Innovation that provides sustainable solutions to complex challenges worldwide

A Bioventing System Destroys Multimillions of Pounds of Petroleum Hydrocarbons - An Inquiry into the Mass Removal Mechanisms

April 10, 2018

Victor Gamez Grijalva (victor.gamezgrijalva@ch2m.com, JACOBS, Phoenix, AZ, USA)
Tom Palaia (JACOBS, Denver, CO, USA)
Robert Frank (JACOBS, Phoenix, AZ, USA)
Rob Hinchee (IST, Panacea, FL, USA)

JACOBS®

CH2M is now Jacobs

www.jacobs.com | worldwide

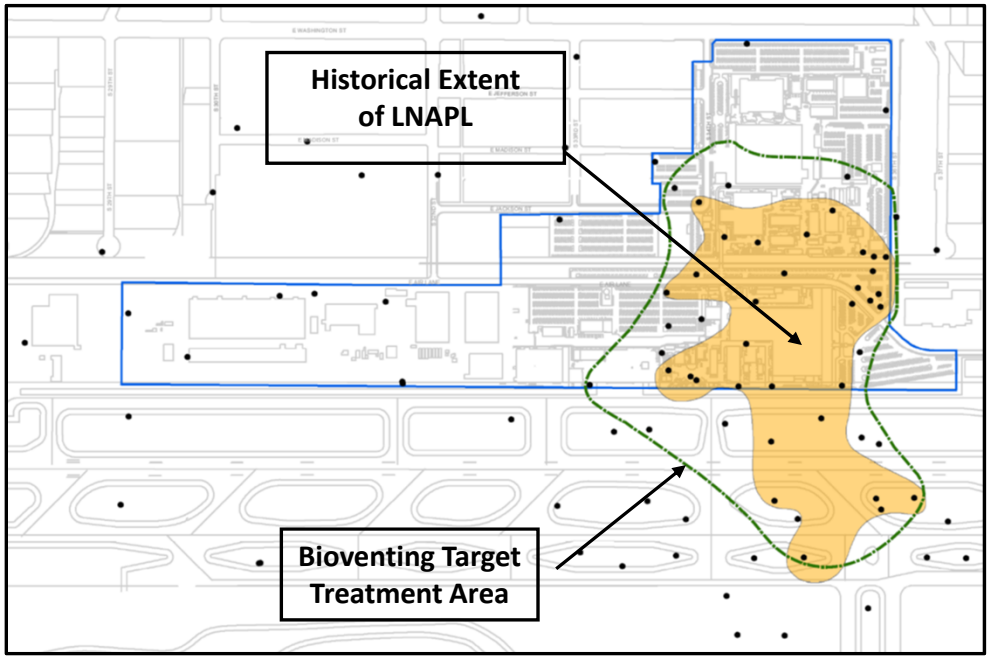
Agenda

- The Site
- Conceptual Site Model
- Site Conditions Pre-Remedy
- Remedial Alternative Selection and Strategy of Operation
- Mass Removal Mechanisms
- Site Conditions Post-Remedy
- Summary

JACOBS

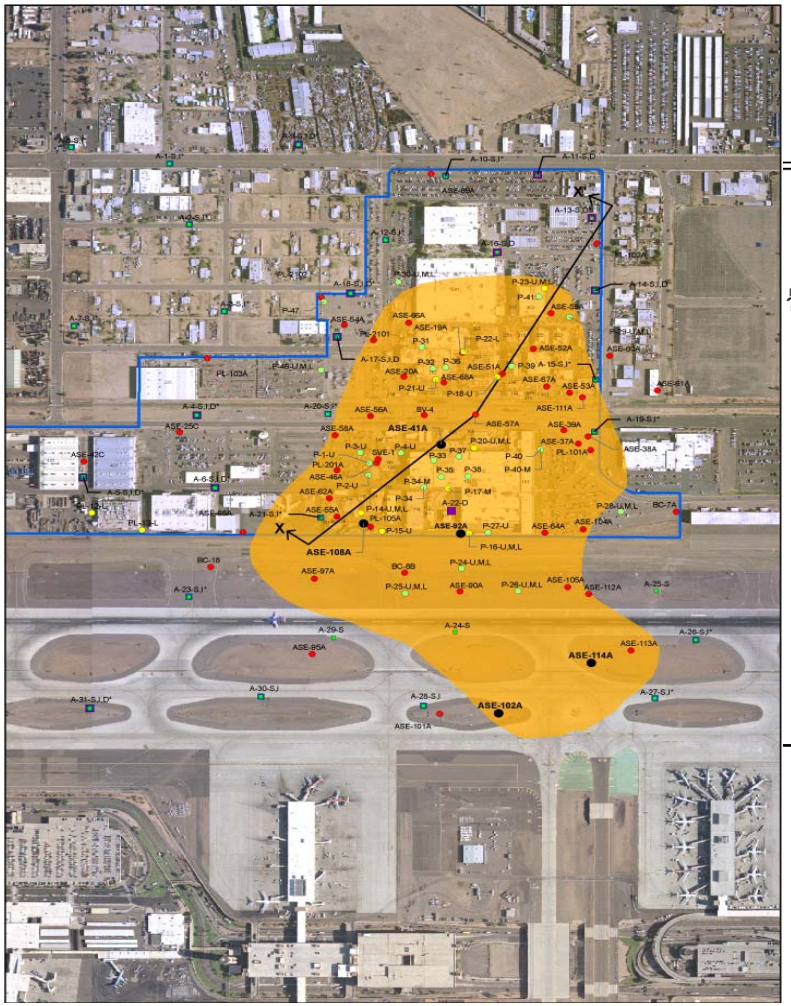
The Site

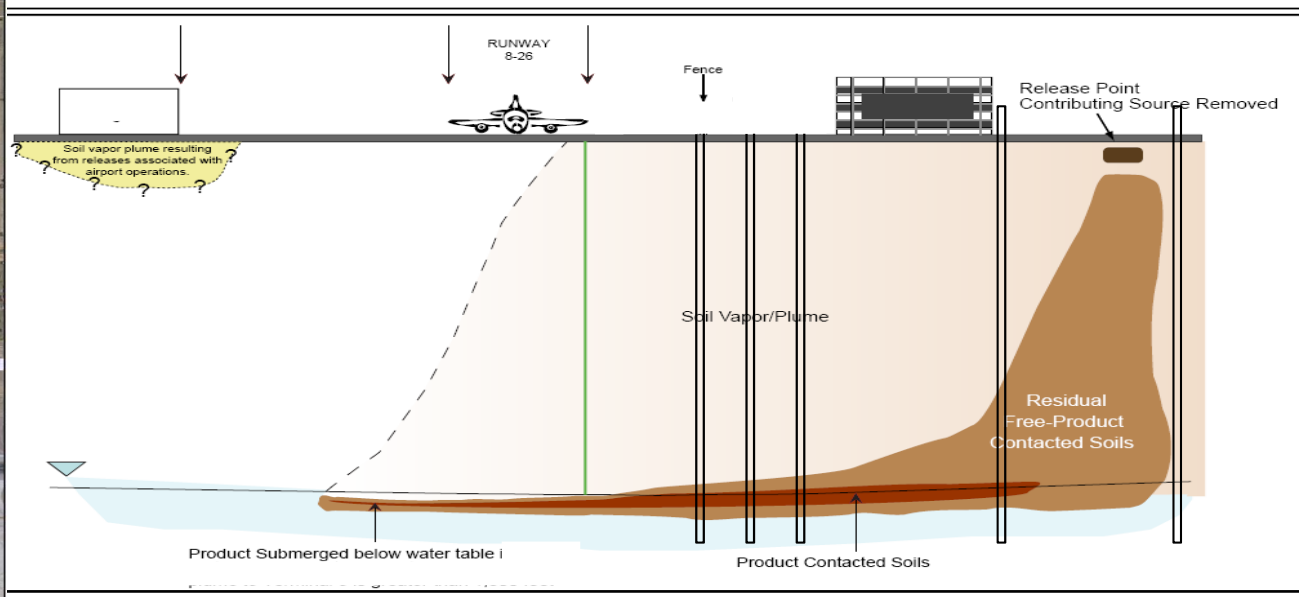
- 118-acre aircraft engine manufacturing and testing facility
- Began operations in the 1950s
- Jet fuel usage of approximately 1 to 2 million gallons per year



JACOBS

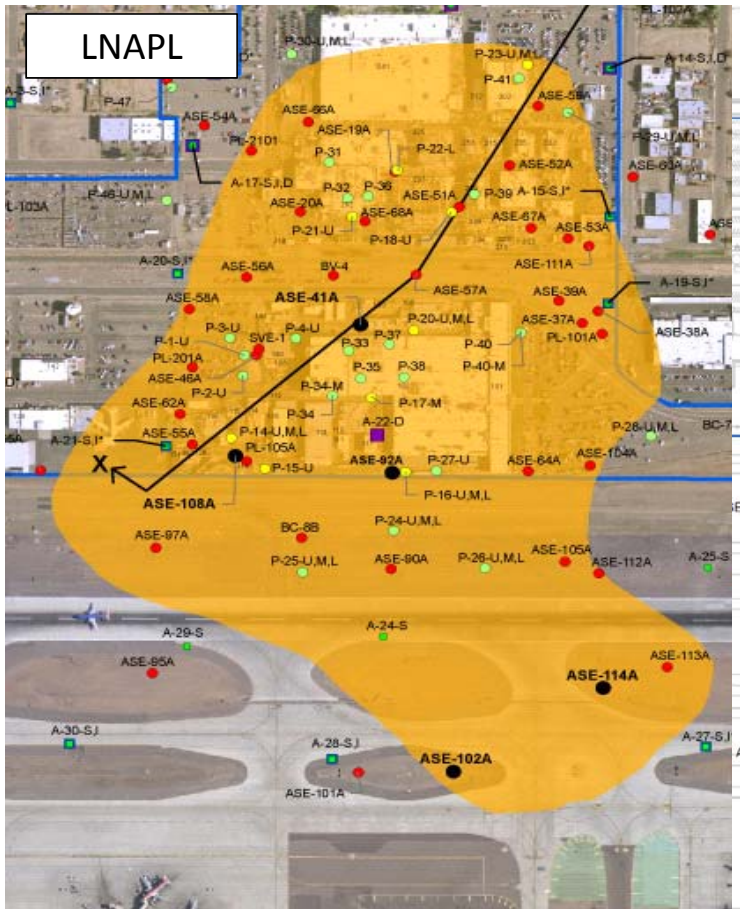
Conceptual Site Model

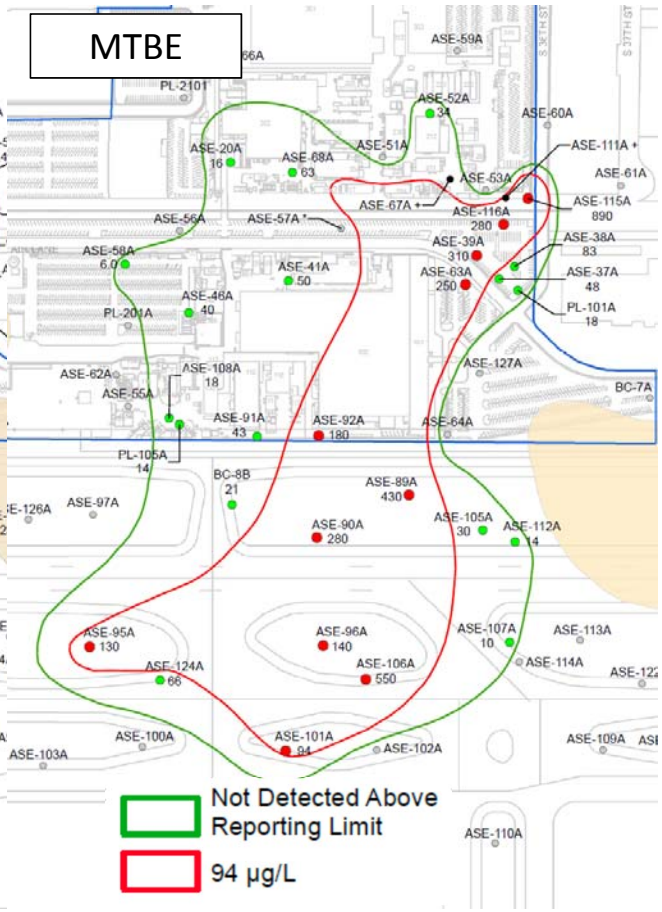




JACOBS®

Groundwater/LNAPL – Pre-Remedy

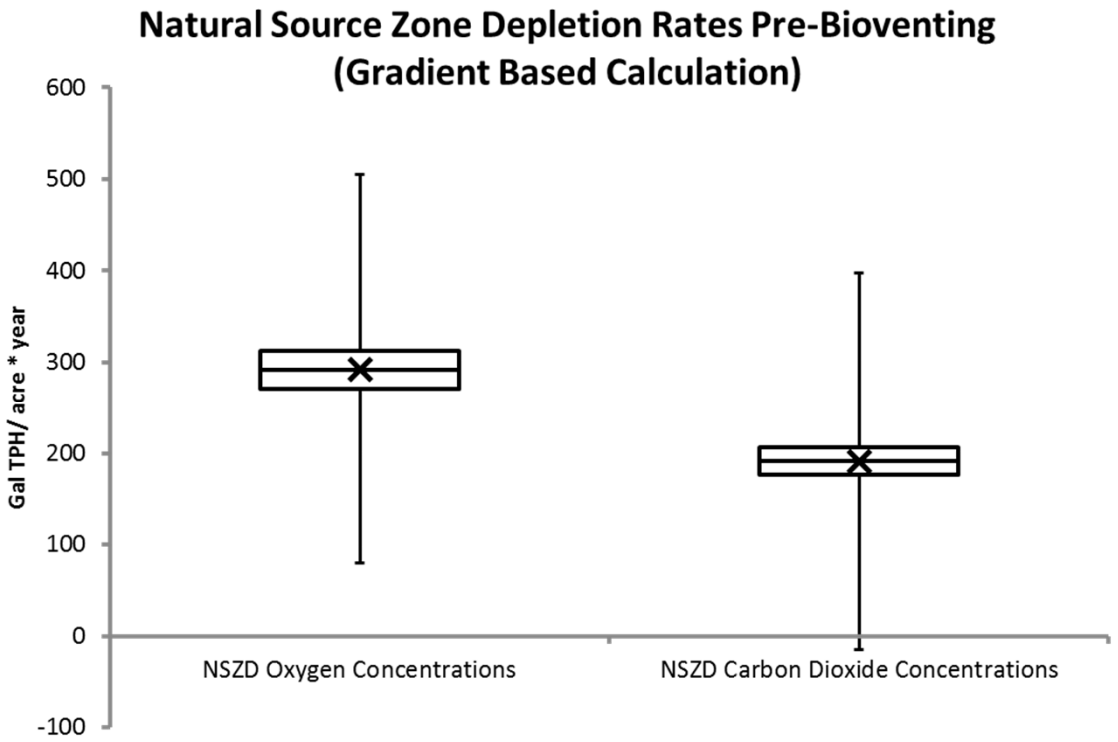


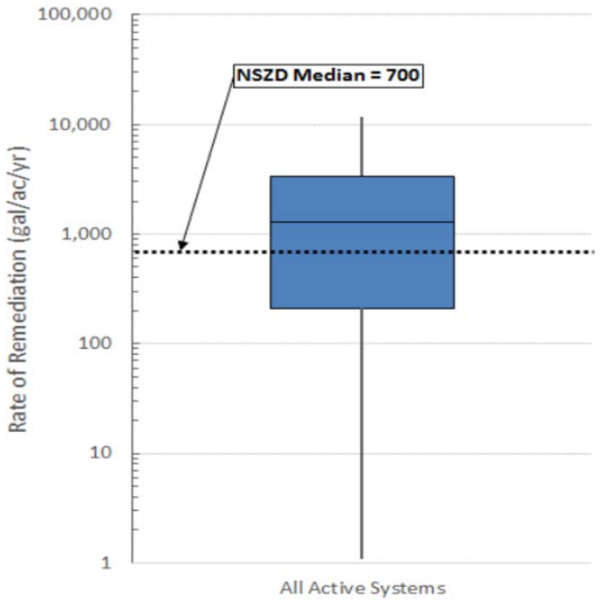


0.5 Miles

JACOBS

NSZD Rates – Pre-Remedy

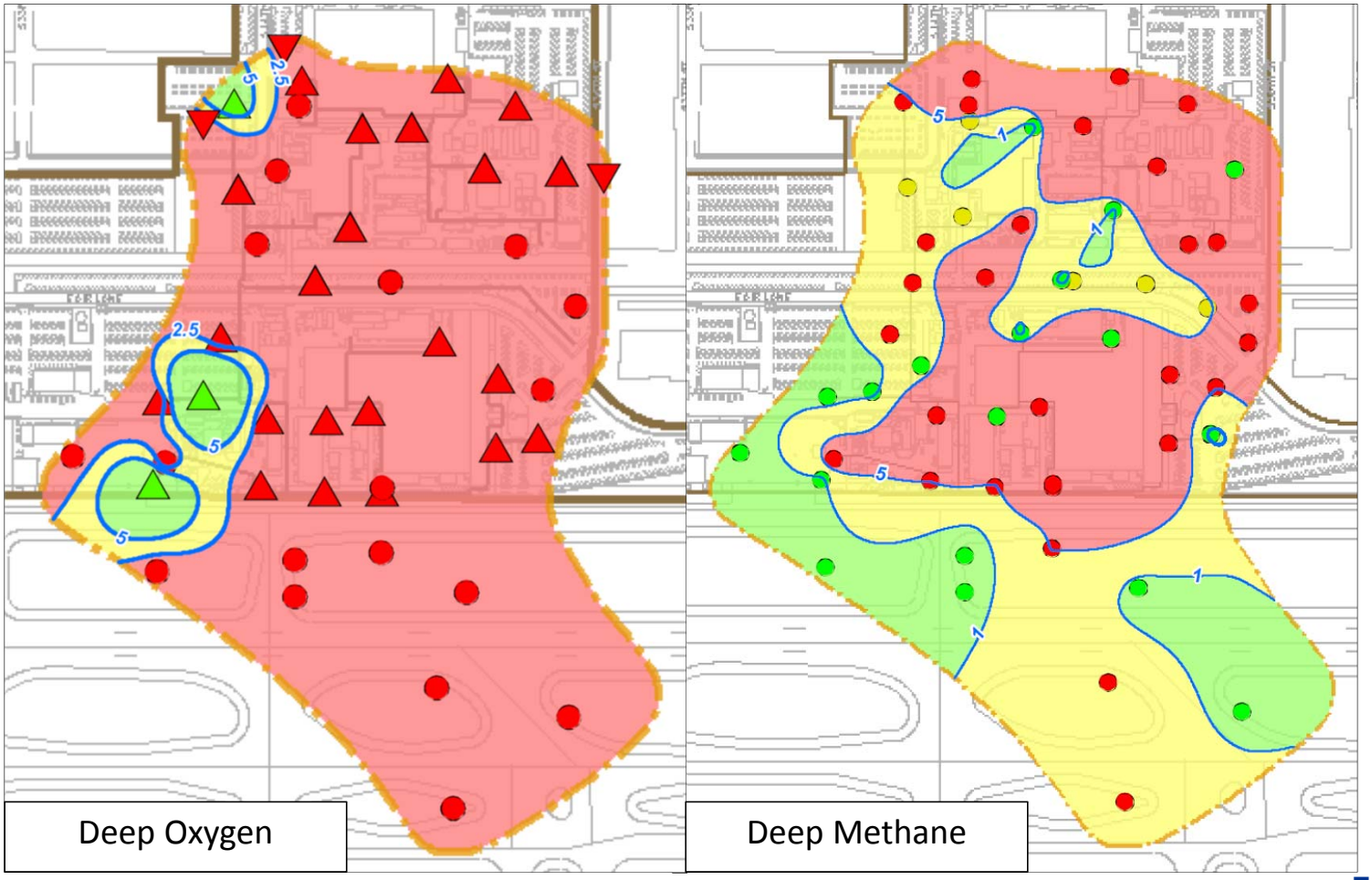




From T.Palaia, 2016. Applied NAPL Science Review, Vol. 6, Issue 1. May.

JACOBS

Vadose Zone – Pre-Remedy



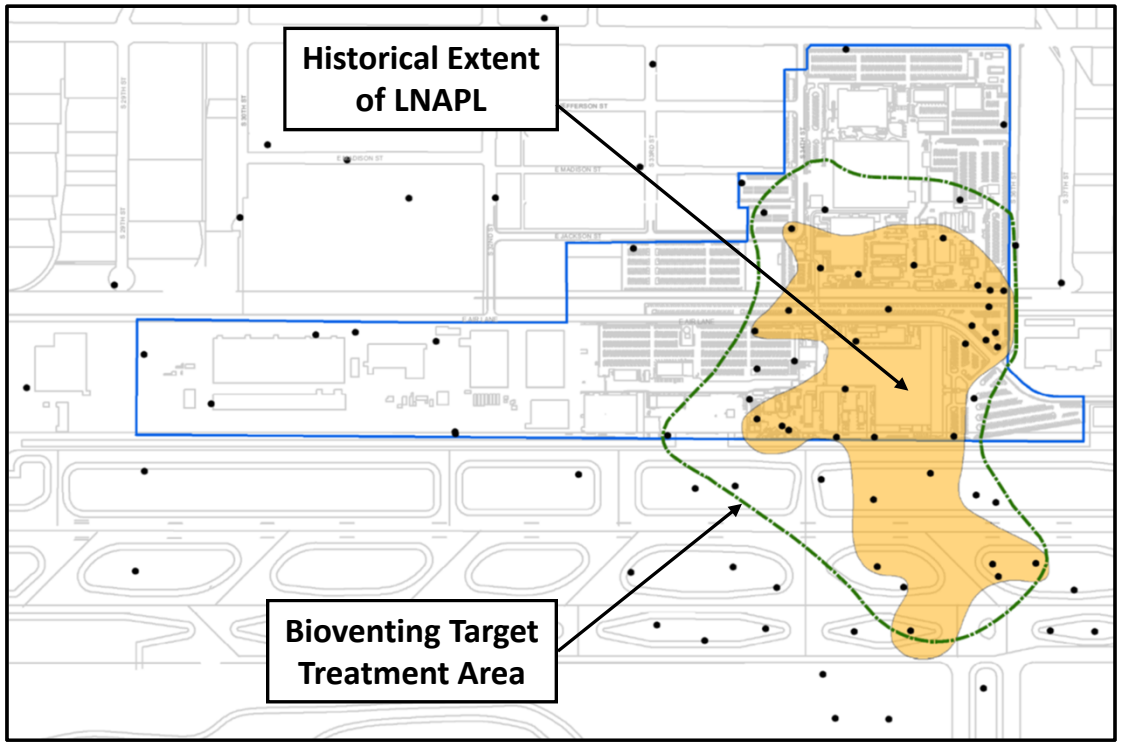
Deep Oxygen

Deep Methane

JACOBS

Remedial Alternative Selection

- Bioventing with limited LNAPL skimming
  - System started in extraction-only mode
  - Transitioned to mixed injection/extraction
  - Once safe, 100% injection
- 77-acre target treatment area
  - Based on historical extent of LNAPL (46 acres)
  - Expanded based on evidence of petroleum-hydrocarbon contamination in soil and soil vapor



JACOBS

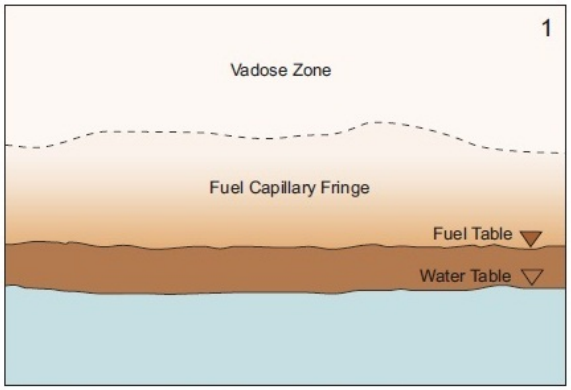
Why Bioventing?

- Release consisted of light and heavy components
  - Jet-A (C8 - C14)
  - JP-4 (C4 – C16)
- Large ROI
  - Able to remediate under buildings
  - Fewer wells needed
    - Active facility
    - Airport
- Anaerobic degradation occurred in the subsurface, resulting in the production of methane.

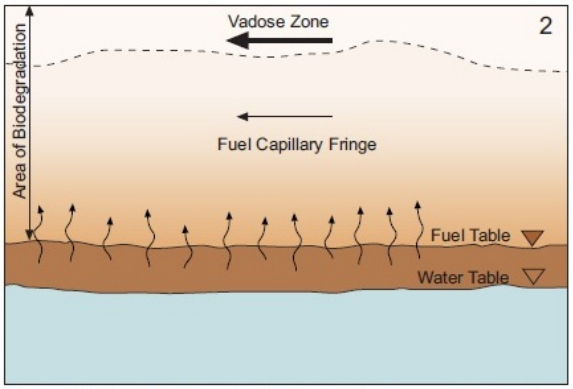
JACOBS

Addressing LNAPL through bioventing

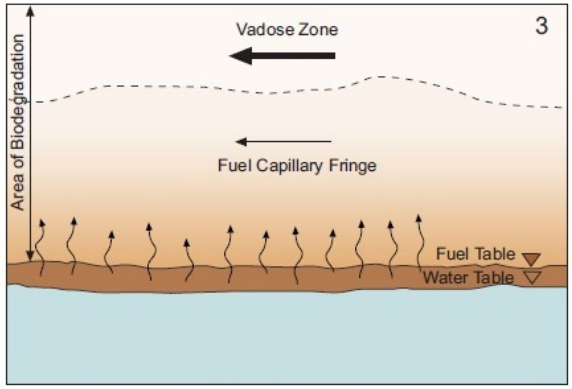
Equilibrium Conditions



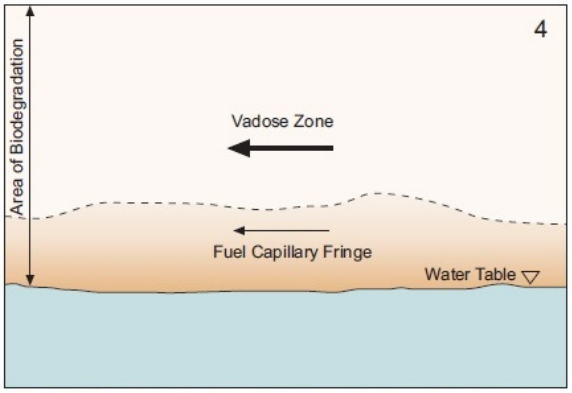
System Start-up



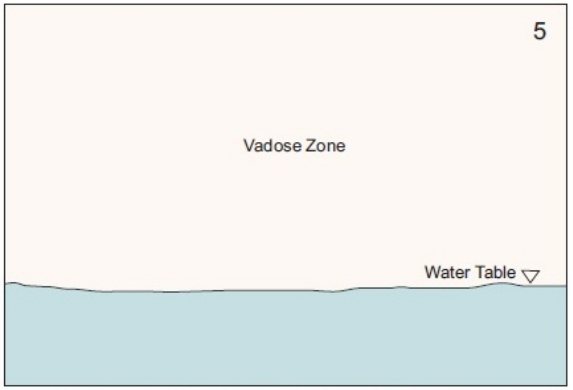
Removal of Free-phase Hydrocarbons



Continued System Operation



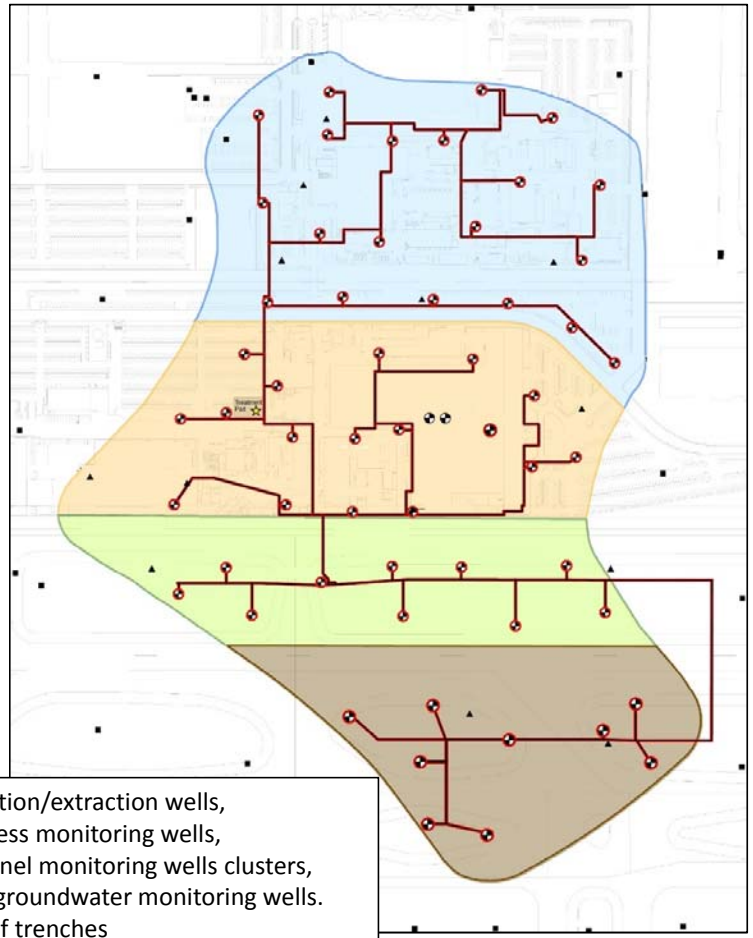
System Shut-down



JACOBS

Strategy of Operation

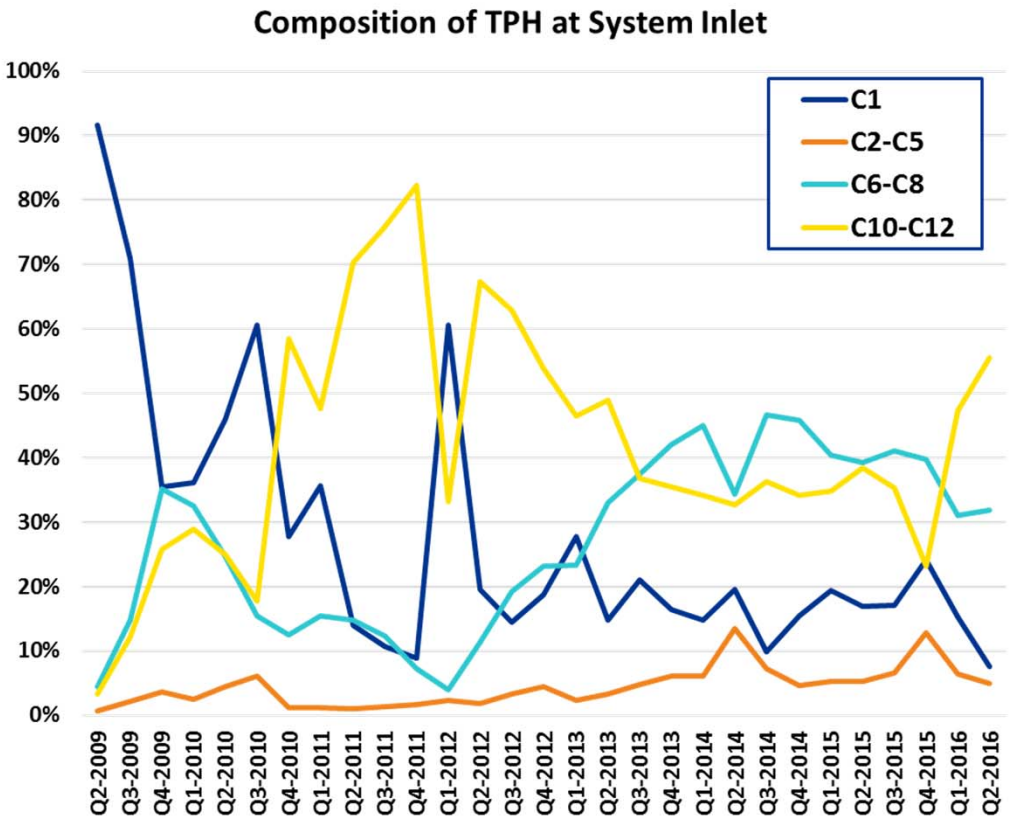
- STAGE 1 (0 – 4 years)
  - Initial stage of extraction based operation:
    - Remove methane.
    - Remove light components of jet fuel.
    - Reduce source strength.
- STAGE 2 (4 – 6 years)
  - Balanced extraction and injection:
    - Continued removal of light components with decreasing water levels.
    - Promote aerobic biodegradation.
- STAGE 3 (6 – 9 years)
  - Injection based operation:
    - Reduce residual mass consisting of heavier compounds.

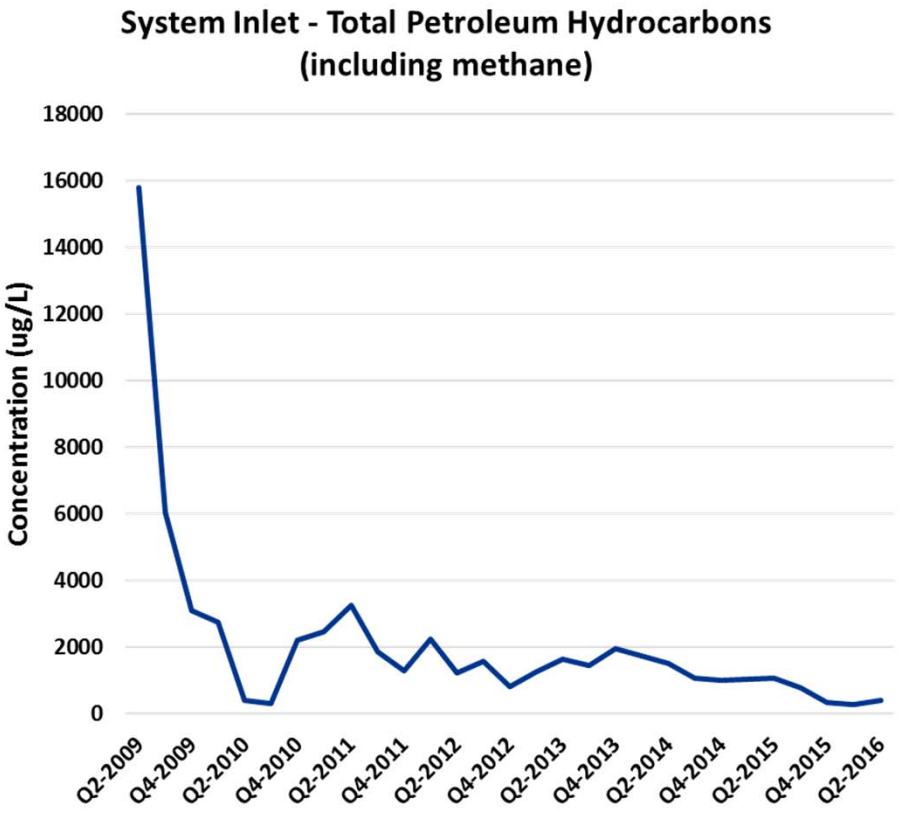


- 58 injection/extraction wells,
- 17 process monitoring wells,
- 14 sentinel monitoring wells clusters,
- and 53 groundwater monitoring wells.
- 1 mile of trenches
- Over 5 miles of subsurface and aboveground piping

JACOBS

Bioventing – Soil Vapor Composition

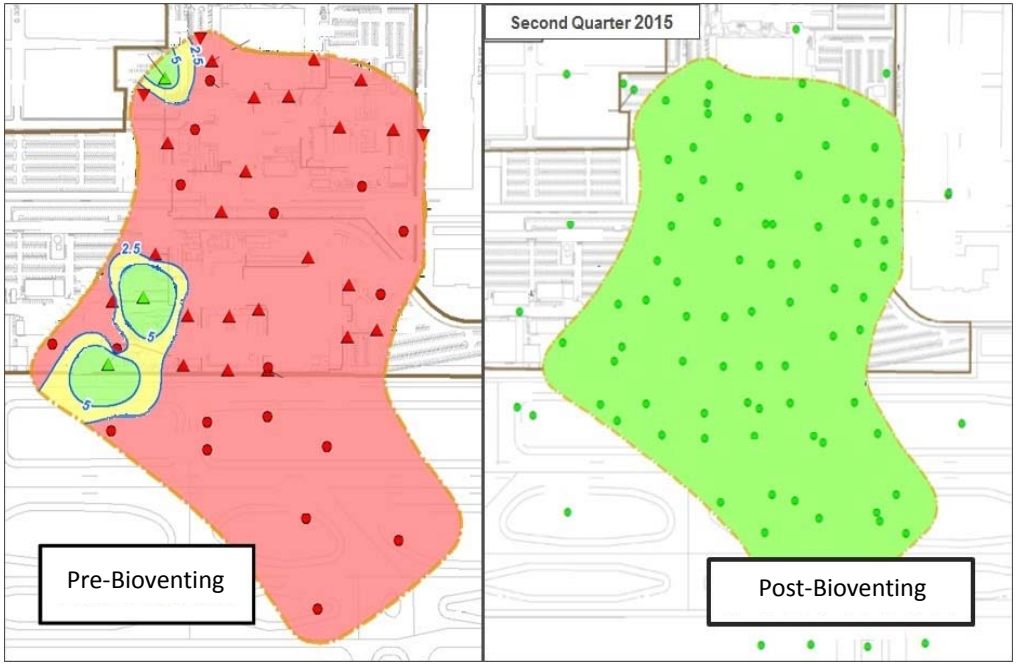




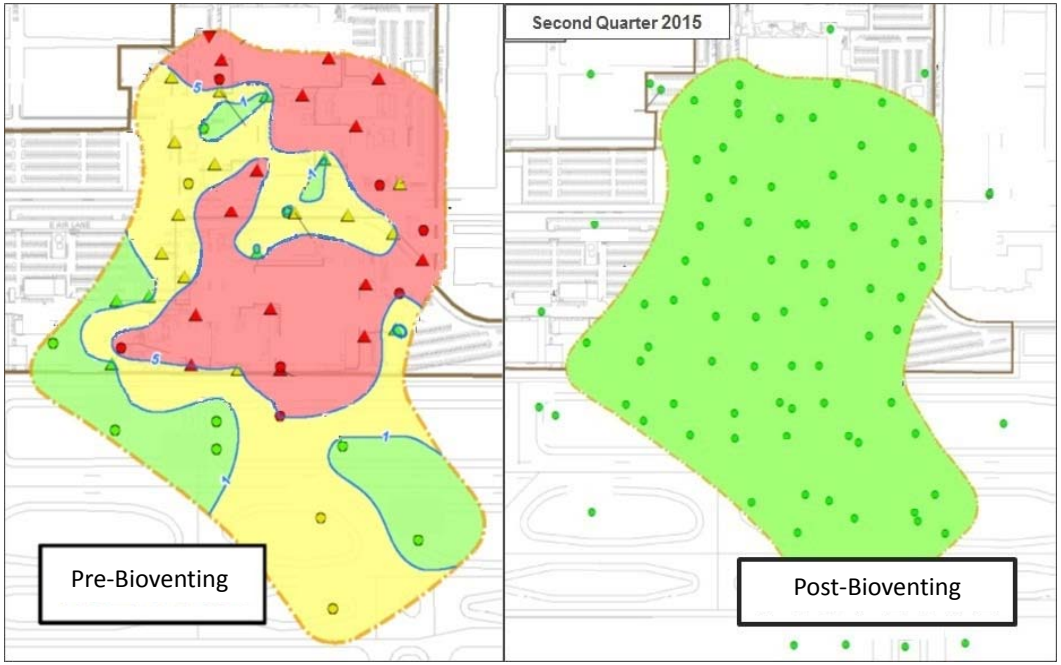
JACOBS

Bioventing – Deep Oxygen/Methane

OXYGEN



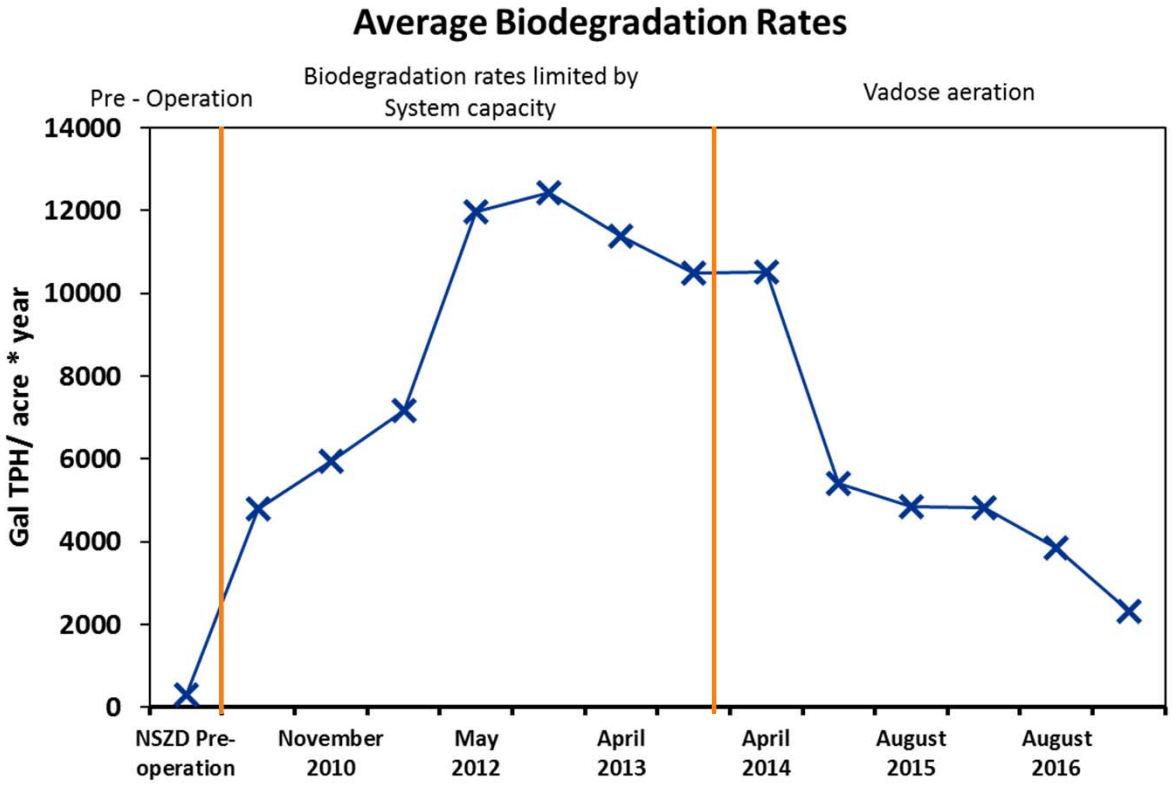
METHANE



JACOBS

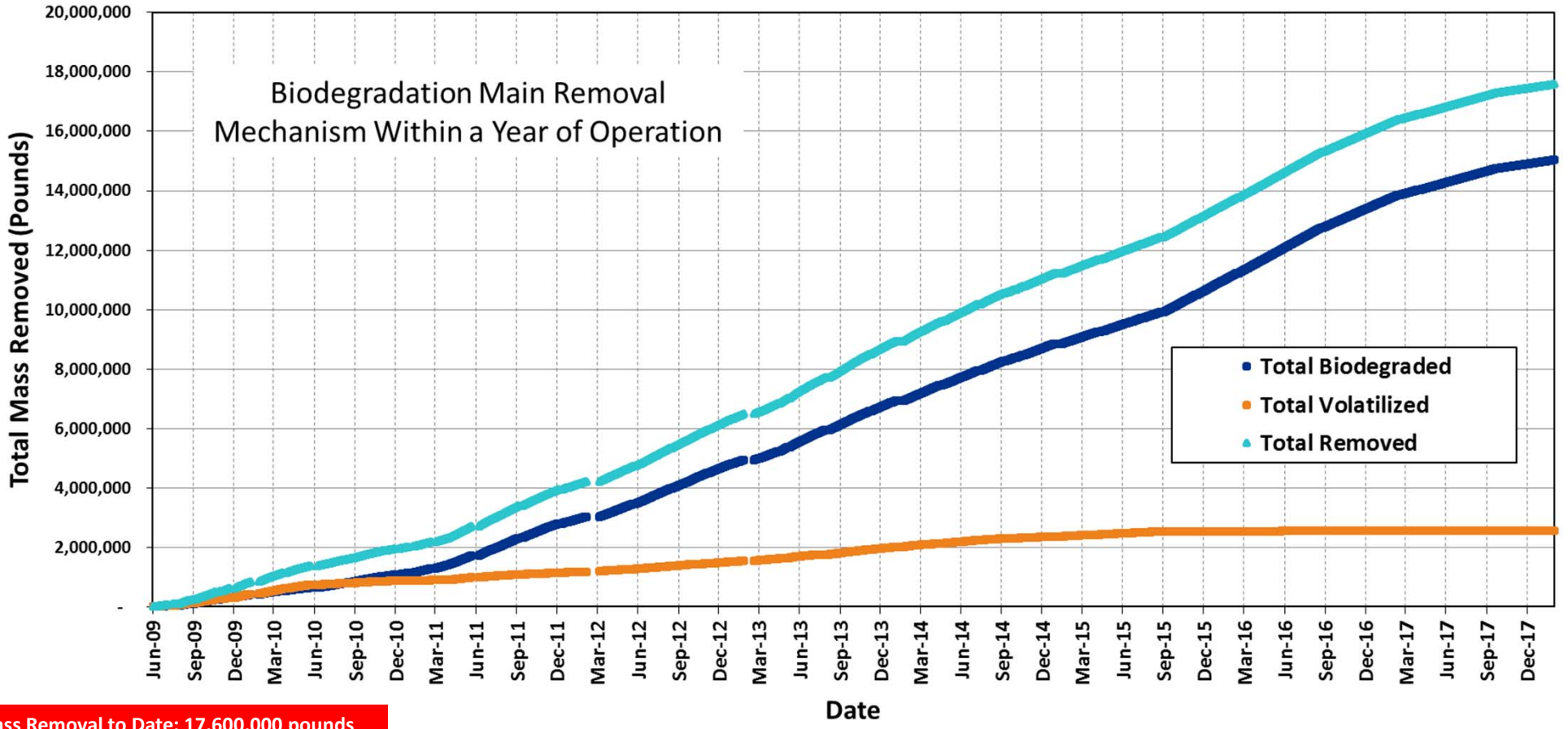
Biodegradation Rates

- At start-up
  - Rates increased several orders of magnitude after startup.
- After startup
  - Rates limited by system capacity to deliver air (extraction + injection).
- Operational end
  - Rates decreasing due to most of mass already removed by system.



JACOBS

Mass Removal

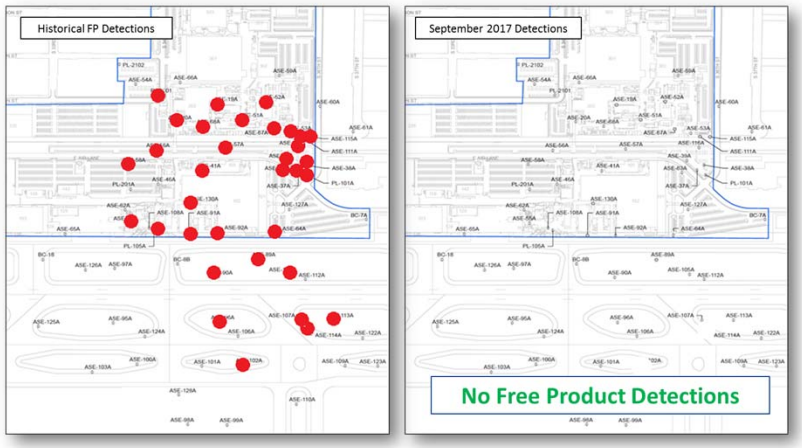


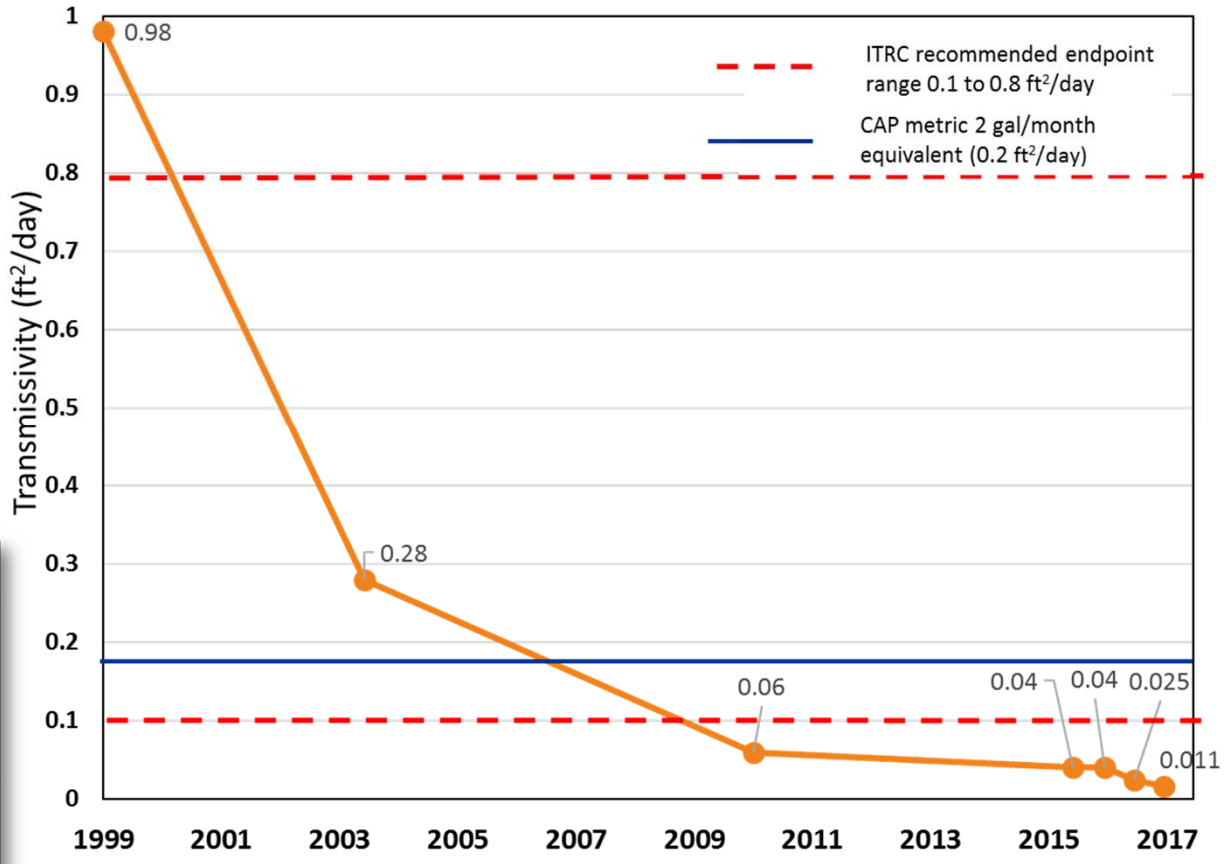
Mass Removal to Date: 17,600,000 pounds
Biodegradation: 15,000,000 pounds;
Volatilization: 2,550,000 pounds (≈60% Methane);
LNAPL recovery: 53,000 pounds

JACOBS

LNAPL Transmissivity

- About 7,500 gal of LNAPL removed by automatic/manual recovery.
- LNAPL recovered accounts for <1% of total mass removed.

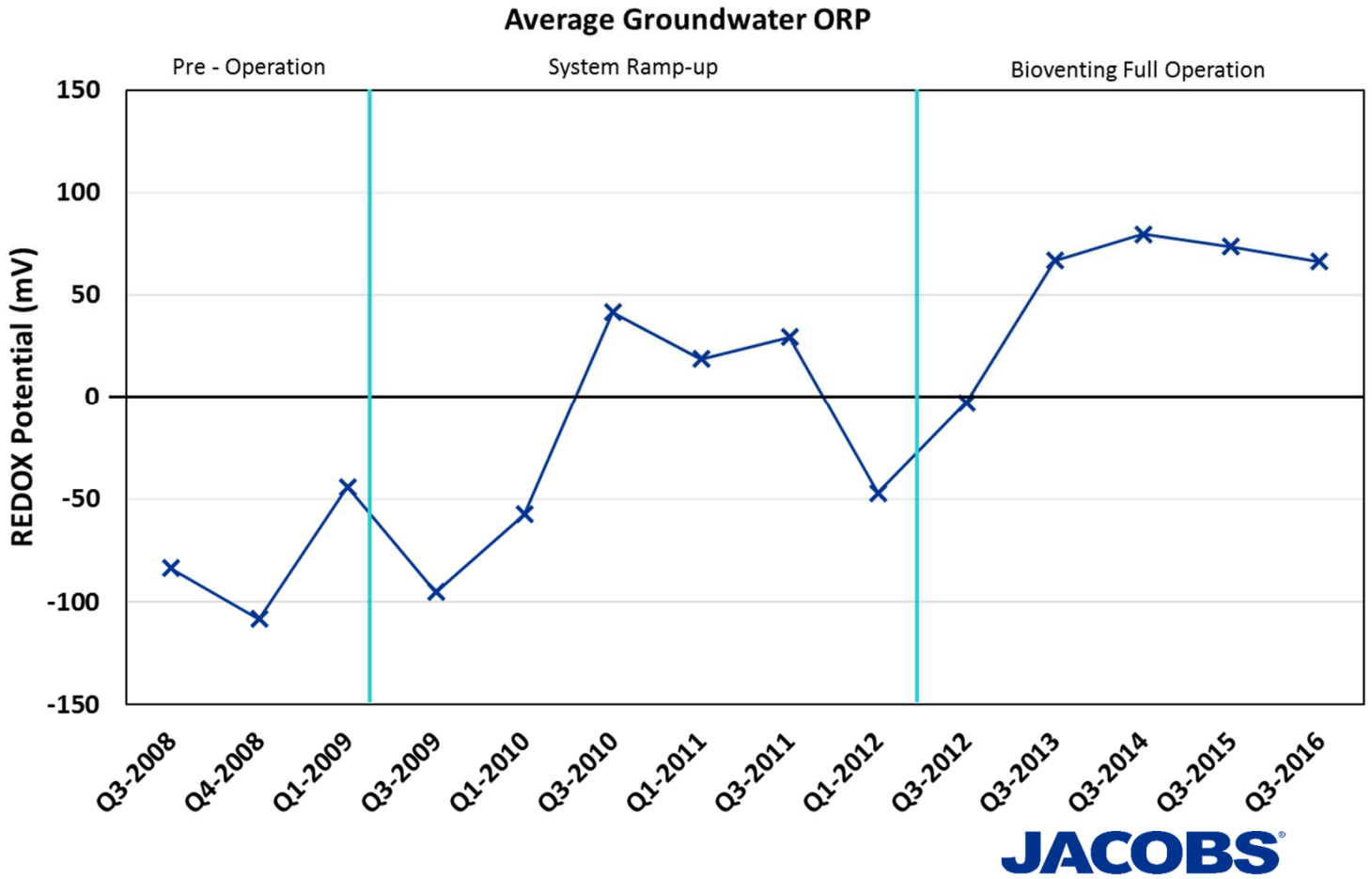




JACOBS

Groundwater Quality – REDOX Potential

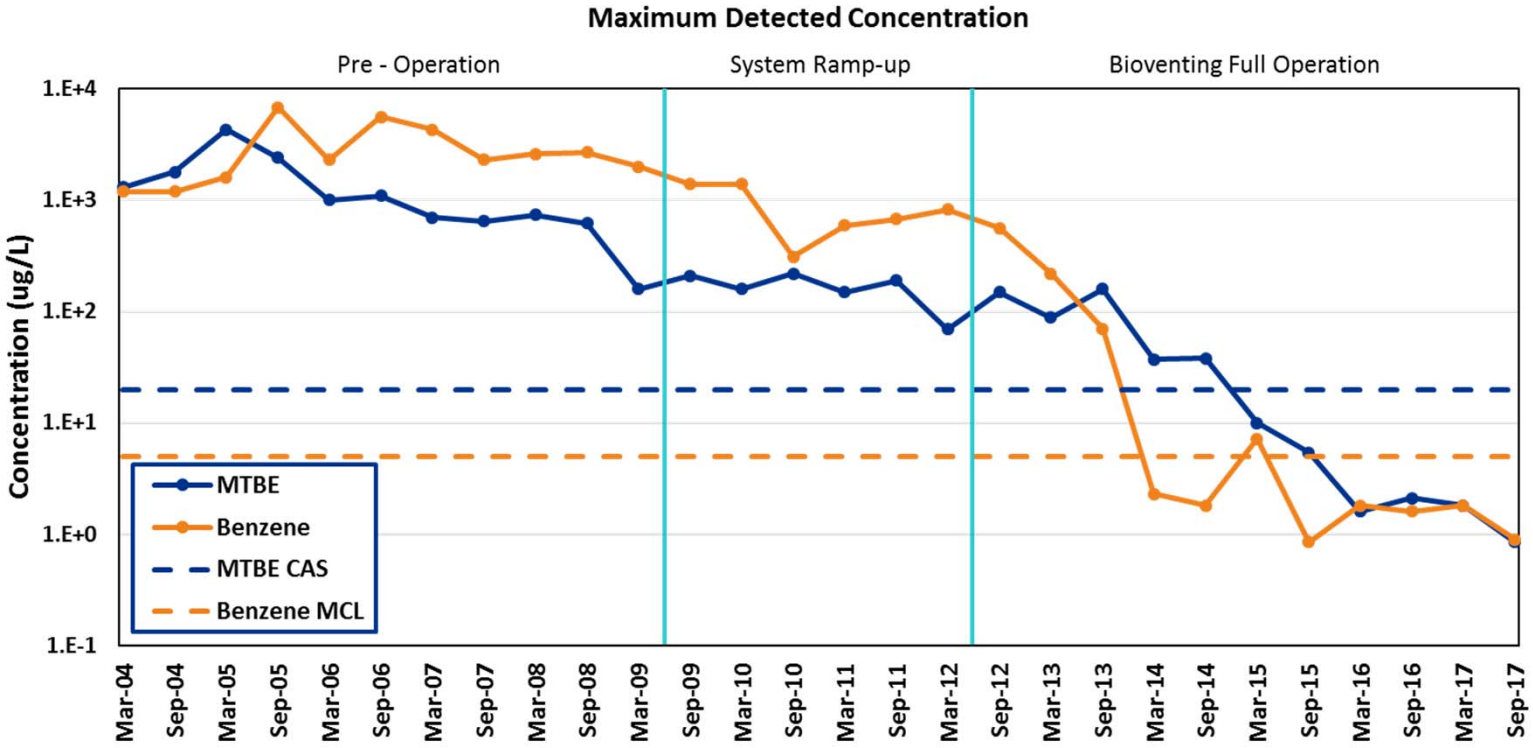
- Groundwater ORP moving from negative (reducing) to positive (oxidizing) after system startup.



JACOBS

Groundwater Quality

- Results < Remediation Standards since September 2015



JACOBS

Summary

- Bioventing successfully remediated the site.
  - State 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.

JACOBS

Bioventing System

JACOBS

Thank you!

Victor Gamez Grijalva

May 8, 2018

www.jacobs.com | worldwide