Remediation: When is Clean, Clean Enough?

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OUTLINE – 2 NEW ENGLAND SITES

• SITE 1: Large LNAPL “Free Oil” Site – urban area
  – Developed during WWII as a bulk oil terminal
  – 30 acres, deep water frontage, highly developed (and valuable) area – no longer used for oil storage
• Non-Aqueous Phase Liquid (LNAPL-oil) over 10 acres

• SITE 2: Small Hydrocarbon and Ethylene Glycol GW Impacted Site – rural area
SITE 1 LAYOUT & IMPACTS

- Barge Dock
- Tank 18
- Bio-piles
- Teen Series
- Tank Dike
- Office
- 20 Series
- Tank Dike
- Boilers
- MPE System
- Condo
- Claire’s
- Garage Bldg
Client spent approx. $12 Million/8 years with another consultant prior to our involvement:

- 420 Monitoring Wells
- Multiphase extraction (MPE) system with thermal oxidizer was being used to remove LNAPL and treat groundwater
- Oil skimmers used to recover small amounts of LNAPL
- Remediation standard = less than 0.5 inches of LNAPL measured in MW
- Remedial approach was to remove “all the oil”
- The client was spending approx. $1 million/yr to address impacts mostly by running the MPE system
SITE 1 - OUR STRATEGY: DEVELOP CONCEPTUAL SITE MODEL

Apply Current LNAPL Science to Evaluate Technical Impracticability of 0.5 inch LNAPL Standard:

- Understand oil types
- Define residual oil saturation $C_{\text{sat}}/C_{\text{res}}$
- Characterize GW, Soil Gas impacts
- Consider oil viscosity
- Understand LNAPL mobility
- Evaluate risks to human health and the environment
- Look at trends

- Assess existing remedial approaches
SITE 1: ASSESS MPE SYSTEM RESULTS (5+ years)

Declining LNAPL recovery
- Pumping more water, less oil
- Increasing energy costs (cracking chemistry, trucking waste streams, etc.)
- Applied Oil Field Recovery Curve Analysis

CONCLUSION: Remedy Not sustainable
Oil Mobility & Recoverability Is Governed By Soil Saturation

Soil Saturation Limit

Zone A
Oil not present

Zone B
Immobile oil present

Residual Saturation

Zone C
Potentially mobile/potentially recoverable oil present

Oil Saturation (%)

Low

High
SITE 1- CSM FINDINGS

• LNAPL Low mobility
• Total oil recovered is 58,000 gallons
• MPE system removed only 15 gal/day LNAPL
• 200,000 to 300,000 gallons of oil remain in soil at residual saturation (not recoverable)
• Oil not readily soluble - GW standard was met
• Oil was not volatile – soil gas concentrations met standards
• LNAPL at steady state or shrinking
SITE 1- UNSUSTAINABLE REMEDY

• We understood that the remedial approach previously implemented by others was not sustainable:
  – LNAPL skimmers were not effective- removing < 1 gal/mo
  – MPE system used 20,000 gal Propane per month
  – Electricity costs $2,000-$3,000 per month
  – Off-site shipments of MPE waste averaged 4,000 gals/3 days
  – MPE system removed 6.1 million gallons of groundwater
  – Actual LNAPL removed was approximately 58,000 gallons (less than 1% of total fluids removed by MPE) and rate of removal was declining
  – Remedial costs were averaging $1M/yr – no end in sight

For every gallon of diesel fuel removed, the MPE system expended energy equal to approximately 140 gallons of diesel to do it.
SITE 1- DATA SHOW SHRINKING LNAPL – 3 YEARS
Natural depletion rate (calculated from methane flux) was much greater than the amount of LNAPL recovered by the active systems

(80 gal/day via natural decay vs 15 gal/day via active treatment)
SITE 1 – CONCLUSION

- MPE system ineffective
- LNAPL recovery efforts would not achieve standards
- Widespread LNAPL and residual soil impacts remain
- Human health risks < 1x10^{-5} ILCR demonstrated
- Natural attenuation effective

Our data supported a regulatory change to eliminate the 0.5 inch LNAPL standard – new standard based upon risk and recoverability

*The site was sold for $29M and is being redeveloped for maritime use.*
SITE 2: Industrial Site in Rural Setting

- Industrial Use (Critical Facility) 50+ Years
- Near sensitive receptors:
  - Bedrock Aquifer with water supply wells
  - National Park
  - Wetlands
- Spills
  - Diesel Fuel (500-1,500 gal)
  - Ethylene Glycol (200-300 gal)
SITE 2- Site Geology Controls Risks

- Receptor Survey (Aquifer)
- Fracture Trace Analysis
- Bedrock Cores/Mapping
- Bedrock Monitoring Wells
- Long Term Monitoring
- GW Flow Travel Time (important for EG release)
- Contaminant Fate/Half Life

*These analyses confirmed the need for a rapid reduction of source concentration of ethylene glycol*
SITE 2- Source Treatment - ChemOx

Hydrogen Peroxide Application

Effervescent Groundwater

ORC Polishing
SITE 2 – Closure

• Source Treatment/Remediation Was Quick (i.e., reactions were over in a few days)
• Long Term Monitoring and Groundwater Analytical Modeling Confirmed Impacts Remained On-Site
• Data Indicated Decay of Source (diesel and EG) By Natural Processes
• No offsite treatment necessary based upon risk analysis
CONCLUSIONS

• Remedies should be selected with the end in mind:
  – Cost Effective Over the Remedy Life Cycle
  – Sustainable (costs, carbon footprint, etc.)
  – Apply Scientific Principles
  – Utilize Natural Processes
  – Consider Future Site Use
  – Manage Exposure Pathways
  – Remedy May Not Need To Remove All Impacts
  – Protection of Human Health and the Environment
Questions?

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