Mid-Columbia FISHERIES ENHANCEMENT GROUP

Benton Conservation District

Quality Assurance Project Plan

Bateman Island Causeway Technical Support – Yakima Delta Temperature Monitoring

November 2022

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Quality Assurance Project Plan

Bateman Island Causeway Technical Support – Yakima Delta Temperature Monitoring

IAA No. C1800180
by Marcella Appel

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1.0 Table of Contents

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2.0 Abstract

Mid-Columbia Fisheries Enhancement Group (MCFEG) is supporting fisheries co-managers in moving the Yakima Delta Restoration project to the selection of a preferred alternative for improved habitat conditions. A critical component of Yakima Delta Restoration project is the removal of an earthen causeway that blocks flows between the Yakima River and the Columbia River.

The causeway, known as Bateman Island Causeway, connects the City of Richland to Bateman Island at the confluence of the Yakima and Columbia Rivers in Benton County, WA. A future modification to the causeway to allow flow through the area is likely to improve temperature conditions in the Yakima mainstem for salmon migrating through the Yakima basin.

This Quality Assurance Project Plan (QAPP) covers the collection of continuous temperature monitoring within the Yakima Delta beginning in 2022. Prior data (2018 – 2021) were covered under a previous QAPP which has expired. These data provide a record of baseline temperature conditions in the Yakima Delta across various water years and will provide river managers the ability to compare pre-and post- remediation conditions in the Yakima Delta.

This QAPP is funded with interagency agreement (IAA) No. C1800180 between the Washington Department of Ecology (Ecology) and the Washington State Recreation and Conservation Office (RCO).

3.0 Background

3.1 Introduction and problem statement

Bateman Island, located at the confluence of the Yakima and Columbia Rivers in Richland, WA is connected to the mainland by an earthen bridge referred to as the Bateman Island Causeway (Figure 1). The earthen causeway is a complete barrier between the Yakima and Columbia Rivers. The backwater area behind the west side of the causeway (Mud Hole) offers ideal habitat for non-native predatory fish such as bass, walleye, and catfish, which feed on out-migrating steelhead, Chinook, sockeye and coho salmon smolts in the spring. Summer temperatures routinely exceed 25°C to 30°C (Figure 2). Such extreme thermal conditions are a migration barrier to late migrating salmon, including sockeye, summer Chinook and fall Chinook.

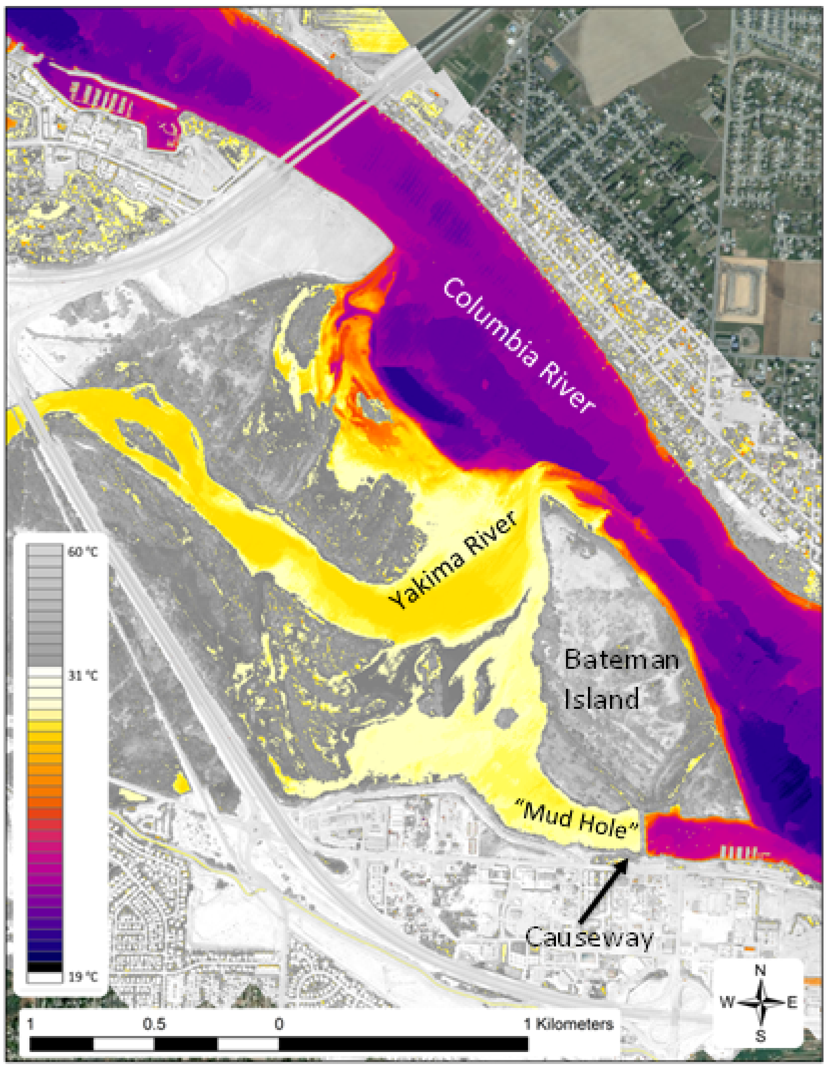

Figure 1. Thermal Infrared Imaging of the Yakima Delta (August 2020). Temperatures in the Yakima River (yellow) are much warmer than those in the cooler Columbia (purple).

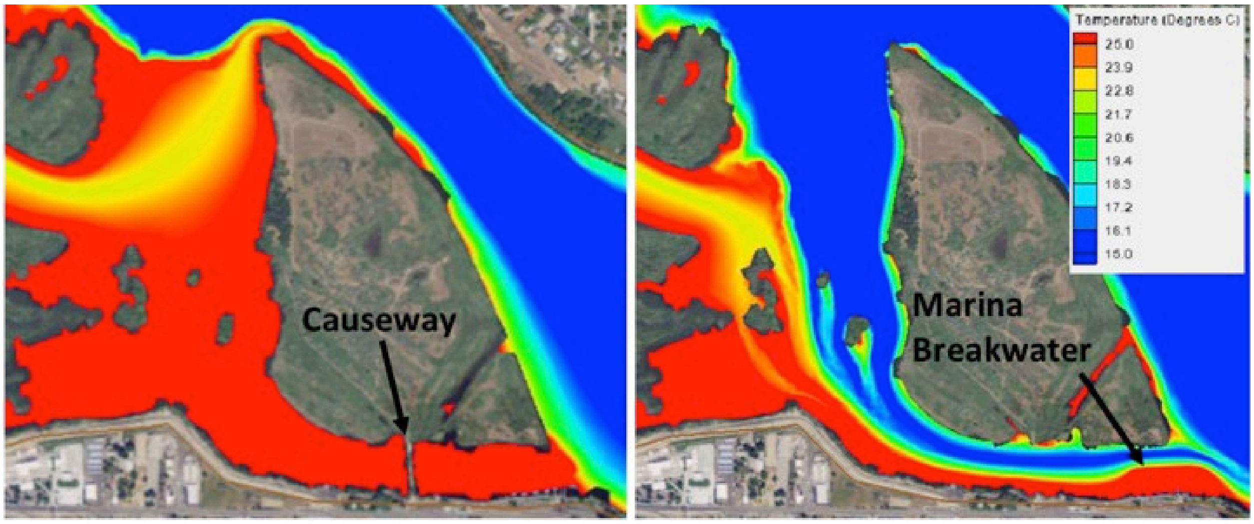

Figure 2. Simulated temperatures for a moderately higher Columbia River Discharge on July 8, 2012. Temperatures for existing conditions (left) and full causeway removal (right) (NHC, 2015).

Mid-Columbia Fisheries Enhancement Group (MCFEG) is supporting fisheries co-managers in evaluating causeway removal as part of a larger Yakima Delta Habitat Enhancement Project through the U.S. Army Corps of Engineers Section 1135 Ecological Restoration program. The Corps has utilized data and studies undertaken by a local partner coalition currently led by the Washington Department of Fish and Wildlife acting as the Non-Federal Sponsor on the project. Hydrodynamic Analysis modeling in 2014 by Northwest Hydraulic Consultants (NHC, 2015), indicated that modification of the causeway to allow flow through the south end of the island would improve temperature conditions in the Yakima mainstem for migrating salmon (Figure 2). Additional fisheries analysis indicates that causeway removal may improve conditions in the delta for native species by decreasing nonnative predator nurseries (McMichael, 2017).

To help inform management decisions, temperature data have been collected in the lower Yakima River delta from 2011 – 2021 by Benton Conservation District under subcontract with the Mid-Columbia Fisheries. Monitoring work from 2018 – 2021 was conducted as part of the expired Quality Assurance Project Plan titled: “Quality Assurance Project Plan: Bateman Island Causeway Technical Support” (Wassell, 2016). This document replaces the outdated QAPP for continued successful long-term temperature monitoring of the Yakima Delta. The resulting temperature data will continue to inform management decisions for delta restoration efforts as well as provide baseline data for comparison of post-remediation conditions after restoration actions are implemented.

This updated QAPP will govern monitoring work for November 2022 through October of 2027. Should sample design locations or methods change within the next 5-year period due to implementation of remediation actions, we will update the QAPP accordingly.

3.2 Study area and surroundings

Bateman Island sits at the confluence of the Yakima River with the Columbia River, in the City of Richland, Washington (Figure 3). The 160-acre island is connected to the mainland by an earthen bridge referred to as the Bateman Island Causeway. The causeway is approximately 500-feet long by 40-feet wide. Aerial photos indicate that the causeway was constructed between 1939 and 1940 for agricultural access. The causeway is composed of earthen material and has been reinforced with rock rip rap over time. It is a complete barrier to river flow, boats, and fish. The presence of the causeway impacts flow and water quality conditions in the Yakima Delta and contributes to a water temperature barrier that can delay adult salmon migration.

The Yakima River hosts anadromous runs of Steelhead Trout, spring, summer, and fall Chinook salmon, coho salmon, and sockeye salmon. Juvenile salmon out-migrate through the Delta area to the Columbia River, and adult fish migrate from the Columbia up into the Delta. Extreme thermal conditions in the lower Yakima River during irrigation season create a migration barrier to local salmonid species and have created habitat ideal for predatory warm water fish species such as smallmouth bass, walleye and channel catfish. The thermal barrier is a particular concern for species that migrate later in the summer, such as Sockeye Salmon and spring, summer, and fall Chinook salmon. Juvenile salmonids and spring adult runs must adapt migration timing to be through the lower Yakima River before temperatures rise rapidly in June and July. Fall adult migratory species hold in the Columbia River while waiting for Yakima River temperatures to decrease in September and October.

Figure 3. Yakima River delta and Bateman Island causeway

3.2.1 History of study area

Land use in the lower Yakima valley is predominantly irrigated agriculture that is heavily reliant on the Yakima River for irrigation water supply. For decades, high temperatures and suspended solids, turbidity, DDT, and other pesticides have been documented in the lower Yakima. By the mid-1990s, water quality evaluations by the USGS indicated that some improvements had been made, but beneficial uses were still impaired by sediment and sediment-borne pollutants, like DDT, from irrigation returns (Rinella et al. 1999). As a result, several reaches of the lower Yakima and several of its tributaries did not meet numerous state water quality criteria and federal guidelines.

Water quality issues of concern in the entire Yakima River basin range from fecal coliform bacteria to suspended sediments and turbidity, as well as toxics, pH, nutrients, dissolved oxygen, and temperature. The water quality issues in the basin impact the beneficial uses of the water, potentially making it unsafe for drinking or recreation and threatening the health of aquatic animals and fish living in it.

At this time there are two fish species listed as Threatened under the federal Endangered Species Act: mid-Columbia bull trout and mid-Columbia steelhead. Conley and others (2009) summarized studies in the upper and middle Yakima River that indicated temperature, toxic chemicals, and lack of foraging habitat and refuge from predators were creating obstacles for survival of these species.

To date, the primary water quality improvement projects conducted on the Yakima River are part of the Yakima River Watershed Toxic Reduction Program. These projects have been implemented to decrease the Total maximum daily loads (TMDLs) of toxics, sediment, and DDT. These projects are in various stages of development across the watershed. The primary TMDL projects in the lower Yakima include:

Yakima River: Toxics Reduction Program

- Water quality monitoring of DDT, dieldrin, and other chlorinated pesticides (Johnson et al. 2010).

Lower Yakima River: Suspended Sediment and DDT

- TMDL evaluation report about the amount and sources of several pollutants in the lower Yakima River (Joy and Patterson 1997).

The work related to these TMDL projects can be accessed through the Washington State Department of Ecology Website at:

Toxics Reduction Program: https://ecology.wa.gov/Water-Shorelines/Water-quality/Water-improvement/Total-Maximum-Daily-Load-process/Directory-of-improvement-projects/Yakima-watershed-toxics-reduction-project

3.2.2 Summary of previous studies and existing data

In 1997, Ecology published a TMDL evaluation report on the lower Yakima (Joy and Patterson 1997). The TMDL noted that the relationship between turbidity, suspended sediment, and DDT would likely change significantly after most of the suspended sediment was removed from the river. The U.S. Environmental Protection Agency (EPA) approved the TMDL for the protection of chronic aquatic life and turbidity criteria in 1998 but did not approve it for achieving compliance with the more restrictive human health pesticide criteria.

The TMDL noted that the relationship between turbidity, suspended sediment, and DDT would likely change significantly after most of the suspended sediment was removed from the river. Therefore, the TMDL intended to identify specific human health load allocations for DDT starting in 2007.

In addition to those TMDLs, temperature monitoring is performed at two lower mainstem Yakima River locations, the Prosser gage and the Kiona gage. Those gages are operated by the USGS and the U.S. Bureau of Reclamation. Temperature data from other locations and for shorter periods of record are also available from several sources. There has not been a TMDL drafted for temperature in the lower Yakima River.

Multiple monitoring stations are maintained on the Columbia River within the McNary Pool. The US Navy Puget Sound Naval Shipyard monitors continuous temperature and stage data for the Columbia River at the Port of Benton. Data for this location are available on the In-Situ host server run by In-Situ, Inc. (In-Situ, Inc. 2016). Temperature and stage data are also monitored at Clover Island by the USGS under funding by the US Army Corps of Engineers, Walla Walla District. The Clover Island data are provided on both the USGS website (USGS 2016) as well as in the Army Corps of Engineers Data query Database, site PAQW (USACE 2016).

US Geological Survey has monitored temperature, dissolved oxygen, sediments, nutrients, and pH at the Kiona (Benton City) and Van Giesen (West Richland) stations on the Yakima River since 2018. These stations are funded annually, and data are available from 2018 through 2022. All data for these stations are available on the National Water Information System (NWIS) (https://waterdata.usgs.gov/wa/nwis/rt).

Water temperatures and habitat concerns related to the Bateman Island Causeway have been evaluated previously by five key studies. These include:

- 1998 – Bureau of Reclamation commissioned a Forward-Looking Infrared (FLIR) flight over the lower Yakima River in August of 1997 (Holroyd, 1998). Collected digital aerial thermography data showed that temperatures in the region west of Bateman Island exceeded 28 degrees C at the same time temperatures in the Columbia River and Yakima Rivers were 20 and 23 degrees C, respectively.
- 2004 – The U.S. Army Corps of Engineers (USACE) performed the "City of Richland Ecosystem Restoration Project" (USACE, 2004). This study evaluated three alternatives to improve habitat in the area west of Bateman Island using multiple measures, including opening the Bateman Island Causeway and riparian improvements. The study highlighted concerns associated with opening the causeway and estimated that the improvements would cost on the order of $2,000,000.

- 2011 – Benton Conservation District (BCD) performed an assessment of temperatures in the Lower Yakima River (Appel et. al, 2011). This study took a close look at temperatures in the Bateman Island vicinity, collecting continuous temperature data at five locations during the summer of 2009. Longitudinal temperature profiles along the lower Yakima River, including the Bateman Island vicinity, were also collected on August 14, 2008, and July 31, 2009. The study confirmed that temperatures west of Bateman Island frequently exceed 30 degrees C, but also found that temperature dynamics including interactions with the Columbia River were more complex than initially thought.
- 2014 – In partnership with the BCD, MCFEG retained a consultant, INTERA, to perform an initial hydrodynamic assessment of flow and temperature patterns in the vicinity of Bateman Island Causeway (Wassell et. al, 2014). This study included collection of bathymetric data of the causeway vicinity in June 2011 and the collection of continuous temperature data at six locations between August 2011 and October 2012. The bathymetry and monitoring data were used by the consultant as inputs to a hydrodynamic model developed of the Bateman Island vicinity. The analysis utilized Environmental Fluid Dynamics Code (EFDC) to calculate flow distributions and MATLAB scripts to calculate temperatures. The model was uncalibrated, but four different opening configurations of the causeway were evaluated, and all indicated that temperatures on the west side of Bateman Island would reduce if flow were allowed around the south end of the Island.
- 2015 – MCFEG worked with BCD and contracted hydrologists with Northwest Hydraulic Consultants to apply a calibrated model to the temperature questions in the Yakima River delta. Hydrodynamic models AdH and CE-QUAL-W2 were used to simulate stream flows, velocities, and temperatures in the Bateman Island vicinity and calculate changes in temperature, velocity, flow, and sediment (NHC, 2015). Temperature data were collected at the same locations within the delta as established for the 2014 study, with data collected from 2013 – 2015 to inform the temperature modeling.
- All of the calculated temperature metrics indicated that adding a breach to the existing causeway will decrease water temperatures and improve salmonid habitat on the west and south sides of Bateman Island. The alternatives with breaches of 260 feet or greater (Alternatives 5, 3 or 8) produced the most benefit, but all the alternatives (also including smaller 130-foot and 200-foot breaches) resulted in some reduction of temperatures west and south of Bateman Island (NHC, 2015).
- 2016 – 2018 – BCD collected temperature data within the delta in collaboration with MCFEG under funding between the Washington State Department of Ecology and the Washington State Resource Conservation Office. Data are available in Ecology's Environmental Information System (EIM) database as part of agreement C1600150.
- 2018 – Present: The Yakima Delta Enhancement project was selected for restoration under the U.S. Army Corps of Engineers Section 1135 authority to address habitat degradation caused by previous Corps activities, in this case impacts from the filling of the McNary Pool after the construction of the McNary Dam. Through its review the Corps confirmed the causeway to be an illegal structure. The Washington Department of

Fish and Wildlife is the Non-Federal Sponsor for the Section 1135 process. Working with a group of local, state, tribal and federal stakeholders, alternatives for restoration of the Yakima Delta are currently under investigation as a part of the Corps Section 1135 Feasibility Study phase. The temperature data collected under the previous QAPP (Wassell, 2016) were evaluated by USACE engineers to understand the potential impacts of causeway removal. A Tentatively Selected Plan will be drafted by the Corps and is anticipated in late 2022 to early 2023 and will be presented to stakeholders and undergo public review as a part of the NEPA process. As part of this effort BCD continues to collect temperature data under a Memorandum of Understanding (MOU) with MCFEG. Data are available in Ecology's EIM database under grant IAA_C1800180.

3.2.3 Parameters of interest and potential sources

The main parameter of interest for this monitoring study is water temperature.

3.2.4 Regulatory criteria or standards

Water Quality Standards for Surface Waters of the State of Washington, Chapter 173-201A WAC (Ecology 2011) established beneficial uses of waters and incorporated specific numeric and narrative criteria for parameters such as water temperature, DO, pH, and turbidity. The criteria define the level of protection necessary to support the beneficial uses. Washington Administrative Code (WAC) 173-201A-600 and WAC 173-201A 602 list the use designations for specific areas. The state has not yet established regulatory criteria for river nutrients.

For the lower Yakima, the designated uses of the waters include the following:

- Primary Contact Recreation
- Water Supply Uses (Domestic Water, Industrial Water, Agricultural Water, Stock Water)
- Wildlife Habitat
- Commerce/Navigation
- Boating
- Aesthetics
- Aquatic Life

Chapter 173-201A WAC defines the aquatic life for the lower Yakima as Salmonid Spawning, Rearing, and Migration. The key-identifying characteristic of this use is salmon or trout spawning and emergence that only occur outside of the summer season (September 16 - June 14). Other common characteristic aquatic life uses for waters in this category include rearing and migration by salmonids.

Table 1 (next page) summarizes the criteria that apply for temperature, DO, pH, and turbidity in the lower Yakima, which we further discuss below.

Table 1. Water quality criteria for the study area.

Waterbody	Dates	Temperature[a]
Yakima River from Cle Elum River to the mouth	Annual	21°C 1-day maximum No human-caused increase of more than 0.3 °C if natural conditions exceed criteria.

[a] These criteria are not currently in effect for Clean Water Act purposes as a result of EPA's 2021 reconsideration and disapproval of Washington's natural conditions criteria in the water quality standards. These criteria remain in effect for other statewide water quality actions. Ecology has initiated rulemaking to revise the natural condition provisions that will respond to EPA's concern and will again meet Clean Water Act approval. For more information, please visit Ecology's website (https://ecology.wa.gov/Regulations-Permits/Laws-rules-rulemaking/Rulemaking/WAC-173-201A-Natural-Conditions).

3.2.4.1 Temperature Criteria

Temperature levels fluctuate over the day and night in response to changes in climatic conditions and river flows. Since the health of aquatic species is tied predominantly to the pattern of maximum temperatures, over most of Washington temperature criteria are expressed as the highest 7-day average of the daily maximum temperatures (7-DADMax) occurring in a waterbody.

However, WAC 173-201A-602 (Ecology 2011) provides the following special criteria for the Yakima River from mouth to Cle Elum River (river mile 186).

> *Temperature shall not exceed a 1-DMax of 21.0°C due to human activities. When natural conditions exceed a 1-Dmax of 21.0°C, no temperature increase will be allowed which will raise the receiving temperature by greater than 0.3°C; nor shall such temperature increases, at any time, exceed t = 34/(T+9).*

3.3 Water quality impairment studies

Not Applicable.

3.4 Effectiveness monitoring studies

Not Applicable.

4.0 Project Description

4.1 Project goals

The project goal is to help increase the understanding of the seasonal temperature conditions in the lower Yakima River and the Yakima River delta behind the causeway. The study will build upon temperature data collected in previous years and increase the understanding of temperatures within the delta across multiple years and under variable flow conditions. Ultimately, these data are available to stakeholders through EIM in support of their efforts for salmon restoration in the Yakima River Basin. These stakeholders include the US Army Corps of Engineers (USACE), Washington State Department of Fish and Wildlife, Yakama Nation, Confederated Tribes of the Umatilla Reservation, City of Richland, Department of Natural Resources (DNR), National Marine Fisheries Service (NMFS) and Yakima River Basin managers, to name a few. Stakeholders will use these to better understand the impact of causeway removal on water temperatures within the lower Yakima River mainstem and delta as well as provide a baseline comparison for post-remediation improvements.

4.2 Project objectives

The objectives of this study are to:

- Monitor established sites for continuous temperature monitoring to provide baseline comparison data. These data will support future analysis after remediation efforts commence.
- Follow established protocols as outlined in this QAPP to ensure that representative stream temperatures are obtained throughout the next five years and to prevent equipment loss to vandalism or high streamflow.
- Attempt to maximize the reliability of the data through pre- and post-deployment calibration checks and quality control procedures designed to locate and remove anomalous data.

4.3 Information needed and sources

The project may use previous collected temperature and flow data on the lower Yakima River from the following sources:

- Previously collected temperature data from Yakima Delta BCD monitoring program as detailed in Section 3.2.2. This includes data from 2014 – 2015 stored on the BCD server, and data from 2016 – 2020 stored within EIM under grant agreements C1600150 and C1800180.
- National Water Quality Assessment Program or USGS Surface-Water Data for Washington (https://waterdata.usgs.gov/wa/nwis/rt) for the lower river gages at Kiona and Van Giesen. These stations provide comparison upstream temperature data. Kiona station provides flow and level data for the lower river.

Additionally, the project will collect seasonal (March – October) temperature data at four locations within the Yakima River Delta. The details of this data collection are provided in Section 7.1 and 7.2. Flow and level data are pulled from the National Water Quality Assessment Program or USGS Surface-Water Data for Washington (https://waterdata.usgs.gov/wa/nwis/rt) at Kiona. The project may also compare the Yakima Delta temperature data to upstream conditions using the USGS Kiona and Van Giesen monitoring stations (https://waterdata.usgs.gov/wa/nwis/rt).

Lastly, Columbia River temperatures and flow may be required by the project. The Columbia River near the delta is currently monitored at Clover Island by the USGS (funded by the US Army Corps of Engineers, Walla Walla District). Data are stored at:

- http://waterdata.usgs.gov/wa/nwis/inventory/?station=12514400
- http://www.nwdwc.usace.army.mil/cgibin/dataquery.pl?k=PAQW

Columbia River flows are utilized when planning field days as entry to the delta requires ferrying through the Columbia River. The project is also comparing Yakima River temperatures to the Columbia for potential improvements, and Columbia River data may be retrieved for comparative purposes only.

4.4 Tasks required

Summary of tasks required to complete this project:

- Pre- calibration checks on temperature loggers.
- Deploy loggers at selected monitoring sites.
- Collect continuous temperature data at monitoring sites during summer migration season (May – October) each year for the duration of this QAPP.
- Collect field check temperature measurements (instantaneous) for deployed loggers every 6-8 weeks during monitoring season.
- Retrieve, download, and perform post-calibration checks of all loggers every 6 – 8 weeks during monitoring season.
- Quality assurance check of the collected temperature data.
- Data Entry for continuous temperature data into EIM for long term storage and management.

4.5 Systematic planning process

This QAPP represent the systematic planning process.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

MCFEG is the implementing agency for Agreement: IAA No. C1800180 between Washington Department of Ecology and the Washington State Recreation and Conservation Office. Contact info is: Mid-Columbia Fisheries Enhancement Group P.O. Box 2211 White Salmon, WA 98926 (509) 281-1311 MCFEG and partner staff involved in this Quality Assurance Project Plan (QAPP) are listed in Table 2.

Table 2. Organization of project staff and responsibilities.

Staff	Title	Responsibilities
Rebecca Wassell Mid-Columbia Fisheries Enhancement Group Phone: 509-281-1311	Yakima Basin Director	Program oversight and coordination.
Merritt Mitchell-Wajeeh Mid-Columbia Fisheries Enhancement Group Phone: 509-840-5600	Outreach and Communications Manager	Overseeing the development of QAPP and monitoring program, tracks progress of monitoring and provides project reporting to OCR.
Marcella Appel Benton Conservation District Phone: 509-736-6000	Water Resource Project Manager	Oversee Benton CD staff for data collection, and tracks project deliverables and timelines to ensure project is completed on time and on budget. Oversees quality assurance check of the collected temperature data. Input data into EIM.
Thomas Sexton Benton Conservation District Phone: 509-736-6000	Resource Conservationist	Pre-calibration and deployment of loggers at selected monitoring sites; collection of data; retrieval, downloading, and post-calibration checks of all loggers.
Scott Tarbutton Washington Department of Ecology, Office of Columbia River Phone: 509-867-6534	Ecology OCR Project Manager and QAPP Coordinator	Provides initial review and feedback of QAPP, approves QAPP.

5.2 Special training and certifications

The field lead and assistants for each survey will be trained in and experienced with the SOPs being used for data collection. This project requires the hiring of a certified diver to retrieve the loggers. Benton CD ensures that the diver has current certification to perform the dives.

5.3 Organization chart

BCD and MCFEG will work collaboratively on this project through a Memorandum of Understanding. Ms. Mitchell-Wajeeh and Ms. Appel will communicate about the project at the monthly at regularly scheduled meetings. Responsible project staff and lines of communication are demonstrated in Figure 4.

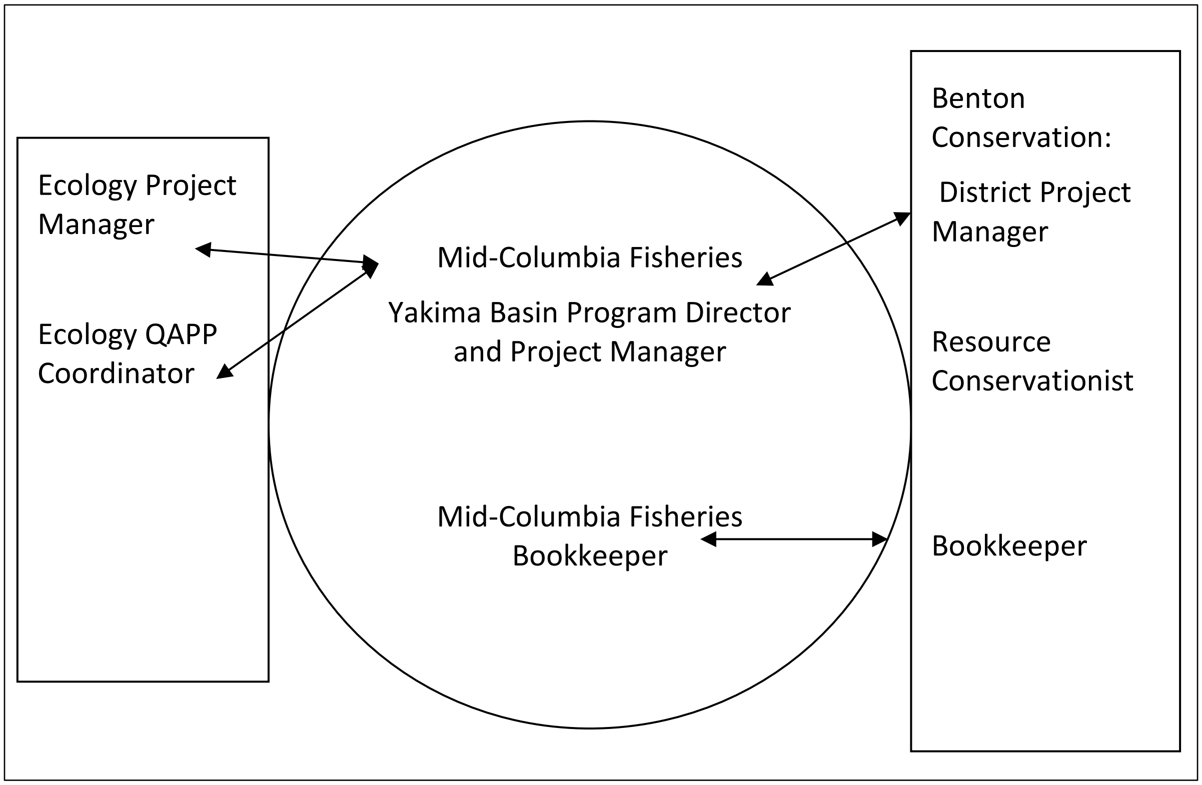

Figure 4. Organizational chart for project communication.

5.4 Proposed project schedule

The proposed project schedule and lead staff for each task is provided in Table 3.

Table 3. Schedule for completing field and laboratory work

Task	Due date	Lead staff
Collection of Temperature data and field checks	May – October from 2022 through 2027	Thomas Sexton BCD
Data Processing, Data QA/QC and EIM Upload	Annually November - March	Marcella Appel BCD
Quarterly PRPR reports	Quarterly from 2022 through 2027	Merritt Mitchell-Wajeeh MCF

5.5 Budget and funding

Project funding is provided through Agreement: IAA No. C1800180 between Washington Department of Ecology and the Washington State Recreation and Conservation Office. Benton CD holds an MOU with Mid-Columbia Fisheries for the delta monitoring. The budget (Table 4) is currently allocated through 2023.

Table 4. Project budget and funding

Cost Category	Cost ($)
Salary, benefits, and indirect/overhead	22,679
Equipment	3,000
Travel and other	321
Diver	4000

6.0 Quality Objectives

6.1 Data quality objectives

The data quality objectives of this project are to collect continuous temperature data at the sample locations which represent the target stream conditions for the Yakima River Delta and collect data that are comparable to previous monitoring years for a development of a long-term record of pre-causeway removal conditions.

6.2 Measurement quality objectives

Temperature logger details are summarized in Table 5, below. The precision and instrument bias measurement quality objectives (MQOs) of each temperature logger are verified through both pre- and post-deployment calibration checks following the procedures described in the Standard Operating Procedures for Continuous Temperature Monitoring of Fresh Water Rivers and Streams (Nelson and Dugger, 2022). The procedures require that the temperature loggers be tested in controlled water temperature baths that bracket the expected monitoring range (near 0ºC and near 20ºC). The results are then compared to those obtained with a certified reference thermometer.

Table 5. Measurement quality objectives for field meter measurements.

MQO →	Accuracy	Bias[2]	Precision (Relative percent Difference)	Sensitivity
Temperature (Onset Pendant)	Within ±0.6 °C of field meter[1]	Within ±1.13 °C of NIST calibrated thermistor.	≤ 20%	Between 0 and 35°C, resolution ±0.1 °C

1. The manufacturer's stated accuracy for the field meter is the combined accuracy for the NIST traceable Digisense meter and EW-20250-94 probe. The meter has an MSA of ±0.5 °C and the probe has an MSA of ±0.1°C giving an accuracy of. ± 0.6 °C
2. The Bias (replicate mean RPD) is the combined manufacturer's stated accuracy for the National Institute of Standards and Technology (NIST) traceable meter (± 0.6 °C) with EW-20250-94 probe and the Onset Temperature Logger (± 0.53 °C).

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 for field replicate measurements of temperature will be expressed as the replicate mean Relative Percent Difference (RPD) between the logger temperature and the mid-deployment check temperature (Table 5).

$$RPD = \frac{ABS(R1 - R2)}{(R1 + R2)/2}$$

ABS = Absolute Value

R1 = Logger Temperature 1

R2 = Deployment Check Temperature 2

If the mean relative percent difference (RPD) between the National Institute of Standards and Technology (NIST)-certified thermistor (Digi-Sense 2) the temperature data logger, is equal to or greater than the precision criteria, then a second check should be performed.   An RPD value is considered acceptable if it is ≤ 20%. If field RPD's regularly fall outside of this range, BCD will evaluate the equipment and methods to determine a course of action. Temperature loggers that fail a second pre-deployment check will not be used.

6.2.1.2 Bias

Bias is the closeness of agreement between an observed measurement value to the expected value or to the most-probable value. Bias is usually addressed by calibrating field and laboratory instruments. Tables 6 list targets for bias.

Instrument bias can be observed in any consistent differences between:

- NIST calibrated thermometer and any deployed continuous temperature logger during field checks, and
- NIST calibrated thermometer and any continuous temperature loggers in pre- and post-deployment calibration checks.

Sampling bias is minimized by following the deployment procedures described in Nelson and Dugger (2022). These procedures specify site selection and deployment methods designed to ensure that the temperature logger results are representative of stream conditions throughout the entire monitoring period and not biased by the effects of solar radiation or low streamflow conditions.

Sample bias can be estimated during the pre- and post- deployment calibration checks by looking for consistent differences between the NIST referenced thermometer and the temperature logger.

Sample bias in deployed thermistors is estimated by comparing the temperature deployed temperature loggers to the field check thermometer (Digi-Sense 2) during field visits. The bias criteria in Table 5 will be used by the Project Manager to assess whether a bias exists for any individual temperature logger.

6.2.1.3 Sensitivity

Sensitivity is a measure of the capability of a method to detect a substance. It is commonly described as detection limit. The detection limit for field measurement of water temperature is 0.1 °C.

6.2.2 Targets for comparability, representativeness, and completeness

6.2.2.1 Comparability

To ensure comparability, field measurements will follow approved Environmental Assessment Program (EAP) SOPs. These are listed in section 8.1. Water temperature loggers will be deployed in the same locations used in previous studies (2011 -2021) so that consistent and representative temperature data may be collected throughout the entire monitoring period. The same PVC structures and methods for deployment will be used so that the data is consistent and comparable between years.

6.2.2.2 Representativeness

The study is designed to have enough monitoring sites and sufficient monitoring frequency to meet study objectives of characterizing the temperature regime in the target areas. The number of sites and locations were determined based on extensive temperature modeling conducted in 2015 (NHC, 2015). There are 4 locations. Data are downloaded every 6 – 8 weeks during the monitoring season.

6.2.2.3 Completeness

The target for this study is to correctly monitor, record, and analyze 95-98% of the time intervals pre-set to record by the temperature loggers at all sites. Completeness will be acceptable if water temperatures monitored at each site allow the 7-DADMax and 1-DMax water temperatures to be evaluated for at least 90% of the range of time during the summer migration season (May – October). Potential problems during data collection that need to be avoided if possible include loss of temperature loggers by flooding or vandalism, loss of valid water temperature recording due to water levels dropping below logger installations, malfunctioning of loggers, and site access problems.

6.3 Acceptance criteria for quality of existing data

Section 3.2.2. and 4.3 lists potential data sources for this study. The project is primarily focused on current data collection and does not rely heavily on use of prior data for completion of objectives. However, some historical data may be used for comparison to current data as outlined in 4.3. For these data sources we will us the best available data, assess the quality of that data and then assess the effects of data quality on the project. To follow a process of quality assessment, we will:

1. Investigate the source of the data for documented data quality procedures.
2. Document and evaluate any qualifications associated with the data.
3. Evaluate the data for outliers or unusual trends that may suggest data quality problems.
4. Censor, qualify, or accept suspect data, based on the evaluation of that data.

5. Conduct an overall assessment of the variability and uncertainty of each data set prior to use.

6.4 Model quality objectives

Not Applicable.

7.0 Study Design

The project objectives will be met through characterizing seasonal temperature in the Yakima Delta. Continuous temperature data collection will be required for future analysis to assess suitability for salmon migration. Monitoring will occur during summer migration season (May through October) as feasible pending flow conditions.

The sampling design will use a fixed network of monitoring sites with continuous temperature loggers. Field temperature checks will be conducted during deployment and retrieval of the loggers in August and October.

7.1 Study boundaries

Benton CD staff will collect continuous temperature data at four locations, with two samples collected at W3, within the Yakima Delta during migration season (May through October). Sampling deployment and retrieval occurs as feasible based on annual flow conditions (Figure 5). These locations were established in earlier monitoring efforts and refined from modeling results from the 2015 Bateman Island Hydrodynamics Report (NHC, 2015).

The upstream boundary includes two loggers cable-attached to the RR Bridge spanning the Yakima River near Highway 240. Two loggers are deployed at this site: one on the north side and one on the south side. Initially the two loggers were deployed to evaluate potential effects of temperature differences from shading by the bridge. Years of data collection, however, show minimal differences between the north and south loggers. More often, these loggers are susceptible to theft so both loggers are now kept for redundancy of data collection.

Two loggers (YR-W1 and YR-USofW1) are located within the Yakima River mainstem before the confluence of the Columbia River. The last monitoring location is within the mudhole behind the west side of the Bateman Island Causeway. The mudhole stratifies during the summer months, so two loggers are deployed at differing depths (3 ft and 5ft above the riverbed) to capture these potential differences. Recreational activities are high during the summer months in the mudhole and as such the loggers are kept at 50% to 65% of the total summer depth to remain well below the surface and out of public view.

Figure 5. Map of monitoring locations (green markers) in the lower Yakima River.

7.2 Field data collection

The sampling design will use a fixed network of monitoring sites with continuous temperature loggers (Table 6). Field temperature checks will be conducted every 6-8 weeks during the diver assisted retrievals to check on the logger function and download data.

All loggers (other than those cabled to the RR bridge) are housed in a PVC structure that sits above the riverbed. The casings are designed so that the diver can unscrew the loggers easily for deployment and retrieval. All loggers are within a depth that the thermistor cable can reach, and the diver assists in making sure the thermistor checks are as close to possible to the position of the deployed logger for accurate readings.

Table 6. Monitoring sites and parameter to be measured.

Site descriptor	Site Number	Latitude	Longitude	Parameter
Confluence of Yakima and Columbia River	YR-W1	46.250106	-119.231984	Water Temperature
Upstream of W1 in the Yakima and Columbia Confluence	YR-USofW1	46.246797	-119.236269	Water Temperature
Railroad (RR) bridge by HWY 240 Bridge Piling	YR-RR Bridge S YR-RR Bridge N	46.253591	-119.257229	Water Temperature
W3 Upstream side of Bateman Island Causeway (Mud Hole) at 3' and 5' above riverbed	YR-W3 at 5ft YR-W3 at 3 ft	46.239230	-119.225704	Water Temperature

7.2.1 Sampling locations and frequency

Data collection will occur between May and October, annually. Monitoring locations are provided in Table 6 and Figure 5

Continuous temperature collection:

- The water temperature loggers will be deployed to log every 60 minutes in locations where representative temperature data may be obtained throughout the entire monitoring period.
- A duplicate logger will be deployed at the upstream boundary location under the HWY240 railroad bridge. A duplicate logger is deployed at this location, as this location is accessible to the public, resulting in potential logger theft or damage.

7.2.2 Field parameters and laboratory analytes to be measured

We will monitor continuous temperature at four locations within the Yakima Delta. Two loggers are located at the railroad bridge for redundancy, and two loggers are located within the mud hole to evaluate differences in temperature resulting from water stratification.

7.3 Modeling and analysis design

Not Applicable.

7.3.1 Analytical framework

Not Applicable.

7.3.2 Model setup and data needs

Not Applicable.

7.4 Assumptions of study design

It is assumed that the data collected are not impacted by location bias and are at a representative location within the water column to adequately reflect the temperatures within the delta and confluence. We also assume that more normative water years will be likely during the two-year study and that unusual flow conditions (drought or floods) will not greatly impact the installed equipment. We also assume that the equipment will not malfunction and will continue to operate to the standards and specifications required for the duration of this project, without theft or loss.

We assume the data collected will be comparable to previous monitoring years. We minimize potential issues by deploying the temperature loggers at fixed locations established in previous years' work and data will be collected following the same sampling protocols to maintain consistency between years. By continuing to monitor water temperature in the delta, seasonal variability can be investigated through comparison to previous years of collected data. Stakeholders will utilize these data to help inform decisions that support salmon migration and survival in the lower Yakima River corridor.

7.5 Possible challenges and contingencies

7.5.1 Logistical problems

Deployment and retrieval of loggers is dependent on river flows, diver availability and health, safe weather conditions (ambient temperatures, low wind, etc.), and air quality during fire season. All loggers are deployed in locations deep enough to be free from interference during higher flow, but there is a risk of equipment being caught by boat propellers or fishing lines during low flows.

7.5.2 Practical constraints

Sampling deployment and retrieval will depend on diver and boat driver availability. Field days will be planned and coordinated in advance to prevent scheduling conflicts, but weather constraints may cause unforeseen delays as dives cannot occur during windy or stormy conditions.

7.5.3 Schedule limitations

The primary limitations on schedule will be diver availability, boat availability, weather, and summer smoke (air quality) constraints. If any of these impact the project schedules, then project timelines will be revisited.

8.0 Field Procedures

8.1 Invasive species evaluation

Field staff will follow the procedures described in Ecology SOP EAP070 – Minimizing the Spread of Invasive Species (Parsons et al. 2018). The study area for this project is not located within areas of extreme concern, however, the boat is carefully inspected for invasive species after each sampling event and washed before stored. Loggers and the thermistor are washed after each deployment to ensure we do not spread invasive species from site to site.

8.2 Measurement and sampling procedures

GPS locations are used to locate and deploy the equipment at the PVC housings. If a PVC housing is broken or needs replacing, great effort is taken to get the redeploying housing at the location as near as possible to the coordinate locations. During deployments we check the GPS coordinate and measure the in-stream temperature with the NIST calibrated thermistor. Site-specific information including field photos will be documented during deployment for aid in retrieval of the submerged probes.

The Onset pendant loggers will be deployed at sites YR-W1, YR-USofW1, and YR-W3 utilizing a polyvinyl chloride (PVC) housing weighted and anchored into the riverbed sediment. The loggers will be 3 feet off the riverbed floor and sit freely in the current for all sites except YR-W3 where a second logger will be placed at 5 feet off the riverbed floor. The loggers will be attached to the PVC housing with a screw cap allowing the temperature probes to be easily detached, downloaded, and replaced with freshly calibrated loggers. A trained rescue diver familiar with sampling protocols will deploy the loggers and as needed, redeploy PVC housings if damaged.

The two loggers deployed at the HWY-240 RR bridge (YR-RR Bridge N and YR-RR Bridge S) will be attached to the bridge pilings using weighted chains. While infrequent, there is a higher level of possible theft and removal of the two probes mounted at the RR Bridge. As such we anchor one to the south side of the bridge and one to the north side. This temperature monitoring site provides the upstream boundary for the Yakima Delta Project Monitoring, and it is important to capture the incoming Yakima River temperatures to the delta.

Mid-deployment checks of the water temperature logger locations and temperature will be conducted every 6-8 weeks. All check observations and measurements will be recorded on the survey form. Damaged instruments and or PVC housings will be removed and replaced if needed.

To ensure comparability, field measurements will follow approved EAP SOPs (Ecology 2016):

- EAP080 – Standard Operating Procedures for Continuous Temperature Monitoring of Fresh Water Rivers and Streams (Nelson and Dugger, 2022).
- EAP011 – Standard Operating Procedure for Instantaneous Measurements of Temperature in Water (Dugger, 2022).

- EAP070 – Standard Operating Procedures to Minimize the Spread of Invasive Species (Parsons et al. 2018).

8.3 Containers, preservation methods, holding times

Not applicable.

8.4 Equipment decontamination

Not applicable

8.5 Sample ID

Site IDs are assigned to the monitoring stations under this QAPP during previous sampling events. These site IDs are provided in Table 7.

8.6 Chain of custody

Not applicable.

8.7 Field log requirements

A field log will be maintained by the field lead and used during monitoring. Observations and measurements for water and air temperature logger checks will be recorded on a continuous temperature survey form (Appendix A).

All observations and measurements will be recorded on forms printed on waterproof paper. They will contain:

- Name of location and site ID.
- Date and time.
- Field staff.
- Field measurement results.
- Instrument IDs.
- Pertinent observations.
- Any temperature logger information.
- Comments.

8.8 Other activities

Not applicable.

9.0 Laboratory Procedures

9.1 Lab procedures table

Not applicable.

9.2 Sample preparation method(s)

Not applicable.

9.3 Special method requirements

Not applicable.

9.4 Laboratories accredited for methods

Not applicable.

10.0 Quality Control Procedures

Prior to deployment, the loggers will be calibrated following procedures recommended by Nelson and Dugger (2022). Each logger will be pre-set for a delayed start so that each logger starts recording at the same pre-set time prior to calibration and continues to log temperature every 1 minute for 10 -15 minutes at 20°C and 20 minutes at near 0.0 °C. A separate watch will be synchronized with the computer start time so that calibration readings would be simultaneous with the watch.

Loggers are placed into two separate water baths with a high and low temperature of 20 and near 0 degrees Celsius (°C), respectively, and allowed to equilibrate prior to recording temperatures. Calibration will be performed using a NIST certified Digi-Sense 2 Thermistor meter. Mean differences calculated from the logger calibration procedures are added or subtracted as appropriate from field data prior to use.

10.1 Table of field and laboratory quality control

In-situ temperature checks are to be collected at each monitoring location. These field checks occur during logger deployment, data downloads and equipment field checks, and logger retrieval (Table 7). Field checks are collected using a handheld NIST certified thermistor with a 20-foot cable.

Table 7. Field checks, types, and frequency.

Parameter	Field Checks	Frequency
Temperature	In-situ temperature check with NIST certified thermistor	Every 6 – 8 weeks*

*Temperature checks are conducted during deployment, retrieval, and logger downloads/equipment checks.

10.2 Corrective action processes

Review of data is an ongoing process throughout the project, and we will reject data or qualify it as needed. Quality control results may indicate problems with data during the course of the project. If the data do not meet quality control then corrective actions will be taken.

Such actions may include:

- Recheck pre- and post-calibration checks.
- Qualify or reject results.
- Clean, repair, or replace sensors if evidence of mid-deployment failures or issues.
- Convene project personnel to decide on the next steps we will take if persistent quality control problems arise.
- Use of quality control (QC) samples to correct datalogger sensor data.

11.0 Data 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 Excel® spreadsheets as soon as practical after they return from the field. The field lead will check data entry against the field notebook data for errors and omissions.

11.2 Laboratory data package requirements

Not applicable.

11.3 Electronic transfer requirements

Not Applicable.

11.4 Data upload procedures

Data will be transferred to Ecology's EIM system annually per online submittal guidelines. The EIM data coordinator will be consulted if data submittal problems arise. Benton CD staff uploading data into EIM data have experience with the database and training in the database. Data are stored under project IAA_C1800180 which houses data collected from 2018.

11.5 Model information management

Not Applicable.

12.0 Audits and Reports

12.1 Audits

Benton CD conducts regular audits and reviews of all finances and projects to ensure project billing, financials and record keeping are compliant. No audits are required or conducted on data collection, procedures or reporting. Results of all audits are available by request.

12.2 Responsible personnel

Please see section 5.3, Figure 4 for responsible personnel.

12.3 Frequency and distribution of reports

Grant progress reporting for this project will be completed according to the requirements outlined in Agreement: IAA No. C1800180 between Washington Department of Ecology and the Washington State Recreation and Conservation Office. Quarterly grant progress reports will be completed by the following schedule:

- October 1 through December 30
- January 1 through March 31
- April 1 through June 30
- July 1 through September 30
- October 1 through December 31

MCF is responsible for all PRPR reports. This monitoring is part of a larger ongoing grant for the Yakima Delta restoration project. The final close-out report will be submitted by MCF at project completion.

12.4 Responsibility for reports

Ms. Mitchell-Wajeeh will be the lead staff for all reports. Ms. Appel and Ms. Wassell will provide support for quarterly reports as needed.

13.0 Data Verification

13.1 Field data verification, requirements, and responsibilities

The data will be verified by following the procedures described in the Standard Operating Procedures for Continuous Temperature Monitoring of Fresh Water Rivers and Streams (Nelson and Duggar, 2022). These procedures are summarized below:

- Calibration checks and field procedures will be documented on appropriate forms.
- Data will be checked for entry errors and completeness.
- Pre- and post-calibration check results and field measurements will be reviewed to ensure the data quality objectives were met.
- Results will be verified using data plots, field measurements, and stream height/flow information (if available).
- Detected data errors will be corrected, flagged with data qualifiers, or deleted. For field measurements, the field lead will verify initial field data before leaving each site. This process involves checking the data sheet for omissions or outliers. If measurement data are missing or a measurement is determined to be an outlier, the measurement will be repeated.

BCD project staff will upload field parameters recorded on field sheets into Excel Spreadsheets within 48 hours of returning from the field and verification by the project manager. Project staff will also:

- Review continuous recording data within 48 hours of download to ensure correct sensor operation and identify possible problems early.
- Store data in the EIM database for long term storage and retrieval.
- Approval of records, including the primary data collector rectifying anomalous data, dates and times and applying any corrections that are needed
- Plotting the data and comparing continuous data to field check data.

13.2 Laboratory data verification

Not applicable.

13.3 Validation requirements, if necessary

Independent data verification is not necessary for this project.

13.4 Model quality assessment

Not applicable.

13.4.1 Calibration and validation

Not applicable.

13.4.1.1 Precision

Not applicable.

13.4.1.2 Bias

Not applicable.

13.4.1.3 Representativeness

Not applicable.

13.4.1.4 Qualitative assessment

Not applicable.

13.4.2 Analysis of sensitivity and uncertainty

Not applicable.

14.0 Data Quality (Usability) Assessment

14.1 Process for determining project objectives were met

After all field data are verified, the field lead or project manager will thoroughly examine the data to determine if MQOs have been met. The project manager will examine the data to determine if all the criteria for MQOs, completeness, representativeness, and comparability have been met. If the criteria have not been met, the project manager will decide if affected data should be qualified or rejected.

14.2 Treatment of non-detects

Not applicable.

14.3 Data analysis and presentation methods

Data analysis and comparison to previously collected Department of Ecology data will occur as appropriate. Data are reviewed in the Onset HOBOware Software post download, and reviewed in Excel after completion of QAQC. No presentations of this data are anticipated.

14.4 Sampling design evaluation

Not applicable.

14.5 Documentation of assessment

Not applicable.

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16.0 Appendices

Appendix A. Parameter Measured: Continuous Temperature Benton CD Procedures

#UA-001-64 Hobo Pendant
Onset Computer Corp.

Measurement range: -20° to 70°C (-4° to 158°F)

Alarms: High and low alarms can be configured for total amount of contiguous or non-contiguous time outside of user-defined limits between -20° and 70°C (-4° to 158°F)

Accuracy: ± 0.53°C from 0° to 50°C (± 0.95°F from 32° to 122°F), see Plot A

Resolution: Temperature: 0.14°C at 25°C (0.25°F at 77°F), see Plot A

Drift: Less than 0.1°C/year (0.2°F/year)

Response Time

Airflow of 2 m/s (4.4 mph): 10 minutes, typical to 90%

Water: 5 minutes, typical to 90%

Time accuracy: ± 1 minute per month at 25°C (77°F), see Plot B

Operating Range

In water/ice: -20° to 50°C (-4° to 122°F)

In air: -20° to 70°C (-4° to 158°F)

Water depth rating: 30 m from -20° to 20°C (100 ft from -4° to 68°F), see Plot C

NIST traceable certification: Available for temperature only at additional charge; temperature range -20° to 70°C (-4° to 158°F)

Battery life: 1-year typical use

Memory

UA-001-64: 64K bytes (approximately 52K sample and event readings)

Calibration Procedure

The logger cannot be calibrated but should be checked for drift twice annually: before deployment and following removal at the end of monitoring season. This will be done using a stable room temperature bath (20 C) for the high range, and a well-mixed ice bath to check the temperature recorded at 0ºC.

Measurement Procedure

Temperature measurement is taken at 60-minute intervals throughout the period of interest. Loggers are placed in late spring or early summer (pending water flow) and removed for the season in October. The monitoring sites are visited bimonthly for data downloading and measurement of other water quality parameters. The placement of the loggers requires that they measure a representative temperature for the river conditions (e.g., Temperature loggers should be placed in the main flow, but not in a backwater or eddy). In placing the loggers, effort is made to place them where they will not be exposed by receding water levels. Before heading into the field to download the loggers, the data shuttle clock is synchronized with that of the PC, so that the clocks on the loggers with also be synchronized when they are re-launched after download.

Appendix B. Glossaries, Acronyms, and Abbreviations

Glossary of General Terms

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

Anthropogenic: Human-caused.

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.

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

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

Diel: Of, or pertaining to, a 24-hour period.

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

Diurnal: Of, or pertaining to, a day or each day; daily. (1) Occurring during the daytime only, as different from nocturnal or crepuscular, or (2) Daily; related to actions which are completed in the course of a calendar day, and which typically recur every calendar day (e.g., diurnal temperature rises during the day, and falls during the night).

Effective shade: The fraction of incoming solar shortwave radiation that is blocked from reaching the surface of a stream or other defined area.

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

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.

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

Reach: A specific portion or segment of a stream.

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

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

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

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

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

Total Maximum Daily Load (TMDL): A distribution of a substance in a water body designed to protect it from not meeting (exceeding) water quality standards. A TMDL is equal to the sum of all 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.

1-DMax or 1-day maximum temperature: The highest water temperature reached on any given day. This measure can be obtained using calibrated maximum/minimum thermometers or continuous monitoring probes having sampling intervals of thirty minutes or less.

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

7-DADMax or 7-day average of the daily maximum temperatures: The arithmetic average of seven consecutive measures of daily maximum temperatures. The 7-DADMax for any individual day is calculated by averaging that day's daily maximum temperature with the daily maximum temperatures of the three days before and the three days after that date.

Acronyms and Abbreviations

Delete all the following that aren't used in this QAPP.

BMP	Best management practice
DO	Dissolved oxygen
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
GPS	Global Positioning System
i.e.	In other words
MQO	Measurement quality objective
NPDES	National Pollutant Discharge Elimination System
QA	Quality assurance
QC	Quality control
RM	River mile
RPD	Relative percent difference
RSD	Relative standard deviation
SOP	Standard operating procedures
TMDL	Total Maximum Daily Load
TSS	Total suspended solids
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
ft	feet
NTU	nephelometric turbidity units

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 (Kammin, 2010). For Ecology, it is defined according to WAC 173-50-040: "Formal recognition by [Ecology] that an environmental laboratory is capable of producing accurate and defensible analytical data."

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* (USEPA, 2014).

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: Discrepancy between the expected value of an estimator and the population parameter being estimated (Gilbert, 1987; USEPA, 2014).

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, 2014; USEPA, 2020).

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, 2014; USEPA 2020).

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

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

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

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

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

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

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

Data validation: The process of determining that the data satisfy the requirements as defined by the data user (USEPA, 2020). There are various levels of data validation (USEPA, 2009).

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, 2014).

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)/LCS duplicate: 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. Monitors a lab’s performance for bias and precision (USEPA, 2014).

Matrix spike/Matrix spike duplicate: A QC sample prepared by adding a known amount of the target analyte(s) to an aliquot of a sample to check for bias and precision errors 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 (USEPA, 2001).

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): The minimum measured concentration of a substance that can be reported with 99% confidence that the measured concentration is distinguishable from method blank results (USEPA, 2016). MDL is a measure of the capability of an analytical method of distinguished samples that do not contain a specific analyte from a sample that contains a low concentration of the analyte (USEPA, 2020).

Minimum level: Either the sample concentration equivalent to the lowest calibration point in a method or a multiple of the method detection limit (MDL), whichever is higher. For the purposes of NPDES compliance monitoring, EPA considers the following terms to be synonymous: “quantitation limit,” “reporting limit,” and “minimum level” (40 CFR 136).

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:

$$RPD = [Abs(a-b)/((a + b)/2)] * 100\%$$

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).

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).

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).

Reporting level: Unless specified otherwise by a regulatory authority or in a discharge permit, results for analytes that meet the identification criteria (i.e., rules for determining qualitative presence/absence of an analyte) are reported down to the concentration of the minimum level established by the laboratory through calibration of the instrument. EPA considers the terms "reporting limit," "quantitation limit," and "minimum level" to be synonymous (40 CFR 136).

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, 1992).

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, 2014).

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, 2014).

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

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