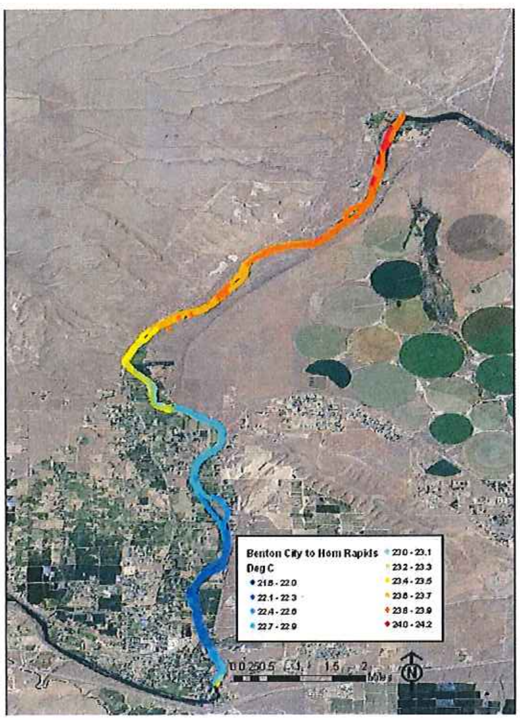
Benton Conservation District

DEPARTMENT OF ECOLOGY
State of Washington

June 25, 2018

Quality Assurance Project Plan

Lower Yakima River Thermal Refuge Profiling



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Benton Conservation District

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Each study, funded in whole or in part with Ecology funding, must have an approved Quality Assurance Project Plan. This plan describes the objectives of the study and the procedures to be followed to achieve those objectives.

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Data for this project will be available on Ecology's Environmental Information Management (EIM) website: https://fortress.wa.gov/ecy/eimreporting.

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Cover photo: Thermal Profile of Yakima River near Benton City, WA. Benton Conservation District.

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Lower Yakima River Thermal Refuge Profiling

June 2018

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Signatures are not available on the Internet version.
EAP: Environmental Assessment Program

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2.0 Abstract

Warm water temperatures in the lower Yakima are a factor in the timing of upstream salmonid migration in the late-summer and early fall. Late spring out-migration survival is also influenced by rapid water warming, especially in drought years. Enhancement of thermal refuge locations on the lower Yakima may support late spring and summer migration of anadromous species when water temperatures are otherwise to warm for fish passage.

This multi-agency project, led by Benton Conservation District (BCD), will map the longitudinal thermal profile of the lower Yakima River (lower Yakima) from Wapato to Richland, WA. Data will be used to identify cool water influents that can be developed for thermal refuge. Profiling will occur during base flow conditions (summer) in 2018 and 2019. Identification of thermal refuge locations is critical for supporting management and habitat action decisions to enhance, promote, or utilize these areas for thermal refuge.

The project goal is to obtain quality longitudinal thermal profiling data for the lower 100 miles of the Yakima River to be used in support of future project development. This project supports Yakima mainstem habitat enhancement goals of the Yakima Basin Integrated Plan and compliments the currently funded lower Yakima River Smolt Survival study. This project is a first step towards managing functional thermal refuge sites on the lower Yakima River in order to address thermal migration barriers. These thermal refuge sites are suspected to increase in-migration survival rates and provide beneficial warmer water for out-migration juvenile smolts during the winter and spring months. With anticipated climate change impacts in the basin resulting in higher river temperatures and lower springtime flows, thermal refuge locations will become increasingly important for migratory species.

3.0 Background

3.1 Introduction and problem statement

In 2008 and 2009, Benton Conservation District (BCD), located in Kennewick WA, identified and documented several locations of "cooler" water on the Yakima River below Prosser Dam. While still warm, these locations ranged from 0.5°C to 2.0°C cooler than the surrounding mainstem Yakima River water temperatures (Appel and others, 2011). These thermally suppressed areas are thought to provide refuge for migrating salmon through the lower Yakima River corridor during times when ambient river temperatures are otherwise too warm. In winter and spring, these areas are likely to provide rearing and growth opportunities for out-migrating juveniles. In 2011, Vaccaro found that incoming shallow groundwater and subsurface flows (likely enhanced or driven by applied irrigation water and overland flows) buffered the daily rise in summer water temperatures in the Prosser reach.

Fish are able to detect water temperature differences to within <0.1°C. Fish respond to these temperature changes by moving laterally and vertically to areas that are cooler and more favorable in an activity called behavioral thermoregulation. Torgersen and others (2012) summarized the current literature on thermal refuge utilization by fish and discuss the hierarchical river structures that contribute to thermal refuge in a basin. It is noted that on a basin and sub-basin level cold water refuges are driven by elevation, topography, geology, channel slope, and interactions between the surface and sub-surface hydrology (Torgersen 2012). Utilization of thermal refuge locations by fish is complex. There are oftentimes physiological and biological trade-offs for fish that move to cool water refuges. Although temperatures may be more favorable, the conditions (cover, dissolved oxygen, connectivity) may be less optimal (Torgersen 2012). Species interaction, predation and feeding, all contribute to favorability of a cool water patch. By studying and identifying thermal refuge on the lower Yakima, we may be able to better-manage and optimize the cool water patches for anadromous species.

While research shows that thermal heterogeneity exists on the lower Yakima, the stability of identified cool water seeps, their utilization by migrating and rearing salmonids, and their seasonal temperature dynamics are not well understood. Furthermore, multiple improvements and efficiencies have been made in the lower basin over the last decade by local irrigators in order to conserve water and in-stream river flows. While these improvements have many water saving benefits, they also decrease the amount of applied irrigated water that contributes to the total volume of subsurface and groundwater flows. Additional work to determine changes in the river's thermal heterogeneity over the past decade is critical for supporting management and habitat action decisions to enhance, promote, or utilize these areas for salmon migration and rearing.

In order to address these data gaps, BCD in partnership with Yakama Nation (YN) and the U.S. Geological Survey (USGS), will conduct a multi-phased analysis of the lower Yakima from Wapato Dam to the mouth (Richland, WA). Phase 1, covered under this QAPP, will consist of multi-day floats at summer flow conditions in 2018 and 2019. BCD and YN will partner together to float approximately 100 miles of the lower Yakima using the thermal profile method developed by Vaccaro and Maloy (2006).

Three boats with attached temperature/level loggers will float the lower river within a Lagrangian framework (i.e., tracking a parcel of water as it moves downstream over time). Float data will be analyzed by the U.S. Geological Survey (USGS) and will be compared to previously collected data by Appel and others (2011) and Vaccaro (2011). Identified locations of cooler water will be further examined to determine their thermal refuge potential and identify potential thermal refuge enhancement projects. Projects may include in-stream shading, in-stream structure (e.g. hole scour) and enhanced sub-surface groundwater flows. BCD will be the project lead and will facilitate a work group as part of this project to provide project management, communication, and coordination between the multiple agencies involved to ensure all deliverables are met and completed on time.

The data collected under this QAPP will be used to support work for Phase 2 of the funded grant. Phase 2 includes selection of 3-4 priority thermal refuge sites for temperature monitoring during the fall of 2018 through winter of 2019. It will also include augmentation of subsurface flows by Kennewick Irrigation District at one of the selected sites to determine utilization of aquifer recharge for thermal refuge enhancement. Phase 2 of the grant scope of work will be conducted under a separate QAPP (currently under development).

The Lower Yakima River Thermal Refuge Assessment and Enhancement project supports the efforts of the Yakima River Basin Integrated Plan (YBIP) to enhance rearing and migratory habitat on the Yakima River. This project is in alignment with the Lower River Action Plan currently under development by the Lower River Subgroup (formed under the Water Use and Habitat Subcommittees of the YBIP). Furthermore, this work will be coordinated with the Groundwater Subcommittee of the YBIP and the Outmigration Smolt Survival Study. This project will coincide with current efforts by Mid-Columbia Fisheries and BCD to enhance thermal refuge at the Mast Farm property located at RM 25 under separate funding through an Ecology Water Quality grant. Project timing also coordinates with the Lower Yakima River Water Quality, Nutrient, and Aquatic Vegetation Dynamics study (funded through an Ecology Centennial grant) designed to investigate the impact of water stargrass on thermal refuge temperatures in lower river side-channels. Lastly, the data gathered from this project may support the future development of the lower Yakima River TMDL for temperature.

3.2 Study area and surroundings

The lower Yakima, located in south-central Washington State, flows through two counties: Yakima and Benton (figure 1). The stretch of river that flows through Yakima County (the Wapato reach) is distinct from that of the lower reach in Benton County (the Kiona reach). The Wapato reach has an established broad alluvial floodplain with a dynamic river channel and extensive riparian forests. Construction of bridges, dikes, and roads within this stretch, however, have constricted and/or cut off portions of the floodplain (Stanford and others 2002). The Wapato reach is a mixture of agricultural, conservation and small urban areas. Significant tributaries entering the Wapato reach include Toppenish Creek and Satus Creek.

The lower Kiona reach is primarily dominated by agricultural use, which is supported by irrigation from the Yakima River. Columbia River basalts dominate in the upper part of the reach and confine the river channel allowing only minimal meandering. Alluvial deposits are present in the lower Kiona reach between Horn Rapids and West Richland. Alluvial islands formed by Quaternary floods are dispersed throughout this reach and mediate changes in channel morphology. There are no natural creeks in this reach, but multiple irrigation wasteways drain into the river (Spring/Snipes; Corral/Knox; Amon). These wasteways are a source of cool water and act like tributaries. The lower Yakima drains into the Columbia River at Richland, WA.

Lower Yakima water quality and seasonal flow are influenced heavily by irrigation use for agriculture and growing urban/residential development. The Yakima River is a highly managed system with regulated yearly flow regimes. Water inputs from the area's heavy irrigation enhance subsurface and overland flows to the river. This irrigation derived inflow has largely supplanted the role of the spring flood in creating and maintaining cool water patches. The spring freshet, which has been dramatically reduced in size by river regulation, typically occurs between April and May in the lower Yakima, with low flows and high temperatures occurring June through August. Lower Yakima summer temperatures are driven primarily by solar radiation. As such, river temperatures rapidly cool with the onset of fall sometime between late August and early September. The irrigation season, which draws water from the Yakima River, runs from mid-March to mid-October.

The lower Yakima hosts anadromous runs of Steelhead Trout, spring, summer, and fall Chinook Salmon, Coho Salmon, and Sockeye Salmon. Juvenile salmon out-migrate through the lower Yakima to the Columbia River, and adult fish migrate from the Columbia up into the lower Yakima. Historically, the lower Yakima hosted fall Chinook spawning habitat. Abundant water stargrass growth in the lower Yakima has resulted in a shift of fall Chinook spawning to above Prosser Dam. As a result, adult and juveniles must migrate further, decreasing their chances of survival.

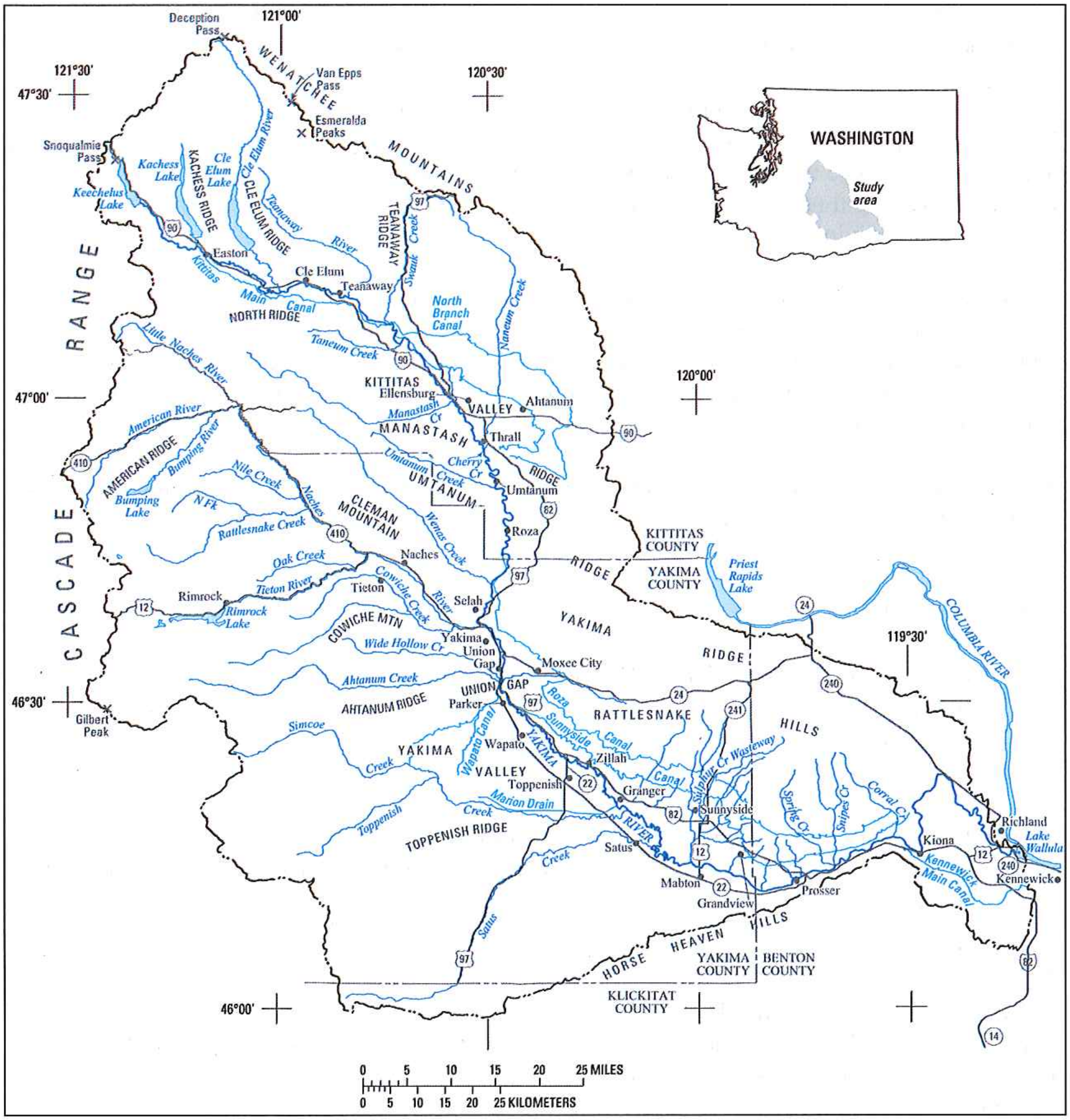

Figure 1. Map of Yakima Basin study area.

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. Consequently, Ecology placed these water bodies on Washington State's 303(d) list.

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.

There are a number of water quality improvement projects, mainly in the form of total maximum daily loads (TMDLs), in various stages of development across the watershed. Those projects in the lower Yakima include:

Yakima River: Toxics

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

Lower Yakima River: Suspended Sediment and DDT

- TMDL study evaluating controls of suspended sediment, which is the primary cause of turbidity and major source of DDT transport in the lower basin during irrigation season (Joy 2002).

3.2.2 Summary of previous studies and existing data

In 1997, Ecology published a TMDL evaluation report about the lower Yakima River (Joy and Patterson 1997). The Environmental Protection Agency (EPA) approved the TMDL for the protection of chronic aquatic life criteria in 1998. The report details the amount and sources of several pollutants in the lower Yakima River.

In 2011, BCD summarized two years of lower Yakima River temperature monitoring and habitat assessments in the *Assessment of the Lower Yakima River in Benton County, Washington* (Appel et al. 2011). Expanding on work by Vaccaro and Maloy (2006), BCD conducted thermal profiles of the Kiona Reach at base flows in 2008 and 2009 to identify temperature heterogeneity within the lower river. Appel et al. noted that river summer temperatures were well above 21°C for the 2008 and 2009 summertime floats; however, thermal heterogeneity within the lower reach was identified with "cooler" areas resulting from non-point source seeps, irrigation wasteways, and deeper "holes". The "cooler" areas are located along the riparian area and in some instances behind side channels (e.g., island at I-182 bridge).

Vaccaro and Maloy (2006) provides the methods used for conducting longitudinal temperature profiles of rivers along with the results and analysis of the profiled reaches. Vaccaro found that the methods were able to adequately document the comprehensive temperature profile of a river's heterogeneity thermal regime that cannot otherwise be captured by a fixed temperature station.

Vaccaro (2011) documented the longitudinal temperature gradient of the Yakima River in 16 reaches covering about 160 river miles. Reaches ranged in length from 5 to 14 miles with a stream gradient range from 0.0002 to 0.0055 ft/ft. Floats were completed in the early 2000s and also included the BCD floats from 2008 and 2009. Vaccaro concluded:

> *"Thermal gradients ranged from as small as 0.00002 to as large as 0.004°C per mile per minute, and unexpectedly, the smaller gradients were not confined to the upper parts of the basin. Effects of river-aquifer exchanges and surface-water inflows were clearly displayed in the profiles. The thermal regime of the river system impacts the overall biological community in the river system including the different life stages and life history patterns of salmonids. It also leads to a logical progression of the longitudinal gradient of fish assemblages, and invertebrate and algal community structure. The longitudinal gradient, overlaid with the distribution of temperature patches, compose a continuum from the headwaters to the mouth, along which habitat, and thus, species, are arranged (2011)."*

Temperature monitoring is performed periodically at the Prosser gage. The gage is operated by the U.S. Bureau of Reclamation. Temperature data from other locations and for shorter periods of record are also available from BCD and Ecology on the lower Yakima River. There has not been a TMDL drafted for temperature in the lower Yakima River.

BCD and USGS will be collecting temperature data at three locations on the lower Yakima within Benton County (Prosser, Benton City, and Richland) from 2018 - 2019 under a separate Ecology Grant (WQC-2018-BentCD-00065). These temperature data are part of a larger study to investigate water quality parameters, flow and water stargrass dynamics on the Yakima River located within Benton County.

3.2.3 Parameters of interest and potential sources

The main parameter of interest for this monitoring study is water temperature. The Lower Yakima River, WRIA 37, is listed as impaired for water temperature on Washington State's list of impaired waterbodies under Section 303d of the Clean Water Act (Category 5 temperature Listing ID: 8311).

High extreme temperatures in the lower Yakima (over 21°C) are primarily a result of the large expanse of slow moving, shallow water, exposed to full sunlight (Snyder and Stanford, 2001). Warm water temperatures favor salmonid predators and create inhospitable conditions for anadromous species.

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. The criteria are intended to 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.

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.

Temperature Criteria

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.

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 temperatures, at any time, exceed $t = 34/(T+9)$.*

The standards recognize, however, that not all waters are naturally capable of staying below the fully protective temperature criteria. When a waterbody is naturally warmer than the above described criteria, the standards provide an allowance for additional warming due to human activities. In this case, the combined effects of all human activities must also not cause more than a 0.3°C (0.54°F) increase above the naturally higher (warmer) temperature condition.

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 investigate thermal heterogeneity of the lower Yakima and obtain quality data that can be evaluated for future thermal refuge project development. Projects will be investigated that enhance, protect, or create lower river thermal refuge habitat. This goal will be accomplished by floating the river in a three-boat method where the boats are positioned on the left, right and center of the river reach. Level loggers are attached to the boats and record temperature every 3 seconds during the float. Temperature data are synchronized to river position using handheld GPS units.

4.2 Project objectives

The project objectives include:

- Conducting 7-10 floats from Wapato to Mabton and from Prosser to Richland using a three-boat method (right bank, left bank and center).
- Collect temperature, level and GPS data at 3-seconds intervals for each profiled reach during near base flow conditions in the summer of 2018 and summer of 2019.
- Collect diurnal temperature at each launch access site for one-two weeks prior to the floats and during the day of the floats.
- Analyze reaches for thermal heterogeneity and develop thermal profile maps using GIS analysis.
- Compare float level data and temperature data in order to identify temperature change related to river depth changes.
- Compare current data to previously collected thermal profile data in order to evaluate changes over time.
- Follow established protocols to ensure that representative measurements are obtained throughout the float period.
- Attempt to maximize the reliability of the data by maintaining quality control procedures outlined in this QAPP.

4.3 Information needed and sources

The collection of thermal profile data and results analysis will be placed into context by reviewing previous water quality, thermal profiling, and flow data collected on the lower Yakima. This project will address data gaps regarding the thermal heterogeneity and thermal refuge potential on the lower Yakima. Temperature, level, and GPS data will be collected by BCD and YN. Analysis of data will be completed by USGS staff at the Water Science Center in Tacoma, WA. We anticipate data may be used from the following sources:

- USGS Surface-Water Data for Washington (https://waterdata.usgs.gov/wa/nwis/rt).
- Thermal Profiles for Selected River Reaches in the Yakima River Basin (Vaccaro, J.J. and others, 2001) https://pubs.usgs.gov/ds/342/.

- Assessment of the Lower Yakima River in Benton County, WA (Appel, M. and others, 2011).
- Water Quality monitoring data collected in 2018 by BCD and USGS under a separate Ecology grant (2018-BentCD-00065).
- Current GIS layers for Benton County compiled by BCD
- AgWeatherNet for ambient air temperatures on float days (https://weather.wsu.edu)

4.4 Tasks required

The tasks required to complete this project are:

- Pre-and post calibration checks on temperature/level loggers.
- Determine safe launch locations for river floats
- Deploy continuously recording temperature loggers (set to record every 30 minutes) at each river access site to capture daily warming at the upstream and downstream float boundaries. Loggers will be deployed one- to-two weeks before the floats.
- Collect continuous temperature/level/and GPS data every 3-seconds for each profiled reach.
- Keep detailed logbooks during floats.
- Collect field checks for temperature using a National Institute of Science and Technology (NIST) calibrated thermometer
- Perform Quality assurance check of the collected temperature/level data.

4.5 Systematic planning process used

This QAPP represents the systematic planning process.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

Key individuals and responsibilities are provided in Table 1.

Table 1. Organization of project staff and responsibilities.

Staff	Title	Responsibilities
Marcella Appel	Water Quality Specialist, Benton Conservation District	Will provide project oversight and ensure project is in compliance with Scope of Work. Is responsible for project communication, organization and data collection, EIM input, reviewing reports, QAPP adherence, project communication, and field team lead.
Tom Elliot	Riparian Ecologist, Yakama Nation	Will provide technical support for thermal profiling, aid in coordination of floats, and provide support for interpretation and analysis of results
Andrew Gendaszek	Research Hydrologist, US Geological Survey	Will provide technical support for thermal profiling; interpretation and analysis of data results
Robert Black	Chief Supervisory Hydrologist, US Geological Survey	Will provide project management for USGS, ensuring that project deliverables are achieved on-time and on-budget with adequate documentation of USGS in-kind contributions.
Rachel Little	Education and Outreach Coordinator, Benton Conservation District	Will handle communication of project to public for BCD. Will provide field support and technical review of reports.
Danielle Squeochs	Project Manager, Ecology, OCR	Will provide initial review and feedback of QAPP, approve QAPP, review and approve annual and final reports.

EIM: Environmental Information Management database
QAPP: Quality Assurance Project Plan

5.2 Special training and certifications

The field lead and assistants for each float will be trained in and experienced with the SOPs being used.

5.3 Organization chart

BCD and USGS will work collaboratively on this project through a Joint Funding Agreement. Ms. Appel and Dr. Gendaszek will communicate about the project every six weeks. YN and

BCD will collaborate to organize the floats and advise the project. YN will provide support as in-kind match. Responsible project staff and lines of communication are demonstrated in figure 2.

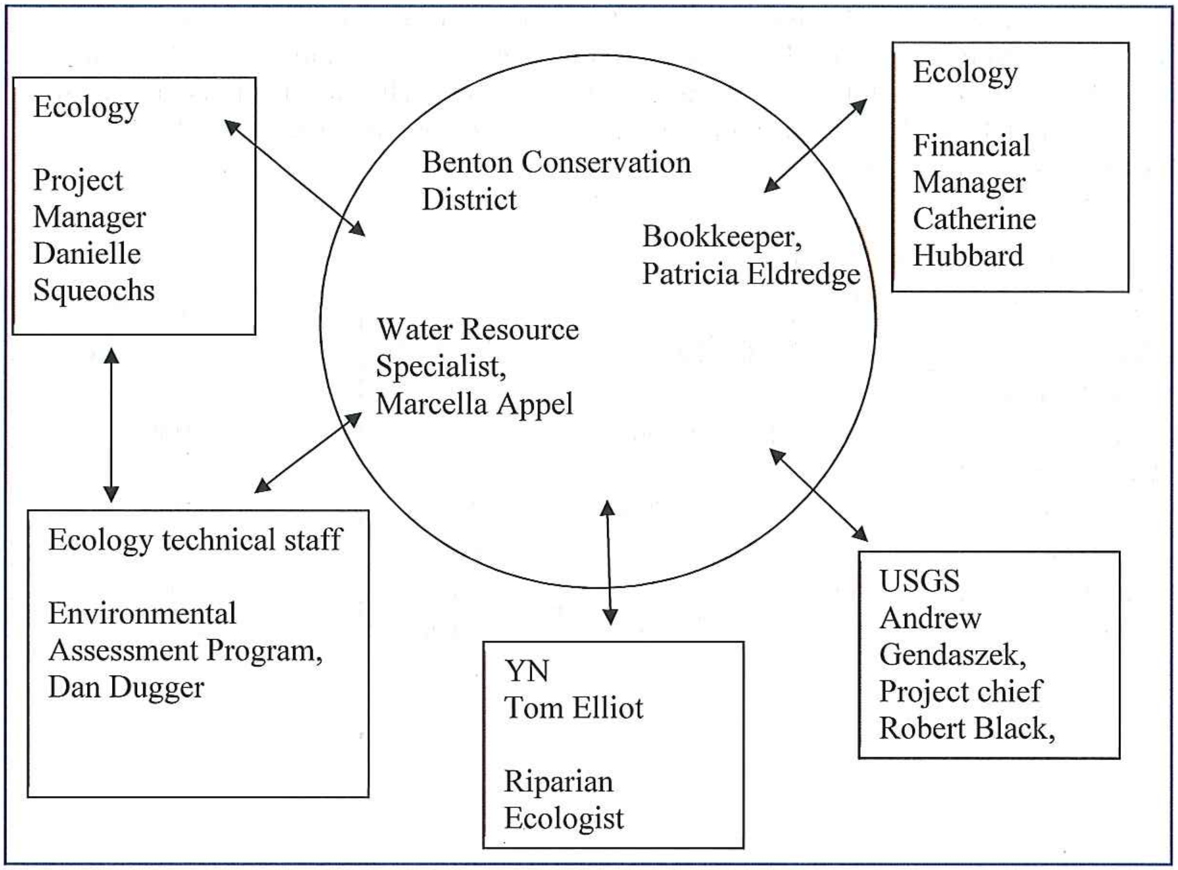

Figure 2. Organizational Chart for Project Communication.

5.4 Proposed project schedule

The project schedule is available in **Table 2.**

Table 2. Proposed schedule for completing field work, EIM data entry, and reports.

Task	Timeline
Thermal Profiling	June –August 2018; June – August 2019
EIM Data Entry Submission	September 2019
Annual progress reports for EAGL	October 2018 and October 2019
Final USGS Report	December 2019
Final BCD report uploaded into EAGL	December 2019

5.5 Budget and funding

Project funding is provided as part of a larger agreement between Ecology and BCD under contract number: WRYBIP-VER1-BentCD-00004. BCD has a Joint Funding Agreement (JFA) in place for the contracted work with USGS. USGS will provide a contribution to the project at a rate of 40% match to the provided Contract amount. YN will be providing in-kind match for the project by supplying staff, boats, and expertise for the floats. This match will be documented and reported through EAGL with the project reports. The Ecology funding budget for the thermal profile float work is provided in Table 3.

Table 3. Project budget and funding.

Element	FY 1 (2018)	FY 2 (2019)	FY 3 (2020)	Total (FY1+FY2+Additional)
Salaries/Benefits Combined-1	900	5,500	5,500	11,900
Contracts (USGS)	0	30,000	30,000	60,000
Travel	0	600	600	1200
Goods/Services-3	1800	0	0	1800
Total	2700	36,100	36,100	74,900

6.0 Quality Objectives

6.1 Data quality objectives

The main data quality objective (DQO) for this project is to collect local-scale temperature and level data along the left bank, right bank and center of the river reach and correlate these data spatially using collected GPS coordinates. Data collected will be used to develop longitudinal temperature profiles of the lower Yakima. This study will use previously developed methods that meet the measurement quality objectives (MQOs) described below and are comparable to previous study results.

6.2 Measurement quality objectives

6.2.1 Targets for precision, bias, and sensitivity

The accuracy and instrument bias MQOs of each temperature/level logger and Hobo pendants will be verified through both pre- and post-deployment calibration checks, along with field temperature verification checks, following the procedures described in the *Standard Operating Procedures for Continuous Temperature Monitoring of Fresh Water Rivers and Streams* (Ward 2018). The procedures require that the loggers be tested in controlled water temperature baths that bracket the expected monitoring range (0°C and 20°C). A controlled water bath will be used to maintain the pre- and post-calibration checks. The results are then compared to those obtained with a certified reference thermometer.

If the mean absolute value of the temperature difference for a logger in each water bath, compared against the NIST-certified thermometer, is equal to or greater than the calibration check, then a second check should be performed. Temperature loggers that fail a second pre-deployment check will not be used.

The pressure readings for the level loggers will be checked seasonally pre and post- field collection in both 2018 and 2019. Loggers will be placed in a controlled bath of known water depth to check functionality of the pressure transducers and to check for drift. If drift is identified, the data will be documented and a determination will be made regarding data usability. If large drift is noticed, or the level loggers are not functioning correctly, then the logger should be replaced. The MQOs are provided in Table 4 and were developed based on the accuracy of the data needed for the project and are greater than the listed sensitivity of the instrumentation to be utilized.

The project will use Solinst Level loggers, or Onset Hobo U20 level loggers. The logger type and brand used to record the float measurements will be recorded in the field notebook. Hobo pendant temperature loggers will be used to monitor the temperatures at the upstream and downstream profiled reach boundaries. Garmin Rhino530HCx model GPS units will be used for tracking boat position.

Table 4. Measurement quality objectives

Parameter	Field replicate (median RSD)	Calibration check	Expected range of results
Temperature	±1.2 °C	±0.4 °C	0 to 40 °C
Level	±0.2 ft	±0.1 ft	0.5 to 12 ft
GPS	±33 ft[a]	NA	NA

[a] RSD from previous work has been demonstrated to be closer to ±10 ft which is less than stated accuracy for the GPS meters. As such, the RSD provided is based off the GPS unit accuracy.

Side-by-side field checks for temperature will be collected twice daily for each probe the day of the floats (e.g., at the start and end of the float). In addition, side-by-side temperature field checks will occur the day loggers are deployed and removed. Checks will be completed using a NIST certified thermometer. The field-check schedule is provided in Table 5, Section 10.1.

In-stream field level checks will be completed once per every 3 floats measuring level at two points: surface and near bottom depth. A stadia rod will be used to measure river depth relative to the reading of each pressure logger. The river depths as measured by the stadia rod will be recorded in field notebook. The field-check schedule for level loggers are provided in Table 5, Section 10.1.

6.2.1.1 Precision

Precision is a measure of variability between results of replicate measurements that is due to random error. It is usually assessed using duplicate field measurements. Side-by-side temperature measurements using a NIST certified temperature thermometer will be collected at the morning launch site and in the evening take-out site for comparison to the level logger temperature readings. Side-by-side measurements will also be collected in the field for the deployed temperature loggers located at each access site. Precision for field replicate measurements of temperature will be expressed as the replicate median Relative Standard Deviation (RSD) between the logger temperature and the NIST certified check temperature.

6.2.1.2 Bias

Bias is the difference between the sample calibration checks used to document logger bias and performance as described in Ward (2018).

6.2.1.3 Sensitivity

Sensitivity is a measure of the capability of a method to detect a substance. It is commonly described as the detection limit and the instrument range of operation. The detection limit for our field measurements of water temperature is 0.1 °C. The specifications for instrument parameter range and accuracy are included in Table 5.

Table 5. Equipment Accuracy, resolution and range of operation.

Equipment	Accuracy	Resolution	Range of operation
Digi-sense 2-input data logging thermistor thermometer, NIST traceable Cal, Item# EW-20250-94	± 0.5 °C	0.10 °C	-40 to125 °C
Temperature Logger (Water/Air) #UA-001-64 HOBO Pendant Onset Computer Corp.	± 0.53 °C	0.14 °C	-20 - 50 °C
Solinst® Levelogger LT Edge (temperature)	± 0.05 °C	± 0.003 °C	-20 – 80 °C
Solinst® Levelogger LT Edge (depth)	± 0.05% full scale (FS) ± 0.5 cm (0.02 ft)	Not reported	10 m (32.8 ft)
Onset U20L level logger (temperature)	± 0.44 °C	± 0.10 °C	-20 - 50 °C
Onset U20L level logger (depth)	± 0.1 % FS typical ± 2.0 cm (0.07 ft)	± 0.21 cm (0.007 ft)	9 m (30 ft)

6.2.2 Targets for comparability, representativeness, and completeness

6.2.2.1 Comparability

To ensure comparability, field measurements will be collected following the same methods as Vaccaro 2006 and Appel et al (2011) as well as follow applicable approved Environmental Assessment Program (EAP) SOPs as listed in section 8.0, Field Procedures.

6.2.2.2 Representativeness

The study is designed using a three-boat method that allows for capturing temperature data from the left bank, right bank, and center position of the river during each thermal profile, except for reaches where only one or two boats can safely pass. This provides a representative cross section of each profiled river reach in order to assess thermal heterogeneity within the river. The data are collected in 3-second intervals so that representative temperature data can be collected along the length of the river relative to the float speed. Thermal profiling of the streambed will supply the lowest temperature of the river along the path of each probe, as the streambed should be the coolest vertical position based on thermal stratification and the lack of solar warming, as well as from groundwater inputs. Therefore, this approach will provide the low temperature bound for the river along the course of each probe, enabling identification of potential thermal refuge, consistent with the goal of this study.

Probes are pulled behind the boat using a tow-rope of sufficient length for the river reaches' water depth. Probes are weighted using slotted PVC casing and weights so they remain near the streambed. The profile method provides a conservative estimate of groundwater inflows and as such is not likely to produce false positives (measure non-existent cool groundwater flows).

6.2.2.3 Completeness

The completeness target for this study is to collect data for 7 lower Yakima reaches with 90% of the reach length surveyed. For safety reasons, there may be sections of the river that cannot be adequately profiled. Completeness will be considered acceptable if water temperature, GPS data, and level data can be sufficiently evaluated for 90% of each profiled river stretch.

Potential problems during data collection that need to be avoided if possible include: loss of temperature loggers, loss of data due to loggers being removed from water (shallow areas, rocky stretches or due to portage), malfunctioning of loggers, stolen loggers at the upstream and downstream float boundaries, GPS satellite connection problems, or electronic GPS equipment overheating in warm weather.

6.3 Acceptance criteria for quality of existing data

Potential data sources for this study are listed in Section 3.2.2, however, during the course of the project additional data sources may be identified. The project will use the best data available, assess the quality of that data and then assess the effects of data quality on the project and the model. A process of quality assessment will be followed:

1. The source of the data will be investigated for documented data quality procedures.
2. Any qualifications associated with the data will be documented and evaluated.
3. The data will be evaluated for outliers or unusual trends that may suggest data quality problems.
4. Based on the evaluation of the data, suspect data may be censored, qualified or accepted.

If available, other documents that already contain this information may be cited.

6.4 Model quality objectives

Not applicable.

7.0 Study Design

Continuous water temperature and Global Positioning System (GPS) data will be collected at 3-second intervals while drifting downstream at ambient stream velocity in a Lagrangian framework following Vaccaro and Maloy (2006). Thermal floats will take place between river mile (RM) 0.0 and 47.0 in Benton County and between RM 60.0 and RM 100.0 in Yakima County.

Profiling at ambient stream velocity in a Lagrangian framework tracks a parcel of water as it moves downstream during the day to capture thermal heterogeneity. Departures from the diurnal heating cycle may be due to groundwater inputs, irrigation inputs, incoming surface-water flows, or riparian shading. Continuous temperature will be measured using a temperature/level logger probe attached by rope to a boat. Position data will be measured using handheld GPS units. The profile method provides a conservative estimate of groundwater inflows and provides the low temperature bound for the river along the course of each probe, enabling identification of potential thermal refuge, consistent with the goal of this study.

Three canoes/rafts/or catarafts will be used to pull the temperature probes along the river bed in order to capture the left bank, right bank and center in-stream temperatures. The temperature probes are housed in a slotted PVC casing attached by rope and carabineer to the back of the boat. A small weight is added to the PVC casing to help weight the probe. In faster flows, and riffles the probe may move vertically to the upper part of the water column. Field staff will make visual confirmation of the probes during the floats and will record times when the probe is not near the streambed. These data will be qualified and a determination made on data usability. Also, if the logger is pulled from the water or out of water for cleaning, field staff will note these times in the field notebook and data will be removed from the analysis.

Some reaches, with increased riffles and boulders, may only be profiled by one or two boats due to safety concerns. The location of each probe is determined by relating the time of the GPS unit to the time of the temperature data. Side-by-side temperature checks will be collected using a NIST certified thermometer after the temperature/level loggers have equilibrated to the water temperature prior to the floats. Side-by-side temperature checks will also be collected at the completion of the float, prior to removing the loggers from the water.

All data will be provided to USGS for data analysis and development of thermal profile maps. If a GPS location is not recorded at the same time as a temperature measurement (due to loss of satellite), the location of the temperature measurement will be determined by linear interpolation of the two GPS known locations that bracket the time of the temperature measurement.

Hobo pendant temperature probes will be deployed at each upstream and downstream float boundary for one-to-two weeks prior to the floats. Side-by-side field checks will be performed using a NIST certified field temperature thermometer after deployment, prior to removal as well as the day of the floats. Temperature data at the float access locations provide information on diurnal temperature warming for the reach boundaries. Departures from this daily warming by the float data may indicate groundwater inputs within a profiled reach.

7.1 Study boundaries

The study area is located in WRIA 37 (Lower Yakima). A map showing the Wapato and Kiona reach boundaries are provided in Figure 3. The stretch of the river below Wapato Dam to Mabton (Wapato reach) and from below the Prosser Dam to Richland, WA (Kiona reach) will be profiled.

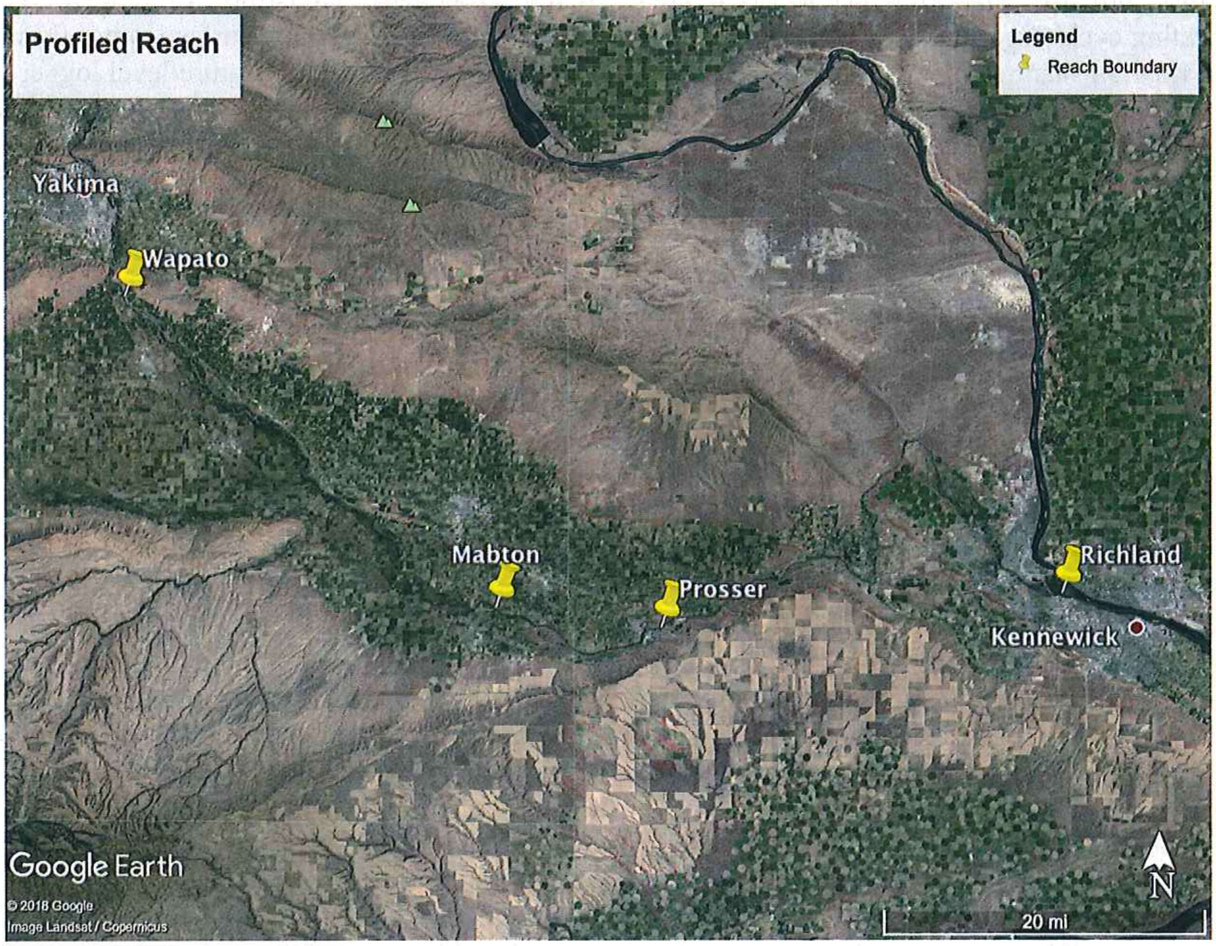

Figure 3. Map showing river profile reach boundaries for the project study area.

7.2 Field data collection

7.2.1 Sampling locations and frequency

The length of river to be profiled is shown in figure 3. The profiled reaches will be analyzed during summer flow conditions (June – August) when the solar warming of the river is at its greatest allowing for greater temperature differentials between cool water inputs and mainstem river temperatures. Float days will be determined based on flow (achieving a compromise between near base flows and high enough water volume for safe passage), partner-agency volunteer availability, as well as weather conditions (clear days with low wind). Each reach segment will be profiled twice, once in 2018 and once in 2019.

The river length from Mabton to the confluence will be broken into 7 – 10 profiled reaches. Reaches will be determined based on length and flow conditions (travel time), safe access points, and dam locations. The length of each profiled reach will be selected so that the floats can be safely completed during daylight hours during the peak hours of daily warming. Optimum daily float times will be between 6-8 hours to ensure data collected is completed before evening cooling. Onset hobo pendant probes will be deployed one- to- two weeks prior to the float days at each river access point to capture diurnal warming for the profiled reaches.

In 2008 and 2009 the Kiona reach was profiled in five days with access points at the Prosser WWTP, Chandler Power House, Benton City Boat Launch, Snively Road Access (West Richland), Duportail Access (Richland), and the mouth at Wye Park near Bateman Island. This project will closely follow the 2008 and 2009 floats, but may divide some of the longer river floats such as the Prosser to Chandler float into shorter reaches to keep float times under 8 hours.

7.2.2 Field parameters and laboratory analytes to be measured

Temperature, water level, and GPS coordinates will be collected within the profiled reaches.

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 in relation to objectives and study area

It is assumed that the temperature probes will adequately capture cool water inputs and that groundwater inflows will not be diluted too quickly to monitor. Assumptions are also made regarding location of the probe based on the GPS unit - problems with the location of measurements can arise because the tow-line length can change based on river depth. Length is also changed when moving through rapids, areas of woody debris, and riprap or to avoid submerged objects that can snag the streambed probe (Vaccaro and Maloy 2006).

It is also assumed that the collection time interval will be small enough relative to the boat velocity in order to observe temperature changes as the boat passes by. Some reaches are difficult to pass at extremely low flows. It is assumed that we will have normative summer water conditions so that the profiled reaches will be safely passable. It is assumed that GPS signal will be adequate for the stretches of the river profiled - loss of GPS reception can result in lost positional data. Lastly, we are assuming that the type of boats used will be suitable for the river reach characteristics and that equipment will not be lost or damaged during floats.

7.5 Possible challenges and contingencies

7.5.1 Logistical problems

There are several logistical problems that may arise when floating the river. First, we assume that adequate public access points will be available for the profiled reaches. Some stretches of the river require portage around difficult areas thus data cannot be collected for safety reasons. In slower river stretches, there are frequently times when paddling must be used in order to move at a reasonable pace down the river resulting in a qualitative Langrangian framework. In large boulder-riffle locations probes can get snagged and lost. Moreover, water stargrass density can impede boating in sections of the river below RM 47 where probes, paddles, and equipment can get tangled in the dense macrophyte beds. Occasionally, probes will need to be pulled from the water to remove caught macrophytes, or prevent snagging on boulders. For safety reasons, probes are attached to the boat by carabineer. This allows for the probe's tow-line to be quickly released should the probe become irrevocably caught. Knives will also be provided for each boat in case the tow-rope needs to be cut free for safety.

7.5.2 Practical constraints

The project currently has two boats. A third boat will be on loan from either WDFW or YN, but timing of boat use will be dependent on their agency needs and may hinder float timing. We also assume that the boats will be suitable and of the right type to safely navigate the various conditions encountered within the lower Yakima. Additionally, for reducing float costs agency partners (YN, WDFW, Ecology, BCD Weed Board) will help man the boat for the floats. We are assuming we can get an adequate number of experienced volunteers to help navigate the boats down the river on the determined float days. Lastly, we assume that we will be able to borrow additional temperature/level loggers necessary to match the purchased in order to meet the required number to collect the required data. If loggers are lost during the floats in 2018, we will need to revisit the procedure for 2019 or determine if additional loggers can be purchased.

7.5.3 Schedule limitations

The biggest limitation to the timeline for this project is the timely submittal and approval of this QAPP. It is very important this work begins by mid June of 2018 to catch river flows as they near base flow conditions and approach the longest day of the year. Flows in July or August may be too low for some river stretches to be safely passable. By September, flows are increasing but the main-stem river begins cooling in response to shorter days. Floods, weather, and drought conditions may impact scheduling. Securing local agency volunteers, boats, and equipment may also impact schedule.

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 and others, 2018).

8.2 Measurement and sampling procedures

This study will adhere to the appropriate techniques and SOPs published by Ecology:

- EAP080 – Continuous temperature monitoring of freshwater rivers and streams
- EAP011 – Instantaneous measurements of temperature in water
- EAP070 – Minimizing the Spread of Invasive Species

8.3 Containers, preservation methods, holding times

8.4 Equipment decontamination

Field staff will follow the procedures described in Ecology SOP EAP070 – Minimizing the Spread of Invasive Species (Parsons and others, 2018). Boats and equipment used will be inspected after use on boat ramps and cleaned accordingly.

8.5 Sample ID

Not applicable.

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 logger checks will be recorded in a field notebook.

During the floats field logs that are bound, waterproof notebooks with pre-numbered pages will be maintained for each boat (right, left, and center) to document:

- Name of boat operators, type of boat and float stretch
- Date and weather conditions
- Unique probe identification number for each boat indicating center (C), right (R), and left (L) probes and the logger number (e.g., C-logger#, R-logger#, L-logger#)
- Start time for probe in the water
- End time for probe out of the water

- Any noticeable overland flows, incoming streams, or subsurface flows
- Sequence of events during floats
- Any issues with the probe (snagging, out of water, caught in macrophyte bed)
- Any deviations from QAPP
- Unusual circumstances that might affect interpretation of results

8.8 Other activities

PVC containers for each temperature probe (as pictured in Vaccaro and Maloy 2006) as well as anchoring units for the upstream and downstream temperature loggers will be assembled at the BCD office prior to the floats.

Before each float begins, the crew will be briefed on safety as well procedures and requirements for completing the field log notebooks during the floats. Boaters will be required to wear a life jacket, and bring appropriate warm weather clothing, water, sunscreen and supplies to withstand summer heat. After float completion, BCD or YN will be responsible for collecting all notebooks, securing all equipment and downloading of all data. BCD will organize the data and provide to USGS for analysis.

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 temperature loggers will be calibrated following procedures recommended by Ward (2018). Temperature level loggers will be placed into two separate water baths controlled by a temperature regulator with a high and low temperature of 20.0 and 0.0 degrees Celsius (°C), respectively, and allowed to equilibrate prior to temperature readings. Calibration will be performed using a NIST certified thermometer. Temperature loggers that do not meet pre-calibration checks will not be deployed.

The day of the floats, the loggers will be placed in the river and allowed to equilibrate with the river temperature 15 minutes prior to the start of the float. A side-by-side instantaneous temperature reading will be taken with the NIST certified thermometer at the end of the equilibration period. In addition, a side-by-side temperature reading will be taken with a NIST certified thermometer at the completion of the float before the temperature loggers are removed from the water. Data will be downloaded nightly following the floats and reviewed for completeness before the next float to ensure that the loggers functioned properly and to inspect any issues with data collection methods. The temperature field-check schedule is provided in Table 6, Section 10.1.

In addition to the thermal temperature profile loggers, in-stream temperature loggers will be deployed one-to-two weeks ahead of the floats at each access point to capture daily temperature warming within the river. These loggers will bracket the upstream and downstream float boundaries. An instantaneous field temperature check will be performed using the NIST certified thermometer on the day of deployment, retrieval, as well as the day of the float. Loggers will be removed following float completion. The temperature field-check schedule is provided in Table 6, Section 10.1.

Level loggers will be checked seasonally pre- and post- field collection in 2018 and 2019. Loggers will be placed in a controlled bath of known water depth to check functionality of the pressure transducers and to check for drift. Drift, while not expected given the short float times, may occur to the unusual conditions the level loggers will be exposed to during floats where they are pulled against rocky beds and swift riffles with boulders. If drift is identified, the data may need to be corrected or qualified. If large drift is noticed, or the level loggers are not functioning correctly, then the logger should be replaced.

In-stream field level checks will be completed once per every 3 floats measuring level at two points: surface and bottom depth. A stadia rod will be used to measure river depth relative to the reading of each pressure logger. The river depths as measured by the stadia rod will be recorded in field notebook. The field-check schedule for level loggers are provided in Table 5, Section 10.1.

The Garmin units do not allow for GPS accuracy checks during the floats. As such, data will be reviewed using GIS. Any GPS readings that are not within the expected locations will be removed.

10.1 Table of field and laboratory quality control

Table provides the field QC procedure required for this study. Detailed side-by-side checks of deployed Onset Hobo loggers to the field meter will occur as described in Section 6.2. Additionally side-by-side checks of deployed temperature/level loggers to the field meter will be collected at the beginning and end of each float daily.

Table 6. Quality control samples, types, and frequency.

Parameter	Field
	Mid-deployment Check
Temperature	1 measurement collected per temperature logger per field check[1,2]
Level	1 field check per logger per every 3 floats[3]

[1]Field checks will occur at the start and end of each float for the level temperature loggers as well as during deployment and removal of in-stream Onset hobo pendant temperature loggers.
[2]Temperature checks will be collected using a NIST certified field thermometer.
3In-stream level checks will be compared to a stadia rod at two points: surface and streambed. Stadia levels will be documented in the field logbook.

Because the Rhino Garmin units do not allow for accuracy checks during the floats, GPS field data coordinates will be verified by mapping in GIS following the floats. Any points that are not within an acceptable location for the float will be removed.

10.2 Corrective action processes

QC procedures may indicate problems with data during the course of the project. Options for corrective actions might include:

- Recheck pre- and post-calibration checks.
- If possible, retrieve missing information (re-do floats if necessary).
- Qualify or reject results as appropriate.

11.0 Data Management Procedures

11.1 Data recording and reporting requirements

Staff will record all field data in a field notebook. Before leaving each site, staff will check field notebooks for missing information. Staff will download data as soon as practical after they return from the field. BCD will check data against the field notebook data for errors and omissions before emailing data to USGS for further analysis.

All continuous data will be entered into Microsoft Excel® spreadsheets and analyzed in GIS. BCD will check that instantaneous water temperatures are within the specified criteria as compared to recorded values.

11.2 Laboratory data package requirements

Not Applicable.

11.3 Electronic transfer requirements

Not Applicable.

11.4 EIM/STORET 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.

11.5 Model information management

Not applicable.

12.0 Audits and Reports

12.1 Field, laboratory, and other audits

Not applicable.

12.2 Responsible personnel

Not applicable.

12.3 Frequency and distribution of reports

Grant progress reporting for this project will be completed according to the requirements outlined in WRYBIP-VER1-BentCD-00004 between BCD and Ecology. Quarterly progress reports will be completed and submitted with each payment request.

A final USGS report will be completed by December 31st, 2019. A draft report will be available for review prior to this date.

A final project report will be completed by BCD by December 31st, 2019. A draft report will be available for review prior to this date.

12.4 Responsibility for reports

Rich Sheibley with USGS will be the lead for the final USGS report.

Marcella Appel with BCD will be responsible for all quarterly progress reports, annual environmental reports, and the final environmental monitoring report.

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* (Ward 2018). 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 and field measurements
- Detected data errors will be corrected, flagged with data qualifiers, or deleted.

Because the Rhino Garmin units do not allow for accuracy checks during the floats, GPS field data coordinates will be verified by mapping in GIS following the floats. Any points that are not within an acceptable location for the float will be removed.

Level logger data will be reviewed against the seasonal pre-and post-calibration checks to document possible drift or logger problems. Results may be verified using data plots and stream height/flow information for stream level gauges (if available).

For side-by-side field check measurements, the field lead will verify initial data before leaving each site. This process involves checking the data sheet for omissions or outliers. If data are missing or a measurement is determined to be an outlier, the measurement will be repeated.

13.2 Laboratory data verification

Not Applicable.

13.3 Validation requirements, if necessary

Not Applicable.

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 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 will be analyzed by the USGS water science center utilizing Microsoft Excel® and GIS. Data will investigate each float separately to determine river heterogeneity, cool water inputs, and groundwater influence within that reach. All float data will be compiled within GIS to highlight locations of potential thermal refuge along the lower Yakima.

14.4 Sampling design evaluation

It is anticipated that the sampling design will be adequate to meet the project goals. BCD has successfully completed similar floats in 2008 and 2009 and the data will be analyzed by the USGS Water Science Center that developed the sample design methods and has performed similar floats on rivers around Washington State. Data procedures and collection methods will be collected in accordance and in close communication with USGS Water Science Center Staff. The data collected during this project will be evaluated to determine thermal refuge potential for the lower Yakima. Identified thermal refuge locations will be further evaluated by fisheries biologists and habitat restoration professionals for future thermal habitat enhancement, protection, or creation.

14.5 Documentation of assessment

The data collected will be documented in accordance with the grant reporting requirements and in accordance with Ecology requirements.

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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.

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.

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

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

Dilution factor: The relative proportion of effluent to stream (receiving water) flows occurring at the edge of a mixing zone during critical discharge conditions as authorized in accordance with the state's mixing zone regulations at WAC 173-201A-100. http://apps.leg.wa.gov/WAC/default.aspx?cite=173-201A-020

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.

Existing uses: Those uses actually attained in fresh and marine waters on or after November 28, 1975, whether or not they are designated uses. Introduced species that are not native to Washington, and put-and-take fisheries comprised of non-self-replicating introduced native species, do not need to receive full support as an existing use.

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

Hyporheic: The area beneath and adjacent to a stream where surface water and groundwater intermix.

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.

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 of the following: (1) individual wasteload allocations for point sources, (2) the load allocations for nonpoint sources, (3) the contribution of natural sources, and (4) a margin of safety to allow for uncertainty in the wasteload determination. A reserve for future growth is also generally provided.

Total suspended solids (TSS): Portion of solids retained by a filter.

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

BCD	Benton Conservation District
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
GPS	Global Positioning System
i.e.	In other words
MQO	Measurement quality objective
NIST	National Institute of Science and Technology
PCB	polychlorinated biphenyls
QA	Quality assurance
QC	Quality control
RM	River mile
RPD	Relative percent difference
RSD	Relative standard deviation
SOP	Standard operating procedures
TMDL	(See Glossary above)
TSS	(See Glossary above)
USGS	United States Geological Survey
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WRIA	Water Resource Inventory Area
YN	Yakama Nation

Units of Measurement

°C	degrees centigrade
cfs	cubic feet per second
cfu	colony forming units
cms	cubic meters per second, a unit of flow
dw	dry weight
ft	feet
m	meter
mg	milligram
mgd	million gallons per day
mg/L	milligrams per liter (parts per million)
mL	milliliter
mmol	millimole or one-thousandth of a mole
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. For Ecology, it is "Formal recognition by (Ecology)…that an environmental laboratory is capable of producing accurate analytical data." [WAC 173-50-040] (Kammin, 2010)

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

- Use of raw or instrument data for evaluation.
- Use of third-party assessors.
- Data set is complex.
- Use of EPA Functional Guidelines or equivalent for review.

Examples of data types commonly validated would be:

- Gas Chromatography (GC).
- Gas Chromatography-Mass Spectrometry (GC-MS).
- Inductively Coupled Plasma (ICP).

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

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

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

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

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

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

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

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

Matrix spike: A QC sample prepared by adding a known amount of the target analyte(s) to an aliquot of a sample to check for bias due to interference or matrix effects. (Ecology, 2004)

Measurement Quality Objectives (MQOs)**:** Performance or acceptance criteria for individual data quality indicators, usually including precision, bias, sensitivity, completeness, comparability, and representativeness. (USEPA, 2006)

Measurement result: A value obtained by performing the procedure described in a method. (Ecology, 2004)

Method: A formalized group of procedures and techniques for performing an activity (e.g., sampling, chemical analysis, data analysis), systematically presented in the order in which they are to be executed. (EPA, 1997)

Method blank: A blank prepared to represent the sample matrix, prepared and analyzed with a batch of samples. A method blank will contain all reagents used in the preparation of a sample, and the same preparation process is used for the method blank and samples. (Ecology, 2004; Kammin, 2010)

Method Detection Limit (MDL): This definition for detection was first formally advanced in 40CFR 136, October 26, 1984 edition. MDL is defined there as the minimum concentration of an analyte that, in a given matrix and with a specific method, has a 99% probability of being identified, and reported to be greater than zero. (Federal Register, October 26, 1984)

Percent Relative Standard Deviation (%RSD): A statistic used to evaluate precision in environmental analysis. It is determined in the following manner:

$$\%RSD = (100 * s)/x$$

where s is the sample standard deviation and x is the mean of results from more than two replicate samples. (Kammin, 2010)

Parameter: A specified characteristic of a population or sample. Also, an analyte or grouping of analytes. Benzene and nitrate + nitrite are all "parameters." (Kammin, 2010; Ecology, 2004)

Population: The hypothetical set of all possible observations of the type being investigated. (Ecology, 2004)

Precision: The extent of random variability among replicate measurements of the same property; a data quality indicator. (USGS, 1998)

Quality assurance (QA): A set of activities designed to establish and document the reliability and usability of measurement data. (Kammin, 2010)

Quality Assurance Project Plan (QAPP): A document that describes the objectives of a project, and the processes and activities necessary to develop data that will support those objectives. (Kammin, 2010; Ecology, 2004)

Quality control (QC): The routine application of measurement and statistical procedures to assess the accuracy of measurement data. (Ecology, 2004)

Relative Percent Difference (RPD): RPD is commonly used to evaluate precision. The following formula is used:

$$[Abs(a-b)/((a + b)/2)] * 100$$

where "Abs()" is absolute value and a and b are results for the two replicate samples. RPD can be used only with 2 values. Percent Relative Standard Deviation is (%RSD) is used if there are results for more than 2 replicate samples (Ecology, 2004).

Replicate samples: Two or more samples taken from the environment at the same time and place, using the same protocols. Replicates are used to estimate the random variability of the material sampled. (USGS, 1998)

Representativeness: The degree to which a sample reflects the population from which it is taken; a data quality indicator. (USGS, 1998)

Sample (field): A portion of a population (environmental entity) that is measured and assumed to represent the entire population. (USGS, 1998)

Sample (statistical): A finite part or subset of a statistical population. (USEPA, 1997)

Sensitivity: In general, denotes the rate at which the analytical response (e.g., absorbance, volume, meter reading) varies with the concentration of the parameter being determined. In a specialized sense, it has the same meaning as the detection limit. (Ecology, 2004)

Spiked blank: A specified amount of reagent blank fortified with a known mass of the target analyte(s); usually used to assess the recovery efficiency of the method. (USEPA, 1997)

Spiked sample: A sample prepared by adding a known mass of target analyte(s) to a specified amount of matrix sample for which an independent estimate of target analyte(s) concentration is available. Spiked samples can be used to determine the effect of the matrix on a method's recovery efficiency. (USEPA, 1997)

Split sample: A discrete sample subdivided into portions, usually duplicates (Kammin, 2010)

Standard Operating Procedure (SOP): A document which describes in detail a reproducible and repeatable organized activity. (Kammin, 2010)

Surrogate: For environmental chemistry, a surrogate is a substance with properties similar to those of the target analyte(s). Surrogates are unlikely to be native to environmental samples. They are added to environmental samples for quality control purposes, to track extraction efficiency and/or measure analyte recovery. Deuterated organic compounds are examples of surrogates commonly used in organic compound analysis. (Kammin, 2010)

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

References for QA Glossary

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