Using Tracer Test Data to Calibrate a Groundwater Flow and Solute Transport Model

Background/Objectives. Groundwater models are routinely used to aid decision-making at former hazardous waste disposal sites. Models are used to evaluate remedial actions, predict future conditions, and understand potential human health or ecological exposure risks. Generally, groundwater modeling is a two-step process in which a hydraulic flow model is constructed and calibrated, and then a solute transport model is constructed and calibrated. At a rural Northeastern National Priorities List (NPL) site, tracer test data were used as a rare additional step to calibrate both models and greatly improve the accuracy of their predictions.

Drums and loose wastes containing chlorinated solvents were disposed in trenches at the site in the late 1970s. The site was placed on the National Priorities List in the early 1980s. A series of remedial actions, including source excavation and soil-vapor extraction (SVE), were successfully implemented at the site. Yet, even after successive remedial actions were completed, some residual source material remained in inaccessible areas. A hydraulic control system was instituted to capture and mitigate the resulting downgradient plume.

In 2012 and 2013, the hydraulic control system was shut down for one year as part of a focused feasibility study to evaluate remedial options for the residual source material. During the shutdown, a comprehensive tracer test was performed. Three independent, conservative tracers (rhodamine, eosine, and fluorescein) were injected at three different source area locations. Fluorescein was injected into glacial till deposits overlying bedrock; rhodamine was injected into shallow bedrock; and eosine was injected into a monitoring well screened across both the glacial till and the shallow bedrock. Downgradient locations were monitored for one year to develop tracer breakthrough curves. Site-wide hydraulic heads and chemistry were monitored to collect additional calibration data for the models. The tracer data, consistent with other hydraulic and chemistry data, revealed a previously uncharacterized, localized preferential flow pathway created by spatially varying thicknesses of highly weathered bedrock.

Approach/Activities. A complex flow and contaminant transport model was updated and calibrated using the tracer test data and other shutdown test results. Groundwater flow and solute transport were simulated using MODFLOW and MT3DMS99, US EPA-approved and industry standard finite difference models. The monitored concentrations of the five site constituents and three conservative tracers provided eight independent systems for calibration and simulation of the preferential flow pathway. Particle tracking was used to calculate a site-specific dispersivity value. The key parameters refined and calibrated in this model included the site source characteristics, the decay rates of the five site constituents, and the geometric/hydrogeological parameters of the site-wide geology and preferential pathway.

Results/Lessons Learned. Using the tracer data to calibrate the model resulted in a significantly more robust and more accurate model than could have been achieved by relying solely on typical hydraulic and contaminant transport calibration. In addition to good breakthrough curve matches at a large number of
wells for all eight solute transport models, a site-wide hydraulic head normalized root mean square error of less than 5% for all modeled times was achieved.