Gibbons Creek Fecal Coliform Post-TMDL Water Quality Monitoring Report

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Gibbons Creek
Fecal Coliform
Post-TMDL Water Quality
Monitoring Report

by

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

WRIA
- 28

HUC number
- 17080001

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Abstract

In 2011, the Washington State Department of Ecology (Ecology) monitored fecal coliform (FC) bacteria levels in the Gibbons Creek watershed to determine whether FC levels were in compliance with water quality standards. Past water quality sampling conducted by volunteers and Clark County, the City of Washougal, and Ecology staff documented high FC concentrations within and around the Gibbons Creek watershed.

Reductions in FC concentrations (improved water quality) were observed at all monitoring stations in the watershed. These reductions were found to be statistically significant at monitoring stations GC1 (Gibbons Creek) and GC2 (Campen Creek). In addition, the summer and winter geometric means were reduced by 72% and 78%, respectively, at GC1 compared to total maximum daily load (TMDL) target limits. Despite these improvements, Gibbons and Campen Creeks continue to exceed (not meet) one or both of the water quality criteria for FC, although substantial progress has been made.

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Background

In 1996, the Washington State Department of Ecology (Ecology) conducted a total maximum daily load (TMDL) assessment for the Gibbons Creek watershed located in Clark County. The federal Clean Water Act, section 303(d) specifies that waterbodies be listed where state water quality standards are not met and that a TMDL be developed. TMDLs define the pollution loading limits required to meet water quality standards throughout the watershed.

Gibbons Creek and its tributary, Campen Creek, are currently on the 303(d) list as not meeting Washington's State water quality standards for fecal coliform (FC) bacteria. In 1996, Ecology's Environmental Assessment Program conducted a TMDL assessment for the Gibbons Creek watershed (Nocon and Erickson, 1996). The TMDL assessment determined that since no permitted discharges (point sources) exist in the Gibbons Creek watershed, elevated FC can only be attributed to nonpoint sources. Potential sources of nonpoint FC in the watershed were identified to be animal waste from small farms and failing septic systems.

The TMDL assessment recommended a phased approach in which load allocations are defined, control measures are implemented, and the basin continues to be monitored to assess the effectiveness of nonpoint source control (Nocon and Erickson, 1996). If water quality targets are not met, additional nonpoint management techniques must be implemented.

In 2000, the Gibbons Creek TMDL was developed, and recommendations were included in the *Gibbons Creek Watershed Fecal Coliform Total Maximum Daily Load Submittal Report* (Post, 2000). This TMDL package was submitted to and approved by the U.S. Environmental Protection Agency (EPA) in 2000.

In 2004, Ecology initiated a collaborative effort with the City of Washougal, and Clark County to implement a long-term FC monitoring strategy in the Gibbons Creek watershed. In 2005, a Detailed Implementation Plan (DIP), developed by Ecology's Water Quality Program, outlined a three-part monitoring plan for the Gibbons Creek watershed (Post, 2005). The plan also identified the types of activities and parties responsible for implementing the activities to achieve pollution reduction targets. All elements of the DIP were expected to be completed by 2010.

In 2011, as part of the phased approach, Ecology conducted a FC monitoring study in the Gibbons Creek watershed (Onwumere and Collyard, 2011). This report summarizes the results of that study and makes recommendations for additional actions.

Study Area

Gibbons Creek and its tributaries are located in eastern Clark County, and Gibbons Creek flows into the Columbia River just east of the City of Washougal (Figure 1). In the upper watershed, the creek and its tributaries flow through relatively steep, incised valleys as the water travels down the northern slope of the Columbia River Gorge. The gradient decreases considerably as the creek reaches the valley floor, near Washington State Highway 14 and the Columbia River.

Land use in the watershed consists largely of rural residential development and small farms along the slopes of the Columbia River. Many of the residents keep a small number of horses or cattle or both. The eastern portion of the City of Washougal extends into the western portion of the watershed and includes a school, a golf course, commercial operations, and new and existing residential development serviced by the local wastewater treatment plant (Figure 1). The remainder of the watershed lies in unincorporated Clark County where residential households use on-site septic systems.

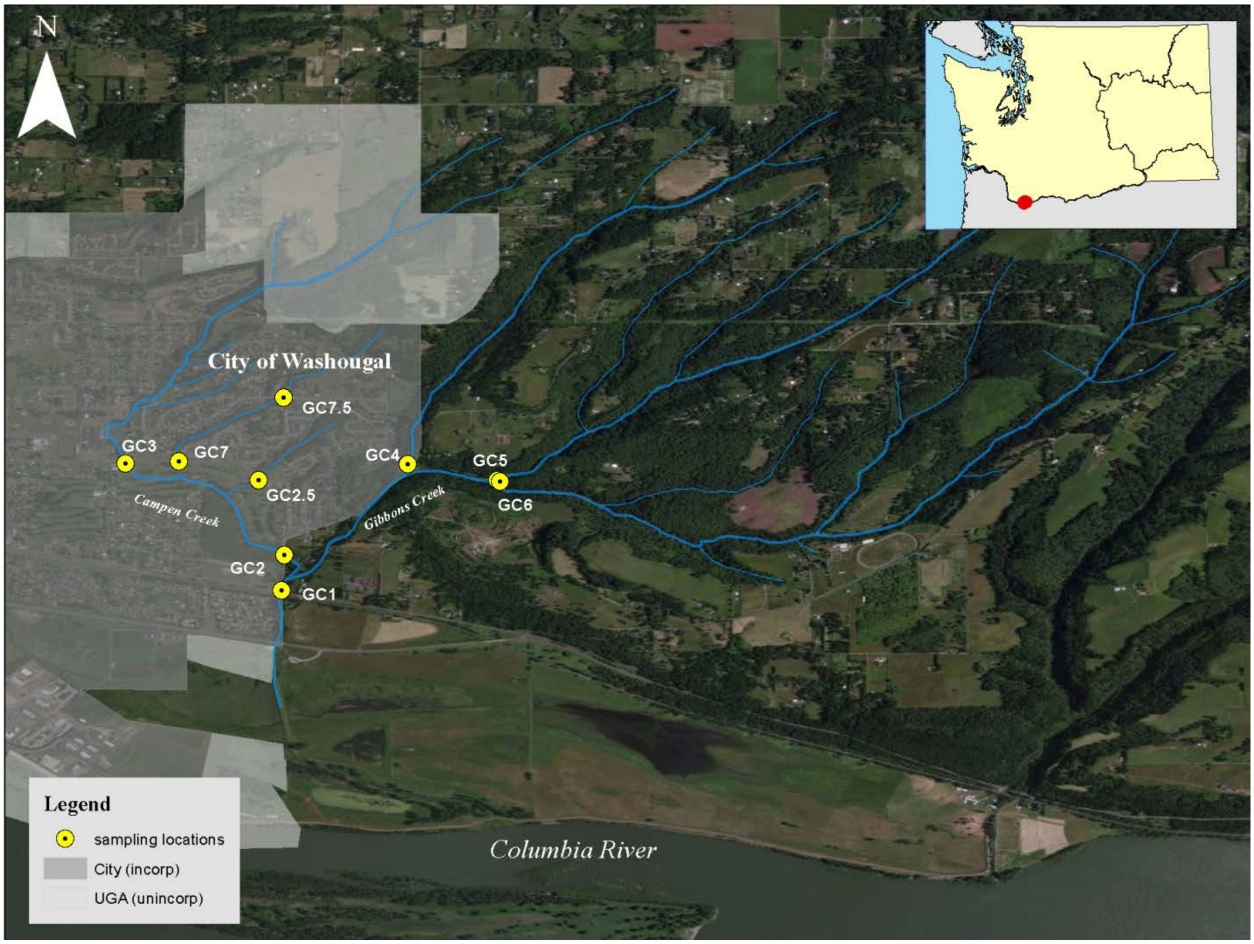

Figure 1. Map of the Gibbons Creek watershed and sampling locations for FC.
UGA: Urban Growth Area

Pollutants Addressed by This Study

Although previous studies indicate water quality problems for temperature and turbidity (Nocan and Erickson, 1996), the Gibbons Creek watershed is currently only listed for FC bacteria. Listed segments, water quality categories, and a link to listing descriptions for the Gibbons Creek watershed are presented in Table 1.

Table 1. Gibbons Creek watershed 2012 303(d) list for FC bacteria.

Water Body	Station ID	Parameter	Category[1]	Listing ID Link
Gibbon Creek	GC1	Bacteria	4A	42635
Campen Creek	GC2	Bacteria	4A	42529

[1] Polluted waters that do not require a TMDL because there is an approved TMDL.
See Appendix A for a full description of all 303(d) listing categories.

Applicable Surface Water Quality Standards

The Washington State surface water quality standards include designated beneficial uses, water body classifications, and numeric and narrative water quality criteria for surface waters of the state. This section provides Washington State water quality information and those standards applicable to the Gibbons Creek watershed.

The FC criteria have two statistical components: a geometric mean and an upper limit value that 10% of the samples cannot exceed (Table 2). Bacteria criteria are set to protect people who work and play in and on the water from waterborne illnesses. In Washington State, Ecology's water quality standards use fecal coliform 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 are shown to maintain low rates of serious intestinal illness (gastroenteritis) in people.

The 303(d) listed segments within the Gibbons Creek watershed have a designated beneficial use of *Primary Contact. Primary Contact* criteria are 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. *Primary Contact* use is designated to any waters where human exposure is likely to include exposure of the eyes, ears, nose, and throat [ECOLOGY, 2011-200(2)(b)]. (Ecology, 2011) The applicable water quality standard is presented in Table 2.

Table 2. Washington State water quality standard for FC in the Gibbons Creek watershed.

Parameter	2011 Classification	2011 Criteria[1]
Fecal Coliform	Primary Contact Recreation	*"Must not exceed a geometric mean value of 100 colonies/100 mL, with not more than 10% of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 200/colonies mL"*

[1] ECOLOGY, 2011-200(2)(b) (Ecology, 2011).

Load Allocations

The 1996 Gibbons Creek FC TMDL assessment recommended a phased approach for the Gibbons Creek TMDL (Nocon and Erickson, 1996). With a phased approach, after load allocations (LAs) are defined and pollution control measures are implemented, monitoring is periodically conducted throughout the basin to assess effectiveness of nonpoint management controls. Use of a phased TMDL approach allows reconsideration of water quality management goals after evaluating the effectiveness of LAs.

Based on data pooled from Ecology's Ambient River and Stream Water Quality Monitoring Program and the 1996 TMDL study, seasonal LAs were set for the mainstem Gibbons Creek at station GC1. Because there was insufficient data to determine seasonal LAs for Campen Creek at the time of the TMDL assessment, year-round LAs were set for GC2 (Table 3). LAs for both stations were simply set to match the geometric mean standards for FC (Nocon and Erickson, 1996).

When sufficient data exist, Washington State surface water quality standards require that FC data be divided into seasons so that high FC values are not masked over time (Ecology, 2011). Nocon and Erickson (1996) identified two distinctly different seasonal log-normal distributions of FC concentrations (dry season: April through October, and wet season: November through March) on Gibbons Creek at GC1 (Table 3).

Table 3. TMDL FC geometric means and recommended percent reductions for Gibbons Creek.

Station ID	Geometric Mean (cfc/100mL)			Load Allocation (cfu/100 mL)	Percent Reduction Needed		
	Dry Season	Wet Season	Year-Round		Dry Season	Wet Season	Annual
GC1	453	101		100	78	1	-
GC2	-	-	590	100	-	-	83

The proposed LAs were intended to bring the water quality of Gibbons Creek into compliance with FC standards. However, it was uncertain whether the LAs would be protective enough to meet the second criterion of the FC standards. Use of a phased TMDL approach will allow reconsideration of water quality management goals after evaluating the effectiveness of LAs.

Watershed Implementation or Restoration Activities

Even before completing the 2005 Detailed Implementation Plan (DIP), stakeholders from the City of Washougal, Clark County, and the Clark Conservation District began trying to identify the sources of FC in the Gibbons Creek watershed. Beginning in 2007, stakeholders started adaptive management meetings to discuss accomplishments and ongoing activities. Since that time, much of the work outlined in the DIP has been accomplished, prompting the 2011-12 monitoring study. Table 4 shows goals and accomplishments associated with the DIP.

Much of this work is summarized on Ecology's TMDL website for Gibbons Creek: www.ecy.wa.gov/programs/wq/tmdl/GibbonsCr/GibbonsCrTMDL.html

Table 4. Goals and accomplishments associated with the *Gibbons Creek Fecal Coliform Total Maximum Daily Load: Detailed Implementation Plan* (Post, 2005).

<table>
<tr><th>Agency/ Organization</th><th>Goals</th><th>Accomplishments</th></tr>
<tr><td rowspan="4">City of Washougal</td><td>Reduce contribution from stormwater</td><td>Ongoing inspection of stormwater system.

Mapping of city stormwater system is complete and is in the Clark County GIS. Will be updated by city staff, as needed.

A stormwater utility was established in late 2007; fees were imposed in January 2009.

Continuing implementation of Phase II NPDES Municipal Stormwater Permit.</td></tr>
<tr><td>Eliminate septic system use and connect all residences/ businesses to city sewer system</td><td>Ongoing maintenance and improvement of existing sewer lines.</td></tr>
<tr><td>Educate septic system owners about inspection and operation of septic systems and encourage connection to city sewer system</td><td>Has not been initiated.</td></tr>
<tr><td>Conduct water quality monitoring</td><td>Analyzed samples collected on Gibbons Creek by Clark County from April 2004 to August 2007.

Analyzed samples collected on Campen Creek by Clark Conservation District and Department of Ecology in summer 2008.

Conducted extensive stream and sewer system sampling in fall 2008 that narrowed the source area and led to ultimate discovery of the raccoon latrine as source of high FC concentrations in Campen Creek.

Participated in visual stream reconnaissance that located and confirmed presence of raccoon latrine.</td></tr>
<tr><td rowspan="2">Clark County Public Health</td><td>Reduce FC input from on-site septic systems</td><td>Between 2004 and 2006, surveyed 179 homeowners in the watershed about their septic systems, and added 60 properties to septic system database.

County septic system regulations strengthened in October 2007, resulting in significant increase in number of inspections.

Continuing implementation of On-site Septic System Inspection and Maintenance Program.</td></tr>
<tr><td>Educate septic system owners about inspection and operation of septic systems</td><td>Between 2004 and 2006, conducted 3 workshops, distributed educational material to 810 homeowners, provided technical assistance to 184 homeowners, and sent 366 reminders for septic system operation and maintenance in the watershed.</td></tr>
</table>

Agency/ Organization	Goals	Accomplishments
Clark County Clean Water Program	Initiate a water quality monitoring program	Established a volunteer monitoring project that collected monthly water quality data from April 2004 to April 2006 and quarterly data from August 2004 to August 2007. Established and populated a monitoring database.
	Conduct source identification monitoring	Provided equipment and training for outfall survey and sampling in Campen Creek by Ecology and the Clark Conservation District during summer 2008. Participated in visual stream reconnaissance that located and confirmed presence of raccoon latrine, and development of a plan to address FC contamination from raccoons in the creek.
	Reduce contribution from stormwater	In 2007, screened 131 stormwater outfalls outside the city limits for illicit discharges; data indicated no illicit discharges in unincorporated Clark County. In 2008, conducted a features inventory to document potential stormwater-related issues outside the city. Continuing implementation of Phase I NPDES Municipal Stormwater Permit. Adopted ordinance and manual in January 2009; ordinance went into effect April 2009.
Clark Conservation District	Conduct livestock survey	Completed survey within city limits in 2006. In 2007, completed survey outside city limits and entered all data in a GIS database. In 2008, completed project report and GIS-based map. In June 2008, submitted proposal to Board of Commissioners for a special property assessment. In summer 2008, surveyed and sampled outfalls on Campen Creek.
	Provide outreach and education to livestock owners	Ongoing
Department of Ecology	Conduct inspections of permitted and non-permitted activities	Ongoing
	Provide assistance to local interests in obtaining grant and loan funds	Ongoing
	Conduct source identification monitoring	Assisted with summer 2008 Campen Creek outfall survey and sampling, as well as development of a plan to address FC contamination from raccoons in the creek.
	Conduct effectiveness monitoring	Fall 2011 and spring 2012

GIS: Geographic Information System software
NPDES: National Pollutant Discharge Elimination System

Goals and Objectives

The project goals for this study are as follows:

- Evaluate whether FC bacteria TMDL implementation actions met the target reductions set in the original TMDL and submittal report (Nocon and Erickson, 1996; Post, 2000).
- Support a systematic review of new water quality data to determine if water quality has improved.

The project goals will be met through the following objectives:

- Determine if FC TMDL target reductions have been met.
- Determine if Washington State water quality standards for FC are being met.

Methods

The Addendum to the Gibbons Creek FC Quality Assurance Project Plan for this study describes procedures used to collect and analyze FC samples (Onwumere and Collyard, 2011). Sampling locations are shown in Figure 1 and described in Table 5.

Ecology sampled nine locations in the Gibbons Creek watershed for FC approximately twice monthly from October 2011 through September 2012 (Figure 1, Table 5). Sampling locations were selected based on historic sampling stations and segments currently listed as impaired for FC (Ecology, 2008). Two additional stations were added on unnamed tributaries which enter Campen Creek at the Orchard Hills Golf and Country Club (Table 5).

Table 5. Location descriptions for the Gibbons Creek watershed monitoring study, 2011-12.

Station ID	Clark County Station Code	Description	Latitude	Longitude
GC1	GIB030	Gibbons Creek below confluence with Campen Creek at Evergreen Highway crossing	45.57486	-122.315
GC2	CMP010	Campen Creek above confluence with Gibbons Creek	45.57724	-122.315
GC2.5	-	Unnamed tributary to Campen Creek upstream of Fairway Drive crossing	45.58331	-122.326
GC3	CMP050	Campen Creek at Bailey Road crossing	45.58327	-122.307
GC4	GIB044	Unnamed tributary to Gibbons Creek upstream of junction of Sunset View and Wooding Roads	45.5822	-122.301
GC5	GIB045	Unnamed tributary to Gibbons Creek upstream of Wooding Road crossing	45.58212	-122.301
GC6	GIB045	Gibbons Creek above confluence of unnamed tributary	45.58345	-122.322
GC7	CMP038	Unnamed tributary to Campen Creek upstream of J Street crossing	45.582	-122.317
GC7.5	-	Unnamed tributary to Campen Creek above GC7 upstream of P Street crossing	45.588	-122.315

FC grab samples were collected from the stream thalweg when possible. Samples from bridges were collected from the upstream side, using a rope and weighted containers. Samples were put directly into sterile, pre-cleaned containers and transferred to a cooler with ice.

Ecology's Manchester Environmental Laboratory (MEL) analyzed all samples using the membrane filtration (MF) method (MEL, 2008). Laboratory analyses for FC were performed in accordance with MEL protocols (MEL, 2008). Laboratory methods and handling procedures are shown in Table 6.

Table 6. Analytical methods, preservation, and holding times.

Parameter	Description	Method/ Lab	Lab	Container	Preservation	Holding Time
Fecal coliform	Membrane filtration	SM 9222 D	MEL	PE, 250 mL, sterile	10˚C, dark	Maximum 24 hours

SM: Standard Methods
PE: polyethylene

Table 7 outlines analytical methods, expected precision of sample replicates, and method reporting limits and resolution. The targets for analytical precision of laboratory analyses are based on historical performance by MEL for environmental samples taken around the state by Ecology's Environmental Assessment Program (Mathieu, 2006). The reporting limits of the methods listed in Table 7 are appropriate for the expected range of results and the required level of sensitivity to meet project objectives. The laboratory's measurement quality objectives (MQOs) and quality control procedures are documented in MEL's Lab Users Manual (MEL, 2008). Results of the quality assurance evaluation are shown in Appendix B.

Table 7. Measurement quality objectives for precision in field measurements and laboratory analysis.

Analysis	Method/ Equipment	Field Replicate MQO (median)	Lab Duplicate MQO	Reporting Limits
FC Membrane Filter (MF)	SM 922D	50% of replicate pairs <20% RSD 90% of replicate pairs <50% RSD	40% RPD	1 cfu/100 mL

RSD: Relative standard deviation
RPD: Relative percent difference
MQO: Measurement Quality Objective
Cfu: colony-forming unit

Data Analysis

Studies

All data used in this report were obtained from Ecology's Environmental Information Management (EIM) system (www.ecy.wa.gov/eim/). A list of studies and data used for the data analysis are presented in Table 8.

Table 8. Gibbons Creek watershed studies in EIM used for the data analysis.

Study Name	Years	User Study ID
Statewide River and Stream Ambient Monitoring	1988-1999	AMS001D
	1999-2009	AMS001E
Clark County Volunteer Monitoring	2002-2006	CC-VOLMONAM
	2004-2006	CC-VOLMGIB
Gibbons Creek Remnant Channel Study	1994-1995	KERI0002
Gibbons Creek Fecal Coliform TMDL Monitoring	2011-2012	MVP004

Compliance with Water Quality Standards

Data collected in 2011-12 were used to determine if 303(d) listed waters within the Gibbon Creek watershed are attaining Washington State water quality standards for FC. Only the most recent 12 months of FC data were used. To determine compliance with water quality standards, data were first separated by seasons (summer: April-October; winter: November-February) based on recommendations in the TMDL (Nocon and Erickson, 1996).

FC geometric means were calculated by back-transforming the mean of log-transformed concentration values. FC 90th percentiles were calculated as the 90th percentile of a log-normal distribution, where the mean and standard deviation are estimated from the log-transformed data (Swanson, 2006). All calculations were performed in Excel 2007.

See Appendix C for details on assessment and data requirements for bacteria.

Trend Monitoring

Ecology used the Seasonal Kendall Trend test (Helsel et al., 2006) for detecting long-term trends in FC data. The test accounts for seasonal variations in data over time and for outliers in data sets. Both of these conditions are common in water quality data sets and can significantly influence regression results. Furthermore, data are not required to be normally distributed.

The Seasonal Kendall test identifies whether or not a statistically significant trend exists in a time-series data set. The absolute values of Z statistics are compared to a table of critical values to determine if there is a trend at the selected level of significance (α=0.1). A positive value of Z indicates an upward trend, while a negative Z value indicates a downward trend. With α=0.1, Z scores greater than 1.64 indicate a significant increasing trend, while Z scores less than -1.64 indicate a significant decreasing trend. All statistical tests were performed using Systat® version 13.0.

Fecal Coliform Target Reductions

The Statistical Rollback Method (Ott, 1995) was used to establish FC reduction targets for stream segments and critical periods not meeting water quality standards in the Gibbons Creek watershed. The method has been applied by Ecology in other FC bacteria TMDL evaluations (Ahmed and Hempleman, 2006; Swanson, 2006).

Results and Discussion

During the 2011-12 study, both parts of the annual water quality criteria for FC were exceeded (not met) at all Campen Creek monitoring stations (Figure 2). The geometric mean of all samples at each site is not to exceed 100 cfu/100mL, and no more than 10% of all samples may exceed 200 cfu/100 mL, interpreted by Ecology as the 90th percentile of results. All Gibbons Creek stations met the annual geometric mean criterion. Part two of the FC criteria was exceeded at all Gibbons Creek stations (Figure 2). Campen Creek sites GC2 to GC7.5 are also shown.

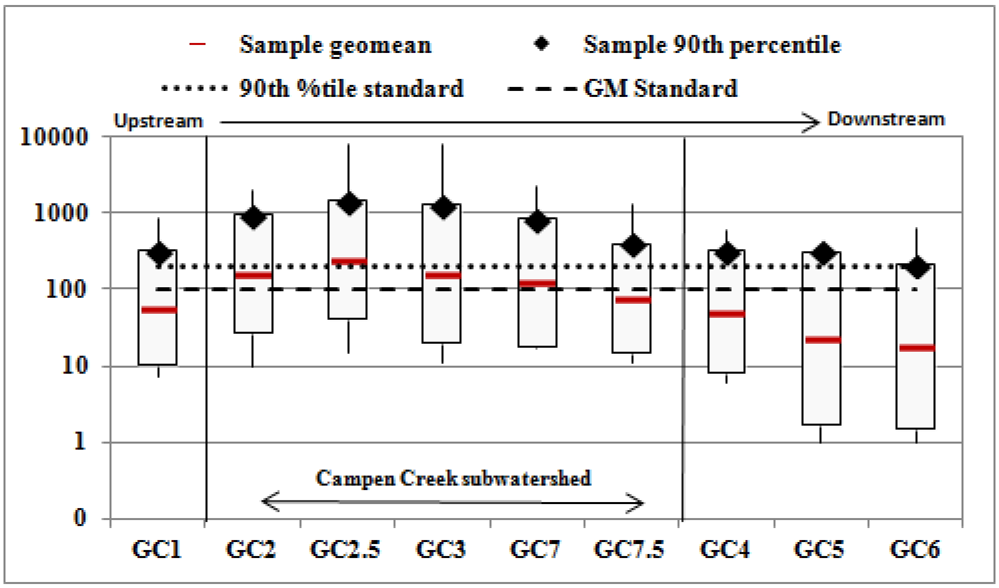

Figure 2. Annual FC geometric means and 90th percentiles in the Gibbons Creek watershed, 2011-12.

Critical Season

If sufficient data exist, water quality standards require that the data be averaged by season (Ecology, 2011). This is done to prevent the masking of high values that sometimes occurs when averaging data over long periods of time. At times, seasonal data analysis can also better identify pollution sources in the watershed.

Using pooled FC data from previous monitoring efforts, Nocon and Erickson (1996) identified two distinct seasonal patterns of FC pollution at stations GC1 and GC2 in the Gibbons Creek watershed: a dry season (April through October) and a wet season (November through March) (see Table 3). The 1996 TMDL assessment recommended target load reductions using these seasons.

FC data collected during the 2011-12 TMDL study were pooled to determine if seasonality of FC loads exists. Median FC concentrations were higher during April through October (Figure 3). Average monthly precipitation data (1948-2012) from Troutdale, Oregon were also used to verify the established seasonal separation for this study (Appendix D, Table D-1). The months of November through March were identified as those having at least 10% of the average annual precipitation.

Based on these results, the critical seasons indentified in the 1996 TMDL study are still applicable.

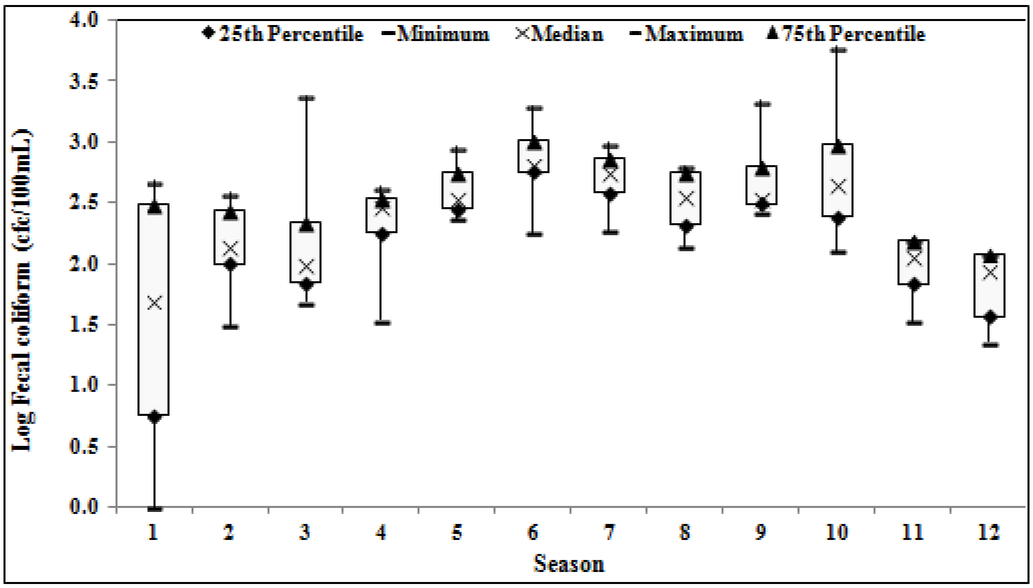

Figure 3. FC data for the Gibbons Creek watershed pooled by month, 2011-12.

Water Quality Standards and TMDL Targets

Summer-season and winter-season geometric mean and 90th percentiles for monitoring stations are presented in Figure 4. Partitioning FC data into summer and winter seasons indicates higher concentrations of FC are being observed during the dry summer season (April through October). The highest FC geometric mean and 90th percentiles were observed in the Campen Creek subwatershed. The highest FC concentrations were observed in two small tributaries of Campen Creek (GC2.5, GC7). These results are consistent with previous monitoring efforts. A table of numeric FC results is presented in Table D-2.

Differences between summer and winter seasons were consistent among sampling stations and likely reflect differences in FC sources or source transport to surface waters. The lower FC concentrations during the winter season likely indicate diluting because of higher streamflow. This is consistent with continuous FC sources that are independent of rainfall, such as animal access, septic systems, or other greywater discharges.

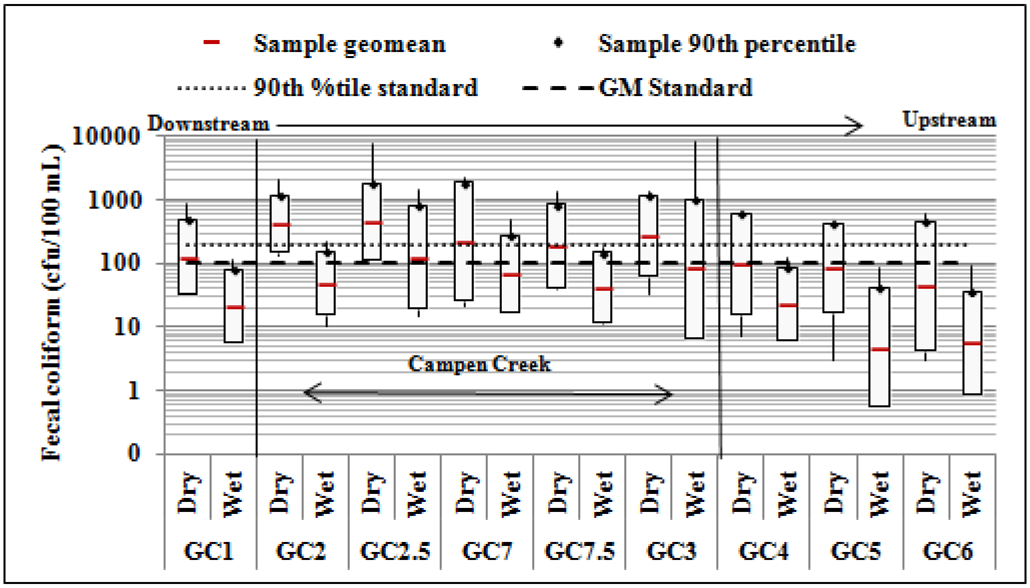

Figure 4. Critical season FC geometric means and 90th percentiles in the Gibbons Creek watershed, 2011-12.

GC2 to GC7.5 are Campen Creek stations.

Supplementary Information

The purpose of this section is to evaluate FC data from this study to help stakeholders prioritize future implementation actions. These data are observational only and will require additional investigation to identify implementation needs.

Precipitation

Total precipitation for the 48 hours prior to FC sampling was plotted with average FC concentrations in Campen Creek and Gibbons Creek (Figure 5). Overall, FC concentrations increased with increasing precipitation. Patterns of FC concentrations are similar between Gibbons and Campen Creek and appear to correlate over time. The exception was for samples collected after June 19, 2012 when little or no rainfall occurred. Patterns of FC concentrations after this period appeared to be converse between watersheds (Figure 5).

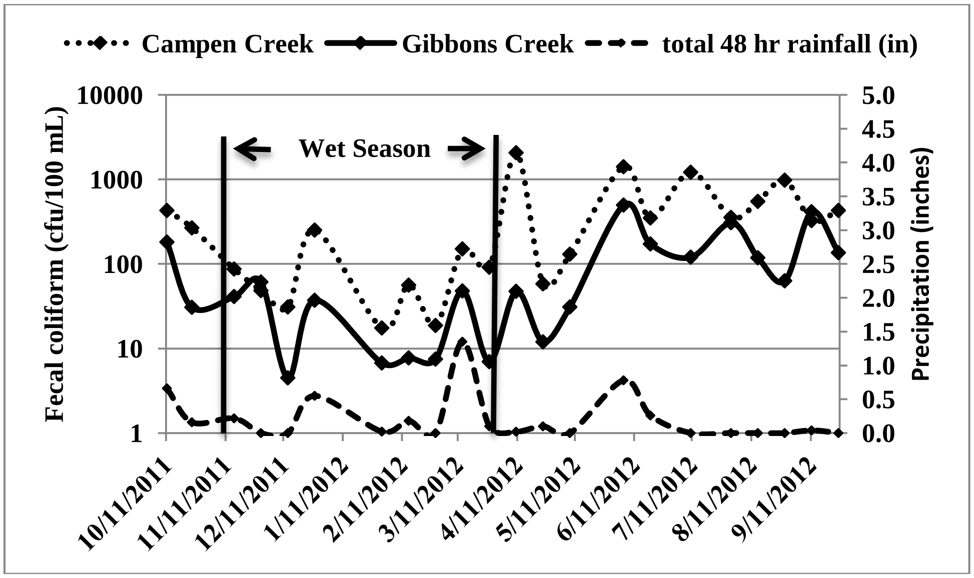

Figure 5. Average FC concentrations of Campen Creek and Gibbons Creek sampling stations plotted against daily precipitation collected near Troutdale, OR.

Land use

Development in the Gibbons Creek watershed is primarily concentrated in the City of Washougal (Figure 6). Many of the residential properties in the city are serviced by a municipal sewer system. However, based on 2008 data obtained from Clark County, several residences within the city limits are still using on-site septic systems (Figure 6).

The uplands of the watershed have historically been cleared for agriculture production; however, much of the agricultural activity is limited to hay production and grassland. In 2009, the Clark Conservation District submitted a regional livestock inventory to Ecology (www.ecy.wa.gov/programs/wq/tmdl/SalmonCr/CCDfinalrptlivestkinventgrant.pdf). The Gibbons Creek watershed was part of this assessment, which was funded through an Ecology Centennial Clean Water Grant. This assessment indicates that large-scale livestock production is limited, although many of the residents in the upper watershed keep low numbers of livestock.

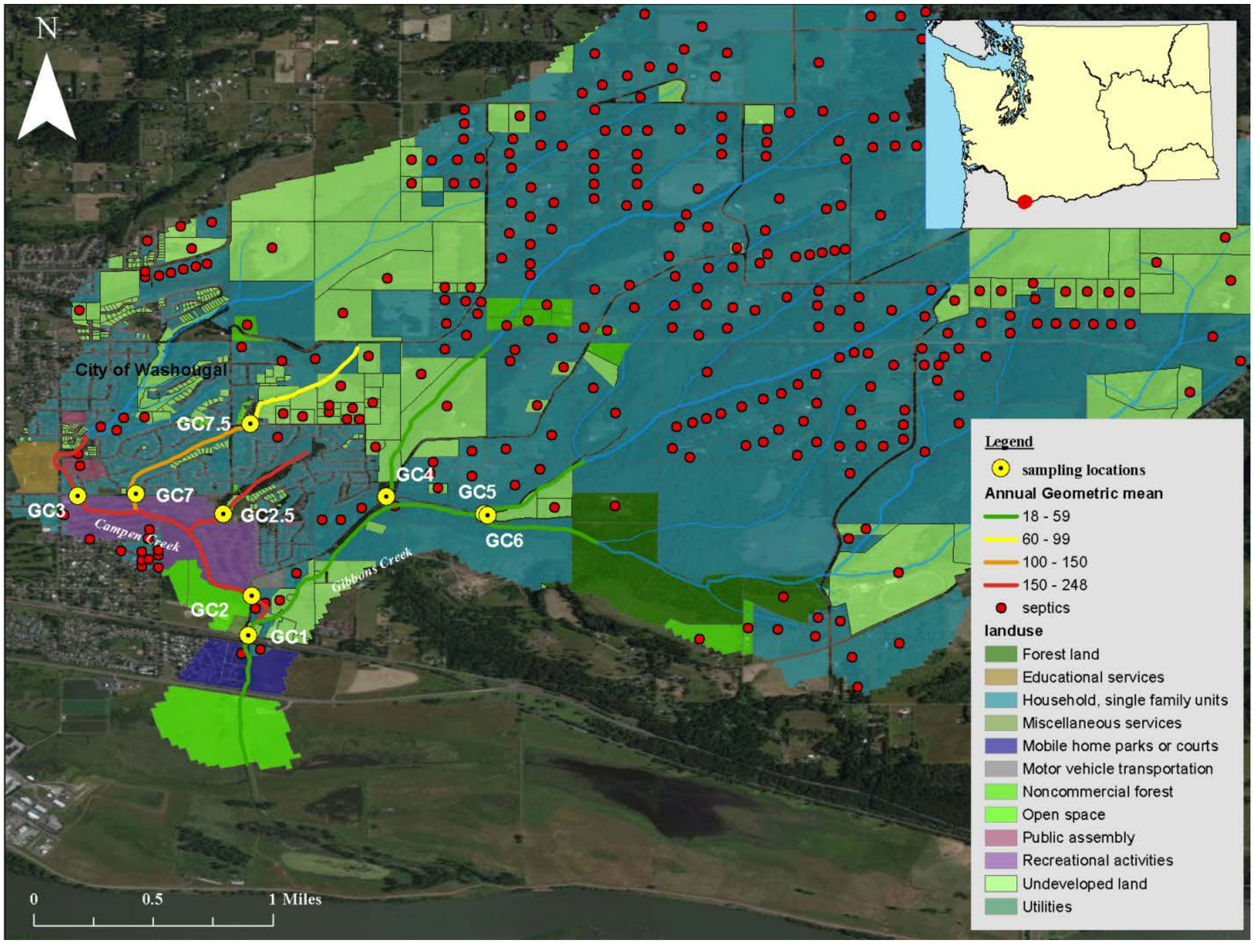

Figure 6. FC geometric means, sampling locations, land use, and septic systems in the Gibbons Creek watershed, 2011-12.

FC Loading

An analysis of FC loading into the mainstem of Gibbons Creek from Campen Creek and the other tributaries was conducted on September 11, 2012. Loads were calculated using the method employed by Nocon and Erickson (1996). The intent of this simplified analysis was to examine the relative contribution of FC loading at stations GC1 and GC2. This estimate did not address the effect of bacterial decay, deposition, and resuspension.

As shown in Figure 7, on September 11, 2012, the area draining into Campen Creek was contributing the greatest proportion (100% relative FC load) of FC load to the watershed relative to Gibbons Creek at GC1. In addition, the greatest load in the Campen Creek watershed was observed in the area draining into Campen Creek above GC3, followed by the drainage area above GC7 and GC2.5. These results are consistent with results observed in the 1996 TMDL assessment and monitoring conducted by Clark County volunteers.

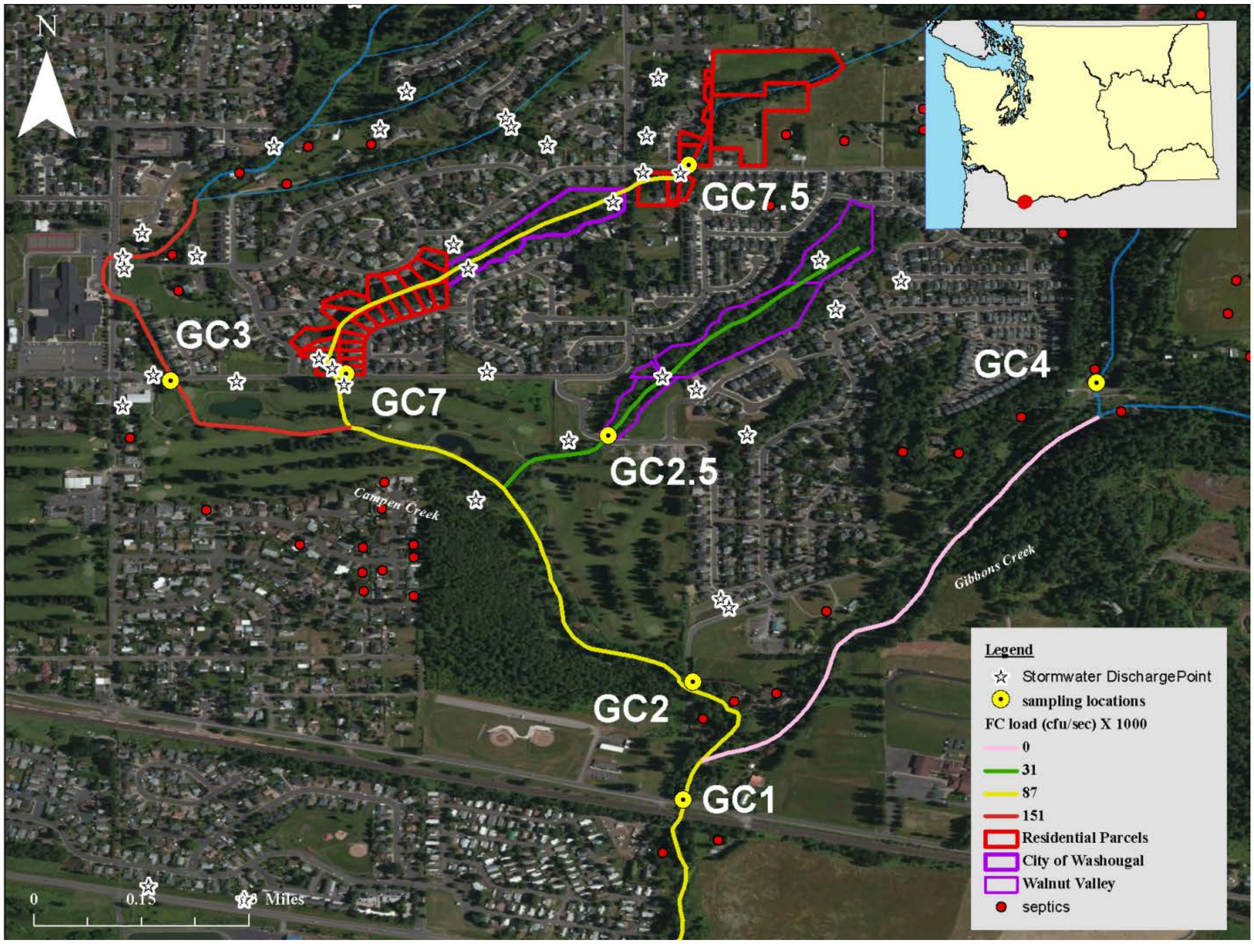

Figure 7. FC loading (cfu/sec) in the Campen Creek subwatershed on September 11, 2012 (x 1000).

Note estimates of FC loads between stations.

Although these results suggest that FC loading on Campen Creek is still problematic, loading during this sampling period was lower than what was observed in 1996 (Table 9).

Table 9. FC loading (cfu/sec) in the Gibbons Creek watershed (x 1000).

Station ID 9/11/12	Flow (cfs)	FC (cfu/100mL)	FC loading on 9/11/12 (cfu/sec)	FC loading on 9/8/96 (cfu/sec)
GC1	3.56	84	85	2000
GC2	1.12	270	86	1400
GC2.5	0.29	390	32	-
GC7	0.16	1900	87	-
GC3	0.90	590	151	1500

- not determined

Two new sampling stations were monitored on tributaries flowing into Campen Creek between GC2 and GC3. The upper terraces of both tributaries are surrounded by dense residential housing (Figure 7). These tributaries flow through deeply incised valleys, and the riparian areas are dominated by dense vegetation. Vegetation adjacent to the streambank is primarily blackberry plants, making accessibility very difficult. Visual inspection of the areas indicated that these corridors, although relatively protected by vegetation, are still being used by both wildlife and domestic pets. Several trails led down from residential yards into the drainages and appeared to be used by pets.

Based on data obtained by the City of Washougal, several stormwater outfalls discharge into these tributaries (Figure 7). Although stormwater runoff is unlikely to be problematic during the dry seasons, graywater discharge from residential lots or undocumented wastewater connections to stormwater lines are possible sources.

Target Reductions

Table 10 lists the TMDL target stations and corresponding observed and target percent reductions needed to bring the FC geometric mean into compliance with water quality standards. Note that because there was not sufficient data to calculate seasonal percent reductions at GC2 at the time of the TMDL assessment, reductions were estimated for the annual geometric mean.

Based on geometric means, significant reduction of FC loading was observed at both target stations in all sampling periods (Table 10). Although considerable progress has been made towards meeting the geometric targets, the targets did not meet the geometric mean water quality criterion for FC in the summer or on an annual basis.

Table 10. Comparison of TMDL and effectiveness monitoring FC geometric means (cfu/100 mL) at GC1 and GC2.

Station ID	Summer			Winter			Annual		
	TMDL	EM	Observed/target % reduction	TMDL	EM	Observed/target % reduction	TMDL	EM	Observed/target % reduction
GC1	453	125	72/78	101	22	78/1	-	57	-
GC2	-	433	-	-	49	-	590	160	73/83

EM: Effectiveness monitoring
- not calculated

Trends Over Time

Table 11 displays results of the Seasonal Kendall test for trends at each of the seven Gibbons Creek TMDL monitoring stations for all data from 1991 through 2011. The test evaluates trends based on the raw data rather than geometric means or percentiles. The test accounts for differences among months, thus avoiding the identification of false trends based on monthly variability. As indicated by negative Z-scores and slope, decreasing FC concentration trends were observed for all stations tested (Table 11). However, statistically significant trends were only observed at GC1 and GC4. Supplemental results for the Seasonal Kendall analysis are presented in Appendix E.

Table 11. Results from Seasonal Kendall Trend analysis of FC data, 1991-2011.

Monitoring station	Z-Score	Trend	Slope	Statistically significant?
GC1	-1.752	Down	-0.021	Yes
GC2	-1.273	Down	-0.038	No
GC3	-1.556	Down	-0.036	No
GC4	-1.714	Down	-0.031	Yes
GC5	-1.400	Down	-0.040	No
GC6	-1.273	Down	-0.069	No
GC7	-0.646	Down	-0.023	No

[1]Z scores great than ± 1.64 indicate a significant trend.

Future Monitoring

Fecal Coliform Compliance Stations and Targets

Although compliance is measured as meeting water quality standards, FC targets are routinely established to assist Water Quality Program managers in assessing the progress toward compliance with water quality criteria. Table 12 provides a list of sampling stations that should be used as part of future monitoring studies. FC target reductions were calculated based on critical seasons and result from the 2011-12 samples. The limiting basis for the reduction was the higher % reduction between the geometric mean and the 90th percentile.

Table 12. Recommended compliance stations and FC targets for future monitoring studies.

Station	Critical season	Geometric mean	90th percentile	Limiting basis for reduction	Target reduction (%)
GC1	summer	125	473	90th percentile	58
GC2	summer	433	1195	90th percentile	83
GC2.5	summer	458	1818	90th percentile	89
GC2.5	winter	126	788	90th percentile	75
GC7	summer	227	1880	90th percentile	89
GC7	winter	67	270	90th percentile	26
GC7.5	summer	185	838	90th percentile	87
GC3	summer	271	1142	90th percentile	83
GC3	winter	83	1016	90th percentile	80
GC4	summer	98	601	90th percentile	67
GC5	summer	93	413	90th percentile	52
GC6	summer	45	458	90th percentile	57

Conclusions

Results of this 2011-12 fecal coliform (FC) monitoring study support the following conclusions:

- FC levels in the Gibbons Creek watershed continue to exceed (not meet) either one or both parts of the Washington State water quality criterion in both the summer and winter seasons.
- Based on data collected from 1991 through 2012, reductions of FC bacteria were observed at all monitoring stations.
- Based on Seasonal Kendall Trend tests, statistically significant reductions of FC concentrations were observed at stations GC1 and GC4.
- When compared to FC targets outlined in the 1996 TMDL assessment, summer and winter geometric means were reduced by 72% and 78%, respectively, at GC1. A 73% reduction was observed in the annual geometric mean at GC2. Seasonal reductions were not originally determined because of insufficient data.
- Substantial progress has been made towards meeting the FC geometric mean targets at GC1 and GC2. However, meeting geometric mean targets in the future does not necessarily ensure that the 90th percentile criterion will be met.
- Reduction of FC levels in the watershed cannot be specifically attributed to any one water cleanup action. Better documentation of best management practices is needed, specifically mapping of locations and identification of where implementation has occurred.
- The highest concentrations of FC bacteria were observed in the Campen Creek subwatershed.
- Some of the highest FC concentrations were observed in the tributaries above GC2.5 and GC7.5 during the 2011-12 study; however, the combined FC loading from these tributaries was lower than what was observed above GC3.
- Dry summer season FC concentrations were higher than those observed during the wet winter season. This observation was consistent between Gibbons and Campen Creeks. However, FC concentrations generally increased with increasing precipitation during the wet winter season. These patterns were similar between Gibbons and Campen Creeks and appeared to correlate over time.

Recommendations

Recommendations are in order of relative priority, based on conclusions of this 2011-12 study:

- Future work to reduce FC loading should be focused in the Campen Creek subwatershed; specifically, above monitoring station GC3 within the Washougal city limits. Work in this area should focus on identifying dry summer season sources of FC such as illegal discharges, failing septic systems, and contributions from residential pet waste. Any dry-season stormwater discharges entering Campen Creek should be evaluated.

- Future efforts above tributary stations GC2.5 and GC7 should include education and outreach to prevent pet waste from entering surface waters. Also, residents should be discouraged from engaging in activities that attract wildlife into the drainages (e.g. feeding). Dry-season stormwater discharges should also be inspected and monitored if necessary.

- Work in the upper Gibbons Creek watershed and the Campen Creek subwatershed should continue to be coordinated through Ecology, Clark County, and the Clark Conservation District.

- Additional monitoring stations should be included in future studies on Campen Creek between GC3 and the Washougal city limits. Tributaries between these stations should also be assessed.

- Future and past implementation of best management practices, source identification and elimination, and other efforts should be documented to included specifics of what, when, and where. This will assist both Ecology and stakeholders in monitoring the effectiveness of TMDL implementation activities.

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Appendices

Appendix A: Water Quality Assessment / Categories 1 to 5

The 303(d) list identifies polluted waters in Washington State. The Water Quality Assessment is a list that tells a more complete story about the condition of Washington's surface waters. It is a state requirement to satisfy federal Clean Water Act requirements and to prioritize TMDL efforts.

The 303(d) list divides waterbodies into five categories

- Category 1 – Meets tested standards for clean water.
- Category 2 – Waters of concern.
- Category 3 – Lack of sufficient data.
- Category 4 – Polluted waters that do not require a TMDL because the problems are being solved in one of three ways:
  - 4a – Has an approved TMDL and it is 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, and culverts.
- Category 5 – Polluted waters that require a TMDL – the 303(d) list.

Applicable Ecology web link

Water Quality Assessment Categories
www.ecy.wa.gov/programs/wq/303d/WQAssessmentCats.html

Appendix B: Study Quality Assurance Evaluation

FC samples met the measurement quality objectives (MQOs) outlined in the Quality Assurance Project Plan (Onwumere and Collyard, 2011). Results for laboratory duplicates and field replicates are presented in Tables B-1 and B-2.

Laboratory duplicates

Analytical precision was determined for this study by calculating the relative percent difference (RPD) of duplicate laboratory FC samples. The MQO used by Manchester Environmental Laboratory (MEL) for membrane-filtered bacteria duplicates is 40% RPD (MEL, 2012). The average RPD of all duplicate samples met the MQOs for laboratory duplicates. Results are presented in Table B-1.

Table B-1. Duplicate laboratory sample statistics.

Parameter	Average percent RPD	MQO precision standard (RPD)	Number of duplicates	Number of samples	Percent of samples duplicated
FC	30	40	21	192	11

Field replicates

Sampling precision was determined for this study by calculating the relative standard deviation (RSD) for replicate FC samples collected in the field. Ecology's MQO for analyzing precision in replicated FC samples requires that at least 50% of the samples be below 20% RSD and that at least 90% of the samples be below 50% RSD (Mathieu, 2006).

Of the 17 replicate FC samples with a concentration above 20 cfu/100 mL, 94% of the replicate pairs were below 20% RSD and 100% were below 50% RSD (Table B-2). FC samples collected for this study met Ecology's MQO quality assurance precision criteria.

Table B-2. Replicate field sample statistics.

Parameter	Average percent RSD	MQO precision	Meets MQO criteria	Number of replicates	Number of samples	Percent of samples replicated
FC	1.9	50% of replicates must be <20% RSD	Yes	20	192	10

Appendix C: Assessment Information and Data Requirements

Designated Uses: Water contact recreation

Numeric Criteria: ECOLOGY, 2011-200 (2)

Narrative Standards: ECOLOGY, 2011-260 & -300

Unit of Measure: Number of colony forming units per 100mL

Assessment Information and Specific Data Requirements

Fecal coliform and Enterococcus spp. data will be assessed by Ecology staff according to the following description:

Sample data for bacteria will typically be assessed in 12-month reporting periods or in reporting periods that represent a distinct climatic regime of less than a year. A distinct climatic regime may be a certain season or certain months, in whatever manner is relevant to bacteria and to the water body. Ecology will determine the assessment periods, case-specific, based on local circumstances such as climate, weather, and associated bacteria data; otherwise, the assessment period will be consistent with the general water year for the State, October through September.

Waters that have previously been assessed based on calendar year, as described in early versions of this policy, will not be reassessed unless new information indicates that these assessments would result in a change of the category determination. Data from incomplete water years may be reserved for the next assessment when further data will allow a geometric mean to be calculated for the entire water year.

The state water quality standards include provisions for determining violations based on either a mean of bacteria values of a set of samples (geometric mean criteria) or the highest levels among the individual samples within that set (percent criteria). Violations are based on either of these provisions.

To reduce concerns of low bias when the data are later used to calculate a geometric mean, an arithmetic mean value will be calculated from multiple data points collected in the same sampling event and water body segment. This averaging helps to reduce the effects of sample variability inherent in determining ambient bacteria concentrations at the time of sampling. The resulting single representative data point for the sampling event will represent the daily value to be included in this assessment methodology.

In some cases, Ecology will allow alternate indicators of bacteria in freshwater when the data submitter is able to demonstrate that the indicator can be used as a surrogate. For example, in some water bodies a strong correlation can be shown between fecal coliform and E. coli values. If this is demonstrated, Ecology will use the alternate indicator for assessment purposes. When collecting data in or around small sensitive areas such as swimming beaches, it is recommended that multiple samples be collected throughout the water body during each visit.

Appendix D: Seasonal Geometric Means and 90th Percentile

Table D-1. Gibbons Creek watershed critical season FC geometric means and 90th percentiles, 2011-2012.

Station ID	Geomean		90th percentile		Geomean	90th percentile
	Summer	Winter	Summer	Winter	Annual	
GC1	**125**	22	**473**	81	57	**316**
GC2	**433**	49	**1195**	150	**160**	**938**
GC2.5	**458**	**126**	**1818**	**788**	**248**	**1473**
GC7	**227**	67	**1880**	**270**	**120**	**799**
GC7.5	**185**	42	**838**	147	68	**512**
GC3	**271**	83	**1142**	**1016**	**159**	**1280**
GC4	98	23	**601**	85	50	**317**
GC5	83	5	**413**	41	24	**354**
GC6	45	6	**458**	36	18	**210**

Bold lettering indicates FC concentration exceeded (did not meet) water quality criteria.

Table D-2. Average monthly precipitation (1948-2012) at Troutdale, Oregon.

Month	Average precipitation (inches)	Percent of total	Critical season
January	6.18	13	Wet season
February	5.28	11	
March	4.64	10	
April	3.85	8	Dry season
May	2.94	6	
June	2.42	5	
July	0.74	2	
August	0.86	2	
September	1.85	4	
October	3.95	8	
November	7.28	15	Wet season
December	7.17	15	

Appendix E: Systat® Results of Seasonal Kendall Analysis

The Seasonal Kendall test (Helsel and Hirsch, 2002) accounts for seasonality by computing the Mann-Kendall test on each of the seasons separately and then combining the results. So for monthly seasons, January data are compared only with January, February only with February, etc. No comparisons are made across season boundaries.

The Seasonal Kendall test calculates the probability of a relationship occurring between the variable (FC) and time (year). With α=0.1, Z scores greater than 1.64 indicate a significant increasing trend, while Z scores less than -1.64 indicate a significant decreasing trend.

A separate test (Sen) calculates the slope of the trend. A negative slope indicates a decreasing trend while a positive slope indicates an increasing trend. The greater or lesser the slope, the larger the rate of change over time.

Table E-1. Mann-Kendall statistics for seasons.

Season	Station GC1				Station GC2				Station GC3			
	n	Statistic	ASE	Tau	n	Statistic	ASE	Tau	n	Statistic	ASE	Tau
Oct	5	-2	4.082	-0.20	3	1.00	1.92	0.33	2.0	-1.0	1.0	-1.0
Nov	4	-2	2.944	-0.33	3	-3.00	1.92	-1.00	3.0	1.0	1.9	0.3
Dec	5	2	4.082	0.20	3	-2.00	1.63	-0.67	3.0	-3.0	1.9	-1.0
Jan	5	-4	4.082	-0.40	4	-2.00	2.94	-0.33	4.0	-1.0	2.8	-0.2
Feb	5	-4	4.082	-0.40	3	-1.00	1.92	-0.33	3.0	-3.0	1.9	-1.0
Mar	5	0	4.082	0.00	3	-1.00	1.92	-0.33	3.0	-3.0	1.9	-1.0
Apr	6	-5	5.323	-0.33	4	-2.00	2.94	-0.33	4.0	0.0	2.9	0.0
May	4	-6	2.944	-1.00	2	1.00	1.00	1.00	2.0	-1.0	1.0	-1.0
June	5	-4	4.082	-0.40	3	3.00	1.92	1.00	3.0	3.0	1.9	1.0
July	5	0	4.082	0.00	2	-1.00	1.00	-1.00	3.0	1.0	1.9	0.3
Aug	4	0	2.944	0.00	2	-1.00	1.00	-1.00	2.0	-1.0	1.0	-1.0
Sept	5	0	4.082	0.00	4	-2.00	2.94	-0.33	4.0	-4.0	2.9	-0.7

ASE (Asymptotic Standard Error): Standard deviation of each parameter.
Tau: A statistic used to measure the association between two measured quantities.

Table E-1 (cont.). Mann-Kendall statistics for seasons.

Season	Station GC7				Station GC4				Station GC5			
	n	Statistic	ASE	Tau	n	Statistic	ASE	Tau	n	Statistic	ASE	Tau
Oct	3	1	1.9	0.33	3	-1	1.9	-0.3	3	1	1.9	0.33
Nov	2	-1	1	-1	3	1	1.9	0.33	3	-1	1.9	-0.3
Dec	3	1	1.9	0.33	3	-2	1.6	-0.7	3	-3	1.9	-1
Jan	3	-1	1.9	-0.3	4	-2	2.9	-0.3	4	0	2.9	0
Feb	3	-3	1.9	-1	3	-3	1.9	-1	3	-1	1.9	-0.3
Mar	3	-3	1.9	-1	3	-3	1.9	-1	3	-3	1.9	-1
Apr	4	2	2.9	0.33	4	1	2.8	0.17	4	-2	2.9	-0.3
May	2	-1	1	-1	2	-1	1	-1	2	1	1	1
June	3	1	1.9	0.33	3	-1	1.9	-0.3	3	1	1.9	0.33
July	3	-1	1.9	-0.3	2	1	1	1	2	-1	1	-1
Aug	2	1	1	1	2	-1	1	-1	2	-1	1	-1
Sept	2	-1	1	-1	4	-2	2.9	-0.3	4	-2	2.9	-0.3

ASE (Asymptotic Standard Error): Standard deviation of each parameter.
Tau: A statistic used to measure the association between two measured quantities.

Table E-1 (cont.). Mann-Kendall statistics for seasons.

Season	Station GC6			
	n	Statistic	ASE	Tau
Oct	3	-1	1.9	-0.3
Nov	3	-1	1.9	-0.3
Dec	3	-1	1.9	-0.3
Jan	4	0	2.9	0
Feb	3	-2	1.6	-0.7
Mar	3	-3	1.9	-1
Apr	4	0	2.9	0
May	2	-1	1	-1
June	3	3	1.9	1
July	2	-1	1	-1
Aug	2	-1	1	-1
Sept	4	-2	2.9	-0.3

ASE (Asymptotic Standard Error): Standard deviation of each parameter.
Tau: A statistic used to measure the association between two measured quantities.

Appendix F. Glossary, Acronyms, and Abbreviations

Glossary

Best management practices (BMPs): Physical, structural, and/or operational practices that, when used singularly or in combination, prevent or reduce pollutant discharges.

Clean Water Act: 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.

Designated uses: Those uses specified in Chapter 173-201A WAC (Water Quality Standards for Surface Waters of the State of Washington) for each water body or segment, regardless of

Effectiveness monitoring: Monitoring to determine whether the recommended Detailed Implementation Plan, after a significant portion of the recommendations or prescriptions have been implemented, is adequate in meeting (1) the goals and objectives for the TMDL project or (2) other desired outcomes over long temporal scales.

Fecal coliform (FC): That portion of the coliform group of bacteria which is present in intestinal tracts and feces of warm-blooded animals as detected by the product of acid or gas from lactose in a suitable culture medium within 24 hours at 44.5 + or - 0.2 ° Celsius. FC are "indicator" organisms that suggest the possible presence of disease-causing organisms. Concentrations are measured in colony forming units per 100 milliliters of water (cfu/100mL).

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 ten 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.

Load allocation: The portion of a receiving waters' loading capacity attributed to one or more of its existing or future sources of nonpoint pollution or to natural background sources.

Nonpoint source: Pollution that enters any waters of the state from any dispersed land-based or water-based activities. This includes, but is 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 National Pollutant Discharge Elimination System 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.

Point source: Sources of pollution that discharge at a specific location from pipes, outfalls, and conveyance channels to a surface water. Examples of point source discharges include municipal wastewater treatment plants, municipal stormwater systems, industrial waste treatment facilities, and construction sites that clear more than 5 acres of land.

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.

Primary contact recreation: Activities where a person would have direct contact with water to the point of complete submergence including, but not limited to, skin diving, swimming, and water skiing.

Riparian: Relating to the banks along a natural course of water.

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, saltwaters, wetlands and all other surface waters and water courses within the jurisdiction of the state of Washington.

Thalweg: The deepest and fastest moving portion of a stream.

Total Maximum Daily Load (TMDL): Water cleanup plan. A distribution of a substance in a water body 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.

Wasteload allocation: The portion of a receiving water's loading capacity allocated to existing or future point sources of pollution. Wasteload allocation constitutes one type of water quality-based effluent limitation.

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 periodically to 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 waterbodies (ocean waters, estuaries, lakes, and streams) that fall short of state surface water quality standards and are not expected to improve within the next two years.

Acronyms and Abbreviations

cfu	cubic forming unit
Ecology	Washington State Department of Ecology
FC	(See Glossary above)
GIS	Geographic Information System software
MEL	Manchester Environmental Laboratory
ml	milliliters
TMDL	(See Glossary above)
WRIA	Water Resource Inventory Area