A Screening Tool for Selection of Treatment Systems for PFAS in Aqueous Solutions

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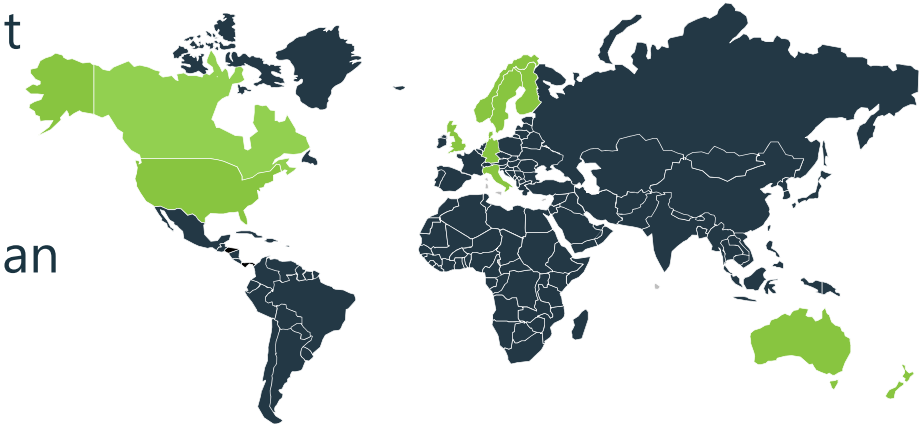
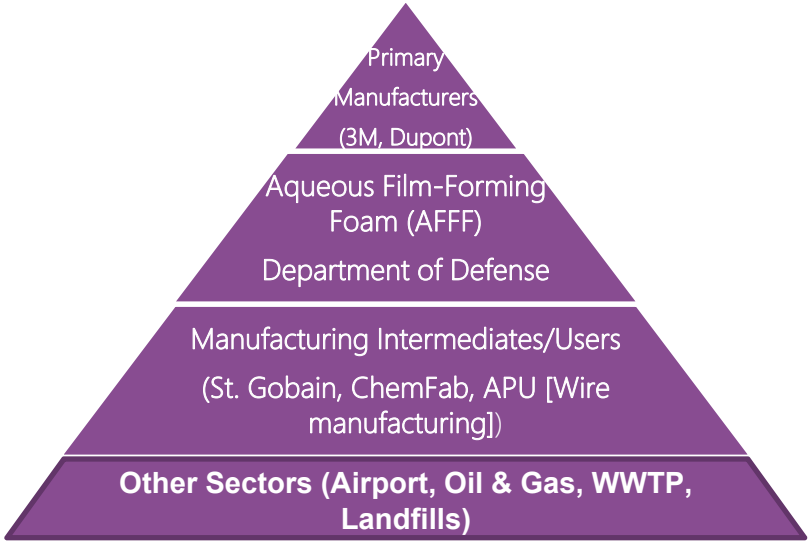
Introduction

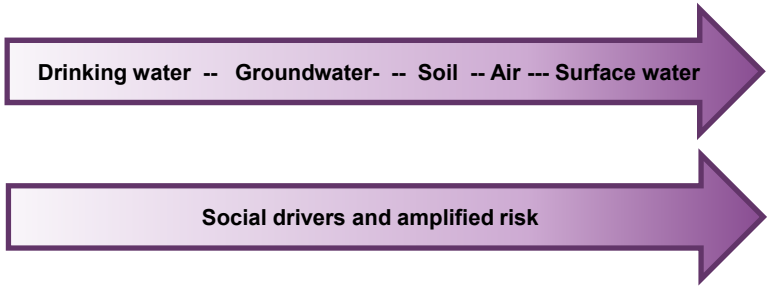
- Background/Drivers
- Remediation and Treatment Scenarios
- Landscape of Treatment Needs
- Screening Tool
- Summary/Conclusions
- Next Steps
- Questions

Background/Drivers

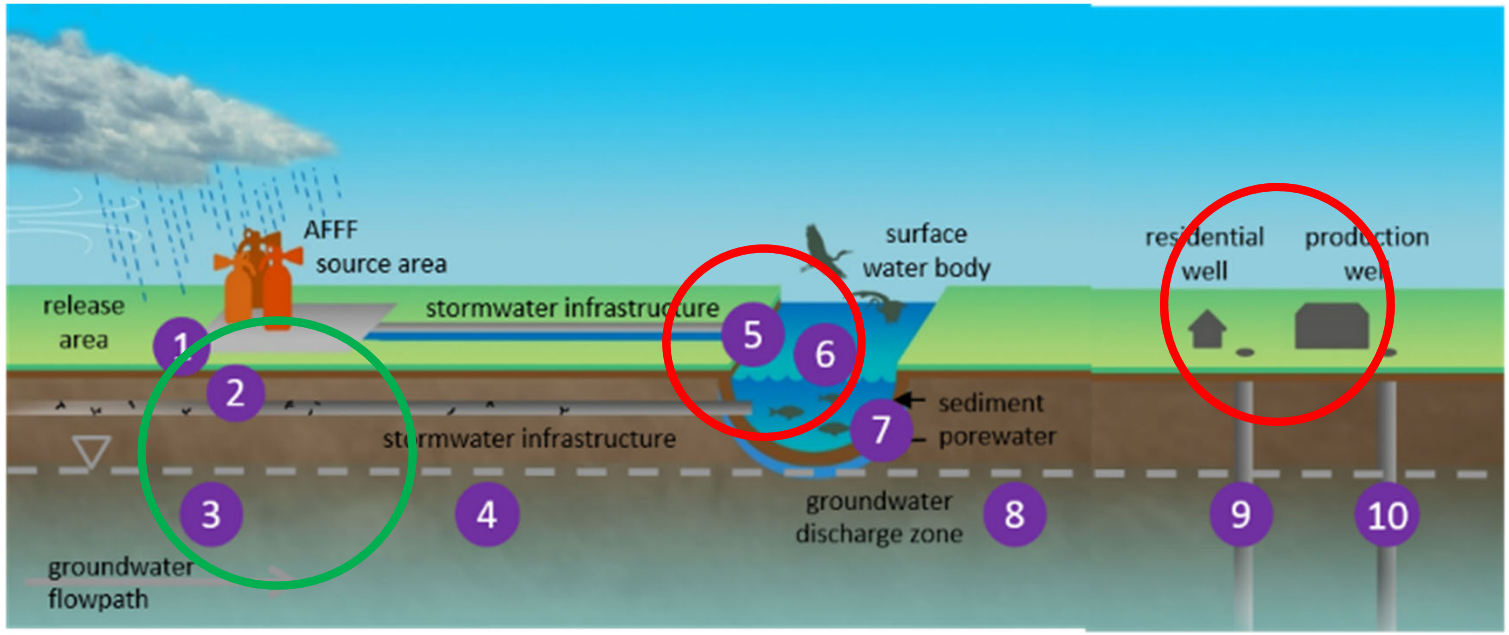
- Rapid and increasingly stringent regulatory thresholds and Statewide Directives
- US EPA National PFAS Action Plan
- Laboratory advancements
- AFFF Legislation
- Increased awareness of non-AFFF sources
- Increasing Litigation







Remediation and Treatment Scenarios



1. Surface soil
2. Subsurface soil
3. Source area GW
4. Downgradient GW containment
5. Stormwater infrastructure containment
6. Surface water
7. Sediment
8. Offsite GW impacted by surface water
9. Residential well GW treatment
10. Production well GW treatment

Focus Thus Far

Targeted Future Focus

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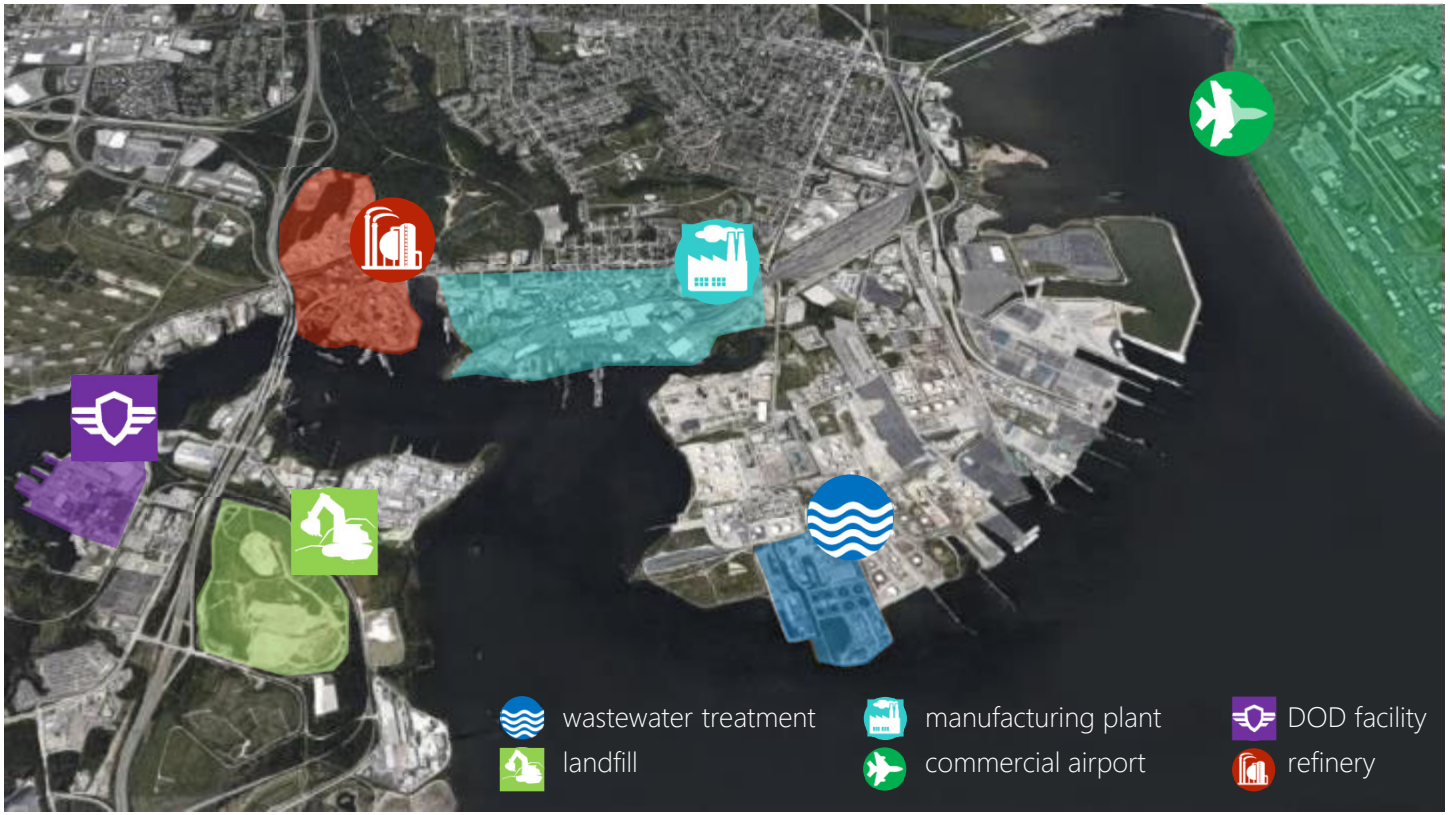
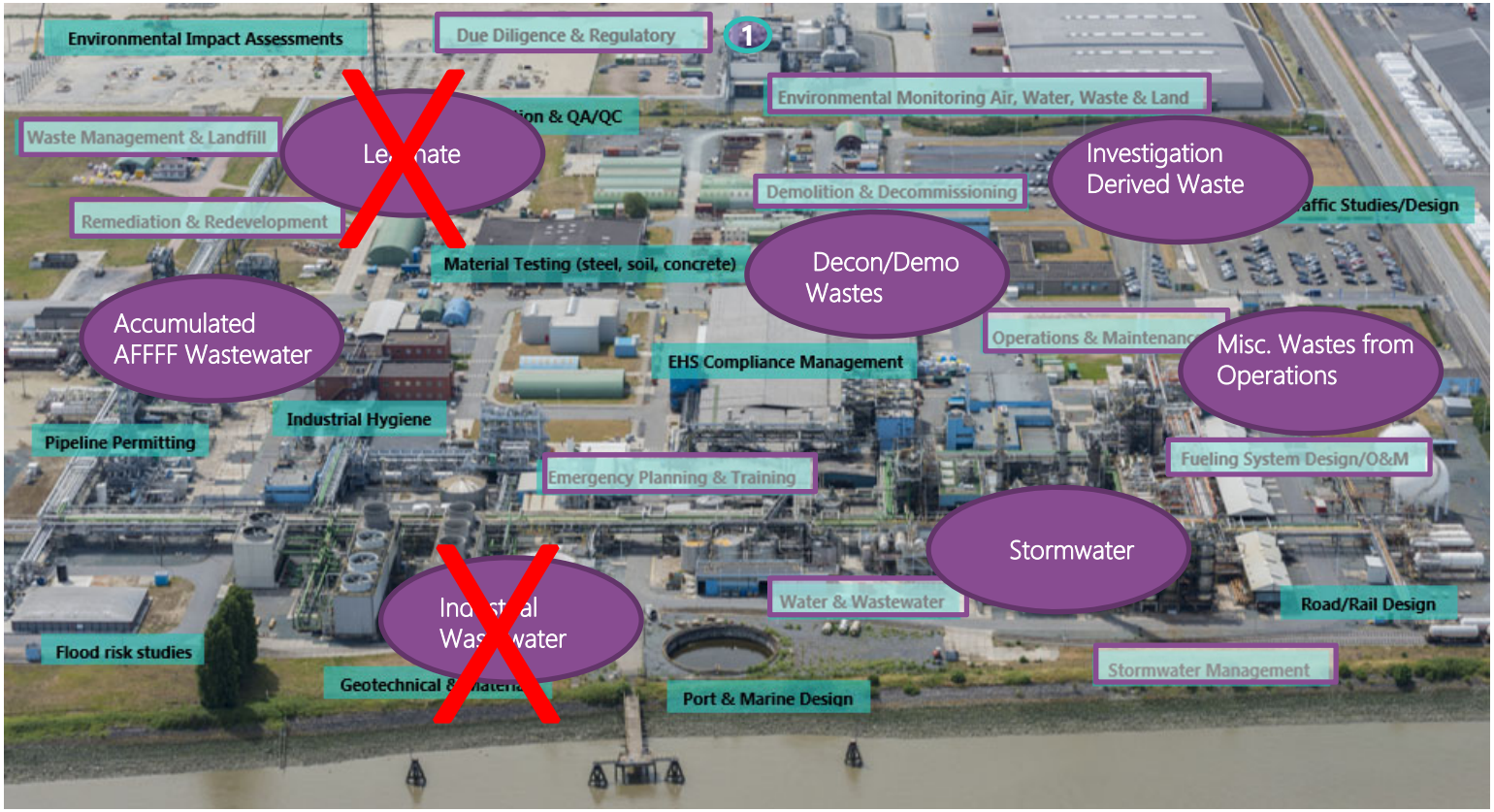
Remediation Scenarios - Fictitious Urban Area



PFAS Throughout a Facility – What about Non-Remediation Treatment Needs?



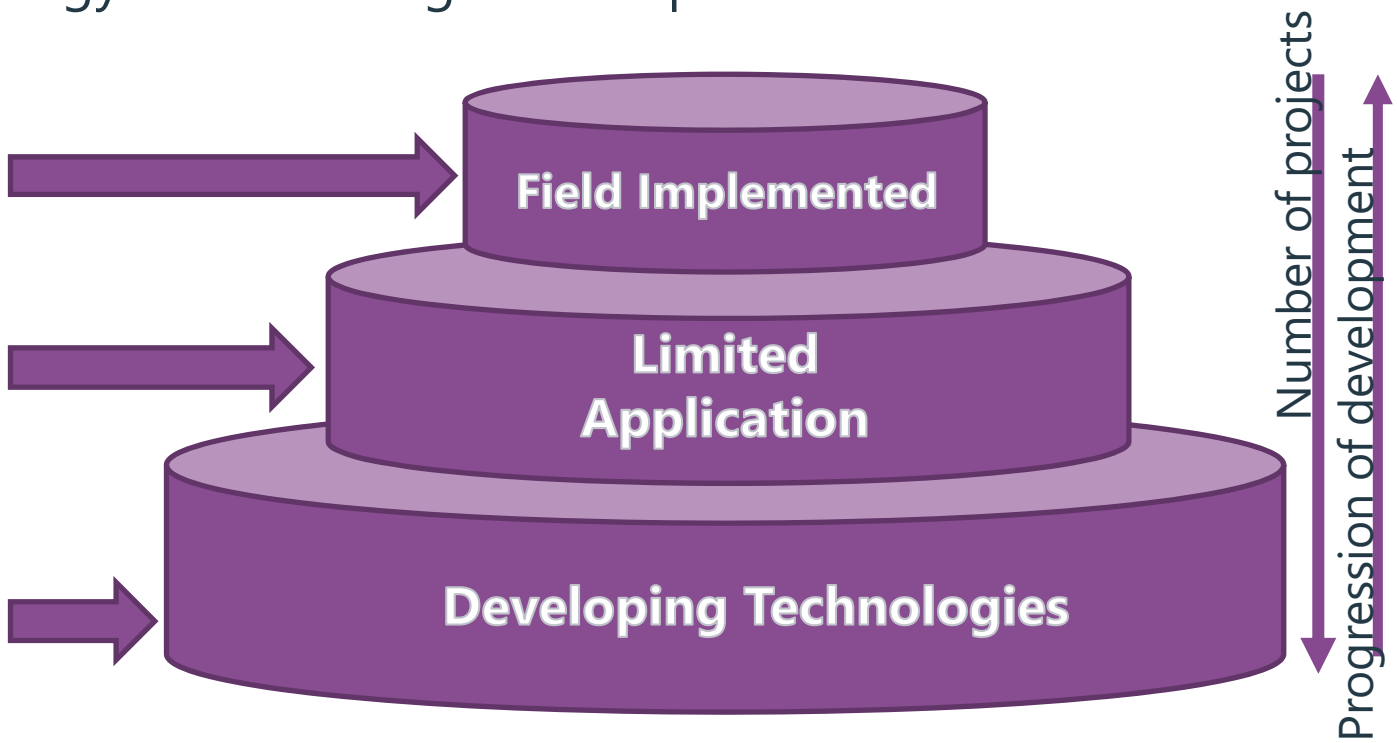
Technology Development Life Cycle

How does technology move through development?

Demonstrated Technologies

Partially Demonstrated Technologies

Promising Technologies



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Water Treatment Technologies Tested on PFAS

Most testing to date on low level PFAS concentrations in water.

	Ex-Situ	In-Situ
Separation	• GAC • Modified zeolite • Ion exchange resin • Reverse osmosis • Chemical or electro-coagulation • Nano membrane filtration	• PlumeStop • Phytoremediation
Destruction	• Incineration • Advanced oxidation • Electrochemical oxidation • Sonolysis • Enhanced Contact Plasma	• Chemical oxidation • Chemical reduction • Microbial degradation • Fungal degradation • Enzyme catalyzed oxidation

Most testing conducted without consideration of co-contaminants.

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Available Full Scale Water Remediation/Treatment Alternatives

- **Granular Activated Carbon Sorption**
  - Conventionally used for water treatment
  - Concerns with short chain PFAS removal
  - Readily available and relatively inexpensive media

  → High Temp Reactivation or Landfill

- **Ion Exchange (IX) Resin Sorption**
  - Effective removal of PFAS – longer bed life than GAC
  - Regenerable and non-regenerable options
  - Life cycle cost advantages

  → High Temp Incineration or Landfill (Resin or Regenerant

- **Reverse Osmosis (Membrane)**
  - Efficient for PFAS removal
  - Produces a concentrated PFAS laden liquid stream
  - Positive barrier

  → High Temp Incineration →IX Resin and Incineration

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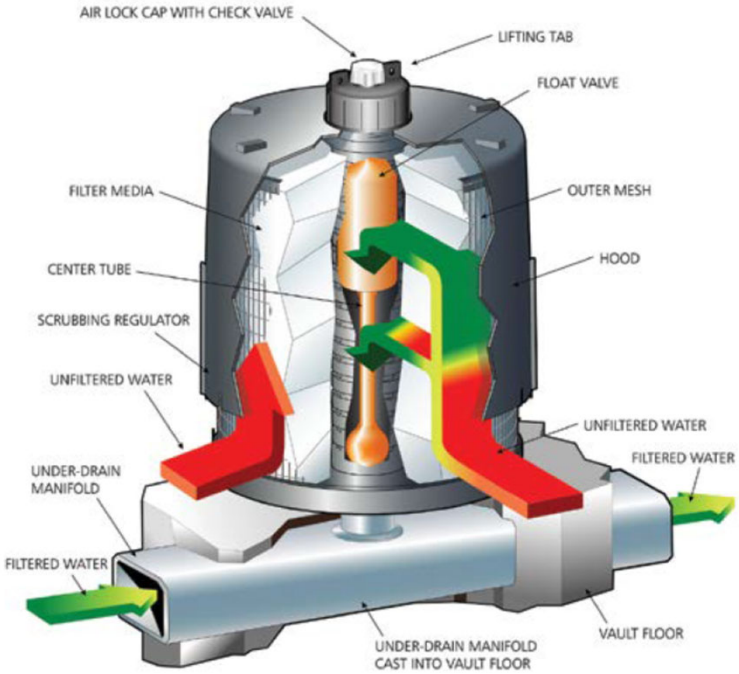
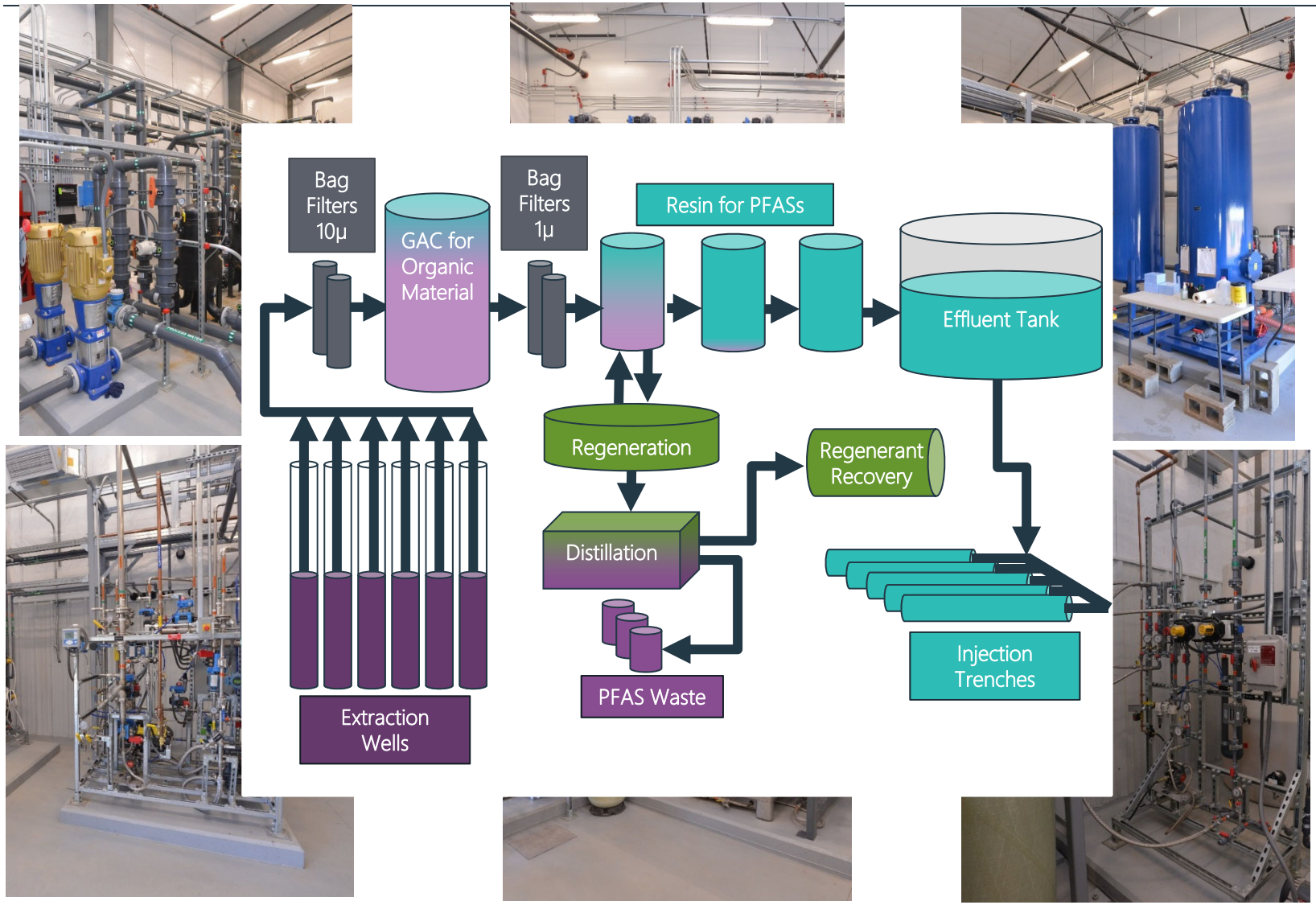
Simple POET GAC or Single Use Resin System – PFAS Only

Passive Stormwater Treatment – PFAS Only



Complex Regenerable IX System with Pre-Treatment



Temporary Treatment of High PFAS in Fire Training Rinsate

- Temporary Treatment of high concentration PFAS and Co-contaminants is especially challenging
- Pilot scale treatment of collected fire training water
  - Up to 6 ppm PFOA and >10 ppm Total PFAS
  - Free oil and grease
  - High concentration of PAHs/TOC
- Treatment flow ~10gpm with sewer discharge below HAL
- Treatment Train:
  - Sequential filtration
  - Organoclay Media – O&G Removal
  - GAC – PAH Removal
  - Non-Regenerable IX Resin – PFAS Removal
  - 99.99999% removal to achieve discharge criteria

Key Considerations for Treatment Alternatives

- RO offers advantage of Removing Other Contaminants but has disadvantage of high volume reject waste
- Evaluate Pre-treatment Needs First for Sorption Technologies
  - Metals/Iron Fouling
  - Petroleum Hydrocarbons and TOC
  - Glycols
  - Chlorinated VOCs
  - PFAS can't be removed without removing these interfering contaminants first
- Other Key Considerations for Sorption Technologies
  - Influent PFAS Concentrations (including Precursors and Short Chains?)
  - PFAS and Non-PFAS Discharge Criteria
  - Flow rate
  - Pressure loss across bed
  - Bed size/Empty Bed Contact Time Requirements
  - Desired or Required Waste Disposal or Destruction Method

Design Implications – Typical Scenarios

- Leachate Treatment
  - Requires significant pretreatment before PFAS can be addressed
  - Significant WW capital investment
- Contaminated Groundwater
  - Ranges from Downgradient Containment to Source Area Extraction
  - TOC and other contaminant impacts to operation of PFAS treatment systems
  - May require pre-treatment for major interfering parameters (VOCs, PAHs)
- Potable & non-potable Groundwater
  - Otherwise clean GW
  - PFAS treatment directly
  - Watch for ionic species interferences/scaling issues
- Stormwater
  - Generally low concentration of PFAS
  - Dramatic flow increases are challenge vs. co-contaminants
  - Can consider passive treatment systems
- Other emerging PFAS – Short Chains and Precursors
  - We are anticipating these treatment requirements and generally are selected technologies better suited to treat them
  - Consider modularity/expandability of systems to accommodate add on treatment trains

Screening Tool PFAS Considerations and Landscape

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

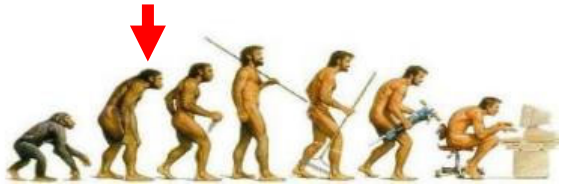
Screening Tool – Development, Purpose, and Use

- Based on experience evaluating treatment at dozens of sites
- Decision Matrix to ensure all key considerations have been evaluated
- Intended to Guide Treatment Alternatives for further evaluation vs. to select Final Treatment Technology
- Bench and/or Pilot Testing likely still required but may be avoided
- Simple applications involving low PFAS influent concentrations and no co-contaminants may not require bench/pilot testing
  - Drinking Water Treatment Low Level PFAS only
  - Pump and Treat Containment Systems Low Level PFAS only
  - Significant adsorption capacity advantage for Non-regenerable Single Use Resins
  - Non-regenerable Single Use Resins offer a number of additional advantages including lower footprint, smaller EBCT, and generally better performance on Short Chains and equal or better performance on Precursors

Conclusions

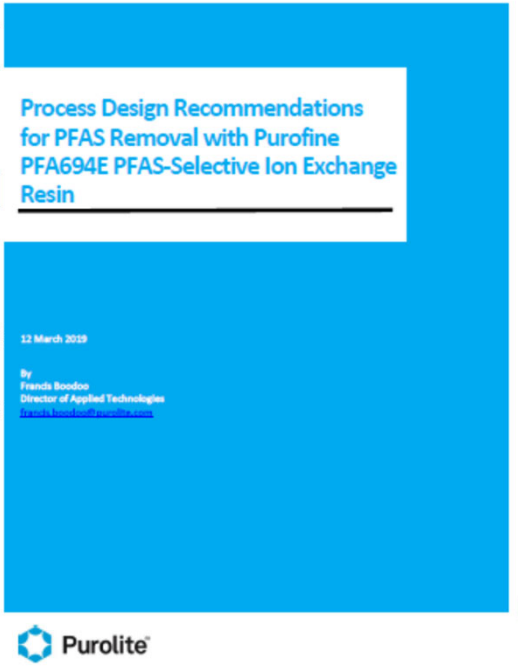
- We've only begun to tackle landscape of PFAS treatment
  - Ranges from simple PFAS removal only at PPT levels to Mixed industrial waste requiring significant treatment train for pre-treatment
- Short chain and Precursor regulations and lab advancements will place additional pressure on treatment systems or require additional technologies
- A Screening Tool can be a valuable guide and inform bench/pilot testing technology selection
- Desire to destroy waste onsite may drive future treatment technology selection
- ????
- ?????

PFAS Treatment Today



Next Steps

- The GAC – IX resin combination is very effective at treating waters impacted by PFAS
- The ability to regenerate on-site provides substantial protection against fluctuations in concentrations
- The IX resin regeneration, regenerant recovery, and superloading process is capable of substantially reducing the PFAS waste stream
- The technology provides resiliency against the sl
  marketplace
- Technology advances in on-site destruction will f
  waste minimization
  - ESTCP plasma destruction – Wood, ECT, Clark
  - Electrochemical Oxidation – ECT, University o



Questions

Thank you to Co-authors:

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- Francis Boodoo, PE - Purolite