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Title:

COMBINED USE OF TRANSIENT ELECTROMAGNETICS, PASSIVE SEISMIC, AND NUCLEAR MAGNETIC RESONANCE METHODS TO CHARACTERIZE AN UNCONSOLIDATED AQUIFER ON CAPE COD, MASSACHUSETTS

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Abstract:

Very few deep boreholes exist near the coast on Cape Cod. In 2016, the U.S. Geological Survey drilled a borehole to bedrock in Falmouth, Massachusetts, to improve understanding of the glacial history and hydrologic properties of the Cape Cod aquifer. Prior to drilling, candidate sites were investigated using transient electromagnetics (TEM) and passive seismic horizontal-to-vertical spectral ratio (HVSR) methods to estimate depths to bedrock and the freshwater/saline-water interface. At the Falmouth site, the TEM results indicated saline water at 49 m below land surface (bls) and bedrock at 92 m bls. The HVSR results indicated bedrock at 88 m bls.

The borehole was drilled using the sonic drilling method, requiring injection of freshwater during drilling. Bedrock was encountered at 93 m bls. The borehole was completed to bedrock using polyvinyl chloride (PVC) casing. Differencing of electromagnetic (EM) logs collected ~10 and 100 days after drilling delineated intervals where formation water displaced drilling fluids in discrete zones of higher porosity and k. These zones were confirmed with borehole nuclear magnetic resonance (NMR) logs that provided water content and k estimates every 0.5 m. NMR results indicate that porosity ranges from 0.19 to 0.42 with an average of 0.33, and k ranges from 0.5 to 405 meters per day (m/d) with an average of 54 m/d, results that are consistent with local- and aquifer-scale measurements. HVSR- and

TEM- derived depths to bedrock were within 5 and 1 percent of the drilled depth, respectively. The TEM-estimated saturated thickness and fresh/saline-water interface was within 2 percent of the contact interpreted from the EM logs.

These results demonstrate the utility of combined TEM and HVSR methods for mapping the subsurface conductivity structure and thickness of unconsolidated aquifers and the efficacy of NMR logging to provide continuous logs of hydrologic properties in PVC-cased boreholes.

Keywords:

NMR, TEM, HVSR