Civil & Environmental Consultants, Inc.

PFAS in New England:
An Assessment of Distribution Data from Known Sites

Presented at:

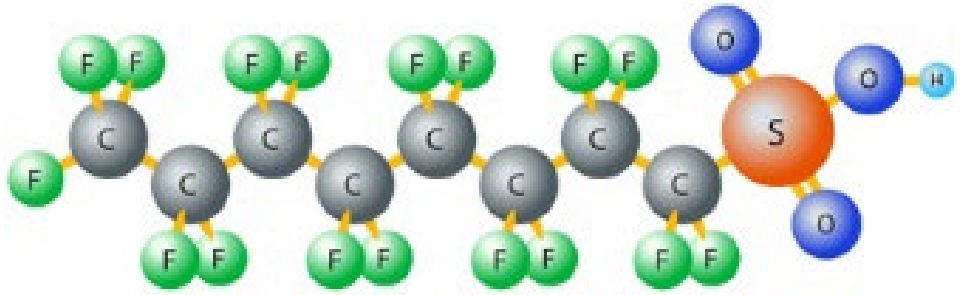
LSP Association
assess. advise. restore.

Jonathan D. Kitchen, PG, LSP

April 14, 2022

Per- and Polyfluoroalkyl Substances (PFAS)

- Group of man-made chemicals that includes PFOA, PFOS, GenX, and many others
- Manufactured and used in a variety of industries around the globe since the 1940's



Thank You!

- Thank you to staff who spent countless hours combing through reports

- Thank you to the LSPA for assistance through a WES Grant

LSP Association
assess. advise. restore.

Reason For Study

- PFAS present a significant public health challenge
- Although this “emerging contaminant” has now been studied for over 20 years, a “big picture” perspective on the current status of this threat is somewhat illusive
- Goal: Review readily available information on sites to gain a better perspective on the status of PFAS impacts in New England

Methods

- Over 330 sites in New England reviewed
- Entered key information regarding each site into database:
  - ✓ Site Use/Type
  - ✓ Location
  - ✓ Concentrations in soil, groundwater
  - ✓ Plume length
  - ✓ Source
  - ✓ Background concentrations, etc.
- Data mined from database to provide information about the universe of PFAS sites

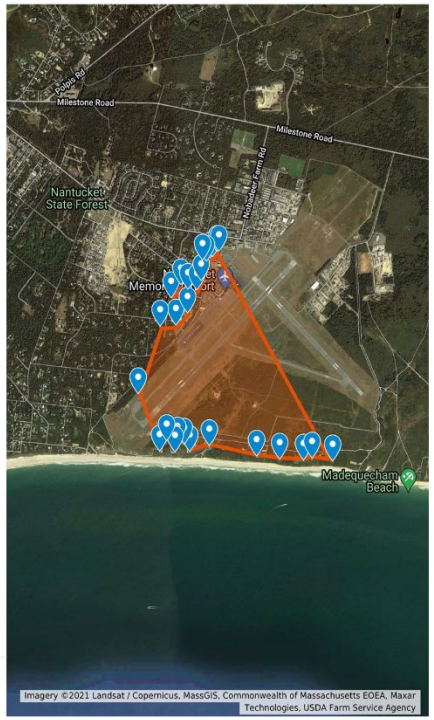
Types of Sites	
Total = 338	
Airport (7)	Other (35)
Auto Service / Repair (5)	Other Fire (16)
Biosolids (4)	Public Water Supply (17)
Car Wash (2)	School (4)
Fire Training (10)	Solid Waste - Landfill Active (43)
Laundry / Uniform (9)	Solid Waste - Landfill Closed (110)
Military (11)	Solid Waste - Transfer Station (10)
Manufacturing, Combined (47)	Wastewater Treatment Plant (4)
Metal Recycling Facility (4)	

Methods – Access Database

MA Standards Nantucket Memorial Airport

PFAS Contamination
- ACK-01
- AG-02
- ACK-14
- ACK-15
- Property EV
- Property FM
- Property XA
- Property CC
- Property NU
- Property RN
- Property QO
- Property KH
- Property TD
- Property VT
- Property IB
- Property UF
- Property MQ
- Property HF
- Property JI
- Property ZW
- Property YD
- Property AY
- Property LG
- Property LW
- Property WU
- Property UL
- Potential Contamination Zone

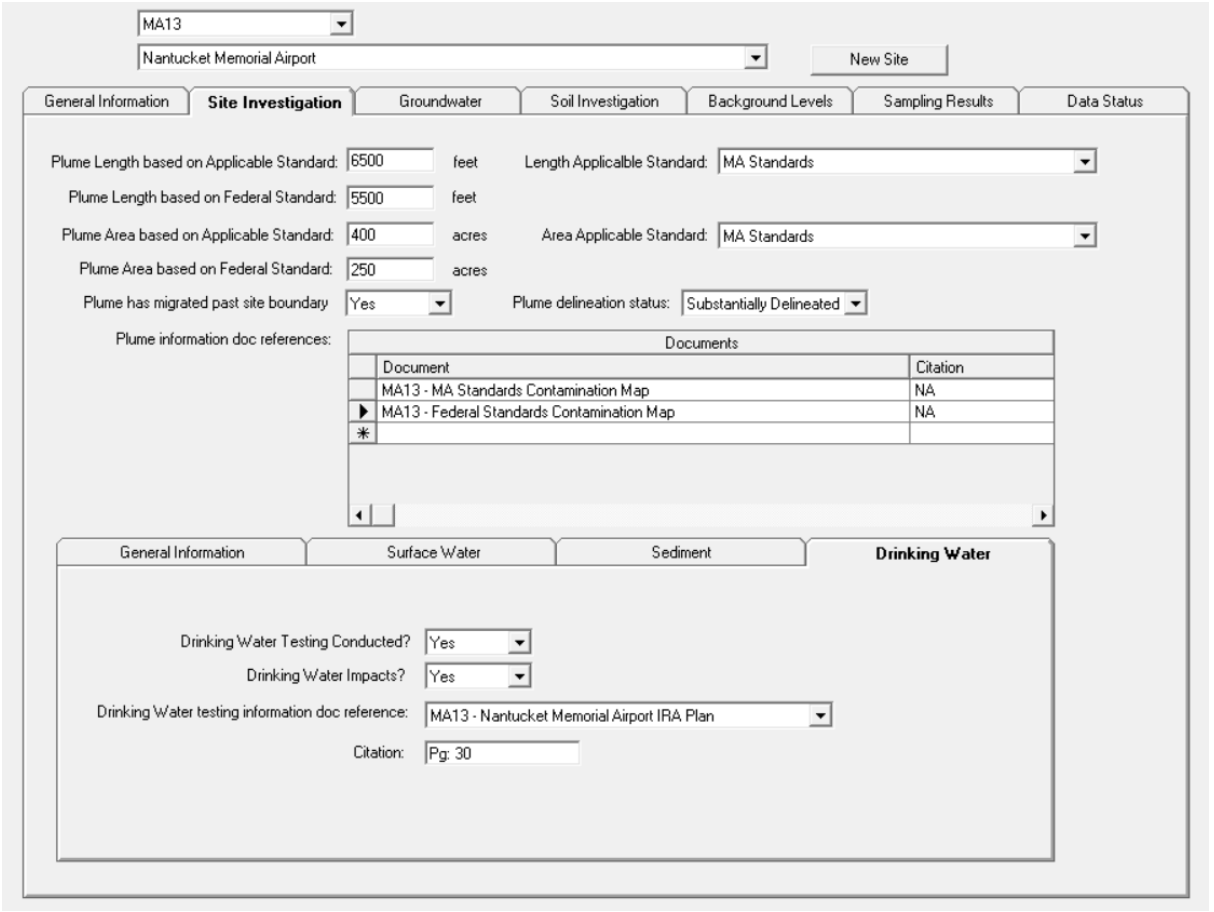
Plume Size:
Area: 394 acres
Length: 6,547 feet



Federal Standards Nantucket Memorial Airport

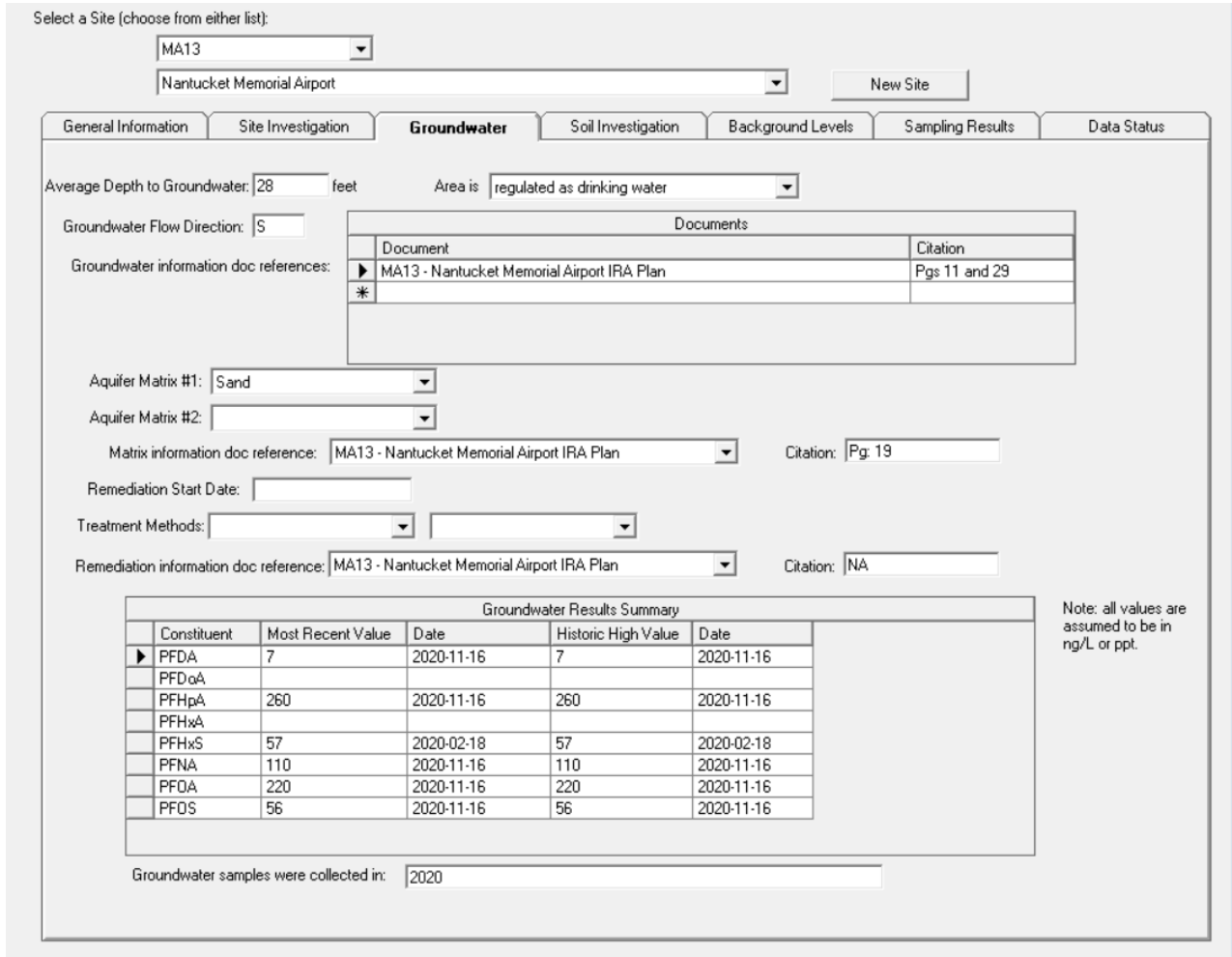
PFAS Contamination
- Nantucket Memorial Airport
- ACK-10
- Property XA
- Property CC
- Property QO
- Property TD
- Property IB
- Property UE
- Property RN
- Property FM
- Property KH
- Potential Contamination Zone

Plume Size:
Area: 261 acres
Length: 5,544 feet



Maps created using Google MyMaps

Methods – Access Database



Select a Site (choose from either list):

MA13

Nantucket Memorial Airport

New Site

General Information | Site Investigation | **Groundwater** | Soil Investigation | Background Levels | Sampling Results | Data Status

Average Depth to Groundwater: 28 feet Area is: regulated as drinking water

Groundwater Flow Direction: S

Groundwater information doc references:

Documents	
Document	Citation
MA13 - Nantucket Memorial Airport IRA Plan	Pgs 11 and 29

Aquifer Matrix #1: Sand

Aquifer Matrix #2:

Matrix information doc reference: MA13 - Nantucket Memorial Airport IRA Plan Citation: Pg: 19

Remediation Start Date:

Treatment Methods:

Remediation information doc reference: MA13 - Nantucket Memorial Airport IRA Plan Citation: NA

Groundwater Results Summary

Constituent	Most Recent Value	Date	Historic High Value	Date
PFDA	7	2020-11-16	7	2020-11-16
PFDoA				
PFHpA	260	2020-11-16	260	2020-11-16
PFHxA				
PFHxS	57	2020-02-18	57	2020-02-18
PFNA	110	2020-11-16	110	2020-11-16
PFOA	220	2020-11-16	220	2020-11-16
PFOS	56	2020-11-16	56	2020-11-16

Note: all values are assumed to be in ng/L or ppt.

Groundwater samples were collected in: 2020

Challenges and Limitations

- Not a statistical sampling
- Biased based upon ease of access to data
- Identification of PFAS contamination sites is inherently biased
- Federal site data often less easy to obtain versus state data
- Systematic judgements are necessary
- A snapshot in time

State vs. Federal Guidelines

New England States vs. USEPA Comparison Parts per trillion (nanogram/liter) in drinking water						
	PFOS	**PFOA**	**PFNA**	**PFHxS**	**PFHpA**	**PFDA**
USEPA Health Advisories	70 Sum of two		--	--	--	--
ATSDR Minimal Risk Levels (MRL) Adult/Child	52/14	78/21	78/21	517/140	--	--
Vermont Health Advisory | Emergency Rule	20 Sum of five					--
Massachusetts Maximum Contaminant Level (MCL)	20 Sum of six					
Connecticut Action Level	70 Sum of five					--
New Hampshire Maximum Contaminant Levels (MCLs)	15	12	11	18	--	--
Rhode Island Follows EPA Health Advisory	70		--	--	--	--
Maine Maximum Contaminant Levels (MCLs)	20 Sum of six					

-- = No standard available

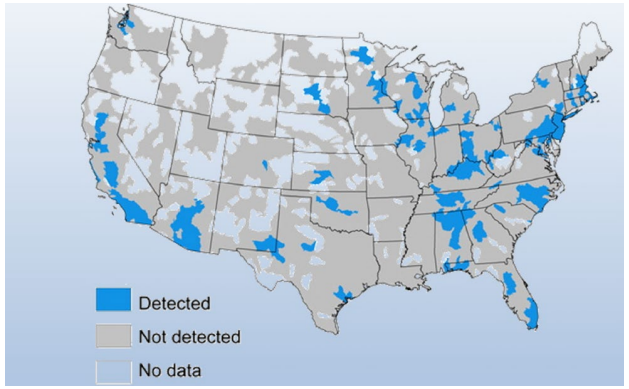
General Observations

- As a society we are still “playing defense”
  - ✓ Focus is on receptors
  - ✓ Little remediation performed
  - ✓ Only the biggest sites and most highly regulated sites have been investigated
  - ✓ Most sites are still poorly delineated

General Observations

Spoiler Alert – Background

As detection limits and standards decreased and as we heard about PFAS showing up in exotic places, many questioned if PFAS would be detected everywhere in all media.

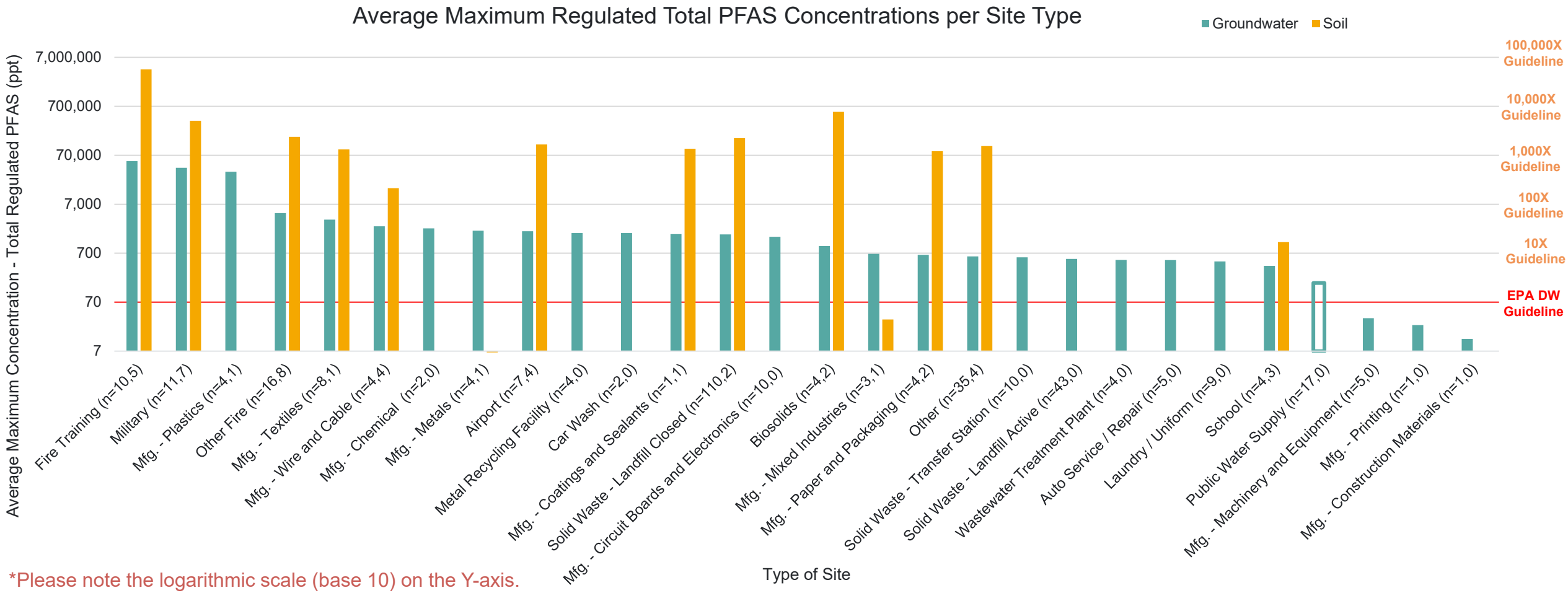


Hu et al. 2016

PFAS is not ubiquitous in all environmental media

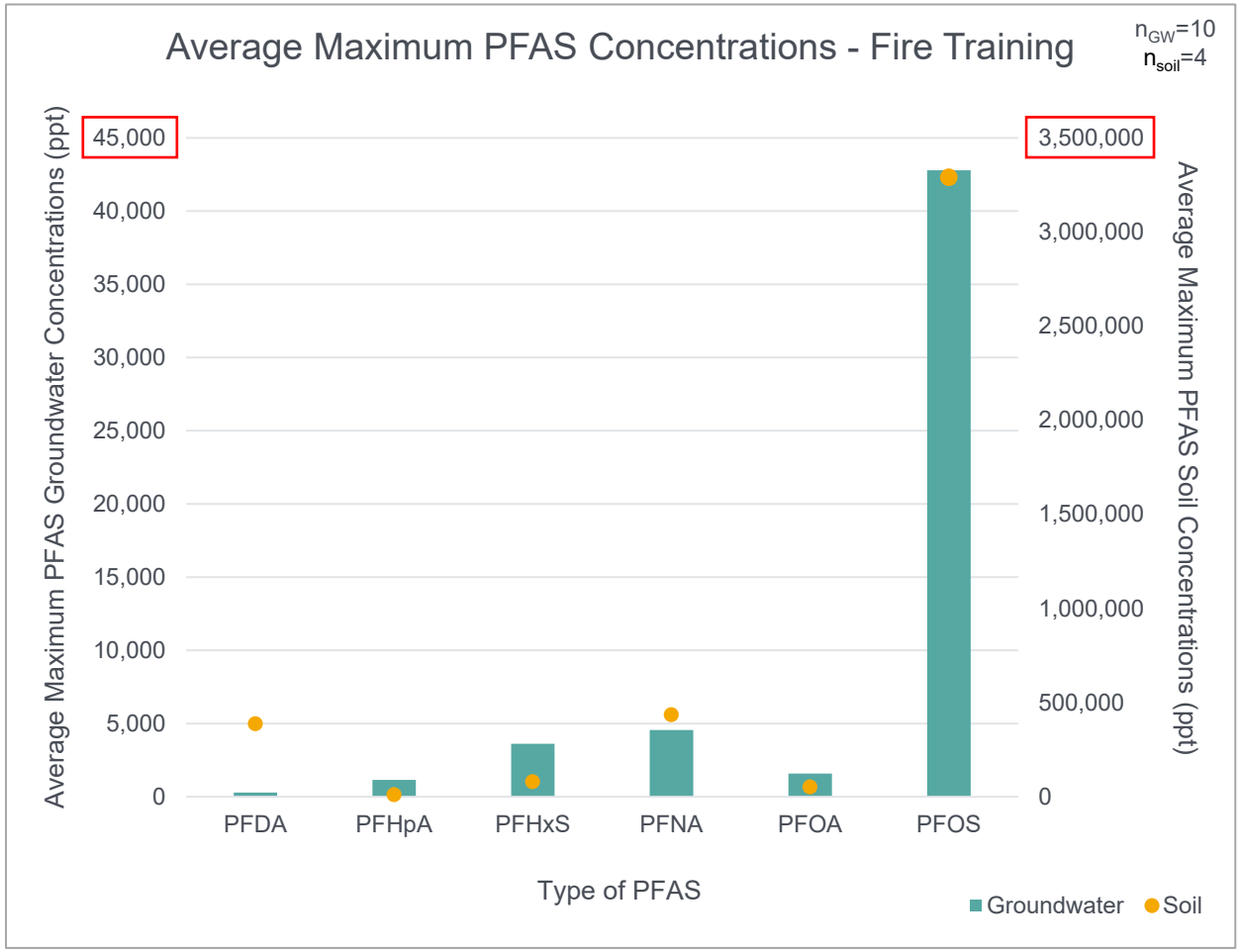
What Did The Database Teach Us?

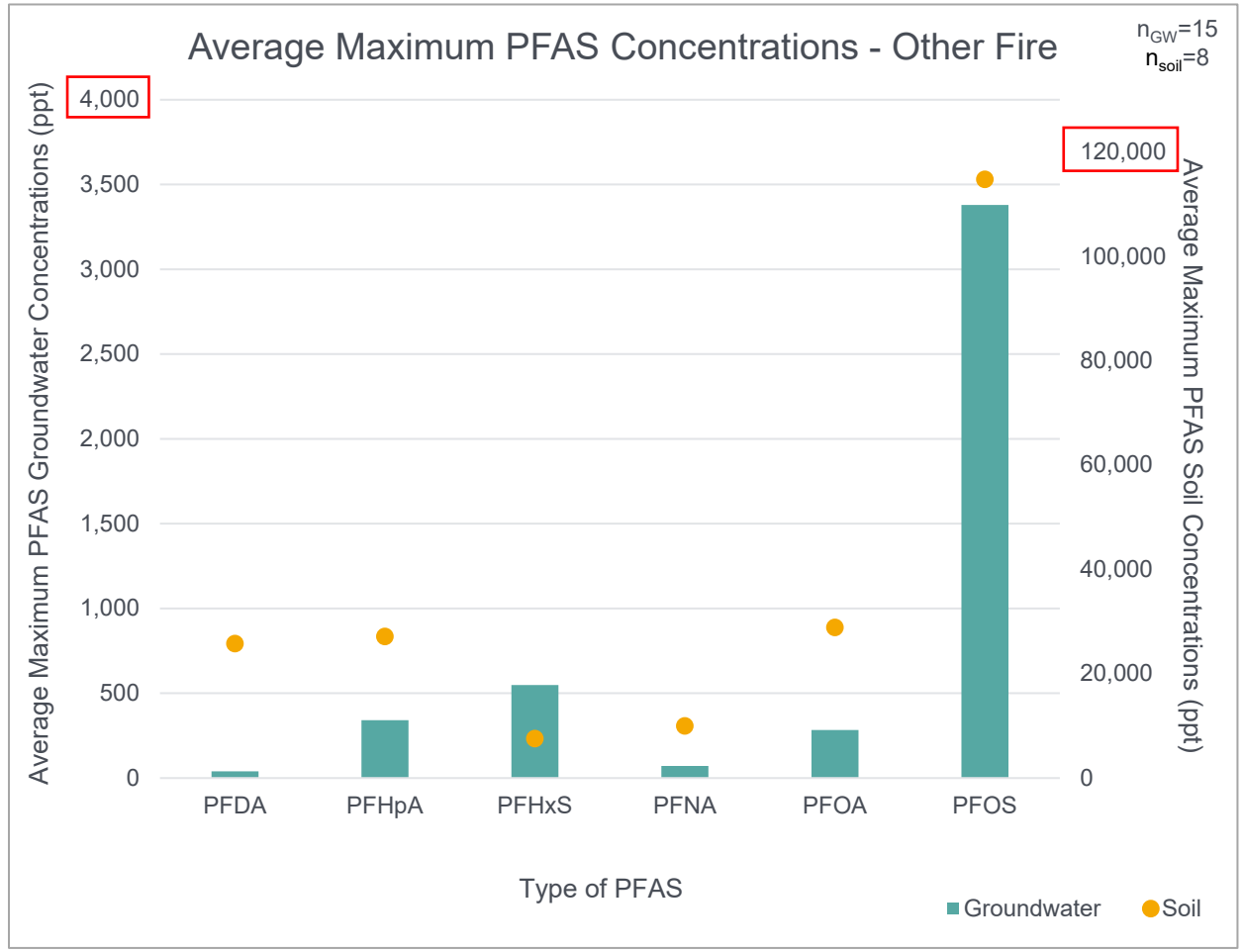
Average Maximum Total Concentrations



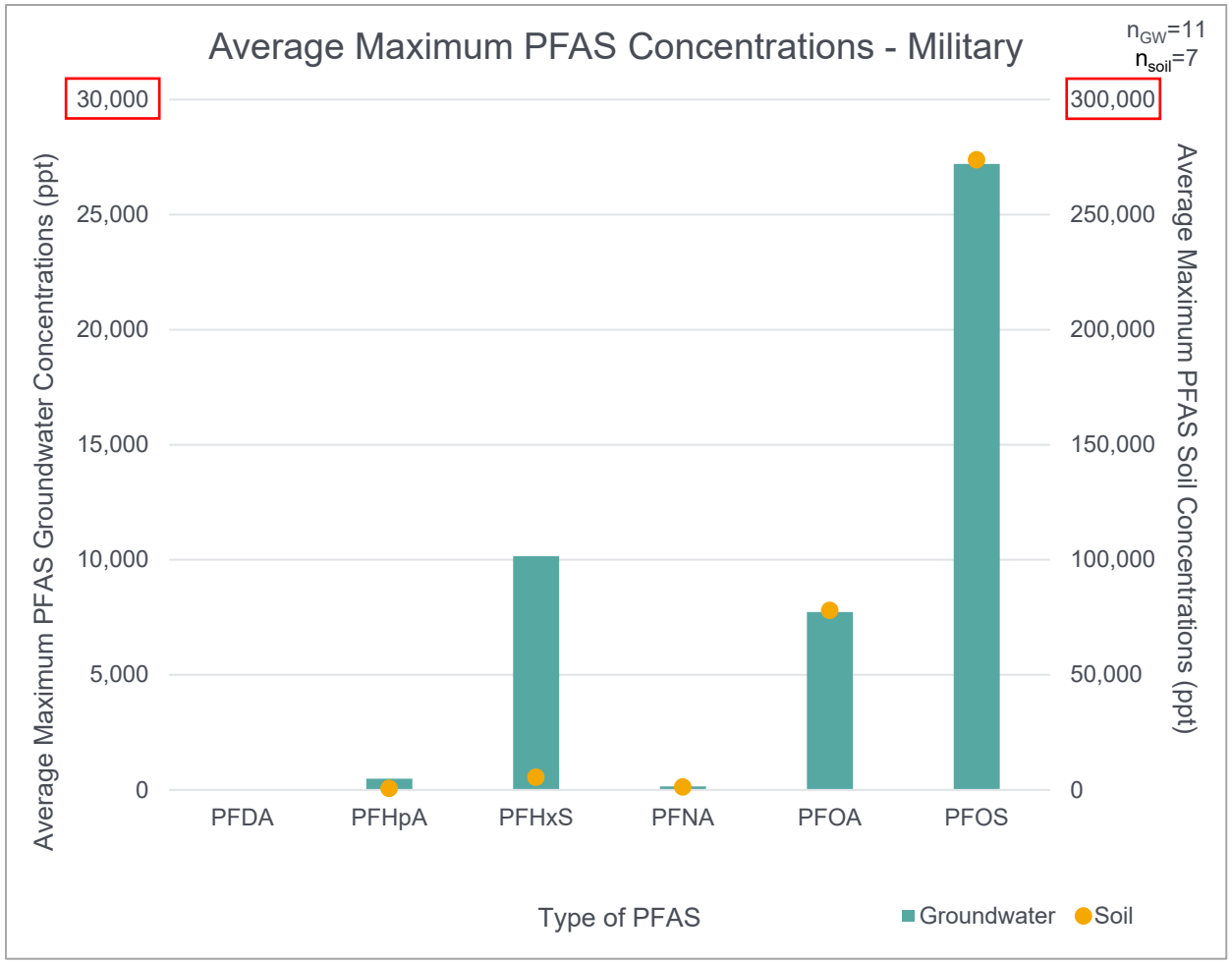
*Please note the logarithmic scale (base 10) on the Y-axis.

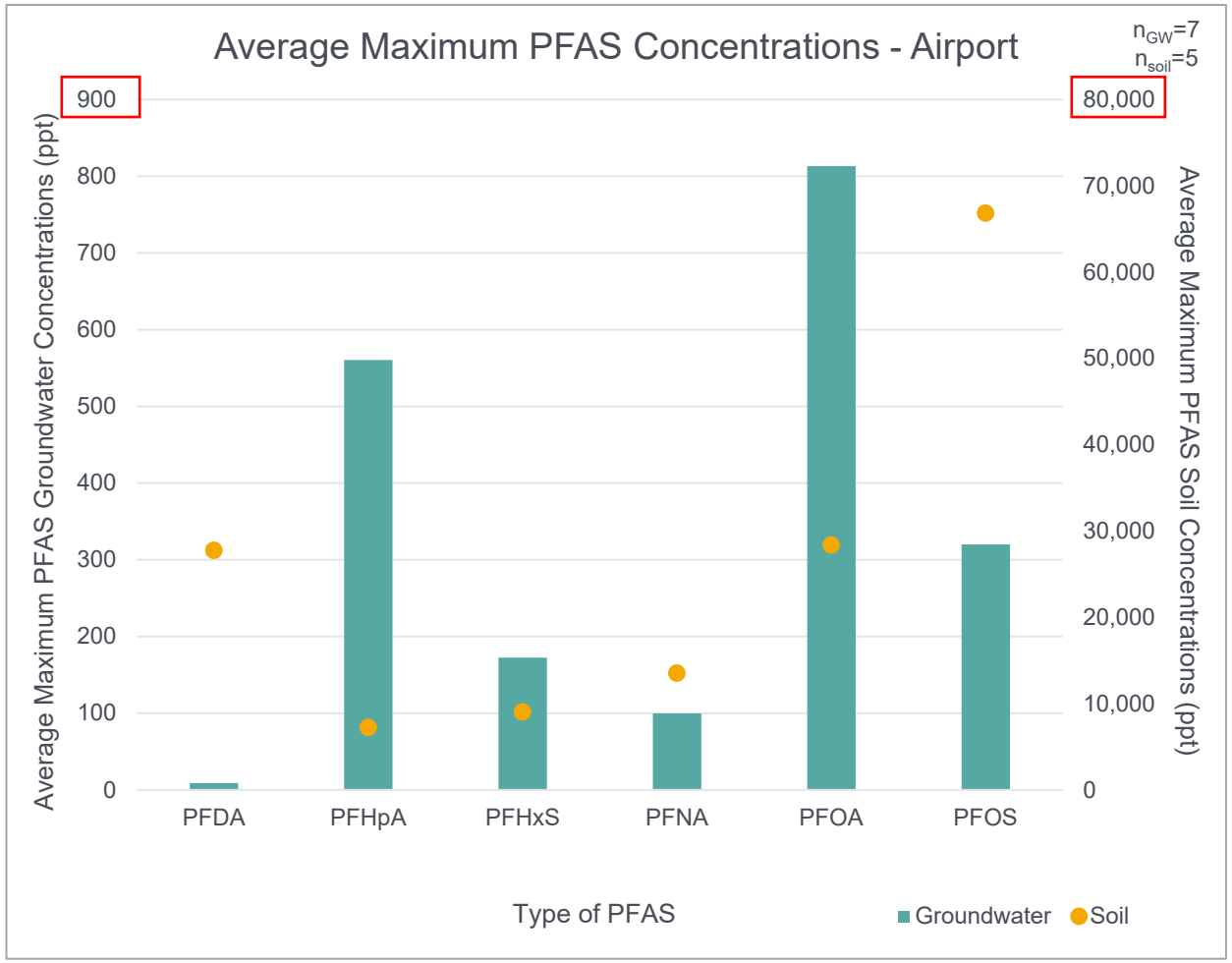
Average Maximum Concentrations by Site Type



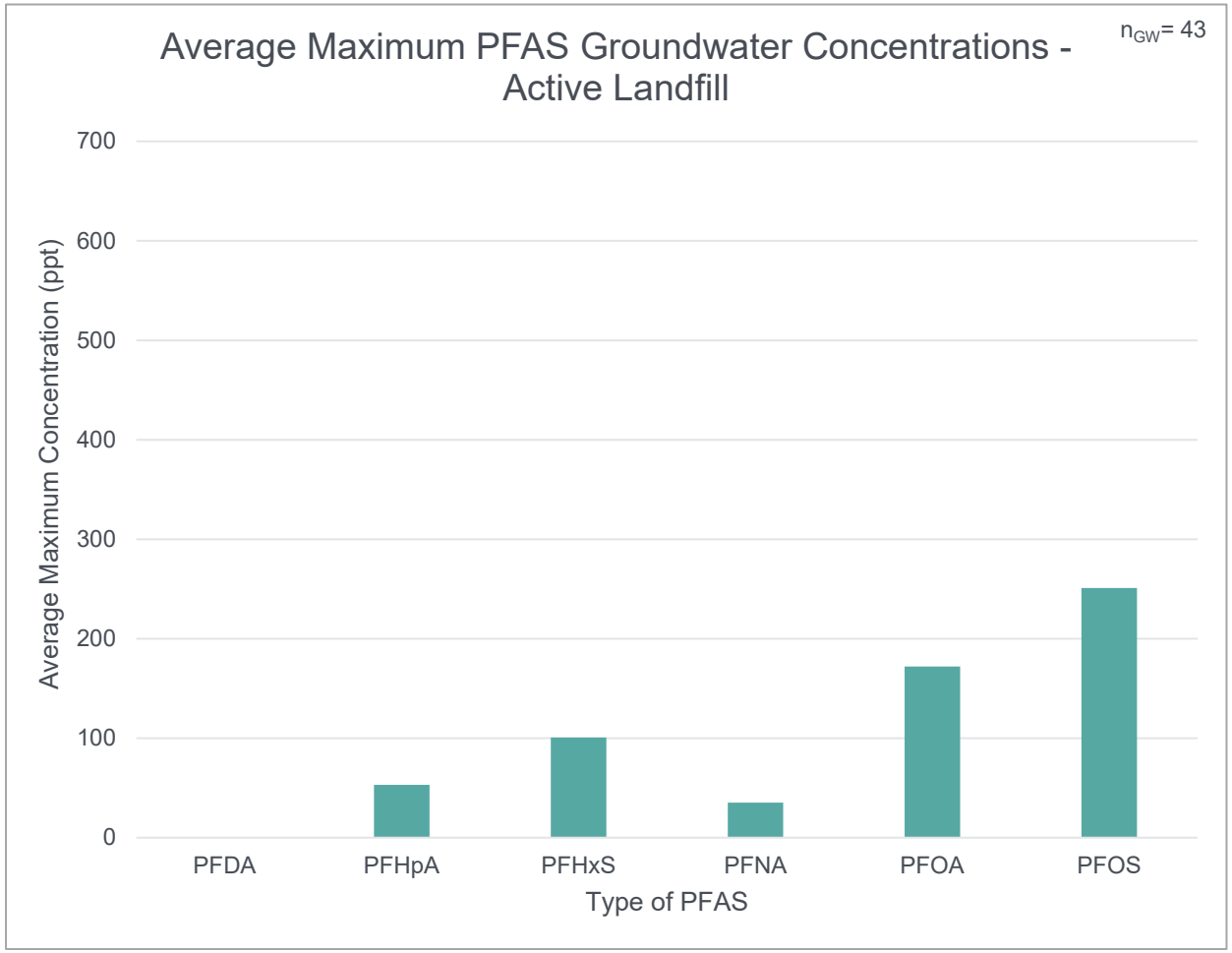


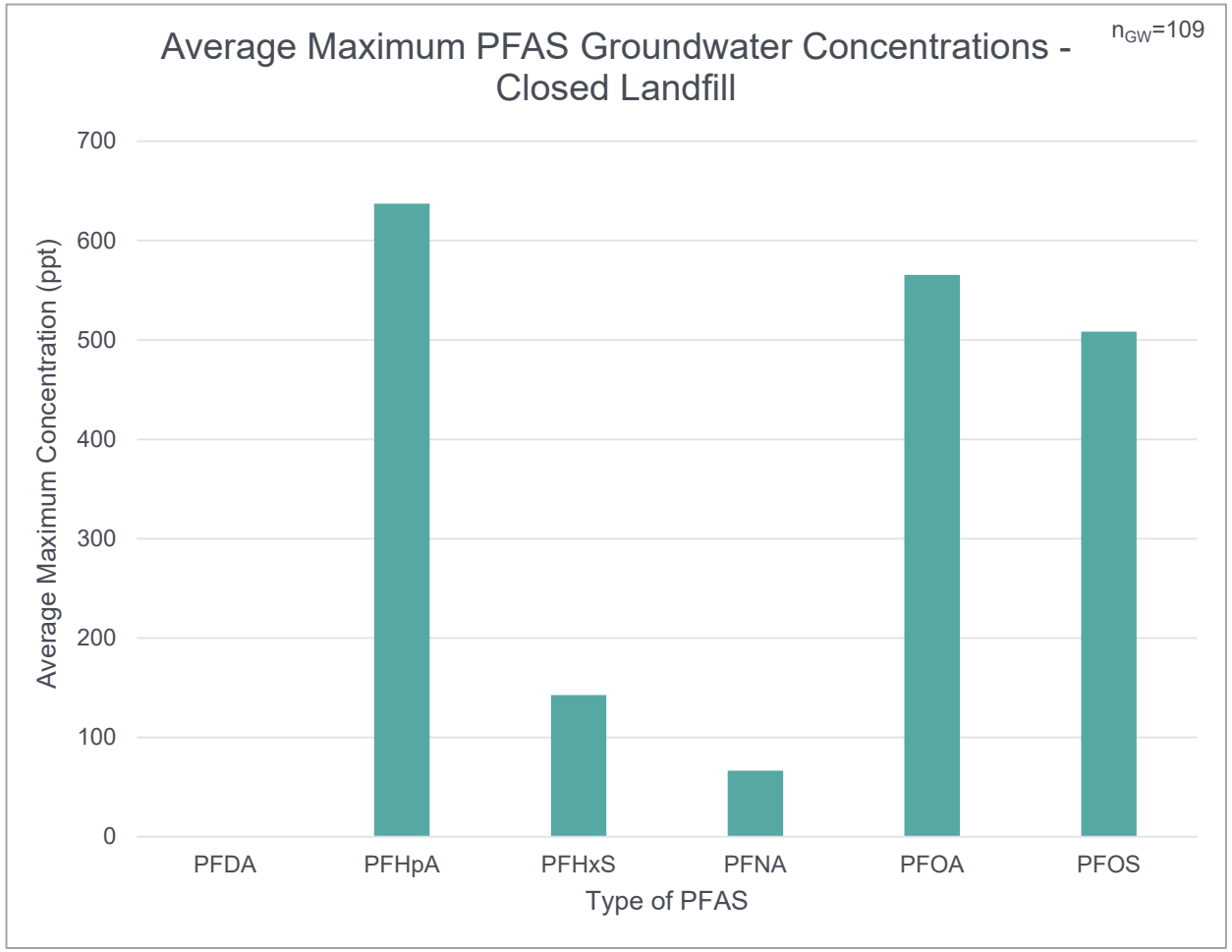
Average Maximum Concentrations by Site Type



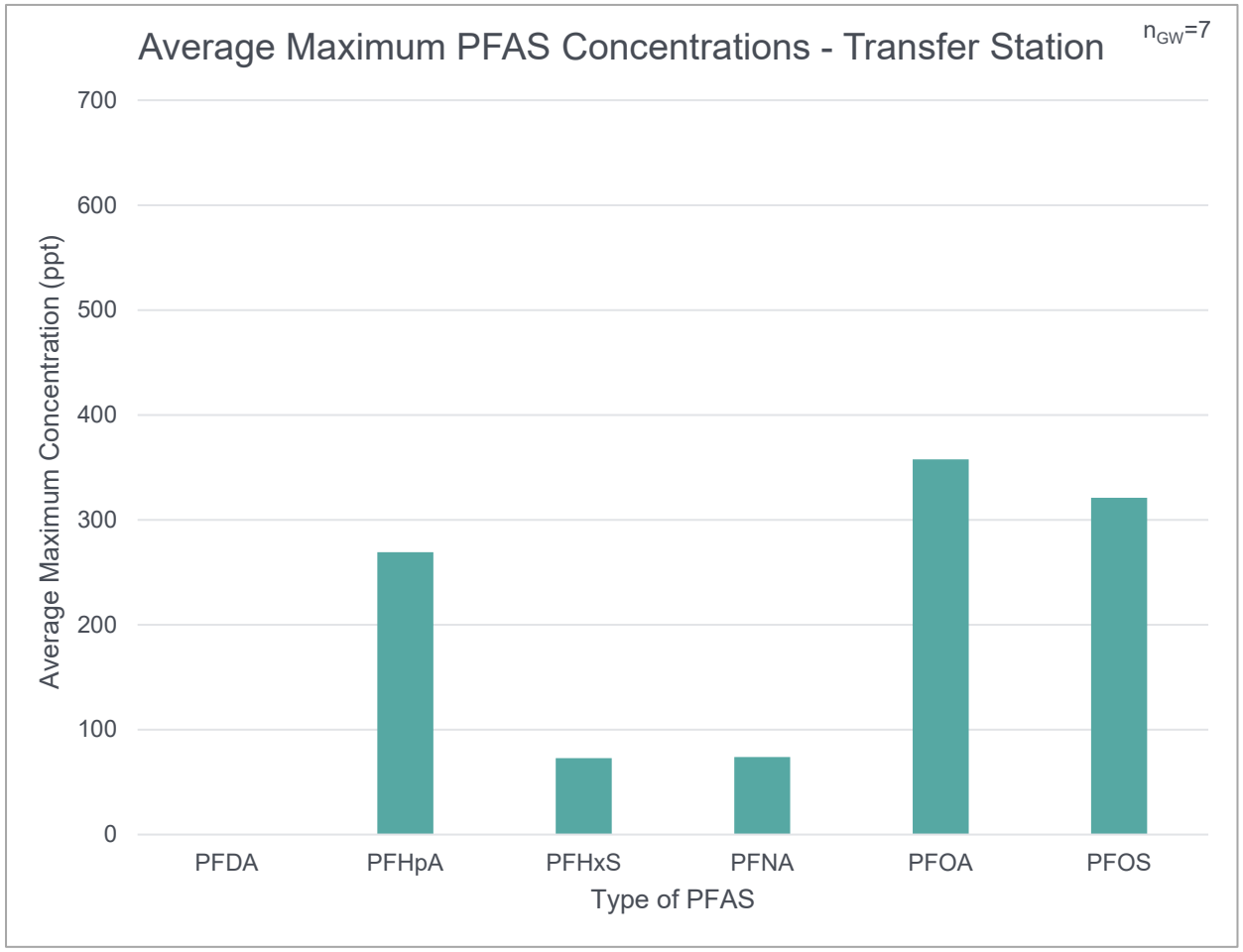


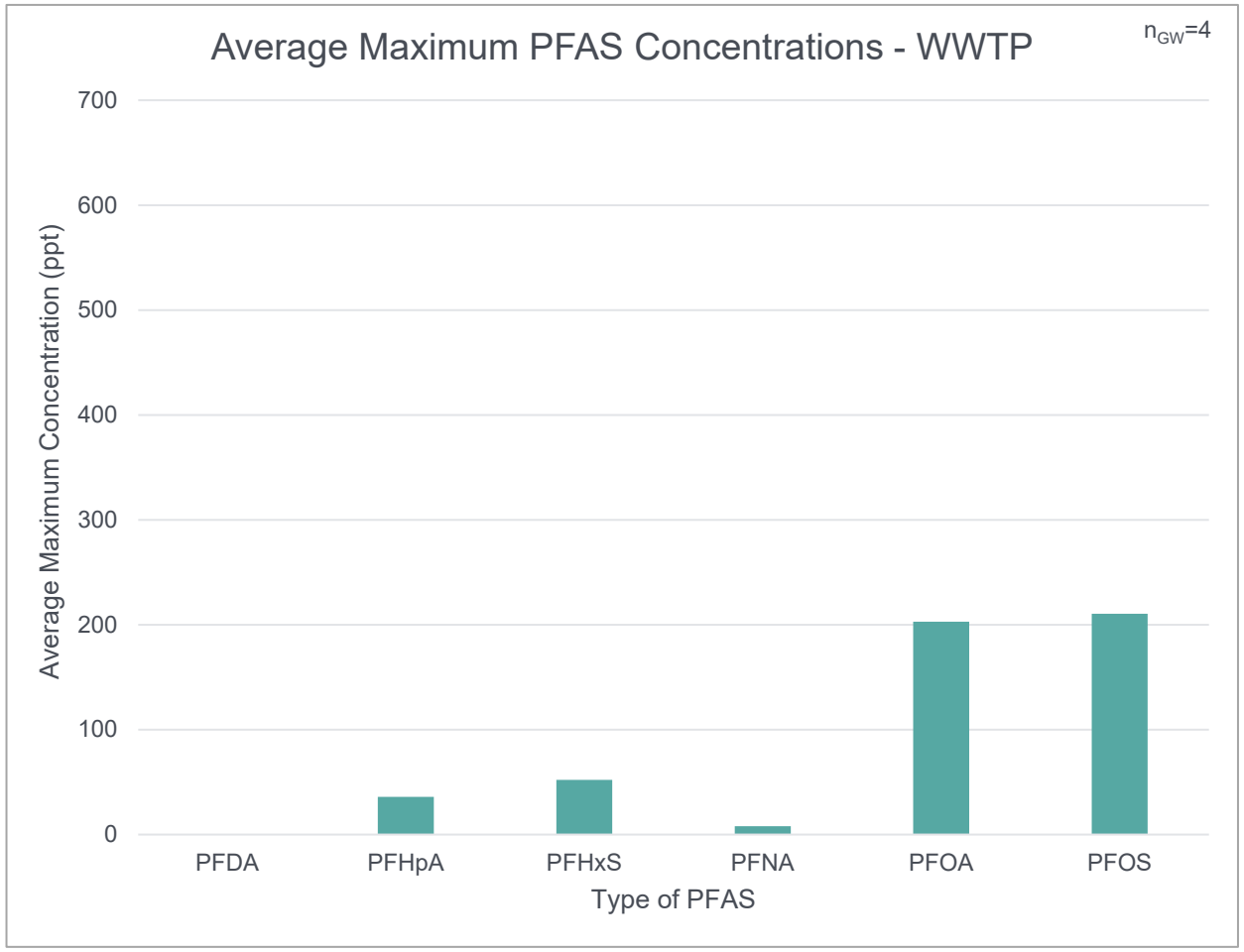
Average Maximum Concentrations by Site Type



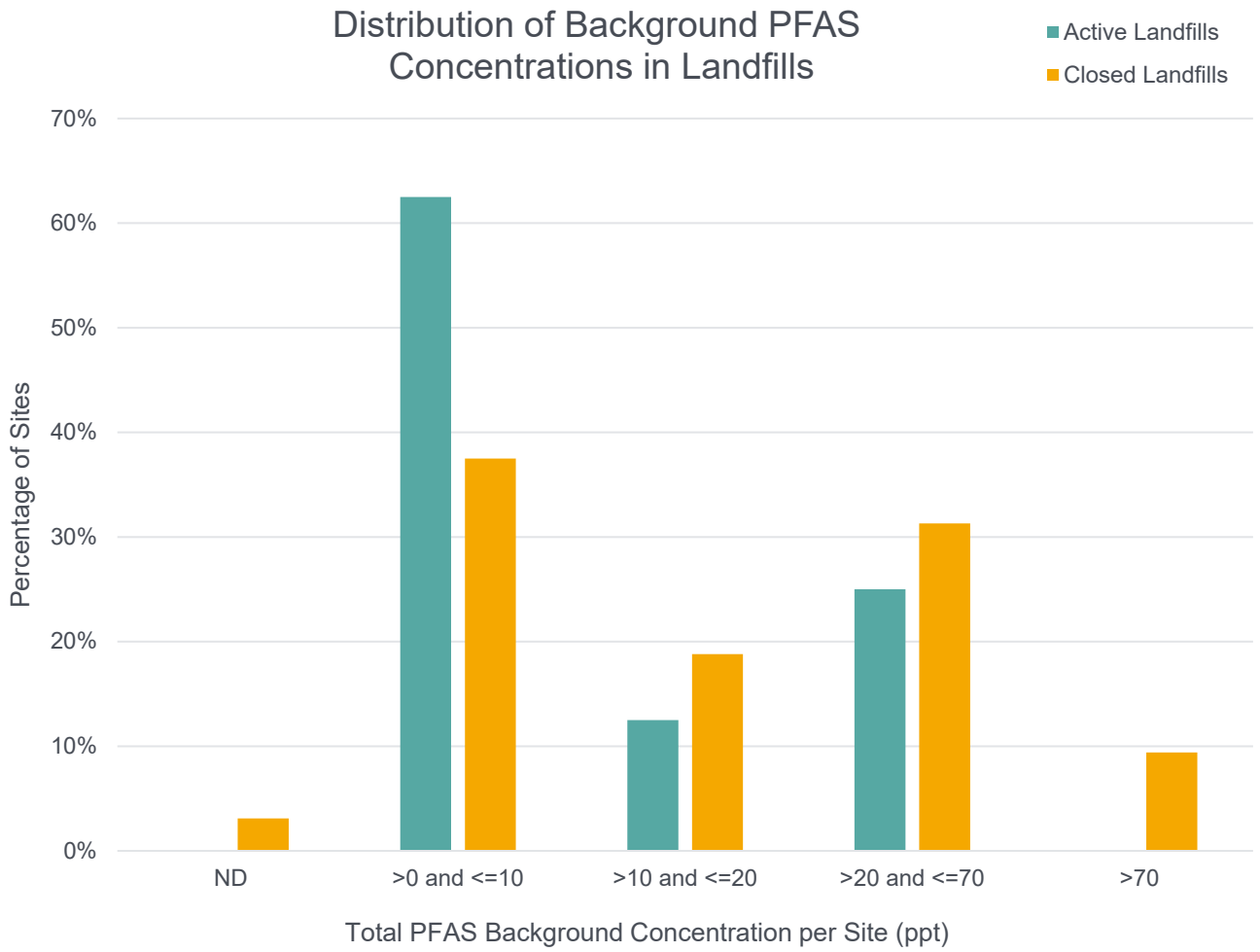


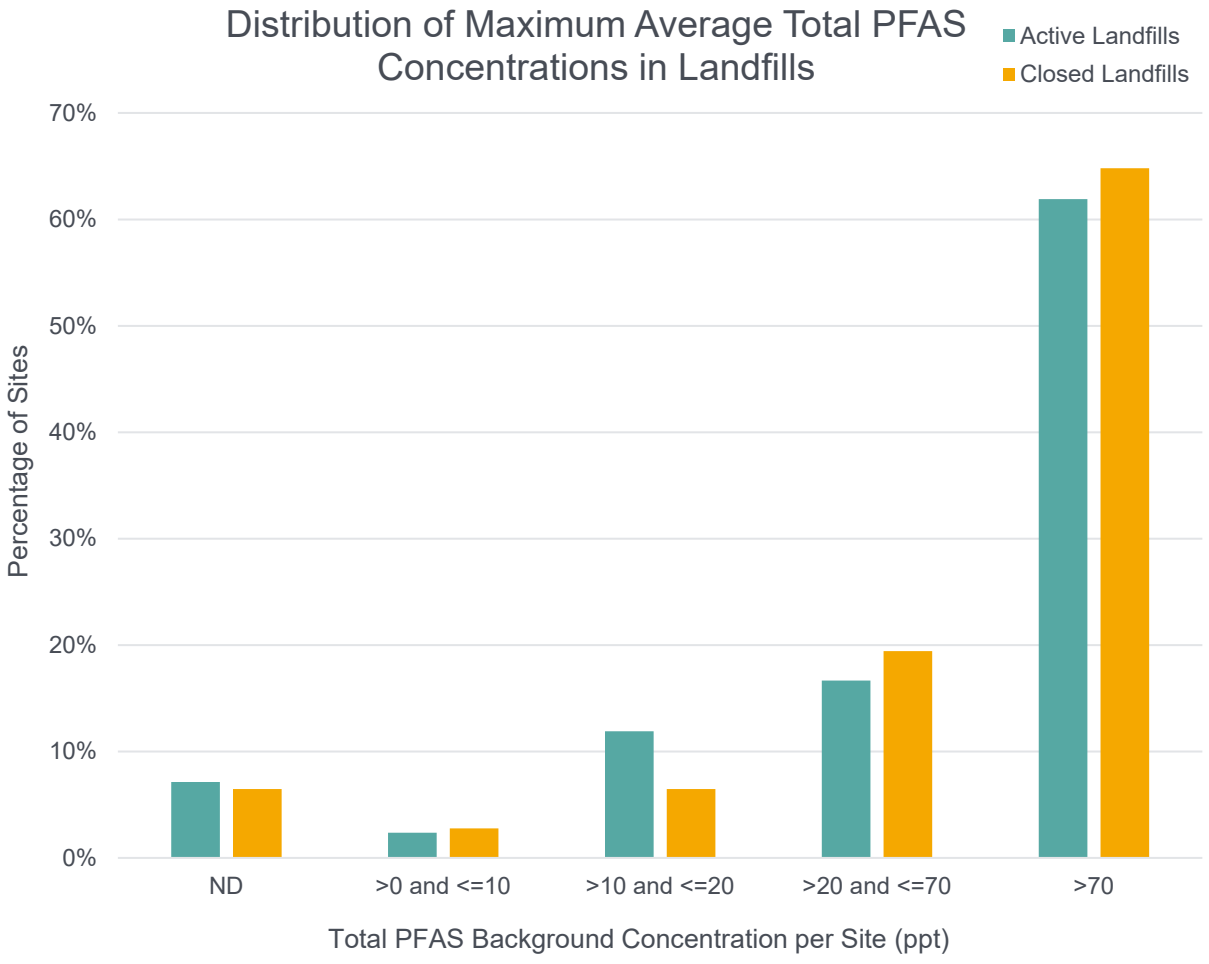
Average Maximum Concentrations by Site Type





Background in Landfills



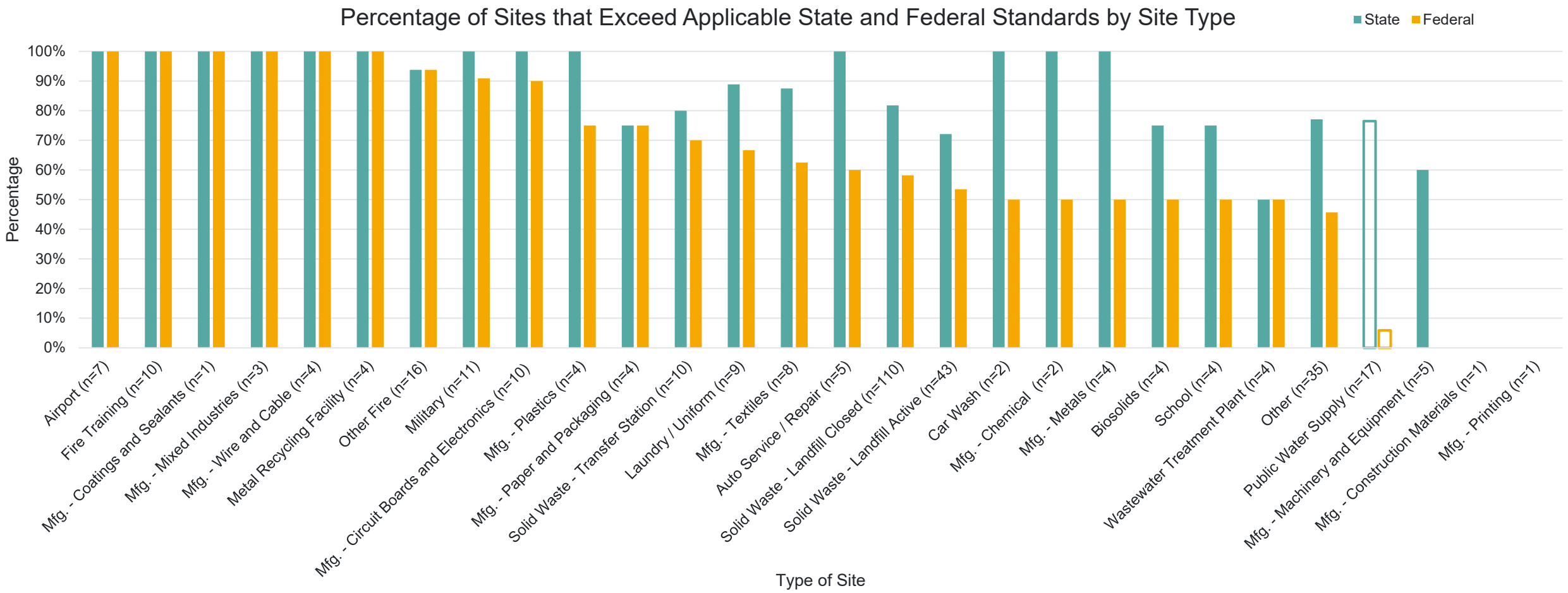


Impact from Solid Waste Sites

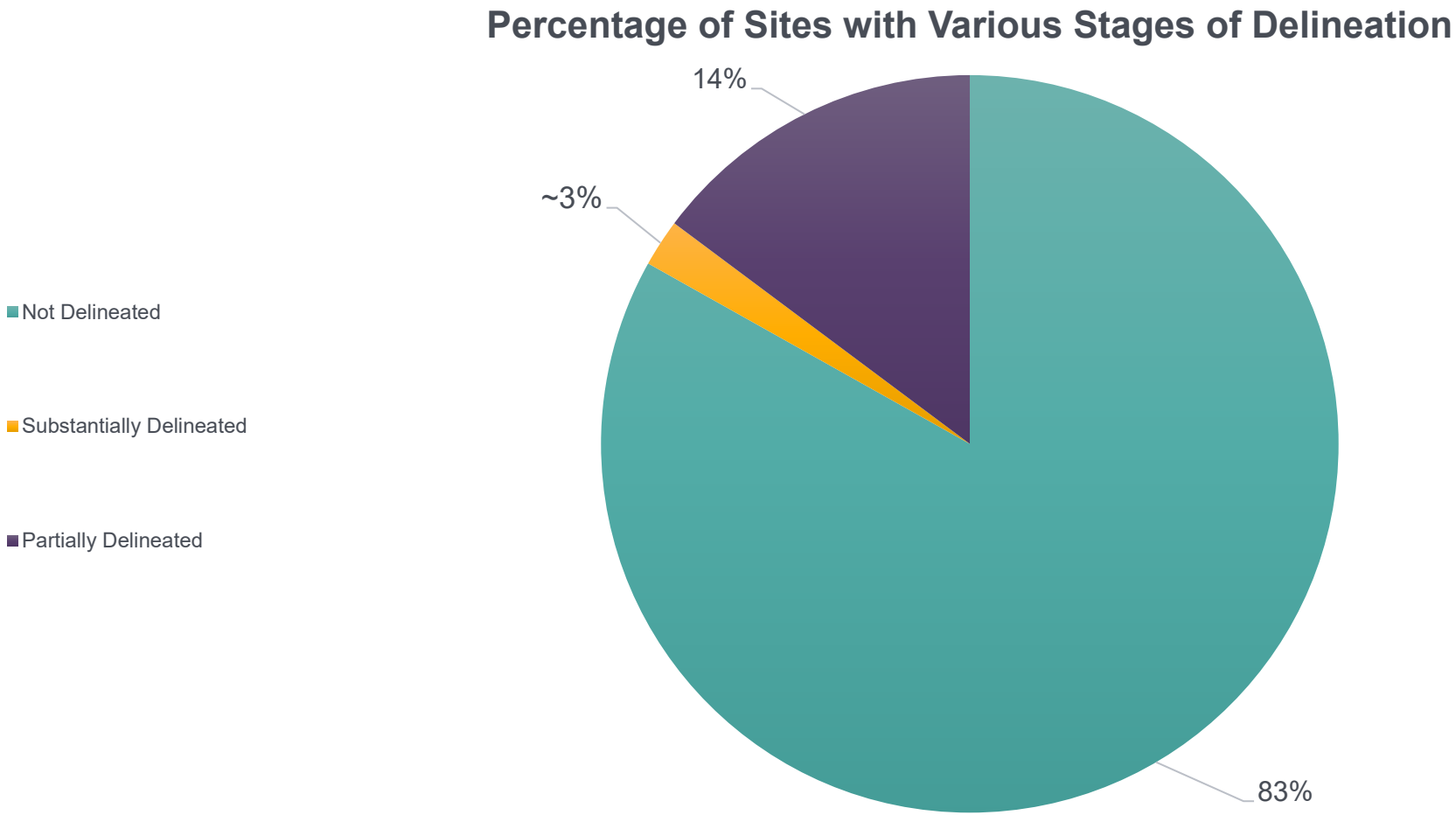
Solid Waste Facilities are highly represented in the dataset because they are easily regulated.

- Not detected in groundwater at 7% of landfills
- 45% of landfills < federal standards
- 18% of closed/capped landfills and 28% of active landfills < state standards
- Impacts to drinking water
  - 30% of closed landfills
  - 23% of active landfills

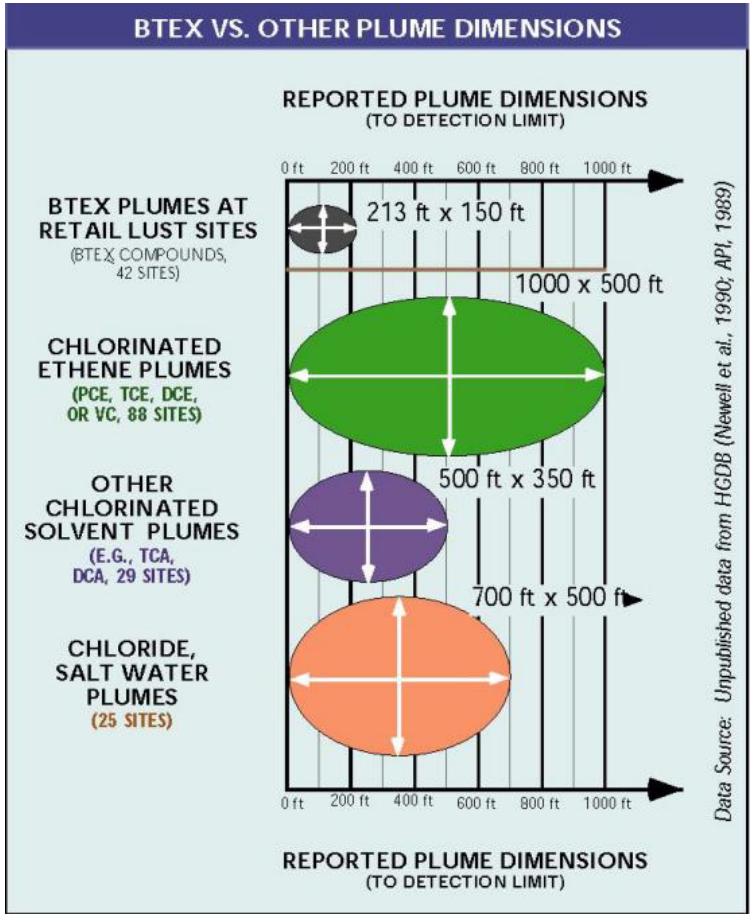
Impact of State Standards



Status of Delineation



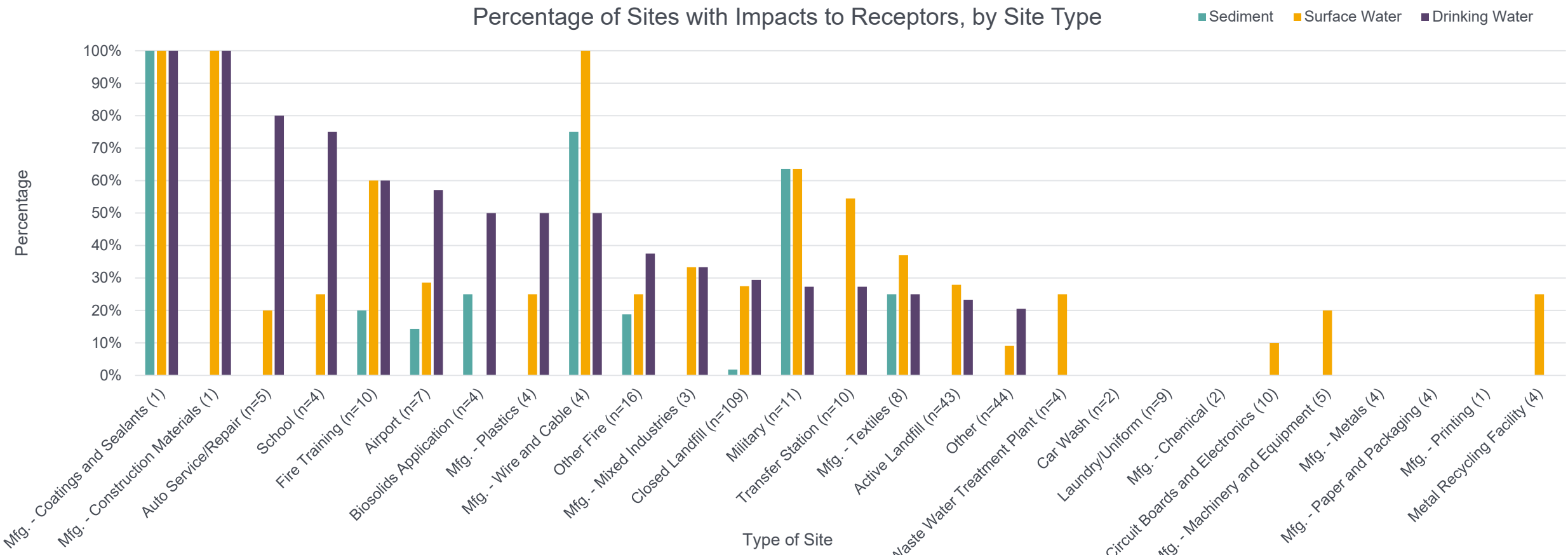
Plume Length



Substantially Delineated Sites

Site Name Location	Plume Length (feet) (State / Federal Standards)	Notes
Barnstable Fire Training Academy Barnstable, Massachusetts	2,000 / 2,000	Surface water, water supply wells, downgradient wells
Beverly Airport Beverly, Massachusetts	1,500 / Negligible	Downgradient wells with low concentrations
Hanscom Air Force Base Middlesex County, Massachusetts	5,800 / 5,800	Non-detect downgradient wells
Martha's Vineyard Airport Martha's Vineyard, Massachusetts	9,000 / 9,000	Low or non-detect concentrations in downgradient public and private water supply wells or monitoring wells
Nantucket Memorial Airport Nantucket, Massachusetts	6,500 / 5,500	Atlantic Ocean, low concentrations or non-detect private wells or monitoring wells
New Boston Air Force Station New Boston, New Hampshire	6,800 / 5,300	Low detections in downgradient monitoring wells
Ottati & Goss-Kingston Steel Drum Superfund Site Kingston, New Hampshire	2,700 / 2,700	Non-detect downgradient wells
Sylvester Superfund Site Nashua, New Hampshire	4,000 / 2,000	Non-detect downgradient wells

Impact to Receptors



152 sites (46%) have impacted a receptor

Status of Remediation

- 3% of sites have started remediation (other than receptor protection)
- Similar to % of substantially delineated sites

We are still in the beginning stages!

Summary

- While PFAS is ubiquitous in the human environment, it is not necessarily present in all environmental media
- Regulators and the regulated community are still “playing defense” and little active remediation is underway
- The typical concentrations detected in groundwater vary substantially depending upon the type/ nature of the release
- Preliminary data supports that plumes from PFAS sites, as expected, are long compared to other contaminants of concern
- A more stringent standard/guidance makes a noticeable difference in capturing certain types of release sites.

Contact Us!

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Boston-Area Environmental Practice Lead

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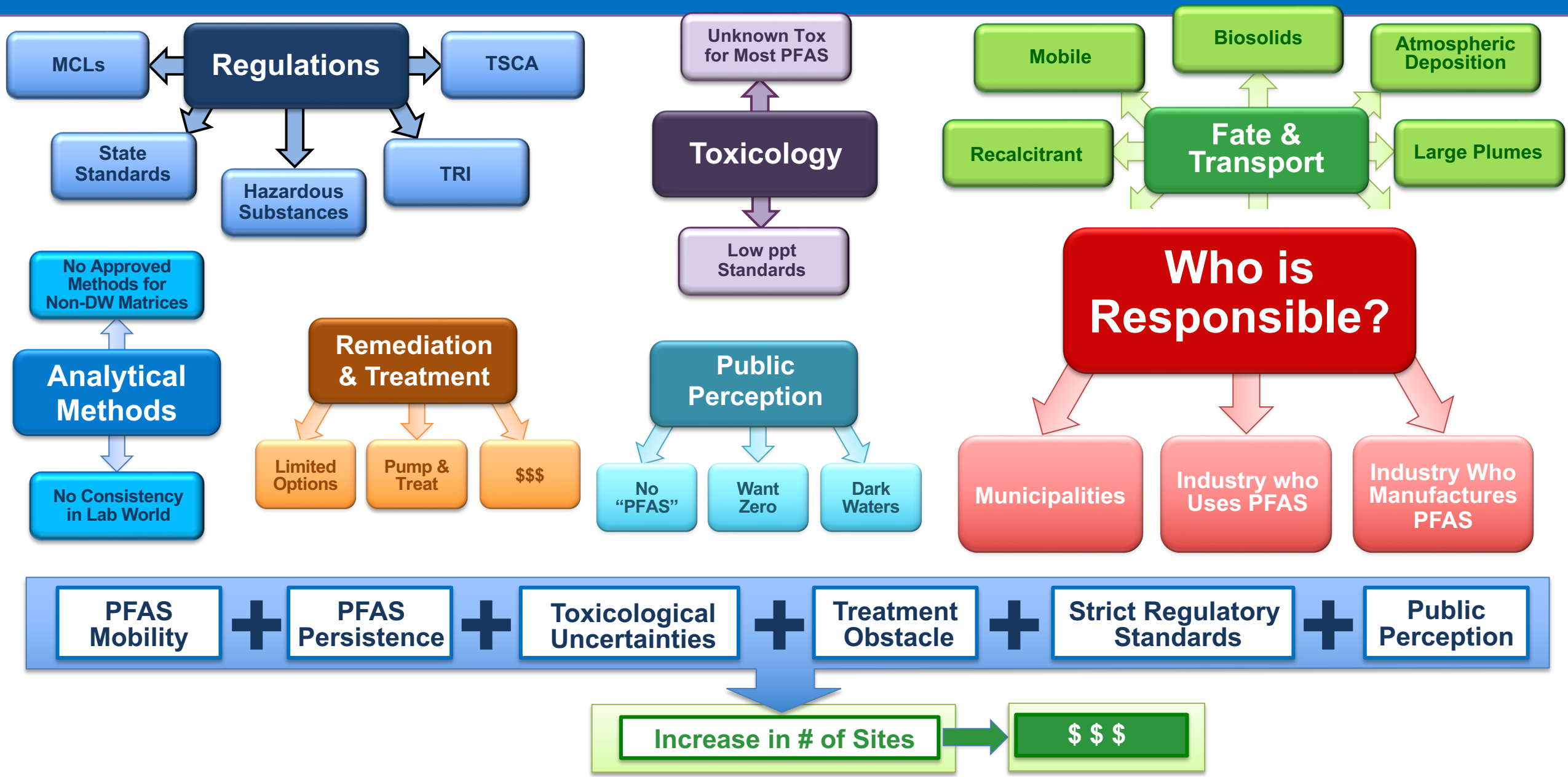
Is that Your PFAS?

Using Forensics to Identify Sources

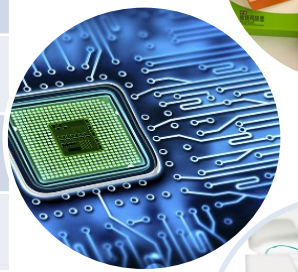
April 14, 2022

PFAS Uncertainties / Challenges



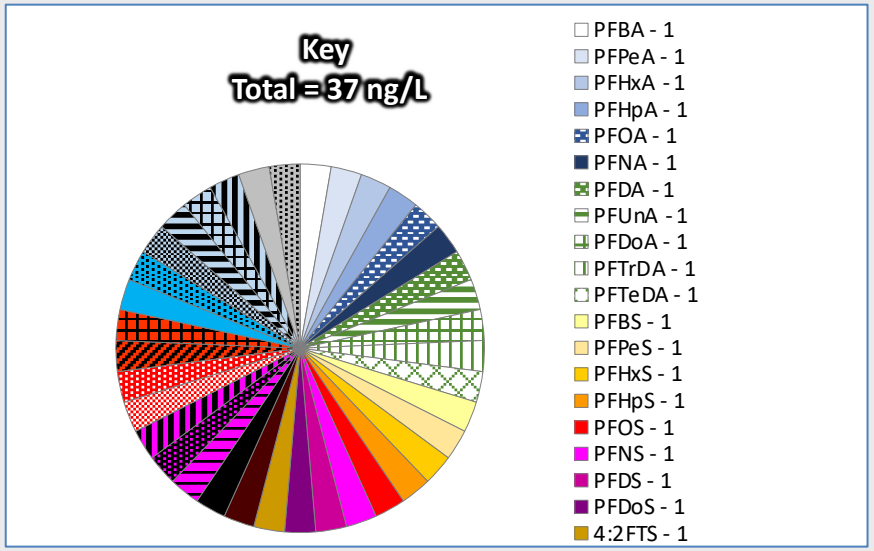
Industry or Product	How PFAS Used
Fire-fighting Foam	
Metal Plating	Mist suppressant, wetting agent
Textiles, Leather & Apparel	Waterproof clothing & shoes, stain-resistant carpeting
Plastics	Processing aid
Paper & Packaging	Water & oil-resistant paper products
Electronics	Magnetic tapes, cables, wires, circuit boards, semiconductors
Photography	Film, medical diagnostics
Cleaning Products	Alkaline cleaners, car wash products, concrete cleaner
Coatings: waxes, paints, inks, varnish	Paints, floor coverings, polishes
Pesticides	
Medicine	X-ray films, stents, contact lenses
Personal Care Products	Cosmetics, sunscreen, dental floss
Refrigerants	
Building & Construction	Concrete mixtures, coatings for buildings & roofs
Explosives	Infrared tracking flares, warheads
Oil & Gas Industry	Enhance recovery in oil wells, hydraulic oils, gasoline
Mining	Enhance metal recovery from oars, mist suppressant



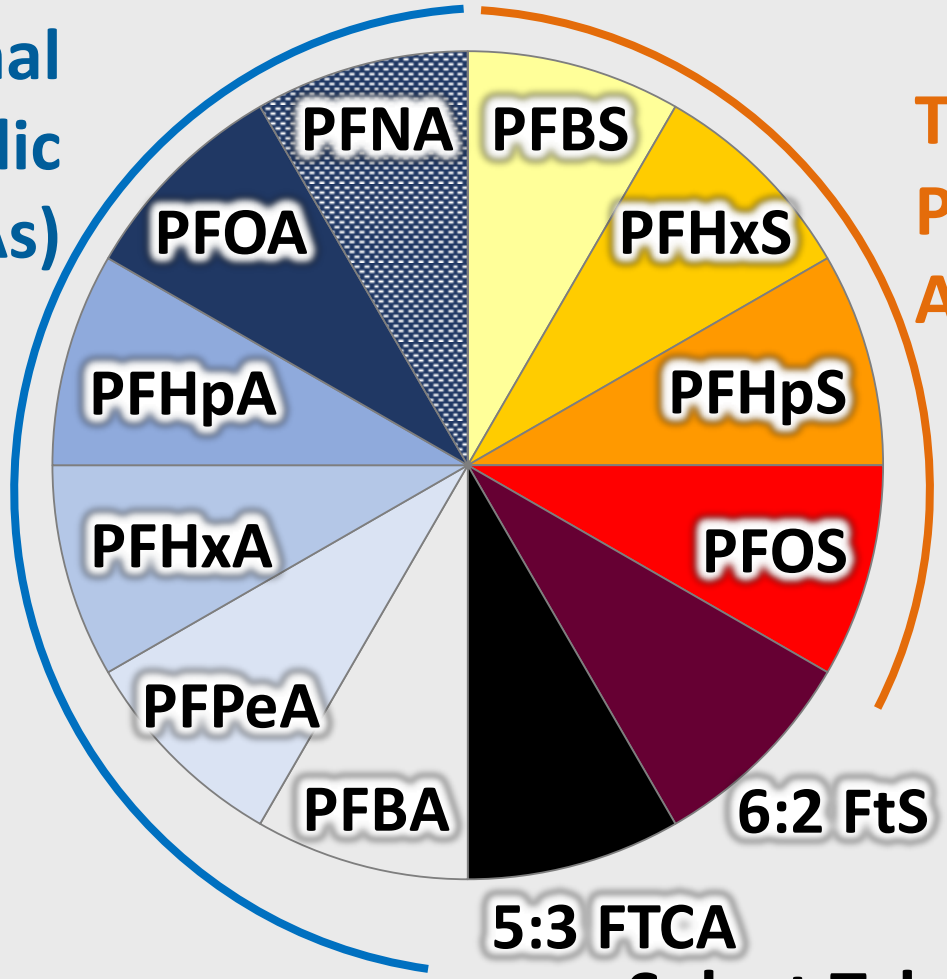


PFAS Forensics: Chemical Signatures

Example Analytes for Comparison



Terminal Perfluorocarboxylic Acids (PFCAs)

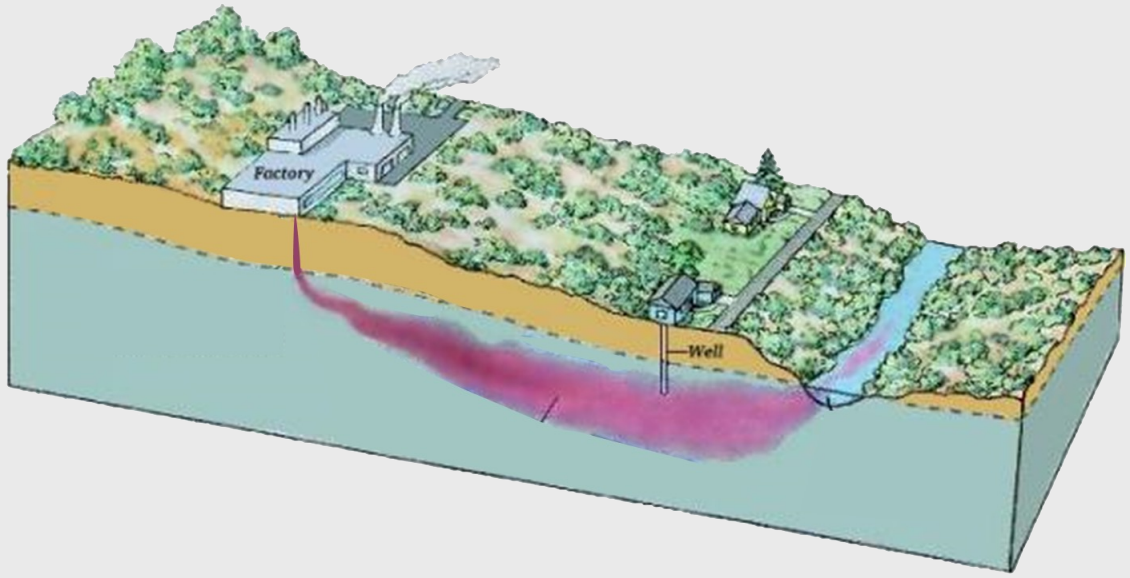


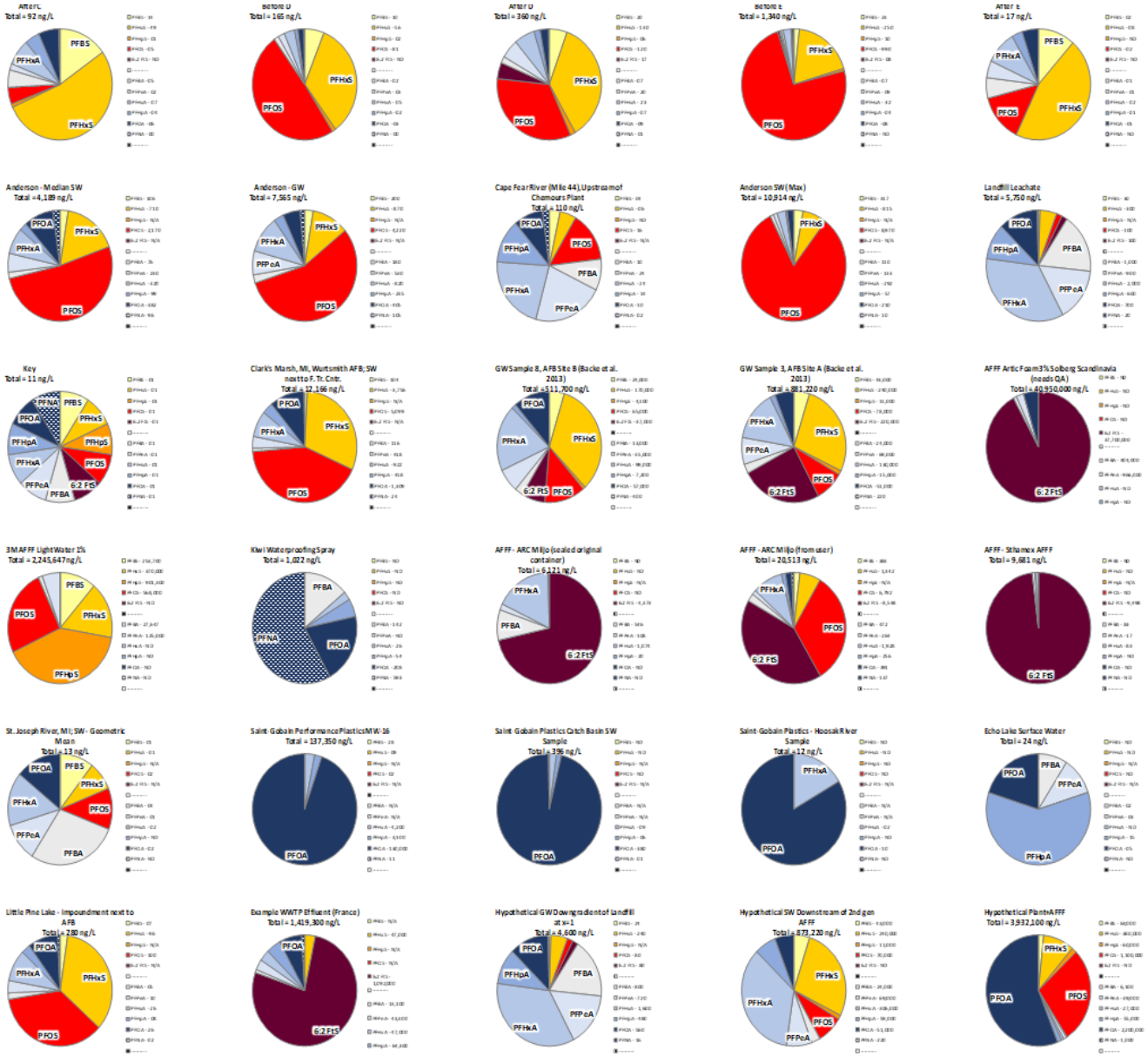
Terminal Perfluorosulfonic Acids (PFSAs)

Select Telomers *(transformable)*

Chemical Signatures

Signatures reflect various source and fate/transport scenarios





We Understand Signatures

Paper & Food Packaging

- **Side-chain fluoropolymers**
- PAPs/diPAPs
- **NEtFOSE**, **NEtFOSAA**, PFBS, PFOA, PFHxA

Textile & Leather

- Polymers
- Polymer raw materials
- PFOA, FTOHs

AFFF

- PFOA, PFOS, PFHxS
- C8 fluorotelomers (8:2 FTS)
- C6 fluorotelomers, PFOA

WWTPs & Landfills

- n:2 FTUCA
- n:3 FTCA **(5:3FTCA)**
- n:2 FTSA
- EtFOSA

Metal Plating

- PFOS
- 6:2 FTS, 8:2 FTS
- F53B

Types of Fluorine-Based AFFF

Legacy PFOS-based AFFF

- PFOS or PFOS "R" (PFOS with a functional group; PFOS derivative) based
- Developed in 1960s
- Production ended in 2002
- 3M "Light Water" (for example)
- Inventory remains in many locations
- Still major source of PFAS at AFFF-impacted sites
- **Contains PFOS & PFHxS; ratios may vary**

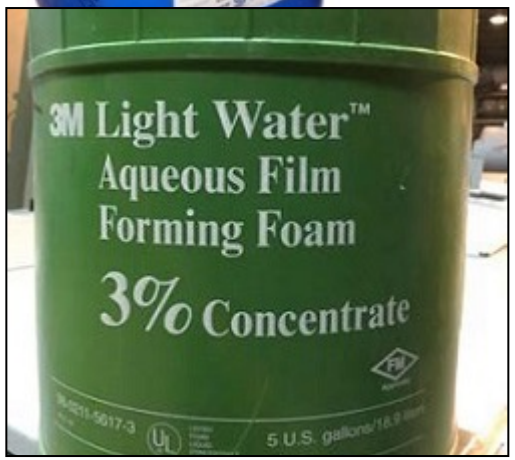
Legacy Fluorotelomer-based AFFF

- Sold from 1970s - 2016
- Mixture of 6:2 FTS and 8:2 FTS
- Fluorotelomer sulfonates can break down to PFCAs (PFBA, PFPeA, PFHxA, PFHpA, PFOA, PFNA)
- **Long-chain fluorotelomers (8:2 FTS) can breakdown to PFOA**

Modern Fluorotelomer AFFF

- 2010-Present
- Short-chain fluorotelomer sulfonates (6:2 and 4:2 FTS)
- Can breakdown to shorter chain PFCAs (PFBA, PFPeA, PFHxA, 5:3 FTCA)
- **Does not contain PFOS and no breakdown to PFOS or PFOA**
- **May contain trace amounts of PFOA as manufacturing impurity or byproduct**

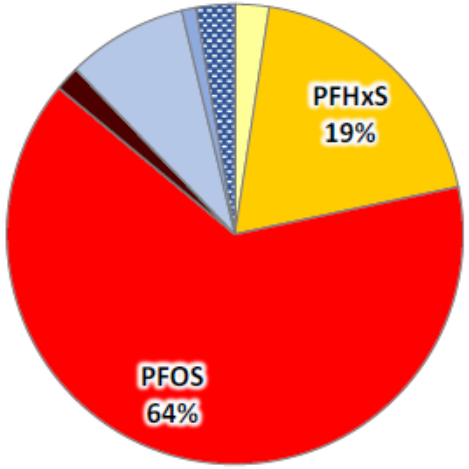
Aqueous Film Forming Foam (AFFF)



Data sources:

1. Swedish Chemicals Agency, 2015. Chemical Analysis of Selected Fire-fighting Foams on the Swedish Market 2014.
2. D. Herzke et al., 2009. Survey, screening and analysis of PFCs in consumer products, Swerea IVF project report 09/47.

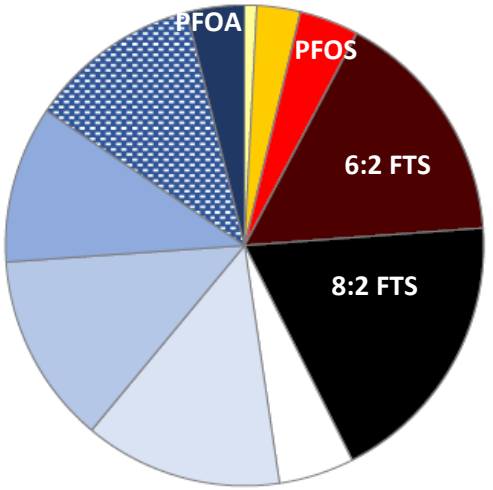
PFOS-Based AFFF



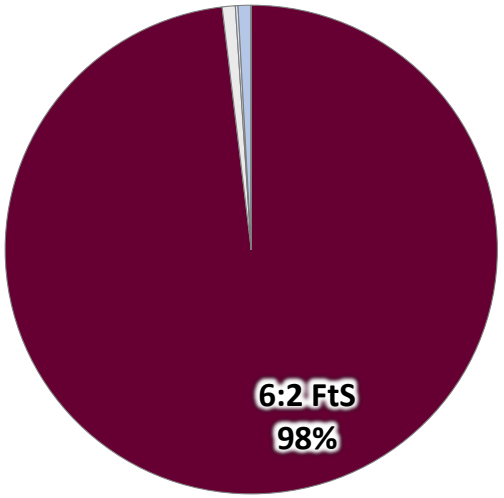
1st Generation

- Note: Typical composition is mainly PFOS and PFHxS
- Different lots may have different ratios of PFOS/PFHxS

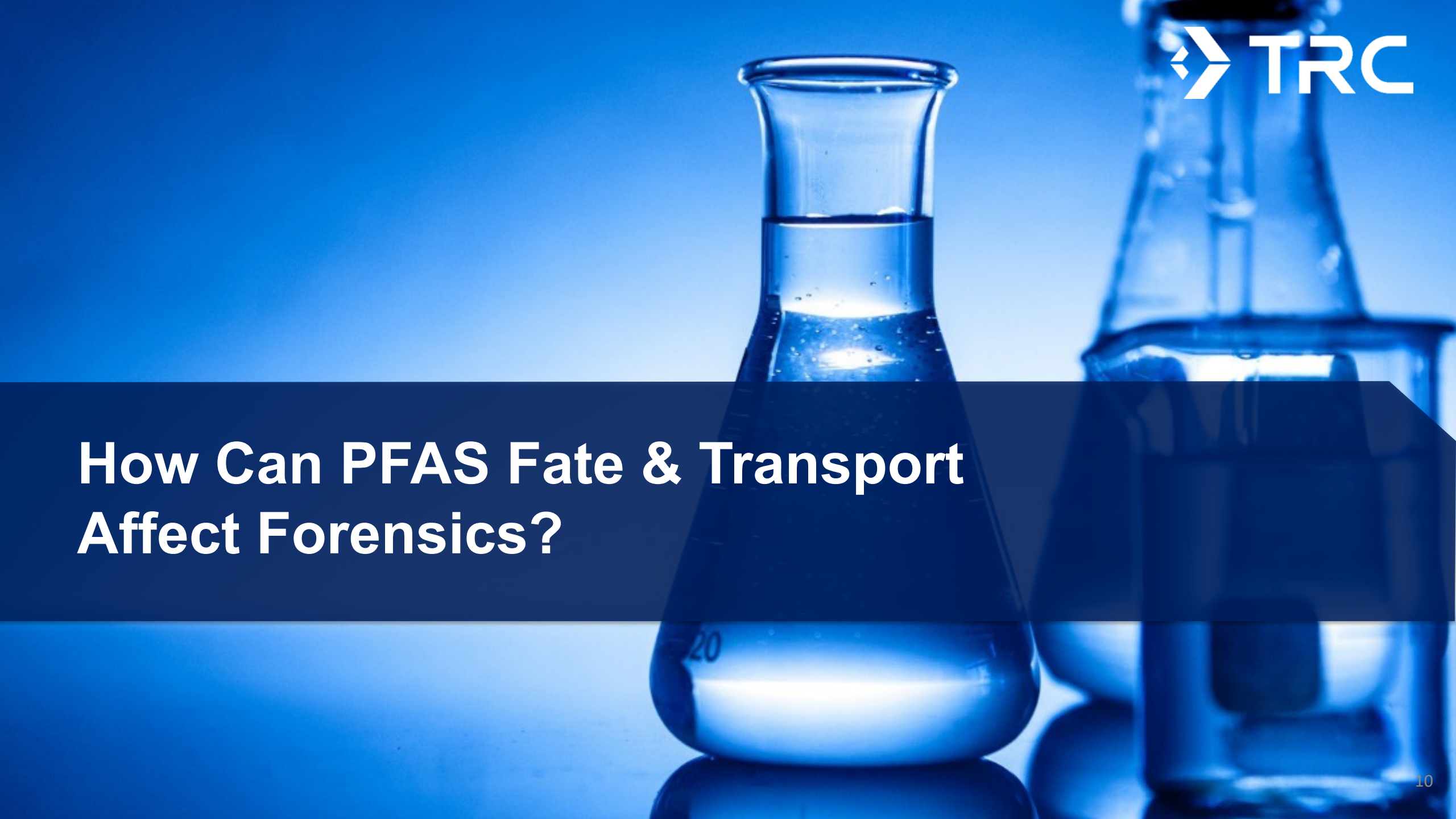
2nd Generation



8:2 and 6:2 FTS-Based



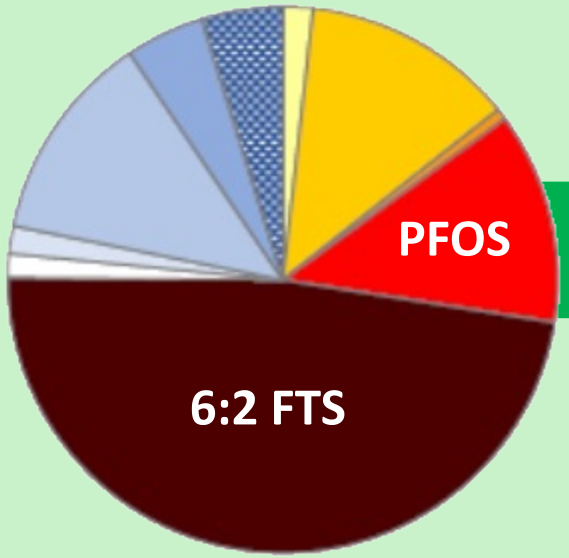
Modern Fluorotelomer (6:2 FTS)



How Can PFAS Fate & Transport Affect Forensics?

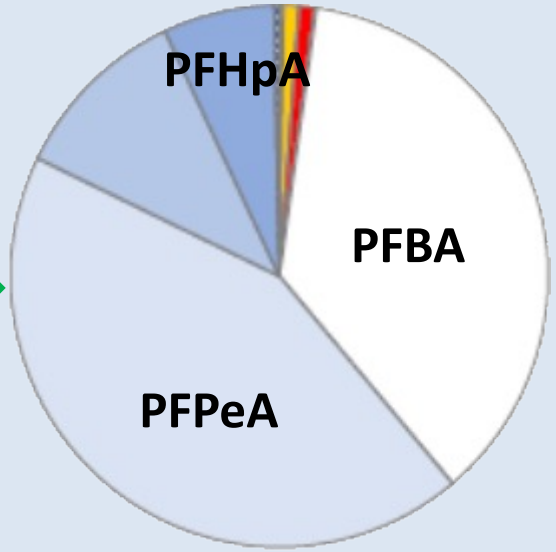
Fate & Transport: PFAS Transformation

Pre-TOP Assay
Total PFAS **100,000 ng/L**



Accelerated Weathering

Post-TOP Assay
Total PFAS **1,200,000 ng/L**



Concentrations ng/L	Pre-TOP	Post-TOP
6:2 FTS	40,000	1,000
PFOS	10,000	11,000
PFPeA	1,300	520,000
PFBA	1,100	400,000
PFHpA	4,000	80,000

Issue: Thousands of PFAS **precursor** compounds can transform in the environment to the persistent PFAS

Example Polyfluoroalkyl Precursors:

- N-methyl perfluorooctane sulfonamidoacetic acid (NMeFOSAA)
- N-ethyl perfluorooctane sulfonamidoacetic acid (NEtFOSAA)
- 6:2 Fluorotelomer sulfonic acid (6:2 FTSA)
- 8:2 Fluorotelomer sulfonic acid (8:2 FTSA)
- 4:2 Fluorotelomer sulfonic acid (4:2 FTSA)
- 10:2 Fluorotelomer sulfonic acid (10:2 FTSA)
- N-Methyl perfluorooctane sulfonamidoethanol (N-MeFOSE)
- N-Ethyl perfluorooctane sulfonamidoethanol (N-EtFOSE)
- N-Methyl perfluorooctane sulfonamide (MeFOSA)
- N-Ethyl perfluorooctane sulfonamide (EtFOSA)

TOP = Total Oxidizable Precursor

Rules of Thumb

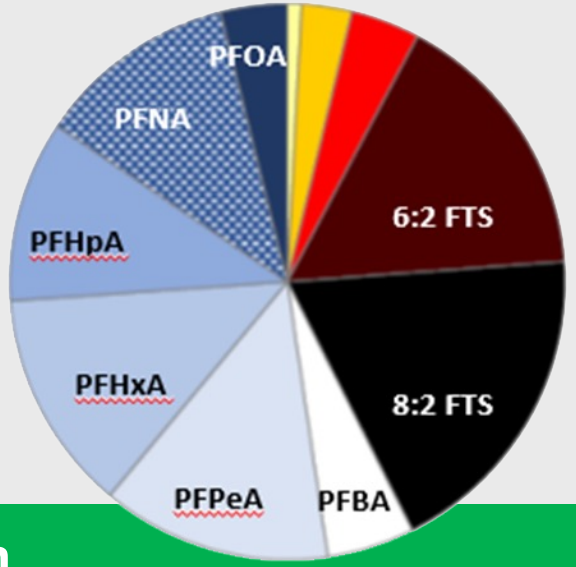
6:2 FTS → PFBA, PFPeA, PFHxA, PFHpA

8:2 FTS → PFBA, PFPeA, PFHxA, PFHpA, PFOA

Fate & Transport: PFAS Transformation
TOP Assay and AFFF: Some Simple Tips on Interpretation

Rules of Thumb	
6:2 FTS →	PFBA, PFPeA, PFHxA, PFHpA
8:2 FTS →	PFBA, PFPeA, PFHxA, PFHpA, PFOA

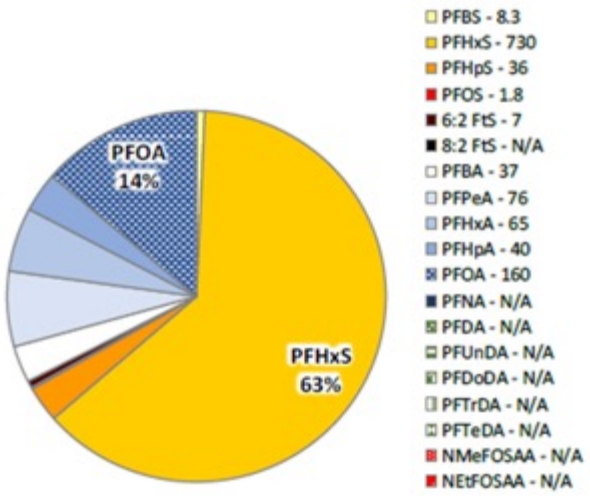
Perfluorocarboxylic acids (PFCAs)



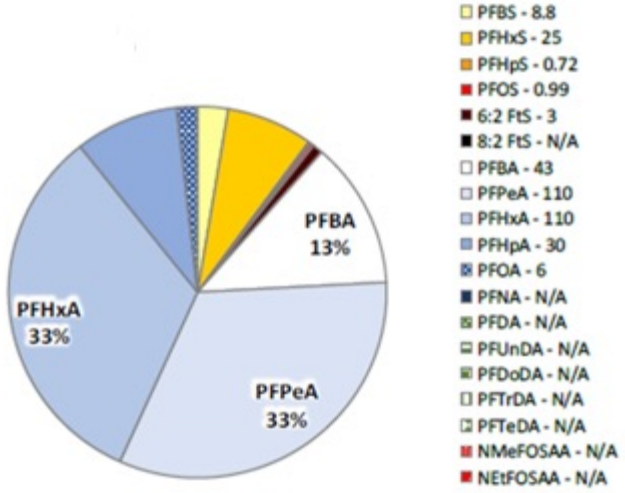
TOP Assay Results	Potential Source Identification
PFBA and PFPeA more prevalent than other PFCAs	Likely 6:2 FTS AFFF
Consistent PFHxA/PFPeA ratio	Likely 6:2 FTS AFFF
High concentration of PFOA with absence of PFHpA	8:2 FTS AFFF likely not main source of PFOA based on aerobic transformation pathway of 6:2 FTS which shows consistent ratios of PFHxA to PFPeA
Presence of PFHpA and PFOA	May indicate presence of 8:2 FTS
Increase in PFHxS/PFOS ratio	Likely ECF-based Legacy AFFF

Fate & Transport: Sorption to Solids

Sample from 1" temporary well turbid



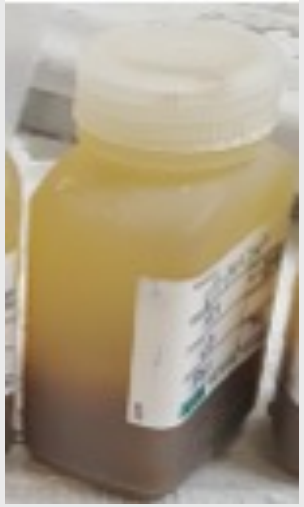
Sample from 2" developed MW clear



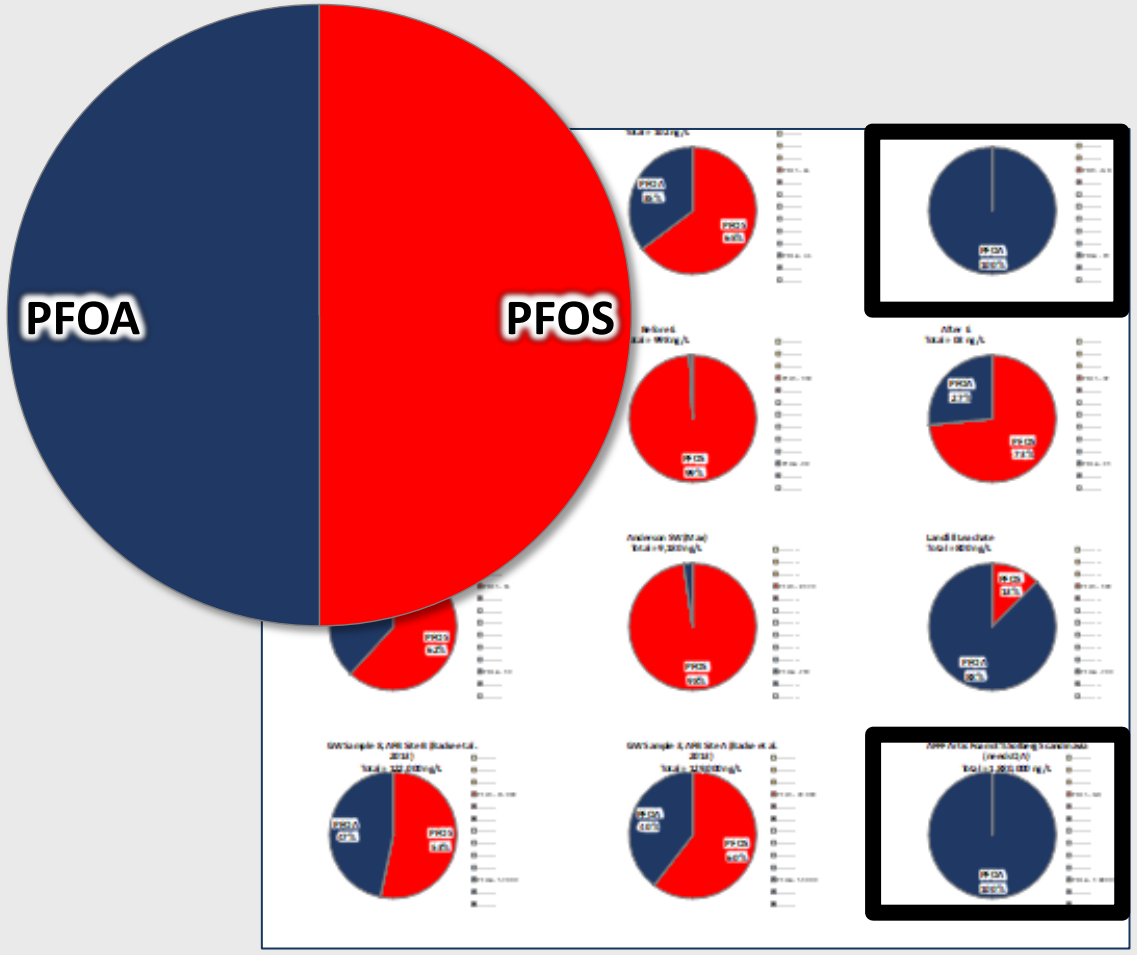
Issue: Chemical sorption of PFAS to particulates or solids. Longer-chain PFAS and PFSAs tend to absorb more to solids.

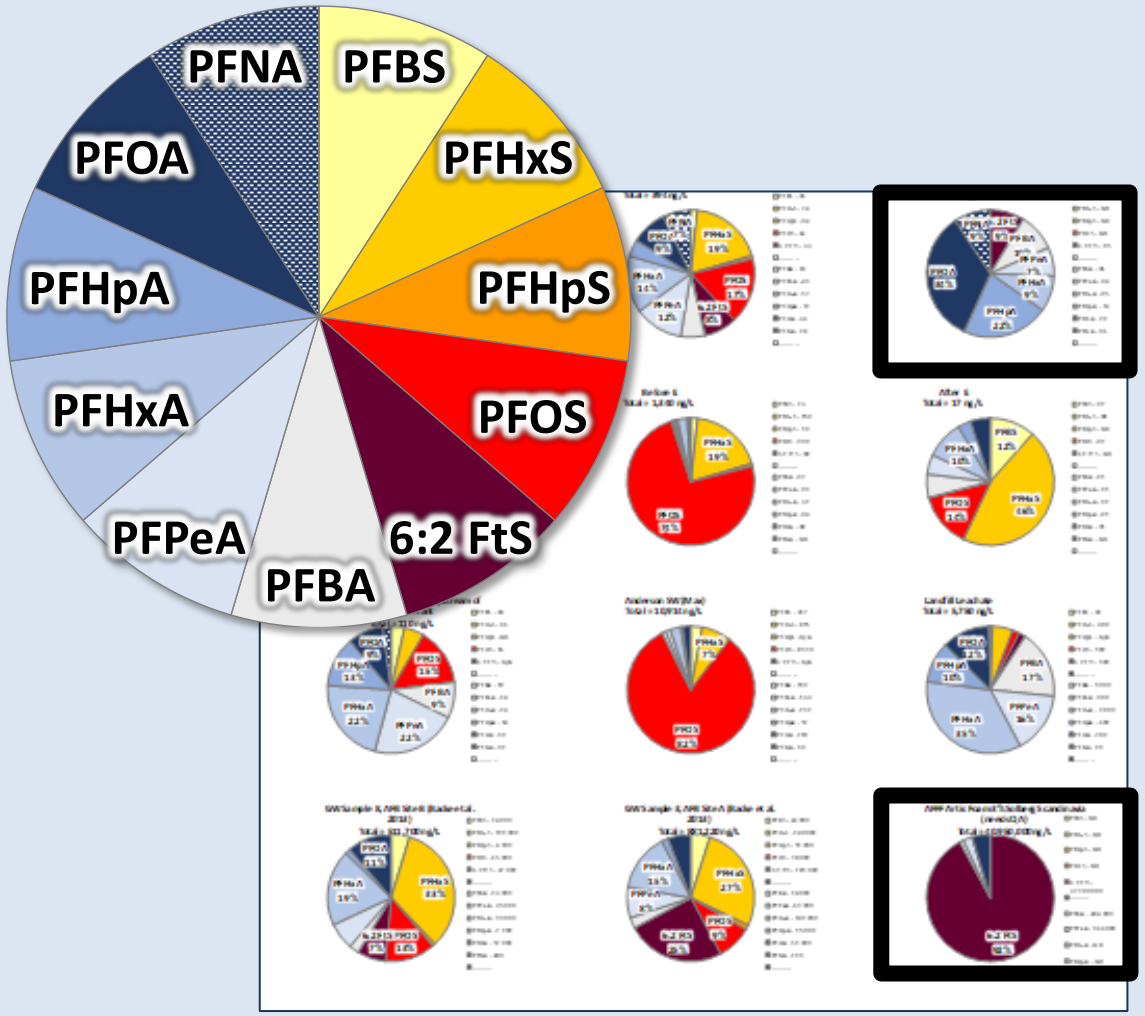
- Particulates in aqueous samples can interfere with extraction procedure.
- Labs have variable procedures for dealing with this; can vary from lab to lab and within a lab.

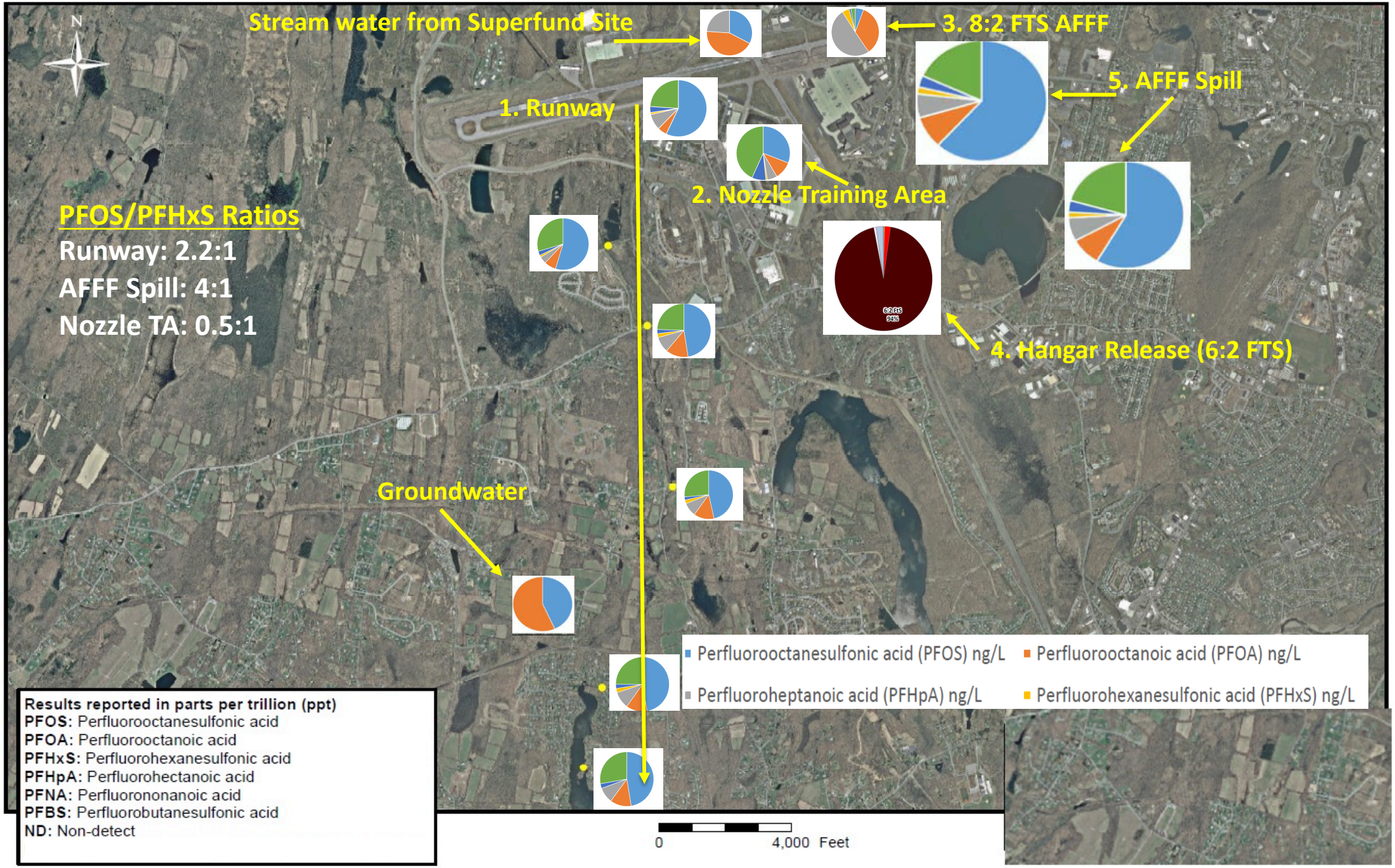
1. *Floating particulates versus sediment which has settled at the bottom of the container*
2. *Centrifuge and decant*
3. *Just decant*
4. *Rinse the remaining particulates or sediment with methanol and include the methanol rinse in the extraction*
5. *Perform an extraction of the particulate or sediment portion of the sample*
6. *Dealing with particulates that clog extraction cartridges*
7. *Documentation of issues with particulates by laboratory*
8. *Cut-off value for total suspended solids (TSS) causing extraction issues*



Example Difference Based on Analytes Selected for Signature Evaluation






Stream water from Superfund Site
3. 8:2 FTS AFFF
5. AFFF Spill
1. Runway
2. Nozzle Training Area
PFOS/PFHxS Ratios
Runway: 2.2:1
AFFF Spill: 4:1
Nozzle TA: 0.5:1
4. Hangar Release (6:2 FTS)
Groundwater
Perfluorooctanesulfonic acid (PFOS) ng/L
Perfluorooctanoic acid (PFOA) ng/L
Perfluoroheptanoic acid (PFHpA) ng/L
Perfluorohexanesulfonic acid (PFHxS) ng/L
Results reported in parts per trillion (ppt)
PFOS: Perfluorooctanesulfonic acid
PFOA: Perfluorooctanoic acid
PFHxS: Perfluorohexanesulfonic acid
PFHpA: Perfluorohectanoic acid
PFNA: Perfluorononanoic acid
PFBS: Perfluorobutanesulfonic acid
ND: Non-detect
0
4,000 Feet

Takeaway Messages

- Chemical signatures can be a useful forensic tool.
- The choice of PFAS selected for signature evaluation must be considered.
- Very large group of transformation intermediates presents a challenge to data interpretation.
- An integrated, multiple lines-of-evidence approach is always warranted.
- High-quality hydrogeologic evaluation is critical.
- Signatures cannot be evaluated in isolation.

Questions?

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Thank you

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