



# ORIN

TECHNOLOGIES



# ABOUT US

- Established in 2001, ORIN Technologies, LLC (ORIN) is an environmental contractor specializing in the application of treatment chemistries that render organic and inorganic contaminants nonhazardous in a safe and cost-effective manner.
- ORIN provides cost effective treatment solutions for contaminated soil and groundwater through innovative chemical solutions.
- ORIN not only provides the latest in chemical solutions, but also has an in-house treatability lab with the ability to analyze a site's contamination situation and apply the best treatment to remedy the problem.
- Unlike most environmental companies, ORIN has in-house technical expertise and technical field experience with a variety of in-situ and ex-situ methodologies to solve a client's problem.



20+

YEARS  
EXPERIENCE

# COMPANY SAFETY ACHIEVEMENT

TOTAL NUMBER OF RECORDABLE INCIDENTS  
DURING ORIN'S 23+ YEARS OF OPERATING  
EXISTENCE:



# In-Situ Immobilization and Bioremediation of PFAS

Larry Kinsman | ORIN Technologies in conjunction with Miller

Introduction

Case Studies

Additional Information

Capabilities



# Current Methodologies

- Landfilling
- Stabilization/Immobilization
  - Carbons, grout blends, polymers and combinations
- Super critical oxidation
- Plasma
- Filtration
  - Activated Carbon, Resins
- Incineration
- RO Systems

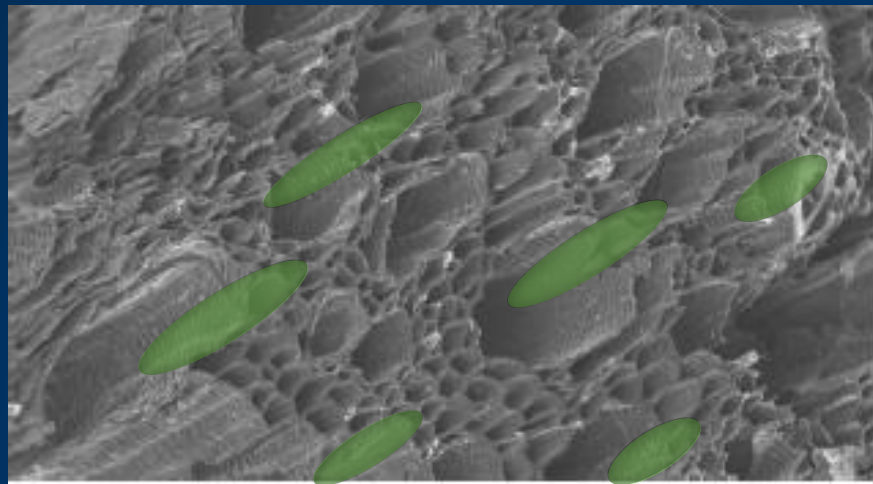


# BIOAVAILABLE ABSORBENT MEDIA (BAM)

- Development began in 2013
- BAM - pyrolyzed, recycled cellulosic biomass
- >80% fixed carbon by weight
- ~Effective due to unique micro-pore structure



Milled BAM.  
Inject in slurry.



Environmental scanning electron microscope (ESEM) image of micro-pore structures

- Surface area = 1,125 m<sup>2</sup>/g
- High absorption capacity
- Prevents exterior surface microfilm buildup
- Niche environments for detoxification

# BAM

- Particle size ranges based on milling procedure
- Surface functional groups (carboxyl, hydroxyl, phenolic hydroxyl, and carbonyl groups)
- High cation exchange capacity
- Vapor Migration & Odor Control
- Immediate clean up of soil & groundwater through absorption and surface area remediation
- Effective on wide range of contaminants
  - Hydrocarbons
  - Chlorinated solvents
  - 1,4 – Dioxane
  - Some heavy metals
  - PCBs
  - PFAS





# METHODS OF APPLICATION

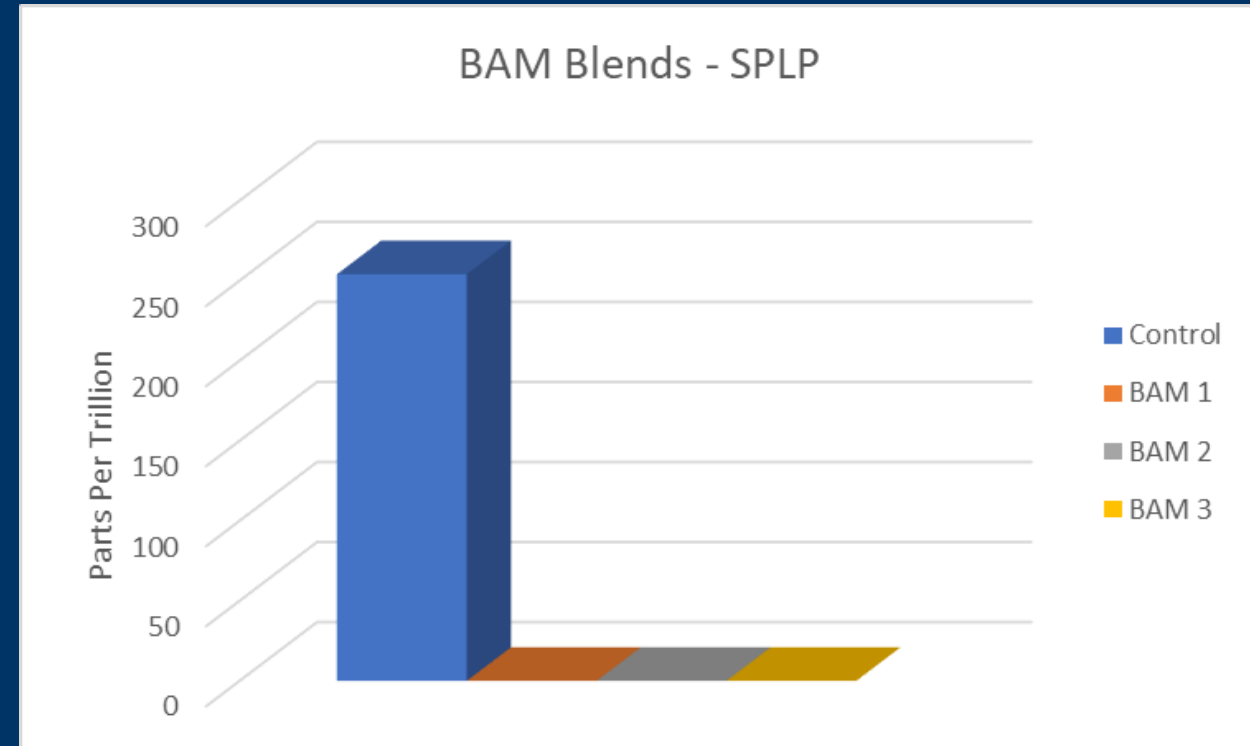
- Can be used as stand alone, with oxidative or reductive treatment chemistries
- Can be injected as a slurry using DPT
- Can be mixed ex situ or in situ utilizing an excavator





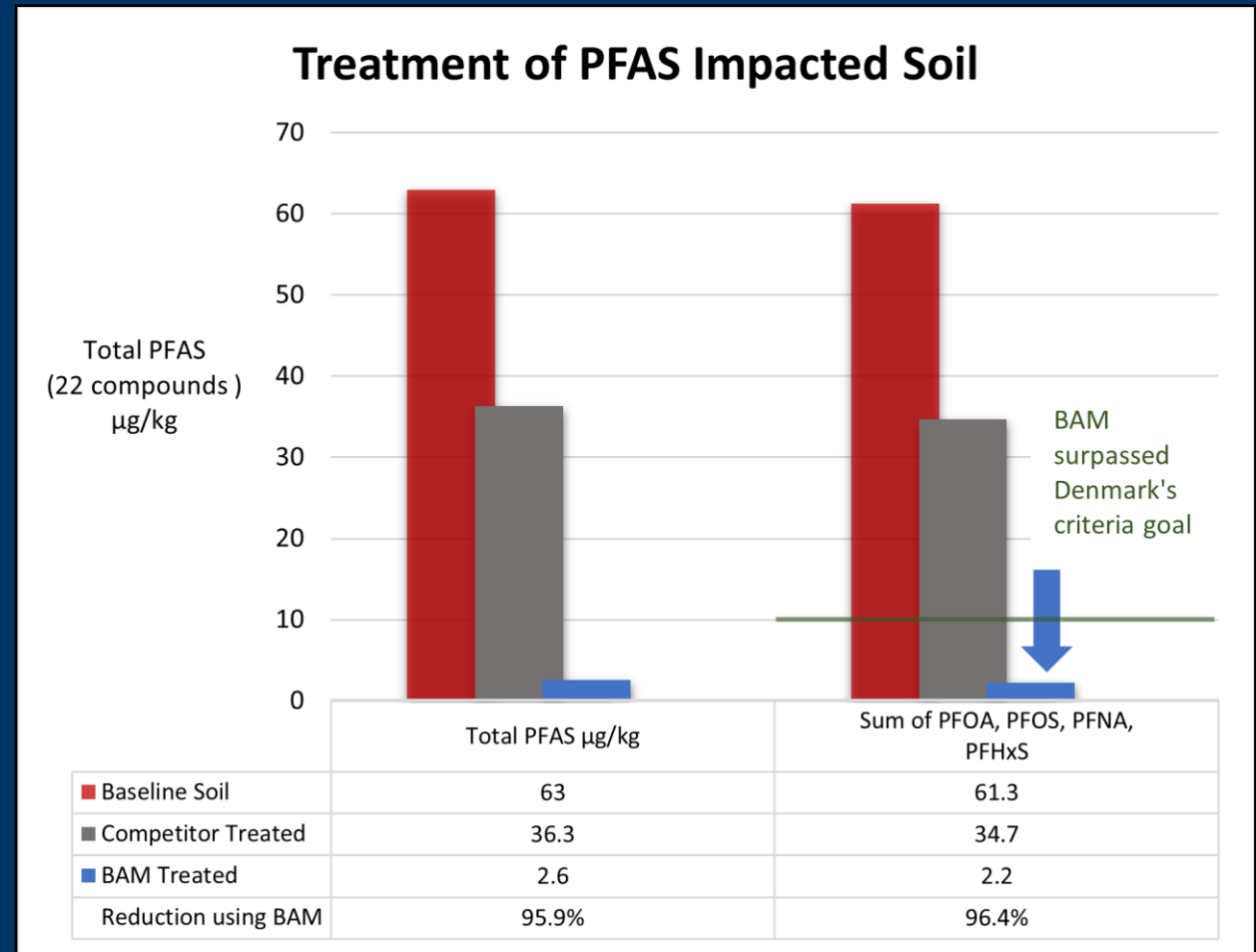
# Air Force Base Soil Pile

- The Air Base had several construction projects that contributed to approximately 30,000 cubic yards.
- Trying to determine options for disposal of soils.
- The Base requested a study to determine if soils could be treated in place and hauled to a local landfill.
- Total PFAS was approximately 8.3 ppb with a leaching number of 254 ppt.
- All samples were non-detect for SPLP leaching.

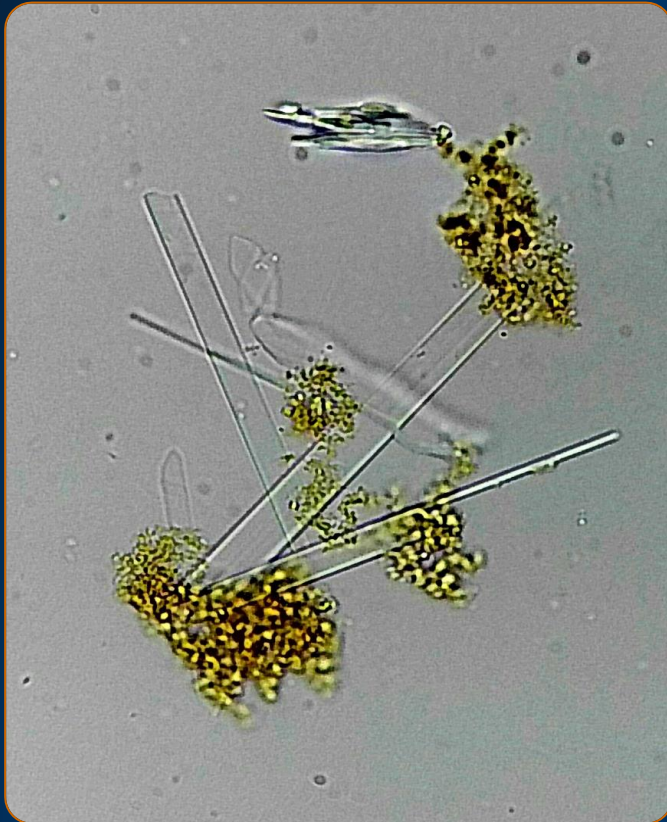


# Fire Fighting Training Facility—Denmark

- A third-party test was performed by a Danish government contractor comparing multiple stabilization technologies.
- BAM was tested.
- Denmark criteria is 10 ug/kg in soil.
- Achieved the Danish Environmental Protection Agency's remedial goal.



# PFAS and Biology: An Impossible Pair



PFAS was considered resistant, if not impossible, to degrade with biology.

Investigations of biological activity in scientific community are generally limited to precursor compounds.

Intuition implies that defluorination should happen in reducing conditions.

First microbe found by Fixed Earth in 2019, many more since

PFAS is degraded and precursors seem to also be destroyed when analyzed via TOPS and TOF

Fluoride formation detected with in-house test

No volatile fluorinated compounds found to-date as by-products



# Site-Specific Microbes



## Obtain Site Media

We take soil, water, and plants from the impacted site or other local sites to act as a source of microbes.



## Develop Microbes

We utilize proprietary methods in our lab to acquire site-specific microbes capable of PFAS breakdown.



## Lab Validation

Before microbes are taken to market, they are tested in the lab using PFAS spiked water or site media, if available.

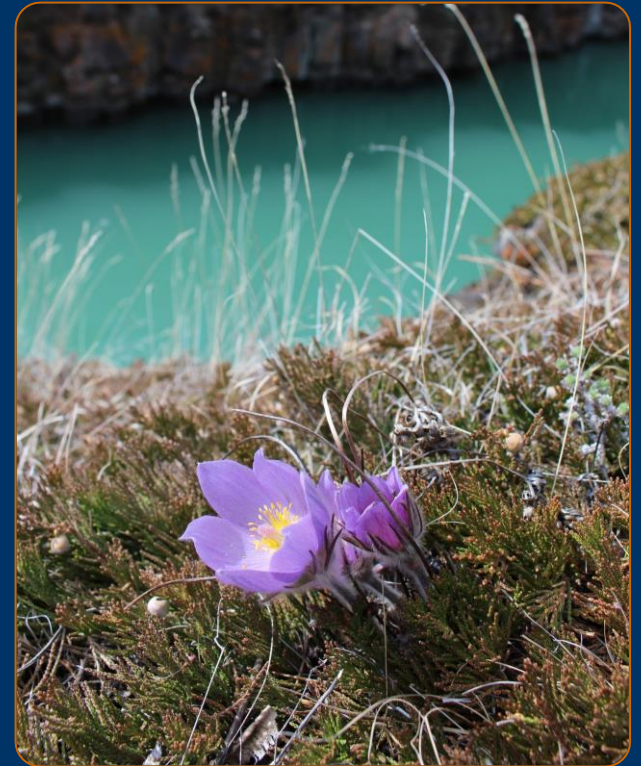


## Deployment of Product

Working with clients and local partners to develop methods to deploy microbes effectively.

# Advantages

- Method can be used over a wide range of climates
- Microbes can degrade a variety of PFAS compounds
- Site-specific microbes are adapted to local conditions
- Site-specific microbes are adapted to PFAS on site
- Non-Genetically Modified
- Unlikely to be invasive or disturb local ecosystems
- Aerobic metabolism is generally faster than anaerobic
- Works at a range of concentrations



# 115<sup>TH</sup> FIGHTER WING FIELD PILOTS

Completed as a joint venture between Fixed Earth and ORIN.

Two field studies in 2021/2022:

- Treatment of highly impacted water ex-situ
- Refinement of in-situ bioremediation methods

Testing of ORIN's BAM product line to enhance microbe performance.

Prior to field studies, site-specific microbes were acquired and tested in lab conditions.

Testing of alternative methods to create aerobic conditions.





# CASE STUDY: TRUCK FLUSH WATER



- Rinse water from flushing fire fighting trucks containing PFAS AFFF.
- Four plastic totes were treated.
- Total PFAS concentrations ranged from 7 to 33 ppm.
- Field pilot commenced in summer 2021 and was monitored for 35 weeks.

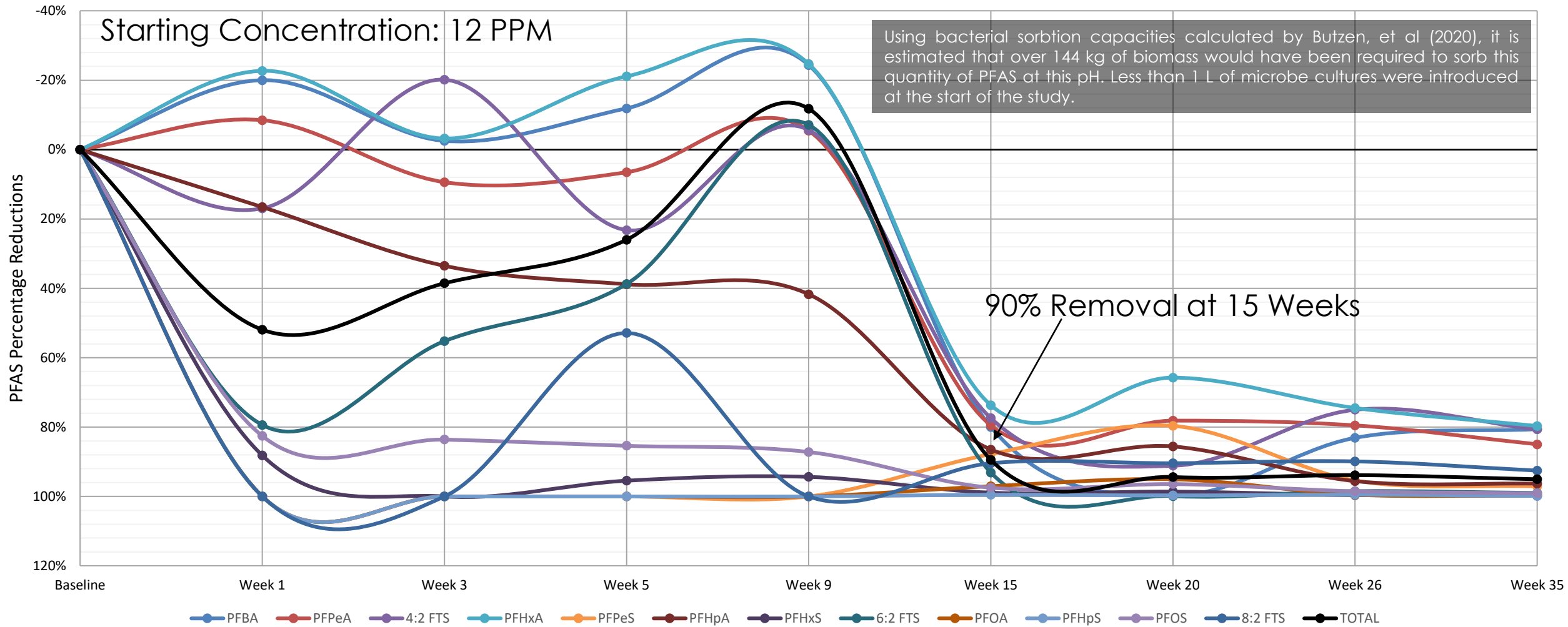


# Case Study: Truck Flush Water

- Dosage consisted of BAM Ultra, PFAS degrading microbes, calcium peroxide, and air sparge
- Only one tote did not receive BAM Ultra to test microbes alone
  - Calcium peroxide for initial oxygen boost
  - Air sparge for sustained oxygen supplementation
- Aeration generated foam
  - Foam control was implemented



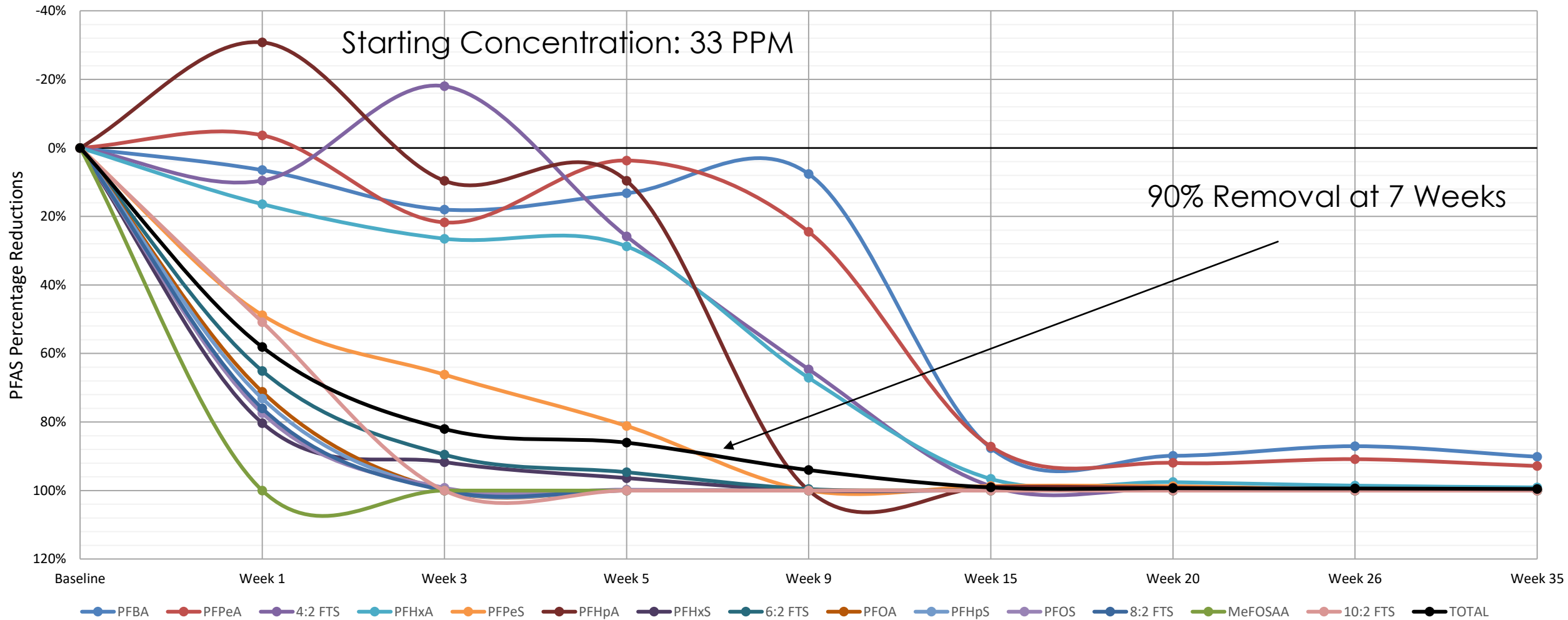
# Tote 2 - PFAS Degrading Bacteria Alone



## TOTE 2 – MICROBES ONLY – PERCENT REMOVAL

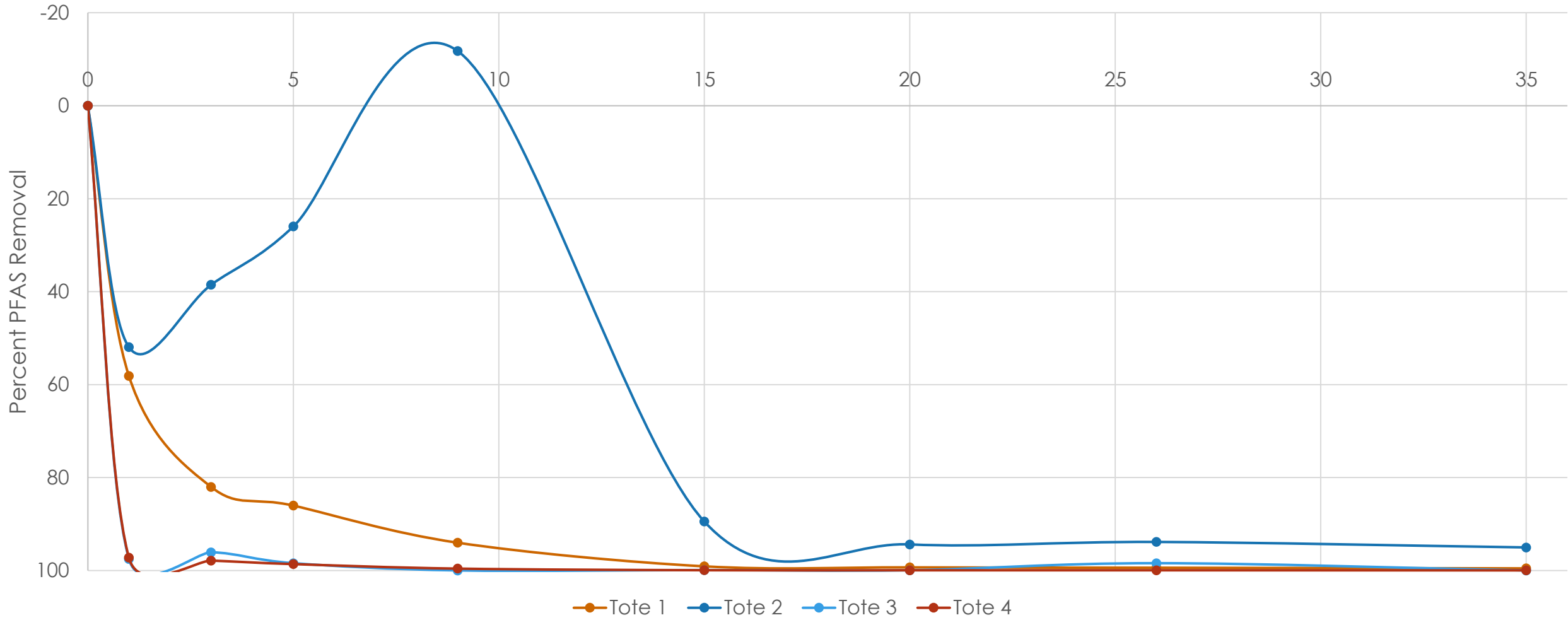


# Tote 1 - BAM Ultra with PFAS Degrading Bacteria



## TOTE 1 – BAM AND MICROBES – PERCENT REMOVAL

# Total PFAS Removal Summary Data



# Totes Total PFAS SUMMARY Data

# PILOT SCALE IN-SITU TREATMENT

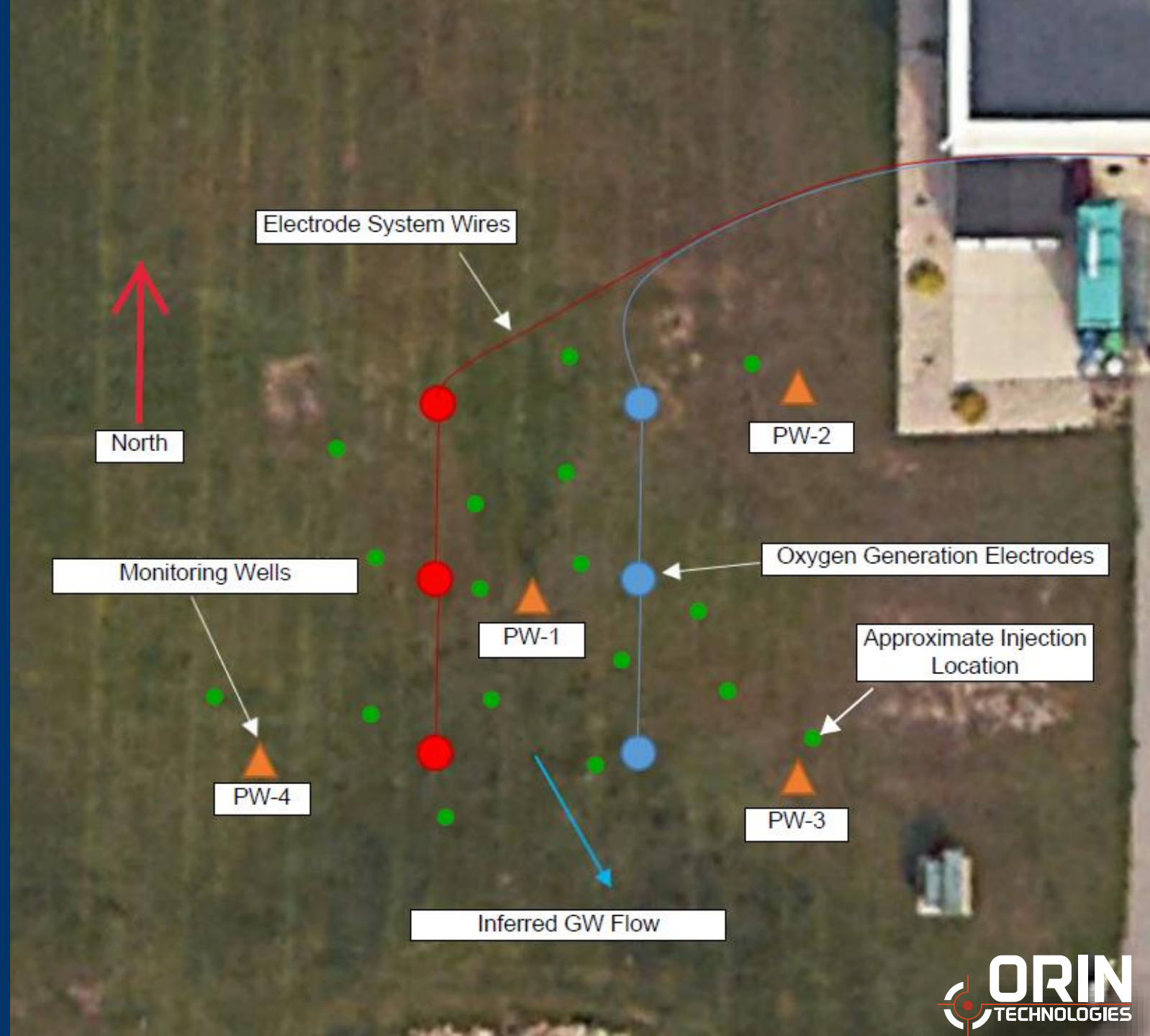
- Small treatment area located adjacent to firefighting building where PFAS was known to occur in groundwater.
- Study commenced in late November 2021.
- Four monitoring wells were installed in treatment area to measure performance.
- Geoprobe was used to inject a mixture of BAM, site-specific microbes, and calcium peroxide over a 20 foot interval.
- 17 Injection points over a 1,600 square foot area with a 25 foot total depth.
- PFAS data has been monitored 1 year with rebound study in progress.
- Groundwater parameters (DO, pH, EC, temperature, etc.) are monitored weekly.
- Groundwater flows to the southeast.
- Aerobic conditions maintained through deployment.



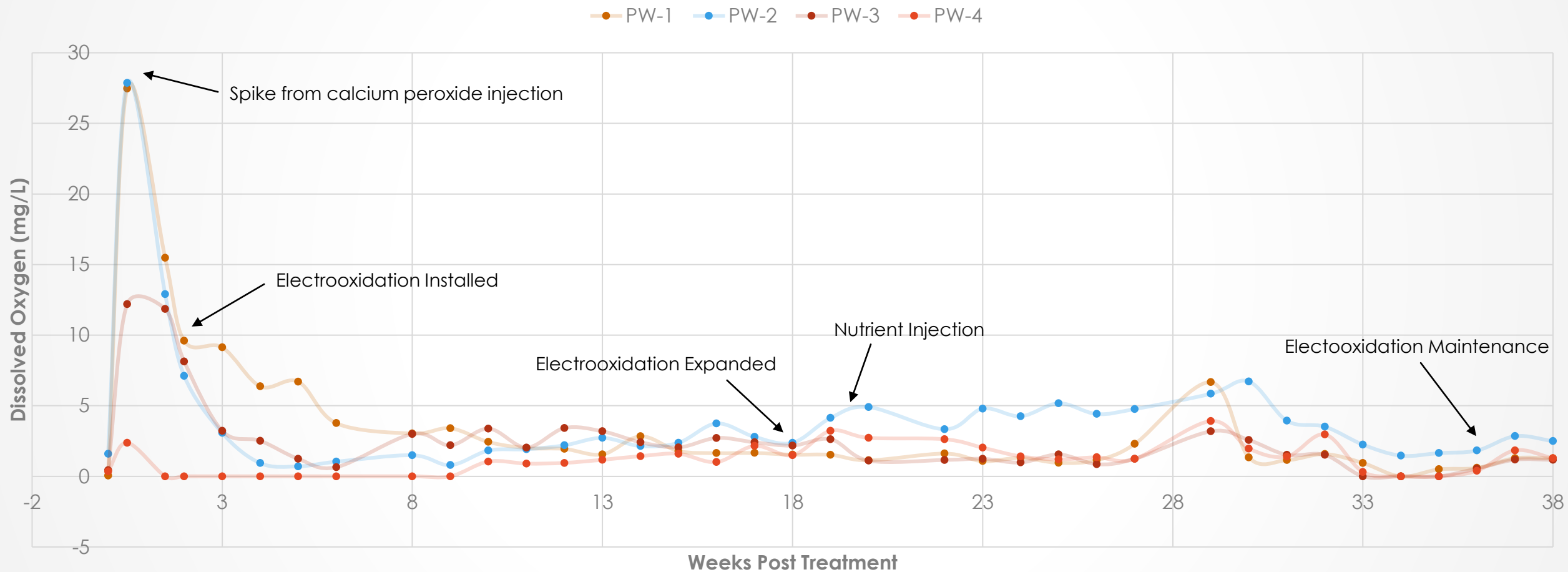


# SITE CONFIGURATION

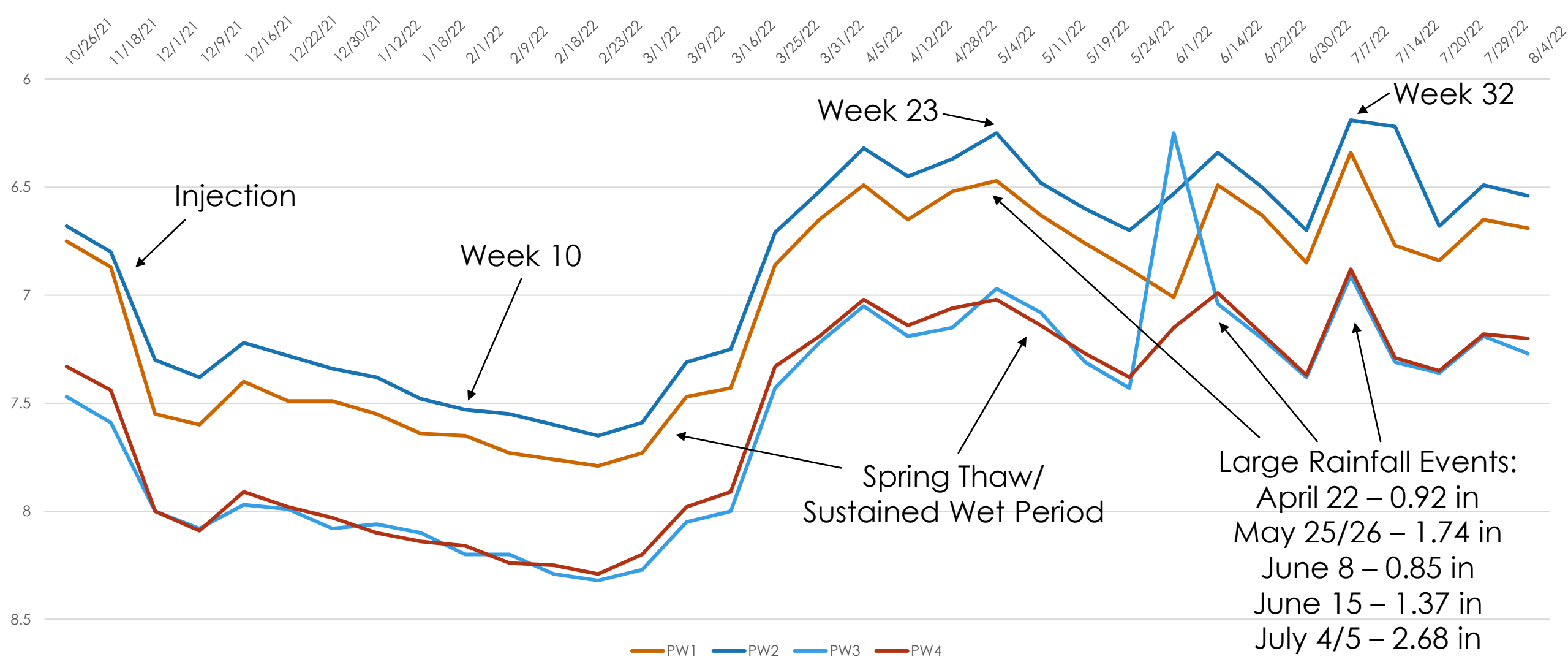
- Two weeks following the injection an electrokinetic unit was installed to maintain elevated dissolved oxygen in the treatment area.
- 10-16 volts are utilized, electrodes and wires are flush with ground, minimizing impacts to airport operations.
- Elevated oxygen is observed in PW-1 and PW-3 and has maintained biological activity in these areas.
- PW-2 and PW-4 returned to anaerobic conditions after the initial injection and minimal biological activity has been observed.



# Dissolved Oxygen Concentrations



## Dissolved Oxygen Monitoring Data

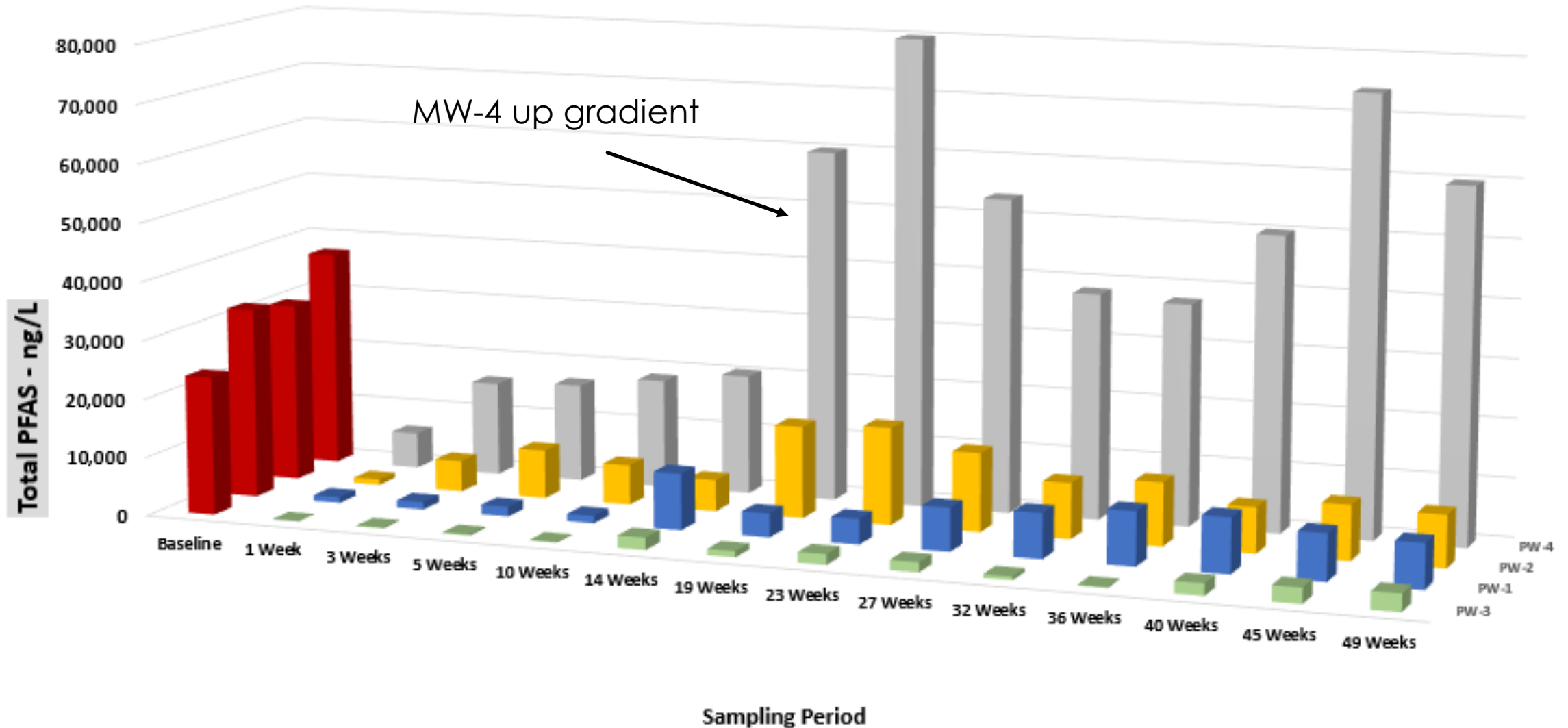


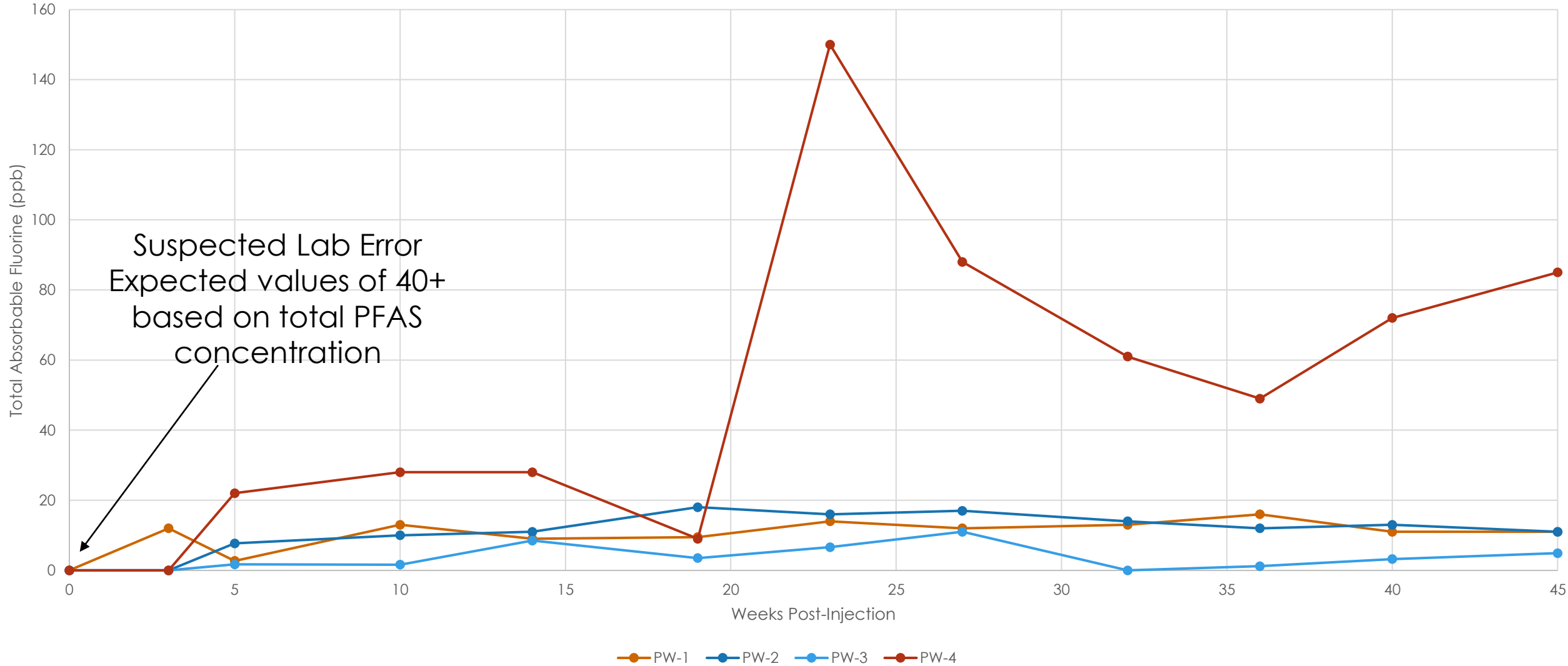
# Depth to GROUNDWATER (ft)



# Groundwater Concentrations

Total PFAS Concentrations in monitoring wells





Suspected Lab Error  
 Expected values of 40+  
 based on total PFAS  
 concentration

# TOTAL ABSORBABLE FLUORINE DATA

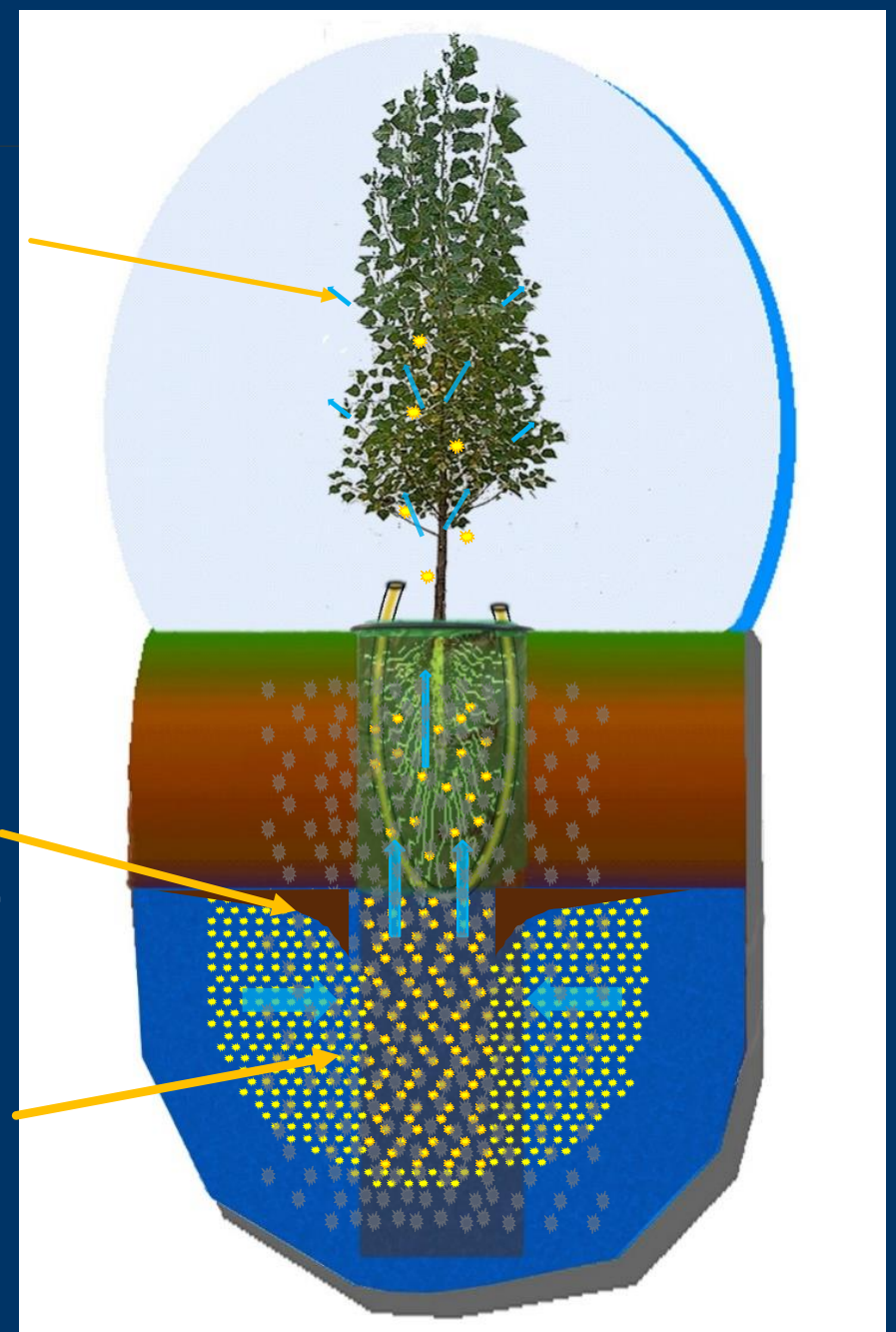
# Nature-Based Containment and Treatment

**Tree Microbes and BAM create a controlled “bioreactor” in rhizosphere and water table**

Trees increases short chain capture efficiency

Cone of depression provides containment

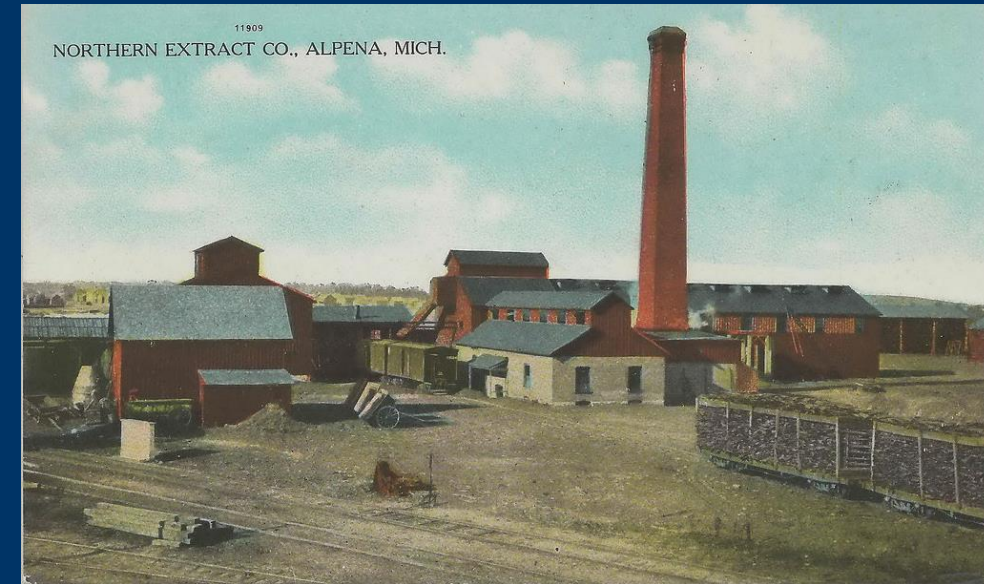
Increase PFAS immobilization efficiency in biochar





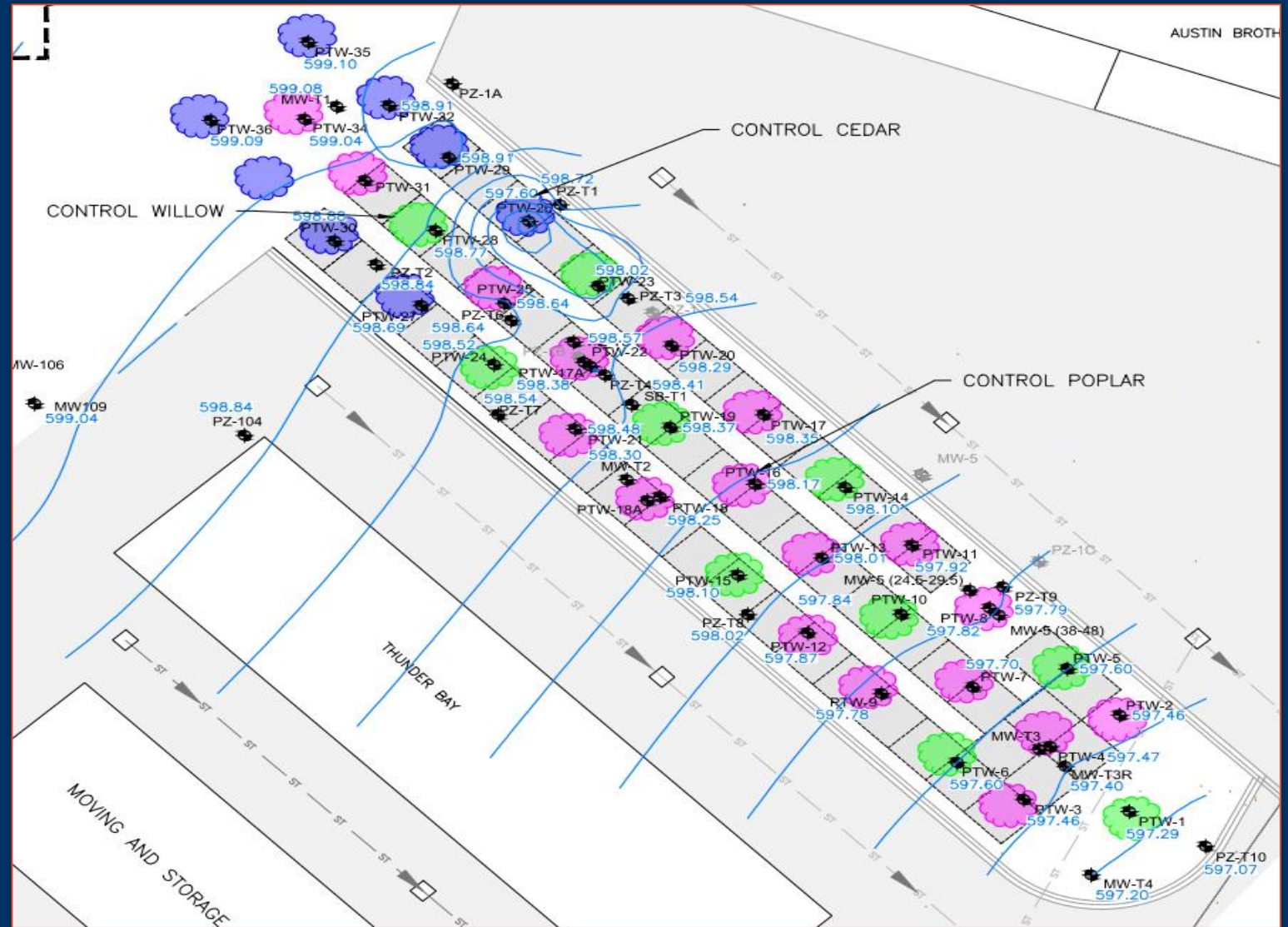
# Former Tannery

- PFOS is detected at elevated levels in soil and groundwater (up to  $\sim 10 \mu\text{g/L}$ ) at a former tannery, located near the Thunder Bay River (Alpena, Michigan).
- Tannery operations ceased in the 1950s. Site buildings burned to the ground in 2005 and aqueous film forming foam (AFFF) use to fight the fire is suspected.
- PFAS were first detected in soil, groundwater and surface water in 2017.
- The groundwater to surface water pathway (GSIP) is complete (PFOS  $> 12 \text{ ng/L}$ ).



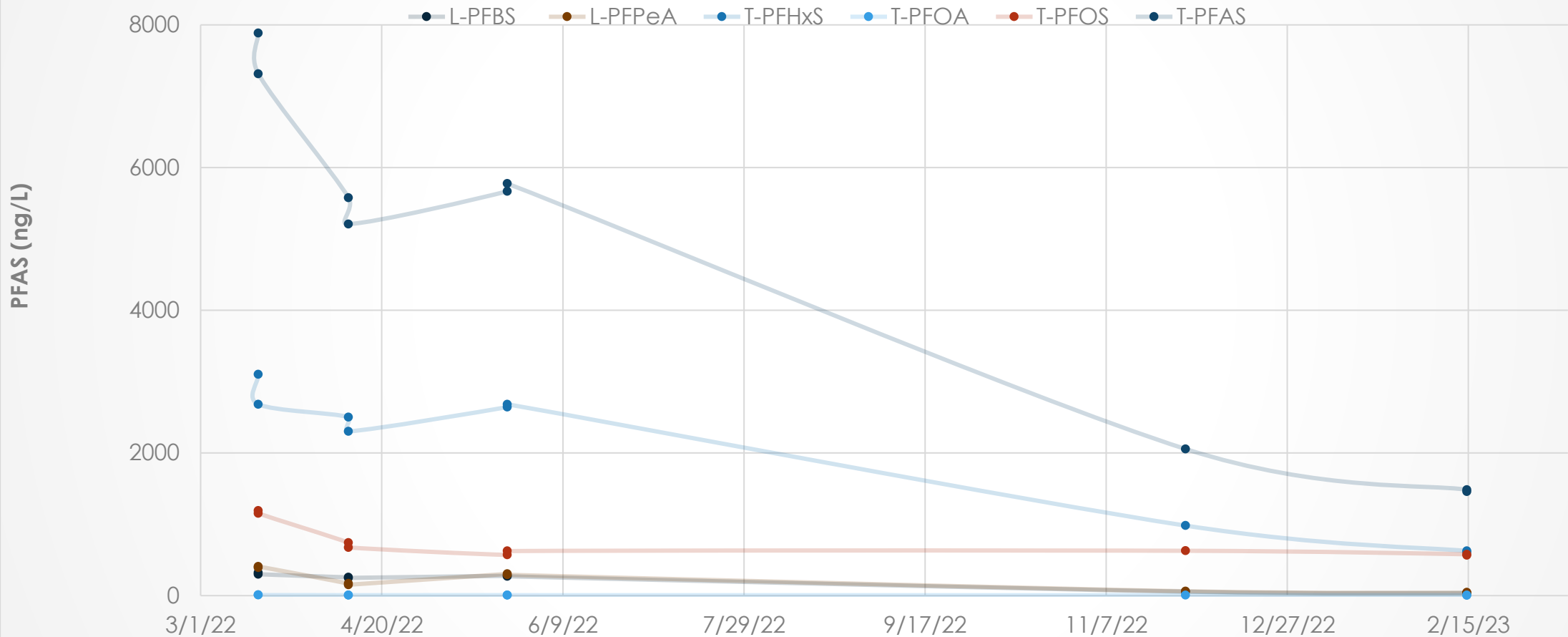
# Site Layout

- 36-inch diameter auger holes advanced to depths of 5 to 9 ft
- Root sleeves and piezometers set to depths of 5-8 ft
- Soil reused as backfill (14% BAM)
- 35 TreeWells (Bareroot; April 2022)
  - 10 Black Willow (local)
  - 18 Hybrid Poplar
  - 7 White Cedars (local)



# Groundwater Results

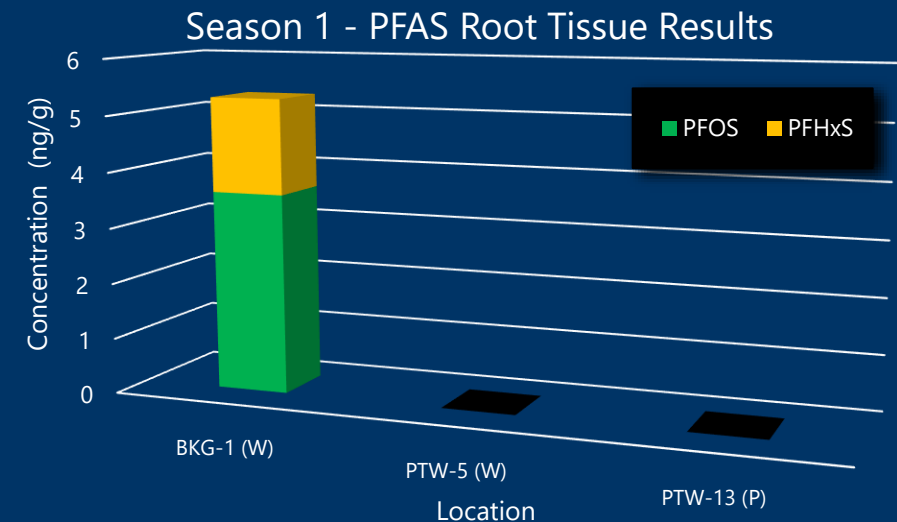
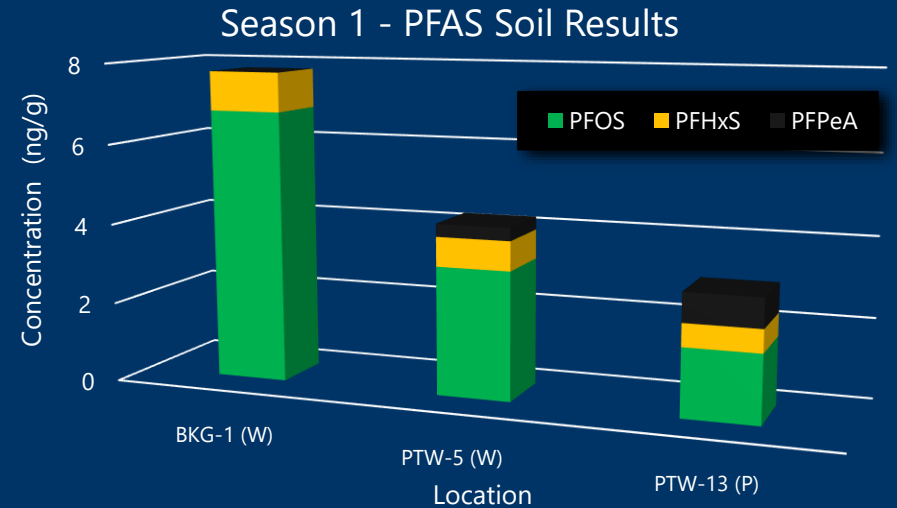
PFAS in Groundwater – Downgradient Well MW-T4





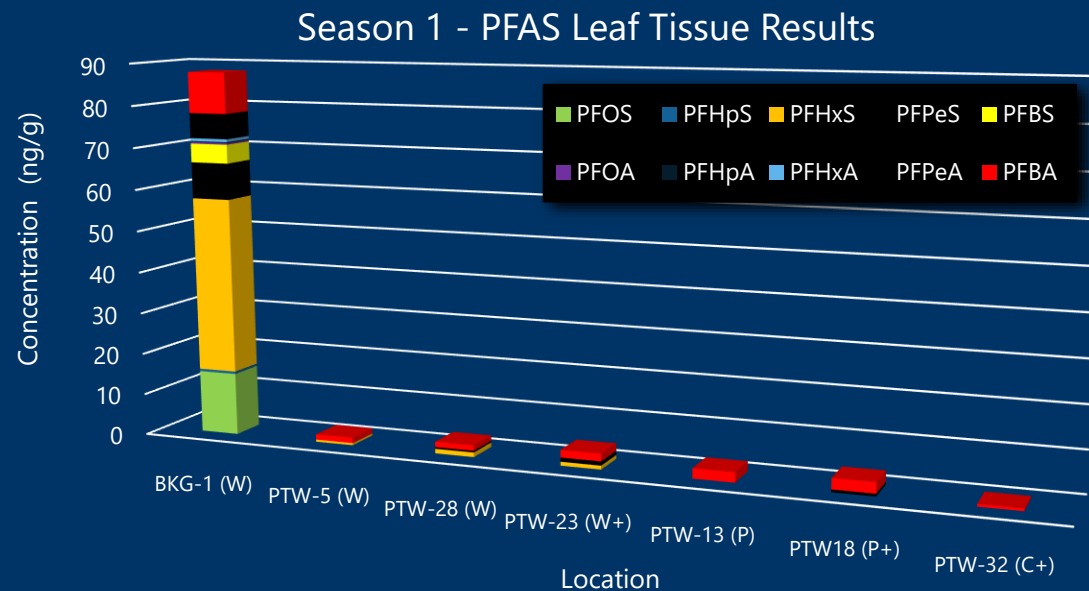
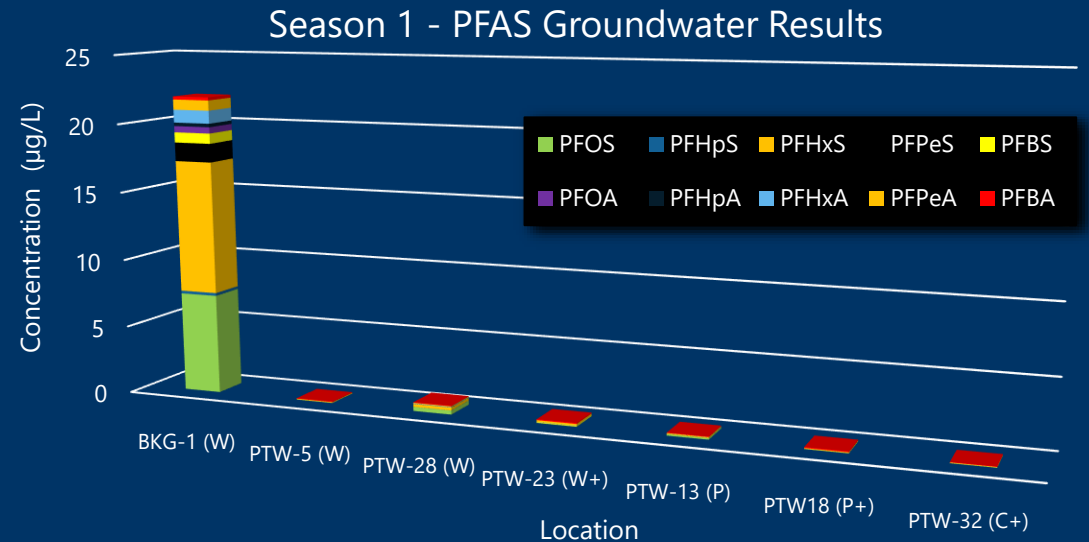
# Tree uptake – Roots and Soil Results

- September 2022 – BUCK!
- Two trees were killed and required replacement (i.e., root testing)
- Wild and free willows (~2-3 yrs in age) used for background
- Background tree detected PFOS > PFHxS in soil and root tissue
- BAM™ treated soils detected PFOS > PFHxS ~ PFPeA
- No PFAS detected in treated roots



# Tree uptake – Leaves and Groundwater Results

- Piezometers used to collect groundwater samples during plant tissue sample collection
- Full suite of PFAS detected near background tree location sample location
- Background leaf samples shows attenuation of PFOS (long chains) but amplification of PFHxS and shorter chains
- Only PFBA, PFPeA & PFHxS detected in treated leaves
- Treated groundwater and leaf tissue results ~ equilibrium
- No PFAS detected in “dropped” leaves (not depicted)



# Summary – Bioaugmentation

- Bioaugmentation results are inconclusive
  - Short term reductions in PFAS (Oxygen is primary limiting factor)
  - See decreased PFHxS relative to longer/shorter chains (benchtop)
  - Is there a critical loading rate? (e.g.,  $D_{hc} > 10^4$ )
  - ORIN, WSP & Fixed Earth are investing in a second benchtop to validate microbial destruction (rule out air-water partitioning and bio-adsorption)

# Summary – Bioaugmentation cont.

- Verifying biologic destruction of PFAS in the field is extremely challenging
  - Direct measures of inorganic fluoride are inconclusive
  - Precursor compounds/degradation rates ~unknown – does precursor breakdown to “end members” (PFOA/PFOS) mask their mineralization?
  - Total organic fluorine (TOF) has limitations (<C4), but one of the best analyses available yet?
- Is there a “critical” microbe or is evolution of local defluorination possible? If so is there a place (in the future) for MNA?



Figure 8. Lab grown putative fluorite crystals (A) and field observed precipitates (B).



# ORIN SERVICES PROVIDED

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## Remediation Services

- In-situ and Ex-situ treatment
- Product Recovery with Oxidant Flooding
- Organic and Inorganic Chemistries

## Waste and Process Water Treatment

- Odor Control
- Recalcitrant Organics
- Foam Control

## In-House Treatability/ Feasibility Laboratory

- Treatability Testing
- Oxidant Demand Testing
- Metal Stabilization Studies
- pH Buffering Studies

# IMPLEMENTED PROJECTS BY REGIONS

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## Waste and Process Water Treatment

- United States
- Canada
- North Africa
- Central Asia

## Supported Specific Projects and Process Applications

- Middle East
- Southern Asia
- Russia
- U.K.

## Remediation Services

- United States
- Canada
- Hawaii
- Puerto Rico
- Colombia

# TURNKEY REMEDIATION SERVICES

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- Treatment Plan Development
- Treatment Plan Implementation
- Equipment Supply
  - Injection trailers
  - Earth moving/yellow iron
  - Drilling
- Chemistry Supply
- Personnel
- Report

Any  
Questions?



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