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Quality Assurance Project Plan

Per- and Polyfluoroalkyl Substances in Freshwater Fish of Ten Lakes, 2023

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Quality Assurance Project Plan

Per- and Polyfluoroalkyl Substances in Freshwater Fish of Ten Lakes, 2023

By Callie Mathieu and Katelyn Foster

September 2023

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EAP: Environmental Assessment Program

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2.0 Abstract

Per- and polyfluoroalkyl substances (PFAS) belong to a group of chemicals that include persistent, bioaccumulative, and toxic (PBT) compounds. PFAS can build up in fish tissue and harm human health and wildlife that eat the fish. Previous Washington state surveys have found PFAS in freshwater fish of several waterbodies throughout the state. A fish consumption advisory was recently issued for three lakes in Western Washington. As thresholds for safe levels of PFAS in fish tissue have lowered, more information is needed on additional fish species, areas of concern, and baseline waterbodies in the state.

In 2023, the Washington State Department of Ecology's (Ecology's) PBT Monitoring Program will conduct a study to fill data gaps on PFAS concentrations in various species of freshwater fish sampled from a variety of waterbodies. Surface water and fish fillet tissue will be collected from 10 lakes and analyzed for 40 PFAS in the fall. Freshwater fish species will include popular angling targets such as cutthroat trout, rainbow trout, kokanee, largemouth bass, smallmouth bass, yellow perch, and walleye.

Lakes to be sampled for this study include:

- Two with heavy local angler presence where selected species have not been tested for PFAS (Lakes Sammamish and Stevens).
- Lakes in areas of concern for PFAS contamination where no fish have been tested (American and Spanaway Lakes).
- Six exploratory lakes where fish are being collected for a separate long-term monitoring study.

This information can inform our understanding of PFAS levels across various contamination potentials. The data will be made available to other agencies for follow-up actions and the public via a final report.

3.0 Background

3.1 Introduction and problem statement

Per- and polyfluoroalkyl substances (PFAS) belong to a large group of chemicals that include persistent, bioaccumulative, and toxic (PBT) compounds. In the early 2000s, perfluorooctane sulfonic acid (PFOS, a perfluoroalkyl substance) was first reported as a widespread contaminant in wildlife throughout the globe (Giesy and Kannan 2001). At the same time, concern was also growing over the effects of PFAS on human health and its persistence in humans and the environment. Manufacturers largely phased out the most bioaccumulative PFAS in the 2000s (PFOS) and 2010s (perfluorooctanoic acid (PFOA) and long-chain perfluoroalkyl acids (PFAAs)).

Many PFAS, particularly those that persist in the environment, harm human health. They have been linked to hepatotoxicity, tumors, developmental effects, immunotoxicity, neurotoxicity, endocrine disruption, liver effects, thyroid effects, and other adverse outcomes like cholesterol changes (Lau 2015, EPA 2016). Nearly all people living in the United States have detectable levels of PFOS, PFOA, and other PFAAs in their blood (CDC 2018). Most people are exposed to PFAS through drinking water, diet, house dust, food packaging, and consumer products (ITRC 2020), but in areas of contamination, drinking water and eating local resident fish are the primary exposure routes (Sunderland et al. 2019).

Toxicity thresholds have been recently refined to show that very small amounts of PFAS can be harmful. As reference doses for human health have lowered, so too have screening levels for fish tissue consumption. In a 2016 Washington State Department of Ecology (Ecology) survey, fish collected from urban lakes in Western Washington had PFOS concentrations that were above the Washington State Department of Health's (DOH's) provisional screening levels at the time (8 and 23 ng/g for high consumers and general population, respectively). Generally, less impacted ambient sites were below levels of concern for human health (Mathieu and McCall 2017). Since then, DOH has developed new screening levels for PFOS that are lower (0.6 and 1.8 ng/g for high consumers and general populations, respectively) (WA DOH 2022).

In response to statewide surveys that showed elevated concentrations of PFAS in urban freshwater fish tissue, Ecology conducted a follow-up study at three Western Washington urban lakes in 2018 to collect enough sample numbers for a fish consumption assessment (Mathieu 2022). The DOH evaluated the data and issued a fish consumption advisory for several species in the three Western Washington lakes (WA DOH 2022). It was the first PFOS fish consumption advisory in the state. Some popular angling species were not found during the 2018 assessment, thus, were not collected and tested. Follow-up testing of those species will be carried out in 2023. Also, with the lower threshold for PFOS concentrations in fish fillets, more data are needed in the state on a wider range of waterbodies.

Ecology's PBT Monitoring Program will carry out a study in 2023 to help fill data gaps in the state on PFAS concentrations of various freshwater fish species and sample a wide variety of lakes. Surface water and fish fillet samples will be collected in the fall of 2023 from 10 lakes and analyzed for PFAS. Freshwater fish species will include popular angling species such as cutthroat trout, rainbow trout, kokanee, largemouth bass, smallmouth bass, yellow perch, and walleye.

3.2 Study area and surroundings

Ecology will collect surface water samples and freshwater fish tissue from 10 waterbodies in Washington state. Figure 1 displays the locations of lakes to be sampled for this study. Study locations selected for analysis include:

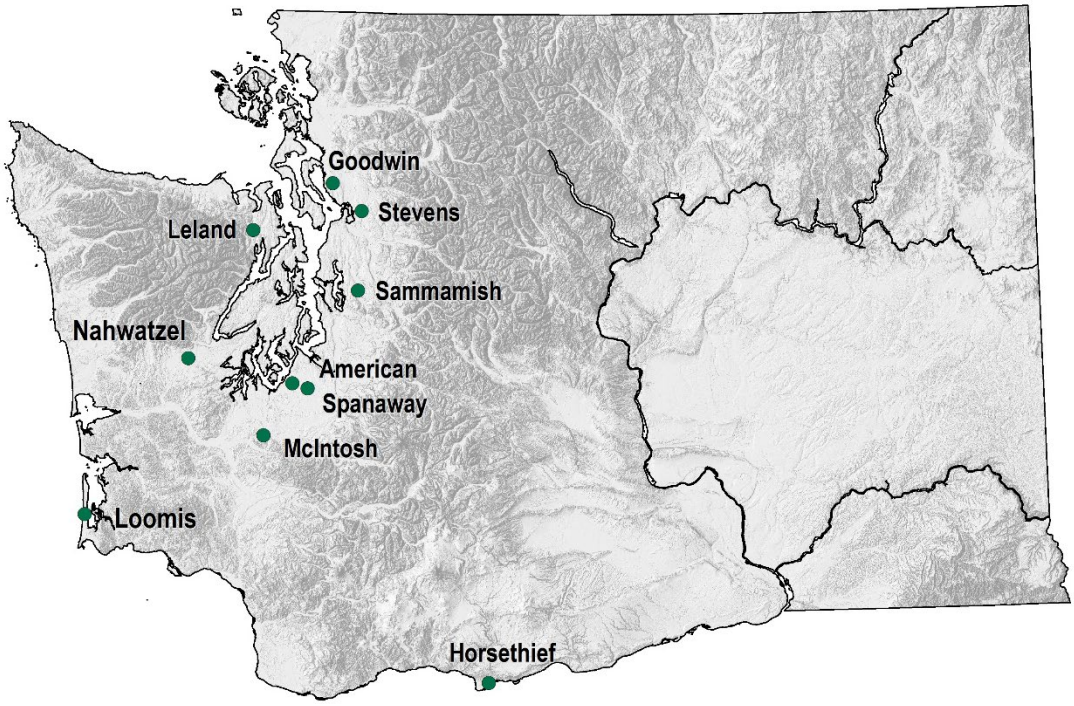
- Lakes with heavy local angler presence (Lakes Sammamish and Stevens).
- Lakes in areas of concern for PFAS contamination based on nearby drinking water detections of PFAS (American and Spanaway Lakes).
- Six exploratory lake sites where fish are being collected for a separate long-term monitoring study (Goodwin, Horsethief, Leland, Loomis, McIntosh, and Nahwatzel Lakes).

Sites were selected based on the above rationale and the following criteria:

- Ability to collect adequate size and number of target fish species.
- Suitable boat access for fish collections.
- Ability to share sampling resources with other programs.
- Obtain data across a wide range of waterbodies to help characterize PFAS in edible fish tissue from different land use types and contamination potential.

The lakes selected for this study are located primarily in western Washington. This is mostly due to co-locating six of the sites with another program's fishing efforts. Dependent on funding, there is potential to include PFAS in future sampling of ongoing efforts. That would expand PFAS testing in eastern Washington waterbodies, as the sites are more equally distributed in other sampling years (Mathieu and Bednarek 2020). Another reason sites are concentrated on the west side of the state is because in past statewide studies the highest concentrations of PFAS in fish tissue were observed in western Washington (Mathieu and McCall 2017). Urban waterbodies in western Washington were found to have the highest PFAS concentrations in the state, and therefore other similar waterbodies are being targeted for sampling.

Figure 1. Map of study locations



3.2.1 History of study area

PFAS, Land Use, and Lakes

PFAS chemicals have been found in a range of land uses and types. Because PFAS are manmade chemicals, soil and water PFAS contamination often overlap with urban, residential, and developed land uses (Brusseau et al. 2020). Aqueous film forming foam (AFFF) used for training and firefighting, wastewater treatment facilities and the application of their byproducts (irrigation with treated water, biosolids), landfills (disposed PFAS-containing materials), and manufacturing facilities are well studied and have been repeatedly identified as emission sources and pathways of PFAS contamination (Brusseau et al. 2020; De Silva et al. 2020).

Although PFAS chemicals are manmade, this does not limit them to urban or developed areas. The effects of PFAS in products can extend beyond their application or emissions through volatilization, leaching, runoff, deposition, and atmospheric transport. Measurable PFAS concentrations have been found in soil or groundwater outside emission points in remote or protected land areas, such as forests (Brusseau et al. 2020; Schroeder et al. 2021).

All the lakes selected for this study are surrounded by a combination of land uses and land types that are similar to other areas in Washington known to have been impacted by PFAS contamination (Brusseau et al. 2020; De Silva et al. 2020; Gaines 2022; Mathieu and McCall 2017; Schroeder et al. 2021). These land use types include urban, residential, and forested areas. Table 1 outlines the study locations for this project, along with their surrounding land uses and PFAS pathways of interest.

Table 1. Study locations, land uses, and primary pathways of interest.

Lake	County	Site type	Land use/Type	Primary pathways of interest
Sammamish	King	Angler concerns	Urban/Residential, Forested	runoff, stormwater, atmospheric deposition
Stevens	Snohomish	Angler concerns	Urban/Residential, Forested	runoff, stormwater, atmospheric deposition
American	Pierce	Contamination potential	Urban/Residential, Military	runoff, stormwater, atmospheric deposition
Spanaway	Pierce	Contamination potential	Urban/Residential, Military	runoff, stormwater, atmospheric deposition
Goodwin	Snohomish	PBT Monitoring site	Residential, Forested	runoff, atmospheric deposition
Horsethief	Klickitat	PBT Monitoring site	Recreation, State Park, grasslands	atmospheric deposition
Leland	Jefferson	PBT Monitoring site	Residential, Forested, Agriculture	atmospheric deposition
Loomis	Pacific	PBT Monitoring site	Residential, Forested	atmospheric deposition
McIntosh	Thurston	PBT Monitoring site	Residential, Forested,	atmospheric deposition, runoff
Nahwatzel	Mason	PBT Monitoring site	Residential, Forested	atmospheric deposition

3.2.1.1 Angler Concern Lakes

Lake Sammamish and Lake Stevens are on the western side of the Cascades in the Puget Sound ecoregion. This area has mild temperatures, wet winters, and dry summers (LandScope America 2023). Lake Sammamish (King County) and Lake Stevens (Snohomish County) are surrounded by forested and residential land uses in well-developed urban areas.

Lake Sammamish is located east of Seattle and Bellevue and is bordered by the city of Issaquah to the south and the city of Sammamish to the east. There have been multi-district reports of PFAS in Issaquah's drinking water. While participating in the U.S. Environmental Protection Agency's (EPA) third unregulated contaminant monitoring rule (UCMR3), the City of Issaquah found measurable concentrations of PFAS in a production well tested between 2013 - 2015 (EPA 2017; Ecology 2021). During this time period, PFOS concentrations were found above the 2009 EPA provisional health advisory of 0.2 ppb.

Sammamish Plateau Water (SPW) district monitors several wells in the city of Issaquah, six of which have reported measurable PFAS concentrations. In 2016, drinking water PFAS concentrations were below the 2016 Environmental Protection Agency (EPA) health advisory at the time (SWP 2022). SPW attributes PFAS presence in these wells to firefighting foam used during training exercises in Issaquah (SWP 2023). Following the inception of Washington state action levels (SALs) for PFAS, some wells were removed from service after repeated testing showed PFAS concentrations above SALs (SWP 2023). The DOH PFAS Testing Results dashboard shows seven SPW wells that still have measurable concentrations of PFAS as of February 2022 (WA DOH 2023). All but two of the wells' PFAS concentrations remain below SALs, and the two exceeding the SALs have been removed from service.

Two species of fish collected from Lake Sammamish in 2018 contained PFOS at levels that prompted a fish consumption advisory: largemouth bass and yellow perch (WA DOH 2022). Brown bullhead were also tested but contained PFOS below screening levels, and no advisory

was issued for that species. Cutthroat trout were not obtained in 2018 but are a species of interest to test and will be targeted for this study.

Lake Stevens is located within the town of Lake Stevens, several miles east of Everett, WA, and Everett Naval Station. No nearby drinking water systems have shown PFAS contamination surrounding Lake Stevens, and contamination in the lake — if any — would likely be due to urban and stormwater inputs. Lake Stevens is included in this study because it is a popular lake for kokanee fishing and angling for other species. Kokanee and rainbow trout are stocked in the spring at this lake, and testing the stocked fish in the fall will give us information on whether these fish are accumulating PFOS. The lake has never been tested for PFAS, either in the water or in the fish.

3.2.1.2 Contaminant Potential Lakes

Spanaway Lake and American Lake are in Pierce County and adjacent to the Joint Base Lewis-McChord (JBLM) military base. The western and southeastern parts of Lake Spanaway's shoreline (approximately 75%) and Enchanted Island to the north side of the lake are well-developed residential properties. The remaining 25% of the shoreline to the northeast of the lake is a partially forested part of Spanaway Park. Much of the area around Lake Spanaway is urban and residential. JBLM's McChord airfield is northwest of Lake Spanaway and overlaps a portion of Lake Spanaway's watershed (Pierce County 2017).

The DOH dashboard shows 4 wells with measurable levels of PFAS in the city of Spanaway, one of which is between Spanaway Lake and McChord airfield. At this well, 3.1 ng/L PFOS was recorded in March 2023. JBLM-PW (2020) identified 6 areas of the McChord airfield as potential PFAS sources that require further investigation. Groundwater and surface water samples in this area had combined concentrations for the six PFAS on the UCMR3 list ranging from 4.24 – 37,170 ng/L. One groundwater well southeast of the airfield on JBLM property had measurable UCMR3 compounds in two samples, one at 5.5 ng/L and one at 5.9 ng/L.

About 50% of American Lake falls within JBLM property. The western shoreline and the surrounding area are part of JBLM Lewis North and are used for military purposes. The eastern shoreline is a heavily developed urban and residential area of Lakewood. Lakewood Water District stated that PFAS had been found in several wells across multiple water districts in Lakewood and attributes PFAS concentrations to AFFF releases (Lakewood Water District 2023). When the Lakewood Water District sampled locations near JBLM (2017 – 2020), 17 samples had measurable levels of PFOA or PFOS. Combined concentrations ranged from 3.95 – 77.1 ng/L. The DOH dashboard showed one well in the district with measurable levels of PFAS that are below the SALs in 2022.

Groundwater, surface water, and effluent samples from areas near American Lake had total PFAS concentrations ranging from 5.0 – 171 ng/L (JBLM-PW 2020). One surface water sample on the west side of American Lake contained a combined PFOA and PFOS concentration of 14.1 ng/L (JBLM-PW 2020).

3.2.1.3 PBT Monitoring Lakes

Lakes Goodwin, Leland, McIntosh, and Nahwatzel are located on the western side of the Cascades and are distributed around Puget Sound within the Puget Trough ecoregion (LandScope America 2023). This region is characterized by a rich combination of Pacific inlet

areas, coastal lowlands and wetlands, prairie grasslands, and conifer and oak woodlands (LandScope America 2023). Urban development has heavily altered these ecosystems. Some of the most densely populated counties in the state, like King and Pierce, fall fully or partially within this ecoregion (USCB 2020). These four lakes have a combination of forested land with varying degrees of residential use. Some have more urban development than others (Table 1). Summers in the Puget Trough are warm and dry, and winters are wet and mild.

Loomis Lake is on the southwestern coast of Washington in the Northwest Coast ecoregion. This region is dominated by coastal valleys and lowlands, estuaries, wetlands, and temperate rainforests (LandScope America 2023). For nearly half of the year, between the fall and spring months, this region experiences a high volume of precipitation and has mild temperatures year-round. Urban development makes up a smaller percentage of this landscape compared to areas around Puget Sound, and private timber management makes up most of this region's land use (LandScope America 2023). The land directly around Loomis Lake is residential or forested, and a portion of the watershed consists of Loomis Lake State Park.

Horsethief Lake lies on the eastern side of the Cascades in southcentral Washington, near the state border with Oregon. This lake falls within the Columbia Plateau ecoregion, which is semi-arid, has less precipitation than the other lakes in this study, and has more dramatic temperature changes between the summer and winter months (LandScope America 2023). Much of the landscape is made up of shrub-steppe and grasslands intermixed with riparian habitats along the rivers and wetlands (LandScope America 2023). The shrub-steppe and grasslands have been heavily developed into crop agriculture and ranches, with expanding urban development along the rivers in the riparian and wetlands ecosystems (LandScope America 2023). Horsethief Lake is an impoundment of the Columbia River and exists because of dam construction. The lake is part of a state park, with the land around the lake being mostly grasslands used for recreation.

3.2.2 Summary of previous studies and existing data

Table 2 shows the range in concentrations of PFOS and other detected PFAS reported in previous studies of Washington state freshwater fish. The table presents PFAS concentrations separated by fish species, with only species relevant to this Quality Assurance Project Plan (QAPP) included in the table. Below are brief descriptions of four Ecology PFAS studies that included freshwater fish in Washington.

2008 Statewide Survey

Ecology conducted the first statewide survey of PFAS in 2008 to determine whether PFAS were present in surface water, fish tissue, osprey eggs, and wastewater treatment plant (WWTP) effluents (Furl and Meredith 2010). Fourteen waterbodies were sampled for surface water, and seven were sampled for fish tissue. PFAS were widely detected in surface water, at concentrations mostly below 10 ng/L (total, T-, or sum of 13 PFAS), in WWTP effluent at 61 – 418 ng/L (T-PFAS), and in osprey eggs at 38 – 910 ng/g (T-PFAS). The study reported much fewer detections in fish tissue, with only 40% of fillet samples having detectable amounts of PFAS. However, this was likely due to the high reporting limits for tissue at the time (10 ng/g). Fish collected from Lake Roosevelt, West Medical Lake, Lake Washington, and Lower Columbia River contained enough PFOS to be detected, ranging from 10 – 75 ng/g.

2011 Bottom Fish Survey

In 2011, Johnson and Friese (2012) analyzed bottom-feeder fish species from four waterbodies in the state and found PFOS in all samples. Fish were collected from Lake Washington, the Lower Columbia River, the Lower Yakima River, and Lake Spokane. PFOS concentrations ranged from 2.1 – 20 ng/g in common carp fillets and 2.9 – 46 ng/g in whole-body samples of largescale sucker.

2016 Statewide Survey

A second statewide PFAS survey was conducted in 2016 with the same matrices from the 2008 survey and most of the same sites (Mathieu and McCall 2017). This sampling showed that PFAS concentrations were generally lower in surface water collected in 2016 compared to 2008 and that a shift had occurred in the PFAS composition of WWTP effluent. However, no consistent change was clear for fish tissue or osprey eggs. With lower reporting limits in 2016, 86% of fillet samples had detections of PFAS. Similar to previous studies, PFOS made up most of the PFAS composition.

Fish were collected from 11 waterbodies, and fillet PFOS concentrations ranged from non-detect to 336 ng/g (median of detected samples = 19.4 ng/g). In general, the highest fish tissue PFAS concentrations were found in urban lakes in western Washington.

2018 PFAS in Fish Collected from Three Urban Waterbodies

In 2018, 76 composite samples were collected from Lakes Meridian, Sammamish, and Washington for analysis of PFAS (Mathieu 2022). All samples contained PFOS, with species-specific differences noted across the waterbodies. Across all sites, largemouth bass contained the highest PFOS concentrations and the widest range (19.1 – 50.1 ng/g), followed by yellow perch (4.1 – 20 ng/g), and brown bullhead, which had much lower concentrations (0.52 – 4.8 ng/g). Many samples had low concentrations of several long-chain perfluoroalkyl carboxylates, and none of the fish contained PFOA or short-chain PFAAs.

Table 2. PFAS concentration ranges from previous fish tissue studies.

Collection Date	Species	Sample type	n	PFOS (ng/g)	PFNA (ng/g)	PFDA (ng/g)	PFUnA (ng/g)	PFDoA (ng/g)	Ref.
2008	CTT	fillet	1	ND	ND	ND	ND	ND	(1)
2008	LMB	fillet	2	34–75	ND	ND	ND	ND	(1)
2008	RBT	fillet	1	ND	ND	ND	ND	ND	(1)
2008	SMB	fillet	1	ND	ND	ND	ND	ND	(1)
2008	WAL	fillet	1	ND	ND	ND	ND	ND	(1)
2008	YP	fillet	1	22.5	ND	ND	ND	ND	(1)
2016	CTT	fillet	1	ND	ND	ND	ND	ND	(2)
2016	LMB	fillet	5	18–74	ND	ND–5.5	ND–5.5	ND–6.0	(2)
2016	RBT	fillet	1	6.9	0.8	2.7	ND	ND	(2)
2016	SMB	fillet	5	1.5–6.3	ND	ND	ND	ND	(2)
2016	WAL	fillet	1	1.9	ND	ND	ND	ND	(2)
2016	YP	fillet	1	27	ND	2.16	0.88	0.633	(2)
2018	CTT	fillet	2	24–44	0.3–0.4	2.2–4.6	2.1–4.8	1.6–3.9	(3)
2018	KOK	fillet	3	6.4–7.8	ND–0.1	0.4–0.6	0.1–0.1	0.1–0.2	(3)
2018	LMB	fillet	22	19–50	ND–0.5	1.2–4.6	1.2–3.5	0.9–4.8	(3)
2018	SMB	fillet	5	60–99.9	ND	5.7–10	2.7–11	2.7–11	(3)
2018	YP	fillet	19	4.1–20	ND–0.2	0.3–2.3	0.2–1.4	0.1–1.9	(3)

(1) = Furl and Meredith 2010; (2) = Mathieu and McCall 2017; (3) = Mathieu 2022
CTT = cutthroat trout; LMB = largemouth bass; RBT = rainbow trout; SMB = smallmouth bass; WAL = walleye; YP = yellow perch; KOK = kokanee; ND = non-detect

3.2.3 Parameters of interest and potential sources

This study's primary parameters of interest are the 40 PFAS listed in Table A-1, Appendix A. This analyte suite includes 19 PFAAs and 7 groups of precursor compounds. In general, PFAAs are the substances found most often in fish tissue, with PFOS and long-chain perfluoroalkyl carboxylates present in the highest concentrations. Several of the precursor compounds to be included in this study have not been tested in freshwater fish of Washington state yet, and it is unknown if any will be detected.

PFAS have been manufactured since the 1950s and used extensively in a wide range of industrial and consumer products. Their primary applications include stain-, oil-, and water-proof coatings, metal plating suppressants, and as a fire-fighting aid in AFFF. While the most well-studied PFAS have been phased out of commerce, thousands of PFAS exist (OECD 2018), and hundreds that the industry considers commercially relevant (Buck et al. 2021). Recent actions in Washington state have included restrictions on PFAS in food packaging, AFFFs, cosmetics, carpets, and after-market stain- and water-proofing treatments. Additional product types are being considered for state restrictions by 2025.

Many general-use products contain PFAS, which increases the public's exposure to these chemicals. A broad category list published by Gaines (2022) names nearly 300 examples of occupational and general-use product applications containing PFAS (Table 3). Gaines (2022) noted an overlap between industries that use PFAS in production and the application of PFAS-

containing products. The list in Table 3 is not exhaustive but displays a good example of the variety and extensive use of PFAS.

Table 3. Gaines (2022) List of Industry Categories that Use PFAS.

Adhesives	Mining
Building, Construction	Oil and Gas
Ceramics, Nanostructure Synthesis	Packaging, Paper, Cardboard
Cleaning	Pesticides and Fertilizer
Coatings, Coated Products	Photography, Lithography
Cosmetics, Personal Care	Plastics, Resins, Rubber
Dry Cleaning	Recycling, Material Recovery
Electronics	Refrigerants
Etching	Scientific, General Use
Explosives, Propellants, Ammunition	Semi-conductors
Fire-fighting Foam	Textiles
Medical Components	Transportation
Metal Plating Products	--

PFAS can be released into the environment during manufacturing processes and when using and disposing of products containing PFAS. After products are used or disposed of, PFAS can be transported into and through the environment through stormwater, discrete releases (e.g., AFFF), WWTP effluent, biosolids application, landfill leachate, and atmospheric deposition. Since no manufacturing facilities exist in Washington that we are aware of, the use and disposal of products are likely the state's most important sources of PFAS release. For the sites included in this study, stormwater, discrete releases of AFFF, and atmospheric deposition are the most likely pathways to the waterbodies.

3.2.4 Regulatory criteria or standards

There are no Washington state or federal regulatory criteria or standards for PFAS in surface water or fish tissue. Laboratory results may be compared to thresholds in Tables 4 and 5 to provide context for results.

Table 4. Risk thresholds for PFAS in drinking water and groundwater.

Parameter	Matrix	EPA MCLG - Proposed	EPA MCL - Proposed	WA DOH SAL (ng/L)	WA TCP Preliminary Groundwater Cleanup Level (ng/L)
PFOA	drinking water	0 ng/L	4 ng/L	10	10
PFOS	drinking water	0 ng/L	4 ng/L	15	15
PFNA	drinking water	1.0 Hazard Index	1.0 Hazard Index	9	9
PFHxS	drinking water	1.0 Hazard Index	1.0 Hazard Index	65	65
PFBS	drinking water	1.0 Hazard Index	1.0 Hazard Index	345	345
HFPO-DA (GenX)	drinking water	1.0 Hazard Index	1.0 Hazard Index	---	24
PFBA	drinking water	1.0 Hazard Index	1.0 Hazard Index	---	8000

EPA MCLG = Environmental Protection Agency Maximum Contaminant Level Goal
MCL = Maximum Contaminant Level
WA DOH = Washington State Department of Health
SAL = State Action Level
TCP = Toxics Cleanup Program

Table 5. Washington State Department of Health fish consumption guidance screening levels for PFOS.

PFOS Concentration (ng/g)	# Meals Recommended Based on Concentration
< 1.8	No advisory
1.8–2.3	8 meals/month
2.4–4.7	4 meals/month
4.8–9.4	2 meals/month
9.5–28.2	1 meal/month
> 28.2	Do not eat

4.0 Project Description

4.1 Project goals

The primary goal of this project is to characterize the presence and concentrations of PFAS in fillet tissue of several species of freshwater fish from ten waterbodies in Washington state. The study is designed to collect sufficient sample sizes for each species and waterbody so that the data will be useful for fish consumption guidance and advisories.

4.2 Project objectives

Project objectives to meet the goal include:

- Collect 30 water samples and up to 110 fish composite samples from 10 waterbodies in Washington state for analysis of PFAS.
- Make results available to the public and other agencies through a written report and Ecology's Environmental Information Management (EIM) database.

4.3 Information needed and sources

This project is being conducted to generate new environmental data and will not require additional sources to carry out objectives.

4.4 Tasks required

The following tasks are required for this study:

- Conduct desk reconnaissance of waterbodies, including access and fish species present.
- Coordinate with other staff in Ecology's Environmental Assessment Program (EAP) to secure scientific collection permits to obtain fish samples.
- Organize and prepare for field collections, including scheduling, laboratory coordination, and inventorying equipment.
- Complete field sample collections and submit water samples to the laboratory for analysis.
- Process/homogenize fish samples at Ecology Headquarters and submit to the laboratory for analysis.
- Review and assess the quality of laboratory results and data validation report.
- Enter field and laboratory data into the EIM database.
- Draft final report documenting results of the sampling and analysis.
- Publish the final report following the internal review process.

4.5 Systematic planning process

This Quality Assurance Project Plan addresses the elements of the systematic planning process.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

Table 6 shows the responsibilities of those involved in this project.

Table 6. Organization of project staff and responsibilities.

Staff	Title	Responsibilities
Jessica Archer SCS, EAP Phone: 360-407-6698	Client and SCS Manager	Clarifies scope of the project. Provides review of the QAPP and approves the final QAPP. Provides review of final report.
James Medlen Toxic Studies Unit SCS, EAP Phone: 360-407-6194	Client and Supervisor for the Project Manager	Clarifies scope of the project. Provides review of the QAPP and approves the final QAPP. Provides review of the final report. Manages budget and staffing needs.
Callie Mathieu Toxic Studies Unit SCS, EAP Phone: 360-407-6965	Project Manager and Principal Investigator	Lead author of the QAPP and final report. Oversees field collections. Conducts QA review of data, analyzes data, and interprets data.
Katelyn Foster Toxic Studies Unit SCS, EAP Phone: 360-706-4888	Field Lead	Co-authors the QAPP and final report. Coordinates with the laboratory. Leads field collections, records field information, and sends samples to the laboratory. Enters data into EIM.
Dean Momohara Manchester Environmental Laboratory Phone: 360-871-8801	Acting Director	Reviews and approves the final QAPP.
Arati Kaza Phone: 360-407-6964	Ecology Quality Assurance Officer	Reviews and approves the final QAPP.

EAP: Environmental Assessment Program
EIM: Environmental Information Management database
QAPP: Quality Assurance Project Plan

5.2 Special training and certifications

All staff conducting field collections for this study will gain the necessary skills through education, field experience, and training by senior staff. Specialized training for this work includes piloting Ecology boats, safely operating electrofishing equipment, and collecting surface water for low-level organics analysis. Staff will follow standard operating procedures listed in Section 8 for all aspects of the field collections.

Ecology staff follow procedures required under EAP's safety program, as detailed in the EAP Safety Manual. Field staff certifies that they review these procedures upon employment and every two years after that. Boat operators of the electrofishing boat used for fish collections must be certified to pilot the boat and must participate in annual refresher training to maintain boat pilot certification.

5.3 Organization chart

Not applicable — see Table 6.

5.4 Proposed project schedule

Tables 7 – 9 list key activities, due dates, and lead staff for this project.

Table 7. Schedule for completing field and laboratory work.

Task	Due date	Lead staff
Fieldwork and sample processing complete	11/30/2023	Katelyn Foster
Laboratory analyses complete	05/31/2024	Callie Mathieu
Contract lab data validation complete	08/31/2024	Callie Mathieu

Table 8. Schedule for data entry.

Task	Due date	Lead staff
EIM data loaded*	02/28/2025	Katelyn Foster
EIM QA	03/31/2025	Callie Mathieu
EIM complete	04/30/2025	Katelyn Foster

*EIM Project ID: PBTMON006
EIM: Environmental Information Management database

Table 9. Schedule for final report.

Task	Due date	Lead staff / Support staff
Draft to supervisor	12/31/2024	Callie Mathieu / Katelyn Foster
Draft to client/ peer reviewer	01/31/2025	Callie Mathieu / Katelyn Foster
Final draft to publications team	02/28/2025	Callie Mathieu / Katelyn Foster
Final report due on web	04/30/2025	Callie Mathieu / Katelyn Foster

5.5 Budget and funding

Table 10 shows the laboratory budget for this study. Funding for all study expenses comes from the PBT Monitoring Program, provided by the state toxics control account.

Table 10. Laboratory budget for this study.

Parameter	Matrix	Field Samples (# of samples)	QA Samples* (# of samples)	Total Number of Samples	Cost per Sample	Lab subtotal
PFAS	water	30	16	46	$500	$23,000
TSS	water	30	2	32	$45	$1,440
DOC	water	30	2	32	$45	$1,872
TOC	water	30	2	32	$45	$1,872
PFAS	fish tissue	110	18	128	$500	$83,200
					Lab Total	$111,384

*Quality Assurance (QA) samples include paying samples: field replicates, field blanks, equipment blanks, laboratory duplicates, matrix spikes, and matrix spike duplicates.
PFAS = per- and polyfluoroalkyl substances; TSS = total suspended solids; DOC = dissolved organic carbon; TOC = total organic carbon.

6.0 Quality Objectives

6.1 Data quality objectives [1]

The data quality objective for this project is to collect enough fish tissue samples to represent species-specific fillet PFAS concentrations and supporting surface water PFAS concentrations for the selected waterbodies. Samples will be analyzed using standard methods to obtain data that meet measurement quality objectives (MQOs) described below.

6.2 Measurement quality objectives

The MQOs for laboratory analyses, expressed in terms of acceptable precision, bias, and sensitivity, are described in this section and summarized in Table 11. Acceptance limits for in-situ measurements are given in Table 12.

[1] DQO can also refer to ***Decision*** Quality Objectives. The need to identify Decision Quality Objectives during the planning phase of a project is less common. For projects that do lead to important decisions, DQOs are often expressed as tolerable limits on the probability or chance (risk) of the collected data leading to an erroneous decision. And for projects that intend to estimate present or future conditions, DQOs are often expressed in terms of acceptable uncertainty (e.g., width of an uncertainty band or interval) associated with a point estimate at a desired level of statistical confidence.

6.2.1 Targets for precision, bias, and sensitivity

Table 11. Measurement quality objectives.

Parameter	Matrix	LCS (% recovery)	Method Blanks	Matrix Spike (% recovery)	Matrix Spike Duplicates (RPD.)	Lab Duplicates (RPD)	Surrogate Standards (% recovery)
PFAS	water	50–150	no analytes detected > 1/2 LOQ	50–150	< 30	< 40	50–150
TSS	water	80–120	< RL	n/a	n/a	≤20	n/a
DOC	water	80–120	< RL	75–125	≤20	≤20	n/a
TOC	water	80–120	< RL	75–125	≤20	≤20	n/a
PFAS	fish tissue	50–150	no analytes detected > 1/2 LOQ	50–150	< 30	< 40	50–150

LCS = laboratory control samples; RPD = relative percent difference; PFAS = per- and polyfluoroalkyl substances; TSS = total suspended solids; DOC = dissolved organic carbon; TOC = total organic carbon; LOQ = limit of quantitation

Table 12. Acceptance limits for in-situ measurement calibration and post-checks.

In-situ Parameter	Units	Accept	Qualify	Reject
pH	std. units	≤ +/- 0.3	≥ +/- 0.3 and ≤ +/- 1.0	≥ +/- 1.0
Conductivity	uS/cm	≤ +/- 10%	≥ +/- 10% and ≤ +/- 20%	≥ +/- 20%
Temperature	°C	≤ +/- 0.2	≥ +/- 0.2 and ≤ +/- 15%	≥ +/- 1.0
Dissolved oxygen	% saturation	≤ +/- 5%	≥ +/- 5% and ≤ +/- 15%	≥ +/- 15%
Dissolved oxygen	mg/L	≤ +/- 0.3	≥ +/- 0.3 and ≤ +/- 0.8	≥ +/- 0.8

6.2.1.1 Precision

Precision is a measure of variability among replicate measurements due to random error. Results from this project will be assessed for precision using replicate field measurements and analysis of laboratory duplicates and matrix spike duplicates. Precision for two replicate samples will be measured as the relative percent difference between the two results. MQOs for precision are presented in Table 11.

Surface water field replicates will be collected for every 10% of samples and analyzed alongside the field samples. A field replicate sample will be collected immediately after the field sample using the same sampling technique. Fish tissue samples will be split in the laboratory for duplicate analyses.

6.2.1.2 Bias

Bias is the difference between the sample result and the true value. Bias will be evaluated and compared to method-specific limits by analyzing laboratory control samples and matrix spikes. Laboratory control samples contain known amounts of analyte and indicate bias due to sample preparation and/or calibration. Matrix spikes indicate bias due to matrix effects, and matrix spike duplicates provide an estimate of the precision of this bias. Table 11 outlines the MQOs for recoveries of laboratory control samples and matrix spikes.

6.2.1.3 Sensitivity

Sensitivity is a measure of the capability of a method to detect a substance above background noise. Laboratory analysis sensitivity is defined for the study as the quantitation limit or reporting limit. The draft EPA Method 1633 for analysis of PFAS defines the quantitation limit as the "minimum level of quantification (ML)." The laboratory may use the term "minimum reporting level (MRL)" or "limit of quantitation (LOQ)" as a synonym for the ML. See Table 16 for quantitation (reporting) limits.

Field and equipment blanks will be collected to help determine background contamination. Field staff will collect blank samples alongside water samples for all parameters analyzed in surface waters. Laboratory-provided blank water will be poured into sample bottles in the same manner as field samples are collected. Equipment blanks will be collected for fish tissue processing equipment. Aluminum foil used to wrap the fish in the field will be tested, as well as the grinding equipment.

6.2.2 Targets for comparability, representativeness, and completeness

6.2.2.1 Comparability

This study will ensure comparability with other projects by using standard operating procedures (SOPs) (see Section 8 for a list of SOPs) and standard laboratory methods. In addition, fish will be collected in the fall months to ensure comparability with other fish tissue studies. Most Ecology fish tissue studies have been conducted in the fall, following EPA guidance to states for fish contaminant monitoring programs to capture high lipid content (EPA 2000).

6.2.2.2 Representativeness

The study design, as described in Section 7 of this QAPP, is expected to capture representative data of the conditions in each waterbody. Three surface water samples from three offshore areas of the lake are being collected at each site to help characterize PFAS concentrations during sampling. All study locations are enclosed lakes, and the fish collected from the sites are assumed to be representative of the entire waterbody, as resident fish can and do freely swim throughout the waterbody.

The number of fish tissue samples targeted for this study is based on the needs of the DOH for use in assessments for fish consumption advisories. The DOH requests five composite samples of each species to represent a central tendency of the PFAS concentrations in the waterbody for that species. The DOH may use a smaller number of fish in their assessments, depending on other factors; therefore, a minimum of three composite samples per species will still be analyzed if that is what is encountered in the field.

6.2.2.3 Completeness

The completeness goal for this project is 80% of the target species/samples collected and 95% of laboratory data deemed usable as qualified by the data validator.

6.3 Acceptance criteria for quality of existing data

This project is being carried out to generate new environmental data. Previously reported data may be used in the final report for comparison to this study's findings or to support the discussion in the report. Any historical data used for this purpose will have been collected under an approved QAPP, with a published report summarizing laboratory methods, data quality, and sampling protocols.

6.4 Model quality objectives

Not applicable.

7.0 Study Design

In fall 2023, Ecology's PBT Monitoring Program will collect samples of surface water and freshwater fish tissue from ten lakes in Washington state to analyze for PFAS. Study locations selected for analysis include those with heavy local angler presence (Lakes Sammamish and Stevens), areas with potential for contamination based on drinking water detections of PFAS nearby (American and Spanaway Lakes), and six exploratory sites where fish are being collected for a separate long-term monitoring study. The long-term monitoring effort is being leveraged to fill data gaps on fish tissue PFAS concentrations in lakes across a range of waterbodies and contamination potential.

To characterize fish PFAS concentrations at the study locations, a variety of species will be collected based on species availability, public health concerns, current project capacity, and concurrent collection for long-term monitoring efforts. Table 13 summarizes the target species to be collected from each lake. Field staff will attempt to collect enough individual fish for five composite samples of each species from a site. Surface water samples will be collected concurrently at all lakes to gather more information on the relationship between PFAS concentrations in the water and the fish tissue.

Table 13. Target freshwater fish species.

Lake	Site type	CTT	RBT	KOK	LMB/ SMB	YP	BG/ BC	BBH	WAL
Sammamish	Angler concerns	**X**	p	p	s	s	X	s	
Stevens	Angler concerns		**X**	**X**	**X**	p	p	p	
American	Contamination potential	p	**X**	**X**	**X**	p			
Spanaway	Contamination potential		**X**		**X**	**X**	p		
Goodwin	PBT Monitoring site	p	p		**X**	**X**	p	p	
Horsethief	PBT Monitoring site				**X**	p		p	**X**
Leland	PBT Monitoring site				**X**	**X**	p	p	
Loomis	PBT Monitoring site				**X**	**X**	p		
McIntosh	PBT Monitoring site				**X**	**X**	p	p	
Nahwatzel	PBT Monitoring site	p	**X**		**X**				

CTT = cutthroat trout; RBT = rainbow trout; KOK = kokanee; LMB = largemouth bass; SMB = smallmouth bass; YP = yellow perch; BG = blue gill; BC = black crappie; BBH = brown bullhead; WAL = walleye. P = species present, not a target species but could be sampled as a backup; X = target species; s = present but already sampled.

This study will target rainbow trout, kokanee, and cutthroat trout in two of the lakes in response to local angler concerns over safety following the DOH fish consumption advisory for PFOS in three King County lakes (WA DOH 2022). A fish consumption advisory issued for Lake Sammamish included several species, but not cutthroat trout — a popular angling species. This study will attempt to fill that gap by targeting that species using offshore collection methods not employed in the past at Lake Sammamish (gill nets, angling, etc.). In addition, Lake Stevens has

an active angling presence focused on kokanee and rainbow trout, and this study will attempt to collect those species to gain information on PFAS concentrations in those fish.

Trout, kokanee, and bass will be targeted at American and Spanaway Lakes. These lakes are in an area of concern for PFAS contamination, and up to three species are being targeted to characterize PFAS concentrations across multiple species. While multiple drinking water wells have shown PFAS in the groundwater near these lakes, it is unknown if PFAS has entered the lake through groundwater interaction. The lakes are also in urbanized watersheds, which have been shown to contain average fish PFAS concentrations above human health concerns for some species (Mathieu 2022). Fish have not been sampled from these lakes previously for PFAS.

Six lakes selected for this study are routinely monitored every five years for mercury by Ecology's PBT Monitoring Program (Mathieu and Bednarek 2020). For these six lakes, project-specific target and ancillary species will be sampled for mercury in addition to PFAS. For mercury trends, the target species is largemouth or smallmouth bass, and the ancillary selection can include up to two additional species that are found at the lake. This project will analyze two species collected from the lakes in the ongoing long-term monitoring effort.

Satisfying the collection requirements for PFAS characterization could be affected by the availability of a species at a lake and any factors that affect the likelihood of catch. It is important to note that not all species are found in all 10 lakes and that lake conditions, population characteristics, and permit-approved sampling methods could limit the size and number of fish we can catch. If insufficient collections of any target species seem likely, Ecology will substitute for another species when possible. If available, Ecology will also utilize additional resources to collect the desired number of target species. Cooperative efforts with other interested parties, like the Washington Department of Fish and Wildlife (WDFW), local tribes, angling clubs, lake associations, and lake events, could help supplement our catch efforts.

7.1 Study boundaries

For each lake, the study boundary is the shoreline perimeter of the waterbody. Table 14 gives the water resource inventory areas (WRIAs) and hydrologic unit codes (HUCs) for each study location. Figure 1 displays the sites as they are distributed in the state.

Table 14. Study locations and surface water sample collection coordinates.

Lake	County	WRIA	HUC	Sample Collection lat. / long. (water sample 1)	Sample Collection lat. / long. (water sample 2)	Sample Collection lat. / long. (water sample 3)
Goodwin	Snohomish	7 - Snohomish	17110019	48.150 / -122.294	48.142 / -122.298	48.132 / -122.293
Horsethief	Klickitat	30 - Klickitat	17070105	45.647 / -121.107	45.645 / -121.100	45.643 / -121.103
Leland	Jefferson	17 - Quilcene - Snow	17110018	47.899 / -122.877	47.895 / -122.883	47.888 / -122.887
Loomis	Pacific	24 - Willapa	17100106	46.437 / -124.043	46.439 / -124.043	46.428 / -124.042
McIntosh	Thurston	13 - Deschutes	17110016	46.872 / -122.759	46.868 / -122.763	46.863 / -122.774
Nahwatzel	Mason	22 - Lower Chehalis	17100104	47.246 / -123.33	47.242 / -123.332	47.238 / -123.335
American	Pierce	12 - Chambers - Clover	17110019	47.136 / -122.545	47.133 / -122.56	47.121 / -122.574
Sammamish	King	8 - Cedar - Sammamish	17110012	47.642 / -122.091	47.606 / -122.092	47.569 / -122.075
Spanaway	Pierce	12 - Chambers - Clover	17110019	47.113 / -122.449	47.109 / -122.447	47.105 / -122.446
Stevens	Snohomish	7 - Snohomish	17110011	48.003 / -122.083	48.006 / -122.076	47.992 / -122.081

WRIA = water resources inventory area; HUC = hydrologic unit code.

7.2 Field data collection

7.2.1 Sampling locations and frequency

All samples will be collected during one sampling event per lake in September – October 2023. If fish collection efforts are unsuccessful, multiple attempts may be made. Fish collections will occur throughout the entire waterbody, either close to the shoreline via electroshocking or offshore via gill netting or angling. Surface water samples will be collected at three distinct offshore areas of the lake. Target geographic coordinates for surface water sampling are given in Table 14 and displayed on maps in Appendix B. Surface water collection coordinates were selected in a targeted approach to reflect surface water PFAS concentrations far from sources along the shore and to obtain well-mixed representative samples.

7.2.2 Field parameters and laboratory analytes to be measured

All surface water and fish tissue samples will be analyzed for the 40 PFAS listed in Table A-1, Appendix A. Surface water samples will also be analyzed for total suspended solids, total organic carbon, and dissolved organic carbon. Field crews will measure temperature, pH, conductivity, and dissolved oxygen in situ at the site of the surface water collections with a multi-parameter probe. These ancillary parameters are being analyzed or measured to examine relationships with PFAS concentrations and to help explain differences or similarities among sites.

Field crews will measure the total fish length and weight for all fish collected. WDFW biologists will determine individual fish ages via age structures collected by project staff. Similar to the ancillary water parameters, these ancillary fish measurements help us understand relationships with PFAS concentrations and may be used as explanatory variables or covariates.

7.3 Modeling and analysis design

Not applicable.

7.4 Assumptions underlying design

This study will be carried out under several assumptions. We assume that quantitation limits will be low enough to characterize PFAS concentrations in the waterbodies, including the sites where we do not expect major PFAS inputs (i.e., remote, undeveloped watersheds). Another major assumption is that the PFAS of particular interest (PFOS and long-chain perfluoroalkyl carboxylates) will be preserved in frozen fish tissue for up to 6 months. See Section 8.3 for a discussion on this holding time assumption.

This study assumes that the number of samples targeted for each waterbody will be sufficient to characterize the level of PFAS in the species being analyzed for that particular site and that the number of surface water samples at the site will provide an accurate picture of PFAS water concentrations at the time of sampling.

7.5 Possible challenges and contingencies

7.5.1 Logistical problems

Potential logistical problems and mitigation strategies include:

- Boat launch access: Staff will carry out detailed site reconnaissance before sampling and coordinate with other agencies and jurisdictions to ensure access to all sites.
- Weather: Poor weather can alter field schedules and delay sample collection. We schedule a broad window of the sampling season with multiple backup weeks to allow for these types of delays.
- Target fish species: Collection of target fish species, including the target size classes and number of individuals, is always challenging in fish tissue studies. Desk reconnaissance and talking with WDFW biologists, tribes, and others with expertise help manage expectations and inform collection strategies.
- Permit restrictions: Our scientific fish collection permits restrict us to a certain number of "takes" of salmonid species listed under the Endangered Species Act. Detailed reconnaissance will help us direct our fishing timing and strategies to avoid listed species.

7.5.2 Practical constraints

Practical constraints of this study include the availability of staff resources for field collections and laboratory analyses. As of the time of writing this QAPP, staff resources are allocated for these activities, but changes may occur, and the project manager will work with management if

issues arise. The project manager will coordinate with the laboratory by giving several months' notice of the project and providing the QAPP for review. The field lead will communicate the timing of samples arriving at the laboratory.

7.5.3 Schedule limitations

The above logistical and practical challenges, delays in laboratory analysis, data validation, and the development of the final report may impact the project schedule. Internal forms and tracking of project schedules will be used to inform management of deadline changes.

8.0 Field Procedures

8.1 Invasive species evaluation

Staff will conduct all fieldwork following EAP's SOP EAP070 Minimizing the Spread of Invasive Species (Parsons 2023). Sites with invasive species will be identified as areas of moderate or extreme concern during desk reconnaissance. Field staff will follow the SOP for decontamination procedures before and between sites.

8.2 Measurement and sampling procedures

The collection, handling, processing, and preservation of fish tissue samples will follow procedures designed to meet the data quality objectives of this project and are guided by EPA's Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories (EPA 2000). Staff will also follow sampling guidance developed by Michigan State's PFAS Action Response Team to minimize PFAS cross-contamination (MDEQ 2018). Staff will follow the Michigan guidance for PFAS-containing equipment and material to avoid while sampling and processing. The EAP standard operating field procedures to be followed for this study include:

- Standard Operating Procedure EAP015, Version 1.4: Manually Obtaining Surface Water Samples (Joy 2021).
- Standard Operating Procedure EAP009, Version 1.3: Field Collection, Processing, and Preservation of Finfish at the Time of Collection in the Field (Sandvik 2023a).
- Standard Operating Procedure EAP007, Version 1.3: Resecting Finfish Whole Body, Body Parts, or Tissue Samples (Sandvik 2023b).
- Standard Operating Procedure EAP090, Version 1.2: Decontaminating Field Equipment for Sampling Toxics in the Environment (Friese 2021).

Surface water collections

Three surface water samples will be collected from each site at the coordinates given in Table 14. Sampling coordinates are in offshore areas, far away from shoreline inputs in a well-mixed part of the lake and will be accessed by boat. Near-surface grabs (15 – 30 cm below the water surface) will be retrieved using polyethylene and stainless-steel telescopic pole samplers with sample bottles attached to the end. Sampling poles will be used to collect samples away from water contacting the boat and upstream of the boat if flow is present. Field staff will use "clean hands/dirty hands" protocols. One staff member is responsible for holding the pole and dipping

the sample bottle. The other staff will be solely responsible for uncapping right before collection and re-capping the bottle immediately after filling. Sample bottles will be labeled and stored in individual plastic bags with zipped locks and then stored on ice until transport to Ecology Headquarters.

Ancillary parameter (total suspended solids, total organic carbon, and dissolved organic carbon) samples will be collected following the PFAS sample at the same depth (15 – 30 cm below the surface) and stored on ice. Water temperature, dissolved oxygen, pH, conductivity, and oxygen reduction potential will be measured with a multi-parameter sonde at the same depth and recorded in the field notebook.

Fish tissue collections

Fish collections will include electrofishing, gill netting, and angling. Field staff will use the best methods that are species and location specific. Ecology will work with fish biologists from WDFW, utilize local information, and pull from field notes of previous sampling events to determine the best approach that mitigates extraneous lethal take. Where feasible, Ecology may collect fish through cooperative efforts with other agencies, like the WDFW, local tribes, or angler donations.

Captured fish will be identified to the species level, with target species kept and non-target species released. The size and condition of the kept fish will be evaluated to ensure they are acceptable for further processing (e.g., correct size, no obvious tissue damage). Once Ecology has collected enough fish to meet the composite number and size range for each target species, field staff will move forward with the field sample collection process. All fish will be euthanized using a blow to the head with a blunt object (such as a fish bat), weighed to the nearest gram, and measured to the nearest millimeter (total length). All data will be recorded in the field using Rite-in-the-Rain field paper.

After the data is recorded, fish will be rinsed in ambient water, double-wrapped in aluminum foil, and stored in a re-sealable polyethylene bag with an identification tag. Each tag will have the date, site, and field ID assigned to the fish. Bagged fish specimens will be stored on ice in the field and then frozen at -20°C at Ecology facilities in Lacey, WA.

Fish tissue sample homogenization

All fish will be processed into composite samples using single-side or both-side fillets. Single-side fillets are processed when sufficient sample size can be obtained from only one side of the fish. Both fillet sides are used for smaller fish. Fillets of 3 – 5 similarly sized individuals will be used for composite samples. While the target number of individuals for each composite is five, the number of fish per composite will be decided based on the number of individuals collected at each lake within the same size class. For each composite sample, the smallest and largest fish lengths will be within 75% of each other (EPA 2000).

All fish will be partially thawed and scrubbed under tap water to remove slime. Scaled species (i.e., bass and yellow perch) will be descaled and processed with skin on. Scaleless species (i.e., catfish) will have the skin removed before processing. Following slime and scale removal, fish will be rinsed with tap water, filleted, and fillets cut into cubes. Cubed fillet tissue for each fish will be ground twice by a KitchenAid food grinder. An equal weight of the twice-ground

homogenate will be taken from all individuals in a composite. Then the aliquots will be combined and homogenized a third time with the KitchenAid food grinder. The ground tissue will be mixed until it has a consistent texture and color. Subsamples of the final composite homogenate will be placed in the appropriate, labeled containers, frozen at -20°C, and transported on ice to the laboratory for analysis. Any excess homogenate will be saved as archives in labeled containers and stored at -20°C at Ecology's Headquarters facility in Lacey, WA.

Following fillet removal, the species-appropriate fish aging structures (scales, otoliths, opercula, or spines, depending on species) will be removed, cleaned, and sent to WDFW for age analysis. Scales for aging will be collected before descaling where appropriate. The sex of the fish will also be determined and recorded after the fillets have been removed.

8.3 Containers, preservation methods, holding times

Table 15 presents the sample containers, preservation methods, and holding times used for this study.

The acceptable holding time for PFAS in fish tissue for this study will be six months. This diverges from the analytical method to meet the time required to collect the samples, process/homogenize them, and then ship them to the laboratory. The draft EPA Method 1633 for analysis of PFAS specifies a holding time of 90 days frozen for all matrices. However, this is based on a holding time study that included only aqueous, solids, and biosolids samples, not fish tissue (Willey et al. 2021). We expect the target PFAS of interest (PFOS and perfluoroalkyl acids) to be preserved in frozen fish tissue beyond 90 days and have used holding times of up to one year in the past for PFAS and other PBT chemicals. Therefore, this study will accept the results of fish tissue analyses performed within six months. Precursor degradation remains a concern for surface waters, and those samples will be held to the 90-day frozen holding time.

Table 15. Sample containers, preservation, and holding times.

Parameter	Matrix	Minimum Quantity Required	Container	Field preservation	Preservation after processing/at HQ	Holding Time
PFAS	water	≤500 mL	certified clean PFAS-free 500 mL HDPE bottle	cool to 4°C, dark	freeze, -20°C, dark	90 days frozen
TSS	water	1 L	1 l widemouth poly bottle	cool to 4°C, dark	cool to 4°C, dark	7 days
DOC	water	125 mL	125 mL widemouth HDPE, pre-preserved, 0.45 um pore size filters	filter in field, 1:1 HCl to pH<2, cool to ≤6°C	cool to 4°C, dark	28 days
TOC	water	125 mL	125 mL widemouth HDPE, pre-preserved	1:1 HCl to pH<2, cool to ≤6°C	cool to 4°C, dark	28 days
PFAS	fish tissue	5 g ww	certified clean PFAS-free 250 mL HDPE	cool to 4°C	freeze, -20°C	90 days frozen[1]; 6 months frozen[2]

[1]As per method; [2]Acceptable for this study. PFAS = per- and polyfluoroalkyl substances;
TSS = total suspended solids; DOC = dissolved organic carbon; TOC = total organic carbon.

8.4 Equipment decontamination

Staff will follow EAP's SOP Number EAP090, Decontaminating Field Equipment for Sampling Toxics in the Environment, Version 1.2 (Friese 2021), to clean sample collection equipment and fish homogenization equipment. Equipment will be scrubbed with Liquinox, rinsed with hot tap water, dried, and rinsed with methanol. Equipment will then be dried in a hood and wrapped in PFAS-free aluminum foil before use.

8.5 Sample ID

Individual fish retained during fish collections are assigned a unique fish field ID following the format of "AAA ##," where AAA = the three-letter code for the species and ## = consecutive numbers starting with 01. After collection, the fish field ID will be written on a sample tag with the waterbody name and collection date and then placed between the two layers of foil wrapping the individual fish.

After homogenization, composite samples are given a "station ID." The station ID consists of the following format: AAAYYY##, where AAA = three-letter abbreviation for the sampling site, YYY = the three-letter species code, and ## = consecutive numbers starting with 01. Station IDs will be written on the top of the laboratory analysis jar lid.

Each sample is assigned a unique lab sample number using the 7-digit Manchester Environmental Laboratory (MEL)-assigned work order number, followed by a dash and a consecutive 2-digit number starting with -01. The Project Manager will assign the 2-digit number. MEL will assign a unique work order number for each sampling event after receiving the pre-sample notification form from the field lead.

8.6 Chain of custody

Chain of custody will be maintained for all samples throughout this project. Samples will be stored in a cooler or freezer in the Ecology Headquarters locked chain of custody room. Ecology staff will use MEL's chain of custody form for shipment to the laboratory.

8.7 Field log requirements

Field notes will be kept for each sampling event as described by SOP EAP009 (Sandvik 2023a). Notes will be entered in a weather-resistant field notebook. Pre-printed forms will be used to facilitate the recording of required info. The info recorded will include:

- Name of the project
- Field personnel
- Location, method, and time of surface water sampling.
- Location, method(s), and timing of fish sampling.
- Field measurements related to electrofishing (temperature, conductivity, electrofishing parameters).
- General weather conditions.

- Estimates of species and sizes encountered not retained.
- Field ID, total length, weight, and species of fish samples collected.
- Any circumstances that may affect interpretation of results.
- Latitude and longitude coordinates, and their datum, will be obtained with a hand-held Global Positioning System device and maps.

Additionally, a fish processing bench sheet form will be used to record various data during processing, such as processing date, processing crew, lab sample ID names, lab sample numbers, fillet weights, sex of individual fish, age structure container references, and any relevant comments.

8.8 Other activities

Scientific collection permits for fish collection must be secured before sampling. Project staff will work with other staff in EAP's Toxics Studies Unit to make sure all necessary permits are approved. This includes permits issued by the WDFW, National Marine Fisheries Service, and the United States Fish and Wildlife Service.

9.0 Laboratory Procedures

9.1 Lab procedures table

Table 16 presents laboratory methods and procedures for this study.

The reporting limit for PFAS is synonymous with the ML, as cited in the method. The ML is the lowest concentration at which the analyte can be measured with a known confidence level. The laboratory will report results down to the method detection limit. Results above the method detection limit but below the reporting limit will be qualified "J" as estimates.

Table 16. Measurement methods (laboratory).

Lab	Parameter	Matrix	Number of samples	Sample arrival to lab date	Expected range of results	Method detection limit	Sample preparation method	Method
MEL	PFAS	water	46	October 2023	<0.2–100 ng/L	0.1–3.0 ng/L*	EPA 1633**	EPA 1633**
MEL	TSS	water	32	October 2023	<1–300 mg/L	1.0 mg/L (RL)	Gravimetric, Dried 103-105C	SM2540D
MEL	DOC	water	32	October 2023	<1–10 mg/L	0.5 mg/L (RL)	n/a	SM5310B
MEL	TOC	water	32	October 2023	<1–10 mg/L	0.5 mg/L (RL)	n/a	SM5310B
Contract lab	PFAS	fish tissue	128	November 2023	<0.2–100 ng/g	0.03–1.2 ng/g ww*	EPA 1633**	EPA 1633**

* Reporting limits for all analytes should meet draft 3 EPA Method 1633 Table 6 reporting limits.
** There are currently three drafts of EPA 1633; the laboratory should use the draft they are accredited for.
RL = reporting limit; MEL = Manchester Environmental Laboratory PFAS = per- and polyfluoroalkyl substances; TSS = total suspended solids; DOC = dissolved organic carbon; TOC = total organic carbon.

9.2 Sample preparation method(s)

Staff will homogenize the fish tissue samples following procedures stated in Section 8.2. The laboratory will prepare samples of all matrices prior to analysis following methods outlined in Table 16.

9.3 Special method requirements

There are currently three drafts of EPA Method 1633 as of the time of writing this QAPP, with the final version expected in late 2023. However, all laboratories accredited for the method by Washington State are accredited for Draft 2 1633. The laboratories involved in this study should use the draft method that they are accredited for, and the state expects laboratories to move toward updates as the method becomes finalized.

9.4 Laboratories accredited for methods

The laboratories conducting analyses must be accredited for the method employed. MEL is seeking accreditation for draft EPA Method 1633 for PFAS in water. MEL has provided an initial demonstration of capability and a method detection limit study. An accreditation waiver will be sought if MEL has not finalized accreditation but has provided the necessary documentation. An accredited contract laboratory will analyze the fish tissues for PFAS.

10.0 Quality Control Procedures

10.1 Table of field and laboratory quality control

Table 17 presents the Quality Control (QC) samples to be included with each analysis. Appendix C gives definitions of the QC sample types.

Table 17. Quality control samples, types, and frequency.

Parameter	Matrix	Field duplicate	Field/ equipment blank	LCS	Method blanks	Matrix spike/ matrix spike duplicate	Laboratory duplicates	Surrogates
PFAS	water	10% of samples	10% of samples	1/batch	1/batch	1/batch	1/batch	each sample
TSS	water	10% of samples	n/a	1/batch	1/batch	---	1/batch	---
DOC	water	10% of samples	10% of samples	1/batch	1/batch	1/batch	1/batch	---
TOC	water	10% of samples	n/a	1/batch	1/batch	1/batch	1/batch	---
PFAS	fish tissue	n/a	4 equipment blanks	1/batch	1/batch	1/batch	1/batch	each sample

Batch = 20 or fewer samples; LCS = laboratory control sample; PFAS = per- and polyfluoroalkyl substances; TSS = total suspended solids; DOC = dissolved organic carbon; TOC = total organic carbon.

10.2 Corrective action processes

The laboratory conducting the analysis will be expected to follow corrective actions described by the methods listed in Table 16. The data validator will examine results that fall outside of the MQOs and laboratory acceptance limits and determine whether the data should be re-analyzed, rejected, or deemed usable with appropriate qualification.

11.0 Data Management Procedures

11.1 Data recording and reporting requirements

All field data and observations will be recorded on waterproof paper in the field and then transferred to Excel spreadsheets after sampling events are completed. Data entries will be independently verified for accuracy by another project team member.

Field measurements and laboratory data for this project will be entered into Ecology's EIM database. Study results will be uploaded into EIM using the EIM XML results template. The EIM Study ID for this project is PBTMON006.

11.2 Laboratory data package requirements

MEL will provide case narratives to the project manager with final qualified results and a description of the data quality. Case narratives should include a full description of data validation performed (for PFAS analyses), any problems encountered with the analyses, corrective actions taken, changes to the referenced method, and an explanation of data qualifiers. Narratives will also address the condition of samples on receipt, sample preparation, analysis methods, instrument calibration, and results of QC tests. Final electronic data deliverables for PFAS analyses should include the following additional columns:

- data validation-amended result value
- data validation-amended result qualifier
- data validation reason code
- data validation level code

The contract laboratory must submit a Tier 4 data package to MEL with the complete raw laboratory dataset.

11.3 Electronic transfer requirements

MEL will email case narratives to the project manager in PDF format. Final validated electronic data deliverables for all PFAS analyses will be emailed to the project manager in Excel spreadsheet format. Conventional data generated by MEL (total suspended solids, total organic carbon, and dissolved organic carbon) will be delivered to the project manager via LIMS.

The contract laboratory will be required to submit data packages to MEL electronically, as specified in the scope of work for the analysis. Typically, the scope of work will specify an electronic file sharing location for storing the data package.

11.4 EIM data upload procedures

All laboratory data will be uploaded to Ecology's EIM database following EAP protocols and business rules. An independent reviewer will conduct a QC review of this data upload, following internal EAP protocols.

11.5 Model information management

Not applicable.

12.0 Audits and Reports

12.1 Field, laboratory, and other audits

MEL and contract laboratories for this project must participate in performance and system audits of their routine procedures. No field audits are planned for this project.

12.2 Responsible personnel

Not applicable.

12.3 Frequency and distribution of reports

A final report of the study findings will be written and published according to the schedule in Table 9. The report will include, at a minimum, the following:

- Map showing all sampling locations and any other pertinent study area features.
- Description of field and laboratory methods.
- Description of data quality and the significance of any problems encountered.
- Final results of PFAS concentrations measured in the samples.
- Analyte concentrations relative to risk thresholds and other studies.
- Conclusions and recommendations based on study results.

12.4 Responsibility for reports

The project manager will be responsible for the written report, with assistance from the field lead.

13.0 Data Verification

13.1 Field data verification, requirements, and responsibilities

The project manager will verify that all field data were recorded without error or omission.

13.2 Laboratory data verification

MEL staff will verify laboratory data before entering results into LIMS or emailing them to the project manager. Verification will include examining the data for errors, omissions, and compliance with QC acceptance criteria and the method. MEL will include a case narrative that discusses whether (1) MQOs were met, (2) proper analytical methods and protocols were followed, (3) calibrations and controls were within limits, and (4) data were consistent, correct, and complete, without errors or omissions. The case narrative will also define data qualifiers and the reason for their use and will be released to the project manager.

The project manager is responsible for the final acceptance of the project data. The complete data package and MEL's written report will be assessed for completeness and reasonableness. Based on these assessments, the data will either be accepted, accepted with qualifications, or rejected and re-analysis considered.

13.3 Validation requirements, if necessary

MEL will conduct a Stage 4 data validation of the PFAS analyses, as defined by EPA (2009), for all PFAS analyses. This includes MEL analyses of PFAS in water and the contract laboratory's analysis of PFAS in fish tissue. An independent data validator employed at MEL — but under separate management from the organics team that did the analyses — will perform the validation. If MEL cannot perform the data validation within 60 days of the completed data analyses, a contract vendor with the appropriate qualification will be selected. MEL or the contract vendor will provide a case narrative summarizing the findings of the data validation, along with the final data validation electronic data deliverable.

13.4 Model quality assessment

Not applicable.

14.0 Data Quality (Usability) Assessment

14.1 Process for determining project objectives were met

Following data verification and validation, the project manager will determine if the data quality is sufficient to meet project goals and objectives. The project manager will review field notes, laboratory case narratives, data validation reports, and results of QC tests to determine whether project objectives were met. Laboratory and Quality Assurance (QA) staff familiar with the data quality assessment may be consulted. The project's final report will discuss data quality and whether the project objectives were met. If limitations in the data are identified, they will be noted. MEL's SOP for data qualification, procedures in the analytical methods, EPA National Functional Guidelines, this QAPP, and best professional judgment will be used in the final determination of data usability.

14.2 Treatment of non-detects

Non-detect samples will be qualified "U" or "UJ" at the reporting limit specific to the method. Results below the reporting limit but above the method detection limit will be reported if qualitative criteria are met and the analyte is not present in the method blank. These values will be qualified "J" as an estimate.

The PFAS data may be presented as a total or summed value in the final report. These summed values will not be entered into EIM. Summed values in the final report will include only detected PFAS results that are unqualified and/or qualified "J" (indicating that the analyte was positively identified and the associated numerical value is approximate). Individual analyte values that have been qualified "NJ" (indicating that the analyte has been "tentatively identified" and the associated value represents its approximate concentration) will not be included in summed values. If a sample is comprised of all non-detected PFAS results, the final summed value will be

assigned “ND” for not detected. Summed values will be qualified “J” if more than 10% of the total result is composed of individual PFAS values containing “J” qualifiers.

All samples will be censored against method blanks following the method protocol. For the PFAS analyses, the “5x times rule” will apply; the sample result will be censored if the result is less than five times the associated method blank detection.

14.3 Data analysis and presentation methods

The final report will include summaries of PFAS results for each waterbody and qualitative comparisons to previously reported data and thresholds. There will be no statistical analyses conducted on the results of this study. Presentation of the findings will include the components listed in Section 12.3.

14.4 Sampling design evaluation

The number and type of samples to be collected and analyzed for this study are expected to meet the goal and objectives of the project.

14.5 Documentation of assessment

The data usability assessment will be documented in the final report.

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Strategic Environmental Research and Development Program (SERDP) Project ER19-1409.

16.0 Appendices

Appendix A. Target PFAS Analytes

Table A-1. PFAS target analytes for the study and reporting limits.

Analyte name	Abbrev.	CAS number	RL (ng/g)
Perfluorobutanoic acid	PFBA	375-22-4	2.0
Perfluoropentanoic acid	PFPeA	2706-90-3	1.0
Perfluorohexanoic acid	PFHxA	307-24-4	0.5
Perfluoroheptanoic acid	PFHpA	375-85-9	0.5
Perfluorooctanoic acid	PFOA	335-67-1	0.5
Perfluorononanoic acid	PFNA	375-95-1	0.5
Perfluorodecanoic acid	PFDA	335-76-2	0.5
Perfluoroundecanoic acid	PFUnA	2058-94-8	0.5
Perfluorododecanoic acid	PFDoA	307-55-1	0.5
Perfluorotridecanoic acid	PFTrDA	72629-94-8	0.5
Perfluorotetradecanoic acid	PFTeDA	376-06-7	0.5
Perfluorobutane sulfonic acid	PFBS	375-73-5	0.5
Perfluoropentane sulfonic acid	PFPeS	2706-91-4	0.5
Perfluorohexane sulfonic acid	PFHxS	355-46-4	0.5
Perfluoroheptane sulfonic acid	PFHpS	375-92-8	0.5
Perfluorooctane sulfonic acid	PFOS	1763-23-1	0.5
Perfluorononane sulfonic acid	PFNS	68259-12-1	0.5
Perfluorodecane sulfonic acid	PFDS	335-77-3	0.5
Perfluorododecane sulfonic acid	PFDoS	79780-39-5	0.5
1H,1H, 2H, 2H-Perfluorohexane sulfonic acid	4:2FTS	757124-72-4	2.0
1H,1H, 2H, 2H-Perfluorooctane sulfonic acid	6:2FTS	27619-97-2	2.0
1H,1H, 2H, 2H-Perfluorodecane sulfonic acid	8:2FTS	39108-34-4	2.0
Perfluorooctanesulfonamide	PFOSA	754-91-6	0.5
N-methyl perfluorooctanesulfonamide	NMeFOSA	31506-32-8	0.5
N-ethyl perfluorooctanesulfonamide	NEtFOSA	4151-50-2	0.5
N-methyl perfluorooctanesulfonamidoacetic acid	NMeFOSAA	2355-31-9	0.5
N-ethyl perfluorooctanesulfonamidoacetic acid	NEtFOSAA	2991-50-6	0.5
N-methyl perfluorooctanesulfonamidoethanol	NMeFOSE	24448-09-7	5.0
N-ethyl perfluorooctanesulfonamidoethanol	NEtFOSE	1691-99-2	5.0
Hexafluoropropylene oxide dimer acid	HFPO-DA	13252-13-6	2.0
4,8-Dioxa-3H-perfluorononanoic acid	ADONA	919005-14-4	2.0
Perfluoro-3-methoxypropanoic acid	PFMPA	377-73-1	1.0
Perfluoro-4-methoxybutanoic acid	PFMBA	863090-89-5	1.0
Nonafluoro-3,6-dioxaheptanoic acid	NFDHA	151772-58-6	1.0
Chlorohexadecafluoro-3-oxanonane-1-sulfonic acid	9Cl-PF3ONS	756426-58-1	2.0
11-Chloroeicosafluoro-3-oxaundecane-1-sulfonic acid	11Cl-PF3OUdS	763051-92-9	2.0
Perfluoro(2-ethoxyethane)sulfonic acid	PFEESA	113507-82-7	1.0
3-Perfluoropropyl propanoic acid	3:3FTCA	356-02-5	2.5
2H,2H,3H,3H-Perfluorooctanoic acid	5:3FTCA	914637-49-3	12.5
3-Perfluoroheptyl propanoic acid	7:3FTCA	812-70-4	12.5

RL = reporting limit; synonymous with “minimum level of quantitation” or ML, referenced in the method.

Appendix B. Bathymetric Maps and Surface Water Sample Locations

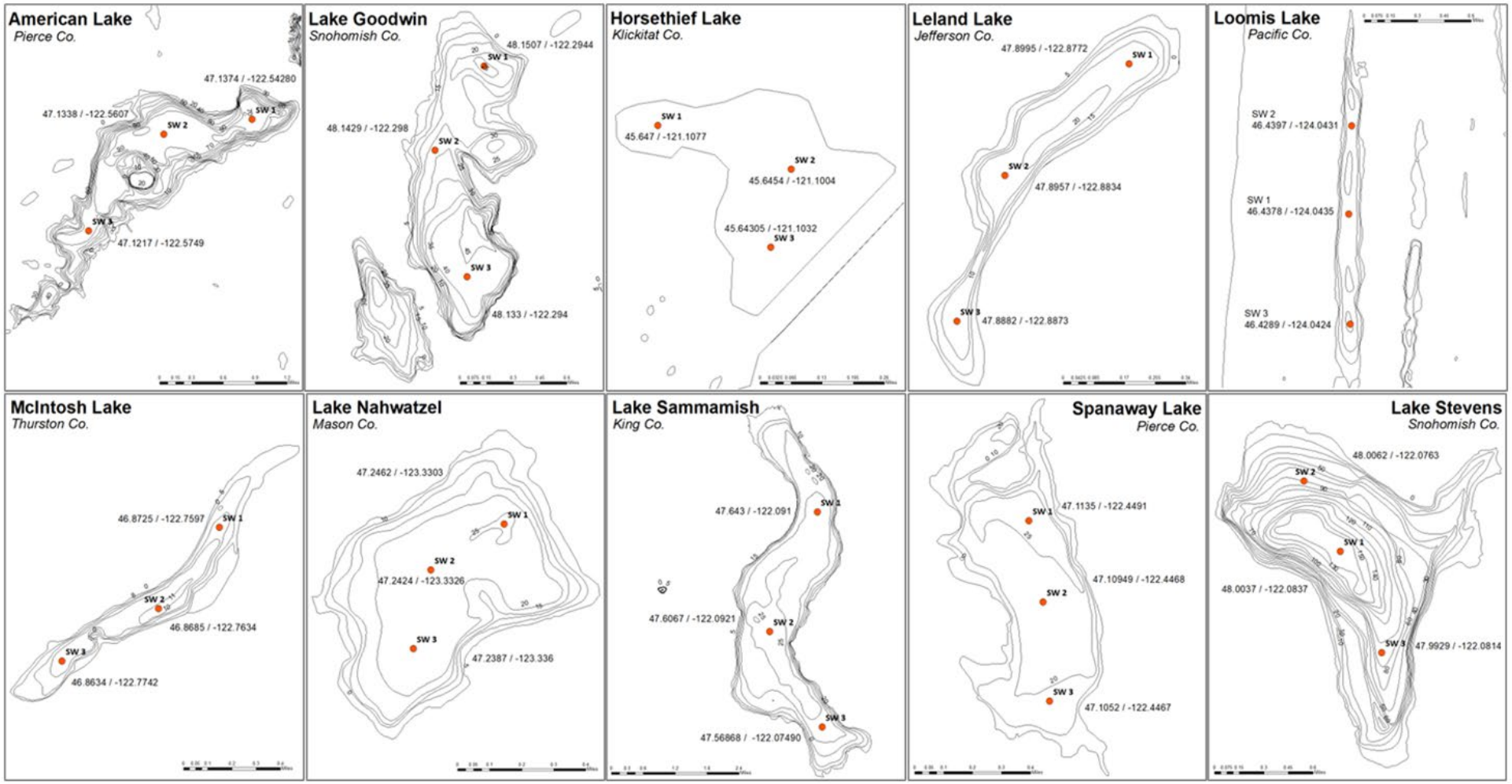

Figure B-1. Bathymetric maps of study locations with target surface water sample coordinates.

Appendix C. Glossaries, Acronyms, and Abbreviations

Glossary of General Terms

Aliquot: A subsample derived by dividing a sample into representative portions.

Ambient: Background or away from point sources of contamination. Surrounding environmental condition.

Anthropogenic: Human-caused.

Bioaccumulative: A compound that increases in concentration in living organisms as the organisms take in contaminated air, water, soil, sediment, or food because the compounds are very slowly metabolized or excreted.

Conductivity: A measure of water's ability to conduct an electrical current. Conductivity is related to the concentration and charge of dissolved ions in water.

Dissolved oxygen (DO): A measure of the amount of oxygen dissolved in water.

Effluent: An outflowing of water from a natural body of water or from a human-made structure. For example, the treated outflow from a wastewater treatment plant.

Persistent: A compound that has the tendency to remain in the environment without transformation or breakdown into another chemical form. It refers to the length of time a chemical is expected to reside in the environment and be available for exposure.

pH: A measure of the acidity or alkalinity of water. A low pH value (0 to 7) indicates that an acidic condition is present, while a high pH (7 to 14) indicates a basic or alkaline condition. A pH of 7 is considered to be neutral. Since the pH scale is logarithmic, a water sample with a pH of 8 is ten times more basic than one with a pH of 7.

Point source: Source of pollution that discharges at a specific location from pipes, outfalls, and conveyance channels to a surface water. Examples of point source discharges include municipal wastewater treatment plants, municipal stormwater systems, industrial waste treatment facilities, and construction sites where more than 5 acres of land have been cleared.

Sediment: Soil and organic matter that is covered with water (for example, river or lake bottom).

Stormwater: The portion of precipitation that does not naturally percolate into the ground or evaporate but instead runs off roads, pavement, and roofs during rainfall or snow melt. Stormwater can also come from hard or saturated grass surfaces such as lawns, pastures, playfields, and from gravel roads and parking lots.

Streamflow: Discharge of water in a surface stream (river or creek).

Total suspended solids (TSS): Portion of solids retained by a filter.

Volatilization: The process of transfer from the aqueous or liquid phase to the gas phase.

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

Acronyms and Abbreviations

AFFF	Aqueous film-forming foam
BC	Black crappie
BG	Blue gill
CTT	Cutthroat trout
DOC	Dissolved organic carbon
DOH	Department of Health
EAP	Environmental Assessment Program
e.g.	For example
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
et al.	And others
HUC	Hydrologic Unit Code
ID	Identification
KOK	Kokanee
LMB	Largemouth bass
MEL	Manchester Environmental Laboratory
MQO	Measurement quality objective
ND	non-detect
PBT	Persistent, bioaccumulative, and toxic substance
PFAA	Perfluoroalkyl acid
PFAS	Per- and polyfluoroalkyl substances
PFBA	Perfluorobutanoic acid
PFBS	Perfluorobutane sulfonic acid
PFDA	Perfluorodecanoic acid
PFNA	Perfluorononanoic acid
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctane sulfonic acid
QA	Quality assurance
QAPP	Quality assurance project plan
QC	Quality control
RBT	Rainbow trout
RPD	Relative percent difference
SAL	State action level
SCS	Statewide Coordination Section
SMB	Smallmouth bass
SOP	Standard operating procedures
TOC	Total organic carbon
TSS	(see Glossary above)
WA	Washington
WAL	Walleye
WDFW	Washington Department of Fish and Wildlife

WRIA	Water Resource Inventory Area
WWTP	Wastewater treatment plant
YP	Yellow perch

Units of Measurement

°C	degrees centigrade
cm	centimeter
mm	millimeter
mg/L	milligrams per liter (parts per million)
ng/g	nanograms per gram (parts per billion)
µS/cm	microsiemens per centimeter, a unit of conductivity
ww	wet weight

Quality Assurance Glossary

Accreditation: A certification process for laboratories, designed to evaluate and document a lab's ability to perform analytical methods and produce acceptable data. For Ecology, it is "Formal recognition by (Ecology)…that an environmental laboratory is capable of producing accurate analytical data." [WAC 173-50-040] (Kammin, 2010)

Accuracy: The degree to which a measured value agrees with the true value of the measured property. USEPA recommends that this term not be used, and that the terms *precision* and *bias* be used to convey the information associated with the term *accuracy* (USGS, 1998).

Analyte: An element, ion, compound, or chemical moiety (pH, alkalinity) which is to be determined. The definition can be expanded to include organisms, e.g., fecal coliform, Klebsiella (Kammin, 2010).

Bias: The difference between the sample mean and the true value. Bias usually describes a systematic difference reproducible over time and is characteristic of both the measurement system and the analyte(s) being measured. Bias is a commonly used data quality indicator (DQI) (Kammin, 2010; Ecology, 2004).

Blank: A synthetic sample, free of the analyte(s) of interest. For example, in water analysis, pure water is used for the blank. In chemical analysis, a blank is used to estimate the analytical response to all factors other than the analyte in the sample. In general, blanks are used to assess possible contamination or inadvertent introduction of analyte during various stages of the sampling and analytical process (USGS, 1998).

Calibration: The process of establishing the relationship between the response of a measurement system and the concentration of the parameter being measured (Ecology, 2004).

Check standard: A substance or reference material obtained from a source independent from the source of the calibration standard; used to assess bias for an analytical method. This is an obsolete term, and its use is highly discouraged. See Calibration Verification Standards, Lab Control Samples (LCS), Certified Reference Materials (CRM), and/or spiked blanks. These are all check standards but should be referred to by their actual designator, e.g., CRM, LCS (Kammin, 2010; Ecology, 2004).

Comparability: The degree to which different methods, data sets and/or decisions agree or can be represented as similar; a data quality indicator (USEPA, 1997).

Completeness: The amount of valid data obtained from a project compared to the planned amount. Usually expressed as a percentage. A data quality indicator (USEPA, 1997).

Continuing Calibration Verification Standard (CCV): A quality control (QC) sample analyzed with samples to check for acceptable bias in the measurement system. The CCV is usually a midpoint calibration standard that is re-run at an established frequency during the course of an analytical run (Kammin, 2010).

Control chart: A graphical representation of quality control results demonstrating the performance of an aspect of a measurement system (Kammin, 2010; Ecology 2004).

Control limits: Statistical warning and action limits calculated based on control charts. Warning limits are generally set at +/- 2 standard deviations from the mean, action limits at +/- 3 standard deviations from the mean (Kammin, 2010).

Data integrity: A qualitative DQI that evaluates the extent to which a data set contains data that is misrepresented, falsified, or deliberately misleading (Kammin, 2010).

Data quality indicators (DQI): Commonly used measures of acceptability for environmental data. The principal DQIs are precision, bias, representativeness, comparability, completeness, sensitivity, and integrity (USEPA, 2006).

Data quality objectives (DQO): Qualitative and quantitative statements derived from systematic planning processes that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions (USEPA, 2006).

Data set: A grouping of samples organized by date, time, analyte, etc. (Kammin, 2010).

Data validation: An analyte-specific and sample-specific process that extends the evaluation of data beyond data verification to determine the usability of a specific data set. It involves a detailed examination of the data package, using both professional judgment and objective criteria, to determine whether the MQOs for precision, bias, and sensitivity have been met. It may also include an assessment of completeness, representativeness, comparability, and integrity, as these criteria relate to the usability of the data set. Ecology considers four key criteria to determine if data validation has actually occurred. These are:

- Use of raw or instrument data for evaluation.
- Use of third-party assessors.
- Data set is complex.
- Use of EPA Functional Guidelines or equivalent for review.

Examples of data types commonly validated would be:

- Gas Chromatography (GC).
- Gas Chromatography-Mass Spectrometry (GC-MS).
- Inductively Coupled Plasma (ICP).

The end result of a formal validation process is a determination of usability that assigns qualifiers to indicate usability status for every measurement result. These qualifiers include:

- No qualifier — data are usable for intended purposes.
- J (or a J variant) — data are estimated, may be usable, may be biased high or low.
- REJ — data are rejected, cannot be used for intended purposes.
  (Kammin, 2010; Ecology, 2004).

Data verification: Examination of a data set for errors or omissions, and assessment of the Data Quality Indicators related to that data set for compliance with acceptance criteria (MQOs). Verification is a detailed quality review of a data set (Ecology, 2004).

Detection limit (limit of detection)**:** The concentration or amount of an analyte which can be determined to a specified level of certainty to be greater than zero (Ecology, 2004).

Duplicate samples: Two samples taken from and representative of the same population, and carried through and steps of the sampling and analytical procedures in an identical manner. Duplicate samples are used to assess variability of all method activities including sampling and analysis (USEPA, 1997).

Field blank: A blank used to obtain information on contamination introduced during sample collection, storage, and transport (Ecology, 2004).

Initial Calibration Verification Standard (ICV): A QC sample prepared independently of calibration standards and analyzed along with the samples to check for acceptable bias in the measurement system. The ICV is analyzed prior to the analysis of any samples (Kammin, 2010).

Laboratory Control Sample (LCS): A sample of known composition prepared using contaminant-free water or an inert solid that is spiked with analytes of interest at the midpoint of the calibration curve or at the level of concern. It is prepared and analyzed in the same batch of regular samples using the same sample preparation method, reagents, and analytical methods employed for regular samples (USEPA, 1997).

Limit of Quantitation (LOQ): The smallest concentration that produces a quantitative result with known and recorded precision and bias. The LOQ shall be set at or above the concentration of the lowest initial calibration standard (the lowest calibration standard must fall within the linear range) (USEPA, 2022).

Low-level Ongoing Precision and Recovery (LLOPR): A version of the ongoing precision and recovery standard that is spiked at twice the concentration of the laboratory's limit of quantitation and used as a routine check of instrument sensitivity (USEPA, 2022).

Matrix spike: A QC sample prepared by adding a known amount of the target analyte(s) to an aliquot of a sample to check for bias due to interference or matrix effects (Ecology, 2004).

Measurement Quality Objectives (MQOs)**:** Performance or acceptance criteria for individual data quality indicators, usually including precision, bias, sensitivity, completeness, comparability, and representativeness (USEPA, 2006).

Measurement result: A value obtained by performing the procedure described in a method (Ecology, 2004).

Method: A formalized group of procedures and techniques for performing an activity (e.g., sampling, chemical analysis, data analysis), systematically presented in the order in which they are to be executed (EPA, 1997).

Method blank: A blank prepared to represent the sample matrix, prepared and analyzed with a batch of samples. A method blank will contain all reagents used in the preparation of a sample, and the same preparation process is used for the method blank and samples (Ecology, 2004; Kammin, 2010).

Method Detection Limit (MDL): This definition for detection was first formally advanced in 40CFR 136, October 26, 1984 edition. MDL is defined there as the minimum concentration of an analyte that, in a given matrix and with a specific method, has a 99% probability of being identified, and reported to be greater than zero (Federal Register, October 26, 1984).

Ongoing Precision and Recovery (OPR): Ongoing precision and recovery standard; a method blank spiked with known quantities of analytes. The OPR is analyzed exactly like a sample. It's purpose is to assure that the results produced by the laboratory remain within the limits specified in this method for precision and recovery (USEPA, 2022).

Percent Relative Standard Deviation (%RSD): A statistic used to evaluate precision in environmental analysis. It is determined in the following manner:

$$\%RSD = (100 * s)/x$$

where s is the sample standard deviation and x is the mean of results from more than two replicate samples (Kammin, 2010).

Parameter: A specified characteristic of a population or sample. Also, an analyte or grouping of analytes. Benzene and nitrate + nitrite are all parameters (Kammin, 2010; Ecology, 2004).

Population: The hypothetical set of all possible observations of the type being investigated (Ecology, 2004).

Precision: The extent of random variability among replicate measurements of the same property; a data quality indicator (USGS, 1998).

Quality assurance (QA): A set of activities designed to establish and document the reliability and usability of measurement data (Kammin, 2010).

Quality Assurance Project Plan (QAPP): A document that describes the objectives of a project, and the processes and activities necessary to develop data that will support those objectives (Kammin, 2010; Ecology, 2004).

Quality control (QC): The routine application of measurement and statistical procedures to assess the accuracy of measurement data (Ecology, 2004).

Relative Percent Difference (RPD): RPD is commonly used to evaluate precision. The following formula is used:

$$[Abs(a-b)/((a + b)/2)] * 100$$

where "Abs()" is absolute value and a and b are results for the two replicate samples. RPD can be used only with 2 values. Percent Relative Standard Deviation is (%RSD) is used if there are results for more than 2 replicate samples (Ecology, 2004).

Replicate samples: Two or more samples taken from the environment at the same time and place, using the same protocols. Replicates are used to estimate the random variability of the material sampled (USGS, 1998).

Representativeness: The degree to which a sample reflects the population from which it is taken; a data quality indicator (USGS, 1998).

Sample (field): A portion of a population (environmental entity) that is measured and assumed to represent the entire population (USGS, 1998).

Sample (statistical): A finite part or subset of a statistical population (USEPA, 1997).

Sensitivity: In general, denotes the rate at which the analytical response (e.g., absorbance, volume, meter reading) varies with the concentration of the parameter being determined. In a specialized sense, it has the same meaning as the detection limit (Ecology, 2004).

Spiked blank: A specified amount of reagent blank fortified with a known mass of the target analyte(s); usually used to assess the recovery efficiency of the method (USEPA, 1997).

Spiked sample: A sample prepared by adding a known mass of target analyte(s) to a specified amount of matrix sample for which an independent estimate of target analyte(s) concentration is available. Spiked samples can be used to determine the effect of the matrix on a method's recovery efficiency (USEPA, 1997).

Split sample: A discrete sample subdivided into portions, usually duplicates (Kammin, 2010).

Standard Operating Procedure (SOP): A document which describes in detail a reproducible and repeatable organized activity (Kammin, 2010).

Surrogate: For environmental chemistry, a surrogate is a substance with properties similar to those of the target analyte(s). Surrogates are unlikely to be native to environmental samples. They are added to environmental samples for quality control purposes, to track extraction efficiency and/or measure analyte recovery. Deuterated organic compounds are examples of surrogates commonly used in organic compound analysis (Kammin, 2010).

Systematic planning: A step-wise process which develops a clear description of the goals and objectives of a project, and produces decisions on the type, quantity, and quality of data that will be needed to meet those goals and objectives. The DQO process is a specialized type of systematic planning (USEPA, 2006).

References for QA Glossary

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