the entrance channel to Allen Harbor to the vicinity of well MW07-19D. In the remaining areas, freshwater is present in the upper sand and silt units and brackish water in the till unit (wells MW07-04D, MW07-10D, and MW07-12D). Freshwater also is present in the upper sand unit with brackish water in the silt and till units near well MW07-28D.



Base map modified from EA Engineering, Science, and Technology, 1997
Rhode Island stateplane coordinate system

Figure 9. Spatial distribution of major salinity types in ground water by lithologic unit, Calf Pasture Point, Davisville, Rhode Island.

SUMMARY AND CONCLUSIONS

Borehole-geophysical logs of wells drilled in the surficial aquifer at Calf Pasture Point were interpreted in conjunction with previously collected salinity data to delineate zones of fresh, brackish, and saline water. These data may be used to help identify potential pathways of contaminants to surface-water bodies in this coastal aquifer and to formulate an effective ground-water-monitoring program.

This site is underlain by a sequence of glacial sediments, marine sands, and fill. The present-day land surface was formed, in part, when a saltwater embayment was filled with dredged sediments from Narragansett Bay in the early 1940's. The distribution of sediments and overlying dredged material in this coastal setting has resulted in a complex distribution of salinity in the surficial aquifer.

Interpretation of the vertical and horizontal distribution of salinity using borehole electromagnetic-induction log data indicates that the upper sand unit contains freshwater (salinities of 0.5 ppt or less) in the north and northwestern part of the site, brackish water (salinity greater than 0.5 ppt to 10 ppt) where the dredged sediments from the Narragansett Bay were deposited, and saline water (greater than 10 ppt) along the shore of the Narragansett Bay and the entrance channel to Allen Harbor. Saline water is present in the silt in the eastern half of the site, most of which can be attributed to the residual saline water since the saltwater embayment was filled with dredged sediment from the Narragansett Bay. In the western half of the site, the silt contains fresh or brackish water. Freshwater is present in till in the western part of the site near Allen Harbor and in the northwestern part of the site. Brackish water is present in the till in the central part of the site, and saline water is present in the till under about half of the site on the eastern and southeastern side. Brackish water underlies saline water in areas along a northeast-southwest band through the middle of the site. Distinct zones of brackish water are present within the till in the southwestern part of this band near the entrance channel to Allen Harbor.

When the former saltwater embayment was filled with dredged sediment from Narragansett Bay, the hydrologic-flow regime changed; this created a complex distribution of salinity in the eastern and central parts of the site. Although saline water from the dredged material may have been added to the filled area, filling the former saltwater embayment virtually eliminated the surface-water source of saline water to the underlying aquifer. By increasing the land surface area, more area was made available for infiltration of fresh water from precipitation. Fresh ground water from upgradient and local recharge appears to be diluting the saline water from the former embayment and gradually expanding the freshwater-flow system as it travels to Narragansett Bay and the entrance channel to Allen Harbor. The distribution of salinity in the western part of the site, which is dominated by freshwater, is likely to have been less affected by filling of the embayment. In the eastern and central parts of the site, however, the distribution of salinity appears to be in a dynamic state that is responding to the loss of a continuous source of saline water. Additionally, the southern and southwestern extremeties of the site, along the Allen Harbor Entrance Channel and its confluence with Naragansett Bay are also likely to continue to be effected by erosional and/or depositional processes, which have resulted in the accretion of a substantial volume of sediment to the shoreline since 1966. The ground-water flow system can be expected to continue to evolve in response to these changes.

The present-day ground-water flow regime at Calf Pasture Point, therefore, represents a complex system that results from the interaction of a number of factors and processes operating on different time scales. In the near-term, interaction of the freshwater flow system with brackish and saline waters is an important process relative to contaminant transport. However, development of an effective long-term monitoring program for ground-water quality must also consider those processes which are evolving on other time scales.

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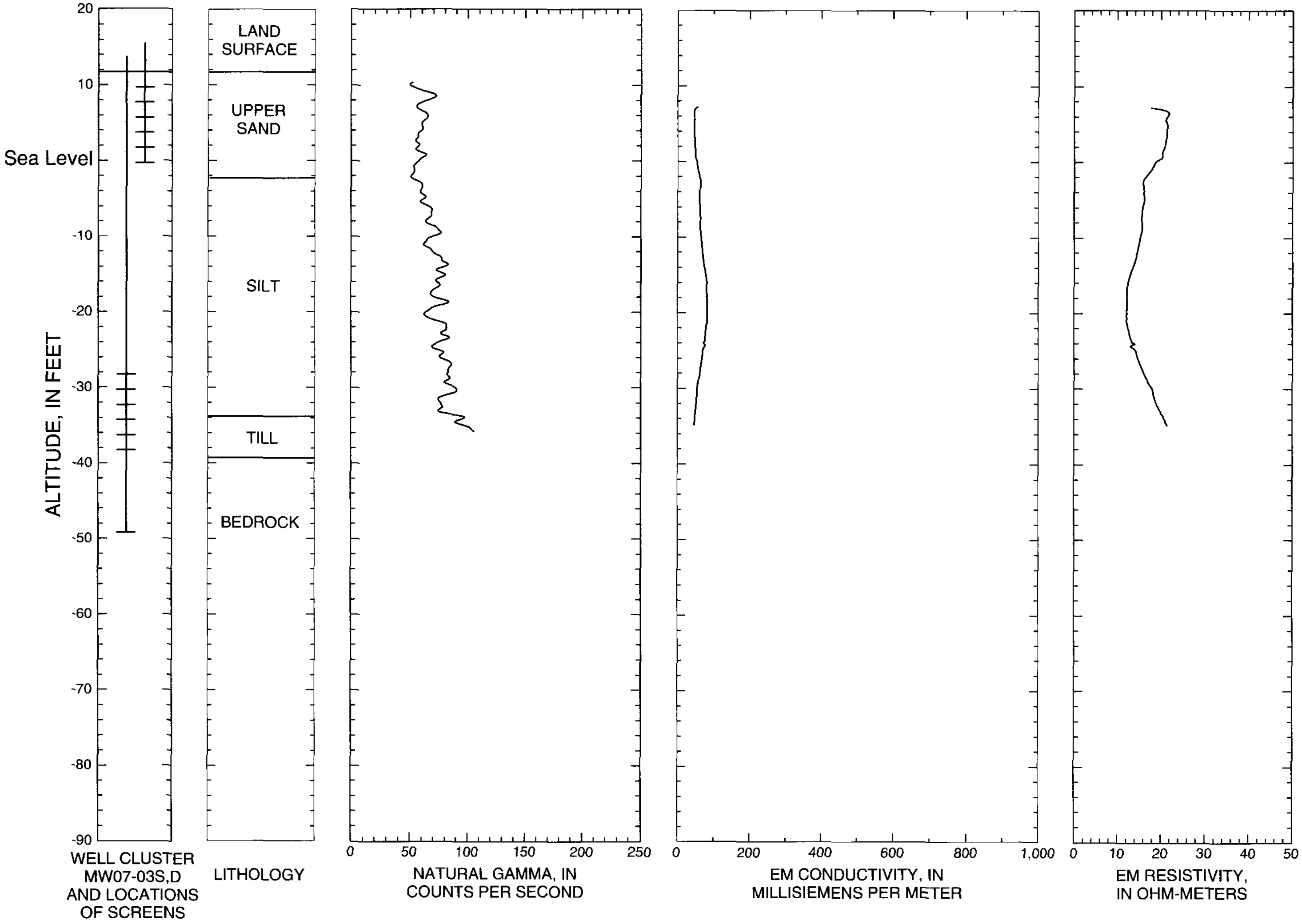
APPENDIX

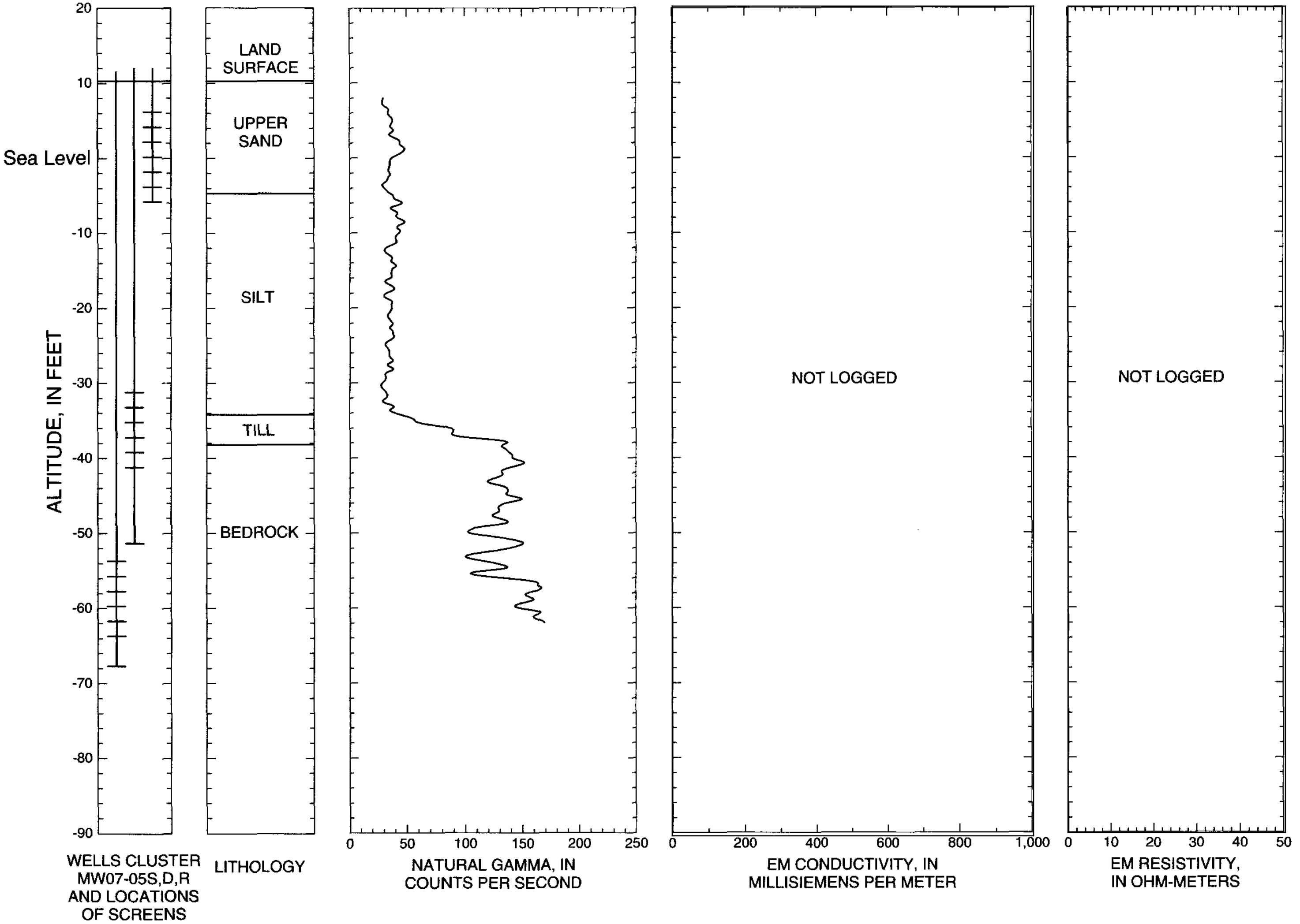
Appendix 1. Lithologic and borehole geophysical logs at Calf Pasture Point, Davisville, Rhode Island.

A. **WELL CLUSTER MW07-03S,D**



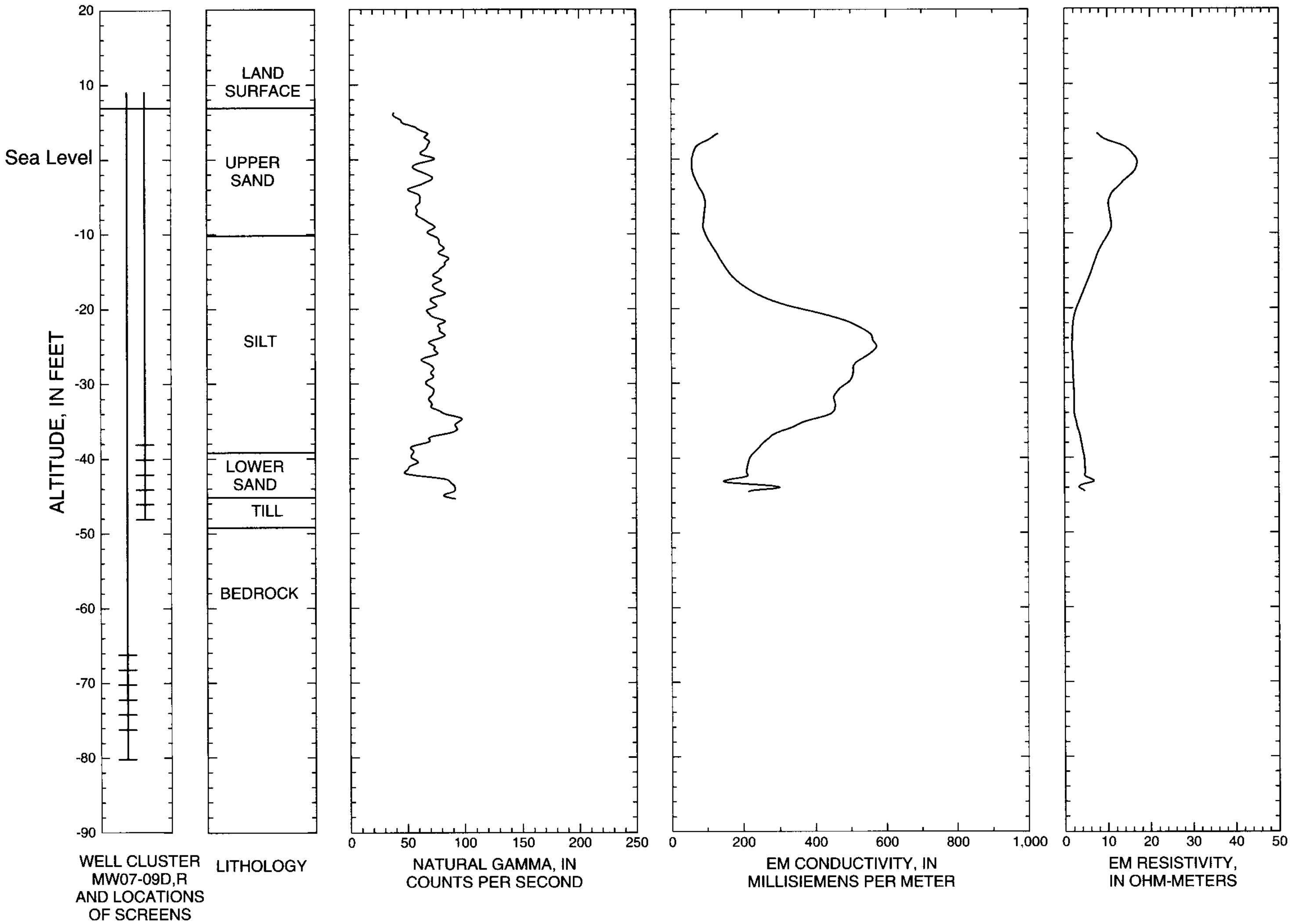
Appendix 1. Lithologic and borehole geophysical logs at Calf Pasture Point, Davisville, Rhode Island.

B. **WELL CLUSTER MW07-05S,D,R**



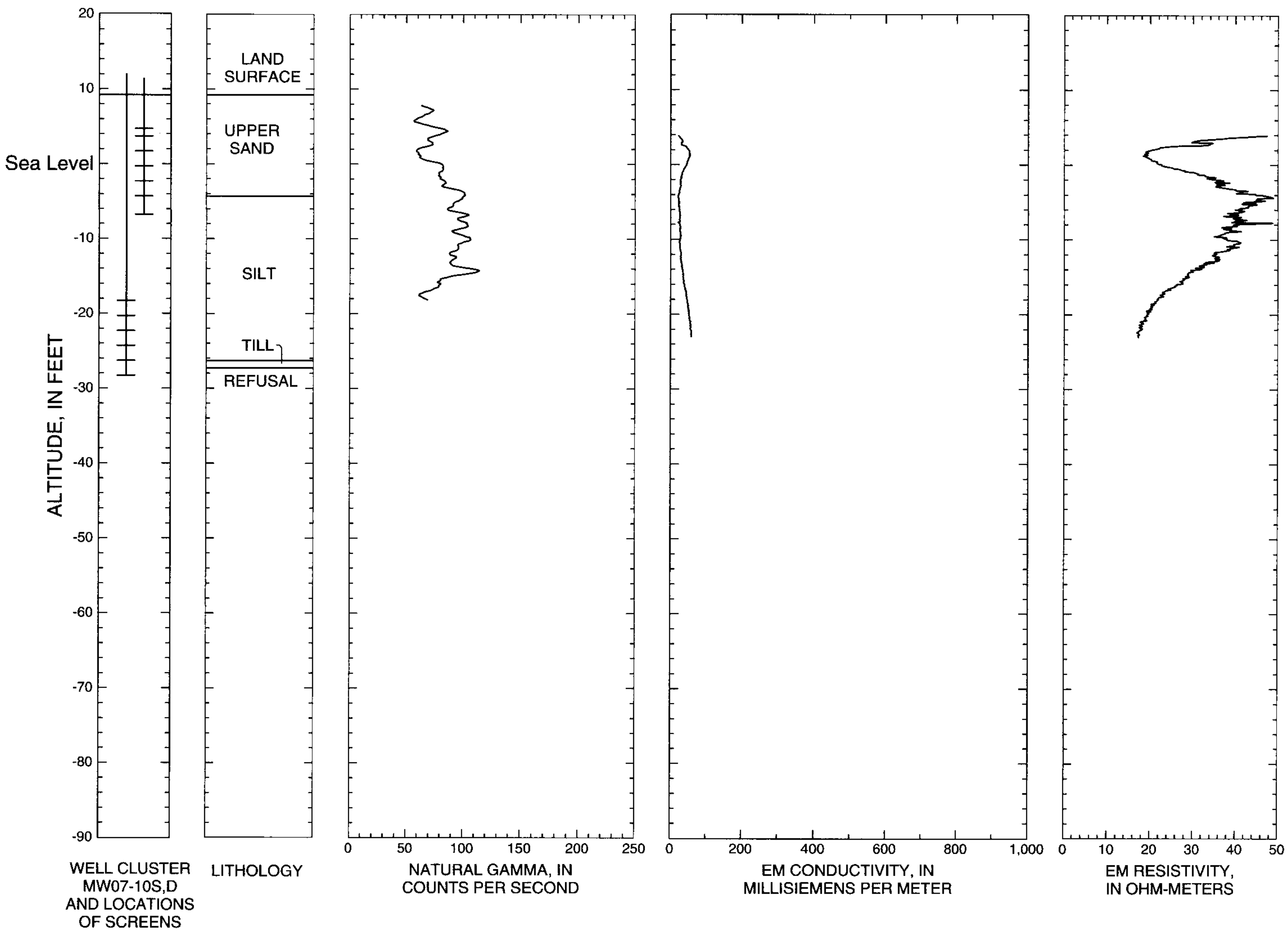
Appendix 1. Lithologic and borehole geophysical logs at Calf Pasture Point, Davisville, Rhode Island—*Continued.*

C. **WELL CLUSTER MW07-09D,R**



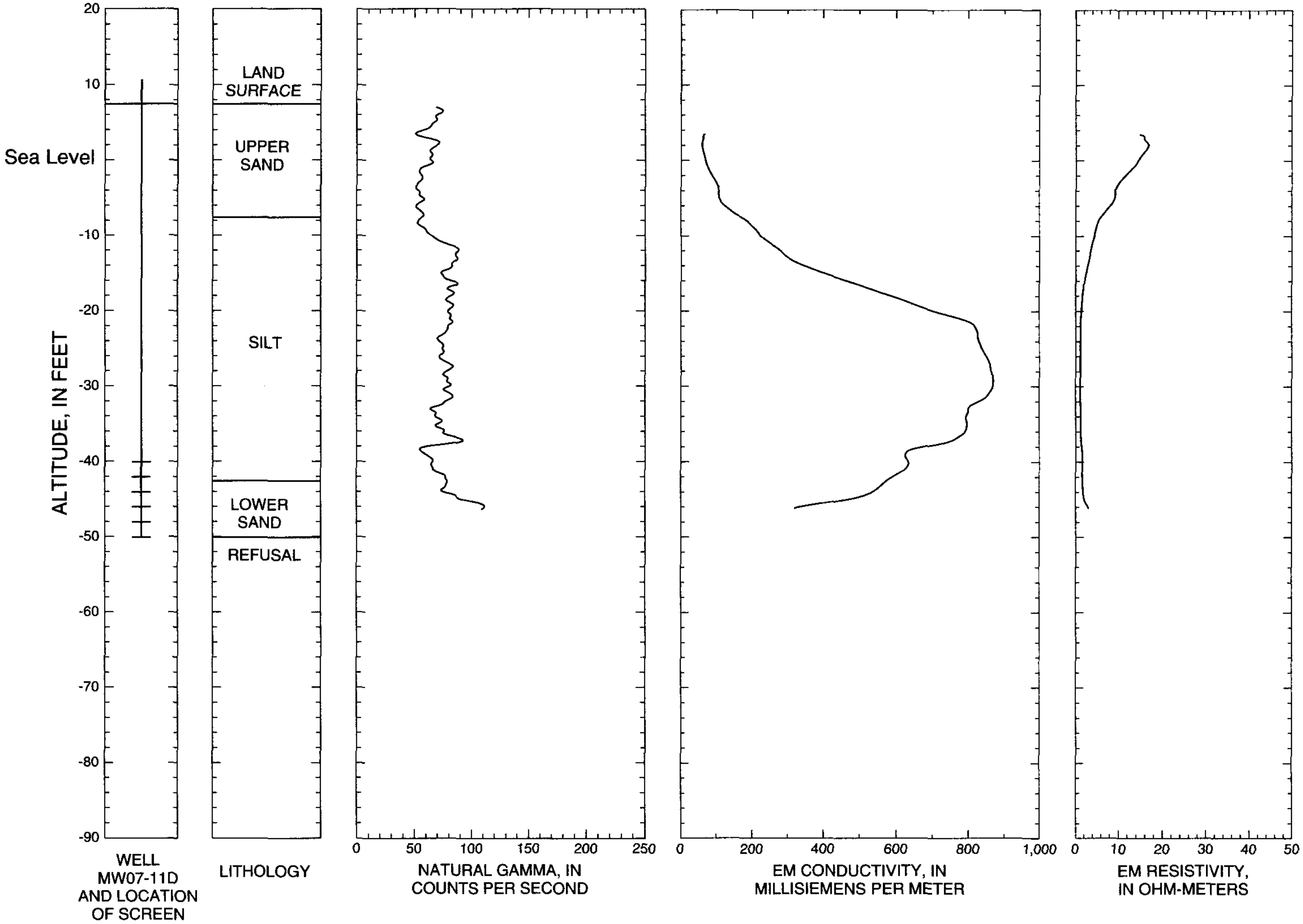
Appendix 1. Lithologic and borehole geophysical logs at Calf Pasture Point, Davisville, Rhode Island—*Continued.*

D. **WELL CLUSTER MW07-10S,D**



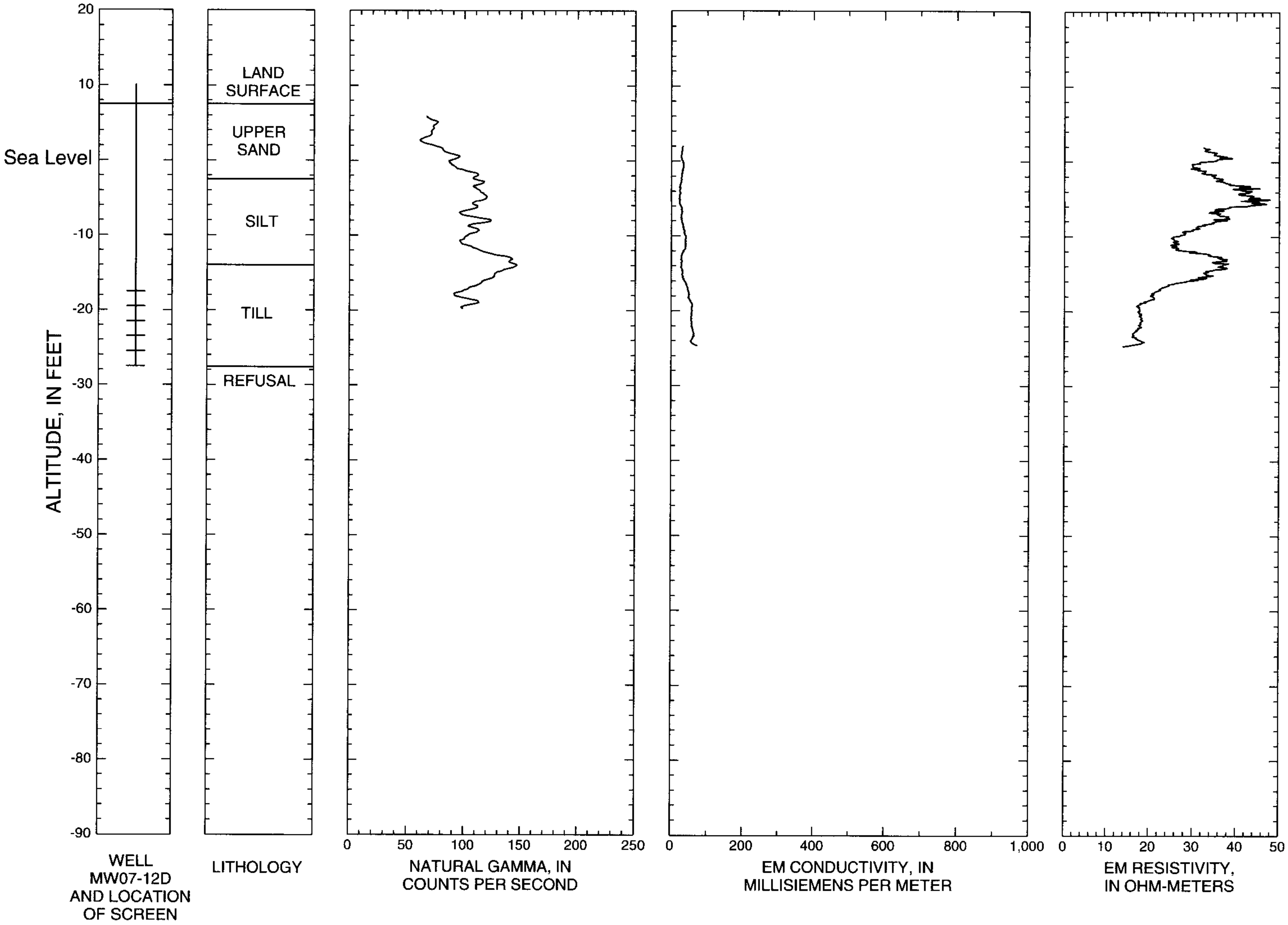
Appendix 1. Lithologic and borehole geophysical logs at Calf Pasture Point, Davisville, Rhode Island—*Continued.*

E. **WELL MW07-11D**



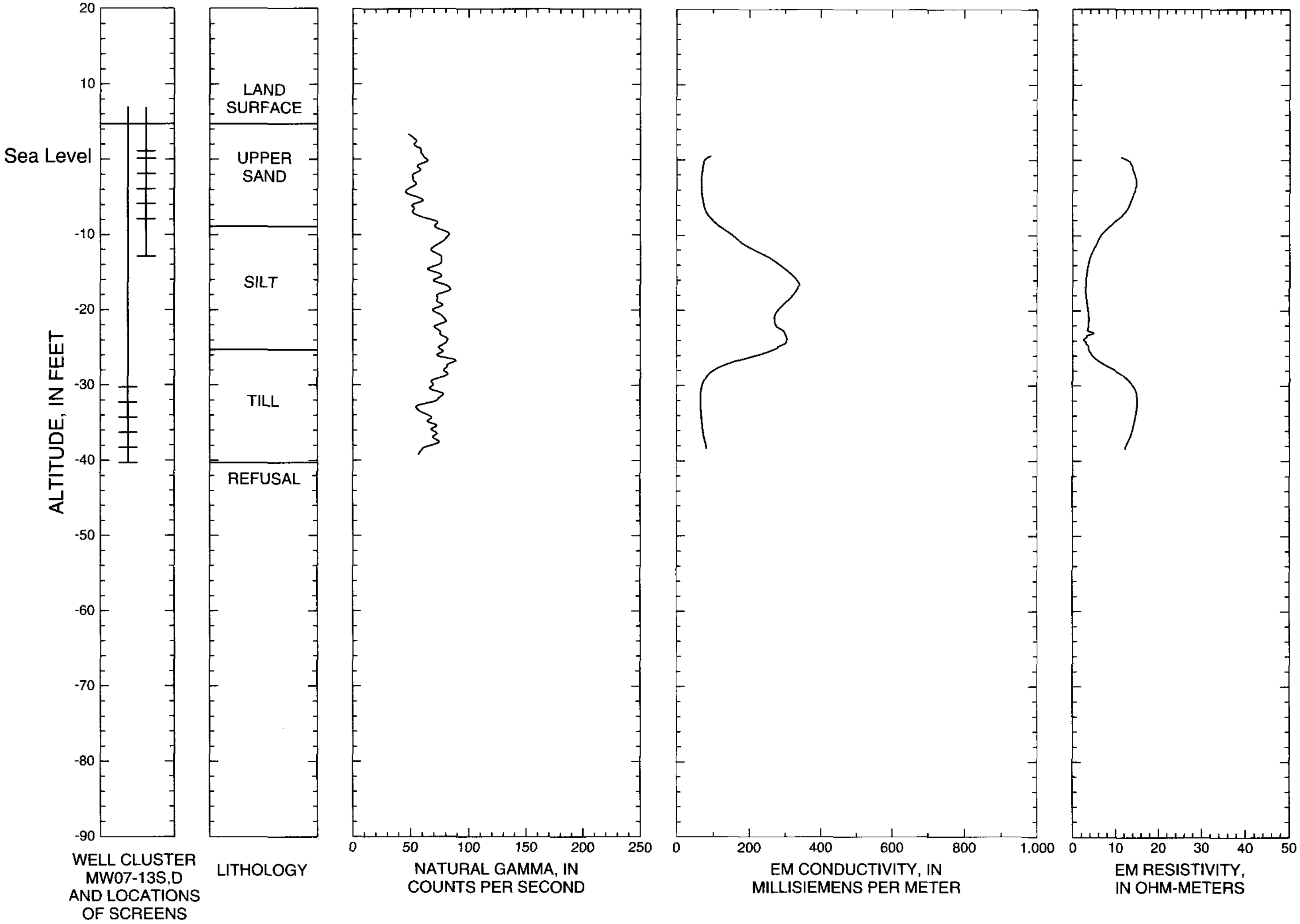
Appendix 1. Lithologic and borehole geophysical logs at Calf Pasture Point, Davisville, Rhode Island—*Continued.*

F. **WELL MW07-12D**



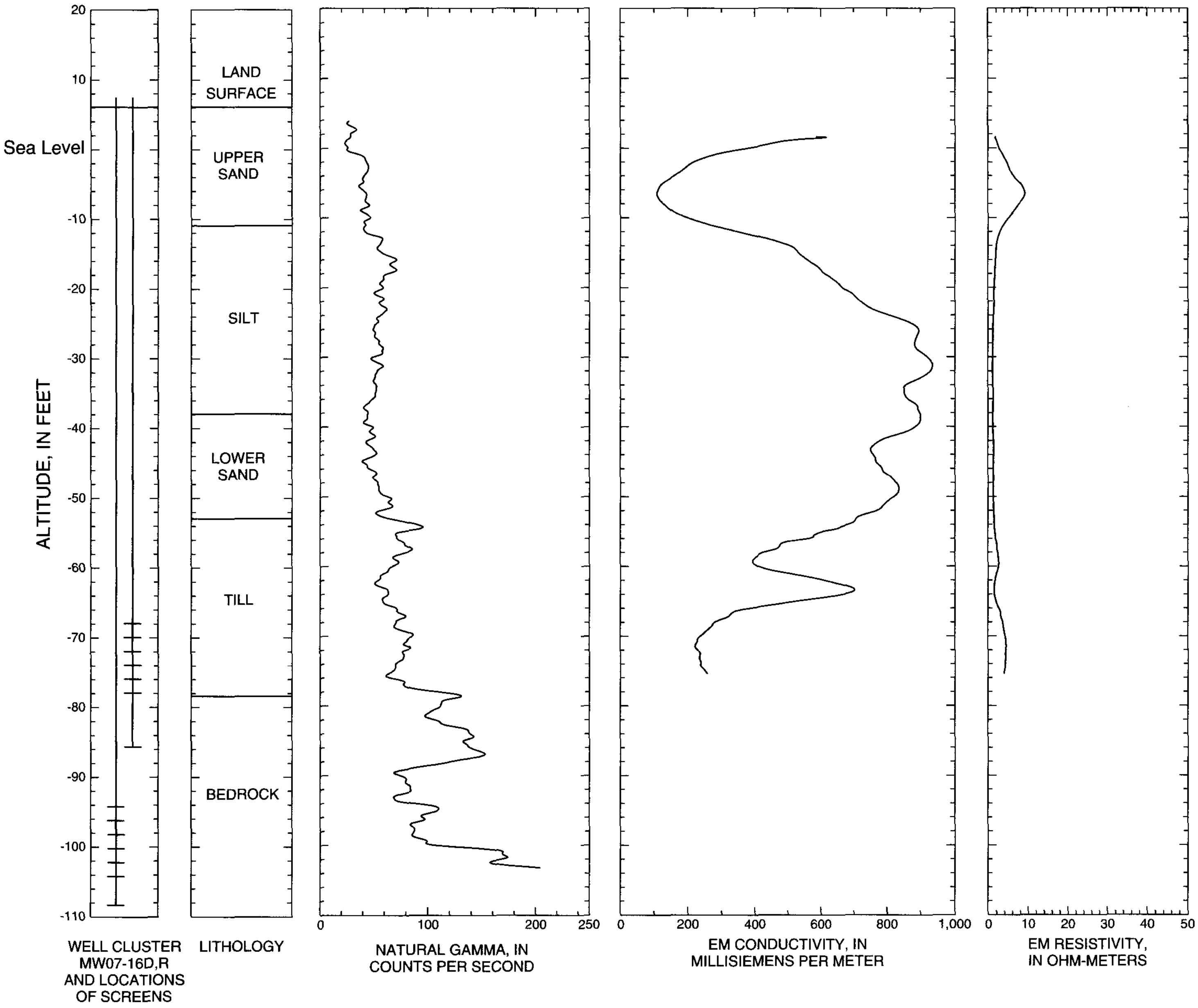
Appendix 1. Lithologic and borehole geophysical logs at Calf Pasture Point, Davisville, Rhode Island—*Continued.*

***G.* WELL CLUSTER MW07-13S,D**



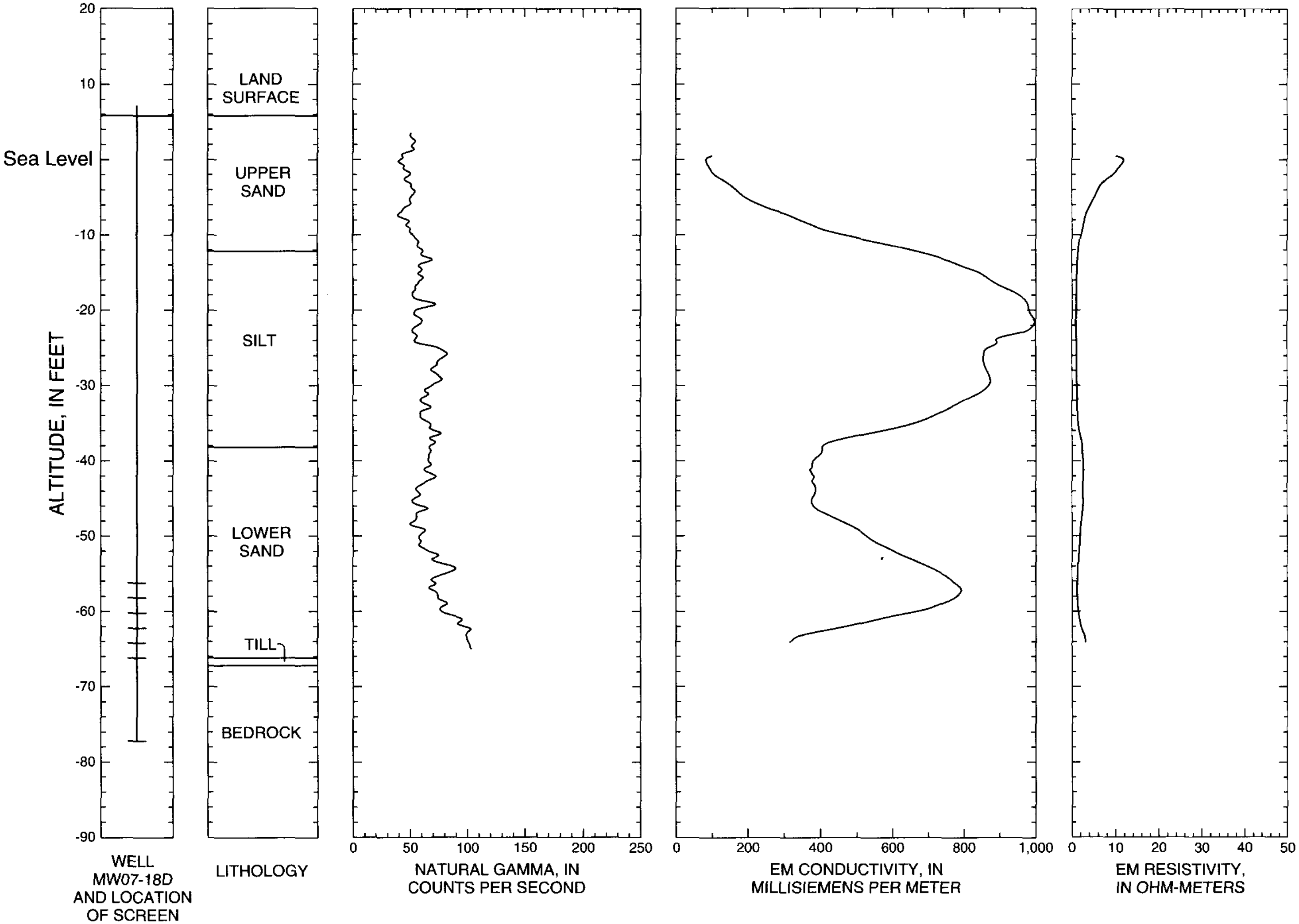
Appendix 1. Lithologic and borehole geophysical logs at Calf Pasture Point, Davisville, Rhode Island—*Continued.*

H. **WELL CLUSTER MW07-16D,R**



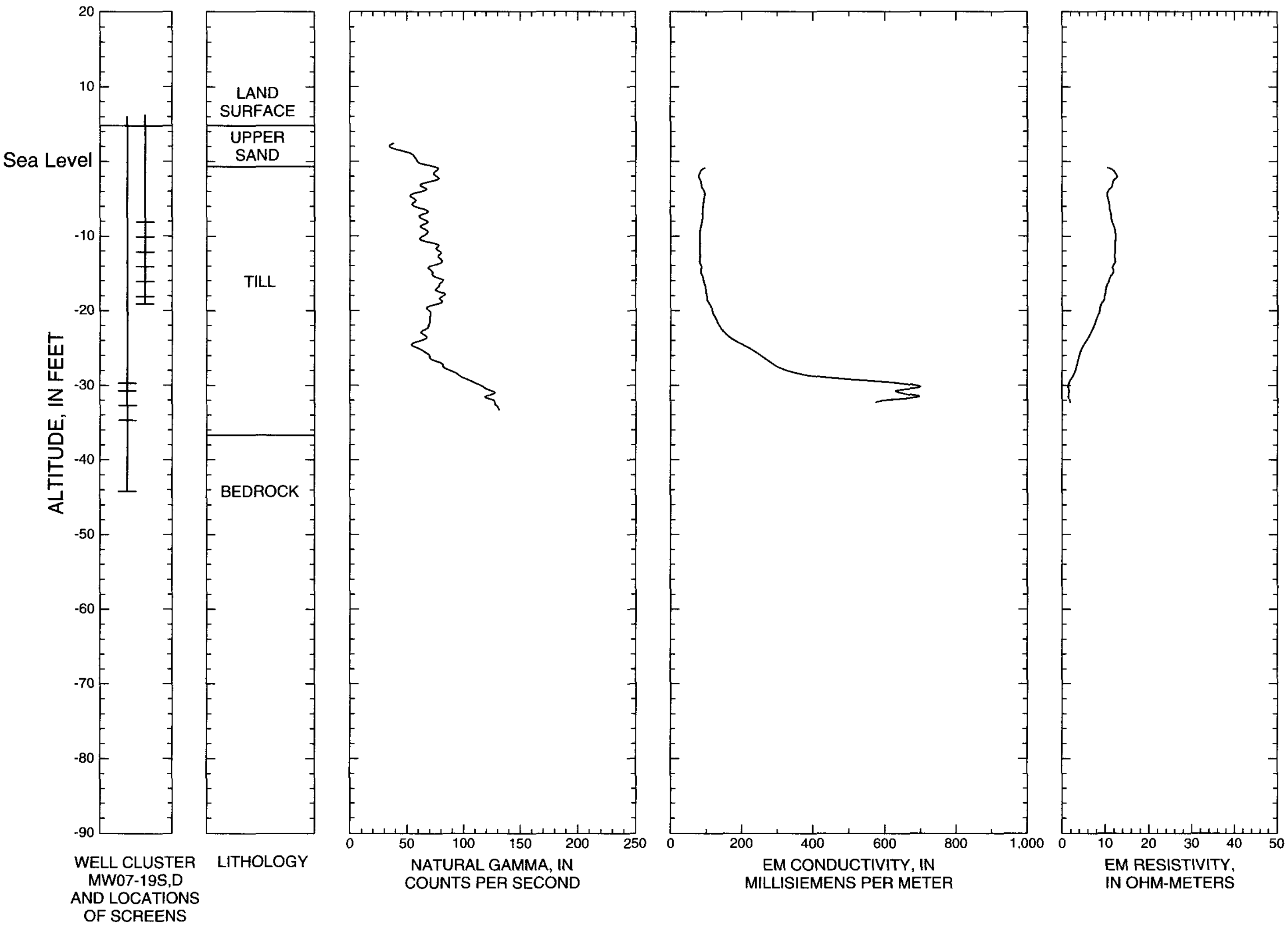
Appendix 1. Lithologic and borehole geophysical logs at Calf Pasture Point, Davisville, Rhode Island—*Continued.*

I. **WELL MW07-18D**



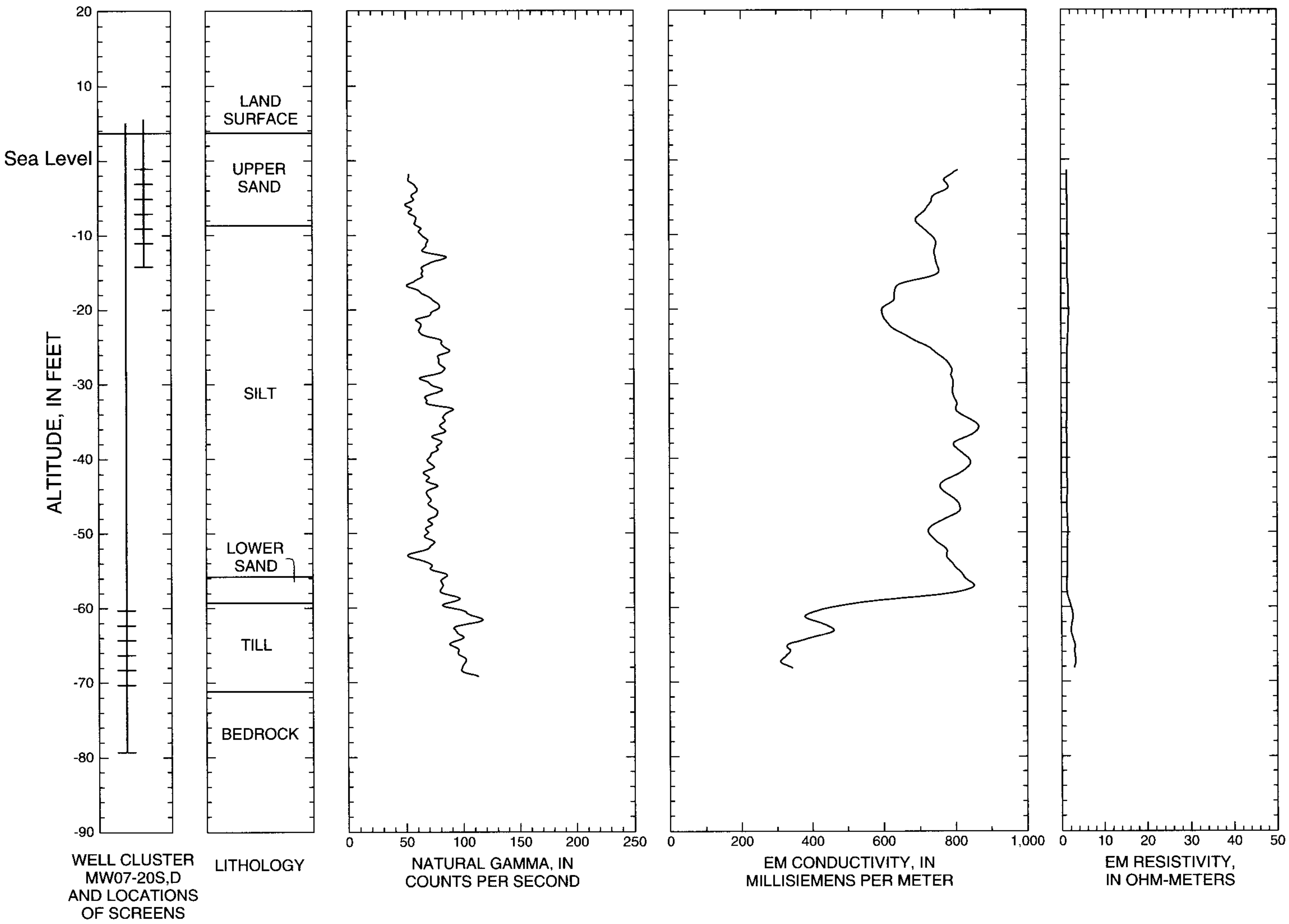
Appendix 1. Lithologic and borehole geophysical logs at Calf Pasture Point, Davisville, Rhode Island—*Continued.*

J. WELL CLUSTER MW07-19S,D

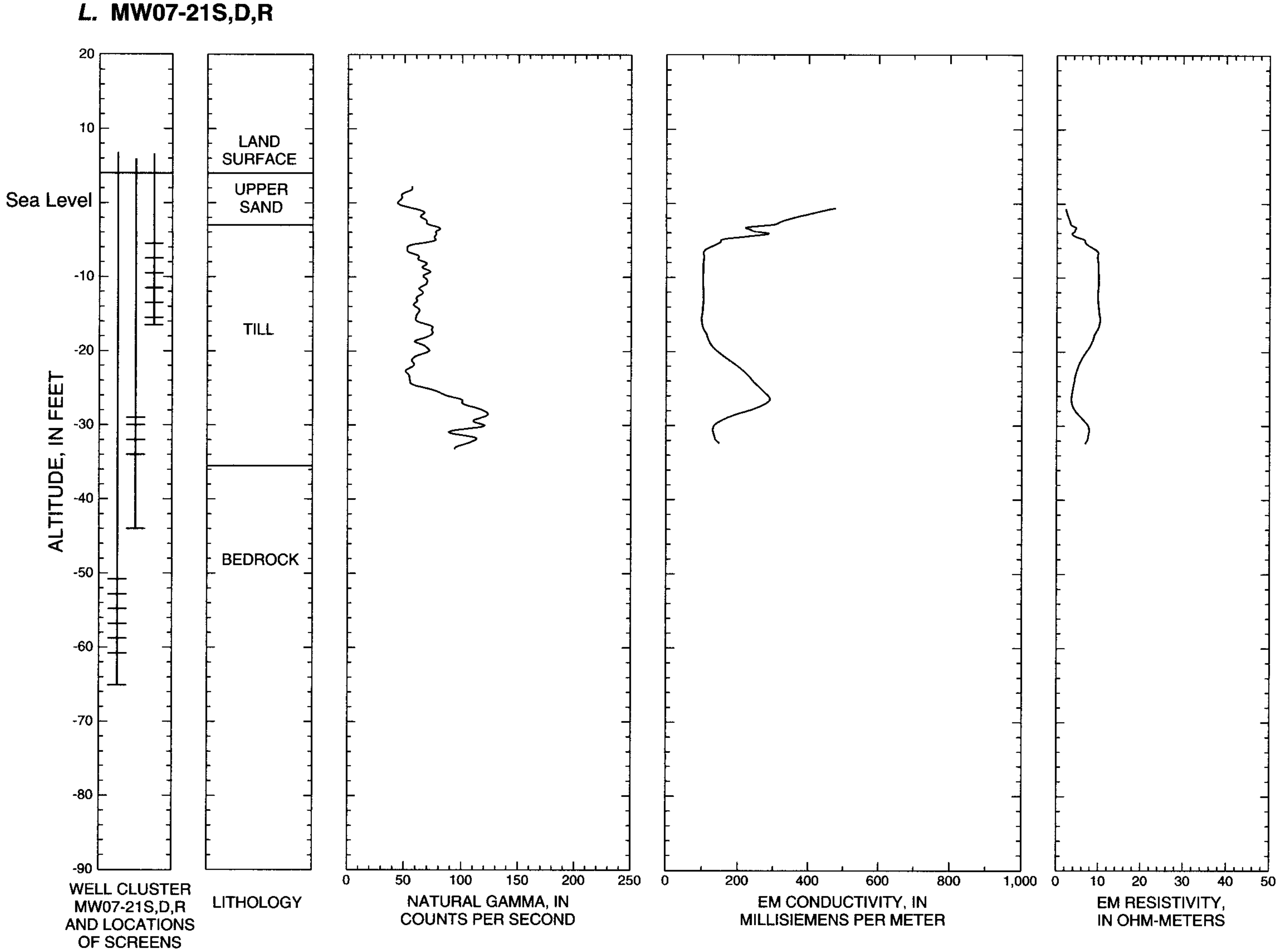


Appendix 1. Lithologic and borehole geophysical logs at Calf Pasture Point, Davisville, Rhode Island—*Continued.*

***K.* WELL CLUSTER MW07-20S,D**

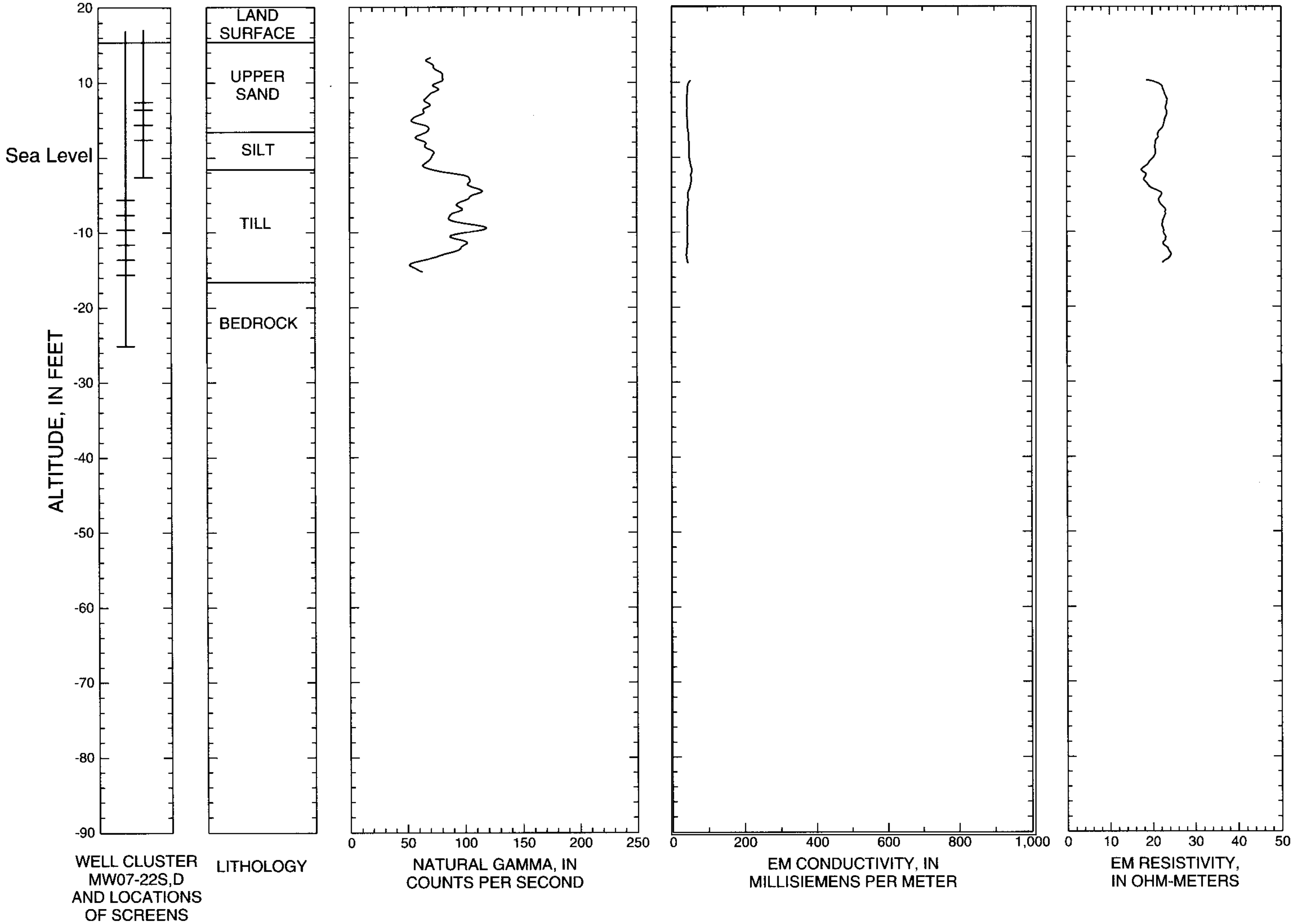


Appendix 1. Lithologic and borehole geophysical logs at Calf Pasture Point, Davisville, Rhode Island—*Continued.*



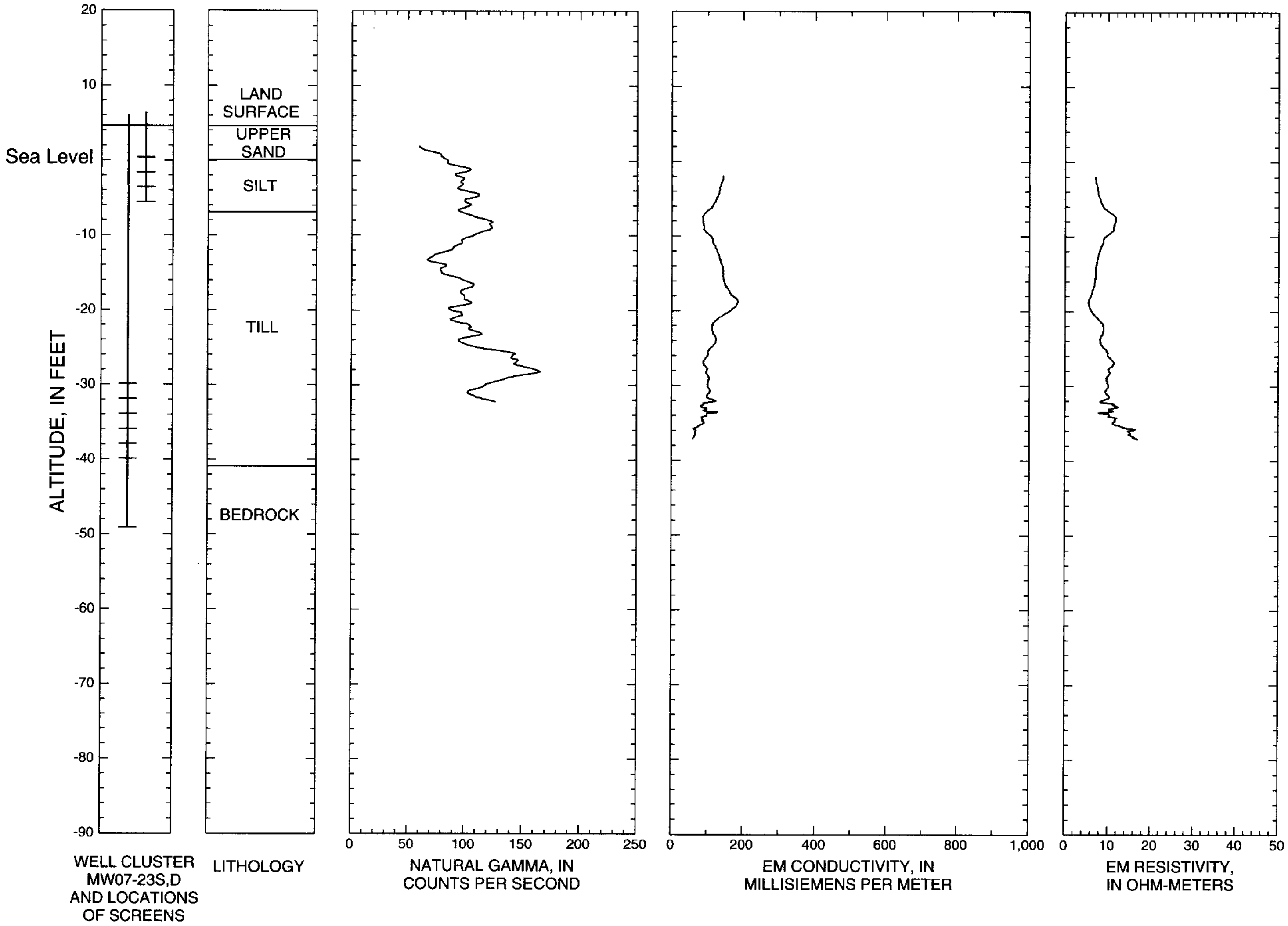
Appendix 1. Lithologic and borehole geophysical logs at Calf Pasture Point, Davisville, Rhode Island—*Continued.*

M. WELL CLUSTER MW07-22S,D



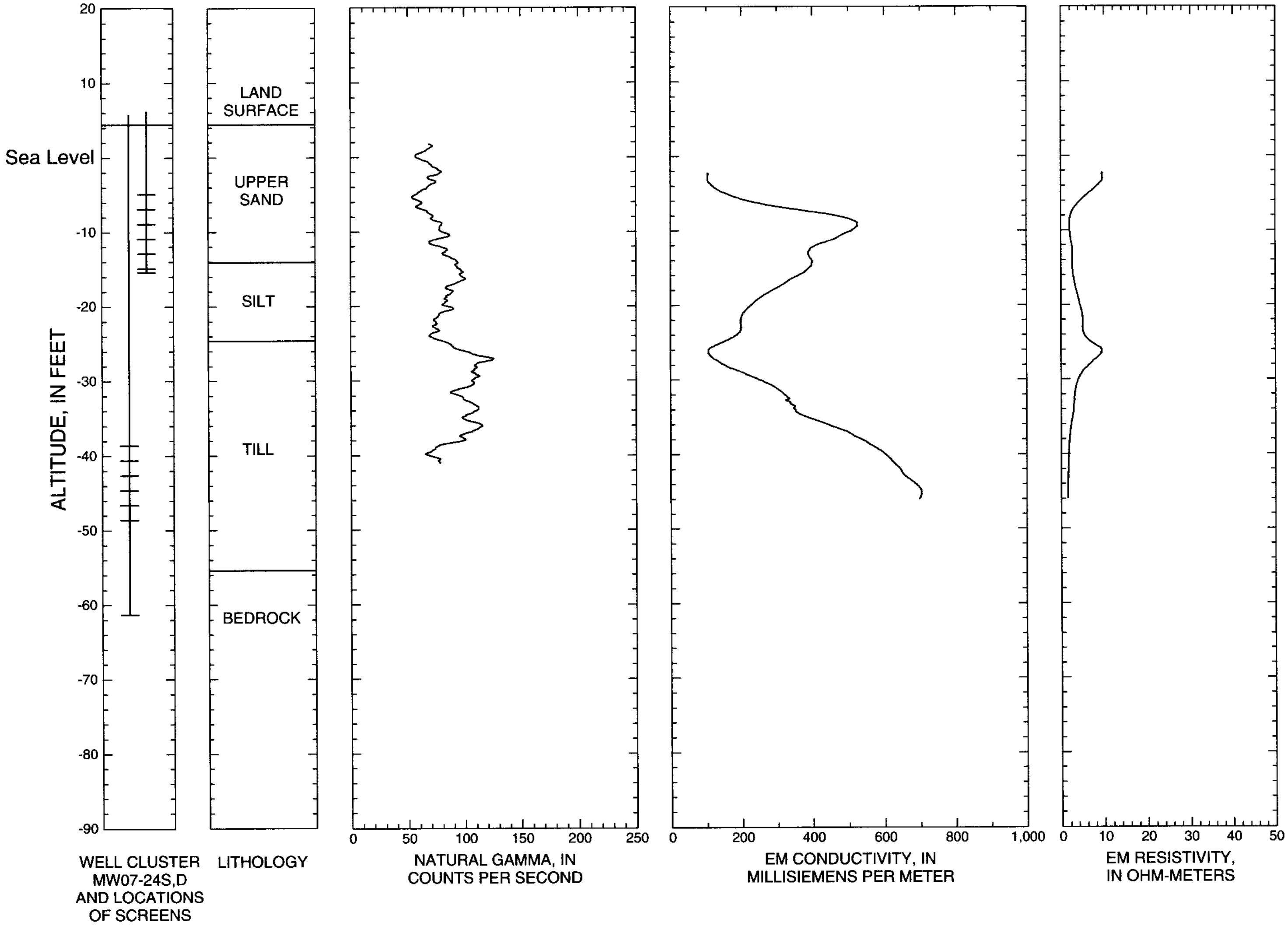
Appendix 1. Lithologic and borehole geophysical logs at Calf Pasture Point, Davisville, Rhode Island—*Continued.*

N. WELL CLUSTER MW07-23S,D



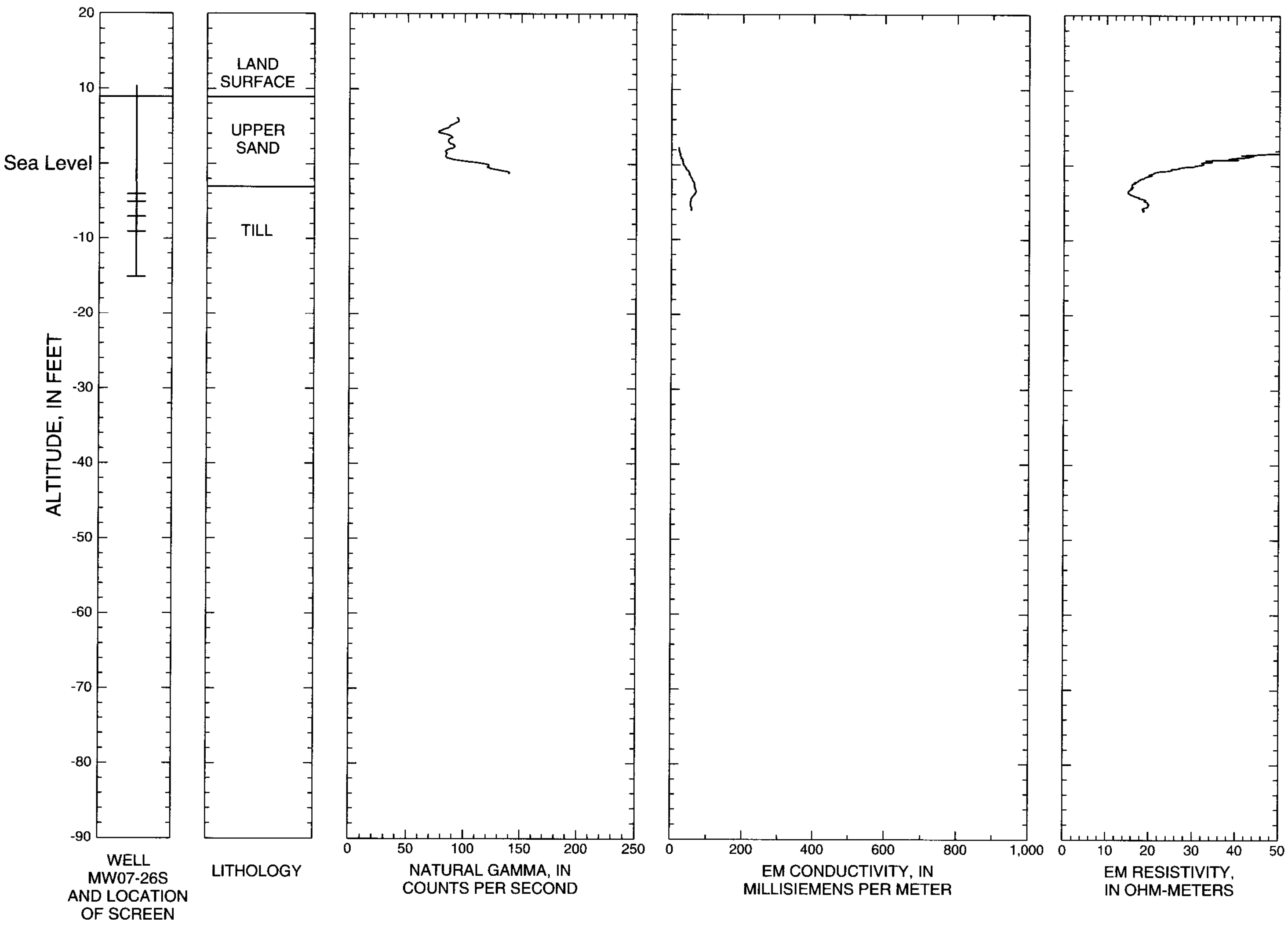
Appendix 1. Lithologic and borehole geophysical logs at Calf Pasture Point, Davisville, Rhode Island—*Continued.*

O. WELL CLUSTER MW07-24S,D



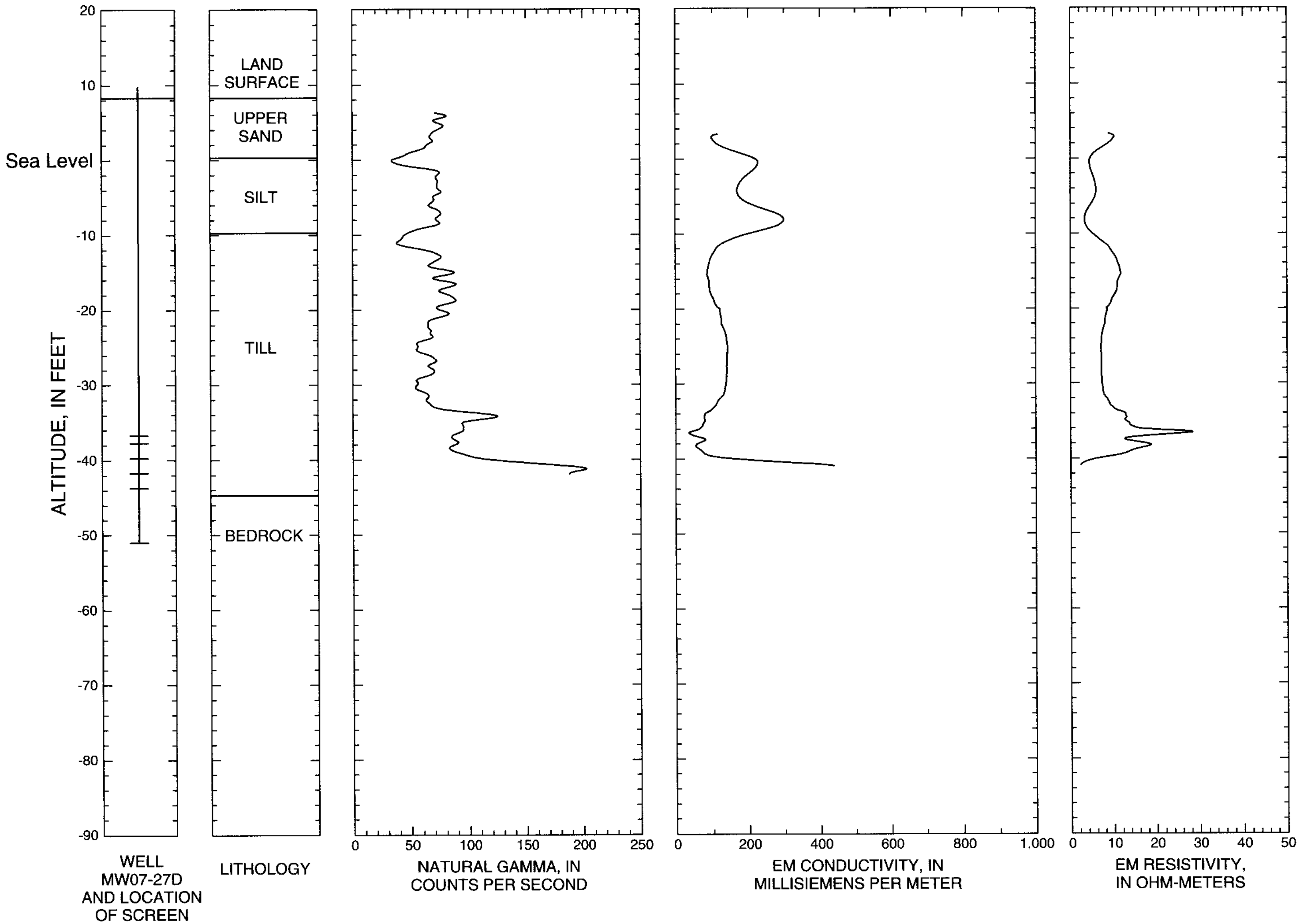
Appendix 1. Lithologic and borehole geophysical logs at Calf Pasture Point, Davisville, Rhode Island—*Continued.*

P. WELL MW07-26S



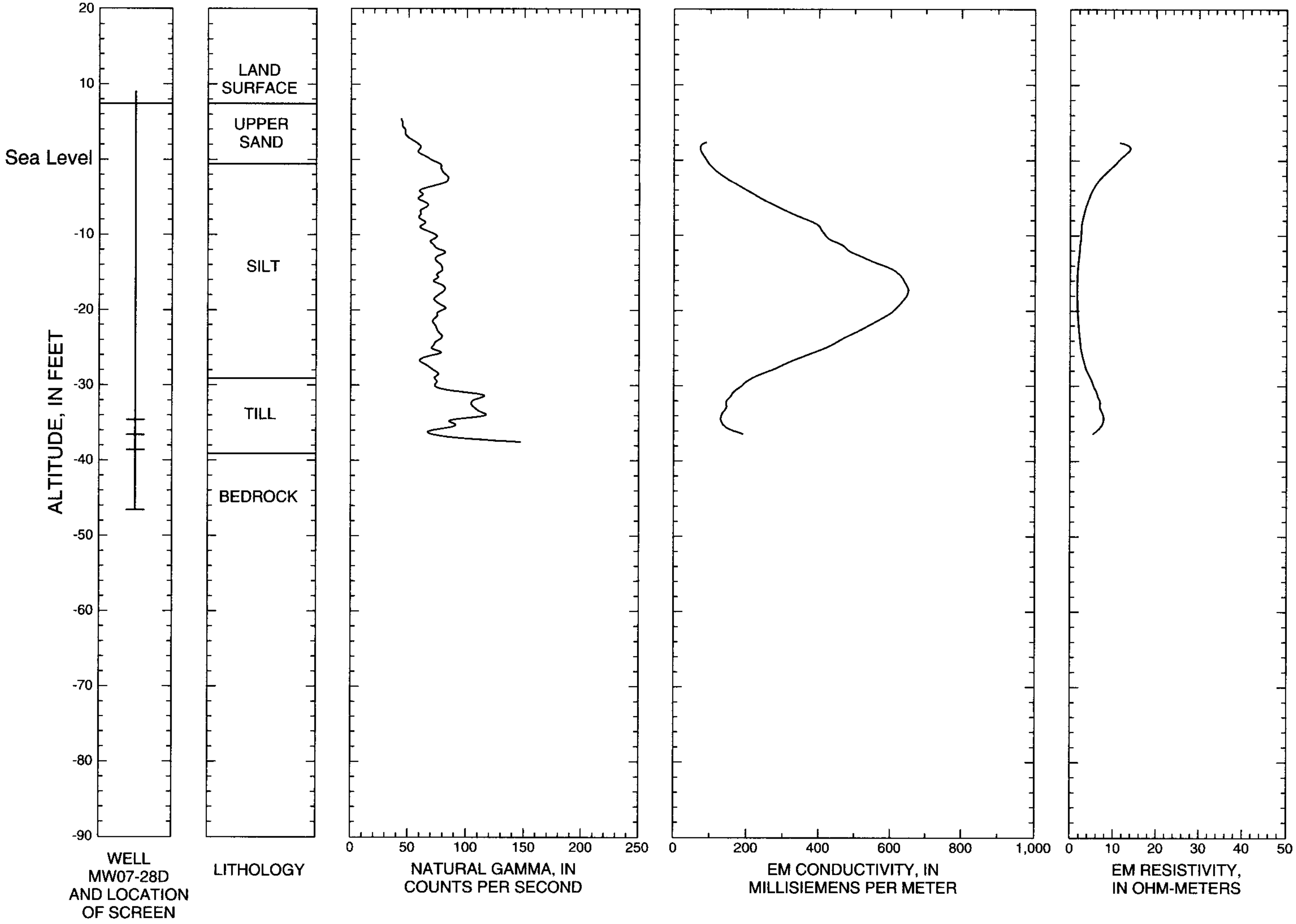
Appendix 1. Lithologic and borehole geophysical logs at Calf Pasture Point, Davisville, Rhode Island—*Continued.*

Q. WELL MW07-27D



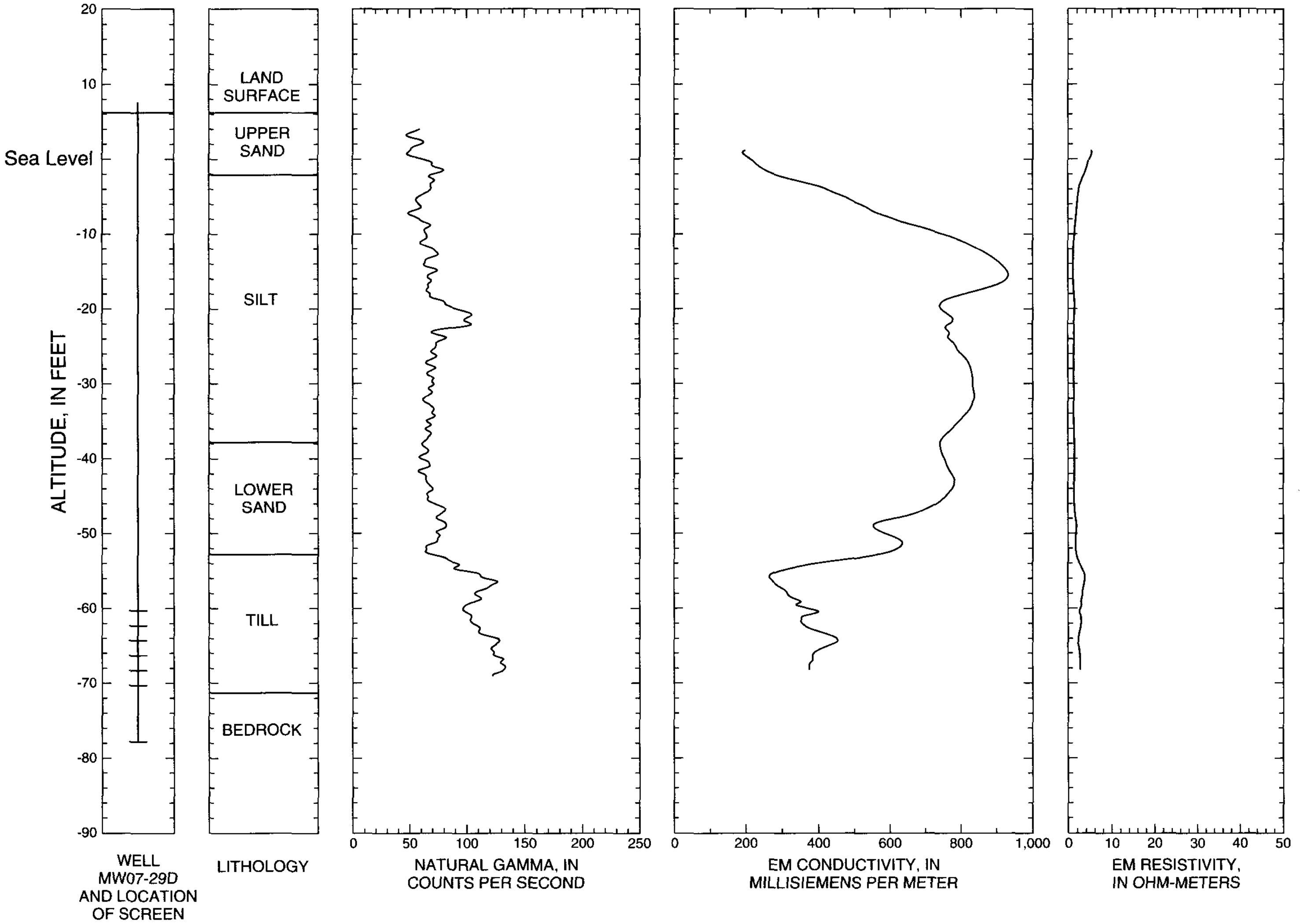
Appendix 1. Lithologic and borehole geophysical logs at Calf Pasture Point, Davisville, Rhode Island—*Continued.*

***R.* WELL MW07-28D**



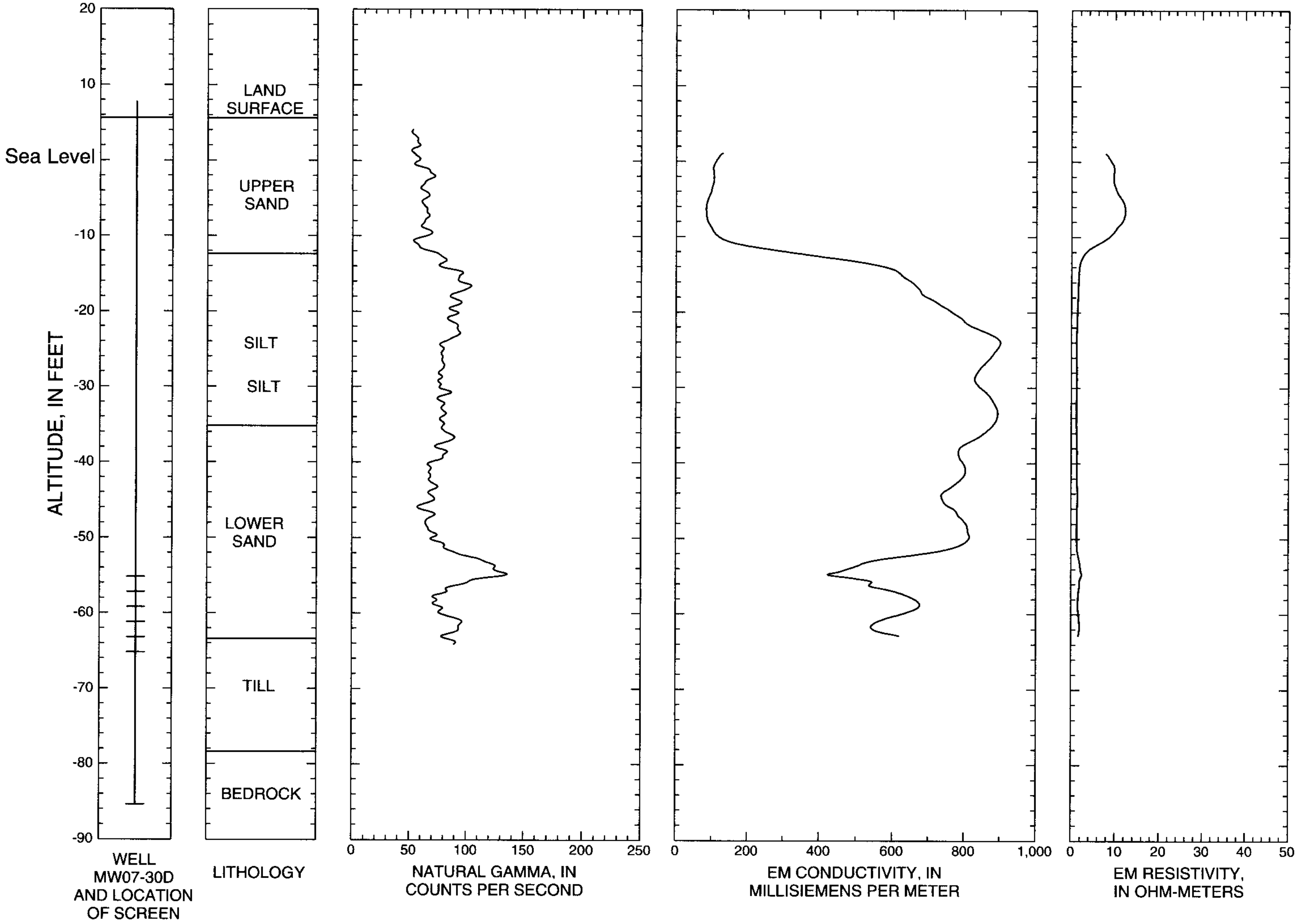
Appendix 1. Lithologic and borehole geophysical logs at Calf Pasture Point, Davisville, Rhode Island—*Continued.*

S. WELL MW07-29D



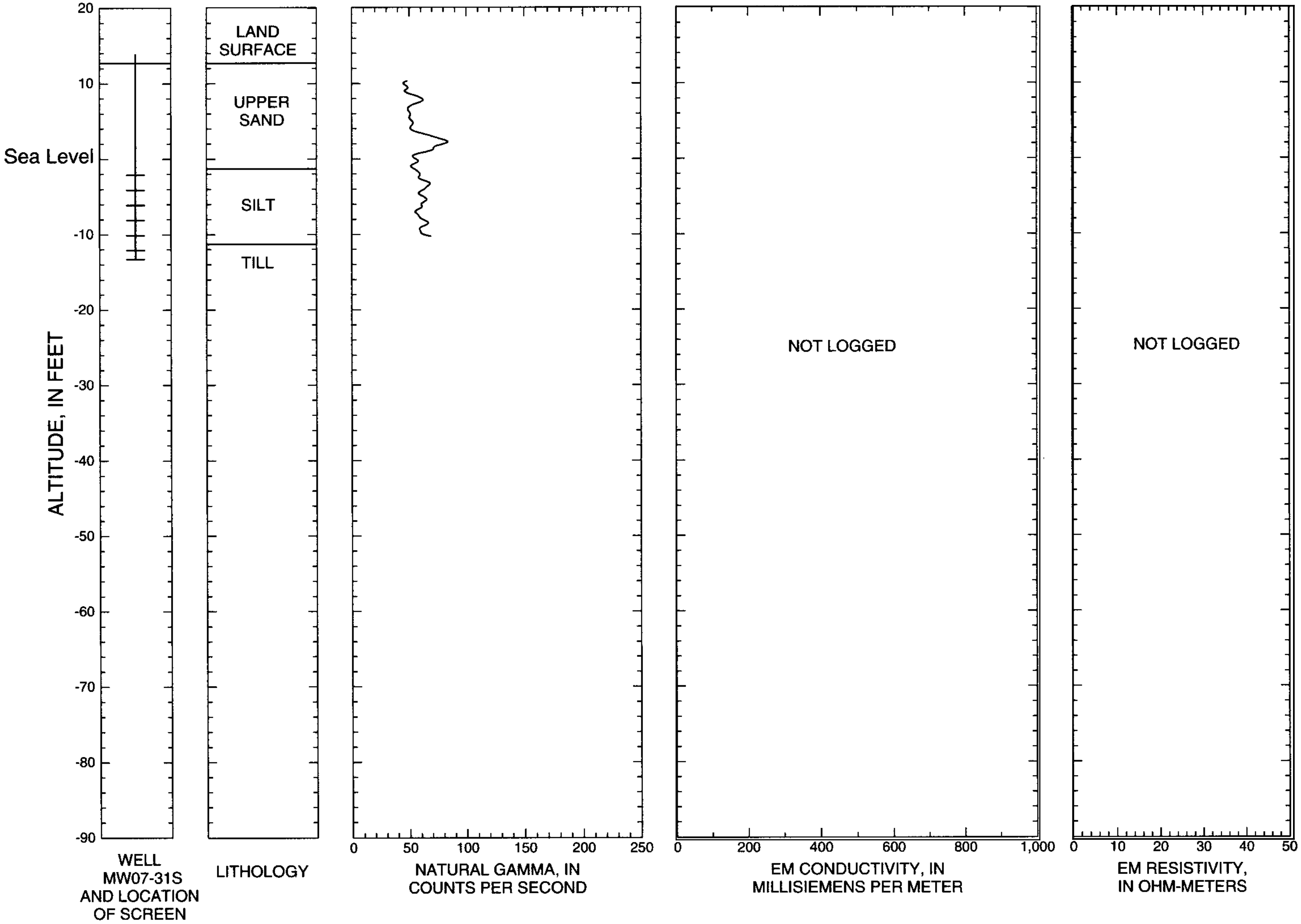
Appendix 1. Lithologic and borehole geophysical logs at Calf Pasture Point, Davisville, Rhode Island—*Continued.*

T. WELL MW07-30D



Appendix 1. Lithologic and borehole geophysical logs at Calf Pasture Point, Davisville, Rhode Island—*Continued.*

U. WELL MW07-31S



Appendix 1. Lithologic and borehole geophysical logs at Calf Pasture Point, Davisville, Rhode Island—*Continued.*

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