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Analysis of a Large-Scale Solute Transport Experiment Conducted in a Discrete Rock Fracture

Matthew Howroyd (1) and Kent Novakowski (2)

(1) Queens University, Kingston, Canada (16mh57@queensu.ca), (2) Queens University, Kingston, Canada (kent.novakowski@queensu.ca)

In bedrock aquifers, fractures complicate contaminant migration by allowing for both rapid transport over long distances through complex fracture pathways and diffusion into the rock matrix adjacent to the fracture. Due to the complexity and experimental difficulty associated with measuring transport in discrete fractures, there are relatively few studies analyzing solute transport at a larger scale (>50m). Processes which could influence transport at this scale include fracture connectivity, spatial heterogeneity of fracture aperture, variable matrix porosity, and regional gradients which vary temporally. In this study, we analyze a large-scale tracer experiment previously conducted at a site in Ontario, Canada. A dye tracer and bromide salt were injected in a very precise fashion into an isolated fracture in the upper 10 m of a fractured dolostone unit and then breakthrough was observed at five downstream observation wells up to 126 m away. The analysis was conducted by creating an initial, finite-element model based on properties estimated from field measurements and then by systematically testing a wide variety of transport processes using defensible parameters to achieve a fit between the model and the measured data. The initial model was developed using a single, uniform fracture having an aperture of 750 μm and a uniform matrix porosity of 7.5%. This model obtained a poor fit to the measured breakthrough curves. Following exhaustive testing using different configurations of parameters, the results show many possible arrangements that match the experimental data, thus presenting the problem of non-uniqueness. Despite this, the configurations that succeed all involve adding multiple horizontal and vertical fractures in a complex network or using a highly variable field of apertures such that transport is controlled by the presence of low conductivity regions. Therefore, the evidence suggests that fracture interconnections and aperture heterogeneity may play the key role in large scale transport through the addition of tortuosity to the flow path.