

Zoom Nguyen

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Problem Statement

PFAS contamination in shallow groundwater emanating from AFFF-impacted source areas is a significant environmental problem.

- Conventional treatment technologies such as GAC/resin/membrane:
 - Media changeout & offsite disposal
 - Not universally applicable
 - Short-chained PFAA breakthrough
 - Concentrate requiring treatment
 - Ex situ
 - Active operation
 - Extensive infrastructure

GAC/resin

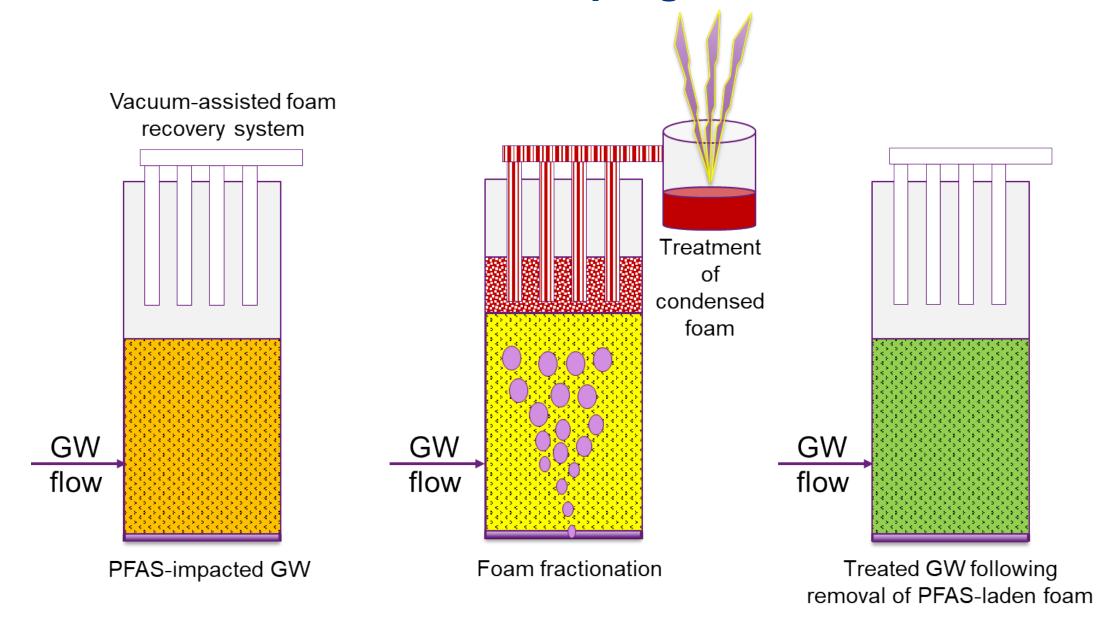
Membrane

GAC/resin/membrane



There is currently no commercially viable passive, in situ treatment technology for PFAS!

Foam Fractionation In An Air Sparge Trench



Technical Objectives

- Overall goal = demonstrate the use of a novel treatment approach for PFAS-impacted groundwater from AFFF source areas
 - Passive
 - In situ
 - Low-cost
 - Readily implementable
 - Commercially viable
- Specific demonstration objectives:
 - Confirm PFAS removal
 - Demonstrate foam recovery and reconstitution
 - Assess PFAS destruction
 - Compare life cycle cost

Air sparge trench



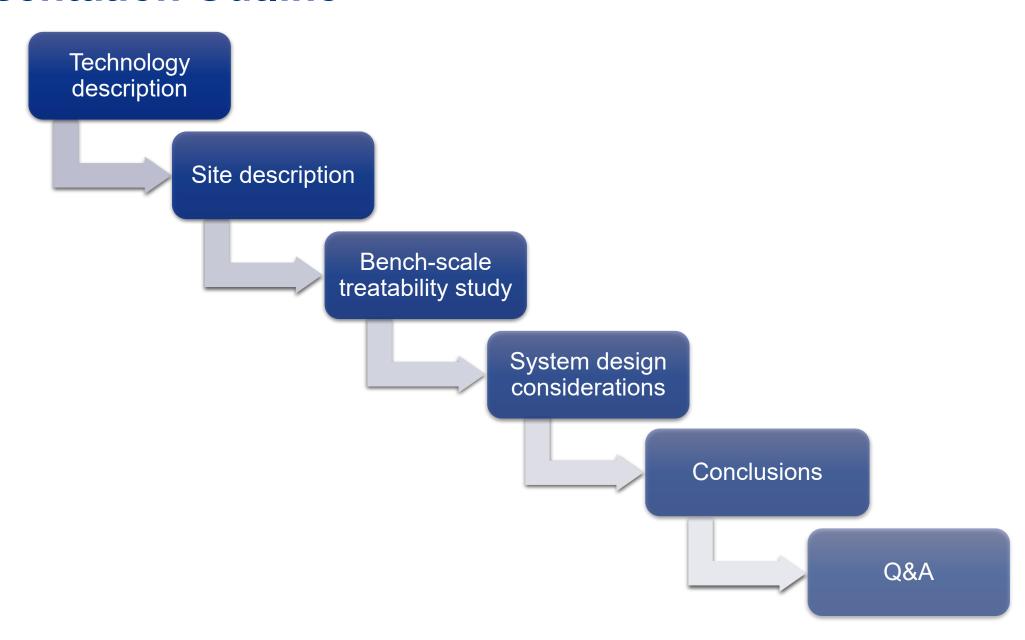
Foam fractionation



ECO/Plasma

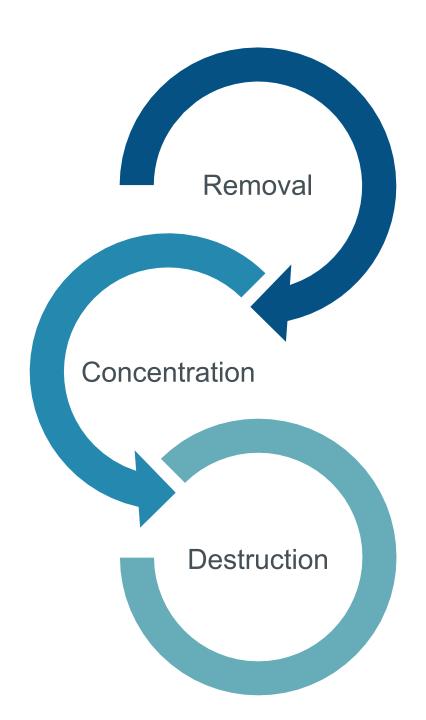


Presentation Outline



Technology Description

- Air sparge groundwater interceptor trench:
 - Mature technology
 - USACE engineer manual EM 200-1-19
- Foam fractionation:
 - Pre-dates PFAS
 - Recently applied for PFAS treatment
 - Demonstrated at the bench- and pilot-scale
 - Ready for field-scale demonstration in the US (ex situ)
- ■PFAS destruction:
 - Demonstrated at the bench- and/or field-scale



PFAS Removal at the Air-Water Interface

- Increasing interfacial partition coefficient (K_{aw}) at lower PFAS concentrations should be able to remove PFAS using foam fractionation technology at very low concentrations
- Should take ~100x longer to remove short-chained compounds such as PFBA, compared to PFOS

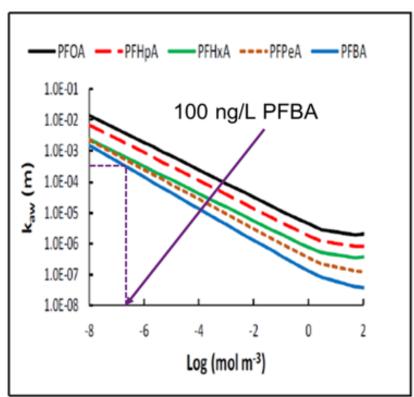
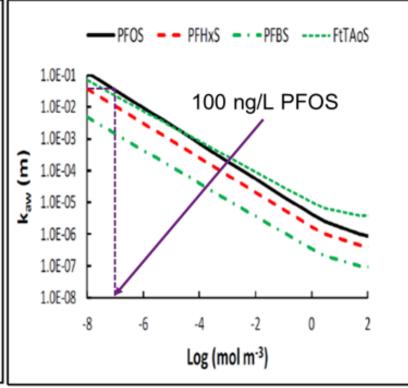
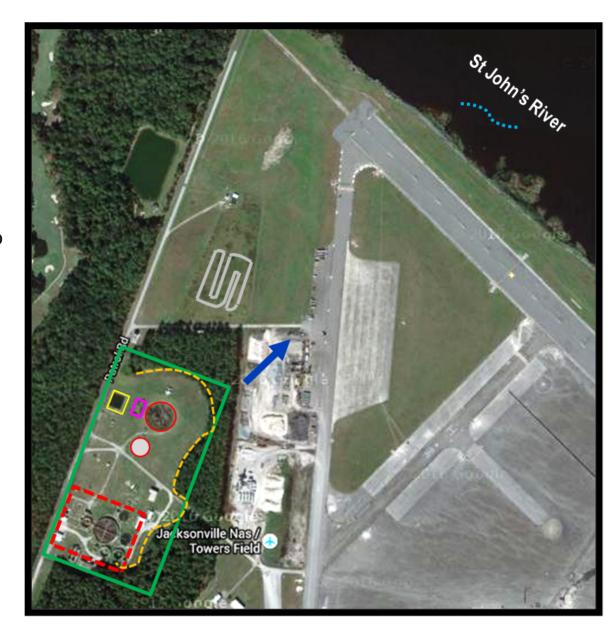


Figure courtesy of Schaefer et al., 2019

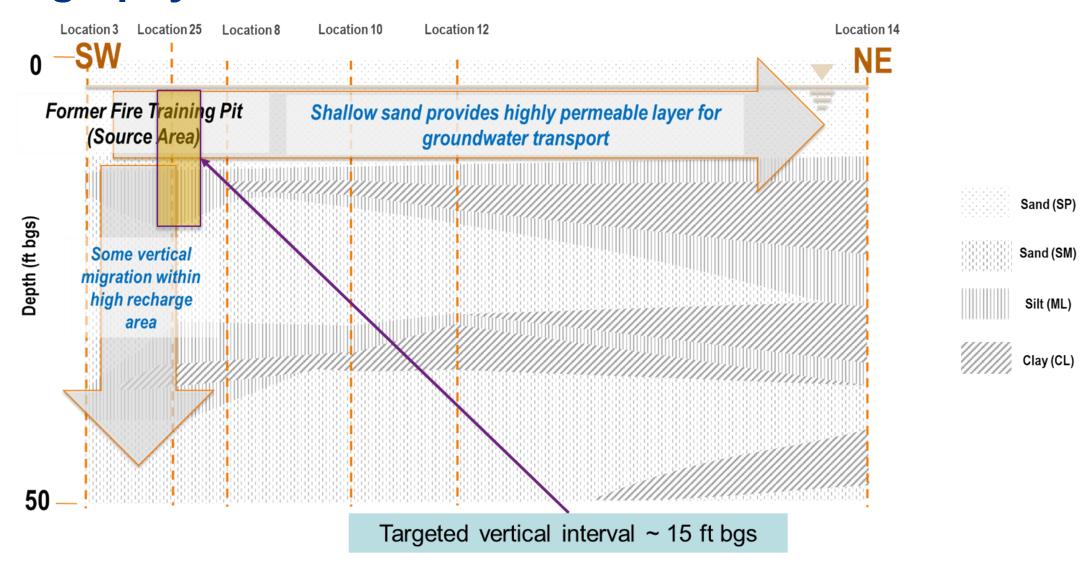


Site Description

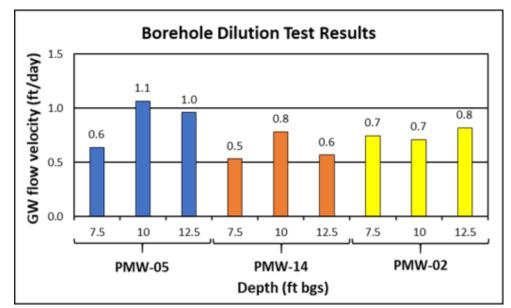
- FT02 at NAS Jax (Jacksonville, FL)
- Shallow GW 3-7 ft bgs
- Relatively high GW velocity ~0.6 ft/day
- Little fluctuations in GW flow direction & elevation yes/no
- Sandy vadose zone yes
- Elevated PFAS concentrations in GW ~200,000 ng/L
- Available site data yes
- Temperate climate yes
- Local support yes
- Available basic infrastructure yes
- No underground/overhead utilities yes
- Complementary of other research work yes
- Site receptiveness yes

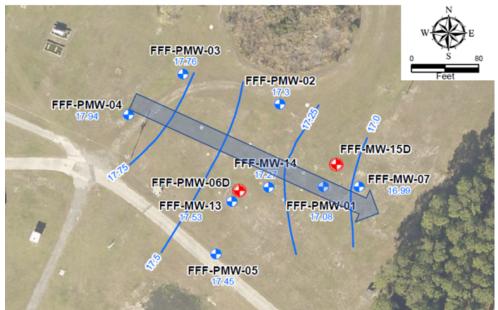


Stratigraphy

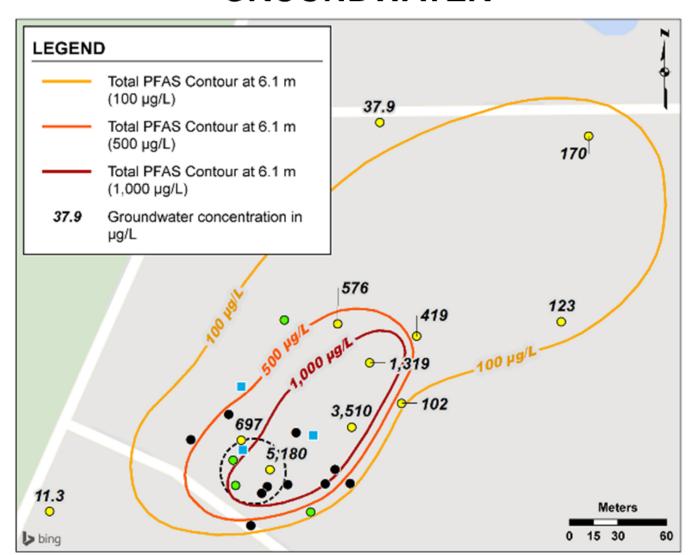


Hydraulic Testing & PFAS Concentration Contours





GROUNDWATER



Bench-Scale Treatability Study

Foam fractionation:

- **Objectives** = assess site-specific foaming potential, PFAS removal efficacy, mass balance, and concentration factor
- Approach:
 - Initial simple batch testing
 - Bigger scale simulation of trench upon completion of simple batch tests
 - Protype testing of foam recovery mechanisms

Foam destruction:

- Objectives = assess destruction of PFAS
- Approach:
 - Site groundwaters used instead of foam fractionates due to insufficient foam volume & relatively high PFAS
 concentration
 - 3 different PFAS destructive technologies (ECO CDM Smith, REM UIC, ECP Clarkson University)

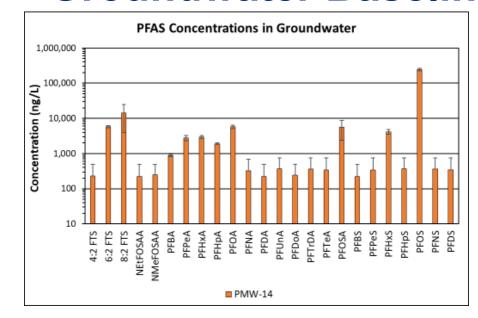


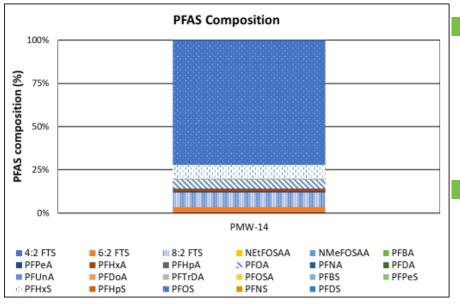


Bench-Scale Study Performance Objectives

Performance Objective	Success Criteria	
PFAS reduction	2-log removal of all long-chained PFAAs	
	Reduction of total PFOS and PFOA to below 70 ng/L	
	1-log removal of total organic fluorine	
Waste reduction	Generate PFAS-rich foam fractionate at less than 0.1% of the volume of groundwater treated	
PFAS concentration	Confirm mass balance between PFAS in groundwater and the collected foam fractionate	
PFAS destruction	2-log destruction of all PFAAs and total organic fluorine in the foam fractionate	
Foam recovery	Recover more than 90% of the foam generated at the surface of the sparge trench	

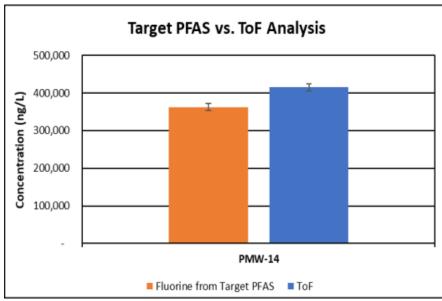
Groundwater Baseline Results

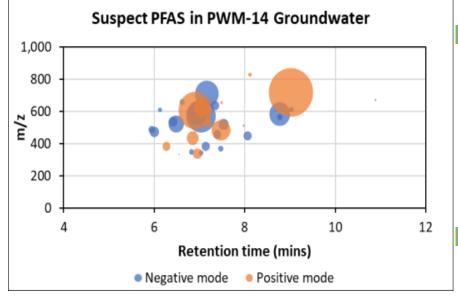




■Total target PFAS ~ 250,000 ng/L

Primary PFAS = PFOS & 8:2 FTS

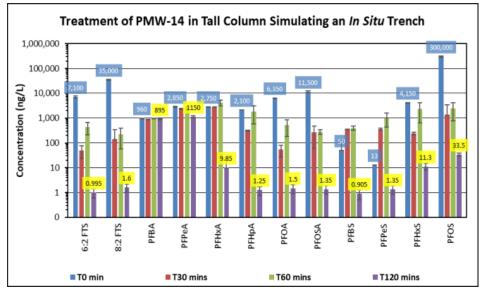


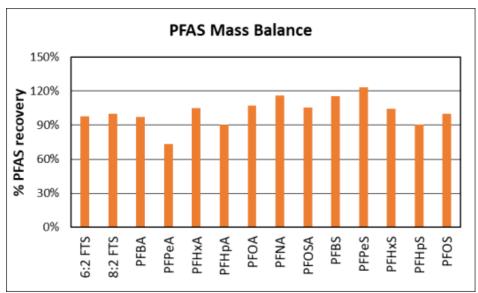


■Target PFAS
accounted for ~ 90%
of organic fluorine

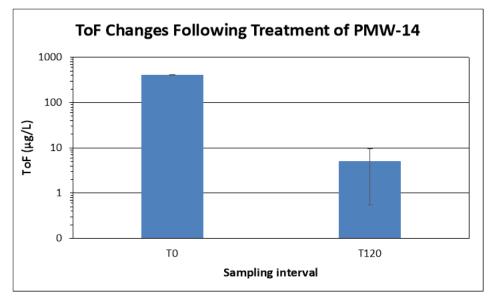
10% suspect PFAS

Tall Column/Field Simulation



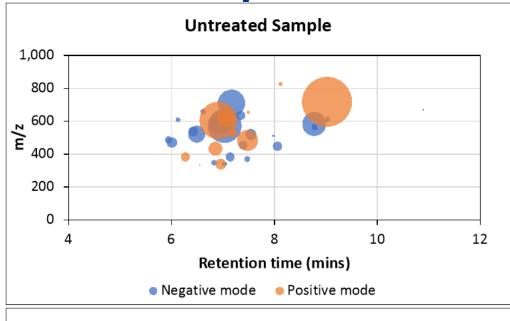


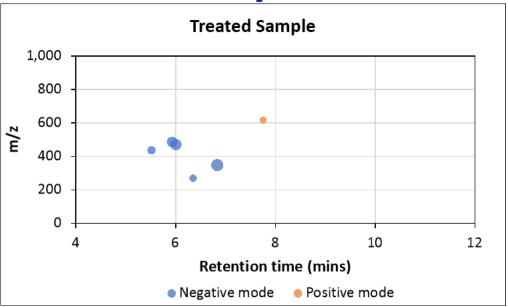


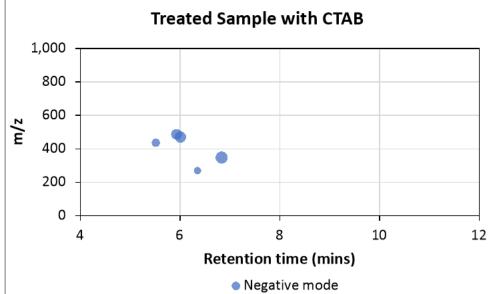


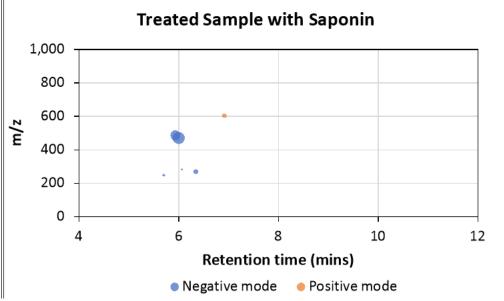
- Multi-log removal of long-chained PFAAs was observed after 60 minutes of aeration
- Little to no removal of short-chained PFAAs, including PFPeA, PFHxA, PFBS, and PFPeS, were observed
- Following addition of CTAB (~60 mins), enhanced removal of many of these compounds were observed
- Good PFAS mass balance
- An approximate 2-log reduction in ToF was achieved for PMW-14 groundwater following treatment
- Similar results seen with other types of surfactants for long-chained PFAS removal

Removal of Suspect PFAS in Treated Samples





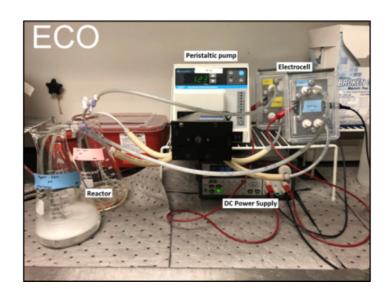


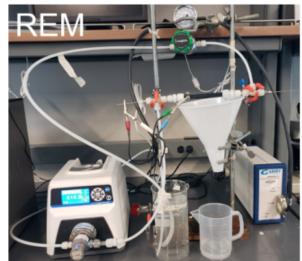


PFAS Destructive Tech Evaluation

	Log Reduction of PFAS			
PFAS	ECO (after 72 hours of treatment)	REM (after 2 hours of treatment)	ECP (after 5 hours of treatment)	
PFOS	3.1	3.5	3.2	
PFOA	1.6	2.9	1.9	
PFHxA	1.3	1.1	2.3	
PFHxS	1.5	3.0	1.6	
PFPeA	1.7	1.1	2.5	
PFBA	1.4	1.8	2.0	

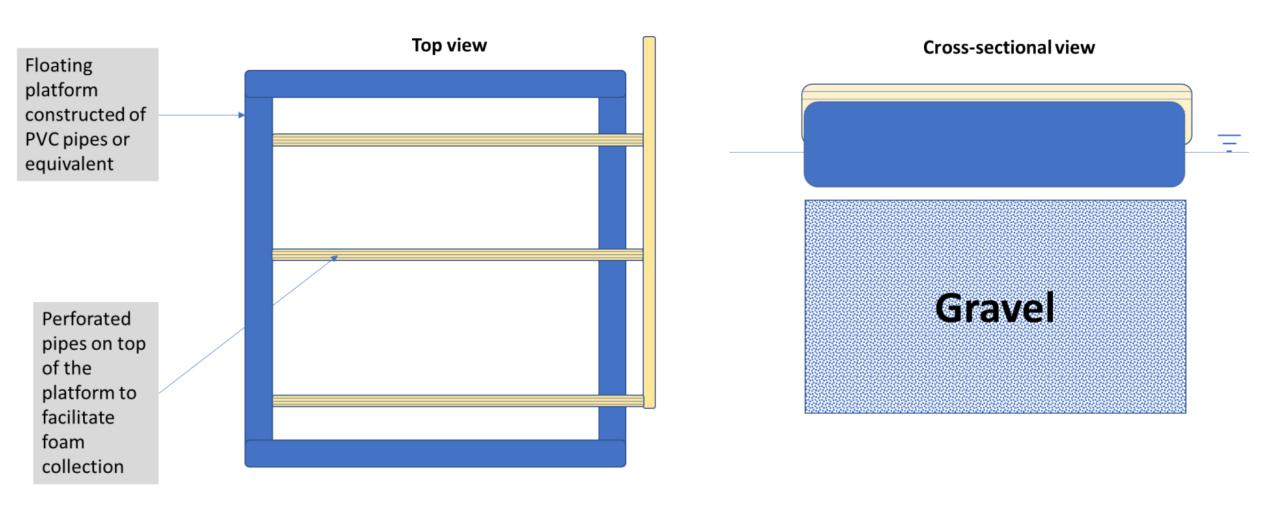
- Multi-log destruction of PFAS can be attained with all three technologies under consideration
- Varying treatment efficiency
- Direct discharge of treated foam fractionates may not be possible!
- Degradation by-products will require further treatment





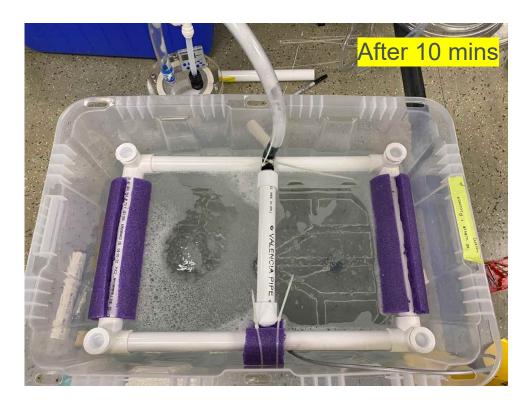


Foam Recovery System Design



Foam Recovery System Testing





- Most of the foam accumulated on the surface can be recovered within 10 mins at 150 mmHg of vacuum
- Data from other studies showed that 100% foam capture is not needed for multi-log PFAS removal

Summary of Bench Results

Performance Objective	Success Criteria	Bench results
PFAS reduction	2-log removal of all long-chained PFAAs	✓
	Reduction of total PFOS and PFOA to below 70 ng/L	✓
	1-log removal of total organic fluorine	✓
Waste reduction	Generate PFAS-rich foam fractionate at less than 0.1% of the volume of groundwater treated	✓
PFAS concentration	Confirm mass balance between PFAS in groundwater and the collected foam fractionate	✓
PFAS destruction	2-log destruction of all PFAAs and total organic fluorine in the foam fractionate	✓
Foam recovery	Recover more than 90% of the foam generated at the surface of the sparge trench	✓

System Design Considerations

■Fluctuating groundwater table → floating design for foam recovery system

■Varying groundwater flow direction → V-shaped trench configuration

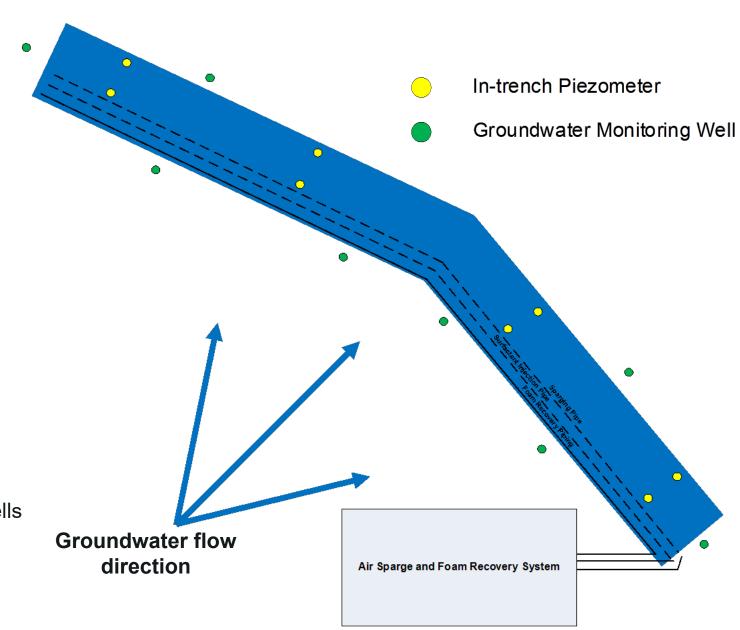
■Potential for PFAS aerosolization → trench cover

■Lack of foaming → surfactant addition

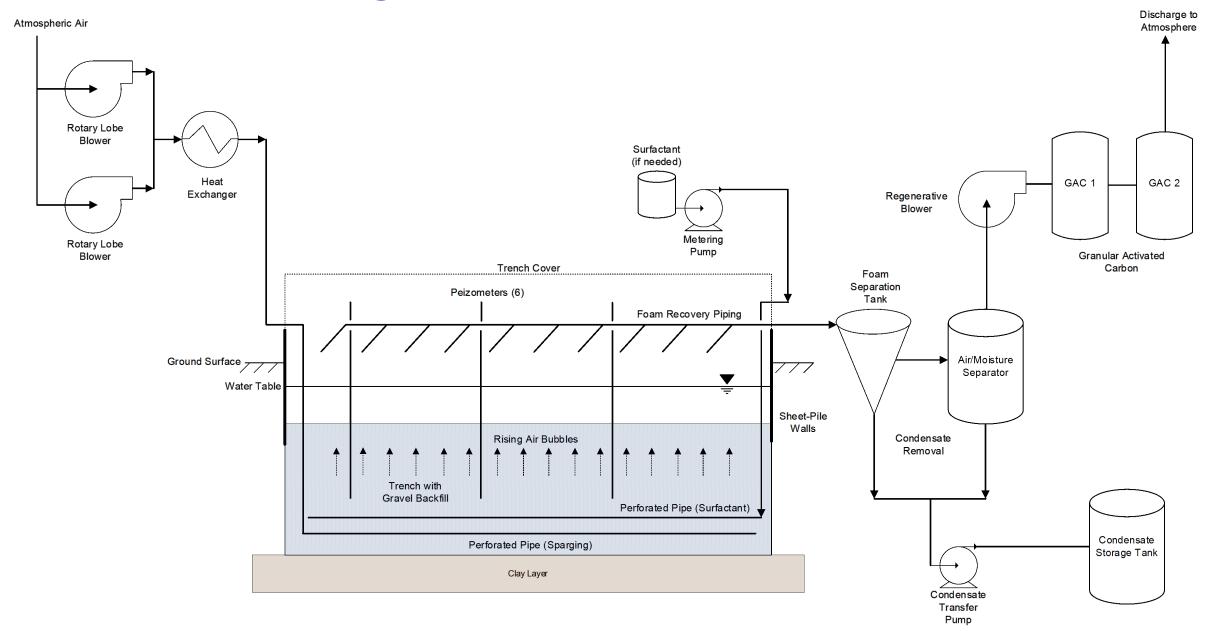
■Elevated PFAS concentrations in soil → use piezometers installed immediately upgradient and downgradient edge of the trench to assess removal

Preliminary Layout

- Trench dimensions:
 - Depth 0-15 ft bgs
 - Length 2 x 25 ft
 - Width 3 ft (~5-day residence time)
- Trench installation:
 - Sheet piling
 - Excavation & dewatering
 - Gravel backfill
 - System installation
- Performance monitoring program:
 - 9-12 months
 - Upgradient & downgradient monitoring wells
 - In-trench piezometers
 - Target/suspect PFAS, TOPA & ToF



Process Flow Diagram



Conclusions

Low-cost, passive, in situ treatment of PFAS-impacted groundwater is a critical need

- The proposed treatment train leverages mature & up-and-coming technologies for effective removal/concentration/destruction of PFAS
 - Effective removal of PFAS using little to no chemicals
 - PFAS concentrated and recovered in foam fractionates
 - PFAS-laden foam fractionates can be effectively destroyed using destructive technologies

NAS Jax is a great site for this technology demonstration

Site-specific characteristics/limitations need to be taken into consideration for system design and implementation





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