The 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.

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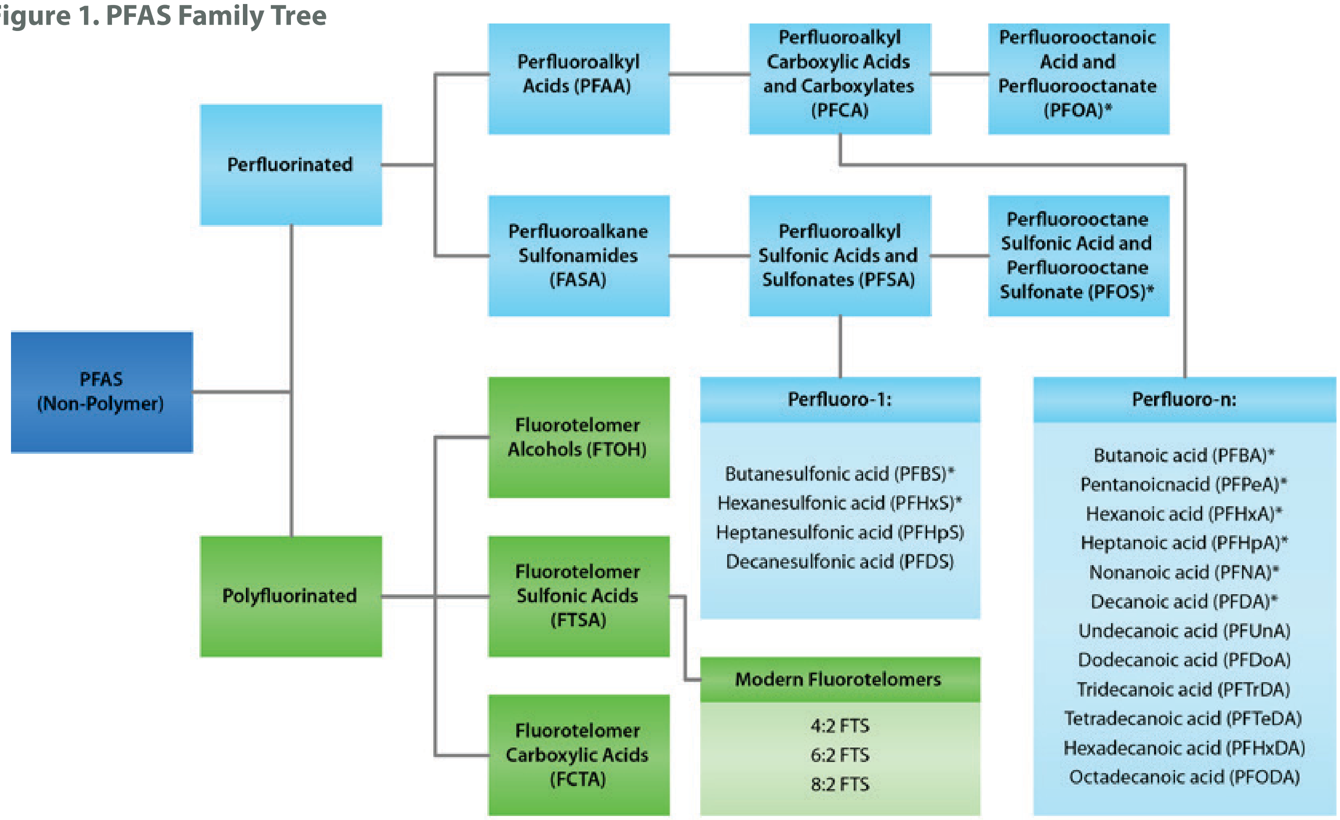
What is PFAS?

PFAS is a family of more than 3,000 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. The chart below 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 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 is expected to grow as more research is conducted and increased environmental sampling for PFAS occurs.

Figure 2. Potential PFAS Sources

MANUFACTURING

- Aerospace
- Automotive
- Chemical
- Electronics
- Metal Coatings & Plating
- Textiles

FIREFIGHTING

- Airports and Aviation Facilities
- Military Bases and Training Centers
- Petroleum Refineries and Terminals
- Petrochemical Production Facilities

WASTE MANAGEMENT

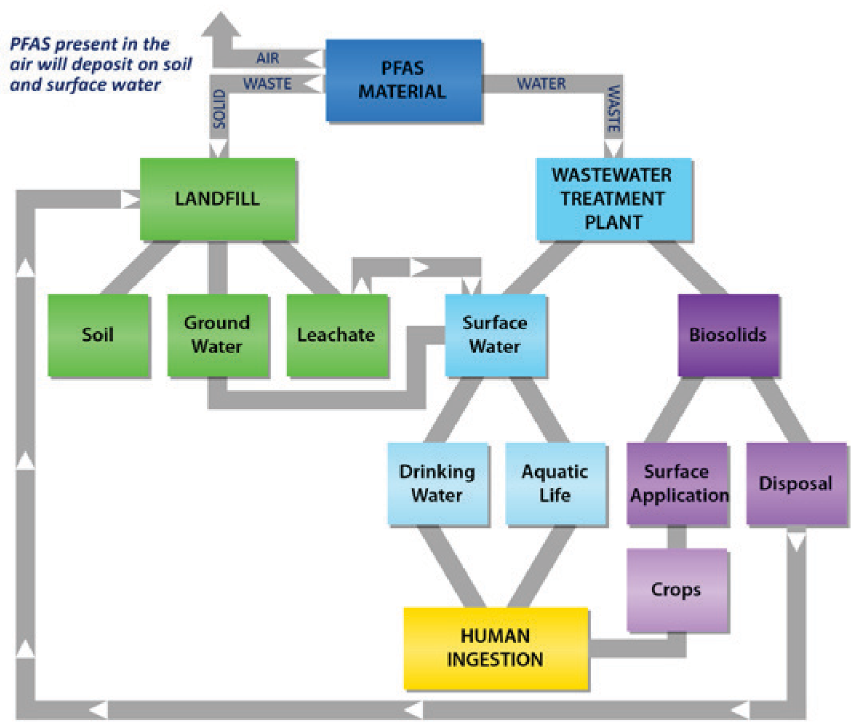
- Waste Disposal Facilities
- Wastewater Treatment Plant Operations
- Biosolids Application for Agriculture

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.

Figure 3. Typical Life Cycle of PFAS in the Environment



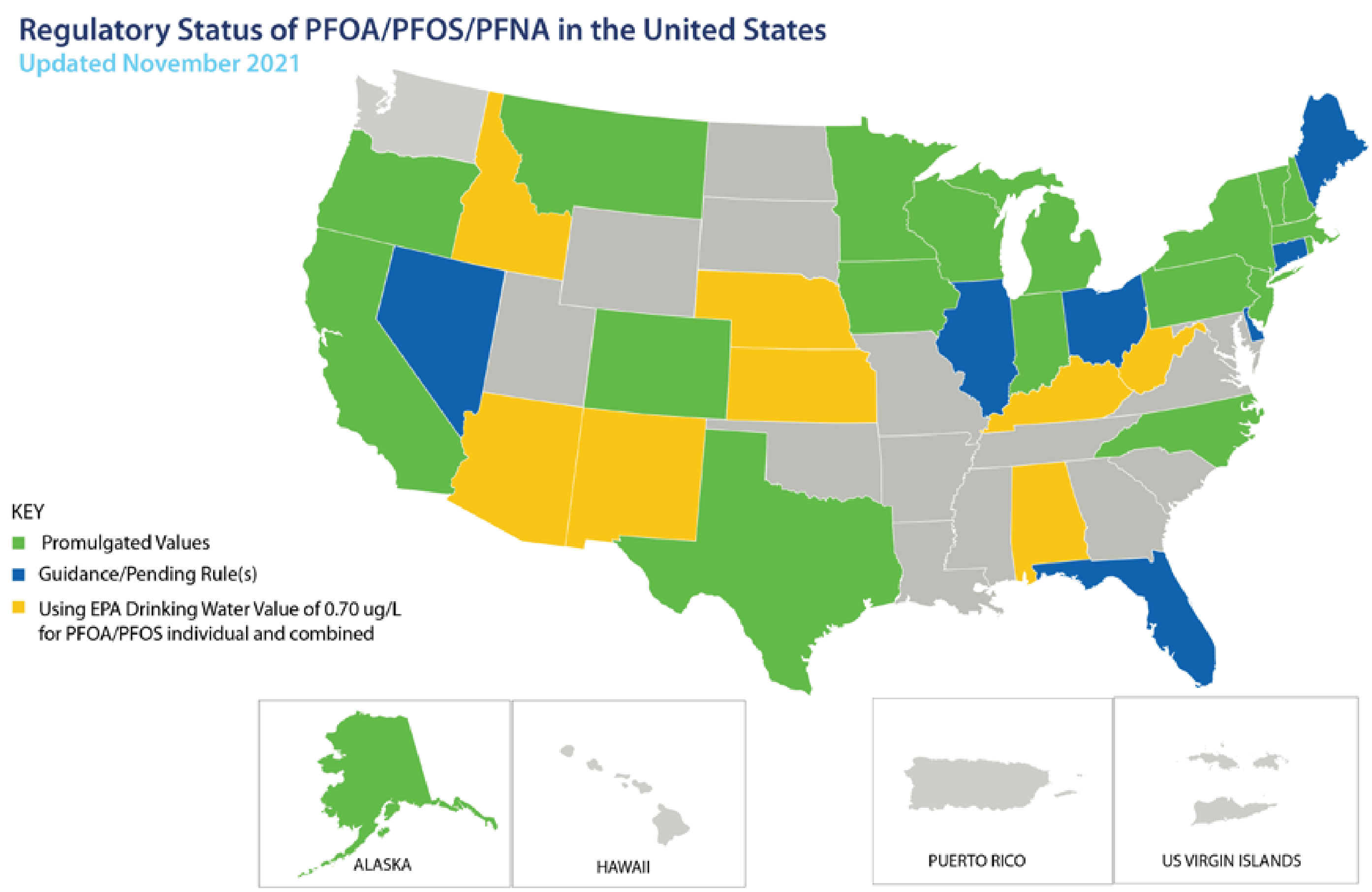
Consumers:

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) are often highlighted, exposure can occur through other means. 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.

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) in drinking water, surface water, and groundwater. Several states have issued orders for PFAS-related sampling. For example, the California Water Boards are taking a phased systematic approach and issued sampling and reporting orders for drinking water systems and chrome plating facilities in 2019, and petroleum refineries in 2021.

The graphic below highlights the current standing of state-level regulation for PFAS compounds, as of December 2020. Some states have both promulgated standards and pending guidance. 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).

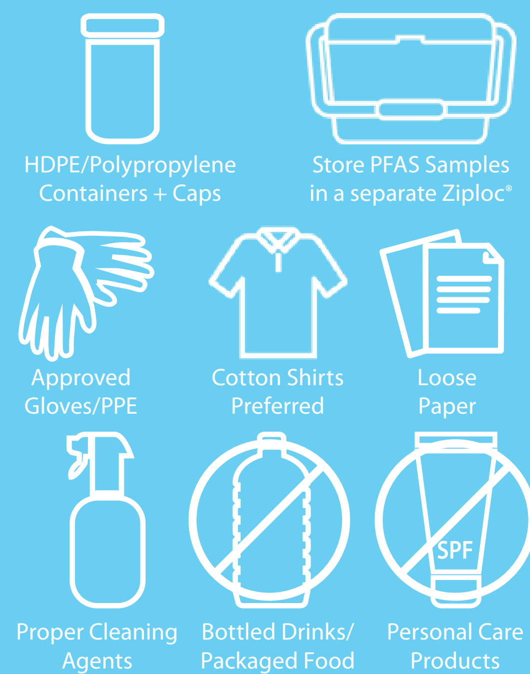


Sampling Approach/Considerations

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



Laboratory Analytical Methods

A few years ago, modified drinking water methods were the only option for laboratory analysis for PFAS chemicals. Today, the options for analytical methods are increasing, the list of PFAS chemicals that can be analyzed continues to grow, and detection limits are getting lower. The EPA has validated EPA Methods 533 and 537.1 for drinking water and EPA SW-846 Method 8327 for non-potable water. Other methods such as EPA Method 537 Modified Isotope Dilution (all aqueous and solid matrices, including soil), ISO 25101, ASTM D7979, and total oxidizable precursors (TOP) analysis are also available. An EPA-validated method for PFAS air-emission sampling and analysis has not yet been developed; modifications of existing air methods are currently being used. Identifying the media to be sampled and understanding regulatory requirements, project data quality objectives, and laboratory capabilities are critical factors in selecting the right analysis and analytical laboratory for your project.

Treatment Alternatives

Treatment and remediation of PFAS is challenging. There is limited understanding of most treatment alternatives, with only a few technologies being demonstrated commercially to date. Granular activated carbon (GAC) has been most commonly applied during initial response actions and full-scale water treatment applications. The use of ion exchange resins is becoming better understood and has shown greater effectiveness compared to GAC in some studies. For treatment of impacted soil media, excavation for disposal at a solid waste landfill or incineration has been the primary remediation alternative.

GAC (water) and excavation (soil) have been commercially demonstrated. Other technologies are between evolving development and field-testing stages of maturity. The table below provides considerations for the various technologies and a relative cost evaluation.

	TECHNOLOGY	IMPLEMENTATION COST ($-$$$$)	CONSIDERATIONS/NOTES
WATER REMEDIATION & TREATMENT	Sorption	$$-$$$	**Commercially Demonstrated.** Granular activated carbon (GAC) has been the most commonly applied technology for point of entry treatment (POET) systems and larger scale treatment systems; coal-based GAC has generally performed better than coconut shell GACs; smaller chain PFAS (≤ 5 carbons) have demonstrated quicker breakthrough than longer chain PFAS (≥ 6 carbons). Anionic exchange resins (AIX) are gaining interest and have performed well in bench studies using single-use and regenerable AIX resins; on-site regeneration of resins is possible, but wastes from regeneration cycles require treatment and/or disposal. Other sorption materials, such as silicas, show promise.
	Membrane Filtration	$$-$$$	Reverse osmosis (RO) and nanofiltration have shown promise; cleaning cycles and rejected water (RO only) with more concentrated PFAS concentrations require treatment and/or disposal.
	Precipitation	$$-$$$	Traditional water treatment using coagulation and flocculation has shown promise; may be applied prior to other treatment methods (e.g., GAC or AIX resins). Developing electrochemical precipitation methods can enhance PFAS removal and destruction; ozone fractionation is another developing technology that uses ozone bubbles to extract and concentrate PFAS and precursors.
	Thermal Destruction	$$$$	In-situ technologies may be effective; energy-intensive ex-situ possibly applicable for concentrated wastes (e.g., RO rejectate water).
	Redox Manipulation	$$	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	$-$$	Research ongoing.
	Plasma Technology	$-$$$	Research ongoing for destruction of PFAS in water and as a method to treat concentrates from AIX regeneration and membrane filtration techniques.
SOIL / SEDIMENT REMEDIATION & TREATMENT	Removal (excavation and disposal)	$$$	**Commercially Demonstrated.** Includes incineration (1470 °- 2010 ° F) and landfill disposal.
	Thermal Destruction	$$$$	Ex-situ and in-situ technologies may be effective; off-gases are a consideration.
	Sorption and Stabilization	$$-$$$	In-situ sorption by activated carbon (granular [GAC] or powdered [PAC]); stabilization methods not commercially demonstrated.
	Capping	$-$$	Covering of impacted materials to isolate them and keep them in place; possibly applicable to soil, sediment, and other solid waste.

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 transmit 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:

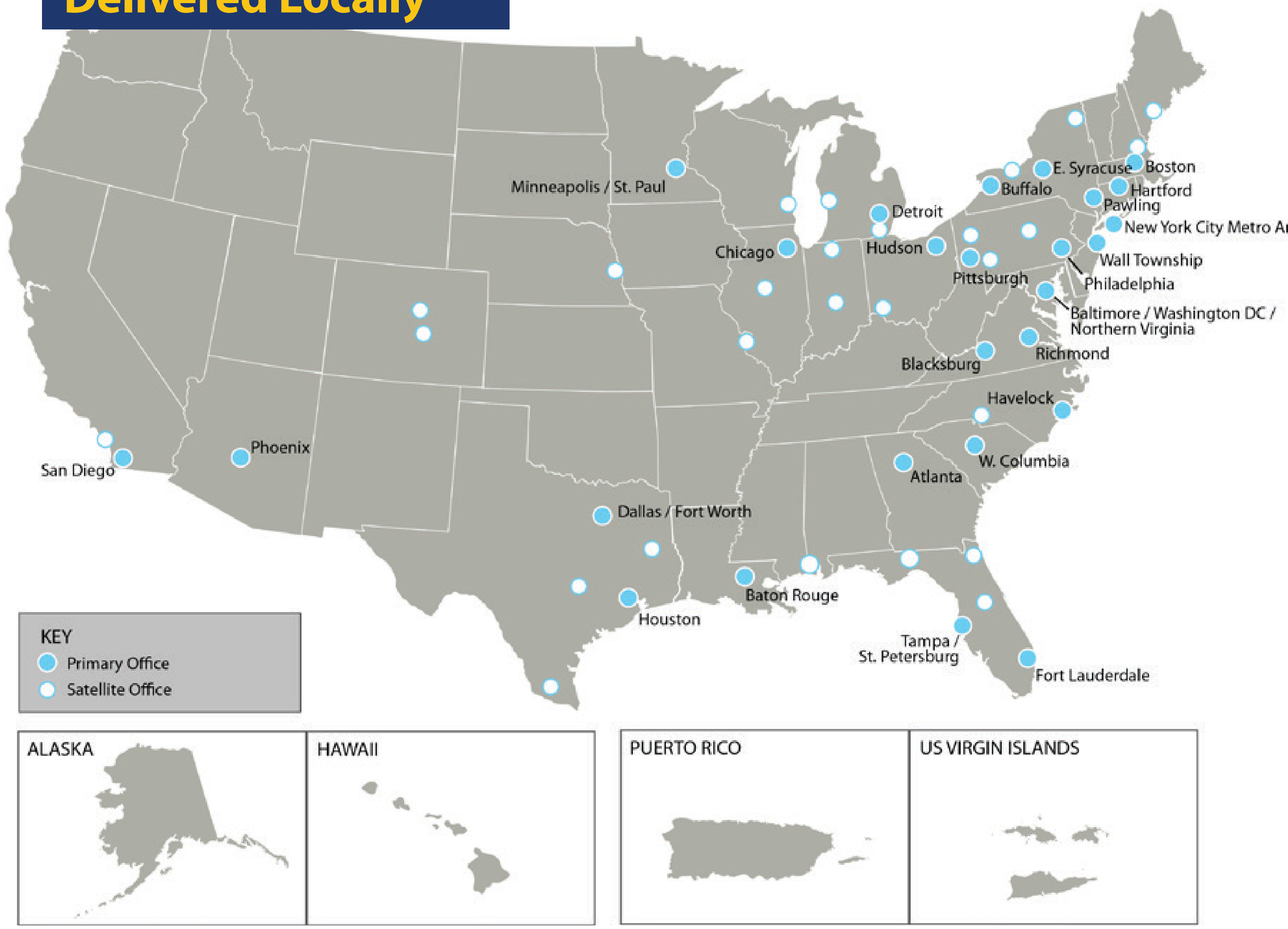
- Multi-media sampling events, data management, and reporting
- Rapid-response management for PFAS release incidents
- POET system design and installation
- PFAS vulnerability assessments
- Design and construction management of PFAS GW treatment facility
- Design, construction, and operation of mobile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

PFAS Areas of Expertise

- Vulnerability Assessment
- 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

Richard K. Evans, PE
Senior Vice President, Technical Functions
O. 800.426.9871 ext. 3014
M. 484.645.2845
E. revans@GESonline.com

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, issued in 2020. The team continues to work diligently on updates to the technical guidance document.

Richard has four 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.