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Lower Salmon Creek Watershed

Fecal Coliform Monitoring On Select Tributaries

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by

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Abstract

Fecal coliform (FC) bacteria criteria are set by Washington State Department of Ecology (Ecology) to protect people who work and play in and on the water from waterborne illnesses. The criteria for bacteria in Salmon Creek and its tributaries are set to protect primary contact recreation. A TMDL technical report published by Ecology in 1995 (Cusimano and Giglio) reflected that certain sites on the main stem and its tributaries were exceeding the water quality standards. However, a recent effectiveness monitoring study by Ecology (Collyard, 2009), analyzed FC data from 2005-2007 that had been collected by Clark County at the same historic sites used for the TMDL. The analysis of these data reflect that implementation efforts conducted by the local jurisdictions and community members, and land-use changes, have resulted in a reduction of bacterial contamination at some of the long-term monitoring sites.

Clark County implemented a follow-up monitoring project was established in 2007 and 2008 (Hoxeng, 2009) focusing on the lower tributaries to Salmon Creek. Many of the sites had little to no previous water quality data. Data from this focused study showed that *none* of the monitoring stations met the Primary Contact state water quality criteria for FC.

Ecology's 2014/2015 project focused on the lower Salmon Creek watershed downstream of Brush Prairie. Ecology staff sampled select lower tributaries as well as some main stem Salmon Creek locations. The goal of this project was to identify sources of FC to the lower Salmon Creek and provide additional information for the local-jurisdictions on key areas to focus implementation efforts.

During 2014/2015, the majority of the monitoring stations exceeded the Primary Contact criteria for FC when looking at data for the entire sampling period as well as during the dry season (June – October). Most of the site specific locations met the FC criteria during the wet season (November through May).

Without bacterial loading calculations (flow measurements were not taken) we were not able to confidently pinpoint specific source reaches even with bracketed sampling. Focusing in on one or a few streams, taking flow measurements, and calculating loads could be beneficial in narrowing in on source reaches. Clark County and other stakeholders are encouraged to explore opportunities to perform additional analyses and monitoring for sources.

Introduction

The Salmon Creek watershed is located in Clark County, in southwest Washington. The streams in this watershed have experienced bacterial water quality problems for decades. The presence of fecal coliform (FC) bacteria is a concern because it indicates the presence of biological waste which can negatively impact human health.

In response to bacterial health concerns, the local jurisdictions and community, worked to clean up Salmon Creek and its tributaries. Concentrations of fecal coliform bacteria have decreased in some areas, but problems still exist (Collyard, 2009). Clark County, (Hoxeng, 2009) documented that many of the small tributaries to lower Salmon Creek exceeded water quality criteria during a 2007 – 2008 FC assessment.

In 2014 – 2015, Ecology conducted a field study to further characterize the lower Salmon Creek tributaries and to see if sources of FC could be located. This report describes the results from the study. The Quality Assurance Project Plan (QAPP) for this 2014/15 study can be found at https://fortress.wa.gov/ecy/publications/SummaryPages/1410051.html, (Dickes, 2014). The QAPP provides more detail regarding study design, field protocol, and quality assurance (QA).

Watershed description

The Salmon Creek watershed (Figure 1), drains an area of approximately 93 square miles immediately north of the city of Vancouver. The creek originates on the slopes of Elkhorn Mountain and flows approximately 26 river miles to its confluence with Lake River. Lake River then flows into the Columbia River.

Land use varies throughout the watershed, with commercial timberland, some agriculture, and rural residences dominating the upper reaches. Urbanization increases moving downstream, with some small communities scattered throughout the mid and upper watershed. The majority of the lower watershed lies in unincorporated Clark County, within the City of Vancouver urban growth area.

Mild, wet, maritime weather dominates the local climate. The watershed receives approximately 60 inches of precipitation annually; over half of which falls from November through February.

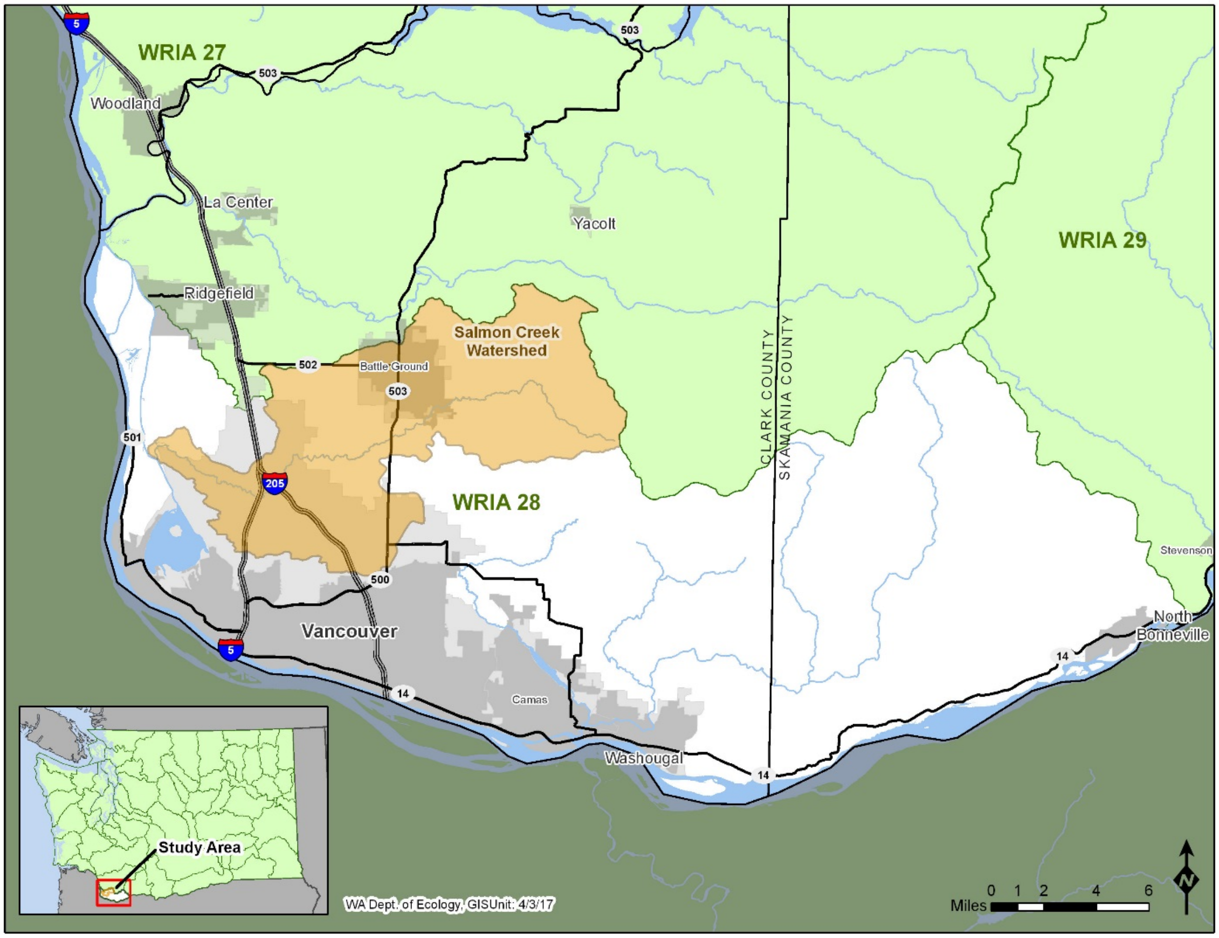

Figure 1. Overview of Salmon Creek watershed.

Water quality criteria

Washington State water quality standards are based on the designated beneficial uses of a water body and the criteria to achieve those uses. For the Salmon Creek watershed, the designated beneficial uses are the aquatic life uses of core summer salmonid habitat and salmonid spawning, rearing, and migration. Other uses include water supply (domestic; industrial; and agricultural); stock watering; fish and shellfish harvesting; wildlife habitat; recreation (primary contact recreation; sport fishing; boating; and aesthetic enjoyment); and commerce and navigation.

The water quality standard for FC in the lower Salmon Creek watershed is for Primary Contact Recreation. FC criteria are set to protect people who work and play in and on the water from waterborne illnesses. FC are used as an “indicator bacteria” for the state’s freshwaters by assuming that the presence of FC in water indicates the presence of waste from humans and or other warm-blooded animals. Waste from warm-blooded animals is more likely to contain pathogens that will cause illness in humans than waste from cold-blooded animals. The FC criteria are set at levels that have been shown to maintain low rates of serious intestinal illness in people.

The Primary Contact designated use is intended for waters "where a person would have direct contact with water to the point of complete submergence including, but not limited to, skin diving, swimming, and waterskiing." (WAC 173-201A, 2011). The use is designated to any waters where human exposure is likely to include exposure of the eyes, ears, nose, and throat. Since children are the most sensitive group for many of the waterborne pathogens of concern, even shallow waters may warrant primary contact protection.

- To protect this use category:
  "Fecal coliform organism levels must not exceed a geometric mean value of 100 colonies/100 mL, with not more than 10% of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 200/colonies mL" [WAC 173-201A-200] (Table 200 (2) (b)).

Compliance with the water quality standards is based on meeting both the geometric mean and the 10% of samples (or single sample if less than ten total samples) criteria. These two measures used in combination ensure that bacterial pollution in a water body will be maintained at levels that will protect the designated use.

In Washington State FC TMDL studies, the upper limit statistic (i.e. not more that 10% of the samples shall exceed) has been interpreted to be comparable to the 90^{th} percentile value of the log normalized values. This is useful for estimating FC percent reductions needed in a TMDL. However, it is not strictly equivalent mathematically and is not a surrogate for part 2 of the FC water quality standard. The 90^{th} percentile calculation is not an accepted value for compliance purposes.

Goals and Objectives

The goal of this project was to identify sources of FC in the study area and provide targeted areas to focus cleanup efforts. Objectives of the study were:

1. Collect FC samples every two weeks at a fixed-network of stream locations.
2. Investigate potential sources for elevated FC concentrations identified at the fixed-network locations by establishing a flexible intensive investigative sampling network.
3. Compare the FC results to the Primary Contact Recreation criteria to determine whether waters are meeting standards.
4. Provide high quality data to guide implementation efforts for cleanup.

Methods

Fecal coliform bacteria sampling

Freshwater samples were collected in the lower portion of the Salmon Creek watershed (Figure 2) using Ecology Standard Operating Procedure (SOP) EAP030 for bacteria (Ward and Mathieu, 2011). The SOP can be found at the Ecology's Quality Assurance Website. Samples were collected in a well-mixed flowing portion of the waterbody. Ecology's Manchester Environmental Laboratory (MEL) performed all the analyses for bacteria using the membrane filter method SM9222D (APHA, 1998).

Fifteen to twenty percent of the samples were replicated during each sampling event for quality control. The replicate samples were collected in a sequential manner, as quickly as possible, to assess variability.

Invasive species de-contamination

Equipment and boot de-contamination was determined to be unnecessary. A study-specific sampling pole, bridge sampler, and footwear were used for this study. Additionally, we stayed on the water's edge rather than stepping into the waterbody.

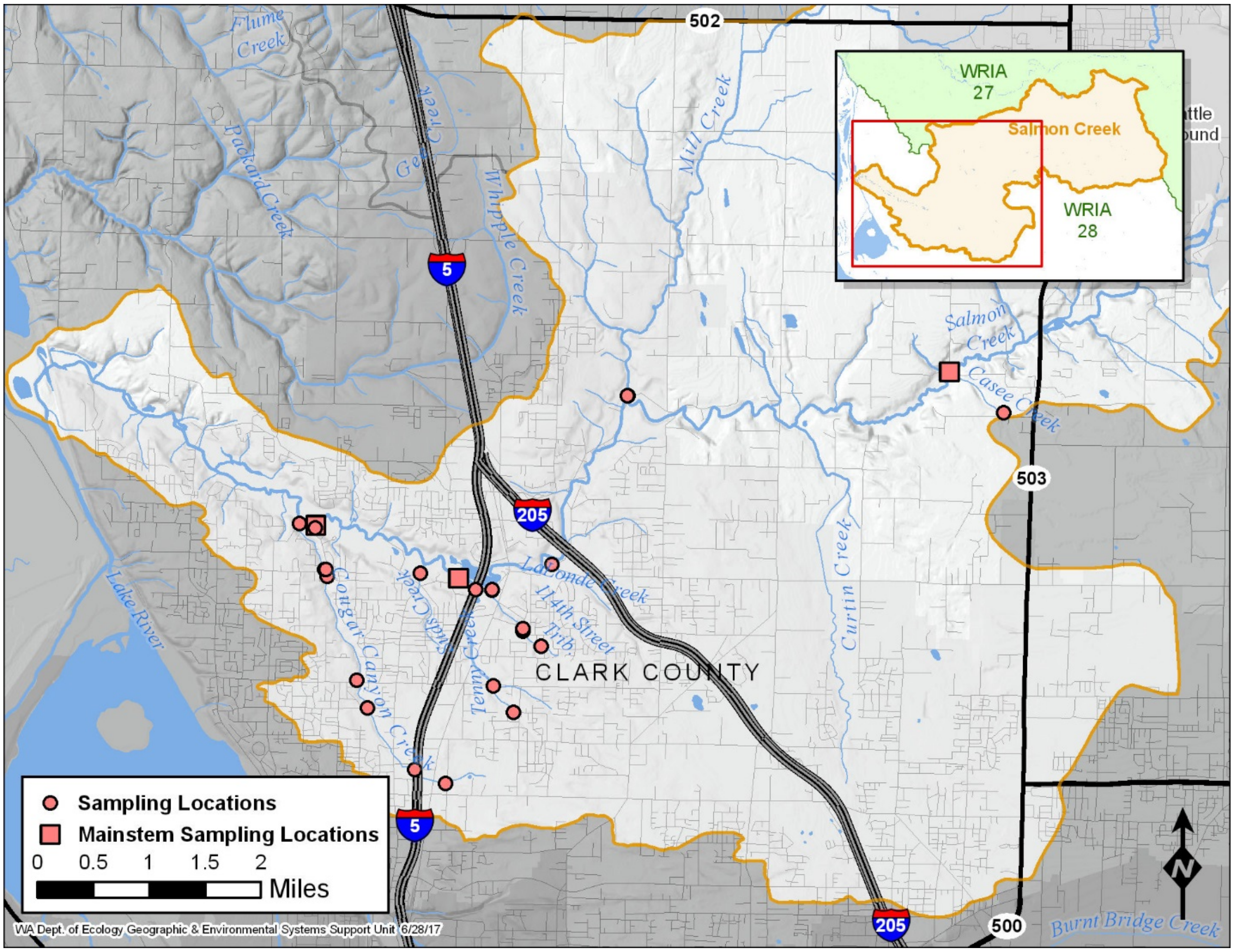

Figure 2. View of lower Salmon Creek watershed showing array of sampling sites.

Study Design

Sampling locations and naming conventions

The initial sampling sites were identified using many of those in the 2009 Clark County Public Works study in lower Salmon Creek (Hoxeng, 2009). Additional sites were added during the study to assist with source identification. By the end of the study, twenty-nine locations were sampled within the lower watershed (Figure 2, Table 1). Three were on the main stem (MS) Salmon Creek and twenty six among eight tributaries.

Several naming conventions exist for sample locations in the watershed. This is the result of varying lead entities expanding sample locations over the years. Existing Environmental Information Management (EIM) location IDs were used in this study if the location ID, name, and description closely matched the intended sampling location and coordinates. There were a few names in this study that warrant further clarification:

- For example, in EIM, the Location Name for CGR020 is *Cougar CR at NW 119th Street*. Initially the Location Description and coordinates had the site *upstream* of 119th. After talking with staff I found out that most had taken water quality samples on the downstream side. The Location Description in EIM now reflects this practice. However, before this clarification was made, we changed the Location ID to reflect the downstream location to be more accurate with coordinates and creek mile (CM) for this study. So the site specific Location ID at NW 119th Street is COU0.5 (COU representing Cougar Creek and 0.5 reflecting CM); the *Location ID* in EIM is 28-Cou-0.5. The sample taken upstream of 119th St. retained the name and coordinates of the original EIM Location ID CGR020 (CGR representing Cougar Creek and 020 is the approximate percent of the total stream length in reference to the mouth as determined by Clark County).
- Another example: In EIM, the Location Name for the Location ID CGR050 is *Cougar Cr at NW 99th Street*. The Location Description is *Cougar Cr at Columbia River H.S.*. We were using CGR050 as our field specific ID. But, we realized our water quality sample site was further upstream at the fish weir. So, a new EIM Location Name was created for the 2014-2015 station which is 28-COU-1.6. The field specific ID used in the report is COU1.6.

Table 1, below, provides a list of the study specific location ID's and location descriptions for this 2014- 2015 study. Table A1 (Appendix A) has a list of the study location ID, study specific location ID, description, and coordinates. Ecology's EIM website contains all the location information as well as the data. Search Study ID ***BEDI0022*** at https://fortress.wa.gov/ecy/eimreporting/.

The time frame for the project included both wet and dry seasons. Seasonal classifications were determined based on previous studies with November through April being the wet season and May through October representing the dry season. Storm events were not defined or targeted, but rain events were sampled if they fell within the pre-determined sample date.

Sample dates

Sampling occurred twice a month from October 2014 through September 2015, with two exceptions. Only one event was completed in December 2014 and only eight samples (of the expected 18 samples) were collected in July 2015 (Table 2).

Table 1. Study Specific Location ID's and descriptions for the 2014-2015 study.

Study-Specific Location ID	Location Description
Cougar Creek	
COU0.01	Cougar Ck near mouth upstream of walking bridge
TCOU0.01	Trib at Cougar Ck near mouth left bank
TCOU0.01C	Storm water trib from culvert left bank near mouth
COU0.5	Cougar Ck *downstream* of NW 119th St.
COU0.5T	Storm water trib to Cougar Ck near COU0.5 - enters right bank
CGR020	Cougar Ck *upstream* at NW 119th St
COU1.6	At Columbia River HS; from drop at first weir
CGRCULV	From left bank culvert only - just upstrm of site COU1.6
COU94	Cougar Ck upstream of NW 94th St
COU94T	Storm water trib Cougar Ck enters left bank near COU94
COU2.6	Cougar Ck behind Safeway
COU13	Cougar Cr at NE 13th Ave
Suds Creek	
SUD020	Suds Cr downstream of 117th St
Tenny Creek	
TEN010	Tenny Cr at 117th St- DS of falls
TEN065	Tenny Creek at 99th St
TEN1.5	Tenny Ck at 94th St.- DS of road
114th Street Trib	
FOR0.1	114th St Trib at 117th St. near mouth
FOR0.1P	114th St trib – Storm water pipe at 117th St.
FORSYL	114th St Trib at NE Sylvan Terrace
FORSYLT	Trib entering right bank of 114th St Trib at NE Sylvan Terrace
FOR28	114th St Trib at NE 28th Ave
LaLonde Creek	
LAL0.1	LaLonde Ck near mouth
Mill Creek	
MIL010	Mill Creek at Salmon Ck Ave
TMIL010	Small trib entering right bank at MIL010
CASEE Creek	
CAS0.5	CASEE Ck-at culvert overflow
Salmon Creek	
SAL3.3	Salmon Ck upstream of Cougar Ck mouth at Trail marker 1 1/2
SMN020	Salmon Ck Klineline footbridge; downstream side
SAL12	Salmon Ck at NE 156th St; downstream side
Unnamed Trib	
TSAL0.01	LB Trib to Salmon Ck nr SAL3.3 collected just above the culvert

Table 2. Sampling dates for the 2014 - 2015 study.

2014	
MONTH	DATE
October	8, 22
November	5, 19
December	3
2015	
January	7, 21
February	4, 18
March	4, 18
April	1, 15
May	13, 26
June	10, 24
July	8, 22
August	5, 19
September	2, 14

Results and Discussion

Data quality

MEL reviewed and accepted the lab data with qualifiers as necessary.

Unfortunately there were those samples with TNTC and post calculated for dilutions. These samples were given values based on the dilutions and then a qualifier of 'G'; unfortunately we do not know how much greater. Additionally, some results came back with a 'J' qualifier. Data qualified with a 'J' reflects that the bacteria were positively identified, but the numerical value is an estimate.

The field data were also reviewed as per the replicate values. The data met the quality objectives (Mathieu, 2006). There were 114 replicate samples over 20 cfu/100mL. 50% of those replicate pairs were below 11% RSD. 90% of the replicate pairs were below 36% RSD. There were 4 replicate pairs with a mean value of ≤20 cfu/100mL. The project manager determined that these data were usable.

Precipitation

Precipitation records were received from the Salmon Creek Wastewater Treatment Plant (WWTP) (45.73157, -122.729654). The WWTP is located in the Salmon Creek watershed northwest of the study area. The 12, 24, and 48 hour summary record (starting at 10 am of the sample day and working backwards) can be found in Table 3.The wet season dates are delineated from the dry season dates with darkened rows.

September 14, 2015, had no rain recorded for the WWTP on the day of sampling. But, the airport did record 0.04 inches of rain during the sampling period of 10:00 – 1:00 which was observed in the field. However, there was no consistency between the precipitation records from the WWTP versus the airport, so the data from the WWTP were used.

October 22, 2014 was the first, most intense and consistent, rain event sampled. The creeks were high and storm water runoff was evident. This type of situation was never seen again during this study period. Looking at the records from the WWTP and Vancouver's Pearson Airport (south of the study area; 45.6223, -122.6559) this may not have been the seasonal "first flush" rain storm, however, it was an early fall event that generated overland flow. Figure 3 shows the elevated FC values throughout most of the watershed. Approximately 0.39 (WWTP) to 0.5 (Pearson Airport) inches of rain fell during the hours we sampled, approximately 10:00 a.m. through 1:00 p.m. An interesting note is that the precipitation total for the day broke a record at 1.70 inches, however, much of that total fell *after* the sampling event.

Table 3. Precipitation records calculated from the Salmon Creek WWTP.

DATE	Previous 12 hour (inches)	Previous 24 hour (inches)	Previous 48 hour (inches)
2014			
10/8	0	0	0
10/22	0.1	0.11	0.33
11/5	0.01	0.01	0.2
11/19	0	0	0
12/3	0	0	0
2015			
1/7	0	0	0
1/21	0	0	0
2/4	0.04	0.07	0.18
2/18	0	0	0
3/4	0	0	0
3/18	0.04	0.08	0.08
4/1	0.02	0.08	0.14
4/15	0	0.11	0.44
5/13	0.02	0.17	0.54
5/26	0	0	0
6/10	0	0	0
6/24	0	0	0
7/8	0	0	0
7/22	0	0	0
8/5	0	0	0
8/19	0	0	0
9/2	0.11	0.13	0.13
9/14	0	0	0

Watershed-wide, October 22, 2014, Rain Storm

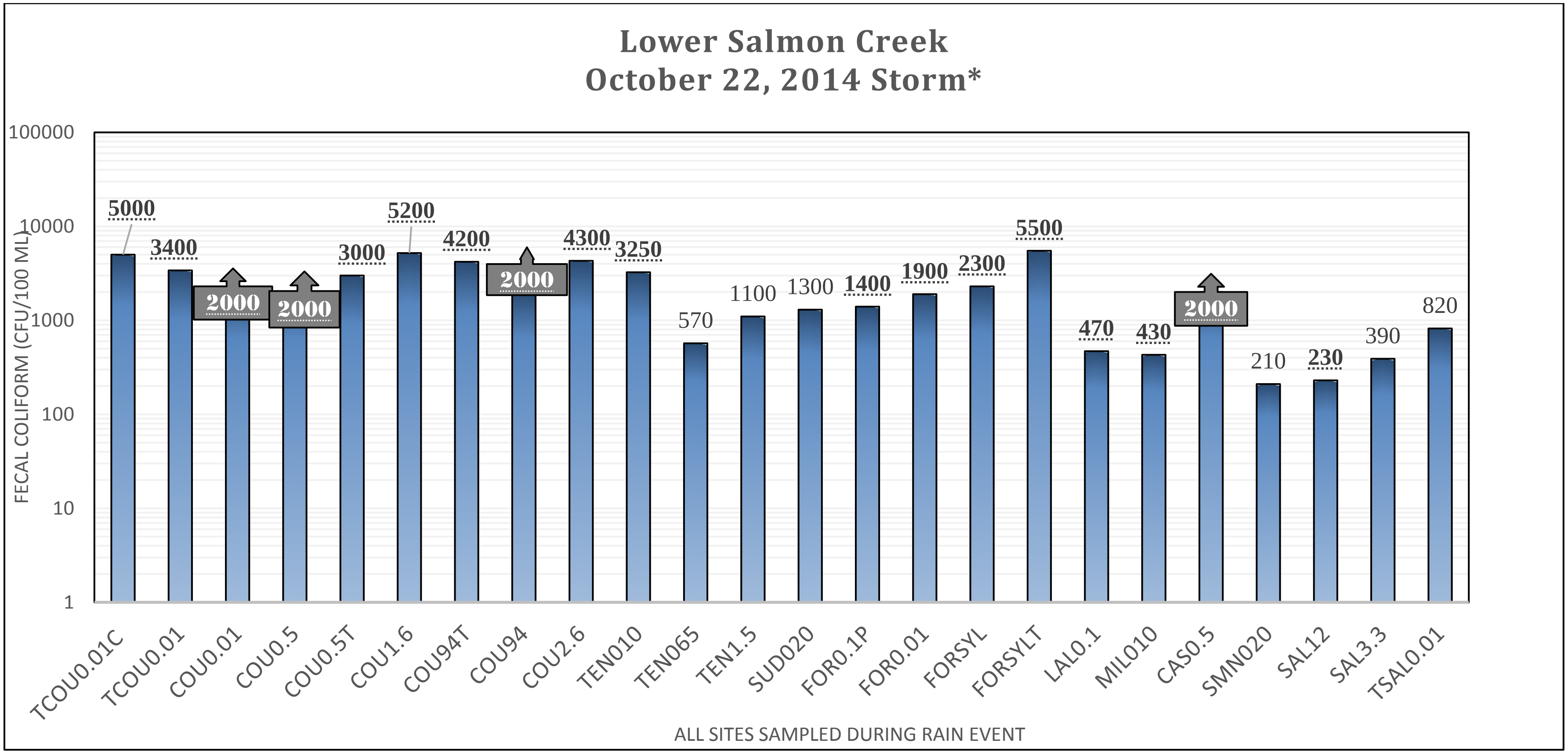

Figure 3. Fecal coliform values (cfu/100mL) at sites sampled during the October 22, 2014, storm.

*Underlined and bolded values are estimates (**J** qualifier).
Boxed and underlined values were **TNTC** with 2000 (with a **G** qualifier) being the lower estimated recalculated value for this sampling run.

Fecal coliform bacteria characteristics

Water quality in the lower Salmon Creek tributaries (N≥5) failed to meet the water quality criteria for primary contact during the 2014-2015 study (Appendix B). All stations failed in the dry season; with most failing both parts of the criteria. However, many of the sites met the criteria in the wet season. This is interpreted graphically in Appendix C. Raw data may be reviewed in Appendix D.

There were two sites that met the FC criteria when looking at the data over the entire 2014-2015 study period: SAL3.3 (Salmon Creek upstream of Cougar Creek mouth), and TSAL0.01 (trib to Salmon Creek near SAL3.3, left bank (LB). Like many of the other sample sites, they met the criteria during the wet season, but not during the dry season (Appendix B). Site TCOU0.01 (trib to Cougar Creek near mouth, LB), also met the criteria over the entire study period, but it went dry in the summer so the sample size was too low (N=3) to compare to the criteria.

The concentration characteristics of bacteria in the Lower Salmon Creek tributaries, and the 3 main stem sites, are described below in tributary specific sections.

Cougar Creek

Cougar Creek had six routine sites on the main stem with additional tributaries and culverts sampled when flowing (Figure 4). The main stem failed the water quality criteria for Primary Contact when looking at the data annually and during the dry season (Appendices B and C-1). In particular, the FC bacteria concentrations in Cougar Creek during the dry season were over 500 cfu/100mL. There were no samples taken at COU13 (Cougar at 13^{th}) during the dry season due to heavy emergent and submergent vegetation growth preventing access. All but the two upper most sample locations (COU2.6 (Cougar behind Safeway) and COU13 (only wet season data)), met the criteria during the wet season (Appendices B and C-1).

COU2.6 and COU13 failed both parts of the criteria during the wet season (Figure 5 and Appendix B). Geometric mean concentrations decreased by about half as samples were collected downstream. COU2.6 (behind the Safeway) often had higher bacteria, but, this was not consistent (Figure 6). There was no recorded precipitation during the January sampling event (Table 3), but the other bacteria spikes could have been the result of run-off. Potential sources could result from unrecorded rain events, the upstream wildlife in the pastures, ducks in the ponded area at COU13 as well as anthropogenic sources. There was a person seen hanging out at the downstream side of the large concrete culvert located between the sampling locations. It was not evident if he was residing there.

A notable event occurred May 26, 2015, in the Cougar Creek Park area (lower watershed near the confluence with Salmon Creek). Young adults were observed frolicking in Cougar Creek when we were sampling COU0.01 located just above the confluence. The sample that day from COU0.01 had a TNTC concentration (800 G cfu/100mL). I would have thought that it could have been due to the in-stream activities releasing bacteria from the sediment, but the upstream site COU0.5 (below 119^{th} St) also had a TNTC recorded (800 G cfu/100mL). It may be that they had been swimming in the entire reach that day or that something occurred between the High School (COU1.6) and the confluence with Salmon Creek.

Additional sites in the Cougar Creek watershed were only sampled once (N=1).

- On November 19, 2014, CGR020 (upstream of 119th) was sampled to see if there was any difference between bacteria levels above and below the road culvert. CGR020 had a value of 8 cfu/100mL and the downstream side of the 119th had 38 J cfu/100mL. It was determined that the resources weren't available to continue to see the impact of culverts.
- On September 14, 2015, the large concrete culvert on the left bank (CGRCULV) upstream of COU1.6 (behind the High School) was discharging for the first and only time in the study. Rain was observed while sampling. However, there was no recorded rainfall at the WWTP. A sample was collected; the bacteria was TNTC and was reported as 800 G cfu/100mL. Site COU2.6, just downstream was also 800 G. We unfortunately did not take a sample of the right bank concrete culvert that carried most of the volume.
- During the October 22, 2014, storm there were three additional locations sampled: TCOU0.01C (concrete culvert at left bank near mouth), COU0.5T (right bank trib near COU0.5, downstream of 119th), and COU94T (left bank trib near COU94 on 94th). The bacteria were high with estimated (J) counts of 5000 J, 3000 J, and 4200 cfu/100mL, respectively. This was the only time TCOU0.01C and COU0.5T were flowing and the only time COU94T had volume enough to sample.

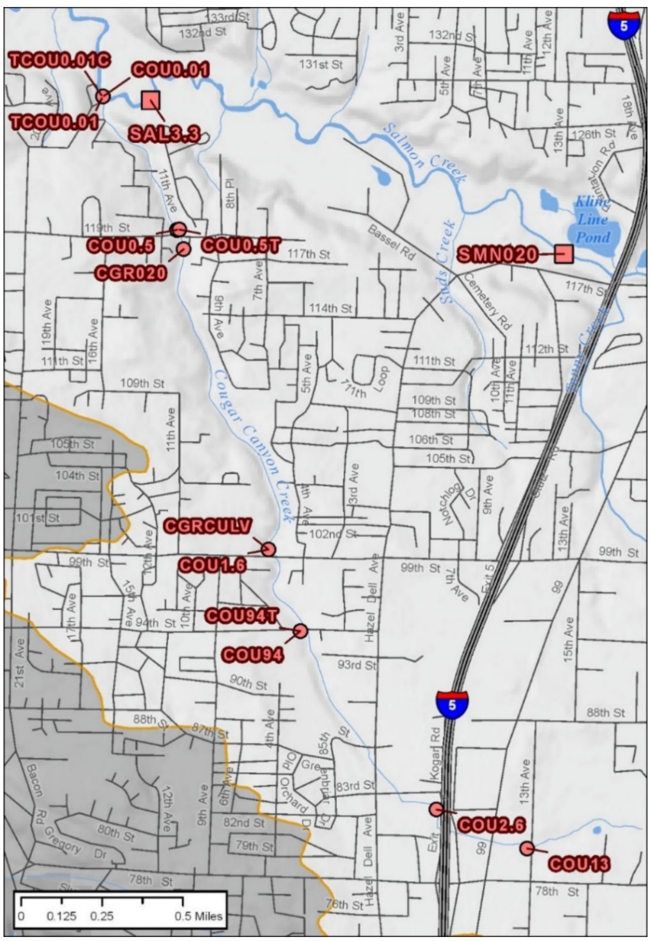

Figure 4. Sample sites on Cougar Creek.

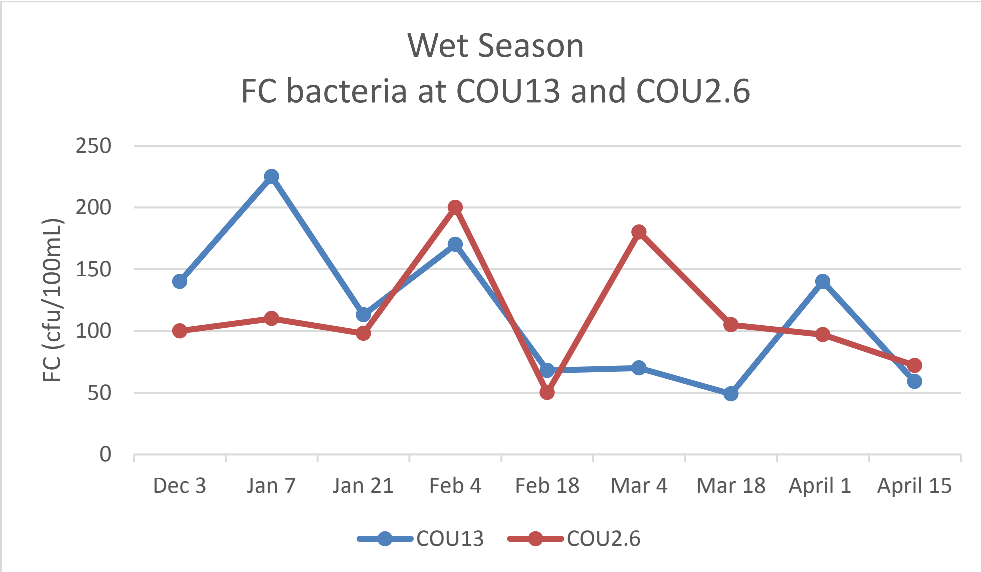

Figure 5. FC concentrations for the uppermost sites on Cougar Creek during the wet season (N=9).

Tenny Creek

There were two routine sites on Tenny Creek TEN010 (Tenny at 117th St) and TEN065 (Tenny at 99th St) (Figure 6). The third site, TEN1.5, (located downstream of 94th St) was usually too shallow to sample (N=3). Due to the low sample size for TEN1.5, statistics were not performed.

The creek exceeded the water quality criteria over study period as well as during the dry season, but met both parts of the criteria in the wet season (Appendices B and C-2). Geometric mean concentrations increased upstream to downstream during all periods.

There were signs of trash and human activity at TEN010. An encampment was noticed in 2015 high on the right bank of the falls. However, the data don't represent bacteria concentrations that would clearly point to a constant source of waste.

On September 14, 2015, TEN065, had a TNTC that was subsequently calculated to greater than 800 cfu/100mL at MEL. The precipitation data from the WWTP recorded no rain, but our field notes do record that it was raining off and on particularly at this site.

Site TEN065 at 99th St had an interesting flow regime. Above this site the creek went subsurface in a concrete pipe then came out into what appears to be a big scour hole. It then flows under 99th St. through a semi-blocked culvert. Sediment is accumulating to such an extent it almost totally clogs the culvert. This area also seems to get human visitation with trash and incidental bathroom breaks observed.

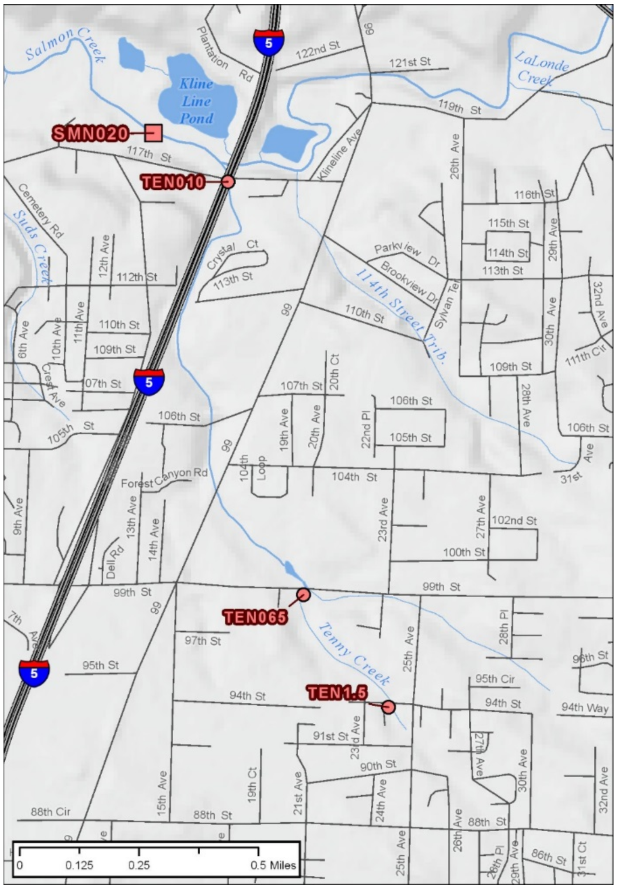

Figure 6. Sample sites on Tenny Creek.

Suds Creek

The sampling location on Suds Creek (SUD020, Figure 7) is located downstream of 117th St accessed via the Salmon Creek Sport's Association Complex. The sampling location is above organized sports activities, but below a residential area. The creek at this site failed to meet both parts of the water quality criteria when looking at the data annually and during the dry season (Appendices B and C-3); the geometric mean was actually twice as high in the dry season. Both parts of the criteria were met in the wet season with a geometric mean of 58 cfu/100mL with no samples exceeding 200 cfu/100mL

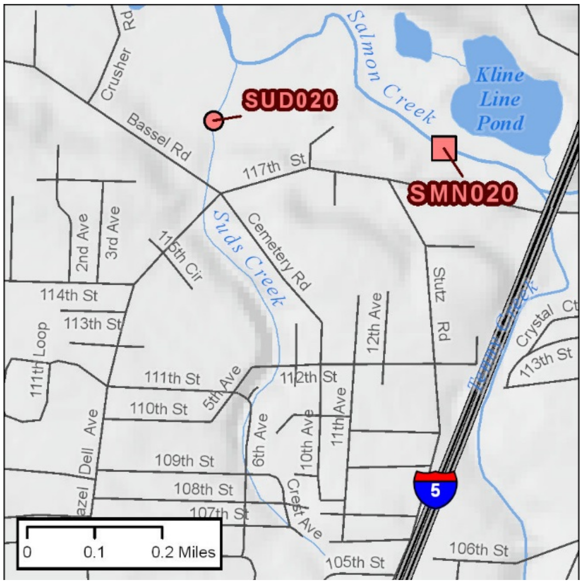

Figure 7. Sampling site on Suds Creek SUD020. The main stem site SMN020 is pictured to provide location reference.

114th Street Trib

Three routine sampling sites, and one tributary site, were located on 114th Street Trib main stem (Figure 8). They all exceeded the criteria for the study period and during the dry season (Appendices B and C-4). FOR0.01, the lower most site (near the mouth and just above 117th St) was the only routine site on the creek that exceeded the criteria during the wet season (GM=70 cfu/100mL, but 18% of the samples were greater than 200 cfu/100mL). Geometric mean concentrations increased in the downstream direction. There was an active human encampment located above Hwy 99. Effects of this activity may have affected water quality downstream.

A hanging storm water pipe (plastic black) was located just downstream of FOR0.01 on the left bank. It was sampled only once due to no or low flow. It was discharging during the October 22, 2014, storm. The concentration was 1400 J.

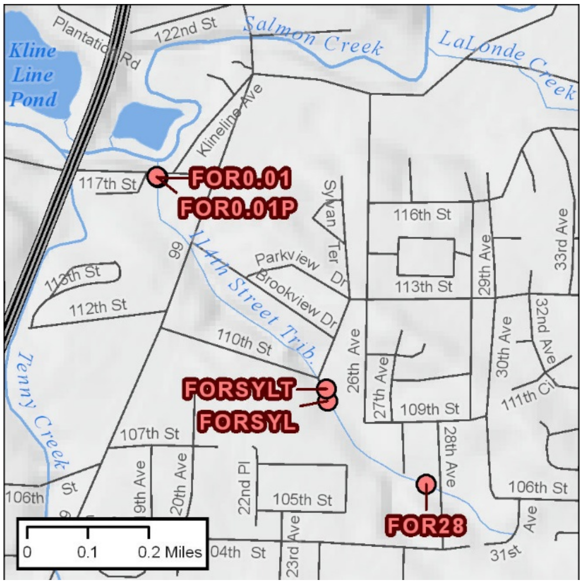

Figure 8. Sample sites for 114th Street Trib.

LaLonde Creek

LaLonde Creek only had one sample site (Figure 9), located upstream of Salmon Creek Ave. The hydrography hasn't been corrected in Ecology's GIS system, but the site, LAL0.1, is upstream of the road and was taken from the upstream side of the bridge and downstream of the concrete culvert. The water quality did not meet the criteria during the study period or during the dry season, though it was met during the wet season (Appendices B and C-5).

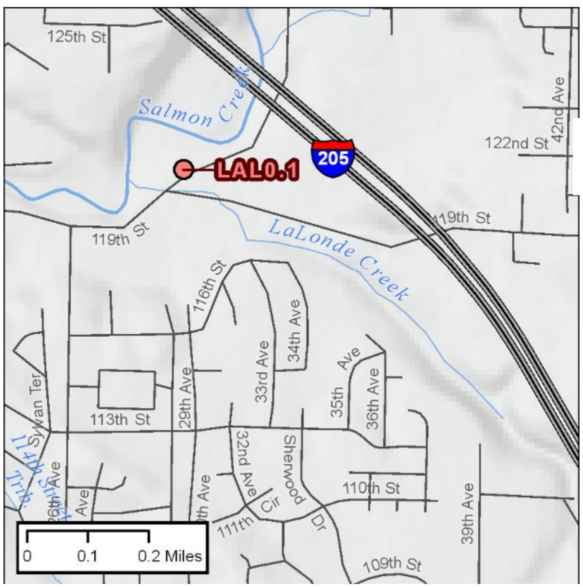

Figure 9. Sample site on LaLonde Creek.

Note: the current hydrography layer is not correct.

Mill Creek

Mill Creek was sampled near its mouth, MIL010, on the upstream side of the bridge over Salmon Creek Ave. (Figure 10). The creek failed to meet the water quality criteria during both the study period and during the dry season, but did meet both parts of the criteria during the wet season (Appendices B and C-6).

The small tributary that enters Mill Creek on the right bank was sampled one time on January 21, 2015. The concentration was low at 2cfu/100mL. Flow volume was too low to sample during other sampling events. The tributary runs through an area that has been revegetated as well as a wetland-like area. The rest of the watershed was also low during this sample event.

Figure 10. Sample sites on Mill Creek.

CASEE Creek

Casee Creek runs through the property of the Center for Agriculture, Science and Environmental Education (CASEE) in Brush Prairie. The water drains a grassy swale adjacent to NE 149th St. and then flows off the concrete culvert lip (CAS0.5) through a primarily forested area and enters Salmon Creek downstream of the NE 156th St bridge (SAL12) sampling site. The sample collected at Casee Creek is near the head of its flowing channel (Figure 11). The main stem site (SAL12) in Figure 11 was the upper most site sampled in this study.

Clark Conservation District collected water samples in previous years on Casee Creek and occasionally found elevated FC. They asked if we could add this site to see if we could further characterize the water quality and determine potential sources.

We collected 23 samples from the water discharging over the lip of the hanging culvert. The creek exceeded the water quality criteria annually and seasonally (Appendices B and C-7). There were enough samples with low bacteria concentrations to bring the geometric mean below 100 cfu/100mL, however, the second part of the criteria was exceeded during all three analytical time periods. It appears that the high ‘hits’ may be due to stormwater wash-off.

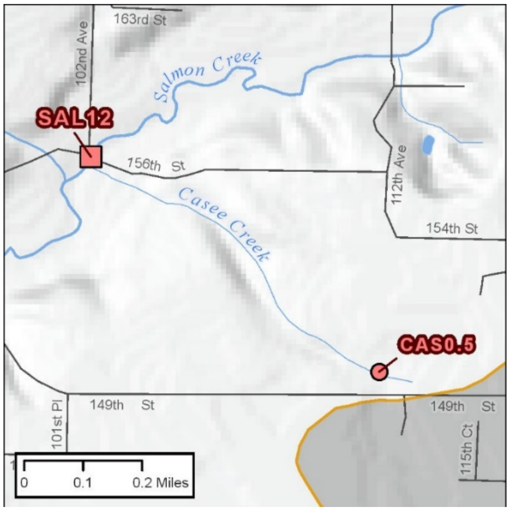

Figure 11. Sample site on Casee Creek.

Trib to Salmon Creek

The trib to salmon creek (TSAL0.01) enters the left bank downstream of the main stem site SAL3.3 (Figure 12). It flows through an area being revegetated and wetland into a culvert under the walkway. The tributary met the FC criteria for both the study period and the wet season (Appendices B and C-8). During these two periods, the concentrations never were above 30 cfu/100mL, and often were below detection (Appendix D). It had the lowest geometric mean values for bacteria in the lower watershed (Appendix B). However, it failed in the dry season due to an elevated sample collected during the October storm at 820 cfu/100mL. One high event was sufficient to cause a violation due to the low sample size (N=8). The wash-off event most likely brought down the build-up of wildlife wastes from this undeveloped wetland area.

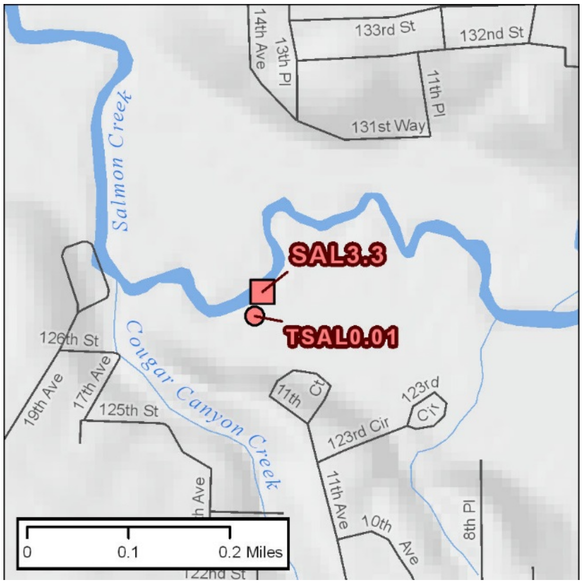

Figure 12. Sample site below SAL3.3 and above Cougar Creek.

Salmon Creek

Figure 13 shows where the three main stem sites were located in the lower watershed. It is not clear how the tributaries specifically affected the water quality.

The geometric mean concentrations decreased upstream to downstream during all of the analytical time periods The lower most site, SAL3.3, met the water quality criteria over the period of the study and the wet season (Appendices B and C-9), but failed to meet the second part of the criteria in the dry season. The other two upstream sites failed the criteria annually and seasonally. The main stem bacteria concentrations were not as affected by the October storm as the tributaries.

Elevated bacteria concentrations were seen on May 13, 2015, after previous rain events (Table 3). The sample collected at this upper most site was highest of all main stem sites at 1000 cfu/100mL. Concentrations of this magnitude with the volume of main stem water would suggest considerable contamination from upstream. Downstream concentrations were also elevated with SMN020 near Kline Line pond having its highest concentration of 500 cfu/100mL, and SAL3.3, just above the confluence with Cougar Creek, with its highest concentration of 440 cfu/100mL.

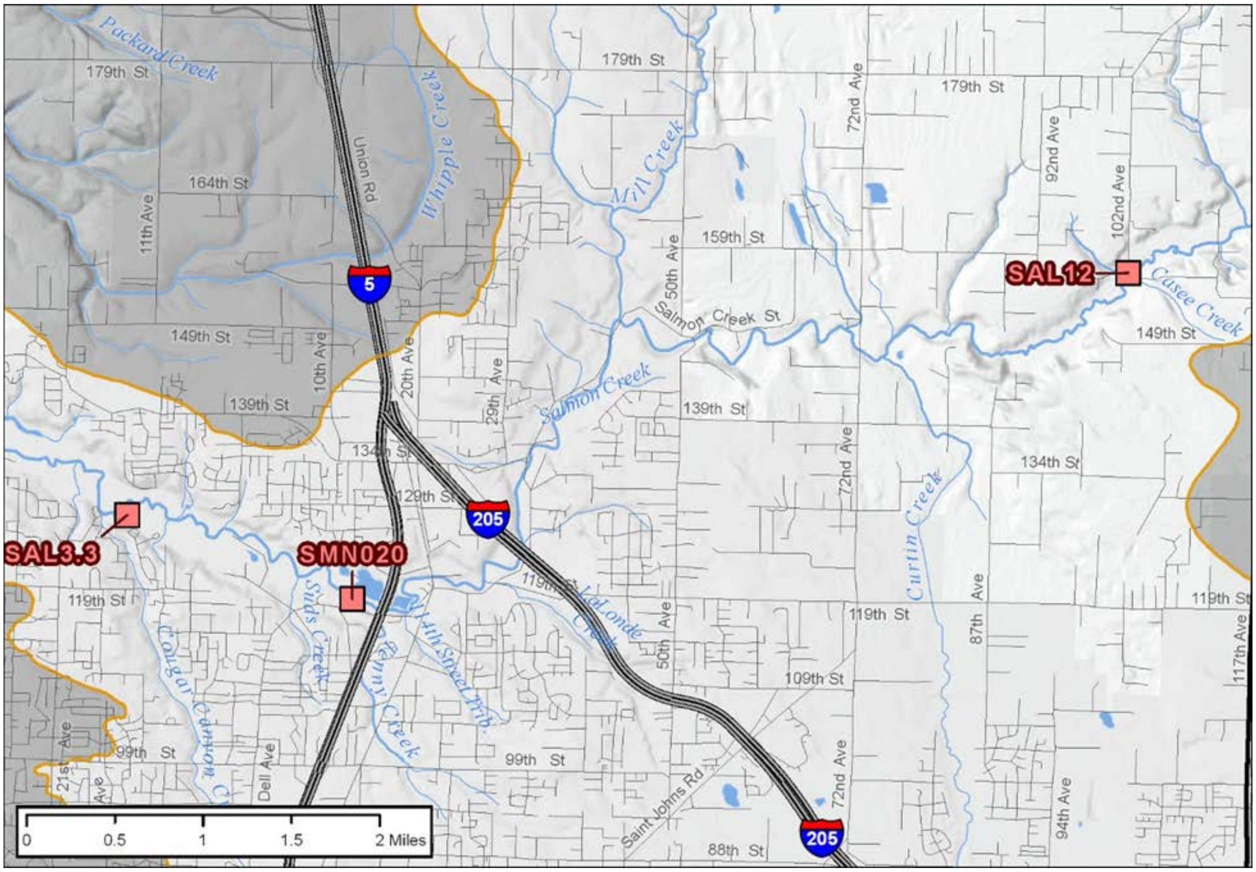

Figure 13. Sampling sites on the Salmon Creek main stem.

Conclusions

Results of the 2014-2015 FC bacteria study support the following conclusions:

- Most of the sample sites in the lower Salmon Creek sampled in this study exceed the Primary Contact criteria for FC over the 12 month period and during the dry season.
- Wet season concentrations were lower than those collected during the dry season and most met one or both of the FC criterion.
- Most of these tributaries flow through residential and commercial properties. Many areas flow through small or large agricultural areas.
- The dry season had the highest number of water quality violations in the sample area, pointing to continual sources as well as than stormwater inputs.
- The systems seem to get diluted in the wet season rather than having increased bacteria concentrations.
- The larger storm sampled in the fall triggered a wash off event resulting in elevated bacteria concentrations.
- Discreet sources of bacteria were not identified, though data did reflect increased concentrations. Clark County and other stakeholders may be able to use their local knowledge to hone in on potential sources.
- Sources of bacteria may include pet waste, wildlife, leaking septic systems, re-suspension, and road run-off and manure from large and small agricultural lands.

Recommendations

Results of the 2014-2015 FC bacteria study support the following recommendations.

- Investigate the dry season bacteria sources to the watersheds. The exceedances are widespread.
- Most stormwater goes directly into these waterbodies. Increase the management of stormwater through appropriate BMPs to reduce water quality impacts.
- In future studies, add flow measurements to see if loading can assist in finding sources and cleaning up the watersheds.
- Continue education throughout the watershed about effects of nonpoint pollution to water quality and human health.

- Continue outreach and education regarding the potential impacts of pet waste to water quality and human health.
- Continue to encourage septic inspections and maintenance in residential and commercial operations.
- Continue to encourage effective agricultural best management practices, on both large and small operations, for the reduction of FC in the waterbodies.
- Conduct stream walks in municipal tributaries to identify and sample unknown/unmapped outfalls, e.g. pipes, culverts, etc.
- Clark County and other stakeholders are encouraged to explore opportunities to perform additional analyses and monitoring for sources.

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Appendices

Appendix A. (Location Details)

Table A-1. Location IDs, description and coordinates for the lower Salmon Creek sampling regime.

Study-Specific Location ID	EIM Location ID	Location	Latitude	Longitude
Cougar Creek				
COU0.01	28-COU-0.01	Cougar Ck near mouth upstream of walking bridge	45.7133	-122.68772
TCOU0.01	28-TCOU-0.01	Trib at Cougar Ck near mouth left bank (LB)	45.7133	-122.68773
TCOU0.01C	28-STCOU-0.01C	Stormwater trib from culvert LB near mouth	45.71331	-122.68774
COU0.5	28-COU-0.5	Cougar Ck *downstream* of NW 119th St.	45.70744	-122.68277
COU0.5T	28-STCOU-0.5	Stormwater trib to Cougar Ck near COU0.5	45.70745	-122.6826
CGR020	CGR020	Cougar Ck *upstream* at NW 119th St	45.70658	-122.68229
COU1.6	28-COU-1.6	Cougar Ck near NW 99th St. at Columbia River HS	45.69326	-122.67635
CGRCULV	28-CCOU-1.6	LB culvert located upstream of site COU1.6	45.69326	-122.67635
COU94	28-COU-1.9	Cougar Ck upstream of NW 94th St	45.68965	-122.67417
COU94T	28-STCOU-1.9	Stormwater trib Cougar Ck enters LB	45.68965	-122.67418
COU2.6	28-COU-2.6	Cougar Ck behind Safeway	45.68184	-122.66517
COU13	CGR080	Cougar Cr at NE 13th Ave	45.68021	-122.65934
Suds Creek				
SUD020	SUD020	Suds Cr downstream of 117th Street	45.70729	-122.6651
Tenny Creek				
TEN010	TEN010	Tenny Cr at 117th St	45.70535	-122.65524
TEN065	TEN065	Tenny Creek at 99th St	45.69295	-122.65099
TEN1.5	28-TEN-1.5	Tenny Ck at 94th St.	45.68961	-122.64716
114th St Trib				
FOR0.1	28-FOR-0.01	114th St Trib near mouth	45.7054	-122.65173
FOR0.1P	28-PFOR-0.01	114th St trib - SW pipe at 117th	45.70542	-122.6518
FORSYL	28-FOR-0.41	114th St Trib at NE Sylvan Terrace	45.7014	-122.64699
FORSYLT	28-TFOR-0.41	Stormwater trib entering RB at NE Sylvan Terrace	45.70151	-122.64716
FOR28	28-FOR-0.71	114th St Trib at NE 28th Ave	45.69828	-122.64235
LaLonde Creek				
LAL0.1	28-LAL-0.1	LaLonde Ck near mouth	45.70895	-122.64085
Mill Creek				
MIL010	MIL010	Mill Creek at Salmon Ck Ave	45.73107	-122.62752
TMIL010	TMIL010	Small trib entering RB at MIL010	45.73106	-122.62773
CASEE Creek				
CAS0.5	28-CAS-0.5	CASEE Ck nr NE 149th St	45.73019	-122.55792
Salmon Creek				
SAL3.3	28-SAL-3.3	Salmon Ck upstream of Cougar Ck mouth	45.71319	-122.68465
SMN020	SMN020	Salmon Ck Klineline footbridge;downstream side	45.70683	-122.65801
SAL12	28-SAL-12	Salmon Ck at NE 156th St; downstream side	45.73528	-122.56823
Unnamed Trib To Salmon Creek				
TSAL0.01	28-TSAL-0.01	LB Trib to Salmon Ck nr SAL3.3	45.71284	-122.68479

Appendix B. Water Quality Criteria

Appendix B-1.Summary for **all data** (N≥5) collected by Ecology during the 2014/2015 Lower Salmon Creek FC study.

			Water Quality Standards **Part 1** (cfu/100 mL)			Water Quality Standards **Part 2** (cfu/100 mL)			Overall
Study Specific Location ID	Description	Sample size	geometric mean	Criterion	Meets?	Percent greater than criterion	Criterion	Meets?	Meets WQ Criteria?
COUGAR									
TCOU0.01	Trib at Cougar Ck near mouth left bank (LB)	14	12	100	meets	7	200	meets	meets both
COU0.01	Cougar Ck near mouth upstream of walking bridge	22	171	100	fails	50	200	fails	fails both
COU0.5	Cougar Ck *downstream* (DS) of NW 119th St.	22	186	100	fails	50	200	fails	fails both
COU1.6	Cougar Ck near NW 99th St. at Columbia River HS	22	190	100	fails	55	200	fails	fails both
COU94	Cougar Ck upstream (US) of NW 94th St	20	195	100	fails	50	200	fails	fails both
COU2.6	Cougar Ck behind Safeway	22	252	100	fails	50	200	fails	fails both
COU13	Cougar Cr at NE 13th Ave	9	102	100	fails	11	200	fails	fails both
TENNY									
TEN010	Tenny Cr at 117th St	22	184	100	fails	50	200	fails	fails both
TEN065	Tenny Creek at 99th St	22	76	100	meets	32	200	fails	fails Part 2
SUDS									
SUD020	Suds Cr downstream of 117th Street	23	150	100	fails	41	200	fails	fails both
114th STREET									
FOR0.01	114th St Trib near mouth	23	161	100	fails	52	200	fails	fails both

FORSYL	114th St Trib at NE Sylvan Terrace	21	138	100	fails	38	200	fails	fails both
FOR28	114th St Trib at NE 28th Ave	19	90	100	meets	16	200	fails	fails Part 2
FORSYLT	SW trib entering RB at NE Sylvan Terrace								
		21	67	100	meets	43	200	fails	fails Part 2
LaLonde Creek									
LAL0.1	LaLonde Ck near mouth on Salmon Creek Ave	23	79	100	meets	22	200	fails	fails Part 2
Mill Creek									
MIL010	Mill Creek at Salmon Ck Ave	23	107	100	fails	17	200	fails	fails both
Casee Creek									
CAS0.5	Casee Ck nr NE 149th St	23	22	100	meets	22	200	fails	fails Part 2
TRIB to SALMON									
TSAL0.01	LB Trib to Salmon Ck nr SAL3.3	19	7	100	meets	5	200	meets	meets both
Salmon Creek									
SAL3.3	Salmon Ck upstream of Cougar Ck mouth	22	54	100	meets	9	200	meets	meets both
SMN020	Salmon Ck Klineline footbridge; DS side	22	92	100	meets	18	200	fails	fails Part 2
SAL12	Salmon Ck at NE 156th St; DS side	23	123	100	fails	26	200	fails	fails both

Appendix B-2. Summary for data collected during the **wet season (Nov - May) (N≥5)** by Ecology during the 2014/2015 Lower Salmon Creek FC study.

Study Specific Location ID	Description	Sample size	Water Quality Standards Part 1 (cfu/100 mL) geometric mean	Criterion	Meets?	Water Quality Standards Part 2 (cfu/100 mL) Percent greater than criterion	Criteria	Meets?	Overall **WET** Season Meets WQ Criteria?
COUGAR									
TCOU0.01	Trib at Cougar Ck near mouth left bank	11	5	100	meets	0	200	meets	meets both
COU0.01	Cougar Ck near mouth upstream of walking bridge	11	58	100	meets	9	200	meets	meets both
COU0.5	Cougar Ck *downstream* of NW 119th St.	11	59	100	meets	0	200	meets	meets both
COU1.6	Cougar Ck near NW 99th St. at Columbia River HS	11	60	100	meets	9	200	meets	meets both
COU94	Cougar Ck upstream of NW 94th St	10	57	100	meets	0	200	meets	meets both
COU2.6	Cougar Ck behind Safeway	9	122	100	fails	11	200	fails	fails both
COU13	Cougar Cr at NE 13th Ave	9	102	100	fails	11	200	fails	fails both
TENNY									
TEN010	Tenny Cr at 117th St	11	78	100	meets	0	200	meets	meets both
TEN065	Tenny Creek at 99th St	11	19	100	meets	0	200	meets	meets both
SUDS									
SUD020	Suds Cr downstream of 117th Street	11	58	100	meets	0	200	meets	meets both
114th STREET									
FOR0.01	114th St Trib near mouth	11	70	100	meets	18	200	fails	fails Part 2

FORSYL	114th St Trib at NE Sylvan Terrace	10	73	100	meets	10	200	meets	meets both
FOR28	114th St Trib at NE 28th Ave	9	58	100	meets	0	200	meets	meets both
FORSYLT	SW trib entering RB at NE Sylvan Terrace	10	8	100	meets	0	200	meets	meets both
LaLonde Creek									
LAL0.1	LaLonde Ck near mouth	11	27	100	meets	0	200	meets	meets both
Mill Creek									
MIL010	Mill Creek at Salmon Ck Ave	11	61	100	meets	0	200	meets	meets both
Casee Creek									
CAS0.5	CASEE Ck nr NE 149th St	11	14	100	meets	18	200	fails	fails Part 2
TRIB to SALMON									
TSAL0.01	LB Trib to Salmon Ck nr SAL3.3	11	2	100	meets	0	200	meets	meets both
Salmon Creek									
SAL3.3	Salmon Ck upstream of Cougar Ck mouth	11	48	100	meets	0	200	meets	meets both
SMN020	Salmon Ck Klineline footbridge; DS side	11	69	100	meets	18	200	fails	fails Part 2
SAL12	Salmon Ck at NE 156th St; downstream side	11	88	100	meets	18	200	fails	fails Part 2

Appendix B-3. Summary for data collected during the **dry season (June - Oct) (N≥5)** by Ecology during the 2014/2015 Lower Salmon Creek FC study.

Study Specific Location ID	Description	Sample size	Water Quality Standards Part 1 (cfu/100 mL) geometric mean	Water Quality Standards Part 1 (cfu/100 mL) Criterion	Water Quality Standards Part 1 (cfu/100 mL) Meets?	Water Quality Standards Part 2 (cfu/100 mL) Percent greater than criterion	Water Quality Standards Part 2 (cfu/100 mL) Criterion	Water Quality Standards Part 2 (cfu/100 mL) Meets?	Overall **DRY** Season Meets WQ Criteria?
COUGAR									
TCOU0.01	Trib at Cougar Ck near mouth left bank	3							
COU0.01	Cougar Ck near mouth upstream of walking bridge	11	503	100	fails	91	200	fail	fails both
COU0.5	Cougar Ck *downstream* of NW 119th St.	11	581	100	fails	100	200	fail	fails both
COU1.6	Cougar Ck near NW 99th St. at Columbia River HS	11	598	100	fails	100	200	fail	fails both
COU94	Cougar Ck upstream of NW 94th St	10	670	100	fails	100	200	fail	fails both
COU2.6	Cougar Ck behind Safeway	11	520	100	fails	91	200	fail	fails both
COU13	Cougar Cr at NE 13th Ave	No data							
TENNY									
TEN010	Tenny Cr at 117th St	11	435	100	fails	100	200	fail	fails both
TEN065	Tenny Creek at 99th St	11	303	100	fails	64	200	fail	fails both
SUDS									
SUD020	Suds Cr downstream of 117th Street	11	389	100	fails	82	200	fail	fails both
114th STREET									
FOR0.01	114th St Trib near mouth	12	344	100	fails	83	200	fail	fails both
FORSYL	114th St Trib at NE Sylvan Terrace	11	246	100	fails	64	200	fail	fails both
FOR28	114th St Trib at NE 28th Ave	10	133	100	fails	30	200	fail	fails both
FORSYLT	SW trib entering RB at NE Sylvan Terrace	11	454	100	fails	82	200	fail	fails both

LaLonde Creek									
LAL0.1	LaLonde Ck near mouth	12	208	100	fails	42	200	fail	fails both
Mill Creek									
MIL010	Mill Creek at Salmon Ck Ave	12	179	100	fails	33	200	fail	fails both
Casee Creek									
CAS0.5	CASEE Ck nr NE 149th St	12	34	100	meets	25	200	fail	fails Part 2
TRIB to SALMON									
TSAL0.01	LB Trib to Salmon Ck nr SAL3.3	8	26	100	meets	12	200	fail	fails Part 2
Salmon Creek									
SAL3.3	Salmon Ck upstream of Cougar Ck mouth	11	62	100	meets	18	200	fail	fails Part 2
SMN020	Salmon Ck Klineline footbridge; DS side	11	123	100	fails	18	200	fail	fails both
SAL12	Salmon Ck at NE 156th St; downstream side	12	168	100	fails	33	200	fails	fails both

Appendix C. Graphical representation of FC data

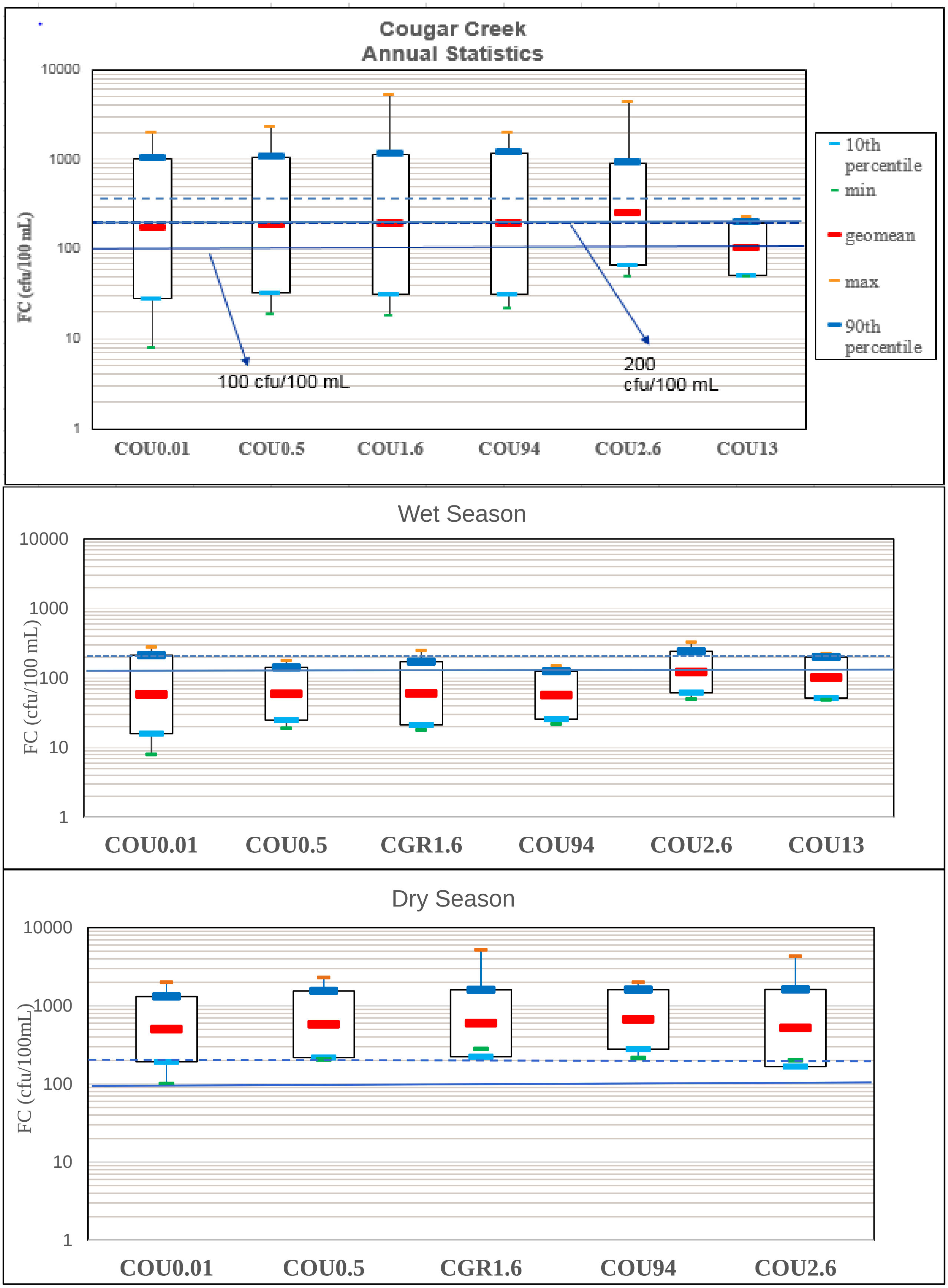
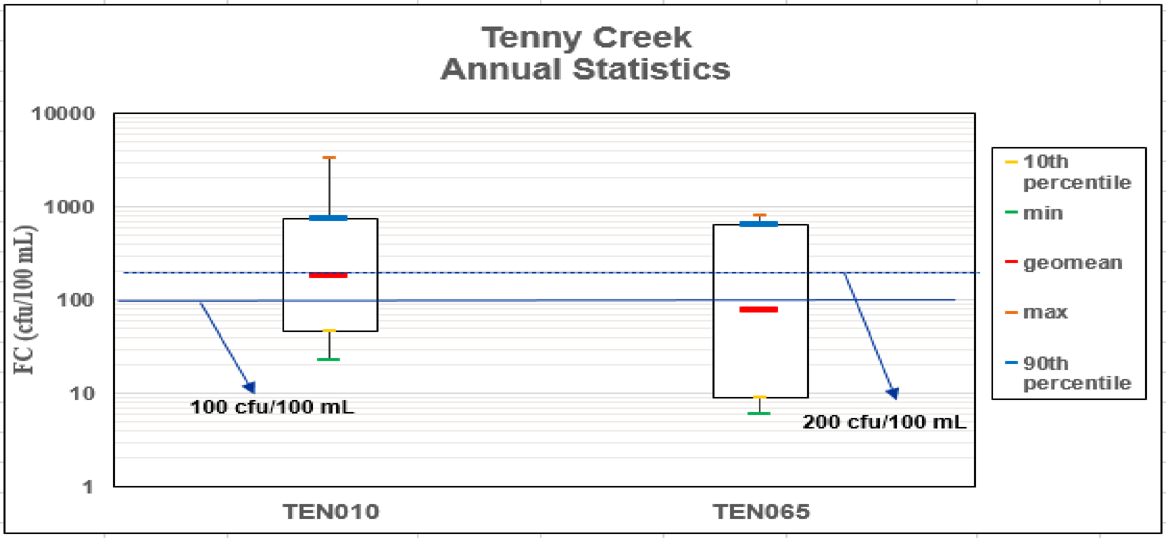
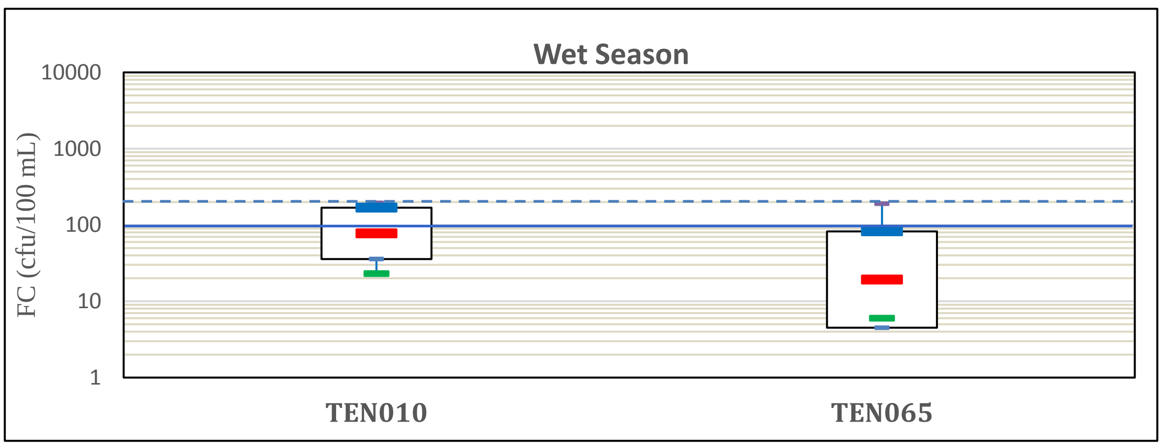


Figure C-1. Cougar Creek annual and seasonal FC graphical display to compare with the water quality standard.





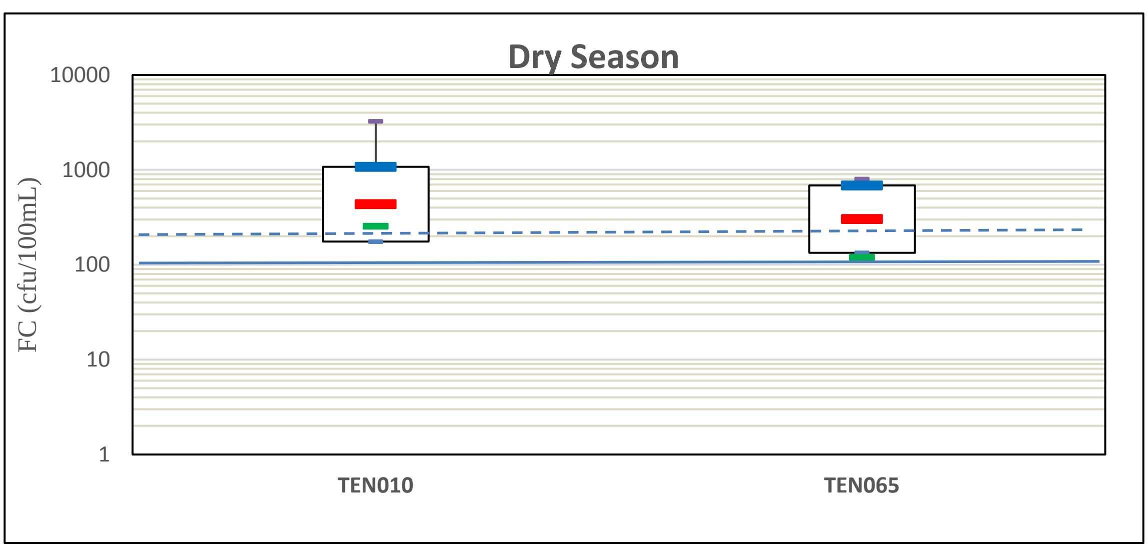


Figure C-2. Tenny Creek annual and seasonal FC graphical display to compare with the water quality standard.

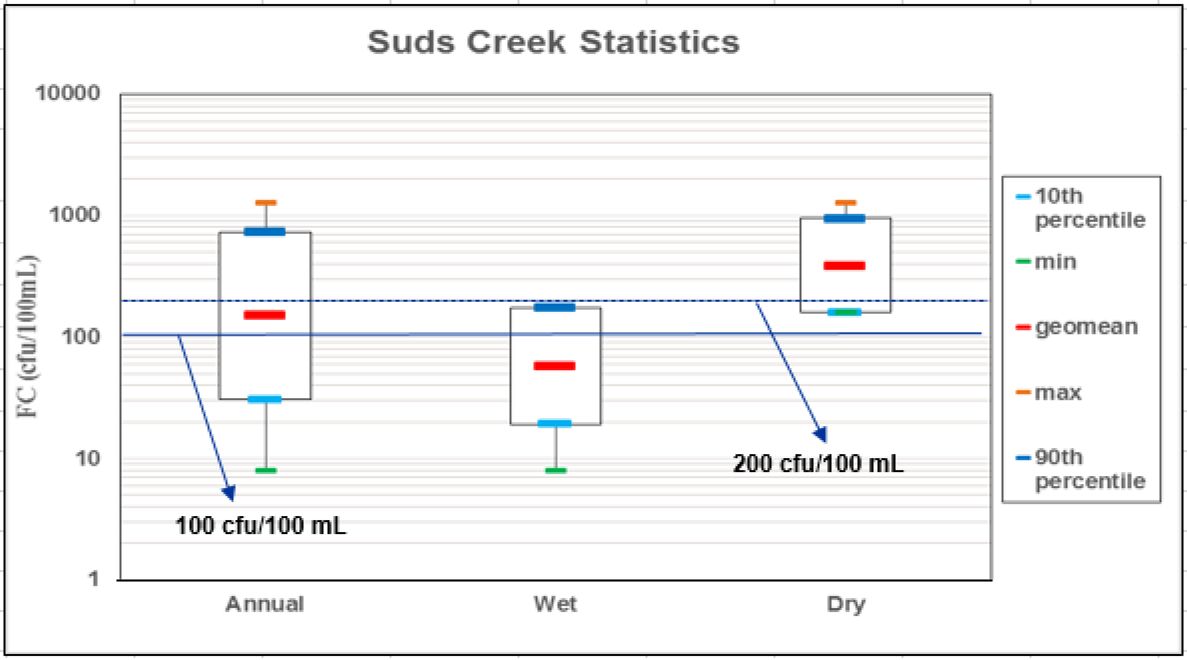


Figure C-3. Suds Creek annual and seasonal FC graphical display to compare with the water quality standard.

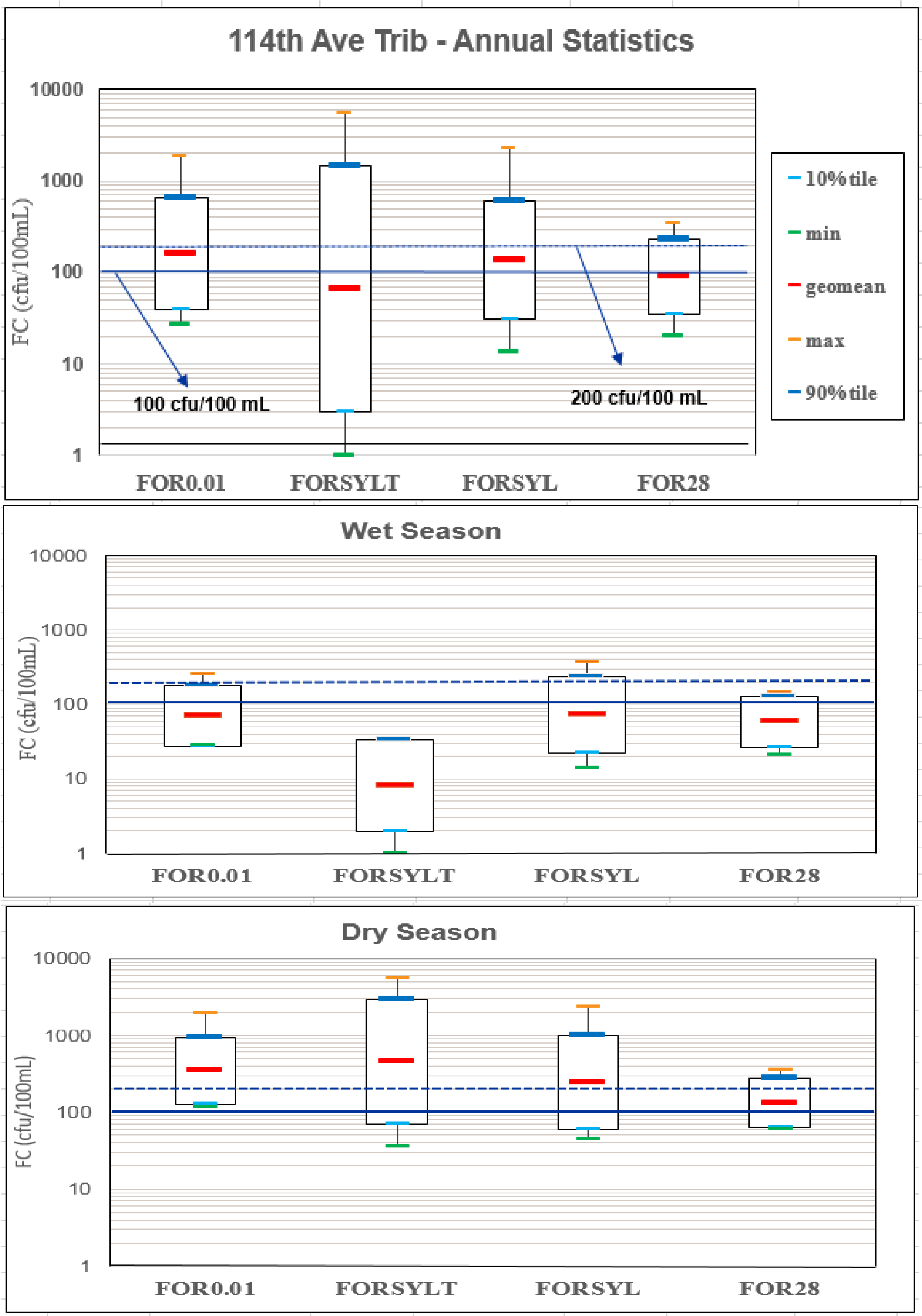


Figure C-4. 114th St Trib annual and seasonal FC graphical display to compare with the water quality standard.

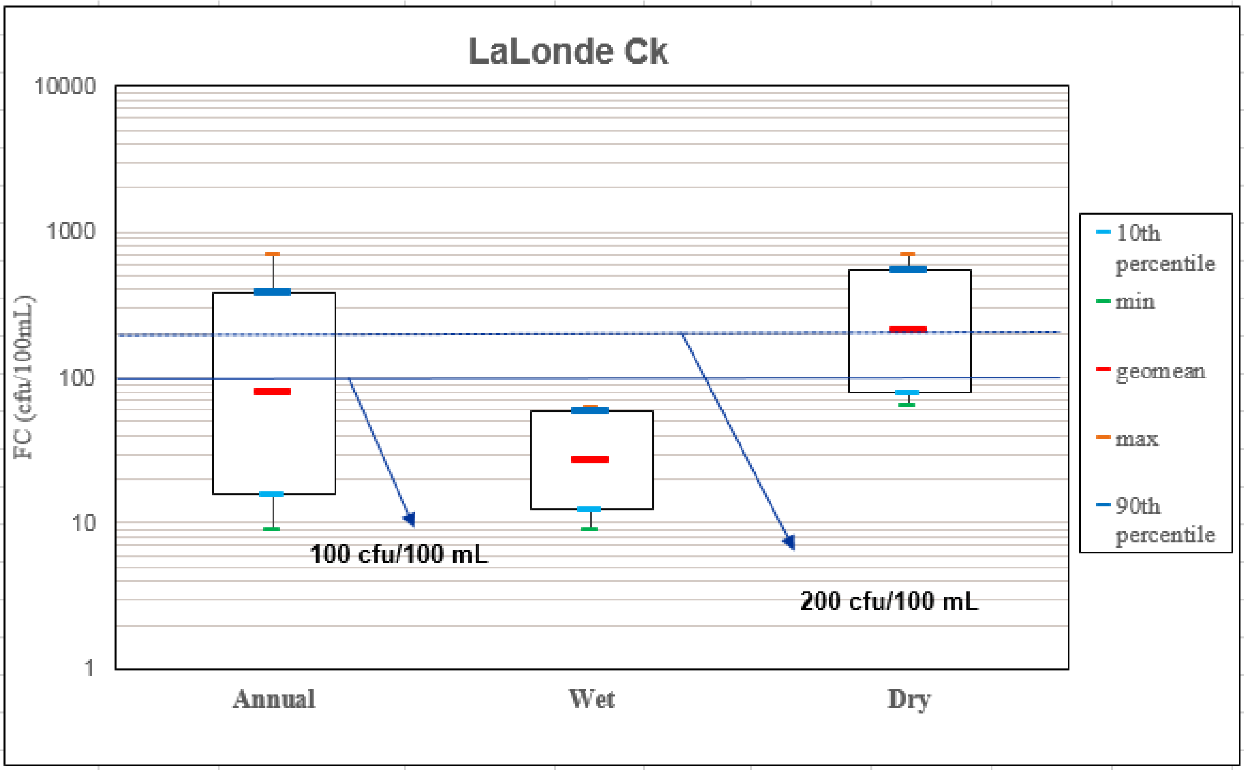


Figure C-5. LaLonde Creek annual and seasonal FC graphical display to compare with the water quality standard.

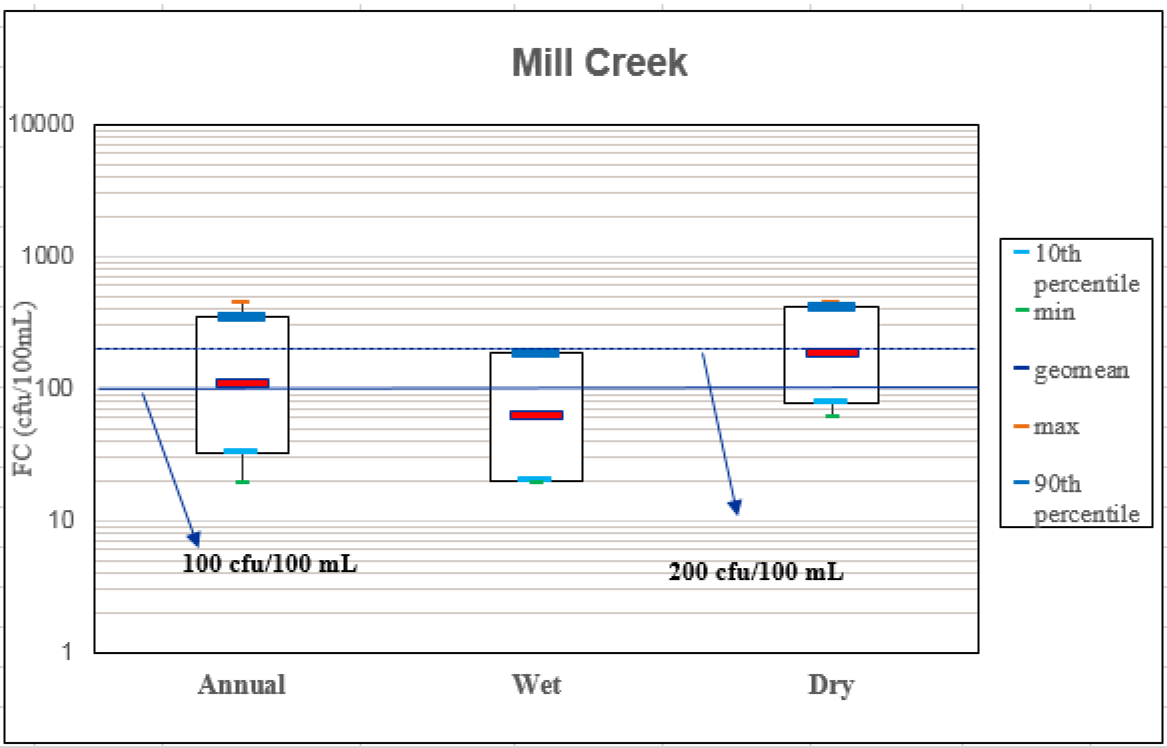


Figure C-6. Mill Creek annual and seasonal FC graphical display to compare with the water quality standard.

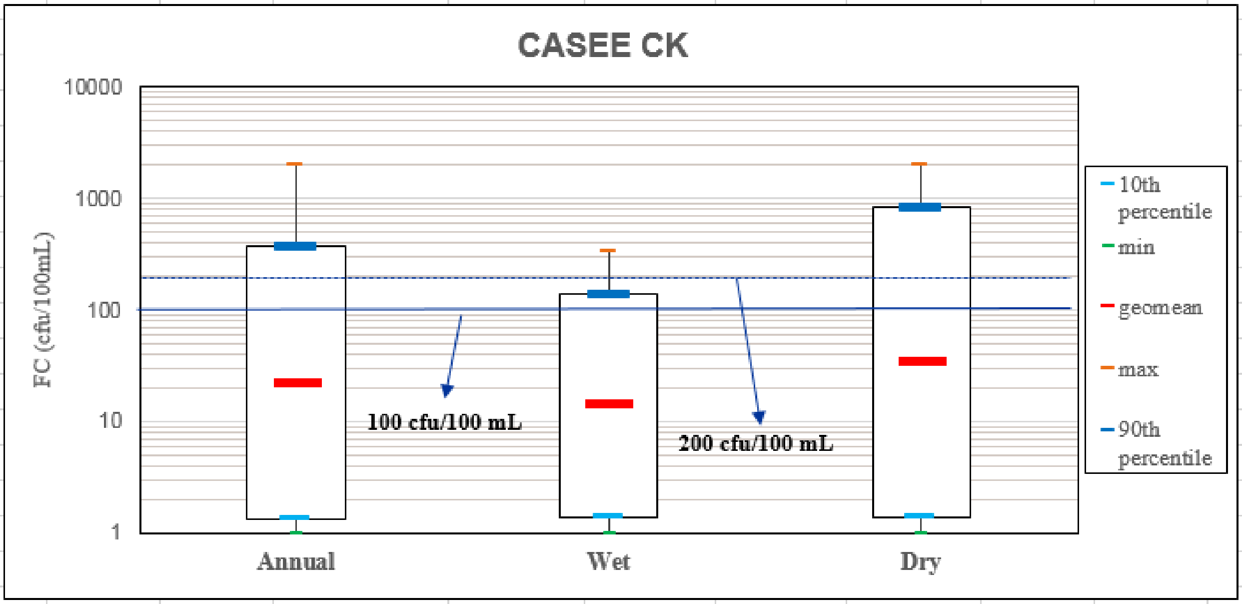


Figure C-7. Casee Creek annual and seasonal FC graphical display to compare with the water quality standard.

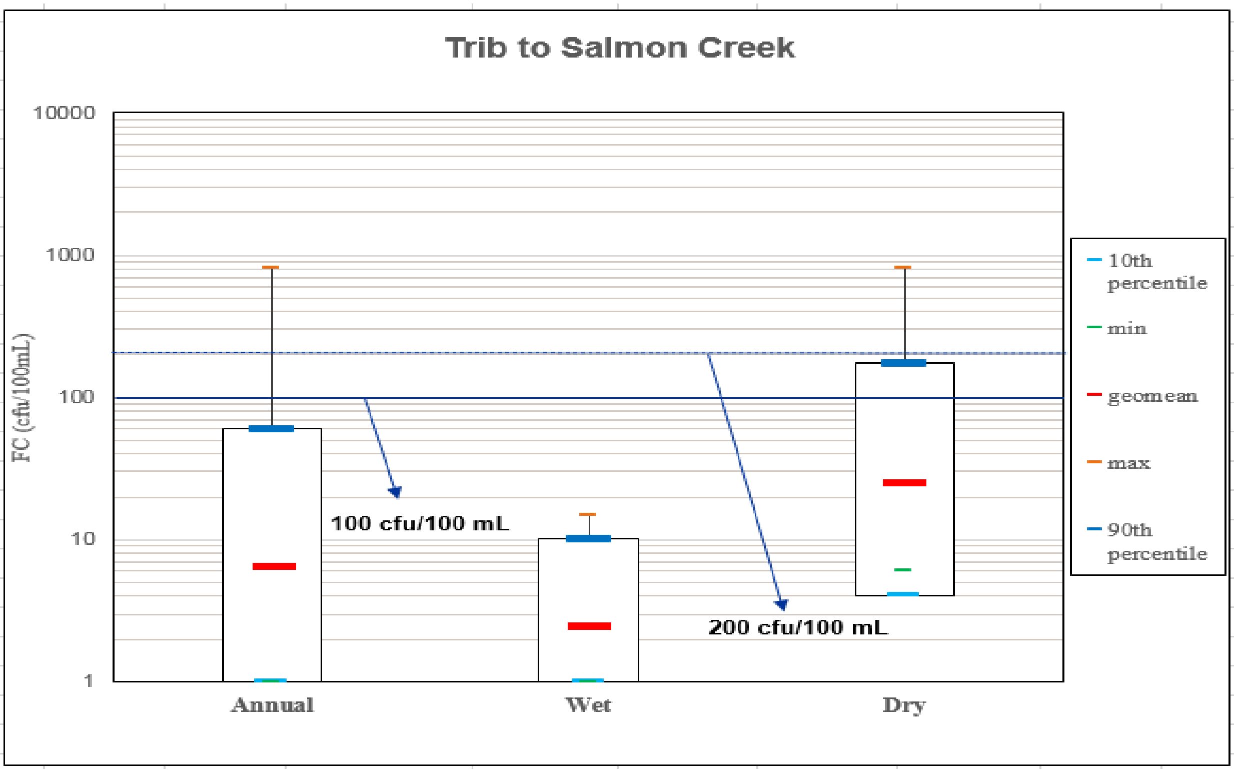


Figure C-8. Trib to Salmon Creek annual and seasonal FC graphical display to compare with the water quality standard.

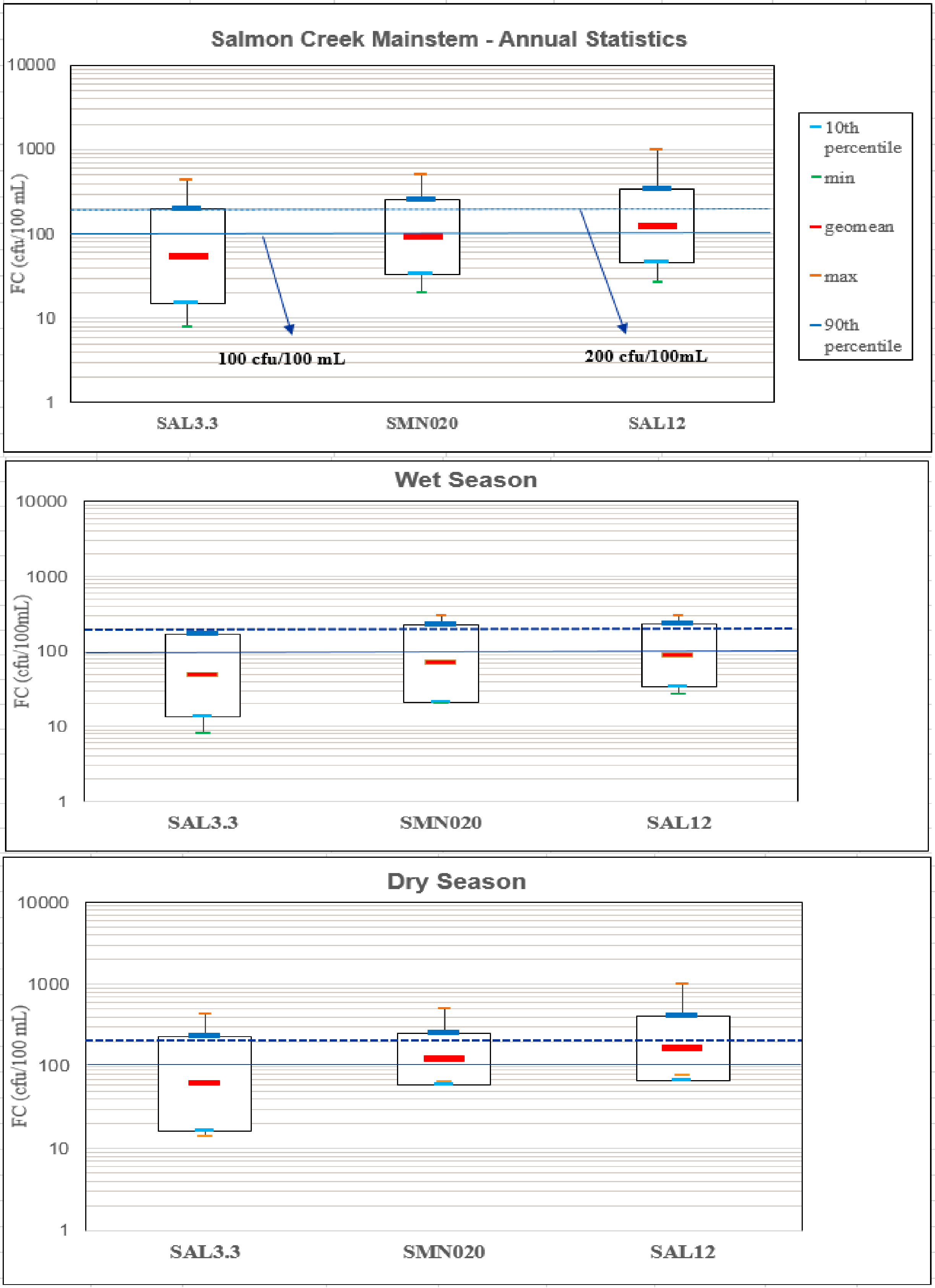


Figure C-9. Salmon Creek annual and seasonal FC graphical display to compare with the water quality standard.

Appendix D. Data and Seasonal Summaries

Date	Name	Time	FC (cfu/100mL)	Q*	Geomean (GM) annual	GM WET Nov-April	GM DRY May-Oct
10/8/2014	TCOU0.01	12:06	96				
10/22/2014	TCOU0.01	13:57	3400	J			
10/22/2014	TCOU0.01C	13:55	5000	J			
11/5/2014	TCOU0.01	13:00	8	U			
11/19/2014	TCOU0.01	12:46	8	U			
12/3/2014	TCOU0.01	13:15	15				
1/7/2015	TCOU0.01	13:15	4				
1/21/2015	TCOU0.01	13:40	1	U			
2/4/2015	TCOU0.01	13:04	8				
2/18/2015	TCOU0.01	12:41	1	U			
3/4/2015	TCOU0.01	12:55	2				
3/18/2015	TCOU0.01	13:36	16				
4/1/2015	TCOU0.01	13:10	6				
4/15/2015	TCOU0.01	13:07	16				
5/13/2015	TCOU0.01	13:32	43		12	5	241
10/8/2014	COU0.01	12:00	395				
10/22/2014	COU0.01	13:51	2000	G			
11/5/2014	COU0.01	12:58	150				
11/19/2014	COU0.01	12:44	62				
12/3/2014	COU0.01	13:12	8				
1/7/2015	COU0.01	13:15	21				
1/21/2015	COU0.01	13:38	280				
2/4/2015	COU0.01	13:02	160				
2/18/2015	COU0.01	12:40	56				
3/4/2015	COU0.01	12:52	52				
3/18/2015	COU0.01	13:35	49				
4/1/2015	COU0.01	13:08	27				
4/15/2015	COU0.01	13:05	96				
5/13/2015	COU0.01	13:30	760	J			
5/26/2015	COU0.01	13:00	800	G			
6/10/2015	COU0.01	12:50	690	J			
6/24/2015	COU0.01	13:06	430				
7/22/2015	COU0.01	13:08	690	J			
8/5/2015	COU0.01	13:57	320				
8/19/2015	COU0.01	13:57	100				
9/2/2015	COU0.01	12:54	530				
9/14/2015	COU0.01	13:04	310		171	58	503
10/8/2014	COU0.5	11:48	2300	J			
10/22/2014	COU0.5	13:37	2000	G			

Date	Name	Time	FC (cfu/100mL)	Q*	Geomean (GM) annual	GM WET Nov-April	GM DRY May-Oct
10/22/2014	COU0.5T	13:34	3000	J			
11/5/2014	COU0.5	12:45	180				
11/19/2014	COU0.5	12:30	38				
12/3/2014	COU0.5	13:00	19				
1/7/2015	COU0.5	13:00	26				
1/21/2015	COU0.5	13:27	97				
2/4/2015	COU0.5	12:48	135				
2/18/2015	COU0.5	12:25	40				
3/4/2015	COU0.5	12:40	80				
3/18/2015	COU0.5	13:23	52				
4/1/2015	COU0.5	12:57	66				
4/15/2015	COU0.5	12:54	68				
5/13/2015	COU0.5	13:19	575	J			
5/26/2015	COU0.5	12:49	800	G			
6/10/2015	COU0.5	12:40	590				
6/24/2015	COU0.5	12:55	670	J			
7/22/2015	COU0.5	12:56	390				
8/5/2015	COU0.5	13:44	240				
8/19/2015	COU0.5	13:46	205				
9/2/2015	COU0.5	12:42	405				
9/14/2015	COU0.5	12:53	390		186	59	581
11/19/2014	CGR020	13:15	8				
10/8/2014	CGR1.6	11:30	440				
10/22/2014	CGR1.6	13:10	5200	J			
11/5/2014	CGR1.6	12:25	250				
11/19/2014	CGR1.6	12:15	19				
12/3/2014	CGR1.6	12:45	38				
1/7/2015	CGR1.6	12:45	18				
1/21/2015	CGR1.6	13:15	57				
2/4/2015	CGR1.6	12:34	150				
2/18/2015	CGR1.6	12:08	130				
3/4/2015	CGR1.6	12:27	78				
3/18/2015	CGR1.6	13:10	60				
4/1/2015	CGR1.6	12:43	42				
4/15/2015	CGR1.6	12:41	55				
5/13/2015	CGR1.6	13:02	360				
5/26/2015	CGR1.6	12:38	280				
6/10/2015	CGR1.6	12:27	390				
6/24/2015	CGR1.6	12:43	455				
7/22/2015	CGR1.6	12:42	665	J			
8/5/2015	CGR1.6	13:27	580	J			
8/19/2015	CGR1.6	13:32	640	J			
9/2/2015	CGR1.6	12:30	655	J			

Date	Name	Time	FC (cfu/100mL)	Q*	Geomean (GM) annual	GM WET Nov-April	GM DRY May-Oct
9/14/2015	CGR1.6	12:34	525		190	60	598
9/14/2015	CGRCULV	12:35	800	G			
10/22/2014	COU94	12:55	2000	G			
10/22/2014	COU94T	12:56	4200	J			
11/19/2014	COU94	12:05	69				
12/3/2014	COU94	12:38	46				
1/7/2015	COU94	12:35	22				
1/21/2015	COU94	13:04	64				
2/4/2015	COU94	12:25	150				
2/18/2015	COU94	12:00	99				
3/4/2015	COU94	12:18	24				
3/18/2015	COU94	13:00	79				
4/1/2015	COU94	12:34	35				
4/15/2015	COU94	12:33	79				
5/13/2015	COU94	12:50	340				
5/26/2015	COU94	12:25	215				
6/10/2015	COU94	12:19	470				
6/24/2015	COU94	12:34	495				
7/22/2015	COU94	12:33	745	J			
8/5/2015	COU94	13:17	575	J			
8/19/2015	COU94	13:23	1700	J			
9/2/2015	COU94	12:21	950	G			
9/14/2015	COU94	12:24	770	J	195	57	670
10/8/2014	COU2.6	11:10	200				
10/22/2014	COU2.6	12:35	4300	J			
11/5/2014	COU2.6	12:15	330				
11/19/2014	COU2.6	11:55	195				
12/3/2014	COU2.6	12:30	100				
1/7/2015	COU2.6	12:20	110				
1/21/2015	COU2.6	12:46	98				
2/4/2015	COU2.6	12:10	200				
2/18/2015	COU2.6	11:56	50				
3/4/2015	COU2.6	12:05	180				
3/18/2015	COU2.6	12:41	105				
4/1/2015	COU2.6	12:27	97				
4/15/2015	COU2.6	12:18	72				
5/13/2015	COU2.6	12:34	245				
5/26/2015	COU2.6	12:10	260				
6/10/2015	COU2.6	11:54	325				
6/24/2015	COU2.6	12:26	540				
7/22/2015	COU2.6	12:10	1250	J			
8/5/2015	COU2.6	12:42	320				
8/19/2015	COU2.6	13:02	510	J			

Date	Name	Time	FC (cfu/100mL)	Q*	Geomean (GM) annual	GM WET Nov-April	GM DRY May-Oct
9/2/2015	COU2.6	12:03	480				
9/14/2015	COU2.6	12:17	800	G	252	122	520
12/3/2014	COU13	11:55	140				
1/7/2015	COU13	12:15	225				
1/21/2015	COU13	12:36	113				
2/4/2015	COU13	12:00	170				
2/18/2015	COU13	11:45	68				
3/4/2015	COU13	11:52	70				
3/18/2015	COU13	12:30	49				
4/1/2015	COU13	12:20	140				
4/15/2015	COU13	12:10	59		102	102	na
10/8/2014	TEN010	10:44	500				
10/22/2014	TEN010	12:25	3250	J			
11/5/2014	TEN010	11:55	101				
11/19/2014	TEN010	11:40	23				
12/3/2014	TEN010	11:35	38				
1/7/2015	TEN010	12:00	56				
1/21/2015	TEN010	12:19	69				
2/4/2015	TEN010	11:42	130				
2/18/2015	TEN010	11:28	74				
3/4/2015	TEN010	11:35	84				
3/18/2015	TEN010	12:13	195				
4/1/2015	TEN010	11:53	140				
4/15/2015	TEN010	11:47	83				
5/13/2015	TEN010	12:01	380				
5/26/2015	TEN010	11:43	255				
6/10/2015	TEN010	11:38	315				
6/24/2015	TEN010	12:11	485				
7/22/2015	TEN010	11:55	255				
8/5/2015	TEN010	12:21	285				
8/19/2015	TEN010	12:48	445				
9/2/2015	TEN010	11:49	360				
9/14/2015	TEN010	11:47	375		184	78	435
10/8/2014	TEN065	10:30	180				
10/22/2014	TEN065	11:50	570				
11/5/2014	TEN065	11:41	15				
11/19/2014	TEN065	11:30	8				
12/3/2014	TEN065	11:20	8				
1/7/2015	TEN065	11:45	9				
1/21/2015	TEN065	12:06	25	J			
2/4/2015	TEN065	11:28	6				
2/18/2015	TEN065	11:16	9				
3/4/2015	TEN065	11:25	16				

Date	Name	Time	FC (cfu/100mL)	Q*	Geomean (GM) annual	GM WET Nov-April	GM DRY May-Oct
3/18/2015	TEN065	11:56	190				
4/1/2015	TEN065	11:40	35				
4/15/2015	TEN065	11:37	110				
5/13/2015	TEN065	11:50	150				
5/26/2015	TEN065	11:30	140				
6/10/2015	TEN065	11:28	120				
6/24/2015	TEN065	12:00	460				
7/22/2015	TEN065	11:45	450				
8/5/2015	TEN065	12:04	330				
8/19/2015	TEN065	12:35	300				
9/2/2015	TEN065	11:39	460				
9/14/2015	TEN065	11:31	800	G	76	19	303
10/22/2014	TEN1.5	11:45	1100				
3/18/2015	TEN1.5	11:50	43				
4/1/2015	TEN1.5	11:35	16				
10/8/2014	SUD020	10:12	320	J			
10/22/2014	SUD020	11:35	1300				
11/5/2014	SUD020	10:45	100				
11/19/2014	SUD020	11:15	38				
12/3/2014	SUD020	11:03	8				
1/7/2015	SUD020	11:25	36				
1/21/2015	SUD020	11:52	29				
2/4/2015	SUD020	11:08	99				
2/18/2015	SUD020	11:00	120				
3/4/2015	SUD020	11:10	51				
3/18/2015	SUD020	11:38	170				
4/1/2015	SUD020	11:17	80				
4/15/2015	SUD020	11:15	92				
5/13/2015	SUD020	11:30	450				
5/26/2015	SUD020	11:12	190				
6/10/2015	SUD020	11:17	160				
6/24/2015	SUD020	11:46	290				
7/22/2015	SUD020	11:34	280				
8/5/2015	SUD020	11:44	320				
8/19/2015	SUD020	12:17	1300	J			
9/2/2015	SUD020	11:19	610	J			
9/14/2015	SUD020	11:17	260		150	58	389
10/8/2014	FOR0.01	9:53	215	J			
10/22/2014	FOR0.01	11:00	1900	J			
10/22/2014	FOR0.1P	11:03	1400	J			
11/5/2014	FOR0.01	10:30	31				
11/19/2014	FOR0.01	11:00	250				
12/3/2014	FOR0.01	10:52	31				

Date	Name	Time	FC (cfu/100mL)	Q*	Geomean (GM) annual	GM WET Nov-April	GM DRY May-Oct
1/7/2015	FOR0.01	11:10	28				
1/21/2015	FOR0.01	11:37	91				
2/4/2015	FOR0.01	10:54	80				
2/18/2015	FOR0.01	10:45	73				
3/4/2015	FOR0.01	10:55	44				
3/18/2015	FOR0.01	11:08	83				
4/1/2015	FOR0.01	11:05	68				
4/15/2015	FOR0.01	11:00	225				
5/13/2015	FOR0.01	11:11	230				
5/26/2015	FOR0.01	10:55	115				
6/10/2015	FOR0.01	11:00	220				
6/24/2015	FOR0.01	11:26	260				
7/8/2015	FOR0.01	11:25	190				
7/22/2015	FOR0.01	11:22	240				
8/5/2015	FOR0.01	11:23	490				
8/19/2015	FOR0.01	12:03	920	J			
9/2/2015	FOR0.01	11:00	390	J			
9/14/2015	FOR0.01	11:04	550		161	70	344
10/22/2014	FORSYLT	12:13	5500	J			
11/19/2014	FORSYLT	10:50	15	J			
12/3/2014	FORSYLT	10:43	8	U			
1/7/2015	FORSYLT	11:00	9				
1/21/2015	FORSYLT	11:28	9				
2/4/2015	FORSYLT	10:45	19				
2/18/2015	FORSYLT	10:36	2				
3/4/2015	FORSYLT	10:45	1	U			
3/18/2015	FORSYLT	10:58	4				
4/1/2015	FORSYLT	10:56	24				
4/15/2015	FORSYLT	10:52	33				
5/13/2015	FORSYLT	11:01	290				
5/26/2015	FORSYLT	10:46	35				
6/10/2015	FORSYLT	10:52	40				
6/24/2015	FORSYLT	11:15	800	G			
7/8/2015	FORSYLT	11:15	420				
7/22/2015	FORSYLT	11:11	920	J			
8/5/2015	FORSYLT	11:11	480				
8/19/2015	FORSYLT	11:52	1300	J			
9/2/2015	FORSYLT	10:47	490				
9/14/2015	FORSYLT	10:50	800	G	67	8	454
10/22/2014	FORSYL	12:10	2300	J			
11/19/2014	FORSYL	10:35	360	J			
12/3/2014	FORSYL	10:45	58				
1/7/2015	FORSYL	11:03	53				

Date	Name	Time	FC (cfu/100mL)	Q*	Geomean (GM) annual	GM WET Nov-April	GM DRY May-Oct
1/21/2015	FORSYL	11:29	28				
2/4/2015	FORSYL	10:46	81				
2/18/2015	FORSYL	10:38	14				
3/4/2015	FORSYL	10:47	51				
3/18/2015	FORSYL	10:59	140				
4/1/2015	FORSYL	10:57	110				
4/15/2015	FORSYL	10:54	150				
5/13/2015	FORSYL	11:02	240				
5/26/2015	FORSYL	10:47	45				
6/10/2015	FORSYL	10:53	150				
6/24/2015	FORSYL	11:17	88				
7/8/2015	FORSYL	11:16	80				
7/22/2015	FORSYL	11:13	330				
8/5/2015	FORSYL	11:13	220				
8/19/2015	FORSYL	11:53	570	J			
9/2/2015	FORSYL	10:49	620	J			
9/14/2015	FORSYL	10:52	300		138	73	246
12/3/2014	FOR28	10:35	38				
1/7/2015	FOR28	10:45	96				
1/21/2015	FOR28	11:23	45				
2/4/2015	FOR28	10:39	39				
2/18/2015	FOR28	10:32	21				
3/4/2015	FOR28	10:40	57				
3/18/2015	FOR28	10:53	60				
4/1/2015	FOR28	10:48	120				
4/15/2015	FOR28	10:50	140				
5/13/2015	FOR28	10:52	73				
5/26/2015	FOR28	10:40	60				
6/10/2015	FOR28	10:45	120				
6/24/2015	FOR28	11:09	150				
7/8/2015	FOR28	11:08	76				
7/22/2015	FOR28	11:05	140				
8/5/2015	FOR28	11:03	290				
8/19/2015	FOR28	11:45	250				
9/2/2015	FOR28	10:40	350				
9/14/2015	FOR28	10:35	83		90	58	133
10/8/2014	LAL0.1	9:45	160	J			
10/22/2014	LAL0.1	10:48	470	J			
11/5/2014	LAL0.1	10:20	31				
11/19/2014	LAL0.1	10:20	23				
12/3/2014	LAL0.1	10:25	38				
1/7/2015	LAL0.1	10:35	33				
1/21/2015	LAL0.1	11:14	10				

Date	Name	Time	FC (cfu/100mL)	Q*	Geomean (GM) annual	GM WET Nov-April	GM DRY May-Oct
2/4/2015	LAL0.1	10:30	32				
2/18/2015	LAL0.1	10:24	19				
3/4/2015	LAL0.1	10:32	9				
3/18/2015	LAL0.1	10:45	48				
4/1/2015	LAL0.1	10:38	39				
4/15/2015	LAL0.1	10:38	63				
5/13/2015	LAL0.1	10:41	160				
5/26/2015	LAL0.1	10:31	690	J			
6/10/2015	LAL0.1	10:37	350				
6/24/2015	LAL0.1	11:00	320				
7/8/2015	LAL0.1	10:55	520				
7/22/2015	LAL0.1	10:55	140				
8/5/2015	LAL0.1	10:52	120				
8/19/2015	LAL0.1	11:35	130				
9/2/2015	LAL0.1	10:30	99				
9/14/2015	LAL0.1	10:27	64		79	27	208
10/8/2014	MIL010	9:30	61	J			
10/22/2014	MIL010	10:35	430	J			
11/5/2014	MIL010	10:05	165	J			
11/19/2014	MIL010	10:10	23				
12/3/2014	MIL010	10:10	23				
1/7/2015	MIL010	10:25	32				
1/21/2015	MIL010	10:50	35				
1/21/2015	MILT010	10:52	2				
2/4/2015	MIL010	10:17	130				
2/18/2015	MIL010	10:15	83				
3/4/2015	MIL010	10:22	19				
3/18/2015	MIL010	10:31	115				
4/1/2015	MIL010	10:26	99				
4/15/2015	MIL010	10:26	185				
5/13/2015	MIL010	10:30	350				
5/26/2015	MIL010	10:20	80				
6/10/2015	MIL010	10:25	180				
6/24/2015	MIL010	10:50	445				
7/8/2015	MIL010	10:43	175				
7/22/2015	MIL010	10:42	185				
8/5/2015	MIL010	10:36	81				
8/19/2015	MIL010	11:25	245				
9/2/2015	MIL010	10:18	190				
9/14/2015	MIL010	10:16	150		107	61	179
10/8/2014	CAS0.5	9:04	220	J			
10/22/2014	CAS0.5	10:15	2000	G			
11/5/2014	CAS0.5	9:30	23	J			

Date	Name	Time	FC (cfu/100mL)	Q*	Geomean (GM) annual	GM WET Nov-April	GM DRY May-Oct
11/19/2014	CAS0.5	9:46	38	J			
11/19/2014	CGR020	13:15	8				
12/3/2014	CAS0.5	9:50	8				
1/7/2015	CAS0.5	10:00	7				
1/21/2015	CAS0.5	10:25	2				
2/4/2015	CAS0.5	9:52	10				
2/18/2015	CAS0.5	9:55	1	U			
3/4/2015	CAS0.5	10:01	3				
3/18/2015	CAS0.5	10:10	19				
4/1/2015	CAS0.5	10:05	200				
4/15/2015	CAS0.5	10:05	340	J			
5/13/2015	CAS0.5	10:04	88				
5/26/2015	CAS0.5	9:57	1	U			
6/10/2015	CAS0.5	10:03	7				
6/24/2015	CAS0.5	10:25	1	U			
7/8/2015	CAS0.5	10:22	2				
7/22/2015	CAS0.5	10:18	16				
8/5/2015	CAS0.5	10:05	85				
8/19/2015	CAS0.5	11:03	77				
9/2/2015	CAS0.5	9:55	800	G			
9/14/2015	CAS0.5	9:54	57		22	14	34
10/8/2014	TSAL0.01	12:18	8				
10/22/2014	TSAL0.01	14:02	820				
11/5/2014	TSAL0.01	13:08	8	U			
11/19/2014	TSAL0.01	12:50	15				
12/3/2014	TSAL0.01	13:20	15				
1/7/2015	TSAL0.01	13:20	1	U			
1/21/2015	TSAL0.01	13:45	2				
2/4/2015	TSAL0.01	13:09	2				
2/18/2015	TSAL0.01	12:41	1	U			
3/4/2015	TSAL0.01	12:58	1	U			
3/18/2015	TSAL0.01	13:41	3				
4/1/2015	TSAL0.01	13:15	1	U			
4/15/2015	TSAL0.01	13:11	1	U			
5/13/2015	TSAL0.01	13:37	21				
5/26/2015	TSAL0.01	13:07	24				
6/10/2015	TSAL0.01	12:55	15				
6/24/2015	TSAL0.01	13:13	6				
7/22/2015	TSAL0.01	13:12	29				
8/5/2015	TSAL0.01	14:02	21		7	2	26
10/8/2014	SAL3.3	12:15	41				
10/22/2014	SAL3.3	14:05	390				
11/5/2014	SAL3.3	13:11	180				

Date	Name	Time	FC (cfu/100mL)	Q*	Geomean (GM) annual	GM WET Nov-April	GM DRY May-Oct
11/19/2014	SAL3.3	12:55	23				
12/3/2014	SAL3.3	13:21	8				
1/7/2015	SAL3.3	13:25	33				
1/21/2015	SAL3.3	13:48	37				
2/4/2015	SAL3.3	13:11	53				
2/18/2015	SAL3.3	12:47	31				
3/4/2015	SAL3.3	13:00	21				
3/18/2015	SAL3.3	13:43	81				
4/1/2015	SAL3.3	13:17	160				
4/15/2015	SAL3.3	13:13	170				
5/13/2015	SAL3.3	13:38	440				
5/26/2015	SAL3.3	13:10	40				
6/10/2015	SAL3.3	13:00	37				
6/24/2015	SAL3.3	13:15	68				
7/22/2015	SAL3.3	13:14	57				
8/5/2015	SAL3.3	14:05	28				
8/19/2015	SAL3.3	14:05	14				
9/2/2015	SAL3.3	13:00	68				
9/14/2015	SAL3.3	13:10	45		54	48	62
10/8/2014	SMN020	10:51	126				
10/22/2014	SMN020	11:30	210				
11/5/2014	SMN020	10:35	161				
11/19/2014	SMN020	11:05	20	U			
12/3/2014	SMN020	11:00	46				
1/7/2015	SMN020	11:15	27				
1/21/2015	SMN020	11:43	41				
2/4/2015	SMN020	11:00	67				
2/18/2015	SMN020	10:50	47				
3/4/2015	SMN020	11:00	33				
3/18/2015	SMN020	11:20	130				
4/1/2015	SMN020	11:10	300				
4/15/2015	SMN020	11:06	260				
5/13/2015	SMN020	11:19	500				
5/26/2015	SMN020	11:02	88				
6/10/2015	SMN020	11:07	100				
6/24/2015	SMN020	11:32	77				
7/22/2015	SMN020	11:28	100				
8/5/2015	SMN020	11:35	65				
8/19/2015	SMN020	12:09	120				
9/2/2015	SMN020	11:07	150				
9/14/2015	SMN020	11:11	92		92	69	123
10/8/2014	SAL12	9:15	100	J			
10/22/2014	SAL12	10:05	230	J			

Date	Name	Time	FC (cfu/100mL)	Q*	Geomean (GM) annual	GM WET Nov-April	GM DRY May-Oct
11/5/2014	SAL12	9:45	92	J			
11/19/2014	SAL12	10:00	160	J			
12/3/2014	SAL12	10:00	54				
1/7/2015	SAL12	10:10	44				
1/21/2015	SAL12	10:34	27				
2/4/2015	SAL12	10:02	230				
2/18/2015	SAL12	10:00	83	J			
3/4/2015	SAL12	10:10	43				
3/18/2015	SAL12	10:18	84				
4/1/2015	SAL12	10:13	300				
4/15/2015	SAL12	10:15	130				
5/13/2015	SAL12	10:15	1000	J			
5/26/2015	SAL12	10:05	160				
6/10/2015	SAL12	10:11	110				
6/24/2015	SAL12	10:32	88				
7/8/2015	SAL12	10:10	120				
7/22/2015	SAL12	10:30	320				
8/5/2015	SAL12	10:19	140				
8/19/2015	SAL12	11:10	240				
9/2/2015	SAL12	10:05	140				
9/14/2015	SAL12	10:02	77		123	88	168

Q = qualifier: G = Greater than. J = estimate. U = below detection limit.

Appendix E. Glossary, Acronyms, and Abbreviations

Anthropogenic: Human-caused.

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.

Geometric mean: 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 10 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.

Pathogen: Disease-causing microorganisms such as bacteria, protozoa, viruses.

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 are 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.

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.

Total Maximum Daily Load (TMDL): Water cleanup plan. 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.

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 standards and are not expected to improve within the next two years.

90th percentile: A statistical number obtained from a distribution of a data set, above which 10% of the data exists and below which 90% of the data exists.

Acronyms and Abbreviations

Following are acronyms and abbreviations used frequently in this report.

CM	Creek mile
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
MEL	Manchester Environmental Laboratory
RSD	Relative standard deviation
SOP	Standard operating procedures
TMDL	(See Glossary above)
WAC	Washington Administrative Code
WRIA	Water Resource Inventory Area
WWTP	Wastewater treatment plant

Units of Measurement

cfu	colony forming units