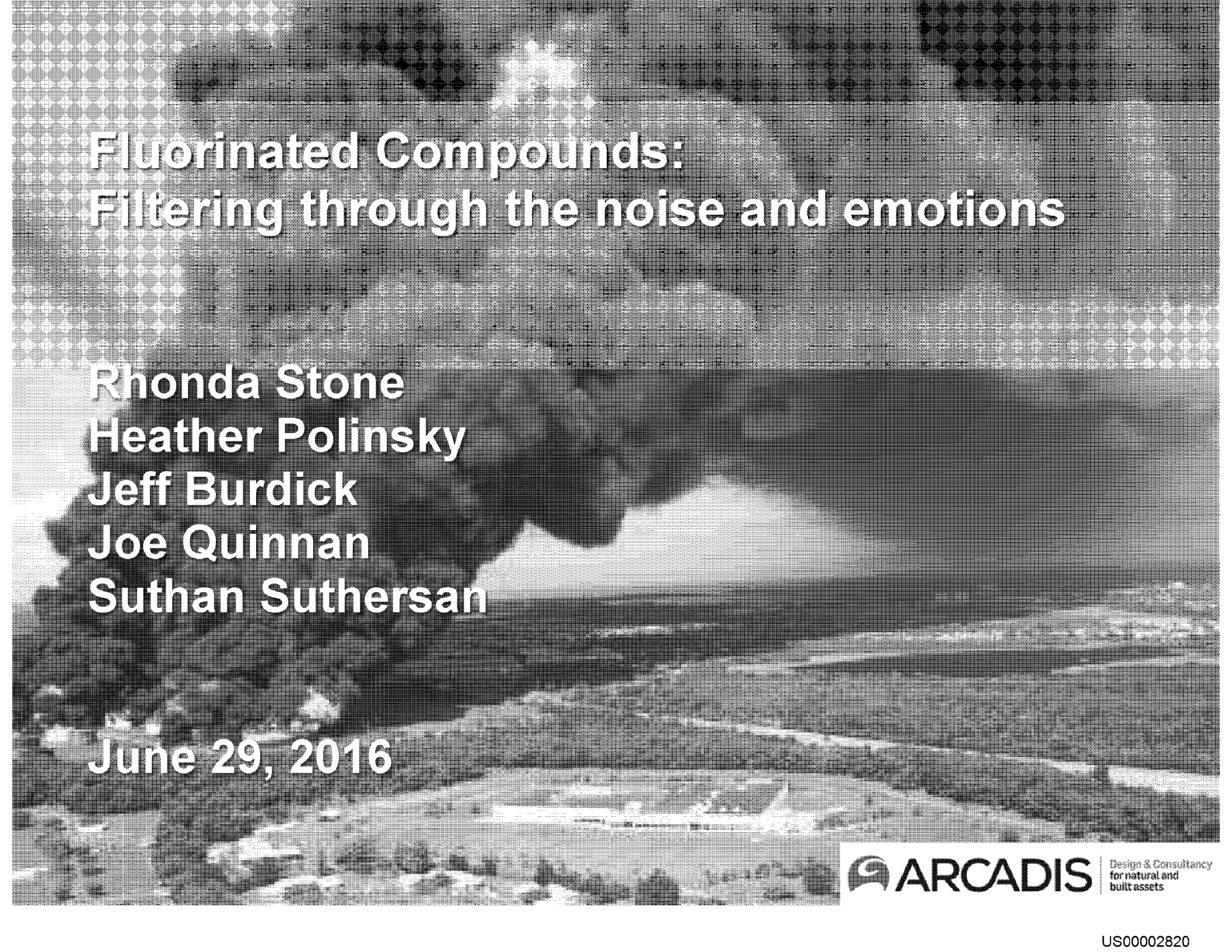




Fluorinated Compounds: Filtering through the noise and emotions

**Rhonda Stone
Heather Polinsky
Jeff Burdick
Joe Quinnan
Suthan Suthersan**

June 29, 2016

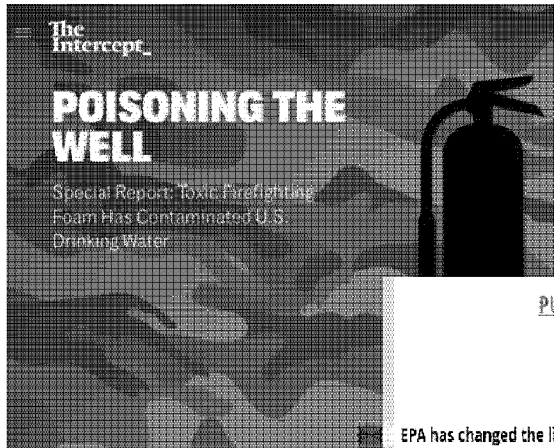
Learning Objectives

- Overview of the PFAS issue to provide the knowledge needed to avoid impulsive reactions
- Understand how PFAS reacts in the environment to ensure the most appropriate sampling and analytical methods and treatment technologies are selected
- Have the information needed to allow you to focus on your mission and direct your program going forward.

Overview of the PFAS Issue

*With knowledge you can avoid
impulsive decisions*

PFAS in the Headlines



Horsham Water and Sewer Authority Takes 2 Wells Out of Service Due to Detection of Perfluorooctane Sulfonate (PFOS) Above Provisional Health Advisory Level

Two of the Authority supply wells, Well No. 26 and Well No. 40 were recently found to have PFOS above the PHA level (detected at 0.7 ppb and 1.0 ppb respectively). PFOS was also detected in other Authority wells but not above the PHA level. After consulting with DEP, the Authority decided to take Well Nos. 26 and 40 off-line.

PUBLIC NOTICE FROM YOUR WATER AUTHORITY

FORMER NASJRS WILLOW GROVE, PA
FORMER NAWC WARMINSTER, PA
HORSHAM AIR GUARD STATION, PA

EPA has changed the limit for PFCs to a health advisory with lower long-term limits. Due to this change the Warminster Authority has removed three additional wells from production. All three wells were currently tested to meet this new standard but at one time tested close or over the limit. Three previous wells taken out of service are under construction for carbon filtration to remove PFC's. We continue to meet the regulatory standards issued by EPA for PFC's.

Contact the appropriate military service representative or visit these websites:

http://www.bracpmo.navy.mil/brac_bases/northeast/reserve_base_willow_grove.html
http://aracpmo.navy.mil/brac_bases/northeast/former_warfare_center_warminster.html
<http://www.11attackwing.af.mil/>

Navy: Mr. Willington Lin, BRAC Environmental Coordinator; 4811 South Broad Street, Philadelphia, PA 19112. Phone (215)897-4900 or e-mail willin.lin@navy.mil
Air National Guard: Mr. Keith Freihofer, Environmental Restoration Program Manager; 3501 Fetched Ave - Sheppard Hall, Joint Base Andrews, MD 20762-5137. Phone (240)612-8762

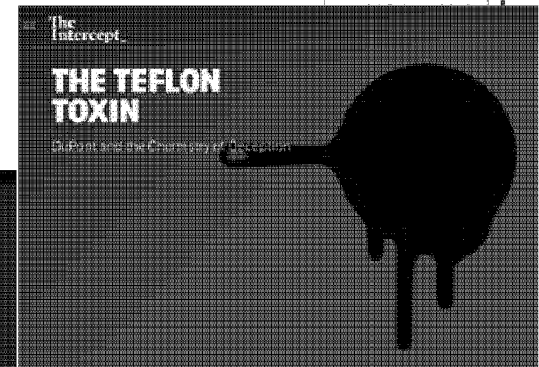
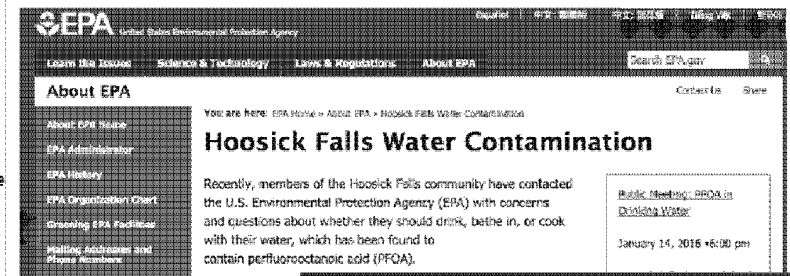


THE WASHINGTON POST

The FDA Just Banned These Chemicals in Food. Are They the Tip of the Iceberg?

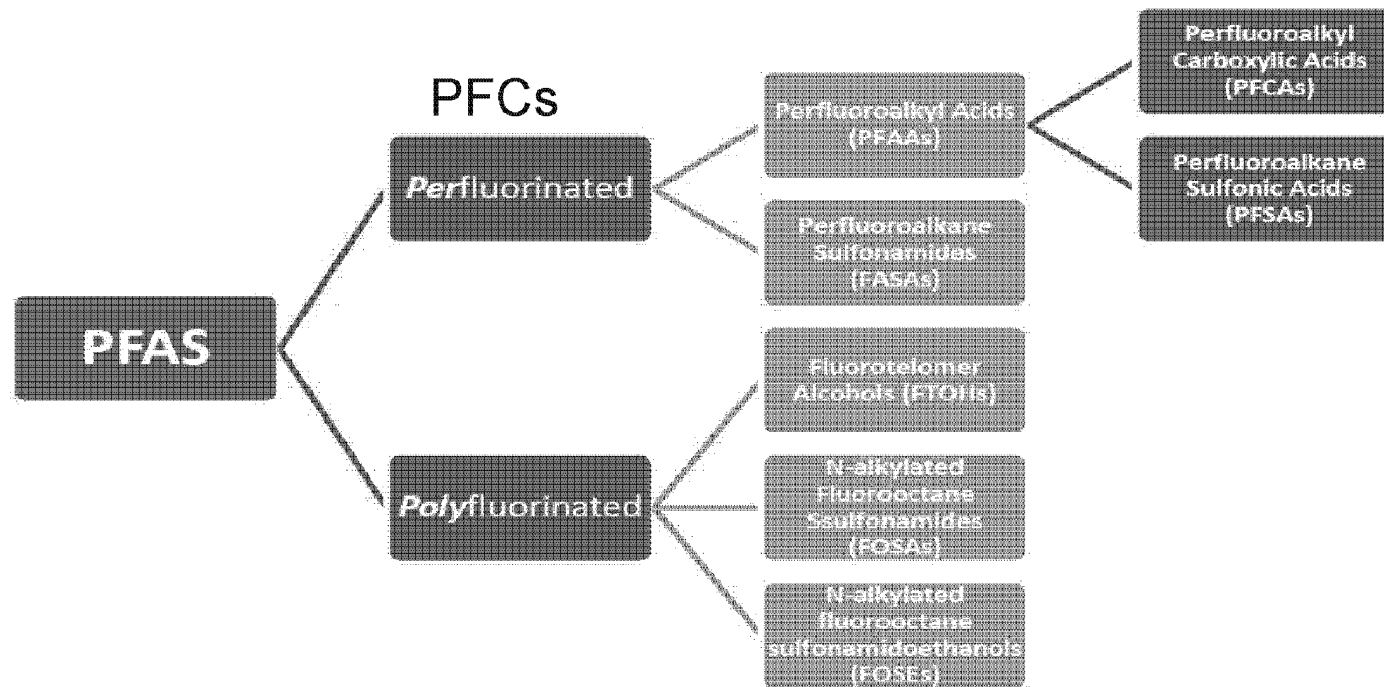
FDA banned three toxic food packaging chemicals and is considering banning seven cancer-causing food flavoring chemicals, but food safety advocates say the process highlights flaws in the system.

THE WASHINGTON POST, JANUARY 13, 2016



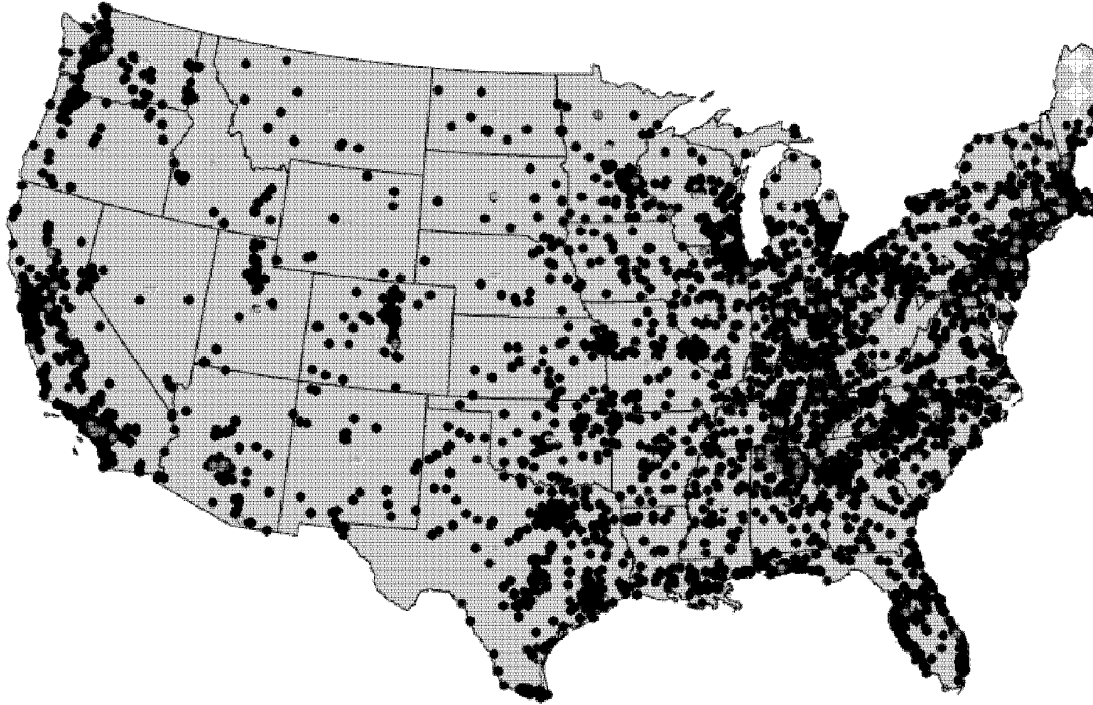
The Emotional State of Heightened Awareness & Accelerated Activity

Some call it “PFAS” and others “PFCs”...



- PFAS include PFOS, PFOA and approximately 6,000 fluorinated compounds
- AFFF contains > 200 PFAS compounds

Magnitude of Problem



USEPA – Unregulated contaminant
monitoring rule #3, UCMR3 2013-15

Detected in ~ 2% of p
Standard has dropped by



63 water utilities with PFOS
and/or PFOA detections
above Health Advisory

Health Advisories for long
term exposure to PFOS and
PFOA in drinking water
(May 2016):

- 70 ppt combined

Previous Provisional Health
Advisories for short term
exposure (2009)

200 ppt PFOS

400 ppt PFOA

**Public water supplies
by an Order of Magnitude**

Challenges Facing DOD

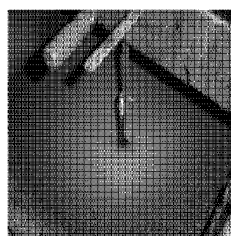
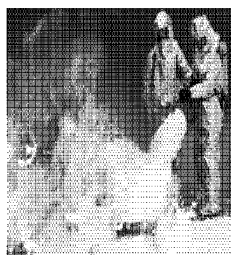
- Regulatory drivers
- Budget constraints
- Need for standardized guidance
- Public outcry
- Congressional pressure
- Impact to 2018/2021 DERP Goals
- Inconclusive and evolving information

What are YOUR Priorities?

PFAS/PFOA Ubiquitous Environment

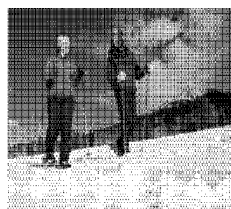
Surface Treatment

- Carpet Protector
- Fabric/upholstery protector
- Apparel and leather protector
- Protective products for consumer applications

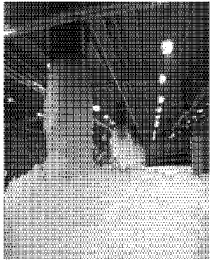


Paper and Packaging Protectors

- Food packaging
- Paper products

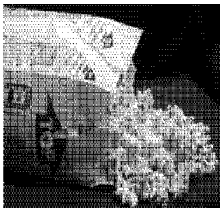
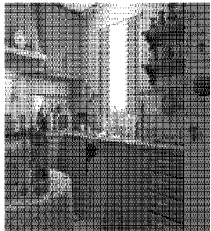


tous in the



Performance Chemicals

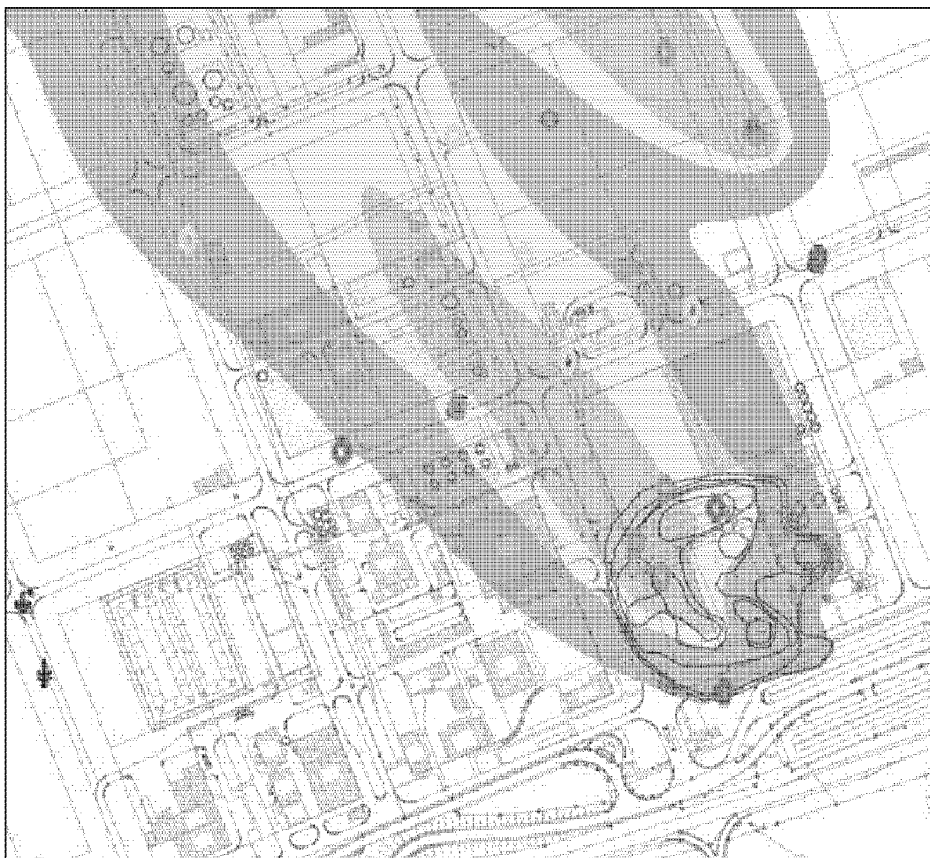
- Fire Extinguishing foam concentrates
- Mining and oil surfactants
- Electroplating and etching bath surfactants
- Household additives
- Chemical intermediates
- Coatings and Coating Additives
- Carpet spot cleaners
- Insecticides raw materials



Many Potential Sources

- Fire Training Areas
- Fire Stations
- Airfields/Airports
- Hangars
- Landfills
- Wastewater
- Plating
- Photo development

es

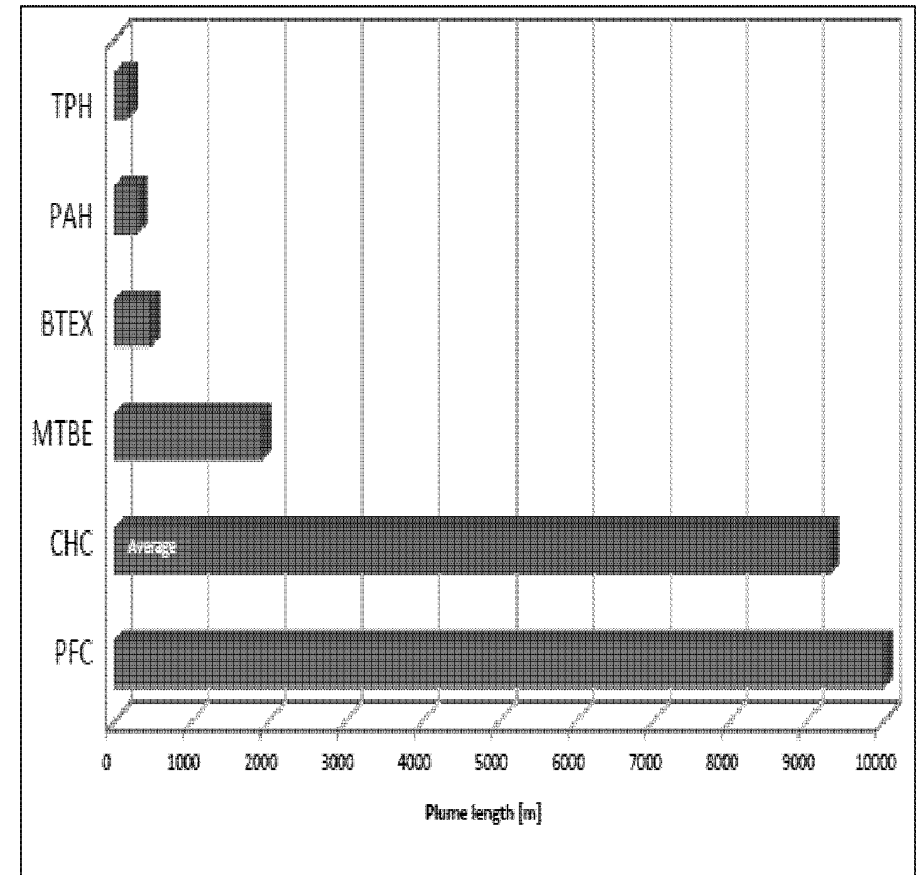


Chemical Properties and Implications

PFAS plumes are generally longer

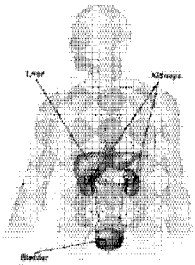
- High solubility
- Low log K_{oc}
- Recalcitrant
- Mostly Anionic

Chemical Properties	PCB (Arochlor 1260)	PFOA	PFOS	TCE	Benzene
Molecular Weight	357.7	414.07	538	131.5	78.11
Solubility (@20-25°C), mg/L	0.0027	3400 – 9500	519	1100	1780
Vapor Pressure (@25°C), mmHg	4.05×10^{-5}	0.5-10	2.48×10^{-6}	77.5	97
Henry's Constant, atm-m ³ /mol	4.6×10^{-3}	1.01×10^{-4}	3.05×10^{-9}	0.01	0.0056
Log Koc	5 – 7	2.06	2.57	2.473	2.13

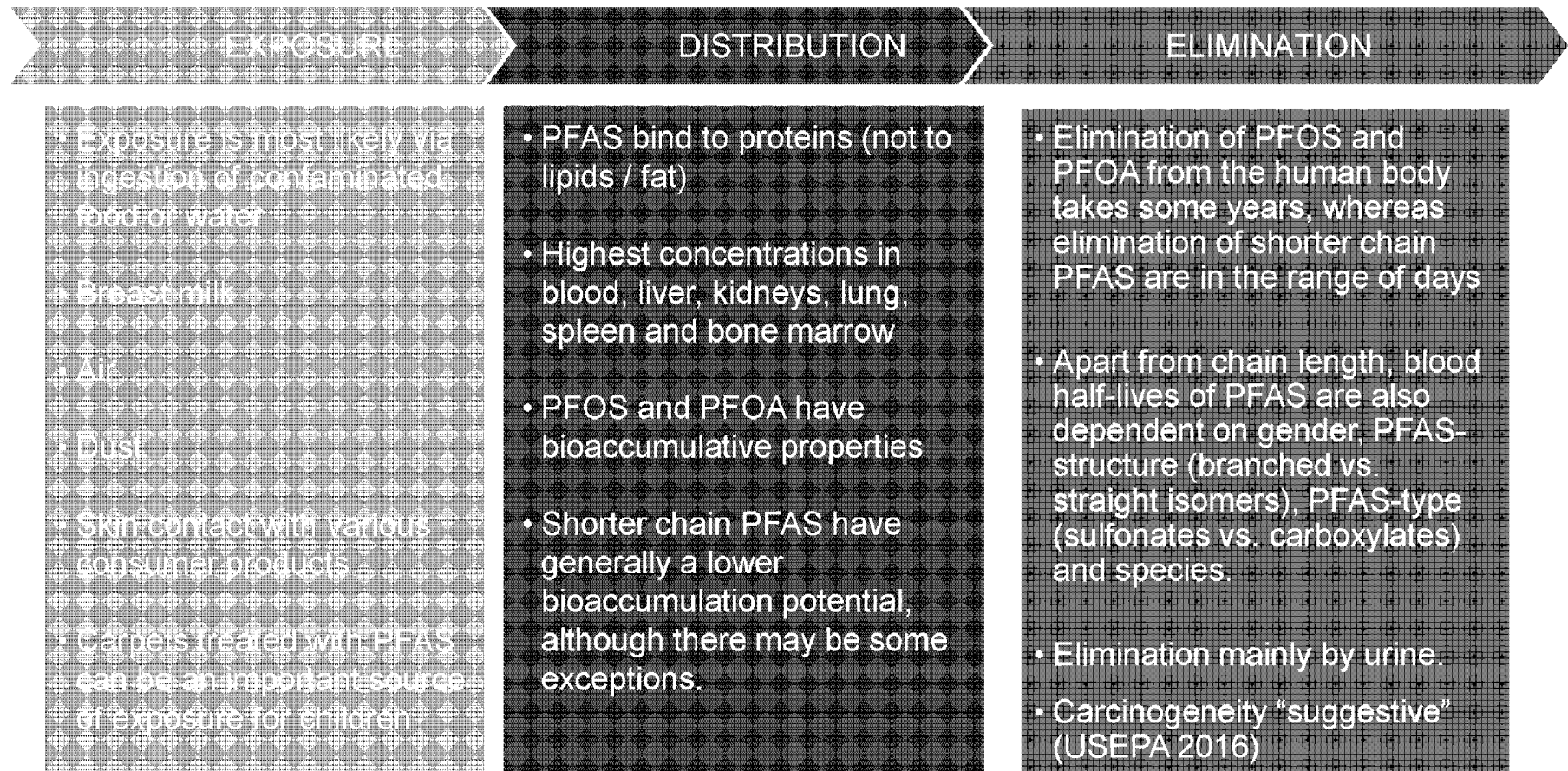


Persistence and mobility can lead to large plumes

28 June 2016

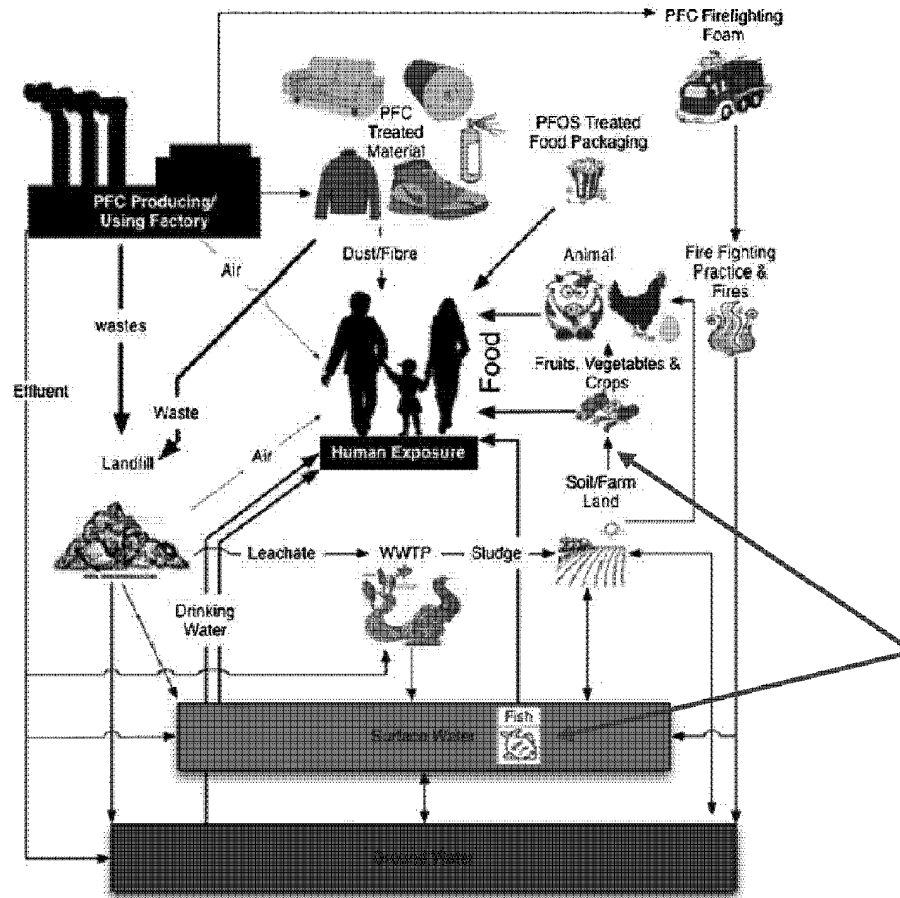


PFAS: Health Effects a Debate over Correlation and Causality



Data on toxicity on other PFAS compounds than PFOS and PFOA is meager and inconsistent.

What's Driving the PFAS Standards?

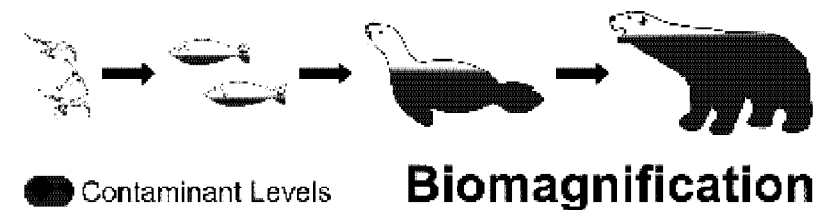
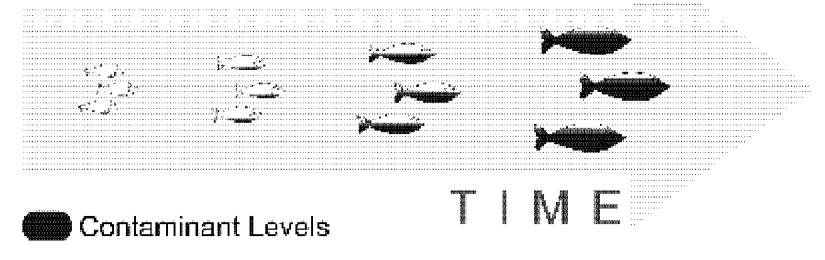


The PFAS web

Oliaei et al. Environ. Sci. Pollut Res (2013) 20: 1977-1992

- USEPA has selected RfD for PFOS and PFOA of 20 ng/kg bw/day (May 2016)
- European Food Safety Authority (2008:) established a TDI for PFOS and PFOA of 150 ng/kg bw/day and 1.500 ng/kg bw/day

Bioaccumulation



Multiple exposure pathways for PFAS compounded via bioaccumulation / biomagnification

Will Europe's Trends Influence the US?

Europe has been regulating PFAS for more than a decade

- Sweden's standard is sum of 12 PFAS compounds < 100 ppt
- Denmark's standard is sum of 7 PFAS < 90 ppt
- Germany, UK and the Netherlands have standards in 100's ppt
- European proposed surface water standard is even lower, 0.65 ppt for inland waters, due to bioaccumulation in fish

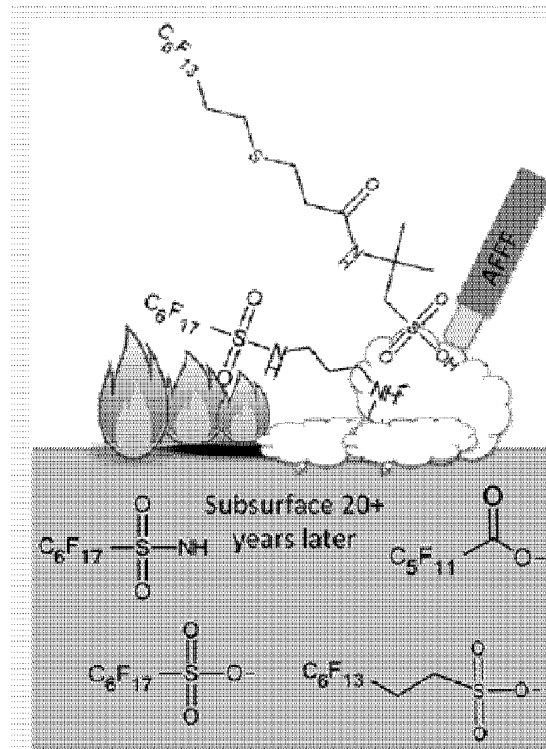
Why so low?

- PFOS and PFOA are classified as persistent, bioaccumulative and toxic
 - PFOS banned globally under Stockholm Convention
 - PFOA voluntarily phased out of manufacturing, replaced by shorter-chained PFAS
- On-going evaluation of shorter-chained PFAS health effects

PFAS In the Environment

*Choose the Right Techniques to
Make Effective Decisions*

Are the current analytical techniques (EPA 537) adequate?



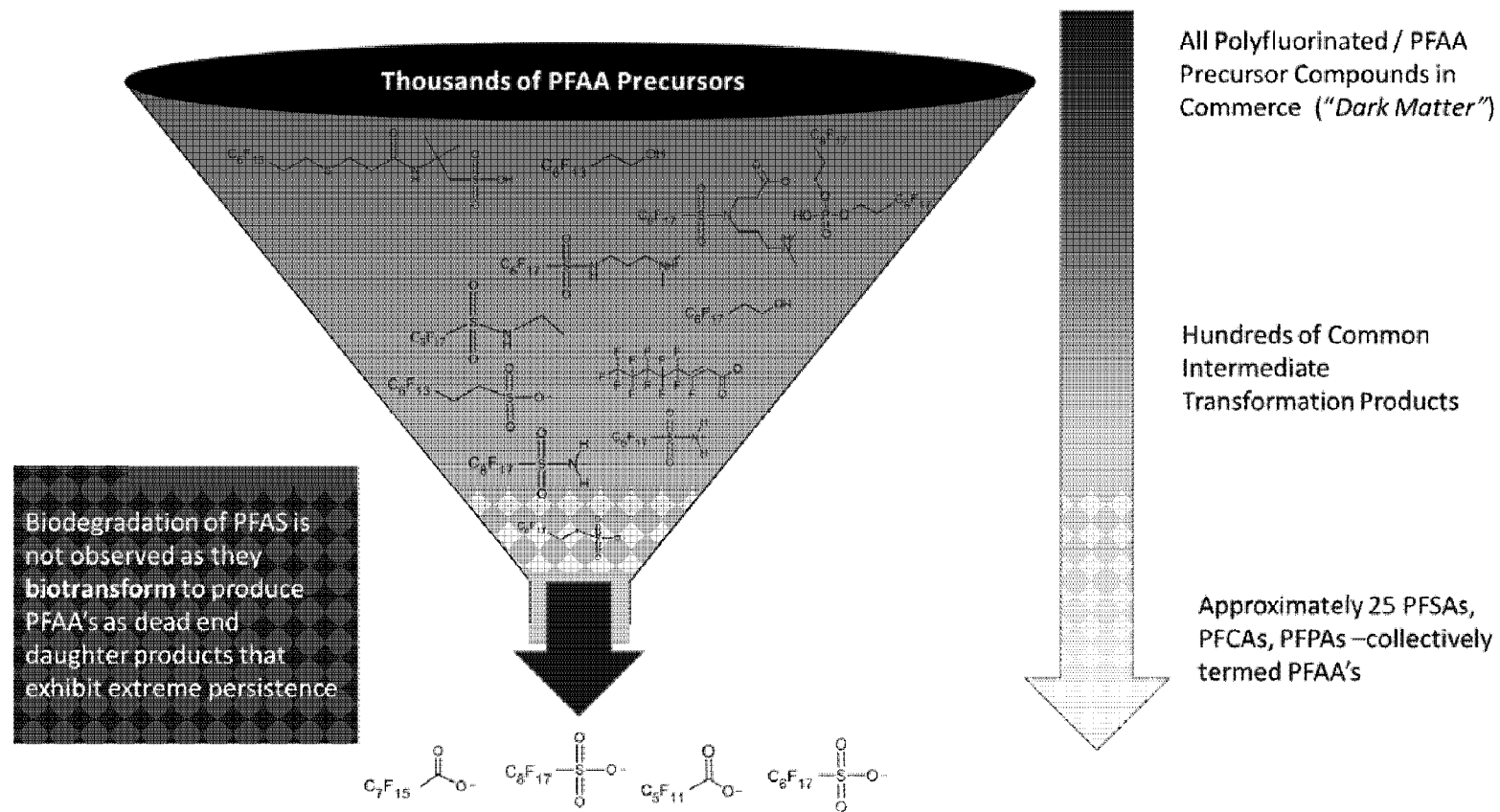
Are you getting a complete picture?

Analysis by EPA Method 537

- Offered by a number of laboratories including TestAmerica, Pace Analytical, ALS Global, SGS Accutest, and BSK Associates
- Sample costs range from ~\$250 to \$550 per groundwater sample and \$250 to \$350 per soil sample
- Analysis for selected perfluorinated alkyl acids (PFAAs)
 - Number of analytes reported for groundwater ranges from six analytes for the UCMR3 list up to 23 analytes using an expanded list
 - Number of analytes reported for soil ranges from 6 for the UCMR3 list to 16 analytes using an expanded list
 - Expanding the list of compounds that could be analyzed by Method 537 is limited by the availability of standards
- Detection limits for groundwater range from 2 and 20 nanograms per liter (ng/L).
- Detection limits for soil range from 0.2 micrograms per kilogram ($\mu\text{g/kg}$) to 25 $\mu\text{g/kg}$.

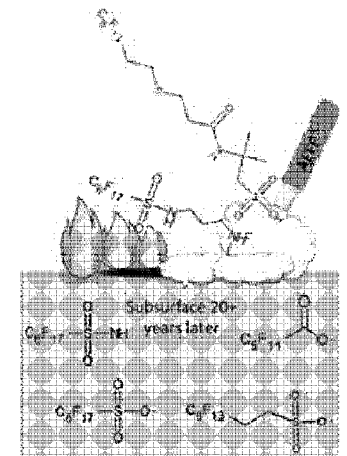
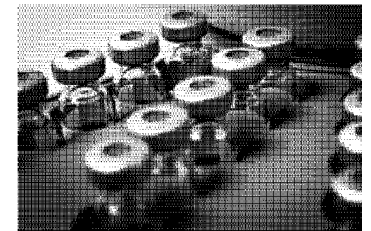
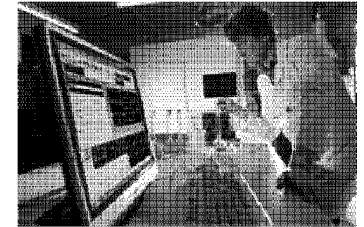
Other sample analyses are needed for site characterization...

Aerobic Biotransformation of Precursors – Implications for Risk, Fate & Transport and Remediation

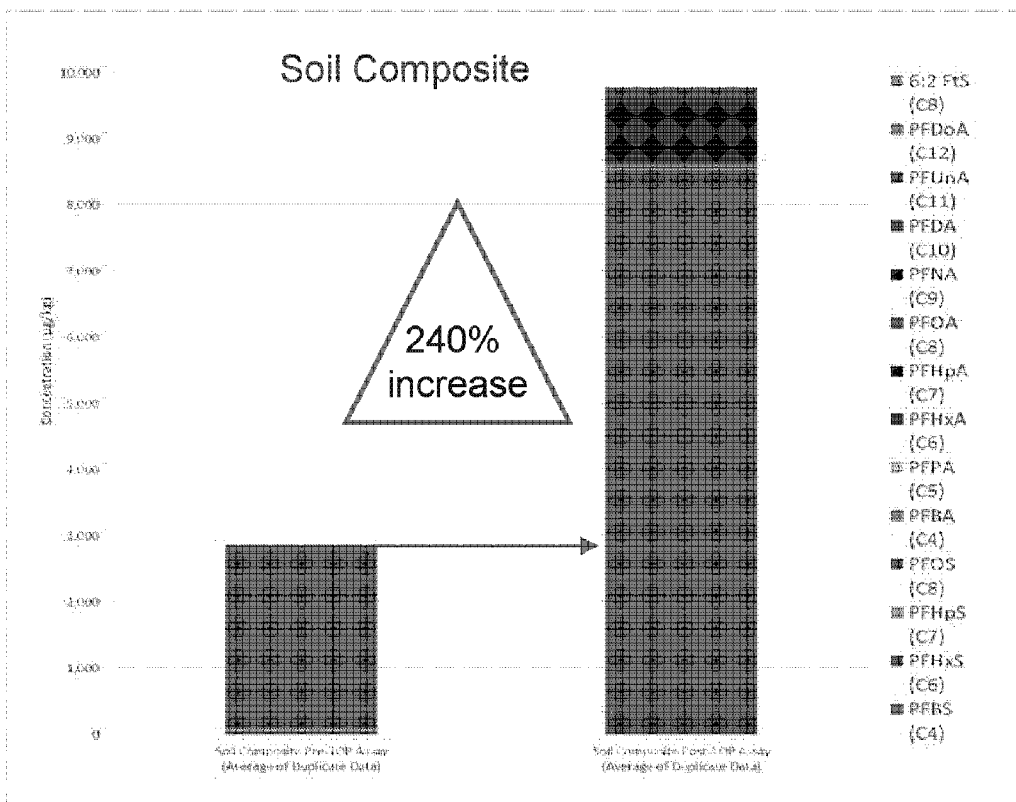


Expanding analytical tool box for precursors

- Total oxidizable precursors (TOP) Assay –
 - Pretreatment of sample prior to LCMSMS
 - Detection limits to ~ 2 ng/L
- Particle-induced gamma emission (PIGE) Spectroscopy
 - Separation of organofluorine compounds + total fluorine analysis (analogous to TPH for hydrocarbons)
 - Detection limits to ~ 2 ug/L F
- Adsorbable organofluorine (AOF)
 - Process with activated carbon and subsequent analysis by CIC
 - Detection limits to ~ 1 ug/L F



EPA Method 537 Under Potential Source Term



**Hidden Mass or “Dark Matter”
CSM, Fate and Transport and**

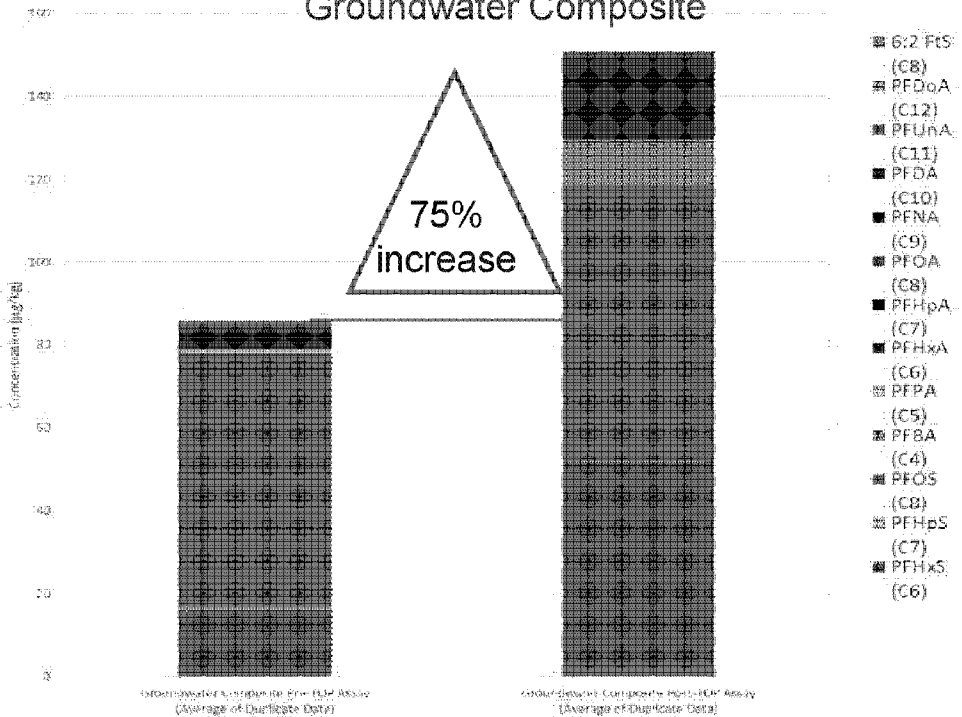


ARCADIS

Design & Consultancy
for natural and
built assets

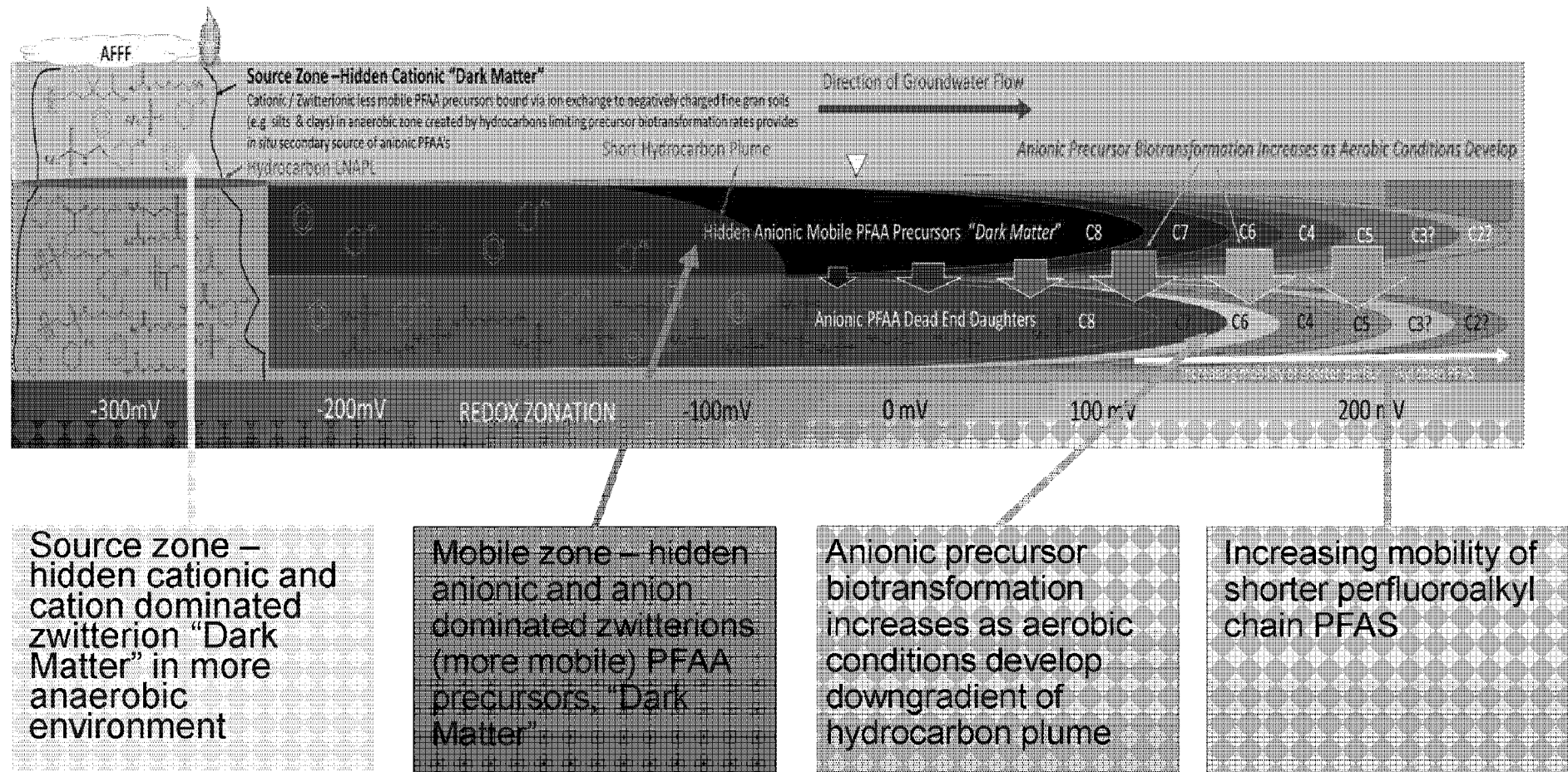
reestimates the

Groundwater Composite



er” – Implications for Risk, nd Remediation

Conceptual Site Model - AFFF Fire Training Area



CSM is critical in framing long term liability/strategy

Understand Your Risks – Make Informed Decisions

- Fire Training Center for AFFF testing and trials since 1970's.
- AFFF/PFAS sprayed daily/9 months/year for 30 to 40 years.
- 3,000 foot benzene plume in groundwater /PFAS presence in soil/groundwater.
- Potential for Significant Brand- PR and 3rd party Liability

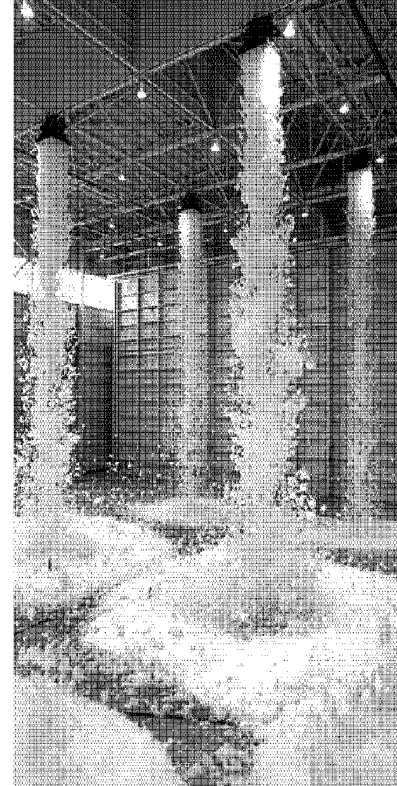
Receptor Survey/Vulnerability Assessment – Vapor Intrusion (VI)

assessment (BTEX) for off site properties; >80 wells within 1 mile of site.

Source (FTA) and Plume Delineation – Real time delineation using mobile labs; aquifer testing to assess transport and off site risk. Assessment of PFAS in soil and groundwater and regulatory reporting/negotiation.

Source Remediation Design/Implementation – Client desires a rapid delineation and source excavation during Fall season business shutdown. PFAS disclosure could increase risk/cost (\$2M to \$40M). Potential for alternative remedies/Arcadis R&D.

PFAS Groundwater Delineation/Remediation – To be determined based on receptor survey. Plume could be more than a mile long.



Approach Not Always As It First Appears

Field Sampling Techniques: What are the Right Ways to Sample



PFAS Sampling Guidelines

- United Nations Environment Programme (UNEP), Division of Technology, Industry and Economics. 2015. *PFAS analysis in water for the Global Monitoring Plan of the Stockholm Convention, Set-up and guidelines for monitoring*. April.
- Government of Western Australia, Department of Environmental Regulation. 2016. *Interim Guideline on the Assessment and Management of Perfluoroalkyl Substances (PFAS), Contaminated Sites Guidelines*. February.
- Environmental Fate and Effects of Poly- and Perfluoroalkyl Substances (PFAS). 2016. CONCAWE (European Industrial Consortium)
- Statement of Requirements for FPAS Site Assessments. 2016 Public Services and Procurement Canada & Transport Canada.

PFAS Water Sampling Protocol

- Precautions for personal field gear including no water proof or stain-treated clothing during sampling event
- Precautions for field personnel to limit contact with certain food products
- Maintain clean work area, consider dedicated plastic sheeting to prevent contact with ground
- Use high density polyethylene (HDPE) bottles fitted with HDPE liner screw cap only
- Use clean hands techniques – use nitrile gloves at all times and don a fresh pair for multiple steps of sampling process
- Avoid markers, use pen or pencil.
- Decontamination procedures include Citranox® cleaning solution, laboratory-provided, “PFAS-free” water, and methanol.
- Include collection of field reagent trip blank to evaluate potential for cross contamination to occur

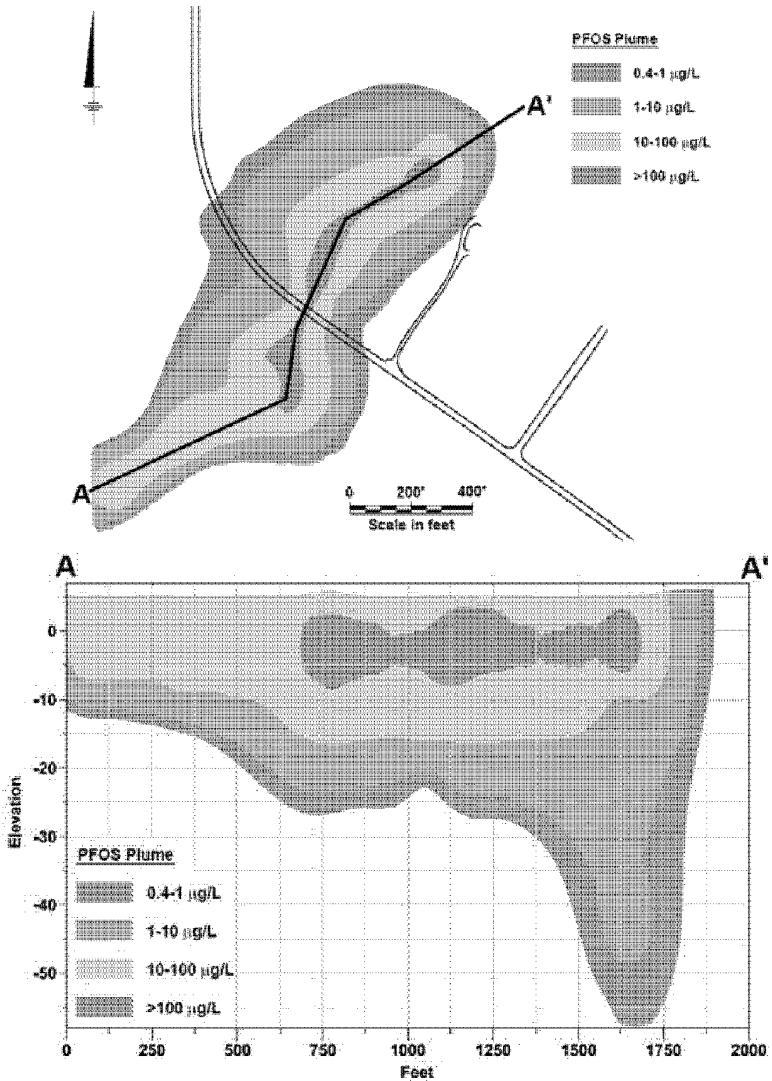


High Resolution Site Characterization

Cape Canaveral Air Force Base

- Completed transects of hydraulic profiling tool to map permeability
- Vertical aquifer profiling to map PFOA and PFOS concentrations
 - Fixed lab EPA method 537
- Incremental sampling to assess sediment impacts due to discharge
- Developing mobile lab capability
 - Real-time EPA Method 537
 - Adaptive delineation
 - Leverage advantages/lessons learned from solvents

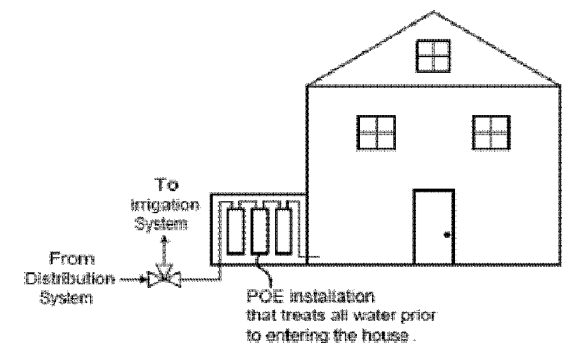
If you find the Mass Flux y



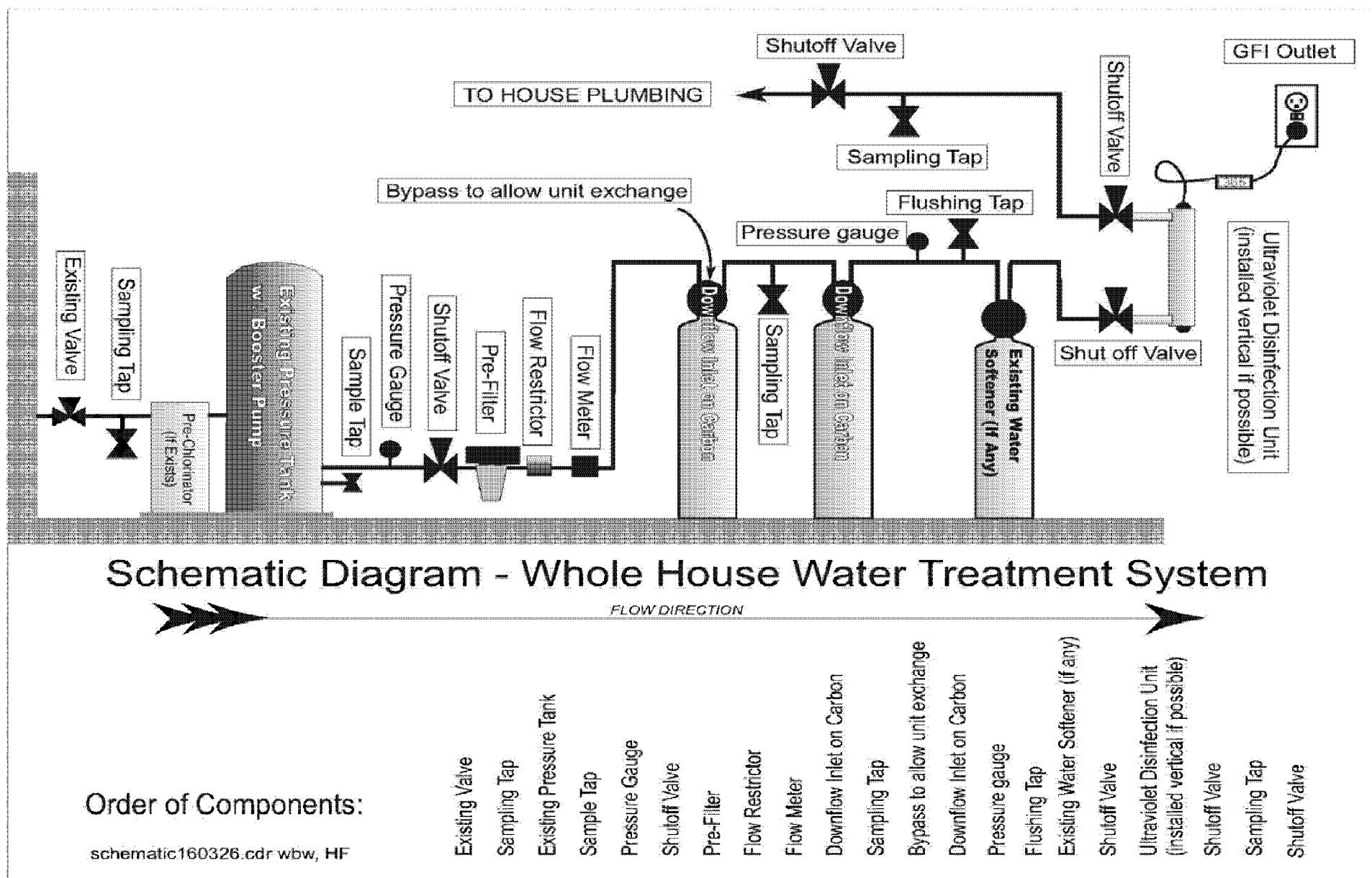
ou can target the remedy

Sampling Considerations for PFAS Point of Entry Treatment (POET) System

- Review state requirements for monitoring and reporting performance of POET systems
- Influent sampling should focus on characterizing any temporal changes in contaminant concentrations that could impact treatment requirements and breakthrough
- Effluent sampling should focus on confirming that treatment goals are met and water produced is protective of public health
- Effluent sampling can also be used to characterize and optimize treatment system operation
- Frequency and exact sample location will depend on treatment system configuration, regulatory requirements, and treatment objectives



Hoosick Falls, NY



Hoosick Falls, NY

POET Sampling Plan

System PFOA Concentration	Sample Frequency	Analysis	Sample Locations	QC Samples	QC Sample Frequency
Greater than 70 ppt	Quarterly	PFOA	PRE MID POST	FD MS/MSD	Every 20 Samples (5%)
	First Visit	TOC	PRE		
	After Each GAC Canister Replacement	METALS	POST		
40 – 70 ppt	Semi-Annually	PFOA	PRE MID POST	FD MS/MSD	Every 20 Samples (5%)
	First Visit	TOC	PRE		
	After Each GAC Canister Replacement	METALS	POST		
Less than 40 ppt	Annually	PFOA	PRE MID POST	FD MS/MSD	Every 20 Samples (5%)
	After Each GAC Canister Replacement	METALS	POST		

Tools to Optimize the POET Sampling Program

Bench tests to characterize POET performance based on site-specific water quality

Review full-scale sampling data for trends and potential to reduce sampling frequency

Provide redundancy in treatment to assure adequate contaminant removal while reducing sampling burden.

Arcadis has applied these tools at a diverse range of POET systems to develop sampling programs that are protective of public health, while taking into account a reasonable frequency of sampling.

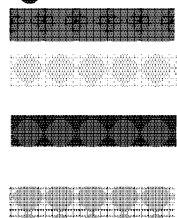
Getting ahead of the issue: Take Actions Now to Shape the Future

*Drinking Water
Environmental Remediation*

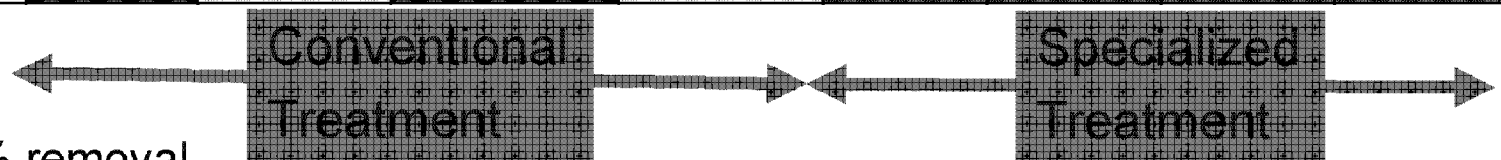
Demonstrated Drinking Water Treatment Options

Compound	M.W. (g/mol)	Aeration	Coagulation Dissolved Air Floatation	Coagulation Flocculation Sedimentation Filtration	Conventional Oxidation (MnO ₄ , O ₃ , ClO ₂ , CLM, UV-AOP)	Anion Exchange	Granular Activated Carbon	Nano Filtration	Reverse Osmosis
PFBA	214	assumed	assumed						
PFPeA	264								
PFHxA	314								
PFHpA	364								
PFOA	414								
PFNA	464					assumed	assumed		
PFDA	514					assumed	assumed		
PFBS	300								
PFHxS	400								
PFOS	500								
FOSA	499						assumed		assumed
N-MeFOSAA	571	assumed				assumed	assumed	assumed	
N-EtFOSAA	585					assumed	assumed	assumed	

Legend



> 90% removal
> 10%, < 90% removal
< 10% removal
unknown



After Dickenson and Higgins, 2016. Treatment mitigation strategies for poly- and perfluoralkyl substances, Water Research Foundation

Current Water Treatment Options for PFOA and PFOS Removal

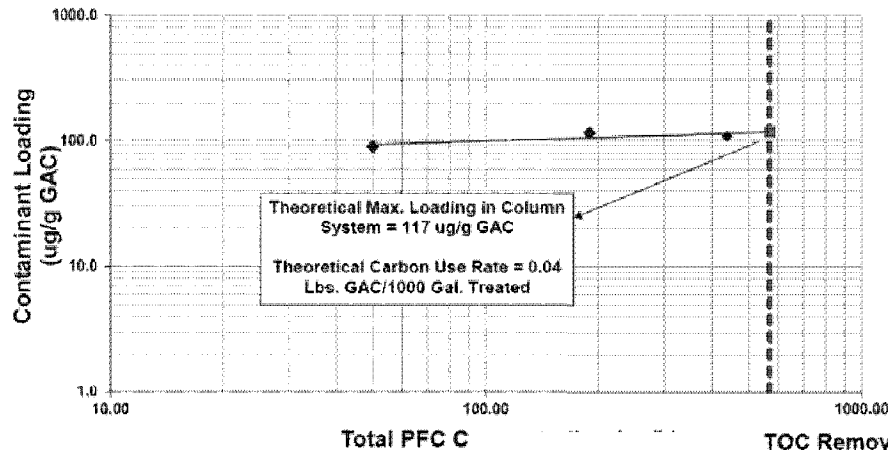
Treatment Strategy	Key Considerations
Granular activated carbon (GAC)	- GAC has been installed at multiple facilities over the past decade for PFOA removal from water supplies - Minimal liquid residual wastes - Spent carbon requires re-activation / disposal
Reverse Osmosis (RO) or Nanofiltration (NF)	- Full-scale applications for PFAS are limited - May reject a broader suite of PFAS - Generates a concentrate stream containing PFAS at higher levels than in source water
Ion Exchange	- Only removes PFOS, not PFOA - Regeneration??



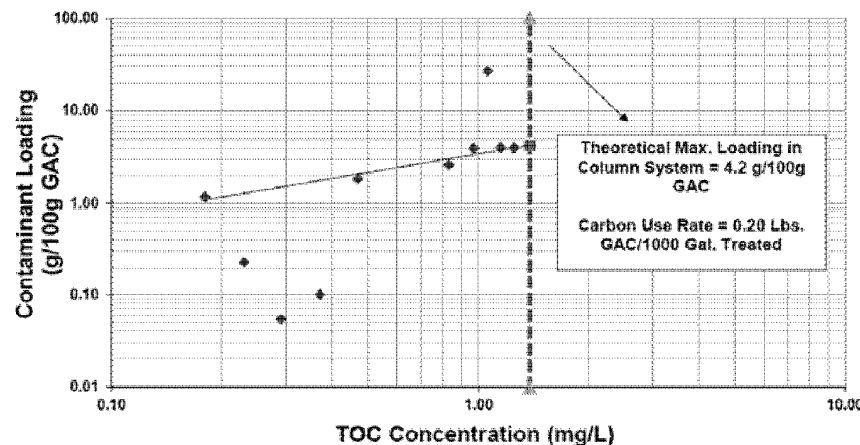
GAC works today for PFOS & PFOA today, but can we do better?

GAC can be 80X more expensive for PFOS/PFOA than BTEX

**PFC Removal - Hoosick Falls
F-400 Isotherm Plot**



**TOC Removal - Hoosick Falls
F-400 Isotherm Plot**



- Column testing required determine GAC needs to treat PFAS
- GAC requirements are site specific
 - PFAS mixtures
 - Competition from
 - TOC from groundwater or surface water
 - Other contaminants

Need to Keep on OPTIMIZING

Continued Investment Is Needed

Short Term: Optimize GAC

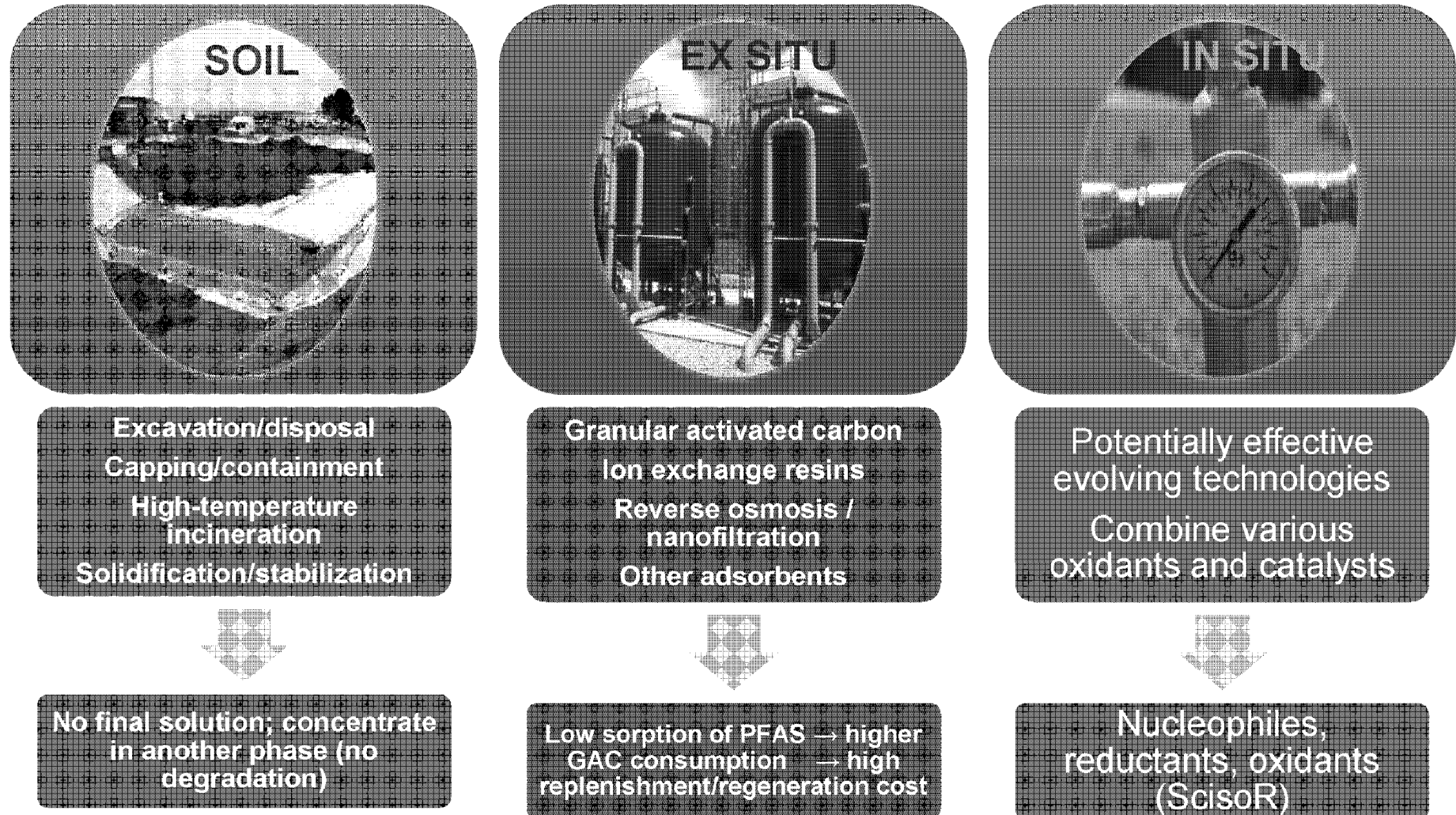
- Rapid small scale column testing (RSSCT) and TOP Assay to understand long-term cost and treatment requirements
- Alternative to high temperature regeneration - ScisoR
- Treatment train –AIX or FluorAdd

Long Term: Broad spectrum capability and reduced cost

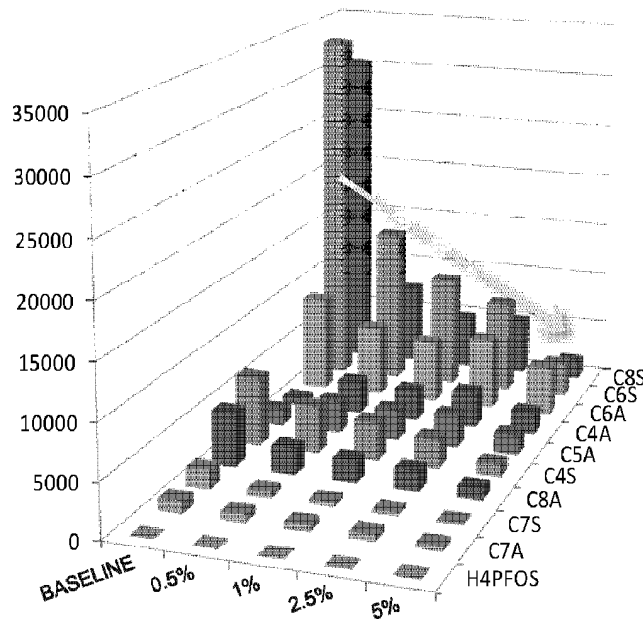
- Treatment train technology
- Absorbing media and regenerable media
- Destructive treatment processes for RO/NF concentrates (ScisoR)
- Destructive treatment processes

In the long-term the greatest life-cycle reduction will be managing the source

Soil and Groundwater Remediation for PFAS



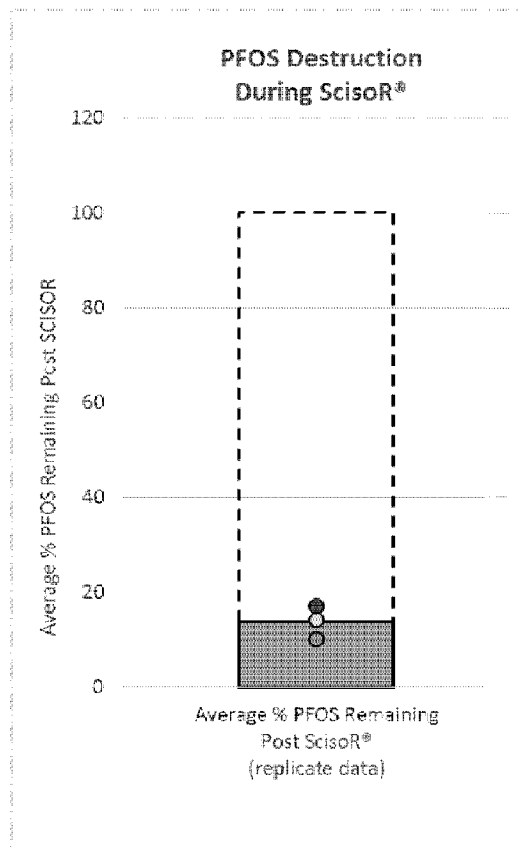
Arcadis' Patented Chemical Oxidation Method to Degrade PFAS



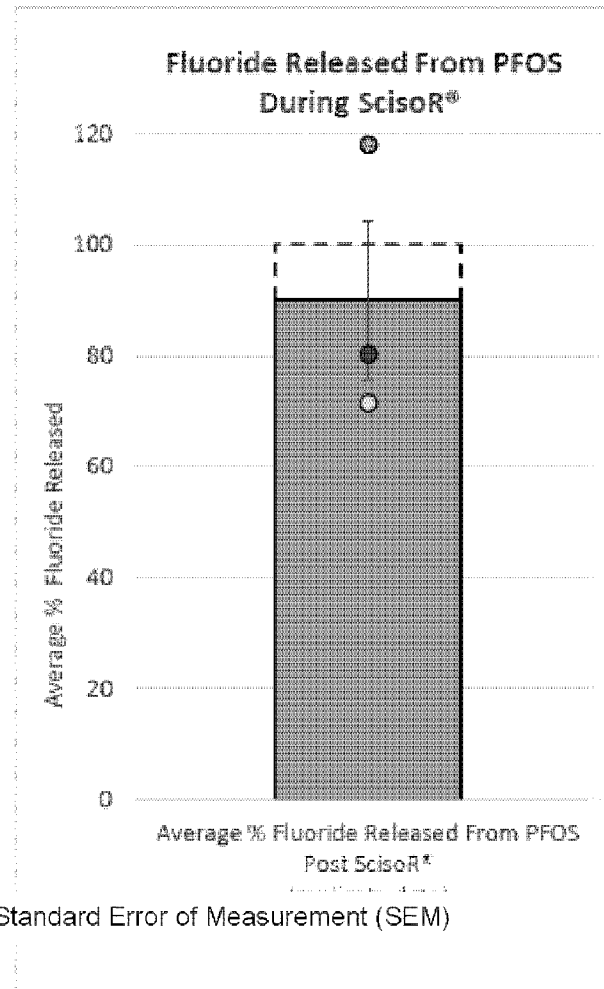
- Destruction of PFAS by chemical oxidation/reduction
- Effective at ambient temperature
- Soluble reagents can be injected or mixed with impacted soil and groundwater
- In situ remediation of AFFF impacted source areas
- Testing ability to treat waste/stockpiled AFFF
- Regeneration of support media (like ion exchange resins and other absorptive media) to destroy PFAS on site

ScisoR® bench scale data shows promise. Now being field tested

ScisoR Bench Scale: 90% PFOS Destruction with Mass Balance



Replicate Data. Error bars are % Standard Error of Measurement (SEM)

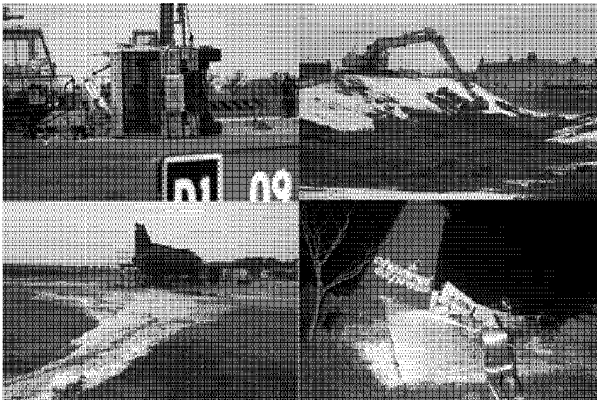


- 10 mg/L PFOS starting concentration
- 3 replicate data sets
- 83 to 90% PFOS destruction after 14 days
- 71% to 118% fluoride released from PFOS during SCISOR
- Overall fluoride mass balance (remaining fluoride in PFOS + fluoride released to solution)
 - 86% to 126% of theoretical
- All treated samples were blind spiked with 10 mg/L fluoride
 - 80% to 99% spike recovery
- Spike analyses demonstrate ion measured is fluoride, results are quantitative
- Longer reaction times and repeat applications of ScisoR will cause complete destruction of PFOS

Useful Graphics

Channel Islands, State of Guernsey

PFOS Management Strategy



Persistent bio-accumulative perfluorinated compounds in the airport's firefighting Aqueous Film-Forming Foam (AFFF) were identified in surface waters which were being used as a primary source of the Island's drinking water supply. In 2009 Arcadis was commissioned to assist the State of Guernsey with a strategy to manage the risk to human health and the environment.

Our Approach

- Desk Based Review & Preliminary Risk Assessment
- Intrusive Assessments and Monitoring
- Fate & Transport Modelling
- Management/Remediation Strategy
- Interim Emergency Response Measures
- Implementation of Remedial Management Strategies

Concurrent Phases to Manage and Mitigate Risk

Getting ahead of the issue: Case Studies

Drinking Water: Hoosick Falls, NY
Best Management Practices: AFFF
Replacement

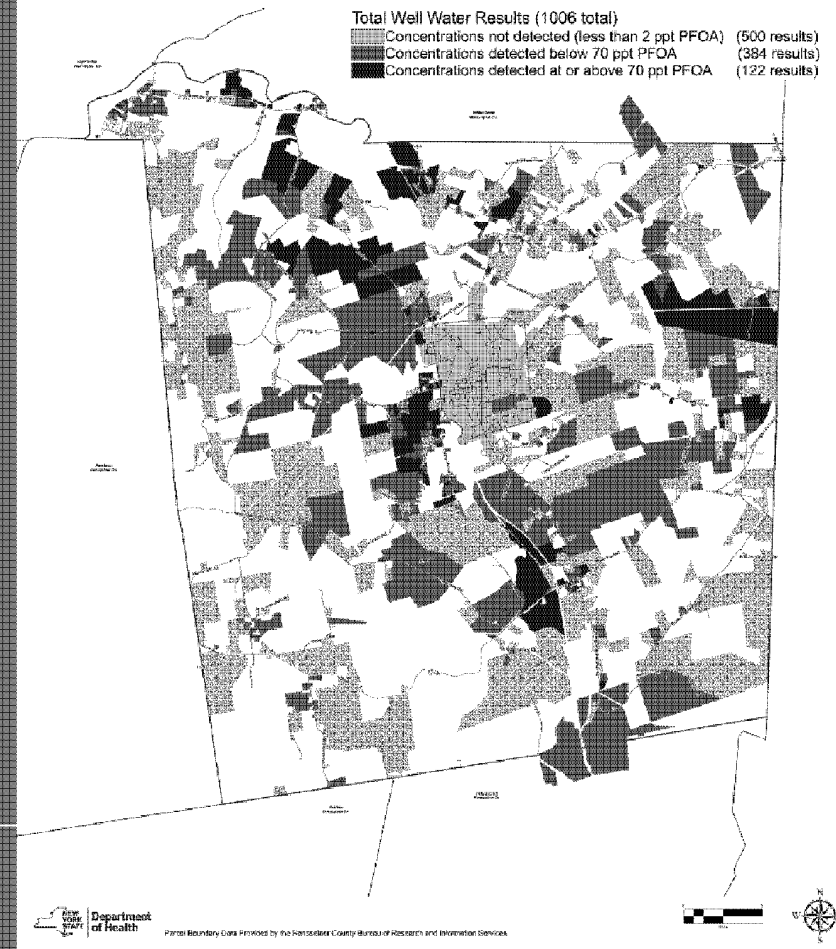
PFOA IN DRINKING WATER

HOOSICK FALLS, NY

NYS Department of
Environmental Conservation

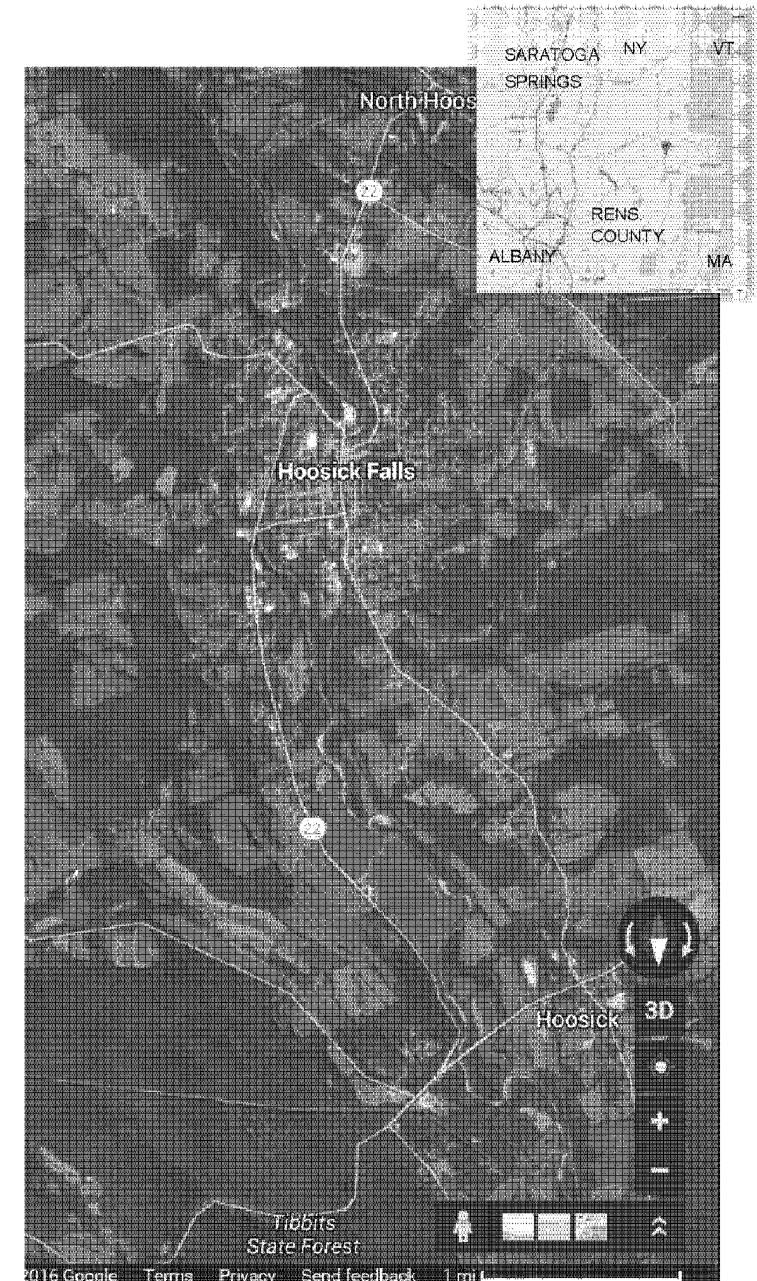
Village of Hoosick Falls and Town of Hoosick Private Well Sampling

Perfluorooctanoic Acid (PFOA) Results Map - Updated May 18, 2016



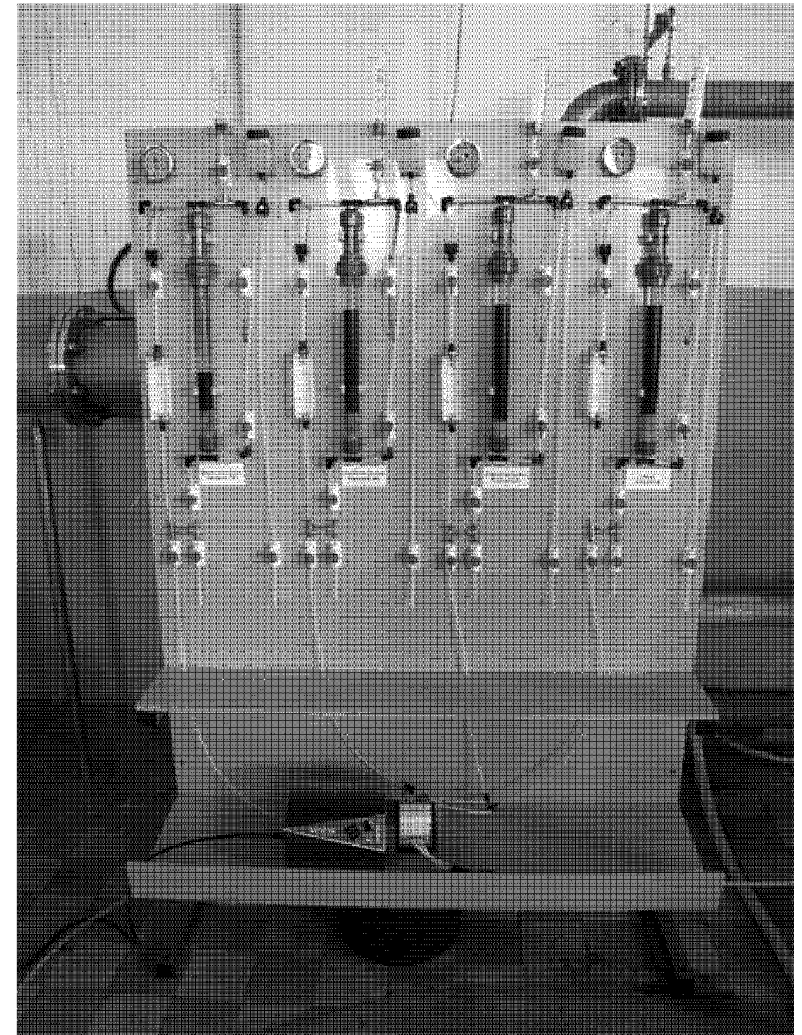
Hoosick Falls, NY

- Community of approximately 3,600 people located in northeastern Rensselaer County, NY– about 10 miles from NY – VT border.
- Situated along the Hoosic River – a 70-mile long tributary to the Hudson River with a 720 square-mile watershed in 3 states – VT, MA, and NY.
- Mix of residential, commercial and industrial zones.
- PFOA detected in Village water supply wells and other private wells.
- New York State responded by listing Saint-Gobain Performance Plastics on the State Superfund List.
- NYSDEC set up an Incident Command Center to respond to needs of residents, business owners and village officials.



Hoosick Falls - NYSDEC Work Assignments

- **Treatment System Design and Construction** – GAC treatment systems on water supply for schools and apartment complex
- **POET System: Bench-scale Testing**
- Small scale treatability testing (e.g. rapid small-scale column testing, RSSCT)
 - correctly design/size the treatment system
 - provides an estimate of expected service life to breakthrough.
 - performed within a much shorter time than a pilot or full-scale test.
- Because of the rapid response needed in this case, POET systems were being installed concurrently with design verification tests using via RSSCTs.



Hoosick Falls - NYSDEC Work Assignments (cont.)

- **Engineering Oversight** – installing Point-of-Entry Treatment (POET) systems on approximately 900 residential and commercial water supply systems.
- **Incident Command Center** - Leading situational and planning tasks, operating call centers, scheduling field tasks, inventorying POET equipment, collecting and recording field and system data.
- **POET System Operation, Maintenance & Monitoring** – 20 months of PFOA water sampling and operations/maintenance of approximately 900 POET systems installed by NYSDEC contractors
- **Alternative Water Supply Development** (2 to 3 MGD: adjacent alluvial Valley): Confined (protected) aquifer identified using geophysics; confirmed with Hydraulic and chemical testing.



**BEST MANAGEMENT
PRACTICES**

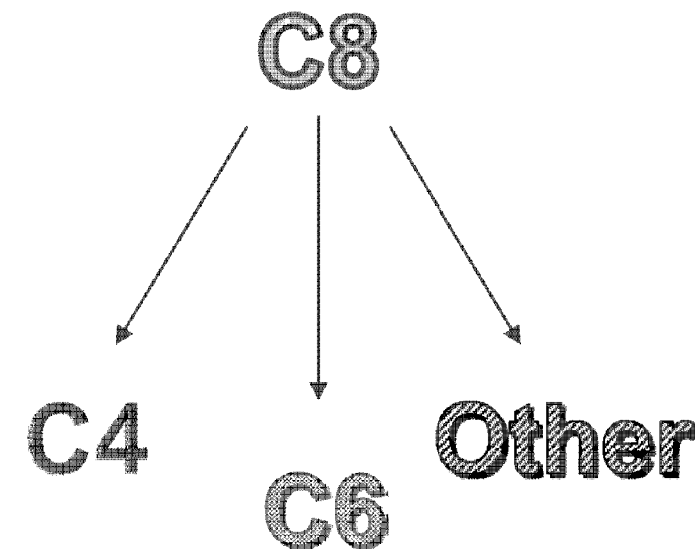
**FOAM INVENTORY &
PRODUCT
SUBSTITUTION**



Design & Consultancy
for natural and
built assets

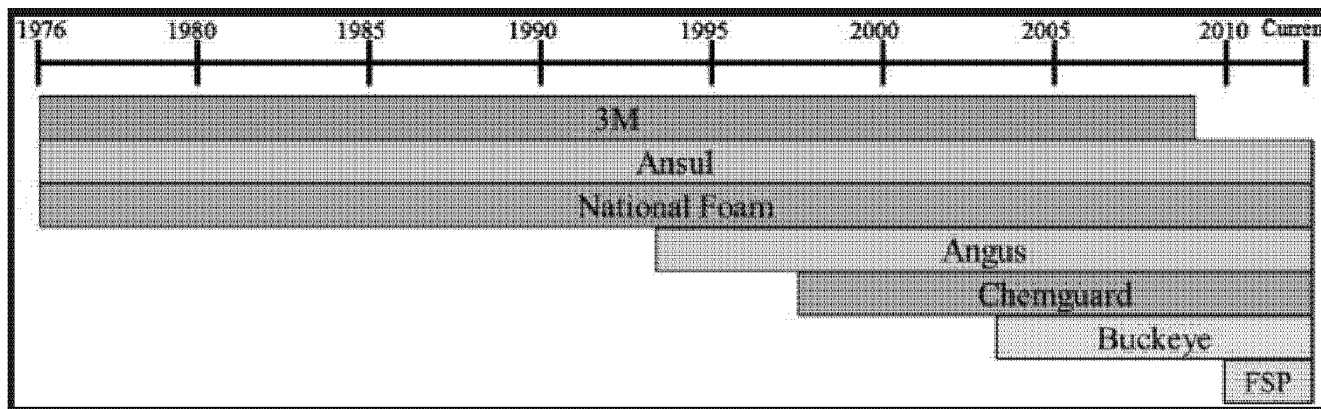
NT

- In most of the U.S. and Europe, C8 PFAS species have been phased-out due to potential health concerns
- PFOS (C8) and PFOA (C8) and related PFAS have been replaced with compounds with shorter (e.g., C4, C6) perfluorinated chains
- Shorter chain replacement chemicals are typically less bioaccumulative, but they are still persistent and more mobile in aqueous systems vs C8.
- Solutions for characterizing all PFAS species, from C4 to C8, are imperative; all carbon chain lengths are present in most environmental samples and even in historical “C8” products

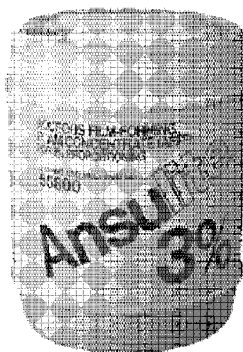


**Non-fluorinated replacement foams
are being adopted widely**

AFFF Usage in U.S.



- Navy developed AFFF with 3M after the devastating USS Forrestal Fire in 1967 (134 dead, 161 injured)
- Historically, AFFF contained PFOS, PFOA, and C8 and C6 precursors – exact PFASs used are manufacturer dependent
- Since early 2000's, U.S. military and airports use fluorotelomer-based foams that contain C6 compounds – they do not contain PFOS/PFOA and PFOS/PFOA precursors
 - Common brand names are Ansulite, National Foam Aer-o-Water, Buckeye, Chemguard (all MilSpec approved)



Fluorine Free Foam Replacements to PFAS-AFFF are Available



JetFoam 1%

Fluorine Free (FF)
Foam Concentrate

Integrity

Doing what's right, rather than what's convenient

Angus Fire prides itself on the open and honest way in which we conduct our business throughout the world. Our foams are an extension of our ethical beliefs and we pride ourselves in being the responsible foam manufacturer, balancing high performance with minimal environmental impact. Our fluorine free foams contain no fluorosurfactants, fluoropolymers, organochlorines, PFAS, PFOA and no PFOS in accordance with EU Directive 2006/122/EC and American Council Directive 207/53/EC.

Innovative Formulation

Angus Fire has developed a revolutionary foam that fulfils the



- Fast knock-down and extinguishment exceeding the requirements of KCAO level B
- True Newtonian (low viscosity) foam to ensure accurate, easy induction and airport crash vehicle compatibility
- Fluorine free to meet airport policy on minimising environmental persistence

JetFoam 1 is a superior quality synthetic fluorine free (FF) foams concentrate, designed for extinguishing and securing flammable aviation fuel spills and fires (Jet A and Jet A1).

JetFoam 1 is a patent pending combination of surfactants and other ingredients and produces a vapour sealing blanket of foam that rapidly spreads over the surface of

Applications

JetFoam 1 is used in high risk situations where hydrocarbon fuels such as Jet-A, Jet-A1 and aviation kerosene are processed, stored or transported. It is designed to be used on Aviation Rescue Fire Fighting Vehicles (ARFFV), Rapid Intervention Vehicles (RIV) and airport crash trucks where fast extinguishment is essential for saving life. JetFoam 1 provides a vapour suppressing foam blanket on Jet-A and Jet-A1 spills.

Approvals and listings

JetFoam 1 is tested to EN1566:2008, part 2.

Performance exceeds the requirements of ICAO 2013 Level B fire performance and is certified to this performance level.

Fluorine Free AFFF

Manufacturer	Foam
Bioex	Ecopol
Fomtec	Enviro 3x3 Plus
Solberg	Re-healing Foam RF6 / RF3
Dr. Sthamer	Moussol F-F3/6

Solberg foams are used by many airports in Europe

Fluorine free foams work via mechanisms that involve aspiration (nozzles that introduce bubbles)

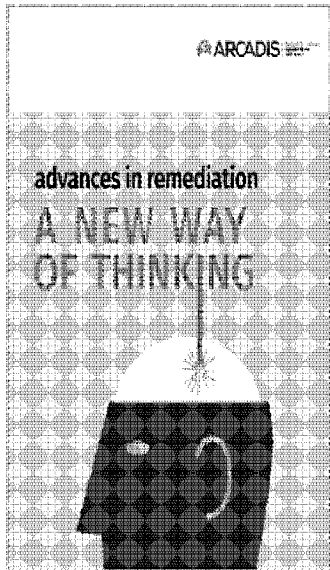
Alternative fluorine free foams may have higher COD/BOD

MILSPEC requires 30s extinguish time, and fluorine free foams currently do not meet this criteria

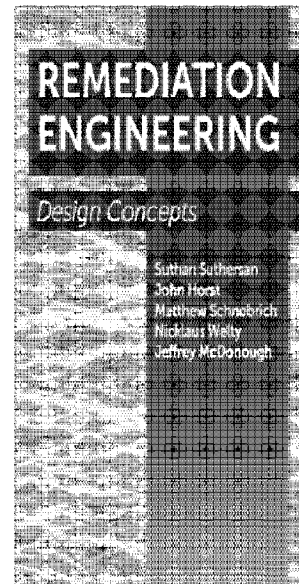
In Summary

- Overview of the PFAS issue to provide the knowledge needed to avoid impulsive reactions
- Understand how PFAS reacts in the environment to ensure the most appropriate sampling and analytical methods and treatment technologies are selected
- Have the information needed to allow you to focus on your mission and direct your program going forward.

We are READY to Help



Discover the innovations that will change the remediation industry. Download your free copy of our new *Advances in Remediation* book today! Go to: www.arcadis.com/emerging-contaminants



Reserve your copy of *Remediation Engineering: Design Concepts*, the industry's premier educational text book. Second edition scheduled for release in November. Preorder now for a 20% discount. Call **800 272 7737** and use code **AQQ80** to receive your discount. (Regular price: \$169.95/£108.00)

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