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ECOLOGY
State of Washington

Quality Assurance Project Plan

Upper Yakima River Basin Suspended Sediment and Turbidity Status Monitoring

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Quality Assurance Project Plan

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March 2016

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EAP: Environmental Assessment Program

WQP: Water Quality Program

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2.0 Abstract

In 2002, the Washington State Department of Ecology (Ecology) set a total maximum daily load (TMDL) for total suspended solids (TSS), turbidity and organochlorine pesticides in the watershed (Creech and Joy, 2002). Interim and final targets were set at 10 sites for levels of TSS and turbidity as part of the TMDL.

After implementation of sediment controls in the basin, effectiveness monitoring was conducted in 2006 to compare TSS and turbidity levels to the target reduction goals. The monitoring showed that many, but not all, of the sites were meeting the final TMDL targets for turbidity. Final status monitoring to see if TSS and turbidity levels were meeting the final TMDL targets was extended to 2016 (Ecology, 2013).

This monitoring project will assess the status of TSS and turbidity levels as called for in the final TMDL schedule. Samples will be collected every two weeks from 13 locations in the Upper Yakima basin. Sampling will occur from March through November 2017, capturing the critical period during the whole irrigation season, as well as some pre- and post-irrigation periods.

3.0 Background

A suspended sediment and organochlorine pesticide TMDL has been established in the Upper Yakima River (Joy, 2002; Creech and Joy, 2002). The TMDL defines the Upper Yakima River basin as the reach from the headwaters to river mile (R.M.) 121.7, just above the city of Selah.

Efforts to reduce agricultural runoff and erosion have been underway in the Upper Yakima basin since the TMDL implementation began in 2003 (Creech, 2003). Riparian fencing and re-vegetation, changes to irrigation practices, outreach and education, and road improvements by the forestry industry have all helped reduce erosion in the Yakima basin (Anderson, 2008). These best management practices (BMPs) have been implemented to reduce erosion and the organochlorine pesticides associated with suspended sediment. Since 2006, Kittitas County Conservation District (KCCD) continues to administer the PAM Cost Share program, conversion from flood irrigation to sprinkler system implementation, and various other programs to encourage and support BMPs throughout the Upper Yakima River basin.

The Upper Yakima River TMDL schedule (Creech and Joy, 2002) called for effectiveness monitoring at 10 sites in 2006 to check on levels of turbidity, DDT, and dieldrin. Ecology led an effort to monitor total suspended solids (TSS) and turbidity during the 2006 irrigation season, as prescribed in the schedule. The organochlorine pesticide levels were addressed in a study conducted by Ecology in 2014 and reported in *Upper Yakima River Watershed DDT and Dieldrin Monitoring, 2014: Status Monitoring for TMDL* (Friese, 2015).

The water quality effectiveness monitoring report (Anderson, 2008) describes the results of the TSS and turbidity monitoring in 2006. The report concluded that as of 2006, implementation of the TMDL had been successful so far and that TSS and turbidity values were lower than in 1999, but not all targets of the TMDL had been met. In 2011, Ecology's Water Quality Program extended the deadline date to meet the final TMDL target reductions from 2011 to 2016.

Ecology will conduct status monitoring study in 2017 to evaluate whether the final TMDL targets have been met for TSS and turbidity levels in the Upper Yakima River basin.

3.1 Study area and surroundings

The study area is located in Water Resource Inventory Area (WRIA) 39, the Upper Yakima River basin. It consists of the mainstem Yakima River and its major tributaries from RM 121.7 (Harrison Bridge, near the town of Selah) upstream to RM 191 (4.5 miles northwest of Cle Elum on Interstate 90). See Figure 1.

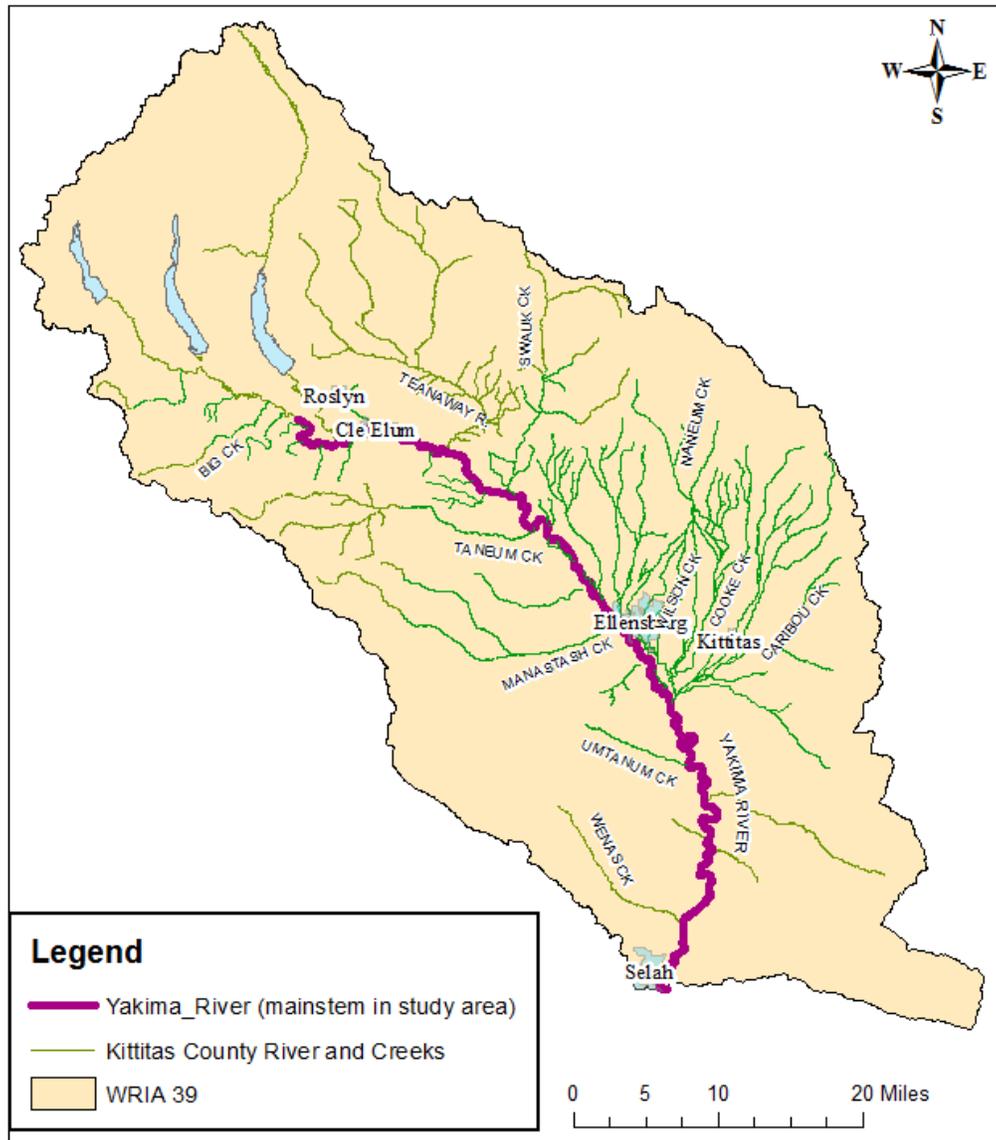


Figure 1. Study area for Upper Yakima River basin suspended sediment and turbidity status monitoring.

The Yakima River basin is located in south-central Washington State. The Yakima River flows 214.5 miles from the dam outlet of Lake Keechelus, southeasterly to its confluence with the Columbia River. The upper portion of the Yakima River basin drains 2,139 square miles on the eastern slope of the Cascade Mountains. Land uses in the basin vary from forestland, rangeland, irrigated agriculture, and urban areas. A network of supply canals, diversions, and irrigation return drains are located all along the Upper Yakima River basin but are especially concentrated in the lower Kittitas Valley. Water from the Yakima River and the streams flowing through the valley is directed through the irrigation network (Creech and Joy, 2002).

Below Lake Keechelus, the main tributaries to the Upper Yakima River are the Kachess River, Cle Elum River, and Teanaway River, but there are also many other smaller tributaries that will be sampled during this study. These tributaries include Taneum Creek, Manastash Creek, Wilson Creek, Naneum Creek, and Wenas Creek.

3.1.1 Logistical problems

Logistical problems are discussed in Section 4.7.

3.1.2 History of study area

Land uses in the Upper Yakima River watershed vary from wilderness, forestland, livestock range, and intensively irrigated agriculture to urban and suburban areas (Joy, 2002). The Yakima River basin is one of the most irrigated areas in Washington. The Upper Yakima River basin has approximately 85,000 acres of irrigated agriculture in the lower elevations. The majority of irrigated acreage drains to the tributaries of Wilson Creek, Manastash Creek, and Sorenson Creek (Anderson, 2008).

The United States Department of the Interior's Bureau of Reclamation (USBR) operates the Yakima Project which greatly influences stream discharge volumes in the Yakima River and some of its tributaries. The USBR delivers water to meet downstream demands, such as irrigation, power production, and instream flow for fish protection. To meet these demands, the USBR releases water from three storage reservoirs in the Upper Yakima River watershed: Lake Keechelus, Lake Kachess and Lake Cle Elum. Some of the water released from the reservoirs meets irrigation demand in the Upper Yakima River watershed. However, much of the released water flows down the Yakima River through the project area to meet irrigation demands in the lower Yakima River watershed (Anderson, 2008).

In order to meet irrigation demands late in the irrigation season, the USBR uses a management strategy descriptively termed "flip-flop." In practice, flip-flop, which was conceived and initiated in 1981, consists of releasing most of the water needed by the lower valley irrigation users from the Upper Yakima reservoirs until September. During this time, releases from the lower reservoirs in the Naches basin are minimized. In early September, the release pattern reverses, when the majority of the flow is provided from Naches basin, and the Upper Yakima releases are curtailed (YSFWPB, 2004).

The purpose of the flip-flop operation is to encourage Chinook salmon, returning to the Upper Yakima in the fall, to spawn at lower river stages. This ensures that the flows required to keep the salmon redds watered and protected during the incubation period (November through March) are minimized; it is also consistent with the “normative” flow concept for the Upper Yakima arm of the basin (Bureau of Reclamation, 2004).

This activity often results in low water levels in the lower Yakima River basin in the summer and fall, even though there is higher streamflow in the Upper Yakima River basin during this time period. The higher discharge volumes in the Upper Yakima River during July and August generally have a lower turbidity because of dilution from reservoirs, but carry higher loads of suspended sediment because of the larger flow volume (Anderson, 2008).

3.1.3 Parameters of interest

The parameters of interest are suspended sediments, which can be measured as total suspended solids (TSS) and turbidity. When total non-volatile suspended solids (TNVSS) is measured with TSS, the inorganic and organic fractions of the suspended solid can be determined.

3.1.4 Results of previous studies

In 2006, Ecology and partner organizations (the Kittitas County Conservation District and the Kittitas County Water Purveyors (KCWP) conducted water sampling to see if the TMDL’s interim target reductions were being met at compliance points and background sites. The results showed that most of the interim turbidity targets were met, most of the time. In 2011, the KCWP again conducted follow-up monitoring to compare results with the final TMDL target reductions. Results indicated that many, *but not all*, of the final TMDL targets for turbidity were being met (Ecology, 2013). A summary report was submitted by KCWP. Ecology’s Water Quality Program reviewed the results of the turbidity levels submitted by KCWP and made the determination that not all the sites met the final targets. KCWP’s results can be found in Ecology’s Environmental Information Management (EIM) database under Study ID G0900051.

Ecology’s 2006 results are summarized in the Tables 1 – 4. For the Yakima River, the 90th percentile of the turbidity values collected at the Yakima River at Umtanum Creek (RM 139.8) and the Yakima River at Harrison Bridge (RM 121.7) will not exceed 10 NTU over the 90th percentile turbidity value of samples collected from the Yakima River at Nelson (RM 191).

For the tributaries, the 90th percentile of the turbidity values collected at the mouths of Teanaway River, Manastash Creek, Sorenson Creek at Fogerty Ditch, and Wilson Creek below Cherry Creek will not exceed 10 NTU over the 90th percentile background value established for the site.

Table 1. The 90th percentile and median turbidity results for mainstem Upper Yakima River in 2006.

Site	90th Percentile Turbidity in NTU	Median Turbidity in NTU	Difference from Background site (90th percentile)
Yakima River at Nelson (background)	4.1	1.7	
Yakima River at Irene Rinehart Park ¹	8.5	1.7	4.4
Yakima River at Umtanum	10.6	4	6.5
Yakima River at Harrison Road Bridge	11.8	4.1	7.7

¹Data collection for this site did not start until May 16, 2006.

No Yakima River mainstem sites had 90th percentile turbidity values that were 10 NTU or more over the background 90th percentile turbidity value. So the Yakima River met the 2006 interim turbidity reduction target.

Table 2. The 90th percentile and median results for turbidity at background and TMDL target sites in 2006.

Site	90th Percentile Turbidity in NTU	Median Turbidity in NTU	Difference from Background Site (90th percentile)
Teaway River at North Fork (background)	12.4	4.5	
Teaway River at Lambert Road ¹	22.2	2.6	9.8
Manastash Creek at Manastash Road (background)	8.4	1.5	
Manastash Creek at Brown Road ¹	10	4.8	1.6
Sorenson Creek at Fogarty Ditch ¹	12.8	5.9	4.4
Naneum Creek at Naneum Road (background)	5.5	1.3	
Wilson Creek at Canyon Road	24.3	10.5	18.8

¹Sites that met the interim 2006 turbidity target.

In 2006, three tributary sites out of four had less than 10 NTU increases in their 90th percentile turbidity values. Wilson Creek did not meet the 2006 interim turbidity target.

Table 3. Sediment loading (in tons per day) in the Yakima River in 1999 and 2006.

Site	Early irrigation season average load		Late irrigation season average daily load		Complete irrigation season average daily load	
	1999	2006	1999	2006	1999	2006
Yakima River at Nelson	28	12	3	0.9	14	6
Yakima River at Umtanum	399	177	78	50.8	215	103
Yakima River at Harrison Rd	271	85	27	19.6	131	46

Suspended sediment loading measured in metric tons per day was lower in 2006 than in 1999 in the mainstem Yakima River.

Table 4. Summary of loading (in tons per day) from Wilson Creek and the Teanaway River during the early, late and complete irrigation season.

Site	Early irrigation season average load		Late irrigation season average daily load		Complete irrigation season average daily load	
	1999	2006	1999	2006	1999	2006
Teanaway River	188	129	0.9	0.2	77	33
Wilson Creek	132	55	31	26.3	71	34

Overall, both tributaries contributed considerably less suspended sediment in 2006.

3.1.5 Regulatory criteria or standards

Designated and beneficial uses

Water Quality Standards for Surface Waters of the State of Washington (WAC 173-201A-200) establish beneficial uses of waters and incorporate specific numeric and narrative criteria for parameters such as turbidity. The criteria are intended to define the level of protection necessary to support the beneficial uses. Washington Administrative Code (WAC) 173-201A-600 and WAC 173-201A 602 list the use designations for specific areas (WAC 173-201A-600 and WAC 173-201A-602).

For the Upper Yakima River, the designated uses of the waters in this specific area are:

- *Aquatic Life Uses*
 - *Core Summer Salmonid Habitat:* Yakima River above the Cle Elum River, Teanaway River mainstem, and Manastash Creek
 - *Salmonid Spawning, Rearing and Migration:* Yakima River and its tributaries, downstream from the Cle Elum River
- *Recreation:* Fishing, Swimming, and Rafting
- *Water Supply (Municipal, Industrial, and Agricultural Water Supply and Stock Watering):* Agricultural enterprises extract water for irrigation and livestock watering. The cities of Cle

Elum and Ellensburg use the Upper Yakima River for a source of drinking water or other municipal uses. Other industries use Yakima River water for its operations.

- *Miscellaneous Uses (Wildlife Habitat, Harvesting, Commerce, Boating, and Aesthetics):* Riparian areas are used by a variety of wildlife species that are dependent on the habitat. Various businesses and private entities use the river for miscellaneous ventures, such as guiding fly fishermen.

Impairments

Levels of suspended sediment, turbidity and organochlorine pesticides were assessed in tributaries and Upper Yakima River during the 1999 TMDL study. DDT and organochlorine pesticides are known to attach to soil particles. The original TMDL correlated the amount of DDT in the water with amount of suspended sediment in the water, so targets were set to limit the amount of suspended sediment in the water. Limits for turbidity levels were also set due to concern that aquatic life could be harmed.

Turbidity

Turbidity is a measure of light refraction in the water, and it is related to the amount of suspended solids in the water. Fish and other aquatic life are affected by suspended solids in the water column and sediment that has settled to the bottom of the water. The turbidity criteria in the state water quality standards are primarily established to protect aquatic life (WAC 173-201A-200). The turbidity criteria for the Upper Yakima River basin is:

- Turbidity shall not exceed 5 NTU over background turbidity when the background turbidity is 50 NTU or less, or
- More than a 10% increase in turbidity when the background is more than 50 NTU.

The background sites are used in evaluating water quality relative to the turbidity criteria. Median and 90th percentile statistics were compared to background values, instead of maximum values, to be consistent with the lower Yakima River TMDL and to allow variation from natural short-term peak turbidity events (Joy, 2003).

The statistical rollback method (Ott, 1995) was applied to the median and 90th percentile statistics of some tributaries (Teaway River, Manastash Creek, Sorenson Creek, and Wilson Creek) to calculate the turbidity reductions required to meet the 10 and 5 NTU guidelines at their mouths.

The effectiveness monitoring project from 2006 looked at comparing the 2006 turbidity results to the interim targets (Anderson, 2008). Interim turbidity targets were based on 90th percentile of background + 10 NTU. The 10 NTU criterion was used as an interim guideline, because natural background turbidity and transport of turbidity along the waterbodies are not well defined.

Based on background levels from the 1999 technical study, the TMDL technical assessment estimated interim and final targets for turbidity levels in several of the tributaries in the Upper Yakima River basin. Estimated seasonal turbidity target levels are shown in Table 5. This study

will compare 2017 turbidity levels at those sites to calculated TMDL final target turbidity levels (90th percentile of background + 5 NTU).

Table 5. Estimated final target turbidity levels for Upper Yakima River tributaries.

Tributary	1999 Median (NTU)	1999 90 th percentile (NTU)	Interim Target (90 th percentile of background + 10 NTU)			Final Target (90 th percentile of background + 5 NTU)		
			Estimated Median (NTU)	Estimated 90 th percentile (NTU)	Estimated reduction %	Estimated Median (NTU)	Estimated 90 th percentile (NTU)	Estimated reduction %
Teanaway River	1.1	26	0.8	18.6	28.5	0.6	13.2	49.2
Taneum Creek	2.9	15.9				2.4	13.2	17.0
Packwood Ditch	8.9	13				8.2	12.0	7.9
Manastash Creek	6.7	19.2	6.5	18.6	3.1	4.6	13.2	31.3
Sorenson Creek	9.8	21.8	8.3	18.6	14.7	5.9	13.2	39.4
Wilson Creek	15.5	24.8	11.6	18.6	25.0	8.2	13.2	46.8
Wenas Creek	3.5	13.4				3.3	13.2	1.5

Suspended Sediments

The TMDL set final targets for suspended sediment loads for several sites. Estimated reductions used in calculating turbidity reductions were applied to the 1999 tributary suspended sediment loads, after converting tributary turbidity values to suspended sediment calculations. Seasonal suspended sediment load capacities are shown in Table 6.

The effectiveness monitoring project from 2006 looked at comparing the 2006 suspended sediment loads to the interim targets (Anderson, 2008). This study will compare 2017 seasonal loads to the TMDL final target loads highlighted in Table 6.

Table 6. Final target load capacities for suspended sediment (tons/day) during the critical season (April through October) for sites in the Upper Yakima River basin.

Site	Site 1999 Load	Mainstem Only	Tributary Based	Tributary Based
		Background + 5 NTU	Interim	Final targets
Yakima River at Nelson	14	14	14	14
Teaway River	77	-	43	28
Taneum Creek	4.1	-	4.1	2.6
Packwood Ditch	1.2	-	1.2	1
Manastash Creek	4.4	-	4.2	2.7
Sorenson Creek	3.2	-	2.7	1.8
Wilson Creek	71	-	47	26
Yakima River at Umtanum Cr.	215	140	159	120
Yakima River at Harrison Br.	131	87	98	75
Estimated % Reduction		35	26	44

4.0 Project Description

4.1 Project goals

The goal of this study is to measure suspended sediments and turbidity and to determine whether levels are meeting the final targets as scheduled in the *Upper Yakima River Basin Suspended Sediment, Turbidity and Organochlorine Pesticide Total Maximum Daily Load* (Creech and Joy, 2002).

4.2 Project objectives

Field work will be conducted from March 2017 through November 2017. The assessment of whether final targets have been achieved will be made by evaluating the results of sampling both during the critical season of April through October and just outside the critical period during the months of March and November.

Specific objectives of the study are to:

- Collect biweekly samples of suspended sediments and turbidity in the Upper Yakima River mainstem and priority tributaries. Suspended sediment samples will be processed for TSS and TNVSS.
- Install continuous turbidity monitoring stations at upstream and downstream boundaries on the Yakima River, and in the Teanaway River and Wilson Creek.
- Obtain streamflow data from USBR, USGS, Ecology, and other sources.
- Conduct an evaluation of the data generated from sampling, continuous monitoring, and stream flow measurements.
- Summarize the results of the evaluation in a published report.

4.3 Information needed and sources

Streamflow data will be needed for the Upper Yakima River and its tributaries from within the study area. It will be downloaded from various online streamflow databases from USBR, USGS, Ecology and other sources. Additional streamflow data may be requested from irrigation districts. Some sampling locations will be measured for streamflow discharge during each sampling survey.

Suspended sediment and turbidity data from past effective monitoring activities may be downloaded from EIM to make any needed comparisons for change in status levels.

4.4 Target population

The target populations for this project are suspended sediments and turbidity levels in the Upper Yakima River basin at locations that were previously studied and where specific target reductions are expected.

4.5 Study boundaries

The study area is in WRIA 39, Upper Yakima. Figure 1 shows the boundary of the project study area.

Water Resource Inventory Area (WRIA) and 8-digit Hydrologic Unit Code (HUC) numbers for the study area:

- WRIA: 39, Upper Yakima
- HUC number: 17030001

4.6 Tasks required

The tasks required to meet project goals are discussed in Section 4.2. More details on field and lab tasks are described in Section 7.

4.7 Practical constraints

Logistical conditions that could interfere with sampling include:

- Scheduling conflicts, sample bottle delivery errors, vehicle or equipment problems, or limited availability of personnel or equipment. This can be mitigated to some extent by having backup equipment on hand and giving clear instructions to field teams on what to do if equipment fails.
- Site access issues. If there are any unforeseen site access issues, we will find a nearby alternate sampling location.
- High streamflow. Excessive precipitation, whether snow, ice or rain, is always a possibility. Safety is always the first consideration. Sampling events may be rescheduled if flows are too high to safely sample.

4.8 Systematic planning process

This QAPP represents the systematic planning process.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

Key responsibilities of individuals is listed in Table 7.

Table 7. Organization of project staff and responsibilities.

Staff (all are EAP except client)	Title	Responsibilities
Jane Creech Water Quality Program Central Regional Office Phone: 509-454-7860	EAP Client	Clarifies scope of the project. Provides internal review of the QAPP and approves the final QAPP.
Jim Carroll Eastern Operations Unit Phone: 360-407-6196	Project Manager	Co-writes the QAPP. Conducts QA review of data and analyzes and interprets data. Co-writes the draft report and final report.
Eiko Urmos-Berry Eastern Operations Unit Phone: 509-575-2397	Principal Investigator	Co-writes the QAPP. Oversees field sampling and transportation of samples to the laboratory. Conducts QA review of data, analyzes and interprets data, and enters data into EIM. Co-writes the draft report and final report.
Dan Dugger Eastern Operations Unit Phone: 509-454-4183	Field Assistant	Helps collect samples and records field information.
Evan Newell Eastern Operations Unit Phone: 509-575-2825	Field Assistant	Helps collect samples and records field information.
Tom Mackie Eastern Operations Section Phone: 509-454-4244	Section Manager for the Project Manager and Study Area	Reviews the project scope and budget, tracks progress, reviews the draft QAPP, and approves the final QAPP.
Joel Bird Manchester Environmental Laboratory Phone: 360-871-8801	Director	Reviews and approves the final QAPP.
William R. Kammin Phone: 360-407-6964	Ecology Quality Assurance Officer	Reviews and approves the draft QAPP and the final QAPP.

EAP: Environmental Assessment Program

EIM: Environmental Information Management database

QAPP: Quality Assurance Project Plan

5.2 Special training and certifications

All field staff involved in this project either already have the relevant experience in following SOPs or will be trained by more senior field staff who do. Any staff helping in the field who lack sufficient experience will always be paired with someone who does have the necessary training and experience and who will then lead the field data collection and oversee/mentor less experienced staff.

5.3 Organization chart

See Table 7, Section 5.1.

5.4 Project schedule

See Table 8 below for project schedule.

Table 8. Proposed schedule for completing field and laboratory work, data entry into EIM, and reports.

Field and laboratory work	Due date	Lead staff
Field work completed	November 2017	Eiko Urmos-Berry
Laboratory analyses completed	December 2017	
Environmental Information System (EIM) database		
EIM Study ID	jica0004	
Product	Due date	Lead staff
EIM data loaded	February 2018	Eiko Urmos-Berry
EIM data entry review	March 2018	TBD
EIM complete	December 2018	Eiko Urmos-Berry
Final report		
Author lead / Support staff	Jim Carroll/Eiko Urmos-Berry	
Schedule		
Draft due to supervisor	September 2018	
Draft due to client/peer reviewer	October 2018	
Draft due to external reviewer(s)	December 2018	
Final (all reviews done) due to publications coordinator	January 2019	
Final report due on web	February 2019	

5.5 Limitations on schedule

Potential field-related constraints are addressed in Section 4.7. Any unforeseen limitations that would affect the project schedule will be discussed with the appropriate supervisor as needed.

5.6 Budget and funding

The budget in Table 9 assumes 20 sampling events. These sampling events will be day trips, since staff from the Union Gap office will be conducting the field work.

Table 9. Tentative project budget and funding.

Parameter	# of Samples	# of Field Duplicates	# of Blanks	Total # of Samples	Cost Per Sample	MEL Subtotal
Total Suspended Sediments	360	72	20	452	\$11.92	\$5388
Total Non-Volatile Suspended Sediments	360	72	20	452	\$14.1	\$6373
Turbidity	360	72	20	452	\$11.92	\$5388
Grand Total =						\$17,149

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 Decision Quality Objectives (DQOs)

All of the suspended sediment, turbidity, and streamflow data collected for this project must meet the measurement quality objectives (MQO) to be used for the project goals.

6.2 Measurement Quality Objectives

Field sampling procedures and laboratory analysis inherently have associated error. Measurement quality objectives state the allowable error for a project. Precision and bias provide measures of data quality and are used to assess agreement with measurement quality objectives.

6.2.1 Targets for precision, bias, and sensitivity

6.2.1.1 Precision

Precision is a measure of the variability in the results of replicate measurements due to random error. Precision is usually assessed by analyzing duplicate field measurements or lab samples. Random error is imparted by the variation in concentrations of samples from the environment as well as other introduced sources of variation (e.g., field and laboratory procedures). Table 6 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.

6.2.1.2 Bias

Bias is the difference between the population mean and the true value of the parameter being measured. Bias is usually addressed by calibrating field and laboratory instruments, and by analyzing lab control samples, matrix spikes, and standard reference materials. Laboratory QC procedures, such as blanks, check standards, and spiked samples will provide a measure of any bias affecting sampling and analytical procedures for this project.

Table 10 presents the MQOs for water samples taken in the field and associated laboratory analyses. Table 11 outlines analytical methods, expected precision of sample duplicates, and method reporting limits. The target expectations for precision of field duplicates are based on historical performance by MEL for environmental samples taken around the state by EAP (Mathieu, 2006). The reporting limits of the methods listed in the table are appropriate for the expected range of results and the required level of sensitivity to meet project objectives.

Table 10. Measurement quality objectives for field measurements and equipment.

Parameter	Equipment/ Method	Bias (median)	Precision– Field Duplicates (median)	Equipment Accuracy	Equipment Resolution	Equipment Range	Expected Range
Continuous Turbidity Monitoring							
Turbidity	FTS DTS-12 Turbidity Sensor	±20%	15% RSD	±2%+0.2 NTU (0-399 NTU)	0.01 NTU	0 to 1600 NTU	0-100 NTU
Streamflow Measurements							
Water velocity	Hach MF Pro	±0.05 ft/s	n/a	±2%	0.01 ft/s	0 to 20 ft/s	0 to 10 ft/s
Water velocity	SonTek® FlowTracker® Handheld ADV®	<0.03 ft/s	n/a	±1%	0.01 ft/s	0.0003 to 13 ft/s	0 to 13 ft/s

Table 11. Measurement quality objectives for laboratory analysis parameters.

Analysis	Method	Method Lower Reporting Limit ^a	Lab Blank Limit	Check Standard (% recovery limits)	Matrix Spikes (% recovery limits)	Precision – Lab Duplicates (RPD)	Precision – Field Duplicates (median) ^b
Total Suspended Solids	SM2540D	1 mg/L	±0.3 mg	80-120%	n/a	20%	15% RSD
Total Non-Volatile Suspended Solids	2540B & E	1 mg/L	±0.3 mg	80-120%	n/a	20%	15% RSD
Turbidity	SM2130	0.5 NTU	< 1/10th RL	90-105%	n/a	20%	15% RSD

RL: reporting limit

^a reporting limit may vary depending on dilutions.

^b field duplicate results with a mean of less than or equal to 5 times the reporting limit will be evaluated separately.

Field staff will minimize bias in field measurements and samples by strictly following measurement, sampling, and handling protocols. Environmental Assessment Program (EAP) staff will assess bias in field samples by submitting field blanks. Field staff will prepare blanks in the field by:

- Filling integrated sampling bottles or grab sample bottles directly with deionized water.
- Handling and transporting the blank samples in the same manner as the rest of the samples.

For continuous turbidity measurements, EAP staff will:

- Minimize bias in the deployed turbidity sensor by factory-calibrating the instrument before deployment.

- Assess bias and precision by comparing turbidity sensor readings to turbidity grab samples taken right next to the sensor each sampling survey.
- Minimize bio-fouling of the turbidity sensor by inspecting the sensor each survey and performing any needed maintenance.

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. In a regulatory sense, the method detection limit (MDL) is usually used to describe sensitivity. The method reporting limit and the reporting limits are the same for the parameters of interest for this project. See Table 12 for MDLs for this project.

Table 12. Method detection limits for this study.

Parameter	Sample Matrix	Expected Range of Results	Method	Method Detection Limit
Total Suspended Solids	Water	<1 – 2000 mg/L	SM 2540D	1 mg/L
Total Non-Volatile Suspended Solids	Water	<1 – 2000 mg/L	SM 540B & E	1 mg/L
Turbidity	Water	0-1000 NTU	SM 2130	0.5 NTU

6.2.2 Targets for comparability, representativeness, and completeness

6.2.2.1 Comparability

To ensure comparability to previously collected Ecology data that were used to set final reduction targets during the 1999 TMDL study, field staff will follow the sampling scheme used in the TMDL, which is supported by EAP protocols and other documented sampling protocols. All data quality procedures for sampling and field measurements will follow approved EAP SOPs. See Section 8.1 for a list of Ecology SOPs and other protocols.

6.2.2.2 Representativeness

The study is designed to collect sufficient data to meet the study objectives. This study will follow the sampling scheme of the original TMDL which collected samples every 2 weeks during the irrigation season (March through October). Sampling locations were decided by the original TMDL study to conduct follow-up monitoring at sites where target reductions were set by the TMDL. This study will also use integrated sampling of suspended sediments and turbidity to ensure complete representation of the cross section sampled, as was done in the original TMDL.

Continuous turbidity monitoring will take place at several sites. Continuous monitoring will allow Ecology to check if the two-week grab sample scheme adequately represents the distribution of suspended sediment. One site will be added to monitoring plan to support continuous turbidity monitoring at that location.

6.2.2.3 Completeness

EPA has defined completeness as a measure of the amount of valid data needed to be obtained from a measurement system (Lombard and Kirchmer, 2004). The goal for this study is to correctly collect and analyze 100% of the samples for each of the sites. However, problems occasionally arise during sample collection that cannot be controlled; thus, a completeness of 95% is acceptable.

Potential problems are site access problems, equipment malfunction, or sample container shortages. If equipment fails or samples are damaged, Ecology will attempt to re-collect the data the following day, if possible. In general, the study is designed to accommodate some data loss and still meet project goals and objectives.

7.0 Sampling Process Design (Experimental Design)

7.1 Study design

The project objectives will be met by sampling at 13 sites in the Upper Yakima River basin. These sites were previously sampled in the original 1999 TMDL study and were designated as sites for follow-up effectiveness monitoring. Some sites are designated as background sites for the purpose of checking background suspended sediment and turbidity levels. Background sites will be measured to see if the background levels have changed from the original TMDL study. Sites will be measured to see if their target reductions set in the original TMDL have been achieved.

TSS, TNVSS, and turbidity samples will be collected using depth-integrated samplers to represent width and depth variations. TNVSS is collected so that inorganic versus organic fractions of the suspended solids can be determined. See Appendix A for details about the depth-integrated sampling. If streamflow in some of the tributary locations are too low or too high to use the depth-integrated samplers, grab samples will be taken. The following exceptions also apply:

- At the Wilson Creek site, samples at this site may be collected using grab sampling techniques due to safety concerns. The KCWP has collected a limited data set comparing grab samples vs. integrated samples; this data set has an average RPD of 17.5% for TSS and 10.5% for turbidity, which Ecology is deeming acceptable for representativeness at this site.
- When the turbidity levels in the Teanaway drop below 5 NTU (historically in June), grab sampling techniques will be used at the Teanaway site.

Continuous turbidity monitoring stations will be installed. Streamflow data for the Upper Yakima River and its tributaries will be acquired from USBR, USGS, and Ecology, as well as measured in the field.

7.1.1 Field measurements

Continuous turbidity monitoring

Ecology's Freshwater Monitoring Unit will install continuous turbidity meters at several locations. Installations will occur in the summer/fall of 2016 to allow for time to gather necessary permissions, associated permits, and installations. These will be installed at or near established gaging stations. These stations may be telemetered, depending on availability of equipment. The monitoring, equipment and data maintenance will be performed by EAP's CRO field staff. See Table 13 for a list of potential sites where continuous turbidity meters might be installed. Alternative sites may be added in cases where landowner permissions are not granted or site locations are not adequate for installation.

The turbidity meters will be installed and maintained following Ecology's statewide ambient monitoring program protocols (Hallock, 2009) and continuous water quality monitoring protocols established by the USGS (Wagner et al., 2006).

Table 13. List of potential sites to install continuous turbidity meters.

Site ID	Continuous Monitoring Sites	Latitude	Longitude
Yakima Mainstem Sites			
01-YKI	Yakima River @ Nelson Siding	47.18565	-121.04451
39-YKWW	Yakima River @ Horlick	47.12390	-120.73940
05-YKUM	Yakima River @ Umtanum Creek Bridge	46.85568	-120.48417
06-YKHA	Yakima River @ Harrison Bridge	46.67946	-120.49120
Tributary Mouth Sites			
YAV240	Teaway River @ Lambert Road	47.17497	-120.83597
17-WIL	Wilson Creek @ Hwy 821	46.91716	-120.50810

Streamflow measurements

Ecology will take streamflow measurements during each survey at tributary locations that do not have continuous streamflow gage stations. Streamflow measurements are made following Ecology protocols (Kardouni, 2013).

7.1.2 Sampling location and frequency

Water sample collection will be conducted on a bi-weekly basis from March-November 2017.

The first sampling will occur before the start of the irrigation season and conclude with samplings after the end of the irrigation season. This will capture conditions as they change and transition into and out of the irrigation season in the Upper Yakima River basin.

There are 13 site locations: 4 on the mainstem of the Yakima River, 7 in tributaries, and 2 in background tributaries. Alternate or additional sites may be added if found necessary. Figure 2 shows a map of site locations and Table 14 shows a list of site locations.

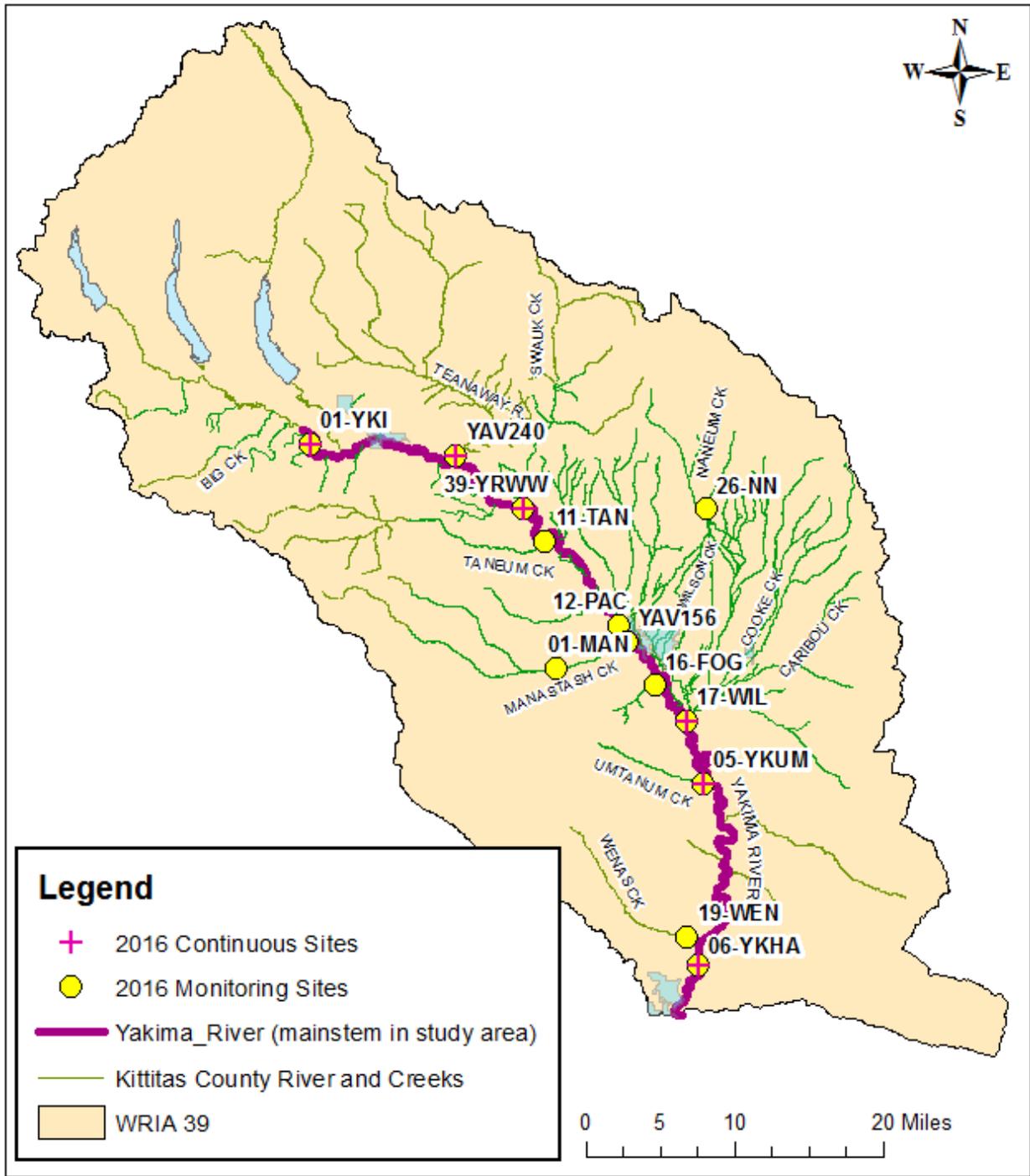


Figure 2. Map of proposed site locations.

Table 14. List of proposed site locations.

Site ID	Monitoring Sites	Latitude	Longitude
YAV240	Teanaway River @ Lambert Road	47.17497	-120.83597
39-YKWW	Yakima River @ Horlick	47.12390	-120.73940
11-TAN	Taneum Creek at Mouth	47.09189	-120.70926
12-PAC	Packwood Canal	47.00990	-120.60425
YAV156	Manastash Creek @ Brown Rd	46.99456	-120.59077
16-FOG	Sorenson/Fogerty @ Riverbottom Road	46.95135	-120.55221
17-WIL	Wilson Creek @ Hwy 821	46.91716	-120.50810
05-YKUM	Yakima River @ Umtanum Creek Bridge	46.85568	-120.48417
19-WEN	Wenas Creek above Mouth	46.70657	-120.50589
06-YKHA	Yakima River @ Harrison Bridge	46.67946	-120.49120
Mainstem Background Site			
01-YKI	Yakima River @ Nelson Siding	47.18565	-121.04451
Tributary Background Sites			
26-NN	Naneum Creek @ Naneum Road	47.12354	-120.47989
01-MAN	Manastash Creek @ Manastash Road	46.96810	-120.69128

Several agencies already measure continuous streamflow at several location on the Mainstem Yakima River as well as some tributaries. Table 15 shows the location and station names of the gages that this project will use to determine streamflow for the project.

Table 15. List of continuous streamflow gages.

Agency	Agency Site ID	Gage Site Location
USBR	EASW	Yakima River near Easton
USBR	YUMW	Yakima River at Cle Elum
USBR	YRWW	Yakima River near Horlick
USBR	ELNW	Yakima River @ Ellensburg
USGS	12484500	Yakima River @ Umtanum
USBR	RBDW	Yakima River below Roza Dam
Ecology	39D110	Teanaway River @ Red Bridge Rd
USBR	TEAW	Teanaway River @ Lambert Rd
USBR	WONW	Wilson Creek @ Thrall Rd
USBR	CHRW	Cherry Creek @ Thrall Rd
Ecology	39J070	Manastash Creek @ Cove Rd

Streamflow will be measured at all tributaries without gages during sampling runs. Streamflow will be used to estimate TSS loads (tons/day) and to compare hydrologic conditions to the last monitoring years (1999 and 2006), since total discharge, its timing, and water velocities have significant influences on suspended sediment loading.

7.1.3 Parameters to be determined

See Table 16 for list of parameters.

Table 16. List of parameters to be determined at each site location.

Site ID	Monitoring Sites	TSS/TNVSS/ Turbidity Integrated sample	Turbidity Grab sample	Continuous Turbidity	Stream flow
01-YKI	Yakima River @ Nelson Siding	X	X	X	
YAV240	Teanaway River @ Lambert Road	X	X	X	
39-YKWW	Yakima River @ Horlick	X	X	X	
11-TAN	Taneum Creek at Mouth	X			X
12-PAC	Packwood Canal	X			X
YAV156	Manastash Creek @ Brown Rd	X			X
16-FOG	Sorenson/Fogerty @ Riverbottom Road	X			X
17-WIL	Wilson Creek @ Hwy 821	X	X	X	
05-YKUM	Yakima River @ Umtanum Creek Bridge	X	X	X	
19-WEN	Wenas Creek above Mouth	X			X
06-YKHA	Yakima River @ Harrison Bridge	X		X	
26-NN	Naneum Creek @ Naneum Road	X			X
01-MAN	Manastash Creek @ Manastash Road	X			X

The parameters to be determined via field data collection are discussed in Section 7.1.

7.2 Maps or diagram

A map of proposed monitoring locations are presented in Figure 2, section 7.1.2.

7.3 Assumptions underlying design

This study and field data collection is specifically designed to follow the recommended effectiveness monitoring proposed in the original 1999 TMDL (Joy, 2002). The results of this study will be compared to final target objectives as set by the TMDL. The results of this monitoring study design should be comparable to the original TMDL final target objectives based on the monitoring scheme. However, changes in background turbidity levels and suspended sediment loads can take place due to annual variation in precipitation, streamflow, and other climate associated forces, in addition to human-caused activities that cause erosion. The study year versus TMDL year (1999) background conditions and final target objectives will be evaluated in the final report.

7.4 Relation to objectives and site characteristics

This study and field data collection is specifically designed to follow the recommended effectiveness monitoring proposed in the original 1999 TMDL (Joy, 2002). The results of this study will be compared to final target objectives set by the TMDL.

7.5 Characteristics of existing data

The original data collection for the TMDL was collected in 1999. The TMDL study had a systematic planning process (QAPP) and followed sampling protocols. A QA assessment of the data was completed and all the data used in the TMDL were deemed good and acceptable for use (Joy, 2002).

The 1999 data were used to characterize the distribution of suspended sediments at sites in the study basin. Reductions in suspended sediment loads and turbidity levels were based on distributions calculated from 2-week interval sampling. The 2006 effectiveness monitoring results showed that both suspended sediment and turbidity levels were improving, but not all of the sites had met the interim targets. See Section 3.1.4 for a summary of results.

For this study, continuous turbidity data will also be collected. This will allow Ecology to examine if a 2-week interval sampling scheme is adequate to characterize the distribution of suspended sediment. The continuous data will not be used to make determinations of whether the final TMDL targets were met. It will be used to help Ecology make decisions on how future work on similar projects should be designed to adequately capture various conditions.

8.0 Sampling Procedures

8.1 Field measurement and field sampling SOPs

Field sampling and measurement protocols will adhere to the following EAP SOPs:

- EAP015 Manually Obtain Surface Water Samples
- EAP024 Standard Operating Procedure for Estimating Streamflow
- EAP070 Minimizing the Spread of Aquatic Invasive Species

Ecology Standard Operating Procedures (SOPs) can be found here:
<http://www.ecy.wa.gov/programs/eap/quality.html> (Ecology, 2016)

In addition to the above procedures, if resources allow, Ecology's Freshwater Monitoring Unit (FMU) may be installing monitoring stations to continuously monitor turbidity for this project following a separate QAPP (Hallock, 2009). These stations would be telemetered, data would be logged onto the FMU database, and preliminary results would be made available on the web.

We will be using a depth-integrated sampler to collect our water quality samples. We will be following the guidelines set up by the USGS in its National Field Manual (U.S. Geological Survey, 2006). The guidelines can be found at: <http://pubs.water.usgs.gov/twri9A4/>, Section A4. Also, see Appendix A for more details on depth-integrated sampling.

8.2 Containers, preservation methods, holding times

Table 17 lists the sample containers, measurement method, preservation, and holding times required to meet the goals and objectives of this project.

Table 17. Sample containers, preservation, and holding times.

Analysis	Matrix	Recommended Quantity	Container	Container Index No.	Holding Time	Preservative
Total Suspended Solids ¹	Water	1000 mL	1000 mL w/m poly bottle	#23	7 days	Cool to $\leq 6^{\circ}\text{C}$
Total Nonvolatile Suspended Solids ¹	Water	1000 mL	1000 mL w/m poly bottle	#23	7 days	Cool to $\leq 6^{\circ}\text{C}$
Turbidity	Water	500 mL	500 mL w/m poly bottle	#22	48 hours	Cool to $\leq 6^{\circ}\text{C}$

¹ Can be collected in the same bottle.

8.3 Invasive species evaluation

Field staff will follow EAP's SOP EAP070 on minimizing the spread of invasive species (Parsons et al., 2012). The Upper Yakima River basin is not in an area of Extreme Concern, but staff will still follow the procedures under the area of Moderate Concern.

For more information, please see Ecology's website on minimizing the spread of invasive species at www.ecy.wa.gov/programs/eap/InvasiveSpecies/AIS-PublicVersion.html.

8.4 Equipment decontamination

After conducting field work, field staff will:

- Inspect and clean all equipment by removing any visible soil, vegetation, vertebrates, invertebrates, plants, algae, or sediment. If necessary, a scrub brush will be used then rinsed with clean water either from the site or brought for that purpose. The process will be continued until all equipment is clean.
- Drain all water in samplers or other equipment that may harbor water from the site. This step will take place before leaving the sampling site or at an interim site. If cleaning after leaving the sampling site, leave no debris on the equipment to avoid spreading invasive species during transit or cleaning.

8.5 Sample ID

MEL will provide the field lead with work order numbers for all scheduled sampling dates. The work order number will be combined with a field ID number that is given by the field lead. This combination of work order number and field ID number constitutes the sample ID. All sample IDs will be recorded in field logs and in an electronic spreadsheet for tracking purposes.

8.6 Chain-of-custody, if required

Once collected, samples will be stored in coolers in the sampling vehicle. When field staff are not in the sampling vehicle, it will be locked to maintain chain-of-custody. Upon return to the Operations Center, the chain-of-custody portion of the Laboratory Analysis Required (LARs) sheet will be filled out and the coolers will be shipped straight to MEL

8.7 Field log requirements

A field log will be maintained by the field lead and used during each sampling event. The following information will be recorded during each visit to each site:

- Name and location of project
- Field staff

- Any changes or deviations from the QAPP
- Environmental conditions
- Date, time, sample ID, samples collected, identity of QC samples
- Size of sampler used
- Field measurement results
- Pertinent observations
- Any problems with sampling

8.8 Other activities

Any field staff new to the type of sampling being conducted for this study will be trained by senior field staff or the project manager, following relevant Ecology SOPs or other cited SOPs.

Before sampling begins, staff will send MEL a schedule of sampling events. This will allow the lab to plan for the arrival of samples. All samples will be collected between Monday and Wednesday so that holding times will be met for all samples. The lab will be notified immediately if there will be any deviations from the scheduled date of sampling. To ensure that the appropriate number and type of required sample containers are available, the field lead will work with the laboratory courier to develop a schedule for delivery of sampling containers.

9.0 Measurement Methods

9.1 Field procedures table/field analysis table

See Table 18 for field procedures and measurement methods.

Table 18. Field procedures and measurement methods for surface water sampling.

Analyte	Sample Matrix	# of Samples	Expected Range of Results	Method/ Equipment Type	Method Detection Limit
Turbidity	Water	Continuous measurement	1 – 100 NTU	FTS DTS-12 optical nephelometry	0.2 NTU
Velocity	Water	≈ 8 flow cross sections/trip	<0.1 – 10 ft/s	Marsh-McBirney/ SonTek® FlowTracker® Handheld ADV®	0.01 ft/s

9.2 Lab procedures table

See Table 19 for lab procedures and measurement methods.

Table 19. Lab procedures and measurement methods for surface water sampling.

Parameters	Sample Matrix	# of Field Samples	Expected Range of Results	Method	Method Detection Limit
Total Suspended Solids	Water	320	1 - 200 mg/L	SM2540D	1 mg/L
Total Non-Volatile Suspended Solids	Water	320	1 - 200 mg/L	SM2540B & E	1 mg/L
Turbidity	Water	320	1 - 100 NTU	SM2130	0.5 NTU

9.2.1 Analyte

TSS, TNVSS, and turbidity. See Table 19.

9.2.2 Matrix

The matrix is water. See Table 19.

9.2.3 Number of samples

See Table 19.

9.2.4 Expected range of results

See Table 19.

9.2.5 Analytical method

See Table 19.

9.2.6 Sensitivity/Method Detection Limit (MDL)

See Table 19.

9.3 Sample preparation method(s)

There are no additional sample preparations that have not already been described.

9.4 Special method requirements

No special methods will be used for this study.

9.5 Lab(s) accredited for method(s)

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

10.0 Quality Control (QC) Procedures

10.1 Table of field and lab QC required

Table 20 shows the QC requirements for this project.

Table 20. Summary of field and lab quality control requirements.

Parameter	Field		Laboratory			
	Field Blanks	Field Replicates	Lab Check Standard	Lab Method Blanks	Lab Replicates	Matrix Spikes
Total Suspended Solids	20/project	20%	1/run	1/run	1/20 samples	n/a
Total Non-Volatile Suspended Solids	20/project	20%	1/run	1/run	1/20 samples	n/a
Turbidity	20/project	20%	1/run	1/run	1/20 samples	1/20 samples

10.2 Corrective action processes

QC results may indicate problems with data during the course of the project. The lab will follow prescribed procedures to resolve the problems. Options for corrective actions might include:

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

11.0 Data Management Procedures

11.1 Data recording/reporting requirements

Staff will record all field data in a field notebook. Before leaving each site, staff will check field notebooks or electronic data forms for missing or improbable measurements. Staff will enter field-generated data into Microsoft (MS) Excel® spreadsheets as soon as practical after they return from the field. The field assistant will check data entry against the field notebook data for errors and omissions. The field assistant will notify the field lead or project manager of missing or unusual data.

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

11.2 Laboratory data package requirements

Laboratory-generated data reduction, review, and reporting will follow the procedures outlined in the MEL *Lab Users Manual* (MEL, 2008). Variability in lab duplicates will also be quantified, using the procedures outlined in the manual. Any estimated results will be qualified and their use restricted as appropriate. A standard case narrative of laboratory QA/QC results will be sent to the project manager for each set of samples.

11.3 Electronic transfer requirements

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

11.4 Acceptance criteria for existing data

See Section 6.2

11.5 EIM/STORET data upload procedures

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

12.0 Audits and Reports

12.1 Number, frequency, type, and schedule of audits

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

12.2 Responsible personnel

See Table 7 found in Section 5.1.

12.3 Frequency and distribution of report

A summary of the data collected under this project and a comparison of study results to target goals set by the original TMDL will be published in a formal, peer-reviewed report that includes results, methods, and data quality assessment. The final report will be published according to the project schedule in Table 8, Section 5.4.

12.4 Responsibility for reports

The project manager and principal investigator will co-author the final report.

13.0 Data Verification

13.1 Field data verification, requirements, and responsibilities

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

Before entering any data into EIM, the field lead will compare all field data to determine compliance with MQOs. The field lead will note values that are out of compliance with the MQOs and will notify the project manager. At the conclusion of the study, the field lead will compile a summary of all out of compliance values (if any) and provide it to the project manager for a decision on usability.

13.2 Lab data verification

MEL staff will perform the laboratory verification following standard laboratory practices. After the laboratory verification, the field lead will perform a secondary verification of each data package. This secondary verification will entail a detailed review of all parts of the laboratory data package with special attention to laboratory QC results. The field lead will bring any discovered issues to the project manager for resolution.

13.3 Validation requirements, if necessary

All laboratory data that have been verified by MEL staff will be validated by a project staff member. Field measurement data that was verified by a project staff member will be validated by a different staff member.

After data entry and data verification tasks are completed, all field, laboratory, and flow data will be entered into the EIM system. EIM data will be independently reviewed by another field assistant for errors at an initial 10% frequency. If significant entry errors are discovered, a more intensive review will be undertaken.

14.0 Data Quality (Usability) Assessment

14.1 Process for determining whether project objectives have been met

After all laboratory and field data are verified, the field lead or project manager will thoroughly examine the data package to determine if MQOs for completeness, representativeness, and comparability have been met. If the criteria have not been met (e.g., if the %RSD for sample duplicates exceeds the MQO), the project manager will decide if affected data should be qualified or whether it should be rejected. The project manager will decide how any qualified data will be used in the technical analysis, and will document this in the final report. The final report will assess all data and analysis results and provide a final determination regarding project goals and objectives.

14.2 Data analysis and presentation methods

The results of this monitoring study design should be comparable to the original TMDL final target objectives based on the monitoring scheme. Changes in background turbidity levels and suspended sediment loads can take place due to annual variation in precipitation, streamflow, and other climate associated forces. In addition, there can be human caused activities that cause erosion. An evaluation of the study year versus TMDL year (1999) background conditions and final target objectives will be made in the final report.

The median and 90th percentile background turbidity statistics will be compared to background values, instead of maximum values, to be consistent with the lower Yakima River TMDL and to allow for variation from natural short-term peak turbidity events.

Loading from the tributaries and other sources affects the mainstem concentrations. The Beales ratio estimator method will be used to calculate suspended sediment loading. Those loads will be compared to the final targets.

14.3 Treatment of non-detects

Non-detects may be included in the study analysis as half of the reporting limit.

14.4 Sampling design evaluation

The sampling design described in this QAPP is based on the data needs to complete the analysis.

14.5 Documentation of assessment

In the final report, a summary of the data quality assessment will be written. This summary is included in the data quality section of reports.

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16.0 Figures

See page 6 for a list of Figures.

17.0 Tables

See page 6 for a list of Tables.

18.0 Appendices

Appendix A. U.S. Geological Survey of Techniques of Water-Resources Investigations

- <http://pubs.water.usgs.gov/twri9A4/> (as viewed 1/7/2016) or
- http://water.usgs.gov/owq/FieldManual/chapter4/pdf/Chap4_v2.pdf

The following is excerpted from the U.S. Geological Survey's Collection of Water Samples: U.S. Geological Survey of Techniques of Water-Resources Investigations, Section 4A

Flowing stream water is collected using either isokinetic, depth-integrating or nonisokinetic sampling methods. Isokinetic, depth-integrating methods are designed to produce a discharge-weighted (velocity-weighted) sample; that is, each unit of stream discharge is equally represented in the sample (Office of Water Quality Technical Memorandum 99.02). The analyte concentrations determined in a discharge-weighted sample are multiplied by the stream discharge to obtain the discharge of the analyte.

Collection of an isokinetic, depth-integrated, discharge-weighted sample is standard procedure; however, site characteristics, sampling-equipment limitations, or study objectives constrain how a sample is collected and could necessitate use of other methods. If the QC plan calls for collection of concurrent samples, then the relevant procedures must be reviewed and the appropriate equipment prepared (section 4.3).

Nonisokinetic sampling methods, such as those involving use of an automated point sampler, generally do not result in a discharge-weighted sample unless the stream is completely mixed laterally and vertically. Thus, the analytical results cannot be used to directly compute analyte discharges.

Document the sampling method used on the appropriate field form for each sample.

4.1.1.A Isokinetic, Depth-Integrated Sampling Methods

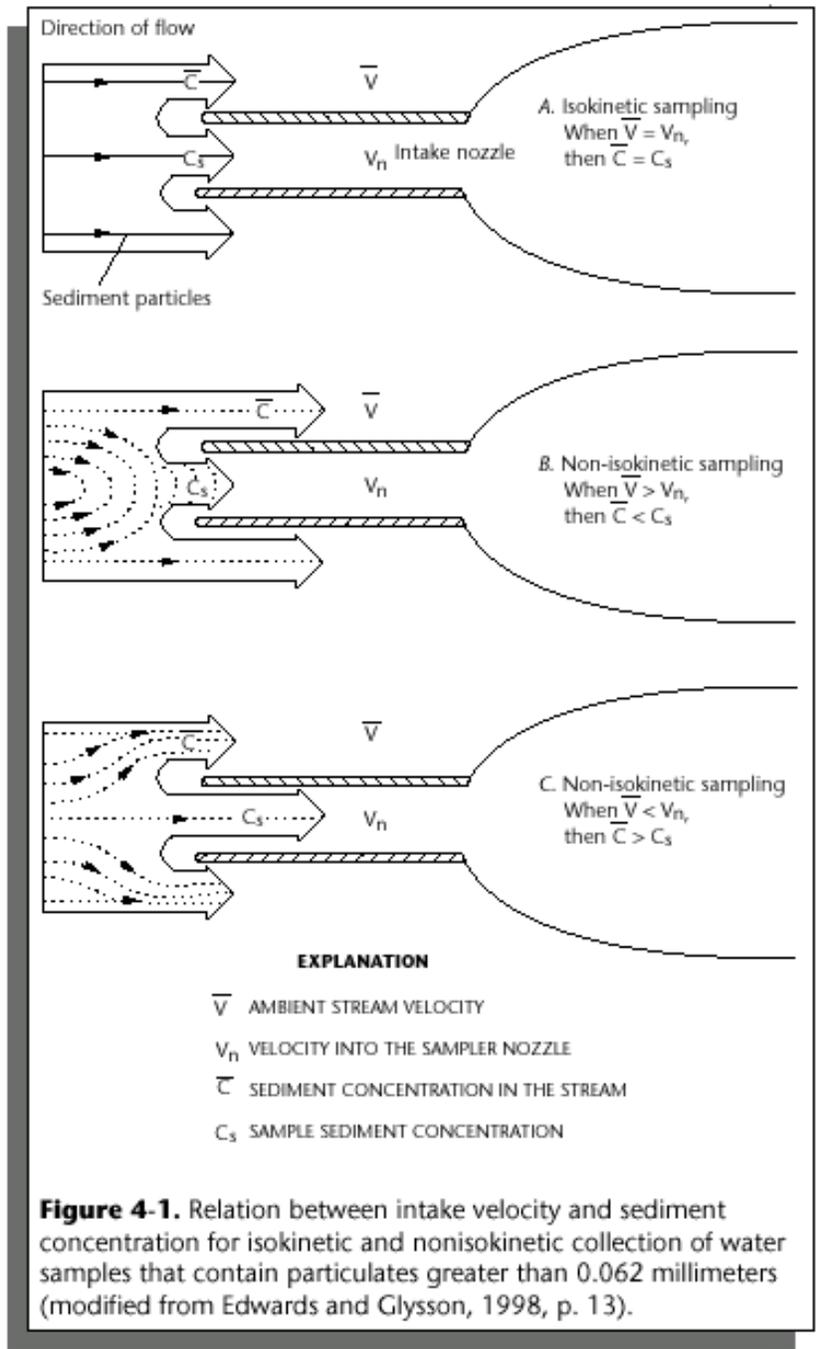
Collection of isokinetic, depth-integrated samples involves using either an equal-width-increment (EWI) or equal-discharge-increment (EDI) sampling method. The EWI or EDI methods usually result in a composite sample that represents the discharge-weighted concentrations of the stream cross section being sampled. The EWI and EDI methods are used to divide a selected cross section of a stream into increments having a specified width. The term **vertical** refers to that location within the increment at which the sampler is lowered and raised through the water column. EWI verticals are located at the midpoint of each width increment.

EDI verticals are located at the centroid, a point within each increment at which stream discharge is equal on either side of the vertical.

Isokinetic samplers usually are used to obtain a discharge-weighted sample along the stream cross section. When using an isokinetic sampler there should be no change in velocity (speed and direction) as the sample enters the intake (fig. 4-1). If properly implemented, EDI and EWI methods should yield identical results. The uses and advantages of each method are summarized below and in table 4-3.

- Collect isokinetic, depth-integrated samples by using a standard depth- and width-integrating method if analysis of a representative sample from a cross section of flowing water is required for discharge computations. Appendix A4-A and Edwards and Glysson (1998, figures 39-43), provide detailed information about isokinetic, depth-integrating transit rates for collecting samples.
- For isokinetic sampling, the mean velocity of the vertical that is sampled must exceed the minimum-velocity requirement of an isokinetic sampler—the minimum velocity requirement is either 1.5 ft/s for a bottle sampler or 3 ft/s for a bag sampler (Appendix A4-A; NFM 2).
 - The transit rate (the rate at which the sampler is lowered or raised) used to collect an isokinetic, depth-integrated sample is mainly a function of the nozzle diameter of the sampler, volume of the sampler container, stream velocity, and sampling depth (Appendix A4-A; NFM 2). Note that water temperature can affect isokinetic sampling. For example, bag samplers do not work isokinetically in water temperatures that are less than about 7 ° C.
 - An error in concentrations of suspended particulates coarser than 62 µm can be significant when the velocity of the sample entering the nozzle and the stream velocity differ significantly. The velocity of the sample entering the nozzle also can be affected by the transit rate: too fast a transit rate will cause a sampler to undersample sand-sized particulates (Edwards and Glysson, 1998).
 - The transit rate must be kept constant during sampler descent through a vertical and also during sampler ascent through a vertical. Although not necessary, usually the same transit rate is used for raising the sampler as was used for lowering the sampler through a given vertical.

RULE OF THUMB: For isokinetic, depth-integrating sampling, do not exceed the designated maximum transit rate.



The number of increments needed in order to get a discharge-weighted sample at a site is related primarily to data objectives (for example, the accuracy needed) and how well-mixed or heterogeneous the stream is with respect to the physical, chemical, and biological characteristics of the cross section. The recommended number of increments for EWI and EDI methods are discussed in the sections to follow. Edwards and Glysson (1998) describe a statistical approach for selecting the number of increments to be used, based on sampling error and suspended-sediment characteristics.

Selecting the number of increments

- Examine the variation in field-measurement values (such as specific electrical conductance, pH, temperature, and dissolved oxygen) along the cross section (NFM 6).
- Consider the distribution of streamflow (discharge), suspended-materials concentration and particle-size distribution, and concentrations of other targeted analytes along the cross section. Consider whether the distribution or analyte concentrations will change during sample collection.
- Consider the type of sampler that will be used and the volume of sample that will have to be collected for the analysis of the target analytes.
- Avoid side-channel eddies. EDI and EWI methods cannot be used at locations with upstream eddy flow.

Table 4-3. Uses and advantages of equal-width-increment (EWI) and equal-discharge-increment (EDI) sampling methods

EWI method	Advantages of the EWI method
<p>EWI is used when information required to determine locations of sampling verticals for the EDI method is not available, and (or) the stream cross section has relatively uniform depth and velocity.</p> <p>Use EWI whenever:</p> <ul style="list-style-type: none"> The location of EDI sampling verticals changes at the same discharge from one sampling time to another. This situation occurs frequently in streams with sand channels. 	<ul style="list-style-type: none"> EWI method is easily learned and implemented for sampling small streams. Generally, less time is required onsite if the EWI method can be used and information required to determine locations of sampling verticals for the EDI method is not available.
EDI method	Advantages of the EDI method
<p>EDI is used when information required to determine locations of sampling verticals for the EDI method is available.</p> <p>Use EDI whenever:</p> <ul style="list-style-type: none"> Small, nonhomogeneous increments need to be sampled separately from the rest of the cross section. The samples from those verticals can be analyzed separately or appropriately composited with the rest of the cross-sectional sample. (Have the sampling scheme approved.) or Flow velocities are less than the isokinetic transit-rate range requirement. A discharge-weighted sample can be obtained, but the sample will not always be isokinetic. or The EWI sampling method cannot be used. For example, isokinetic samples cannot be collected because stream velocities and depths vary so much that the isokinetic requirements of the sampler are not met at several sampling verticals. or Stage is changing rapidly. (EDI requires less sampling time than EWI, provided the locations of the sampling verticals can be determined quickly.) 	<ul style="list-style-type: none"> Fewer increments are necessary, resulting in a shortened sampling time (provided the locations of sampling verticals can be determined quickly and constituents are adequately mixed in the increment). Sampling during rapidly changing stages is facilitated by the shorter sampling time. Subsamples making up a sample set may be analyzed separately or may be proportionally composited with the rest of the cross-sectional sample. The cross-sectional variation in constituent discharge can be determined if subsample bottles are analyzed individually. A greater range in velocity and depths can be sampled isokinetically at a cross section. The total composite volume of the sample is known and can be adjusted before sampling begins.

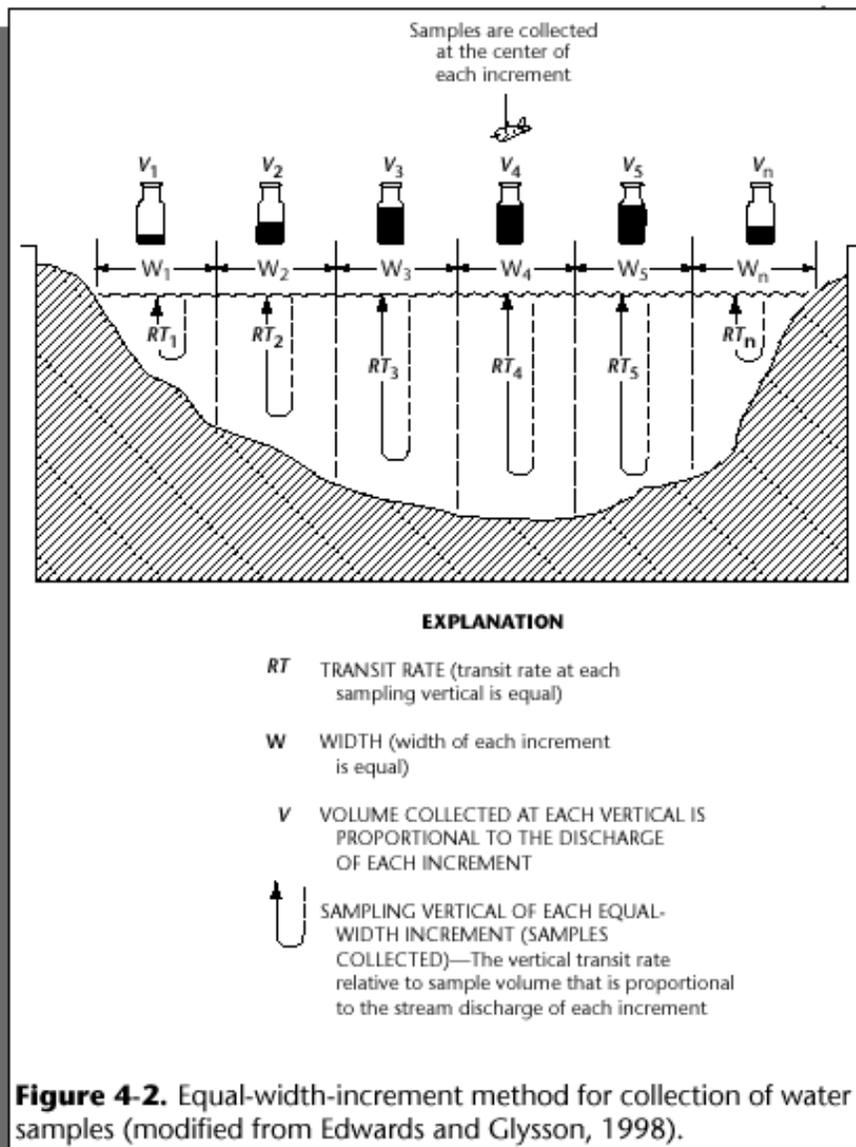
Equal-width-increment (EWI) method

For the EWI sampling method, the stream cross section is divided into a number of equal-width increments (fig. 4-2). Samples are collected by lowering and raising a sampler through the water column at the center of each increment. (This sampling location is referred to as the vertical.) The combination of the same constant transit rate used to sample at each vertical and the isokinetic property of the sampler results in a discharge-weighted sample that is proportional to total streamflow.

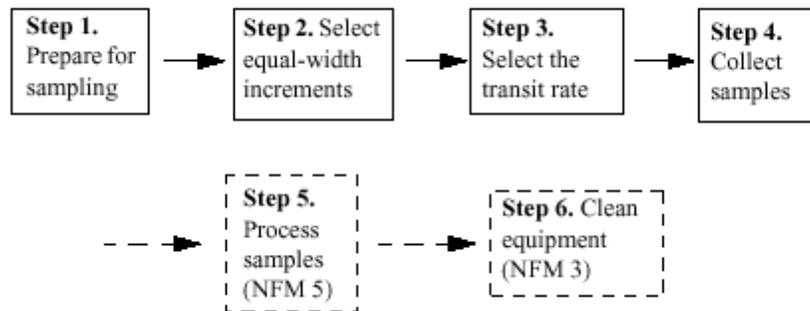
- **Isokinetic sampling is required for the EWI method.** Use isokinetic, depth-integrating sampling equipment (NFM 2).
 - **Use the same size sampler container (bottle or bag) and nozzle** at each of the sampling verticals (fig. 4-2).
 - **Collect samples using the same transit rate** at each vertical during descent and ascent of the sampler. The transit rate must be constant and within the operational range of the sampler (Appendix A4-A).
- Composite the subsamples from all verticals in a churn splitter or process subsamples through the cone splitter (NFM 5).

Do not use EWI when stream velocities are less than the minimum velocity required for the isokinetic sampler selected:

- **1.5 ft/s for the bottle sampler**
- **3 ft/s for the bag sampler**



Guidelines for the EWI sampling method:



Be sure that the field effort is adequately staffed and equipped. Check QC requirements before departing—QC samples require additional equipment and supplies.

Step 1. Prepare for sampling

- Upon arrival at the field site, set out safety equipment such as traffic cones and signs. Park vehicle in a location and direction so as to prevent sample contamination from vehicle emissions.
- Assemble sampling equipment and set up a clean work space.
 - **Organic compounds.** Select equipment with fluorocarbon polymer, glass, or metal components if components will directly contact samples to be analyzed for organic compounds. **Do not use plastics other than fluorocarbon polymers.**
 - **Inorganic constituents.** Select equipment with components made of fluorocarbon polymer or other relatively inert and uncolored plastics or glass if components will directly contact samples to be analyzed for inorganic constituents. **Do not use metal or rubber components for trace-element sampling.**
 - **Microbiological analyses.** Collect samples for microbiological analyses using equipment and techniques described in NFM 7.

Step 2. Select the number and width of equal-width increments.

- Visually inspect the stream from bank to bank and longitudinally, observing velocity, width, and depth distribution, and apparent distribution of sediment and aquatic biota along the cross section. Note and document the location of stagnant water, eddies, backwater, reverse flows, areas of faster than normal flow, and piers or other features along the cross section.
- Determine stream width from a tagline or from distance markings on a bridge railing or cableway.

- At sites with little sampling history, measure and record the cross-sectional variation of field measurements (such as specific electrical conductance, pH, temperature, and dissolved oxygen). Review the magnitude of the variations along the cross section.
- Determine the width of the increment. To obtain the number of increments, divide the stream width by the increment width. The number of increments must be a whole number. Increment width is based on study objectives, variation in field measurements and flow, and stream-channel characteristics along the cross section.
 - Collect the subsample at the center of each equal-width increment (the vertical).
 - If the subsample does not represent the mean value for that increment, decrease the increment width until the mean value for the increment is represented. This will increase the number of increments sampled.
- Locate the first sampling vertical at a distance of one-half of the selected increment width from the edge of the water. Locate all the other verticals at the center of each remaining equal-width increment along the cross section.

Example:

If a stream 56 ft wide has been divided into 14 increments of 4 ft each, the first sampling vertical would be 2 ft from the water's edge and subsequent verticals would be at 6, 10, 14 ft from the water's edge, and so forth. Even if streamflow is divided, as in a braided channel, equal-width increments must be identical from channel to channel, and the same constant transit rate must be used at each vertical.

- Make slight adjustments to sampling locations, if necessary, to avoid sampling where the flow is affected by a pier or other obstruction.

TECHNICAL NOTE: Sampling near or downstream from large in-stream obstructions such as bridges and piers could result in artificially elevated concentrations of suspended sediments if the sampler is immersed in an eddy that is caused by the obstruction. If it is necessary to include an eddy in the cross section to be sampled, consider treating the eddy as a solid obstruction: subtract the eddy width from that of the total cross section, and determine the width of the increments based on the remaining stream width.

RULE OF THUMB

When selecting the number of equal-width increments:

- Cross-sectional width 5 ft—use a minimum of 10 equal-width increments.
- Cross-sectional width <5 ft—use as many increments as practical, but equally spaced a minimum of 3 in. apart.

Equipment limitations also constrain the number of increments selected; for example:

- When using a D-95 at maximum depth with a 14-L churn splitter, EWI samples can be collected at approximately 14 verticals. If an 8-L churn splitter is used, samples can be collected at approximately 10 verticals.
- When using a D-77 and a 14-L churn splitter, the maximum average depth must not exceed 5 ft when samples are collected at 10 verticals.

Step 3. Select the transit rate.

- Refer to Appendix A4-A for guidelines for determining the transit rates for collecting isokinetic, depth-integrated samples. Unless the mean velocity is actually determined, use the trial-and-error method to determine the minimum transit rate.
- Locate the equal-width increment containing the largest discharge (largest product of depth times velocity) by sounding for depth and either measuring or estimating velocity. At the vertical for this increment, use of the minimum transit rate results in the maximum allowable filling of the sampler bottle or bag during one vertical traverse.
- Determine the minimum transit rate at this vertical for the type of sampler (bottle or bag), size of sampler nozzle, and the desired sample volume.
 - Approximate the mean velocity of the vertical in feet per second by timing a floating marker (such as a peanut) as it travels a known distance. (A known length of flagging tape tied to the cable where the sampler is attached often is used to measure the distance.) Divide the distance (in feet) by the time (in seconds) and multiply by 0.86.
 - Make sure that the transit rate does not exceed the maximum allowable transit rate to be used at any of the remaining verticals along the cross section. This can be determined by sampling the slowest increment. **If the minimum volume of sample (relative to depth of the vertical) is not collected at this vertical, then the EWI method cannot be used at this cross section to collect a discharge-weighted sample (Appendix A4-A).**

Guidelines for selecting the transit rate for EWI sampling

- **The descending and ascending transit rate must be constant in each direction and must be the same for each vertical along the cross section.**
- **Do not exceed the maximum allowable transit rate if using EWI.** If the transit rate must exceed the maximum allowable rate, use EDI instead of EWI.
- The transit rate selected must be sufficiently rapid to keep from overfilling the sampler. The sampler is overfilled when the water surface in the sampler container is above the bottom edge of the nozzle when the sampler is held in the sampling position.
- The same size sampler nozzle and container must be used at all verticals along the cross section.
- If the total volume collected will exceed the recommended volume for the churn splitter, then a cone splitter must be used.

Step 4. Collect samples.

- The sample-collection procedure is the same whether you are wading or using the reel-and-cable suspension method. Use CH/DH techniques, as required (section 4.0.1). Always follow safety procedures (NFM 9).
- Move to the first vertical (midpoint of first EWI near edge of water) and field rinse equipment (section 4.0.2).
- Record start time and gage height.
- Lower field-rinsed sampler at the predetermined constant transit rate until slight contact is made with the streambed. Do not pause upon contacting the streambed. Raise the sampler immediately at the same constant transit rate until sampler completes the vertical traverse.
 - Take care not to disturb the streambed by bumping the sampler on it; bed material may enter the nozzle, resulting in erroneous data.
 - Do not overfill the sampler container. Overfilling results in a sample that is not isokinetic and that could be enriched with heavy particulates because of secondary circulation of water through the sampler (from nozzle through air exhaust). This enrichment will result in an artificially increased sediment concentration and will bias particle-size distribution toward heavier and larger particulates.
 - Do not underfill the sampler container (Appendix A4-A). Underfilling will result in a sample that is not isokinetically collected because the maximum transit rate has been exceeded.

- If the required volume cannot be collected, use the EDI method to obtain discharge-weighted samples.
- Inspect each subsample as it is collected, looking for overfilling or underfilling of the sampler container and (or) the presence of anomalously large amounts of particulates that might have been captured because of excessive streambed disturbance during sample collection. If you note any of these conditions, discard the sample, making sure there are no residual particulates left in the container, and resample.
- Move sampling equipment to the next vertical. Maintain the selected transit rate. The volume of the subsample can vary considerably among verticals. Subsamples can be collected at several verticals before emptying the sampler container, as long as the maximum volume of sample in a bottle or bag sampler has not been exceeded. If the container is overfilled, it is necessary to resample.

TECHNICAL NOTE: The tables in Appendix A4-A apply to the first complete round-trip transit starting with an empty sampler container. These tables cannot be used if the sampler is not emptied between verticals.

- Continue to the next vertical until no more samples can be collected without overfilling the sampler container. Empty the subsample into a field-rinsed churn or cone splitter and repeat sample collection in the same manner until subsamples have been collected at all the verticals.
 - If the total volume of the subsamples to be collected will exceed the operational capacity of the churn, select from the following options: use either a sampler with a smaller bottle or a bag sampler with a smaller nozzle; or use a cone splitter; or use the EDI method, if appropriate.
 - To ensure that all particulates are transferred with the sample, swirl the subsample gently to keep particulates suspended and pour the subsample quickly into the churn or cone splitter.
 - Sample EWV verticals as many times as necessary to ensure that an adequate sample volume is collected as required for analysis, but sample at each vertical an equal number of times. (The composite cross-sectional sample will remain proportional to flow at the time of sampling.)
 - If flow is stable during sampling, then multiple samples can be collected at each vertical during a single traverse along the cross section. If flow is changing, however, study objectives should determine whether to collect multiple samples at each vertical during a single traverse or to collect one sample at each vertical during multiple traverses along the cross section. Document on field forms the method used.
- Record the following information after all samples have been collected:
 - Sampling end time.

- Ending gage height.
- All field observations and any deviations from standard sampling procedures.

Step 5. Process Samples Refer to NFM 5.

Step 6. Clean Equipment Refer to NFM 3.

- If the sampler will not be reused during a field trip, rinse sampler components with deionized water before they dry and place them into a plastic bag for transporting to the office laboratory to be cleaned.
- If the sampler will be reused during the field trip, rinse the components with DIW while still wet from sampling and then field-clean while at the sampling site using the prescribed procedures (NFM 3). Reassemble the sampler.
- Collect a field blank, if required, after sampling equipment has been cleaned at the sampling site.
- Place the cleaned sampler into a plastic bag and seal for transport to the next site.

Appendix B. Glossaries, Acronyms, and Abbreviations

Glossary of General Terms

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.

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

Total Maximum Daily Load (TMDL): A distribution of a substance in a water body designed to protect it from not meeting (exceeding) water quality standards. A TMDL is equal to the sum of all of the following: (1) individual 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.

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.

90th percentile: An estimated portion of a sample population based on a statistical determination of distribution characteristics. The 90th percentile value is a statistically derived estimate of the division between 90% of samples, which should be less than the value, and 10% of samples, which are expected to exceed the value.

Acronyms and Abbreviations

BMP	Best management practice
Ecology	Washington State Department of Ecology
e.g.	For example
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
et al.	And others
i.e.	In other words
MEL	Manchester Environmental Laboratory
MQO	Measurement quality objective
QA	Quality assurance
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
WRIA	Water Resource Inventory Area

Units of Measurement

cfs	cubic feet per second
ft	feet
mg/L	milligrams per liter (parts per million)
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 population mean and the true value. Bias usually describes a systematic difference reproducible over time, and is characteristic of both the measurement system, and the analyte(s) being measured. Bias is a commonly used data quality indicator (DQI). (Kammin, 2010; Ecology, 2004)

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Examples of data types commonly validated would be:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Method Detection Limit (MDL): This definition for detection was first formally advanced in 40CFR 136, October 26, 1984 edition. MDL is defined there as the minimum concentration of

an analyte that, in a given matrix and with a specific method, has a 99% probability of being identified, and reported to be greater than zero. (Federal Register, October 26, 1984)

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

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

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

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

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

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

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

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

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

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

$$[\text{Abs}(a-b)/((a + b)/2)] * 100$$

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 that is further 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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