Salmon Creek Focused Assessment: Fecal Coliform and Turbidity (SCFA)

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Executive Summary

This study supports Washington State Department of Ecology ongoing Total Maximum Daily Load (TMDL) implementation for Salmon Creek. The Salmon Creek watershed has a TMDL in place for fecal coliform bacteria and turbidity. Fecal coliform is a major concern because it indicates that biological waste is entering waterways. Turbidity is a major concern because turbid waters impair the ability of fish to survive and spawn by degrading habitat for fish and their food sources.

The lower Salmon Creek subwatersheds are highly urbanized; indicators such as total impervious area, forest cover, and road density suggest a high level of human impact on water quality. However, little to no water quality data exists for multiple tributaries of Salmon Creek that flow through these areas. This study supports Ecology's TMDL efforts by collecting fecal coliform and turbidity data from six tributaries of lower Salmon Creek.

Eight stations were monitored bimonthly by Clean Water Program staff and volunteers from October 2007 through September 2008. Fecal coliform and turbidity data were analyzed by station as well as by weather and season. Results showed that:

- No station met the state water quality criteria for fecal coliform concentration.
- In tributaries with multiple stations, fecal coliform increased considerably from the upper stations to the lower stations.
- Wet weather fecal coliform values during the dry season are significantly higher than all other event categories.
- Dry weather fecal coliform values during the wet season are significantly lower than all other event categories.
- Dry weather fecal coliform values are significantly higher during the dry season than the wet season.
- Wet weather fecal coliform values are significantly higher in the wet season than dry weather.
- The highest fecal coliform and turbidity levels occurred during a "seasonal first flush" storm event.
- Stations exceeded background turbidity levels (>7.5 NTU) 13 - 79 percent of the time.
- Turbidity levels are significantly higher during wet weather than dry weather.
- Turbidity levels are *not* significantly different between dry weather in the dry season and dry weather during the wet season.

The following recommendations are possible next-steps for locating and removing sources of fecal coliform and turbidity to stormwater and surface water resources to further support TMDL efforts.

- Initiate specific technical assistance visits and public contacts at known locations that discharge to the municipal separate storm sewer system or directly to streams. Initial priority should be given to those locations listed in the 2008 Stormwater Needs Assessment Report for Salmon Creek (r.m. 03.83) and Cougar Creek.
- Promote focused septic system inspection, education programs, and agricultural best management practice implementation directed at reductions in fecal coliform.
- Initiate additional source control activities, focused on the Cougar Creek and Tenny Creek tributaries. These could include map-based research to locate potential pollution generating sites in these areas, site-specific technical assistance visits, focused mailings, septic system educational programs and other activities.
- Continue long-term monthly monitoring at the SMN010 and CGR020 stations.

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(SCFA)

Background

Salmon Creek Watershed

This study takes place in the Salmon Creek watershed. The Salmon Creek watershed is comprised of 89 square miles of rural, residential, commercial, forest, and industrial land. Located near the center of the Clark County, the watershed extends from the Cascade foothills east of Hockinson, west to Lake River on the Columbia River flood plain. Salmon Creek itself flows 26 miles from forested headwaters on Elkhorn Mountain, through rural, agricultural, residential, and urban areas. The upper reaches of the watershed include forested areas, large-lot residential parcels, and agricultural lands. The lower watershed is a mixture of developed and rapidly urbanizing areas. The watershed, and thus the water quality, has been intensely impacted by land development and human activities. Impacts to the stream hydrology, biology, and chemical integrity have all been documented (Ecology, 1995, 2001, and 2005).

Indicators such as total impervious area (TIA), forest cover, and road density (Table 1) suggest a high level of human impact on water quality in the Salmon Creek watershed; particularly within its more urbanized subwatersheds (Wierenga, 2005). All three indicators exceed healthy watershed targets in the Salmon Creek watershed as a whole, and three of its more urbanized subwatersheds in the lower watershed.

Table 1. Watershed characteristics for the Salmon Creek Watershed and three of its more urbanized subwatersheds. Targets for healthy watersheds taken from Center for Watershed Protection, 1998 and NOAA Fisheries, 2003. Highlighted characteristics exceed targets for healthy watersheds.

Watershed Characteristic	Salmon Creek Watershed	Cougar Creek Subwatershed	Salmon Creek r.m. 3.83 Subwatershed	Tenny Subwatershed	Target for healthy watershed
Area ($mile^2$)	89.0	3.0	6.3	1.6	N/A
Total Impervious Area (%)	24	50.6	41.1	48.1	< 10% Total Impervious Area
Forest Cover (%)	29	7.1	12.5	6.5	> 50% Forest Cover
Road Density (per $mile^2$)	8.0	16.5	14.3	17.5	< 3 miles per $mile^2$
Population Density (per $mile^2$)	N/A	3196	2348	4644	N/A

Total Maximum Daily Load (TMDL) Implementation

Clark County supports TMDL implementation through the stormwater management program under its NPDES Municipal Permit. Washington state water quality criteria established under Chapter 173-210A of the Washington Administrative Code classify Salmon Creek and its tributaries as Core Salmonid Habitat. Under this classification, it is expected that water quality "shall meet or exceed the requirements for all or substantially all of the following characteristic uses: domestic, industrial, and agricultural water supply; stock watering; salmonid and other fish migration, rearing, spawning, and harvesting; and primary contact recreation" (Ecology, 2005).

A study completed in 1995 by Ecology found significant violations of water quality standards in Salmon Creek for fecal coliform and turbidity. Water quality monitoring by Clark public Utilities (CPU) from 1995 to 1999 and by Clark County Clean Water Program (CWP) from 2002 to present have demonstrated that exceedances of water standards for fecal coliform and turbidity are continuing.

Fecal coliform is a major concern because it indicates that biological waste is entering waterways. Common sources of fecal coliform are pet waste, wildlife, leaking or failing septic systems, and agricultural wastes. The primary contact recreation criteria states that fecal coliform organisms must not exceed a geometric mean value of 100 colony forming units (CFU) per 100mL sample, with no more than 10% of samples (90th Percentile Values) exceeding 200 CFU/ 100mL (WAC 173-201A-200).

Turbidity, commonly measured in Nephelometric Turbidity Units (NTU), is a measure of the ability of light to pass through water and indicates suspended solids such as clay, silt, organic matter, small biological organisms, and inorganic particles. Turbidity is a major concern because turbid waters impair the ability of fish to survive and spawn by reducing clean gravel spawning habitat. Higher turbidity also degrades habitat needed for aquatic macroinvertebrates that are a food source for fish. Increased stormwater runoff, and runoff from construction sites and washouts, has been known to increase turbidity. Washington State water quality criteria for Salmon Creek state that “Turbidity shall not exceed 5 NTU over *background* turbidity when the background turbidity is 50 NTU or less, or have more than a 10 percent increase in turbidity when the background turbidity is more than 50 NTU” (WAC173-201A-200)”.

Under section 303(d) of the Clean Water Act, Ecology is required to submit a list of impaired water bodies which fail to meet one or more water quality criteria. For each listed water body, Ecology is responsible for developing a TMDL or Water Cleanup Plan to address water quality issues. Ecology then coordinates with local jurisdictions and groups to implement activities to improve water quality under the TMDL.

The Salmon Creek watershed has a TMDL in place for fecal coliform bacteria and turbidity. Implementation activities are ongoing, and Ecology coordinates an adaptive management process to guide local TMDL-related efforts. The Salmon Creek Focused Assessment (SCFA) focuses on small urbanized streams where bacteria and sediment sources are suspected. The SCFA is one of several ways Clark County Clean Water Program supports TMDL implementation; all data collected will be shared with Ecology to further TMDL-related efforts to improve water quality.

Existing Data

This study fills a significant data gap by assessing water quality of multiple tributaries of lower Salmon Creek that have little to no existing data. Although recent data analysis demonstrates that fecal coliform concentrations in Salmon Creek and some its tributaries have improved significantly since the 1995 TMDL study, multiple stations in lower Salmon Creek still have not met water quality criteria (Ecology, 2009).

Monitoring efforts by the CWP have also indicated that the Salmon Creek mainstem and multiple tributaries continue to exceed state water quality criteria for fecal coliform and turbidity.
Since October 2002, the CWP has collected monthly water quality data from four mainstem and four tributary stations in Salmon Creek as part of the Salmon Creek Monitoring Project. The mainstem stations, as seen in Figure 1, include Salmon Creek at NW 36th Avenue (SMN010), Salmon Creek at NE 50th Avenue (SMN030), Salmon Creek at Caples Road (SMN050), and the reference site for Salmon

Creek at 199th Street (SMN080). These datasets have indicated frequent exceedances of Ecology's fecal coliform bacteria standard during the dry season (Figure 2).

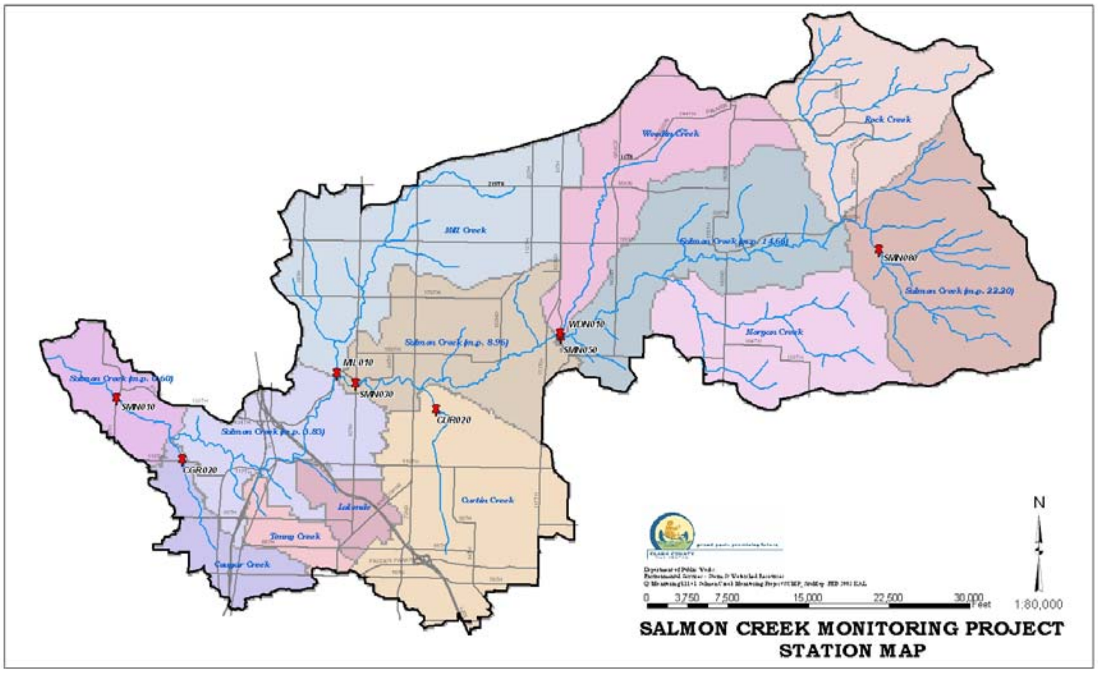

Figure 1. Salmon Creek Monitoring Project stations (from SCMP QAPP, 2003).

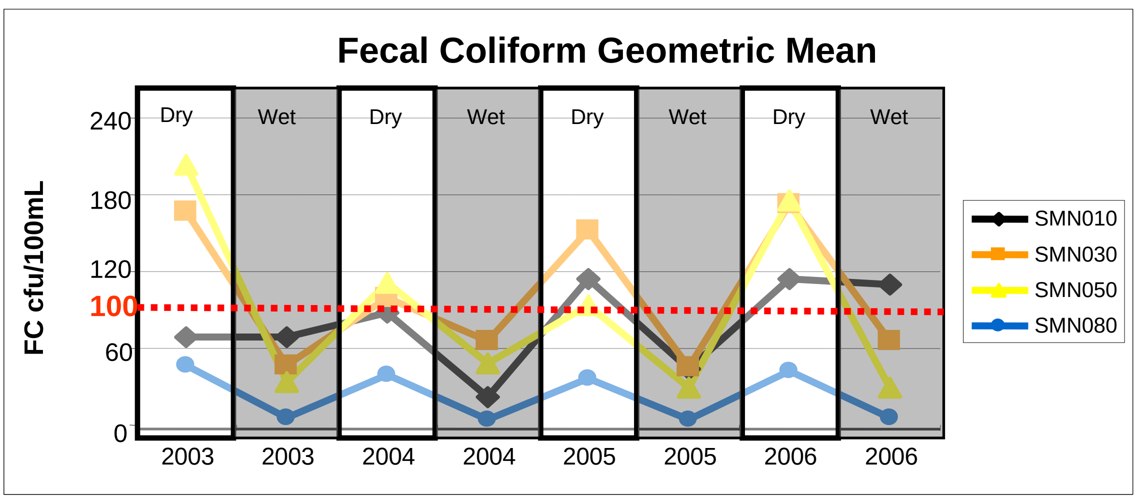

Figure 2. Geometric mean of fecal coliform data collected during the wet (November through May) and dry (June through October) seasons from four SCMP stations from 2003 through 2006.

Samples collected by CWP from 2003-2006 at SMN010, just downstream of the SCFA project area, suggest that fecal coliform numbers have increased over the past several years (Table 2). The fecal coliform geometric mean has increased every year from 2003 through 2006. The percentages of exceedances over 200 CFU has also increased from 2003 through 2006. The 2006 fecal coliform geometric mean and the exceedances over 200 CFU exceeded state criteria.

Table 2. Results of Fecal Coliform Bacteria Sampling from Salmon Creek at NW 36th Ave (SMN010).

	2003	2004	2005	2006
*Geometric mean (Standard = 100 CFU/ 100mL)	44	69	71	112
Exceedences over 200 CFU (not to be greater than 10%)	0	8.3%	8.3%	25%

*The geometric mean, is a type of mean, which indicates the central tendency or typical value of a set of numbers. 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 drastically over a given period

To meet the TMDL, Ecology established target limits and target limit reductions for multiple monitoring stations within lower Salmon Creek including SMN010, SMN030, and SMN050 (Ecology, 2001). Target limits were established such that turbidity levels would not exceed 5 NTU over background 90% of the time. Background turbidity was assumed to be equal to turbidity at the uppermost sampling site on Salmon Creek (see SMN080; Figure 1). Target limit reductions were calculated as the percent reduction required per monitoring station for the 90th percentile of the data to meet the target limits.

Recent data analysis (Ecology, 2009), has demonstrated that all stations meet the 2001 TMDL target limits based on 2005 through 2007 data. Although overall TMDL targets have been met, occasional exceedances of the target limits occur in lower Salmon Creek. For example, Figure 3 shows the turbidity levels and target limits (which are 5 NTU over background turbidity), for stations SMN050, SMN030, and SMN010 from August 2002 through December 2006.

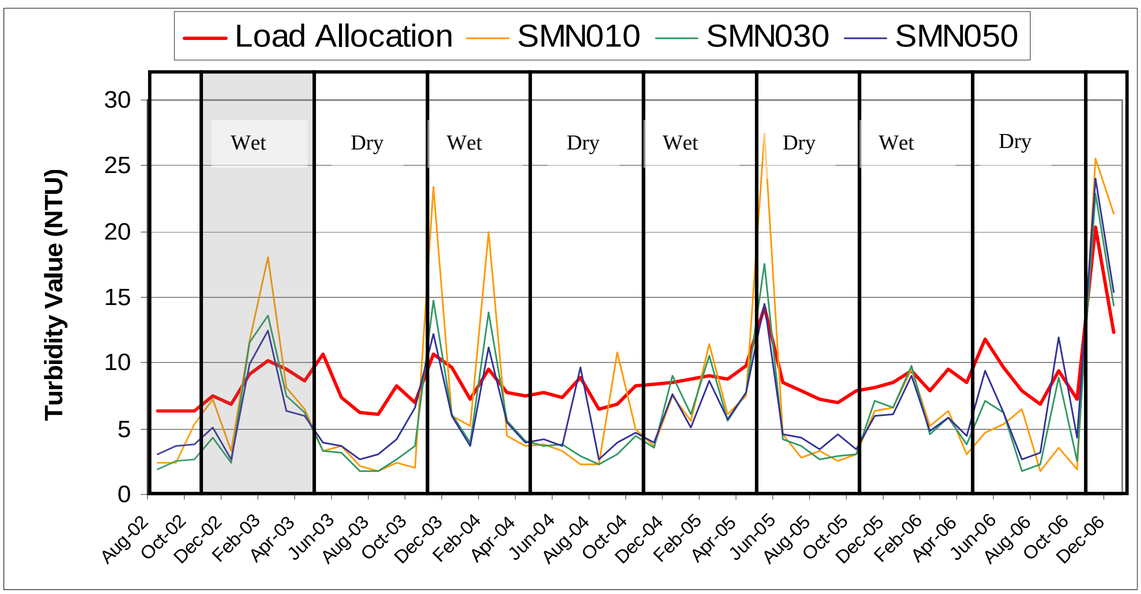

Figure 3. Turbidity levels and target limits (shown as a Load Allocation of 5 NTU over the SMN080 turbidity value), at stations SMN050, SMN030, and SMN010 from August 2002 - December 2006.

Goals and Objectives

The goal of the SCFA is to assess water quality of multiple tributaries that have little to no existing data within lower Salmon Creek to further TMDL-related implementation efforts. The objectives of the SCFA project include:

- Select an urban area within the Salmon Creek watershed to monitor as part of the 2008 Stormwater Needs Assessment Program (SNAP)

- Select tributaries that have little to no existing data to evaluate water quality
- Design the SCFA project to be conducted with volunteer efforts to enhance public participation, reduce staff expenditures, and to increase public awareness of water quality monitoring efforts
- Collect water quality data bimonthly for one year
- Analyze monitoring data, compile a detailed report, and share both data and results with Ecology

SCFA Project Methods
Volunteer monitors were used to implement this monitoring project. Project guidance, equipment, and volunteer coordination were provided by CWP staff through the Volunteer Monitoring Program and the Monitoring Resource Center. Analytical services were provided by the Salmon Creek Wastewater Treatment Plant laboratory. The lab is accredited by Ecology and routinely analyzes samples in accordance with their wastewater discharge permit.

CWP staff conducted the first two months of monitoring surveys in 2007. A training event was held for volunteers in January 2008. The volunteers were trained to follow a general flow of sampling procedures. Monitoring dates were arranged by teams of two or three people using an online calendar service and confirmed by CWP staff. Equipment was stored at the treatment plant for the duration of the project. Prior to sampling, arrangements were made with the treatment plant staff to drop off water samples, allowing sufficient time to analyze them within holding-time requirements. Volunteers reported to the treatment plant to pick up field equipment kits. Typically samples were collected beginning at the station furthest downstream and moving upstream through the watershed. All samples were collected within 2 - 3 hours of each other. The station name, sample date and time uniquely identified the samples.

The monitoring surveys utilized eight monitoring stations that were visited by volunteers at bi-monthly intervals for one year (Table 3 for site location description; Figure 4 for a map of stations). Water samples were analyzed for fecal coliform bacteria and turbidity. The study design was intended to provide data representing seasonal variations and weather conditions, as well as spatial variation in the watershed. Methods for individual parameters are described in Table 4.

Table 3. Description of Monitoring Stations for Salmon Creek Focused Assessment.

Station Code	Description
CGR020	Cougar Creek at 119th Street
SUD020	Suds Creek at Salmon Creek Sports Complex
TEN010	Tenny Creek at 117th Street near I-5 overpass
LAL030	LaLonde Creek at 119th Street
LAL030A	LaLonde Creek at 119th Street Replicate Sample
RCW010	Rockwell Creek at Salmon Creek Ave.
FOR010	114th Street Tributary at Park View Drive (first left past 119th Street on Highway 99)
TEN065	Tenny Creek at 99th Street
CGR080	Cougar Creek at 13th Street

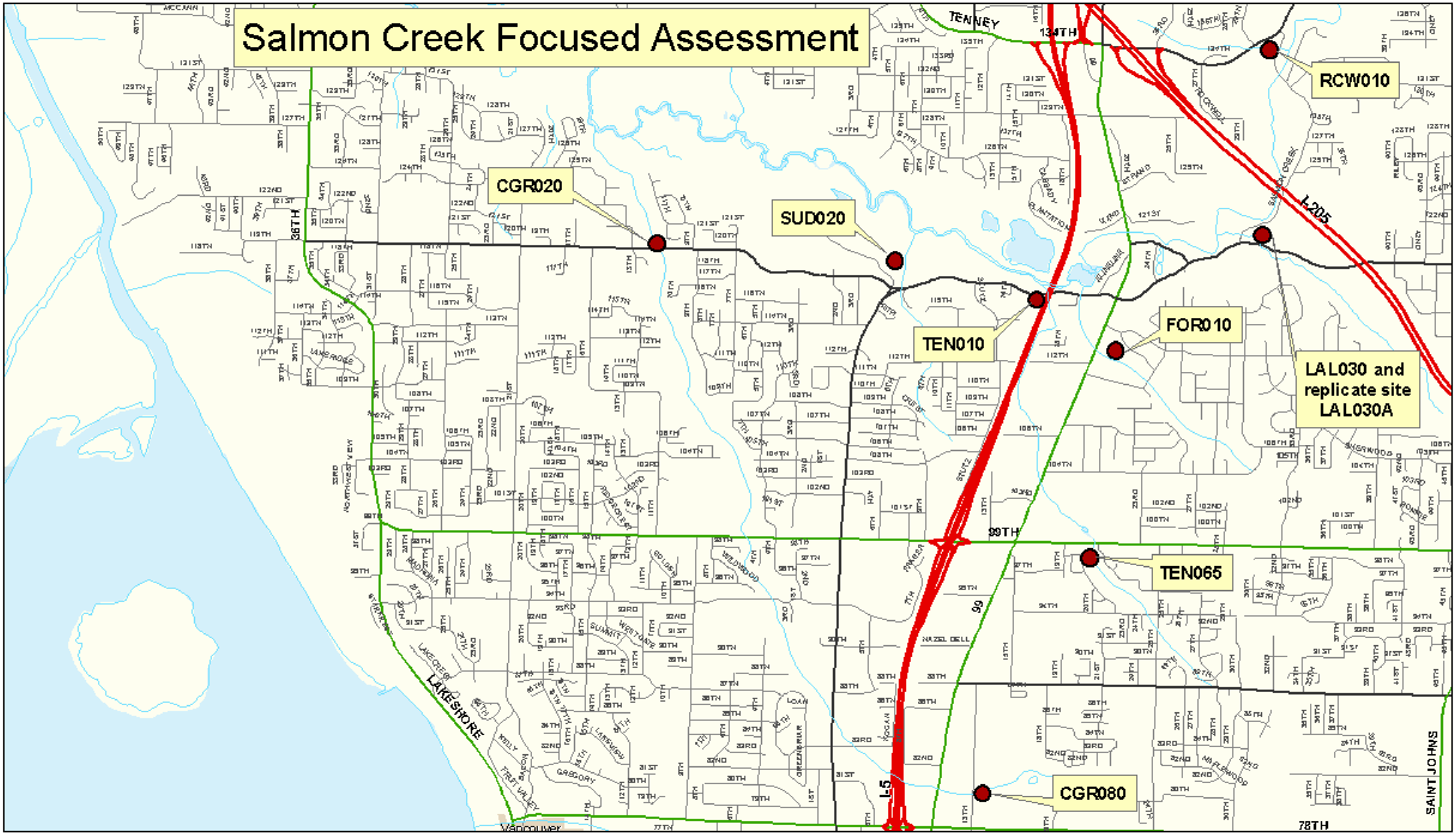

Figure 4. Location of monitoring stations for Salmon Creek Focused Assessment Study.

Table 4. Methods for field measurements and lab parameters.

Field Activity Type	Sampling Frequency	Method	Equipment	Sample Size	Container Preservation	Holding Time
Fecal Coliform	Twice Monthly	Standard Methods (SM) 9222D Membrane Filtration	NA	111-mL	250-mL sterile HDPE	30 hours
Turbidity	Twice Monthly	EPA 180.1 Nephelometric	Hach 2100P	10-mL	15-mL glass vial	48 hours

Data Summary
Data collected during the SCFA project indicated state water quality criterion were regularly exceeded within the duration of this study. Bacteria levels at all of the monitoring stations exceeded one or both portions of the fecal coliform water quality criteria over the monitoring period. Seven of the eight stations exceeded both criteria (geometric mean and 90th percentile).

Activity Summary
A team of fourteen volunteers and two CWP staff monitored water quality at each station for one year, completing 24 sampling events in a variety of weather conditions and seasons.

Fecal Coliform Bacteria by Location
Fecal coliform data summary per station are presented in Table 5 and in Figure 5. The complete data set is available from the CWP. Geometric mean values (must not exceed a value of 100 CFU per 100mL sample) and 90th percentile values (no more than 10% of samples exceeding 200 CFU/ 100mL) are calculated to evaluate the data relative to the water quality criteria.

A total of six tributaries to Salmon Creek were sampled during this study. Two of these tributaries, Cougar Creek and Tenny Creek had two sample stations; one in the upper portion of the drainage basin and another in the lower portion of the drainage basin near the confluence with Salmon Creek. Fecal coliform increased considerably from the upper station to the lower station for both creeks. For stations CGR020 and CGR080, there was nearly a doubling of the geometric mean concentration of fecal coliform between the two stations. In addition, the 90th percentile fecal coliform concentration increased approximately 700 cfu/mL between CGR020 and CGR080. Sampling station TEN065 had the lowest range of fecal coliform concentration and was the only location to not exceed the geometric mean fecal coliform water quality criterion, but did exceed the 90th percentile fecal coliform water quality criterion. There was nearly a tripling of the geometric mean concentration between stations TEN010 and TEN065. The 90th percentile fecal coliform concentration increased approximately 1,400 cfu/mL between TEN010 and TEN065.

Two stations (CGR020 and SUD020) exceeded the geometric mean fecal coliform water quality criterion by over four-fold. Three other stations (LAL030, FOR010, and CGR080) exceeded the same criterion by over two-fold.

All stations exceeded the 90th percentile fecal coliform water quality criterion; seven of which exceeded the criterion by four to five-fold, or more. Station CGR020 was over ten times greater than the 90th percentile criterion.

Cougar Creek station CGR020 had the second lowest range of overall fecal coliform concentrations, yet the highest overall geometric mean and 90th percentile fecal coliform concentrations. Rockwell Creek (RCW010) had the highest range of fecal coliform concentration (3 - 28,600 cfu/mL).

Table 5. Summary of fecal coliform sample data from October 2007 to September 2008; highlighted values indicate cases where the state water quality criteria were not met (WAC173-201A-200).

Monitoring Station Code	Number of Samples	Range of Fecal Coliform Concentrations cfu/100 mL	Geometric Mean Fecal Coliform Concentrations cfu/100 mL	90th Percentile Fecal Coliform Concentrations cfu/200 mL
CGR020	24	44-3,000	450	2200
SUD020	24	20-10,900	405	1197
TEN010	24	30-17,100	173	1600
LAL030	24	41-8,900	250	883
RCW010	24	3-28,600	115	1033
FOR010	24	41-4,400	205	1345
TEN065	23	7-709	69.5	313
CGR080	24	27-24,600	235	1507

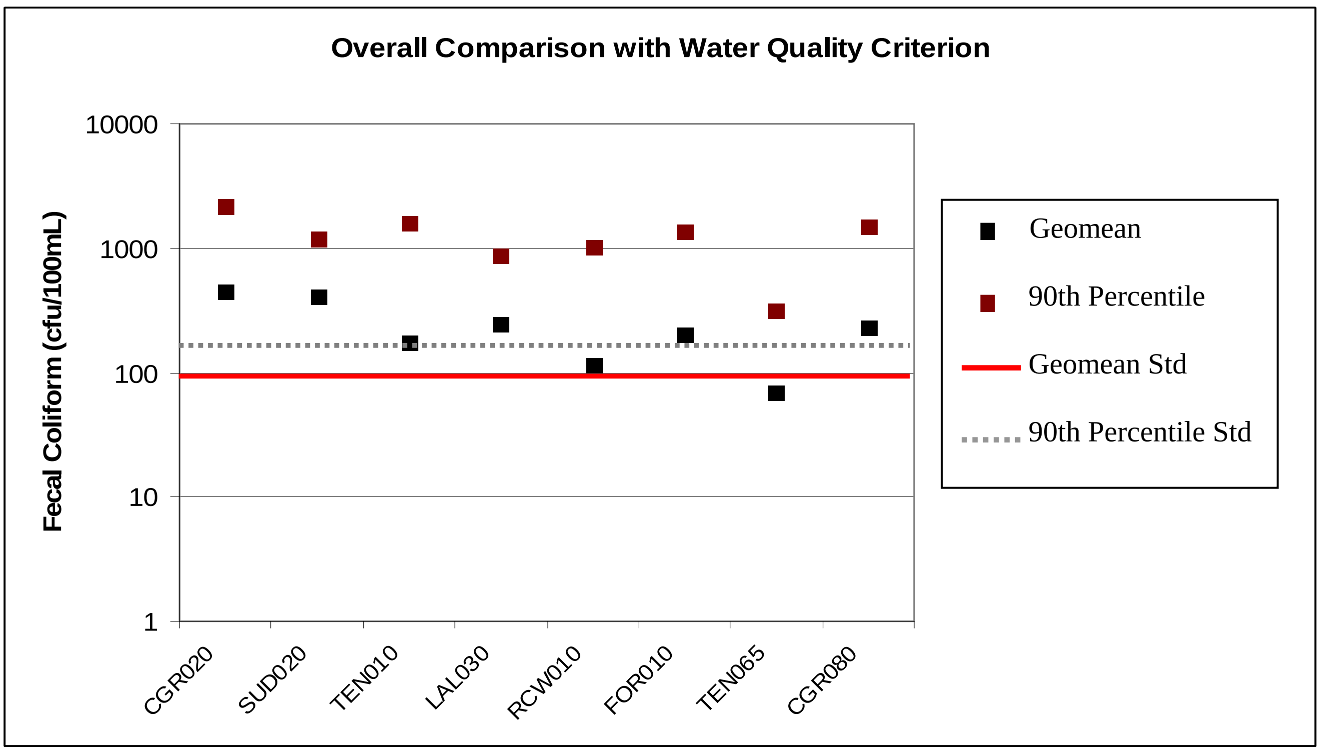

Figure 5. Summary of fecal coliform data from October 2007 to September 2008. Calculations of the geometric mean (GeoMean) concentrations and 90^{th} percentile concentrations are shown as symbols; the lines show the Washington State water quality criteria for each calculation.

Fecal Coliform Bacteria by Weather and Season

Individual sampling events were classified by weather and season in order to identify critical periods for exceedances of water quality criteria. Utilizing data from three nearby precipitation gages, categories for weather were assigned by calculating the 48-hour total rainfall amount prior to each event. Precipitation totals greater than or equal to 0.10 inches indicated 'wet' weather, while other events were classified as 'dry' weather. Categories for season were assigned by the month of the sampling event. Events taking place from November through May were classified as 'wet' season, while events taking place from June through October were classified as 'dry' season. A summary of the classifications for the sampling events is shown in Table 6 below.

Tentative sampling dates were selected by volunteers, with final dates being subject to volunteer schedules and availability. Sampling events were distributed somewhat unevenly among the categories, with more overall events taking place in dry weather relative to wet weather, and only a single event occurring during wet weather in the dry season (Table 7).

Table 6. Summary of weather conditions during sampling over the one- year sampling period. The 48-hr precipitation totals were used to classify the sampling event as 'wet' or 'dry' weather; seasons were assigned using the month of sampling. The 24-hour, 2-yr model rainfall event is about 3".

Event Date	Weather (Rainfall)	Season (Time of Year)	24-hr Precip (inches)	48-hr Precip (inches)
10/12/07	Dry Weather	Dry Season	0.02	0.05
10/30/07	Dry Weather	Dry Season	0.00	0.00
11/13/07	Wet Weather	Wet Season	0.11	0.11
11/27/07	Wet Weather	Wet Season	0.24	0.24
12/10/07	Dry Weather	Wet Season	0.06	0.06
12/27/07	Wet Weather	Wet Season	0.25	0.57
1/12/08	Wet Weather	Wet Season	0.39	0.74
1/26/08	Dry Weather	Wet Season	0.00	0.00
2/9/08	Wet Weather	Wet Season	0.19	0.23
2/23/08	Dry Weather	Wet Season	0.00	0.00
3/8/08	Wet Weather	Wet Season	0.46	0.46
3/22/08	Wet Weather	Wet Season	0.00	0.12
4/13/08	Dry Weather	Wet Season	0.00	0.00
4/26/08	Dry Weather	Wet Season	0.01	0.01
5/11/08	Dry Weather	Wet Season	0.01	0.01
5/25/08	Wet Weather	Wet Season	0.18	0.30
6/12/08	Dry Weather	Dry Season	0.00	0.06
6/28/08	Dry Weather	Dry Season	0.00	0.00
7/13/08	Dry Weather	Dry Season	0.00	0.00
7/27/08	Dry Weather	Dry Season	0.00	0.00
8/18/08 *	Wet Weather	Dry Season	0.19	0.19
8/24/08	Dry Weather	Dry Season	0.00	0.00
9/14/08	Dry Weather	Dry Season	0.00	0.00
9/28/08	Dry Weather	Dry Season	0.00	0.00

* The seasonal first-flush storm event is defined as an event in August or September with at least a one-week antecedent dry period (no more than 0.02 inches in previous 168 hours *or* no recorded storm flow at outfall.

Table 7. Fecal coliform calculations from all stations, grouped by categories or weather and season.

Event Category	Event Count	Geometric Mean Value	90th Percent Value	Number of Observations
Dry Weather/Dry Season	9	309	845	72
Wet Weather/Dry Season	1	6851	25400	8
Dry Weather/Wet Season	8	74	310	56
Wet Weather/Wet Season	6	197	1072	48

After combining the data from all of the stations in the SCFA study, inferences about fecal coliform levels relative to weather and seasons are possible:

- Wet weather fecal coliform values during the dry season are significantly higher than all other event categories*
- Dry weather fecal coliform values during the wet season are significantly lower than all other event categories*
- Dry weather fecal coliform values are significantly higher during the dry season than the wet season*
- Wet weather fecal coliform values are significantly higher than dry weather during the wet season*
- Wet weather during the dry season resulted in the highest fecal coliform levels
- Dry weather during the wet season resulted in the lowest fecal coliform levels

* Minitab statistical software was used to run one-way ANOVA on ranked fecal coliform values, utilizing the Tukey-Kramer method to obtain confidence intervals for all pair-wise differences between rank means; differences between categories that were greater or less than zero were considered statistically significant.

These observations generally held for the individual sample stations in SCFA study area (Table 8; Figures 6 and 7). A notable finding is that all monitoring stations failed to meet the state fecal coliform criteria (geometric mean and 90th percentile value) during dry weather in the dry season. This overall pattern of dry weather coinciding with high levels of fecal coliform likely indicates the presence of continuous, dry weather sources of bacteria on these tributaries, for example illegal connections of sewer to drainage ways, failing septic systems, wildlife, or direct livestock access to the stream.

Table 8. Fecal coliform level calculations for the SCFA stations, grouped by categories of weather and season. Values in ***bold italics*** meet water quality criteria for bacteria; event categories are listed according to weather/season.

Event Category	CGR020	SUD020	TEN010	LAL030	RCW010	FOR010	TEN065	CGR080
Weather/Season	**Geometric Mean Value**							
Dry/Dry	637	410	288	330	294	296	114	333
Wet/Dry*								
Dry/Wet	157	115	***51***	144	***13***	117	***22***	***82***
Wet/Wet	360	317	438	161	***97***	179	***75***	330
	90th Percentile Value							
Dry/Dry	1707	817	661	717	650	1028	240	992
Wet/Dry*								
Dry/Wet	278	346	***104***	374	***39***	266	***43***	218
Wet/Wet	1226	1072	1720	674	1093	735	488	1554

* Only one Wet/Dry event occurred; geometric mean and 90th percentile were not calculated.

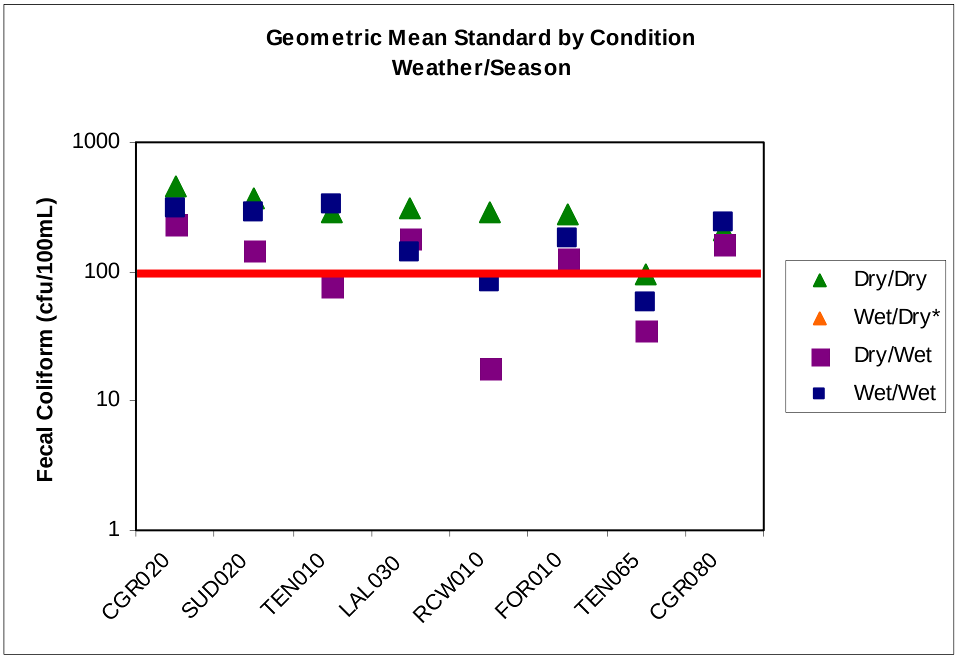

Figure 6. Fecal coliform levels for each of the stations showing data grouped into categories of weather and season, for example, 'Dry/Dry' is the category for 'Dry Weather during the Dry Season'. Dry and wet weather were determined with a 48-hr rainfall total of 0.1 inches, and dry and wet seasons were determined by the sample month (June-October is the dry season). Red line represents the geometric mean fecal coliform water quality criteria (100 cfu/mL).
* Only one Wet/Dry event occurred; geometric mean was not calculated.

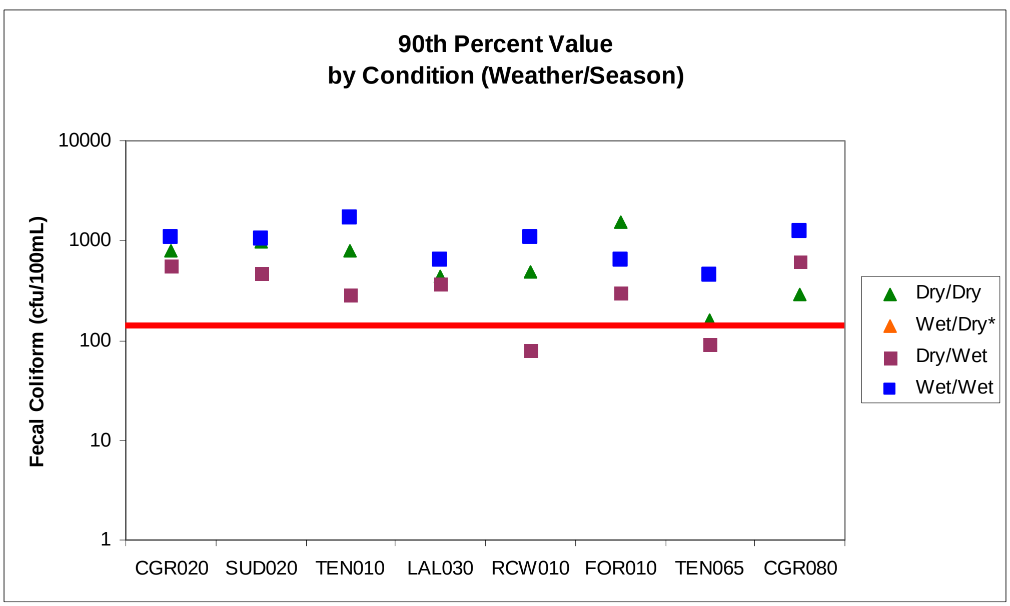

Figure 7. Fecal coliform levels for each of the stations showing data grouped into categories of weather and season as described in the previous Figure 6. Red line represents the 90th percentile fecal coliform water quality criteria (200 cfu/mL).
* Only one Wet/Dry event occurred; 90^{th} percentile were not calculated.

Only three out of the eight stations met water quality standards for fecal coliform during dry weather in the wet season. No station met water quality standards for fecal coliform during wet weather during the wet season. Only one sampling event occurred during wet weather in the dry season. This wet weather event can be classified as a "seasonal first-flush" storm event, which is defined as an event in August or September with at least a one-week antecedent dry period (no more than 0.02 inches in previous 168 hours *or* no recorded storm flow at outfall). The geometric mean and 90th percentile value for individual stations were not calculated for these data. However, fecal coliform values that were analyzed far exceeded any other collection event (Table 9).

Time series for the fecal coliform levels throughout the calendar year are shown in Figure 8. All but one month (January) had two sample events over the one-year period for the analysis. Higher fecal coliform levels were found throughout the dry season for most stations, with the highest values during dry season rain events which are likely carrying pollutants from a variety of sources. Lower values are typically observed during the wet season months.

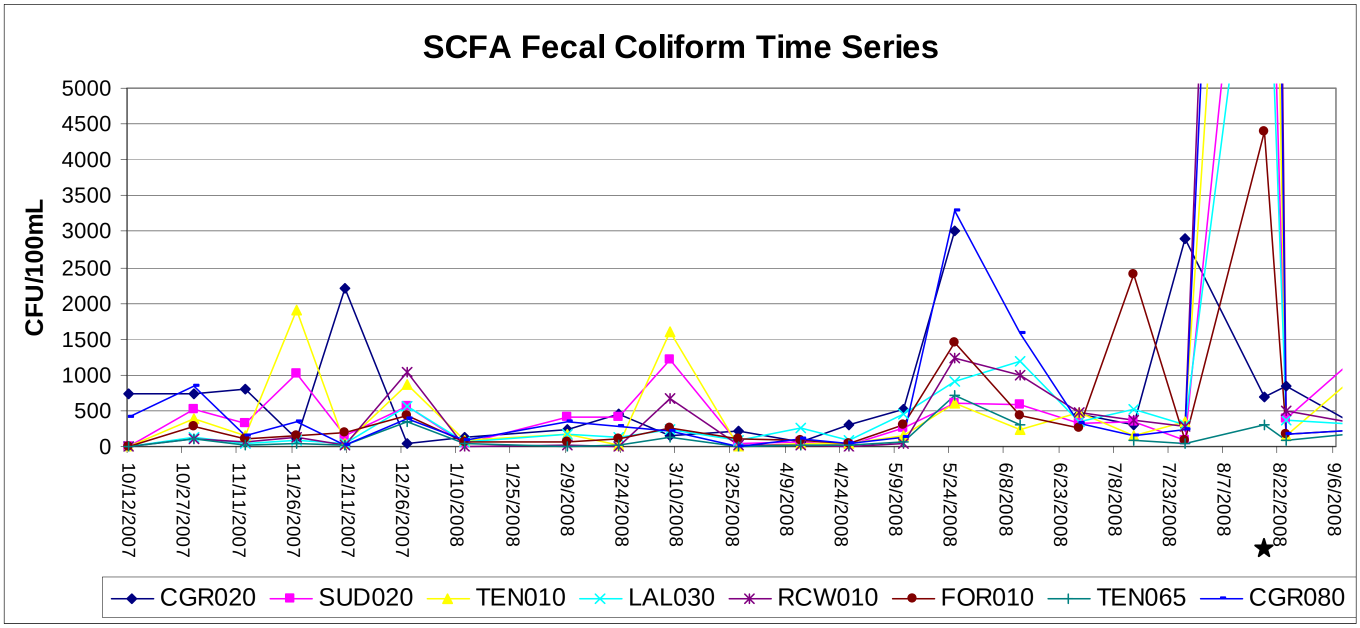

Figure 8. Fecal coliform levels for SCFA stations time series from October 2007 through September 2008.

★ **Table 9.** Fecal coliform levels of the "First Flush Storm Event" collected on August 18, 2008.

Event Category	CGR020	SUD020	TEN010	LAL030	RCW010	FOR010	TEN065	CGR080
Seasonal First Flush Storm Event	**Fecal Coliform Levels (100 cfu/mL)**							
8/18/2008	2900	10900	17100	8900	28600	4400	310	24600

Notable findings at individual stations include:

- No station met the state water quality criteria for fecal coliform concentration (geometric mean fecal coliform concentration not to exceed 100 colonies/100mL, and not more than 10% of samples exceeding 200 colonies/100mL.)
- Values for CGR020 were typically the highest for any station during the dry season.
- Values for SUD020 were typically the highest for any station during the wet season.
- TEN065 had significantly lower fecal coliform levels than CGR020, CGR080, LAL030, and SUD020*
- TEN065 was the only station to meet geometric mean fecal coliform concentration standard (not to exceed 100 colonies/100mL)
- The highest fecal coliform values occurred during a "seasonal first flush" storm event** (Table 9)
- All stations except TEN065 had maximum fecal coliform concentrations greater than 3000 CFU/100mL.

* Minitab statistical software was used to run one-way ANOVA on ranked fecal coliform values, utilizing the Tukey-Kramer method to obtain confidence intervals for all pair-wise differences between rank means; differences between categories that were greater or less than zero were considered statistically significant.

** The seasonal first-flush storm event is defined as an event in August or September with at least a one-week antecedent dry period (no more than 0.02 inches in previous 168 hours *or* no recorded storm flow at outfall.

Turbidity

Washington State water quality criteria for Salmon Creek state that "Turbidity shall not exceed 5 NTU over *background* turbidity when the background turbidity is 50 NTU or less, or have more than a 10 percent increase in turbidity when the background turbidity is more than 50 NTU" (WAC173-201A-200)". Although background turbidity for these creeks has not been determined, it is likely similar to the lower range of values observed at the sample stations. Background turbidity between 1-5 NTU for these tributaries is realistic.

Turbidity values are summarized in Table 10. Typically, the observed values were somewhat elevated; the median value at each of the monitoring stations was between 1.98 - 9.78 NTU. All of the SCFA tributaries are in highly developed areas with similar lower range turbidity values. If background turbidity was conservatively assumed to be about 2.5 NTU, then SCFA stations with routine turbidity levels >7.5 NTU would exceed the turbidity criterion. SCFA stations exceeded 7.5 NTU 13 - 79 percent of the time.

Table 10. Summary of turbidity sample data from October 2007 to September 2008.

Monitoring Station Code	Number of Samples	Range of Turbidity Values NTU	Median Turbidity NTU
CGR020	24	1.34-28.2	3.33
SUD020	24	0.84-87.2	1.98
TEN010	24	1.86-40.2	5.47
LAL030	24	1.94-116	9.78
RCW010	24	2.25-36.1	4.15
FOR010	24	2.98-40.2	6.28
TEN065	23	1.40-14.7	3.06
CGR080	24	1.68-64.0	5.45

Considering a threshold of 7.5 NTU, the most consistently turbid station was LaLonde Creek (LAL030), which exceeded 7.5 NTU during 19 of the 24 sampling events (79%). LaLonde Creek also had the highest range of turbidity vales (1.94 - 116 NTU) and the highest median turbidity value (9.78 NTU). Suds Creek (SUD020) had the lowest turbidity value sampled and the lowest mean turbidity overall, but the second highest individual turbidity value recorded.

As with the fecal coliform data, turbidity results were classified by weather and season in order to describe possible critical periods for exceedances of water quality criteria (see Figure 6 for event classification). As described in Table 11, the largest range of values (8.1 - 119 NTU) occurred during wet weather in the dry season. Wet weather turbidity values were significantly higher than dry weather events. Wet weather in the dry season was found to be higher than wet weather in the wet season.

Table 11. Turbidity values calculations from all stations, grouped by categories or weather and season.

Event Category	Event Count	Range of Turbidity Values	Average Turbidity NTU	Number of Observations
Dry Weather/Dry Season	9	0.84 - 14.2	5.2	72
Wet Weather/Dry Season	1	8.1 - 119	55.2	8
Dry Weather/Wet Season	8	1.3 - 16.1	4.9	64
Wet Weather/Wet Season	6	1.8 - 64.0	10.7	48

Time series for turbidity values throughout the calendar year are shown in Figure 9 below. The graph shows higher turbidity levels throughout the wet season for most stations, with the highest values during rain events which are likely carrying pollutants from a variety of sources. Lower values are typically observed during the dry weather events. The highest turbidity values were recorded during a "First Flush Storm Event" (Table 12).

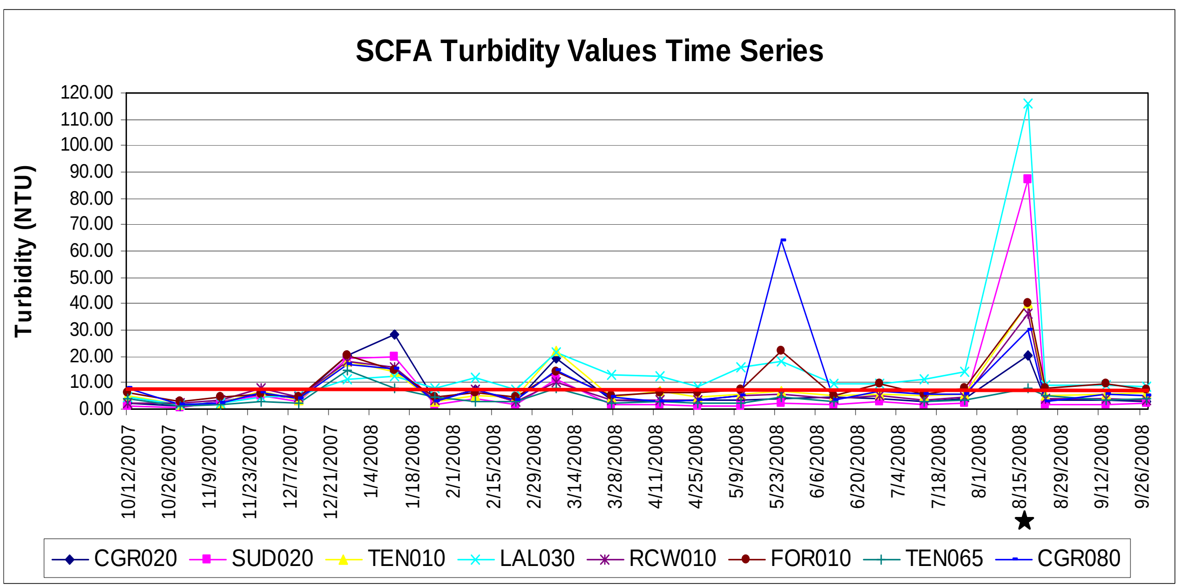

Figure 9. Turbidity values for SCFA stations, time series. Redline represents assumed background turbidity value criterion of 7.5 NTU.

★**Table 12.** Turbidity values of the "First Flush Storm Event" collected on August 18, 2008.

Event Category	CGR020	SUD020	TEN010	LAL030	RCW010	FOR010	TEN065	CGR080
First Flush Storm Event	Turbidity Value (NTU)							
8/18/2008	20.10	87.20	40.20	116.00	36.10	40.20	8.08	30.00

Combining the data from all of the SCFA stations, inferences about turbidity levels relative to weather and seasons are possible:

- Turbidity levels are significantly higher during wet weather than dry weather, in either season*.
- Turbidity levels are *not* significantly different between dry weather in the dry season and dry weather during the wet season*.
- Turbidity levels are significantly higher during wet weather in the dry season than wet weather during the wet season*.

* Minitab statistical software was used to run one-way ANOVA on ranked turbidity values, utilizing the Tukey-Kramer method to obtain confidence intervals for all pair-wise differences between rank means; differences between categories that were greater or less than zero were considered statistically significant .

Quality Control Summary

Data completeness
There were 24 sampling events scheduled from October 2007 to September 2008. Fecal coliform events were 100% complete, with 24 events completed. Turbidity events were also 100% complete, with 24 events completed.

There was an instance where data was collected by volunteers, but laboratory scheduling caused one sample event not to be analyzed. Data from this event (January 12, 2008) was not used in this analysis. There was another instance where one SCFA station could not be located.

Quality Control Results
This project's quality control (QC) sample types, frequencies, and definitions are listed in Table 13. The overall goal was to duplicate fecal coliform samples and field meter measurements at one sample site during each monthly survey.

Table 13. QC sample types, frequencies, and definitions required for the project.

QC Sample Type	Frequency	Definition
Field measurement replicate	One per survey	Repeat field meter measurements
Sample duplicate	One per survey	Duplicate sample collected for laboratory analysis

All meters were calibrated and maintained by CWP staff in accordance with the manufacturer's instructions. Secondary standards for turbidity were used to verify the calibration of field meters. Calibration logs were completed during each calibration and were archived in CWP files.

Laboratory QC samples were analyzed in accordance with the Ecology accredited Salmon Creek Wastewater Treatment Plant Laboratory's quality assurance plan. Other than results from sample blanks there was no QC data provided by the lab with the data reports.

In summary, QC data for precision was very good. Twenty-three duplicate pairs of samples were used for fecal coliform QC analysis. The data quality objective for fecal coliform duplicate samples was 25% RSD on log-transformed data (Table 14). All fecal coliform QC samples met this objective, and the RSD ranged from less than 0.1% to 15.7%.

Twenty-four turbidity measurements were replicated in the field by the volunteer teams to estimate precision. The data quality objective for the replicate turbidity measurements was an RSD of 10% (Table 14). Twenty-two of the 24 QC measurements met the objective, while two had RSDs between 10 and 21%; in each case the difference was less than 2.1 NTU.

The Salmon Creek Wastewater Treatment Plant laboratory did not report any problems or cases of contamination in sample blanks that were run with each batch of samples.

T**able 14.** Summary Measurement Quality Objectives (MQO's) of laboratory and field parameters.

Parameter	Accuracy	Precision	Bias	Required Reporting Limit
	Percent (%) deviation from true value or units of measurement	*Relative Standard Deviation*	*Percent (%) of true value*	*Concentration units*
Turbidity	25%	10%	5%	1 NTU
Fecal Coliform	NA	25% (log transformed data)	NA	2 CFU/100mL

Conclusions and Recommendations

The goal of the SCFA was to collect data to assess water quality of multiple tributaries that have little to no existing historic data within lower Salmon Creek to further TMDL-related efforts to improve water quality. The objectives of the SCFA project included: selecting an urban area within the Salmon Creek watershed to monitor as part of the 2008 Stormwater Needs Assessment Program (SNAP); selecting tributaries that have little to no existing data to evaluate water quality; designing the SCFA project to be conducted with volunteer efforts to enhance public participation, reduce staff expenditures, and to increase public awareness of water quality monitoring efforts; collecting water quality data bimonthly for one year; analyzing monitoring data, compile a detailed report, and sharing data with Ecology. Due to the planning and design efforts of CWP staff and the enthusiasm and dedication of the SCFA volunteers, the goal and objectives of the SCFA study were met.

Conclusion

The Salmon Creek watershed has a TMDL in place for fecal coliform bacteria and turbidity. Recent data analysis by Ecology has demonstrated that fecal coliform concentrations in Salmon Creek and some its tributaries have improved significantly since the 1995 TMDL study (Ecology, 2009). The Ecology report also recommends that further implementation efforts should address dry-season fecal coliform sources throughout the watershed downstream of station SMN080 and wet season fecal coliform sources near the mouth of Salmon Creek and in the Cougar and Mill subbasins.

Previous monitoring by Clark County and community volunteers from 2002- present has provided insight into how fecal coliform and turbidity levels vary throughout the year and from year to year at multiple locations in Salmon Creek. The Salmon Creek Focused Assessment (SCFA) is one of several ways the Clark County Clean Water Program continues to support TMDL implementation and address recommendations put forth by Ecology. This study fills a significant data gap by assessing water quality of multiple tributaries of lower Salmon Creek where little to no existing data and where bacteria and sediment sources are suspected.

This SCFA study provided greater detail describing fecal coliform and turbidity distribution throughout the more urbanized subwatersheds of Salmon Creek and indicated potential areas where future source control efforts may be most productive. These results suggest that fecal coliform water quality standard exceedances are widespread and frequent within tributaries of lower Salmon Creek. None of the eight stations within the six tributaries studied during 2007 and 2008 were in compliance with the state water quality criteria for fecal coliform.

Two tributaries, Cougar Creek and Tenny Creek had two sample stations; one in the upper portion of the drainage basin and another in the lower portion of the drainage basin near the confluence with Salmon Creek. Conditions decreased considerably between the upper drainage area sampling location and the lower drainage area sampling location for both creeks. The increases in fecal coliform and turbidity between the upper portion of the drainage basin and the lower portion of the drainage basin suggest that water quality has been significantly impacted by land development and human activities.

The lower station of Cougar Creek (CGR020) and Suds Creek (SUD040) had the highest overall geometric mean concentration and were consistently the most impacted stations during the dry season. The lower station of Cougar Creek and Tenny Creek (CGR020 and TEN010) had the highest 90^{th} percentile concentration and showed several very high concentrations during wet weather.

Wet weather during the dry season produced the highest fecal coliform values. The one wet weather event during the dry season can be classified as a "seasonal first flush" storm event. Both fecal coliform concentration and turbidity values during the seasonal first-flush storm were higher than any other event category. Half of the stations had fecal coliform concentrations of over 10,000 cfu/mL and turbidity values of over 40 NTU. Overall, turbidity values were typically much higher during wet weather, regardless of season.

Sources of bacteria may include pet waste, wildlife, leaking septic systems, and sewer lines mistakenly connected to stormwater pipes. Due to widespread fecal coliform problems, source removal efforts are needed throughout the lower Salmon Creek subwatersheds. There are several areas where concentrated source control efforts may result in particularly significant improvements; these include both Cougar Creek and Tenny Creek subwatersheds.

Overall, wet weather during the dry season appears to be the most critical period for controlling large pulses of fecal coliform and turbidity to the creek.

Interestingly, dry weather fecal coliform values are significantly higher during the dry season than the wet season. In addition, all stations exceeded the geometric mean fecal coliform water quality criteria and the 90th percentile fecal coliform water quality criteria during dry weather in the dry season. In contrast, three of the eight stations met both criterions during the dry weather in the wet season. Bacteria levels were typically higher during the dry season regardless of weather. This suggests continuous, non-stormwater runoff related sources of bacteria appears to be an important pathway for conveying pollutants to the waterways.

Recommendations

The following recommendations are possible next-steps for locating and removing sources of fecal coliform and turbidity to stormwater and surface water resources. Work in the near term will fall under the existing programs of local jurisdictions and groups. For example, Clark County's NPDES municipal stormwater permit requires detecting and removing sources of pollution to the storm sewer system, including ditches along county roads, implementing and enforcing erosion and development regulations required by Clark County code, and source control inspections of pollutant generating sources at commercial, industrial, and multifamily properties to enforce implantation of required Best Management Practices (BMPs).

During 2008, the Salmon Creek (r.m. 03.83) and Cougar Creek subwatersheds were included in Clark County's Stormwater Needs Assessment Program. Assessment activities included illicit discharge screening at 212 public stormwater outfalls and resulted in the removal of two serious ongoing sources of fecal coliform pollution. Additional recommendations for stormwater and watershed improvement may be found in the 2008 Stormwater Needs Assessment Report for Salmon Creek (r.m. 03.83) and Cougar Creek. Opportunities may exist for several agencies, jurisdictions, and groups to begin addressing the following recommendations, including the Salmon Creek Watershed Council, Clark Conservation District, Washington Department of Fish and Wildlife, WSU Watershed Stewards Program, Clark County, and Ecology. This report will be shared with all of the above-listed groups.

Recommendations include:

1. Continue implementation of stormwater program as required by Phase 1 Stormwater Permit under NPDES
2. Initiate specific technical assistance visits and public contacts at known locations that discharge to the municipal separate storm sewer system or directly to streams. Initial priority should be given to those locations listed in the 2008 Stormwater Needs Assessment Report for Salmon Creek (r.m. 03.83) and Cougar Creek.
3. Promote focused septic system inspection, education programs, and agricultural best management practice implementation directed at reductions in fecal coliform.

4. Initiate additional source control activities, focused on the Cougar Creek and Tenny Creek tributaries. These should include map-based research to locate potential pollution generating sites in these areas, site-specific technical assistance visits, focused mailings, septic system educational programs and other activities.
5. Continue monthly monitoring at the SMN010 and CGR020 stations.

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http://www.clark.wa.gov/water-resources/

For more information regarding the Salmon Creek TMDL, visit the Department of Ecology website:
http://www.ecy.wa.gov/programs/wq/tmdl/SalmonCr/SalmonCr.html

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