Interpretation of 2-D and 3-D Images of Ultraviolet Optical Image Profiler (OIP-UV), Hydraulic Profiling, and Electrical Conductivity (HPT/EC) Log Data at Complex LNAPL Sites

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Background/Objectives: At petroleum contaminated sites that no longer have significant non-aqueous phase liquids (LNAPL) present in groundwater monitor wells, and show mostly the presence of dissolved phase hydrocarbons, some may believe little LNAPL is remaining, and mainly dissolved phase contamination is present. Persistent parts per million levels of aromatic and aliphatic hydrocarbons that degrade slowly over time indicate the likely presence of significant residual petroleum LNAPL that cannot be seen or located using conventional soil and groundwater sampling methods.

Conceptual site models (CSM) of sites with petroleum LNAPL based on conventional soil and groundwater samples can be relatively straight forward in unconsolidated coarse grained medium sand and gravel formations. The LNAPL floats on groundwater and is present as a thickness or sheen in monitor wells, similar to the thickness in the formation, and is easily mapped. However, in many sites with heterogeneous sediments that include interbedded clays, silts and fine sand mixtures, the CSM can become quite complex and difficult to interpret using conventional soil and groundwater sampling methods. Even saturated very fine sand can redirect or confine some LNAPL. Some of these sites show few or trace signs of LNAPL in monitor wells. Another example has a strong dissolved phase plume migrating opposite of groundwater flow. A site has with significant concentrations well below a confining clay layer in unexplained. A site with several feet of LNAPL in a monitor well turns out to have only inches of it in a confined sand.

The Ultra-Violet Optical Image Profiler (OIP-UV), combined with the Hydraulic Profiling Tool (HPT) and Electrical Conductivity (EC) was used on these sites with the objective to interpret these complex sites puzzles and develop improved CSMs.

Approach/Activities: The OIP-UV is a direct-push fluorescence tool that was recently combined with the HPT and EC tool to form the Optical Image and Hydraulic Profiling Tool, or OiHPT-UV for short. The OIP-UV tool projects 275 nm ultraviolet light on the soil through a sapphire window to induce, and subsequently detect, the resulting fluorescence of petroleum LNAPL. Measuring water injection flow rate and pressure allows the HPT to identify zones of high and low permeability where LNAPL may be mobile, trapped, or confined. The Membrane Interface Probe and Hydraulic Profiling Tool (MiHPT) was also used on some sites to map dissolved phase concentration beyond the LNAPL plume. Borings logs were evaluated using 2-D and 3-D imaging methods. OiHPT-UV, and MiHPT data was combined with monitor well data, LNAPL measurements, and conventional soil samples, and input into three-dimensional (3-D) modeling software to clarify and explain the patterns which previously confused site investigators using only soil and groundwater data.

Results/Lessons Learned: In one of the examples, it was evident that the initial LNAPL release penetrated very deep below the water table and found confined stratigraphic layers that allowed it to migrate counter to the groundwater gradient as it tried to float back up to the water table. The data also showed that an air sparge and vapor extraction system had effectively cleaned up LNAPL in the smear zone but was not able to reach the confined LNAPL. Another site with random LNAPL in monitor wells was found to have LNAPL present mostly in a perched water bearing zone and also in a deeper confined zone. The deeper confined LNAPL may have migrated there via deep wells screens. 2-D and 3-D models of several examples are shown that demonstrate how the HRSC tools and a significantly improved CSM can be used to explain these site complexities.