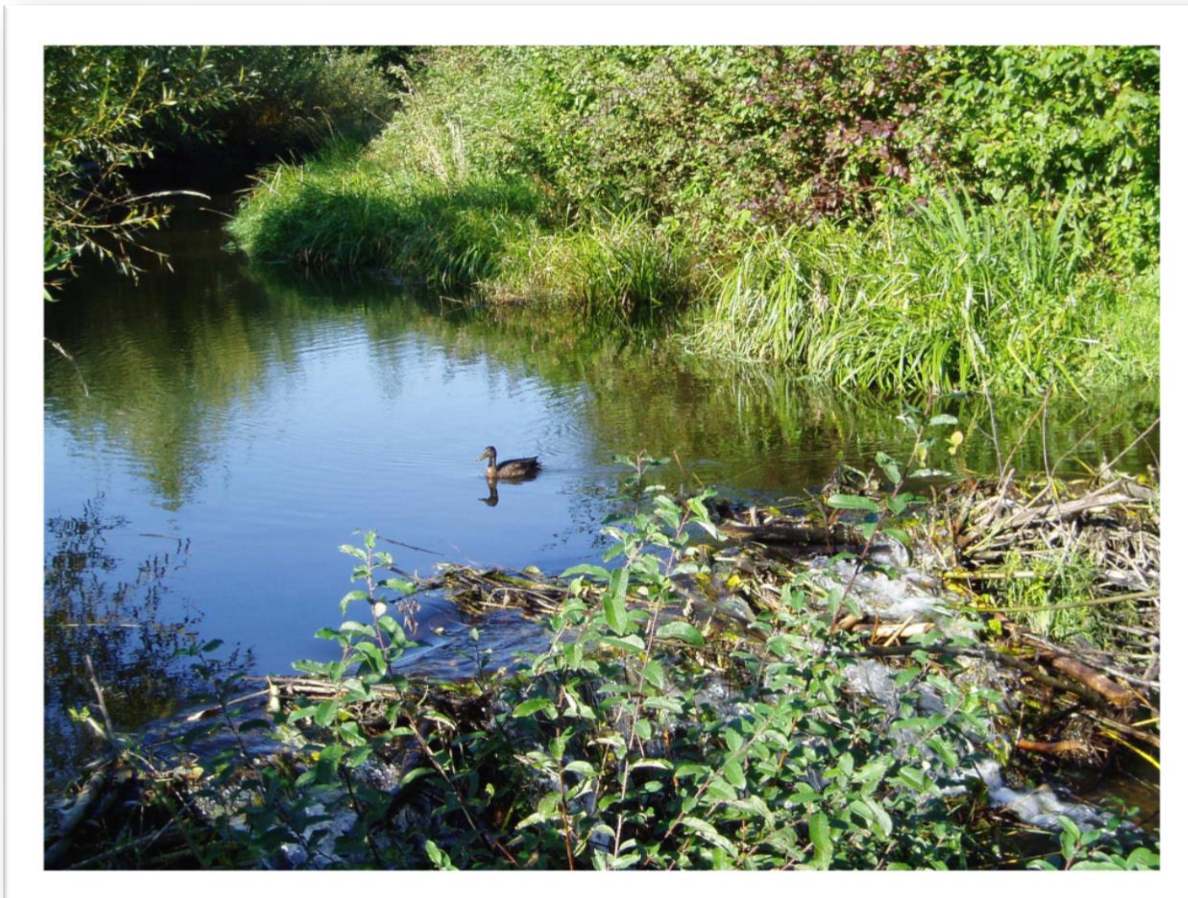
North Creek and Little Swamp Creek
Sample Results
2015

Fecal Coliform Bacteria
Total Maximum Daily Loads



Water Quality Monitoring

Annual Summary Report

February 2016

City of Bothell™

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Andy Loch

City of Bothell™

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Introduction

In 1996, the Washington State Department of Ecology (WDOE) listed North Creek and Swamp Creek on the 303 (d) list of impaired water bodies for fecal coliform bacteria (FCB) and dissolved oxygen Total Maximum Daily Loads (TMDLs). (http://www.ecy.wa.gov/programs/wq/303d/1996/index-1996.html).

North Creek and Swamp Creek are contaminated by excessive levels of bacterial pollution. As a result of the bacterial pollution problem, WDOE worked with local municipalities to develop the **North Creek Fecal Coliform Total Maximum Daily Load Detailed Implementation Plan** (Svrjcek, 2003) and **Swamp Creek Fecal Coliform Bacteria Total Maximum Daily Load, Water Quality Improvement Report and Implementation Plan** (Svrjcek, 2006). In the plans, WDOE established water quality monitoring requirements for local municipalities that collect, treat, and/or convey stormwater.

In 2007 and renewed in 2013, WDOE issued a National Pollution Discharge Elimination System (NPDES) stormwater permit to all small municipalities. The NPDES permit required TMDL(s) to identify long-term monitoring sites. Collection of data and site selection was detailed in Quality Assurance Project Plan (QAPP) (Kalenius, 2007). The Department of Ecology's goal for all areas of North and Swamp Creeks is to consistently meet the Washington State Water Quality Standards for bacteria (Svrjcek 2003 and 2006).

Specific source contributors in North Creek have been identified through the use of DNA testing (Kalenius, 2008). Pet waste, failing septic tanks, sewage, wildlife, and illegal discharges were all identified as sources. North and Swamp Creek have similar bacteria source profiles (Svrjcek 2006).

This report provides an annual update on monitoring, as described in the 2007 QAPP (Kalenius, 2007). The City of Bothell understands the need to work together with others to understand the bacterial pollution problem in North Creek and Swamp Creek and find solutions. The water quality monitoring activities reported here support those efforts. Still, more can be done; and in 2014, the City initiated bi-watershed quarterly meetings of all interested parties to discuss potential collaborations of sharing data and watershed management actions. Initial response has been positive.

Applicable Water Quality Standards

Allowable bacteria concentrations in North Creek are designed to protect Lake Washington, one of the most important recreational waterbodies in Washington State. State Water Quality Standards (Washington Administrative Code 173-201A) establish the use of extraordinary primary recreational contact for both waterbodies. The Standards requires that water quality in these streams meet a geometric mean of 50 cfu/100 mL, and an upper 10th percentile value not to exceed 100 cfu/100 mL.

Basin and Sampling Site Descriptions

North Creek

The North Creek basin drains approximately 30 square miles and discharges to the Sammamish River, which is a tributary to Lake Washington. The watershed is comprised of the main stem of North Creek and all the tributaries that contribute to it. Land use within the basin is primarily urban or suburban with some pockets of rural and forested land. The basin is being rapidly developed for residential and commercial use. Urbanization and land development activities greatly affect water quality in the basin through riparian corridor alteration, conversion of forests, inadequate retention/detention of stormwater from new and existing impervious surfaces, and poorly treated stormwater runoff.

North Creek is located predominantly in south Snohomish County (Figure 1). The headwaters originate in the Everett Mall Way area of south Everett and flow southerly for 12.6 miles before discharging to the Sammamish River, within the city of Bothell. The Sammamish River drains into Lake Washington and ultimately through the Ballard Locks to Puget Sound. The last 1.5 miles of North Creek is located in King County (Bothell). The stream gradient is flat, decreasing from about 50 feet per mile in the upper basin to less than 20 feet per mile near the mouth. The seven major subbasins within the watershed are main stem North Creek, Penny Creek, Silver Lake Creek, Nickel Creek, Silver Creek, Tambark Creek, and Sulphur Springs Creek (Figure 1). The major lakes are Silver Lake, Ruggs Lake, and Thomas Lake.

The watershed is nearly 10 miles long and 3 miles wide, and encompasses an area of about 19,000 acres. Approximately 10 percent of the watershed lies within the city of Everett; 23 percent lies within the city of Bothell; 12 percent lies within the city of Mill Creek; and the remaining 55 percent lies within unincorporated Snohomish County. Five percent of the total area lies within King County, and this area is within Bothell's city limits.

North Creek watershed in Bothell is comprised of several land uses: residential, retail, and business parks containing business and light industry, with residual open space. The residential development is mixed sewer and septic averaging four to six dwellings per acre. Three sample locations were selected to best represent the various land uses (Figure 2).

In 2011, the sample site NCLD was moved upstream to just north of 228th Street SE. This was due to the sample location at 240th Street SE undergoing a bridge replacement and ongoing issues with accurate flow gage information.

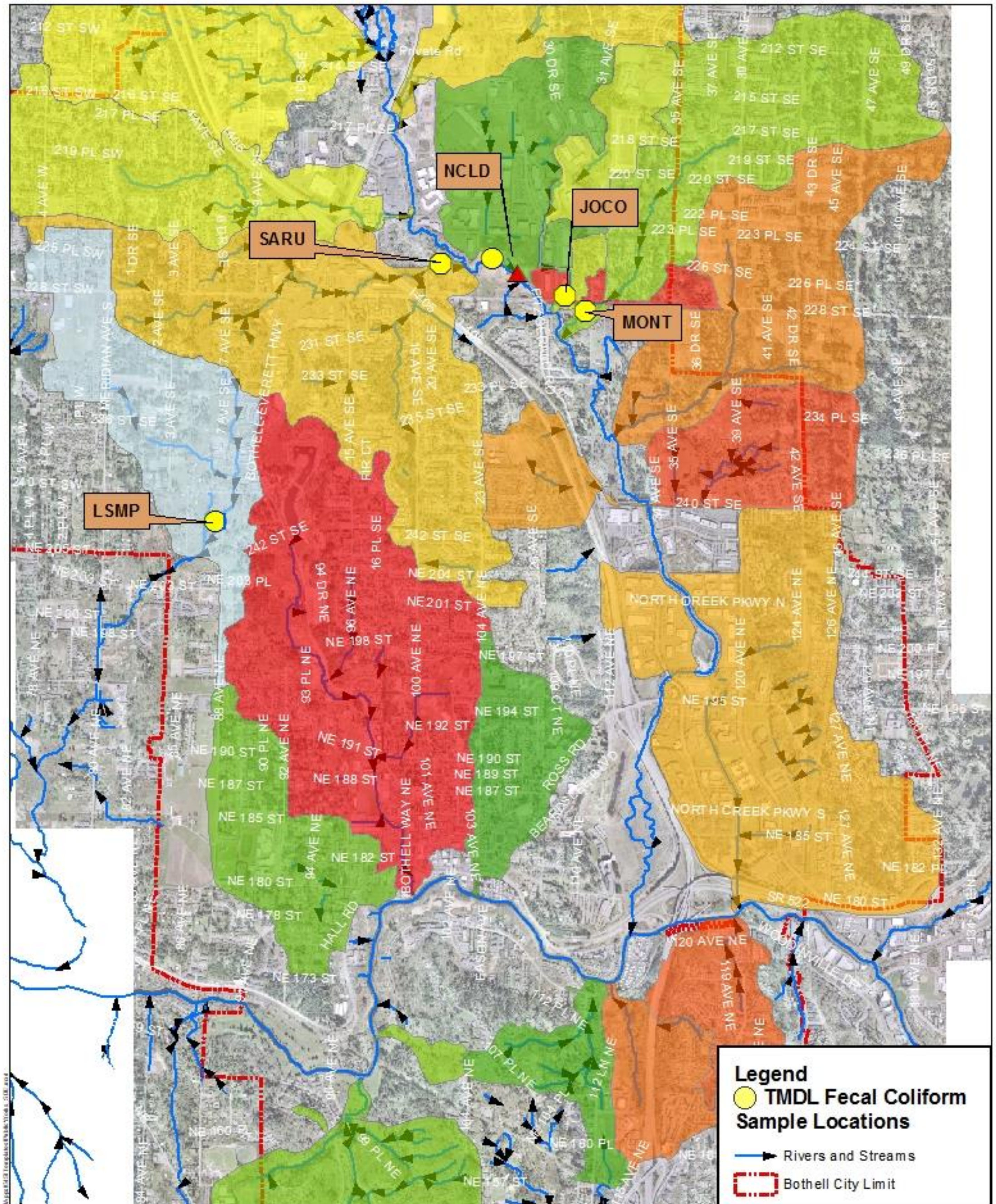

Figure 1. TMDL fecal coliform bacteria sample locations in North and Swamp Creek..

Swamp Creek

The Swamp Creek watershed spans about 12 miles in length from top to bottom. Starting just below State Route 526 in Everett, the main stem of the creek winds 14 miles through the watershed before it flows into the Sammamish River at Kenmore. Swamp Creek contributes to the quality of water in the Sammamish River, which empties to upper Lake Washington 0.7 miles below the Swamp Creek confluence.

Swamp Creek is typical of Puget Sound lowland watersheds. In the gently sloping upper basin, Swamp Creek flows through a narrow valley which gradually broadens to a floodplain almost .75 miles wide in the lower basin. The middle basin also contains a narrow valley with steep slopes in excess of 15 percent just south of the I-405 and I-5 crossing. Elevation in the headwaters is approximately 520 feet, while the elevation at the mouth is about 20 feet above sea level. The stream gradient is flat, decreasing from about 50 feet per mile in the upper basin to less than 20 feet per mile near the mouth. Scriber Creek, Little Swamp Creek, and Martha Creek are the largest of the 19 tributaries to Swamp Creek. Major lakes in the Swamp Creek watershed are Scriber Lake, Martha Lake, and Stickney Lake (SWM 1994 & 2000).

The watershed is nearly 12 miles long and encompasses an area of about 7,500 acres. Approximately 20 percent of the watershed lies within the city of Lynnwood; 8 percent lies within the city of Kenmore, 5 percent lies within the city of Bothell, 5 percent lies within the city of Brier, 5 percent lies within the city of Everett, and the remaining 57 percent lies within unincorporated Snohomish County.

Most of Swamp Creek and its tributaries are shallow and unsuitable for full-immersion swimming activities. However, several noteworthy exceptions are Wallace Park in Kenmore, Lake Martha, and Lake Stickney. Lake Scriber in Lynnwood is large and deep enough for swimming, but this activity is not encouraged by the City. Although public access to the creek is largely limited to road crossings and a few parks, Swamp Creek is fully accessible to adjacent land owners, their children, and in some cases, their neighbors. Limited boating opportunities exist where Swamp Creek meets the Sammamish River.

In the late 1990s, the Swamp Creek watershed was highly urbanized with about 50 percent of the land in residential or commercial use, 30 percent with forest cover, 10 percent in commercial use, and less than 10 percent rural property (MRLC, 1999 & SWM, 2002). Commercial and light industrial uses are primarily located within Lynnwood and Everett. Small farms and pastures are most common in the middle of the watershed, especially in Brier and unincorporated Snohomish County. The watershed is located within the US Census Defined Urbanized Area; therefore, it is expected that population growth and urban development will be concentrated in this area.

An examination of orthophotos taken in 1995 was performed as part of the Habitat Inventory and Assessment of North, Swamp, and Little Bear Creeks (KCWLR, 2001). This land use analysis method is different than the one used for Swamp Creek's Water Quality Improvement Plan and suggested that forested cover is only 20 percent, mostly composed of deciduous trees. Road density was highest in the Scriber Creek subbasin.

City of Bothell Sampling Sites Descriptions

North Creek Basin

Perry Creek sample site (SARU) is located directly behind Salmon Run Apartments. This stream has two branches. One drains from 9th Avenue SE wetland through I-405 and a commercial area. The second drains from ponds in the Green Acres Mobile Home Park northward through a steep, eroded gully. Both of these drainages pass through a wetland behind the Village Square neighborhood, where local flooding occurs during heavy rains before entering North Creek.

Figure 2. Perry Creek after a heavy rain event.

JOCO site is an unnamed creek running south out of the Highlands Campus Business Park property north of 228th Street SE and east of 29th Drive SE. A headwater wetland feeds the channeled and piped stream corridor. The site location is on the north side of 228th Street SE.

Figure 3. JOCO monitoring site, an unnamed tributary that flows through a business park.

The Palm Creek sampling site, MONT, is located at Whole Earth Montessori. Palm Creek's water source is a large wetland in a ravine below the area of R-1 zoning. The stream enters a pipe in a trailer park, returning to an open channel in a defunct trout farm that channels the stream through cement weirs. Sediment fills the channel and the surrounding knotweed does not provide adequate shading. The stream reenters a pipe to cross under 228th Street SE, daylighting again on the south side just above the sample site.

Figure 4. Palm Creek, upstream view of sample station site MONT.

Swamp Creek Basin

Little Swamp Creek (LSWP) was added as a new sample location beginning in 2010. In 2009, sampling by others found elevated levels of fecal coliform in the stream along 7th Avenue SE. The site follows all the same protocol for North Creek's QAQC plan. The site was moved in 2011 to just downstream of the 7th Avenue SE stream crossing.

Figure 5. Little Swamp Creek, view across 7th Avenue SE and upstream of Little Swamp Creek sample station site LSMP-II.

Pollution Sources – North and Swamp Creek

Pollution in the basin(s) comes from both point and nonpoint sources. The point source contributions come from stormwater and include those discharges currently covered by National Pollutant Discharge Elimination System (NPDES) stormwater permits[1], as well as those from municipal separate storm sewer systems (MS4s) that are currently covered by NPDES stormwater permits that meet the definition of a points source in 40 CFR 122.2. Nonpoint water pollution most commonly results from poor land use management, such as inadequate agricultural practices, failing on-site septic systems, and untreated stormwater runoff.

Stormwater runoff can not only carry bacteria from pet wastes on the ground, but also surfacing wastewater from failing septic tanks, excess nutrients from lawns and gardens, and pollutants associated with activities such as car washing and sidewalk cleaning. Urban and suburban development is continuing in the North Creek and Swamp Creek

[1] More information available at http://www.epa.gov/ow/regs/permit.html.

watersheds; thus, water quality impacts from stormwater runoff are expected to increase over time.

Some areas are still rich in wildlife, such as water fowl, deer, and beaver. Fecal coliform bacteria originating from these sources are considered part of the natural background and are generally not considered a source of pollution.

Impaired Areas

North Creek

North Creek was included on Washington's 1996 303(d) list because of numerous exceedances of fecal coliform bacteria standards; 29 percent to 45 percent of samples collected at several locations in North Creek by Snohomish and King Counties between 1992 and 1997 exceeded the upper fecal coliform criterion. Based on monitoring conducted by the various municipalities in the watershed, we now know that the extent of the bacterial pollution problem stretches throughout the basin.

Swamp Creek

Since 2000, a consistent pattern of bacterial pollution has been observed in Swamp Creek. It was placed on Washington's 1996 303(d) list for fecal coliform exceedance and low dissolved oxygen. All areas previously sampled in the basin exceed state criteria for bacteria at all times of the year (Svrjcek, 2006). During the dry summer months when stream flows are low, bacteria levels rise far beyond both the geometric mean criterion of 50 cfu/100 mL and the 90th percentile criterion of 100 cfu/100 mL. During the wetter months of the year, bacteria concentrations improve at each site, but not enough to meet state standards.

Since 2010, the City has been monitoring Little Swamp Creek, a tributary to Swamp Creek (Figure 1). Sampling has shown periods of high bacteria levels during the dry season and lower concentrations during the wet season. Source tracking investigations found potentially contributing sources from a failed septic system and a duck feeding pond. The septic system was repaired in 2010 and efforts are ongoing at the duck pond to discourage people from feeding the ducks. Recent surveys in 2014 have found no evidence of people feeding ducks, yet the ducks remain at the pond. Year on year bacteria levels decreased from 2011 through 2014 but increased in 2015.

Project Description

Monitoring at established long-term monitoring stations is used to develop a trend analysis to determine the direction of bacteria concentrations (i.e., whether it is falling or rising). The City has established four long-term stations in North Creek basin and one in Swamp Creek basin. The North Creek stations are mainstem North Creek (NCLD) and three tributaries – Perry Creek (SARU), Junco Creek (JOCO), and Palm Creek (MONT). Swamp Creek's station is located on Little Swamp Creek (LSMP-II). Currently, the City has about seven years of data for North Creek with a total of 84 data points for each site. Swamp Creek has four years of data and 48 data points. Decreases in fecal bacteria have been noted at most sites, yet there is no direct evidence; i.e., was there a shift in bird densities or fixing of a failed septic system, that accounts for the decrease.

This report provides monitoring procedures and results. The basic procedures for sample collection and processing of samples at the long-term sites are sufficient for simple trend comparison among and between sites.

Relationship of this Monitoring with Existing Programs

Long-term monitoring currently performed by King and Snohomish counties has not been integrated to this monitoring program. It remains an unmet need to utilize existing monitoring data from others, outside and within the city, to inform the City's monitoring efforts. Flow gaging stations operated by these entities are critical for establishing when stream flow is dominated by stormwater runoff. At this time, the City has established five monthly monitoring stations.

Source Tracking

Beginning in 2010, the City of Bothell and Snohomish County entered into an interlocal agreement to improve monitoring within North Creek. In 2010, the City contracted with Snohomish County to conduct bacteria microbial source tracking efforts (Britsch, 2009). The microbial source tracking was triggered by monitoring results indicating prolonged elevated levels of fecal bacteria exceeding 200 colonies per 100 mL.

In late 2009 and throughout 2010, WDOE lead a collaborative effort with the City to identify sources of high fecal coliform bacteria in Little Swamp Creek. Results from the intensive sampling regime allowed for source tracking of potentially active sources of bacteria discharges to Little Swamp Creek. In 2010, the City added a long-term monitoring station for fecal coliform bacteria in Little Swamp Creek.

In 2010, Snohomish County Surface Water Management Program staff carried out a contaminant source survey in Perry Creek. A similar survey was conducted in 2012 on Queensborough Creek. Each survey provided its findings and recommended actions. Perry Creek had no identified point source illicit discharges linked to fecal bacteria, and likely sources of nonpoint were from wildlife in wetland ponds, pet waste, and potential nutrient loading from residential lawns and parks. Similar nonpoint sources were found in Queensborough Creek, except no wildlife concerns were noted. Point sources were identified but could not be verified. Potential discharges of human waste from aging sewer standpipes and human use was observed. The latter is part of ongoing source tracking efforts initiated in August 2014. The results are not yet available.

Little Swamp Creek is receiving targeted source identification and elimination efforts (Loch, 2014). The ongoing effort began in August 2014. The goal is to determine the effectiveness of eliminating duck feeding activities at a small duck pond located in the business site of Country Village. Early indications are that duck feeding is no longer occurring, but a significant number of ducks remain at the pond, possibly feeding on aquatic algae, plankton, and zooplankton.

The results of the two targeted source identification and elimination efforts will be forthcoming in a separate report (Loch 2015).

Data Quality Objectives

Data quality objectives are qualitative and quantitative statements of the precision, bias, representativeness, completeness, and comparability necessary for the data to address project objectives. The primary indicators of data quality are precision and bias, which together, express the data's accuracy.

Precision, expressed as the standard deviation of replicate sample analyses, is a measure of data scatter due to random error. Bias is a measure of the difference between the result for a parameter and the true value due to systematic errors. Potential sources of errors include sample collection, physical and chemical instability of samples, interference effects, instrument calibration, and contamination. Random error affects the determination of bias; thus, bias estimation may be problematic. Consequently, dedication to established protocols is one method used to reduce concern over sources of bias (Lombard & Kirchmer, 2004).

Fecal coliform bacteria levels are highly influenced by the biological component in the aquatic environment and can be subject to sample contamination problems. Table 1 summarizes the laboratory accuracy and analytical reporting limits for parameters that can reliably be used for decision making. Seasonal sampling and other sampling design features will be used to better evaluate critical conditions to determine water quality compliance with state bacteria standards.

Our goals for evaluating impacts to water quality require the ability to detect "differences." These differences can be based on: 1) a simple comparison of upstream and downstream locations (e.g., "bracketing," BMP effectiveness evaluations), or 2) determining a trend over time at points on a stream in the absence of changes to upstream land use activities.

Table 1. Quantitative Data Quality Objectives

Analysis	**Accuracy** % deviation from true value	**Precision** relative standard deviation	**Bias** % deviation from true value	**Required Reporting Limits** (concentration)
		LABORATORY ANALYSIS		
Fecal Coliform (MF)[1]	N/A	RSD ± 30%	N/A	1 colony forming unit per 100 mL

[1] Using Standard Method 9222D

Upstream/Downstream Differences

Sources of very high fecal coliform concentrations, such as failing septic systems or leaking sewer lines, can have severe effects on overall stream concentrations even when the volume discharged is low. However, when the concentration upstream of a source is high, the change due to the source can be undetectable.

Trends Over Time

The ability to detect changes in water quality (trends) is the cornerstone of a long-term sampling design. A historical perspective, which only long-term records can provide, is necessary in order to make informed decisions about water quality assessments. Data quality objectives were developed to support statistical requirements for trend analysis.

Sampling Process Design

To detect trends and compare sample results to the state water quality standards requires collection of samples at regular intervals and at the same stations over a long time span. This approach will provide randomly collected data for unbiased analysis in the future. No attempt will be made to avoid sampling due to weather or other environmental conditions unless staff safety is compromised.

Sampling related to the TMDL is limited to bacterial pollution measured using fecal coliform testing. WDOE requires high quality flow monitoring (daily flows) at selected representative stations throughout the basin. Although WDOE encourages monitoring of temperature and dissolved oxygen levels as well, these additional parameters are not required.

The frequency for monitoring at the long-term sites is monthly. The City of Bothell will attempt to sample the first Monday/Tuesday of the month. Small deviations for holidays, illness, and other business reasons are anticipated. This sampling regime will occur throughout the NPDES Phase II Permit life.

Figure 1 shows water quality stations for the long-term monitoring component of this project. North Creek's long-term flow monitoring is conducted by Snohomish County Surface Water Management at 240th Street SE, site NCLD (Figure 1). Swamp Creek's long-term flow monitoring is conducted by Snohomish County Surface Water Management at two locations; one near State Route 524, and the other at Locust Way just north of 228th Street SE (Figure 2). King County conducts long-term flow monitoring at one location in the lower basin (Figure 2).

Source Tracking Surveys

North Creek

Snohomish County Surface Water Management has developed source tracking methodology for fecal coliform bacteria (Britsch, 2009). Perry Creek was subject to a Phase II contaminant source survey (CSS). Field surveys included a windshield survey (driving the roads) and stream walk, where and when feasible, to identify presence of specific sources of bacteria. Types of activities included identifying illicit connections, evidence of failing septic systems, catch basins with accumulated sediment greater than 40 percent, presence of dog parks, and presence and numbers of birds and dogs. For a complete description of methods, refer to Perry Creek Contaminant Source Survey, 2010 Summary Report (SWM, 2010). The results were then translated into a set of recommendations. A similar effort occurred in 2012 on Crystal Creek. Those results and recommendations are included in SWM 2012.

Swamp Creek

The source tracking effort followed a simple pattern of collecting multiple upstream and downstream samples. The sampling was conducted on multiple occurrences and modified based on the previous sample results. The selection of sampling sites was based on narrowing down to a finite world of possible contributing sources. In this manner, sampling typically progressed upstream until no other possible sources of bacteria could be identified.

Data Results 2015

Verification

Verification of data found it to be consistent, correct, and complete, with no errors or omissions. Results of QC were calculated and found to be within acceptable tolerance (Appendix A). Hence, established criteria for QC results were met. Data qualifiers were properly assigned by laboratory and by field personnel as needed. Data specified in Sampling Process Design were obtained. Methods and protocols specified in the QA Project Plan were followed.

Validation

Data validation found no anomalies. Method quality objectives were met with a Relative Standard Difference (RSD) of replicates to within the ± 30 percent tolerance range (Appendix A).

Duplicate analysis of percent relative difference was within RSD of ± 30 percent.

Field Sampling

Field sampling occurred on 12 separate occasions in 2015. No unusual observations were detected. Staff typically sampled on the first Monday or Tuesday of each month. This shifted to later in the month at times, due to staff availability. In 2014, sampling shifted to the third Wednesday of the month. The change was a watershed-wide agreement with all other jurisdictions. It was chosen to see if relationships exist between sampling stations throughout the watershed of North and Swamp Creeks. This was not adhered to in 2015 due to staff time constraints to conduct sampling.

Results

Results of sampling are tabulated in Table 4 under wet and dry season. The wet season is from November through the following May and is seven months long. The dry season is June through October and is five months long. The highlighted red font are for results that exceed state water quality standards of less than 50 Fecal Coliform colonies per 100 mL or having a geometric mean of 90th percentile greater than 100 Fecal Coliform colonies per 100 mL.

The trend observed during wet season (November through May) and dry season (June through October) since 2006 to 2015 is variable between streams (Table 2, Figure 6, and Figure 7). The trend has been one of decreasing or unchanged since 2010 during dry season sampling, and a consistent increase since 2010 during wet season, until this past year in 2015, when levels of fecal coliform bacteria decreased from the previous year. There is as of yet no causal element identified for this trend change.

Data is tabulated by the water year period which runs from October 1 to September 31 of the following year. Ecology utilizes the water year as standard protocol for assessing water quality data such as fecal coliform bacteria. The general trend from 2008 to 2011 was a decrease in fecal bacteria (Figure 8). Since 2011, three sites (MONT, JOCO, & NCLD) have leveled off with minor variations between years. Two sites showed opposite trends to each other with Perry Creek (SARU) seeing an increase but then a drop in 2015. Little Swamp Creek had been decreasing but spiked up in 2015. For the past three consecutive years, Junco Creek is the only site to meet state standards for criteria of less than 50 fecal coliform bacteria colonies per 100 mL; and two of those years also achieved a 90th percentile of less than 100 fecal coliform bacteria colonies per 100 mL.

Table 2. Annual Results for Fecal Coliform Bacteria Sampling. Reported as geometric mean (GMV) of Fecal Coliform bacteria per 100 mL for North and Swamp Creek sample locations. Red indicates exceedance of state water quality standards.

Monitoring Location	# of Samples	FC/100ml GMV	90th percentile	# of Samples	GMV	90th percentile
	2006-7 Dry Season			2007 Wet Season (Spring)		
SARU	10	209	632	9	42	109
JOCO	10	55	173	10	7	35
MONT	10	187	510	10	93	207
	2008 Dry Season			2007-08 Wet Season Fall to spring		
SARU	3	115	139	7	192	452
JOCO	3	49	196	7	43	272
MONT	3	114	166	7	62	192
	2009 Dry Season			2008-09 Wet Season Fall to spring		
SARU	8	800	3980	8	184	1682
JOCO	8	59	1832	8	9	85
MONT	8	219	1040	8	132	698
	2010 Dry Season			2009-10 Wet Season Fall to spring		
SARU	5	104	1270	7	78	215
JOCO	5	32	190	7	15	38
MONT	5	100	740	7	65	230
LSWP	5	47	268	Not Applicable		
	2011 Dry Season			2010-11 Wet Season Fall to spring		
SARU	6	112	232	7	22	130
JOCO	6	20	54	7	11	32
MONT	6	181	832	7	20	98
LSWP	6	244	694	7	29	139
	2012 Dry Season			2011-12 Wet Season Fall to spring		
SARU	5	110	1136	7	25	58
JOCO	5	108	340	7	16	223
MONT	5	233	588	7	24	308
LSWP	5	185	2580	7	43	238
	2013 Dry Season			2012-13 Wet Season Fall to spring		
SARU	5	154	526	7	110	228
JOCO	5	16	46	7	14	23
MONT	5	66	873	7	47	130
LSWP	5	24	112	7	167	1562
	2014 Dry Season			2013-14 Wet Season Fall to spring		
SARU	5	341	696	7	80	314
JOCO	5	37	68	7	11	43
MONT	5	95	186	7	48	129
LSWP	5	117	3156	7	51	393
	2015 Dry Season			2014-15 Wet Season Fall to spring		
SARU	5	141	242	7	52	100
JOCO	5	25	122	7	3	12.6
MONT	5	75	170	7	64	170
LSWP	5	158	430	7	184	316
NCLD	5	142	198	7	64	120

State water quality standards: geometric mean < 50 cfu/100ml and upper tenth percentile < 100 cfu/100ml.

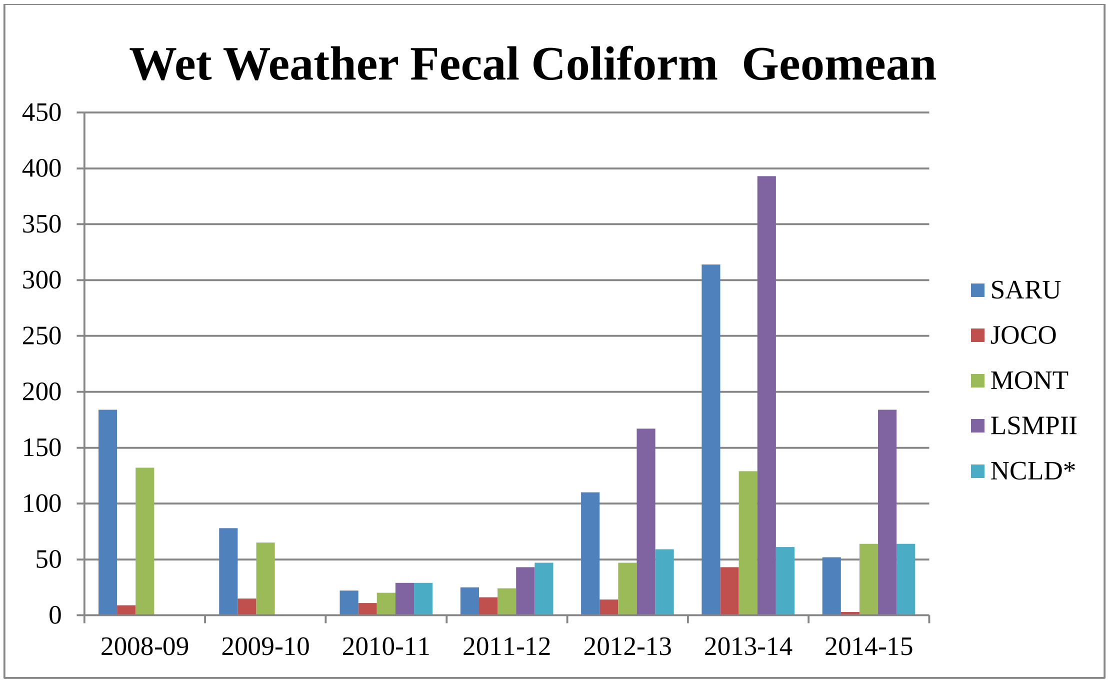

Figure 6. Wet Weather Fecal Coliform Geometric Mean from 2008-09 through 2013-15.

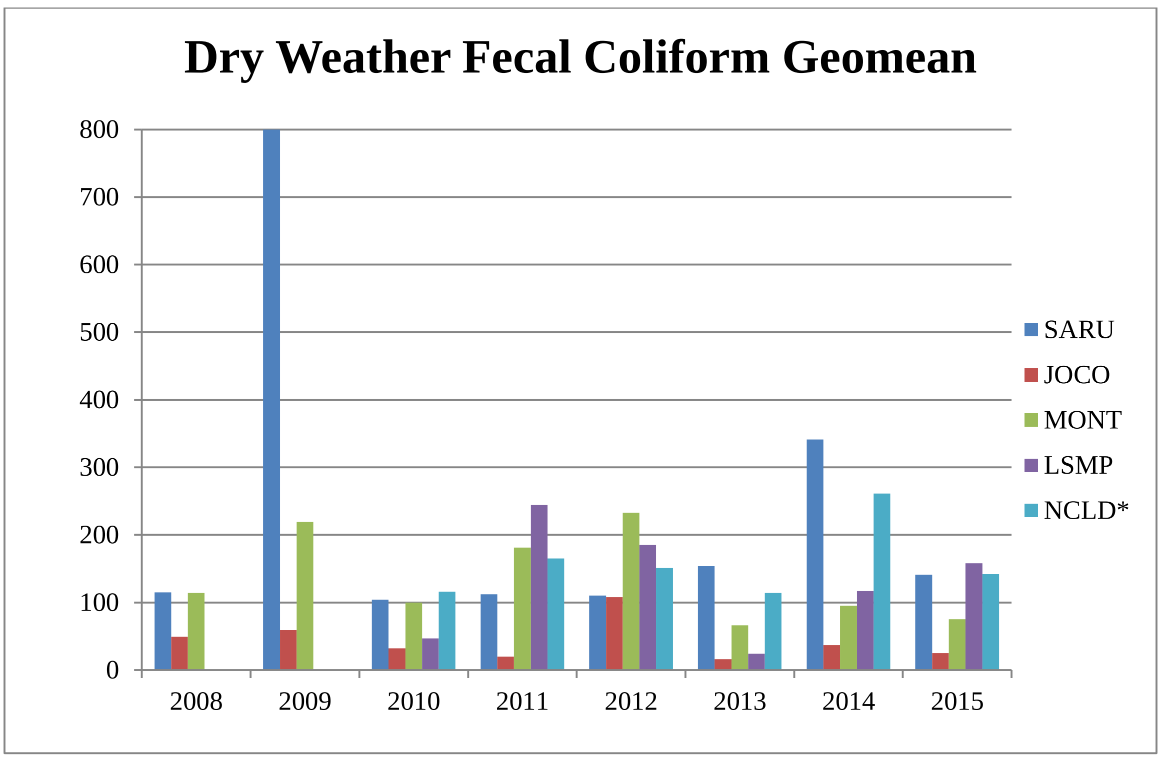

Figure 7. Dry Weather Fecal Coliform Geometric Mean from 2008 through 2015.

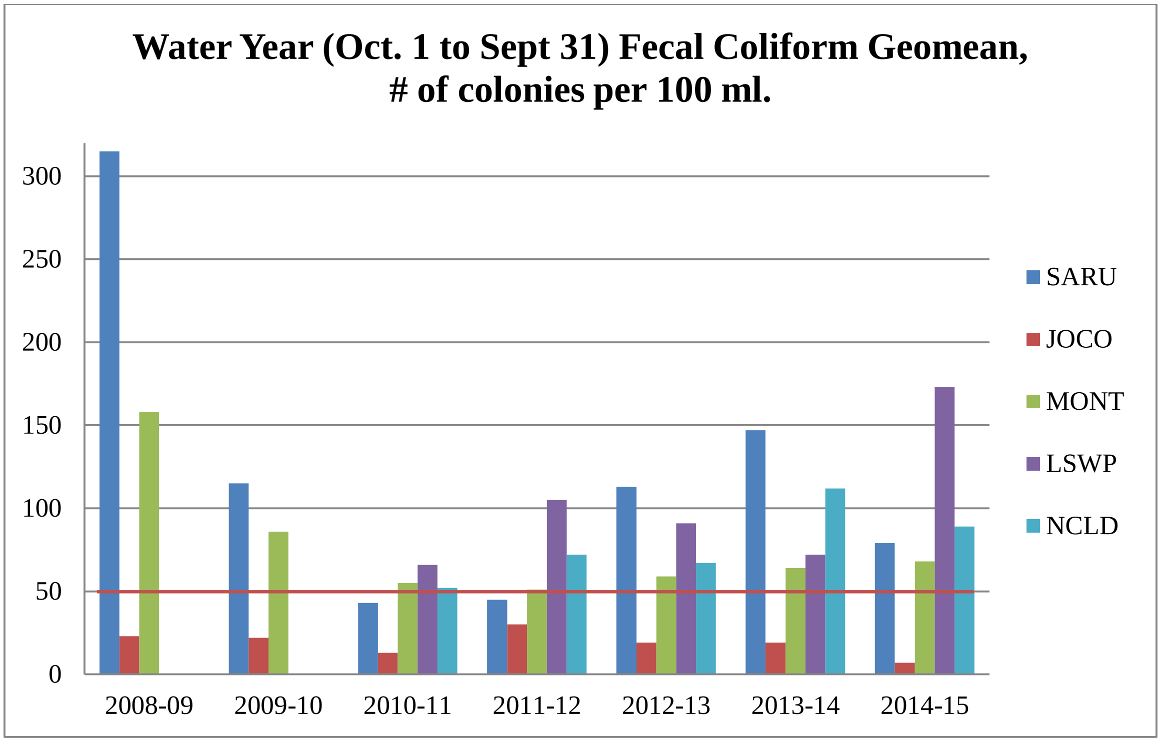

Figure 8. Water Year (October through September) Fecal Coliform Geometric Mean Bar Chart, 2008 to 2015.

Source Tracking Surveys

Two source tracking surveys were initiated in 2014 (Loch, 2014). One was in Little Swamp Creek, and the other in Queensborough Creek. Sample results remain preliminary at this time and will be addressed in a future report.

Summary

What is unknown absolutely is why any of the sites showed an increase or decrease in bacteria concentrations. There is no systematic data collection that monitors the absolute sources of fecal bacteria. The lack of empirical data to establish cause and effect of bacteria concentrations creates an inability to accurately measure effectiveness of bacteria reducing land use actions.

The City has been actively engaged on several fronts to reduce pet and duck waste. Programs have focused on picking up dog waste and reducing the behavior of feeding ducks. It is possible that these programs directly resulted in the decline of fecal bacteria, but they may be losing their effectiveness as time progresses.

Previous source tracking surveys have had limited success (Snohomish County, 2010 and 2012). In Little Swamp Creek, source-tracking investigations found potentially contributing sources from a failed septic system and a duck feeding pond. The septic system was repaired in 2010 and efforts are ongoing to eliminate feeding the ducks at the duck pond. Recent surveys in 2014 have found no evidence of people feeding ducks, yet the ducks remain at the pond. The levels of fecal bacteria down stream of these two sources show modest improvements but not to the level of state water quality standards.

The TMDL monitoring shall remain an ongoing project as stipulated in the renewal of the National Pollution Discharge Elimination System permit. In February 2015 the City submitted a sampling plan, Quality Assurance Project Plan, for Ecology's review. The plan was approved by Ecology. The plan was implemented in February 2015. It maintains the current sampling regime with one additional sample site, NCLD. This site had been previously sampled by Snohomish County but the County is no longer able to provide their services. An additional feature of the renewed NPDES permit is the requirement to enter the water quality data into Ecology's Environmental Information Management System database beginning in May 2016.

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Appendix A

Sampling Procedures
Data Management Procedures
Field Replicate and Lab Duplicate Analysis for 2015

Sampling Procedures

Overview

Fecal coliform bacteria is the preferred indicator of disease-causing microorganisms in Washington State. There are two standard methods for the detection of coliform bacteria – the Membrane Filter (MF) technique and the Most Probable Number (MPN) index. The MF and MPN methods are frequently not comparable. The United States Environmental Protection Agency (USEPA) currently recommends the MF procedure because it is faster and more precise than the MPN technique (EPA, 2001). However, MPN is better for use in chlorinated effluents, highly turbid waters, and salt or brackish waters. Ecology requires all partners in this program to have samples analyzed by state-accredited laboratories using the MF technique SM9222D. The City of Bothell used TestAmerica Analytical for this purpose until June 2008, and then switched to AmTest, Inc.

Planning

Bacteria samples will be collected in sterilized bottles obtained from AmTest, Inc.

Downstream samples are collected first. Samples will be taken downstream working upstream to minimize the possibility of collecting fecal coliform from sediments that may have been disturbed during the current sampling activities.

Field Procedures

Ambient water quality samples collected as part of this QAPP will generally use the “dipping method.” The dipping method is intended to collect the most representative sample taken at a single point in time (also called a grab sample). Staff will avoid collecting water from near the surface and collect samples from the center of flow (thalweg) when possible. A notation will be made in the field notebook if surface samples are taken.

Field measurements and comments are recorded on either a form prepared prior to sampling, ideally in a notebook of water-resistant paper, or loose-leaf water resistant paper. All notes should be stored in a safe location after a sampling run. At a minimum, staff should record project name, station location, date and time of sample collection, and sample number. Other useful information may include staff gauge or tape down measurements, estimates of discharge, field quality control information, field meter measurements (if applicable), weather conditions, and comments about turbidity, color, and odor.

A word about safety: Safety is a primary concern whenever working in or near waterbodies. Many times, sampling locations are established close to roadway crossings to facilitate access in right-of-ways and to reduce travel times to the actual sample site. In these cases, the need for life vests, reflective clothing, orange marking cones, and flashing lights will be considered to protect staff from injury and to alert passing drivers to their presence on the roadside.

Here are the general procedures for taking a proper fecal coliform sample.

Sampling Procedure

1. A sterilized polypropylene sample container provided by the accredited laboratory is used. The minimum sample size is 250 mL.
2. For sites that require entering the stream, care is taken to not stir up sediment. Sites are approached from a downstream to upstream direction.
3. The sample bottle is uncapped. Care is taken not to contaminate the inside of the bottle or the cap.
4. The bottle is inverted and plunged, mouth down, through the surface to a depth of 15 to 30 cm (6 to 12 inches, mid-depth of stream where feasible). While under water, the mouth of the bottle is rotated into the current. The sample bottle is brought back to the surface in an upright position. Water is poured off enough until the water level is at the shoulder of the bottle. This allows room for mixing the sample before analysis at the lab.
5. After recapping the bottle, the bottle is placed on ice upon reaching the vehicle.
6. Other notes:
   - **Do not rinse the bottle.**
   - **Do not pour water into the fecal bottle from another container.**

Field Quality Control

Field Replicates

Total variability (precision) for field sampling and laboratory analysis will be assessed by collecting field replicates. In some cases, field duplicates, field blanks, and field splits may also be appropriate.

Field replicates are two samples collected from the same location at the same time. A second bottle is plunged side-by-side with the regular sample. Field replicates will be collected at the rate of 10 percent, with a minimum of one field replicate per sampling run. If using a pole to collect samples, it may not be possible to collect the samples side-by-side. In this case, the field replicate is collected at the same time as the regular sample. Staff is directed to make comments in the field notes if the samples were not collected side-by-side.

Replicate results that are “non-detects” cannot be used to estimate precision. Similarly, the variability found at low concentrations cannot be used to estimate the variability at higher concentrations, and vice versa. Variability, or precision, is estimated as the standard deviation of a number of results. The standard deviation varies with the magnitude of the results. Separate estimates of standard deviation will be determined for each range of concentration. By collecting field replicates often over a long time period, we should be able to calculate standard deviations for a wide range of concentrations.

Field replicates are labeled in such a way as to give the impression that they are completely separate samples before they are sent to the laboratory. The laboratory analysts are not made aware of the fact that they are handling field replicates.

Sample Container

A sterile glass or polypropylene bottle will be used for all samples collected. (When working with laboratories associated with wastewater treatment plants, it should be specified that the bottle must be empty, with no sodium thiosulfate or other dechlorinating agents.) Although the type and size of bottle will likely be determined by the laboratory's preferences, WDOE routinely uses polypropylene 250 and 500 mL bottles without preservative for stream samples. Sample bottles should be autoclaved with caps covered in aluminum foil or otherwise sterilized and supplied by an accredited laboratory.

Select a bottle according to the following criteria:

- Use the 500 mL bottle if sampling for enterococci in addition to fecal coliform.
- Use bottles with EDTA added if high metal concentrations are suspected.

At WDOE, empty bottles have a holding time; three months for bottles without thiosulfate or EDTA, and one month for bottles with thiosulfate or EDTA. Individual laboratories may have different recommendations.

Field Processing

No field processing is required.

Sample Storage

All samples are placed in an ice chest with ice packs immediately upon return to the vehicle. The samples are stored in the dark. For chain-of-custody procedures, the vehicle is locked whenever it is not in view of sampling personnel.

Measurement Procedures

Field

Station Information

The City of Bothell has already determined the coordinate information for its proposed long-term sites and entered this information into Ecology's EIM database. Ecology has indicated that it is not necessary to determine coordinate information for short-term monitoring locations associated with source tracking activities.

Office

Stream Discharge Data

Currently, stream gauging networks are provided by Snohomish County and King County. At present, three stream gauges are functioning on Swamp Creek and North Creek. Snohomish County monitors at site NCLD, which is located in lower North Creek just upstream of 228th Street SE in Bothell. In 2011, the NCLU site was at 240th Street SE but was abandoned due to a bridge replacement project. It was relocated upstream to 228th Street SE in late 2011. Mill Creek and Snohomish County jointly maintain and operate a flow-monitoring station on Penny Creek near its confluence with North Creek.

Lab

Fecal Coliform – Membrane Filtration Method

Laboratory analyses for fecal coliform bacteria were performed by two separate laboratories accredited by Ecology. The analytical method used is described by Standard Methods for the Examination of Water and Wastewater, No: 9222 D, 24-hour Membrane Filter (MF) procedure. The detection limit and the precision for this method are both 1 colony per 100 mL. Densities were reported as fecal coliform bacteria per 100 mL.

Quality Control

Quality control procedures used during field sampling and laboratory analysis provided estimates of the accuracy of the monitoring data. Field replicates were used to determine compliance with measurement quality objectives. Total variation for field sampling and analytical variation were assessed by collecting replicate samples and performing lab replicates as discussed below.

Summary of Field and Laboratory Quality Control Procedures

Analysis	Field Blanks	Field Replicates	Lab Check Standard	Lab Method Blank	Lab Replicates	Matrix Spikes
Fecal Coliform (MF)	N/A	1/10 samples	N/A	1/run	1/10 samples	N/A

Field

Field Notes

The notes from each field run were tabulated and compared to chain-of-custody forms and laboratory results for completeness and accuracy. Any problems and associated corrective actions were recorded. Any unresolved problems were flagged and discussed in the data report.

Fecal Coliform and E. Coli Bacteria

Total variability for field sampling and laboratory analysis were assessed by collecting replicate samples at the rate of 10 percent of regular samples collected, and a minimum of one replicate per sampling run.

Laboratory

Fecal Coliform and E. Coli.

Routine laboratory quality control procedures will be followed. Laboratories should perform at least one analytical duplicate per sampling run. Duplicate laboratory analysis refers to analyzing duplicate aliquots from a single sample container. Each sample is carried through all steps of sample preparation and analysis. The results for laboratory duplicates provide an estimate of analytical precision, including the homogeneity of the sample matrix.

Field personnel may want to request that the analytical duplicate be performed on the same sample that accompanies the field replicate, as this allows staff to estimate total and analytical variability from results for the same sample. There is no advantage to randomly selecting samples for duplicate analysis.

If the samples selected for duplicate analyses do not contain measurable amounts of fecal coliform, the results provide no information on precision. Similarly, if the laboratory selects samples from another study with significantly different levels of fecal coliform or different matrices, the estimate of precision may not be applicable to the samples.

The laboratory must report the results of their analytical duplicates.

Data Qualifiers

Each laboratory had its own list of data qualifiers. Test America Analytical and AMTest, Inc. supplied the City of Bothell with a list of relevant data qualifiers and supporting documentation so that a cross-reference list could be developed. The laboratories were instructed to contact the City immediately if values over 1000 cfu/100 mL were observed.

Data Management Procedures

Recording field measurements

Time, location, weather conditions, and other observations and environmental factors were recorded at the time of sampling and maintained for public record purposes. Laboratory reports, worksheets, and chain-of-custody records were filed together and stored in a binder and other organized forms.

Data qualifiers were explained in all reports as needed. Tables were used to track seasonal compliance with water quality standards using a dry season period of June through September.

Data Verification and Validation

Verification

Data was verified by examining the data for errors, omissions, and compliance with quality control (QC) acceptance criteria. Once measurement results were recorded, they were verified to ensure that:

- Data are consistent, correct, and complete, with no errors or omissions.
- Results for QC samples accompany the sample results.
- Established criteria for QC results were met.
- Data qualifiers were properly assigned where necessary.
- Data specified in Sampling Process Design were obtained.
- Methods and protocols specified in the QAPP were followed.

Qualified and experienced laboratory staff examined lab results for errors, omissions, and compliance with QC acceptance criteria. Findings were documented in each case narrative, if and when they occurred.

Validation

Data validation followed verification. It involved a detailed examination of the data package, using professional judgment to determine whether the method quality objectives (MQOs) were met. Validation involved evaluation of relative percent differences between field duplicates and lab splits.

Field Replicate and Lab Duplicate Analysis for 2015

Field Replicate Analysis, 2015 FC Bacteria

Field	FC cfus/100ml		
Date	Site	Replicate	%RPD
1/21/2015	28	**28**	0
2/18/2015	16	**20**	-22.2
4/6/2015	65	**75**	-14.3
4/21/2015	110	**130**	16.7
5/20/2015	130	**120**	-8.0
6/22/2015	100	**120**	-18.2
7/15/2015	130	**470**	-113.3
8/18/2015	160	**170**	-6.1
9/15/2015	30	**30**	0.0
10/19/2015	44	**30**	-37.8
11/9/2015	410	**380**	-7.6
12/22/2015	160	**190**	17.1
avg	**115**	**147**	-24.2
Std	**106.1347**	**143.2083**	-29.7
RSD=	**92.09082**	**97.4759**	

Duplicate Analysis, 2015 FC Bac.

Lab	FC cfus/100ml		
	Sample	Duplicate	%RPD
	18	20	10.5
	16	18	-11.8
	150	170	12.5
	110	120	8.7
	190	220	14.6
	42	38	-10.0
	210	290	-32.0
	160	170	6.1
	30	16	-60.9
	1	1	0.0
	410	290	-34.3
	96	62	43.0
avg	**119**	**118**	-1.3
Std	**116.7113**	**107.9633**	-7.391
	97.73455	**91.55902**	

# of Samples Collected= 48

# of Field Replicates Collected = 12

Field replicates = 25% for sampling period.

RSD= 92.09082 @ + or - 30% = +/ - 27.6 Field Replicate results fall within the 30% RSD.