



TRS Group
25TH Anniversary

Thermal Remediation of VOCs, SVOCs & PFAS

TRS Group, Inc. A Parsons Company
Safe. Fast. Certain. Guaranteed.
ATripleF.com

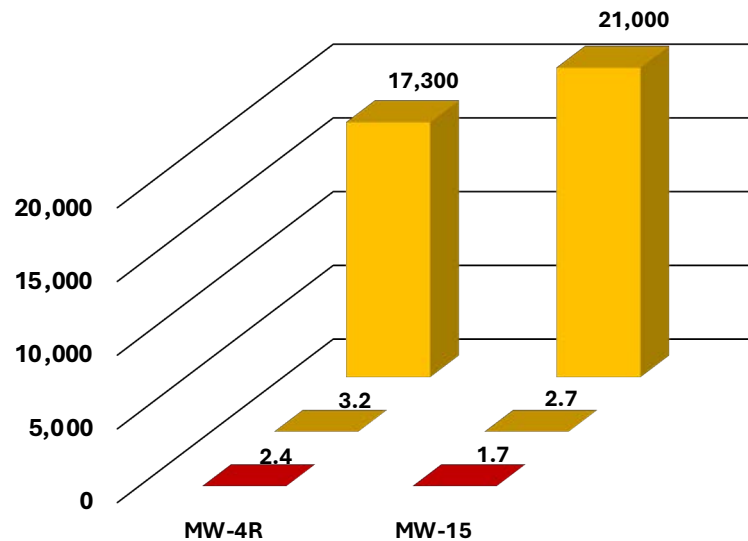
thermalrs.com



In Situ Thermal Remediation Basics

DRY CLEANER

Alexandria, Virginia



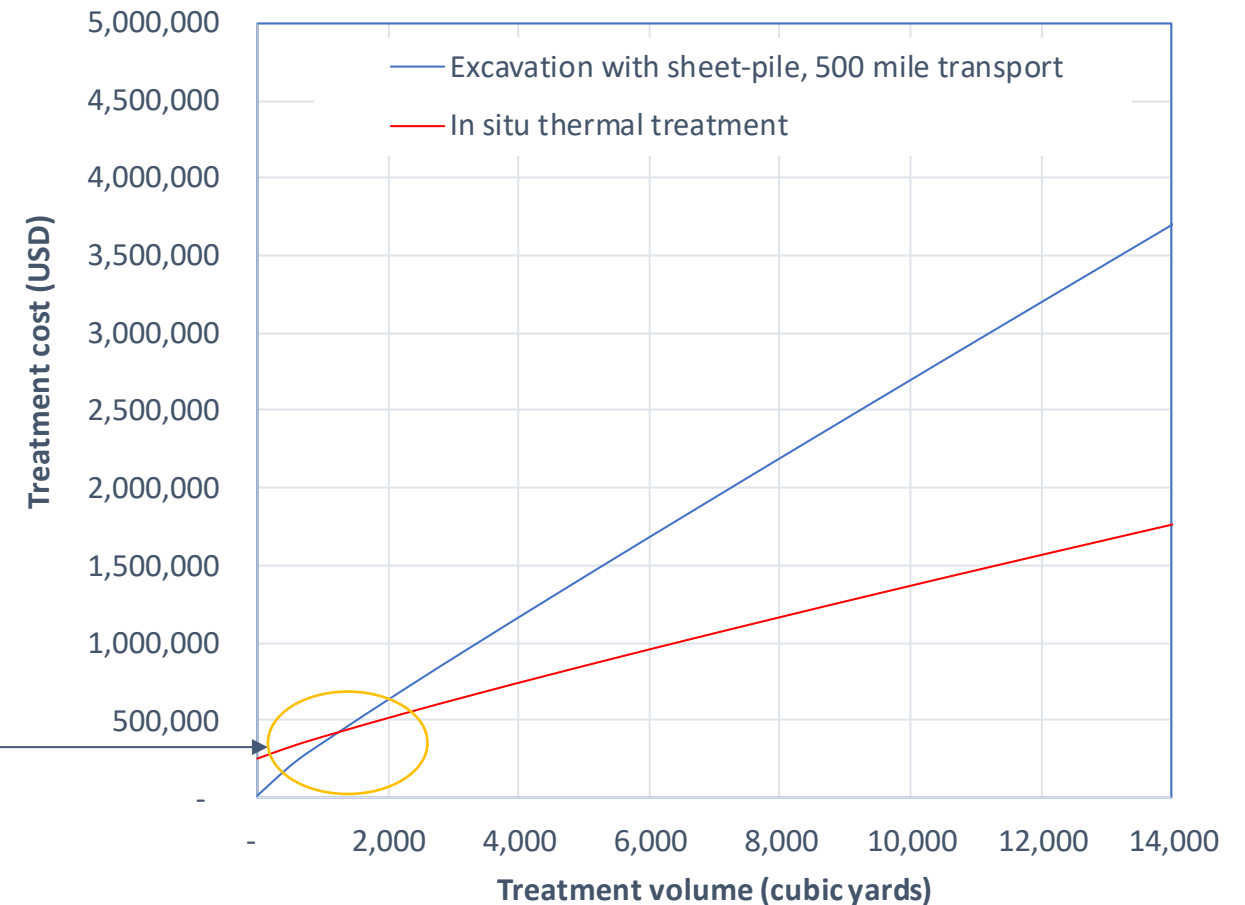
PCE concentrations (µg/L)

99.995% reduction

- Source zone solution; DNAPL remediated first
- Volatilizes VOCs in all matrices
- Volatilizes SVOCs and PFAS in vadose zone (or ex situ)
- Integral vapor capture; treatment at surface
- Fast – 3 to 6 months heating
- Typical mass reductions > 99.9%

ISTR v. Dig & Haul

- ISTR readily applied under buildings
- Dig & haul may retain liability
- Digging subject to volume growth
- Apply heat when less expensive
- Small projects may favor digging
- Minimum ISTR price: \$1,000,000



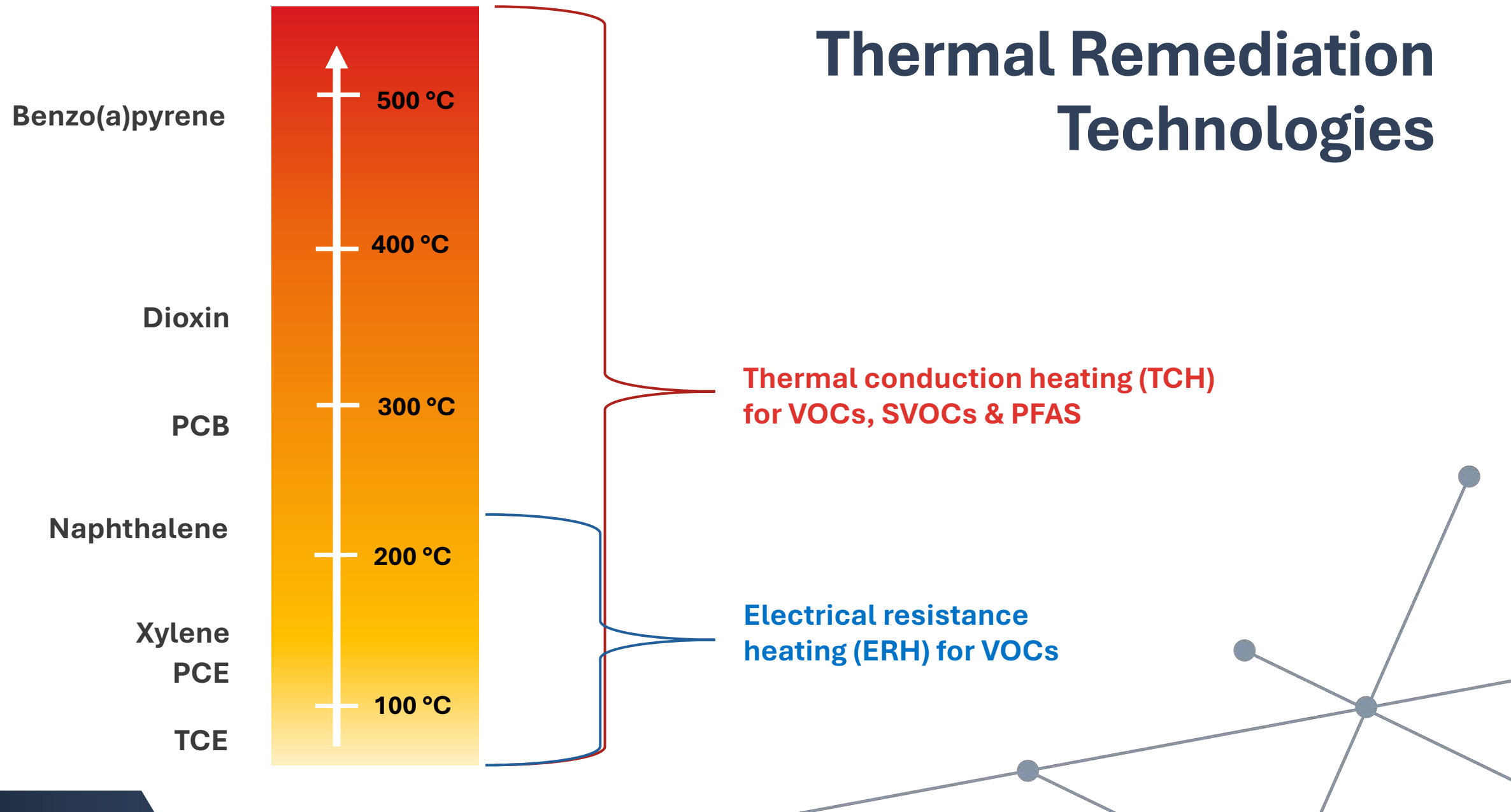
Hazardous waste: chlorinated solvents
Assumed dig & haul cost: \$350/ton

Guarantees to Reduce Client Risk

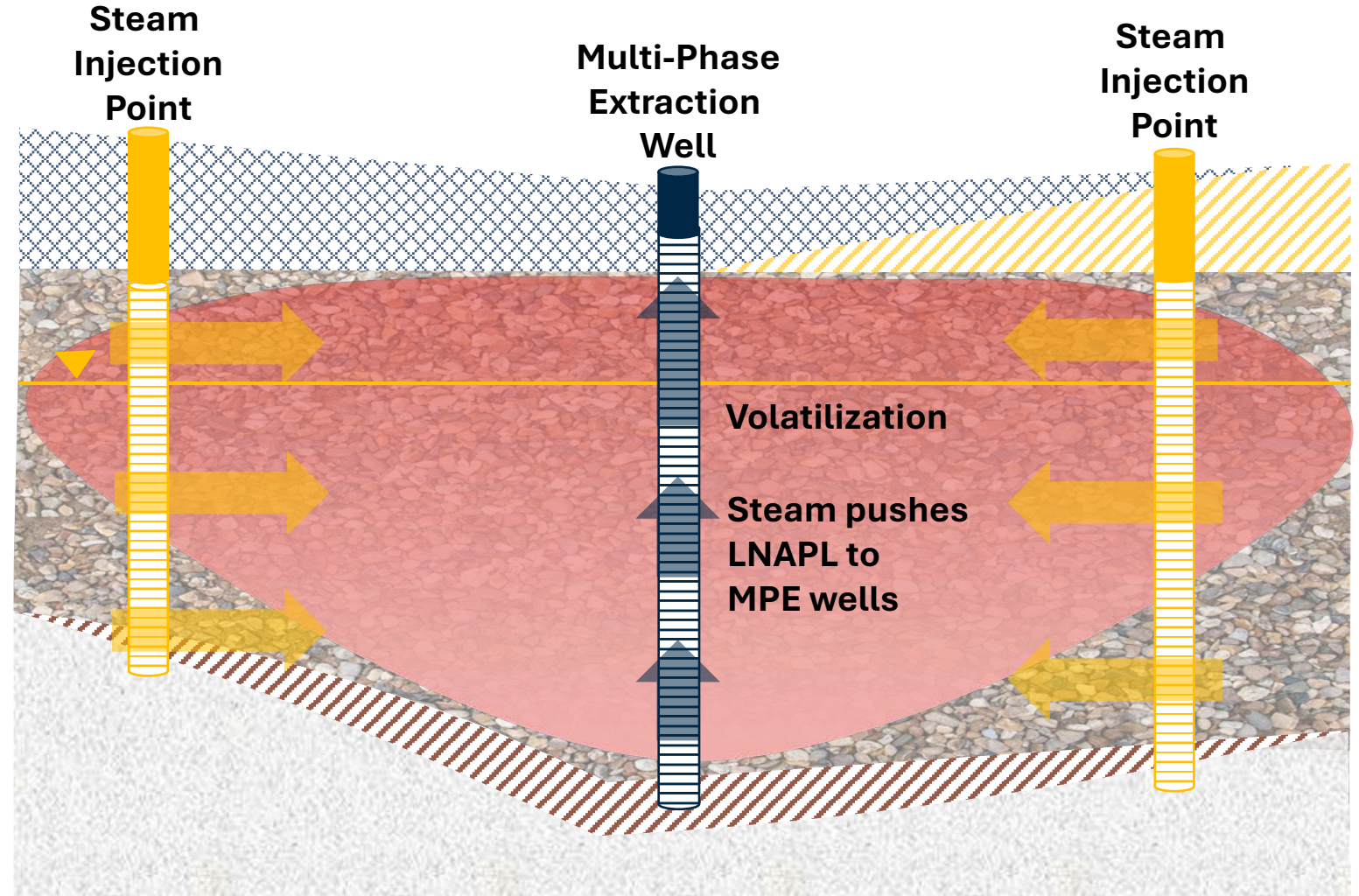


- Guarantees to meet concentration goals
- Based on conceptual site model
- TRS assumes risk
- Price impact – typically 15 to 30%
- Clients appreciate price certainty

Thermal Remediation Technologies



Steam Enhanced Extraction



Comparison: ERH v TCH

Parameters	ERH	TCH
Temperature (vadose zone or ex situ)	Boiling point of water	400+° Celsius
Temperature (saturated zone)	Boiling point of water	Boiling point of water
Well spacing	14 to 18 feet	8 to 15 feet
Time to target temperature	2 months	3 months
Practitioners	3	4
Soil impacts	No desiccation	Desiccation in vadose zone
Total organic carbon impacts	Minor	Significant in vadose zone

Thermal Remediation Services

FlexHeater® Thermal Conduction Heating

OptiFlux® Electrical Resistance Heating

Temperature

Energetics
Pesticides

Chlorinated
Solvents

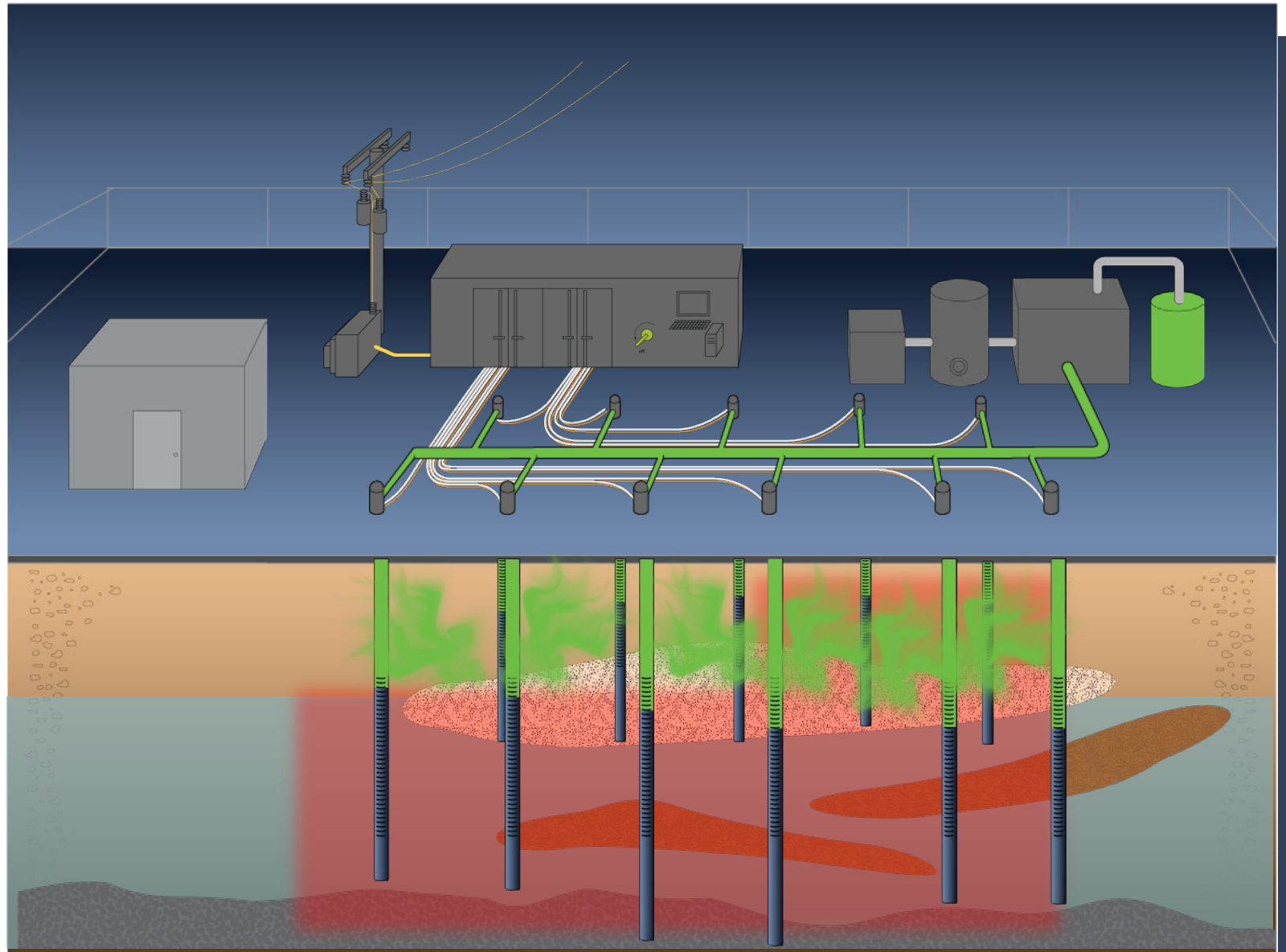
Petroleum
Hydrocarbons

PAHs
PCBs

PFAS

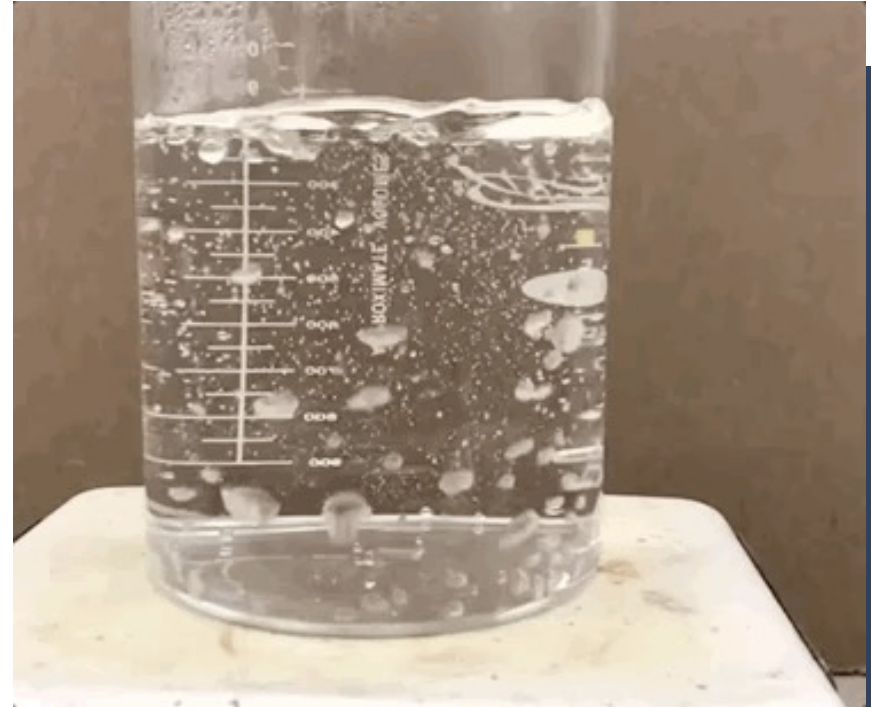
HEPA® Remediation (subset of ERH)

In Situ Thermal Remediation



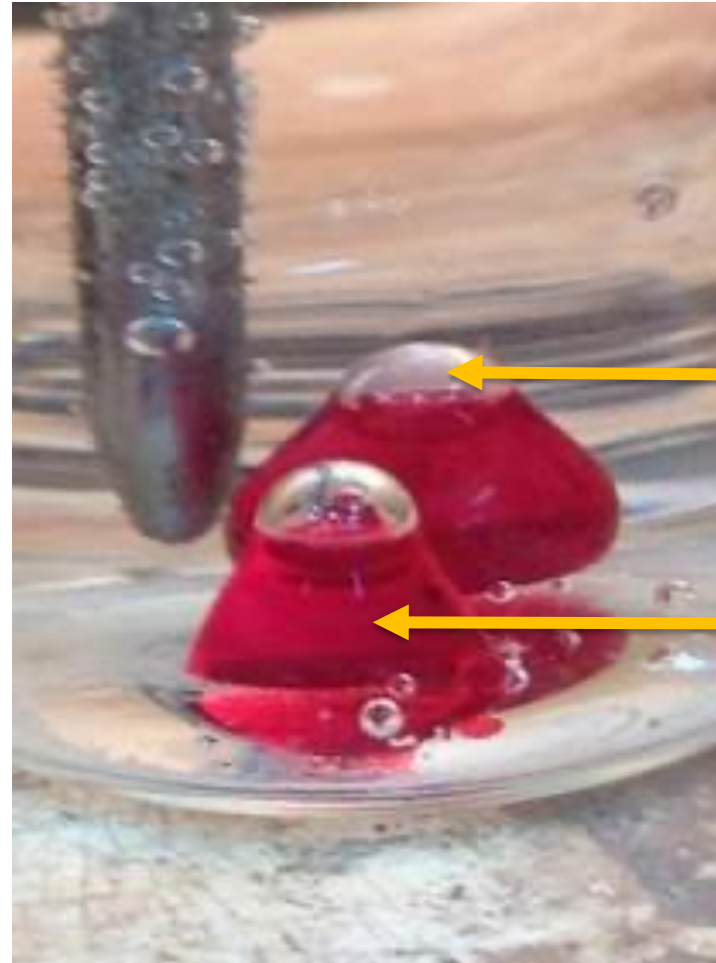
What is Boiling?

- Vapor pressure of liquid = ambient pressure
- NAPL in water forms heteroazeotropes
- Daltons law of partial pressures
- Azeotropic boiling point lower than water



Heteroazeotrope of 1,2-Dichlorobenzene

1,2-DCB boils at 179°C

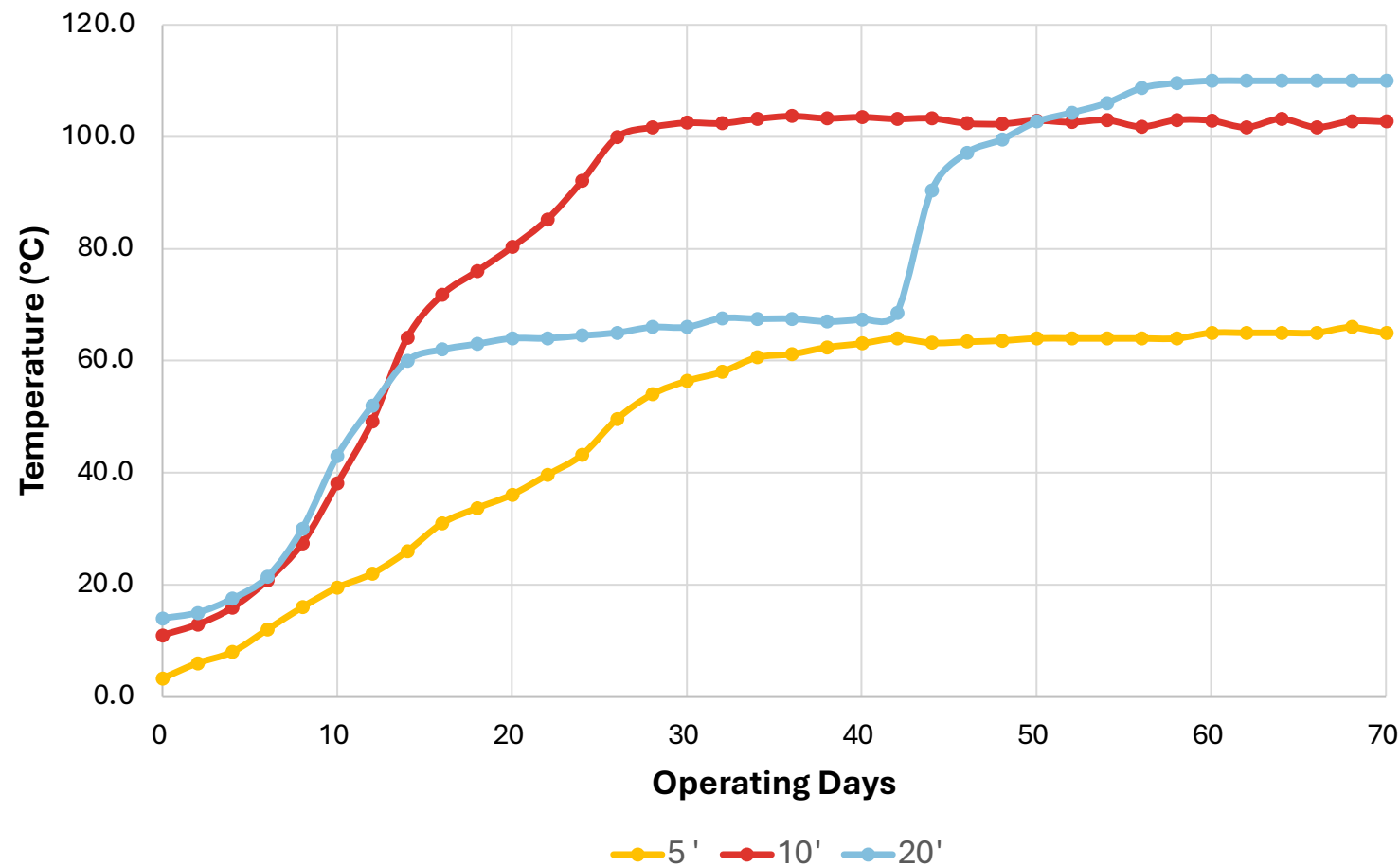


Azeotrope boils at 98°C

60% steam
40% 1,2-DCB

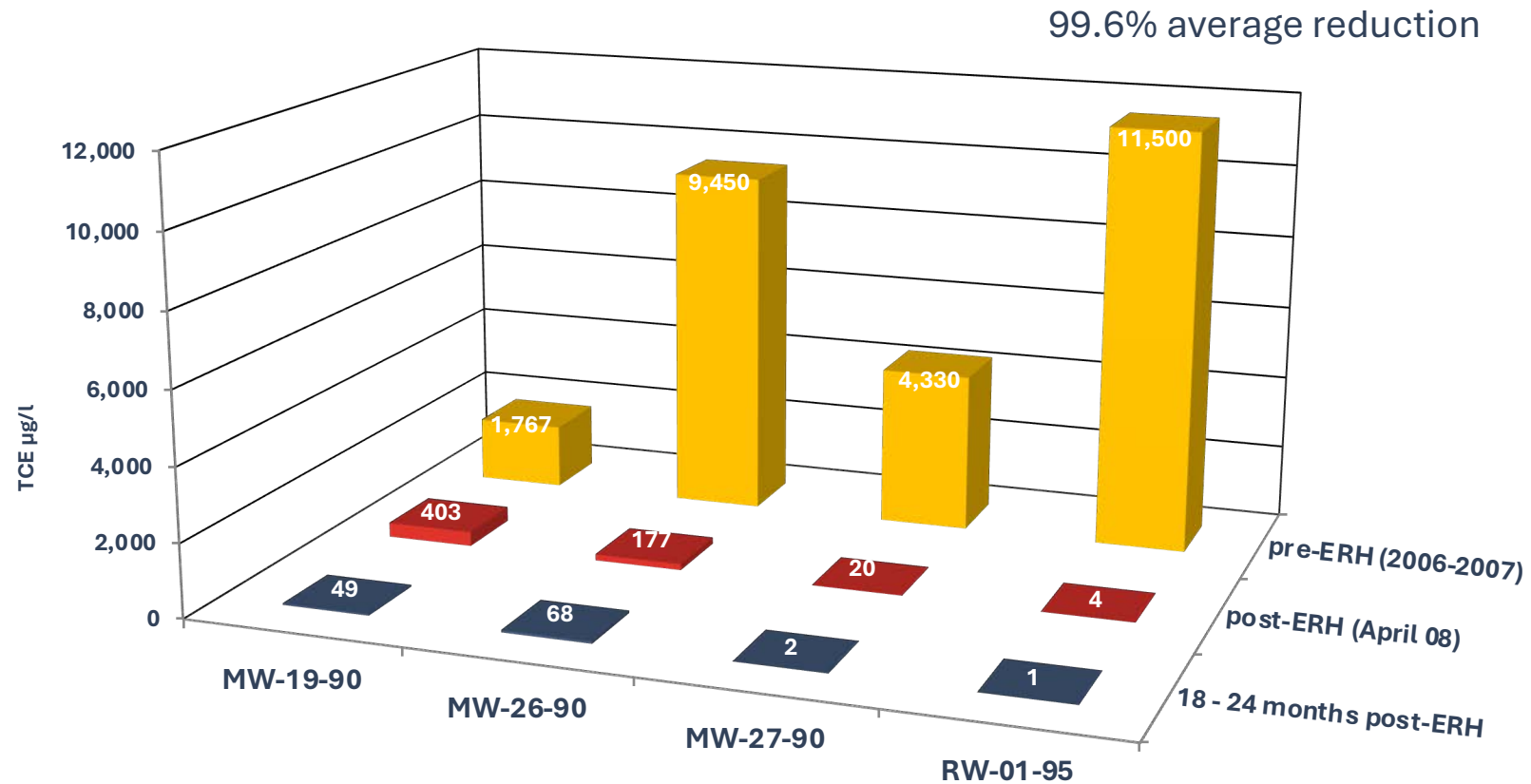
1,2-DCB DNAPL

Sensible & Latent Heating



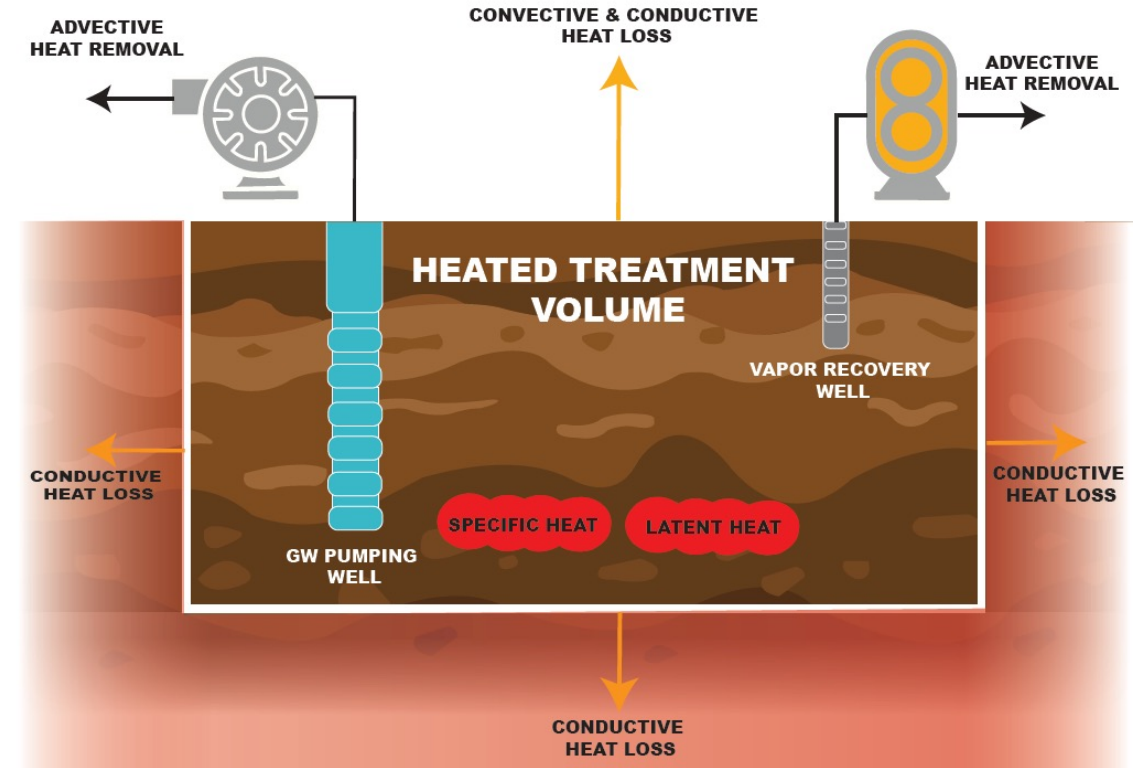
Water table at 9 feet
DNAPL (1,1,1-TCA) at 20 feet

Concentrations Decline Post ISTR



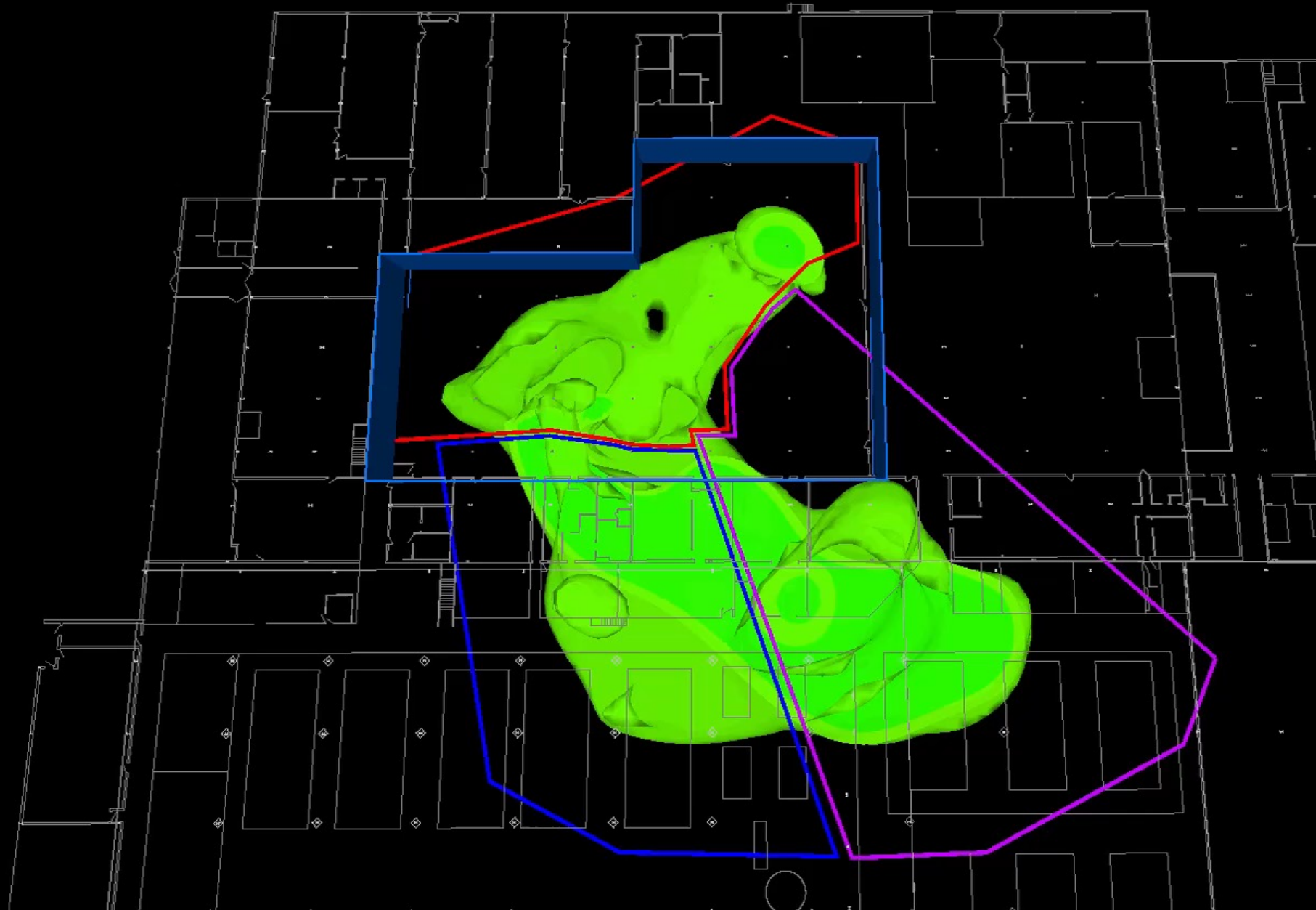
HeatWave[®] Modeling Services

- Integrates CSM, COCs & goals
- Informs technology selection
- Improves remedial outcomes
- Analyzes impact of removing water
- Creates a hot floor
- Optimizes power & energy



ENERGY BALANCE

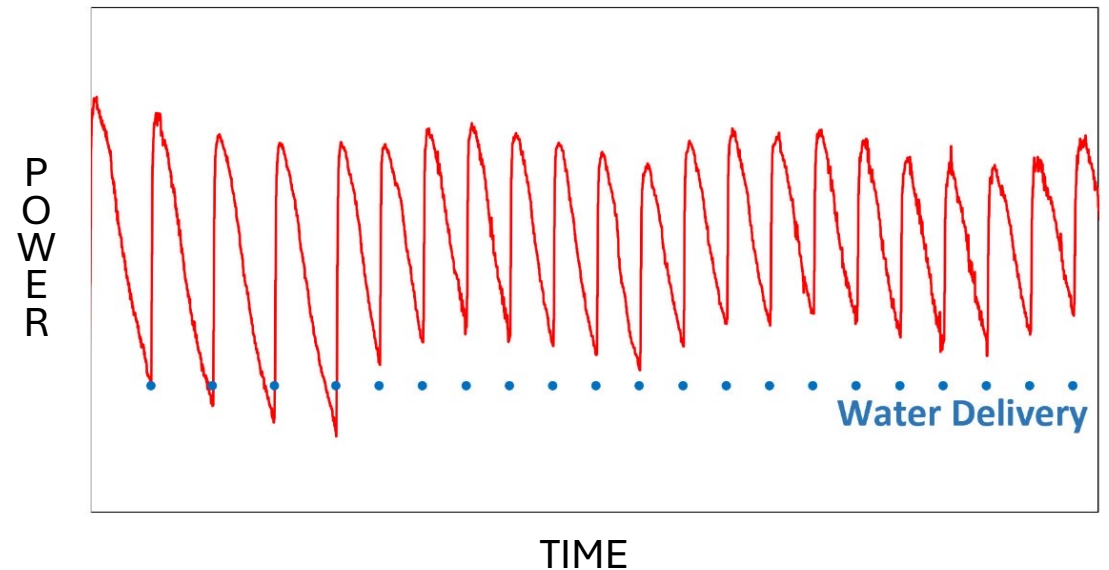
Visualization of Heater Well Installation



Power Delivery

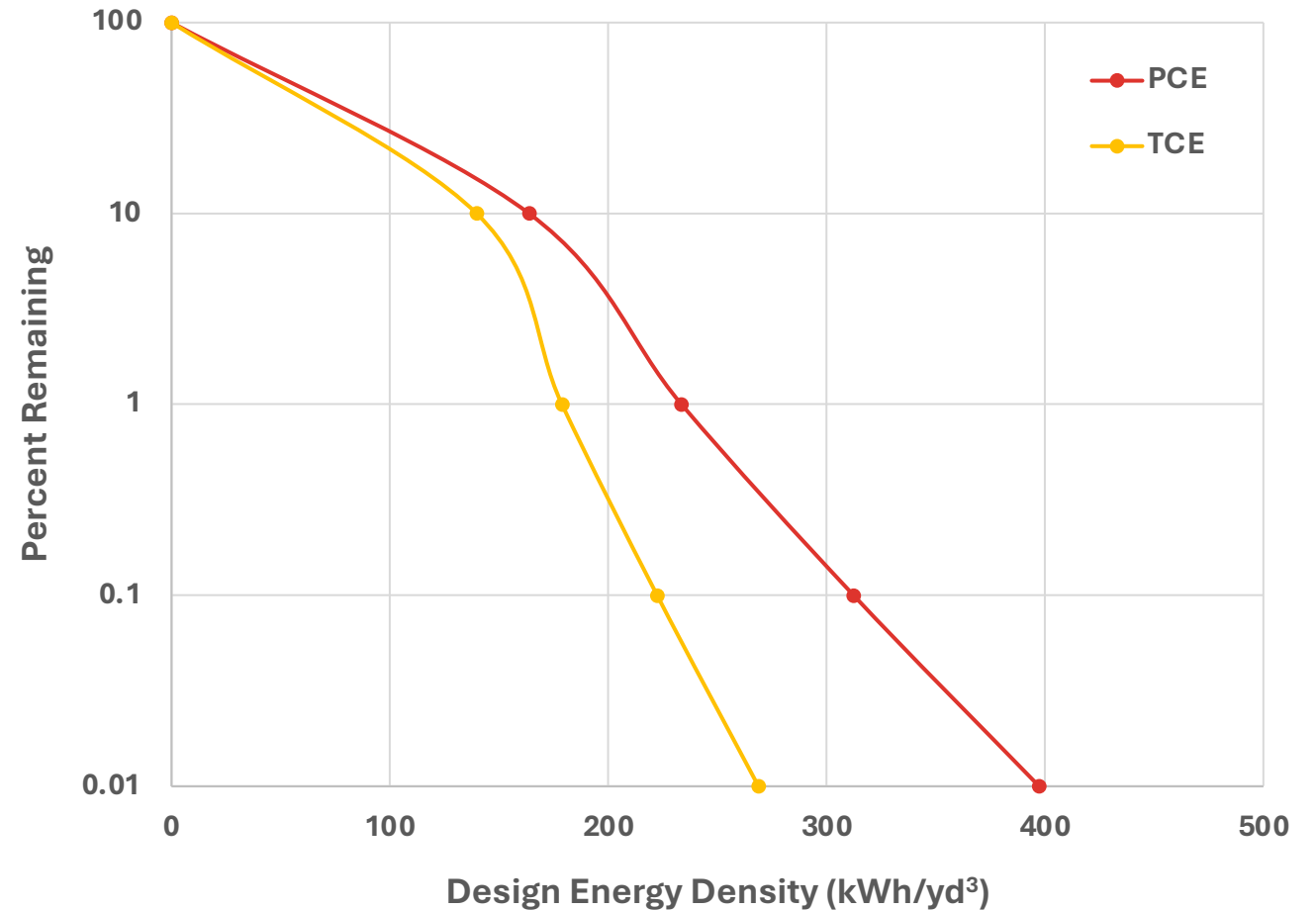
- Power density (W/yd³)
 - Critical design parameter
 - Determines time to steaming
 - Overcomes matrix heat losses
- Heating element spacing good proxy
- Perhaps surprising: ERH > TCH

Patented *OptiFlux*[®] services:
automated drip control



Power & Energy Densities

- **Power density** (W/yd^3) to overcome heat losses
- **ERH > TCH** (not intuitive)
- **Energy density** (kWh/yd^3) to achieve goals





OptiFlux[®]

ERH Services

OptiFlux[®]

ERH

Services

Indianapolis, Indiana

Step-down transformer

Power control unit

Condenser

Back-up generator

Blower

GAC vessel



Under Railroad Tracks

Guaranteed remediation

County roadway

Active CSX railroad tracks

No road or track closures

Track deflection monitoring

Sheet pile & bored
electrodes

Brandywine, Maryland





OptiFlux[®] ERH **Services in** **New York City**

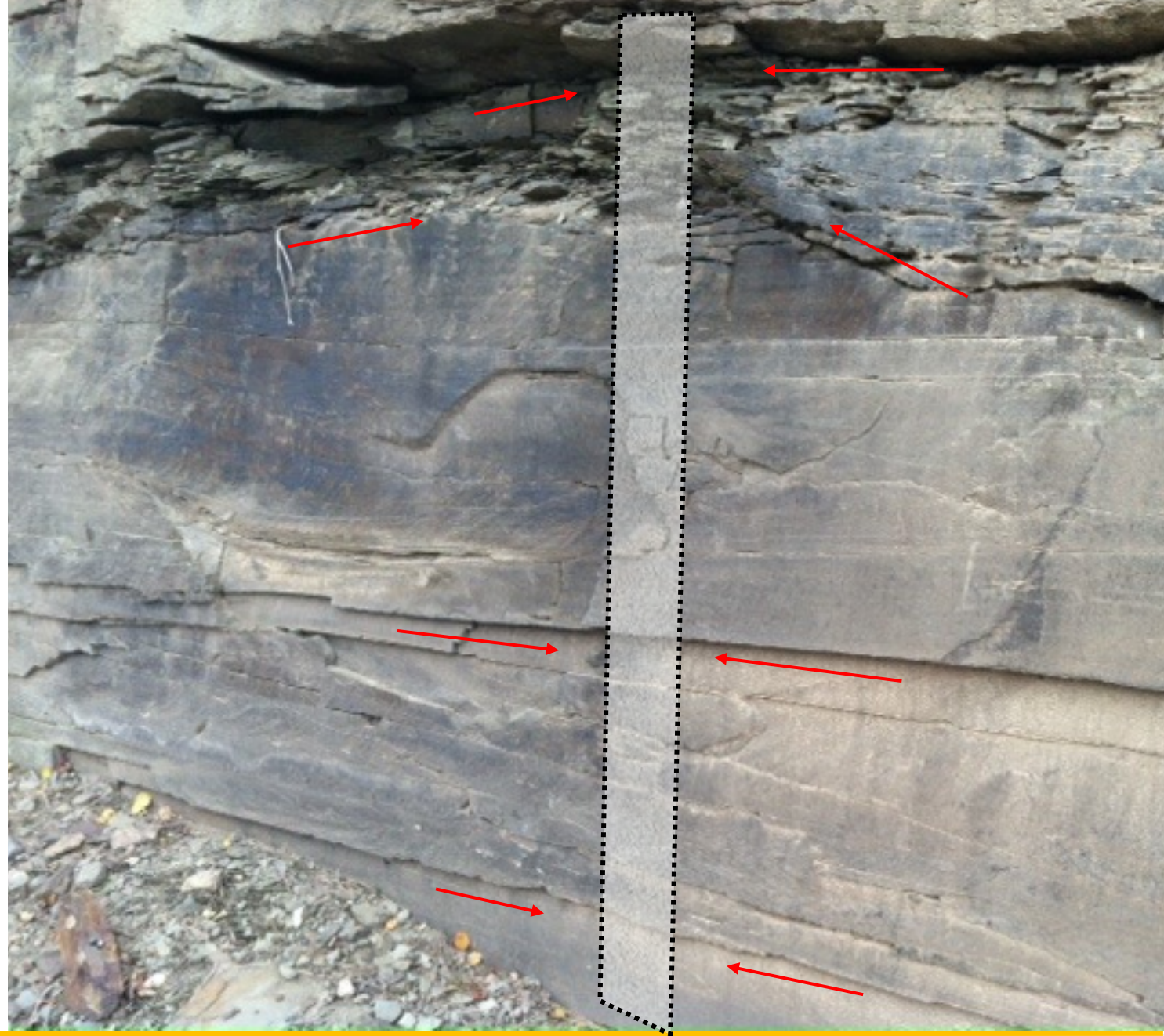
Photo from Google Earth

Bedrock Site in Pennsylvania

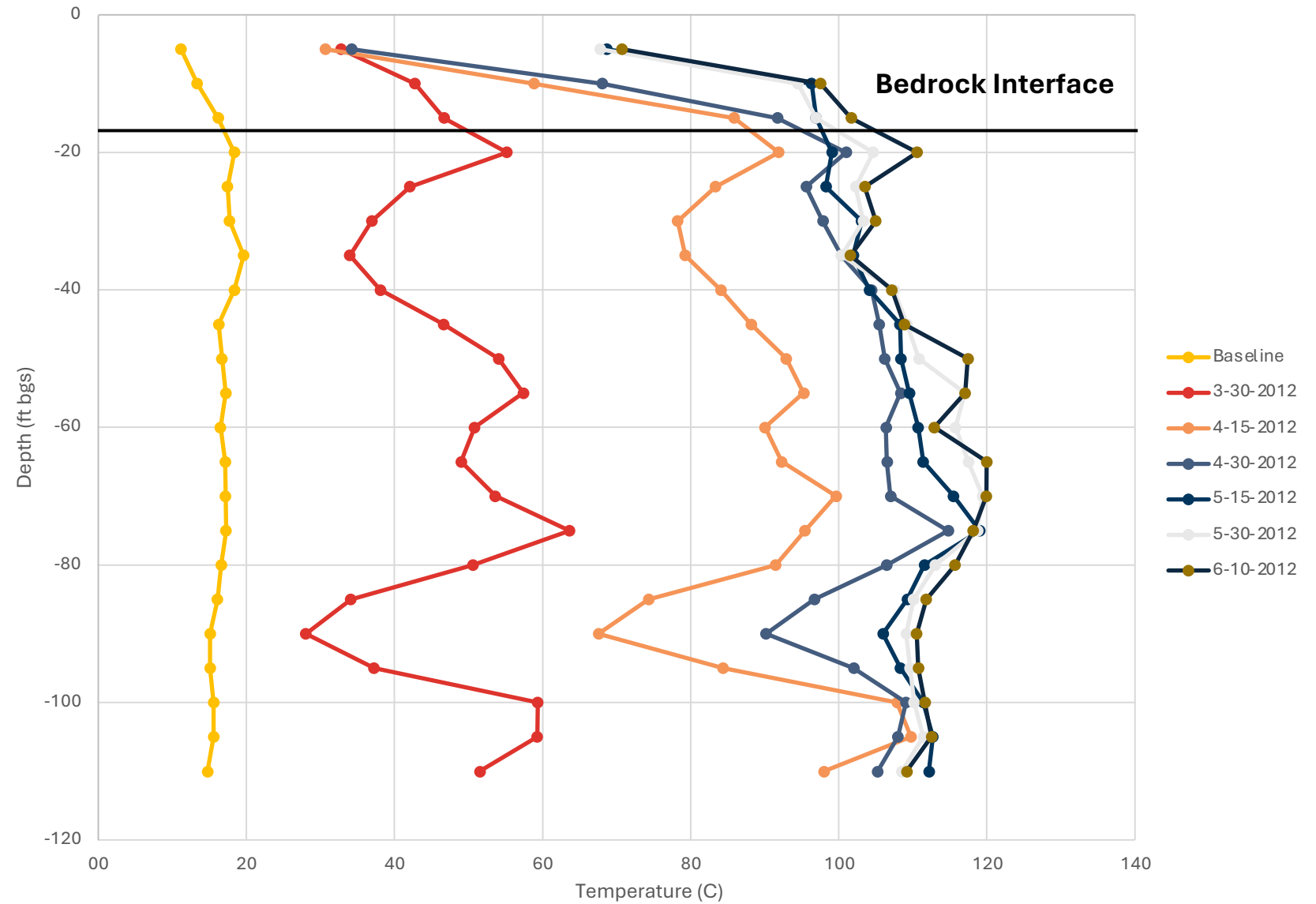
- 90' sandstone sequence
- **82 days of heating**
- 99.9% TCE concentration reduction

Also, TRS has remediated:

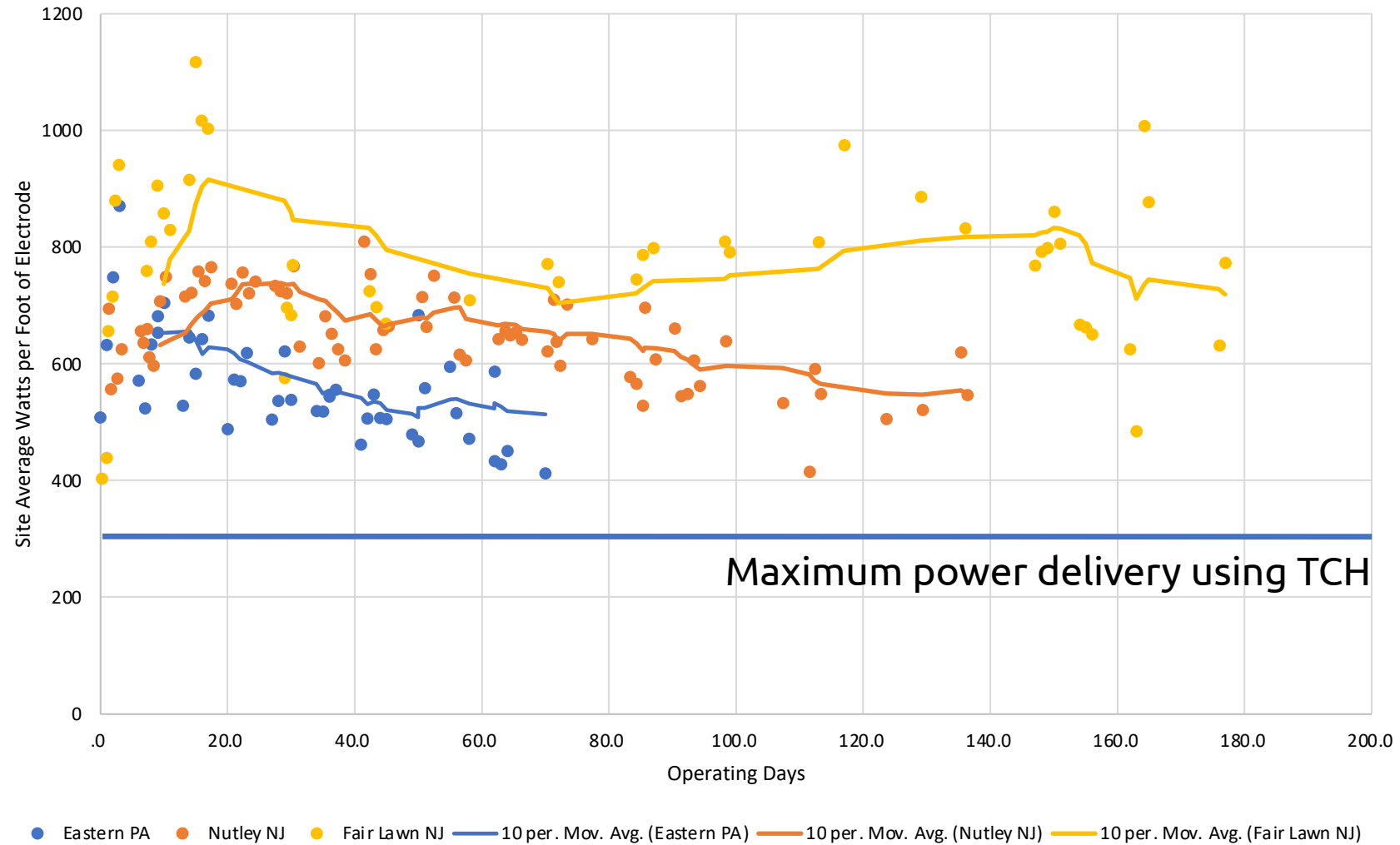
- Karst
- Metamorphic rock



Temperature Profile



ERH Performance in Sedimentary Rock





FlexHeater®

TCH Services

FlexHeater System

- Certified safe; meets UL standards
- Patented
- Variable power output along length
- Low power loss
- 600 to 800 degrees Celsius
- Small diameter casing

CONFORMS TO UL STD 1030

 **TRS** Group
Accelerating Value

Model:

Serial Number:

Mfg. Date:

Voltage Range: 0-480 Volts AC

Power: 0-450 watts/foot

RECOGNIZED COMPONENT
 **US**
Intertek
5019825

Manufactured:
8901 Rawles Avenue, Indianapolis, IN 46219

Powered by TRS Group FlexHeater® Services
www.thermalrs.com

FlexHeater® TCH Services



Pohatcong Valley Groundwater Superfund Site

- > 200,000 man-hours with zero injuries or incidents
- Limited access; complex installation
- Piping & cables roof-routed
- 230-foot heaters
- Heater fans
- Five miles of drilling under manufacturing facility

Pohatcong Roof Construction

Minimizing disturbance to manufacturing facility operations



FlexHeater Installation



Heater length: 230 feet Site total: 5 miles

FlexHeater® TCH Services
Pacific Northwest



FlexHeater® TCH Services
Pacific Northwest



FlexHeater® TCH Services
Pacific Northwest



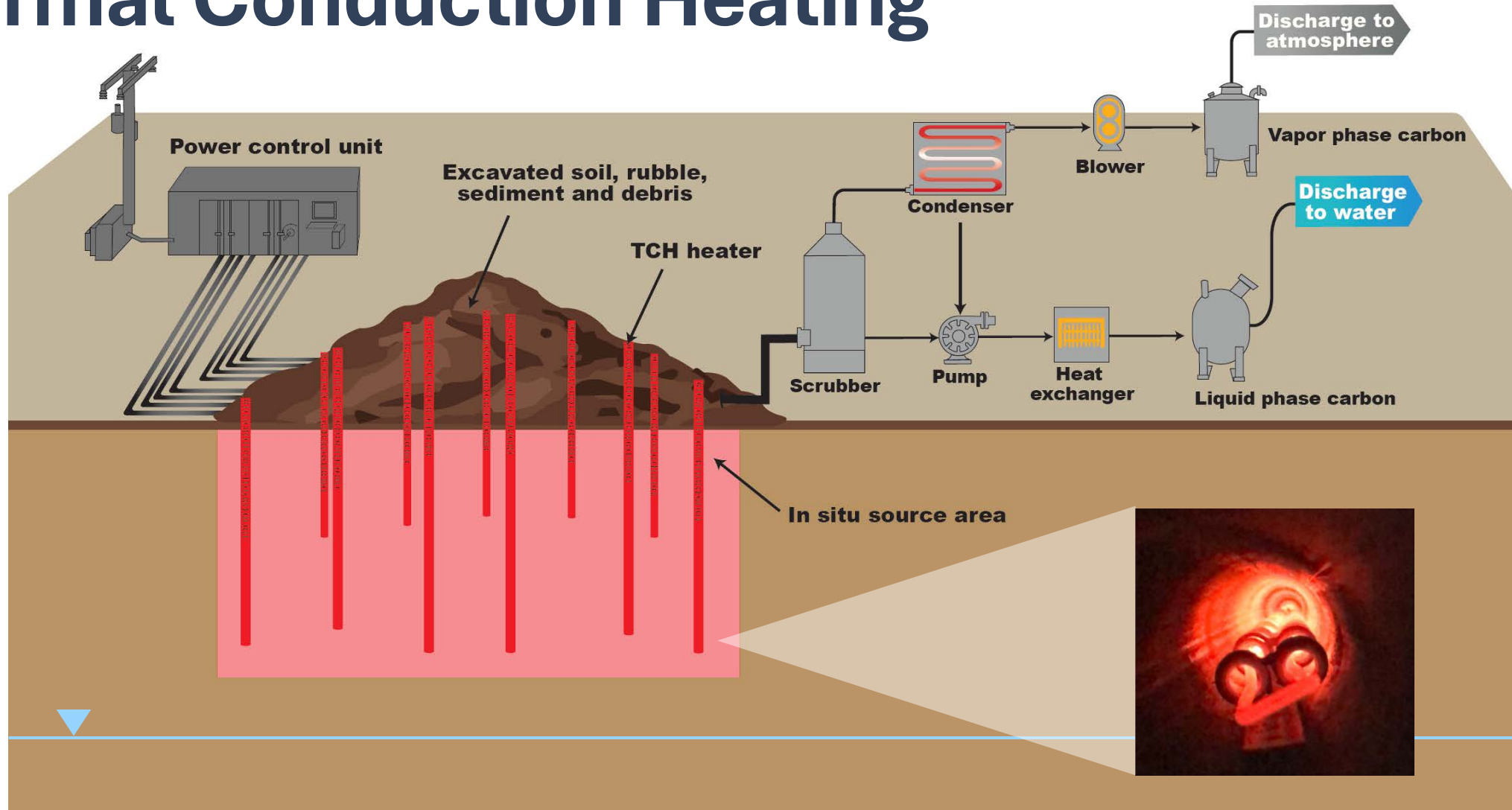
FlexHeater® TCH Services
Pacific Northwest

***FlexHeater*® TCH Services**
Pacific Northwest



Applying TCH for PFAS-impacted Soil Remediation

Thermal Conduction Heating



PFAS Boiling Points

Benzo(a)pyrene

500 °C

Dioxin

400 °C

PCB

300 °C

Naphthalene

200 °C

Xylene

PCE

100 °C

TCE

Carbon chain length

PFTeDS

PFOS

PFHxS

PFBS

Sulfonates/
Sulfonic acids

PFDoDA

PFDA

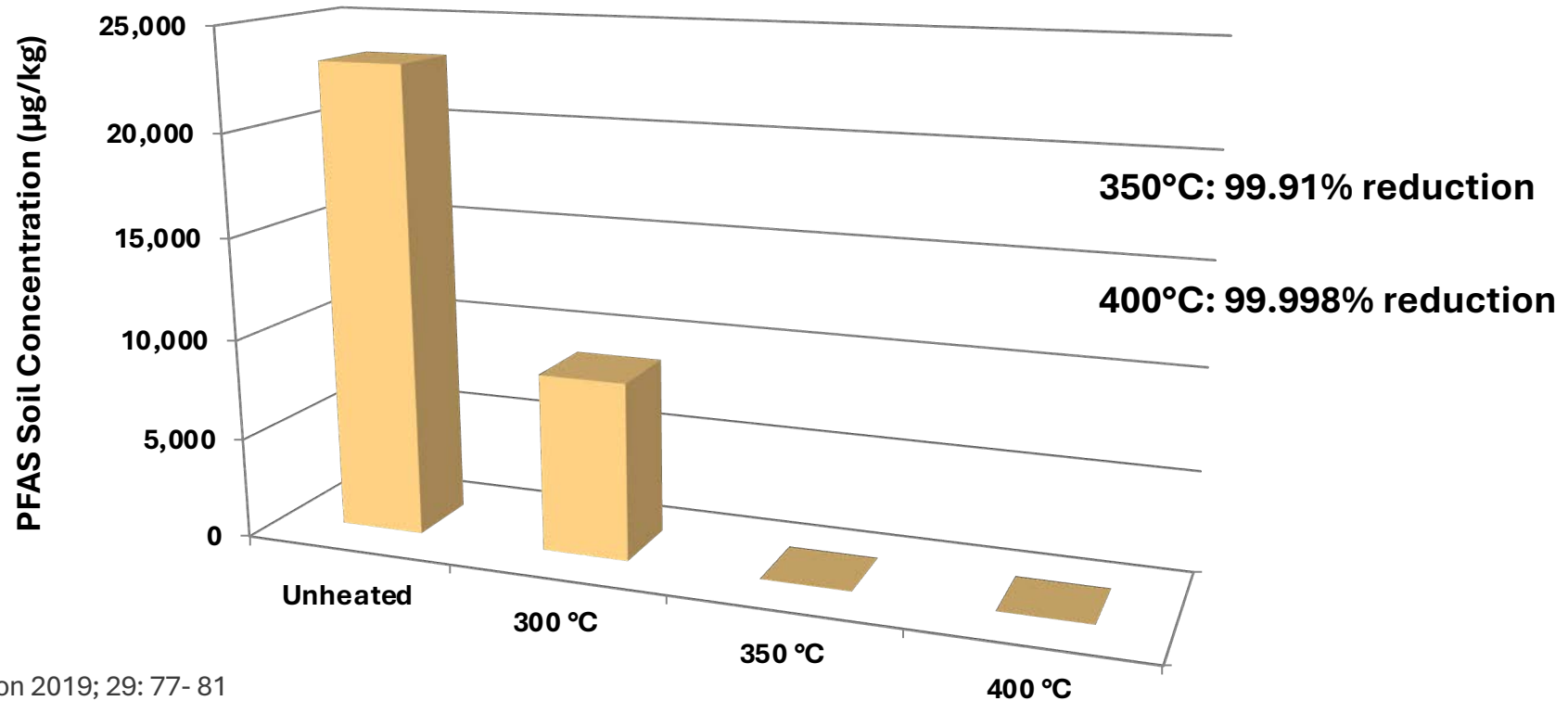
PFOA

PFHxA

PFBA

Carboxylates/
Carboxylic acids

Patented PFAS Treatment



Remediation 2019; 29: 77- 81

Two Weeks at Temperature

ESTCP PFAS Soil Remediation Projects

- Eielson AFB (ER20-5198)

- Ex situ soil pile (134 yd³)
- Pilot study completed

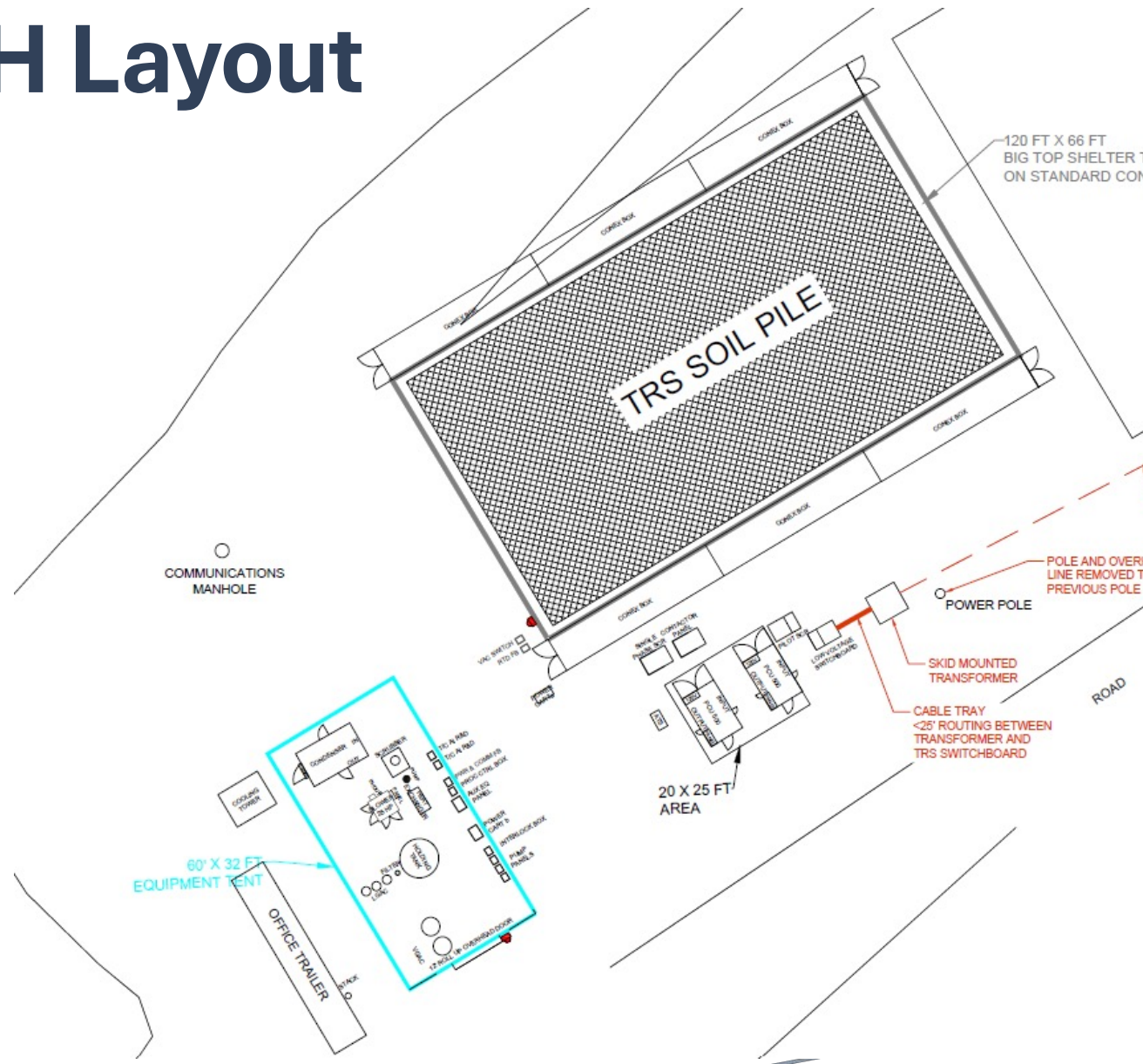


- Beale AFB (ER20-5250)

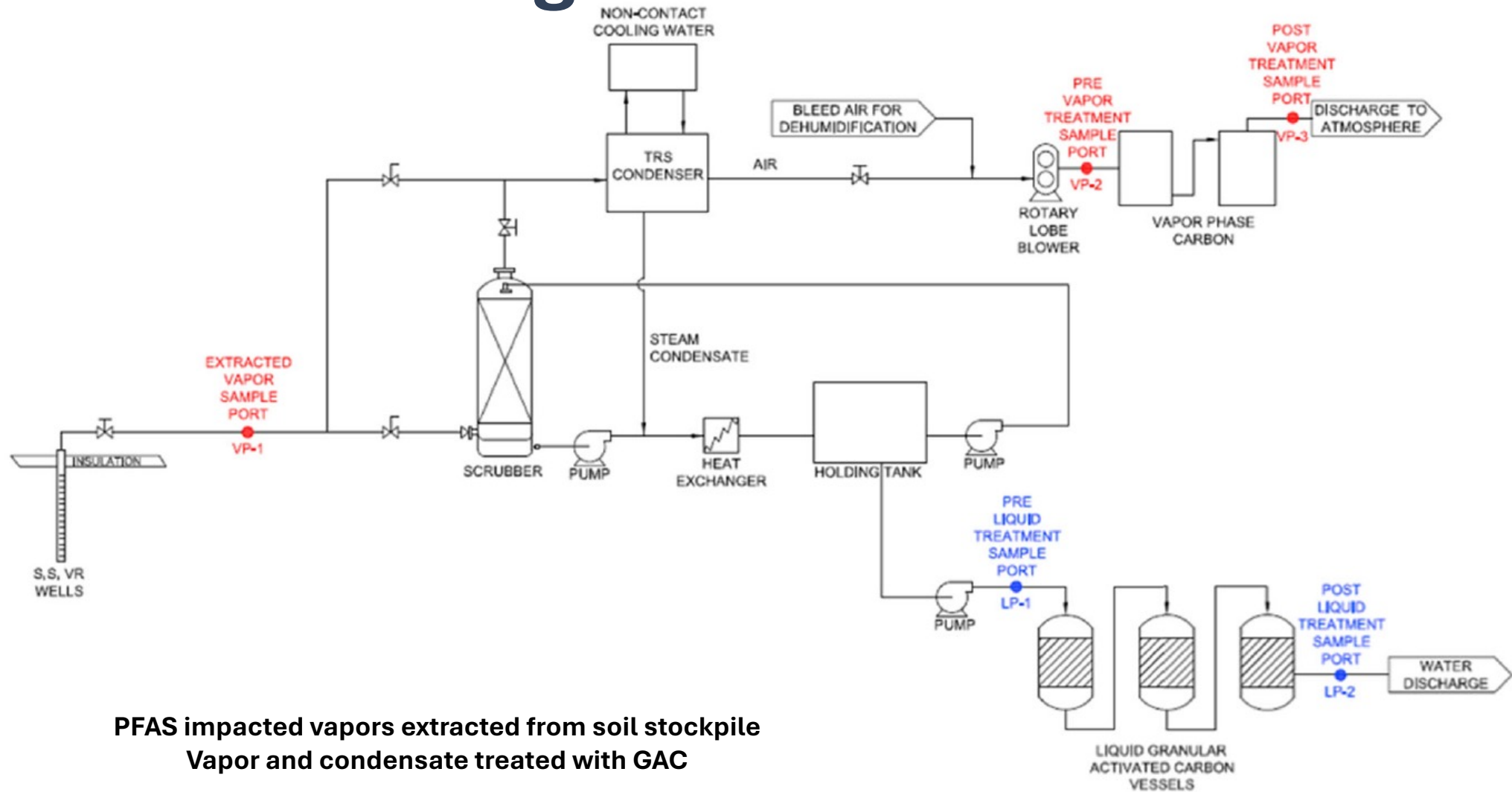
- In situ vadose zone (120 yd³)
- Pilot study completed



JBER TCH Layout



Process Flow Diagram



PFAS impacted vapors extracted from soil stockpile
Vapor and condensate treated with GAC

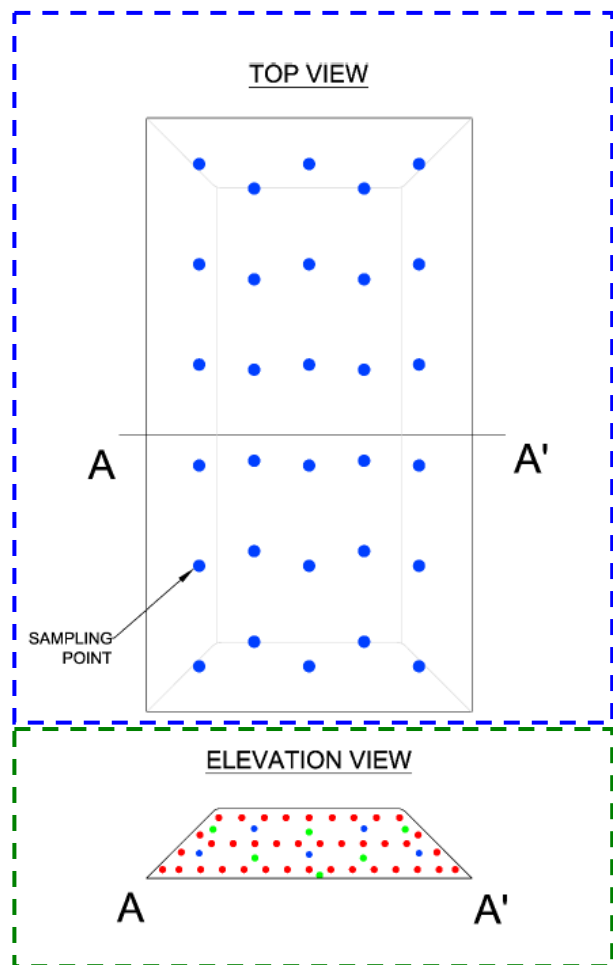
2,000 yd³ Pile Construction - Heaters



2,000 yd³ Pile Construction - Insulation



JBER Soil Pile: Total PFAS Baseline

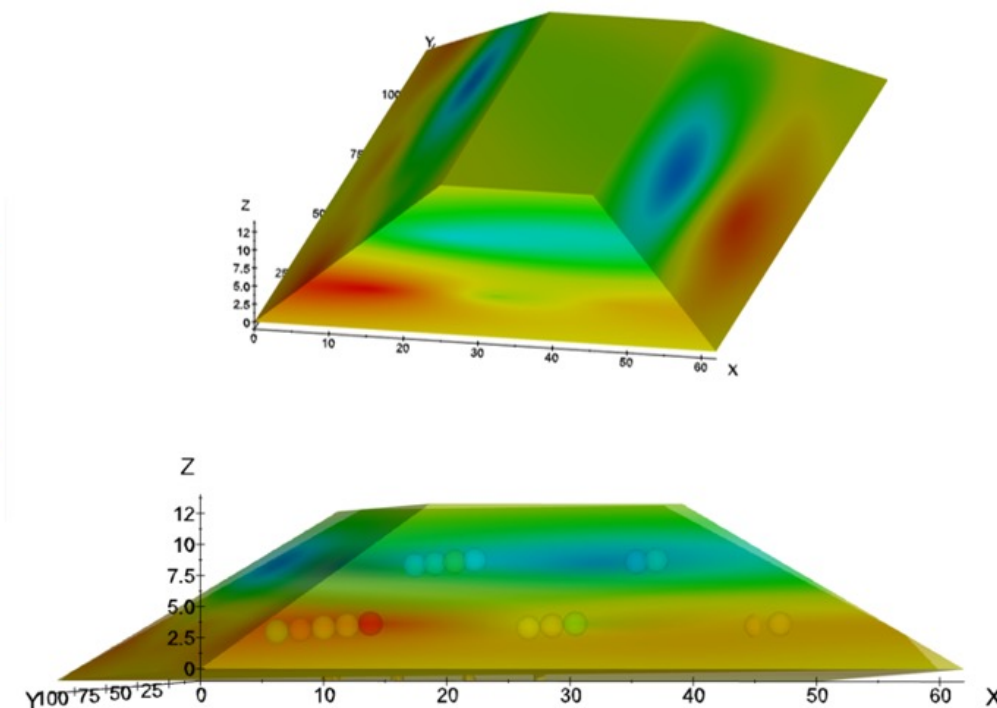


● Co-located soil sample and temperature sensor

● Horizontal heater

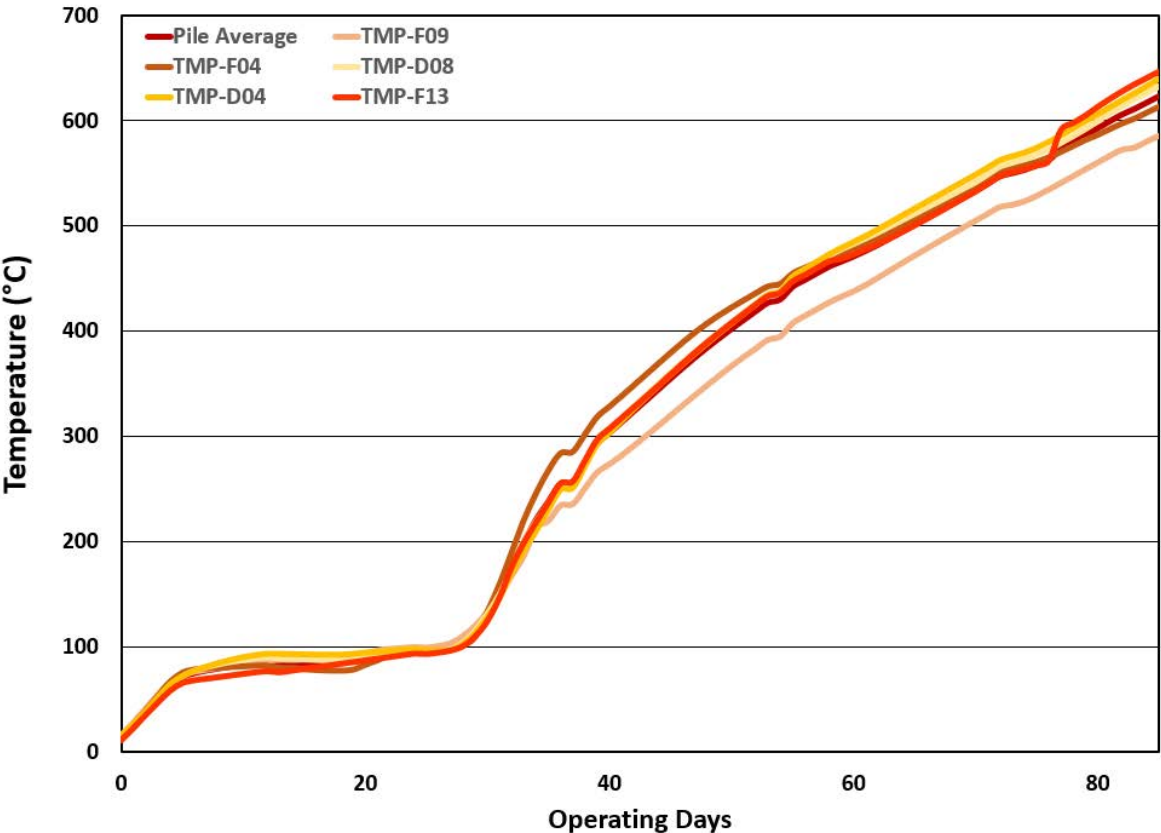
● Vapor extraction point

53 ug/kg
46 ug/kg
40 ug/kg
33 ug/kg
27 ug/kg
20 ug/kg
13 ug/kg
6.6 ug/kg
0.0010 ug/kg
Total PFAS

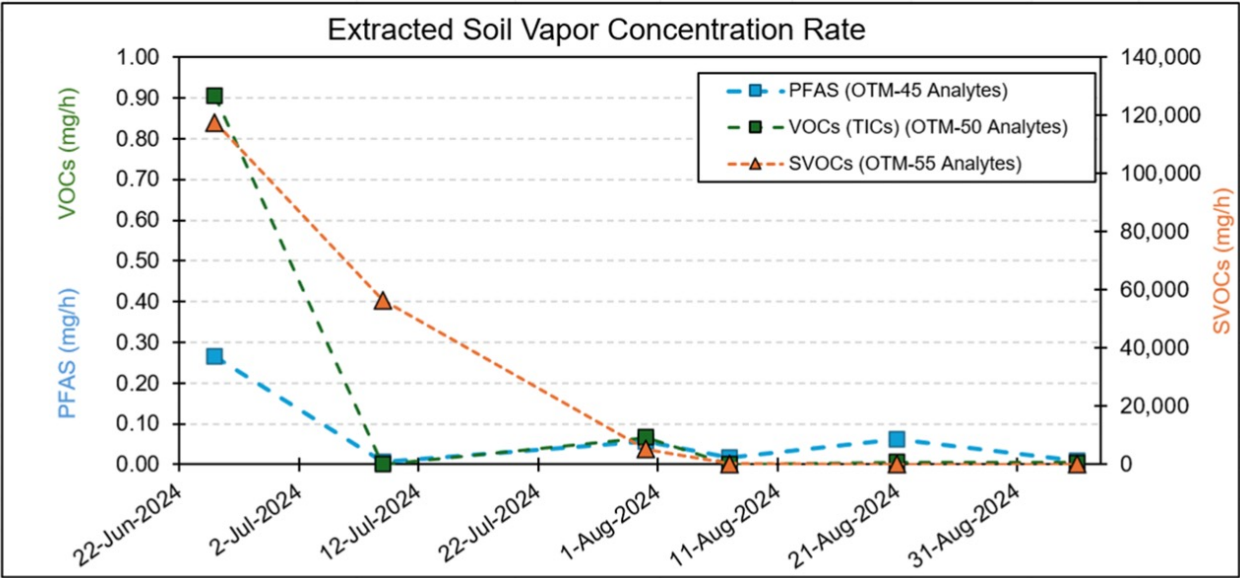


PFOS, PFOA, & 8:2FTS

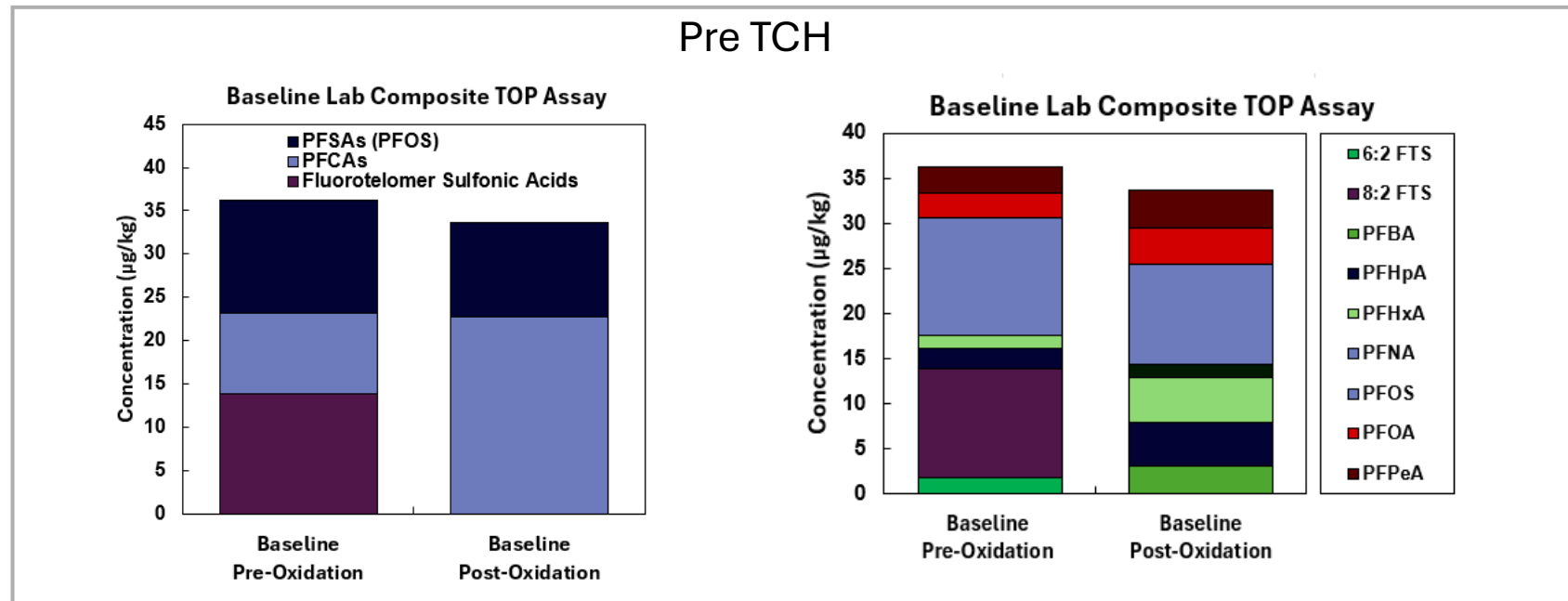
JBER Operations



OTM-45, OTM-50, OTM-55 analytes



JBER Soil Total Oxidizable Precursor Assay



Post TCH composite soil sample below detection limits for all targeted PFAS (EPA Method 1633) and post-TOP assay (post-oxidation)

All 30 discrete soil samples below detection limits for all 1633 PFAS analytes, except three J qualified analytes below reporting limits

Key Points

- >99.9% COC reductions
- Guarantees reduce client risk
- Sophisticated modeling
- Extensive R&D
- In situ, ex situ, & hybrid applications



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