Quality Assurance Project Plan

Puyallup River Tributaries Effectiveness Monitoring

October 2019
Publication No. 19-10-040

Publication Information

Each study conducted by the Washington State Department of Ecology must have an approved Quality Assurance Project Plan (QAPP). The plan describes the objectives of the study and the procedures to be followed to achieve those objectives. After completing the study, Ecology will post the final report of the study to the Internet.

This Quality Assurance Project Plan is available on Ecology's website at
https://fortress.wa.gov/ecy/publications/SummaryPages/1910040.html

Data for this project are available in Ecology's EIM Database.
Study ID: EFF_PRT.

This QAPP was written using QAPP Template Version 1.0. Revision date: 8/27/2018.

Federal Clean Water Act 1996 303(d) Listings Addressed in this Study. See Section 3.1.

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Cover photo: Boise Creek taken by Allison Brownlee 6-25-2019

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2.0 Abstract

In 2011, the Department of Ecology (Ecology) wrote a water quality cleanup plan known as a Total Maximum Daily Load (TMDL) for the Puyallup River Watershed (Mathieu and James, 2011, Ecology report 11-10-040). For the last few years, Ecology has focused TMDL implementation and follow up actions in the large and complex watershed. During the TMDL, Ecology found that Boise Creek was the largest fecal coliform loading source of any tributary to the Puyallup River and identified it as a high priority for cleanup. A subsequent study of Second and Pussyfoot Creeks (Dickes, 2015, Ecology report 15-10-048) found fecal coliform exceedances at several locations in both tributaries to the Puyallup River. In addition to bacteria, there are other parameters of concern including temperature, pH, and dissolved oxygen. Boise, Pussyfoot, and Second Creeks are all tributaries to the White River which then feeds into the lower Puyallup River. Ecology is currently preparing a pH TMDL for the Lower White River with a focus on reducing inputs of phosphorus.

As part of Ecology's focused TMDL implementation effort, Ecology's nonpoint staff and partners are currently working together to address bacteria pollution sources in the three tributaries: Boise Creek, Pussyfoot Creek, and Second Creek. It is the goal of the implementation work plan that efforts to reduce sources of bacteria will simultaneously improve water quality overall including the other parameters of concern. This effectiveness monitoring study will meet the following objectives:

- Track general water quality trends in each of the tributaries.
- Provide the information feedback needed for adaptive management purposes.
- Trace sources of pollution and identify likely causes.

To meet these objectives, a long-term (10 year) study has been developed that includes monthly sampling with more extensive sampling efforts in years 1, 5, and 10.

3.0 Background

3.1 Introduction and problem statement

The 2011 Puyallup River Watershed TMDL called for the reduction of bacteria concentrations to meet Washington state water quality standards by 2022. The TMDL documented specific actions for partners to take in order to make such reductions and called for an effectiveness monitoring study as described in this document. This effectiveness monitoring study will focus on three tributaries to the White River where water quality standards have not been met and where implementation efforts have been prioritized: Boise, Pussyfoot, and Second Creeks. The White River flows into the lower portion of the Puyallup River near the city of Sumner. A map of the three tributaries, where they enter the White River, and where the White River flows into the Puyallup River is presented in Figure 1.

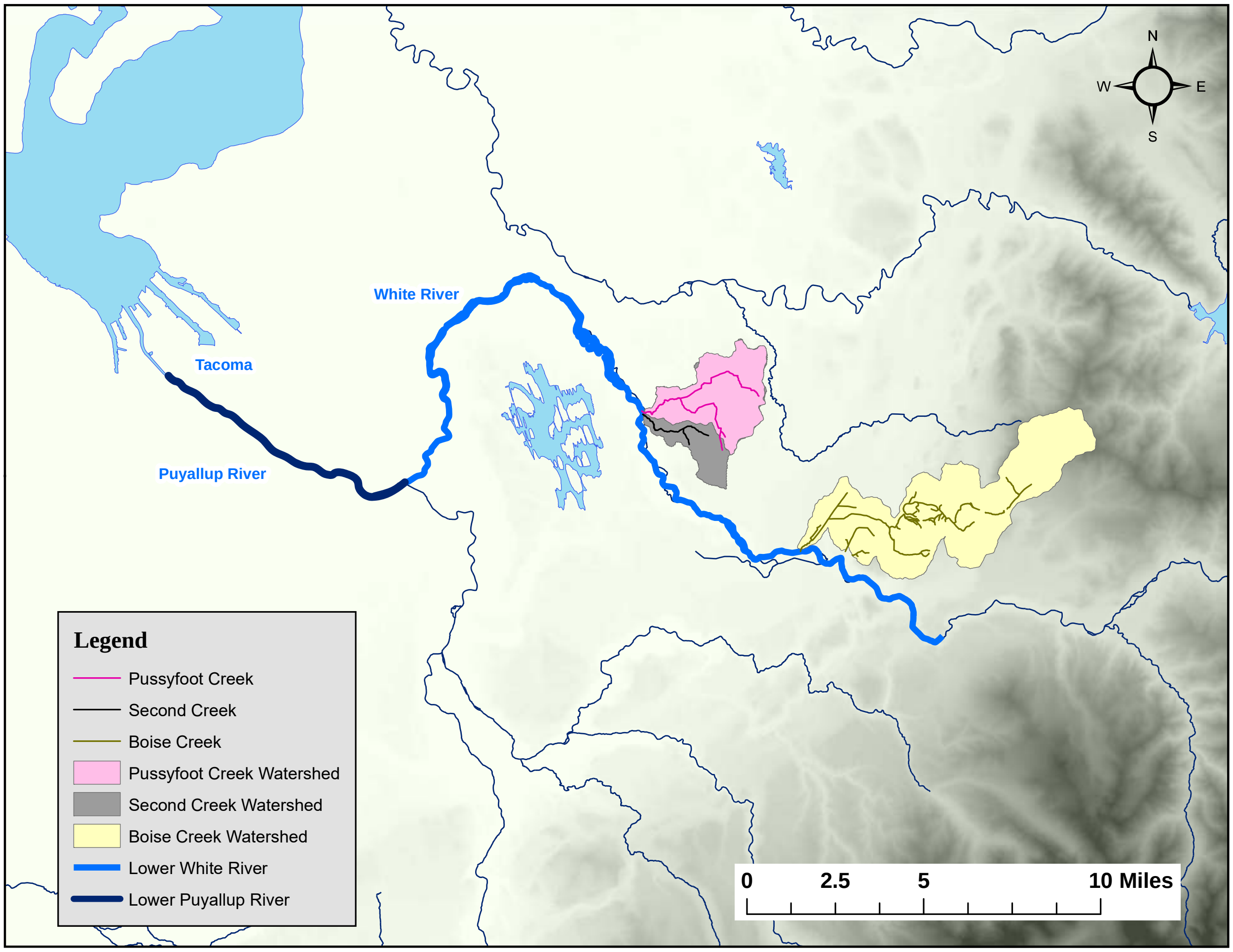

Figure 1. The flow path of Boise, Pussyfoot, and Second Creeks as they each flow into the lower White River, which then enters the lower Puyallup River and eventually into Puget Sound.

Boise, Pussyfoot, and Second Creeks are largely rural and rural-residential watersheds. During the 2011 Puyallup TMDL, Boise Creek was found to be the largest fecal coliform loading source of any tributary to the Puyallup River. Since 2011, some sources of bacteria have been found and resolved, while other sources remain or have been newly identified. Implementation efforts by Ecology and other stakeholders have been focused on failing septic systems, livestock agriculture, and stormwater.

Data from a 2012-2013 study (Dickes, 2015, Ecology report 15-10-048) found that the mainstem sites as well as many of the tributaries and ditches on Pussyfoot Creek and Second Creek exceeded bacteria standards. Ecology identified a dairy in the Pussyfoot watershed that had manure management issues as well as several other sites with direct livestock access to Pussyfoot Creek. Second Creek also had elevated bacteria concentrations, but the sources were not as evident. Both Pussyfoot Creek and Second Creek flow into the White River through the Muckleshoot Indian Tribe’s Reservation and were not meeting standards prior to entering the Reservation.

In addition to bacteria, other water quality parameters are of current concern. Ecology is preparing a pH TMDL in the Lower White River with a focus on reducing levels of phosphorus. Surplus nutrients via inputs such as agricultural runoff can cause excessive algal growth. Algae naturally take up carbon dioxide from water for cellular growth, but when excessive algae is present, the increased uptake of carbon can increase the pH of the river. Ecology has documented exceedances of pH in the lower White River since 1990 (Mathieu, 2012).

Currently, there are at least two water quality impairments per watershed, including three listings for pH or temperature on the state water quality assessment 303(d) list. The 303(d) list contains polluted waters of the state that require a TMDL (Category 5). Table 1 summarizes the water quality impairments for each watershed.

Table 1. Summary of current water quality impairments for Boise, Pussyfoot, and Second Creeks.

Watershed	Parameter	Impairment Category	Listing IDs
Boise Creek	Temperature	2	35343
Boise Creek	Temperature	5	7496, 9382
Boise Creek	Dissolved Oxygen	2	9380
Boise Creek	pH	2	9381, 35338
Boise Creek	pH	5	35337
Boise Creek	Bacteria	4a	74205, 74206
Boise Creek	Bacteria	4a	16706
Pussyfoot Creek	Temperature	2	73828
Pussyfoot Creek	pH	5	71272
Pussyfoot Creek	Bacteria	4a	45691
Pussyfoot Creek	Mercury	2	79845
Second Creek	Dissolved Oxygen	2	14763
Second Creek	pH	2	14764

Category 2 - water of concern
Category 4a - impaired with a water quality improvement project in place
Category 5 - impaired with no water quality improvement project in place

This effectiveness monitoring study will assess the efficacy of implementation efforts to reduce sources of pollution in the three focus tributaries to the Puyallup River. It will also aid in the identification and source tracing of additional sources. Further, Ecology has changed its bacteria indicator from fecal coliform to *Escherichia coli* (*E.coli*) in the state water quality standards to more accurately protect against waterborne diseases. This study will monitor both fecal coliform bacteria and *E. coli*, in addition to other water quality parameters.

3.2 Study area and surroundings

This study focuses on three tributaries in the Puyallup River basin: Boise, Pussyfoot, and Second Creeks. The Puyallup River basin, Water Resource Inventory Area (WRIA) 10, drains an area of approximately 1,065 square miles. The watershed contains more than a dozen cities and towns, including part of Washington State's third largest city, Tacoma. The Puyallup River originates from the Puyallup glacier of Mount Rainier in the Cascade Range and empties into Puget Sound at Commencement Bay in Tacoma. The major rivers of the basin are the Puyallup River and its two largest tributaries: the White River (sometimes known as the Stuck River) and the Carbon River. Boise Creek, Pussyfoot Creek, and Second Creek are all sub-watersheds within the larger Puyallup River Watershed (Figure 2).

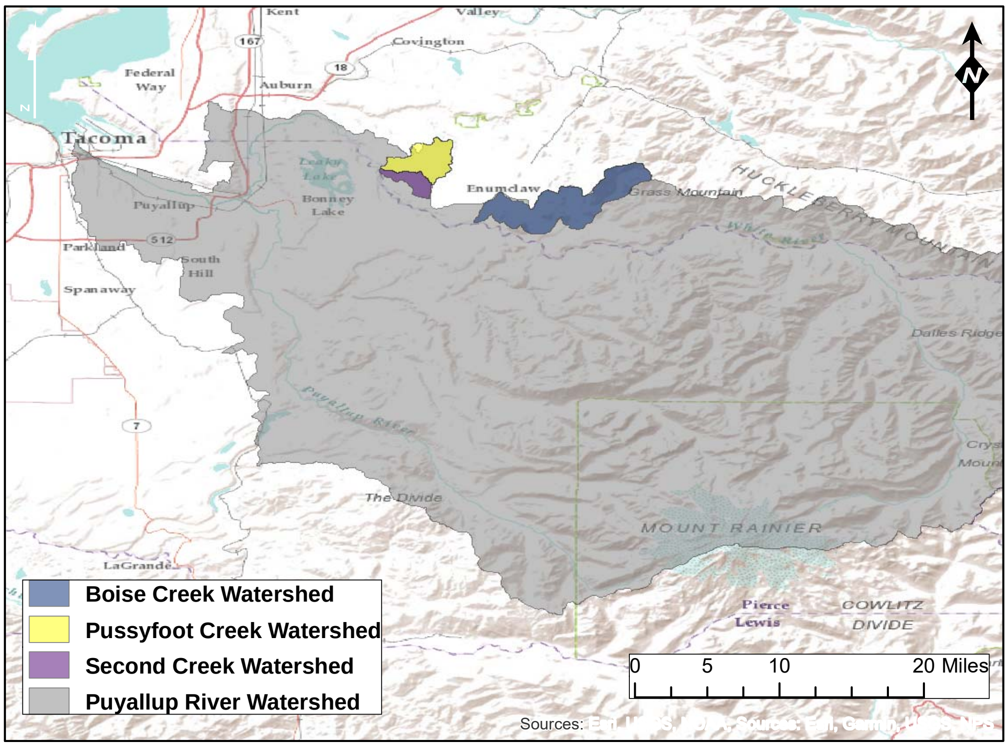

Figure 2. The three watersheds within the larger Puyallup River Watershed: Boise Creek, Pussyfoot Creek, and Second Creek.

The Puyallup River basin has a temperate marine climate with warm, dry summers and cool, wet winters. The mean annual air temperature is about 52°F. The warmest month is July, with an average temperature of about 64°F. The coolest month is January, with an average temperature of about 39°F. Eighty percent of the annual precipitation occurs during October through March. A more detailed description of the Puyallup River basin can be found in the Puyallup River fecal coliform TMDL (Mathieu and James, 2011).

The headwaters of Boise Creek begin in the Cascade Mountains east of the City of Enumclaw, Washington and drain more than 18 square miles (nearly 12,000 acres) within King County. Although the headwaters begin in steeper, forested, mountainous terrain, this quickly gives way to the flatter terrain of the Puget Sound lowlands which dominate the watershed. Boise Creek enters the lower White River almost directly north of the city of Buckley.

Pussyfoot and Second creeks are located in King County south of the town of Auburn and north of the cities of Enumclaw and Buckley. Both enter the right bank of the White River. They are often mapped as unnamed tributaries. However, this study has used the names given by the local community. Pussyfoot Creek (stream number 10.0048, Williams, et al., 1975) enters at river mile (RM) 15.45 and Second Creek (stream number 10.0050, Williams, et al., 1975) enters just upstream at RM 15.5.

The White River flows through the Muckleshoot Indian Tribe's Reservation between RM 15.5 and RM 8.9. Surface waters that flow into the reservation boundaries are considered waters of the state upstream of the boundary and tribal waters downstream of the boundary. The opposite applies to waters flowing out of tribal land. The lower segments of Pussyfoot Creek and Second Creek are on tribal property.

3.2.1 History of study area

The Puyallup River basin has been substantially altered from its historic condition. In particular, the lower river bears little resemblance to its historic past. Extensive urban growth, heavy industry, a large modern marine port, an extended revetment and levee system, and agriculture have combined to significantly alter the natural landscape. The area is experiencing rapid residential growth, generally into areas that were previously agricultural. The upper watershed is still primarily rural residential and agricultural, with very low housing densities. The lower watershed is more urbanized where housing densities are typically higher and mixed with commercial and industrial properties.

The upper basin of Boise Creek is primarily forestland, while the lower basin drains part of the city of Enumclaw and is a mix of rural residential, agriculture, and commercial (Figure 3). More than half of the drainage area is forested (mostly Weyerhaeuser property) with the remainder of the drainage dominated by shrub and grasses, development, and agricultural land cover (Table 2). Slightly more than 3% of the land area is comprised of farms that are enrolled in King County's Farmland Preservation Program, which preserves farmland by purchasing development rights. In addition, there are many small tributaries and ditches that drain from agricultural land within the drainage (King County, 2013).

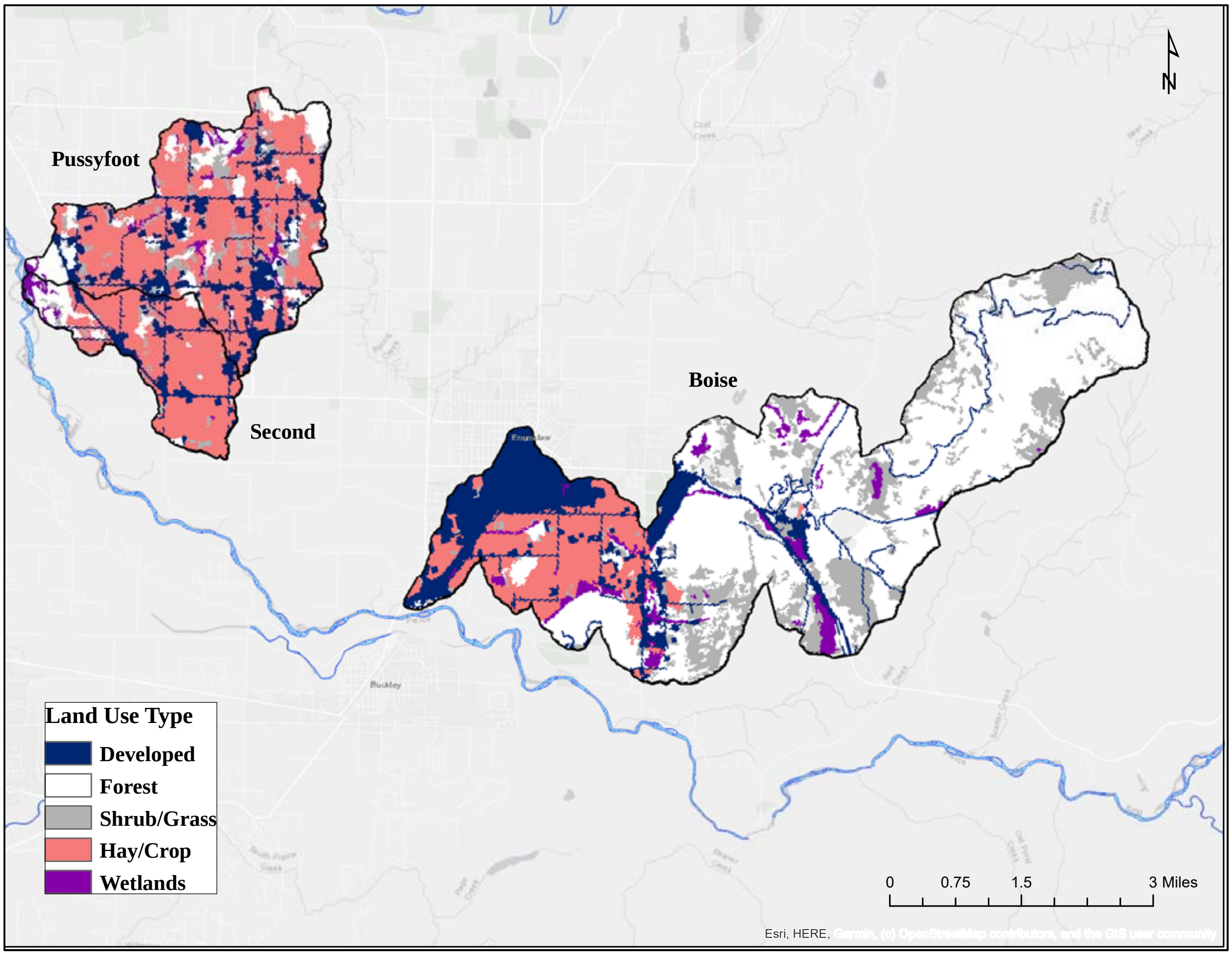

Figure 3. Land uses of the three watersheds. Source: National Land Cover Database, 2011.

Table 2. Land uses of the three watersheds. Source: National Land Cover Database, 2011.

Land Use	Boise	Second	Pussyfoot
Developed	16%	15%	19%
Forest	53%	10%	14%
Shrub/Grass	17%	4%	8%
Hay/Crop	11%	69%	55%
Wetlands	3%	2%	2%

Both Pussyfoot and Second watersheds are largely agricultural (69% and 55%, respectively, Figure 3 and Table 2). The second most dominant land use for both is developed land. The land use in the upper watersheds is rural residential. There are many farms pasturing livestock such as cattle, horses, alpaca, and sheep. There are also dairies in the area. The lower area of both watersheds are less developed.

3.2.2 Summary of previous studies and existing data

Several TMDL and related studies have been completed for watersheds within the Puyallup Basin and have consistently identified Boise Creek as a problem area. Ecology studies that have sampled in Boise, Pussyfoot, and/or Second creeks are listed in Table 3.

Table 3. Ecology water quality data that includes Boise Creek, Pussyfoot Creek, and/or Second Creek.

EIM Study ID	Relevant Watersheds	Study Name	Collection Date	Parameters
AMS001B	Boise	Statewide River and Stream Ambient Monitoring	1941-1979	Multiple including bacteria, nutrients, and pH
AMS001E	Boise	Statewide River and Stream Ambient Monitoring	2000-2009	Multiple including bacteria, nutrients, and pH
BEDI0020 and BEDI0021	Pussyfoot, Second	Pussyfoot Creek and Second Creek Fecal Coliform Characterization Monitoring	2012-2013	Fecal Coliform
fwbenth1	Boise	Freshwater Ambient Biological Assessment Program	93-2004	Dissolved oxygen, pH, temperature, conductivity
GPEL0010	Boise, Pussyfoot, Second	Lower White River pH TMDL	2012	pH
GPEL0002	Boise	Puyallup River TMDL	Sep-Oct, 1990	Biological oxygen demand, ammonia, chlorine
KERI0003	Boise	Lower White River Nutrient TMDL	1996-1997	Multiple including bacteria, nutrients, and pH
LSUL0001	Boise, Pussyfoot	2011 Puyallup River TMDL	2006-2007	Fecal Coliform
PSTox001	Pussyfoot	Toxics in Surface Runoff to Puget Sound	2009-2010	Toxics, nutrients

Ecology collected bacteria and streamflow data between October 2006 and September 2007 for the development of the 2011 Puyallup River TMDL (Mathieu and James, 2011). Data was collected twice a month from 55 sites throughout the watershed. Two of these sites were on Pussyfoot Creek and six along Boise Creek. This study concluded that Boise Creek was the largest fecal coliform loading source that violated water quality standards and designated it as the number one priority cleanup basin for the Puyallup River Basin TMDL. Target reductions recommended from this study were made for Boise Creek in the dry season (Figure 4) and both Boise and Pussyfoot creeks in the wet season (Figure 5).

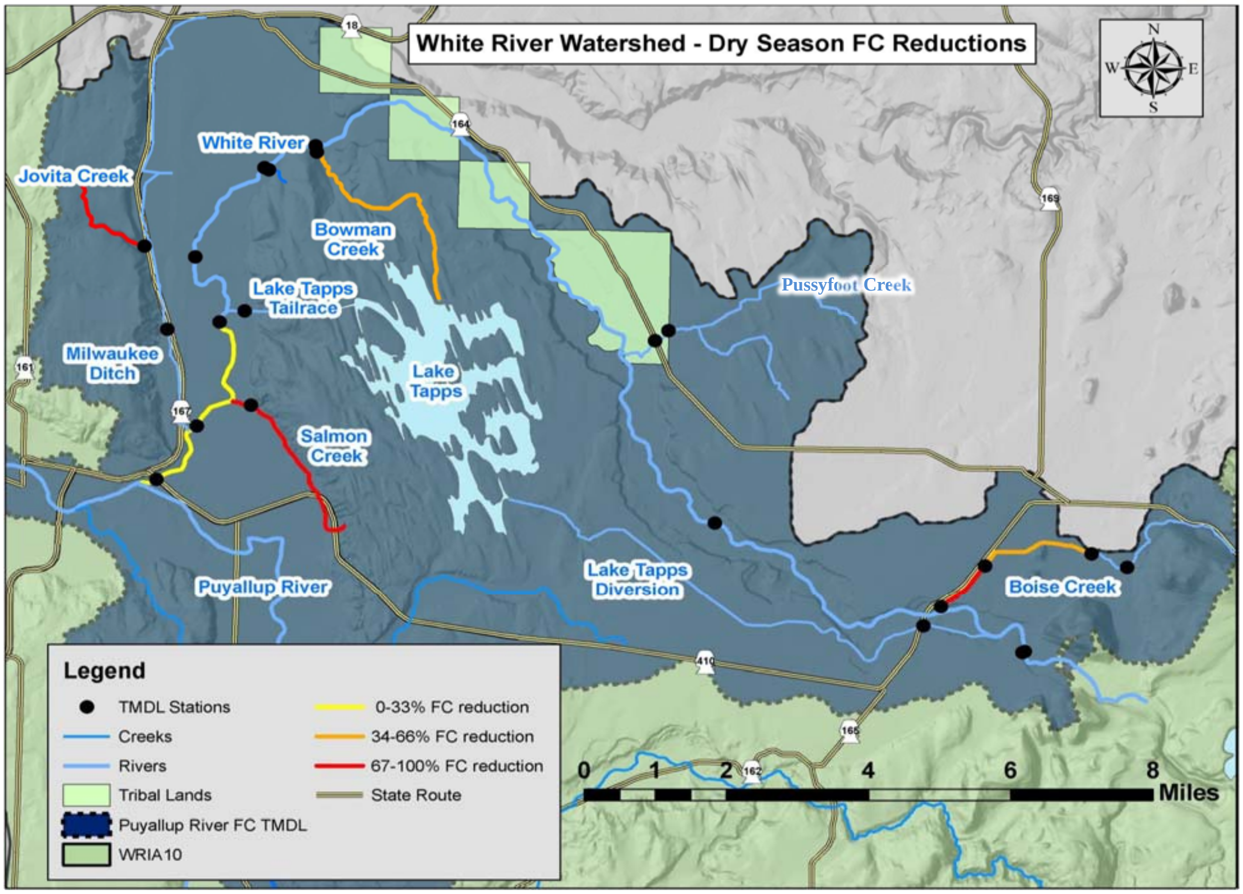

Figure 4. Target dry season (July-October) fecal coliform reductions in the White River watershed (Mathieu and James, 2011, Ecology report 11-10-040).

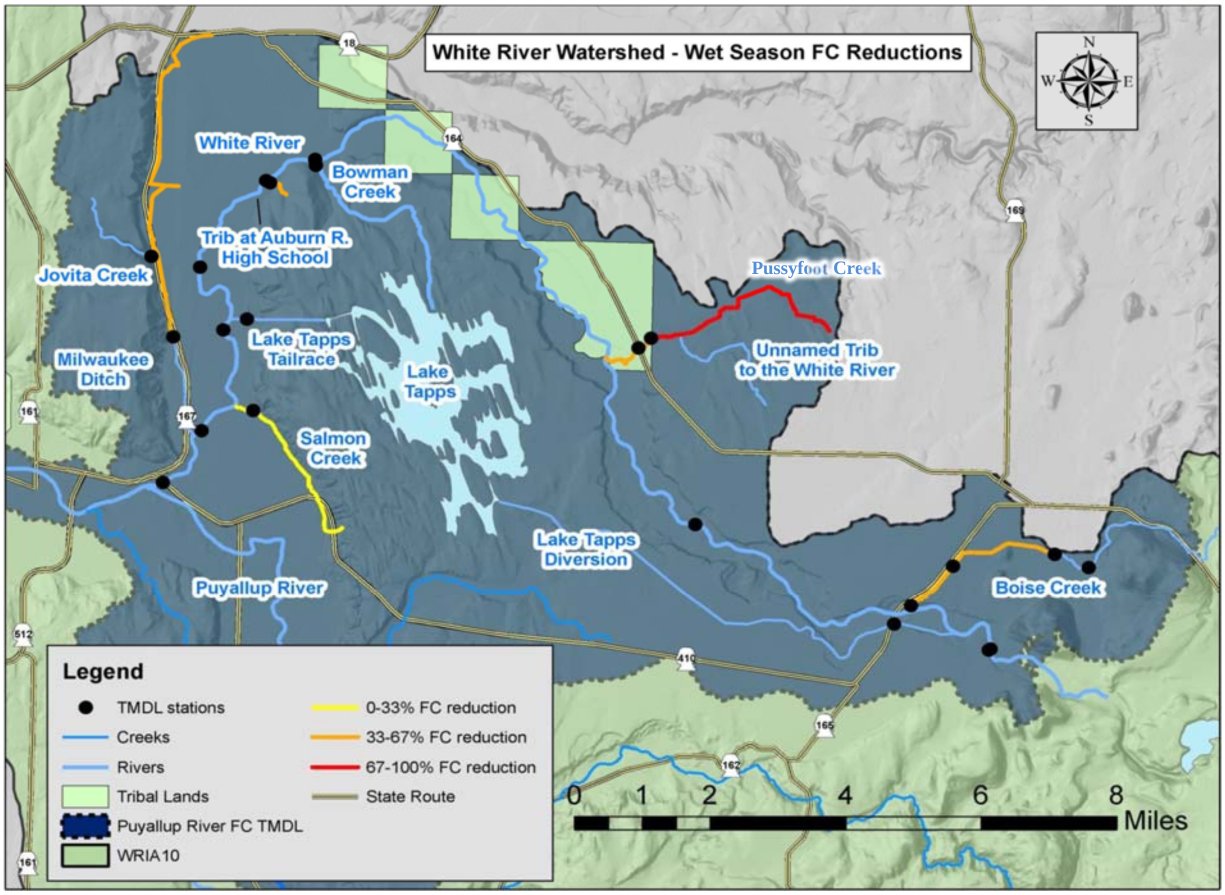

Figure 5. Target wet season (November-June) fecal coliform reductions in the White River watershed (Mathieu and James, 2011, Ecology report 11-10-040). Pussyfoot Creek is labeled as the Unnamed Trib to the White River.

As a result of the 2011 TMDL recommendations, Ecology conducted additional fecal coliform source identification sampling in Pussyfoot and Second creeks from November 2012 to June 2013. This study concluded that the mainstem sites on both creeks exceeded the Primary Contact Recreation standards for fecal coliform bacteria. Additionally, many of the tributaries and ditches also exceeded the standards. The study identified several sources in Pussyfoot Creek and recommended improving land and livestock management. Second Creek had elevated fecal coliforms, however the sources were not determined and further investigation was recommended.

Due to elevated levels of nutrients and pH, there is a TMDL currently under development for the Lower White River including Boise, Pussyfoot, and Second Creeks. Between July and December of 2012, 54 sites along the White River were sampled for pH and a suite of water quality parameters (Mathieu, 2012). The goal of the study is to establish a TMDL for phosphorus, including load and wasteload allocations for current and future sources.

In addition to Ecology, several other organizations have collected water quality data in the focus areas of this study (Table 4). Many of these projects are ongoing and data will be assessed and potentially included when analyzing the results of this effectiveness study.

Table 4. List of other organizations collecting data in study area.

Organization	Relevant Watersheds	Description	Collection Date	Parameters
King County Science and Technical Support Group	Boise	Monthly sampling at Mud Mtn Rd crossing	2015-current	temperature, conductivity, DO, pH, turbidity, TSS, total phosphorus, orthophosphate, total nitrogen, total alkalinity, NO_3, NO_2, NH_3, FC, *E.coli*
King County Stormwater Services Group	Boise	Municipal stormwater (MS4) sampling	Unknown	*E.coli*
Muckleshoot Indian Tribe	Pussyfoot	Water quality sampling on tribal land	Unknown	FC
City of Enumclaw	Boise	Municipal stormwater (MS4) sampling	Unknown	FC
King Conservation District – Stream Steward Program	Boise	Monthly volunteer program	2013-current	temperature, pH, NO_3, DO, turbidity, *E.coli*

DO: Dissolved Oxygen
TSS: Total Suspended Solids
FC: Fecal Coliform

3.2.3 Parameters of interest and potential sources

This study will address a standard suite of ambient parameters including all parameters listed in the state water quality impairment list for Boise, Pussyfoot, and Second Creeks (Table 1). Source tracing may require the collection of additional parameters including optical brighteners and streamflow.

Bacteria

Fecal coliform and *E. coli* bacteria primarily enter waterways from one or more of the following sources:

- Livestock with direct access to streams or operations with poor manure management.
- Failing or improperly constructed septic systems.
- Pet waste.
- Wildlife.
- Improperly treated sewage or other illicit discharges to the MS4 or the creek itself.

The only point source bacteria discharge within the Boise Creek watershed is municipal stormwater. Stormwater appears to be a significant source within the urban boundary of the city of Enumclaw. Outside Enumclaw, road outfalls are secondary sources. The Puyallup River Fecal Coliform TMDL assigned Enumclaw, Washington State Department of Transportation, and King County bacteria wasteload allocations for municipal stormwater.

Given the land uses described in Table 2, nonpoint pollution sources are dominant. The Puyallup River Fecal Coliform TMDL concluded that livestock and failing septic systems are the most significant sources of bacteria in the Boise Creek watershed. Implementation actions identified in the Puyallup River Fecal Coliform TMDL focus on these sources, and are likewise a focus of this effectiveness monitoring study. The Pussyfoot Creek and Second Creek Fecal Coliform Characterization Monitoring Study (Dickes, 2015) found manure management issues and several locations with direct livestock access on Pussyfoot Creek. Sources of bacterial exceedances were not evident on Second Creek and further investigation was suggested.

pH

The Lower White River pH TMDL is currently in development and sources remain undetermined. Early indications are that pH is naturally high, but that anthropogenic sources are contributing to the exceedances. Specifically phosphorus discharges from the Enumclaw and Buckley Wastewater Treatment Plants (WWTPs) appear to be the primary contributors. However, neither WWTP discharge to Boise Creek, instead they both discharge to the White River directly. No point sources have been identified in Boise, Pussyfoot, or Second creeks.

Nutrients

When excess phosphorus or nitrogen is available, excessive algal growth can ultimately lead to higher pH and lower dissolved oxygen. Nonpoint sources can include groundwater inflows, stormwater, erosion, and direct discharges such as from livestock standing in a stream. Several potential nutrient loading sources are present within the watersheds and include:

- Failing on-site septic systems.
- Municipal stormwater.
- Poor livestock or pet manure management.
- Livestock with direct access to the creek.
- Fertilization.
- Bank erosion.
- Wildlife.

Temperature

No temperature TMDL has been completed or is planned for Boise, Pussyfoot, or Second creeks. The only point source in the watersheds is municipal stormwater, but peak stormwater flows usually occur during winter when temperature criteria are not exceeded. Stormwater infrastructure may be indirectly influencing temperature in that impervious surfaces can disrupt natural hydrology and impede or interrupt cool groundwater exchange in summer. But as the three creeks are mostly rural, this is probably not the primary cause of the temperature problem.

Dissolved Oxygen

An old Puyallup River TMDL (June, 1993) exists for biological oxygen demand (BOD) and ammonia. The TMDL concluded that 'municipal permits' (i.e. WWTPs) represented the largest BOD and ammonia loads. However, no WWTPs discharge to Boise, Pussyfoot, or Second creeks. The BOD and ammonia TMDL did assign load allocations to nonpoint sources but they were rudimentary in that little attempt was made to characterize the loading amongst tributaries within the smaller watersheds.

Dissolved oxygen levels are most likely co-dependent to nutrient loads and temperature. Excessive algal growth from nutrient loading can cause anoxic conditions. Potential sources are thus the same as those listed above for nutrients and temperature.

3.2.4 Regulatory criteria or standards

Ecology is responsible for establishing water quality standards for surface waters in Washington. The water quality standards are found in Washington Administration Code (WAC) Chapter 173-201A. The standards use existing scientific information to develop numeric and narrative criteria as well as designate beneficial uses for different water bodies. The standards also include an anti-degradation policy that requires the protection and maintenance of existing uses and water quality of a higher quality than required by the numeric criteria. Water quality standards are designed to protect public health and public enjoyment of state waters as well as the propagation and protection of fish, shellfish, and wildlife.

The water quality standards for Boise, Pussyfoot, and Second creeks are established to protect aquatic wildlife, recreation, water supply, and other miscellaneous uses. These three tributaries to the White River are designated for primary contact recreation and core summer salmonid habitat (WAC 173-201A-602). Specific water quality criteria for measured variables are detailed in Table 5.

Table 5. Water quality criteria for parameters assessed in this study.

Parameter	Criteria
Bacteria	Fecal coliform organism levels within an averaging period must not exceed a geometric mean value of 100 CFU or MPN per 100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained within an averaging period exceeding 200 CFU or MPN per 100mL. *E. coli* organism levels within an averaging period must not exceed a geometric mean value of 100 CFU or MPN per 100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained within the averaging period exceeding 320 CFU or MPN per 100 mL.
Dissolved Oxygen	DO concentration will not fall below 9.5 mg/L more than once every ten years on average. When a waterbody's DO is lower than 9.5 mg/L (or within 0.2 mg/L) and that condition is due to natural conditions, then human actions considered cumulatively may not cause the DO of that water body to decrease more than 0.2 mg/L.
Temperature	7-day average of the daily maximum temperature (7-DADMax) will not exceed 16°C for core summer salmonid habitat more than once every ten years on average. When a waterbody's temperature is warmer than the criteria (or within 0.3°C) and that condition is due to natural conditions, then human actions considered cumulatively may not cause the 7-DADMax temperature of that water body to increase more than 0.3°C. Boise Creek has supplemental spawning/incubation criteria of 13°C from September 1 to July 1.
Turbidity	Turbidity shall not exceed 5 nephelometric turbidity units (NTU) over background when the background is 50 NTU or less or a 10% increase in turbidity when the background is more than 50 NTU.
pH	pH shall be within the range of 6.5 to 8.5 with human-caused variation within above range of less than 0.2 units.

CFU: Colony forming units
MPN: Most probable number

3.3 Water quality impairment studies

Ecology's periodic Water Quality Assessment designates waterbodies that are impaired. Based on data from water quality impairment studies and results of the Water Quality Assessment, TMDLs are created. This effectiveness monitoring study follows up on implementation activities resulting from the Puyallup fecal coliform TMDL and resultant studies.

3.4 Effectiveness monitoring studies

Effectiveness monitoring is a vital part of TMDL implementation efforts. This effectiveness monitoring study will measure the extent to which Boise, Pussyfoot, and Second creeks have improved and whether implementation efforts have been successful in bringing these waterbodies into compliance with state water quality standards. This is a long-term study that will monitor current and future implementation efforts between 2019 and 2029.

This TMDL effectiveness monitoring study will provide the following information to facilitate adaptive management needs:

- A measure of progress toward implementation of recommendations - how much watershed restoration has been achieved and how much more effort is required.
- More efficient allocation of funding and optimization in planning and decision-making.
- Identification of restoration activities that worked and those that were most successful for the money spent.
- Technical feedback to refine the initial TMDL model, best management practices, nonpoint source plans, and permits.

Current and past implementation efforts have focused on locating failing septic systems, updating the Enumclaw MS4 permit to include focused bacteria monitoring, conducting drive-by observations and site-visits for area of potential concern, public outreach, and continued collaboration with local agencies.

4.0 Project Description

This Quality Assurance Project Plan (QAPP) serves jointly with the following documents:

- Programmatic QAPP for Water Quality Impairment Studies (McCarthy and Mathieu, 2017).
- Standard Operating Procedures for the Collection, Processing, and Analysis of Stream Samples (Ward, 2016).
- Guidance for Effectiveness Monitoring of Total Maximum Daily Loads in Surface Water (Collyard and Onwumere, 2013).

The above documents address elements that apply to all water quality impairment projects, while this QAPP addresses elements specific to this project.

4.1 Project goals

The main goals of this effectiveness monitoring study are to:

1. Track general water quality trends in each of the tributaries.
2. Provide the information feedback needed for adaptive management purposes.
3. Trace sources of pollution and identify likely causes.

Monitoring should continue throughout the length of the implementation period (i.e. 10 years).

4.2 Project objectives

The goals of this study will be met by achieving the following project objectives:

Objective 1: Status and Trends

The status and trends portion of this project will monitor the lower most accessible location in each waterbody monthly for 10 years. An additional upstream site on Boise Creek was added to this category based on previous exceedances from municipal stormwater in the area. These sites will be sampled to track general water quality trends in each of the tributaries by monitoring a larger suite of parameters. The lab analytes will be bacteria (fecal coliform, *E.coli*) and nutrients (total phosphorus, orthophosphate, total persulfate nitrogen, nitrate-nitrite, ammonia). These parameters will be analyzed by Manchester Lab. Field parameters collected using a calibrated YSI ProDSS (multi-parameter digital sampling system) will include temperature, conductivity, dissolved oxygen, turbidity, and pH.

Objective 2: Implementation and Adaptive Management

The implementation and adaptive management objective will be met by sampling all 26 established sites twice per month during years 1, 5, and 10. During these focused years, there is overlap with the monthly sampling at the status and trends locations. The sites that are not included with the status trends objective will not be visited during the intervening years. All sites are spread more-or-less evenly throughout the study area and are restricted by public access (e.g. private roads) and safety concerns. The results from this objective will provide information needed for adaptive management purposes. Lab parameters sampled will be limited to bacteria (fecal coliform, *E. coli*). If ample water is available, field parameters including temperature, conductivity, dissolved oxygen, turbidity, and pH will be collected using a calibrated YSI ProDSS. Although site visits will be conducted all months of the year, Pussyfoot and Second creeks are expected to be dry between the months of August through October, due to the ephemeral nature of the streams. For this reason, the sample plan and budget includes only 9 months of sampling at these two watersheds.

If samples are collected during the dry months, the cost will come out of the ten percent set aside for source tracing (see below) or other funding opportunities.

Objective 3: Source Tracing

Ten percent of the budget has been set aside for uncertain sampling needs. Monitoring for this objective will trace sources of bacteria pollution and identify likely causes as they arise. The sites are currently unplanned locations and will be necessary to further narrow and/or trace suspected pollution sources on an as needed basis. Site locations will be identified through results from routine sampling locations and nonpoint field assessments. These could also be incidental locations (such as ditches and drains) that typically do not carry water, but are discharging into the waterbody due to increased rain or other discharges. Bacteria samples and field parameters will be collected at these locations.

4.3 Information needed and sources

- Bacteria and nutrients – to be collected by Ecology's Watershed Health & Effectiveness Monitoring Unit (WHEMU) and the Southwest Regional Office Water Cleanup Technical Unit (WCTU) during this project.

- Temperature, conductivity, dissolved oxygen, turbidity, and pH data – to be collected by WHEMU and WCTU with calibrated multi-parameter YSI ProDSS when conditions allow.

- Streamflow – daily discharge from Boise Creek will be obtained from USGS gauge (12099600) located at RM 0.1 (https://waterdata.usgs.gov/wa/nwis/uv/?site_no=12099600&PARAmeter_cd=00060,00065) and King County's gauge (69B) located at 268th Ave NE (https://green2.kingcounty.gov/hydrology/DataDownload.aspx)

- Meteorology data – daily precipitation will be obtained from King County's Enumclaw Rain gauge (44u) (Hydrologic Information Center Gauge Map https://green2.kingcounty.gov/hydrology/gaugemap.aspx).

- Implementation information of water quality improvement projects including non-Ecology efforts– to be collected through the TMDL lead and non-point South West Regional Office staff.

- Stakeholder information including local monitoring results – to be obtained from King County, City of Enumclaw, Muckleshoot Indian Tribe, and King Conservation District through public websites or personal communication and direct collaboration.

4.4 Tasks required

A general overview of the tasks required to meet the project goals for this effort are discussed below and in Section 4.2. Additional detail on the technical approach and field and lab tasks are described in Section 7.

The following tasks will be performed to support the goals and objectives of this study:

- Collect surface water samples from Boise Creek, Pussyfoot Creek, and Second Creek for bacteria and nutrient analysis.
- Collect surface water quality data including temperature, conductivity, dissolved oxygen, turbidity, and pH from surface waters of each site when ample water is present. A calibrated YSI ProDSS will be used to accomplish this task.
- Collect observational data at each site visit including any evidence of likely sources of pollution. Images taken as necessary.

This project also uses various tools to accomplish the required tasks, such as:

- Standard Operating Procedures (SOPs) for field and calibration activities.
- Checklists for field supplies and calibrations.
- Paper and digital logs for calibration activities.
- Chain of Custody forms for all lab samples.
- Sample collection gear such as personal protective equipment, poles, boots, and coolers.
- Computer programs for compiling, storing, organizing, analyzing, and reporting of information such as field and laboratory sample data.

4.5 Systematic planning process used

This QAPP, in combination with the Programmatic QAPP for Water Quality Impairment Studies, represent the systematic planning process.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

Table 6. Organization of project staff and responsibilities.

Staff (All Ecology)	Title	Responsibilities
Donovan Gray Water Quality Program SWRO Phone: 360-407-6407	TMDL Lead	Clarifies scope of the project. Provides internal review of the QAPP and approves the final QAPP. Occasionally assists with field work.
Allison Brownlee WQ, SWRO WCTU Phone: 360-407-6296	Project Manager/ Principal Investigator	Writes the QAPP. Oversees joint field sampling with EAP and transportation of samples to the laboratory. Conducts QA review of data, analyzes and interprets data, and enters data into EIM. Writes the draft report and final report.
Niamh O'Rourke EAP WHEMU Phone: 360-407-7614	Co-Principal Investigator	Oversees initiation of field work, assists with field work, and provides general technical assistance, data management, web reporting, and enters data into EIM. Technical review of QAPP and report.
Andrew Kolosseus WQ, SWRO WCTU Phone: 360-407-6271	Unit Supervisor for the Project Manager	Provides internal review of the QAPP, approves the budget, and approves the final QAPP.
Andrew Kolosseus WQ, SWRO Phone: 360-407-6271	Section Manager for the Project Manager	Reviews the project scope and budget, tracks progress, reviews the draft QAPP, and approves the final QAPP.
Alan Rue Manchester Environmental Laboratory Phone: 360-871-8801	Director	Reviews and approves the final QAPP.
Arati Kaza EAP Phone: 360-407-6445	Ecology Quality Assurance Officer	Reviews and approves the draft QAPP and the final QAPP and addendums. Ensures adherence to QC-related SOPs and practices

EAP: Environmental Assessment Program
EIM: Environmental Information Management database
QAPP: Quality Assurance Project Plan
SWRO: Southwest Regional Office
WCTU: Water Quality Cleanup Technical Unit
WHEMU: Watershed Health and Effectiveness Monitoring Unit
WQ: Water Quality

5.2 Special training and certifications

Ecology field staff are trained through education and experience. Field staff are required to be familiar with all study related SOPs and are required to adhere to task specific procedures documented in the EAP and WQ Safety Plans. Field staff certify review of these procedures every two years. Key personnel involved in the collection of water quality data and interpretation of results for this study have extensive experience in similar efforts.

5.3 Organization chart

Table 6 lists the individuals involved in this study. All are employees of the Department of Ecology.

5.4 Proposed project schedule

This study is a multiyear study and is expected to be conducted over a ten year period (2019- 2029). Sampling will begin in July of 2019.

- Water quality monitoring for the status and trends objective will occur monthly at the mouths of all three creeks (Boise, Pussyfoot, Second), as well as the one added location upstream on Boise Creek.
- Water quality monitoring for the implementation and adaptive management objective will occur twice monthly at all sites during years 1, 5, and 10 (sampling at the four stations mentioned above has overlap between both objectives). Pussyfoot Creek and Second Creek are expected to only include 9 months of sampling due to the creeks running dry between August and October.
- Water quality monitoring for source tracing will occur as deemed necessary by non-point specialists working in the watershed or by the need to follow up on pollution sources found during the study.

Ecology's WHEMU will co-lead the study with WCTU staff during years 1, 5, and 10. Table 7 shows the schedule for completing field and laboratory work, data entry into Ecology's Environmental Information Management database (EIM), and the final report.

Table 7. Proposed schedule for completing field and laboratory work, and data entry into EIM for the 10-year study. The EIM Study ID is EFF_PRT.

Field and laboratory work	**Due date**	**Lead staff**
Field work completed	June 2029	Niamh O'Rourke and Allison Brownlee
Laboratory analyses completed	August 2029	Laboratory
Environmental Information System (EIM) database	**Due date**	**Lead staff**
EIM data loaded	October 2029	Niamh O'Rourke and Allison Brownlee
EIM data entry review	November 2029	Allison Brownlee and Niamh O'Rourke
EIM complete	December 2029	Allison Brownlee
Final report	**Due date**	**Lead staff**
Draft due to supervisor	March 2030	Allison Brownlee
Draft due to client/peer reviewer	April 2030	Allison Brownlee
Final report	**Due date**	**Lead staff**
Draft due to external reviewer(s)	May 2030	Allison Brownlee
Final (all reviews done) due to publications coordinator	June 2030	Allison Brownlee
Final report due on web	July 2030	Allison Brownlee

5.5 Budget and funding

The project budget is divided between lab and field costs. All lab samples will be analyzed at Ecology's accredited Manchester Environmental Laboratory (MEL). The 10 year estimated lab budget is detailed in Tables 8 and 9. The total project lab budget is $151,589, which includes 10% ($13,781) for source tracing. Field costs are estimated with considerations for equipment replacement and sensor calibrations throughout the 10 year study period and are listed in Table 10.

Table 8. Laboratory budget for status and trends component of project (all years).

Parameter	Creek	No. Sites	Surveys per Year	Field Reps per Year	No. Years	Total Samples	Cost per Sample	Sub-total
Bacteria	Boise	2	12	6	10	300	$42	$12,600
Bacteria	Pussyfoot	1	9	3	10	120	$42	$5,040
Bacteria	Second	1	9	3	10	120	$42	$5,040
TP	Boise	2	12	6	10	300	$20	$6,000
TP	Pussyfoot	1	9	3	10	120	$20	$2,400
TP	Second	1	9	3	10	120	$20	$2,400
Orthophosphate	Boise	2	12	6	10	300	$20	$6,000
Orthophosphate	Pussyfoot	1	9	3	10	120	$20	$2,400
Orthophosphate	Second	1	9	3	10	120	$20	$2,400
TPN	Boise	2	12	6	10	300	$20	$6,000
TPN	Pussyfoot	1	9	3	10	120	$20	$2,400
TPN	Second	1	9	3	10	120	$20	$2,400
Ammonia-N	Boise	2	12	6	10	300	$15	$4,500
Ammonia-N	Pussyfoot	1	9	3	10	120	$15	$1,800
Ammonia-N	Second	1	9	3	10	120	$15	$1,800
Nitrate + Nitrite	Boise	2	12	6	10	300	$15	$4,500
Nitrate + Nitrite	Pussyfoot	1	9	3	10	120	$15	$1,800
Nitrate + Nitrite	Second	1	9	3	10	120	$15	$1,800

Bacteria: Fecal coliform (MF) + E.coli (MF)

TPN: Total Persulfate Nitrogen

TP: Total Phosphorus

Table 9. Laboratory budget for implementation and adaptive management component of project (years 1, 5, 10).

Parameter	Creek	No. Sites	Surveys per Year	Field Reps per Year	No. Years	Total Samples	Cost per Sample	Sub-total
Bacteria	Boise: S&T sites	2	12	0	3	72	$ 42	$3,024
Bacteria	Boise: non S&T sites	7	24	24	3	576	$ 42	$24,192
Bacteria	Pussyfoot: S&T	1	9	0	3	27	$ 42	$1,134

Parameter	Creek	No. Sites	Surveys per Year	Field Reps per Year	No. Years	Total Samples	Cost per Sample	Sub-total
Bacteria	Pussyfoot: non S&T	9	18	12	3	522	$ 42	$21,924
Bacteria	Second: S&T	1	9	0	3	27	$ 42	$1,134
Bacteria	Second: non S&T	6	18	12	3	360	$ 42	$15,120

Bacteria: Fecal coliform (MF) + E.coli (MF)

Table 10. Additional estimated budget for field equipment.

Item	Quantity	Cost	Total
YSI ProDSS Handheld w/GPS	1	$ 2,160	$ 2,160
ProDSS 1m 4 port cable w/Depth	1	$ 2,540	$ 2,540
ProDSS Turbidity Sensor	1	$ 1,100	$ 1,100
ProDSS Conductivity and Temperature Sensor	1	$ 700	$ 700
ProDSS pH Sensor	1	$ 450	$ 450
ProDSS ODO Dissolved Oxygen Sensor	1	$ 1,000	$ 1,000
ProDSS calibration/storage cup	1	$ 160	$ 160
ProDSS Probe Guard kit	1	$ 70	$ 70
Large, hard sided carrying case	1	$ 350	$ 350
pH 4 buffer	45	$ 15	$ 675
pH 7 buffer	45	$ 15	$ 675
pH 10 buffer	45	$ 15	$ 675
Conductivity standard 100 uS/cm	35	$ 26	$ 910
YSI Turbidity Standard 12.4 NTU	6	$ 309	$ 1,854
YSI Turbidity Standard 124 NTU	6	$ 340	$ 2,040

6.0 Quality Objectives

6.1 Data quality objectives

The main data quality objective (DQO) for this study is to collect data of sufficient quantity and quality for effectiveness monitoring of TMDL implementation efforts. This objective will be met by using standard methods that meet the measurement quality objectives (MQOs) that are described below and that are comparable to previous study results.

6.2 Measurement quality objectives

MQOs are performance or acceptance criteria for data quality indicators including precision, bias, sensitivity, representativeness, comparability, and completeness. Field measurements and laboratory analyses both have inherent data variability and as such, MQOs are equally important for both methods. For a measurement of data accuracy, precision and bias are addressed.

6.2.1 Targets for precision, bias, and sensitivity

The MQOs for project results, expressed in terms of acceptable precision, bias, and sensitivity, are described in this section and summarized in Tables 11 and 12 below.

6.2.1.1 Precision

Precision is a measure of variability between results of replicate measurements that is due to random error. It will be assessed by analyzing duplicate field measurements or laboratory samples. Random error can occur from the environment, field procedures, and/or lab methods. Common sources of random error include field sampling procedures, sample handling, sample transportation, lab sample preparation and analysis, and data handling. Field precision will be addressed by collecting replicate samples or measurements. Lab precision will be assessed by MEL and will follow their standard quality control procedures (MEL, 2016). Precision will be expressed as percent relative standard deviation (% RSD) or absolute error and assessed using the MQOs defined in Tables 11 and 12. The targets for precision of field duplicates are based on historical performance by MEL for environmental samples taken around the state by EAP (Mathieu, 2006).

6.2.1.2 Bias

Bias is the difference between the sample mean and the true value. Bias will be addressed by calibrating field and laboratory instruments, and by analyzing lab control samples, matrix spikes, and/or standard reference materials. Bias can originate from instrument sensor drift or improper calibration, sample instability during transportation or storage, sample or equipment contamination, or the inability of analytical methods to detect all forms of the parameter. Field bias will be assessed through frequent calibrations and sensor performance checks, as well as following appropriate sample collection procedures outlined in published SOPs. MQOs for field parameters are listed in Table 11. Lab bias will be assessed by MEL through the use of blanks and spiked samples. MQOs for lab parameters are presented in Table 12.

6.2.1.3 Sensitivity

Sensitivity is a measure of the capability of a field instrument or lab method to detect a substance. It is commonly described as a detection limit. Field instruments have a sensitivity typically reported by the manufacturer that is determined by its range, accuracy, and resolution. Sensitivity levels for all field sensors are detailed in Table 11. For lab data, the method detection limit (MDL) is usually used to describe sensitivity. The method reporting limit (MRL) is typically a little higher than the MDL and is used to represent sensitivity for lab parameters listed in Table 12. MDLs for these parameters are listed in Section 9.1 (Table 17).

Table 11. MQOs for parameters measured in the field.

Parameter	Equipment	Duplicate Measurements: Precision	Equipment Information: Accuracy	Equipment Information: Resolution	Equipment Information: Range	Expected Range
Water Temperature	YSI ProDSS	± 0.2°C	± 0.2°C	0.1°C	-5 - 70°C	0-30°C
Conductivity	YSI ProDSS	5% RSD	±0.5% of reading or 0.001 mS/cm, w.i.g.[a]	0.001 mS/cm (range dependent)[b]	0 - 200 mS/cm	20 – 1,000 uS/cm
Dissolved Oxygen	YSI ProDSS	5% RSD	± 0.1 mg/L or ± 1% of reading, w.i.g.[a]	0.01 or 0.1 mg/L (auto-scaling)[a]	0 - 50 mg/L	0.1 - 15 mg/L
pH	YSI ProDSS	± 0.2 s.u.	± 0.2 s.u.	0.01 s.u.	0 - 14 s.u.	6 - 10 s.u.
Turbidity	YSI ProDSS	15% RSD	0 – 399.99 NTU: ± 2% of reading 400 – 1600 NTU: ±4% of reading	0.01 NTU	0 – 1,600 NTU	0 - 500 NTU

w.i.g.: whichever is greater
a: for 1,4 m cables; for 10 m, 20 m, 30 m cables: ±2.0% of the reading or 1.0 uS/cm, whichever is greater
b: range dependent, for 0.501 to 50.00 mS/cm: 0.01; for 50.01 to 200 mS/cm: 0.1

Table 12. MQOs for lab parameters.

Parameter	Analytical Method	Precision: Lab Duplicates (RPD)	Precision: Field Duplicates (median)[b]	Bias (% recovery): Matrix Spikes or SRMs	Bias (% recovery): Lab Control Samples	Bias (% recovery): Calibration Standards/ Blanks	Bias (% recovery): Method Blank Limit	Sensitivity: Method Lower Reporting Limit[a]
Ammonia-N	SM4500-NH3 H	20%	10% RSD	75-125%	80-120%	ICV/CCV: 90-110% ICB/CCB: <½ RL[c]	<½ RL[c]	0.01 mg/L
Nitrate + Nitrite-N	SM4500-NO3 I	20%	10% RSD	75-125%	80-120%	ICV/CCV: 90-110% ICB/CCB: <½ RL[c]	<½ RL[c]	0.01 mg/L
Total Persulfate Nitrogen	SM4500-N B	20%	10% RSD	75-125%	80-120%	ICV/CCV: 90-110% ICB/CCB: <½ RL[c]	<½ RL[c]	0.025 mg/L
Ortho-phosphate	SM4500-P G	20%	10% RSD	75-125%	80-120%	ICV/CCV: 90-110%	<½ RL[c]	0.003 mg/L

Parameter	Analytical Method	Precision: Lab Duplicates (RPD)	Precision: Field Duplicates (median)[b]	Bias (% recovery): Matrix Spikes or SRMs	Bias (% recovery): Lab Control Samples	Bias (% recovery): Calibration Standards/ Blanks	Bias (% recovery): Method Blank Limit	Sensitivity: Method Lower Reporting Limit[a]
						ICB/CCB: <½ RL[c]		
Total Phosphorus	SM4500-P H	20%	10% RSD	75-125%	80-120%	ICV/CCV: 90-110% ICB/CCB: <½ RL[c]	<½ RL[c]	0.01 mg/L
Fecal coliform (MF) + *E. coli* (MF)	SM9222 D + SM9222 G	40%	≤ 20% RSD & 90% of replicate pairs ≤ 50% RSD[b]	n/a	n/a	n/a	<MDL	1 cfu/100 mL

RL: reporting limit; MDL: method detection limit; CCV: Continuing Calibration Verification CCB: Continuing Calibration Blank; ICV: Initial Calibration Verification; ICB: Initial Calibration Blank; RPD: Relative Percent Difference; SRM: Standard Reference Material;
RSD: Relative Standard Deviation
a reporting limit may vary depending on dilutions
b field duplicate results with a mean of less than or equal to 5x the reporting limit will be evaluated separately
c or less than 10% of the lowest sample concentration for all samples in the batch

6.2.2 Targets for comparability, representativeness, and completeness

6.2.2.1 Comparability

The comparability of study results to previously collected data will be achieved through following Ecology's strict protocols and by following published Ecology SOPs. Many factors can affect comparability including quality assurance documents such as QAPPs and SOPs, staff training, sample locations, seasonality and weather conditions, lab methods, calibration practices, equipment maintenance, and data entry quality control procedures. This study will adhere to the following Ecology SOPs and refer to equipment manuals for instrument-specific quality procedures:

- Programmatic QAPP for Water Quality Impairment Studies (McCarthy and Mathieu, 2017).
- Standard Operating Procedures for the Collection, Processing, and Analysis of Stream Samples (Ward, 2016).
- Guidance for Effectiveness Monitoring of Total Maximum Daily Loads in Surface Water (Collyard and Onwumere, 2013).
- Standard Operation Procedure for Hydrolab®, DataSonde®,MiniSonde® and HL4 Multiprobes (Anderson, 2016).
- Standard Operating Procedure for Measuring Streamflow for Water Quality Studies (Mathieu, 2016).

6.2.2.2 Representativeness

Representativeness is mainly a function of individual study design. Each study is designed to collect sufficient data, meet study-specific objectives, and assess spatial and temporal variability of the measured parameters throughout the study area. Sampling locations are distributed throughout each watershed in a manner designed to meet study objectives. Sampling will be conducted throughout the year, capturing both dry and wet seasons for a 10 year period, which was also designed to meet study objectives.

6.2.2.3 Completeness

Completeness is a measure of the amount of valid data required to meet project objectives. The goal for this effectiveness study is to collect and analyze 100% of the samples or measurements when proper water levels allow. Due to unforeseen problems that may arise from site access problems, weather conditions, or equipment malfunction, a completeness of 95% will be acceptable. If equipment fails or samples are damaged, Ecology will attempt to recollect the data under similar conditions, such as the following day, if possible. In general, each project should be designed to accommodate some data loss and still meet project goals and objectives.

If completeness targets are not met, the study report will analyze the effect of the incomplete data on meeting the study objectives, account for data completeness (or incompleteness) in any data analyses, and document data completeness and its consequences in any study reports.

Investigative samples may not meet the minimum requirements for statistical or other data analysis, but will still be useful for source location identification, recommendations, or other analyses.

6.3 Acceptance criteria for quality of existing data

This study will likely use data collected through monitoring efforts conducted by others, including Ecology, King County, Muckleshoot Indian Tribe, King Conservation District, and the City of Enumclaw. The primary source of historical data will be Ecology's EIM database and project files for Ecology-sponsored studies. EIM will be used to access all analytical results and observational data whereas project files will be used to gather more detailed information such as site specific sampling locations and method descriptions. These data and all data from outside Ecology will be reviewed to assess comparability with this study.

6.4 Model quality objectives

NA

7.0 Study Design

7.1 Study boundaries

All field samples will be collected within the watersheds of Boise, Pussyfoot, and Second creeks. Reference Figure 1 for a map of these watersheds. Figures 6-8 show sampling locations within each watershed. Additional sampling locations could be added for source tracing or if sites become inaccessible over the duration of the project. Sites could also be abandoned or moved due to accessibility during the 10 year study.

7.2 Field data collection

7.2.1 Sampling locations and frequency

Sampling locations are listed in Table 13 and Figures 6-8. Fieldwork will begin July 2019 and continue through June 2029. During years 1, 5, and 10 of the study, all sites will be visited twice a month, approximately every 2 weeks. For all intervening years, only status and trends sites will be visited on a monthly basis, approximately four weeks apart. Due to the length of time required by MEL for processing bacteria samples, site visits will be conducted on Mondays and Tuesdays whenever possible.

Table 13. Latitude and longitude of all planned sample sites.

Map Site ID	EIM Site ID	Status and Trends	Implementation	Description	NAD83 Latitude	NAD83 Longitude
Boise_ST1	10-BOI-0.1	x	x	Boise Creek at mouth (bridge at SE Mud Mtn Rd)	47.1761	-122.0186
Boise_ST2	10-BOID-0.3	x	x	Boise Creek at SE 456th St	47.1923	-121.9985
Boise_I1	10-BOI-1.0		x	Boise Creek at 252nd Ave SE	47.1857	-122.0054
Boise_I2	10-BOI-1.2		x	Boise Creek via Foothills Trail	47.1882	-122.0028
Boise_I3	10-BOI-1.7		x	Boise Creek at 268th Ave SE	47.1903	-121.9841
Boise_I4	10-BOI-2.2		x	Boise Creek at 276th Ave SE	47.1885	-121.9737
Boise_I5	10-BOI-3.2		x	Boise Creek at 284th Ave SE, north	47.1854	-121.9633
Boise_I6	10-BOIT-0.4		x	Boise Creek at 284th Ave SE, north of SE 470th St	47.1800	-121.9634

Map Site ID	EIM Site ID	Status and Trends	Implementation	Description	NAD83 Latitude	NAD83 Longitude
Boise_I7	10-BOIT-0.7		x	Boise Creek at 284th Ave SE, south of SE 472nd St, southeast tributary	47.1760	-121.9633
Psyft_ST1	10-UNW-0.2	x	x	Pussyfoot at 180th Ave SE, upstream side of road	47.2356	-122.1012
Psyft_I1	10-SFPUS-0.23		x	Pussyfoot at 188th Ave SE	47.2334	-122.0908
Psyft_I2	10-SFPUS-0.92		x	Pussyfoot at 196th Ave SE, south of	47.2333	-122.0800
Psyft_I3	10-SFPUS-1.75		x	Pussyfoot at SE 416th St, upstream side of road	47.2282	-122.0717
Psyft_I4	10-SFPUS-2.4		x	Pussyfoot at SE 424th St, near 208th	47.221	-122.0656
Psyft_I5	10-PUS-2.10		x	Pussyfoot at 196th Ave SE, north of SE	47.2409	-122.0803
Psyft_I6	10-PUS-2.22		x	Pussyfoot at 196th Ave SE, south of	47.2423	-122.0801
Psyft_I7	10-PUS-2.6		x	Pussyfoot at 200th Ave SE	47.245	-122.0748
Psyft_I8	10-PUS-3.46		x	Pussyfoot at 212th Ave SE	47.2463	-122.0591
Psyft_I9	10-PUS-3.7		x	Pussyfoot at SE 400th St	47.2426	-122.0566
Second_ST1	10-SEC-1.1	x	x	Second at Auburn Enumclaw Rd SE, hard to access	47.2229	-122.0969
Second_ST1 (alternative)	10-SEC-1.4	x	x	Second at 188th Ave SE, downstream	47.2241	-122.0910
Second_I1	10-SECT-0.01		x	Second at 188th Ave SE, upstream of tributary	47.2241	-122.0910
Second_I2	10-SEC-1.50		x	Tributary to Second at 188th Ave SE	47.2242	-122.0909
Second_I3	10-SEC-2.07		x	Second at 196th Ave SE, downstream side of	47.2229	-122.0804
Second_I4	10-SEC-2.08		x	Second at 196th Ave SE, upstream side of road above ditch and pipe	47.2229	-122.0801

Map Site ID	EIM Site ID	Status and Trends	Implementation	Description	NAD83 Latitude	NAD83 Longitude
Second_I5	10-SEC-2.33		x	Second at 424th St, north side of road	47.2211	-122.0756
Second_I6	10-SEC-2.34		x	Second at 424th St, south side of road	47.2209	-122.0756

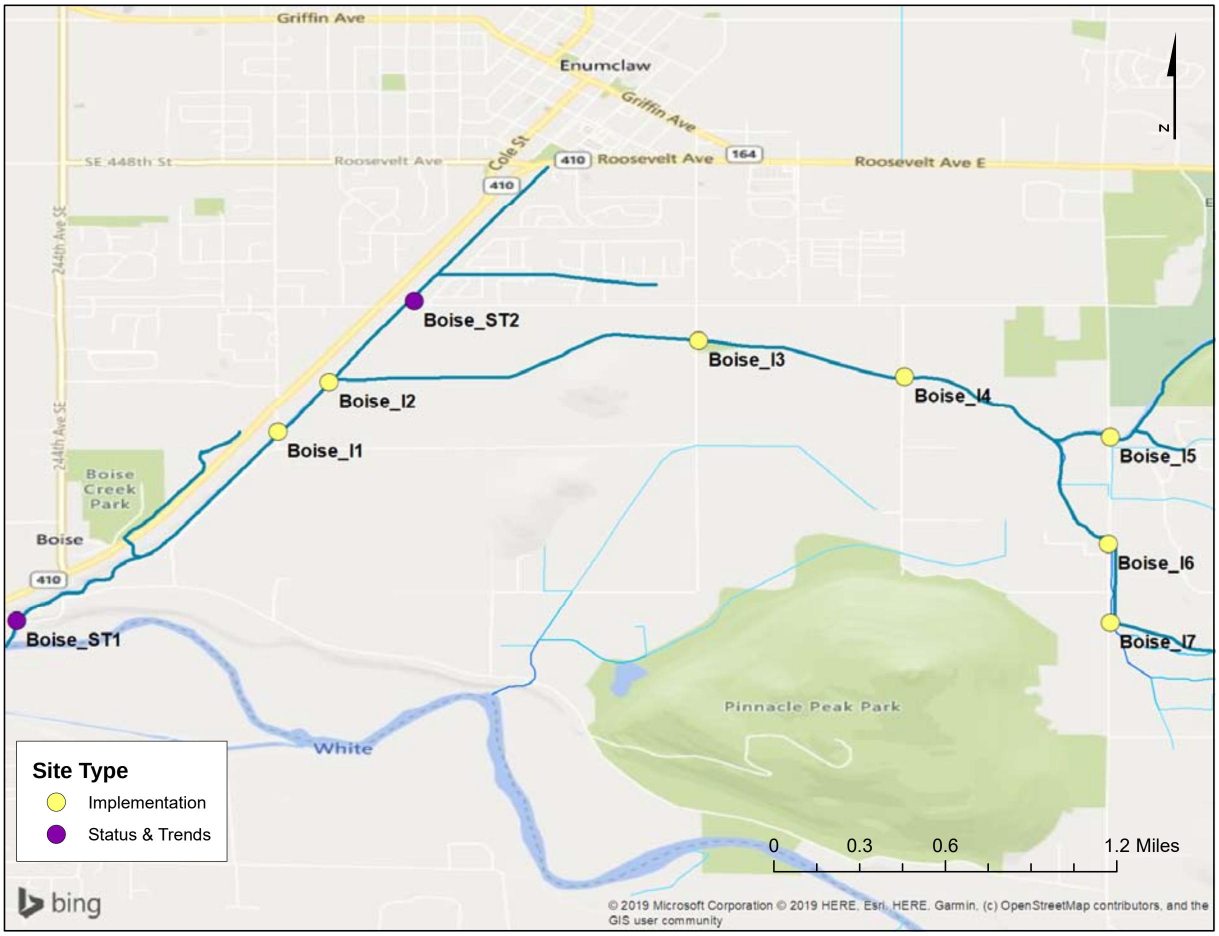

Figure 6. Sampling locations along Boise Creek.

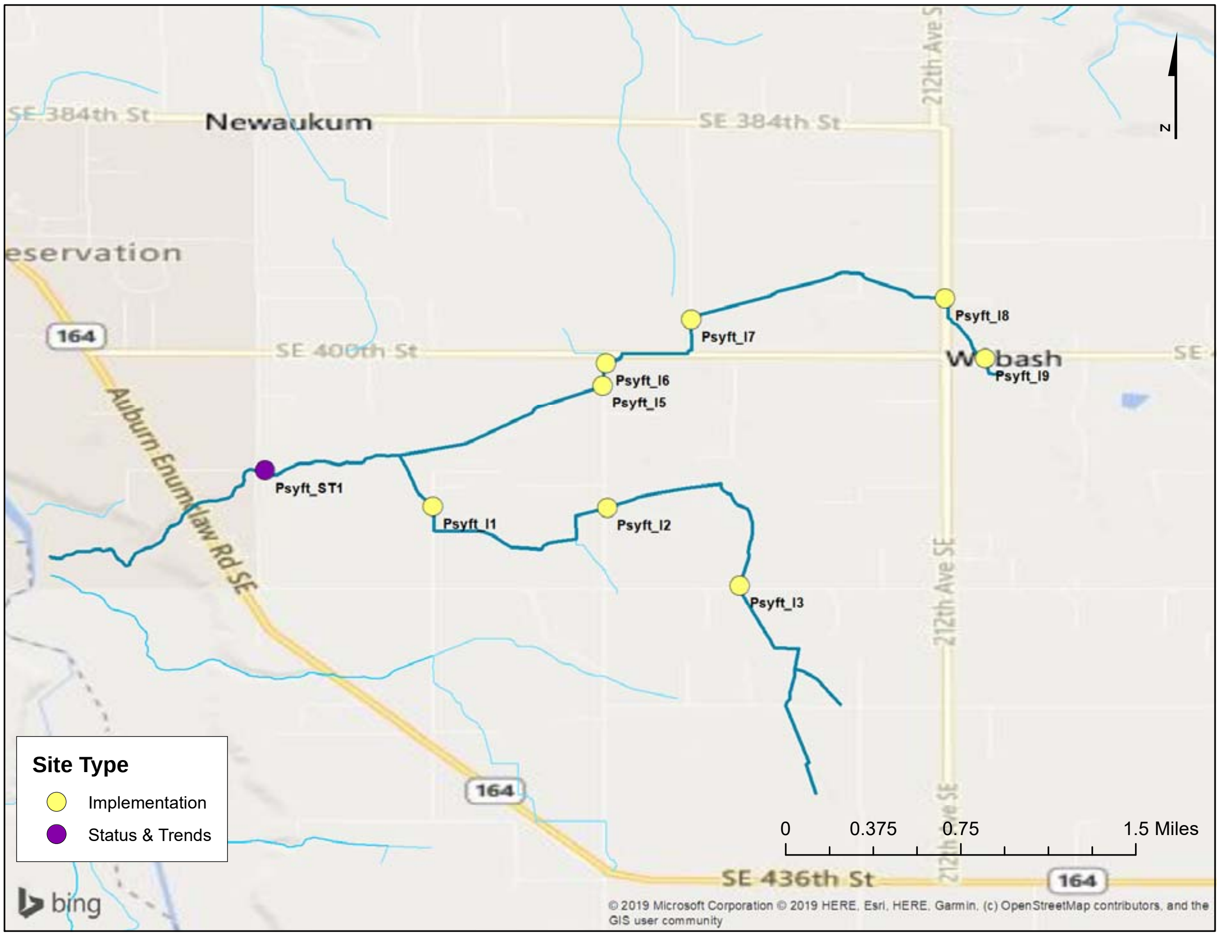

Figure 7. Sampling locations in Pussyfoot Creek.

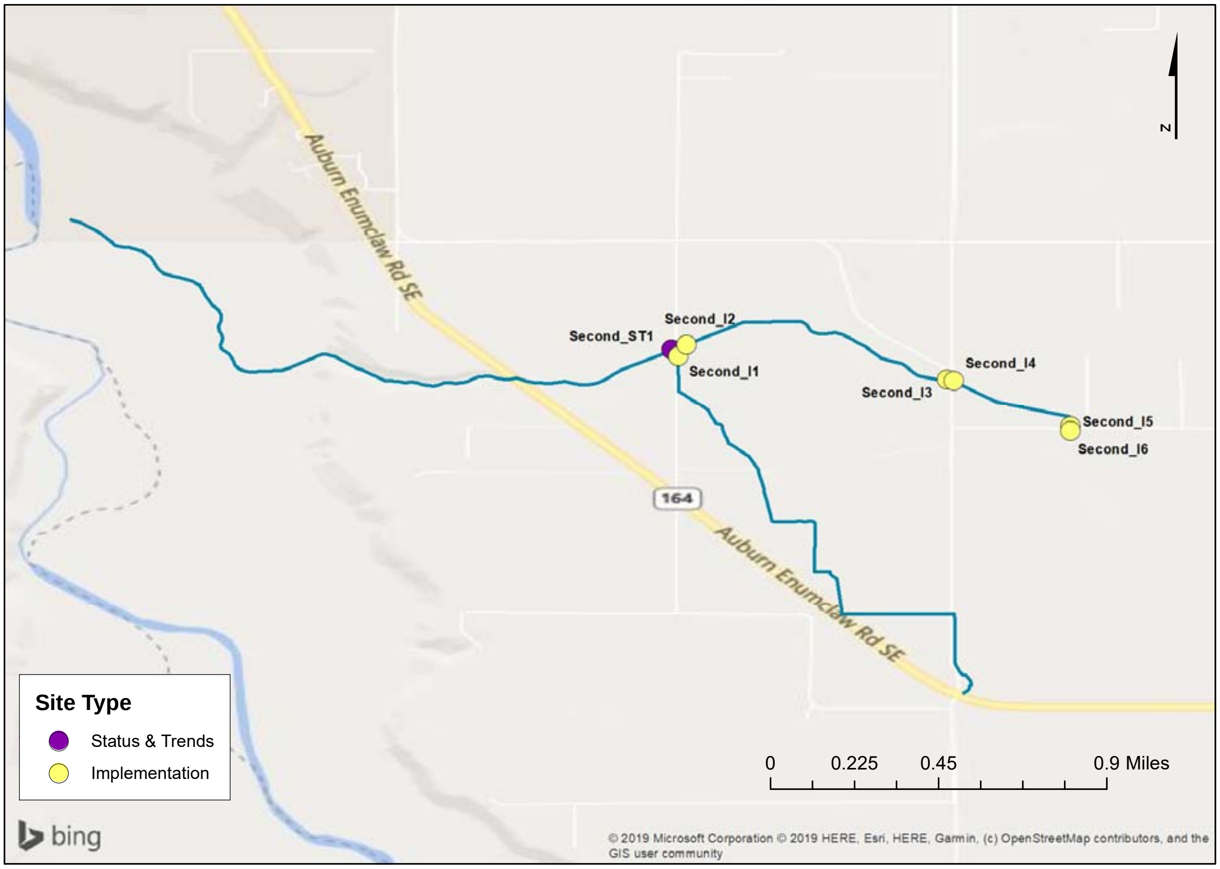

Figure 8. Sampling locations in Second Creek.

7.2.2 Field parameters and laboratory analytes to be measured

Tables 14 and 15 show the list of parameters required to meet the data needs of the study. Parameters may be added or removed from the study design as the project advances.

Table 14. Laboratory parameters to be sampled.

Parameter	Status and Trends	Implementation	Source Tracing
Fecal coliform (MF)	X	X	To be determined as needed
E. coli (MF)	X	X	To be determined as needed
Total Phosphorus	X		To be determined as needed
Orthophosphate	X		To be determined as needed
Total Persulfate Nitrogen	X		To be determined as needed

Parameter	Status and Trends	Implementation	Source Tracing
Ammonia-N	X		To be determined as needed
Nitrate + nitrite-N	X		To be determined as needed

Table 15. Field parameters to be collected (in-situ).

Parameter	Status and Trends	Implementation	Source Tracing
Temperature	X	X	To be determined as needed
Conductivity	X	X	To be determined as needed
Dissolved Oxygen	X	X	To be determined as needed
pH	X	X	To be determined as needed
Turbidity	X	X	To be determined as needed

7.3 Modeling and analysis design

NA

7.4 Assumptions in relation to objectives and study area

Assumptions that underlie the project design include:

- Funding and resources will continue for the duration of the long-term effectiveness monitoring to adequately assess the efficacy of TMDL implementation efforts.
- Water quality management actions will reduce pollutant loading to the watersheds and will result in higher water quality over time.
- The project design including site selection and sample frequency will adequately represent the watersheds. It will also sufficiently monitor the effectiveness of TMDL implementation efforts and aid in source tracing of new pollutants.

7.5 Possible challenges and contingencies

7.5.1 Logistical problems

Due to the long duration of this effectiveness monitoring study, site accessibility could become a possible challenge. If a site becomes inaccessible due to road changes, erosion, etc., the addition of a new site will be considered based on the needs of the project objectives.

In addition, the ephemeral nature of both Pussyfoot Creek and Second Creek could present challenges for sample collection if adequate water levels are not present or if weather patterns are conducive to longer drought periods. These events will be documented throughout the project. If equipment failure occurs during a sampling event, troubleshooting will be attempted in the field. If troubleshooting fails, any missed sites will be revisited at the next most convenient time dependent on staff priorities and lab availability.

7.5.2 Practical constraints

Practical constraints to this study may include unforeseen budget cuts and staff reductions or vacancies. Contingencies would include site or parameter reductions, a reduction in sample frequency, and/or sampling postponement.

7.5.3 Schedule limitations

The project schedule could be affected by the various factors listed above. Strong efforts will be made to ensure the sampling schedule stays consistent with the project plan. These efforts may include re-prioritizing budget needs within the program, collaborating with other work groups, and ensuring all sampling equipment is properly maintained and calibrated prior to sampling.

8.0 Field Procedures

8.1 Invasive species evaluation

Although the Boise Creek, Pussyfoot Creek, and Second Creek watersheds are not areas of extreme concern, field staff will follow SOP EAP070 on minimizing the spread of invasive species (Parsons et al., 2018).

8.2 Measurement and sampling procedures

All water samples will be collected using Ecology's SOP for the Collection, Processing, and Analysis of Stream Samples (Ward, 2016). Water quality data collected by multi-parameter sondes will follow guidance from Ecology's SOP for Hydrolab® DataSonde®, MiniSonde®, and HL4 Multiprobes (Anderson, 2016), supplemented with details from equipment manuals as needed. If deemed necessary, streamflow measurements will be conducted following Ecology's SOP for Measuring Streamflow for Water Quality Studies (Mathieu, 2016).

8.3 Containers, preservation methods, holding times

Field staff will collect discrete samples directly into pre-cleaned or sterilized containers supplied by MEL and described in their Lab User's Manual (MEL, 2016).

Table 16 lists the sample parameters, containers, volumes, preservation requirements, and holding times for all lab samples. Field staff will store samples for laboratory analysis on ice in a walk-in cooler and arrange for sample pick-up via MEL staff. MEL follows standard analytical methods outlined in their Lab User's Manual (MEL, 2016).

Table 16. Sample containers, preservation, and holding times.

Parameter	Matrix	Minimum Quantity	Container	Holding Time	Preservative
Ammonia-N	Water	125 mL	125 mL clear w/m poly bottle	28 days	H_2SO4 to pH <2; Cool to ≤6°C
Nitrate + Nitrite-N	Water	125 mL	125 mL clear w/m poly bottle	28 days	H_2SO4 to pH <2; Cool to ≤6°C
Total Persulfate Nitrogen	Water	125 mL	125 mL clear w/m poly bottle	28 days	H_2SO4 to pH <2; Cool to ≤6°C
Orthophosphate	Water	125 mL	125 mL amber w/m poly bottle, 0.45 um pore size filters	48 hrs	Filter in field with 0.45 um pore size filter; Cool to ≤6°C
Total Phosphorus	Water	60 mL	125 mL clear w/m poly bottle	28 days	1:1 HCl to pH <2; Cool to ≤6°C
Fecal coliform (MF) + *E. coli* (MF)	Water	250 mL	250 mL clear w/m poly autoclaved bottle	24 hours	Fill the bottle to the shoulder; Cool to ≤10°C

w/m: wide mouth

8.4 Equipment decontamination

Staff will follow all recommended protocols from instrument manufacturers for cleaning, maintaining, and calibrating sensors.

8.5 Sample ID

All samples will be labeled with station, date, time, parameter, sample identification number, and work order number, which are recorded in the field log and on the chain of custody (COC) form. Each lab sample is automatically given a unique identification number once loaded into the database. This number is transferred to analyses logs for internal lab samples. All sample bottles are reconciled against forms to verify completeness as samples move through the analytical process, described in the Quality Control section of this QAPP.

8.6 Chain of custody

Based on field log data, COC forms will be created and filled out for each sample event. COC logs are delivered to the lab with the corresponding samples for management of sample counts, scheduling, and tracking. Once the samples are delivered, lab personnel log in each sample and assign a lab number to each, using the sample label number and date. Each laboratory sample number must correspond to a particular date, station, and depth.

When data results are received from MEL, COC forms are reconciled with data to ensure complete delivery and correct invoicing for all results. If discrepancies exist, research and investigation of the discrepancy is conducted in coordination with MEL until the problem is resolved.

8.7 Field log requirements

Field logs will consist of pre-printed templates that will include the following information:

- Field personnel.
- Site, date and time of which data is collected.
- Observational data (flow, weather, water color, etc.).
- Field measurement results.
- Any deviation from the sampling plan that might affect interpretation of results.
- Notes of potential sources of pollution.

Field measurements collected with a multi-parameter sonde will be recorded both internally within the data logger and handwritten into the field log. These recordings will be verified for uniformity once data is uploaded. Photos will also be taken as necessary to record observations and events. These photos will be used to document each sampling event and for the creation of reports, procedures, and other documents. Digital copies of all field and sample logs (COCs) will be stored for future reference on a shared, secure, and frequently backed up network server.

8.8 Other activities

Other activities related to field work include sensor and equipment maintenance, correspondence with MEL personnel for sample delivery and bottle ordering, budget tracking, and field staff training.

The project manager or field lead for each sample event is responsible for:

- Conducting all pre-sampling sensor calibrations.
- Prepping all field gear including sampling poles, gloves, filters, etc.
- Ensuring adequate supply of sample bottles.
- Cancelling assessments if conditions warrant.

- Complying with field and safety procedures.
- Knowledge of use and location of the safety equipment.
- Sample handling and processing, including chemical safety protocols.
- Emergency procedures.

9.0 Laboratory Procedures

9.1 Lab procedures table

Ecology's Manchester Environmental Laboratory (MEL) conducts laboratory analyses and procedures following Standard Operating Procedures (SOPs) and other guidance documents. Analytical methods and lower reporting limits are listed in Table 17.

Table 17. Measurement methods (laboratory).

Analyte	Matrix	Expected Range of Results	Method	Method Detection Limit
Ammonia-N	Water	<0.01 – 30 mg/L	SM4500-NH3 H	0.004 mg/L
Nitrate + Nitrite-N	Water	<0.01 – 30 mg/L	SM4500-NO3 I	0.0025 mg/L
Total Persulfate Nitrogen	Water	0.5 – 50 mg/L	SM4500-N B	0.013 mg/L
Orthophosphate	Water	0.01 – 5.0 mg/L	SM4500-P G	0.0017 mg/L
Total Phosphorus	Water	0.01 – 10 mg/L	SM4500-P H	0.006 mg/L
Fecal coliform (MF)	Water	1 – 15,000 cfu/100 mL	SM9222 D	1.0 cfu/100 mL (RL)
E. coli (MF)	Water	1-15,000 cfu/100 mL	SM9222 G	1.0 cfu/100 mL (RL)

RL: Reporting Limit

9.2 Sample preparation method(s)

Sample preparation methods are listed in standard operating procedures for lab analyses or in analytical methods.

9.3 Special method requirements

NA

9.4 Laboratories accredited for methods

All chemical analysis will be performed at MEL, which is accredited for all methods.

10.0 Quality Control Procedures

Implementing quality control (QC) procedures provides the information needed to assess the quality of the data that is collected. These procedures also help identify problems or issues associated with data collection and/or data analysis while the project is underway.

For field instruments, the following QC procedures will be performed:

- Pre check: Prior to each sample event, all sensors will be checked and if necessary, calibrated, following recommendations by the manufacturer.
- Post check: At the conclusion of each sample event, all sensors will be checked again to assess for any potential bias from instrument drift, fouling, or interference.
- The YSI ProDSS, a multi-parameter probe used for all field measurements, requires periodic calibrations for all sensors excluding temperature to maintain accurate measurements. According the manufacturer, temperature calibration is not available nor required for accurate temperature measurements.
- Pre and post checks for each sensor will be conducted as following:

    - For conductivity, pH, and turbidity, using certified standards specific to each parameter.
    - For dissolved oxygen (DO), checking the probe against 100% water saturated air or in a 100% air saturated water bath.
    - The results from each field instrument will be assigned an accuracy rating based on the criteria in Table 18.

- If a pre-check falls below the excellent accuracy rating, the sensor will be re-calibrated.
- If a post-check falls below the good accuracy rating, the data will be investigated and potentially flagged with a qualifier.

Table 18. Rating of accuracy for field instruments.

Measured Field Parameter	Excellent	Good	Fair	Poor
Water Temperature	≤ ± 0.2°C	> ± 0.2 – 0.5°C	> ± 0.5 – 0.8°C	> ± 0.8°C
Specific Conductance	≤ ± 3%	> ± 3 – 10%	> ± 10 – 15%	> ± 15%
Dissolved Oxygen	≤ ± 5%	> ± 5 – 10%	> ± 10 – 15%	> ± 15%
pH	≤ ± 0.2 units	> ± 0.2 – 0.5 units	> ± 0.5 – 0.8 units	> ± 0.8 units
Turbidity	≤ ± 0.5 NTU or ≤ ± 5%, whichever is greater	> ± 0.5 – 1.0 NTU or > ± 5 – 10%, whichever is greater	> ±1.0 – 2.0 NTU or > ± 10 – 20%, whichever is greater	> ± 2.0 NTU or > ± 20%, whichever is greater

10.1 Table of field and laboratory quality control

The primary types of QC samples used to evaluate and control the accuracy of laboratory analyses are check standards, duplicates, spikes, and blanks (MEL, 2016). Check standards serve as an independent check on the calibration of the analytical system and can be used to evaluate bias. MEL routinely duplicates sample analyses in the laboratory to determine laboratory precision. Matrix spikes are used to check for matrix interference with detection of the analyte and can be used to evaluate bias as it relates to matrix effects. Blanks are used to check for sample contamination in the laboratory process. Laboratory and field QC procedures are presented in Table 19.

Table 19. Quality control samples, type, and frequency.

Parameter	Field Replicates	Field Blanks	Lab Check Standards	Lab Method Blanks	Lab Analytical Duplicates	Lab Matrix Spikes
Ammonia-N	20-30%	10%	1/batch	1/batch	1/batch	1/batch
Nitrate + Nitrite-N	20-30%	10%	1/batch	1/batch	1/batch	1/batch
Total Persulfate Nitrogen	20-30%	10%	1/batch	1/batch	1/batch	1/batch
Orthophosphate	20-30%	10%	1/batch	1/batch	1/batch	1/batch
Total Phosphorus	20-30%	10%	1/batch	1/batch	1/batch	1/batch
Fecal coliform	10-30%	n/a	n/a	n/a	1/batch	n/a
E. coli	10-30%	n/a	n/a	n/a	1/batch	n/a

10.2 Corrective action processes

QC results may indicate problems with data during the course of the project. Corrective action processes will be used if activities are found to be inconsistent with this QAPP, if field instruments yield unusual results, if results do not meet MQOs or performance expectations, or if some other unforeseen problems arise. There may be cause for field instruments to be recalibrated, following SOPs, while still on site. Options for corrective actions might include:

- Retrieving missing information.
- Re-calibrating the measurement system.
- Re-analyzing samples within holding time requirements.
- Modifying the analytical procedures.
- Requesting additional sample collection or additional field measurements.
- Qualifying results.

11.0 Data Management Procedures

11.1 Data recording and reporting requirements

Staff will record all field data in a field notebook. Before leaving each site, staff will check field notebooks for missing or improbable measurements. Staff will enter field-generated data into EIM as soon as is practical after they return from the field. Data entry will be checked against the field notebook data for errors and omissions.

Lab results will be checked for missing and/or improbable data. MEL will send data through Ecology's Laboratory Information Management System (LIMS). Data will be checked for completeness and reviewed for any additional required qualifiers.

In addition, data summaries and web maps will be either presented in free form on Ecology's Effectiveness Monitoring web page (https://ecology.wa.gov/Research-Data/Monitoring-assessment/Water-quality-improvement-effectiveness-monitoring), or Ecology's EIM.

11.2 Laboratory data package requirements

Laboratory-generated data reduction, review, and reporting will follow procedures outlined in MEL's Lab Users Manual (MEL, 2016). Variability in lab duplicates will be quantified, also using procedures in this manual. Any estimated results will be qualified and their use restricted as appropriate. A standard case narrative of laboratory QA/QC results will be sent to the project manager for each set of samples.

11.3 Electronic transfer requirements

MEL will provide all data electronically to the project manager through the LIMS to EIM data feed. There is already a protocol in place for how and what MEL transfers to EIM through LIMS.

11.4 EIM/STORET data upload procedures

All water quality data will be entered into EIM, following all existing Ecology business rules and the EIM User's Manual for loading, data quality checks, and editing.

11.5 Model information management

NA

12.0 Audits and Reports

12.1 Field, laboratory, and other audits

Audits will be conducted annually on all EIM data to check for missing values, extreme outliers, negative values, and duplicates. Any errors found will be investigated and corrected if possible. Audits of field procedures and sample processing are not planned for this study.

12.2 Responsible personnel

The project manager conducts audits of all data and works with field sampling staff and lab technicians to complete reviews.

12.3 Frequency and distribution of reports

A peer-reviewed technical report or water quality improvement report will be completed and published to Ecology's website. The final report will also be distributed to all managers, clients, tribes, municipalities, and other stakeholders involved or interested in the study. Ecology has specific publication guidelines depending on the type of final report that describe the exact requirements necessary for publication.

12.4 Responsibility for reports

The project manager is responsible for the final report. The project manager is also responsible for communicating with TMDL and non-point staff about status and trends throughout the study period. This may be in the form of various products and presentations of results.

13.0 Data Verification

Data verification and review is conducted by the project manager and WHEMU team by examining all field and laboratory-generated data to ensure:

- Specified methods and protocols were followed.
- Data are consistent, correct, and complete, with no errors or omissions.
- Data specified in the Sampling Process Design section were obtained.
- Results for QC samples, as specified in the Measurement Quality Objectives and Quality Control, accompany the sample results.
- Established criteria for QC results were met.
- Data qualifiers (QC codes) are properly assigned.

13.1 Field data verification, requirements, and responsibilities

Throughout field sampling, the field staff are responsible for carrying out station positioning, sample collection, and field measurement procedures as specified in the QAPP and SOPs. Additionally, staff systematically review all field documents (such as field logs, COCs, and sample labels) to ensure data entries are consistent, correct, and complete, with no errors or omissions. Field notebooks will be checked for missing or improbable measurements, and initial data will be verified before leaving each site. This process involves checking the data sheet for omissions or outliers. If measurement data are missing or a measurement is determined to be an outlier, the measurement will be flagged in the data sheet and repeated if possible.

Upon returning from the field, data are both manually entered and downloaded from instruments and then uploaded into the appropriate database or project folder (see Data Management Section). Manually entered data will be verified/checked against the original form. If errors or omissions are found, the source of the data (e.g., field crew, instruments) will be consulted to determine the correct value or form of the data in question.

Following data entry verification, raw field measurement data will undergo the following quality analysis verification process to evaluate the performance of the sensors:

Review discrete field QC checks

1. Review post-check data for field QC check instruments, reject data as appropriate.
2. Assign a quality rating to the field check values (excellent, good, fair, poor) based on the post-check criteria in Table 18.

After data have been finalized and entered into the EIM database, data will be reviewed for completeness and potential errors following Ecology's internal EIM review protocols.

13.2 Laboratory data verification

MEL staff will perform laboratory verification following standard laboratory practices (MEL, 2016). After the lab verification, the project manager will perform a secondary verification of the data. This secondary verification will entail a detailed review of all parts of the lab data with special attention to lab QC results. After data entry and data validation tasks are completed, all field and laboratory data will be entered into the EIM system. EIM data will be independently reviewed by staff for errors at an initial 10% frequency. If significant entry errors are discovered, a more intensive review will be undertaken.

13.3 Validation requirements, if necessary

NA

13.4 Model quality assessment

NA

14.0 Data Quality (Usability) Assessment

14.1 Process for determining project objectives were met

After all laboratory and field data are verified and validated, the project manager will thoroughly examine the data, using statistics and professional judgment, to determine if MQOs have been met for completeness, representativeness, and comparability. If the criteria have not been met, the project manager will decide if affected data should be qualified or rejected based upon the decision criteria in the QAPP. The project manager will decide how any qualified data will be used in the technical analysis.

14.2 Treatment of non-detects

Any non-detects will be included in the study analysis. For bacteria values below the detection limit, a conservative value of the detection limit minus one significant digit will be used (Sargent and Lowe, 2014). For bacteria values above the detection limit, the upper detection limit plus one significant digit will be used.

14.3 Data analysis and presentation methods

Data analysis consists of comparing results to water quality standards and detecting changes in monitoring parameters over time. Procedures comparing results to water quality standards are defined in the following:

- Ecology's Water Quality Program Policy 1-11 (https://ecology.wa.gov/Water-Shorelines/Water-quality/Water-improvement/Assessment-of-state-waters-303d/Assessment-policy-1-11).
- Guidance for Effectiveness Monitoring of Total Maximum Daily Loads in Surface Waters (Collyard and Onwumere, 2013).
- Programmatic QAPP for Water Quality Impairment Studies (McCarthy and Mathieu, 2017).

14.4 Sampling design evaluation

The project manager will decide whether data meet the MQOs, criteria for completeness, representativeness, and comparability, and whether meaningful conclusions (with enough statistical power) can be drawn from the results and analysis. If so, the sampling design will be considered effective. The sampling design will be considered successful if project objectives are met.

14.5 Documentation of assessment

In the technical report, the project manager will include a summary of the data quality assessment findings. This summary will be included in the data quality section of the report.

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16.0 Appendices

Appendix A. Glossaries, Acronyms, and Abbreviations

Glossary of General Terms

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

Anthropogenic: Human-caused.

Clean Water Act: A federal act passed in 1972 that contains provisions to restore and maintain the quality of the nation's waters. Section 303(d) of the Clean Water Act establishes the TMDL program.

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

Designated uses: Those uses specified in Chapter 173-201A WAC (Water Quality Standards for Surface Waters of the State of Washington) for each water body or segment, regardless of whether or not the uses are currently attained.

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

E. coli: A bacterium (*Escherichia coli*) commonly found in the intestines of humans and other animals, some strains of which can cause severe food poisoning.

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

Eutrophic: Nutrient rich and high in productivity resulting from human activities such as fertilizer runoff and leaky septic systems.

Extraordinary primary contact: Waters providing extraordinary protection against waterborne disease or that serve as tributaries to extraordinary quality shellfish harvesting areas.

Fecal coliform (FC): That portion of the coliform group of bacteria which is present in intestinal tracts and feces of warm-blooded animals as detected by the product of acid or gas from lactose in a suitable culture medium within 24 hours at 44.5 plus or minus 0.2 degrees Celsius. Fecal coliform bacteria are "indicator" organisms that suggest the possible presence of disease-causing organisms. Concentrations are measured in colony forming units per 100 milliliters of water (cfu/100 mL).

Geometric mean: A mathematical expression of the central tendency (an average) of multiple sample values. A geometric mean, unlike an arithmetic mean, tends to dampen the effect of very high or low values, which might bias the mean if a straight average (arithmetic mean) were calculated. This is helpful when analyzing bacteria concentrations, because levels may vary anywhere from 10 to 10,000 fold over a given period. The calculation is performed by either:
(1) taking the nth root of a product of n factors, or (2) taking the antilogarithm of the arithmetic mean of the logarithms of the individual values.

Load allocation: The portion of a receiving water's loading capacity attributed to one or more of its existing or future sources of nonpoint pollution or to natural background sources.

Loading capacity: The greatest amount of a substance that a water body can receive and still meet water quality standards.

Municipal separate storm sewer systems (MS4): A conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, manmade channels, or storm drains): (1) owned or operated by a state, city, town, borough, county, parish, district, association, or other public body having jurisdiction over disposal of wastes, stormwater, or other wastes and (2) designed or used for collecting or conveying stormwater; (3) which is not a combined sewer; and (4) which is not part of a Publicly Owned Treatment Works (POTW) as defined in the Code of Federal Regulations at 40 CFR 122.2.

National Pollutant Discharge Elimination System (NPDES): National program for issuing, modifying, revoking and reissuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements under the Clean Water Act. The NPDES program regulates discharges from wastewater treatment plants, large factories, and other facilities that use, process, and discharge water back into lakes, streams, rivers, bays, and oceans.

Nonpoint source: Pollution that enters any waters of the state from any dispersed land-based or water-based activities, including but not limited to atmospheric deposition, surface-water runoff from agricultural lands, urban areas, or forest lands, subsurface or underground sources, or discharges from boats or marine vessels not otherwise regulated under the NPDES program. Generally, any unconfined and diffuse source of contamination. Legally, any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act.

Nutrient: Substance such as carbon, nitrogen, and phosphorus used by organisms to live and grow. Too many nutrients in the water can promote algal blooms and rob the water of oxygen vital to aquatic organisms.

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

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

Pollution: Contamination or other alteration of the physical, chemical, or biological properties of any waters of the state. This includes change in temperature, taste, color, turbidity, or odor of the waters. It also includes discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state. This definition assumes that these changes will,
or are likely to, create a nuisance or render such waters harmful, detrimental, or injurious to
(1) public health, safety, or welfare, or (2) domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or (3) livestock, wild animals, birds, fish, or other aquatic life.

Primary contact recreation: Activities where a person would have direct contact with water to the point of complete submergence including, but not limited to, skin diving, swimming, and water skiing.

Reach: A specific portion or segment of a stream.

Riparian: Relating to the banks along a natural course of water.

Salmonid: Fish that belong to the family Salmonidae. Species of salmon, trout, or char.

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

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

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

Surface waters of the state: Lakes, rivers, ponds, streams, inland waters, salt waters, wetlands and all other surface waters and water courses within the jurisdiction of Washington State.

Thalweg: The deepest and fastest moving portion of a stream.

Total Maximum Daily Load (TMDL): A distribution of a substance in a water body designed to protect it from not meeting (exceeding) water quality standards. A TMDL is equal to the sum of all of the following: (1) individual wasteload allocations for point sources, (2) the load allocations for nonpoint sources, (3) the contribution of natural sources, and (4) a margin of safety to allow for uncertainty in the wasteload determination. A reserve for future growth is also generally provided.

Turbidity: A measure of water clarity. High levels of turbidity can have a negative impact on aquatic life.

Wasteload allocation: The portion of a receiving water's loading capacity allocated to existing or future point sources of pollution. Wasteload allocations constitute one type of water quality-based effluent limitation.

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

303(d) list: Section 303(d) of the federal Clean Water Act, requiring Washington State to periodically prepare a list of all surface waters in the state for which beneficial uses of the water – such as for drinking, recreation, aquatic habitat, and industrial use – are impaired by pollutants. These are water quality-limited estuaries, lakes, and streams that fall short of state surface water quality standards and are not expected to improve within the next two years.

Acronyms and Abbreviations

BMP	Best management practice
CM	Creek mile
DO	(see Glossary above)
e.g.	For example
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
et al.	And others
FC	(see Glossary above)
GIS	Geographic Information System software
GPS	Global Positioning System
i.e.	In other words
MEL	Manchester Environmental Laboratory
MQO	Measurement quality objective
NPDES	(See Glossary above)
QA	Quality assurance
QC	Quality control
RM	River mile
RPD	Relative percent difference
RSD	Relative standard deviation
SOP	Standard operating procedures
SRM	Standard reference materials
TMDL	(See Glossary above)
WAC	Washington Administrative Code
WQA	Water Quality Assessment
WRIA	Water Resource Inventory Area
WWTP	Wastewater treatment plant

Units of Measurement

°C	degrees centigrade
cfs	cubic feet per second
cfu	colony forming units
cms	cubic meters per second, a unit of flow
ft	feet
g	gram, a unit of mass
kcfs	1000 cubic feet per second
kg	kilograms, a unit of mass equal to 1,000 grams
kg/d	kilograms per day
km	kilometer, a unit of length equal to 1,000 meters
l/s	liters per second (0.03531 cubic foot per second)
m	meter
mm	millimeter
mg	milligram

mgd	million gallons per day
mg/d	milligrams per day
mg/Kg	milligrams per kilogram (parts per million)
mg/L	milligrams per liter (parts per million)
mg/L/hr	milligrams per liter per hour
mL	milliliter
mmol	millimole or one-thousandth of a mole
mole	an International System of Units (IS) unit of matter
NTU	nephelometric turbidity units
psu	practical salinity units
s.u.	standard units
µg/g	micrograms per gram (parts per million)
µg/Kg	micrograms per kilogram (parts per billion)
µg/L	micrograms per liter (parts per billion)
µm	micrometer
µM	micromolar (a chemistry unit)
µmhos/cm	micromhos per centimeter
µS/cm	microsiemens per centimeter, a unit of conductivity
ww	wet weight

Quality Assurance Glossary

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Examples of data types commonly validated would be:
- Gas Chromatography (GC).
- Gas Chromatography-Mass Spectrometry (GC-MS).
- Inductively Coupled Plasma (ICP).

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

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

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

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

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

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

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

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

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).

References for QA Glossary

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