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ECOLOGY
State of Washington

Addendum 2 to Quality Assurance Project Plan

Long-term Monitoring of Persistent, Bioaccumulative, and Toxic Chemicals Using Age-dated Lake Sediment Cores

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Long-term Monitoring of Persistent, Bioaccumulative, and Toxic Chemicals Using Age-dated Lake Sediment Cores

December 2019

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EAP: Environmental Assessment Program

3.0 Background

The Washington State Department of Ecology (Ecology)'s Persistent, Bioaccumulative, and Toxics (PBT) Monitoring Program began a long-term study to assess PBT chemical trends through age-dated lake sediment cores in 2006. Ecology collects a single sediment core from three lakes each year to construct historical deposition profiles of PBTs in the environment. Sediment core samples are analyzed for a rotating PBT contaminant selected annually to fill data gaps in Washington State. New lakes are also chosen each year to achieve a broad spatial coverage of the state and to target waterbodies based on the parameters to be analyzed.

The quality assurance project plan (QAPP) for this study outlined a process of writing annual addenda to document the target PBT analyte and study locations for that sampling year (Mathieu, 2016). This addendum describes the following for 2019:

- The target analyte group will be per- and poly-fluoroalkyl substances (PFAS).
- Sediment cores will be collected from Blackmans Lake, Lake Sutherland, and Wildcat Lake.

PFAS are next on the rotating list of parameters for this project (Figure 1). The analyte group was last evaluated in sediment cores during the 2012 sampling year (Mathieu, 2013). The term PFAS refers to a large group of chemicals containing carbon-fluorine bonds. They are used in many applications, as the compounds exhibit both hydrophobic and lipophobic properties and are extremely stable (Buck et al., 2011). They can be found in both industrial and consumer products, such as water-, stain-, and oil-repelling coatings, metal plating suppressants, and aqueous film-forming foams (AFFFs) used to fight hydrocarbon fires. Ecology and the Department of Health (DOH) are currently drafting a chemical action plan for PFAS to recommend actions to take to reduce the exposure and harm of the class of chemicals in Washington.

2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Hg	Hg	PAHs	PAHs	PAHs	PAHs	PFAS	HBCD	CPs	PBDEs	PCBs	PAHs	---	PFAS

Figure 1. Target analytes in sediment cores from 2006 to 2019.

Hg: mercury; PAHs: polycyclic aromatic hydrocarbons; PFAS: per- and poly-fluoroalkyl substances; HBCD: hexabromocyclododecane; CPs: chlorinated paraffins; PBDEs: polybrominated diphenyl ethers; PCBs: polychlorinated biphenyls.

3.1 Study area and surroundings

Three waterbodies are selected each year for sediment core collection. Selection of target waterbodies is based on proximity to known and potential sources. Each year, two lakes are chosen close to or within known or potential sources of the target organic PBT. The third lake is located far from sources or in an area where atmospheric deposition is the predominant source. Other considerations for waterbody selection include:

- Spatial distribution to achieve statewide coverage.
- Suitable access to the waterbody for the coring boat.
- Waterbodies where data from other studies are available.
- Watersheds within a range of land-use types.

- Physical features of the lake and watershed, including lake depositional patterns, maximum and mean depths, and elevation.
- Collaboration with other programs and agencies.

Figure 2 displays the waterbodies where sediment cores were collected between 2006 and 2017, as well as the 2019 coring locations. In 2019, sediment cores will be collected from Blackmans Lake (Snohomish County), Lake Sutherland (Clallam County), and Wildcat Lake (Kitsap County).

Blackmans Lake was selected to capture PFAS concentrations and fluxes in a lake with urban and residential development. Wildcat Lake was chosen based on its proximity to potential AFFF release sites at a nearby military base and a small private airport, although the lake is not hydrologically connected to known AFFF releases. Other potential sources at Wildcat Lake include residential septic systems.

Lake Sutherland will serve as a reference lake for this project. Lake Sutherland lies in a primarily forested, undeveloped watershed near the edge of Olympic National Forest, with logging activity in the basin. PFAS sources will likely be dominated by atmospheric deposition at this site, though there are several residences along the shoreline, as well as a state highway near the northern shore.

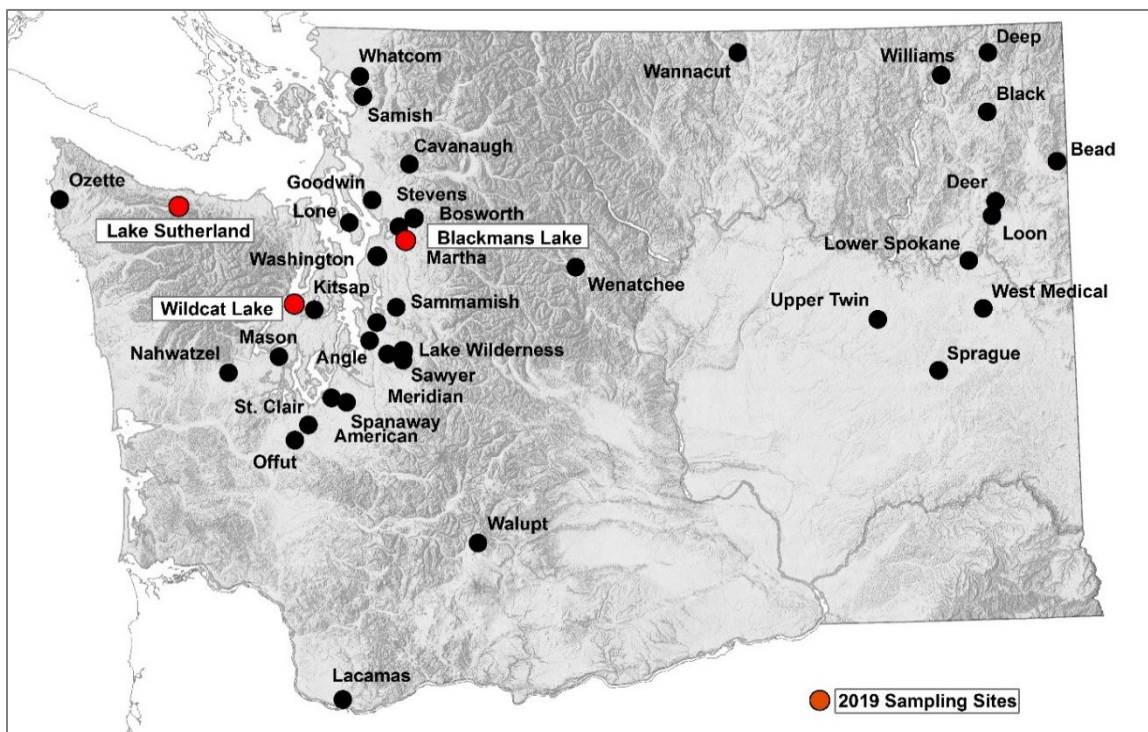


Figure 2. Sediment core sample locations from 2006 to 2017 (black circles) and 2019 (red circles).

Table 1. Study lakes for 2019.

Waterbody	County	Elevation (ft)	Max. Depth (ft)	Mean Depth (ft)	Lake Area (ac)	Watershed Area (ac)	WA:LA
Blackmans Lake	Snohomish	140	29	14	57	518	9
Lake Sutherland	Clallam	525	86	57	370	5107	14
Wildcat Lake	Kitsap	377	33	18	120	1600	13

3.1.2 History of study area

The 2019 sampling locations were chosen based on previously determined criteria in the original QAPP and described in Section 3.1. The lakes have not been sampled previously as part of this project. There are no known PFAS data available for the 2019 study locations and therefore no known history of PFAS contamination in the lakes. Sources of PFAS to the lakes are likely from degradation of PFAS-containing consumer and industrial products carried by stormwater or septic systems, historical AFFF release, and atmospheric deposition.

3.1.3 Parameters of interest

The target analytes in 2019 include 15 PFAS compounds (Table 2). The analyte group consists of perfluoroalkyl acids (PFAAs) having a carbon chain length between 4 and 14, as well as two perfluoroalkane sulfonamides (NEtFOSAA and NMeFOSAA). While the target analyte list includes PFAAs with chain lengths of 4 to 6, the analytes of interest are those with longer chain lengths of 7 or more, which sorb strongly to sediments. The short chain compounds are more water soluble and may or may not be reliably preserved in sediments.

The entire PFAS class includes up to thousands of individual compounds, many of which are intermediate transformation products, or precursors, which break down into PFAAs. Perfluoroalkyl acids are the terminal degradation products that are resistant to further breakdown and are typically the PFAS type found in the environment and biota.

Some PFAS, in particular the long-chain PFAAs, are widespread in the environment, highly persistent, bioaccumulative, and toxic. The majority of toxicity studies have focused on perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA). The EPA concluded that there is suggestive evidence of carcinogenic potential from PFOS exposure (liver, thyroid, and mammary), as well as high cholesterol and reproductive, developmental, and immunological effects (US EPA, 2016a). PFOA exposure is associated with several health concerns in humans, including high cholesterol, increased liver enzymes, decreased vaccination response, thyroid disorders, pregnancy-induced hypertension and preeclampsia, and cancer (testicular and kidney) (US EPA, 2016b). PFOS and PFOA, as well as other long-chain PFAS have been largely phased out of U.S. production due to human health concerns. Manufacturers have replaced them with PFAS consisting of shorter chain lengths.

PFAS can be released to the environment as emissions during manufacturing and during the use and disposal of products containing PFAS (OECD, 2013). After products containing PFAS are used or disposed of, PFAS — particularly PFAAs — are transported into and through the environment by pathways such as stormwater, discrete releases from product use,

wastewater treatment plant (WWTP) effluent, biosolids application, landfill leachate, and atmospheric deposition (ITRC, 2018).

Table 2. Target PFAS compounds to be analyzed in 2019.

Analyte	Acronym	Chain length
Perfluorobutane sulfonate	PFBS	C4
Perfluoropentanoate	PFPeA	C5
Perfluorohexane sulfonate	PFHxS	C6
Perfluorohexanoate	PFHxA	C6
Perfluoroheptanoate	PFHpA	C7
Perfluorooctane sulfonate	PFOS	C8
Perfluorooctanoate	PFOA	C8
Perfluorononanoate	PFNA	C9
Perfluorodecanoate	PFDA	C10
Perfluoroundecanoate	PFUnA	C11
Perfluorododecanoate	PFDoDA	C12
Perfluorotridecanoate	PFTTrDA	C13
Perfluorotetradecanoate	PFTeDA	C14
N-ethyl perfluorooctanesulfonamidoacetic acid	NEtFOSAA	C8
N-methyl perfluorooctanesulfonamidoacetic acid	NMeFOSAA	C8

Note: the anion form of the perfluoroalkyl acids will be reported.

3.1.4 Results of previous studies

This monitoring program analyzed PFAS in sediment cores during the 2012 sampling year (Mathieu, 2013). Cores were collected from Deer Lake, Lake Stevens, and West Medical Lake (Table 3). Total PFAS concentrations in the lakes ranged from <234 to 7,008 ng/kg dw and T-PFAS fluxes ranged from 0.003 to 0.399 ng/cm²/yr. PFAS concentrations in Deer Lake — a forested reference site — were lower than the other two cores and did not follow a linear temporal pattern. PFAS were detected in the Lake Stevens core samples between 1980 and 2012 (the top of the core). Total PFAS were fairly low and within a consistent range between 1980 and 2000, and then increased substantially in the late 2000s to a concentration of 2,350 ng/kg dw in 2012. In West Medical Lake, PFAS were detected beginning in the 1970s. T-PFAS concentrations increased throughout the core, until a maximum of 7,008 ng/kg dw in the topmost sediment horizon (2010).

The use of sediment cores to reconstruct temporal trends in PFAS accumulation has been demonstrated in arctic lakes (MacInnis et al., 2019; Stock et al., 2007), alpine lakes (Benskin et al., 2011), the Great Lakes (Myers et al., 2012; Codling et al., 2018a; Codling et al., 2018b), Swedish lakes (Mussabek et al., 2019), and Tokyo Bay (Ahrens et al., 2009; Zushi et al., 2010). PFAS concentrations and fluxes in lake sediment cores have been shown to reflect production and use of PFAS (Myers et al., 2012; Codling et al., 2018b; MacInnis et al., 2019). Codling et al. (2018a) reported that PFAAs with chain lengths of 7 or more were well

preserved in sediment cores, while shorter chained PFAs did not reflect an accurate record in sediment cores.

Table 3. Total PFAS concentrations and fluxes reported in previous Washington State sediment cores by Mathieu (2013).

Waterbody	Year	T-PFAS (ng/kg dw)	T-PFAS flux (ng/cm ² /yr)
Deer Lake	2009	392	0.008
	2005	123	0.003
	1993	188 U	---
	1985	665	0.029
	1980	224 U	---
	1974	250 U	---
	1967	234 U	---
	1956	849	0.073
Lake Stevens	2010	2,350	0.059
	2007	2,194	0.038
	1998	721	0.016
	1989	610	0.015
	1981	717	0.016
	1965	300 U	---
	1947	302 U	---
	1921	384 U	---
West Medical Lake	2010	7,008	0.379
	2007	4,956	0.305
	2002	5,209	0.354
	1999	3,362	0.399
	1995	3,241	0.250
	1986	1,056	0.242
	1981	983	0.154
	1974	828	0.106

U = not detected at or above the level indicated.

3.1.5 Regulatory criteria or standards

No environmental regulatory thresholds exist for PFAS in lake sediments for Washington State. This study does not collect data to determine compliance with regulatory standards or criteria.

4.0 Project Description

4.2 Project objectives

Specific objectives for the 2019 sampling year include:

- Collect a single sediment core each from Blackmans Lake, Lake Sutherland, and Wildcat Lake, and analyze 12 horizons in each core for a suite of 15 PFAS.

4.5 Study boundaries

At each study lake, a sediment core will be collected from a discrete sampling point in the deepest flat part of the lake. Figures 3 through 5 display the target sampling locations for 2019.

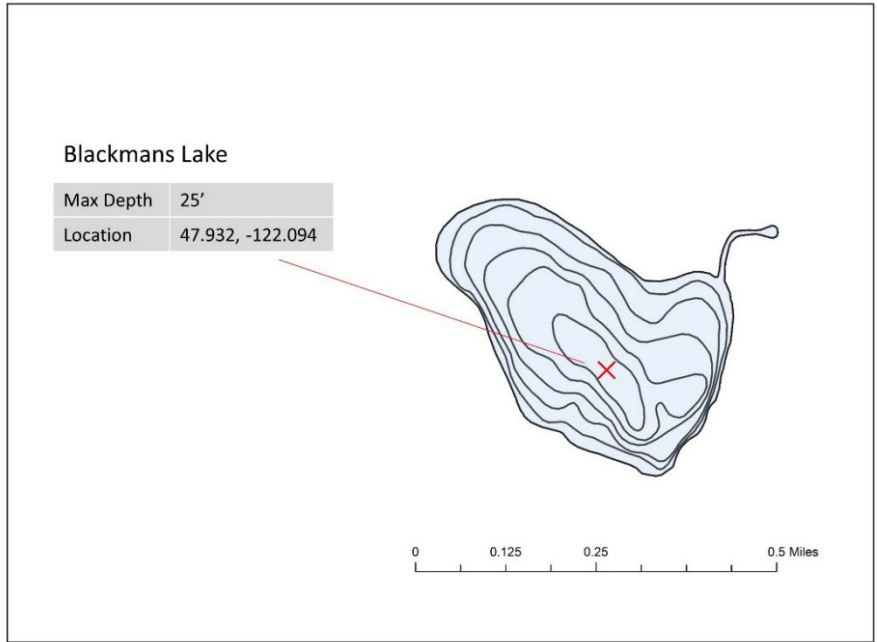


Figure 3. Target sampling location for Blackmans Lake.

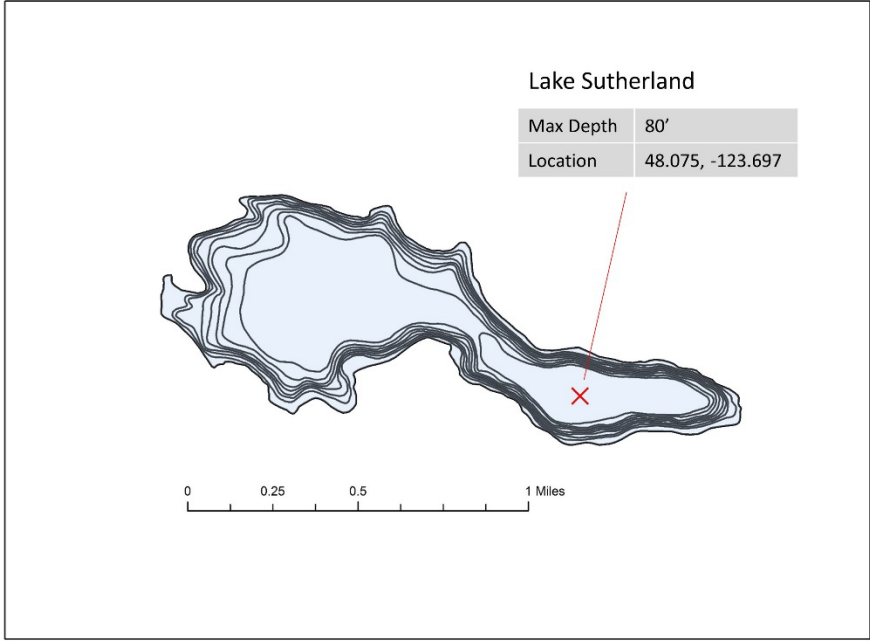


Figure 4. Target sampling location for Lake Sutherland.

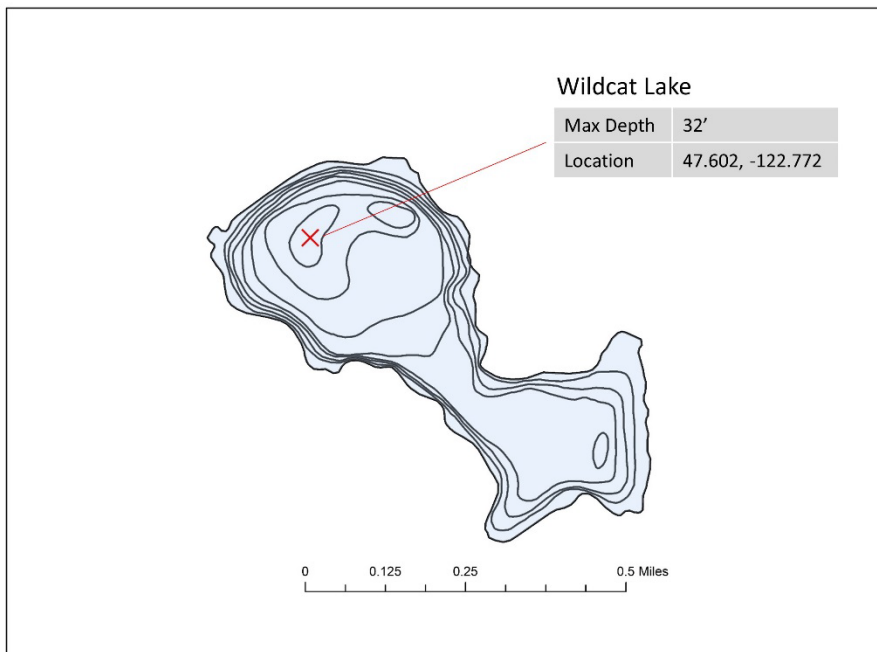


Figure 5. Target sampling location for Wildcat Lake.

WRIAs

- Blackmans Lake: 7
- Lake Sutherland: 18
- Wildcat Lake: 15

HUC numbers

- Blackmans Lake: 17110011
- Lake Sutherland: 17110020
- Wildcat Lake: 17110019

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

Table 4. Organization of project staff and responsibilities.

EAP Staff	Title	Responsibilities
James Medlen Toxics Studies Unit SCS Phone: 360-407-6194	Acting Client and Supervisor for the Project Manager	Clarifies scope of the project. Provides internal review of the QAPP addendum, and final report. Approves the final QAPP and addendums. Manages budget and staffing needs.
Jessica Archer SCS Phone: 360-407-6698	Client and SCS Manager	Clarifies scope of the project. Provides internal review of the QAPP addendum and final report. Approves the final QAPP addendum.
Callie Mathieu Toxics Studies Unit SCS Phone: 360-407-6965	Project Manager and Principal Investigator	Writes the original QAPP and final report. Coordinates with MEL and contract laboratory. Oversees field collections. Conducts QA review of data, analyzes and interprets data.
Dave Serdar Toxics Studies Unit SCS Phone: 360-407-6479	Field Lead	Leads field collections, records field information, and sends samples to the laboratory. Enters data into EIM.
Alan Rue Manchester Environmental Laboratory Phone: 360-871-8801	Director	Reviews and approves the final QAPP addendum.
Arati Kaza Phone: 360-407-6964	Ecology Quality Assurance Officer	Reviews and approves the draft QAPP addendum and the final QAPP addendum.

EAP: Environmental Assessment Program
 EIM: Environmental Information Management database
 QAPP: Quality Assurance Project Plan
 SCS: Statewide Coordination Section

5.4 Project schedule

Table 5. Proposed schedule for completing field and laboratory work, data entry into EIM, and reports.

Field and laboratory work	Due date	Lead staff
Field work completed	08/2019	Dave Serdar
Laboratory analyses completed	11/2019	
Environmental Information System (EIM) database		
EIM Study ID	SEDCORE19	
Product	Due date	Lead staff
EIM data loaded	06/2020	To be determined
EIM QA	07/2020	Callie Mathieu
EIM complete	08/2020	To be determined
Final report		
Author lead / support staff	Callie Mathieu	
Schedule		
Draft due to supervisor	05/2020	
Draft due to client/peer reviewer	06/2020	
Final (all reviews done) due to publications coordinator	07/2020	
Final report due on web	10/2020	

5.6 Budget and funding

Laboratory costs estimated in Table 6 will be fully funded by PBT Monitoring funds.

Table 6. Project budget and funding.

Parameter	Field Samples (# of samples)	QA Samples* (# of samples)	Total Number of Samples	Cost per Sample	MEL Subtotal	Contract Lab Subtotal	MEL Contract Fee
PFAS	36	6	42	\$500	\$21,000	—	—
T-Pb	30	4	34	\$50	\$1,700	—	—
TOC, TN	30	2	32	\$50	\$1,600	—	—
LOI	30	2	32	\$50	\$1,600	—	—
²¹⁰ Pb	45	3	48	\$150	—	\$7,200	\$360
²²⁶ Ra	9	1	10	\$100	—	\$1,000	\$50
Grain Size	3	2	5	\$120	—	\$600	\$30
MEL subtotal					\$25,900	—	—
Contracting Subtotal					—	\$9,240	
Lab Grand Total						\$35,140	

*Includes only QA samples that are not free of charge with the analysis (laboratory duplicates, matrix spikes, and matrix spike duplicates).

**MEL fee of 5% to manage contract without data validation.

6.0 Quality Objectives

6.2 Measurement quality objectives

Measurement quality objectives (MQOs) for laboratory analyses are shown in Table 7.

Table 7. Measurement quality objectives.

Analyte	LCS (recovery)	Lab Duplicates (RPD)	Method blanks	Matrix Spike (recovery)	Matrix Spike Duplicates (RPD)	Surrogate Standards (recovery)
PFAS	50 - 150%	<40%	< LOQ	50 - 150%	< 40%	20 - 200%
T-Pb	85 - 115%	<20%	< LOQ	75 - 125%	< 20%	—
TOC, TN	—	< 20%	—	—	—	—
LOI	—	< 20%	—	—	—	—
²¹⁰ Pb	80 - 120%	< 30%	< LOQ	—	—	—
²²⁶ Ra	80 - 120%	< 30%	< LOQ			
Grain Size	—	< 25%	—	—	—	—

LCS = laboratory control samples; RPD = relative percent difference; MDL = method detection limit; RL = reporting limit

7.0 Study Design

7.1 Study boundaries

7.1.3 Parameters to be determined

In 2019, sediment core samples will be analyzed for the individual PFAS stated in Table 2, as well as the parameters listed in Table 9. The 15 PFAS will be analyzed in 12 sediment horizons per core, and horizons will be selected as outlined in the original QAPP. In addition to PFAS, loss on ignition (LOI) and ^{226}Ra will be analyzed in 2019 to help interpret the sediment core profile. Loss on ignition will be analyzed in the same 10 intervals per core selected for total lead and TOC. Three intervals per core will be analyzed for ^{226}Ra to confirm background ^{210}Pb concentrations.

7.2 Maps or diagram

The study area and sampling locations are displayed in Figure 3.

8.0 Field Procedures

8.2 Containers, preservation methods, holding times

Sample containers, minimum sample sizes, preservation methods, and sample holding-time requirements are shown below in Table 8.

Table 8. Containers, Sample Size, Preservation Methods, and Holding Times.

Parameter	Minimum Quantity Required	Container	Field preservation	Preservation after processing	Holding Time
PFAS	50 g ww	500 mL HDPE	cool to 4° C	Freeze, -18° C	1 year frozen; 30 days after extraction ¹
T-Pb	25 g ww	4 oz glass jar	cool to 4° C	Freeze, -18° C	1 year frozen
TOC, TN	20 g ww	4 oz glass jar	cool to 4° C	Freeze, -18° C	6 months
LOI	25 g ww	4 oz glass jar	cool to 4° C	Freeze, -18° C	6 months
²¹⁰ Pb	20 g ww	2 oz glass jar	cool to 4° C	none required	n/a
²²⁶ Ra	360g ww	8 oz glass jar	cool to 4° C	none required	n/a
Grain Size	150 g ww	8 oz HDPE jar	cool to 4° C	cool to 4° C	6 months

dw = dry weight

¹Standard method holding times have not been established for PFAS in sediment.

8.4 Equipment decontamination

Equipment decontamination will follow the original QAPP with the following exception: tap water will be used instead of deionized water (to avoid potential fluorinated substances in the deionization unit) and 100% methanol will be used instead of acetone and hexane.

Field and laboratory processing staff will follow guidance issued by Michigan State on steps to avoid PFAS cross-contamination (MDEQ, 2018). Briefly, staff will not use any equipment or material containing fluoropolymers or Teflon[®], blue ice, paper towels, Sharpie[®] markers, water-resistant clothing such as those containing Gore-Tex[™], and other clothing and personal care products listed in MDEQ (2018).

9.0 Laboratory Procedures

9.2 Lab procedures table

Ecology's Manchester Environmental Laboratory (MEL) will conduct all analyses outlined in Table 9 except for ^{210}Pb , ^{226}Ra , and grain size, which will be conducted by contract laboratories. MEL will analyze PFAS in sediments following their in-house standard operating procedure #730133, which is a modification of EPA Method 8321B.

Table 9. Laboratory procedures.

Parameter	Number of samples	Arrival date	Expected range of results	Reporting limit	Sample Prep Method	Analytical Method
PFAS	36	8/29/2019	< 100 – 10,000 ng/kg dw	100 ng/kg dw	Laboratory-specific method	LC-MS/MS isotopic dilution
T-Pb	30	8/29/2019	1.0 - 1,000 mg/Kg	0.1 mg/Kg	EPA 6020	ICP-MS
TOC, TN	30	8/29/2019	0.1 – 20% of DW	0.1% of DW	SM5310B (preacidified)	TM-440
LOI	30	8/29/2019	0.1 – 20% of DW	0.1% of DW	ASTM D2584	Muffle furnace
^{210}Pb	45	8/29/2019	< 0.45 - 30 pCi/g	0.45 pCi/g	Alpha spectroscopy	Alpha spectroscopy
^{226}Ra	9	8/29/2019	<0.5 - 2.0 pCi/g	0.5 - 1.0 pCi/g	Gamma spectroscopy	Gamma spectroscopy
Grain Size	3	8/29/2019	—	0.001	PSEP-EPA, 1986	Sieve-pipette

EPA = Environmental Protection Agency; dw = dry weight; LC-MS/MS = liquid chromatography tandem mass spectrometry; ICP-MS = inductively coupled plasma-mass spectrometry; PSEP = Puget Sound Estuary Program

9.3 Sample preparation method

Because there are no standard EPA methods for PFAS in sediment, MEL will use their laboratory-specific method for preparation and extraction. MEL will extract the samples using an optimized QuEChERS method based on AOAC method 2007.01, then clean up the extracts using dispersive solid phase extraction (dSPE) with extended matrix removal (EMR). MEL's extraction method will follow MEL standard operating procedure 730124v1.1.

10.0 Quality Control Procedures

10.1 Table of field and lab QC required

MEL and contract laboratories will perform the quality control (QC) tests presented in Table 10. Two QC tests are being added in 2019 for PFAS analysis: matrix spikes and matrix-spike duplicates. No standard reference materials for PFAS in freshwater sediments was identified, as of the writing of this QAPP. If a standard reference material is identified or becomes available, analysis of one per batch will be required.

Table 10. Laboratory quality control samples, types, and frequency.

Parameter	LCS	Method blanks	Matrix spikes	Matrix spike duplicates	Laboratory duplicates	Surrogates
PFAS	1/batch	1/batch	1/batch	1/batch	1/batch	each sample
T-Pb	1/batch	1/batch	1/batch	1/batch	—	—
TOC, TN	1/batch	1/batch	—	—	1/batch	—
LOI	1/batch	1/batch	—	—	1/batch	—
²¹⁰ Pb	1/batch	1/batch	—	—	1/batch	—
²²⁶ Ra	1/batch	1/batch	—	—	1/batch	—
Grain Size	1/batch	1/batch	—	—	1/batch	—

LCS = laboratory control sample
One batch equals 20 samples or fewer.

14.0 Data Quality (Usability) Assessment

14.2 Data analysis and presentation methods

A summary of the data will be presented in the final report. Contaminant results will be presented as both concentrations and fluxes. Fluxes will be calculated as the contaminant concentration multiplied by the sedimentation rate for the sediment core interval.

In 2019, PFAS concentrations and fluxes will be calculated and presented as total (T-) PFAS (sum of all perfluoroalkyl acids) and individually.

14.3 Treatment of non-detects

Methods for calculating T-PFASs will follow the same logic presented in the original QAPP outlined for polychlorinated biphenyls.

Blank censoring of the PFAS analytical data will follow a “five-times rule.” Results will be considered a non-detect if the concentration in the native sample is less than five times the concentration of the associated laboratory method blank.

15.0 References

- Ahrens, L., N. Yamashita, L.W.Y. Yeung, S. Taniyasu, Y. Horii, P.K.S. Lam, and R. Ebinghaus. 2009. Partitioning Behavior of Per- and Polyfluoroalkyl Compounds between Pore Water and Sediment in Two Sediment Cores from Tokyo Bay, Japan. *Environmental Science and Technology*, Vol. 43: 6969-6975.
- Benskin, J.P., V. Phillips, V.L. St. Louis, and J.W. Martin. 2011. Source Elucidation of Perfluorinated Carboxylic Acids in Remote Alpine Lake Sediment Cores. *Environmental Science and Technology*, Vol. 45: 7188-7194.
- Buck, R.C., J. Franklin, U. Berger, J.M. Conder, I.T. Cousins, P. de Voogt, A. Astrup Jensen, K. Kannan, S.A. Mabury, and S.P.J. van Leeuwen. 2011. Perfluoroalkyl and Polyfluoroalkyl Substances in the Environment: Terminology, Classification, and Origins. *Integrated Environmental Assessment and Management*, Vol. 4: 513-541.
- Codling, G., S. Hosseini, M.B. Corcoran, S. Bonina, T. Lin, A. Li, N.C. Sturchio, K.J. Rockne, K. Ji, H. Peng, and J.P. Giesy. 2018a. Current and historical concentrations of poly and perfluorinated compounds in sediments of the northern Great Lakes – Superior, Huron, and Michigan. *Environmental Pollution*, Vol. 236: 373-381.
- Codling, G., N.C. Sturchio, K.J. Rockne, A. Li, H. Peng, T.J. Tse, P.D. Jones, and J.P. Giesy. 2018b. Spatial and temporal trends in poly- and per-fluorinated compounds in the Laurentian Great Lakes Erie, Ontario and St. Clair. *Environmental Pollution*, Vol. 237: 396-405.
- ITRC, 2018. ITRC PFAS Fact Sheets: Environmental Fate and Transport for Per- and Polyfluoroalkyl Substances. Interstate Technology Regulatory Council (ITRC). Retrieved from <https://pfas-1.itrcweb.org/fact-sheets>.
- MacInnis, J.J., I. Lehnerr, D.C.G. Muir, R. Quinlan, and A.O. De Silva. 2019. Characterization of perfluoroalkyl substances in sediment cores from High and Low Arctic Lakes in Canada. *Science of the Total Environment*, Vol. 666: 414-422.
- Mathieu, C. 2013. PBT Chemical Trends in Washington State Determined from Age-Dated Lake Sediment Cores, 2012 Sampling Results. Washington State Department of Ecology, Olympia, WA. Publication number 13-03-036. <https://fortress.wa.gov/ecy/publications/SummaryPages/1303036.html>.
- Mathieu, C. 2016. Quality Assurance Project Plan: Long-Term Monitoring of Persistent, Bioaccumulative, and Toxic Chemicals using Age-Dated Lake Sediment Cores. Washington State Department of Ecology, Olympia, WA. Publication number 16-03-118. <https://fortress.wa.gov/ecy/publications/SummaryPages/1603118.html>.
- MDEQ. 2018. Sediment PFAS Sampling Guidance. Michigan Department of Environmental Quality.
- Mussabek, D., L. Ahrens, K.M. Persson, and R. Berndtsson. 2019. Temporal trends and sediment-water partitioning of per- and polyfluoroalkyl substances (PFAS) in lake sediment. *Chemosphere*, Vol. 227: 624-629.
- Myers, A.L., P.W. Crozier, P.A. Helm, C. Brimacombe, V.I. Furdui, E.J. Reiner, D. Burniston, and C.H. Marvin. 2012. Fate, distribution, and contrasting temporal trends

of perfluoroalkyl substances (PFASs) in Lake Ontario, Canada. *Environment International*, Vol. 44: 92-99.

OECD, 2013. OECD/UNEP Global PFC Group, Synthesis paper on per- and polyfluorinated chemicals (PFCs), Environment, Health and Safety, Environment Directorate, OECD.

Stock, N.L., V.I. Furdui, D.C.G. Muir, and S.A. Mabury. 2007. Perfluoroalkyl Contaminants in the Canadian Arctic: Evidence of Atmospheric Transport and Local Contamination. *Environmental Science and Technology*, Vol. 41: 3529-3536.

US EPA. 2009. Guidance for Labeling Externally Validated Laboratory Analytical Data for Superfund Use. United States Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC. Publication number EPA 540-R-08-005.

US EPA. 2016a. Health Effects Support Document for Perfluorooctane Sulfonate (PFOS). United States Environmental Protection Agency, Office of Water. Publication number EPA 822-R-16-002.

US EPA. 2016b. Health Effects Support Document for Perfluorooctanoic Acid (PFOA). United States Environmental Protection Agency, Office of Water. Publication number EPA 822-R-16-003.

Zushi, Y., M. Tamada, Y. Kanai, and S. Masunaga. 2010. Time trends of perfluorinated compounds from the sediment core of Tokyo Bay, Japan (1950s-2004). *Environmental Pollution*, Vol. 158: 756-763.