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Research and Development, Demonstration and Validation of a PFAS Treatment Train

Presentation for 104th John J. (Jack) Lagrosa
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Water Environment Association, May 6 2019

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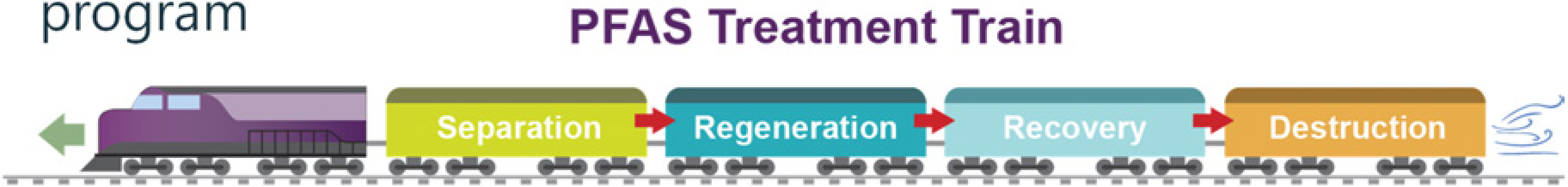
Presentation Outline

Overview of PFAS Treatment Train by Component:

- ISCO Pretreatment
- Regenerable Ion Exchange for PFAS Removal
- Plasma for PFAS Destruction
- Full-scale groundwater treatment

Research And Development through SERDP and ESTCP program

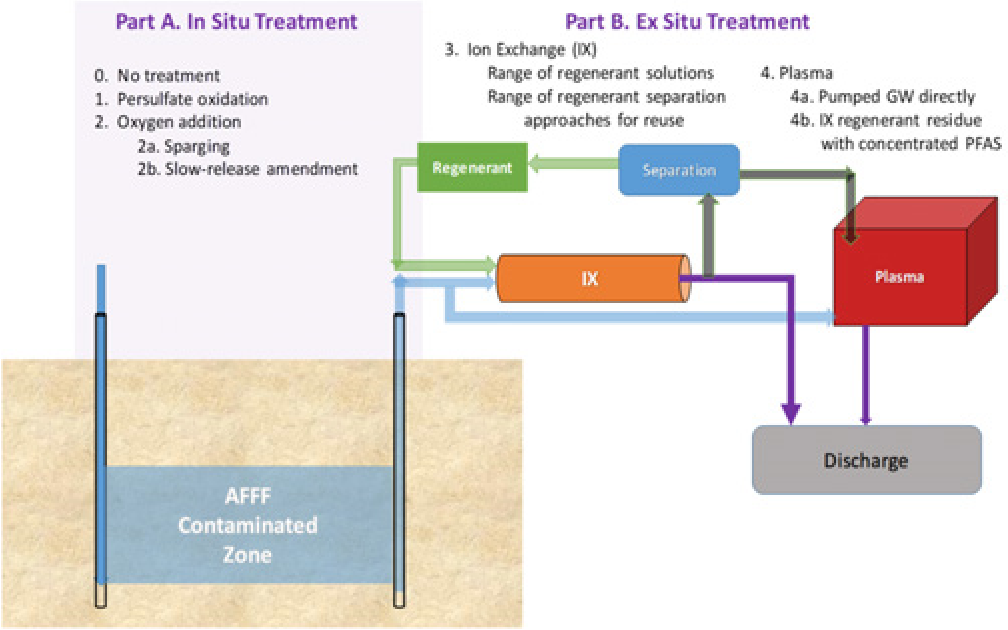


ISCO Pre-treatment

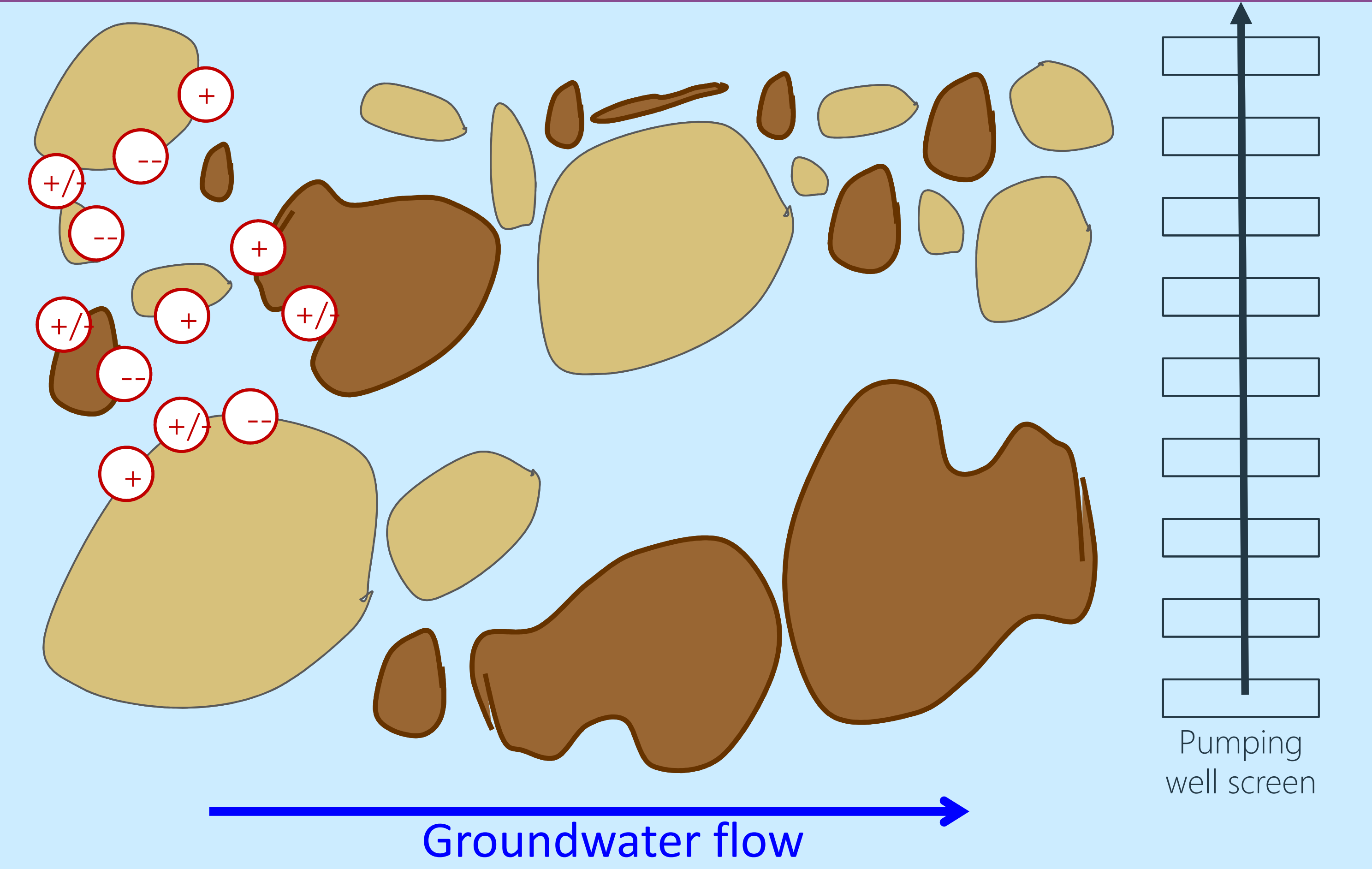
Bench Testing

Pre-Treatment for Efficient Removal

- A process for dealing with the "Dark Matter"
- Transformation through oxidation
- Simplifying the ion mix
- Increasing the mobility of PFAS
- Delivering the compounds we know how to treat



IN SITU PRE-TREATMENT



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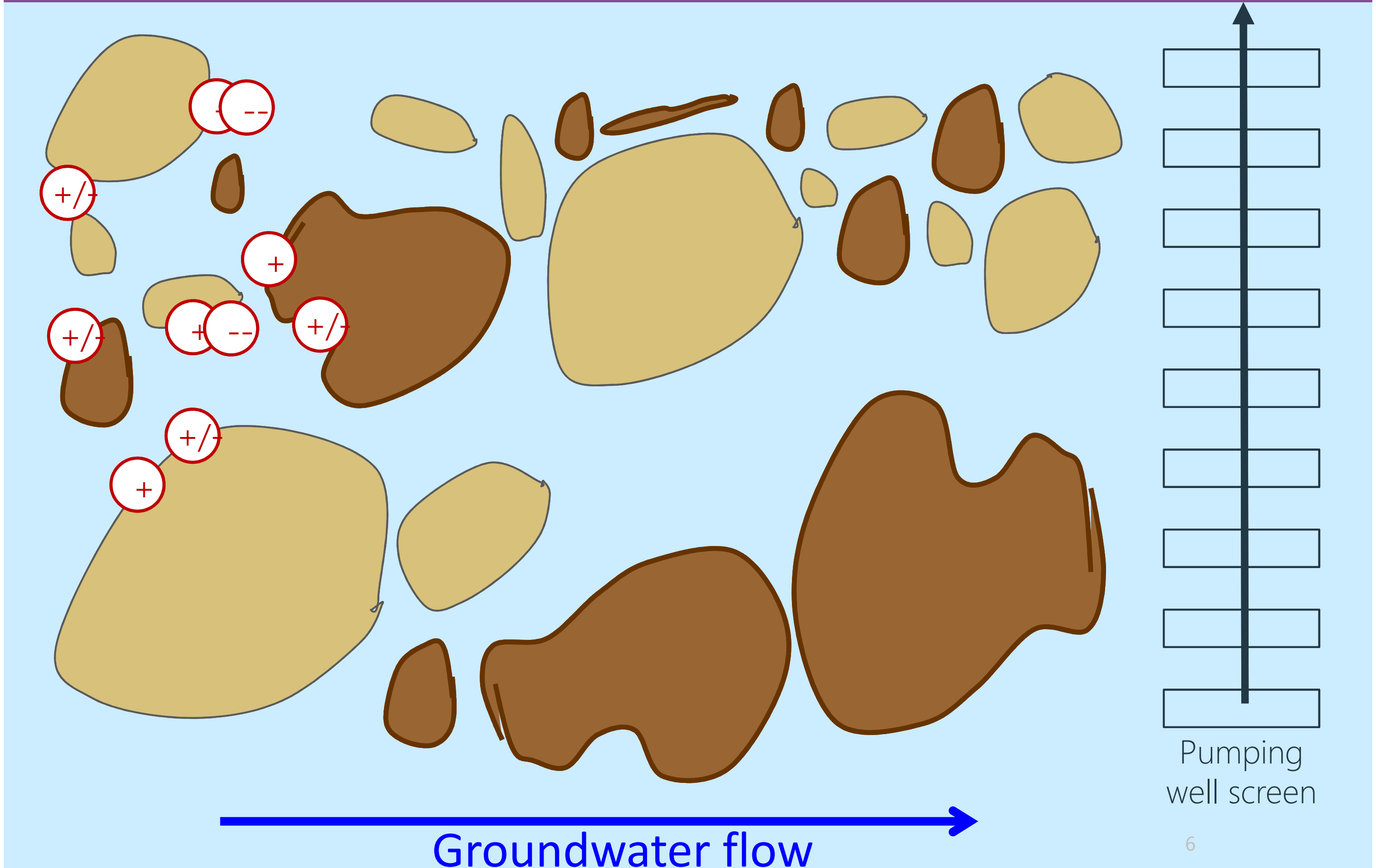

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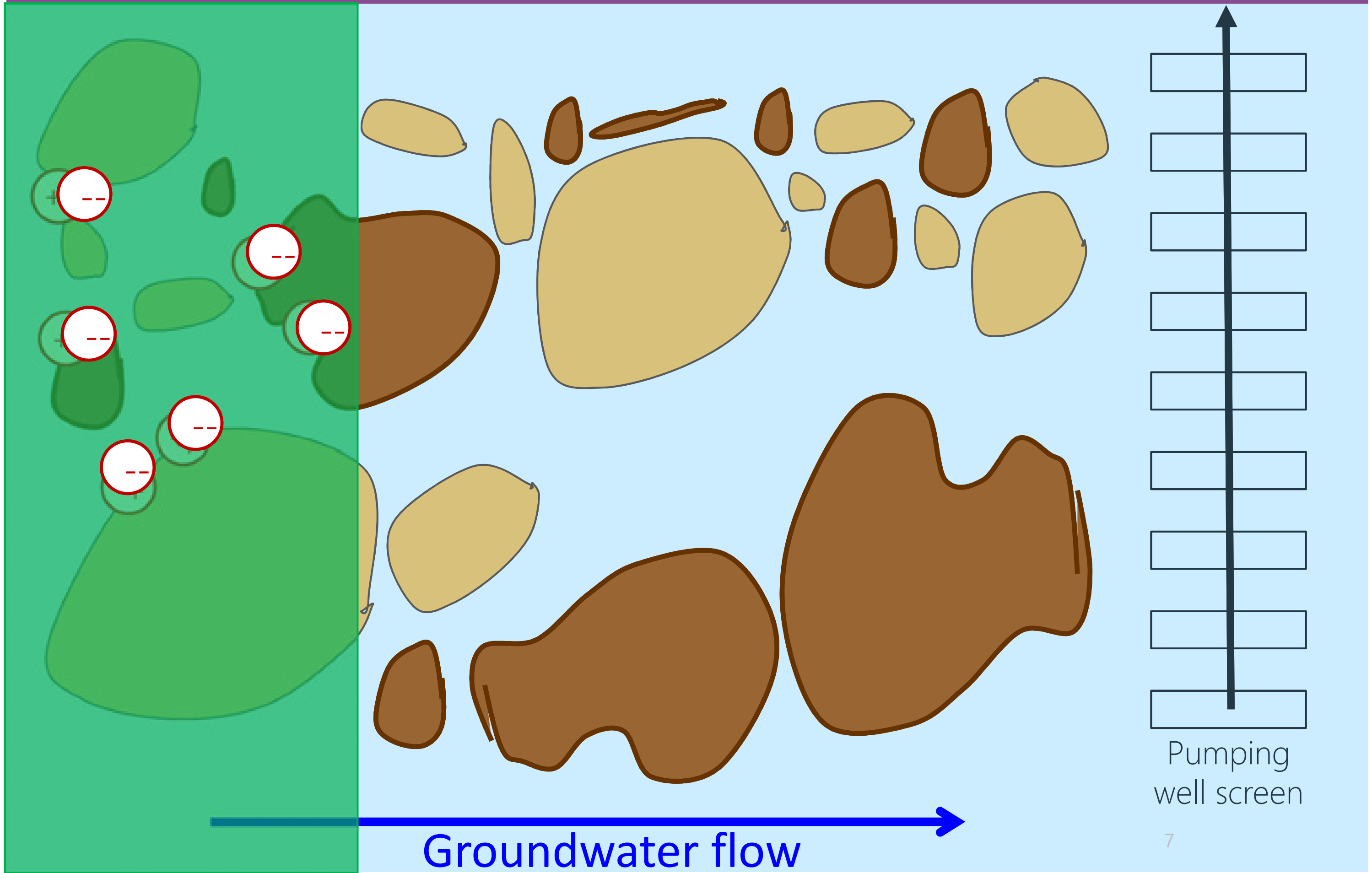
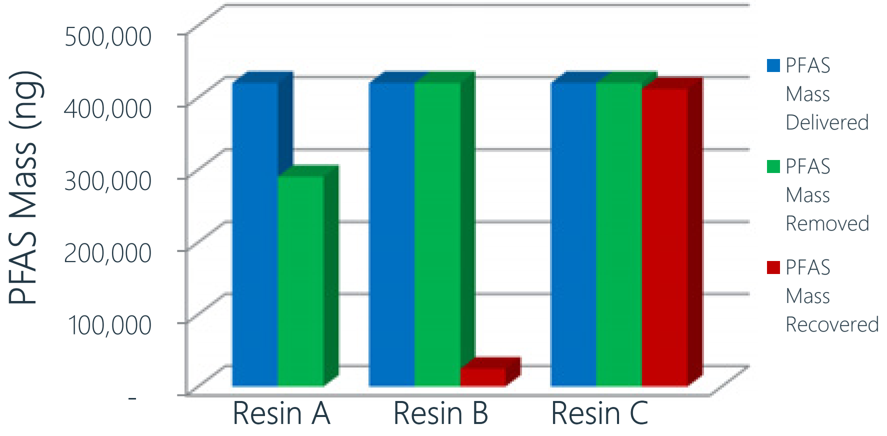


Regenerable IX for PFAS Removal

Bench and Pilot Scale Testing

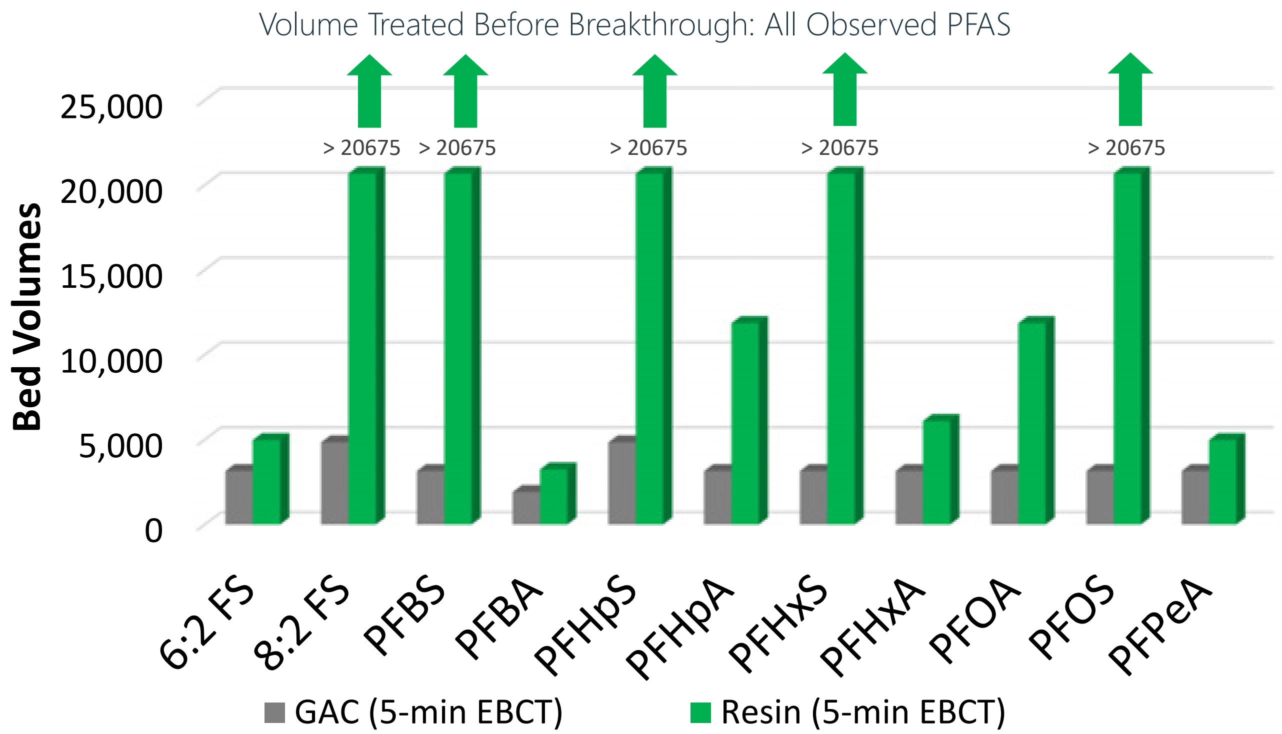
Ion Exchange Bench Scale Trials

- Adsorption of PFASs to resin below detection limits
- No breakthrough observed
- >99% regeneration of media with solvent/brine solution
- Success of bench test led to a pilot test for evaluation at the Site

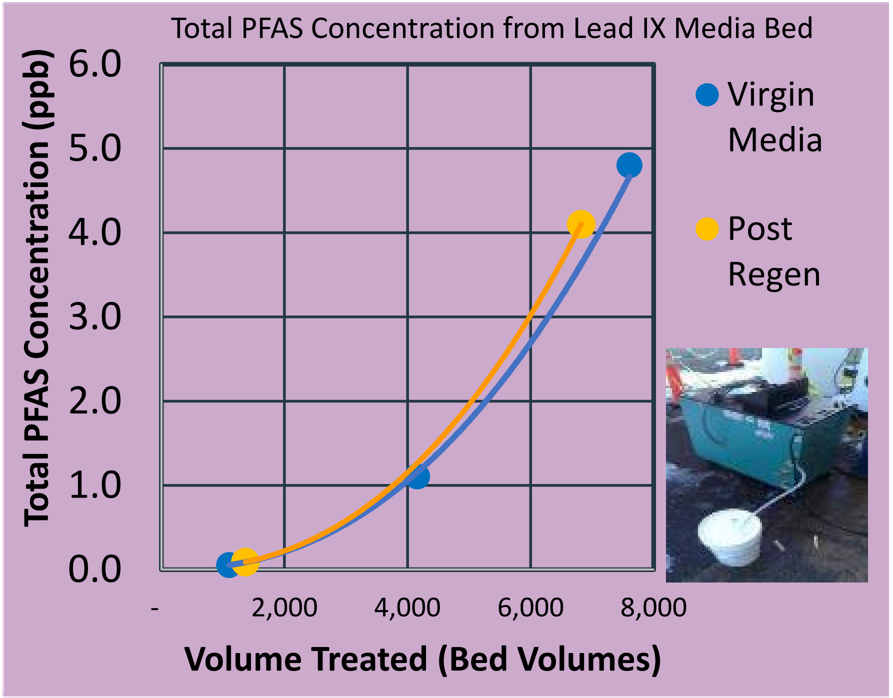


Best Performing Resin

Ion Exchange Pilot Study



Pilot Study Regeneration Success and Full-scale Construction



- Lifecycle cost evaluation performed for full-scale 200 gpm system at Former Pease AFB
- Capital cost for Resin system is +/- 15% higher than GAC
  - Media cost
  - Regeneration system
- O&M cost is +/- 50% lower than GAC
  - Resin has higher capacity
  - No media replacement
- Even without regeneration, lifecycle cost of resin system is lower, depending upon PFAS mix
- Pease full-scale system start up April 2018

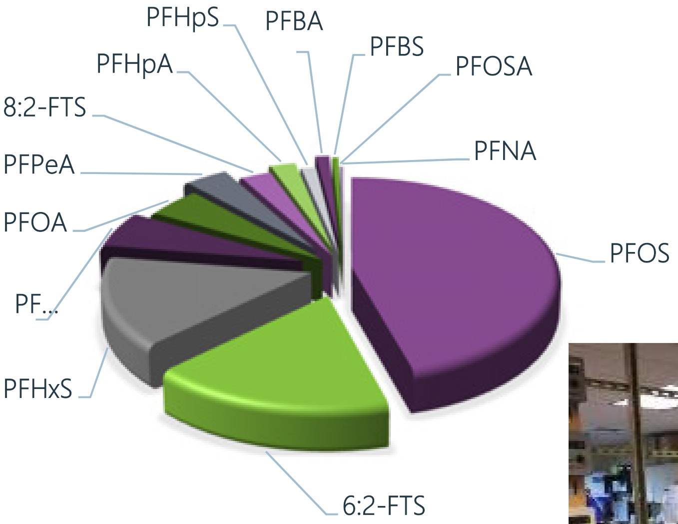
Multi-media Bench-Scale Trials

Influent Water Composition

	% of Total PFAS Mass	Average Concentration (ug/L)	Fluorinated Carbon Chain Length
PFBA	1.2%	0.408	3
PFPeA	3.8%	1.323	4
PFBS	0.5%	0.188	4
PFHxA	5.8%	2.032	5
6:2-FTS	17.2%	6.021	6
PFHpA	2.2%	0.762	6
PFHxS	14.6%	5.111	6
PFOA	4.8%	1.663	7
PFHpS	1.3%	0.438	7
PFOS	45.5%	15.895	8
8:2-FTS	2.6%	0.909	8
PFOSA	0.2%	0.057	8
PFNA	0.1%	0.043	8
EtFOSE	0.0%	0.013	8
EtFOSA	0.0%	0.013	8
MeFOSE	0.0%	0.012	8
MeFOSE	0.0%	0.009	8
PFDA	0.0%	0.012	9
PFDS	0.0%	0.011	10
PFUnA	0.0%	0.009	10
PFDoA	0.0%	0.009	11
PFTrDA	0.0%	0.008	12
PFTeDA	0.0%	0.010	13
Total		34.96	

Short Chains

Average Influent Composition



- Media Tested
  - One GAC
  - Two regenerable IX media
  - Three non regenerable IX media
- Column Set-up:
- GAC Column = 10 min EBCT
- IX Columns = 2 min EBCT

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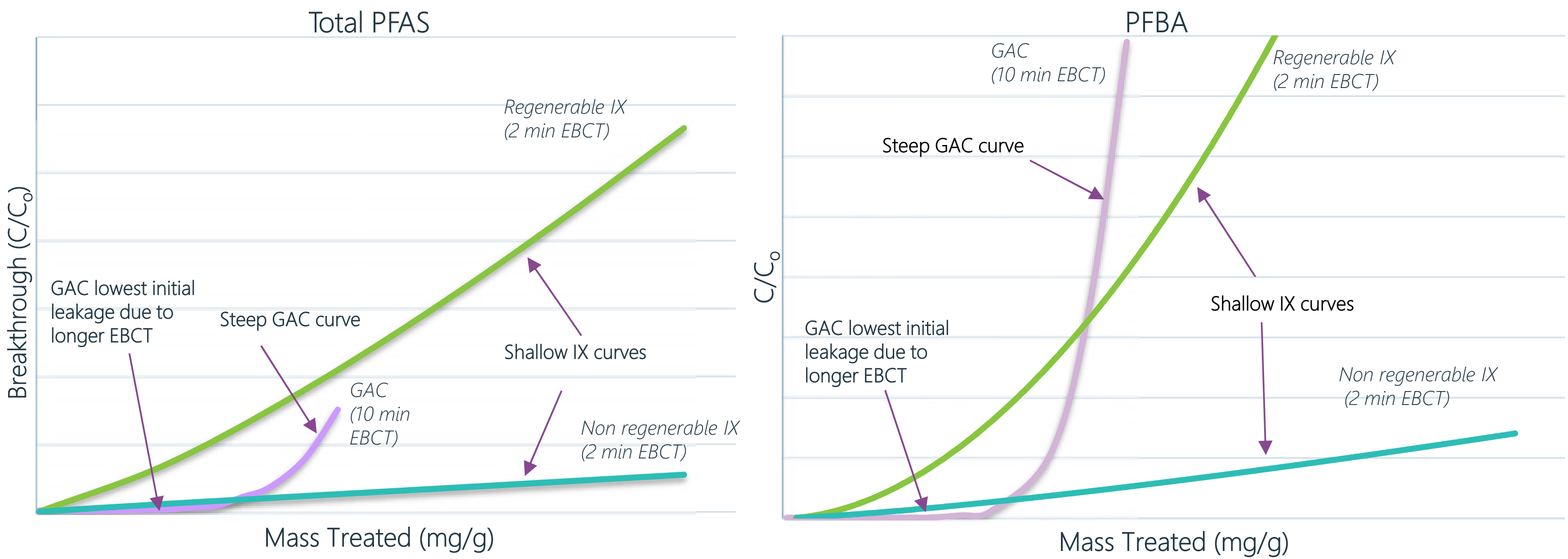
Multi-media Bench-Scale Trials

Study Results

Illustrative curves for GAC and IX media for total PFAS from site-specific groundwater



Note: Site-specific pilot testing recommended to determine media performance

Findings on Media Selection

- IX and GAC remove PFASs, perform better for long chains, and sulfonates
- IX systems use less media, smaller footprint, faster EBCT than GAC
- Regenerable IX adds capital cost but pays for itself over time – 10-25 ppb threshold
- Media selection depends upon a number of key factors:
  - Influent PFASs concentration – ppb vs ppt
  - Co-contaminants – combined media may be most efficient
  - Treatment objectives – analytes, non-detect, health advisory, other
  - Treatment configuration – single or multi vessel systems
  - Regeneration availability
  - Application – drinking water versus groundwater

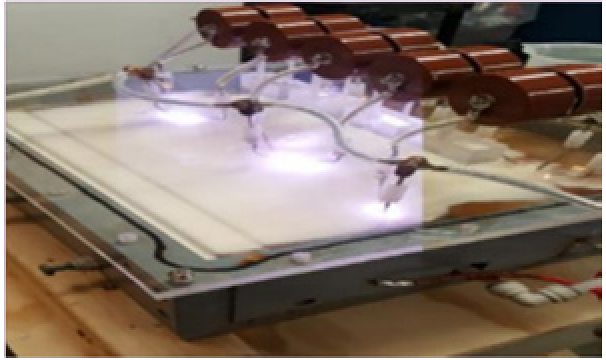
Plasma for PFAS Destruction

PLASMA for PFAS Destruction

- Technology developed by Clarkson University
- Enhanced contact, low energy plasma reactor for two applications
  - Treatment of Investigation Derived Waste – low C aqueous solutions
  - Treatment of still bottom waste from regenerable IX – high C brine solution
- Technology demonstrated for IDW
- Technology under development for still bottoms through SERDP and ESTCP

Prototype Plasma Reactor for high C PFAS

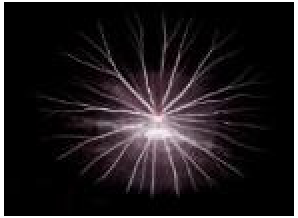
Inventors: Mededovic and Holsen, Clarkson University



Plasma Based Treatment Processes for PFAS Investigation Derived Waste (ER18-1624)

- 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})
- Electrical discharge plasma formed *directly in* or *above* water
- Benefits of plasma-based water treatment:
  - Wide variety of reactive chemical species
  - Generates ultraviolet-range radiation (UV), shockwaves capable of inducing cavitation, and localized high temperatures capable of thermally decomposing molecules
  - No chemical additives required

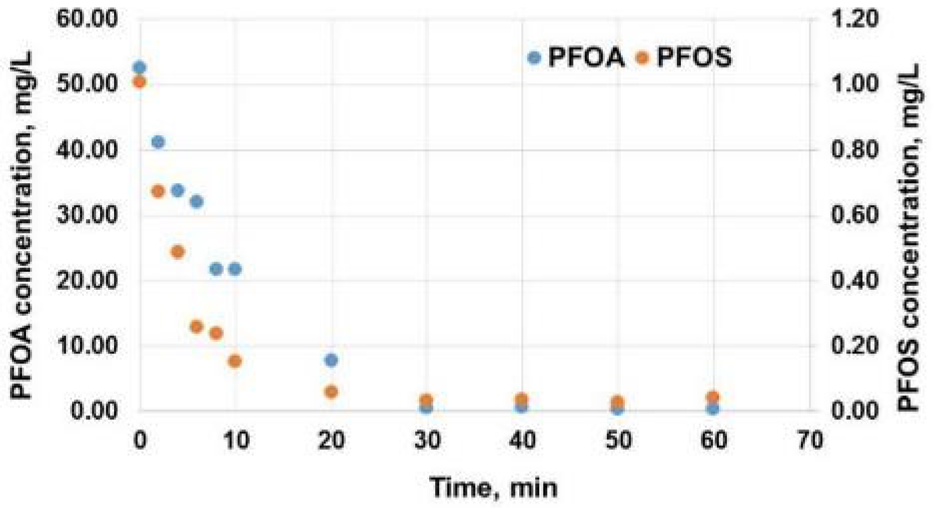
https://www.serdp-estcp.org/Program-Areas/Environmental-Restoration/ER18-1624

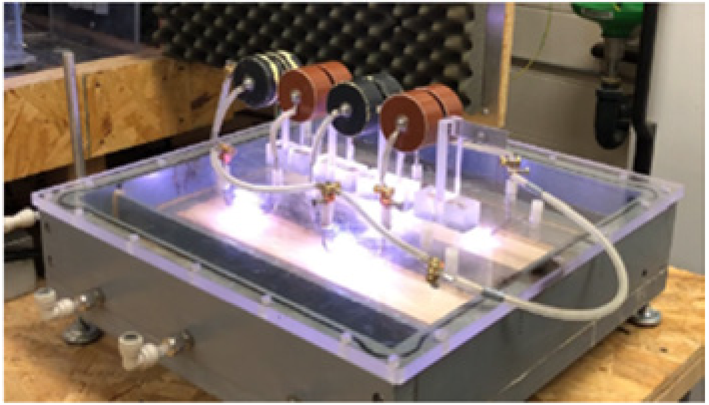



Pictures: Plasma Research Laboratory, Clarkson University

On-Site destruction of high C PFAS

Potential no-waste solution

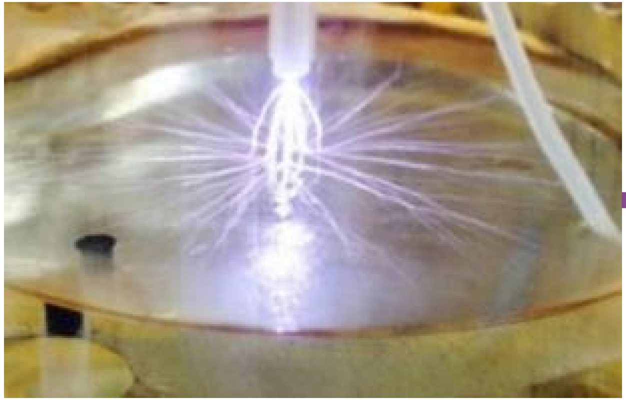




Treatment of high C still bottom waste

Plasma Formation

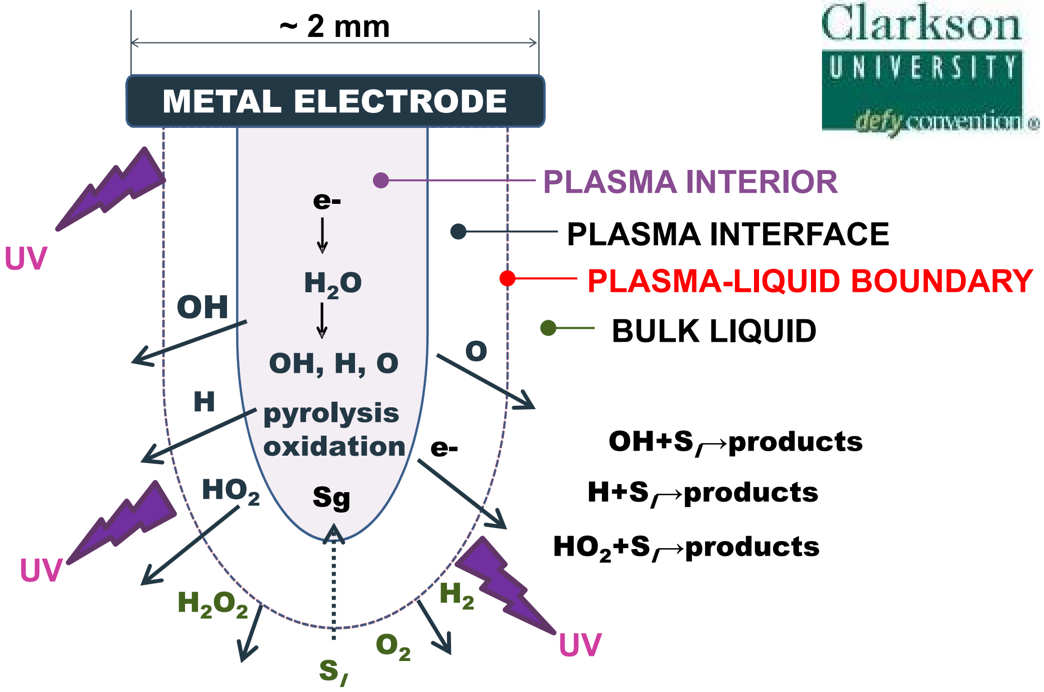
Clarkson UNIVERSITY defy convention



Plasma in argon gas contacting water

Courtesy of: Plasma Research Laboratory, Clarkson University

GSI ENVIRONMENTAL



S_l=liquid solute S_g=gas solute

Full-Scale IX Groundwater Remediation

Regenerable and Non-Regenerable IX Systems

Former Pease AFB Full-Scale Application of Regenerable IX

US Air Force – Base Realignment and Closure (BRAC) Program – Fire Training Area

Investigations, pilot testing, FS, design, construct, and operate two groundwater extraction and treatment systems

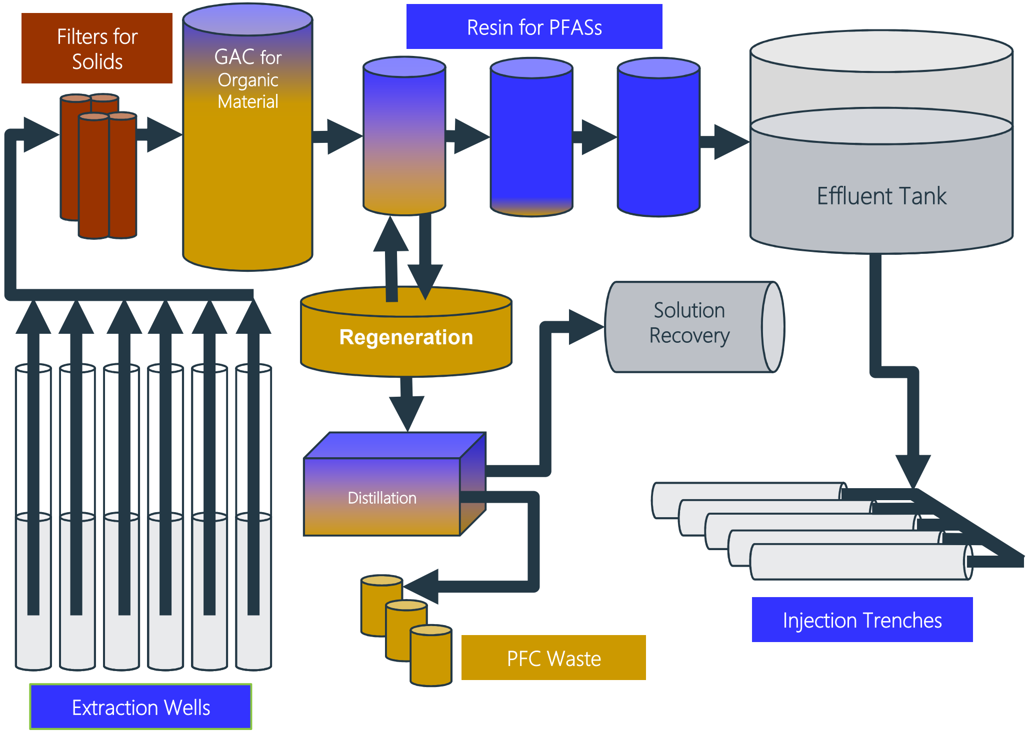
PFAS impacts to groundwater and drinking water

Design incorporates innovative Regenerable Ion Exchange Resins

Smaller bed volume, less frequent and onsite regeneration

Former Pease AFB Regenerable IX Treatment Train

- Design Flow: 200 gallons per minute
- Number of extraction wells: 10
- Treatment process: Particle filters, granular activated carbon, sorbent media, in-place regeneration of media
- Construction completed April 2018
- On-going optimization



Pease Regenerable IX System

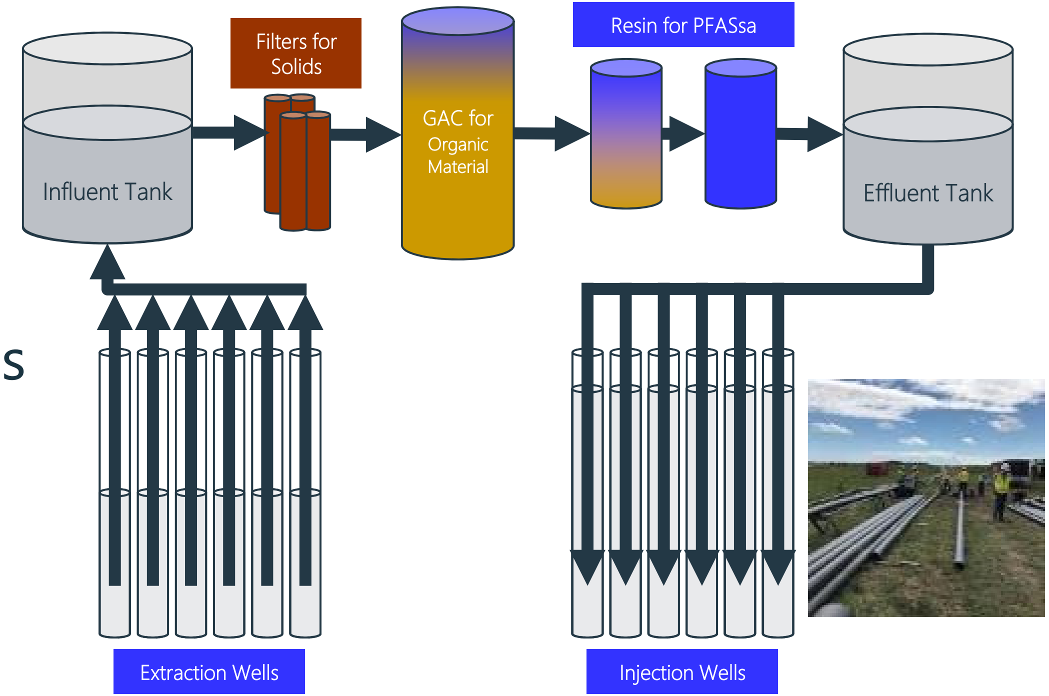
IX Resin System

In-vessel IX Resin
Regeneration System

Distillation Regeneration
Recovery System

Former Pease AFB Non-Regenerable IX System

- Design Flow: 700 gpm
- 6 extraction wells
- 18 injection wells
- Treatment process:
  - Particle filters for solids
  - GAC for organics removal
  - DOWEX™ PSR2 for PFAS removal



SERDP ER18-1306 & ESTCP ER18-5015

Pre-treatment-Separation-Regeneration-Recovery-Destruction

Two companion projects in SERDP/ESTCP program

Strategic Environmental Research and Development Program (SERDP) U.S. DoD Basic and Applied Research Program

"Removal and Destruction of PFAS and Co-Contaminants from Groundwater" ER18-5015

"Combined In Situ / Ex Situ Treatment Train for Remediation of PFAS Contaminated Groundwater" ER18-1306

Environmental Security Technology Certification Program (ESTCP)
U.S. DoD Technology Demonstration and Validation

Research Team:

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NAVFAC

SERDP ER18-1306 Technical Objective

- Evaluate feasibility and effectiveness of range of treatment train approaches
- Estimate and compare scaled-up cost and design challenges for implementation

Pre-treatment *in situ*

1. Determine if in situ pre-treatment can eliminate precursors
2. Quantify precursor transformation
3. Quantify change in mass flux of PFAAs following pre-treatment
4. Compare heat-activated persulfate, slow release oxygen, and oxygen sparging

Ion exchange (IX) *ex situ*

5. Compare regeneration procedures
6. ComScreen IX regenerant solutions
7. pare effectiveness regenerant solution recovery for reuse

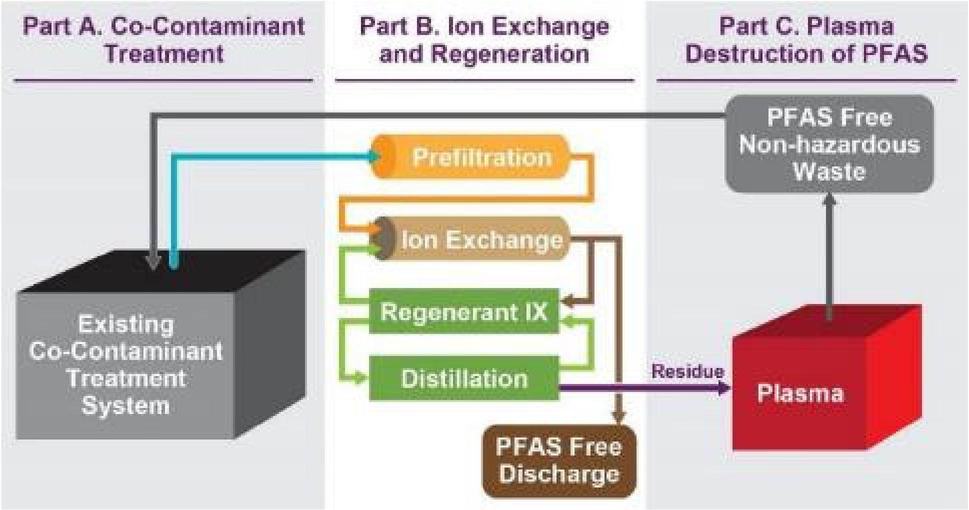
Plasma treatment *ex situ*

8. Quantify destruction of PFASs at varied concentrations and with co-contaminants
9. Compare treatment of groundwater, pre-treated groundwater, and concentrated IX regenerant residue
10. Determine the influence of GW conditions on treatment

11. Determine viable combinations of in situ and ex situ treatment trains and their potential limitations / challenges
12. Compare anticipated effectiveness, treatment time, energy requirement, amendment requirement, cost

ESTCP ER18-5015 Technical Objectives

- Demonstrate the PFAS Treatment Train
  - Field-scale demonstration of an optimized PFAS Treatment Train
  - Measure the effectiveness of each component
  - Verify waste minimization via IX resin reuse, PFAS concentration and destruction
  - Develop guidance for end users



Current Status of ESTCP ER18-5015

- Pease AFB selected as demonstration site:
- PFAS @ 100 ppb
- +/- 5 gpm flow rate available
- Available space for treatment
- Iron removal pre-treatment required
- Proof of concept – Bench testing of IX and Plasma

Path forward

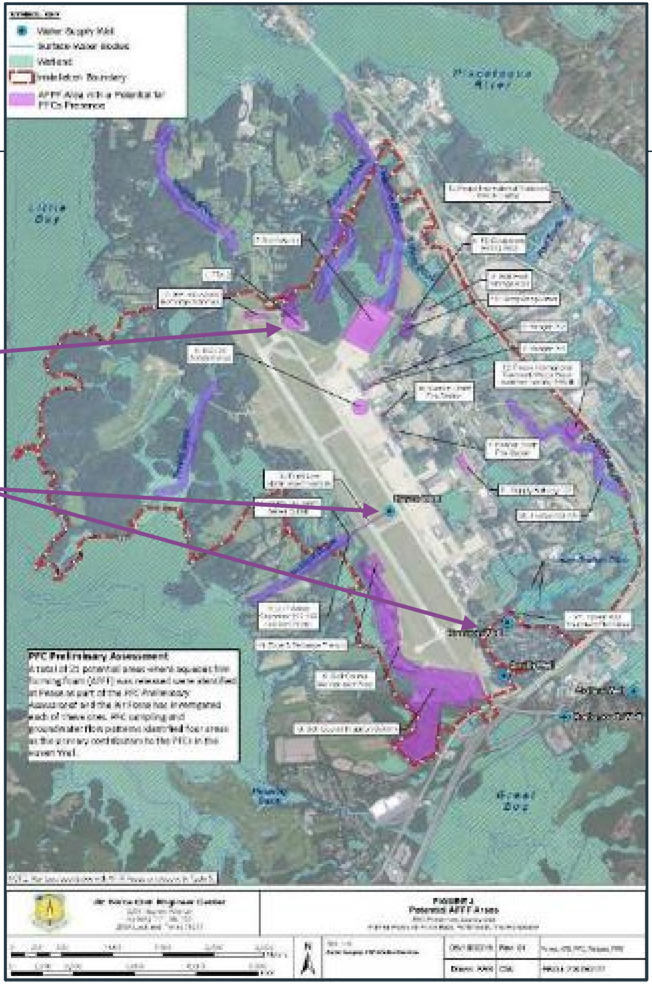
- Bench test – proof of concept
- Demonstration Plan – 2019
- Pilot scale system design, build, operate – 2020
- Technology Transfer – 2020-2021

Proof of Concept

Pease Air Force Base

FTA

Supply Wells



EW-6035
100 μg/L PFAS

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Steve Woodard, ECT_2
John Kornic, NAVFAC

Backup

Initial Media Selection Decision Framework

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Application/scenario	Drinking water	POET	Pump & Treat	Industrial Waste	AFFF Decon	Leachate
Short Chain (>50%)	Non-regenerable IX	Non-regenerable IX	Non-regenerable IX	Non-regenerable IX	Non-regenerable IX	Non-regenerable IX
Long Chain (>50%)	Non-regenerable IX	Non-regenerable IX	Non-regenerable IX	Non-regenerable IX	Non-regenerable IX	Non-regenerable IX
Influent (order of magnitude)						
infleunt ppm	GAC	GAC	GAC	GAC	GAC	GAC
influent ppb	Non-regenerable IX	Non-regenerable IX	Non-regenerable IX	Non-regenerable IX	Non-regenerable IX	Non-regenerable IX
influent ppt	Best Practice	Best Practice	Best Practice	Best Practice	Best Practice	Best Practice
Target Treatment Levels						
effluent ND	GAC	GAC	GAC	GAC	GAC	GAC
effluent < .07 ppb	Non-regenerable IX	Non-regenerable IX	Non-regenerable IX	Non-regenerable IX	Non-regenerable IX	Non-regenerable IX
effluent .07 - 1 ppb	GAC/Regenerable IX	GAC/Regenerable IX	GAC/Regenerable IX	GAC/Regenerable	GAC/Regenerable IX	GAC/Regenerable IX
effluent > 10 ppb	Regeneralbe IX	Regeneralbe IX	Regeneralbe IX	Regeneralbe IX	Regeneralbe IX	Regeneralbe IX

Optimal solutions depends on PFAS mix, co-contaminants, and treatment goals

Full-Scale Site 8 Resin System

In-vessel resin regeneration system

Distillation for recovery of regeneration solution