

# Natural Source Zone Depletion of LNAPL - How to Get to Yes

(A Quality LNAPL Conceptual Site Model Decision Tree)

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**ABSTRACT:** Until most recently, remediation of Light Non-aqueous Phase Liquids (“LNAPL”) has been a remedial area of substantial challenge driven largely by a regulatory position that if LNAPL could be detected in a monitoring well it must be removed even if no demonstrable risk had been shown. To address this challenge it is proposed that if a well prepared Conceptual Site Model is developed sufficient quality information should exist to support, in appropriate circumstances, an agency determination that Natural Source Zone Depletion (“NSZD”), or in the alternative, Monitored Natural Attenuation is an acceptable final LNAPL remedy. This process establishes a record that may, if the facts are aligned, allow an agency to confidently approve an LNAPL remedy that acknowledges leaving LNAPL in place is the most appropriate outcome relying on NSZD (Natural Attenuation) consistent with sound risk management principles. *The co-authors of this paper are part of a working partnership between the Michigan Department of Environmental Quality (MDEQ), Conestoga-Rovers & Associates, ARCADIS and RACER Trust. The views of the authors represented in the paper do not necessarily reflect the policy of the MDEQ. However, the use of a conceptual site model is consistent with the MDEQ approach of evaluating risks at each site allowing for flexibility in risk management decisions.*

**PROLOGUE.** The Revitalizing Auto Communities Environmental Response (RACER) Trust was formed by the New York bankruptcy court with the active support of lead regulatory agencies in 14 States (and U.S. EPA) to cleanup and redevelop properties in 89 locations formerly owned by General Motors Corporation. While RACER works closely with each lead regulatory agency across its portfolio of sites, the bulk of RACER's sites requiring remedial work (39 of 60) are in Michigan. RACER's two largest budgets (sites) in Michigan (combined over \$65 million) are for sites dominated by LNAPL issues. Consequently, RACER has worked with Kevin Lund, the lead MDEQ Project Manager for the former Willow Run manufacturing site on the development of an analytical and decision process to determine the most appropriate remedial solution for the Willow Run site. That effort led to the development of the attached flow chart and decision process that could be applicable to any LNAPL remedial evaluation.

**INTRODUCTION** Environmental regulatory policy has historically required aggressive/active removal of LNAPL from soil and groundwater. This policy was largely driven by limited knowledge of LNAPL subsurface behavior and a concern that LNAPL could be an infinite source of environmental impact. Consequently, managing LNAPL in place and allowing natural attenuation through Natural Source Zone Depletion ("NSZD") was not considered a reliable or appropriate remedy. As knowledge of LNAPL behavior has improved and policy is shifting, an LNAPL Conceptual Site Model Decision Tree has been developed that considers health risk issues and LNAPL plume expansion risk when making corrective action decisions. Improved site/remedial management decisions can be made using a comprehensive LNAPL Conceptual Site Model ("LCSM"). A robust LCSM provides all stakeholders with increased confidence in the reliability and appropriateness of corrective action decisions, whether through aggressive LNAPL remediation or a more sustainable approach relying on NSZD.

**BACKGROUND/OBJECTIVES** Numerous sites across the country are contaminated by various types of petroleum substances (LNAPL) with a common site characteristic; no matter how much effort is expended it is not practical or cost effective to remove all of the LNAPL. Consequently, regardless of the technology applied (with rare costly exception) residual LNAPL will remain on the site. Because it is inevitable that most LNAPL sites will include NSZD as a component of the final remedy, it is important to determine the point at which NSZD makes sense within the overall remedial strategy (after, or in lieu of, implementation of engineered systems).

**LCSM** The Interstate Technology & Regulatory Council ("ITRC") LNAPL work, "*Evaluating LNAPL Remedial Technologies for Achieving Project Goals, December 2009*", is creatively combined with the ASTM E2531-06(2007) *Standard Guide for Development of Conceptual Site Models and Remediation Strategies for Light Nonaqueous-Phase Liquids Released to the Subsurface*. The resulting decision tree (flow chart) describes how the information from the site characterization process, and assembled to form the LCSM, is used to orderly evaluate the composition and saturation concerns ITRC identified for LNAPL.

The LNAPL Decision Tree process promotes a more sustainable approach to LNAPL management through the incorporation of the following fundamental concepts:

- Specific remedial drivers are established based on a comprehensive and technically sound LCSM. The rationale is that better (and often times more) site characterization data will result in more appropriate and ultimately more effective LNAPL management strategies (less cost, more benefit).
- Active engineered systems are not assumed in advance. Rather, the significant technical limitations of LNAPL remediation are acknowledged, and potential costs and benefits of active remedial systems are scrutinized against other LNAPL management options such as different types of controls and/or NSZD.

As previously noted, the effectiveness of the Decision Tree process hinges upon the development of a technically-sound LCSM. The level of complexity of the LCSM and sophistication of the techniques employed in its development will mimic the complexity of the site. That is, more complex sites with a higher degree of potential exposure scenarios may require more data and potentially more sophisticated means to obtain the data. In addition, we now know that many of the commonly held assumptions regarding LNAPL sites will not be true in many cases. For example, the following points represent common misperceptions regarding LNAPL bodies:

- LNAPL bodies always possess the potential to migrate – In fact; the opposite is generally the case since an LNAPL body’s ability to migrate/expand dissipates fairly quickly once a release is stopped. As such, many (if not most) LNAPL bodies will be found to be stable (not migrating).
- A significant fraction of an LNAPL body can be recovered – However, in practice, the fraction of an LNAPL body that will be potentially mobile and/or recoverable is typically quite low.
- LNAPL bodies will act as a continuing source of dissolved and/or vapor phase impacts – which is heavily dependent on LNAPL type and degree of weathering/degradation (NSZD). However, experience has shown that many LNAPL bodies produce limited levels of dissolved and/or vapor phase contamination that are either undetectable or well within risk-based screening levels. In addition, LNAPL constituents are depleted over time through NSZD processes because, in part, LNAPL is not an infinite source.

Clearly, a more sophisticated approach to LNAPL remedial evaluation is needed to move beyond past practices in order to build a sound LCSM, particularly if we are to take a more sustainable risk-based approach to LNAPL management. The first page of the LNAPL Decision Tree document (Figure 1) provides a quick reference to potential elements of a comprehensive LCSM, as well as possible evaluation techniques and associated metrics. The development of the LCSM is discussed in more detail in numerous LNAPL guidance documents, most notably ASTM (2007) and ITRC (2009). The LCSM should answer the hard questions such as:

- Is the LNAPL really at risk of migrating?
- How much of the LNAPL might actually be mobile and/or recoverable?
- Are there really any potential risk exposure scenarios if the LNAPL stays in place?

These are certainly not the only questions that will need to be answered, and there are obviously important non-technical questions that require consideration as well (regulatory requirements, other stakeholder interests). However, these are key when it comes to a sustainable risk-based approach. With the hard questions answered (in a

science-based manner), the remedial drivers become clear and the remedial decision-making process dictates the formation of the overall strategy for the site.

**DECISION TREE** The Decision Tree (page 2 of Figure 1) follows two concurrent paths based on the nature of the LNAPL concern. Consistent with ITRC, the concurrent paths are designed to independently consider compositional concerns and saturation-based concerns. Compositional concerns represent ‘traditional’ risk-based drivers where a change in LNAPL chemistry may be advantageous to limit dissolution, volatilization, etc. of petroleum constituents (ITRC, 2009). Examples of compositional change techniques include enhanced biodegradation, in-situ chemical oxidation and air sparging. Non-risk or aesthetic drivers typically represent saturation-based concerns where the reduction of LNAPL saturations may be warranted to mitigate some issue with LNAPL mobility or migration (ITRC, 2009). Saturation-based remedial techniques are therefore based on the mass recovery of LNAPL. It is important to separate these two paths since the strategy to deal with one will often be ineffective at addressing the other (with some exceptions, of course). For example, saturation reduction through LNAPL recovery will seldom reduce a compositional risk since the mole fraction of the COCs in the LNAPL remains unchanged and it is unlikely that a significant fraction of the LNAPL body will be removed (i.e., neither the magnitude or longevity of the compositional risk will be effectively mitigated). In terms of sustainability, the cost-benefit considerations included in both branches of the Decision Tree are intended to consider potential costs and benefits such as remediation risk, environmental impact, and societal factors that may not typically have been included in LNAPL remedial decision-making process.

Because residual LNAPL in soils and groundwater is essentially inevitable active LNAPL removal will generally provide limited net benefit. It is likely that many of the LNAPL remedial efforts of the past produced little risk reduction benefit and may have through energy and resource consumption caused more harm than good. The cost-benefit considerations integrated into the Decision Tree seeks to avoid this by applying sustainability and risk-based thinking not only to the LNAPL body, but to the potential remedial activities themselves.

**COMPOSITIONAL CONCERNS** The decision-making process on the compositional side of the Decision Tree (page 2 of Figure 1) is guided by the following thought process:

- Risk due to the presence of LNAPL is not assumed; rather, the Decision Tree treats LNAPL and other phases of contamination equally in terms of the potential for compositional risk. Consequently, ‘no further action’ with respect to compositional considerations would be appropriate in the absence of compositional risk notwithstanding the presence of LNAPL.
- The benefit of the implementation of a full-scale compositional change technique or partial treatment/removal (i.e., ‘hot spot’ treatment or removal) is scrutinized against the use of controls. In other words, the potential benefit of active LNAPL compositional change remediation is weighed against the potential costs in terms of the associated expenditure of financial and natural resources, the risks involved in implementation, and the contamination potentially resulting from the remedial action (i.e., sustainability considerations). The net environmental benefit of active

engineered LNAPL remedial systems is scrutinized in terms of whether a significant level of risk reduction can be achieved compared with NSZD.

**SATURATION CONCERNS** The saturation side of the Decision Tree is configured to scrutinize the need for and benefit of LNAPL mass recovery on several different levels because such a recovery effort has a significant potential to be an unsustainable and generally unbeneficial activity. The general concepts are summarized as follows:

- The need for LNAPL saturation reduction and/or controls where LNAPL is migrating (i.e., the footprint of the LNAPL body is expanding) is acknowledged.
- The benefit of LNAPL mass recovery where an LNAPL body is stable is much less obvious and the question of when LNAPL recovery might still make sense in this very common case (recall LNAPL is usually found to be stable).
- If LNAPL is deemed to be potentially mobile according to an observation of LNAPL in wells or other lines of evidence, the potential recoverability is evaluated via a metric such as LNAPL transmissivity. LNAPL transmissivity is becoming a widely used metric that provides a standardized way to evaluate whether some minimum LNAPL recovery rate can be maintained at a given well/site such that LNAPL mass recovery might be considered technically feasible (see ASTM, 2013). However, the Decision Tree takes it a step further before concluding LNAPL is ‘readily recoverable’ by including a consideration of the overall fraction of the LNAPL body that may be recoverable. In other words, the ability to maintain some minimum LNAPL recovery rate (with transmissivity as a surrogate for recovery rate) does not necessarily mean that a significant portion of an LNAPL body would be recovered should a recovery effort be implemented.
- Where LNAPL is concluded to be ‘readily recoverable’, the potential benefit of the activity is examined in a similar manner to the cost-benefit decision point on the compositional branch of the Decision Tree. This type of examination is perhaps more complicated in terms of LNAPL recovery than it is with compositional change since the actual benefit of the activity is much less clear and potentially much more difficult to quantify. For example, the only real benefit of LNAPL recovery may be a societal benefit or sense of doing something other than nothing (even though the actual change in conditions is likely to be negligible and NSZD processes are likely to efficiently address site conditions). Such benefits, however, are very difficult to monetize for cost-benefit purposes. The core concept is to rigorously evaluate what LNAPL recovery might actually accomplish and to implement it when a net benefit can be demonstrated over NSZD alone. This ensures a much more sustainable approach than what has typically been the case with LNAPL.

**CONCLUSIONS** Experience has demonstrated that removing LNAPL for the sake of removing LNAPL has not produced material risk reduction. With increased recognition of the benefits and effectiveness of NSZD a decision process that provides a record in support of reliance on NSZD is overdue.

It is not reasonable to expect an agency to approve a remedy based on NSZD unless a reliable LNAPL Conceptual Site Model (“LCSM”) supports that result. It may be necessary to devote more resources (and budget) to the development of the LCSM if the result is the selection and approval of a more cost effective final remedy. It is proposed that the Decision Tree provides a reasoned means to organize a systematic evaluation of the LCSM and the applicability of NSZD as a final remedy.