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Ground Water Currents

Developments in Innovative Ground Water Treatment

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About this Issue

This issue highlights various approaches to system optimization for the characterization or remediation of contaminated ground water.

Pump and Treat Optimization Technology Brings Significant Cost Savings

by Kathleen Yager, U.S. EPA Technology Innovation Office, and Robert Greenwald, HSI GeoTrans

The U.S. EPA Technology Innovation Office (TIO) and Office of Research and Development (ORD) recently teamed with HSI GeoTrans in a study evaluating the effectiveness of an optimization technology for pump and treat (P&T) systems. The optimization approach consists of using ground-water flow models coupled with mathematical optimization techniques to develop improved pumping strategies. Study results indicated that significant savings in annual operation and maintenance (O&M) costs are possible from optimization-simulation analyses. Potential cost savings at two of the three sites evaluated in the study ranged from $200,000 to $550,000, annually.

Nearly 700 pump and treat systems have been selected, are under construction, or currently operate at Superfund sites across the county. These systems are not only costly to construct but can be extremely expensive to operate and maintain for the long periods of time commonly required for site cleanup. A primary objective of the study was to evaluate a technology that could improve the efficiency of P&T systems while significantly reducing O&M costs. EPA also aimed to highlight the importance of evaluating system performance on a regular basis, and to develop guidance on when a detailed optimization analysis may be beneficial.

The scope of the study included selection of three sites with existing P&T systems, screening of the sites for optimization potential, and application of a hydraulic optimization code (MODMAN) at each site. MODMAN couples a ground-water flow model (MODFLOW) with mathematical optimization techniques (linear and mixed-integer programing) to determine the best locations and rates for extraction and/or injection wells. A major advantage of hydraulic optimization is that it considers all possible combinations of flow rates at potential well locations, so that the best combination is identified. Three diverse sites (located in Kentucky, Utah, and Nebraska) were selected for the study to allow for demonstration of the optimization technology under various conditions. The sites differed in total ground water flow rate, the number of extraction/injection wells, the type of aboveground treatment, and the annual O&M cost.

Results of the study can be illustrated by selected findings from the Kentucky site,

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which studied 18 extraction wells used to prevent a dissolved plume of volatile organics from discharging to an adjacent river. In addition, "hot spot" wells for more aggressive mass removal were included. Based on trial and error analysis using an existing ground-water flow model, a total pumping rate of 500 gallons per minute was recommended at the 18 barrier wells. An objective of the optimization analysis was to determine the minimum pumping rate that satisfied the containment constraints at the river, while maintaining the existing pumping rates at the "hot spot" wells. Results indicated that the total pumping rate at the barrier wells could be reduced by nearly 50 percent, and that fewer than 18 wells were required. This reduction in pumping rate represented a potential savings of $550,000 from the original $1.8 million estimated for annual O&M costs, most of which were associated with operation of an aboveground steam stripping treatment system.

Based on these and earlier findings, EPA developed guidance to assist site managers in determining if a detailed optimization analysis is likely to reduce costs. The guidance outlines critical operating parameters and cost information that should be evaluated as a first step in the optimization process. Information in the guidance is compiled in a simple spreadsheet that may be manipulated to evaluate alternative operating scenarios.

In addition, EPA plans to conduct national workshops to encourage the widespread application of this, as well as other, approaches to P&T system optimization. For more information on the study or workshops, or to obtain copies of the optimization guidance, contact Kathleen Yager (TIO) at 732-321-6738 or yager.kathleen@epa.gov, or Robert Greenwald (HSI GeoTrans) at 732-409-0344 or rgreenwald@ hsigeotrans.com.

AFCEE Develops Algorithm to Optimize Long-Term Ground-Water Monitoring Networks

by Philip Hunter, P.G., Air Force Center for Environmental Excellence, and Kirk Cameron, Ph.D., MacStat Consulting, Ltd.

The Air Force Center for Environmental Excellence (AFCEE) has developed a spatial and temporal algorithm for optimizing long-term monitoring (LTM) networks at U.S. Air Force installations. In a pilot project at the Massachusetts Military Reservation (MMR) on Cape Cod, MA, data from two ground-water plumes were used to develop the algorithm. The purpose of the project was to determine how an LTM network could be optimized so that resources are wisely dedicated and not unnecessarily expended for sampling, laboratory analysis, and/or well construction. The primary objective was to determine the degree to which these resources could be pared without losing key statistical information concerning the plumes being monitored. Through use of this algorithm, it was determined that an estimated $240,000 in remediation costs could be saved at MMR each year.

The network that monitors a plume known as FS-12 is associated with a remediation system that has been in place for more than two years. The second network, which is associated with the Eastern Briarwood plume, currently does not have a remediation system in place. Two primary constituents of concern were analyzed at each site: ethylene dibromide and benzene at FS-12, and trichloroethylene (TCE) and perchloroethylene (PCE) at Eastern Briarwood. Concentrations of these contaminants exceeded applicable maximum contaminant levels only a small fraction of the time, and generally were non-detect. "Hits" were concentrated in a fairly small subset of the known monitoring wells.

To optimize an LTM network, an accurate assessment of ground-water quality over time is needed to construct an interpolated map of the concentration levels, and to accurately assess trends or other changes in individual monitoring wells. Typically, interpolated maps are used to assess whether a contaminated ground-water plume exists, and, if so, its extent and characteristics. Changes in such maps over time indicate whether ground-water quality has improved or declined. Changes in concentration patterns or the identification of trends at individual "sentinel" wells also can serve the same purpose.

To implement this optimization process, the algorithm and decision pathway analysis are separated into separate components of temporal redundancy and spatial redundancy. Temporal redundancy, which indicates samples are collected so often that there is a significant degree of autocorrelation between closely spaced measurements, may be reduced or eliminated by lengthening the time between sample collection. Spatial redundancy, which indicates too many wells are being monitored and providing redundant information, may be reduced or eliminated by removing selected wells from the network without sacrificing the ability to map ground-water quality.

The optimization algorithm consists of three basic steps: (1) identifying temporal redundancies in currently monitored wells;

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(2) identifying spatially redundant wells; and (3) projecting cost savings gained by eliminating wells and/or reducing sampling frequencies. The temporal algorithm involves both computation of a composite temporal variogram to determine the least redundant overall sampling interval, and "iterative thinning" of the sampling data at selected wells to determine well-specific sampling frequencies. A temporal variogram is a one-dimensional geostatistical measure of autocorrelation across a range of lag times between sampling events. The smallest lag time at which the variogram reaches a stable plateau or "sill" is the sampling interval at which the same-well measurements become essentially uncorrelated and, therefore, non-redundant. "Iterative thinning" involves an estimation of a baseline trend at each well, followed by re-estimation of the trend after random deletion of sampling events from the well's historical record.

The spatial algorithm is predicated on the notion that well locations are redundant if nearby wells offer nearly the same statistical information about the underlying plume. At MMR, a well was considered redundant if its removal did not significantly change a concentration map of the plume. To identify well redundancy, indicator kriging was used to generate an initial plume map. Kriging weights assigned to each well location then were used to gauge each well's relative contribution to this initial map. By temporarily removing that subset of wells with the lowest global kriging weights and re-estimating the plume map, it was possible to determine how many wells could be removed without substantially altering the map, leading to a list of potentially redundant wells.

Based on application of the optimization algorithm at MMR, close to 20 percent of the known monitoring locations were tagged as spatially redundant at each site. Furthermore, the temporal variogram indicated that quarterly sampling could be relaxed and replaced by annual sampling at FS-12 and by once-per-5-quarters sampling at Eastern Briarwood. The overall reduction in MMR's total annual sampling and analytical budget for these ground water plumes was estimated to be 36 percent for Eastern Briarwood and 42 percent for FS-12.

AFCEE currently is testing the algorithm at other Air Force sites. For additional information, contact Philip Hunter (AFCEE) at 210-536-5281 or e-mail philip.hunter@hq.afcee.brooks.af.mil.

Remediation System Evaluations Help to Optimize Systems

by Dave Becker, U.S. Army Corps of Engineers/Hazardous, Toxic, and Radioactive Waste Center of Expertise

The Remediation System Evaluation (RSE) process can help reduce operating costs substantially for long-term cleanups and help identify performance problems. Developed by the U.S. Army Corps of Engineers (USACE) to identify cost savings and assure the protectiveness of remedies, the RSE process: recommends cost-saving changes in system operations or technologies applied at a site, verifies a reasonable closure strategy, and assesses maintenance of government-owned equipment. Besides identifying potential cost savings, the RSE process serves as an extension of the CERCLA 5-year review process. The evaluation addresses protectiveness issues such as system performance relative to remedial action objectives, monitoring or operational deficiencies that may jeopardize a remedy's protectiveness, and changes in surrounding land use or risk-based/ regulatory cleanup standards.

The USACE Hazardous, Toxic, and Radioactive Waste Center of Expertise, with assistance from USACE district staff and other agency personnel, has applied the RSE process at three sites. The RSEs identified potential cost savings of $80,000 to more than $300,000 per year in operations and maintenance at each site. On average, each evaluation cost slightly under $20,000 to conduct, including associated travel for a site visit and final report generation. The costs that may be incurred in addressing protectiveness issues, however are not shown to offset the reported cost savings.

In order to assist the USACE district personnel and contractors in performing these RSEs, a suite of checklists was developed. These checklists address the overall system goals, subsurface performance, above-ground treatment effectiveness, and equipment maintenance, and offer possible cost saving alternatives. The checklists are intended for use by experienced technical staff when conducting RSEs on a variety of long-term remedies, including pump and treat, soil vapor extraction, bioventing, and air sparging.

Over 20 RSE checklists are available. The checkists assist in assessment of subsurface system performance, above-ground treatment plant effectiveness, monitoring programs, and alternatives for treatment water discharge. Specific equipment that can be evaluated through the RSE checklists include air strippers, carbon adsorption systems, metals precipitation units, piping, pumps, blowers, control systems, solids handling systems, thermal treatment units,

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advanced oxidation processes, chemical feed systems, oil/water separators, and extraction/injection wells. During site visits, the checklists are useful as mental prompts and a means to record observations, if desired.

The RSE checklists, a sample report, and an instruction guide are available on the Internet at http://www.environmental.usace.army.mil/library/guide/rsechk/rsechk.html. For more information, contact Dave Becker (USACE Hazardous, Toxic, and Radioactive Waste Center of Expertise) at 402-697-2655 or dave.j.becker@usace.army.mil.

New Case Studies on Ground-Water Cleanup Systems Released

EPA's Technology Innovation Office recently compiled information from 28 case studies of ground-water cleanup systems. These systems included 26 pump and treat (P&T) systems (plus *in situ* bioremediation and air sparging used in conjunction with several P&T systems) and three permeable reactive barriers. The case study report contains sections addressing site characteristics such as contaminants/concentrations, ground-water plume size, hydrogeology, system design/operation (including cleanup goals), numbers of wells, ground-water flow rates, types of above-ground systems, optimization efforts, performance data, cost information on both capital and operating expenses, and factors affecting performance/cost. The full 28 case studies (document number EPA 542-R-99-006), as well as 112 additional studies, are available on the Internet at http://www.frtr.gov, under "Cost and Performance."

Field-Based Technologies Training Program

The *Field-Based Site Characterization Technologies Training Program* is a five-day, advanced-level training program designed to provide a detailed introduction to on-site technologies that can be used to characterize a site, and an overview of the planning and process issues associated with field analytical and sampling technologies. This course is designed for experienced environmental professionals who are involved in the use of field-based technologies, related data interpretation, or related report preparation.

The training will be offered in various cities over the coming year at no cost to participants. To obtain additional information, contact the CERCLA Education Center at 703-603-9910 or visit EPA's Internet home page on training opportunities at http://www.trainex.org.

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