Smoldering Combustion (STAR): Challenges Encountered and Lessons Learned

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Overview

- **Smoldering Combustion Basics**
- **STAR (in situ)**
  - Case Study 1: Full-scale application of STAR to treat coal tar
  - Case Study 2: Pilot test to treat coal tar at a former MGP
  - Case Study 3: Pilot test to treat gasoline and diesel at a former refinery
  - Case Study 4: Pilot test to treat NSFO at a Naval Facility
- **Summary**

Smoldering Combustion

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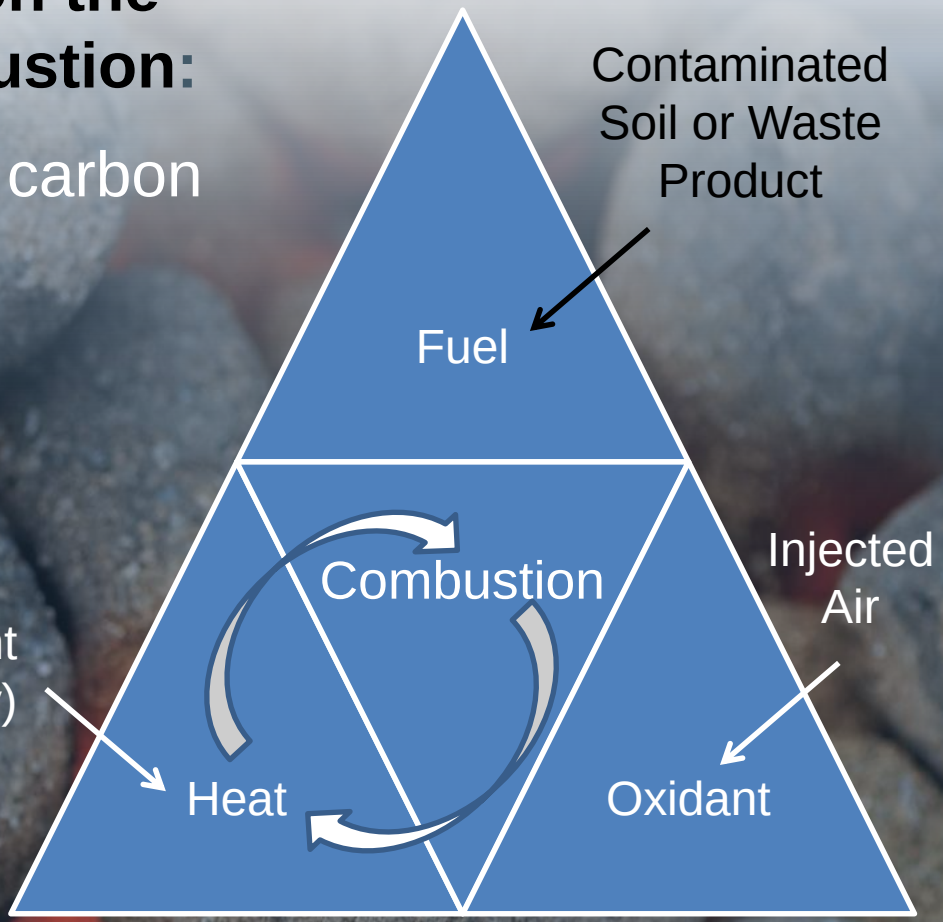
Smoldering Combustion

STAR and STARx are based on the process of smoldering combustion:

Exothermic reaction converting carbon compounds to $CO_2 + H_2O$



Smoldering possible due to large surface area of organic liquids (e.g., NAPL) within the presence of a porous matrix (e.g., aquifer)

Modes of Application

STAR

- **In situ (below water table)**
  - Applied via wells in portable in-well heaters
- **Range of contaminants:**
  - Petroleum Hydrocarbons
  - Coal tar
  - Creosote
- **High volatility compounds require fuel surrogate (CS#3)**

STARx

- **Ex situ (above ground)**
  - Soil piles placed on “Hottpad” system
- **Highly effective and controlled applications**
- **Ideal for:**
  - Excavated contaminated soils and sediments
  - Waste oils / tank bottom residuals
  - Lagoon sludge

STAR – In Situ Systems

STAR

Case Study 1: Full-scale application of STAR to treat coal tar

with John Vidumsky, DuPont

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Case Study - Site Overview

- **37-acre former manufacturing facility in Newark, New Jersey**
- **Coal tar associated with former waste lagoons (now in-filled)**
- **55,000 CY impacted soils:**
  - Shallow fill (0-10 ft bgs)
  - Deep Sand (~10-40 ft bgs)

Pre-Design Evaluation

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Smoldering Remediation of Coal-Tar-Contaminated Soil: Pilot Field Tests of STAR

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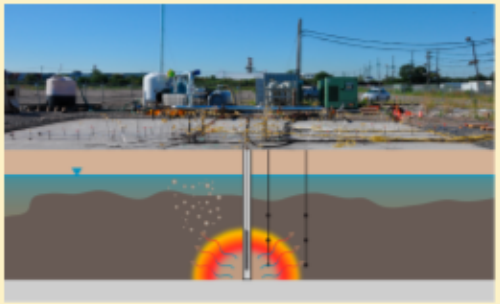
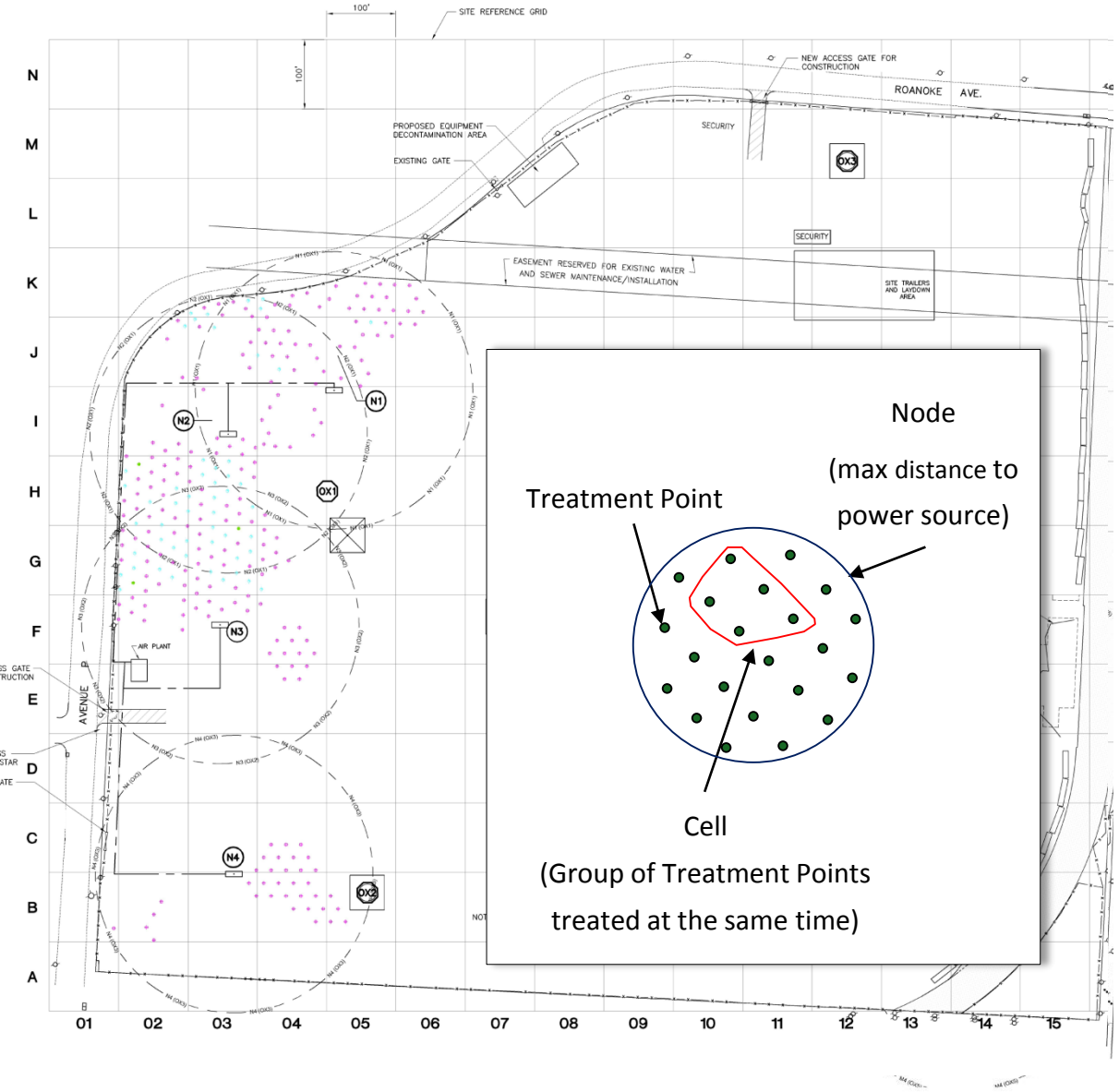
Supporting Information

ABSTRACT: Self-sustaining treatment for active remediation (STAR) is an emerging, smoldering-based technology for non-aqueous-phase liquid (NAPL) remediation. This work presents the first in situ field evaluation of STAR. Pilot field tests were performed at 3.0 m (shallow test) and 7.9 m (deep test) below ground surface within distinct lithological units contaminated with coal tar at a former industrial facility. Self-sustained smoldering (i.e., after the in-well ignition heater was terminated) was demonstrated below the water table for the first time. The outward propagation of a NAPL smoldering front was mapped, and the NAPL destruction rate was quantified in real time. A total of 3700 kg of coal tar over 12 days in the shallow test and 860 kg over 11 days in the deep test was destroyed; less than 2% of total mass removed was volatilized. Self-sustaining propagation was relatively uniform radially outward in the deep test, achieving a radius of influence of 3.7 m; strong permeability contrasts and installed barriers influenced the front propagation geometry in the shallow test. Reductions in soil hydrocarbon concentrations of 99.3% and 97.3% were achieved in the shallow and deep tests, respectively. Overall, this provides the first field evaluation of STAR and demonstrates that it is effective in situ and under a variety of conditions and provides the information necessary for designing the full-scale site treatment.

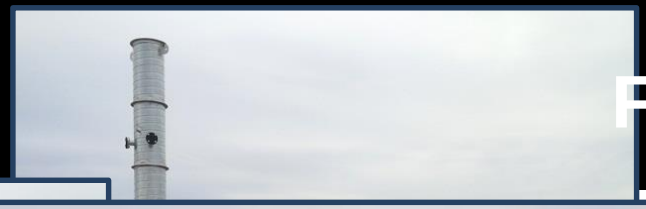


Deployment Strategy



- Two target layers:
  - Shallow Fill
  - Deep Sand
- Shallow Fill:
  - 1700 wells
  - 20-well Cells
  - 10’ separation
- Deep Sand:
  - 300 wells
  - 6-well Cells
  - 20’ separation
- Operation organized by:
  - Well
  - Cell (groups of Wells operated simultaneously)
  - Node (groups of Cells serviced by single system deployment)

Full-scale System



Well h

Air Injection for Well Points

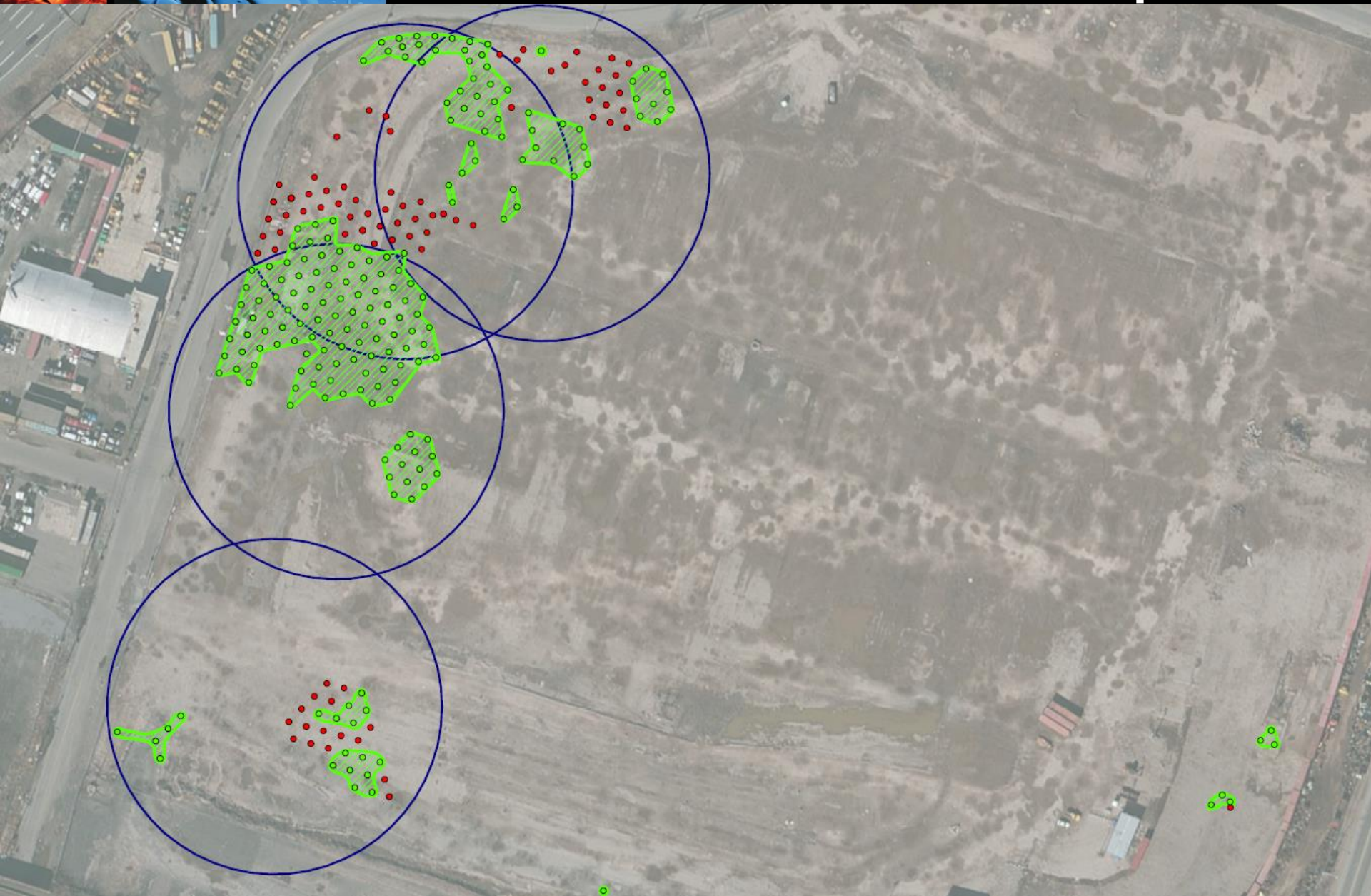
xtraction

ors to RTC

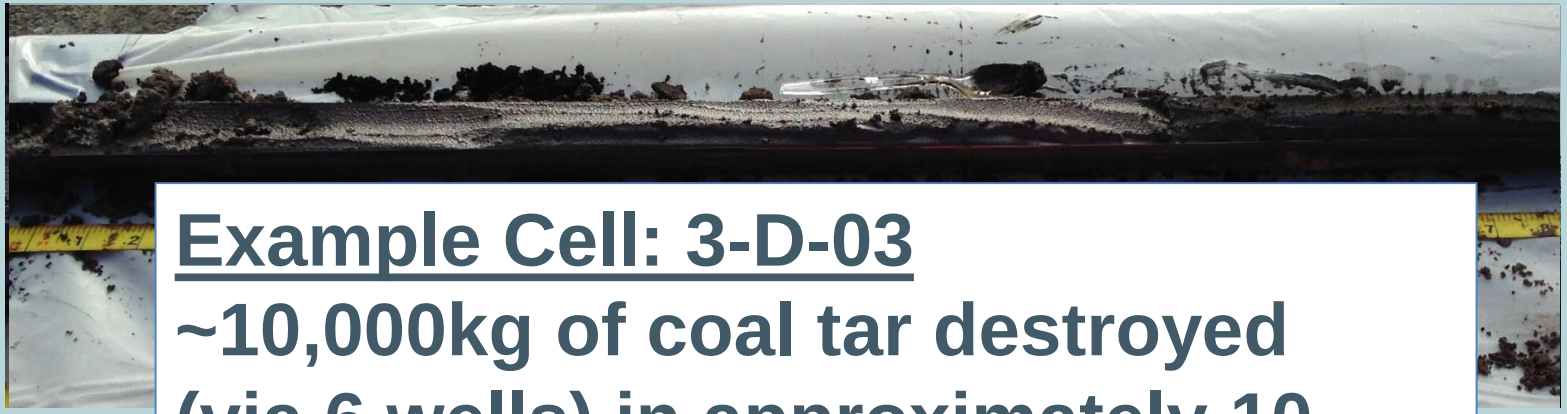
Treatment Trailer

Full-scale Results
Shallow Fill

Full-scale Results
Deep Sand



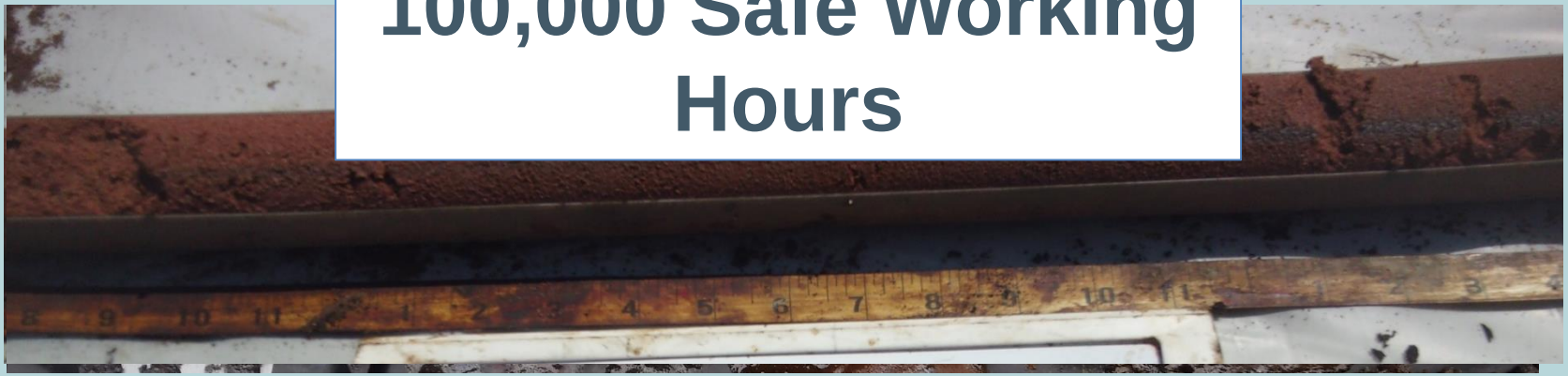
Full-scale Results



Example Cell: 3-D-03

~10,000kg of coal tar destroyed (via 6 wells) in approximately 10 days

100,000 Safe Working Hours



After

STAR

Case Study 2: Pilot Test to Treat Coal Tar at a Former MGP

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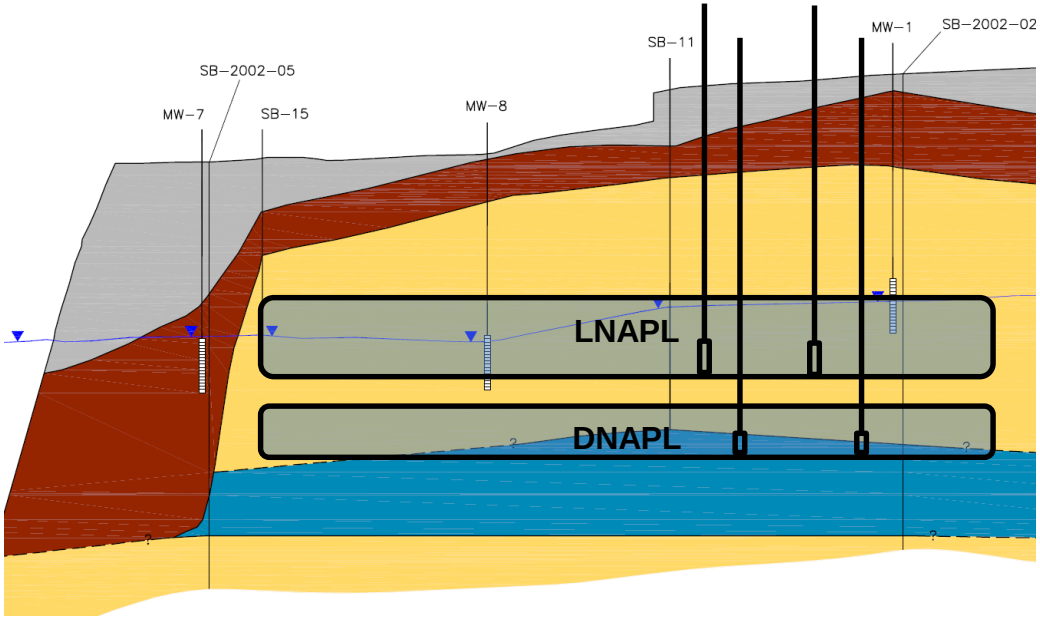
Former MGP, MI

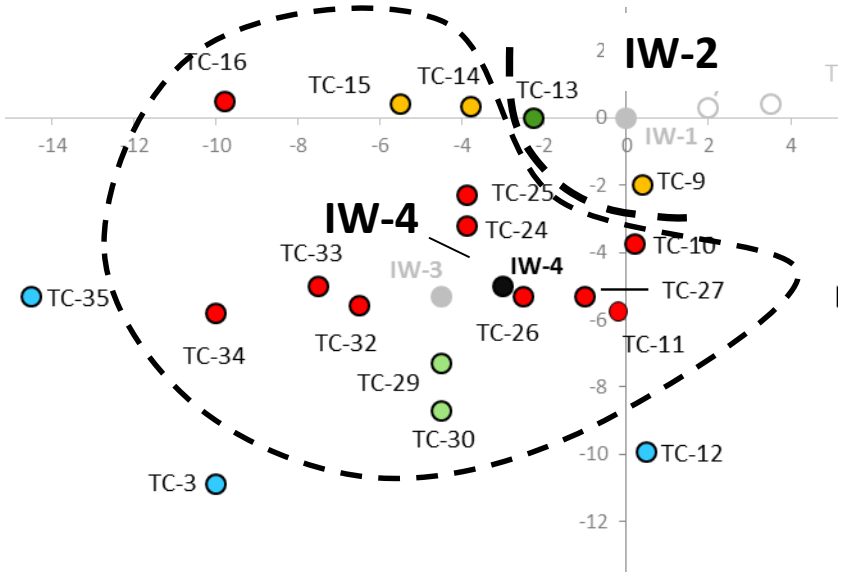
- **Fine sand aquifer**
- **Coal tar-impacted horizon in 2 distinct layers:**
  - LNAPL - water table (18 ft bgs) to 24 ft bgs
  - DNAPL – 27 to 33 ft bgs (above clay layer)



Former MGP, MI

Post-pilot Summary

- ROI = 7.5 – 8 ft
- 1 ft/d propagation rate
- LNAPL and DNAPL zones
- 937 kg of coal tar destroyed



Post-Pilot Soil

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Case Study 3: Pilot test to treat gasoline and diesel at a former refinery

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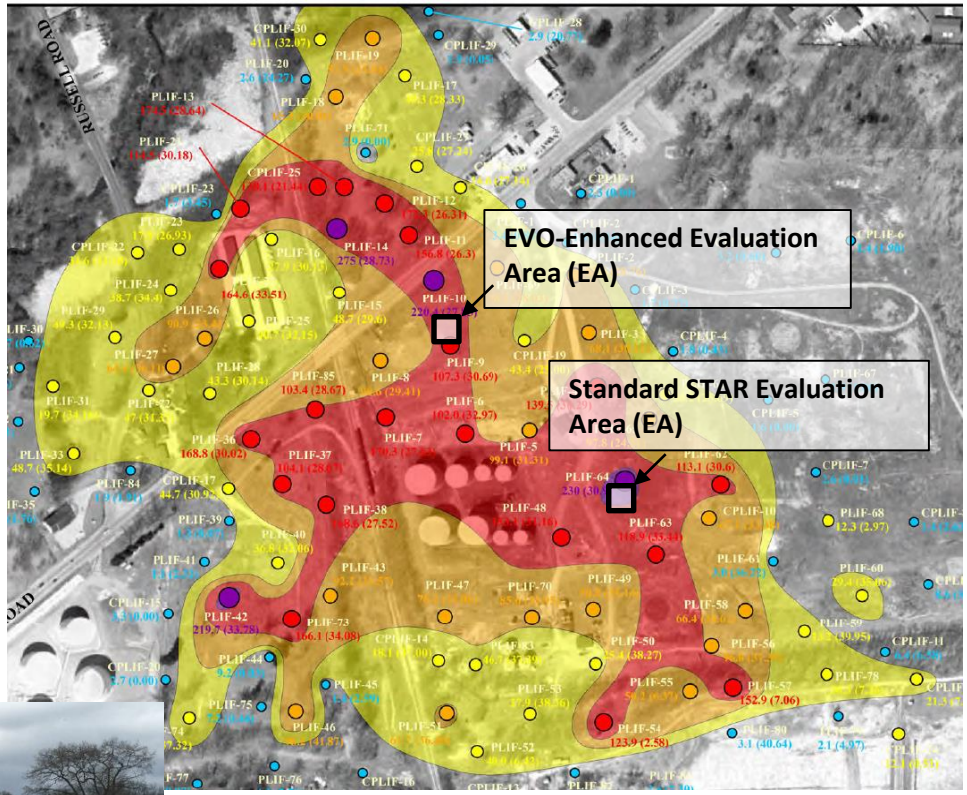
Former Refinery, MI

- **Sandy aquifer**
- **Impacted with refined (light) petroleum hydrocarbons**
  - Requires surrogate fuel (EVO) to drive volatilization
- **Two Tests:**
  - “Standard” STAR
  - EVO-enhanced STAR



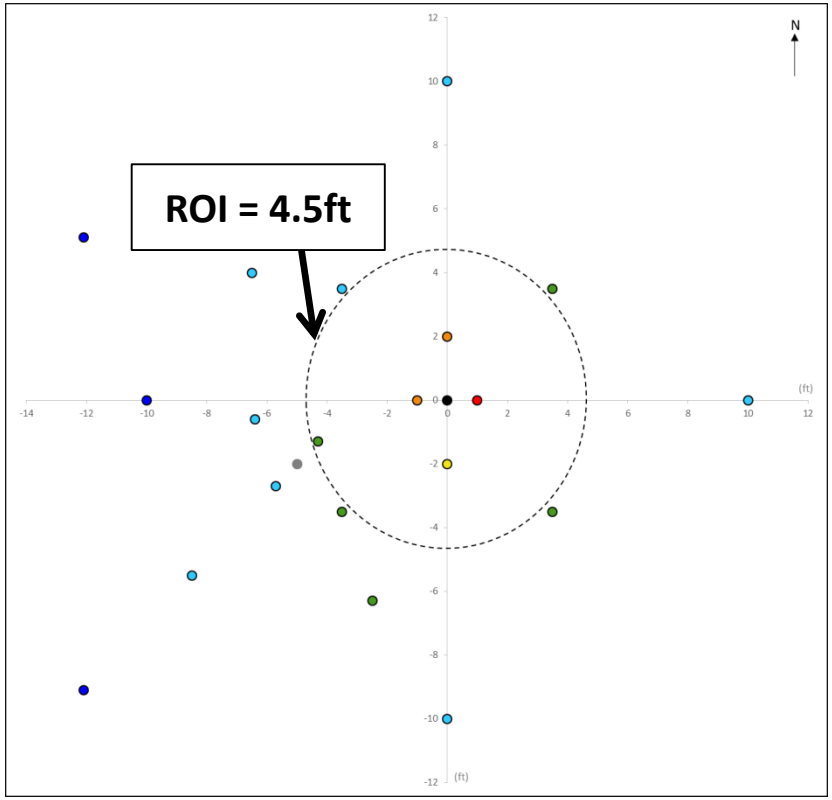
Former Refinery, MI

“Standard” STAR Test

- Excellent soil treatment
- Limited ROI (4.5 ft) due to volatility

Before
(TPH = 7,300 mg/kg)

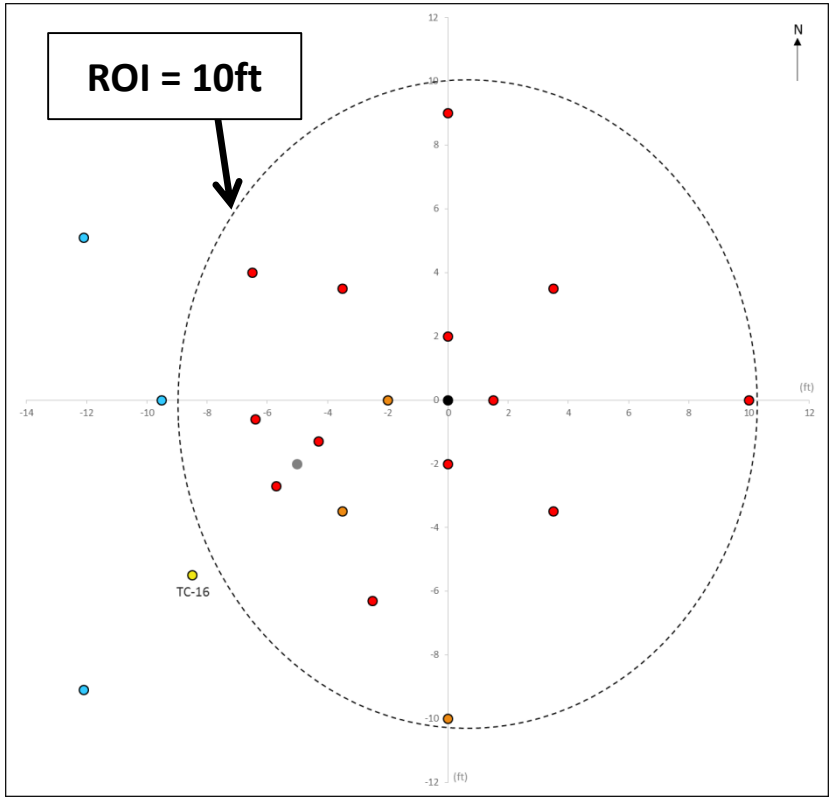
After
(TPH = 22 mg/kg)

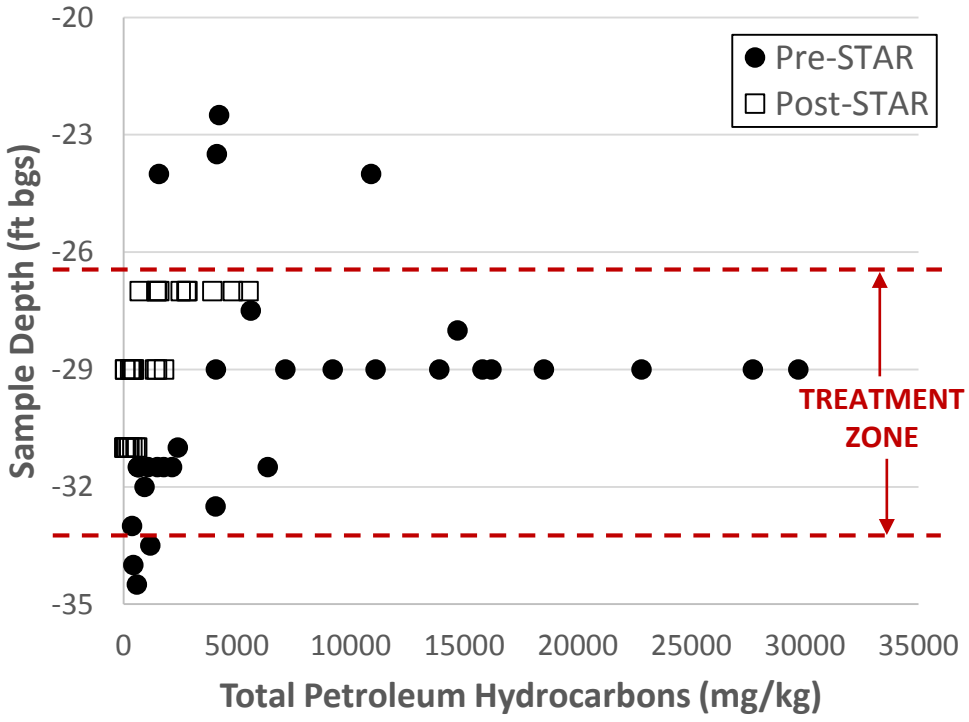


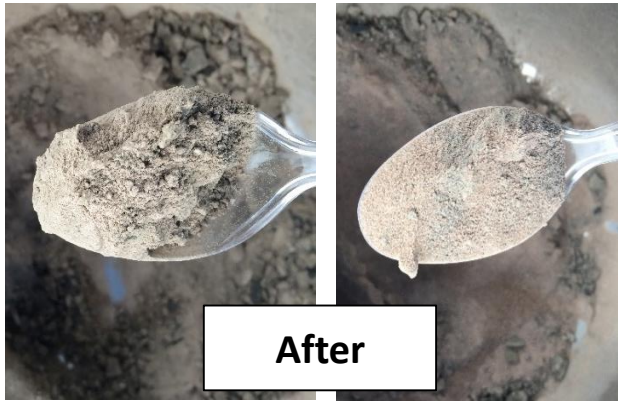
Former Refinery, MI

EVO-enhanced STAR Test

- Excellent soil treatment
- ROI = 10 ft
- 6 ft zone combusted







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Case Study 4: Pilot test to treat Navy Special Fuel Oil (NSFO) at a Naval Facility

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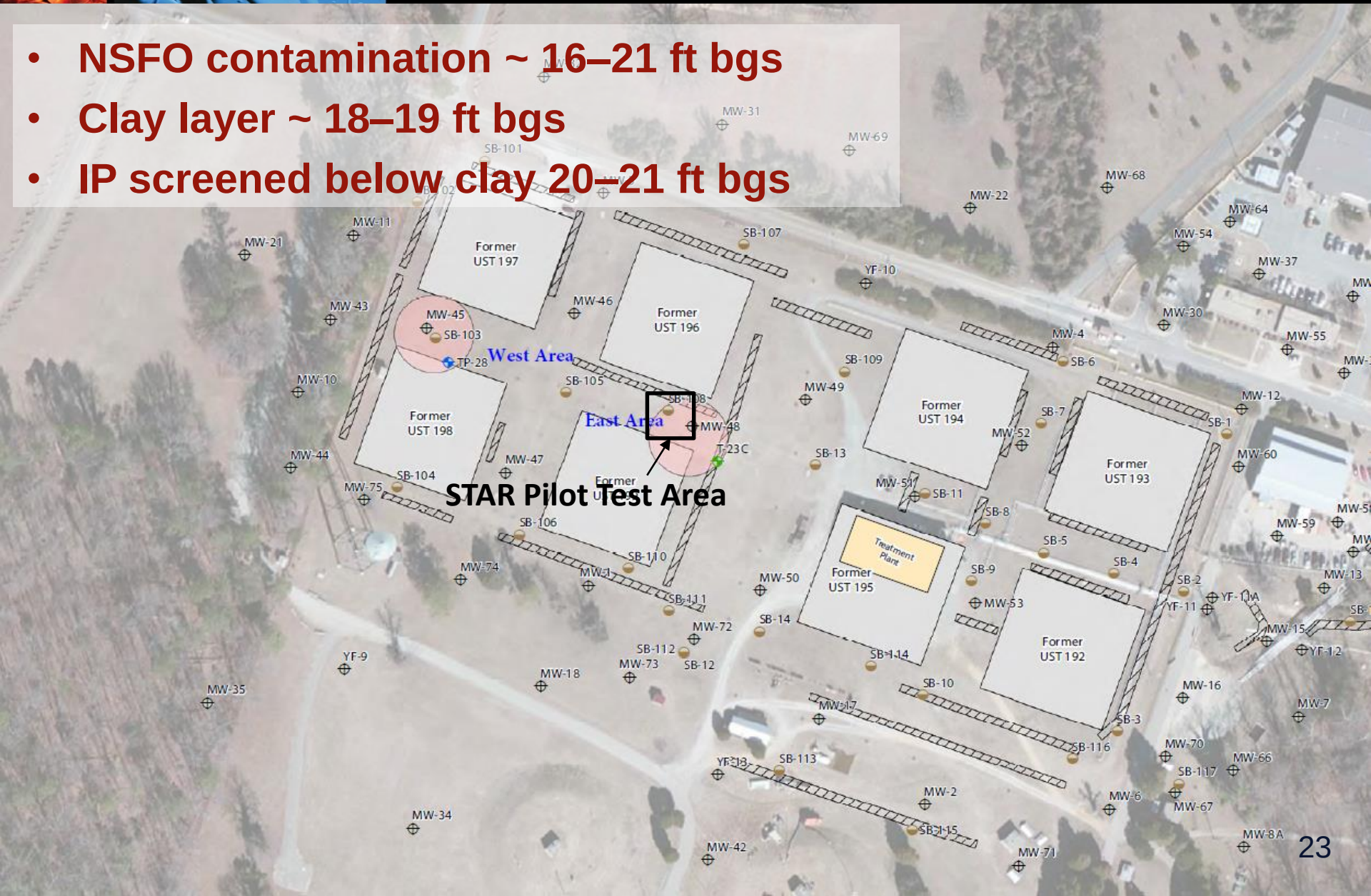
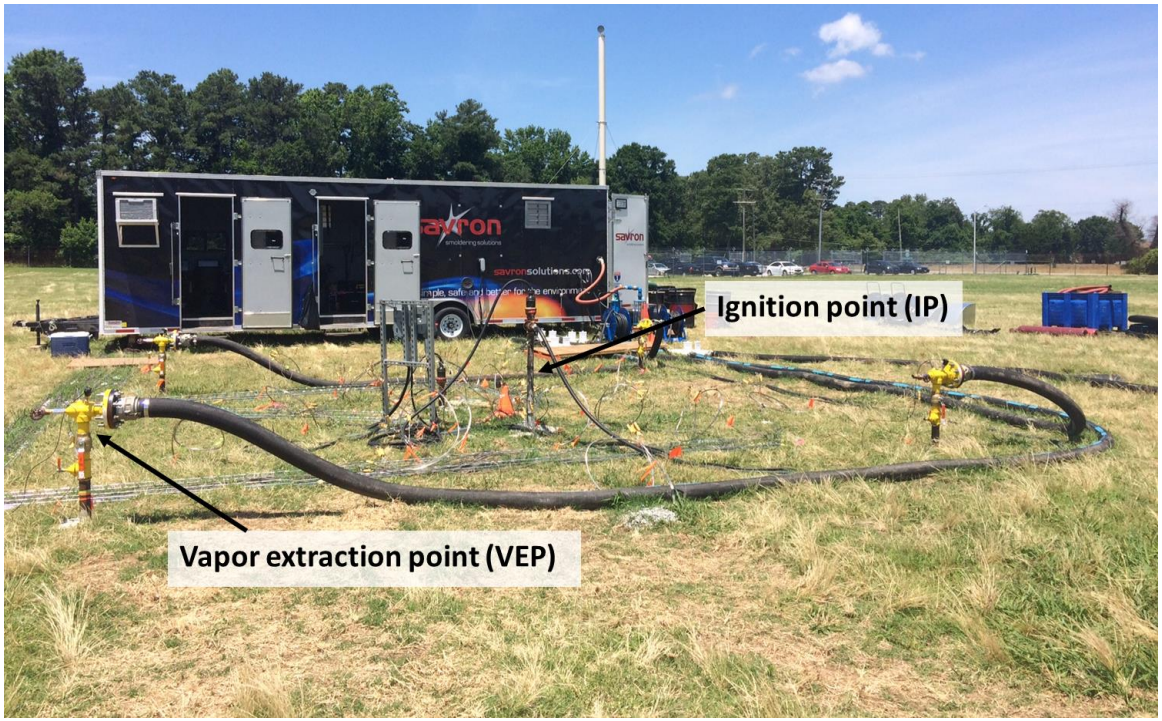
Naval Facility, VA

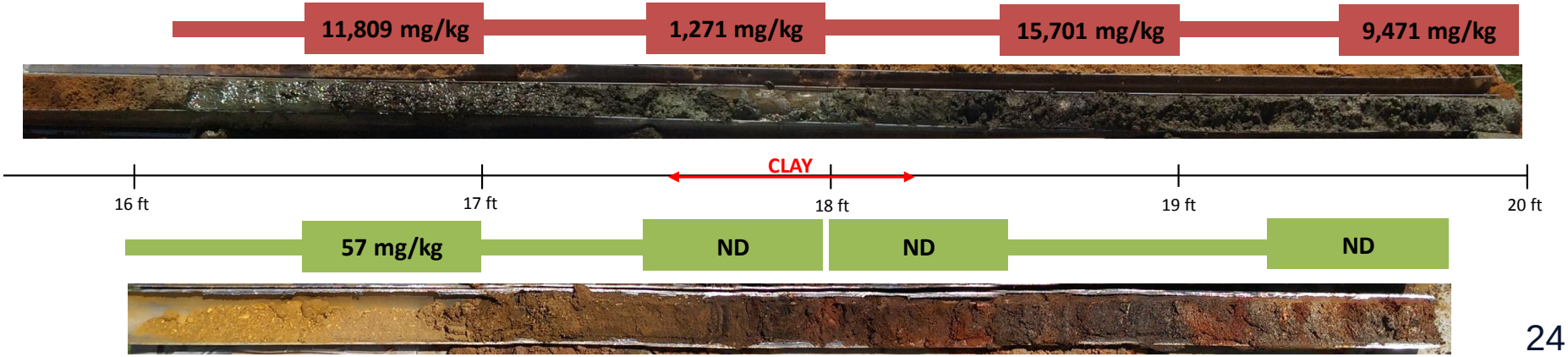
- NSFO contamination ~ 16–21 ft bgs
- Clay layer ~ 18–19 ft bgs
- IP screened below clay 20–21 ft bgs



Naval Facility, VA

- Treatment above and below clay
- 632.7 kg NSFO destroyed
- 7.5 ft ROI





Summary

- **STAR is robust and works both above and below the water table under fully saturated conditions**
- **Well suited for coal tar, creosote, and petroleum hydrocarbons**
  - Surrogate fuels expand range of compounds that can be treated
- **Can be applied in situ or ex situ (Hottpad systems)**
- **STAR is rapid, sustainable, and cost-effective**
- **Technology backed by nearly a decade of world-class research**

Upcoming Projects

- **Waterfront Toronto – Portlands**
  - Dual STAR / STARx pilot test
- **Pitt Consol – New Jersey**
  - On-going operations
- **Taiwan**
  - TWEPA (Chia-Yi)
  - CPC (Kaohsiung Harbor)
- **Numerous STARx projects**
  - China, Kuwait, Indonesia, Philippines, Australia, USA

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Questions?

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