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Bowman Creek

Fecal Coliform Bacteria Characterization Monitoring

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Publication Information

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

The plan for this study is available on Ecology's website at <https://fortress.wa.gov/ecy/publications/SummaryPages/1210021.html>

Data for this project will be available on Ecology's Environmental Information Management (EIM) website at www.ecy.wa.gov/eim/index.htm. Search User Study ID, BEDI0019.

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Bowman Creek

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by

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Water Resource Inventory Area (WRIA) and 8-digit Hydrologic Unit Code (HUC) numbers for the study area:

WRIA

- 10

HUC number

- 17110014

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Abstract

The Puyallup River Watershed is in Water Resource Inventory Area (WRIA) 10. The watershed includes the White River, which enters the right bank of the Puyallup River at approximately river mile (RM) 10.4. Both rivers have been on the Washington State's 303(d) list of impaired water bodies for not meeting contact recreation water quality standards for fecal coliform (FC) bacteria. Meeting the FC standard is important because it helps make our streams and rivers safe places to swim, fish, and do other recreational activities.

Data collected during the total maximum daily load (TMDL) project identified that Bowman Creek, a tributary to the Lower White River, was not meeting water quality standards near its mouth during the dry season. As a result, the TMDL improvement report and implementation plan recommended that the creek be sampled to determine the sources of FC pollution. It was also recommended for addition to the 303(d) list of impaired waterbodies. The lower reach of the creek is currently proposed for listing on the 2014 303(d) list for bacteria (4a candidate listing #9844).

This 2012/2013 characterization project collected samples in the Bowman Creek basin. They were analyzed for FC bacteria. The creek mainstem met the water quality criterion for Primary Contact Recreation when seasonal data were combined. The annual geometric means for all mainstem sites were 50 cfu/100mL or less during the dry season and the wet season. However, the two lower-most mainstem sites and the upper-most site exceeded the second part of the criterion during the dry season by having one out of eight samples exceeding 200 colony forming units (cfu)/100 milliliters (mL).

Stormwater runoff had elevated bacteria concentrations. Water samples collected at BSW0.3, BT0.01, and BD2.29 violated the water quality criterion for Primary Contact Recreation during the wet season. The water collected from the unnamed tributary (BT0.01) also failed to meet the criterion during the wet season.

The potential sources of FC include on-site septic systems, livestock, pets, wildlife, other natural sources, and associated stormwater runoff.

Introduction

Background

The Puyallup and White Rivers are in WRIA 10 (Figure 1). The White River enters the right bank of the Puyallup River at approximately RM 10.4 (Williams, et al, 1975). Both rivers have been on the Washington State's 303(d) list of impaired water bodies for not meeting contact recreation water quality standards for bacteria. The federal Clean Water Act of 1972 requires that Washington State develop a TMDL and implement activities that will bring the water bodies back into compliance with the appropriate water quality standards.

Ecology conducted a FC bacteria TMDL project in the Puyallup River Watershed in October 2006 through September 2007 (Mathieu and James, 2011). The TMDL identified water bodies that did not meet water quality criterion for FC bacteria. Ecology and the local community developed a plan of implementation activities that would improve water quality (Mathieu and James, 2011).

The TMDL study demonstrated that Primary Contact Recreation was impaired in many areas of the Puyallup River basin due to bacteria. Some potential sources within the watershed were identified as:

- Livestock with direct access to stream or with poor manure management.
- Failing or improperly constructed septic systems.
- Urban stormwater.
- Pet waste.

Bowman Creek was one of the waterbodies found to exceed the water quality criterion for FC bacteria. Specifically, the creek exceeded the criterion during the dry season. The TMDL study suggested that the potential sources of FC included leaking sewer lines or on-site septic systems, wildlife, and urban runoff. As a result of the TMDL project, Ecology was tasked to conduct a more intensive characterization of FC bacteria concentrations in Bowman Creek (Mathieu and James, 2011).

Watershed Description

Bowman Creek watershed is relatively small at approximately 3.6 square miles. It is a tributary to the Lower White River and enters on the left bank at approximately RM 7.65 (Williams, et al, 1975). The creek is mostly in King County with the upper reaches in Pierce County (Figures 1 and 2). The lower reach of the creek currently is proposed for the 2014 303(d) list for bacteria (4a candidate listing #9844).

In the northcentral area of the watershed, off R St. and Oravetz Road, is a relatively large (665 acres) sand and gravel operation, ICON Materials. It is covered under Ecology's Sand and Gravel General Permit (WAG501386). There were no discharges to Bowman Creek from this facility during the time of the study (Jana McDonald, personal communication, March 23, 2016). Though FC bacteria would not be expected in a discharge from this facility, the lack of discharge during the study is notable.

The rest of the watershed is primarily low density rural residential with an increase in residential developments. There are small farms and older residences with newer homes interspersed in the watershed. The older residences are not sewered (Brown and Caldwell, 2015). It is expected that sewage is managed with on-site septic systems but little information was found about on-site system construction or maintenance. During this study there was an increase in new residential properties, notably in the area to the west of 53rd St. SE and Kersey Way. This area was planned to be sewered (Brown and Caldwell, 2015). Horses, alpaca, dogs, and wildlife were observed in the watershed, particularly along both 53rd St. SE and Randall Ave. SE.

Bowman Creek receives approximately 1 cfs via Lake Tapps. The release from Lake Tapps is made through a pipeline and generally occurs continuously throughout the year (Aspect Consulting, LLC, 2010). As can be seen in Figure 2, there are two other relatively small lakes upstream, Bowman Lake and Hille Lake.

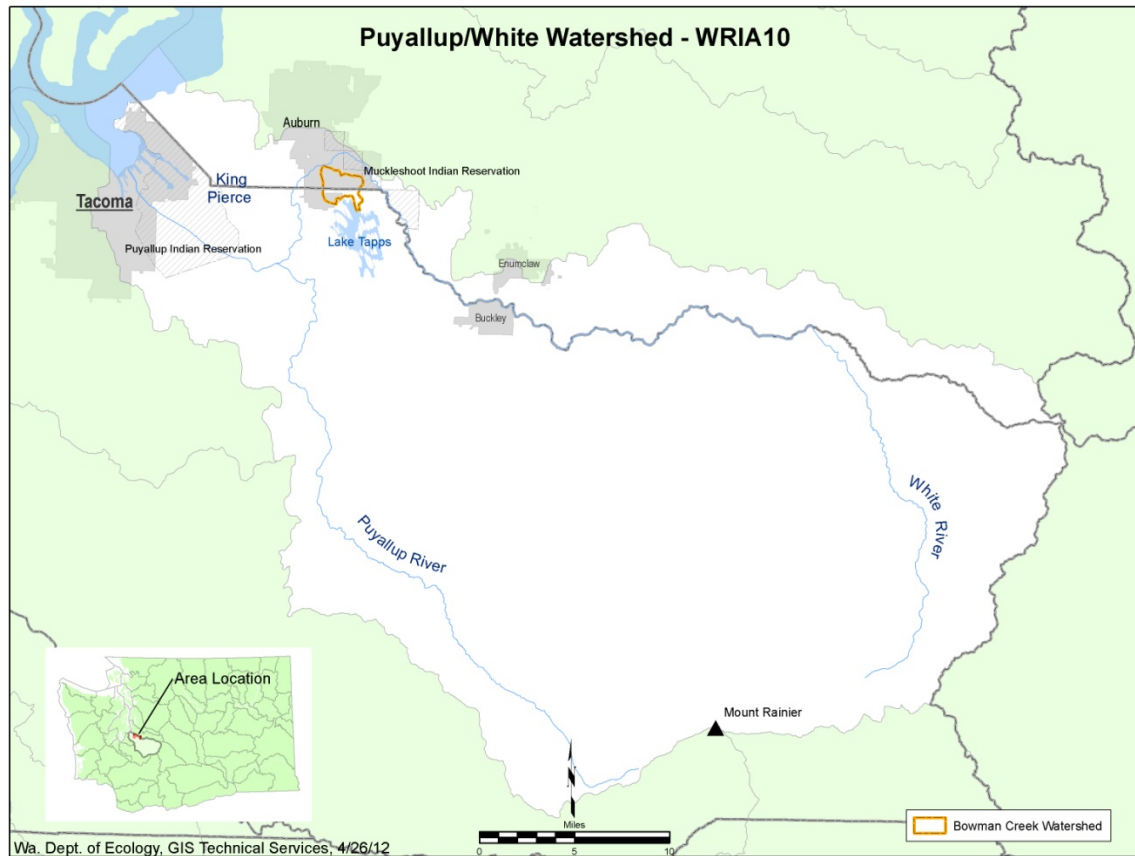


Figure 1. Puyallup River and White River Watershed, WRIA 10. The Bowman Creek sub-watershed is outlined in the upper left corner of the map.

Study Goal and Objectives

The goal of this study was to reduce FC contamination to the 303(d) listed Lower White River.

The objectives of this study were to:

- Characterize FC concentrations in Bowman Creek.
- Compare results to the Primary Contact Recreation criterion.
- Use study results to guide implementation activities for cleaner water.

Water Quality Criterion

Bacteria criteria are set to protect people who work, fish, and play in and on the water from waterborne illnesses. Bowman Creek watershed must meet the Primary Contact Recreation criterion since the creek flows into the Lower White River with this designated use.

The Primary Contact Recreation criterion for fecal coliform bacteria has two-parts to the criterion:

Fecal coliform organism levels must not exceed a geometric mean value of 100 colonies/100mL, **with** not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean values exceeding 200 colonies/100mL (Ecology, 2006).

Field Data Collection

Ecology loaded all data in its online Environmental Information Management (EIM) database. EIM also contains information about the study and sampling stations.

To access the data:

- Go to www.ecy.wa.gov/eim/
- Click on Search for Data. Then click Studies.
- Enter BEDI0019 into the *Study ID* field
- Click the arrow under the *Studies* tab. Then click the *List of results* tab.

Samples were collected from August 2012 through July 2013. Table 1 lists the sampling dates divided into the wet (November through June) and dry (July through October) seasons as defined in the Puyallup TMDL (Mathieu and James, 2011). Sampling was conducted twice a month during the critical dry season and once a month during the wet season.

The associated precipitation is also provided in Table 1. Precipitation records were obtained from the King County Hydrologic Information Center at the Lakeland Hill-Orovitz Pump Station (LHPS) I & I rain gage, west of the creek (47.26994657, -122.2208496) near the city of Auburn. The data can be found at this internet address: <http://green2.kingcounty.gov/hydrology/>

Sampling Locations

Eleven surface water monitoring sites were selected in the Bowman Creek watershed. The sampling sites are shown in Figure 2 and described in Table 2. The site BC1.44 is labeled and described in the map and table. However, no water exited the culvert during the entire study period.

Naming Conventions for Sites

The formal site names in EIM depict the WRIA (10), the creek name abbreviation, and the approximate creek mile. In this report the formal site names are abbreviated. For example 10-Bow-0.15, as identified in EIM, will be shown in graphs, tables, and text in this report as B0.15.

This naming convention refers to the fact that the site is in Bowman Creek (B) at the approximate creek mile 0.15. Additionally, the site name usually identifies whether the site is a tributary (T), ditch (D), or stormwater (SW).

The original sample area used for the TMDL, 10-Bow-0.3 was not used since the creek in this area was not in a confined channel. However, this TMDL site name highlights the inconsistency with the creek mile signature in this report. I used the EIM mapping tool to determine the creek mile for the study sites. So, the site just upstream, on the other side of Kersey Way, is B0.15 as per my measurements. But, when naming the stormwater that flows into the downstream area of 10-Bow-0.3, I retained that naming convention (i.e. BSW0.3). See Figure 2 and Table 2 for further clarification.

Table 1. Sampling dates and associated precipitation at LHPS.

Sample Dates	Precipitation (inches)
Wet Season	<i>Previous 24 hours</i>
November 7, 2012	0.04
December 5, 2012	0.27
January 9, 2013	0.68*
February 6, 2013	0.12
March 6, 2013	0.04
April 3, 2013	0
May 22, 2013	0.41*
June 5, 2013	0
Dry Season	<i>Previous 12 hours</i>
August 8, 2012	0
August 22, 2012	0
September 5, 2012	0
September 19, 2012	0
October 10, 2012	0
October 24, 2012	0.09
July 9, 2013	0
July 29, 2013	0

*exceeded wet season storm event = >0.4 inches (Mathieu and James, 2011)

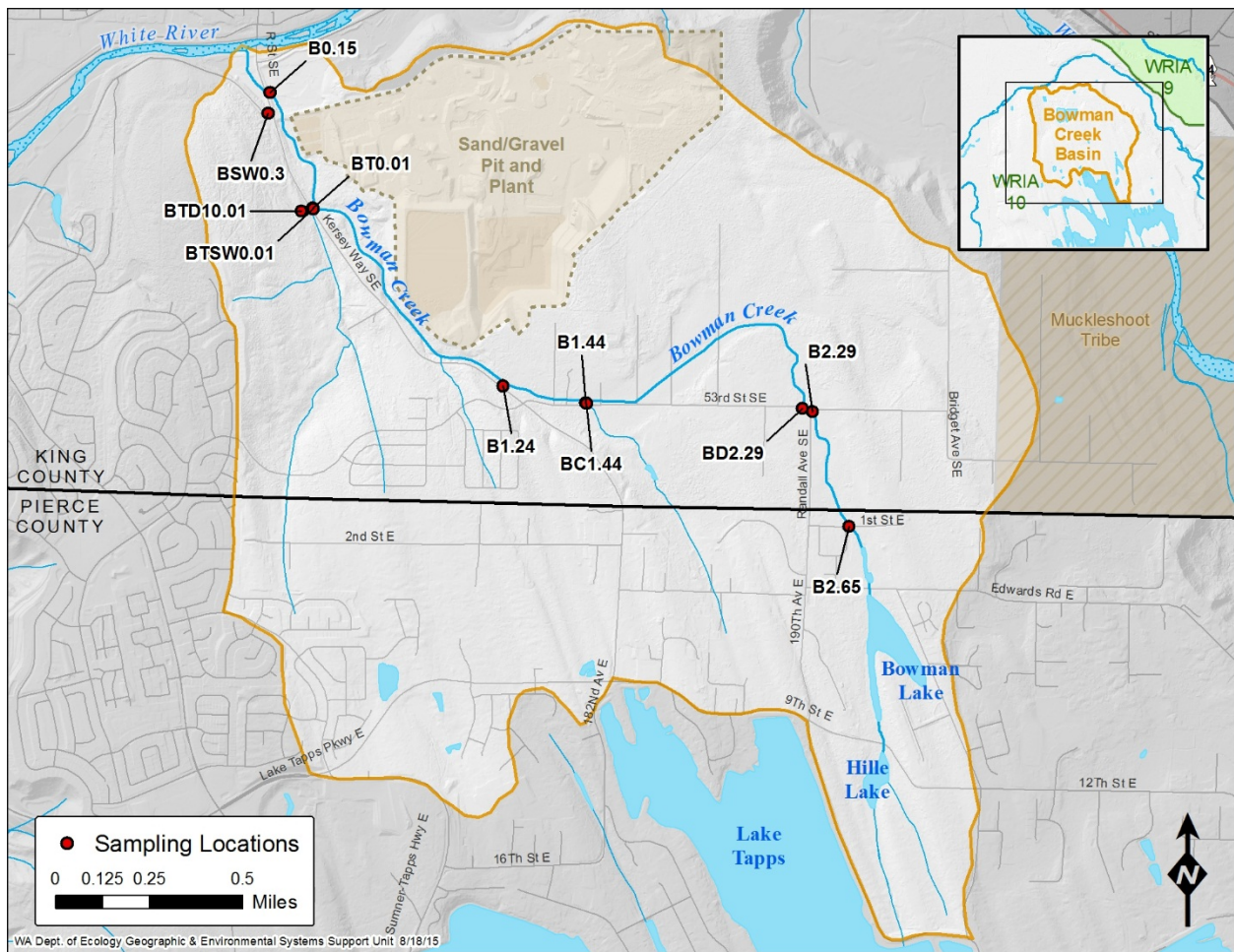


Figure 2. Map of sampling locations in the Bowman Creek watershed.

Table 2. Field location ID, location description and geographic coordinates (NAD83).

Field Location ID	Location Description	Latitude	Longitude
B0.15	Bowman Creek near mouth. Upstream side of Kersey Way.	47.27299	-122.20726
BSW0.3	Stormwater that comes in on downstream side of Oravetz Road and flows into Bowman Creek. It enters Bowman Creek downstream of Kersey Way near the culvert.	47.27219	-122.20737
BT0.01	Tributary to Bowman Creek at black fence, downstream side of Kersey Way. Tributary enters mainstem at CM 0.55.	47.26856	-122.20469
BTSW0.01	Beehive stormwater structure at black fence, downstream side of Kersey Way, collects water from Edgeview Housing development stormwater ponds and from along Kersey Way.	47.26854	-122.20466
BTD10.01	Driveway tributary ditch (1) from the residence driveway up the hill. Enters the tributary on the left bank.	47.26844	-122.20533
B1.24	Bowman Creek at CM1.24 via driveway at 5202 Kersey Way, upstream side.	47.261861	-122.193667
B1.44	Bowman Creek at CM 1.44 on 53rd St SE, E of Irene Ave. upstream of 3001 53rd Ave SE driveway at driveway culvert	47.26116	-122.189416
BC1.44	Ditch at Bowman Creek CM 1.44, crosses under the road and intersects with the left bank of Bowman Creek.	47.261251	-122.188931
B2.29	Bowman Creek at CM2.29. Corner of 53rd St. SE. and Randall Ave. SE, upstream side of road at culvert.	47.26107	-122.17617
BD2.29	Roadside ditch. Flows under 53rd St SE. Enters on left bank of Bowman Creek.	47.26126	-122.17666

B2.65	Bowman Creek at CM 2.65 where crosses 1st St E., downstream side of road. This has been a Pierce County water quality sampling location.	47.256716	-122.173839
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Methods

The Quality Assurance Project Plan (QAPP) written for this project can be reviewed at <https://fortress.wa.gov/ecy/publications/SummaryPages/1210021.html> (Dickes, 2012). The QAPP provides details for field and laboratory methods and project quality control guidelines.

Experienced field staff collected bacteria samples following established and documented Ecology protocols (Ward and Mathieu, 2011). All bacteria samples were analyzed at the Manchester Environmental Laboratory (MEL 2008, 2012) using the membrane filter method (SM9992D, APHA, et al., 1998).

Minimizing the spread of invasive species

Gear was air dried for over 48 hours in between sampling events as per Parsons, 2012. Therefore, the use of hydrogen peroxide, as mentioned in the QAPP, was not necessary. Additionally, felt soled boots were not worn.

Streamflow

Streamflow was measured for this study, however, the data may not fully represent stream conditions. The meter was zeroed before every event, however, due to oversight, the meter had not undergone a recent calibration by the manufacturer. The meter had been instead checked with another Marsh-McBirney flow meter that had undergone an annual calibration by the manufacturer. Subsequently, it was determined that we weren't confident in making conclusions using the flow data collected. The streamflow data will not be analyzed or entered into EIM.

Data Quality

Samples were collected and analyzed for bacteria in a manner similar to those in the Puyallup TMDL. The Ecology standard sampling protocol was followed (Ward and Mathieu, 2011). MEL was also the laboratory that conducted the analyses. Ecology evaluated the study data and determined that the data are useable for the project objectives. Data quality is described in the following sections.

Precision

Precision is the measure of variability in the results of replicate measurements due to random error. The random error includes error inherently associated with field sampling and laboratory analysis. Bacteria was assessed for field precision through 16 percent replication during the wet season and 22 percent replication during the dry season.

The Method Quality Objectives (MQOs) set for precision were based on an analysis conducted by Mathieu, 2006, using replicate data from TMDLs in much larger watersheds. However, we used the criteria for assessing this smaller watershed. Under this MQO, 50% of the replicate pairs must be at or below 20% relative standard deviation (RSD), and 90% of the pairs must be at or below 50% RSD.

Ninety percent of the 16 field-replicate pairs had a RSD of 45.73%, thus meeting the 50% RSD precision criteria. However, 50 % of the replicate pairs had an RSD of 22%, exceeding the precision criteria of 20 % RSD. The variability in the replicates may result from smaller watershed size relative to a TMDL and reduced mixing after sources enter the water. Bacteria also have a patchy distribution. Since the replicate samples were collected one-right-after the other, this may have increased the potential to reflect the natural variability.

MEL measured lab precision by analyzing aliquots from a single sample container. MEL compared the relative percent difference (RPD) of each duplicate pair to their acceptance criteria of less than 40% RPD. There were a few events when this criteria was exceeded, but the lab did not qualify any of the field data.

Completeness

The plan for the study was that 100% of the samples would be collected and analyzed (Dickes, 2012). It was also assumed that unexpected circumstances may interfere with this plan. Circumstances did arise that prevented sample collection. Some samples were not collected due to stagnant water or a lack of water during the dry season. However, all samples collected were analyzed.

Bias and Representativeness

Some fecal coliform results were analyzed beyond the 24 hour holding time. However, all analyses were done within 30 hours of sample collection. An Ecology holding time study has shown that FC samples analyzed by MEL within 30 hours were comparable to samples analyzed with 6-8 hours (Mathieu, 2005). Therefore, results were used in the calculated statistics. Some values were given a J qualifier by the laboratory. This resulted when >150 colonies were on the plate. It's described that two or more bacteria could land in the same place during filtration; therefore the true value may be greater than or equal to the reported values. Those estimated values were analyzed in the data set.

One result (BTD10.01, on 5/22/13) was reported as Too Numerous to Count. The result was then calculated by MEL using the maximum countable value of 200 colonies and then multiplied by its dilution factor. The value (800 cfu/100mL) was then given a G qualifier to signify that the actual FC concentration was greater than reported. This value was used in the summary statistics, but it underestimates the actual contamination at the site for this day.

As mentioned in the Sampling Location section, the original sample site used for the TMDL, 10-Bow-0.3, was dropped since the creek in this area was not in a confined channel. The site was relocated just upstream on the other side of Kersey Way. There were no known sources entering the mainstem between these two locations. It is assumed that the short length of culvert does not provide measureable losses or gains for bacteria.

Results and Discussion

Data were summarized to determine compliance with the water quality standard for Primary Contact Recreation. Boxplots were primarily used in this report for visual reinforcement.

Bowman Creek Mainstem

Annual Summary

Bowman Creek met the water quality criterion for Primary Contact recreation when seasonal data were combined (Table 3 and Figure 3).

Table 3. Bowman Creek mainstem sites identifying whether the water quality criterion was met.

Location ID	Bowman Creek Sample Location Description	Observed FC cfu/100 mL		N	#>200	Criteria Met?
		Geomean	90th %tile			
B0.15	Near mouth upstream of Kersey Way	35	197	16	1	Yes
B1.24	5202 Kersey Way upstream of driveway	23	125	16	1	Yes
B1.44	Upstream of Irene Ave on 53rd St. SE	14	94	16	0	Yes
B2.29	Upstream of intersection of 53rd St. SE and Randall Ave SE	13	102	16	0	Yes
B2.65	1 st St E, downstream side of road in channel	17	135	16	1	Yes

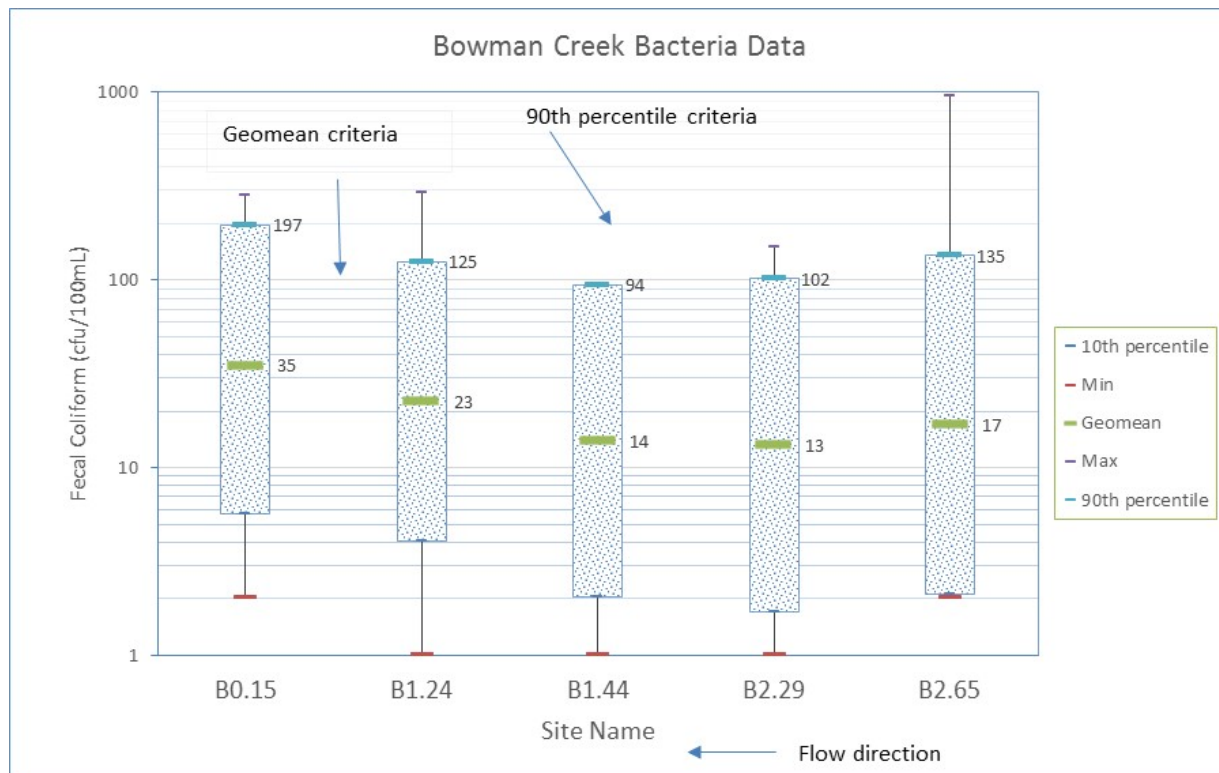


Figure 3. Boxplots depicting the distribution of FC bacteria concentrations in the mainstem.

The lowermost sampling site (B0.15) had both the highest geometric mean (35 cfu/100 mL) and the highest 90th percentile (197 cfu/100mL) compared with all other mainstem sites. However, both parts of the water quality criterion were met (Table 3 and Figure 3).

Wet and Dry Season Summary

Table 4 shows the dry season and wet season summary for the Bowman Creek mainstem. The geometric means for all mainstem sites were 50 cfu/100mL or less during each season. However, excursions of the second part of the water quality criterion were seen on the mainstem during the dry season. One out of eight samples exceeded 200 cfu/100mL at sites B0.15, B1.24 and B2.65.

The excursions for the lower two mainstem sites occurred on July 9, 2013 (Figure 4, blue line). The lower most site, B0.15 had a FC concentration of 285 cfu/100mL. The concentration at the next site upstream, B1.24, was 290 cfu/100mL. The concentrations upstream of site B1.24 on the mainstem were at least half of these downstream sites. The unnamed tributary (BT0.01) and the stormwater from the beehive structure (BTSW0.01) entered the mainstem between sites

B0.15 and B1.24. The unnamed tributary entered the mainstem at approximately 190 cfu/100mL. The water exiting the beehive structure was below detection for FC and the driveway tributary ditch (1) site was dry so neither were a contributing source.

Additionally, the lower site B0.15 had a bacteria concentration of 195 cfu/100ml on July 29, 2013. This time all upstream sites had low concentrations. So it appears on this day something

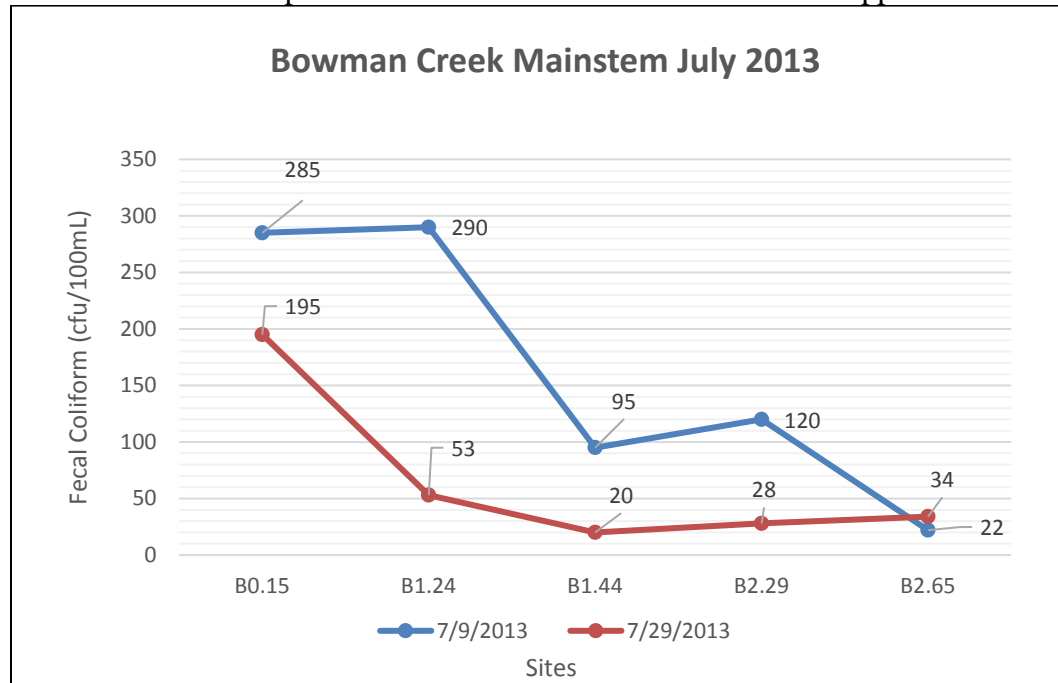


Figure 4. FC concentrations in Bowman Creek mainstem July 2013.

was occurring that impacted between B0.15 and B1.24. The sites upstream of B0.15 on this day were all approximately a quarter or less of the B0.15 concentration (Figure 4).

There were no activities observed during July that would explain these high concentrations.

The uppermost site, B2.65 was the other site that did not meet the criterion during the dry season (Table 4). On August 8, 2012, it had an unusually high FC concentration of 960 cfu/100mL. The rest of the watershed was below 50 cfu/100mL. All protocols were followed and there is no reason to suspect sampler or laboratory contamination. The only other elevated bacteria count at this site (165 cfu/100mL) was seen during the storm event on May 22, 2013 (Figure 5).

TMDL Comparison

A data comparison with the TMDL was not part of the project objectives. However, it is worth mentioning a few things that arise when looking at the data from both studies.

The dry season geometric mean during the TMDL was calculated at 99 cfu/100mL (Mathieu and James, 2011). During July through early September five out of eight FC samples at 10-BOW-0.3

were over 100 cfu/100mL. This included a storm event. The TMDL set the load allocation at 39 cfu/100mL with the 90th percentile at 200 cfu/100mL.

In comparison, the data from 2012/2013 study resulted in a dry season geometric mean of 49 cfu/100mL (Table 4) at B0.15. There was no storm event during 2012/2013 dry season and only July had concentrations over 100 cfu/100mL.

The 2012/2013 dry season geometric mean at 49 cfu/100mL is approaching the TMDL load allocation at 39 cfu/100mL. It was determined that the 90th percentile would not be calculated for sample sizes less than 10. However, I ran the data for this comparison and the 90th percentile obtained was 200 cfu/100mL. A 90th percentile of 200 cfu/100mL was the value set for the load allocation.

Table 4. Dry season and wet season summary for the Bowman Creek mainstem.

Location ID	Location Description	Season	Geomean (cfu/100mL)	N*	#>200	Criteria Met?
B0.15	Near mouth upstream of Kersey Way	dry	49	8	1	No
		wet	24	8	0	Yes
B1.24	5202 Kersey Way upstream of driveway	dry	50	8	1	No
		wet	10	8	0	Yes
B1.44	Upstream of Irene Ave on 53rd St. SE	dry	37	8	0	Yes
		wet	5	8	0	Yes
B2.29	Upstream of intersection of 53rd St. SE and Randall Ave SE	dry	29	8	0	Yes
		wet	6	8	0	Yes
B2.65	1 st St E, downstream side of road in channel	dry	20	8	1	No
		wet	14	8	0	Yes

*The 90th percentile was not calculated for samples sizes less than ten.

Tributaries and Stormwater

Table 5 summarizes the seasonal bacteria concentrations found in waters entering the Bowman Creek mainstem.

Table 5. Wet season summary statistics for stormwater and tributaries entering Bowman Creek.

Site	Location Description	Season	Geomean	N*	#>200	Criteria met?
BSW0.3	Roadside ditch that comes in off Oravetz Rd and flows into Bowman Creek on downstream side of Kersey Way.	wet only	6	7	1	No
BTD10.01	Driveway tributary ditch #1 that enters the left bank of tributary (BT0.01)	wet only	151	6	3	No
BT0.01	Tributary reach that eventually enters creek at about CM0.55.	annual	26	15	1	Yes
		dry	32	7	0	Yes
		wet	22	8	1	No
BTSW0.01	Beehive stormwater structure that eventually discharges into the tributary below BT0.01	annual	13	16	0	Yes
		dry	13	8	0	Yes
		wet	14	8	0	Yes
BD2.29	Roadside ditch that goes under 53rd St SE up near Randall Ave. SE	wet only	15	6	1	No

**The 90th percentile was not calculated for samples sizes less than ten.

The stormwater running off of Oravetz Road (BSW0.3) was sampled from the water flowing off the culvert lip. The water then flows along Kersey Way and into Bowman Creek near the TMDL sampling site 10-Bow0.3. It had an elevated concentration of 440 cfu/100mL in December. This seemed to reflect the first flush off the roadway. Due to this one exceedence the water at the site did not meet the criterion. For the rest of the wet season concentrations were below 10 cfu/100mL except for during the May storm event (Figure 5), when the sample at this site had a bacteria concentration of 13 cfu/100mL.

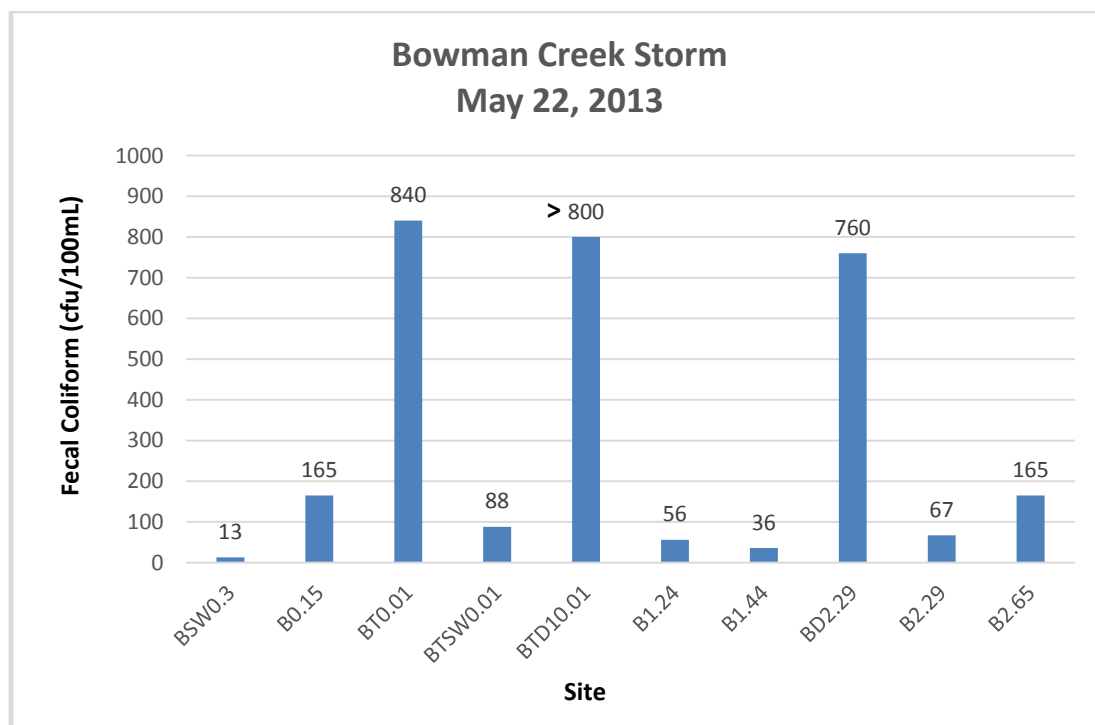


Figure 5. Bowman Creek FC bacteria concentrations at all sites during the May 22, 2013 storm event. Three sites are notably elevated.

There were four sampling locations that were primarily stormwater driven. The water exiting from the beehive structure (BTSW0.01) was the only stormwater sampled that met the criterion in the wet season (Table 5). This stormwater is pretreated by stormwater ponds up the hill on the other side of Kersey Way. The water may also be ground water inflow. The water sampled during the dry season also met the criterion at this location.

The water in the small driveway tributary ditch (1) (BTD10.01) that enters the unnamed tributary (BT0.01) was flowing high enough to be sampled during the wet season. Elevated bacteria concentrations were found with and without rain as a driver. In April there was no rain but concentrations were 2300 cfu/100mL. During the May storm event the FC concentrations at this site were too numerous to count (but reported as >800 cfu/100mL by MEL, Figure 5). During the storm event in January the bacteria concentration was also elevated at 480 cfu/100mL. The geometric mean for this site was 151 cfu/100mL and since three out of the six samples were above 200 cfu/100mL this site failed both parts of the water quality criteria criterion (Table 5). The water sampled at this site was also as low as 6 cfu/100mL in February.

An unnamed tributary (BT0.01) crosses under Kersey Way near the beehive structure. The water from the driveway tributary ditch (1) (BTD10.01), described previously, enters upstream of where this tributary sample was collected. The one notably high concentration (840 cfu/100mL) was reported during the May storm event (Figure 5). This elevated concentration could have been partially due to the extremely high bacteria entering from the driveway tributary ditch (1) during this same storm. This site (BT0.01) failed to meet the second part of the water quality criteria with one out of eight samples being greater than 200 cfu/100mL.

There was a small roadside ditch that enters Bowman Creek at creek mile 2.29 (BD2.29) near the intersection of 53rd and Randall Ave SE. It was only deep enough to sample during the wet season. It failed to meet the water quality criterion due to a high concentration (760 cfu/100mL) during the May storm event (Figure 5). This was the one sample out of six that exceeded 200 cfu/100mL. It was also elevated (180 cfu/100mL) during the January storm event. Most of the samples were below 20 cfu/100 mL with the samples in March and April being non-detectable FC bacteria.

Conclusions

- The Bowman Creek mainstem continues to exceed the Primary Contact Recreation water quality standard in the dry season.
- Wet season stormwater has elevated bacteria concentrations. Bacteria in the stormwater ditches and the unnamed tributary violate the water quality criterion for Primary Contact Recreation during the wet season.
- The sources of bacteria in this study could be due to old and failing, or improperly maintained, on-site septic systems.
- Sources could also be from livestock grazing and ineffective manure management practices. Other domestic animals or wildlife could also be a source.
- The water flowing out of the beehive structure near Kersey Way met the water quality criterion for Primary Contact Recreation.

Recommendations

1. The results from this study support the proposed 2014 303(d) listing for FC bacteria. The data from this study should be reviewed to determine if the listing should be extended upstream.
2. The Bowman Creek basin should be investigated to determine the cause for the high FC bacteria concentrations. The following options should be considered:
 - a. On-site septic system inspections for effective operation and adequate maintenance. Repair of any failing system along the creek is strongly recommended. Specific areas to investigate are prioritized below by sampling site name:

1. BTD10.01. The driveway tributary (1) across Kersey Way from the beehive stormwater structure. This site is about a half mile up the hill on the right side of Kersey Way driving from Oravetz Rd. toward 53rd St SE.
 2. BT0.01. This unnamed tributary comes off the hill and flows in a culvert, under Kersey Way, near the beehive stormwater structure.
 3. Site BD2.29. This is the roadside ditch near the intersection of 53rd St SE and Randall Ave SE.
 - b. No obvious problems were observed with livestock or pet waste management in the watershed. However, it may be warranted to ensure animal grazing and manure management practices are consistent with best management practices i.e. that manure or pet waste isn't getting into the creek or ditches.
3. Consider establishing local educational and public education involvement programs to provide information on the potential causes of bacteria contamination, septic system maintenance, the potential implications of high bacteria in the creek (why it matters), and what they can do to decrease the potential for bacterial contamination.
 4. Refer to the TMDL Implementation Plan (Mathieu and James, 2011) for additional details.

References

APHA, 2005. Standard Methods for the Analysis of Water and Wastewater, 21st Edition. Joint publication of the American Public Health Association, American Water Works Association, and Water Environment Federation. www.standardmethods.org/

Aspect Consulting, LLC. 2010. Water Quantity and Water Quality Analyses for the Lake Tapps Water Rights Application. Project No. 020071A-001-03.
<https://fortress.wa.gov/ecy/wrx/wrx/fsvr/ecylcyfsvrfile/WaterRights/ScanToWRTS/hq4/06709557.pdf>

Brown and Caldwell, 2015. 2016 Comprehensive Sewer Plan (General Sewer Plan); Prepared for the City of Auburn, Washington December 2015.
<http://weblink.auburnwa.gov/External/ElectronicFile.aspx?docid=270919&dbid=0>

Dickes, B, 2012. Quality Assurance Project Plan. Bowman Creek Fecal Coliform Bacteria Characterization Monitoring. Washington State Department of Ecology, Olympia, WA. Publication No.12-10-021.
<https://fortress.wa.gov/ecy/publications/SummaryPages/1210021.html>

Ecology, 2006. WAC 173-201A. Water Quality Standards for Surface Waters in the State of Washington. Washington State Department of Ecology, Olympia, WA.
<https://fortress.wa.gov/ecy/publications/SummaryPages/0610091.html>

Mathieu, N., 2005. Yakima Area Creeks Fecal Coliform TMDL Quarterly Progress Report #3 (July 2005 through September 2005). Environmental Assessment Program, Washington State Department of Ecology. Olympia, WA.

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

Mathieu, N and Cindy James, 2011. Puyallup River Watershed Fecal Coliform Total Maximum Daily Load Water Quality Improvement Report and Implementation Plan. Washington State Department of Ecology, Olympia, WA. Publication No. 11-10-040.
<https://fortress.wa.gov/ecy/publications/SummaryPages/1110040.html>

McDonald, Jana, personal communication, March 23, 2016. Email.

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

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

MEL, 2012. Manchester Environmental Laboratory Quality Assurance Manual. Manchester Environmental Laboratory, Washington State Department of Ecology, Manchester, WA.

Parson, J., et.al. 2012. Standard Operating Procedures to Minimize the Spread of Invasive Species, Version 2.0. Washington State Department of Ecology, Olympia, WA. SOP Number EAP070.

www.ecy.wa.gov/programs/eap/quality.html

Ward, W.J., and Nuri Mathieu, 2011. Standard Operating Procedures for the Collection of Fecal Coliform Bacteria Samples in Surface water, Version 2.1. Washington State Department of Ecology, Olympia, WA. SOP Number EAP030. www.ecy.wa.gov/programs/eap/quality.html

Williams, R. Walter, Richard M. Laramie and James J. Ames, 1975. A Catalog of Washington Streams and Salmon Utilization, Volume 1, Puget Sound Region. Washington Department of Fisheries. Olympia, WA.

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Appendices

Appendix A. Glossary, Acronyms, and Abbreviations

Anthropogenic: Human-caused.

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

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

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

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

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

Surface waters of the state: Lakes, rivers, ponds, streams, inland waters, salt waters, wetlands and all other surface waters and water courses within the jurisdiction of Washington State.

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

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

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

90th percentile: A statistical number obtained from a distribution of a data set. The 90th percentile is used as an equivalent expression to the “no more than 10%” criterion found in the second part of the water quality standard for fecal coliform bacteria. The 90th percentile was calculated as the antilog of the mean of the log-transformed data plus 1.28 times the standard deviation of the log-transformed data.