Free Product Recovery Technologies

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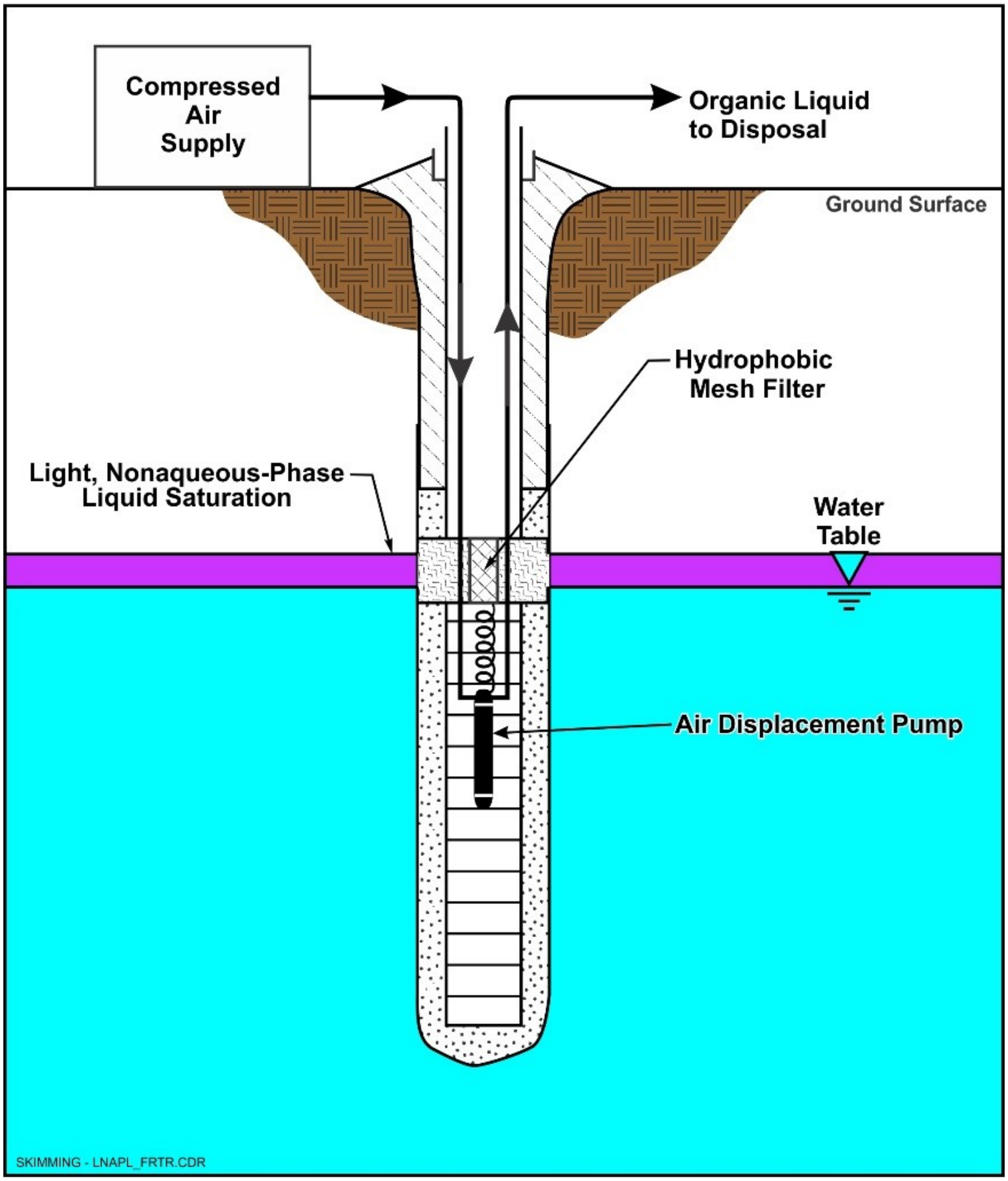
Schematic



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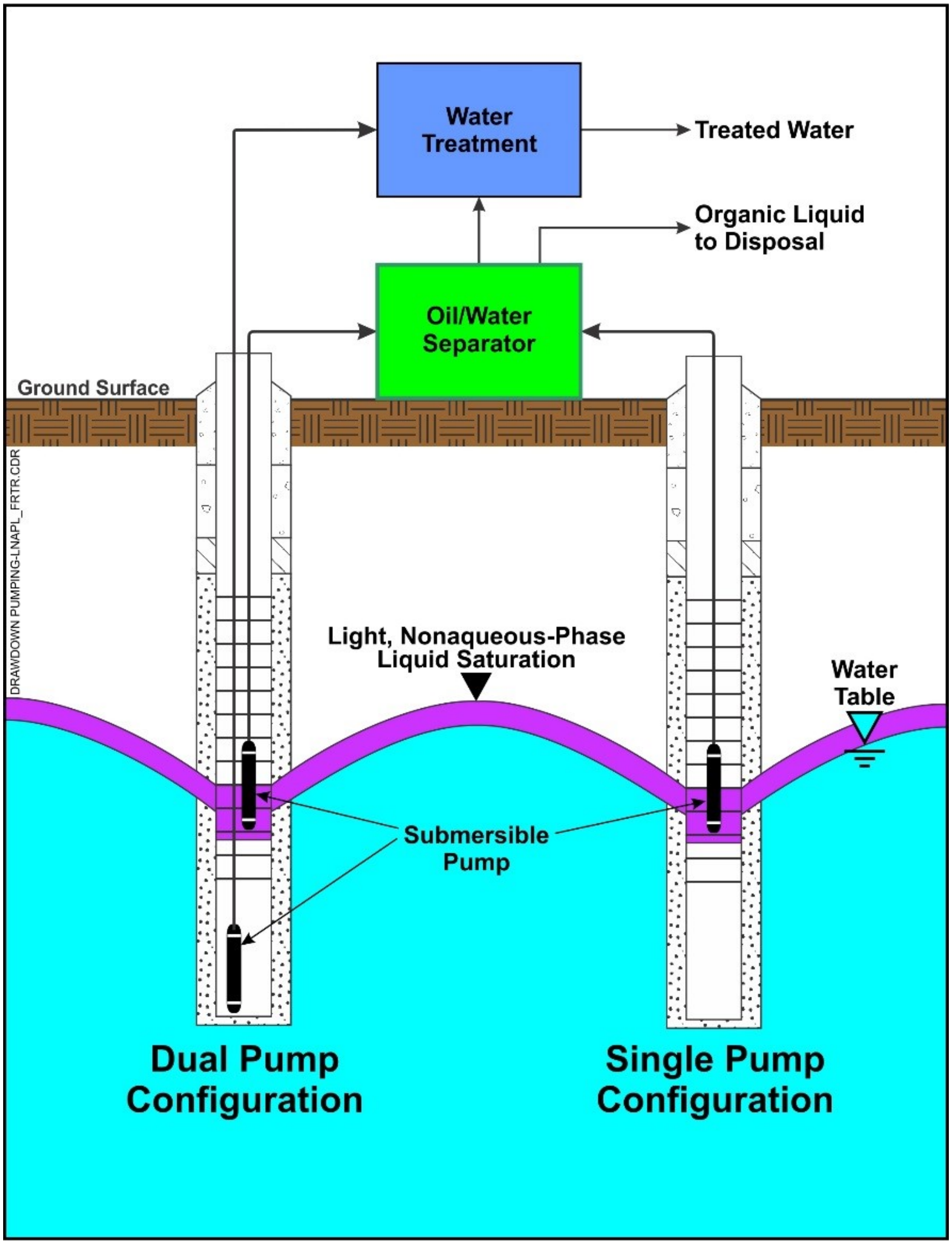
Skimming Free Product Recovery Technologies



Single and Dual Pump Free Product Recovery Technologies

Introduction

Free product recovery consists of several technologies ranging from simple hand bailers and passive skimmer systems to more complex active skimming systems and large-scale total fluids recovery systems. The objective of these recovery techniques is to remove light nonaqueous phase liquid (LNAPL) to the extent practicable, prevent its migration and reduce its impact to dissolved phase contaminants in groundwater.

Other Technology Names

Skimming LNAPL Skimming
Drawdown Recovery
Total Fluids Recovery
Vacuum Enhanced Free Product Recovery
Multi-phase Extraction

Description

Free product recovery systems in order of increasing complexity and cost include the following:

Hand Bailing

Hand bailing generally is performed when there is little LNAPL remaining at the site as evidenced by relatively thin but measurable LNAPL thicknesses in one or more wells. It may be performed after a more aggressive (and costly) recovery technology has been implemented. Bailing is performed using either a reusable or disposal bailer that is lowered into the well to remove remaining LNAPL from the well casing. A check valve at the bottom of the bailer allows LNAPL (and some water) to enter, but prevents the fluids from exiting as the bailer is raised from the well. Bailing can be performed daily, weekly, or monthly; an appropriate frequency is determined based on the time it takes for the well to recharge as well as any applicable regulatory requirements/agreements.

Free Product Skimming

Free product skimming can be accomplished in a variety of methods that can be categorized as active skimming and passive skimming, described as follows:

- **Passive skimming** techniques are designed to remove LNAPL as it flows naturally (without pumping) into a recovery well or trench. Similar to hand bailing, passive skimmers generally are used to recover LNAPL when little LNAPL remains at a site. It should be noted, however, that skimming methods don't recover a substantial volume of LNAPL and LNAPL generally is not migrating at times when passive skimming technologies are used. Hence, an alternative technology, such as natural source zone depletion (NSZD), should be evaluated in lieu of passive skimmer methods.

  Passive skimmers selectively recover LNAPL floating on the surface of the water table within a well or trench without the use of any hoses, external electric or pneumatic power. They typically consist of two types of devices: 1) LNAPL absorbent media (e.g., absorbent socks), or 2) a specially designed bailer that consists of a hydrophobic element that will allow LNAPL to pass but not water. When using LNAPL absorbent media, the media is placed inside a supporting canister or cage and then lowered into the well such that the media extends across the LNAPL-water interface. The media length can vary, but typically is 3 ft, which allows LNAPL to continue to be recovered if the groundwater level raises or lowers to some extent. The media is periodically pulled from the well and either disposed or the LNAPL is squeezed from the media and placed into a container for disposal.

Bailer-type skimmer systems are lowered to the elevation of the LNAPL-water interface. Some systems include a floatation device that allows the skimmer to move up and down as the water elevation changes. The LNAPL is usually collected in a reservoir at the bottom of the unit. To recover the LNAPL, the skimmer is pulled out of the well and a valve on the bottom is opened to drain it. If the hydrophobic element is subjected to hydrostatic pressure from being submerged in water, the element will permit water to pass through it. If the element collects water, it can be removed and dried out to remove the water from the pores, which allows the element to revert to hydrophobic operation. Passive skimmers are ideal in areas where free product contamination is minimal, the LNAPL recharge rate is slow, and where a source of power is not readily available. However, as noted above, NSZD may be a more appropriate technology to apply when these conditions are present at a site.

- **Active skimming** uses a mechanical device or system designed to promote LNAPL migration into a recovery well and to remove it as it enters the well. Active skimming is typically achieved using pneumatic or electric pumps equipped with fixed intakes equipped with timer operation or a floating filter of oleophilic/hydrophobic mesh having a high affinity for nonpolar hydrocarbons and the ability to reject polar molecules such as water. A mesh cylinder is designed to float in the LNAPL layer inside a recovery well. LNAPL floating on the water surface passes through the mesh, while the mesh prevents water from entering. The LNAPL flows down into a collection reservoir and periodically is discharged by air pressure or mechanical means to a central holding tank placed on the ground surface. The pressurization cycle may be controlled by a timer, high- and low-level switches, or manual operation.

  Rope wick or belt skimmers can be used in shallow wells that exhibit low recovery rates. These types of skimmers use a continuous loop of rope or belt made of an oleophilic/hydrophobic material. The rope or belt is strung through the LNAPL layer and up through a pair of compression rollers. The rollers provide the motive force for the rope or belt while squeezing out any retained LNAPL into a small container. LNAPL collected in the container is periodically pumped to a central holding tank. Large trench recovery points can be fitted with drum or disk skimmers that are too large to fit into a well.

More aggressive methods of active skimming, which entail the development of an additional driving force to pull LNAPL into the recovery point, can be employed to enhance recovery. Modifications include applying a vacuum and/or extracting groundwater from the recovery point. A vacuum can be generated at the well using a blower that is connected to the same well containing the active skimmer. In this scenario, LNAPL and soil vapor are recovered simultaneously.

Total Fluids Recovery

Total fluids recovery, a form of pump and treat, is performed using one or more pumps in a well or trench to recover LNAPL and groundwater. A pump is placed at a specified depth beneath the groundwater-LNAPL interface. A pumping rate is set sufficiently high to create a groundwater cone of depression, which provides a gradient to induce the flow of LNAPL into the well or trench. The pump can be used to recover LNAPL and groundwater in a single stream, or a second pump can be placed at a shallow interval to recover LNAPL (and some water). Total fluids recovery systems generate a large volume of water that must be treated and disposed. However, the greater driving force creates a localized depression in the water table that can result in a greater volume of LNAPL recovered in a shorter period. Total fluids recovery systems generally are used when substantial LNAPL remains at a site. They also are used when it is desirable to prevent migration of the LNAPL or the associated dissolved phase plume since the cone of depression also creates a groundwater capture zone. Groundwater modeling using site-specific data should be performed to determine the extraction flowrate needed to establish the desired capture zone and to design an appropriate number and spacing of recovery wells.

Multi-phase extraction (MPE) is a specialized type of total fluids recovery that recovers vapors and stimulates biodegradation in the vadose zone, while applying a high vacuum to the subsurface to enhance LNAPL recovery. Additional information pertaining to MPE can be found here.

Development Status and Availability

The following checklist provides a summary of the development and implementation status of free product recovery technologies:

☐ At the laboratory/bench scale and shows promise

☐ In pilot studies

☒ At full scale

☐ To remediate an entire site (source and plume)

☒ To remediate a source only

☒ As part of a technology train

☐ As the final remedy at multiple sites

☐ To successfully attain cleanup goals in multiple sites

Free product recovery technologies are available through the following vendors:

☒ Commercially available nationwide

☐ Commercially available through limited vendors because of licensing or specialized equipment

☐ Research organizations and academia

Applicability

Contaminant Class Applicability Rating for Free Product Recovery Technologies

(Rating codes: ● Demonstrated Effectiveness, ◐ Limited Effectiveness, ○ No Demonstrated Effectiveness,
◊ Level of Effectiveness dependent upon specific contaminant and its application/design, I/D Insufficient Data)

	Halogenated VOC	Nonhalogenated SVO	Halogenated SVOC	Fuels	Inorganics	Radionuclides	Munitions	Emerging Contamina
◐	◐	◐	◐	●	N/A	N/A	N/A	◐

Free product recovery technologies apply to the recovery of an LNAPL source in the capillary fringe and saturated zones. In the case of free product recovery technologies that also recover groundwater (i.e., total fluids recovery), dissolved phase constituents including volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs) and emerging contaminants that are dissolved in water also can be removed in the aqueous phase and must be subsequently treated using one or more water treatment technologies. Free product recovery technologies are not applied to remove inorganics, radionuclides, and munitions constituents, other than the fraction that are dissolved in groundwater.

Cost

The costs of free product recovery technologies vary considerably due to the diversity of treatment methods. Passive, less aggressive technologies tend to have a much lower cost; however, they also recover much less LNAPL. Conversely, more aggressive technologies, such as total fluids recovery, will have a much greater cost, but recover more LNAPL. Major cost drivers include:

Upfront Costs

- The number of recovery wells/trenches required, which is dictated by the areal extent of contamination, volume of LNAPL to be treated, site hydrogeologic conditions, and achievable radius of influence.
- The type, size and quantity of skimmers and pumps for active skimming and total fluids recovery systems.
- Aqueous treatment requirements for drawdown and total fluid recovery systems. Water treatment can include oil-water separation followed by granular activated carbon or air stripping to remove dissolved phase constituents. In some cases, especially for large total fluid recovery systems, more complex treatment to remove emulsified oils and heavy metals using

coagulation/flocculation, dissolved air flotation, and hydrophobic clay may be required.

- For drawdown or total recovery systems, the type of recovery manifold (aboveground or subsurface) can have a significant impact on cost.

Operation and Maintenance Costs

- Number of wells in which LNAPL recovery is performed.
- Number of pumps used.
- Fouling of skimmers, pumps and other associated equipment and frequency and complexity of cleaning required.
- Frequency of hand bailing and frequency of LNAPL removal of passive skimming systems.
- Complexity of fluids recovery system(s).
- Containerization and disposal of recovered free product.
- Volume of water recovered and aqueous treatment requirements.

The list above highlights those cost dependencies specific to free product recovery technologies and does not consider the dependencies that are general to most in situ remediation technologies. Click here for a general discussion on costing which includes definitions and repetitive costs for remediation technologies. A project-specific cost estimate can be obtained using an integrated cost-estimating application such as RACER® or consulting with a subject matter expert.

Duration

Free product recovery is a short- to medium-term (e.g., 1 to 3 years) treatment technology if properly designed and applied to achieve reasonable endpoint criteria. However, oftentimes endpoint criteria such as "recover until less than or equal to 0.01 ft or 1/8 inch of LNAPL remain in a well" are required, which cannot be achieved in a short to medium timeframe if at all. In these instances, it could take years to decades to remediate an LNAPL source area. Oftentimes LNAPL recovery will approach an asymptotic recovery level before thicknesses measured in monitoring wells achieve required regulatory/project endpoints, and transitioning to less costly, passive methods, including NSZD, may be warranted. Realistic endpoints should be discussed and approved by all site stakeholders and should be based on the risk the LNAPL poses to human health and the environment (e.g., potential for migration, impact to nearby receptors and impacts to groundwater). Transition from active recovery to NSZD should be included as part of the proposed remedy and LNAPL management strategy.

Implementability Considerations

The following are key considerations associated with implementing ex situ thermal desorption and incineration treatment technologies:

- Site geology will influence contaminant mass removal effectiveness:
  - Subsurface heterogeneity can interfere with LNAPL flow to the well.
  - At sites having low-permeability soils, such as glacial tills, it may be difficult to mobilize the LNAPL using forced gradient methods. Use of soil permeability enhancement techniques (e.g., fracturing) can be considered, along with alternative risk-based management strategies.
- The rate of LNAPL recovery is dependent on a range of site-specific conditions including soil, LNAPL, and groundwater properties. LNAPL recovery should not be implemented at a site unless there is sufficient "recoverability". Insufficient "recoverability" will result in a failed remedy that will result in wasted capital expenses and yield minimal LNAPL volume and generate a large quantity of water requiring treatment/disposal. It must be recognized that "recoverability" is not based on measured LNAPL thicknesses within individual monitoring wells, especially within finer-grained lithologies. LNAPL transmissivity testing and recovery estimates should be performed in accordance with ASTM Method 2856-13 to evaluate the potential for recovery prior to moving forward with implementation.
- LNAPL transmissivity testing and other published performance evaluation techniques should be used to decide when to discontinue free product recovery activities. Other treatment technologies may still be required to address potential risk exposure pathways associated with the release once free product recovery is discontinued (or if not implemented due to insufficient "recoverability").
- LNAPL recovery rates for bailing and skimmers are low because they rely on the passive movement of LNAPL into the product recovery wells or trenches.
- Total fluids recovery with drawdown can pull LNAPL deeper into the formation and smear it across less contaminated or uncontaminated soil.
- The passive action of bailing and skimming results in a small radius of influence around the recovery point.
- Iron fouling of well screens can be problematic at some sites for skimmers and total fluid recovery systems.

- Biofouling of the oleophilic filter in skimmers can occur at some sites.
- As LNAPL and dissolved hydrocarbons are recovered, the need to continue operation of any water treatment equipment should be re-evaluated as treatment tends to be a high percentage of operation and maintenance costs.
- Low levels of residual LNAPL will remain in wells after extended treatment periods, with thicknesses changing as the groundwater table fluctuates. It may not be possible to recover all LNAPL at a site using the free product recovery methods described in this technology profile.
- Passive techniques become costly when substantial LNAPL remains at a site. Oftentimes, it is more cost effective to apply an aggressive technology for a short time and then transition to a passive technique after the majority of LNAPL has been recovered.
- Active skimmer and total fluids pumps can be rotated between wells to facilitate LNAPL recovery. The skimmers/pumps may be used to recover LNAPL in one or more wells for a set period of time, after which they are moved to different wells. This alternating recovery approach allows time for the formation to naturally recharge while recovering LNAPL in wells that have not been recently used.
- For active skimming systems with fixed intakes or timer operation, LNAPL/water interface levels need to be frequently monitored to make proper adjustments for fluctuating groundwater conditions and LNAPL saturation levels in order to avoid extracting large volumes of groundwater requiring treatment or disposal.
- For vacuum-enhanced recovery systems, if the applied vacuum is high, there may be upwelling in the recovery point, which could cause smearing and the LNAPL to "pinch out", thereby impeding its recovery. To address this problem, a timer may be employed such that LNAPL is only recovered while the vacuum is not applied to the well. Alternating between vacuum application and LNAPL recovery has been found to increase recovery rates without the need for aqueous phase recovery. Alternatively, a second submersible pump can be used to remove groundwater at a rate that counteracts the upwelling. However, the resulting water must be treated and/or disposed, which increases restoration costs.

Resources

H2A Environmental. Applied LNAPL Science Review
This electronic scientific journal provides insight into the science behind the characterization and remediation of NAPLs.

Interstate Technology and Regulatory Council (ITRC). LNAPL Remedial Technologies for Achieving Project Goals (2009) (PDF) (157 pp, 1.98 MB)
This guidance provides a framework to help stakeholders select the best suited LNAPL remedial technology for an LNAPL site and understand what technologies apply in different site situations. Seventeen LNAPL remedial technologies are considered including skimming.

ITRC. Light Non-Aqueous Phase Liquid (LNAPL) Site Management: LCSM Evolution, Decision Process, and Remedial Technologies. LNAPL-3 (2018) (PDF) (76 pp, 2.97 MB)
This guidance document provides best practices for management and cleanup of LNAPL sites.

Naval Facilities Engineering Command (NAVFAC). Site Management Handbook (2010) (PDF) (23 pp, 2.23 MB)
This handbook provides an overview of effective strategies for managing LNAPL-contaminated sites to ensure protectiveness of human health and the environment, while simultaneously avoiding unnecessary and prolonged remedial efforts.

NAVFAC. Guidance for Optimizing Remedial Action Operation (2012) (PDF) (94 pp, 2.76 MB)
The document describes optimizing remedial action operations including an overview of free product recovery and describes common operational problems and optimization strategies.

NAVFAC. Environmental Restoration. New Developments in LNAPL Site Management (2017) (PDF) (8 pp, 2.77 MB)
This document describes recent research and tools for evaluating NSZD and provides data demonstrating the importance of anaerobic methane-generating biodegradation processes in the vadose and saturated zones.

United States Environmental Protection Agency (USEPA). How to Effectively Recover Free Product at Leaking Underground Storage Tank Sites: A Guide for State Regulators (1996) (PDF) (162 pp, 3.16 MB)
This document includes scientific and engineering considerations for evaluating technologies for the recovery of free product from the subsurface.

United States Environmental Protection Agency (USEPA). A Decision-Making Framework for Cleanup of Sites Impacted with LNAPL(2005) (PDF) (86 pp, 878 KB)
This document provides approaches for management of LNAPL petroleum hydrocarbons in the subsurface. It includes a consensus-based process to

develop a long-term site-specific management strategy, which incorporates specific goals and endpoints to measure progress during each phase of the LNAPL management project.