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Techniques Used to Evaluate Potential LNAPL Mobility

Submitted by: David A. Fursevich, M.Sc.,
R. Donald Burnett, M.Sc., P.Eng., and Christopher P. Lach, P.Eng.

Morrow Environmental Consultants Inc.,
Member of the SNC-Lavalin Group, Burnaby, BC, Canada

Abstract

The objective of this ongoing study is to evaluate potential light nonaqueous phase (LNAPL) mobility at a former refinery property to assess future migration risk and recovery strategies. Emphasis during the evaluation was placed on risk management of migration rather than assuming measurable LNAPL thicknesses on site required active recovery. Factors evaluated thus far affecting the risk of migration include soil permeability, hydraulic gradient, LNAPL density and viscosity, and smear zone thickness.

LNAPL mobility was quantitatively estimated for all wells considered using an internally written spreadsheet model that solves the three-phase equations of Parker et al. (1994) and was verified against available industry standard models. The spreadsheet model developed by Morrow also allowed the estimation of total and recoverable LNAPL specific volumes.

The quantitative estimates were periodically updated as field data was collected. Depth to water and apparent product thickness (APT) measurements were made on a regular basis to characterize the smear zone. The density and viscosity of different LNAPL types was determined in the laboratory. Soil hydraulic conductivity was estimated from slug tests done in monitoring wells that showed no significant apparent LNAPL during periods of high groundwater. Where no field data exists, default values from the API Interactive LNAPL Guide, Version 2.0 (August 2004) were used.

The findings suggest that significant volumes of LNAPL are immobilized from smearing due to seasonal water table fluctuation. The results also confirm that potential mobility and apparent oil thicknesses increase with declining water levels. This suggests that although a LNAPL plume may appear to be stable, LNAPL migration could occur during periods of extremely low water due to enhanced drainage of LNAPL and greater measurable thicknesses. Extreme low groundwater conditions have not been encountered since data collection commenced for verification of the mobility calculations; however, similar results have been observed at other sites.

Estimates calculated for wells near the centre of the LNAPL plume indicate higher mobility potential and recoverability than the plume fringe. Caution is suggested in interpreting the LNAPL mobility results at the plume centre since it is not indicative of conditions at the fringe. LNAPL recoverability, which estimates the volume of oil that could potentially be extracted through active recovery, is regarded to be a more practical evaluation criterion for wells in the plume centre. The recoverable LNAPL product in the centre of a plume is LNAPL that provides the source for mobility at the plume fringe. Prior to implementing LNAPL recovery activities an evaluation of risk reduction options could be performed to assess the benefit of removing recoverable LNAPL.

Measurement of LNAPL thickness and calculated free oil volumes confirm that similar to mobility, recoverability decreases with a rising water table during the rainy season. This suggests that seasonal effects can have a large impact on the effectiveness of a free phase recovery system and should be considered during the risk evaluation phase and detailed design.

Introduction

Light non-aqueous phase liquid (LNAPL) is commonly encountered in the ground at sites where fuel or oil storage has occurred, such as gasoline service stations, bulk plants and refinery properties. LNAPL may be measured in monitoring wells screened across the water table that are installed as part of environmental assessments. Typical tasks that occur include monitoring apparent LNAPL thicknesses in the field, delineation of its extent in the subsurface with additional monitoring wells, and preparation of a remedial options evaluation in preparation for site cleanup. It is often assumed that the presence of LNAPL in monitoring wells equates to unacceptable risk. Is this a reasonable assumption to make? Do measurable LNAPL thicknesses on-site necessitate active recovery or control?

The objective of this ongoing study is to evaluate potential LNAPL mobility at a former refinery property. The study focuses on LNAPL existing primarily beneath the former refining area and adjacent fuel storage locations. Several product types are present, ranging from light natural naphtha to heavy oil. The site geology generally consists of variable thicknesses of glacial till and glaciofluvial and fluvial sands, gravels and cobbles overlying granitic bedrock. Significant thicknesses of fill can also occur in tank lots. The hydraulic gradient is variable similar to topography and ranging from less than 0.5% to over 10%. The depth to water ranges from less than 2 m to over 18 m below grade. The affected area is approximately 15 hectares in extent.

A risk management approach with emphasis placed on LNAPL migration risk to evaluate future management strategies is being undertaken. This approach is continually being updated and improved as new data is collected and evaluated. The aim of the approach is to be able to estimate potential migration risk with reasonable confidence from apparent LNAPL thicknesses in monitoring wells, and to evaluate the necessity of active recovery and/or control.

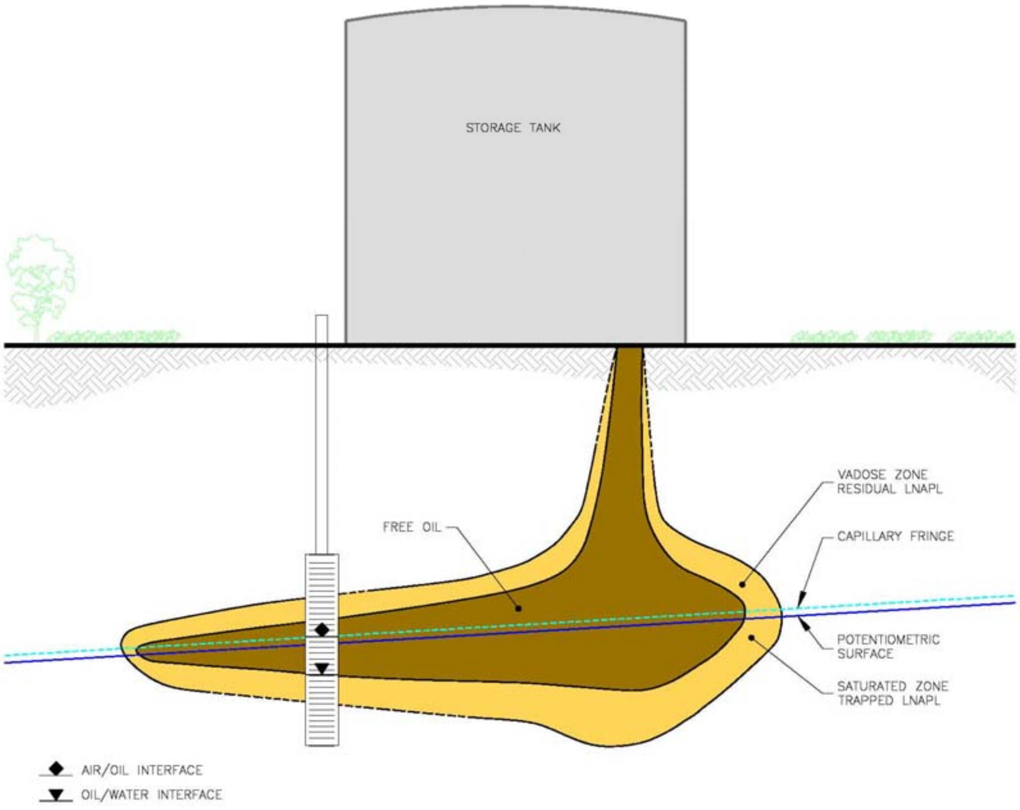
To demonstrate the approach and our findings to date, actual monitoring well field data and mobility results for two (2) monitoring wells are included in this paper.

Theory Overview

A conceptual overview of LNAPL distribution in soil and mobility is presented in this section.

When LNAPL is released to the ground, vertical migration occurs under gravity through the unsaturated zone toward the groundwater capillary fringe. A fraction of the LNAPL volume is retained within the soil pores surrounding the release area and within the unsaturated zone along the migration path. If sufficient volume is released, vertical migration reaches the groundwater capillary fringe where downward LNAPL movement slows due to high water saturation in the capillary fringe and buoyancy effects. Water is displaced as the LNAPL moves deeper into the capillary fringe, reducing water saturation while increasing oil saturation. As vertical migration slows, lateral migration begins to occur as rate of LNAPL reaching the capillary fringe exceeds the rate at which LNAPL can penetrate the fringe. Oil saturation increases and then decreases with depth within the saturated zone until zero oil saturation is reached and pore space is completely filled with water. Figure 1 is an illustration of a typical release area.

Figure 1: EXAMPLE LNAPL RELEASE AREA



Away from the source area, residual LNAPL volumes are restricted to the smear zone which is controlled by seasonal groundwater fluctuation. The vertical saturation profile at any given point within a LNAPL plume therefore changes with time. As water levels rise, oil is displaced upward, increasing water saturation while trapping residual product within the saturated zone. As water levels drop, LNAPL is released from previously water saturated areas and drains with gravity, increasing oil saturation in the vicinity of groundwater capillary fringe leading to LNAPL mobility. Relative low groundwater elevation therefore increases LNAPL mobility potential as it increases oil saturation that contributes to the free oil volume in the groundwater capillary fringe area.

The presence of LNAPL within the soil profile creates a multiphase distribution that includes water and air. Lenhard and Parker (1990) have demonstrated that under vertical equilibrium, the distribution of LNAPL in the subsurface will be a function of the pore sizes of the soil profile, fluid densities, capillary pressures and interfacial tensions. With this data, hydrocarbon and water saturations in the soil profile can be predicted from observed LNAPL and water levels in monitoring wells. Vertical integration of the calculated oil saturation profile results in an estimate of the actual LNAPL volume in soil per unit area around the well. This is termed the ‘total oil specific volume’.

The multiphase distribution relationship between LNAPL, air and water in the soil profile is commonly misinterpreted. A distinct LNAPL layer does not form above the groundwater capillary fringe, as full oil saturation does not occur. This fluid distribution in the ground violates the fundamental equations that describe the fluid pressure distributions in porous media under the condition of mechanical equilibrium. The groundwater capillary fringe and upper saturated zone becomes a zone where LNAPL and groundwater co-exist at varying saturations. Only partial oil saturation occurs in the soil profile. Maximum oil saturations throughout the soil profile can range from 5 to 70% of porosity (API Interactive LNAPL Guide Volume 2.0, August 2004).

Lateral migration in the direction of the hydraulic gradient begins when oil saturation exceeds the residual capacity of the soil and free oil occurs in the groundwater capillary fringe area. In areas with a shallow hydraulic gradient or with significant LNAPL volumes reaching the capillary fringe, radial oil spreading can also result. As LNAPL migrates laterally, free oil volumes will diminish as residual LNAPL is always left behind, unless an ongoing source continues contributing LNAPL to the subsurface.

Assessment Methodology

The LNAPL mobility assessment methodology is a spreadsheet-based analytical model which calculates the oil saturation profile and transmissivity from fluid properties, soil characteristics and monitoring well data. The analytical program was written by Morrow based on the quasi-equilibrium vertical integration equations in Parker et al (1994) and was verified against available industry standard models.

The LNAPL analytical mobility model can only predict the oil saturation profile under unconfined conditions, and is therefore not applicable for LNAPL trapped beneath finer grained confining soil layers. LNAPL must also occur within the primary porosity of granular soils, and therefore predictions would be not be valid when LNAPL occurs within fractures (i.e. potentially within glacial till) or within large soil voids (i.e. peat and heterogeneous fill soils).

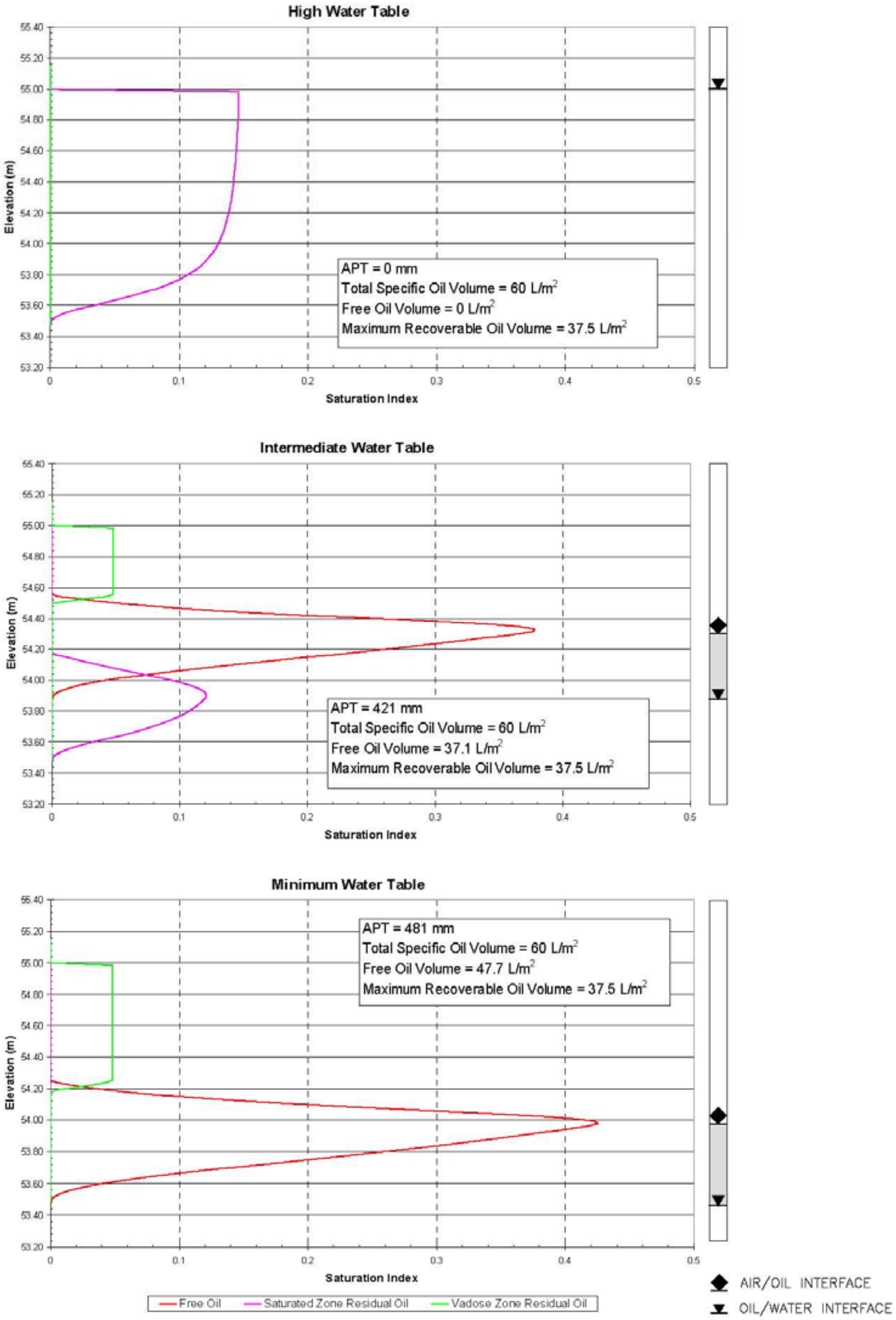
In addition to the total oil specific volume per unit area in the soil profile, specific oil estimates for vadose zone residual oil, saturated zone trapped oil, and free oil available for mobility are made. The theoretical maximum recoverable specific oil volume is also calculated, which is the total oil specific volume minus the total residual volume at extreme low water conditions. It can also be characterized as the estimated free oil specific volume at extreme low water conditions minus what would be left as residual after recovery. Figure 2 illustrates typical oil saturation curves and estimated volumes at high, intermediate and low groundwater conditions.

The estimated LNAPL front migration rate is calculated from LNAPL transmissivity. LNAPL transmissivity is analogous to water transmissivity, which is defined as hydraulic conductivity times saturated thickness. However, as free LNAPL only partially saturates a portion of the smear zone, the oil conductivity will vary with depth, while water is generally assumed to be fully saturated over the entire aquifer thickness beneath the water table with a constant hydraulic conductivity. The LNAPL transmissivity is estimated by integrating the calculated oil conductivity at each point in the vertical profile of the smear zone over the thickness of the smear zone.

The resulting LNAPL transmissivity divided by the total oil specific volume results in the LNAPL mobility term. It can be compared to hydraulic conductivity, however its quantification is again different due to partial oil saturation through the smear zone. Because LNAPL is required to saturate the soil profile before it can move through the zone, the volume of oil required to reach that degree of saturation controls the rate of migration of the plume into soils that do not yet contain residual LNAPL. LNAPL mobility is therefore a measure of how fast the front of the LNAPL plume could migrate under a unit gradient.

The LNAPL mobility multiplied by the hydraulic gradient is the estimated LNAPL front migration rate. However, the actual rate of front migration is controlled by the gradient on an LNAPL plume which is the slope of the air/oil surface. In the vicinity of a sudden release, this may be much steeper than the hydraulic gradient. However, for an older plume or an LNAPL plume distant from its source, the slope of the air-oil interface is usually approximated by the hydraulic gradient.

Figure 2: TYPICAL OIL SATURATION CURVES AND ESTIMATED VOLUMES



Input Parameters

The input parameters required in the spreadsheet model to calculate mobility estimates are presented in Table 1 for the two (2) monitoring wells referenced in this study. Further detail is provided below.

Table 1: Input Parameters for Mobility Modelling

Monitoring Wells			**A**	**B**
Soil Properties	ϕ	porosity	0.33	0.33
	S_m	water saturation at field capacity	0.27	0.27
	f_{og}	retention factor above water table	0.3	0.3
	f_{or}	retention factor below water table	0.3	0.3
	α	Van Genuchten parameter (1/m)	3.87	3.87
	n	Van Genuchten parameter	1.62	1.62
	K_{sw}	Saturated Hydraulic Conductivity (m/day)	30	11.6
Fluid Properties	ρ_{ro}	oil specific gravity	0.837	0.765
	η_o	oil dynamic viscosity at 15 C (cp)	4.83	0.79
	σ_{ao}	oil surface tension (dynes/cm)	23.7	22.9
	σ_{ow}	oil/water interfacial tension (dynes/cm)	24.3	19.1
	σ_{aw}	water surface tension (dynes/cm)	48.0	41.0
Well Data	z_{ao}	elevation of air/oil interface in well (m)	various	various
	z_{ow}	elevation of oil/water interface in well (m)	various	various
	z_{ow}^{min}	elevation of historical minimum z_{ow} (m)	53.93	53.42
	z_{oa}^{max}	elevation of historical maximum z_{oa} (m)	56.37	55.07
	water table rising?		yes/no	yes/no

Soil Properties

Accurate multi-phase LNAPL modelling requires knowledge of capillary drainage characteristics of the soil unit containing the LNAPL. This is dependent on the pore size distribution of the soil which is characterized by the Van Genuchten parameters. A physical determination of soil drainage characteristics can be done in the laboratory; however, it is difficult and expensive. It is also extremely difficult to obtain undisturbed soil samples of granular soils (sand and gravels) for laboratory testing. Therefore, estimates from the API Interactive LNAPL Guide Volume 2.0 (August 2004) database were used for soil drainage parameter values and hydrocarbon retention factors.

Saturated hydraulic conductivity values for many wells were estimated from slug tests. Where it was observed through regular monitoring at the site that trace to no LNAPL occurred within the monitoring well during high water conditions, slug tests were conducted to provide site-specific estimates of soil hydraulic conductivity. Since hydraulic conductivity and oil conductivity are measures of soil permeability for different fluids, and these parameters are directly proportional to groundwater and oil velocity, respectively, the magnitude of the saturated hydraulic conductivity input will have a large effect on the LNAPL migration rate. It is therefore important to have good estimates of saturated hydraulic conductivity.

Fluid Properties

Fluid properties were determined for selected LNAPL and water samples in the laboratory. Analyses were conducted in a staged approach, and based on field observations during LNAPL bailing and interpretations regarding product type from GC/MS scan results.

The fluid properties were important to quantify as values can vary widely for refined petroleum products, leaving uncertainty where the type of hydrocarbon is unknown. Samples could only be collected where sufficient LNAPL was available in monitoring wells. Parameter estimates were used for adjacent wells when field observations indicated similar characteristics.

Well Data

Water and LNAPL level data is collected at the site during regularly scheduled monitoring events. The monitoring data set is used to estimate the thickness of the hydrocarbon smear zone for the mobility calculation. The hydrocarbon smear zone thickness is estimated to be the difference between the highest oil-air elevation and lowest oil-water elevation. Accurate estimation of the smear zone thickness is critical to obtaining reasonable mobility results. An underestimation of the smear zone will underestimate oil volumes in the soil profile.

Rising and falling water table scenarios generate different saturation conditions (wetting and drainage situations) which can be represented by hysteresis curves. Rising water table conditions will infer a larger volume of LNAPL per unit area than falling water table conditions. This is accounted for by using an α value for the wetting situation which is twice that for the drainage scenario (Kool and Parker, 1987).

Results

The LNAPL mobility calculation results are summarized in Tables 2a and 2b. Monitoring well A was selected to be representative of a monitoring well located near the source of a LNAPL plume, and B to be representative of near the fringe of the LNAPL plume. The estimated specific oil volumes are calculated for four (4) distinct monitoring events which are regarded to be generally representative of the entire monitoring data set. The LNAPL transmissivity for each are also calculated directly within the mobility spreadsheet. The LNAPL mobility term and estimated front migration rate is subsequently calculated from these results, as specified previously.

Table 2a LNAPL Mobility Calculation Results – Well A

Monitoring Date	10/6/2003	11/10/2004	2/22/2005	5/25/2005
Apparent oil thickness in well (m)	**0.51**	**0.38**	**0.10**	**0.25**
Mobility Estimate Oil Transmissivity (m2/day)	**0.55**	**0.05**	**0.00**	**0.01**
Bail Test Oil Transmissivity (m2/day)	0.14	0.14	0.14	0.14
Elevation of air/oil interface in well (m)	53.955	54.408	54.932	54.542
Elevation of oil/water interface in well (m)	53.441	54.030	54.828	54.292
Estimated free oil specific volume (L/m2)	**21.8**	**11.5**	**0.5**	**4.6**
Estimated saturated zone trapped oil specific volume (L/m2)	0.40	25.11	58.95	35.909
Estimated vadose zone residual oil specific volume (L/m2)	16.95	9.46	2.30	8.209
Estimated total oil specific volume (L/m2)	**39.2**	**46.1**	**61.8**	**48.7**
Theoretical maximum recoverable oil specific volume (L/m2)	**9.7**	**16.7**	**32.4**	**19.3**
LNAPL Mobility (m/day)	14.1	1.2	0.0	0.2
Estimated Gradient (m/m)	0.05	0.05	0.05	0.05
LNAPL Front Migration (m/day)	**0.70**	**0.06**	**0.00**	**0.01**

Table 2b LNAPL Mobility Calculation Results – Well B

Monitoring Date	10/19/2004	2/8/2005	3/11/2005	6/21/2005
Apparent oil thickness in well (m)	**0.44**	**0.00**	**0.04**	**0.20**
Mobility Estimate Oil Transmissivity (m2/day)	**0.09**	**0.00**	**0.00**	**0.00**
Bail Test Oil Transmissivity (m2/day)	---	---	---	---
Elevation of air/oil interface in well (m)	54.37	56.37	55.35	54.77
Elevation of oil/water interface in well (m)	53.93	56.37	55.31	54.57
Estimated free oil specific volume (L/m2)	**6.8**	**0.0**	**0.0**	**1.0**
Estimated saturated zone trapped oil specific volume (L/m2)	0.00	97.14	42.27	15.93
Estimated vadose zone residual oil specific volume (L/m2)	37.34	0.00	19.52	30.62
Estimated total oil specific volume (L/m2)	**44.1**	**97.1**	**61.8**	**47.6**
Theoretical maximum recoverable oil specific volume (L/m2)	**1.0**	**16.7**	**18.7**	**4.5**
LNAPL Mobility (m/day)	2.1	0.0	0.0	0.0
Estimated Gradient (m/m)	0.05	0.05	0.05	0.05
LNAPL Front Migration (m/day)	**0.10**	**0.00**	**0.00**	**0.00**

A LNAPL bail down recovery test was conducted at monitoring well A during low water conditions to estimate oil transmissivity independently for comparison with the mobility model results. The test consisted of rapidly bailing only LNAPL from the well, then monitoring the recovery of the LNAPL and water levels within the well periodically over several hours.

Oil conductivity was estimated with the data using the method of Bouwer and Rice (1976) as adapted for LNAPL by Lundy and Zimmerman, 1996 and Huntley, 2000. The result was multiplied by the apparent LNAPL thickness to obtain the LNAPL transmissivity, which is included in Table 2. The LNAPL transmissivity value is within an order of magnitude of the low water mobility spreadsheet value, which is regarded to be a good comparison given the assumptions made in input parameter values.

The estimated potential LNAPL migration rates are presented in units of metres per day. As presented in Tables 2a and 2b, daily oil migration rates for the two (2) monitoring wells were estimated to range from 0.0 m/d to 0.7 m/d. Monitoring well A shows higher migration potential, and is interpreted to be near or within the source area of the LNAPL plume as it exhibits oil thicknesses all year around. The well B calculations predict LNAPL migration risk for the low water condition only. As LNAPL is not consistently present in monitoring well B (not present in winter), it is considered more indicative of saturation conditions near the plume fringe. This is typical as an LNAPL plume tends to thin towards its edges, decreasing the total specific oil volume (and oil saturation) within the soil profile with distance from the source, consistent with the above interpretation.

The results suggest that mobility potential and apparent oil thicknesses increase at lower water level elevations. Free oil volume estimates increase due to enhanced drainage of LNAPL which contributes to increasing oil transmissivity. Although evidence of actual mobility has not been detected in the field during this study, our experience with other sites has revealed that should LNAPL migration result it occurs at extreme low groundwater conditions.

Just as free oil volumes increase with a lower water table, they decrease and are residualized during high water conditions. This is direct evidence that the position of the water table has a large impact on the effectiveness of a recovery system and should be considered during the risk evaluation phase and detailed design. Comparison of the total oil specific volumes with the theoretical maximum recoverable volumes reveal that a large percentage of total oil in the soil profile occurs as residual in the vadose zone or trapped in the saturated zone. This suggests that significant volumes of LNAPL can be immobilized through smearing of hydrocarbon from seasonal water table fluctuations.

Therefore, active recovery would have limited effectiveness at monitoring well location B. Free oil volumes were not present in B during two (2) of four (4) monitoring events and lower maximum theoretical recoverable volumes relative to the total oil volumes were predicted than for monitoring well A. Monitoring well A would be a better candidate for active recovery efforts, although likely still limited at higher groundwater conditions. Maximum theoretical volumes for monitoring well A were approximately 25-50% of the total specific oil volume.

Discussion

Quantification of the potential migration risk given the above predicted oil migration rates is subject to interpretation. No evidence of further LNAPL migration is indicated from monitoring data collected on-site to date since this study was initiated, although mobility potential is predicted from model calculations. The model results indicate that the potential migration risk is greater for monitoring well A than B. However, the following assumptions regarding saturation requirements and migration rate extrapolation should be considered prior to reaching an interpretation of potential LNAPL migration risk.

As discussed earlier, the LNAPL mobility term (i.e. oil conductivity) is calculated to be the LNAPL transmissivity divided by the total hydrocarbon specific volume across the smear zone. This is done to approximate oil migration from one specific volume of soil profile to the next, to satisfy the condition that it must effectively saturate the specific volume throughout the smear zone it resides in prior to migrating to adjacent soils. However, during an extended period of low or extreme low groundwater conditions, saturation of the soil profile thickness only along which LNAPL is migrating would be required for mobility to occur. Therefore, this assumption could contribute to an underestimation of potential LNAPL migration risk.

Extrapolation of the calculated daily LNAPL migration rate over a longer period of time (i.e. weeks or months) assumes that sufficient free oil is available upgradient to source migration at this rate over time. Other attenuation mechanisms such as volatilization and dissolution of LNAPL also are not accounted for. As the LNAPL plume thins out over time as it spreads laterally from the source area (in the absence of an ongoing source) total and free oil volumes will decrease to zero at the oil plume fringe. Therefore, using the calculated LNAPL migration rate to predict future migration over a period of weeks to months could overestimate the potential LNAPL migration risk.

Consequently, LNAPL migration rate estimates for wells located near the source are not representative of oil saturations at the plume fringe where migration occurs. Therefore, predicted mobility potential at monitoring wells upgradient from the plume fringe such monitoring well A would be overestimated. Monitoring well data from wells located near the inferred plume fringe are regarded to be more representative of migration potential. However, although monitoring well B is interpreted to be located near the plume fringe, oil saturation and mobility potential will continue to decrease downgradient to zero at the limit of LNAPL influence. Although the calculated LNAPL migration rates provide a quantitative indicator of relative risk, the complexity of a partially saturated system requires all data to be viewed with caution.

The theoretical maximum recoverable specific oil volume is regarded to be a more representative evaluation parameter for monitoring wells such as A that are located towards the oil source. As the theoretical maximum recoverable volume is an estimate of the LNAPL volume that could potentially be extracted from the soil profile through active recovery, it can also be interpreted as a measure of the volume of LNAPL that is available to contribute to future migration at the plume fringe. In general it has been observed that estimates calculated for wells near the oil source tend to exhibit LNAPL more consistently and therefore indicate higher mobility potential and recoverability than the plume fringe.

For wells located near the inferred plume fringe such as B, the front migration rate is more useful in assessing relative risk, however interpretation should be conducted with caution. Oil saturation and mobility potential will continue to decrease downgradient to zero at the limit of LNAPL influence, therefore the predicted migration rate will also. Although the calculated LNAPL migration rates provide quantitative indicators of mobility risk, mobility interpretations are complicated by oil saturation variability within a LNAPL affected area.

Conclusion

This risk management approach was found to be useful so far in assessing relative LNAPL migration risk and the need for active LNAPL recovery. It grants the ability to interpret LNAPL thicknesses in monitoring wells measured in the field and allows for prioritization of resources based on risk management. This approach is also regarded to be a valuable risk communication tool.

It is believed that reasonable confidence has been achieved in the results in the absence of field verification through the collection of regular monitoring data, estimation of saturated hydraulic conductivity and oil transmissivity from field tests and laboratory analyses of fluid properties.

Although quantitative estimates of potential oil mobility can be made from field data, several sources of uncertainty exist in the interpretation and prediction of potential LNAPL migration rates. The complexity of a partial LNAPL saturated system with a finite volume makes data interpretation challenging. The assessment, characterization and delineation of a LNAPL plume is therefore regarded to be very important. A groundwater and LNAPL monitoring program with properly screened wells within the LNAPL plume and downgradient is regarded to be necessary to monitor the evolution of the LNAPL volume over time and to predict LNAPL migration risk with confidence.

Moving forward with this approach the focus will be to reduce the identified calculation uncertainties from soil property assumptions. The default API values are based on soil gradation and have been a reasonable starting point however it is believed that obtaining site-specific values will improve confidence in the results. The assumptions regarding residual and trapped LNAPL saturations, and the thickness of hydrocarbon smear zones will also likely be further investigated. It is possible to estimate LNAPL saturation from total petroleum hydrocarbons (TPH)-type laboratory test values. Further characterization of the smear zone location thickness and residual saturation values can be obtained by continuous coring and soils analysis through the LNAPL plume, assuming appropriate soil types and drilling equipment.

The focus of this study was to assess the risk of LNAPL mobility and quantify relative risk from LNAPL measurements made in monitoring wells on-site, however it has become apparent that another important benefit of this ongoing evaluation is the ability to estimate the volume of potentially recoverable LNAPL within a plume. The volume of potentially recoverable LNAPL can also be interpreted as a measure of the LNAPL volume available to contribute to future migration at the plume fringe and therefore is also valuable data in the development of the site risk management strategy.

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Biographical Sketches

David A. Fursevich, M.Sc.

Mr. Fursevich is a Hydrogeologist with 9 years experience in the environmental consulting industry. He has experience with hydrogeologic and geochemical assessments, groundwater flow and transport modelling, and design and implementation of aquifer characterization programs. He provides technical support for field investigations and interprets geological and hydrogeological data to develop conceptual site models.

Morrow Environmental Consultants Inc., 8648 Commerce Court, Burnaby, BC, V5A 4N6, 604-515-5151 (phone), 604-515-5150 (fax); david.fursevich@snclavalin.com.

R. Donald (Don) Burnett, M.Sc., P.Eng.

Mr. Burnett is a Senior Hydrogeologist with 19 years experience in the environmental industry in Canada. He obtained his M.Sc. from University of Waterloo in 1986. He is recognized as a technical expert in the evaluation and modelling (both 2-D and 3-D models) for groundwater flow and contaminant transport. His extensive knowledge of hydrogeological and hydrochemical behaviour of contaminants allows him to design field programs aimed at investigation, quantification, and remediation of contamination associated with subsurface soils and groundwater. He has specific experience in the design and execution of field investigation programs aimed at delineation and quantification of contamination associated with hydrocarbons, wood preservative chemicals, chlorinated solvents, metals and landfills.

Morrow Environmental Consultants Inc., 8648 Commerce Court, Burnaby, BC, V5A 4N6, 604-515-5151 (phone), 604-515-5150 (fax); don.burnett@snclavalin.com.

Christopher (Chris) P. Lach, P.Eng., MBA

Mr. Lach has 16 years experience in the environmental industry. Mr. Lach's area of specialty focuses on remediation system design with specialization in pilot scale testing, assessment of remediation options for groundwater and soil contamination, system design, specification, installation, and commissioning of full scale remediation systems. Mr. Lach's remediation system project management focuses on assessing and optimizing performance of operating systems, reducing costs and time for remediation. He has been involved in over 70 in situ remediation system designs located at petro-chemical bulk plants, service stations, refineries, railyards, airports, and wood processing plants.

Morrow Environmental Consultants Inc., 8648 Commerce Court, Burnaby, BC, V5A 4N6, 604-515-5151 (phone), 604-515-5150 (fax); chris.lach@snclavalin.com.