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QUALITY ASSURANCE PROJECT PLAN

REDMOND PAIRED WATERSHED STUDY

Prepared for
City of Redmond

Prepared by
Herrera Environmental Consultants, Inc.

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REDMOND PAIRED WATERSHED STUDY

Prepared for
City of Redmond
15670 Northeast 85th Street
Redmond, Washington 98052

Prepared by
Herrera Environmental Consultants, Inc.
2200 Sixth Avenue, Suite 1100
Seattle, Washington 98121
Telephone: 206-441-9080

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Signature Page

Approved by: Date

Andy Rheaume, Study Manager, City of Redmond

Brandi Lubliner, Regional Stormwater Monitoring Program Manager,
Washington State Department of Ecology

John Lenth, Quality Assurance Project Plan Lead Author,
Herrera Environmental Consultants, Inc.

Jenée Colton, Quality Assurance Project Plan Secondary Author,
King County

David Funke, Quality Assurance Project Plan Secondary Author,
King County

Distribution List

Name	Affiliation	Project Role	Phone	E-mail
Andy Rheaume	City of Redmond	Study Manager	425-556-2741	ajrheaume@redmond.gov
Brandi Lubliner	Washington State Department of Ecology	Regional Stormwater Monitoring Program Manager	360-407-7140	brandi.lubliner@ecy.wa.gov
John Lenth	Herrera	Quality Assurance Project Plan Lead Author	206-787-8265	jlenth@herrerainc.com
Jenée Colton	King County	Quality Assurance Project Plan Secondary Author	206-477-4075	Jenee.Colton@kingcounty.gov
David Funke	King County	Quality Assurance Project Plan Secondary Author	206-477-4692	David.Funke@kingcounty.gov
Jerallyn Roetemeyer	City of Redmond	Technical Advisory Committee	425-556.2820	JRoetemeyer@redmond.gov
Doug Hutchinson	City of Seattle	Technical Advisory Committee	206-233-7899	doug.hutchinson@seattle.gov
Jeff Burkey	King County	Technical Advisory Committee	206-477-4658	jeff.burkey@kingcounty.gov
Kate Macneale	King County	Technical Advisory Committee	206-477.4769	Kate.Macneale@kingcounty.gov
Chris May	Kitsap County	Technical Advisory Committee	360-337-7295	cmay@co.kitsap.wa.us
Dino Marshalonis	US Environmental Protection Agency	Technical Advisory Committee	206-553-1519	Marshalonis.Dino@epamail.epa.gov
Rick Dinicola	US Geological Survey	Technical Advisory Committee	253-552-1603	dinicola@usgs.gov
Chris Konrad	US Geological Survey	Technical Advisory Committee	253-552-1634	cpkonrad@usgs.gov
Rich Sheibley	US Geological Survey	Technical Advisory Committee	253-552-1611	sheibley@usgs.gov
Karen Dinicola	Washington State Department of Ecology	Technical Advisory Committee	360-407.6550	karen.dinicola@ecy.wa.gov
Ed O'Brien	Washington State Department of Ecology	Technical Advisory Committee	360-407-6438	eobr461@ecy.wa.gov
Mindy Roberts	Washington State Department of Ecology	Technical Advisory Committee	360-407-6804	mindy.roberts@ecy.wa.gov

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1. INTRODUCTION

The Redmond Paired Watershed Study (RPWS) is one of four effectiveness monitoring studies that was selected for implementation starting in 2014 for the Regional Stormwater Monitoring Program (RSMP) for Puget Sound. The goal of effectiveness monitoring under the RSMP is to provide widely applicable information for improving stormwater management in the region. Phase I and Phase II Municipal Stormwater Permittees in the Puget Sound Region contribute to a Pooled Stormwater Resources Fund that supports the RSMP and associated effectiveness monitoring studies. Selection of the RPWS for implementation under the RSMP was made based on a monitoring proposal that was presented to permittee representatives at workshops that were held on March 20, 2014 and May 6, 2014. The specific study question to be addressed through the RPWS is as follows:

> *How effective are watershed rehabilitation efforts at improving receiving water conditions at the watershed scale?*

To address this study question, a conceptual experimental design for the RPWS was subsequently developed and summarized in the *Redmond Paired Watershed Study Experimental Design Report* (Herrera 2015a). This conceptual experimental design was informed by a literature review (Herrera 2015b) that was conducted to identify lessons learned from past studies that have been implemented to achieve similar objectives. The conceptual experimental design was also developed based on input from a technical advisory committee that was formed for the study. This technical advisory committee includes representation from the following agencies:

- City of Redmond
- City of Seattle
- King County
- Kitsap County
- US Environmental Protection Agency
- US Geological Society
- Washington State Department of Ecology (Ecology)

Building on this previous work, this document represents the Quality Assurance Project Plan (QAPP) that will guide the implementation of all subsequent phases of the RPWS. This QAPP documents the experimental design and procedures that will be used during data collection, processing, and analysis to ensure all results obtained for the RPWS are scientifically defensible. It was prepared in accordance with Washington State Department of Ecology (Ecology) *Guidelines for Quality Assurance Project Plans* (Ecology 2004), and includes the following sections:

- **Background** – An explanation of why the project is needed
- **Project Description** – Project goals and objectives, and the information required to meet the objectives
- **Organization and Schedule** – Project roles and responsibilities, and the schedule for completing the work
- **Quality Objectives** – Performance (or acceptance) thresholds for collected data
- **Experimental Design** – The sampling process design for the study, including sample types, monitoring locations, and sampling frequency
- **Sampling Procedures** – A detailed description of sampling procedures and associated equipment requirements
- **Measurement Procedures** – Laboratory procedures that will be performed on collected samples
- **Quality Control** – Quality control (QC) requirements for both laboratory and field measurements
- **Data Management Procedures** – How data will be managed from field or laboratory recording to final use and archiving
- **Audits and Reports** – The process that will be followed to ensure this QAPP is being implemented correctly and the quality of the data is acceptable
- **Data Verification and Validation** – The data evaluation process, including the steps required for verification, validation, and data quality assessment
- **Data Quality (Usability) Assessment** – The procedures that will be used to determine if collected data are of the right type, quality, and quantity to meet project objectives

2. BACKGROUND

Municipal Stormwater Permits are issued by Ecology to regulate discharges from separated storm sewers owned or operated by Phase I and Phase II cities and counties. The Municipal Stormwater Permits establish the minimum requirements for permittees to address existing and future impacts to receiving waters from urbanization. Municipal Stormwater Permits require cities and counties to execute programmatic (nonstructural) activities and establish design standards for stormwater structural controls triggered by development (low impact development, runoff treatment, and flow control facilities). In theory, if all developed land in a watershed is equipped with nonstructural and structural stormwater controls, the receiving water would be protected from hydrologic and water quality impacts caused by urbanization. However, while the effectiveness of nonstructural and structural controls has been well documented at the site scale, limited data exists on the effectiveness of these controls in aggregate for actually improving conditions in receiving waters.

In February 2014, Ecology approved a Citywide Watershed Management Plan (WMP) (Herrera 2013) for the City of Redmond (City) that allows the City to use a watershed approach for stormwater management pursuant to the Municipal Stormwater Permit, Section 303(d) of the Clean Water Act, and salmon recovery. Through the implementation of this WMP, the City will focus stormwater best management practices (BMPs) in a subset of priority watersheds that are moderately impacted by urbanization and therefore expected to respond more quickly to rehabilitation efforts. This provides a unique opportunity to study the effectiveness of stormwater BMPs for improving receiving water conditions on an accelerated time frame. Recognizing this opportunity, the City is implementing the RPWS to quantify improvements in receiving water conditions.

To guide the development of the experimental design for the RPWS, a literature review was conducted to obtain information on past studies that have been implemented to achieve similar objectives. This literature review specifically involved online searches to identify published journals, proceedings, and gray literature on the following types of studies:

- Studies to quantify trends (5 years plus) in receiving water conditions following implementation of stormwater controls and/or habitat improvements
- Paired watershed studies looking at the effectiveness of stormwater controls for improving receiving water conditions
- Studies to quantify changes in receiving water conditions in response to increased watershed urbanization
- General references on sampling strategies/methodologies for detecting change in receiving water conditions.

These searches yielded 123 study references that were then reviewed in detail to identify a subset of 11 priority studies that were found to be the most relevant for informing the experimental design of the RPWS. Detailed descriptions of these studies were subsequently provided in a summary report for the literature review (Herrera 2015b). In addition, all the studies were reviewed to determine if they utilized specific indicators for receiving water conditions in any of the following categories: hydrologic, chemical, physical habitat, and biological. These results were subsequently used to synthesize information on the effectiveness of specific indicators in these categories for assessing change in receiving water conditions. Key conclusions and recommendations from the literature review are as follows:

- The scope and nature of the RPWS is unprecedented in the literature. Numerous studies have been conducted with similar goals, but they were generally conducted at the sub-basin scale. In these studies, a hydrologic monitoring station was typically located at the mouth of the study basin. Therefore, monitoring stations at the mouth of the study watersheds for the RPWS was also recommended. However, because the study watersheds for the RPWS will be substantially larger than the sub-basins used in previous studies and rehabilitation efforts will likely occur in the upper reaches of these watersheds, additional hydrologic monitoring stations at a mid-point location was also recommended for the RPWS.

- Continuous flow data collection was used in each applicable study reviewed and is recommended for the RPWS. Furthermore, the most useful and pervasive hydrologic indicator appeared to be frequency and duration of high and low pulse count. These indicators at the least were specifically recommended for the RPWS to assess the success of rehabilitation efforts. Annual flow volume was also commonly used in the literature and should be considered when selecting indicators of hydrologic change. Modeling to quantify changes in hydrology as a function of land use changes and stormwater treatment applications has also been performed in a number of relevant studies. The RPWS provides an opportunity to validate the results from this modeling.

- The literature review indicated that most basin-scale studies have not been able to detect a difference in pollutant concentrations between basins with and without stormwater treatment facilities including low impact development (LID) practices. Load reductions were more easily quantified, but with concentration alone, natural variability tended to overwhelm any signal that could be associated with stormwater treatment applications. The most common parameter groups measured in the literature of relevant studies where nutrients, suspended solids, and metals. Parameters from these groups at the least were recommended for the RPWS.

- The majority of studies that assessed physical habitat response to watershed rehabilitation were conducted in reaches in which channel rehabilitation measures were applied. Consequently, they were designed to assess the localized effects of channel alterations. The RPWS will involve both channel rehabilitation and basin-wide BMP application. Consequently, a more synoptic approach was recommended for the RPWS to assess physical habitat recovery. Stations should be selected in reaches that will be restored and in reaches where there will be no physical alterations to the channel. In this way, the RPWS can assess physical habitat response to both localized and basin-wide drivers.

- Studies linking macroinvertebrate and fish response to watershed restoration have primarily focused on responses to in-channel work. Macroinvertebrate metrics can show considerable variation across small spatial scales and will be sensitive to local conditions in the channel which may override influences from higher up in the watershed. Because an objective of the RPWS is to measure both localized and watershed effects on biologic recovery, it was recommended that the biological monitoring program mirror the habitat monitoring program discussed above. Specifically, multiple monitoring locations should be located in both reaches where channel rehabilitation will occur and in reaches that will only be affected by upstream stormwater management activities. Annual monitoring coinciding with the collection of habitat data was recommended. Monitoring of fish response was dropped from consideration because few studies were identified in the literature that showed this was an effective indicator for documenting improving conditions at the watershed scale.

Results from the literature review were subsequently used to develop a conceptual experimental design for the RPWS that was summarized in the *Redmond Paired Watershed Study Experimental Design Report* (Herrera 2015a). Following review and approval by the technical advisory committee for the RPWS, the contents of this report provided the foundation for the experimental design identified in this QAPP.

3. PROJECT DESCRIPTION

As described in the *Introduction* to this QAPP, the specific study question to be addressed through the RPWS is as follows:

> *How effective are watershed rehabilitation efforts at improving receiving water conditions at the watershed scale?*

In this context, rehabilitation efforts could include any of the following practices:

- Stormwater retrofits in upland areas that would include facilities for onsite stormwater management (e.g., low impact development [LID] practices), runoff treatment, and flow control
- Riparian and in-stream habitat improvements
- Programmatic practices for stormwater management

To answer the study question identified above, the RPWS will involve the collection of routine and continuous measurements of various hydrologic, chemical, physical habitat, and biological indicators of stream health over an extended time frame to quantify improvements in receiving water conditions in watersheds that have been targeted for rehabilitation efforts. At the same time these measurements will also be collected in watersheds that are not similarly targeted for these efforts. The trend of interest will be evidence that receiving water conditions are improving in the former watersheds while conditions in the latter watersheds remain relatively static. In addition to this monitoring, the effectiveness of specific structural stormwater controls in the watersheds that have been targeted for rehabilitation efforts will also be confirmed based on measurements of hydrologic and chemical parameters that are collected over a shorter timeframe. A more detailed description of the procedures that will be used for this monitoring is provided in the *Experimental Design* section of this QAPP.

4. PROJECT ORGANIZATION AND SCHEDULE

This section describes how the project is organized, key personnel, and the project schedule.

4.1. Organization and Key Personnel

Herrera and King County are jointly responsible for developing and implementing this QAPP with oversight from the City and Ecology. Herrera will oversee monitoring that is related to chemical, physical habitat, and biological indicators of stream health. King County will oversee monitoring that is related to hydrologic indicators of stream health. Key personnel that will be involved in this effort are identified below with their respective roles:

City of Redmond
15670 Northeast 85th Street
Redmond, Washington 98503
425-556-2741

Andy Rheaume, City Project Manager

Herrera Environmental Consultants, Inc.
2200 Sixth Avenue, Suite 1100
Seattle, WA 98121
206-441-9080

John Lenth, Herrera Project Manager, Water Quality and Biological Monitoring Lead
Dylan Ahearn, Ph.D., Monitoring Coordinator
Josh Wozniak, Physical Habitat Monitoring Lead
Rob Zisette, Sediment Quality Monitoring Lead
Gina Catarra, Data Quality Assurance Officer

King County
Department of Natural Resources and Parks
Water and Land Resources Division
201 South Jackson Street – Suite 600
Seattle, WA 98104-3855
206-296-0100

Jenée Colton, King County Project Manager
Dave Funke, Hydrologic Monitoring Lead

Washington State Department of Ecology
Headquarter Office
P.O. Box 47600
Olympia, WA 98504-7600
360-407-7140

Brandi Lubliner, Ecology Project Manager

Ongoing technical oversight of the RPWS will also be provided by the following members of the technical advisory committee that was formed for the study:

Jerallyn Roetemeyer, City of Redmond

Doug Hutchinson, City of Seattle

Jeff Burkey, King County

Kate Macneale, King County

Chris May, Kitsap County

Dino Marshalonis, US Environmental Protection Agency

Rick Dinicola, US Geological Survey

Chris Konrad, US Geological Survey

Rich Sheibley, US Geological Survey

Karen Dinicola, Washington State Department of Ecology

Ed O'Brien, Washington State Department of Ecology

Mindy Roberts, Washington State Department of Ecology

4.2. Schedule

Monitoring of the RPWS will begin in October 2015 and continue for a period of approximately 10 years. On an annual basis, the following monitoring activities will occur according to the schedule indicated:

- Hydrologic Monitoring: Continuous
- Water Quality Monitoring: Continuous
- Physical Habitat Monitoring: July through September
- Sediment Quality Monitoring: May through June
- Biological Monitoring: – July through August

5. QUALITY OBJECTIVES

The goal of this QAPP is to ensure that the data collected for this study are scientifically accurate, useful for the intended analysis, and legally defensible. To achieve this goal, the collected data will be evaluated relative to the following indicators of quality assurance:

- **Precision**: A measure of the variability in the results of replicate measurements due to random error
- **Bias**: The systematic or persistent distortion of a measurement process that causes errors in one direction (for example the measured mean is different from the true value)
- **Representativeness**: The degree to which the data accurately describe the conditions being evaluated based on the selected sampling locations, sampling frequency and duration, and sampling methods
- **Completeness**: The amount of data obtained from the measurement system
- **Comparability**: The ability to compare data from the current study to data from other similar studies, regulatory requirements, and historical data

Measurement quality objectives (MQOs) are performance or acceptance criteria that have been established for each of these quality assurance indicators. These MQOs are described below in separate subsections for hydrologic data, chemistry data, *in situ* water quality data, physical habitat monitoring, and biological monitoring.

5.1. Measurement Quality Objectives for Continuous Hydrologic Data

Hydrologic monitoring will include measurements of water level at individual monitoring locations. These measurements will then be converted to estimates of discharge using stream discharge rating curves (see next section). The MQOs for hydrologic monitoring are defined below.

5.1.1. Precision

Because it is difficult to obtain replicate measurements from hydrologic monitoring equipment during continuously changing site conditions, precision of the hydrologic data will be assessed based on a controlled test that is performed prior to installing the monitoring equipment in the field. This test will specifically involve the following steps:

1. Place a pressure transducers obtained for this project into a large bucket.
2. Fill bucket with 1 foot of water.
3. Seal bucket tightly to reduce/eliminate evaporation, but leave small gap for pressure equilibration.

4. Zero the pressure transducer.
5. Run the test for 24 hours, collecting data at 5-minute intervals.
6. Repeat the test with 3.0 feet of water in the bucket.

The MQO for precision is less than 5 percent change in water level readings from one measurement to the next over the duration of two tests performed at different water levels (i.e., 1 and 2 feet).

5.1.2. Bias

The bias of hydrologic monitoring data will be assessed based on comparisons of monitoring equipment readings to an independently measured "true" value. In this case the true value will be derived from manual measurements of water level that are obtained from a staff gauge at each monitoring location. These manual measurements will be made in conjunction with routine visits to each monitoring location (see next section).

If the monitoring equipment is not affected by drift or other operational problems, the difference between the equipment's reading and the manual measurement of water level ("instrument offset") should remain constant over time and varying water depths. Therefore, bias in these data will be assessed based on the change in the instrument drift value relative to all previous measurements. Specifically, a change in the instrument drift value of plus or minus 2 standard deviations relative to the mean from all previous measurements will trigger an assessment of the monitoring equipment to determine proper functioning. Practically, if the instrument offset changes due to instrument "drift" three consecutive observations, a replacement or repair will be made.

5.1.3. Representativeness

The representativeness of the hydrologic and continuous water quality data will be ensured by the proper installation of the monitoring equipment, including primary and secondary devices.

5.1.4. Completeness

Completeness will be assessed based on the occurrence of gaps that may occur in the data record for all monitoring equipment. The associated MQO is less than 10 percent of the total data record missing due to equipment malfunctions or other operational problems. Completeness will be ensured through routine maintenance of all monitoring equipment and immediate implementation of corrective actions if problems arise.

5.1.5. Comparability

Standard monitoring procedures, units of measurement, and reporting conventions will be applied to meet the goal of data comparability.

5.2. Measurement Quality Objectives for Rainfall Data

Hydrologic monitoring will include the installation of three rain gauges at representative locations. The rain gauges will be installed in the south study area to characterize rainfall in the Country Creek and Tosh Creek watersheds; in the north study area to characterize rainfall in the Tyler Creek and Monticello Creek watersheds, and in the east study area to characterize rainfall in the Evans Creek Tributary 108 watershed. King County already operates rain gauges near the Colin Creek and Seidel Creek watersheds. The rain gauges will be tipping bucket types, with 8-inch-diameter funnels, recording rainfall in 0.01-inch increments. Data loggers will record the time of each 0.01-inch event. The MQOs for rainfall monitoring are defined below.

5.2.1. Precision

Precision will be insured by proper installation, calibration, and maintenance of the rain gauge. Manufacturer's instructions for installation will be followed, with special care to make the gauge level. The instrument calibration will be checked three times annually by running a measured amount of water into the funnel. The MQO for precision is less than 5 percent difference in the number of tips actually recorded compared to the anticipated number of tips that should be recorded given the amount of water supplied. The instrument will be adjusted if the MQO is not achieved.

5.2.2. Bias

There is no practical method to determine the actual amount of rainfall compared to what the rain gauge is recording. The methods used to ensure precision will also minimize bias.

5.2.3. Representativeness

The representativeness of the rainfall data will depend on the location of the installation. While it is not always possible to achieve a perfect location, efforts will be made to ensure the rainfall measurements are representative of the actual rain falling on a given area based on a careful consideration of multiple installation location characteristics. Some of the more important factors which influence the representativeness of a gauge are as follows:

- Site the gauge on level ground where possible. Avoid sloping sites.
- Site should have adequate protection from strong winds.
- Site should be free of large obstructions such as buildings and trees.
- Provide suitable ground surface to avoid splashing into the gauge.

It is not anticipated that the rain gauges will be supplied with heaters to melt snow and ice. Therefore, precipitation from snow and ice will not be accurately measured.

5.2.4. Completeness

Completeness will be assessed based on the occurrence of gaps that may occur in the data record for all monitoring equipment. The associated MQO is less than 10 percent of the total data record missing due to equipment malfunctions or other operational problems. Completeness will be ensured through routine maintenance of all monitoring equipment and immediate implementation of corrective actions if problems arise.

5.2.5. Comparability

Standard monitoring procedures, units of measurement, and reporting conventions will be applied to meet the goal of data comparability.

5.3. Measurement Quality Objectives for Discrete Water and Sediment Quality Data

Quality assurance indicators for discrete water and sediment quality data are expressed in terms of precision, bias, representativeness, completeness, and comparability. To ensure data obtained for the RPWS are of comparable quality to those collected through other RSMP monitoring efforts, the specific MQOs that have been identified for this study were generally derived from the *Quality Assurance Project Plan for Status and Trends Monitoring of Small Streams in the Puget Lowlands Ecoregion* (Ecology 2014). These MQOs are described below and summarized in Tables 1 and 2. Note that the term "reporting limit" in this document refers to the practical quantification limit established by the laboratory, not the method detection limit.

5.3.1. Precision

Precision will be assessed by laboratory duplicates, field duplicates, matrix spike/matrix spike duplicates (if required), and laboratory control sample/laboratory control sample duplicates (if performed) (see below, under *Bias*). These will be assessed using relative percent difference (*RPD*) as calculated using the following equation:

$$RPD = \left(\frac{|C_1 - C_2|}{C_1 + C_2} \right) \times 200\%$$

Where: RPD = Relative percent difference

C_1 and C_2 = Concentration values

If either the sample or duplicate sample is at or below the reporting limit the MQO cannot be calculated. *RPD* values exceeding those identified in Tables 1 and 2 will trigger an assessment as to whether there are any problems with laboratory methodology, which might warrant remediation.

5.3.2. Bias

Bias will be assessed based on analyses of method blanks, matrix spikes, matrix spike duplicates, and laboratory control samples (LCS).

Table 1. Measurement Quality Objectives for Water Quality Data.							
Parameter	Analytical Method	Reporting Limit Target	Laboratory Method Blank[a]	Control Standard Recovery	Matrix Spike Recovery[b]	Laboratory Duplicate RPD	Field Duplicate RPD
Laboratory Analysis							
Total suspended solids	SM 2540D	1 mg/L	≤ RL	80–120%	NA	≤ 25%	≤ 25%
Turbidity	SM 2130B	0.5 NTU	≤ RL	90–110%	NA	≤ 25%	≤ 25%
Hardness	EPA 200.7and SM 2340B	0.3 mg/L	≤ RL	85–115%	75–125%	≤ 20%	≤ 20%
Dissolved organic carbon	SM 5310B	1 mg/L	≤ RL	85–115%	75 – 125	≤ 20%	≤ 20%
Fecal coliform bacteria	SM 9222D	1 cfu/100 mL	≤ RL	NA	NA	≤ 35%	≤ 50%
Total phosphorus	SM 4500 P-E	0.005 – 0.01 mg/L	≤ RL	80–120%	75–125%	≤ 20%	≤ 20%
Total nitrogen	SM 4500 N-B	0.025 – 0.1 mg/L	≤ RL	80–120%	75–125%	≤ 20%	≤ 20%
Total/dissolved copper and zinc	EPA 200.8	0.5 µg/L (Cu) 5.0 µg/L (Zn)	≤ RL	85–115%	75–125%	≤ 20%	≤ 20%
Field Analysis							
Dissolved oxygen	Field meter	0.2 mg/L	NA	NA	NA	NA	≤ 10%
Conductivity	Field meter	+1 mS/cm	NA	NA	NA	NA	≤ 10%
Temperature	Field meter	+ 0.2°C	NA	NA	NA	NA	≤ 10%

[a] If criteria is not met, project sample data within 5 times the blank concentration are flagged with a J.

[b] For inorganics, the Contract Laboratory Program (CLP) Functional Guidelines state that the spike recovery limits do not apply when the sample concentration exceeds the spike concentration by a factor of four or more (Ecology 2005).

NA = not applicable.

RL = reporting limit.

RPD = relative percent difference.

Table 2. Measurement Quality Objectives for Sediment Data.

Parameter	Analytical Method	Reporting Limit Target	Laboratory Method Blank[a]	Control Standard Recovery	Surrogate Recovery	Matrix Spike Recovery[b]	Duplicate RPD	Field Duplicate RPD
Total organic carbon	PSEP	0.1%	≤ RL	80–120%	NA	NA	≤ 20%	≤ 35%
Metals (copper and zinc)	EPA 6020	0.5 mg/kg (Cu) 5.0 mg/kg (Zn)	≤ RL	85–115%	NA	75–125%	≤ 20%	≤ 35%
Polycyclic aromatic hydrocarbons	EPA 8270D	70 µg/kg	≤ RL	Lab specified	Lab specified	Lab specified	≤ 40%	≤ 50%
Phthalates	EPA 8270D	70–250 µg/kg	≤ RL	Lab specified	Lab specified	Lab specified	≤ 40%	≤ 50%

[a] If criteria is not met, project sample data within 5 times the blank concentration are flagged with a J.

[b] For inorganics, the Contract Laboratory Program (CLP) Functional Guidelines state that the spike recovery limits do not apply when the sample concentration exceeds the spike concentration by a factor of four or more (Ecology 2005).

NA = not applicable.

RL = reporting limit.

RPD = relative percent difference.

The values for method blanks will not exceed the reporting limit. The acceptable percent recoveries for matrix spikes and LCS are identified for each parameter in Tables 1 and 2. Percent recovery will be calculated using the following equation:

$$\%R = \frac{(S - U)}{C_{sa}} \times 100\%$$

Where:	%R	=	Percent recovery
	S	=	Measured concentration in spike sample
	U	=	Measured concentration in unspiked sample
	C_{sa}	=	Actual concentration of spike added

If the analyte is not detected in the unspiked sample, then a value of zero will be used in the equation.

Percent recovery for LCS will be calculated using the following equation:

$$\%R = \frac{M}{T} \times 100\%$$

Where:	%R	=	Percent recovery
	M	=	Measured value
	T	=	True value

5.3.3. Representativeness

To ensure the representativeness of the collected samples, this project will assess a range of water quality conditions, both seasonally and during periods of base and storm flow. Sample representativeness will be ensured by employing consistent and standard sampling procedures.

5.3.4. Completeness

Completeness will be assessed based on the percentage of specified samples (listed in this QAPP) collected. The completeness goal shall be 90 percent. Completeness for acceptable data is defined as the percentage of acceptable data out of the total amount of data generated. Acceptable data is either data that passes all QC criteria, or data that may not pass all QC criteria but has appropriate corrective actions taken.

5.3.5. Comparability

Standard sampling procedures, analytical methods, units of measurement, and reporting limits will be applied in this study to meet the goal of data comparability. The results will be tabulated in standard spreadsheets to facilitate analysis and comparison with water quality threshold limits (e.g., WAC 173-201A), where appropriate.

5.4. Measurement Quality Objectives for Continuous *In Situ* Water Quality Data

In situ water quality monitoring will include continuous measurements of water temperature and conductivity at individual monitoring locations. These measurements will then be used to determine specific conductance. The MQOs for *in situ* water quality monitoring are defined below.

5.4.1. Precision

The instruments used to measure temperature and conductivity rely on user performed calibrations to ensure maximum accuracy. Before deployment, each data logging instrument will be calibrated with stock conductivity solution according to the manufacturer's instructions. They will then be tested in solutions of known temperature and conductivity to assess precision. The temperature and conductivity of the test solutions will be determined with a recently calibrated handheld instrument with specified accuracy of 0.1°C and +/- 1 percent of the conductivity reading. The test solutions will be room temperature tap water, refrigerated tap water, and room temperature prepared conductivity solution approximately 300 µS.

The MQO for precision for temperature is 0.2°C from the observed reading. The MQO for precision for conductivity is 5 µS or 5 percent of the reading (whichever is greater) from the observed conductivity.

5.4.2. Bias

The bias of the continuous *in situ* water temperature and conductivity readings will be assessed based on comparisons of monitoring equipment readings to an independently measured "true" value. In this case the true value will be derived from manual measurements of temperature and conductivity that are obtained from a hand held instrument reading at the monitoring location. These manual measurements will be made in conjunction with routine visits to each monitoring location (see next section).

If the monitoring equipment is not affected by drift or other operational problems, the difference between the equipment's reading and the manual measurement should be less than the precision specified above. If the instrument readings exceed the precision limits due to instrument "drift" for two consecutive observations, the instrument will be re-calibrated. If precision limits are exceeded after recalibration, a replacement or repair will be made.

5.4.3. Representativeness

The representativeness of the continuous water quality data will be ensured by the proper installation of the monitoring equipment.

5.4.4. Completeness

Completeness will be assessed based on the occurrence of gaps that may occur in the data record for all monitoring equipment. The associated MQO is less than 10 percent of the total data record missing due to equipment malfunctions or other operational problems. Completeness will be ensured through routine maintenance of all monitoring equipment and immediate implementation of corrective actions if problems arise. At some locations, flow may be so low that there is insufficient depth for the water quality instruments to function. These “dry” periods will not be construed as missing record.

5.4.5. Comparability

Standard monitoring procedures, units of measurement, and reporting conventions will be applied to meet the goal of data comparability. The conductivity of water is highly dependent on temperature. In order to make comparisons, conductivity is normally corrected to a chosen reference temperature to give specific conductance. All *in situ* conductivity readings will be converted to specific conductance at 25°C (K25) with the formula:

$$K25 = C / (1 + (1.91/100)*(T-25))$$

Where C is the measured conductivity and T is the measured temperature in degrees Celsius.

5.5. Measurement Quality Objectives for Biological Monitoring

Quality assurance indicators for benthic macroinvertebrates are expressed in terms of visit precision, bias, representativeness, completeness, and comparability. The MQOs that have been identified for this study follow those from Appendix B-1 of the *Quality Assurance Project Plan for Status and Trends Monitoring of Small Streams in the Puget Lowlands Ecoregion* (Ecology 2014). For reference, this appendix is reproduced in Appendix A of this QAPP.

6. EXPERIMENTAL DESIGN

To answer the study question identified in the *Introduction* to this document, the experimental design for the RPWP has two primary components:

- **Status and Trends Monitoring**: routine and continuous measurements of various hydrologic, chemical, physical habitat, and biological indicators of stream health over an extended time frame to quantify improvements in receiving water conditions in response to watershed rehabilitation efforts.

- **Effectiveness Monitoring**: measurements of hydrologic and chemical parameters over a relatively short timeframe to document the effectiveness of specific structural stormwater controls that have been constructed to improve receiving water conditions.

The Status and Trends Monitoring will utilize a "paired watershed" experimental design that will involve the collection of these measurements in seven watersheds categorized as follows:

- Three "Application" watersheds with wadeable lowland streams that are moderately impacted by urbanization and prioritized for rehabilitation efforts.

- Two "Reference" watersheds with relatively pristine wadeable lowland streams that do not require rehabilitation.

- Two "Control" watersheds with significantly impacted wadeable lowland streams by urbanization that are not currently targeted for rehabilitation pursuant to the WMP.

As described below, fixed monitoring stations will be established in each watershed for monitoring various indicators of stream health. Due to the scale of the RPWP and the anticipated lag between applying stormwater controls and resultant improvements in receiving water conditions, quantifying a cause and effect relationship between these events may take many years. Therefore, monitoring at the fixed monitoring stations will occur over an anticipated 10-year timeframe. Furthermore, because the effectiveness of watershed rehabilitation practices to be implemented in the Application watersheds (e.g., stormwater retrofits, in-stream habitat improvements, and programmatic practices) may vary for different types of receiving water impairments, a broad suite of indicators for assessing potential improvements will be monitored within the following categories: hydrologic, water quality, physical habitat, sediment quality, and biological. The trend of interest will be evidence that receiving water conditions are improving based on one or more of these indicators in the Application watersheds while conditions in the Reference and Control watersheds remain relatively static.

To implement the Effectiveness Monitoring, roving stations will be established in association with specific structural stormwater controls to verify they are constructed properly and performing as designed. The roving stations will be moved from one year to the next once a facility's effectiveness has been verified and new facilities come online. These sites will be essential to the study, as the explanation of the signal observed within the receiving waters must be tied to the efficacy of rehabilitation efforts within the watersheds.

The Application, Reference, and Control watersheds that have been selected for the RPWS are described in the following subsection. Subsequent subsections then provide more detailed information on the Status and Trends Monitoring and Effectiveness Monitoring, respectively, including the monitoring stations, measurement frequency, indicators, and data analysis methods where applicable.

6.1. Study Watersheds

As described above, monitoring for the RPWS will occur in a total of seven watersheds: three Application watersheds, two Reference watersheds, and two Control watersheds. Table 3 identifies the name, predominant land use/cover, and size of each watershed; the location of all the watersheds is shown in Figure 1. A detailed summary of conditions within each watershed is also provided below with information on planned rehabilitation efforts in the Application watersheds as applicable.

Table 3. Application, Reference, and Control Watersheds for the Redmond Paired Watershed Study.

Watershed Name	Watershed Type	Dominant Land Use/Cover	Watershed Total Area (acres)	Watershed Areas inside Redmond (acres)
Evans Creek Tributary 108	Application	Residential	397	NA[a]
Monticello Creek	Application	Residential/Commercial	345	264
Tosh Creek	Application	Residential/Commercial	299	276
Colin Creek	Reference	Forest	1,990	90
Seidel Creek	Reference	Forest	1,188	615
Country Creek	Control	Residential/Commercial	212	212
Tyler's Creek	Control	Residential/Commercial	168	167

[a] Entire watershed is located within King County's jurisdiction boundaries.

6.1.1. Application Watersheds

The watersheds for Evans Creek Tributary 108, Monticello Creek, and Tosh Creek were selected as Application watersheds for the RPWS. Conditions within each of these watersheds are described in the following subsections.

6.1.1.1. Evans Creek Tributary 108 Watershed

Evans Creek Tributary 108 is located in the Northeast Quarter, Sections 4, 5, 8, and 9, Township 25, Range 6 East WM, in King County (Figures 1 and 2). Evans Creek Tributary 108 is within the Bear-Evans Creek watershed. The watershed is approximately 397 acres with dominantly Alderwood and Everett soils; land cover in the watershed is approximately 37 percent forest and 16 percent impervious area. The Evans Creek Tributary 108 watershed has experienced a significant amount of residential development that occurred before adequate stormwater controls were required on new development, which has degraded the tributary's water quality/health and contributed to documented degradation of Evans Creek. Currently, average median benthic index of biotic integrity (B-IBI) scores for three stations in the watershed range from 28 to 31, which indicates the stream's health is on the low side of "fair."

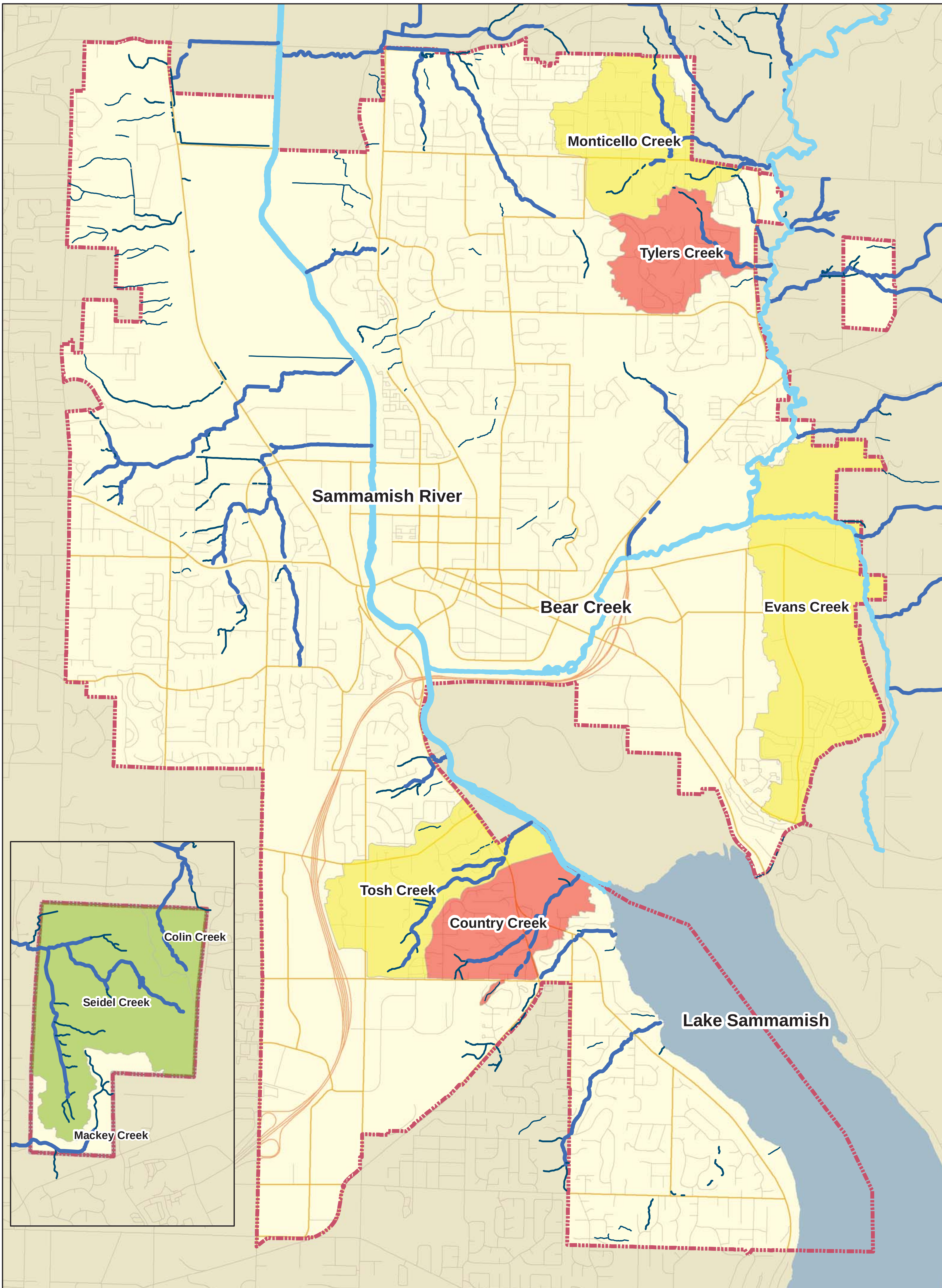


Figure 1 - Application, Reference, and Control Watersheds

City of Redmond, Washington
06/18/2015

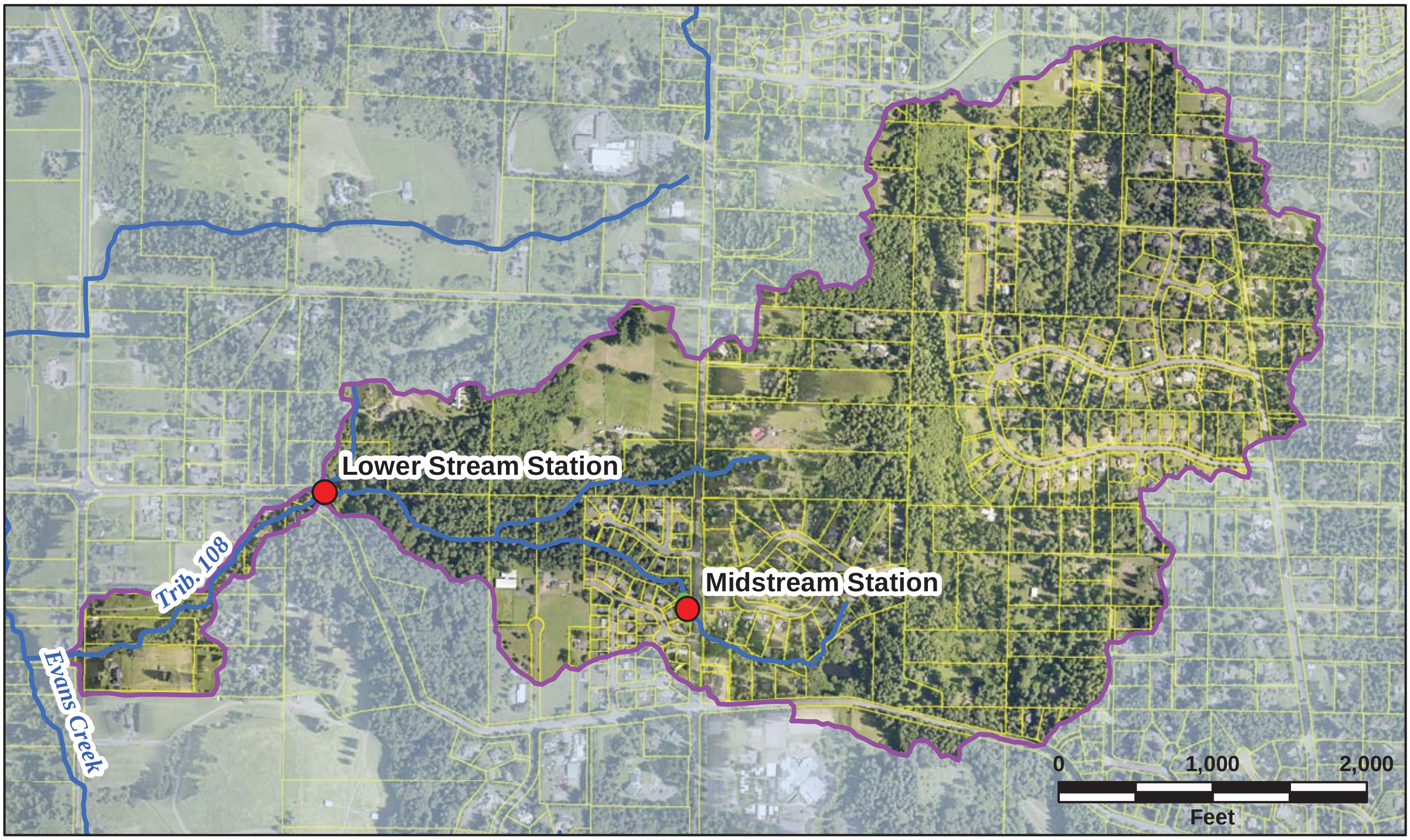
0 0.25 0.5 1 1.5 Miles

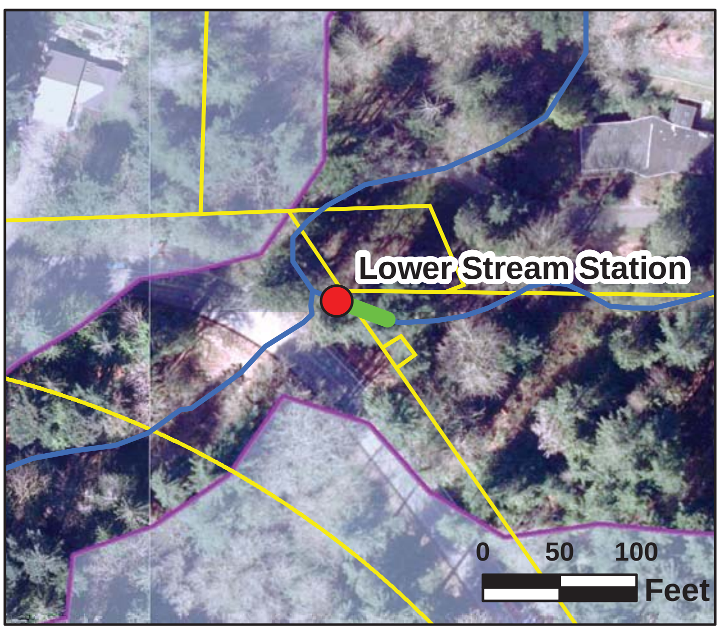
Legend

- Class I Stream
- Class II Stream
- Class III Stream
- Class IV Stream
- City Limits
- Reference Watersheds
- Application Watersheds
- Control Watersheds

City of Redmond WASHINGTON

Disclaimer: This map is created and maintained by the Natural Resources Division of the City of Redmond, Washington, for reference purposes only. The City makes no guarantee as to the accuracy or completeness of the features shown on this map.





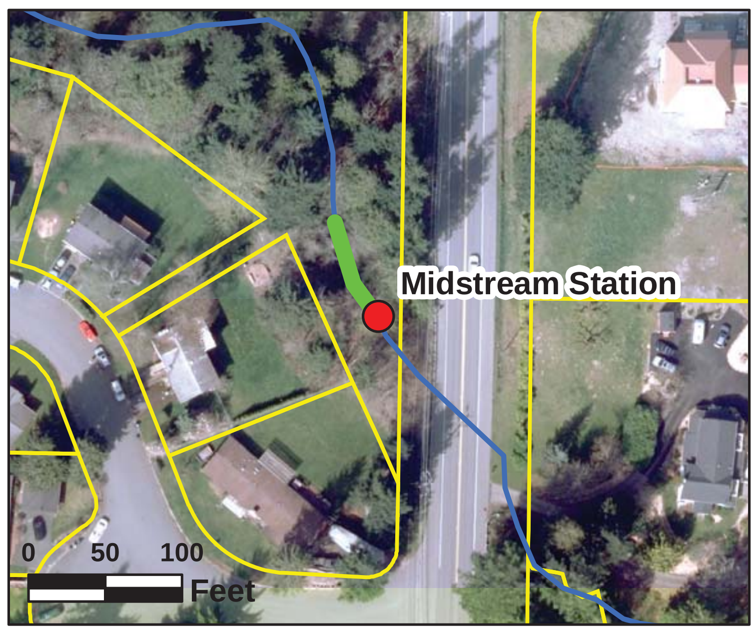


Figure 2 - Evans Trib. 108 Paired Basin Study Monitoring Locations

King County, Washington

Oct. 20, 2015

King County
Department of Natural Resources and Parks
Water and Land Resources Division

- Flow and WQ Monitoring
- Habitat, Biological, and Sediment Monitoring
- Streams and Rivers
- King County Parcels
- Basin Boundary

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A recent habitat investigation found that Evans Creek Tributary 108 is lacking in riparian corridor, channel bed stability, large woody debris and riparian vegetation (Berge and Lantz 2014). However, the presence of chinook has been documented. The tributary is thought to also support coho and cutthroat trout although the habitat may only be suitable for spawning in some reaches.

In September 2015, King County received a draft water quality funding agreement through the Stormwater Financial Assistance Program to design and construct two stormwater retrofit detention vaults in a residential area within the Evans Creek Tributary 108 watershed. These retrofits will be designed to meet performance standards that are identified in the *Stormwater Management Manual for Western Washington* for on-site stormwater management and flow control. The goal of these retrofits is to improve B-IBI scores in the watershed to a "good" condition or better (i.e., 38 to 50).

6.1.1.2. Monticello Creek Watershed

Monticello Creek is a right bank tributary of Bear Creek (Figure 1). The main stem originates in King County, north of the city boundary, and flows south and east. A right bank tributary joins the main stem from the west within the city, and another right bank tributary enters the stream from the south in King County. The headwaters of Monticello Creek are in King County and are dominated by large lots and pastures. The northernmost reach within the city limits flows through Northeast Redmond Neighborhood Park, a 5-acre wooded parcel. The mouth of the creek is located in the Middle Bear Creek Natural Area. The total stream length is 9,878 linear feet; 6,125 linear feet are within the city, of which 3,170 linear feet are designated as a Class II stream. An average of 3.5 stormwater outfalls can be found per 1,000 feet along the creek.

The Monticello Creek watershed is 345 acres; 264 acres are within the city limits. Land use is predominantly single-family residential, parks and undeveloped land. There is a relatively low effective impervious surface (EIS) area within the city portion of the watershed (23 percent). Land cover is mostly landscaping (Figure 3). The watershed is experiencing significant redevelopment, converting low density (1- to 5-acre lots) to high density residential development (less than 0.25-acre lots). Most of the development is vested to current flow control standards, meaning vaults or ponds designed to mimic forested runoff conditions for storms ranging from one-half the 2-year through the 50-year storm events.

Ecology included a segment of Monticello Creek on the 2012 Section 303(d) list as a Category 5 waterbody due to high temperature. Monticello Creek also has an Ecology drafted and US Environmental Protection Agency approved Total Maximum Daily Load (TMDL) study and Implementation Plan to address impairment from fecal coliform bacteria. The listed segment is located in King County from the east boundary of the city near 178th Street downstream to the mouth (Ecology 2012). The median B-IBI score for Monticello Creek based on data collected by the City as part of the Annual Benthic Monitoring study (2005 through 2010) is 36, indicating "fair" conditions (PSSB 2011). Next to the scores for Mackey Creek, these are the highest B-IBI scores on any City stream outside the Redmond Watershed Preserve Park, and above the B-IBI score threshold indicative of supporting self-sustaining salmonid populations.

Riparian buffers are relatively dense in the upper stream channel, with a narrow band of trees on both sides of the channel. Riparian buffers on the main stem downstream, along Avondale Road NE, are modest. Riparian buffers on the west tributary lack tree cover in most areas (Washington Trout 2005).

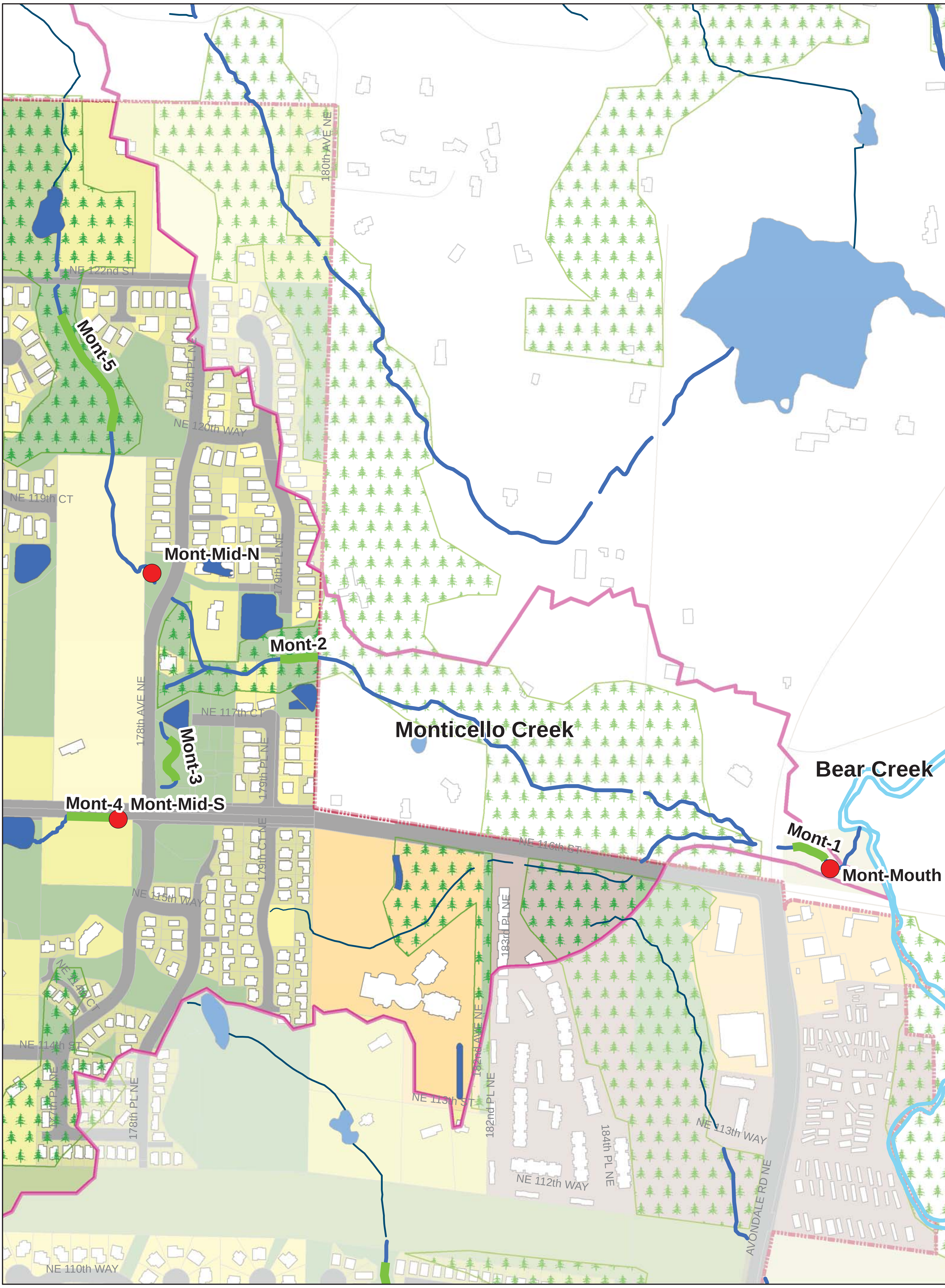

Figure 3. Monticello Creek Paired Basin Study Monitoring Locations

City of Redmond, Washington

6/25/2015

0 0.0375 0.075 0.15 Miles

Legend

- Class I Stream
- Class II Stream
- Class III Stream
- Class IV Stream
- Ponds
- City Limits
- Watershed Boundary
- Commercial
- Industrial
- Multifamily
- Park / Undeveloped
- Public ROW
- Single Family HighDensity
- Single Family Low Density
- Single Family Medium Density
- Single Family Rural Density
- Flow & WQ Monitoring
- Habitat, Sediment & Biological Monitoring

There are five full fish passage barriers on the main stem and west tributary and two other partial barriers. In addition, steep gradients and unknown channel conditions between the city limits and Avondale Road NE may create fish passage issues. Fish passage through the culvert under Avondale Road NE is questionable. Significant salmonid use has been documented in the lower 2,400 feet of the main stem (Washington Trout 2005).

The City has recently initiated development of the Monticello Creek Watershed Restoration Plan. This plan will provide detailed engineering analysis to identify a comprehensive rehabilitation strategy for Monticello Creek. With partial funding obtained through a National Estuaries Program grant, King County and the City have partnered to develop this plan. After its completion in 2017, the plan will identify all projects required to fully rehabilitate the creek and provide preliminary designs for the three highest ranked projects in terms of their overall benefit. It is anticipated that these projects will not be constructed and operational in the Monticello watershed until 2020. Because the benefits of these structural stormwater controls will not be realized in the watershed for some time, the City is targeted this watershed for non-structural stormwater controls (such as increased street sweeping, public outreach, business inspections, municipal best management practices, etc.) in the near-term. Furthermore, the significant pace of redevelopment in the watershed described above is also triggering requirements for implementing structural stormwater controls at the individual project site scale. Monitoring conducted through the RPWS will initially be performed to evaluate potential improvements to stream health from these later rehabilitation strategies until the structural stormwater controls from the Monticello Creek Watershed Restoration Plan come online.

6.1.1.3. Tosh Creek Watershed

Tosh Creek is located in the southwest portion of the city (Figure 1). Tosh Creek enters the left bank of the Sammamish River just upstream of the Willowmoor weir at the boundary of Marymoor Park. The upper reaches flow through residential areas. The majority of the valley reaches are in good condition with wide forested buffers. Numerous seeps and small tributaries help maintain consistent base flows. The channel is straightened and ditched in the reach downstream of West Lake Sammamish Parkway (WLSP). The total stream length is 10,370 linear feet, of which 7,215 linear feet is designated as a Class II stream. The stormwater influence in the Tosh Creek watershed is not as significant as in some of the adjacent watersheds because some of the developed commercial area in the upper reaches is piped to Villa Marina Creek via a stormwater trunk line. An average of 0.8 stormwater outfalls can be found per 1,000 feet along the creek.

The Tosh Creek watershed within the city is 276 acres; the entire watershed is 299 acres. The remainder of the watershed is in unincorporated King County. The Tosh Creek watershed is highly developed with predominantly single-family dwellings (see Figure 4). Within the watershed, approximately 39 percent of the area can be considered EIS. Land cover is divided evenly between landscaped yards and impervious surface (39 percent each), with minor amounts of forest and pasture.

Ecology included a segment of Tosh Creek upstream of WLSP on the 2012 Section 303(d) list as a Category 5 waterbody due to impairment from fecal coliform bacteria (Ecology 2012). The median B-IBI score for Tosh Creek based on data collected by the City as part of the Annual

Benthic Monitoring study (2008, 2009, and 2010) is 19, indicating poor conditions (PSSB 2011). This rating may be misleading because the samplers inadvertently chose locations with some of the poorest water quality on the stream (R. Dane, personal communication, December 5, 2011). The City expects higher B-IBI scores for Tosh Creek in future sampling efforts as a number of other indicators suggest this stream is relatively healthy.

Riparian buffers are generally broad and mostly in good condition with abundant trees in the valley wall reaches. In the upper reaches through residential areas, the riparian buffers are narrower and mature trees are less abundant. However, the steep valley slopes in the upper reaches provide a natural buffer against further development and there are sufficient deciduous trees to provide shade (Washington Trout 2005). There is a minor amount of development (4 percent) within the 30-foot stream buffer.

There are three fish passage barriers on Tosh Creek, and one former barrier that has been removed for fish passage. One of the barriers on a left bank tributary near WLSP is a complete barrier. The other two are partial barriers on the main stem at WLSP. Significant salmonid use has been documented in Tosh Creek as far upstream as the south fork at the headwaters. Abundant gravel in the lower reach makes this stream a potentially important coho spawning stream (Washington Trout 2005).

In February 2015, the City completed the Tosh Creek Watershed Restoration Plan which identifies a comprehensive rehabilitation strategy for Tosh Creek based on modeling and engineering analyses (City of Redmond et al. 2015). The plan also provides preliminary designs for the three highest ranked projects in terms of their overall benefit to the Creek. One of these projects recently received $6,000,000 in funding through Ecology's Stormwater Financial Assistance Program (Fiscal Year 2016) and will involve the construction of a flow control vault to stabilize erosive flows in Tosh Creek and improve water quality. This vault is expected to be operational in 2016. Monitoring conducted through the RPWS will initially be performed to evaluate potential improvements to stream health from this project. For example, midpoint monitoring stations in the watershed (see descriptions below) were specifically selected to evaluate potential improvements to stream health at locations immediately downstream of the vault. With supplementation of grant and loan funding from Ecology, Redmond could potentially build all three top priority projects within 6 years (i.e., by 2021).

6.1.2. Reference Watersheds

The watersheds for Colin Creek and Seidel Creek were selected as Reference watersheds for the RPWS. Conditions within each of these watersheds are described in the following subsections.

6.1.2.1. Colin Creek Watershed

Colin Creek has its headwaters in the City-owned Redmond Watershed Preserve Park (Figure 1). The Redmond Watershed Preserve Park was purchased in 1926 for a domestic water supply (City of Redmond 2011). It occupies an 800-acre parcel of land that is outside the city's contiguous limits but within the City's jurisdiction. In addition to Colin Creek, two other creeks within the city (Mackey Creek and Seidel Creek) also have their headwaters in the park. Because the City has prohibited development within the Redmond Watershed Preserve Park, it is considered one of the most pristine lowland forests in King County (Luchetti, personal communication, 2011).

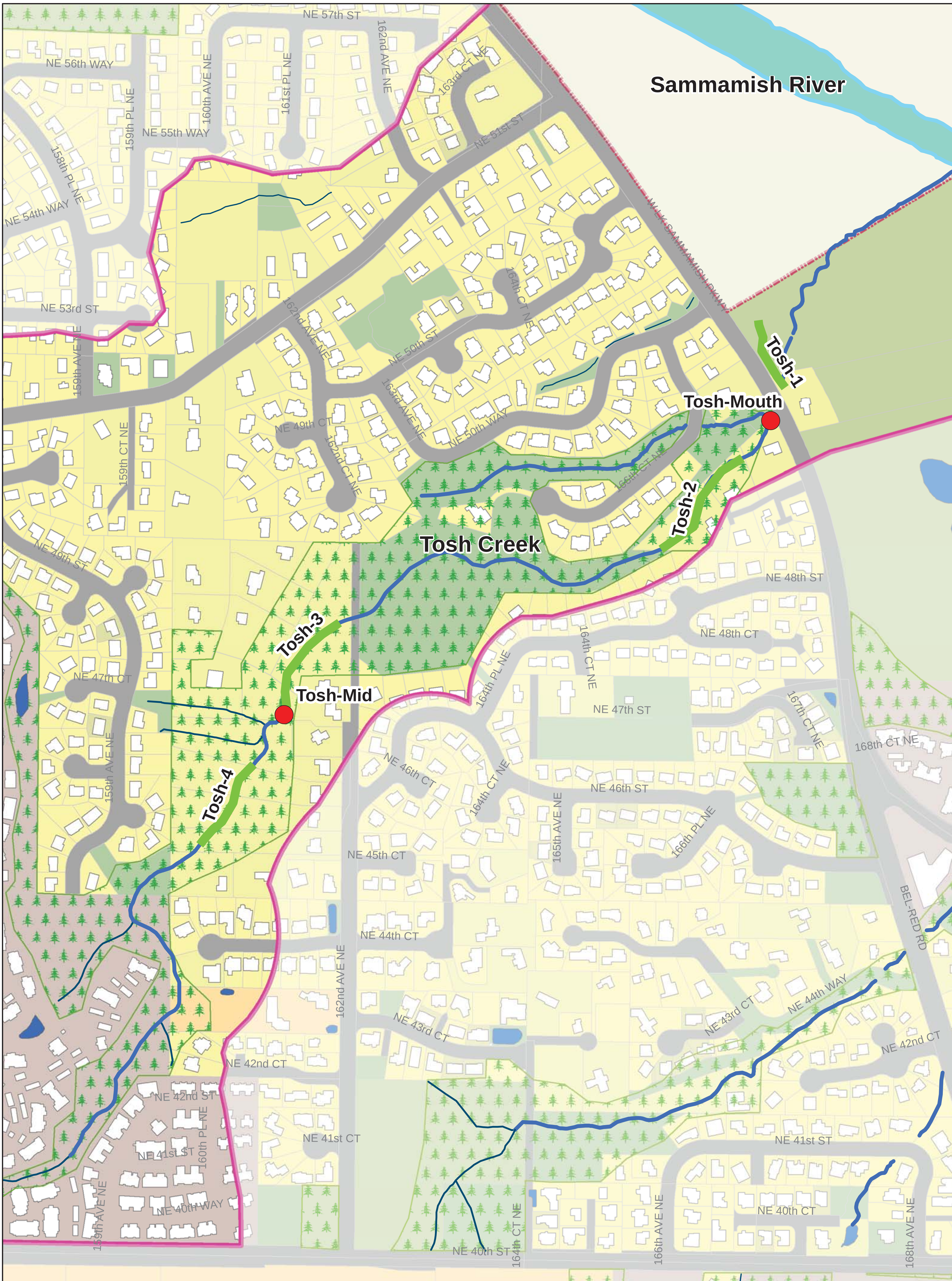

Figure 4. Tosh Creek Paired Basin Study Monitoring Locations

City of Redmond, Washington

11/22/2013

CityofRedmond
WASHINGTON

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Colin Creek flows north out of a large wetland through the Redmond Watershed Preserve Park, enters Welcome Lake, exits the lake over a spillway with a fishway of questionable function, and then enters a steep ravine. Colin Creek then joins Struve Creek, a left bank tributary of Bear Creek. Only 2,260 linear feet, out of a total of 29,265 linear feet, are located within city boundaries. The entire stream within the city is designated as a Class II stream. No stormwater outfalls exist along the creek.

The watershed within the city limits is 90 acres, and is 100 percent comprised of parks and undeveloped land (see Figure 5). It consists of dense stands of mature conifer forest, which provide good cover for the stream. The channel has substantial amounts of large woody debris that contribute to a diverse instream habitat.

Colin Creek is not listed on the 2008 Section 303(d) list of threatened and impaired waterbodies (Ecology 2012). B-IBI sampling was not performed by the City on Colin Creek; however, King County conducted sampling in this watershed from 1997 through 2010. The median B-IBI score for Colin Creek is 28; indicating "fair" conditions (PSSB 2011).

Dense stands of second generation forest flank both sides of Colin creek as it meanders through the Redmond Watershed Preserve Park, north into unincorporated King County. The riparian zone is one of the most pristine in Redmond with 97 percent forest cover. The system is complex with thick vegetation providing shade for the majority of the channel. Very few invasive species are found within Colin Creek's buffers, or within the portion of its watershed located in Redmond. A large wetland complex is present in the headwaters that feed both Colin and Seidel Creek.

Neither Washington Trout or City crews officially surveyed Colin Creek for fish presence, but there are anecdotal reports of numerous cutthroat trout present. WDFW maps show coho spawning in the reach below Welcome Lake (WDFW 2011). There is one fish passage barrier within the watershed preserve.

6.1.2.2. Seidel Creek Watershed

Seidel Creek has its headwaters in the Redmond Watershed Preserve Park (Figure 1). The East Fork of Seidel Creek joins the main stem within the park. The topography at the headwaters is relatively flat with numerous wetlands, beaver dams, and ponds. The headwaters for Seidel Creek are connected with the same large wetland that is the headwater for Colin Creek. The stream flows through rural King County pasture and wood lots before it enters the left bank of Bear Creek just east of the city limits. The entire stream length is 31,121 linear feet (of which 22,220 linear feet are located within the city and 8,901 linear feet are outside the city). Approximately 13,260 linear feet of Seidel Creek within the city is designated as a Class II stream. There are no stormwater outfalls mapped along the creek.

The Seidel Creek watershed comprises 615 acres and land use is considered 100 percent parks and undeveloped land. Land cover is mostly forest (see Figure 6), and the watershed is generally undisturbed. The eastern two-thirds of the watershed was logged in the 1930s, and the western third was logged during World War II. The forest has naturally regenerated since then, being protected initially as a municipal water supply, and more recently as a natural park, with a focus on protecting its wide variety of habitats, including ponds and wetlands.

In general, water quality in Seidel Creek is good due to the low level of development. However, Ecology included the lowest 0.1 mile, in unincorporated King County, on the 2012 Section 303(d) list as a Category 5 waterbody due to high temperature (Ecology 2012). This reach is also listed as Category 2 for dissolved oxygen. B-IBI sampling was not performed by the City on Seidel Creek; however, King County conducted B-IBI sampling in the watershed from 2002 through 2010. Their median B-IBI score for Seidel Creek was 32; indicating "fair" conditions (PSSB 2011).

All reaches of Seidel Creek are flanked with densely wooded second growth forest. Its headwater is a large wetland complex that feeds both Seidel and Colin Creek. The upper reaches contribute to a manmade water impoundment that is flanked by wetlands and dense forest. Below the dam is also heavily wooded with some prairie within the buffer. The entire portion of Seidel Creek's Watershed within Redmond is within the Redmond Watershed Preserve and is characterized by 83 percent tree cover in the riparian zone.

A low dam backs up water below the confluence with the East Fork of Seidel Creek to create a reservoir. The reservoir was originally used as a municipal water supply but due to water quality issues was abandoned in 1953. However, this dam now represents a complete fish passage barrier. There are two other barriers upstream on the East Fork, and one partial barrier (a concrete flume) upstream on the main stem. There are large numbers of resident salmonids that use Seidel Creek, but no anadromous fish due to the fish passage barriers. This issue is being addressed with a fish passage project. No surveys of Seidel Creek were done by Washington Trout.

6.1.3. Control Watersheds

The watersheds for Country Creek and Tyler's Creek were selected as Control watersheds for the RPWS. Conditions within each of these watersheds are described in the following subsections.

6.1.3.1. Country Creek Watershed

Country Creek is located in the southwest portion of the city (Figure 1). Country Creek enters the Sammamish River near the outlet of Lake Sammamish approximately 1,500 feet upstream of the weir. The lower reach of Country Creek on the valley floor flows through a seasonally flooded and wooded wetland complex that is backwatered from the lake. Closer to WLSP, the stream flows through stands of dense blackberry and reed canarygrass with little native vegetation. Upstream of the valley floor, the channel runs through residential neighborhoods. The headwaters of Country Creek are located in Cascade View Neighborhood Park where several springs feed the modest flow in the upper reach. A right bank tributary enters the stream just upstream of WLSP. The total stream length is 7,210 feet of which 5,000 feet are designated as a Class II stream. An average of 1.6 stormwater outfalls can be found per 1,000 feet along the creek.

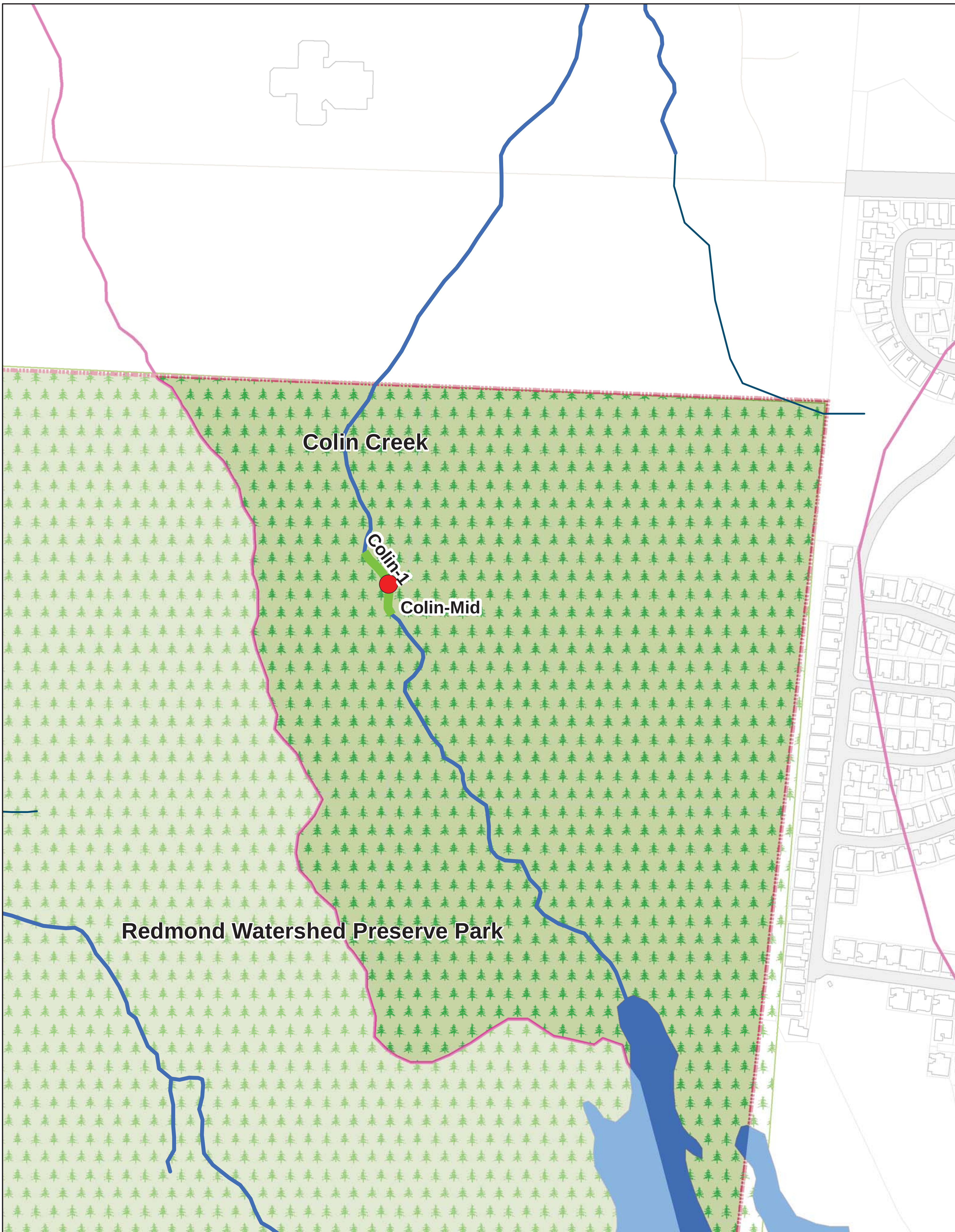

Figure 5 - Colin Creek Paired Basin Study Monitoring Locations

City of Redmond, Washington

6/25/2015

N

0 0.0325 0.065 0.13 Miles

Legend

- Class I Stream
- Class II Stream
- Class III Stream
- Class IV Stream
- Ponds
- City Limits
- Watershed Boundary
- Commercial
- Industrial
- Multifamily
- Park / Undeveloped
- Public ROW
- Single Family HighDensity
- Single Family Low Density
- Single Family Medium Density
- Single Family Rural Density
- Flow & WQ Monitoring
- Habitat, sediment & Biological Monitoring

City of Redmond WASHINGTON

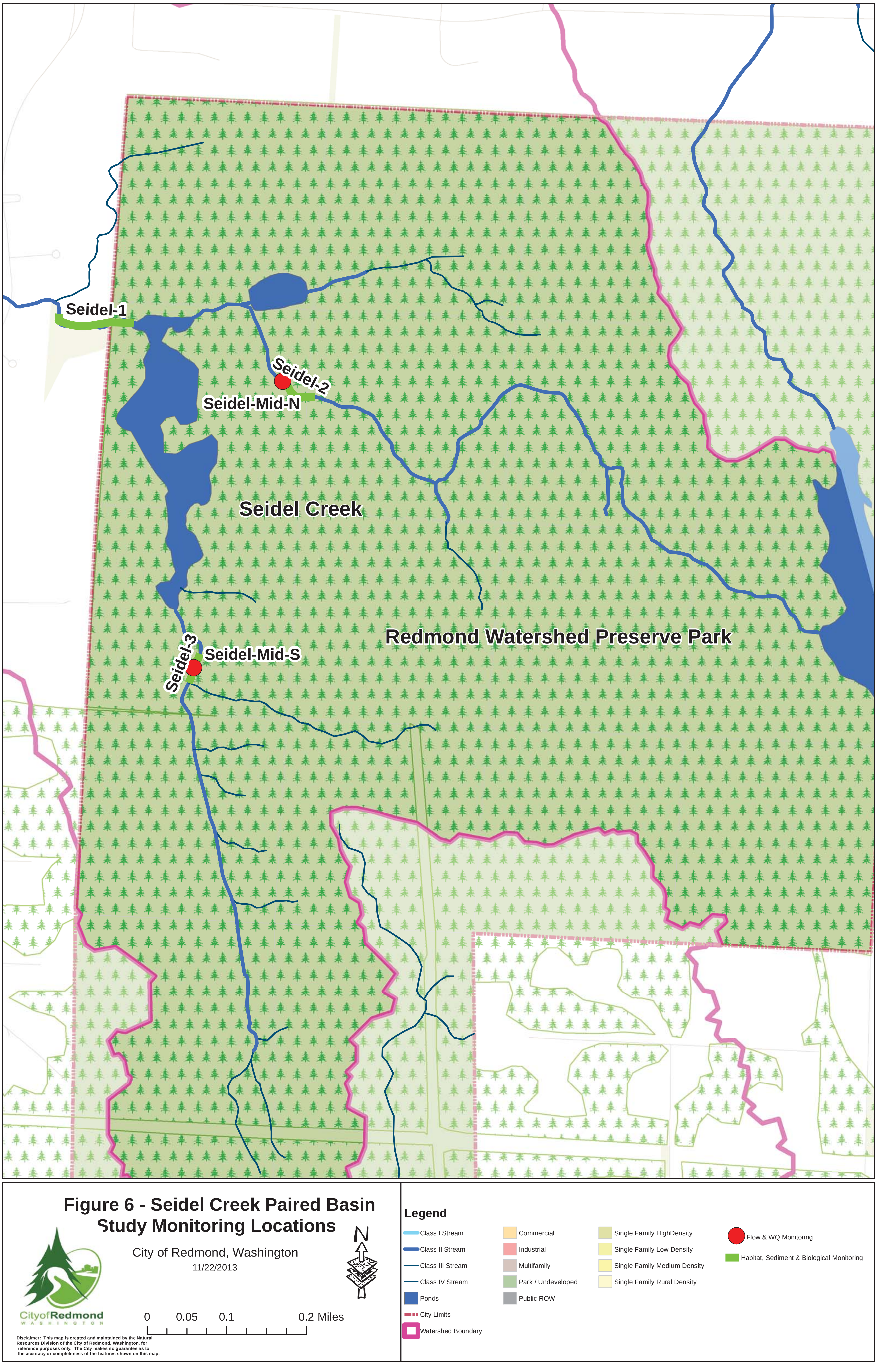

Figure 6 - Seidel Creek Paired Basin Study Monitoring Locations

City of Redmond, Washington

11/22/2013

City of Redmond WASHINGTON

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The Country Creek watershed consists of 212 acres located entirely within city boundaries. The lower 800 feet of the stream channel flows through King County-owned open space property. Land use is predominantly single-family dwellings (see Figure 7). The EIS area in the watershed is 22 percent. Land cover is predominantly landscaped yards.

Country Creek is listed as a Category 5 waterbody on Ecology's 2012 Section 303(d) list due to impairment from fecal coliform bacteria (Ecology 2012). The median B-IBI score for Country Creek is 20, indicating "poor" conditions (PSSB 2011).

Riparian buffers are narrow in the middle reaches near WLSP, but broad in the upper reach with thick vegetation and mature conifers. On average, development encroaches on 17 percent of the 30 foot riparian buffer.

There are 10 fish passage barriers on Country Creek and the right bank tributary; six are complete barriers and four are partial barriers. The undersized culvert under WLSP is a partial barrier. The first complete barrier is on the main stem upstream of the right bank tributary. There has been no observed salmonid use in Country Creek based on surveys by Washington Trout crews (Washington Trout 2005), likely due to these multiple barriers.

6.1.3.2. Tyler's Creek Watershed

Tyler's Creek is a right bank tributary of Bear Creek. It originates west of Avondale Road NE in the northeast portion of the city and flows south and east, joining Bear Creek just east of the city limits (Figure 1). Sediment loads from the steep channel on the hillside and thick vegetation combine to create a braided channel through the wetland at the base of the valley wall. The total stream length is 3,417 linear feet; 2,990 linear feet are within the city, of which 2,020 linear feet are designated as a Class II stream. An average of three stormwater outfalls can be found per 1,000 feet along the creek.

The Tyler's Creek watershed is 168 acres, and 167 acres are located in the city. Land use is predominantly single-family residential (Figure 8). There are large tracts of undeveloped land in the headwaters. Land cover is primarily landscaping (43 percent) and impervious surface (35 percent). There are a relatively high number of stormwater outfalls along Tyler's Creek (three outfalls per 1,000 linear feet).

Ecology included all of Tyler's Creek on the 2008 Section 303(d) list as a Category 5 waterbody due to high temperature (Ecology 2012). The median B IBI score for Tyler's Creek based on data collected by the City as part of the Annual Benthic Monitoring study (2005, 2006, and 2007) is 20, indicating poor conditions (PSSB 2011). These samples were collected from two sites west of Avondale Road NE.

Riparian buffers are in fair condition, with only 10 percent encroachment within 30 feet of the stream and well-established riparian plantings. Most of the buffers are protected within Native Growth Protection Easements (NGPEs) or tracts within the city limits. However, the protected easements are much narrower than present standards. Some upper reaches of the stream channel were rehabilitated and several fish barriers corrected, but the habitat is poor quality having uniformly sized rock, plastic fabric, and large riprap weirs.

There are two partial fish passage barriers on Tyler's Creek: a baffled culvert under Avondale Road NE and a second barrier upstream. There are two other potential barriers, one at the mouth and one near the headwaters. No significant salmonid use has been documented in Tyler's Creek, although Washington Trout crews did document salmonids upstream of Avondale Road NE (Washington Trout 2005).

6.2. Status and Trends Monitoring

This section describes the monitoring stations, measurement frequency, indicators, and data analysis methods that will be used for the Status and Trends Monitoring component of the RPWS. This information is organized under separate subsections for the following monitoring categories: hydrologic, water quality, physical habitat, sediment quality, and biological. The specific indicators of stream health that will be evaluated in these categories are also summarized in Table 4 with their associated measurement frequency.

Table 4. Indicators of Stream Health for the Redmond Paired Watershed Study.

Indicator	Measurement Frequency
Hydrology Monitoring	
• Flow	• Continuous
• High pulse count • High pulse frequency • High pulse count duration • High pulse count range • Low pulse count • Low pulse count frequency • Low pulse count duration • Low pulse count range • Richards-Baker (RB) flashiness index • TQ Mean • Storm volume • Base volume • Total flow volume	• Post-processed from continuous flow measurements
Water Quality Monitoring	
• Total suspended solids • Turbidity • Conductivity • Hardness • Dissolved organic carbon • Fecal coliform bacteria • Total phosphorus • Total nitrogen • Copper, total and dissolved • Zinc, total and dissolved	• Twelve grab samples collected annually during storm events (three each quarter) • Four grab samples collected annually during base flow (one each quarter)
• Temperature • Conductivity	• Continuous
Physical Habitat Monitoring	
• Bank-full width • Wetted width • Cumulative bar width • Bank-full depth • Wetted depth • Substrate class	• Annually

Table 4 (continued). Indicators of Stream Health for the Redmond Paired Watershed Study.

Indicator	Measurement Frequency
Physical Habitat Monitoring (continued)	
• Substrate embeddedness • Fish cover • Thalweg depth • Presence of bars • Presence of edge pools • Main channel slope and bearing • Large woody debris tally, including notation of diameter, length, category, zone, and key-pieces • Evidence of vegetation colonization below OHWM that persists more than 1 year • Slopes vegetated over the crown of the bank • Presence of desirable native plant species • Presence of invasive plant species • Presence of good-habitat indicator liverwort species • Channel incision or aggradation • Channel widening, narrowing, or migration • Changes in channel slope, sinuousity, and/or bed-form type	• Annually
Sediment Quality Monitoring	
• Total organic carbon • Copper • Zinc • Polycyclic aromatic hydrocarbons • Phthalates	• Annually
Biological Monitoring	
• Benthic macroinvertebrates	• Annually
• Benthic Index of Biotic Integrity • Taxa Richness • Ephemeroptera Richness • Plecoptera Richness • Trichoptera Richness • Clinger Percent • Long-Lived Richness • Intolerant Richness • Percent Dominant • Predator Percent • Tolerant Percent	• Post-processed from benthic macroinvertebrate data

OHWM: ordinary high water mark.

6.2.1. Hydrologic Monitoring

A total of 14 fixed monitoring stations will be established to facilitate hydrologic monitoring in each of the study watersheds. Per the recommendations from the literature review (see *Background* section), monitoring stations were established at the mouth and a mid-point location within each watershed where feasible given the watershed's size. The specific monitoring stations established based on this goal are as follows:

Application Watersheds

- Evans Creek Tributary 108: two stations designated Lower Stream Station (EVALSS) and Midstream Station (EVAMS), respectively (see locations in Figure 2).
- Monticello Creek: one station at the mouth designated Mont-Mouth (MONM); one station at the approximate midpoint of the watershed on north tributary designated Mont–Mid-N (MONMN); and one station at the approximate midpoint of the watershed on south tributary designated Mont–Mid-S (MONMS) (see locations in Figure 3).
- Tosh Creek: one station at the mouth designated Tosh-Mouth (TOSMO); and one station at the approximate midpoint of the watershed designated Tosh-Mid (TOSMI) (see locations in Figure 4).

Reference Watersheds

- Colin Creek: one station at the approximate midpoint of the watershed designated Colin-Mid (COLM) (see locations in Figure 5).
- Seidel Creek: one station at the approximate midpoint of the watershed on north tributary designated Seidel-Mid-N (SEIMN); one station at the approximate midpoint of the watershed on south tributary designated Seidel-Mid-S (SEIMS) (see locations in Figure 6).

Control Watersheds

- Country Creek: one station at the mouth designated Country-Mouth (COUMO); and one station at the approximate midpoint of the watershed designated Country-Mid (COUMI) (see locations in Figure 7).
- Tyler's Creek: one station at the mouth designated Tylers-Mouth (TYLMO); and one station at the approximate midpoint of the watershed designated Tylers-Mid (TYLMI) (see locations in Figure 8).

Continuous flow monitoring will occur at all 14 monitoring stations for the duration of the RPWS. Data from the continuous flow monitoring will be processed to calculate the following indicators for evaluating hydrologic impacts from urban development as described in DeGasperi et al. (2009):

- **High pulse count**: occurrence of daily average flows that are equal to or greater than a threshold set at twice (two times) the long-term daily average flow rate.
- **High pulse frequency**: number of days each water year that discrete high flow pulses occur.

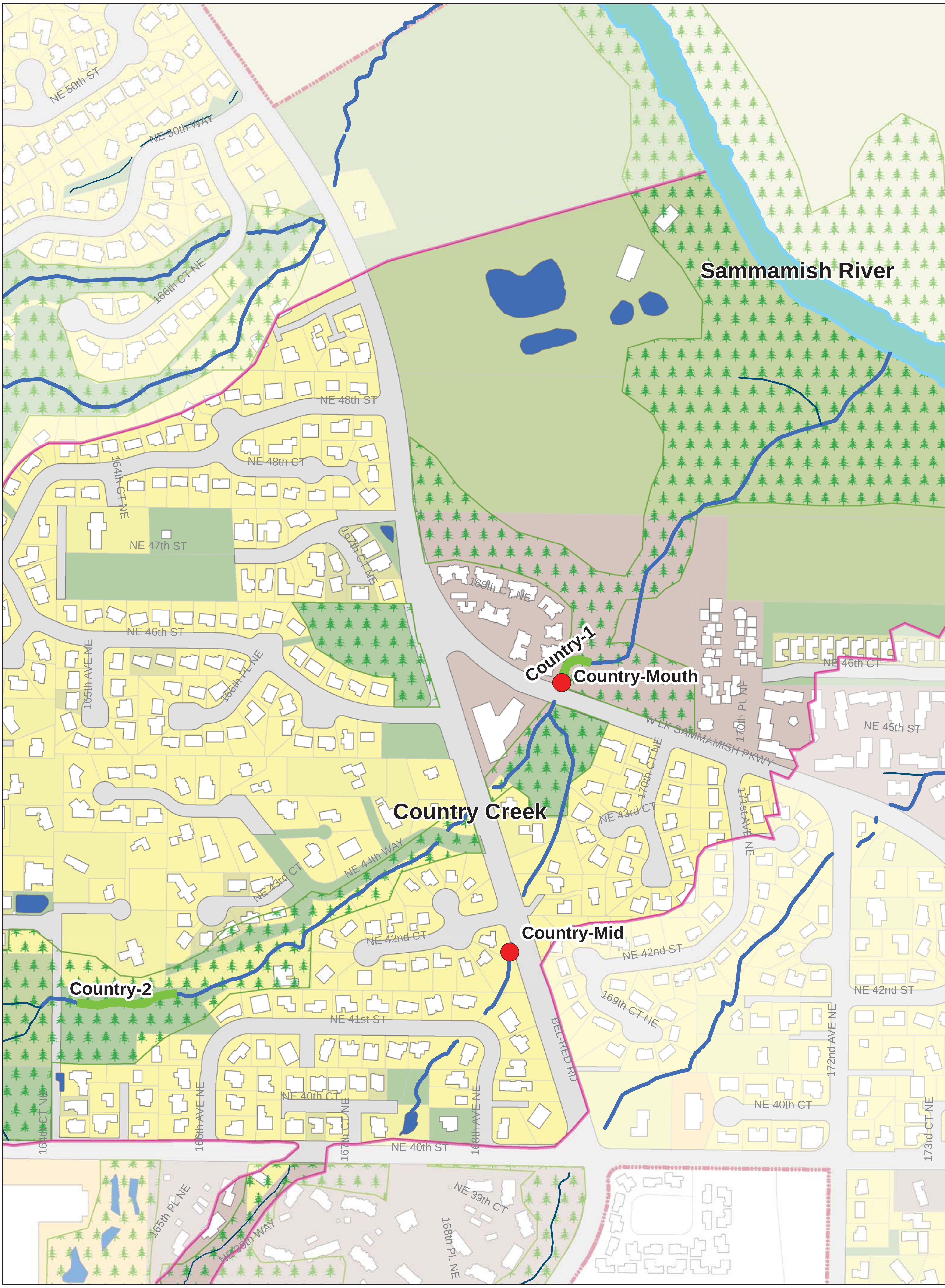

Figure 7 - Country Creek Paired Basin Study Monitoring Locations

City of Redmond, Washington

6/25/2015

0 0.0325 0.065 0.13 Miles

N

Legend

- Class I Stream
- Class II Stream
- Class III Stream
- Class IV Stream
- Ponds
- City Limits
- Watershed Boundary
- Commercial
- Industrial
- Multifamily
- Park / Undeveloped
- Public ROW
- Single Family HighDensity
- Single Family Low Density
- Single Family Medium Density
- Single Family Rural Density
- Flow & WQ Monitoring
- Habitat, Sediment, & Biological Monitoring

CityofRedmond WASHINGTON

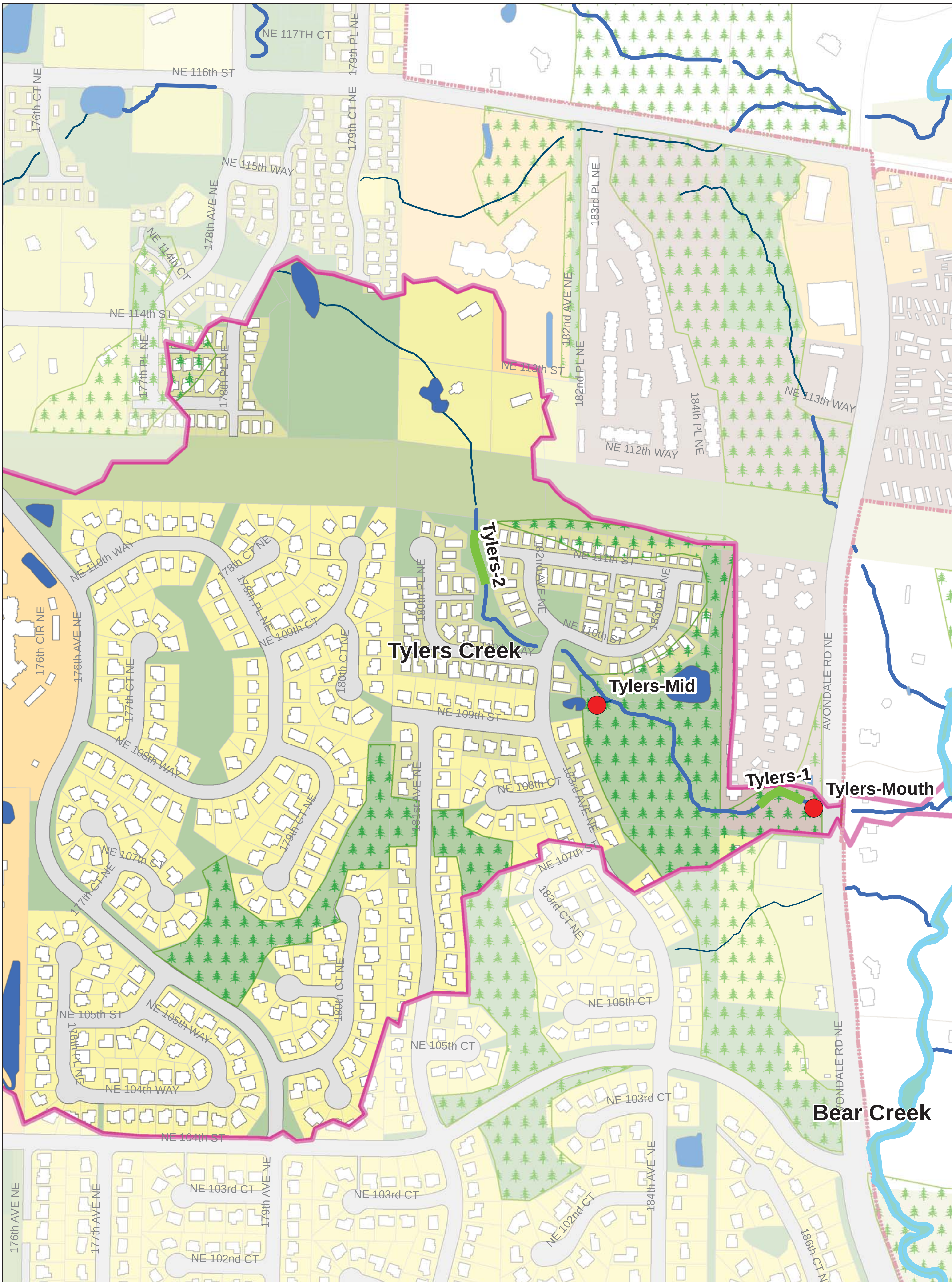

Figure 8 - Tyler's Creek Paired Basin Study Monitoring Locations

City of Redmond, Washington

6/25/2015

0 0.0375 0.075 0.15 Miles

Disclaimer: This map is created and maintained by the Natural Resources Division of the City of Redmond, Washington, for reference purposes only. The City makes no guarantee as to the accuracy or completeness of the features shown on this map.

Legend

- Class I Stream
- Class II Stream
- Class III Stream
- Class IV Stream
- Ponds
- City Limits
- Watershed Boundary
- Commercial
- Industrial
- Multifamily
- Park / Undeveloped
- Public ROW
- Single Family HighDensity
- Single Family Low Density
- Single Family Medium Density
- Single Family Rural Density
- Flow & WQ Monitoring
- Habitat, Sediment & Biological Monitoring

- **High pulse count duration**: annual average duration of high flow pulses during a water year.
- **High pulse count range**: range in days between the start of the first high flow pulse and the end of the last high flow pulse during a water year.
- **Low pulse count**: occurrence of daily average flows that are equal to or less than a threshold set at 50 percent of the long-term daily average flow rate.
- **Low pulse count frequency**: number of times each calendar year that discrete low flow pulses occurred.
- **Low pulse count duration**: annual average duration of low flow pulses during a calendar year.
- **Low pulse count range**: range in days between the start of the first low flow pulse and the end of the last low flow pulse during a calendar year.
- **Richards-Baker (RB) flashiness index**: a dimensionless index of flow oscillations relative to total flow based on daily average discharge measured during a water year.
- **TQ Mean**: the fraction of a year that mean daily discharge exceeds annual mean discharge.
- **Storm volume**: total discharge volume during storm events over a water year.
- **Base volume**: total discharge volume during base flow over a water year.
- **Total flow volume**: total discharge volume over a water year.

Trends over time at each monitoring station will be evaluated using parametric (Pearson's r) and nonparametric (Kendall's tau or Spearman's rho) tests of correlation between these indicators and time. Statistical significance of the correlation coefficients will be evaluated based on an α-level of 0.05 for a one-tailed test. The trend of interest will be evidence that receiving water conditions are improving based on one or more of these indicators in the Application watersheds while conditions in the Reference and Control watersheds remain relatively static.

In addition to the correlation analyses, separate analyses will be performed to compare measured flows in Tosh Creek and Monticello Creek to modeled flows for forested and existing conditions (i.e., conditions when the models were developed) that were derived from existing hydrologic models that have been developed for these watersheds using Hydrological Simulation Program—Fortran (HSPF). For these analyses, the measured and modeled flows will be post-processed to delineate individual periods of base and storm flow, respectively, across the entire time series for a given water year. Separate statistical analyses (Wilcoxon signed rank tests) will then be performed to determine if measured peak flows and flow volumes, respectively, during storm flow are significantly different from modeled flows for either the forested and existing conditions. Statistical significance in these tests will be evaluated based on an α-level of 0.05 for a one-tailed test. If watershed rehabilitation efforts are effective, measured peak flows and flow volumes should depart from the modeled equivalent for existing conditions and more closely resemble those for forested conditions.

6.2.2. *Water Quality Monitoring*

A total of 14 fixed monitoring stations will be established to facilitate water quality monitoring in each of the study watersheds. These stations will be co-located with the monitoring stations described above for hydrologic monitoring (see Figures 2 through 7). Twelve grab samples will be collected annually during storm events (three each quarter) at all 14 monitoring stations for the duration of the RPWS. In addition, four grabs samples will also be collected annually during base flow (one each quarter) at these stations. Each sample will be analyzed for the following indicators for evaluating water quality impacts from urban development:

- Total suspended solids
- Turbidity
- Conductivity
- Hardness
- Dissolved organic carbon
- Fecal coliform bacteria
- Total phosphorus
- Total nitrogen
- Copper, total and dissolved
- Zinc, total and dissolved

In addition, the following indicators will be continuously measured *in situ* at each station using probes:

- Temperature
- Conductivity

Trends over time at each monitoring station will be evaluated using parametric (Pearson's r) and nonparametric (Kendall's tau or Spearman's rho) tests of correlation between these indicators and time. Where possible, variation in the indicator data related to changes in stream flow will be removed prior to performing the correlation analyses using methods described in Helsel and Hirsch (2002). Use of these methods is generally applicable for indicators that tend to increase (or decrease) as a function of flow (e.g., total suspended solids). By removing this variation, trends in the indicator data can be more readily detected in the correlation analyses. In all cases, statistical significance of the correlation coefficients will be evaluated based on an α-level of 0.05 for a one-tailed test.

The sample frequency identified above for water quality monitoring was evaluated using power tests that were performed for totals suspended solids and total zinc. Power tests are used to determine the probability of detecting a trend given: 1) sample size, 2) the desired α-level, 3) magnitude of the trend, and 4) amount of variation within the data. With 16 samples collected annually (12 samples during storm events and 4 samples during base flow) over a 10-year period and a desired α-level of 0.05, results from these tests showed there was a 66 to 100 percent probability of detecting a 4 milligram per liter (mg/L) decrease in total suspended solids concentrations depending on the variability that is assumed for the data and characteristics of the trend over time (i.e., linear or non-linear). These same tests showed there is a 38 to 100 percent probability of detecting a 2 microgram per liter (μg/L) decrease in total zinc concentrations. Results from these tests are documented in Appendix B of this QAPP.

Annual mass load estimates will also be derived for the following subset of indicators using the nonparametric “smearing” approach described in Helsel and Hirsch (2002): total suspended solids, total phosphorus, total nitrogen, total copper, and total zinc. Trends over time at each monitoring station will again be evaluated using parametric (Pearson’s r) and nonparametric (Kendall’s tau or Spearman’s rho) tests of correlation between these mass load estimates and time. Statistical significance of the correlation coefficients will be evaluated based on an α-level of 0.05 for a one-tailed test. These analyses will be used to detect potential improvement in receiving water conditions from the combined effects of improved water quality and reduced stormwater runoff.

In all cases, the trend of interest will be evidence that receiving water conditions are improving based on one or more of these indicators in the Application watersheds while conditions in the Reference and Control watersheds remain relatively static.

6.2.3. Physical Habitat Monitoring

A total of 19 fixed monitoring stations will be established to facilitate physical habitat monitoring in each of the study watersheds as follows:

Application Watersheds

- Evans Creek Tributary 108: two stations designated Lower Stream Station (EVALSS) and Midstream Station (EVAMS), respectively (see locations in Figure 2).
- Monticello Creek: five stations designated Mont-1, Mont-2, Mont-3, Mont-4, and Mont-5, respectively (see locations in Figure 3).
- Tosh Creek: four stations designated Tosh-1, Tosh-2, Tosh-3, and Tosh-4, respectively (see locations in Figure 4).

Reference Watersheds

- Colin Creek: one designated Colin-1 (see locations in Figure 5).
- Seidel Creek: three stations designated Seidel-1, Seidel-2, and Seidel-3, respectively (see locations in Figure 6).

Control Watersheds

- Country Creek: two stations designated Country-1 and Country-2, respectively (see locations in Figure 7).
- Tyler’s Creek: two stations designated Tylers-1 and Tylers-2, respectively (see locations in Figure 8).

Per the recommendations from the literature review (see *Background* section), monitoring stations were established in reaches that will be restored and in reaches where there will be no physical alterations to the channel. The following monitoring stations were specifically selected to capture reaches that have either been recently restored or are likely to be restored in the future:

- Mont-3
- Mont-4
- Mont-5
- Tosh-1
- Tosh-3
- Tosh-4

Physical habitat monitoring will be conducted annually at each monitoring station for the duration of the RPWS. The characteristic bed-form type will be recorded at each monitoring station as a whole, and physical habitat quality indicators will be measured at 11 cross-sections (transects) and one longitudinal (thalweg) profile for each habitat monitoring station.

The following indicators will be measured at each transect:

- Bank-full width, wetted width, and cumulative bar width
- Bank-full depth, wetted depth, substrate class and embeddedness at 11 or more stations across the section
- Fish cover
- Human influence
- Riparian shading
- Riparian vegetation structure
- Presence of desirable/undesirable plant species

The following indicators will be measured along the thalweg profile:

- Thalweg depth and the presence of bars and/or edge pools
- Large woody debris and habit unit descriptions
- Side-channel descriptions
- Main channel slope and bearing

Post-processing of recorded physical habitat indicators will allow monitoring of:

- Channel incision or aggradation
- Channel widening, narrowing, or migration
- Changes in channel slope, sinuousity, and/or bed-form type

6.2.4. Sediment Quality Monitoring

A total of 19 fixed monitoring stations will be established to facilitate sediment quality monitoring in each of the study watersheds. These stations will be co-located with the monitoring stations described above for physical habitat monitoring (see Figures 2 through 7). Sediment samples will be collected annually at all 19 monitoring stations for the duration of the RPWS. Each sample will be analyzed for the following indicators for evaluating sediment quality impacts from urban development:

- Total organic carbon
- Copper
- Zinc
- Polycyclic aromatic hydrocarbons
- Phthalates

Trends over time at each monitoring station will be evaluated using parametric (Pearson's r) and nonparametric (Kendall's tau or Spearman's rho) tests of correlation between these indicators and time. Statistical significance of the correlation coefficients will be evaluated based on an α-level of 0.05 for a one-tailed test. The trend of interest will be evidence that receiving water conditions are improving based on one or more of these indicators in the Application watersheds while conditions in the Reference and Control watersheds remain relatively static.

6.2.5. Biological Monitoring

A total of 19 fixed monitoring stations will be established to facilitate biological monitoring in each of the study watersheds. These stations will be co-located with the monitoring stations described above for physical habitat monitoring (see Figures 2 through 7). Benthic macroinvertebrate samples will be collected annually at each monitoring station for the duration of the RPWS. Each sample will be processed to calculate the following indicators for use in evaluating stream health:

- Benthic Index of Biotic Integrity (B-IBI)
- Taxa Richness
- Ephemeroptera Richness
- Plecoptera Richness
- Trichoptera Richness
- Clinger Percent
- Long-Lived Richness
- Intolerant Richness
- Percent Dominant

- Predator Percent
- Tolerant Percent

Trends over time at each monitoring station will be evaluated using parametric (Pearson's r) and nonparametric (Kendall's tau or Spearman's rho) tests of correlation between these indicators and time. Statistical significance of the correlation coefficients will be evaluated based on an α-level of 0.1 for a one-tailed test. The trend of interest will be evidence that receiving water conditions are improving based on one or more of these indicators in the Application watersheds while conditions in the Reference and Control watersheds remain relatively static.

The sampling frequency identified above for biological monitoring was evaluated using the power tests described above in the *Water Quality Monitoring* subsection. With samples collected annually over a 10-year period and a desired α-level of 0.05, results from these tests showed there was a 63 to 96 percent probability of detecting a 9-unit increase in B-IBI scores (equivalent to a change from "fair" to "good" in biological condition) depending on the variability that is assumed for the data and characteristics of the trend over time (i.e., linear or non-linear). Results from these tests are documented in Appendix B of this QAPP.

6.3. Effectiveness Monitoring

As described above, roving stations will be established for the Effectiveness Monitoring component of the RPWS to verify specific structural stormwater controls are constructed properly and performing as designed. The roving stations will be moved from one year to the next once a facility's effectiveness has been verified and new facilities come online. The specific types of monitoring to be performed at each roving station will depend on the type of structural stormwater control that is being evaluated. For example, it is anticipated that only hydrologic monitoring would be performed at roving stations for facilities that are only designed for flow control (e.g., vaults). In these cases, a facility's performance would be verified based on comparisons of measured flow from the roving station to the facility's predicted flow based on models used in its design. For facilities that are designed for runoff treatment, monitoring will follow guidelines from Ecology's Technology Assessment Protocol-Ecology (TAPE) (Ecology 2011) and include both hydrologic (e.g., influent and effluent flow) and water quality monitoring. In these cases, a facility's performance would be verified based on comparisons of its measured pollutant removal efficiency relative to targets that are identified in TAPE for specific treatment categories.

At present, no new structural stormwater controls have come online in an Application watershed that are suitable for Effectiveness Monitoring. For planning purposes, it is anticipated that two separate facilities will be completed and made available for monitoring in years 2 and 3 of the study, respectively. For each facility, detailed information on the procedures that will be used for data collection, quality assurance and control, management, and analysis will be provided in separate addendums to this QAPP.

7. SAMPLING PROCEDURES

This section describes field sampling procedures to be employed for the RPWS. It begins with an overview of safety procedures that will be employed during all field sampling. Separate subsections then describe the specific field sampling procedures to be employed for the following monitoring categories: hydrologic, water quality, physical habitat, sediment quality, and biological. To ensure data obtained for the RPWS are of comparable to those collected through other RSMP monitoring efforts, field sampling procedures identified for this study have generally been adopted from the *Quality Assurance Project Plan for Status and Trends Monitoring of Small Streams in the Puget Lowlands Ecoregion* (Ecology 2014).

7.1. Safety

Most field activities will be conducted by two people. Routine hydrologic monitoring station maintenance will generally be performed by one person. If access to private property is required, permission will be obtained from the property owner prior to any field activities. Sampling activities may take place at all hours of the day. Therefore, a designated contact person will be notified by the field personnel prior to and upon completion of sampling.

Care should be taken in the field when handling sample bottles containing preservatives (e.g., nitric acid, sulfuric acid) or when adding preservative (i.e., denatured ethanol) to biological samples immediately following collection.

7.2. Hydrologic Monitoring

Continuous monitoring of discharge will be performed over the anticipated 10-year timeframe for implementing the RPWS at each of the stations identified in Figures 2 through 7 for hydrologic monitoring. To facilitate this monitoring, a staff gauge will be installed at each station for obtaining a manual measurement of water level at a fixed location within the stream channel. The staff gauge may be a visible graduated scale or a designated constructed point over the water from which to measure the water level. A data logger and pressure transducer will also be installed at each station to facilitate the continuous collection of water level data with a 5-minute logging interval. The pressure transducer will be housed in a vandal-resistant stilling well submerged within the stream channel. Where feasible, telemetry will be installed to allow remote data acquisition. Typical installation configurations for the hydrologic monitoring equipment are shown in Appendix C. Specifications for the pressure transducer and data logger that will be used for this application are provided in Appendix D.

Site visits will be performed every 2 to 5 weeks to check the operational status of the data loggers at each monitoring location, download the associated water level data and make measurements. Downloaded data files will be named with the programmed site name plus the date as _YYYY_MM_DD. Field downloaded data files and telemetered data files will be stored in directories on a King County network server managed by King County Department of Information and Technology Services. Field notes and workup materials will be stored in paper files in the KCDNRP gauging program Seattle office work area. Software applications developed by KCDNRP gauging program will be used to input data to the KCDNRP Hydrologic

Information Center database. Once in the database, data is available for download from the County internet site.

The data collected and processed by King County will be available for transfer to a secure server located in Herrera's Seattle office that is backed-up on a daily basis. The AQUARIUS Time-Series software will then be used for all subsequent tasks related to the processing and analysis of the compiled water level data.

To convert the water level data to estimates of discharge, stream discharge rating curves will be developed for each monitoring station based on manual measurements of discharge that are made over a range of flows. It is anticipated that ongoing manual measurements of discharge will be obtained for each station to facilitate rating curve development. Effort will be made to measure flows at the high and low extremes. Procedures for making manual measurements of discharge will follow those identified in Appendix E-5 of the *Quality Assurance Project Plan for Status and Trends Monitoring of Small Streams in the Puget Lowlands Ecoregion* (Ecology 2014). For reference, this appendix is reproduced in Appendix A of this QAPP.

KCDNRP gauging staff will develop stream discharge rating curves using USGS protocols from the manual measurements of discharge at each monitoring station. Rating curve shifts will be applied based on the results of the ongoing discharge measurements. Rating curve development and applied data corrections will be documented and reviewed.

7.3. Discrete Water Quality Sampling

Water quality monitoring will involve the collection of twelve grabs samples annually during storm events (three each quarter) at all 14 monitoring stations to be established for this purpose (see *Experimental Design* section). In addition, four grabs samples will also be collected annually during base flow (one each quarter) at these stations. Sample collection procedures will follow those identified in the *Quality Assurance Project Plan for Status and Trends Monitoring of Small Streams in the Puget Lowlands Ecoregion* (Ecology 2014). Specifically, the following procedures identified in Appendix E of this document will be followed where applicable:

- Appendix E-1: Day of sample collection
- Appendix E-2: Water quality sample containers
- Appendix E-3: Water quality sample processing and preservation

For reference, these appendices are reproduced in Appendix A of this QAPP. Table 5 also summarizes applicable water quality sample collection requirements including analytical methods, sample containers, holding times, sample preservation, and reporting limits.

To collect samples during storm events, antecedent conditions and storm predictions will be monitored via the Internet, and a determination will be made as to whether to target an approaching storm for sampling. The following criteria will serve as guidelines for defining the acceptability of specific storm events for sampling:

- **Target storm depth**: A minimum of 0.10 inches of precipitation over a 24-hour period
- **Antecedent conditions**: A period of at least 12 hours preceding the event with less than 0.04 inches of precipitation

Table 5. Sample Collection Requirements.

Parameter	Analytical Method	Method Number[a]	Sample Container	Pre-Extraction Holding Time	Analytical Holding Time[c]	Sample Preservation	Reporting Limit	Units
Water Analyses								
Total suspended solids	Gravimetric, dried at 103–105°C	SM 2540D	1 L HDPE	NA	7 days	Cool ≤ 6°C	1	mg/L
Turbidity	Nephelometric	SM 2130B	500 mL HDPE	NA	48 hours		0.5	NTU
Hardness	ICP/calculation	EPA 200.7/ SM 2340B	500 mL HDPE[b]	NA	6 months	HNO_3 to pH < 2, cool ≤ 6°C	0.3	mg/L
Dissolved organic carbon	High temperature combustion	SM 5310B	125 mL glass	NA	28 days	Field filter (0.45 µm), H_2SO_4 to pH < 2, cool to ≤ 6°C	1	mg/L
Fecal coliform bacteria	Membrane filtration	SM 9222D	250 mL autoclaved	NA	24 hours (Hallock, 2007)	Cool to <10°C	1	cfu/100 mL
Total phosphorus	Ascorbic Acid	SM 4500 P-E	500 mL HDPE	NA	28 days	H_2SO_4 to pH< 2, cool ≤ 6°C	0.005–0.01	mg/L
Total nitrogen	In-line UV/persulfate digestion and oxidation with flow injection	SM 4500 N-B					0.025–0.1	
Copper, dissolved	ICP-MS	EPA 200.8	500 mL HDPE	NA	180 days	Field filter (0.45 µm), HNO_3 to pH < 2, cool to ≤ 6°C	0.5	µg/L
Copper, total			500 mL HDPE[b]			HNO_3 to pH < 2, cool to ≤ 6°C		
Zinc, dissolved			500 mL HDPE			Field filter (0.45 µm), HNO_3 to pH < 2, cool to ≤ 6°C	5.0	
Zinc, total			500 mL HDPE[b]			HNO_3 to pH < 2, cool to ≤ 6°C		
Sediment Analyses								
Total organic carbon	Combustion	PSEP	4 oz glass jar	NA	14 days	Cool ≤ 6°C	0.1	percent
Copper	ICP-MS	EPA 6020			180 days		0.5	mg/kg
Zinc							5.0	mg/kg
Polycyclic aromatic hydrocarbons	Gas chromatography/mass spectrometry (GC/MS)	EPA 8270D	8 oz glass jar	14 days	40 days		70	µg/kg
Phthalates							70–250	µg/kg
Biological Analyses								
Macroinvertebrate	Taxonomic Identification	NA	3.8 L wide-mouth poly jar	NA	Indefinite	Field preserve with ethanol, store in quiescent location	NA	NA

[a] SM method numbers are from APHA et al. (1998); EPA method numbers are from US EPA (1983, 1984). The 18th edition of *Standard Methods for the Examination of Water and Wastewater* (APHA et al. 1992) is the current legally adopted version in the *Code of Federal Regulations*.

[b] Hardness, total copper, and total zinc analyses performed from one 500-mL HDPE bottle.

[c] Holding time specified in US EPA guidance (US EPA 1983, 1984) or referenced in APHA et al. (1992) for equivalent method.

C = Celsius.
CFU/100mL = colony forming units per 100 milliliters.
GC/MS = gas chromatography/mass spectrometry.
HDPE = High-Density Polyethylene.
ICP = inductively coupled plasma/atomic emission spectroscopy.
ICP-MS = inductively coupled plasma/mass spectrometry.
mg/L = milligrams per liter.
mg/kg = milligrams per kilogram.
µg/L = micrograms per liter.
µg/kg = micrograms per kilogram
NTU = Nephelometric Turbidity Units.
NA = not applicable.
oz = ounces.

Once a storm event has been targeted for sampling, the laboratory will be given prior notice of a pending sampling event to ensure that adequate laboratory staff will be available to process the incoming samples.

Nominally, all 14 stations will be sampled during each storm event. Once deployed, sampling personnel will maintain communication with Herrera's Monitoring Coordinator (see *Organization and Key Personnel* section) who will have access to real-time Doppler radar images showing the distribution of rainfall in the watersheds and the surrounding region. If rainfall appears to be unevenly distributed among the sampling locations in the watersheds, or if the rainfall appears to be dissipating prior to the completion of the required sampling, the Herrera Project Manager will be notified and a determination will be made as to whether the sampling event should be terminated. In the event specific stations are not sampled because a sampling event was terminated, they will be prioritized for sampling in subsequent events to ensure the annual sampling goals that have been established for the study are ultimately met for every station.

Base flow samples will be collected following a period of at least 48 hours without rain. All 14 stations will be sampled on the same day during base flow events.

7.4. Continuous Water Quality Monitoring

Continuous monitoring of water temperature and conductivity will be performed over the anticipated 10-year timeframe for implementing the RPWS at each of the stations identified in Figures 2 through 7 for hydrologic monitoring. The measurements will be made by commercially available manufactured instruments such as the Onset U24 conductivity logger or the Instrumentation Northwest AquiStar® CT2X conductivity and temperature sensor. These sensors have internal data logging capability that will be used to collect the continuous data with a 15 minute logging interval. At stations with telemetry, additional temperature or conductivity sensors will be interfaced with the station data logger where feasible. Specifications for the water quality sensors that will be used for this application are provided in Appendix D. The sensors will be placed in the main channel in in flowing water. The sensor placement may need to be adjusted throughout the year to maintain a position in representative flow.

During the routine site visits performed every 2 to 5 weeks, the water quality sensors will be downloaded, repositioned, and point water temperature and conductivity measurements will be made with hand held instruments such as the YSI Pro 2030. Downloaded data files will be named with the programmed site name (SSSS) plus the date as _YYYY_MM_DD and _K for conductivity, e.g., MONM_2015_10_01_K. Field downloaded data files and telemetered data files will be stored in directories on a King County network server managed by King County Department of Information and Technology Services. Field notes and workup materials will be stored in paper files in the KCDNRP gauging program Seattle office work area. Software applications developed by KCDNRP gauging program will be used to input data to the KCDNRP Hydrologic Information Center database. Once in the database, data is available for download from the County internet site.

7.5. Physical Habitat Monitoring

Physical habitat monitoring will occur annually at all 19 monitoring stations to be established for this purpose (see *Experimental Design* section). Physical habitat monitoring procedures will largely follow those identified in the *Quality Assurance Project Plan for Status and Trends Monitoring of Small Streams in the Puget Lowlands Ecoregion* (Ecology 2014). Following procedures identified in Appendix C-1 of this document, the characteristic bed-form type will be recorded at each habitat monitoring station as a whole, and physical habitat quality indicators will be measured at 11 transects and one thalweg profile for each monitoring station.

The following specific procedures for assessing physical habitat will be implemented at each transect:

- Appendix C-5: Bank measurements at major transects in waded streams
- Appendix C-6: Substrate and depth measurements at major transects in waded streams
- Appendix C-7: Shade measurements at major transects in waded streams
- Appendix C-8: Estimating fish cover at major transects in waded streams
- Appendix C-9: Human influence at major transects in waded streams
- Appendix C-10. Riparian vegetation structure at major transects in waded streams

The following procedures for assessing physical habitat will also be implemented along the thalweg profile:

- Appendix C-11: Measuring thalweg depth in waded streams
- Appendix C-12: Large woody debris tally for waded streams of western Washington
- Appendix C-13: Habitat unit descriptions along the main channel thalweg
- Appendix C-14: Side-channel descriptions
- Appendix C-15: Width and substrate measurements at minor transects in waded streams
- Appendix C-16: Measuring slope and bearing in small streams

For reference, these appendices are reproduced in Appendix A of this QAPP.

Stream hydrology has very limited influence on overall riparian cover or tree cover (compared to other factors – site history, vegetation management) so neither is likely to be responsive to watershed-level hydrologic restoration. In addition to the methods and indicators proposed in Appendix C-10 of the *Quality Assurance Project Plan for Status and Trends Monitoring of Small Streams in the Puget Lowlands Ecoregion* (Ecology 2014), supplemental monitoring will be implemented that is calibrated to the range of conditions in Redmond and can differentiate between “good” and “impaired” vegetation states that are more likely to be responsive to watershed-level restoration activities.

This monitoring consists of recording following indicators at each cross-section:

- Evidence of vegetation colonization below the ordinary high water mark (OHWM) that persists more than 1 year
- Slopes vegetated over the crown of the bank
- Presence of desirable native plant species (e.g., cottonwood, willow)
- Presence of invasive plant species (e.g., reed-canarygrass)
- Presence of good-habitat indicator liverwort species

Physical habitat monitoring will occur in the July through September timeframe when riparian foliage has had a chance to reestablish after winter lows.

7.6. Sediment Quality Monitoring

Sediment samples will be collected annually at all 19 monitoring stations to be established for this purpose (see *Experimental Design* section). Sample collection procedures will follow those identified in Appendix C-4 of the *Quality Assurance Project Plan for Status and Trends Monitoring of Small Streams in the Puget Lowlands Ecoregion* (Ecology 2014). For reference, this appendix is reproduced in Appendix A of this QAPP. Table 5 also summarizes applicable sediment sample collection requirements including analytical methods, sample containers, holding times, sample preservation, and reporting limits. Sediment sampling will occur in the May through June timeframe when flows in the creeks have dissipated from winter highs.

7.7. Biological Monitoring

Biological monitoring will occur annually at all 19 monitoring stations to be established for this purpose (see *Experimental Design* section). Biological monitoring procedures will follow procedures identified in Appendix D-1 of the *Quality Assurance Project Plan for Status and Trends Monitoring of Small Streams in the Puget Lowlands Ecoregion* (Ecology 2014). For reference, this appendix are reproduced in Appendix A of this QAPP. Table 5 also summarizes applicable biological sample collection requirements including sample containers and sample preservation.

Prior to monitoring, the necessary permit for sampling macroinvertebrates will be obtained from the Washington Department of Fish and Wildlife (http://wdfw.wa.gov/licensing/scp/). Biological monitoring will occur in the July through September timeframe due to the following considerations: allows time for the stream environment to stabilize following natural disturbances (e.g., spring floods); targets a period when many macroinvertebrates reach body sizes that can be readily identified; and targets periods when benthic macroinvertebrate species diversity reaches a maximum prior to fall emergence.

7.8. Rainfall Monitoring

Continuous monitoring of rainfall will be performed at three locations over the anticipated 10-year timeframe for implementing the RPWS. Tipping bucket rain gauges with data logging capability will be used to collect the continuous data. Data collected will be the time of each tip and 15-minute accumulations. The stations will have telemetry and additional temperature barometric pressure sensors that will record at 15-minute intervals. The atmospheric sensors are not intended to provide research quality data, but to provide context to the main hydrologic data. Barometric pressure data will be used to adjust the readings from any sealed pressure transducers deployed to measure water level. Specifications for the meteorological sensors that will be used for this application are provided in Appendix D.

Rain gauge stations will be visited three times annually. During the routine site visits the rain gauge will be cleaned and the calibration checked. The data loggers will be downloaded. Downloaded data files will be named with the programmed site name (SSSS) plus the date as _YYYY_MM_DD. Field downloaded data files and telemetered data files will be stored in directories on a King County network server managed by King County Department of Information and Technology Services. Field notes and workup materials will be stored in paper files in the KCDNRP gauging program Seattle office work area. Software applications developed by KCDNRP gauging program will be used to input data to the KCDNRP Hydrologic Information Center database. Once in the database, data is available for download from the County internet site.

8. MEASUREMENT PROCEDURES

8.1. Water and Sediment Data

Laboratory analytical procedures for this project will follow US Environmental Protection Agency (US EPA) approved methods (APHA et al. 1992; US EPA 1983, 1984, 1986; ASTM 2007). These methods provide reporting limits that allow low-level pollutant concentrations in water and sediment samples to be compared to applicable state and federal regulatory criteria or guidelines. The preservation methods, analytical methods, reporting limits, and sample holding times are presented in Table 5.

Samples for the parameters requiring filtration (dissolved metals and dissolved organic carbon) will be immediately filtered and preserved in the field during sample collection in accordance with procedures identified in Appendix E-1 of the *Quality Assurance Project Plan for Status and Trends Monitoring of Small Streams in the Puget Lowlands Ecoregion* (Ecology 2014). For reference, this appendix is reproduced in Appendix A of this QAPP.

The laboratory identified for this project will be certified by Ecology and participate in audits and inter-laboratory studies by Ecology and the US EPA. These performance and system audits have verified the adequacy of the laboratory's standard operating procedures, which include preventive maintenance, data reduction, and quality assurance/quality control (QA/QC) procedures.

The laboratory will report the analytical results within 30 days of receipt of the samples. The laboratory will provide all sample and quality control data in standardized reports that are suitable for evaluating the project data. Submittals will include all raw data, including but not limited to:

- All raw values including those below the reporting limit and between the method detection limit and the laboratory reporting limit.
- The laboratory method detection limits and reporting limits for all analytes for each batch.
- All field duplicate and laboratory split results.

Data are to be submitted in hard copy and electronically using one of the following file formats: a MS Excel (version 97 or later) spreadsheet, Access database table (version 97 or later), or a dBase IV database table. The reports will also include a case narrative summarizing any problems encountered in the analyses.

8.2. Biological Data

Taxonomic identification will be conducted by a laboratory that employs taxonomists certified by the Society for Freshwater Science at the genus level with experience with the freshwater macroinvertebrates of the Pacific Northwest. Taxonomic lab sampling will be performed using procedures identified in Appendix D-2 of the *Quality Assurance Project Plan for Status and Trends Monitoring of Small Streams in the Puget Lowlands Ecoregion* (Ecology 2014). Taxonomic level of effort will also follow guidance from Appendices I and J from this same document. For reference, these appendices are reproduced in Appendix A of this QAPP.

9. QUALITY CONTROL

Quality control procedures are identified in separate subsections below for field and laboratory activities. The overall objective of these procedures is to ensure that data collected for this project are of a known and acceptable quality.

9.1. Field Quality Control Procedures

Quality control procedures that will be implemented for field activities are described in the following subsections. The frequency and type of quality control samples to be collected in the field are also summarized in Tables 6 and 7 for water and sediment quality samples, respectively.

9.1.1. Instrument Maintenance and Calibration

Portable electronic field instruments will be used to measure water temperature and conductivity. Direct measurements of streamflow require an instrument to measure water velocity. The instrument manufacturers give direction for the maintenance and calibration of the instruments.

9.1.1.1. YSI Pro 2030

The YSI Pro Model 2030 will be used to make *in situ* measurements of water temperature and conductivity. The instruments calibration for temperature is robust and cannot be changed. Two point calibrations of conductivity with a KCL solution are recommended. The following maintenance and calibration procedures will be followed for the conductivity sensor:

- Monthly: Check instrument batteries. Clean conductivity cells with soap and water and appropriate brush.
- Four-month interval: Calibrate conductivity following the procedure in the instrument manual. Use distilled water and 1,000 µS standard.
- Annually: Verify temperature calibration using and ice bath and room temperature water bath measured with NIST traceable laboratory thermometer.

9.1.1.2. Water Velocity Instruments

The Swoffer Model 3000 Current Velocity indicator can be used with a variety of sensors, including various sized horizontal axis sensors and the USGS style pygmy and AA meters. Each has a specific calibration number to convert rotations to velocity. Before each measurement, the calibration number and sensor type will be noted. In addition, a spin test will be performed and the results noted.

The Hach FH950 Portable Velocity Flow Meter use an elector-magnetic sensor to determine current velocity. Prior to each field trip, the battery status will be checked. The sensor will also be cleaned after each field trip.

Table 6. Quality Assurance Requirements and Anticipated Number of Water Quality Samples per Water Year.

Parameter	Number of Stations	Storm Samples per Quarter per Station	Base Flow Samples per Quarter per Station	Total Number of Samples Annually	Laboratory Method Blanks	Laboratory Control Standard	Matrix Spike	Field Duplicates	Lab Duplicates	Total Number of Samples Including Field Duplicates
Total suspended solids	14	3	1	224	1/batch[a]	1/batch[a]	NA	16[b]	1/batch[a]	240
Turbidity	14	3	1	224	1/batch[a]	1/batch[a]	NA	16[b]	1/batch[a]	240
Hardness	14	3	1	224	1/batch[a]	1/batch[a]	1/batch[a]	16[b]	1/batch[a]	240
Dissolved organic carbon	14	3	1	224	1/batch[a]	1/batch[a]	1/batch[a]	16[b]	1/batch[a]	240
Fecal coliform bacteria	14	3	1	224	1/batch[a]	NA	NA	16[b]	1/batch[a]	240
Total phosphorus	14	3	1	224	1/batch[a]	1/batch[a]	1/batch[a]	16[b]	1/batch[a]	240
Total nitrogen	14	3	1	224	1/batch[a]	1/batch[a]	1/batch[a]	16[b]	1/batch[a]	240
Total/dissolved copper and zinc	14	3	1	224	1/batch[a]	1/batch[a]	1/batch[a]	16[b]	1/batch[a]	240

NA = not applicable.

[a] Laboratory quality assurance samples will be analyzed with each batch of samples submitted to the laboratory for analysis. A laboratory batch will consist of no more than 20 samples.

[b] One field duplicate sample will be collected and analyzed for each storm or baseline sampling event (total of 14 samples per event). Therefore, field duplicates will be collected at a frequency of 7 percent of the total number of submitted samples.

Table 7. Quality Assurance Requirements and Anticipated Number of Sediment Quality Samples per Water Year.									
Parameter	**Number of Stations**	**Samples per Year per Station**	**Total Number of Samples Annually**	**Laboratory Method Blanks**	**Laboratory Control Standard**	**Matrix Spike**	**Field Duplicates**	**Lab Duplicates**	**Total Number of Samples Including Field Duplicates**
Total organic carbon	19	1	19	1/batch[a]	1/batch[a]	NA	1[b]	1/batch[a]	20
Metals (copper and zinc)	19	1	19	1/batch[a]	1/batch[a]	1/batch[a]	1[b]	1/batch[a]	20
Polycyclic aromatic hydrocarbons	19	1	19	1/batch[a]	1/batch[a]	1/batch[a]	1[b]	1/batch[a]	20
Phthalates	19	1	19	1/batch[a]	1/batch[a]	1/batch[a]	1[b]	1/batch[a]	20

NA = not applicable.

[a] Laboratory quality assurance samples will be analyzed with each batch of samples submitted to the laboratory for analysis. A laboratory batch will consist of no more than 20 samples.

[b] One field duplicate sample will be collected and analyzed for annual sampling event. Therefore, field duplicates will be collected at a frequency of 5 percent of the total number of submitted samples.

9.1.2. Field Notes

During each site visit to each monitoring station, the following information will be recorded on a waterproof standardized field form (Appendix E):

- Site name
- Date and time of visit and sample collection
- Name(s) of field personnel present
- Weather and flow conditions
- Sample duplicated? (if sampled)
- Unusual conditions (e.g., oily sheen, odor, color, turbidity, discharges or spills, and land disturbances)
- Modifications of sampling procedures

9.1.3. Field Duplicates

Field duplicates will be collected at a sufficient frequency to represent 7 percent of the total number of project samples analyzed. The number of field duplicates to be collected during the sampling season is listed in Tables 6 and 7. For water quality samples, two successive grabs will be collected for each analyte.

9.1.4. Sample Handling

All sample bottles will be transported in coolers with ice and kept below 6 degrees Celsius until delivery to the laboratory within 24 hours of sample collection (the shortest holding time of any of the measured parameters). The temperature of the samples will be measured upon sample delivery and recorded on the chain of custody form.

9.1.5. Sample Identification and Labeling

All sample containers will be labeled with the following information using indelible ink and labeling tape:

- Site/station name (e.g., EVALSS)
- Date of sample collection (year/month/day: yyyy/mm/dd)
- Time of sample collection (international format [24 hour])
- Field personnel initials (such as DSA)

Quality assurance samples (field duplicates and blanks) will only be labeled as QA1, QA2, etc., for delivery to lab; but field staff will maintain a cross-check list of which stations and sample types the quality assurance samples represent. When results are returned from the laboratory, the consultant will associate full label information with the results, and populate database fields for quality assurance sample and type.

Waterproof labels will be placed on dry sample-container lids by self-adhesion or with tape. Any written marks will be made with waterproof ink.

9.1.6. Sample Containers and Preservation

Clean, decontaminated sample bottles will be obtained from the analytical laboratory in advance of each storm event. Spare sample bottles will be carried by the sampling team in case of breakage or possible contamination. Sample containers and preservation techniques will follow US EPA (2007) guidelines.

9.1.7. Chain-of-Custody Record

A chain-of-custody record will be maintained for each sample batch listing the sampling date and time, sample identification numbers, analytical parameters and methods, persons relinquishing and receiving custody, dates and times of custody transfer, and temperature of sample upon delivery.

9.2. Laboratory Quality Control Procedures

Quality control procedures that will be implemented in the laboratory are described in the following subsections. The frequency and type of quality control samples to be analyzed by the laboratory are also summarized in Tables 6 and 7.

9.2.1. Method Blanks

Method blanks consisting of deionized and micro-filtered pure water will be analyzed with every laboratory sample batch. A laboratory sample batch will consist of no more than 20 samples and may include samples from other projects. The total number of method blanks anticipated for this study is shown in Tables 6 and 7 by parameter. Blank values will be presented in each laboratory report.

9.2.2. Control Standards

Control standards for each parameter will be analyzed by the laboratory with every sample batch. A laboratory sample batch will consist of no more than 20 samples and may include samples from other projects. The total number of control standards anticipated for this study is shown in Tables 6 and 7 by parameter. Raw values and percent recovery (see formula in the *Quality Objectives* section) for the control standards will be presented in each laboratory report.

9.2.3. Matrix Spikes

For applicable parameters, matrix spikes will be analyzed by the laboratory with every sample batch. A laboratory sample batch will consist of no more than 20 samples and may include samples from other projects. The total number of matrix spikes anticipated for this study is shown in Tables 6 and 7 by parameter. Raw values and percent recovery (see formula in the *Quality Objectives* section) for the matrix spikes will be presented in each laboratory report.

9.2.4. Laboratory Duplicates

Laboratory duplicate samples for each parameter will be analyzed for specifically labeled quality assurance samples submitted with every sample batch. This will represent no less than 20 percent of the project submitted samples. The total number of laboratory duplicates anticipated for this study is shown in Tables 6 and 7 by parameter. Raw values and relative percent difference (see formula in the *Quality Objectives* section) of the duplicate results will be presented in each laboratory report.

10. DATA MANAGEMENT AND DOCUMENTATION PROCEDURES

This section discusses data management, which addresses the path of data from recording in the field or laboratory to final use and archiving. The data management and documentation strategy provides for consistency when collecting, assessing, and documenting environmental data and electronic storage of all documents and records on servers that are regularly backed up.

10.1. Data Management

Data from each data logger used for hydrologic monitoring will be remotely transferred on a weekly basis and imported directly into a database (Aquarius data management software) for subsequent analysis and archiving purposes. These data will be immediately checked for evidence of an equipment malfunction or other operational problems. Gaps in flow data may need to be interpolated; if this occurs, data will be stored and presented in a manner that makes it clear what data are from measurements, and what data have been interpolated.

Hydrologic data collected by the King County DNRP Hydrologic Monitoring Program are stored in an electronic relational database (Hydrologic Information Center, aka HIC) consisting of indexed tables on a SQL server maintained by the King County Department of Information Technology. A desktop computer user interface allows data files to be imported to the database, adjustments to the data made, field notes input, and data management and export functions performed. A web interface allows public access to all data in the HIC (http://green2.kingcounty.gov/hydrology/).

Continuous hydrologic and water quality data acquired by telemetry will be automatically input to the HIC. These data are provisional. The individual electronic files downloaded (by telemetry or directly) from the project data loggers will be stored in designated directories on a King County networked server. Data from the paper field forms are input to the HIC. The paper forms are stored in a project file.

Telemetered data is automatically input to the HIC with computer routines that use stored settings to make offset corrections and apply rating tables. Alerts are sent when data exceeds set value limits. Staff check daily that telemetered stations are reporting and giving reasonable values. Telemetered data are flagged “provisional.”

After each site visit, the results of the field measurements are input to HIC tables. The discharge measurement is plotted and compared to the current rating curve. If an update to the rating is indicated, data since the last supervised data input is prepared and run from the desktop application. The telemetry import settings are adjusted. The procedure for importing and processing directly downloaded (non-telemetered) data is similar to the process for revising data from telemetered sites. The downloaded data is examined and proofed before being imported to the HIC. The comma delimited text file is imported to a spreadsheet, where the time is checked and the data charted. The first or last records may be adjusted if it is apparent that the logger had not equilibrated to the stream conditions when the reading was made (removable data logging sensors). The chart of the data over time is printed and any anomalies noted on that for the project file. Data that are believed to be in error may be removed from the data set to be imported. The reasons for this must be noted on the printout. This is more typical for continuous water quality data. Typical reasons for exclusion of data are observing the logger out of water at the time of download, noticing that the range of fluctuation in a day is unreasonable and matches air temperature fluctuations, odd spikes in reading that are physically unlikely to have occurred. Exclusions must be approved by the Lead Hydrologic Engineer. Once the data have been proofed, a clean sheet of time stamps and values is created and the spreadsheet saved. An import text file of the clean data is created.

The HIC data import form allows offset and drift corrections to be applied to the data. Both the raw and corrected values are stored in the HIC. The data are automatically flagged Provisional and remain so until verified. Once imported, the data are available for viewing and download from the public HIC website.

The laboratory will report the analytical results within 30 days of receipt of the samples. The laboratory will provide sample and quality control data in standardized reports that are suitable for evaluating the project data. These reports will include all data including raw quality assurance results, and all quality control results associated with the data. The reports will also include a case narrative summarizing any problems encountered in the analyses, corrective actions taken, changes to the referenced method, and an explanation of data qualifiers. Laboratory analytical and quality assurance sample results will be delivered from the laboratory in both electronic and hard copy form.

Analytical data for the project will be stored in a Structure Query Language (SQL) database. The Herrera Quality Assurance Officer (see *Organization and Key Personnel* section) will perform an independent review of the data to ensure that all sample values were entered without error. Specifically, 10 percent of the sample values will be randomly selected for rechecking and cross checking with laboratory reports. If errors are detected, they will be corrected, and then an additional 10 percent will be selected for validation. This process will be repeated until no errors are found. Results from these reviews will be documented on standardized forms (see Appendix E)

Both the laboratory and Herrera will retain project related data for 5 years after completion of the project.

10.2. Documentation and Records

Four types of documentation will be managed: 1) field operation records, 2) laboratory records, 3) data handling records, and 4) QAPP revision documentation.

10.2.1. Field Operation Records

Field operation records may include data sheets and field notes, and photographs taken of the described activities (when taken).

10.2.2. Laboratory Records

Laboratory records will include a data package (lab report in Excel® format). Hard copy laboratory reports will not be issued by the project laboratory.

10.2.3. Data Handling Records

All documents associated with a sampling event will be stored electronically. Paper copies will not be archived. Each sampling event will be documented with the following records:

- Chain-of-Custody (COC)
- Field Reports (field notes)
- Data Package

All documents will be provided in portable document format (PDF) with the exception of the lab reports, which will be in Excel® format. All project documentation will be stored on a SQL server organized by sampled event.

10.2.4. Revisions to the QAPP

In the event that significant changes to this QAPP are required prior to the completion of the study, a revised version of the document (with changes tracked) shall be prepared and submitted to the City and Ecology for review. The approved version of the QAPP shall remain in effect until the revised version has been approved. Justifications, summaries, and details of expedited changes to the QAPP will be documented and distributed to all persons on the QAPP distribution list by the Project Manager.

11. AUDITS AND REPORTS

The following sections describe routine audits and reporting activities that will take place in connection with this performance verification.

11.1. Audits

Audits will be performed to detect potential deficiencies in the data collected for this project. Audits of the data from hydrologic monitoring will on occur following their transfer from data loggers at each station (see *Data Management and Documentation Procedures* section). In connection with these audits, data collected from each monitoring station will be compared to data from the previous week and data from the rain gauge station to identify potential data quality issues. This audit will specifically include an examination of the data record for gaps, anomalies, or inconsistencies between the discharge and water level data relative to data collected over the preceding week. Any data generated from calibration checks that were performed at a particular monitoring station will also be reviewed to detect potential instrument drift or other operational problems.

In the event that quality assurance issues are identified on the basis of these audits, measures will be taken to troubleshoot the problem(s) and to implement corrective actions if needed. Further, if bias in the hydrologic record is detected and can be corrected by calibration, corrective actions will be documented in the database. All quality assurance issues identified in the hydrologic data and the associated corrective actions will be documented.

Audits performed for water and sediment quality data will occur within 14 business days of receiving results from the laboratory. This review will be performed to ensure that all data are consistent, correct, and complete, and that all required quality control information has been provided. Specific quality control elements for the data (see Tables 1 and 2) and raw data will also be examined to determine if the MQOs for the project have been met. Results from these audits will be documented in quality assurance worksheets (see Appendix E) that will be prepared for each batch of samples.

In the event that a potential quality assurance issue is identified through these audits, Herrera's Data Quality Assurance Officer (see *Organization and Key Personnel* section) will review the data to determine if any response actions are required. Response actions in this case might include the collection of additional samples, reanalysis of existing samples if not yet past holding time, or advising the laboratory that methodologies or QA/QC procedures need to be improved.

11.2. Reporting

Data summary reports will be prepared on an annual basis over the anticipated 10-year timeframe for implementing the RPWS. These reports will provide tabular and/or graphical summaries of all data that were collected over the preceding year in connection with the following monitoring components of the RPWS: hydrologic, water quality, sediment quality, physical habitat, and biological. These reports will provide a detailed description of any quality assurance issues associated with these data based on results from the audits (see *Audits and Reports* section) and data usability assessments (see *Data Quality Assessment* section). Any corrective actions that were undertaken to address quality assurance issues will also be described. Finally, these reports will document all rehabilitation efforts that have occurred in the Application watersheds over the previous year. Included will be detailed information on the design and operational status of structural stormwater controls and the frequency and geographic extent of nonstructural stormwater control implementation.

In years 4, 6, 8, and 10 of the RPWS implementation, trend analyses reports will also be prepared as companion documents to the data summary reports described above. These reports will summarize the results of statistical analyses that are described in the *Experimental Design* and *Data Quality Assessment* sections of this QAPP. These reports will specifically document statistically significant trends identified through these analyses in the Application, Reference, and Control. A detailed discussion of these trends will be provided with a specific emphasis on their relationship to rehabilitation efforts in the Application watersheds. Finally, a summary of major conclusions from these analyses will also be provided.

Finally, stand-alone reports will be prepared to summarize performance of specific structural stormwater controls that are evaluated through the Effectiveness Monitoring component of the RPWS. These reports will be prepared in accordance with guidelines from Ecology's TAPE program (Ecology 2011). Results from these reports will also be referenced as applicable in the discussion provided for the trend analysis reports described above.

12. DATA VERIFICATION AND VALIDATION

Data verification and validation will be performed on both the hydrologic and water quality data that are collected through the duration of this project. The specific procedures that will be used to verify and validate each type of data are described in the following sections.

12.1. Verification and Validation Methods for Hydrologic Data

The verification and validation process for hydrologic data will involve the following steps:

1. Precipitation data from the study will be reviewed to identify any significant gaps. If possible, these gaps will be filled using data obtained from a nearby rain gauge.
2. The available discharge and water level data from the monitoring stations will be verified based on comparisons of the associated hydrographs to the hyetographs for individual storm events. Gross anomalies (such as data spikes), gaps, or inconsistencies that are identified through this review will be investigated to determine if there are quality assurance issues associated with the data that limit their usability.
3. If minor quality assurance issues are identified in any portion of the discharge record or in the water level data from a particular station and storm event, the data from that station and event will be considered an estimate and assigned a (E) qualifier. If major quality assurance issues are identified in any portion of the data from a particular station and/or storm event, the data from that station and event will be rejected and assigned an (*W*) qualifier. Estimated values will be used for evaluation purposes while rejected values will not.

12.2. Verification and Validation Methods for Water and Sediment Quality Data

Data will be reviewed and audited within 14 business days of receiving the results from the laboratory (see *Audits and Reports* section). This review will be performed to ensure that all data are consistent, correct and complete, and that all required quality control information has been provided. Specific quality control elements for the data (see Tables 1 and 2) will also be examined to determine if the MQOs for the project have been met. Values associated with minor quality control problems will be considered estimates and assigned *J* qualifiers. Values associated with major quality control problems will be rejected and qualified *R*. Estimated values may be used for evaluation purposes, while rejected values will not be used. The following sections describe in detail the data validation procedures for these quality control elements:

- Completeness
- Methodology
- Holding times

- Method blanks
- Reporting limits
- Duplicates
- Matrix spikes
- Control standards
- Sample representativeness

12.2.1. Completeness

Completeness will be assessed by comparing valid sample data with this QAPP and the chain-of-custody records. Completeness will be calculated by dividing the number of valid values by the total number of values. If fewer than 95 percent of the samples submitted to the laboratory are judged to be valid, then more samples will be collected until at least 95 percent are judged to be valid.

12.2.2. Methodology

Methodologies for analytical procedures will follow US EPA approved methods (APHA et al. 1992, 1998; US EPA 1983, 1984, 1986; ASTM 2007) specified in Tables 1 and 3. Field procedures will follow the methodologies described in this QAPP. Any deviations from these methodologies must be approved by the City and Ecology and documented in an addendum to this QAPP. The database will include a field for identifying analytical method. Deviations that are deemed unacceptable will result in rejected values (*R*) and will be corrected for future analyses.

12.2.3. Holding Times

Holding times for each analytical parameter in this study are summarized in Table 5. Holding time compliance will be assessed by comparing sample collection dates and times analytical dates and times.

Data from samples that exceed the specified maximum holding times by less than 2 times the holding time will be considered estimates (*J*). Data from samples that exceed the maximum holding times by more than 2 times holding time will be rejected values (*R*).

12.2.4. Method Blanks

Method blank values will be compared to the MQOs that have been identified for this project (see Tables 1 and 2). If an analyte is detected in a method blank at or below the reporting limit, no action will be taken. If blank concentrations are greater than the reporting limit, the associated method blank data will be labeled with a *U* (in essence increasing the reporting limit for the affected samples), and associated project samples within five times the de facto reporting limit will be flagged with a *J*.

12.2.5. Reporting Limits

Both raw values and reporting limits will be presented in each laboratory report. If the proposed reporting limits are not met by the laboratory, the laboratory will be requested to reanalyze the samples or revise the method, if time permits. Proposed reporting limits for this project are summarized in Table 5.

12.2.6. Duplicates

Duplicate results exceeding the MQOs for this project (see Tables 1 and 2) will be noted, and associated values may be flagged as estimates (*J*). If the objectives are severely exceeded (such as more than twice the objective), then associated values may be rejected (*R*).

12.2.7. Matrix Spikes

Matrix spike results exceeding the MQOs for this project (see Tables 1 and 2) will be noted, and associated values may be flagged as estimates (*J*). However, if the percent recovery exceeds the MQOs and a value is less than the reporting limit, the result will not be flagged as an estimate. Nondetected values will be rejected (*R*) if the percent recovery is less than 10 percent.

12.2.8. Control Standards

Control standard results exceeding the MQOs for this project (see Tables 1 and 2) will be noted, and associated values will be flagged as estimates (*J*). If the objectives are severely exceeded (such as more than twice the objective), then associated values will be rejected (*R*).

12.2.9. Sample Representativeness

The data collected for this study will be labeled with unique quality assurance flags for both laboratory and field data quality issues. Table 8 presents the flagging scheme that will be used in the reports produced for this project.

Table 8. Data Qualifier Definitions and Usage Criteria.		
Data Qualifier	**Definition**	**Criteria for Use**
J	Value is an estimate based on analytical results.	MQOs for field duplicates, laboratory duplicates, matrix spikes, laboratory control samples, holding times, or blanks have not been met.
R	Value is rejected based on analytical results.	Major quality control problems with the analytical results.
U	Value is below the reporting limit.	Based on laboratory method reporting limit.
UJ	Value is below the reporting limit and is an estimate based on analytical results.	Based on laboratory method reporting limit; MQOs for analytical results have not been met.

13. DATA QUALITY ASSESSMENT

Separate subsections herein describe the procedures that will be used to assess the usability of the data, and analyze the data.

13.1. Data Usability Assessment

The Herrera Data Quality Assurance Officer (see *Project Organization and Schedule* section) will provide an independent review of the laboratory QC data from each sampling event using the MQOs that have been identified in this QAPP. The results will be presented in water and sediment quality data quality memorandums that will be prepared with the annual data summary reports (see *Audits and Reports* section). The data quality memorandums will summarize quality control results, identify when data quality objectives were not met, and discuss the resulting limitations (if any) on the use or interpretation of the data. Specific quality assurance information that will be noted in the data quality assessment report includes the following:

- Changes in and deviations from the QAPP
- Results of performance or system audits
- Significant quality assurance problems and recommended solutions
- Data quality assessment results in terms of precision, bias, representativeness, completeness, comparability, and reporting limits
- Discussion of whether the quality assurance objectives were met, and the resulting impact on decision-making
- Limitations on use of the measurement data

To assess the quality of the flow data, the King County Data Quality Assurance Officer will review results from the verification and validation process that was applied to the hydrologic data (see *Data Verification and Validation* section). Based on this review, specific data points or periods in the continuous time series data that are considered estimated or rejected values will be summarized in a tabular format. These results will then be presented in hydrologic data quality assessment report that will include a discussion of the resulting limitations, if any, on the use or interpretation of the data. The hydrologic data quality assessment report will also be prepared with the annual data summary reports.

13.2. Data Analysis Procedures

As described previously, the RPWS is being implemented to evaluate the effectiveness of watershed rehabilitation efforts for improving receiving water conditions at the watershed scale. To answer this question, the Status and Trends Monitoring component of the RPWS will utilize a “paired watershed” experimental design that will involve the collection of various hydrologic, chemical, physical habitat, and biological indicators of stream health over an extended time frame in watersheds classified as Application, Reference, and Control. Statistical analyses will be performed to detect trends in these watersheds with the trend of interest being evidence that receiving water conditions are improving based on one or more of these indicators in the Application watersheds while conditions in the Reference and Control watersheds remain relatively static. The specific statistical analyses procedures that will be used to detect these trends are summarized in Table 9 by indicator type.

Table 9. Data Analysis Procedures for the Redmond Paired Watershed Study.

Indicator	Data Analysis Procedures
Hydrology Monitoring	
• Continuous Flow	• Measured flows in Tosh Creek and Monticello Creek will be compared to modeled flows for forested and existing conditions (i.e., conditions when the models were developed) that were derived from existing hydrologic models that have been developed for these watersheds using Hydrological Simulation Program—Fortran (HSPF). For these analyses, the measured and modeled flows will be post-processed to delineate individual periods of base and storm flow, respectively, across the entire time series for a given water year. Separate statistical analyses (Wilcoxon signed rank tests) will then be performed to determine if measured peak flows and flow volumes, respectively, during storm flow are significantly different from modeled flows for either the forested and existing conditions. Statistical significance in these tests will be evaluated based on an α-level of 0.05.
• High pulse count • High pulse frequency • High pulse count duration • High pulse count range • Low pulse count • Low pulse count frequency • Low pulse count duration • Low pulse count range • Richards-Baker (RB) flashiness index • TQ Mean • Storm volume • Base volume • Total flow volume	• Trends over time at each monitoring station will be evaluated using parametric (Pearson's r) and nonparametric (Kendall's tau or Spearman's rho) tests of correlation between these indicators and time. Statistical significance of the correlation coefficients will be evaluated based on an α-level of 0.05.

Table 9 (continued). Data Analysis Procedures for the Redmond Paired Watershed Study.	
Indicator	**Data Analysis Procedures**
Water Quality Monitoring	
• Total suspended solids • Turbidity • Conductivity • Hardness • Dissolved organic carbon • Fecal coliform bacteria • Total phosphorus • Total nitrogen • Copper, total and dissolved • Zinc, total and dissolved	• Trends over time at each monitoring station will be evaluated using parametric (Pearson's r) and nonparametric (Kendall's tau or Spearman's rho) tests of correlation between these indicators and time. Where possible, variation in the indicator data related to changes in stream flow will be removed prior to performing the correlation analyses using methods described in Helsel and Hirsch (2002). In all cases, statistical significance of the correlation coefficients will be evaluated based on an α-level of 0.05. • Annual mass load estimates will also be derived for the following subset of indicators using the nonparametric "smearing" approach described in Helsel and Hirsch (2002): total suspended solids, total phosphorus, total nitrogen, total copper, and total zinc. Trends over time at each monitoring station will be evaluated using parametric (Pearson's r) and nonparametric (Kendall's tau or Spearman's rho) tests of correlation between these mass load estimates and time. Statistical significance of the correlation coefficients will be evaluated based on an α-level of 0.05.
• Temperature • Conductivity	• Continuous data for temperature and conductivity will be post processed to compute monthly average and peak values form the time series. Trends over time at each monitoring station will be evaluated using a seasonal Kendall test (Helsel and Hirsch 2002) of correlation between these values and time. Statistical significance of the correlation coefficients will be evaluated based on an α-level of 0.05.
Sediment Quality Monitoring	
• Total organic carbon • Copper • Zinc • Polycyclic aromatic hydrocarbons • Phthalates	• Trends over time at each monitoring station will be evaluated using parametric (Pearson's r) and nonparametric (Kendall's tau or Spearman's rho) tests of correlation between these indicators and time. Statistical significance of the correlation coefficients will be evaluated based on an α-level of 0.05.
Physical Habitat Monitoring	
• Bank-full width • Wetted width • Cumulative bar width • Bank-full depth • Wetted depth • Substrate class • Substrate embeddedness • Fish cover	• No statistical analyses will be performed on the data from physical habitat monitoring. Instead, the data from all indicators will be evaluated collectively from each year of monitoring to the next to obtain an overall assessment of physical habitat conditions. Improving or degrading conditions at specific stations will then be identified based on best professional judgement.

Table 9 (continued). Data Analysis Procedures for the Redmond Paired Watershed Study.	
Indicator	**Data Analysis Procedures**
Physical Habitat Monitoring (continued)	
• Thalweg depth • Presence of bars • Presence of edge pools • Main channel slope and bearing • Large woody debris tally, including notation of diameter, length, category, zone, and key-pieces • Evidence of vegetation colonization below OHWM that persists more than 1 year • Slopes vegetated over the crown of the bank • Presence of desirable native plant species • Presence of invasive plant species • Presence of good-habitat indicator liverwort species • Channel incision or aggradation • Channel widening, narrowing, or migration • Changes in channel slope, sinuousity, and/or bed-form type	• No statistical analyses will be performed on the data from physical habitat monitoring. Instead, the data from all indicators will be evaluated collectively from each year of monitoring to the next to obtain an overall assessment of physical habitat conditions. Improving or degrading conditions at specific stations will then be identified based on best professional judgement.
Biological Monitoring	
• Benthic Index of Biotic Integrity • Taxa Richness • Ephemeroptera Richness • Plecoptera Richness • Trichoptera Richness • Clinger Percent • Long-Lived Richness • Intolerant Richness • Percent Dominant • Predator Percent • Tolerant Percent	• Trends over time at each monitoring station will be evaluated using parametric (Pearson's r) and nonparametric (Kendall's tau or Spearman's rho) tests of correlation between these indicators and time. Statistical significance of the correlation coefficients will be evaluated based on an α-level of 0.1.

As described in the *Audits and Reporting* section, these analyses identified in Table 9 will be performed for trend analyses reports that will be prepared in years 4, 6, 8, and 10 of the RPWS implementation. The 4-year delay in conducting the analyses will allow sufficient time for the broad implementation of rehabilitation efforts in the Application watersheds that could contribute to detectable improvements in receiving water conditions.

Finally, existing data analysis procedures from Ecology's TAPE guidelines (Ecology 2011) will used to evaluate the performance of specific structural stormwater controls that are monitored through the Effectiveness Monitoring component of the RPWS.

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APPENDIX A

Monitoring Procedures from QAPP for Status and Trends Monitoring of Small Streams in the Puget Lowlands Ecoregion

Appendix B. Data quality assurance

B-1. Data quality indicators for benthic macroinvertebrates and periphyton

The integrity of the data collected by this project is upheld by maintaining a high quality and addressing the five objectives below. The quality of the sampling protocol is checked by analyzing the degree of sampling and visit precision, attempting to maintain less than 20% variation among reference stream data for taxa richness in benthos and periphyton samples. The aim is to collect samples that are representative of community and ecological conditions for each stream. Data are collected with common protocols used by other regional biological monitoring programs. This improves data comparability and usefulness among colleagues in biomonitoring.

Visit precision

Visit precision measures variability in the sampling method and is related to the variability of collecting a composite sample in a reach. Visit precision is estimated by collecting duplicate composite samples of the invertebrate and periphyton communities within the same reach during the same day at 10% of the reaches sampled annually. Visit precision is calculated using the RSD from two replicate composite samples and should be < 20% in reference streams when using the taxa richness metric.

Bias

Sampling bias is 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 (Kammin, 2010). Bias may be caused by the same field investigator conducting the same task at each site. It may also occur due to consistent misinterpretation of protocols by a group of field investigators.

Representativeness

Representativeness measures the degree to which a sample reflects the population from which it came - a data quality indicator (USGS, 1998). For ambient monitoring, sites should be representative of minimally- or least-disturbed conditions in the sampled stream. For targeted monitoring, the sites should be representative of the range of conditions in the sample area. The sampling protocols in the appendices are designed to produce consistent and repeatable results in each stream reach. Physical variability within reaches is accounted for through reach-wide sampling of the various depths, substrates, and flow conditions throughout the stream.

Completeness

Completeness is defined as the amount of valid data obtained from a data collection project compared to the planned amount and is usually expressed as a percentage (EPA, 1997). Our target for completeness of data is 100%. Sample loss is minimized with sturdy sample storage vessels and adequate labeling of each vessel. Sample vessel type and labeling information are described under the sections "Sampling Stream Macroinvertebrates", and "Sampling Periphyton" in the Appendix D. Sample contamination occurs when containers are improperly sealed or stored. Loss of material or desiccation diminishes the integrity of the sample. If the validity of the information from the sample is in question, the sample will be flagged and excluded from analysis.

Completeness is determined by four criteria:

- Number of samples collected compared to the sampling plan.
- Number of samples shipped and received in good condition by the laboratory and the taxonomy contractor.
- Laboratory's ability to produce usable results for each sampling event.
- Sample results accepted by the project manager.

Comparability

Comparability describes the degree to which different methods, data sets, and decisions agree or can be represented as similar (EPA, 1997). Comparable data sets allow for sharing data with other organizations that adhere to the same protocols, such as field sampling and analytical methods.

In the spring of the year prior to monitoring the project manager will organize a training session for the WHM field work. Field staff will be expected to follow the protocols presented during training, especially when they are updated over the SOPs listed in this QAPP. At this time, the staff will verify, by signature, that applicable SOPs and protocols were reviewed during the training. This will improve the comparability of data collected within the program.

Biological monitoring efforts within Ecology use the applicable protocols followed by Washington's Status and Trends Monitoring Program. These protocols are similar to those of others in the region, including the Oregon Department of Environmental Quality's bioassessment program, and EPA's Regional Environmental Monitoring and Assessment Program (R-EMAP). Following these commonly accepted protocols will result in data that is comparable to other regional programs.

B-2. Data quality indicators for water and sediment chemistry

Accuracy

Accuracy is the measure of agreement between a measurement's result and the true or known value. Analytical accuracy can be found by analyzing known reference materials or known standards (LCS, ms/msd, and/or surrogates). A common metric is the percent recovery of a spike. Factors that influence analytical accuracy include laboratory calibration procedures, sample (field and laboratory) preparation procedures, and laboratory equipment or deionized water contamination.

Sensitivity

Sensitivity refers to the concentration that the analytical method can positively identify and report analytical results. The laboratory's "detection" limit indicates their sensitivity for a given method. The reporting limits specified in Tables 20-21 indicate the target quantitation limit established from experience at Manchester Environmental Laboratory (MEL) and King County

Appendix C. Watershed health measurement procedures

C-1. Site verification and layout for small streams

Personnel responsibilities

This method is performed by 2 or more trained staff. Agencies conducting monitoring are responsible for gathering permissions for property access, if necessary.

Equipment, reagents, supplies

- GPS
- *GPS Positions Form*
- Measuring rod
- 50-m tape
- Flagging
- Permanent marker
- Laser rangefinder
- Soft-lead pencil
- *Site Verification Form*
- Wading gear
- No. 2 pencil
- Maps

Summary of procedure

The crew first establishes the data collection event by:

(1) Navigating to the site using the Master Sample site coordinates provided on the RSMP website (www.ecy.wa.gov/programs/wq/stormwater/municipal/rsmp.html).
(2) Verifying that they are at the correct location and determining the site suitability for sampling.
(3) Defining the upper and lower boundaries and transects within the site.

Establish the data collection event

Before leaving the office, refer to the *GPS Positions Form* (Figure C-1.1). Enter the SITE_ID portion of the Data Collection Event (DCE) using a number 2 pencil. Enter the Latitude and Longitude as listed. Navigate to the site using the GPS receiver. Upon arrival, record the date (MMDD) and time (military) portion of the DCE. Record the GPS-measured coordinates for the Index Station. Identify the bank at which these coordinates were measured (left and right are interpreted when facing downstream). Also note the precision of the GPS measurement. Other notes on location can also be recorded. Record the turn-by-turn directions taken to reach the site's access point.

Reviewed by (Initials): [illegible]

Status and Trends Program - GPS Positions Form

Site Number		YY	MMDD	HH	MM
DCE: WAM0600-000018-DCE-		2009-	0815-	09:	00

Station	Bank (circle one)	Master Lat dec deg e.g. 47.123456	Master Lon dec deg e.g. 120.123456	GPSlatDD e.g. 47.123456	GPSLonDD e.g. 120.123456	Accuracy	Accuracy Units (ft, EPE, etc.)	Flag
INDEX STATION	L (R)	46.62843992	-122.04131986	46.62844	-122.04132	3	meters	
A0	L (R)			46.62770	-122.04160	3	meters	
B0	L R							
C0	L R							
D0	L R							
E0	L R							
F0	L (R)			46.62844	-122.04132	3	meters	
G0	L R							
H0	L R							
I0	L R							
J0	L R							
K0	(L) R			46.6290	-122.0410	3	meters	
PUTIN	L R							
TAKEOUT	L R							

ALL COORDINATES TO BE RECORDED IN NAD83

Position comments including accuracy: Index station is at transect F0

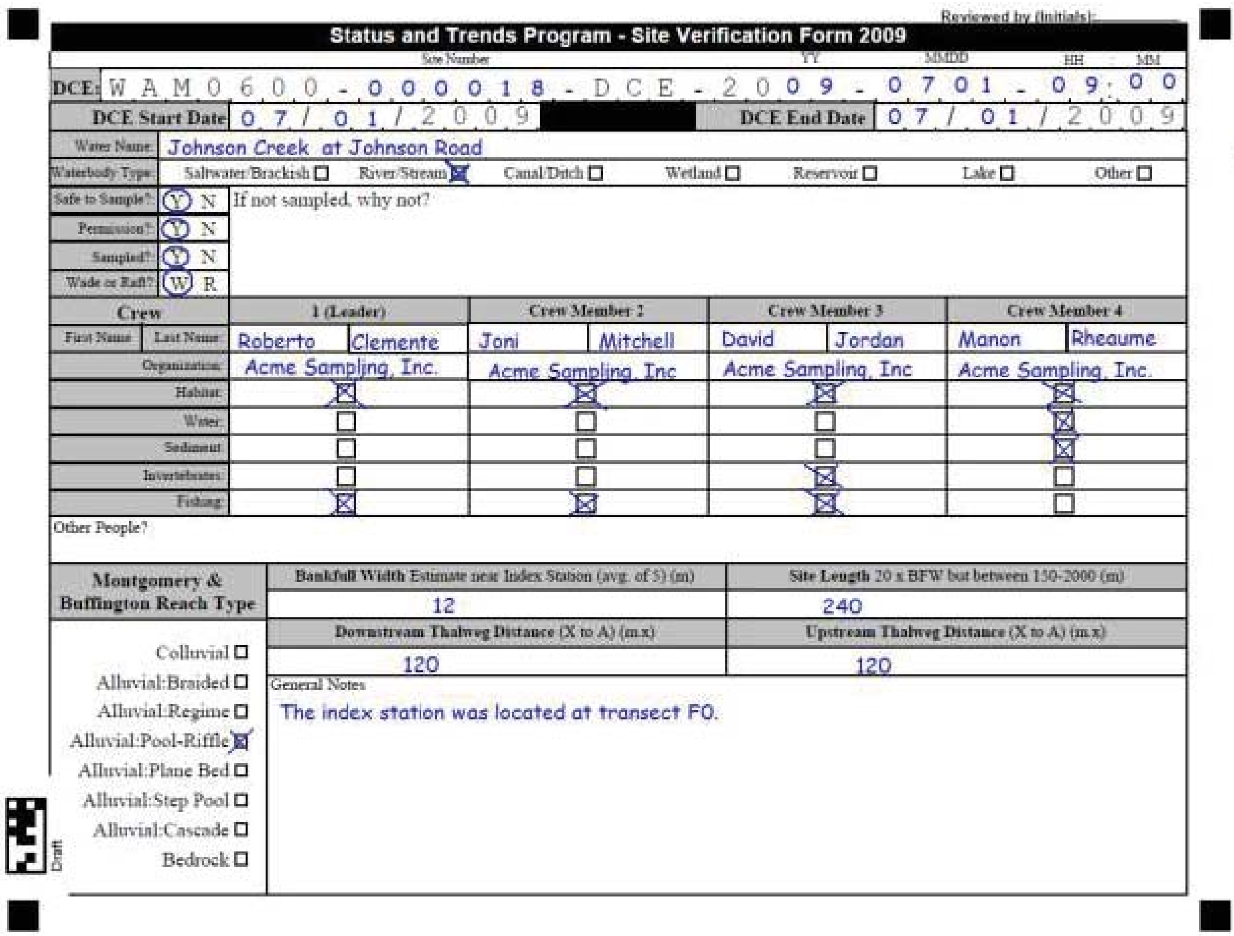
Directions to access point: From Hwy 706 in Ashford, drive south on FR26 for 10 miles. Hike west about 0.5 miles (no trail).

Draft

Figure C-1.1. The *GPS Positions Form* with example data. Note: Sometimes streams have re-routed after production of the map from which the Master coordinates were generated. In these cases navigate to the closest (most representative) point on the stream.

Determine site suitability

After arriving and recording the DCE, determine whether the site is suitable for sampling. Refer to the *Site Verification Form* (Figures C-1.2, and C-1.3).



Reviewed by (Initials):

Status and Trends Program - Site Verification Form 2009

	Site Number	YY	MMDD	HH : MM
DCE:	WAM06600-000018-DCE-	2009-	0701-	09:00

DCE Start Date: 07/01/2009 | DCE End Date: 07/01/2009

Water Name: Johnson Creek at Johnson Road

Waterbody Type: Saltwater/Brackish ☐ River/Stream ☒ Canal/Ditch ☐ Wetland ☐ Reservoir ☐ Lake ☐ Other ☐

Safe to Sample?: (Y) N

Permission?: (Y) N

Sampled?: (Y) N

Wade or Raft?: (W) R

If not sampled, why not?

Crew	1 (Leader)		Crew Member 2		Crew Member 3		Crew Member 4	
First Name / Last Name	Roberto	Clemente	Joni	Mitchell	David	Jordan	Manon	Rheaume
Organization	Acme Sampling, Inc.		Acme Sampling, Inc		Acme Sampling, Inc		Acme Sampling, Inc.	
Habitat	☒		☒		☒		☒	
Water	☐		☐		☐		☒	
Sediment	☐		☐		☐		☒	
Invertebrates	☐		☐		☒		☐	
Fishing	☒		☒		☒		☐	

Other People?

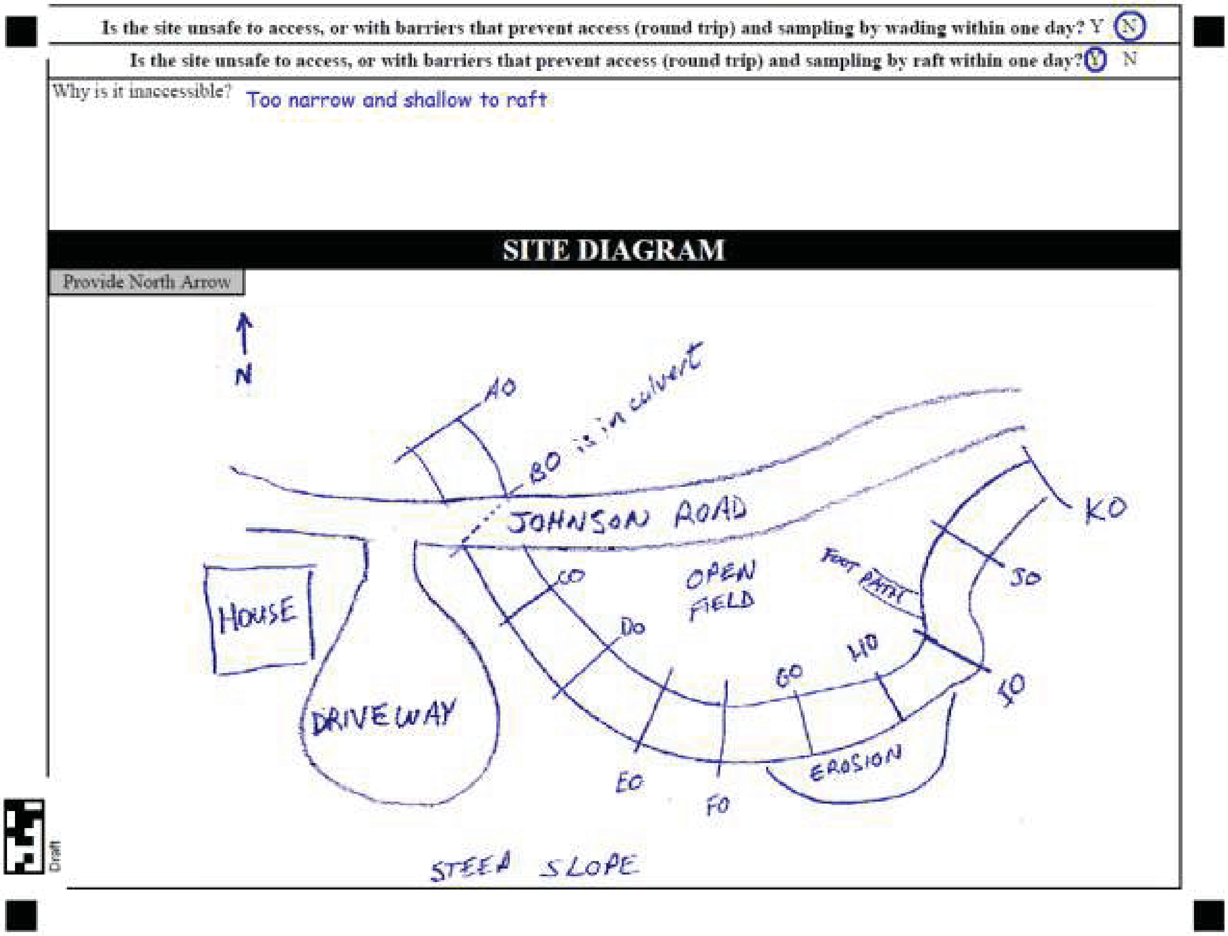
Montgomery & Buffington Reach Type	Bankfull Width Estimate near Index Station (avg. of 5) (m)	Site Length 20 x BFW but between 150-2000 (m)
	12	240
	Downstream Thalweg Distance (X to A) (m.x)	Upstream Thalweg Distance (X to A) (m.x)
	120	120

Colluvial ☐
Alluvial:Braided ☐
Alluvial:Regime ☐
Alluvial:Pool-Riffle ☒
Alluvial:Plane Bed ☐
Alluvial:Step Pool ☐
Alluvial:Cascade ☐
Bedrock ☐

General Notes: The index station was located at transect F0.

Draft

Figure C-1.2. The front side of the Site Verification Form with example data.



Is the site unsafe to access, or with barriers that prevent access (round trip) and sampling by wading within one day? Y (N)

Is the site unsafe to access, or with barriers that prevent access (round trip) and sampling by raft within one day? (Y) N

Why is it inaccessible? Too narrow and shallow to raft

SITE DIAGRAM

Provide North Arrow

Figure C-1.3. The backside of the Site Verification Form, with example data.

Desktop evaluation of the site was performed earlier according to the method described elsewhere in this protocol. Verify that conditions at the site are truly suitable for sampling during the day of arrival. Complete the appropriate fields in the top third of the front side of the *Site Verification Form,* indicating whether the site is being sampled. The site should not be sampled if it is deemed:

- Unsafe to enter.
- To have permission denied by land owners.
- Not a stream or river (e.g., a wetland, lake).
- Not freshwater.
- Within an artificial channel (e.g., canal or ditch).
- Not perennial.
- Not with surface flow for more than 50% of the length.

Record event information

Next, on the *Site Verification Form* (Figure C-1.2), record the information below about the data collection event.

<u>Crew</u>

Record the names of those who are in the crew. Also note the organization that each staff represents. The crew lead will be recorded in column 1. Staff sampling roles can be recorded later, after the day is done, by using the check boxes provided on the form.

<u>Site</u>

BANKFULL STAGE

Near the Index Station (X), visually estimate the bankfull stage. This is best done after considerable training. There are good on-line sources of training materials for identifying bankfull stage identified on PNAMP monitoring methods website (https://www.monitoringmethods.org/Method/Details/3838), including:

1. www.pnamp.org/sites/default/files/BuffingtonPPT_v.2.ppt (Buffington, 2006)
2. www.dnr.wa.gov/Publications/fp_bfw_video_pt1.wmv
   www.dnr.wa.gov/Publications/fp_bfw_video_pt2.wmv (Grizzel, 2008)
3. www.stream.fs.fed.us/publications/bankfull_west.html (Leopold, et al., 1995)

Bankfull stage height is *not* a value that gets recorded on the *Site Verification Form*. The crew merely uses their visual estimate to help understand where to measure bankfull width.

BANKFULL WIDTH

Using the estimated bankfull level, measure the channel width at each of 5 transects near the Index Station:

1. The Index Station (X)
2. 1 bankfull width upstream from X
3. 2 bankfull widths upstream from X
4. 1 bankfull width downstream from X
5. 2 bankfull widths downstream from X

Record the average (nearest meter) of these 5 bankfull width measurements on the *Site Verification Form* (Figure C-1.2). Width measurements can be made using a 50-m tape, a measuring rod, or (if the channel is wide) a laser rangefinder.

SITE LENGTH

Multiply the average bankfull width times 20. This value (whole meters) is the site length for a path that follows the main flow of the river. However, for any site with bankfull width less than 8 meters, the site length will be extended to 150 m, the minimum length for a sampling reach. Record the site length on the *Site Verification Form* (Figure C-1.2). Sampling methods for waded streams are restricted to sites that are less than 25 meters wide (less than 500 m long).

RELATIVE POSITION OF THE INDEX STATION (X) WITHIN THE SITE

The index station (X) is normally located at the middle of the site (i.e. at major transect F). On the *Site Verification Form* (Figure C-1.2), record the distance (tenths of meters) from X to the bottom of the site (i.e., to major transect A) and the distance from X to the top of the site (i.e., to major transect K). This distance is measured along the thalweg channel. Unless there is a reason to adjust the position of X, the distance will be equal to half the site length, in each direction. The relative position of X can be adjusted for several reasons: to keep the top or bottom of the site in lands where permission has not been denied, to keep from changing Strahler (1957) stream order (at the 1:100,000 scale), or to account for barriers such as lakes. The location of the Index Station's coordinates can never be changed. These are pre-defined by the survey design. Although the site position can change relative to X (called "sliding" the site), the site must always contain X.

BED FORM

Assess the site for its predominant reach type according to Montgomery and Buffington (1993, 1997). Review the source materials hot-linked in the references to help understand the differences between bed forms. These references discuss details and provide images of examples. First decide whether the site is predominated by a reach that is colluvial, alluvial, or bedrock. Colluvial streams have a low chance of being sampled by this status and trends program, because we are limiting our sample to perennial streams. Bedrock streams are confined locations with little depositional material present. Most streams sampled will be alluvial. Next, if the site is predominantly alluvial, decide which one of the following sub-classifications can be used to describe the site.

- cascade
- step-pool
- plane-bed
- pool-riffle
- regime
- braided

Place an X in the appropriate box of the *Site Verification Form* (Figure C-1.2) to describe the predominant bed form within the site. Refer to the references (Montgomery and Buffington, 1993, 1997, 1998) for help. Figures C-1.4 and C-1.5 might help.

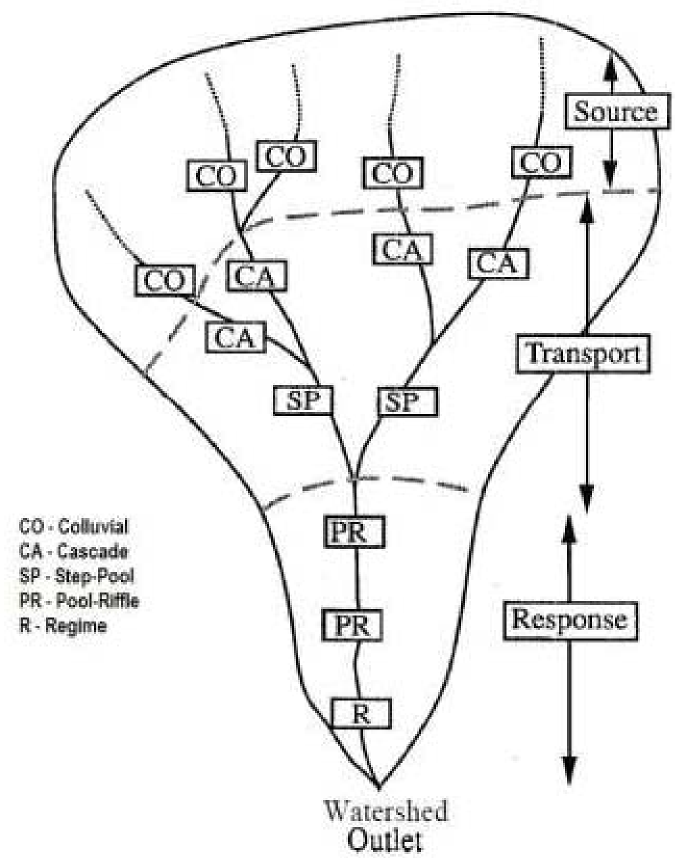


Figure C-1.4. Idealized positions (aerial view) of bed form types within a watershed.

Modified from Figure 22 of Montgomery and Buffington (1993).

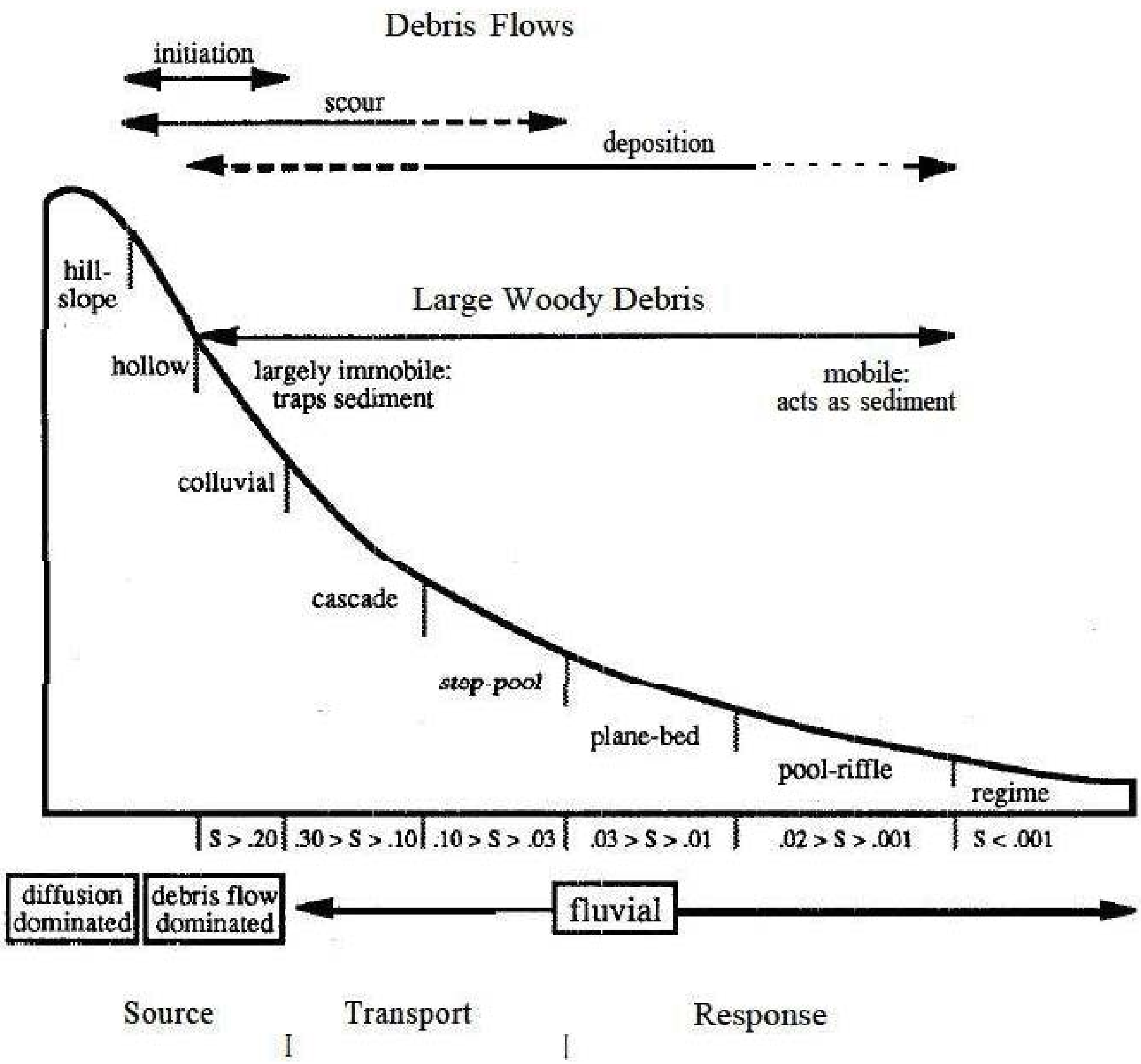


Figure C-1.5. Idealized positions (plan view) of bed form types within a watershed.

From Figure 16 of Montgomery and Buffington (1993).

Lay out the reach

There are 3 types of transects that define the stream site (Table C-1.1): thalweg transects, major transects, and minor transects.

Thalweg transects

Conceptually divide the stream site length using 101 transects which are perpendicular to the thalweg. These are called Thalweg Transects. They occur at regular intervals (0.2 bankfull widths). Thalweg transects, except for those that are also major transects (see below), do not need to be marked. Thalweg transects are useful in concept for describing relative positions within the site.

Major transects

Use orange flagging and a permanent marker to mark each of the 11 equidistant major transects. The lowest is *transect A0*, the highest is *transect K0*. Measure the distance between transects using either a 50-m tape or a measuring rod, by following the thalweg of the stream. The distance between flags should be 1/10th of the site length or (or 2 times the estimated bankfull width at the index station).

Minor transects

Ten minor transects occur midway between the 11 major transects (Table C-1.1). The distance between major and minor transects is 1/5th of the site length (or 1 bankfull width). Minor transects don't need to be marked.

Table C-1.1. The relative position of all transects on a stream site.

Station	Thalweg Transect	Major Transect	Minor Transect	Distance from Bottom (Bankfull Widths*)
A0	Yes	Yes		0
A1	Yes			0.2
A2	Yes			0.4
A3	Yes			0.6
A4	Yes			0.8
A5	Yes		Yes	1
A6	Yes			1.2
A7	Yes			1.4
A8	Yes			1.6
A9	Yes			1.8
B0	Yes	Yes		2
B1	Yes			2.2
B2	Yes			2.4
B3	Yes			2.6
B4	Yes			2.8
B5	Yes		Yes	3
B6	Yes			3.2
B7	Yes			3.4
B8	Yes			3.6
B9	Yes			3.8
C0	Yes	Yes		4
C1	Yes			4.2
C2	Yes			4.4
C3	Yes			4.6
C4	Yes			4.8
C5	Yes		Yes	5
C6	Yes			5.2
C7	Yes			5.4
C8	Yes			5.6
C9	Yes			5.8
D0	Yes	Yes		6
D1	Yes			6.2
D2	Yes			6.4
D3	Yes			6.6

Station	Thalweg Transect	Major Transect	Minor Transect	Distance from Bottom (Bankfull Widths*)
D4	Yes			6.8
D5	Yes		Yes	7
D6	Yes			7.2
D7	Yes			7.4
D8	Yes			7.6
D9	Yes			7.8
E0	Yes	Yes		8
E1	Yes			8.2
E2	Yes			8.4
E3	Yes			8.6
E4	Yes			8.8
E5	Yes		Yes	9
E6	Yes			9.2
E7	Yes			9.4
E8	Yes			9.6
E9	Yes			9.8
F0	Yes	Yes		10
F1	Yes			10.2
F2	Yes			10.4
F3	Yes			10.6
F4	Yes			10.8
F5	Yes		Yes	11
F6	Yes			11.2
F7	Yes			11.4
F8	Yes			11.6
F9	Yes			11.8
G0	Yes	Yes		12
G1	Yes			12.2
G2	Yes			12.4
G3	Yes			12.6
G4	Yes			12.8
G5	Yes		Yes	13
G6	Yes			13.2
G7	Yes			13.4
G8	Yes			13.6
G9	Yes			13.8
H0	Yes	Yes		14
H1	Yes			14.2
H2	Yes			14.4
H3	Yes			14.6
H4	Yes			14.8
H5	Yes		Yes	15
H6	Yes			15.2
H7	Yes			15.4
H8	Yes			15.6
H9	Yes			15.8
I0	Yes	Yes		16
I1	Yes			16.2
I2	Yes			16.4
I3	Yes			16.6

Station	Thalweg Transect	Major Transect	Minor Transect	Distance from Bottom (Bankfull Widths*)
I4	Yes			16.8
I5	Yes		Yes	17
I6	Yes			17.2
I7	Yes			17.4
I8	Yes			17.6
I9	Yes			17.8
J0	Yes	Yes		18
J1	Yes			18.2
J2	Yes			18.4
J3	Yes			18.6
J4	Yes			18.8
J5	Yes		Yes	19
J6	Yes			19.2
J7	Yes			19.4
J8	Yes			19.6
J9	Yes			19.8
K0	Yes	Yes		20

*For very small (with length of 150 m), the transect spacing is 1/100th of the site length, and might not be 0.2 bankfull widths.

Record coordinates

Record the GPS-measured coordinates at the bottom of the site (transect A0), and at the top of the site (transect K0). Note the bank at which the GPS was used and the accuracy of the measurements. You might also record coordinates for other major transects too, but this is not required for the waded streams.

C-2. In-situ measurements in small streams

Purpose and scope

This explains the methods to collect in-situ measures of temperature, dissolved oxygen, pH, and conductivity at small streams using a multi-probe, based on SOP EAP033. Grab sample collection methods are described in SOP EAP034.

Ecology's ambient water quality program collects dissolved oxygen data using the Winkler titration method in the field; however, this is not necessary for permittees conducting monitoring. Therefore the sections of SOP EAP034 referencing DO samples should be disregarded and the protocol for use of LDO meters EAP033 used instead. The calibration techniques are discussed in EAP033 and in the manufacturer's websites. Relevant information from Adams (2010b) is retained here.

Personnel responsibilities

This method is performed by 1 or more persons. This method is applied at every DCE, at the start of the sampling event. Staff performing this method must have been trained.

Equipment, reagents, supplies

- No. 2 pencil.
- *Chemistry and Sampling Form*.
- Calibration Form.
- Hydrolab (or equivalent), components, maintenance kit (Swanson, 2007).
- Hydrolab (or equivalent) Manuals (Hach 1999; 2006a; 2006b).

Summary of procedure

Calibrate the instrument before sampling. Measure the stream twice.

Verify quality control

<u>Prior to sampling</u>

Ensure that the calibrations and that QC checks have been performed according to EAP033. Record calibration information on *Meter Calibration form* (Table C-2.1). Circle "Yes" on the top section of the *Chemistry and Sampling Form* (Figure C-2.1) for each sensor that checked out. Proceed with measurements using sensors that are within criteria.

Table C-2.1. An example Meter Calibration Form, with examples data records.

Recorder:

Project Name: ______________________ **Date:** ____________

Sonde #: ________ **Time** ____________

Temp: ________ **Barometric Pressure:** ____________

PRE Field Run CALIBRATION

	Meter Reading	**Buffer Value**	**Buffer Temp**	**Comments**
Conductivity-100 µS/cm	*94*	*100*		*post-calibration reading was unstable in buffer; ranging between 95 - 105*
Conductivity-1000 µS/cm				
pH - 7				
pH - 10				
pH - 4				*linearity check; not calibrated to buffer value*
DO % Saturation				
Temperature check with NIST thermometer				

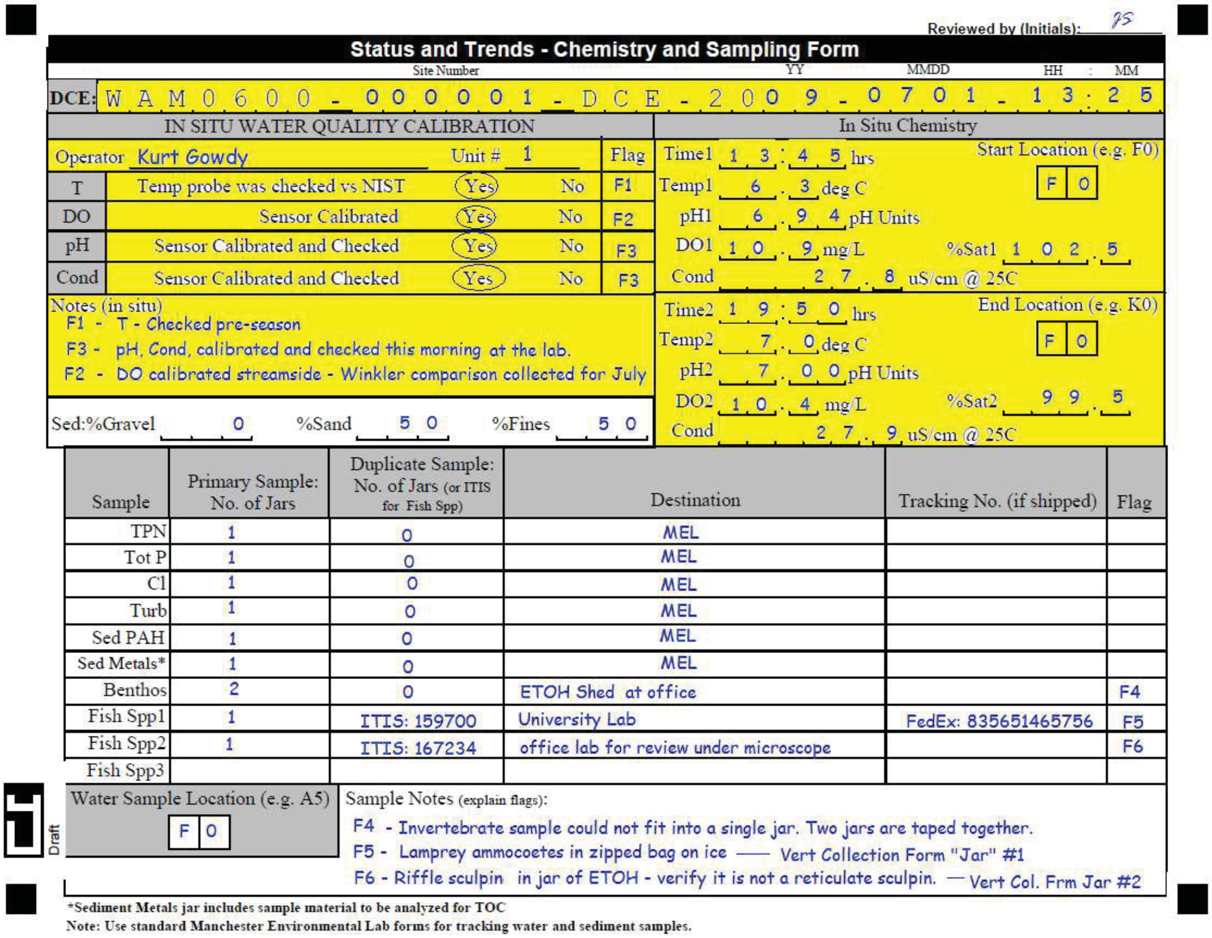
POST Field Run Check

	Meter	**Buffer**	**Comments**
Conductivity-100 µS/cm	*98*	*100*	
Conductivity-1000 µS/cm			
pH - 7			
pH - 10			
pH - 4			
DO % Saturation			

Measure

Measure pH, water temperature, dissolved oxygen, oxygen percent saturation, and specific conductivity during a DCE. Record time (military) and location (thalweg transect). Both sets of in-situ measurements should usually be made near the middle elevation of the site, on the main channel. Measurements should *always* be taken within the boundaries of the site (between transects A0 and K0).

Place the probes into the stream and let them thermally equilibrate to the stream temperature. This might take 3-5 minutes. Then hold the sensors so that they are just below the surface of the water, and completely immersed. Avoid any turbulence. Make sure that readings are stable. On the *Chemistry and Sampling Form* (Figure C-2.1), record temperature (˚ C, nearest tenth), pH (pH unit, nearest hundredth), specific conductivity (uS/cm at 25˚ C, nearest tenth), dissolved oxygen (mg/L, nearest tenth), and oxygen percent saturation (nearest tenth).



Reviewed by (Initials): JS

Status and Trends - Chemistry and Sampling Form

Site Number			YY	MMDD	HH : MM
DCE: WAM06600	- 000001	- DCE	- 2009	- 0701	- 13:25

IN SITU WATER QUALITY CALIBRATION

Operator Kurt Gowdy Unit # 1

				Flag
T	Temp probe was checked vs NIST	(Yes)	No	F1
DO	Sensor Calibrated	(Yes)	No	F2
pH	Sensor Calibrated and Checked	(Yes)	No	F3
Cond	Sensor Calibrated and Checked	(Yes)	No	F3

Notes (in situ)
F1 - T - Checked pre-season
F3 - pH, Cond, calibrated and checked this morning at the lab.
F2 - DO calibrated streamside - Winkler comparison collected for July

Sed:%Gravel 0 %Sand 50 %Fines 50

In Situ Chemistry

Time1 13:45 hrs Start Location (e.g. F0) F0
Temp1 6.3 deg C
pH1 6.94 pH Units
DO1 10.9 mg/L %Sat1 102.5
Cond 27.8 uS/cm @ 25C

Time2 19:50 hrs End Location (e.g. K0) F0
Temp2 7.0 deg C
pH2 7.00 pH Units
DO2 10.4 mg/L %Sat2 99.5
Cond 27.9 uS/cm @ 25C

Sample	Primary Sample: No. of Jars	Duplicate Sample: No. of Jars (or ITIS for Fish Spp)	Destination	Tracking No. (if shipped)	Flag
TPN	1	0	MEL		
Tot P	1	0	MEL		
Cl	1	0	MEL		
Turb	1	0	MEL		
Sed PAH	1	0	MEL		
Sed Metals*	1	0	MEL		
Benthos	2	0	ETOH Shed at office		F4
Fish Spp1	1	ITIS: 159700	University Lab	FedEx: 835651465756	F5
Fish Spp2	1	ITIS: 167234	office lab for review under microscope		F6
Fish Spp3					

Water Sample Location (e.g. A5) F0

Sample Notes (explain flags):
F4 - Invertebrate sample could not fit into a single jar. Two jars are taped together.
F5 - Lamprey ammocoetes in zipped bag on ice —— Vert Collection Form "Jar" #1
F6 - Riffle sculpin in jar of ETOH - verify it is not a reticulate sculpin. — Vert Col. Frm Jar #2

Draft

*Sediment Metals jar includes sample material to be analyzed for TOC
Note: Use standard Manchester Environmental Lab forms for tracking water and sediment samples.

Figure C-2.1. The *Chemistry and Sampling Form*, with examples of in-situ data records.

C-4. Sediment chemistry sampling

This section draws on sediment sampling protocols for sampling and sieving composite sediment samples in streams from USGS National Field Manual (USGS, 2005) and NAWQA protocols (USGS, 1994).

This method explains how to collect and process bed-sediment samples for Watershed Health monitoring. A composite sediment sample will be composed of sub-samples taken from 5 different shallow-water stations in the site. The composite sample will be processed (sieved) in the field to make two unique samples. The first sample will be sieved to less than 2.0 mm and analyzed for multiple organic compounds (PAHs, pesticides, phthalates, PBDEs, PCBs, PPCPs, and H/S) percent solids, total-organic carbon (TOC) and grain size. The second sample will be sieved to less than 63 µm and analyzed for metals (arsenic, cadmium, chromium, copper, lead, silver and zinc).

Personnel requirements

This sampling can be performed by one person in the field, but would likely be done more efficiently by a two-person team during a day-long Watershed Health Sampling event. Pre-sampling cleaning activities should be performed by staff familiar with MSDS and safety procedures. Staff collecting sediments should not use sunscreen and mosquito repellent until finished collecting the samples.

Equipment, reagents, supplies

Equipment and supplies for collecting and processing stream bed-sediment samples for analyses of trace elements and organic contaminants are listed in Table C-4.1. The use of each is explained in the following discussions of preparation for sampling, sampling procedures, and sample processing. The number of supplies depends on the total number of sites permittees are responsible for.

Summary of procedure

These procedures are derived from methods described in Johnson (1997), Blakley (2008a), and Manchester Environmental Laboratory (2008), with the additional sieving procedures described by Radke (2005) and Shelton and Capel (1994). The sample-collection strategy focuses on obtaining samples of fine-grained surficial sediments from natural depositional zones during low-flow conditions and on compositing samples from several depositional zones within a stream reach.

Table B-4.1. Equipment and supplies for collecting and processing bed sediment samples. Use uncolored or white non-metallic sieve and utensils to process bottom material for samples that will be analyzed for metals. Use a stainless steel sieve and polyfluorocarbon (Teflon) utensils to process bottom material for samples that will be analyzed for organic compounds. Brass is acceptable but not recommended.

Sampling and Processing
Bowl, glass, flat bottom, approximately 5 L, 12-in diameter
Sieve, stainless steel, 2.0 mm, 3" diameter (for organics sample)
Sieve Frame, Nylon, 8" diameter (for metals sample)
Nylon sieve cloth, 63 micron (for metals sample)
Funnel, polyethylene, 8" diameter
Policeman, Teflon (to aid sieving)
Spatula, scoop, and spoon, all Teflon
Syringe, plastic, 50ml
Wash bottle (labeled) with Liquinox or Alconox
Wash bottle (labeled) with acetone (pesticide grade)
Wash bottle (labeled) with 10% nitric acid
Wash bottle, plastic 500-ml
Wash bottle, Teflon 500-ml
Deionized water
Personal protective gear as specified by the MSDS
Sample containers (analytical laboratory will supply) – see Table 12 in QAPP
Miscellaneous
MSDS
Gloves - Non-powdered nitrile
Cooler and Ice
Polyethylene bags
Foam sleeves for shipping
Ice
5-gallon plastic bags
Sample Tags/bottle labels (with laboratory-assigned sample numbers)
Aluminum foil

Pre-sampling preparation

Sample Numbers, Jars, and Tags

Prior to sampling staff will obtain sample numbers, sample jars, and labels from laboratories conducting the analysis.

Cleaning

Prior to sampling, the field crew will clean necessary sampling tools (including spares). These are the cleaning steps for each reusable piece of sampling equipment that comes in contact with the sediment sample:

1. Washing in non-phosphate detergent and hot tap water
2. Rinsing with hot tap water
3. Rinsing with 10% nitric acid
4. Rinsing with deionized water three times
5. Air drying in clean area free of contaminants

6. Rinsing with pesticide-grade acetone
7. Air drying in clean area free of contaminants

After drying, equipment will be wrapped in aluminum foil (shiny side out) and stored in polyethylene bags until used in the field. Sampling equipment will be dedicated to the station and will only be used at subsequent stations following cleaning in accordance with the above procedures, which are based on EPA guidelines (EPA, 1990).

Sampling

Use clean equipment at each site. Collect the composite sample by sampling quiescent sediment from each of three suitable locations at each of three to five stations at the site. A suitable location will have these characteristics:

- Surface sediment is dominated by particles < 2 mm diameter (coarse sand or smaller),
- Water depth above the sediment is < than 30 cm,
- The station is always under water throughout the day.
- Anywhere within 10 bankfull widths (upstream or downstream) of the index station.
- Upstream from where staff have entered the stream channel.

Using a Teflon spoon, scoop, or spatula, carefully remove the top 2 cm of sediment and place it into a glass mixing bowl. The spatula can remove thin layers of surficial sediments, and the scoop or spoon can remove the bed material from between rocks and debris. Sieving is easier if the sandy material is avoided. Care must be taken to prevent the fine sediments from being washed away by the stream when bringing the sample to the surface. Collect a total of about 1.5 L of wet sediment.

Sample processing

Sediment samples for several types of analyses will be processed from the single composite sample from a site. One sample will be sieved to less than 63 µm and analyzed for metals. A second sample will be sieved to less than 2.0 mm and analyzed for multiple organic compounds and total-organic carbon. The third sample also will be sieved to less than 2.0 mm and analyzed for percent particle-size distribution less than 63 µm (sand/silt).

Prepare for sample processing:

1. Park the field vehicle as far away from any nearby road(s) as possible and turn off motor (road dust and vehicle emissions can contaminate samples) in order to isolate the sample-processing area from potential contaminants.
2. Set up field-processing area. Preferable areas would be in a van or a building located near the sampling site. If not available, a foldable table can be used onsite.
    a. Spread a large, uncolored or white plastic (non-metallic) sheet over the area where inorganic sample processing is taking place.
    b. Use heavy-duty aluminum sheeting over the area where organic sample processing is taking place.
    c. Keep sample-processing equipment covered (when not processing sample), and keep all sample containers covered or capped.

3. Field rinse processing equipment with native stream water to ensure that all cleaning solution residues are removed, and to equilibrate equipment with sampling environment.
4. Wear powderless, disposable gloves while processing sample. Avoid contact with any potential source(s) of contamination. For example, keep gloved hands off any reactive (metal or plastic) objects when processing samples.

Sieving

Two different sieves are required to process a sample for trace elements and organic contaminants. A 63-µm mesh nylon-sieve cloth held in a plastic frame is used for sieving sediment samples for trace-element analyses, and a 2.0-mm stainless-steel sieve is used for processing samples for organic-contaminants analyses. Wear nitrile gloves and thoroughly mix (homogenize) the composite sample in the glass bowl using the Teflon spatula until a uniform color and texture is achieved. Decant excess water from sample into an appropriate, nonreactive wash bottle, being careful not to lose fine material.

<u>Metals samples</u>

- Stretch the 63-µm mesh nylon-sieve cloth over the plastic-sieve frame and attach retaining ring. Assemble in series the 63-µm mesh nylon cloth sieve and the plastic funnel over a 500-mL plastic sample container.
- Place a small amount of composite sample onto the 63-µm mesh nylon sieve with the spatula. "Pressure sieve" the sample using native water that has been collected directly from the stream into the 500-mL plastic-wash bottle. The fine sediments pass through the sieve with the stream of water delivered by the wash bottle.
- Work small amounts of bed material through the sieve at a time, discarding the material remaining on the sieve. It is not necessary to sieve all the material that is less than 63 µm in each aliquot.

  NOTE: Shaking the sieve aggressively will help separate the fines.

- If additional wash water is needed, allow the sieved sediment/native water to settle several minutes and decant only the native water back into the wash bottle for reuse. Continue to reuse the native water until the necessary amount of sediment sample is obtained (a depth of approximately 1 cm in the sample container). The specific analytical laboratory can tell you how much sample material is needed for the analyses of inorganic constituents; typically that will be about 10 g (dry weight) of sieved sediment.

<u>Organics samples</u>

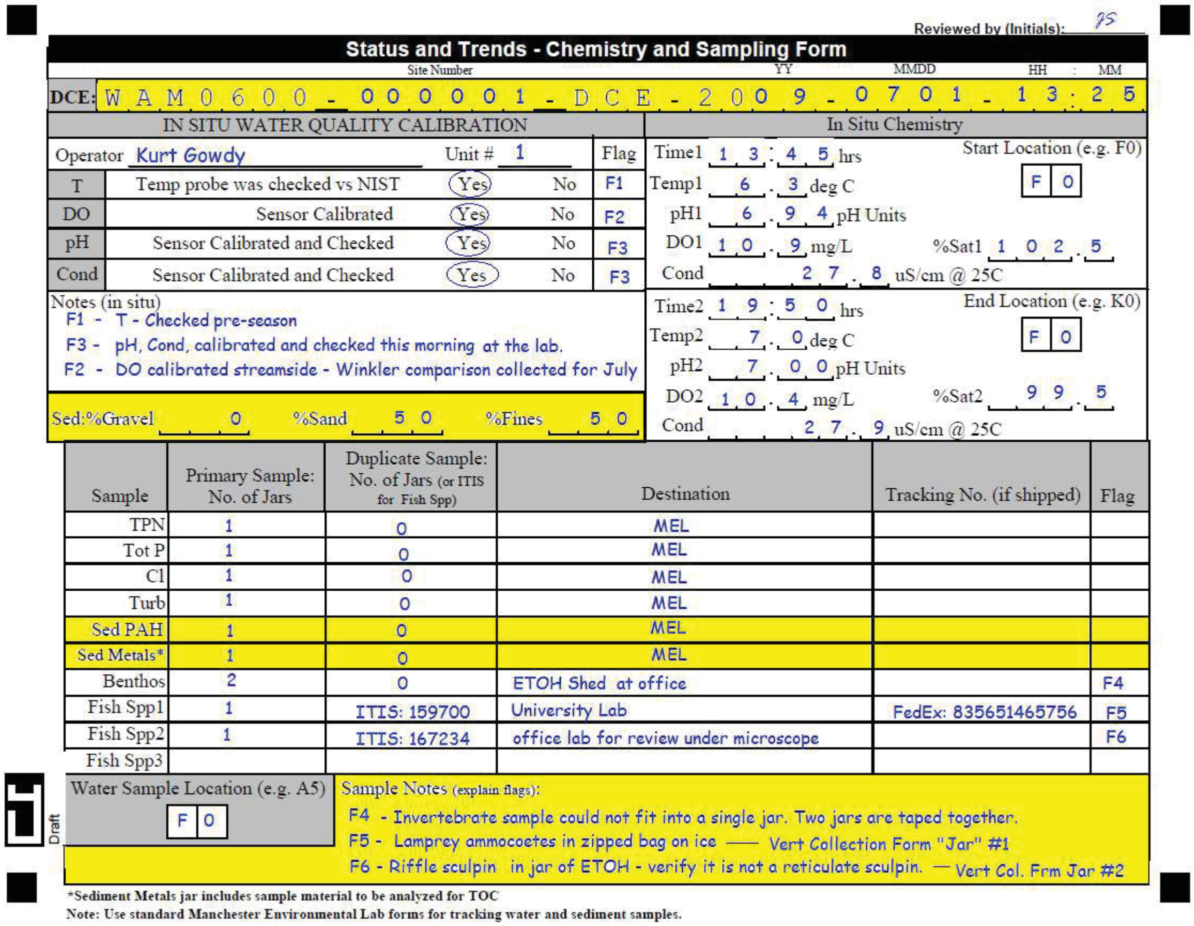
Place the 2.0-mm stainless-steel sieve over a 500-1,000-mL glass sample container. Gently work an aliquot of the sample through the sieve with a teflon policeman or spatula. Do not use water. The bottom of the sieve may require periodic removal of the material that adheres to it. Fill the sample container approximately half full or until an adequate amount of sample material has been collected; about 500 mL of wet sediment is typically needed for analyses of organic contaminants and TOC.

Particle size samples
Using the same 2.0-mm sieve described above, continue to sieve until approximately 2 cm of wet sediment accumulates into a 500-1,000-mL plastic sample container.

Reserve a scoop of the homogenized sample for conducting an estimate on the physical composition of the sediment. Gravel should never be a dominant component of the sample. Sand is gritty to the touch. Fines are not. Record percent gravel, percent sand, and percent fines on the field form. Field-determined grain size estimation is categorized as follows: gravel (>2 mm), sand (2-16 mm), and fines (silt/clay/muck).

Labeling, storage, and shipping

For all samples, label each jar, place into polyethylene bags, and store in a small portable cooler of ice. Record sample information, including number of jars representing each sample on a field form. Figure C-4.1 provides an example form for *Chemistry and Sampling*. Use the appropriate column depending upon whether documenting the primary sample or a duplicate for the date.



Reviewed by (Initials): JS

Status and Trends - Chemistry and Sampling Form

DCE: W A M 0 6 0 0 - 0 0 0 0 0 1 - D C E - 2 0 0 9 - 0 7 0 1 - 1 3 : 2 5
(Site Number; YY; MMDD; HH : MM)

IN SITU WATER QUALITY CALIBRATION				
Operator Kurt Gowdy		Unit # 1		Flag
T	Temp probe was checked vs NIST	(Yes)	No	F1
DO	Sensor Calibrated	(Yes)	No	F2
pH	Sensor Calibrated and Checked	(Yes)	No	F3
Cond	Sensor Calibrated and Checked	(Yes)	No	F3

Notes (in situ)
F1 - T - Checked pre-season
F3 - pH, Cond, calibrated and checked this morning at the lab.
F2 - DO calibrated streamside - Winkler comparison collected for July

Sed:%Gravel 0 %Sand 50 %Fines 50

In Situ Chemistry

Time1 13:45 hrs — Start Location (e.g. F0): F0
Temp1 6.3 deg C
pH1 6.94 pH Units
DO1 10.9 mg/L — %Sat1 102.5
Cond 27.8 uS/cm @ 25C

Time2 19:50 hrs — End Location (e.g. K0): F0
Temp2 7.0 deg C
pH2 7.00 pH Units
DO2 10.4 mg/L — %Sat2 99.5
Cond 27.9 uS/cm @ 25C

Sample	Primary Sample: No. of Jars	Duplicate Sample: No. of Jars (or ITIS for Fish Spp)	Destination	Tracking No. (if shipped)	Flag
TPN	1	0	MEL		
Tot P	1	0	MEL		
Cl	1	0	MEL		
Turb	1	0	MEL		
Sed PAH	1	0	MEL		
Sed Metals*	1	0	MEL		
Benthos	2	0	ETOH Shed at office		F4
Fish Spp1	1	ITIS: 159700	University Lab	FedEx: 835651465756	F5
Fish Spp2	1	ITIS: 167234	office lab for review under microscope		F6
Fish Spp3					

Water Sample Location (e.g. A5): F0

Sample Notes (explain flags):
F4 - Invertebrate sample could not fit into a single jar. Two jars are taped together.
F5 - Lamprey ammocoetes in zipped bag on ice — Vert Collection Form "Jar" #1
F6 - Riffle sculpin in jar of ETOH - verify it is not a reticulate sculpin. — Vert Col. Frm Jar #2

Draft

*Sediment Metals jar includes sample material to be analyzed for TOC
Note: Use standard Manchester Environmental Lab forms for tracking water and sediment samples.

Figure C-4.1. The *Chemistry and Sampling Form*, with fields for sediment chemistry data highlighted.

If you are sampling close to your vehicle, immediately place samples in a cooler of ice. Otherwise bring a small cooler for samples to the field sampling location. Place samples into a cooler of ice as soon as possible.

Check the tag to ensure that the SITE_ID number is recorded. Also record in waterproof ink or pencil:

- Project name
- Data and time that appears in the DCE
- Field sampler names
- Laboratory number
- Parameters for analysis
- Other information needed

Label information will meet the contract laboratory needs.

Sample crews will complete laboratory analysis forms and chain-of-custody forms (if separate) and submit samples to a courier or directly to a laboratory.

C-5. Bank measurements at major transects in waded streams

Purpose and scope

This method explains how to collect measurements for Watershed Health monitoring at each of 11 equidistant transects at each site. Measurements in this procedure will be restricted to one main channel. Instruments included on the procedure include distance measuring devices (e.g., measuring rod, laser rangefinder, 50-m measuring tape), and hand-levels.

Personnel responsibilities

This method is performed by two people. This method is applied at every DCE, at each major transect. Staff performing this method must have been trained.

Equipment, reagents, supplies

- No. 2 pencil
- Measuring rod
- 50-m tape
- Laser rangefinder
- Hand level
- Clinometers
- Calculator

Summary of procedure

Refer to the *Major Transect Form* (Figures C-5.1 and C-5.2). At each of the major Transects (A0- K0), assess the main channel. Measure these channel characters: bankfull width, wetted width, bar width, bankfull height, and bank instability. Describe flags.

BANK		Flag
Wetted Width XXX.X m	3.2	
Bar Width XX.X m	0	
Bankfull Width XXX.X m	5.4	
R Bankfull Height cm	35	
L BankfullHeight cm	32	
LB Instability %	50	F1
RB Instability %	0	

Figure C-5.1. A portion of the Major Transect Form, with example data for this method.

Flag	Comments
F1	slumping bank with cow prints

Figure C-5.2. A portion of the Major Transect Form, with an example flag qualifier.

Channel dimensions

Bankfull stage

At the transect, visually estimate the bankfull stage. This is best done after considerable training, see Section C-2.Use this visual estimate to help understand where to measure bankfull width and bankfull height.

Bankfull width

After locating the bankfull stage at each bank, measure the bankfull width (Figure C-5.3) to the nearest tenth of a meter. Record this value on the *Major Transect Data Form* (Figure C-5.1). Width measurements can be made using either a 50-m tape, a measuring rod, or (if the channel is wide) with a laser rangefinder.

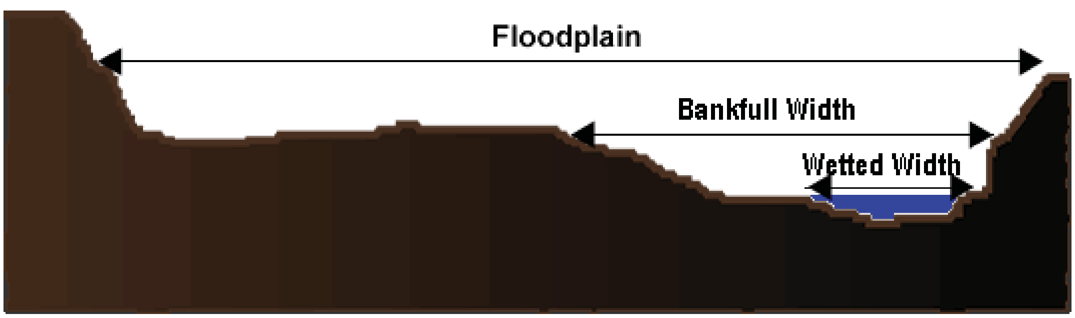


Figure C-5.3. Diagram of widths at the transect (Modified from Endreny 2009).

Wetted width

Observe the wetted margins of the channel. On the *Major Transect Data Form* (Figure C-5.1), record the wetted width (or horizontal distance between these margins) to the nearest tenth of a meter. Do *not* subtract for bars.

Bar width

Using the measuring rod, measure the width of each bar within the wetted channel. Record the sum (nearest tenth of a meter) for bar width.

Bankfull height

Bankfull height is measured using a surveyor's rod with hand level or clinometer. On the *Major Transect Form* (Figure C-5.1), record bankfull height data in whole centimeters. Record the right bankfull height and left bankfull height (Figure C-5.4).

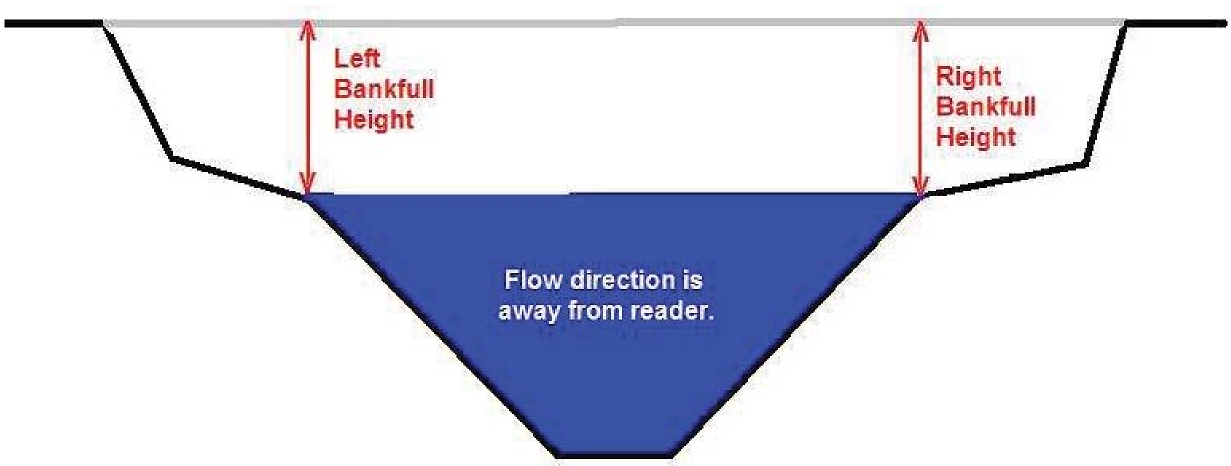


Figure C-5.4. Diagram of the left and right bankfull height measurements.

Bank instability

For waded streams, evaluate how much of a 10-m length of each bank (centered on the primary transect) is unstable. Limit your observations of bank stability to the portion of the bank at and below the bankfull stage. A bank is unstable if it has eroding or collapsing banks. It may have the following characteristics:

- Sparse vegetation on a steep surface
- Tension cracks
- Sloughing

On the *Major Transect Form* (Figure C-5.1), record right bank instability (%) and left bank instability (%).

C-6. Substrate and depth measurements at major transects in waded streams

Purpose and scope

This method explains how to measure substrate characteristics for Watershed Health monitoring at each of 11 equidistant transects at each site. Measurements in this procedure will be restricted to one main channel. This method must be preceded by the Major Transects Method. Instruments included on the procedure include distance measuring devices (e.g., measuring rod, or 50-m measuring tape, caliper), leveling device (hand level or clinometer) and a10-cm PVC ring.

Personnel responsibilities

This method is performed by two people. This method is applied at every DCE, at each major transect. Staff performing this method must have been trained.

Equipment, reagents, supplies

- No. 2 pencil
- measuring rod
- 50-m tape
- PVC ring
- hand-level
- Clinometers
- Calculator

Summary of procedure

Refer to the *Major Transect Data Form* (Figure C-6.1). At each of the major Transects (A0-K0), assess the main channel (channel number 0). Record these characters at each of 11 equidistant stations across the bankfull width:

- Wetted depth
- Bankfull depth
- Substrate type code
- Embeddedness

Station location

Identify the position along the transect. Example stations along a transect would be:

1. **left bank** – at the left bankfull stage.
2. **.1** – 10% distance across the channel.
3. **.2** – 20% distance across the channel.
4. **.3** – 30% distance across the channel.
5. **.4** – 40% distance across the channel.
6. **.5** – halfway across the channel.
7. **.6** – 60% distance across the channel.
8. **.7** – 70% distance across the channel.
9. **.8** – 80% distance across the channel.
10. **.9** – 90% distance across the channel.
11. **right bank** – at the right bankfull stage.

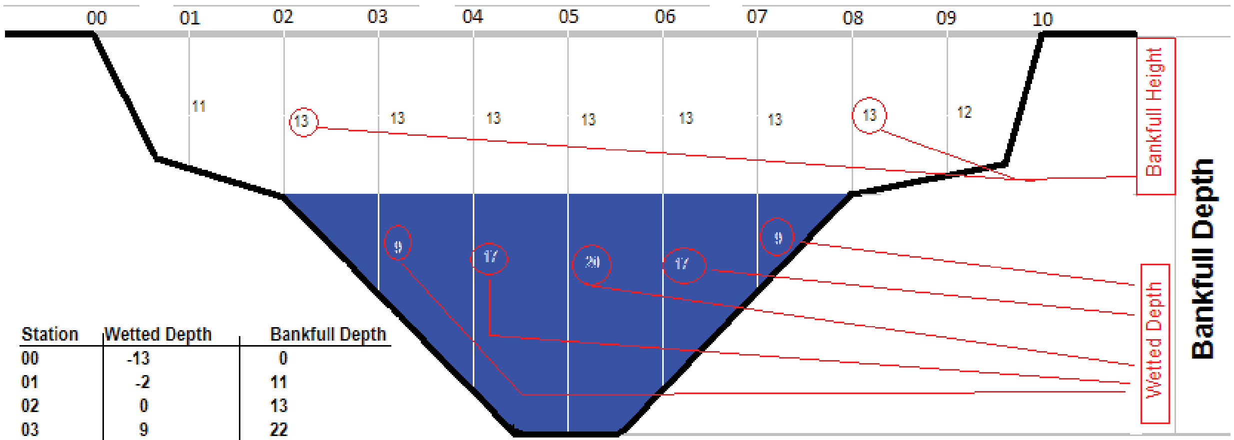
On the Major Transect Form (Figure C-6.1), insert data for depths, substrate type and embeddedness next to each station code. Describe flags (Figure C-6.2). Examples of data can be found in Figures C-6.1, C-6.2, and C-6.3.

SUBSTRATE					
	Wet Depth	BF Depth XXX CM	Size Class	Embd. 0-100%	Flag
left bank	-13	0	SA	100	
.1	-2	11	GF	90	
.2	0	13	GC	50	
.3	9	22	CB	25	
.4	17	30	SB	5	
.5	20	33	CB	25	
.6	17	30	CB	10	
.7	9	22	GC	10	
.8	0	13	WD	90	F1
.9	-1	12	FN	100	
right bank	-13	0	SA	100	

Figure C-6.1. Part of the Major Transect Form with example data for this method.

Flag	Comments
F1	WD = partially buried Douglas fir log, about 60 cm diameter

Figure C-6.2. Part of the Major Transect Form with example flag descriptions.



Station	Wetted Depth	Bankfull Depth
00	-13	0
01	-2	11
02	0	13
03	9	22
04	17	30
05	20	33
06	17	30
07	9	22
08	0	13
09	-1	12
10	-13	0

Figure C-6.3. Transect diagram showing example data for wetted depth, bankfull depth, and bankfull height. The bankfull depth equals the wetted depth plus average bankfull height.

Station depth

For each station, record depth in whole centimeters. This should be the easiest to measure of either wetted depth or bankfull depth. The bankfull depth equals the wetted depth plus average bankfull height. Therefore, if you know one type of depth and the mean bankfull height, you also know the other type of depth.

Substrate type

After recording depth, estimate the substrate particle type at the front of the measuring rod, where it rests on the surface of the streambed. Estimate the size class of that particle based on the intermediate axis length. Record the substrate type code. The choices are listed in Table C-6.1. For fine gravel, coarse gravel, and cobble, use calipers to measure the intermediate axis length of the particle and confirm your estimate of size. For larger sizes, use the measuring rod to confirm your estimate.

Particles smaller than 100 mm are evaluated using a 10-cm ring surrounding the sample point. All particles within the ring are evaluated for size and embeddedness, not just the point. Record the estimated average for surface substrate within the ring.

Table C-6.1. Substrate codes, types, and sizes.

Code	Type	Range Size	Size Gauge
RS	Bedrock (smooth)	>4 m	larger than a car
RR	Bedrock (rough)	>4 m	larger than a car
RC	Concrete/Asphalt	>4 m	larger than a car
XB	Large boulder	1-4 m	meter stick to car
SB	Small boulder	>250 mm–1 m	basketball to meter stick
CB	Cobble	>64 mm–250 mm	tennis ball to basketball
GC	Gravel, coarse	>16 mm to 64 mm	marble to tennis ball
GF	Gravel, fine	>2 mm to 16 mm	ladybug to marble
SA	Sand(2-16 mm)	>0.06 mm to 2 mm	gritty to ladybug
FN	Fines(silt/clay/muck)	<0.06 mm	non gritty
HP	Hardpan- hardened fines	any size	
WD	Wood	any size	
OT	Other (doesn't fit choices above)	any size	

Embeddedness

At each station, touch the nearest particle to foot of the measuring rod then look at it. Estimate embeddedness (%). This is the fraction of a particle's surface that is surrounded by (embedded in) sand or finer sediments (≤ 2 mm). By default, sand or fines are 100% embedded. By default, bedrock is 0% embedded.

Particles smaller than 100 mm are evaluated using a 10-cm ring surrounding the sample point. All particles within the ring are evaluated for size and embeddedness, not just the point. Record the estimated average for surface substrate within the ring.

C-7. Shade measurements at major transects in waded streams

Purpose and scope

This method explains how to measure shade for Watershed Health monitoring at each of 11 equidistant transects at each site. Measurements in this procedure will be restricted to one main channel. This method must be preceded by the Major Transects Method. Instruments included on the procedure include a distance measuring device (e.g., measuring rod) and a convex densiometer (modified according to Mulvey, et al., 1992).

Personnel responsibilities

This method is performed by one person. This method is applied at every DCE, at each major transect. Staff performing this method must have been trained.

Equipment, reagents, supplies

- No. 2 pencil
- *Major Transect Form*
- Measuring rod or 50-m tape
- Modified convex densitometer

Summary of procedure

Refer to the *Major Transect Form* (Figure C-7.1). At each of the major Transects (A0-K0), assess the main channel (channel number 0). Use a convex densiometer (Lemmon, 1957) that has been modified according to Mulvey, et al. (1992). It has 17 intersections. See Figure C-7.2.

DENSIOMETER MEASUREMENTS

(0-17Max)

		Flag			Flag
CenUp	5		CenR	9	
CenL	0		Left	0	
CenDwn	4		Right	17	

Figure C-7.1. Densiometer portion of The Major Transects Form, with example data.

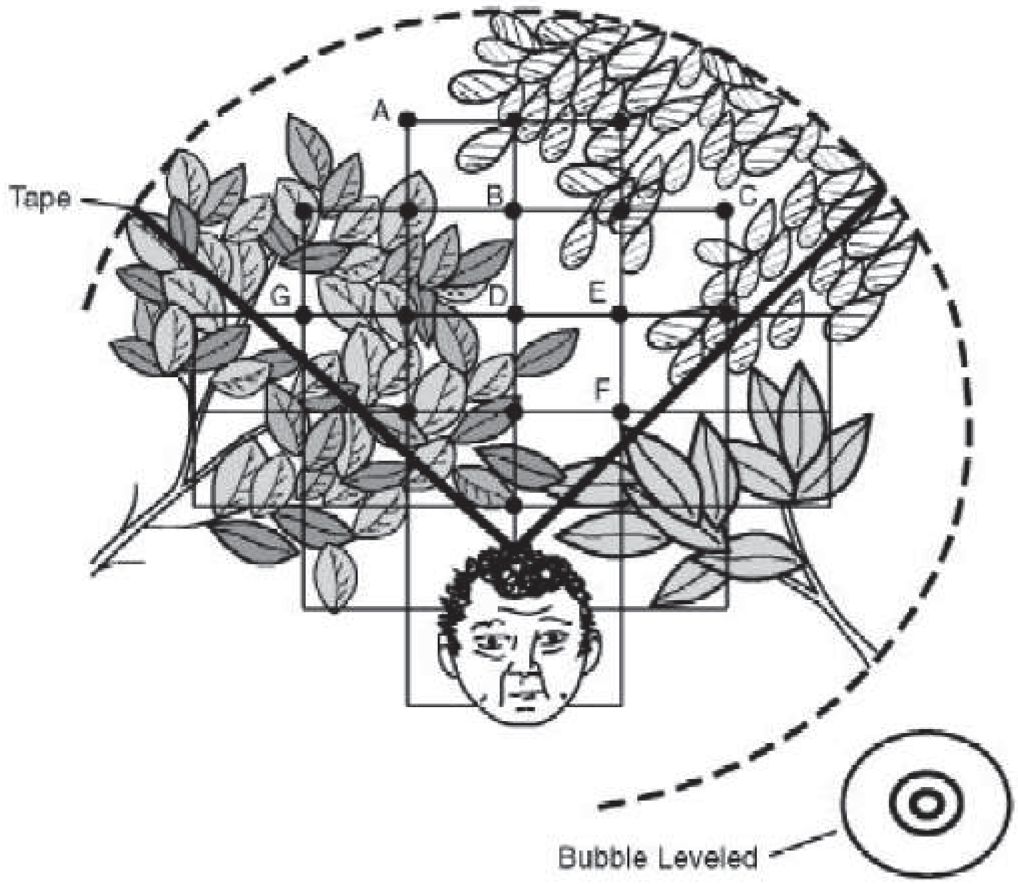


Figure C-7.2. An example reading from a modified convex densiometer. It shows 10 of 17 intersections with shade (a score of "10").

Note the proper positions of the bubble and head reflection (from Mulvey, et al., 1992).

Record how many of the 17 cross-hairs have shade over them. Record for each of six directions on the major transect (Figure C-7.3):

- Facing the left bankfull stage.
- Facing the right bankfull stage.
- Bankfull channel center, facing upstream.
- Bankfull channel center, facing right.
- Bankfull channel center, facing downstream.
- Bankfull channel center, facing left.

At each wetted station, hold the densiometer 30 cm above the water. At each dry station, hold the densiometer 30 cm above the ground. Bank readings should be able to detect shade from riparian understory vegetation such as ferns.

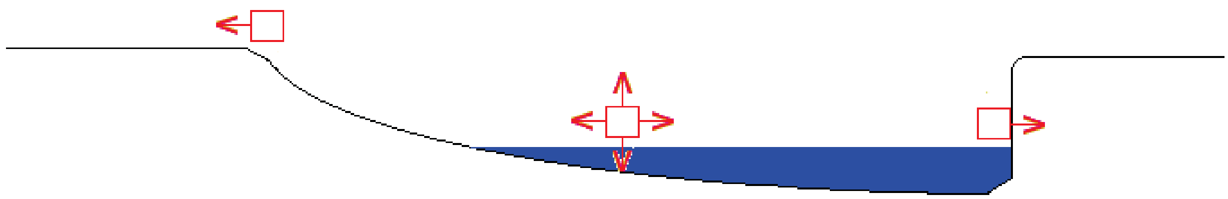


Figure C-7.3. Stations for densiometer measurement on each major transect. The densiometer is held level, and 30 cm above water for wet stations and 30 cm above ground for dry stations.

C-8. Estimating fish cover at major transects in waded streams

Purpose and scope

This method explains how to estimate fish cover for Watershed Health monitoring at each of 11 equidistant transects at each site. Measurements in this procedure will be restricted to one main channel. This method must be preceded by the Major Transects Method. Instruments included on the procedure include a distance-measuring device (e.g., measuring rod).

Personnel responsibilities

This method is performed by one person. This method is applied at every DCE, at each major transect. Staff performing this method must have been trained.

Equipment, reagents, supplies

- No. 2 pencil
- *Major Transect Form*
- Measuring rod or 50-m tape

Summary of procedure

This method is derived from that of Peck, et al. (2006). Within the main channel, evaluate 11 plots (Figure C-8.1) with these characteristics:

- Centered at each major transect.
- Extends 5 meters upstream of each transect.
- Extends 5 meters downstream of each transect.
- Beneath the wetted surface.
- Visually assess the percentage of the water surface that has fish cover provided by each of 10 cover types.

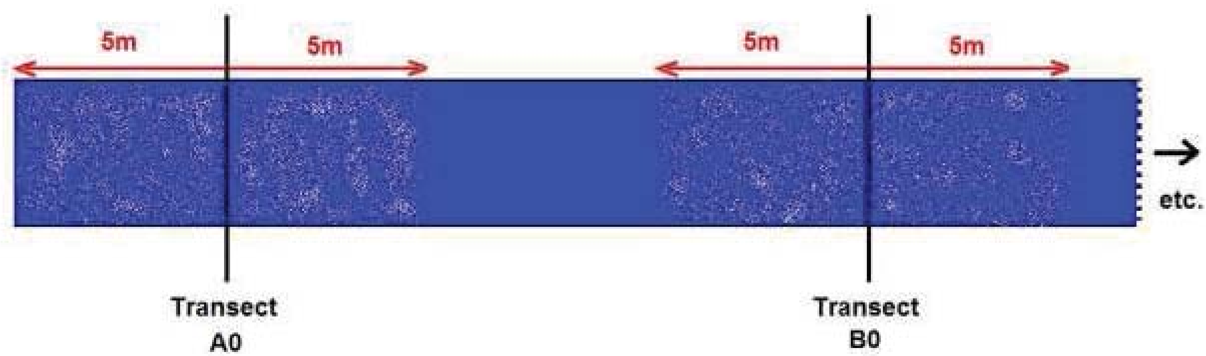


Figure C-8.1. Diagram of fish cover plots at each major transect of the main channel.

Refer to the *Major Transect Form* (Figure C-8.2). Circle the cover code that best characterizes each cover type.

FISH COVER	0 = Absent (0%) 1 = Sparse (<10%) 2 = Moderate (10-40%) 3 = Heavy (40-75%) 4 = Very Heavy (>75%) (circle one)					
	Cover in Channel					Flag
Filamentous Algae	(0)	1	2	3	4	
Macrophytes	(0)	1	2	3	4	
Woody Debris	0	(1)	2	3	4	
Brush	0	1	(2)	3	4	
Live Trees or Roots	(0)	1	2	3	4	
Overhanging Veg. =<1 m of Surface	0	1	2	(3)	4	
Undercut Banks	0	(1)	2	3	4	
Boulders	(0)	1	2	3	4	
Artificial Structures	(0)	1	2	3	4	
Bryophytes	(0)	1	2	3	4	

Figure C-8.2. Fish Cover portion of The Major Transects Form, with example records.

C-9. Human influence at major transects in waded streams

Purpose and scope

This method explains how to collect measurements for Watershed Health monitoring at each of 11 equidistant transects at each site. Measurements in this procedure will be restricted to one main channel. This method must follow the method for establishing major transects.

Personnel responsibilities

This method is performed by one person. This method is applied at every DCE, at each major transect. Observations are made at each bank of the main channel. Staff performing this method must have been trained.

Equipment, reagents, supplies

- No. 2 pencil
- *Major Transect Data Form*
- Measuring device (rod, tape, rangefinder)

Summary of procedure

This procedure is derived from Peck, et al. (2006) and Moberg (2007). Refer to the *Major Transect Data Form* (Figures C-9.1 and C-9.2). At each of the major Transects (A0-K0), assess the main channel. Record the appropriate *influence proximity code* for each of 13 human *influence types* (Figure C-9.1) relative to riparian plots (Figure C-9.3) on each bank of the transect. Influence proximity codes are:

- 0 = absent.
- 1 = beyond the plot, but within 30 meters of the bankfull margin.
- 2 = within the 10 meter by 10 m riparian plot.
- 3 = at least partially within the bankfull channel.

HUMAN INFLUENCE	0=not present, 1= 10-30m, 2= 0-10m, 3= on bank		
	Left Bank	Right Bank	Flag
Wall/Dike/Revetment/ Riprap/Dam	**0** 1 2 3	**0** 1 2 3	
Buildings	**0** 1 2 3	0 1 **2** 3	F1
Unpaved Motor Trail	0 **1** 2 3	**0** 1 2 3	
Clearing or Lot	**0** 1 2 3	**0** 1 2 3	
Human Foot Path	**0** 1 2 3	**0** 1 2 3	
PavedRoad/Railroad	0 **1** 2 3	**0** 1 2 3	
Pipes (Inlet/Outlet)	**0** 1 2 3	0 1 2 **3**	F2
Landfill/Trash	0 **1** 2 3	0 1 2 **3**	F3
Park/Lawn	0 1 **2** 3	**0** 1 2 3	
Row Crops	**0** 1 2 3	**0** 1 2 3	
Pasture/Range/Hay Field	**0** 1 2 3	**0** 1 2 3	
Logging Operations	**0** 1 2 3	**0** 1 2 3	
Mining Activity	**0** 1 2 3	**0** 1 2 3	

Figure C-9.1. A portion of the Major Transect Form, with example data.

Flag	Comments
F1	single-family home
F2	possible irrigation source
F3	beer cans

Figure C-9.2. A portion of the Major Transect Form with example comments for data flags.

PLOTS FOR WADED STREAMS

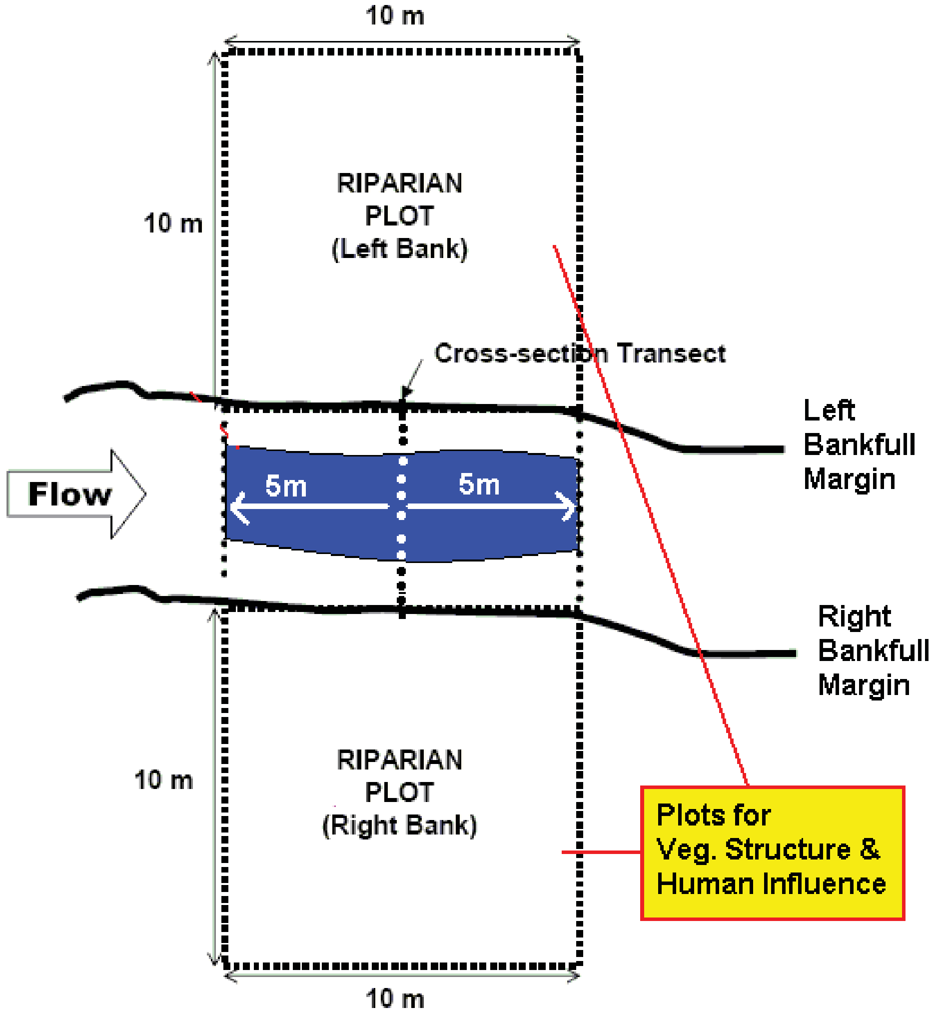


Figure C-9.3. Riparian plots.

C-10. Riparian vegetation structure at major transects in waded streams

Purpose and scope

This method explains how to collect measurements for Watershed Health monitoring at each of 11 equidistant transects at each site. Observations in this procedure will be restricted to one main channel. This method must follow the method for establishing major transects.

Personnel responsibilities

This method is performed by one person. This method is applied at every DCE, at each major transect. Observations are made at each bank of the main channel. Staff performing this method must have been trained.

Equipment, reagents, supplies

- No. 2 pencil
- *Major Transect Data Form*

Summary of procedure

This procedure is derived from Peck, et al. (2006) and Moberg (2007). Refer to the *Major Transect Data Form* (Figure C-10.1).

RIPARIAN	0 = Absent (0%) 1 = Sparse (<10%) 2 = Moderate (10-40%) 3 = Heavy (40-75%) 4 = Very Heavy (>75%)	D = Deciduous C = Coniferous E = Broadleaf Evergreen M = Mixed N = None	
RIPARIAN VEGETATION COVER	Left Bank	Right Bank	Flag
	Canopy (>5 m high)		
Woody Vegetation Type	D C E **M** N	D **C** E M N	
BIG Trees (Trunk >0.3 m DBH)	0 **1** 2 3 4	0 1 2 **3** 4	
SMALL Trees (Trunk <0.3 m DBH)	0 1 2 **3** 4	0 **1** 2 3 4	
	Understory (0.5 to 5 m high)		
Woody Vegetation Type	D C E **M** N	D C E **M** N	
Woody Shrubs & Saplings	0 1 2 **3** 4	0 1 **2** 3 4	
Non-Woody Herbs, Grasses, & Forbs	0 **1** 2 3 4	0 **1** 2 3 4	
	Ground Cover (<0.5 m high)		
Woody Shrubs & Saplings	0 1 2 **3** 4	0 1 **2** 3 4	
Non-Woody Herbs, Grasses and Forbs	0 1 **2** 3 4	0 1 **2** 3 4	
Barren, Bare Dirt or Duff	0 **1** 2 3 4	0 1 **2** 3 4	

Figure C-10.1. A portion of the Major Transect Data Form, with example data.

On each major transect of the main channel, assess a plot on each bank. Each plot extends 5 meters downstream, 5 meters upstream, and 10 meters back from the bankfull margin (Figure C-10.2). The riparian plot dimensions can be estimated rather than measured. On steeply sloping channel margins, plot boundaries are defined as if they were projected down from an aerial view.

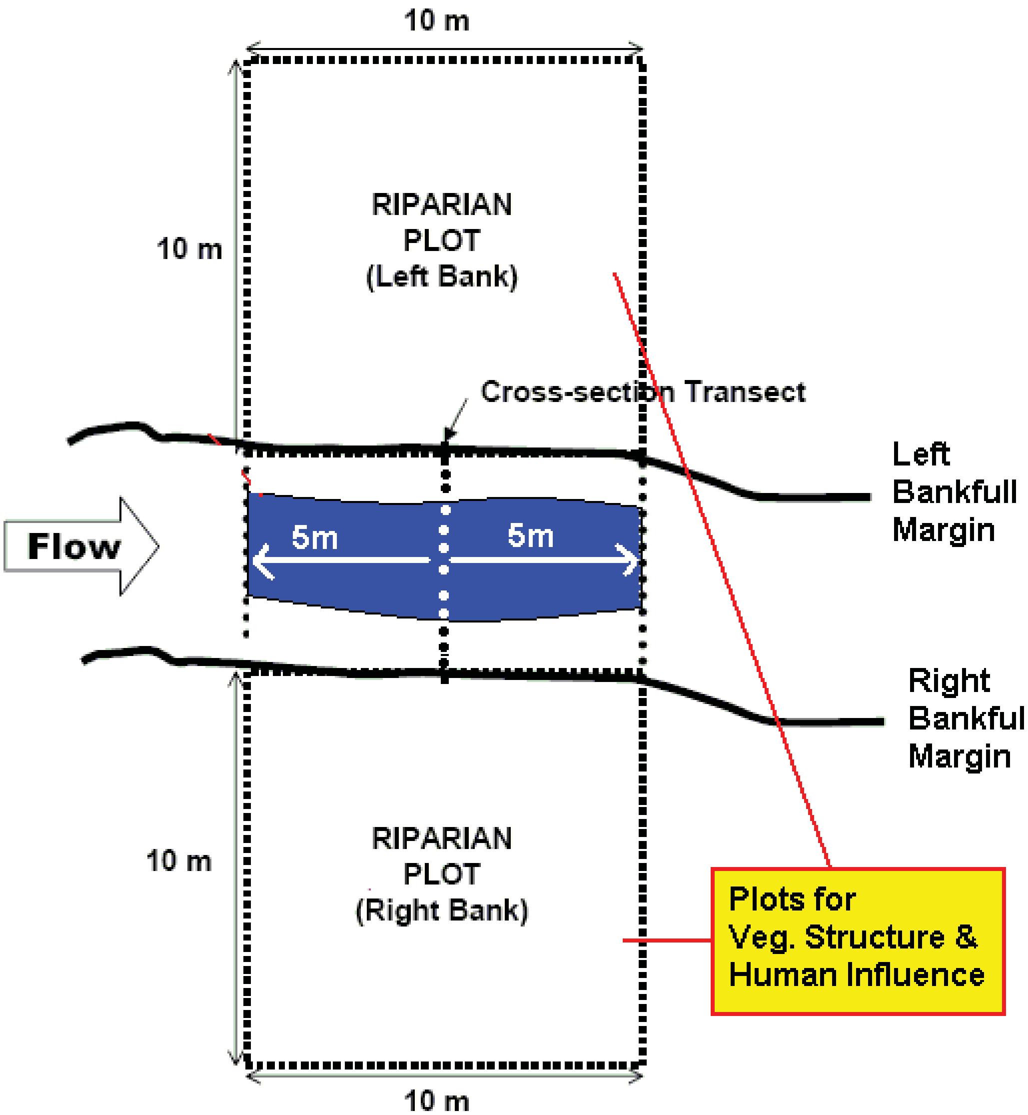


Figure C-10.2. Riparian plots.

Conceptually divide the riparian vegetation into three layers:

- Canopy (> 5 m high).
- Understory (0.5 to 5 m high).
- Ground Cover layer (< 0.5 m high).

Within each layer, consider the type of vegetation present and the amount of cover provided. Do this independently of what is contained in higher layers. Cover quantity is coded on the field form (Figure C-10.1) as follows:

- 0 - absent.
- sparse (< 10% cover).
- 2 - moderate (10-40% cover).
- 3 - heavy (40-75% cover).
- 4 - very heavy (> 75% cover).

The maximum cover in each layer is 100%, so the sum of the cover for the combined three layers could add up to 300%.

Canopy

On the *Major Transect Form* (Figure C-10.1), circle the appropriate vegetation type code (D, C, E, M, or N). Type codes are defined on the form. Then circle the appropriate cover quantity code (0, 1, 2, 3, or 4) for each of 2 classes:

- Big trees - trees having trunks larger than 0.3 m diameter (at breast height).
- Small trees - trees having trunks smaller than 0.3 m diameter (at breast height).

Understory

On the *Major Transect Form* (Figure C-10.1), circle the appropriate vegetation type code (D, C, E, M, or N) for any *woody* vegetation that might be present. Then circle the appropriate cover quantity code (0, 1, 2, 3, or 4) for each of 2 classes:

- Woody vegetation - such as shrubs or saplings.
- Non-woody vegetation - such as herbs, grasses, or forbs.

Ground cover

Circle the appropriate cover quantity code (0, 1, 2, 3, or 4) for each of 3 classes:

- Woody (living).
- Non-woody (living).
- Bare dirt (or decomposing debris).

The sum of cover quantity ranges for these 3 types of ground cover should include 100%.

C-11. Measuring thalweg depth in waded streams

Purpose and scope

This method explains how to collect incremental depth measurements for Watershed Health monitoring when traversing the length of the stream site. It also describes assessing the presence of bars and edge pools. Observations in this method will be restricted to the main channel.

Personnel responsibilities

This method is performed by two people: one person measures and another person records. This method is limited to the main channel. It must be preceded by the method for verification and site layout. Staff performing this method must have been trained.

Equipment, reagents, supplies

- No. 2 pencil
- *Thalweg Data Form*
- Measuring rod

Summary of procedure

This procedure is derived from Peck, et al. (2006) and Moberg (2007). Refer to the *Thalweg Data Form* (Figure C-11.1).

Transect A	Thalweg Depth (cm)	Bar? (circle)	Edge Pool? (circle)
.0	69	Y (N)	(Y) N
.1	70	Y (N)	Y N
.2	75	Y (N)	Y N
.3	87	Y (N)	Y N
.4	70	Y (N)	Y N
.5	75	Y (N)	Y N
.6	33	Y (N)	Y N
.7	34	Y (N)	Y N
.8	32	(Y) N	Y N
.9	33	Y (N)	(Y) N

Figure C-11.1. A portion of the Thalweg Data Form, with example data.

While walking up the main channel, measure thalweg depth (cm) at each of 101 thalweg transects. To reference location:

- Record the letter code for the lowest major transect referenced (e.g., A).
- Record depth and occurrence data into the appropriate thalweg transect row (e.g., .0).

These thalweg stations are located 0.2 bankfull widths apart from each other; bankfull width is based on an estimate made during the site layout. While measuring thalweg depth, also evaluate whether each of these features is present at each thalweg transect:

- Bar.
- Edge pool.
- Circle “Y” for “yes” and “N” for “no”.

C-12. Large woody debris tally for waded streams of western Washington

Purpose and scope

This method explains how to count pieces of large woody debris in waded streams for Watershed Health monitoring when traversing the length of the stream site. Observations are limited to the main channel. This method applies to streams of western Washington (west of the Cascade ridge), where natural conditions are expected to include larger sizes of wood.

Personnel responsibilities

This method is performed by one person. This method is applied at every DCE. Observations are made while walking upstream in the main channel. Staff performing this method must have been trained.

Equipment, reagents, supplies

- No. 2 pencil
- *Thalweg Data Form*
- Measuring rod
- Calipers

Summary of procedure

This procedure is derived from Peck, et al. (2006) and Moberg (2007). One person, while walking upstream, counts the number of pieces of large woody debris (LWD), that are (at least partially) within the bankfull channel of each stream segment (e.g., A0 to B0) in the main channel. Pieces are tallied according to size classes (Table C-12.1), which differ by region (Table C-12.2).

Table C-12.1. Size classes for large woody debris.

Large Woody Debris measured in each thalweg			
Length (meters)			
West	>2-5 m	>5-15 m	>15 m
10-30 dia (cm)			
30-60 dia (cm)			
60-80 dia (cm)			
>80 dia (cm)			
Central & East	>1-3 m	>3-6 m	>6 m
10-15 dia (cm)			
15-30 dia (cm)			
30-60 dia (cm)			
>60 dia (cm)			

Table C-12.2. Washington State regions used to determine which size class of woody debris to use during bioassessment.

Region	LWD Size Class Used
Puget Sound	West
Coastal	West
Lower Columbia	West
Mid Columbia	East
Upper Columbia	East
Snake	East
Northeast Washington	East
Unlisted Washington	East

LWD: Large, woody debris

Considering taper

Wood pieces have a taper. Considerations for taper are illustrated in Figure C-12.1. The diameter of a log is based on the thickest end. The length of a log only counts the portion that has a diameter of more than 10 cm.

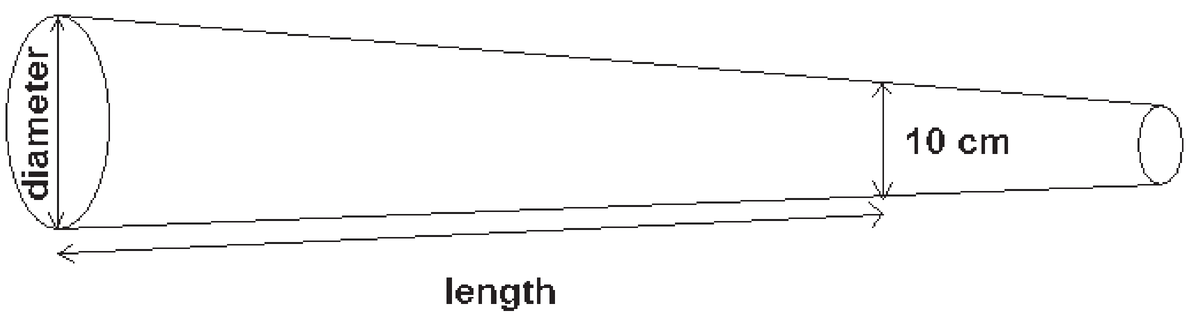


Figure C-12.1. Diagram of how to estimate the dimensions of a log.

Record

Refer to the *Thalweg Data Form* (Figure C-12.2). Identify and tally large, woody debris (LWD) pieces that lie in the bankfull channel. After tallying, sum the marks separately for each size class and enter the number into the corresponding box for each class.

LWD Count	Example: ||||/ | 6				Check box if all are zero ☐		
	2-5 m		5-15 m		>15 m		Flag
10-30 cm	|||	3	||||/	5	||	2	
30-60 cm	|	1	|||	3	/	1	
60-80 cm		0		0		0	
>80 cm		0		0		0	
LWD Notes:							

Figure C-12.2. A portion of the Thalweg Data Form, with example data.

C-13. Habitat unit descriptions along the main channel thalweg

Purpose and scope

This method explains how to identify and count habitat units for Watershed Health monitoring when traversing the length of the stream site. The habitat unit descriptions are based on the Hawkins, et al. (1993) classification system (Figure C-13.1). Observations in this method will be restricted to the main channel.

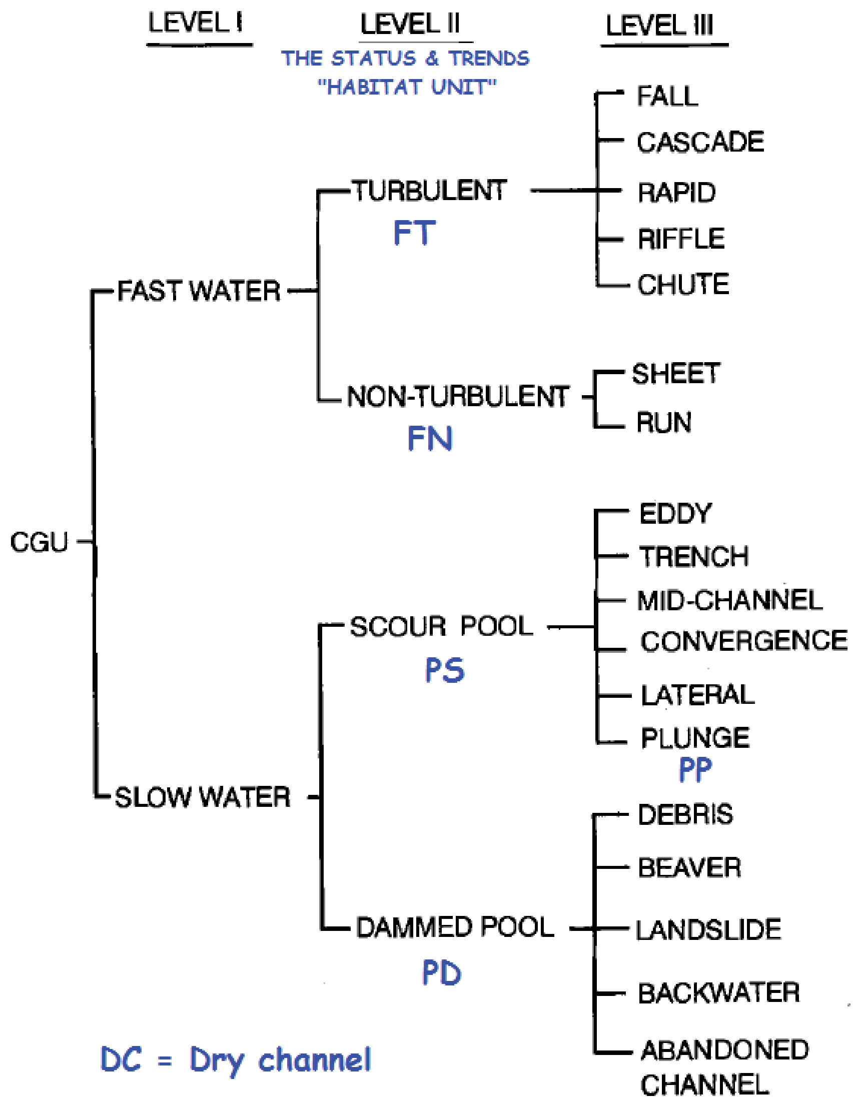


Figure C-13.1. Categories of channel geomorphic units (CGU) described by Hawkins, et al. (1993) and their three levels of resolution.

This figure is modified from Hawkins, et al. (1993), with status and trends habitat unit codes displayed in blue text.

Personnel responsibilities

This method is performed by one person and who dictates data to a second person who records. This method is applied at every DCE. Observations are made while walking upstream in the thalweg of the main channel. Staff performing this method must have been trained.

Equipment, reagents, supplies

- No. 2 pencil
- *Thalweg Data Form*
- Measuring rod
- 50-m tape or laser rangefinder

Summary of procedure

This procedure is derived from Moberg (2007). Refer to the *Thalweg Data Form* (Figures C-13.2 and C-13.3). Identify and code habitat units consecutively during the walk upstream. A separate Thalweg Data Form is recorded for sets of observations that span between major transects. Data will include:

- Type code
- Unit identity (number)
- Pool forming code
- Depths (for pools)

Habitat Unit Number	Habitat Unit Type FT, FN, PS, PD, PP, DC	Pool Forming Code (N, W, R, B, F)		HU Width (m.x)	Max Pool Depth (cm)	Crest Pool Depth (cm)	Channel Unit Notes:
		Code 1	Code 2				
1	PD	W	B	3.5	90	30	Pool formed by both boulder & wood
2	PP	W		4.2	75	15	
3	FN	N		4.8			

Figure C-13.2. A portion of the Thalweg Data Form, with example data for habitat unit type, pool forming code, habitat unit width, and pool depths.

Transect A	Thalweg Depth (cm)	Bar? (circle)	Edge Pool? (circle)	Habitat Unit Number
.0		Y N	Y N	1
.1		Y N	Y N	1
.2		Y N	Y N	1
.3		Y N	Y N	1
.4		Y N	Y N	2
.5		Y N	Y N	2
.6		Y N	Y N	3
.7		Y N	Y N	3
.8		Y N	Y N	3
.9		Y N	Y N	3

Figure C-13.3 A portion of the Thalweg Data Form, with example data for habitat unit locations relative to thalweg transects.

Type code

With each step up the thalweg, evaluate the wetted channel for conformity to the Hawkins, et al. (1993) classification system (Figure C-13.1). We are focusing on Level II designations. The main division is between slow water (pools) and fast water (e.g., cascades, riffles, or runs). All habitat units (except plunge pools or dry channels) must be at least as long as half the wetted width. All pools have specific depth criteria: the maximum depth must be at least 1.5 times the depth at the pool crest. Record the unit type code (Table C-13.1) on the *Thalweg Data Form*.

Table C-13.1. Habitat unit type codes.

Unit	Type	Description
FT	Fast Turbulent	(riffle, cascade, waterfall)
FN	Fast Non-Turbulent	(sheet, run)
PS	Scour	pool
PD	Dammed	pool
PP	Plunge	pool
DC	Dry	channel

Unit number

After you designate the habitat unit type (Table C-13.1), assign a habitat unit number. These are consecutive number counts for the whole stream site. For each form, record data for any new habitat units that appear since the last encountered major transect. For example, if habitat units numbered 1, 2, and 3 were recorded between major transects A and B, then new units encountered between B and C would begin with habitat unit number 4.

Pool forming code

On the *Thalweg Data Form* (Figure C-13.2), record the pool forming code (Table C-13.2) to describe the obstruction that led to pool formation. Assign "N" for habitat units other than pools. If pool formation could be associated with two types (e.g., boulder *and* large wood), use both columns on the form, with one code per column.

Table C-13.2. Pool forming codes.

Pool Forming Code	Description
N	Not a pool
W	Large Woody Debris
R	Root wad
B	Boulder/Bedrock
F	Fluvial (non-specific stream process)

Habitat unit width

Estimate the average wetted width (nearest tenth of a meter) of the habitat unit for the full course of its length. Record this value on the *Thalweg Data Form* (Figure C-13.2) A measurement is not required. Just consider the relative width compared to the width measurements performed at nearby major transects and minor transects.

Pool depths

With a measuring rod, measure water depth (cm) in each of two locations in the thalweg of pools:

- at the crest.
- at maximum depth.

Crest depth is measured differently, depending upon the pool type. For scour pools and plunge pools, the crest depth is measured where water exits the pool. For dammed pools, the crest depth is measured where water enters the pool. Record crest depth and maximum depth on the *Thalweg Data Form* (Figure C-13.2). No data needs to be recorded for non-pool habitat units.

Position

After identifying and describing habitat units (Figure C-13.2), record the position of each habitat unit relative to thalweg stations (Figure C-13.3).

C-14. Side-channel descriptions

Purpose and scope

This method explains how to identify and count side-channels of waded streams for Watershed Health monitoring when traversing the length of the stream site. Observations are limited to portions of side channels that occur next to the sampled part of the main channel (above Transect A0 and below Transect K0).

Personnel responsibilities

This method is performed by one person who dictates to another. This method is applied at every DCE. Observations are made while walking upstream to measure thalweg depths of the main channel. Staff performing this method must have been trained.

Equipment, reagents, supplies

- No. 2 pencil
- *Thalweg Data Form*
- Measuring rod
- Field notebook

Summary of procedure

This procedure is derived from Moberg (2007). Refer to the *Thalweg Data Form* (Figures C-14.1 and C-14.2). Identify and count side channels occurring within the length of the sample site. Estimate their widths.

Identify and count

Identify and code side channels consecutively for the entire streams site. Number them as encountered while walking upstream. Note their presence for each of the 101 Thalweg Transects of the stream site. This will require 11 *Thalweg Data Forms* to complete (A-K).

Transect A	Thalweg Depth (cm)	Bar? (circle)	Edge Pool? (circle)	Habitat Unit Number	Side Channel Numbers				
.0		Y N	Y N						
.1		Y N	Y N		1				
.2		Y N	Y N		1				
.3		Y N	Y N		1				
.4		Y N	Y N		1	2			
.5		Y N	Y N		1	2			
.6		Y N	Y N		1	2			
.7		Y N	Y N		1	2			
.8		Y N	Y N		1	2	3		
.9		Y N	Y N		1	2	3		

Figure C-14.1. A portion of the Thalweg Data Form, with example data showing the presence or absence of side-channels at each Thalweg Transect.

Estimate width

For each channel, estimate wetted width (nearest tenth of a meter). Make at least one representative measurement (in a notebook) between each major transect then visually estimate an average value for the length of the side-channel. Record this channel average on the *Thalweg Data Form* (Figure C-14.1). In your width estimate, do *not* include portions of the channel that occur below transect A0 or above K0.

Side Channel Number	Width (m.x)	Side Channel Notes:
1	1.0	left side of main channel
2	2.3	diverts from channel 1, not from main channel
3	3.7	Right side of main channel

Figure C-14.2. A portion of the Thalweg Data Form, with example data for channel width.

C-15. Width and substrate measurements at minor transects in waded streams

Purpose and scope

This method explains how to measure width and substrate characteristics for Watershed Health monitoring at each of 10 equidistant transects at each site. Measurements in this procedure will be restricted to one main channel. This method is performed in conjunction with the method for measuring thalweg depth. Instruments included on the procedure include distance-measuring devices (e.g., measuring rod, or 50-m measuring tape, caliper) and a10-cm ring.

Personnel responsibilities

This method is performed by two people: an observer and a recorder. This method is applied at each minor transect. It is performed in conjunction with the method for measuring thalweg depth. Staff performing this method must have been trained.

Equipment, reagents, supplies

- No. 2 pencil
- Measuring rod
- 50-m tape
- Calculator
- 10-cm ring

Summary of procedure

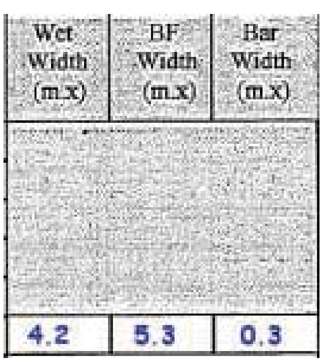
Measure the channel width and then make observations about substrate size at 11 equidistant stations across the minor transect.

Widths

At each minor transect, measure distance (tenth of meters) for:

- Bankfull width.
- Wetted width.
- Total bar width (sum for all bars).

Record these widths on the *Thalweg Data Form* (Figure C-15.1).



Wet Width (m.x)	BF Width (m.x)	Bar Width (m.x)
4.2	5.3	0.3

Figure C-15.1. Part of the Thalweg Data Form, with example data for widths at the minor transect.

Station location

Identify the ***Transect Station LeftRight***. Example stations for minor transect A5 would be:

12. **A500** – at the left bankfull stage.
13. **A501** – 10% distance across the channel.
14. **A502** – 20% distance across the channel.
15. **A503** – 30% distance across the channel.
16. **A504** – 40% distance across the channel.
17. **A505** – half way across the channel.
18. **A506** – 60% distance across the channel.
19. **A507** – 70% distance across the channel.
20. **A508** – 80% distance across the channel.
21. **A509** – 90% distance across the channel.
22. **A510** – at the right bankfull stage.

Substrate type

Hold the measuring rod vertically and rest it on the substrate at each station. Estimate the substrate particle type at the front of the measuring rod, where it rests on the surface of the streambed. Estimate the size class of that particle based on the intermediate axis length. Record the *substrate type code* (Table C-15.1) on the *Thalweg Data Form* (Figure C-15.2) for each station. For coarse gravel and cobble, use calipers to measure the intermediate axis length of the particle and confirm your estimate of size. For larger sizes, use the measuring rod to confirm your estimate. Particles smaller than 100 mm are evaluated using a 10-cm ring surrounding the sample point. All particles within the ring are evaluated for size and embeddedness, not just the point. Record the estimated average for surface substrate within the ring.

Substrates at 5	LB	01	02	03	04	05	06	07	08	09	RB	Substrate Notes:
	SA	GF	GC	CB	CB	XB	XB	XB	XB	XB	FN	Stations 5-9 are one boulder

Figure C-15.2. Part of the Thalweg Data Form, with example data for substrate types along the minor transect.

Table C-15.1. Substrate codes, types, and sizes.

Code	Type	Range Size	Size Gauge
RS	Bedrock (smooth)	>4 m	larger than a car
RR	Bedrock (rough)	>4 m	larger than a car
RC	Concrete/Asphalt	>4 m	larger than a car
XB	Large Boulder	1-4 m	meter stick to car
SB	Small boulder	>250 mm–1 m	basketball to meter stick
CB	Cobble	>64 mm–250 mm	tennis ball to basketball
GC	Gravel, coarse	>16 mm to 64 mm	marble to tennis ball
GF	Gravel, fine	>2 mm to 16 mm	ladybug to marble
SA	Sand(2-16 mm)	>0.06 mm to 2 mm	gritty to ladybug
FN	Fines(silt/clay/muck)	<0.06 mm	non gritty
HP	Hardpan- hardened fines	any size	
WD	Wood	any size	
OT	Other (doesn't fit choices above)	any size	

C-16. Measuring slope and bearing in small streams

Purpose and scope

This method describes how to measure slope and bearing of the main channel at each site during a data collection event (DCE) for Watershed Health monitoring. It applies to waded streams. This method requires use of a hand level, measuring rod, and a compass to make incremental measurements across each of at least 20 segments of the stream site.

Personnel responsibilities

Two persons perform this activity: one *rodder* who holds a measuring rod in a vertical position and a *sighter* who sights on the rodder with a hand level and compass to record data. Crew members must be trained prior to performing this method.

Equipment, reagents, supplies

- Hand level (5x magnification)
- Monopod for hand level
- Measuring rod (telescoping)
- Compass (handheld, magnetic)
- Range finder
- 50-meter tape
- *Slope and Bearing Form*
- Pencil

Summary of procedure

A two person-crew performs this procedure incrementally, once for each of at least 20 segments of the main channel for the entire site. Segments evaluated are normally between major and minor transects (e.g., A5-A0), but intermediate measurements may be used if necessary (e.g., due to thick vegetation or sharp bends in the channel). There should be no space between segments and no overlap of segments. The crew can either work moving up the stream or down, depending on efficiency of overall work flow. We will describe the technique for working from the top of the stream, downward. This method is based on modifications of Peck, et al. (2006) and Moberg (2007).

Slope

The sighter stands at the water's edge of a transect at a higher elevation (Figure C-16.1). This person will sight downstream toward a measuring rod at a lower transect. Use a monopod to rest the hand level at a fixed eye height. The rodder holds the measuring rod vertically, with its base at the surface of the water. The rodder can assist by pointing to the numbers on rod and adjusting up or down as directed by the sighter. Record these things on the *Slope and Bearing Form* (Figure C-16.2):

- Identity of transect where the sighter stands
- Identity of transect where the rodder stands
- Eye height (cm)
- Level height (cm)

Note: Sometimes it is easier to sight in the wetted channel rather than at the edge, to avoid vegetation. If the monopod or measuring rod rests below the surface of the water, subtract that depth from the eye height or level height.

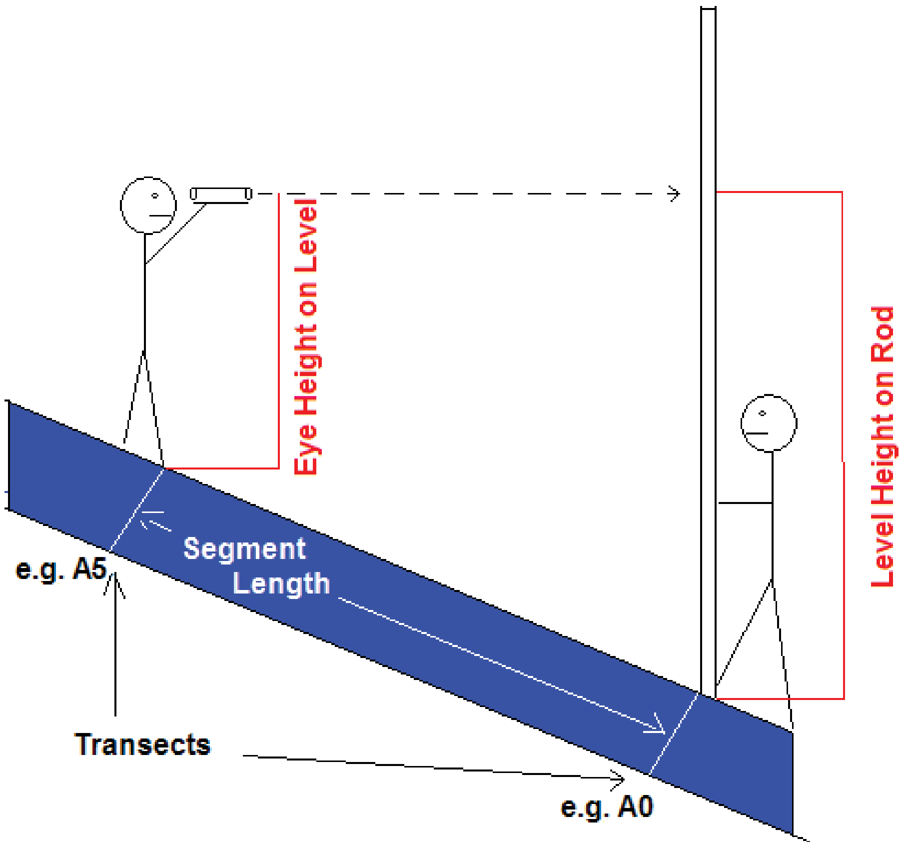


Figure C-16.1. Crew positions when measuring the slope and bearing.

Status & Trends - Slope and Bearing Form

DCE: W A M 0 6 0 0 - 0 0 0 1 5 2 - D C E - 2 0 0 9 - 0 7 1 5 - 1 0 : 0 0

Top Transect* LEVEL COMPASS	Bottom Transect* ROD	Segment Length (m.x)	Eye Height on Level (cm)	Level Height on Rod (cm)	Bearing (deg)	Flag	Comment
K0	J5	7.5	150	172	333		Started here
J5	J0	7.5	150	154	326		
J0	I5	7.5	150	154	293		
I5	I0	7.5	150	203	251		
I0	H5	7.5	150	285	262		
H5	H0	7.5	150	163	249		
H0	G5	7.5	150	225	227		
G5	G0	7.5	150	174	226		
G0	F5	7.5	150	173	237		
F5	F0	7.5	150	160	248		
F0	E5	7.5	150	171	259		
E5	E0	7.5	150	166	276		
E0	D5	7.5	150	230	310		
D5	D0	7.5	150	172	289		
D0	C5	7.5	150	188	301		
C5	C0	7.5	150	166	263		
C0	B5	7.5	150	172	237		
B5	B0	7.5	150	173	234		
B0	A5	7.5	150	166	262		
A5	A0	7.5	150	171	242		

*Normally sight between major and minor transects: K0 to J5, J5 to J0, J0 to I5, etc. unless there is a need for intermediate measurements. For intermediate measurements, always sight to/from a transect station 0-9 (for example K0 to J7 and J7 to J5). Bearings are magnetic north facing downstream(not adjusted).

Figure C-16.2. The *Slope and Bearing Form*, with example data.

Bearing

The sighter stands at a transect at a higher elevation (Figure C-16.1). This person will sight downstream toward the rodder at a lower transect. The sighter will then point the compass toward the rodder and parallel to the thalweg. On the *Slope and Bearing Form*, record the bearing (magnetic north) of the thalweg between the top and bottom of the segment.
Note: If sighting from bottom to top, record the bearing south.

Appendix D. Field and laboratory sampling procedures for benthos and periphyton

D-1. Field sampling benthos in small streams

Purpose and scope

This method describes how to collect benthic macroinvertebrate samples for conducting community-level assessments for Washington's Watershed Health Monitoring Program. Data will be used to describe biological integrity and ecological quality (or taxonomic loss). It applies to waded streams. This method requires measurement of the associated physical and chemical environmental variables described in other methods within this protocol.

Personnel responsibilities

One person or more performs this activity. Staff performing this method must have been trained.

Equipment, reagents, supplies

- Wide-mouth polyethylene jar (128 oz or 3.8 L).
- D-Frame kick net with these characteristics.
    - Frame mouth that is 1 ft (30.5 cm) wide by 1 ft tall.
    - 500-µm mesh net.
- 95% Ethanol (add 3 parts by volume for each part sample).
- Label (waterproof) for jar exterior.
- Label (waterproof) for jar interior.
- Soft-lead pencil.
- Clear tape.
- Electrical tape.
- Pocket knife.
- Wading gear.

Summary of procedure

Invertebrate sampling is one of the first methods to be performed on-site, after site verification and layout. It starts concurrently with water sampling, with initial components of the benthos sample collected downstream of the water sample. One kick sample is collected at each of 8 transects and added to the composite sample for the site. This method is taken from Hayslip (2007) with some details provided by Peck, et al. (2006).

Choose transects

Randomly choose 8 transect stations out of these 11:

- A0
- B0
- C0
- D0
- E0
- F0
- G0
- H0
- I0
- J0
- K0

Identify kick stations

Start at the lowest transect and work upstream. At each transect, visually estimate the distance from left to right where the stream bottom will be sampled (Table D-1.1). Half the stations are in mid-channel. Half are in margins. If the water is too deep to sample at any station, collect the sample from the nearest feasible location. The kick net normally allows sampling up to about 50 cm depths.

Table D-1.1. Components of the macroinvertebrate composite sample.

Kick Station	Distance across wetted channel (left to right)
1st	25%
2nd	50%
3rd	75%
4th	50%
5th	25%
6th	50%
7th	75%
8th	50%

Collect each kick

A different procedure is needed depending upon whether the station sits within flowing water or slack water. Flowing water is where the stream current can sweep organisms into the net. Slack water is where water is so slow that active net movement is required to collect organisms.

<u>Flowing water stations</u>

Once the kick station is determined, place the net opening into the face of flow. Position the net quickly and securely on the stream bottom to eliminate gaps under the frame. Collect benthic macroinvertebrates from a 1ft^2 (0.9 m^2) quadrant located directly in front of the frame mouth. Work from the upstream edge of the quadrant backward and carefully pick up and rub stones directly in front of the net to remove attached animals. Quickly inspect each stone to make sure you have dislodged everything and then set it aside. If a rock is lodged in the stream bottom, rub it a few times, concentrating on any cracks or indentations.

After removing all large stones, keeping the sampler securely in position, starting at the upstream end of the quadrant, kick the top 4 to 5 cm of the remaining finer substrate within the quadrant for 30 seconds. Pull the net up out of the water. Immerse the net in the stream several times or splash the outside of the net with stream water to remove fine sediments and to concentrate organisms at the end of the net. After completing the sample, hold the net vertically and rinse material to the bottom of the net.

After taking a sample, examine the contents of the net. Pick out coarse rocks and sticks. Closely examine them for clinging organisms; pick these animals off of the debris and place them into the sample jar. Discard the debris and empty the net's remaining contents into the sample jar. Add enough ethanol to the sample jar so that the resulting solution consists of 1/3 sample and 2/3 ethanol (by volume).

<u>Slack water stations</u>

Visually define a rectangular quadrant with an area of 1 ft^2 (0.09 m^2). Inspect the stream bottom within the quadrant for any heavy organisms, such as mussels and snails. Remove these organisms by hand and place them into the sample jar. Pick up any loose rocks or other larger substrate particles within the quadrant and hold them in front of the net. Use your hands to rub any clinging organisms off of rocks or other pieces of larger substrate (especially those covered with algae or other debris) into the net. After scrubbing, place the larger substrate particles outside of the quadrant.

Vigorously kick the remaining finer substrate within the quadrant with your feet while dragging the net repeatedly through the disturbed area just above the bottom. Keep moving the net all the time so that the organisms trapped in the net will not escape. Continue kicking the substrate and moving the net for 30 seconds.

After 30 seconds, remove the net from the water with a quick upstream motion to wash the organisms to the bottom of the net. After taking a sample, examine the contents of the net. Pick out coarse rocks and sticks. Closely examine them for clinging organisms; pick these animals off of the debris and place them into the sample jar. Discard the debris and empty the net's remaining contents into the sample jar. Add enough ethanol to the sample jar so that the resulting solution consists of 1/3 sample and 2/3 ethanol (by volume).

<u>Special circumstances</u>

For samples located within dense beds of long, filamentous aquatic vegetation, kicking may not be effective. Use a knife to sample only the vegetation that lies within the quadrant. Don't include parts of the strands that extend beyond the quadrant.

Label and seal the composite sample

Using a number 2 pencil, complete two benthos jar labels (Figure D-1.1). Place one into the sample. Screw on the lid and seal it closed using electrical tape. Attach the other benthos label to the outside of the jar using clear tape. Record the DCE, which includes the Site ID, and site arrival time (year, month, day, hour, and minute). It should match the DCE recorded on the Site Verification Form. Be sure to note which transects were sampled, and which of these were sampled using the slack water technique.

500 µ D-frame kick	**Benthos Jar Label** Jar ___ of ___
Project	Date____ Name____________________________
Stream	
Who collected? (full name)	
8 1-ft^2 Transects **(circle all sampled)**	A B C D E F G H I J K Transects sampled using slack-water technique: ________________________
Collectors Notes	
DCE	WAM06600-__ __ __ __ __ __-dce-2015__ __ __ __-__ __ __ __ m m d d h h m m

Figure D-1.1. The benthos jar label.

Enter data to the C*hemistry and Sampling Form*

The sample jars will be stored by field crews and delivered *en mass* to the analytical laboratory at the end of the field season. The *Chemistry and Sampling Form* (Figure D-1.2) will be used to keep track of sample jar information. Note the Sample ID and number of jars per Sample ID. If there is more than one jar for a Sample ID, then ensure that the jars are located together. Taping the jars together with clear tape may be helpful. For destination, note the immediate place to where the sample will be stored, shipped, or delivered.

Reviewed by (Initials): JS

Status and Trends - Chemistry and Sampling Form

	Site Number		YY	MMDD	HH	MM
DCE:	WAM06600 - 000001	- DCE -	2009	- 0701 -	13 :	25

IN SITU WATER QUALITY CALIBRATION

Operator Kurt Gowdy Unit # 1

				Flag
T	Temp probe was checked vs NIST	(Yes)	No	F1
DO	Sensor Calibrated	(Yes)	No	F2
pH	Sensor Calibrated and Checked	(Yes)	No	F3
Cond	Sensor Calibrated and Checked	(Yes)	No	F3

Notes (in situ)
F1 - T - Checked pre-season
F3 - pH, Cond, calibrated and checked this morning at the lab.
F2 - DO calibrated streamside - Winkler comparison collected for July

Sed:%Gravel 0 %Sand 50 %Fines 50

In Situ Chemistry

Time1 13:45 hrs Start Location (e.g. F0) F0
Temp1 6.3 deg C
pH1 6.94 pH Units
DO1 10.9 mg/L %Sat1 102.5
Cond 27.8 uS/cm @ 25C

Time2 19:50 hrs End Location (e.g. K0) F0
Temp2 7.0 deg C
pH2 7.00 pH Units
DO2 10.4 mg/L %Sat2 99.5
Cond 27.9 uS/cm @ 25C

Sample	Primary Sample: No. of Jars	Duplicate Sample: No. of Jars (or ITIS for Fish Spp)	Destination	Tracking No. (if shipped)	Flag
TPN	1	0	MEL		
Tot P	1	0	MEL		
Cl	1	0	MEL		
Turb	1	0	MEL		
Sed PAH	1	0	MEL		
Sed Metals*	1	0	MEL		
Benthos	2	0	ETOH Shed at office		F4
Fish Spp1	1	ITIS: 159700	University Lab	FedEx: 835651465756	F5
Fish Spp2	1	ITIS: 167234	office lab for review under microscope		F6
Fish Spp3					

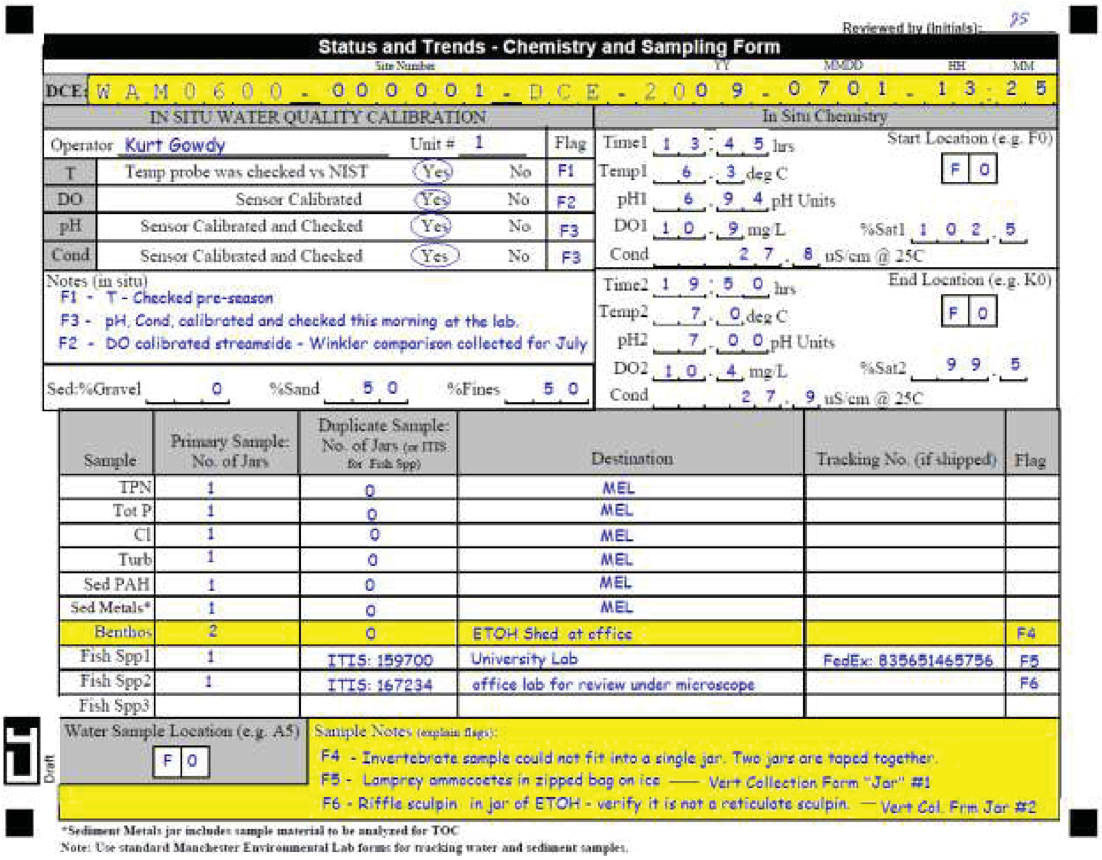
Water Sample Location (e.g. A5) F0

Sample Notes (explain flags):
F4 - Invertebrate sample could not fit into a single jar. Two jars are taped together.
F5 - Lamprey ammocoetes in zipped bag on ice —— Vert Collection Form "Jar" #1
F6 - Riffle sculpin in jar of ETOH - verify it is not a reticulate sculpin. — Vert Col. Frm Jar #2

Draft

*Sediment Metals jar includes sample material to be analyzed for TOC
Note: Use standard Manchester Environmental Lab forms for tracking water and sediment samples.

Figure D-1.2. The *Chemistry and Sampling Form,* with fields that are relevant to benthos sampling highlighted.



Reviewed by (Initials): JS

Status and Trends - Chemistry and Sampling Form

DCE: W A M 0 6 0 0 - 0 0 0 0 0 1 - D C E - 2 0 0 9 - 0 7 0 1 - 1 3 : 2 5 (Site Number, YY, MMDD, HH, MM)

IN SITU WATER QUALITY CALIBRATION

Operator: Kurt Gowdy — Unit #: 1

				Flag
T	Temp probe was checked vs NIST	(Yes)	No	F1
DO	Sensor Calibrated	(Yes)	No	F2
pH	Sensor Calibrated and Checked	(Yes)	No	F3
Cond	Sensor Calibrated and Checked	(Yes)	No	F3

Notes (in situ)
F1 - T - Checked pre-season
F3 - pH, Cond, calibrated and checked this morning at the lab.
F2 - DO calibrated streamside - Winkler comparison collected for July

Sed:%Gravel 0 %Sand 5 0 %Fines 5 0

In Situ Chemistry

Time1 1 3 : 4 5 hrs — Start Location (e.g. F0): F 0
Temp1 6 . 3 deg C
pH1 6 . 9 4 pH Units
DO1 1 0 . 9 mg/L — %Sat1 1 0 2 . 5
Cond 2 7 . 8 uS/cm @ 25C

Time2 1 9 : 5 0 hrs — End Location (e.g. K0): F 0
Temp2 7 . 0 deg C
pH2 7 . 0 0 pH Units
DO2 1 0 . 4 mg/L — %Sat2 9 9 . 5
Cond 2 7 . 9 uS/cm @ 25C

Sample	Primary Sample: No. of Jars	Duplicate Sample: No. of Jars (or ITIS for Fish Spp)	Destination	Tracking No. (if shipped)	Flag
TPN	1	0	MEL		
Tot P	1	0	MEL		
Cl	1	0	MEL		
Turb	1	0	MEL		
Sed PAH	1	0	MEL		
Sed Metals*	1	0	MEL		
Benthos	2	0	ETOH Shed at office		F4
Fish Spp1	1	ITIS: 159700	University Lab	FedEx: 835651465756	F5
Fish Spp2	1	ITIS: 167234	office lab for review under microscope		F6
Fish Spp3					

Water Sample Location (e.g. A5): F 0

Sample Notes (explain flags):
F4 - Invertebrate sample could not fit into a single jar. Two jars are taped together.
F5 - Lamprey ammocoetes in zipped bag on ice —— Vert Collection Form "Jar" #1
F6 - Riffle sculpin in jar of ETOH - verify it is not a reticulate sculpin. — Vert Col. Frm Jar #2

Draft

*Sediment Metals jar includes sample material to be analyzed for TOC
Note: Use standard Manchester Environmental Lab forms for tracking water and sediment samples.

Figure D-1.2. The *Chemistry and Sampling Form,* with fields that are relevant to benthos sampling highlighted.

D-2. Taxonomic lab sampling benthos from small streams

Purpose and scope

Taxonomic identification is conducted by a lab that employs taxonomists certified by the Society for Freshwater Science at the genus level. The taxonomist should have experience with the freshwater macroinvertebrates of the Pacific Northwest. All major orders of freshwater macroinvertebrates are identified to at least the genus level (see Appendix I), including the Chironomidae (See Appendix J) and Simuliidae, and to species where existing taxonomic keys are available. Taxon groups normally identified to coarser taxonomic levels include: Lumbriculidae, Naididae, Oligochaeta, select families of the Coleoptera, Planariidae, and Acari. If the taxonomist has a compelling reason (Appendix K) that a specimen cannot be identified to the genus level, they may decide to aggregate individuals in the next highest taxonomic level.

Personnel responsibilities

One person or more performs this activity. Staff performing this method must have been trained.

Summary of procedure

Sample preparation

Samples are sub-sampled using a 500-organism count. According to Ecology protocols (Plotnikoff and Wiseman, 2001), macroinvertebrates are removed from a minimum of two randomly chosen squares from a 30 square sub-sampling grid. The dimension of each square is 6 cm x 6 cm and the grids overall dimensions are 30 cm x 36 cm. The sample material is thoroughly mixed and spread evenly across the grid. All organisms are removed from randomly chosen squares until a minimum of 500 macroinvertebrates are removed from the sample and placed in alcohol for subsequent identification under the dissecting scope. If a grid square is dominated by a single taxon, additional grids are selected and sorted, and notes are made in the report. In some cases, there may be less than 500 organisms in the whole sample. When the target count of organisms has been reached or the specified amount of material has been sorted, a special large and rare protocol may be followed, with these organisms placed in an additional labeled vial.

Large and rare specimen identification

The remainder of the sample material in the tray will be searched for any large or rare taxa that may have been missed in the sub-sampled fraction. These specimens will be identified and placed together in a vial labeled “Large and Rare Taxa” for the voucher collection. This scan will include any adult aquatic invertebrates, which will be archived separately (not to be identified and included in data set) for anyone interested in looking at the material in the future.

Appendix E. Water quality sampling procedures

E-1. Day of sample collection

Samples and measurements should be collected from well-mixed and representative locations within the reach. The methods are summarized below:

- Dissolved oxygen, temperature, conductivity, and pH are measured in-situ with field meters. For the RSMP, dissolved oxygen will be measured by an LDO field meter, and not titrated by the Winkler method as described in SOP EAP034.
- Turbidity, total suspended solids, and nutrient samples are measured in a laboratory in samples collected using either a bucket collection or hand-dipped bottles.
- Fecal coliform samples are measured in a laboratory in samples collected with the flow-orienting bacteria sampler or hand-dipped using an autoclaved bottle.

Field processing of samples fulfills three essential purposes: (1) preserve (fix) samples, (2) prepare samples for shipment to the lab, and (3) conduct the first quality control checks (e.g., completeness of sampling).

Field meters

Multiprobe meters may be used to make in-situ field measurements. Methods for use of these multi-meters are described in Appendix D; use of meters will follow the manufacturer's website instructions for the most up-to-date guidelines.

On the day of sampling, field staff will calibrate the meters/probes as follows:

- For pH, using a two-point calibration with NIST-certified standards. Most small streams west of the Cascades or in moderate to high elevations will need to be calibrated with pH 7 and pH 4 standards. A 10 standard may be used as a linearity check. r.
- For conductivity, using a one-point calibration with NIST-certified 100 uS/cm conductivity standards. A zero conductivity check will also be performed.
- For dissolved oxygen, a water saturated air calibration method is suitable, following recommendations by the manufacturer.
- For temperature, probes must be factory calibrated. Instead of calibration, probes will be checked against a NIST-certified thermometer prior to the start of the project and at the end of the project.
- Recording the barometric pressure within an hour of sampling, recording results on the field data form, and noting the location (and elevation) of the barometric meter.

E-2. Water quality sample containers

For all samples, pre-cleaned sample containers will be used. For many of the sediment organic contaminants samples, the homogenized sample will be placed in the appropriate glass jars, which are supplied pre-cleaned by the laboratory to EPA QA/QC specifications (EPA, 1990) and that carry a certification of cleanliness from the suppliers. The sample container shipment documentation will record batch numbers for the containers.

E-3. Water quality sample processing and preservation

Some of the parameters to be analyzed (ammonia, nitrate-nitrite, total nitrogen, and total phosphorus) require chemical preservation to maintain the integrity of the samples and prevent them from degrading prior to laboratory analysis. Other parameters require filtration in the field.

Field filtered parameters

Orthophosphate

Filtration is required for orthophosphate within 15 minutes after sample collection. Samples for orthophosphate will be filtered using a disposable syringe and filter. Prior to filtering the sample, an aliquot of field sample will be passed through the syringe and filter as a rinse. After rinsing, the filtered sample will be collected and distributed into the laboratory sample bottles. Disposable filter set-ups may be used for each sample. A field filtration blank is prepared by bringing 250 mL of deionized water from the lab and filling the syringe in the same manner as a field sample.

Dissolved Metals

Filtration for dissolved metals will be done using disposable filtration units that are operated by a separate vacuum pump (peristaltic or hand pump). The water to be filtered will typically be collected as a grab sample using a separate 500 mL metals sample container (that is later discarded). The filtration units are pre-cleaned before use thus rinsing with extra field sample is not needed. Once filtered, the collection vessel of the filtration unit is removed, or sample is transferred to appropriate container, and labeled. A field filtration blank is prepared by bringing 500 mL of deionized water from the lab and filling the filtration unit in the same manner as a field sample.

Dissolved Organic Carbon

Samples for dissolved organic carbon will be filtered using a disposable syringe and filter. Prior to filtering the sample, an aliquot of field sample will be passed through the filter to rinse the filter and syringe. After rinsing, the filtered sample will be collected and distributed into the pre-preserved dissolved organic carbon laboratory sample bottles. Disposable filter set-ups may be used for each sample. A field filtration blank is prepared by bringing 250 mL of deionized water from the lab and filling the syringe in the same manner as a field sample.

For all filtered samples, filtering should occur within 15 minutes after sample collection. If filtering occurs after 15 minutes and before 24 hours, the sample will be J qualified. If field filtering occurs after 24 hours for orthophosphate, the sample will be rejected and labeled with an *R* on the field forms. Field sampling efforts, including time of collection and time of filtration and other activities, will be documented on a field sampling form.

Preservation

Sample cooling to 4º to 6ºC or less, but not freezing, is necessary for preservation of most of the parameters to be analyzed. Collected samples must be transferred from the field station to the lab in an ice-filled or blue-ice-filled cooler to maintain temperature requirements.

E-5. Stage Height and Stream Discharge Measurement

Purpose and scope

This method describes how to collect stage height and flow data necessary for estimating instantaneous discharge (in cubic feet per second) during each monthly visit.

Personnel responsibilities

One person performs this activity. Staff performing this method must have been trained.

Equipment, reagents, supplies

- Soft-lead pencil.
- Distance measuring device (50-m tape or measuring rod).
- Flow Meter.
- Wading rod (top setting).
- Orange or other neutrally buoyant object (if needed).
- 5-gallon bucket.
- Stop watch.
- Field notebook.
- Calculator.

Preferred approach for measuring and estimating stage and stream flow for the RSMP sites

This section provides guidance for the RSMP contractors to follow when measuring stage (water-surface elevation) and stream flow during the monthly water quality sampling trips. Some detail on how to take a discharge measurement is provided below; however each agency is assumed to be capable of measuring discharge in a wadeable stream.

<u>Stage</u>

Every month a stage height measurement will be made. During a site visit, choose a suitable location where you can measure the stage every time to visit the site. A measurement of the stage is best done by installing and reading a staff gage at the site. However, any stable measurement point you can either install (rebar, T-post, staff gage, etc.) or is already there (bridge deck or railing, vertical armored wall, large rock, etc.) will work. The important thing is to measure the stage relative to the same point every time. Note that stream depth is generally not a reliable measure of stage since the stream bed can change over time. However, if there is a stable in-channel feature that acts as a control (bedrock or a cement weir, or culvert for example) where you can measure the depth in the same place every time, then that works.

A pressure transducer may also be installed at the site to measure stream depths. A manual stage measurement point is still needed so data are available to confirm/correct the pressure transducer data.

Stage data will be used to develop a rudimentary stage-discharge curve for each site to estimate flow for the visits when only stage was measured. These discharge estimates will be highly uncertain because the nature of the stage-discharge relationship at high stages is difficult to predict. The relationship tends to have the most error at the higher end, which is when you will likely have only stage, but is the better than no estimate.

<u>Velocity- Area Discharge Measurement</u>

For most months of the year the sites should be wadeable and stream flow measured. Discharge is normally measured near the index station ("X") where there is uniform (non-turbulent) flow, but can be done anywhere in the reach. For method references see SOP EAP024 (Kardouni, 2013) and Kaufmann (2006). For operation of the flow meter, refer to the manufacturer's manual.

Use the Discharge Worksheet (Figure C-3.1), located on the back of the *Chemistry and Sampling Form*. Discharge can be calculated by converting widths to units of feet (nearest tenth) and applying the QWIN program (Larsen, 2005) as provided by PSNS&IMF (2006).

Flow Location - Thalweg Station (e.g. A5) : F 0   Flow Meter (Model / Unit #) Marsh McBirney Flo-Mate 2000 / 2

Discharge Worksheet

Flow Meter Zeroed Out? (Y) N   Wetted Width: 1026 cm

Cell	Tape Distance Left to Right (cm)	Wetted Depth (ft.x)	Velocity (ft.xx/s)	Notes
01	10	0	0	Left edge of water
02	64	0.5	0.65	
03	118	1.0	0.49	
04	172	1.0	0.76	
05	226	1.3	2.29	
06	280	1.2	0.51	
07	334	1.8	1.66	
08	388	2.0	3.77	
09	442	2.1	3.61	
10	496	2.3	3.26	
11	550	2.2	3.21	
12	604	2.3	2.37	
13	658	1.7	1.74	
14	712	1.5	1.10	
15	766	1.0	0.95	
16	820	0.7	0.66	
17	874	0.5	0.54	
18	928	0.3	0.32	
19	982	0	0.15	
20	1036	0	0	Right wetted margin

Describe Alternate Method: N/A

Draft

Discharge: 88.2 cfs

Figure E-4.1. The Discharge Worksheet with example field data in blue.

Establish the cross-section

The velocity-area method is used at a transect location within the site that has the most of these conditions (based on Rantz, et al., 1982).

- The stream is straight.
- Depths are mostly greater than 0.5 ft (15 cm).
- Velocities are mostly greater than 50 ft/s (0.15 ms/s).
- Local habitat is not a pool.
- The channel is "U-shaped".
- The streambed is uniform and free of objects that cause turbulence.

Preference should be given to locations that are close to "X". Record the name of the nearest *Thalweg Transect*. Pull a measuring tape taught, perpendicular to the stream, and parallel to the stream surface (a measuring rod can be used for small streams). Record the tape value (cm) at the left wetted margin and at the right wetted margin. Subtract the left value from right value to determine the transect's wetted width. Record wetted width (cm) on the worksheet (Figure C-3.1).

Measure distance, depth, and velocity

Define about 15-20 equally spaced stations across the stream (possibly fewer for very small streams). To determine spacing between stations, divide the width by 20 and round up to a convenient number. Stations should not be closer than 10 cm to each other, even if this results in less than 15 stations. The first station is located at the left wetted margin, and the last station is located at the right wetted margin.

Use a calibrated flow meter equipped with a top-setting wading rod that has depth increments in tenths of feet. At each station, record the tape distance (cm) from left to right. Record the water depth (nearest 0.1 ft). Place the sensor 60% of the distance down from the surface (Figure C-3.2). Measure and record water velocity (nearest 0.01 f/s).

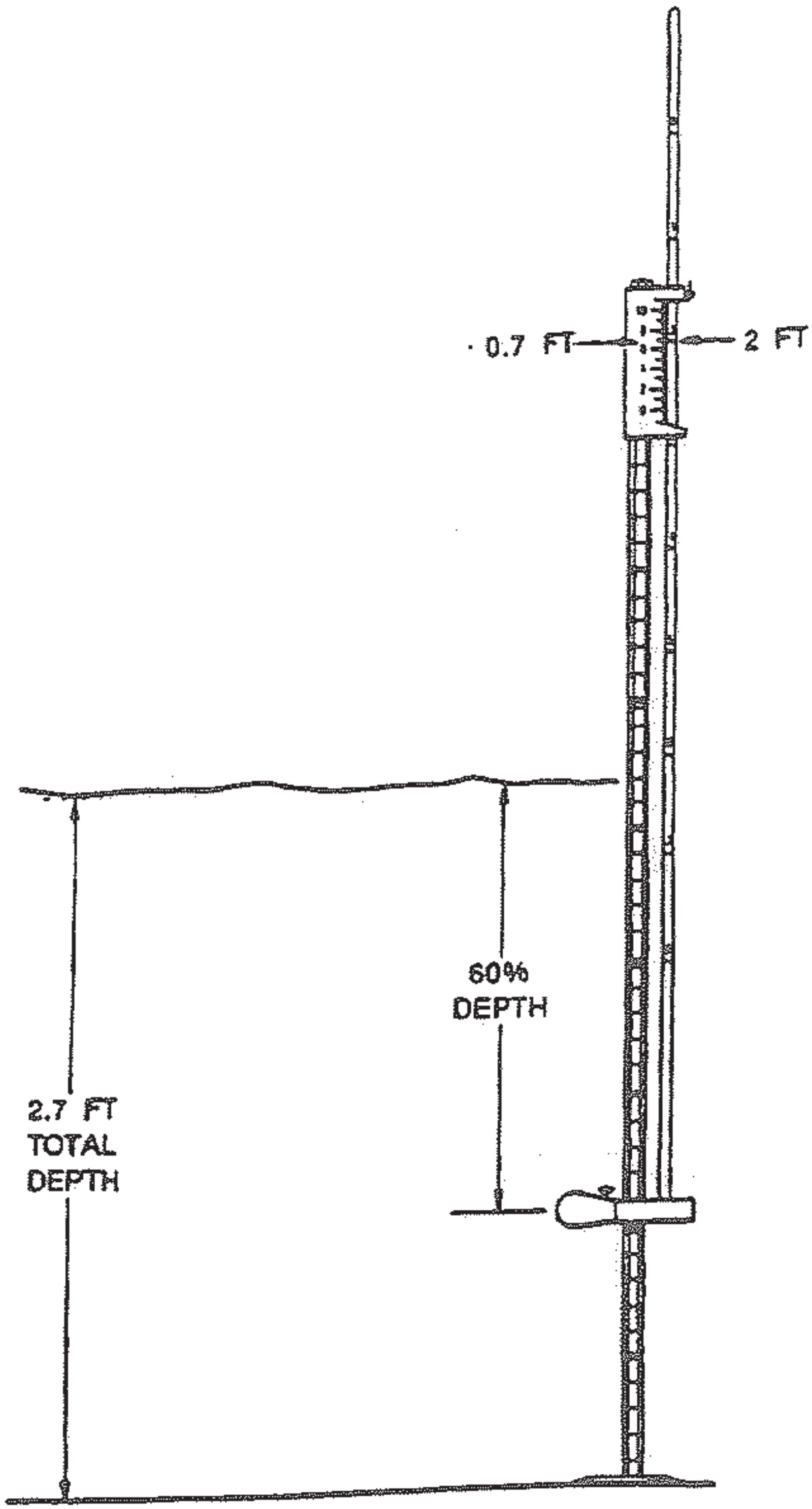


Figure E-4.2. Setting the wading rod at 60% depth when at a station that is 2.7 meters deep.

There may be some months when stream flow is too high or too low to measure directly. The following alternate methods are provided for those occasions.

- High flow – At a minimum, measure the stage as described above. If possible, estimate the mid-stream velocity using floating debris.
- Low flow – Measure the stage. If the flow is too low to measure discharge with your meter, try to estimate the flow volumetrically using a bucket and stopwatch or similar. Locate a place on the reach where flow is focused and can be collected into a bucket (e.g., hanging culvert). You might need to move some rocks to focus flow. You can also try to attempt to add a temporary weir for the collection, but it is not advised you leave this in place in order to not disturb the stream too much, especially around the habitat sampling.

Alternate methods

Mid-stream velocity using timed float

In the absence of a current meter, you can time the transport of a neutrally-buoyant object (e.g., oranges, plastic golf balls, sticks).to estimate velocity. This method is similar to the Velocity-Area method because discharge is calculated as the product of water velocity and the stream cross-sectional area. Requirements are:

- The object must float, but very low in the water.
- The object must be small enough to *not* drag bottom.
- The segment must be somewhat strait, uniform, and non-turbulent.
- The segment must be long enough that it takes 10 to 30 seconds for the float to pass.

<u>Velocity</u>

Compute water column velocity in a field notebook. Determine the average time (seconds) for the float to travel the segment. Repeat twice more, each time releasing at a different position across the width of the stream. Compute an average for the three times. Measure the length of the segment (ft). Divide the segment length by the average time of travel(s) to estimate surface velocity (ft/s). Multiply this surface velocity by 0.85 to estimate water column velocity.

<u>Cross-sectional area</u>

Compute cross-sectional area (ft^2) in a field notebook. This can be done by summing the area for at least two trapezoids to approximate the cross section of the stream (Figure C-3.3). These should be centered on the thalweg.

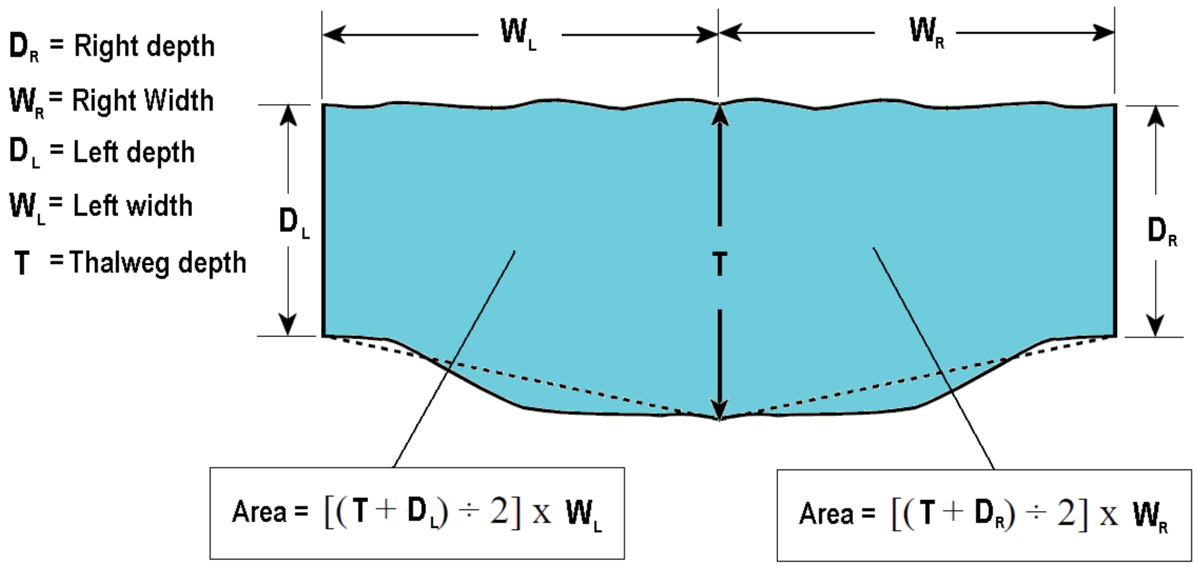


Figure E-4.3. The cross-sectional area of a stream segment as estimated by calculating the area of component trapezoids, centered on the thalweg.

Measure area for one or more cross-sections and average them. Only one cross-section is adequate if the channel is relatively uniform through the segment. Otherwise measure at these cross-sections:

- Near the top of the segment.
- Near the middle of the segment.
- Near the bottom of the segment.

If there is little change in channel width or depth, obtain measurements from a single "typical" cross-section within the segment.

Discharge

Convert cross-sectional area calculations to square feet (1 m^2 = 10.76391 ft^2). Then multiply water column velocity (ft/s) times the cross-sectional area (ft^2) to determine stream discharge for the site. Record this discharge (cfs) on the bottom of the discharge worksheet (Figure C-3.1). Also record "timed float" next to "Describe alternate method".

Timed bucket-filling

Place a bucket or other container with known volume below the discharge. Time how long it takes to fill the container. Repeat at least three times. Calculate discharge as the volume of the container divided by the average time to fill it. Use Table C-3.1 to translate from gallons or milliliters to cubic feet. Record discharge (cfs) at the bottom of the Discharge Worksheet (Figure C-3.1). Also record that the alternate method was by use of a timed bucket-filling.

Table E-4.1. Conversions for gallons or milliliters to cubic feet.

Gallons	Milliliters	Cubic Feet
0.1321	500	0.0176573
0.2642	1,000	0.0353147
1	3,785	0.1336806
5	18,927	0.6684028
7.480519	28,317	1

Existing gage data

If a nearby USGS, Ecology, or County gage is active, record discharge (cfs) at the bottom of the Discharge Worksheet (Figure C-3.1) and note the data source, next to "Describe alternate method".

For these sites located on the same stream as an existing gage, calculate the corresponding unit area discharge at the gaged location and adjust proportionally to estimate discharge at the ungagged site. Uncertainty due to changes in flow due to time-of-travel between the two gages will likely be very small relative to uncertainties in the proportional adjustment of discharge.

Appendix F. Quality control procedures

F-1. Quality control for in-situ meters

Purpose and scope

This method explains how to verify that in-situ meters used for the water quality monitoring are working properly. This section was written for certain meters used by Ecology and is provided as an example of a QC program for meters for permittees conducting monitoring. Permittees are not expected to conduct Winkler titrations for verification of dissolved oxygen measurements as is done by Ecology (Adams, 2010a and SOP EAP034).

Instruments included in the procedure include probes for measuring temperature, pH, conductivity, and dissolved oxygen (Minisonde Multiprobes). It also includes the instrument used for measuring water velocity (Marsh-McBirney FloMate-2000).

Personnel responsibilities

This method is performed by 1 or more persons. This method is applied at every DCE, before sampling. Staff performing this method must have been trained.

Equipment, reagents, supplies

- No. 2 pencil.
- Calibration Form.
- Flow Meter.
- Flow Meter batteries.
- Wading rod.
- Flow Meter Manual (e.g., Marsh-McBirney, 1990).
- Five-gallon bucket (for flow meter zero-adjust).
- Hydrolab, YSI (or equivalent), components, maintenance kit (Swanson, 2007).
- Multimeter Manuals.
- pH 7 buffer (7.00) – e.g., VWR - 23197-996.
- pH 4 buffer (4.01) – e.g., VWR - 23197-998.
- pH 10 buffer (10.01) – e.g., VWR - 23197-994.
- Conductivity Standard (100 uS) – e.g., VWR 23226-589.
- Conductivity Standard (1,000 uS) – e.g., VWR 23226-603.
- Conductivity Standard (alternate as available).
- Deionized water (DI).
- Tap Water.
- Lab tissues (e.g., KimWipes®).
- Barometer.

Appendix I. Standard taxonomic effort (except chironomidae)

Ephemeroptera

- Genus, with exceptions noted:
- Baetidae
  - Acentrella—species.
  - Acerpenna—species.
  - Baetis—species.
  - Baetodes—species.
  - Cloeodes—species.
  - Diphetor hageni—monotypic.
  - Fallceon quilleri—distribution, genus for far SW US projects.
  - Paracloeodes minutus—distribution.
  - Psuedocloeon sp.—species.
- Caenidae
  - Amercaenis ridens—distribution.
  - Caenis—species.
- Ephemerellidae
  - Attenella—species.
  - Caudatella—species.
    - Note that C. cascadia has been synonymized with C. hystrix.
  - Caurinella idahoensis—monotypic.
  - Drunella—species.
    - Use D. coloradensis/flavinea for D. coloradensis and D. flavinea.
  - Ephemerella—species.
    - Use E. inermis/infrequens for E. inermis and E. infrequens.
  - Eurylophella—species.
  - Serratella—species.
  - Timpanoga hecuba—monotypic.
- Ephemeridae
  - Ephemera simulans—distribution.
- Heptageniidae
  - Epeorus—species for Rocky Mountain specimens, genus otherwise.
  - Stenacron—species.
  - McCaffertium—species.
- Leptophlebiidae
  - Neochoroterpes—species.
  - Thraulodes—species.
  - Traverella sp.—species.
- Leptohyphidae
  - Leptohyphes—species.
  - Vacupernius packeri—monotypic.

Odonata

Species for mature specimens of most taxa (exception below), genus otherwise:

Coenagrionidae—genus.

Plecoptera

Genus for most taxa (exceptions below):

Capniidae—family except for late instar larvae.

Leuctridae—family except for late instar larvae.

Despaxia augusta—monotypic.

Moselia infuscata—monotypic.

Nemouridae

Visoka cataractae—monotypic.

Zapada—species.

Use Z. oregonensis gr. for members of that species group.

Perlodidae

Frisonia picticeps—monotypic.

Kogotus/Rickera—for indeterminate specimens.

Osbenus yakimae—monotypic.

Perlinodes aurea—monotypic.

Pictetiella expansa—monotypic.

Rickera sorpta—monotypic.

Perlidae

Acroneuria—species.

Calineuria californica—monotypic.

Claassenia sabulosa—distribution.

Hesperoperla—species.

Pteronarcyidae

Pteronarcys—species for mature specimens.

Hemiptera

Genus for most taxa (exceptions below):

Gerridae—ignore.

Veliidae—ignore.

Coleoptera

Genus for most taxa (exceptions below):

Elmidae

Ampumixis dispar—monotypic.

Atractelmis wawona—monotypic.

C. Barr undescribed sp.—used for that genus soon to be described by C. Barr.

Cleptelmis addenda—monotypic.

Macronychus glabratus—monotypic.

Ordobrevia nubifera—monotypic.

Rhizelmis nigra—monotypic.

Psephenidae

Eubrianax edwardsi—monotypic.

Megaloptera

Genus except for:

Orohermes crepusculus—monotypic.

Diptera

Larvae to genus with a few exceptions noted below and the following to family:
Thaumaleidae, Dolichopodidae, Syrphidae, Tabanidae, Ephydridae, Muscidae, Sciomyzidae
pupae to family except cased Simuliidae to genus, Antocha to genus.

Tipulidae

Rhabdomastix—larvae to species group.

Ceratopogonidae

Bezzia/Palpomyia—use for those two genera inseparable as larvae.

Chaoboridae

Eucorethra underwoodi—monotypic.

Psychodidae

Pericoma/Telmatoscopus—use for those two genera inseparable as larvae.

Stratiomyidae

Hedriodiscus/Odontomyia—use for inseparable larval specimens.

Trichoptera

Larvae generally to genus except monotypic species, other exceptions noted below:
Pupae to family.

Rhyacophilidae

Rhyacophila—most larvae to species group using Smith designations, with the following exceptions:

R. betteni gr.

R. malkini—distinctive.

R. leiftincki gr.

R. arnaudi—only N.A. species in group.

R. sibirica gr.

R. narvae—usually distinctive, leave at species group if unsure.
R. blarina—distinctive.
R. pellisa/valuma—use this for all R. atrata subgroup.

Hydropsychidae

Arctopsyche—larvae to species.
Parapsyche—larvae to species.
Potamyia flava—distribution.
Smicridea—to subgenus.

Polycentropodidae

Cyrnellus fraternus—distribution.

Psychomyiidae

Psychomyia—larvae to species.

Apataniidae

Pedomoecus sierra—monotypic.

Brachycentridae

Amiocentrus aspilus—monotypic.
Brachycentrus—larvae to species.

Calamoceratidae

Heteroplectron californicum—distribution.

Leptoceridae

Mystacides—larvae to species.
Oecetis—larvae of O. avara, O. disjuncta to species, all others to genus.
Limnephilidae
Allocosmoecus partitus—monotypic.
Amphicosmoecus canax—monotypic.
Chyranda centralis—monotypic.
Clostoeca disjuncta—monotypic.
Dicosmoecus—larvae to species.
Ecclicosmoecus scylla—distribution.
Hydatophylax hesperus—distribution.
Uenoidae
Neophylax—larvae to species.
Sericostriata surdickae—monotypic.
Lepidoptera
Larvae—Petrophila and Paraponyx to genus, most others to family, order if uncertain pupae—order.
Cnidaria
Genus.
Nemertea
Genus.
Turbellaria
Phylum, except Polycelis to genus.
Nematoda
Phylum.
Nematomorpha
Phylum.
Gastropoda
Genus in most cases, with exceptions noted:
Valvatidae
Species for mature specimens, if immature leave at genus.
Hydrobiidae—family.
Lymnaeidae
Radix auricularia—monotypic.
Bivalvia
Genus for mature specimens.
Branchiobdella
Order (Branchiobdellida).
Polychaeta
Manayunkia speciosa—distinctive.
Hirudinea
Genus, with exceptions noted:
Erpobdellidae—family.
Glossiphoniidae
Glossiphonia complanata—distinctive.
Helobdella stagnalis—distinctive.
Piscicolidae
Piscicola—species for mature specimens.

Crustacea

Genus, with exceptions noted:
Astacidae—species.
Cambaridae—species for mature males.
Ostracoda—class.
Branchiopoda—ignore.
Copepoda—ignore.

Acarina

Genus for adults, use ‘Acari’ for indeterminate specimens, leave Oribatei at suborder (Oribatei).

Appendix J. Taxonomic effort for chironomidae

To maintain data consistency, Chironomidae identifications should be to the genus level when practical except for the following taxa:

Cardiocladius albiplumus

Cricotopus (Isocladius) Type I.

(EcoAnalysts in-house designation) presence of two "racing stripes" on the dorsum of the light colored (yellow) head, body with gray mottling, dark mentum with 15 teeth, first lateral teeth closely pressed to the median teeth, and the last two pairs of lateral teeth appear to be reduced and slightly separated from the other lateral teeth.

Cricotopus (Nostococladius) nostocicola

(previously referred to as *Cricotopus (Nostocladius)* sp. by EcoAnalysts, changed in 2002.)

Cricotopus bicinctus gr.

Cricotopus trifascia gr.

Heterotrissocladius

(identify to species group following Wiederholm, 1983 and 1986.)

Hyporhygma quadripunctatum (monotypic).

Lauterborniella agrayloides (monotypic).

Microtendipes

(identify to species group following Wiederholm, 1983 and 1986.)

Orthocladius Complex

(encompasses *Orthocladius* sp.; and *Cricotopus* sp. that are inseparable from *Orthocladius* sp.; and *Paratrichocladius* sp.)

Orthocladius (Symposiocladius) lignicola

Paralauterborniella nigrohalteralis (monotypic)

Paramerina/Zavrelimyia sp.

(This includes *Reomyia* sp.)

Paraphaenocladius "n. sp."

(EcoAnalysts in-house designation) single median tooth, "long" antenna, six antennal segments (sixth hairlike), second antennal segment with a "break."

Platysmittia

(identify to species following Epler, 2001 and Jacobsen, 1998.)

Potthastia

(identify to species group following Wiederholm, 1983 and 1986.)

Robackia

(identify to species following Wiederholm, 1983 and Epler, 2001.)

Saetheria tylus

(larval diagrams in Epler, 2001 and Merritt and Cummins, 1996.)

Tempisquitoneura merrillorum

Thienemannimyia gr. sp.

(consists of the genera *Arctopelopia*, *Conchapelopia*, *Hayesomyia*, *Helopelopia*, *Meropelopia*, *Rheopelopia*, *Telopelopia*, and *Thienemannimyia*.)

Tribelos jucundum

Tvetenia

(identify to species group following Bode, 1983 ie. discoloripes grp. and bavarica grp.)

Unniella multivirga (monotypic).

Xenochironomus xenolabis (monotypic).

Xylotopus par (monotypic).

APPENDIX B

Power Test Results

HERRERA

TECHNICAL MEMORANDUM

Date: October 5, 2015

To: Andy Rheaume, City of Redmond

From: John Lenth and Kristen Matsumura, Herrera Environmental Consultants, Inc.

Subject: Statistical Power of Trend Tests for the Redmond Paired Watershed Study

Introduction

The Redmond Paired Watershed Study (RPWS) is one of several effectiveness monitoring studies that was selected for implementation starting in 2014 for the Regional Stormwater Monitoring Program for Puget Sound. The specific study question to be addressed through the RPWS is as follows:

> *How effective are watershed rehabilitation efforts at improving receiving water conditions at the watershed scale?*

To answer this study question, the RPWS will involve the collection of routine and continuous measurements of various hydrologic, chemical, physical habitat, and biological indicators of stream health over an extended time frame to quantify improvements in receiving water conditions in watersheds that have been targeted for rehabilitation efforts. At the same time these measurements will also be collected in watersheds that are not similarly targeted for these efforts. The trend of interest will be evidence that receiving water conditions are improving in the former watersheds while conditions in the latter watersheds remain relatively static.

In order to further develop the experimental design for the RPWS, the statistical power of trend tests to be performed for this study was investigated. The statistical power of a test is the probability that it will correctly reject the null hypothesis (H0) when the alternative hypothesis (H1) is true. Power analyses can be used to calculate the minimum sample size required for detecting an effect of a given size with a reasonably high probability. In this case, these analyses were specifically performed to investigate the power of Mann-Kendall trend tests for detecting significant trends in time series data given: 1) sample size, 2) the desired significance level, 3) magnitude of the trend, and 4) amount of variation within existing datasets. These power analyses were performed to determine adequate sample collection frequencies for detecting trends in benthic index of biotic integrity (B-IBI) scores, total suspended solids (TSS) and total zinc over the expected 10-year period of implementation for the RPWS.

This memorandum describes the methods that were used to perform these analyses. Results from these analyses are then then summarized and briefly discussed.

2200 Sixth Avenue | Suite 1100 | Seattle, Washington | 98121 | p 206 441 9080 | f 206 441 9108
PORTLAND, OR | MISSOULA, MT | OLYMPIA, WA | WINTHROP, WA | BELLINGHAM, WA

Methods

Power analyses for B-IBI scores, TSS and total zinc were performed in a Microsoft Excel spreadsheet using a custom program written in Visual Basic. This program performs Monte Carlo simulations to evaluate the probability of detecting hypothetical trends in the data for each of these parameters using Kendall Tau trend tests given different sized sample sets. The total size of the sample set can be scaled up or down to evaluate the statistical power that can be obtained using different hypothetical annual sampling frequencies. During each simulation, the following two steps are performed:

1. A sample set is randomly drawn from a synthetic time series dataset with a fixed probability distribution that has been defined using actual monitoring data for each parameter (see more detailed discussion below). A predefined trend of a given magnitude has also been introduced to the synthetic time series dataset so that mean values gradually increase (for B-IBI scores) or decrease (for TSS and total zinc) over time. Figure 1 shows and example plot of a sample set that was randomly drawn from a synthetic time series dataset.
2. A Mann-Kendall trend test is performed on the sample set to determine if the predefined trend was detected using the randomly drawn samples. Specifically, a one-tailed Mann-Kendall trend test is performed using a significance level of 0.1 for B-IBI scores and 0.05 for TSS and total zinc.

These simulations are subsequently repeated 500 times; upon completion, the power of the Kendall Tau trend test is quantified based on the proportion of samples sets that successfully detected the predefined trend relative to the total number of simulations performed. For example, if 300 samples sets successfully detected the trend, the power of the test was assumed to be 60 percent (0.60 = 300/500). In other words, a sample set of the size used in the power analysis would have a 60 percent probability of detecting a trend if it were equal in magnitude to the one introduced to the synthetic time series dataset.

These simulations were repeated to evaluate the power of Kendall Tau trend tests given different scenarios with the following inputs:

- Different annual sampling frequencies (high, medium, and low) over a 10-year period.
- Trends of different magnitudes (high, medium, low) that were incorporated into the synthetic data sets
- Characteristics of the trend (linear or nonlinear)
- Assumed variation (high, medium, and low) within the existing datasets for each parameter.

Each of these inputs is defined in more detail in the following subsections. Table 2 also identifies all the various scenarios that were evaluated based on different permutations of these inputs.

Annual Sampling Frequencies

The specific goal of this analysis was to identify annual sampling frequencies for B-IBI scores, TSS, and total zinc that would allow trends of an anticipated magnitude to be detected with a reasonably high probability over the expected 10-year period of implementation for the RPWS. As sample size increases, the statistical power of the Mann Kendall trend test will also increase. For this analyses, Monte Carlo simulations were performed to evaluate the power of Kendall Tau trend tests using the following annual sampling frequencies for each parameter:

B-IBI scores: 1, 2, and 3 samples collected annually; yielding a total of 10, 20, and 30 samples over a 10-year period, respectively, for trend tests.

TSS: 12, 16, and 20 samples collected annually; yielding a total of 120, 160, and 200 samples over a 10-year period, respectively, for trend tests.

Total Zinc: 12, 16, and 20 samples collected annually; yielding a total of 120, 160, and 200 samples over a 10-year period, respectively, for trend tests.

Trend Magnitude

As the magnitude of the trend increases, the statistical power of the Mann Kendall trend test will also increase. For this analysis, professional judgement was used to identify a range of predefined trends (high, medium, and low) for B-IBI scores, TSS, and total zinc that could potentially be realized through watershed rehabilitation efforts. The specific predefined trends evaluated in the Monte Carlo simulations are as follows:

B-IBI Scores:

High – 28 unit increase in B-IBI scores over a 10-year period representing a change in biological condition from very poor to good

Medium – 19 unit increase in B-IBI scores over a 10-year period representing a change in biological condition from poor to good

Low- 9 unit increase in B-IBI scores over a 10-year period representing a change in biological condition from fair to good

TSS:

High – 4 mg/L decrease in TSS concentrations over a 10-year period

Medium – 2 mg/L decrease in TSS concentrations over a 10-year period

Low – 1 mg/L decrease in TSS concentrations over a 10-year period

Total Zinc:

High – 4 μg/L decrease in total zinc concentrations over a 10-year period

Medium – 2 μg/L decrease in total zinc concentrations over a 10-year period

Low – 1 μg/L decrease in total zinc concentrations over a 10-year period

Trend Characteristics

To evaluate the sensitivity a the power analyses, separate Monte Carlo simulations were performed for B-IBI scores assuming the associated predefined increasing trends were both linear and logarithmic, respectively. Similarly, separate Monte Carlo simulations were also performed for TSS and total zinc assuming the associated predefined decreasing trends were linear and logarithmic. In general, the Mann Kendall trend test is a nonparametric measure of correlation that should be relatively effective for detecting non-linear trends (Helsel and Hirsch 2002).

Assumed Variation

In general, the statistical power of the Mann Kendall trend test will decrease as the amount of variation within the dataset increases. For this analysis, the assumed variation across the synthetic time series datasets for B-IBI scores, TSS, and total zinc was defined using actual monitoring data for each parameter. Specifically, the Puget Sound Stream Benthos database was queried to obtain representative data for B-IBI scores from small streams in western Washington. This queries yielded data from 1,431 sampling locations. These data were further processed to identify a subset of sampling locations with four or more B-IBI scores. This process yielded data from 522 sampling locations. The standard deviation of the B-IBI scores for each of these sampling locations was then computed. To obtain high, medium, and low estimates of the variation in B-IBI scores that might be encountered during the RPWS, the 75th, 50th (median), and 25th percentile values, respectively, were selected from all the standard deviation values computed for this subset of sampling locations (see Table 2). These estimates of variation in B-IBI scores were subsequently used to define the probability distributions for the synthetic times series datasets used in the Monte Carlo simulations.

For TSS and total zinc, the Washington State Department of Ecology's Environmental Information Management database was queried to obtain representative data from small streams in western Washington. These queries yielded data from 438 sampling locations for TSS and 63 sampling locations for total zinc. These data were further processed to identify a subset of sampling locations having greater than six samples for TSS and greater than 5 samples for total zinc, respectively. This processing yielded data from 81 sampling locations for TSS and 45 sampling locations for total zinc. The same process described above for the B-IBI scores was then used to generate high, medium, and low estimates of variation that might be encountered during the RPWS (see Table 2). These estimates of variation for TSS and total zinc were subsequently used to define the probability distributions for the synthetic times series datasets used in the Monte Carlo simulations.

Results

Results from the power analyses are summarized in Tables 4, 5, and 6 for B-IBI scores, TSS, and total zinc, respectively. The results generally show the following predictable patterns:

- Power increases with increased annual sampling frequency
- Power decreases as the magnitude of the trend decreases
- Power decreases as the variability in the data increases
- Power is lower when trying to detect logarithmic trends relative to linear trends

Statistical power for detecting trends in B-IBI scores exceeded 80 percent in the majority of scenarios evaluated. In contrast, statistical power for detecting trends in TSS generally only exceeded 80 percent when the magnitude of the trend was a 4 mg/L decrease in concentration regardless of the sample size and standard deviation used in the scenario. Statistical power for detecting trends in total zinc exceeded 80 percent for multiple combinations of scenarios where the magnitude of the trend was at least a 2 mg/L decrease in concentration.

References

Helsel, D.R. and R. M. Hirsch, 2002. Statistical Methods in Water Resources Techniques of Water Resources Investigations, Book 4, chapter A3. US Geological Survey. 522 pages.

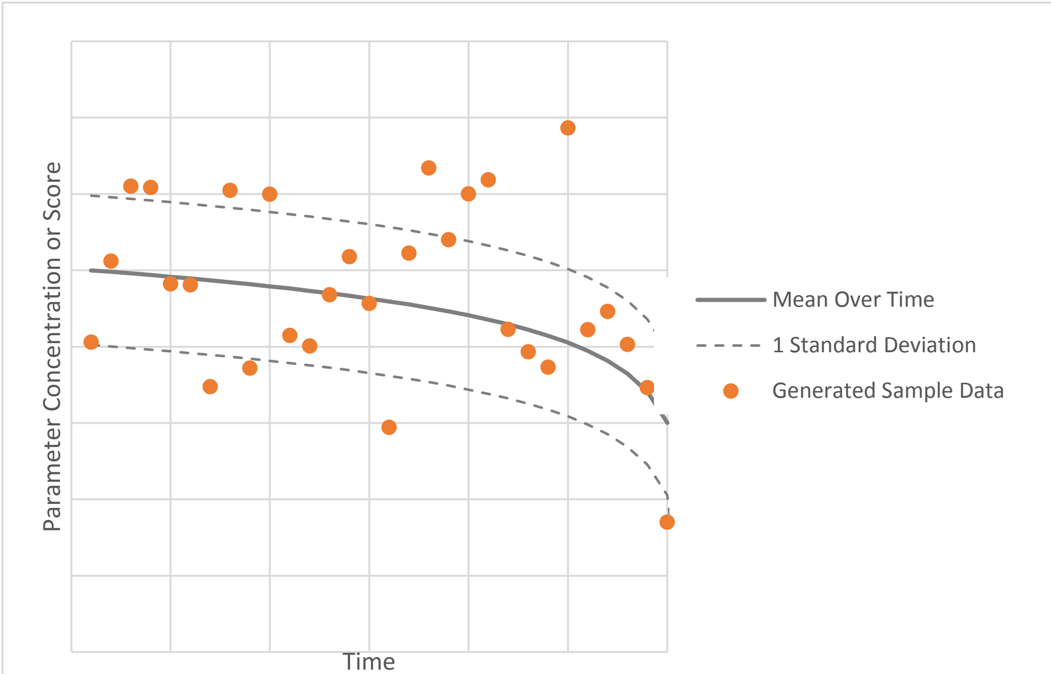


Figure 1. Example Plot of a Sample Set that was Randomly Drawn from a Synthetic Time Series Dataset.

Table 1. Inputs for Monte Carlo Simulations Performed to Evaluate the Statistical Power of Mann Kendall Trend Tests.

	Total Suspended Solids	Total Zinc	BIBI
Initial Mean Concentration for Trend	7.94 mg/L	7.25 µg/L	13
			22
			32
Standard deviation around mean	5.08 mg/L	5.08 µg/L	2.83
	9.81 mg/L	9.81 µg/L	3.90
	18.86 mg/L	18.86 µg/L	5.29
Final Mean Concentration for Trend	6.94 mg/L	6.25 µg/l	41
	5.94 mg/L	5.25 µg/L	
	3.94 mg/L	3.25 µg/L	
Samples per Year	12	12	1
	16	16	2
	20	20	3
Trend Characteristic over Time	Linear	Linear	Linear
	Logarithmic	Logarithmic	Logarithmic
Total Number of Scenarios	54	54	54

Table 2. Estimates of Variation Used to Define the Probability Distributions for the Synthetic Times Series Datasets.

Percentile	B-IBI Standard Deviation[a]	Total Suspended Solids Standard Deviation[b] (mg/L)	Total Zinc Standard Deviation[b] (µg/L)
25th	2.83	5.08	1.76
50th	3.90	9.81	7.06
75th	5.29	18.86	13.86

[a] Data obtained from the Puget Sound Stream Benthos database

[b] Data from obtained the Environmental Information Management database

B-IBI: benthic index of biotic integrity

Table 3. Power Analysis Results for Benthic Index of Biotic Integrity (B-IBI) Scores.

Samples per Year	Mean B-IBI Score at Trend Start	Mean B-IBI Score at Trend Finish	Standard Deviation	Power Linear Trend	Power Logarithmic Trend
1	13	41	2.83	100%	100%
			3.90	100%	100%
			5.29	100%	100%
	22	41	2.83	100%	100%
			3.90	100%	99%
			5.29	98%	96%
	32	41	2.83	96%	91%
			3.90	84%	78%
			5.29	71%	63%
2	13	41	2.83	100%	100%
			3.90	100%	100%
			5.29	100%	100%
	22	41	2.83	100%	100%
			3.90	100%	100%
			5.29	100%	100%
	32	41	2.83	100%	98%
			3.90	97%	91%
			5.29	90%	79%
4	13	41	2.83	100%	100%
			3.90	100%	100%
			5.29	100%	100%
	22	41	2.83	100%	100%
			3.90	100%	100%
			5.29	100%	100%
	32	41	2.83	100%	100%
			3.90	100%	95%
			5.29	96%	86%

Table 4. Power Analysis Results for Total Suspended Solids (TSS).

Samples per Year	Mean TSS Concentration at Trend Start (mg/L)	Mean TSS Concentration at Trend Finish (mg/L)	Magnitude of Change (mg/L)	Standard Deviation (mg/L)	Power Linear Trend	Power Logarithmic Trend
12	7.94	6.94	-1	5.08	36%	24%
				9.81	27%	21%
				18.86	20%	19%
		5.94	-2	5.08	74%	46%
				9.81	57%	34%
				18.86	46%	27%
		3.94	-4	5.08	100%	84%
				9.81	96%	70%
				18.86	91%	57%
16		6.94	-1	5.08	41%	28%
				9.81	31%	22%
				18.86	29%	20%
		5.94	-2	5.08	82%	49%
				9.81	63%	37%
				18.86	52%	30%
		3.94	-4	5.08	100%	88%
				9.81	99%	73%
				18.86	95%	66%
20		6.94	-1	5.08	48%	25%
				9.81	40%	23%
				18.86	28%	20%
		5.94	-2	5.08	88%	51%
				9.81	75%	39%
				18.86	64%	36%
		3.94	-4	5.08	100%	91%
				9.81	100%	83%
				18.86	99%	71%

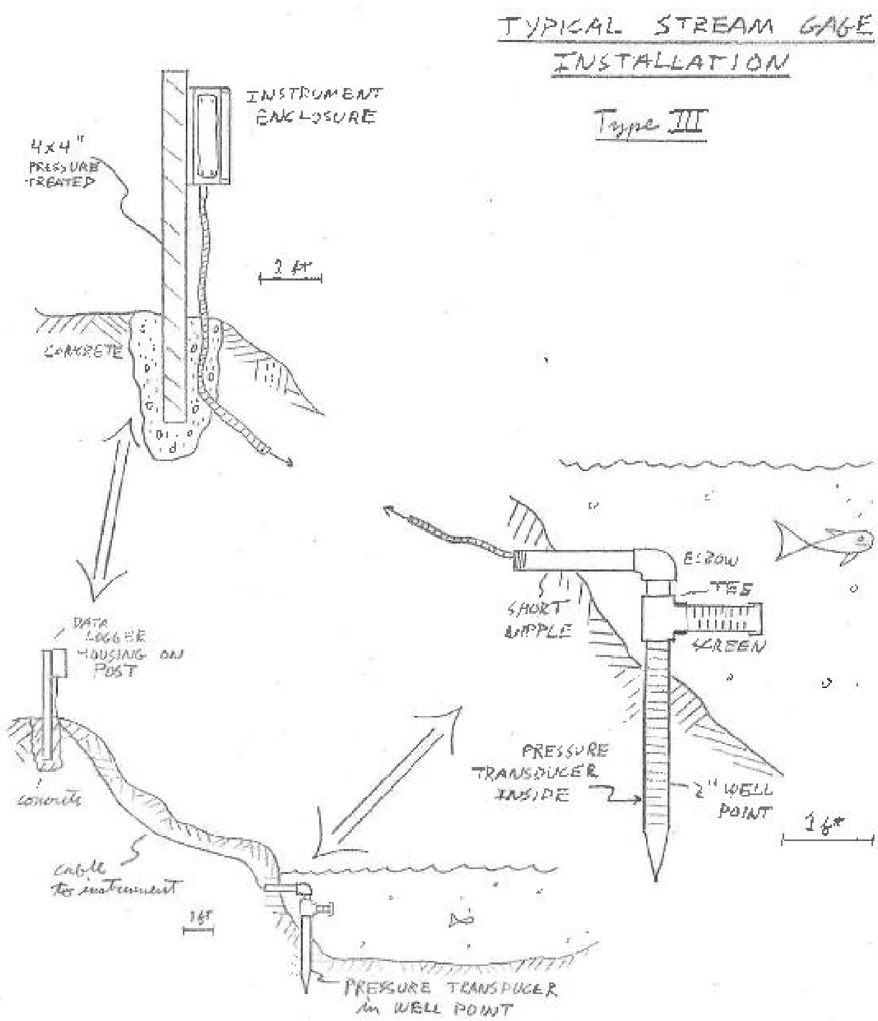
Table 5. Power Analysis Results for Total Zinc.

Samples per Year	Mean Total Zinc Concentration at Trend Start (mg/L)	Mean Total Zinc Concentration at Trend Finish (mg/L)	Magnitude of Change (mg/L)	Standard Deviation (mg/L)	Power Linear Trend	Power Logarithmic Trend
12	7.25	6.25	-1	1.76	73%	47%
				7.06	36%	22%
				13.86	28%	17%
		5.25	-2	1.76	99%	85%
				7.06	70%	38%
				13.86	57%	29%
		3.25	-4	1.76	100%	100%
				7.06	99%	78%
				13.86	97%	65%
16		6.25	-1	1.76	85%	48%
				7.06	38%	24%
				13.86	34%	24%
		5.25	-2	1.76	100%	89%
				7.06	78%	46%
				13.86	60%	38%
		3.25	-4	1.76	100%	100%
				7.06	100%	86%
				13.86	99%	73%
20		6.25	-1	1.76	90%	57%
				7.06	44%	25%
				13.86	39%	23%
		5.25	-2	1.76	100%	93%
				7.06	83%	47%
				13.86	74%	38%
		3.25	-4	1.76	100%	100%
				7.06	100%	87%
				13.86	100%	77%

APPENDIX C

Typical Equipment Installations for Hydrologic Monitoring

King County
Department of
Natural Resources and Parks
Water and Land Resources Division
201 South Jackson Street, Suite 600
Seattle, WA 98104



APPENDIX D

Monitoring Equipment Specifications

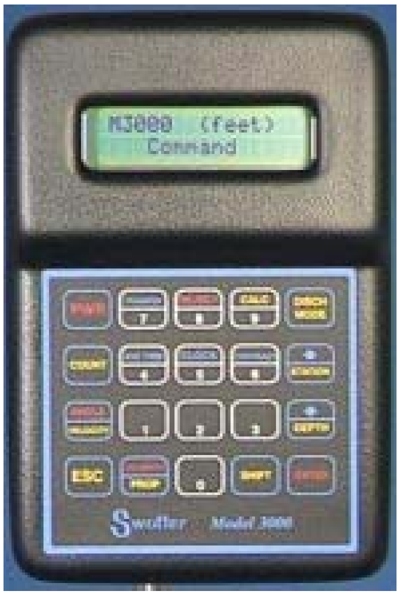
SWOFFER INSTRUMENTS, INC.

MODEL 3000

Still the best Choice !

Current meter, Flow Calculator - Datalogger

The new Model 3000 is a hand held computer and data logger designed specifically for the measurement of open channel velocities and the on-site computation of stream discharges (flow). Features Include:



The Model 3000 Indicator is a data-logging version of the Model 2100, allowing the operator to input all measurement data usually kept on a clip-board while crossing a stream. The Model 3000 records depths, widths, velocities and angles along with time & date of measurements. It figures the “Q” and can upload all this information in spreadsheet-acceptable format to your PC for further study and

- Efficient *Photo-Fiber-Optic* sensor coupled with precision quartz crystal controlled electronics provide accurate repeatable data in most flow conditions.
- The *Model 3000* Indicator displays data in feet and meters per second. Toggle the 0 key at the main screen to change from one to the other.
- Velocity averaging is fully user adjustable. Anything from 1 to 999 seconds of averaging can be chosen. The *Model 3000* automatically powers up using your last averaging time period. If you use 40 seconds, it stays at 40 seconds until you change it.
- Velocities can be a single averaged measurement or can be the ***accumulated average*** of as many measurements as desired, all controlled from the keypad.
- Sensor components (propeller, rotor, and rotor shaft) are easily and inexpensively replaceable. Carry spares into remote locations and you’ll never have to return early because of a bent propeller or bucketwheel, or a lost propeller magnet or rotor shaft.
- Wide choice of sensor carriers or “wands” to accommodate virtually any open stream velocity measuring requirement.
- Indicator keys are color coded, grouping related functions into like colors.
- Lightweight, portable system is easy to work with all day in the field. *Model 3000* Indicator uses the same rugged, weatherproof instrument housing as the earlier Model 2100 and Model 2200 but with added water incursion protection and data storage features.
- A simple and ***accurate*** method of user-accomplished calibration is provided with the *Model 3000*. No other current meter provides the user a method of checking and changing calibrations in the field.
- Calibration settings for 10 different sensors/propellers can be stored in the indicator and the *Model 3000* is completely compatible with all earlier Swoffer Instruments’ sensors (Models 1000, 2000, 2100 and 2200).
- The *Model 3000* is also specifically designed to function with Price type AA & Pygmy current meters using either the optical adapters pioneered by Swoffer Instruments in the Models 2200 and USGS-HIF Optic-Head sensors or with meters using the newer magnetic head contactors. The Model 3000 can in fact be field calibrated to operate with any sensor

3000-1514 and 3000-1518 wands

3000-LX, 3000-STDX, 3000-12, -13, -14 wands

*MODEL 3000 CURRENT METER SPECIFICATIONS **

VELOCITY RANGE	0.1 to 25 Feet Per Second (propeller meters) (0.03 to 7.5 Meters Per Second)
DISPLAY	Two line by 16 character Liquid Crystal Digital.
RESOLUTION	To three decimals, both feet and meters.
ACCURACY	Can be held to within 1% with periodic user-required calibration tests and adjustments.
DISPLAY AVERAGING	User adjustable from 1 to 999 seconds. Remains unchanged with each power-up until purposely reset. Velocities obtained within each sampling period can be averaged with successive periods .
OPERATING TEMPERATURE	LCD Min. -4° F (-20°C) Max. 158°F (70°C) Sensor Min. 0° F (-17.8°C) Max. 194° F (90°C)
POWER REQUIRED	Four AA batteries. Alkaline or rechargeable nicads.
INDICATOR SIZE	4 by 6 by 2 inches (15.2 by 10.2 by 5.1 cm)
INDICATOR WEIGHT	25 oz. (including 4 AA batteries).
INDICATOR MATERIAL	Vacuum-formed ABS with a clear acrylic viewing lens over the LCD.
INDICATOR KEYPAD	Back-printed polycarbonate in four colors plus black. Tactile feedback membrane type contacts with minimum actuation pressure required for long life and water resistance.
FASTENERS	Stainless Steel & Brass.
SENSOR WAND MATERIALS	Aluminum = 6061-T6, Stainless Steel = #303
SENSOR BODY AND ROTOR	*Acetron GP (rotor body) & Ertalyte® TX, an internally lubricated thermoplastic polyester that provides enhanced wear over all previous rotor materials.*
SENSOR PROPELLER	Glass-filled nylon. 2" diameter is supplied. Other

HOBO® Waterproof Shuttle (U-DTW-1) Manual

The HOBO Waterproof Shuttle performs several major functions:

- Reads out all logger information (serial number, deployment number, data, etc.) from loggers in the field for transfer to host computer, and stores each logger's data in a "bank"
- Nonvolatile memory preserves data, even if batteries are depleted
- Relaunches the logger, resetting the logger's time to the shuttle's time and synchronizing the logging interval on relaunch
- Can be used as an optic-to-USB base station
- Can be used to read out and relaunch loggers underwater

Although the HOBO Waterproof Shuttle is easy to use, Onset strongly recommends that you spend a few minutes reading this manual and trying out the procedures described here before taking the shuttle into the field.

HOBO Waterproof Shuttle

U-DTW-1

Included Items:

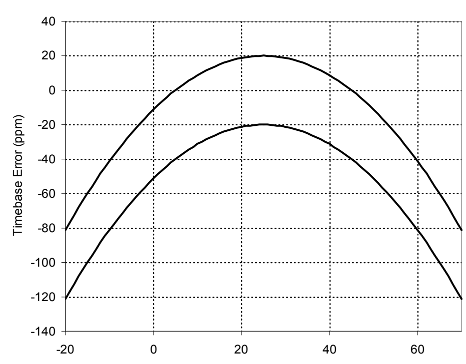
- USB cable
- Set of couplers;
  - For UA Pendant (COUPLER2-A)
  - For U20 Water Level (COUPLER2-B)
  - For U20L Water Level, U22 Water Temp Pro v2, U24 Conductivity, and U26 DO (COUPLER2-C)
  - For UTBI TidbiT v2 (COUPLER2-D)
  - For U23 HOBO Pro v2 (COUPLER2-E)

Required Items:

- HOBOware 2.2 or later
- Compatible logger and matching coupler

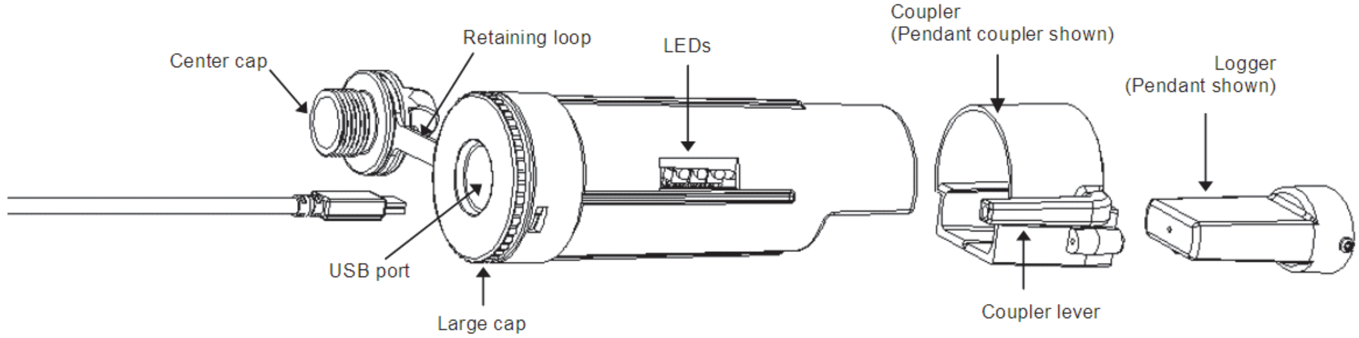
Specifications

Compatibility	All HOBO U-Series loggers with optic USB. Not compatible with the HOBO U-Shuttle (U-DT-1).
Data Capacity	63 logger readouts of up to 64K each
Operating Temperature	0° to 50°C (32° to 122°F)
Storage Temperature	-20° to 50°C (-4° to 122°F)
Wetted Materials	Polycarbonate case, EPDM o-rings and retaining loop
Waterproof	To 20 m (66 feet)
Time Accuracy	±1 minute per month at 25°C (77°F); see Plot A
Logger-to-Shuttle Transfer Speed	Reads out one full 64K logger in about 30 seconds
Shuttle-to-Host Transfer Speed	Full shuttle offload (4 MB) to host computer in 10 to 20 minutes, depending on computer
Batteries	2 AA alkaline batteries required for remote operation
Battery Life	One year or at least 50 complete memory fills, typical use
Weight	150 g (4 oz)
Dimensions	15.2 x 4.8 cm (6.0 x 1.9 inches)
CE	The CE Marking identifies this product as complying with all relevant directives in the European Union (EU). To maintain CE compliance, this product must be used with the supplied USB cable or equivalent (less than 3 m long).



Plot A

HOBO Waterproof Shuttle Features



Preparing to Go on Location

Before using the shuttle for the first time, you must launch it with HOBOware 2.2 or greater. You must also launch any compatible loggers that were last launched with an earlier version of HOBOware, or have never been launched at all.

1. Use HOBOware 2.2 or greater to launch each logger you wish to read out and relaunch with the shuttle later. (Read "Using the shuttle as a base station" for instructions if you do not have another base station for the loggers.) The shuttle cannot relaunch loggers that were last launched with an earlier version of HOBOware. (You only have to do this once for each logger.)
2. Plug the large end of a USB interface cable into a USB port on the computer. (Avoid using a USB hub, if possible.)
3. Unscrew the center cap on the shuttle. If the cap is too tight to loosen by hand, insert a screwdriver through the lanyard hole and rotate counterclockwise until the cap is loosened.
4. Plug the small end of the USB interface cable into the USB port in the shuttle. (If the shuttle has never been connected to the computer before, it may take a few seconds for the new hardware to be detected.)
5. Follow the instructions in the *HOBOware User's Guide* to access the **Manage Shuttle** dialog. Make sure the battery level is good, and change the batteries now if they are weak.

Important: If you change the batteries in the field, the shuttle's clock will stop, and the shuttle will not read out loggers again until you relaunch it in HOBOware.

6. If you are using the shuttle for the first time, launch the shuttle as described in the *HOBOware User's Guide*. Launching synchronizes the shuttle's clock to the host computer and initializes the shuttle's header.

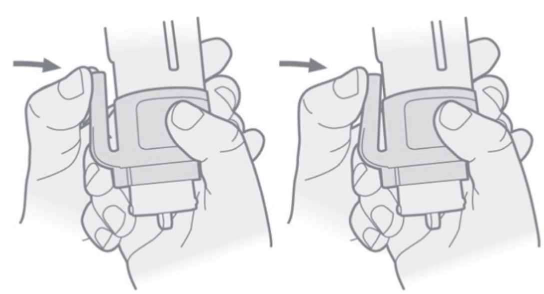
Important: The shuttle's clock is used to set the logger's clock at relaunch. For most accurate results, make sure the host computer's clock is correct before launching the shuttle. If you need to adjust the computer's clock, quit HOBOware, set the computer's clock, then reopen HOBOware and launch the shuttle.

7. If you have used the shuttle before, make sure there are enough banks available to accommodate the loggers you plan to read out.
8. Disconnect the USB cable from the shuttle and replace the center cap securely.

Reading Out and Relaunching Loggers in the Field

After you have ensured that the shuttle's batteries are good, there is sufficient memory available, and the shuttle's clock is synchronized, follow these steps to read out and relaunch a logger in the field:

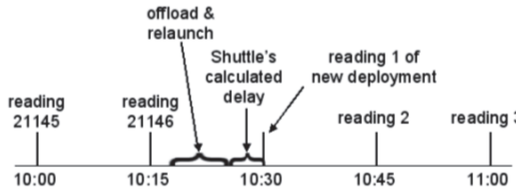
1. Make sure the shuttle's large cap and center cap are closed securely. Tighten the center cap until it is just flush with the large cap, or until the O-ring is no longer visible.
2. Make sure the communication end of the shuttle is clean. Attach the correct coupler for the logger, and ensure that it is seated properly.
3. Insert the logger into the coupler, following the instructions that came with the coupler.
4. Momentarily press the coupler lever (pressing hard enough so the lever bends).



Readout should begin immediately. The amber LED blinks continuously while readout and relaunch are in progress. Do not remove the logger when the amber LED is blinking.

5. After reading out the logger, the shuttle synchronizes the logger's clock to the shuttle's internal clock and relaunches the logger, using the description, channels to log, logging interval, and other settings that are already in the logger. (If the logger was launched with multiple logging intervals, the final defined logging interval will be used.) The logger is

launched with a slight delay that causes its readings to be synchronized with those of the previous deployment, as shown in the following diagram.



Important: If the logger was launched with multiple logging intervals, there will be no synchronizing delay. The logger will start immediately with the last defined logging interval.

6. When the relaunch has completed, the green LED blinks for 15 minutes, or until you momentarily press the coupler lever to stop it (press hard enough so the lever bends). If the red LED blinks instead, there was an error, and the logger may have stopped. Refer to "Troubleshooting" in this manual for details.
7. Remove the logger from the coupler.

Checking Shuttle Status in the Field

The shuttle's memory has 63 "banks." One logger readout can be stored in each bank. To check the shuttle's memory and batteries in the field, remove the logger and press the coupler's lever for at least three seconds (pressing hard enough so the lever bends). When you release the lever, the green LED blinks once for each unoccupied bank in the shuttle's memory. (Press the lever momentarily to stop the blinking, pressing hard enough so the lever bends.)

If the shuttle's batteries are running low, all of the shuttle banks are full, or the clock has not been set, the red LED blinks. (Press the lever momentarily to stop the blinking, pressing hard enough so the lever bends) Use HOBOware to check the shuttle's battery level, available memory, and clock. You may need to change the batteries, or offload the datafiles to the host computer and delete them from the shuttle to free up memory before you can continue reading out loggers.

Offloading Data to the Host Computer

You can offload the data stored in the shuttle even when the batteries are depleted. Take the following steps:

1. Connect the shuttle to a host computer running HOBOware.
2. Follow the instructions in the *HOBOware User's Guide* to offload the new datafiles or access the **Manage Shuttle** dialog. The **Manage Shuttle** dialog shows you how many banks are occupied, and whether they have already been offloaded and saved to the host computer.
3. Offload and save data from the banks of your choice. Refer to the *HOBOware User's Guide* for details on saving datafiles offloaded from the shuttle.
4. Review the list of banks and delete any that are no longer needed. Make sure the battery level is good, and change the batteries now if they are weak. (If you change the batteries in the field, the shuttle's clock will stop, and the shuttle will not read out loggers.) Update the shuttle's clock, if necessary.
5. When finished, disconnect the shuttle from the computer and close the center cap securely.

Using the Shuttle as a Base Station

You can use the shuttle as a base station for any U-Series logger with an optic USB interface. (This function is available even when the batteries are depleted.) To use the shuttle as a base station:

1. Connect the shuttle to the host computer running HOBOware.
2. Attach a compatible logger and coupler.
3. Momentarily press the coupler's lever (pressing hard enough so the lever bends).
4. The amber LED blinks momentarily, then the green LED should glow steadily to indicate that the logger is ready to communicate with HOBOware. (If the red LED blinks instead, the logger was not found. Make sure the logger and coupler are aligned and seated properly, and that there is no dirt or strong sunlight interfering with communications.)
5. When finished, remove the logger from the coupler. The green LED stops glowing when you disconnect the logger or the USB cable.

Important: The Waterproof Shuttle cannot be used *as a base station* with Pendant logger models UA-001 and UA-003 (including rain gauges RG3 and RG3-M) with serial numbers less than 988278. These loggers require a BASE-U-1 for communication with the host computer.

Indicator Lights

Green "OK" LED
The green "OK" LED blinks when HOBOware recognizes it as a base station; when it finishes reading out and relaunching a logger; and when you press the coupler lever to check the shuttle's status (see "Checking shuttle status in the field" for details). Momentarily press the coupler lever to stop the blinking (pressing hard enough so the lever bends).

The green LED glows steadily when the shuttle is being used as a base station.

Amber "Transfer" LED
The amber "Transfer" LED blinks when the shuttle is reading out a logger and relaunching it. Do not remove the logger when the Transfer light is lit.

Red "Fail" LED
The red "Fail" LED blinks whenever the shuttle encounters an error condition. Refer to "Troubleshooting" for details.

All LEDs
All LEDs blink in unison when the shuttle has just been powered up, either by installing fresh batteries or (if batteries are not installed) by connecting to the computer's USB port.

Troubleshooting

This section describes problems you may encounter while using the shuttle.

Shuttle is not recognized by host computer
If HOBOware does not recognize the shuttle when you connect it to the computer, simply disconnect and reconnect the shuttle.

Red "Fail" LED blinks
The red "Fail" LED blinks (for 15 minutes, or until you press the coupler lever, pressing hard enough so the lever bends) whenever the shuttle encounters an error. There are several conditions that might cause an error:

- **Shuttle is full:** If the red LED blinks when you try to read out a logger, check whether all of the banks are full, as described in "Checking shuttle status in the field." Or, use HOBOware to check the shuttle's memory.
- **Shuttle batteries are low:** If you cannot read out any loggers at all, check the logger's status, as described in "Checking shuttle status in the field," or use HOBOware to check the shuttle's batteries. The batteries may simply need to be replaced.
- **Compatibility:** The shuttle cannot read out or relaunch loggers that were last launched from HOBOware prior to version 2.2. You will need to read out these loggers on the host computer and relaunch them in HOBOware 2.2 or greater before you can use them with the shuttle.
- **Shuttle clock is not set:** The shuttle has experienced a power failure that caused the clock to reset. You must use HOBOware to offload the files that are already on the shuttle, then relaunch the shuttle before you can read out another logger.
- **Can't communicate with logger:** Remove the logger and coupler. Inspect them and the shuttle to ensure that all are free of dirt that could block the optic communication sensor. Carefully reassemble the shuttle, coupler, and logger, and make sure they are all seated properly. Shield the shuttle from strong sunlight, if applicable, which can interfere with optic communications.
- **Other logger problems:** If you can read out some loggers but not others, or if you cannot read out any loggers even with fresh batteries in the shuttle, check the loggers in HOBOware. Make sure their batteries are at acceptable levels and that there is no "corrupted header" message.

Amber "Transfer" LED stays on without blinking
The amber light is magnetically activated when you press the coupler lever. If it glows steadily at any other time, the magnet in the lever may be too close to the magnetic switch in the shuttle, or another strong magnet may be present. Try bending the lever away from the coupler to reduce the magnet's effect.

LEDs do not function
If the LEDs are not functioning at all, the batteries may be completely exhausted. To test this, attach the shuttle to the host computer and check the battery level. The shuttle should be able to communicate with the host computer, blink its LEDs normally, and perform as a base station even when the batteries are missing or depleted.

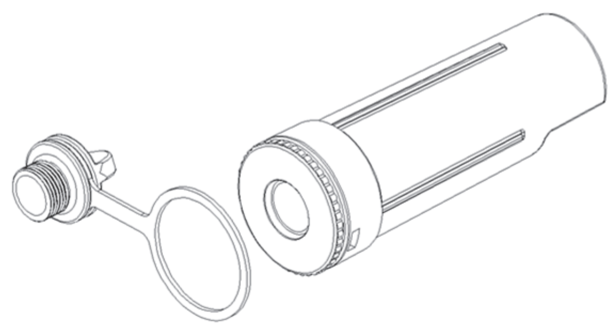
Replacing the Shuttle's Batteries

The shuttle's batteries should last about one year or at least 50 complete memory fills in typical conditions. When the shuttle's batteries run low (2.2 V or less), any logger data that is already in the shuttle will remain safe, but the shuttle will not read out another logger until its batteries are replaced.

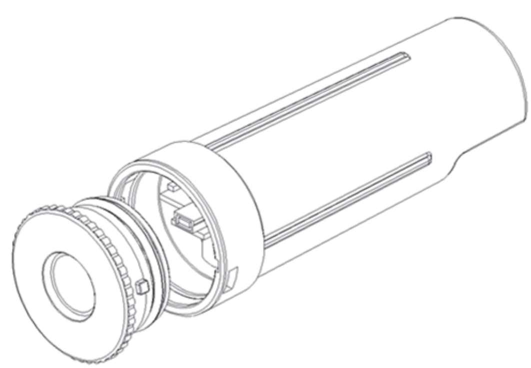
To avoid battery problems, always check the shuttle's batteries in HOBOware before going into the field, and replace them if needed. If you cannot replace the bad batteries right away, you should remove them as soon as possible to ensure that they do not leak and damage the shuttle.

To change the shuttle's batteries:

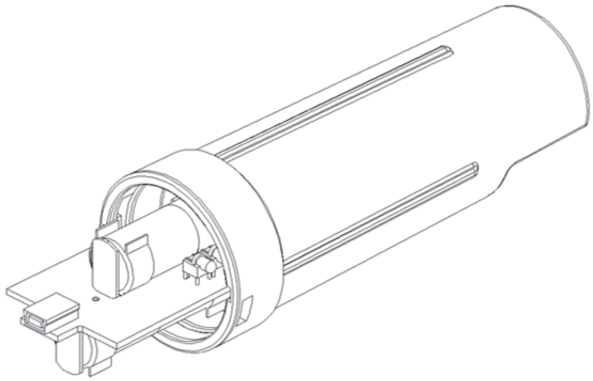
1. Work over a clean surface to provide a safe platform for the disassembly.
2. Unscrew the center cap on the shuttle. If the cap is too tight to loosen by hand, insert a screwdriver through the lanyard hole and rotate counterclockwise until the cap is loosened.
3. Use the center cap to help you carefully pull the rubber loop free of the large cap. The large cap cannot be removed while the rubber loop is in place.



4. Turn the large cap counter-clockwise slightly, then pull it off.



5. Turn the shuttle over and tap it gently. The circuit board should slide into your hand.



6. Remove the old batteries and install two new ones in the correct orientation. Both batteries should be turned the same way, with their positive ends facing the USB port on the board. (When the second battery makes contact, all of the shuttle's LEDs will blink in unison.)
7. Put the board back into the case, taking care not to bend the communication LEDs. Align the circuit board with the runners in the case. The USB port should face the open end of the shuttle, and the LEDs should show through the window on the label.
8. Close the shuttle's case. Line up the tabs on the large cap with the slots on the case, press gently, and turn slightly clockwise until the large cap is closed securely.
9. Replace the rubber loop and center cap. Tighten the center cap until it is just flush with the large cap, or until the O-ring is no longer visible.
10. Using HOBOware, offload any datafiles that are on the shuttle and launch the shuttle before going into the field again. The shuttle will not read out and relaunch loggers until the clock has been synchronized.

⚠ **WARNING:** Do not install batteries backwards, recharge, put in fire, expose to extreme heat, or mix with other battery types, as the batteries may explode or leak. Contents of an open or leaking battery can cause chemical burn injuries. **Replace all used batteries at the same time.** Recycle or dispose of batteries according to applicable federal, state, and local regulations.

CT2X Submersible Smart Sensor

CONDUCTIVITY/TEMPERATURE WITH DEPTH/LEVEL OPTION

AquiStar™
Data Collection Systems

APPLICATIONS

Wetland surveys

Saltwater intrusion monitoring

Agricultural runoff studies

Discharge monitoring

Measure and record conductivity, temperature, depth/level, salinity, all with one low power, easy-to-use smart sensor

Features

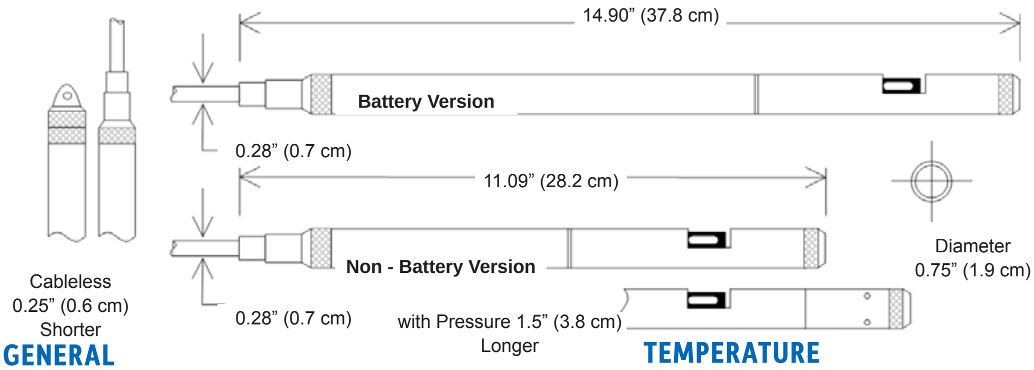
- Measures and records conductivity, temperature, and time with depth/level option
- Low power — *field replaceable batteries*
- Modbus® RTU (RS485) and SDI-12 interface — *great flexibility*
- 0 – 300,000 microSiemens/cm
- Also measures salinity and TDS
- Linear and nLFn temperature compensation
- Small diameter — *0.75" (1.9 cm)*
- 349,000 records in non-volatile memory — *no data loss in the event of a power failure*
- Wireless connectivity — *radios and/or cellular*
- Barometric compensation utility for use with absolute sensors
- Free, easy-to-use software

EASY-TO-USE SOFTWARE

- Easy, in-field calibration
- Flexible logging sequences
- Real-time viewing
- Easy export to spreadsheets and databases
- Firmware upgradable in the field

CT2X Submersible Smart Sensor Conductivity/Temperature with Depth/Level Option

AquiStar™ Data Collection Systems



[1] Storage without batteries

[2] Requires freeze protection kit if using pressure option in water below freezing

[3] Approx. 650 feet or 200 meters

[4] Higher pressure ranges available upon request

[5] Accuracy reduced at levels <10 µS/cm and >100,000 µS/cm

[6] May vary due to environmental factors

[7] ±0.25% accuracy FSO (max) at this range

[8] Depth range for absolute sensors has 14.7 PSI subtracted to give actual depth allowed.

GENERAL

	w/pressure	w/o pressure
Length w/batteries	16.40" (41.6 cm)	12.59" (32.0 cm)
Length w/o batteries	14.90" (37.8 cm)	11.09" (28.2 cm)
	Cableless 0.25" (0.6 cm) shorter	
Diameter	0.75" (1.9 cm)	
Weight	1.0lb. (0.5 kg)	
Body Material	Acetal & 316 stainless *or* titanium	
Wire Seal Materials	Fluoropolymer and PTFE	
Submersible Cable	Polyurethane, polyethylene, *or* ETFE	
Cable Weight	4lbs./100 ft (1.8 kg/30 m)	
Protection Rating	IP68, NEMA 6P	
Desiccant	1-3mm indicating silica gel *(high or standard capacity)*	
Terminating Connector	Available	
Communication	RS485 Modbus® RTU	
	SDI-12 (ver.1.3)	
Recommended Operating Temp. Range[2]	-5° C to 40° C	
Storage Temp. Range[1]	-40° C to 80° C	

LOGGING

Memory	4MB - 349,000 records
Log Types	Variable, user-defined, logarithmic, profiled
Programmable Baud Rate	9600, 19200, 38400
Logging Rate	4x/sec maximum
Software	Complimentary Aqua4Plus and Aqua4Plus Lite
Networking	32 available addresses per junction w/ batching capabilities (up to 255)
File Formats	.xls / .csv / .a4d

POWER

Internal Battery	2 x 1.5V AA
Auxiliary Power	12VDC - Nominal
	6-15VDC - Range
Exp. Alkaline Battery Life	12 months at 15m polling interval[6]

TEMPERATURE

Element Type	30K ohm thermistor
Element Material	Epoxy bead/external housing
Accuracy	± 0.25°C
Resolution	0.1° C
Range	-5° C to 40° C
Units	Celsius, Fahrenheit, Kelvin

DEPTH/LEVEL

Transducer Type	Silicon strain gauge
Transducer Material	316 stainless steel or titanium
Units	PSI, FtH_2O, inH_2O, cmH_2O, mmH_2O, mH_2O,inHg, cmHg, mmHg, Bars, mBars, kPa
Static Accuracy	± 0.05% FSO (typical) ± 0.1% FSO (maximum) *(B.F.S.L. 20°C)*
Resolution	0.0034% FS (typical)
Maximum Operating	1.1 x FS
Over Range Protection	3x FS (for > 300psi, contact INW)[3]
Burst Pressure	1000psi (approx. 2000 feet or 600 meters)
Compensated Range	0°C to 40°C

PRESSURE RANGES[4]

Gauge

PSI	1[7], 5, 15, 30, 50, 100, 300
FtH_20	2.3[7],12, 35, 69, 115, 231, 692
mH_2O	0.7[7],3.5,10.5,21,35,70,210

Absolute[8]

PSI	30, 50, 100, 300
FtH_20	35, 81, 196, 658
mH_20	10, 24, 59, 200

CONDUCTIVITY

Probe Material	Epoxy/Graphite
Electrode	4-pole
Static Accuracy	± 0.5% of measured value (0-100,000 µS/cm)
Resolution	32 bit
Ranges	
Conductivity[5]	0-300,000 µS/cm
TDS	4.9-147,000 mg/L
Salinity	2-42 PSU
Units	µS/cm, mS/cm, mg/L, PSU
Resolution	0.1 µS/cm / 0.001 mS/cm / 0.1 mg/L (TDS) / 0.001 PSU
Warm-Up Time	200 msec
Thermal Compensation	None, linear, or nLFn

INW, A division of Seametrics
SALES & SERVICE
19026 72nd Avenue South
Kent, WA 98032 USA
253.872.0284
FAX 253.872.0285 / info@inwusa.com

1-800-PRO-WELL
WWW.INWUSA.COM
INW™ A Division of Seametrics

HACH FH950 HANDHELD FLOW METER

Applications

- Wastewater
- Collection Systems
- Environmental

The perfect handheld solution for wastewater and environmental flow monitoring.

Knowledge gained through years of in-the-field flow measurement experience has come together in the Hach FH950 Handheld Flow Meter. Designed for use in both environmental and sewer/wastewater flow measurement scenarios—whether you're profiling streams and rivers or providing redundant verification of wastewater flow data—even the smallest hassles have been addressed. And the result for you? Massive time savings. From the field to the office, the Hach FH950 increases your efficiency at every turn.

Designed for Accuracy and Efficiency

The lightweight, battery-powered Hach FH950 was designed to provide accurate velocity and level measurements while simplifying the entire measurement process in rugged field environments. Multiple user-friendly features designed into the FH950 allow you to quickly and easily determine stream velocities for required discharge measurements, calibrate area velocity flow meters, or verify primary devices such as weirs and flumes.

Easy Programming and Data Transfer

The FH950's rugged, lightweight and user-friendly design allows for easy set-up, operation and data management. With an easy-to-use, menu-driven user interface that is readable even in bright sunlight, the FH950 has the ability to store both velocity and level information right within the meter, minimizing field time by up to 50%. Once the data is collected, simply download to a PC via the USB connection, eliminating the need for labor intensive manual data transfer.

Maintenance-Free Electromagnetic Sensor

Available with either Velocity or Velocity and Level capabilities, the FH950's electromagnetic sensor has no moving parts and never requires mechanical maintenance, making it one of the lowest maintenance solutions on the market.

Smart Sensor Capabilities

With an innovative and compact sensor shape with intelligently-designed flow characteristics, the FH950 delivers reliable measurements at low velocities, in very shallow water, and in turbulent flow conditions. It even takes accurate readings in sediment, weed or organic debris-choked water. Plus, with an optional pressure cell for automatic level measurement and sensor positioning, the Hach FH950 is known for having as much brain as it has brawn.

Quickly profile streams and rivers. Easily verify other metering tools or use to select optimal monitoring sites.

MARSH McBIRNEY SIGMA

HACH® Be Right™

Specifications*

Sensor

VELOCITY MEASUREMENT

Method	Electromagnetic
Accuracy	±2% of reading ±0.05 ft/s (±0.015 m/s) through the range 0 to 10 ft/s (0 to 3.04 m/s); ±4% of reading from 10 to 16 ft/s. (3.04 to 4.87 m/s)
Zero Stability	±0.05 ft/s (± 0.015 m/s)
Resolution	0.01 value <100; 0.1 value <1000; 1.0 value ≥1000
Range	0 to +20 ft/s (0 to +6.09 m/s)

LEVEL MEASUREMENT

Method	Diaphragm type: Absolute pressure with single point calibration
Accuracy (static)	The larger of ±2% of reading or ±0.504 in (0.015 m). Steady state temperature and static non-flowing water.
Range	0 to 10 ft (0 to 3.05 m)
Resolution	0.01 value <100; 0.1 value <1000; 1.0 value ≥1000
Minimum Water Level	1.25 in (3.18 cm)

GENERAL ATTRIBUTES

Material	ABS, glass-filled
Environmental Rating	IP68
Dimensions of Sensor	4.7" L x 1.7" W x 2.5" H (11.9 cm L x 4.3 cm W x 6.3 H cm)
Cable Material	Polyurethane jacketed
Cable Lengths	6.5, 20, 40, and 100 ft. (2, 6.1,12.2, and 30.5 m)

Portable Meter

GENERAL ATTRIBUTES

Material	Polycarbonate with a thermoplastic elastomer (TPE) overmold
Environmental Rating	IP67
Dimensions of Portable Meter	8.6" L x 3.7" W x 2.1" H (21.8 L x 9.3 W x 5.3 H cm)
Storage Temperature Range	-4 to 140°F (-20 to 60°C)
Operating Temperature Range	-4 to 131°F (-20 to 55°C)
Battery Charge Temperature Range	32 to 104°F (0 to 40°C)
Battery Type	Lithium-Ion, rechargeable
Battery Life Gauge	5 segment bar graph
Battery Life	18 hours heavy typical day use†; 68°F (20°C)

†Defined as 30 minutes of set up, 6 one-hour periods of continuous use with sensor active and display at maximum brightness, 30 minutes of sleep mode between use periods, data download and power off.

Battery Charger	AC wall outlet charger
USB Connector	Type Mini-B, 5-pin, rated to IP67 when capped

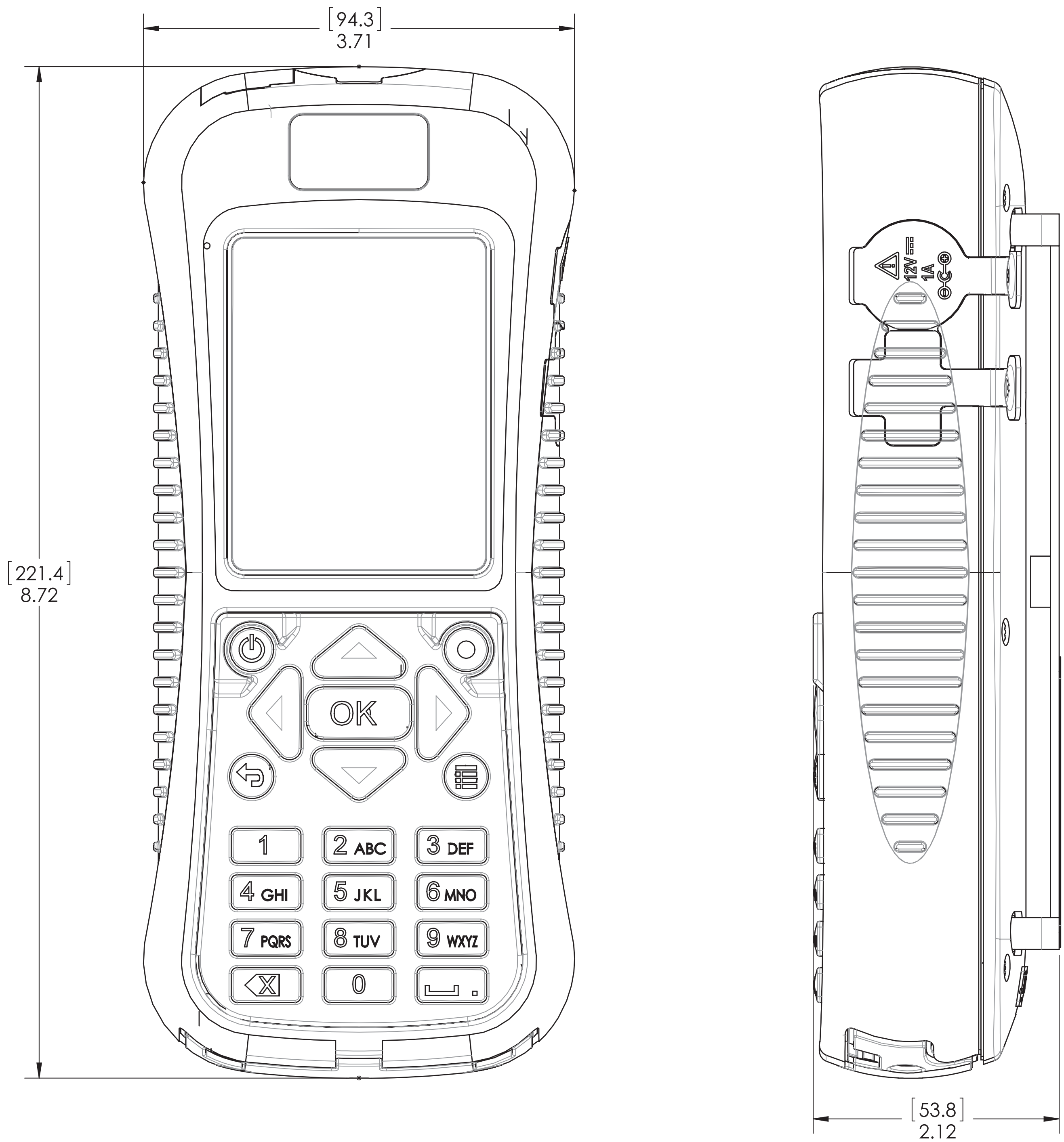
USER INTERFACE AND PROGRAMMING

Graphics Display	Color, LCD; 3.5" QVGA, transflective (readable in direct sunlight)
Measurement Resolution	0.01 value <100; 0.1 value <1000; 1.0 value ≥1000
Keypad	Alpha-numeric
Operating Modes	Real-time, Profiling
Profiling Types	Stream, Conduit
Conduit Shapes	Circular, Rectangular, Trapezoidal, 2/3 Egg, Inverted 2/3 Egg
Stream Entries	Fixed, Non-Fixed Stations
Firmware	Sensor and portable meter firmware are field upgradeable via USB
Noise Rejection	User selectable 50Hz, 60Hz
Units of Measure	Velocity: ft/s, m/s, cm/s, mm/s Flow: ft^3/sec, million gal/day, gal/day, gal/min, m^3/sec, m^3/min, m^3/hour, m^3/day, liters/s, liters/min Level: in, ft, m, cm, mm
Stream Flow Calculation	Mean-section, Mid-section
Diagnostics	Self test, keypad, display, event log
Conduit Profile Methods	0.9 x Vmax, 0.2/0.4/0.8, velocity and level integrator, 2D
Stream Profile Methods	1, 2, 3, 5 and 6 point (Velocity method - USGS and ISO)
File Types	Real-time, Profiling, Event Log
Profiles	Data storage for up to 10 profiles with 32 stations per profile.
Maximum Number of Real-Time Files	Three each with up to 75 readings captured by the user.
Language Support	English, Bulgarian, Chinese, Czech, Danish, Dutch, Finnish, French, German, Greek, Hungarian, Italian, Japanese, Korean, Polish, Portuguese, Romanian, Russian, Slovenian, Spanish, Swedish, Turkish

**Subject to change without notice.*

Dimensions

In inches and [millimeters}.



Ordering Information

FH950 Portable Flow Meter System

System includes portable flow meter, electromagnetic sensor with specified cable length, universal sensor mount, USB cable, wading rod mount, power supply/charger, neck strap, thumb screw kit, soft case, and disposable cloth for cleaning.

FH950 Meter and Sensor System FH950.	1	X	X	X	X
Portable Meter (Hach FH950, with User Manual)	1				
Electromagnetic Sensor (Velocity)		0			
Electromagnetic Sensor (Velocity and Level)		1			
Cable Length					
6.5 foot (2m)			0	0	5
20 foot (6.1m)			0	2	0
40 foot (12.2m)			0	4	0
100 foot (30.5m)			1	0	0

Replacement Parts & Accessories

FH950 Portable Meter

FH950.1 FH950 Handheld Flow Meter (includes battery, battery charger and meter), English

Electromagnetic Sensors

EM950.0005 Velocity Sensor w/6.5 ft (2 m) cable
EM950.0020 Velocity Sensor w/20 ft (6.1 m) cable
EM950.0040 Velocity Sensor w/40 ft (12.2 m) cable
EM950.0100 Velocity Sensor w/100 ft (30.5 m) cable
EM950.1005 Velocity and Level Sensor w/6.5 ft (2 m) cable
EM950.1020 Velocity and Level Sensor w/20 ft (6.1 m) cable
EM950.1040 Velocity and Level Sensor w/40 ft (12.2 m) cable
EM950.1100 Velocity and Level Sensor w/100 ft (30.5 m) cable

Accessories

9073400 Fabric Carrying Case
9073600 Lithium Ion Battery
9072600 Battery Charger
9070800 USB Cable, 3 ft (1 m)
75015 Universal Sensor Mount
9071700 Adjustable Meter Mount
9073500 Wipe Cloth, used for cleaning
9073200 Sensor Thumb Screw Kit
9072700 Lanyard

Contact factory for information on Standard and Top Setting Wading Rod Kits or Suspension Cable Kits.

NOTE: Additional cable cannot be added after order is entered.

HACH COMPANY World Headquarters: Loveland, Colorado USA

United States: 800-368-2723 tel 970-619-5150 fax hachflowsales@hach.com
Outside United States: 970-622-7120 tel
hachflow.com

LIT2568 Rev 5
A142.5 Printed in U.S.A.

Be Right™

HOBO® Water Level Loggers

Accurate, affordable water level monitoring

HOBO Water Level data loggers offer high accuracy at an affordable price, with no cumbersome vent tubes or desiccants to maintain. These data loggers are ideal for recording water levels and temperatures in wells, streams, lakes, and freshwater wetlands.

Supported Measurements: Water Level, Pressure, Temperature

Key Advantages:

- Available in 4 depth ranges
- No-vent-tube design for easy and reliable deployment
- Available in stainless steel and titanium* versions
- Durable ceramic pressure sensor for reliable performance
- Calibration certificate included

Minimum System Requirements:

Software   Base Station[1]   Coupler[2]

*Titanium version recommended for saltwater deployment.
[1]HOBO Base Station or HOBO Waterproof Shuttle required. See page 37 for more details.
[2]Coupler included with HOBO Base Station or HOBO Waterproof Shuttle.

For complete information and accessories, please visit: **www.onsetcomp.com**

Part number	U20-001-04/ U20-001-04-Ti	U20-001-01/ U20-001-01-Ti	U20-001-02/ U20-001-02-Ti	U20-001-03/ U20-001-03-Ti
	HOBO Water Level Specifications			
Range	0-4 m (0-13 ft) 0-145 kPa (0-21 psia)	0-9 m (0-30 ft) 0-207 kPa (0-30 psia)	0-30 m (0-100 ft) 0-400 kPa (0-58 psia)	0-76 m (0-250 ft) 0-850 kPa (0-123 psia)
Factory Calibrated Range (0° to 40°C; 32° to 104°F)	69 to 145 kPa (10-21 psia)	69 to 207 kPa (10-30 psia)	69 to 400 kPa (10-58 psia)	69 to 850 kPa (10-123 psia)
Water Level Accuracy (Typical Error)	± 0.3 cm (0.01 ft) (± 0.075% FS)	± 0.5 cm (0.015 ft) (± 0.05% FS)	± 1.5 cm (0.05 ft) (± 0.05% FS)	± 3.8 cm (0.125 ft) (± 0.05% FS)
Resolution	0.14 cm (0.005 ft)	0.21 cm (0.007 ft)	0.41 cm (0.013 ft)	0.87 cm (0.028 ft)
Burst Pressure	310 kPa (45 psia) 18 m (60 ft) depth		500 kPa (72.5 psia) 40.8 m (134 ft) depth	1200 kPa (174 psia) 112 m (368 ft) depth
	Temperature Specifications (all models)			
Range	-20° to 50°C (-4° to 122°F)			
Accuracy	± 0.37° @ 20°C (± 0.67° @ 68°F) ± 0.44° from 0° to 50°C (± 0.79° from 32° to 122°F)			
Resolution (10 bit)	0.1° @ 20°C (0.18° @ 68°F)			
Response time	3.5 minutes (to 90% in water)			
Dimensions	2.46 cm diameter x 15 cm (0.97 x 5.9 in) hole in mounting bail 6.3 mm (0.25 in)			
CE compliant	Yes			

Contact Us

Sales (8am to 5pm ET, Monday through Friday)

- Email sales@onsetcomp.com
- Call 1-508-759-9500
- In U.S. toll free 1-800-564-4377
- Fax 1-508-759-9100

Technical Support (8am to 8pm ET, Monday through Friday)

- Contact Product Support onsetcomp.com/support/contact
- Call 1-508-759-9500
- In U.S. toll free 1-877-564-4377

Onset Computer Corporation
470 MacArthur Boulevard
Bourne, MA 02532

onset®
HOBO® Data Loggers

HOBO® Conductivity Loggers

Conductivity monitoring for freshwater and stable saltwater applications

HOBO Conductivity Loggers are convenient, rugged, and cost-effective data loggers for a variety of freshwater and saltwater monitoring applications.

The HOBO U24-001 model provides high-accuracy conductivity data in freshwater environments, for applications such as environmental impact monitoring, stormwater management, and water quality studies.

The HOBO U24-002-C model is for saltwater environments with relatively small changes in salinity (±5,000 μS/cm) such as saltwater bays, or to detect salinity events such as upwelling, rainstorm, and discharge events. This logger can also be used to gather salinity data for salinity compensation of HOBO U26 Dissolved Oxygen logger data. **Note:** This logger is not intended for monitoring salinity levels in waters with widely changing salinities as it can have significant measurement error and drift in those environments.

Supported Measurements: Conductivity, Salinity, Temperature

Key Advantages:

- Non-contact capacitive sensor provides long life
- Easy access to sensor for cleaning and shedding air bubbles
- HOBOware Pro software provides compensation for fouling using calibration points from the start and end of each deployment
- Optical interface provides high-speed, reliable data offload in wet environments
- Compatible with HOBO Waterproof Shuttle for easy and reliable data retrieval

Minimum System Requirements:

Software Base Station* Coupler[1]

*HOBO Base Station or HOBO Waterproof Shuttle required.
[1]Coupler included with HOBO Base Station or HOBO Waterproof Shuttle.

For complete information and accessories, please visit: **www.onsetcomp.com**

Part number	**U24-001** Conductivity	**U24-002-C** Conductivity/Salinity
Memory	18,500 temperature and conductivity measurements when using one conductivity range; 14,400 sets of measurements when using both conductivity ranges (64 kbytes)	
Conductivity Calibrated Measurement Ranges	Low Range: 0 to 1,000 µS/cm Full Range: 0 to 10,000 µS/cm	Low Range: 100 to 10,000 µS/cm High Range: 5,000 to 55,000 µS/cm
Conductivity Calibrated Range – Temperature Range	5° to 35°C (41° to 95°F)	
Specific Conductance Accuracy (in Calibrated Range using Conductivity Assistant and Calibration Measurements)	Low Range: 3% of reading, or 5 µS/cm Full Range: 3% of reading, or 20 µS/cm, whichever is greater	Low Range: 3% of reading or 50 µS/cm, whichever is greater High Range: 5% of reading, in waters within a range of ±3,000 µS/cm; waters with greater variation can have substantially greater error
Conductivity Resolution (typical)	1 µS/cm	2 µS/cm
Conductivity Drift	Less than 3% sensor drift per year	Up to 12% sensor drift per month. Use monthly start & end-point calibration to compensate
Temperature Accuracy (in Calibrated Range)	0.1°C (0.2°F)	
Temperature Resolution	0.01°C (0.02°F)	
Response Time	1 second to 90% of change (in water)	
Measurement and Operating Range	0° to 36°C (32° to 97°F) -non-freezing	-2° to 36°C (28° to 97°F) -non-freezing
Sample rate	1 second to 18 hrs, fixed or multiple-rate sampling with up to 8 user-defined sampling intervals	
Time Accuracy	± 1 minute per month	
Battery	3.6 Volt lithium battery, life: 3 years (at 1 minute logging), typical	
Maximum Depth	70 m (225 ft)	
Dimensions	3.18 cm diameter x 16.5 cm, with 6.3 mm mounting hole (1.25 in diameter x 6.5”, ¼ in hole)	
CE compliant	Yes	

Contact Us

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- Fax 1-508-759-9100

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Onset Computer Corporation
470 MacArthur Boulevard
Bourne, MA 02532

Y S I Environmental

WE KNOW D.O.™

YSI Pro2030 Dissolved Oxygen/Conductivity

Handheld DO, Conductivity, Salinity, TDS, Temperature

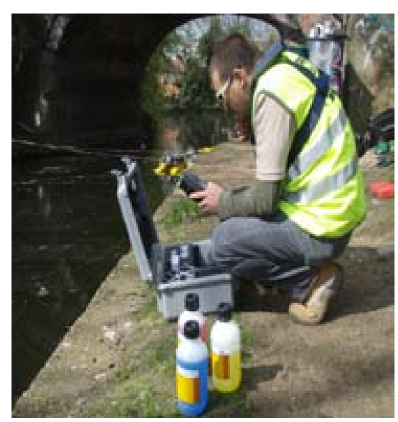
Rugged and reliable, the YSI **Pro2030** provides everything you need in a handheld dissolved oxygen instrument with conductivity. ***Automatically compensates DO readings for changes in salinity***. User-replaceable DO sensors and cables, 50 data set memory, and simple DO calibration makes the Pro2030 user friendly. Rugged design and 1-meter drop tests ensure the instrument remains in your hands to provide years of sampling even in the harshest field conditions. Fast response times allow you to complete your sampling routine quickly, saving time and money.

- **3-year instrument; 2-year cable warranty**
- **User-replaceable cables and sensors. Choose either polarographic or galvanic DO. Conductivity sensor built into cable.**
- **Quick DO cal allows easy DO calibrations within seconds with the press of a button. Automatic internal barometric pressure compensation.**
- **Stores 50 data sets; no need to write down data**
- **Graphic, backlit display and glow in the dark keypad**
- **Tough. IP-67, impact-resistant, waterproof case even without the battery cover. Rubber over molded case provides extra durability. Military spec connectors.**
- **Quick response times; 95% DO response time in approximately 8 seconds with standard membrane (fastest response time in the market)**
- **Super-stable 4-electrode conductivity sensor is built for true field performance and designed for rugged conditions**

Ideal replacement for the YSI Model 85!

Pure Data for a Healthy Planet.®

A rugged, cost-effective handheld designed for true field performance



www.YSI.com/pro2030

+1 937 767 7241
800 897 4151 (US)
www.ysi.com
environmental@ysi.com

SonTek/YSI
+1 858 546 8327
inquiry@sontek.com

YSI Gulf Coast
+1 225 753 2650
environmental@ysi.com

AMJ Environmental
+1 877 392 9950
amj@ysi.com

YSI Hydrodata (UK)
+44 1462 673 581
europe@ysi.com
ireland@ysi.com

YSI Abu Dhabi Co. Ltd.
+971 2 56 31 316
samer@nanotech.co.jp

YSI Middle East (Bahrain)
+973 17536222
halsalem@ysi.com

YSI (Hong Kong) Limited
+852 2891 8154
hongkong@ysi.com

YSI (China) Limited
+86 532 575 3636
beijing@ysi-china.com

YSI Nanotech (Japan)
+81 44 222 0009
nanotech@ysi.com

YSI Australia
+61 7 390 17233
acorbett@ysi.com

YSI South Asia
+91 989 122 0639
sham@ysi.com

YSI Brazil
+55 48 9942 7840
psterling@ysi.com

ISO 9001
ISO 14001

Specifications are subject to change. Please visit YSI.com to verify all specs.

YSI incorporated
Who's Minding the Planet?™

Pro2030 *System* Specifications (instrument w/ cable and sensor)

Dissolved Oxygen (% saturation)	Sensor Type	Polarographic or Galvanic
	Range	0 to 500% air saturation
	Accuracy	0 to 200% air saturation, ±2% of the reading or ±2% air saturation, whichever is greater; 200 to 500% air saturation, ±6% of the reading
	Resolution	0.1% or 1% air saturation (user selectable)
Dissolved Oxygen (mg/L)	Sensor Type	Polarographic or Galvanic
	Range	0 to 50 mg/L
	Accuracy	0 to 20 mg/L, ±2% of the reading or ±0.2 mg/L, whichever is greater; 20 to 50 mg/L, ±6% of the reading
	Resolution	0.01 or 0.1 mg/L (user selectable)
Conductivity (mS, uS)	Sensor Type	Four-electrode cell
	Range	0 to 200 mS/cm (auto range)
	Accuracy	1-m or 4-m cable, ±1.0% of reading or 1.0 uS/cm, whichever greater; 10- 20- or 30-m cable, ±2.0% of reading or 1.0 uS/cm, whichever is greater
	Resolution	0.0001 to 0.1 mS/cm (range dependent)
Salinity (ppt, PSU)	Range	0 to 70 ppt
	Accuracy	±1.0% of the reading or 0.1 ppt, whichever is greater
	Resolution	0.1 ppt
Temperature (°C, °F)	Range	-5 to 55°C (0 to 45°C; DO compensation range for mg/L)
	Accuracy	±0.3°C
	Resolution	0.1°C
Total Dissolved Solids (TDS) (mg/L, g/L)	Range	0 to 100 g/L TDS constant range 0.30 to 1.00 (0.65 default)
	Accuracy	Dependent on temp and conductivity; calculated from those parameters
	Resolution	0.0001, 0.01, 0.1 g/L
Barometer (mmHg, inHg, mbars, Psi, KPa)	Range	500 to 800 mmHg
	Accuracy	±5 mm Hg within ±15°C of calibration temperature
	Resolution	0.1 mm Hg

Pro2030 Instrument Specifications

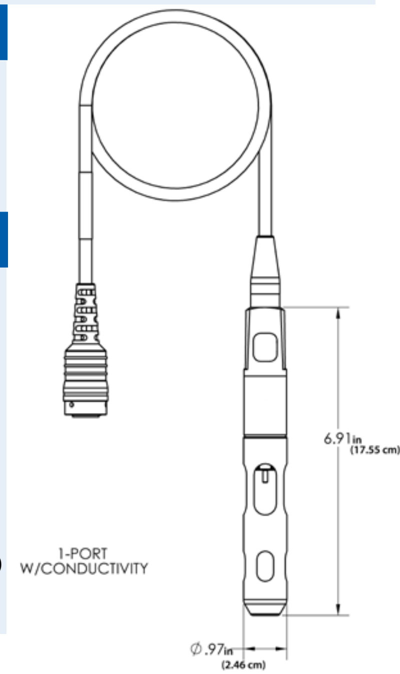
Conductivity	±0.5% of reading or 1.0 uS/cm, whichever greater
Size	8.3 cm width x 21.6 cm length x 5.7 cm depth (3.25 in. x 8.5 in. x 2.25 in.)
Weight with batteries	475 grams (1.05 lbs.)
Power	2 alkaline C-cells providing 400 hours of battery life; low battery indicator on Pro2030
Cables	1- 4- 10- 20- and 30-m lengths (3.28, 13.1, 32.8, 65.6 ft.)
Warranty	3-year instrument; 2-year cable; 1-year Polarographic sensors; 6-months Galvanic sensors
Salinity Input Range	0-70 ppt; automatic based on conductivity
Conductivity Reference Temp	Adjustable; range 15°C to 25°C
Specific Conductance Temp Comp	0 to 4%
Data Memory	50 data sets
Languages	English, Spanish, German, French
Certifications	RoHS, CE, WEEE, IP-67, 1-meter drop test

Pro2030 Ordering Information (Order items separately*)

6052030	Pro2030 Handheld instrument
6052030-X	1- 4- 10- 20- or 30-m cable for DO/Cond/temp (cable management kit included on all except 1-meter)
605202	Galvanic Sensor
605203	Polarographic Sensor

Accessories Ordering Information

603077	Flow cell, 203 mL, with single port adapter
603075	Soft-sided carrying case
603074	Hard-sided carrying case
603069	Belt clip to attach instrument to belt
063517	Ultra clamp (attach to instrument to secure it to a desk, boat, etc)
063507	Small tripod (attach to instrument to sit on any flat surface)
626444	Lab Dock (instrument dock)
603062	Cable management kit (included with 4- 10- 20- and 30-m cables)
605978	Cable weight, 4.9 oz., attach to stainless steel probe guard
5913**	1.25 mil PE membranes for galvanic (6 yellow caps and solution)
5908**	1.25 mil PE membranes for polarographic (6 yellow caps and solution)
5914	2 mil PE membranes for galvanic (6 blue caps and solution)
5909	2 mil PE membranes for polarographic (6 blue caps and solution)



* Conductivity sensors are built into the cable and are included with all cables.

APPENDIX E

Standardized Forms

Data Entry Review Worksheet

HERRERA ENVIRONMENTAL CONSULTANTS

Project Name/No./Client: ______________________ Page ______ of ______

Data entered by: ______________________ Data reviewed by: ______________________

Laboratories: ______________________ Date reviewed: ______________________

Event ID ____________ Sample Date ______________________

Monitoring Stations: ______________________

Parameters: ______________________

Percentage of Data Reviewed:

Data Source (i.e., Lab or Field)	Monitoring Station	Parameter	Incorrect Value	Correct Value	Corrective Action

Notes:

FIELD SAMPLING AND FLOW MONITORING LOG SHEET

Field Personnel:

Sample Date: Time:

SITE ID:

EVENT ID:

Project Number:

Project Name:

Current Weather:

Flow Conditions:

HERRERA ENVIRONMENTAL CONSULTANTS

Water Quality Sampling

Sample ID:

Parameter	Bottle Type	Bottle Volume	# Bottles	Preservation	Duplicated?

Visual Conditions:

Odor:

LABORATORY DELIVERY

Date: Time:

Sample Temperature (^oC):

COC signed? YES NO

Quality Assurance

Checked By: Signature:

Date Checked: Time:

Data Entered into Database? YES NO initials:

Date Entered: Time:

Notes:

Flow Measurement

METER & CALIBRATION	
Meter Make:	
Meter Model:	S/N:
SWFR Propeller ID:	
SWFR Blow Count:	
MMB Zero Reading (cfs):	
HEC Cal. Date:	Time:
Factory Cal. Date:	

MEASUREMENT INFORMATION	
Start Date:	Time:
Stop Date:	Time:
Staff Gauge- Start (ft):	
Staff Gauge- Stop (ft):	
Continuous Gauge? YES NO	ID:
Stream Width (ft):	
Method:	

	Distance from right bank (ft)	Depth (ft)	Velocity (ft/s) 2/10	6/10	8/10
RB					
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					

Cross section sketch (not to scale)

Calculated Stream Discharge (cfs):

Notes (equipment problems, blockages, unusual stream conditions, etc.):

Data Quality Assurance Worksheet

By ______________________

Project Name/No./Client: ______________________ Date ____________ Page ____ of ____

Laboratory/Parameters: ______________________ Checked: initials ____________

Sample Date/Sample ID: ______________________ date ____________

Parameter	Completeness/ Methodology	Pre-preservation Holding Times (hours)		Total Holding Times (hours)		Method Blanks Reporting Limit	Matrix Spikes/ Surrogate Recovery (%)		Lab Control Samples Recovery (%)		Lab Duplicates RPD (%)		Field Duplicates RPD (%)		Instrument Calibration/ Performance	ACTION
		Reported	Goal	Reported	Goal		Reported	Goal	Reported	Goal	Reported	Goal[1]	Reported	Goal[1]		
Fecal Coliform			**≤12**		**≤12**	2		**NA**		**NA**		**≤ 35**		**≤ 35**		

[1] If the sample or duplicate value is less than five times the reporting limit, the difference is calculated rather than the relative percent difference (RPD). The QA goal is a difference <2 times the detection limit instead of the number indicated in the goal column.

NA – not applicable or not available

NC – not calculable due to one or more values below the detection limit

NS – field duplicate not sampled.