WHITE PAPER / **GROUNDWATER REMEDIATION**

DESIGN OPTIMIZATION REDUCES THE COST AND UNCERTAINTY OF REMEDIATION

BY John Hesemann, PE

Groundwater extraction and treatment — or pump and treat — is making a comeback in the remediation industry, primarily due to technological advancements that focus this remedy to meet project objectives more predictably and at a significantly lower cost.

Recent advancements in understanding the role complex subsurface heterogeneities play in contaminant storage, distribution and transport have led to improved pump-and-treat system designs and optimized, lower cost applications. These improved systems focus groundwater extraction efforts on aquifer zones that are most critical for contamination containment or mass flux reduction. This approach to pump-and-treat remediation has been supported by the advent of high-resolution site characterization (HRSC) tools that produce the type and quantity of data needed to generate quantitative conceptual site models (CSMs) and use groundwater fate and transport modeling tools to optimize system designs while reducing uncertainty.

These advanced HRSC and modeling methods were recently applied on a project requiring pump-and-treat remediation, with treated water injection, to address uranium and nitrate groundwater contamination plumes extending over 200 acres and threatening potential human health and ecological receptors. Vertical profiling activities were conducted using depth-discrete groundwater sampling methodology at 23 proposed groundwater extraction well locations to refine the vertical delineation of uranium and nitrate concentrations. In addition, HRSC direct sensing technology was used to assess relative permeability and lithology with depth at each well location. Finally, continuous soil sampling and logging were conducted at select locations to correlate direct sensing results and collect soil samples for grain size distribution (GSD) analysis.

The results of these design investigation efforts were used to target extraction well screens on the saturated zone intervals conveying the greatest contamination mass, as determined by contaminant concentrations and estimated hydraulic conductivity. This design optimization approach maximizes the mass of contaminant removed during groundwater remediation efforts while minimizing the recovery and treatment of minimally contaminated groundwater. This improves operational efficiency and reduces the time required to achieve remediation goals, particularly if zones of relatively low contaminant concentration coincide with zones of higher permeability.

Relative permeability and inferred lithological data were collected at each proposed extraction well location using a hydraulic profiling tool (HPT) and electrical conductivity (EC) direct sensing technologies. The data provided by these tools, along with vertical contaminant profiling data, soil boring log observations and GSD results, were used to select optimal screen intervals and extraction pump intake elevations. The GSD results were also used to finalize extraction well design details, including filter pack gradation and well screen slot size.

DESIGN DATA COLLECTION

High-resolution, direct-push investigation techniques were used as a quick and economical means of collecting the data needed to support design optimization efforts. Previous site investigation data, CSM evaluation and numerical groundwater modeling were used to select groundwater extraction well locations within a heterogeneous alluvial formation at the site.

Vertical profiling was conducted by advancing a Geoprobe® HPT-Groundwater Sampler (GWS) tool in close proximity to each proposed extraction well location. The HPT-GWS tool was advanced to generate continuous, real-time logs of hydrostatic pressure (representing relative permeability) and EC, as well as to collect discrete groundwater samples for laboratory analysis of uranium and nitrate. Groundwater samples were generally collected at 2-foot intervals, from approximately 1 foot below the detected groundwater level to the top of bedrock.

Continuous soil sampling for lithological logging and GSD analysis was also conducted at a subset of the extraction well locations to confirm lithology and permeability data provided by the EC/HPT profiling, and to provide the data needed to specify well filter pack gradation. At these locations, a continuous soil core was recovered for logging of subsurface materials encountered and one composite sample for GSD analysis was collected from every 5-foot interval near the detected potentiometric surface to the base of the alluvium.

RESULTS AND INTERPRETATION

The vertical profiling and sampling described above was used, along with preexisting data, to prepare cross sections to visually evaluate the subsurface and select

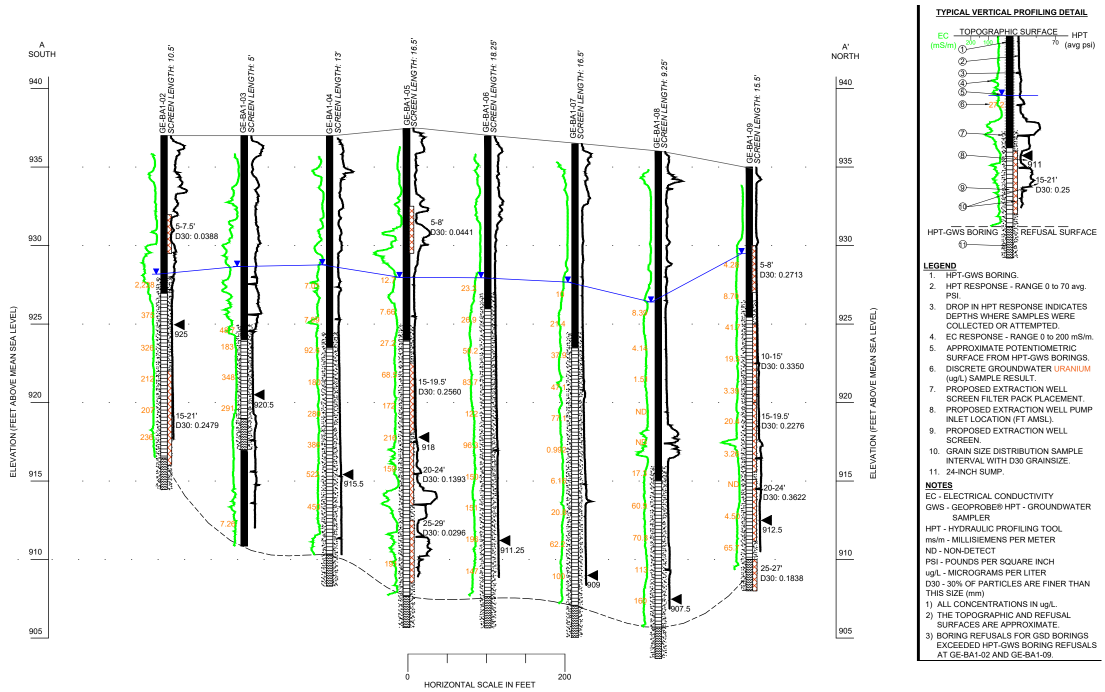

FIGURE 1: *Cross section depicting HRSC, depth-discrete laboratory data and selected screen intervals and pump intake elevations at extraction well locations.*

optimal well screen intervals. EC and HPT pressure curves, depth-discrete groundwater analytical results and GSD results for each boring location were plotted on the cross sections. An example cross section, including depth-discrete uranium groundwater concentration data, is presented in Figure 1.

In general, the HPT measures the relative hydraulic properties of unconsolidated materials by using a pump to inject a small volume of clean water into the formation and measure the pressure and flow rate response. Zones of relatively high permeability generate lower pressure responses and lower permeability zones generate higher pressures. The HPT pressure response for each boring is depicted by the black analog lines presented in Figure 1. An increase in HPT pressure, represented by a peak in the curve, is indicative of a finer-grained, low permeability material such as clay, while a decrease in HPT pressure indicates a coarser-grained, higher permeability material such as sand.

The alluvial aquifer at the subject site consists of sand and silt with minor occurrences of clay and gravel. The EC generally exhibits an inverse relationship with soil particle size — sands and gravels with larger particle sizes typically correspond to lower EC responses than silts and clays with smaller particle sizes. However, it is important to consider that factors such as soil saturation and chemical constituents (natural and anthropogenic) may also impact EC. As a result, HPT pressure data may provide a more accurate representation of physical soil properties, particularly within the saturated zone. The EC response for each boring is depicted by the green analog lines presented in Figure 1.

The EC and HPT pressure data were used to characterize the saturated zone and identify areas of relatively low and high permeability. Combined with the groundwater analytical and GSD results — and geologic observations obtained from direct inspection of soil cores — these data were used to provide high-resolution characterization of hydrogeologic conditions, contaminant distribution and potential contaminant transport pathways near each proposed alluvial extraction well location.

The uranium concentration data presented in Figure 1 indicate that the highest uranium concentrations are present in the most upgradient borings (GE-BA1-02 through GE-BA1-05) and the highest uranium concentrations at each location occur at progressively deeper elevations with increasing distance downgradient (north). While groundwater samples could not be collected from some low permeability intervals, the results generally indicate that zones of low permeability — and, thus, lower groundwater production during remediation — generally exhibited lower uranium concentrations. This provided an opportunity for optimization at most extraction well locations by limiting well screen intervals to zones of elevated contaminant flux, characterized by elevated contaminant concentration and permeability.

DESIGN IMPLICATIONS

As shown in Figure 1, the GE-BA1-03 and GE-BA1-08 well screen lengths were significantly reduced to avoid zones of fine-grained, low permeability sediment and zones of low uranium concentrations. In addition, multiple screen sections were selected for GE-BA1-05 and GE-BA1-07 to avoid zones of reduced permeability and/or contamination. These design optimization measures will improve performance by limiting the potential for sediment recovery and will improve efficiency by significantly reducing the recovery of minimally impacted groundwater.

The results of the GSD analysis were used to refine extraction well design details, including screen slot size, filter pack gradation and screen length/interval placement. The diameter on the GSD curve corresponding to the particle size for which 30% of the soil grains are finer (i.e., D_{30}) was used to select the filter pack gradation and screen slot size for each extraction well. The filter pack gradation was selected based on the smallest D_{30} value within the proposed screen interval. A D_{30} grain size less than 0.1 millimeter generally corresponds to a material that is considered nonfilterable and/or may result in excessive solids recovery during extraction well operation. A D_{30} grain size greater than 0.22 millimeter generally corresponds to fine- to coarse-grained sand. D_{30} grain sizes within this range are generally considered favorable for efficient and effective filter pack gradation and screen slot size design. The D_{30} values for each GSD sample interval are included on Figure 1.

The GSD results and boring log observations — along with depth-discrete groundwater contaminant data and EC and HPT direct sensing data — were used to specify extraction well pump intake elevations to further optimize the rate of contaminant mass removal and minimize the recovery and treatment of minimally contaminated groundwater. Submersible pump operating requirements were used to select the appropriate pump intake elevation within each proposed extraction well screen interval, as shown in Figure 1. The submersible pumps planned for use require a minimum submergence of 24 inches, as measured from the water surface to the top of the pump unit. Additionally, the bottom of the pump unit cannot be allowed to extend below the screened interval; otherwise overheating of the pump motor could occur.

Extraction well efficiency and aquifer solids recovery/accumulation were both considered in the selection of alluvial well screen intervals, pump intake elevations, filter pack gradation and well screen slot size. As allowed by equipment specifications, most of the proposed pump intakes were positioned at depths generally corresponding to zones of highest observed uranium and/or nitrate concentrations. Minimization of solids recovery is particularly important when extracting groundwater contaminated with radionuclides such as uranium since the handling and disposal of radiologically impacted solids can be very costly.

CONCLUSIONS

The design investigation results provided an improved understanding of subsurface materials and the distribution of permeability and contaminant concentrations within the saturated zone at each extraction well location. Based on this understanding, extraction well designs were optimized to minimize the recovery and treatment of minimally contaminated groundwater, and reduce the time required to achieve remediation goals.

The use of HRSC techniques and improved CSMs to inform the use of groundwater modeling tools, remediation designs, and even cost and duration projections can add significant value to pump-and-treat remediation programs. These optimization efforts, combined with advanced treated water injection methods, renewable energy sources and other enhancements, are transforming pump and treat from a costly technology with an indefinite endpoint to a practical, economical solution for many sites.

BIOGRAPHY

JOHN HESEMANN, PE, is an environmental remediation engineer with extensive experience in remediation and environmental engineering. His experience includes the selection, design, evaluation and safe implementation of environmental remediation technologies to address a wide variety of contaminants, including petroleum hydrocarbons, chlorinated ethenes, and methanes, radionuclides, energetics, metals and inorganics. As the remediation technical service leader for Burns & McDonnell, he supports nationwide remediation field implementation, optimization and operation and maintenance efforts. John specializes in rapid remedial progress through effective remedy selection, pilot testing, design, field application and optimization. He has served on the Interstate Technology & Regulatory Council (ITRC) Green & Sustainable Remdiation and Optimizing In Situ Remediation Performance & Injection Strategies Teams and has authored, presented and published several technical papers on in situ remediation and other topics.

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