PFAS 2021: STATE OF THE SCIENCE & INVESTIGATIVE APPROACHES AT DOD SITES

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AGENDA

- Introductions
- Weston at a Glance
- The Four Ws of PFAS
- State of PFAS Treatment Technologies
- Investigative Approaches at DOD Sites

Lisa Kammer, P.G.

- Principal Project Geologist and licensed Professional Geologist with 16 years of experience. Lisa has worked with a variety of clients to investigate and characterize hazardous waste sites, apply innovative tools and methods for remediation, and she enjoys employing project optimization strategies. Her focus is with emergent and recalcitrant compounds. She serves as Weston's Senior PFAS Leader and Emerging Contaminants Technical Community of Practice Leader and is an active member of the ITRC PFAS Team.

Shaun Cwick, P.G.

- Senior Geoscientist and licensed Professional Geologist with 11 years of experience. Shaun has worked with USACE and EPA to apply innovative techniques in the characterization and remediation of soils and groundwater impacted by a variety of contaminants. Mr. Cwick co-chairs Weston's Emerging Contaminants Technical Community of Practice, applying a strong background in groundwater modeling and more than four years of experience working at PFAS-impacted DoD installations and military bases.

WESTON AT A GLANCE

ACCOMPLISHMENTS AND ACHIEVEMENTS

- PFAS experience
  - Developed original PFAS sampling and analysis protocols for soil, groundwater, and biota with EPA
  - Initiated first-of-its-kind EPA and state-approved SI/RI program
  - Completed ecosystem bioaccumulation studies and exposure assessments
  - Developed air emissions testing and analytical protocols
- Active member of the *Interstate Technology and Regulatory Council* PFAS Team
  - Co-authored revised Fact Sheet
  - Participated in drafting and revisions of the PFAS Technical and Regulatory Guidance document
  - Co-lead monthly updates of the regulatory soil and water values table
  - Supporting sub-group developing basis of regulations table – publication date TBD
- Emissions Testing
  - Nationally recognized and trusted leaders in air emissions stack sampling for PFAS
  - Completed emissions stack sampling as part of first-of-its-kind mass balance analysis at a fluidized bed (sewage sludge) incinerator
  - Completed hundreds of PFAS sampling test runs and developed methods EPA has adopted as OTM-45

THE FOUR Ws OF PFAS

WHAT, WHEN, WHERE, & WHY ARE PFAS?

- Large family of man-made chemicals with a complicated chemistry
- Discovered in 1930s & manufactured & used world-wide since 1940s
- Some are known to be persistent, bioaccumulative, & toxic at relatively low levels
- Two most studied:
  - Perfluorooctanoic acid (PFOA) - $C_8HF_{15}O_2$
  - Perfluorooctanesulfonic acid (PFOS) - $C_8HF_{17}O_3S$

Twin-engine Cessna crash at Oroville Municipal Airport
Image source: https://katu.com/news/nation-world/atlanta-based-company-execs-survived-california-plane-crash-bound-for-portland

NATIONAL

1930s Begin PFAS production

1940s Worldwide use begins

1990s Manufacturers inform EPA that PFOS bioaccumulates

2000s Voluntary phase out SNUR & other initiatives EPA Action Plan

2010s EPA issues HA for PFOS/PFOA 2012 UCMR3

2016 Exposure assessments & health studies

2018 ATSDER draft tox profile for PFOA/PFOS

2019 EPA Action Plan

2021 EPA Human Health & Tox for PFBS

COLORADO

Site-specific GWQS of 70 ppt PFOA/PFOS El Paso County

2017 PFAS contamination in Fountain, Security, & Widefield

2018 Peterson AFB PFAS impacts addressed

2019 Colorado adopts PFAS Action Plan

CDPHE

STATE OF PFAS TREATMENT TECHNOLOGIES

SOIL TREATMENT TECHNOLOGIES

- Technologies in Development (In- & Ex-Situ)
  - Excavation and off-site disposal
  - Thermal/incineration
  - Soil washing
  - Smoldering
  - Solidification/stabilization
  - Biodegradation
  - Chemical oxidation/reduction
  - Electrochemical oxidation
  - Sonochemical degradation

Source: Soil mixing remediation project at Kearsarge Metallurgical Corporation Superfund Site, Weston Solutions, Inc.

ADVANTAGES AND DISADVANTAGES OF PRIMARY SOIL TREATMENT TECHNOLOGIES

Excavation, Disposal, Incineration

- Tried and true
- Effective
- Removes co-contaminants
- Easily scalable

- Can be expensive
- Limited applicability in certain hydrogeologic regimes
- Many facilities not accepting PFAS-impacted soils
- Thermal destruction must be complete – air transport

Soil Washing

- Specialized
- Somewhat effective
- Ex-situ treatment of concentration with proven technologies

- Labor intensive
- Co-contaminants may limit effectiveness
- Limited applicability in certain hydrogeologic regimes
- Does not achieve total destruction

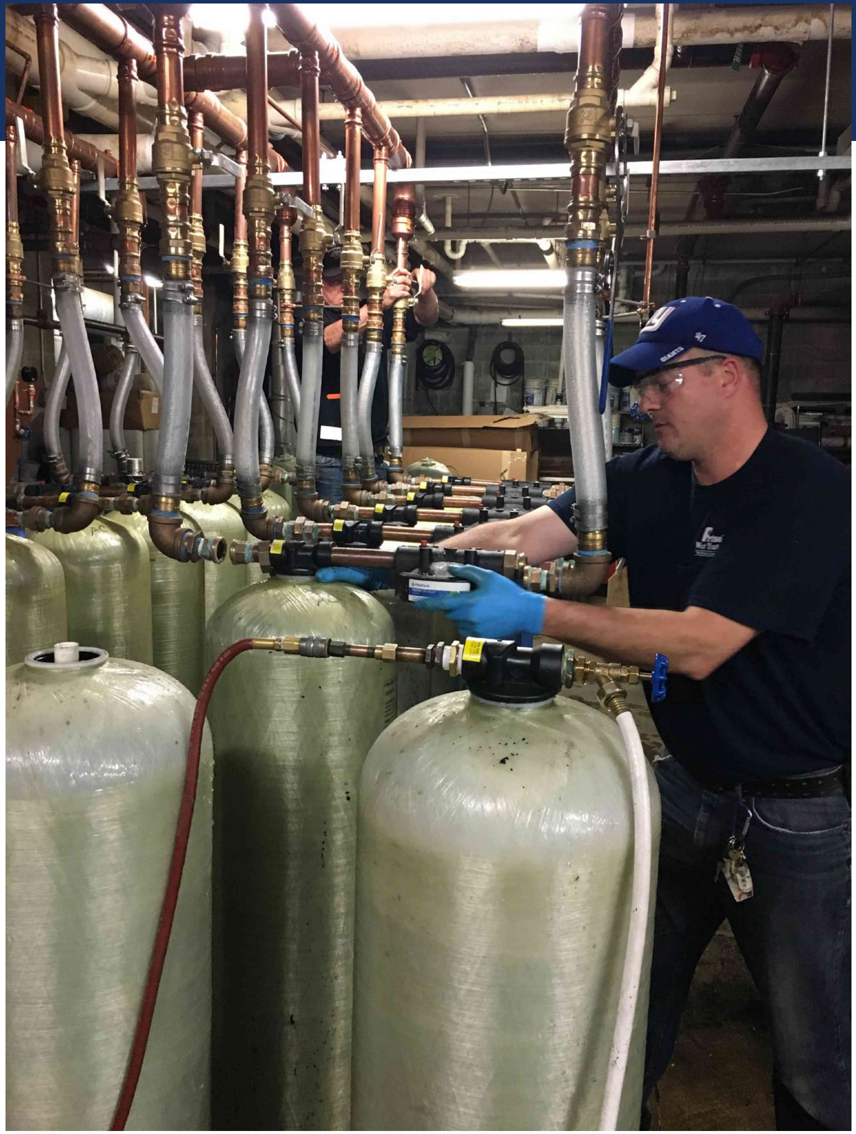
Binding

- Effective
- Scalable and fast
- Low cost

- Effectiveness limited by soil type/lithology
- Immobilization vs destruction
- Concerns of long-term viability

WATER TREATMENT TECHNOLOGIES

- Proven Technologies – Ex-Situ
  - Adsorption (activated carbon & resins)
  - Reverse osmosis
- Technologies in Development (In- & Ex-Situ)
  - Different formulations of activated carbon and amendments
  - Hydrothermal alkaline treatment
  - Nanofiltration
  - Foam fractionation
  - Bioremediation
  - Chemical oxidation/reduction
  - Enhanced contact plasma reactor
  - Sequestration
  - …and others



Source: Weston Solutions, Inc. 2016

ADVANTAGES AND DISADVANTAGES OF PRIMARY WATER TREATMENT TECHNOLOGIES

Granular Activated Carbon (GAC)

- Most widely studied and used
- Effective
- Removes co-contaminants
- Easily scalable
- Inexpensive

- Faster breakthrough with short chain PFAS
- May require pre-treatment removal of particulates
- Carbon regeneration/ disposal costs
- Less sustainable than other ex-situ technologies

Ion Exchange Resins (IX)

- Specialized
- Smaller footprint compared to GAC
- Effective
- Higher loading capacity for short chain PFAS

- Does not remove co-contaminants
- May require pre-treatment
- Expensive to regenerate resin on-site
- Disposal costs for resin and/or regenerant

Reverse Osmosis (RO)

- Very effective
- Small footprint
- Effectively removes co-contaminants
- Preferred option for point-of-use treatment

- Highly susceptible to fouling
- Sensitive to water quality parameters & temperature
- Low capacity
- Up to 20% of water is rejected and requires disposal

WATER AND SOIL TREATMENT TECHNOLOGIES

General Conclusions – *Every Case is Unique*

- Currently available destructive technologies are ex-situ and rarely 100% destructive as concentrations near asymptotic conditions
- All available, proven remedies are one part of a total remedial solution
- Economics, co-contaminants, and hydrogeology are important considerations
- Water quality and soil type influence performance of selected remedy(ies)
- Treatability testing is the best way to know for sure which options are best
- May result in more than one treatment option being selected

CURRENT FOCUS OF PROMISING TECHNOLOGIES

Direct Destruction

in-situ technologies – in development/prove out

- Biodegradation
- Oxidation / Reduction
- Thermal

Concentrate and Destroy

ex-situ technologies – most promising

"Concentrate" option

- Improve existing technologies for:
  - Effectiveness
  - Cost reduction
  - Simplicity

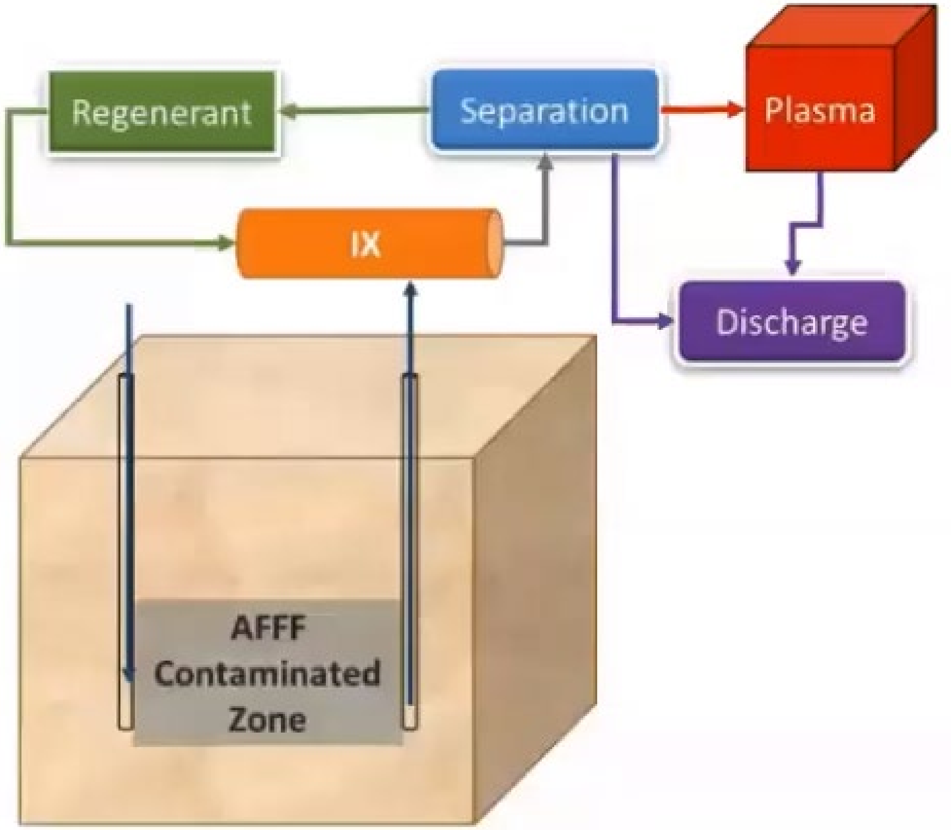
"Destroy" option

- Plasma
- Hydrothermal
- Photo-chemical
- Smoldering combustion
- …and more

CONCENTRATE AND DESTROY: COMBINED IN-SITU / EX-SITU REMEDIATION

DR. MICHELLE CRIMI (CLARKSON UNIVERSITY)

- Step 1 – Convert precursors to PFAA endpoints (in-situ)
  - Persulfate Oxidation (alkaline heat-activated)
  - Air Sparge
- Step 2 – Ion Exchange (ex-situ)
- Step 3 – Plasma Treatment of concentrated PFAS waste



IN-SITU / EX-SITU REMEDIATION – PLASMA TREATMENT

- Uses electricity to convert water into mixture of highly reactive species
  - $OH\bullet$, O, $H\bullet$, $HO_2\bullet$, $O_2\bullet^-$, H_2, O_2, H_2O_2 and aqueous electrons (e^-_{aq})

Concerns

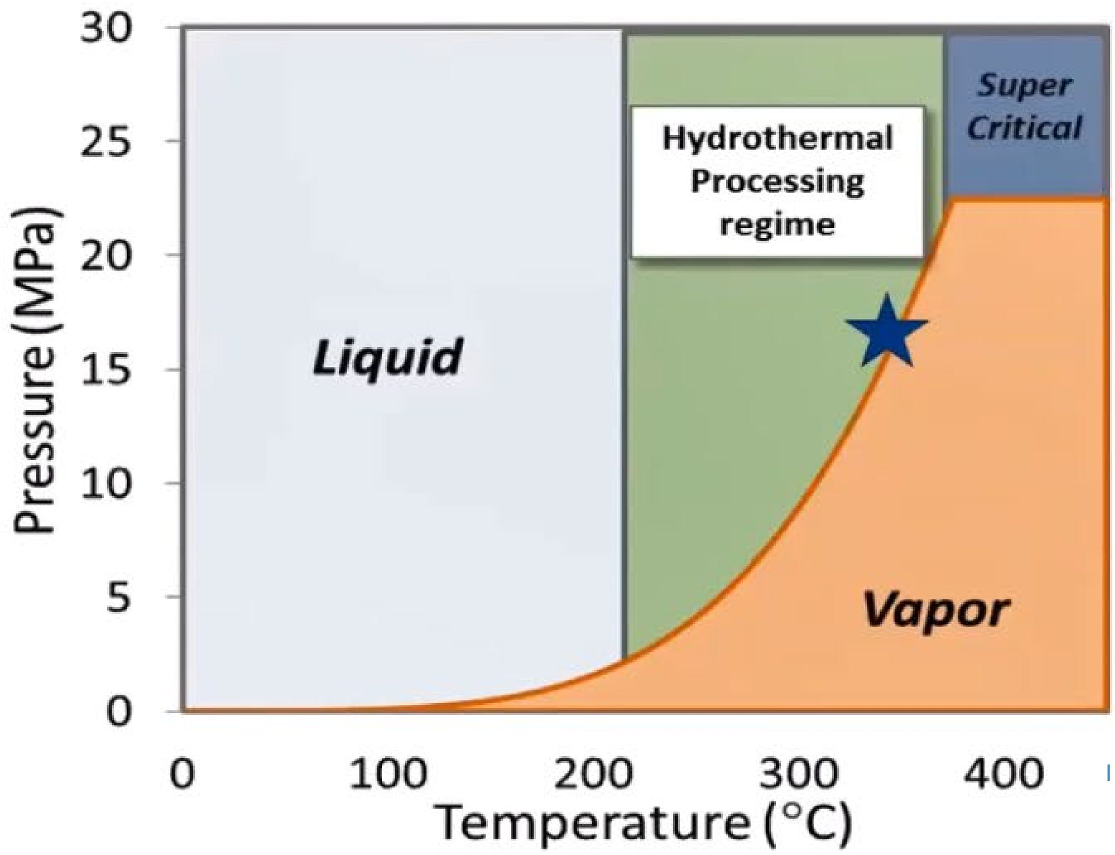
- Significantly more effective for long-chain than short-chain compounds
- Requires use of 2 reactors: high-concentration for bulk removal and low-concentration for "polishing"

HYDROTHERMAL ALKALINE TREATMENT OF PFAS (HALT)

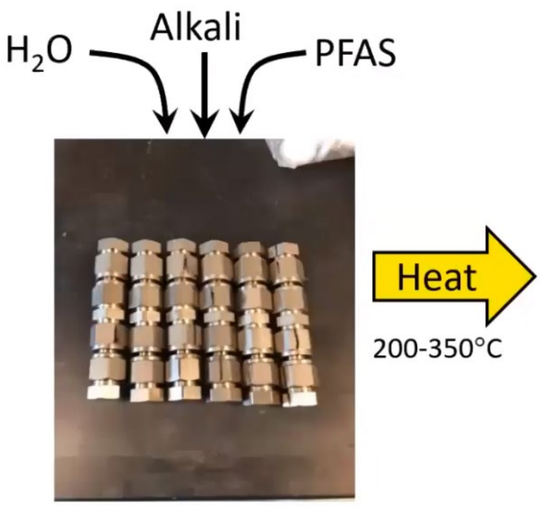
DR. TIMOTHY STRATHMANN (COLORADO SCHOOL OF MINES)

- Properties of water change as near critical temperature
- Hydrothermal processing exploited for biomass conversion to fuel
- Efficient for thermal processing of "wet" feeds

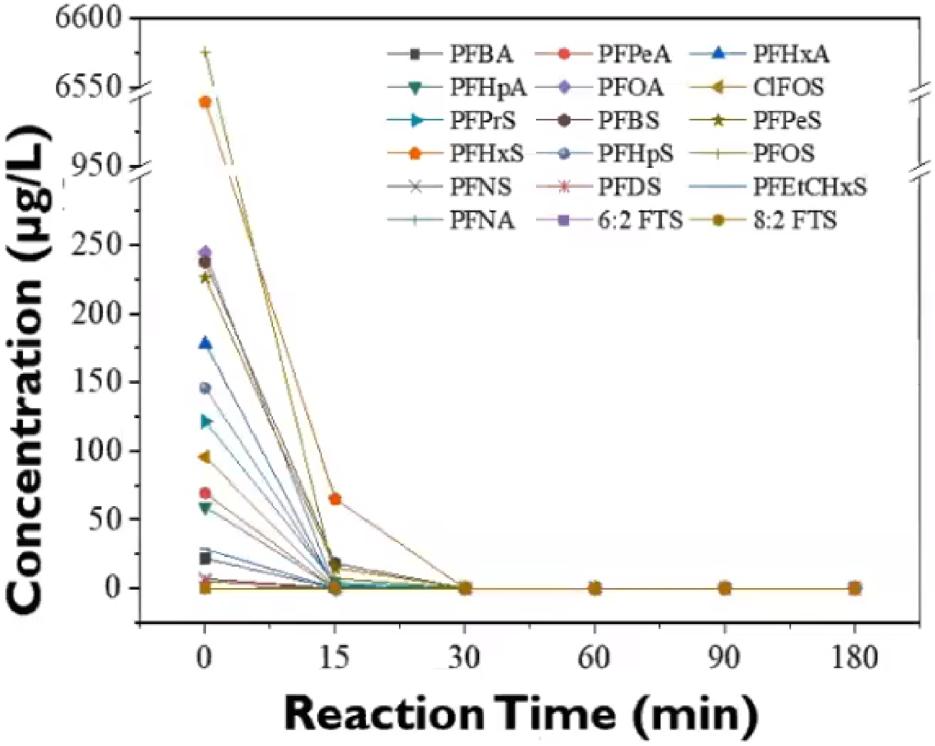
H_2O: $\Delta H_{25\rightarrow350} = 1.1$ MJ/kg
$\Delta H_{vap} = 2.6$ MJ/kg

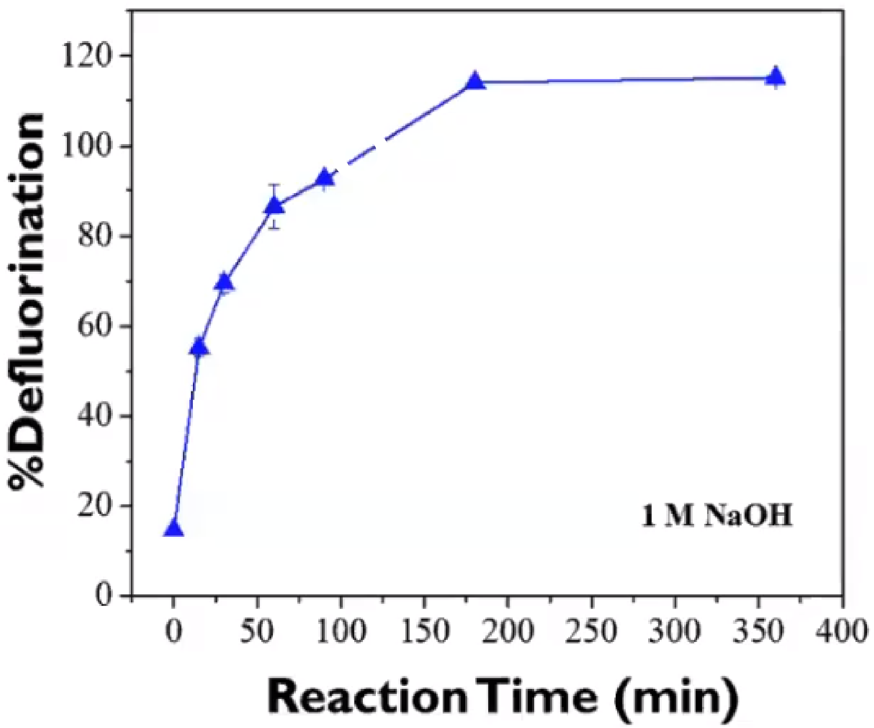


HYDROTHERMAL ALKALINE TREATMENT OF PFAS



AFFF diluted 1000-fold in 1 M NaOH, 350°C





HYDROTHERMAL ALKALINE TREATMENT OF PFAS

350°C, t = 90 min,
14 wt% solids, 5 M NaOH

PFAS	Conc. ($ng\ g^{-1}$)	%Destruction
PFOA	150	>99%
PFOS	22,900	94%
PFHxA	340	>99%
PFHxS	3,960	93%
FOSA	223	>99%
MeFOSAA	619	>99%
6:2 FTS	215	>99%
PFNS	1,894	>99%
PFDS	1,388	>99%

U.S. EPA CHALLENGE

Link: Innovative Ways to Destroy PFAS Challenge | US EPA

1st Place Winner

- HALT technology with >99.9% destruction

  Features:

  1. Complete PFAS destruction
  2. Field deployability
  3. Low energy consumption
  4. High throughputs
  5. No toxic byproducts

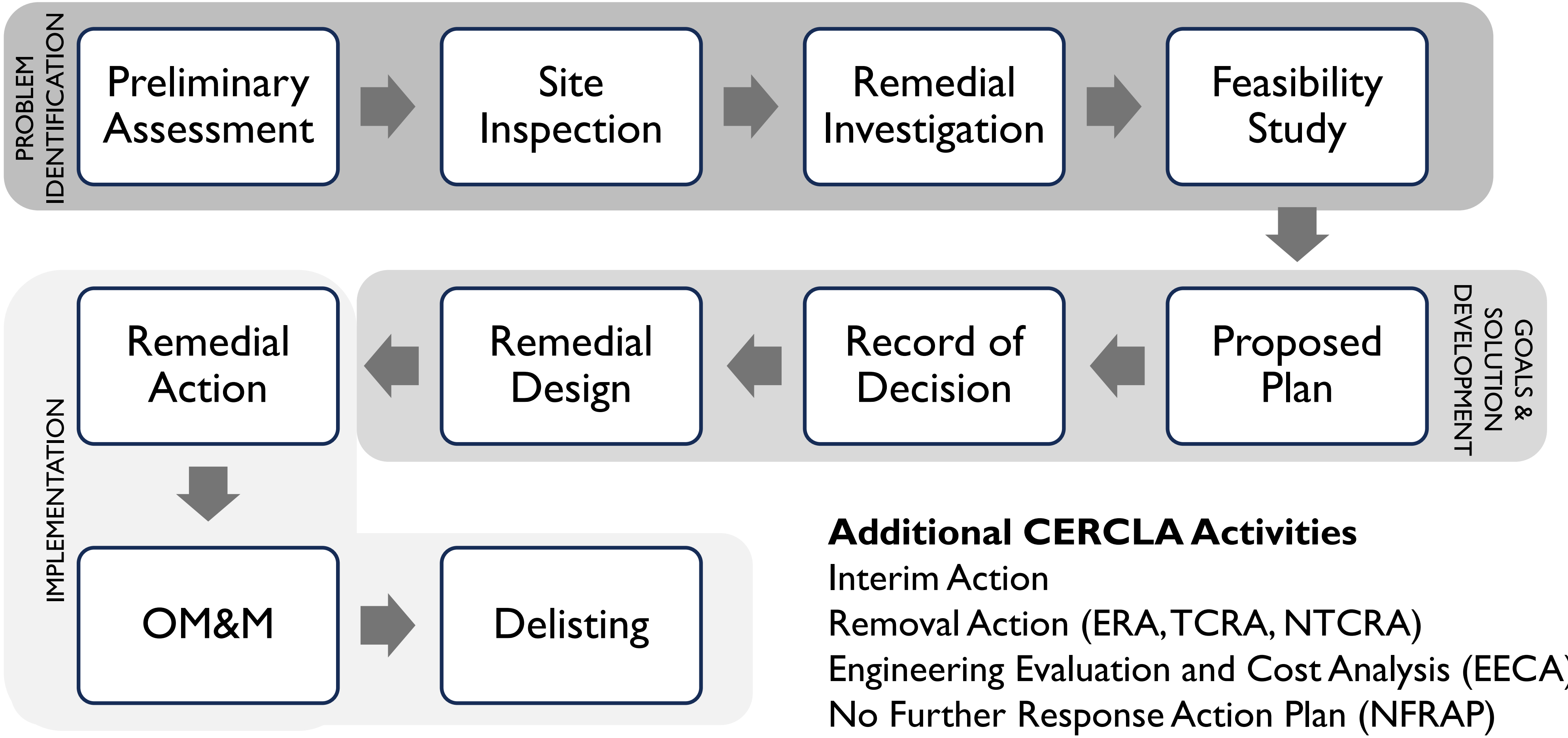
2nd Place Winners (tie)

- Ultraviolet light & non-toxic additives
- Continuous flow liquid-phase plasma discharge

INVESTIGATIVE APPROACHES

DEPARTMENT OF DEFENSE SITES

CERCLA PROCESS (REMEDIAL)



Additional CERCLA Activities

Interim Action

Removal Action (ERA, TCRA, NTCRA)

Engineering Evaluation and Cost Analysis (EECA)

No Further Response Action Plan (NFRAP)

Public Involvement

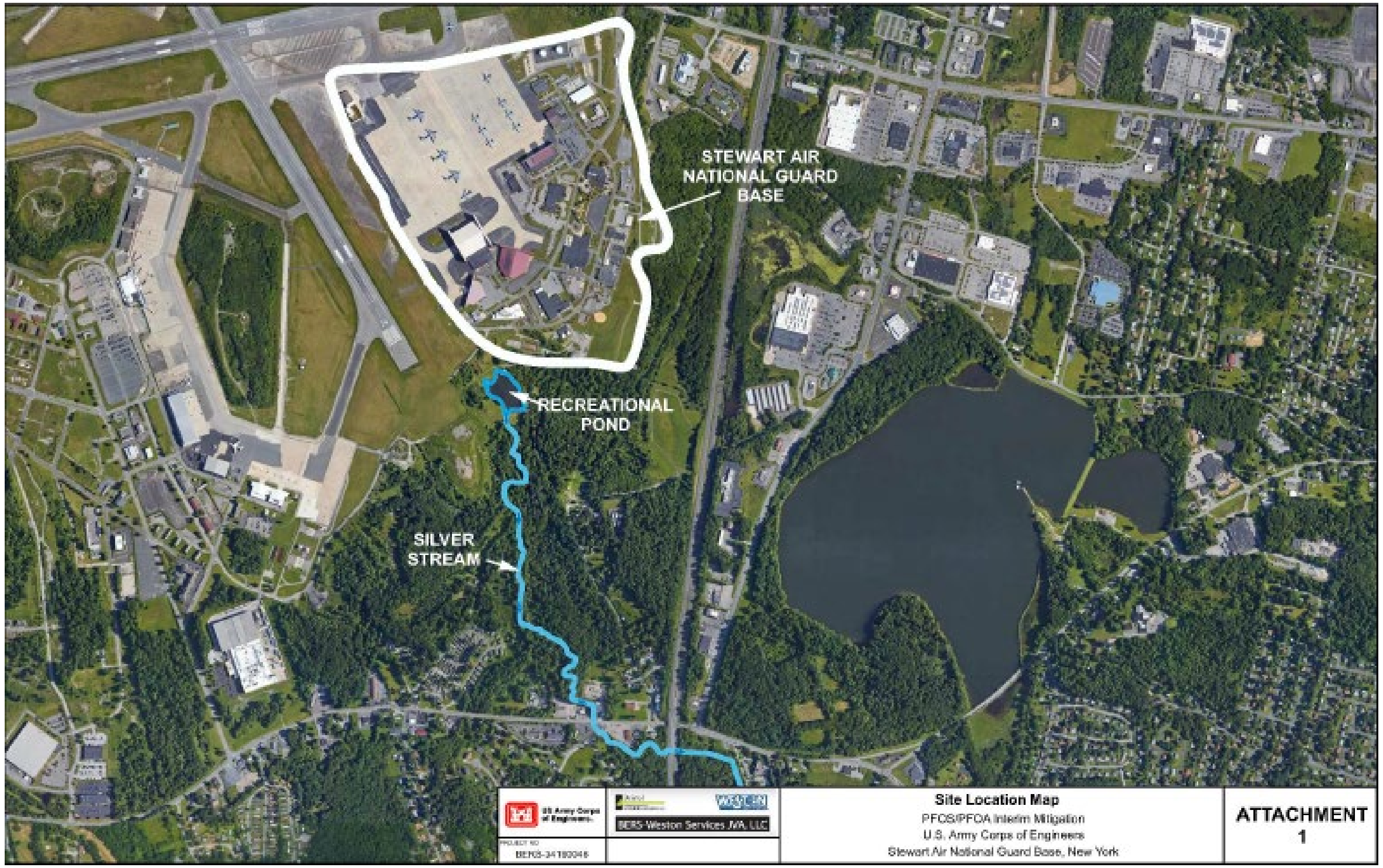
STEWART AIR NATIONAL GUARD BASE

NEW YORK

INTERIM STORMWATER TREATMENT SYSTEM STEWART AIR NATIONAL GUARD BASE

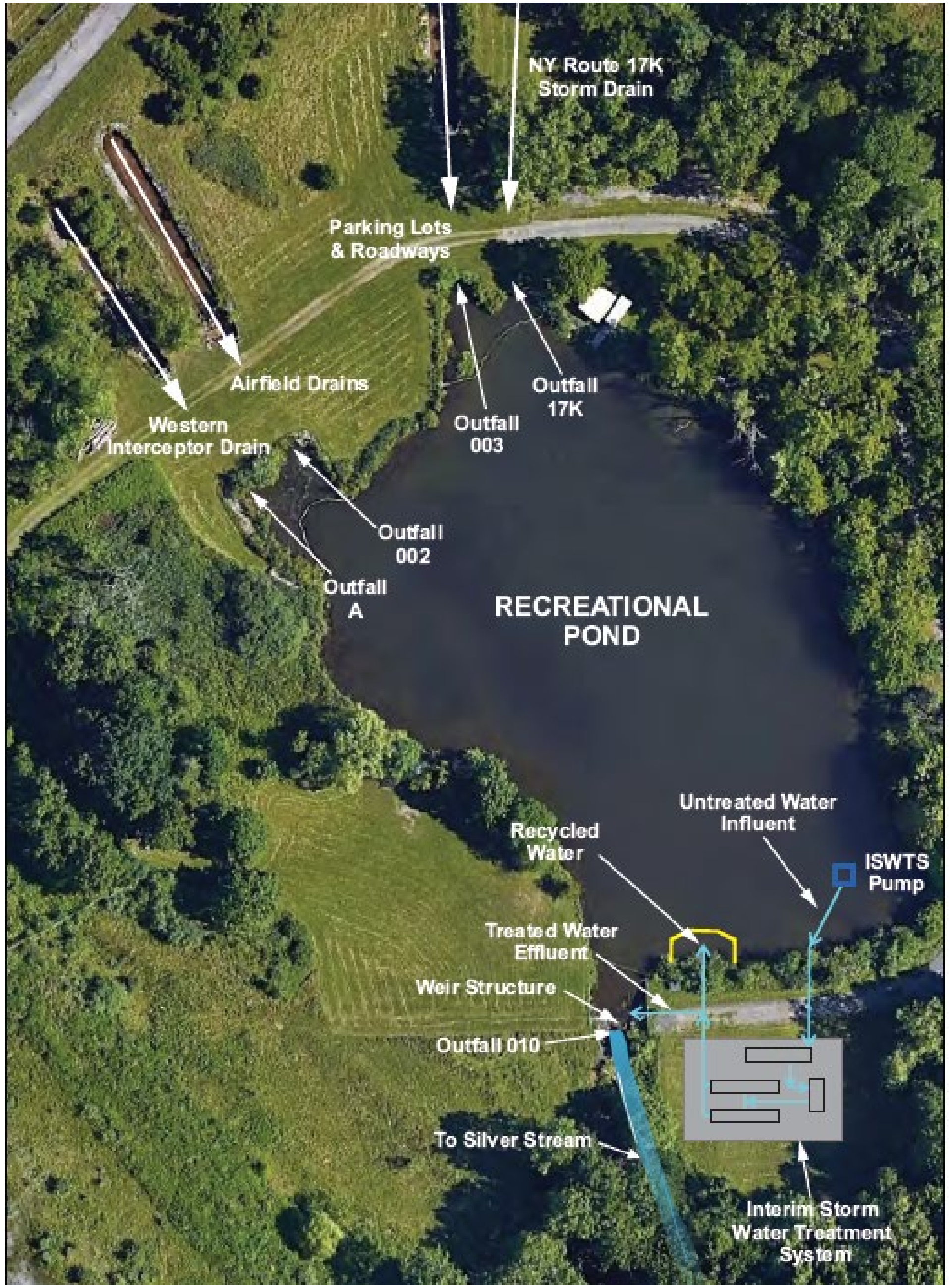
NEWBURGH, NEW YORK

- BERS-Weston Services JVA
- Stormwater discharge from Base impacted with PFAS resulting from AFFF discharges
- Stormwater discharges to the Recreational Pond
- Pond discharges through weir outfall to Silver Stream to Moodna Creek and ultimately the Hudson River
- Diversionary stream directs Silver Stream to Lake Washington – drinking water reservoir for City of Newburgh

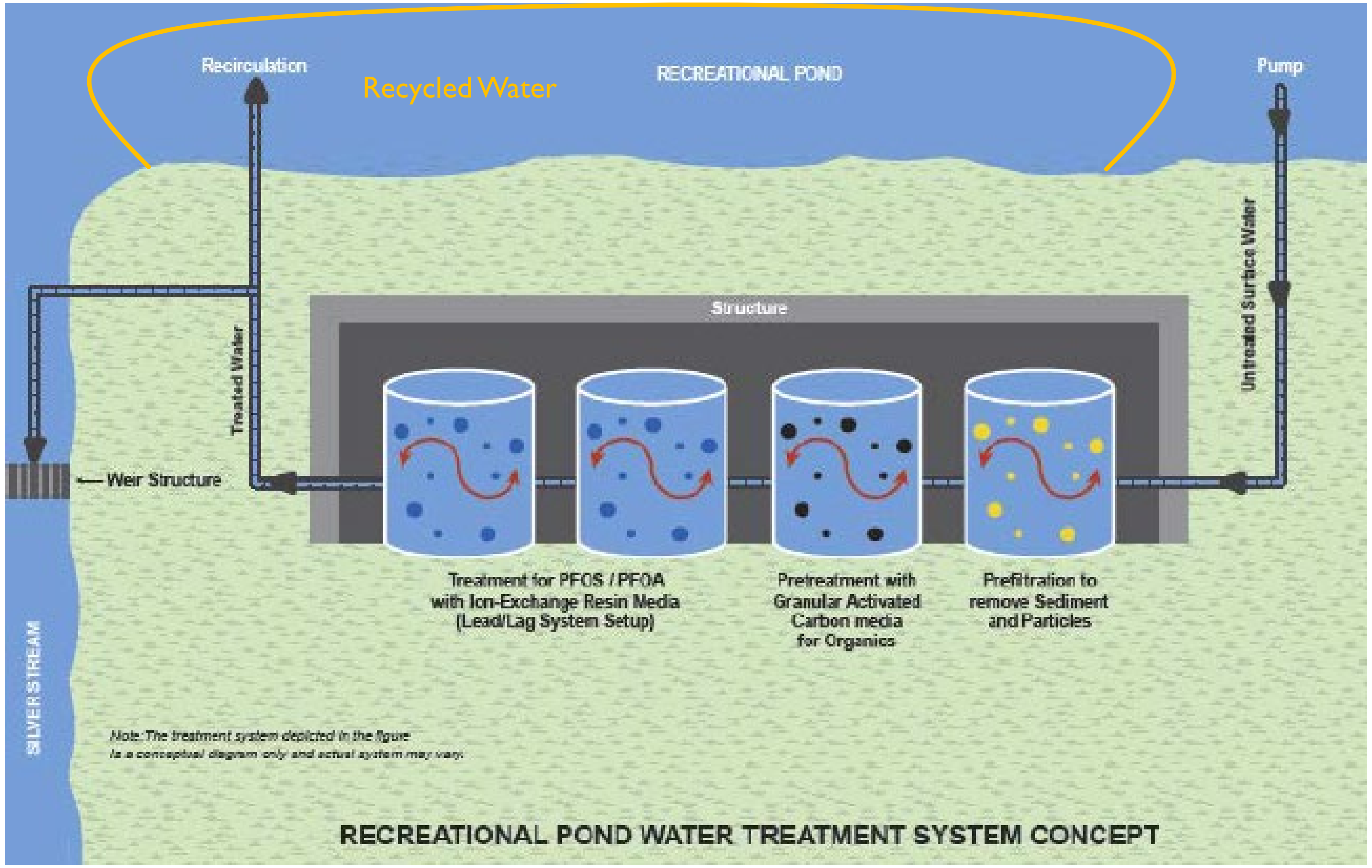


STEWART AIR NATIONAL GUARD BASE
NEWBURGH, NEW YORK

- Development and installation of mitigation system for temporary water treatment
- Ancillary infrastructure
- Operation, maintenance, and monitoring
- System developed with upcoming lower standards in mind
- State Pollutant Discharge Elimination System (SPDES) requirements
- Operating as a full-scale pilot
  - 165+ million gallons treated to-date
  - Large rain events can send 100,000+gpm into the pond



STEWART AIR NATIONAL GUARD BASE
NEWBURGH, NEW YORK



- Mobile systems set up in winterized Conex boxes
- 4 treatment trains running in parallel:
  - Pretreatment: centrifugal separator, bag filter, sand filter
  - GAC treatment – 4 vessels/ 2,500lbs of carbon each
  - IX – 8 vessels/ 560 cubic feet of media
  - Turbidity barrier
- Programmable logic controller
  - Pressure transducers and gauges
  - Alarm dialer and alarm management system

STEWART AIR NATIONAL GUARD BASE
NEWBURGH, NEW YORK

- Treatment system installed as an interim mitigation system while the site proceeds through the CERCLA process
  - Implementation of multiple available technologies
- Additional activities
  - Stormwater drainage monitoring
  - Sampling and modeling of PFAS contributions into the pond
  - Collection of data that will allow for evaluating long-term strategies to mitigate or remediate PFAS from stormwater discharges
- Challenges
  - Stormwater subject to rapid changes in water quality, elevated levels of TOC, algae growth during warm weather periods, and biofouling on internal treatment process components
- Any further modifications would be evaluated once the site is through the CERCLA process

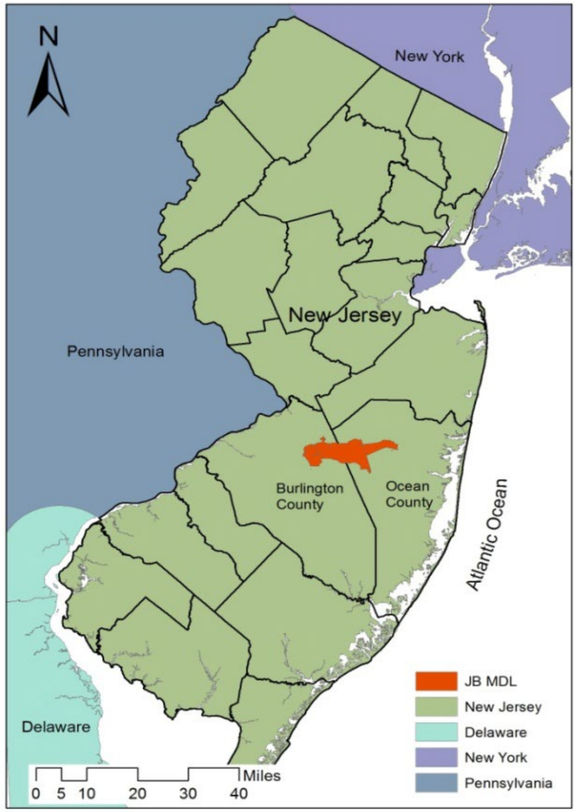
Stewart Air National Guard Base

Source: https://images.app.goo.gl/zYmDjD9TcZGyRxMD7

JOINT BASE MCGUIRE-DIX-LAKEHURST

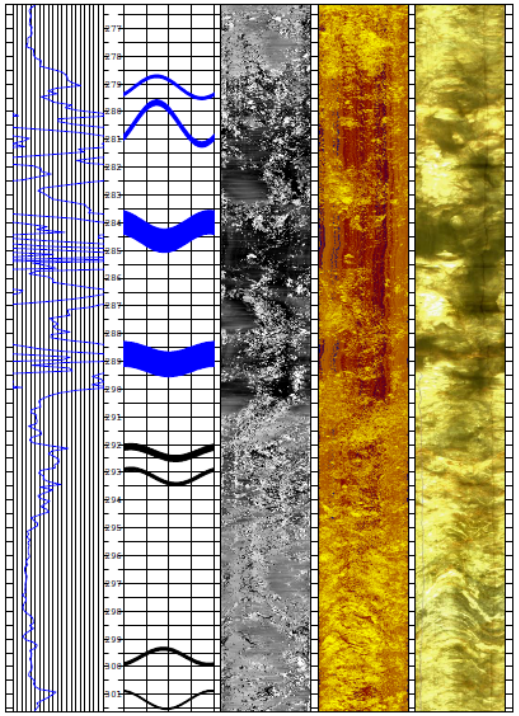
NEW JERSEY

JOINT BASE McGUIRE-DIX-LAKEHURST NEW JERSEY



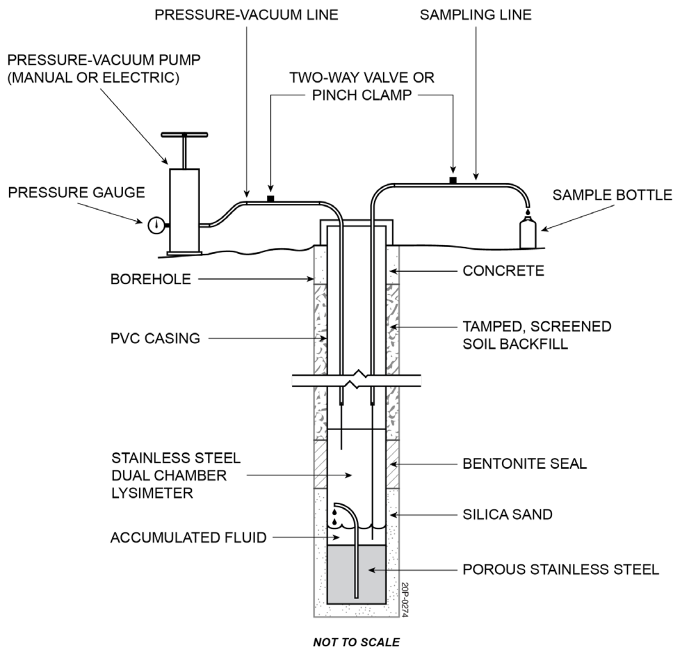
- 42,000 acres spanning over 20 miles from east to west
- PFAS-containing AFFF was used at all 3 facilities for fire training and firefighting purposes
- Stormwater runoff, migration from soil to shallow groundwater, and groundwater discharge to surface water are among the main migration pathways
- Impacted areas identified on-site and off-site
- PA and SI completed in 2015–2019
- SI was expanded in 2019
- Phase I Remedial Investigation (RI) underway

PHASE 1 REMEDIAL INVESTIGATION



- A Phase 1 RI is currently being performed by Weston Solutions, Inc. under the direction of USACE Baltimore and AFCEC with the following goals:
  - Delineate nature and extent of PFAS contamination in soil, groundwater, surface water, and sediment at each facility at JB MDL
  - Evaluate migration pathways of PFAS both on- and off-base
  - Collect lysimeter data to evaluate PFAS present in unsaturated zone, and evaluate the residual mass in release areas and potential transport to GW
  - Perform borehole geophysics to verify/document the site stratigraphy
  - Collect sufficient data to support future risk assessment efforts
  - The RI will focus on 21 validated sites with documented AFFF releases and consideration of unvalidated sites

LYSIMETRY



ATTACHMENT SOP-15-1
LYSIMETER FOR VADOSE ZONE WATER SAMPLING

- Lysimeters will be utilized within source areas to assess PFAS source strength and quantitatively characterize transport of PFAS leached from the soil column to shallow groundwater
- Lysimetry accounts for air/water interface effects within the unsaturated zone
- Preferred approach to SPLP analyses of soil samples
- Soil pore water data will be used for developing pore water action levels, assessing PFAS fate and transport, and evaluating remedial alternatives in the subsequent Feasibility Study phase

SUMMARY OF PROCESS STREAMLINING EXAMPLES

Key Takeaways

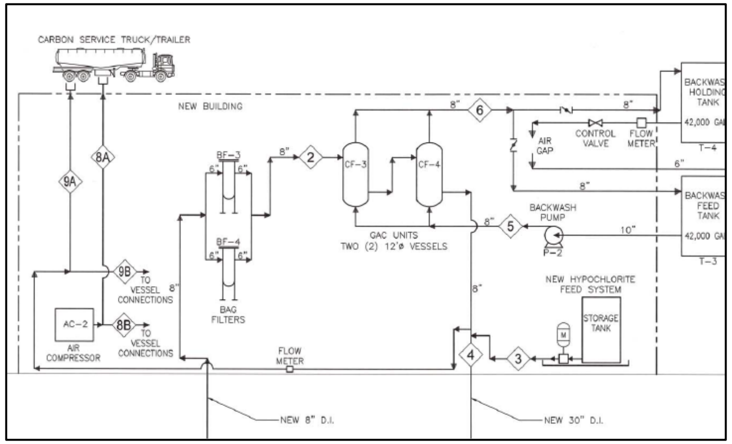
- Use daily PFAS protocol checklist to ensure compliance and prevent cross-contamination of samples
- PFAS characterization will follow a phased approach for efficient data collection and interpretation
- Because multiple sites are being investigated, a continuous approach will be used to collect initial data with return for subsequent step-in/step-out sampling to fully delineate nature and extent. This eliminates the need and costs for additional mobilizations or the use of rapid turnaround time of sample analyses to support decision-making by the project team.
- Lysimetry is expected to provide critical data on the soil to groundwater pathway for reliably determining the need, type, and extent of potential remedial measures for controlling releases from each of the source areas.

JOINT BASE LEWIS-MCCHORD

WASHINGTON

CERCLA TIME-SENSITIVE INTERIM ACTIONS – JBLM, WA

- Time-sensitive CERCLA services of site investigation through remedial action
- 4 drinking water well production facilities
- 18 PFAS compounds, geochemical, geotechnical, and bacteriological analysis
- Remedial alternatives analysis (GAC and AIX)
- Treatment systems design, construction, and maintenance for one month (flow ranging between 500 and 1,065 gpm)

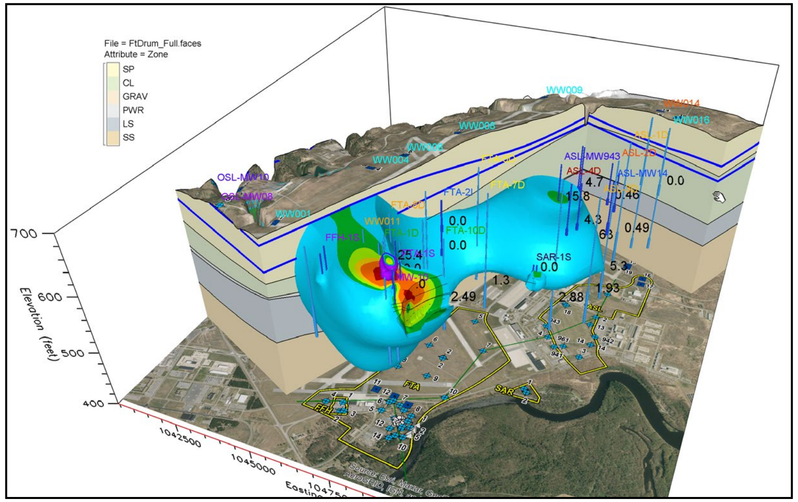


FORT DRUM

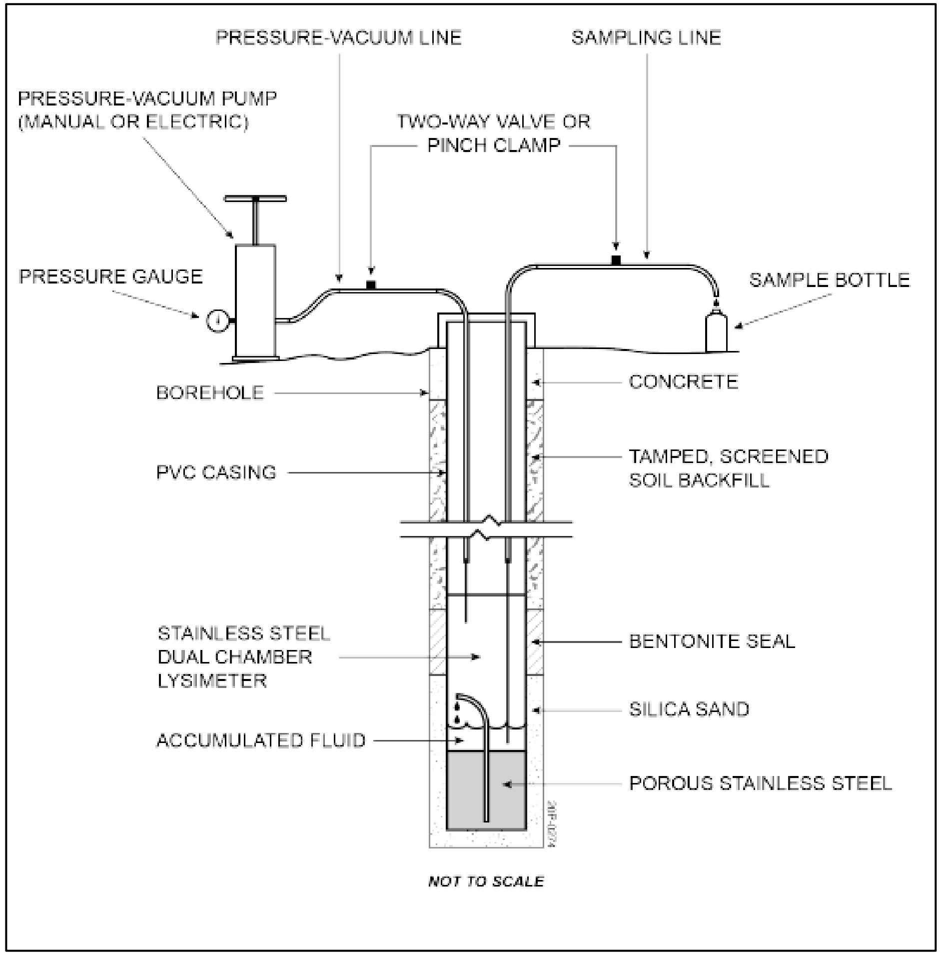
NEW YORK

FORT DRUM – PAST AND PROPOSED INVESTIGATION APPROACHES

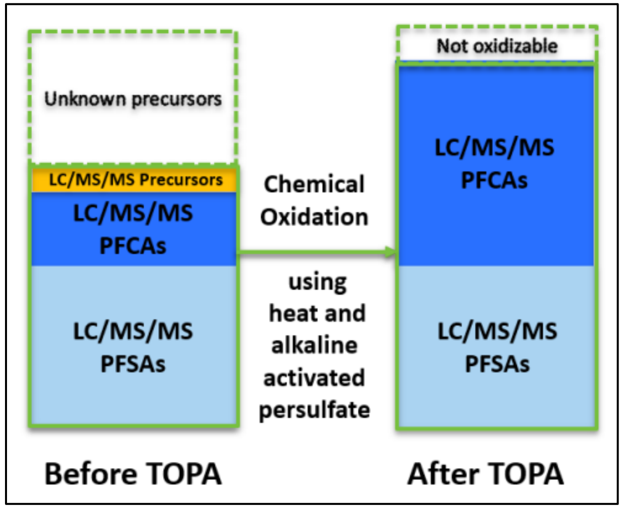
3D EarthVision® Model



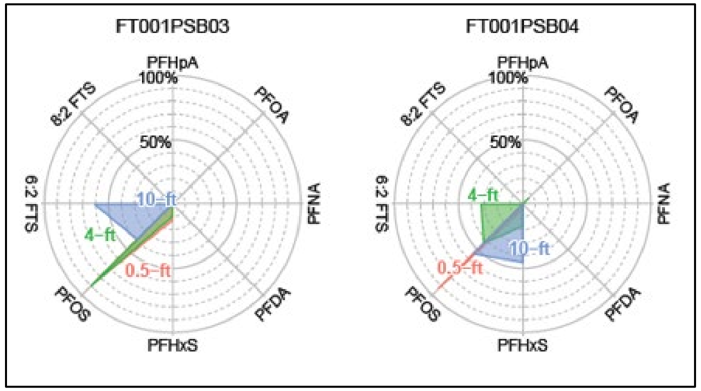
Lysimeter Sampling



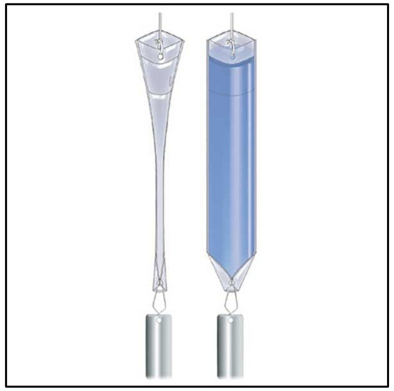
TOP Assay Analysis



Radial Plots



HDPE HydraSleeves

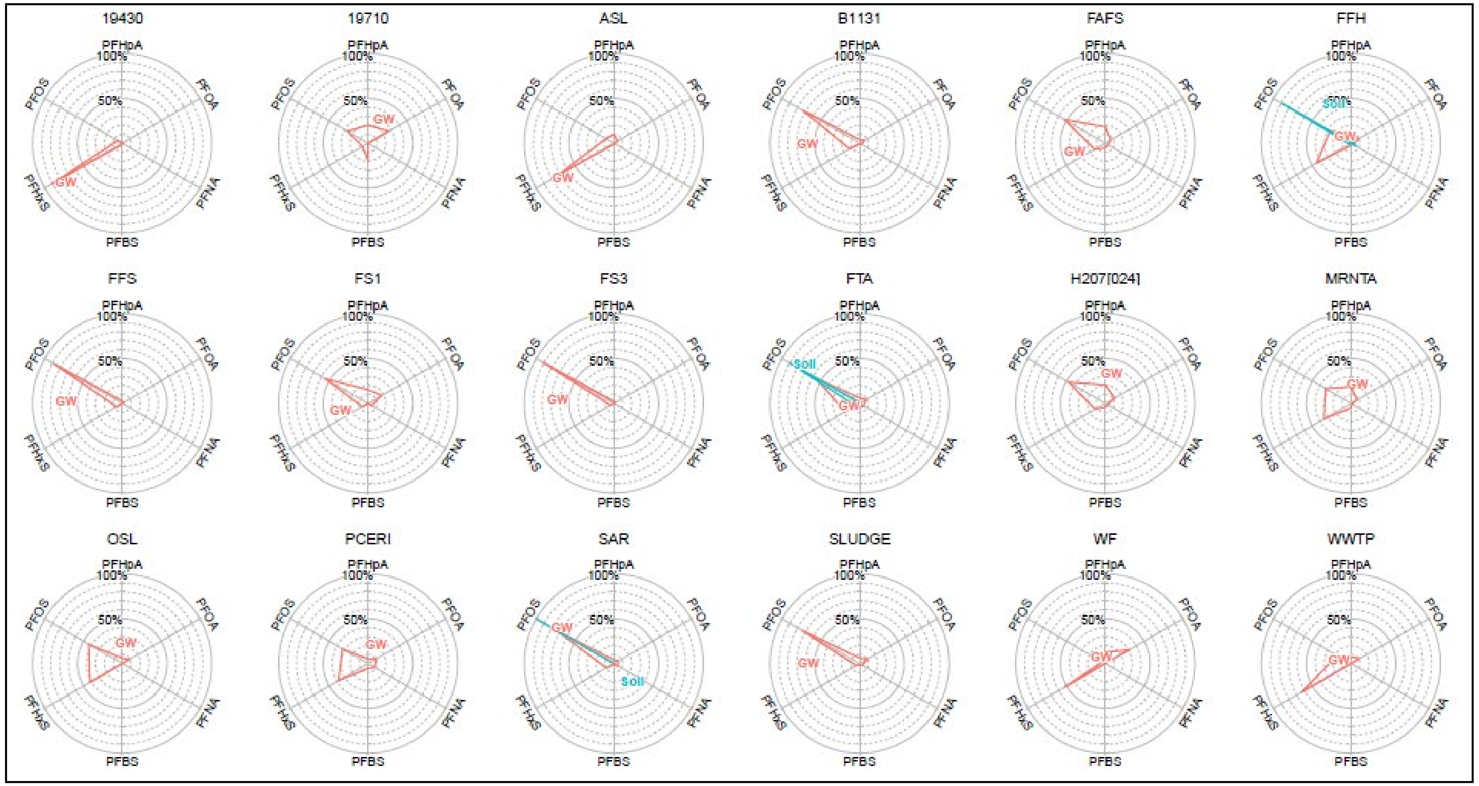


MULTIPLE LINES OF EVIDENCE APPROACH
Relative Concentrations

Radial Plots:

- Proportions may indicate different sources and/or preferential transport/ partitioning
- Spatial plotting may help with the fingerprinting process
- Cost-effective tool and easily understood by stakeholders

Fort Drum radial plots produced via batch automation



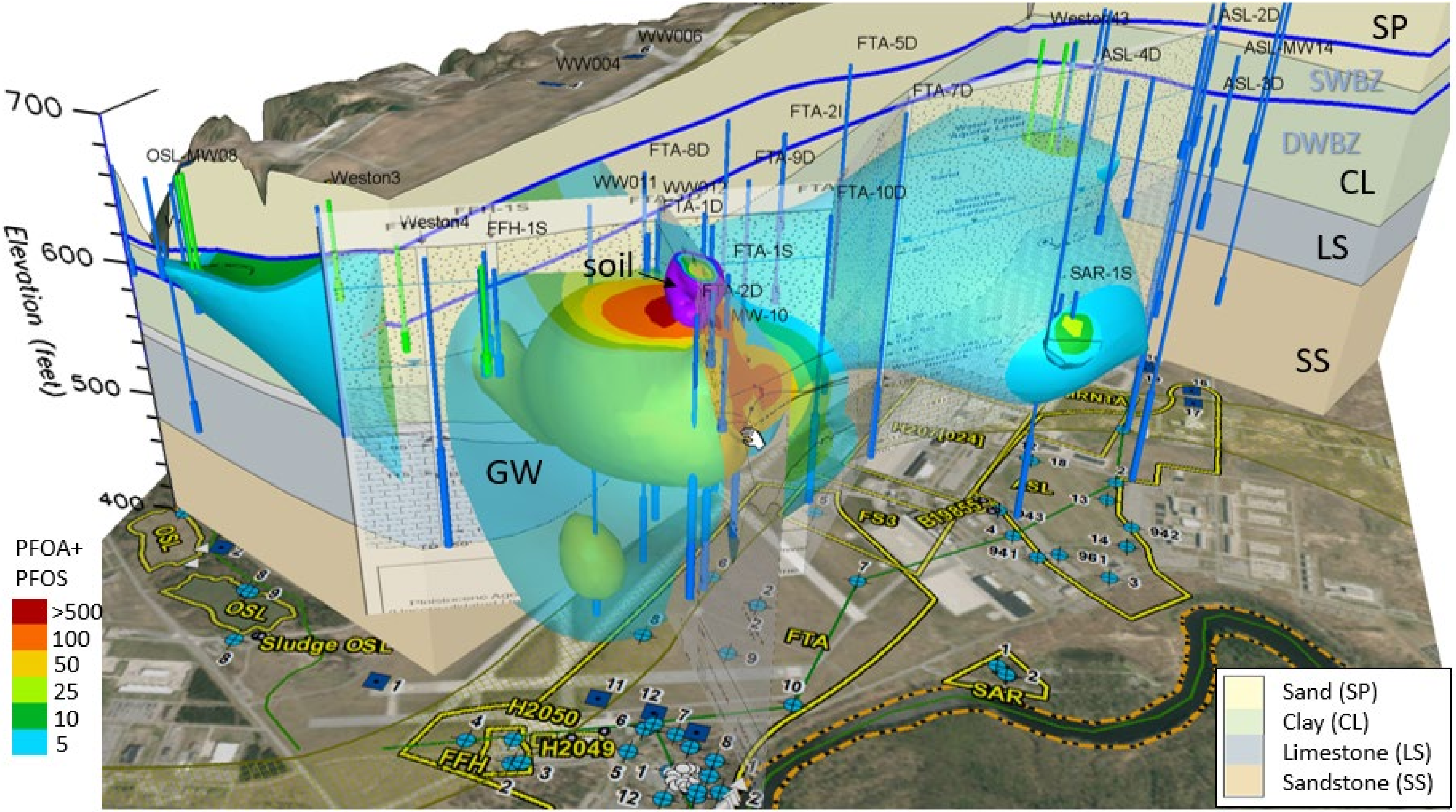
PFAS SAMPLING METHODOLOGY
HDPE HydraSleeves

- Advantages:
  - Limited equipment
  - Simple setup (pre-sampling setup)
  - Quick sampling
  - No purge / IDW water disposal
- Limitations:
  - No purge – single set of water quality parameter readings
  - Large volume samplers
  - Technical acceptance

ADVANTAGES AND LIMITATIONS OF PFAS TEST METHODS
Total Oxidizable Precursors (TOP) Assay

TEST NAME PROJECT	OBJECTIVE	ADVANTAGES	LIMITATIONS
PFAS by LC/MS/MS	• Characterization of individual PFAS • Target PFAS delineation • Risk Assessment • Regulatory Compliance	• Provides accurate concentrations for individual PFAS • Typical parameter lists include 20–50 compounds • 1–2 ng/L reporting limits meets all current regulatory standards	• Higher cost test • "Targeted analysis", i.e., 30 individual compounds out of a potential 4,000+
Total Oxidizable Precursors (TOPs) Assay	• ***Indication*** of total PFAS contamination • PFAS (target and non-target) delineation • Risk Assessment • Regulatory Compliance • Future Liability	• Provides accurate concentrations for individual PFAS • Indicates the presence of compounds not measured by PFAS by LC/MS/MS • Indicates potential for future liability due to transformation of precursor compounds	• Labor intensive assay, leads to longer turnaround times • High cost • Not fully quantitative • High sample variability • Does not necessarily provide a "total" PFAS result
Total Organic Fluorine (TOF)	• ***Measure*** of total PFAS contamination • "Is my sample PFAS-free?"	• Complements existing approaches • Provides concentration of organic fluorine, which is ***representative*** of the presence or absence of PFAS • Less labor intensive • Lower priced analysis	• Reporting limits 1–2 µg/L (total F) in water

FORT DRUM
3D Conceptual Site Model



QUESTIONS?

THANK YOU!

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