



TWO LNAPL MOBILITY ASSESSMENTS: A Coarse Grained Site in British Columbia and a Fine Grained Site in Alberta

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Introduction

Why LNAPL Mobility Assessments?

- Allows operators to Risk Manage sites, especially operating sites rather than aggressive remediation on non mobile LNAPL plumes
- Focus remediation and risk reduction to only portions of large LNAPL plumes that are mobile or higher risk

What are LNAPL Mobility Assessments?

- LNAPL Mobility assessments are based on “lines of evidence” approach
- Similar to MNA of Dissolved phase plumes

Introduction

- Significant advancement/acceptance of the LNAPL multiphase model since the API LNAPL Mobility tool was released in 2004 – soil moisture retention curve key parameter
- ASTM E2531 – 06 Standard Guide for Development of Conceptual Site Models and Remediation Strategies for LNAPL Released to the subsurface
- Acceptance of LNAPL Mobility assessments by regulators: BC Ministry of Environment Protocol 16 Determining the Presence and Mobility of Nonaqueous Phase Liquids and Odorous Substances – clay not considered

Introduction

Two LNAPL Mobility Assessments

- A coarse grained site in BC
- A fine grained site in AB

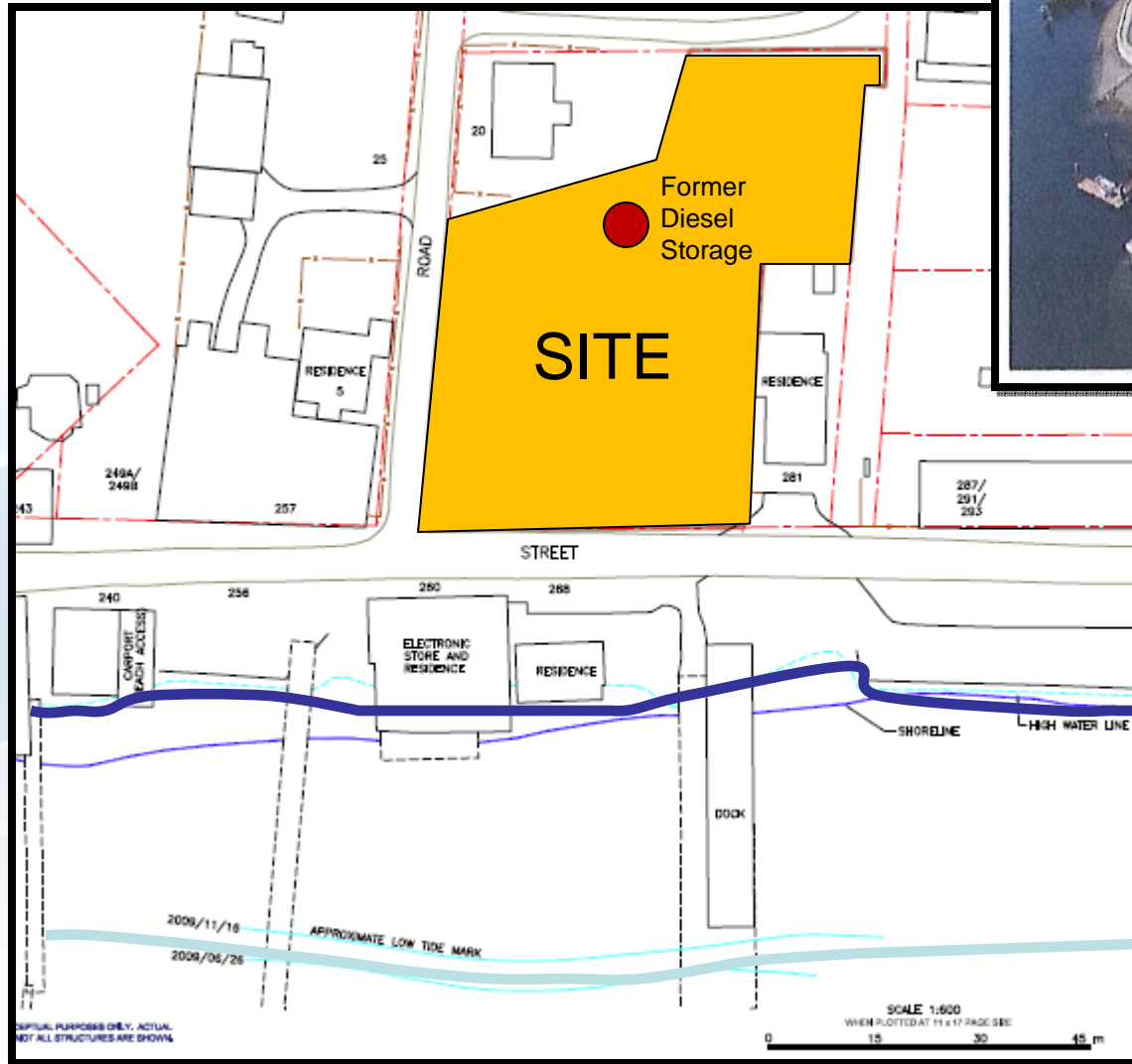
LNAPL mobility can be conducted on sand and gravel sites with tidal influences to fine grained sites with meters of apparent LNAPL present ...

Which site has mobile LNAPL?

Site Description

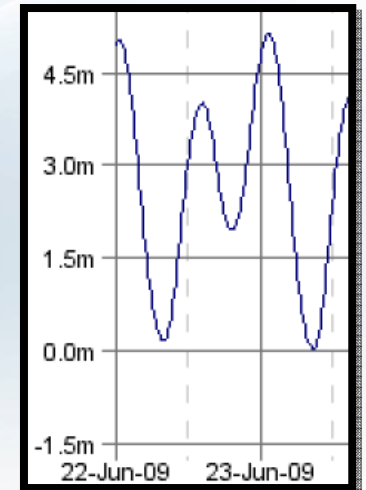
- Former Diesel Power Generating Station that operated from 1940's to the late 1970's
- Site located on the shoreline of Vancouver Island
- High tide within 30 m of site

Site Layout



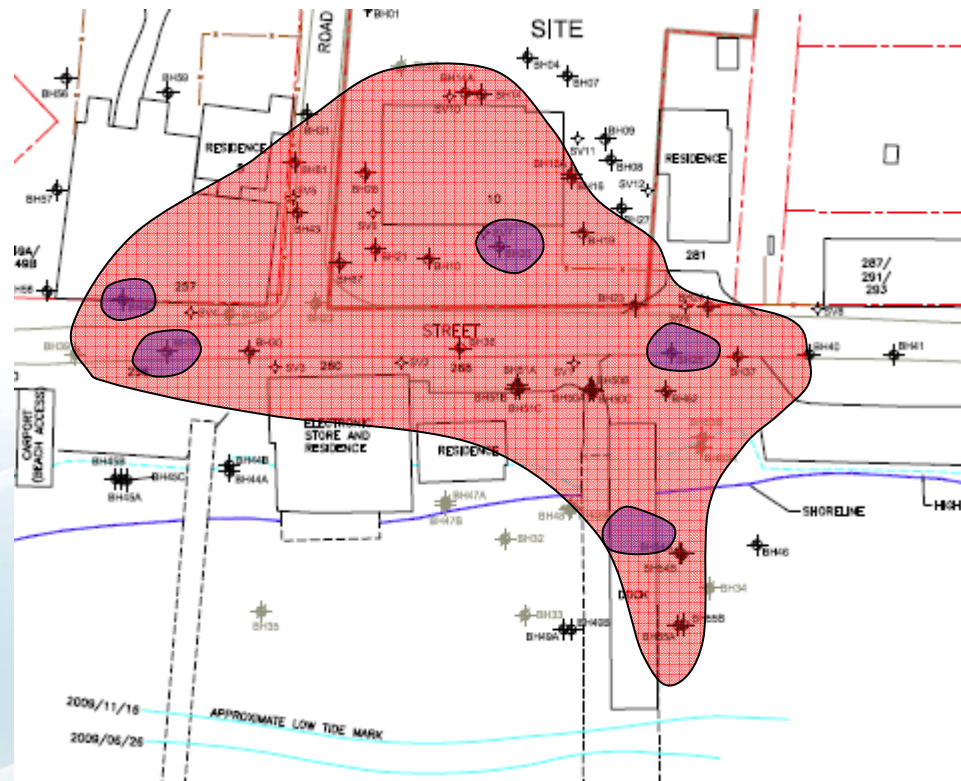
HIGH TIDE MARK

LOW TIDE MARK



Previous Investigations

- Investigated in stages since mid-1990's
- Irregular shaped dissolved diesel contaminant plume with "finger" into foreshore
- Intermittent Light Non-Aqueous Phase Liquid (LNAPL), free-phase diesel
- potential tidal influence not fully understood with respect to LNAPL and dissolved phase concentrations



Site Description

- Stratigraphy : Sand with some gravel to 8.5 m bgs
- Groundwater: 3 m to 6 m below ground surface. Significantly influenced by the tide
- Hydraulic Conductivity: 10^{-4} m/s to 10^{-5} m/s
- LNAPL: Historically present in 4 wells on the uplands and one well on the foreshore
- Apparent thicknesses have ranged from 1 mm to 322 mm
- LNAPL mobility focused on two areas where measureable LNAPL has been most persistent

British MOE Changes

- BC Ministry of Environment (MoE) has developed 3 new protocols relating to LNAPL and risk classification
- Under these new protocols the site would be classified as “high risk” based on two defined conditions under which LNAPL is considered to be mobile:
 - Measureable LNAPL is present over an inferred area of at least 10m²; and
 - Seasonal water table fluctuations exceed 1 metre
- Observational data can be collected to obtain an exemption from these conditions and thus lower the risk classification
- Lower risk classification = More flexible site management and less cost to client
- Theoretical LNAPL mobility assessment provides an additional line of evidence of LNAPL stability

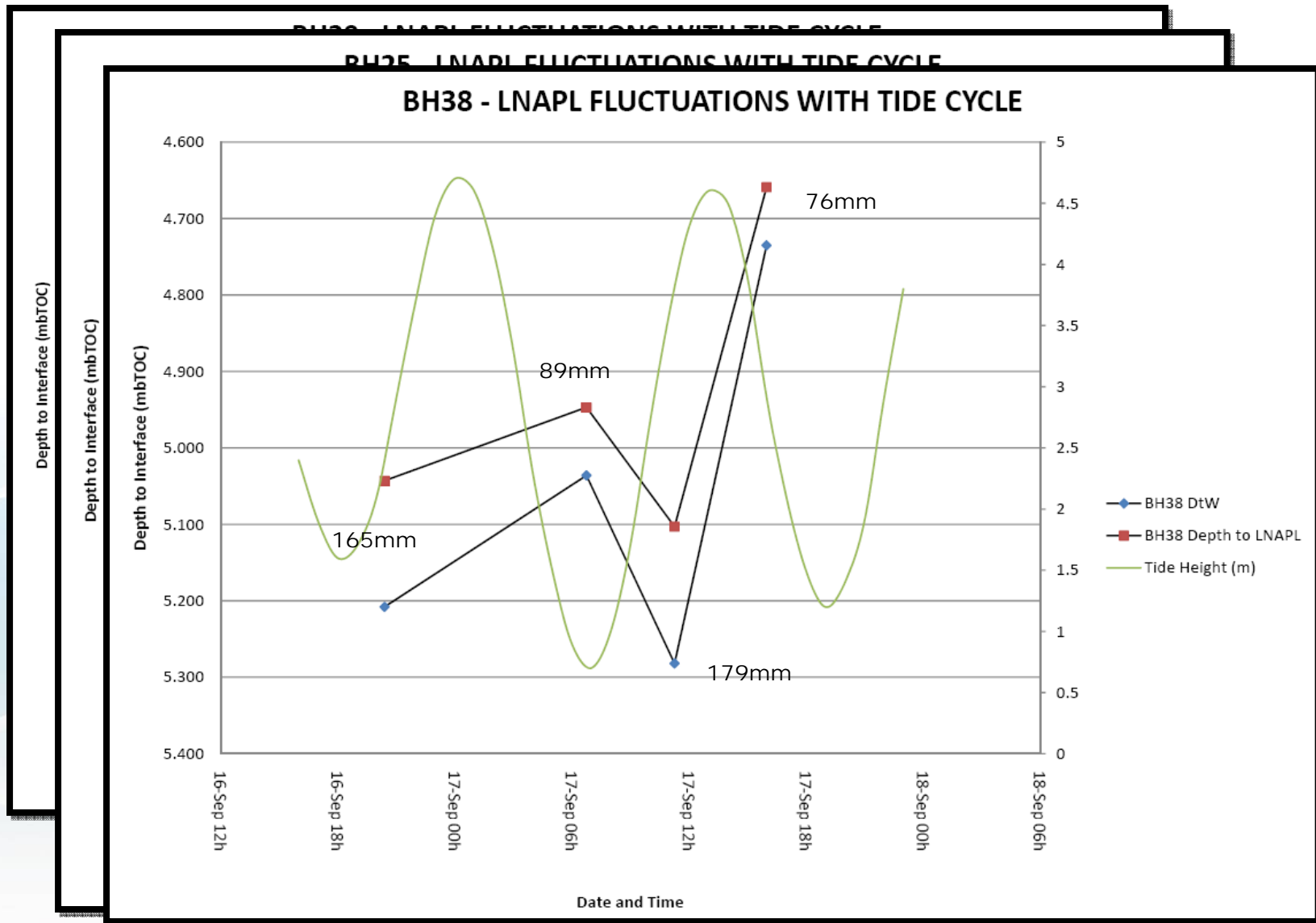
Approach

- Review LNAPL Monitoring Results
- Evaluate dissolved phase plume stability
- Assess LNAPL mobility Macro Scale
- Assess LNAPL mobility Micro Scale

Review LNAPL Monitoring

- Historically present in 4 wells on the uplands and one well on the foreshore – no new occurrences of LNAPL
- LNAPL thicknesses have fluctuated with significant water table (and tide) fluctuations and generally decreased over time
- Maximum thickness 322 mm measured in 2009

Effect of Tides on LNAPL

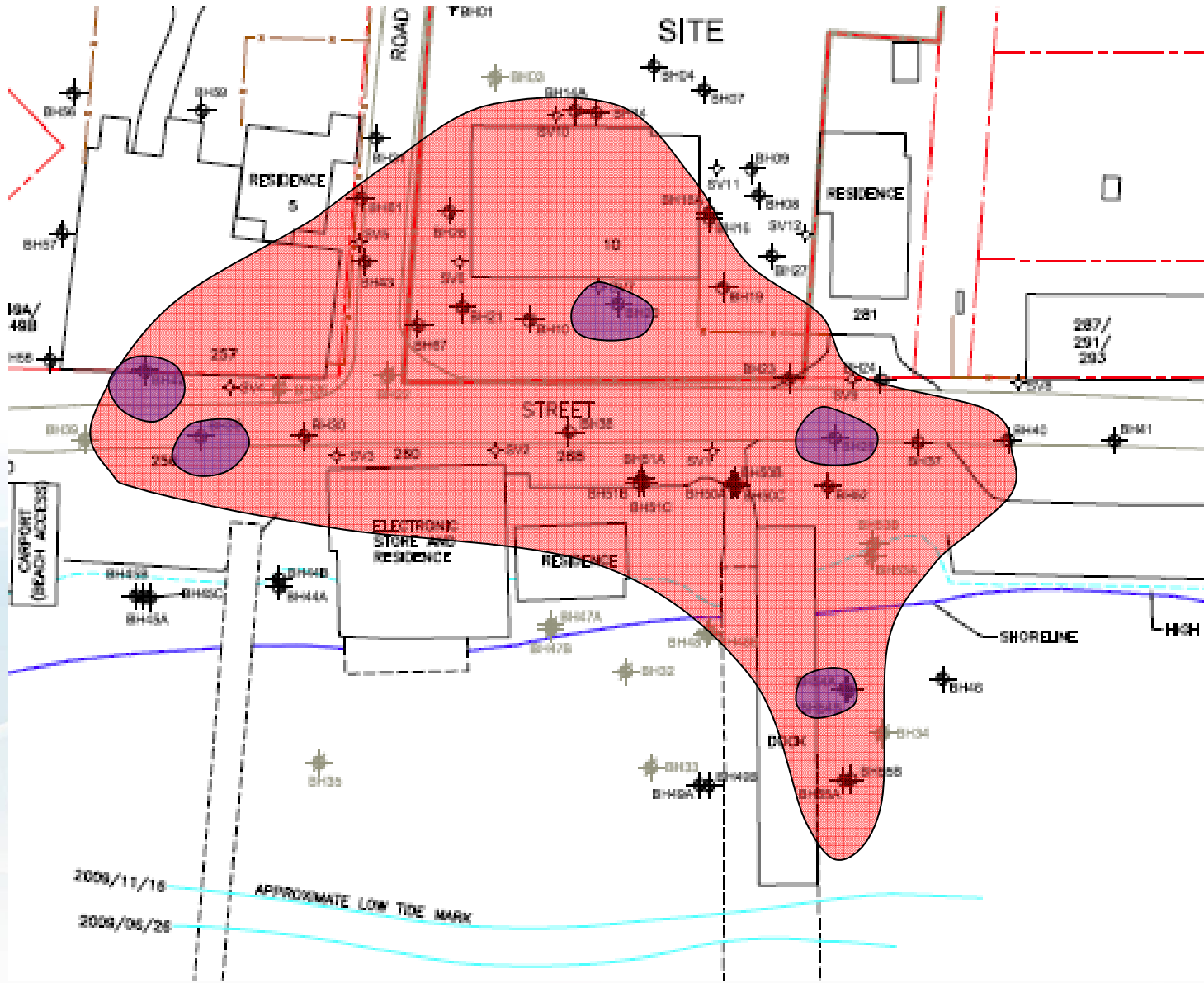


Dissolved Phase Trends

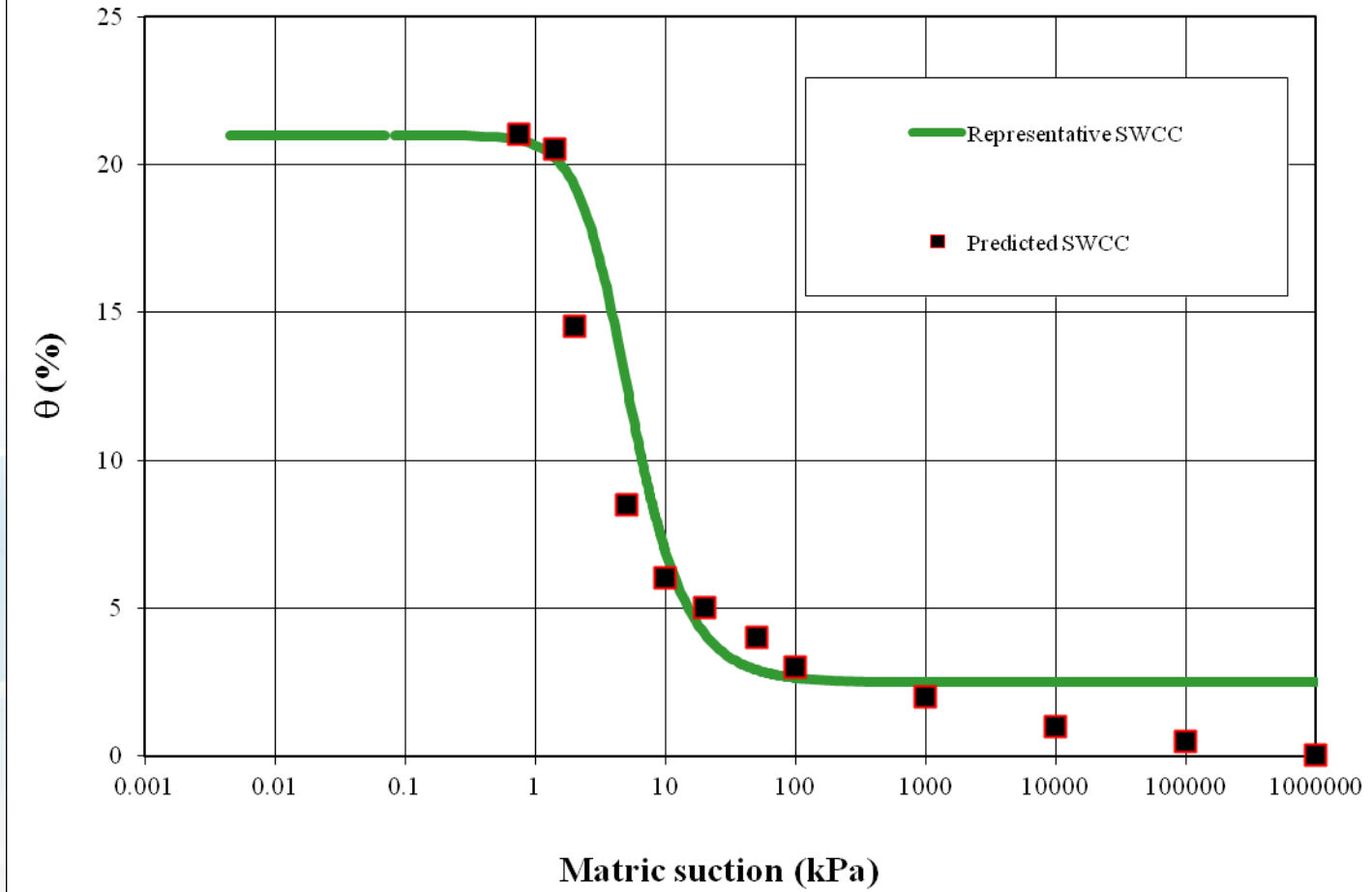
- Highest concentrations in June on the flood tide, in both the intertidal zone and the uplands (dry season and extreme low tides)
- Variability observed over the tide cycle demonstrates the need for tidally correlated data
- Insufficient data to evaluate dissolved phase plume stability at this time

LNAPL mobility Marco Scale

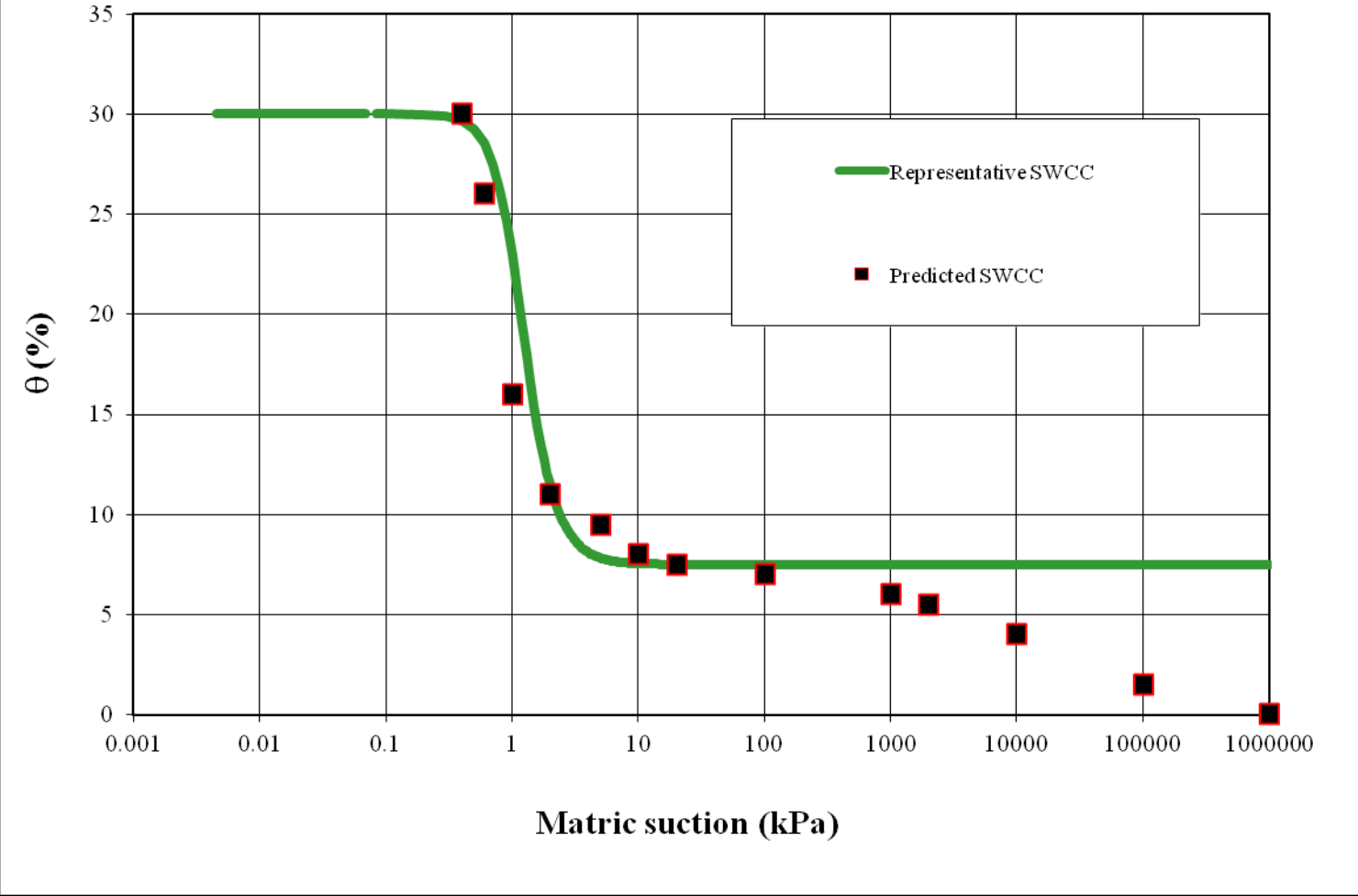
- Determined using the API LNAPL Mobility Assessment Tool
- Used estimated moisture retention curve from site grain size data, bulk density and moisture content from site samples, hydraulic conductivity from site data, diesel properties, maximum LNAPL thickness
- Calibrated using site oil saturations from soil hydrocarbon data versus API oil saturations – reasonably good fit
- Velocity lower than ASTM de minimum criteria (0.3 m/yr)



**Chart 1 - Soil-Water Characteristic Curve
for Sample BH09-68 S9**

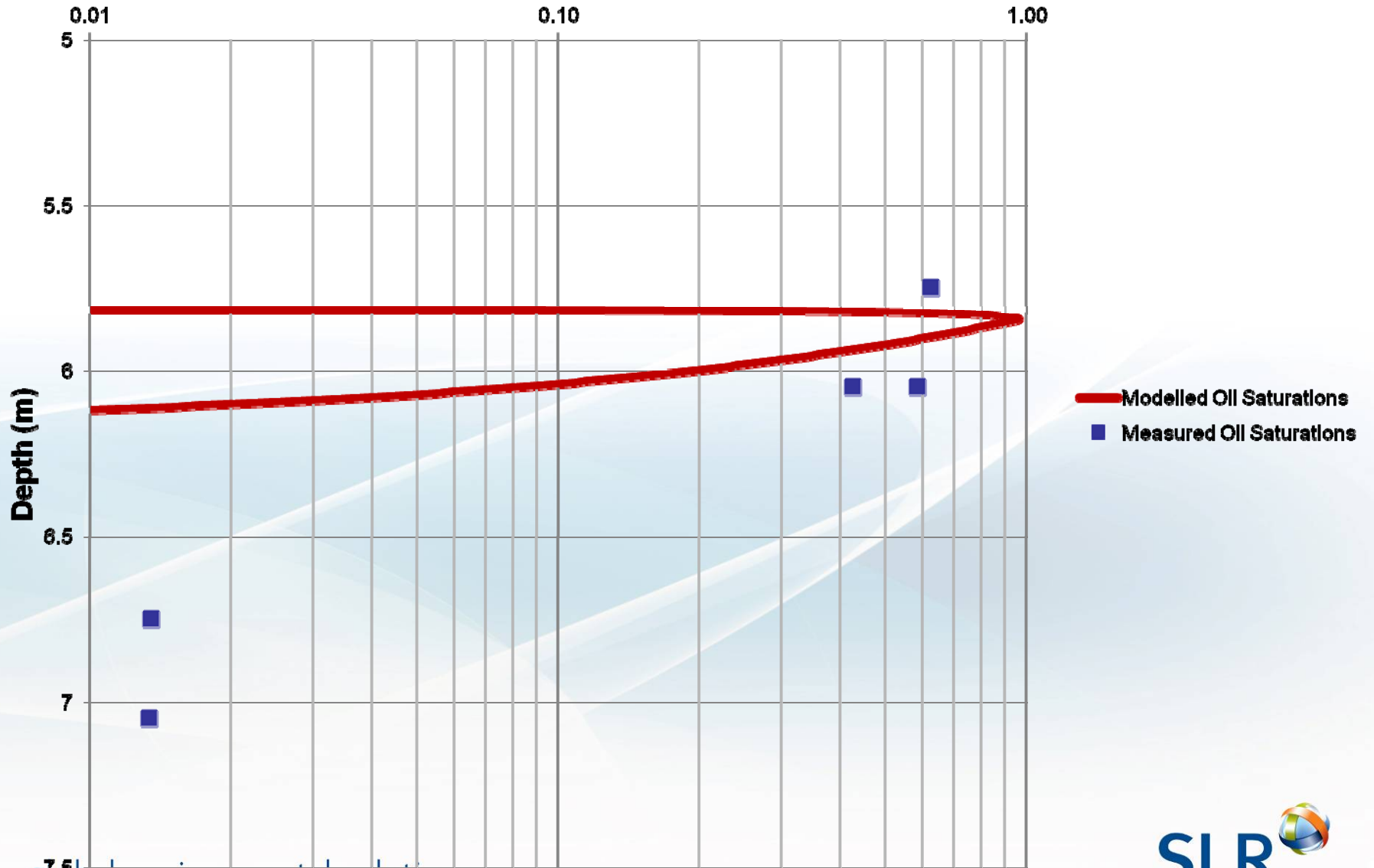


**Chart 2 - Soil-Water Characteristic Curve
for Sample BH09-69 S10**



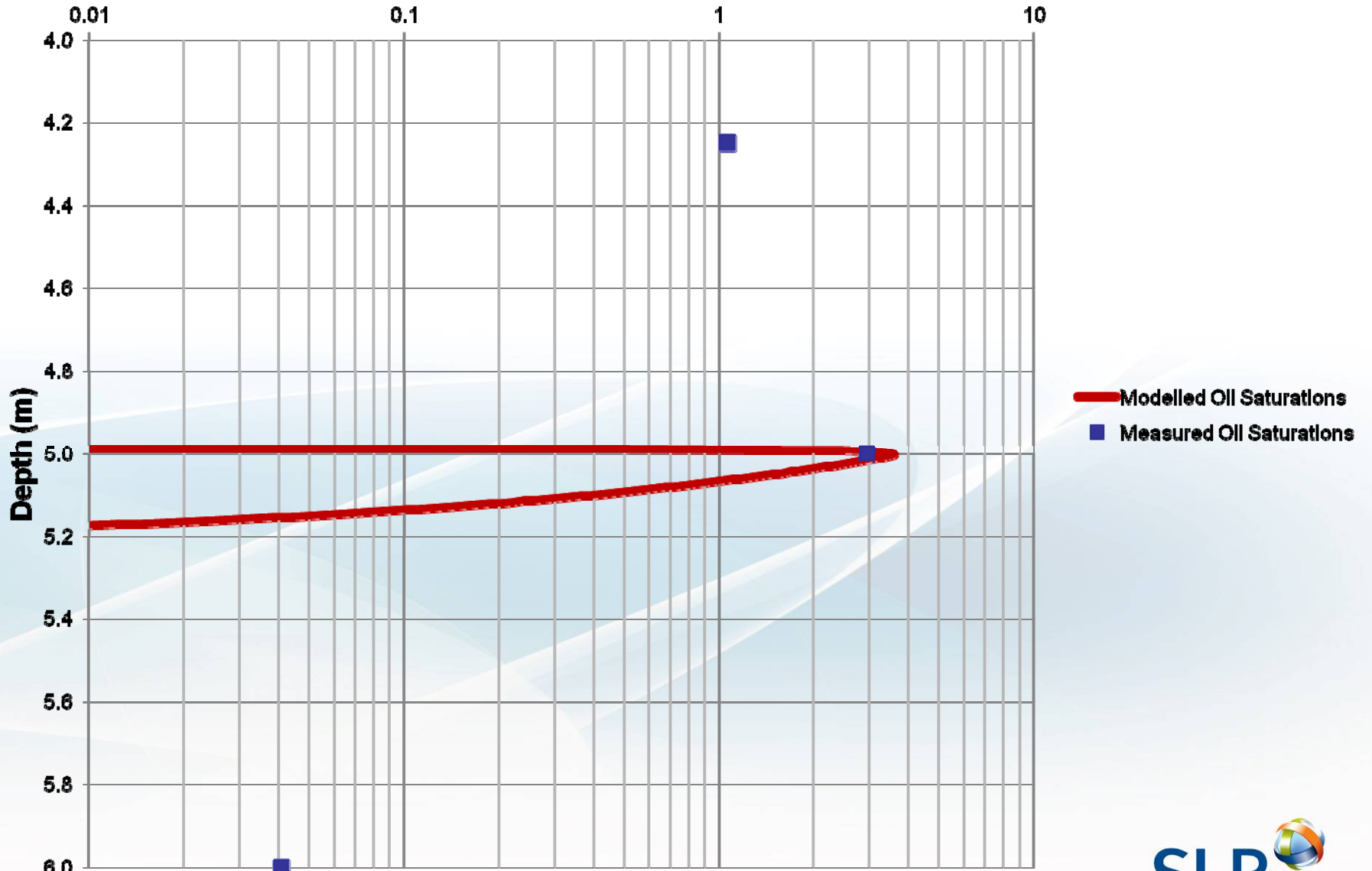
BH09-68

Oil Saturation (%)



BH09-69

Oil Saturation (%)



LNAPL mobility Micro Scale

- Local scale mobility calculated using the air entry value from the moisture retention curve
- Resulting LNAPL displacement head ranges from 400 mm to 1,500 mm
- Maximum thickness measured is 322 mm

LNAPL Mobility Assessment

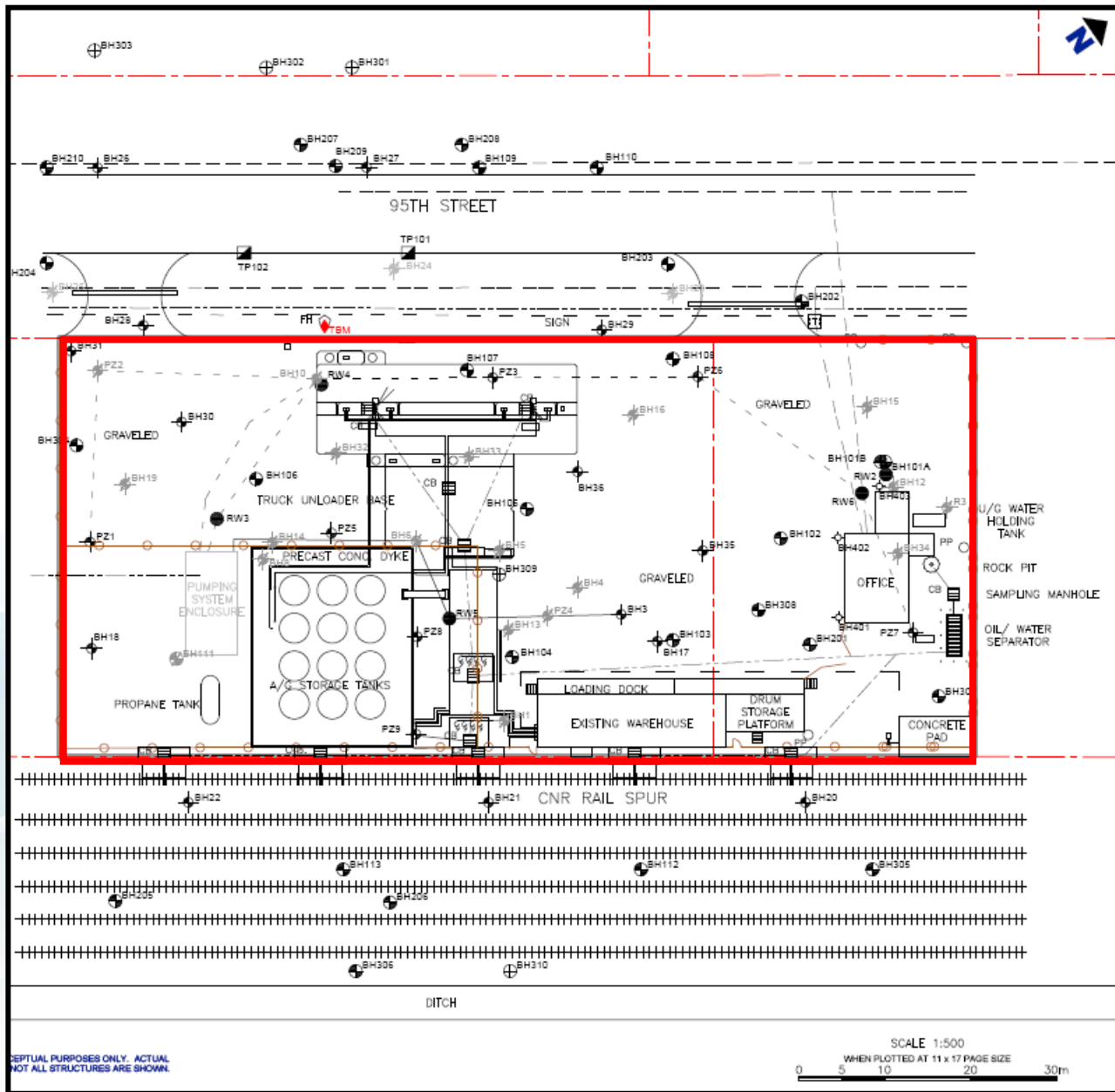
- Mobility was assessed at two locations where maximum LNAPL thickness were 322 mm and 210 mm respectively
- Local-scale mobility should occur only if LNAPL thicknesses exceeding 400 mm therefore Local-scale LNAPL mobility is unlikely
- Plume-scale mobility calculated using the API LNAPL mobility assessment tool predicted that the plume is not likely mobile

LNAPL Mobility

- Continue to monitor dissolved phase and build a data set to conduct dissolved phase plume stability assessment
- Continue to monitor LNAPL thicknesses
- Apply to BC MOE for an exemption consistent with protocol 16

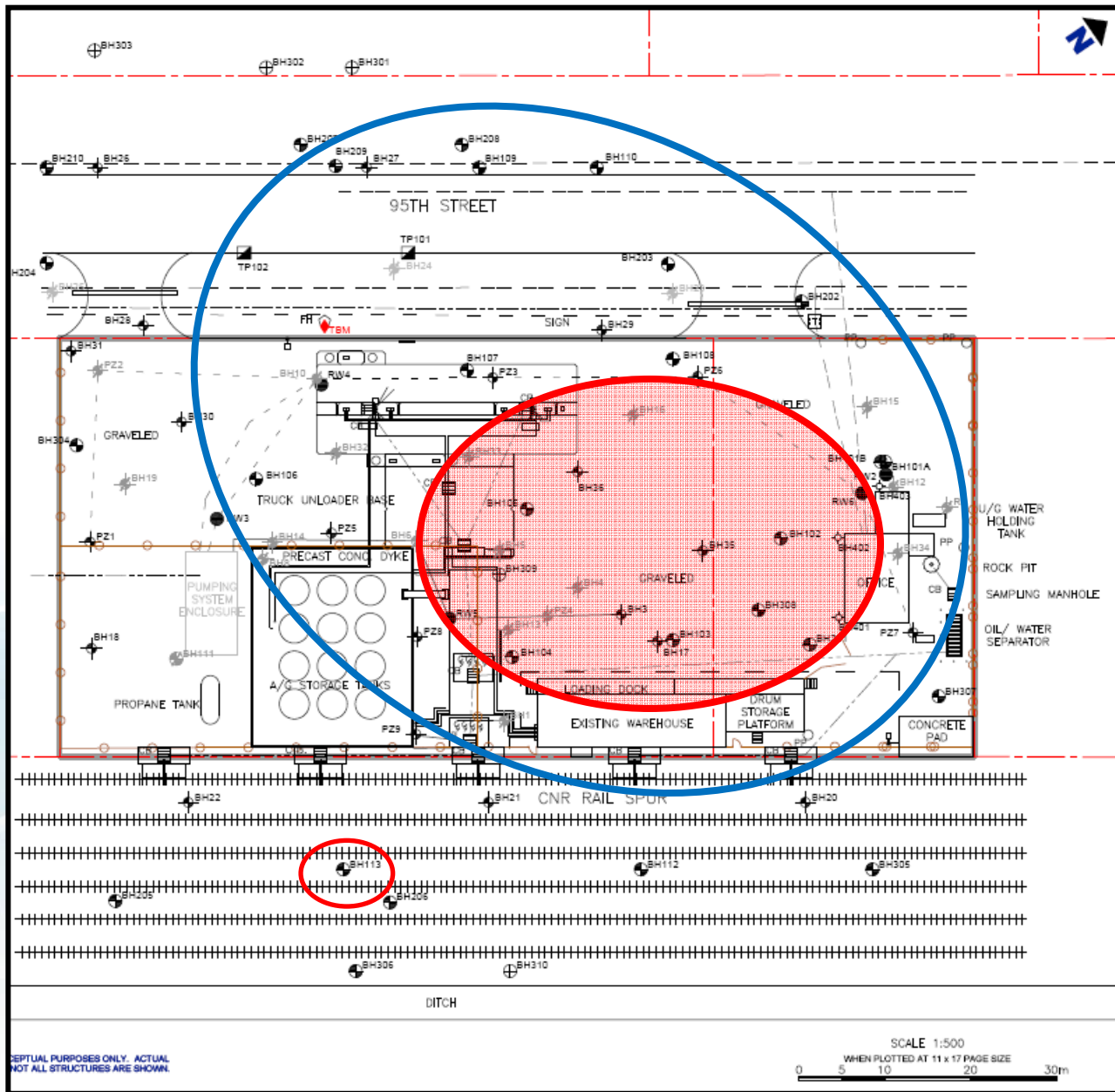
Site Description

- Bulk Plant in Northwest AB operated for over 50 years
- Several Site Assessments completed on site and off site since mid 1980's. In 2005 re-assessment of the site was initiated and is on going
- Total 14 monitor wells on site and 15 monitor wells off site



Site Description

- Stratigraphy : Clay to 12 m
- Groundwater: 1 m to 4 m below ground surface
- Hydraulic Conductivity: 1×10^{-8} m/s
- LNAPL: Historically present in 6 wells on site and one well off site
- Apparent thicknesses have ranged from 1 mm to 3,645 mm
- LNAPL Mobility was initiated as part of the Site Management Plan submitted to AENV



Approach

- Review LNAPL Monitoring
- Evaluate dissolved phase plume stability
- Assess LNAPL mobility Macro Scale
- Assess LNAPL mobility Micro Scale

Review LNAPL Monitoring

- Historically present in 6 wells on site and one well off site – no new occurrences of LNAPL since initiating re assessment of the site in 2005
- LNAPL thicknesses have fluctuated with water table fluctuations but no increases in apparent thickness only decreases
- LNAPL recovery from bailing wells has been constant or decreasing in volume each year.

Dissolved phase plume stability

- Mann-Kendall test were conducted on a total of 9 wells that had detectable concentrations of benzene for 3 or more monitoring events
- 3 wells on site and 6 wells off site
- Diminishing plume trend in one well
- Stable or no trend in seven wells
- Expanding plume trend in one well – off site well that may be linked to another source

LNAPL mobility Marco Scale

- Determined using the API LNAPL Mobility Assessment Tool
- Used estimated moisture retention curve from literature, bulk density and moisture content from site samples, hydraulic conductivity from site data, gasoline properties, maximum LNAPL thickness
- Calibrated using site oil saturations from soil hydrocarbon data versus API oil saturations – reasonably good fit
- Velocity lower than ASTM de minimum criteria (0.3 m/yr)

**Chart 2 - Soil Moisture Retention Curve
for Clay**

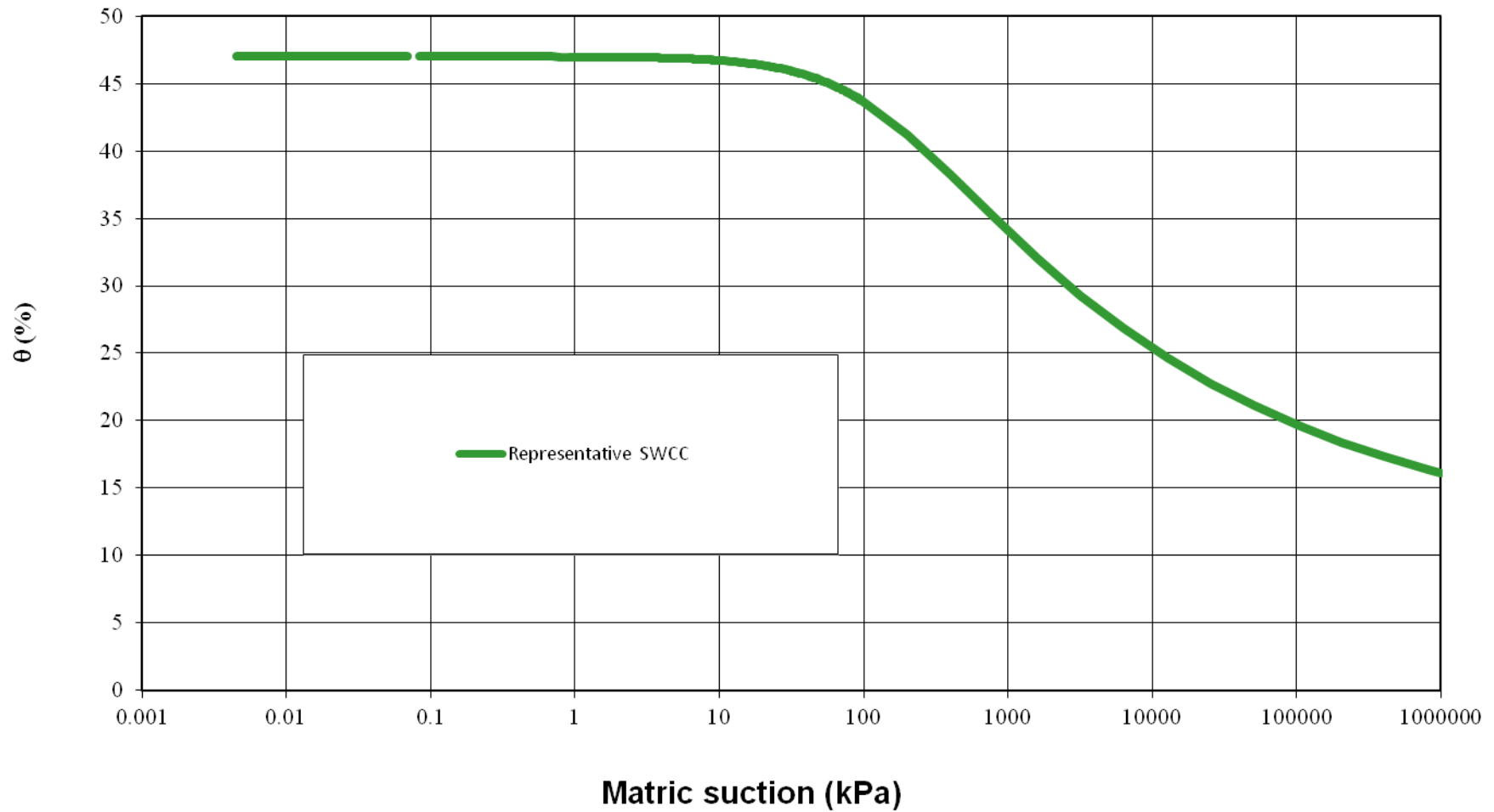
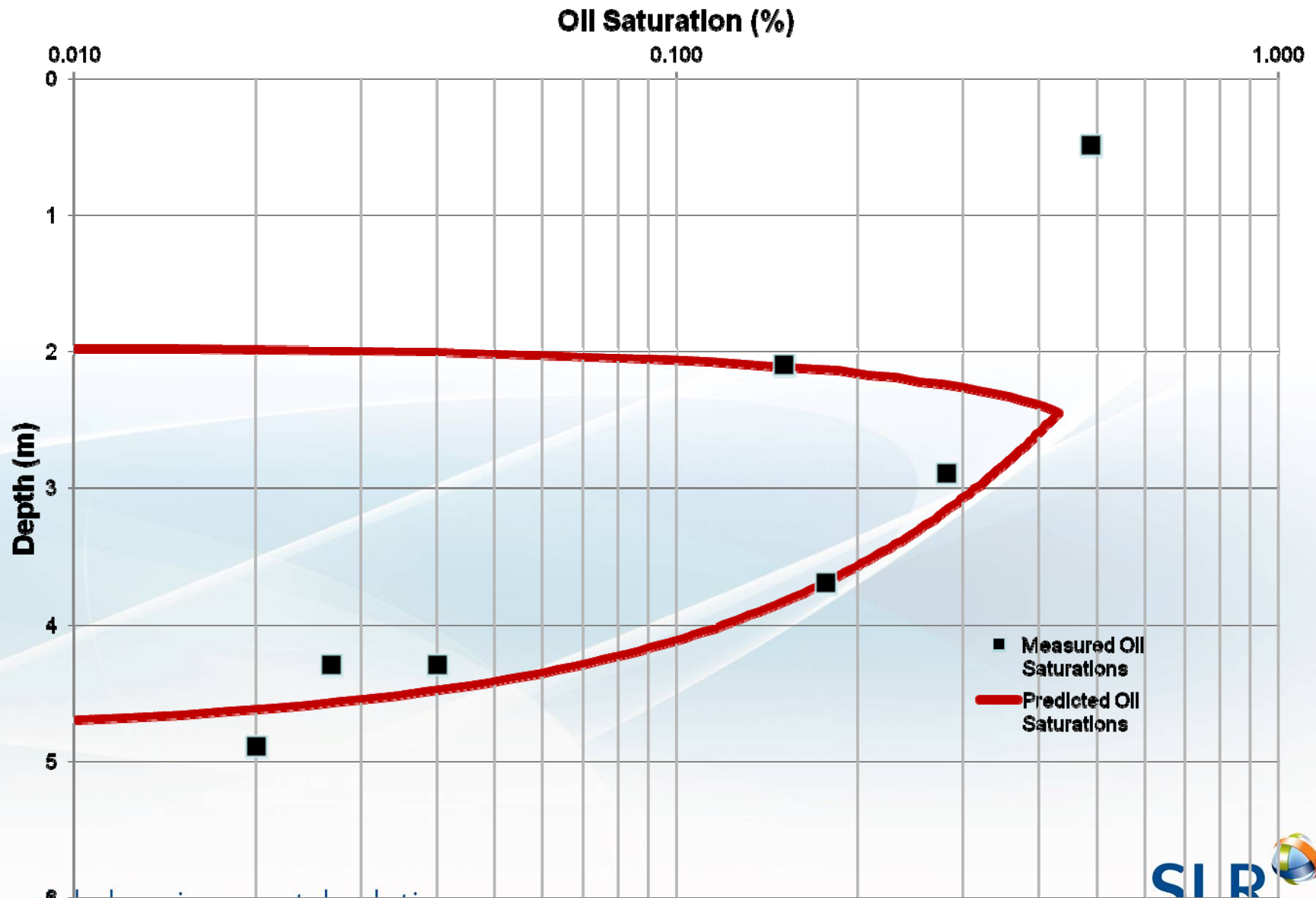


Chart 3 Measured and Predicted Oil Saturations



LNAPL mobility Micro Scale

- Local scale mobility calculated using the air entry value from the moisture retention curve
- Air entry value estimated to be 50 kPa
- Resulting LNAPL head displacement is approximately 11 m
- Maximum thickness was 3.6 m in 2006

Conclusion

- Based on the lines of evidence the LNAPL plume is not mobile
- AENV has agreed with our conclusion that the LNAPL plume is stable and our recommendations for monitoring
- Monitoring and risk management measures with some LNAPL skimming at the perimeter is planned
- No aggressive LNAPL recovery or remediation is planned until operations cease
- Neither site has mobile LNAPL



Questions

SLR Consulting (Canada) Ltd.