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Hydraulic Tomography: Estimating 3-D Hydraulic Conductivity in a DNAPL-Contaminated Fractured Rock Aquifer, Newark Basin, New Jersey, USA

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Background/Objectives. Fractured-rock aquifers are very challenging to remediate, in large part because of the difficulty in characterizing the 3-D distribution of hydraulic conductivity (K). Detailed knowledge of fracture network geometry and connectivity, and of variations in K for both the fractures and the rock matrix can significantly assist design and operation of bioremediation in contaminated fractured-rock aquifers. Hydraulic tomography (HT), an emerging field and modeling method for 3-D high-resolution characterization of heterogeneous K, is being applied to a fractured mudstone aquifer contaminated with chlorinated solvents at the former Naval Air Warfare Center (NAWC) in the Newark Basin near Trenton, New Jersey.

Approach/Activities. HT in the field consists of a series of pumping tests, each from a different individual packer-isolated well zone, with drawdowns continuously monitored in a dense network of other packer-isolated zones. For HT testing at NAWC, we investigate a volume with six wells in a circle of 9 m diameter, a seventh central well, and an aquifer thickness of 15-20 m. In 2015 and 2016 we conducted 48 pumping tests in isolated zones at rates from >5 L/min to <50 mL/min while measuring drawdown in about 30 to 40 zones that collectively span all wells, the full aquifer thickness, and all stratigraphic units. The current modeling approach involves inversion of all tests together to estimate the 3-D K distribution, with uncertainty calculations and validation (using five tests withheld from the initial inversion) to evaluate the quality of results. We use minimal prior site information and assumptions about the fracture system in the models to avoid biasing the solution.

Results/Lessons Learned. The collective set of drawdown data from all tests displays a wide range of behavior suggestive of highly heterogeneous K and local variations in connectivity such as: drawdown curves for different well intervals crossing one another; variable drawdown curve shapes; and major variation in the order of drawdown initiation and magnitude for sequences of intervals within and between wells – including intervals with early and large drawdown located between intervals with distinctly later and smaller drawdown, or vice versa. Televiewer log expressions of fractures and rock matrix do not always correlate with observed pumping or drawdown behavior. Tomographic inversion, in progress, is estimating 3-D K distributions consistent with a conceptual model that includes distributed fractures of moderate K at the shallowest depths, connected high-K bedding-plane-parting fractures at intermediate depths, and sparse low-K fractures in the deeper rocks. The 3-D K distribution from an initial inversion shows variable connectivity between fractures and variable K within fractures. Resolution of the fracture network increases progressively inward to the middle of the investigated volume, as expected, due to increasing density of test coverage toward the center of the wellfield. Next steps include: completing the tomographic inversion for 3-D K; assessing quality of results; estimating 3-D specific storage (Ss); and assessing the limits of resolution for K estimation by using a more refined parameter discretization.