Overview – NAPL Transport

- Transport along water-sediment interface
  - Capillary pressures
  - Air forces (usually negligible)
  - Surface tension differences (sheening)

- Transport as submerged NAPL
  - Capillary pressures
  - Gravity
  - Hydrodynamic forces
  - Ebullition
NAPL Migration Pathways

- Sheen Migration
- Seep Migration
- Groundwater Transport
- Ebullition
- Ecological receptors potentially at risk

Not to Scale
CSM Example – Hydrodynamic and Gravity Forces
Puget Sound Site Tide Cycle

~4.5 meter
NAPL Impact Characterization
## Data Needs for NAPL Conceptual Site Model

<table>
<thead>
<tr>
<th>Description</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAPL Distribution</td>
<td>Laser induced fluorescence boreholes or above-ground resistivity surveys</td>
</tr>
<tr>
<td>NAPL intensity</td>
<td>Undisturbed soil cores, core photography, specialty lab analyses for pore fluid saturations</td>
</tr>
<tr>
<td>NAPL mobility</td>
<td>Water drive (submerged NAPL) or centrifuge (LNAPL) testing for NAPL mobility</td>
</tr>
<tr>
<td>Hydrodynamic force</td>
<td>Groundwater horizontal and vertical gradient</td>
</tr>
<tr>
<td>Total Petroleum Hydrocarbon Analysis</td>
<td>Can be used to correlate with pore fluid data</td>
</tr>
<tr>
<td>NAPL Properties</td>
<td>Density and surface tensions  Composition</td>
</tr>
</tbody>
</table>
NAPL Tools
Laser Induced Fluorescence and Resistivity Survey

**Laser Induced Fluorescence**
(TarGOST®)

**Resistivity Transects**
(GeoTrax Surveys™)
For this site, 50% reflectance indicated potentially mobile NAPL
GeoTrax Survey™ Results on Shoreline

Brown indicates high resistive sediment
GeoTrax™ Survey Results in Sand Flat

- Resistive at shoreline indicating NAPL
- Conductive zone indicates biodegradation
- Loosing conductive zone where “food” is depleted
TarGOST® and GeoTrax Survey™ Comparison

Upper Shoreline GeoTrax™, Lower Interpolated Shoreline TarGOST®
Ebullition
Ebullition Overview

- Ebullition is a natural process from anaerobic degradation of organic matter.
- Ebullition itself is not typically caused by contamination impacts.
- Ebullition can be a significant migration pathway by:
  - Transporting NAPL to the surface
  - Creating preferential pathways from the bubble channels.

*Figure from McLinn and Stolzenberg 2009*
Ebullition Events

- **Favorable Conditions**
  - High organic content
  - High temperature
  - Low water Depth

- **Triggers**
  - Tides
  - Air Pressure
NAPL Mobility Testing
Core Photography

- Shelby tube or other undisturbed sample collected
- Frozen in dry ice in the field to retain pore fluids
- Shipped to lab and cut into 2-inch “pucks”
- Photographed in visible and ultra-violet light to identify NAPL impacts
  - Some NAPLs will fluoresce in ultra-violet light
Pore Fluid Saturations
How “concentrated” are the NAPL impacts?

- NAPL, water and air share the pore space of the sediment
- NAPL pore fluid saturations are the measure of the pore volume occupied by NAPL
  - % NAPL is used in NAPL mobility calculations
  - Can be used after NAPL mobility tests to determine the “residual “ saturation
- Results can be placed in cross section and in 3-D renderings
NAPL Mobility by Water Drive Tool to Test NAPL Mobility in Sediment

- Undisturbed sediment sample placed in O-ring seals to allow water to be injected
Water Drive Eluate – Highly Mobile Sample

Undisturbed Sediment Sample

Water Velocity 0.4 ft/day

Water Velocity 0.8 ft/day

0.4 ft/day = 100 ml eluate in 4 hours!
Mobility Analysis Summary

- Graphing the Darcy Flux and the Pore Fluid Saturation allows a mobility threshold to be identified.
Remedial Technologies
Remedial Technologies
Permeable Absorptive Barrier Wall

- Permeable wall of 25% Organoclay® and 75% native sand installed in 2005 along NAPL in Great Lakes as an interim measure
- NAPL appearance on sand flat reduced from 200’ x 100’ foot area in 2005 to a small 20’x20’ foot area in 2013
- Bench tests showed NAPL blocking at leading edge
- No operational cost
Permeable Absorptive Barrier Installed with Continuous Trencher - PAB Installation

Continuous Trench PAB Wall Installation Methods

Trench installed in one day!
Stabilization Can Greatly Reduce or Eliminate NAPL Mobility

- Untreated Sediment
- NAPL Migration During Water Flood Top View
- NAPL Migration During Water Flood Side View
- Stabilized Sediment
- Stabilized Sediment for Water Drive Test
- NAPL-Free Eluate
Remedial Technologies
In Situ Sediment Stabilization

- Sediment in situ stabilization technology being developed to address sediment impacts
- Uses standard deep soil mixing equipment, but barge mounted and work through the overlying water
- Can eliminate NAPL migration potential and reduce leaching
Conclusions

- NAPL CSM development and refinement are critical to implementing effective solutions.
- Both LIF and Resistivity Mapping are excellent tools to develop NAPL site conceptual models.
  - LIF measures NAPL impacts, but you have to interpolate between borings.
  - Resistivity Mapping does not require interpolation along a transect, but it does not actually measure NAPL impacts but the resistivity signal left by them.
Each requires confirmation borings and mobility testing to determine where NAPL is actually mobile.

Understanding the forces that cause NAPL migration is key to developing an accurate NAPL Conceptual Site Model.

Permeable barrier walls and in situ sediment stabilization can be potential remedial technologies that should be considered.
Thank You For Your Time

Jeff Gentry, P.E.
CH2M HILL Principal Technologist

Direct: 503.736.4390
Jeff.Gentry@ch2m.com