Applied NAPL Science Review (ANSR)
Vol 1, Issue 6 - June 2011
Demystifying NAPL Science for the Remediation Manager

Introduction

Applied NAPL Science Review (ANSR) is a scientific ejournal that provides insight into the science behind the characterization and remediation of Non-Aqueous Phase Liquids (NAPLs) using plain English. We welcome feedback, suggestions for future topics, questions, and recommended links to NAPL resources. All submittals should be sent to Mike Hawthorne. If you know someone who is interested in NAPL science, please forward this issue to them using the "Forward" link at the bottom of the page.

Context

Volume 1 (2011) of *Applied NAPL Science Review* (ANSR) is focused on tools and scientific concepts to improve NAPL conceptual site models (CSM). An accurate, detailed CSM will cost-effectively guide risk evaluations, remedial action determinations, technology selection, remedial design, and end point attainment (closure) evaluations.

Terminology conventions:

AN: Air/NAPL interface (previously AOI)

NW: NAPL/Water interface (previously OWI)

CGWS: Calculated Ground Water Surface

ANT: Apparent NAPL Thickness

Announcements

LNAPL Site Management Strategies Session (multiple platform presentations by ANSR Board Members and others). June 27-30, 2011, Reno, Nevada. Bioremediation and Sustainable Environmental Technologies, BATTELLE. Click Here for link to conference web page.

Coming Up

Look for articles on LNAPL transmissivity as well as more detailed explanations of confined and perched LNAPL in coming newsletters.

Related Links

API LNAPL Resources

ASTM LCSM Guide

Env Canada Oil Properties DB

EPA NAPL Guidance

ITRC LNAPL Resources

ITRC DNAPL Documents

RTDF NAPL Training

RTDF NAPL Publications

USGS LNAPL Facts

ANSR Archives

ANSR Online

Perched LNAPL

J. Michael Hawthorne, PG - H2A Environmental, Ltd.
Mark Adamski - BP America
Sanjay Garg, PhD - Shell Global Solutions (US) Inc.
Andrew Kirkman, PE - AECOM

Have you ever wondered why the apparent NAPL thickness (ANT) gauged in wells at a site is large, but increased groundwater extraction does not increase LNAPL recovery rate? The cause may be perched LNAPL.

> Both LNAPL and groundwater can be perched, but the perching mechanism for groundwater is a low hydraulic conductivity layer that retards groundwater migration while for LNAPL it is a water saturated layer with a pore entry pressure too large for LNAPL migration. Since pore entry pressure typically increases and hydraulic conductivity typically decreases as grain size decreases, the same fine-grained layer may perch both groundwater and LNAPL.

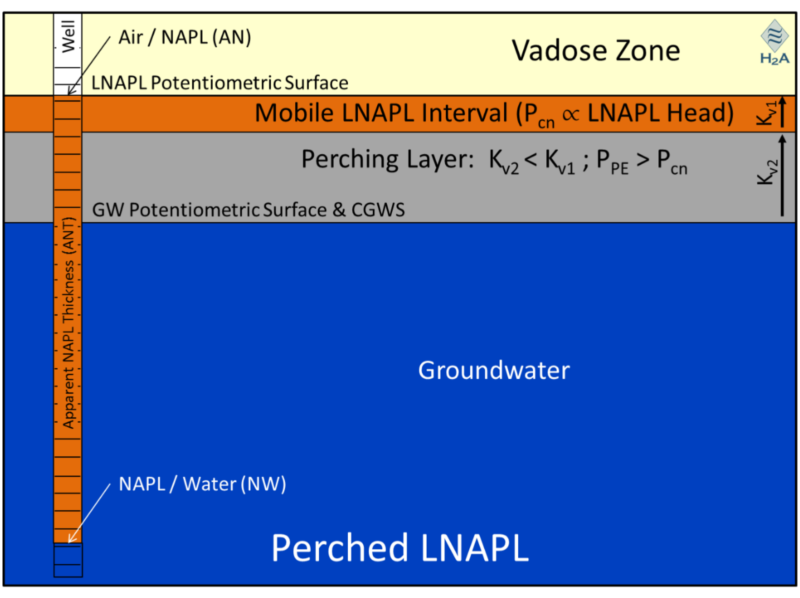
BACKGROUND: Much like groundwater, LNAPL can be perched on finer-grained soils in the vadose zone, although the underlying processes that cause LNAPL and groundwater to perch are different. Apparent NAPL thickness (ANT) and recovery from wells that are cross-screened across perching layers down to the water table can exhibit behavior that is contrary to expectations. Perched LNAPL may create exaggerated ANTs that are not representative of LNAPL mobility or recoverability in wells and could lead to misdirected remediation efforts.

In previous issues we have discussed various explanations for exaggerated ANT gauged in wells, including Confined and Perched LNAPL. In this issue we will define what we mean by Perched LNAPL, identify conditions under which it may occur and outline some diagnostic approaches for identifying perched LNAPL.

Definition: Perched light non-aqueous phase liquid (LNAPL) is mobile LNAPL that accumulates in the vadose zone of a site for some time period above a layer that exhibits a pore entry pressure greater than the LNAPL head pressure, thereby impeding the downward migration of LNAPL.

INTERPRETATION: As described in the ANSR issue on Confined LNAPL, groundwater is typically considered to be the "wetting" fluid when both groundwater and LNAPL are present because water preferentially adheres to sediment surfaces and fills small pores. LNAPL (the "non-wetting" fluid) typically occurs in the center of large pores isolated from pore walls by water. A measure of the resistance to non-wetting phase (LNAPL) displacement of wetting phase (water) from pore space is called the entry pressure, which can be significant at locations exhibiting large variations in pore size.

As grain size and associated pore sizes decrease, finer soils have a lower hydraulic conductivity and tend to retain more moisture. Due to this retained moisture the finer-grained soils possess pore entry pressure inhibiting LNAPL downward migration. In contrast to this pore entry pressure barrier, it is the lower conductivity of the soil that retards the downward migration of water (wetting fluid not subject to pore entry pressure).



Cross-sectional view of perched LNAPL. AN and NW are Air/NAPL and NAPL/Water interfaces, respectively; P_{PE} is pore entry pressure, P_{cn} is NAPL capillary pressure, and the symbol following P_{cn}means "is proportional to"; K_{v1} and K_{v2} are vertical hydraulic conductivities of the layer containing mobile LNAPL and the perching layer, respectively; GW is groundwater and CGWS is calculated groundwater surface.

Typically an LNAPL perching layer can be identified by the expected changes in soil properties such as grain size and permeability that lead to high pore entry pressures. In such cases, LNAPL in cross-screened monitoring wells will exhibit a perched response on a Hydrostratigraph. Adequate site characterization (e.g., continuous cores, CPT/LIF) and well completion intervals are critical to the recognition of perched LNAPL. If a well is screened only across a perched LNAPL zone (with or without the presence of perched groundwater) and terminates at or above the top of the perching layer below, a Diagnostic Gauge Plot or Discharge versus Drawdown Graph will typically indicate unconfined conditions. If a well is screened across and below the perched mobile LNAPL interval, a Diagnostic Gauge Plot or Discharge versus Drawdown Graph may indicate perched LNAPL.

SUMMARY: Mobile LNAPL is perched when pore entry pressure in the vadose zone layer underlying the LNAPL is greater than the LNAPL capillary pressure. If a well is screened across the mobile LNAPL interval above the perching layer and is also completed below the top of the perching layer, then the well may act as a sump for LNAPL to accumulate until it equalizes with the top of the mobile LNAPL interval above the perching layer. This sump effect results in an exaggerated apparent NAPL thickness (ANT) in the well that is not representative of LNAPL mobility or recoverability. In addition, the well may act as a conduit for perched LNAPL to migrate to deeper groundwater.

The maximum drawdown that perched LNAPL can "see" is the thickness of mobile LNAPL above the perching layer. Consequently, no matter how much groundwater drawdown is applied to an aquifer below the perched LNAPL, LNAPL production will not increase. Applied vacuum may be more effective in perched conditions for increasing drawdown to LNAPL.

REAL WORLD LIMITATIONS: A word of caution – Perched LNAPL may be ephemeral in fluctuating groundwater conditions. Vertical gradients or macropores with low pore entry pressures (e.g., faults, fractures, root holes) often naturally present in fine-grained soils may result in vertical migration of LNAPL through otherwise perching layers. The conditions described represent selected points within a large range of complex realizations of combinations of liquid pressures, multiphase fluid mechanics, and hydrodynamic groundwater conditions. Diagnostic Gauge Plots, Hydrostratigraphs, and Discharge versus Drawdown Graphs may help to distinguish these various conceptual site model conditions. As always, multiple lines of evidence should be used.