Groundwater Contaminated By Residual LNAPL

Why Clean It Up Anyway?

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Introduction

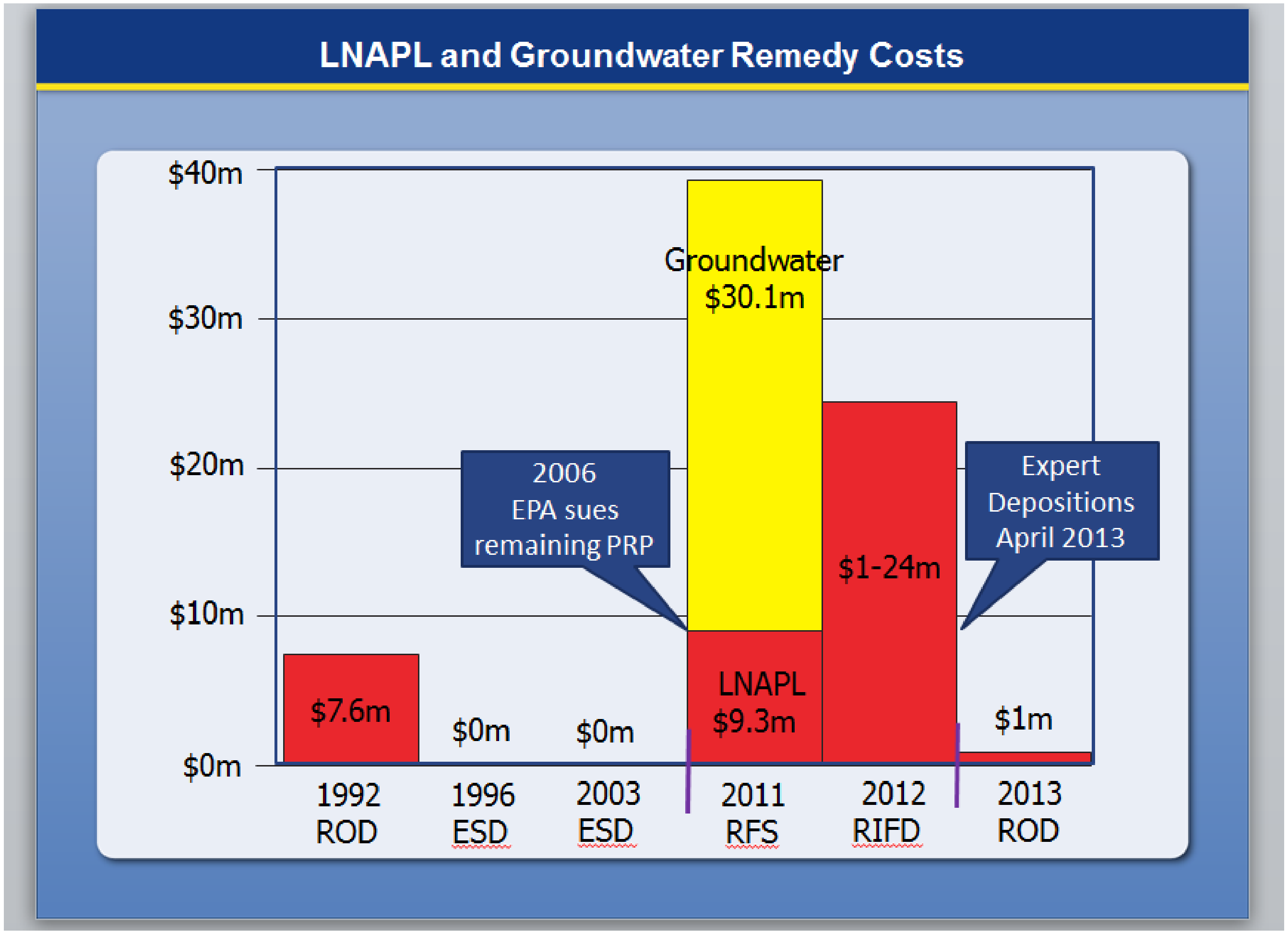
Analyze whether:

LNAPL and groundwater should be remediated:

- To the extent practicable
- Even if it does not impact receptors
- Even if it does not reduce dissolved phase constituent concentrations

Presentation Framework

A. Background on LNAPL science
B. Examine Governments law and guidance on LNAPL removal
   - NCP
   - LNAPL removal guidance
C. Industry Perspectives on the practicability of LNAPL remediation
D. Experience at the Oklahoma Superfund Site where PRP was able, through litigation, to convince EPA to lower LNAPL remediation costs from $24mm to $1mm based on:
   - Government admissions and prior investigations
   - Depositions of government experts
   - PRP's scientific testing


LNAPL and Groundwater Remedy Costs
$40m
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$7.6m
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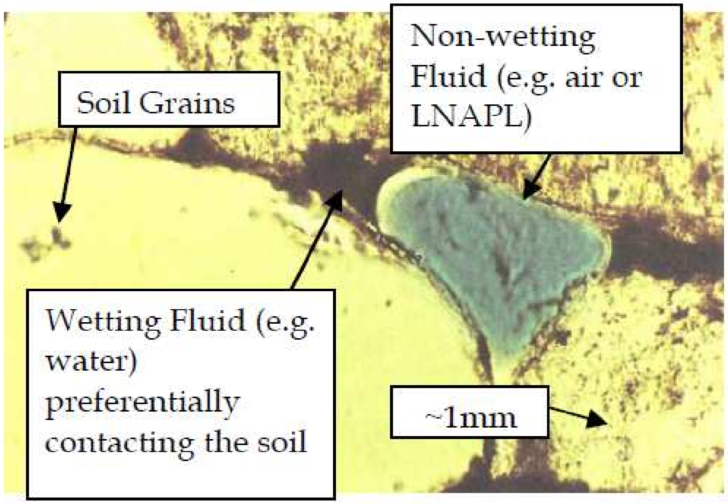
LNAPL
$9.3m
$1m
1992
ROD
1996
ESD
2003
ESD
2011
RFS
2012
RIFD
2013
ROD

BACKGROUND INFORMATION ON LNAPL OCCURRENCE, BEHAVIOR AND MIGRATION

LNAPL Physics

- LNAPL Co-exists with water in pore network
- Degree of saturation depends upon lithology and fluid properties
- LNAPL partially fills aquifer pore space



Source: U.S. EPA Remediation Technologies Development Forum

Figure 1: LNAPL Locked in Geologic Pore Spaces

LNAPL Residual Formation

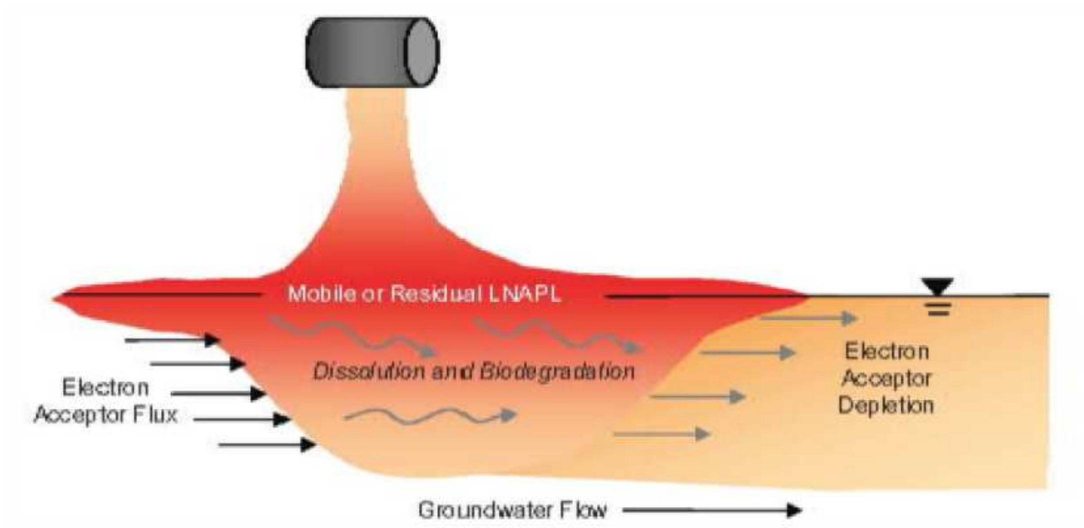


figure 3.10
LNAPL IS REMEDIATED BY NATURAL PROCESSES

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LNAPL – Residual Saturation Indicators

- LNAPL saturation is so low that the LNAPL begins to break apart as separate droplets, stringers or ganglia.
- LNAPL velocity approaches zero
- LNAPL body may have one or more localized areas containing potentially mobile consequently, and still be in residual form if it has a stable footprint.
- LNAPL in a well does not necessarily indicate that LNAPL saturations in the undisturbed soil exceed residual levels.

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Agency Regulations and Guidance

1990 National Contingency Plan Preamble, Meaning of "*Practicability*" Relative to Cost Effectiveness

"Cost and practicability. Some commenters requested clarification of the proper analysis of trade-offs between cost-effectiveness and the practical limitations of treatment technologies on one hand, and the mandate to utilize treatment to the maximum extent practicable on the other. In addition, one commenter wrote that the proposed process blurs the two concepts of cost effectiveness and practicability. Some commenters noted that cost must be considered in determining what is "practicable". EPA responds that cost is considered in making both findings as are certain other criteria. Cost is considered in determining cost-effectiveness to decide which options offer a reasonable value for the money in light of the results they achieve." *(EPA, 1990)*

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EPA TECHNICAL IMPRACTICABILITY WAIVER GUIDANCE

- EPA has stated that NAPLs, soil heterogeneity and sorption of chemicals onto soil are some of the contributing factors that can lead to a TI waiver. TI Waiver is appropriate whenever remediation is impracticable. Under 40 CFR 300.430(f), Guidance for Evaluating the Technical Impracticability of Ground-Water Restoration (EPA, 1993) and Technical Impracticability Decisions for Ground-Water at CERCLA Response Action and RCRA Corrective Action Sites (EPA,1998).
- TI Waivers can be sought during the remedy selection process which is known as a “front-end” TI decision. (EPA, 1993).
- At Oklahoma refinery, government witness testified that no pilot or bench scale tests had been done and that a TI waiver would be re-examined after the remedy had been implemented.

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Key Guidance Documents

Table 9.3 – GPs Fail to Adhere to Their Own Guidelines for Remedy Selection

Guidance Document	Relevance to Remedy Selection	Reference
EPA 1995 Guidance on LNAPL Characterization	Guidance provides procedures for characterizing LNAPL so that the practicality of remediation can be evaluated. RFS does not reference or discuss EPA guidance.	EPA, 1995
ITRC, 2009 Evaluation, LNAPL Remedial Technologies for Achieving Project Goals	Guidance provides procedures for characterizing LNAPL so that the practicality of remediation can be evaluated. RFS does not reference or discuss ITRC guidance.	ITRC, 2009a
ITRC, 2009 Guidance on NSZD	Guidance explains processes of NSZD and where this technology is practicable.	ITRC, 2009b
EPA, 1993 and 1998 Guidance on Technical Impracticability Waivers	Guidance provides technical and regulatory framework for addressing LNAPL where aquifer restoration is impracticable. RFS does not reference or discuss ITRC guidance.	EPA, 1993 and EPA, 1998
EPA, 2004 Guidance on How to Evaluate Alternate Cleanup Technologies for USTs	Guidance on the factors to be considered when evaluating the practicability of remediation of LNAPL. RFS does not reference or discuss ITRC guidance	EPA, 1994
EPA 2000 Guidance on Institutional Controls (ICs)	Guidance on the use of ICs to meet ARARs where LNAPL remediation is impracticable. RFS does not reference or discuss ITRC guidance.	EPA, 2000
API 2002 Guidance on LNAPL remediation	API provides procedures for evaluating LNAPL remediation effectiveness. RFS does not reference or discuss ITRC guidance.	API, 2002
US Army Guidance on Technical Impracticability	Guidance provides technical evaluation on conditions where remediation is impracticable	US Army, 2004

EPA Extraction Matrix Guidance

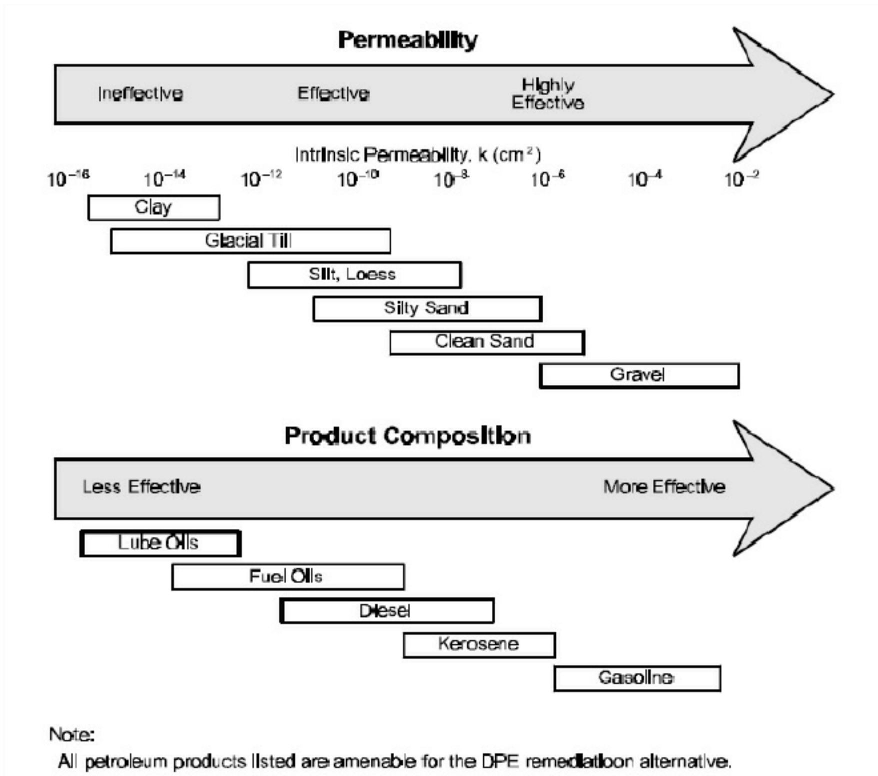


figure 3.11b

MPE INEFFECTIVE AT SITE DUE TO CLAY SOILS, BEDROCK AND PETROLEUM CHARACTERISTICS

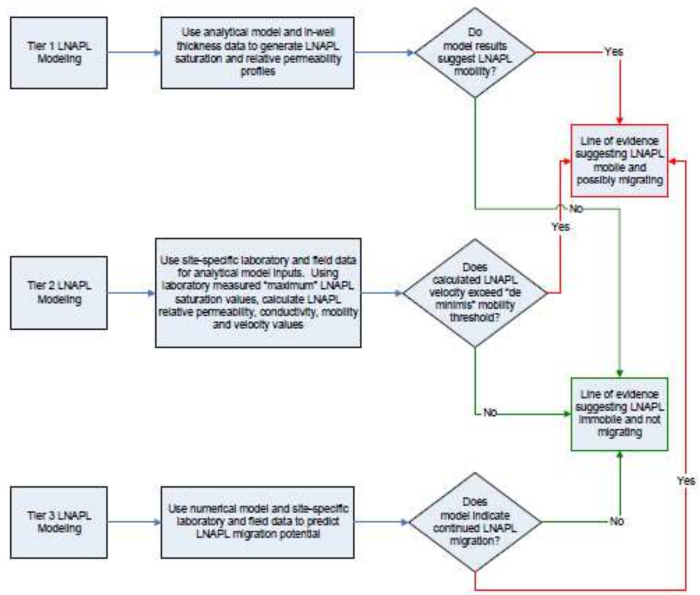
SOURCE:

EPA, 2004b, EXHIBIT XI-8

EPA LNAPL Mobility and Recoverability Guidance

Figure 20

[redacted]



EPA LNAPL Migration Guidance

Figure 19

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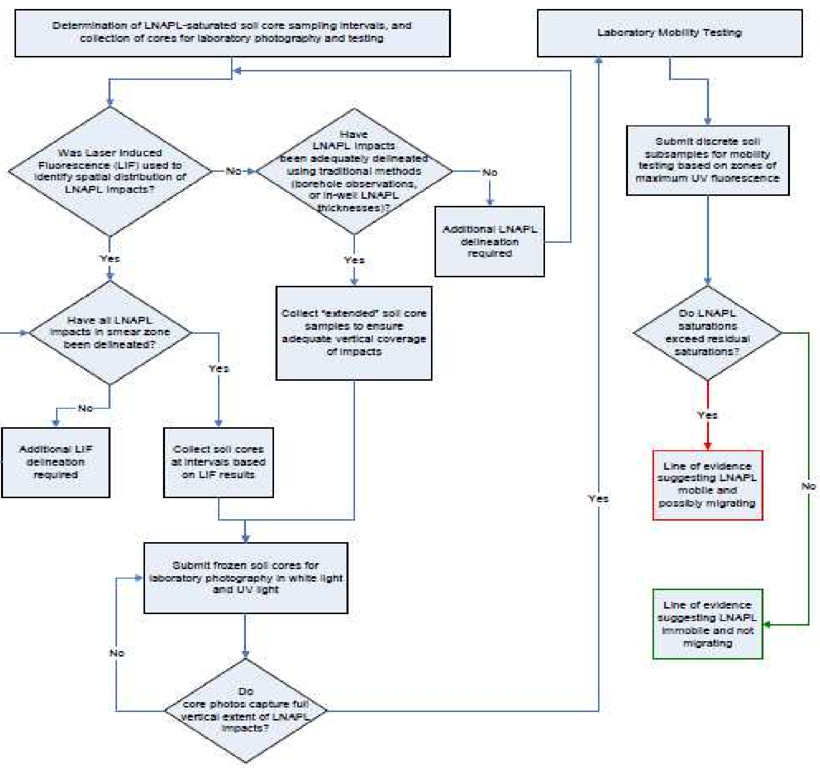
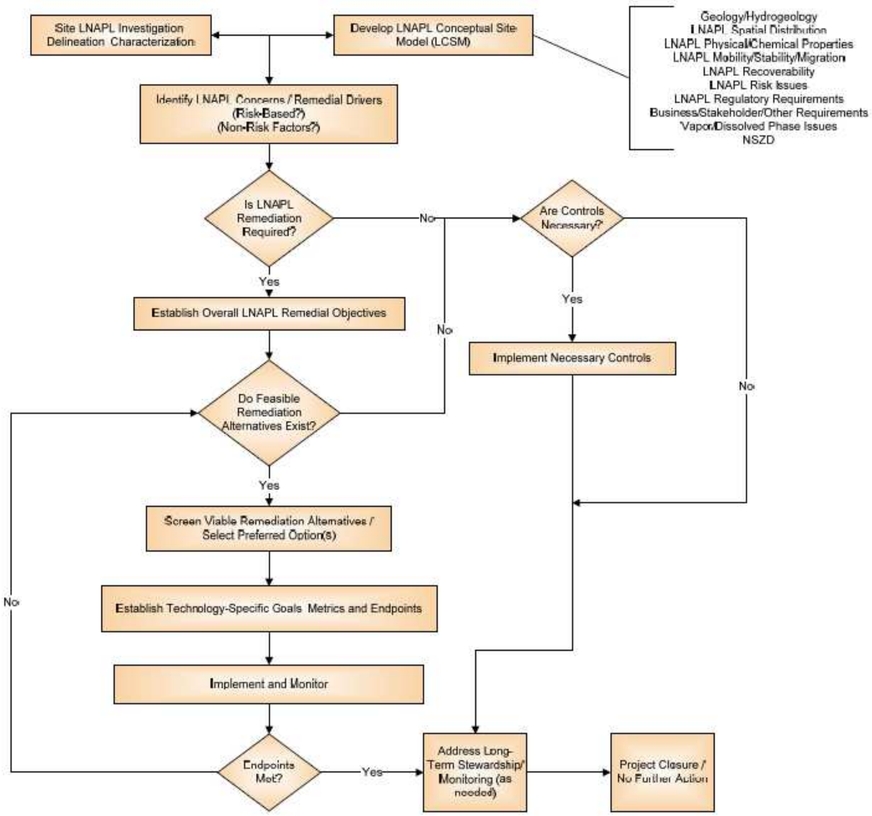


EPA LNAPL Remedian Decision Process Guidance



[redacted] (modified from ITRC 2009a and ASTM 2007)

EPA Treatability Study Decision Tree

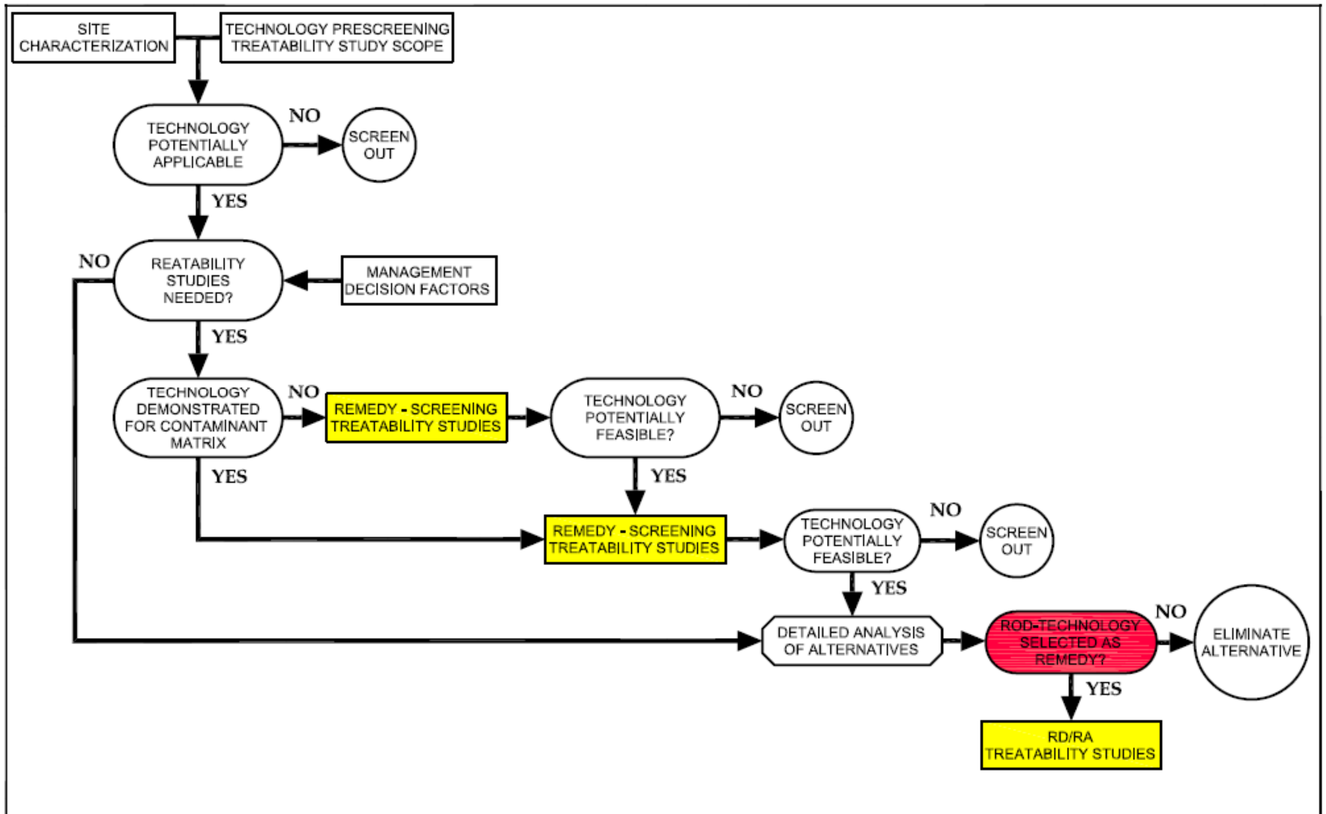


figure 5.2

GOVERNMENT PARTIES HAVE FAILED TO COMPLY WITH THEIR OWN TREATABILITY STUDY AND REMEDY SELECTION DECISION TREE

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INDUSTRY STUDIES ON THE LIMITATIONS OF LNAPL REMEDIATION

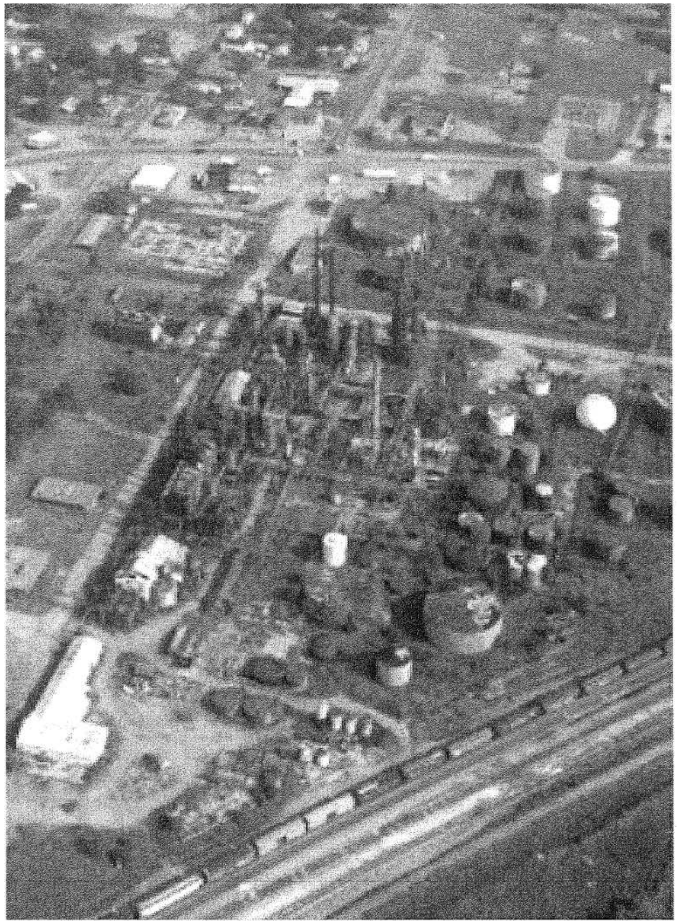
American Petroleum Institute (API, 2002, pg 4-8)

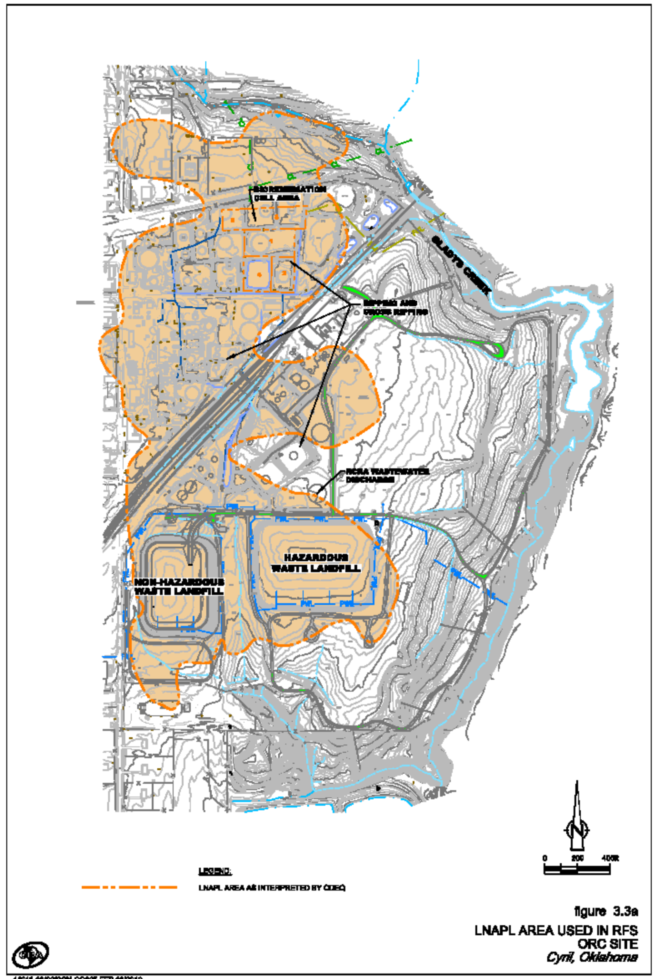
"…for most of the hydraulic recovery cases evaluated from literature and in our own records, the total LNAPL recovery was less than 30% of the original volume in-place with the upper end being as high as 60%...The implication is that for most sites, recovery of more than 30% of the LNAPL in-place would be the exception rather than the rule. In finer-grained materials, recovery of more than 15% of the LNAPL in place would be unusual."

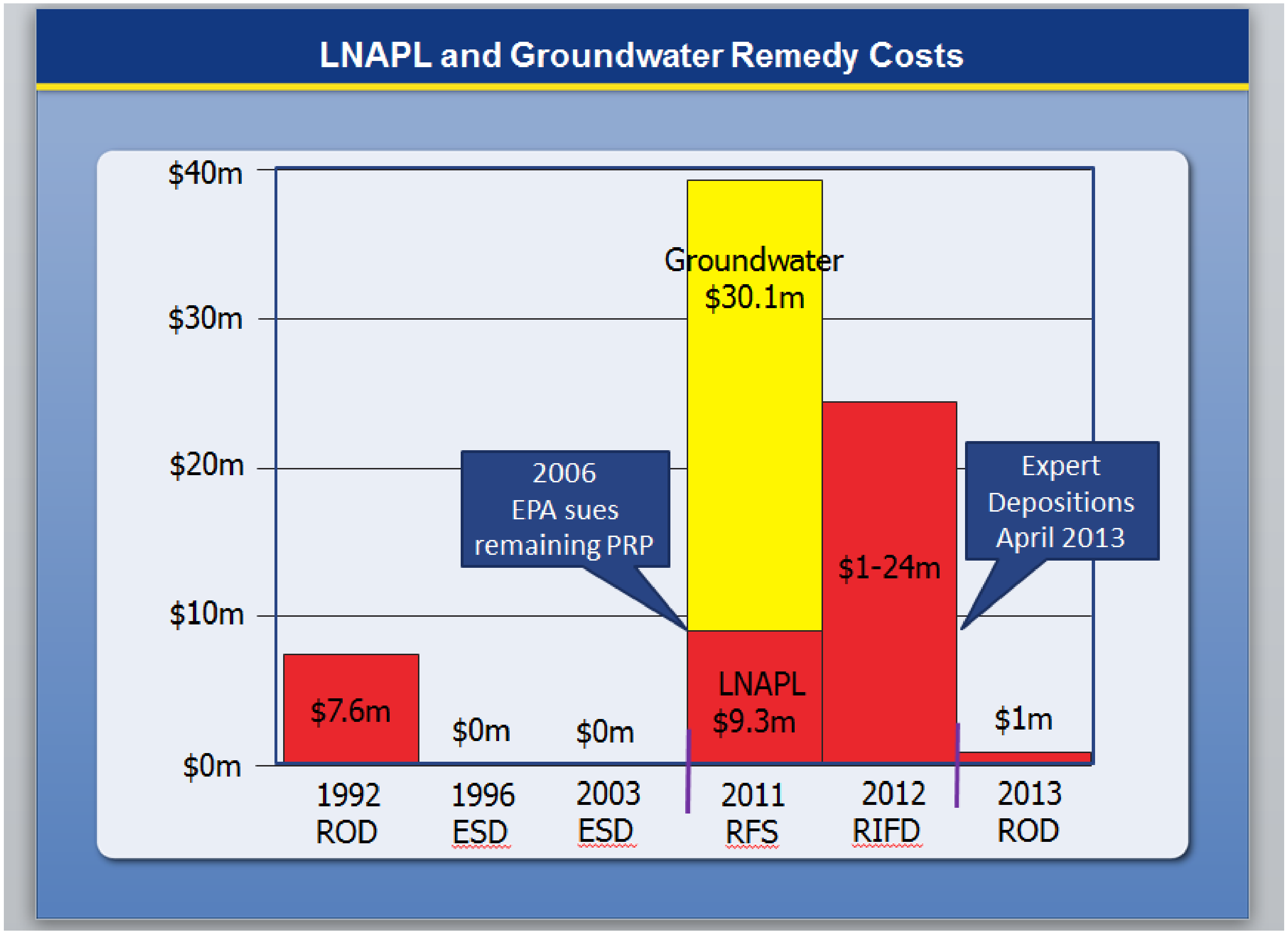
The Interstate Technology & Regulatory Council, 2009 (ITRC)

- LNAPL "presents some of the greatest challenges to corrective action…" and "once in the subsurface, LNAPL can be difficult to adequately assess and recover and thus can be a long-term source". (ITRC, 2009a, pg iii).
- Once LNAPL is in the residual range, it is very difficult to recover and that most active technologies such as air sparging and MPE, are not effective in fine-grained soils and bedrock.
- When LNAPL is above the residual phase, neither DPE, MPE, solvent flushing, nor AS/SVE are effective in fine-grained soils.
- To abate constituent concentrations in soil vapor and/or dissolved phase from the LNAPL source, the appropriate remedy is containment and NSZD.
- Bench scale and pilot testing of LNAPL remedial technologies is encouraged (ITRC, 2009a).

Oklahoma Superfund Site




HAZARDOUS
WASTE LANDFILL
NON-HAZARDOUS
WASTE LANDFILL
LEGEND:
LNAPL AREA AS INTERPRETED BY ODEQ
0
200
400ft
figure 3.3a
LNAPL AREA USED IN RFS
ORC SITE
Cyril, Oklahoma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History

A. Oklahoma Superfund Site
B. 200 Acres/80 acres of LNAPL
C. EPA – LNAPL up to 16' thick, Trust – LNAPL less than 1" thick
D. Surrounded by creek on all sides – no indicative concentration of organics and metals in the creek
E. Long history of remediation
   a. 1985 – 5,000 barrels removed
   b. 1992 – ROD: pump & treat, containment recommended: $7.5m
   c. 1996 – ESD-LNAPL and groundwater remedy postponed
   d. 1997 – 2002 – Surface remedy implemented – Landfill constructed on-top of plume, hazardous waste discharged to groundwater, Creek
   e. 2003 – ESD-LNAPL and groundwater remedy postponed
   f. 2003-2004 – removal action implemented, hazardous waste discharged to LNAPL, Creek
   g. 2006 – EPA commences litigation against PRP
   h. 2011 Client studies
   i. 2011 Draft RFS – LNAPL remedy $39m; final feasibility study - $1m - $24m
   j. 2011 Deposition of EPA experts – LNAPL remedy impracticable and will not reduce g.w. containment
   k. 2013 – ROD – LNAPL remediation = $1 million

Apco Trust Factual Analysis and Testing

Mobility and stability was evaluated based on:

- Available historical information including, but not limited to:
  - Regulator admissions,
  - Age of the LNAPL release(s),
  - LNAPL types,
  - LNAPL spatial distribution,
  - Geologic/hydrogeologic setting,
  - Dissolved phase concentration trends;
- Site-specific LNAPL mobility and body stability testing (based on soil/rock cores obtained immediately adjacent to wells exhibiting LNAPL); and
- LNAPL mobility/migration modeling.

Geologic Units

- **Silt and Clay Unit**: Characterized by low to very low permeabilities, and high organic content
- **Weatherford Gypsum**: A massive gypsum deposit with an extremely low permeability and can transmit fluids only in the isolated locations where it contains fractures or solution cavities.
- **Rush Springs Sandstone**: The Rush Springs Sandstone is not used as a source of drinking water in the vicinity of the Site due to the intrinsically poor quality of the water. The grain size and silt content of the Rush Springs Sandstone limits the rate of water and contaminant movement in this formation.

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Table 9.1 – GPs Repeated Rejection of Currently Proposed Remedies

Date	Document/Author	Remedy Considered	Reason for Rejection
1992	ROD/Government Parties	81 Extraction wells for LNAPL and 56 extraction wells for groundwater near Gladys Creek	Post-ROD pilot test shows that extraction wells are not practical for LNAPL remediation
1995	OPD/Mittelhauser	1992 ROD Remedy Tested	Extraction of LNAPL using wells not practical and a passive LNAPL trench was proposed
1995	Value Engineering Report/FHC	2,200 ft long passive LNAPL trench	Passive LNAPL trench is not practicable
1996	ESD/Government Parties	Passive LNAPL Trench selected remedy postponed	Groundwater discharge to Gladys Creek not an adverse risk to the public.
1997	Dixon, 2010, Exhibit 297 Soil Remediation Activity Plan for Remedial Action and 300-Notes from 11/7/2002 ORC Conference Call	2,200 ft long trench proposed but was not installed.	LNAPL remediation using passive LNAPL trenches is not practical
2000	Technical Memo/ODEQ	Evaluation of LNAPL trench	LNAPL recovery would be minimal
2000	Dixon, 2010, Exhibit 313-Rationale for Alternative LNAPL Trench Ground Water Remedy Proposed for ORC	LNAPL and dissolved phase plume boundaries are stable. No LNAPL remedy implemented.	LNAPL and dissolved plumes do not require remediation due to absence of potential for migration
Prior to 2003	Dixon, 2010, pg 54 and ESD 2003, pg 5	LNAPL removal using trenches would be minimal. Trenches not installed.	Passive LNAPL collection is not practicable
2003	ESD/Government Parties	2,200 ft long passive LNAPL trench system	LNAPL trench is not practicable
2004	Roberts, 2010, Exhibit 274-ORC North	Getting all or even 50% LNAPL is "pretty much unbelievable". No LNAPL remedy implemented.	LNAPL remediation is not practicable
2004	Letter/Ray Roberts	Comments on feasibility of LNAPL recovery	LNAPL recovery impracticable
2007	Keeley, 2007, pg 12	LNAPL not a plume but more like soil contamination study continues.	LNAPL recovery is not practicable
2010	Roberts, 2010, pg 89	Low permeability of soil results in less remedial options for LNAPL	LNAPL recovery in low permeable soils is not practicable
2011	RFS	Narrow list of ARAR/RAO compliant remedies. (Aquifer flushing & MPE)	Remedy not yet selected

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Table 9.2 – Prior Studies Established LNAPL Remediation is Unnecessary and Impracticable

ORC Studies	Study Results	Relevance to Remedy Selection and Practicability	Reference
True LNAPL Thickness	True LNAPL thickness much less than Pre-ROD apparent LNAPL thickness	LNAPL recovery not practicable	Optimal Design Report (OPD), Section 4.4 (begin COL0041295) and CRA, 2011
LNAPL Plume Stability	LNAPL "plume" is stable (not expanding)	LNAPL migration is not an off-site threat	Dixon, 2010, Exhibit 312; Keeley 2007, Pg 12 and CRA, 2011
Low Permeability of Soils and Bedrock	Low permeability of soils and bedrock limits water and LNAPL movement and recovery	LNAPL recovery is impracticable	OPD, Section 4.5.3 (COL0041301) and Roberts, 2010
LNAPL Baildown Tests	LNAPL recovery is very low	LNAPL recovery is impracticable	Mittelhauser, 1995
LNAPL Studies	LNAPL residual cannot be removed	Partial removal of LNAPL will not meet RAOs. LNAPL removal is impractical	Mittelhauser, 1995
LNAPL Studies	Residual LNAPL is all that remains	Partial removal of LNAPL leaves continuing source to groundwater which does not meet RAOs	Mittelhauser, 1995
LNAPL Studies	LNAPL residual cannot be removed and soil/bedrock has low permeability	Aquifer flushing and MPE are impractical for LNAPL	Mittelhauser, 1995 and CRA, 2011

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Table 3.7 – GPs do Not Know Critical Factors for Selecting Aquifer Flushing

Factor/Consideration	Government Parties' Position	Reference
Low permeability limits effectiveness	Contamination is likely present in clay	Dixon, 2011, pg 241
Impermeable layers limit effectiveness	Impermeable layers and heterogeneity exists	Dixon, 2011, pg 235-236
Pilot testing is required to determine pumping rates and well spacing	No pilot studies are planned	Dixon, 2011, pg 211

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Historic Government and Contractor Admissions

- 1995: *"none of the in-situ remediation scenarios modeled are predicted to achieve site-specific RAOs across the entire site within **50 years** of treatment".*
- 2007: *"Increasing LNAPL thicknesses in a monitoring well may lead an observer to believe that a mobile "pool" of LNAPL is migrating past the well. This may be the case if there is a significant on-going release of LNAPL to the subsurface. However, this is not occurring at the site. . . to a large degree, many of the **changes in LNAPL thicknesses are due to fluctuations** in groundwater levels and not to migration of the plume."*
- 2007: *"An assessment of electron acceptors available at the site indicates generally favorable conditions for anaerobic biodegradation and suitable electron acceptors. Most significantly, the high concentrations of dissolved-phase sulfate suggest **adequate electron acceptor for sulfate reduction of the BTEX components** of the LNAPL."*
- 2010: *"New information collected during the recent remedial design field work shows the **true thickness of the LNAPL is three inches or less** and is not homogeneously distributed within the area of contamination. This is in contrast to the two feet of thickness estimated across that area of contamination at the completion of the Remedial Investigation (RI). The borings drilled during the RI show that the LNAPL has not migrated appreciably since the RI. The current scope of work directs the contractor to design LNAPL recovery using extraction wells. Based on the new information on the true thickness of the LNAPL in the Rush Spring Sandstone formation, the ODEQ concludes that **extraction wells are technically infeasible**. The ODEQ directed the remedial design contractor to put the LNAPL extraction system design on hold until a decision was made regarding the new information and its impact on the design." ODEQ Memorandum 2010.*

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The results of the CRA 2010 Site-specific LNAPL mobility and body stability/migration study indicates that the LNAPL body(ies) is/are stable.

- Residual saturation testing (via the Water Drive method) – no LNAPL produced.
- Modeling using Site-specific laboratory test results, field data and modeling techniques (based on capillary pressure principles) -- LNAPL velocities less than <1 x 10-6 cm/s.
- Soil core photographs -- LNAPL is present at discrete intervals only -- in the largest soil pores within the soil/rock.
- Fluid properties physical testing (density and viscosity) – LNAPL composition vaires based on location: LNAPL at the Site is lighter-end gasoline-range materials, diesel and a mixture of gasoline and diesel.
- Saturations – 10% - 19% (API guidance <20% = residual).
- Bail down tests – well recovered only 1% to 1.6% after one month.

CONCLUSION: Only 5% of residual could be removed.

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LNAPL Removal Efficiency

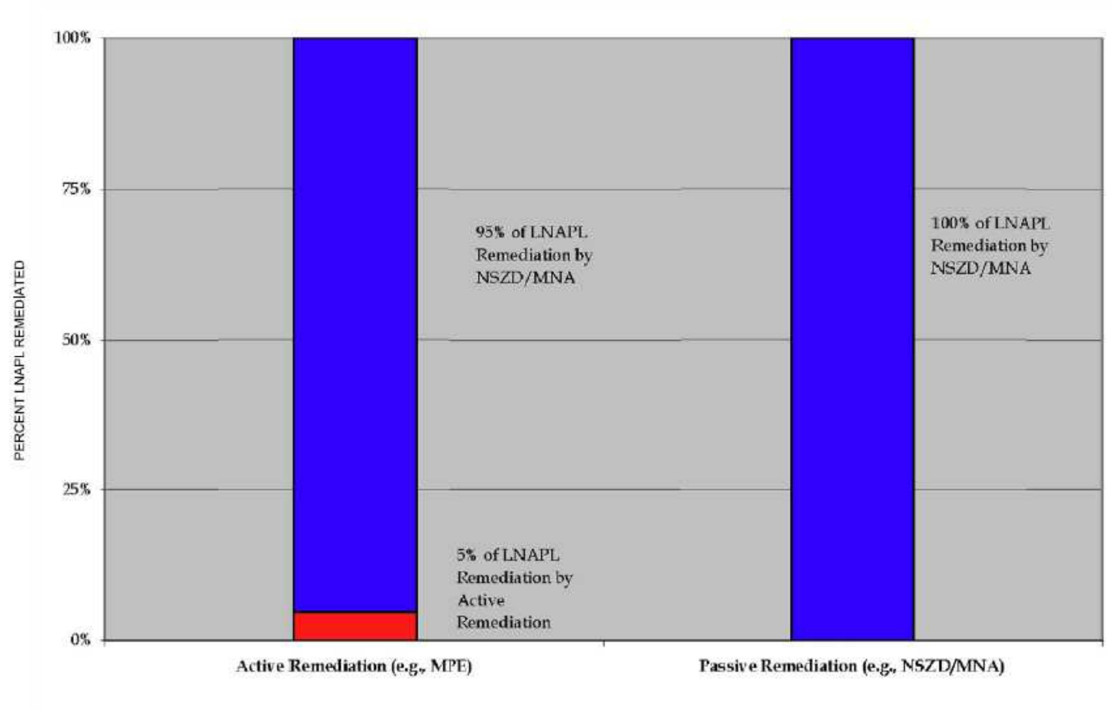

figure 8.2

NATURAL REMEDIATION IS JUST AS EFFECTIVE AS ACTIVE REMEDIATION

[redacted]

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GOVERNMENT EXPERT TESTIMONY

Government Expert 1
Report

"Groundwater cleanup to potential remedial action objectives (e.g., maximum contaminant level goals, MCLs, under the Safe Drinking Water Act) would present a great challenge because it may be technically impracticable to remove all of the subsurface LNAPL which will remain for many years under any conditions."

Government Expert 1
Deposition Testimony

Q. Why would achieving MCLs for groundwater at the ORC site pose a great challenge?

A. Cleaning up a large area of contaminated groundwater in general poses a great challenge to clean it up to MCL levels, and if there is LNAPL product there that has to be removed and remediated first prior to getting dissolved constituents at a groundwater, that makes it even more of a challenge.

Q. Why does it make it more of a challenge if LNAPL is present?

A. Because the LNAPL is a continuing source of dissolved contamination into groundwater.

Q. Why is it difficult to extract the LNAPL at a site such as the ORC site?

THE WITNESS: The LNAPL area is very large and it's difficult to remove LNAPL from large areas. You have to put in -- it is just difficult. It's very difficult in large areas to remove LNAPL completely.

Q. If you don't remove LNAPL completely, will it be possible to achieve MCLs?

THE WITNESS: No.

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Government Expert 2
Report

"In general, and consistent with prior remedial investigation findings, the field and laboratory investigation results showed that, one, subsurface soil and rock at the ORC site have limited permeability that permitted variable contaminant migration and redistribution in the subsurface over decades, and, two, the mobility and recoverability of subsurface LNAPL by pumping at the site is also limited."

Government Expert 2
Deposition Testimony

Q. So is it your opinion that the mobility and recovery of subsurface LNAPL at this site is also limited?

A. It's my opinion that the mobility and recoverability of subsurface LNAPL by pumping at the site is also limited.

Q. What is the basis for that opinion?

A. The basis for that opinion is the results of prior remedial investigation findings, the field and laboratory investigation results provided in the CRA report, and other evidence regarding the permeability of the subsurface, the mobility of LNAPL in the subsurface and the recoverability of the subsurface LNAPL.

Q. Is the mobility and recoverability of the subsurface LNAPL affected by the heterogeneity of key lithography and soil units at the site?

A. Yes.

Q. How so?

A. The mobility and recoverability of LNAPL in the subsurface can have a very complex relationship with subsurface heterogeneity, but from a simplistic perspective for a given saturation of LNAPL in a porous media, the mobility and recoverability of that subsurface LNAPL will generally increase with increasing permeability.

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Q. So generally, the less permeable the soil, the less recoverable the LNAPL, right?

A. In general, in lower permeability soils, there will often be a lower saturation of LNAPL to begin with for a given pressure that is exerted on that LNAPL, and the ability to recover LNAPL at a given saturation from a lower permeability media will generally be less than the ability to recover LNAPL that is present at that same saturation from the higher permeability media.

Q. So even if you could remove the LNAPL from, say, some geologic medias with higher permeability, you may not be able to move the LNAPL from other geologic units with lower permeability at this site. Would you agree with that?

A. In general, it's very difficult to remove all of the LNAPL from the subsurface whether it be in high permeability or low permeability media.

Q. How much LNAPL can be removed from the subsurface geologic units at this site?

A. Except if extraordinary measures were used, a substantial quantity of LNAPL would remain trapped in the subsurface.

Proposed Plan and Record of Decision

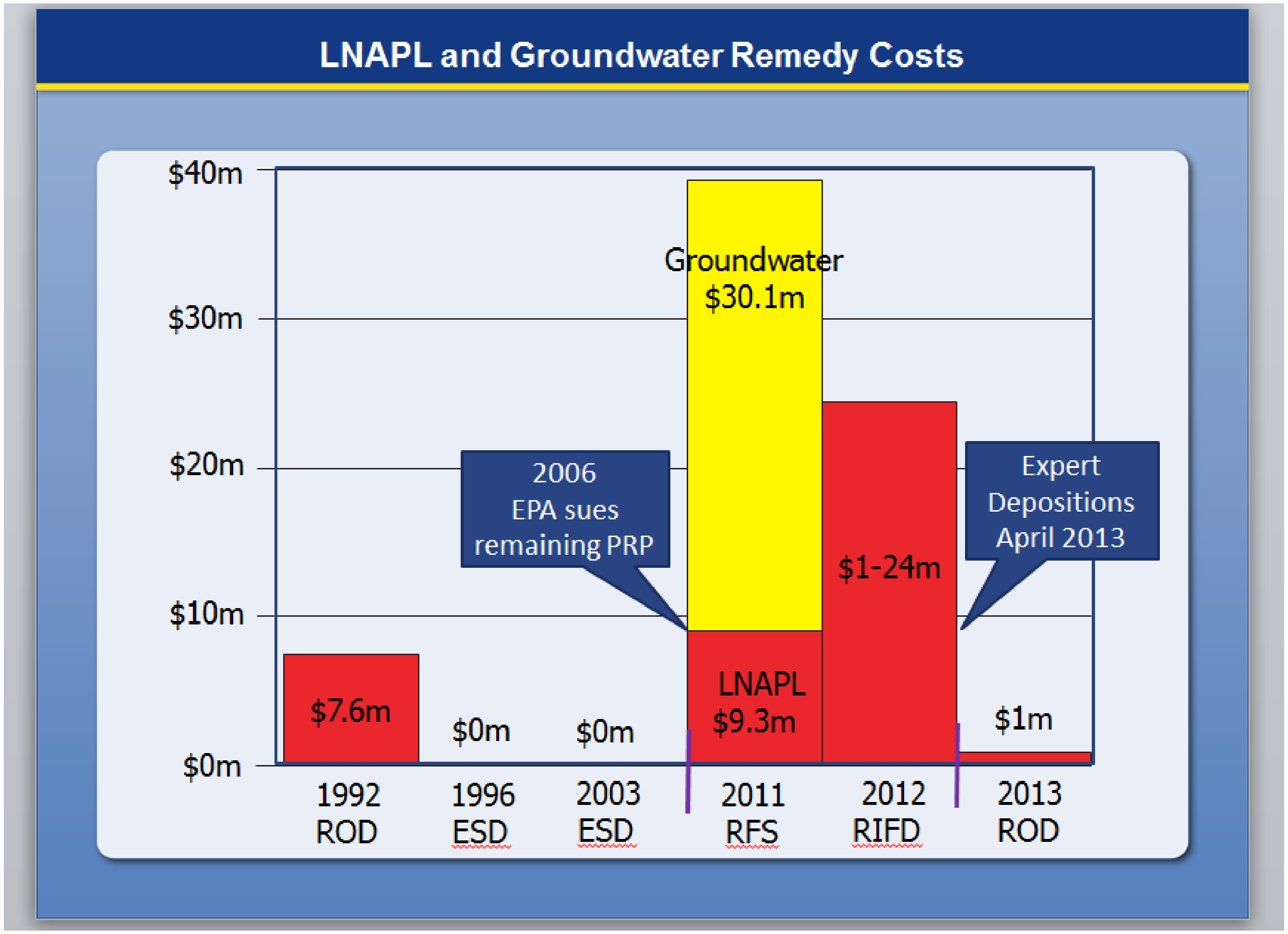
“A considerable amount of LNAPL could be removed using technologies proposed; however, a considerable percentage of LNAPL will remain due to low permeability and heterogeneity of the subsurface materials. The remaining quantity of LNAPL would be enough to provide a contaminant source to ground water for many years. Therefore there is a high degree of uncertainty whether the remedial approaches considered will provide remediation of the site in 30 years or less.”

- **Alternative 6: LNAPL Recovery / Monitoring**

  Estimated Capital Cost: $357,541
  Estimated Annual O&M Cost: $19,333
  Estimated 30 Year Present Worth cost: $950,218
  Estimated 100 Year Present Worth cost: $1,017,525
  Estimated Construction Timeframe: 1 month
  Estimated Time to Achieve RAOs: 100 Years

"Alternative 6 provides a cost effective method of LNAPL recovery to the extent practicable. As stated in the 199 6 USEPA Guidance document, How to Effectively Recover Free Product at Leaking Underground Storage Tank Sites, LNAPL would be removed from the ground water until the performance standard (a threshold thickness of 0.1 foot of LNAPL, measured using an interface probe in monitoring or extraction wells) is attained."

"This alternative would be compliant with the Oklahoma Solid Waste Management Act (OAC 252:515), the Oklahoma Hazardous Waste Management Act (OAC252:505) and the Federal Hazardous Waste Management Regulations (40 CFR Parts 262 & 263 and CERCLA Offsite Rule, 40 CFR 300.440). Transportation of recovered LNAPL to an off-site disposal facility would be conducted pursuant to Federal and State transportation and disposal regulations."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