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State of Washington

Medicine Creek

Water Quality Monitoring for Fecal Coliform Bacteria and Nitrate + Nitrite-Nitrogen

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Medicine Creek
Water Quality Monitoring for Fecal Coliform Bacteria and Nitrate+Nitrite-Nitrogen

by
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Water Quality Program
Washington State Department of Ecology
Olympia, Washington

Fecal Coliform Bacteria
Waterbody ID - 1227259470546
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Abstract

Washington State Department of Ecology (Ecology) conducted a water quality monitoring study in Medicine Creek during the 2007/2008 wet season. Medicine Creek, a tributary to McAllister Creek, is located in Ecology's Water Resource Inventory Area (WRIA) 11 in South Puget Sound, Thurston County. The creek flows into the Nisqually Reach of South Puget Sound, which has active commercial and recreational shellfish harvesting. This investigation was initiated in response to elevated concentrations of fecal coliform (FC) bacteria and nitrate+nitrite-nitrogen (nitrate+nitrite-N) found in Medicine Creek during the Nisqually River Basin Total Maximum Daily Load (TMDL) study (Sargeant, et al, 2005). Water samples were collected during an ebbing low tide and analyzed for FC bacteria and nitrate+nitrite-N. FC bacteria concentrations increased from river mile (RM) 0.3 downstream to RM 0.05 but the state water quality standard for Extraordinary Primary Contact was met at both sites. Nitrate+nitrite-N concentrations also increased between RM 0.3 and RM 0.05. There are no state water quality standards for nitrate+nitrite-N, but nitrate+nitrite-N concentrations in Medicine Creek are elevated in comparison to EPA guidance for this region. Additional FC bacteria sampling to characterize water quality improvements in Medicine Creek's lower reach should focus on sampling during storm events and summer low flow conditions. Sources of nitrate+nitrite-N in should be investigated.

Introduction

Medicine Creek is located in Ecology's Water Resource Inventory Area (WRIA) 11 in Thurston County. Medicine Creek flows about 3.5 miles before its confluence with McAllister Creek, at river mile (RM) 4.4. McAllister Creek then flows into the Nisqually Reach of South Puget Sound, which has active commercial and recreational shellfish harvesting (Figures 1 and 2).

The primary land uses in the Medicine Creek watershed are rural residential and agriculture. The residential area is primarily in the upper watershed transitioning to agriculture for about a mile before discharging to McAllister Creek. The lower reach of the creek has very little canopy cover and is choked with vegetation, especially in the summer. Potential sources for bacterial pollution in the watershed include agricultural activities, such as cattle grazing and vegetable crops, domesticated animals and wildlife. There are septic systems in the watershed, but it is unclear if they are impacting the lower reach of Medicine Creek. There are no state criteria for nitrate+nitrite-N concentrations. However, relative to the United States Environmental Protection Agency (EPA, 2000) guidance nitrate+nitrite-N concentrations in Medicine Creek are elevated due to groundwater inputs (Sargeant et al., 2005). Agricultural fertilizers could be another potential source.

The project goal for Washington Department of Ecology's (Ecology) water quality sampling in Medicine Creek is:

- Characterize the FC bacteria and nitrate+nitrite-N concentrations in the lower reach of the Medicine Creek watershed.

Project objectives for Medicine Creek water quality monitoring are:

- Collect water quality samples to be analyzed for FC bacteria and nitrate+nitrite-N.
- Assess compliance with State Extraordinary Primary Contact Recreational water quality standards for FC bacteria.
- Document current water quality conditions in the lower reach for fecal coliform bacteria and nitrate+nitrite-N that may be contaminating McAllister Creek.

Background

In 1998, McAllister Creek and Nisqually Reach were placed on Ecology's list of impaired water bodies (303(d) list) as a result of elevated FC bacteria concentrations. Under the federal Clean Water Act of 1972, a Total Maximum Daily Load (TMDL) must be performed on water bodies on the 303(d) list (Appendix A). The Nisqually TMDL technical report (Sargeant et al., 2005) identified elevated FC bacteria and nitrate+nitrite-N concentrations in Medicine Creek, a tributary to McAllister Creek. Medicine Creek, as part of the TMDL conducted on McAllister Creek, would be classified as a 4a water body (Appendix A). The 4a classification identifies a water body as impaired but water quality improvements are being implemented based on the TMDL assessment and recommendations.

Medicine Creek must meet the FC bacteria freshwater standard for Extraordinary Primary Contact Recreation (Appendix B). The freshwater FC standard for this classification requires:

> "Fecal coliform organism levels must not exceed a geometric mean value of 50 colonies/100 milliliters (mL), 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 value exceeding 100/colonies mL" (Washington State Department of Ecology, 2006).

Currently, Washington State does not have surface water standards for nitrate+nitrite-N or other nutrients. However, nitrate+nitrite-N concentrations in streams reflect a close association with land use. Nitrate+nitrite-N concentrations can result from runoff from fertilizers, septic systems, livestock manure, and erosion of natural deposits. Monitoring changes in nitrate+nitrite-N may assist in identifying sources of bacteria. High nitrate+nitrite-N-N can have an effect on algae and aquatic plant growth and therefore affect dissolved oxygen concentrations. Characterizing dissolved oxygen was not part of this study.

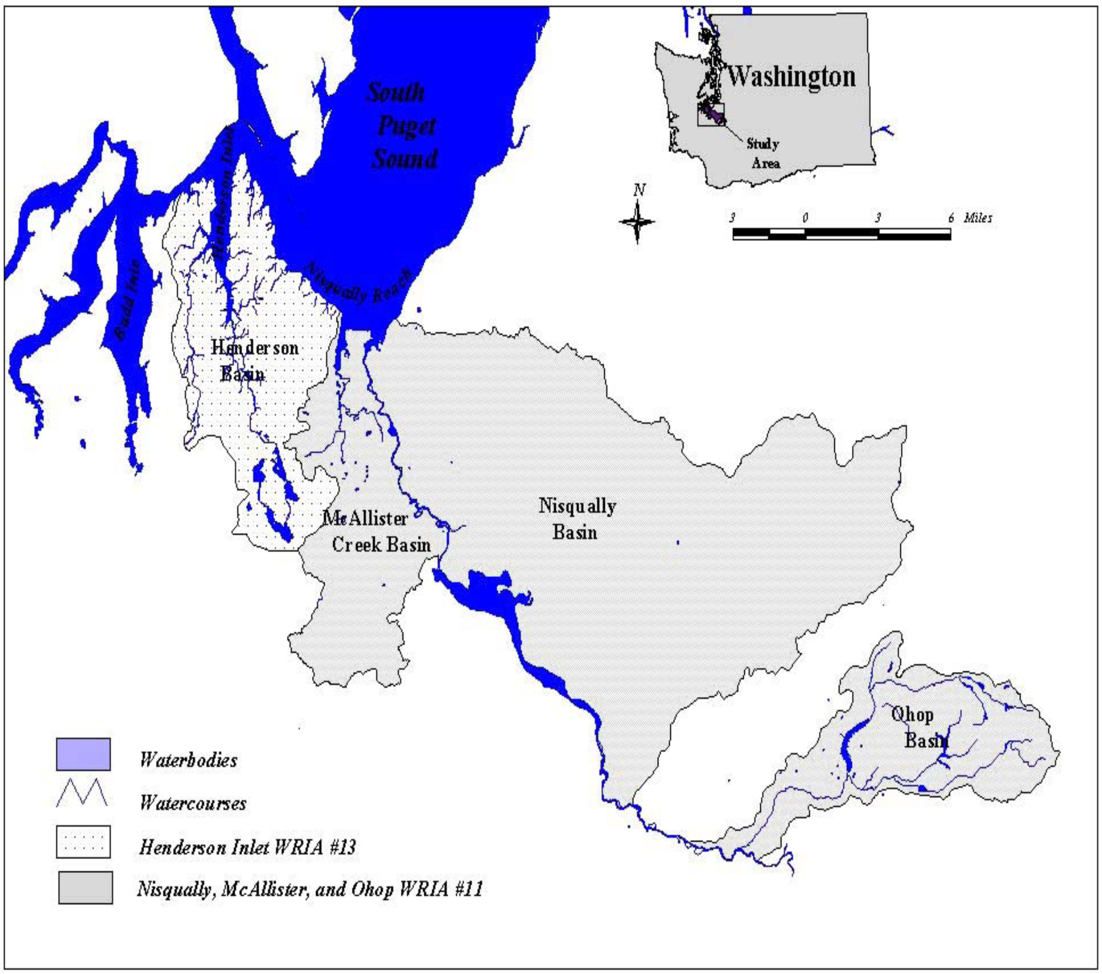

Figure 1. Map of General Study Area *(Includes the McAllister Creek Basin)*

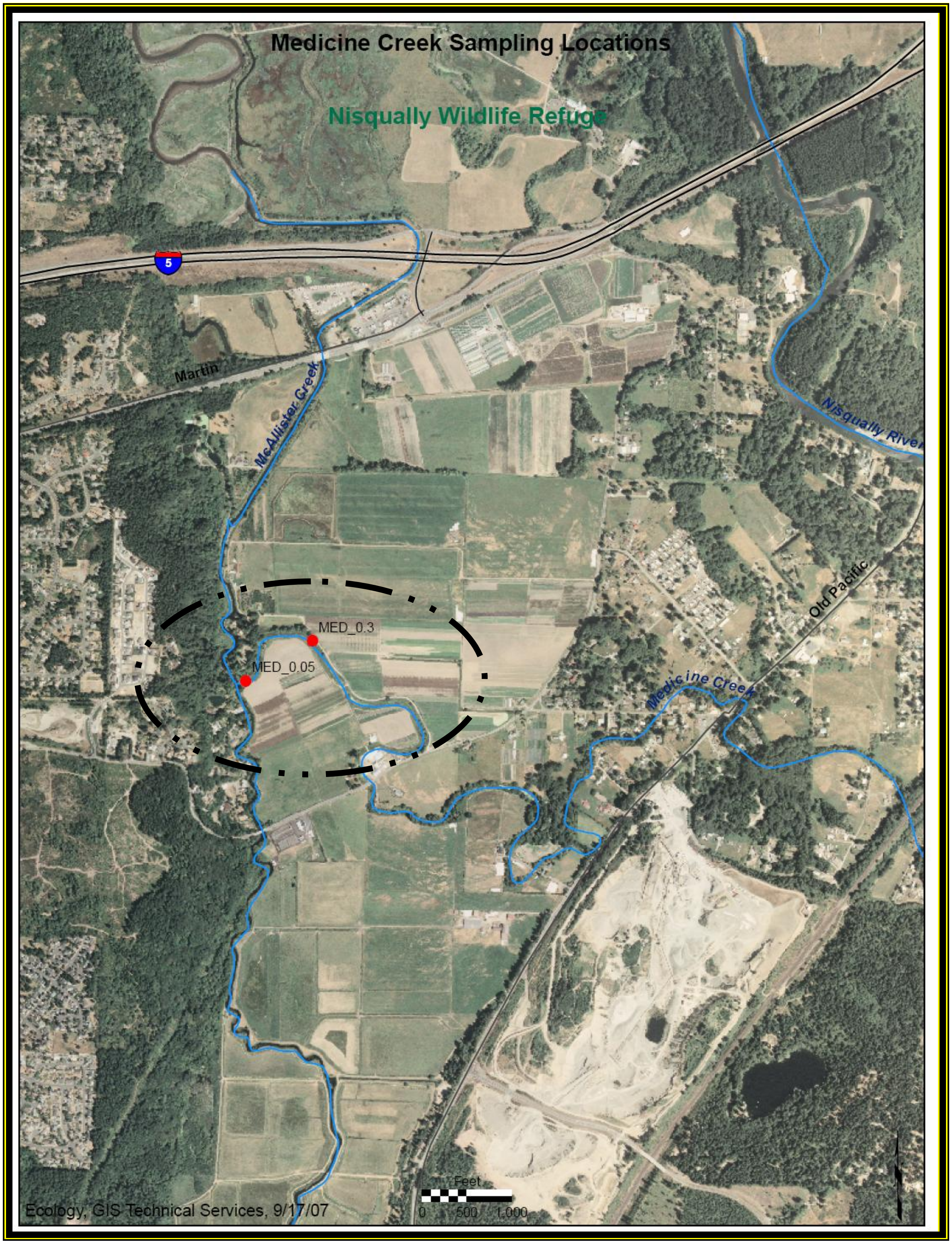

Figure 2. Study Area with the Medicine Creek Sampling Sites Identified

Methods

Twelve sample events were conducted at Medicine Creek from October 8, 2007, through April 7, 2008. Standard sampling methods were used for fecal coliform bacteria (Mathieu, 2007) and for safely collecting nutrients using bottles that have the liquid preservative pre-prepared by the lab (Joy, 2006). Two sites were selected to characterize freshwater conditions in the lower reach of the creek. Site locations are described in Table 1 and mapped in Figure 2. The mouth site, RM 0.05, is tidally influenced; therefore, samples were collected during an ebbing tide. Tidal elevation was determined using information for the DuPont Wharf, Nisqually tide station (Station ID 1093) in lower Puget Sound. Low tide at the mouth of Medicine Creek has a one to two hour lag from the low tide reported at the Nisqually tide station. Conductivity was used to verify freshwater conditions.

The sampling site at river mile (RM) 0.3 (RM 0.3) is the same site used in the Nisqually TMDL (Sargeant et al., 2005). The site located at the mouth (RM 0.05) is as close to the mouth of Medicine Creek as possible, considering safety, and access without a boat. Water flow measurements were not taken at either site due to the deep mud substrate.

Table 1. Site Description and Locations

Site Name	Site Description	Latitude*	Longitude
RM 0.05	Near mouth, right bank, below tide gates	N47° 03” 21.0’	W122° 43" 35.1’
RM 0.3	Mid-channel. Upstream side of road bridge. Just upstream of the wooden culvert.	N47° 03" 16.7’	W122° 43" 21.2’

*obtained using a Garmin 76CSx handheld GPS. WGS84.

The stream sampling locations were mapped using field Global Positioning System (GPS) data. The GPS readings were accurate within 20 feet. Map source data was obtained using Washington Hydrography Framework 1:24,000 scale stream layer, USGS 7.5 minute, and 1:24,000 scale map image. The accuracy of that system is within 40 feet.

Data analysis

Field and laboratory data were compiled and managed using Microsoft Excel® software. The average of field replicate pairs was used in data analyses. Duplicate samples taken in the laboratory were used to provide laboratory quality assurance information; these data were not used in analyses.

Quality assurance (QA)

Field and laboratory QA data for fecal coliform and nitrate+nitrite-N data are available for review in Appendix C.

The laboratory’s data quality objectives and quality control procedures are documented in the Manchester Environmental Laboratory Users Manual (MEL, 2005) and the MEL Quality Assurance Manual (MEL, 2006).

Laboratory QA

Laboratory duplicates for FC bacteria are analyzed in the laboratory by taking a sub-sample of a field sample. The sub-samples are analyzed to determine variability within the laboratory procedures. One laboratory duplicate exceeded the quality assurance limits of 40 percent relative percent difference (RPD):

- On April 7, 2008, at site RM 0.05, the field replicate FC sample was 18 cfu/100 mL and the laboratory duplicate was 10 cfu/100 mL. The relative percent difference was outside the laboratory quality objectives of 40 percent. The laboratory qualified both data points with a "J" categorizing the values as estimates. The RPD is artificially high as a result of being close to the detection limit. The author accepted the value of 18 cfu/100 mL and used it when analyzing data.

Laboratory duplicates for nitrate+nitrite-N were all within acceptable limits as were the methods blanks, matrix spikes, and laboratory control samples.

Field data QA

Field replicates are two samples taken at the same location and as close as possible in time and space. Data from these samples represents total variability, that is, the sum of variability from both field and laboratory methods. Replicates were taken at each site for both parameters when possible (Appendix C).

The data quality objective for FC field replicate samples was to have 50 percent of the replicates below a 20 percent relative standard deviation (RSD) and 90 percent of the samples below a RSD of 50 percent (Mathieu, 2006). The field replicate pairs met both quality assurance criteria; all were below 50 percent RSD.

The quality objectives for nitrate+nitrite-N were for the RSD to be at or below 10 percent. All but two replicates met this criterion.

- On October 8, 2007, the nitrate+nitrite-N results for RM 0.3 were 0.010 and 0.012 with an RSD of 13. These values are close to detection creating an artificially elevated RSD. The values were averaged and the result used in the analyses.
- On October 22, 2007, the nitrate+nitrite-N results for RM 0.3 were 0.065 and 0.096 with an RSD of 27. The replicate results are most likely higher due to the suspension of algae that came off plants after the first sample was taken. The values were averaged and the result used in the analyses.

Sampling, on November 19, 2007, was initiated too late in the tidal cycle to get freshwater samples. Therefore, samples were not taken at RM 0.05. The upper site, RM 0.3 was not affected by the tide, but there were no nitrate+nitrite-N sample bottles available to take samples. FC samples were taken, but due to incomplete information, the results were not included in data analyses; the FC data can be reviewed in Appendix C.

Conductivity was used as a surrogate for salinity to verify freshwater samples were being collected. The meter was calibrated but strict quality assurance methods were not followed. The conductivity data are not provided in this report.

Sample collection and transport met specifications in the Quality Assurance Project Plan (Dickes, B., 2007), including chain of custody expectations, the 24-hour analytical holding time for bacteria and 48-hour holding time for nitrate+nitrite-N.

Results and Discussion

Field and laboratory data are provided in Appendix C. Graphical presentations of summary data are provided in Figure 3 and Figure 4. Precipitation for the study period is provided in Appendix D. Appendix E offers preliminary comparison with the 2003 TMDL data.

Fecal Coliform Bacteria

The lower reach of Medicine Creek, from RM 0.3 to RM 0.05, met FC water quality standards for Extraordinary Primary Contact Recreation during the study period. The upstream site, RM 0.3 had a geometric mean of 3 cfu/100 mL (n=11) with the downstream site (RM 0.05) increasing to a geometric mean of 16 cfu/100 mL (n=11). All sample results were below 100 cfu/100mL.

The higher FC concentrations seen on at RM 0.05 on November 5, 2007, and February 25, 2008, do not appear to be a response to precipitation (Figure 3, Appendix D). However, the high FC concentrations on February 25, 2008 and March 10, 2008 may be in response to the precipitation that fell in the previous 12 hours.

On April 7, 2008, the sampling event occurred during a storm event (0.45 inches in 24 hours, Appendix D). Though concentrations did increase from 5 cfu/100 mL (March 24, 2008) to 19 cfu/100 mL (April 7, 2008) at the lower site, these concentrations are not of concern. The lower reach did not appear to respond to the rain event with an increase in FC concentrations (Figure 3).

There are no obvious septic systems in the sampling reach area; but, there was a Sanican on the left bank immediately below RM 0.3.

The critical season for the McAllister Creek basin is during rain events. Since precipitation was low during the study period it is difficult to determine if FC concentrations are low due to low rainfall or improved land management.

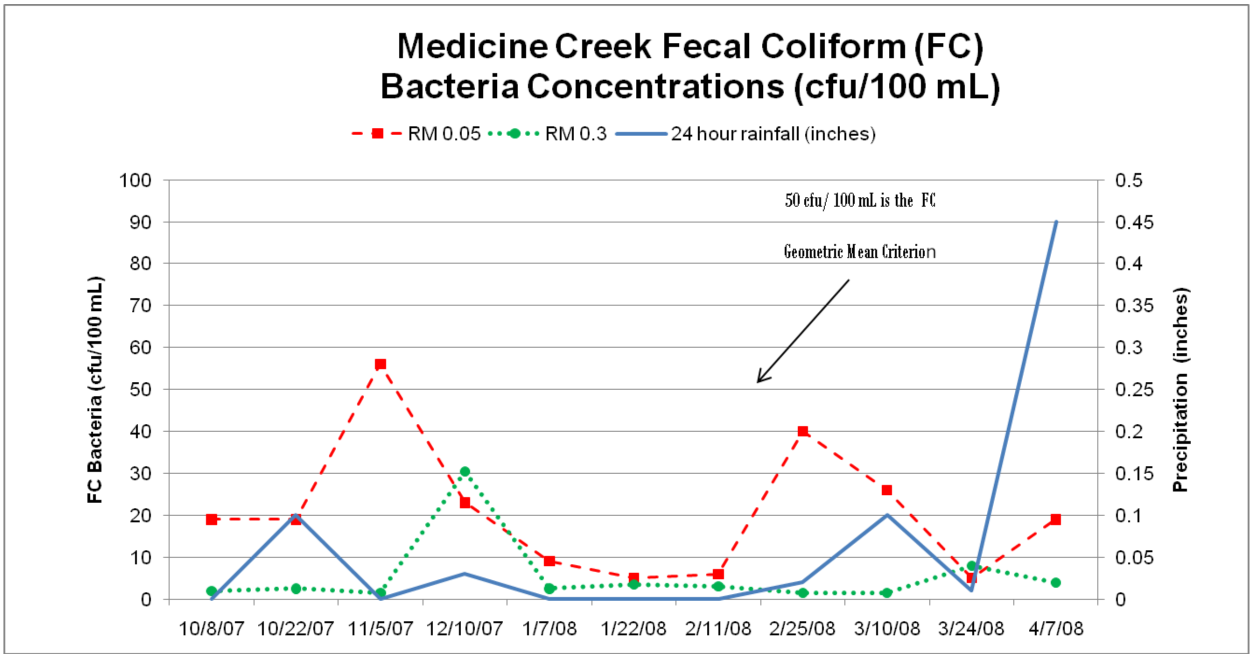

Figure 3. Medicine Creek Fecal Coliform Bacteria.
FC concentrations must not exceed a geometric mean of 50 cfu/100 mL and not more than 10 percent of samples exceed 100 cfu/100mL.

Nitrate+Nitrite-N

There are no state water quality standards for nitrate+nitrite-N. However, the EPA nutrient guidance used by Sargeant (Sargeant et al., 2005) are as follows:

- Total nitrogen (TN) concentrations are recommended to be 0.24 mg/L or less and
- Nitrate+nitrite-N concentrations are recommended to be 0.08 mg/L or less.

As can be seen in Figure 4 and Appendix C the nitrate+nitrite-N levels in Medicine Creek are much higher than the recommended guidance for nitrate+nitrite-N and for the total nitrogen component. The mean nitrate+nitrite-N concentration at RM 0.3 was 0.5 mg/L, and the mean nitrate+nitrite-N concentration at RM 0.05 increased to 1.5 mg/L. In a very short distance there is a mean increase of 1 mg/L nitrate+nitrite-N in the lower reach of Medicine Creek. The highest increase from upstream to downstream occurred on January 7, 2008 where there was a 2.2 mg/L increase. It has been determined that at least part of this increase is due to groudwater inflow (Sargeant et al., 2005), but intense agriculture and other land uses may also affect concentrations. There are no obvious septic systems in the sampling reach area; but, there was a Sanican on the left bank immediately below RM0.3.

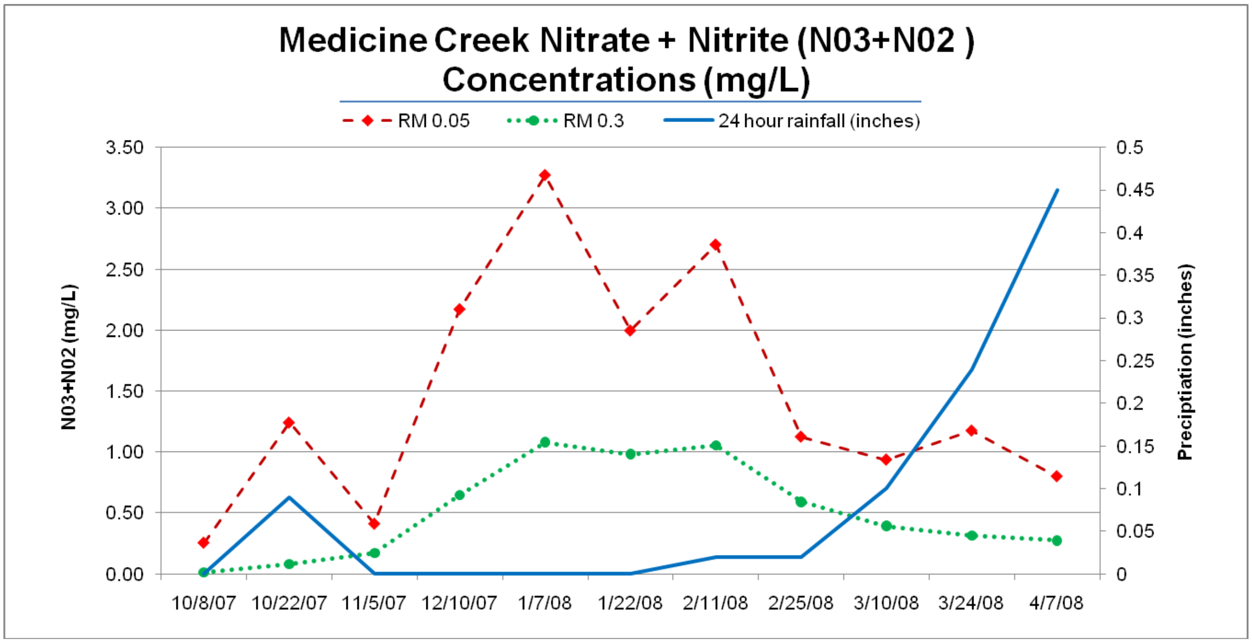

Figure 4. Medicine Creek Nitrate+Nitrite-N Concentrations

Comparison with the 2003 TMDL data

This 2007/2008 study was designed to characterize the current water quality in Medicine Creek and not to determine the effectiveness of the TMDL implementation efforts. However, a brief comparison is provided here in Appendix E. There are only 4 data points from the 2003 TMDL that can be compared to this 2007/2008 study. Due to the low sample size (four months for comparable sample data), the results of the FC comparison are inconclusive. The nitrate+nitrite-N data were not reviewed since there was only one data point for comparison between the years.

Conclusions

- The lower reach of Medicine Creek, from RM 0.3 to RM 0.05, met FC water quality standards for Extraordinary Primary Contact Recreation during the study period from October 8, 2007 to April 7, 2008. This may be due to improvements in waste management activities in the watershed or low precipitation and runoff during the study period; this study was not designed to make this determination.

- The FC concentrations generally did increase from upstream to downstream. However, concentrations did not consistently respond to rainfall or storm events. The previous 12-hour rain may affect water quality conditions more than 24-hour rain.

- The critical season for the McAllister Creek basin is during rain events. Since precipitation was low during the study period it is difficult to determine if low FC concentrations are due to low rainfall or improved land management.

- Nitrate+nitrite-N concentrations are elevated in Medicine Creek. Mean concentrations increased 1 mg/ L from upstream to downstream. Possible contributors to nitrate+nitrite-N in surface water may be from groundwater or agricultural fertilizers.

- There appears to be an inverse response to concentrations of FC and nitrate+nitrite-N. If groundwater is the primary source of nitrates, then the groundwater may be diluting bacteria concentrations as it contributes nitrate+nitrite-N.

Recommendations

- Target storm events if additional wet season monitoring is considered for FC bacteria.

- Monitor FC bacteria concentrations during the summer months to characterize conditions during low flow and active agriculture.

- Investigate sources of nitrate+nitrite-N in the lower reach of Medicine Creek. For example, investigate whether fertilizer with nitrate+nitrite-N is being applied at agronomic rates to adjacent agricultural fields and verify whether there are septic systems that could be contributing nitrate+nitrite-N to this reach of the creek.

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Appendix A
Federal Clean Water Act Requirements
Water Quality Assessment

The Clean Water Act established a process to identify and clean up polluted waters. Under the Clean Water Act, each state is required to have its own water quality standards designed to protect, restore, and preserve water quality. Water quality standards consist of designated uses for protection, such as cold water biota and drinking water supply, as well as criteria, usually numeric criteria, to achieve those uses.

Every two years, states are required to prepare a list of waterbodies – lakes, rivers, streams, or marine waters – that do not meet water quality standards. This list is called the 303(d) list. To develop the list, Ecology compiles its own water quality data along with data submitted by local, state, and federal governments, tribes, industries, and citizen monitoring groups. All data are reviewed to ensure that they were collected using appropriate scientific methods before the data are used to develop the 303(d) list. The 303(d) list is part of the larger Water Quality Assessment.

The Water Quality Assessment is a list that tells a more complete story about the condition of Washington's water. This list divides waterbodies into one of five categories:

Category 1 – Meets standards for parameter(s) for which it has been tested.

Category 2 – Waters of concern.

Category 3 – Waters with no data available.

Category 4 – Polluted waters that do not require a TMDL because:

- 4a. – Has a TMDL approved and it's being implemented
- 4b. – Has a pollution control plan in place that should solve the problem
- 4c. – Is impaired by a non-pollutant such as low water flow, dams, culverts.

Category 5 – Polluted waters that make up the 303(d) list and require a TMDL.

TMDL process overview

The Clean Water Act requires that a Total Maximum Daily Load be developed for each of the waterbodies on the 303(d) list. A TMDL identifies how much pollution needs to be reduced or eliminated and still meet Washington State's Water Quality Standards, Chapter 173-201A of the Washington Administrative Code. Then Ecology works with the local community to develop (1) a strategy to control the pollution and (2) a monitoring plan to assess effectiveness of the water quality improvement activities.

Elements required in a TMDL

The goal of a TMDL is to ensure the impaired water will attain water quality standards. A TMDL includes a written, quantitative assessment of water quality problems and of the pollutant sources that cause the problem. The TMDL determines the amount of a given pollutant that can be discharged to the water body and still meet standards (the loading capacity) and allocates that load among the various sources.

If the pollutant comes from a discrete (point) source such as a municipal or industrial facility's discharge pipe, that facility's share of the loading capacity is called a *wasteload allocation*. If the pollutant comes from a set of diffuse (nonpoint) source such as general urban, residential, or farm run-off, the cumulative share is called a *load allocation*.

The TMDL must also consider seasonal variations and include a margin of safety that takes into account any lack of knowledge about the causes of the water quality problem or its loading capacity. A reserve capacity for future loads from growth pressures is sometimes included as well. The sum of the wasteload and load allocations, the margin of safety, and any reserve capacity must be equal to or less than the loading capacity.

TMDL = Loading Capacity = sum of all wasteload allocations + sum of all load allocations + margin of safety.

Total Maximum Daily Load analyses: Loading capacity

Identification of the contaminant loading capacity for a water body is an important step in developing a TMDL. The Environmental Protection Agency (EPA) defines the loading capacity as "the greatest amount of loading that a water body can receive without violating water quality standards" (EPA, 2001). The loading capacity provides a reference for calculating the amount of pollution reduction needed to bring a water body into compliance with standards. The portion of the receiving water's loading capacity assigned to a particular source is a load or wasteload allocation. By definition, a TMDL is the sum of the allocations, which must not exceed the loading capacity.

Appendix B
Water Quality Criteria for Fecal Coliform Bacteria

Table B1. Water Contact Recreation Bacteria Criteria in Freshwater

Water Contact Recreation Bacteria Criteria in Freshwater	
Category	Bacteria Indicator
Extraordinary Primary Contact Recreation	Fecal coliform organism levels must not exceed a geometric mean value of 50 colonies/100 mL, with not more than 10 percent of all samples (or any single sample when less than 10 sample points exist) obtained for calculating the geometric mean value exceeding 100 colonies/100 mL.
Primary Contact Recreation	Fecal coliform organism levels must not exceed a geometric mean value of 100 colonies /100 mL, with not more than 10 percent of all samples (or any single sample when less than 10 sample points exist) obtained for Calculating the geometric mean value exceeding 200 colonies /100 mL.
Secondary Contact Recreation	Fecal coliform organism levels must not exceed a geometric mean value of 200 colonies/100 mL, with not more than 10 percent of all samples (or any single sample when less than 10 sample points exist) obtained for calculating the geometric mean value exceeding 400 colonies /100 mL.

Bacteria, fresh waters

Bacteria criteria are set to protect people who work and play in and on the water from waterborne illnesses. In the Washington State water quality standards, fecal coliform is used as an "indicator bacteria" for the state's freshwaters (e.g., lakes and streams). Fecal coliform in water "indicates" the presence of waste from humans and other warm-blooded animals. Waste from warm-blooded animals is more likely to contain pathogens that will cause illness in humans than waste from cold-blooded animals. The fecal coliform criteria are set at levels that have been shown to maintain low rates of serious intestinal illness (gastroenteritis) in people.

Use categories

There are three use categories related to the freshwater bacteria criteria in Washington:

(1) The *Extraordinary Primary Contact* use is intended for waters capable of "providing extraordinary protection against waterborne disease or that serve as tributaries to extraordinary quality shellfish harvesting areas." To protect this use category: Fecal coliform organism levels must not exceed a geometric mean value of 50 colonies/100 mL, with not more than 10 percent of all samples (or any single sample when less than 10 sample points exist) obtained for calculating the geometric mean value exceeding 100/colonies mL" [WAC 173-201A-200(2)(b), 2003 edition].

(2) The *Primary Contact* use is intended for waters "where a person would have direct contact with water to the point of complete submergence including, but not limited to, skin diving, swimming, and waterskiing." More to the point, however, the use is to be designated to any waters where human exposure is likely to include exposure of the eyes, ears, nose, and throat. Since children are also the most sensitive group for many of the waterborne pathogens of concern, even shallow waters may warrant primary contact protection. To protect this use category: "Fecal coliform organism levels must not exceed a geometric mean value of 100 colonies/100 mL, with not more than 10 percent of all samples (or any single sample when less than 10 sample points exist) obtained for calculating the geometric mean value exceeding 200/colonies mL" [WAC 173-201A-200(2)(b), 2003 edition].

(3**)** The *Secondary Contact* use is intended for waters "where a person's water contact would be limited (e.g., wading or fishing) to the extent that bacterial infections of the eyes, ears, respiratory or digestive systems, or urogenital areas would be normally avoided." To protect this use category: "Fecal coliform organism levels must not exceed a geometric mean value of 200 colonies/100 mL, with not more than 10 percent of all samples (or any single sample when less than 10 sample points exist) obtained for calculating the geometric mean value exceeding 400/colonies mL" [WAC 173-201A-200(2)(b), 2003 edition].

Compliance is based on meeting both the geometric mean criterion and the 10% of samples (or single sample if less than 10 total samples) limit. These two measures used in combination ensure that bacterial pollution in a water body will be maintained at levels that will not cause a greater risk to human health than intended. While some discretion exists for selecting sample averaging periods, compliance will be evaluated for both monthly (if five or more samples exist) and seasonal (summer versus winter) data sets.

Appendix C
Field and Laboratory Data

Table C-1. Laboratory and field data for fecal coliform (FC) bacteria samples collected in Medicine Creek watershed. *Fields with an "x" represent no data collected.*

Site Name (River Mile)	Sample Date	Sample Time	FC Bacteria Result (cfu/100 mL)		FC Lab Duplicate (cfu/ 100 mL)		FC Field Replicate (cfu/ 100 mL)		FC Lab Duplicate (cfu/ 100 mL)	
RM 0.05	10/8/07	1135	24		x		14		x	
	10/22/07	1111	22		x		15		x	
	11/5/07	1100	45		x		66		x	
	11/19/07 *	x	x		x		x		x	
	12/10/07	1425	19		x		26		22	
	1/7/08	1336	9		7		9		x	
	1/22/08	1257	6		4		4		x	
	2/11/08	1545	3		x		9		5	
	2/25/08	1557	41		x		39		x	
	3/10/08	1459	24		x		28		32	
	3/24/08	1455	6		x		4		x	
	4/7/08	1455	19		x		18	J	10	J
RM 0.3	10/8/07	1145	2		3		2		x	
	10/22/07	1125	1	U	x		4		2	
	11/5/07	1110	1	U	x		2		1	U
	11/19/07	1055	5		3		7		x	
	12/10/07	1440	30		x		31		x	
	1/7/08	1350	4		x		1		x	
	1/22/08	1310	3		x		4		x	
	2/11/08	1532	2		x		4		x	
	2/25/08	1545	2		1	U	1	U	x	
	3/10/08	1448	2		x		1	U	x	
	3/24/08	1444	8		x		8		12	
	4/7/08	1431	4		x		4		x	

*tide too high to access

J - Organism positively identified, but didn't meet laboratory QA objective.

U - Organism not detected at or above the reported result.

Table C-2. Laboratory and field data for nitrate+nitrite-N (NO2+NO3) samples collected in Medicine Creek watershed. Data values as reported by the laboratory. *Fields with an "x" represent no data collected.*

Site Name (River Mile)	Sample Date	Sample Time	NO2+NO3 (mg/L) Result		NO2+NO3 (mg/L) Lab Duplicate		NO2+NO3 (mg/L) Field Replicate	NO2+NO3 (mg/L) Lab Duplicate
MED 0.05	10/8/07	1135	0.255		x		x	x
	10/22/07	1111	1.24		x		1.25	x
	11/5/07	1100	0.41		x		0.412	x
	11/19/07*	x	x		x		x	x
	12/10/07	1425	2.08		x		2.26	x
	1/7/08	1336	3.29		x		3.25	x
	1/22/08	1257	1.99		x		2	1.99
	2/11/08	1545	2.83		x		2.57	x
	2/25/08	1557	1.09		x		1.16	x
	3/10/08	1459	0.942		x		0.932	x
	3/24/08	1455	1.17		x		1.18	x
	4/7/08	1455	0.754		x		0.847	x
MED 0.3	10/8/07	1145	0.010	U	0.01	U	0.012	x
	10/22/07	1125	0.065		0.063		0.096	
	11/5/07	1110	0.169		0.169		0.17	x
	11/19/07*	x	x		x		x	x
	12/10/07	1440	0.642		0.646		0.648	x
	1/7/08	1350	1.08		1.05		1.08	x
	1/22/08	1310	0.98		x		0.983	x
	2/11/08	1532	1.05		1.05		1.06	x
	2/25/08	1545	0.591		0.592		0.591	x
	3/10/08	1448	0.396		x		0.389	0.391
	3/24/08	1444	0.315		0.317		0.313	x
	4/7/08	1431	0.275		x		0.274	x

*no nitrate bottles available

U - Organism not detected at or above the reported result.

Appendix D
Precipitation

Table D-1. Rainfall for Medicine Creek for the 12 and 24-hour periods prior to sampling time at RM 0.05. *The storm event criterion was at least 0.2 inches of rain fall in the previous 24 hours. National Weather Service data are for the Olympia Airport.*

Sampling Date	Sampling Time	12 hour rainfall (inches)	24 hour rainfall (inches)
10/8/2007	1135	0	0
10/22/07	1111	0.01	0.1
11/5/07	1100	0	0
11/19/07	1055	0.03	0.03
12/10/07	1425	0	0
1/7/08	1336	0	0
1/22/08	1257	0	0
2/11/08	1545	0	0
2/25/08	1557	0.02	0.02
3/10/08	1459	0.09	0.1
3/24/08	1455	0	0.01
4/7/08	1455	0.36	0.45

Sampling Date	Sampling Time	12 hour rainfall (inches)	24 hour rainfall (inches)
10/8/2007	1135	0	0
10/22/07	1111	0.01	0.1
11/5/07	1100	0	0
11/19/07	1055	0.03	0.03
12/10/07	1425	0	0
1/7/08	1336	0	0
1/22/08	1257	0	0
2/11/08	1545	0	0
2/25/08	1557	0.02	0.02
3/10/08	1459	0.09	0.1
3/24/08	1455	0	0.01
4/7/08	1455	0.36	0.45

Appendix E
Preliminary comparison
With TMDL data

The sample size is too small for comparing the years with statistical confidence.

Fecal Coliform Bacteria (cfu/100 mL) in Medicine Creek						
Month	Downstream Site			Upstream Site	
	2003	**2008**		*2003*	**2008**
Feb	*15*	23*		*2*	3
March	*53*	26		*1*	2
March	*36*	5		*10*	8
April	*31*	19		*16*	4
Geometric mean	*31*	14		*4*	4
Estimated 90th percentile	*48*	25		*14*	7

* an average of two samples taken in February 2008