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*For the best of reasons*

# Embracing the Complexities of PFAS Site Management

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2025 RemPlex Global Summit

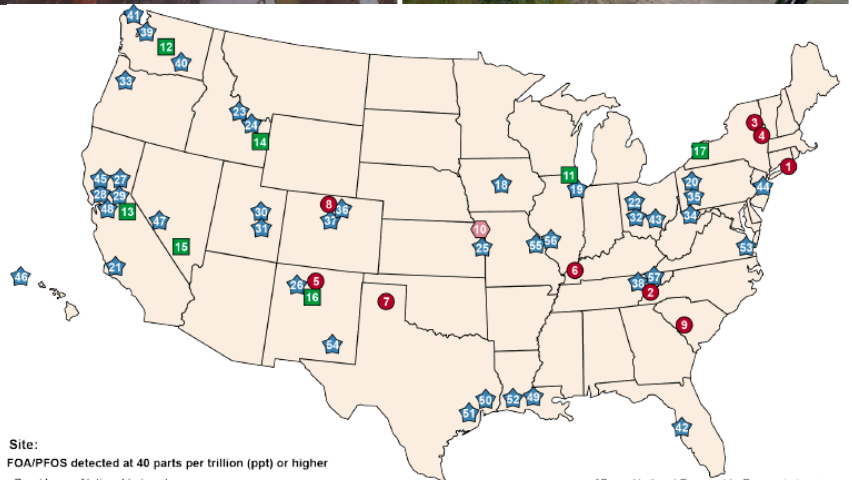
6 November 2025

# Talk Overview

- DOE Relevance and Drivers
- Challenges with PFAS Site Management
- PFAS Site Investigation
- PFAS Response Actions / Site Management

# PFAS at DOE Sites

- 57 sites surveyed but over 100 remain to be surveyed
- 3 sites exceeded PFAS MCLs in drinking water systems
- 10 sites exceeded PFAS MCLs in groundwater
- 2 sites have started cleanup actions (~$20M spend through 2024)
- Complete initial review of all sites by an established deadline




*Source: 2025 GAO report on DOE*

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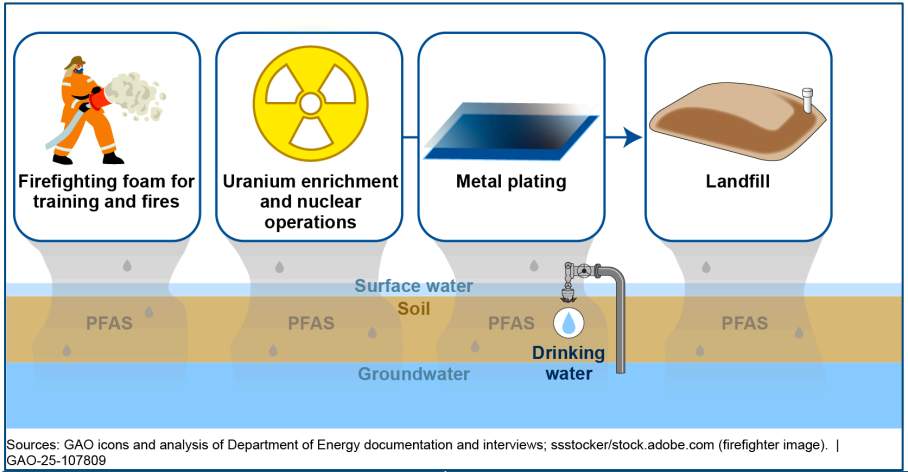
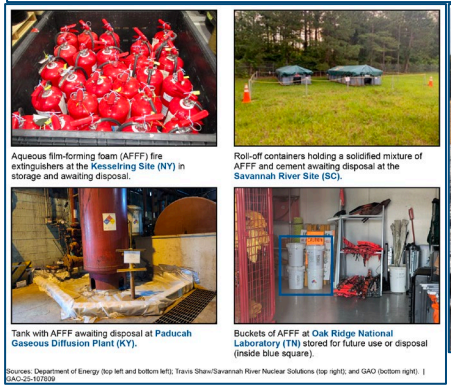
# PFAS Challenges at DOE Facilities

- Multiple PFAS release sources
- Disposal of PFAS-impacted materials
  - Stock AFFF
  - Solidified AFFF mixtures
  - Excavated PFAS-impacted soils
- Provision of alternate drinking water supply
  - Bottled water




Sources: GAO icons and analysis of Department of Energy documentation and interviews; ssstocker/stock.adobe.com (firefighter image). | GAO-25-107809



Aqueous film-forming foam (AFFF) fire extinguishers at the Kesselring Site (NY) in storage and awaiting disposal.

Roll-off containers holding a solidified mixture of AFFF and cement awaiting disposal at the Savannah River Site (SC).

Tank with AFFF awaiting disposal at Paducah Gaseous Diffusion Plant (KY).

Buckets of AFFF at Oak Ridge National Laboratory (TN) stored for future use or disposal (inside blue square).

Sources: Department of Energy (top left and bottom left); Travis Shaw/Savannah River Nuclear Solutions (top right); and GAO (bottom right). | GAO-25-107809

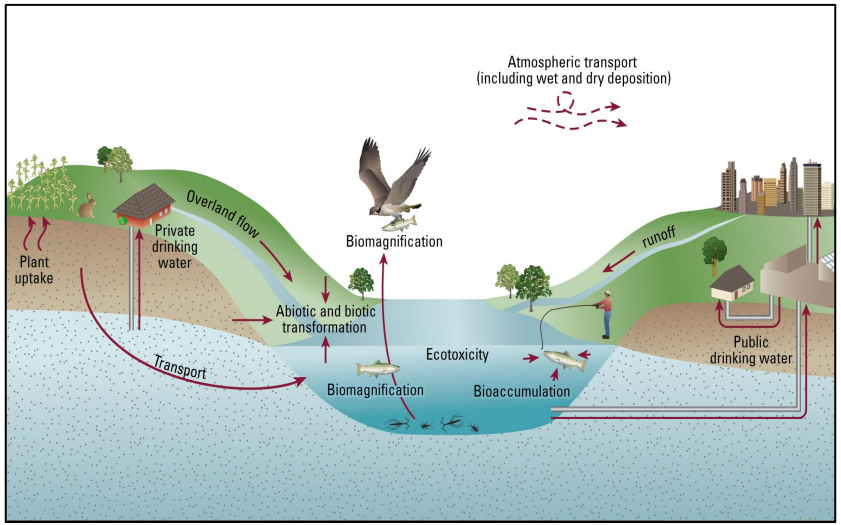
*Source: 2025 GAO report on DOE*

# PFAS Regulatory and Risk Drivers

- CERCLA
  - PFOA and PFOS as hazardous substances
- CWA / SDWA
  - Drinking water MCLs for five PFAS
  - Discharges regulated under NPDES / SPDES
  - Freshwater and saltwater aquatic life water quality criteria and benchmarks
- RCRA
  - 9 PFAS listed as hazardous constituents*

*to be finalized in April 2026

- PFAS bioaccumulation
  - known human health effects

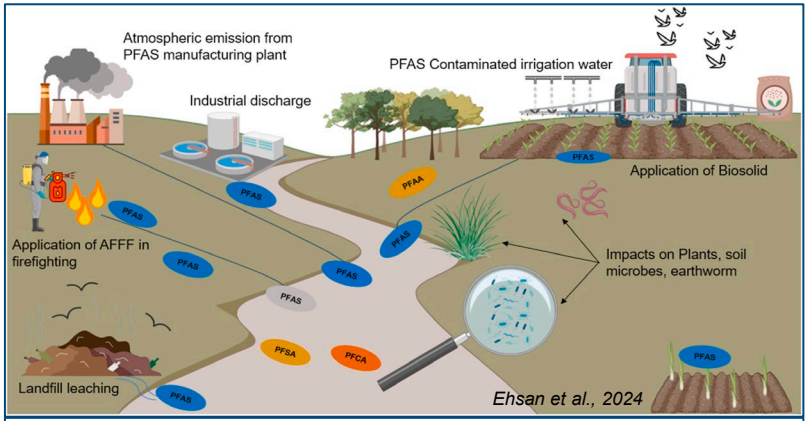




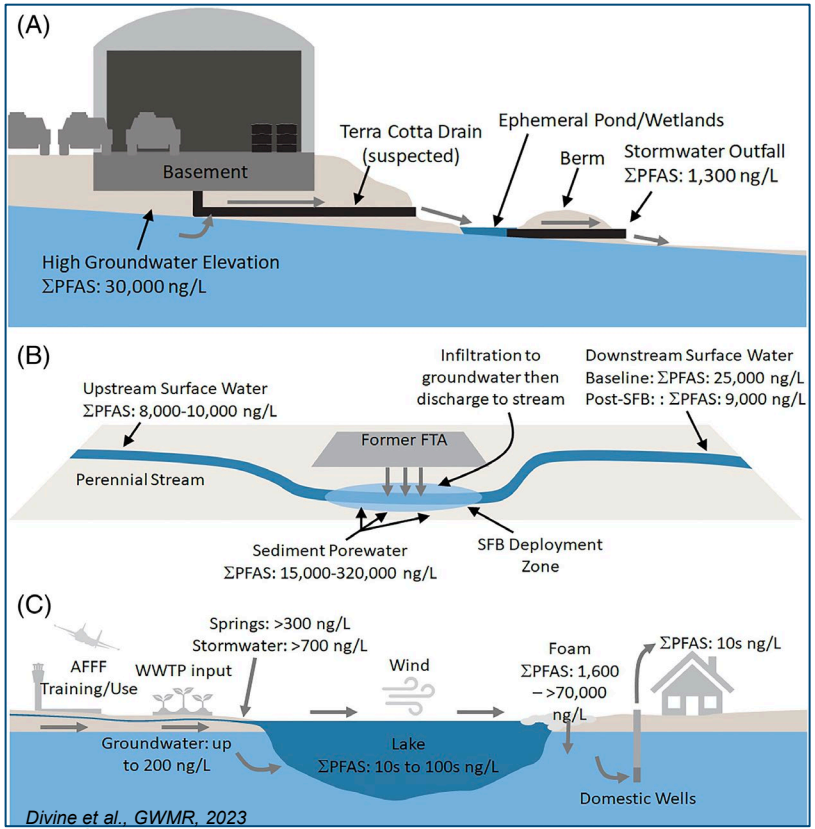
*USGS, https://www.usgs.gov/media/images/and-polyfluoroalkyl-substances-movement-through-environment*

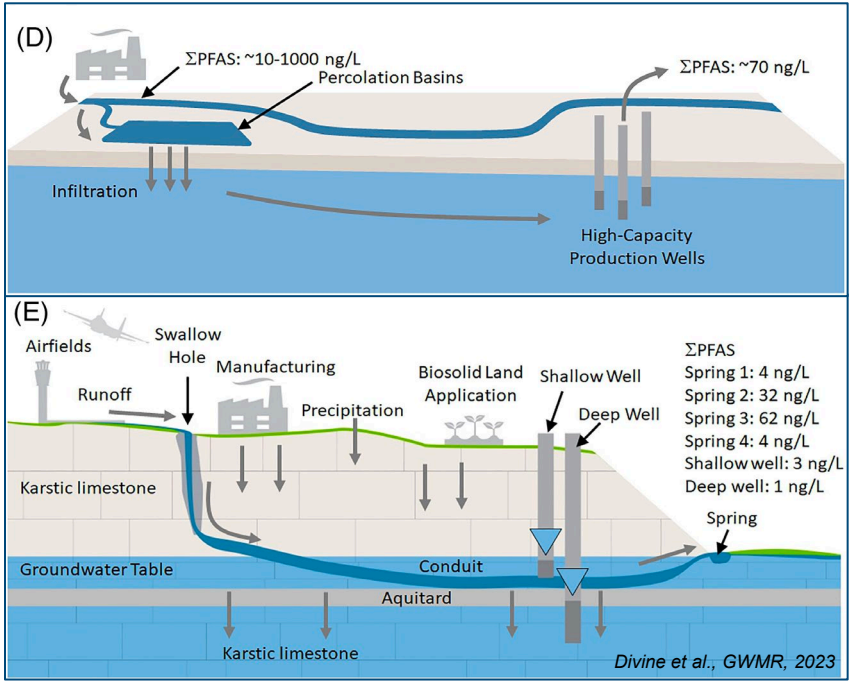
# Challenges in PFAS Site Management

- Several point and non-point sources and multiple release mechanisms
- Low regulatory levels and evolving regulations
- Complex site investigations
  - Muti-media interactions, transformation, and transport pathways
  - Delineation of nature and extent
  - Background evaluation and risk assessment
  - Comingled / radioactive impacted soil and water
- Comprehensive response action
  - Complex treatment / destruction technologies
  - Management of PFAS-impacted materials



# Complex PFAS Transport and Exposure Pathways

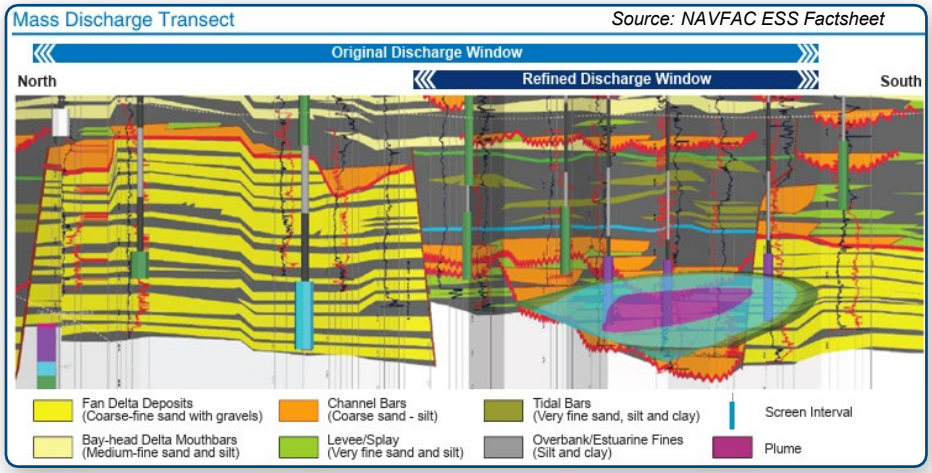



PFAS properties and hydrogeologic processes result in complex distribution and exposure pathways to receptors

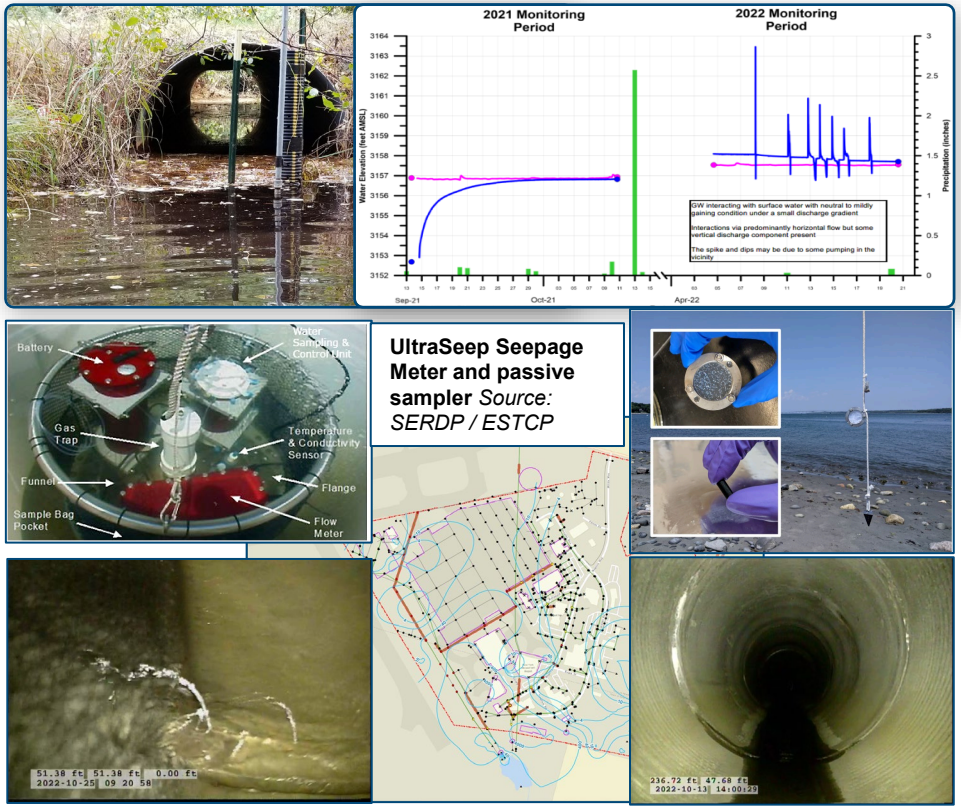
# High Resolution Site Characterization (HRSC)

- Environmental sequence stratigraphy (ESS)
  - Soil cores / boring logs
  - Geophysics
- Hydraulic investigation
  - Hydraulic profiling tool (HPT)
  - Vertical aquifer profiling (VAP)
  - FLUTe
- Molecular biological tools (MBTs)
- Advanced models



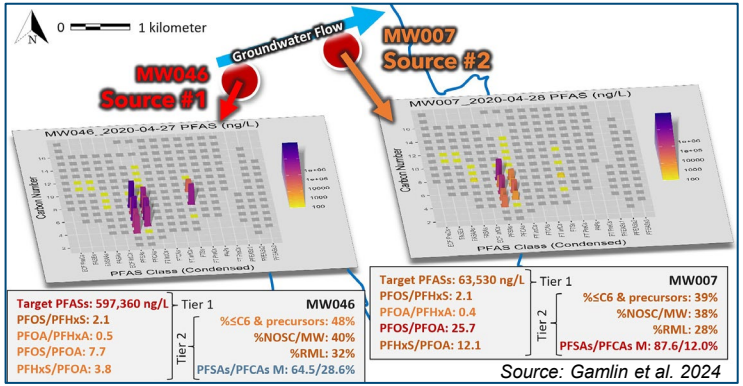
# PFAS-Specific Investigations

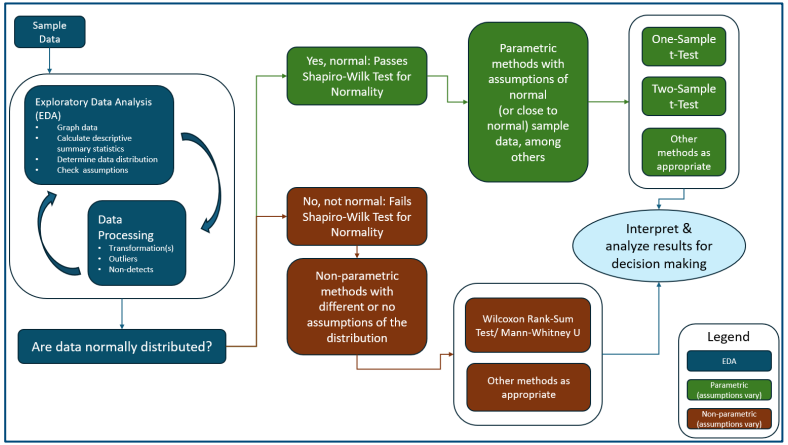
- Soil Leaching
  - Lysimeters and modeling
- GSI
  - Stilling wells and piezometers
  - Trace studies
  - Passive samplers, distributed temperature sensing (DTS), point velocity probe (PVP), seepage meter, trident probe
- Stormwater
  - GW infiltration and runoff assessment
  - In-line video camera survey
  - PFAS fractionation assessment



# Background / Source Investigations

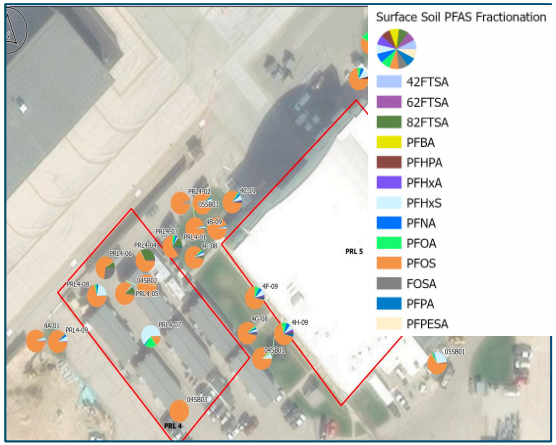
- Understanding sources
- Background investigation design
  - Review of site history, land use, and CSM
  - Considerations for sampling
    - Upgradient, upstream, upwind, sheet flow / overland flow, etc.
    - Sampling depths and intervals
    - Seasonality and data density
  - Data evaluation and statistical analysis
    - Sample size
    - Parametric vs non-parametric methods

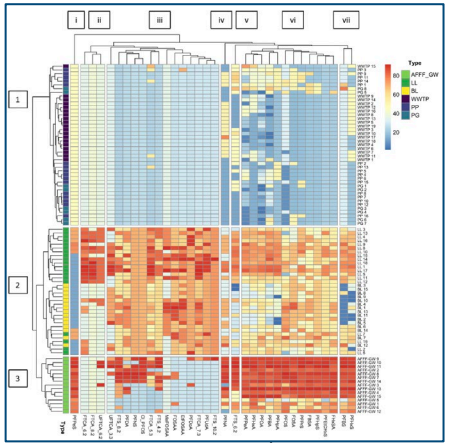


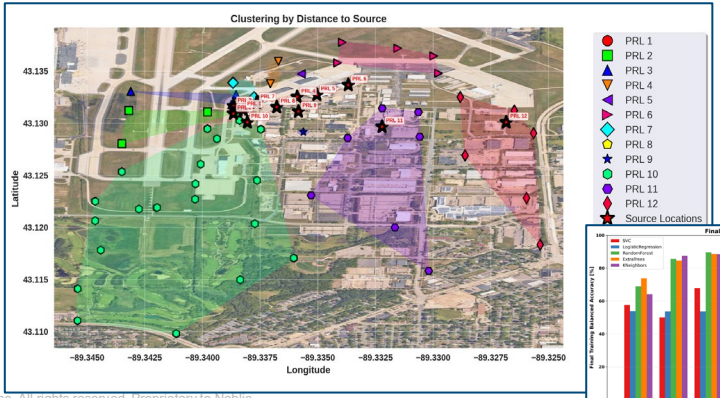



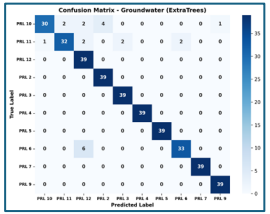
# PFAS Fingerprint Analysis (Forensics)

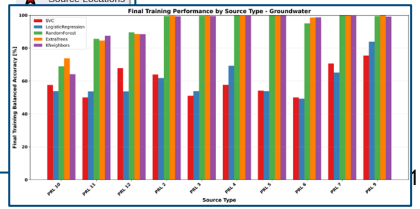
- Target PFAS fractionation
- Non-Target analysis
- Statistical data evaluation
  - Radio, spider, rose, stacked plots
  - Cluster analysis
  - Hierarchical analysis
- Artificial Intelligence – Machine Learning (AI-ML)
  - Supervised and unsupervised learning models
  - Neural networks
  - Deep learning models



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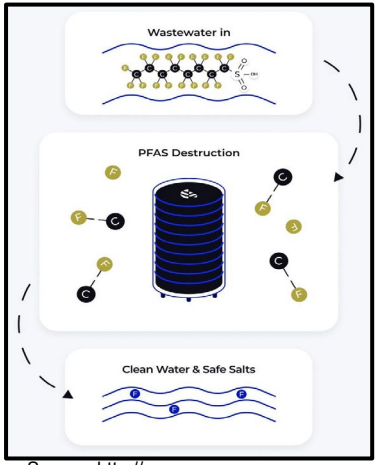
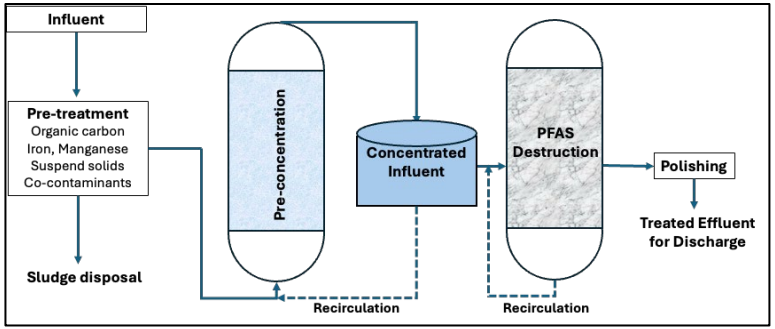
# PFAS Treatment Considerations

- Target PFAS constituents
- Influent PFAS concentrations, treatment volume, and flow rates
- Water quality characteristics that may require pre-treatment
- System footprint, deployment, and scalability
- Effluent polishing and discharge requirements
- Operation and maintenance needs

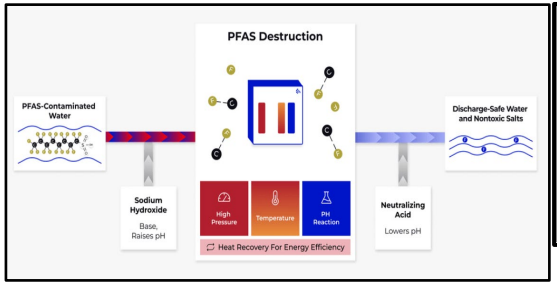



Source: http://www.aquagga.com



# PFAS Treatment Technologies

- Liquids
  - Adsorption and ion-exchange
  - Electrochemical Oxidation
  - Non-thermal Plasma
  - Sonolysis
  - Photocatalytic destruction
  - Hydro alkaline thermal treatment (HALT)
  - Super critical water oxidation (SCWO)
  - Foam Fractionation
- Solids
  - Solidification / Stabilization
  - Thermal desorption
  - Smoldering combustion
  - Incineration

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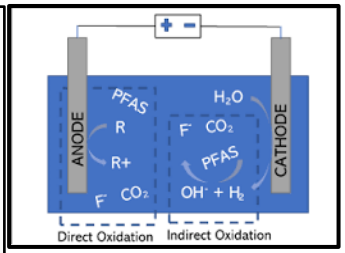


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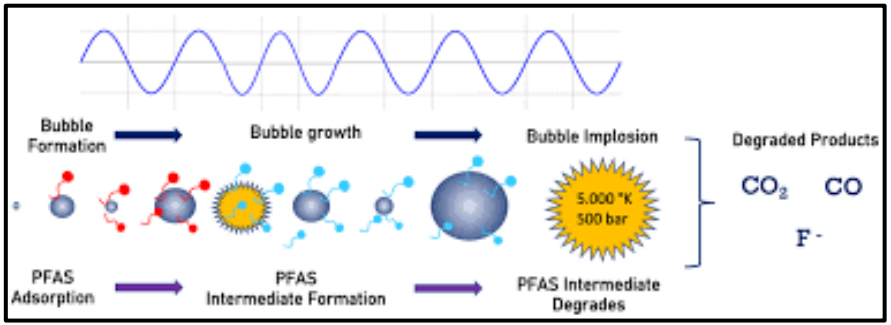


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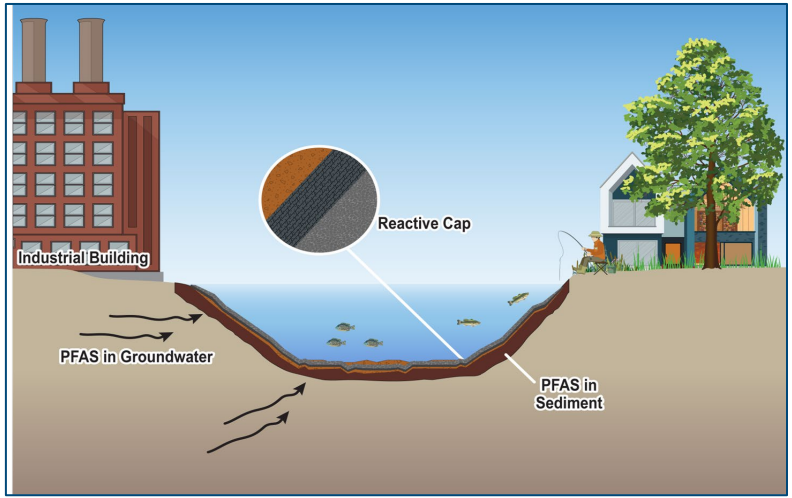
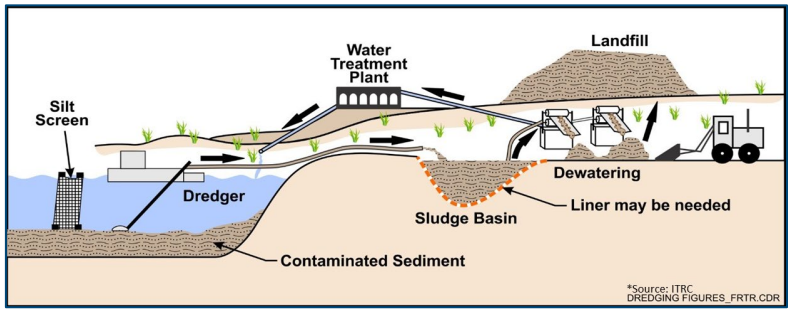
# PFAS Destruction Technologies

| Key Factors | EOx | Plasma (Nonthermal) | HALT | Sonolysis | SCWO |
|---|---|---|---|---|---|
| Long-chain (≥C6) PFAS Removal | X | X | X | X | X |
| Short-chain (<C6) PFAS Removal | X | | X | | X |
| Effective for concentrated streams | X | | X | X | X |
| Hazardous by-product formation | | X | | X | X |
| Pretreatment may be needed | | | X | | |
| Post-treatment may be needed | | X | X | | X |
| Treats other media (e.g., solids, sludge) | | | X | X | X |
| Lab (L), Pilot (P), or Full (F) Scale | F | F | P | P | F |

# Aquatic Environment Management

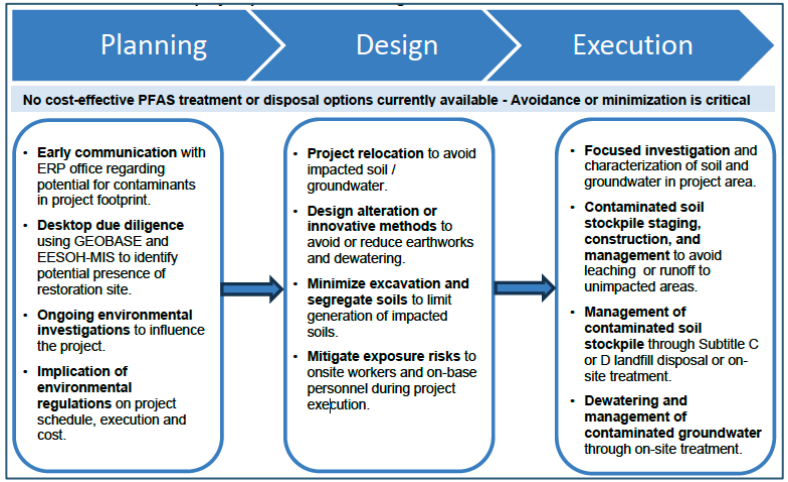
- In-situ Capping / Mixing
  - GAC alone insufficient for PFAS removal
  - Tailored adsorbents or IER required for removal of short chain PFAS
  - Media combinations or multiple chemical isolation layers with different thickness may be required
  - Interference from organic carbon and/or co-contaminants may reduce removal efficiency
- Dredging
  - Dewatered sediment disposal
  - Effluent treatment and discharge

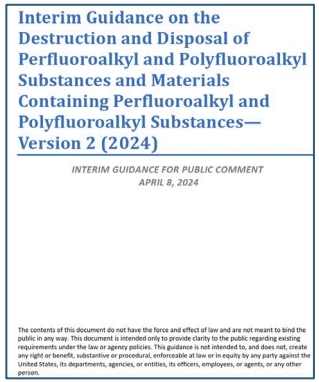


# Best Management Practices

- Construction and facilities upgrade projects
  - Excavated soils
  - Dewatering and treatment
  - Construction and demolition debris
- WWTP effluent
  - Treatment and discharge
  - Land application
- Biosolids
  - Disposal
  - Land application





Interim Guidance on the Destruction and Disposal of Perfluoroalkyl and Polyfluoroalkyl Substances and Materials Containing Perfluoroalkyl and Polyfluoroalkyl Substances—Version 2 (2024)

INTERIM GUIDANCE FOR PUBLIC COMMENT
APRIL 8, 2024

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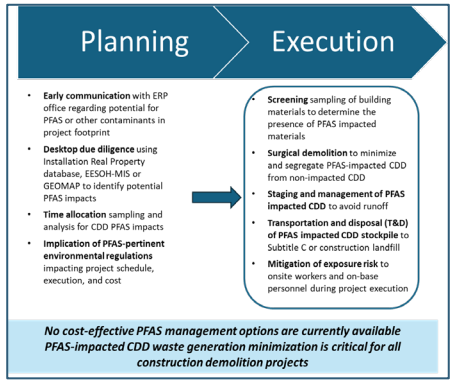
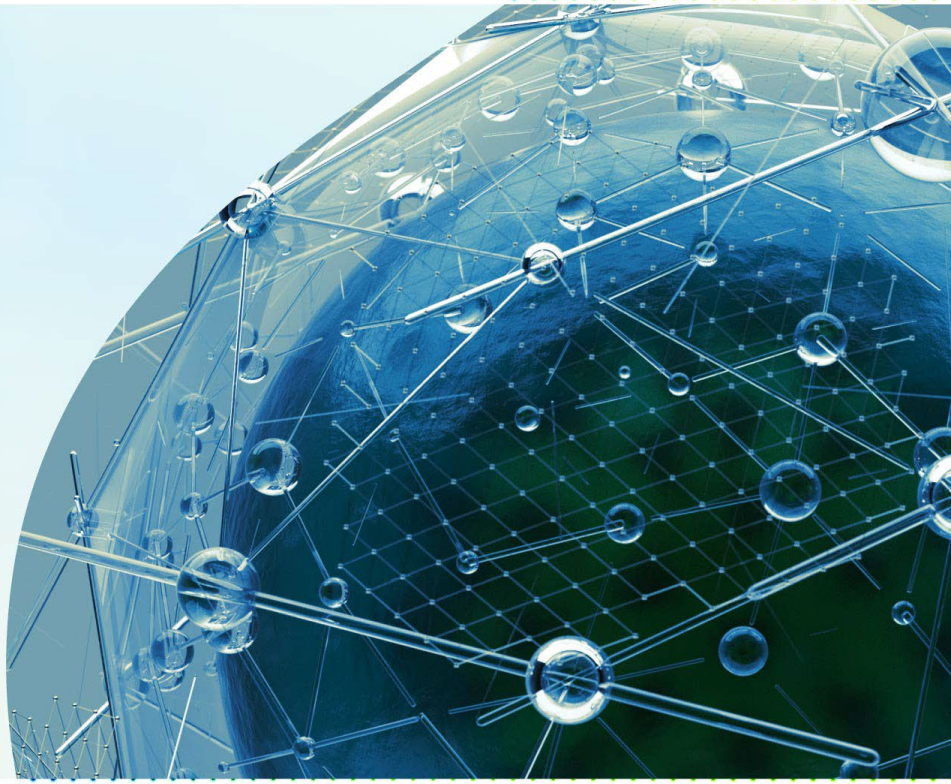


# Key Takeaway

***Embrace the complexities of PFAS site management as opportunities for innovation and growth.***



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