DEPARTMENT OF
ECOLOGY
State of Washington

Quality Assurance Project Plan

Salmon Creek Watershed
Low Dissolved Oxygen and pH
Characterization Study

September 2011
Publication No. 11-03-110

Publication Information

Each study conducted by the Washington State Department of Ecology (Ecology) must have an approved Quality Assurance Project Plan. The plan describes the objectives of the study and the procedures to be followed to achieve those objectives. After completing the study, Ecology will post the final report of the study to the Internet.

The plan for this study is available on Ecology's website at www.ecy.wa.gov/biblio/1103110.html.

Data for this project will be available on Ecology's Environmental Information Management (EIM) website at www.ecy.wa.gov/eim/index.htm. Search User Study ID, NMat0004.

Ecology's Activity Tracker Code for this study is 11-046.

Waterbody Number: WA-28-1020.

Author and Contact Information

Nuri Mathieu
P.O. Box 47600
Environmental Assessment Program
Washington State Department of Ecology
Olympia, WA 98504-7710

For more information contact: Communications Consultant, phone 360-407-6834.

Washington State Department of Ecology - www.ecy.wa.gov/

- Headquarters, Olympia 360-407-6000
- Northwest Regional Office, Bellevue 425-649-7000
- Southwest Regional Office, Olympia 360-407-6300
- Central Regional Office, Yakima 509-575-2490
- Eastern Regional Office, Spokane 509-329-3400

Any use of product or firm names in this publication is for descriptive purposes only and does not imply endorsement by the author or the Department of Ecology.

If you need this document in a format for the visually impaired, call 360-407-6834.
Persons with hearing loss can call 711 for Washington Relay Service.
Persons with a speech disability can call 877-833-6341.

Quality Assurance Project Plan

Salmon Creek Watershed Low Dissolved Oxygen and pH Characterization Study

September 2011

Approved by:

Signature:	Date: September 2011
Brett Raunig, Client, Water Quality Program, Vancouver Field Office	
Signature:	Date: September 2011
Kim McKee, Client's Unit Supervisor, Water Quality Program, Southwest Regional Office	
Signature:	Date: September 2011
Bob Bergquist, Client's Section Manager, Water Quality Program, Southwest Regional Office	
Signature:	Date: August 2011
Nuri Mathieu, Author / Project Manager, Principal Investigator, and EIM Data Engineer, EAP	
Signature:	Date: September 2011
George Onwumere, Author's Unit Supervisor, EAP	
Signature:	Date: September 2011
Robert F. Cusimano, Author's Section Manager, EAP	
Signature:	Date: September 2011
Stuart Magoon, Director, Manchester Environmental Laboratory, EAP	
Signature:	Date: September 2011
Bill Kammin, Ecology Quality Assurance Officer	

Signatures are not available on the Internet version.
EAP: Environmental Assessment Program
EIM: Environmental Information Management database

Table of Contents

Page

List of Figures and Tables ... 3

Abstract ... 4

Background ... 5
- Introduction ... 5
- Watershed description ... 5
- Potential causes of low pH ... 7
- Potential cause of low DO ... 8
- Historical data review ... 8

Project Description ... 16
- Goal 1: Characterize DO and pH conditions ... 17
- Goal 2: Characterize influence of natural processes on low pH and DO conditions ... 17

Quality Objectives ... 18
- Precision ... 18
- Bias ... 20
- Comparability ... 21
- Representativeness ... 21
- Completeness ... 21

Sampling Process Design (Experimental Design) ... 22
- Monthly monitoring (Base Network) ... 23
- Summer productivity synoptic survey (Base + Extended Network) ... 23
- Wet season low pH synoptic surveys (Base + Extended Network) ... 24

Sampling and Measurement Procedures ... 28

Quality Control Procedures ... 30
- Field ... 30
- Laboratory ... 30

Data Management Procedures ... 30

Audits and Reports ... 31

Data Verification and Validation ... 31

Data Quality (Usability) Assessment ... 32

Organization and Schedule ... 33

Laboratory Budget ... 35

References ... 36

Appendix. Glossary, Acronyms, and Abbreviations ... 38

List of Figures and Tables

Page

Figures

Figure 1. Overview map of Salmon Creek watershed. 6

Figure 2. Clark County Salmon Creek watershed monitoring sites (from Collyard 2009). .9

Figure 3. DO box plots in Salmon Creek watershed (1997-2007; chart from Collyard, 2009)...10

Figure 4. pH box plots in Salmon Creek watershed (1997-2007; chart from Collyard, 2009)...11

Figure 5. Monthly DO box plots for Salmon Creek at 199th (1988-2007). 12

Figure 6. Seasonal pH boxplots at Salmon Creek at 199th during two different time periods. 12

Figure 7. Monthly DO box plots for Curtin Creek at 139th (1988-2007). 13

Figure 8. Seasonal pH levels at Curtin Creek at 139th during two different time periods....13

Figure 9. Map of base network sites for 2011-12 Salmon Creek study...............................22

Figure 10. Potential extended network measurement sites in the Curtin Creek subbasin. ...26

Figure 11. Potential extended network measurement sites in the upper Salmon Creek subbasin. 27

Tables

Table 1. Water quality criteria for pH and DO in the Salmon Creek watershed. 5

Table 2. 2003-04 USGS water quality data from Salmon Creek at 167th St. 15

Table 3. Measurement quality objectives for field measurements and laboratory analyses.19

Table 4. Measurement quality objectives for Hydrolab post-deployment checks...............20

Table 5. Location names, descriptions, and coordinates for base network sites. 23

Table 6. Field sampling and measurement methods and protocols 28

Table 7. Containers, preservation techniques, and holding times for sampled parameters. .29

Table 8. Organization of project staff and responsibilities. 33

Table 9. Proposed schedule for completing field and laboratory work, data entry into EIM, and reports..34

Table 10. Lab budget for the 2011-12 study...35

Abstract

Washington State water quality criteria set minimum acceptable values for dissolved oxygen (DO) concentrations and an acceptable range of values for pH. Low DO and pH values, below minimum criteria, can be influenced by both natural processes and human-caused activities.

Clark County has measured low DO and pH values at several locations in the Salmon Creek watershed, including at their furthest upstream site on Salmon Creek. The occurrences of low DO and pH conditions at this site in the upper watershed, where impacts should be relatively low, suggest these conditions may be influenced by natural processes.

The goal of this study is to characterize the extent and duration of low DO and pH in the Salmon Creek watershed. A secondary goal is to investigate whether or not these conditions are significantly influenced by natural processes. The results may also point to human-caused sources. Ecology will collect water quality and biological measurements and samples throughout the watershed to achieve the study goals and objectives.

This Quality Assurance Project Plan describes the methods, data quality procedures, study design, and other project details for the study.

Background

Introduction

Washington State water quality criteria (WAC 173-201A) set minimum acceptable values for dissolved oxygen (DO) concentrations and an acceptable range of values for pH (Table 1). Low DO and pH values, below minimum criteria, can be influenced by both natural processes and human-caused activities.

Clark County has measured low DO and pH values in situ at several locations in the Salmon Creek watershed, including at their furthest upstream site on Salmon Creek (SMN080). SMN080 served as the background site for Salmon Creek Bacteria Total Maximum Daily Load (TMDL) study (Cusimano and Giglio, 1995) and the subsequent TMDL effectiveness monitoring study (Collyard, 2009). The occurrences of low DO and pH conditions at this site in the upper watershed, where human-caused impacts should be relatively low, suggest these conditions may be influenced by natural processes.

Table 1. Water quality criteria for pH and DO in the Salmon Creek watershed.

Parameter	Classification	Criteria
Salmon Creek and tributaries from mouth to latitude 45.7176, longitude -122.6958 (~RM 3)		
pH	Salmonid Spawning, Rearing, and Migration	pH shall be within the range of 6.5 to 8.5 with a human-caused variation within the above range of less than 0.5 units.
DO		Lowest 1-day minimum = 8.0 mg/L
Salmon Creek and tributaries upstream of latitude 45.7176, longitude -122.6958 (~RM 3)		
pH	Core Summer Salmonid Habitat	pH shall be within the range of 6.5 to 8.5, with a human-caused variation within the above range of less than 0.2 units.
DO		Lowest 1-day minimum = 9.5 mg/L

RM: River mile

Watershed description

The Salmon Creek watershed (Figure 1), located in Clark County in southwest Washington , drains an area of approximately 93 square miles immediately north of the city of Vancouver. Salmon Creek originates on the slopes of Elkhorn Mountain (elevation = 2230 ft) and flows approximately 26 river miles to its confluence with Lake River (elevation = ~10 ft) 1.5 miles downstream of Vancouver Lake.

Land use varies throughout the watershed, with commercial timberland and rural residences dominating the upper watershed and increasing urbanization moving downstream resulting in fairly developed commercial and residential areas in the lower watershed. The city of Battle Ground (population of 17,571), north of Salmon Creek mid-watershed, is the largest urban center. Some small communities are scattered throughout the mid and upper watershed. The majority of the lower watershed is within the City of Vancouver urban growth area.

The climate is dominated by the mild, wet maritime weather regime typical of lower elevation areas of western Washington. The air temperatures in Battle Ground reach an average daily high of 79°F (26°C) in July and August with the average daily low dropping to 31°F (-0.6°C) in January (WRCC, 2011). The watershed receives an average of 58 inches of precipitation annually, over half of which falls from November through February.

The geology of the watershed is characterized by older consolidated bedrock that has been filled, particularly at lower elevations, by a series of younger sedimentary deposits (Mundorf, 1964). Hydrogeologic units of Clark County have been identified by R.D. Swanson, amongst others, and summarized in a U.S. Geological Survey (USGS) report (Turney, 1990). In general, the surficial geology consists of the older bedrock unit in the upper Salmon Creek watershed and an unconsolidated sedimentary aquifer in the lower watershed. Due to its productivity, the Troutdale gravel aquifer unit is the primary source of groundwater in Clark County. This unit begins in the mid to upper Salmon Creek watershed as the surface unit and is present throughout the rest of the watershed (down gradient), immediately beneath the unconsolidated sedimentary aquifer unit. A more detailed description of geology and hydrogeology in the watershed can be found in Mundorf (1964) and Turney (1990).

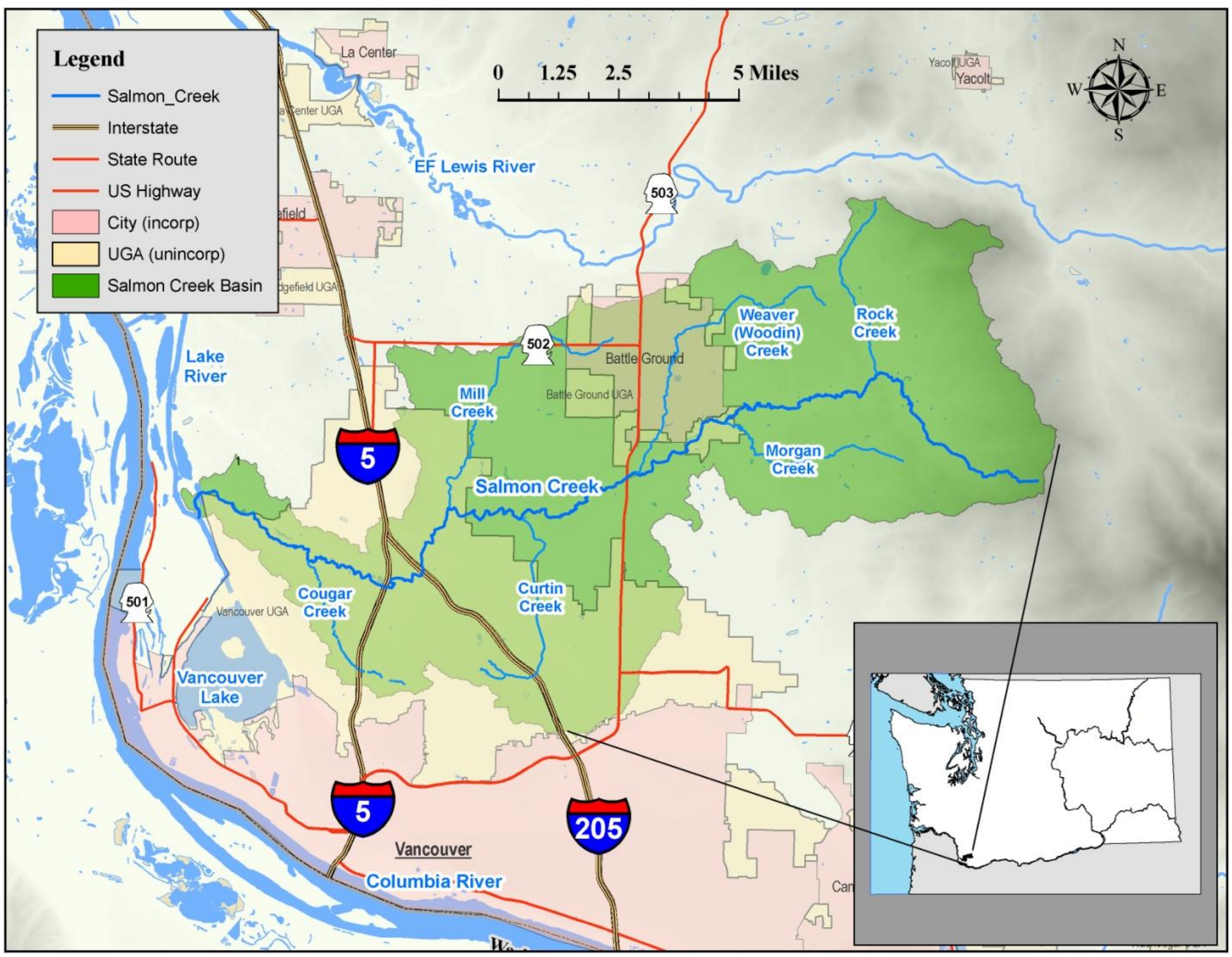

Figure 1. Overview map of Salmon Creek watershed.

Potential causes of low pH

Human-caused influences

Human activity and development can lower instream pH through many mechanisms including, but not limited to:

- Mining activities.
- Industrial or other point source discharges of acidic substances directly to surface water.
- Atmospheric deposition of sulfuric compounds emitted by industry.
- Reduced soil buffering capacity with export of base cations (from the watershed) through forest harvest.
- Increased algal and plant photosynthesis and respiration due to cultural eutrophication.

Municipal stormwater, discharged by Clark County under their Phase 1 Municipal Stormwater permit, is the only point source discharge within the upper Salmon Creek subbasin. While Phase 1 stormwater is treated as a point source for regulatory purposes, within the upper watershed it originates primarily as surface runoff, or subsurface discharge, from rural land that drains to a network of roadside ditches.

No active, or known historical, mining operations exist upstream of SMN080. Atmospheric deposition from industry in the upper watershed is unlikely to be greater than other areas of southwest Washington, given that no industrial facilities are in close proximity.

Commercial forestry is the predominant land use in the upper watershed; however, research has shown that forest harvest could potentially lower, raise, or not affect pH, depending on site-specific conditions. A site-specific, multi-year (possibly multi-decade) study would likely be necessary to evaluate this potential factor within the watershed.

Increased photosynthesis and respiration in response to cultural eutrophication is not the suspected cause of lower pH. Typically, eutrophication would occur during a growing season when temperatures are warmer and biological activity increased. This would result in a greater diurnal swing in pH resulting in both low and high pH values. Given that low pH in Salmon Creek typically occurs during the late fall and early winter, it is unlikely that increased productivity is the cause. Also, more recent data does not show an increase in diurnal pH fluctuation during the months when pH is low.

Natural influences

Under natural conditions, low pH could be caused or influenced by many factors including:

- Drainage from wetlands where plant decay and biological activity produce organic acids.
- Acidic rain during storm events coupled with low buffering capacity of soil and water.
- Groundwater with low pH and short residence time contributing a significant portion of streamflow.
- Algal and plant photosynthesis and respiration.

- Atmospheric deposition of acidic compounds emitted by natural sources, for example, volcanic ash.

Low pH in the watershed appears to occur on an infrequent basis, typically in response to late fall and winter storm events. Given this observation, this study will focus on investigating what role the flushing of wetlands, buffering capacity of soils, and precipitation events play in lowering pH in Salmon Creek. Winter precipitation in southwestern Washington typically ranges in pH from 4.8 to 5.5 with a median of 5.1[1].

Potential cause of low DO

Clark County has observed stream temperatures above the water quality standards in the upper Salmon Creek watershed. Currently, a TMDL is under development for temperature improvement. The relatively high DO saturation levels in the summer indicate that low DO in the upper watershed could be caused, primarily, by increased stream temperatures. Given this observation and limitation of resources available, this study will characterize diel DO fluctuations during summer months, but will not thoroughly investigate natural causes of low DO.

Curtin Creek has low stream temperatures, yet has the lowest DO levels of all the sites. There is a relatively large amount of groundwater input to the creek and DO may be low primarily due to this. However, the upper Curtin Creek watershed is fairly developed and it may be difficult to separate human-caused from natural influences.

Historical data review

Salmon Creek nonpoint source pollution TMDL effectiveness monitoring

In 2009, Ecology published the *Salmon Creek Nonpoint Source Pollution Total Maximum Daily Load Water Quality Effectiveness Monitoring Report* (Collyard, 2009). The report compared ambient monthly water quality data collected at eight sites (Figure 2) by Clark County from 1997-2007 to state water quality standards.

[1] Based on data collected for the National Atmospheric Deposition Program at two National Trend Network stations: La Grande (WA21) and the Columbia River Gorge (WA98). Data collection range: Months= November to February; Years= 1988-2004 (NADP, 2011).

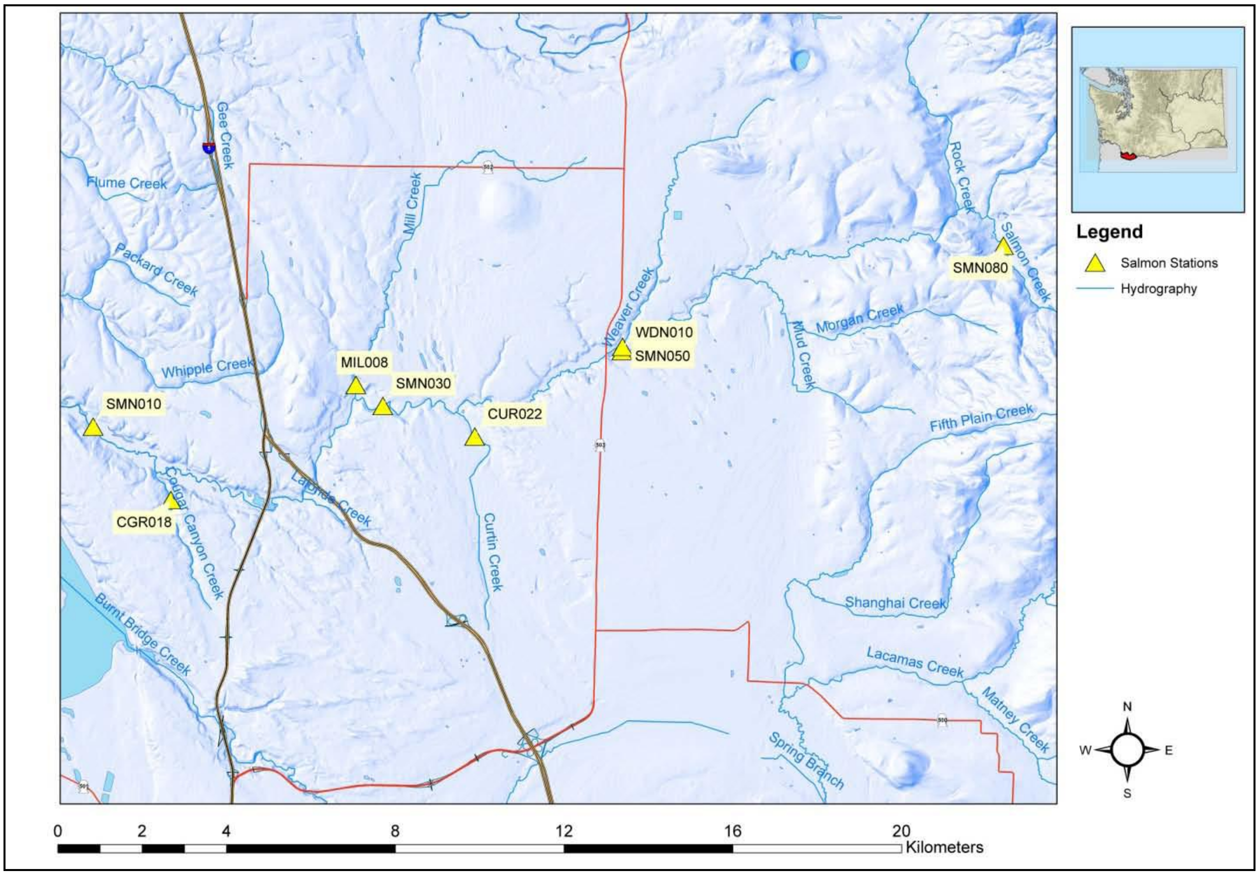

Figure 2. Clark County Salmon Creek watershed monitoring sites (from Collyard 2009).

Results of the comparison showed that:

- DO was below standards at all 8 sites throughout the watershed (Figure 3)
  - DO was lower at Curtin Creek near the mouth (CUR022) and Salmon Creek at 36th (SMN010), relative to the other sites in the watershed.
  - Based on analysis of the most recent Clark County data, the most likely outcome in the upcoming 2012 Water Quality Assessment would be:
    - Category 5 (303(d) list) designation for 7 of the 8 sites, with Weaver Creek (WDN) remaining in Category 4A (TMDL in progress).
- Single pH excursions below the water quality criterion of 6.5 occurred at all 8 sites (Figure 4);
  - However, only Curtin Creek had greater than 10% of the single samples below 6.5.
  - Upper Salmon Creek (SMN080), Weaver Creek at the mouth (WDN010), and SMN010 had greater than 5% of the samples below 6.5.
  - Based on this analysis, the most likely outcome in the upcoming 2012 Water Quality Assessment would be:
    - All Category 2 and 5 listings would remain the same.
    - Weaver Creek would be given a Category 2 designation.

- Note: the 2012 Water Quality Assessment will not be based on exactly the same data set, but rather will be based on all available data from the watershed at the time of the assessment. The 2012 assessment will not include data from this study, as the cutoff for data collection was May 1, 2011. This data set and the analysis of natural conditions will be considered in the next assessment cycle.

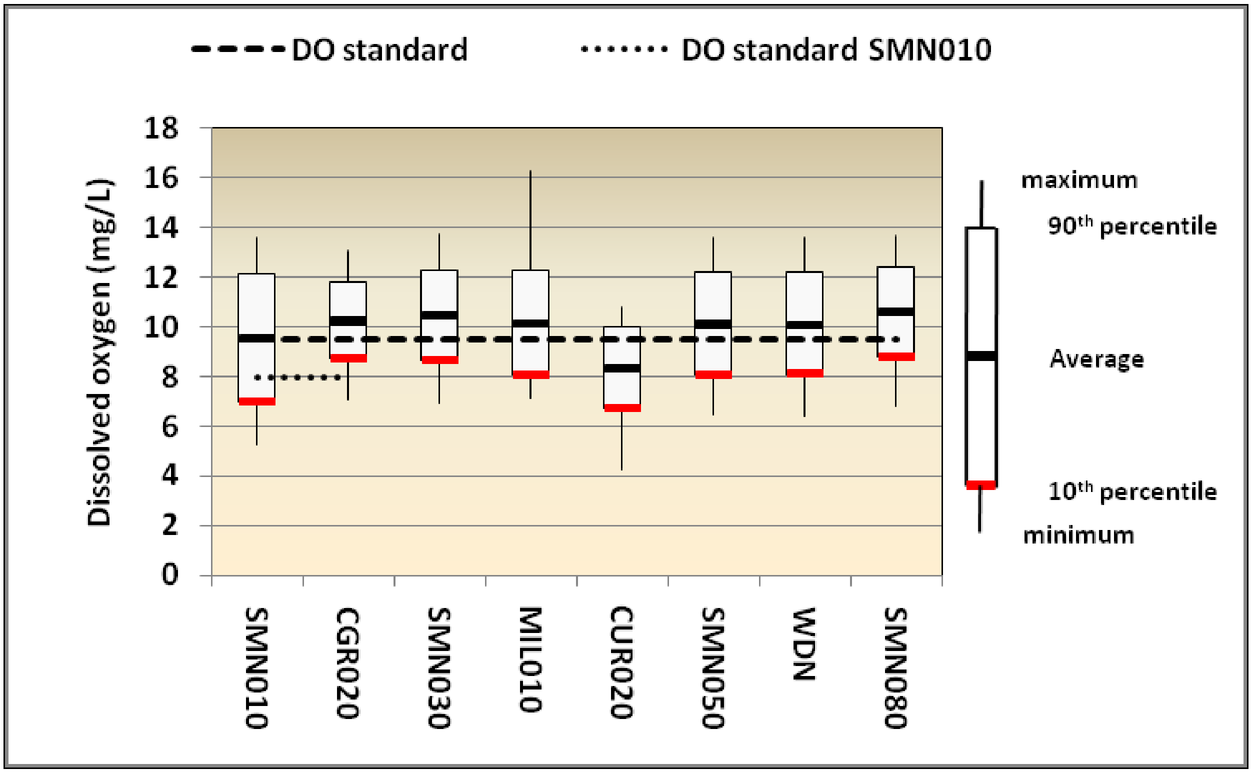

Figure 3. DO box plots in Salmon Creek watershed (1997-2007; chart from Collyard, 2009)

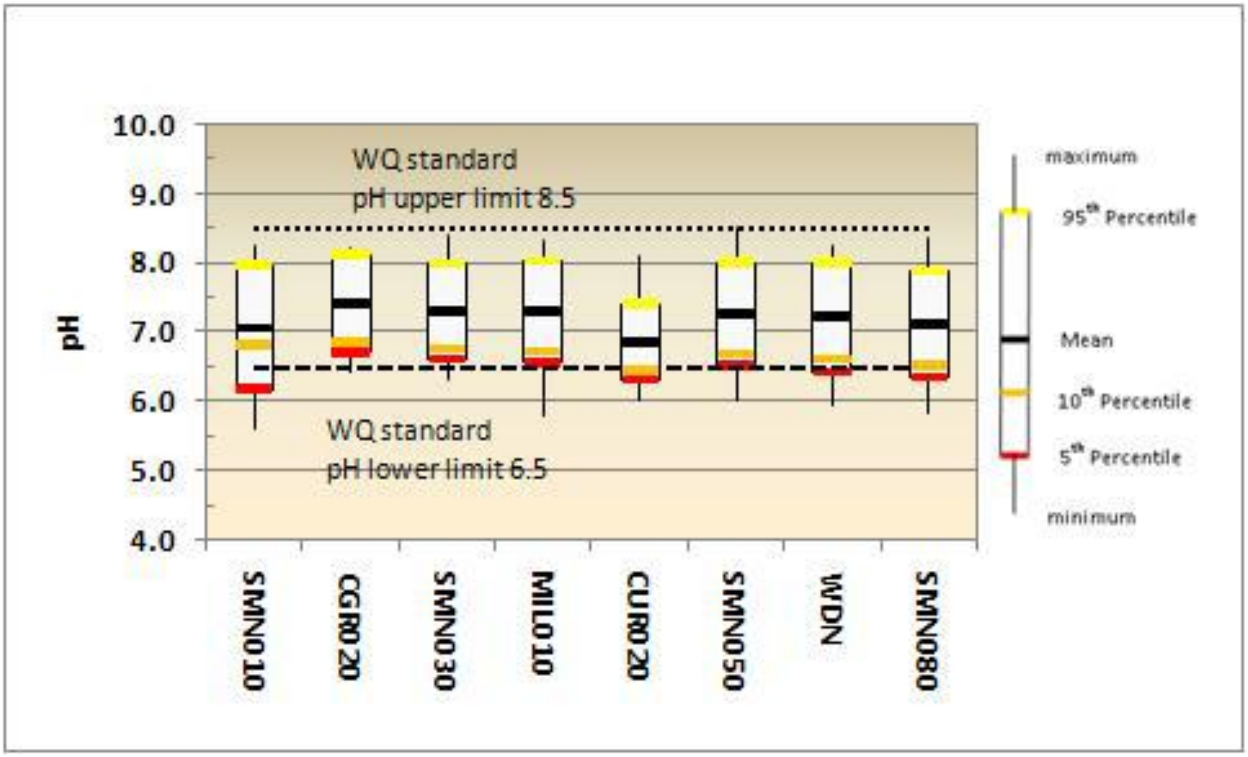

Figure 4. pH box plots in Salmon Creek watershed (1997-2007; chart from Collyard, 2009)

Clark County ambient monitoring, 1988-2007

Historically, Clark County has collected routine water quality data in the Salmon Creek watershed. Collyard (2009) compiled the Clark County data, reviewed it for quality, and presented it in an appendix in the 2009 report. Figures 5 through 8 provide a graphical summary of that data set.

Based on a review of the data for station SMN080, low DO (below 9.5 mg/L) typically occurs from June through October (Figure 5). Low pH excursions (below 6.5) typically occur in the fall and winter months, with a few historical excursions (prior to 1999) in the spring and summer (Figure 6). In more recent years (2002-2007), low pH has occurred exclusively from November to February. On specific winter dates with low pH there is typically significant antecedent rainfall and a large spike in streamflow.

At Curtin Creek, low DO occurs year-round with frequent excursions from November to April (between 25 and 85 percent of total monthly measurements) and DO levels remaining below 9.5 mg/L for the entire dry season, May through October (Figure 7). The lower summer DO levels are likely caused by a combination of increased stream temperatures and increased percent contribution of groundwater (to streamflow). Seasonal pH patterns in Curtin Creek were similar to those in Salmon Creek with more recent data showing excursions from November to February (Figure 8).

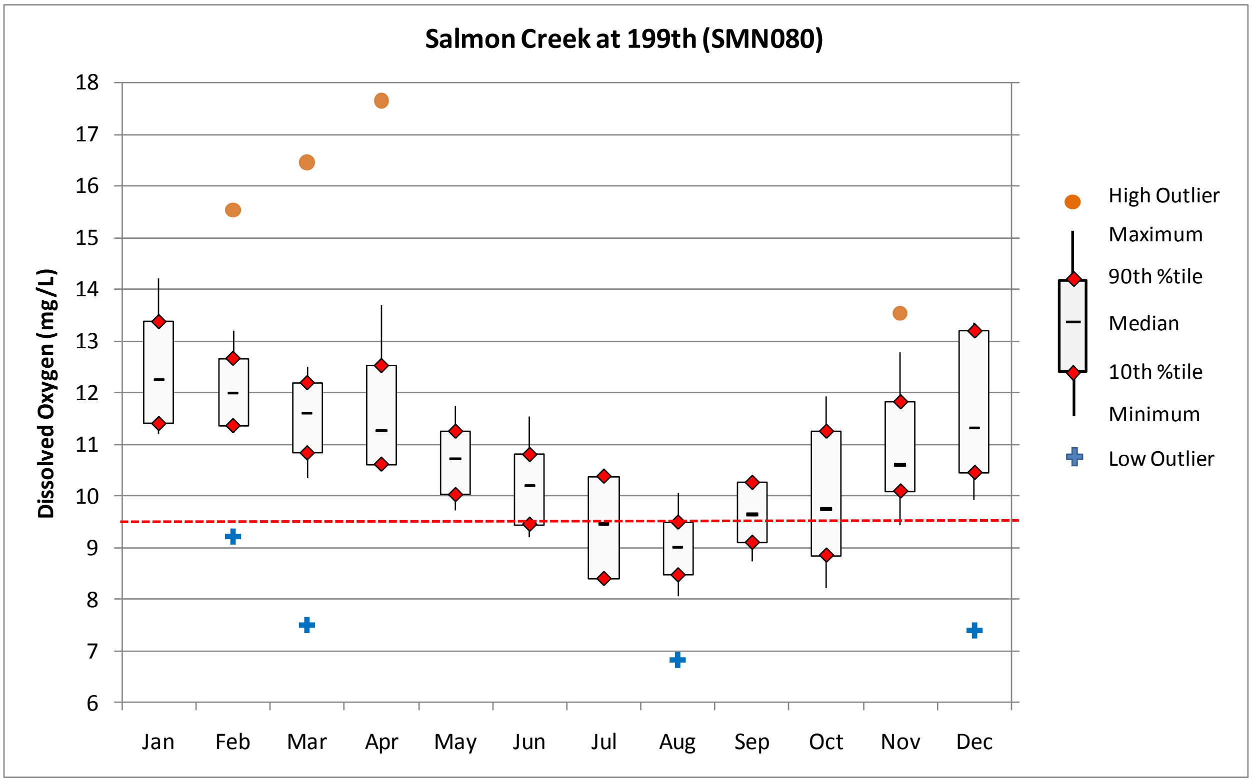

Figure 5. Monthly DO box plots for Salmon Creek at 199th (1988-2007).

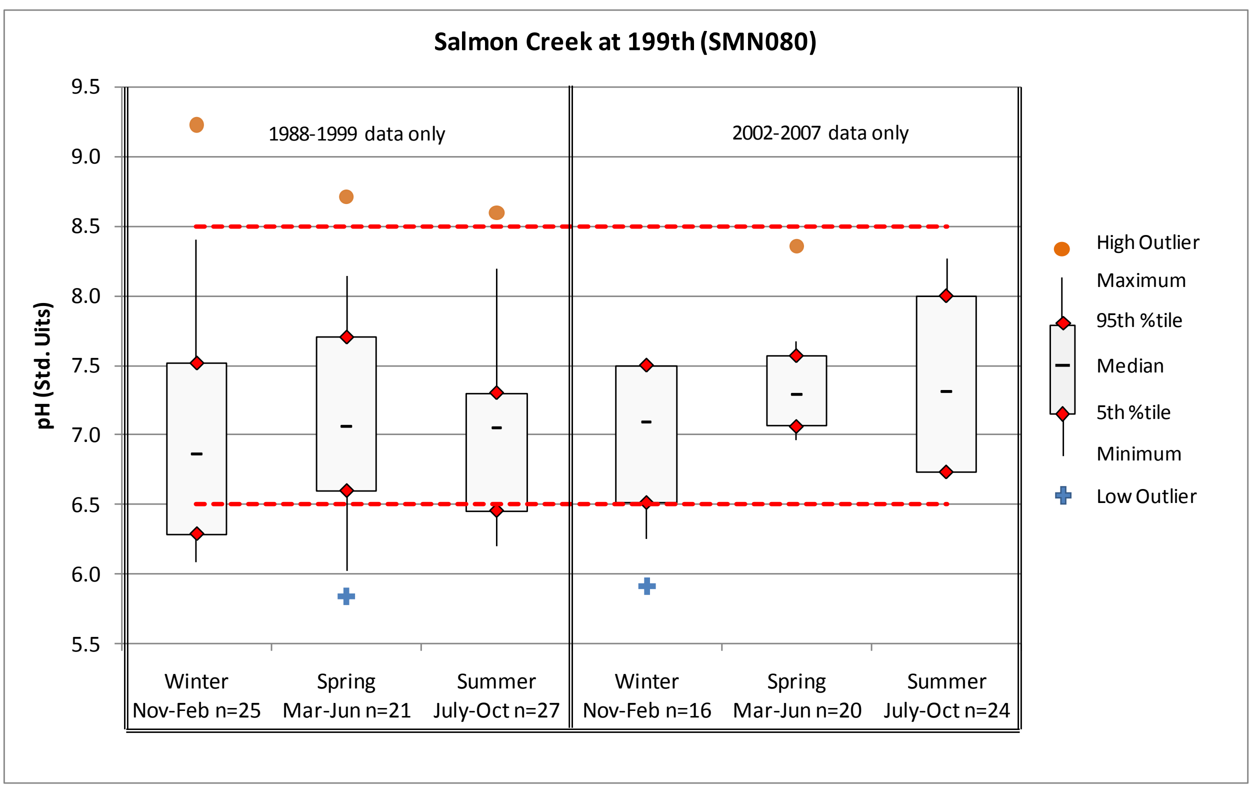

Figure 6. Seasonal pH boxplots at Salmon Creek at 199th during two different time periods.

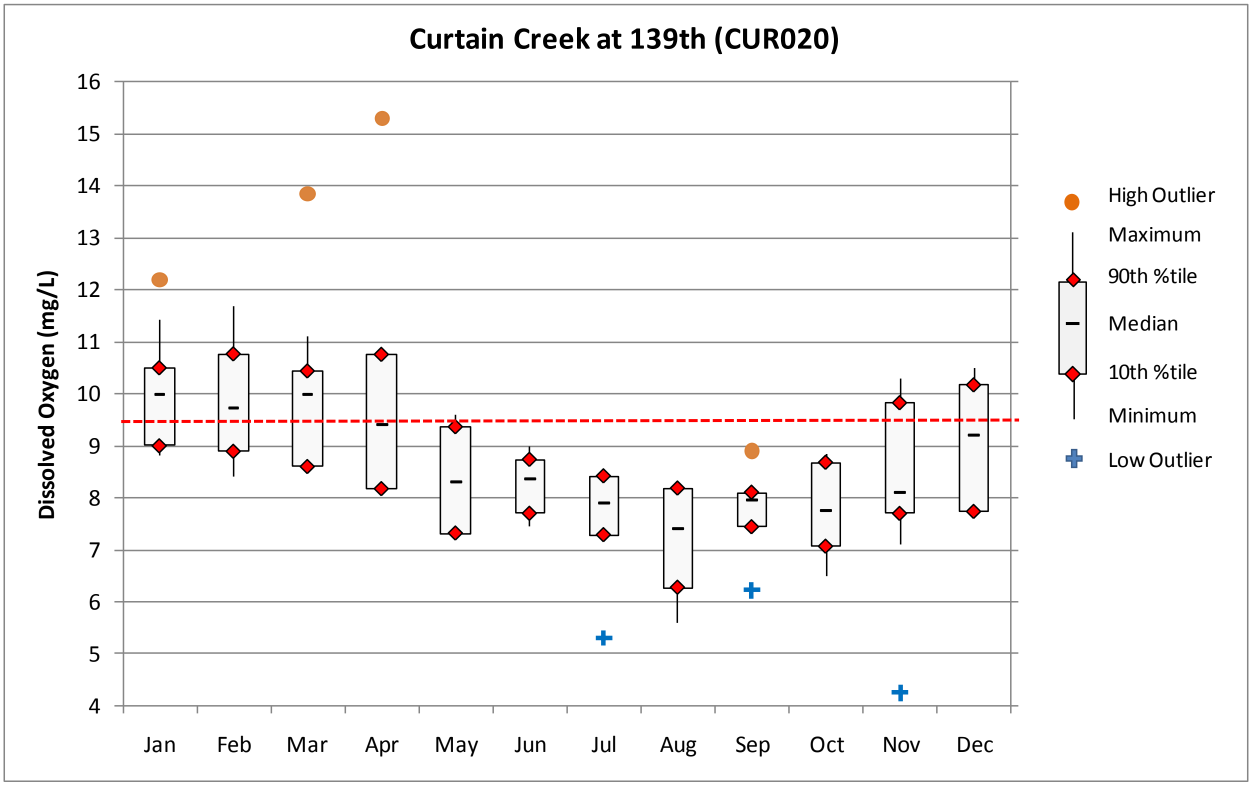

Figure 7. Monthly DO box plots for Curtin Creek at 139th (1988-2007).

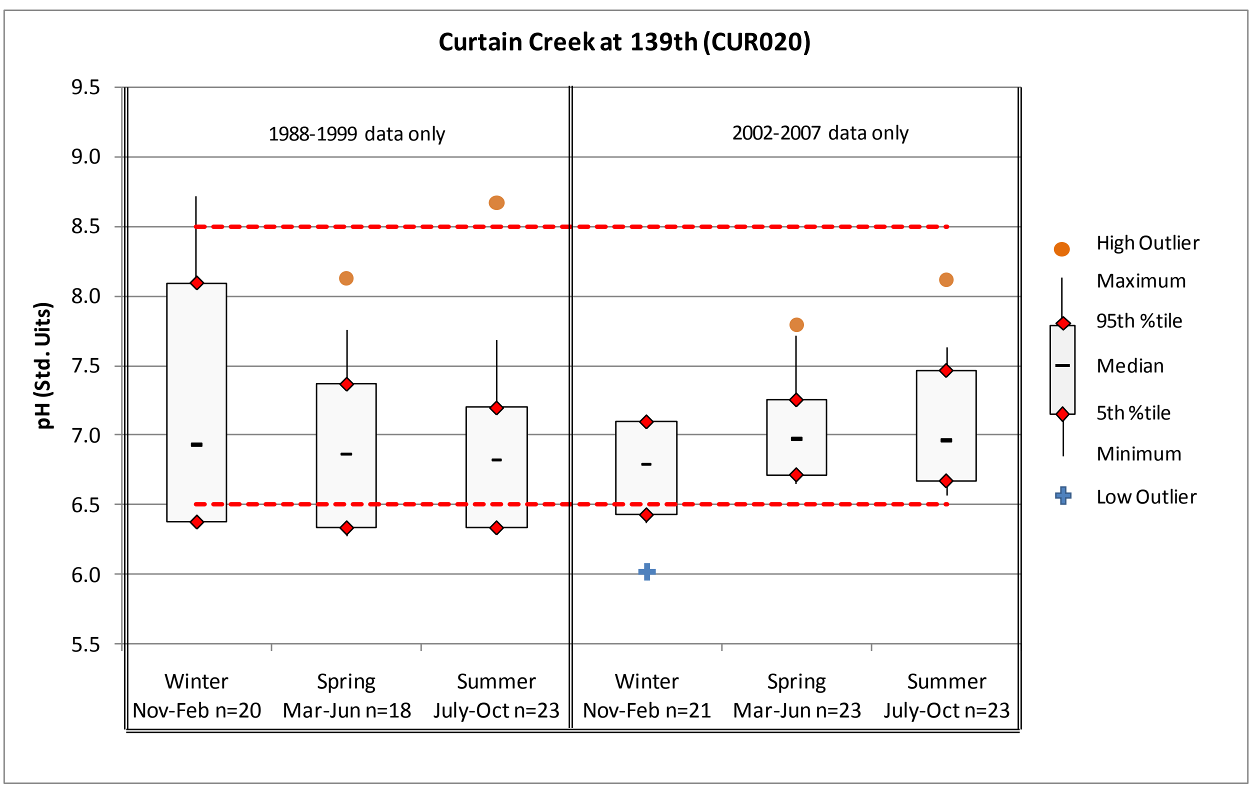

Figure 8. Seasonal pH levels at Curtin Creek at 139th during two different time periods.

USGS groundwater quality study 1988

In 1988, the USGS measured water quality in off-stream wells throughout Clark County, including multiple wells in the Salmon Creek watershed (Turney, 1990).

Out of 76 wells sampled throughout the county, only three samples had a pH below 6.5. All three wells were located outside the Salmon Creek watershed. The report suggests that "pH values that did not meet standards probably are caused by natural processes… [for low pH values] low residence time, usually in recharge areas, where the low pH of precipitation is a factor. The upper Salmon Creek (pH=6.8) and upper Curtin Creek (pH=6.6) wells were below the median of 7.1 for all wells in the county.

Upper Salmon Creek

Upper Salmon Creek groundwater appears influenced by the surficial geology with the older bedrock resulting in low alkalinity, soft groundwater.

In general, wells in the older bedrock geohydrologic unit had lower median values than other units in the county for hardness, calcium, magnesium, potassium, bicarbonate, and alkalinity. Samples at the upper Salmon Creek well had values, for these same constituents, even lower than the median values for the sub-set of older bedrock wells suggesting that there is likely not much buffering capacity in the upper watershed. DO, at 6.9 mg/L, was above the median of 5.0 mg/L for the county.

Curtin Creek

In contrast to the upper Salmon Creek well, the upper Curtin Creek well was set in the Troutdale Gravel aquifer layer and had higher than county-wide median values for hardness, calcium, magnesium, potassium, bicarbonate, and alkalinity. DO, at 4.2 mg/L, was slightly below the median for the county.

USGS surface water quality data

In 2003-04, USGS collected surface water samples (Table 2) at Salmon Creek at 167th St (~RM 18.3). Instream alkalinity and bicarbonate were very low, indicating limited buffering capacity. Alkalinity and pH were lowest during winter storms. DO was lowest in summer months, with an afternoon low of 8.5 mg/L on 8/16/2004. The low DO levels appear mostly temperature related as DO percent saturation was near 100 percent when the DO was below 9.5 mg/L. Instream temperatures were well above water quality criteria when DO was lowest.

Table 2. 2003-04 USGS water quality data from Salmon Creek at 167th St.

Sample Date and Time	Temp water, (deg C)	Temp air, (deg C)	Flow (ft3/s)	DO (mg/L)	DO (% Sat)	pH, (std Units)	Bi-carbonate field filtered (mg/L)	Alkalinity field filtered (mg/L as CaCO3)
11/3/2003 11:50	3.6	4.9	2.2	12.5	94	7.3	34	28
1/15/2004 13:30	6.9	8.8	213	12.4	102	6.8	E 13	E 11
3/8/2004 14:30	10	13	105	9.9	87	7	15	13
5/5/2004 12:00	13.4	19.1	14	10.1	98	7.3	26	21
6/30/2004 14:30	18.7	20.1	14	9.3	101	7	24	20
8/16/2004 15:40	23.4	27.5	3.4	8.5	100	7.2	33	27

Project Description

The goal of this study is to characterize the extent and duration of low DO and pH conditions in the Salmon Creek watershed. A secondary goal is to investigate whether or not these conditions are significantly influenced by natural processes. Ultimately, Ecology will use the data collected for this study in future Water Quality Assessments and to inform local and state water quality managers when making future cleanup and monitoring decisions in the watershed. Analysis of the results and subsequent discussion could potentially lead to several outcomes (with no presumption either way):

- Recommendation to place some of the Category 2 and 5 waterbody segments into Category 1 based on impairment due to natural conditions.
- Recommendation to retain Category 2 and 5 listings based on evidence of human-caused influence or inconclusive data results. In this case, a water quality modeling study, to show the human-caused variation in pH or DO was within the allowable range, may be necessary in the future in order to place any waterbody segments in Category 1 due to natural conditions.

EPA guidance states that a waterbody can be removed from the 303(d) list if the impairment is caused by natural conditions; however, the state must provide a "site-specific, scientifically defensible rationale" that does one of the following (EPA, 2005):

- Explain why human activities in a watershed are not directly or indirectly the cause of the exceedance of WQS for the pollutant of concern.
- Show that there has been minimal human activity in the watershed that would affect the water quality parameter in question.
- Explain how natural processes alone are adequate to explain the observed exceedance of the water quality standard for the pollutant of concern.
- Show that the water quality in the watershed is similar to that measured in an undisturbed or minimally disturbed reference location.

Ecology has developed the study design and objectives to document whether or not any of these criteria apply to DO and pH listings in the Salmon Creek watershed.

The project may be limited by some practical constraints including available staff time, available resources, access to private property, laboratory holding times, hours of daylight, extreme weather conditions, wadeable stream conditions, and other unanticipated constraints.

Goal 1: Characterize DO and pH conditions

Objectives:

- Collect continuous temperature, pH, DO, and conductivity data from Salmon Creek, its tributaries, and a reference basin during low flows and elevated stream temperatures during summer 2011.
- Collect continuous temperature, pH, DO, and conductivity data from Salmon Creek at 199th (SMN080) for a period of one year from August 2011 to July 2012.
- In general, the objectives listed for Goal 2 will provide context and data to support Goal 1.

Goal 2: Characterize influence of natural processes on low pH and DO conditions

Objectives:

- Investigate natural influences on low DO and pH in the Curtin Creek and upper Salmon Creek subbasins.
- Inventory major wetlands within each subbasin with hydrologic connectivity to the creek and assess whether or not wetlands impact DO and pH levels, as well as biological productivity, by bracketing wetlands with water quality measurements.
- Characterize pH, DO, productivity (chlorophyll a and periphyton) and flow levels in situ at a high resolution of sites throughout each subbasin during summer 2011 continuous water quality monitoring.
- Characterize pH and flow levels at a high resolution of sites throughout each subbasin during wet season storm events.
- Assess periphyton and macroinvertebrate communities in the upper Salmon Creek watershed and in a reference basin.
- Compare biological communities to assess human-caused impact to upper Salmon Creek.

Quality Objectives

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

Table 3 outlines analytical methods, expected precision of sample replicates, and method reporting limits and/or resolution. The targets for precision of field replicates are based on historical performance by MEL for environmental samples taken around the state by EAP (Mathieu, 2006). The reporting limits of the methods listed in the table are appropriate for the expected range of results and the required level of sensitivity to meet project objectives. The laboratory's measurement quality objectives and quality control procedures are documented in the MEL *Lab Users Manual* (MEL, 2008).

Field staff will calibrate pH meters with conventional buffers and, periodically, check probes against low-ionic strength buffers to assess any bias due to low-ionic strength waters. Immediately following deployment field staff will check deployed sonde against in situ check probe.

Precision

Precision is defined as the measure of variability in the results of replicate measurements due to random error. Random error is imparted by the variation in concentrations of samples from the environment as well as other introduced sources of variation, e.g., field and laboratory procedures. Precision for replicates will be expressed as percent relative standard deviation (%RSD) and assessed following the MQOs outlined in Table 3.

Table 3. Measurement quality objectives for field measurements and laboratory analyses.

Analysis	Method	Bias (deviation from true value)	Precision – Field Duplicates (median RSD)	Precision – Lab Duplicates (RPD)	Method Lower Reporting Limit and/or Resolution	Expected Range
Field Measurements						
Water Temperature[1]	Hydrolab®	See Table 3	+/- 0.2° C	n/a	0.01° C	0 – 30° C
Specific Conductance[2]	Hydrolab®	See Table 3	5% RSD	n/a	0.1 uS/cm	20 – 200 uS/cm
pH[1]	Hydrolab®	See Table 3	0.20 s.u.	n/a	0.01 s.u.	1 to 14 s.u.
Dissolved Oxygen	Hydrolab®	See Table 3	5% RSD	n/a	0.1 mg/L	0.1 - 15 mg/L
Chlorophyll a	Hydrolab®	n/a	20% RSD	n/a	0.03 ug/L	0.1 – 100 ug/L
Oxidation-Reduction Potential	Hydrolab®	n/a	20% RSD	n/a	1 mV	-999 to 999 mV
Dissolved Oxygen[1]	Winkler Titration	n/a	+/- 0.2 mg/L	n/a	0.1 mg/L	0.1 - 15 mg/L
Streamflow	EAP SOP#024	n/a	10% RSD	n/a	0.01 cfs	0.01 – 1,000 cfs
Laboratory Analyses						
Total Alkalinity	SM 2320	10%	10% RSD[3]	20%	5 mg/L	5 – 100 mg/L
Chloride	EPA 300.0	5%	5% RSD3	20%	0.1 mg/L	0.1 - 250 mg/L
Chlorophyll a -water	SM 10200H(3)	5%	20% RSD3	n/a	0.05 ug/L	0.1 – 100 ug/L
Chlorophyll a –plant tissue	SM 10200H(3)	n/a	50% RSD3	n/a	0.05 ug/L	0.1 – 100 ug/L
Dissolved Organic Carbon	SM 5310	10%	10% RSD3	20%	1 mg/L	1 – 20 mg/L
Total Organic Carbon	SM 5310	5%	10% RSD3	20%	1 mg/L	1 – 20 mg/L
Total Persulfate Nitrogen	SM 4500-NO3-B	15%	10% RSD3	20%	0.025 mg/L	0.025 – 20 mg/L
Ammonia	SM 4500-NH3-H	10%	10% RSD3	20%	0.01 mg/L	0.01 – 20 mg/L
Nitrate/Nitrite	4500-NO3- I	15%	10% RSD3	20%	0.01 mg/L	0.01 – 10 mg/L
Orthophosphate	SM 4500-P G	20%	10% RSD3	20%	0.003 mg/L	0.003 – 1 mg/L
Total Phosphorus	SM 4500-P	10%	10% RSD3	20%	0.005 mg/L	0.005 – 10 mg/L
Turbidity	SM 2130	5%	15% RSD3	20%	0.5 NTU	0.5 – 100 NTU

[1] as units of measurement, not percentages
[2] as percentage of reading, not RSD
[3] field duplicate results with a mean of less than or equal to 5X the reporting limit will be evaluated separately

Bias

Bias is defined as the difference between the population mean and true value of the parameter being measured. Field and laboratory QC procedures, such as blanks, check standards, and spiked samples, provide a measure of any bias affecting measurement procedures. Field staff will minimize bias in field measurements and samples by strictly following measurement, sampling, and handling protocols

EAP staff will assess bias in field samples by submitting field blanks. Field staff will prepare blanks in the field by:

- For water quality samples, filling the bottles directly with deionized water.
- Handling and transporting the samples to MEL in the same manner that the rest of the samples are processed.

For field measurements, EAP staff will:

- Minimize bias in the Hydrolab® sonde field measurements by pre-calibrating before each run.
- Assess any potential bias from instrument drift in probe measurements by
    - For pH and conductivity, post-checking the probes against National Institute of Standards and Technology (NIST) certified pH and conductivity standards.
    - For DO, post-checking the probe against 100% saturation and comparing Winkler DO samples to field measured DO values.
    - For temperature, checking the probe's temperature readings before and after each run using an NIST certified thermometer.

Table 4 contains the data quality bias objectives for both instrument drift and fouling checks.

Table 4. Measurement quality objectives for Hydrolab post-deployment checks.

Parameter	Units	Accept	Qualify	Reject
pH	std. units	< or = ± 0.2	> ± 0.2 and < or = ± 0.5	> ± 0.5
Conductivity*	uS/cm	< or = ± 5%	> ± 5% and < or = ± 15%	> ± 15%
Temperature	° C	< or = ± 0.2	> ± 0.2 and < or = ± 0.5	> ± 0.5
Dissolved Oxygen**	% saturation	< or = ± 5%	> ± 5% and < or = ± 10%	> ± 10%

* Criteria expressed as a percentage of readings; for example, buffer = 100.2 uS/cm and Hydrolab = 98.7 uS/cm; (100.2-98.7)/100.2 = 1.49% variation, which would fall into the acceptable data criteria of less than 5%.
**When Winkler data is available, it will be used to evaluate acceptability of data in lieu of % saturation criteria.

Comparability

Comparability to previously collected data will be established by strictly following EAP protocols and adhering to data quality criteria.

Representativeness

Representativeness will be assessed by periodic measurements across both width and depth of channel. A sample location will be considered representative if it meets the 'accept' criteria in Table 4.

Completeness

EPA has defined completeness as a measure of the amount of valid data needed to be obtained from a measurement system (Lombard and Kirchmer, 2004). The goal for this study is to correctly collect and analyze a minimum of 95% of the samples for all sites. Problems occasionally arise during sample collection that cannot be controlled, including flooding, stagnant or no flow during dry periods, or samples damaged in transit.

Sampling Process Design (Experimental Design)

A continuous water quality monitoring instrument (Hydrolab multi-parameter sonde) will be deployed in the upper watershed at 199th St (SMN080) from October 2011 to September 2012 at the main or *master* station. This master station will provide a baseline of water quality, throughout the year, in the Salmon Creek headwaters. This meets objective #2.

Additional data collection will occur at two different networks of sites: base-network (Figure 9) and extended-network. Extended network sites are subject to change based on field reconnaissance, flow conditions, and preliminary study results. Figures 10 and 11 illustrate potential extended network site locations. Table 6 outlines the data collection schedule.

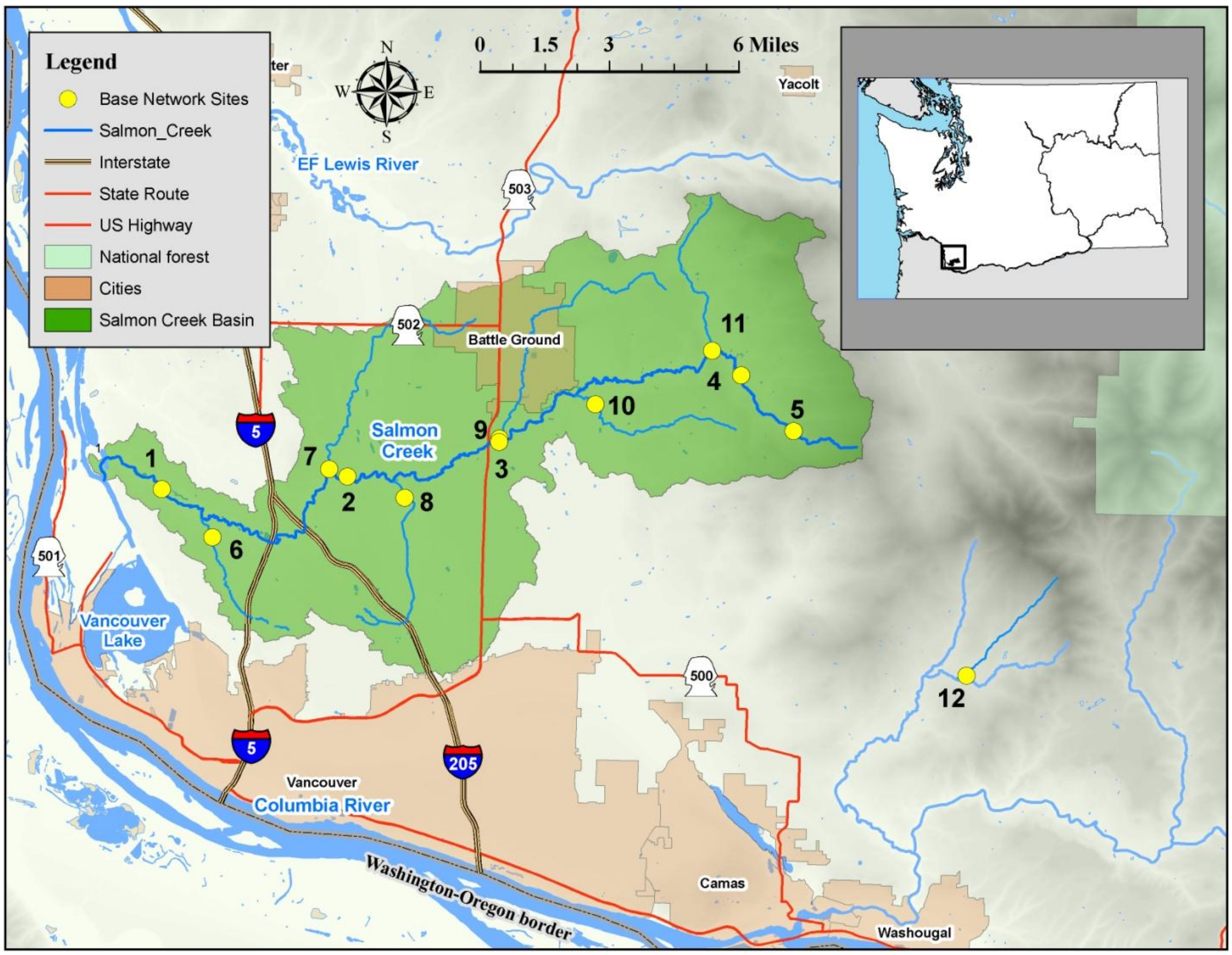

Figure 9. Map of base network sites for 2011-12 Salmon Creek study.

Monthly monitoring (Base Network)

Monthly monitoring will occur from August through January at 12 'base network' stations located at 11 locations in the Salmon Creek basin plus an additional reference site, Jones Creek, a tributary to the Little Washougal River (Figure 9; Table 5).

Table 5. Location names, descriptions, and coordinates for base network sites.

Map ID#	User Location ID	Study Location Name	Station Description	Latitude (Degree Decimal)	Longitude (Degree Decimal)
1	28-SMN-2.2	SMN010	Salmon Creek at 36th Ave	45.72287758	-122.70754378
2	28-SMN-9.4	SMN030	Salmon Creek at 50th Ave	45.72886236	-122.61857766
3	28-SMN-14.7	SMN050	Salmon Creek at Caples Rd	45.74180846	-122.54639805
4	28-SMN-23.3	SMN080	Salmon Creek at 199th St	45.76614460	-122.43103274
5	28-SMN-25.3	SMN095	Salmon Ck at end of Westerholm	45.74781548	-122.40521459
6	28-CGR-0.6	CGR020	Cougar Creek at 119th St	45.70717275	-122.68254702
7	28-MIL-0.1	MIL010	Mill Creek at Salmon Ck Rd	45.73113810	-122.62754723
8	28-CUR-0.5	CUR020	Curtin Creek at 139th St	45.72225906	-122.59098664
9	28-WDN-0.1	WDN010	Weaver(Woodin) Creek at Caples Rd	45.74292195	-122.54617523
10	28-MOR-0.6	MOR010	Morgan Creek at 167th Ave	45.75519180	-122.50055519
11	28-RCK-0.0	RCK010	Rock Creek at Risto Rd	45.77420103	-122.44515857
12	28-JON-0.3	JON010	Jones Creek at Boulder Creek Rd	45.667165	-122.319519

Ecology will collect total nitrogen and total phosphorus samples at SMN095 and the reference site to compare background nutrient levels between the two basins. Monthly monitoring will also include a rapid assessment of periphyton growth at all sites to characterize relative biological growth throughout the watershed. Field staff will also collect in situ measurements for flow pH, temperature, DO, specific conductance, oxidation-reduction Potential (ORP), and *in vivo* Chlorophyll *a* at all sites.

In general, water quality results will be summarized and compared throughout the watershed. Results from the background Salmon Creek site (SMN095) will be compared to the results from the reference basin.

Summer productivity synoptic survey (Base + Extended Network)

Field staff will deploy Hydrolabs in August 2011 at base network sites. Staff may deploy instruments at additional sites in upper Salmon and Curtin Creek subbasins, depending on equipment availability and logistical constraints. Hydrolabs will collect continuous water quality measurements for a minimum of 2 days and up to 1 week; length of deployment subject to sonde availability. This meets objective #1.

Given that existing data shows that lowest DO levels typically occur in July and August, Ecology will collect in situ measurements of DO, as well as pH, temperature, conductivity, chlorophyll *a*, and ORP, at an additional extended network of sites in upper Salmon and Curtin Creek subbasins during low DO trough (Figures 10 and 11). This supports objectives #5 and #6. Due to logistical constraints, field staff will collect only one set of measurements per site. Flow measurements may also be collected at extended network sites, depending on time constraints.

In addition, the summer synoptic will include:

- periphyton sampling for biomass at base network sites; and
- periphyton and macroinvertebrate taxonomic identification at Salmon Creek at 199th (SMN080), Upper Salmon Creek (SMN095) and reference site. Macroinvertebrate sampling: taxonomic identification at SMN080, SMN095 and reference site. This supports objectives #8 and #9.

Wet season low pH synoptic surveys (Base + Extended Network)

Given that existing data shows that low pH occurs during the wet season in response to storm events, field staff will respond to drops in pH (storm events) at the master station by conducting a wet season low pH synoptic survey. The synoptic survey will include collecting in situ pH and flow measurements at as many sites as possible in the upper Salmon and Curtin Creek subbasins (extended network; Figures 10 and 11), as well as at base network sites. Field staff will also collect total nitrogen, total phosphorus, and alkalinity samples, plus water quality and flow measurements, at SMN095 and the reference site (meets objective #7).

At a minimum, Ecology staff will check the weather forecast, streamflow, and stage levels from Clark County stream gage (real-time data online), and pH at the master station (real-time data online) at the beginning of each work week from November through February. If rain is forecasted for the week, staff will continually check the flows and pH levels online throughout the rest of the week.

If (1) pH levels drop below 6.8 standard units, (2) streamflow levels are rising, (3) and significant rain has fallen in the past 24 hours (or more rain is forecasted); then field staff will respond by performing a winter low pH synoptic survey. Ecology's response time will vary based on staff availability and other work commitments. The estimated response time to start of sampling is 4 hours (2 hours preparation and 2 hours driving).

Table 6. Data collection event schedule.

Data Collection Event	July 2011	Aug[1] 2011	Sept 2011	Oct 2011	Nov 2011	Dec 2011	Jan 2012	Feb 2012
Field reconnaissance	B, E							
Monthly: in situ water quality, rapid periphyton, nutrients at reference sites		B	B	B	B	B	B	B
Summer Synoptic Survey: Hydrolab deployments, nutrient sampling, and periphyton biomass		B						
Summer Synoptic Survey: In situ DO and water quality		E						
Periphyton and Macroinvertebrate identification[2]		R	R					
Winter Synoptic Survey: In situ pH and water quality at extended network during storm event					B,E	B,E	B,E	B,E

B: Base network sites; E: extended Network sites; R: reference comparison sites, which includes JON010, SMN080, and SMN095

[1] Synoptic survey week of 8/15/2011.

[2] Biological identification sampling will be collected once in either late August or September.

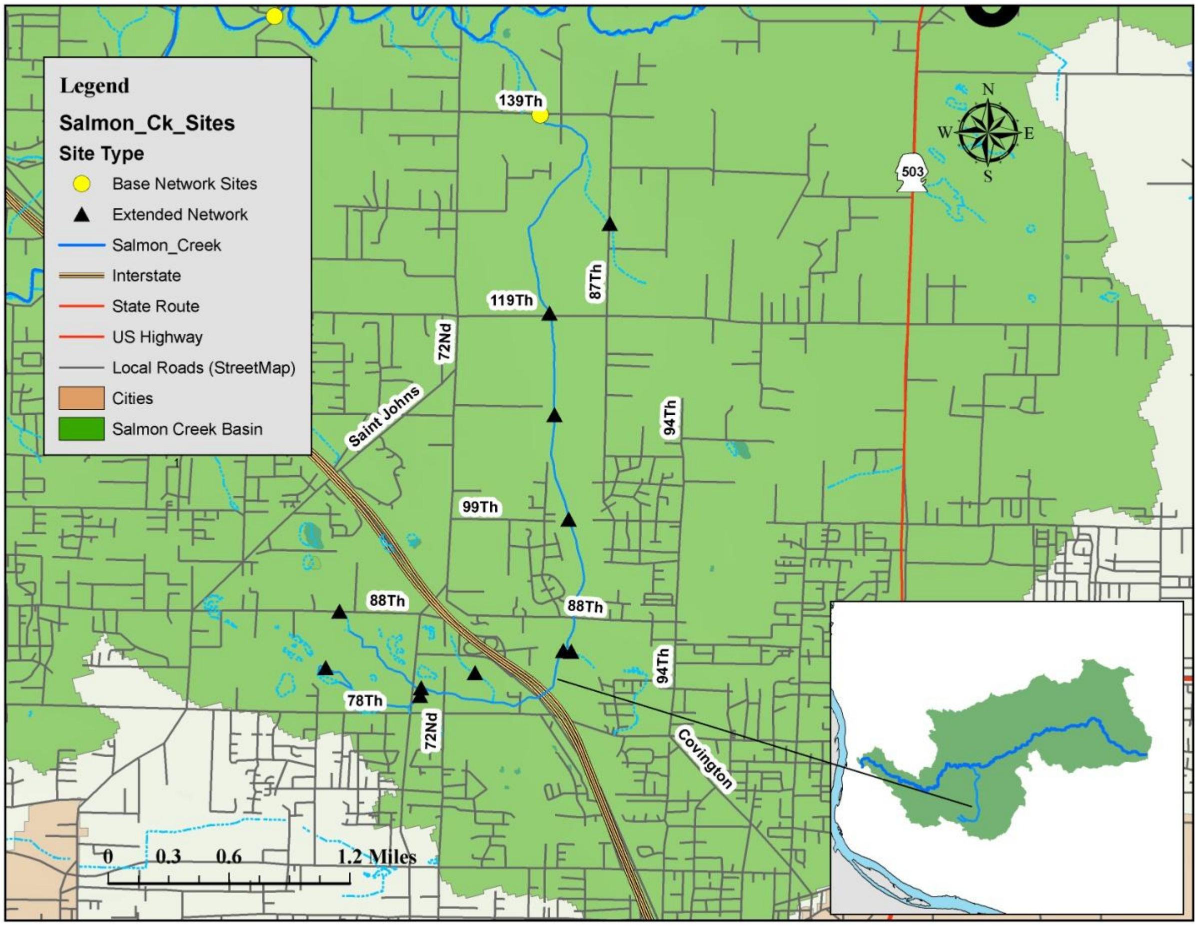

Figure 10. Potential extended network measurement sites in the Curtin Creek subbasin.

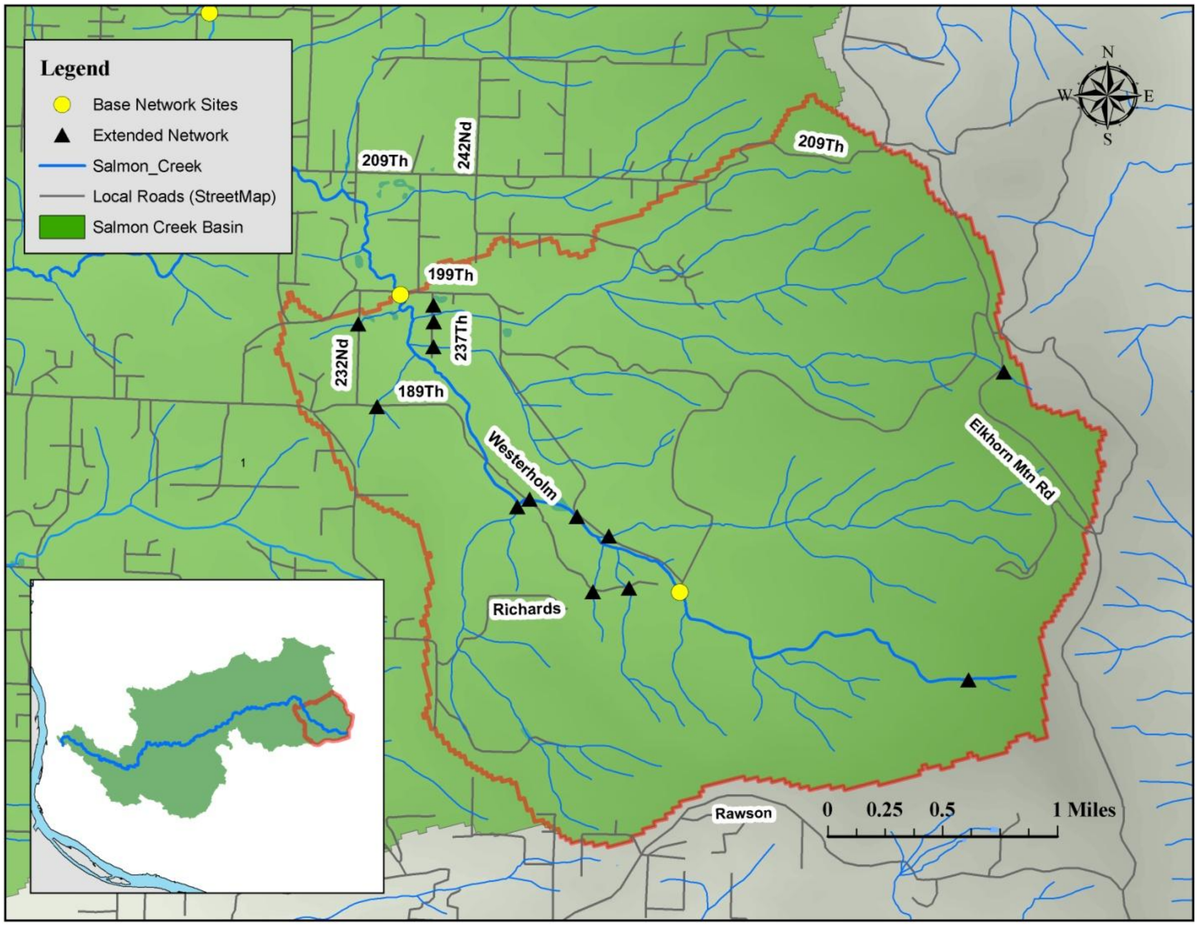

Figure 11. Potential extended network measurement sites in the upper Salmon Creek subbasin.

Sampling and Measurement Procedures

Field sampling and measurement protocols will follow Standard Operating Procedures (SOP) developed by the Environmental Assessment Program for TMDL development (Table 6) Field measurements for pH, DO, conductivity and temperature will be collected using a calibrated Hydrolab® sonde (Datasonde or Minisonde; Series 4 or 5). DO samples will be hand-collected using a displacement sampler and analyzed using the Winkler titration method (APHA, 2005; Ward and Mathieu, 2011). Field staff will measure instantaneous flows with a Marsh McBirney Flow-mate meter.

Table 6. Field sampling and measurement methods and protocols

Parameter	Measurement/ Sample Type	Lab Method	Field Protocol #
Water quality samples (see Table 2 for list)	Grab samples	See Table 2	EAP015 (Joy, 2006)
Dissolved Oxygen	Displacement Sample	SM 4500 OC	EAP023 (Ward and Mathieu, 2011)
DO, pH, Conductivity, ORP, Chl *a*, and Temperature	Hydrolab® multi-parameter sonde	n/a	EAP033 (Swanson, 2007)
Flow	Instantaneous	n/a	EAP024 (Sullivan, 2007)

Field staff will collect grab samples directly into pre-cleaned/sterilized containers supplied by MEL and described in the MEL User's Manual (2008). Table 7 lists the sample parameters, containers, volumes, preservation requirements, and holding times. Field staff will store samples for laboratory analysis on ice and deliver to MEL within 24 hours of collection via either the Ecology courier or direct drop-off after sampling.

Ecology will collect replicate field samples, in a side-by-side manner, for ten percent of all samples to assess field and lab variability.

MEL will follow their standard analytical methods following the MEL *Lab Users Manual* (MEL, 2008).

Periphyton and benthic macroinvertebrate identification samples will be collected following methods described in *Quality Assurance Monitoring Plan: Ambient Biological Monitoring in Rivers and Streams: Benthic Macroinvertebrates and Periphyton* (Adams, 2010).

In general, periphyton will be collected using a top scrape method and benthic macroinvertebrates using a D-net and kick-frame.

At the end of each field visit, field staff will clean field gear in accordance with the Standard Operating Procedure for minimizing the spread of invasive species for areas of moderate concern and extreme concern. This document is available at www.ecy.wa.gov/programs/eap/InvasiveSpecies/AIS-PublicVersion.html.

Table 7. Containers, preservation techniques, and holding times for sampled parameters.

Parameter	Sample Matrix	Container	Preservative	Holding Time
Alkalinity	Surface water, POTW effluent, & runoff	500 mL poly – NO Headspace	Cool to 0-6ºC; Fill bottle completely; Don't agitate sample.	14 days
Ammonia	Surface water, POTW effluent, & runoff	125 mL clear poly	H_2SO_4 to pH<2; Cool to 0-6°C.	28 days
Chloride	Surface water, POTW effluent, & runoff	500 mL w/m poly bottle	Cool to ≤6°C.	28 days
Chlorophyll a	Surface water, POTW effluent, & runoff	1000 mL amber poly bottle	Cool to ≤6°C; keep in dark.	24 hrs to filtration 28 days after filtration
Dissolved Organic Carbon	Surface water, POTW effluent, & runoff	60 mL poly with: 0.45 um pore size filters[1]	Filter in field with 0.45 um pore size filter; 1:1 HCl to pH<2; Cool to 0-6°C.	28 days
Nitrate/Nitrite	Surface water, POTW effluent, & runoff	125 mL clear poly	H_2SO_4 to pH<2; Cool to 0-6°C.	28 days
Total Persulfate Nitrogen	Surface water, POTW effluent, & runoff	125 mL clear poly	H_2SO_4 to pH<2; Cool to 0-6°C.	28 days
Orthophosphate	Surface water, POTW effluent, & runoff	125 mL amber poly w/ 0.45 um pore size filters[2]	Filter in field with 0.45 um pore size filter; Cool to 0-6°C.	48 hours
Total Phosphorus	Surface water, POTW effluent, & runoff	60 mL clear poly	1:1 HCl to pH<2; Cool to 0-6°C.	28 days
Total Organic Carbon	Surface water, POTW effluent, & runoff	60 mL clear poly	1:1 HCl to pH<2; Cool to 70-6°C.	28 days
Turbidity	Surface water, POTW effluent, & runoff	500 mL w/m poly bottle	48 hours	28 days

[1] Whatman PuradiscTM 25pp or equivalent, with a polypropylene media filter designed for aqueous and organic solutions containing high debris levels and for hard-to-filter solutions;
[2] Whatman GD/X 25mm or equivalent, with a cellulose acetate filter membrane. A glass microfiber prefilter may be used for "hard to filter" OP samples.

Quality Control Procedures

Total variation from field sampling and analytical processes will be assessed by collecting and analyzing replicate samples. Sample precision will be assessed by collecting replicates for approximately 10-20% of samples in each survey. MEL routinely duplicates sample analyses in the laboratory to determine the presence of bias in analytical methods. The difference between field variability and laboratory variability is an estimate of the sample field variability.

Field

Field sampling and measurements will follow quality control protocols described in Ecology's field sampling protocols (Table 6). If any of these quality control procedures are not met, the associated results will be qualified and used with caution, or not used at all.

Laboratory

All samples will be analyzed at MEL. The laboratory's measurement quality objectives and quality control procedures are documented in the MEL Quality Assurance Manual (MEL, 2006). MEL will follow standard quality control procedures (MEL, 2006).

Data Management Procedures

Field measurement data will be entered into a field book with waterproof paper in the field and then entered into Excel® spreadsheets (Microsoft, 2007) as soon as practical after returning from the field. This database will be used for preliminary analysis and to create a table to upload data into Ecology's Environmental Information Management (EIM) System.

Sample result data received from MEL by Ecology's Laboratory Information Management System (LIMS) will be exported prior to entry into EIM and added to a cumulative spreadsheet for laboratory results. This spreadsheet will be used to informally review and analyze data during the course of the project.

An EIM user study (NMat0004) has been created for this study and all monitoring data will be available via the internet once the project data has been validated. The URL address for this geospatial database is: www.ecy.wa.gov/eim/. All data will be uploaded to EIM by the EIM data engineer once it has been reviewed for quality assurance and finalized.

All spreadsheet files, paper field notes, and Geographic Information System software products created as part of the data analysis will be kept with the project data files.

Audits and Reports

Audits on field work and data analysis may be conducted at any time during the course of the project, by the project manager's unit supervisor. The project manager will be responsible for submitting a short technical report to the client for this project according to the project schedule. The report will include recommendations for the 303(d) listings for pH and DO.

The project manager may provide an addendum to the final report, beyond the current project schedule, after data collection has been completed at the 'master' station (SMN080) in September 2012. The addendum will be dependent on the implications of data results and available resources.

Data Verification and Validation

MEL will provide verification for laboratory-generated data. Data reduction, review, and reporting will follow the procedures outlined in the MEL *QA Manual* (MEL, 2006). Lab results will be checked for missing or improbable data. Variability in lab duplicates will be quantified using the procedures outlined in the MEL *QA Manual* (MEL, 2006). Any estimated results will be qualified and their use restricted as appropriate. A standard case narrative of laboratory Quality Assurance/ Quality Control (QA/QC) results will be sent to the project manager for each set of samples.

Field notebooks will be checked for missing or improbable measurements before leaving each site. The Excel® Workbook file containing field data will be labeled "DRAFT" until data verification and validation are completed. Data entry will be checked against the field notebook data for errors and omissions.

Field replicate sample results will be compared to quality objectives in Table 3. Data requiring additional qualifiers will be reviewed and verified by the project manager.

The project manager will validate data received from LIMS by:

- Checking for omissions against the "Request for Analysis" forms.
- Checking result values against expected range of results and data from previous surveys.

After data verification is complete, all field, laboratory, and flow data will be entered into Ecology's EIM system. An independent data reviewer will validate the EIM data by checking for errors following standard EAP protocols.

Once the EIM data has been validated, the project manager will compile all project data in a data summary report. Internal (within Ecology) and external (project stakeholders) reviewers will provide validation of the report.

Data Quality (Usability) Assessment

The project manager will verify that all measurement and data quality objectives have been met for each monitoring station. If the objectives have not been met (such as percent RSD for sample replicates exceeds the MQO), then the project manager will decide how to qualify the data and how it should be used in the analysis or whether it should be rejected. Documentation of the data quality assessment will be summarized in the final report and all assessment files will be archived with the project data.

The project manager will summarize data in the results section of final report and present the data analysis in the discussion section of the report. Results will be summarized using standard statistical measures and presented using tables and charts. Data analysis and discussion may include, but will not be limited to, statistical tests for significant differences between sites (for example upstream vs. downstream or SMN095 vs. reference site), comparison of data to other studies, and correlation analysis between parameters or sites. During data analysis, the project manager will evaluate the adequacy of the study design, based on the results, to draw conclusions and make recommendations.

The project manager will handle any non-detects (sample results below the reporting limit) using methods described in Chapter 13, “Methods for Data Below the Reporting Limit,” of Helsel and Hirsch (2002). In general, the robust probability plot method will be used to calculate summary statistics for parameters with results below the reporting limit.

Organization and Schedule

Table 8 lists the people involved in this project. All are employees of the Washington State Department of Ecology. Table 9 presents the proposed schedule for this project. The schedule may be limited by staff workload priorities or date that all lab data is received.

Table 8. Organization of project staff and responsibilities.

Staff (all are EAP except client)	Title	Responsibilities
Brett Raunig Water Quality Program Vancouver Field Office Phone: 360-690-4660	EAP Client	Clarifies scopes of the project. Provides internal review of the QAPP and approves the final QAPP.
Nuri Mathieu Directed Studies Unit Western Operations Section Phone: 360-407-7359	Project Manager and Principal Investigator	Writes the QAPP. Oversees field sampling and transportation of samples to the laboratory. Conducts QA review of data, analyzes and interprets data, and enters data into EIM. Writes the draft report and final report.
George Onwumere Directed Studies Unit Western Operations Section Phone: 360-407-6730	Unit Supervisor for the Project Manager	Reviews the project scope and budget. Tracks progress. Provides internal review of the QAPP, approves the budget, and approves the final QAPP.
Robert F. Cusimano Western Operations Section Phone: 360-407-6596	Section Manager for the Project Manager	Reviews the draft QAPP and approves the final QAPP.
Stuart Magoon Manchester Environmental Laboratory Phone: 360-871-8801	Director	Approves the final QAPP.
William R. Kammin Phone: 360-407-6964	Ecology Quality Assurance Officer	Reviews the draft QAPP and approves the final QAPP.

EAP: Environmental Assessment Program.
EIM: Environmental Information Management database.
QAPP: Quality Assurance Project Plan.

Table 9. Proposed schedule for completing field and laboratory work, data entry into EIM, and reports.

Field and laboratory work	Due date	Lead staff
Field work completed	Feb 2012	Nuri Mathieu
Continuous station removal	Sept 2012	Bill Ward
Laboratory analyses completed	Feb 2012	
Environmental Information System (EIM) database		
EIM user study ID	NMat0004	
Product	Due date	Lead staff
EIM data loaded	April 2012	Nuri Mathieu
EIM quality assurance	May 2012	George Onwumere
EIM complete	June 2012	Nuri Mathieu
Final report		
Author lead	Nuri Mathieu	
Schedule		
Draft due to supervisor	March 2012	
Draft due to client/peer reviewer	March 2012	
Draft due to external reviewer(s)	April 2012	
Final (all reviews done) due to publications coordinator	Mid-June 2012	
Final report due on web	July 2012	

Laboratory Budget

Table 10 summarizes the laboratory costs for the study. Ecology's Manchester Environmental Laboratory (MEL) will perform all analyses, with the exception of identification of macroinvertebrate and periphyton samples, which will be subcontracted out. Project laboratory costs include a 50% discount for using MEL.

Table 10. Lab budget for the 2011-12 study.

Parameter/analysis	Samples	Replicates	Field blanks	Total Samples	$/ sample	Subtotal
Summer Synoptic Productivity Survey						
Turbidity	12	1	1	14	$11	$160
Alkalinity	12	1	1	14	$18	$247
Chloride	12	1	1	14	$13	$182
Chlorophyll a - water	5	1	1	7	$57	$400
Chlorophyll a - plant tissue	10	0	0	10	$57	$571
Total Persulfate Nitrogen (TPN)	12	1	1	14	$18	$247
NH3	24	2	1	27	$13	$364
NO2/NO3	24	2	1	27	$13	$364
Ortho P	24	2	1	27	$16	$420
TP - colorimetric	12	1	1	14	$19	$262
Dissolved Organic Carbon	12	1	1	14	$37	$523
Total Organic Carbon	12	1	1	14	$34	$480
						$4,220
Monthly Nutrient/Winter Low pH Sampling						
Total Persulfate Nitrogen (TPN)	12	1	1	14	$18	$247
TP - colorimetric	12	1	1	14	$19	$262
Alkalinity	8	1	1	10	$18	$176
						$685
Macroinvertebrate/Periphyton ID						
Macroinvertebrate ID (contract)	3	1	n/a	4	$295	$1,180
Periphyton ID (contract)	3	1	n/a	4	$300	$1,200
						$2,380
					Total	**$7,285**

References

Adams, K., 2010. Quality Assurance Monitoring Plan: Ambient Biological Monitoring in Rivers and Streams: Benthic Macroinvertebrates and Periphyton. Washington State Department of Ecology, Olympia, WA. Publication No. 10-03-109. www.ecy.wa.gov/biblio/1003109.html

APHA, AWWA, and WEF, 2005. Standard Methods for the Examination of Water and Wastewater; 21st Edition; American Public Health Association, Washington, D.C.

Collyard, S., 2009. Salmon Creek Nonpoint Source Pollution Total Maximum Daily Load: Water Quality Effectiveness Monitoring Report. Washington State Department of Ecology, Olympia, WA. Publication No. 09-03-042. www.ecy.wa.gov/biblio/0903042.html

Cusimano, R.F. and D. Giglio, 1995. Salmon Creek Nonpoint Source Pollution TMDL. Washington State Department of Ecology, Olympia, WA. Publication No. 95-355. www.ecy.wa.gov/biblio/95355.html

EPA, 2005. EPA Region 10 Natural Conditions Workgroup Report on Principles to Consider When Reviewing and Using Natural Conditions Provisions. U.S. Environmental Protection Agency, Region 10, Office of Water and Watersheds.

Helsel, D.R. and R.M. Hirsch, 2002. Statistical Methods in Water Resources. Techniques of Water-Resources Investigations of the United States Geological Survey. Book 4, Hydrologic Analysis and Interpretation. U.S. Geological Survey.

Joy, J., 2006. Standard Operating Procedure for Manually Obtaining Surface Water Samples, Version 1.0. Washington State Department of Ecology, Olympia, WA. SOP Number EAP015. www.ecy.wa.gov/programs/eap/quality.html

Lombard, S. and C. Kirchmer, 2004. Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies. Washington State Department of Ecology, Olympia, WA. Publication No. 04-03-030. www.ecy.wa.gov/biblio/0403030.html

Mathieu, N., 2006. Replicate Precision for 12 TMDL Studies and Recommendations for Precision Measurement Quality Objectives for Water Quality Parameters. Washington State Department of Ecology, Olympia, WA. Publication No. 06-03-044. www.ecy.wa.gov/biblio/0603044.html

MEL, 2006. Manchester Environmental Laboratory Quality Assurance Manual. Manchester Environmental Laboratory, Washington State Department of Ecology, Manchester, WA.

MEL, 2008. Manchester Environmental Laboratory Lab Users Manual, Ninth Edition. Manchester Environmental Laboratory, Washington State Department of Ecology, Manchester, WA.

Microsoft, 2007. Microsoft Office XP Professional, Version 10.0. Microsoft Corporation.

Mundorff, M.J., 1964. Geology and ground-water conditions of Clark County, Washington, with a description of a major alluvial aquifer along the Columbia River. U.S. Geological Survey. Water Supply Paper 1600.

NADP, 2011. Data accessed on 6/28/2011. National Atmospheric Deposition Program. http://nadp.sws.uiuc.edu/Default.aspx

Sullivan, L., 2007. Standard Operating Procedure for Estimating Streamflow, Version 1.0. Washington State Department of Ecology, Olympia, WA. SOP Number EAP024. www.ecy.wa.gov/programs/eap/quality.html

Swanson, T., 2007. Standard Operating Procedure for Hydrolab®, DataSonde®, and MiniSonde® Multiprobes, Version 1.0. Washington State Department of Ecology, Olympia, WA. SOP Number EAP033. www.ecy.wa.gov/programs/eap/quality.html

Turney, G.L., 1990. Quality of Groundwater in Clark County, Washington, 1988. United States Geological Survey. Water Resource Investigation Report 90-4149. Tacoma, WA.

WAC 173-201A. Water Quality Standards for Surface Waters in the State of Washington Washington State Department of Ecology, Olympia, WA. www.ecy.wa.gov/laws-rules/ecywac.html

Ward, W.J. and N. Mathieu, 2011. Standard Operating Procedures for the Collection and Analysis of Dissolved Oxygen (Winkler Method), Version 2.1. Washington State Department of Ecology, Olympia, WA. SOP Number EAP023. www.ecy.wa.gov/programs/eap/quality.html

Western Regional Climate Center (WRCC), 2011. Data summary for Battle Ground, Washington COOP site (#450482). Period of Record 5/27/1928 to 12/31/10. Accessed on 6/16/2011. www.wrcc.dri.edu/summary/Climsmwa.html

Appendix. Glossary, Acronyms, and Abbreviations

Glossary

Ambient: Background or away from point sources of contamination.

Clean Water Act: A federal act passed in 1972 that contains provisions to restore and maintain the quality of the nation's waters. Section 303(d) of the Clean Water Act establishes the TMDL program.

Conductivity: A measure of water's ability to conduct an electrical current. Conductivity is related to the concentration and charge of dissolved ions in water.

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

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

Effluent: An outflowing of water from a natural body of water or from a man-made structure. For example, the treated outflow from a wastewater treatment plant.

Eutrophication: An increase in productivity resulting from human activities such as fertilizer runoff and leaky septic systems.

Nonpoint source: Pollution that enters any waters of the state from any dispersed land-based or water-based activities. This includes, but is not limited to, atmospheric deposition, surface-water runoff from agricultural lands, urban areas, or forest lands, subsurface or underground sources, or discharges from boats or marine vessels not otherwise regulated under the NPDES program. Generally, any unconfined and diffuse source of contamination. Legally, any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act.

Nutrient: Substance such as carbon, nitrogen, and phosphorus used by organisms to live and grow. Too many nutrients in the water can promote algal blooms and rob the water of oxygen vital to aquatic organisms.

Parameter: A physical chemical or biological property whose values determine environmental characteristics or behavior.

pH: A measure of the acidity or alkalinity of water. A low pH value (0 to 7) indicates that an acidic condition is present, while a high pH (7 to 14) indicates a basic or alkaline condition. A pH of 7 is considered to be neutral. Since the pH scale is logarithmic, a water sample with a pH of 8 is ten times more basic than one with a pH of 7.

Point source: Sources of pollution that discharge at a specific location from pipes, outfalls, and conveyance channels to a surface water. Examples of point source discharges include municipal wastewater treatment plants, municipal stormwater systems, industrial waste treatment facilities, and construction sites that clear more than 5 acres of land.

Pollution: Contamination or other alteration of the physical, chemical, or biological properties of any waters of the state. This includes change in temperature, taste, color, turbidity, or odor of the waters. It also includes discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state. This definition assumes that these changes will, or is likely to, create a nuisance or render such waters harmful, detrimental, or injurious to (1) public health, safety, or welfare, or (2) domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or (3) livestock, wild animals, birds, fish, or other aquatic life.

Salmonid: Any fish that belong to the family *Salmonidae*. Basically, any species of salmon, trout, or char. www.fws.gov/le/ImpExp/FactSheetSalmonids.htm

Stormwater: The portion of precipitation that does not naturally percolate into the ground or evaporate but instead runs off roads, pavement, and roofs during rainfall or snow melt. Stormwater can also come from hard or saturated grass surfaces such as lawns, pastures, playfields, and from gravel roads and parking lots.

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

Synoptic survey: Data collected simultaneously or over a short period of time.

Total Maximum Daily Load (TMDL): A distribution of a substance in a waterbody designed to protect it from not meeting (exceeding) water quality standards. A TMDL is equal to the sum of all of the following: (1) individual wasteload allocations for point sources, (2) the load allocations for nonpoint sources, (3) the contribution of natural sources, and (4) a margin of safety to allow for uncertainty in the wasteload determination. A reserve for future growth is also generally provided.

Turbidity: A measure of water clarity. High levels of turbidity can have a negative impact on aquatic life.

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

303(d) list: Section 303(d) of the federal Clean Water Act requires Washington State to periodically prepare a list of all surface waters in the state for which beneficial uses of the water – such as for drinking, recreation, aquatic habitat, and industrial use – are impaired by pollutants. These are water quality-limited estuaries, lakes, and streams that fall short of state surface water quality standard and are not expected to improve within the next two years.

Acronyms and Abbreviations

Following are acronyms and abbreviations used frequently in this report.

e.g.	For example
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
et al.	And others
MEL	Manchester Environmental Laboratory
MQO	Measurement quality objective
QA	Quality assurance
RPD	Relative percent difference
RSD	Relative standard deviation
SOP	Standard operating procedures
TMDL	(See Glossary above)
USGS	U.S. Geological Survey
WAC	Washington Administrative Code

Units of Measurement

°C	degrees centigrade
ft	feet
g	gram, a unit of mass
m	meter
mg/L	milligrams per liter (parts per million)
mL	milliliters
mm	millimeter
ng/Kg	nanograms per kilogram (parts per trillion)
NTU	nephelometric turbidity units
s.u.	standard units
um	micrometer
uS/cm	microsiemens per centimeter, a unit of conductivity