Quality Assurance Project Plan

Water Stargrass Scour Analysis



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- Water Stargrass at Yakima River (Photo by Aaron Balagot, Mid-Columbia Fisheries)

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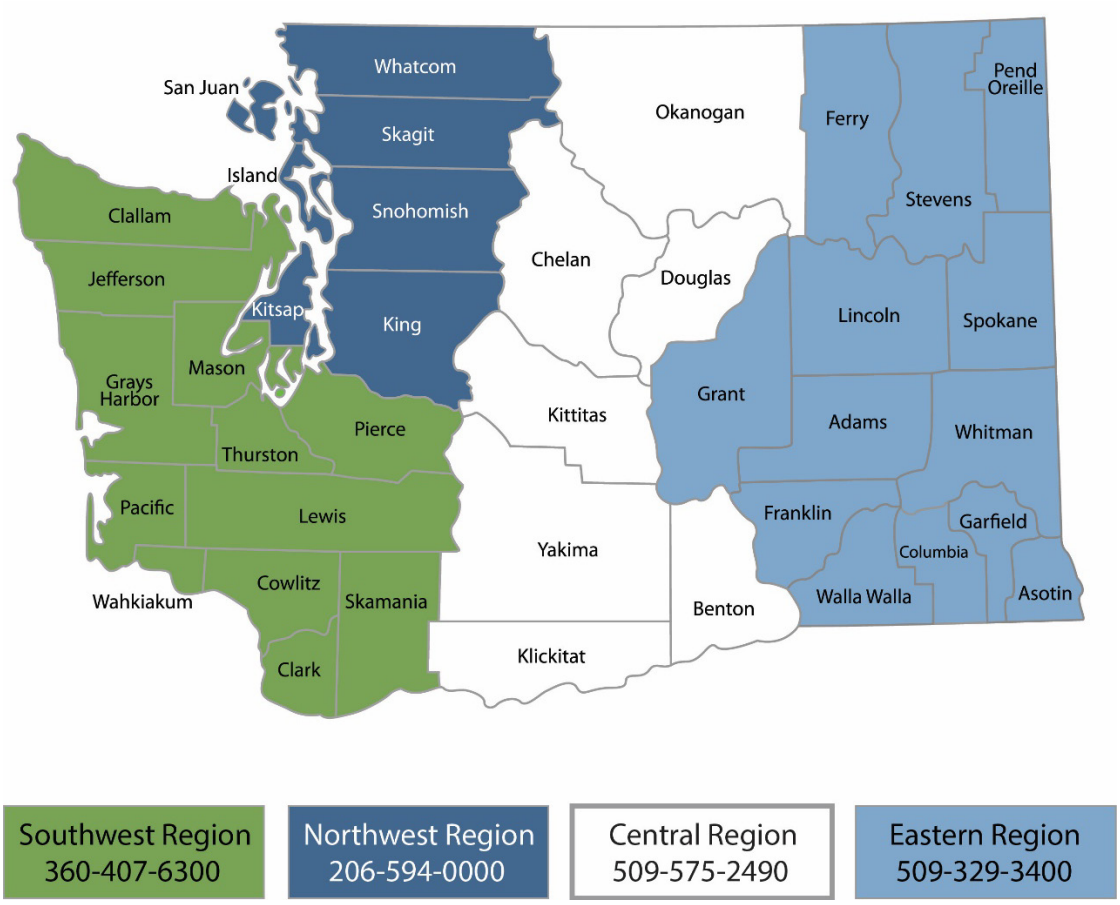
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Quality Assurance Project Plan

Water Stargrass Scour Analysis

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1.0 Table of Contents

1.0 Table of Contents i
List of Figures iii
List of Tables iii

2.0 Abstract 1

3.0 Background 2
3.1 Introduction and problem statement 2
3.2 Study area and surroundings 4
3.3 Water quality impairment studies 9
3.4 Effectiveness monitoring studies 9

4.0 Project Description 10
4.1 Project goals 10
4.2 Project Objectives 10
4.3 Information needed and sources 11
4.4 Tasks required 11
4.5 Systematic planning process 12

5.0 Organization and Schedule 13
5.1 Key individuals and their responsibilities 13
5.2 Special training and certifications 14
5.4 Proposed project schedule 15
5.5 Budget and funding 15

6.0 Quality Objectives 16
6.1 Data quality objectives 16
6.2 Measurement quality objectives 16
6.3 Acceptance criteria for quality of existing data 19
6.4 Model quality objectives 20

7.0 Study Design 21
7.1 Study boundaries 21
7.2 Field data collection 21
7.3 Modeling and analysis design 23
7.4 Assumptions of study design 23
7.5 Possible challenges and contingencies 23

8.0 Field Procedures 26
8.1 Invasive species evaluation 26
8.2 Measurement and sampling procedures 26
8.3 Containers, preservation methods, holding times 31
8.4 Equipment decontamination 31
8.5 Sample ID 31
8.6 Chain of custody 31
8.7 Field log requirements 31
8.8 Other activities 32

9.0 Laboratory Procedures 33
9.1 Lab procedures table 33
9.2 Sample preparation method(s) 33
9.3 Special method requirements 33
9.4 Laboratories accredited for methods 33
10.0 Quality Control Procedures 34
10.1 Table of field and laboratory quality control 34
10.2 Corrective action processes 34
11.0 Data Management Procedures 35
11.1 Data recording and reporting requirements 35
11.2 Laboratory data package requirements 35
11.3 Electronic transfer requirements 35
11.4 Data upload procedures 35
11.5 Model information management 35
12.0 Audits and Reports 36
12.1 Audits 36
12.2 Responsible personnel 36
12.3 Frequency and distribution of reports 36
12.4 Responsibility for reports 36
13.0 Data Verification 37
13.1 Field data verification, requirements, and responsibilities 37
13.2 Laboratory data verification 37
13.3 Validation requirements, if necessary 37
13.4 Model quality assessment 37
14.0 Data Quality (Usability) Assessment 38
14.1 Process for determining project objectives were met 38
14.2 Treatment of non-detects 38
14.3 Data analysis and presentation methods 38
14.4 Sampling design evaluation 39
14.5 Documentation of assessment 39
15.0 References 40
16.0 Appendices 44
Appendix A. Glossaries, Acronyms, and Abbreviations 44

List of Figures

Figure 1. Map of larger study area 5

Figure 2. Project Organization Chart. 14

Figure 3. Map of the lower Yakima River with zoomed-in view of the proposed sampling location (red star, RM 15) 21

Figure 4. Estimated velocities required to mobilize armor layer of the Lower Yakima River for varying depths in a one-meter-wide flume, based on predicted shear stress (0.2 to 1 meters deep) 27

Figure 5. Simplified drawing of the proposed flume setup, with raft and boat engine used to suck water into the flume from downstream (top: plan view, bottom: section view) 29

Figure 6. Detailed drawing of the flume setup (omitting the raft and engine for clarity) 30

Figure 7. Graph depicting the proposed experimental measurement sequence, with dotted line representing incremental increases in velocity, cameras representing repeat photography, and the Sontek ADV representing repeat velocity measurements 31

List of Tables

Table 1. Organization of project staff and responsibilities. 13

Table 2. Schedule for completing field work 15

Table 3. Project budget and funding from the WRYBIP-2325-BentCD-00070 Ecology Grant 15

Table 4. Measurement quality objectives for field meter measurements. 17

2.0 Abstract

Benton Conservation District (BCD) will partner with the Northwest Hydraulic Consultants to better understand the shear stress and velocities for mobilization of the river bed in areas of known water stargrass growth in the lower Yakima River (lower Yakima). This project supports total maximum daily load (TMDL) work in the lower Yakima River and will help inform future river management as related to aquatic plant growth. During salmon migration season, dissolved oxygen (DO) and pH greatly fluctuate in the lower Yakima, and are in violation of Washington State's water quality criteria. We attribute the degraded water quality to the abundant growth of water stargrass, a native aquatic plant, acting as a nuisance species, that dominates during baseflow conditions. Excessive water stargrass growth has caused further declines in lower river water quality. Water stargrass alters river flow, contributes to degraded water quality and likely exacerbates summertime river warming.

We will conduct in-situ experiments to estimate the hydraulic conditions necessary for mobilization of river bed materials in areas of known biomass growth. This analysis will be conducted at RM 15, which is representative of lower Yakima substrate and aquatic plant conditions. The in-situ study will include evaluations of sediment mobilization (from fines to cobble-sized particles), along with water stargrass roots from applied variable pressure forces. The specific specifications of the testing apparatus will be determined through a research and development task in NHC's fabrication shop. Water will be pumped across a narrow flume (less than 4-ft wide) placed on the bed of the river at increasing velocities until erosion occurs or maximum velocity is achieved. Shear stress will be derived from the recorded depth and velocity data, which will be evaluated against known hydrological conditions in the Yakima River to establish a critical shear stress for erosion and the estimated discharge needed to reach this critical level.

If erosion does not occur in the flume due to experimental velocity constraints, we will erode the roots with the same jet engine that was used to suck water into the flume, except direct force downward onto the bed to break up the roots in the armor layer. These flume test patches will then be monitored during subsequent growing seasons to understand how long it takes a scoured patch of channel bed to regrow stargrass. The study helps inform river managers on the possibility of using velocity and scour as an environmental control for biomass mitigation. Data and a Technical Report will be given at project completion and will include a summary of the research and development findings, locations, analysis of tests and results, and summary of recommendations based on results.

3.0 Background

3.1 Introduction and problem statement

The lower Yakima River in Benton County, Washington is a migration corridor for multiple salmon species and is a primary water source for irrigated agriculture. Impaired water quality (dissolved oxygen and pH) and warm water temperatures have impacted the listed beneficial uses of the lower Yakima (see 3.2.4). The water quality, temperature, flow regime and habitat challenges in the lowest 50 river miles are directly related to the abundant growth of a native aquatic plant known as water stargrass (*Heteranthera dubia*). The plant began establishing in the lower river after the TMDL clean-up in the late 1990s, when total suspended sediment limits were set and enforced starting in 1998. The increase in light penetration and altered system has seen an increase in biomass in a once free flowing river. The water stargrass is so abundant that it can physically displace the surface elevation of the river near the USGS Kiona Gage (Benton City, WA) by three feet in low water years, converting the free-flowing water into marshy habitat.

During the summer months, the lower Yakima is the warmest stretch of the entire river basin with most of the 50 river miles inhospitable for adult salmon migration at baseflow conditions. In-stream water temperatures often exceed 21°C (Appel et. al., 2011; Sheibley et al., 2022) which is limiting for adult migration of steelhead, sockeye, chinook, and Pacific lamprey. Rapidly warming spring/summer waters can also limit success of late season juvenile out-migration. Additionally, dense biomass leads to rapid depletions of nighttime dissolved oxygen levels. DO levels fell as early as March when juvenile salmon migrate and as late as October when adult salmon return. Similarly, the pH levels were also impacted by whole stream metabolism and fall out of compliance with state criteria (Sheibley et al. 2022). The abundance of water stargrass has physically displaced fall Chinook spawning, once prevalent in the lower Yakima River, as salmon redds are covered by sediments and vegetation. McMichael (2017) noted that dense water stargrass strands provide favorable conditions for the recruitment and refuge of non-native warm water species to the detriment of native salmon, increasing predation pressure.

Specifically, this project builds upon the preliminary conclusions from previous studies that high shear stress on the channel bed can lead to reductions in total WSG biomass in a growing season by breaking up their roots in the armor layer. The plant must be removed entirely, including the roots, in order to prevent growth during subsequent growing seasons. The lower Yakima has a highly regulated flow regime, which reduces high flow magnitude and frequency, and therefore reduces the possible shear stresses able to mobilize the channel bed. The lower Yakima is also downstream of a major depositional zone in Mabton, cutting the lower reach off from upstream sediment supply. The resulting channel bed is therefore highly armored, which has allowed WSG roots to establish and remain in place for years if not decades. This has created a positive feedback loop, where year after year roots establish

in the innately stable armor layer and further increase the velocity and therefore shear stress required to mobilize the bed.

BCD, Yakama Nation and others have been piloting the use of mechanical measures to remove stargrass from the bed, including harvesters and excavators. These methods can be effective in small areas but lack the speed and efficiency to cover whole reaches of river. The magnitude of the water stargrass problem requires an equally scaled mitigation plan, or something that can efficiently remove approximately 1,800 acres of grass in a year (50 miles of river multiplied by an average channel width of 300 feet).

The results of this study are expected to help river managers evaluate new strategies for plant biomass control using water as a means to erode it by the roots. The methods will be evaluated during flow conditions when water stargrass strands and crowns are dormant (optimal time to target the roots). To test the hypothesis that high flow pulses (and therefore high velocity and shear stress) can mobilize the bed and therefore dislodge the roots, a flume will be constructed and placed in the river to create a small-scale test where velocity can be incrementally increased to mimic a high shear stress environment. Velocities will be increased until the maximum operational velocity is achieved or widespread mobilization of the armor layer occurs, whichever is first. The goal with the new data collection is to determine feasibility for river bed movement as a method to disrupt plant biomass within the given flow velocities of the lower Yakima. This will help develop a predictive tool based on data analysis of the flow metrics and water stargrass biomass that can be used by river managers to evaluate flows necessary to control biomass growth. If feasible, it will allow river managers to address the large-scale problem with an equally far-reaching removal strategy, i.e. remove tens of miles of grass in one pulse.

There is a chance that the flume will not be able to generate velocities high enough to mobilize the armor layer, which could reflect either operational equipment limitations at this scale of study as well as the high shear strength of the root-enforced armor layer. In this event, the boat engine that is responsible for sucking water into the flume will be adjusted so that water propulsion is directed downward on the bed of the flume. This method will reliably induce scour and allow for the final study question to be answered, which is: if roots are successfully scoured from the bed, how long does the bed remain free of water stargrass? This grant only covers one to two growing seasons, depending on the test date, so a follow-up monitoring plan may be needed for the subsequent growing seasons to confirm the time estimate for repopulation of water stargrass after it is scoured from the bed. This QAPP only covers up to one growing season for monitoring, and thus any extended monitoring is not part of this QAPP. This type of mechanical removal method is both fast, efficient, and highly mobile (on a floating river craft) and could allow local stakeholders to tackle larger areas of river than an excavator or harvester and also tackle the problem at the root. This could take the form of a mailbox blower, which redirects thrust from a boat engine downward rather than horizontally.

We anticipate that the data from this project will help local stakeholders with future actions that may improve water quality, mitigate water stargrass growth, and/or improve lower Yakima water quality conditions and river function. Results of this study may help inform whether reservoir releases during higher flow events may help scour plant root matter, thereby decreasing total plant biomass. Alternatively, placement of constriction structures within the river may be able to increase velocities, thereby inducing scour and mitigate biomass growth. It will take years to establish a process flow protocol or to build large narrowing structures in the river. Mechanical removal methods, such as jet scour, could provide some relief in the near term, or when water levels in the reservoirs are too low for a flow release. The Yakima River Basin is considered one of the most vulnerable watersheds in Washington State for climate change impacts, with summers predicted to become warmer and dryer (Pickett 2016). As water demands in the basin increase, it is imperative to find watershed level controls to improve lower Yakima function.

3.2 Study area and surroundings

The lower Yakima River, located in south-central Washington State, flows through arid Benton County (Figure 1). Agriculture is the primary dominant land use in Benton County, supported by irrigation from the Yakima River. Columbia River basalts dominate between Prosser and Benton City, confining the river channel throughout this reach with minimal area for braiding and meander. Alluvial deposits are present between Horn Rapids and West Richland. Alluvial islands formed by Quaternary floods are dispersed throughout this reach and mediate changes in channel morphology.

Previous USGS geology studies indicate the lower Yakima to be a gaining reach, from Prosser to below the Chandler Power House. Above Benton City, the river transitions from a gaining reach to a predominantly losing reach. Possible sources of nutrients to the lower river include several overland irrigation return flows, shallow subsurface irrigation flows, and irrigation wasteways on the lower Yakima that also contribute cooler water (Sheibley and others, 2024). There are few floodplains and island side-channels on the lower river. The minimal floodplains that exist on the lower river are within West Richland and Richland, WA.

The lower Yakima passes through the towns of Prosser and Benton City, and forms the dividing line between Richland and West Richland in the Tri-cities before joining the Columbia River in Richland. The county's irrigation use for agriculture and growing urban/residential development heavily influence Yakima River water quality and seasonal flow. The Yakima River is a highly managed system with regulated yearly flow regimes. The spring freshet typically occurs between April and May, with low flows and high temperatures occurring June through August. 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 (WDFW unpublished data 2000 – 2018, data source P. Hoffarth). As a result, adult and juveniles must migrate further, decreasing their chances of survival.

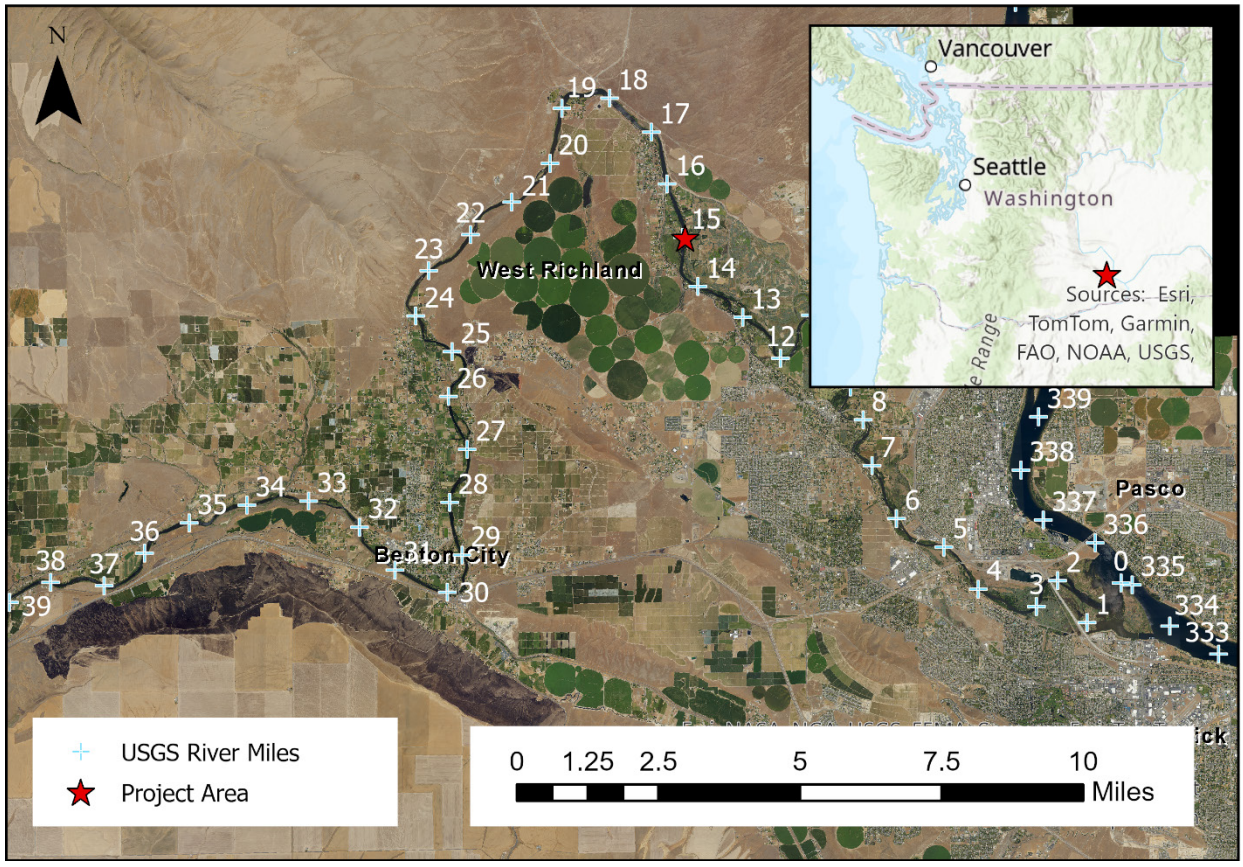


Figure 1. Map of larger study area

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 im-

provements 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. The impacts of WSG on these conditions have been shown to have negative impacts on water quality, river ecology, river morphology, and harbor disease carrying mosquitos.

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. Water Stargrass has been linked to deleterious impacts to these fish species, and has shifted the spawning locations of Fall Chinook completely out of the lower Yakima (Appel et al., 2011).

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. This report outlines the water quality conditions in the river prior to water stargrass abundance.

The Eutrophication Study (Wise et al. 2009) monitored water quality parameters, nutrients, temperature, and flow during the irrigation season along the lowest 116 miles of the Yakima River, dividing the river into three reaches based on geomorphology, habitat, aquatic plant, and water quality conditions. The Kiona reach (Prosser to Richland) experienced abundant macrophyte (primarily water stargrass) and epiphytic algae growth, relatively high nutrient concentrations, and large daily fluctuations in DO and pH levels. The study noted that due to abundant macrophyte growth, pH and DO levels exceeded state water quality standards in all years sampled. The study included monitoring in 2005, which was a drought year.

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 (2001), BCD conducted thermal profiles of the Kiona Reach at baseflows in 2008 and 2009 to identify temperature heterogeneity within the lower river. Appel et al (2009) noted that river summer temperatures were well above 21°C for the 2008 and 2009 summertime floats; however, they identified thermal heterogeneity within the lower reach 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 (island at I-182 bridge). BCD and the Yakama Nation, under a separate Ecology grant (WRYBIP-VER1-BentCD-00004), collected thermal profiling data during the summers of 2018 and 2019 which was summarized by Gendaszek et al. (2021). A second temperature study conducted by BCD and USGS (Sheibley et al. 2024) documented the extent and duration of cold water areas in the lower river through instrumentation of multiple areas identified in the Gendaszek et al. (2021) study. The results of these combined temperature projects demonstrated the potential for cold water sources to reduce thermal stress in the lower river. This work documents the effects of water stargrass on increasing water temperature in summer months due to its high roughness in the water column, which slows the velocities and increases residence time, therefore creating reservoir-like conditions for the water to heat up in the hot and sunny climate of the lower river.

Pickett (2016) provided a summary of past studies and data relevant to multiple Yakima River reaches. Relevant past studies in his review have included modeling of Yakima River temperatures; modeling of DO and pH in the lower Yakima below Prosser; numerous studies of hydrogeology, groundwater, flood plain morphology, and thermal regimes; routine ambient monitoring; and an Ecology reconnaissance survey during the summer of 2015 in which pH, DO, and temperature were monitored in the lower river. The 2015 reconnaissance survey collected synoptic data samples in August and September during the most recent drought year.

USGS and BCD (2018 – 2021) collected water quality data (temperature, DO, specific conductance, pH, turbidity) at three locations on the lower Yakima within Benton County (Prosser, Benton City, and Richland) under a Water Quality Combined Funding grant through Department of Ecology (WQC-2018-BentCD-00065). These data were part of a larger study to investigate reach scale temperature data and aquatic vegetation. Data are stored in National Water Information System (NWIS) (https://waterdata.usgs.gov/wa/nwis/rt).

Washington State University – Tri-cities and BCD (2021 – 2023) evaluated the relationships of large-scale harvesting on dissolved oxygen near Benton City as part of a Yakima Basin Integrated Plan grant: WRYBIP-BentCD-00018). The water quality evaluations were near Benton City, and to support the research the USGS water quality stations at Benton City and Van Giesen were kept operational in 2021 and 2022. These support the theory that removing water stargrass improves dissolved oxygen in the water column.

BCD (2022 – 2025). BCD conducted biomass samplings at Benton City and Van Giesen for multiple growing seasons. These samples were collected to maintain a record of annual biomass variation with water year. Biomass samples were processed in collaboration with USGS using the same protocols outlined by the 2018 Project QAPP for WQC-2018-BentCD-00065 (Appel and Sheibley, 2018). These samples may be able to help address questions between hydrograph trends and biomass, specifically if the timing and duration of low flows has an effect on late summer biomass.

NHC (2020-2025). NHC has conducted multiple reach assessments between RM 30 and RM 2. These assessments consisted of geomorphic investigations as well as localized hydraulic modeling to support bank stabilization and river restoration designs. Data for these projects include 2D hydraulic model outputs, substrate characterization, and UAV mapping. NHC has collected repeat UAV imagery at RM 15, both in 2024 and in 2025. Through these studies and repeat observations, NHC has developed a more comprehensive understanding of water stargrass life history in the Lower Yakima and bio-geomorphic interactions.

3.2.3 Parameters of interest and potential sources

The primary parameter of interest in this study is water velocity, which will be manipulated inside of a flume structure. The induced water velocities in this study will be measured and used to examine equivalent flow rates of the Yakima river to ascertain if similar hydraulics can be achieved within the Yakima Basin to induce bed scour.

Qualitative evaluation of bed movement will be conducted through visual identification of substrate mobility between incremental velocity increases during the flume testing. Pebble counts will be conducted after each incremental velocity increase.

These results will be provided to river managers to analyze possible outcomes from stored water releases for the benefit of lower river function. It will also allow for potential actions to reduce river width and depth rations to increase velocities in portions of the lower Yakima. Water stargrass colonization impacts DO, pH, turbidity and temperature – but these parameters are not the focus of this study. This project is focused on understanding shear stress and velocities required to induce bed disturbance in an area heavily dominated by plant matter to reduce colonization, thereby improving water quality outcomes.

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 nu-

meric and narrative criteria for turbidity. Additionally, parameters such as water temperature, DO, and pH have set criteria. 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. There is no criteria for river velocity or flow. All the below uses and standards are impacted by water stargrass biomass and extent.

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.

There is no criteria for water velocities in the lower Yakima.

The following permits may be required for this study and applications have been submitted:

- Washington Department of Fish and Wildlife Hydraulic Project Approval (HPA) - Fish Habitat Enhancement Permit
- Washington Department of Ecology Section 401 Water Quality Certification
- U.S. Army Corps of Engineers NWP and Section 404

Benton County has issued a shoreline exemption for this project.

3.3 Water quality impairment studies

Not Applicable

3.4 Effectiveness monitoring studies

Not Applicable

4.0 Project Description

Benton Conservation District has partnered with the Northwest Hydraulic Consultants (NHC) to develop, implement and analyze a river bed scour study at a minimum of one site in the mainstem of the lower Yakima. The project is a continuation of the efforts started under a previous Department of Ecology grant (WQC-2018-BENTCD-00065) and is TASK 3 in the WRYBIP-2325-BentCD-00070 grant. This effort will directly address the velocities needed to move bed material in the lower Yakima that will inform river managers of conditions needed to improve lower Yakima river functions.

This work takes place within a section of the river heavily dominated by rooted aquatic macrophytes and susceptible to warm in-stream summer temperatures. For this effort, NHC will perform at least one in-situ field study at RM 15 and will include evaluations of sediment and root mobilization from applied variable pressure forces pumped across a flume within the channel bed where water stargrass is colonized.

The project goals and objectives specific to this project are outlined below.

4.1 Project goals

The primary project goals include:

- Evaluate feasibility of induced root scour and bed mobilization in the lower Yakima River
- Define relationship between flow and armor layer mobility in order to examine whether flushing flows can be used as a watershed level management technique in the Yakima Basin for macrophyte growth control by comparing in-situ results to known Yakima River hydrology
- Examine whether a cheaper, more efficient and more mobile mechanical grass removal system using propelled water on a floating platform can be used to effectively force scour of roots
- Determine how long the channel bed remains free of water stargrass once roots have been removed from the armor layer (timeframe may extend outside of this grant contract period)

4.2 Project Objectives

The objectives of the flume study are to:

1. Perform at least one in-situ flume shear stress investigation in the lower Yakima to determine root and channel bed movement (each investigation will consist of up to three flume placements to test across variable substrate)

2. Collect variably induced velocity and depth measurements inside of a flume using the method outlined in EAP 058, v. 1.2. Measurements will be collected at two points along the flume (1/3 and 2/3 distance).
3. Calculate shear stress from measured depth and velocity and compare these required hydraulics needed to induce bed movement to those naturally occurring in the Yakima Basin.
4. Follow established protocols to ensure that representative measurements are obtained throughout the investigation.
5. Maximize the reliability of the data by maintaining quality control procedures.
6. Monitor the flume patch(es) over at least one growing season to determine how long one scour event can prevent regrowth

4.3 Information needed and sources

We anticipate we may use previous collected data on the lower Yakima from the following sources:

- National Water Quality Assessment Program or USGS Surface-Water Data for Washington (https://waterdata.usgs.gov/wa/nwis/rt) for the Kiona and Van Giesen gages from 2018 – 2025 in additional to historical flow data records
- Biomass sample data from 2018 -2025 collected by Benton Conservation District.
- 2023 Pebble count data from RM 16 to RM 10 from NHC (2023)
- 2D Hydraulic Model outputs of RM 15 from NHC (2025) Basis of Design Report
- 2D Hydraulic Model of the lower Yakima from the US Army Corps of Engineers (in progress, schedule pending)

4.4 Tasks required

Outlined below are the main tasks for this project.

- Conduct a research and development study (R&D) to design two experimental platforms:
  1. A mobile engineered flume approximately 3-ft by 10-ft that can be deployed in the lower Yakima at RM 15 to induce locally high velocities to investigate what shear stress is required to mobilize the armor layer
  2. A stable floating platform capable of propelling water down on to the river bed, which may be used to induce scour and remove water stargrass roots from the armor layer
- Calculate shear stress from the processed the depth and velocity flume measurements and compare induced shear stress hydraulics to those naturally occurring under a typical lower Yakima hydrograph

- Monitor the test patch for signs of water stargrass growth over at least one growing season using visual monitoring
- Produce a 'Technical Report' of testing methods that include locations, analysis of findings, and summary of recommendations based on test results.

4.5 Systematic planning process

This QAPP represents the systematic planning process.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

Table 1 shows the responsibilities of those who will be involved in this project.

Table 1. Organization of project staff and responsibilities.

Project Team	Title	Responsibilities
Marcella Appel Benton Conservation District	Lower Yakima River Project Manager, District Manager	Clarifies scope of the project. Arranges and oversees cooperative agreement with NHC. Responsible for grant reporting and communication with Ecology Project Manager.
Derek Stuart, Northwest Hydraulic Consultants	Principal	Responsible for NHC contract with BCD, signatory on QAPP and NHC team management.
Annie Dufficy, Northwest Hydraulic Consultants	Senior Water Resource GeoScientist	Develops experiment protocols, ensures QAPP objectives are met, oversees field experiments, data analysis and project report writing.
Andrew Nelson, Northwest Hydraulic Consultants	Principal Geomorphologist	Provides principal oversight of the project, including field methods and sediment transport analysis, and provides QA/QC of all deliverables.
Ed Zapel, Northwest Hydraulic Consultants	Principal Hydraulic Engineer	Leads the R&D task for constructing and engineering the experiment flume
Shawna Warehime Office of Columbia River, Department of Ecology	Project Manager	Reviews the project scope, tracks progress, approves and signs the final QAPP.
McKenna Murray Office of Columbia River, Department of Ecology	QA/QC Coordinator	Reviews QAPP, signs final QAPP, ensures project QA has been met.

QAPP: Quality Assurance Project Plan
QA/QC: Quality Assurance Quality Control

5.2 Special training and certifications

No special certifications or trainings are required for this project. 5.3 Organization chart

BCD and NHC will work collaboratively on this project through a Joint Funding Agreement. Ms. Appel and Annie Dufficy will facilitate communication about the project between partners about every six weeks. Responsible project staff and lines of communication are in Figure 2.

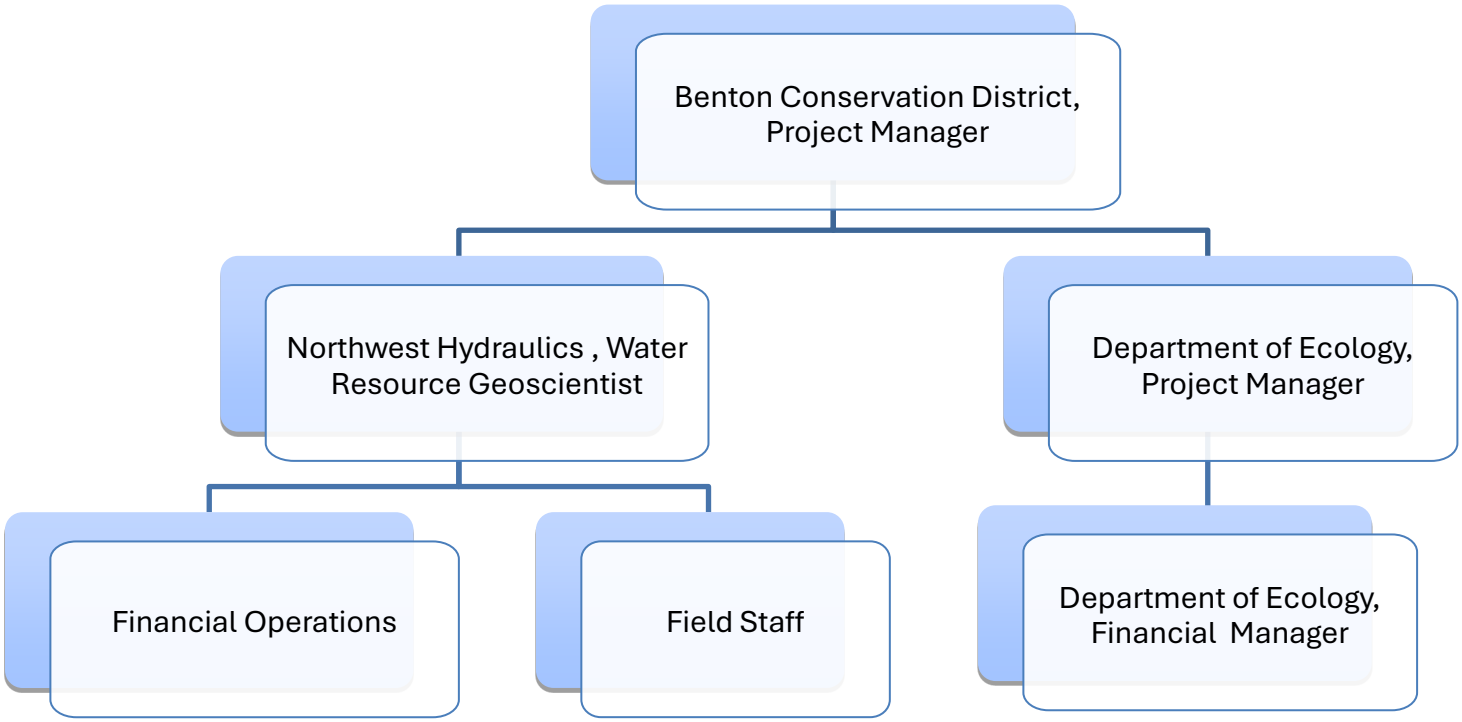


Figure 2. Project Organization Chart.

5.4 Proposed project schedule

The proposed project schedule and lead staff for each task is provided in Table 2.

Table 2. Schedule for completing field work

Task	Due date	Lead staff
Flume Development Complete (research and development, internal testing at NHC fabrication shop)	February 2026	Annie Dufficy
Permits Secured	April 2026	Marcella Appel
In-Situ Scour Test (First Test)	August 2026 (or whenever in-water work flows and permit procurement align)	Annie Dufficy
Data Processing and Analysis	Three months after In-Situ Scour Test	Annie Dufficy
In-Situ Scour Test (Second Test, budget pending)	November 2026 – March 2027 (pending budget)	Annie Dufficy
Engineer Report	Three months after Data Processing and Analysis	Annie Dufficy
Quarterly PRPR Reports	Quarterly from December 2025 – June 2027	Marcella Appel (BCD)

5.5 Budget and funding

This project is funded by a Department of Ecology grant through the Yakima Basin Integrated Plan (WRYBIP-2325-BentCD-00070) and match funding from the Washington State Conservation Commission in the amount of $15,000 for FY26. The project funding was awarded to Benton Conservation District and NHC will be a contract partner through the Biennium On-Call engineering contract 2025 - 2027. The funding allocation for the part of the grant covered under this QAPP is provided in Table 3; NHC is responsible for the data collection, field investigation, and Engineer's report.

Table 3. Project budget and funding from the WRYBIP-2325-BentCD-00070 Ecology Grant

Cost Category	Cost ($)
BCD Salary and Benefits	$8,333
BCD Indirect	$1,666
Engineering Contract	$125,000
Total	$135,000

6.0 Quality Objectives

Quality objectives are statements of the precision, bias, and lower reporting limits necessary to meet project objectives. Precision and bias together express data accuracy. Other considerations of quality objectives include representativeness and completeness.

6.1 Data quality objectives

The main data quality objective for this project will be to ensure collection of high quality and scientifically defensible data to inform the relationship between shear stress and bed mobility in order to support future aquatic macrophyte control. The quantitative parameter to be measured is velocity. To evaluate scour, velocity data will be collected during artificially induced scour "events".

To ensure the quality of all data, field staff will calibrate and maintain field equipment for velocity data. The investigation and data collection during the study will follow established protocols for collection of velocity as specified in EAP 058, v 1.2.

6.2 Measurement quality objectives

Measurement quality objectives (MQOs) for shear stress and bed movement investigation described here are to obtain and analyze sufficient numbers of high-quality samples to meet the goals and objectives of this program. Data quality indicators include precision, bias, sensitivity, representativeness, comparability, and completeness (defined in Appendix A).

6.2.1 Targets for precision, bias, and sensitivity

6.2.1.1 Precision

Precision is a measure of the variability in the results of replicate measurements due to random error. Precision is usually assessed by running duplicate field measurements. Random error is imparted by the variation in concentrations of samples from the environment as well as other introduced sources of variation (e.g., field procedures). Table 4 presents field measurement MQOs for precision and bias, as well as the manufacturer's stated accuracy, resolution, and range for the field equipment that will be used in this study.

Sediment gradation will need to be analyzed using a non-invasive method. Traditional Wolman pebble counts require dry conditions, which cannot be met for this study that is occurring in flowing water. Additionally, pebble counts disturb the armor layer, which would bias the results of this study. Therefore, pebble counts must be conducted using photo-sieving methods from the repeat scaled photographs. Replicate samples are not typically conducted for pebble counts, which by design include many replicates in each sample (this why a sample size of 100 grains is the standard). Photo-sieving methods have potentially hundreds of built-in replicates by incorporating more than 100 grains in an analysis (thousands of grains is possible depending on area). Repeat scaled photos of the bed will

be used in the Python-based module Segmenteverygrain[2], which is a photo-sieving method used for grain size analysis (Sylvester et al., 2025).

Bed mobility parameters will be investigated at differing flows using repeat scaled photographs between velocity tests. Repeat scaled photographs offer a precise, instantaneous measurement of resulting bed conditions following flows to analyze qualitatively for both bed movement, and stargrass mobilization. Repeat photographs will be compared against each other to establish whether sediment mobility occurred. This will be done first through ArcGIS Pro analysis tools (such as Count Overlapping Features, intersect, and Spatial Joins), which will be used to access differences between the sequential *Segmenteverygrain* software outputs (segmented grain polygons). Repeat photographs will also be assessed visually, for redundancy and to confirm the results of the polygon change detection methods and especially in areas that require more scrutiny (such as areas that are obscured by fine sediment and roots, which may not be accurately depicted by the *Segmenteverygrain* software). Video recordings for each experiment will be used to help confirm when and where mobility occurred.

Table 4. Measurement quality objectives for field meter measurements.

	Equipment/Method	Precision	Bias	Sensitivity
		Comparison to calibrated field meter.	Comparison to standards	
Velocity	Sontek Flowtracker 2 (ADV)	5% RSD +/- 1% of measured velocity	<0.03 ft/s	0.0003 ft/s
Pebble Count	Photo-sieving software using scaled photographs (image created from Olympus Tough TG-6 12 megapixel underwater camera)	NA	Less than 22%	0.01 inch per pixel

[2] Documentation of the Python package is available from the GitHub Repository at https://zsylvester.github.io/segmenteverygrain/index.html

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 instruments. Table 4 lists targets for bias.

Staff will calibrate the Sontek ADV used for measurements of velocity using manufacturer specifications and note that the calibration values are acceptable compared to the calibration value. Staff will maintain and preserve calibration records throughout the project. Staff will calibrate all parameters prior to testing. If the parameters are within the calibration parameters in Table 4, data are considered usable.

Digital grainsize methods can suffer from similar bias that is present in a typical Wolman pebble count depending on the ground sampling distance (GSD) that is achieved from the photograph. Typical Wolman samples tend to under-represent the finer fraction of the distribution. A 12-megapixel camera will be used, which should achieve a ground sampling distance (GSD) of 0.01 inches per pixel. This should capture sand and fine gravel. The grainsize digitization allows for a calculation of the percent fines, which is something that is not captured in a typical pebble count. This calculation of percent fines will be visually checked visually for each photograph. Because typical pebble counts only record 100 grains and photo sieving methods record all grains, which could be thousands, it ends up being a far less biased result compared to a typical Wolman pebble count.

Bias for Wolman pebble counts is listed in Bunte and Abt (2001). The paper identified an uncertainty band of +/- 22% for the heel-to-toe pebble count method as determined in the study by Wohl et al. (1996) for an approximately normal distributed 100-particle pebble count with a sorting coefficient of 1.6. This error is mostly based on bias that the heel-to-toe sampling method introduces to the fine gravel fraction and the cobble/boulder fraction.

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. Table 4 lists the range, accuracy, and resolution of each instrument to be used in the study. The listed instrument sensitivity is the reporting limit for this project.

6.2.2 Targets for comparability, representativeness, and completeness

6.2.2.1 Comparability

Comparability expresses the confidence with which we can compare data sets to one another. For this project, we will achieve comparability by using standard approved field methods and maintaining consistency in methods for all sites and sample collection as provided in Section 8.0.

6.2.2.2 Representativeness

Representativeness expresses the degree to which data accurately and precisely represents a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition. For this project, we will meet representativeness by following the protocols outlined within the Project QAPP.

To ensure data are representative, we will:

- Follow manufactured recommended protocols for data accuracy for operation and maintenance of all equipment
- Conduct 2 repeat velocity measurements at 60% of the depth (which corresponds to the average velocity of the water column following the log of the wall) for every incremental flow increase in the flume to ensure that uniform and equilibrium flow conditions were achieved in the flume experiments. If velocities vary, then conduct additional velocity measurements at 20% and 80% depths.
- Conduct an additional velocity measurement at 30% of the depth to confirm the log of the wall relationship holds for the velocity in the flume

6.2.2.3 Completeness

Completeness is a measure of the amount of acceptable analytical data obtained from a measurement system compared to the amount expected under normal conditions. Completeness is not a target metric for the Sontek Flowtracker2. Using percent of valid measurements as a proxy, the target for the velocity measurements will be 100%. If the signal-to-noise ratio, standard error of velocity, spike percentage, or velocity angles are out of range, which will occur as an error in the user interface, the measurement will be taken again following the recommended protocols[3].

6.3 Acceptance criteria for quality of existing data

Section 3.2.2 lists potential data sources for this study, however, during the course of the project we may identify additional data sources. The project will use the best available data, assess the quality of that data, and then assess the effects of data quality on the project. Data collected outside this project, but used for project analysis will undergo evaluation prior to use.

To follow a process of quality assessment, we will

- Document and evaluate any qualifications associated with the data.
- Evaluate the data for outliers or unusual trends that may suggest data quality problems.
- Censor, qualify, or accept suspect data, based on the evaluation of that data.

[3] https://www.ysi.com/File%20Library/Documents/Guides/flowtracker2-qc-warnings-field-guide.pdf?srsltid=AfmBOoqpSUEN-tlrx8FpQ7CanNmodR1Nzi9mZvChQYYNtQkVckGca9e6

- Conduct an overall assessment of the variability and uncertainty of each data set and source of the data set, including the established level of quality assurance and review

6.4 Model quality objectives

Not applicable.

7.0 Study Design

7.1 Study boundaries

The proposed sampling location is RM 15 (Figure 3), which has an existing landowner relationship and existing conditions knowledge from NHC (2023, 2025). The site consists of two channels, with the mainstem and side channel flowing around an established forested island to create varying hydraulic and substrate conditions and therefore varying degrees of stargrass establishment.

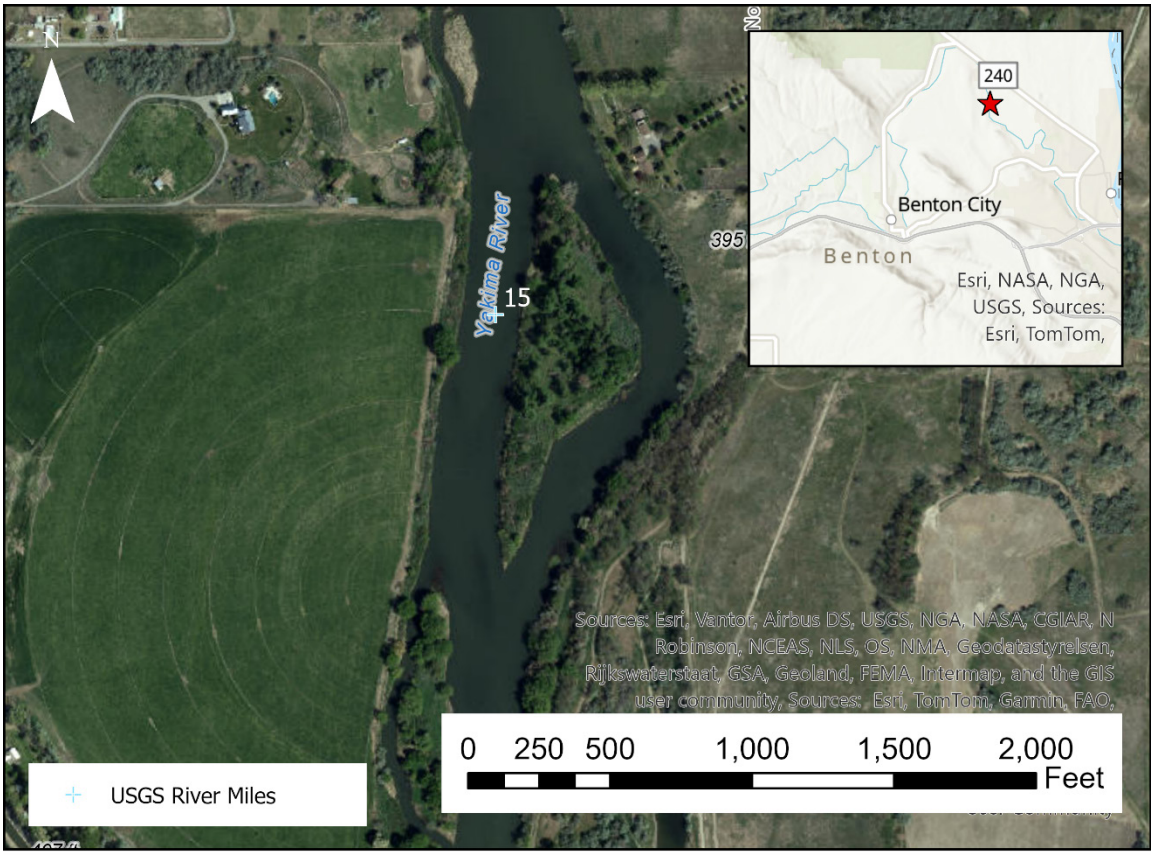


Figure 3. Map of the lower Yakima River with zoomed-in view of the proposed sampling location (red star, RM 15)

7.2 Field data collection

7.2.1 Sampling locations and frequency

Up to six locations will be chosen to conduct the flume experiments at RM 15 to represent a range of variable substrate conditions. Locations for the first test, which will be completed in the summer of 2026, will be identified in early summer. Staff will snorkel the area and chose three locations of channel bed that were recently mobilized during the winter 2025-2026 floods (identified as areas where water stargrass has been eroded from the bed) and three locations of the channel bed where the armor layer did not mobilize during

these floods. Due to budget constraints, only two days of fieldwork are scoped for each test, with up to three tests per day seen as realistic and viable given the transport time and anticipated setup/breakdown times between experiments. Because erodibility of water stargrass beds is the focus of the study, priority will be given to areas of the channel bed that did not mobilize during the 2025-2026 floods. Three tests should be sufficient to draw conclusions on the erodibility of the test area if operational constraints (such as time spent setting up and taking down the flume) prevent completion of six full testing locations. The grain size does not vary widely in the reach, as determined by the pebble count data from NHC (2023) and NHC (2025), so three tests in varying hydraulic conditions (thalweg, near island head, near bank margins) should be sufficient to capture the range of erodibility with enough overlapping grain size to constitute as repeat analysis.

The flume experiment will ideally be conducted twice, once while biomass is present and another prior to water stargrass emergence (November to March). They should be conducted over two days of relatively uniform discharge. The reason for a low biomass test is that after water stargrass has emerged, the hydraulic roughness increases, stage increases, and velocities substantially decrease, which would not be ideal conditions for a scheduled flow release. Water column conditions also need to be relatively clear for the use of underwater photography, so the tests cannot be conducted during times of high irrigation return flows. The stage should be at least two feet deep for the flume to operate, but not too high that prohibit safe wading conditions and stabilization of the flume.

The test patches used for the flume will not be located near known salmon redd locations. There have been no known salmon redds located within the study area since water stargrass density increased.

7.2.2 Field parameters and laboratory analytes to be measured

Flume experiment:

During the flume experiments, repeat measurements of velocity and depth will be recorded to calculate shear stress during post-processing. Repeat photographs will be taken in the field to assess during post-processing for bed texture and substrate mobility.

Field measurements:

- Velocity (variably induced in a flume)
- Depth (variably induced in a flume)
- Repeat photographs
- Video

Post-processing:

- Shear stress (calculated from depth and velocity as described in Section 7.3)
- Substrate mobility (yes/no, assessed from repeat scaled photographs and video)

- Grainsize distributions (Digitized from scaled photographs)

7.3 Modeling and analysis design

Bed shear stress will be calculated for each flume run as the reach-averaged boundary shear stress, using the standard open-channel relation (Henderson, 1966):

$$\tau = \rho g R S$$

where τ is bed shear stress (Pa), ρ is water density (kg/m^3), g is gravitational acceleration (9.81 m/s^2), R is hydraulic radius (m), and S is the water-surface slope. For the rectangular flume, hydraulic radius will be calculated as R = A/P, where A is the flow area (defined by the flow depth multiplied by the width of the flume) and P is the wetted perimeter. Mean velocity and flow depth will be measured during each run and used to confirm steady, uniform flow conditions. The flume is being designed to create uniform flow, but in the very unlikely result that flow is nonuniform, shear stress will be interpreted as a reach-averaged estimate and reported with the associated measured depth, velocity, and slope. This approach is based on the standard force-balance formulation for open-channel boundary shear stress and is commonly used to estimate bulk shear velocity and bed shear stress in open-channel flow.

7.3.1 Analytical framework

Not Applicable.

7.3.2 Model setup and data needs

Not Applicable.

7.4 Assumptions of study design

The underlying assumption of this study is that water stargrass can be eroded from the bed at shear stresses typical of an annual spring freshet. The assumption is that this freshet may have kept the water stargrass in check before heavy regulation of flows, and flow velocities required to erode the stargrass are within a reasonable level. The study design assumes that the WSG roots will be prevalent enough during the study period to select sites that match observed overgrown conditions over the past few years. The study also assumes that a normative water year will be likely during the time period and that no unusual flow conditions will impact prevalence of WSG in the areas of interest.

The study also assumes that shear stress can be calculated from the depth and velocity measurements taken from the flume measurements and that this can be scaled to typical flood flows in the open channel of the lower Yakima.

7.5 Possible challenges and contingencies

7.5.1 Logistical problems

In-situ measurements in the areas of interest will require accessing the site with all necessary equipment. This includes rafts equipped with boat engines, the constructed flume, and supporting staff and equipment. Flow is the primary limiting factor for site access, as flows that are too high or too low will be inoperable for the flume. Tests will be performed in wadable areas, which will be accessed with the existing 2D hydraulic model from NHC (2025). Tests must be performed in clear water conditions (underwater photographs) which eliminates the spring and early summer during intensive irrigation practices. Ideally, tests will be performed in two conditions: first during summer low flow conditions, when biomass is present, and also when biomass is dormant during the late fall to early spring (when flushing flows would be expected in a more natural hydrologic regime).

Delays can arise from many factors including: permitting delays, drought, high turbidity, and flood events. River levels and forecasts will be monitored prior to beginning the data collection, and an appropriate time to visit the river will be chosen. In most cases, the tests will be able to occur when operable conditions resume, but tests will need to be delayed if permit acquisition is delayed. If permits are delayed for the 2026 in-water work window, then the first test will be conducted once permits are acquired and flow conditions are within operable limits of the flume raft. In the permit application, tests both inside (high biomass) and outside (dormant, low biomass) of the in-water work window were specified. If permits are not secured for the in-water window of 2026, then the high-biomass tests will be conducted in summer of 2027.

7.5.2 Practical constraints

The size of the flume design and boat engine are the most important constraints for this project. The constructed flume will have to be floated out to the test locations and will limit the size of the experiment design. The relative increase in velocity that can be achieved in the flume is related to the flume cross sectional area and the size of the boat engine that is being used on the downstream side to suck water inside. The flume must be large enough to accommodate several D_{84} sized particles (size particle that represents the 84^{th} percentile), to reduce edge effects from the side walls. The larger the flume, the larger the engine will need to be. The size of the engine is dependent on cost and operational safety/security. Flows must be at least two feet deep for the flume to operate, so that is one primary constraint. Observations during August of 2025 confirmed that most of the study area would be considered operable during August flows, assuming that at least 1,000 cfs is present (i.e. assuming that extreme low flow conditions do not exist that lower the stage below two feet in the study area).

7.5.3 Schedule limitations

Scheduling of site visits for data collection will be based on flow conditions, turbidity, water stargrass dormancy period, permit timelines and staff availability. The timing has been chosen as late summer (during the in-water work window) and anytime between November

and March for a second test, budget permitting. Field work will be able to be re-scheduled for the next year should conditions delay the project.

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. 2023). The study area for this project is not located within areas of extreme concern. However, the New Zealand Mud Snail has been sighted upriver near Zillah and caution should be taken so that if present downstream it is not transported. It is common practice for field personnel to decontaminate field gear used between sites to ensure we do not spread invasive species from site to site.

All equipment will be properly cleaned prior to the field effort to minimize the spread of invasive species from elsewhere.

8.2 Measurement and sampling procedures

The first task of this project is a research and development (R&D) study where a team of engineers will build a submergible flume in the NHC fabrication shop based on engineering drawings and calculations. The flume will be built to simulate the velocities needed to erode an armor layer that is strengthened by water stargrass roots. The average particle size of the project area varies from 60 mm to 90 mm for the D_{84} (NHC, 2023; NHC, 2025).

In the absence of stargrass roots, a bed of this gradation would require a shear stress of between 40 to 65 Pa to mobilize the bed (Figure 4). Water stargrass roots and fine sediment cementation in the armor layer has increased the critical shear stress required for mobilization, but the exact amount is not known and is the primary focus of this study. Therefore, the flume should be able to simulate a much larger velocity and associated shear stress to mobilize this very strong armor layer. This upper range is unknown, but simulating velocities for at least two times the sediment size (or up to 256 mm cobble) will be the goal for the study design and inform the flume cross section and engine size.

Setup and breakdown of the raft, flume, and all equipment will be verified in the fabrication shop prior to initial deployment in the Yakima River to assure that everything will perform under flowing conditions prior to initial deployment in the Yakima River. This is not an official test, as the fabrication shop cannot simulate Yakima River conditions, but will be mainly used to establish field protocols for setting up, running, and breaking down the materials so that the team can operate safely and efficiently. All drawings and structure details are therefore approximate and subject to change as the R&D task progresses and efficiencies or improvements are found (Figure 5, Figure 6, Figure 7).

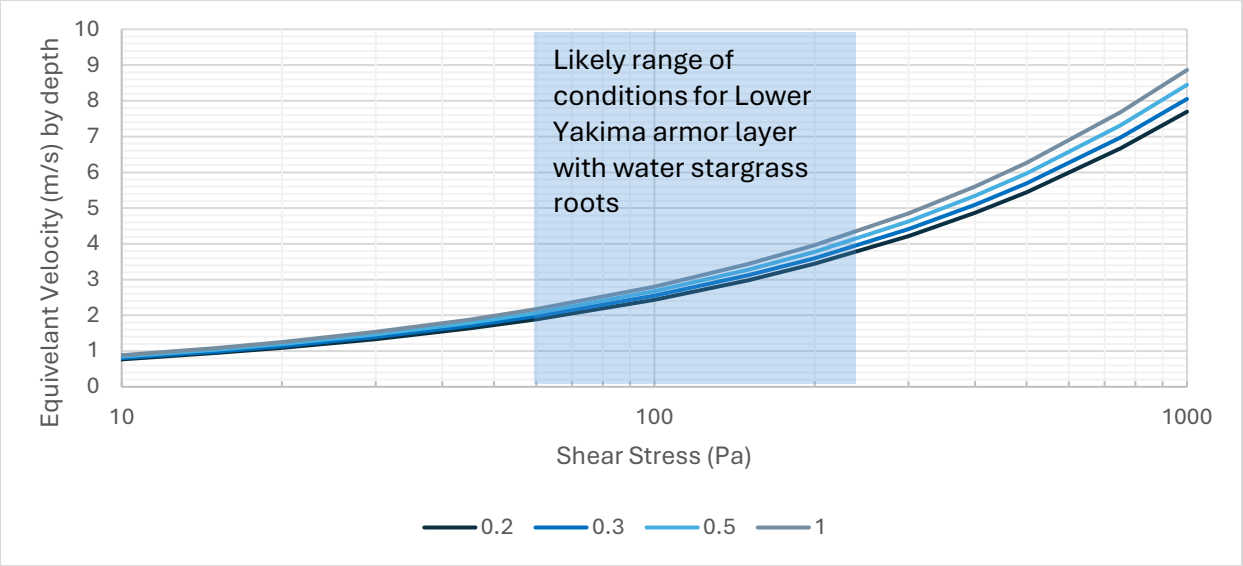


Figure 4. Estimated velocities required to mobilize armor layer of the Lower Yakima River for varying depths in a one-meter-wide flume, based on predicted shear stress (0.2 to 1 meters deep)

Within the area of interest (RM 15), up to six locations will be chosen for placement of the flume during the initial test. These locations will be characterized by substrate type, water stargrass density, relative river stage, etc. The study will be conducted at least once, but ideally twice, during both high macrophyte growth (summer) as well as the dormant season when root mats are present, but biomass density is low (fall to early spring). The dormant season is the period when flushing flows are most likely to occur in nature and coincide with bed movement. Sampling must also occur when turbidity is low, which occurs outside of the spring and early summer irrigation window. Sample locations will be marked with GPS.

A constructed flume will be placed over top of the area of interest containing water stargrass from a floating raft at areas where depths exceed two feet (the height of the flume). The flume will be three-sided, consisting of two sidewalls and a top or roof, held together by several braces and will likely span up to three feet in width and twelve feet in length. Prior to beginning the experiment, staff will take underwater scaled photos and document initial conditions inside the flume.

Staff will position a floating raft over the flume with a boat engine positioned at the downstream outlet of the flume (Figure 5). Staff will increase the throttle of the engine to adjust the relative discharge through the flume, and therefore adjust the velocity. The raft and flume will be anchored into the bed using steel spuds. Video cameras will be used in profile view along flume walls to capture bed motion (Figure 6). These cameras will be turned on and recording prior to commencing the experiment. An underwater camera will be mounted to a pole to capture photos of the entire streambed.

Velocity will be measured at two points in the flume, at 1/3 and 2/3 length along the flume, to measure initial conditions. Velocity will be measured with a Sontek Flowtracker 2

handheld ADV in accordance with the Standard Operating Procedure EAP058, v 1.2. Depth will be recorded along a stage plate located inside of the flume at the velocity locations. After initial conditions are recorded, staff will turn on the engine and increase the throttle to increase flows through the flume incrementally. During each incremental increase, flows will remain constant for several minutes while staff repeat the velocity and depth measurements (Figure 7). After each velocity increase, flows will be brought back down to the initial conditions and wait until the water column is clear enough to re-photograph the bed. This process will be repeated, with increasing flows in steps until one of two conditions is met: sediment transport occurs within the armor layer or maximum flows are achieved (equipment constraint).

In the event that the flume setup reaches its maximum velocity and cannot induce scouring flows, an alternate approach will be used. A deflector, such as a mailbox blower, will be placed on the boat engine to direct thrust downward onto the bed. This downward thrust of water will be applied to the entire flume bed, which is assumed to be enough force to properly break up the armor layer and free the WSG roots. After completing this, a final round of photographs will be taken.

Each patch of river bed from the flume tests will be monitored throughout the next growing season for signs of WSG growth using repeat visual observations, taking repeat submerged videos and photographs. If timing allows, the patches will be monitored for a second growing season as well.

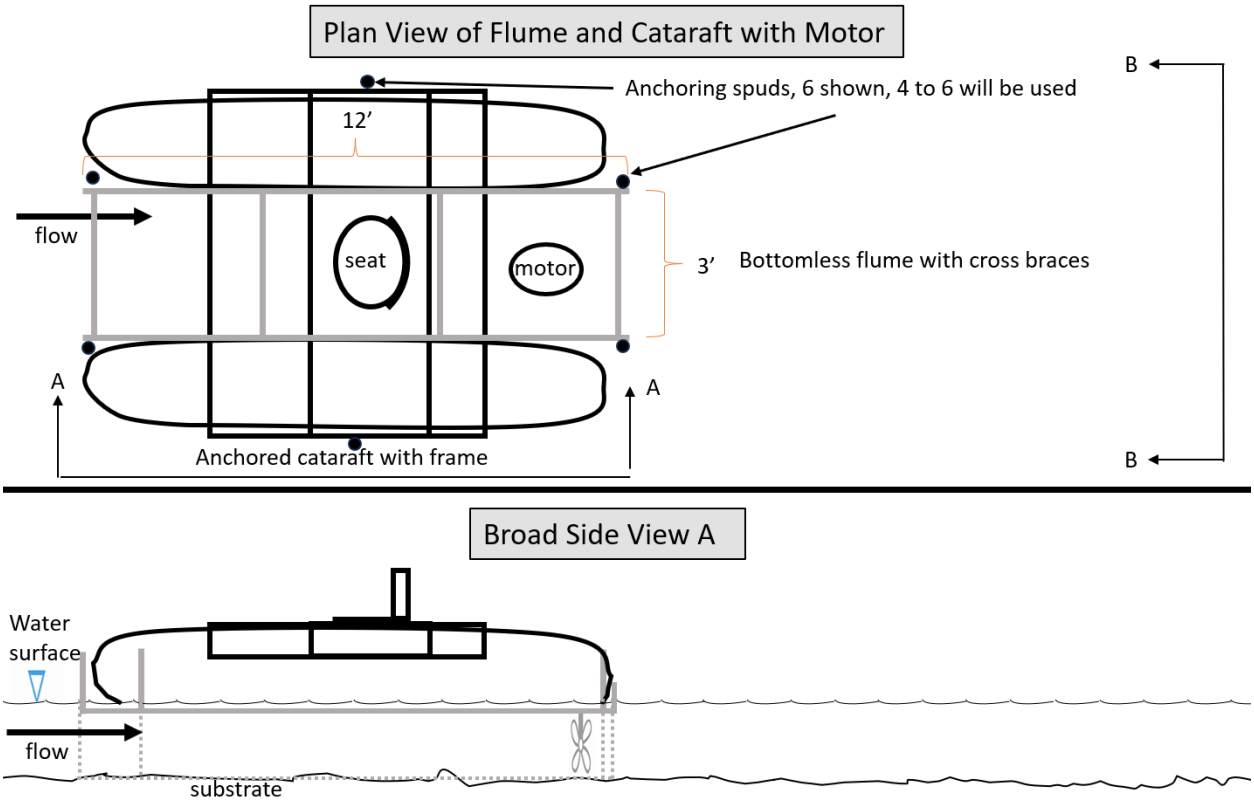


Figure 5. Simplified drawing of the proposed flume setup, with raft and boat engine used to suck water into the flume from downstream (top: plan view, bottom: section view)

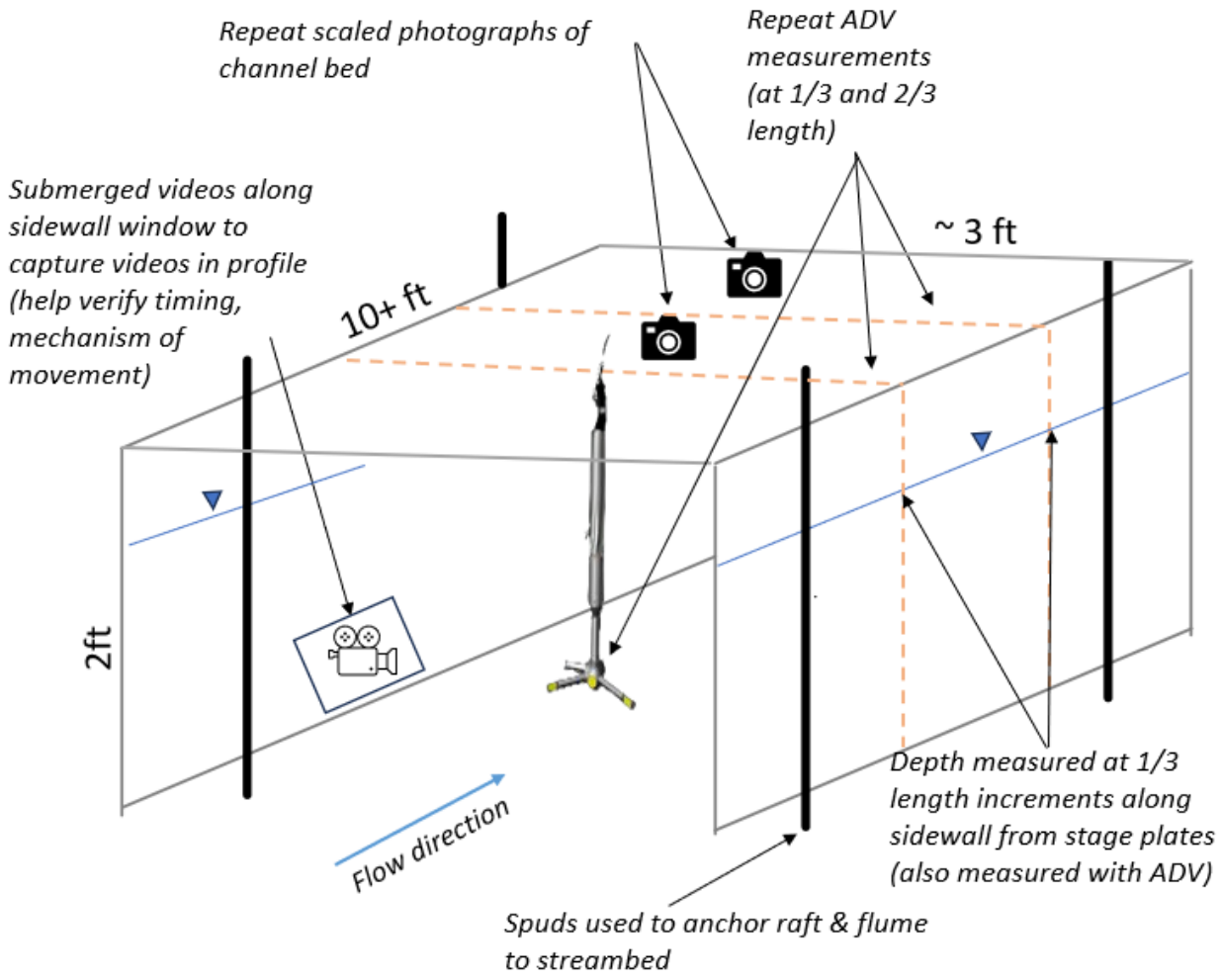


Figure 6. Detailed drawing of the flume setup (omitting the raft and engine for clarity)

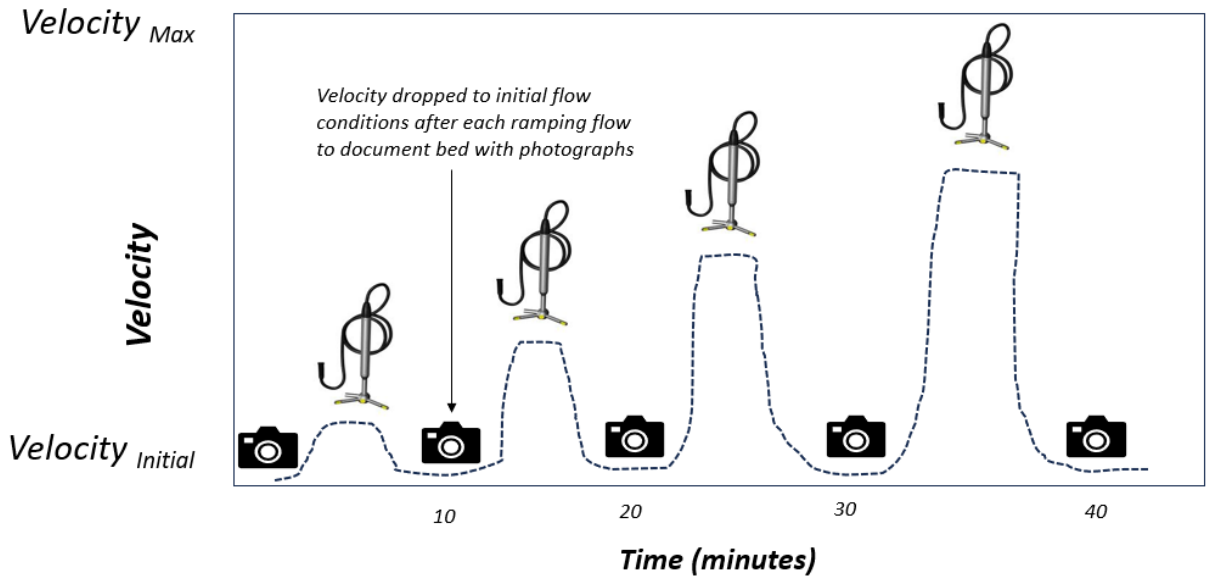


Figure 7. Graph depicting the proposed experimental measurement sequence, with dotted line representing incremental increases in velocity, cameras representing repeat photography, and the Sontek ADV representing repeat velocity measurements

8.3 Containers, preservation methods, holding times

Not Applicable

8.4 Equipment decontamination

Invasive species decontamination will follow the Department of Ecology's SOP (EAP070). Anticipated personal gear that will require decontamination before the start of each field deployment includes wading boots (rubber soles), waders (except if in summer, then staff will wet wade in wading socks and boots), and snorkel masks. Equipment used that will require decontamination include raft, motor, and ADV.

8.5 Sample ID

Not Applicable.

8.6 Chain of custody

Not Applicable.

8.7 Field log requirements

Field technicians will record all field-sampling activities in standard field notebooks. Information captured includes (but is not limited to):

- Name and location of project.
- Date, time, location, and description of site.
- GPS measurement of the site
- Field personnel
- Sequence of events (number of velocity increases)
- Depth recordings at each velocity reading
- Average velocity for each measurement (as back up to the digital records)
- Unusual circumstances that may affect interpretation of results.
- Environmental conditions.

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

Field QC procedures for measurements of velocity will follow the SOPs listed in Section 8.2. Section 6 details the Quality control procedures for velocity measurements.

10.1 Table of field and laboratory quality control

Not applicable.

10.2 Corrective action processes

Review of data during the field experiments will take place during the in-situ study. Data that is anomalous or suspect will be qualified or rejected as needed both in the field and post-analysis. Quality control results may indicate problems with data during the course of the project. Options for corrective actions might include:

- Recheck of equipment if fails calibration or is outside expected range
- Qualify or reject results.
- Clean, repair, or replace equipment if evidence of failures or issues.
- Convene project personnel to decide on the next steps we will take if persistent quality control problems arise.

11.0 Data Management Procedures

11.1 Data recording and reporting requirements

NHC Field Staff will record all field data and observations on waterproof paper kept in field notebooks. NHC staff will scan field notebooks into a PDF format upon returning from the field and transfer information contained in field notebooks to Excel spreadsheets for sample tracking.

Another member of the project team will independently verify data entries for accuracy. That team member will upload field data (values of field parameters, sample conditions, QC information, etc.) from each sample trip and provided to Benton Conservation District for long-term storage on their internal servers. The final data will be reported in the NHC Shear Stress and Recommendations Report.

11.2 Laboratory data package requirements

Not applicable.

11.3 Electronic transfer requirements

Project staff will provide data to Benton Conservation District for long term storage and retrieval.

11.4 Data upload procedures

Velocity data will be uploaded to the Benton Conservation District long-term data storage drive. As the data are artificially induced velocities they will not be maintained in Ecology's EIM database but will be open source and available to the public upon request by Benton Conservation District.

11.5 Model information management

Not applicable.

12.0 Audits and Reports

12.1 Audits

This project does not warrant an audit. Project status will be periodically evaluated and informally reported at meetings with the lower Yakima River project partners and at the water stargrass coalition meetings.

12.2 Responsible personnel

BCD's District Manager, Marcella Appel, will be responsible for periodic evaluation and reporting of progress for the project in EAGL.

12.3 Frequency and distribution of reports

BCD will complete grant progress reporting for this project according to the requirements outlined in agreement WRYBIP-2123-BentCD-00070 between BCD and Ecology. BCD will complete and submit quarterly progress reports with each payment request. One Engineer report will be written as part of the project contract report. The report will be uploaded to EAGL with grant close-out for long-term storage and retrieval.

12.4 Responsibility for reports

Marcella Appel with BCD will be responsible for all quarterly progress reports and the final grant close-out report. Annie Dufficy will be lead for the final Technical Report, which will consist of a summary of the following sections: background, methods and study design, field assessment, results of the shear stress assessment, and conclusion. The report will undergo additional review by the NHC Principal, Derek Stuart, prior to report finalization.

13.0 Data Verification

13.1 Field data verification, requirements, and responsibilities

Field technicians will verify all field data and notes after each sample trip. The project manager will then double-check them. Verification will include:

- If measurement data are determined to be an outlier, then we will repeat the measurement.
- Documenting velocity calibration checks and field procedures.
- Checking data for entry errors and completeness.

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 we have reviewed and verified the project data, the NHC project manager will determine if the data are of sufficient quality to make determinations and decisions. The project manager will ensure we have met the criteria of completeness, representativeness, and comparability. We will detail our achievement toward project goals and objectives in the final project report. If there are limitations in the data, we will note those limitations and qualify them in a timely fashion.

14.2 Treatment of non-detects

Not applicable.

14.3 Data analysis and presentation methods

After reviewing the data to ensure that it meets the quality control procedures outlined in Section 10, the data will be analyzed to answer the question: what are the required hydraulic conditions necessary to erode water stargrass roots from the bed of the lower Yakima?

This will be done using a shear stress evaluation. Shear stress is the force exerted by flowing water parallel to the riverbed, measured by how water velocity changes near the bottom (boundary layer) at a given slope. Velocity alone does not determine when sediment transport occurs because it is dependent on depth, slope and density. Instead, shear stress, which incorporates velocity, slope, depth, and relative densities, defines the threshold (critical shear stress) needed to lift and move sediment (erosion).

First, shear stress will be calculated from the depth and velocity measurements for all incremental flow increases for each individual flume experiment (using the equation described in Section 7.2). Verification of sediment transport occurring during the incremental flow increases will be confirmed using the scaled photo comparisons and submerged video. If sediment transport does occur, then a critical shear stress can be established for that grain size. Critical shear stress is the minimum shear stress required for sediment transport. This process will be repeated for all incremental flow increases, or until full mobilization of the bed occurs.

Mobilization of the roots will require mobilization of the armor layer. If this does not occur, then it can be assumed that the critical velocity and therefore critical shear stress required to mobilize the armor layer is greater than those possible of replication in the flume. This is still a valuable result, as it will help inform the lower bound estimate for the critical velocity that flows will need to reach in order to erode the armor layer. This will be confirmed against the theoretical shear stress for mobilization of the given sediment distribution.

Results of the data analysis will be presented in a Technical Report. Pending results, data will be presented at local basin conferences, as well as within water stargrass coalition work group meetings and lower river project update meetings.

14.4 Sampling design evaluation

The sample design will allow for a detailed characterization of plant scour and impact of shear stress on bed movement within the vicinity of the pilot study. The shear stress required to mobilize the bed will give an initial understanding of the relationships between flow and plant scour, but more research in the future will be needed to understand shear stress and bed mobility in reaches with different bed compositions, plant biomass densities, and hydraulic conditions. This design is adequate for this study because the local sub-reach conditions are critical for a first step in understanding what type of hydraulics are required to induce scour, and if those are found within the lower Yakima River. The study design outlined by this QAPP will answer this initial question allowing for future study development on which to expand.

14.5 Documentation of assessment

We will document the assessment in the final Engineer Report.

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16.0 Appendices

Appendix A. Glossaries, Acronyms, and Abbreviations

Glossary of General Terms

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

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).

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.

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
Bureau	U.S. Bureau of Reclamation
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
NWIS	National Water Information System
PCB	polychlorinated biphenyls
QA	Quality assurance
QC	Quality control
QSI	Quantum Spatial Inc
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
cms	cubic meters per second
ft	feet
m	meter
mg	milligram
mg/L	milligrams per liter (parts per million)

mL	milliliter
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 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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