DEPARTMENT OF ECOLOGY
State of Washington

Quality Assurance Project Plan

Newaukum River Monitoring of the Effectiveness of Best Management Practices (BMPs) for Sediment and Nutrient Reduction

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Each study conducted by the Washington State Department of Ecology (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/1803101.html

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January 2018

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WQP: Water Quality Program
EAP: Environmental Assessment Program

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2.0 Abstract

The Newaukum River, a tributary to the Chehalis River, and its tributaries are on the 2012 303(d) list of impaired waterbodies due to violations of one or more water quality criteria. Total maximum daily loads (TMDLs) for bacteria, temperature, and dissolved oxygen were established between 1994 and 2000. In 2004, a water quality cleanup plan recommended actions to increase stream shade and reduce sediment loads in order to improve water quality in the Newaukum River watershed.

Recently, the Newaukum River became an area of focus within the Chehalis Basin for implementing actions to restore and protect salmon habitat. Many of the factors identified as limiting or threatening salmon populations within the watershed are also responsible for water quality impairments identified in the TMDL. It is expected that projects and actions implemented over the next several years to support salmon will also improve water quality over time. To support both efforts, the Washington State Department of Ecology (Ecology) will conduct a long-term effectiveness monitoring study that will provide (1) monitoring support to both TMDL water-cleanup and salmon-recovery efforts in order to assess the effectiveness of actions and (2) information to assist stakeholders in adaptively managing water cleanup and recovery plans.

This Quality Assurance Project Plan describes a long-term monitoring strategy which leverages existing statewide programs implemented by Ecology to support the federal Clean Water Act and the Endangered Species Act listings in Washington State. Specifically, overall effectiveness of restoration actions will be assessed by measuring nutrient and sediment loading in relation to implementation actions over time. In addition, biological and instream habitat measures will be used to assess the effectiveness of a selection of individual projects at the site scale. Additional water quality data will also be collected to provide assessment of 303(d) listed areas and identify locations which need additional improvement. This information is intended to provide a holistic assessment of watershed health in relation to restoration or water cleanup activities over time that is consistent with other data being collected statewide.

3.0 Background

3.1 Introduction and problem statement

The Newaukum River is a major tributary to the Chehalis River and provides important habitat for salmonid spawning and rearing. Within this Newaukum River drainage area, there are no Endangered Species Act (ESA) listed species of salmon (CRBFA, 2010); however, water quality and habitat issues are threatening the health of all aquatic species. In 2004, Ecology developed a plan to address high temperatures and low dissolved oxygen in the Newaukum River watershed (Rountry 2004). The plan recommended increasing shade and decreasing width to depth ratios to improve water quality. Although numerous projects have been implemented throughout the Chehalis River watershed, relatively few have been implemented with the Newaukum River watershed.

In a recent effort to improve water quality and restore and protect instream and riparian habitat conditions in a systematic way, the Newaukum River watershed has been designated a focus area by the Chehalis Basin Lead Entity (Chehalis Basin Lead Entity, 2016). As part of this effort stakeholders are coordinating work to identify, prioritize and implement restoration activities which support clean water and salmon recovery in the watershed. Ecology's nonpoint source pollution reduction program staff, Lewis County Conservation District, Lewis County Public Works, Coast Salmon Partnership, the Wild Fish Conservancy, Natural Resources Conservation Service, Washington Department of Fish and Wildlife, US Fish and Wildlife Service, Chehalis Tribe, and the Fish Barrier Removal Board are all actively working cooperatively to support restoration and monitoring activities in the watershed.

Because of the current focus on the watershed, Ecology's Environmental Assessment Program will conduct a long term monitoring study. The intent of this study is to provide support to stakeholders by assessing the effectiveness of restoration actions on improving water quality and habitat conditions in the watershed at multiple scales. This Quality Assurance Project Plan (QAPP) outlines data collection efforts that will be used for this assessment.

The Chehalis River Basin *Salmon Habitat Restoration and Preservation Strategy for WRIA 22 and 23* outlines the most pressing limiting factors identified within the subbasins of the Chehalis (Grays Harbor Lead Entity Work Group, 2011). Restoration and protection actions within the Newaukum River watershed (a subbasin) will largely be driven by addressing limiting factors which were identified as impacting salmonid populations. The limiting factors and actions to remedy causes were used to develop the study design for this project (Table 1).

Table 1. Results of a limiting factors analysis and proposed actions for the Newaukum River watershed.

Limiting Factor	Cause	Actions	Expected Instream Response
Riparian	• Conversion of forestland to agriculture and rural residences • Bank vegetation loss	• Riparian Fencing • Protection of sensitive areas • Revegetate open riparian areas	• Sediment and nutrient reductions • Decreased temperature
Fish Passage	• Undersized culverts and or fish barriers	• Replace barrier culverts • Remove dams where feasible	• Increase in LWD • Reduced scouring of channel
Sediment	• Likely due to the livestock access, high road densities, landslides caused by roads, and high amounts of bank erosion	• Remove roads on steep geologically sensitive areas. • Riparian fencing • Revegetate open riparian areas • Natural bank stabilization	• Sediment and nutrient reductions • Decreased temperature
Water Quality/ Quantity	• Over allocation or misuse of water resources • Loss of wetlands • Poor riparian canopy conditions	• Revegetate open riparian areas • Assess water withdrawals • Restoration and protection of wetlands	• Sediment, temperature and nutrient reductions. • Changes in flow regime
Large Woody Debris	• Instream wood removal • Undersized culverts • Lack of recruitment	• Installation of log jams • Riparian fencing • Revegetate open riparian areas	• Increase in LWD
Floodplain	• Riprap, parallel roads limit meandering • Lack of wetlands restricts flood water storage capacity • Removal of beaver	• Reconnect, enhance, and/or restore potential off-channel, • floodplain, and wetland habitat • Remove hard armoring (riprap)	• Changes in flow metrics • Sediment and nutrient reductions

3.2 Study area and surroundings

The Newaukum River watershed drains 158 square miles and is located within the Upper Chehalis watershed (Figure 1). The mainstem Newaukum River enters the Chehalis River near river mile (RM) 75.2, south of the City of Chehalis. It has a low gradient and runs through farmland. The mainstem Newaukum River is formed by the convergence of the North Fork Newaukum River and the South Fork Newaukum River.

- The **North Fork Newaukum River** originates in steep hills and then flows into a broad valley in its lower reaches. Stream gradients are steep in the upper North Fork watershed. In the lower ten miles of the river the stream gradient is moderate. The middle and upper watershed are dominated by private timber lands. Land use in the lower watershed is primarily agriculture. Larger tributaries to the North Fork include the Middle Fork Newaukum River and also Lucas, Bear, Mitchell, and Johns Fork Creeks.

- The **Middle Fork Newaukum River** is the shortest of the three forks and originates near the base of the Cascade Mountain Range. Gradients are moderate, and the stream flows through mostly open and hilly terrain. The Middle Fork joins the North Fork approximately one mile upstream of the North and South Fork confluence. Land use in the watershed is primarily timber lands.

- The **South Fork Newaukum River** originates in the steep terrain of the Cascade Mountain Range. In the upper watershed, the stream gradients are steep and the channel is narrow. As the river heads into Newaukum Lake, the terrain begins to broaden and the gradient moderates. Land use in the upper watershed is dominated by forestry, while land use in the lower watershed is a mix of agriculture, residential, and forestry.

The City of Napavine is the only incorporated city within the Newaukum River watershed. Napavine has a population of 1988 and covers approximately 4.8 square miles across the upper mainstem of the Newaukum River. Portions of the City of Chehalis and its urban growth cross the watershed boundary near the mainstem Newaukum River. The second largest community within the watershed is the unincorporated town of Onalaska, located near the South Fork Newaukum River.

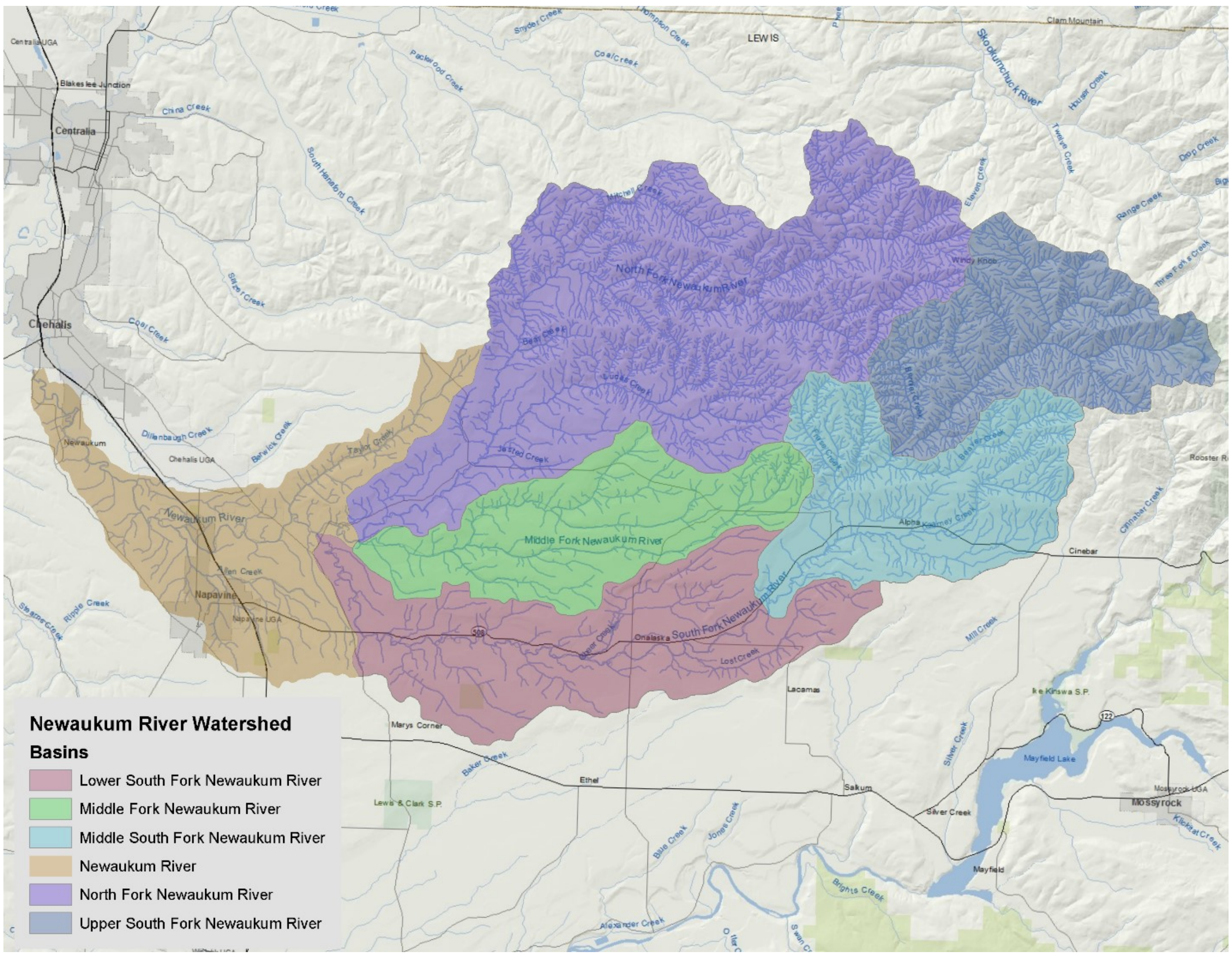

Figure 1. Newaukum River watershed study area.

Land use

Figure 2 shows land use in the Newaukum River watershed. Greater than 70% of the land use in the watershed is classified as resource production (timber harvest). Residential and agricultural land uses make up 12% and 10% respectively. Resource production is dominant in the upper watershed while residential and agricultural parcels are along the stream corridors of the waterways.

A comparison of land use classification between 2006 and 2016 indicate major land use categories which increased in land coverage (acres) within the watershed, including resource production and residential parcels. Major land categories that decreased in size over time included agriculture and undeveloped properties (Figure 3). The total number of parcels in the watershed increased from 6066 in 2006 to 6389 in 2016. Most of the increase was from the sub-division of undeveloped land into residential.

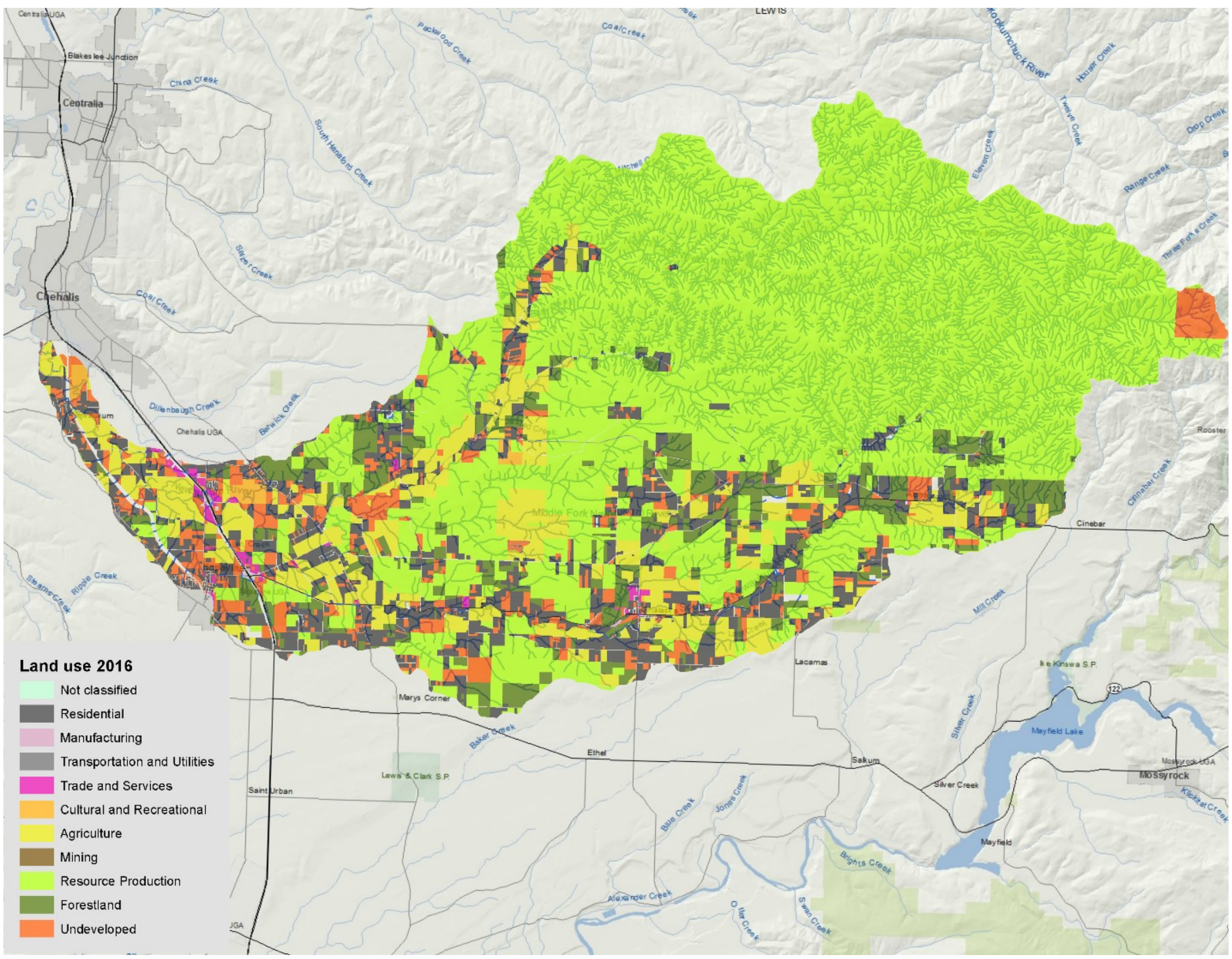

Figure 2. Land use classification in the Newaukum River watershed, 2016.

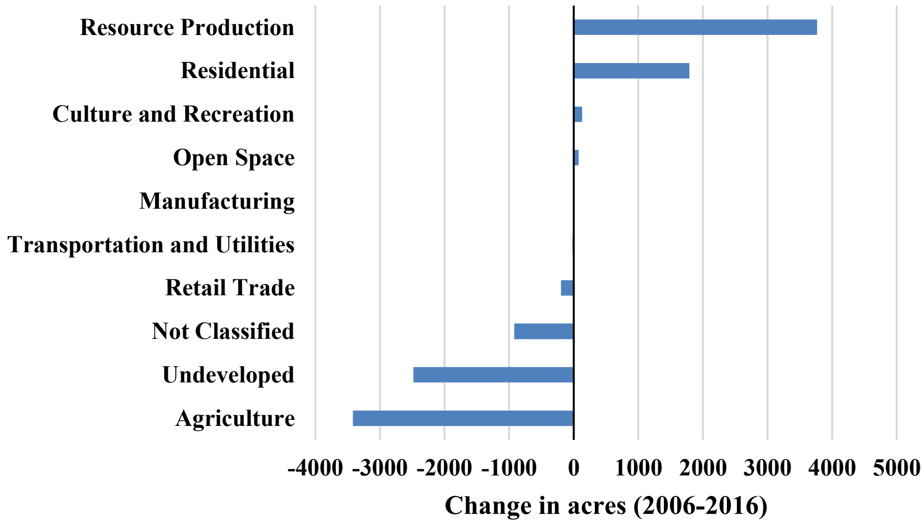

Figure 3. Land use classification changes in the Newaukum River watershed, 2006-2016.

Hydrology

Figure 4 illustrates stream discharge patterns of the Newaukum River 4.1 miles upstream of the confluence with the Chehalis River (USGS 120205000). Flows typically begin increasing in October-November before peaking in January. Flows drop quickly from April through July and reach the yearly low-flow period in September. Discharges in excess of 10,000 cfs occasionally occur. Figure 5 illustrates annual peak flow at this station from 1929-2015. Best fit line indicates peak flows have been increasing over time in addition to becoming more variable.

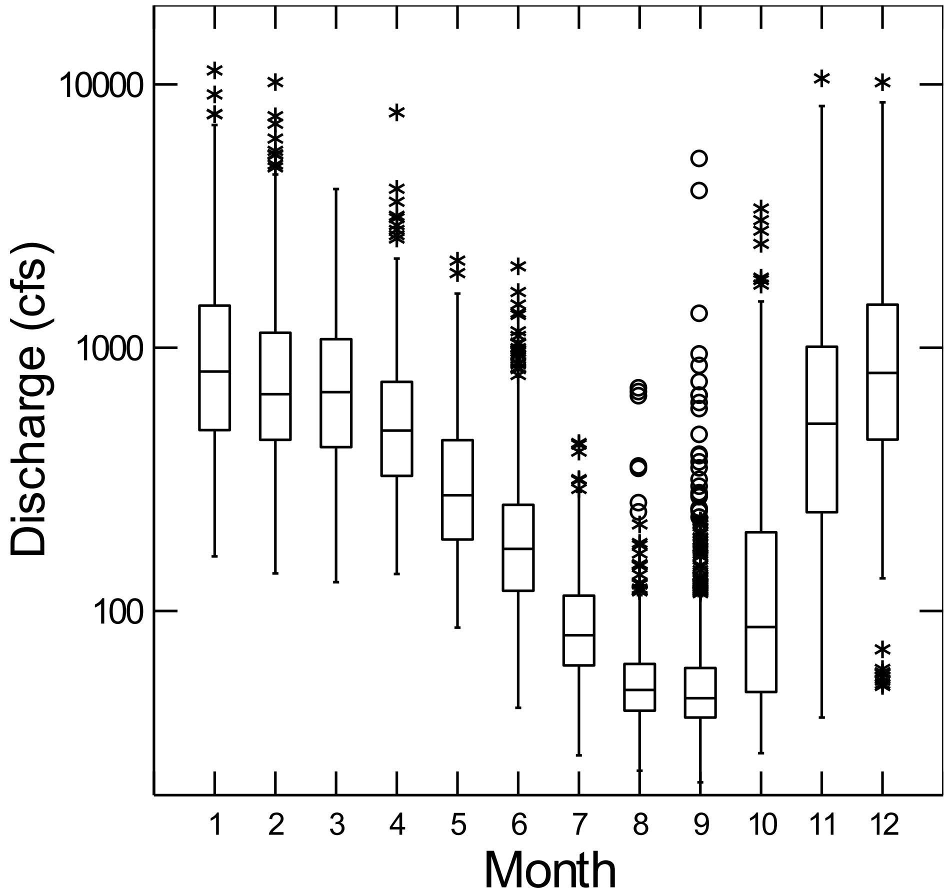

Figure 4. USGS stream-gage monthly flow statistics for Newaukum River near mouth, 1929-2017.

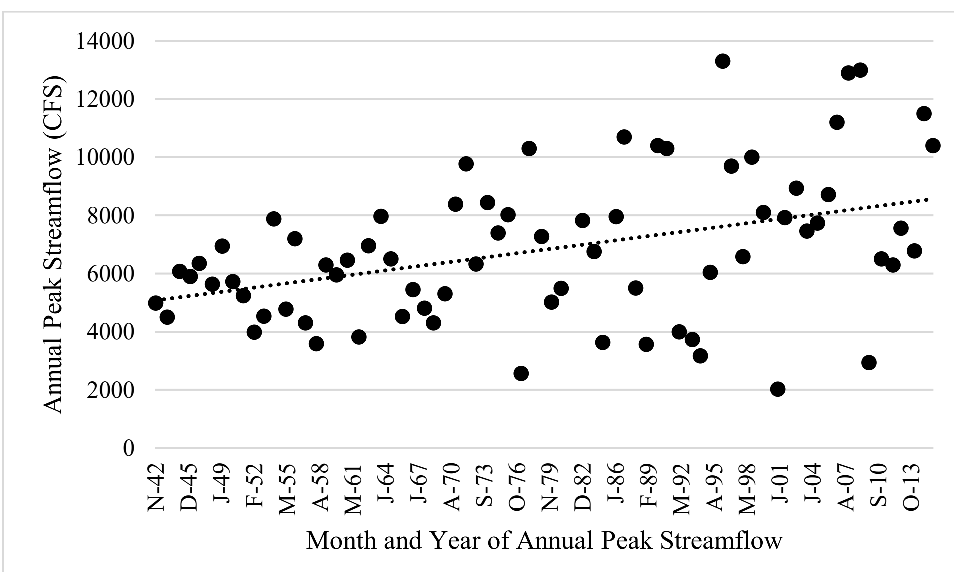

Figure 5. Annual peak flow from USGS (120205000) gage station at Newaukum River near Chehalis, 1942-2013.

3.2.1 History of study area

Many of the streams in the Upper Chehalis watershed are of great significance to the commercial and sport fishing industry locally and up and down the western coast of North America (Wildrick et al., 1995). The Newaukum River is a part of the Upper Chehalis watershed and is an important stream for anadromous fish (Verd and Wilson, 2002). Spring Chinook, fall Chinook, Coho, winter steelhead, cutthroat trout and other native char all use the watershed for spawning, rearing, and summer habitat (Wildrick et al., 1995).

As early as 1975, it was documented that low summer flows coupled with habitat degradation were factors limiting the size of fish populations (Phinney and Bucknell, 1975). Further study in the early 1990s showed that common degradations in the Upper Chehalis watershed included: canopy and vegetation loss along stream banks, bank erosion by livestock and vehicles, barriers and logjams, excessive stream siltation, logging impacts, and poor water quality (Wampler et al., 1993).

Water quality degradations in the Upper Chehalis watershed were documented in a Total Maximum Daily Load (TMDL) study in 1994 (Pickett, 1994) as well as a separate TMDL study for dissolved oxygen in 2000 (Jennings and Pickett, 2000). Currently, the mainstem and three tributaries of the Newaukum River have at least one water quality impairment. There are multiple water quality impairments on several sections of the South Fork Newaukum River. Table 2 summarizes the water quality impairments for the Newaukum River watershed.

Table 2. Water quality impairments for the Newaukum River watershed.

Waterbody Name	Parameter	Impairment Category
Mainstem Newaukum	Temperature	4a
	Dissolved Oxygen	4a
	Bacteria	4a
South Fork Newaukum	Temperature	4a
	Dissolved Oxygen	4a
	Bacteria	2
	Temperature	2
Middle Fork Newaukum	Dissolved Oxygen	4a
	Bacteria	2
	pH	2
	Temperature	2
North Fork Newaukum	Temperature	4a
	Dissolved Oxygen	4a
Carlisle Lake	Bacteria	5
	Total Phosphorus	5

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

3.2.2 Summary of previous studies and existing data

No studies specific to the Newaukum River watershed were identified with Ecology's Environmental Information Management System (EIM). Instead, studies were focused on the Upper Chehalis River watershed or the greater Chehalis River basin (Table 3).

Table 3. Newaukum River water quality, habitat, and biological data in EIM.

EIM Study ID	Description	Collection Date
AMS001-2	Statewide River and Stream Ambient Monitoring	2015-present
AMS001B	Statewide River and Stream Ambient Monitoring	1960-1977
AMS001D	Statewide River and Stream Ambient Monitoring	1992-1997
BEDI0001	Chehalis River Basin Water Quality Screening Study	1991
fwbenth1	Ecology's Freshwater Ambient Biological Assessment Program	1998
G0200280	Chehalis River Council Volunteer Monitoring Project	2002-2006
G0700116	WRIA 22-23 Water Quality Monitoring	2006-2009
GAP0001	GAP Chehalis	2003
PPIC0002	Upper Chehalis River TMDL	1991-1992
SWROSWDB	Ecology's Southwest Regional Office Surface Water	1986-1991
WHM_WAM0	Ecology's Watershed Health Monitoring	2010, 2014

Relevant sample parameters from each monitoring effort are summarized in the preceding sections. Figure 6 shows the monitoring locations, and Figure 7 summarizes data described from the preceding sections. Flow data collected by the United States Geological Survey (USGS) in the watershed is presented in Figures 4 and 5.

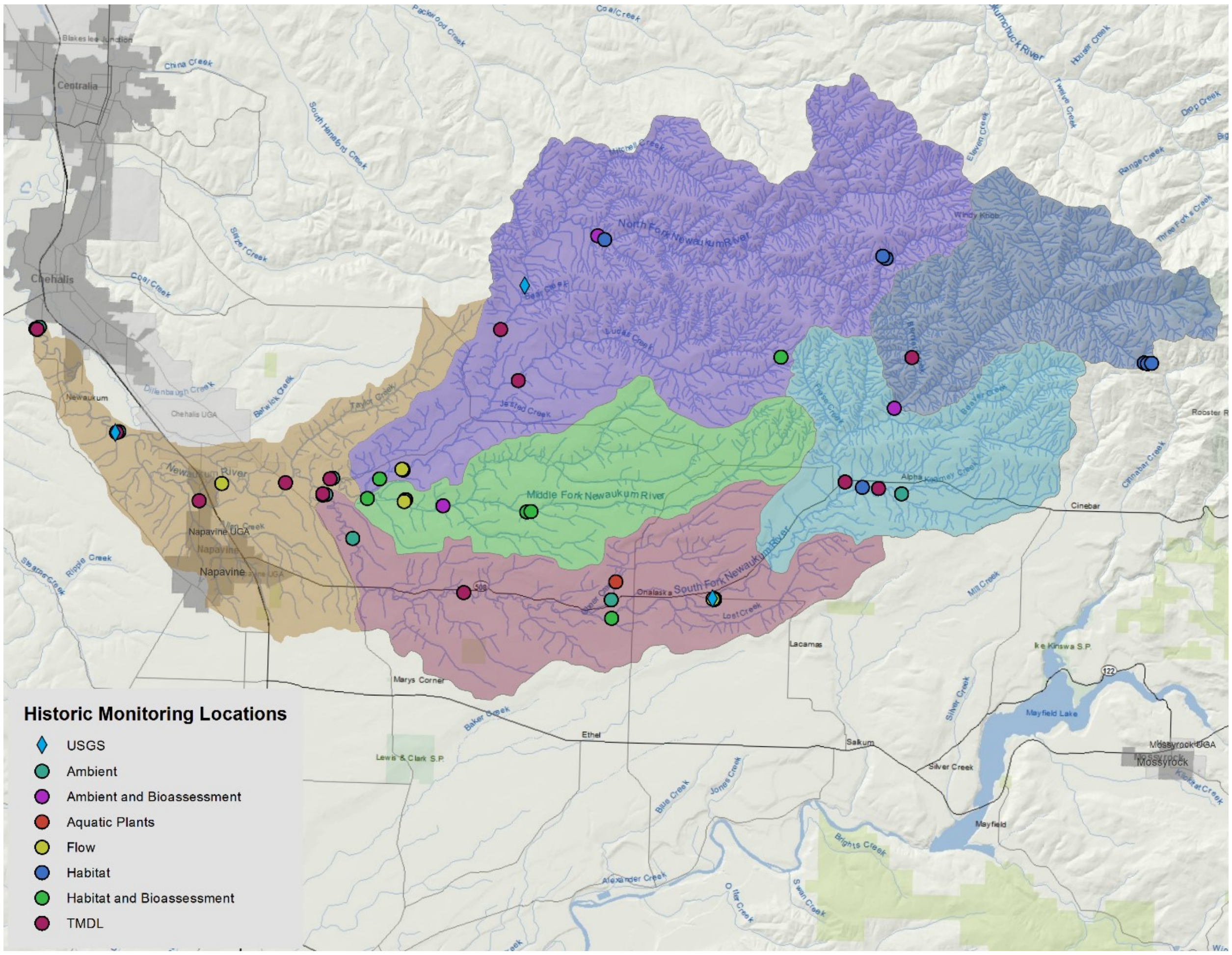

Figure 6. Map showing the locations and types of past monitoring in the Newaukum River watershed.

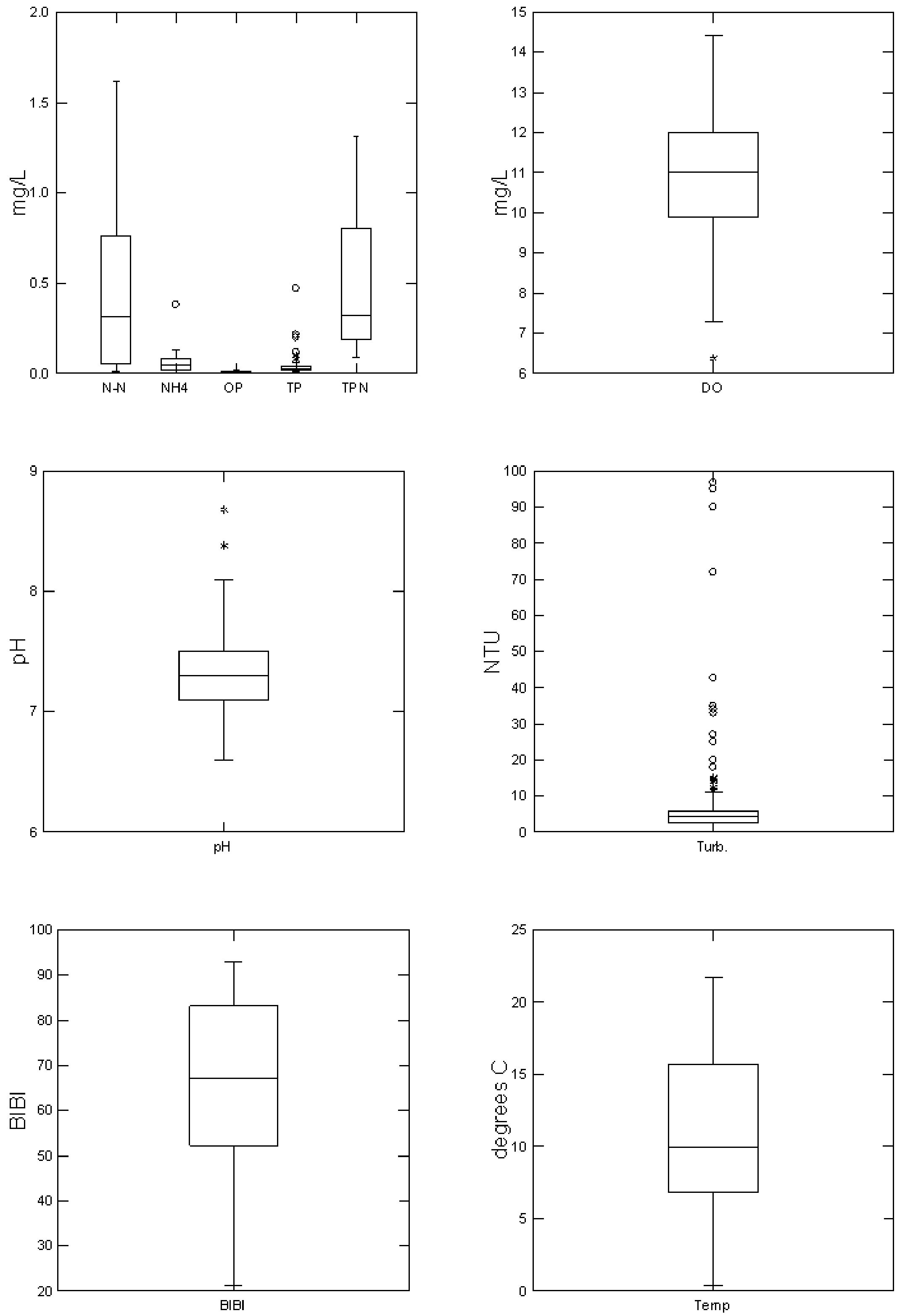

Figure 7. Summary of relevant water quality data from the Newaukum River watershed, 1960 to present.

3.2.2.1 Ecology Ambient Water Quality Monitoring Program

Ecology has a statewide network of stations that are sampled monthly for conventional water quality parameters. There are 62 long-term stations and 20 rotating stations. Monitoring occurs on a water year basis which runs from October 1 to September 30. The Newaukum River does not have any long-term stations but had two short-term stations. One station was located at the mouth of the mainstem Newaukum River in water year 1993. The other station was located on the mainstem Newaukum River at LaBree Road in water year 1997. This station has recently been reinstated and now has continuous and discrete data collection.

3.2.2.1 Chehalis River Basin Water Quality Screening Study

To better manage the Chehalis basin, the Chehalis Tribe in collaboration with Grays Harbor Community College studied water quality in the Chehalis River and its tributaries. Beginning in 2006, monthly water samples were collected from 86 sites. These samples were analyzed for dissolved oxygen, pH, temperature, turbidity, and fecal coliform. Sampling continued through 2009. Data from the Newaukum River show that overall pH falls within water quality criteria. The exception is the mainstem Newaukum River at Shorey Road. Dissolved oxygen, turbidity, and water temperature data show degraded water quality at all sampling locations when compared to water quality criteria. As is described in Green et al. (2009), impacts to water quality were seasonal and parameter specific.

3.2.2.2 Upper Chehalis River TMDL

Data collected from the Newaukum River by the Upper Chehalis River Dry Season TMDL show degraded water quality in the Newaukum River watershed. Dissolved oxygen and temperature do not meet water quality standards. The study indicates that the temperature problems in the Newaukum River watershed are due to loss of riparian canopy vegetation as documented by the USFWS (Pickett, 1994). To improve temperature and riparian canopy the TMDL recommends implementing best management practices (BMPs) to restore riparian vegetation.

3.2.2.3 Washington State Department of Ecology's Watershed Health Monitoring Program

The Watershed Health Monitoring (WHM) program samples streams and rivers across the state to provide a consistent representation of habitat and biological conditions. WHM is designed to answer questions about the overall conditions within watersheds and how conditions change over time (Hartman, 2015). Although the WHM program uses a statistical survey design to answer larger scale (Salmon Recovery Regions) questions of watershed health, the methodologies are applicable to smaller scale, targeted designs. This allows data to be compared and assessed with a larger statewide and national network of similar data collection efforts.

3.3.2.4 Watershed Health Assessment of Culvert Replacement

In 2016, Ecology conducted watershed health assessments on the Middle Fork Newaukum River above and below the site of a culvert replacement project. The primary goal of this project was to assess the practicality of using WHM methods to detect impacts from undersized culverts on instream habitat and biological conditions. A secondary goal of this assessment was to use the same methods to measure habitat and biological changes after replacement of the culvert with a bridge over time. In total, 11 habitat metrics used to describe bed load/stability, channel scouring, entrenchment, canopy cover and pool area were identified. Downstream and upstream results and expected change to downstream metrics over time are presented in Table 4.

These metrics provide the basis for development of the long-term monitoring of selected BMPs described in this QAPP.

A full list of available WHM metrics are presented in Appendix B.

Table 4. Results of Watershed Health Monitoring (WHM) downstream and upstream of culvert on the Middle Fork Newaukum River.

Metric	Units	Downstream	Upstream	Expected Downstream Change
Mean Substrate size	mm	33.1	12.9	Decrease
Mean Embeddedness	%	35	27	Decrease
Large Woody Debris	(m^3/100m)	0.011	0.007	Unknown
Bed Stability	-	-1.9	-2.1	Increase
Canopy Cover	%	58	51	None
Sinuosity	-	1.26	1.39	Increase
Slope	%	2	1.7	Decrease
With to Depth	cm	32.6	25.0	Decrease
Bankfull Area	m^2	4107	2948	Decrease
Pool Area	m^2	27	17	Decrease
Pool Depth	cm	74.4	49.6	Decrease

3.2.3 Implementation assessment

Each year in Washington State, several federal, state, and local agencies award millions of dollars in grants and loans to protect, restore, or enhance degraded waterbodies. Although many of these projects are not implemented as the result of the TMDL process, most contribute to net improvements in water quality and watershed health. When effectiveness assessments are made at a watershed scale, all such actions should be taken into account in order to provide a comprehensive assessment. With a more holistic view of actions, stakeholders from various groups may more easily become aligned with similar goals and make informed decisions regarding future projects.

Washington's Recreation and Conservation Office (RCO) provides funding for building community recreational opportunities and for protecting and restoring wild areas. Grants and projects implemented within this framework are tracked via two databases. RCO's Project Information System (PRISM) tracks both recreational and restoration grants. Habitat Work Schedule system is a mapping and project tracking tool that allows community-based salmon recovery programs (Lead Entity Program) to share habitat protection and restoration projects with funders and the public. Both databases provided summaries and outcomes of grant projects at a site scale.

For purposes of this assessment, grant, loan, and project data for activities implemented within the Newaukum River watershed area were obtained from three sources; Ecology's Water Quality Program (WQP), Habitat Work Schedule, and PRISM. In excess of 2.3 million dollars grants and loans were given to recipients to implement pollution prevention and restoration projects in the watershed since 1990 (Figure 8).

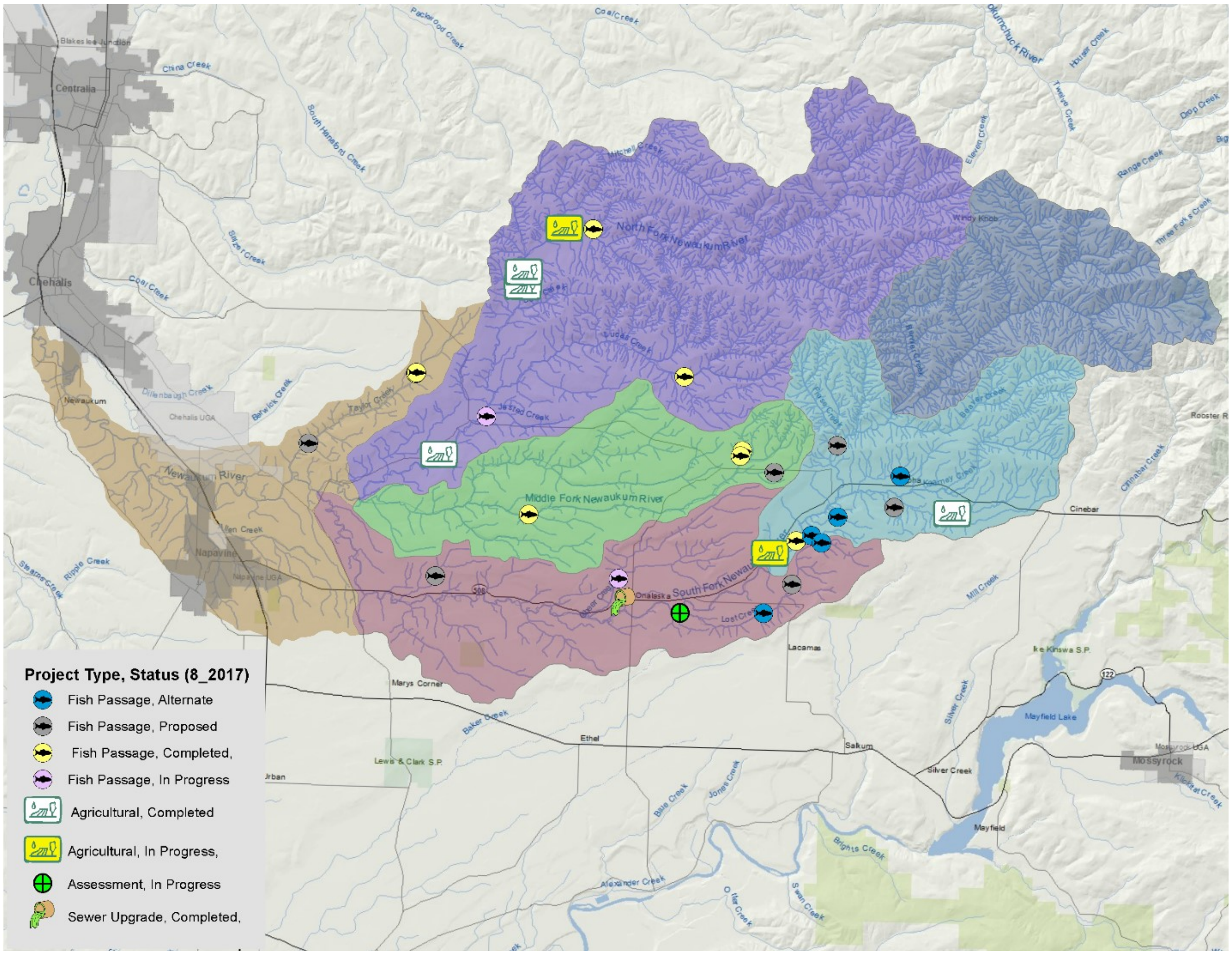

Figure 8. Overview of projects implemented in the Newaukum River watershed, 1990-2017.

Although this list includes much of the implementation work in the watershed, it does not account for all projects. Lewis County and the Washington Department of Transportation (WSDOT) support capital improvement projects as well as ongoing stormwater and OSS management, inspection, and enforcement programs within the watershed. In addition, implementation and periodic updates of local land use ordinances can affect water quality over time. Likewise, the Lewis County Conservation District, the Natural Resources Conservation Service, and other state and federal agencies provide assistance to agricultural operations to protect water quality, and these are not factored into this assessment.

Table 5. Additional sources of Newaukum River water quality data.

Site ID	Description	Period of Record	Parameters
USGS 12024000	Newaukum River near Chehalis	1929-present	Discharge
USGS 12024400	NF Newaukum River above Bear Creek	1997-present	Flow, precipitation
USGS 12025000	SF Newaukum River near Onalaska	1998-present	Flow, precipitation

3.2.3 Parameters of interest and potential sources

3.2.3.1 Parameters of interest

This study addresses all 303(d) parameters in the Newaukum watershed (Table 2). Past studies within the Chehalis River basin indicate that these parameters are generally driven by excess nutrients, sediment, high temperature and low streamflows (Pickett, 1994). Because of this, the study will also focus on using temperature, discharge, sediment and nutrient loading as the primary indicators of water quality improvements. Monitoring of these parameters will occur at the watershed (Hydrologic Unit Code (HUC) 10) and sub-watershed scale (HUC 12). In addition, biological and habitat data obtained from watershed health surveys will be used to assess changes over time at the project scale as appropriate.

3.2.3.2 Nonpoint sources

Nonpoint sources of pollutants contributing to water quality issues in the watershed may include diffuse sources of nutrients, sediment, heat and lack of flow. Excess nutrients and lack of riparian vegetation along reaches can cause excessive growth of aquatic plants and algae. This may lead to low dissolved oxygen levels in the summer months.

Residential and urban areas supply nutrients via overland run-off and can have bare riparian areas. Fertilizers, on-site septic systems, and pets or small hobby farms can be sources of nutrients as well as sediment. Riprap used to prevent channel migration and flooding to residential areas is not uncommon in this watershed and can cause downstream scouring of the stream channel.

Timber management and farming practices are potential sources of nutrients and sediment. Much of the watershed is designated as private timberlands which are managed through implementation of Washington forest and fish laws to meet federal Clean Water Act requirements. The majority of the farming in the Newaukum includes hay production and commercial tree farming. Also, there are five dairies operating in the watershed and several small livestock operations.

3.2.3.3 Point Sources

The Newaukum River watershed has one permitted wastewater facility. Residences and businesses in the town of Onalaska rely on a small facility for wastewater treatment which discharges into the South Fork of the Newaukum River at river mile 20.1. The facility is operated by the Lewis County water district (Table 6).

The City of Napavine operates its own wastewater collection system; however, wastewater is processed by a regional wastewater treatment plant in Chehalis.

Stormwater in the watershed is covered under the City of Chehalis Municipal Stormwater Permit which regulates pollutants carried to waterbodies within the urban growth areas by stormwater. The Washington State Department of Transportation (WSDOT) also has a stormwater permit which covers runoff from state highways and associated facilities. Table 6 lists all current permitted point sources in the Newaukum River watershed.

Table 6. Permitted point sources in the Newaukum River watershed.

Facility	Permit Number	Permit Type	City	Waterbody
Lewis County Water District 2	WA0024546	Municipal	Onalaska	SF Newaukum
Butteville Lumber Company	WAR010301	Industrial	Onalaska	SF Newaukum
Onalaska Wood Energy	WAR303014	Industrial	Onalaska	SF Newaukum
WSDOT SR 508 SF Newaukum Bridge	WAR304722	Construction	Onalaska	SF Newaukum
Lewis County PW Union Vegetation	WAG501487	Sand and Gravel	Chehalis	Newaukum

3.2.4 Regulatory criteria or standards

The Clean Water Act (CWA) established a process to identify and clean up polluted waters. The CWA requires each state to develop and maintain water quality standards that protect, restore, and preserve water quality. Water quality standards consist of:

- A set of designated uses for all water bodies, such as salmon spawning, swimming, and fish and shellfish harvesting.
- Numeric and narrative criteria to achieve those uses (Table 7).
- An antidegradation policy to protect high-quality waters that surpass these conditions.

Ecology has established designated uses for the mainstem Newaukum River and all three of its forks: North, Middle, and South. These are established to protect aquatic life, recreation, water supply, and other miscellaneous uses. The Newaukum River and all three forks are designated for primary contact recreation, core summer habitat, and char spawning and rearing (WAC 173-201A-600).

Table 7. Applicable water quality criteria for the Newaukum River watershed.

Parameter	Criteria
Bacteria	Fecal coliform organism levels must not exceed a geometric mean value of 100 colonies /100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 200 colonies /100 mL.
Dissolved Oxygen	Dissolved oxygen (DO) concentration will not fall below 9.5 mg/L more than once every ten years on average. When a water body'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 12°C for char spawning and rearing and 16°C for core summer salmonid habitat more than once every ten years on average. When a water body'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.
Turbidity	Turbidity shall not exceed: 5 nephelometric turbidity units (NTU) over background when the background is 50 NTU or less or a 10 percent 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 a human-caused variation within above range of less than 0.5 units.

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).
- QAPP: Ambient Biological Monitoring in Rivers and Stream: Benthic Macroinvertebrates and Periphyton (Merritt, 2009).

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

Several best management practice (BMP) projects designed to enhance fish passage, stabilize river banks, and improve riparian habitat have been selected for implementation. While the fish passage BMPs are intended to enhance fish passage by removing barriers, they will ultimately help to restore sediment and nutrient transport as well as improve the overall quality of the water and aquatic habitat. Riparian habitat improvement and bank stabilization BMPs will reduce bank erosion and improve riparian vegetation, which will reduce fine sediment concentrations and lower water temperature in streams (Medina et al., 2005; Roni et al., 2008; Lawrence et al., 2013; Bassett, 2009).

The intention of this study is to collect data to help assess the collective effectiveness of best management practices (BMPs) on improving water quality and habitat conditions in the watershed at multiple scales over time (Table 8). Many, if not all of actions identified in both the TMDL (Pickett, 1999) and the *Chehalis Basin Salmon Habitat Restoration and Preservation Strategy for WRIA 22 & 23* (Grays Harbor County Lead Entity Habitat Work Group, 2011) would address sediment and nutrient inputs into surface waters as well as improve temperature. Thus the primary focus of this study will be to use discharge, sediment, and nutrient data to estimate loading in the Newaukum River mainstem and its three main tributaries (South Fork, Middle Fork and North Fork) over time.

A secondary focus of this study is to assess the effectiveness of a subset of individual BMPs implemented during the study period using standard habitat and biological assessments. In addition, a combination of bracketed discrete and continuous water quality monitoring will occur to assess 303(d) listed parameters and help identify or eliminate potential sources of pollutants.

Table 8. Core water quality sampling locations, scale of assessment, sampling schedule, and expected time for water quality response to implementation actions.

Location	Scale	Anticipated Period of Record	Expected Response Time
Mainstem Newaukum near mouth	HUC 10	2017-2027	Decades
North Fork Newaukum	HUC 12	2017, 2022, 2027	Years-Decades
Middle Fork Newaukum	HUC 12	2017, 2022, 2027	Years-Decades
South Fork Newaukum	HUC 12	2017, 2022, 2027	Years-Decades
Middle Fork Newaukum	Site Scale	2016, 2017, 2022, 2027	Years

Scale of Monitoring

Watershed (HUC 10)

Beginning in 2017, nutrient and sediment loading be will estimated continuously at the mouth of the mainstem Newaukum River. These data will be considered baseline and used to assess long-term changes over time at a watershed scale. Data collection at Ecology's ambient and continuous water quality monitoring station (23B070) will be used for this assessment. Implementation actions categorized and summarized at this scale will be compared with water quality data over time.

Sub-watershed (HUC12)

Short-term sediment and nutrient loads will be estimated near the mouths of the North, Middle, and South Forks of the Newaukum using a combination of continuous stage, turbidity, and monthly grab samples. Effectiveness of BMPs at these scales will be assessed by estimating load reductions over time in relation to cumulative implementation of projects above each sampling location over time.

Project scale monitoring

To assess changes in habitat and biological conditions, watershed health assessments will be conducted over time for a select number of BMPs. These assessments will be conducted by Ecology's Watershed Health Monitoring (WHM) program. An overview of sampling activities by station is provided in Figure 9. Monitoring will begin before the BMPs are implemented and continue over a 10-year period. Currently, two culvert-replacement projects within the Middle Fork Newaukum River have been identified and will be assessed. Monitoring will occur either upstream, downstream or within BMP treatment areas in order to capture the overall change. If opportunity arises within the study period, additional BMPs will be considered for this type of assessment.

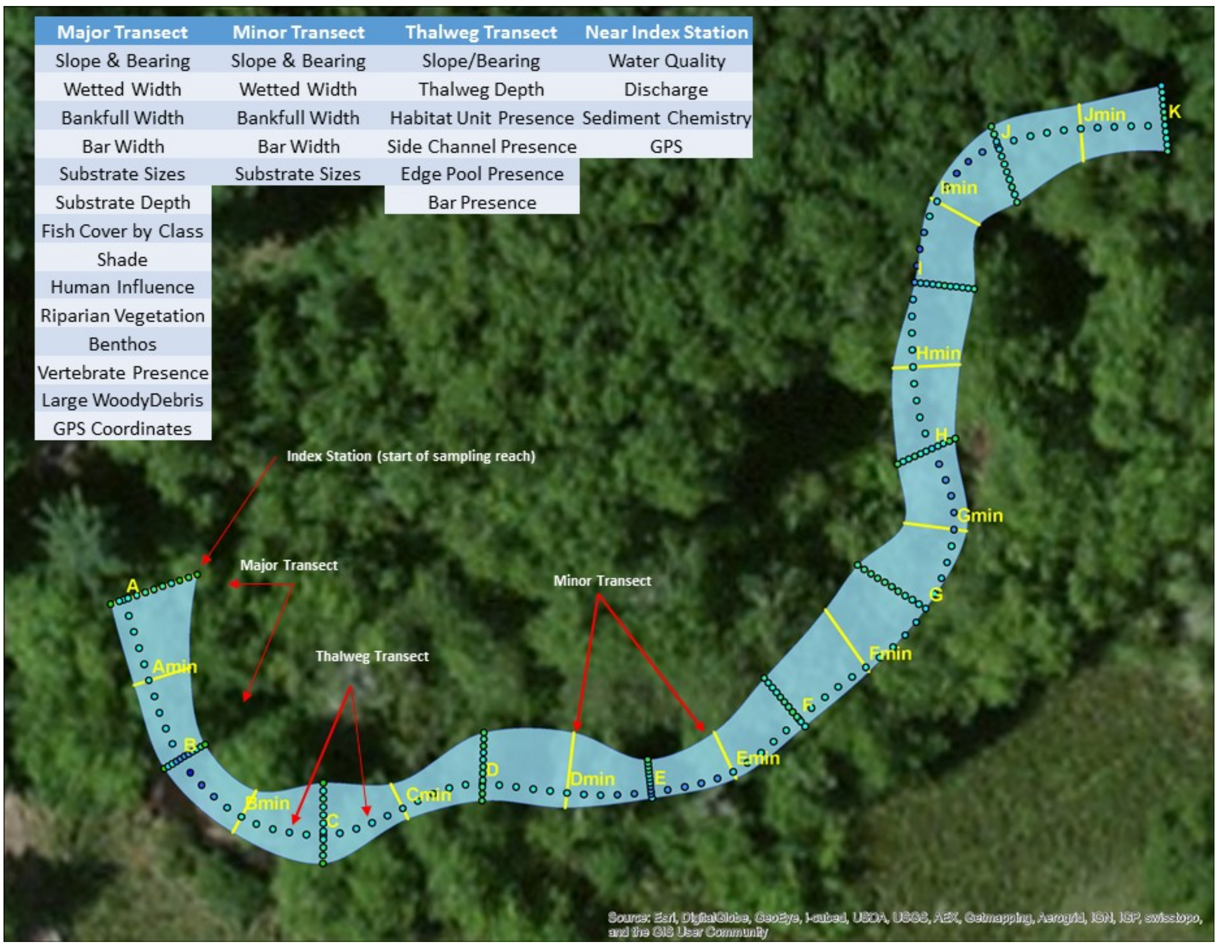

Figure 9. Sampling activities within a watershed health assessment reach.

4.1 Project goals

The goals of this study are to:

- Assess the collective effectiveness of BMPs at a watershed (HUC 10) and sub-watershed scale (HUC 12) at reducing sediment and nutrient loading over time.
- Assess the effectiveness of a sub-set of individual BMPs at the site scale using water quality, habitat and biological parameters over time.
- Identify and quantify sources of pollutants to help focus implementation activities in the watershed.
- Determine if water quality standards are being met in the watershed.

4.2 Project objectives

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

Watershed Scale

- Using existing USGS flow (12025000), Ecology ambient and continuous monitoring (23B070) on the Newaukum River near the mouth (Labree Rd) to develop continuous estimates of sediment and nutrient loading.
- Supplement existing ambient monitoring during the wet season and high-flow events.
- Establish one watershed health assessment site upstream of Labree Road.
- Catalog and map BMP activities and changes in land use throughout the watershed using geographic information systems (GIS) technology.
- Provide assessment of 303(d) listed parameters at this location.
- Compare and evaluate changes in water quality and habitat in relation to BMP implementation.

Sub-Watershed Scale

- Collect continuous stage and turbidity sites at North Fork Newaukum River near mouth (North Fork Rd), Middle Fork Newaukum River near mouth (off Rosebrook Rd), and the South Fork Newaukum near mouth (North Fork Road).
- Establish ambient monitoring stations at these locations.
- Establish one watershed health assessment site upstream of water quality sampling locations.
- Catalog and map BMP activities and land use changes throughout the sub-watershed using geographic information systems (GIS) technology.
- Provide assessment of 303(d) listed parameters at these locations.
- Compare and evaluate changes in water quality and habitat in relation to BMP implementation.

Site Scale

- Establish monitoring stations above and below two culvert replacement projects on the Middle Fork Newaukum River prior to replacement.

- Evaluate changes in habitat, biological condition, and fish populations over time above and below culvert replacement.
- Compare and evaluate changes in water quality and habitat in relation to BMP implementation.

Additional Sampling

- Conduct periodic discrete or continuous bracketed sampling of fecal coliform, nutrients, dissolved oxygen, pH, optical brighteners, and temperature within the watershed to assess water quality standards and identify or eliminate potential sources of pollution. Optical brighteners, contained in many laundry detergents, will be used to help identify potential sources of pollution. Because household plumbing systems mix effluent from washing machines and toilets together, optical brighteners are associated with human sewage in septic systems and wastewater treatment plants (Hartel, 2008).
- Collect periphyton biomass and use nutrient, metal, and nitrogen isotope measurements at bracketed sampling locations to identify potential sources of nutrient inputs. Periphyton readily accumulate both nutrients and metals in aquatic systems and can be indicative of surrounding land-use practices. Soil amendments such as fertilizers and chelates, which are commonly used in agricultural areas, can create acidic soils and promote the release of metals such as aluminum, iron, and phosphates as well as other compounds from the soils into aquatic systems (Yang, 2013).

If the opportunity arises, additional site-scale BMP projects may be assessed during this study. Study of these BMP projects will be dealt with through addenda to this QAPP.

4.3 Information needed and sources

- Nutrient, organic carbon, and sediment sample data – *to be collected by Ecology's Watershed Health & Effectiveness Monitoring Unit (WHEMU) during this project.*
- Continuous dissolved oxygen, pH, temperature, and turbidity data at the mouth of the Newaukum River mainstem – *to be collected by Ecology's Freshwater Monitoring Unit.*
- Continuous streamflow data – *three USGS gaging stations will be used.*
- Continuous gauge height, temperature, and turbidity data collected near the mouths of NF, MF, and SF of the Newaukum River – *to be collected by WHEMU during this project.*
- Habitat and biological data – *to be collected by WHEMU during this project.*
- Meteorology data – *daily precipitation will be obtained from the National Weather Service stations at the Chehalis Airport and USGS gaging stations.*
- Stream Shade data – *will be assessed by WHEMU with ArcGIS data.*
- Periphyton biomass data – *to be collected by WHEMU during this project.*
- Implementation information of water quality and habitat improvement projects – *to be collected though the Newaukum River watershed group, habitat work schedule, Washington State Fish Passage Map Application, and Ecology's grant management system.*

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, flow measurements, continuous stage, turbidity and temperature from NF, MF and SF Newaukum River near the confluences with the Newaukum River main stem.
- Perform watershed health assessments one time per year in conjunction with tributary water quality and flow monitoring.
- Document locations of BMPs, changes in land uses, and land use practices during the study period.

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 9 lists the key people involved with this project and their responsibilities.

Table 9. Organization of project staff and responsibilities.

Staff (All EAP except client)	Title	Responsibilities
Jessica Archer SCS Phone: 360-407-6698	Client and Section Manager for the Project Manager	Clarifies scope of the project. Provides internal review of the QAPP and approves the final QAPP.
Scott Collyard WHEM Unit, SCS Phone: 360-407-6455	Project Manager	Writes the QAPP. Conducts QA review of data, analyzes and interprets data, and enters data into EIM. Writes the mid-term monitoring report and final report. Reviews web content and story maps.
Jennifer Wolfe WHEM Unit, SCS Phone: 360-407-6672	Principal Investigator	Co-authors technical sections of the mid-term monitoring report and final report. Creates web content and story maps related to monitoring data and final report. Collects field samples and records field information. Assists project manager with project duties as needed.
Niamh O'Rourke WHEM Unit, SCS Phone: 360-407-7614	Field Lead	Collects samples and records field information. Oversees field sampling and transportation of samples to the laboratory.
Stacy Polkowske WHEM Unit, SCS Phone: 360-407-6730	Unit Supervisor for the Project Manager	Reviews and approves the project scope and budget, and tracks progress. Provides internal review of the QAPP, approves the final QAPP, and project associated reports.
Dale Norton Western Operations Section Phone: 360-407-6596	Section Manager for the Study Area	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.
William R. Kammin Phone: 360-407-6964	Ecology Quality Assurance Officer	Reviews and approves the draft QAPP and the final QAPP.

EAP: Environmental Assessment Program
EIM: Environmental Information Management database
QAPP: Quality Assurance Project Plan
SCS: Statewide Coordination Section
WHEM: Watershed Health and Effectiveness Monitoring

5.2 Special training and certifications

Key personnel involved in the collection of biological and habitat data and interpretation of results have extensive experience in similar efforts.

5.3 Organization chart

Table 9 lists the individuals involved in this project. All are employees of Ecology unless otherwise noted.

5.4 Proposed project schedule

This study is a multiyear study and is expected to be conducted over a ten year period (2017-2027). Water quality monitoring at the Newaukum River mainstem location is expected to be monitored yearly by Ecology Freshwater Monitoring Unit while other sampling is expected to occur every 5 years by Ecology Watershed Health & Effectiveness Unit. Field work described in proposed project schedule is for 2017-2018 however it is expected to be duplicated in subsequent years.

Field work will be performed during the following time periods:

- Water quality sampling – July 2017 through September 2018.
- Dry season bracketed water quality sampling – August through September 2017.
- Wet season bracketed water quality sampling – December 2017 through May 2018.
- Watershed health assessments – September 2017.

Table 10 shows the schedule for completing field and laboratory work, data entry into EIM, and reports. Field, laboratory, and EIM dates are for the 2017 study year. The final report due dates are at the end of the 10-year study period. Table 10 shows annual deliverables over the 10-year study period.

Scheduling future work will be addressed in addenda to this QAPP prior to each proposed sampling event (Table 11). Interim results will be reported through development of a project web page and data summary reports. A final report is expected to be produced following completion of the final study.

Table 10. Proposed schedule for completing field and laboratory work, data entry into EIM, and reports for 2017-2019 study period.

Field and laboratory work	**Due date**	**Lead staff**
Field work completed	Oct 2018	Jenny Wolfe
Post sample processing	Jan 2019	
Laboratory analyses completed	Feb 2019	
Taxonomic analyses completed	May 2019	
Environmental Information System (EIM) database		
EIM Study ID	WHM_EFF3	
Product	Due date	Lead staff
EIM data loaded	Jan 2019	TBD
EIM data entry review	Feb 2019	TBD
EIM complete	Mar 2019	TBD
Taxonomic data loaded (EIM)	May 2019	TBD
Taxonomic data entry review (EIM)	June 2019	Chad Larson
Taxonomic data complete (EIM)	July 2019	TBD
Final report		
Author lead / Support staff	Scott Collyard	
Schedule		
Draft due to supervisor	Dec 2028	
Draft due to client/peer reviewer	Jan 2029	
Draft due to external reviewer(s)	Feb 2029	
Final (all reviews done) due to publications coordinator	Mar 2029	
Final report, story map update due on web	April 2029	

TBD – to be determined

Table 11. Proposed long-term monitoring schedule for completing project.

Sampling period	**Station**
2017-2029	Ambient and continuous water quality monitoring of mainstem Newaukum River
2017, 2022, 2027	North Fork (NF) Newaukum River
2017, 2022, 2027	South Fork (SF) Newaukum River
2017, 2022, 2027	Middle Fork Newaukum River

5.5 Budget and funding

The estimated annual laboratory budget and number of lab samples shown in Table 12 are based on the proposed schedule in Tables 9 and 10. Efforts will be made to keep the submitted number of samples within the estimate; however, this is only an estimate.

Table 12. Annual project budget.

Parameter /Analysis	Sites	Surveys	Field Replicates	Total Samples	Cost per Sample ($)	Subtotal ($)
Ambient Monitoring						
Ammonia-N	4	22	3	91	$15	1365
Nitrate + nitrite-N	4	22	3	91	$15	1365
Total persulfate nitrogen	4	22	3	91	$20	1820
Orthophosphate	4	22	3	91	$20	1820
Phosphorus, total	4	22	3	91	$20	1820
Total suspended solids	4	22	3	91	$15	1365
Suspended sediment concentration	4	22	3	91	$20	1820
Fecal coliform (MF)	4	22	3	91	$25	2275
E. coli (MF)	4	22	3	91	$25	2275
Total						$15925
Storm-Event Ambient Monitoring						
Persulfate nitrogen, total	4	5	1	21	$20	420
Phosphorus, total	4	5	1	21	$20	420
Total suspended solids	4	10	1	41	$15	615
Suspended sediment concentration	4	10	1	41	$20	820
Total						$2275
Watershed Health Assessment						
Periphyton taxonomy	10	1	1	11	$310	$3,410
Macroinvertebrate taxonomy	10	1	1	11	$300	$3,300
Sediment metals[1]	10	1	1	11	$193	$2,123
Sediment total organic carbon	10	1	1	11	$50	$550
Persulfate nitrogen, total	10	1	1	11	$20	$220
Phosphorus, total	10	1	1	11	$20	$220
Chloride	10	1	1	11	$15	$165
Turbidity	10	1	1	11	$15	$165
Total suspended solids	10	1	1	11	$15	$165
Chlorophyll a, periphyton	10	1	1	11	$50	$550
Ash free dry weight, periphyton	10	1	1	11	$25	$275
Total solids, periphyton	10	1	1	11	$30	$330
Total metals[1] , periphyton	10	1	1	11	$193	$2,123

Parameter /Analysis	Sites	Surveys	Field Replicates	Total Samples	Cost per Sample ($)	Subtotal ($)
Percent total organic carbon, periphyton	10	1	1	11	$50	$550
Total carbon/nitrogen, periphyton	10	1	1	11	$50	$550
15N, 13C periphyton	10	1	1	11	$58	$638
Total						$15,334
Periphyton Source Assessment						
Ash free dry weight, periphyton	10	1	1	11	$25	$275
Total solids, periphyton	10	1	1	11	$12	$132
Total metals[1], periphyton	10	1	1	11	$193	$2123
Percent total organic carbon, periphyton	10	1	1	11	$46	$506
Total carbon/nitrogen, periphyton	10	1	1	11	$50	$550
15N, 13C periphyton	10	1	1	11	$58	$638
Total						$8184
Carlisle Lake						
Chlorophyll-a	3	4	1	15	$50	$750
Orthophosphate	3	4	1	15	$20	$300
Total Phosphorus	3	4	1	15	$20	$300
Fecal coliform	3	4	1	15	$25	$375
						$1725
Water Quality Source Assessment						
Fecal coliform (MF)	10	12	2	120	$25	$3000
E. coli (MF)	10	12	2	120	$25	$3000
Total						**$6000**
Study Total						**$49443**

[1] Al, As, Cd, Cu, Fe, K, Mn, Mg, TP, Pb, Zn

6.0 Quality Objectives

Quality objectives are statements of the precision, bias, and lower reporting limits necessary to meet project objectives. Precision and bias together express data accuracy. Other considerations of quality objectives include representativeness, completeness, and comparability. Quality objectives apply equally to laboratory and field data collected by Ecology, to data used in this study collected by entities external to Ecology, and to other analysis methods used in this study

6.1 Data quality objectives

The main data quality objective (DQO) for this project is to collect water quality, biological, and habitat data in the Newaukum River watershed using standard methods that meet the measurement quality objectives (MQOs) for this project.

6.2 Measurement quality objectives

MQOs are performance or acceptance criteria for individual data quality indicators, including precision, bias, sensitivity, completeness, comparability, and representativeness. Field sampling procedures and laboratory analyses inherently have associated uncertainty, which results in data variability. Together precision and bias express data accuracy. MQOs apply equally to laboratory and field data collected by Ecology, to data collected by entities external to Ecology, and to other analysis methods used in water quality impairment studies (Lombard and Kirchmer, 2004).

Table 13 presents MQOs for precision and bias, as well as the manufacturer's stated accuracy, resolution, and range for field equipment that will be used in water quality impairment studies. These MQOs are intended for use in both major and minor work projects; however, a project-specific QAPP may set different MQOs, provided a justification for the deviation is given.

6.2.1 Targets for precision, bias, and sensitivity

6.2.1.1 Precision

Precision is a measure of the variability in the results of replicate measurements due to random error. Precision is usually assessed by analyzing duplicate field measurements or lab samples. Random error is imparted by the variation in concentrations of samples from the environment as well as other introduced sources of variation (e.g., field and laboratory procedures). Field sampling precision will be addressed by submitting replicate samples or collecting replicate measurements.

Precision is also influenced by random error. Potential sources of random error include:

- Field sampling procedures.
- Handling, transporting, and preparing samples for shipment to the laboratory.
- Obtaining a subsample from the field sample for analysis.
- Preparing the sample for analysis at the laboratory.
- Analysis of the sample (including data handling errors).

Precision for replicates will be expressed as percent relative standard deviation (% RSD) or absolute error and assessed following the MQOs outlined in Tables 13, 14, and 15. The targets for precision of field duplicates are based on historical performance by Ecology's Manchester Environmental Laboratory (MEL) for environmental samples taken around the state by EAP (Mathieu, 2006).

6.2.1.2 Bias

Bias is the difference between the population mean and the true value of the parameter being measured. Bias is usually addressed by calibrating field and laboratory instruments and also by analyzing lab control samples, matrix spikes, and standard reference materials. MQOs for laboratory QC samples (e.g., blanks, check standards, and spiked samples) presented in Tables 13 and 14 will provide a measure of any bias affecting sampling and analytical procedures. Bias affecting measurement procedures can be inferred from the results of QC procedures. MEL will assess bias in the laboratory through the use of blanks (further explained in Section 8.3). Field staff will minimize bias in field measurements and samples by strictly following equipment calibration, measurement, sampling, and handling protocols (explained in detail in Section 10.0).

Potential sources of field and laboratory bias in samples include the following sampling procedures:

- Instability of samples during transportation, storage, or processing.
- Interference and matrix effects.
- Inability to measure all forms of the parameter of interest.
- Calibration problems with the measurement system or instruments.
- Contamination of equipment, reagents, or containers.

Table 13 presents the bias data quality objectives for multi-parameter sonde data for instrument QC checks. First the sonde measurement data are reviewed, adjusted (if applicable), and finalized (see Data Verification section). The median residual of the finalized data and QC checks is then calculated and compared to the MQOs listed in Table 13.

6.2.1.3 Sensitivity

Sensitivity is a measure of the capability of a lab or field method used to detect a substance. It is commonly described as detection limit.

For field data, the sensitivity of the instrument is described by its range, accuracy, and resolution. This is usually reported for each instrument by the manufacturer. Examples of this information are provided in Table 13.

For laboratory data in a regulatory context, the method detection limit (MDL) is usually used to describe sensitivity. The method reporting limit (MRL) is usually a little higher than the MDL and can also be used. The MRL for each laboratory method is reported in Tables 14 and 15, and MDLs are presented in Section 9.1 (Table 11). The reporting limits of the methods listed in Tables 14 and 15 are appropriate for the expected range of results and the required level of sensitivity to meet the objectives outlined in this QAPP.

Table 13. Field procedure MQOs and field equipment information.

Parameter	Equipment/ Method	Bias (median)	Precision- Field Duplicates (median)	Equipment Information				
				Equipment Accuracy	Equipment Resolution	Equipment Range	Expected Range
Water Quality Measurements							
Water Temperature	YSI Exo		±0.2 ˚C	± 0.01 ◦C	± 0.001 ˚C	-5 to 50 ◦C	0-30˚C
	FTS DTS-12		±0.2 ˚C	± 0.1 ◦C	± 0.01 ˚C	0 to + 40 ◦C	0-30˚C
	YST Pro DSS		± 0.2°C	± 0.2°C	0.1°C	-5 - 70°C	0-30°C
Conductivity/ Specific Conductance	YSI EXO		5% RSD	±0.5% of reading or .001 mS/cm, w.i.g[a]	0.0001 to 0.1 mS/cm (range dependent)[c]	0 - 200 mS/cm	20 – 1,000 uS/cm
	YSI ProDSS			±0.5% of reading or 0.001 mS/cm, w.i.g. [a]	0.001 mS/cm (range dependent)[c]	0 - 200 mS/cm	20 – 1,000 uS/cm
Dissolved Oxygen	YSI EXO		5 % RSD	0 to 20 mg/L: ±0.1 mg/L or 1% of reading, w.i.g. [a]	0.01 mg/L[a]	0 - 50 mg/L	0.1 - 15 mg/L
	YSI ProDSS			± 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 EXO YSI ProDSS		± 0.2 s.u.	± 0.2 s.u.	0.01 s.u.	0 - 14 s.u.	6 - 10 s.u.
Optical Brighteners	Turner Designs Cyclops 7		10% RSD	NA	0.1 ppb	0.6-2,500 ppb	0-500 ppb
Turbidity	FTS DTS-12 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
Flow Measurements							
Streamflow	SOP EAP024	n/a	10% RSD	n/a	n/a	n/a	0.01-2,000 cfs
Velocity	SonTek® FlowTracker® Handheld ADV®	<0.03 ft/s	5% RSD	±1%	0.01 ft/s	0.0003 - 13 ft/s	0.01 - 10 ft/s
Water Level	Hobo barometric pressure transducer	n/a	5% RSD	±1.5 mbar at 25°C	0.1 mbar	660 – 1,070 mbar	660 – 1,070 mbar

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 for 1,4 m cables; for 20 m cable: ±1% of reading or 0.001 mS/cm, whichever is greater
c range dependent, for 0.501 to 50.00 mS/cm: 0.01; for 50.01 to 200 mS/cm: 0.1

Table 14. MQOs for inorganic/general chemistry lab procedures.

Analysis	Method Lower Reporting and (Detection) Limit[a]	Method Blank Limit	Calibration Standards/ Blanks	Lab Control Samples (% recovery limits)	Matrix Spikes or SRMs (% recovery limits)	Precision – Lab Duplicates (RPD)	Precision – Field Duplicates (median)[b]
Water Quality							
Dissolved Oxygen - Winkler	0.1 mg/L	n/a	n/a	n/a	n/a	± 0.2 mg/L	± 0.2 mg/L
Chlorophyll *a* - water	0.05 ug/L	<½ RLc	n/a	n/a	n/a	20%	20% RSD
Ammonia	0.01 (0.002) mg/L	<MDLc	ICV/CCV: 90-110% ICB/CCB: <MDL[c]	80-120%	75-125%	20%	10% RSD
Nitrate + nitrite-N	0.01 (0.005) mg/L	<½ RLc					
Chloride	0.1 (0.03) mg/L	<MDLc		90-110%	75-125%	20%	5% RSD
Persulfate Nitrogen, Total	0.025 (0.013) mg/L			80-120%	75-125%	20%	10% RSD
Orthophosphate	0.003 (0.0013) mg/L						
Phosphorus, total	0.005 (0.0024) mg/L	<2.2x MDLc					
Total suspended solids	1 mg/L	±0.3 mg/L[d]	n/a		n/a	5%[b]	15% RSD
Suspended sediment concentration	1 mg/L		n/a	90-110%	n/a	n/a	15% RSD
Fecal coliform - MF	1 cfu/100 mL	<MDL	n/a	n/a	n/a	40% RPD	50% of replicate pairs < 20% RSD 90% of replicate pairs <50% RSD[b]
E. coli – MPN or MF	1 cfu/100 mL	<MDL	n/a	n/a	n/a	40% RPD	50% of replicate pairs < 20% RSD 90% of replicate pairs <50% RSD[b]
Periphyton Tissue							
Ash Free Dry Weight	10 mg/kg DW	±0.6 mg/L[d] <MDL[ce]	n/a	n/a	n/a	20%	50% RSD
Chl a	0.05 mg/L	<½ RL[c]	n/a	n/a	n/a		
Total Solids	1 mg/L		n/a	n/a	n/a	5%[b]	15% RSD
Total Metals	a		ICV/CCV: 90-110% ICB/CCB: <MDLc	80-120%	75-125%	20%	10% RSD
Total Carbon/Nitrogen	10 mg/kg DW	<2.2x MDLc	ICV/CCV: 90-110% ICB/CCB: <MDLc	90-110%	90-110%	20%	50% RSD
15N, 13C[f]	a	na	na	90-110%	n/a	20%	10% RSD

RL: reporting limit; MDL: method detection limit; CCV: Continuing Calibration Verification CCB: Continuing Calibration Blank; ICV: Initial Calibration Verification; ICB: Initial Calibration Blank
a reporting limit may vary depending on dilutions; detection limit in parentheses, no parentheses means MDL = lowest possible RL
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
d filter blank
e reinstate blank
f standard reference material (SRM) recovery, no matrix spikes preformed on this analyte

Table 15. MQOs for multi-parameter sondes.

Parameter	Unit	Accept	Quality	Reject
Dissolved Oxygen	% Saturation	≤ ± 5%	≤ ± 5%	≤ ± 5%
	mg/L	≤ ± 0.5	≤ ± 0.5	≤ ± 0.5
pH	≤ ± 0.5	≤ ± 0.5	≤ ± 0.5	≤ ± 0.5
Specific Conductance	uS/cm	≤ ± 10%	≤ ± 10%	≤ ± 10%
Water Temperature	°C	≤ ± 0.2	> ± 0.2 and ≤ ± 0.8	> ± 0.8
Turbidity	NTU	≤ ± 10%	≤ ± 10%	≤ ± 10%

Criteria expressed as a percentage of readings. For example, buffer = 100.2 uS/cm and Hydrolab = 98.7 uS/cm; (100.2-98.7)/100.2 = 1.49% variation, which would fall into the acceptable data criteria of less than 5%.
* Turbidity use stand-alone probe (i.e., FTS DTS-12).

6.2.2 Targets for comparability, representativeness, and completeness

6.2.2.1 Comparability

To improve comparability to previously collected Ecology data, field staff will strictly follow EAP protocols and adhere to data quality criteria. In addition, all field measurements will follow approved EAP SOPs (see Table 9, Section 8.2).

Factors that influence comparability between studies can include the availability and extent of previous data, training of field staff, field data-collection similarities including site locations, duration, time of year and weather conditions, lab methods, SOPs, and sensitivity.
Ecology may compare data collected from the study to data collected by other entities or for other projects, if:

- Data were collected with approved QAPP(s) and functionally equivalent SOP(s), and also accredited laboratories analyzed the data. The entity that collected the data is an organization whose data are regularly used and is known to produce known and usable data (see Section 4.3),
- Documentation such as QAPPs, SOPs, and data QC assessments are available to demonstrate that the data are of known and usable quality, *or*
- The minimum analytical sensitivity for the methods used is comparable to the detection and reporting limits in this QAPP and is lower than applicable regulatory criteria.

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 and frequency are distributed throughout the watershed or water body in a manner designed to meet study objectives. Typically, a combination of continuous measurements, grab samples, spot measurements, and historic data will be needed to represent the expected variability of spatial and temporal conditions. These elements that influence data quality are addressed in greater detail in Study Design (Section 7.0).

The ability for continuous monitoring equipment (such as temperature loggers or multi-parameter sondes) to capture the representativeness of the river or stream's characteristics at the deployment location is assessed through recommended spot and check measurements.

- For shallow or well-mixed rivers and streams:
  - A transect of spot measurements may be taken across the width of the channel that includes, at a minimum, a measurement at the desired deployment location, within several feet of both banks, and in the thalweg (if different from the deployment location).
  - Good reconnaissance of the deployment location (both in the field and with GIS/aerial photography) to ensure there are no tributaries, outfalls, or groundwater seepage immediately upstream. As a general rule, equipment should be deployed upstream of bridge crossings to avoid influence from roadside drainage ditches and also upstream of recreational wading/swimming.
- For deeper or vertically-stratified rivers and streams:
  - In addition to the above, vertical profiles of spot measurements should be made at the deployment location and in the thalweg or deepest location nearby. At a minimum, profile measurements should be taken just below the water surface, at the deployment depth, and near the streambed, with measurements at other levels to provide a representative profile.

6.2.2.3 Completeness

EPA has defined completeness as a measure of the amount of valid data needed to be obtained from a measurement system to meet project objectives (Lombard and Kirchmer, 2004). The goal for the water quality impairment study is to correctly collect and analyze 100% of the samples for each project. However, problems occasionally arise during sample collection, such as site access problems, equipment malfunction, or sample container shortages, that cannot be controlled; thus, a completeness of 95% is acceptable for sampling and discrete measurements. 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.

For continuous deployed measurements, additional variables can negatively impact completeness including vandalism/theft/tampering, equipment failure, unacceptable fouling or drift, and unpredictable hydrologic events (large storms or steep drops in water level between visits). For these reasons, a completeness of 80% is acceptable for continuous measurements. Given these difficulties, redundancy is an important component when designing studies with continuous data collection, particularly at key boundary conditions and within the most critical areas.

If completeness targets are not achieved, then a determination will be made as to whether the data that were successfully collected are sufficient to meet project needs. This will depend on a number of factors, such as the needs of the modeling/analysis framework, and the times and locations where data were lost. If successfully collected data are not sufficient, then one or a combination of the following approaches will be used:

- Estimate missing data values from existing data if this can be done with reasonable confidence.

- Conduct targeted additional sampling to fill data gaps.
- Re-collect all or a portion of data.

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 Model quality objectives

To meet project goals and objectives, model quality results for nutrient and sediment estimates should be comparable to models used in similar TMDL or other water quality impairment modeling studies. A summary of results for comparison purposes is available in *A Synopsis of Model Quality from the Department of Ecology's Total Maximum Daily Load Technical Studies* (Sanderson and Pickett, 2014). Sensitivity and uncertainty analyses should also be conducted to assess the variability of the model results to specific parameters and level confidence in key output values.

Model quality includes the following considerations:

- **Goodness-of-fit**: The accuracy with which the model is able to predict observed data. This can be described by (1) precision, using statistics such as Root Mean Squared Error (RMSE), (2) bias, using statistics such as the relative error and (3) accuracy, visually using plots of modeled and observed values.
- **Accurate representation of processes**: Mechanistic models should achieve accurate predictions by invoking correct explanations of observed data and reasonably simulating real-world processes. For example, a model might accurately predict low stream temperatures by incorrectly invoking groundwater instead of shade. Such a model might have good goodness-of-fit, but for the wrong reasons, which is termed "curve-fitting". Selection of model parameters based on physical principles and careful multi-dimensional analysis of model results should help to ensure that curve-fitting is not occurring.
- **Sensitivity to key inputs**: Estimates should accurately predict the sensitivity of water body response to key inputs, such as the sensitivity of temperature to shade or of dissolved oxygen (DO) to nutrients.

7.0 Study Design

7.1 Study boundaries

All field activities will be conducted within the Newaukum River watershed (Figure 10). These represent planned locations for field activities. Additional sampling locations could be added if additional BMP projects or water quality sampling locations become available. Figure 11 presents possible bracketed water quality sampling locations at road crossings.

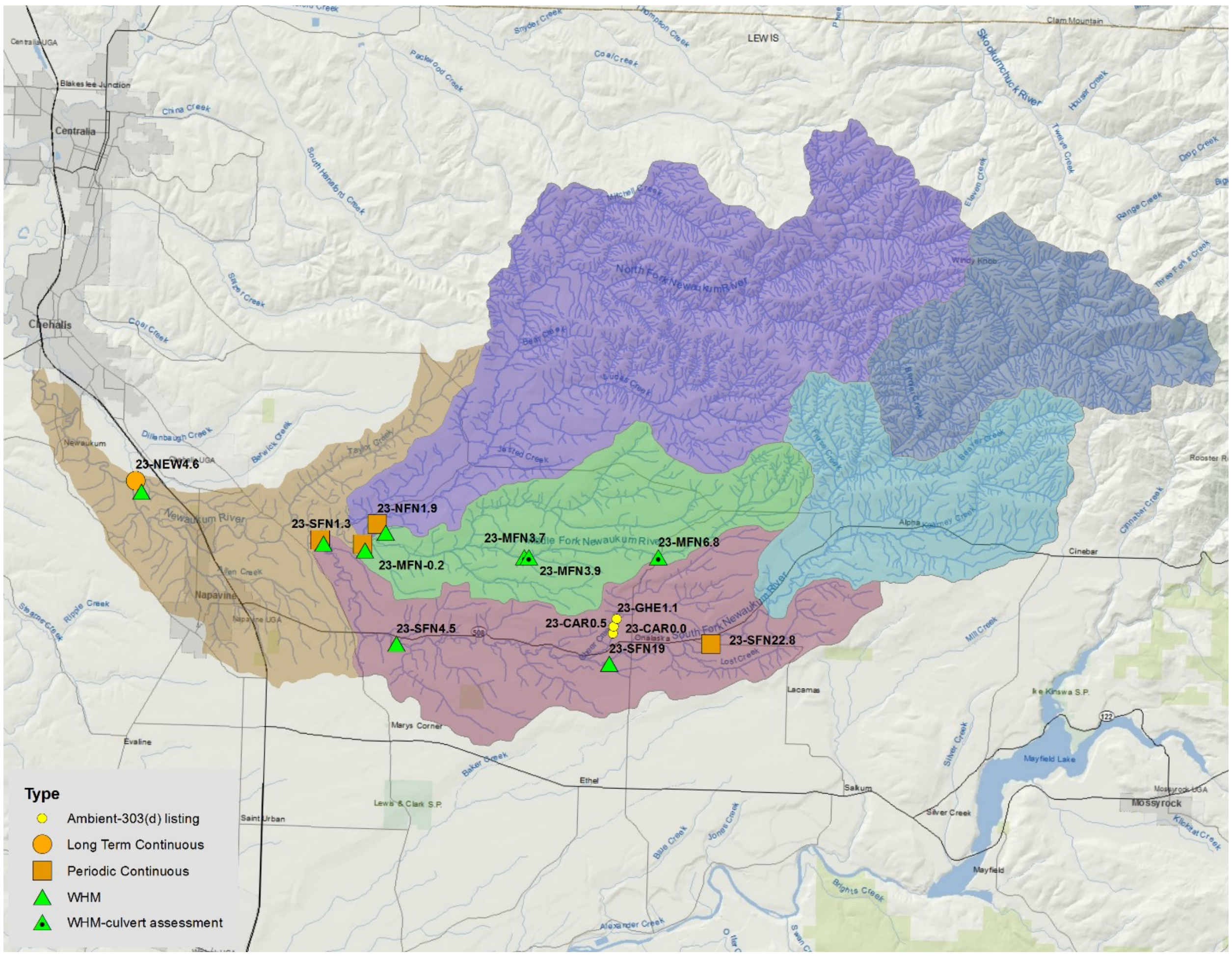

Figure 10. Map of the Newaukum River watershed with the proposed water quality and watershed health sampling locations.

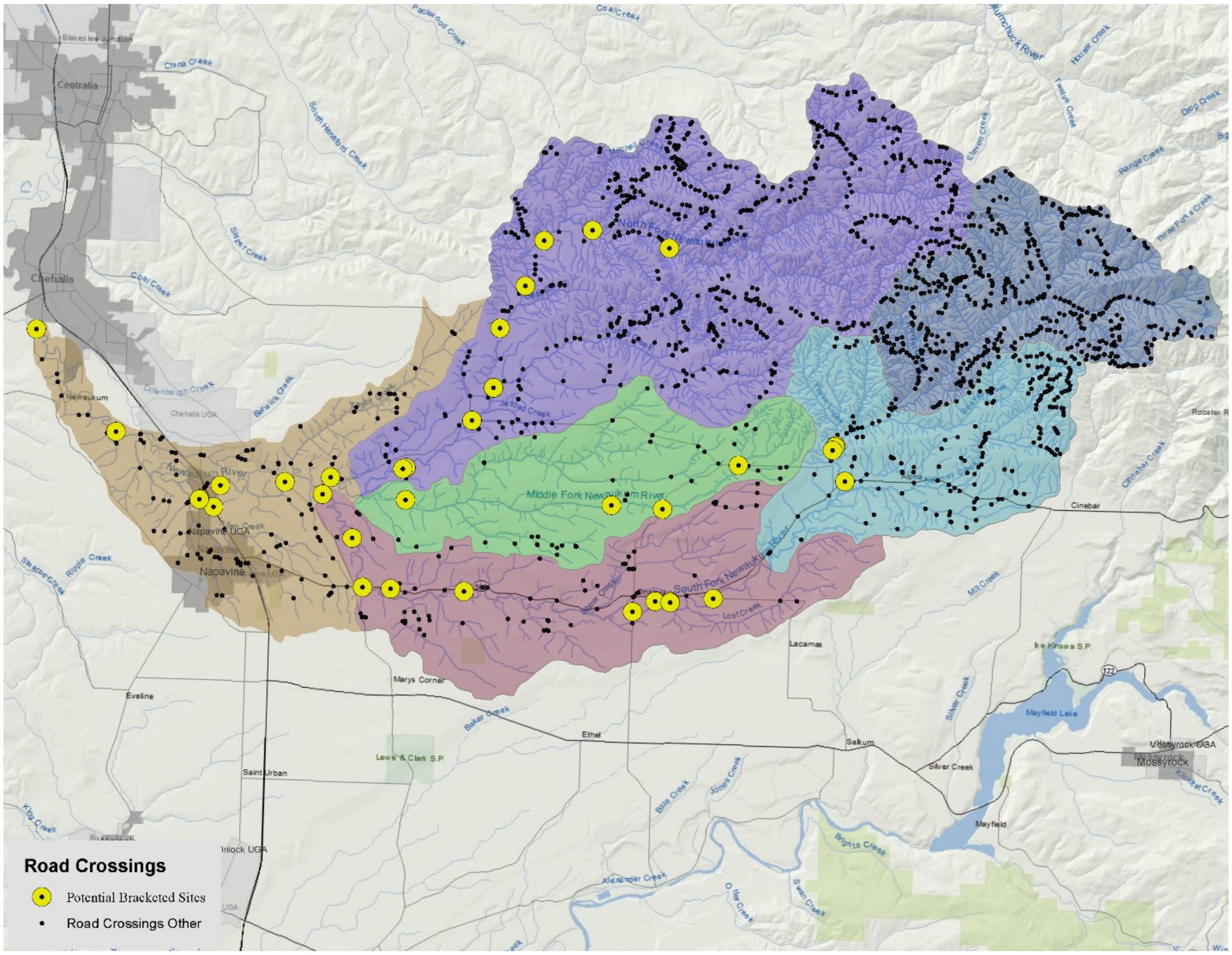

Figure 11. Road crossings in the Newaukum River watershed and potential bracketed sampling locations.

7.2 Field data collection

7.2.1 Sampling locations and frequency

Sampling locations are described in Table 16 and presented in Figures 10 and 11. Ecology's Environmental Assessment Program (EAP) staff began field work in July 2017:

- Staff will perform sampling and field measurement tasks.
- Freshwater Monitoring staff will install and maintain ambient and continuous monitoring equipment at Newaukum at Chehalis and SF Newaukum near mouth.
- Effectiveness Monitoring staff will install and maintain standalone Hobo® unvented water level loggers and turbidity sensors near the mouths of the MF and NF of the Newaukum River and on the SF of the Newaukum River at Jorgensen Road.
- Effectiveness Monitoring staff will sample for nutrient and sediment during 1 to 2 storm events using ISCO samplers at turbidity monitoring stations.

- Effectiveness Monitoring staff will collect monthly water quality monitoring, record stage, and measure flow during the low-flow period (July-Aug) and biweekly during the high-flow period (Oct-May).
- Watershed Health Monitoring staff will perform watershed health assessments (1 event per site) between September and October of 2017.
- Effectiveness Monitoring staff will collect biweekly nutrient and pathogen data from Carlisle Lake and from Gheer Creek above Carlisle Lake during the low-flow period.
- Effectiveness Monitoring staff will deploy artificial periphyton samplers, and continuous water quality sensors during low-flow periods as needed.

Table 16. Sampling locations for the monitoring study.

Station ID	**Ambient Water Quality Sampling**	**Continuous Turbidity**	**Ecology Unvented Flow**	**USGS Continuous Flow**	**Watershed Health Assessment**	**Description**	**NAD83 Latitude**	**NAD83 Longitude**
23-NEW4.6	X	X		X	X	Mainstem Newaukum near Chehalis	46.619293	-122.935618
23-NFN1.9	X	X	X		X	North Fork Newaukum near Mouth	46.608513	-122.830521
23-MFN-0.2	X	X	X		X	Middle Fork Newaukum near Mouth	46.602414	-122.836617
23-MFN3.7					X	Middle Fork Newaukum below Culvert	46.59995	-122.76656
23-MFN3.9					X	Middle Fork Newaukum above Culvert	46.600062	-122.764626
23-MFN6.8					X	Middle Fork Newaukum below Culvert	46.6010534	-122.70867
23-SFN1.3	X	X	X		X	South Fork Newaukum near Mouth	46.603437	-122.854435
23-SFN4.5					X	South Fork Newaukum river mile (RM) 4.5	46.573145	-122.820755
23-SFN6.3					X	South Fork Newaukum RM 6.3	46.568989	-122.72856
23-CAR0.0[1]	X					Carlisle Lake Outfall	46.57802	-122.727217
23-CAR0.5[1]	X					Carlisle Lake Center	46.582354	-122.727504
23-GHE1.1[1]	X					Gheer Creek above Carlisle Lake	46.582398	-122.725796
23-SFN19					X	South Fork Newaukum above Gheer Creek	46.568989	-122.72856
23-SFN22.8	X		X[2]	X		South Fork Newaukum at Jorgenson Rd bridge	46.5757	-122.68485

[2] USGS flow station will serve as a quality assurance check for development of flow rating curve using pressure sensors.

7.2.2 Field parameters and laboratory analytes to be measured

Table 17 shows 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 17. Parameters to be collected during the study.

Parameter	Ambient	Storm Event	Watershed Health	Carlisle Lake	Bracketed Monitoring
Laboratory sample parameters					
Ammonia-N	X	X			
Nitrate + nitrite-N	X	X			X
Chloride			X		
Chlorophyll a				X	
Persulfate Nitrogen, Total	X	X	X		
Ortho Phosphate	X			X	
Phosphorus, soluble reactive	X	X		X	
Phosphorus, total	X	X	X	X	X
Total suspended solids	X	X	X		
Suspended sediment concentration	X	X			
Fecal coliform	X				
E. coli	X	X			X
Field measurement parameters (continuous or discrete)					
Conductivity			X	X	X
Dissolved Oxygen			X	X	X
Nitrate-nitrite					X
Optical brighter					X
pH	X		X	X	X
Turbidity			X		X
Streamflow	X				X
Temperature	X				X
Biological parameters					
Macroinvertebrates			X		
Periphyton			X		
Chlorophyll a			X		X
Ash Free Dry Weight			X		X
Total Solids			X		X
Total Metals			X		X
Percent Total Organic Carbon			X		X
Total Carbon/Nitrogen			X		X
NO3- (15N, 17O, 18O)			X		X
Habitat Parameters					
Mean substrate size			X		
Mean embeddedness			X		
Large woody debris			X		
Bed stability			X		
Canopy Cover			X		
Sinuosity			X		
Width-to-depth ratio			X		
Bankfull area			X		
Pool area			X		
Pool depth			X		
Slope			X		

7.3 Modeling and analysis design

Because flow and sediment conditions in streams are dynamic, especially during the winter and spring months, this study will assess the relative contribution of sediment and nutrients using continuous monitoring. Continuous flow and turbidity data will be collected and correlated with discrete measurements of total phosphorus (TP), total nitrogen (TN), total suspended solids (TSS) and suspended sediment concentrations (SSC). Continuous flow will be collected using either existing USGS flow gauges or by using stand-alone unvented pressure sensors.

Seasonal average loads of TP, TN, SSC, and TSS will be calculated for each of the ambient monitoring stations. This will be performed using one or more of the following methods:

- Cohn multiple-regression model (Cohn et al., 1989; Cohn et al., 1992).
- Beales ratio estimator (Thomann and Mueller, 1987).

Uncertainty analysis will be performed on each of these methods by evaluating the correlations/regressions on which they are based.

8.0 Field Procedures

8.1 Invasive species evaluation

Field staff will follow SOP EAP070 on minimizing the spread of invasive species (Parsons et al., 2012). The Newaukum River watershed is not in an area of extreme concern. Areas of extreme concern have, or may have invasive species like New Zealand mud snails that are particularly hard to clean off equipment and are especially disruptive to native ecological communities. For more information, please see Ecology's website on minimizing the spread of invasive species at www.ecy.wa.gov/programs/eap/InvasiveSpecies/AIS-PublicVersion.html.

8.2 Measurement and sampling procedures

All ambient water samples will be collected using Ecology SOP EAP034 (Ward, 2016). Periphyton tissue samples will be collected following Ecology SOP EAP085 (Anderson et al., 2016). Stream habitat measurement will be collected using methods in (Merritt, 2009). Benthic macroinvertebrates will be collected using Ecology SOP EAP073 (Larson, 2016).

Continuous measurement of water quality parameters will be made following Ecology SOP EAP033 (Swanson, 2007). When continuous measurements are being made in conjunction with a data logger Ecology SOP EAP072 will be followed (Bookter, 2016). Streamflow measurements will be performed following Ecology SOP EAP024 (Mathieu, 2016).

8.3 Containers, preservation methods, and holding times

Field staff will collect discrete samples directly into pre-cleaned containers supplied by Manchester Environmental Laboratory (MEL) and described in their *Lab Users Manual* (MEL, 2016). Table 18 lists the sample parameters, containers, volumes, preservation requirements, and holding times. Field staff will store samples for laboratory analysis on ice and deliver to MEL via courier. MEL follows standard analytical methods outlined in their *Lab Users Manual* (MEL, 2016).

Table 18. 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	H2SO4 to pH <2; Cool to ≤6°C
Nitrate + nitrite-N	Water	125 mL	125 mL clear w/m poly bottle	28 days	H2SO4 to pH <2; Cool to ≤6°C
Total persulfate nitrogen	Water	125 mL	125 mL clear w/m poly bottle 0.45 um pore size filters for dissolved TPN	28 days	H2SO4 to pH <2; Cool to ≤6°C
Phosphorus, soluble reactive	Water	125 mL	125 mL amber w/m poly bottle 0.45 um pore size	48 hrs	Filter in field with 0.45 um pore size filter; Cool to ≤6°C
Phosphorus, total	Water	60 mL	125 mL clear n/m poly bottle	28 days	1:1 HCl to pH <2; Cool to ≤6°C
Total suspended solids	Water	1,000 mL	1,000 mL w/m poly bottle	7 days	Cool to ≤6°C
Suspended sediment concentration	Water	1,000 mL	1,000 mL w/m poly bottle	7 days	Cool to ≤6°C
Fecal coliform/E. coli	Water	250 mL	250 mL glass/polypropylene autoclaved bottle	24 hours	Fill the bottle to the shoulder; Cool to ≤10°C
Invertebrates	Tissue	NA	Wide mouth polyethylene jar (128 oz or 3.8 L)	Roughly 3 months	95% Ethanol (add 3 parts by volume for each part sample)
Periphyton	Tissue	<1,000 mL	1,000 mL amber w/m poly jar (1 L)	24 hours to filtration; 28 days after filtration (frozen)	Cool to ≤6°C
Chlorophyll *a*	Tissue	10 mL	Glass test tube w/acetone	Cool to <6°C keep in dark	28 days post
Total Carbon & Nitrogen - Periphyton	Tissue	1 g ww	50 mL poly centrifuge tube	6 months	Cool to ≤6°C store in dark
Total Metals Periphyton[1]	Tissue	1 g ww	50 mL poly centrifuge tube	6 months	Cool to ≤6°C store in dark
Ash Free Dry Weight Periphyton	Tissue	30 mL	50 mL amber poly jar	Cool to <6°C	7 Days
Total Solids Periphyton	Tissue	30	50 mL amber poly jar	Cool to <6°C	7 Days
15N, 18O	Tissue	1 g ww	50 mL poly centrifuge tube	Cool to <6°C	200 days
Metals	Sediment	50 g ww	4 oz glass jar	Cool to <4°C keep in dark	6 months
Percent Total Organic Carbon	Sediment	50 g ww	4 oz glass jar	Cool to <4°C keep in dark	6 months

[1] Al, As, Cd, Cu, Fe, K, Mn, P, Pb, Zn

8.4 Equipment decontamination

Staff will follow all recommended protocols from instrument manufacturers for cleaning and, if needed, re-calibrating sensors. For in-situ equipment, staff will follow Ecology's SOP EAP090, *Decontamination of Sampling Equipment for Use in Collecting Toxic Chemical Samples* when cleaning equipment used for in-situ sample collection and sample preparation (Friese, 2014).

8.5 Sample ID

All samples will be labeled with station, date, time, parameter and sample identification numbers, and these are recorded in the field log. Each lab sample is automatically given a unique identification number once loaded in the database. This number is transferred to analyses logs (for internal lab samples) or chain-of-custody forms sent to external labs. 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

During sample collection, a chain–of-custody form is generated for samples, based on field logs. Chain-of-custody logs are delivered to the lab with the corresponding samples for management of sample counts, scheduling, and tracking analysis. 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 labs, chain-of-custody 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 the lab(s) until the problem is resolved.

8.7 Field log requirements

In-situ measurements made in surface waters will either be recorded internally within the data logger or collected as water samples and analyzed at the laboratory. Information on samples will be recorded in a digital field log. The field log form also includes data logger information for data processing, such as cast start time, file names, replicate cast number, instrument information, and survey ID. In addition, any changes or deviations from the sampling plan or unusual circumstances that might affect interpretation of results are recorded.

Collection data sheets will also be generated on each survey, to record collected samples to be sent to the lab. A paper log is brought along on every survey to use as a backup if the electronic form or device fails. Digital copies of the field and sample logs are stored for future reference on a shared, secure, frequently backed up network server. Photos will be taken during each survey to record observations and events. These photos are used to document each sampling event and for the creation of reports, procedures, and other documents.

8.8 Other activities

The project manager or field lead for each survey crew is the designated safety officer for that survey. The safety officer will have the following responsibilities:

- Cancelling assessments if conditions warrant.
- Complying with field and safety procedures.
- Knowledge of radio use.
- 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 laboratory procedures following Standard Operating Procedures (SOPs) and other guidance documents. Analytical methods and lower reporting limits are listed in Table 19. University of Washington Seattle will conduct the periphyton nitrogen isotope analyses following laboratory procedures and methods.

Table 19. Measurement methods (laboratory).

Analyte	Matrix	Expected Range of Results	Method	Method Detection Limit
Ammonia-N	Water	<0.01 – 30 mg/L	SM 4500 NH3H	0.002 mg/L
Nitrate + nitrite-N	Water	<0.01 – 30 mg/L	SM 4500NO3I	0.005 mg/L
Total persulfate nitrogen	Water	0.5 – 50 mg/L	SM 4500-NB	0.013 mg/L
Phosphorus, soluble reactive	Water	0.01 – 5.0 mg/L	SM 4500PG	0.0013 mg/L
Phosphorus, total	Water	0.01 – 10 mg/L	SM 4500-PH	0.0024 mg/L
Total suspended solids	Water	<1 – 2,000 mg/L	SM 2540D	1.0 mg/L (RL)
Suspended sediment concentration	Water			
Fecal coliform	Water	1 – 15,000 cfu/100 mL	SM 9222 D	1.0 cfu/100 mL (RL)
E. coli (MF or MPN)	Water	1-15,000	SM 9223B or EPA1105	1
Chlorophyll *a*	Tissue	10 – 10,000 ug/L	SM 10200H(3)	.05 mg/L (RL)
Total carbon periphyton	Tissue	1 – 20%	EPA 440.0	0.1% of DW
Total nitrogen periphyton	Tissue	0.1 – 5%	EPA 440.0	0.1% of DW
Ash free dry weight periphyton	Tissue	50-3200 mg/kg	SM 10300C	0.05 mg/kg
Total solids periphyton	Tissue	400-20,000 mg/L	SM 2540B	0.01 mg/L
15N	Tissue	-1.0 – 20 permil	Continuous flow isotope MS with CHN analyzer	0.049911 permil
13C	Tissue	-40 – (-18) permil	Continuous flow isotope MS with CHN analyzer	-0.00373 permil
Al	Tissue	200-250,000 mg/kg	SW6010D	1.1 mg/kg
As	Tissue	0.05-500 mg/kg	SW6020B	0.10 mg/kg
Cd	Tissue	0.001-50 mg/kg	SW6020B	0.34 mg/kg
Cu	Tissue	0.5-2000 mg/kg	SW6020B	0.36 mg/kg
K	Tissue	100-40,000 mg/kg	SW6010D	10.6 mg/kg
Fe	Tissue	300-500,000 mg/kg	SW6010D	5.0 mg/kg
Mn	Tissue	10-200,000 mg/kg	SW6020B	0.14 mg/kg
Ni	Tissue	0.5-500 mg/kg	SW6020B	0.17 mg/kg
Pb	Tissue	0.05-500 mg/kg	SW6020B	0.052 mg/kg
P	Tissue	100-30,000 mg/kg	SW6020B	1.71 mg/kg
Zn	Tissue	1-25,000 mg/kg	SW6020B	0.43 mg/kg

Permil: parts per thousand

9.2 Sample preparation method(s)

Periphyton tissue samples will be prepared for analysis using Ecology SOP EAP085 (Anderson, et al., 2016).

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

9.3 Special method requirements

Not applicable.

9.4 Laboratories accredited for methods

All chemical analysis, except for periphyton nitrogen isotopes, will be performed at MEL, which is accredited for all methods (Table 14). University of Washington's Isotope Laboratory is not accredited by Ecology for periphyton isotopes of nitrogen and carbon. The lab has a rigorous quality control program, and analysis of stable isotopes is a routine analysis for this lab. Because there is currently no other lab accredited by Ecology to do this analysis, a request to waive required use of accredited lab has been obtained. Rhithron Associates, Inc. in Missoula, Montana will process and analyze macroinvertebrate and periphyton taxonomy samples.

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, data analysis, or modeling, while the project is underway.

Field Quality Control Procedures

Field blanks are used to check for sample contamination. Field staff will prepare blanks in the field by:

- Filling the bottles directly with deionized water for most water quality samples. For filtered parameters, deionized water will be filtered through a new syringe and filtered into the sample bottle.
- For samples where a secondary container other than the sample bottle is used (such as composite), the secondary container will be cleaned and used in the same way to produce blanks as for field samples.
- Handling and transporting the filtering equipment and blank samples to MEL in the same manner that the rest of the samples are processed.

For field instruments, EAP staff will perform the following QC procedures:

- Pre-calibration: Minimize bias in the Hydrolab® or other multi-parameter sonde field measurements by pre-calibrating the instrument before each run, using NIST standards when possible.
- NIST post check: Assess any potential bias from instrument drift, fouling, or interference in probe measurements by:
    - For pH and conductivity, post-checking the probes against NIST-certified pH and conductivity standards.
    - For dissolved oxygen (DO), post-checking the probe against 100% saturation with an air check or saturated water bath (as recommended by the meter instruction manual).
    - For temperature, checking the probe's temperature readings before and after each project using an NIST-certified thermometer.
    - For turbidity, post-checking the probes against NIST-certified turbidity standards.
    - For other parameters, post-check with a NIST-certified, if feasible.
    - The results from each field instrument will be assigned an accuracy rating based on the criteria in Table 20.
- QC meter field checks
    - Collect a minimum of three field checks using an NIST calibrated field meter (MQO) or a meter of comparable accuracy, resolution, and range.
    - One field check will be collected at deployment, one mid-deployment, and one upon retrieval of the deployed instrument.
    - DO meters used for field checks must use an optical DO technology, such as Luminescent Dissolved Oxygen (LDO).

- Winkler QC field checks
  - For DO deployments, in addition to field DO meter checks, a minimum of three Winkler samples must be collected.
- Fouling checks
  - For deployments of longer than two weeks or sites with heavy fouling, assess bias from instrument fouling by collecting a final measurement upon retrieval of a deployed sonde, then immediately cleaning the sensors at the site, and finally taking another measurement immediately after cleaning.
- Field calibration frequency
  - For discrete/field check instruments, these should be checked weekly, unless otherwise specified in a project-specific QAPP. If the instrument's check results exceed the *Excellent* criteria in Table 20, then the instrument must be recalibrated. For instruments capable of holding a calibration for an extended period of time such as optical DO sensors, it is recommended to avoid recalibrating instruments that pass check criteria; this allows for more consistent results throughout the course of the project.
  - For deployed instruments, these are checked during pre-deployment and after retrieval only. Deployed instruments are not buffer checked or recalibrated mid-deployment, unless otherwise specified in a project-specific QAPP.

Table 20. 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*	≤ ± 0.3 mg/L or ≤ ± 5%, whichever is greater	> ± 0.3 – 0.5 mg/L or > ± 5 – 10%, whichever is greater	> ± 0.5 – 0.8 mg/L or > ± 10 – 15%, whichever is greater	> ± 0.8 mg/L or > ± 15%, whichever is greater
pH	≤ ± 0.2 units	> ± 0.2 – 0.5 units	> ± 0.5 – 0.8 units	> ± 0.8 units
Turbidity	≤ ± 0.5 units or ≤ ± 5%, whichever is greater	> ± 0.5 – 1.0 units or > ± 5 – 10%, whichever is greater	> ±1.0 – 2.0 units or > ± 10 – 20%, whichever is greater	> ± 2.0 units or > ± 20%, whichever is greater

*Percent criteria based on saturation check; mg/L criteria based on Winkler field checks

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 Tables 21 and 14 for field measurements.

Table 21. Quality control samples, types, and frequency.

Parameter	Field		Laboratory			
	Blanks	Replicates	Check Standards	Method Blanks	Analytical Duplicates	Matrix Spikes
Water						
Ammonia-N	n/a	10%	1/batch	1/batch	1/batch	1/batch
Nitrate + nitrite-N	n/a	10%	1/batch	1/batch	1/batch	1/batch
Total persulfate nitrogen	n/a	10%	1/batch	1/batch	1/batch	1/batch
Phosphorus, soluble reactive	n/a	10%	1/batch	1/batch	1/batch	1/batch
Phosphorus, total	n/a	10%	1/batch	1/batch	1/batch	1/batch
Total suspended solids	n/a	10%	1/batch	1/batch	1/batch	1/batch
Suspended sediment concentration	n/a	10%	1/batch	1/batch	1/batch	1/batch
Fecal coliform	n/a	10%	n/a	n/a	1/batch	n/a
E. coli	n/a	10%	n/a	n/a	1/batch	n/a
Periphyton Tissue						
Chlorophyll *a*	n/a	10%	n/a	n/a	1/batch	n/a
Total Carbon Periphyton	n/a	10%	1/batch	n/a	1/batch	n/a
Total Nitrogen Periphyton	n/a	10%	1/batch	n/a	1/batch	n/a
Ash Free Dry Weight Periphyton	n/a	10%	n/a	n/a	1/batch	n/a
Total Solids Periphyton	n/a	10%	n/a	n/a	1/batch	n/a
Sediment						
Total metals	n/a	10%	1/batch	1/batch	1/batch	1/batch
Total Carbon	n/a	10%	1/batch	n/a	1/batch	n/a
Taxonomy						
Periphyton	n/a	10%	n/a	n/a	n/a	n/a
Macroinvertebrate	n/a	10%	n/a	n/a	n/a	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 the QAPP, if field instruments yield unusual results, if results do not meet MQOs or performance expectations, or if some other unforeseen problem arises. There may be cause for field instruments to be recalibrated, following SOPs, while still on site. For data analysis and modeling work, this may involve activity from project personnel and technical experts to decide on the next steps that need to be taken to improve model performance. 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 Management Procedures

11.1 Data recording and reporting requirements

Staff will record all field data in a field notebook or an equivalent electronic collection platform. Before leaving each site, staff will check field notebooks or electronic data forms for missing or improbable measurements. Staff will enter field-generated data into Microsoft (MS) Excel® spreadsheets as soon as is practical after they return from the field. If data were collected electronically, data will be backed up on Ecology servers when staff returns from the field. The field assistant will check data entry against the field notebook data for errors and omissions. The field assistant will notify the field lead or project manager of missing or unusual data.

Lab results will be checked for missing and/or improbable data. MEL will send data through Ecology's Laboratory Information Management System (LIMS). The field lead will check MEL's data for omissions against the "Request for Analysis" forms. The project manager will review data requiring additional 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 and statistical information management

Data management for modeling work ranges from basic spreadsheets to the development of large relational databases. Modeling data can include input data, version management, output files, and post-processing of results.

Ecology will maintain and provide the final version of the model, including input, output, executables, electronic copies of the data, GIS, and other supporting documentation (including records documenting model development). Intermediate versions will be saved during model development; some data from intermediate versions may be archived to document the development process or preserve critical earlier versions. Ecology will maintain copies of these in a task subdirectory, subject to regular system backups, for a maximum period of 3 years after task termination, unless otherwise directed by agency management. The underlying data sets, having been determined to be of acceptable quality and used for the model, will be organized prior to the public comment phase of the project, so that they can be easily shared upon request.

Staff will be instructed about the importance of routinely archiving work assignment data files from hard drive to compact disc or server storage. Information will be stored on Ecology servers that are routinely backed up. Screening for viruses on electronic files loaded on microcomputers or the network is standard company policy. Automated screening systems are updated regularly to ensure that viruses are identified and destroyed. Annual maintenance of software is performed to keep up with evolutionary changes in computer storage, media, and programs.

12.0 Audits and Reports

12.1 Field, laboratory, and other audits

There is no need for audits for this study. However, there could be a field consistency review by another experienced EAP field staff during this project. The aim of this review is to improve field work consistency, improve adherence to SOPs, provide a forum for sharing innovations, and strengthen our data QA program.

12.2 Responsible personnel

The project manager conducts audits of all data and works with field and lab technicians to complete reviews. The senior field lead participates in checking data before it is finalized and made public.

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 as determined by the EAP publications distribution form. EAP has specific publication guidelines depending on the type of final report that describe the exact requirements necessary for publication.

12.4 Responsibility for reports

Given the long-term nature of the study, the data set will be extensive. Analyzing and interpreting data results require an intensive team approach. The project manager leads reporting on status and trends on various products and presentation of results. Members of the WHM team assist in reports and presentations.

13.0 Data Verification

Data verification and review is conducted by the project manager and WHM 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 lead and all crew members are responsible for carrying out station-positioning, sample-collection, and sensor deployment procedures as specified in the QAPP and SOPs. Additionally, technicians systematically review all field documents (such as field logs, chain-of-custody sheets, and sample labels) to ensure data entries are consistent, correct, and complete, with no errors or omissions. A second staff person always checks the work of the staff person who primarily collected or generated data results.

13.1.1 In-field data verification

Field notebooks and electronic information storage 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 (written or electronic) 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. The field lead is responsible for in-field data verification.

13.1.2 Post-field work data verification

Upon returning from the field, data are either manually entered (data recorded on paper) or downloaded from instruments and then uploaded into the appropriate database or project folder (see Data Management Section). Manually entered data will be verified/checked by a staff member who did not enter the data. Downloaded electronic data files will also be checked for completeness and appropriate metadata (e.g., filename, time code).

13.1.3 Raw sensor data verification and adjustment

Following data entry verification, raw field measurement data will undergo a quality analysis verification process to evaluate the performance of the sensors. Field measurement data may be adjusted for bias or drift (increasing bias over time) based on the results of fouling, field, or standards checks following general USGS guidelines (Wagner, 2007) and this process:

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 20.

Review/adjust time series (continuous) data

1. Plot raw time series with field checks.
2. Reject data based on deployment/retrieval times, site visit disruption, blatant fouling events, and sensor/equipment failure.
3. Review sensor offsets for both pre-calibration and post-deployment buffer/standard checks. Flag any potential chronic drift or bias issues specific to the instrument.
4. If applicable, review fouling check and make drift adjustment if necessary. In some situations, an event fouling adjustment may be warranted based on abrupt changes in flow, stage, sediment loading, etc.
5. Review residuals from both field checks and post-checks, together referred to as QC checks. Adjust data as appropriate, using a weight-of-evidence approach. Give the most weight to post-checks with NIST standards, then field checks rated excellent, then good, and then fair. Do not use field checks rated poor. Potential data adjustments include:
   a. *Bias* – Data are adjusted by the average difference between the QC checks and deployed sonde. Majority of QC checks must show bias to use this method.
   b. *Regression* – Data adjusted using regression, typically linear, between QC checks and deployed data sonde. This accounts for both a slope and bias adjustment. The regression must have at least 5 data points and an R2 value of >0.95 to use for adjustment. Do not extrapolate regressions beyond the range of the QC checks.
   c. *Calibration/Sensor Drift* – Data adjusted using linear regression with time from calibration or deployment to post-check or retrieval. Majority of QC checks, particularly post checks, must confirm pattern of drift.
6. Typically, choose the adjustment that results in the smallest residuals and bias between the adjusted values and QC checks. Best professional judgement and visual review are necessary to confirm adjustment.
7. If the evidence is weak or inconclusive, do not adjust the data.

If Ecology staff adjust any data, it will be noted in the final report. Data adjustment must be performed or reviewed by a project manager or principal investigator with the appropriate training and experience in processing raw sensor data. Water quality impairment staff are currently drafting an SOP for continuous data collection and adjustment; this SOP will contain more detail and be referenced in a subsequent version of this QAPP.

13.1.4 EIM data verification

After data have been finalized and entered into the EIM database, a staff member who was not involved in the EIM data entry will review the data in EIM for completeness and potential errors following Ecology's internal EIM review protocols.

13.2 Verification of laboratory data

MEL staff will perform laboratory verification following standard laboratory practices (MEL, 2016). After the lab verification, the field lead, principal investigator, or project manager will perform a secondary verification of each data package. This secondary verification will entail a detailed review of all parts of the lab data package with special attention to lab QC results. The reviewer will bring any discovered issues to the project manager for resolution. The project manager will review data requiring additional qualifiers.

13.3 Validation requirements, if necessary

Data validation is an analyte- and sample-specific process that extends the evaluation of data beyond method, procedural, or contractual compliance (i.e., data verification) to determine the analytical quality of a specific data set (EPA, QA/G-8, 2002).

The data validation process follows verification and is almost always performed by a qualified chemist who is independent of the data collectors and users. Validation involves a detailed review of laboratory data packages, using professional judgment and objective criteria, to determine if MQOs for precision, bias, and sensitivity specified in an approved QAPP have been met. However, validation also requires the reviewer to assess data quality using instrument calibration records, results for QC samples (e.g., blanks, replicates, spiked recovery samples, standard reference materials), sample-specific instrument records, and other appropriate information. All laboratory data that have been verified by MEL staff will be validated by a project staff member. Field measurements data that was verified by a project staff member will be validated by a different staff member.

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.

13.4 Model quality assessment

To provide a credible basis for predicting and evaluating water quality scenarios and management options, the ability of the model to represent real-world conditions should be optimized and evaluated through a process of model calibration and, if appropriate, through validation (CREM, 2009; EPA, 2002).

Model calibration is necessary because of the inherent uncertainty of water quality models. The water quality models used are mechanistic, based on mass balance processes, but use kinetics to quantify these processes that may be derived empirically, from laboratory studies or from other ecological systems. Model calibration is the method of adjusting model parameters and kinetics to achieve an optimal match between the predicted trends of the model to the observed conditions. Model calibration involves a qualitative graphical comparison and basic statistical methods that are used to compare model predictions and observations. See *Programmatic QAPP for Water Quality Impairment Studies* (McCarthy and Mathieu, 2017).

14.0 Data Quality (Usability) Assessment

14.1 Process for determining if project objectives were met

After all laboratory and field data are verified and validated, the field lead or project manager will thoroughly examine the data package, using statistics and professional judgment, to determine if MQOs have been met. The project manager will examine the entire data package to determine if all the criteria for MQOs, completeness, representativeness, and comparability have been met. If the criteria have not been met, the field lead and 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

A general practice for data management is that results or concentrations between the method detection limit (MDL) and the reporting limit are reported as detected but not quantified due to the potential for misuse or misinterpretation of low-level data which has relatively high quantitative uncertainty.

Data results or concentrations of all analytes reported between the MDL and reporting limit are quantified and annotated with a “J” qualifier (estimated concentration); this indicates a higher level of uncertainty in the quantitative value. Statistical evaluations of data whose uncertainties are “high” can lead to erroneous conclusions, especially if the sample populations are limited in size or have high percentages of non-detect data results where analytes are not present at detectable concentrations.

For lab data, the only sample results considered “detected” are those quantified at concentrations at least three times greater than the corresponding results in the method blank and in the field blank samples. Sample results that are not at least three times greater than the corresponding results in the method blank are qualified with a “U” to indicate “not detected.” Sample results that are not at least three times greater than the corresponding results in the field or reagent blank samples are qualified with a “JB” to indicate “not detected due to contamination of the field or reagent blank”.

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:

- 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), and
- Programmatic QAPP for Water Quality Impairment Studies (McCarthy and Mathieu, 2017).

The sampling design will be considered successful if project objectives are met.

14.4 Sampling design evaluation

The project manager will decide whether the data package meets 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.

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.

Bankfull stage: Formally defined as the stream level that "corresponds to the discharge at which channel maintenance is most effective, that is, the discharge at which moving sediment, forming or removing bars, forming or changing bends and meanders, and generally doing work that results in the average morphologic characteristics of channels (Dunne and Leopold, 1978).

Baseflow: The component of total streamflow that originates from direct groundwater discharges to a stream.

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.

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.

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.

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*. Any 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).

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 waste load 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 waste load 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.

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

Acronyms and Abbreviations

BMP	Best management practice
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
GIS	Geographic Information System software
i.e.	In other words

MEL	Manchester Environmental Laboratory
MQO	Measurement quality objective
NF	North Fork
QA	Quality assurance
QAPP	Quality Assurance Project Plan
QC	Quality control
RM	River mile
RPD	Relative percent difference
RSD	Relative standard deviation
SF	South Fork
SOP	Standard operating procedure
TMDL	(See Glossary above)
TOC	Total organic carbon
USFS	United States Forest Service
USGS	United States Geological Survey
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WRIA	Water Resource Inventory Area

Units of Measurement

°C	degrees centigrade
cfs	cubic feet per second
cm^2	square centimeters
dw	dry weight
ft^2	square feet
ft/s	feet per second
g	gram, a unit of mass
kg	kilograms, a unit of mass equal to 1,000 grams
m	meter
m^2	square meters
m^3	cubic meters
m^3/100 m	cubic meters per 100 meters
mm	millimeter
mg	milligram
mg/Kg	milligrams per kilogram (parts per million)
mg/L	milligrams per liter (parts per million)
mL	milliliter
NTU	nephelometric turbidity units
oz	ounces
s.u.	standard units
ug/L	micrograms per liter (parts per billion)
uS/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 population 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 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 is usable for intended purposes.
- J (or a J variant), data is estimated, may be usable, may be biased high or low.
- REJ, data is 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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Appendix B. Watershed Health Assessment Metrics

Table B-1. Watershed health data matrix and associated metrics.

Matrix	Metric Category	Metric Name	Units	Method Description
Solid/Sediment	Large Woody Debris	LWDPieces	count	Large woody debris count per site of all pieces
		LWDPieces100m	/100 m	Large woody debris count per 100 m of all pieces
		LWDSiteVolume	m3	Large woody debris volume per site of all pieces
		LWDSiteVolume100m	m3/100m	Large woody debris volume per 100 m of all pieces
		LWDVolumeMSq	m3/m2	Large woody debris volume per square meter of bankfull channel surface area of all pieces
	Bed Stability	Dgm	mm	Geometric mean substrate diameter
		DgmLog10	None	Log10 estimated geometric mean substrate diameter
		LRBS	None	Log-transformed Relative Bed stability
		RBS	None	index, of the influence of human disturbance on stream sediments, as the ratio of bed surface geometric mean particle diameter (Dgm) divided by estimated critical diameter (Dcbf) at bankfull flow, based on a modified Shield criterion for incipient motion (Kaufmann et al., 2008).
	Substrate	PCT Bedrock	%	PCT Bedrock - Percent of all transects in a site with a substrate size class of Bedrock (smooth) or Bedrock (rough)
		PCT BedrockR	%	PCT Bedrock Rough - Percent of all transects in a site with a substrate size class of Bedrock (rough)
		PCT BedrockS	%	PCT Bedrock Smooth - Percent of all transects in a site with a substrate size class of Bedrock (smooth)
		PCT Boulder	%	PCT Boulder - Percent of all transects in a site with a substrate size class of Large boulder or Small boulder
		PCT BoulderL	%	PCT Boulder Large - Percent of all transects in a site with a substrate size class of Large boulder
		PCT BoulderS	%	PCT Boulder Small - Percent of all transects in a site with a substrate size class of Small boulder
		PCT Cobble	%	PCT Cobble - Percent of all transects in a site with a substrate size class of Cobble
		PCT Fines	%	PCT Fines - Percent of all transects in a site with a substrate size class of Silt/Clay
		PCT GravelC	%	PCT Gravel Coarse - Percent of all transects in a site with a substrate size class of Course Gravel
		PCT GravelCx	%	PCT Gravel Coarse/Above - Percent of all transects in a site with a substrate size class of: Course gravel, Cobble, Small boulder, Large boulder, Concrete/asphalt, Bedrock (smooth) or Bedrock (rough)
		PCT GravelF	%	PCT Gravel Fine - Percent of all transects in a site with a substrate size class of Fine gravel

Matrix	Metric Category	Metric Name	Units	Method Description
Solid/Sediment	Substrate	PCT GravelFb	%	PCT Gravel Fine/Below - Percent of all transects in a site with a substrate size class of Fine gravel, Sand or Silt/Clay
		PCT Hardpan	%	PCT Hardpan - Percent of all transects in a site with a substrate size class of Hardpan
		PCT Other	%	PCT Other - Percent of all transects in a site with a substrate size class of Other
		PCT Pavement	%	PCT Pavement - Percent of all transects in a site with a substrate size class of Concrete/asphalt
		PCT Sand	%	PCT Sand - Percent of all transects in a site with a substrate size class of Sand
		PCT SandFines	%	PCT Sand/Fines - Percent of all transects in a site with a substrate size class of Sand or Silt/Clay
		PCT Wood	%	PCT Wood - Percent of all transects in a site with a substrate size class of Wood (any size)
		X Embed	%	PCT Embeddedness All - Mean embeddedness for a site [normally n = 121 for waded streams]
		X EmbedCenter	%	PCT Embeddedness Mid - Mean embeddedness for a site, mid-channel
	Riparian Cover	X DensioBank	%	average as summation of densiometer readings on left and right banks of each cross-channel transect per DCE, as Center left, Center right, Center upstream, Center downstream, for all observations within the site reach, divided by the number of readings.
		X DensioCenter	%	average as summation of densiometer readings on left and right banks of each cross-channel transect per DCE, as Center left, Center right, Center upstream, Center downstream, for all observations within the site reach, divided by the number of readings.
Habitat	Riparian Vegetation Structure	IDX Canopy	%	average, per DCE, as summation of categorical vegetative cover ratings, as contributed by large and small trees, on left and right banks of each cross-channel transect, for all observation within the site reach, divided by the total number of observations.
		IDX CanopyLT	%	average per DCE as summation of categorical vegetative cover ratings, as contributed by large trees, on left and right banks of each cross-channel transect, as one reading per bank per transect, for all observation within the site reach, divided by the total number of observations.

(table continued on next page)

Matrix	Metric Category	Metric Name	Units	Method Description
Habitat	Riparian Vegetation Structure	IDX CanopyST	%	average per DCE as summation of categorical vegetative cover ratings, as contributed by small trees, on left and right banks of each cross-channel transect, as one reading per bank per transect, for all observation within the site reach, divided by the total number of observations.
		IDX CanUnderstory	%	average, per DCE, as summation of categorical vegetative cover ratings, as contributed by two vegetation layers (overstory and understory) at left bank and right bank for each cross-channel transect, for all observations within the site reach, divided by total number of observations.
		IDX CanUnderstoryGnd	%	average, per DCE, as summation of categorical vegetative cover ratings, as contributed by three vegetation layers (overstory, understory, groundcover), at left bank and right bank for each cross-channel transect, for all observations within the site reach, divided by total number of observations.
		IDX CanUnderstoryWood	%	average, per DCE, as summation of categorical vegetative cover ratings, as contributed by two vegetation layers (overstory and woody understory) at left bank and right bank for each cross-channel transect, for all observations within the site reach, divided by total number of observations.
		IDX CanUnderstoryWoodGndWood	%	average, per DCE, as summation of categorical vegetative cover ratings, as contributed by three vegetation layers (overstory, woody understory, woody groundcover), at left bank and right bank for each cross-channel transect, for all observations within the site reach, divided by total number of observations.
		IDX Ground	%	average, per DCE, as summation of categorical vegetative cover ratings, as contributed by woody and herbaceous vegetation >0.5 m to <5 m in height, on left and right banks of each cross-channel transect, for all observation within the site reach, divided by the total number of observations.
		IDX GroundBare	%	average per DCE as summation of categorical cover ratings, as contributed by exposed mineral soil and litter, on left and right banks of each cross-channel transect, as one reading per bank per transect, for all observation within the site reach, divided by the total number of observations.
		IDX GroundHerb	%	average per DCE as summation of categorical vegetative cover ratings, as contributed by herbaceous vegetation <0.5 m in height, on left and right banks of each cross-channel transect, as one reading per bank per transect, for all observation within the site reach, divided by the total number of observations.
		IDX GroundWood	%	average per DCE as summation of categorical vegetative cover ratings, as contributed by woody vegetation <0.5 m in height, on left and right banks of each cross-channel transect, as one reading per bank

Matrix	Metric Category	Metric Name	Units	Method Description
				per transect, for all observation within the site reach, divided by the total number of observations.
		IDX Understory	%	average, per DCE, as summation of categorical vegetative cover ratings, as contributed by woody and herbaceous understory >0.5 m to <5 m in height, on left and right banks of each cross-channel transect, for all observation within the site reach, divided by the total number of observations.
		IDX UnderstoryHerb	%	average per DCE as summation of categorical cover ratings, as contributed by herbaceous vegetation > 0.5 m and < 5 m in height, on left and right banks of each cross-channel transect, as one reading per bank per transect, for all observation within the site reach, divided by the total number of observations.
		IDX UnderstoryWood	%	average per DCE as summation of categorical cover ratings, as contributed by woody vegetation > 0.5 m and < 5 m in height, on left and right banks of each cross-channel transect, as one reading per bank per transect, for all observation within the site reach, divided by the total number of observations.
		PPN Canopy	None	proportion as count of presence of overstory vegetation, as contributed by large and small trees, at left bank and right bank for each cross-channel transect, per DCE, for all observations within the site reach, divided by total number of observations.
Habitat	Channel Dimensions	Site Length	m	length, per DCE, of the site reach of the main channel (channel 0) which was measured and surveyed
			m	length, per DCE, of the site reach of the main channel (channel 0) which was measured and surveyed
		ResPoolArea	m2	summation, as total vertical cross-sectional area of residual pools intersected by the thalweg profile as observed along the site reach, where incremental cross sectional areas are approximated as (residual pool depth per thalweg station X thalweg increment).
		ResPoolArea100	cm	average, vertical cross-sectional area of residual pools, as observed along the site reach, per 100 m of site reach
		TWIncrement	m	distance, per DCE, between thalweg stations along the site reach of the main channel (channel 0) which was measured and surveyed
		X BF WxD	m2	average, per DCE, of paired cross section calculations, as Bankfull_Width x Bankfull_Depth, associated with the main channel (channel 0), where Bankfull_Depth = Avg_Bankfull_Height+Thalweg_Depth
		X BFDepth	cm	Site average Bankfull Depth - Sum of SiteAverageThalwegDepth and SiteAverageBankfulHeight. Bankfull depth is vertical distance between substrate in deepest part of the channel and bankfull stage height.
		X BFHeight	cm	Site Average Bankfull Height - Bankfull height averaged across all transects at a site
		X BFWidth	m	average, per DCE, sum of bankfull width observations for the main channel (channel) divided

Matrix	Metric Category	Metric Name	Units	Method Description
				by count of bankfull-width observations, for the site reach.
		X Slope	%	estimated elevational change between upstream and downstream ends of a site reach as observed during a DCE, derived from a DEM
		X TWDepth	cm	Site Average Thalweg Depth - Average of thalweg depth from all Thalweg stations at a site
		X Wet WxD	m2	average, per DCE, of paired cross section calculations, as Bankfull_Width x Bankfull_Depth, associated with the main channel (channel 0), where Bankfull_Depth = Avg_Bankfull_Height+Thalweg_Depth
		X WetWidth	m	average, per DCE, as sum of total wetted width observations for the main channel (channel 0) divided by count of wetted width observations, for the site reach.
		Sinuosity	None	index, per DCE, of deviation from the straight-line, point-to-point distance between the upper and lower ends of the site reach.
		Bankfull Area	m2	

(table continued on next page)

Matrix	Metric Category	Metric Name	Units	Method Description
Habitat	Fish Cover	XFC Bryophytes	%	XFC Bryophytes - Percent fish cover provided by bryophytes, averaged for all transects in a site
		XFC LWD	%	XFC Large Woody Debris - Percent fish cover provided by large woody debris, averaged for all transects in a site
		XFC Macrophytes	%	XFC Macrophytes - Percent fish cover provided by macrophytes, averaged for all transects in a site
		XFC Natural	%	XFC Natural Types - Percent fish cover provided by all natural cover types, averaged for all transects in a site
		XFC NoAqVeg	%	XFC All Types Except Aqua Veg - Percent fish cover provided by all cover types except aquatic vegetation, averaged for all transects in a site
		XFC OvHgVeg	%	XFC Overhanging Vegetation - Percent fish cover provided by overhanging vegetation, averaged for all transects in a site
		XFC Persistent	%	XFC BigTypes - Percent fish cover provided by all large cover types, averaged for all transects in a site
		XFC TreesRoots	%	XFC Live Trees/Roots - Percent fish cover provided by live trees or roots, averaged for all transects in a site
		XFC Undercut	%	XFC Undercut Banks - Percent fish cover provided by undercut banks, averaged for all transects in a site
	Riparian Disturbance	PCT BankAg	%	percent disturbance, per DCE, as sum of weighted proximity of agricultural human influence types, if any, observed within or on the banks (L & R) of the main channel (channel 0), along the site reach, divided by N HumanInfluence.
		PCT BankAny	%	percent disturbance, per DCE, as sum of weighted proximity of all human influence types, if any, observed within or on the banks (L & R) of the main channel (channel 0), along the site reach, divided by N HumanInfluence.
		PCT CloseAg	%	percent disturbance proximity, per DCE, as count of plots where at least one agricultural human influence-type score was >1, divided by count of rated plots associated with the main channel along the site reach.
		PCT CloseAny	%	percent disturbance proximity, per DCE, as count of plots where at least one human influence-type score was >1, divided by count of rated plots associated with the main channel along the site reach.