Adaptive Dynamic Groundwater Recirculation: A Strategy for Expedited Plume Cleanup

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Background/Objectives. The evolving understanding of groundwater transport including acknowledging the importance of the mass transfer between storage, low advection and high advection zones has led to stronger conceptual site models (CSMs) and more targeted and effective remediation strategies. Dynamic groundwater recirculation (DGR) – strategic groundwater extraction combined with re-injection – is one such emerging dissolved phase remediation strategy for large plumes. The most important difference between DGR and conventional pump and treat strategies is the reliance on the CSM to develop a hydraulic flushing framework, a dynamic operation plan, and continuous adaptation based on actual remedial performance. The DGR approach includes targeted re-injections of treated water to generate hydraulic control, increase pore volume exchange, and thereby, significantly reduce the remedial timeframes.

This presentation will discuss the design and performance of a remedial system that was implemented to support the transfer of a high value property near Boston, Massachusetts (U.S.A.). The property transfer required cleanup of a 12-acre chlorinated volatile organic compound (CVOC) groundwater plume to strict standards within a very short timeframe.

Approach/Activities. The remedial strategy included source zone excavation and electrical resistivity heating (ERH) and plume DGR with targeted in-situ chemical oxidation outside the DGR area. Initial excavation targeted shallow vadose zone soil CVOC impacts. The ERH system was implemented in a 2.1 acre source area to address back diffusion from clays underlying the impacted alluvial sand and gravel aquifer. Outside the ERH area, DGR was implemented to address dissolved-phase CVOC concentrations in the plume. The DGR system design was based on groundwater modeling to predict the number of pore volume exchanges to achieve the cleanup goals. The number of extraction and injection wells, the well positioning, and the flow rates were designed to meet the required pore volume exchange within 1.5 years of operation. The ex-situ treatment train included iron removal, air stripping, and granular activated carbon, plus a nitrogen scrub to strip oxygen from the reinjection water to limit injection well fouling. Well fouling mitigation steps were a significant consideration due to prevailing reduced groundwater geochemistry and elevated dissolved metals concentrations.

Results/Lessons Learned. The DGR operations resulted in up to three orders of magnitude reduction in CVOC concentrations in the plume within 36 weeks of operation; well ahead of the predicted removal rates. Within 78 weeks, the majority of monitoring wells in the plume were below the analytical detection limit of 1 microgram per liter (µg/L). In two source zone monitoring wells, remaining groundwater CVOC concentrations of up to 76 µg/L were related to residual concentrations in the clay layer below the alluvial aquifer. These residual hotspots where addressed by a targeted excavation effort in the spring of 2017. An adaptive remedial strategy was key to the successful completion of the project. The adaptive approach was underpinned by bi-weekly performance monitoring data that informed adjustments to the ERH and DGR programs to continuously refine operations in areas of residual contaminant mass and to achieve a continuous reduction in the treatment area footprint. Active remediation was concluded in the summer of 2017, demonstrating that maximum contaminant levels can be achieved in interbedded geologies in a rapid timeframe.