Bear-Evans Watershed Fecal Coliform Bacteria Total Maximum Daily Load

Water Quality Improvement Report

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Cover photo: Bear Creek and Evans Creek confluence, taken by Anne Dettelbach.

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by

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Special thanks to the following Bear-Evans Watershed TMDL Advisory Group for providing significant insight that improved our understanding of water quality problems in the Bear-Evans Watershed. They shared their comments and early interest in supporting water quality improvement efforts in the watershed.

Bear-Evans Watershed TMDL Advisory Group:

- City of Redmond: Keith MacDonald, Peter Holte, Jerallyn Roetemeyer, Elaine Dilley, Scott McQuary, Roger Dane, Rebecca Borker
- City of Sammamish: John Cunningham
- City of Woodinville: Tom Hansen
- King Conservation District: Matt Dunnahoe, Gayle Hoffman, Brandy Reed
- King County: Richard Jack, Mary Maier, Kate Rhoads, Hans Berg, Rick Reinsloder, Tom Beavers
- Muckleshoot Indian Tribe: Nancy Rapin, Joel Massmann
- Northeast Sammamish Sewer and Water District: Laura Szentes, Steve Nelson, Geoff Clayton
- Snohomish Conservation District: Bobbi Lindemulder
- Snohomish County: Frank Leonetti, Kathleen Thornburgh
- Union Hill Water Association: Laura Szentes, Don West
- Water Tenders: Dick Schaetzel, Wendy Walsh, Jonathan Morrison
- Upper Bear Creek Community Council: Nancy Stafford

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Bear Creek below the confluence with Evans Creek. Photo: Anne Dettelbach

Executive Summary

Introduction

Bear, Evans, and Cottage Lake Creeks have fecal coliform bacteria levels beyond what Washington State allows in our freshwater streams. These typically harmless bacteria tend to exist along with disease-causing bacteria and viruses (i.e., pathogens), so they serve to indicate the potential for pathogens in the water. Long-term data tell us fecal coliform bacteria levels have declined near the mouth of Bear Creek since 1994. However, recent data show certain stream portions in the Bear-Evans Watershed still do not meet our state's water quality standards that protect recreational use during the year, especially in the dry period between May and September.

Washington State Department of Ecology (Ecology) placed Bear, Evans, and Cottage Lake Creeks on the state's 303(d) list of polluted waters based on monitoring data from King County and the city of Redmond. As required by the federal Clean Water Act (CWA), states must produce a Total Maximum Daily Load (TMDL) study for each 303(d)-listed water body. The TMDL study identifies pollution problems in the watershed, then specifies how much pollution needs to be reduced to achieve clean water. It also estimates how much different sources of bacteria contribute to the overall pollution problem. Then, working with the local community, Ecology details the current efforts and prepares an outline of actions needed to control the pollution, called the "implementation strategy".

This report, *Bear-Evans Watershed Fecal Coliform Bacteria TMDL Water Quality Improvement Report*, documents Ecology's TMDL study and the local efforts to address the fecal coliform bacteria problem in the Bear-Evans Watershed. This report has three major sections:

I. Introduction and Background.
II. TMDL Study.
III. Implementation Strategy.

Ecology prepared this TMDL study for fecal coliform bacteria to coincide with the ongoing TMDL studies on the temperature and dissolved oxygen problems in the Bear-Evans Watershed. For the fecal coliform bacteria TMDL study, Ecology used available water quality data from six King County monitoring stations along Bear, Evans, and Cottage Lake Creeks. In addition, the city of Redmond monitors water quality at an unnamed tributary to Bear Creek (Avondale Road and 116th). Flow data (measured or estimated) were available only at the King County stations.

Bear-Evans Watershed

Photo: King County DNR

The Bear-Evans Watershed, in northern King and southern Snohomish Counties, drains approximately 51 square miles of land area and includes the cities of Redmond, Sammamish, and Woodinville. Bear Creek is the major stream of the system, with Cottage Lake Creek and Evans Creek as its main tributaries. Bear Creek flows southerly for 12 miles through rural and suburban neighborhoods before joining the Sammamish River in the commercial district of Redmond. The Sammamish River flows north and eventually empties into Lake Washington at the city of Kenmore.

Satellite imagery from the late 1990s shows much of the watershed is urbanized, with about 30 percent of the land in residential use; 4 percent in commercial or industrial use; 54 percent still covered by forest; and 11 percent make up agricultural or rural land use. Three state highways cross parts of the watershed: SR 520 passes along lower Bear Creek in Redmond, SR 202 stretches along portions of Evans Creek, and SR 522 bypasses the upper Cottage Lake Creek sub-basin in Snohomish County.

Potential sources of fecal coliform bacteria in the streams include pet and livestock wastes, domestic wastewater and sewage, urban stormwater, and wildlife. (See pp. 19 for more information on potential pollution sources.)

TMDL Targets and Allocations

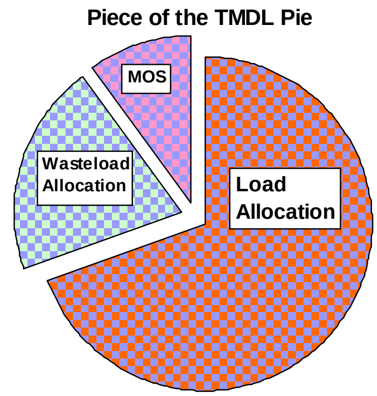
Through the TMDL study, Ecology sets targets for stations along Bear, Evans, and Cottage Lake Creeks for reaching the state's two-part fecal coliform bacteria standard. The following standard is based on protecting the recreational use in the Bear-Evans Watershed:

Part 1 - Geometric mean (an average) of 50 bacteria colonies per 100 milliliters of water (cfu/100 mL).

Part 2 - No more than 10 percent of samples should exceed 100 cfu/100mL. This is called the "90th percentile" criterion.

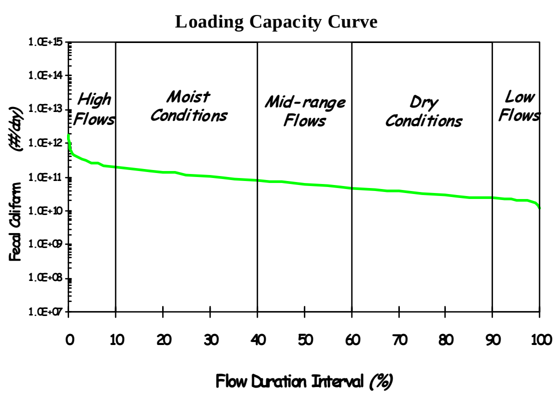
Ecology expresses these TMDL numeric targets as "percent reduction goals" and as "loading capacities". A percent reduction goal is the percent of the current bacteria level that needs to be eliminated to meet standards during the most critical condition. (Critical condition can be a flow regime or seasonal period when the greatest current fecal coliform problem exists.)

Loading capacity is the greatest amount of fecal coliform bacteria that the creek can receive each day and still meet standards. Because bacteria loading (number of bacteria per day) is calculated from flow data, Ecology established loading capacities at stations with measured or estimated flow data. Then, based on these loading capacities, Ecology set limits for how much sources can contribute to creeks without exceeding standards. These limits are called "load allocations" for nonpoint sources and "wasteload allocations" for point sources. If the loading capacity is the pie, then allocations are pieces of the pie.



Overall, the TMDL goal is to achieve state water quality standards for bacteria on an annual and seasonal basis. The following summarizes the numerical TMDL targets and allocations at the monitoring stations along Bear, Evans, and Cottage Lake Creeks:

- For the Bear Creek system to comply with the state's upper 90th percentile criterion during critical streamflow conditions, it will take 57 percent to 91 percent reductions in current bacteria loadings at the various King County monitoring stations. To meet standards near the mouth of Bear Creek (station O484), it will take an 88 percent reduction in current bacteria loadings from all upstream sources. These are the "percent reduction goals" for the TMDL. See Critical Flow Conditions section for details on how these were established.



Ecology established the loading capacities for fecal coliform based on meeting in-stream concentrations of 50 cfu/100mL under five streamflow conditions (low, dry, mid-range, moist, and high). The loading capacity is displayed on the left as a curve and changes as the allowable bacteria load varies with streamflow. See Appendix E for details on how the loading capacities were established.

- Ecology distributes responsibility for reducing bacteria levels among point and nonpoint pollution sources on a daily basis and under all flow conditions. Most of the stations along Cottage Lake, Bear, and Evans Creeks show excessive bacteria loads during mid-range to dry flow conditions, suggesting significant nonpoint sources. At most locations samples collected during storm events contribute to non-compliance. Compared to upstream stations, loadings near Bear Creek's mouth show a very noticeable increase during wet weather months and during storm events. For future allowable pollutant loadings to Bear Creek near the mouth (station O484), this TMDL sets a wasteload allocation of 70 percent of the loading capacity to point sources under the five different flow conditions, 20 percent to nonpoint sources, and 10 percent for a margin of safety (MOS).

Implementation Strategy

To reduce fecal coliform bacteria loadings to Bear, Evans, and Cottage Lake Creeks, actions must be applied on a watershed or sub-basin scale. Working at this level, there is a sense of shared responsibility for reducing upstream sources that contribute to the downstream problem.

Key organizations involved in improving water quality in the Bear-Evans Watershed include the counties and cities in the watershed; sewer districts (Northeast Sammamish Sewer and Water District, Woodinville Sewer and Water District); King and Snohomish Conservation Districts; Public Health Seattle-King County; Washington State Department of Transportation; and local volunteer groups. Most importantly, watershed residents, local businesses, and citizens play an important role as well.

Ecology considers stormwater discharges from municipal separate storm sewer systems (MS4s) as point sources. Some of the actions needed are required as part of the current National Pollutant Discharge Elimination System (NPDES**)** municipal stormwater permits. The cities and counties in the watershed and WA State Department of Transportation hold municipal NPDES permits for stormwater.

The following summarizes the implementation strategy needed to bring the Bear Creek system to good health (see the implementation strategy section for more details):

- Source Tracking
  - Increase understanding of land uses and animal handling facilities in the basin.
  - Investigate and repair sewer leaks and failing onsite septics.
  - Identify and eliminate illicit connections to the stormwater drainage system.
  - Detect bacteria sources through targeted water quality monitoring.

- Source Controls
  - Implement structural (as appropriate) and non-structural stormwater source control best management practices (BMPs).
  - Restore riparian vegetation to help filter out stormwater pollutants.
  - Properly manage domestic animal and livestock wastes.

- Increasing Public Awareness
  - Outreach and educate the public on local bacteria pollution issues and watershed stewardship.

This TMDL study gives the technical justification for key partners to develop and implement a detailed plan of action. This next effort will build upon their accomplishments and current activities. During implementation, the overall goal is to achieve state water quality standards for bacteria in the watershed. If state and local coordination proceed as planned, Ecology expects the Bear Creek system will comply with the state water quality standards by December 2015.

What is a Total Maximum Daily Load (TMDL)?

Federal Clean Water Act requirements

The Clean Water Act (CWA) established a process to identify and clean up polluted waters. It requires each state to have its own water quality standards designed to protect, restore, and preserve water quality. Washington State Water Quality Standards (Chapter 173-201a Washington Administrative Code [WAC]) establish (1) designated uses for protection, such as cold water biota and contact recreation, and (2) criteria, usually numeric criteria, to achieve those uses.

Every two years, states prepare a list of surface waters of the state – 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, the Washington State Department of Ecology (Ecology) compiles its own water quality data along with data from local, state, and federal governments, tribes, industries, and citizen monitoring groups. Ecology reviews all data to ensure that they were collected using appropriate scientific methods before using them to develop the 303(d) list. The 303(d) list is part of a separate, larger process called the Water Quality Assessment for Washington State.

The Water Quality Assessment is basically the state's constantly expanding body of knowledge about the status of our state's water quality. It categorizes all water bodies for which data are available in relation to water quality standards. This list divides water bodies 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 program 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 303d list.

TMDL process overview

The Clean Water Act requires that states develop a Total Maximum Daily Load (TMDL) for each of the water bodies in Category 5 of the 303(d) list. The TMDL process begins with a study that identifies pollution problems in the watershed and then specifies how much that pollution must be reduced or eliminated to achieve clean water. Ecology shares this information with the local community to set goals for restoring the impaired water body to good health.

Once the U.S. Environmental Protection Agency (EPA) approves the report, a detailed plan of action must be developed within one year. This plan will identify specific tasks, responsible parties, and timelines for achieving clean water.

TMDL Elements

EPA requires the TMDL process to include a quantitative assessment of the water quality problems, and the pollutant sources contributing to the pollution problem using the best available information. This TMDL study determines the amount of a given pollutant that can be discharged to the water body and still meet state water quality standards (called the 'loading capacity'), and allocates that maximum "allowable" daily load among the various sources.

Identifying the pollutant loading capacity for a water body is an important step in developing a TMDL. 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 the standards.

The portion of the receiving water's loading capacity assigned to 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 (WLA). If the pollutant comes from a set of diffuse nonpoint sources such as general urban, residential, or farm runoff, the cumulative share is called a load allocation (LA).

The TMDL study must also consider seasonal variation and, when appropriate, include a margin of safety (MOS) 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. By definition, a TMDL is the sum of the allocations, which must not exceed the loading capacity. 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 WLAs + sum of all LAs + MOS

In this *Bear-Evans Watershed Fecal Coliform Bacteria TMDL Water Quality Improvement Report* (report), Ecology set the limits on fecal coliform bacteria that Bear Creek system can receive without exceeding water quality standards; assigned load and wasteload allocations for pollution sources; outlined an implementation strategy as a framework for the detailed plan of actions; and described the involvement with the community.

Why is Ecology Doing a TMDL Study in the Bear-Evans Watershed?

Overview

Bear, Evans, and Cottage Lake Creeks have fecal coliform bacteria levels beyond what our state allows in freshwater streams. As the first step to reduce these levels, Ecology learned about the pollution problem and set targets for improving the water quality through the TMDL study. This TMDL study on fecal coliform bacteria coincided with Ecology's other TMDL effort to improve temperature and dissolved oxygen in the Bear Creek system for fish. Ecology has engaged local partners on the temperature and dissolved oxygen TMDL study since the summer of 2006.

Study area

The Bear-Evans Watershed includes portions of King and Snohomish counties as well as the cities of Redmond, Sammamish, and Woodinville (Figure 1). Bear Creek is the major stream of the system, with Cottage Lake Creek and Evans Creek as main branches to the system. King County monitors water quality along these streams at six stations (Table 1). Land area above the stations in Cottage Lake Creek near Woodinville (N484) and in upper and middle Bear Creek (J484 and C484) characterizes the Bear Creek sub-basin. Land area above the stations in upper and lower Evans Creek (S484 and B484) characterizes the Evans Creek sub-basin. The most downstream station, Bear Creek near the mouth (O484) below Redmond Way, represents the whole Bear-Evans Watershed. The city of Redmond monitors water quality of an unnamed tributary to Bear Creek at Avondale Road and 116th (35).

Table 1. Monitoring stations in the Bear-Evans Watershed.

Station	Description	Monitored By
N484	Cottage Lake Creek at Avondale Rd	King County
J484	Bear Creek (upper) at 133rd (Seidel Rd)	King County
35	Unnamed tributary to Bear Creek at Avondale Rd and 116th	City of Redmond
C484	Bear Creek (mid) at Bridge 119A on 95th Ave	King County
S484	Evans Creek (upper) at 50th St	King County
B484	Evans Creek (lower) at Union Hill Rd	King County
O484	Bear Creek (near mouth) 1 mi. above Sammamish River	King County

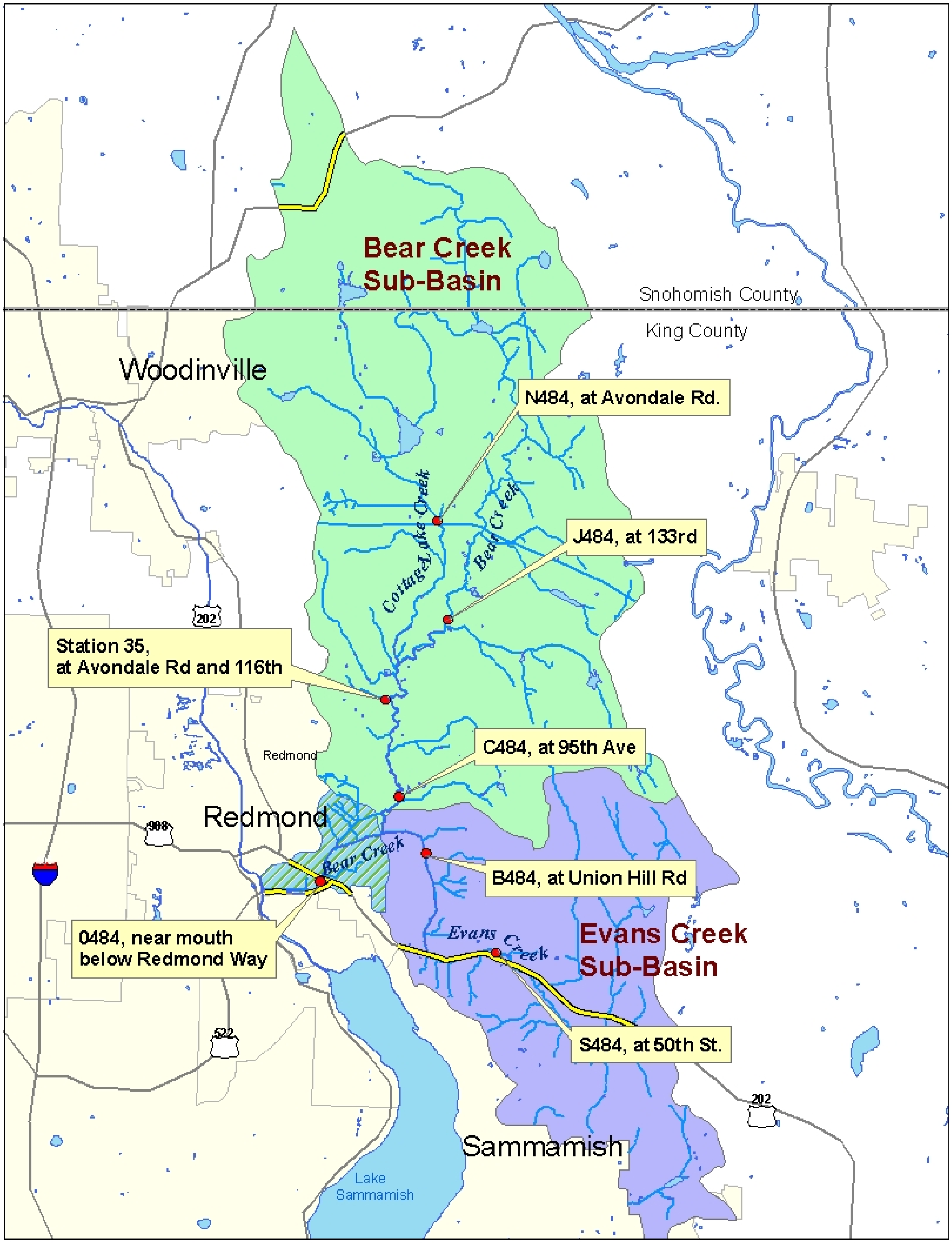
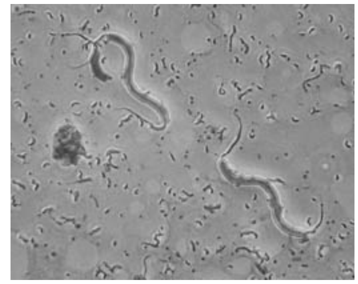


Figure 1. Map of monitoring stations in the Bear-Evans Watershed. The two major sub-basins are Bear Creek sub-basin (green) and Evans Creek sub-basin (purple). Station O484 near the mouth of Bear Creek represents the whole watershed.

Pollutants addressed by this TMDL

This TMDL study focuses on the fecal coliform bacteria problem along Bear, Evans, and Cottage Lake Creeks. These bacteria may enter the aquatic environment directly from humans and animals, agricultural and stormwater runoff, and wastewater. These typically harmless bacteria tend to exist along with disease-causing bacteria and viruses (i.e., pathogens), so they serve to indicate the potential for pathogens in the water. Generally, a high fecal coliform count means a greater chance for pathogens to be present. Fecal coliform bacteria are typically found in higher numbers than pathogens and are easier to analyze in the laboratory.



View of fecal coliform bacteria under a microscope.

Ecology's Water Quality Assessment 303(d) list

Water quality monitoring indicates that Bear, Evans, and Cottage Lake Creeks have problems with fecal coliform bacteria pollution, measured as bacteria counts in the water (colony forming units per 100 mL or cfu/100mL). Unpublished King County data show standards were not met each year in samples collected between 1998 and 2002 for Cottage Lake Creek (N484) and mid Bear Creek (C484), and in 1998 for upper Evans Creek (S484). As part of the 2004 Water Quality Assessment process, Ecology identified Bear Creek, Evans Creek, and Cottage Lake Creek as having levels of fecal coliform bacteria beyond what our state allows in our freshwater streams (Table 2).

Table 2. Streams in the Bear-Evans Watershed on the 2004 303(d) list for fecal coliform bacteria.

Water body/Station ID		Listing ID	Parameter	Water body ID	Township	Range	Section
Bear Creek Sub-Basin							
Cottage Lake Creek	N484	13147	Fecal coliform	NO74J5	26N	06E	18
Bear Creek (upper)	J484	13146	Fecal coliform	EW54VY	26N	06E	30
Unnamed tributary	35	42154	Fecal coliform	EU47RU	26N	06E	30
Bear Creek (mid)	C484	13144	Fecal coliform	BA64JJ	25N	06E	06
Evans Creek Sub-Basin							
Evans Creek (upper)	S484	13148	Fecal coliform	MI67EG	25N	06E	16
Evans Creek (lower)	B484	13142	Fecal coliform	MI67EG	25N	06E	07
Whole Bear-Evans Watershed							
Bear Creek (mouth)	O484	13133	Fecal coliform	WR69YU	25N	05E	12

In a separate TMDL study, Ecology addresses stream temperature and dissolved oxygen issues in this watershed. In particular, Table 3 lists pollutants other than fecal coliform bacteria on the 2004 303(d) list for this watershed. The temperature and dissolved oxygen TMDL for this watershed is in progress at the time of this report and is not included here.

Table 3. Additional pollutants in the Bear-Evans Watershed on the 303(d) list of water quality problems not addressed by this TMDL.

Water body/Station ID		Listing ID	Parameter	Water body ID	Township	Range	Section
Cottage Lake Creek	N484	4814	Temperature	NO74JS	26N	06E	18
Bear Creek (upper)	J484	42095	Temperature	EW54VY	25N	06E	31
Bear Creek (upper)	J484	4813	Temperature	EW54VY	26N	06E	30
Bear Creek (mid)	C484	4811	Temperature	BA64JJ	25N	06E	06
Evans Creek (upper)	S484	4809	Temperature	MI67EG	25N	06E	06
Bear Creek (mouth)	O484	4804	Temperature	WR69YO	25N	05E	12
Cottage Lake Creek	N484	12688	Dissolved Oxygen	NO74JS	26N	06E	18
Bear Creek (mid)	C484	12687	Dissolved Oxygen	BA64JJ	25N	06E	06
Evans Creek (upper)	S484	12689	Dissolved Oxygen	MI67EG	25N	06E	16
Evans Creek (lower)	B484	12685	Dissolved Oxygen	MI67EG	25N	06E	07
Bear Creek	21	42087	Dissolved Oxygen	NC11TV	25N	05E	12

Water Quality Standards and Beneficial Uses

Ecology sets standards for fecal coliform bacteria 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 bacteria as an "indicator bacteria" for the state's freshwaters (e.g., lakes and streams). Fecal coliform bacteria in water "indicate" 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. Ecology sets fecal coliform bacteria standards at levels shown to minimize rates of serious intestinal illness (gastroenteritis) in people and reduce possible associated virally transmitted diseases.

Ecology protects the recreational quality of Bear, Evans, and Cottage Lake Creeks at the highest level of "extraordinary primary contact" because these freshwater streams feed into a lake [WAC 173-201A-600(1)(a)(ii)]. In these waters, the "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 ten sample points exist) exceeding 100 colonies/100mL" (called the 90th percentile criterion) [WAC 173-201A-200(2)(b), 2003 ed.]. Streams comply with the fecal coliform bacteria standards when they meet both the geometric mean (an average) and 90th percentile limits. In applying both measures, Ecology makes sure fecal coliform bacteria levels in freshwaters will not cause an unacceptable greater risk to human health.

While some discretion exists for selecting sample averaging periods, Ecology evaluates compliance on both annual and seasonal (summer versus winter) basis. For the purpose of comparing with water quality standards, averaging of data collected beyond a 30-day period, or beyond a specific discharge event under investigation, is not permitted when such averaging would skew the data set so as to mask noncompliance periods [WAC 173-201A-200(2)(b)].

Ecology established fecal coliform bacteria standards based on not allowing more than the pre-determined acceptable risk of illness to people working or recreating in a water body. These state limits aim to prevent no more than seven illnesses out of every 1,000 people engaged in primary contact activities. Once the fecal coliform bacteria levels in the water reach the state limits, Ecology does not allow for human activities that would increase levels beyond standards. If levels exceed standards, then Ecology requires that human activities be conducted in a manner in which fecal coliform bacteria levels will comply with standards.

Recreational activities that can put people in contact with fecal coliform bacteria in the Bear, Evans, and Cottage Lake Creeks include children playing in the creek or people walking in the waters.

If natural conditions in the watershed cause fecal coliform bacteria levels to exceed standards, then Ecology does not allow human activities to measurably increase bacteria pollution. While the specific level of illness rates caused by animal versus human sources has not been quantitatively determined, all warm-blooded animals are potential sources of serious waterborne illness for humans.

Bear Creek near Millennium Office Park in Redmond. Photo: Anne Dettelbach

Bear-Evans Watershed

The Bear-Evans Watershed, in northern King and southern Snohomish Counties, drains approximately 51 square miles of land area. It includes the cities of Redmond, Sammamish, and Woodinville (Figure 1). Three state highways cross parts of the watershed: State Route (SR) 520 passes along lower Bear Creek in Redmond, SR 202 stretches along portions of Evans Creek, and SR 522 bypasses the upper Cottage Lake Creek sub-basin in Snohomish County. Within that area, over 100 miles of stream channel, eight named lakes, and over 100 inventoried wetlands compose some of the most valuable salmon spawning habitat in central Puget Sound's Water Resource Inventory Area (WRIA) number 8 (King County, 1990).

The watershed is divided into three sub-basins: Bear Creek (14,300 acres), Evans Creek (9,800 acres), and Cottage Lake Creek (8,000 acres). Bear Creek is the major stream of the system, with Cottage Lake Creek and Evans Creek as the two major tributaries to Bear Creek.

Bear Creek originates about 480 feet above sea level in an extensive network of wetlands near Paradise and Echo Lakes of Snohomish County. Bear Creek flows southerly for 12 miles through rural and suburban neighborhoods before joining the Sammamish River in the commercial district of Redmond. The Sammamish River flows north and eventually empties into Lake Washington at the city of Kenmore.

Cottage Lake Creek flows about 6.7 miles from Cottage Lake to the confluence with Bear Creek. Evans Creek starts in the wetlands between Novelty Hill and Union Hill roads and runs about 8.2 miles before converging with Bear Creek.

The lowest reaches of both Bear and Evans Creeks drain west to the Sammamish River through the city of Redmond (population 47,000), and both show impacts of more intense urbanization. The lowest mile of Bear Creek is constrained within a narrow corridor between State Route 520 and Marymoor Park to the south, and the Redmond Town Center, one of Redmond's largest shopping centers and business parks, to the north.

Physical Features

Situated in the Puget Sound Lowlands, the topography of the area was shaped by deposition and erosion that occurred during the 12,000 to 13,000 years since the last glaciation. The layered geology is a result of depositional processes associated with repeated glacial advancements and retreats (Morgan and Jones, 1999).

The Bear Creek system is comprised of a north-south trending ridge that creates two major drainage valleys. The northern valley has Bear and Cottage Lake Creeks and drains a rolling countryside generally underlain by poorly permeable glacial till. In contrast to the languid nature of Bear Creek, the tributary valley of Evans Creek is uniquely characterized by steep-sided walls from the preexisting glacial landscape. In this southern valley, the drainage courses plunge steeply over the edge of the upland plateau, whose sideslopes are underlain by thick and easily eroded advance outwash deposits, resulting in slope instability (King County, 1990). Lower Evans Creek valley is comparable to the lower gradient Bear Creek valley.

Warm, dry summers and cool, wet winters characterize the climate in the area. Most of the precipitation falls between October and April (Figure 2). Average yearly rainfall from 1993 to 2006 is 44.1 inches.

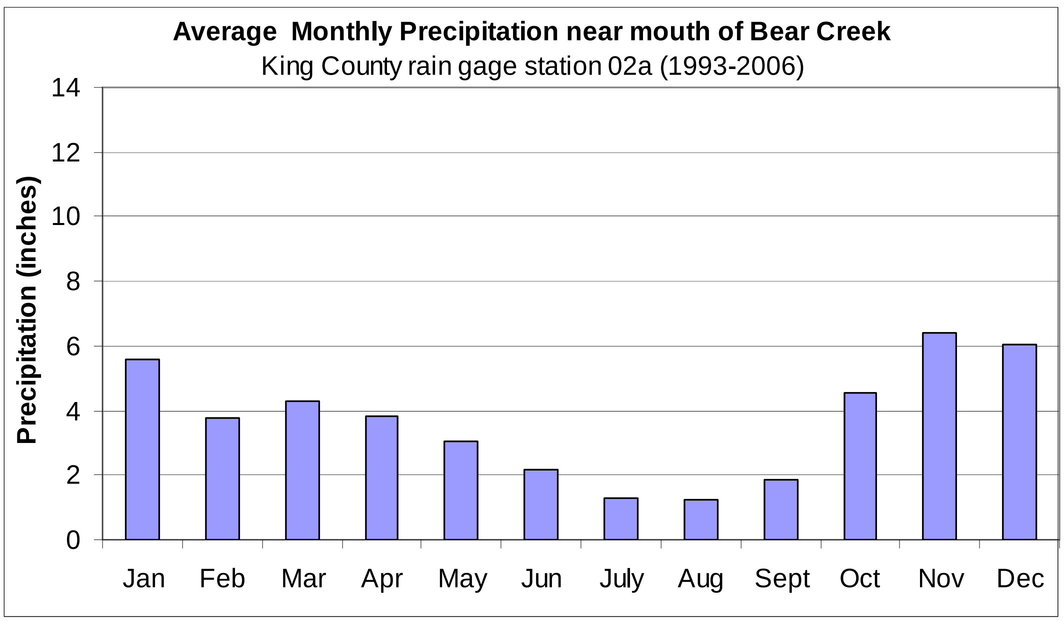


Figure 2. Average precipitation in the Bear-Evans Watershed based on 1993 to 2006 King County data from rain gage 02w on Cottage Lake Creek.

The basin has vegetation typical of western Washington lowland forest ecosystems, which is dominated by evergreen conifers including Douglas fir, western hemlock, and western red cedar. Understory growth includes shade tolerant wild flowers. Wetland areas are predominantly scrub shrub and forested wetlands, providing extensive areas of wildlife habitat and water storage.

Land Use

Land use in the Bear-Evans Watershed has changed markedly in the past 150 years as development in the area has increased. What was once primarily forest has become a mix of forest, grass, and impervious surfaces. The area has experienced a tremendous level of growth since the 1960s, transitioning from mostly agricultural to sub-rural/urban land uses (Williams et al., 1975). Lower portions of the basin have expanding commercial and industrial zones, while all areas of the watershed show an increase in residential growth and density.

In the 1980s the basin was largely rural, characterized by numerous cattle and horse farms, including dairies as well as woodlots of various acreages. Today, numerous woodlots and horse farms can still be found in the basin. King County estimated approximately three-fourths of the entire basin, in 1985, was forest (King County, 1989). The developed area of the basin was predominantly single-family residences. Tributary areas averaged 76 percent forest cover, 14 percent grass cover, 8 percent wetlands and 2 percent effective impervious areas (EIA). EIA includes only impervious surfaces that drain to stormwater conveyances or receiving waters. Satellite imagery from the late 1990s shows the watershed is urbanized, with about 30 percent of the land in residential use, 4 percent in commercial or industrial use, 54 percent with forest cover, and 11 percent in agricultural or rural use (MRLC, 1999; Figure 3).

Development has continued in the watershed since the 1990s, and likely a greater percent of the watershed is now in residential use. The watershed is located within the US Census Defined Urbanized Area. Therefore, it is expected that future population growth and urban development will be concentrated in this area. In 2002, Snohomish County estimated the Bear-Evans Watershed was 9 percent high impervious surface and 18 percent medium impervious surface[1] (Snohomish County, 2002).

During storms, areas of impervious surfaces lead surface runoff to be shunted into the creeks, causing "flashy" streamflows with high peaks. This results in high levels of pollutants reaching the creeks quickly after a rain storm. Impervious surfaces, combined with development practices that quickly shunt stormwater to the nearest stream can add pollutants, create turbid water, widen the stream, and contribute to the loss of fish habitat (CWP, 2001).

[1] High impervious surface is described as "urban residential, commercial, and industrial; road, exposed rock, sedimented river, sand/gravel bar." Medium impervious surface is described as "suburban residential and commercial, talus slope, bare earth, and sand."

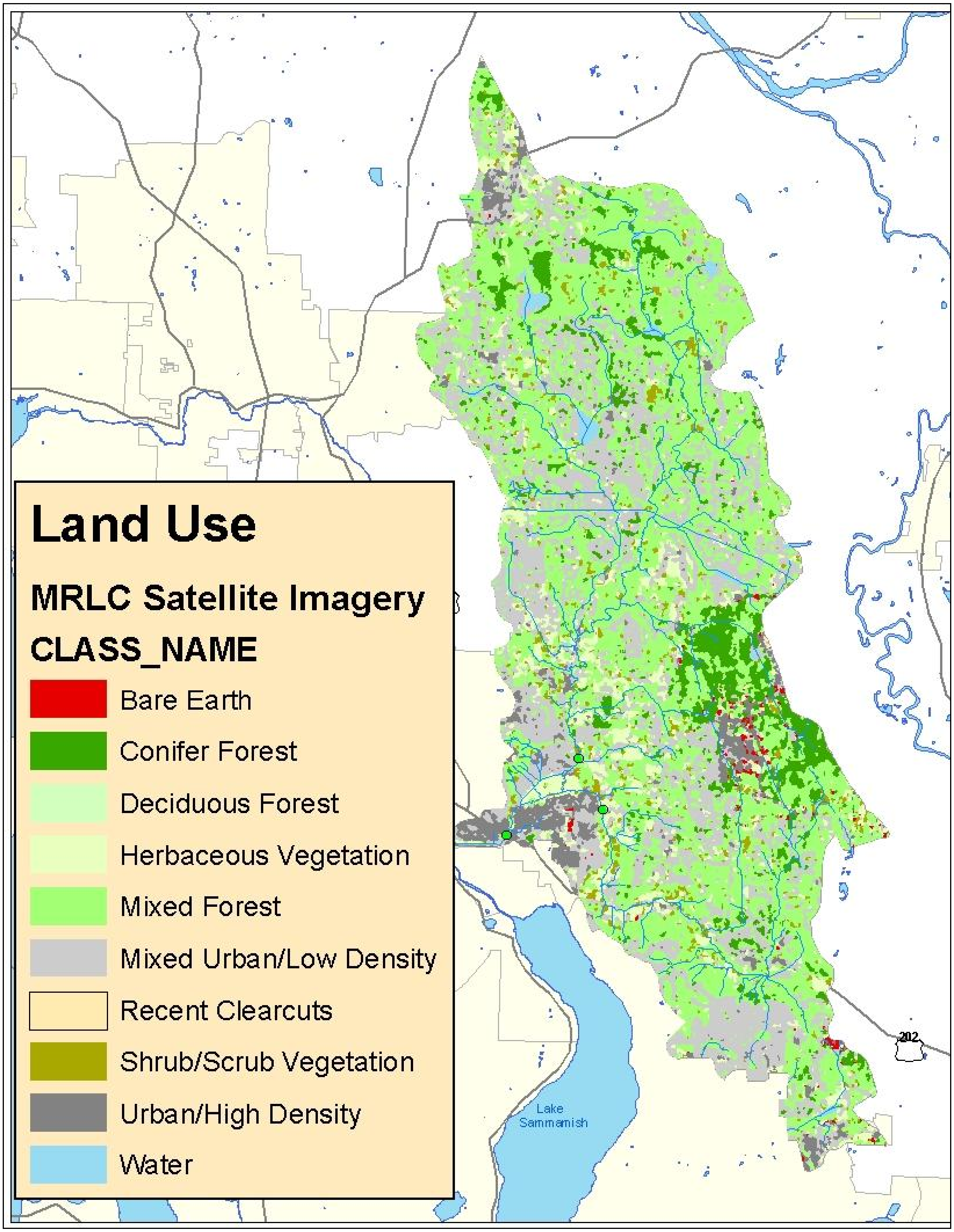


Figure 3. Land use analysis for Bear-Evans watershed (MRLC, 1999). Geographical information system (GIS) software allows users to sort by land use in a given area. Rural development and agricultural areas are a combination of herbaceous and shrub/scrub vegetation and recent clearcuts.

Streamflows

Both surface runoff during rains and groundwater recharge feed the Bear Creek system. The amount of water in Bear and Evans Creeks varies depending partly on the season and partly on recent rainfall patterns. Figure 4 depicts average monthly streamflows near the mouth of Bear Creek above the confluence with Sammamish River based on King County data (King County, 2007). Average flows between 1993 and 2006 are below 50 cubic feet per second (cfs) from June to October and as low as 22 cfs in August. Winter rains result in peak flows that have averaged over 150 cfs in January. Strong rain storms can dramatically increase instantaneous peak flows to as high as 650 cfs. King County also collects stream flow information in the lower part of Evans Creek.

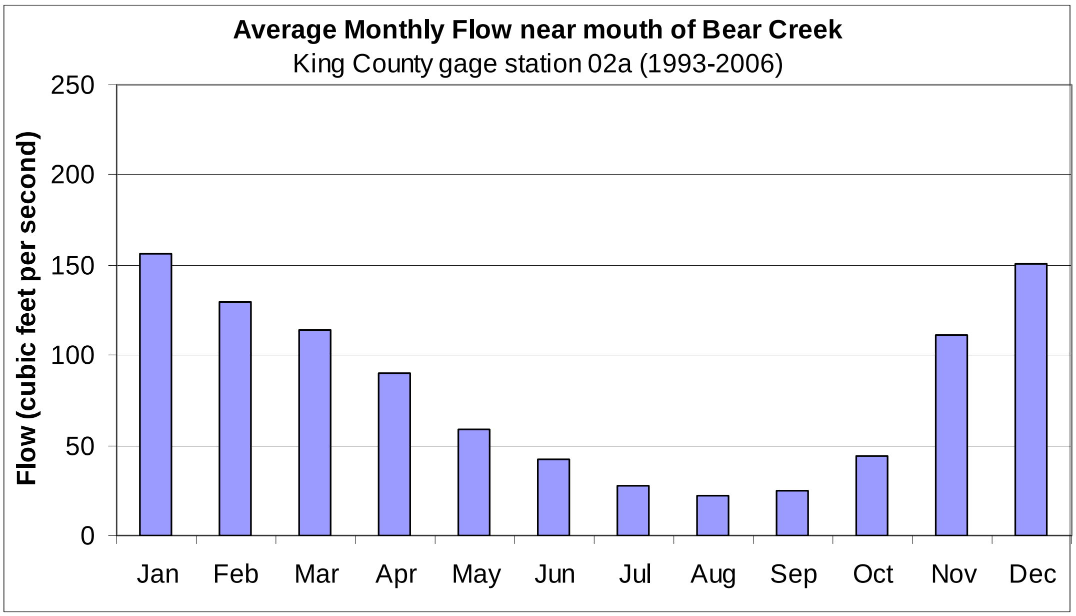


Figure 4. Average monthly streamflow at the mouth of Bear Creek based on 2000-2006 King County data from gage station 02a at monitoring site O484.

In addition to precipitation, ground water enhances the flows of Bear and Evans Creeks year-round. Ground water is also an important drinking water resource for the communities in the basin. Approximately 40 percent of Redmond's drinking water supply comes from groundwater wells that are primarily replenished from aquifers beneath Bear and Evans Creek valleys. The Northeast Sammamish Sewer and Water District (NESSWD) has five wells in the Evans Creek valley and two reservoirs in the area, providing water for over 10,000 people east of Lake Sammamish.

The Union Hill Water Association and the Sahalee and Bear Creek Golf Courses also rely on large groundwater volumes from the Bear-Evans basin. The City of Redmond, NESSWD, and others are cooperative partners on the *Redmond-Bear Creek Valley Ground Water Management Plan* for water quantity and quality in the region.

Exempt wells also take ground water. These wells provide water for a single home or groups of homes (limited to 5,000 gallons per day) and are excused from needing a state permit. There are approximately 400 exempt wells within a rough estimation of the Bear-Evans watershed (Cook, 2008). The exact amount of exempt well withdrawal is unknown.

The Woodinville Water District imports water into the basin from the South Fork Tolt River watershed, and occasionally from the Cedar River watershed.

Recreational Uses and Aquatic Life Resources

The Bear-Evans Watershed supports many recreational uses. The Bear Creek system exhibits high quality aquatic habitat, salmonid diversity and abundance, and a demonstrated contribution to the regional fishery resource. The fishery resources provide opportunities for both freshwater fishing and salmon fishing in Puget Sound. Cool, well-oxygenated water and an abundance of suitable spawning and rearing areas are needed to sustain and support these important fisheries.

Most of Bear and Evans Creeks and their tributaries are shallow and unsuitable for full-immersion swimming activities, but children love to play in the water. However, many of the lakes are deep enough for swimming. The most noteworthy and accessible to the public is Cottage Lake Park in King County. Although public access to the creeks, lakes, and ponds in the watershed is largely limited to road crossings and a few parks, they are fully accessible to adjacent landowners, their children, and in some cases, their neighbors. Limited boating opportunities exist on the lakes and where Bear Creek meets the Sammamish River.

WA Department of Fish and Wildlife smolt trap on Bear Creek.
Photo: Anne Dettelbach

Potential Pollution Sources

Many human activities impact the natural environment. When activities are done properly, the impact can be managed and surface waters can remain safe and clean. Recognized water quality problems in the basin are fecal coliform bacteria, high water temperatures, and low dissolved oxygen. Ecology identified the following fecal coliform bacteria sources in the Bear-Evans Watershed by looking at monitoring data and available literature; watershed studies; interviewing stakeholders and watershed residents; and surveying the area by driving around (Table 4).

Table 4. Potential sources of bacteria pollution in Bear-Evans watershed.

Source	Explanation
Urban stormwater	Conveys contaminated runoff from roads, parking lots, roofs, roadside ditches, yards, dumpsters and other areas. Sources of contamination include nutrients that may support bacteria re-growth in storm sewers.
Livestock, equestrian and commercial animal handling facilities	Improper management of manure and disposal of animal wastes.
Domestic wastewater/sewage	Potential leakage from municipal sanitary sewer lines and on-site septics; illicit cross-connections to stormwater drainage system.
Domestic pet wastes	Runoff and drainage from dog walks and animal play areas; improper waste management and/or storage practices of domestic pet waste.
Wildlife (including avian)	Excrement from wildlife in the watershed such as beavers, raccoons, and coyotes; and excrement from avian sources associated with wetland areas and stormwater runoff.
Loss of riparian habitat	Not a source in itself, stream buffers with healthy riparian vegetation can help filter and treat pollutants.

Urban Stormwater

Stormwater starts as rainwater and other precipitation and either infiltrates into the ground, which is beneficial, or accumulates and flows over impervious surfaces adding to management problems. Land uses and activities in urban areas, coupled with an increase in impervious surfaces and accumulation of contaminants, typically result in polluted stormwater. Heavy rainfall and runoff wash contaminants off impervious areas, including rooftops, driveways, sideways, parking lots, and roads into storm drains, or directly into streams. Stormwater systems allow pollutants to move quickly from drainage surfaces to local waters. During typical storms, pollutants reach stream systems quickly and in high concentrations. Stormwater flows are erratic and may not be predictable.

Most stormwater that enters streams is untreated and can contain toxic metals, organic compounds, and bacterial and viral pathogens. Urban stormwater can carry bacteria from pet wastes on the ground; failing on-site septic systems; leaky sanitary sewer lines; excess nutrients from lawns and gardens; and pollutants associated with activities such as car washing and sidewalk cleaning. The specific water quality impact of stormwater may be hard to quantify, partly because of the transient nature of storms and the difficulty of storm sampling.

Managing nutrients can help control bacteria levels in storm sewers and in streambeds. Fertilizer runoff, food, grease wastes, and waste wash waters all provide nutrients that could support bacteria growth. Landscaping in the watershed often involves applying chemicals like fertilizers and pesticides to the yard. Fertilizing may cause increased nutrient levels, which are associated with supplying a rich environment for bacteria lining storm drains and adsorbed to organic debris and clays in settled sediments.

Fecal coliform bacteria can survive in sediment by bonding to sediment grains (e.g., clay) or organic matter. This phenomenon has been documented in Puget Sound and is often referred to as "sediment archiving" of bacteria. Fecal coliform has been shown to survive for days to months in sediment (Van Donsel, Geldreich, and Clarke, 1967). Agricultural areas are likely locations where sediment archiving of bacteria has already occurred. The presence and prevalence of sediment archiving in urban streams was not investigated as part of this TMDL study. Local water quality professionals speculate that wash waters and fertilizer runoff could put excessive nutrients to streams and stormwater systems. These nutrients could support bacterial regrowth in sediments and films on stream and pipe surfaces.

In many locations where roads pass along or over the stream, untreated road runoff can enter stormwater drainage systems or wash off directly to the water. The exact sources of bacteria from road runoff are unknown but may be generally due to wildlife, roadside litter, and unsecured loads. Specific best management practices (BMPs) may be appropriate to address roadway stormwater runoff.

Stormwater that is generated within the basin reaches Bear and Evans Creeks through a system of surface ditches and culverts. Forty-three direct pipe outfalls to the creeks were documented during an Adopt-A-Stream Foundation culvert inventory and habitat assessment (AASF, 2004). A dozen or more small catchments (sub-watersheds) located on the city of Redmond's eastside carry tributary stream flow and stormwater runoff directly into the creeks.

No point sources discharge to the Bear Creek system under individual NPDES permits except those covered by stormwater permits. Ecology regulates municipal separate storm sewer system (MS4) dischargers as point sources under Ecology's National Pollutant Discharge Elimination (NPDES) Municipal Phase I and II Stormwater Management Program. The watershed is covered by general municipal stormwater Phase I and Phase II permits (Figure 5), as well as several general permits for sand and gravel, construction, and industrial stormwater. King County, Snohomish County, and WA State Department of Transportation are covered under the Phase I and the cities of Redmond, Woodinville, and Sammamish are covered under Phase II.

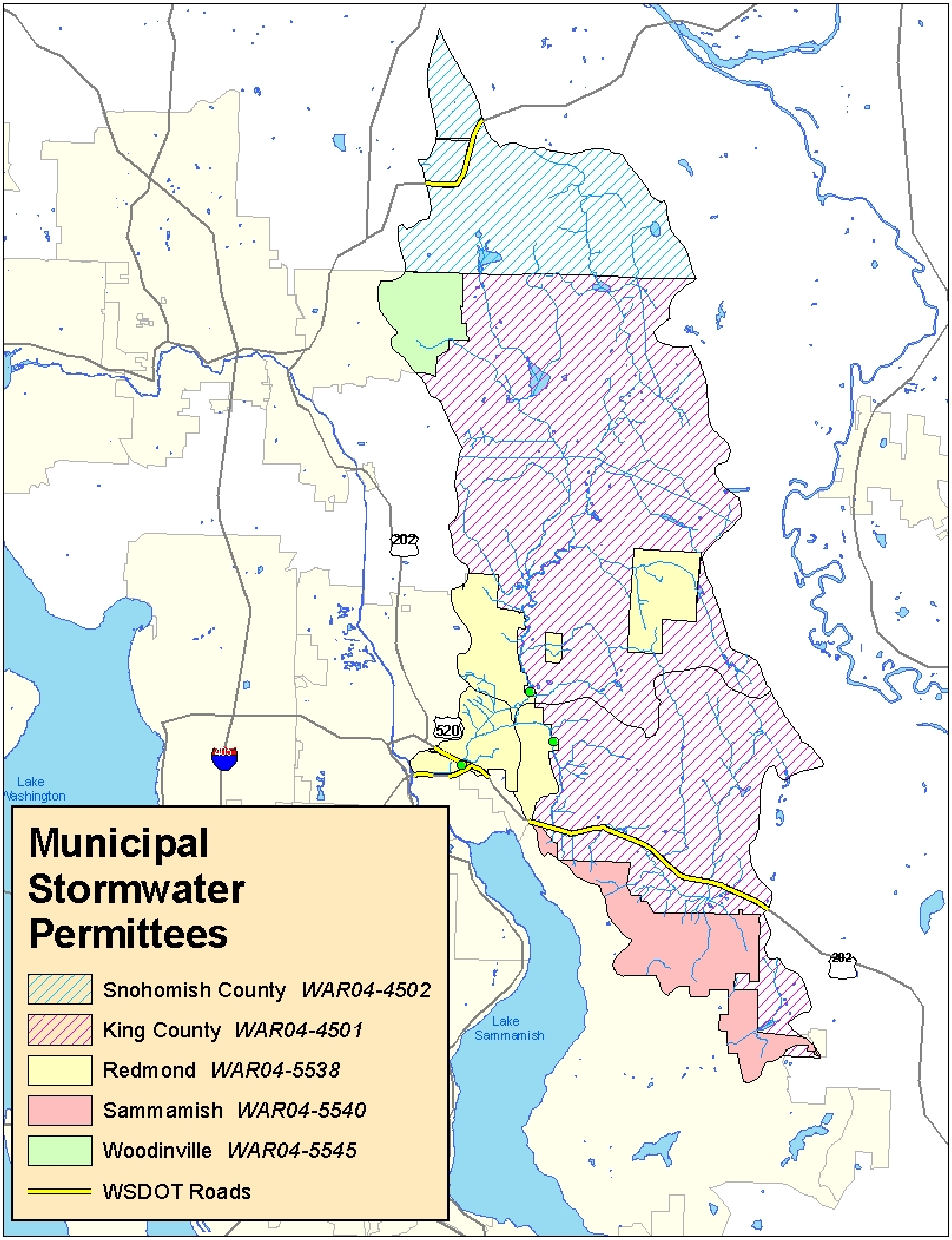


Figure 5. Municipalities (and associated permit IDs) covered under NPDES stormwater permits within the Bear-Evans Watershed. WSDOT's permit ID will be issued in late 2008.

Livestock, Residential Equestrian Facilities, and Commercial Animal Handling Facilities

Many small farms and horse stables exist in Cottage Lake Creek and upper Bear Creek sub-basins. There are at least a dozen horse boarding and training facilities in the Bear-Evans Watershed (Figure 6). Animal kennels and horse boarding facilities are not directly regulated by the Snohomish Health District, Public Health Seattle-King County or the Department of Ecology unless they violate water quality regulations. Veterinary offices, animal kennels, and other commercial animal handling facilities generate significant amounts of animal wastes as a byproduct of boarding and other services. How much these wastes contribute is unknown. If present in the watershed, these businesses must properly manage animal wastes in order for this water cleanup effort to succeed.

Overused horse area near stream.
Photo: Mary Maier

Removal of forested riparian corridors to provide pasture and unrestricted water access for livestock were main factors contributing to fecal coliform bacteria contamination in the early years. Dairy waste runoff and livestock access from dairy farms was observed along Bear and Evans Creeks at their confluence (King County, 1989). Dairies no longer exist in the basin but numerous small farms with livestock do. Today, many landowners in the basin are new to owning agricultural properties and lack knowledge or background in how to successfully manage livestock on smaller acreages. Pasture land for agriculture and small livestock was observed along Mink Road near upper Bear Creek.

The majority of land dedicated to caring for horses is usually associated with homeowners and their personal stables. For budgetary and other reasons, residential horse owners frequently have limited area for grazing and exercise. Thus, many times horses live in wooded conditions or are confined to small outdoor paddocks where grass and vegetation is quickly consumed or destroyed. Manure deposited by animals frequently finds its way into natural drainage corridors and can become a source of water pollution.

There are extensive trails and parks in the basin that support equestrian recreation. About 60 miles of horseback riding trails exist in addition to private tracks and pastures. The city of Redmond has a soft surface trail for horseback riding within the Farrel-McWhirter Park. Mackey Creek, tributary to Bear Creek, passes through the park which has muddy pastures with several horses, ponies and goats. Redmond/Puget Power Trail crosses over Bear Creek and links Sammamish River Trail to Farrel McWhirter Park. Tolt Pipeline Trail (15 miles) also crosses over Bear Creek. It extends from the Sammamish River Trail south of Woodinville to Snoqualmie Valley Road over the Tolt Pipeline corridor. There is a new riding area in Kathryn Taylor Park at the north end of the Trilogy Redmond Ridge development along the Tolt Pipeline.

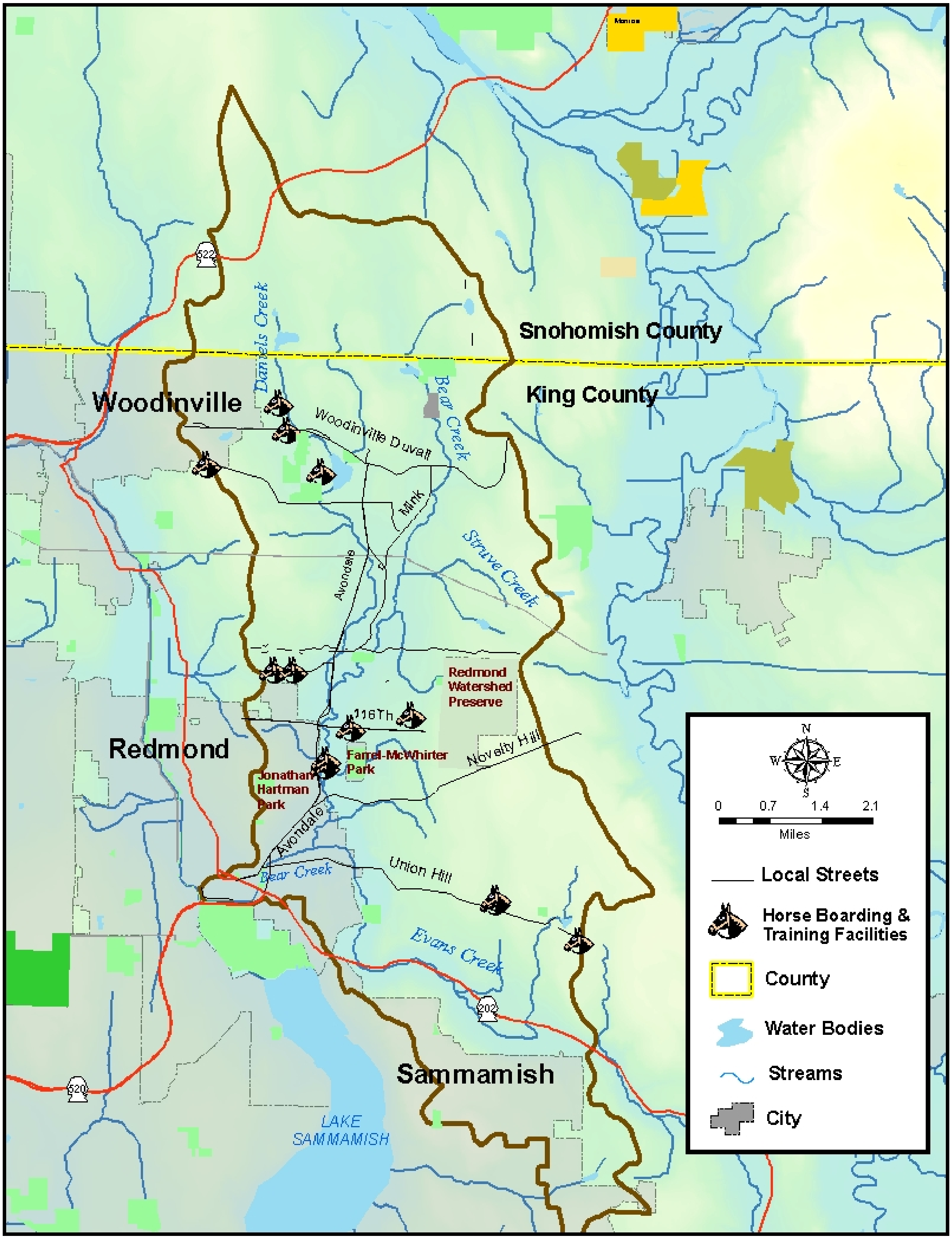
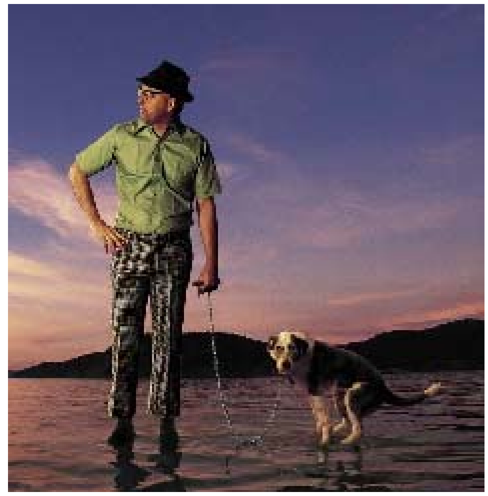


Figure 6. Horse boarding and training facilities in Bear-Evans Watershed.

Domestic Pet Waste



In the urban watershed, dogs are significant contributors of bacteria and may also contribute a substantial amount of nutrients. Pet wastes generated both at individual homes and public areas such as parks, trails, and playgrounds may contribute fecal coliform to creeks or other areas that ultimately drain to creeks.

Microbial source tracing (MST) studies use DNA ribotyping methods to identify sources of fecal coliform bacteria. Such studies consistently show the presence of fecal coliform bacteria from dogs and cats in streams and creeks in urban and suburban Puget Sound streams.

Domestic Wastewater/Sewage

Wastewater from showers, toilets, and sinks is defined as "domestic wastewater." Domestic wastewater is generated in private residences or commercial businesses and is either treated by onsite septic systems or is conveyed to a wastewater treatment facility through a regional sewage conveyance system. Domestic wastewater typically contains high levels of fecal coliform bacteria.

Regional Conveyance Systems

Centrally conveyed sewage could enter surface waters under several scenarios: sanitary sewer line breakages, illicit cross-connections to stormwater sewers, or overflows. These can be significant sources of fecal coliform contamination (with concentrations in the tens of thousands of bacteria colonies per 100 mL) and pose great human health risk to people in contact with the water.

There are several possible scenarios that leaky sewer lines might pollute local surface waters. One possible way is when a leaky force main or gravity sewer in close proximity to surface water. For sewer systems that rely on gravity to ensure good flow, the favorable natural grade adjacent to a stream makes it a practical place to locate lines at relatively economical cost. Leaky joints due to shifting earth, line deterioration, or improper installation could lead to leakage to a local stream in these situations. Sewer system breakdowns or illegal cross-connections are generally corrected as soon as they are detected.

Most of the incorporated area of the cities of Redmond, Sammamish, and Woodinville are on sanitary sewer systems (Figure 7). Redmond's Public Works Department provides sewer service roughly the area east of 132nd Avenue N.E., south of N.E. 124th Street, west of 196th Avenue N.E., north of N.E. 20th Street, and specifically excluding Marymoor Park and Lake Sammamish. In addition, the city covers the Novelty Hill Service Area east of 196th Avenue N.E., south of Novelty Hill Road and east of 212th Avenue N.E., north of Novelty Hill Road.

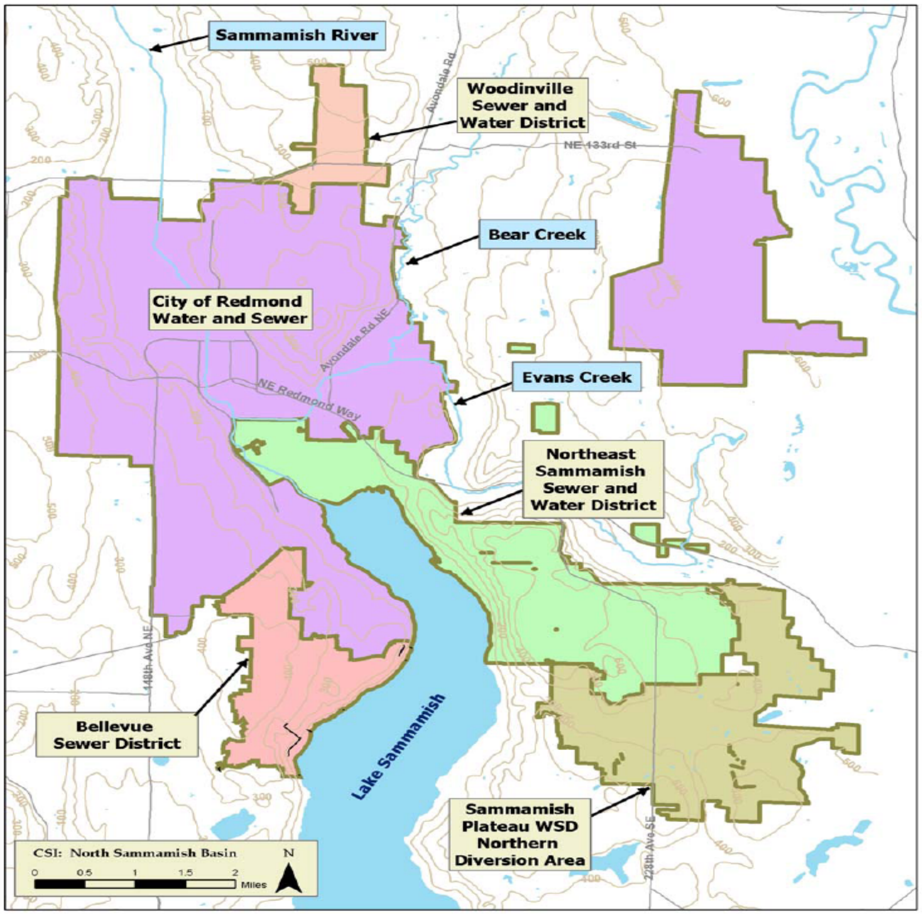


Figure 7. King County DNR map of sewer service providers in and near Bear-Evans Watershed (King County, 2003).

Northeast Sammamish Sewer and Water District (NESSWD) serves mostly the city of Sammamish. The sewer system encompasses an area of approximately 5.25 square miles with about 4,657 connections serving approximately 14,500 people east of Lake Sammamish. The District's sewer system collects the sewage and conveys it to King County Metro through a sewer forcemain on Redmond-Fall City Road and a sewer interceptor on East Lake Sammamish Parkway. Metro provides all treatment of the sewage. The sewer system consists of nine lift stations, 55 miles of sewer main and 1,395 manholes. The district maintains the "sewer lift station" at 50th near Evans Creek. The station experienced problems with sewage overflow into the creek in the past. After NESSWD constructed a larger capacity around 2002, no sewage overflows have occurred. This correction most likely contributed to the lower levels of fecal coliform bacteria seen in recent years at station S484 in upper Evans Creek at 50th.

Woodinville Water and Sewer District provides sanitary sewer service to all customers requesting service of the district who are located within the urban growth area as established by King County. The district presently is the fifth largest sewer district in King County, serving approximately 2,500 customers. Future predictions state that there may be 25,000 sewer and water connections by the year 2020.

Onsite Septic Systems

Onsite septic systems (OSSs), both community-based and individual systems, are not a problem when designed, sited, and operated properly. A properly functioning OSS uses the soil surrounding the drainfield to remove bacteria and some nutrients from the wastewater. However, soil compaction, clogging of the soil with solids, plant roots, and hydraulic overload can all cause a failure of the system to adequately treat wastewater. If there are signs of odors, surfacing sewage, wet spots, or lush vegetation in the drainfield area, then it is possible that this surfacing wastewater could go directly to a nearby stream, or it could be carried there when it rains and water travels over the land surface. Other signs of OSS failure include plumbing or septic tank backups; slow draining fixtures; and gurgling sounds in the plumbing system.

Connecting septic systems to stormwater sewers or piping them directly to surface waters is occasionally discovered and is illegal. Another problem observed in some older septic systems is the subsurface movement of wastewater through extremely porous soils. This latter problem can be difficult to detect.

There are still many parcels within the city of Redmond that are currently serviced by septic tanks. Within the city of Sammamish, there are still on-site septics near Lake Sammamish and in the Evans Creek sub-basin. On-site septics can also be found in unincorporated King County portion of the basin.

Wildlife

Wildlife contributes bacteria to surface waters at typically low natural levels and this is not considered pollution. In those cases where man-caused alterations of the natural environment have increased wildlife levels, their contributions may be considered a source of pollution. Some practices such as unkempt dumpster areas, littered parking lots or grass lawns along shorelines can attract birds and other wildlife, and cause excess bacteria loading.

Bears, cougars, bobcats, pileated woodpeckers, western redback salamanders, deer, coyotes, beavers, and many other species of wildlife have been observed in the Bear-Evans watershed.

Loss of Riparian Habitat

Riparian habitat (streamside buffers) plays a valuable role in water quality. Adequately sized and healthy riparian buffers help filter and treat a variety of pollutants, including fecal coliform bacteria and substances, that can lead to the depletion of oxygen in streams. The Puget Sound Lowland Study (May et al. 1997) found that a key determinant of the biological integrity of a stream appears to be the quality and quantity of the riparian zone available to buffer the stream ecosystem from adverse effects in the watershed.

Much of the wooded stream buffers in the Bear-Evans watershed were removed to create lawns, establish pasture or cropland, or to make room for development. The riparian corridor in many reaches of the basin is reduced or totally cleared right up to the stream edge. The removal of large riparian vegetation reduces the capability of stream buffers to infiltrate pollutants before reaching the streams.

During the Adopt-A-Stream Foundation culvert barrier assessment and pollution identification project, the most common form of non-point source pollution observed was associated with degraded riparian conditions (AASF, 2004). This included lack of native riparian vegetation, the presence of invasive plants, and landscaping to the ordinary high water mark. Restoring streamside buffers where feasible will help improve water quality.

Lack of mature streamside buffers can lead to eroded streambanks. Photo: Mary Maier

Ecology staff measuring streamflow on Bear Creek. Photo: Anne Dettelbach

Goals and Objectives

Project Goal

As the first steps to improve water quality in the Bear-Evans Watershed, Ecology assesses the pollution problem, establishes numeric targets for reaching cleaner water, and starts working with partners to identify the actions needed to improve the water quality. The overall goal of this TMDL effort is to achieve state water quality standards for fecal coliform bacteria in the watershed by December 2015.

Study Objectives

- Assess the long-term trends, current conditions, and seasonal variation of fecal coliform bacteria levels in Bear, Evans, and Cottage Lake Creeks.
- Establish the percent reduction goals of lowering current bacteria loadings to meet standards in the creeks during critical flow conditions.
- Establish the loading capacity of the creeks to receive fecal coliform bacteria without exceeding standards under various flow conditions.
- Establish bacteria load allocations for nonpoint sources and wasteload allocations for point sources as portions of the loading capacities in the creeks.

Appendix C describes the data sources, methods of collection, and data quality used in this technical analysis.

Results and Discussion

Long-term trends

For over 30 years, patterns of fecal coliform bacteria levels in Bear, Evans, and Cottage Lake Creeks varied among the monitoring stations but showed an overall trend of decreasing bacteria concentrations. This general trend was especially evident near the mouth of Bear Creek since 1994 (Figure 8). The reasons for the decline could partly be attributed to the changes in land use from predominantly agriculture/farming to a more sub-rural/urban landscape, particularly in the lower Bear Creek basin. Upstream stations along Bear Creek and Cottage Lake Creek show relatively steady fecal coliform bacteria levels from 1994 to 2007.

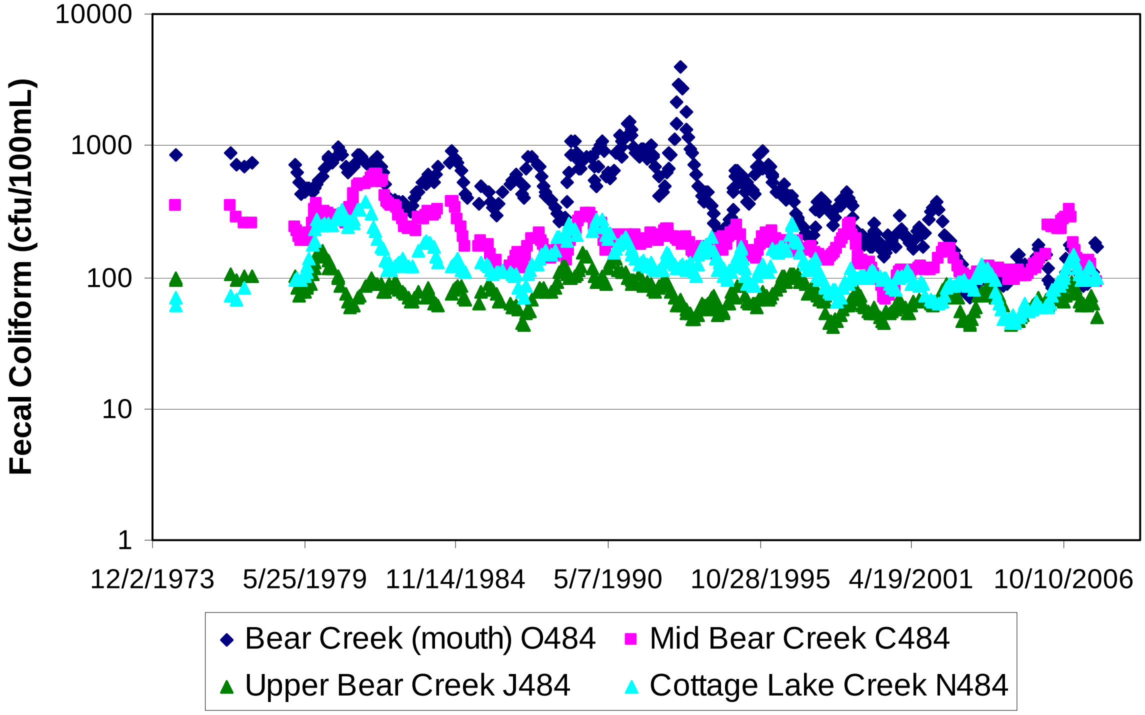


Figure 8. Long-term trends in fecal coliform bacteria levels along Bear Creek and Cottage Lake Creeks. Data plotted are 12-sample rolling geometric mean values. Red dotted line indicates geometric mean standard of 50 cfu/100mL.

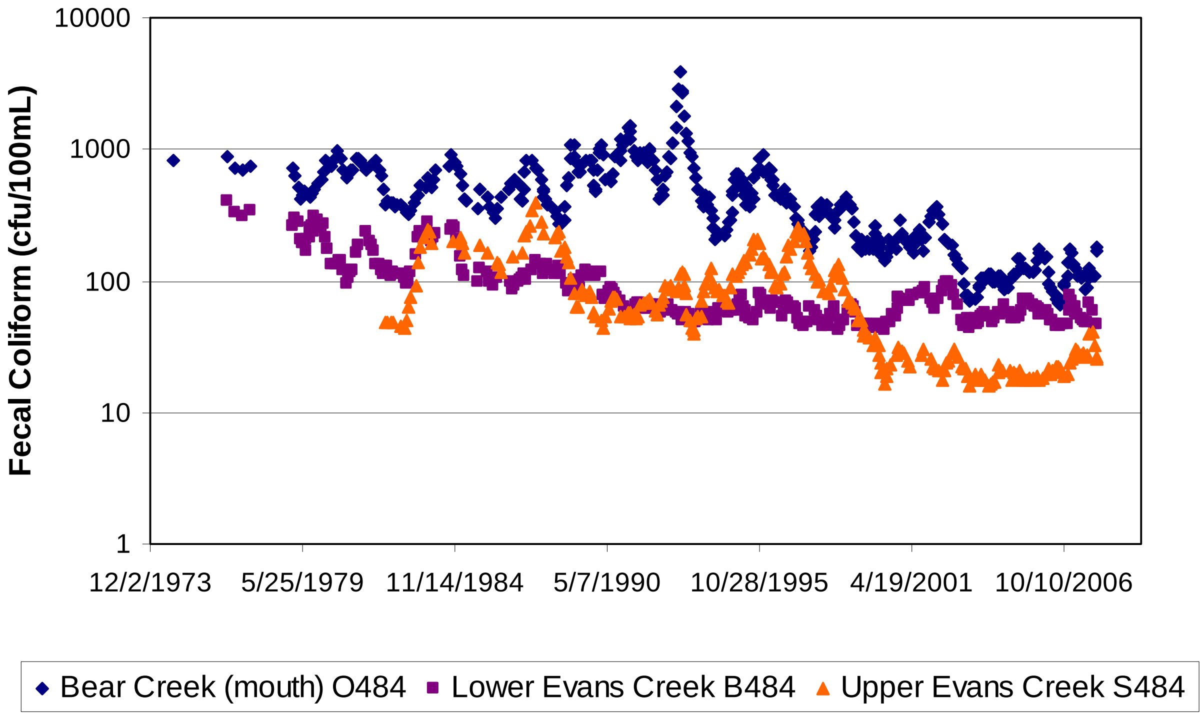


Figure 9. Long-term trends fecal coliform bacteria along Evans Creek compared to lower Bear Creek near the mouth. Data plotted are 12-sample rolling geometric mean values. Red dotted line indicates geometric mean standard of 50 cfu/100mL.

In more recent years, fecal coliform bacteria levels in the Evans Creek branch of the watershed were lower than the Bear Creek branch (Figure 9). The three stations on the Bear Creek branch (C484, N484, J484) fluctuated within a consistent range for the entire period of record without any pronounced trends. In contrast, water quality improved in Evans Creek (B484 and S484). Fecal coliform bacteria levels in lower Evans Creek (B484) declined before stabilizing in geometric mean concentrations around 1992. Upper Evans Creek (S484) shows a dramatic drop in concentrations after 1996, with recent years meeting the geometric mean standard of 50 cfu/100 mL.

Current conditions and seasonal variation

To properly assess the current water quality conditions (Table 5), Ecology used the most recent and stable period of fecal coliform bacteria data for each monitoring station:

- 2000-2007 data from Bear Creek near the mouth (O484) and upper Evans Creek (S484)
- 1993-2007 data from Cottage Lake Creek (N484), lower Evans Creek (B484), and upper and mid Bear Creek (J484 and C484).

Monitoring of water quality at the unnamed tributary to Bear Creek (35) began in 2001. Ecology analyzed these data sets to see if the creeks comply with the state's standards–geometric mean limit (GMV) of 50 cfu/100 mL and the 90th percentile limit of 100 cfu/100 mL–on a seasonal and annual basis (Table 5).

As shown earlier, more than three decades of data show a varied pattern of bacteria levels among the main monitoring stations along Bear, Evans, and Cottage Lake Creeks. All sites, including the unnamed tributary to Bear Creek (35), exceed the state's standards on a seasonal basis (Table 5). All stations except upper Evans Creek (S484) exceeded standards during both wet (October through April) and dry (May through September) seasons. Only upper Evans Creek (S484) met standards on an annual basis. The 90th percentile limit was exceeded more than the geometric mean limit.

Table 5. Current water quality conditions and target bacteria reductions in Bear, Cottage Lake, and Evans Creeks**.** The analysis used 1993 to 2007 data for sites C484, J484, N484, B484; 2000 to 2007 data for sites S484 and O484; and 2001 to 2007 for site 35. Number of samples used in statistical analysis is in parenthesis.

Water Body/Station ID		**Current Conditions** (cfu/100 mL)							
		Wet Season (Oct - Apr)			Dry Season (May – Sept)			Annual	
		GMV	90th %tile	# Samples (n)	GMV	90th %tile	# Samples (n)	GMV	90th %tile
Bear Creek Sub-Basin									
Cottage Lake Creek	N484	72	725	(115)	160	443	(78)	99	372
Bear Creek (upper)	J484	45	126	(108)	108	252	(74)	64	194
Unnamed tributary	35	69	366	(26)	415	2725	(20)	150	1220
Bear Creek (mid)	C484	95	328	(113)	243	559	(79)	121	465
Evans Creek Sub-Basin									
Evans Creek (upper)	S484	13	48	(54)	49	163	(33)	22	99
Evans Creek (lower)	B484	36	128	(108)	116	308	(73)	58	227
Whole Bear-Evans Watershed									
Bear Creek (mouth)	O484	88	491	(66)	251	905	(46)	136	729

Ecology also evaluated streamflow data collected at a King County gauge (2004a) to further describe the current water quality in Bear Creek near the mouth (O484). Figures 10-11 display the general relationships between average monthly streamflows and bacteria levels (concentration and loadings) at this site. During the dry season, concentrations (cfu per 100mL) are highest and rise far beyond standards when dilution is less and conditions are warm and better for fecal coliform bacteria survival or growth. However, during the wet season, total fecal coliform loadings (bacteria colonies per day) are highest when more stormwater runoff carries greater numbers of fecal coliform bacteria into the creek. The higher flows potentially resuspend the fecal coliform bacteria in the sediments.

During the wetter months of the year, bacteria loadings to Bear Creek near the mouth increase by approximately 50 percent. However, the higher streamflows during those months could dilute the bacteria concentrations (Figure 10). This may explain why concentrations decline in the wet season at all stations. However, dilution is not high enough to return waters to standards except for upper Evans Creek (S484) (Table 5). The "first flush" of pollutants into streams by stormwater runoff during first heavy rains of the wet season may explain the November peak loads at Bear Creek near the mouth (Figure 11). Decreasing average loads from December through March may be due to many possible factors: lower in-stream bacteria regrowth, washing of land surfaces over time, or seasonal change in livestock access to the creeks.

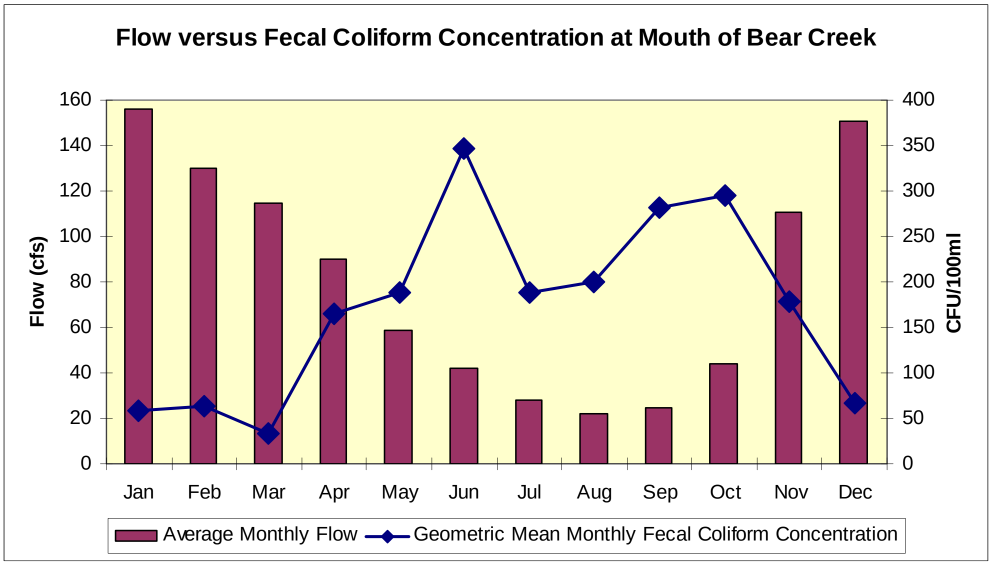


Figure 10. Comparison of fecal coliform concentrations and average monthly flows near mouth of Bear Creek (station O484). Streamflow data collected at King County gage station 02a.

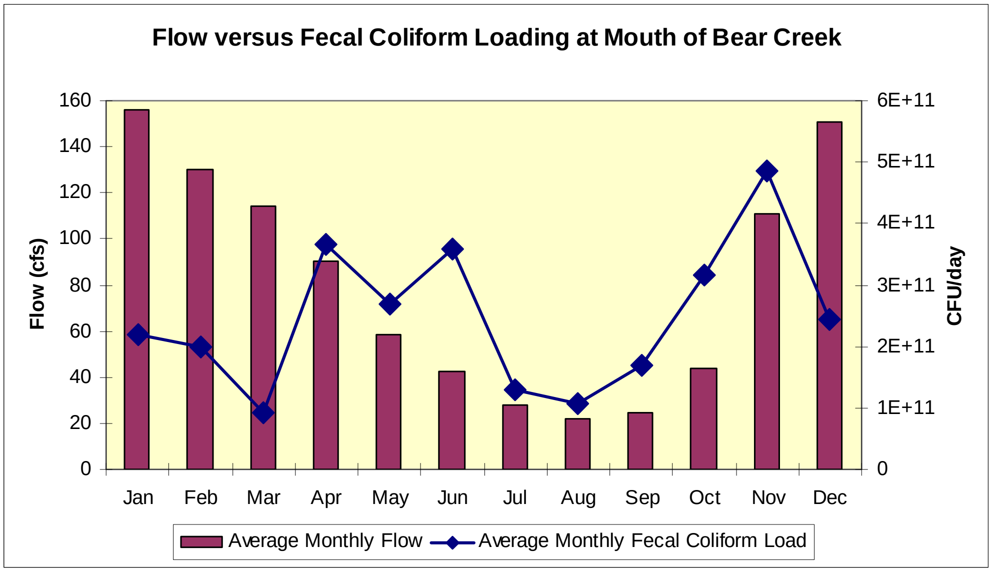


Figure 11. Comparison of fecal coliform loadings and average monthly flows near mouth of Bear Creek (station O484). Streamflow data collected at King County gage station 02a.

Critical flow conditions and percent reduction goals

Knowing how much bacteria enters the creeks on a daily basis provides an extra tool for understanding the distribution of bacteria in the watershed. Bacteria loadings (number of bacteria colonies per day) can tell us changes in the degree of potential fecal coliform sources between sites along a stream, or between seasons and flow conditions at a site. However, fecal coliform sources can vary greatly and different sources can cause standard violations under different loading scenarios (e.g., poor dilution of contaminated sources during low-streamflow conditions or increased source loading during storm run-off). Therefore, it is also necessary to look at bacteria concentration to determine compliance with state standards. In this TMDL, Ecology used both measures to explain the TMDL goals for reaching cleaner water. Looking at either the daily loading of bacteria to the creeks, or the concentrations in a set of representative samples, the percentage reduction needed is the same.

Because Washington State's standards for bacteria have two parts, Ecology needs to quantify how large the reduction would be to achieve the in-stream geometric mean bacteria limit of 50 cfu/100 mL with no more than 10 percent of the samples above 100 cfu/100mL. Seasonally and annually, meeting the upper 90th percentile limit of 100 cfu/100mL is typically tougher, and therefore more restrictive, than meeting the geometric mean limit. Therefore, Ecology establishes the percent reduction goals based on meeting this more restrictive upper 90th percentile criterion.

Bacteria loadings directly relate to streamflows. Ecology characterized the bacteria loadings under five flow conditions: high flows, moist conditions, mid-range flows, dry conditions, and low flows (See Appendix E). The flow condition during which current fecal coliform bacteria loads need the greatest reduction to meet the 90th percentile criterion is defined as the 'critical flow condition'. This is when the greatest current fecal coliform bacteria problem exits.

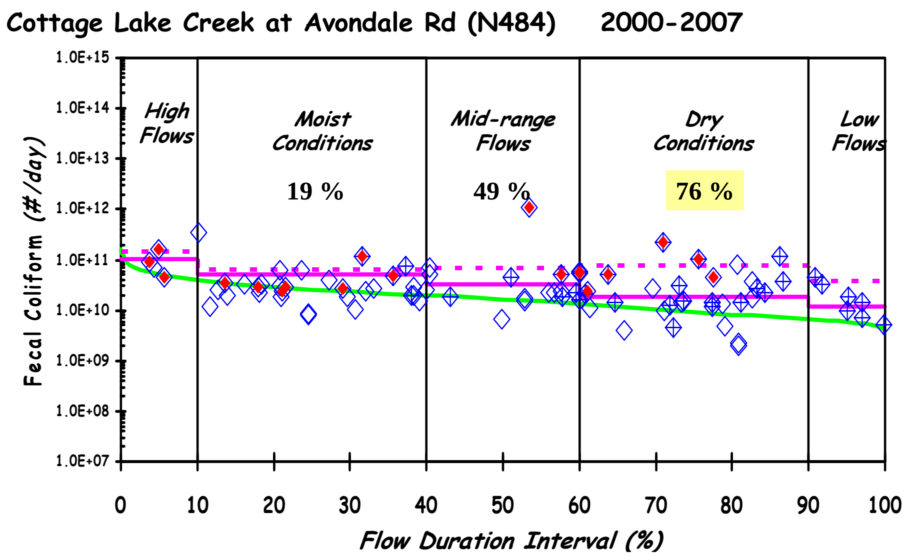
The percent reduction needed during the critical flow condition was chosen as the TMDL goal for the stations along the main branches of Cottage Lake Creek and Evans Creek and the mainstem of Bear Creek (Table 6). For the unnamed tributary to Bear Creek (station 35) where no streamflow data exists or can be estimated, the critical condition is defined by the season. The unnamed tributary requires a 96 percent reduction in the critical dry season (May-September).

The percentage reduction goals estimate the degree the stream exceeds the more restrictive 90th percentile limit. As a rule of thumb, areas of the watershed that require aggressive reductions in fecal coliform sources will have a high percentage reduction goal (greater than 60 percent), while areas with minor problems will have a low fecal coliform percentage reduction value (less than 30 percent). But we expect to see big reductions even when correcting one big bacteria source, such as a failing on-site septic system.

Table 6. Critical conditions and percent reduction goals in the Bear-Evans Watershed. Percent reductions are based on reaching the 90th percentile criterion of 100 cfu/100mL from the current levels. Station 35 on unnamed tributary to Bear Creek has a seasonal critical condition due to lack of flow data at this location. For all other stations, critical condition is defined by as a flow range.

Stream Location	Station	Critical Condition	Reduction Goal (%)
Bear-Creek Sub-Basin			
Cottage Lake Creek	N484	Dry flows	76%
Bear Creek (upper)	J484	Dry flows	57%
Unnamed tributary	35	Dry season	96%
Bear Creek (mid)	C484	Dry flows	78%
Evans Creek Sub-Basin			
Evans Creek (upper)	S484	Dry flows	91%
Evans Creek (lower)	B484	Mid-range flows, Dry flows	63%, 62%
Whole Bear-Evans Watershed			
Bear Creek (mouth)	O484	Mid-range flows	88%

Plotting fecal coliform bacteria data as loadings distributed across all flow conditions can provide insight into potential types of bacteria sources (Figure 12-14). Each plot displays the bacteria loads calculated from recent years of water quality data and the daily average streamflow on the sample date. Loads that plot above the green ‘loading capacity’ curve contribute to violating the geometric mean limit of 50 cfu/100mL, while those below the curve contribute to compliance. To characterize wet-weather concerns, Ecology assumes fecal coliform bacteria loads associated with any one-day increase in streamflow above 50 percent result from storm runoff. These ‘stormflow’ bacteria loads are depicted as red diamonds in the plots.



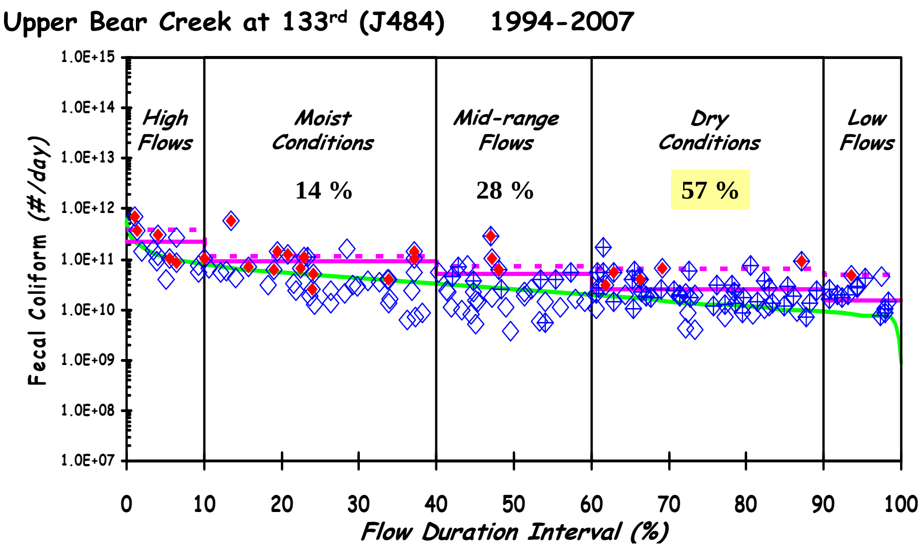
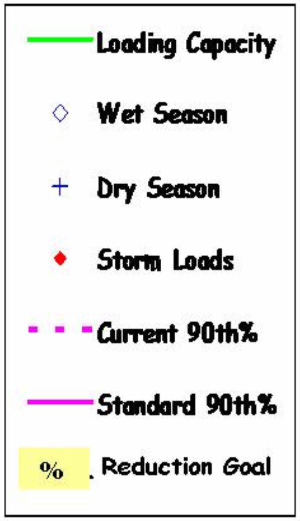
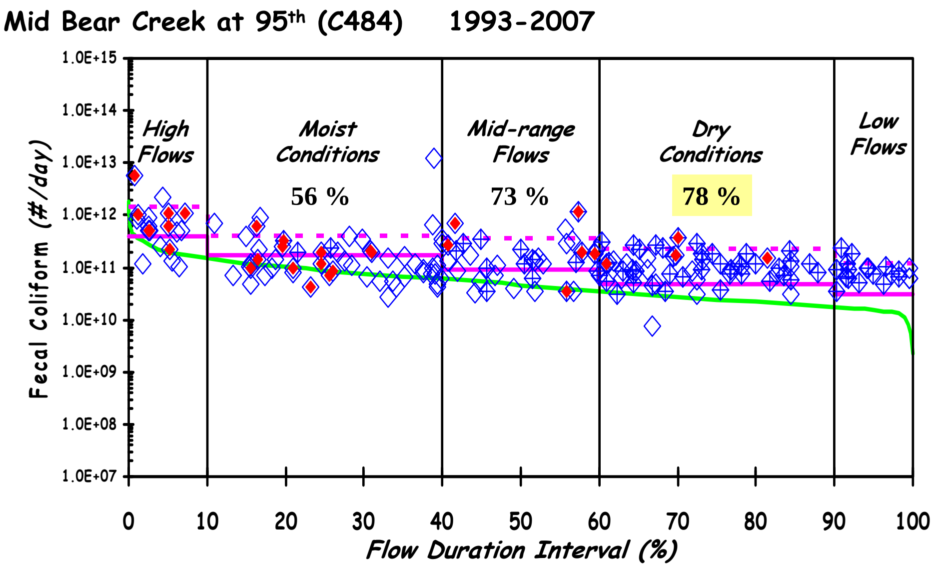


Figure 12. Fecal coliform bacteria loadings across all flow ranges in Bear Creek Sub-basin: Cottage Lake Creek (N484), upper and mid-Bear Creek (J484, C484). The green curve is the loading capacity based on meeting the geometric mean concentration of 50 cfu/100mL. Percent reductions are based on meeting the 90th percentile concentration of 100 cfu/100mL.





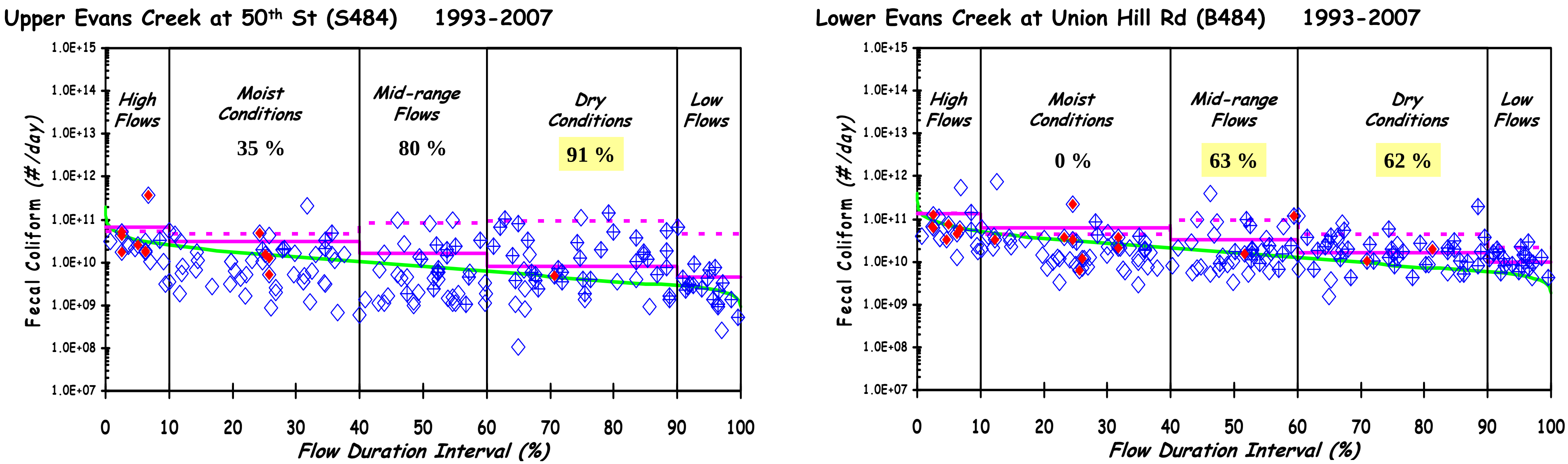


Figure 13. Fecal coliform bacteria loadings across all flow ranges in Evans Creek Sub-basin: lower and upper Evans Creek (S484, B484). The green curve is the loading capacity based on meeting the geometric mean concentration of 50 cfu/100mL. Percent reductions are based on meeting the 90th percentile concentration of 100 cfu/100mL.

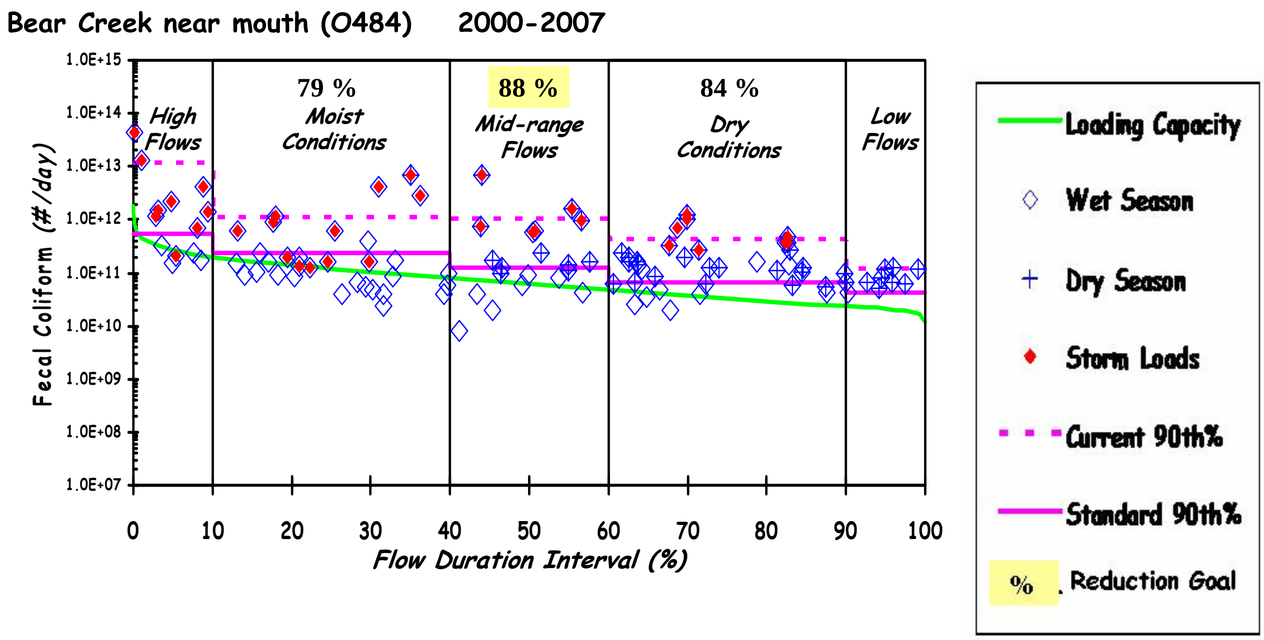


Figure 14. Fecal coliform bacteria loadings across all flow ranges in Bear Creek near the mouth (O484). The green curve is the loading capacity based on meeting the geometric mean concentration of 50 cfu/100mL. Percent reductions are based on meeting the 90th percentile concentration of 100 cfu/100mL.

Bear Creek near the mouth has a critical mid-range flow condition (Figure 14). Most of the stormflow loads and dry season loads contribute to non-compliance at this site. So this site needs large reductions in bacteria sources under moist and dry conditions as well. The bacteria load conditions here represent cumulative impacts throughout the watershed from all upstream areas. Since the lower Evans Creek (B484) (Figure 13) shows no problems under moist conditions (0 percent reduction needed), there could be significant increase in bacteria sources from surface runoff between that upstream station and the mouth of Bear Creek.

Most of the stations show critical conditions during dry flows. Particularly for Cottage Lake Creek at Avondale Road (N484) and upper Bear Creek at 133rd (J484), dry conditions result in bacteria exceedances much greater than in the other flow regimes (Figure 12). Whereas for mid Bear Creek (C484) and Evans Creek (B484, S484), much of the loads contribute to non-compliance during mid-range flows and dry flow conditions. Comparison of these critical flow conditions suggests the presence of continuous sources that become more concentrated at low flows or other nonpoint sources, e.g., access by wildlife or livestock, pet waste dumping, or malfunctioning on-site sanitary systems. It is important to note that fecal coliform sources from surface runoff can still occur during these critical conditions, as depicted by the storm flow loads in Figures 12-14.

For these reasons, it is necessary to establish a TMDL for fecal coliform in the Bear-Evans watershed that especially targets the critical flow conditions for water quality improvement. To meet standards near the mouth of Bear Creek (O484), it will take an 88 percent reduction in current bacteria loadings from upstream sources to the watershed.

Since Ecology expects the necessary best management practices (BMPs) are the same year round, the TMDL percent reduction targets apply year round. Reductions are needed throughout the year and depend on the flow conditions. The more stringent percent reduction goal for each station occurs during the most critical flow condition.

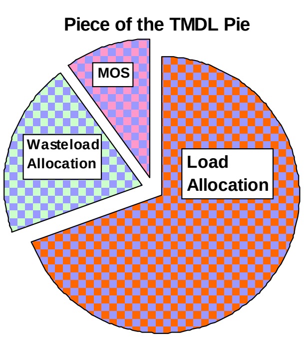
Ecology anticipates that if state and local coordination proceed as expected and effective BMPs can be identified and implemented, by December 2015 each of the sampling stations within the watershed will show that the watershed is in compliance with the state extraordinary primary contact recreation standards. An interim target of compliance with the primary contact standards should be achieved by 2012.

TMDL Analysis

Overview of analytical framework

In doing this TMDL study, Ecology aims to achieve state water quality standards for fecal coliform bacteria in the Bear-Evans Watershed. As part of this process, Ecology must set limits on how much fecal coliform bacteria a creek can receive each day and still meet standards. This is the Total Maximum Daily Load (TMDL), also known as the "loading capacity", the total number of bacteria colonies in the creek that can pass by a monitoring station over the course of a day.

Using the EPA (2007) Load Duration Curve Approach, Ecology established the daily loading capacity based on complying with the geometric mean standard of 50 cfu/100 mL under five different streamflow conditions. Loading is calculated from the fecal coliform concentration and streamflow data at a location (See Appendix D for loading capacity equation). Ecology established loading capacities at the six King County monitoring stations along Bear, Evans, and Cottage Lake Creeks, where streamflow data exists or can be estimated (See Appendix C for flow data sources). The loading capacity is displayed as the green curve in Figures 12-14 and changes as the allowable bacteria load varies with streamflow. With higher streamflows, the creek can handle greater bacteria loadings before exceeding the standards.



Based on the TMDL or loading capacity, Ecology gives sources in the drainage area of each monitoring station a piece of the total TMDL 'pie'. Ecology groups all nonpoint sources together into a category called the 'load allocation (LA)'. Combined point sources create the wasteload allocation (WLA) category. Ecology reserves a portion of the pie as a "margin of safety" (MOS) to account for uncertainties in our analysis. Taken together, the allocations and the margin of safety must not exceed the total loading capacity for each drainage area as measured at the monitoring station.

TMDL (Loading Capacity) = LA + WLAs + MOS

All pollution sources that have a National Pollution Discharge Elimination System (NPDES) permit are point sources. Ecology issued NPDES permits to six municipal separate storm sewer systems (MS4s) in the watershed. No industrial stormwater discharges that could potentially discharge fecal coliform bacteria pollution were found to be a significant problem in this basin. Stormwater from future industrial sources must meet water quality standards at end of their discharge pipe.

To determine how much bacteria come from point and nonpoint sources when it rains, Ecology first uses the land-use-based Simple Method Model to estimate the relative contributions from the individual MS4s and nonpoint sources. Then, using data from the Load Duration Curve analysis, we determined how much of the total observed bacteria loadings to the creek occurred during stormflow conditions. We adjusted the final relative load and wasteload allocations in the model based on the percentages of the observed stormflow loads and non-stormflow loads. Non-stormflow loads are assumed to be associated with only nonpoint sources.

See Appendix E for a detailed analytical framework.

Estimated loading capacity (or TMDL)

Ecology expresses the loading capacity at monitoring stations along Bear, Evans, and Cottage Lake Creeks as the green loading capacity curves in Figures 12-14. The 50 cfu/100 mL criterion was used to set the target because it is the standard that must be met on a daily basis. The loading capacity is expressed as a curve because the allowable bacteria load varies with streamflow. For Bear Creek near the mouth (O484), the loading capacity ranges from 1.15×10^{10} to 1.84×10^{12} bacteria colonies per day depending on flow. The approach for distributing this loading capacity or TMDL pie into load and wasteload allocations is discussed in Appendix E.

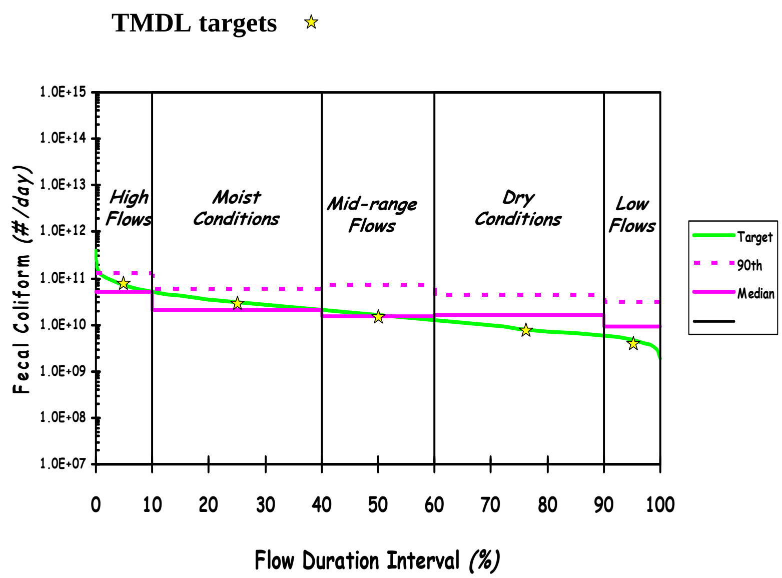


Figure 15. Under each flow range, the TMDL or loading capacity target is set as the midpoint on the green loading capacity curve.

Estimated load and wasteload allocations

Bacteria loads can vary greatly due to ever-changing flows, the tendency of bacteria to attach to particles, and the natural variability in bacteria numbers. Thus, it is difficult to assign and track fixed allocations for sources. Instead, Ecology recommends allocations that express the reduction of bacteria needed under flow conditions.

Expressed numerically (Tables 7-9), load and wasteload allocations are percentages of the loading capacity targets under different flow regimes (Figure 15).

Ecology set general load allocations (LA) for nonpoint sources and specific wasteload allocations (WLA) for point sources, and also a margin of safety (MOS). The margin of safety accounts for uncertainty in the estimates. No attempt was made to allocate fecal coliform loads separately among nonpoint sources. During times when storm runoff does not occur, the load allocation for nonpoint sources shall equal the total loading capacity minus the margin of safety. Such nonpoint sources can include direct runoff from streamside backyards, failing septic tanks, improperly managed animal wastes, excessive concentrations of wildlife, and perhaps leaky sewer lines.

Because stormwater can contain high levels of fecal coliform bacteria, communities regulated under the NPDES permits for municipal separate stormwater sewer systems (MS4s) in this watershed receive WLAs for bacteria. These WLAs vary according to flow and reflect allowable bacteria loads during stormflow conditions.

Table 7 (a-c). Daily load and wasteload allocations for stations in the Bear Creek Sub-Basin: Cottage Lake Creek (N484), Upper Bear Creek (J484), and Mid Bear Creek (C484).

[a] Cottage Lake Creek (Above Station N484)
Targets a 76% reduction in current bacteria loadings.

			Bacteria Loadings (billion colonies per day)				
			High flows	Moist flows	Mid-range flows	Dry flows	Low flows
TMDL (Loading Capacity Targets)		100%	**51.20**	**25.60**	**16.40**	**9.18**	**5.90**
		Allocations (%)					
MOS		10%	5.12	2.56	1.64	0.92	0.59
LA		51.53%	26.40	13.20	8.47	4.73	3.04
WLAs	**Woodinville**	6.51%	3.34	1.67	1.07	0.60	0.38
	King Co.	17.82%	9.13	4.56	2.93	1.63	1.05
	Snoh Co.	13.07%	6.70	3.35	2.15	1.20	0.77
	WSDOT	1.13%	0.58	0.29	0.19	0.10	0.07

[b] Upper Bear Creek (Above Station J484)
Targets a 57% reduction in current bacteria loadings.

			Bacteria Loadings (billion colonies per day)				
			High flows	Moist flows	Mid-range flows	Dry flows	Low flows
TMDL (Loading Capacity Targets)		100%	110.00	46.70	25.30	13.00	7.40
		Allocations (%)					
MOS		10%	11.00	4.67	2.53	1.30	0.74
LA		56.19%	62.00	26.30	14.20	7.28	4.16
WLAs	**King Co.**	27.43%	30.02	12.80	6.94	3.55	2.03
	Snoh Co.	6.38%	7.03	2.98	1.61	0.83	0.47

[c] Mid Bear Creek (Above Station C484)
Targets a 78% reduction in current bacteria loadings.

			Bacteria Loadings (billion colonies per day)				
			High flows	Moist flows	Mid-range flows	Dry flows	Low flows
TMDL (Loading Capacity Targets)		100%	197.00	87.80	46.00	24.50	15.20
		Allocations (%)					
MOS		10%	19.7	8.78	4.60	2.45	1.52
LA		70.76%	139.00	62.00	32.60	17.30	10.70
WLAs	**Redmond**	1.52%	2.99	1.34	0.70	0.37	0.23
	Woodinville	1.14%	2.25	1.00	0.53	0.28	0.17
	King Co.	13.20%	25.90	11.60	6.08	3.24	2.00
	Snoh Co.	3.27%	6.44	2.87	1.51	0.80	0.50
	WSDOT	0.10%	0.20	0.09	0.05	0.03	0.02

Table 8. Daily load and wasteload allocations set at stations in Evans Creek Sub-Basin: Upper Evans Creek (S484) and Lower Evans Creek (B484).

[a] Upper Evans Creek (Above Station S484)
Targets a 91% reduction in current bacteria loadings.

			Bacteria Loadings (billion colonies per day)				
			High flows	**Moist flows**	**Mid-range flows**	**Dry flows**	**Low flows**
TMDL (Loading Capacity Targets)		100%	33.70	15.00	8.02	4.02	2.33
		Allocations (%)					
MOS		10%	3.37	1.50	0.80	0.40	0.23
LA		79.36%	26.72	11.88	6.37	3.19	1.85
WLAs	**Sammamish**	4.87%	1.64	0.73	0.39	0.20	0.11
	King Co.	5.61%	1.89	0.84	0.45	0.23	0.13
	WSDOT	0.14%	0.05	0.02	0.01	0.006	0.003

[b] Lower Evans Creek (Above Station B484)
Targets a 63% reduction in current bacteria loadings.

			Bacteria Loadings (billion colonies per day)				
			High flows	**Moist flows**	**Mid-range flows**	**Dry flows**	**Low flows**
TMDL (Loading Capacity Targets)		100%	68.50	30.80	16.60	8.26	4.77
		Allocations (%)					
MOS		10%	6.85	3.08	1.66	0.83	0.48
LA		82.10%	56.27	25.32	13.65	6.78	3.92
WLAs	**Redmond**	0.77%	0.53	0.24	0.13	0.06	0.04
	Sammamish	2.63%	1.80	0.81	0.44	0.22	0.13
	King Co.	4.43%	3.03	1.37	0.74	0.37	0.21
	WSDOT	0.06%	0.04	0.02	0.01	0.005	0.003

Table 9. Daily load and wasteload allocations set at Bear Creek near the mouth (O484).

Bear Creek near mouth (Above Station O484)
Targets an 88% reduction in current bacteria loadings.

			Bacteria Loadings (billion colonies per day)				
			High flows	Moist flows	Mid-range flows	Dry flows	Low flows
TMDL (Loading Capacity Targets)		100%	268.00	120.00	62.80	33.00	20.80
		Allocations (%)					
MOS		10%	26.80	12.00	6.28	3.30	2.08
LA		20.48%	54.87	24.52	12.86	6.77	4.26
WLAs	**Redmond**	9.24%	24.75	11.06	5.80	3.05	1.92
	Sammamish	7.50%	20.10	8.98	4.71	2.48	1.56
	Woodinville	2.56%	6.86	3.07	1.61	0.85	0.53
	King Co.	42.26%	113.23	50.60	26.55	13.96	8.79
	Snoh Co.	7.41%	19.85	8.87	4.65	2.45	1.54
	WSDOT	0.55%	1.47	0.66	0.34	0.18	0.11

Compliance with the wasteload allocations (WLAs)

Although infrequent, summer rains do occur in western Washington. Thus, municipal stormwater can convey fecal coliform bacteria into creeks during dry periods when these rains occur. The little stormwater that does reach the stream during the summer can be heavily loaded with the build-up of pollutants from upland sources. Discharges from stormwater systems that are not associated with precipitation events are generally not allowed under the municipal stormwater NPDES permit. Therefore, the WLAs for permitted stormwater systems shall only apply as a result of precipitation events.

Discharge from MS4s may continue beyond the period when rainfall occurs. The duration of this period cannot be reasonably estimated due to variation in lag times in delivery through MS4s, the size of the MS4 collection area, types of stormwater treatment systems, and other factors such as snow buildup.

Due to the complexities in accurately characterizing bacteria loadings from MS4s, Ecology intends to evaluate compliance with TMDLs and water quality standards through analysis of ambient water quality data collected as part of a random sampling program. TMDL and water quality conditions will be re-evaluated on an approximately 5-year basis. At that time, the seasonal compliance with water quality standards will be re-evaluated with additional consideration given to new data sources such as from Phase I/II municipal stormwater monitoring. Water quality load duration analysis may also be used to help characterize water quality when seasonal compliance is achieved. Compliance with the WLA shall be determined by compliance with NPDES permit conditions.

Ecology recognizes the difficulty of characterizing the highly variable frequency and duration of bacteria loads in stormwater. Numeric effluent limits for municipal stormwater discharges that are consistent with TMDLs are not often feasible or appropriate when expressing WLAs in municipal stormwater permits. At this time, Ecology intends to express the WLAs in this TMDL as best management practices (BMPs) in the municipal stormwater permits. BMPs are considered the appropriate form of effluent limits in permits for control of pollutants in stormwater (Wayland and Hanlon, 2002).

Margin of safety

Bacteria concentrations in surface water tend to show more variation than other water quality parameters. During storms, bacteria counts tend to be high, but then low counts can follow after pollutant sources have been thoroughly rinsed. The simplifications in the Simple Method Model, flow estimations in mid Bear Creek (C484) and upper Evans Creek (S484), and stormflow load analysis may lead to uncertainty in the estimates of stormwater bacteria loads and relative allocations.

This TMDL accounts for uncertainty by including a margin of safety (MOS) to ensure that load and wasteload allocations remain protective of water quality. This TMDL provides an explicit MOS for the estimates made for Bear, Evans, and Cottage Lake Creeks by reserving 10 percent of the available bacteria loading capacity for the MOS during the year.

The loading equations and calculations also use an implicit MOS in the assumption that there is no bacteria decay rate in the watershed. Although temperature and sunlight affect survival of fecal coliform bacteria, Ecology made a conservative assumption (more protective of water quality) in the loading analysis that the bacteria flowing from upper reaches will not die-off before impacting downstream segments. In other words, all bacteria entering the creek from tributaries or pollution sources will stay active and suspended in the water column to the mouth of the creek.

Growth allocation

There is not much room for growth unless it is properly designed. Bear, Evans, and Cottage Lake Creeks have no additional loading capacity for fecal coliform bacteria. Therefore, this TMDL makes the assumption that in order to achieve and maintain compliance with water quality regulations, the community in the Bear-Evans Watershed will need to respond to growth pressures by ensuring that new development or land use changes does not contribute to increased nonpoint source loading of fecal coliform bacteria to the Bear Creek system. This TMDL presently provides zero allocation for future growth.

Reasonable assurances of success

When establishing a TMDL, reductions of a particular pollutant are allocated among the pollutant sources (both point and nonpoint sources) in the water body. In the Bear-Evans watershed, both point and nonpoint sources exist. TMDLs (and related action plans) must show "reasonable assurance" that these sources will be reduced to their allocated amount. Education, outreach, technical and financial assistance, permit administration, and enforcement will all be used to ensure that the goals of this water clean up plan are met.

Ecology believes that the following activities already support this TMDL and add to the assurance that bacteria in Bear, Evans, and Cottage Lake Creeks will meet conditions provided by Washington State water quality standards. This assumes that the activities described below are continued and maintained.

- Local governments are expected to continue exercising their authority to administer and enforce their ordinances. Ordinances that can help control fecal coliform pollution include Critical Area Ordinances, King County Livestock Program, and county clearing and grading permits. Local governments must also enforce their ordinances protecting stormwater drainage systems from illicit discharges.

- Water Tenders watershed group meets regularly and works to improve habitat, water quality, and salmon awareness in the Bear Creek sub-basin.

- In 2004, King County adopted a major update to its critical area ordinances (CAO) regulations. Key elements of the regulations include:
  - 165 foot buffers on all rural lakes, rivers, streams, and marine shorelines that support salmonids.
  - Wetland buffers based on Ecology's wetland rating system. The buffers are based on a combination of the wetland's category, habitat value, and development intensity.
  - Limits on the amount of land clearing in rural areas. Rural development must leave between 50 and 65 percent of native vegetation. Reducing the amount of cleared land in a watershed will help preserve the ecological integrity for the future.
  - Separate from the CAO regulations, stormwater management regulations place emphasis on infiltration and dispersion of stormwater in both urban and rural areas.

- A significant method of finding and responding to water quality problems is through citizen action. King and Snohomish counties have complaint forms on their websites and local jurisdictions will have a complaint hotline that citizens can use to report problems as part of their municipal stormwater programs.

- King County and city of Redmond have ongoing ambient monitoring programs which provide the data for this TMDL study and will help identify pollution sources and enable tracking of the water quality in the Bear-Evans Watershed. Ecology will also periodically conduct special sampling surveys to help further define pollution sources and promote source correction. Ecology gives priority to water cleanup-related projects applying for Centennial Clean Water Grant monies.

- Snohomish Conservation District is partnering with King Conservation District on a collaborative outreach and education project in Bear Creek sub-basin that will be funded by Ecology's Centennial Grant Program. The project will provide technical assistance and education on BMPs to horse/livestock and onsite septic owners in the Bear Creek sub-basin.

- Snohomish Health District regulates on-site sewage systems in accordance with Ch. 246-272 WAC and the Snohomish Health District Sanitary Code (Chapter 8). Public Health Seattle-King County's Wastewater Program regulates on-site septic systems in accordance with Chapter 246-272 WAC. Snohomish County is working with Snohomish Health District through a septic grant to merge the Health District septic system records with Snohomish Surface Water Management's Geographic Information System (GIS); identify hot spots and target improvements; conduct sanitary surveys and provide technical assistance to landowners; and provide prevention-based landowner training to ensure proper system operation and maintenance.

- Ecology's municipal stormwater permit program will also address pollution from stormwater generated by Phase I communities, King County, Snohomish County, WSDOT and by Phase II cities, Redmond, Woodinville, and Sammamish. Ecology will work closely with these permit holders to set reasonable, achievable, and effective strategies for meeting the loading reduction targets set forth in this water cleanup plan. The need for TMDL-related permit requirements will be re-evaluated prior to permit re-issuance.

While Ecology is authorized under Chapter 90.48 RCW to impose strict requirements or issue enforcement actions to achieve compliance with state water quality standards, it is the goal of all participants in the Bear-Evans Watershed TMDL process to achieve clean water through voluntary control actions. Ecology will consider and issue notices of noncompliance, in accordance with the Regulatory Reform Act, or other enforcement tools in situations where the cause or contribution to the cause of noncompliance with load or wasteload allocations can be established.

Conclusions

Ecology evaluated the current bacteria conditions in the Bear Creek system and determined that an 88 percent reduction in bacteria loading will bring Bear Creek, near the mouth, into compliance with state water quality standards. The study also demonstrated a pattern of seasonal variation in bacteria levels in the creek. As shown in Figure 10, bacteria levels across the watershed were generally higher during summer compared to winter (seasonal variation), but exceed the water quality criterion during all seasons. Most of the stations along Bear, Evans, and Cottage Lake Creeks show the greatest problems during the mid-range to dry flows. Many stations show fecal coliform bacteria concerns during moist flow conditions as well.

As part of the TMDL analysis, Ecology assigned load and wasteload allocations at the six monitoring stations along Bear, Evans, and Cottage Lake Creeks. These numeric allocations are stepped accordingly to the five flow ranges (Figures 12-14). Consequently, load and wasteload allocations differ at each of the six sampling stations and are variable depending on stream discharge and the presence of precipitation in the watershed (Tables 8-10).

The analysis concludes that a total of 88 percent reduction is needed in current overall bacteria loading as measured in Bear Creek near the mouth during mid-range flows. All nonpoint sources above this location are assigned a combined load allocation of 20 percent of the total reduction needed (Table 10). Interestingly, the load allocation at this most downstream station is the smallest of the six sampling stations due likely to the larger cumulative effect of point source stormwater above Bear Creek near the mouth. Like the other stations used in this analysis, the actual combined load allocation at station O484 is variable depending on stream discharge at the time of sampling.

The six wasteload allocations established at station O484 correspond to all the municipal stormwater permit holders represented in the watershed. King County, being the largest jurisdiction, is assigned the largest wasteload allocation 42 percent of the total reduction needed.

Summary of implementation strategy

The implementation strategy in this report outlines the following actions needed to bring the Bear Creek system to good health.

- Source Tracking
  - Increase understanding of land uses and animal handling facilities in the basin.
  - Investigate and repair sewer leaks and failing on-site septic systems.
  - Identify and eliminate illicit connections to the stormwater drainage system.
  - Identify specific sources of bacteria pollution through bacteria source detection monitoring.
- Source Controls
  - Implement structural (as appropriate) and non-structural stormwater source control best management practices (BMPs).
  - Restore riparian vegetation to help filter out stormwater pollutants.
  - Properly manage domestic animal and livestock wastes.

- Increasing Public Awareness
  - Outreach to and educate the public on local bacteria pollution issues.
  - Promote watershed stewardship education to provide opportunities to learn how to protect Bear and Evans creeks from water quality degradation.

Riparian restoration project. Photo: King County

Protecting high value riparian habitat is essential for protecting water quality.
Photo: Anne Dettelbach

Implementation Strategy

Introduction

This implementation strategy outlines potential actions to improve water quality. It describes the roles and authorities of cleanup partners (that is, those organizations with jurisdiction, authority, or direct responsibility for cleanup) and the programs or other means through which they will address these water quality issues.

After the U.S. Environmental Protection Agency (EPA) approves this TMDL, interested and responsible parties will work together to develop a Water Quality Implementation Plan. The plan will describe and prioritize specific actions needed to improve water quality and achieve water quality standards.

The plan will help ensure that impaired water bodies improve and can attain water quality standards. Ecology facilitates this process by encouraging and (in some cases) funding local governments, agencies, districts, businesses, and communities to participate in actions that will help identify and correct pollution sources and protect stream quality.

Several agencies and groups in the Bear-Evans watershed actively conduct educational and stream restoration projects that help remediate the problem of excess bacteria in these creeks. Jurisdictions in the Bear-Evans watershed acquired significant riparian area and conservation easements to help preserve habitat and water quality. Ecology supports these and additional future acquisitions and easements to further protect water quality.

Local governments and several citizen groups, such as Adopt-a-Stream Foundation and the Water Tenders, actively plan and develop stream restoration and other watershed activities that will help reduce fecal coliform contamination in the watershed.

What needs to be done?

The following is a summary of implementation actions and parties likely to play a critical role in correcting sources of fecal coliform bacteria. Ecology will discuss these and related activities with the key parties and will refine the list of implementation actions during the implementation planning process. Agreements or commitments to implement specific actions will be documented in the Water Quality Implementation Plan.

Source tracking

Increase understanding of the area and land use draining to the creeks to help define other actions needed to improve water quality. Additional information to be gathered may include the location of animal handling businesses and small farms.

Investigate and repair possible sewer leaks and failing on-site septic systems, which involves responding immediately and appropriately to sewer leaks or failing onsite septic systems by responsible parties.

Identify and eliminate illicit discharges to stormwater drainage systems. There are several methods available to detect and eliminate illicit discharges and connections, including outfall surveys to help isolate and identify dry weather flows. Elements in the NPDES Municipal Stormwater Permits increase the cities' and counties' responsibilities to detect and eliminate illicit discharges and connections.

Detect bacteria sources through targeted water quality monitoring to identify specific sources of bacteria pollution. Targeted water quality monitoring can help partners focus Best Management Practice (BMP) resources where they are needed most.

Source controls

Employ and promote low impact development techniques, such as the use of rain gardens, pervious pavements, and bioinfiltration swales, where feasible, to reduce effective impervious surface and stormwater runoff.

Implement stormwater source control BMPs, which may include structural treatment practices, where feasible. Stormwater control programs should incorporate operational and structural treatment practices as needed to address urban bacteria source control and stormwater treatment.

Preserve and restore riparian areas with native riparian vegetation to establish stream buffers that enhance water quality and habitat. Adequately sized and healthy riparian buffers help filter out a variety of pollutants including fecal coliform bacteria.

Education and public awareness

Public outreach to Bear-Evans Watershed communities involves developing and disseminating educational materials (such as pamphlets, mailers, displays, public workshops, and signage) about local water pollution problems and solutions. Information could promote proper management of pet and livestock waste; "do not feed the waterfowl" campaigns; maintaining on-site septic systems; and reducing illicit discharges into storm sewers. Education can involve cross-program training of code enforcement staff on water quality protection ordinances.

Watershed stewardship education involves opportunities for citizens to learn about the values and benefits of protecting the Bear and Evans creeks from water quality degradation. Activities could include targeting riparian neighbors with tailored information that emphasizes erosion control and creek stewardship, and targeting students to engage in scientific discovery of the watershed.

Monitoring

Monitoring is needed during all phases of the TMDL implementation to identify polluted areas, contributing sources, poor practices, and to verify that corrective actions taken have been and remain appropriate in protecting local waters.

Bacteria source detection monitoring is described under “Source Tracking”.

Effectiveness monitoring of the streams in the Bear-Evans Watershed will tell us whether the actions are effective in reducing bacteria levels. Ecology reviews all the relevant actions taken to improve water quality in the creeks over a five-year period and compares them with the water quality data. This allows us to see what is working, what is not working, and what changes are needed to continue the water cleanup programs.

Who needs to participate?

The following government agencies, citizen groups, and tribes have regulatory authority, influence, information, resources or other involvement in activities to protect and restore the health of the Bear-Evans watershed.

Federal, tribal, and state entities

U.S. Environmental Protection Agency

The 1997 Memorandum of Agreement between the Environmental Protection Agency, Region 10 and Ecology requires that EPA and Ecology jointly evaluate the implementation of TMDLs in Washington. These evaluations address whether interim targets are being met, whether implementation measures such as BMPs have been put into effect, and whether actions taken by NPDES permits are consistent with TMDL wasteload allocations.

EPA provides technical assistance and funding to states and tribes to implement the Clean Water Act (CWA). For example, EPA’s CWA Section 319 grants, combined with Ecology’s grant and loan funds, are made available to stakeholders through Ecology’s annual Water Quality Grant and Loan Process. On occasion EPA also has other grant monies available (104(b)(3)) to address storm water pollution problems.

Washington State Department of Ecology

EPA delegated authority to Ecology to implement many aspects of the federal Clean Water Act. These include the National Pollution Discharge Elimination System (NPDES) permitting and the Total Maximum Daily Load (TMDL) program. In addition to the Clean Water Act, Ecology administers the State Water Pollution Control Act. The Cedar-Sammamish-Lake Washington watershed (WRIA 8), which includes the Bear-Evans Watershed, is under the jurisdiction of Ecology’s Northwest Regional Office (NWRO). To address the municipal permitting needs of this TMDL, the NWRO has one municipal stormwater engineer and three municipal stormwater specialists who provide technical assistance and auditing activities for the Phase I and Phase II municipal stormwater permits across the region. Ecology's headquarters also has several staff that can help identify and distribute education and outreach materials to stormwater permit holders.

Ecology has a Water Quality Improvement Lead assigned to the implementation of the Bear-Evans Watershed Fecal Coliform TMDL who will assist the stormwater permit holder and other environmental agencies and groups. The NWRO also has a water quality monitoring specialist who is available to provide assistance in the development of ambient monitoring and source identification monitoring projects. Ecology's Environmental Assessment Program may assist in effectiveness monitoring as the TMDL is implemented.

Ecology also helps local governments with funding for water quality facilities and activities through the Centennial Clean Water Fund, 319 Fund, and State Revolving Loan Fund. Ecology funding opportunities are listed in Table 10. Ecology's grant specialists assist local governments in the development of stream restoration and water quality improvement projects.

Ecology will be responsible for organizing meetings of a stakeholders' workgroup no less than annually and will lead additional meetings as requested by the workgroup.

Washington State Department of Transportation

The Washington State Department of Transportation (WSDOT) water quality program provides guidance and technical support to road planning, design, construction, and maintenance of state transportation projects. To achieve compliance with the federal Clean Water Act and state water quality laws, WSDOT prepares stormwater pollution prevention plans for major road projects, prepares annual NPDES compliance reports and plans, conducts mitigation projects, and monitors water quality.

Since 1995, WSDOT has been regulated under the Phase I Municipal Stormwater permit. Based on that NPDES permit, WSDOT submitted a stormwater management plan (SWMP) in 1997 to Ecology which identified six elements as having the highest priority: (1) construction of structural stormwater BMP facilities; (2) monitoring and research related to stormwater BMPs; (3) erosion and sediment control programs; (4) attaining full funding for operations and maintenance programs; (5) watershed-based mitigation strategies; and (6) water quality-related training. These elements continue to be high priorities for WSDOT.

Ecology is revising WSDOT's municipal permit for re-issuance in late 2008.
WSDOT will actively participate in the TMDL process in cases where WSDOT facilities or operations are identified as important contributing sources to the pollutant being characterized in the TMDL. Check Ecology's Water Quality Program website for the most up-to-date information (http://www.ecy.wa.gov/programs/wq/stormwater/municipal/wsdot.html).

In 2004, WSDOT initiated a limited fecal coliform sampling program to get preliminary data on fecal coliform bacteria in: (1) water flowing onto highway rights-of-way from adjacent properties; (2) untreated highway runoff; and (3) treated runoff. WSDOT is currently assessing the quality of that data. The WSDOT sampling program involved limited samples (two to ten at each site). WSDOT also manages the vegetation next to stormwater ponds to discourage waterfowl use of the ponds.

Three state highways cross parts of the watershed: SR 520 passes along lower Bear Creek in Redmond; SR 202 stretches along portions of Evans Creek; and SR 522 bypasses the upper Cottage Lake Creek sub-basin in Snohomish County.

Muckleshoot Indian Tribe

The Muckleshoot Indian Tribe's Usual and Accustomed Area (U&A) was determined in the U.S. Supreme Court case U.S. v. Washington for fisheries resources that are culturally and economically important to the Tribe. The U&A area covers all or portions of several basins; the Lake Washington/Cedar/Sammamish watershed is one of these basins. The Bear and Evans system is part of the Washington/Cedar/Sammamish watershed. The Muckleshoot Indian Tribe Fisheries Division (MITFD) has an active resource protection staff and may assist in stream restoration and water quality improvement efforts. MITFD staff review permits for all of the jurisdictions in the TMDL area and continues to monitor these permits and restoration projects to evaluate whether the TMDL is implemented and not adversely affected by future land actions.

WRIA 8 Cedar-Sammamish-Lake Washington Salmon Recovery Council

The WRIA 8 Salmon Recovery Council (SRC) is comprised of representatives of 27 local governments, businesses, community groups, and state and federal agencies that have worked together since 2000 to protect and restore salmon habitat. King and Snohomish Counties and 25 cities in the watershed pooled resources to develop the WRIA 8 Chinook Salmon Conservation Plan. In 2005, all 27 jurisdictions ratified the plan. In 2007, National Oceanic and Atmospheric Agency Fisheries approved it as part of the Puget Sound Chinook Conservation Plan. The same jurisdictions fund a small team to coordinate implementation of the Chinook Recovery Plan.

Bear-Evans watershed is among the most important basins for salmon habitat in urban King County. In the WRIA 8 Chinook Salmon Conservation Plan, many of the planned stream restoration projects can help reduce bacteria in the basin streams. Among their highest priority salmon restoration projects for Bear Creek and the WRIA 8 watershed is the Lower Bear Creek Restoration. The project provides an enhanced channel alternative to the ditched and leveed lower 3,000 feet of Bear Creek, including a new refuge confluence with the Sammamish River with added large woody debris, and restore riparian conditions.

Local government resources

King County

The Water and Land Resources Division (WLRD) in King County Department of Natural Resources and Parks has programs in watershed and natural resource stewardship, stormwater compliance, and water quality monitoring. These programs are described below.

- The ***Stormwater Services Section*** provides education and technical assistance to prevent the contamination of stormwater through implementation of King County Code 9.12: Water Quality. Programs include source control inspections and technical assistance to businesses in the basin, which help to curb such bacterial sources as littered parking areas and poorly managed dumpsters. The section also responds to drainage and water quality complaints that frequently include poor pet waste management and other bacterial pollution. Additionally, the section identifies and facilitates the removal of any illicit discharges to the storm drainage system, including such bacteria sources as illicit sanitary sewer connections.

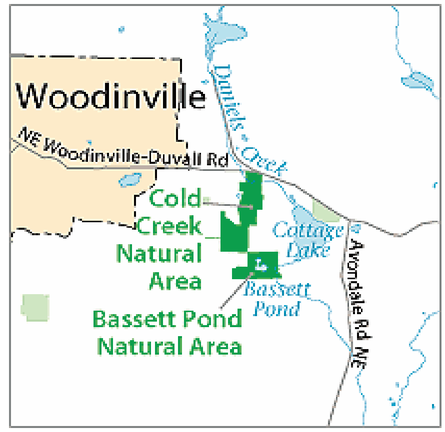
- The ***Development and Environmental Services*** **(DDES)** reviews development proposals to ensure that they are designed to be consistent with the *Surface Water Design Manual*. DDES also inspects developments during construction to ensure that stormwater runoff is controlled and that required stormwater facilities are installed according to required standards. Code Enforcement officers within the section investigate complaints of irresponsible or hazardous development, in unincorporated King County, that are also violations of King County Code including zoning, housing and building, shorelines, and critical areas.

- The ***Livestock Program*** promotes proper livestock management practices and financially assists agricultural landowners with BMP implementation. Some of these BMPs include, but are not limited to stream and wetland buffer fencing; native revegetation; manure storage structures; heavy use area protection; pasture restoration; roof runoff management; etc. The program implements the County's 1993 Livestock Management Ordinance (LMO) which supports the raising and keeping of livestock while minimizing the adverse impacts of livestock on water quality and salmonid fisheries habitat. Proper management of manure will help reduce the potential for bacterial pollution in nearby streams. The LMO recommends implementing Farm Plans for farms with livestock.

- ***Small Habitat Restoration Program*** helps keep bacteria out of streams by providing fencing to keep livestock from streams and enhancing buffers. Typical projects include streamside and wetland planting; livestock fencing; in-stream habitat improvements; removal of barriers to fish migration; and removal of invasive/non-native plants.

- ***Lake Stewardship Program*** documents trends in water quality, plans and implements restoration projects, encourages citizen stewardship, and provides educational outreach and technical support to lake residents. The program is currently implementing water quality improvement efforts (i.e., riparian restoration, water quality monitoring, and educational workshops) around Cottage Lake as part of Ecology's Centennial Clean Water Grant project. The program will implement a restoration project in Cottage Lake Creek starting in summer 2008.

- ***Natural Resources Lands Program*** manages the Cold Creek Natural Area and adjacent Bassett Pond Natural Area under the Cold Creek Natural Area plan. These natural areas cover about 250 acres in the upper reaches of Cottage Lake Creek and contain extensive wetland systems, numerous springs, and one of the highest quality salmon-bearing streams in the Bear Creek drainage basin. This program also manages natural riparian areas along mainstem Bear and Evans Creeks.



- ***WRIA 8 Basin Steward*** serves as a liaison between residents and the cities, King County, state and federal agencies, and tribes. The basin steward provides technical assistance to basin residents on stream restoration, nonpoint pollution prevention, and revegetation of disturbed areas. The basin steward also responds to inquiries about land use, restoration, salmon, water quality, and other issues. In the past, the basin steward specific to Bear-Evans basin has been very effective at initiating and coordinating significant acquisition and restoration projects in the Bear-Evans Basin.

- ***Waterways 2000 program*** seeks to preserve quality habitat through property acquisition and a long term commitment to its stewardship. The Bear Creek community set aside aquatic lands and their riparian buffers to maintain high quality habitat. Volunteers in the program set examples for the rest of the Northwest by showing strong support in the program. Through the Waterways 2000 program and the Upper Bear Creek Conservation Area, over 1100 acres of high-value aquatic land is targeted for protection.

Snohomish County

Snohomish County has several programs that can affect the overall water quality in the upper Bear Creek sub-basin. Snohomish County Public Works carry out the bulk of water quality-related activities, including a variety of pollution identification and prevention activities.

- ***Surface Water Management*** of Public Works is involved in a wide range of water pollution control activities including education, water quality monitoring, riparian restoration, salmon recovery, native plant salvaging, and Phase I Municipal Stormwater Permit (Ecology, 2007a) administration. Education is conducted through targeted programs as well as through the activities of a South County Basin Watershed Steward. Surface Water Management also provides funding for and coordinates with the Snohomish Conservation District. Water quality is tracked through comprehensive ambient stream monitoring, targeted source identification, and illicit discharge monitoring.

- ***Surface Water Management conducts a number of grant funded programs. The Animal Waste Control Project, which ended on March 1 2008,*** researched the problem of pet waste management at the residential and commercial level. The Stormwater Management Project is studying two urban issues: how to maximize Native Growth Protection Areas for removal of pollutants in stormwater, and how to perform low-cost stormwater capture and treatment in established residential neighborhoods. Surface Water Management is working with the Snohomish Health District, through a septic grant, to merge the Health District septic system records with Surface Water Management's Geographic Information System (GIS); identify hot spots and target improvements; conduct sanitary surveys; provide technical assistance to landowners; and provide landowner training to ensure proper system operation and maintenance.

- ***Solid Waste Management*** of Public Works has programs that affect both pet waste and livestock waste management issues. In collaboration with Surface Water Management, Solid Waste Management developed a brochure on how to best manage pet wastes.

- ***Snohomish County Planning and Development Services (PDS)*** develops and administers county regulations for commercial and residential development as well as public projects. The PDS also enforces the Snohomish County Code as it relates to protection of water quality, implements the Critical Areas Ordinance and other development regulations, and works closely with the agricultural community through its agricultural liaison and the Agricultural Advisory Board. PDS affects the generation and treatment of stormwater by researching stormwater BMPs and providing educational outreach to contractors on proper BMP use. Along with other parts of the county, the PDS promotes Low Impact Development (LID) principles. The county sponsors the Sustainable Development Task Force, which is a public/private partnership that adopts strategies that promote wise use of building materials, energy efficiency, and the reduction of stormwater. An experimental LID ordinance was written in 2001, and county staff are now updating that ordinance.

- ***Snohomish County Parks and Recreation Department*** oversees over 9,000 acres of public land for recreational use and conservation purposes. The Department works with other parts of county government to manage county lands, administers a variety of educational programs, and develops and maintains park facilities. Snohomish County, King County Land and Natural Resources, and the Cascade Land Conservancy secured funding in 2000 to purchase over 600 acres of the site now considered the Paradise Valley Conservation Area. Recently this year, new acquisition increased the conservation area to 800 acres. This area protects the biological integrity of a significant portion of the headwaters of Bear Creek.

Northeast Sammamish Sewer and Water District

The Northeast Sammamish Sewer and Water District (NESSWD) serves mostly the city of Sammamish, with two water customers in unincorporated King County. The District provides water for over 10,000 people and sewer service for 15,000 people east of Lake Sammamish. The

District receives its water entirely from groundwater sources located beneath the Sammamish Plateau and Evans Creek valley. They operate and manage five wells and two reservoirs in the area. Sewer facilities are located throughout the District.

NESSWD is committed to protecting the environment with the intention to operate, maintain, and repair the water and sewer systems in a manner that does not adversely affect the environment. The district follows BMPs specifically designed to avoid or reduce impacts to aquatic habitat that might otherwise occur in the course of activities associated with the routine operation, replacement and maintenance of sewer and water facilities. Additionally, the District participates in the following activities:

- ***Redmond-Bear Creek Valley GroundWater Management Plan*** contains strategies to address the potential threats to groundwater quality and quantity in region. NESSWD developed the plan in partnership with Redmond, King County, and other local entities.

- ***Local streams monitoring*** by the utility district includes maintaining a groundwater, surface water, and atmospheric monitoring network in the Bear/Evans system. When the District constructs facilities near a stream, monitoring devices are placed in the stream to measure water quality. This ensures that construction run-off is carefully monitored and controlled. The District also collects rain data, which is used to study interactions between water systems operations and the local aquatic system. The District monitors temperatures along Evans Creek for good stewardship and to detect if their construction of new facilities impacts temperature. In addition, in partnership with King County, the District provides real-time air temperature, water temperature, water level, and flows data for Evans Creek on its web site.

- ***The District works with the King County's Inflow and Infiltration (I&I) Program*** to maintain a very low level of I&I (or excess water that enters the sewer system unnecessarily). This means a lower amount of ground water that enters the sewer system, and therefore a greater amount of water remains in the local ecosystem. This is not only important for stream quantity, quality and fish habitat but also for the District's wells. Ground water recharges the District's wells, which allows the District to continue to provide high quality water to its customers.

Woodinville Water and Sewer District

Woodinville Water and Sewer District strives to provide safe and reliable service to all their customers at an economical cost, provide potable drinking water to all customers of the district, and provide sanitary sewer service to all customers requesting service of the district who are located within the urban growth area as established by King County. The district educates customers in the efficient use of water and safe disposal of wastewater. The district presently is the fifth largest district in King County, serving approximately 13,300 water customers and 2,500 sewer customers. Future forecasts predict that there may be 25,000 sewer and water connections by the year 2020.

City of Redmond

Redmond is a suburban city encompassing an area of about 37 square kilometers and with a 2004 population of 46,900. In 1963, the Evergreen Point Floating Bridge (Highway 520) was completed, spanning Lake Washington and connecting Seattle to the eastside of Lake Washington. This transportation access and the availability of relatively inexpensive (historically) undeveloped land led to major land use changes over the past 30 years. Redmond changed from a largely agricultural community to a highly developed residential and commercial landscape.

The city of Redmond is an active partner in improving water quality in the Bear-Evans basin. They facilitated construction of numerous stream restoration projects identified in the Bear Creek Restoration Plan (King County, 1989). The bulk of water quality-related activities are carried out by the city's Public Works Department Natural Resources Division, which monitors the city's water quality, and designs and implements stream improvements and stabilization projects through the Stormwater Utility funds.

The Stormwater Capital Improvement Program implements capital improvement projects (CIP) that are necessary to alleviate problems caused by stormwater from existing development, as well as to prevent future problems that could result from planned development. In the Division of Natural Resources, typical capital improvements include large stream or habitat protection or restoration improvement projects; fisheries enhancement projects; stream bank stabilization or erosion repair projects; detention ponds; water quality treatment; and structural upgrades and repairs.

The city's Planning and Community Development Department oversees building and land development activities and performs enforcement. Because past land use practices so greatly affect water quality, the activities of this department are especially important to pollution prevention.

The Parks and Recreation Department manages 21 developed parks consisting of over 1000 acres and 17 miles of developed trails. In addition, the city has eight undeveloped parks consisting of almost 300 acres and nine miles of undeveloped trails. Many of these trails are open for equestrian use.

City of Sammamish

Located partially in the Evans Creek sub-basin, the city of Sammamish was incorporated in August 1999. Characterized primarily by a suburban residential development, the city supports two commercial centers. As of January 2003, the city owned and operated 39.5 acres of developed park properties. In 2000, the city purchased the Evans Creek Preserve, a 178-acre property off of Highway 202, just north of the city limits. The preserve includes a variety of habitats including wetland, riparian and forested upland. There are several dilapidated historical buildings and some areas overgrown with invasives. The city is currently developing its stormwater management program under the Phase II Municipal Stormwater Permit.

City of Woodinville

Portions of the city of Woodinville are in the upper Bear Creek sub-basin, most of which drains to the Cottage Lake Creek branch. With a population of about 9,194 in 2000, the city has a total area of 5.7 square miles. The following city programs could be involved in improving water quality in the Bear Creek system:

- The ***Public Works Department*** provides safe and reliable motorized and non-motorized facilities, protects and enhances the quality of waterways and habitats. It maintains the public infrastructure including roadways; sidewalks; street lighting; traffic signals and signs; storm water systems; and public construction improvement projects. The Department consists of three divisions: Engineering, Traffic Management, and Operations and Maintenance (O&M). The Public Works carries out NPDES stormwater permit requirements.

- The ***Parks and Recreation Department*** is responsible for meeting the public need for parks, recreation and open space. Staff works with the Parks and Recreation Commission for the future of Woodinville parks and recreation. The staff carries out city council directives for the purchase, design, construction, maintenance, management and programming of city facilities including parks, trails, playgrounds, landscaped areas, and habitat and resource areas. Opportunities for the installation of pet waste stations can be explored.

- The ***Development Services Department*** provides services that achieve the community's vision by implementing the goals and policies of the city's comprehensive plan. Development Services also conducts long-range planning and permitting functions that protect the public's life, health, safety and welfare as it relates to land use standards and construction practices. Proper land use planning is a critical element in improving and protecting watershed health.

Snohomish Conservation District

The Snohomish Conservation District (SCD) is a non-regulatory public agency that provides many services to commercial dairies, small farms, and rural residents. These services include education, technical assistance, farm planning, and financial assistance, when available. SCD has a model farm program that recognizes outstanding efforts by landowners in water quality improvements. Model farm tours are often held to highlight these improvements for other small farm owners. Landowners can request a free farm plan, or they can be referred to SCD to develop a farm plan if a documented water quality problem exists. SCD currently has several cost-share programs available to landowners. Projects eligible for funding include fencing, planting, manure management, roof runoff management, off-stream watering, and riparian corridor.

In partnership with King Conservation District, SCD will develop a targeted collaborative watershed education project to implement technical assistance through workshops and farm planning services on-site. Targeted water quality monitoring will assess potential hot spots for fecal coliform. The project will be funded by Ecology's Centennial Grant program.

King Conservation District (KCD)

As a separate municipal state corporation created under Chapter 89 RCW, the KCD administers programs to conserve the natural resources of King County. KCD efforts focus on individual contact with farm owners and residents within the entire King County. The goal of the district is to promote practices that maximize productive land use while conserving natural resources and protecting water quality through education, funding assistance, and cooperation.

KCD advises landowners on the implementation of BMPs to protect water quality and fish and wildlife habitat, and designs and installs stream enhancement projects. KCD holds classes, conducts farm tours, and provides grants and cost-share funding for water quality-related farm improvements. KCD will partner with Snohomish CD on a Centennial Clean Water Fund grant application for a targeted collaborative watershed education project that will include the Bear-Evans Watershed.

Through the development of farm plans, KCD advises farm owners on practices that help improve water quality and protect fish and wildlife habitat. Such BMPs include proper animal waste management, streamside and wetland planting, and livestock fencing. The KCD also financially assists land owners through grants and cost share funding for water quality-related farm practice improvements. The King Conservation District developed approximately 59 small farm plans within the Bear-Evans watershed over the last 10 years. The more recent planning efforts address water quality concerns in these farm plans.

Snohomish Health District

The Environmental Health Division of the Snohomish Health District (SHD) issues solid waste permits for solid waste disposal sites and handling facilities in Snohomish County, provides regulatory oversight for the On-Site Sewer System Program, investigates (and may take enforcement action related to) sewage discharge complaints, and conducts some water quality monitoring for bacteria in the county. The SHD is responsible for investigating complaints of failed on-site septic systems and requiring corrective measures such as on-site system maintenance, renovation, or hook-up to sewer systems where available. Unreported failing septic systems create a potential health threat as well as contribute to bacterial pollution in local surface waters.

In addition to certifying on-site system installers and licensing on-site system pumpers, the SHD educates homeowners on the proper operation and maintenance of on-site systems. Ongoing implementation of such programs will help reduce future failures and prepare homeowners to recognize existing problems that may be contributing bacterial pollution in the upper Bear Creek sub-basin.

Public Health Seattle-King County

Public Health-Seattle and King County (PHSKC) enforces rules adopted by the state Board of Health, including rules necessary to assure safe and reliable public drinking water and protect public health. PHSKC is responsible for assuring that installed, modified, or repaired onsite sewage systems in King County meet state and local regulations. PHSKC is fee funded and staffing, therefore, is geared primarily toward processing permit applications. There is little funding available to find and properly correct failing septic systems throughout the county.

The Wastewater Program regulates on-site septic systems in accordance with Chapter 246-272 WAC. PHSKC requires pumpers and installers of on-site septic systems to be county certified. Staff of the Wastewater Program issues installation and repair permits for septic systems, investigates sewage complaints for septic systems, educates homeowners, and conducts enforcement. The program considers development and operation of community wastewater treatment systems to replace inadequate and, in some cases, failing septic systems. The Public Health Wastewater Program educates, advises, and permits owners of on-site septic systems.

PHSKC is responsible for assuring that installed, modified, or repaired onsite sewage systems (septic tank systems) in King County meet state and local regulations. In addition, PHSKC is required to identify areas where marine water quality is threatened or impaired as a result of contamination from on-site sewage systems, to designate these areas as Marine Recovery Areas (MRAs), and to develop a plan to identify failed septic systems within the MRAs and assure that the systems are repaired and maintained. Future state funding commitments allow for 0.35 FTE, which PHSKC anticipates will be used primarily to help build systems or processes to assure that septic systems are monitored in MRAs.

Nonprofit and volunteer organizations

Water Tenders

Water Tenders is a very active group of people who care about the wetlands and streams in the Bear Creek watershed. They volunteer their time and energy to help preserve, protect, and restore the wonderful natural heritage of Bear Creek and its resources. Water Tenders has been in existence since 1989 and has accomplished many activities, including monitoring; salvaging native plants; removing non-native plants; adopting park conservation lands; community outreach; basin newsletter; and watershed advocacy. For information on how you can get involved visit their website at http://www.watertenders.org/.

Adopt-A-Stream Foundation

The Adopt-A-Stream Foundation (AASF) is a non-profit organization based in south Everett, Washington. Created in 1981, AASF's mission is to increase public awareness of the importance of the 3,000 miles of creeks, streams and rivers and the fish that inhabit them in Snohomish County, and to restore to health those waterways damaged by people or nature.

AASF carries out its mission by producing and distributing environmental education materials nationally and internationally, conducting S*treamkeeper Academy*™ events for school and community group audiences throughout the Pacific Northwest, and providing local communities with stream and wetland restoration assistance. In addition, AASF operates the Northwest Stream Center, a regional environmental learning facility that has stream and wetland ecology and fish and wildlife habitat as its central themes. AASF's long-term goal is to stimulate everyone to become a *Streamkeeper*™, taking actions necessary to protect and enhance their home watersheds.

In 2004, AASF conducted a culvert fish barrier and pollution identification field survey in the Bear-Evans watershed funded through a Centennial Grant from Ecology. They spent considerable effort educating citizens on the water quality, habitat, and fish passage requirements that salmonids need to achieve optimum survival. Interactions with residents revealed that many streamside residents are misinformed or lack knowledge regarding the lifecycle of salmon and their habitat needs (AASF 2004). Staff distributed several educational pamphlets. AASF field crews took the time to answer specific questions from streamside residents regarding stream bank erosion, native riparian vegetation planting, flooding/drainage issues, and habitat creation for fish and wildlife. For more information on how you can get involved visit their website at http://www.streamkeeper.org/foundation.htm.

Stewardship Partners

Stewardship Partners helps private landowners restore and preserve the natural landscapes of Washington State. They promote and implement incentive-based programs that encourage landowners to participate in fish and wildlife conservation and restoration activities while simultaneously meeting their economic needs through sustainable land management.

Stewardship Partners is collaborating with the Oregon-based Salmon-Safe certification program to recognize farm operations which adopt conservation practices that help restore native salmon habitat in Pacific Northwest rivers and streams. Salmon-Safe farms protect water quality, fish and wildlife habitat, and overall watershed health. The independent eco-label is gaining national recognition and appears on a variety of products including wine, dairy, produce, and fruit. There is interest in expanding the Salmon Safe certification program to include city parks as well as golf courses.

For more information on how you can get involved visit their website at http://stewardshippartners.org/

Friends of Cottage Lake

Friends of Cottage Lake (FOCL) is a grass-roots non-profit community organization committed to improving and defending the health and continued enjoyment of Cottage Lake and its environs. The FOCL consists of residents that live on or near Cottage Lake. They are currently involved efforts to reduce nutrients into Cottage Lake as part of Cottage Lake Phosphorous TMDL (Ecology, 2007c). FOCL maintains a website and publishes a newsletter to promote community outreach and education on water quality and other issues. You can learn more about their efforts to protect the water quality of Cottage Lake and its surrounding watershed by visiting http://friendsofcottagelake.org

Upper Bear Creek Community Council

The purpose of the council is to inform, assist, and represent the community in dealing with King County government and other entities with respect to issues that affect the community. The council is recognized by King County as the unincorporated area council serving the Upper Bear Creek area. The council is a volunteer organization with an elected board, and residents are welcome and encouraged to participate by visiting http://www.upperbearcreek.com/.

King County Executive Horse Council

The King County Executive Horse Council is an umbrella organization, uniting horsemen of all breeds and interests. The KCEHC supports the horse industry and equestrian way of life by advocating for the protection and creation of equestrian trails and facilities. They are the official horse advisors to government and developers. The KCEHC promoted the creation of a trail ordinance, equestrian overlays, and trail language for comprehensive and community plans, inventoried trails for community plans, and developed educational brochures. The KCEHC publishes the Equestrian Trail Guide for King County and three brochures: *Share the Road with Horses, Basic Horse Management,* and *Trail Etiquette, Safety and Equipment.*

Horses for Clean Water

For the past ten years, Horses for Clean Water has offered horse owners ways to care for horses that benefit the animals, the farm, the owner, the community and the environment. They actively educate horse owners through classroom series, workshops, farm tours and educational material development. Educational outreach is also achieved through partnerships between Horses for Clean Water and many different Conservation Districts, natural resource agencies, extension offices, environmental groups, horse organizations and other equine professionals.

Educational presentations are done on mud management, manure management, pasture management, and naturescaping for horse farms. Recently produced presentations, *Fall in Place for Winter, Natural Ways to Control Mud, Dust, Bugs & Weeds,* and *Shopping for Horse Property* emphasize how to beat the mud and be more chore efficient, reducing chemical use and selecting a suitable horse property from the soil up.

Also covered in these presentations are topics including composting manure; fencing; dust control; weed management; equine nutrition; seed choices; naturescaping on horse farms; and insect control.

Horses for Clean Water produces a monthly electronic newsletter, *The Green Horse*, which covers a variety of topics on horse management while encouraging a sustainable lifestyle. *The Green Horse* is sent electronically to over 1000 subscribers and is also available on their web site at http://www.horsesforcleanwater.com/index.html.

Horses for Clean Water is funded by grants and contracts from different funding agencies and through individual consultations and sponsorship donations. Sponsorships allow Horses for Clean Water to extend its educational outreach and to increase environmental and horse health awareness.

Local Businesses

Ecology plans to work with partners to help educate local businesses on actions they can take to prevent bacteria pollution their activities may generate. In turn, local businesses can be partners in increasing public awareness on the local water quality issues in Bear and Evans creeks.

Local Citizens

Local citizens play a critical role in improving the water quality of Bear and Evans creeks. Many citizens can have an immediate impact on local water quality by doing certain tasks differently. By properly disposing of pet wastes and avoiding the addition of grass clippings or any other foreign substance into neighboring creeks, the bacteria levels can be reduced. Local citizens can also get involved in stream rehabilitation, communicate their interest in the environment to local elected officials, and educate others on how to improve water quality in Bear-Evans watershed.

Property owners can take it upon themselves to minimize runoff of nonpoint sources of pollution from their yards, repair failing on-site septic systems, and enhance streamside riparian vegetation.

Schedule for achieving water quality standards

The progress of this TMDL effort will be measured by (1) assessing the pollution control activities underway or completed and (2) direct measurement of stream water quality. The goal is for Bear Creek system and the tributaries to consistently meet the Washington State Water Quality Standards for bacteria. Ecology anticipates that if state and local coordination proceed as expected and resources remain available, by December 2015 each of the sampling stations within the watershed will be in compliance with the state extraordinary primary contact recreation standards. An interim target of compliance with the primary contact standards should be achieved by 2012.

Adaptive management

Compliance with state water quality standards for extraordinary primary recreation should be achieved by 2015. An interim target of compliance with the primary contact standards should be achieved by 2012. Partners will work together to monitor progress towards these goals, evaluate successes, obstacles, and changing needs, and make adjustments to the cleanup strategy as needed.

This TMDL effort will use an adaptive management approach to ensure the progress and overall success of this plan. Opportunities for adaptive management include conducting special inspections in identified areas of pollution sources; evaluating Best Management Practice (BMP) effectiveness; modifying stream sampling frequency and/or locations; helping develop and fund additional water quality projects that address bacteria pollution; administering local educational initiatives; and other means of conforming management measures to current information on the bacteria problem.

As bacteria source control measures and activities are successfully completed, those activities will be documented along with expected improvements in water quality. If the planned activities are not effective, the implementation activities as set out in this plan will be reexamined and modified as part of the adaptive management process. The results of ambient water quality monitoring will play a key role in determining the effectiveness of the plan. If new fecal coliform sources are found that were not previously identified, they will be corrected through appropriate action involving the responsible parties.

Monitoring progress

In order to gauge the progress of this TMDL implementation, Ecology will convene a meeting of municipal stakeholders no less than annually to share information on the state of water quality in the Bear-Evans watershed and status of implementation activities. Water quality data, trends (where applicable), regulatory changes, new and innovative concepts and initiatives, and funding sources will be discussed to evaluate the overall status and progress of the TMDL. Ecology will solicit input from the workgroup and watershed community at this time to help direct the adaptive management of this TMDL. Ecology will track implementation no less than annually, using a tracking table to be developed in the Water Quality Implementation Plan.

Ecology will continue to offer grant funding for water quality studies, stream restoration projects, BMP effectiveness evaluations, and development and implementation of monitoring programs through its annual Centennial Clean Water Fund.

The Water Quality Implementation Plan will describe the coordinated monitoring strategy to ensure that creeks in the Bear-Evans watershed are progressing toward TMDL goals. Compliance monitoring will be needed when water quality standards are believed to be achieved.

Organizations with enforcement authority are responsible for following up on any enforcement actions. Stormwater permit holders are responsible for meeting the requirements of their permits. Those conducting restoration projects or installing best management practices (BMPs) are responsible for monitoring plant survival rates and maintenance of improvements, structures and fencing.

The coordinated monitoring strategy will include responsible parties and monitoring programs that will provide periodic assessment of water quality. Current data on streams in the Bear-Evans Watershed will be used to track progress and will help adaptively management implementation.

Potential funding sources

Table 10 describes several possible funding sources for activities needed to correct bacteria problems in Bear-Evans Watershed. Ecology will work with partners to prepare appropriate scopes of work, assist with grant applications, and help in other ways to implement the TMDL.

Table 10. Possible funding opportunities to support implementation.

Sponsoring Entity	Funding Source	Uses to be Made of Funds
United States Environmental Protection Agency	Environmental Education Grants http://www.epa.gov/enviroed/grants.html	▪ Environmental education projects implemented by nonprofit organizations
Department of Ecology 3190 160th Ave SE Bellevue, 98008 (425) 425-7269	Clean Water Fund, Section 319, and State Revolving Fund http://www.ecy.wa.gov/programs/wq/funding Coastal Protection Fund (CPF) http://www.ecy.wa.gov/programs/sea/sea-grants.htm	▪ Implementation, design, acquisition, construction, and improvement of water pollution control. ▪ Facilities and water pollution control related activities. ▪ Priorities include: implementing TMDL plans, keeping pollution out of streams and aquifers, modernizing aging wastewater treatment facilities, reclaiming and reusing waste water. ▪ CPF is discretionary monies made available to regional Ecology offices to support on-the-ground projects to perform environmental restoration and enhancement.
King County Department of Natural Resources 201 S. Jackson Suite 600 Seattle, 98104 (206) 296-6519	King County Grant Exchange, including six grant programs http://dnr.metrokc.gov/grants/	Projects that protect or improve natural resources; such as water quality, salmon and wildlife habitat, reforestation, water conservation, and related educational efforts.

Summary of public involvement methods

Ecology engaged the public in several ways during the TMDL process to address fecal coliform bacteria, temperature, and dissolved oxygen problems in the Bear-Evans Watershed. Beginning in spring 2006, Ecology staff met with key stakeholders in the basin as part of the Bear-Evans Watershed TMDL Advisory Group: Muckleshoot Indian Tribe, King County, Snohomish County, City of Redmond, Bear Creek Water Tenders, Upper Bear Creek Community Council, Northeast Sammamish Sewer and Water District, Snohomish and King Conservation Districts, and others.

The advisory group met five times to discuss provisional findings from the TMDL studies and to share input on the strategy to restore the creeks to good health. Members also reviewed and commented on draft sections of the *Draft Bear-Evans Watershed Fecal Coliform Bacteria TMDL/Water Quality Improvement Report* (draft report) between meetings. In addition, Ecology staff met with some stakeholders individually to further discuss their input on the TMDL study and implementation strategy. Ecology held the advisory group meetings on the following dates:

- April 20, 2006
- January 4, 2007
- June 21, 2007
- January 5, 2008
- March 5, 2008

To engage citizens in the watershed during the process, Ecology staff gave a presentation on the status of the TMDL efforts at the Water Tenders meeting on May 23, 2007 and March 13, 2008.

The public comment period ran from May 9 to June 9, 2008 and gave the public, including key stakeholders, a chance to review and provide feedback on the proposed final draft report. On May 27, 2008, Ecology co-hosted a public meeting with the Upper Bear Creek Community Council and Water Tenders, to share highlights from the fecal coliform bacteria TMDL effort and plans for improving the water quality in the watershed.

Next steps

Once EPA approves the TMDL, a Water Quality Implementation Plan must be developed within one year. Ecology will work with local government, businesses, and the public to create this plan, choosing the combination of possible solutions they think will be most effective in the Implementation Area. Elements of this plan will include:

- Who will commit to do what.
- A schedule for completing implementation actions.
- How to determine if the implementation plan works.
- What to do if the implementation plan doesn't work.
- Potential funding sources.

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Appendices

Appendix A. Glossary and Acronyms

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.

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: 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.

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 whether or not the uses are currently attained.

Extraordinary primary contact: Waters providing extraordinary protection against waterborne disease or that serve as tributaries to extraordinary quality shellfish harvesting areas.

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 twenty-four hours at 44.5 plus or minus 0.2 degrees Celsius. Fecal coliform bacteria 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 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.

Impervious Surfaces: A hard surface area that either prevents or retards the entry of water into the soil mantle as under natural conditions prior to development and/or a hard surface area that causes water to run off the surface in greater quantities or at an increased rate of flow from the flow present under natural conditions prior to development. Common impervious surfaces include, but are not limited to, rooftops, walkways, patios, driveways, parking lots, storage areas, concrete or asphalt paving, gravel roads, packed earthen materials, and oiled, macadam, or other surfaces that similarly impede the natural infiltration of urban runoff. Open, uncovered retention/detention facilities shall not be considered as impervious surfaces.

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.

Loading capacity: The greatest amount of a substance that a water body can receive and still meet water quality standards.

Load duration curve: A visual display of pollutant loadings expressed over the cumulative frequency of historical streamflow data.

Low Impact Development (LID): A stormwater management and land development strategy applied at the parcel and subdivision scale that emphasizes conservation and use of on-site natural features integrated with engineered, small-scale hydrologic controls to more closely mimic pre-development hydrologic functions.

Margin of safety: Required component of TMDLs that accounts for uncertainty about the relationship between pollutant loads and quality of the receiving water body.

Municipal separate storm sewer systems (MS4): A conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, manmade channels, or storm drains): (i) owned or operated by a state, city, town, borough, county, parish, district, association, or other public body having jurisdiction over disposal of wastes, storm water, or other wastes and (ii) designed or used for collecting or conveying stormwater; (iii) which is not a combined sewer; and (iv) which is not part of a Publicly Owned Treatment Works (POTW) as defined in the Code of Federal Regulations at 40 CFR 122.2.

National Pollutant Discharge Elimination System (NPDES): National program for issuing, modifying, revoking and reissuing, terminating, monitoring and enforcing permits, and imposing and enforcing pretreatment requirements under the Clean Water Act. The NPDES program regulates discharges from wastewater treatment plants, large factories, and other facilities that use, process, and discharge water back into lakes, streams, rivers, bays, and oceans.

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 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.

Pathogen: Disease-causing microorganisms such as bacteria, protozoa, viruses.

Percent reduction goal: A numeric target based on the level of current fecal coliform bacteria loadings needed to be reduced in order to meet standards.

Phase I stormwater permit: The first phase of stormwater regulation required under the federal Clean Water Act. The permit is issued to medium and large municipal separate storm sewer systems (MS4s) and construction sites of five or more acres.

Phase II stormwater permit: The second phase of stormwater regulation required under the federal Clean Water Act. The permit is issued to smaller municipal separate storm sewer systems (MS4s) and construction sites over one acre.

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: Such contamination, or other alteration of the physical, chemical, or biological properties, of any waters of the state, including change in temperature, taste, color, turbidity, or odor of the waters, or such discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state as will or is likely to create a nuisance or render such waters harmful, detrimental, or injurious to the public health, safety, or welfare, or to domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or to 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, salt waters, wetlands and all other surface waters and watercourses within the jurisdiction of Washington State.

Total Maximum Daily Load (TMDL): A distribution of a substance in a water body designed to protect it from 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 allocations constitute 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.

90th percentile: A statistical number obtained from a distribution of a data set, above which 10 percent of the data exists and below which 90 percent of the data exists.

Acronyms and Abbreviations

Following are acronyms and abbreviations used frequently in this report.

BMP	best management practices
cfs	cubic feet per second
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
GIS	Geographic Information System software
LID	Low Impact Development
NAF	New Approximation Flow
NPDES	National Pollution Discharge Elimination System
NSDZ	near-stream disturbance zones
RM	river mile
TIR	thermal infrared radiation
TMDL	Total Maximum Daily Load (water cleanup plan)
USFS	United States Forest Service
USGS	United States Geological Survey
WDFW	Washington Department of Fish and Wildlife
WRIA	Water Resources Inventory Area
WWTP	wastewater treatment plant

Appendix B. Record of Public Participation

Introduction

Ecology engaged the public in several ways in the TMDL process to address fecal coliform bacteria, temperature, and dissolved oxygen problems in the Bear-Evans Watershed. Beginning in spring 2006, Ecology staff met with key stakeholders in the basin as part of the Bear-Evans Watershed TMDL Advisory Group: Muckleshoot Indian Tribe, King County, Snohomish County, city of Redmond, Bear Creek Water Tenders, Upper Bear Creek Community Council, Northeast Sammamish Sewer and Water District, Snohomish and King Conservation Districts, and others.

The advisory group met five times to discuss provisional findings from the TMDL studies and to share input on the strategy to restore the creeks to good health. Members also reviewed and commented on draft sections of the *Draft Bear-Evans Watershed Fecal Coliform Bacteria TMDL/Water Quality Improvement Report* (draft report) between meetings. In addition, Ecology staff met with some stakeholders individually to further discuss their input on the TMDL study and implementation strategy. Ecology held the advisory group meetings on the following dates:

- April 20, 2006
- January 4, 2007
- June 21, 2007
- January 5, 2008
- March 5, 2008

To engage citizens in the watershed during the process, Ecology staff gave a presentation on the status of the TMDL efforts at the Water Tenders meeting on May 23, 2007 and March 13, 2008.

The public comment period ran from May 9 to June 9, 2008 and gave the public, including key stakeholders, a chance to review and provide feedback on the proposed final draft report. On May 27, 2008, Ecology co-hosted a public meeting with the Upper Bear Creek Community Council and Water Tenders, to share highlights from the fecal coliform bacteria TMDL effort and plans for improving the water quality in the watershed.

Summary of comments and responses

Ecology received the following summarized comments during the public comment period for the draft report. Comments regarding factual inaccuracies, improved wording, or those that clarify policy positions by other government agencies have been directly incorporated into the text of the final report. All other comments are summarized or paraphrased below.

1. **Comment:** Provide the particulars on the data intervals and methods the EPA's Load Duration Curve Approach is using to calculate the baseflow for the creek, which then is used to define storm events for the system.

Response: Streamflow hydrographs can be separated into baseflow and surface runoff components. The baseflow component is traditionally associated with groundwater discharge and the surface runoff component with precipitation that enters the stream as overland flow. The load duration curve analysis incorporates an algorithm from the USGS Hydrograph Separation Computer Program (*sliding interval method*)[2] to estimate the percentage (or fraction) of total flow that consists of baseflow and stormflow. The *sliding interval method* finds the lowest discharge in one half the interval minus 1 day before and after the day being considered and assigns it to that day. The assigned daily values are then connected to define the baseflow hydrograph.

The load duration curve analysis in this TMDL uses a 1-day change in flow and the hydrograph separation percentage value (with 50% as the threshold) to define stormflows. In other words, if flow on day 2 is 50% higher than flow on day 1, the flow is considered predominantly stormflow.

2. **Comment:** There are periodic and recurring destruction of beaver dams blocking the outlet channel from Cottage Lake, and these events might mimic a storm event, based on the storm flow criteria described in the report: "…*stormflow events (defined as any one-day increase in streamflow above a minimum threshold of 50 percent*)." The precipitation record to verify storm conditions might account for most of these occurrences, although it is potentially possible that rain and dam breaking could be concurrent on occasion. It is important to differentiate between the surges due to dam destruction and regionally-caused storm flows because a surge will represent a mass of water coming from the lake rather than accumulated surface water flows from throughout the watershed below the lake. In addition, a surge caused by a drop in the lake outlet threshold may scour the sides of the creek in a different way than gradually accreted flows, thus changing the character and amount of the suspended sediments.

Response: Thank you for pointing out the beaver dam phenomenon near the Cottage Lake outlet. Since precipitation is the driving mechanism responsible for stormflows and associated surface runoff, Ecology reviewed the daily precipitation record from King County's Cottage Lake Rain Gauge 02w to verify storm conditions on the sample days that the load duration curve analysis defined as stormflow. For middle Bear Creek (C484) and upper Bear Creek (J484), Ecology found three sample days during the dry period in which no precipitation occurred on the day or the preceding day. Likewise for Cottage Lake Creek (N484), there was no rain on or before two samples days that the load duration curve analysis defined as stormflow. Therefore, Ecology redefined these sample days as having non-stormflow conditions. The load duration curve plots (Figure 12) and load and wasteload allocations (Table 7 a-c) for these stations reflect the corrected stormflow data.

3. **Comment:** Provide permit identification numbers for the municipalities in the Bear-Evans Watershed covered by Ecology's Phase I and Phase II Stormwater Management Permit.

[2] Sloto. R and M Crouse, 1996. HYSEP: A computer program for streamflow hydrograph separation and analysis. US Geological Survey (USGS) Water Resources Investigation Report 96-4040. Lemoyne, PA.

Response: On the municipal stormwater permittees map (Figure 5), Ecology added the permit identification numbers for all municipalities except for WSDOT. Ecology will issue a permit identification number for WSDOT in late 2008, after the publication of this report.

4. **Comment:** King County Lakes Stewardship Program is currently implementing riparian restoration activities and monitoring water quality in Daniels Creek and Cottage Lake as part of the Cottage Lake Phosphorous TMDL. A description of this program should be included as partners helping with implementation.

Response: Ecology agrees, and in response to this comment, a brief description of the King County Lakes Stewardship Program has been included.

List of public meetings

Ecology held a public meeting on May 27, 2008, from 6:30-8:00 pm, at the Woodinville Water District to present the draft report. The meeting was co-hosted by the Upper Bear Creek Community Council and Water Tenders. King Conservation District co-presented at the meeting, focusing on agricultural/farm best management practices. Sixteen local citizens attended the meeting.

Outreach and announcements

- Published *Draft Bear-Evans Watershed Fecal Coliform Bacteria TMDL/ Water Quality Improvement Report* (May 9) on Ecology's Bear-Evans Watershed TMDL Project webpage: http://www.ecy.wa.gov/programs/wq/tmdl/BearEvans/BearEvansFCTMDLSummary.html
- Announced the public meeting and public comment period on the webpage above.
- Posted public meeting announcements at the Cottage Lake Community Center, Redmond Public Library, Woodinville Public Library, and Sammamish Public Library.
- Mailed announcement postcards to members of the Water Tenders.
- Ran an ad in the Woodinville Weekly newspaper on May 20, 2008.
- Mailed hard copies of the draft report to members of the Bear-Evans Watershed TMDL Advisory Group.
- Placed hard copies of the draft report at the Redmond Public Library, Woodinville Public Library, and Sammamish Public Library (May 9 – June 9).
- Used listserve of the Upper Bear Creek Community Council, Water Tenders, and Horses for Clean Water to announce the public meeting and keep stakeholders informed on the TMDL progress.

Printed outreach materials

- Announcement cards were posted at the Cottage Lake Community Center and the public libraries of Redmond, Sammamish, and Woodinville.

WASHINGTON STATE DEPARTMENT OF ECOLOGY

Together, We Can Improve Water Quality in the Bear-Evans Watershed

Department of Ecology, Co-hosted by Upper Bear Creek Community Council

Public Meeting
Woodinville Water District
17238 NE Woodinville Rd.

Tuesday, May 27

6:30 -7:00 p.m. *open house*
7:00 - 8:00 p.m. *presentations*

Learn about recent studies and plans to improve bacteria pollution in Bear, Evans, and Cottage Lake Creeks.

For more information, contact:

Sinang H. Lee
sile461@ecy.wa.gov
425-649-7110

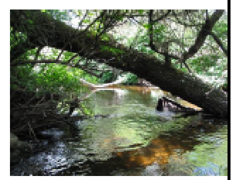
Come learn about:

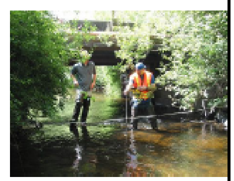
- Department of Ecology's recent study on the bacteria pollution problem in the watershed
- King and Snohomish Conservation Districts' plans to help reduce bacteria pollution in the Bear Creek sub-basin

Come share your:

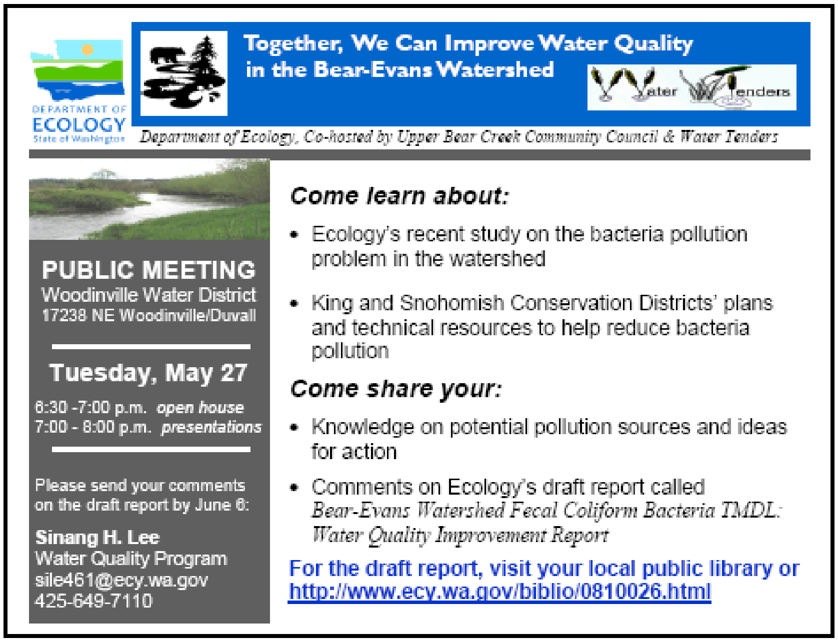
- Knowledge on bacteria pollution sources and ideas for action
- Comments on Ecology's draft report called *Bear-Evans Watershed Fecal Coliform Bacteria TMDL/Water Quality Improvement Report*

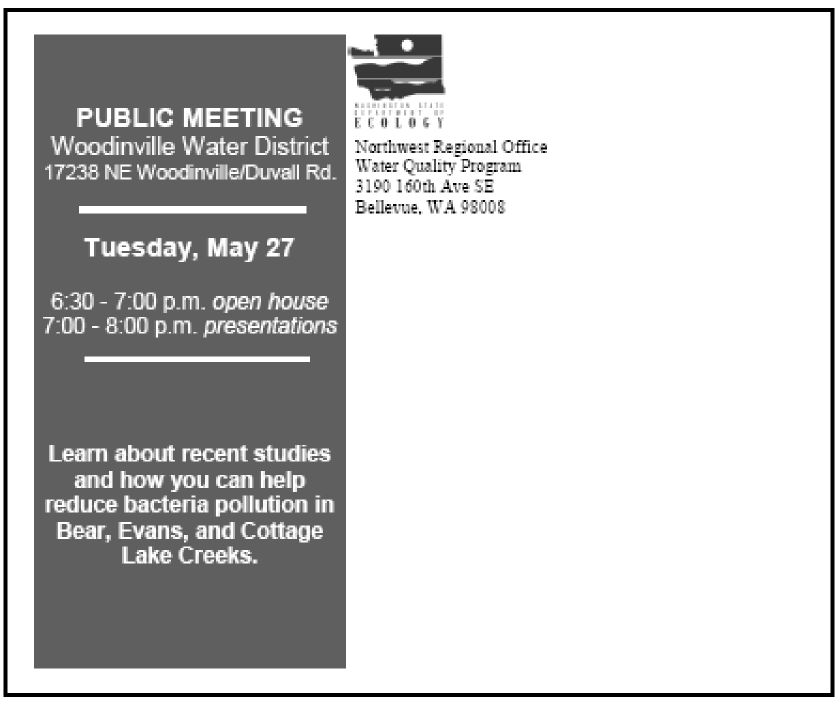
Copies of the draft report are at your local public library and http://www.ecy.wa.gov/biblio/0810026.html. Please comment at this meeting or send comments to Sinang Lee by June 9.





- Postcards were mailed to members of Water Tenders and Bear-Evans Watershed TMDL Advisory Group.





- A newspaper ad was placed in the Woodinville Weekly newspaper on May 20, 2008.

WASHINGTON STATE DEPARTMENT OF ECOLOGY

The Department of Ecology seeks your comments

Draft Bear-Evans Watershed Fecal Coliform Bacteria TMDL/Water Quality Improvement Report

PUBLIC MEETING:

Tuesday evening, May 27, 2008
Open House 6:30, Presentations 7:00-8:00
Woodinville Water Dist. 17238 NE Woodinville Rd.

The Washington State Department of Ecology has prepared a draft of the above Report to address the problem of high fecal coliform bacteria levels in Bear-Evans Watershed streams. Its purpose is to provide findings and a strategy of recommended actions to help reduce bacteria levels and health risks in these streams. Our goal is to improve overall water quality to meet State standards.

We are seeking your comments about how well the draft document seems to address bacteria cleanup. Ecology needs your ideas and suggestions to develop an effective plan and we welcome you to share your thoughts with us. Thank you for your efforts to improve the quality of our water.

To obtain a copy of the Report, call 425-649-7110; or go to:

- www.ecy.wa.gov/biblio/0810026.html
- Redmond, Sammamish, and Woodinville Public Libraries,
- The Ecology Department office (at the address below)

Please send comments by **June 9, 2008** to Sinang Lee
Dept. of Ecology, 3190 160th Ave SE, Bellevue WA 98008-5452;
or by email to: sile461@ecy.wa.gov

If you have special accommodation needs, please call (425) 649-7041 or (425) 649-4259 (TDD)

- Focus sheet (4 pgs) on the fecal coliform bacteria in Bear-Evans Watershed.

Focus on Bear-Evans Watershed

DEPARTMENT OF ECOLOGY State of Washington

Water Quality May 2008

Problem: Too much bacteria in our streams

Bear Creek, Cottage Lake Creek, and Evans Creek have too much bacteria pollution

Water samples from these streams indicate that fecal coliform bacteria measurements fail to meet Washington's freshwater water quality standards. These kinds of bacteria are mostly harmless but indicate that more serious disease-causing organisms (known as pathogens) may also be in the water. Where pathogens are present in polluted water, humans can be infected through skin contact, ingestion of water, or by consuming contaminated shellfish.

Fecal coliform bacteria are a common water quality problem in our state's urban streams and the Bear Creek Watershed is not unique. These bacteria are found in large numbers in the feces of people and other warm-blooded animals such as pets, livestock, and wildlife. Failing septic systems can send bacteria directly into our surface and ground waters or add it to bacteria pollution from many other sources when stormwater carries everything down to local streams.

There are many sources of bacteria that we can help reduce (also see *SEVEN SIMPLE THINGS* page 3)

Cats and dogs are primary sources of bacteria in urban Puget Sound watersheds. Other non-human sources include waterfowl (such as ducks and geese), gulls, pigeons, rats, raccoons, squirrels, beaver, deer, muskrats, and other warm-blooded wildlife. When people feed wildlife they create another kind of problem by forming a domestic relationship with these `unlicensed pets.'

(Both the new `pets' and the waste food can result in large amounts of concentrated bacteria that are directly linked to those causing the pollution and doing the feeding!)

PUBLIC MEETING & COMMENT

Tuesday, May 27, 2008

6:30 - 7 p.m. Open House
7:00 - 8 p.m. Presentations

Woodinville Water District
7238 NE Woodinville Rd.

We have developed a detailed report to guide further work to control bacteria pollution -- the ***Draft Bear-Evans Watershed Fecal Coliform Bacteria TMDL/Water Quality Improvement Report.***

We value your comments

You can find a copy of the report at the Redmond, Sammamish, and Woodinville public libraries. Or download a copy from: http://www.ecy.wa.gov/biblio/0810026.html

You can request a copy or send comments by June 9, 2008 to **Sinang H. Lee** at:

Department of Ecology
3190 160th Ave. SE
Bellevue, WA 98008
425-649-7110 |
sile461@ecy.wa.gov

Special accommodations:

If you need this publication in an alternate format, call the Water Quality Program at 360-407-6404. Persons with hearing loss, call 711 for Washington Relay Service. Persons with a speech disability, call 877-833-6341.

Publication Number: 08-10-047 1

Other sources of bacteria we can help reduce:

- Livestock such as horses, cattle, llamas, sheep, poultry, and rabbits can generate significant bacteria. If livestock fields and manure are properly managed, bacteria can be prevented from polluting our waters. (see page 3, *SEVEN SIMPLE THINGS* #3)
- In areas of watersheds with sanitary sewer lines that are improperly connected or leak, bacteria from humans can enter our waters. Domestic sewage has typically two to three times as much bacteria as stormwater runoff and four to five times as much as runoff from forests that are influenced only by wildlife sources. (see *SEVEN SIMPLE THINGS* #7)
- Humans also create problems in non-sewered watersheds, where failing on-site septic systems can be very significant human sources of bacteria. Contaminated runoff can enter our streams -- or worse, enter ground water near wells creating a serious threat to human health. (*SEVEN SIMPLE THINGS* #1)

Efforts are underway to improve water quality in the watershed

For waters that do not meet Washington's water quality standards, the Department of Ecology (Ecology) uses a water quality improvement process that determines what is called the Total Maximum Daily Load (TMDL) of allowable pollution. Through this process, Ecology:

- Evaluates the water quality conditions.
- Estimates how much the pollution needs to be reduced to meet standards.
- Describes how citizens, state and local governments, and other organizations and businesses will control pollution and improve conditions in the affected water body.

King County, the City of Redmond, Water Tenders, and other groups have already done much to restore and improve water quality in the Bear-Evans Watershed, but more work is needed. Working with community partners, we can identify and correct the remaining problem sources of bacteria in the watershed.

WORKING AS PARTNERS, WE CAN ALL RESTORE AND HELP PROTECT CLEAN AND HEALTHY STREAMS.

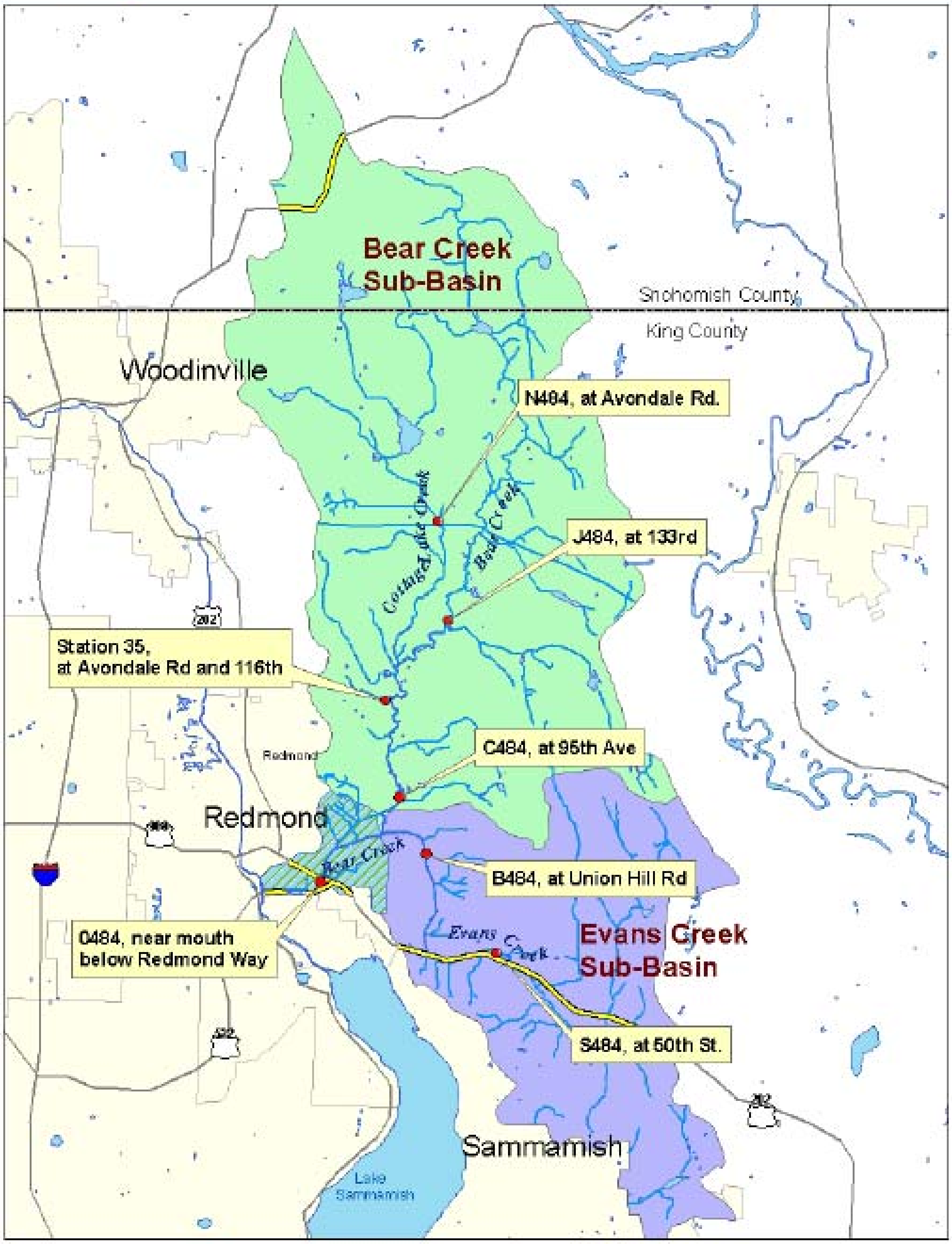
What did we learn and what does the report tell us?

- More than 30 years of data show bacteria pollution levels have generally declined in the Bear Creek system, especially near the mouth of Bear Creek since 1994. In more recent years, the Evans Creek branch of the system shows lower bacteria pollution levels than the Bear Creek branch.
- Bacteria pollution varies seasonally near the mouth of Bear Creek. In the dry season (May-Sept), bacteria concentrations are highest. In contrast, during the wet season (Oct-Apr), the total numbers of bacteria in the creek per day are the highest—more stormwater runoff means larger amounts of bacteria into the creek.
- It will take an estimated 57 to 91 percent reduction in current bacteria loadings to bring the creeks to state water quality standards.
- **We must all work together to fix this.** By doing our part and helping our neighbors better understand the problem and solutions, we can track and control bacteria sources.

Here are *SEVEN SIMPLE THINGS* we can all do to protect our water:

1. **CHECK your on-site septic system.** Make *$ure* yours is working right; test regularly (every three years) and pump when needed.
2. **DISPOSE of household hazardous waste properly.** Learn the *important* information about which products are hazardous or dangerous to health and how to properly dispose of them. DON'T FLUSH DRUGS!
3. **MANAGE livestock.** Water animals away from streams or lakes; safeguard manure piles from rain and surface run-off. Contact your local Conservation District for help.
4. **PROTECT natural vegetation.** Consider additional plantings to help filter pollutants and prevent run-off from reaching streams, lakes, and rivers. Use minimal fertilizers, pesticides, and water to cause the least impact to ground water and water bodies.
5. **RECYCLE and PREVENT litter From people and pets.** Put *recycling* in proper containers. Double-bag and put *pet waste* and other litter with garbage.
6. **WASH vehicles at commercial carwash or on lawns.** Dirty run-off from driveways may carry greasy, oily, and soapy water straight to our streams and rivers, feeding unwelcome 'problem' water weeds and reducing the oxygen needed for healthy waters.
7. **PARTICIPATE!** If you see a spill or illegal dumping, call your nearest Department of Ecology regional office, or call 800-258-5990. Work with local government and environmental groups; help keep yourself and others informed!

Water Quality **May 2008**



Publication Number: 08-10-047 4 Please reuse and recycle

Appendix C. Data Sources

King County's Water and Land Resources Division supports a comprehensive long-term monitoring program to assess water quality in freshwater bodies throughout and adjacent to the county. Monitoring programs typically collect samples on a monthly basis. Samples were collected at approximately knee-depth by inverting sample containers just above the water surface, then sinking the bottle down to approximately 12-inches below the water surface (King County, 2004c). The bottles were not filled completely in order to allow room for mixing. Fecal coliform were analyzed using membrane filtration methodology according to Standard Methods 9222D (APHA, 1998). All samples were analyzed within the recommended holding times and quality assurance/quality control procedures included the use of blanks, duplicates, and spikes when appropriate. King County reviewed all data prior to entry into their LIMS (Laboratory Information Management System) database (King County, 2004c).

Ecology evaluated water quality and flow gage data collected by King County Water and Land Resources Division to characterize bacteria levels in the Bear-Evans watershed. King County monitors water quality at six stations in the Bear-Evans watershed since 1971. These stations characterize lower, middle and upper Bear Creek (O484, C484 and J484) and lower and upper Evans Creek (B484 and S484). Cottage Lake Creek, a major tributary to Bear Creek above it's confluence with Evans Creek is also monitored (N484).

City of Redmond monitors at an unnamed Bear Creek tributary at Avondale Road and 116th (station 35). From mid 2001 through December 2003, quarterly samples were collected. Since October 2004, the city began collecting monthly samples for fecal coliform.

To assess the current bacteria conditions, Ecology compiled and analyzed recent data records for the six monitoring sites:

- 1993 to 2007 for sites C484, J484, N484, B484
- 2000 to 2007 for sites S484 and O484
- 2001 to 2007 for station 35

To estimate the loading capacity, Ecology used daily average discharge rates measured by the following gages and available for the period from October 1, 1987 to August 22, 2007:

- Gage station 02a, co-located with water quality site 0484 near the mouth of Bear Creek
- Gage station 02g, co-located with water quality site N484 on Cottage Lake Creek
- Gage station 02e, co-located with water quality site J484 on upper Bear Creek
- Gage station 18a, co-located with water quality site B484 on Evans Creek

No gage exists with water quality monitoring sites C484 on Bear Creek at 95th Ave and S484 on upper Evans Creek. Ecology estimated flows at site C484 by subtracting the Evans Creek flow at gage 18a from the flow at the mouth of Bear Creek at gage 02a. On July 18, 2006, Ecology measured instantaneous summer baseflow at sites S484 and B484 and determined the flow at site S484 was about half of the flow at site B484. Therefore, Ecology used this proportion to estimate long-term flows at site S484 based on gage 18a. This may result in an underestimation of wet season flows which will be accounted for in the margin of safety.

For each station (0484, B484, and C484), the loading duration curve analysis combined the continuous flow data and bacteria concentration data for the period from 1987 to 2007. This combination provided the best loading relationships given the available data.

Water quality data at http://dnr.metrokc.gov/wlr/waterres/streamsdata/SamplingSites.aspx
Flow gage data at http://dnrp.metrokc.gov/WLR/Waterres/hydrology/GaugeTextSearch.aspx

Appendix D. Equations for TMDL Analysis

Simple Method Formula

$$L = 1.03\ E\text{-}3 * R * C * A$$

Where….

L = Seasonal load in billions of colonies
R = Seasonal runoff in inches
C = Bacteria concentration in #/100 mL
A = Area in acres
1.03 E-3 = unit conversion factor

$$R = P * Pj * Rv$$

P = Seasonal rainfall in inches

Pj = Fraction of annual rainfall events that produce runoff (assumed 85 percent)

Rv = Runoff coefficient

Rv = 0.05 + 0.9Ia

Deriving the 90th Percentile Value

The federal Food and Drug Administration developed a statistically-based formula to evaluate growing areas for shellfish sanitation. The National Shellfish Sanitation Program Model Ordinance (NSSP, 2003) states:

The estimated 90th percentile shall be calculated by:

(a) Calculation the arithmetic mean and standard deviation of the sample result logarithms (base 10);

(b) Multiplying the standard deviation in (a) by 1.28;

(c) Adding the product from (b) to arithmetic mean;

(d) Taking the antilog (base 10) of the results in (c) to get the estimated 90th percentile; and

(e) The most probable number (MPN) values that signify the upper or lower ranger of sensitivity of the MPN tests in the 90th percentile calculation shall be increased or decreased by one significant number.

The 90th percentile derived using this formula assumes a lognormal distribution of the fecal coliform data. The variability in the data is expressed by the standard deviation, and with some data sets it is possible to calculate a 90th percentile greater than any of the measured data.

Loading Capacity

There are several ways to estimate the number of bacteria in the creek. For example, numbers of bacteria can be counted over a day, month, or year. Ecology used the following method to estimate the loading capacity and daily bacteria loads:

$$\underset{(ft^3/\text{second})}{\textit{Flow}} \times \underset{(\text{cfu}/100\text{ mL})}{\underset{\textit{Target}}{\textit{Bacteria Concentration}}} \times \underset{(2.447 \times 10^7)}{\textit{Conversion Factor}} = \textit{Number of Bacteria per day}$$

Flow for each flow interval was taken as the midpoint value of each flow interval identified by the duration curve analysis. The midpoints of the moist, mid-range, and dry zones correlate with the 25th, 50th, and 75th percentiles, respectively. The high flow zone is centered at the 5th percentile, while the low flow zone is centered at the 95th percentile.

The bacteria concentration target is the geometric mean criterion of the water quality standards for Bear, Evans, and Cottage Lake Creeks, 50 cfu per 100 mL.

Appendix E. TMDL Analytical Framework

Estimating the loading capacity - Load Duration Curve

The loading capacity was estimated using the duration curve approach (EPA, 2007). This approach allows for characterizing water quality data at different flow regimes and accounts for changes in the water quality at different flow stages, therefore accounting for seasonal variation.

Daily average discharge rates from King County gage station 02a at the mouth of Bear Creek and gage station 18a on Evans Creek at Union Hill Road were available to develop flow duration curves for their co-located water quality monitoring sites, O484 and B484, respectively. For the engaged monitoring site C484 on Bear Creek at 95th avenue above the confluence with Evans Creek, flows were estimated by subtracting the Evans Creek flow from the flow at the mouth of Bear Creek.

First step in developing the load duration curve is to look at the cumulative frequency of historic flow data, sorting from the highest value to the lowest. This produces the 'flow duration curve' which relates the flow values to the percent of time those values have been met or exceeded. Using this convention, flow duration intervals are expressed as a percentage, with zero corresponding to the highest discharge in the record (i.e., flood conditions) and 100 to the lowest (i.e., drought conditions).

Duration curve analysis identifies intervals, which can be used as a general indicator of hydrologic condition (i.e., wet versus dry and to what degree). The flows for this TMDL are categorized into zones to provide additional insight about conditions and patterns associated with the impairment: high flows (0-10 percent), moist conditions (10-40 percent), mid-range flows (40-60 percent), dry conditions (60-90 percent), and low flows (90-100 percent).

The bacteria load values are estimated by multiplying actual fecal coliform sample values with the streamflow taken at the time of each sample and a conversion factor. Load values are then plotted with respect to the flow range at the time of the sample for comparison with other loads at other flow intervals. Ecology expressed bacteria loading in terms of colony forming units per day (cfu/day) which worked out to billions of cfu per day for typical loads in the Bear-Evans watershed.

Flow duration curves serve as the foundation for development of load duration curves, which are useful in TMDLs. Loads are directly proportional to flows. A load duration target is developed by multiplying the stream flow value at the midpoint of each flow zone with the numeric water quality target (geometric mean value of 50 cfu/100mL) and a conversion factor. The target of 50 cfu/100mL is constant across all flow conditions.

Setting load and wasteload allocations – Simple Method Model and Stormflow Load Analysis

Urban watersheds are very complex and contain many potential pollutant sources making detailed quantifications of sources difficult. Although this study does not provide a high level of detail on the bacteria sources to Bear and Evans Creeks, it broadly categorizes pollution into "point" and "nonpoint" sources.

- **Point sources** are locations where pollution can enter local streams by pipes or channels owned or operated by municipal government or businesses. Ecology regulates discharges from these outfalls through its NPDES permit program. The city of Seattle owns and operates the storm sewer system of ditches and culverts in the study area.

- **Nonpoint source** pollution enters a local stream from dispersed land-based or water-based activities. These could include failing on-site septics, improperly managed pet wastes, excessive concentrations of wildlife, and perhaps leaky sewer lines and illicit discharges. These activities are very hard to count and add up because they occur in so many locations.

The amount of impervious cover strongly correlates with water quality; the more impervious cover, the higher the bacteria levels (PSAT, 2007). Impervious surfaces such as roads, roof tops, and parking lots accumulate contaminants and prevent water from infiltrating as would occur on vegetated grounds. Due to the rush of water off these surfaces, stormwater can carry much of the bacteria directly into a stream during the wet season. Stormwater is largely conveyed to surface waters through stormwater drainage systems (point source) but can also flow off the land as nonpoint sources.

In the dry season, stormwater drainage systems still contribute some pollution during summer storm events. In this study area, an estimated six inches of rainfall occur on average in a dry season. This is little compared to the stormwater generated during the wet season. Therefore, the main source of bacteria pollution in the dry season is likely from nonpoint sources.

Bacteria are a difficult subject for watershed modeling because of the episodic nature of bacteria standards violations, the importance of secondary sources to total loads, variability in monitoring data, and bacteria's ability to survive and reproduce in storm drains and stream sediments (CWP, 2001). This study did not collect data to specifically characterize bacteria concentrations in stormwater.

Simple Method Model

Without extensive data, Ecology used a land-use-based approach, the Simple Method Model (Schueler, 1987), to estimate the relative contribution of point and nonpoint sources to bacteria loads in stormwater runoff in the study area. The model uses estimates of drainage area, impervious cover, stormwater runoff bacteria concentrations, and annual precipitation. In this TMDL, point source wasteload allocations are assigned to areas with residential, commercial, industrial, and state roadway land use. Nonpoint source load allocations are assigned to areas with forest land use. The agricultural and rural land use was divided between load allocation and wasteload allocation.

The following process estimate contribution from sources during precipitation-driven conditions:

1. Perform Geographic Information Systems (GIS) analysis on land use types above the three monitoring sites using MRLC satellite imagery (MRLC, 1999)

2. For each land use, calculate relative stormwater bacteria loads from nonpoint and point sources with a ten percent margin of safety using the Simple Method Model.

3. Based upon the proportional contributions to stormwater bacteria loads, assign load allocations (LA) for nonpoint sources and specific wasteload allocations (WLA) for the point sources.

Determine land uses above each water quality monitoring station

Ecology used several sources of data and assumptions to estimate land uses above monitoring sites C484, B484, and O484 (Table 12):

- The Multi-resolution Land Characterization Consortium (MRLC 1999) identified ten different types of land uses in the basin. These were consolidated into: Forest, Agriculture/Rural, Residential, Commercial/Industrial, and Roadway.

- The assumed width of roads plus their right-of-way areas were used in calculating their acreage with GIS (**Table 11**). Lane widths are assumed to be 12 feet. Additional right-of-ways on larger roads (Hwy 520, 522, and 524) were assumed to be 30 feet and shoulders were assumed to be 20 feet on the outer perimeter of highways. A smaller shoulder width (5 feet) and right of way (5 feet) were assumed for roads crossing more urbanized areas (Hwy 202).

Table 11. Road widths used to calculate roadway acreages. Total widths are considered to be estimates that generally characterize the roadway characteristics in an urban setting.

Roadway name	# of Lanes	Road Width	Shoulder Width	Right of Way	Total Width
Highway 520	4	48	40	60	148
Highway 522	4	48	40	60	148
Highway 524	4	48	40	60	148
Highway 202	4	48	10	10	68

Table 12(a-c). Land use estimates in the drainage areas above stations in Bear Creek sub-basin.

[a] Land Use above Station N484 on Cottage Lake Creek

	Acreage (total acreage 6,467 (not counting open water)						
	Area (acres)	City of Redmond	City of Sammamish	City of Woodinville	King Co.	Snoh. Co.	WSDOT
Forest	3,429	0	0	419	1,484	1,524	2
Agricultural/Rural	577	0	0	68	216	291	2
Residential	2,247	0	0	413	1,168	647	19
Commercial/Industrial	214	0	0	28	23	145	18
State Roadway	41	0	0	0	0	0	41
Total	6,467	0	0	929	2,892	2,607	41
% of total land use		0.0%	0.0%	14.4%	44.7%	40.3%	0.6%

[b] Land Use above Station J484 on Bear Creek (upper)

	Acreage (total acreage 7,271 (not counting open water)						
	Area (acres)	City of Redmond	City of Sammamish	City of Woodinville	King Co.	Snoh. Co.	WSDOT
Forest	4,960	32	0	0	3,060	1,868	0
Agricultural/Rural	561	0	0	0	416	145	0
Residential	1,714	0	0	0	1,410	304	0
Commercial/Industrial	35	0	0	0	31	4	0
State Roadway	0	0	0	0	0	0	0
Total	7,271	32	0	0	4,917	2,321	0
% of total land use		0.4%	0.0%	0.0%	67.6%	31.9%	0.0%

[c] Land Use above Station C484 on Bear Creek

	Acreage (total acreage 21,415 (not counting open water)						
	Area (acres)	City of Redmond	City of Sammamish	City of Woodinville	King Co.	Snoh. Co.	WSDOT
Forest	12,310	1,147	0	419	7,349	3,394	0
Agricultural/Rural	2,174	146	0	68	1,523	438	0
Residential	6,369	451	0	413	4,533	971	0
Commercial/Industrial	521	112	0	28	214	167	0
State Roadway	41	0	0	0	0	0	41
Total	21,415	1,856	0	929	13,619	4,971	41
% of total land use		8.7%	0.0%	4.3%	63.6%	23.2%	0.2%

Table 13(a-b). Land use estimates in drainage areas above the stations in Evans Creek sub-basin.

[a] Land Use above Station S484 on Evans Creek (upper)

	Acreage (total acreage 9,744 (not counting open water)						
	Area (acres)	City of Redmond	City of Sammamish	City of Woodinville	King Co.	Snoh. Co.	WSDOT
Forest	4,104	0	814	0	3,285	0	5
Agricultural/Rural	677	0	91	0	582	0	4
Residential	2,173	0	1,165	0	996	0	11
Commercial/Industrial	343	0	125	0	216	0	2
State Roadway	23	0	0	0	0	0	23
Total	7,297	0	2,195	0	5,079	0	23
% of total land use		0.0%	30.1%	0.0%	69.6%	0.0%	0.3%

[b] Land Use above Station B484 on Evans Creek (lower)

	Acreage (total acreage 9,744 (not counting open water)						
	Area (acres)	City of Redmond	City of Sammamish	City of Woodinville	King Co.	Snoh. Co.	WSDOT
Forest	5,001	36	886	0	4,079	0	0
Agricultural/Rural	1,216	85	95	0	1,037	0	0
Residential	2,975	203	1,225	0	1,547	0	0
Commercial/Industrial	520	157	128	0	234	0	0
State Roadway	32	0	0	0	0	0	32
Total	9,744	482	2,335	0	6,896	0	32
% of total land use		4.9%	24.0%	0.0%	70.8%	0.0%	0.3%

Table 14. Land use estimates in whole Bear-Evans Watershed, as represented by the drainage area above station O484.

Land Use above Station O484 on Bear Creek (whole watershed)

	Acreage (total acreage 32,005 (not counting open water)						
	Area (acres)	City of Redmond	City of Sammamish	City of Woodinville	King Co.	Snoh. Co.	WSDOT
Forest	17,412	1,285	886	419	11,428	3,394	0
Agricultural/Rural	3,534	374	95	68	2,559	438	0
Residential	9,573	883	1,225	413	6,080	971	0
Commercial/Industrial	1,386	614	128	28	448	167	0
State Roadway	99	0	0	0	0	0	99
Total	32,005	3,157	2,335	929	20,515	4,971	99
% of total land use		9.9%	7.3%	2.9%	64.1%	15.5%	0.3%

Estimating the impervious cover and stormwater bacteria loads associated with land uses

Impervious cover percentages were taken from several sources (Table 15):

- The Center for Watershed Protection (2005) provided impervious cover percentages for Residential and Commercial/Industrial land uses based on studies in the Pacific Northwest.

- Ecology used the impervious coverage figure of 60 percent for WSDOT roads based on the assumption that their area was a combination of roadway and right-of-way.

- Joy (2004) compiled impervious coverage values for Forest and agriculture/Rural from regional and national databases. Forested areas were assumed to meet the 90^{th} percentile standard of 100 cfu/100 mL and have some small amount of runoff due to their generally small size, proximity to municipal separate storm sewer systems (MS4s), and the likelihood of roads and trails due to their anticipated high usage in urban areas

The Simple Method (CWP 2005) used the available data and assumptions above to approximate the seasonal number of bacteria discharged in stormwater from different land use areas within the Bear Creek (mid-upper) and Evans Creek sub-basins and for the whole Bear-Evans watershed. Estimated percentage of total fecal coliform loading ('loading proportion') was then computed for each land use category. This provides a relative contribution of stormwater bacteria loads from point sources based on the land use (type and area) covered under each jurisdiction. The Washington State Department of Transportation (WSDOT) wasteload allocations (WLAs) were based on the respective road areas in each watershed sub area.

Table 15. Stormwater runoff characteristics and impervious cover estimates.

Land use type	Fecal coliform (cfu/100 mL)	Impervious cover (percent)
Forest	100	20
Agriculture/Rural	3,000	30
Residential	2,000	40
Commercial/Industrial	980	87
Road Only	1,400	60

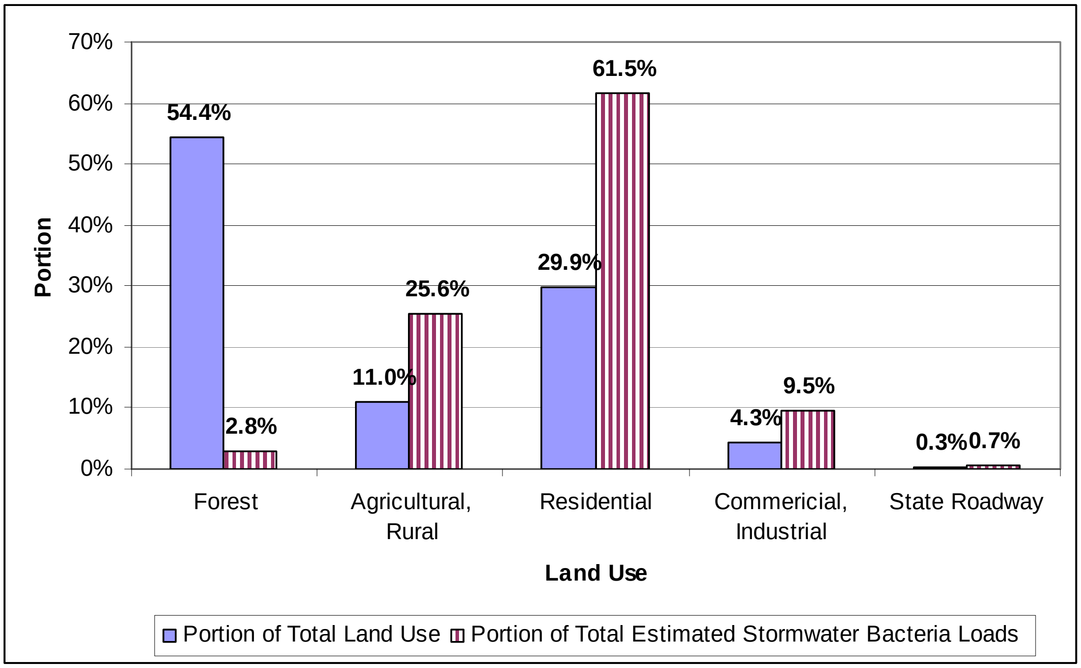


Figure 16. Estimated contribution of stormwater bacteria loads from different land uses in the Bear-Evans Watershed (drainage area above station O484 near the mouth of Bear Creek) based on the Simple Method Model.

Figure 16 shows that the Bear-Evans Watershed, as represented by the drainage area above the station near the mouth of Bear Creek (O484), has primarily forest, agricultural/rural, and residential land uses. Also shown in Figure 16, the Simple Method Model estimates that the stormwater runoff from residential land use, including local roads, contributes more than 50 percent of the total estimated stormwater bacteria loadings to the Bear Creek near the mouth (O484). Highly concentrated stormwater bacteria loads of 2,000 cfu/100mL and a moderate amount of impervious cover of 40 percent characterize residential land use (Table 15). This analysis assumes agricultural/rural land contributes to both point and nonpoint sources of stormwater bacteria loads.

Stormwater bacteria load analysis

So how much does stormwater runoff contribute to the fecal coliform bacteria problem in the Bear-Evans Watershed? Stormwater bacteria loadings to a stream strongly correlate with the amount of impervious cover in the drainage area (PSAT, 2007). Water running off impervious surfaces can carry bacteria directly into a stream during storm events. Stormwater is largely conveyed to surface waters through stormwater drainage systems such as the MS4s (point sources). When it flows off the land directly into a stream, stormwater is considered a nonpoint source.

To determine how much bacteria come from point and nonpoint sources when it rains, Ecology first estimates the relative contributions from the individual MS4s and nonpoint sources in the drainage area of the monitoring station. To determine these relative contributions, Ecology uses a modified version of Simple Method Model (Schueler, 1987). The Simple Method Model estimates stormwater pollution under precipitation-driven conditions from different land uses above the station. Inputs into the model include estimates on the drainage area above the monitoring station, land uses in the drainage area, percent impervious cover of different land uses, and average precipitation in the watershed.

Ecology refined the Simple Method Model to better characterize storm-driven loadings. First, we modified the model to estimate nonpoint source inputs from different land uses. We assume all forest conditions in the basin contributes 100 percent to the nonpoint discharges during storm events; whereas, commercial/industrial uses and state roadways contributes 0 percent to nonpoint discharges.

Then using data from the Load Duration Curve analysis, Ecology determined how much of the total observed bacteria loadings to the creek occurred during stormflow events (defined as any one-day increase in streamflow above a minimum threshold of 50 percent). The Load Duration Curve analysis divides bacteria loads into samples collected during stormflow and non-storm flow events throughout the year. Stormflow loads are assumed to be precipitation driven and can enter the creek from both point and nonpoint sources in the model. Non-stormflow loads are assumed to come from only nonpoint sources. We adjusted the final relative load and wasteload allocations in the model based on the percentages of the observed stormflow loads and non-stormflow loads, as depicted conceptually in Figure 17.

Table 16 provides the 'stormflow load portion' sampled at each monitoring station. Stormflow loads contribute 16 percent to 92 percent of all bacteria loadings to the creeks and support the assumption that the critical conditions for this TMDL are in the mid-range flow to dry flow conditions. Storms can occur under any of the five different streamflow conditions defined in the Load Duration Curve analysis.

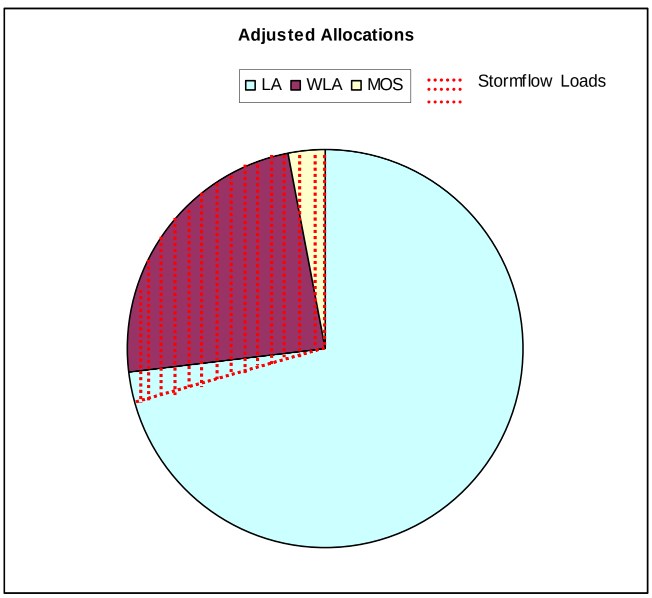


Figure 17. Conceptual display of final relative estimated allocations from the Simple Method Model adjusted for the observed loadings (stormflow vs. nonstormflow) used in the Loading Duration Curve analysis.

Table 16. Portion of stormflow loads sampled at each station. N is number of samples.

Water body/Station ID		All sampled loads		% Stormflow Loads		% Non-Stormflow Loads	
		N	billion colonies per day	N	Proportion	N	Proportion
Bear Creek Sub-Basin							
Cottage Lake Creek	N484	89	4,420	21	56%	68	45%
Bear Creek (upper)	J484	154	8,150	30	52%	124	48%
Bear Creek (mid)	C484	186	54,700	36	32%	150	68%
Evans Creek Sub-Basin							
Evans Creek (upper)	S484	171	3,210	12	19%	159	81%
Evans Creek (lower)	B484	176	6,450	19	16%	157	84%
Whole Bear-Evans Watershed							
Bear Creek (mouth)	O484	111	110,000	35	92%	76	8%