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ECOLOGY
State of Washington

Addendum to Quality Assurance Project Plan

Upper Mainstem Stillaguamish River Dissolved Oxygen Study

June 2012

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Publication Information

Addendum

This addendum is an addition to an original Quality Assurance Project Plan. The addendum is not a correction (errata) to the original plan.

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DEPARTMENT OF ECOLOGY

Environmental Assessment Program

June 26, 2012

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THROUGH: George Onwumere, Unit Supervisor, Environmental Assessment Program
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FROM: Markus Von Prause, Environmental Assessment Program

SUBJECT: **Addendum to Quality Assurance Project Plan for Upper Mainstem Stillaguamish River Dissolved Oxygen Study**
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The Stillaguamish River dissolved oxygen survey was originally scheduled for the summer of 2011 when streamflow conditions were expected to reach under <1000 cfs. However, due to various circumstances, the survey was postponed until adequate resources required to conduct the survey were approved by Ecology. In accordance with the original Quality Assurance (QA) Project Plan (Von Prause, 2010), Ecology conducted a longitudinal temperature and DO profile of the Stillaguamish River mainstem between river miles 11.36 and 6.92 during August 2011. Results from the survey event provided water quality data (i.e., temperature, DO, pH, and conductivity) useful for the placement of groundwater stations and the identification of groundwater inputs and losses.

This addendum provides a few modifications to the sampling design, sampling timeline, and laboratory budget outlined in the original QA Project Plan (Von Prause, 2010) to investigate currently un-quantified sources of DO deficits such as sediment oxygen demand, biological respiration, and groundwater DO levels. The data will be used to rerun the Stillaguamish River QUAL2Kw model for the Island Reach and to recommend load and wasteload allocations for various pollutant sources.

cc: Dean Momohara, Acting Lab Director, Manchester Environmental Laboratory
Bill Kammin, Ecology Quality Assurance Officer

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Abstract

During 2012, the Washington State Department of Ecology (Ecology) will be conducting a study of Stillaguamish River dissolved oxygen (DO) levels near Arlington between river miles 11.36 and 6.92 (the Island Reach). In 2004, Ecology completed a Total Maximum Daily Load (TMDL) study of DO in the Stillaguamish River (Joy, 2004). The study indicated low DO concentrations in a pool reach downstream of the City of Arlington's Wastewater Treatment Plant (WWTP). Results from the QUAL2Kw water quality model indicated that the pool reach is susceptible to DO sags and even with no contributions from anthropogenic sources, DO concentrations would likely drop below the water quality criterion of 8 mg/L to about 7.0 mg/L in some locations.

Ecology's 2004 study could not determine all the sources contributing to low DO conditions in the river. Ecology attributed the downstream DO depression to a combination of nonpoint source pollution inputs, discharge from the Arlington WWTP, and other possible unknown factors. Clearly understanding the factors that affect DO levels is critical for meeting water quality standards and for treating and discharging municipal wastewater in a cost-effective manner. For that reason, Ecology did not establish nutrient and oxygen-demand wasteload allocations for the Arlington WWTP in 2004.

Background

The QUAL2Kw water quality model simulations used in Ecology's 2004 TMDL study indicated that dissolved oxygen (DO) concentrations would likely drop below the water quality criterion of 8 mg/L to about 7.0 mg/L in some locations with no contributions from anthropogenic sources. The model also predicted that even a target DO concentration of 7 mg/L could not be achieved at this river location during periods of low river flows, unless upstream nutrient levels and WWTP effluent nutrient discharges are kept at lower concentrations than reported in 2001 (Joy, 2004).

Recent simulations of estimated daily average gross primary production and ecosystem respiration were provided by the QUAL2Kw River Metabolism Analyzer component (RMA) from continuous diel October 2001 data collected at RM 13.5 (22.89 RKM). These simulations indicated that the daily average respiration is greater than daily average primary production by about 6.8 g $O_2/m^2/day$ (Table 1).

The combination of heterotrophic respiration from periphyton and phytoplankton communities residing within the streambed, aerobic hyporheic metabolism, anoxic sediment oxygen demand, and water column oxidation of dissolved organic carbon (CBOD) may be contributing factors for excess respiration. Respiration levels of 6.8 g $O_2/m^2/day$ are greater than typical anoxic sediment oxygen demand (SOD) reported for sandy or gravelly sediment (Naegeli and Uehlinger, 1997). Typical sandy sediments have an SOD of about 0.2-1 g $O_2/m^2/day$, while the SOD levels of 1-2 g $O_2/m^2 day$, in muddy sediments, have been observed. Respiration in the Stillaguamish River, which could be due to a combination of aerobic and anaerobic metabolism, is similar in magnitude to very organic sediments found in the vicinity of sewage outfalls ranging from 2-10 g $O_2/m^2/day$. The RMA analysis provided a fairly close prediction of the actual DO levels at RM 13.5 (22.89 RKM) as shown in Figure 1.

Table 1. RMA results from continuous diel data from October 2001 collected at RM 13.5 (22.89 RKM).

RMA Parameter	Result
Daily average gross primary production 'GPP' (g $O_2/m^2/day$)	4.95
Daily average ecosystem respiration 'ER' (g $O_2/m^2/day$)	11.79
Ratio of daily average GPP:ER (dimensionless)	0.42
Excess daily average ecosystem respiration (ER-GPP) (g $O_2/m^2/day$)	6.84
Excess daily average ecosystem respiration (ER-GPP) (mg O_2/L/day)	7.52
Excess daily average ecosystem respiration (ER-GPP) (mg C/L/day)	2.82

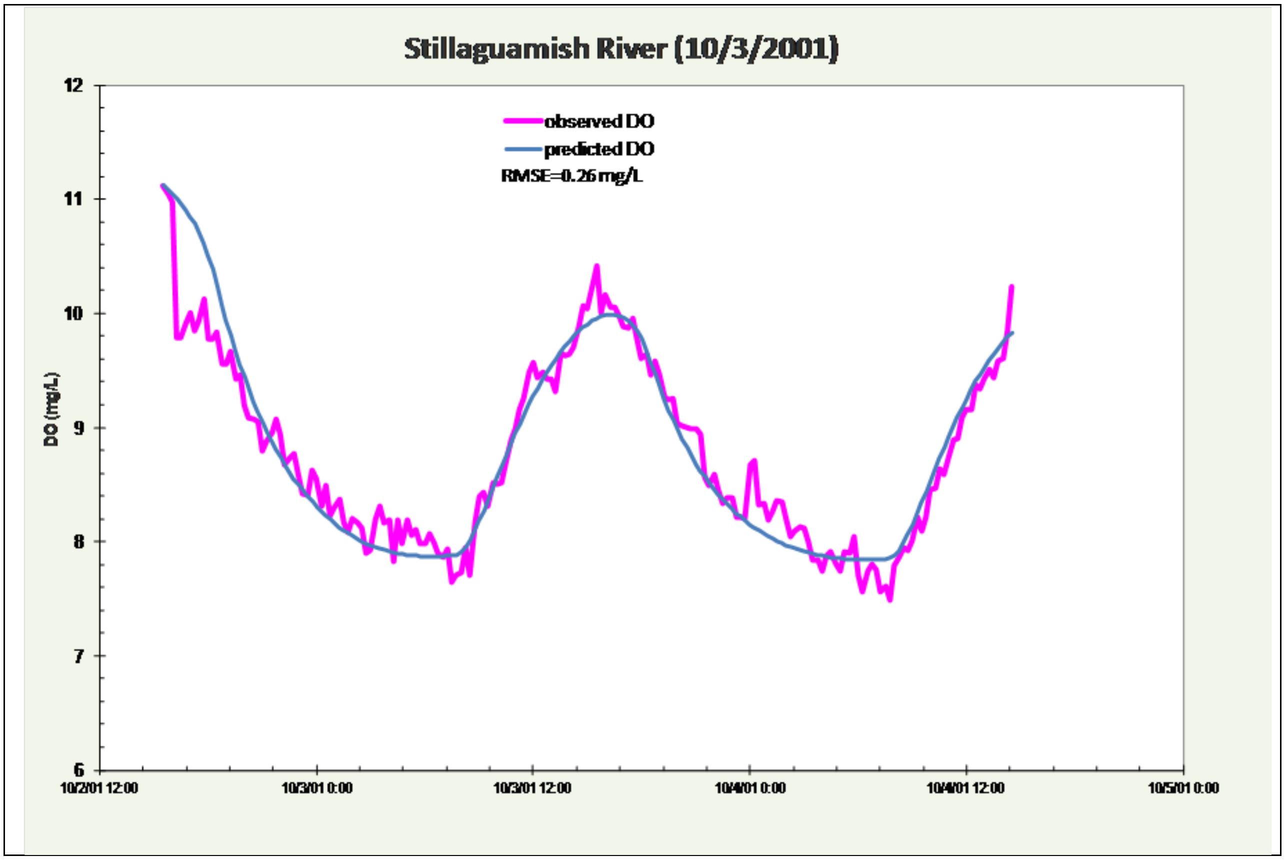

Figure 1. Comparison of predicted and observed DO levels from the River Metabolism Analyzer RMA at the pool reach of the Stillaguamish RM 13.5 (22.89 RKM). DO measurements were retrieved from continuous diel monitoring at RM 13.5 (22.89 RKM) during October 2001. Observed DO values are indicated in pink and predicted values are indicated in blue.

Project Goal and Objectives

Goal

The overall goal of the project is to characterize processes causing low DO in the Stillaguamish River Island Reach between RM 16.86 (RKM 28.5) near Arlington to RM 11.35 (RKM 19.19) near Interstate 5 for the critical low-flow period during July through October of 2012.

Objective

The objective of this study is to collect adequate data on the processes controlling DO levels so that the QUAL2Kw model can better simulate the critical condition in the Stillaguamish Island Reach. The objective of this study is outlined in the original Quality Assurance (QA) Project Plan (Von Prause, 2010) and will be achieved with completion of the following steps:

- Characterize surface water physical and chemical processes governing low DO levels in the Stillaguamish River Island Reach, including the influence of tributaries.
- Characterize groundwater physical and chemical processes impacting low DO in the Island Reach.
- Characterize sediment oxygen demand processes within the Island Reach during critical conditions.
- Complete a QUAL2Kw model simulation of collected field data and recommended load allocations for background sources and wasteload allocations for point sources, to meet the DO water quality criterion and protect beneficial uses along the Island Reach during the critical period.
- Characterize hyporheic transient storage (HTS) processes including size and exchange within the main channel.

Study Design

Overview

Three synoptic surveys are planned for the complete characterization of all major stream processes and local environmental conditions over a 3-day period for 13 fixed network surface water sampling locations (Von Prause, 2010). Two additional headwater stations (5-NFH-0.0 and 5-SFH-0.0) are proposed at the North and South Forks by Twin Rivers Park to replace Station 5-APR-28.5. The revised fixed network surface water sampling locations are presented in Table 2.

Based on the survey results from the August 2010 longitudinal temperature and DO profile survey, six groundwater stations are proposed (Table 3). Three additional groundwater stations may be added depending on the results of the seepage run surveys. The synoptic surveys will allow Ecology to obtain the required environmental data necessary to develop and test the QUAL2Kw model's ability to simulate DO levels under critical conditions (i.e., approximately

1,000 cfs). Field study methods used to characterize physical and chemical processes influencing DO conditions in the river during critical conditions are provided in the original QA Project Plan (Von Prause, 2010).

Surface Water Sampling Locations

The 13 fixed surface water sampling locations are presented in Table 2 and Figure 2. Sampling site 5-APR-28.5 was removed from the network because of cross-channel hydrological variability resulting from the confluence of the north and south forks. Two headwater stations (5-NFH-0.0 and 5-SFH-0.0) are proposed at the north and south forks.

Ecology's Freshwater Monitoring Unit (FMU) will conduct seepage runs to collect discharge information along the mainstem of the Stillaguamish River approximately every kilometer from the headwater stations (5-NFH-0.0 and 5-SFH-0.0) to Interstate 5 (5-STILLi5-19.19) in conjunction with the monthly surface water surveys.

Table 2. Fixed network surface water sites for the 2012 study.

Station ID	Latitude*	Longitude*	Description
5-NFH-0.0◈	48.20608	-122.12778	North Fork by Twin River Park.
5-SFH-0.0◈	48.20102	-122.11735	South Fork by Twin River Park.
ARLINGTON WWTP	48.20276	-122.12833	WWTP; Surface water and treated effluent collected by 24-hr compositor.
5-STILLBARM-25.88◈ ¤	48.20898	-122.15259	Below mouth of Armstrong Creek.
5-ARM-.28	48.21292	-122.15045	Armstrong Creek.
5-STILL-24.0	48.19698	-122.16421	Mainstem of Stillaguamish before March Creek.
5-MAR-.10	48.19222	-122.16447	Mouth of March Creek.
5-STILL-22.89◈¤	48.18911	-122.17185	Mainstem Stillaguamish after mouth of March Creek.
5-UN1-0.01	48.18990	-122.17641	Unnamed tributary.
STILLDOSAG2◈ ¤	48.1957	-122.18437	Critical area station by unnamed tributary.
STILLDOSAG1◈ ¤	48.1902	-122.17887	Critical area station before 5-STILL-21.7.
5-STILL-21.7	48.19702	-122.18407	Mainstem of Stillaguamish before 27th Avenue.
5-UN-.01	48.19947	-122.19857	Unnamed tributary before Interstate 5.
5-STILLi5-19.19◈¤	48.19693	-122.21072	Mainstem of Stillaguamish at Interstate 5.

*Geographic Coordinate System and Projections: 83NAD 1983 HARN State Plane Washington South FIPS, Lambert Conformal Conic. USGS river miles were converted to kilometer units by using x miles * 1.69 km.
◈ 48 hour continuous diel monitoring for pH, DO, conductivity, temperature and benthic flux.
¤ Monitoring for rhodamine during slug injection dye tracer survey.

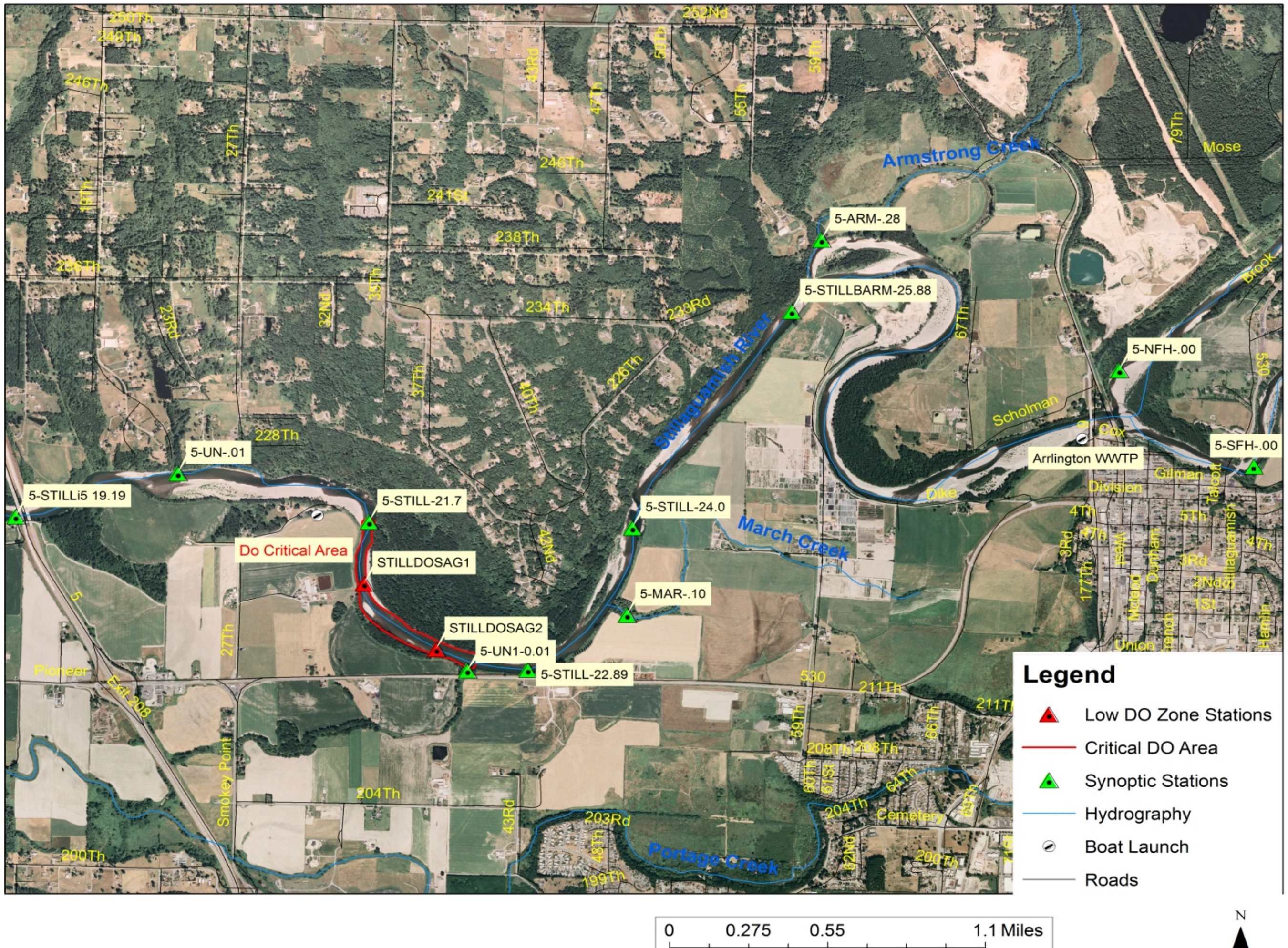

Figure 2. Location of surface water stations for the proposed synoptic surveys.

Surface water synoptic surveys

Continuous stream discharge will be estimated on the north and south forks of the Stillaguamish River by developing a regression curve with existing continuous streamflow gage data. Both the USGS gage on the North Fork Stillaguamish River at Arlington (12200500) and the Ecology gage on the South Fork Stillaguamish River at Jordan Road Bridge (05A105) will be used as the independent variables for the regression. The dependent variable will be instantaneous discharge measurements on the north and south forks (5-NFH-0.0, 5-SFH-0.0), 5-ARM-.28 and 5-MAR-.10. These discharge measurements will be collected during each synoptic survey and during times in between synoptic surveys to establish a strong regression curve. Continuous daily discharge estimates at Arlington WWTP will be made by the collection of discharge monitoring report (DMR) measurements at the wastewater treatment facility.

Measurements to assist in describing stream channel hydraulic geometry will be conducted during 1 synoptic survey. Ecology field staff will float down the river in a motorized raft equipped with a Hydro lab field meter recording depth measurements along the thalweg of the Stillaguamish River mainstem. A global positioning system (GPS) will simultaneously record location coordinates. Measurements will be made in a single longitudinal pass from Arlington WWTP to RM 11.35 (RKM 19.19). Depth measurements obtained from the stream channel survey will be incorporated into a GIS environment for estimation of channel hydraulic geometry.

Additional water chemistry measurements will include dissolved organic carbon (DOC) sampling at all surface water and groundwater stations. Dissolved organic carbon in the water column is a likely source for the large unexplained extra respiration that may be causing DO depletion in the streambed. In order to characterize heterotrophic metabolism processes, ultimate CBOD measurements at stations 5-NFH-0.0, 5-SFH-0.0, Arlington WWTP effluent, STILLDOSAG1 and 5-STILL-24.0 will be conducted during September and October. Stream sediment samples will be collected at all surface water stations for the analysis of grain size and total organic content.

Continuous monitoring surveys for pH, DO, conductivity and temperature will be conducted at the headwaters stations (5-NFH-0.0, 5-SFH-0.0) and the DO sag area (STILLDOSAG1) for the entire study period (i.e., July-October 2012). Furthermore, real-time telemetry will be provided by the Freshwater Monitoring Unit for pH, DO, conductivity, and temperature measurements during the entire study period at 5-NFH-0.0, 5-SFH-0.0, STILLDOSAG1. Additional continuous diel monitoring for pH, DO, conductivity, and temperature will be conducted during each synoptic survey at the following stations 5-STILLBARM-25.88, 5-STILL-22.89, STILLDOSAG2 and 5-STILLi5-19.19 (Table 2). The time interval for recording Hydro lab datasonde readings during the diel surveys will be every 15 minutes. Benthic chambers will be deployed at all continuous diel monitoring stations following the procedures outlined in Von Prause 2010.

A slug injection dye tracer study will be conducted during each synoptic survey according to methods described by EAP SOP 037, Hubbard et al. 1982 and Wilson et al. 1986. The previous TMDL study suggested that there was significant hyporheic transient storage that accounted for a major loss of DO in the reach below the confluence of the north and south forks. Estimation of the size and exchange rate of conservative solutes within transient storage zones (i.e., hyporheic flow paths in the sediment zone, pools and backwaters) will be necessary characterize advection and dispersion processes along the Stillaguamish River mainstem that are potentially responsible for variations in DO concentrations.

Specifically, the QUAL2Kw model determines the difference of solute concentration between the surface water and the hyporheic sediment zone by data inputs retrieved from field measurements of solute concentration (i.e., rhodamine), water velocity (cfs) and travel time of solutes (i.e., response curves) between reach monitoring points located downstream from the injection point (i.e., dye release point).

Rhodamine dye concentrations will be measured at the five diel monitoring stations (i.e., 5-STILLBARM-26.88, 5-STILL-22.89 RKM, STILLDOSAG2, STILLDOSAG1 and 5-STILLi5 19.19) after a slug injection of tracer dye is released below the confluence of the north and south forks of the river (5-NFH-0.0 and 5-SFH-0.0) during the 48-hour continuous the diel survey. Each of the Hydrolab DataSondes® units will be fitted with a rhodamine WT sensor (fluorometer) to measure rhodamine concentrations (i.e., degree of fluorescence). Time of travel measurements for the rhodamine tracer dye will be logged from the point of initial slug injection until rhodamine concentrations are no longer detected at each diel monitoring station. A press release will be issued to the community several days in advance of the dye injection to notify local residents.

Determinations for the quantity of rhodamine WT to be released at the slug injection point will be calculated as shown in equation 1 **(**Kilpatrick, 1970):

$$\boldsymbol{V_s} = 3.4 \text{ x } 10^{-4} (Q_m \ \frac{L}{v})^{0.94} C_p \qquad \text{(eq. 1)}$$

V_s =volume of stock rhodamine WT 20-percent dye, in liters ;
Q_m=maximum stream discharge at the downstream site, in cubic feet per second
L= distance to the downstream site, in miles;
v= mean stream velocity, in feet per second;
C_p =peak concentration at the downstream sampling site, in micrograms per liter

Groundwater Sampling Locations

Groundwater/surface water interactions will be evaluated monthly via a combination of field techniques described in the original QA Project Plan (Von Prause, 2010). Six instream piezometers will be installed in July 2012 within the vicinity of the fixed-network sites (Table 3, Figure 3) according to the methods described in Sinclair and Pitz (2009). Additional groundwater stations may be added or relocated based on the results of seepage run surveys, vertical hydraulic gradient measurements, groundwater chemistry and the best professional judgment of the ground water principal investigators. Thermistors will collect water temperature data at 15-minute intervals. Additional water chemistry parameters (i.e., dissolved organic carbon and biological oxygen demand) will be obtained at all groundwater stations from July to October 2012. Sediment porewater samples will be analyzed for DO as well.

Data Analysis of hydraulic geometry

Prior to QUAL2Kw modeling, analysis of stream channel hydraulic geometry will be conducted in ESRI ArcGIS™. Cross-section measurements will be made by referencing historical orthophotos for every kilometer from headwater stations (5-NFH-0.0 and 5-SFH-0.0) to I-5 (5-STILL-22.89 RKM). Analysis of stream channel hydraulic geometry under previous river flow events will improve the estimates of relationships between flow, velocity, and depth in the reach being modeled using QUAL2Kw.

Table 3. Proposed Groundwater Stations for the 2012 synoptic survey.

Station ID	Latitude*	Longitude*	Description
GW 1	48.19890	-122.19801	Piezometer @ near Unnamed Trib before 1-5
GW 2	48.19675	-122.18442	Piezometer @ Stillaguamish Mainstem 21.7 RKM
GW 3	48.19927	-122.17609	Piezometer @ at Unnamed Trib1
GW 4	48.19287	-122.16549	Piezometer @ month of March Creek
GW 5	48.19691	-122.16345	Piezometer @ Stillaguamish Mainstem 24.0 RKM
GW 6	48.20164	-122.14995	Piezometer @ Stillaguamish Mainstem 20.3 RKM by Dike Rd

*Geographic Coordinate System and Projections: 83NAD 1983 HARN State Plane Washington South FIPS, Lambert Conformal Conic. USGS river miles were converted to kilometer units by using x miles * 1.69 km

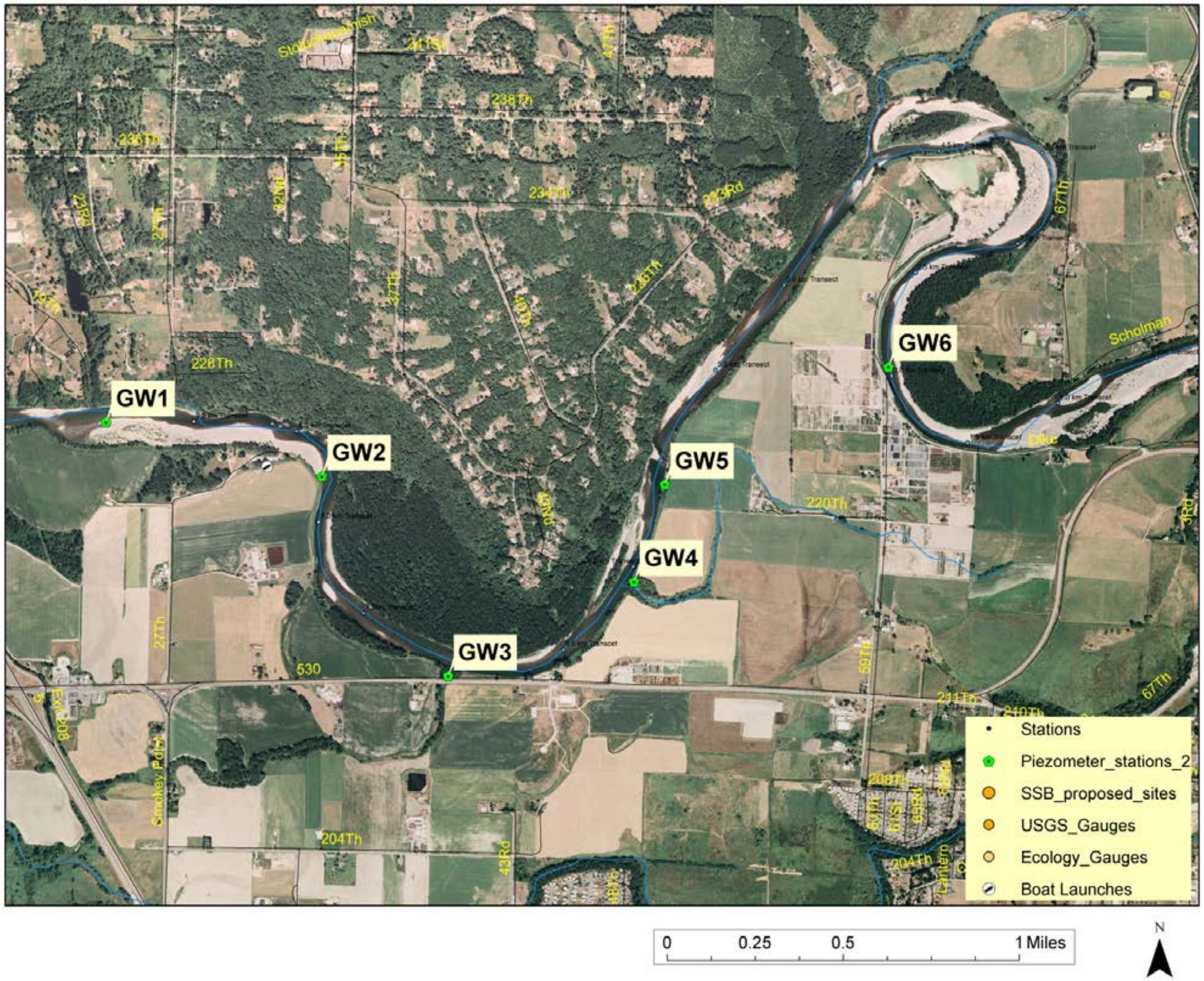

Figure 3. Location of groundwater stations for the synoptic surveys.

Project Organization and Schedule

Table 4. Organization of project staff and responsibilities.

Staff	Title	Responsibilities
Dave Garland WQP, NWRO (425) 649-7031	Unit Supervisor of EAP Client	Provides internal review of the QAPP, assists with field surveys and approves the final QAPP.
Ralph Svrjcek WQP, NWRO (425) 649-7165	EAP Client	Clarifies scope of the project, provides internal review of the QAPP, assists with field surveys, and approves the final QAPP.
Markus Von Prause Western DSU/EAP 360-407-7406	Project Manager	Writes and Implements final QAPP. Coordinates field surveys and oversees field sampling. Organizes synoptic surface water field crews. Collects field samples and records field information. Conducts QA review of data, analyzes and interprets data. Manages data for entry into EIM. Assists with model development, calibration, and application.
James Kardouni Western DSU/EAP 360-407-6517	Field Lead	Provides assistance with synoptic survey logistics and operations. Coordinates with the laboratory regarding transportation of samples. Provides additional support with the data analysis.
Barb Carey Groundwater Unit/EAP (360) 407-6769	Licensed Hydro geologist	Provides hydrogeologic assistance with study design including interpretation of historical geology and groundwater data in the basin. Selects piezometer sites. Oversees equipment installation and groundwater data collection. Performs data analysis. Writes data summary report. Provides project manager with relevant data and analyses.
Brad Hopkins WOS/EAP (360) 407-6686	Freshwater Monitoring Unit (FMU) lead	Leads seepage runs, collects surface water discharge data, and provides real-time telemetry assistance at continuous monitoring locations. Supplies project manager with verified data and analyses.
Greg Pelletier MIS Unit/EAP (360) 407-6485	QUAL2Kw Modeler	Conducts QUAL2Kw modeling re-simulation and analysis of survey data. Provides project manager with relevant data and analyses and prepares a technical memo presenting the results of model calibration and waste load allocation scenarios.
Robert F. Cusimano WOS/EAP (360) 407-6596	Section Manager of the QAPP Author	Approves the QAPP and the final report.
George Onwumere Western DSU/EAP (360) 407-6730	Unit Supervisor of the QAPP Author	Reviews and approves the QAPP, staffing plan, technical study budget, and the final report.
Dean Momohara Manchester Lab/EAP (360) 871-8801	Acting Lab Director	Provides laboratory staff and resources, sample processing, analytical results, and QA/QC data. Approves the QAPP.
William R. Kammin EAP, (360) 407-6964	Ecology Quality Assurance Officer	Provides technical assistance on QA/QC issues. Reviews the draft QAPP and approves the final QAPP.

WQP=Water Quality Program, NWRO=Northwest Regional Office, EAP=Environmental Assessment Program, DSU=Directed Studies Unit, EIM= Environmental Information Management system, WOS=Western Operations Section. MIS=Modeling and Information Support Unit, QAPP=Quality Assurance Project Plan.

Project Schedule

Table 5. Proposed schedule for completing field and laboratory work, data entry into EIM, data summaries and final technical memo.

Field and laboratory work	
Team selection	Jan 2012 – May 2012
Pre-survey preparation	Jan 2012 – Jun 2012
Field work	Jul 2012 – October 2012
Laboratory analyses completed	November 2012
Environmental Information System (EIM) system	
EIM data engineer	Markus Von Prause
EIM user study ID	MVP003
EIM study name	Additional Study of Low DO Levels In The Upper Stillaguamish River Mainstem
Surface water Monitoring Data Summary	
Author lead	Markus Von Prause
Schedule	
Analysis and data provided to modeler	January 2013
Data Summary Draft due to supervisor	February 2013
Data Summary Draft due to client/peer reviewer	March 2013
Data Summary Draft due to external reviewer	April 2013
Final Data Summary due in EIM	June 2013
Groundwater Monitoring Data Summary	
Author lead	Barb Carey
Schedule	
Analysis and data provided to modeler	January 2013
Data Summary Draft due to supervisor	February 2013
Data Summary Draft due to client/peer reviewer	February 2013
Data Summary Draft due to external reviewer	April 2013
Final Data Summary report due in EIM	June 2013
Technical Memo For Model Calibration and Waste Load Allocation Scenarios	
Author lead	Greg Pelletier
Schedule	
QUAL2Kw modeling development starts	May 2014
QUAL2Kw modeling completed	June 2015
Draft due to supervisor	August 2015
Draft due to client/peer reviewer	September 2015
Draft due to external reviewer	November 2015
Final report due on web	December 2015

Sampling Schedule

Table 6 represents the proposed survey schedule for the Stillaguamish DO study. Synoptic surveys will be completed during the critical period (under 1,000 cfs). Critical conditions for the Stillaguamish River Island Reach are defined in the original QA Project Plan (Von Prause, 2010). If the critical conditions are not met for the proposed 2012 sampling timeline, then the field surveys will be postponed until critical environmental conditions are established. A complete overview of survey components, sampling methods, timeline, and logistics is presented in Appendix C of the original QA Project Plan (Von Prause, 2010).

Table 6. Proposed survey schedule for the Upper Mainstem Stillaguamish River DO Study.

D1= Synoptic Survey Day 1, DSU=Directed Studies Unit, GWU=Groundwater Unit
D2= Synoptic Survey Day 2, FMU=Freshwater Monitoring Unit, MAN=Manchester Laboratory

Survey Parameter	Owner	JUL 2012				AUG 2012					SEP 2012				OCT 2012			
		W1 1-7	**W2 8-14**	**W3 15-21**	**W4 22-28**	**W1 1-4**	**W2 5-11**	**W3 12-18**	**W4 19-25**	**W5 26-31**	**W1 1-8**	**W2 9-15**	**W3 16-22**	**W4 23-29**	**W1 1-6**	**W2 7-13**	**W3 14-20**	**W4 21-27**
Pre Survey Logistics																		
Flow monitoring for < 1000cfs; Conditions and continuous monitoring for water quality parameters.	DSU/ FMU	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Piezometer Install	GWU				■			■										
Synoptic Survey																		
D1: Seepage Run(SP1A) Field Measurements	SHU							■				■				■		
D1: Seepage Run (SP1B) Data Processing and Analysis	SHU							■				■				■		
D1: Surface Water Sampling (SW1) Instrument Deployment	FMU							■				■				■		
D2: Groundwater (GW1) Analysis of SP1A	GWU							■				■				■		
D2:Groundwater Sampling (GW3)	GWU							■				■				■		
D2: Porewater Sampling (GW3)	GWU							■				■				■		
D2: FMU Surface Water Sampling (SW2)* Sample Collection	FMU							■				■				■		
D3: FMU Surface Water Sampling (SW3) Instrument Collection	FMU							■				■				■		
D3: Sample Transportation	FMU/ GWU							■				■				■		
Laboratory Analysis of Samples	MAN								■	■	■		■	■			■	■

D3= Synoptic Survey Day 3, SHU=Surface water Hydrology Unit.

Data Quality Objectives

Analytical methods, expected precision of sample replicates, and method reporting limits and resolution are given in Table 7. The targets for analytical precision of laboratory analyses are based on historical performance by Manchester Environmental Laboratory (MEL) for environmental samples taken during TMDL studies around the state by the Environmental Assessment Program (Mathieu, 2006). The laboratory's measurement quality objectives (MQOs) and quality control procedures are documented in the Manchester Laboratory Users Manual (MEL, 2008). The accuracy and instrument bias MQOs of each sonde and/or sensor will be verified through post-deployment calibration checks according to the procedures described in *Standard Operating Procedures for Hydrolab® DataSonde® and MiniSonde® Multiprobes* (Swanson, 2007).

Table 7. Target for precision and reporting limits for measurement systems update.

Parameter	Equipment Type and Method	Duplicate Samples Relative Standard Deviation (RSD)	Method Reporting Limits and/or Resolution
WT Rhodamine	Hydrolab MiniSonde® Sensor	+/- 3% for signal level equivalents of 1 ppb	0.01 ppb
Dissolved Organic Carbon (DOC)	5310B	<10% RSD	1 mg/L
5-day Biological Oxygen Demand (BOD 5) (CBOD)	5210B	<10% RSD	2 mg/L
Ultimate Carbonaceous Biological Demand Oxygen Demand (UCBOD)	5210C	<10% RSD	2 mg/L
Periphyton C	EPA 440	±20% RSD	0.01% Total C
Periphyton N	EPA 440	±20% RSD	0.01% Total N
Periphyton Total P	EPA 200.2 (Preparation) EPA 200.7 (Analysis)	<=20%RSD	5.0 mg/Kg
Grain Size	PSEP -0 through 8 phi	±20% RSD	0.01%

Field meter and retrieval grab-sample checks (i.e., by Winkler method), as described by Ward (2007) and Hallock (2009), will be collected at the long-term continuous monitoring and diel monitoring locations to evaluate the accuracy criteria defined in Table 8. Field meter and grab-sample checks will be obtained at each diel monitoring location during the start and end of each synoptic survey. Additional field meter and grab-samples may be collected at the continuous monitoring locations at times of minimum and maximum DO concentration. Sampling times for minimum and maximum DO concentrations will depend on the continuous monitoring DO profile results obtained from the 1st synoptic survey.

Table 8. Measurement methods and specifications for Hydrolab® DataSonde® and MiniSonde® Multiprobes at the diel and continuous monitoring locations.

Parameter	Method	Resolution	Accuracy
Oxygen	Hach LDO or other brand luminescent technology	0.01 mg/L	±0.2 mg/L at > 8 mg/L
Temperature	30K ohm thermistor	0.01 º C	± 0.10 º C
pH	Glass electrode with refillable reference	0.01 standard units	± 0.2 standard units
Conductivity	Graphic electrodes (four)	0.001	± 0.5 % + 1 µS/cm

Laboratory Budget

The 2012 budgets for surface water, groundwater, benthic flux, and porewater sampling, as well as the total laboratory budget for all components, are represented in Tables 9-13. The estimated budget and lab sample load is based on (1) one longitudinal temperature/DO profile survey, (2) three synoptic surface water surveys (including QA/QC replicates), (3) three groundwater quality surveys (including QA/QC replicates), and (4) three periphyton assessments. All sites have not yet been selected; this is an estimate only. Table 9 presents the revised 2012 surface water laboratory budget.

Table 9. Revised surface water sampling laboratory budget for all fixed network stations.

Parameter	Cost per Sample	Number of Sites	Number of Samples Including field QA + field replicates	Number of Surveys	Total Cost
Turbidity	$12.17	13	46	3	$559.82
Total Suspended (TSS) + TNVSS	$26.56	13	46	3	$1,221.76
Alkalinity	$18.81	13	46	3	$865.26
Chloride	$14.39	13	46	3	$661.94
Periphyton Biomass + Nutrients (Chlorophyll a mg A/m², AFDW g D/m², Total N,C and P)	$245.00	13	46	3	$11,270.00
Grain Size (PSEP -0 through 8 phi)	$110.0	13	17	3	$5,060.00
Ammonia (NH3)	$14.39	13	46	3	$661.94
Nitrite-Nitrate (NO2/NO3)	$14.39	13	46	3	$661.94
Total Persulfate Nitrogen (TPN)	$18.81	13	46	3	$865.26
Orthophosphate (OP)	$16.60	13	46	3	$763.60
Total Phosphorus (TP)	$19.92	13	46	3	$916.32
Dissolved Organic Carbon	$39.80	13	46	3	$1,830.80
Total Organic Carbon in H_2O	$34.26	13	46	3	$1,575.96
Total Organic Carbon in Soil/Sediment	$66.40	13	46	3	$3,054.40
Iron	$41.19	13	46	3	$1,894.74
Biological Oxygen Demand 5 (BOD 5 Inhibited) (CBOD)	$66.40	13	46	3	$3,054.40
Ultimate Carbonaceous Biological Oxygen Demand (UCBOD)	$1,038.50	5	13	2	$13,500.50
				Total:	$ 48,418.64

Table 10. Groundwater sampling laboratory budget.

Parameter	Cost per Sample	Number of Sites (9 piezo-meters)	Number of Samples including QA + field replicates	Number of Surveys	Total Cost
Alkalinity	$18.81	9	33	3	$620.73
Chloride	$14.39	9	33	3	$474.87
Ammonia-N (NH3-N)	$14.39	9	33	3	$474.87
Nitrite-Nitrate-N (NO2+NO3-N)	$14.39	9	33	3	$474.87
Total Persulfate Nitrogen (TPN)	$18.81	9	33	3	$620.73
Orthophosphate (OP)	$16.60	9	33	3	$547.80
Total Phosphorus (TP)	$19.92	9	33	3	$657.36
Iron	$41.19	9	33	3	$1,359.27
Dissolved Organic Carbon	$39.80	9	33	3	$1,313.40
5-day Biological Oxygen Demand (BOD 5 Inhibited) (CBOD)	$66.40	9	33	3	$2,191.20
				Total:	$8,735.10

Table 11. Benthic flux sampling laboratory budget.

Parameter	Cost per Sample	Number of Benthic Flux Chambers	Number of Samples including QA + field replicates	Number of Surveys	Total Cost
Nitrite-Nitrate-N (NO2+NO3-N)	$14.39	7	24	3	$345.36
Total Phosphorus (TP- IPC/MS)	$19.92	7	24	3	$478.08
Orthophosphate (OP)	$16.60	7	24	3	$398.40
				Total:	$1221.84

Table 12. Porewater sampling laboratory budget.

Parameter	Cost per Sample	Number of Porewater Samples	Number of Samples including QA+ field replicates	Number of Surveys	Total Cost
Nitrite-Nitrate-N (NO2+NO3-N)	$14.39	9	33	3	$474.87
Ammonia-N (NH3-N)	$14.39	9	33	3	$474.87
Total Phosphorus (TP)	$19.92	9	33	3	$657.36
Dissolved Organic Carbon	$39.80	9	33	3	$1,313.40
Orthophosphate (OP)	$16.60	9	33	3	$547.80
Biological Oxygen Demand 5 (BOD 5) (CBOD)	$66.40	9	33	3	$2,191.20
				Total:	$5,659.50

Table 13. Total laboratory budget for the Stillaguamish Island Reach low DO study.

Budget Component	Total Cost
Surface water Sampling	$48,418.64
Groundwater Sampling	$8,735.10
Benthic Flux Sampling	$1,221.84
Porewater Sampling	$5,659.50
Total:	**$64,035.08**

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