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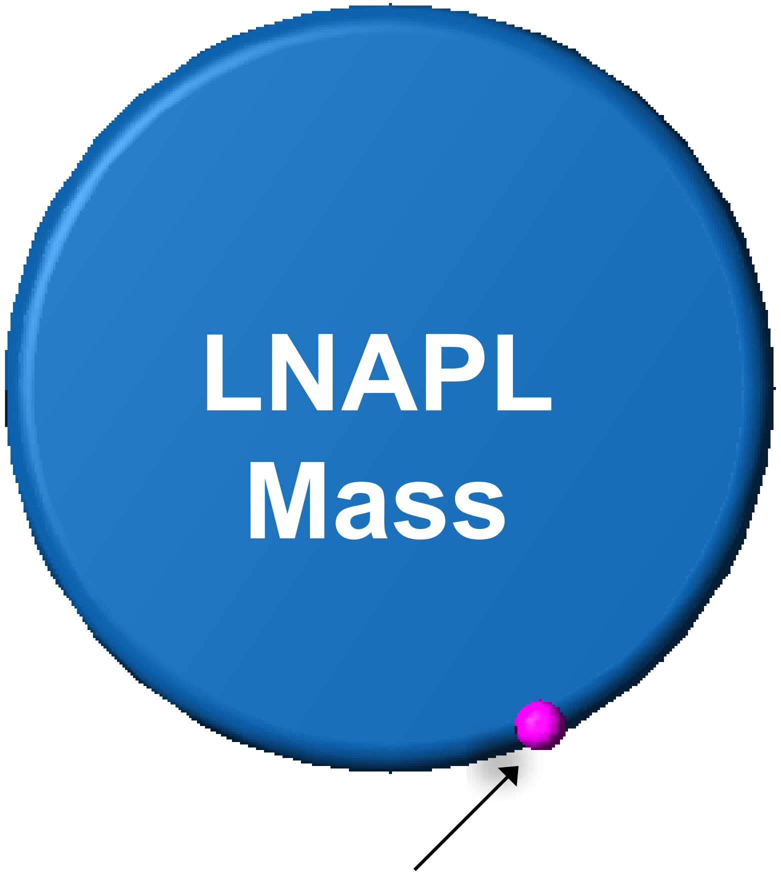
Managing LNAPL Sites Using the Latest Tools and Science



Vapor, Dissolved, and Adsorbed Phase Mass

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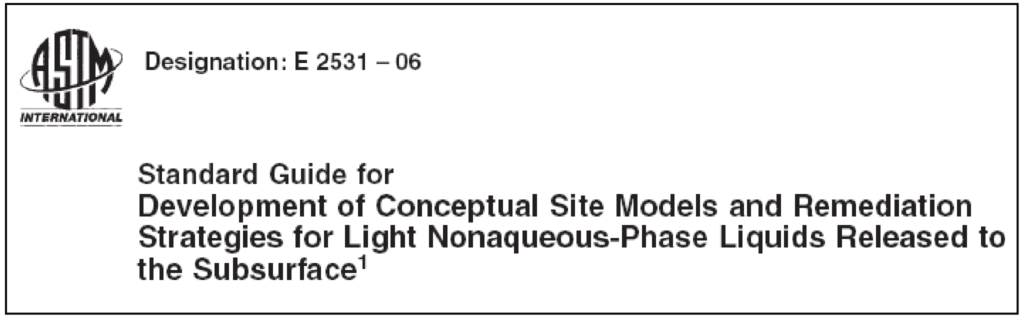
LNAPL: The Times Are a-Changin

What’s New:

- Fewer Large Spills – better storage tank systems
- LNAPL behavior is widely understood - much better than in past
- Efforts by API, ASTM, CLAIRE, ITRC and USGS have broadened our knowledge base
- Meaningful metrics have been developed to guide decision making – we all like numbers
- The majority of a LNAPL body will degrade under natural conditions (NSZD)
- Diagnostic tools continue to improve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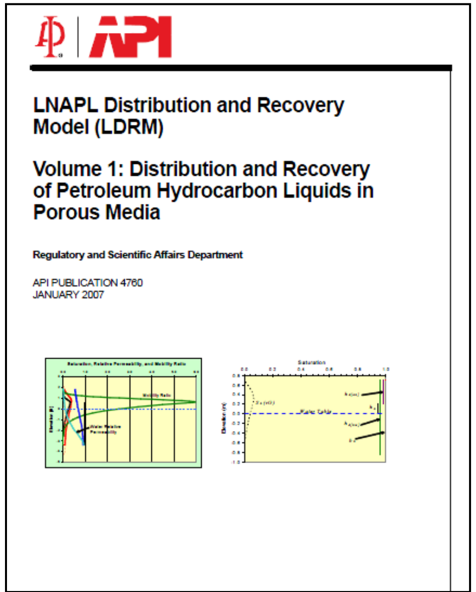
INTERNATIONAL

Standard Guide for
Development of Conceptual Site Models and Remediation Strategies for Light Nonaqueous-Phase Liquids Released to the Subsurface[1]

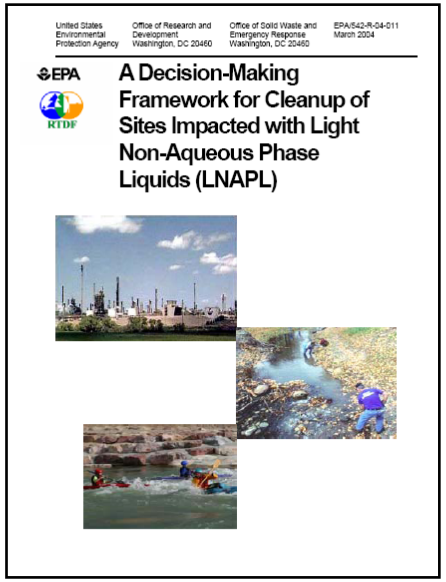

API

LNAPL Distribution and Recovery Model (LDRM)

Volume 1: Distribution and Recovery of Petroleum Hydrocarbon Liquids in Porous Media

Regulatory and Scientific Affairs Department

API PUBLICATION 4760
JANUARY 2007


United States Environmental Protection Agency | Office of Research and Development Washington, DC 20460 | Office of Solid Waste and Emergency Response Washington, DC 20460 | EPA/542-R-04-011 March 2004

EPA
RTDF

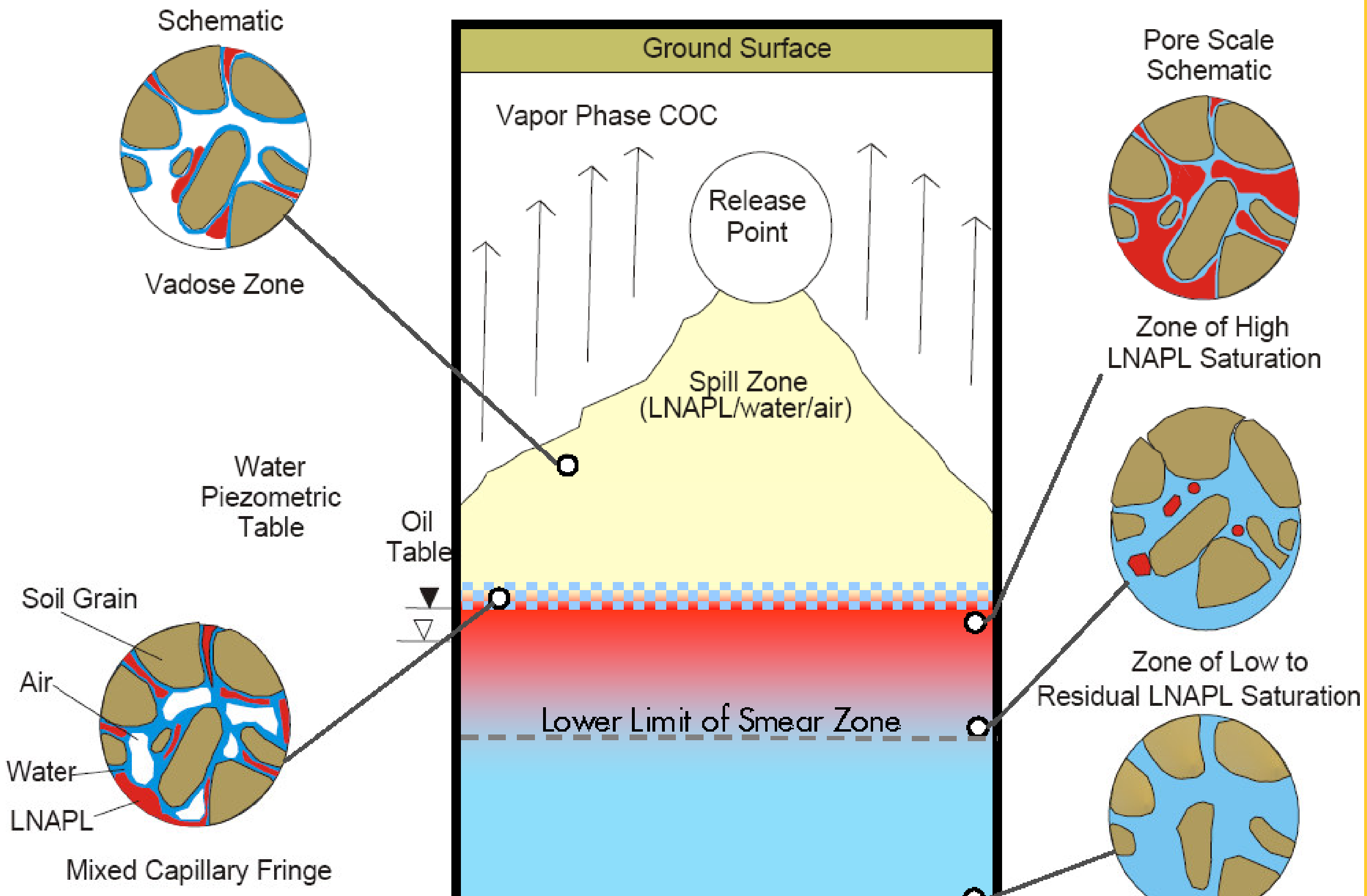
A Decision-Making Framework for Cleanup of Sites Impacted with Light Non-Aqueous Phase Liquids (LNAPL)

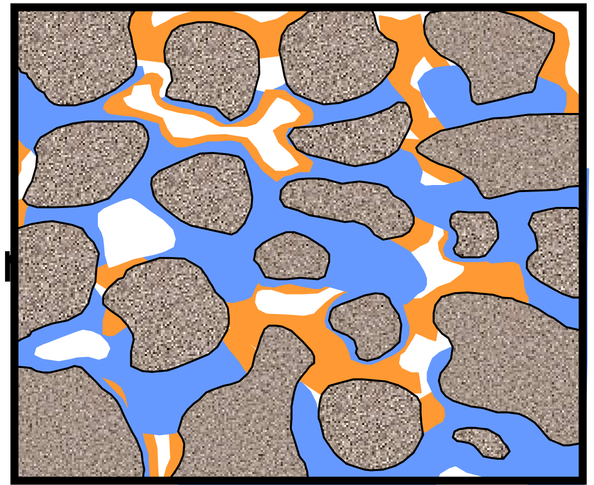

TECHNICAL REPORT NO. 46

The role of natural source zone depletion in the management of light non-aqueous phase liquid (LNAPL) contaminated sites

What We All Now Know

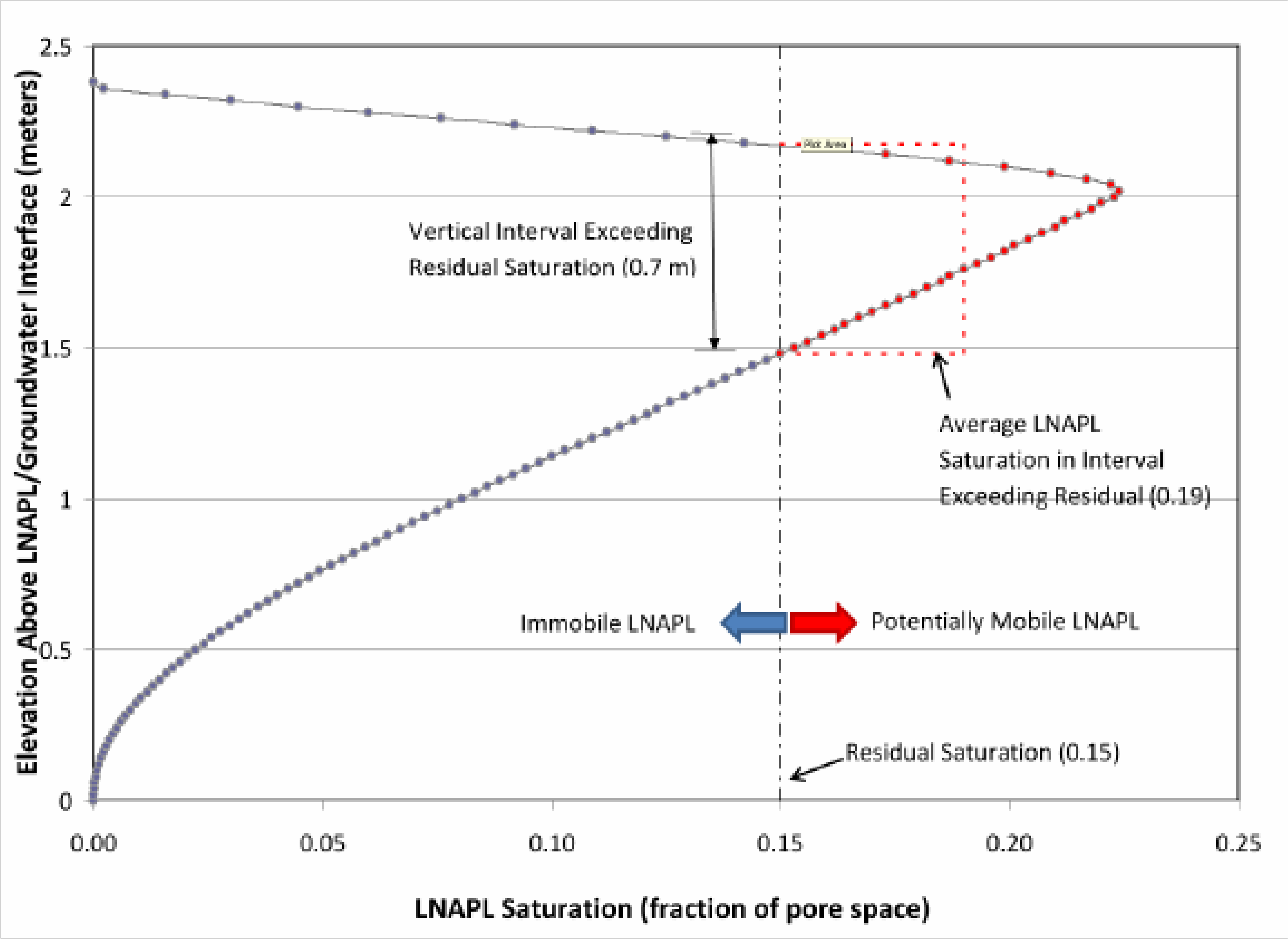
- LNAPL Saturation is highly variable in space
- Soil properties are critical to LCSM
  $\theta_r \approx$ displacement head
- Water typically outcompetes LNAPL in pore space
- LNAPL plumes stabilize quickly
- Changing remedies (treatment trains) are required for efficacy
- Measured in-well thickness is a poor metric for decision making
- ITRC's 0.1 – 0.8 ft^2/day T_n recover threshold holds up well





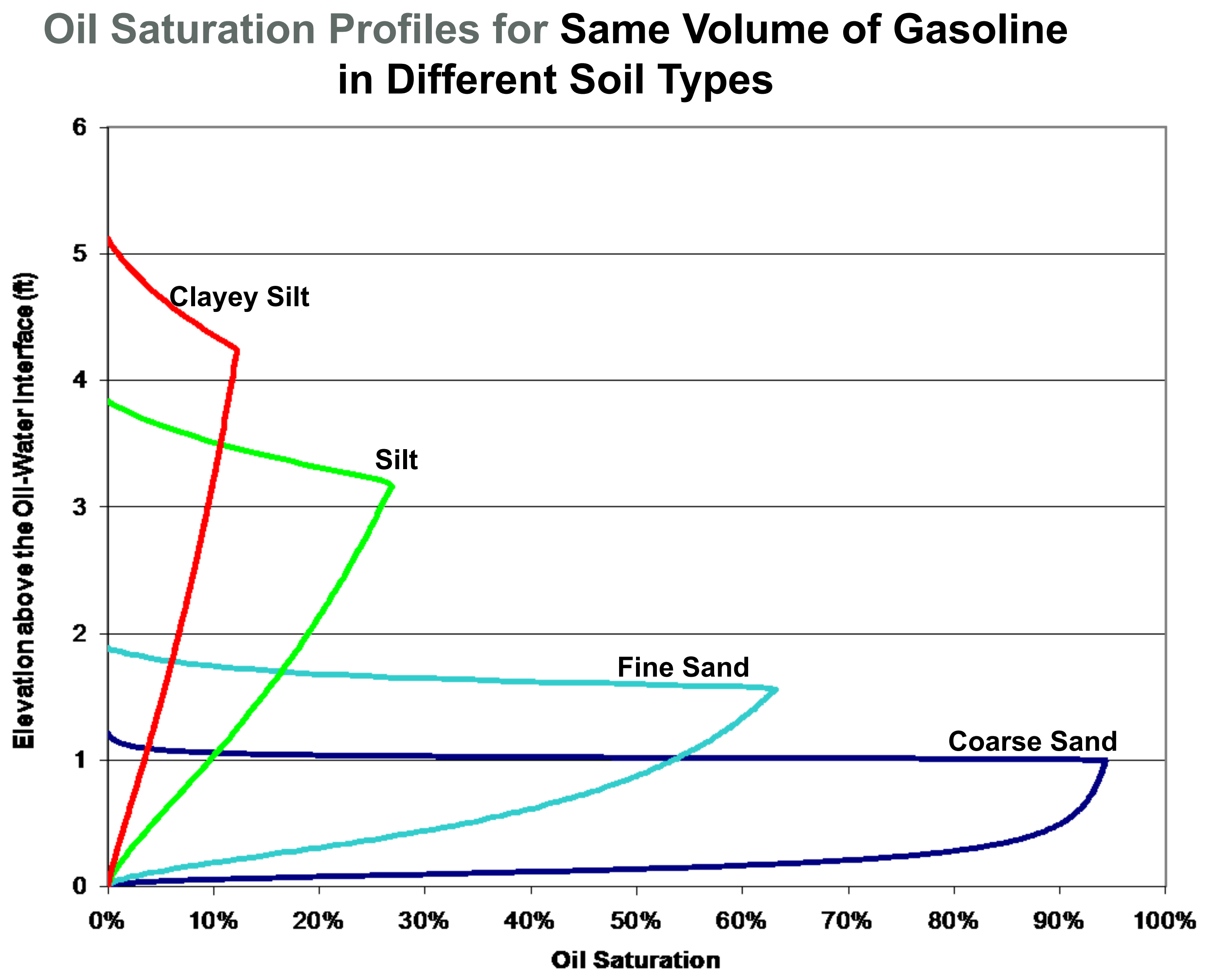
Wetting Affinity: Water > Oil > Air

Saturation Profile Curve Analysis

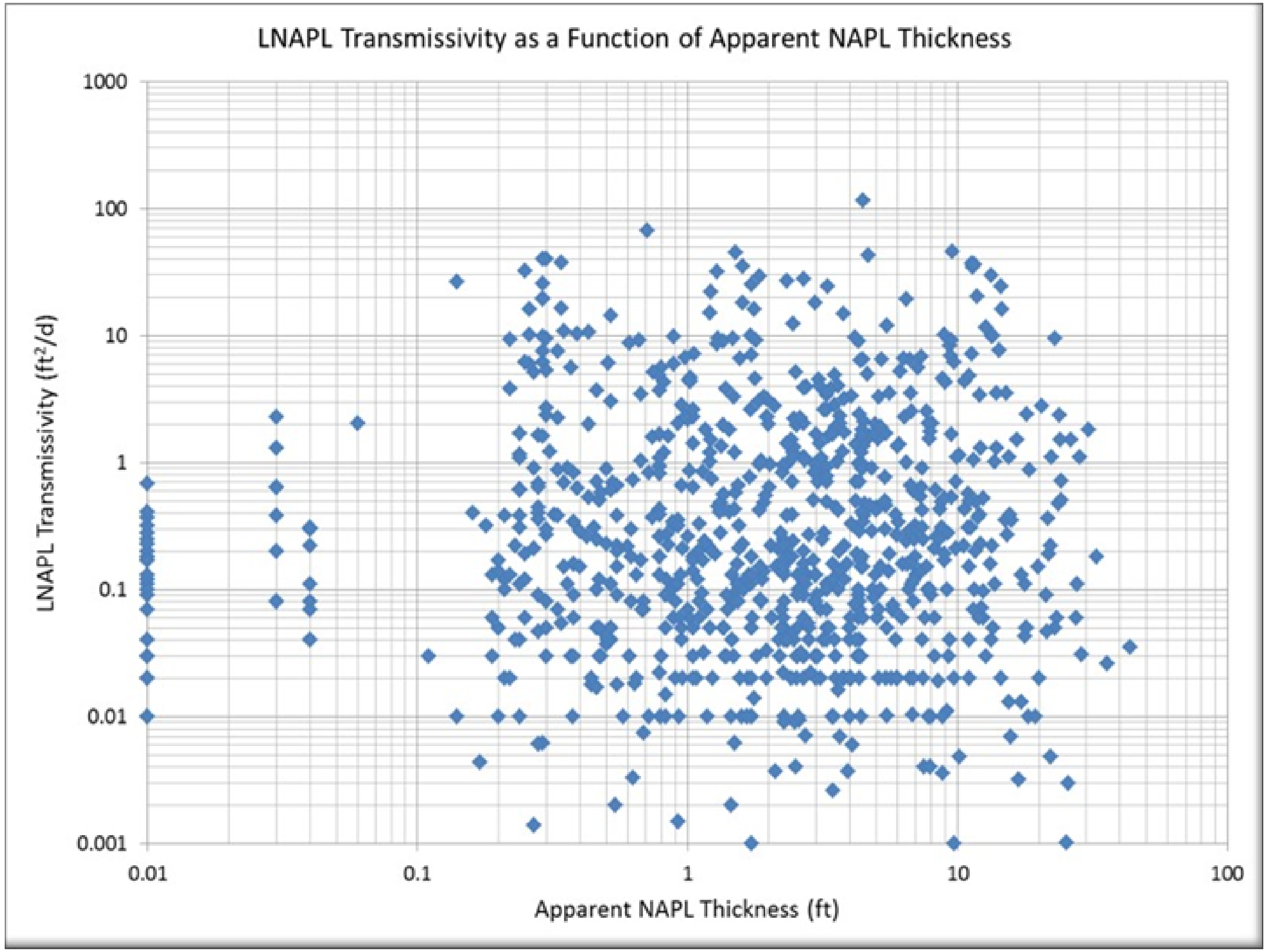


Volume Comparison

↓ Smear Zone ↑



LNAPL Thickness as a Useful Metric?

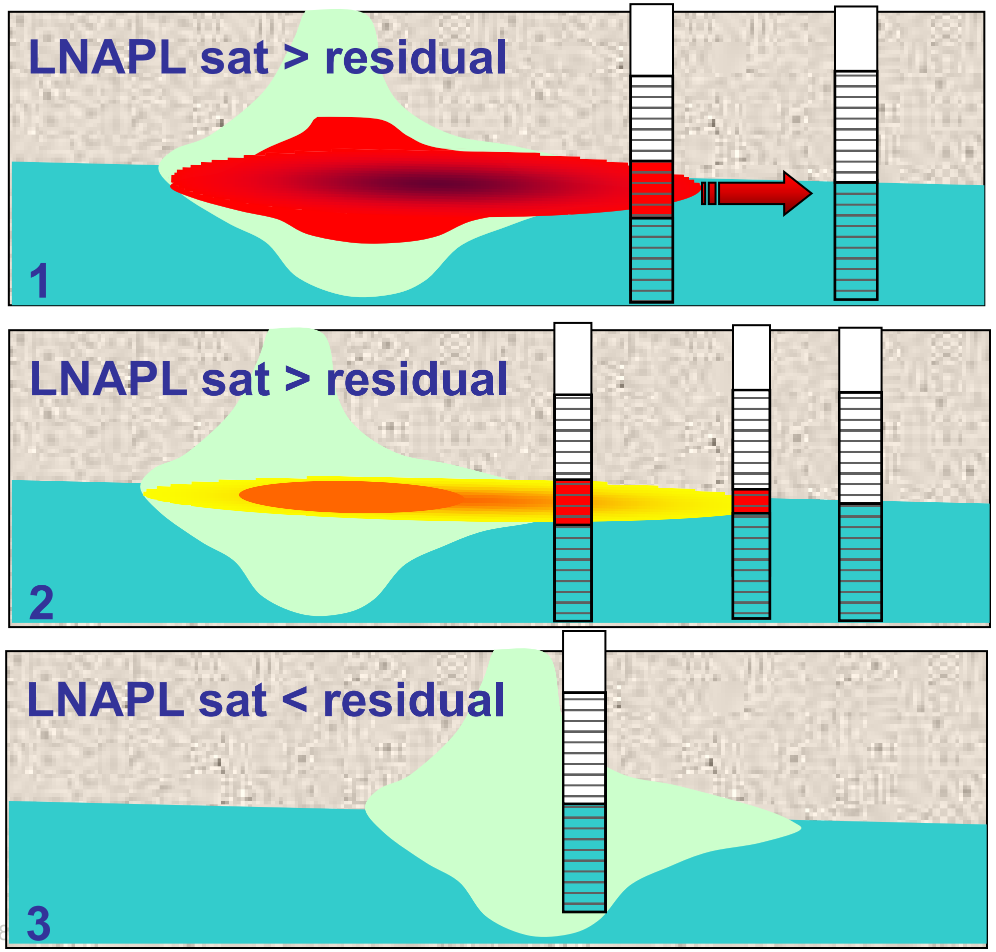


What's the Correlation factor here?

From American Petroleum Institute, 2018, Managing Risks at LNAPL Sites, Soil and Groundwater Technical Bulletin No.18

Some Key Issues in Managing LNAPL Sites

- LCSM Development is critically important
  - All CSMs incorporate MLEs – screening data, lab data, lithology
  - HRSC tools can greatly improve LCSMs
- Recognize Migrating, Mobile and Residual LNAPL state and manage risks accordingly



Condition: LNAPL in wells, migrating
Driver: LNAPL saturation

Migrating LNAPL

Condition: LNAPL in wells, mobile
Driver: LNAPL composition, saturation

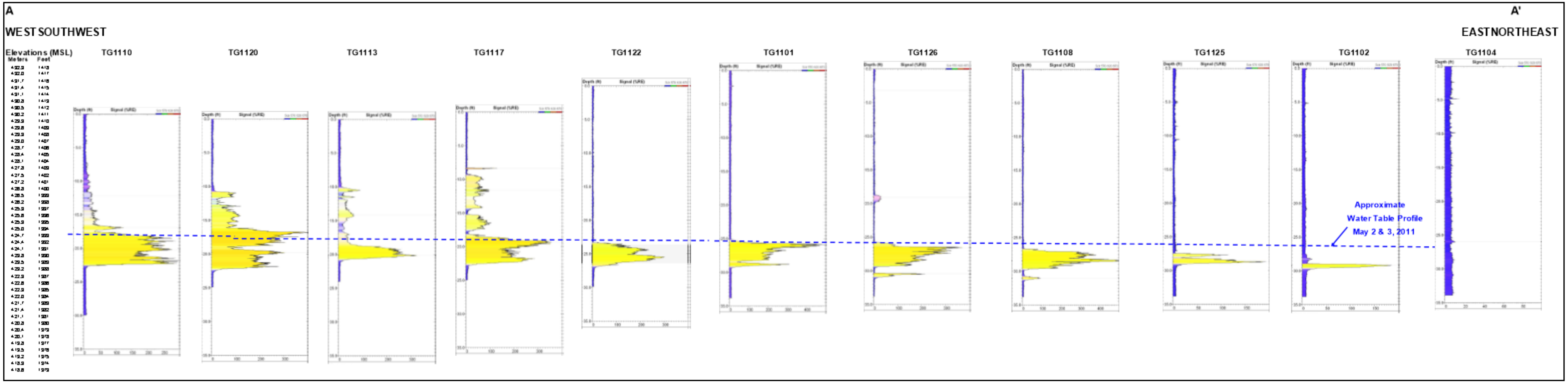
Mobile LNAPL

Condition: No LNAPL in wells, residual
Driver: LNAPL composition

Residual LNAPL

From ITRC

HRSC Tools and LCSM Development



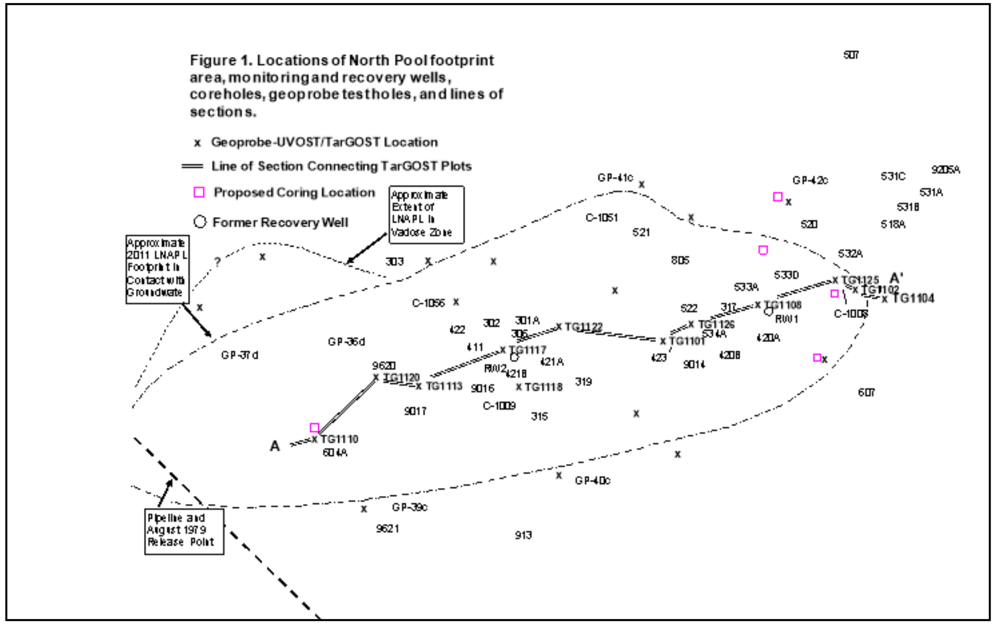


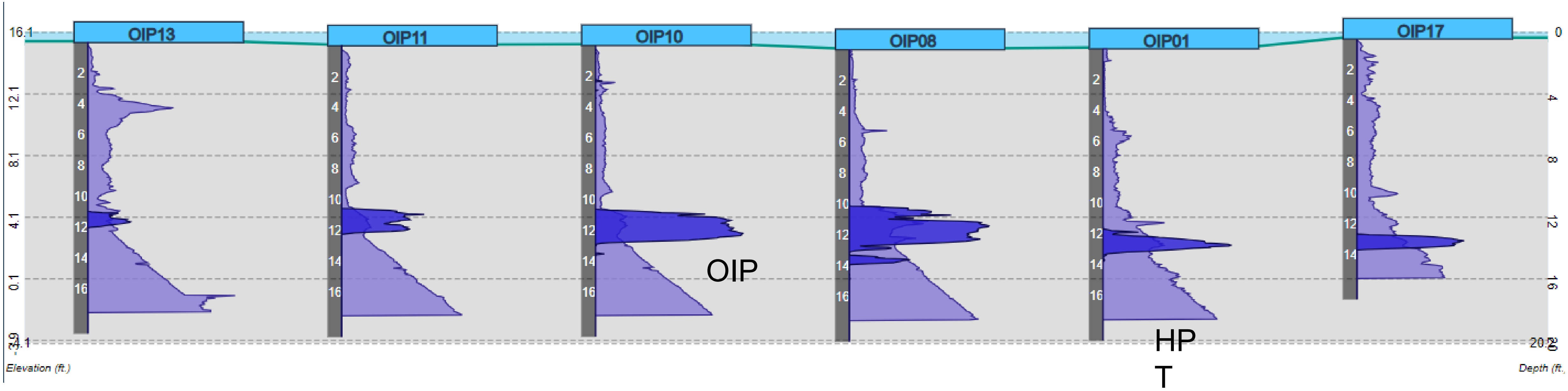
Figure 1. Locations of North Pool footprint area, monitoring and recovery wells, coreholes, geoprobe testholes, and lines of sections.

Plume Delineation via TarGOST, Bemidji, MN

source: Don Lundy, personal communication

https://mn.water.usgs.gov/projects/bemidji/

OIP/HPT Profile



HRSC Tools offer rapid, high quality screening data

Tool selection to include NAPL, hydraulic properties, soil analogues and total VOC

Ability to readily correlate data sets (OIP/HPT above)

Broad options for graphical display – ease of interpretation

Can be used to optimize placement of borings/wells for required laboratory analysis

Cross- section from medium-grained sand (SW) within one month of gasoline release

LNAPL Characterization Tools

Source: Steve Gaito, AECOM/ITRC working forum

Data Need	Description	Examples	ITRC Guidance Document References
LNAPL Delineation	Presence	LIF, Soil borings (visual, PID, shake tests, dye tests), soil concentrations, dissolved-phase concentrations, soil vapor (VOCs and/or biogenic gases)	LNAPL-3: Table 3-2
	Mobile	Monitoring wells, core LNAPL saturations	LNAPL-3: Section 3.5
LNAPL Properties	Chemical	Site history, Gas Chromatography, Biomarkers, Distillation, PIANO	LNAPL-3: Table 4-2
	Physical	Density, viscosity, interfacial tension	LNAPL-3: Table 4-2
LNAPL Hydrogeologic Condition	Unconfined, confined, or perched	Hydrographs, diagnostic gauge plots	LNAPL-3: Section 3.4
LNAPL Stability	Apply multiple lines of evidence	Release date, mobile LNAPL extent, dissolved and/or vapor footprint, hydrographs,	LNAPL-3: Table 4-1
LNAPL Recoverability	LNAPL transmissivity	Baildown, Manual Skimming, LNAPL Recovery System Evaluations	LNAPL-3: Appendix C, Section 2
Natural Biodegradation Processes	NSZD	Gradient, CO2 flux, temperature methods, LNAPL composition, polar metabolites	LNAPL-3: Appendix B, Section 4

Case Study: Transmissivity Comparison

Site	# Wells Tested	APT Range (ft)	Avg. APT (Ft)	T_n Range (ft^2/day)	Avg. T_n (ft^2/day)	Avg. Soil Core Sat'n (%)
SC Piedmont weathered jet	11	0.92 – 6.86	4.26	0.07 – 2.05	0.45	6.9
SC Coastal Plain weathered gas	3	0.36 – 1.13	0.64	0.12 – 0.29	0.19	2.0
GA Coastal Plain weathered gas	2	0.52 – 0.70	0.61	0.02 – 0.09	0.06	6.6
FL Coastal Plain fresh gas	6	0.80 – 1.52	1.22	14.5 – 72.4	30.8	NA

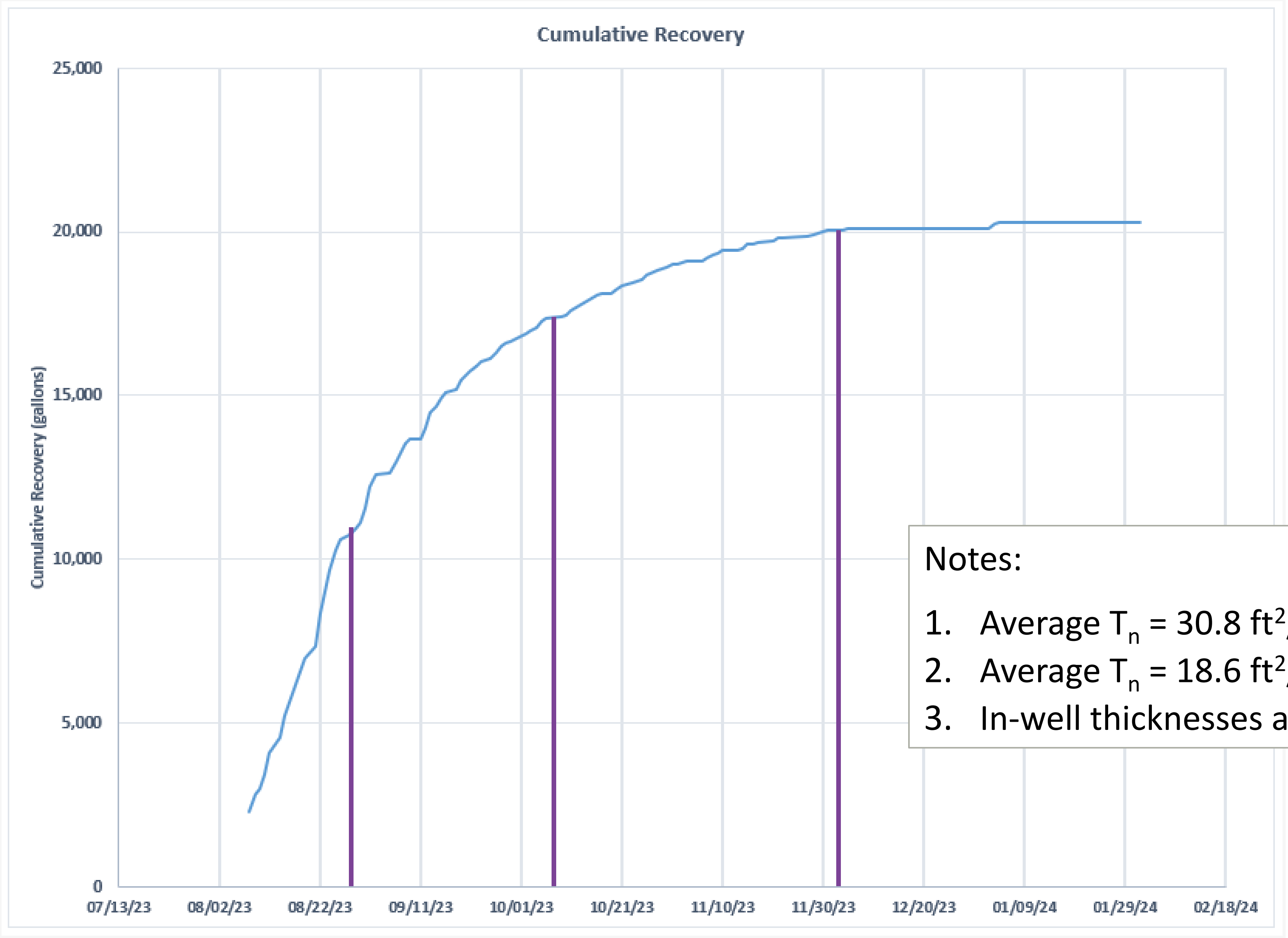
Site 1: Limited recovery from 2 wells, annual recovery less than 200 gals/yr

Site 2: No appreciable hydraulic recovery

Site 3: No appreciable hydraulic recovery

Site 4: 20,300 gals recovery in approx. 4 months

Hydraulic Recovery is a function of LNAPL T_n

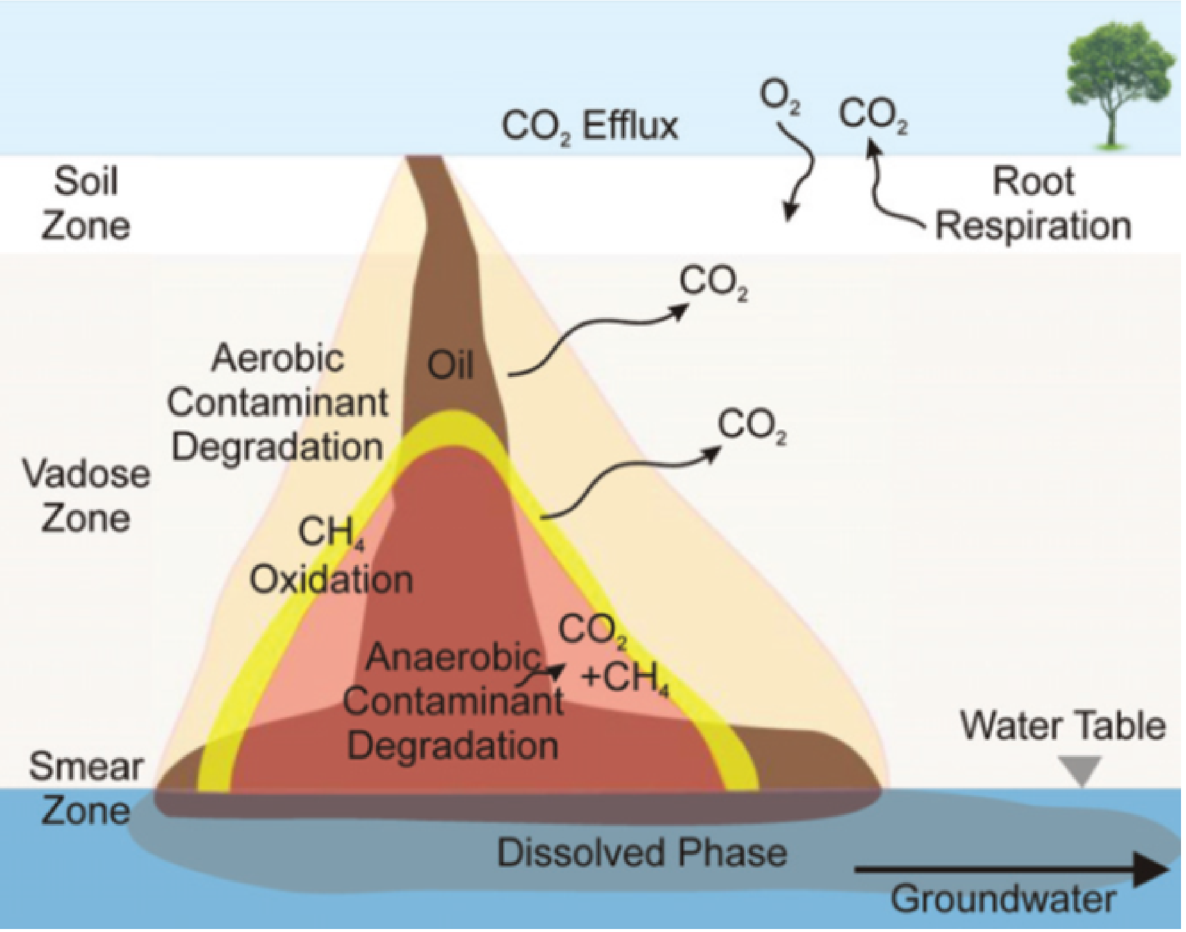


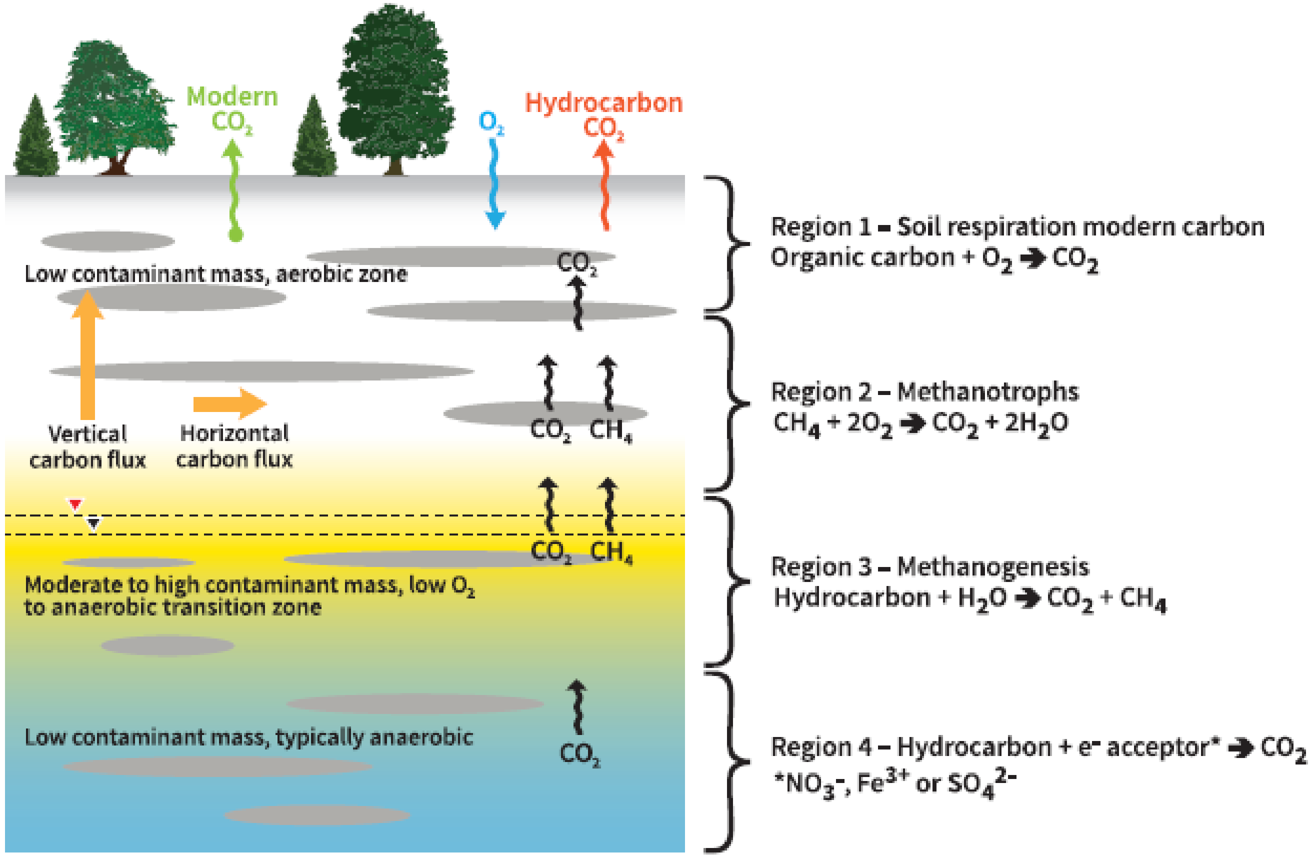
Notes:

1. Average T_n = 30.8 ft^2/day
2. Average T_n = 18.6 ft^2/day
3. In-well thicknesses all < 0.5 ft

NSZD: Conceptual Model of CO_2 Efflux

Rate of Biogenic Gases Reaching the Land Surface can Represent 95 % of LNAPL Mass Depletion at Bemidji, MN





Tracy (2015) following Amos et al. (2005), Irianni-Renno (2015), and Stockwell (2015)

Why Measure NSZD Rates?

- Remediation Baseline
- Remediation Metric
  - Treatment trains are accepted best practices
  - Remedy transition should be based upon an established performance metric
- Define LNAPL Footprint
  - This can also be done using field analysis for methane in deep soil gas
- Support LNAPL Stability
  - One of a multiple lines of evidence approach

NSZD is well suited for mature sites with residual LNAPL, low risk profile and limited practical remedial options

Baseline Comparison - Example

Technology	Potential Recovery Rate (gallons/year)	Disadvantage	Advantages
LNAPL Skimming	100	Limited to mobile LNAPL only and areas outside building footprint	Implementable, relatively low cost
Bioventing	5,000	Vapor treatment and discharge permitting may be required	May increase microbial activity if system is oxygen limited
NSZD	1,030	Vapor generation, longer timeframe than bioventing	No system maintenance, treats complete LNAPL footprint, sustainable remedy

Source: ITRC LNAPL-3

NSZD Case Study Results – CO_2 Eflux Method

Site	# CO_2 Traps	NSZD Range (gals/acre/yr)	NSZD Avg. (gals/acre/yr)	Plume Size (acres)
SC Piedmont weathered jet	7	86 – 570	306	1.25
SC Coastal Plain weathered gas	10	51 – 324	165	1.15
GA Coastal Plain weathered gas	6	196 - 664	356	0.34

Factoring in plume size, avg annual destruction is 382, 190 and 121 gals/yr, respectively

How does this compare to actual recovery?

Changing Guidance

Timeline for Significant Regulatory Updates – selected, not comprehensive

- ITRC LNAPL –1, 2009 – Explains saturation profile, setting, mobility, and risk
- CA DTSC, 2012 – "Low Threat Closure Policy" introduced
- VADEQ, 2012 - "Case Closure Evaluation of Sites with Free Product" – allows MLE approach
- TCEQ (TRRP), 2013 – risk-based evaluation
- MADEP (MCP), 2016 – moved from fixed thickness to technical and risk evaluation
- ITRC LNAPL –3, 2018 – added detailed appendices on T_n determination and NSZD
- MI EGLE, 2023 – was 100% recovery, now incorporates T_n metric, provides MLE spreadsheet
- USEPA OUST, 2023 – provided clarification on LNAPL state intended for recovery per "MEP"

What are some common factors?

One-size does not fit all. Every LNAPL site requires site-specific determination of setting, behavior and risk (LCSM).

MADEP Example - 2016

- Moved away from fixed thickness
- Requires prelim and updated CSM
- Recognizes residual saturation as function of soil type
- Emphasizes MLE approach (recover decline curve, soil saturation, T_n, and TPH conc. correlation)
- Allows for Technical Impracticability
- Defines LNAPL stability
- Introduces risk-based performance standards

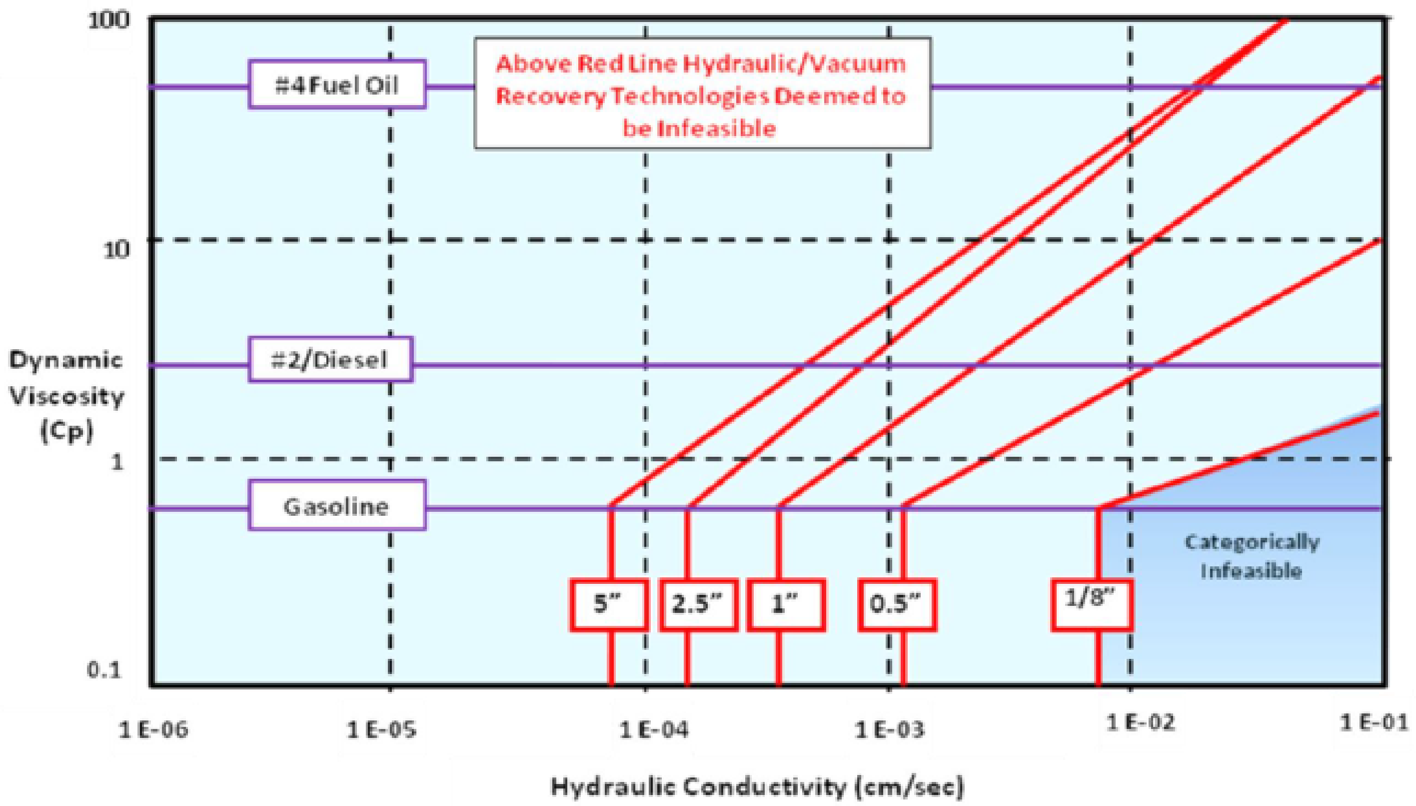


Figure 8: Conditions of Infeasibility of LNAPL Recovery by Conventional Technologies (based on a modification of modeling results from API, 2007)

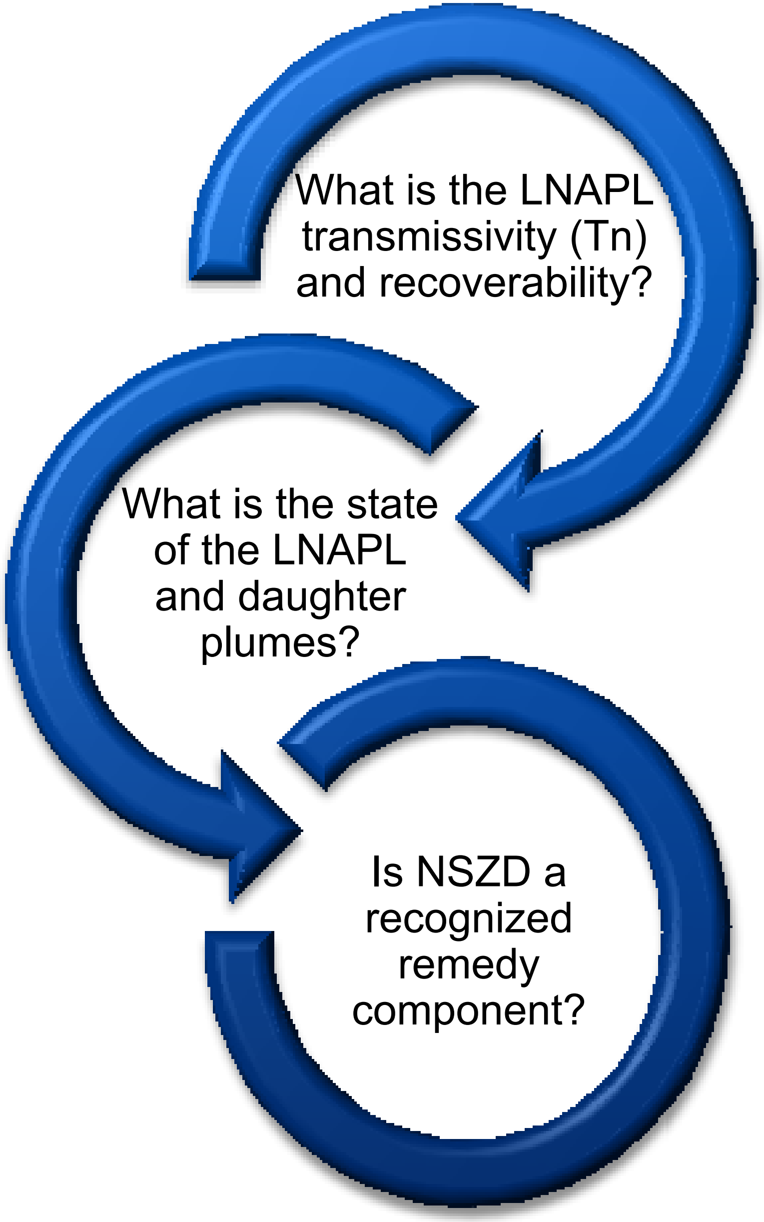
Is Closure an Option for Sites with LNAPL?

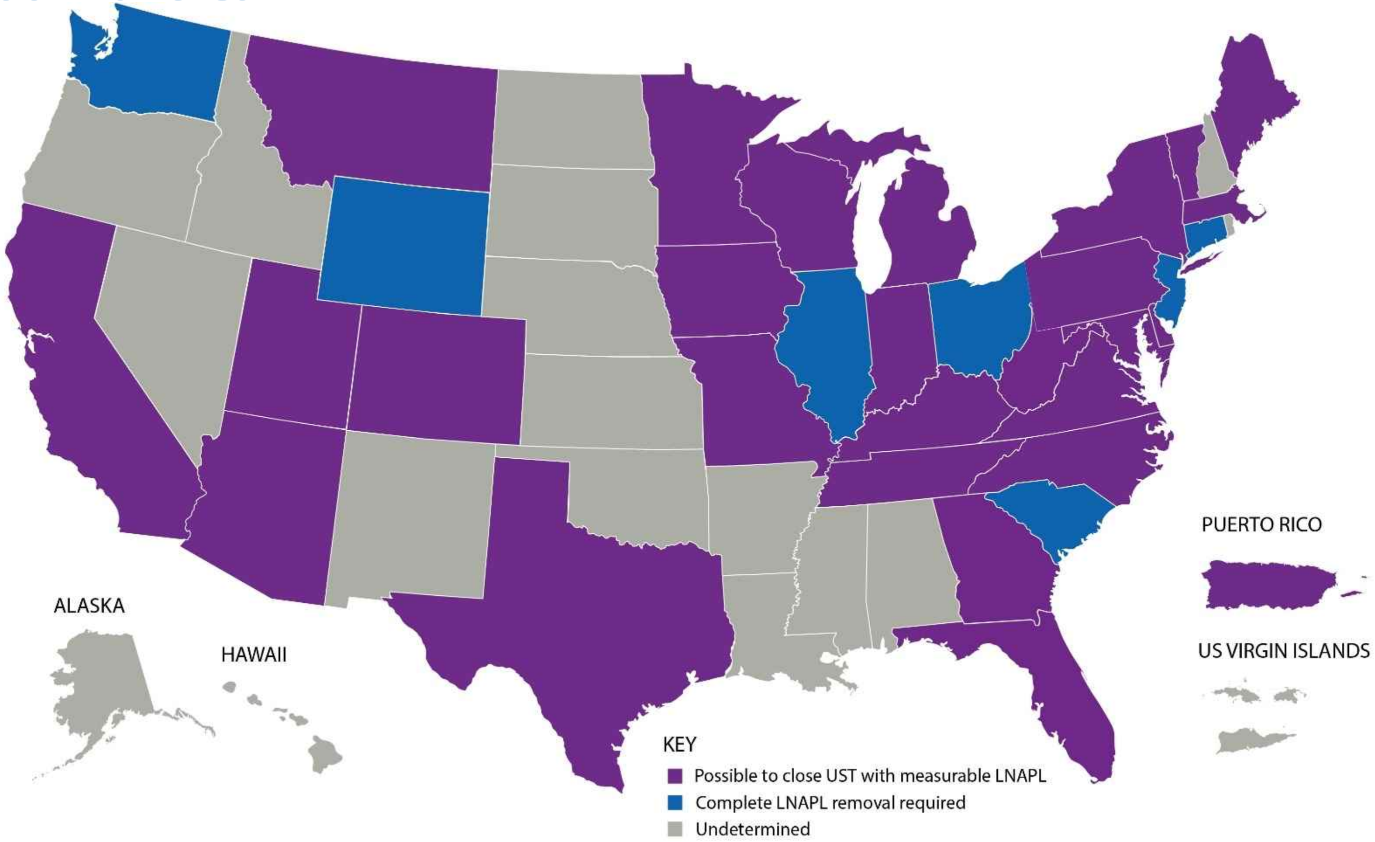
Federal regulation requires free product removal “to the maximum extent practicable as determined by the implementing agency”

In Feb 2023, USEPA clarified the definition of “free product recovery” *to specifically state:*

“abatement of mobile and residual LNAPL is not necessary to meet the requirement of 40 Code for Federal Regulations (CFR) 280.64 to prevent the migration of “free product” into previously uncontaminated soil or groundwater”.

Advocacy For Sites with LNAPL





*Map data obtained from the ITRC LNAPL team (2017) and GES' experience with state regulatory programs

Conceptualize the desired outcome:

- Determine potential LNAPL recovery
- Achieve MEP per applicable state requirements
- Eliminate LNAPL as a media of concern and transition to MNA for groundwater
- Use Natural Source Zone Depletion (NSZD) metrics to quantify intrinsic source destruction and manage remedy transition

Tools to support site closure with LNAPL remaining

- Build a credible **Conceptual Site Model**
  - Incorporate screening data (MLE)
  - Utilize high resolution tools
  - Identify and manage data gaps
  - Frame your argument for the desired outcome

- Guidance Documents:
  - American Society for Testing and Materials (ASTM) "**Moving Sites to Closure (MStC)**" document coming out later this year
    - Offers a more robust performance tool relative to ITRC "guidance"
    - Similar to CA's 2012 Low Threat Closure Policy
    - Provides specific LNAPL plume stability criteria
  - ITRC guidance documents (LNAPL-3, PVI, TPH Risk)
  - ASTM (2007) Standard Guide for Development Of CSMs and Remediation Strategies for LNAPL Released to the Subsurface
  - API (2018) Managing Risk at LNAPL Sites

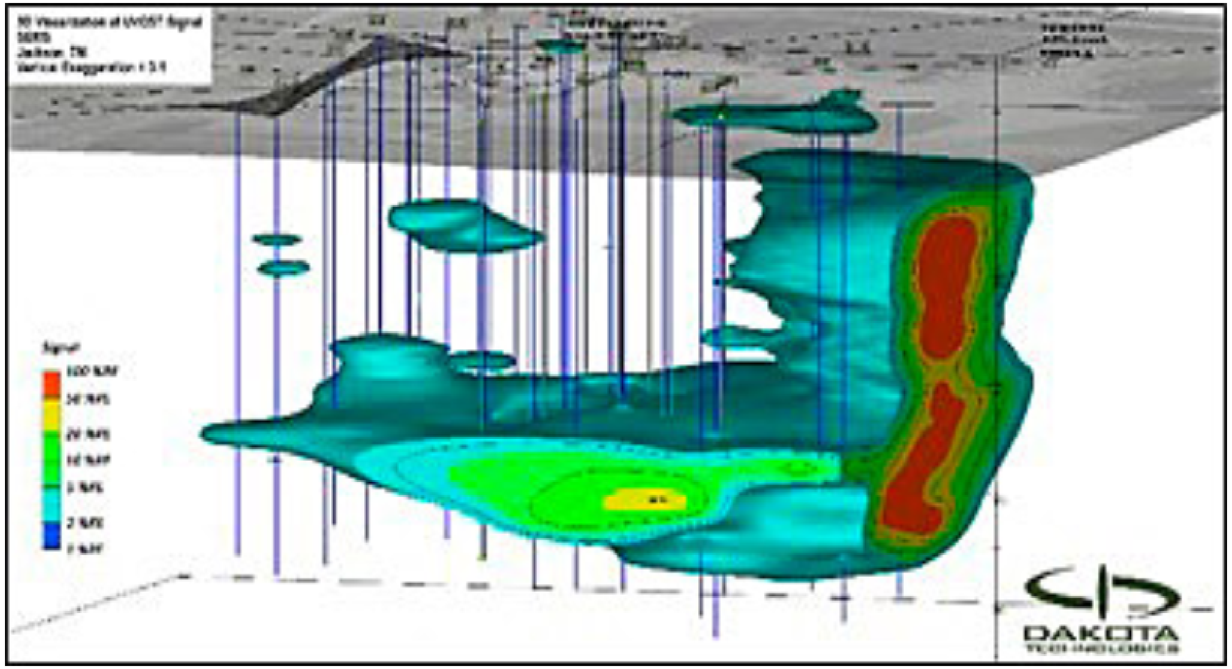


Image source: https://asct-1.itrcweb.org/9-5-uvost-differentiates-lnapl-types-to-allocate-financial-liabilities-at-a-retail-petroleum-facility-in-tennessee/

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