Remediating 46 Acres of Jet Fuel with Biologically-enhanced Soil Vapor Extraction/Bioventing

Endpoint Strategy and Regulatory Closure Process

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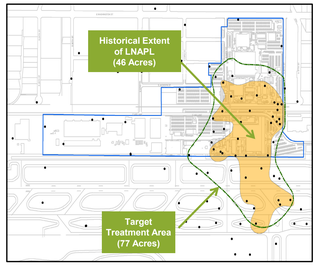
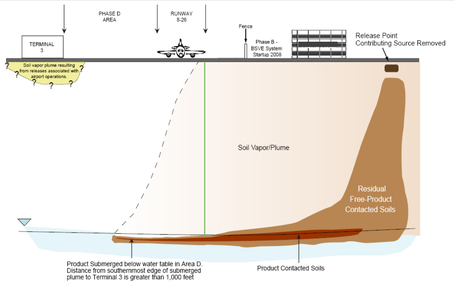
The Site

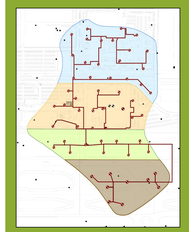


- 118-acre aircraft engine manufacturing and testing facility
- Began operations in the 1950s
- Jet fuel usage of approximately 1 to 2 million gallons per year

Historical Conceptual Site Model



Remedial Alternative Selection

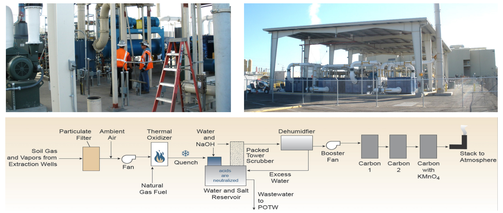


BSVE/bioventing with limited LNAPL skimming

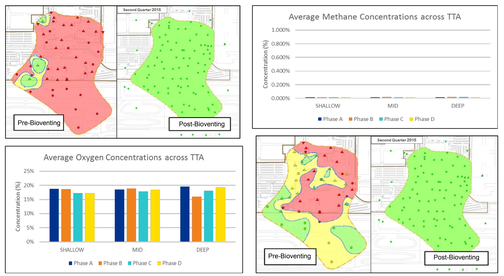
- 77-acre target treatment area
- 58 injection/extraction wells
- 17 process monitoring wells
- 14 sentinel monitoring wells clusters, and 53 groundwater monitoring wells
- 1 mile of trenches
- Over 5 miles of subsurface and aboveground piping

Major Events Timeline

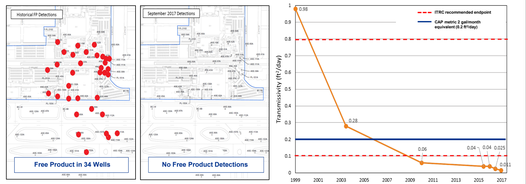
BSVE/Bioventing System



Deep Oxygen/Methane



LNAPL Detection and Transmissivity



Corrective Action Confirmation

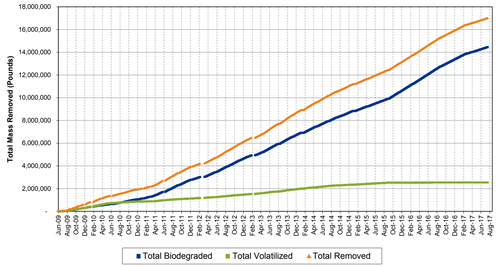
2005 Corrective Action Plan Confirmation Requirements

- LNAPL: LNAPL thickness <0.1 foot or LNAPL recovery rates <2 gallons per month
- Groundwater (Tier 1): COC concentrations below MCLs
- Soil (Tier 1): COC concentrations below Soil Remediation Levels in whole soil samples quotient <1

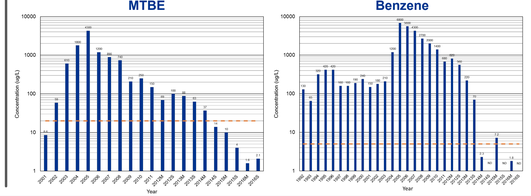
2017 Final Confirmation Requirements

- LNAPL: Based on LNAPL not being a source to groundwater and (indirectly) decreasing LNAPL transmissivity
- Groundwater (Tier 1): Based on declining benzene and MTBE concentrations to levels below MCLs
- Soil (Tier 3): Based on historical soil data and modeling new soil-gas sample data showing cumulative cancer risk <1x10-6 and hazard quotient <1

Petroleum Hydrocarbon Mass Removal



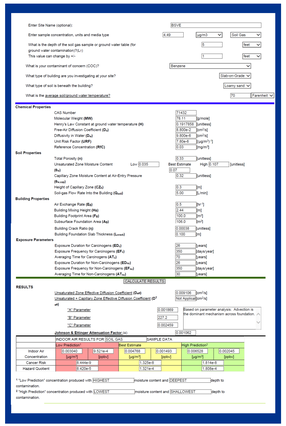
Historical Groundwater Quality



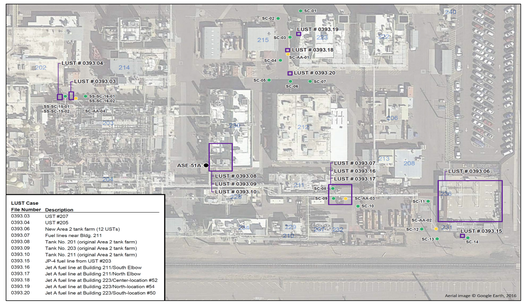
Johnson and Ettinger Vapor Intrusion Model

Forward Calculation

- All compounds with a maximum concentration exceeding 10 percent of the RSL were modeled
- Model inputs
  - Chemical-specific properties
  - Soil properties
  - Structural properties of the building
  - Exposure parameters
- High indoor air prediction results were used for a conservative approach
  - Cumulative cancer and hazard risks calculated separately
  - petroleum-based COCs (associated with the UST jet fuel releases)
  - nonpetroleum based compounds
  - Standards were <1x10-6 (cancer risk) and <1 (hazard quotient)



Confirmation Soil and Soil-gas Sampling Locations



Results

- Remediation
  - Removed more than 7,500 gallons of free product via direct liquid recovery
  - Removed over 17 million pounds of petroleum hydrocarbons via BSVE/bioventing
  - Reduced dissolved-phase concentrations to below corrective action standards
- Confirmation Sampling and Risk Modeling
  - Results from soil samples collected at seven LUST locations were below residential standards
  - Results from soil-gas samples collected at eight LUST locations with subsequent modeling were below risk-based corrective action standards
  - Cumulative cancer and hazard risks for petroleum-based COCs ranged from 4.30 x 10-7 and 0.0136 to 4.87 x 10-7 and 0.0527, respectively
  - 80 percent of compounds not detected

Summary

- BSVE/bioventing successfully remediated the site
  - Full LUST case closure granted November, 2017
  - Free product was reduced from a 46-acre plume to undetectable
  - Dissolved benzene and MTBE concentrations reduced from thousands of µg/L range to below drinking water standards
  - Total operational cost below $1.00 per pound
- Biodegradation was the primary treatment mechanism
  - 15,000,000 pounds (86% of total) biodegraded
  - 2,550,000 pounds (14% of total) volatilized
  - 53,000 pounds (<1% of total) removed as free product
- Confirmation of soil remediation was conducted with soil-gas sampling and site closure was approved using a risk-based approach
  - Saved client thousands of dollars in drilling/soil sampling costs