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State of Washington

Quality Assurance Project Plan

Toxic Chemicals in Stormwater Runoff from Artificial Turf Installations

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Cover photo: Aerial view of an artificial turf soccer field.
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Quality Assurance Project Plan

Toxic Chemicals in Stormwater Runoff From Artificial Turf Installations

By Amy Salamone

January 2025

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Signatures are not available on the Internet version.
EAP: Environmental Assessment Program
HWTR: Hazardous Waste and Toxics Reduction

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2.0 Abstract

Artificial turf installations, like youth athletic playfields, school and university playfields, and community playgrounds have been installed in many communities across Washington. Artificial turf is used as ground cover material designed to mimic natural grass and is made of thin plastic blades secured to turf backing material. Artificial turf fields used for sports also have a shock-absorbing pad installed below the turf and infill material between the turf blades. The majority of artificial turf installations use plastic blades as artificial grass and recycled tire crumb rubber as infill. Concerns about the health and environmental effects of crumb rubber materials have encouraged a growing market of alternative infills, like cork, coconut fiber, olive pits, or engineered wood particles. The materials used in artificial turf installations have changed over time and can vary from one field to another, complicating the task of assessing their environmental impacts.

This study will measure specific toxic chemicals in stormwater runoff from artificial turf installations in Washington. This study will collect runoff samples from artificial turf installations located across the state and made of different materials, including crumb rubber and alternative infill types. Findings from this study will be used in the potential development of a product replacement program for artificial turf.

3.0 Background

3.1 Introduction and problem statement

Removing toxic chemicals from consumer products before they cause personal or environmental harm is one of the most effective ways to help protect Washington’s public health, environment, and economy. Washington State Department of Ecology’s (Ecology) Product Replacement Program (PRP), in collaboration with local government partners, provides financial incentives to Washington businesses and organizations to remove or replace some of the worst toxic chemicals through product upgrades, disposal programs, and best management practices. Ecology’s Environmental Assessment Program (EAP) conducts scientific studies to assess the presence of toxic chemicals in products and to monitor the release and persistence of toxic chemicals in the environment.

Artificial turf is a synthetic ground cover material designed to mimic the appearance of natural grass. Artificial turf has become increasingly popular, with overall sales having increased 15% in North America since 2017 (STC 2020). In North America, there are an estimated 16,000 artificial turf fields and 65 million square feet of installed artificial turf (Penta Group 2022; DTSC 2024). Artificial turf fields have estimated lifespans ranging between 5 and 15 years (STC 2020). Since natural turf requires periods of inactivity to recover and remain healthy, artificial turf fields can provide more playing time and can be used for more events on the same surface than natural turf (Cheng et al. 2014).

Artificial turf is generally installed with several components including a base layer made from gravel and sand, an optional shock-absorbing pad, a layer of turf backing material, turf blades, and one or more infill types. Turf blades are commonly made of extruded polyethylene, nylon, or polypropylene that is cut into strips, twisted together, and stitched or tufted into the backing material (Jastifer et al. 2019). Infill is the portion of a turf installation that mimics the role of soil, serving to hold turf blades upright and provide cushioning for players. The most common type of turf infill used on sports fields is crumb rubber, which is made of shredded end-of-life tires (STC 2020). Alternative turf infill materials are cork, sand, coconut fiber, olive pits, and engineered word particles (Bauer et al. 2017; Jastifer et al. 2019; Brockfill 2020). An average artificial turf field contains about 40,000 pounds of infill and 40,000 pounds of turf blades and backing (STC 2020).

Extensive literature has been generated on chemicals present in, and released from artificial turf blades, turf backing materials, and crumb rubber infill (see Section 3.2.2). Materials like the plastics and rubbers used for artificial turf components are often manufactured with stabilizing additives to help withstand environmental and human influences (e.g., sunlight, temperature changes, rainfall, playing, maintenance, cleaning, etc.) (Bertling et al. 2021). Environmental factors play a large role in the degradation of artificial turf. Heat and sunlight accelerate oxidative degradation of plastic or rubber components, while freeze thaw cycles can cause fracturing, accelerating annual weathering effects (Cheng et al. 2014). Abrasion from consistent use breaks down plastic and rubber particles making it easier for them to be airborne or runoff during rain events (Cheng et al. 2014).

Artificial turf installations could release toxic chemicals into the environment during rain events, posing contamination risks. Understanding if, and at what levels, toxic chemicals are released from artificial turf installations is crucial for informed decision-making. This study is designed to investigate environmental contamination by measuring the metals arsenic (As), cadmium (Cd), copper (Cu), lead (Pb), nickel (Ni), and zinc (Zn), and toxic chemicals — N-(1,3-Dimethylbutyl)-N′-phenyl-p-phenylenediamine-quinone (6PPDQ) and per- and polyfluoroalkyl substances (PFAS), in stormwater runoff from artificial turf installations.

3.2 Study area and surroundings

This study is designed to sample stormwater runoff from up to 30 artificial turf installations in Washington. Artificial turf installations are mixed use sites since drainage infrastructure may combine runoff from multiple fields, playgrounds, and/or parking lots into the same downstream outfall site. This study will use the term artificial turf installations to describe that study boundaries will include the whole combined drainage area. See sections 7.1 through 7.4 for additional study design information.

This study will use four regional study areas of Washington to group and code field site locations (Figure 1). Artificial turf installations are located primarily near more-heavily populated areas of the northwest and southwest regions of Washington. As of 2020, the population residing in the northwest region is 3,834,276, southwest region is 2,202,261, central region is 796,110, and eastern region is 873,681 (OFM 2024).

Figure 1. Map of four regional study areas in Washington.

In addition to population differences, the regional study areas of Washington receive extremely different levels of annual precipitation (Figure 2). Northwest and southwest regions receive drastically more precipitation than the central and eastern regions of Washington. The short wet season in central and eastern Washington usually lasts from November through January, and there is very little precipitation during warmer months.

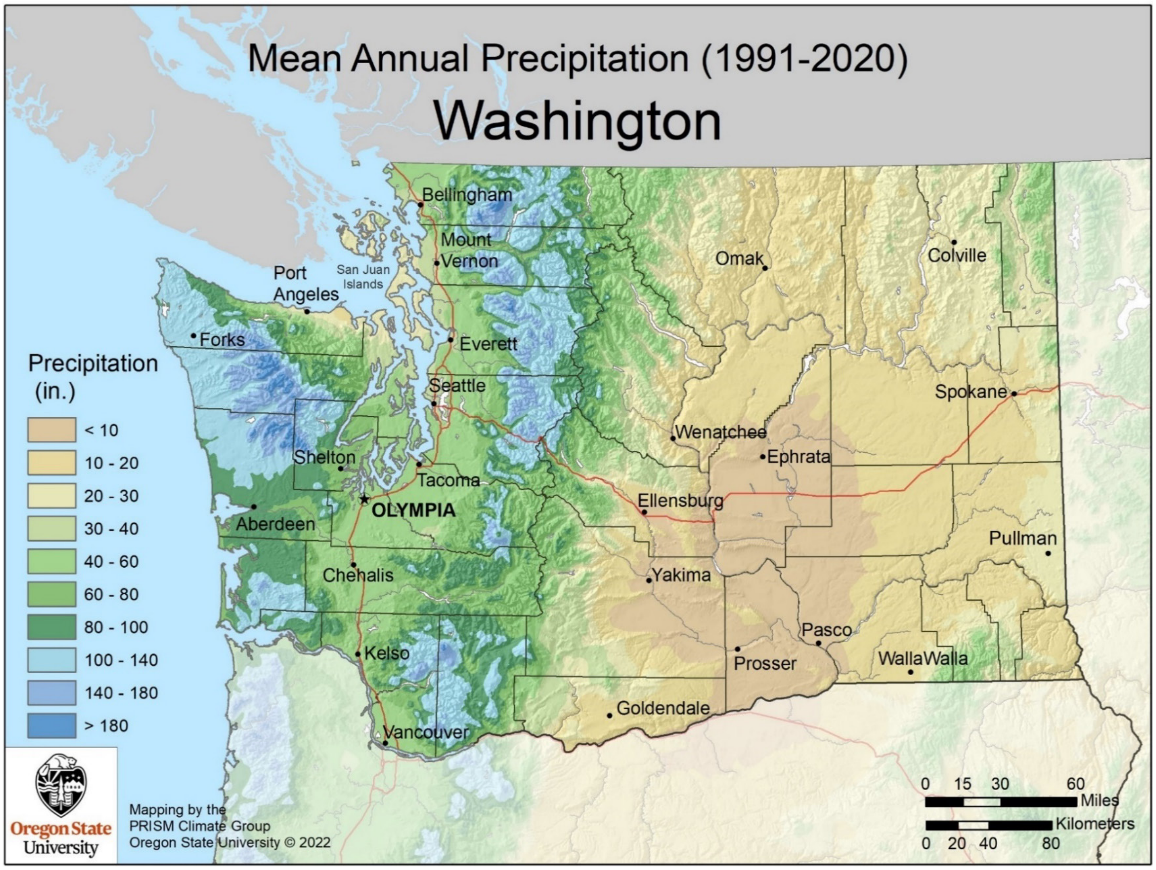

Figure 2. Map of mean annual precipitation in Washington from 1991 to 2020 (PRISM Climate Group, 2022).

Due to the differences in population, precipitation, and field site availability, the number of sampling sites will not be equal across the regional study areas. All efforts will be made to sample from at least three artificial turf installations in the four regional study areas.

3.2.1 History of study area

This study is designed to sample from artificial turf installations of variable ages and use-types. Most artificial turf installations are used for playing sports, like football, baseball, and soccer, while others may serve as school or community playgrounds. There has not previously been an investigative study of metals and toxic chemicals, 6PPDQ and PFAS, in stormwater runoff from artificial turf installations in Washington.

3.2.2 Summary of previous studies and existing data

This quality assurance project plan (QAPP) presents previous studies of artificial turf materials for 6PPDQ, PFAS, and metals the toxic chemicals that will be measured in this study. This section is not meant to serve as a comprehensive resource for all toxic chemicals that have been detected in or from artificial turf installations and component materials. Studies have been published on many other chemicals present in, and released from, artificial turf blades, turf backing materials, and crumb rubber infill (Bocca et al. 2008; Menichini et al. 2011; Kruger et al. 2012; Cheng et al. 2014; Massey et al. 2020; Gomes et al. 2021; Zhang et al. 2021; Murphy and Warner 2022; Ferreira et al. 2024).

6PPD (N-(1,3-Dimethylbutyl)-N′-phenyl-p-phenylenediamine) is a rubber protectant added to most vehicle tires at 1 to 2% (10,000 to 20,000 µg/g) (DTSC 2022). When 6PPD reacts with oxygen it forms 6PPD-quinone (6PPDQ), a chemical that was recently discovered to be highly toxic to coho salmon, which is very concerning to Washington (Tian et al. 2021; Ecology 2022). Crumb rubber infill is made almost exclusively of recycled vehicle tires. A study of crumb rubber samples from artificial turf infills across the U.S. tentatively identified, but did not quantify, 6PPD (EPA and CDC 2019). A recent study collected and analyzed crumb rubber infill from 9 artificial turf locations in Washington and found that all crumb rubber samples contained measurable 6PPD and 6PPDQ (Zhao et al. 2023). Results of a laboratory study indicate that warm weather may cause faster formation and release of 6PPDQ from crumb rubber infill than in cold weather (Zhao et al. 2024).

PFAS have been used in the production of plastic and rubber to lower surface tension and act as processing aids to increase the efficiency and quality of plastic and rubber manufacturing (Buck et al. 2011; Glüge et al. 2020). Studies have detected PFAS from artificial turf materials by assessing specific PFAS compounds, total fluorine, extractable organic fluorine, fluoride analysis, and/or total oxidizable precursor assay (Lauria et al. 2022; Zuccaro et al. 2023). An assessment of a small class of PFAS (fluorotelomer alcohols) indicates that samples of turf backing, plastic grass blades, and crumb rubber infill contained 8:2 fluorotelomer alcohol (Zuccaro et al. 2023). Targeted PFAS analysis may be problematic since PFAS in artificial turf materials are difficult to extract (Lauria et al. 2022).

Early and current research has focused on assessing metals present in or leaching from artificial turf materials. A number of studies have detected the metals cadmium, copper, lead, nickel, and zinc associated with artificial turf materials, mainly from crumb rubber infill (Li et al. 2010;

Menichini et al. 2011; Pavilonis et al. 2014; Cheng et al. 2014; Marsili et al. 2014; Vineyard et al. 2018; Massey et al. 2020; Zhang et al. 2021; Grynkiewicz-Bylina et al. 2022).

3.2.3 Parameters of interest and potential sources

Table 1 presents the chemicals of interest for this study. Automobile tires are currently understood to be the main source of 6PPD and 6PPDQ, although more research is needed to evaluate additional consumer product sources of 6PPD (Ecology 2022; DTSC 2022; Zhao et al. 2023). Since most athletic artificial turf fields use recycled tire crumb rubber as infill, they may be a source for 6PPDQ in the environment (Smith 2023).

PFAS are used in plastic artificial grass blades is to act as an extrusion aid to keep the plastic from sticking to the extruder as it is melted and shaped (Glüge et al. 2020). The production uses of PFAS likely explain why PFAS have been found in artificial turf (Lauria et al. 2022; Zuccaro et al. 2023).

Metals are known to be present in recycled tire crumb rubber infill. Certain metals may also be used as colorants or stabilizers in artificial grass blades, like green copper metallic complexes or mixed metal-oxide pigments (DTSC 2024; Vineyard et al. 2018).

Table 1. Chemicals of interest in this study.

Abbreviation	Chemical Name	CAS RN
6PPDQ	N-(1,3-dimethylbutyl)-N'-phenyl-p-phenylenediamine-quinone	2754428-18-5
PFBA	Perfluorobutanoate	45048-62-2
PFPeA	Perfluoropentanoate	45167-47-3
PFHxA	Perfluorohexanoate	92612-52-7
PFHpA	Perflluoroheptanoate	120885-29-2
PFOA	Pefluorooctanoate	45285-51-6
PFNA	Perfluorononanoate	72007-68-2
PFDA	Perfluorodecanoate	73829-36-4
PFUnA	Perfluoroundecanoate	196859-54-8
PFDoA	Perfluorododecanoate	171978-95-3
PFTrDA	Perfluorotridecanoate	862374-87-6
PFTeDA	Perfluorotetradecanoate	365971-87-5
PFBS	Perfluorobutane sulfonate	45187-15-3
PFPeS	Perfluoropentane sulfonate	175905-36-9
PFHxS	Perfluorohexane sulfonate	108427-53-8
PFHpS	Perfluoroheptane sulfonate	146689-46-5
PFOS	Perfluorooctane sulfonate	45298-90-6
PFNS	Perfluorononane sulfonate	474511-07-4
PFDS	Perfluorodecane sulfonate	126105-34-8
PFDoS	Perfluorododecane sulfonate	343629-43- 6
4:2 FTS	1H,1H,2H,2H-Perfluorohexane sulfonate	414911-30-1
6:2 FTS	1H,1H,2H,2H-Perfluorooctane sulfonate	425670-75-3
8:2 FTS	1H,1H,2H,2H-Perfluorodecane sulfonate	481071-78-7
PFOSA	Perfluorooctanesulfonamide	754-91-6
NMeFOSA	N-methyl perfluorooctanesulfonamide	31506-32-8
NEtFOSA	N-ethyl perfluorooctanesulfonamide	4151-50-2

Abbreviation	Chemical Name	CAS RN
NMeFOSAA	N-methyl perfluorooctanesulfonamidoacetate	none
NEtFOSAA	N-ethyl perfluorooctanesulfonamidoacetate	none
NMeFOSE	N-methyl perfluorooctanesulfonamidoethanol	24448-09-7
NEtFOSE	N-ethyl perfluorooctanesulfonamidoethanol	1691-99-2
HFPO-DA/GenX	2,3,3,3-Tetrafluoro-2-(1,1,2,2,3,3,3-heptafluoropropoxy)propanoate	122499-17-6
ADONA	4,8-Dioxa-3H-perfluorononanoate	2127366-90-7
PFMPA	Perfluoro-3-methoxypropanoate	none
PFMBA	Perfluoro-4-methoxybutanoate	1432017-36-1
NFDHA	Nonafluoro-3,6-dioxaheptanoate	39187-41-2
9Cl-PF3ONS	9-chlorohexadecafluoro-3-oxanonane-1-sulfonate	1621485-21-9
11Cl-PF3OUdS	11-chloroeicosafluoro-3-oxaundecane-1-sulfonate	2196242-82-5
PFEESA	Perfluoro(2-ethoxyethane)sulfonate	220689-13-4
3:3 FTCA	3-Perfluoropropyl propanoate	1169706-83-5
5:3 FTCA	2H,2H,3H,3H-Perfluorooctanoate	1799325-94-2
7:3 FTCA	3-Perfluoroheptyl propanoate	1799325-95-3
As	Arsenic	7440-38-2
Cd	Cadmium	7440-43-9
Cu	Copper	7440-50-8
Pb	Lead	7439-92-7
Ni	Nickel	7440-02-0
Zn	Zinc	7440-66-6

3.2.4 Regulatory criteria or standards

This study does not collect data to determine compliance with any regulatory standards. Below are regulatory criteria for specific consumer products containing metals and/or PFAS.

In 2009, Washington passed the Children's Safe Products Act (70A.430 RCW) prohibiting the manufacture and sale of children's products containing lead at 90 mg/L and cadmium at 40 mg/L. Established in 2011, Washington's Children's Safe Products Reporting Rule (173-334 WAC) requires manufacturers to notify the state if their children's products for sale in Washington contain PFOS (as of 2011) and PFOA (as of 2017) as well as arsenic and cadmium (as of 2011).

In 2010, Washington passed the Better Brakes Law (70A.340 RCW), restricting the use of cadmium and lead by 2015, and significantly phasing down copper by 2025, in brake friction materials.

In 2018, Washington passed two regulations regarding PFAS, which apply to the use and purchase of PFAS-containing firefighting foams and personal protective equipment (70.75A RCW) and the use of PFAS in food packaging (70.95G RCW).

In 2022, House Bill 1694 was passed into law, which gave Ecology authority to address PFAS in products named in the PFAS Chemical Action Plan as a "priority product" under the Safer Products for Washington program (70A.350 RCW). The first set of regulations will restrict PFAS in carpet, textile, and leather furnishings and aftermarket stain and water resistance treatments.

In 2023, Washington passed the Toxic Chemicals in Cosmetic Products Act (70A.560 RCW) which applies to PFAS in any cosmetic product.

4.0 Project Description

This study is designed to assess whether artificial turf installations in Washington release 6PPDQ, PFAS, and metals into stormwater runoff. Community members and field owners are concerned about potential toxic chemical runoff from these fields into the environment, particularly during rain events. Study data will inform the potential development of a product replacement program that may provide financial support to replace artificial turf installations with safer options.

4.1 Project goals

The primary goal of this study is to characterize the presence and concentrations of 6PPDQ, PFAS, and metals in stormwater runoff from artificial turf installations in Washington.

4.2 Project objectives

Project objectives to meet the goal are:

- Perform two collection events for rainwater runoff samples from up to 30 artificial turf installations in Washington.
- Analyze 6PPDQ, PFAS, and metals in up to 60 samples of stormwater runoff and up to 24 quality control (QC) samples.

4.3 Information needed and sources

To determine the most representative sampling location, the principal investigator will request from field owners or designated representatives all available site maps, engineering drawings, or drainage reports for each artificial turf installation. In the absence of this information, the principal investigator will select a representative downstream site as described in Ecology's SOP WQP001 for grab samples from stormwater discharges (Lowe et al. 2024).

To gather product information, the principal investigator will ask field owners or designated representatives the following list of questions:

- When was your artificial turf installed?
- What type of infill do you use?
- When did you last replace your infill?
- Does your installation include the optional shock pad?
- What are the brands of artificial turf products (plastic grass blades, turf backing, infill, shock pad) you have installed?

4.4 Tasks required

The following tasks will be performed for this study:

- Desktop review of artificial turf installations in Washington, including identifying installations made with crumb rubber and alternative infill materials.
- Coordinate with Ecology's Hazardous Waste and Toxics Reduction Program, Water Quality Program, and Solid Waste Management Program to perform outreach to and recruitment for participant field owners, local parks and recreation departments, and school districts.
- Obtain permission to access sample locations.
- Request information from field owners or designated representatives.
- Conduct field reconnaissance site visits to assess the feasibility of sample locations.
- Coordinate with Manchester Environmental Laboratory (MEL) during project planning and sample submission.
- Collect up to 60 stormwater runoff samples and submit to MEL for 6PPDQ and metals analysis following the schedule in section 8.3.
- Collect up to 60 stormwater runoff samples and submit to a contract laboratory for PFAS analysis following the schedule in section 8.3.
- Review laboratory data and data validation report.
- Document and publish results into Ecology's Environmental Information Management (EIM) System
- Write and publish a report of study results.

4.5 Systematic planning process

This QAPP represents systematic planning for this study.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

Table 2 shows the responsibilities of those who will be involved in this project.

Table 2. Organization of project staff and responsibilities.

Staff[1]	Title	Responsibilities
Sean Smith Product Replacement Program HWTR Phone: 425-324-0328	Product Replacement Program (PRP) Coordinator	Clarifies scope of the project. Reviews the budget. Reviews the draft QAPP and approves the final QAPP.
Elaine Snouwaert Eastern Regional Office HWTR Phone: 509-385-5169	Section Manager for PRP	Approves the budget. Reviews and approves the final QAPP.
Amy Salamone Product Testing Unit Statewide Coordination Section Phone: 564-669-1760	Principal Investigator/ Project Manager	Writes the QAPP. Oversees field sampling, chain of custody, and transportation of samples to the laboratory. Conducts QA review of data, analyzes and interprets data, and assists with entering data into EIM. Writes the draft report and final report.
Jenna Rushing Product Testing Unit Statewide Coordination Section Phone: 360-819-3670	Field Assistant	Assists with QAPP writing. Reviews the final QAPP. Collects field samples and records chain of custody information. Conducts QA review of data and enters data into EIM. Reviews draft report.
Sara Sekerak Product Testing Unit Statewide Coordination Section Phone: 360-480-9501	Unit Supervisor for Project Manager	Provides internal review of the QAPP, approves the budget, and approves the final QAPP. Reviews draft report.
Jessica Archer Statewide Coordination Section Phone: 360-890-2721	Section Manager for Project Manager	Reviews the project scope and budget, tracks progress, reviews the draft QAPP, and approves the final QAPP.
Rob Waldrop Manchester Environmental Laboratory Phone: 360-871-8801	Director	Reviews and approves the final QAPP.
Contract Laboratory	Project Manager	Reviews final QAPP. Coordinates with MEL QA Coordinator
Christina Frans Phone: 360-995-2473	Acting Ecology Quality Assurance Officer	Reviews and approves the draft QAPP and the final QAPP. Signs the Approval to Begin Work form.

EAP= Environmental Assessment Program
EIM= Environmental Information Management system
HWTR= Hazardous Waste and Toxics Reduction
QA= Quality Assurance
QAPP= Quality Assurance Project Plan
[1] All staff except the PRP team, and contract laboratory project manager are from EAP.

5.2 Special training and certifications

All field staff will be trained to conduct stormwater runoff sampling following safety and quality assurance guidelines outlined in section 8. Training includes special procedures for avoiding cross-contamination while conducting 6PPDQ and PFAS sampling, equipment decontamination procedures, and proper storage and transport of field samples to the designated laboratories (see sections 8.2-8.4 for details).

5.3 Organization chart

Not Applicable — See Table 2

5.4 Proposed project schedule

Tables 3 through 5 list the schedule of key activities, due dates, and lead staff for this study.

Table 3. Schedule for completing field and laboratory work

Task	Due date	Lead staff
Field work	December 31, 2025	Amy Salamone
Sample submission to MEL	Weekly from November 1, 2024 to December 31, 2025; Variable depending on rain events; Less likely from June to September	Jenna Rushing
Sample submission to contract lab	Monthly from November 1, 2024 to December 31, 2025; Variable depending on rain events; Less likely from June to September	Jenna Rushing
Laboratory analyses (all)	February 27, 2026	MEL
Lab data validation (all)	June 30, 2026	MEL

MEL= Manchester Environmental Laboratory

Table 4. Schedule for data entry

Task	Due date	Lead staff
EIM data loaded*	July 31, 2026	Jenna Rushing
EIM QA	August 14, 2026	Amy Salamone
EIM complete	August 31, 2026	Jenna Rushing

*EIM Project ID: AMSA0001
EIM= Environmental Information Management database
QA= Quality AssuranceTable

Table 5. Schedule for final report

Task	Due date	Lead staff
Draft to supervisor	August 31, 2026	Amy Salamone
Draft to client/ peer reviewer	September 28, 2026	Amy Salamone
Final draft to publications team	October 30, 2026	Amy Salamone
Final report due on web	November 30, 2026	Publications Team

5.5 Budget and funding

Tables 6 and 7 list the budget details for this study.

Table 6. Project budget and funding

Item	Cost ($)
Equipment	$300
Shipping[1]	$4,200
Travel and other	$6,000
Laboratory (See Table 7 for details.)	$76,121
Project Total	**$86,621**

[1]Estimated ten overnight shipping events from Lacey, Washington to the contract laboratory.

Table 7. Laboratory budget details

Parameter	Number of Field Samples	Number of QC[1] Samples	Total Number of Samples	Cost Per Sample	Lab Subtotal
PFAS (40 compounds)	≤ 60	12	72	$385	$27,720
6PPDQ	≤ 60	24	84	$275	$23,100
Metals (6 elements)	≤ 60	24	84	$150.70	$12,659
MEL Contract Lab Fee	—	—	84	30% of PFAS total	$9,702
Contract Lab Data Deliverable Fee	—	—	84	$35	$2,940
				Laboratory Total	**$76,121**

6PPDQ = N-(1,3-Dimethylbutyl)-N′-phenyl-p-phenylenediamine-quinone
PFAS = per- and polyfluoroalkyl substances
QC = quality control

[1] QC samples include field duplicates (n=6) and field blanks (n=6) and/or matrix spike/matrix spike duplicates (n=12).

6.0 Quality Objectives

6.1 Data quality objectives

The main data quality objective (DQO) for this project is to conduct two stormwater runoff sample events from up to 30 artificial turf installations and to have the samples analyzed at the laboratory. The analysis will use standard methods to obtain total 6PPDQ, PFAS, and metals concentration data that meet measurement quality objectives (MQOs) that are described below.

6.2 Measurement quality objectives

The MQOs for this study are detailed in Tables 8 and 9.

6.2.1 Targets for precision, bias, and sensitivity

Table 8. Measurement quality objectives for laboratory organic analyses of stormwater runoff samples.

Parameter	Lab, Field, Matrix Spike Duplicates (RPD)	Lab, Field Blanks	OPR/LLOPR (% Recovery)	Matrix Spike (% Recovery)	Extracted Internal Standard (% Recovery)	LLOQ/ML
6PPDQ	±40%	< LLOQ	50–150	50–150	25–200	2.0 ng/L
PFBA	±40%	<1/2 LLOQ	70–140	50–150	70–135	1.6 ng/L
PFPeA	±40%	<1/2 LLOQ	65–135	50–150	70–135	0.8 ng/L
PFHxA	±40%	<1/2 LLOQ	70–145	50–150	70–135	0.4 ng/L
PFHpA	±40%	<1/2 LLOQ	70–150	50–150	70–135	0.4 ng/L
PFOA	±40%	<1/2 LLOQ	70–150	50–150	65–155	0.4 ng/L
PFNA	±40%	<1/2 LLOQ	70–150	50–150	70–140	0.4 ng/L
PFDA	±40%	<1/2 LLOQ	70–140	50–150	65–140	0.4 ng/L
PFUnA	±40%	<1/2 LLOQ	70–145	50–150	70–135	0.4 ng/L
PFDoA	±40%	<1/2 LLOQ	70–140	50–150	70–130	0.4 ng/L
PFTrDA	±40%	<1/2 LLOQ	65–140	50–150	65–140	0.4 ng/L
PFTeDA	±40%	<1/2 LLOQ	60–140	50–150	70–145	0.4 ng/L
PFBS	±40%	<1/2 LLOQ	60–145	50–150	70–140	0.4 ng/L
PFPeS	±40%	<1/2 LLOQ	65–140	50–150	70–135	0.4 ng/L
PFHxS	±40%	<1/2 LLOQ	65–145	50–150	70–135	0.4 ng/L
PFHpS	±40%	<1/2 LLOQ	70–150	50–150	70–140	0.4 ng/L
PFOS	±40%	<1/2 LLOQ	55–150	50–150	70–140	0.4 ng/L
PFNS	±40%	<1/2 LLOQ	65–145	50–150	70–135	0.4 ng/L

Parameter	Lab, Field, Matrix Spike Duplicates (RPD)	Lab, Field Blanks	OPR/LLOPR (% Recovery)	Matrix Spike (% Recovery)	Extracted Internal Standard (% Recovery)	LLOQ/ML
PFDS	±40%	<1/2 LLOQ	60–145	50–150	70–135	0.4 ng/L
PFDoS	±40%	<1/2 LLOQ	50–145	50–150	45–135	0.4 ng/L
4:2FTS	±40%	<1/2 LLOQ	70–145	50–150	70–135	1.6 ng/L
6:2FTS	±40%	<1/2 LLOQ	65–155	50–150	70–135	5 ng/L
8:2FTS	±40%	<1/2 LLOQ	60–150	50–150	70–140	1.6 ng/L
PFOSA	±40%	<1/2 LLOQ	70–145	50–150	70–135	0.4 ng/L
NMeFOSA	±40%	<1/2 LLOQ	60–150	50–150	70–135	0.4 ng/L
NEtFOSA	±40%	<1/2 LLOQ	65–145	50–150	70–130	0.4 ng/L
NMeFOSAA	±40%	<1/2 LLOQ	50–140	50–150	65–140	0.4 ng/L
NEtFOSAA	±40%	<1/2 LLOQ	70–145	50–150	70–135	0.4 ng/L
NMeFOSE	±40%	<1/2 LLOQ	70–145	50–150	70–135	4 ng/L
NEtFOSE	±40%	<1/2 LLOQ	70–135	50–150	70–130	4 ng/L
HFPO-DA/GenX	±40%	<1/2 LLOQ	70–140	50–150	70–135	1.6 ng/L
ADONA	±40%	<1/2 LLOQ	65–145	50–150	70–135	1.6 ng/L
PFMPA	±40%	<1/2 LLOQ	55–140	50–150	60–140	0.4 ng/L
PFMBA	±40%	<1/2 LLOQ	60–150	50–150	65–145	0.4 ng/L
NFDHA	±40%	<1/2 LLOQ	50–150	50–150	65–140	0.8 ng/L
9Cl-PF3ONS	±40%	<1/2 LLOQ	70–155	50–150	70–145	1.6 ng/L
11Cl-PF3OUdS	±40%	<1/2 LLOQ	55–160	50–150	50–150	1.6 ng/L
PFEESA	±40%	<1/2 LLOQ	70–140	50–150	70–135	0.4 ng/L
3:3FTCA	±40%	<1/2 LLOQ	65–130	50–150	70–130	1.6 ng/L
5:3FTCA	±40%	<1/2 LLOQ	70–135	50–150	70–130	10 ng/L
7:3FTCA	±40%	<1/2 LLOQ	50–145	50–150	55–130	10 ng/L

6PPDQ = N-(1,3-Dimethylbutyl)-N′-phenyl-p-phenylenediamine-quinone
LLOPR = low-level spiked ongoing precision and recovery standards
LLOQ = lower limit of quantification
ML = minimum level of quantitation
OPR = ongoing precision and recovery standards
RPD = relative percent difference

Table 9. Measurement quality objectives for laboratory inorganic analyses of stormwater runoff samples.

Parameter	Lab, Field, Matrix Spike Duplicates (RPD)	Lab, Field Blanks	LCS/LCSD (% Recovery)	Matrix Spike (% Recovery)	Internal Standard (% Recovery)	MRL
As	±20%	< ½ MRL	85–115	75–125	60–125	0.1 mg/L
Cd	±20%	< ½ MRL	85–115	75–125	60–125	0.1 mg/L
Cu	±20%	< ½ MRL	85–115	75–125	60–125	0.4 mg/L
Ni	±20%	< ½ MRL	85–115	75–125	60–125	0.1 mg/L
Pb	±20%	< ½ MRL	85–115	75–125	60–125	0.1 mg/L
Zn	±20%	< ½ MRL	85–115	75–125	60–125	5 mg/L

LCS = laboratory control sample
LCSD = laboratory control sample duplicate
MRL = method reporting limit
RPD = relative percent difference

6.2.1.1 Precision

Precision is a measure of variability among replicate measurements due to random error. Results from this study will be assessed for precision using duplicate field measurements and laboratory analysis of duplicate samples 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 Tables 8 and 9.

Field duplicate samples will be collected for every 10% of samples and analyzed alongside the field samples. A field duplicate will be collected immediately after the field sample using the same sampling technique.

6.2.1.2 Bias

Bias is the difference between the sample mean 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. Tables 8 and 9 outline 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. Sensitivity for laboratory analyses is defined as the lower limit of quantification (LLOQ), minimum level of quantitation (ML), or the method reporting limit (MRL). See Tables 8 and 9 for specified quantitation limits.

Field blanks will be collected for every 10% of samples to help determine background contamination during handling and transportation. Laboratory-provided blank water will be poured into sample bottles and transported in the same manner as field samples are handled and transported.

6.2.2 Targets for comparability, representativeness, and completeness

6.2.2.1 Comparability

This study will ensure comparability with other studies by using standard operating procedures (SOPs) (see Section 8 for a list of SOPs) and standard laboratory methods. Specifically, procedures used in this study for metals and 6PPDQ sample collection and analysis will follow those outlined in the Quality Assurance Project Plan: Monitoring of Tire Contaminants in Coho Salmon (Smith 2023). Procedures for PFAS sample collection and analysis will follow those outlined in the Programmatic Quality Assurance Project Plan: Statewide PFAS Preliminary Assessments (Carnes et al. 2024).

6.2.2.2 Representativeness

Representativeness is a measure of whether the sample media reflects reality. We will ensure proper representatives by adhering to the approved SOPs and sampling protocols in section 8. Samples collected for this study are only representative of environmental conditions at the point in time at which they were collected, and do not represent the highest or lowest concentrations of 6PPDQ, PFAS, or metals that may be present in stormwater runoff from artificial turf field installations (see section 7.4).

6.2.2.3 Completeness

Completeness is a measure of the amount of valid data necessary to meet project objectives. Issues such as site access, time constraints, and equipment malfunction may affect the completeness of the data set. Since this is an investigative study that will not generate data used for modeling or compliance, there are no completeness criteria.

6.3 Acceptance criteria for quality of existing data

Not applicable to this study.

6.4 Model quality objectives

Not applicable to this study.

7.0 Study Design

7.1 Study boundaries

This study will only include artificial turf installations within Washington. Boundaries of each artificial turf installation will be determined by the drainage outfall location. Individual boundaries will be documented in field notes, or by reference to materials supplied by the site's facility or recreation manager. The perimeter of each installation may include multiple contributing factors like multiple athletic playfields, playgrounds, and/or parking lots. The sampling site for each artificial turf installation will be placed at the most downstream location that incorporates all of the targeted drainage area (see section 8.2).

7.2 Field data collection

7.2.1 Sampling locations and frequency

The amount and duration of rainfall it takes to transport product-derived chemicals from artificial turf installations is unknown and likely varies from one location to another. Sample timing will target variable rain event durations and intensities. A rain event will be defined as at least 0.1 inches of rainfall following a minimum antecedent period of <0.04 inches of rainfall in the last 6 hours (ITRC 2024). As much as is practical, the ideal timing to sample is 1 to 2 hours after a rain event has started (Smith 2023). As possible, the first flush (within 12 hours) of each rain event will be collected.

All sampling locations will have two sampling events. One sampling event for each location will be during the warmest months, as much as possible (see section 7.4). However, the eastern and central regions of Washington receive very little rain during warmer months (see section 7.5.1).

7.2.2 Field parameters and laboratory analytes to be measured

Field staff will use field logs (section 8.7) for all sampling events and will include recordings of the following:

- Date and duration (in hours) of the rainfall event
- Rainfall total (in inches) for that rainfall event
- Temperature minimum and maximum for the day of the rainfall event
- Time (in hours or days) since the previous measurable rainfall event
- Contributing land use to the drainage area (e.g., multiple artificial turf fields, playgrounds, parking lots)
- Presence and identification of any debris in runoff (e.g., trash)
- Any discoloration or odors in runoff
- Excessive sediment or solids deposits in runoff (note if solids appear to be infill material)

7.3 Modeling and analysis design

Not applicable to this study.

7.4 Assumptions underlying design

This study is designed to assess stormwater runoff from artificial turf installations for 6PPDQ, PFAS, and metals. Besides artificial turf materials, other products may contribute 6PPDQ, PFAS, and/or metals to runoff samples. There is no way to differentiate between 6PPDQ, PFAS, and metals released from artificial turf materials compared to release from other materials at or around the artificial turf installation, or from air and rain deposition. The impact of other sources of 6PPDQ, PFAS, or metals cannot be determined in this study.

The impact of environmental factors on the release and transport of 6PPDQ, PFAS, and metals likely varies from one installation to another. It is thought that high temperatures may increase the release rate of 6PPDQ (Zhao et al. 2024), but the effects of temperature on the release of 6PPDQ and PFAS into stormwater are not well understood. The optimal sampling time to capture the highest release of 6PPDQ, PFAS, or metals from artificial turf installations is not known.

Grab samples collected for this study are only assumed to be representative of conditions at that point in time and cannot be assumed to represent the highest or lowest concentrations of 6PPDQ, PFAS, or metals that may be present in stormwater runoff from artificial turf installations.

7.5 Possible challenges and contingencies

The possible logistical challenges, constraints, and schedule limitations for this study are described below.

7.5.1 Logistical problems

Rain event sampling can be challenging. Timing of rain events is not always predictable so sampling events will be scheduled as soon as possible after weather forecasts are released. Different regions in Washington receive variable levels of annual rain. It may be difficult to collect samples from locations in central or eastern regions during the warmest months since they receive very little rain compared to the northwest and southwest regions (Figure 2).

An agreement of participation must be obtained from artificial turf owners or representatives prior to sampling events. If participation is denied by any artificial turf owners or representatives for any reason during the study, the site will be removed from the study. The study will commence with the remaining participating artificial turf sites.

7.5.2 Practical constraints

This project will take place at up to 30 artificial turf installations in Washington state. Travel from Ecology duty stations to the artificial turf installations may be complicated by weather or traffic conditions. Travel for sample events will be planned to minimize risk.

7.5.3 Schedule limitations

This project schedule for field sampling is planned to last from November 1, 2024 to December 31, 2025. Even with thorough planning, schedule limitations may arise in the availability of the project assistant, and artificial turf installation representatives. Every effort will be made to sample at all scheduled events and if needed, sampling may be rescheduled until completed up until December 31, 2025.

8.0 Field Procedures

8.1 Invasive species evaluation

Field staff will follow Ecology's SOP EAP070 for minimizing the spread of invasive species (Glisson 2024). The principal investigator will determine if the assessment area is located within an area of concern for invasives by checking current maps available on Ecology's website. Field staff will decontaminate any field equipment as needed following SOP EAP070.

8.2 Measurement and sampling procedures

Field staff will follow safety procedures outlined in the EAP Safety Manual. Field staff will follow Ecology's SOP WQP001 (Lowe et al. 2024) to collect grab samples from stormwater runoff discharge sites.

Sample timing will target variable rain event durations and intensities. A rain event will be defined as at least 0.1 inches of rainfall following a minimum antecedent period of <0.04 inches of rainfall in the last 6 hours (ITRC 2024). As much as is practical, the ideal timing to sample is 1 to 2 hours after a rain event has started (Smith 2023). As possible, the first flush (within 12 hours) of each rain event will be collected.

The sampling site for each artificial turf installation will be placed at the most downstream location that incorporates all the targeted drainage area. Drainage areas for artificial turf installations are considered mixed use sites since drainage infrastructure may combine runoff from multiple athletic fields, play grounds, or parking lots into the same outfall site. Prior to sample collection, the principal investigator will review all available site maps, engineering drawings, or drainage logs to determine an appropriate sampling location to collect representative samples (Lowe at al. 2024).

Field staff must wear clean, powderless nitrile gloves during sample collection, handling of sample containers, and handling sampling equipment. Gloves should always be changed between sampling events.

The different types of sample containers will be kept separate by storing and transporting in separate secondary containers (i.e., cardboard box or cooler). Each sample container must be kept sealed and only opened during the sample collection. The sampling container cap or lid should never be placed on any surface or on the ground.

8.2.1 PFAS sampling procedures

To avoid PFAS cross contamination during field sampling, field staff will follow sampling guidance developed by the Michigan Department of Environment, Great Lakes, and Energy's (EGLE) Michigan PFAS Action Response Team (EGLE 2024). EGLE's general PFAS sampling guidance is also recommended in the Programmatic Quality Assurance Project Plan: Statewide PFAS Preliminary Assessments (Carnes et al. 2024).

Only certified clean and PFAS-free sample containers made of high-density polyethylene (HDPE) with non-lined lids will be used to collect samples for PFAS analysis (Table 9). Only approved ballpoint pens, or ultra-fine point Sharpie® markers may be used to label samples and write in field logs (EGLE 2018). Only non-waterproof and non-recycled paper may be used for field log forms.

As much as possible, field staff will wear PFAS-free field gear including boots and rain jackets. Field staff will avoid wearing or using materials containing PFAS marketed as Teflon©, water-resistant treated clothing, and some personal care products (EGLE 2024). Field staff will refrain from handling or consuming pre-wrapped food or snacks before or during sampling events.

For every sampling event, the PFAS sample collection will be done before the metals and 6PPDQ sample collection to avoid cross contamination potential with the required Teflon-lined lids.

8.2.2 6PPDQ sampling procedures

6PPDQ readily attaches to many plastics and other rubber products (Hu et al. 2023). Therefore, certified clean glass bottles with Teflon-lined lids will be used to minimize the loss of 6PPDQ during sampling (Table 9). The sample will be collected in an amber glass bottle to avoid photodegradation. Minimal headspace should be left in the bottle to prevent 6PPDQ oxygenation reactions (Smith 2023). 6PPDQ sample collection will be done after PFAS sample collection.

To avoid 6PPDQ cross contamination during field sampling, field staff will not wear rubber boots or handle tires, rubber hoses, or rubber mats before or during sampling events.

8.2.3 Metals sampling procedures

Metals samples will be collected in certified clean high-density polyethylene bottles with Teflon-lined lids (Table 9). Metals sample collection will be done after PFAS sample collection.

8.3 Containers, preservation methods, holding times

Table 9 outlines the sample containers, preservation methods, and established holding times that will be used for this study.

Samples collected for 6PPDQ and metals analysis will be stored on ice packs during transportation to Ecology headquarters in Lacey, Washington. Upon arrival, samples will be stored in a 4°C cooler for up to four days. Samples will then be transported with ice packs via courier to MEL. Samples will be submitted to MEL weekly as they are collected throughout the study period. Sample submissions will be variable week by week depending on rain events and/or contingencies outlined in section 7.5.

Samples collected for PFAS analysis will be stored on ice packs during transportation to Ecology headquarters in Lacey, Washington. Upon arrival, samples will be stored in a -20°C freezer for up to 30 days. Samples will then be packed with ice packs and sent to the contract lab via mail service. Samples for PFAS analysis will be submitted to the contract lab on a monthly basis throughout the study period.

Table 10. Sample containers, preservation, and holding times.

Parameter	Matrix	Minimum Quantity Required	Container	Preservative	Holding Time
6PPDQ	water[1]	250 ml	Certified clean 250 ml small mouth amber glass with Teflon-lined lid	Cool to 4°C	14 days at 4°C
PFAS (40 compounds)	water	500 ml	Certified clean 500 ml PFAS-free HDPE bottle with linerless HDPE or polypropylene caps	Cool to 4°C at collection; freeze at -20°C within 48 hours	90 days at -20°C
Metals (6 elements)	water	500 ml	Certified clean 500 ml HDPE bottle with Teflon-lined lid	5 ml 1:1 nitric acid upon arrival to lab	≥ 24 hours after preservation to 180 days

6PPDQ = N-(1,3-Dimethylbutyl)-N′-phenyl-p-phenylenediamine-quinone
HDPE = high density polyethylene
PFAS = per- and polyfluoroalkyl substances
[1] Minimize head space; no preservative is currently available for 6PPDQ. Studies are underway to investigate preservative temperatures and holding times (Smith 2023).

8.4 Equipment decontamination

Equipment decontamination between sampling events will follow Ecology’s SOP EAP090, Decontaminating Field Sampling Equipment for Sampling Toxics in the Environment (Friese 2021).

8.5 Sample ID

Field locations will be assigned IDs based on their regional study area of Washington (Figure 1). For example, in each region, Northwest Region (NR), Southwest Region (SR), Central Region (CR), and Eastern Region (ER), the first field location will be labeled as “01”, the second field location as “02”, and so on. Therefore, “NR-01-01” is the first sample from the first field location sampled from the Northwest Region of Washington.

Samples will be assigned laboratory IDs based on the work order number assigned by MEL.

8.6 Chain of custody

Chain of custody will be maintained for all samples throughout the project. This study will use the MEL chain of custody form for field collection and submission of samples to MEL and the contract laboratory.

8.7 Field log requirements

A field log will be maintained for all sampling events (see section 7.2.2).

Field staff should use only approved PFAS-free permanent ink pens for all entries (see section 8.2.1). Staff should make corrections with single line strikethroughs, initial and date corrections, and not use any type of correction fluid or tape.

8.8 Other activities

Not applicable to this study.

9.0 Laboratory Procedures

9.1 Lab procedures table

Table 11 outlines the laboratory procedures that will be used for this study.

Table 11. Measurement methods (laboratory).

Analyte	Sample Matrix	Number of Samples	Expected Range of Results	LLOQ/MRL	Sample Prep Method	Analytical Method
6PPDQ	Water	≤ 84	< 2.0–500 ng/L	2.0 ng/L	MEL 730136[1]	MEL 730136[1]
PFAS (40 compounds)	Water	≤ 72	< 0.8–60 ng/L per compound	0.1–4 ng/L (Table 8)	EPA 1633[2]	EPA 1633[2]
Metals (6 elements)	Water	≤ 84	< 0.02–10,000 mg/L per element	0.1–5 mg/L (Table 9)	EPA 200.8[3]	EPA 200.8[3]

6PPDQ = N-(1,3-Dimethylbutyl)-N′-phenyl-p-phenylenediamine-quinone
EPA = United States Environmental Protection Agency
LLOQ = lower limit of quantification
MRL = method reporting limit
PFAS = per- and polyfluoroalkyl substances

[1] Manchester Environmental Laboratory method published July 2024, or most recent version

[2] EPA method 1633 published January 2024

[3] EPA method 200.8 published 1994

9.2 Sample preparation method(s)

Sample preparation methods for each analyte are given in Table 10.

9.3 Special method requirements

Not applicable to this study.

9.4 Laboratories accredited for methods

MEL is accredited for analysis of 6PPDQ in aqueous samples following standard operating procedure MEL 730136 (Protasio 2024). MEL is accredited for analysis of selected metals in aqueous samples by EPA 200.8.

MEL is currently seeking accreditation for EPA method 1633. An accredited contract laboratory will analyze runoff water samples by EPA method 1633 for 40 PFAS compounds for this study.

10.0 Quality Control Procedures

10.1 Table of field and laboratory quality control

Table 12 presents the quality control (QC) sample types and frequency for this study.

Samples from this study may be analyzed alongside other samples of the same matrix within the same batch of 20 or fewer samples.

Table 12. Quality control samples, types, and frequency.

Parameter	Field Blanks	Field Replicates/ Lab Duplicates	Lab Control Standards	Lab Method Blanks	Lab Matrix Spikes	Surrogate Standards
6PPDQ	10% of samples	10% of samples	1 OPR per batch	1 per batch	10% of samples	all samples
PFAS (40 compounds)	10% of samples	10% of samples	1 OPR/LLOPR per batch	1 per batch	10% of samples	all samples
Metals (6 elements)	10% of samples	10% of samples	1 LCS/LCSD per batch	1 per batch	1 MS/MSD per batch	NA

6PPDQ = N-(1,3-Dimethylbutyl)-N’-phenyl-p-phenylenediamine-quinone
Batch = 20 or fewer samples which are analyzed together
LCS = laboratory control sample
LCSD = laboratory control sample duplicate
LLOPR = low-level ongoing precision and recovery
MS = matrix spike
MSD = matrix spike duplicate
OPR = ongoing precision and recovery
PFAS = per- and polyfluoroalkyl substances

10.2 Corrective action processes

When laboratory QC criteria are not met, laboratories are to take appropriate corrective actions and discuss those actions in the case narrative. Deviations from accredited laboratory methods, deviations from the required corrective actions, or data that do not meet laboratory QC criteria will be documented by the laboratory analyst and communicated with the principal investigator. The principal investigator will determine the best course of action, which may include qualifying the data, rejecting the data, or recollecting and resubmitting the samples.

An assessment of data quality will be provided in the final report. Any departures from this QAPP will be documented in the final report.

11.0 Data Management Procedures

11.1 Data recording and reporting requirements

The Environmental Information System (EIM) Study ID for this study is AMSA0001.

Laboratory data will be received electronically as an electronic data deliverable (EDD), or comparable, package. The principal investigator will perform a final quality assurance (QA) review of all data before they are uploaded into EIM.

Study data will be stored in Ecology's EIM according to the EIM User's Manual for Ecology Staff version 4.3. The project assistant is responsible for uploading and publishing data in EIM and the principal investigator is responsible for data QA verification in EIM (see section 13.2).

11.2 Laboratory data package requirements

For contract laboratory data, a Level 4 data package per EPA National Functional Guidelines will be required. For MEL data, all required content for data validation must be provided to the data validator. The lab data will contain all required specific content, along with sample and QC data. The data package must include all sample raw data, QA/QC sample raw data, and chain of custody forms needed to perform an independent verification of the results and sample handling procedures.

Case narratives will be included to discuss any problems encountered with the analyses, corrective action taken, changes to the requested analytical method, and a glossary for data flags and qualifiers.

MEL's QA Coordinator and/or Data Validator will review and verify that all data packages are complete and in accordance with the Statement of Work and project QAPP.

11.3 Electronic transfer requirements

Laboratory case narratives and data packages will be transferred electronically in PDF format and EDDs, respectively. EDDs will be in a .csv or .xlsx spreadsheet format that meets Ecology's standard EIM formatting requirements.

11.4 EIM/STORET data upload procedures

The laboratory data for this project will be stored in Ecology's EIM system according to Ecology's EIM User's Manual for Ecology Staff version 4.3.

11.5 Model information management

Not applicable to this study.

12.0 Audits and Reports

12.1 Field, laboratory, and other audits

No defined audit exists for the fieldwork in this study.

Analytical labs must participate in performance and system audits of their routine procedures as prescribed by Ecology's Lab Accreditation Unit.

12.2 Responsible personnel

Laboratory audits are conducted by Ecology's Laboratory Accreditation Unit.

12.3 Frequency and distribution of reports

A final published report summarizing the data and findings will be written when the study is completed.

The final report will be available online at:
https://apps.ecology.wa.gov/publications/UIPages/PublicationList.aspx?IndexTypeName=Topic&NameValue=Product+Testing&DocumentTypeName=Publication

12.4 Responsibility for reports

The principal investigator is responsible for writing the final report as stated in Table 2.

13.0 Data Verification

13.1 Field data verification, requirements, and responsibilities

The principal investigator and project assistant will review field logs for completeness and clarity.

13.2 Laboratory data verification

Lab data verification is the process of evaluating the completeness, correctness, and conformance/compliance of a specific data set against the method, procedural, or contractual requirements. The principal investigator will review data packages and data quality reports and conduct a verification review of the data to assess suitability. The principal investigator, with guidance from Ecology's QA Officer, will be responsible for the final acceptance of lab data. Based on these verification assessments, the data will be either accepted, accepted with qualifications, rejected with re-analysis considered, or rejected without re-analysis considered.

Study data will be stored in Ecology's EIM according to the EIM User's Manual for Ecology Staff version 4.3. The project assistant is responsible for uploading and publishing data in EIM and the principal investigator is responsible for data QA verification in EIM.

13.3 Validation requirements, if necessary

Lab data validation is an analyte and sample-specific process that extends the evaluation of data beyond data verification to determine the analytical quality of a specific data set.

A stage 4 data validation for 6PPDQ analyses will be completed using the technical specifications outlined in MEL SOP 73022 v4.0 Organics Data Review (September 2018) and QAPP specific MQOs.

A stage 4 data validation for PFAS analyses will be completed using the technical specifications outlined in MEL SOP 770046 Data Validation of Analytical PFAS Data (April 2024) and QAPP specific MQOs.

A stage 3 data validation for metals analyses will be completed using recommended validation checks described in National Functional Guidelines for Inorganic Superfund Methods Data Review (EPA 2020) or equivalent, and QAPP specific MQOs.

13.4 Model quality assessment

Not applicable to this study.

14.0 Data Quality (Usability) Assessment

14.1 Process for determining project objectives were met

The project manager will assess the quality and suitability of the data based on case narratives, data packages, the data verification report, and the data validation report. Laboratory QC information will be evaluated to determine if QAPP specific MQOs were met. If all MQOs and QC criteria are met, the quality of the data will be considered suitable for meeting study objectives. The final report for this study will discuss the data quality findings.

14.2 Treatment of non-detects

For 6PPDQ, PFAS, and metals analyses, laboratory data will be reported down to the lower limit of quantitation or the method reporting limit, with an associated "U" (analyte not detected above the method reporting limit) or "UJ" (analyte not detected above an estimated value method reporting limit) qualifier.

For PFAS identification, laboratory results flagged due to identification failures will be qualified "NJ" (evidence that the analyte is present but does not meet identification criteria; the result is an estimate), accepted as detected, and included in total PFAS calculations.

For PFAS quantification, any PFAS analyte data with lab blank detections above the MQO will be reported with an associated "U" due to blank contamination. All samples will be evaluated against the associated method blank for each analytical batch. Sample results less than or equal to 5x the method blank concentration will be qualified as non-detect due to lab background. Total PFAS calculations will only include detected results.

14.3 Data analysis and presentation methods

Total 6PPDQ, total (analyzed) PFAS, individual PFAS, and individual metals analyte concentrations will be presented by location codes, events, and regions. The final report will include a summary of the results of this study. Simple summary statistics and data will be presented in tables and graphs. Example summary statistics may include minimum, maximum, median, and frequencies of detection.

14.4 Sampling design evaluation

The number and type of samples outlined in this QAPP were designed to meet the objectives of this study.

14.5 Documentation of assessment

A documentation of assessment will be in the final report.

15.0 References

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16.0 Appendices

Appendix A. Glossaries, Acronyms, and Abbreviations

Glossary of General Terms

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.

Acronyms and Abbreviations

6PPDQ	N-(1,3-Dimethylbutyl)-N′-phenyl-p-phenylenediamine-quinone
EAP	Environmental Assessment Program
Ecology	Washington State Department of Ecology
EDD	Electronic data deliverable
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
et al.	And others
HDPE	High density polyethylene
HWTR	Hazardous Waste and Toxics Reduction Program
LCS	Laboratory control sample
LCSD	Laboratory control sample duplicate
LLOPR	Low-level spiked ongoing precision and recovery standards
LLOQ	Lower limit of quantification
MEL	Manchester Environmental Laboratory
ML	Minimum level of quantitation
MQO	Measurement quality objective
MRL	Method reporting limit
MS	Matrix spike
MSD	Matrix spike duplicate
OPR	Ongoing precision and recovery standards
PFAS	per- and polyfluoroalkyl substances
PRP	Product Replacement Program
QA	Quality assurance
QAPP	Quality Assurance Project Plan
QC	Quality control
RCW	Revised Code of Washington
RPD	Relative percent difference
SOP	Standard operating procedure
WAC	Washington Administrative Code

Units of Measurement

mg/L	milligrams per liter (parts per million)
ng/L	nanograms per liter (parts per trillion)
µg/g	micrograms per liter (parts per billion)

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).

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).

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).

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