# Optimizing an Adaptive Remedy in a Highly Heterogeneous Aquifer Using Modeling

***Peter P. Brussock*** (ppbrussock@elminc.com) and Hank Martin
(The ELM Group Inc., Holicong, PA, USA)
Daniel K. Burnell (dan.burnell@tetratech.com) and Jie Xu (Tetra Tech Inc., Sterling, VA, USA)

**Background/Objectives.** In highly heterogeneous coastal plain aquifers, mass transport to recovery wells follows preferential pathways with eventually tailing in monitoring wells in which concentrations may decrease slowly over time. The primary objective of this paper is to examine how modeling can be applied to optimize mass reduction rates and reduce mass flux, particularly in both low permeability and stagnant zones that can occur in areas between recovery wells. Based on recent water level and pumping rate data collected at the well-characterized Bridgeport Oil Rental and Oil Services (BROS) Superfund Site, a groundwater flow model was recalibrated with a high quality match to the observed data. Groundwater flow modeling and particle tracking were then applied to determine recovery locations and then optimize particle travel times within stagnant zones of hot spot areas while ensuring that each recovery well pumping rate was managed to provide a total extraction rate that optimizes mass removal with the minimum pumping rate.

**Approach/Activities.** The Record of Decision specifies an adaptively managed site that began pumping-and-treatment in October 2013 following completion of In-situ chemical oxidation source reduction measures. The complex hydrogeologic setting beneath the BROS property consists of heterogeneous layers of highly permeable sands and discontinuous lower permeability clay zones that affect mass removal rates. In order to determine the 3-D capture zone and mass removal rates, the USGS MODFLOW groundwater flow model was first recalibrated to match the observed water level and pumping rate data in order to simulate the 3-D groundwater velocity field within the capture zone. In order to examine local pore volume exchange rates, particles were placed in each cell of the 3-D model grid and the USGS particle tracking code MODPATH was applied to examine the travel time for each cell in the capture zone. Based on individual well and treatment system constraints, flow modeling and particle tracking were applied to optimize recovery well locations and pumping rates. The solute transport model MT3DMS was then applied to examine improvements in mass flux reduction and removal rates based on subsequent data collected in both monitor and recovery wells.

**Results/Lessons Learned.** Through iterative data collection and modeling, the primary clay zones structures that affected mass transport to the recovery well were well characterized to understand and simulate the 3-D preferential transport pathways in the treatment zone. By recalibrating the groundwater flow model to both measured pumping rates and water level measurements over a range of groundwater extraction rates, increased accuracy of the simulated 3-D velocity distribution and mass removal rate was achieved. Results of this 3-D particle tracking modeling analysis demonstrated the utility of contouring the capture travel times from each cell in order to identify potential stagnation zones both near and between the recovery wells. By adjusting pumping dynamics, including new well locations and pumping rates during flow model optimization simulations, potential stagnation zones of lower velocity were eliminated particularly in the areas of elevated VOC concentrations. Using the MT3DMS model, subsequent solute transport modeling simulations confirmed the increased mass removal rates in the optimized remedial system. Performance monitoring and modeling will also be used to design and optimize the enhanced biodegradation system that will follow the pumping and treatment portion of the remedy.