# The 2023 PFAS Primer

## Preparing for Successful PFAS Sampling, Analysis, and Treatment Selection.

Groundwater & Environmental Services, Inc.

We know a lot more today about per- and polyfluoroalkyl substances (PFAS) than we did when these compounds first became recognized as contaminants of emerging concern in the early 2000s. Scientific research and advancements in technology have helped industry gain a better understanding of the potential contamination sources, human health risks, biological impacts, characterization methods, and treatment alternatives. As regulatory guidance of PFAS continues to evolve, there is a growing sense of uncertainty and urgency in both industry and the regulatory community.

We're helping clients sharpen their understanding of the current science and regulatory landscape while taking proactive steps towards future compliance in the form of data collection, modeling, and treatment alternatives to address these potential risks. The enclosed guide is intended to serve as an educational tool for industry stakeholders and decision makers who may have a current or future PFAS concern.

# The 2023 PFAS Primer

## Successful PFAS Sampling, Analysis, and Treatment Selection

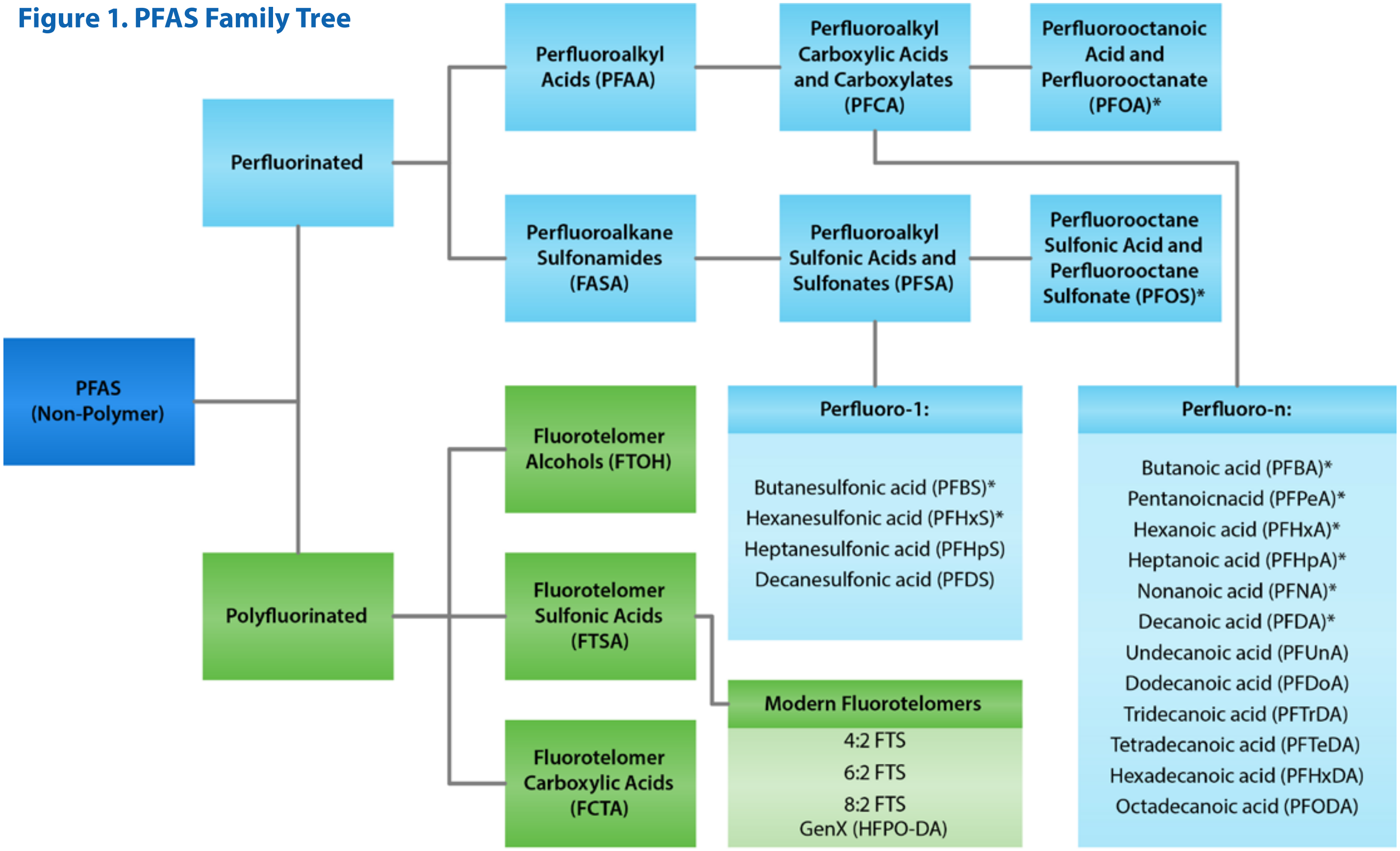
### What is PFAS?

PFAS is a family of more than 9,000 man-made fluorinated organic chemicals that have been produced since the mid-1900s. They are mobile, persistent, and, in some cases, bioaccumulative. PFAS are resistant to degradation in the environment, and when degradation occurs, it often results in the formation of other PFAS compounds. PFAS compounds have markedly different physical and chemical properties.

### What are the different compounds?

The PFAS family is divided into subgroups. Figure 1 illustrates the major PFAS classifications recognized by the scientific community. Currently, the key classes of concern are perfluoroalkyl carbolic acids (PFCAs) such as PFOA, and perfluoroalkyl sulfonic acids (PFSAs) such as PFOS. Other PFAS may transform in the environment through biological or geochemical processes to PFCAs and PFSAs.

**Figure 1. PFAS Family Tree**



* Denotes compounds with at least one state-specific standard.

### PFAS Terminology

Perfluorinated chemicals are those where every carbon atom is bonded to a fluorine atom except one where a functional group, often a carboxylate (e.g., PFOA) or sulfonate (e.g., PFOS), is attached. Polyflourinated chemicals have two or more carbons that are not fully fluorinated. These represent locations where polyfluorinated chemicals can "break" and transform to perfluorinated chemicals. Fluorotelomer sulfonic acids (FTSA) are common examples of polyfluorinated chemicals and are used in the manufacture of modern Aqueous Film-Forming Foam (AFFF). In general, the longer fluorinated chain PFAS are less mobile (but still highly mobile) and more toxic but more amenable to treatment.

## Where is PFAS found?

PFAS are manufactured globally and have been used in the production of a wide range of industrial and household products. Production of PFAS chemicals in the United States has been largely phased out over the last 20 years, as health concerns have grown. Primary potential sources of PFAS releases are typically associated with a number of industries in the manufacturing sector as well as facilities that have historically stored and used Class B fluorine-containing firefighting foams, regularly referred to as Aqueous Film-Forming Foams (AFFF). Several waste streams, such as landfills and wastewater treatment plants, are considered potential secondary sources for PFAS releases in the environment. The list of potential sources (see Figure 2) is expected to grow as more research conducted and increased environmental sampling for PFAS occurs.

**Figure 2. Potential PFAS Sources**

**MANUFACTURING**

- Aerospace
- Automotive
- Chemical
- Electronics
- Metal coating and plating
- Textiles

**FIREFIGHTING**

- Airports and aviation facilities
- Military bases and training centers
- Petroleum refineries and terminals
- Petrochemical production facilities

**WASTE MANAGEMENT**

- Waste disposal facilities
- Wastewater treatment plant operations
- Biosolids application for agriculture

**COMMERCIAL & CONSUMER PRODUCTS**

- Grounds maintenance
- Cleaning agents
- Construction materials
- Fluorine gas treated plastic containers

## How does PFAS affect me?

### Industry:

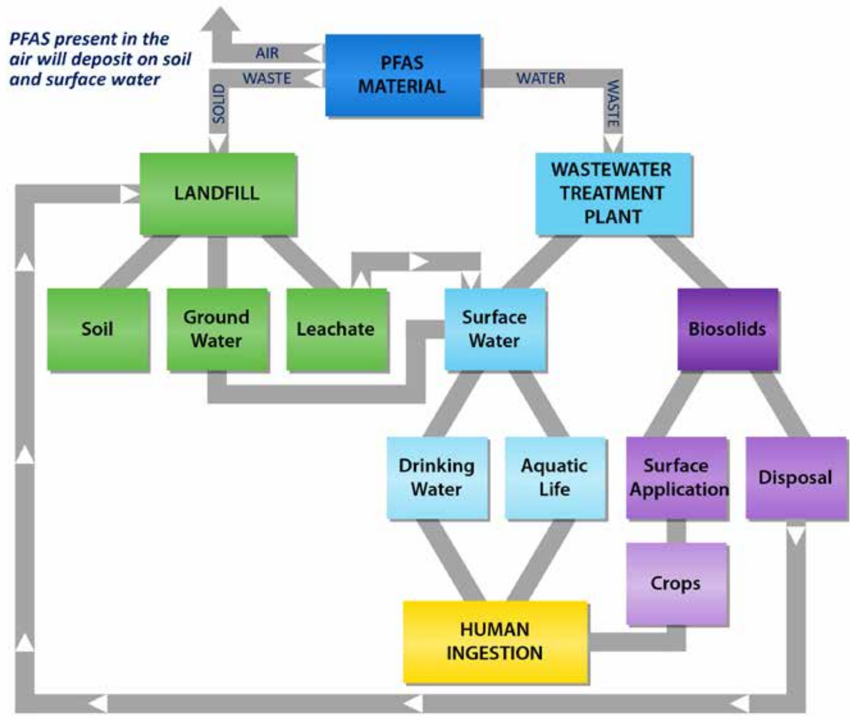
You may have a PFAS concern if your facility used a PFAS-containing feedstock, produced PFAS materials, stored or transferred PFAS chemicals, handled or recycled containers that were used to store PFAS-containing materials, disposed of PFAS-containing waste or residuals, or used AFFF. PFAS can be introduced to the environment from spills, air emissions, and discharge of waters, such as on-site wastewater treatment facilities. PFAS chemicals have historically been referred to by well-known trade names as well as common names and abbreviations such as “C8” for PFOA, making it challenging to readily identify PFAS chemicals.

### Consumers:

As consumers, we have likely all been exposed to PFAS. While consumer sources such as water- and grease-repelling materials (e.g., rain coats, carpets, fast food wrappers, and pizza boxes) and personal care products, are often highlighted, exposure can occur through other means.

Figure 3 illustrates the typical life cycle of PFAS in the environment. Drinking water supply systems have been identified as PFAS exposure sources due to lack of appropriate treatment units and/or the recognition of the presence of PFAS. Wastewater treatment plants not designed to remove PFAS usually discharge to surface water. Biosolids from wastewater treatment plants are commonly land applied for agricultural use, which results in another potential exposure pathway.

**Figure 3. Typical Life Cycle of PFAS in the Environment**



## Source Identification and Forensics

There is a fast-growing need to identify PFAS sources and how they enter the environment. Today's science can distinguish PFAS sources by their chemical fingerprint. Data which offer insight to the source(s) include: the specific PFAS compounds present and absent, ratios between the various detected PFAS chemicals, the presence of precursors and degradation products, geospatial sample data, and evaluation of branched and linear isomers.

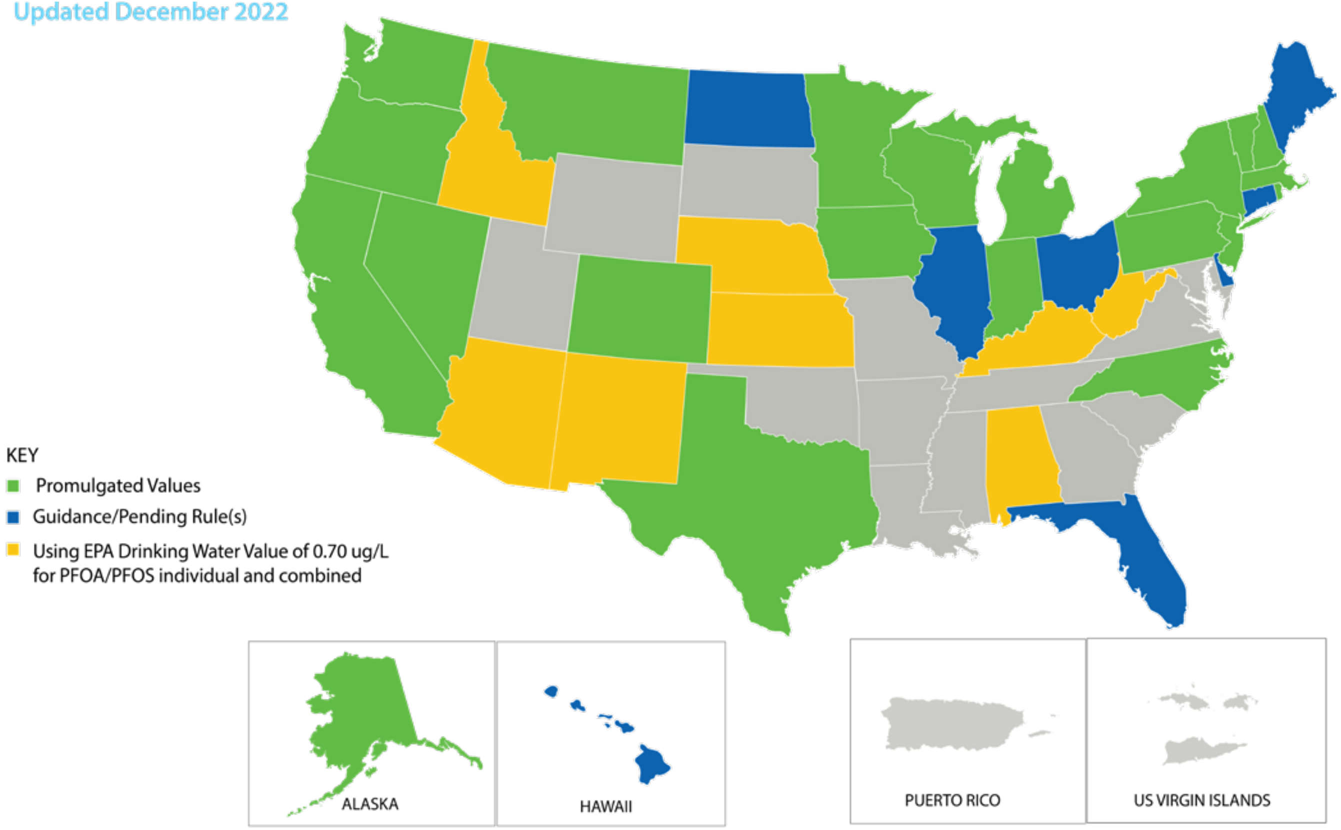
Environmental forensics, can assist in the identification of the type of release and/or potential sources — even in mixed plumes. Forensics can pinpoint potential sources using specific PFAS chemical signatures, such as modern fluorotelomer mixes found in an AFFF discharge or the stain-resistant mix of PFAS that are typical of a municipal solid waste landfill leachate. A key component in accurate forensic identification is a comprehensive understanding of the site and surrounding property, historical and current use, which facilitates appropriate selection of sampling locations and laboratory analytical methods. Qualitative, quantitative, and statistical analysis of the data to identify potential sources allows you to focus on managing your specific environmental liability.

## Regulatory Status

The regulatory landscape surrounding PFAS continues to take shape at both the federal and state levels. Final regulations have not yet been promulgated for PFAS at the federal level. The United States Environmental Protection Agency (EPA) developed a Drinking Water Lifetime Health Advisory (LHA) of 70 parts per trillion for PFOA and PFOS (individual and combined), replacing previously-published provisional values. States continue to develop standards, screening values, guidance, and interim criteria for one or more PFAS including PFOS, PFOA, perfluorobutanesulfonic acid (PFBS), perfluorobutanoic acid (PFBA), and perfluorononanoic acid (PFNA), and GenX in drinking water, surface water, and groundwater. Several states have issued orders for PFAS-related information and sampling, and this trend is expected to continue across the US. The map below highlights the current standing of state-level regulation for PFAS compounds. For specific information on the standards and guidance, the listed PFAS chemicals, and the affected water type, the Interstate Technology & Regulatory Council (ITRC) maintains a detailed listing of information on their PFAS Fact Sheets website (pfas-1.itrcweb.org/fact-sheets).

**Figure 4. Regulatory Status of PFOA/PFOS/PFNA in the United States**

Updated December 2022



## Sampling Approach/Considerations

Due to the presence of PFAS in equipment typically used to collect soil, groundwater, surface water, sediment, and drinking-water samples, as well as the need for very low reporting limits, special precautions must be taken when collecting samples for PFAS analysis to avoid sample contamination. The sampling process itself remains similar to sampling techniques for other contaminants; however, equipment modifications and use of alternative materials can add costs to your sampling program. Provided below is an abbreviated list of sampling guidelines that we have developed for our staff, clients, and subcontractors.

- Always sample for PFAS first, before collecting samples for any other parameters.
- Store PFAS sample bottle(s) in a separately-sealed plastic bag, away from other sample parameter bottles.
- Use high density polyethylene (HDPE) or silicon tubing materials rather than Teflon™ and other fluoropolymer-containing materials.
- Carefully consider the materials of construction of passive diffusion bag (PDB) samplers; many are constructed of LDPE and may contain or adsorb PFAS chemicals.
- Use HDPE or polypropylene containers and caps rather than traditional LDPE bottles; pack with regular ice.
- Sampling personnel should avoid wearing personal protective equipment (PPE) with commonly-found PFAS materials, such as boots with Gore-Tex®, Tyvek material, and other water- or stain-resistant materials.
- When sampling, avoid the use of waterproof/treated paper or field books, plastic clipboards, water-resistant markers, and other adhesive paper products.
- Sampling team members should avoid the application of personal care products (cosmetics, sunscreen, insect repellent, etc.) and contact with pre-packaged food wrappers/containers.
- Consider the presence of other analytes. For example, while Liquinox® is an acceptable cleaning agent for PFAS sampling equipment, it is not acceptable for 1,4-Dioxane sampling.

### GEARING UP FOR PFAS SAMPLING

HDPE/Polypropylene Containers + Caps

Approved Gloves/PPE

Store PFAS Samples in a separate Ziploc®

Cotton Shirts Preferred

Proper Cleaning Agents

Bottled Drinks/ Packaged Food

Personal Care Products

## Laboratory Analytical Methods

Identifying the media to be sampled and understanding the regulatory requirements, project data quality objectives, and laboratory capabilities are critical factors in selecting the right analysis and analytical laboratory for your project.

Modified drinking water-only methods, EPA Methods 533 and 537.1, remain the most commonly used laboratory analytical methods for PFAS in aqueous and solid media, with or without the addition of the total oxidizable precursor (TOP) assay method, which further allows the analyst to obtain data on PFAS precursors that may be present in samples. Although widely used, these are not the only EPA validated methods for PFAS analysis. There are other, less well-known, method options for non-drinking water matrices. These include ASTM Method D7968-17 specific for soil analysis and EPA Method 8327 that is valid for all media. Unfortunately, these methods have not been widely adopted and may not be readily available at every laboratory.

Because of the regulatory environment, advancements in laboratory analytical methods for PFAS are ongoing. The latest, draft EPA Method 1633, when validated, will be applicable for both aqueous and solid matrices and has a 40-compound analyte list. Although specifically intended for groundwater, wastewater, surface water, soil, sediment, and biosolid, it has the significant disadvantage of requiring extra sample volume when compared to modified Methods 533 and 537.1.

## Treatment and Disposal Alternatives

Treatment and disposal of PFAS and PFAS-containing materials is challenging for several reasons. There is limited understanding of most treatment alternatives, with only a few technologies being demonstrated commercially. Granular activated carbon (GAC) is the most commonly applied water treatment method during initial response actions and full-scale water treatment applications. The use of ion exchange resins continues to increase and has shown greater effectiveness compared to GAC in some studies. Additionally, multiple GAC treatment systems have underperformed against expected time until breakthrough.

Uncertainty around the destruction efficiency of incineration operations has limited incineration as a disposal option. Landfill acceptance of PFAS-impacted materials has also decreased. As a result, the ability to dispose of contaminated solids (soil, biosolids, and sediments) off-site is effectively decreasing, driving the need for new on-site treatment technologies to be developed.

| TECHNOLOGY | CONSIDERATIONS/NOTES |
|---|---|
| **Water Remediation & Treatment** | |
| **Sorption** | Granular activated carbon (GAC) has been the most commonly applied technology for PFAS applications, including point of entry treatment (POET) systems and larger scale treatment systems; coal-based GAC has generally performed better than coconut shell GACs, but specialty coconut-based GAC materials have been effective in some applications; shorter chain PFAS (≤ 5 carbons) have demonstrated quicker breakthrough than longer chain PFAS (≥ 6 carbons).<br>Anionic exchange resins (AIX) have performed well in field applications and bench studies using single-use and regenerable AIX resins; wastes from regeneration cycles require treatment and/or disposal.<br>GAC and AIX have been field implemented as a combined technology, typically with GAC as the initial treatment material and AIX as the polishing step; both GAC and AIX are susceptible to fouling from particulate such as iron; pre-treatment is often required.<br>Other sorption materials, such as silicas and biochar, show promise; in situ sorption using colloidal activated carbon is also a developing technique. |
| **Membrane Filtration** | Reverse osmosis (RO) and nanofiltration have shown promise; cleaning cycles and rejected water (RO only) with more concentrated PFAS concentrations require treatment and/or disposal. Pre-treatment to remove solids is essential for membrane filtration systems. |
| **Precipitation** | Traditional water treatment using coagulation and flocculation has effectively reduced PFAS but may require further treatment to further remove PFAS; may be applied prior to other treatment methods (i.e., as a pre-treatment step). Developing electrochemical precipitation methods can enhance PFAS removal and destruction. |
| **Foam Fractionation** | Separates PFAS from water and other liquids (e.g., AFFF solutions) using ambient compressed air or ozone bubbles to extract and concentrate PFAS and precursors; generates a lower volume of PFAS-laden foam for disposal/treatment; has been field implemented at a limited number of sites as an ex-situ treatment, and in situ application is being studied. |
| **Thermal Destruction** | On-site ex-situ and in-situ technologies may be effective; demonstration projects have used temperature ranges of 650°-1800° F with the current focus on techniques at the lower end of the range; off-gases are a consideration. |
| **Redox Manipulation** | Possible in- and ex-situ with techniques such as electrochemical and sonochemical; oxidation methods have shown promising effectiveness and may transform PFCAs and PFSAs to other PFAAs; research ongoing. |
| **Bioremediation** | Research ongoing for aerobic and anaerobic pathways with bacteria and fungi. |
| **Plasma Technology** | Research ongoing for destruction of PFAS in water and as a method to treat concentrates from AIX regeneration, membrane filtration, and fractionation techniques. |
| **Soil / Sediment Remediation & Treatment** | |
| **Removal and Disposal** | Excavated soils are transported off-site for landfill disposal or incineration; acceptance of PFAS impacted soils at disposal and incineration facilities may be a challenge; see disposal section of this table. |
| **Thermal Destruction** | On-site ex-situ and in-situ technologies may be effective; demonstration projects have used temperature ranges of 650°-1800° F with the current focus on techniques at the lower end of the range; off-gases are a consideration. |
| **Sorption and Stabilization** | In-situ sorption by activated carbon (granular [GAC] or powdered [PAC]); stabilization methods not commercially demonstrated. |
| **Capping** | Covering of impacted materials to isolate them and retain in place; possibly applicable to soil, sediment, biosolids, and other solid waste. |
| **Disposal** | |
| **Landfill Disposal** | Some facilities no longer accept PFAS wastes for disposal; leachate treatment for PFAS likely required by landfill. |
| **Deep Well Injection** | Permitted class I wells are being used for deep well injection of liquid PFAS wastes, including AFFF, leachate, manufacturing residuals, and contaminated water streams. |
| **Incineration** | Facilities operating at high temperature (1470°- 2010° F) are required for PFAS destruction; some facilities have been prohibited from accepting PFAS contaminated material due to incomplete destruction and PFAS air emissions; the Department of Defense issued a moratorium on incineration by the military in April 2022. |

## Identifying historical AFFF use and re-evaluating firefighting methods are critical steps for reducing environmental impacts from AFFF.

Aqueous Film-Forming foam (AFFF) has been widely used in firefighting at facilities that manufacture, use, and store highly flammable materials. As a result, PFAS-related concerns affect many industries and types of facilities — military bases, aviation facilities, petroleum refineries and terminals, and petrochemical plants. AFFF can be released to the environment from firefighting, training exercises, and accidental discharges which can result in impacts to air, soil, groundwater, surface water, sediments, flora and fauna.

Fluorine-free foams (FFF) are an available alternative to AFFF. Research continues to improve the firefighting properties of FFF. However, legacy and modern AFFF remain a source of PFAS to the environment. Modern AFFF are made using short-chain PFAS chemicals and contain polyfluorinated fluorotelomers that can degrade to perfluorinated chemicals. Perfluorinated chemicals can be present in modern AFFF as impurities from the manufacturing process. Additionally, the firefighting systems that may now contain modern AFFF likely contain residual PFAS chemicals from legacy AFFF.

When AFFF is dispensed, it can transfer into soil and groundwater, runoff into surface water, and be transmitted through the air. When AFFF releases impact surface water, large areas of foam form on the top of the water and deposit onto surrounding land. Response actions can generate significant volumes of water and foam that must be managed as PFAS-containing waste and treated or disposed of accordingly.

## About GES

GES is a US-based company serving global clients with an engaged workforce and leadership team committed to excellence. We focus on delivering right-sized, practical solutions centered around your objectives — whether those are to invest in new infrastructure, unlock operational efficiencies, or maintain compliance. By combining specific industry experience with technical know-how and regulatory expertise, we help our clients think outside the box, delivering value-based solutions. This approach carries through all of our services, from strategic consulting to safe and efficient project execution. GES continues to build its PFAS project experience with ongoing and completed PFAS projects that have included:

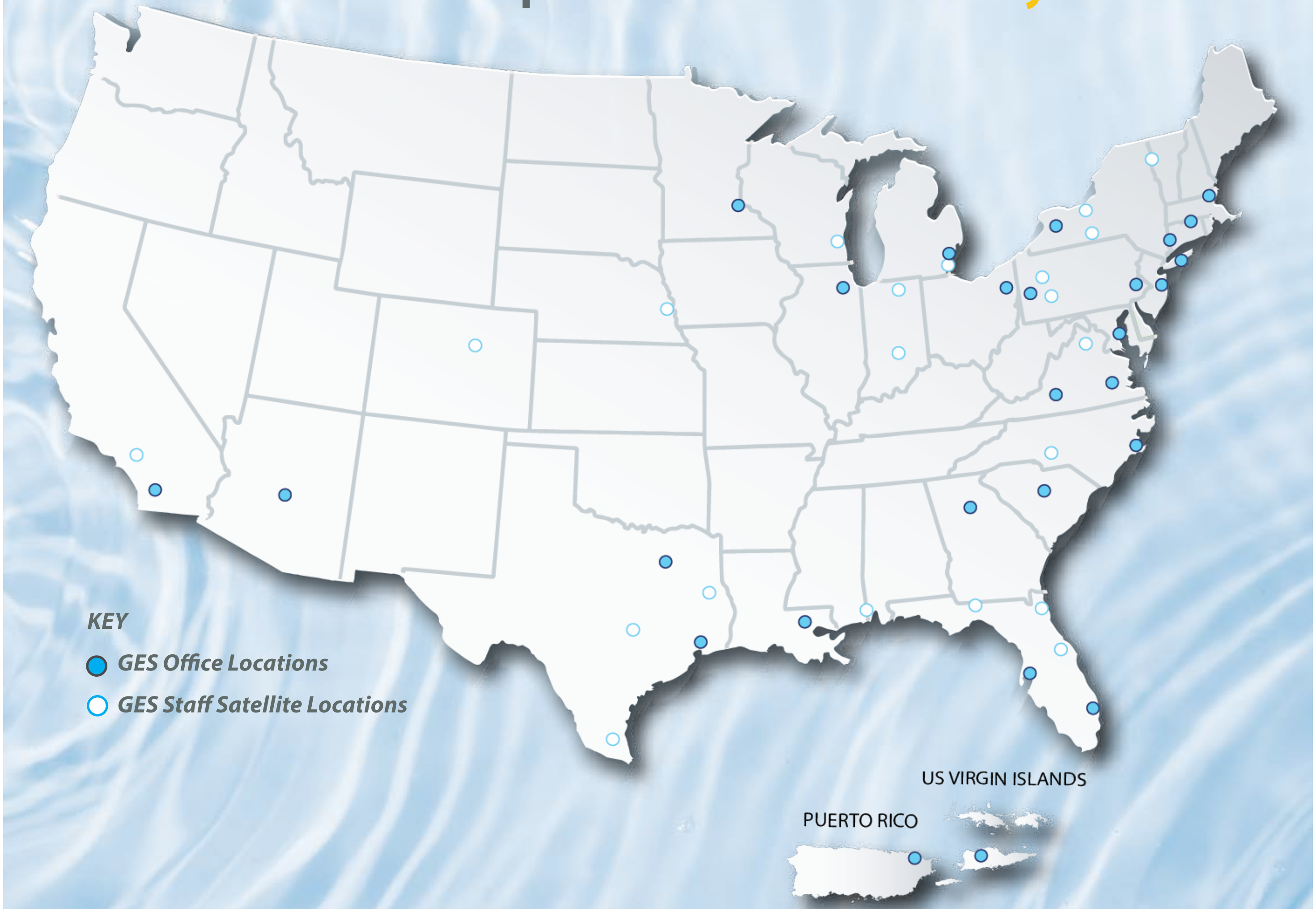
- Multi-media sampling events, data management, and reporting
- Rapid-response management for PFAS release incidents
- POET system design and installation
- PFAS vulnerability assessments
- Design and construction management of PFAS GW treatment facility
- Design, construction, and operation of mobile treatment systems
- Regulatory reporting and client advocacy

### PFAS Areas of Expertise

- Vulnerability Assessment
- Source Identification and Forensics
- Site Investigation
- Multi-Media Sampling
- Remedy Selection and Design
- Treatment and Remediation
- Rapid Response
- Ecological Services
- Data Management, Mapping, and Visualization
- Regulatory-Client Advocacy
- Public Participation Support
- Waste Management

We face the future with the strength of our past, an innovative perspective, and a shared mission to provide responsive, effective, and superior quality services to our clients and a safe workplace that fosters professional development for our employees. **That's GES.**

## National Perspective Delivered Locally



## About the Author

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Richard Evans is a Senior Vice President at GES with overall responsibility for the firm's technical practices in the areas of engineering, construction, hydrogeology, and drafting. He leads GES' internal PFAS task force focused on developing internal best practices and transferring knowledge and lessons learned from GES' PFAS-related tasks across the country. Rich is an active member of the Interstate Technology & Regulatory Council (ITRC) PFAS team, contributing to the development of the PFAS technical guidance document and updated fact sheets. The team continues to work diligently on updates to the technical guidance document.

Richard has five years of experience researching and working with PFAS chemicals to develop best management practices for sampling, investigation, and remediation. In addition, he provides PFAS training to clients and other consultants and contractors throughout the region via webinars.