Directional Flow Tracking in Open Boreholes of Fractured-Rock Aquifers Under Ambient, Standard, and Zonal Pumping Conditions, Northeastern U.S.

Philip T. Harte (ptharte@usgs.gov) (U.S. Geological Survey, NH/VT Water Science Center, Pembroke, New Hampshire, USA)
*William Brandon (Brandon.bill@epa.gov) (U.S. Environmental Protection Agency, Region 1, Boston, Massachusetts, USA)
Randall Bayless (ebayless@usgs.gov) (U.S. Geological Survey, IN Water Science Center, Indianapolis, Indiana, USA)

Program session suggestions:
Characterization, Fate and Transport, Risk Assessment of Chlorinated and Recalcitrant Compounds
1a1 Advances in high-resolution site characterization technologies
1k Incremental sampling
*Presenter

Background/Objectives; Understanding flow paths in open rock boreholes over a sub-meter scale allows for tracking and identification of contaminant transport pathways. Further it helps map the RSV (representative sample volume) of water samples. Knowing the RSV is a fundamental building block in the evaluation of contaminant concentrations from open boreholes, essentially answering the important question of "what does it measure".

Approach/Activities; Directional flow tracking using advanced tools such as horizontal heat-pulse and colloidal borescope flowmeters were deployed in open boreholes under a variety of hydraulic conditions to map the RSV. The horizontal flowmeter measures the horizontal direction and velocity of groundwater flow. The colloidal borescope identifies the trajectory of particles moving in the borehole fluid. Both tools are useful in the identification of flow in the borehole and changes in flow that result from different conditions and pumping configurations, particularly those used to isolate zonal flow during hydraulic containment sampling in open boreholes.

Results/Lessons Learned; Directional flow tracking from both tools helped identify the direction of inflow at fracture locations intersecting an open borehole set in a granite formation at the Naval Air Station South Weymouth, MA. Open borehole inflow directions at fractures showed strong directional tendencies under ambient conditions. Conversely, inflow directions showed large directional scatter under pumping conditions that mimicked standard (i.e., low-flow) sampling procedures at the site. Results suggest water from both sides of the fracture (radially planar) contributes to flow during pumping of the open borehole. When utilizing a multilevel pumping configuration, which is used for hydraulic containment sampling (ZONFLO), the development of stagnation or minimal velocity zones between pumps were observed as indicated by a significant decrease in particle velocities.

This poster presentation will illustrate directional and velocity results from the horizontal flowmeter and colloidal borescope tools under a variety of hydraulic conditions. Implications for transport, sampling, and monitoring at the site will be discussed.