2021 ITRC Final Proposal Template

Proposed Project Title

Performance-Based Optimization of Pump and Treat Systems

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Abstract

Optimization of pump-and-treat (P&T) remedies is important for maintaining contaminant removal effectiveness throughout the remedy operation lifetime (which typically span decades) and managing the P&T system toward an exit strategy. The most critical element of P&T performance optimization in relation to plume remediation efficiency and effectiveness is developing a well-network design and dynamic management approach for effective pumping strategies that adapt to evolving plume and subsurface conditions as the remedy progresses. The proposed project aims to develop technical guidance that summarizes existing information and best practices and develops a systematic and adaptive optimization framework specifically for P&T well-network design and management. This guidance will complement existing and well-established broader remedy optimization programs, such as the US. Environmental Protection Agency's optimization strategy, with regard to the technical aspects of optimizing P&T systems as the remedy progresses.

Problem Statement and Highlight the Importance to the States and to the Broader Environmental Community

Pump-and-treat (P&T) systems have been one of the most commonly used methods for hydraulic containment and treatment of contaminated groundwater at sites with large groundwater plumes. Even though other new technologies are being developed and implemented, P&T continues to be used either as a standalone approach or as part of a hybrid treatment approach (e.g., in situ source treatment and plume P&T).[1] As described in more detail below, routine optimization of P&T remedies is critical for maintaining contaminant removal effectiveness throughout the remedy lifetime and managing these systems toward an exit strategy. The proposed project aims to develop technical guidance that summarizes existing information and best practices, and develops a systematic and adaptive optimization framework specifically for P&T well-network design and management that will be complementary to existing/well-established optimization programs.

At many contaminated sites using P&T, short-term response actions are needed to focus on immediate

[1] EPA, 1999. State Policy and Regulatory Barriers to In Situ Ground Water Remediation. EPA 542-R-96-001.

risks. As a result, the initial design of P&T systems usually address large-scale containment and bulk treatment. However, performance of these systems depends on complex factors such as heterogeneous geology, large capture zones requiring multiple pore volume flushes, the presence of source zones, diffusion-limited mass transfer, co-located and/or recalcitrant contaminants, and dispersed contaminant distributions.[2,3] As the remedy progresses from initial implementation through continued operation over time, contaminant removal typically diminishes due to these complexities. This reduction in remedy effectiveness hinders achievement of concentration reduction-based performance objectives and can result in cleanup timeframes that span decades or more.[4,5] In many cases, suboptimal operations (e.g., above ground treatment processes, well-network configurations) contributes to plume persistence and limited effectiveness of P&T. As plume conditions and removal effectiveness evolve over the course of treatment, the primary challenge at these sites is to maintain effectiveness and manage the P&T system toward an exit strategy or transition to other treatment or passive approaches.[6]

In the last several decades, state and federal agencies, and other entities, have recognized the need for periodic optimization of remediation systems for cost savings and improving remedy effectiveness.[7, 8] While periodic optimization of remedy systems is not a regulatory requirement, within the regulatory environment (i.e., CERCLA, RCRA, and/or state regulatory programs) of the applicable cleanup site, remedy optimization – conducted in conjunction with periodic evaluation of remedial system performance – can provide significant benefits to decision makers, regulators, and stakeholders.

Approaches developed to provide high-level optimization assessment include the Remedial Process Optimization (RPO-1 to -6) or the Remediation System Evaluations (RSEs), the latter which is used by the Army and has also been adopted by the U.S. Environmental Protection Agency (EPA).[7, 8] These optimization assessment approaches recognize the inefficiencies associated with the traditional "study-design-build" linear approach, and instead aim to manage uncertainties that result in remedy performance limitations through a systematic evaluation of remedy objectives and continuous improvement and optimization of remedy technologies. Briefly, these approaches involve a remedy review by an independent team to assess progress toward achieving remedial action objectives and to provide recommendations for system optimization. While RSE focuses on only engineered remedies, RPOs have a broader scope, including evaluation of the exit strategies, reviewing elements such as remedial action objectives in addition to the conceptual site model (CSM), remedy performance metrics, remedial action design and performance, and cost-efficiency.

Several of these independent optimization efforts later were unified under a strategy developed by EPA to expand and formalize optimization practices as an operating business model for the Superfund (CERCLA)

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[2] NRC, 2013. Alternatives for Managing the Nation's Complex Contaminated Groundwater Sites: National Academies of Sciences, Engineering, and Medicine.
[3] Guo, Z. L., and M. L. Brusseau. 2017. "The impact of well-field configuration on contaminant mass removal and plume persistence for homogeneous versus layered systems." *Hydrological Processes* 31 (26):4748-4756. doi: 10.1002/hyp.11393
[4] EPA, 1997. Ground Water Issue: Design Guidelines for Conventional Pump-and-Treat Systems. EPA/540/S-97/504.
[5] EPA, 1996. Pump-and-Treat Ground-Water Remediation: A Guide for Decision Makers and Practitioners. EPA/625/R-95/005.
[6] Truex, M., C. Johnson, T. Macbeth, D. Becker, K. Lynch, D. Giaudrone, A. Frantz, and H. Lee. 2017. "Performance Assessment of Pump-and-Treat Systems." *Ground Water Monitoring and Remediation* 37 (3):28-44. doi: 10.1111/gwmr.12218
[7] ITRC (Interstate Technology & Regulatory Council), 2004. Remediation Process Optimization: Identifying Opportunities for Enhanced and More Efficient Site Remediation.
[8] EPA, 2013. Remediation Optimization: Definition, Scope and Approach. 542-R-13-008.

program.[9] This strategy emphasizes the importance of applying optimization concepts to support decision making throughout all phases of the Superfund project lifetime. Application of this broader optimization approach has been demonstrated to achieve significant cost savings at many sites, while meeting the remedial objectives.[7,8]

For P&T systems, there are technical elements of optimization specific to the P&T technology that are needed to support an overall remedy optimization effort. The most critical element for P&T performance optimization in relation to plume remediation efficiency and effectiveness is adapting the well-network approach (well locations and pumping rates) to evolving plume conditions as the remedy progresses. There is a need to describe this element of P&T optimization to support sites in achieving overall remedy optimization goals (e.g., to provide the technical details and decision approaches for well-network optimization in a way that feeds into application of overall remedy optimization frameworks).

Remedy performance evaluations for P&T operations are required to demonstrate compliance, track progress toward achieving cleanup goals, and support decision-making for remedy modifications and closure (or transition to passive remedy technologies, such as monitored natural attenuation [MNA]). A structured approach for P&T remedy performance evaluations was recently developed, consisting of several primary evaluations and supporting decision outcomes such as the need for optimizing the P&T system.[6] These approaches, along with advancements in the use of predictive fate and transport evaluations and integration of optimization methods, allow an adaptive strategy to be implemented for well-network design and management for P&T operations. A similar phased or integrated approach has been highlighted in several EPA guidance documents to prevent over-designing initial P&T systems to account for uncertainty in site characterization, and instead recommending implementation that is governed by a set of system expansion requirements.[10] An adaptive strategy can facilitate dynamic changes in pumping strategies; for example, an initial bulk treatment and capture approach can be fine-tuned, or modified over time based on system characteristics (e.g., related to changes in plume size, distribution, remedy efficiencies, etc.) and a refined CSM.

Existing guidance documents provide detailed technical information on P&T system design, operations, monitoring, and capture assessments.[4,5, 10,11,12] As demonstrated in these guidance documents, predictive modeling capabilities are critical for the design and operation of P&T systems. These predictive models are used to: describe/predict distribution and behavior of contaminants; assess remedy effectiveness; improve understanding of subsurface processes; provide a platform for data integration/interpretation; and provide input for the monitoring strategy. Well-network optimization can also be achieved through the use of predictive models (i.e., simulation models) and/or coupled simulation-optimization models.[13,14,15,16] Coupled simulation-optimization models include flow and transport simulators with various optimization

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[9] EPA, 2012. National Strategy to Expand Superfund Optimization Practices from Site Assessment to Site Completion. OSWER 9200.2-75.
[10] EPA, 1994. Methods for monitoring pump-and-treat performance. EPA/600/R-94/123.
[11] EPA, 2005. Cost-Effective Design of Pump and Treat System. EPA 542-R-05-008.
[12] EPA, 2008. A Systematic Approach for Evaluation of Capture Zones at Pump and Treat Systems. EPA 600/R-08/003.
[13] Minsker et al. 2004. Final Technical Report for Application of Flow and Transport Codes to Groundwater Pump and Treat Systems. Technical Report: TR-2237-ENV
[14] Zhang et al. 2004. Final Cost and Performance Report Application of Flow and Transport Optimization Codes to Groundwater Pump and Treat Systems. Technical Report: TR-2238-ENV
[15] EPA, 1999. Hydraulic Optimization Demonstration for Groundwater Pump and Treat Systems, Volume II: Application of Hydraulic Optimization. EPA/542/R-99/011B.
[16] Peralta, R. C. 2001. Remediation simulation/optimization demonstrations. In Proceedings of MODFLOW and Other Modeling Odysseys. 2001. Eds, Seo, Poeter, Zheng and Poeter, Pub. IGWMC. p. 651-657.

algorithms for hydraulic and/or transport optimization. As reported in the literature, well-network optimization efforts typically target evaluations of total well numbers, well locations, pumping rates (individual well and total), and total remediation costs. [17] Potential additional considerations include cleanup times or other system characteristics, such as well screen placements.

While these studies collectively demonstrate potential significant benefits of well-network optimization as part of a larger remedy optimization effort and performance assessments, the results are only available to decision-makers via discrete publications of limited scope (papers, reports, etc.). Given the long and resource-intensive operational lifetimes of P&T systems, performance-based optimization approaches for P&T well-network operations need to be compiled and better described in a guidance document to facilitate their use in accelerating progress toward cleanup goals and use of adaptive site management for sites with existing or planned P&T systems.[18] Therefore, the proposed project aims to develop technical guidance that unifies existing information/approaches in a systematic, adaptive optimization framework for P&T well-network design and management, which would be supplementary to existing broader optimization programs.

TARGETED AUDIENCE: Primary targeted audience for the technical guidance document proposed to be developed under this effort are the operators, owners, regulators, and stakeholders of sites where groundwater P&T systems have been installed or are being planned to be installed for cleanup purposes. The document is intended to help all site parties understand the P&T optimization process and to provide technical framework as a resource for conducting optimization efforts.

Project Deliverables

Document Products: Technical Regulatory Guidance Document

Listed below are some examples of subjects to be covered in the document.

- Inventory and description of existing optimization programs
- Description of adaptive site management in relation to P&T remedy management
- Description of performance-based and adaptive P&T well-network optimization framework and how it can be used to supplement the efforts of broader optimization programs and within an adaptive management approach
- Summary of technical information on well-network optimization approaches and their applications
- Presentation of a number of selected case studies to represent the potential range of well-network optimization approaches and how they could be used within the proposed framework

Training Products: Training Modules

The content of the training modules will be determined following the development of the Technical Regulatory Guidance Document.

[17] Ko et al. 2005. Optimal groundwater remediation design of a pump and treat system considering clean-up time. *Geosciences Journal*. 9. 23-31.

[18] ITRC (Interstate Technology & Regulatory Council), 2017. Remediation Management of Complex Sites. Prepared by the ITRC RMCS team.

Additional Information

Subject Matter Experts Interested in Joining this Project Team (confirmed):

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The team will comprise additional interested academics and regulatory and regulated entities, including state and federal agencies, tribes, consultants and industry.