MODALL: A Tool for Effective Design and Operation of DGR™ Systems to Advance Plume Restoration

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Background/Objectives. Dynamic Groundwater Recirculation or DGR™ is an innovative remedial strategy that significantly advances conventional pump and treat (P&T) designs of the past. In contrast to a traditional P&T system, a DGR™ system creates dynamic groundwater flow conditions that serve to boost natural flushing processes occurring within an impacted aquifer. Because the underlying concept of a DGR™ system is relatively simple— accelerate the influx of clean groundwater to promote aquifer flushing by driving contaminant mass out of the aquifer (both flow and storage zones) via enhanced advection and diffusion—DGR™ can be a highly effective remedial technology. Through our collective experience a systematic approach for design and operation of an effective DGR™ system has evolved. This approach includes development and application of site-specific 3-D numerical models to establish a design basis and, subsequently, to help interpret field data and inform operational decisions as remediation progresses. MODALL (Potter et al., 2008) is a unique modeling tool initially developed to aid in the design and optimization of capture systems but has since been modified to generate output that make it wholly applicable and exceptionally useful in the design, evaluation, and operation of DGR™ systems.

Approach/Activities. MODALL uses the MODFLOW-calculated cell-by-cell flow terms to quantify and evaluate internodal flow balances. Initially, MODALL output was used to determine the percentage of flow in each cell either originating from a given source or flowing to a specified sink (i.e., capture fraction). Since MODALL's flow allocation is based on complete mix theory, which is consistent with the underlying concept that drives the DGR™ strategy (i.e., maximizing pore volume flushes), the code has been modified to provide additional output capabilities that directly accommodate the design and evaluation of DGR™ systems. The latest version of the code computes the pore volume exchange (PVE) rate on a cell-by-cell basis that, when combined with initial COC concentration data, is used to estimate the period of performance (POP) by calculating the number of pore volume flushes required to reach the specified remedial goals. Several examples are presented to illustrate the guiding principles of this approach and to highlight the functionality and value of MODALL.

Results/Lessons Learned. As with any remedial technology, proper design and operation are critical to the success of a DGR™ system. We have successfully implemented DGR™ systems at numerous contaminated sites across the U.S., and the application of MODALL has been a key element of those successes. MODALL has several unique features that make it advantageous when evaluating these multifaceted systems. MODALL interfaces with MODFLOW so hydraulic influences (of injection and extraction wells) are explicitly calculated. Output is formatted as a MODFLOW head-save file that is easily imported into any visualization software for display and interpretation: isopleths can be generated to show or target areas where a faster PVE may lead to faster restoration or, conversely, where stagnation may occur. All of which greatly aids in comparing the relative merits of different designs, thereby streamlining the optimization process. We have also found that MODALL results are easily communicated to both technical and nontechnical stakeholders. Finally, because MODALL does not solve the solute transport equations, it is much more computationally efficient than methods using solute transport codes.