



# Weaver Creek (Mason County) Fecal Coliform Attainment Monitoring Report

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## Abstract

In 2007, the Washington State Department of Ecology (Ecology) published a water quality attainment monitoring report on the Skokomish River basin. The study concluded that all the sites assessed, with the exception of Weaver Creek, met the 2001 Total Maximum Daily Load (TMDL) target limits for fecal coliform bacteria (FC).

In 2015, Ecology developed an addendum to the original attainment monitoring Quality Assurance Project Plan. The purpose of the resulting study was to provide data to determine if Weaver Creek is currently meeting the original TMDL target limits for FC.

Results from the 2015 study indicate that FC standards were met in Weaver Creek at the TMDL target location; however, established critical season (May-Feb) FC target concentrations were not met. Also, two upstream locations in Weaver Creek, in addition to Hunter Creek, did not meet FC water quality standards.

The likely source of FC in Weaver Creek is livestock activities along the creek upstream of the Skokomish Valley Road Bridge.

## Publication Information

This report is available on the Department of Ecology's website at <https://fortress.wa.gov/ecy/publications/SummaryPages/1703002.html>

Data for this project are available at Ecology's Environmental Information Management (EIM) website [www.ecy.wa.gov/eim/index.htm](http://www.ecy.wa.gov/eim/index.htm). Search Study ID, scol0001.

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## Contact Information

Author: Scott Collyard  
Environmental Assessment Program  
P.O. Box 47600  
Olympia, WA 98504-7600

Communications Consultant  
Phone: (360) 407-6764

Washington State Department of Ecology - [www.ecy.wa.gov/](http://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, Union Gap (509) 575-2490
- Eastern Regional Office, Spokane (509) 329-3400

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## Background

Ecology's 2007 water quality attainment monitoring report on the Skokomish River basin concluded that all the sites assessed, with the exception of Weaver Creek, met the 2001 TMDL target limits for FC (Sargeant and Hempleman, 2007; Seiders et al., 2001). Although Weaver Creek met the *Extraordinary Primary Contact* water quality standard (50 cfu/100 mL) for recreation, an additional 20% reduction in FC levels was needed to meet the required downstream TMDL target value. Since 2007, additional water cleanup activities have occurred on Weaver Creek.

In 2015, an addendum to the original attainment monitoring Quality Assurance Project Plan (QAPP) (Batts, 2005) was developed (Collyard, 2009). The resulting study was to provide sufficient data to determine if Weaver Creek is currently meeting the original TMDL target limits for FC.

## Project Goals and Study Objectives

The 2015 project goal was to evaluate whether TMDL implementation actions for FC have resulted in Weaver Creek meeting the TMDL target limit.

The project goal was met through the following objectives:

- Determine if FC targets set by the 2001 TMDL study are being met.
- Determine if Washington State water quality standards for FC are being met.

## Study Design

FC concentrations were sampled every other week from sampling site Bourgault Rd. Bridge (BRB) on Weaver Creek from January through December of 2015. An additional four sites were sampled to determine sources and extent of FC pollution.

To stay consistent with the original TMDL analysis, water samples from all stations were analyzed by the Most Probable Number (MPN) method.

Additional information about the study design can be found in the QAPP addendum (Collyard, 2009). Quality assurance and control results are presented in Appendix B.

## Sampling Locations

The 2001 TMDL study (Seiders et al., 2001) identified FC target limits required to meet water quality standards on Weaver Creek at river mile 1.0 (BRB). The recommended FC concentrations and targets are presented in Table 1 as geometric mean values (GMV) and 90<sup>th</sup> percentiles, including the reduction requirement. In 2015, additional sites were sampled to help identify potential sources of FC pollution (Figure 1, Table 2).

Table 1. Weaver Creek TMDL recommended FC targets, TMDL results, and TMDL attainment monitoring results for the critical period (May-February).

Sampling Site	2001 TMDL Study		2015 TMDL Target		Required change
	GMV FC/100ml	Geometric 90 <sup>th</sup> %tile FC/100ml	GMV FC/100ml	Geometric 90 <sup>th</sup> %tile FC/100ml	
Weaver Creek (BRB)	55.0	314.6	17.5	100.0	-20%

GMV: geometric mean value.

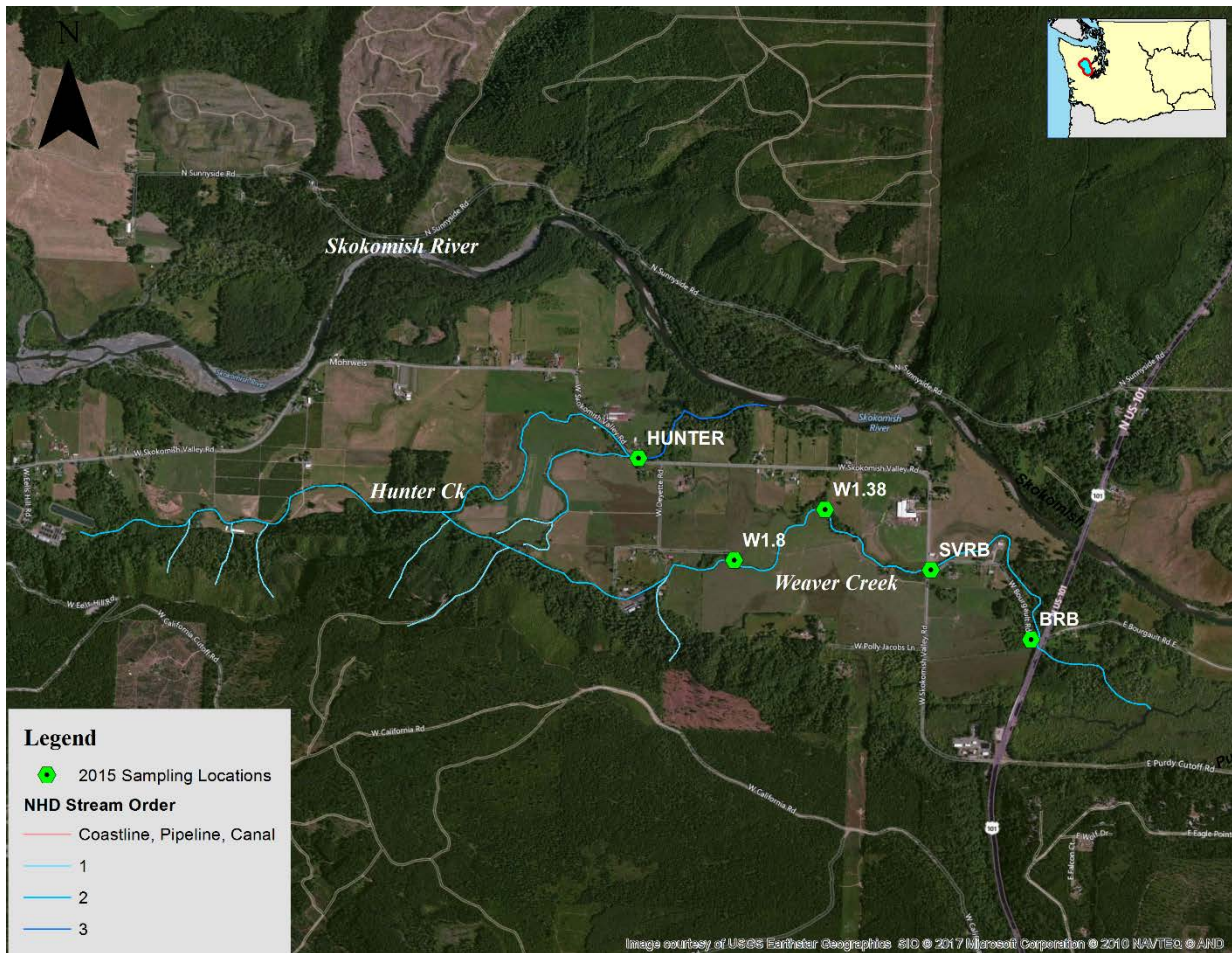


Figure 1. Weaver Creek FC sampling locations, 2015.

Table 2. Auxiliary information for Weaver Creek sampling locations.

Location ID	Station Description	Latitude	Longitude
BRB	Weaver Creek at W Bourgault Rd. Bridge	47.3088	-123.1857
W1.0	Weaver Creek at W Skokomish Bridge	47.30872	-123.18575
W1.38	Weaver Creek at Mason County Property	47.31099	-123.19199
W1.8	Weaver Creek at W Deyette Rd.	47.30882	-123.19782
HUNTER	Hunter Creek at Skokomish Valley Rd.	47.31281	-123.20317

## Results

### Water Quality Standards and Targets

During the 2015 attainment monitoring study, FC levels met the TMDL critical season water quality standard for FC in Weaver Creek at BRB and at river mile 1.8 (W1.8; Figure 2). However, FC levels failed to meet TMDL target established at BRB (Table 3). FC did not meet the critical season water quality standards at river mile 1.38 (W1.38), Skokomish Valley Road Bridge (SVRB), and Hunter Creek (HUNTER) sites (Figure 2, Table 3).

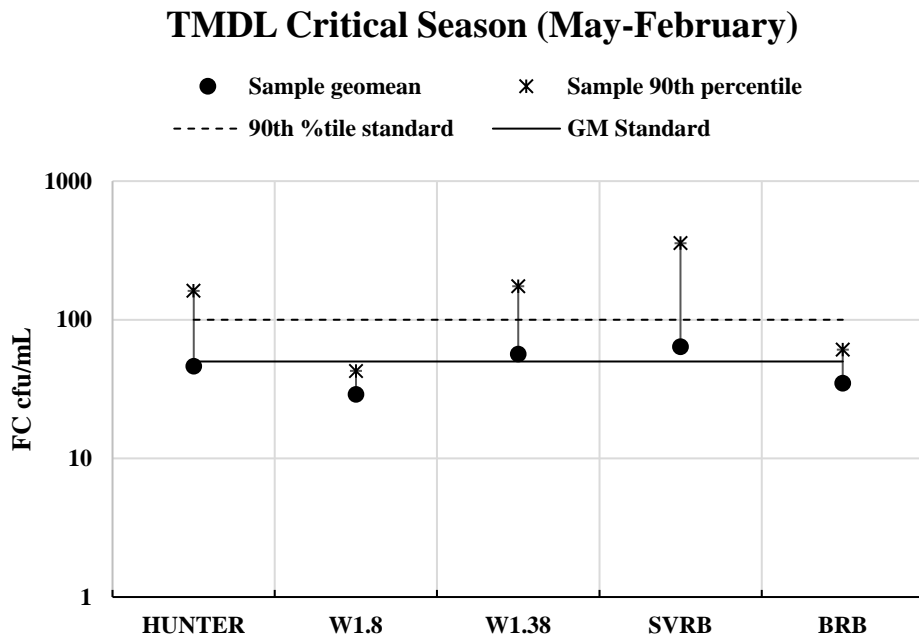


Figure 2. Weaver Creek critical season FC results for the 2015 attainment monitoring stations.

Table 3. Weaver Creek TMDL recommended FC target, and TMDL attainment monitoring results for the critical period (May-February).

Sampling Site	2001 TMDL Target		2015 Attainment Monitoring Study		Meets Water Quality Standards?	Meets TMDL Targets?
	GM FC/100ml	Geometric 90 <sup>th</sup> %tile FC/100ml	GM FC/100ml	Geometric 90 <sup>th</sup> %tile FC/100ml		
BRB	17.5	100.0	35	61	Yes	No
SVRB	-	-	64	356	No	-
W1.38	-	-	57	174	No	-
W1.8	-	-	29	43	Yes	-
Hunter	-	-	46	162	No	-

GM: Geometric Mean  
 - Not determined.

### Water Quality Trends

To determine if FC concentrations are declining in Weaver Creek, FC results from the TMDL target station (BRB) from previous attainment monitoring studies were compared over time (Collyard, 2009). Also, FC data collected by the Skokomish Tribe from Hunter Creek and Weaver Creek at the Skokomish Valley Road Bridge (SVRB) were assessed for long-term trends using ordinary least squares (OLS) regression (Appendix C). The Tribe has collected monthly FC data at SVRB from 1995 through the present. The Tribe conducts membrane filter analysis to determine FC counts; samples are collected under the guidance of a QAPP (Dublanica, 2005).

Figure 3 compares BRB station geometric mean (GM) and 90<sup>th</sup> percentile FC results by year for the TMDL critical season (May-February). Results show that FC levels at BRB are variable over time; however, the FC GM mean has remained below the 50 cfu GM standard over the five years assessed. In addition, the 90<sup>th</sup> percentile FC has been below the 100 cfu standard during three of the five years assessed.

Results of OLS regression analysis indicate that FC concentrations have declined steadily from 1995-2015 in both Hunter and Weaver Creeks (Figure 4). The FC decline was significant at both locations as indicated by p-values of <0.05 (Appendix C).

### BRB Critical Season (May-February)

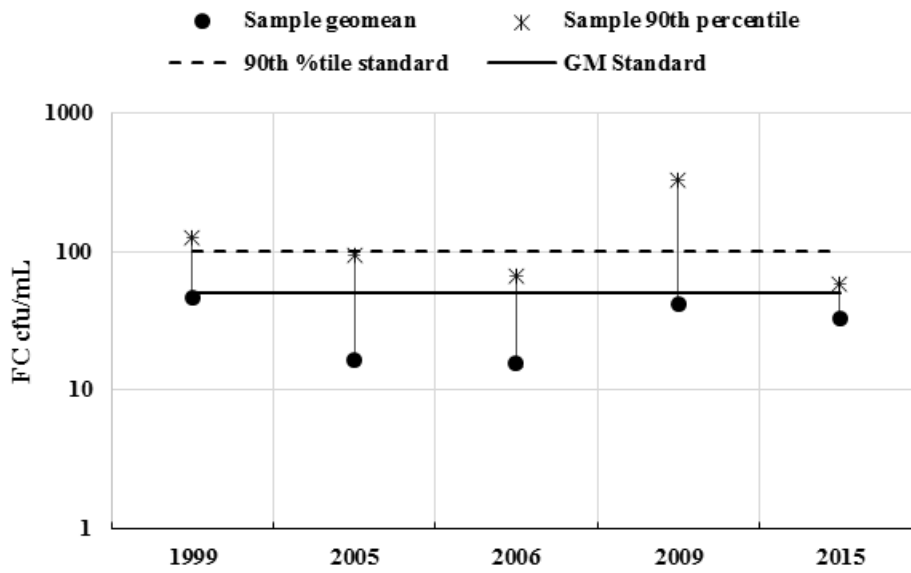
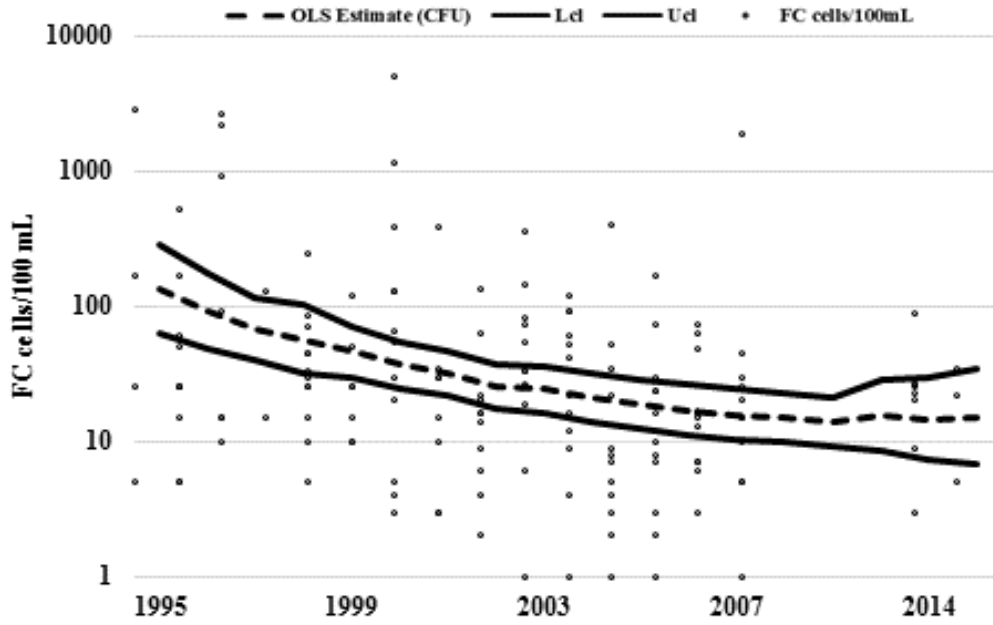


Figure 3. Study results comparison for FC: 1999 TMDL and 2005, 2006, 2009-10, and 2015 attainment monitoring.

### A. Weaver Creek



### B. Hunter Creek

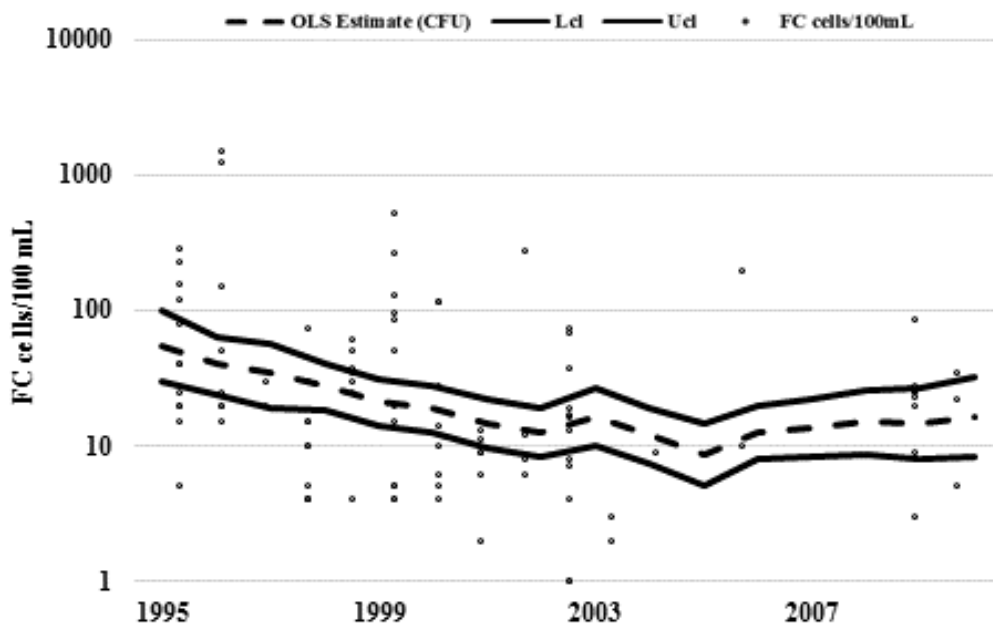


Figure 4. Results of ordinary least squares (OLS) regression for FC data from:  
(A) Weaver Creek at Skokomish Valley Road Bridge (SVRB).  
(B) Hunter Creek at Skokomish Valley Road Bridge crossing.



## Field Observations

During the 2015 study, field staff noted the presence and absence of livestock in pastures boarding Hunter and Weaver Creeks during sampling events. Using GIS and aerial photographs, livestock pastures were delineated into nine distinct areas, and the presence and absence values were summed for each pasture over the sampling period (Figure 5). These results were compared with the average yearly FC concentrations at all sampling locations. The resulting map suggests that pastures with the greatest presence of livestock (as noted during 2015 sampling), were located between sites SVRB and W1.8. Average yearly FC levels were highest in Hunter Creek and in Weaver Creek between W1.8 and SVRB (Figure 5).

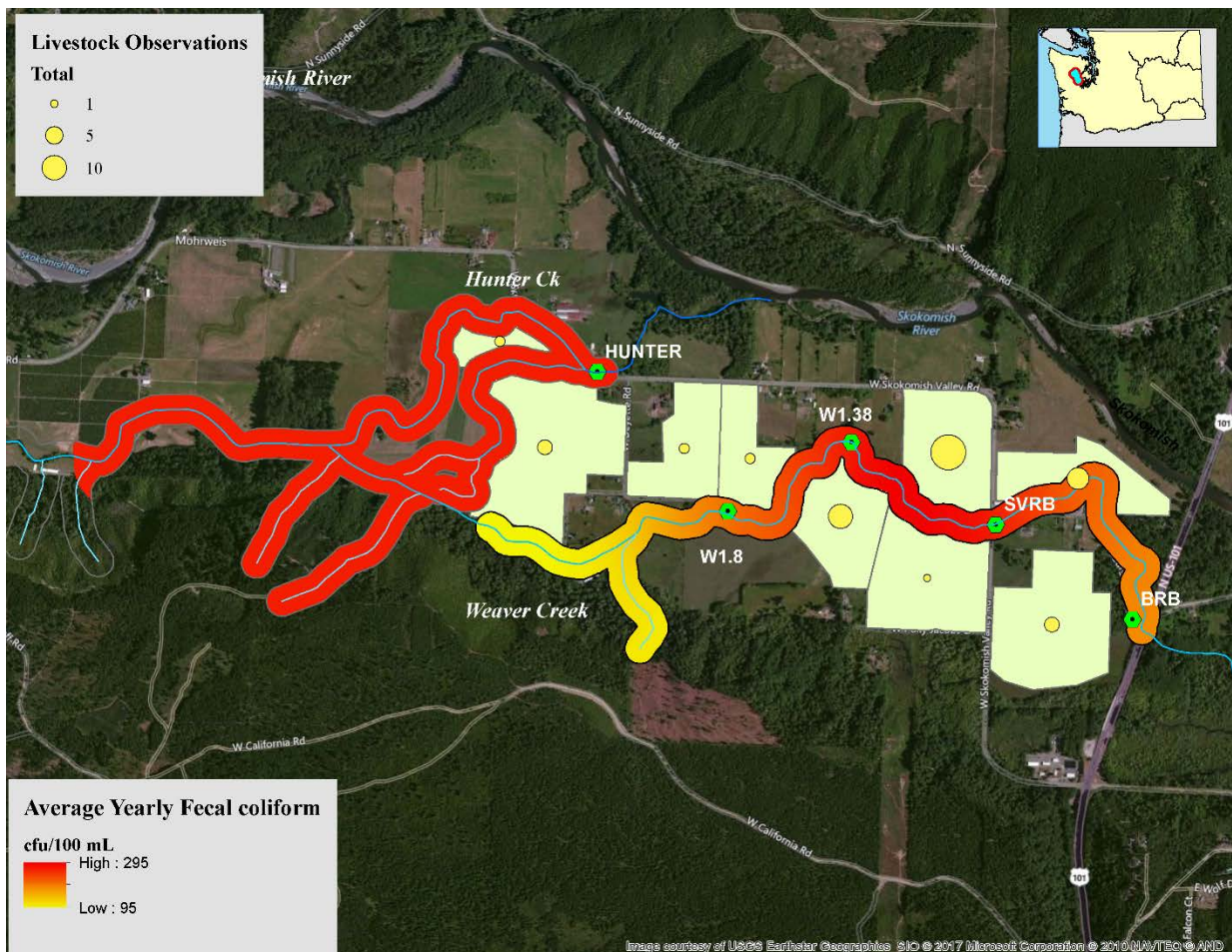


Figure 5. Observations of livestock in the Weaver Creek watershed during 2015 sampling.

## Conclusions and Recommendations

Results of this 2015 study support the following conclusions and recommendation.

- Although fecal coliform bacteria (FC) levels in Weaver Creek at Bourgault Road Bridge (BRB) met critical season (May-Feb) water quality standards, FC levels did not meet the TMDL established critical season target limits.
- Critical season FC standards were not met in Weaver Creek at BRB, Skokomish Valley Road Bridge (SVRB), and at river mile 1.38 (W1.38), and also in Hunter Creek (Hunter). No FC target limits have been establish for these locations.
- Results of long-term FC trend analysis determined by the Skokomish Tribe indicate FC levels on both Weaver and Hunter Creeks have been declining during 1995-2015. FC levels are still not meeting critical season water quality standards.
- Livestock observations made during the 2015 sampling may suggest a correlation between grazing livestock and elevated FC in Weaver Creek.
- Recommend continuing to work with land owners to limit cattle access and protect riparian areas adjacent to Hunter Creek and Weaver Creek between the Skokomish Valley Road Bridge and river mile 1.8 (W1.8).

## References

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Seiders, K., G. Hoyle-Dodson, and P. Pickett, 2001. Skokomish River Basin Fecal Coliform Bacteria Total Maximum Daily Load Study. Washington State Department of Ecology, Olympia, WA. Publication No. 01-03-014.

<https://fortress.wa.gov/ecy/publications/SummaryPages/0103014.html>

# Appendix A. Glossary, Acronyms, and Abbreviations

## Glossary

**Extraordinary Primary Contact:** Waters providing extraordinary protection against waterborne disease or that serve as tributaries to extraordinary quality shellfish harvesting areas.

**Fecal Coliform Bacteria (FC):** That portion of the coliform group of bacteria which is present in intestinal tracts and feces of warm-blooded animals as detected by the product of acid or gas from lactose in a suitable culture medium within 24 hours at 44.5 plus or minus 0.2 degrees Celsius. FC are “indicator” organisms that suggest the possible presence of disease-causing organisms. Concentrations are measured in colony forming units per 100 milliliters of water (cfu/100 mL).

**Geometric Mean (GM):** A mathematical expression of the central tendency (an average) of multiple sample values. A geometric mean, unlike an arithmetic mean, tends to dampen the effect of very high or low values, which might bias the mean if a straight average (arithmetic mean) were calculated. This is helpful when analyzing bacteria concentrations, because levels may vary anywhere from ten to 10,000 fold over a given period. The calculation is performed by either: (1) taking the nth root of a product of n factors, or (2) taking the antilogarithm of the arithmetic mean of the logarithms of the individual values.

**Riparian:** Relating to the banks along a natural course of water.

**Total Maximum Daily Load (TMDL):** A distribution of a substance in a waterbody designed to protect it from 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.

## Acronyms

BRB	Bourgault Road Bridge sampling site
FC	(See Glossary above)
Ecology	Washington State Department of Ecology
GM	(See Glossary above)
GMV	Geometric mean value
OLS	Ordinary least squares
QAPP	Quality Assurance Project Plan
SVRB	Skokomish Valley Road Bridge sampling site
TMDL	(See Glossary above)

## Appendix B. Quality Assurance and Quality Control Results

Ecology's Manchester Environmental Laboratory analyzed FC samples in accordance with their quality assurance/quality control procedures (MEL, 2006). The laboratory used the FC most probable number (MPN) method 9221 EW (APHA, 1998).

All data quality objectives specified in the original QAPP (Batts, 2005) were met for the 2015 study (Table B-1). The TMDL specified acceptable precision for the total data set of duplicate pairs as root mean square of the coefficient of variation (RMSCV%) equal to or less than 45%. Table B-1 presents the precision estimates for FC data.

### B-1. Precision estimate for 2015 study FC data.

Parameter	Replicate Pairs	Number of Samples	Duplicate Rate	Completeness	RMSCV <sup>1</sup>
Fecal coliform	23	115	20%	100%	38%

<sup>1</sup> Root mean square coefficient of variation; consistent with Seiders et al. (2001).

## Appendix C. Fecal Coliform Trend Results

Ordinary least squares (OLS) regression was used to test for FC trends and nutrient data. The OLS regression analysis is based on linear regression of the water quality parameter against time. Variability in the data was reduced by including the variables month, year, and year<sup>2</sup> in the OLS regression analysis. The resulting FC residual data were then averaged by month and plotted over time. This approach was used for long-term data collected by the Skokomish Tribe. All FC data were log normalized before regression analysis was performed. P values of <0.05 indicate if the relationship between the variables is significant. The coefficient indicates the direction of the trend (negative or positive) as well as the rate of change over time.

C-1. Results of ordinary least squares (OLS) regression test from long-term water quality monitoring data collected by the Skokomish Tribe.

Site	Parameter	SS	Df	Mean Squares	F-Ratio	Trend	p-value
SVRB	FC	62.249	2	31.124	56.608	-	<b>0.000</b>
Hunter	FC	5.760	3	1.920	5.840	-	<b>0.001</b>

SS: Sum of squares.

**Bold** text indicates p-Value for regression model is <0.05.

F-Ratio: Variance

C-2. Systat results for OLS regression analysis.

Site	Parameter	N	Multiple R	Multiple R <sup>2</sup>	ASMR	SE
SVRB	FC	167	0.639	0.408	0.401	0.742
Hunter	FC	108	0.380	0.144	0.119	0.573

N: number

ASMR: adjusted squared multiple R

SE: standard error of estimate

C-3. Results of OLS regression analysis for SVRB.

Effect	Coefficient	SE	Std. Coefficient	Tolerance	p-value
CONSTANT	67512.226	6936.888	0.000	.	0.000
YEAR	-67.389	6.920	-379.604	0.000	0.000
YEAR <sup>2</sup>	0.017	0.002	379.861	0.000	0.000

C-4. Results of OLS regression analysis for Hunter.

Effect	Coefficient	SE	Std. Coefficient	Tolerance	p-value
CONSTANT	19348.103	6715.790	0.000	.	0.005
YEAR	-19.268	6.697	-191.924	0.000	0.005
YEAR <sup>2</sup>	0.005	0.002	191.681	0.000	0.005