Using the Combined UV Optical Image Profiler and Hydraulic Profile Tool with Modeling Tools to Visualize Complex Petroleum LNAPL Migration

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Background/Objectives. Many sites with petroleum based residual and mobile non-aqueous phase liquid (LNAPL) have puzzled investigators using conventional drilling and sampling investigation methods. Limited interval sampling from split-spoon cores, or even selected samples from a continuous core, create significant data gaps that limit our ability to see where LNAPL has migrated, how it got there, and where it is going within the subsurface. Conventional thinking regarding conceptual site models (CSMs) for LNAPL migration says that we would expect to find LNAPL smeared along the capillary fringe, rising/falling groundwater table elevations, in the source area, and down gradient. However, subtle soil heterogeneity, and other site conditions, can create a much more complex migration pattern.

One example is shown where high levels of dissolved gasoline concentrations, including BTEX components, indicate the presence of LNAPL, but little or no LNAPL shows up in wells or core samples. The high concentration dissolved phase plume was also migrating in the opposite direction of the groundwater flow. In another example, LNAPL was found in random wells across a site, but was not present in the wells located between those which had LNAPL, resulting in a complicated pattern of discontinuous LNAPL distribution. The presence of a perched water table was suspected of causing some complications.

Advances with high resolution site characterization (HRSC) direct-push enabled tools now allow us to literally see the LNAPL in the subsurface and identify what the hydrostratigraphic pathways are that got it there. The objective in these projects was to apply HRSC tools to acquire a dense data set and create a conceptual site model that could explain such site complexities.

Approach/Activities. The Ultraviolet Optical Image Profiler (OIP-UV) is a direct-push tool that was recently combined with the Hydraulic Profile Tool (HPT) and Electrical Conductivity (EC) tool, called OiHPT for short. The OIP-UV tool shines 275 nm ultraviolet light on the soil through a sapphire window to induce and detect fluorescence of petroleum LNAPL. Measuring water injection flow and pressure the HPT identifies zones of high and low permeability where LNAPL is mobile, trapped, or confined. The Membrane Interface Probe (MIP) was also used on some sites to map dissolved concentrations. A three-dimensional (3-D) grid of OIP-UV, HPT, and MIP probe data was combined with monitor well data, LNAPL measurements, conventional soil samples, and input into 3-D modeling software to clarify and explain the complicated patterns.

Results/Lessons Learned. In one of the examples, 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. The 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. 3-D models of several examples are shown that demonstrate how the HRSC tools and 3-D models can be used to explain these site complexities.