IDENTIFICATION AND ENHANCEMENT OF NATURALLY-OCCURRING IN-SITU AEROBIC METABOLIC BIODEGRADATION OF 1,4-DIOXANE

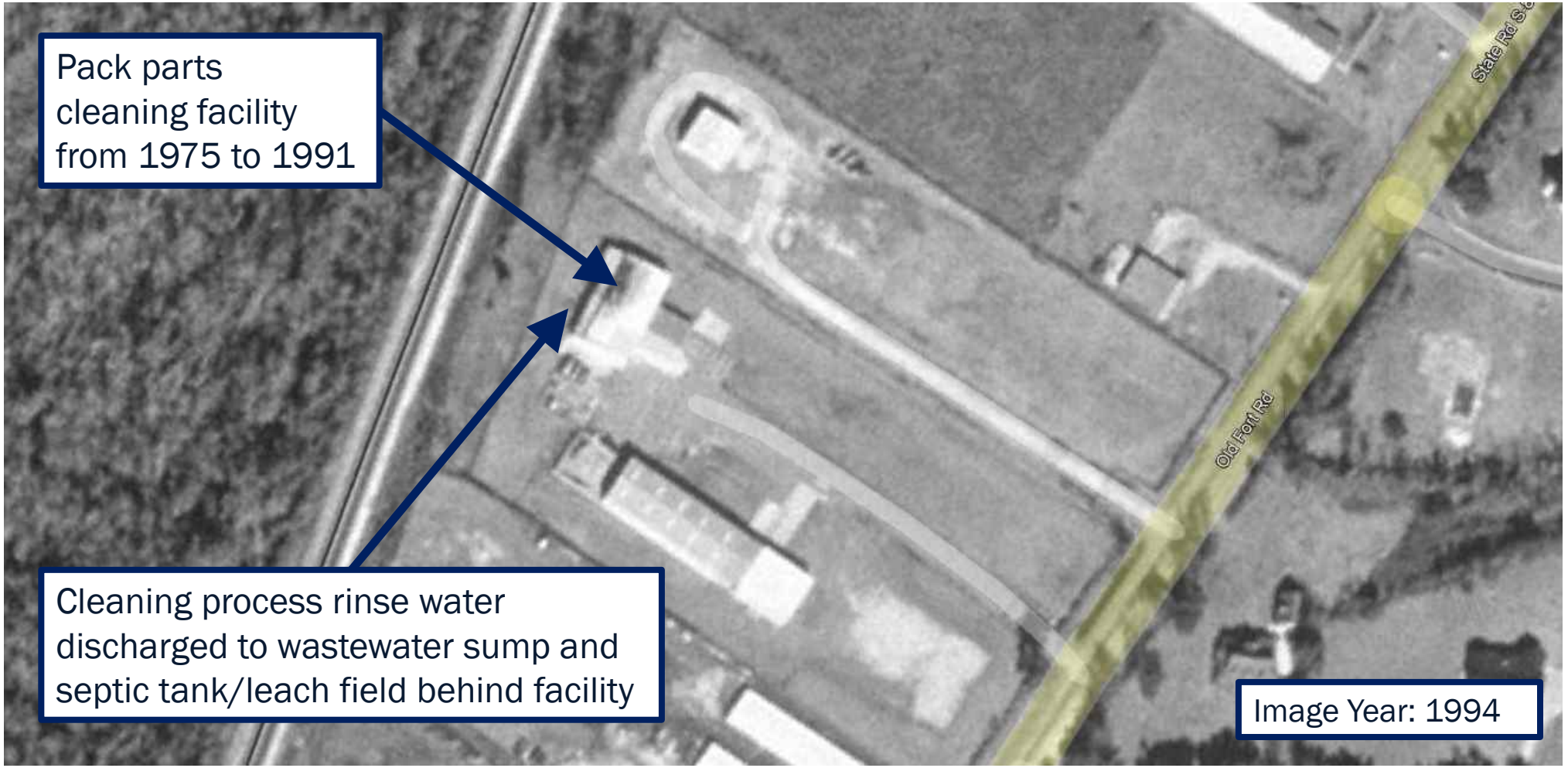
Visit Parsons at Booth #135

Kristi Diller (Parsons, CO)
Daniel R. Griffiths (Parsons, Denver, CO), Tracy Ovbey (Parsons, Wilmington, NC), E. Erin Mack (Corteva Corporate Remediation Group, Newark, DE), Douglas P. Fletcher (Corteva Corporate Remediation Group, Charlotte, NC)
June 6, 2024

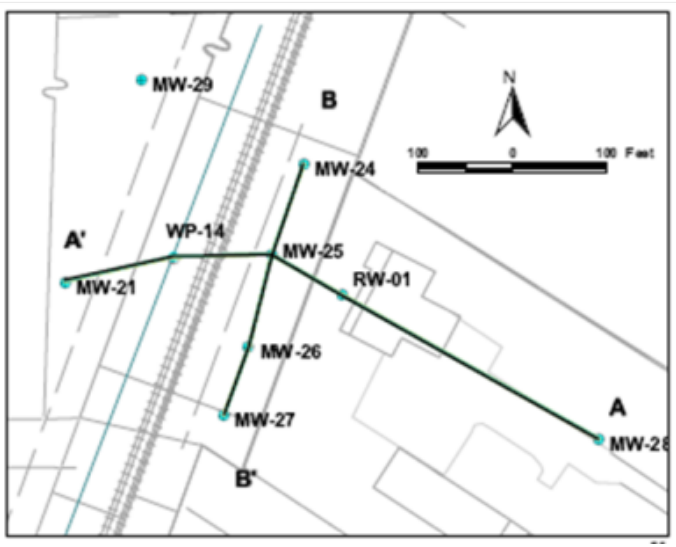
BACKGROUND AND OBJECTIVE

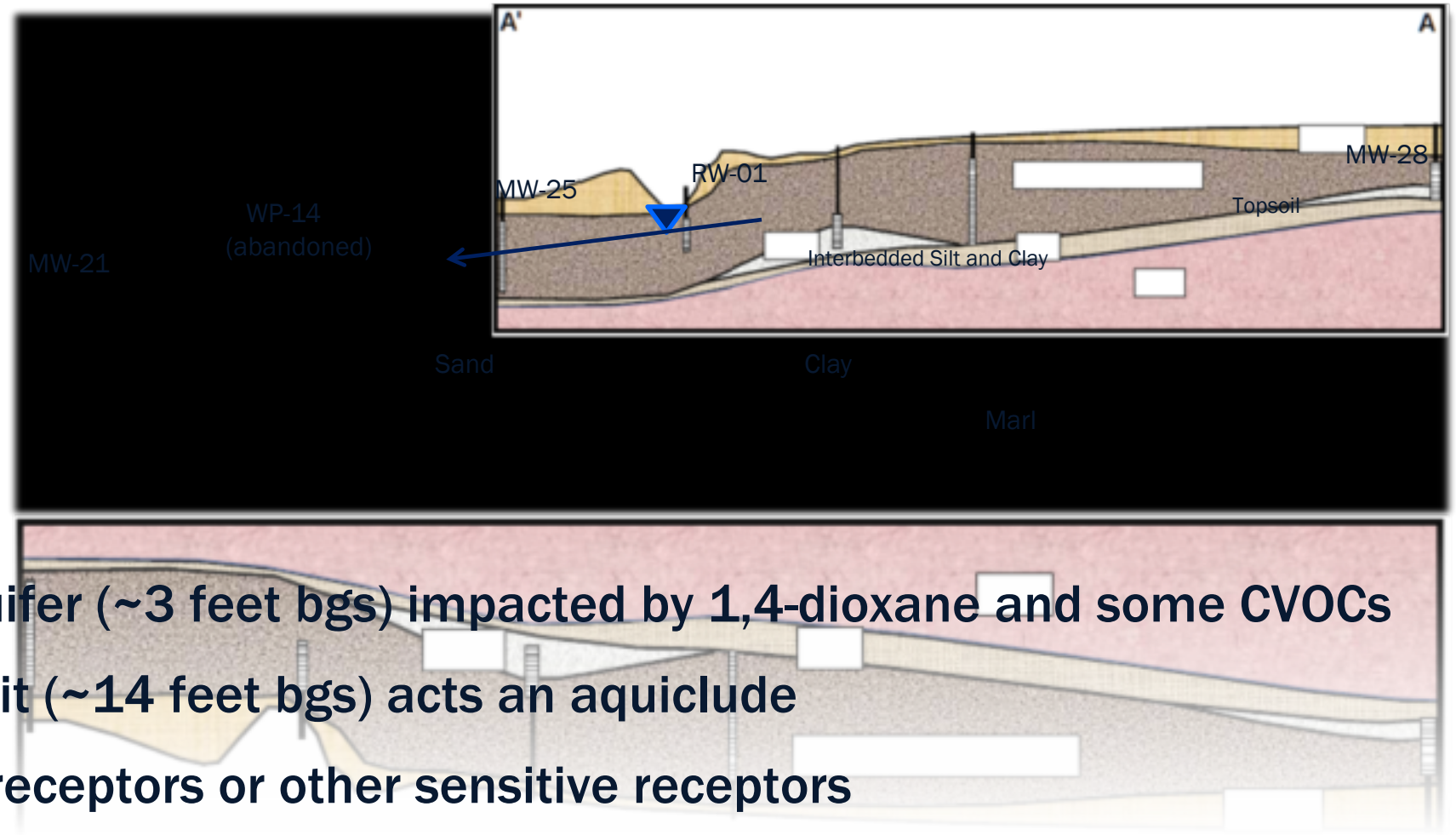
- 1,4-Dioxane impacted shallow groundwater
- Phytoremediation pilot study implemented in 2007
- Rate of contaminant concentration decline determined to be slower than desired
- State regulators requiring active remediation through a pilot study expansion
- Goals:
  - Increase the rate of contaminant concentration decline
  - Reduce contaminant mass flux at the property line

SITE OPERATIONAL HISTORY



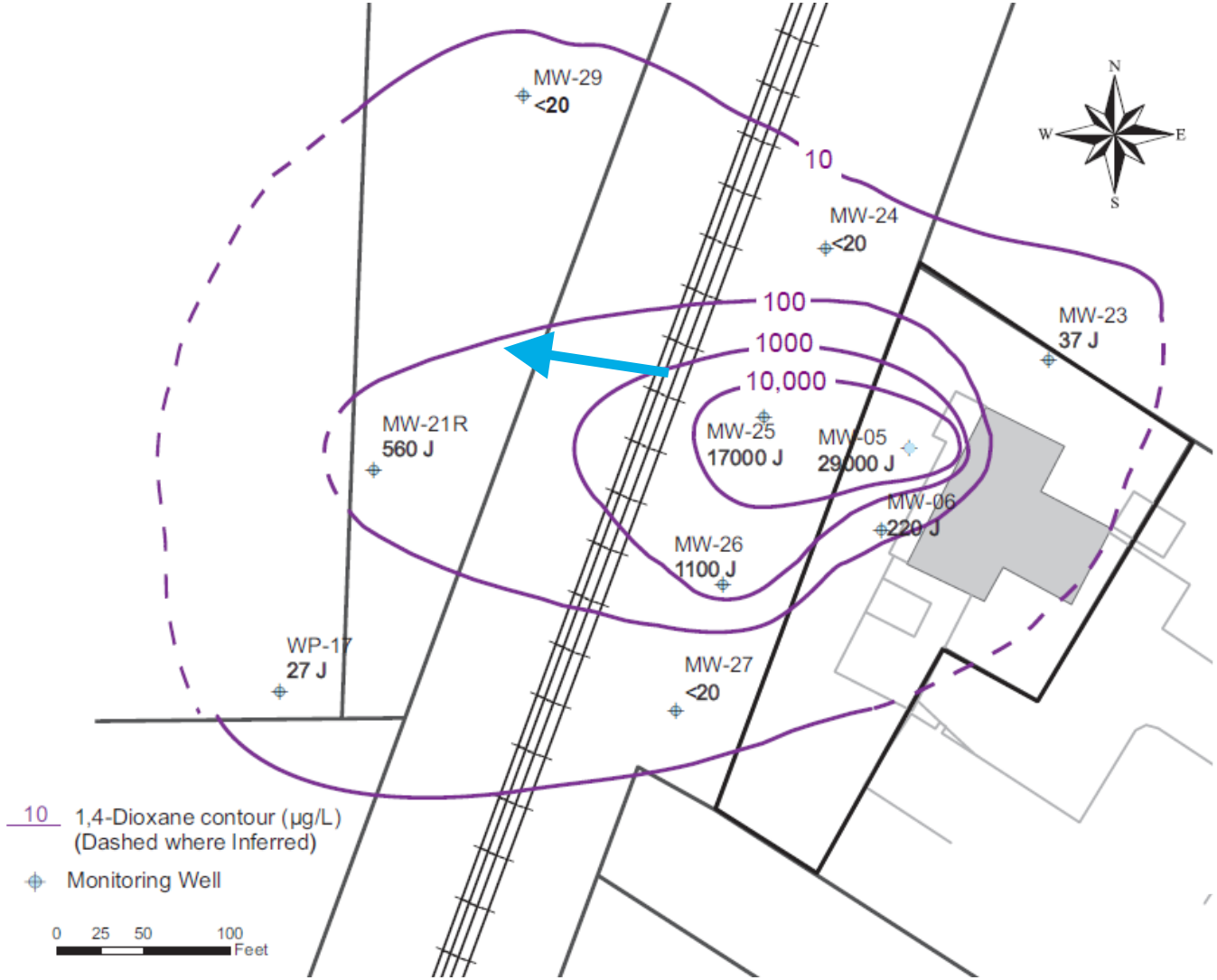
CONCEPTUAL SITE MODEL



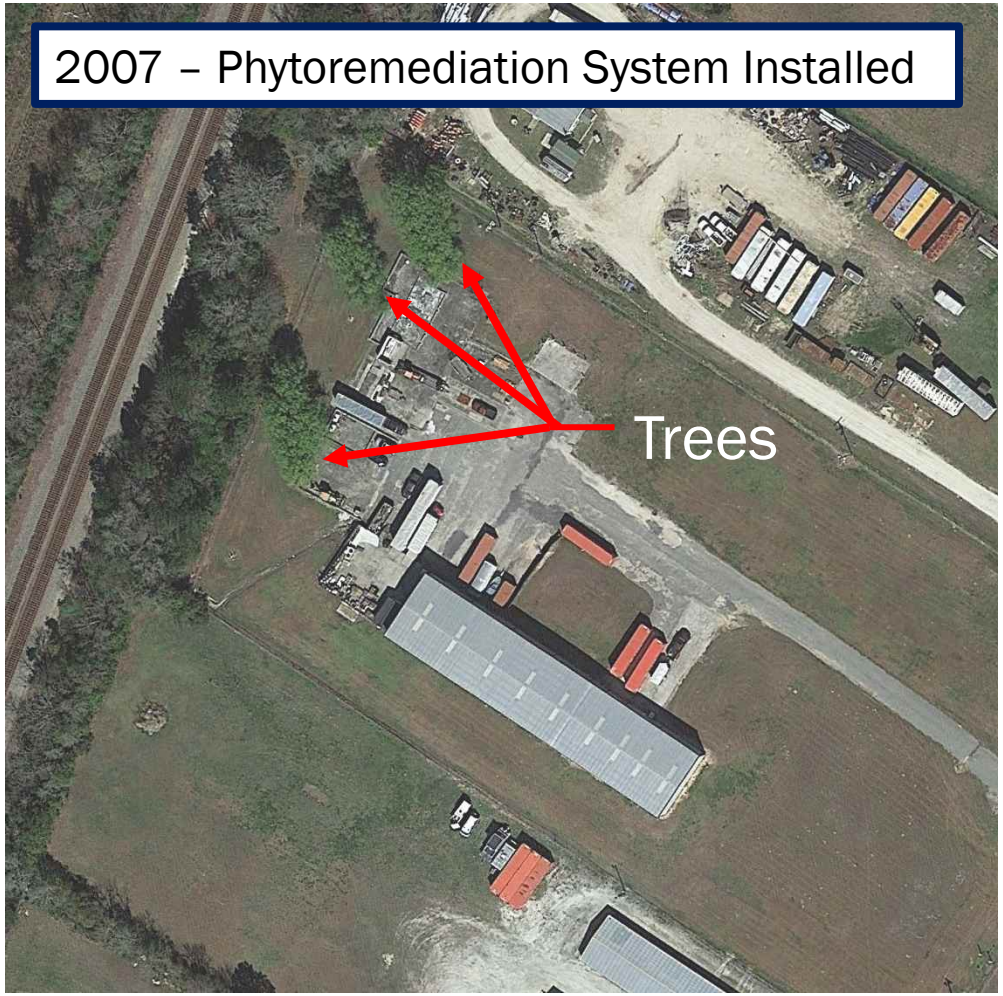


- Anoxic shallow aquifer (~3 feet bgs) impacted by 1,4-dioxane and some CVOCs
- Underlying marl unit (~14 feet bgs) acts an aquiclude
- No drinking water receptors or other sensitive receptors

1,4-DIOXANE GROUNDWATER PLUME – 2017



PILOT STUDY HISTORY



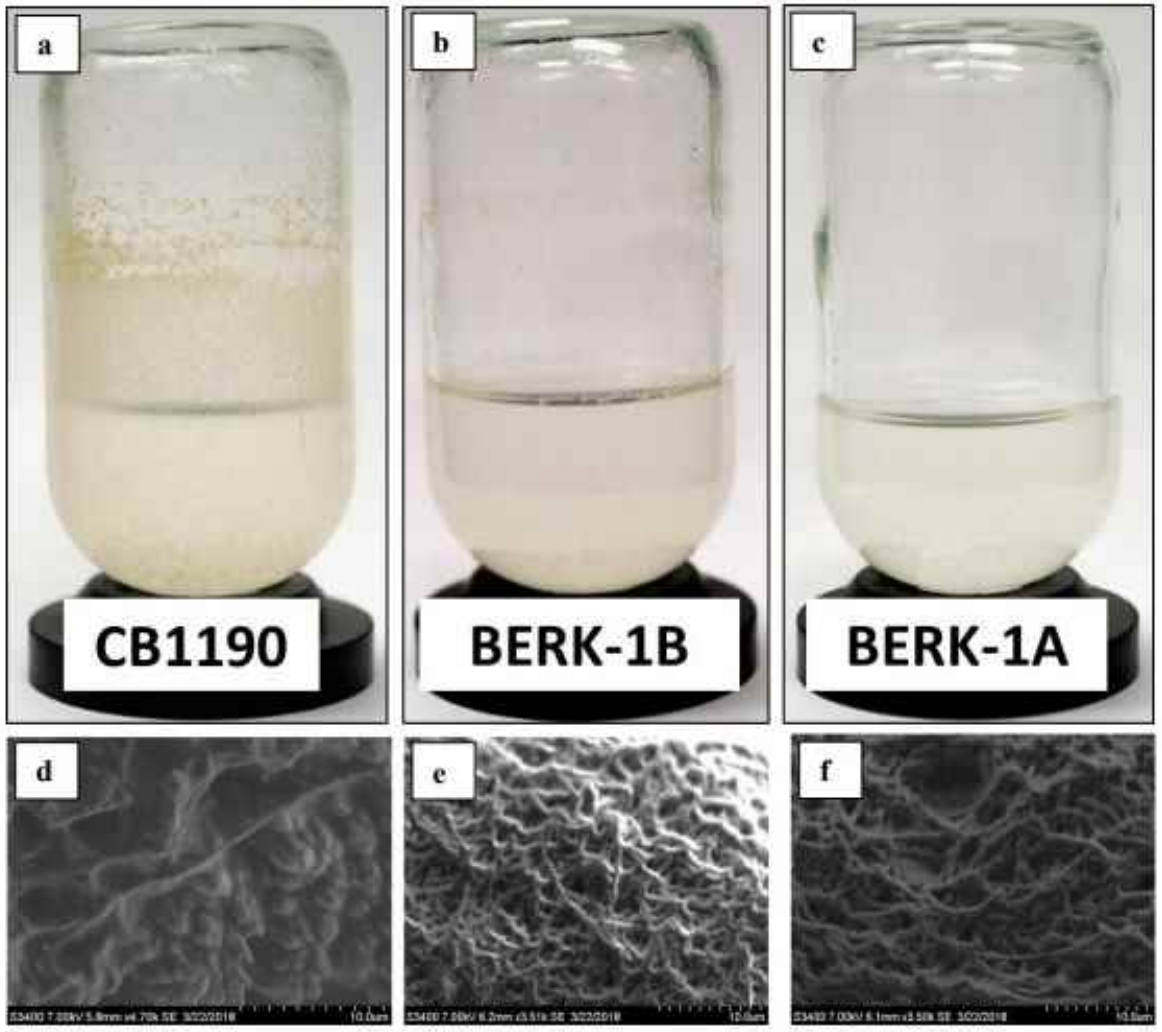
- In 2011 and 2012, tree core analyses showed that 1,4-dioxane was being taken up by phytoremediation trees and native trees
- Groundwater concentrations not significantly reduced
- Trees likely only taking up groundwater at the water table interface

The site needed an expanded pilot study.

WOULD IN-SITU BIOREMEDIATION WORK?

ISOLATING BERK-1

- Laboratory testing conducted at Clemson University
- Isolated metabolic 1,4-dioxane degrader *Pseudonocardia dioxanivorans* BERK-1 from site aquifer materials
- BERK-1 grows on 1,4-dioxane at concentrations as high as 1,000 mg/liter



Sources:

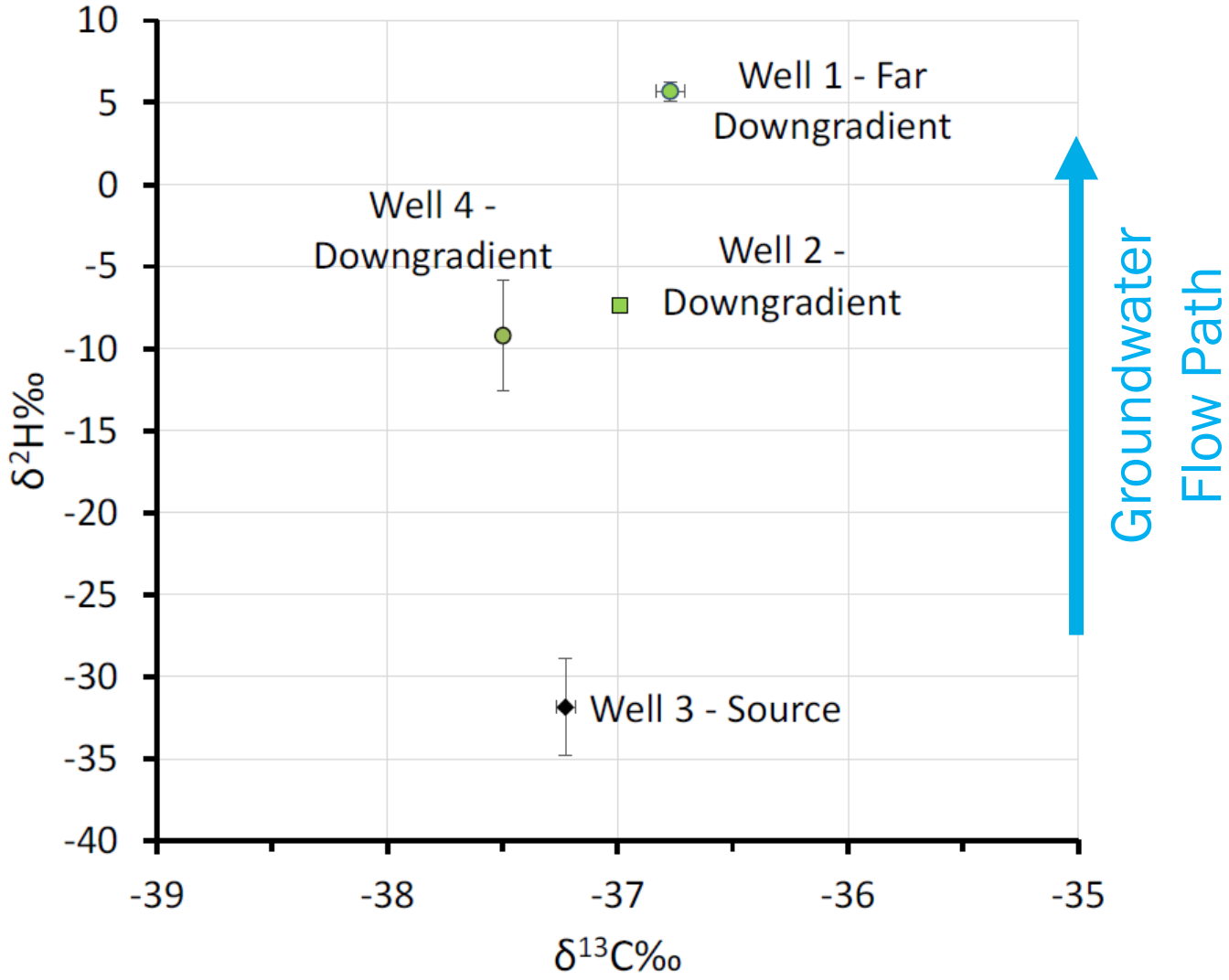
Ramos Garcia AA, Shankar V, Saski CA, Hsiang T, Freedman DL. Draft Genome Sequence of the 1,4-Dioxane-Degrading Bacterium *Pseudonocardia dioxanivorans* BERK-1. Genome Announc. 2018 Apr 5;6(14):e00207-18. doi: 10.1128/genomeA.00207-18. PMID: 29622610; PMCID: PMC5887028.

Ramos Garcia, AA (2020). Evaluation of In Situ Bioremediation of 1,4-Dioxane Under Aerobic and Anaerobic Conditions, Doctoral Dissertation, Clemson University.

Ramos García, AA, Adamson, DT, Wilson JT, Lebrón, C, Danko, AS, Freedman, DL, Evaluation of natural attenuation of 1,4-dioxane in groundwater using a 14C assay, Journal of Hazardous Materials, Volume 424, Part C,2022,127540, https://doi.org/10.1016/j.jhazmat.2021.127540

CLEMSON

COMPOUND SPECIFIC ISOTOPE ANALYSIS



- **Evidence of isotope fractionation along the downgradient groundwater flow path**
- **Indicative of 1,4-dioxane degradation**

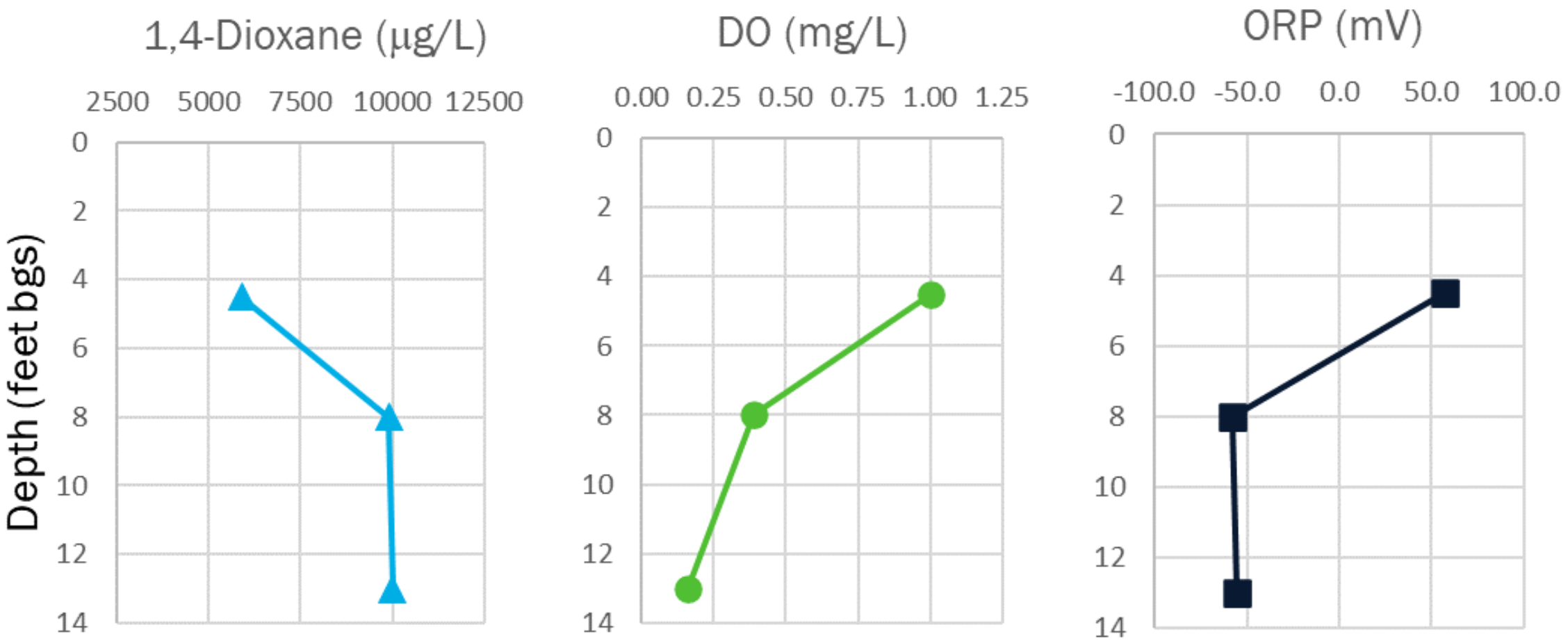
Source:

Adamson DT, Wilson JT, Freedman DL, Ramos-García AA, Lebrón C, Danko A. Establishing the prevalence and relative rates of 1,4-dioxane biodegradation in groundwater to improve remedy evaluations. J Hazard Mater. 2022 Feb 15;424 (Pt D):127736. doi: 10.1016/j.jhazmat.2021.127736. Epub 2021 Nov 12. PMID: 34802822.

SITE-SPECIFIC LINES OF EVIDENCE FOR BIODEGRADATION REMEDIES

- ✓ Loss of mass in situ (concentrations reduced time and space)
- ✓ Documented biological mechanism for degradation (BERK-1)
- ✓ Evidence of in-situ degradation (CSIA results)
- ? In-situ conditions conducive to the proposed degradation mechanism

DATA GAP INVESTIGATION

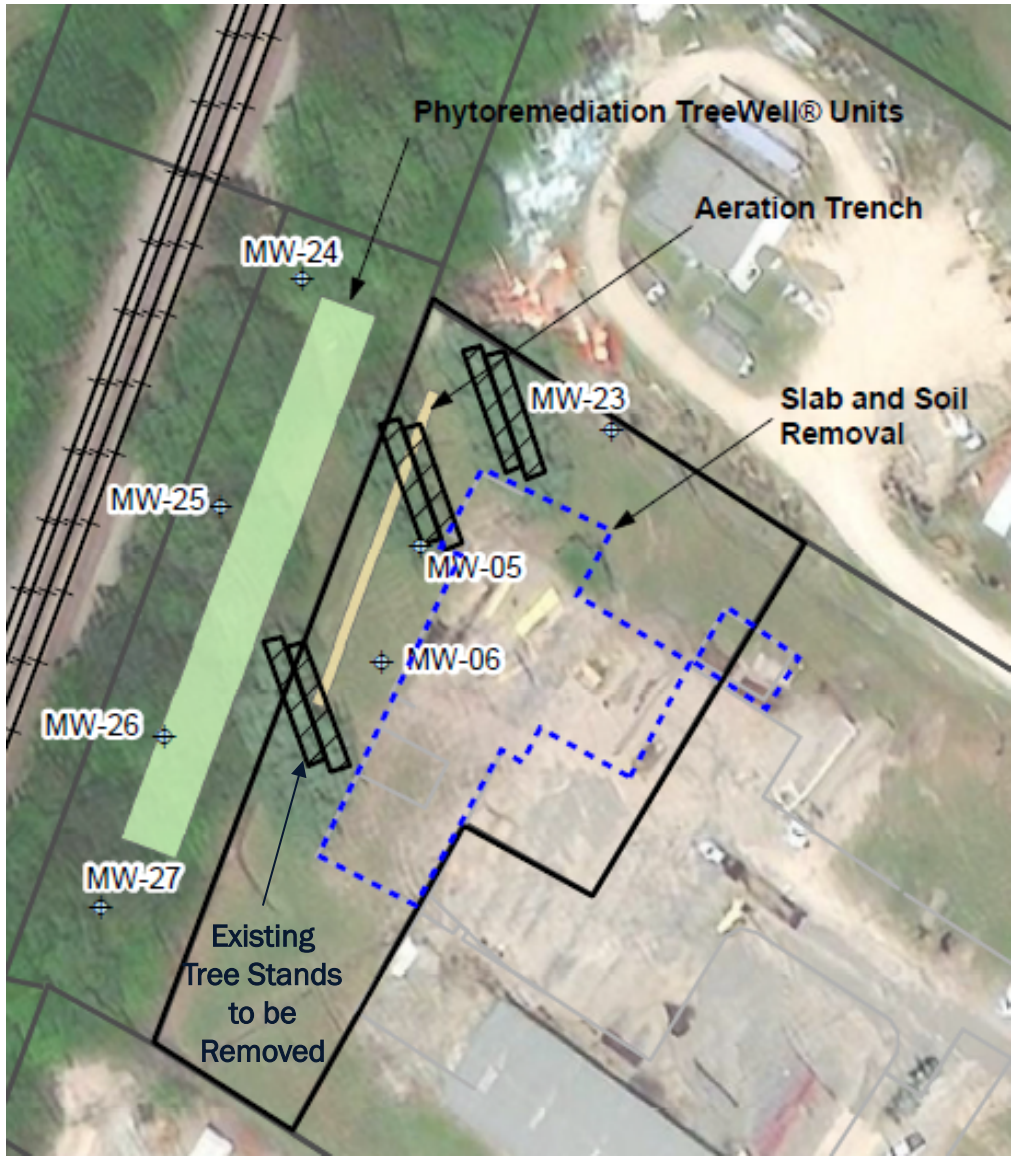


- 1,4-dioxane concentrations were lowest in the oxic shallow zone
- Natural 1,4-dioxane biodegradation limited by oxygen availability

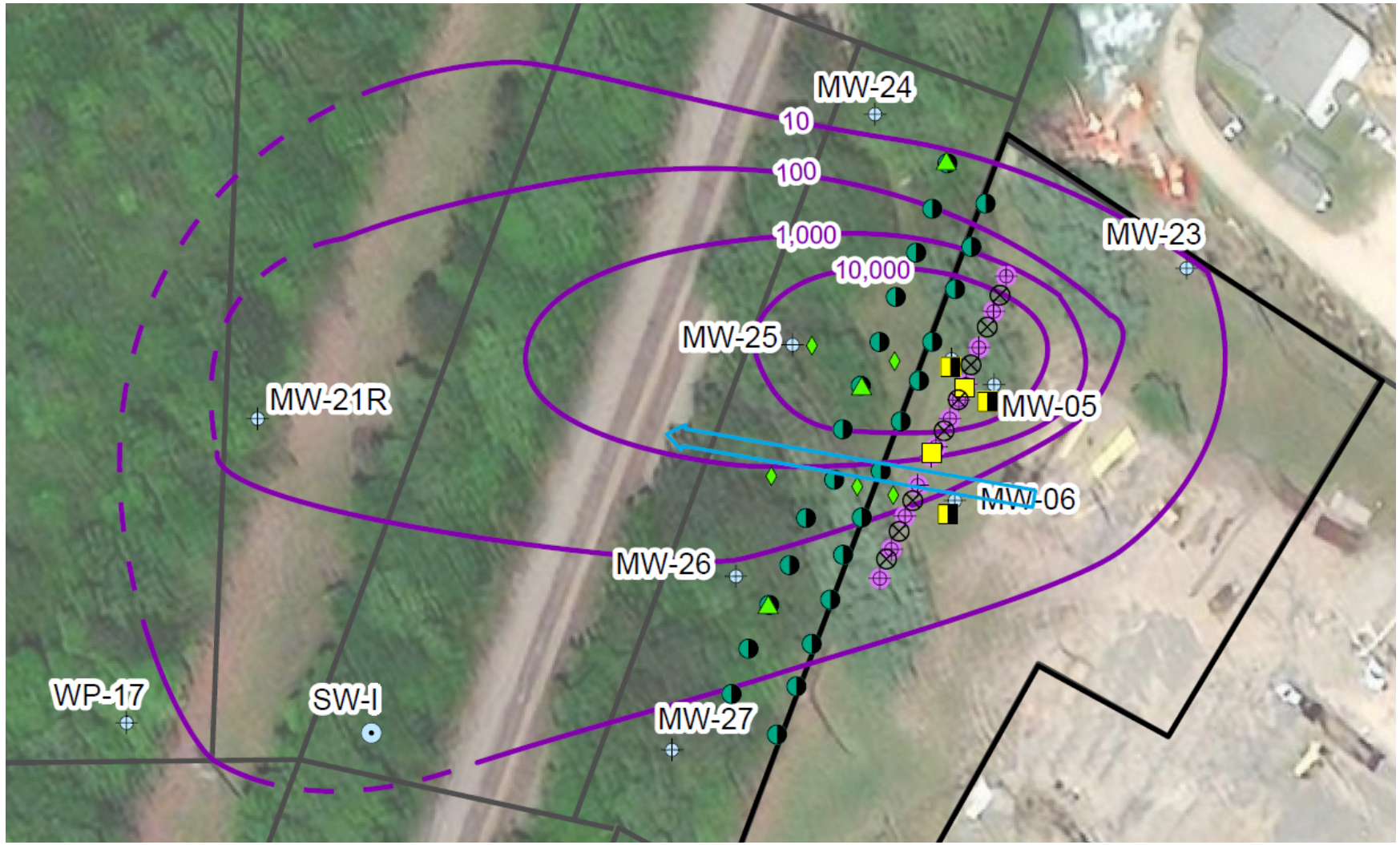
PROPOSED PILOT STUDY EXPANSION

1. **In situ bioremediation via aeration trench**
   - Addition of oxygen to stimulate biodegradation by native microbes
   - Across the core of the plume near the release area
2. **Enhanced phytoremediation system**
   - Remove existing tree stands
   - Downgradient TreeWell® units

Applied Natural Sciences, Inc.



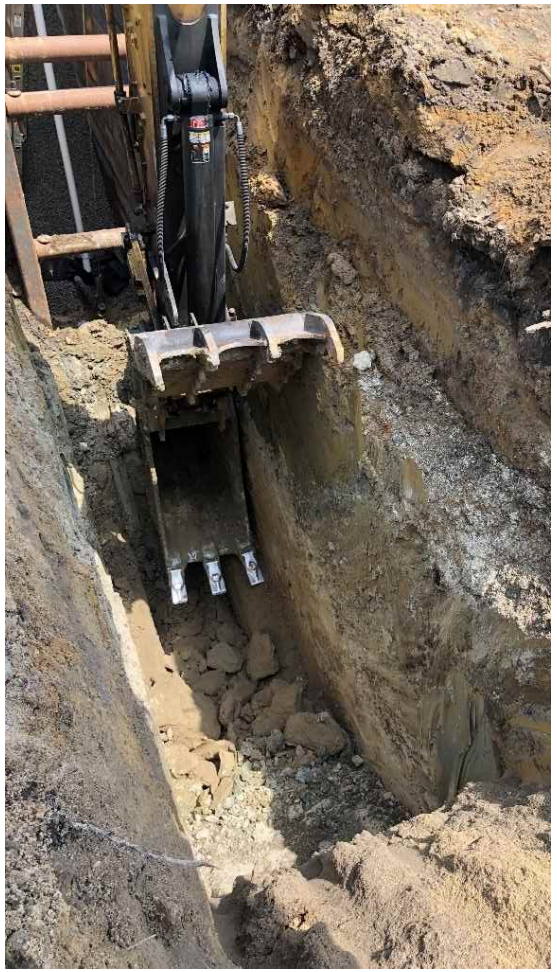
PILOT STUDY EXPANSION



- Air Sparge Well
- Transducer Sensor
- ORP and Transducer Sensor
- ORP Sensor
- Monitoring Point Cluster
- Piezometer
- Phytoremediation TreeWell Unit
- Monitoring Well
- Surface Water
- Site_Boundary
- Parcel Boundary
- 10 — 1,4-Dioxane Contour (ug/L) in December 2023 Dashed where Inferred
- Shallow Groundwater Flow Direction

N

AERATION TRENCH INSTALLATION

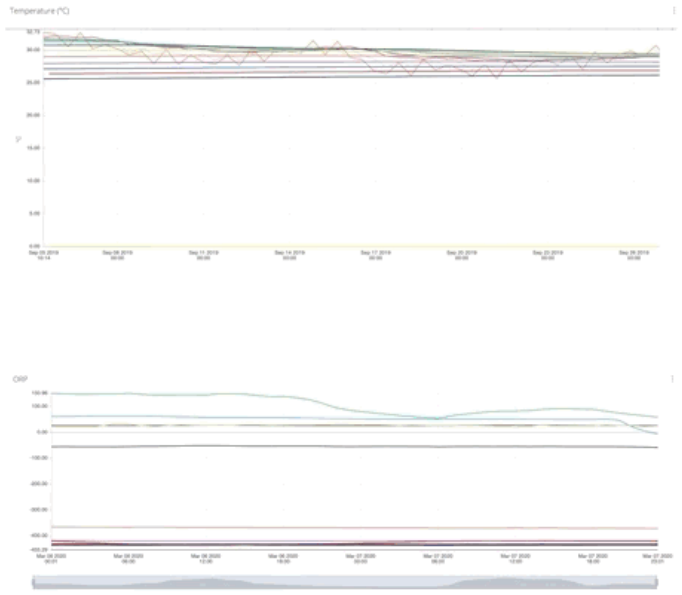


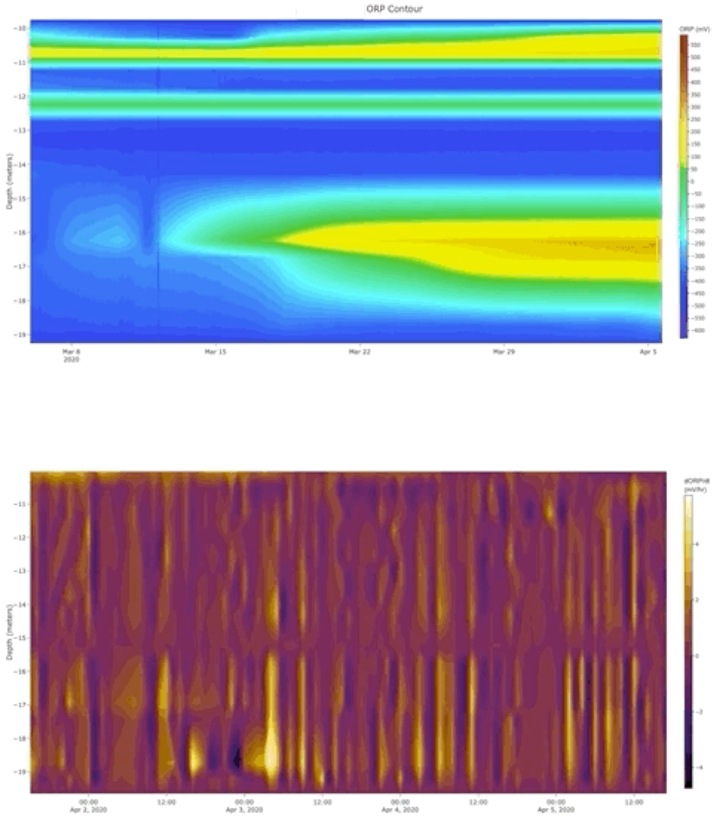
AERATION TRENCH INSTALLATION

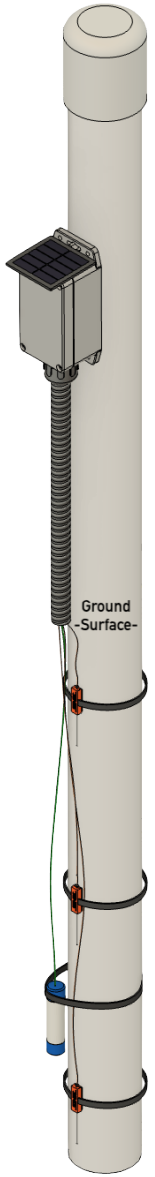
REAL-TIME SENSORS

S3NSE

EXAMPLE DATA





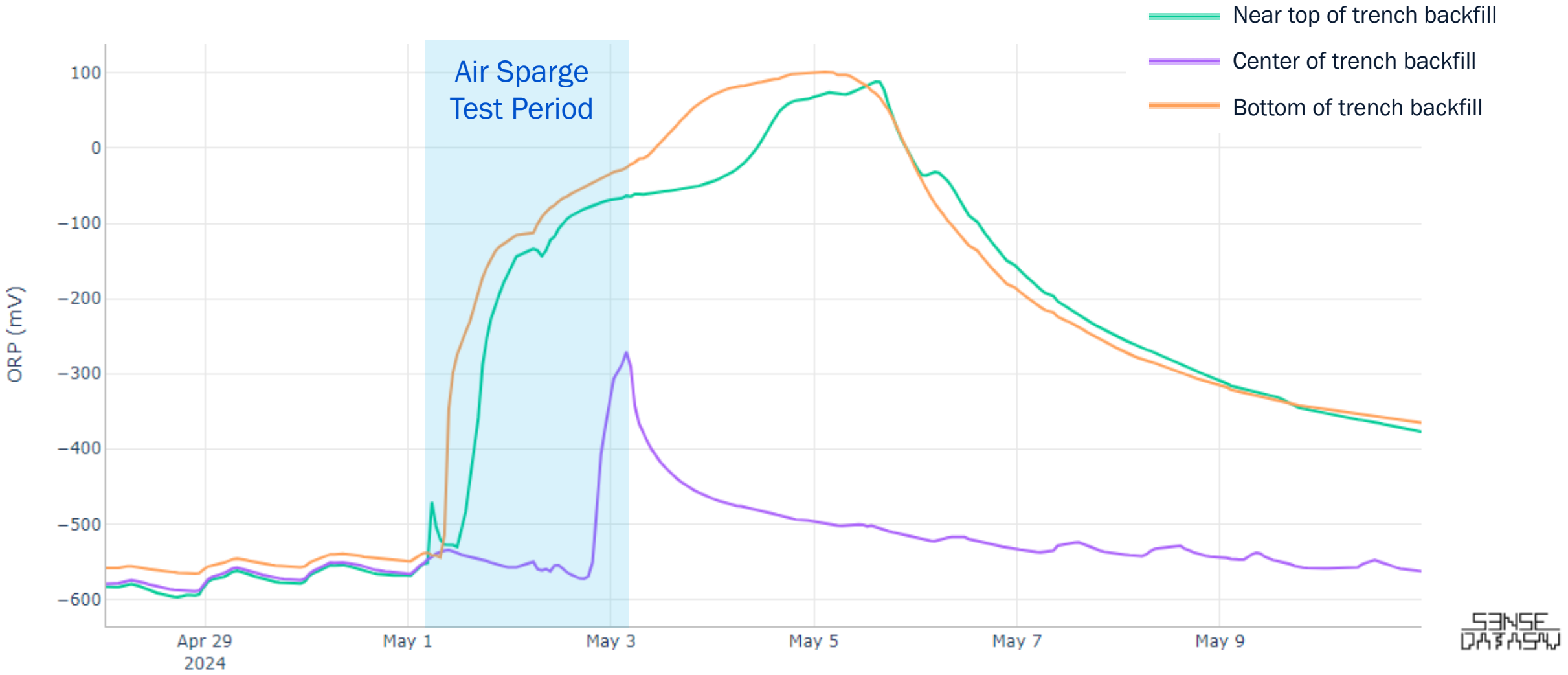


Source: S3NSE Technologies, Inc.
https://www.s3nsetech.com/

PRELIMINARY OPTIMIZATION TEST

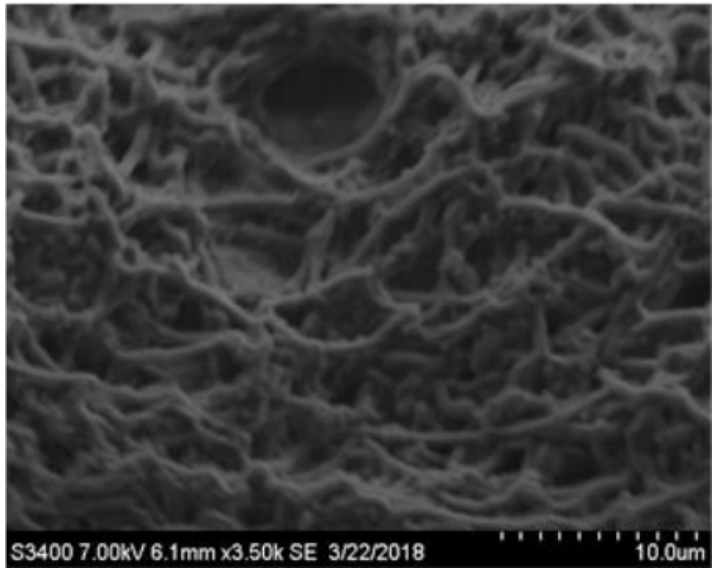
PRELIMINARY OPTIMIZATION TEST

In-Trench ORP Sensor Results



KEY TAKEAWAYS

- Demonstrated natural aerobic biodegradation of 1,4-dioxane
- Limited by anoxic aquifer conditions
- Installed novel engineered approach, an aeration trench, to enhance aerobic metabolic bioremediation
- What's next?
  - Design and start-up of full-scale air injection system
  - Performance monitoring
  - Continued research



PARSONS®

QUESTIONS?

IDENTIFICATION AND ENHANCEMENT OF NATURALLY-OCCURRING IN-SITU AEROBIC METABOLIC BIODEGRADATION OF 1,4-DIOXANE

Kristi Diller, PG
kristi.diller@parsons.com
Direct: + 1 303.764.8803

Visit www.parsons.com or stop by our booth #135 to learn more.