Monitoring Movement of the Saltwater Transition Zone Beneath the Virginia Eastern Shore by Electromagnetic (EM)-Induction Logging

OBJECTIVE

To gain knowledge of movement of the saltwater transition zone beneath the Virginia Eastern Shore that supports sound management of this sole-source groundwater supply.

PROBLEM DESCRIPTION

Because of the lack of fresh surface water on the Virginia Eastern Shore, nearly all freshwater is supplied by a shallow and laterally constrained aquifer system. Expanding well withdrawals for diverse uses continually lower water levels, alter flow directions, and steepen hydraulic gradients to increase the likelihood of saltwater intrusion from nearby Chesapeake Bay to the west and the Atlantic Ocean to the east. Withdrawal amounts currently permitted by the Virginia Department of Environmental Quality (DEQ) could result in possible future increases in groundwater salinity on both sides of the peninsula, as indicated from a computer model developed by the U.S. Geological Survey (USGS). This groundwater model provides a means for DEQ and Eastern Shore planners to better manage the groundwater resource. Calibration of the model was based on an array of chemical tracers sampled by USGS from over 50 wells during the fall of 2003. Chloride-concentration data further indicate past and present positions of the transition zone between fresh and salty ground water. A need now exists to monitor possible future movement of the transition zone.

BENEFITS

This study will monitor possible movement of the saltwater transition zone – the primary boundary on the sole freshwater resource of the Virginia Eastern Shore – and thereby provide fundamental information needed for resource-management efforts to address increasing groundwater withdrawals.

EM-INDUCTION LOGGING

Sampling provides the most direct determination of groundwater chemistry, but is costly and provides only a single composition integrated over the well screen. Sampling of adequate scale and duration to monitor the transition zone beneath the Eastern Shore would require a relatively large effort.

In contrast to well sampling, borehole geophysical logging can be selectively applied to more cost-effectively monitor chemistry changes. Geophysical logging entails controlled movement of an instrument along a borehole that records a vertical profile of various properties of surrounding materials. An array of logging techniques has been developed to fulfill various purposes. Among them, electromagnetic (EM)-induction measures bulk electrical conductivity. A probe lowered into the borehole generates an electromagnetic field that induces an electrical current in the surrounding material. The induced current then generates a secondary electromagnetic field that generally is proportional in strength to the electrical conductivity of the material. Vertical variations in conductivity result from differences in borehole diameter, sediment properties, and groundwater chemistry (fig.1).

EM-induction logging is advantageous in determining changes in groundwater chemistry over time. Vertical resolution is precise, and instrument response is primarily from materials beyond the borehole and generally unaffected by borehole fluid. Thus, unlike many logging techniques that require unfinished open boreholes, EM-induction can be performed on completed wells cased with non-magnetic pipe such as PVC. Completed wells can thereby be repeatedly logged at widely spaced time intervals. Assuming that borehole diameter and sediment properties remain constant, any differences among logs from an individual well result from changes in groundwater chemistry during the period.

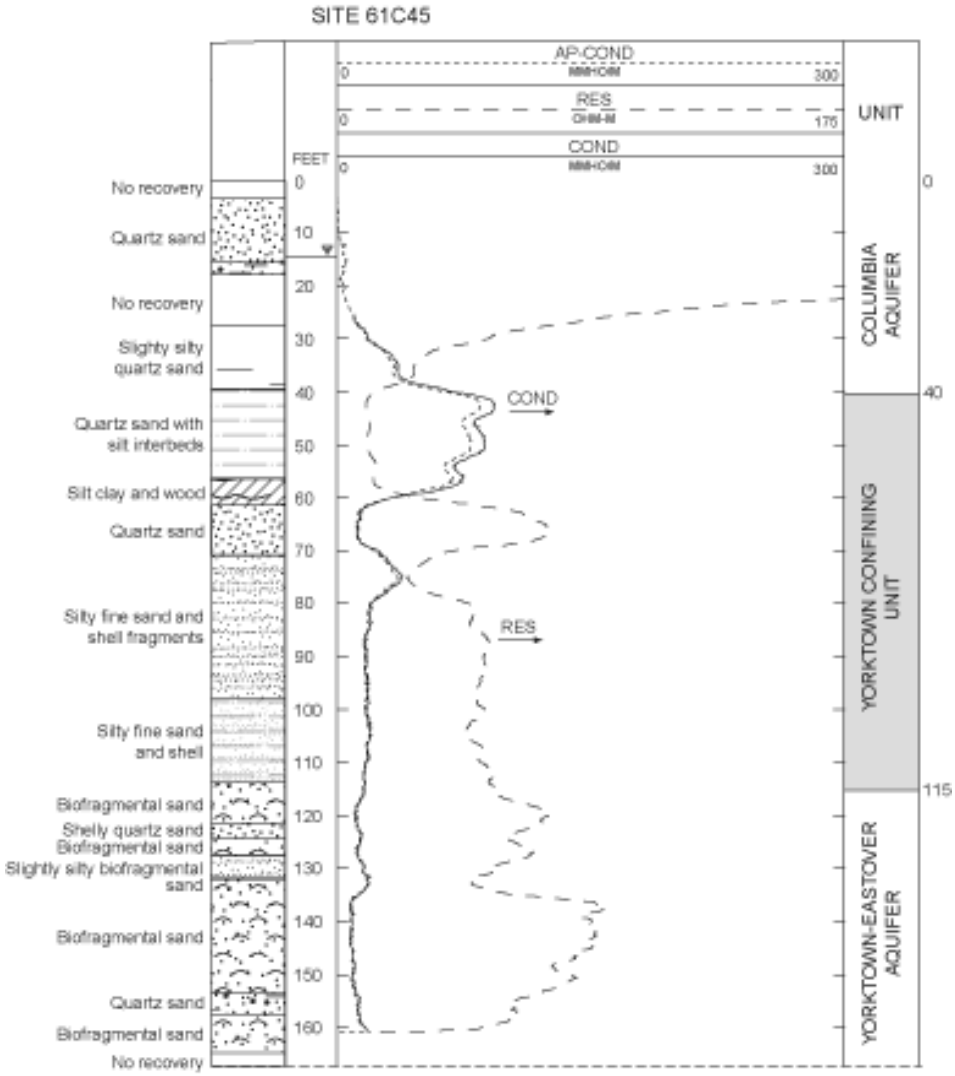

Figure 1.
EM-induction log and related borehole information on USGS well 61C 45 at Virginia Beach

STUDY APPROACH

Groundwater chemistry on the peninsula is dominated by the contrast between freshwater and saltwater. Differences over time among EM-induction logs obtained from an area-wide network of existing wells can provide a cost-effective means of monitoring transition-zone movement.

A program was proposed in 2008 for EM-induction logging to monitor possible future movement of the saltwater transition zone beneath the Virginia Eastern Shore. An initial network of 12 wells was developed based on model simulations of future transition-zone movement, and on observed magnitudes and temporal trends in chloride-sample concentrations. To establish a common baseline among the wells and in time, the response across the well screen on the log obtained from each well was correlated to the chloride-sample concentrations from 2003. To determine any changes resulting from movement of the saltwater transition zone, the proposed program originally included logging of an expanded well network on a repeated yearly basis but to-date has not received further funding.

All 12 of the network wells initially logged in 2008 will continue to be logged again during 2020, contingent upon well condition, accessibility, and other logistical constraints. Log data files will be shared with the Accomack-Northampton Planning District Commission (ANPDC), and provisional results will be provided by an oral presentation and project progress report. Total cost for this program during FY 2020 (October 1, 2019 through September 30, 2020) is $28,000, to be shared equally by the USGS ($14,000, subject to availability) and the ANPDC ($14,000). A senior hydrologist and hydrologic technicians will staff the project part-time.

For further information, contact Sam Caldwell (804-381-8381; scaldwell@usgs.gov) or Kurt McCoy (804-261-2656: kjmccoy@usgs.gov) at the USGS Virginia Water Science Center, Richmond, Virginia.