Characterization of fractured rock to develop conceptual models of ground-water flow and transport of mercury

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ABSTRACT
Mercury (elemental and dissolved) is detected throughout the site of a former chlor-alkali plant along the bank of the Androscoggin River in Berlin, N.H. Elemental mercury is detected in fractured depressions and potholes on the exposed bedrock surface in the river channel. Dissolved forms of mercury are detected in ground water in the overburden and bedrock. The site is adjacent to a dam with impounded water on the upgradient side and channelized river flow below the dam on the downgradient side, which induces a steep hydraulic gradient within the bedrock.

Results from ground-penetrating radar and two-dimensional resistivity surveys along the riverbank indicate electrically conductive zones that are interpreted as bedrock fractures. Geologic mapping along the riverbank shows that the bedrock is more fractured in gneiss than in pegmatite. Fractures are prevalent in schist in shear zones that correspond to geophysical anomalies. Fractures in the gneiss were observed to truncate against pegmatite contacts. Ground-penetrating radar surveys, in areas mapped as containing pegmatite, identified nearly horizontal anomalies that may represent vertical fractures in gneiss that truncate at a horizontal fractured contact between the gneiss and pegmatite.

Hydraulic connections were identified by comparing stage changes in the Androscoggin River with ground-water levels in bedrock observation wells. The magnitude of response of ground-water levels in the bedrock to changes in river stage varied spatially, indicating heterogeneity in the bedrock. The direction of maximum head gradient is similar to the fracture orientations found by the geophysical and geologic mapping. A simplified ground-water model of bulk fluid flow was constructed to test the conceptual model that fracture strike orientations impart a strong preferential anisotropy to the flow system. To replicate the observed direction of maximum head gradients, a horizontal anisotropy (100:1) was needed in the model.

Results from this study will be used to plan for additional monitoring studies and to develop remedial strategies to help reduce the amount of mercury discharge to the river. Remedial strategies will benefit from the improved conceptual models of flow developed.

Biographical Sketches

Philip T. Harte is a research grade hydrologist with the USGS (U.S. Geological Survey, NH/VT District, 361 Commerce Way, Pembroke, NH 03275; 603-226-7813; ptharte@usgs.gov). He has a bachelors degree in Geology from CUNY Queens College and a MS in Hydrology from the University of New Hampshire. As a hydrologist with the USGS, he has 20 years of experience in ground -water studies and chemical sampling. He specializes in ground-water flow and solute- transport modeling. He also has worked as an environmental specialist with the U.S. Naval Reserve.

James R. Degnan attended the University of New Hampshire in Durham, and obtained a BS degree in Geology in 1997. James began working for the U.S. Geological Survey in New Hampshire in 1994 as a student (3 years), and has been working fulltime since 1997 (7 years) on ground water research projects, utilizing geophysics and remote sensing.

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Tom Mack received a Bachelor of Arts degree in geology from Hartwick College in 1980 and a Master of Science degree in hydrology from the University of New Hampshire in 1982. He has been a hydrologist with the USGS since 1983. He specializes in ground-water-flow modeling and geophysical investigation of surficial and bedrock aquifers.