NEBC Plenary Session –

PFAS Management, Source Evaluations, and Remediation

HALEY ALDRICH

Panelists

- Tiffany Thomas, PhD – Background and forensics
- John Xiong, PhD, PE – Remediation
- Priscilla Tomlinson – Regulatory perspectives
- Megan King – Challenges of managing/remediating PFAS at airports
- Jessica Ferrell – Legal perspectives

Privileged and Confidential

Forensic analysis of sources of PFAS

October 2022

Tiffany Thomas, Ph.D.
Principal Chemist

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Brief introduction to PFAS

Class of >9,000 unique manufactured compounds

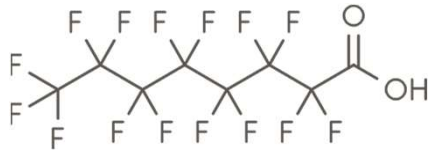
MONOMERS

***Per*fluorinated**

- fully fluorinated "tail"

PFOA

PFOS



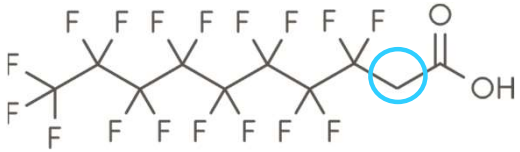
Perfluorooctanoic acid

***Poly*fluorinated**

- one or more non-fluorinated carbons

Fluorotelomers

Polyfluoroalkyl ether acids



8:2 Fluorotelomer carboxylic acid

POLYMERS

- Fluoropolymers (e.g. PTFE)
- Perfluoropolyether
- Side-chain fluorinated polymers (e.g. fluorinated acrylate and methacrylate polymer)

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Importance of multiple lines of evidence

1.	**Conceptual site model**	Establishes physical connectivity, definition of study area
2.	**Historical records review** (regional assessment)	Identification of possible contributing source(s)
3.	**Forensic chemistry of PFAS**	Chemical data to create a 4-dimensional understanding of physical fate and transport of PFAS: 1. Chemical "marker" compounds – indication of commingled releases, industrial fingerprints 2. Isomeric analyses 3. Signatures of PFAS

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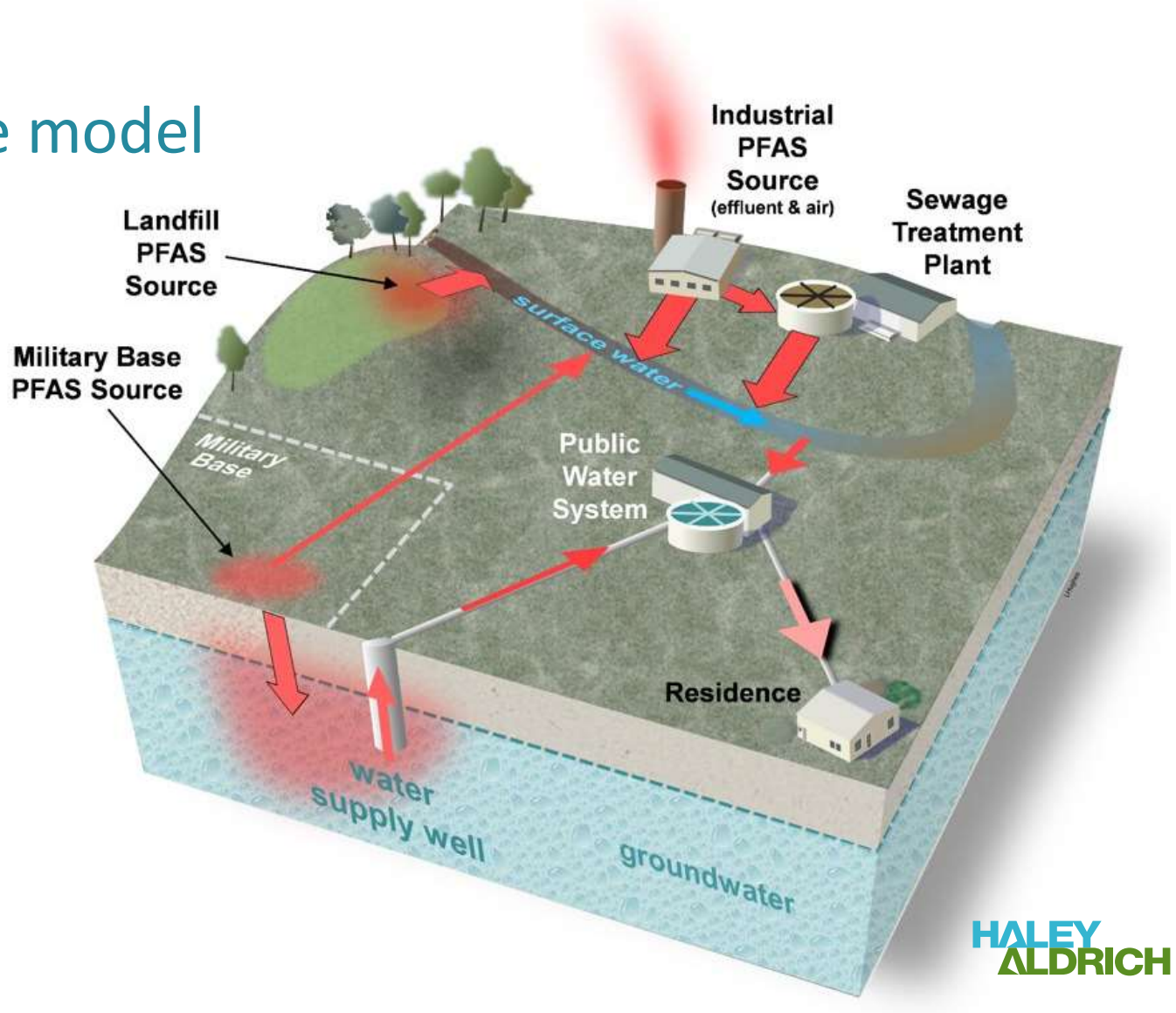
1. Conceptual site model



2. Historical records review – Partial screening list of users/emitters of PFAS

Known AFFF users	Known or suspected users/ emitters of PFAS		
Fire training facilities	Landfills	Carpet treatment	Flexible circuit board manufacturers
Airports	Wastewater treatment	Molded plastics	Paints
Military installations	Chrome platers	Dry cleaners	Lithography
Tank farms	Incineration facilities	Car washes	Biosolids (farms)
	Semiconductors	Pesticides/herbicides	Auto parts manufacturing
	Paper facilities (recycling and manufacturing)	Electronics manufacturing	Battery manufacturing and recycling

AFFF: Aqueous Film-Forming Foam

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3. Forensic chemistry of PFAS – available tools

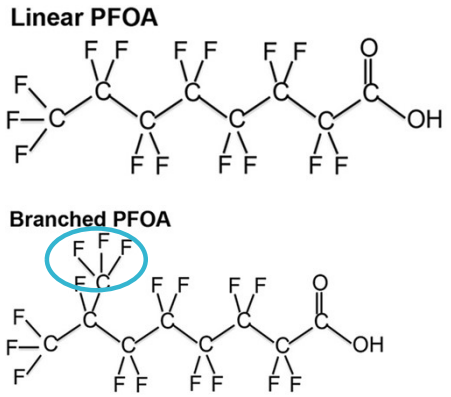
Landfills = 5:3 FTCA

Chrome platers = PFOS and/or 6:2 FTS

Fuel farms/refineries = BTEX, VOCs

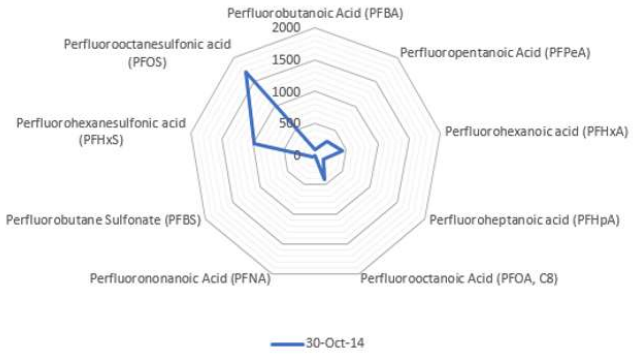
Chemical markers

- Process-specific indicators
- PFAS and traditional contaminants



Isomeric analyses

- Identifies manufacturing process, NOT specific product
- Influenced by environmental fractionation



Chemical signatures

- Visual comparison of composition of PFAS
- Readily identifiable source “shapes”

Remediation of PFAS

Challenges and Brief Overview of Promising Technologies

John Xiong, Ph.D., P.E.
October 6, 2022

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Unique challenges for remediation of PFAS

- Remediation objectives are stringent and are evolving
  - ppt levels, long- and short-chain PFAS
  - For example, WA Ecology's groundwater cleanup levels
- Complex chemistry and properties of PFAS
  - A mixture of thousands of compounds
  - Anionic, cationic, and zwitterionic
  - Surfactant property – sorption on air-water interface
  - Precursor transformation
- Strong carbon-fluorine bond is very difficult to break

ppt = parts per trillion

WA = Washington

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Existing and evolving remediation technologies for PFAS

Separation Technologies	Stabilization/Immobilization Technologies	Destruction Technologies
Activated carbon	Activated carbon	High-temperature incineration
Ion exchange resin	Colloidal activated carbon	Chemical oxidation
Membrane filtration	Biochar	Plasma
Flocculation and coagulation	Modified clay	Supercritical water oxidation
Foam fractionation and ozone fractionation	Modified activated carbon	Hydrothermal
Soil washing	Cyclodextrin-based sorbent	Hydrated electrons
Thermal desorption		Electrochemical oxidation
		Smoldering combustion
		Sonolysis

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Promising separation technologies

Inputs	Granular Activated Carbon	Ion Exchange Resin	Foam Fractionation
Long-chain removal	Effective	Effective	Effective
Short-chain removal	Not effective	Moderately effective	Moderately effective (with amendment)
Empty bed contact time	10 minutes	2.5-4 minutes	Semicontinuous treatment
Equipment	Pressure vessels	Pressure vessels and regeneration process units (regenerable resins only)	Series fractionation tanks
Primary foulants	Organics, oxidants	Organics, oxidants, high levels of inorganic anions	Oxidant, metal precipitates
Regenerable	Not regenerable	Select resins are regenerable	NA
Co-contaminant removal	VOCs and other organics	Not effective	VOCs

VOCs = volatile organic compounds

NA = not applicable

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Promising destruction technologies

- A number of destructive technologies are under development or being pilot-tested
  - Nonthermal plasma
  - Supercritical water oxidation
  - Electrochemical oxidation
  - Hydrated electrons by UV/sulfite
- Key considerations include defluorination efficiency, treatment capacity, energy costs, and H&S
- Treatment train combining separation technology and destructive technologies

UV = ultraviolet

H&S = health and safety

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DEPARTMENT OF ECOLOGY
State of Washington

Regulatory Perspectives on PFAS

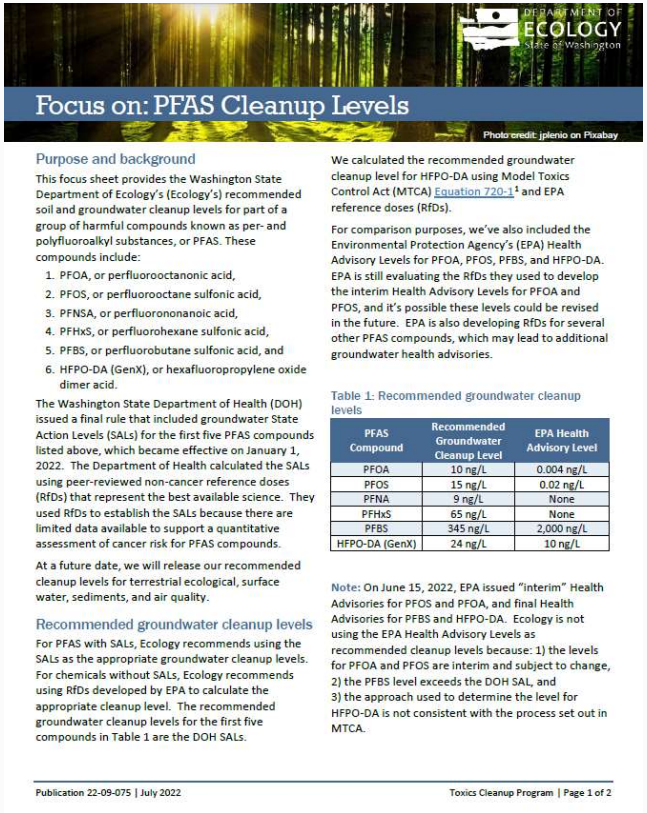
2022 Northwest Remediation Conference

Priscilla Tomlinson, Toxicologist

Ecology Northwest Regional Office, Shoreline

Ecology regulates PFAS under MTCA

- Entire PFAS class are hazardous substances under MTCA
- Cleanup levels based on Department of Health's state action levels and EPA's Integrated Risk Information System
  - Will include maximum contaminant levels when final
- Guidance coming for public review this fall



DEPARTMENT OF ECOLOGY State of Washington

Focus on: PFAS Cleanup Levels

Photo credit: jplenio on Pixabay

Purpose and background

This focus sheet provides the Washington State Department of Ecology's (Ecology's) recommended soil and groundwater cleanup levels for part of a group of harmful compounds known as per- and polyfluoroalkyl substances, or PFAS. These compounds include:

1. PFOA, or perfluorooctanoic acid,
2. PFOS, or perfluorooctane sulfonic acid,
3. PFNSA, or perfluorononanoic acid,
4. PFHxS, or perfluorohexane sulfonic acid,
5. PFBS, or perfluorobutane sulfonic acid, and
6. HFPO-DA (GenX), or hexafluoropropylene oxide dimer acid.

The Washington State Department of Health (DOH) issued a final rule that included groundwater State Action Levels (SALs) for the first five PFAS compounds listed above, which became effective on January 1, 2022. The Department of Health calculated the SALs using peer-reviewed non-cancer reference doses (RfDs) that represent the best available science. They used RfDs to establish the SALs because there are limited data available to support a quantitative assessment of cancer risk for PFAS compounds.

At a future date, we will release our recommended cleanup levels for terrestrial ecological, surface water, sediments, and air quality.

Recommended groundwater cleanup levels

For PFAS with SALs, Ecology recommends using the SALs as the appropriate groundwater cleanup levels. For chemicals without SALs, Ecology recommends using RfDs developed by EPA to calculate the appropriate cleanup level. The recommended groundwater cleanup levels for the first five compounds in Table 1 are the DOH SALs.

We calculated the recommended groundwater cleanup level for HFPO-DA using Model Toxics Control Act (MTCA) Equation 720-1[1] and EPA reference doses (RfDs).

For comparison purposes, we've also included the Environmental Protection Agency's (EPA) Health Advisory Levels for PFOA, PFOS, PFBS, and HFPO-DA. EPA is still evaluating the RfDs they used to develop the interim Health Advisory Levels for PFOA and PFOS, and it's possible these levels could be revised in the future. EPA is also developing RfDs for several other PFAS compounds, which may lead to additional groundwater health advisories.

Table 1: Recommended groundwater cleanup levels

PFAS Compound	Recommended Groundwater Cleanup Level	EPA Health Advisory Level
PFOA	10 ng/L	0.004 ng/L
PFOS	15 ng/L	0.02 ng/L
PFNA	9 ng/L	None
PFHxS	65 ng/L	None
PFBS	345 ng/L	2,000 ng/L
HFPO-DA (GenX)	24 ng/L	10 ng/L

Note: On June 15, 2022, EPA issued "interim" Health Advisories for PFOS and PFOA, and final Health Advisories for PFBS and HFPO-DA. Ecology is not using the EPA Health Advisory Levels as recommended cleanup levels because: 1) the levels for PFOA and PFOS are interim and subject to change, 2) the PFBS level exceeds the DOH SAL, and 3) the approach used to determine the level for HFPO-DA is not consistent with the process set out in MTCA.

Publication 22-09-075 | July 2022 Toxics Cleanup Program | Page 1 of 2

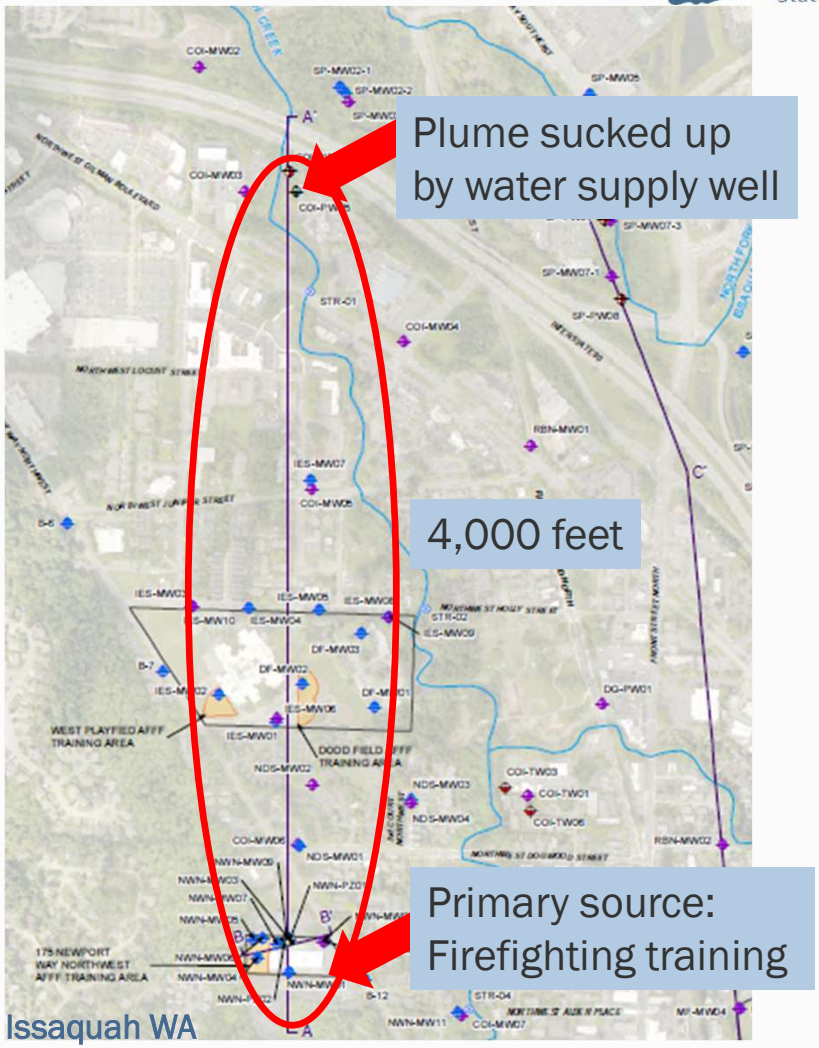
Challenges

Site investigations usually start with contaminated property and work out

Sometimes find PFAS in drinking water and need to work back to find source

Long plumes

Possibly multiple sources



Challenges

- Huge family of chemicals with cleanup levels for six
  - No consensus on analytical or toxicological approaches to address entire family
- PFAS haven't been analyzed at many sites that could have them
  - Firefighting training
  - Bulk fuel storage
  - Chrome platers
  - Landfills
  - High temperature operations
  - Many industries

PFBS

PFHxS

PFOS

PFOA

PFNA

GenX

Megan King, PE

Senior Environmental Program Manager – Aviation Environment & Sustainability

SEA
Seattle-Tacoma
International
Airport

SEA
Seattle-Tacoma
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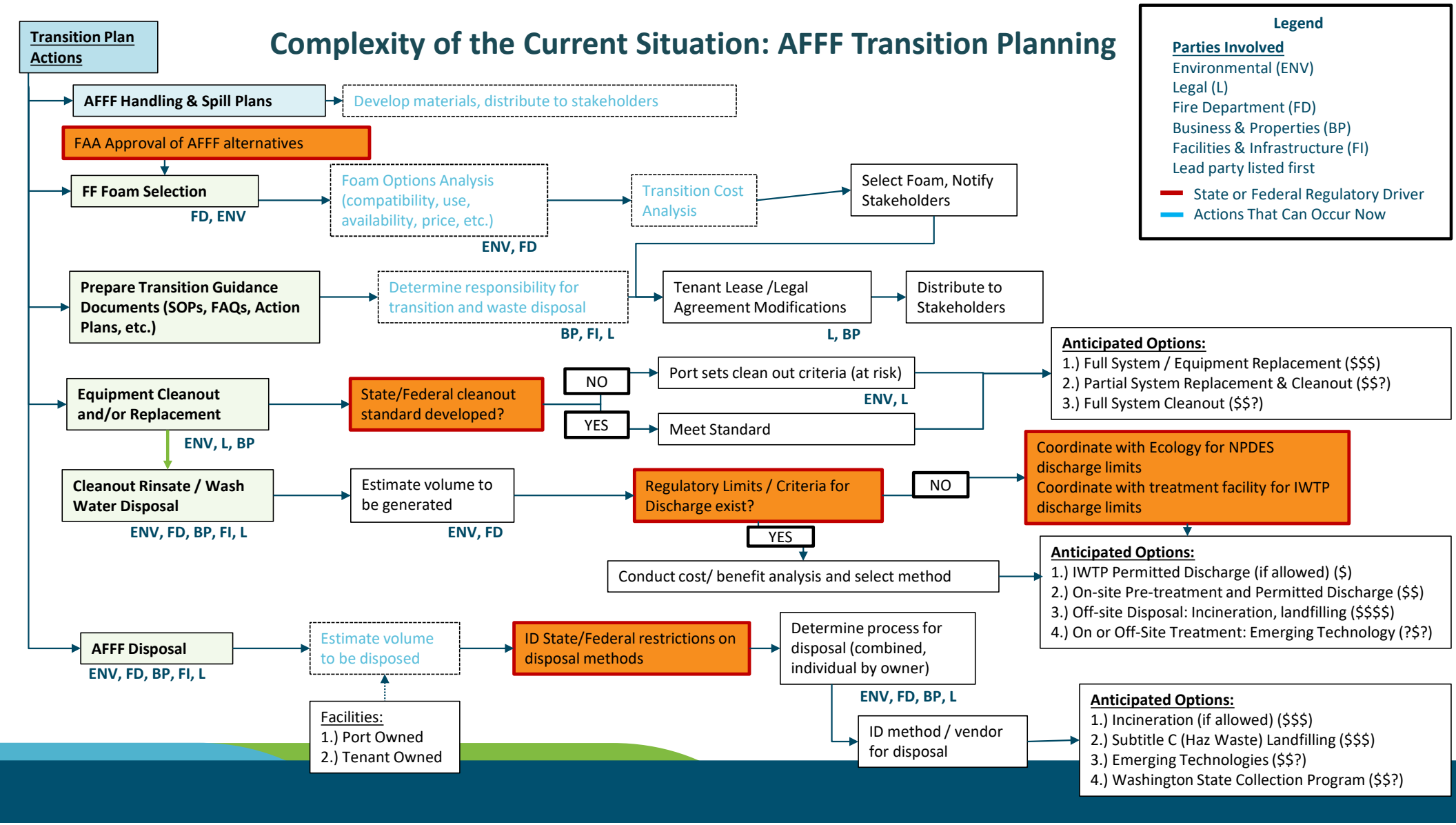
Airport

Complexity of the Current Situation: AFFF Transition Planning



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NEBC Conference