
Andrew Michalski, Ph.D., CGWP, Michalski & Associates, Inc.

Abstract

Thousands of contaminated groundwater sites have been identified in fractured shales, mudstones and sandstones of the Newark Basin and other Mesozoic rift basins scattered along the East Coast. Our data from numerous sites in New Jersey show that conceptualization of this type of bedrock as a leaky multiunit aquifer system (LMAS) provides a realistic and predictable hydrogeologic framework that can significantly improve the effectiveness of the characterization and remediation of contaminated groundwater at such sites.

In this hybrid conceptual model, the bulk of groundwater flow in the bedrock is transmitted through only a few bedding fractures with the largest hydraulic apertures. These fractures function as discrete tabular aquifers and collectors of flows from sub-vertical joints in adjacent beds that assume the role of semi-confining/aquitard units. Thick mudstone beds tend to behave as major aquitard units. Groundwater flow within a major bedding fracture generally parallels the strike of bedrock layers. The major bedding fractures occur at uneven stratigraphic intervals of tens to hundreds of feet, and typically exhibit transmissivity values greater than 1,000 gpd/ft (15,000 gpd/ft in one case). Measured storativity values are very low ($1 \times 10^{-5}$ - $1 \times 10^{-6}$). Tracer groundwater velocity in a major bedding fracture can exceed 10 ft/d at low ambient horizontal hydraulic gradient values (0.001-0.0001). Such major bedding fractures provide preferential flow pathways for groundwater (and contaminants) derived from adjoining aquitards, weathered bedrock zone and overburden zones. The weathered bedrock zone (30-100 ft thick) is superimposed on the multiunit bedrock. This zone exhibits a large number of poorly integrated fractures, which increases its bulk porosity and storage, while reducing its permeability. Strong vertical gradients are common between piezometers installed in the weathered zone and up-dip extensions of major bedding fractures into this zone. Overall, the multi-aquifer structure imparts a strongly anisotropic behavior to the entire set of dipping bedrock layers.

The LMAS framework should become a default conceptual model for groundwater characterization, remediation and monitoring at most sedimentary bedrock sites. Past practices of portraying the bedrock in convenient terms of depth zones (shallow, deep and sometimes intermediate) generally ignored the discrete multi-unit structure of dipping bedrock layers. Common adverse consequences of such practices range from distorted potentiometric data and flow direction, mis-delineated contaminant plumes, to induced migration of NAPLs and dissolved plumes via inadvertent cross-flows, and ultimately to failed remediation efforts. Re-evaluation of such problem sites in terms of the postulated LMAS framework is a necessary remediation step.

A practical strategy for an expedited bedrock characterization relies on a controlled short-circuiting of transmissive bedrock fractures in a long temporary test hole (TTH) to develop a site-specific LMAS model and to quantify the transmissivity, head, and contaminant concentration values for individual transmissive fractures. A set of fracture characterization tests includes: the televviewer, caliper, electrical conductivity and temperature logs, in-hole flow tracing (or flowmeter log), discrete-depth fluid sampling, and packer testing. In addition to routing packer sampling, the packer test is used to estimate transmissivity and head values for each transmissive fracture interval tested, and to assess near-field vertical connections between such fractures. When converting a TTH to monitoring wells, receiving fractures become prime targets for future monitoring. Routine well purging is also used as short-term pumping tests to verify the hydraulic continuity of transmissive fractures between the TTH locations. For a rapid assessment of a suspected DNAPL site, two TTHs are first installed along the strike of bedding: one upgradient and the other downgradient (and at a safe distance) of the suspected DNAPL entry area. Then the third TTH is installed down-section of the entry area to assess a possible DNAPL migration down-dip of transmissive bedding fractures identified by the first two TTHs.

Biographical Sketch
Andrew Michalski, Ph.D., CGWP, is principal consultant at Michalski & Associates, Inc., 1301 Jankowski Court, South Plainfield, NJ 07080, E-mail: amicha1301@aol.com, tel. 908-757-8867, fax 908-757-8587.

During the last 20 years, he conducted hands-on groundwater investigations at more than 50 fractured bedrock sites in the Newark Basin, and assisted other consulting firms in re-evaluating bedrock hydrogeology and remediation strategies at many DNAPL sites ranging from one to 500 acres. He authored seminal papers on the hydrogeology of fractured bedrock of the Passaic Formation, and developed a practical approach to the hydrogeologic characterization of fractured bedrock that included an improved in-well flow tracing. Dr. Michalski received a M.Sc. in Mine Hydrogeology and a Ph.D. in Technical Sciences from Krakow, Poland. He held senior-level positions with the Whitman Companies, TRC, Earth Tech, and taught a hydrogeology course at Rutgers University.