Bear-Evans Watershed Temperature and Dissolved Oxygen Total Maximum Daily Load

Water Quality Improvement Report

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For more information contact:

Publications Coordinator
Water Quality Program
P.O. Box 47600
Olympia, WA 98504-7600

E-mail: khig461@ecy.wa.gov
Phone: (360) 407-6722

Washington State Department of Ecology - www.ecy.wa.gov/

- Headquarters, Olympia 360-407-6000
- Northwest Regional Office, Bellevue 425-649-7000
- Southwest Regional Office, Olympia 360-407-6300
- Central Regional Office, Yakima 509-575-2490
- Eastern Regional Office, Spokane 509-329-3400

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Cover photo: Bear Creek at Woodinville Duvall Road, taken by Craig Homan.

Bear-Evans Watershed Temperature and Dissolved Oxygen Total Maximum Daily Load

Water Quality Improvement Report

by

Teizeen Mohamedali
Environmental Assessment Program
Washington State Department of Ecology
Olympia, Washington 98504-7710

and

Sinang Lee
Water Quality Program
Northwest Regional Office
Washington State Department of Ecology
Bellevue, Washington 98008-5452

Waterbody Number: WA-08-1095

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Abstract

The Bear-Evans watershed is located in northern King and southern Snohomish Counties, within the Cedar-Sammamish basin.

Bear, Evans, and Cottage Lake Creeks all have 303(d) listings as impaired water bodies for high temperature and low dissolved oxygen (DO). Because of these impairments, a Total Maximum Daily Load (TMDL) study is required.

In 2006 the Washington State Department of Ecology conducted TMDL field surveys in collaboration with King County, the city of Redmond, and the Northeast Sammamish and Sewer Water District. Stream temperature, nutrient, and DO data generated from this monitoring effort were used to calibrate QUAL2Kw, a stream water quality model. Once calibrated, the model was used to predict the response of Bear, Evans, and Cottage Lake Creeks to different hypothetical meteorological, shade, flow, and nutrient conditions.

Stream temperature reductions of 5.2°C, 5.7°C, and 2.7°C are predicted for Bear, Evans, and Cottage Lake Creeks (respectively) with the establishment of system potential mature riparian vegetation and microclimate improvements. Additional temperature reductions of 3.3-4.6°C, 3.2-5.1°C, and 0.7-0.9°C are predicted for Bear, Evans, and Cottage Lake Creeks (respectively) with the range of potential baseflow increases.

The resulting stream temperatures would be below the 22ºC threshold for fish lethality in all of the evaluated stream segments, and below the 16ºC Washington State water quality criterion in some segments of Bear and Evans Creeks.

The influence of lakes, wetlands, and groundwater suggest that low DO concentrations are, to some degree, a result of natural conditions. Modeling simulations demonstrated that DO concentrations were insensitive to changing nutrient conditions since the creeks are light-limited rather than nutrient-limited. However, some improvement (increases) in DO was predicted with increased shade and subsequent cooling of water temperatures.

Effective shade load allocations are prescribed to improve both temperature and DO conditions in the watershed. In addition, other management activities which enhance summer baseflows are needed for compliance with the Washington State water quality standards.

Acknowledgements

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Special thanks also go to the Bear-Evans 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. They also collaborated on the field work for this study.

Bear-Evans Watershed TMDL Advisory Group:

- City of Redmond: Keith MacDonald, Peter Holte, Jerallyn Roetemeyer, Elaine Dilley, Scott McQuary, Roger Dane, Rebecca Borker, Andy Rheaume.
- City of Sammamish: John Cunningham.
- City of Woodinville: Tom Hansen.
- King Conservation District: Matt Dunnahoe, Brandy Reed.
- King County: Richard Jack, Mary Maier, Kate Rhoads, Hans Berg, Rick Reinsloder, Tom Beavers, Beth Cullen, Sally Abella.
- Muckleshoot Indian Tribe: Nancy Rapin, Karen Walters, 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, Shirley Doolittle-Egerdahl, Jonathan Morrison.

Executive Summary

Introduction


Bear Creek above Avondale Road.

Streams within the Bear-Evans watershed are included on Washington State's 303(d) list of water quality impaired waters because of high temperatures and low dissolved oxygen (DO) concentrations. Major streams within the watershed include Bear, Evans, and Cottage Lake Creeks.

The federal Clean Water Act requires that a Total Maximum Daily Load (TMDL; water cleanup plan) be developed for each of the water bodies on the 303(d) list. The TMDL study identifies pollution problems in the watershed, and specifies how much pollution needs to be reduced or eliminated to achieve clean water. Ecology then works with the local community to develop (1) an overall approach to control the pollution, called the *Implementation Strategy,* and (2) a monitoring plan to assess the effectiveness of the water quality improvement activities.

In accordance with this requirement, the Washington State Department of Ecology (Ecology), King County, city of Redmond, and others initiated a cooperative effort to develop a temperature and DO TMDL in the Bear-Evans watershed. Sampling began in the summer of 2006.

QUAL2Kw, a stream water quality model, was calibrated using field data collected in summer 2006. The model was then used to investigate the stream's response to different meteorological, shade, nutrient, and flow conditions.

Effective shade was used as a surrogate measure of heat flux to fulfill the requirements of Section 303(d) of the Clean Water Act for a temperature TMDL. Effective shade is defined as the fraction of incoming solar shortwave radiation that is blocked from reaching the surface of the stream by vegetation and topography.

Bear-Evans watershed

The Bear-Evans watershed is located within the Cedar-Sammamish basin in Water Resources Inventory Area (WRIA) 8 in western Washington State. Bear Creek is the longest creek in the system, draining an area of 51 square miles in northern King and southern Snohomish Counties, including the cities of Redmond, Sammamish, and Woodinville. Evans and Cottage Lake Creek are two major tributaries of Bear Creek (Figure ES-1).

Land use has changed markedly in the past 150 years as development in the area has increased. Loss of riparian and wetland areas as well as changes in the hydrologic regime have resulted in the loss of valuable aquatic habitat and are likely triggers of the water quality impairments observed in the creeks.

Washington State water quality standards

All three creeks have designated aquatic life uses for core summer salmonid habitat and salmonid spawning, rearing, and migration. Washington State water quality standards state that the 7-day average of daily maximum temperatures in these waters should not exceed 16°C, while minimum DO concentrations should not fall below 9.5 mg/L more than once every ten years on average.

Stream water quality assessment

As a result of this study, the following assessments are made:

- Historical data indicate that all three creeks are violating Washington State water quality numeric criteria for temperature and DO.
- Summer 2006 field surveys included the collection of continuous temperature and DO data, a synoptic flow and productivity survey, and travel-time dye studies on all three creeks at sampling locations scattered throughout the watershed (Figure ES-2).
- The warmest temperatures were recorded at the headwaters of Bear and Cottage Lake Creeks, both of which drain lakes. Bear Creek cools downstream, but warms up again as it makes its way to the Sammamish River. Cottage Lake Creek experiences consistent warming downstream. Evans Creek is cooler than the rest of the system, and influenced by groundwater inflows and cooler tributaries. In general, maximum stream temperatures in the majority of the watershed were higher than the 16°C state water quality standard (Figure ES-3).
- Minimum DO concentrations were lower than the 9.5 mg/L state water quality standard at most sampling locations on the mainstem of each creek. Some tributaries had higher DO concentrations. The lowest DO concentrations were recorded in Evans Creek.

Water quality modeling

Ecology set up QUAL2Kw, a steady-flow stream and river water quality model, for each of the three creeks to evaluate their capacity to assimilate heat and nutrient loads. Once calibrated and validated to summer 2006 instream data, the model was used to simulate hypothetical scenarios. These scenarios were compared to current 7-day average 10-year return critical flow conditions (7Q10).

Near-stream vegetation cover, channel morphology, and stream hydrology represent some of the most important factors that influence stream temperature. The modeling predicted stream temperatures could be reduced by 5.2°C, 5.7°C, and 2.7°C for Bear, Evans, and Cottage Lake Creeks (respectively) with the implementation of mature riparian vegetation and additional microclimate improvements. Additional temperature reductions of 3.3-4.6°C, 3.2-5.1°C, and 0.7-0.9°C were predicted for Bear, Evans, and Cottage Lake Creeks (respectively) with the range of potential baseflow increases from increased groundwater recharge.

Predicted reductions would result in stream temperatures below (1) the 22ºC threshold for fish lethality in all of the evaluated stream segments, and (2) the 16ºC water quality criterion in some segments of Bear and Evans Creeks. Lakes upstream of Bear and Cottage Lake Creeks and wetlands in Evans Creek are all potential sources of natural warming to the system.

Dissolved oxygen predictions showed insensitivity to changes in nutrient loading, and productivity was found to be light-limited. The nutrient capacity for the Bear-Evans basin was therefore not determined. Slight improvements in DO were predicted with improvements in shade and temperature, but all predictions were below the 9.5 mg/L numeric criteria. Lake, wetland, and groundwater influences are cited as possible natural causes of the low DO levels observed in the creeks, particularly in Evans Creek.

Load allocations

The load allocation for both temperature and DO in Bear, Evans, and Cottage Lake Creeks is the effective shade that would occur from system potential mature riparian vegetation (Table 17 through Table 19).

In the Bear-Evans watershed, system potential temperatures resulting from the implementation of system potential mature riparian vegetation are predicted to be higher than the 16°C water quality criterion during the hottest period of the year. However, since this load allocation does not account for baseflow loss, it is not entirely representative of the natural condition. The natural condition would be characterized by both system potential effective shade and restored summer baseflows, resulting in even cooler stream temperatures.

Effective shade load allocations are based on our best available knowledge. Our current understanding of baseflow loss is limited to Hartley's (2001) estimates, and we do not have a value for the exact magnitude of baseflow loss in comparison to natural conditions. We do, however, have strong evidence to show that baseflow loss is a significant factor in the Bear-Evans basin and that it does affect stream temperatures. This reinforces a need to find ways to mitigate baseflow losses in addition to implementing system potential mature riparian vegetation.

No wasteload allocations for point sources were established for this TMDL. However, the TMDL stresses the importance of (1) infiltrating stormwater throughout the Bear-Evans watershed, (2) reducing the effective impervious area in the watershed, and (3) monitoring the temperature of stormwater in the fall (to determine its effect on the 13°C fall supplemental standard).

Recommendations

As a result of this study, this TMDL calls for the following summary of actions:

Volunteers help restore riparian areas along the upper Bear Creek. Photo: Water Tenders.

- Plant and grow trees as well as preserve existing trees to eventually reach system potential riparian vegetation along the lengths of all three creeks, where possible, particularly in areas highlighted to have greater shade deficits. Implementation efforts should be executed quickly and efficiently.
- Investigate opportunities to enhance groundwater recharge through infiltration where feasible, such as (1) using reclaimed water and stormwater to percolate into areas where water will benefit streamflow (e.g., through wetlands or in areas of groundwater recharge) and (2) low-impact development practices for new and re-developments.
- Restore and protect wetlands in areas which will benefit the stream and enhance habitat.
- Consider a water management strategy that recognizes the benefits of maintaining summer baseflows while meeting the community's need for water. This strategy should accommodate projected future growth and increases in water demand.
- Maintain the closed basin status, eliminate illegal withdrawals, and investigate, address, and mitigate the impacts of exempt wells.
- Continue water conservation efforts already required by those who have existing water rights by the Department of Health's Water Efficiency Rules (WAC 246-290-010-840) and encourage water conservation by those with exempt wells.
- Minimize human-caused sources of nutrients in the watershed, such as runoff from agricultural fields, failing on-site septic systems, and fertilizer from lawn and garden areas, to prevent exacerbating the DO concentrations. Though nutrient allocations are not assigned to address DO impairments in this TMDL, activities that increase nutrient inputs to streams could potentially exacerbate already low DO concentrations and affect downstream waters.
- Conduct stream monitoring efforts throughout the watershed and incorporate stormwater temperature monitoring during fall 2010. Periodically assess monitoring needs and adaptively manage according to monitoring results.

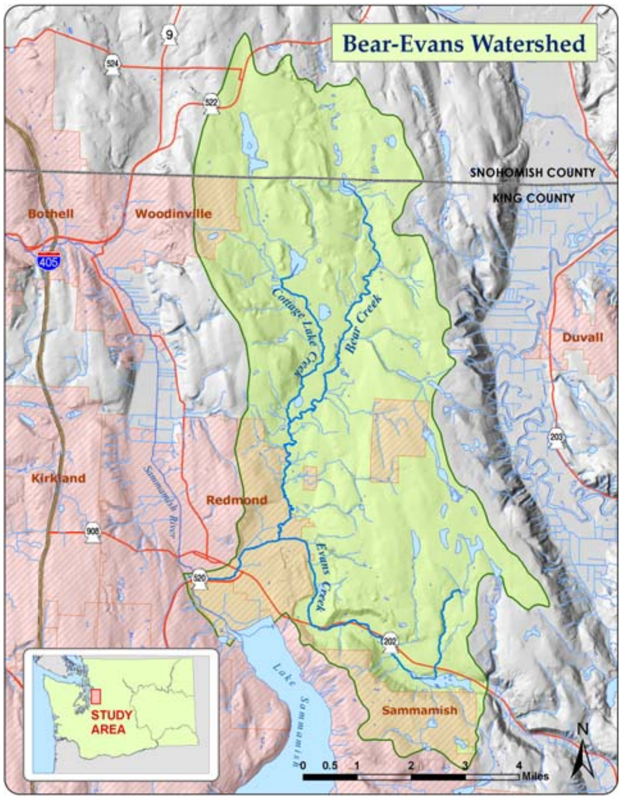

Figure ES-1. The Bear-Evans watershed.

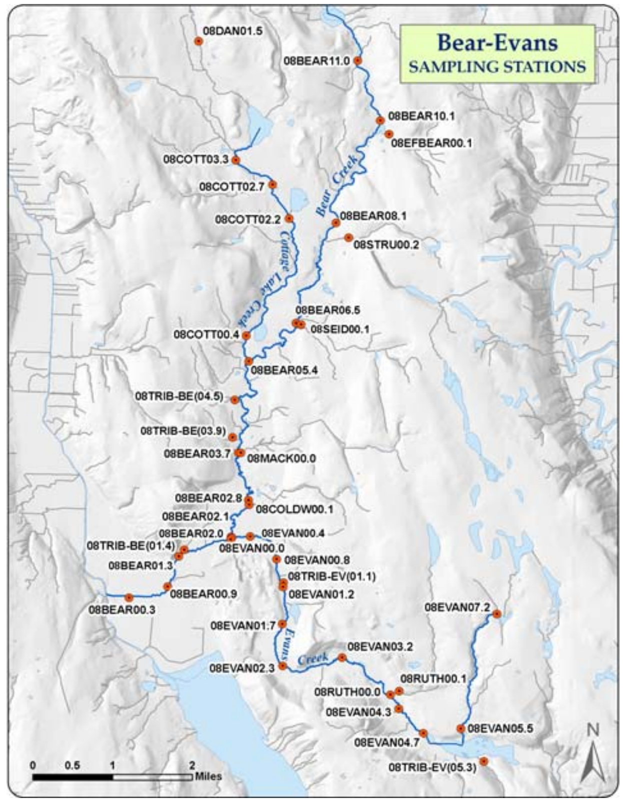

Figure ES-2. Sampling locations for summer 2006 field surveys.

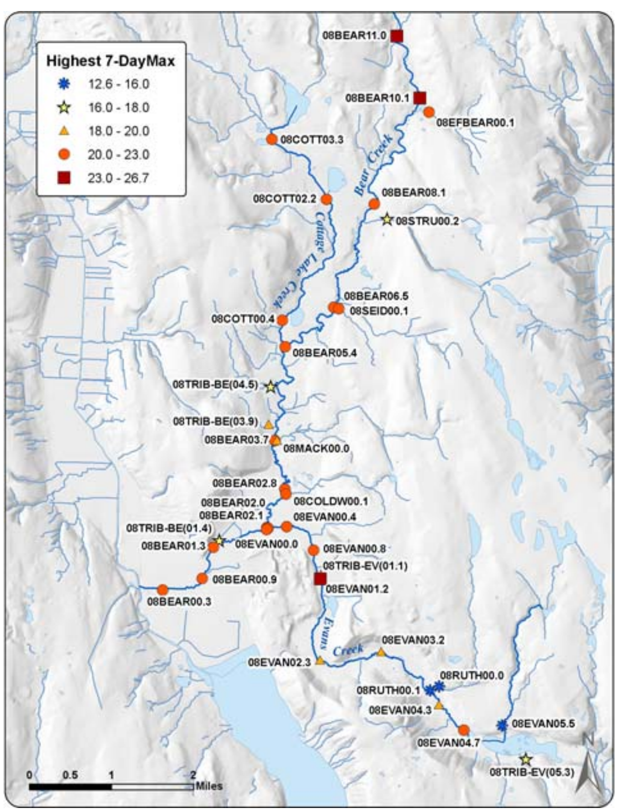

Figure ES-3. Highest 7-DADMax temperatures recorded.

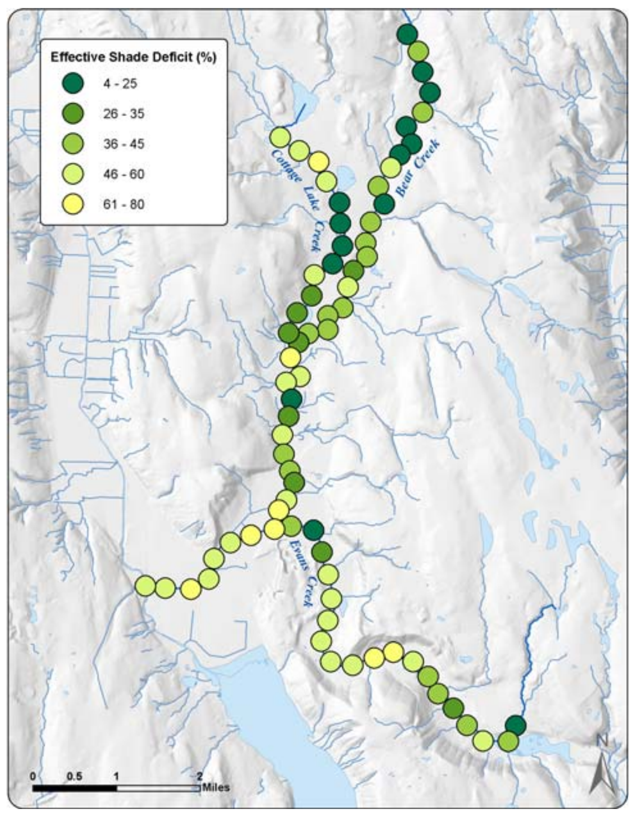

Figure ES-4. Effective shade deficits and shade load allocations.

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What is a Total Maximum Daily Load (TMDL)?

Federal Clean Water Act requirements

The Clean Water Act 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 WAC) establish (1) designated uses for protection, such as cold water biota and drinking water supply, and (2) criteria, usually numeric criteria, to achieve those uses.

Every two years, states are required to prepare a list of water bodies – lakes, rivers, streams, or marine waters – that do not meet water quality standards. This is called the 303(d) list. To develop the list, the 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. All data are reviewed to ensure that they were collected using appropriate scientific methods before the data are used to develop the 303(d) list. The 303(d) list is part of the larger Water Quality Assessment.

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

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

Category 2 – Waters of concern is for waters where there is some evidence of a water quality problem, but not enough to require production of a TMDL at this time.

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 is 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, culverts.

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

TMDL process overview

The Clean Water Act requires that a Total Maximum Daily Load (TMDL) be developed for each of the water bodies on the 303(d) list. The TMDL identifies pollution problems in the watershed and then specifies how much pollution needs to be reduced or eliminated to achieve clean water. Then Ecology works with the local community to develop an overall approach to control the pollution, called the Implementation Strategy, and a monitoring plan to assess effectiveness of the water quality improvement activities. Once the TMDL has been approved by EPA, a *Water Quality Implementation Plan* must be developed within one year. This Plan identifies specific tasks, responsible parties, and timelines for achieving clean water.

Elements required in a TMDL

The goal of this TMDL is to establish pollutant loadings for Bear, Evans, and Cottage Lake Creeks and begin working with the local communities to restore the creeks to good health. The TMDL study includes a written, quantitative assessment of pollutant sources that are causing the pollution and water quality problems using the best available information. The study determines the amount of a given pollutant that can be discharged to the water body and still meet Washington State water quality standards (loading capacity), and allocates that 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 particular source is a load or wasteload allocation (WLA). If the pollutant comes from a discrete (point) source, such as a municipal or industrial facility’s discharge pipe, that facility’s share of the loading capacity is called a wasteload allocation. If the pollutant comes from a set of diffuse (nonpoint) 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 variations, and, when appropriate, include a margin of safety that takes into account any lack of knowledge about the causes of the water quality problem or its loading capacity. A reserve capacity for future loads from growth pressures is sometimes included as well. 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 (MOS), 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

What part of the process are we in?

At this stage, Ecology has (1) assigned effective shade load allocations for Bear, Evans, and Cottage Lake Creeks, and (2) developed an Implementation Strategy of management activities needed for compliance with the water quality standards.

Why is Ecology Conducting a TMDL Study in this Watershed?

Overview

Ecology staff measuring streamflow.

Ecology is conducting a TMDL study in this watershed because the federal Clean Water Act requires that impaired water bodies on the 303(d) list be restored to meet water quality standards through a TMDL process. Ecology's Northwest Regional Office prioritized the watersheds needing TMDLs in northwest Washington. Producing a TMDL in the Bear-Evans watershed is in accordance with that prioritization.

In the summer of 2006 Ecology, King County, the city of Redmond, and others initiated a cooperative effort to develop a temperature and DO TMDL in the Bear-Evans watershed. The effort included water quality monitoring in Bear, Evans, and Cottage Lake Creeks. The monitoring supplemented existing data collection programs and provided input data for the water quality model used in this study as well as data to compare to the model.

Study area

The Bear-Evans watershed is located in western Washington State, in Water Resource Inventory Area (WRIA) 8 (Figure 1). It is situated west of the Cascades mountain range and east of Lake Washington, in the Puget Sound lowlands within northern King and southern Snohomish counties.

This TMDL is focused on mainstem Bear Creek from river mile (RM) 11.0 to its confluence with the Sammamish River. Cottage Lake Creek and Evans Creek, both tributaries to Bear Creek, are also included, from RM 3.3 and RM 5.5 respectively, until their confluence with Bear Creek.

The Bear Creek system flows into the Sammamish River, which eventually drains into Lake Washington and then into Puget Sound.

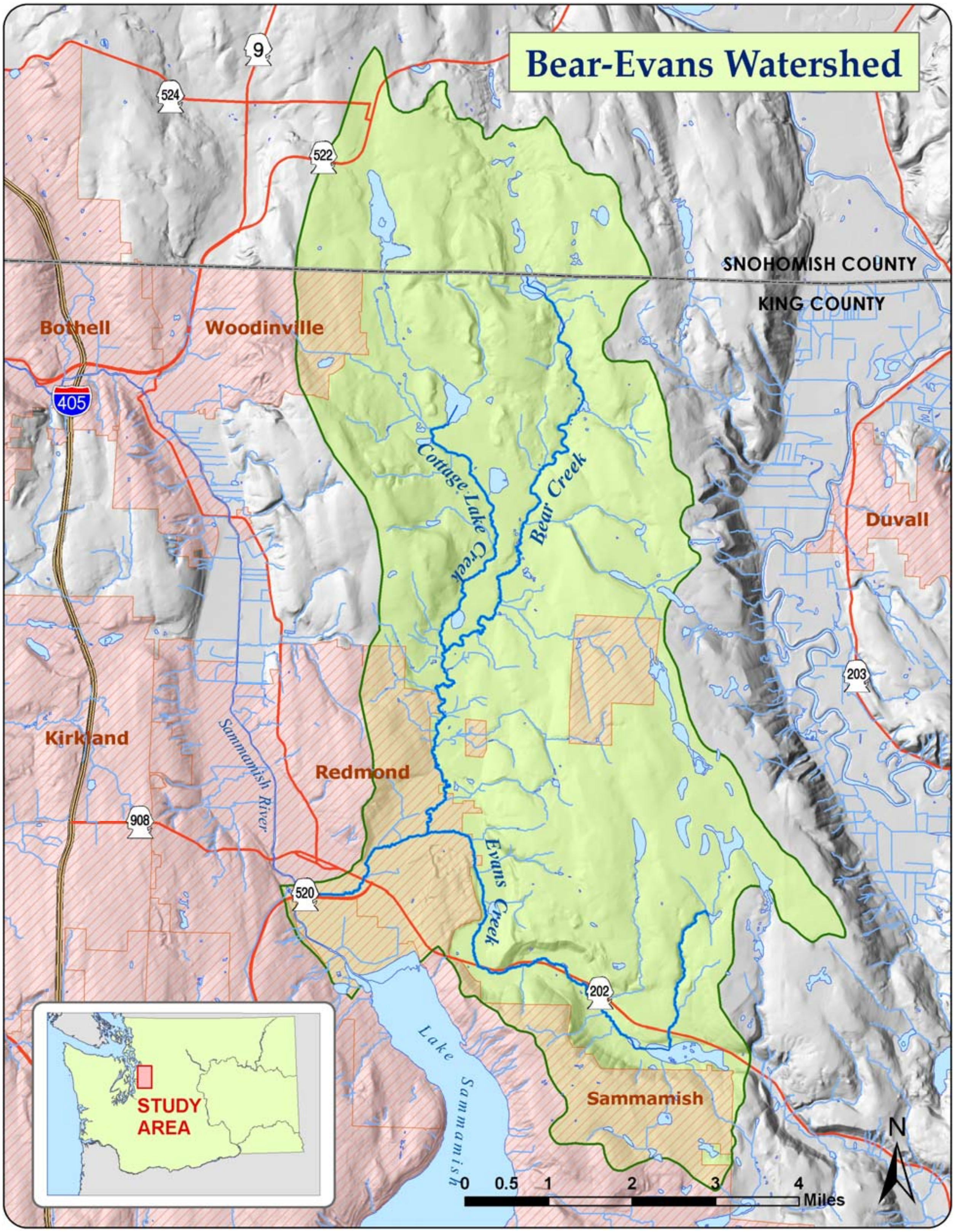

Figure 1. Map of the Bear-Evans watershed.

Pollutants addressed in this TMDL

This TMDL addresses both temperature and DO impairments in Bear, Evans, and Cottage Lake Creeks. Sampling results from 2006 indicate that all three creeks currently violate Washington State water quality standards for both of these parameters.

Pollutants and Surrogate Measures

Temperature

Temperature represents the equivalent of heat concentration within a water body, and water temperatures increase as a result of increased heat flux loads. Therefore, when temperature standards are violated, heat is considered the pollutant. Processes that affect the heat load in the Bear-Evans watershed include:

- Riparian vegetation disturbance that affects stream surface shading and microclimate.
- Reduced exchange of cool groundwater.
- Reduced summer baseflows (reducing the volume of water available to absorb heat).
- Tributaries discharging warm water into the mainstem.

Heat loads (from incoming solar radiation) to the stream are calculated in this TMDL in units of watts per square meter (W/m^2). However, heat loads are of limited value in guiding management activities needed to solve identified water quality problems.

Appropriate "surrogate measures" were therefore used in this TMDL to fulfill the requirements of Section 303(d) as provided under EPA regulations [40 CFR 130.2(i)]. The "Report of the Federal Advisory Committee on the Total Maximum Daily Load (TMDL) Program" (EPA, 1998) includes the following guidance on the use of surrogate measures for TMDL development:

"When the impairment is tied to a pollutant for which a numeric criterion is not possible, or where the impairment is identified but cannot be attributed to a single traditional 'pollutant,' the state should try to identify another (surrogate) environmental indicator that can be used to develop a quantified TMDL, using numeric analytical techniques where they are available, and best professional judgment (BPJ) where they are not."

The technical assessment in this TMDL uses effective shade as a surrogate measure of heat flux from solar radiation. Effective shade is defined as the fraction of potential solar shortwave radiation that is blocked by vegetation and topography before it reaches the stream surface. The definition of effective shade allows direct translation of the solar radiation loading capacity. Other factors influencing heat flux and water temperature were also considered, including microclimate, channel geometry, groundwater recharge, and instream flow.

Dissolved oxygen

The concentration of DO within a water body is affected by numerous variables including temperature and nutrients. Although Washington State water quality standards do not have numeric nutrient criteria for streams, nutrients do result in DO criteria violations. Nutrients feed algae growth, which in turn respire and decompose through oxygen consuming processes. Sources of nutrients in the Bear-Evans basin include runoff, tributary inputs and, for Bear and Cottage Lake Creeks, headwater concentrations which are governed by the lakes from which these two streams originate. Target pollutant reductions may be expressed as loads, concentrations, or other appropriate measures [40 CFR 130.2(I)]. Limits on surrogates are allowed in TMDLs to prevent degradation of beneficial uses when a direct connection can be shown in the data.

Recommendations for increased shading, water cooling, and seasonal instream flows are also examined as measures to help DO criteria compliance.

Impaired beneficial uses and water bodies on Ecology's 303(d) list

The main beneficial uses to be protected by this TMDL are Aquatic Life Uses, including core summer salmonid habitat, salmonid spawning, rearing, and migration. In addition, these water bodies are also to be protected for primary contact recreation and for domestic, industrial, and agricultural water supply.

Washington State has established water quality standards to protect these beneficial uses. Table 1 includes listings for temperature and DO which violate these standards within the Bear-Evans watershed. Figure 2 illustrates the locations of the creek segments in the following listed.

Sockeye salmon in Bear Creek.

Table 1. Bear-Evans water bodies on the 2008 303(d) list for temperature and DO.

Water Body (monitoring station)*	Listing ID	Parameter	Waterbody ID	Township	Range	Section
Bear Creek (KC O484)	4804	Temperature	WR69YO	25N	05E	12
Bear Creek (KC C484)	4811	Temperature	BA64JJ	25N	06E	06
Bear Creek (KC J484)	42095	Temperature	EW54VY	25N	06E	31
Bear Creek (KC J484)	4813	Temperature	EW54VY	26N	06E	30
Bear Creek (ECY 08BEAR01.3)	48602	Temperature	--	25N	05E	01
Bear Creek (ECY 08BEAR06.5)	48605	Temperature	--	26N	06E	20
Bear Creek (ECY 08BEAR08.1)	48606	Temperature	--	26N	06E	17
Bear Creek (ECY 08BEAR10.1)	48607	Temperature	--	26N	06E	08
Bear Creek (ECY 08BEAR11.0)	48608	Temperature	--	26N	06E	05
Bear Creek (ECY 08BEAR02.0, 08BEAR02.1, 08BEAR02.8)	42090	Temperature	--	25N	06E	06
Cottage Lake Creek (KC N484)	4814	Temperature	NO74JS	26N	06E	18
Cottage Lake Creek (ECY 08COTT00.4)	48590	Temperature	--	26N	06E	30
Evans Creek (KC S484)	4809	Temperature	MI67EG	25N	06E	06
Evans Creek (ECY 08EVAN00.8, 08EVAN01.2)	48236	Temperature	--	25N	06E	07
Evans Creek (ECY 08EVAN02.3, 08EVAN03.2)	48237	Temperature	--	25N	06E	17
Evans Creek (ECY 08EVAN04.7B, 08EVAN04.7T)	48238	Temperature	--	25N	06E	21
Evans Creek (ECY 08EVAN04.3)	48594	Temperature	--	25N	06E	16
Evans Creek (ECY 08EVAN07.2)	48596	Temperature	--	25N	06E	10
Bear Creek (Redmond 21)	42087	DO	NC11TV	25N	05E	12
Bear Creek (KC C484)	12687	DO	BA64JJ	25N	06E	06
Bear Creek (ECY 08BEAR11.0)	47472	DO	--	26N	06E	05
Cottage Lake Creek (KC N484)	12688	DO	NO74JS	26N	06E	18
Cottage Lake Creek (ECY 08COTT00.4)	47956	DO	--	26N	06E	30
Evans Creek (KC S484)	12689	DO	MI67EG	25N	06E	16
Evans Creek (KC B484)	12685	DO	MI67EG	25N	06E	07
Evans Creek (ECY 08EVAN01.7)	47962	DO	--	25N	06E	07
Evans Creek (ECY 08EVAN05.5)	47964	DO	--	25N	06E	22

*KC – King County
ECY – Washington State Department of Ecology

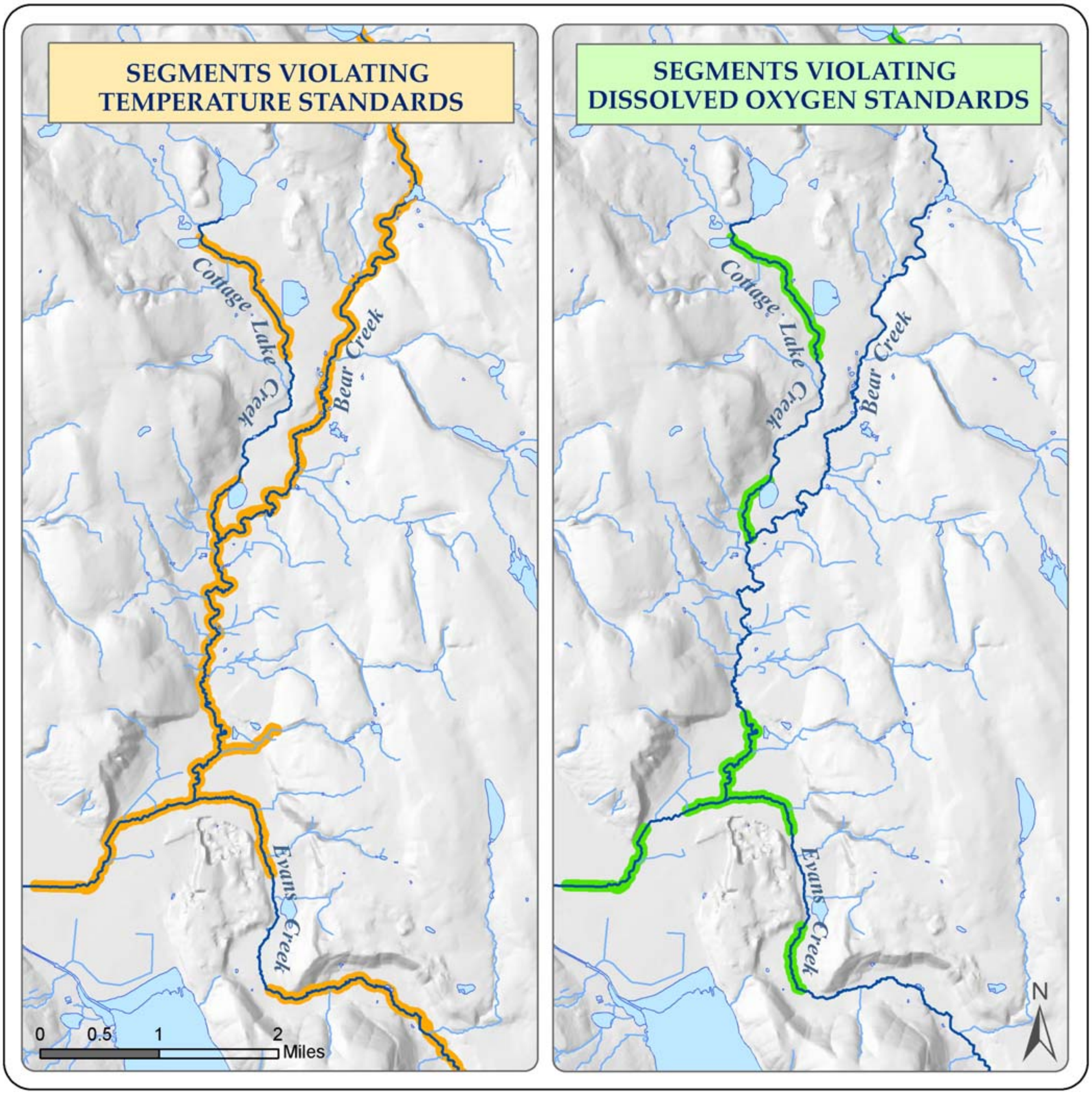

Figure 2. Maps of stream segments listed for temperature and DO on 2008 303(d) list.

In addition to temperature and DO impairments in the Bear-Evans watershed, data also indicate violations of fecal coliform bacteria standards. Ecology prepared the TMDL study on fecal coliform bacteria in the watershed and submitted the report to EPA in June 2008. EPA approved the Bear-Evans Watershed Fecal Coliform Bacteria TMDL in August 2008. Table 2 lists these additional fecal coliform bacteria listings based on the 2004 303(d) list.

Table 2. Fecal coliform 2004 303(d) listings in the Bear-Evans watershed not addressed by this report.

Water body (King County/Redmond monitoring station)	Listing ID	Parameter	Waterbody ID	Township	Range	Section
Bear Creek (KC O484)	13133	Fecal Coliform	WR69YU	25N	05E	12
Bear Creek (KC C484)	13144	Fecal Coliform	BA64JJ	25N	06E	06
Tributary to Bear Creek (Redmond 35)	42154	Fecal Coliform	EU47RU	26N	06E	30
Bear Creek (KC J484)	13146	Fecal Coliform	EW54VY	26N	06E	30
Cottage Lake Creek (KC N484)	13147	Fecal Coliform	NO74J5	26N	06E	18
Evans Creek (KC B484)	13142	Fecal Coliform	MI67EG	25N	06E	07
Evans Creek (KC S484)	13148	Fecal Coliform	MI67EG	25N	06E	16

Why are we doing this TMDL now?

Ecology initiated this TMDL study in support of local priorities to address water quality problems impacting the salmonid populations in the tributaries to north Lake Washington. Ecology initiated the field studies in 2006 through a cooperative effort with King County, the City of Redmond, Bear Creek Water Tenders, and the Northeast Sammamish Sewer and Water District.

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Water Quality Standards and Beneficial Uses

Washington State Water Quality Standards, set forth in Chapter 173-201A of the Washington Administrative Code (WAC; Ecology, 2006), include designated beneficial uses, water body classifications, and numeric and narrative water quality criteria for surface waters of the state. Though water bodies within the Bear-Evans basin are not explicitly listed in the WAC, they receive classifications as discharges to Lake Washington (WAC 173-201A-600).

The designated aquatic life uses for Bear, Evans, and Cottage Lake Creeks include (WAC 173-201A-200):

- *Core summer salmonid habitat*. This use protects summer season (June 15 through September 15) salmonid spawning or emergence, or adult holding; summer rearing habitat by one or more salmonids; or foraging by adult and sub-adult native char. Other protected uses include spawning outside of the summer season, rearing, and migration by salmonids.
- *Salmonid spawning, rearing, and migration.* This use protects salmon or trout spawning and emergence that only occur outside of the summer season (September 16 – June 14). Other uses include rearing and migration by salmonids.

Other non-aquatic life uses include water supply (domestic, industrial, and agricultural), stock watering, fish and shellfish (salmonid and other fish migration, rearing, spawning, and harvesting), wildlife habitat, recreation (primary contact recreation, sport fishing, boating, and aesthetic enjoyment), and commerce and navigation. Numeric criteria for specific water quality parameters are intended to protect these designated uses.

Ecology revised the state water quality standards in July 2003 and in 2006. EPA approved these changes in February 2008. In the Bear-Evans watershed, there was no change to the designated aquatic life use of core rearing (EPA, 2006).

Each beneficial use designation described above has associated water quality criteria. The relevant temperature and DO criteria that apply to the Bear-Evans watershed are detailed in the next section.

Temperature

Temperature affects the physiology and behavior of fish and other aquatic life. Temperature may be the most influential factor limiting the distribution and health of aquatic life and can be greatly influenced by human activities.

Temperature levels fluctuate over the day and night in response to changes in climatic conditions and river flows. Since the health of aquatic species is tied predominantly to the pattern of maximum temperatures, the criteria are expressed as the highest 7-day average of the daily maximum temperatures (7-DADMax) occurring in a water body.

In the state water quality standards, aquatic life use categories are described using key species (salmon versus warm-water species) and life-stage conditions (spawning versus rearing) [WAC 173-201A-200; 2006 edition].

The beneficial uses to be protected within the Bear-Evans watershed include (1) Core Summer Salmonid Habitat and (2) Salmonid Spawning, Rearing, and Migration. The applicable temperature criteria for these designated uses are contained in 173-201A-200(c) as:

1. To protect the designated aquatic life uses of "Core Summer Salmonid Habitat," the highest 7-DADMax temperature must not exceed 16°C (60.8°F) at a probability frequency of more than once every ten years on average.
2. To protect the designated aquatic life uses of "Salmonid Spawning, Rearing, and Migration, and Salmonid Rearing and Migration Only," the highest 7-DADMax temperature must not exceed 17.5°C (63.5°F) at a probability frequency of more than once every ten years on average.

In addition, all portions of the Bear and Cottage Lake Creeks, as well as Evans Creek downstream of river mile 0.8, must not exceed 13°C between September 15 and May 15. This study was designed to evaluate summer peak temperatures; other conditions are not evaluated explicitly.

Washington State uses the criteria described above to ensure that where a water body is naturally capable of providing full support for its designated aquatic life uses, that condition will be maintained. The standards recognize, however, that not all waters are naturally capable of staying below the fully protective temperature criteria. When a water body is naturally warmer than the above-described criteria, the state provides an allowance for additional warming due to human activities. In this case, the combined effects of all human activities must also not cause more than a 0.3°C (0.54°F) increase above the naturally higher (inferior) temperature condition.

In addition to the maximum criteria noted above, compliance must be assessed against criteria that limit the incremental amount of warming of otherwise cool waters due to human activities. When water is cooler than the criteria noted above, the allowable rate of warming up to, but not exceeding, the numeric criteria from human actions is restricted to: (1) incremental temperature increases resulting from individual point source activities must not, at any time, exceed 28/T[1]+7 as measured at the edge of a mixing zone boundary, and (2) incremental temperature increases resulting from the combined effect of all nonpoint source activities in the water body must not at any time exceed 2.8°C (5.04°F).

Special consideration is also required to protect spawning and incubation of salmonid species. Where Ecology determines the temperature criteria established for a water body would likely not result in protective spawning and incubation temperatures, the following criteria apply: (1) maximum 7-DADMax temperatures of 9°C (48.2°F) at the initiation of spawning and at fry emergence for char; and (2) maximum 7-DADMax temperatures of 13°C (55.4°F) at the initiation of spawning for salmon and at fry emergence for salmon and trout.

While the criteria generally apply throughout a water body, they are not intended to apply to discretely anomalous areas such as in shallow stagnant eddy pools where natural features unrelated to human influences are the cause of not meeting the criteria. For this reason the standards direct that one take measurements from well-mixed portions of rivers and streams. For similar reasons, it is not appropriate to take samples from anomalously cold areas such as at discrete points where cold groundwater flows into the water body.

Effect of Climate Change

For information on Ecology's Climate Change program, visit http://www.ecy.wa.gov/climatechange/.

Changes in climate are expected to affect both water quantity and quality in the Pacific Northwest (Casola et al., 2005). Ten climate change models predicted an average warming rate in the range of 0.1-0.6°C (0.2-1.0°F) per decade, with a best estimate of 0.3°C (0.5°F) (Mote et al., 2005). Eight of the ten models predicted proportionately higher summer temperatures, with three indicating summer temperature increases at least two times higher than winter increases. Summer streamflows are also predicted to decrease as a consequence of climate change (Hamlet and Lettenmaier, 1999).

The expected changes coming to our region's climate highlight the importance of protecting and restoring the mechanisms that help keep stream temperatures cool. Stream temperature improvements obtained by growing mature riparian vegetation corridors along stream banks, reducing channel widths, and enhancing summer baseflows may all help offset the changes expected from climate change – keeping conditions from getting worse. It will take considerable time, however, to reverse those human actions that contribute to excess stream warming. The sooner such restoration actions begin and the more complete they are, the more effective we will be in offsetting some of the detrimental effects on our stream resources.

These efforts may not cause streams to meet the numeric temperature criteria everywhere or in all years. However, they will maximize the extent and frequency of healthy temperature

[1] "T" represents the background temperature as measured at a point or points unaffected by the discharge.

conditions, creating long-term and crucial benefits for fish and other aquatic species. As climate change progresses, the thermal regime of the stream itself will likely change due to reduced summer streamflows and increased air temperatures.

The state is writing this TMDL to meet Washington State's water quality standards based on current and historic patterns of climate. Changes in stream temperature associated with climate change may require further modifications to the human-source allocations at some time in the future. However, the best way to preserve our aquatic resources and to minimize future disturbance to human industry would be to begin now to protect as much of the thermal health of our streams as possible.

Dissolved oxygen

Aquatic organisms are very sensitive to reductions in the level of DO in the water. The health of fish and other aquatic species depends on maintaining an adequate supply of oxygen dissolved in the water. Oxygen levels affect growth rates, swimming ability, susceptibility to disease, and the relative ability to endure other environmental stressors and pollutants. While direct mortality due to inadequate oxygen can occur, the state designed the criteria to maintain conditions that support healthy populations of fish and other aquatic life.

Oxygen levels can fluctuate over the day and night in response to changes in climatic conditions as well as the respiratory requirements of aquatic plants and algae. Since the health of aquatic species is tied predominantly to the pattern of daily minimum oxygen concentrations, the criteria are the lowest 1-day minimum oxygen concentrations that occur in a water body.

In the state water quality standards, freshwater aquatic life use categories are described using key species (salmonid versus warm-water species) and life-stage conditions (spawning versus rearing). Minimum concentrations of DO are used as criteria to protect different categories of aquatic communities [WAC 173-201A-200; 2006 edition]. In this TMDL the following designated aquatic life use(s) and criteria are to be protected:

The beneficial uses to be protected within the Bear-Evans watershed include (1) Core Summer Salmonid Habitat and (2) Salmonid Spawning, Rearing, and Migration. The applicable temperature criteria for these designated uses are contained in 173-201A-200(c) as:

1. To protect the designated aquatic life use of "Core Summer Salmonid Habitat," the lowest 1-day minimum oxygen level must not fall below 9.5 mg/L more than once every ten years on average.
2. To protect the designated aquatic life use of "Salmonid Spawning, Rearing, and Migration," the lowest 1-day minimum oxygen level must not fall below 8.0 mg/L more than once every ten years on average.

These criteria are used to ensure that where a water body is naturally capable of providing full support for its designated aquatic life uses, that condition will be maintained. The standards recognize, however, that not all waters are naturally capable of staying above the fully protective DO criteria. When a water body is naturally lower in oxygen than the criteria, the state provides an allowance for further depression of oxygen conditions due to human activities. In this case, the combined effects of all human activities must not cause more than a 0.2 mg/L decrease below that naturally lower (inferior) oxygen condition.

While the numeric criteria generally apply throughout a water body, they are not intended to apply to discretely anomalous areas such as in shallow stagnant eddy pools where natural features unrelated to human influences are the cause of not meeting the criteria. For this reason, the standards direct that one take measurements from well-mixed portions of rivers and streams. For similar reasons, it is not appropriate to take samples from anomalously oxygen rich areas. For example, in a slow moving stream, sampling on surface areas within a uniquely turbulent area would provide data that are erroneous for comparing to the criteria.

Watershed Description

The Bear-Evans watershed, in northern King and southern Snohomish Counties drains approximately 51 square miles (132 km^2) of land area, and 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, 57.8 km^2), Evans Creek (9,800 acres, 39.7 km^2), and Cottage Lake Creek (8,000 acres, 32.4 km^2). 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 at 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 over 12 miles (19.3 km) 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 (10.8 km) from Cottage Lake to the confluence with Bear Creek. Evans Creek starts between Novelty Hill and Union Hill Roads and runs about 8.2 miles (13.2 km) before converging with Bear Creek. The Evans Creek portions of this TMDL are limited to the lower 5.0 miles of the creek.

Bear Creek near Millennium office park in Redmond.

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 SR 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 Bear-Evans watershed has been shaped by deposition and erosion that has 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 comprises a north-south trending ridge creating two major drainage valleys. The northern valley has Bear and Cottage Lake Creeks and drains a rolling countryside generally underlain by relatively impermeable till. In contrast to the languid nature of Bear Creek, the tributary valley of Evans Creek is uniquely characterized by steep side walls formed by glacial processes. In this southern valley, the drainage courses plunge steeply over the edge of upland plateaus, where sideslopes are underlain by thick and easily eroded advance outwash deposits, resulting in slope instability (King County, 1990).

The climate in the area is characterized by warm, dry summers and cool, wet winters. Most of the precipitation falls between October and April. Annual average precipitation in the basin varies between 40-45 inches. Precipitation for the summer of 2006, when field monitoring for this TMDL was conducted, was slightly below average historical levels.

A unique resource in the Bear-Evans basin is Cold Creek, a cold-water spring and tributary of Cottage Lake Creek. This spring is a source of cooler water into Bear Creek with temperatures 5 to 7°C colder than the rest of Bear-Evans basin (Kerwin, 2001). Bear Creek provides a cooling effect on the salmonid migratory corridor of the Sammamish River, which frequently exceeds the lethal 22˚C threshold.

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 predominantly agricultural to sub-rural and urban land uses (Williams et al., 1975).

In the 1980s the basin was largely rural, characterized by numerous cattle and horse farms, including dairies, as well as woodlots of various acreages. King County estimated that in 1985, approximately three-fourths of the entire basin was forest (King County, 1990). The developed area of the basin was predominantly single-family residences. Tributary areas averaged 76% forest cover, 14% grass cover, 8% wetlands, and 2% "effective impervious surfaces."

Satellite imagery from the late 1990s shows the watershed has been urbanized, with about 30% of the land in residential use, 4% in commercial or industrial use, 54% with forest cover, and 11% in agricultural or rural use (MRLC, 1999).

Development has continued to occur in the watershed since the 1990s, and likely a greater percent of the watershed is now in residential use. 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. Numerous woodlots and horse farms can still be found in the basin.

The watershed is located within the US Census Defined Urbanized Area; therefore, it is expected that population growth and urban development will be concentrated in this area. In 2002, Snohomish County estimated the Bear-Evans basin was 9% high impervious surface and 18% medium impervious surface[2] (Snohomish County, 2002).

Streamflows and groundwater use

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 3 depicts average monthly flows at 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 events can dramatically increase instantaneous peak flows to as high as 650 cfs. King County also collects streamflow information in Cottage Lake Creek, upper Bear Creek, and the lower part of Evans Creek.

In addition to precipitation, groundwater enhances the flows of Bear and Evans Creeks year-round. Groundwater is also an important drinking water resource for the communities in the basin. Approximately 40% of Redmond's drinking water supply comes from groundwater wells that are at least partially replenished from aquifers beneath Bear and Evans Creek valleys. The Northeast Sammamish Sewer and Water District (NESSWD) has five wells and two reservoirs in the area, providing water for over 10,000 people and sewer service for 15,000 people east of Lake Sammamish.

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

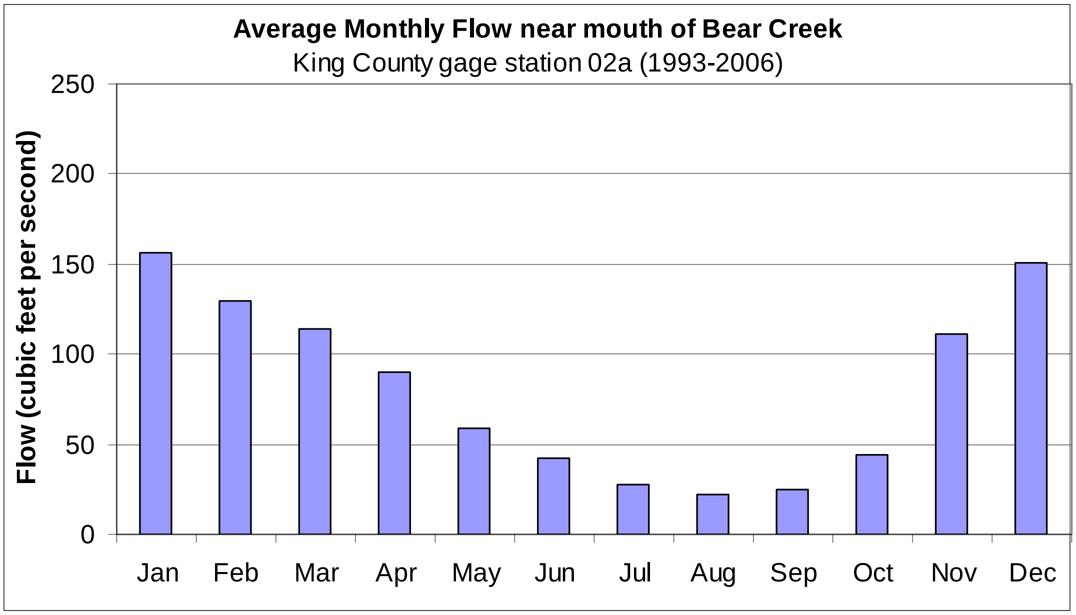

Figure 3. Average monthly flow near the mouth of Bear Creek based on 1993-2006 King County data from gage station 02a, co-located at monitoring station O484.

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 groundwater. 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.

Aquatic life resources

The Bear Creek system exhibits high-quality aquatic habitat, salmonid diversity and abundance, and a demonstrated contribution to the regional fishery resource (King County, 1990). Freshwater mussels, freshwater sponges, river otters, crayfish, and a diversity of aquatic insects are found extensively in the Bear-Evans watershed. Because of its diversity, the watershed was distinguished as one of the top six natural resource basins in King County in the Waterways 2000 program. In 1990, King County designated Bear Creek and Cottage Lake Creek as Regionally Significant Resource Areas in the *Bear Creek Basin Plan* (King County, 1990).

Bear Creek and Cottage Lake Creek provide excellent spawning and rearing habitat for Chinook, coho, sockeye, and kokanee salmon and steelhead trout. Approximately 90% of adult Chinook spawning of the north Lake Washington Chinook salmon populations occurs in Bear Creek (WRIA 8 Salmon Recovery Council, 2005). The higher level of habitat quality in Cottage Lake Creek is due to its forested wetlands and forested riparian corridor, as well as extensive, relatively undisturbed wetland complexes in its upper and middle reaches. After spawning, the fish use the Sammamish River above Woodinville for migration and rearing.

WDFW smolt trap on Bear Creek.

Chinook have been occasionally observed in Evans Creek by Washington Department of Fish and Wildlife (WDFW) and by RH2 Engineering staff during 1999 to 2005. There have not been enough fish observed in Evans Creek to be considered common. During recent stream surveys, Berge et al. (2006) identified three Chinook redds in Evans Creek in 2003, none in 2004, and none in 2005. Observed Chinook may be strays that would otherwise enter Bear Creek (RH2 Engineering, 2008). The 2006 Tributary Streamflow Final Report concluded that Evans Creek has limited spawning potential for Chinook due to inherent stream characteristics of low gradient and fine-grained substrate material (RWSP, 2006).

Table 3 summarizes the health of salmonid species as reported by Washington State Salmon and Steelhead Stock Inventory (SASSI, 1993 and 2002) in north Lake Washington and Sammamish tributaries, which includes Bear Creek system. Data were index escapement estimates based on counts of live Chinook in Bear Creek (RM 1.3 to 8.8) and in Cottage Lake Creek (RM 0.0 to 2.3), in addition to other portions of the watershed surveyed annually. Spawner surveys by the WDFW (WDFW, 2008) and King County (Berg, 2008) indicate a large percentage of returning adult Chinook in the Bear Creek system are hatchery strays. WDFW did not assess steelhead production due to insufficient catch. Only a handful of juveniles have been found in the system during their fish trap monitoring since it started in 1999.

Table 3. Status and condition of fish stocks in north Lake Washington and Sammamish tributaries (SASSI, 1993; 2002).

Salmonid Species	Federally Listed Species	State Listed Species	Stock Origin/ Production Type	Stock Status 1992	Stock Status 2002
Chinook	Yes	No	Mixed/Composite	Unknown	Healthy
Coho	No	No	Mixed/Composite	Depressed	Depressed
Sockeye	No	No	Unknown/Wild	Depressed	Healthy
Steelhead	Yes	No	Native/Wild	Depressed	Critical
Coastal Cutthroat	No	No	Mixed/Composite	Unknown	Unknown

Pacific salmon have been the symbol of natural resource conservation in the Pacific Northwest, but people are also learning that the fate of freshwater mussels and salmon are intertwined. Freshwater mussels are excellent indicators of the long-term health of aquatic ecosystems due to their sensitivity to changing water quality, habitat, and fish communities (King County, 2005b).

Recreational uses

The Bear-Evans watershed supports many recreational uses. The fishery resources provide opportunities for both freshwater and marine (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. However, many of the lakes are deep enough for full-immersion activities and used for recreation. 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, these water bodies are fully accessible to adjacent land owners and, in some cases, their neighbors. Limited boating opportunities exist where Bear Creek meets the Sammamish River.

Potential pollution sources

Many human activities impact the natural environment. Recognized water quality problems in the basin are high water temperatures and low DO. Possible sources of pollution that affect stream temperature and DO are discussed below.

Loss of riparian habitat

Riparian habitat plays a valuable role in water quality. 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 negative influences in the watershed. Adequately sized and healthy riparian buffers help filter out a variety of pollutants, including substances that can lead to the depletion of oxygen in streams.

Eroded banks and loss of riparian habitat.

Direct shading from trees is a critical component affecting stream temperatures. When wooded stream buffers are removed to create lawns, establish pasture or cropland, or make room for development, water temperatures increase. This is because greater portions of the stream are exposed to warm air and sunlight.

Residential and commercial development has reduced riparian buffer widths along most of the tributaries to the Sammamish River (Tetra Tech, 2002). From 1979 to 1999, stream temperatures showed an increasing trend. This was likely associated with removal of riparian vegetation and increasing impervious surfaces due to urbanization, or changes in regional climate conditions (King County, 2002). The riparian corridor in many reaches of the Bear-Evans basin is reduced or cleared right up to the stream edge.

Removal of the large riparian vegetation also reduced the amount and type of large organic debris reaching the stream and increased the solar radiation to the stream. Solar radiation, in the form of heat, is considered a pollutant. Increases in heat loads can result in the loss of fish habitat and an increase in summer water temperatures. In addition, temperature plays an important role in determining how much oxygen water can hold.

Other human actions, such as adding riprap or having inadequate culverts, can alter channel morphology, particularly stream width and depth. These can make some areas of the watershed more vulnerable to the effects of riparian vegetation removal.

During the Adopt-A-Stream Foundation culvert fish barrier assessment and pollution identification project, the most common form of nonpoint source pollution observed was associated with degraded riparian conditions (AASF, 2004). This includes lack of native riparian vegetation, the presence of invasive plants, and landscaping to the ordinary high water mark.

Nutrients

A fertilized lawn next to the stream.

King County tested Bear Creek and its tributaries for phosphorous, nitrogen, and DO levels between 1979 and 1999. Phosphorous levels decreased during this time period, but ammonia and nitrate concentrations increased, while DO concentrations did not meet water quality standards 13% of the time at the mouth of Bear Creek (King County, 2002). Ammonia-nitrogen concentrations, in general, were higher in the fall and winter and have shown an increasing trend on the mainstem Bear Creek, Cottage Lake Creek, and upstream Evans Creek since 1979. No cause for the increase was determined. Excessive nutrient loads can fuel high productivity, which in turn can result in depressed DO levels.

Landscaping in the watershed is common and often involves applying fertilizers to the yards and gardens. Some streamside landowners have lawns up to the edge of the creek. These practices may cause increased nutrient levels, associated with algal growth, and decreased DO in adjacent stream reaches.

In addition, agricultural and rural activities in the basin can add excess nutrients into the creeks. Many new small farm owners in the basin lack the background in how to successfully manage livestock on smaller acreages. For those with personal stables, many times the 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.

Urban stormwater

Ecology considers permitted stormwater systems as point sources, although the contaminants are often released in an uncontrolled and dispersed manner. Stormwater may not be a pollutant source in itself, but is often an efficient conveyor of pollutants from drainage surfaces to local waters. Stormwater starts as rainwater and other precipitation, and either infiltrates into the ground or accumulates and flows over impervious surfaces. Land uses and activities in urban areas, coupled with an increase in impervious area and accumulation of contaminants, typically results in polluted stormwater.

Heavy rainfall washes contaminants off of impervious surfaces, including rooftops, driveways, sidewalks, parking lots, and roads, into storm drains or directly into streams. During typical storms, pollutants mixed in with stormwater reach streams quickly and in high concentrations. Stormwater runoff from parking lots and other impervious surfaces can also be a source of warm water to streams. Stormwater flows are erratic and may not exhibit distinct seasonal trends.

Stormwater in the Bear-Evans basin is transported through a system of surface ditches and culverts. Forty-three direct pipe outfalls to the creeks in this basin were documented during an Adopt-A-Stream Foundation's culvert inventory and habitat assessment (AASF, 2004). Small stormwater drainage systems (sub-watersheds) carry tributary streamflow and stormwater directly to creeks.

Since this TMDL is focused on summer critical conditions for temperature and DO, when rain events are infrequent, stormwater is mentioned but it is not considered a significant source that impacts temperature and DO during dry summer months.

Ecology regulates municipal separate storm sewer systems (MS4) as point sources under Ecology's National Pollutant Discharge Elimination (NPDES) Municipal Phase I and II Stormwater Management Program. The entire watershed is covered by municipal stormwater Phase I and Phase II permit jurisdictions (Table 4). Several local sites are covered by general permits for sand, gravel, and construction stormwater. Ecology's General Stormwater Construction permit provides a measure to control phosphorus, a nutrient source to the creeks.

A review of facilities in the water shed under Ecology's General Stormwater Industrial and General Industrial permits on Ecology's GIS Facility Site/Atlas (http://www.ecy.wa.gov/fs/) show none that could contribute to temperature and DO impairments.

Table 4. Facilities covered under stormwater permits within the Bear-Evans watershed.

Type of Permit	Permit Holder	Ecology Permit Number
Individual		
Phase I stormwater	Snohomish County	WAR04-4502
Phase I stormwater	King County	WAR04-4501
Phase I stormwater	Department of Transportation	To be issued in late 2008
Phase II stormwater	City of Redmond	WAR04-5538
Phase II stormwater	City of Sammamish	WAR04-5540
Phase II stormwater	City of Woodinville	WAR04-5545
General		
Sand and Gravel	(Varies over time)	--
Construction Stormwater	(Varies over time)	--

Altered hydrology/loss of baseflows

Changes in stream hydrology can influence water quality of urban streams. Under natural conditions, rain water is captured by plants, infiltrated, evapotranspired, or stored in wetlands. When water is stored within the system, as in the ground or wetlands, it can feed local streams during dry summer periods. The natural environment also provides opportunities to filter out pollutants through natural processes wherever adequate soils and vegetation are retained. Figure 4 illustrates how changes in land use and increases in development can alter the natural hydrologic regime.

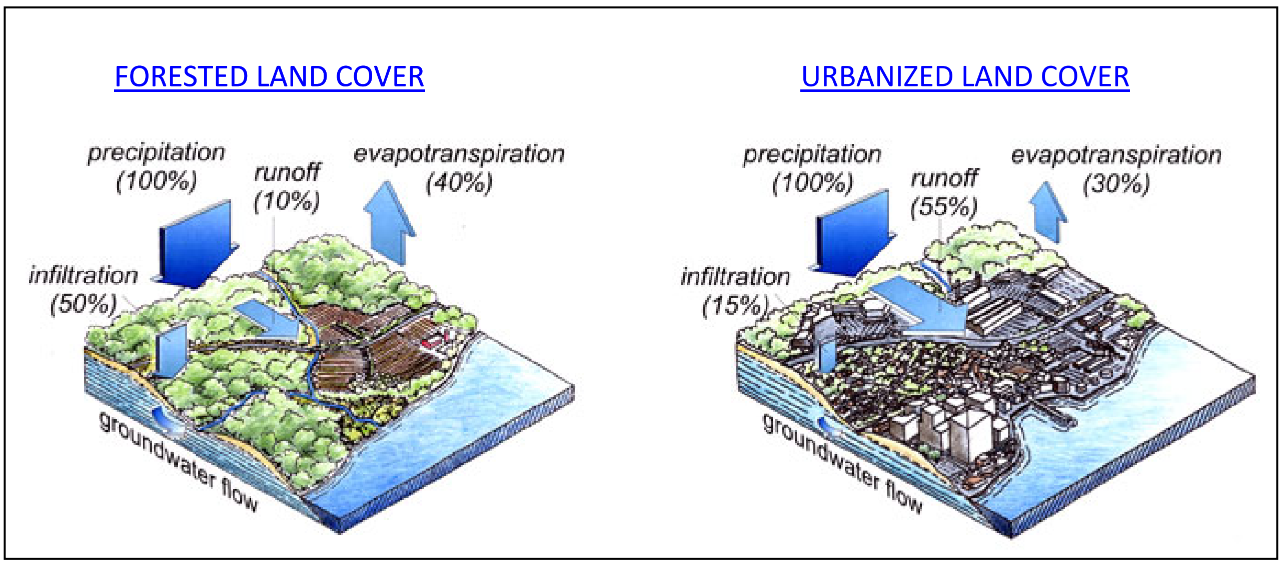

Figure 4. Altered Hydrology: roads, rooftops, and sidewalks change the percentage of water transported in different processes of the hydrologic cycle (EOEA, 2004).

Reduced Baseflows

Increasing amounts of impervious surfaces can limit groundwater infiltration and subsequent recharge into streams during summer low-flow conditions. Urbanization in the Bear-Evans basin is potentially a factor in observed summer low flows.

Hartley and Funke (2001) combined hydrologic and watershed modeling to detect changes in streamflow characteristics in the Bear-Evans watershed based on the land use changes from 1985 to 1995. Accounting for model bias, the results indicated a 16-25% decline in summer baseflow in upper Bear Creek and 11- 22% decline in Evans Creek. The study concluded that predicted reductions in summer baseflow are too large to be explained only by loss of recharge due to impervious surfaces. The study suggested that an increase in consumptive uses (e.g., groundwater withdrawals and irrigation) is a likely factor.

A report on the effect of groundwater withdrawals on discharge to Puget Sound lowland streams concluded that "groundwater development will, in most cases, affect the baseflow to streams" (Morgan and Jones, 1999).

Goals and Objectives

Project goals

The project goals are (1) to conduct a TMDL study on temperature and dissolved oxygen in Bear-Evans watershed during critical low-flow conditions and (2) to establish an implementation strategy to meet water quality standards for temperature and dissolved oxygen in this basin.

Study objectives

The objectives for the TMDL study were as follows:

- Characterize stream temperatures and processes governing the thermal regime in Bear, Evans, and Cottage Lake Creeks during critical conditions.
- Develop predictive temperature models of the Bear-Evans basin under critical conditions. Apply the models to determine load allocations for effective shade and other surrogate measures to meet temperature water quality standards. Identify the areas influenced by lakes and wetlands and, if necessary, estimate the natural temperature regime.
- Conduct supplemental critical-period surveys for physical, chemical, and biological measures relevant to DO levels in the creek system. Characterize nutrient levels in the creek system.
- Develop predictive DO models and use the results to establish pollutant load reduction targets.

Ecology staff collecting field data in Bear-Evans watershed.

Field Data Collection

The field data collection for this study was a collaborative effort between Ecology, King County, City of Redmond, NESSWD, Union Hill Water Association, and citizen volunteers. Data collection, compilation, and assessment were governed by the data requirements of the temperature and DO model as described in the *Sampling and Analysis Plan/Quality Assurance Project Plan* (QAPP) for this study (Roberts and Jack, 2006).

During summer low-flow and high temperature conditions in 2006, the following types of field surveys were conducted:

1. Continuous monitoring of water and air temperatures and relative humidity.
2. Deployment of YSI® multi-probes to generate continuous pH, DO, and conductivity measurements.
3. A Synoptic productivity survey which included grab nutrient samples for laboratory analysis and periphyton sampling.
4. Synoptic flow and travel-time dye studies in each creek.
5. HemiView photographs of riparian canopy at select locations.

Figure 5 illustrates all sampling stations in the Bear-Evans watersheds. Appendix A describes monitoring locations, coordinates, and the data collected at each station.

Study methods

Each type of field survey is described briefly below. More details on the sampling and measurement procedures can be found in the QAPP (Roberts and Jack, 2006).

Continuous temperature and relative humidity

Ecology installed 18 continuous air and 27 continuous water temperature loggers in the Bear-Evans watershed. The instruments collected temperature data at 30-minute intervals from June 16 to October 4, 2006. Data were downloaded once mid-deployment during the week of August 7 – 11 and after removal in early October. In addition, three relative humidity loggers were installed.

Two water temperature loggers were missing at the end of the study. Ecology retrieved data from both of these loggers during the August download event. These loggers collected data during the synoptic productivity monitoring event as well as the hottest week of the summer, but not throughout the course of the study.

The city of Redmond and RH2 Engineering (on behalf of NESSWD and UHWA) also installed continuous water temperature loggers at select locations during the same time period. Several RH2 sampling locations overlapped with Ecology's stations and were used to confirm comparability. This added nine continuous water temperature stations in the study area.

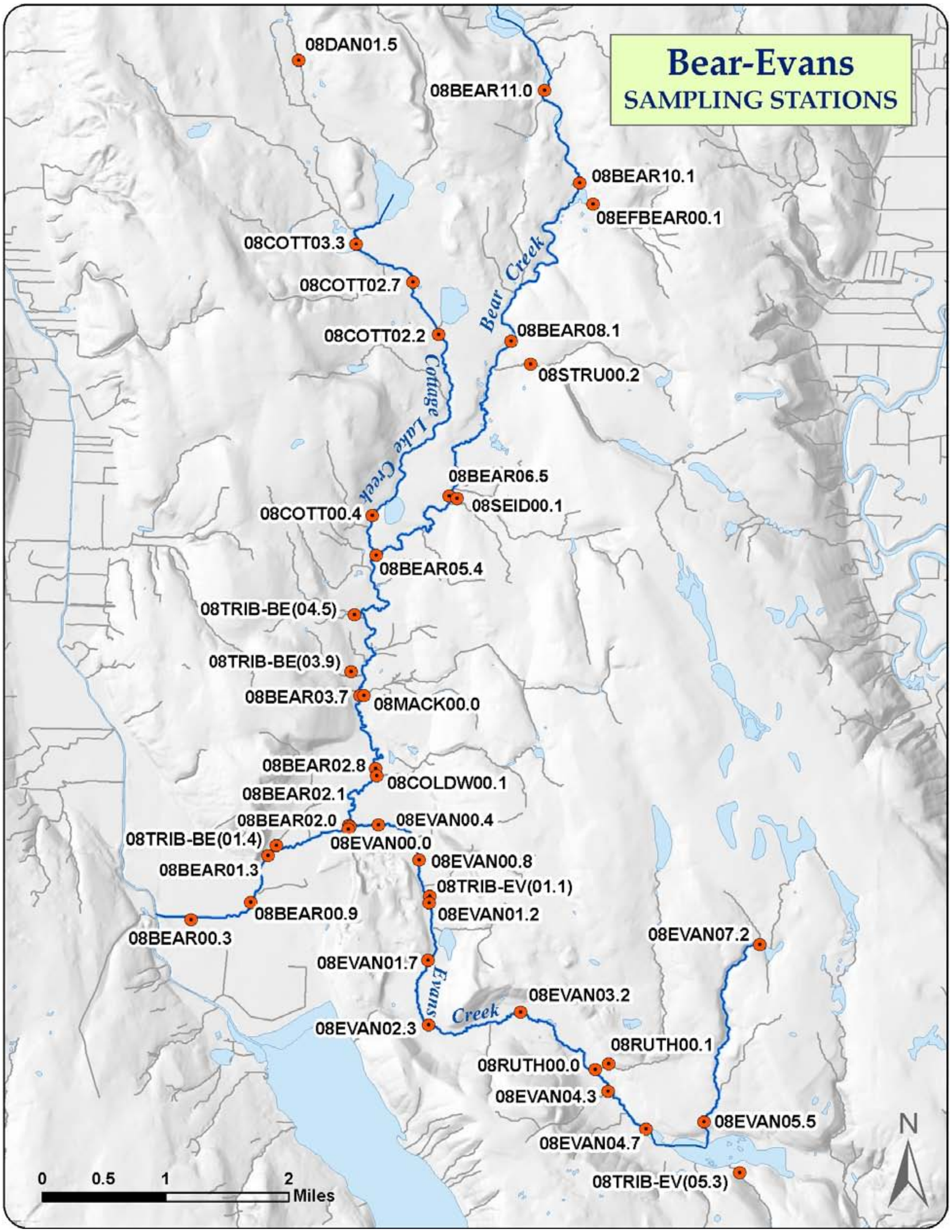

Figure 5. Field sampling stations in the Bear-Evans watershed.

Continuous DO, pH, and conductivity using YSI® multi-probes

King County Environmental Laboratory (KCEL) staff calibrated 12 YSI® multi-probes and then deployed the instruments at 11 key sites throughout both Bear and Evans watersheds, with the 12th probe placed as a replicate at one site. Each YSI® probe collected continuous DO, pH, temperature and conductivity data at 15-minute intervals from July 17-20, 2006. At the end of their deployment, the probes were returned to the KCEL lab for post deployment end checks and data upload.

Synoptic productivity monitoring

Synoptic monitoring of ten stations in the Bear Creek watershed and six stations in the Evans Creek watershed took place on July 18 and 19 during summer low-flow conditions when temperature and DO can reach critical levels. Monitoring took place in the early morning and late afternoon on each day.

King County field teams recorded in-situ parameters (temperature, DO, pH, and conductivity) and collected nutrient grab samples for laboratory analysis. Grab samples were analyzed by KCEL for total nitrogen, nitrate plus nitrite, ammonium, total phosphorus, soluble reactive phosphorus (orthophosphate), total organic carbon, dissolved organic carbon, alkalinity, pheophytin, and chlorophyll a.

Ecology field teams measured rock surface areas and collected periphyton samples from four locations in the Bear Creek watershed and three in the Evans Creek watershed. Grab samples were analyzed by Manchester Environmental Laboratory (MEL) for chlorophyll a and ash-free dry weight (volatile organic matter).

Synoptic flow and travel time

On July 18, during KCEL synoptic productivity monitoring, three field teams measured instantaneous streamflows at 19 stations in the Bear Creek watershed and 9 stations in the Evans Creek watershed. Discharge was calculated by measuring velocities and depths in 20 or more divisions of a cross-section (Ecology, 1993). Fewer divisions were measured when necessary on smaller stream sections. Several replicate flows were taken throughout the course of the day to characterize variability.

A total of seven King County streamflow gages exist along Bear, Evans, and Cottage Lake Creeks. Except for one gage (gage 70c at the outlet of Cottage Lake) that was decommissioned in 1995, all the others have continuous discharge data that covered the 2006 field monitoring period. Data from these flow monitoring locations were used to complement the fine-scale monitoring data collected during the synoptic flow study.

Ecology conducted time-of-travel dye studies during the week of August 7-11 using rhodamine WT as a tracer and Hydrolab continuous dataloggers to record rhodamine concentrations. A dye study was done on all three creeks, with three dye releases on Bear and Evans Creeks and two on Cottage Lake Creek.

HemiView photographs

Ecology took HemiView photographs of riparian canopy at the center of stream reaches to determine in-situ riparian shade levels for comparison with predicted values. HemiView images were processed using manufacturer's software to calculate effective shade from canopy cover.

Study quality assurance evaluation

Replicates and duplicates

KCEL and MEL performed laboratory duplicate analyses on 6 to 13% of all samples collected, which exceeded the 5% minimum set forth in the QAPP (Roberts and Jack, 2006). Results are presented in Table 5. KCEL analyzed method blanks, spike blanks, lab control samples, lab duplicates, matrix spikes, and check standards at the required frequencies. All of the quality control (QC) samples fell within the limits specified in the respective methods and the QAPP developed for the project. There were no systemic biases, and the data have not been qualified based on the QC results (Jack, 2006). MEL followed standard QC procedures documented in the MEL Lab Users Manual (MEL, 2005).

Table 5. Summary of laboratory duplicates for KCEL and MEL, respectively.

Parameter	Median RSD%	ECY MQO (RSD%)	Mean RSD%	Mean RPD	KCEL MQO (RPD)	# of dups taken	# of dups above detect limit	Total # of samples (less dups)	% of total samples duplicated
King County Environmental Laboratory Results									
Ammonia-Nitrogen	1.27	5	2.84	4.01	20	4	3	68	6%
Chlorophyll a (grab sample)	0.00	5	0.00	0.00	25	4	1	68	6%
Dissolved Organic Carbon	4.45	5	4.39	6.21	20	4	4	68	6%
Nitrite + Nitrate Nitrogen	0.53	5	0.72	1.01	20	4	4	68	6%
Orthophosphate Phosphorus	2.54	5	3.77	5.33	20	4	4	68	6%
Pheophytin a	n/a	n/a	n/a	n/a	n/a	4	0	68	6%
Total Alkalinity	0.63	5	0.75	1.05	10	5	5	68	7%
Total Nitrogen	0.97	5	1.05	1.49	20	4	4	68	6%
Total Organic Carbon	1.28	5	3.55	5.02	20	4	4	68	6%
Total Phosphorus	3.04	5	4.11	5.81	20	4	4	68	6%
Manchester Environmental Laboratory Results									
Periphyton – Chlorophyll a	0.28	5	0.28	0.40	n/a	1	1	8	13%
Periphyton - AFDW	4.94	5	4.94	6.99	n/a	1	1	8	13%

KCEL collected and analyzed field replicate samples to assess the precision of both sampling and analysis. Field replicates are two samples collected from the same location at the same time. The percentage of replicates taken per parameter is presented in Table 6. The percent of samples collected did not meet the 10% goal set forth in the QAPP. Subsequent to publication of the QAPP, it was determined that, given the number of nutrient-collection stations, this frequency would overload KCEL's analytical capacity. KCEL concluded that a minimum of 1 in 20 samples, or 1 sample per half day run, would be adequate to assess precision.

Table 6. Summary of field replicates for KCEL.

Parameter	Median RSD%	ECY MQO (RSD%)	Mean RSD%	Mean RPD	KCEL MQO (RPD)	# of reps taken	# of reps above detect limit	Total # of samples (less reps)	% of total samples replicated
Ammonia-Nitrogen	0.28	10	0.28	0.40	20	4	1	64	6%
Chlorophyll a (grab sample)	5.33	20	5.33	7.54	25	4	1	64	6%
Dissolved Organic Carbon	0.70	10	0.93	1.31	20	4	4	64	6%
Nitrite + Nitrate Nitrogen	2.33	10	2.11	2.99	20	4	3	64	6%
Orthophosphate Phosphorus	4.65	10	4.25	6.01	20	4	4	64	6%
Pheophytin a	n/a	n/a	n/a	n/a	n/a	4	0	64	6%
Total Alkalinity	0.55	10	0.44	0.62	10	4	4	64	6%
Total Nitrogen	5.19	10	5.09	7.19	20	4	4	64	6%
Total Organic Carbon	0.78	10	0.91	1.29	20	4	4	64	6%
Total Phosphorus	2.29	10	3.05	4.31	20	4	4	64	6%

Continuous temperature

Ecology field staff checked the data loggers with a hand-held alcohol thermometer checked against a NIST-certified reference thermometer at all Ecology sites on September 13 and upon removal at the end of the study period.

The temperature loggers were pre- and post-calibrated by Ecology in accordance with standard Ecology protocols (Ward et al., 2001) to document instrument bias and performance at representative temperatures. A NIST-certified reference thermometer was used for the calibration.

In general, continuous water temperature data collected by RH2 Engineering (on behalf of NEWSSD and UHWA) correlated well with Ecology data at all three overlapping stations where both entities installed temperature loggers (Appendix B, Figures B-10 through B-12). At 08COLDW00.1, the Ecology temperature logger recorded slightly higher maximum water temperatures, particularly at the beginning of August.

In-situ and continuous DO, pH, and conductivity

King County calibrated all field monitoring equipment according to agency protocols or manufacturer's specifications. This included pre-calibration and post-checks of in-situ and continuous YSI® meters with certified standards. King County checked continuous YSI® meters with another calibrated meter in-situ during nutrient sample collection.

Ecology collected Winkler DO measurements to compare to KCEL YSI® continuous DO measurements. DO data were adjusted based on Winkler-titration samples collected throughout the deployment using either a regression or bias correction factor. This correction minimizes bias and improves the relationship between datalogger and Winkler DO data, giving a more accurate picture of the sites' diel DO characteristics. YSI® field checks were also performed on all four parameters as instantaneous measurements using a separate calibrated YSI® meter.

All YSI® multi-probes passed their respective post-deployment end checks, with the exception of one failed DO probe at Rutherford Creek at Hwy 202 mile 11 (08RUTH00.1). Two conductivity probes passed their end checks but experienced difficulties during deployment. These conductivity data were not used for modeling analysis or entered into Ecology's EIM database. All other data from 08RUTH00.1 passed checks.

Laboratory data qualifiers

MEL and KCEL performed all laboratory analyses within specified holding times using appropriate quality assurance measures unless noted with qualifier codes (Table 7). Qualifiers place specific conditions on the laboratory data. Data reported with qualifiers should be used with caution, and data variability must be taken into consideration when interpreting results and applying data to other analyses. All other data reported by KCEL and MEL may be used without qualification. Since data were collected and analyzed by KCEL, the data qualifiers have been changed to the MEL equivalent for EIM data entry purposes.

Table 7. Laboratory qualifier used in data summaries.

KCEL qualifier	MEL qualifier	Narrative
<MDL	U	Analyte not detected at or above the reported result.
<RDL	J	Analyte positively identified at or above the maximum detection limit but below the practical quantitation limit. The numeric value should be treated as an estimate.
E, TA	J	These DO concentrations were back calculated from the percent saturation and should be considered estimates.

Results and discussion

All data that passed quality control checks are available in Ecology's EIM database under User Study ID MROB002.

During the 2006 field monitoring effort, the Washington State Department of Transportation (WSDOT) was conducting some construction work near SR-202 near Evans Creek, just downstream of 08EVAN02.3. Activities included temporary diversion of Evans Creek, pumping groundwater into ponds and allowing it to infiltrate through sand bags, and adding about one truckload full of clean water per day into Evans Creek. Construction activities, however, were not consistent through the summer, and there were times when there were no activities.

These construction activities did not affect data collected at station 08EVAN02.3 and at all sampling stations upstream of this one.

Continuous temperature data, presented in Appendix B, were recorded throughout the summer. One obvious trend in the temperature data is downstream warming. But this warming was observed both upstream (between 08EVAN03.2 and 08EVAN02.3) and downstream (between 08EVAN02.3 and 08EVAN01.2) of the construction activities.

Construction activities may have potentially affected the monitoring data, but the continuous summer temperature data record from the summer shows consistent relationships and trends between stations throughout the summer, regardless of whether construction activities were being conducted. The construction might have had a localized effect on stream water quality parameters, but this effect could have dissipated within the 1.1 mile stretch between monitoring stations 08EVAN02.3 and 08EVAN01.2.

During the dye study, a Hydrolab was placed briefly in the retention ponds to see if any of the Rhodamine dye had been siphoned out, but we did not detect any measurable concentrations. In conclusion, the 2006 construction activities probably had minimal impact on temperature and DO.

All collected data are presented in the form of plots and tables in the Appendices. These data are discussed further below.

Temperature

Appendix B contains plots showing the continuous 7-day average of daily maximum water and air temperatures. Figures B-10 to B-12 compare 30-minute continuous water temperature data collected at the same stations by both Ecology and RH2.

Table 8 provides a summary of the temperature data in terms of the highest 7-day average of daily maximum temperatures recorded during summer 2006. Water temperatures in Bear, Evans, and Cottage Lake Creeks (and tributaries) were relatively cool in mid-June at the start of monitoring. Hottest air and water temperatures, representative of the summer's critical conditions, were recorded between July 21 and 27.

Table 8. Highest 7-day average of daily maximum temperature recorded in the Bear-Evans watershed during summer 2006.

Station ID	Station Description	Temperature (^oC)	
		Highest 7-DADMax	WQ Standard
Bear Creek			
08BEAR11.0	Bear Creek, east of 204th Ave	26.70	16.0
08BEAR10.1	Bear Creek at Woodinville Duvall Rd	23.47	16.0
08BEAR08.1	Bear Creek at Tolt Pipeline Trail off 148th	21.77	16.0
08BEAR06.5	Bear Creek at crossing with NE 133rd St	22.19	16.0
08BEAR05.4	Bear Creek east of Avondale	21.83	16.0
08BEAR03.7	Bear Creek at NE 106th St	21.41	16.0
08BEAR02.8	Bear Creek at NE 95th St	21.51	16.0
08BEAR02.1	Bear Creek upstream of Evans confluence	22.01	16.0
08BEAR02.0	Bear Creek downstream of Evans confluence	21.71	16.0
08BEAR01.3	Bear Creek at King County Gage 02a	21.94	16.0
08BEAR00.9	Bear Creek near mouth at smolt trap	22.14	16.0
08BEAR00.3	Bear Creek near mouth	22.35	16.0
Bear Creek Tributaries			
08EFBEAR00.1	East fork of Bear Creek	20.33	16.0
08STRU00.2	Struve Creek near mouth	17.99	16.0
08SEID00.1	Seidel Creek at 198th Ave NE	20.48	16.0
08TRIB-BE(04.5)	Tributary near Avondale & NE 116th St	17.76	16.0
08TRIB-BE(03.9)	Tributary at Essex Park	18.10	16.0
08MACK00.0	Mackey Creek near mouth	18.77	16.0
08COLDW00.1	Coldwater Creek at trail crossing, off NE 95th St	20.98	16.0
08TRIB-BE(01.4)	Tributary known locally as Perrigo Creek	17.38	16.0
Evans Creek			
08EVAN05.5	Evans Creek at Hwy 202 fish ladder, mile 12	14.57	16.0
08EVAN04.7	Evans Creek at wetland 22 outlet	22.06	16.0
08EVAN04.3	Evans Creek at NE 44th St off 220th Ave	19.33	16.0
08EVAN03.2	Evans Creek at Sahalee Way	18.34	16.0
08EVAN02.3	Evans Creek at 196th (south); just south of Hwy 202	19.78	16.0
08EVAN01.2	Evans Creek at 196th (north)	23.33	16.0
08EVAN00.8	Evans Creek at Union Hill Rd	21.31	16.0
08EVAN00.4	Evans Creek behind Supply Co.	20.52	16.0
08EVAN00.0	Evans Creek at mouth	21.06	16.0
Evans Creek Tributaries			
08TRIB-EV(05.3)	Tributary off logging road	16.08	16.0
08RUTH00.0	Rutherford Creek near mouth at Hwy 202, mile 11	14.16	16.0
08RUTH00.1	Rutherford Creek at mouth	12.62	16.0
08TRIB-EV(01.1)	Tributary near Evans Creek at 196th (north)	18.41	16.0
Cottage Lake Creek			
08COTT03.3	Cottage Lake Creek at NE 165th St	21.42	16.0
08COTT02.2	Cottage Lake Creek at Tolt pipeline trail	20.32	16.0
08COTT00.4	Cottage Lake Creek at 128th St	20.21	16.0

The headwaters of Bear Creek flow out of Paradise Lake, which imparts a high heat signature to upper Bear Creek. Approximately 5°C of cooling occurred along the 2.9-mile stretch between 08BEAR11.0 (the most upstream station on Bear Creek) and 08BEAR08.1. From this point, Bear Creek tends to warm up consistently all the way to its confluence with the Sammamish River.

Downstream cooling occurred in Cottage Lake Creek from the headwaters out of Cottage Lake all the way to its confluence with Bear Creek.

In contrast, Evans Creek has relatively cool headwaters, and the water temperatures tend to fluctuate slightly with an overall warming as it flows downstream. Evans Creek tributaries are sources of cooler water into Evans Creek.

Dissolved oxygen, pH, and conductivity

Appendix C contains plots for 15-minute continuous DO, pH, temperature, and conductivity data. The plots depict both the raw and adjusted DO values, as well as Winkler DO values measured with a Winkler titration method and YSI® field meter checks. Seven out of 12 stations required corrections of less than 0.5 mg/L.

Station 08BEAR11.0 has a wider diel range in DO than station 08BEAR08.1, indicative of greater biological activity in the headwaters. Struve Creek, a tributary to Bear Creek, brings in water with higher DO concentrations than in the mainstem Bear Creek.

Stations in Evans Creek showed limited diel variation in DO, suggesting a strong groundwater influence. Continuous DO values from Evans Creek at the SR 202 fishladder displayed no diel pattern (08EVAN05.5). This station was located in a weir pool and may be influenced by groundwater input.

In general, Cottage Lake Creek has higher DO concentrations and conductivity than the rest of the Bear-Evans watershed.

Nutrients

Appendix D contains all nutrient and in-situ field measurement data collected during the synoptic productivity monitoring event. Appendix D also contains summary data from periphyton sampling.

Bear Creek tributaries were found to bring in higher nutrient concentrations relative to the mainstem. Upper portions of Bear Creek are possibly nitrogen-limited (N:P ratios are less than 7.2), while lower portions are phosphorus-limited (N:P ratios are greater than 7.2).

The reverse trend is true for Evans Creek, where upper reaches are phosphorus-limited and lower reaches are nitrogen-limited. The headwaters of Evans Creek have relatively high nitrate concentrations in comparison to the rest of the Bear-Evans basin.

Flow and travel time

Instantaneous-flow and travel-time study results are presented in Appendix E. Figures E-1 and E-2 present continuous flow data from King County stream gages over the summer. These figures illustrate that both the synoptic survey and travel-time studies were conducted during the summer's low-flow periods.

Travel time results show that total travel time for Bear Creek is just less than two days (1.91 days) from station 08BEAR11.0 to the confluence with Evans Creek, and a little less than half a day (0.41 days) for Cottage Lake Creek from 08COTT03.3 at 165th Street to the confluence with Bear Creek near NE 124th street.

On Evans Creek, no Rhodamine dye was detected after about 51 hours of monitoring since the initial dye release on Evans Creek. The datalogger was removed as it was scheduled to be deployed for other dye releases. The dye may have dispersed in the approximately one-mile stretch of inaccessible wetlands immediately downstream of the release site through which water movement is slow. As a result of the lengthy travel time through wetlands, additional releases and monitoring stations were added to subsequent dye releases in order to minimize data loss.

For those stretches of Evans Creek where no dye was detected, the travel time is listed as greater than the duration of monitoring. The total travel time for Evans Creek is estimated to be greater than 3.5 days. Despite data loss in upper Evans Creek, the dye study did give an estimate of the minimal travel time in upper Evans Creek. The dye release in lower Evans Creek was successful, and travel time for the lower reaches could therefore be determined. Slower travel times, in general, means a greater residence time and an opportunity for the water body to experience thermal gain.

Ecology scientist releases red dye to determine the travel time.

TMDL Analyses for Temperature and Dissolved Oxygen

Seasonal variation

The Clean Water Act Section 303(d)(1) requires that TMDLs "be established at the level necessary to implement the applicable water quality standards with seasonal variations." The current regulation also states that determination of "TMDLs shall take into account critical conditions for streamflow, loading, and water quality parameters" [40 CFR 130.7(c)(1)]. Finally, Section 303(d)(1)(D) suggests consideration of normal conditions, flows, and dissipative capacity.

Existing conditions for stream temperatures in the Bear-Evans watershed reflect seasonal variation. Cooler temperatures occur in the winter, while warmer temperatures are observed in the summer. Highest temperatures typically occur in July and August, which is the critical period for temperature TMDL development. Figure 6 illustrates where the highest 7-day average maximum water temperatures were recorded in 2006. The majority of these were recorded on July 24, 2006.

The critical condition for DO (when the lowest minimum DO levels might occur) often corresponds to the critical condition for temperature, but can sometimes occur later in the summer season or early fall. Since data were limited to a single synoptic survey, the critical DO condition was assumed to overlap with critical temperature conditions.

Estimates of solar flux, streamflow, and climatic variables were chosen to correspond with critical conditions for the TMDL model.

The critical period for evaluation of solar flux and effective shade was assumed to be July 24 because it was the mid-point of the period when water temperatures recorded in summer 2006 were at a seasonal peak.

Critical streamflows were evaluated as the lowest 7-day average flows with a 10-year recurrence interval (7Q10) for July and August, and were assumed to represent a reasonable worst-case climatic year.

Critical air temperatures were the lowest 7-day average of maximum air temperatures with a 10-year recurrence interval (7Q10) for July and August. The 7Q10 air temperatures were then used to back-calculate critical dewpoint point temperatures using summer 2006 relative humidity data.

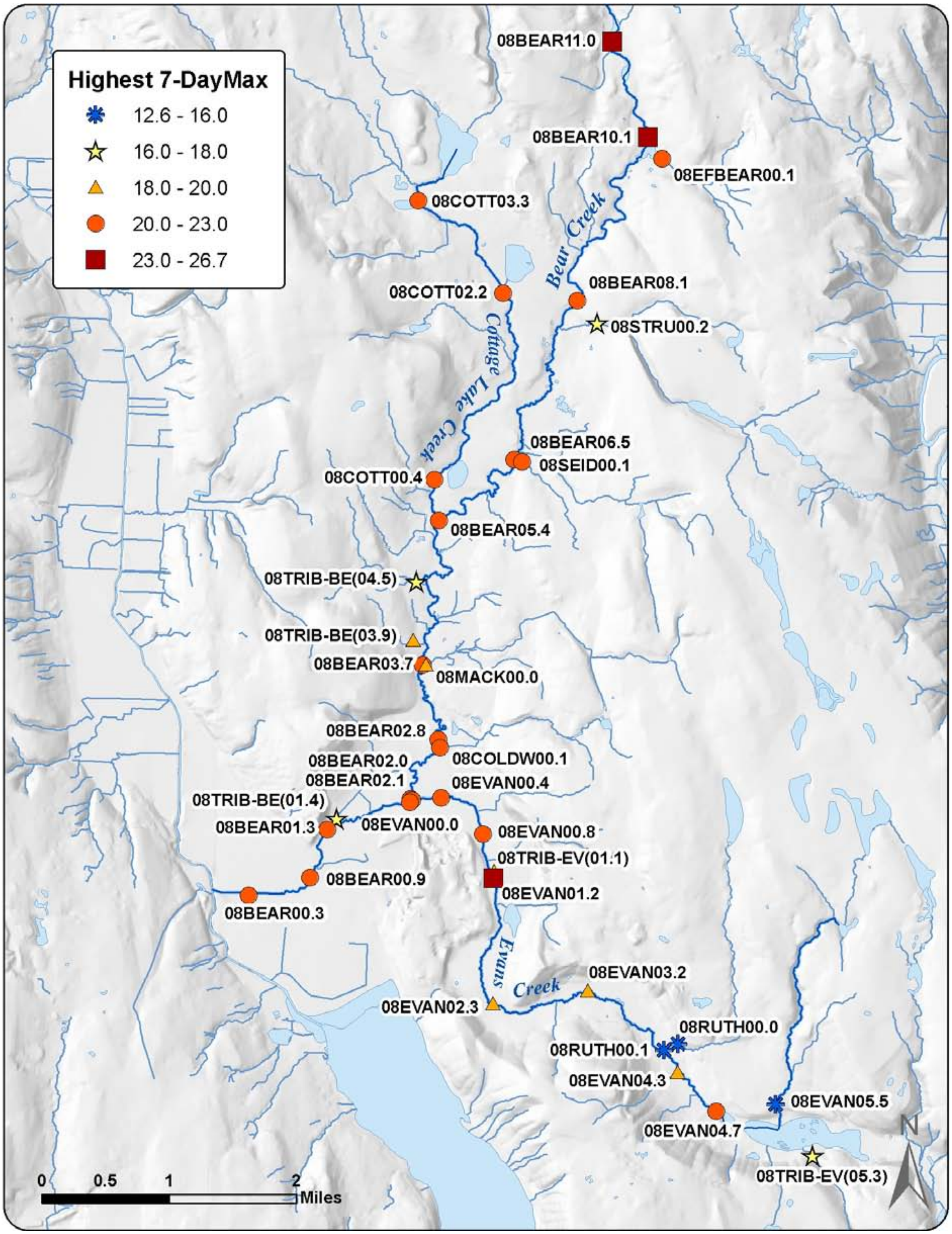

Figure 6. Map illustrating the highest 7-day average daily maximum water temperatures recorded in the Bear-Evans watershed in summer 2006.

(The most severely temperature-impaired segments are indicated by red squares.)

Effective shade analysis

Link between effective shade and temperature

Effective shade is defined as the fraction of incoming shortwave solar radiation that is blocked by vegetation and topography before it reaches the stream surface. Shade is an important parameter that controls stream heating derived from solar radiation. Stream temperature represents the concentration of heat. If heat loads gained by a stream reach exceed losses, the temperature increases.

The rate of warming of water temperatures as a stream flows downstream can be dramatically reduced when high levels of shade exist and heat flux from solar radiation is minimized. Solar radiation has the potential to be one of the largest heat-transfer mechanisms in a stream system. The overriding justification for increases in shade from riparian vegetation is to minimize the contribution of solar heat flux in stream heating. Trees in riparian areas provide shade to streams and minimize undesirable water temperature changes (Brazier and Brown 1973; Steinblums et al., 1984).

Human activities can degrade riparian vegetation and/or channel morphology, and in turn, decrease shade. Reductions in stream surface shade have the potential to cause significant increases in heat delivery to a stream system. Effective shade generated from riparian vegetation is therefore an important factor in describing the heat budget for this analysis.

Effective shade is a function of several landscape and stream geometric relationships. Some of the factors that influence effective shade include the following:

- Latitude and longitude.
- Time of year.
- Stream aspect and width.
- Vegetation buffer height, width, overhang, and canopy density.
- Topographic shade angles.

Percent effective shade is a straightforward stream parameter to monitor and calculate, and it is easily translated into quantifiable water quality management and restoration objectives.

The effective shade analysis for this study was carried out in three steps as listed below:

1. Digitizing and sampling current stream channel and riparian vegetation.
2. Generating effective shade from current riparian vegetation.
3. Determining system potential effective shade from system potential mature riparian vegetation.

Digitizing and sampling stream channel and riparian vegetation

To obtain a detailed description of the existing riparian conditions in the Bear-Evans watershed, a combination of Geographic Information System (GIS) analysis and aerial photography interpretation was used. Full color 2005 Aerial Express Ortho-imagery with 12” resolution was obtained courtesy of King County GIS. The analysis described below was performed on each of the three creeks (Bear, Evans, and Cottage Lake).

Stream channels (stream centerline and stream banks) were first digitized by modifying an existing water course (streams) layer which was originally digitized by King County at a scale of 1:2000 to 1:3000 and updated in 2005/2006. This layer was refined, where needed, to match aerial images at an approximate scale of 1:900.

Tree height information was derived from 6 foot resolution Light Detection and Ranging (LiDAR) data, also courtesy of King County GIS. LiDAR is a remote sensing system used to generate digital elevation data. LiDAR sensors, mounted on an airborne device, emit laser pulses. When this laser pulse hits the ground, it 'returns' back to the sensor where it is recorded. The timing and speed of pulses are used to calculate the distance between the sensor and the ground (i.e., elevation).

LiDAR sensors are capable of receiving multiple returns. The first return is when the laser pulse hits the first object on the ground (e.g., a forest canopy), and the last return is received when the pulse continues down to the bare earth. The first and last returns are processed to generate two data sets: a Digital Ground Model (DGM) representing the first return and a Digital Surface Model (DSM) representing the last return. These two grids were subtracted from each other to generate a Digital Height Model (DHM), which represented the height of features, such as trees, on the ground.

Current vegetation was digitized within a 100-meter (328-foot) buffer on each side of the stream using visual interpretation of aerial imagery in combination with the LiDAR DHM layer. Vegetation polygons were delineated so that each polygon represented a cluster of homogeneous vegetation represented by three characteristics: tree height, canopy density, and overhang. Each vegetation polygon was assigned a 'vegetation code' that represented these three characteristics. Digitizing was performed at an approximate scale of 1:1000. Roadways, buildings, and other urban features were also digitized. The same vegetation classification was used for all three creeks, except for Evans Creek, where shrub heights, identified by the DHM, were shorter relative to the rest of the basin. Table 9 lists the vegetation codes and classifications used.

LiDAR data have been used in other studies to determine individual tree heights (CTUIR, 2005; Kwak et al., 2007; and St-Onge et al., 2004). Since ground/field measurements to confirm tree heights from LiDAR data were not available, we did not use the LiDAR DHM layer to get absolute tree heights of individual trees. Instead we used it to inform our polygon delineations which clumped regions with similar tree height into a single polygon.

Table 9. Vegetation codes and classifications used when digitizing riparian vegetation.

Code	Vegetation/Cover type	Height (meters)	Density	Overhang (meters)
100	water	0.0	0%	0.0
200	built, paved, barren	0.0	0%	0.0
300	pasture, scattered trees	0.2	75%	0.0
410	shrub (small)	2.0	75%	0.2
420	shrub (large)	5.0	75%	0.5
511	deciduous (small, sparse)	10.0	25%	1.0
512	deciduous (small, dense)	10.0	75%	1.0
521	deciduous (large, sparse)	20.0	50%	2.0
522	deciduous (large, dense)	20.0	75%	2.0
610	conifer (small)	15.0	90%	1.5
620	conifer (med)	25.0	90%	2.5
630	conifer (large)	30.0	90%	3.0
640	conifer (x-large)	40.0	80%	4.0
710	mixed (small)	10.0	75%	1.0
720	mixed (med, very sparse)	20.0	25%	2.0
721	mixed (med, sparse)	20.0	50%	2.0
722	mixed (med, dense)	20.0	80%	2.0
731	mixed (large, sparse)	25.0	50%	2.5
732	mixed (large, dense)	25.0	80%	2.5
Adjusted shrub heights for Evans Creek				
410	shrub (small)	1.0	75%	0.0
420	shrub (large)	3.0	75%	0.0

Figure 7 illustrates the GIS process used to digitize and sample the stream channel and riparian vegetation. Stream widths and aspect, topographic shade angles (west, east, and south), elevation, and riparian vegetation were sampled with TTools 7.5.2. TTools is an ArcGIS extension originally developed by the Oregon Department of Environmental Quality (ODEQ, 2001) and updated by Ecology to work with ArcGIS 9.1. Creeks were sampled every 100 meters along their length to generate a longitudinal profile of each creek. The profile included latitude/longitude, stream aspect and width, elevation, and riparian vegetation present within the riparian buffer. All these parameters were input into Ecology's Shade model to generate effective shade profiles for each creek (Ecology, 2003).

GIS Digitizing

This figure walks through the different steps used to digitize the stream channel and riparian vegetation. Image 3 illustrated the LiDAR digital height model where darker (more red) colors represent taller features on the ground. Image 5 shows how the channel and vegetation is sampled every 100 meters, as signified by the dots.

Image 1. Digitize stream channel

Image 2. Create riparian buffer

Image 3. Analyze LiDAR height layer

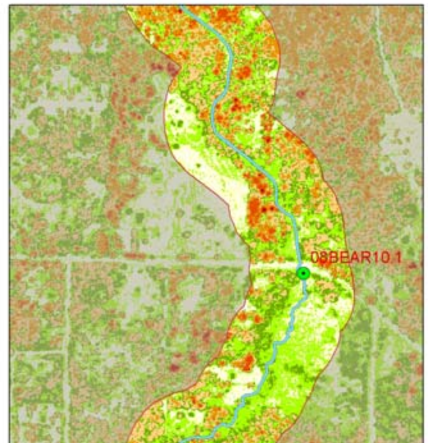

Image 4. Delineate vegetation polygons

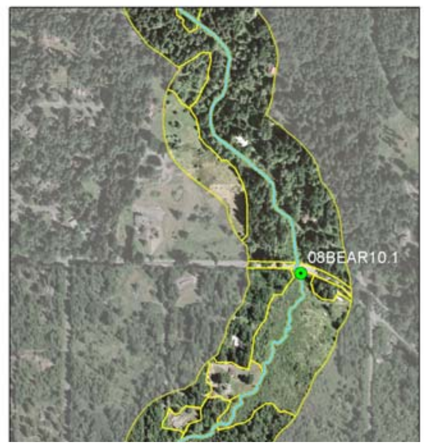

Image 5. Assign vegetation codes

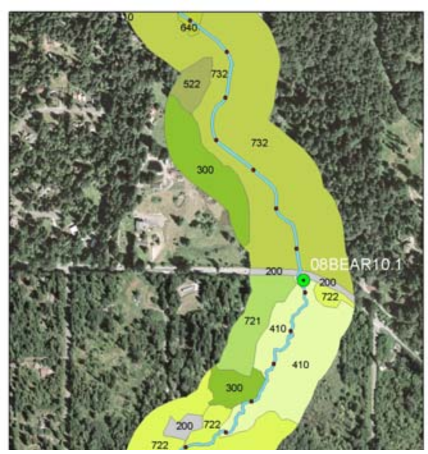

Figure 7. Steps carried out for digitizing stream channel and riparian vegetation using aerial imagery and LiDAR tree height data in GIS.

Generating effective shade from current riparian vegetation

Ecology's Shade model (Ecology, 2003) uses mathematical simulations to quantify potential daily solar load and generate percent effective shade values. The data generated from the TTools analysis were used as input into the Shade model to generate longitudinal effective shade profiles for Bear, Evans, and Cottage Lake Creeks. The Shade model was run for 7-day average conditions centered on July 24, 2006 to represent summer critical conditions as observed from field temperature data.

The Shade model uses an effective shade algorithm, modified from Boyd (1996) using the methods of Chen et al. (1998a and 1998b). Riparian vegetation codes in each zone, stream aspect, topographic shade angles, and latitude/longitude were used to estimate effective shade for each of the 100-meter segments. Results were then averaged for ten segments to create shade characteristics for 1000-meter reaches, which were input into the QUAL2K model discussed later.

Figure 8 through Figure 10 illustrate the current longitudinal effective shade profiles for Bear, Evans, and Cottage Lake Creeks generated from the Shade model along with field HemiView shade measurements. For illustrative purposes, the solid lines in Figures 8 through 10 show effective shade averaged over 500 meters rather than the 1000-meter averages input into QUAL2Kw.

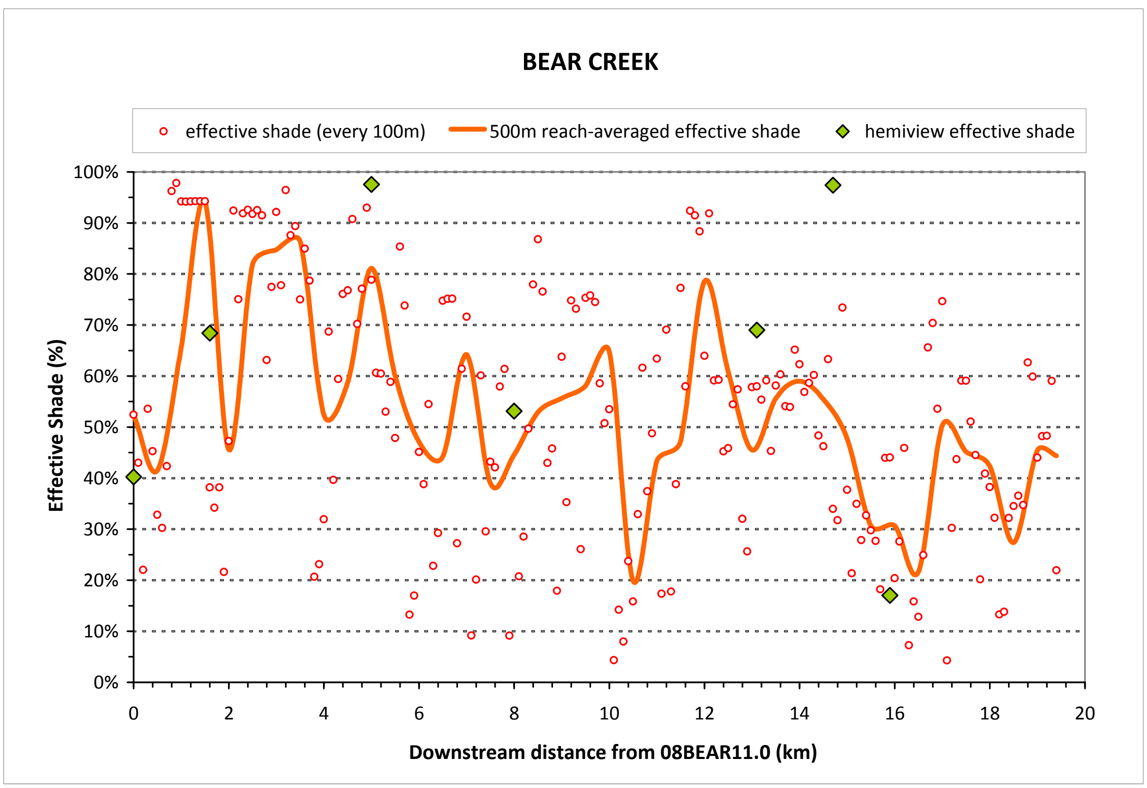

Figure 8. Current longitudinal effective shade profile for Bear Creek.

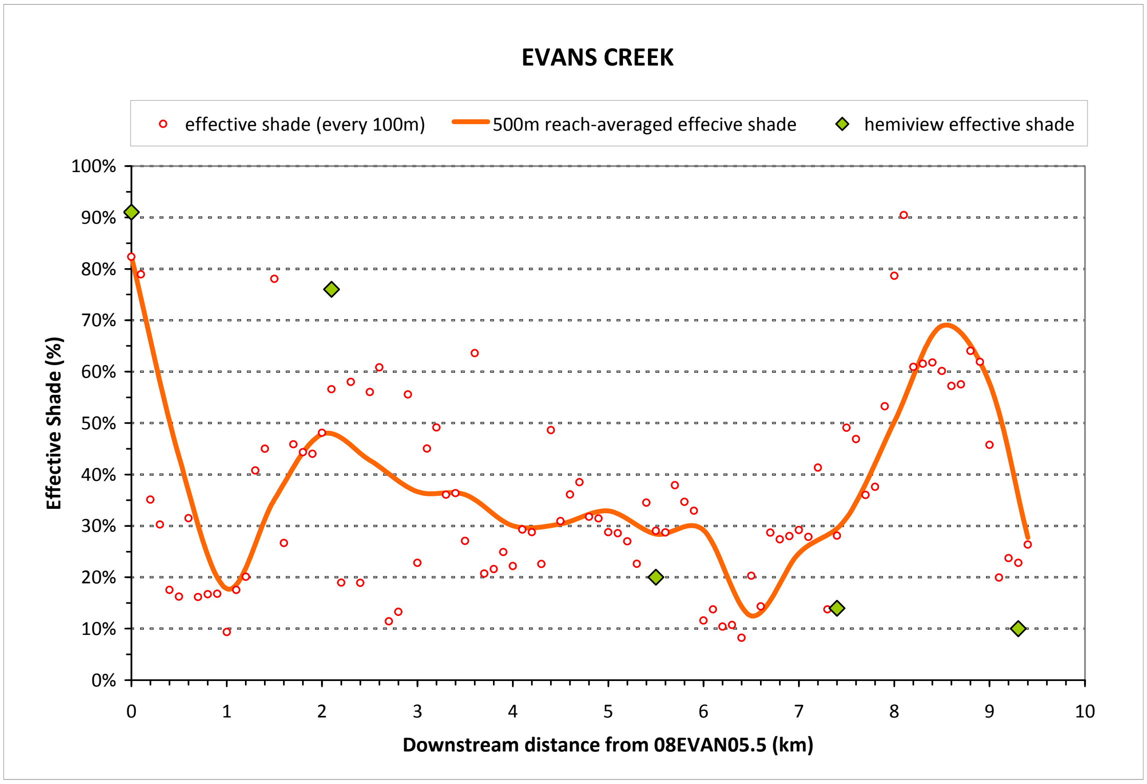

Figure 9. Current longitudinal effective shade profile for Evans Creek.

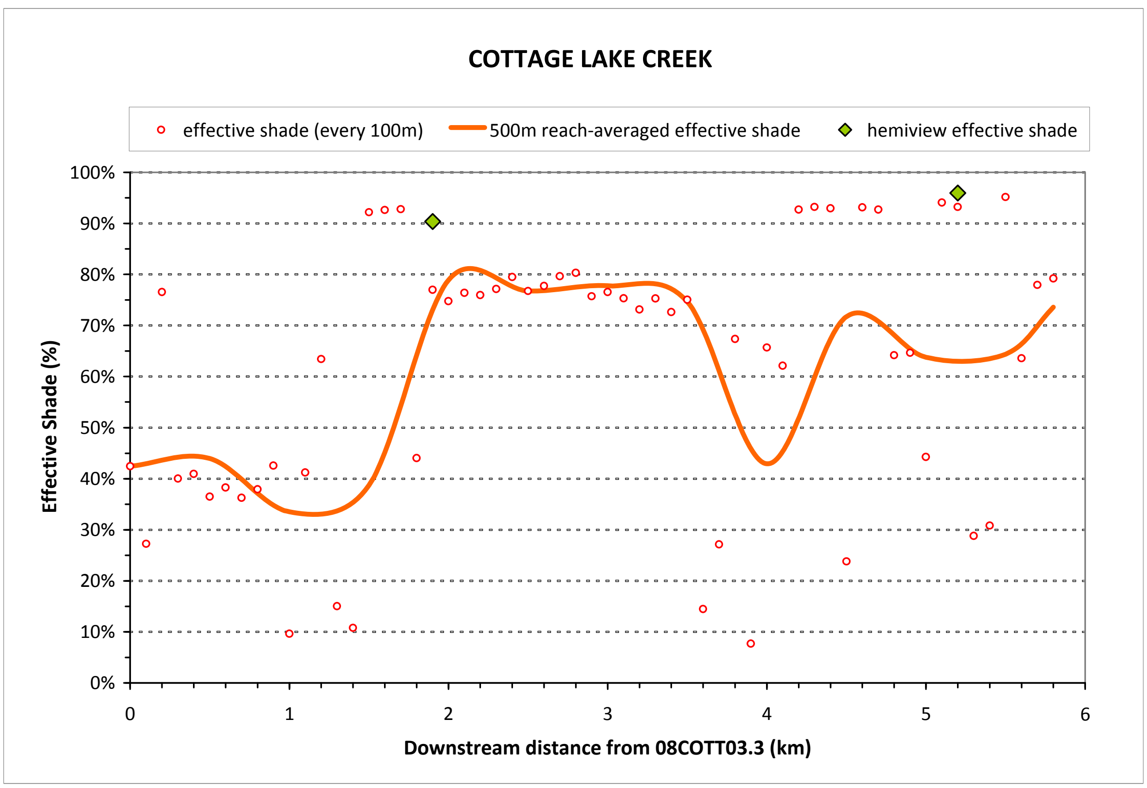

Figure 10. Current longitudinal effective shade profile for Cottage Lake Creek.

Determining system potential effective shade from mature riparian vegetation

System potential effective shade is the natural maximum level of shade that a given stream is capable of attaining with the growth of "system potential mature riparian vegetation," defined as *that vegetation which can grow and reproduce on a site, given climate, elevation, soil properties, plant biology, and hydrologic processes.* The Puget Sound River History Project has attempted to study and recreate historical vegetation in the Puget Sound lowlands using archival studies and field investigations documented in the form of General Land Office survey notes.

Historically (mid-19th century), mixed hardwood-conifer riverine forests in the Puget Sound lowlands were heavily weighted toward hardwoods. Though less abundant, evergreen conifers accounted for the majority of biomass, and several species grew quite large (Collins et al., 2003). Common hardwoods included maples, cottonwoods, willows and red alders; common conifers included the western red cedar, Douglas fir, Sitka spruce and western hemlock (Collins and Montgomery, 2002). The General Land Office surveys noted vegetation species and tree diameters, but did not include tree heights. Mature stands of these different species are known to grow from 50 meters to over 70 meters tall.

Tree heights are specific to an area and dependent on several variables including soils, climate, elevation, and hydrologic processes. GIS soils datasets are often linked to an index with values of 50- or 100-year tree heights which the soils in the area can support. Both the Natural Resources Conservation Service Soil Survey Geographic Database and the Washington State Department of Natural Resources provide soils coverage for the State of Washington. However, data within the Bear-Evans basin from both these soil data sources were limited, and the soils approach to determine system potential tree heights could not be used.

Due to these limitations, a different approach was used to determine system potential tree heights. The LiDAR DHM was used to identify some of the tallest stands in the study area, which were found to be approximately 50 meters tall. Dominant tree species in western Washington typically reach heights of 50 to 75 meters (Franklin and Dyrness, 1973). A height of 50 meters was therefore used as the system potential tree height.

In addition, wetlands cover significant portions of the riparian buffer around Evans Creek and smaller portions around Bear Creeks. These wetland soils are unlikely to support trees as tall as 50 meters. Wetland areas were identified using a wetland GIS coverage developed by the United States Fish and Wildlife Service. Those wetland areas within the 100-meter buffer around Bear and Evans Creeks were given a system potential vegetation height of 10 meters, based on willow characteristics (Pojar and MacKinnon, 1994). The combination of 50-meter (85% density) and 10-meter (75% density) trees in non-wetland and wetland areas, respectively, were used in the Shade model to determine system potential effective shade. Figure 11 through Figure 13 compare current and system potential effective shade profiles for each creek.

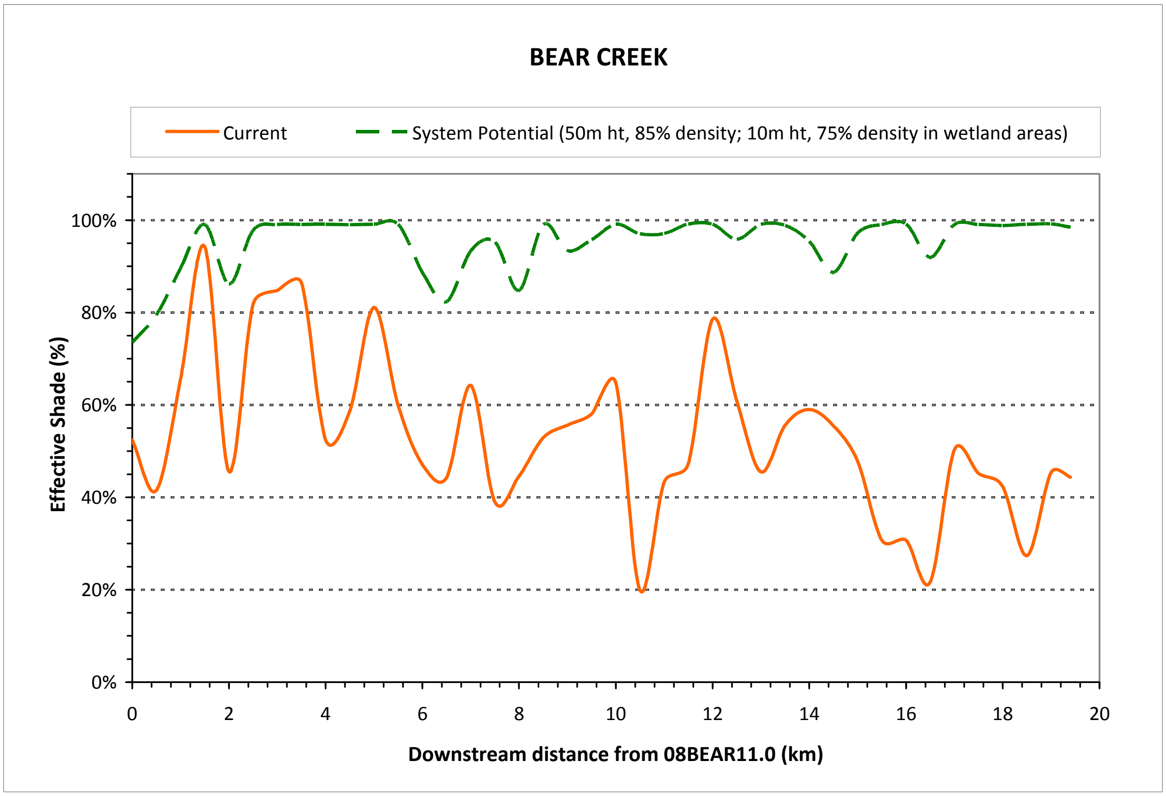

Figure 11. Current and system potential effective shade profile for Bear Creek.

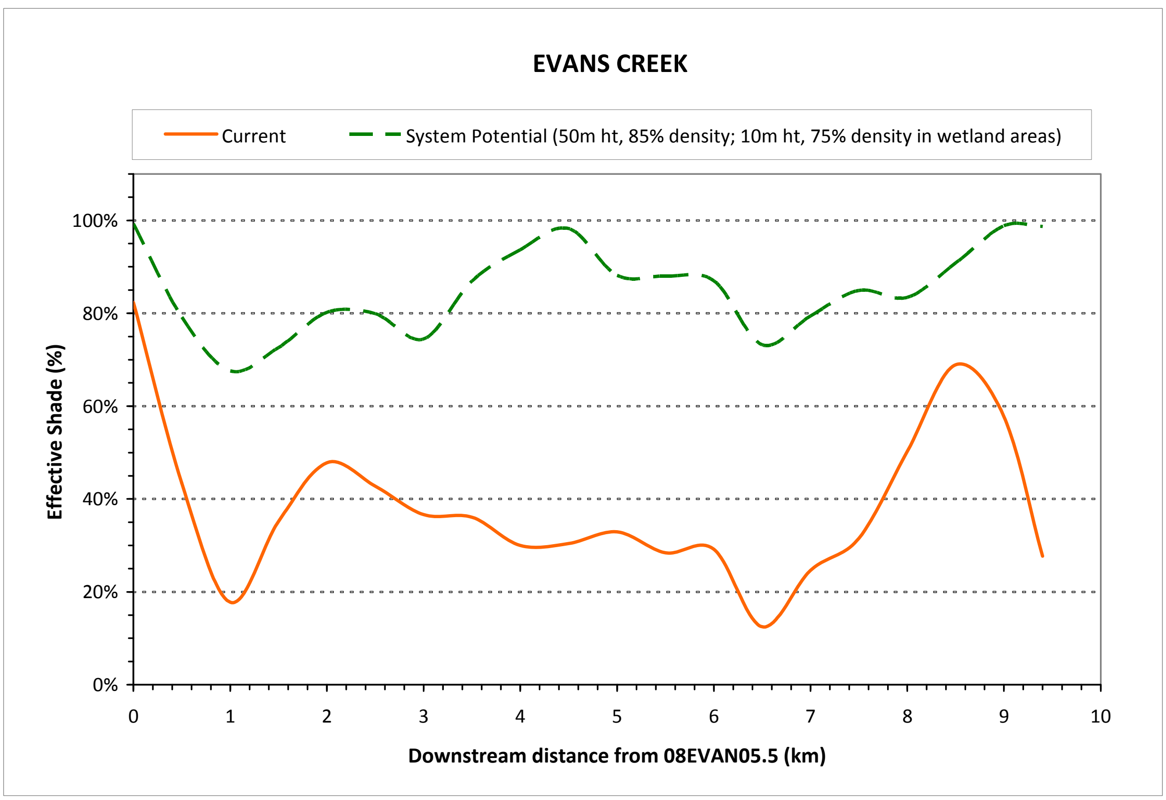

Figure 12. Current and system potential effective shade profile for Evans Creek.

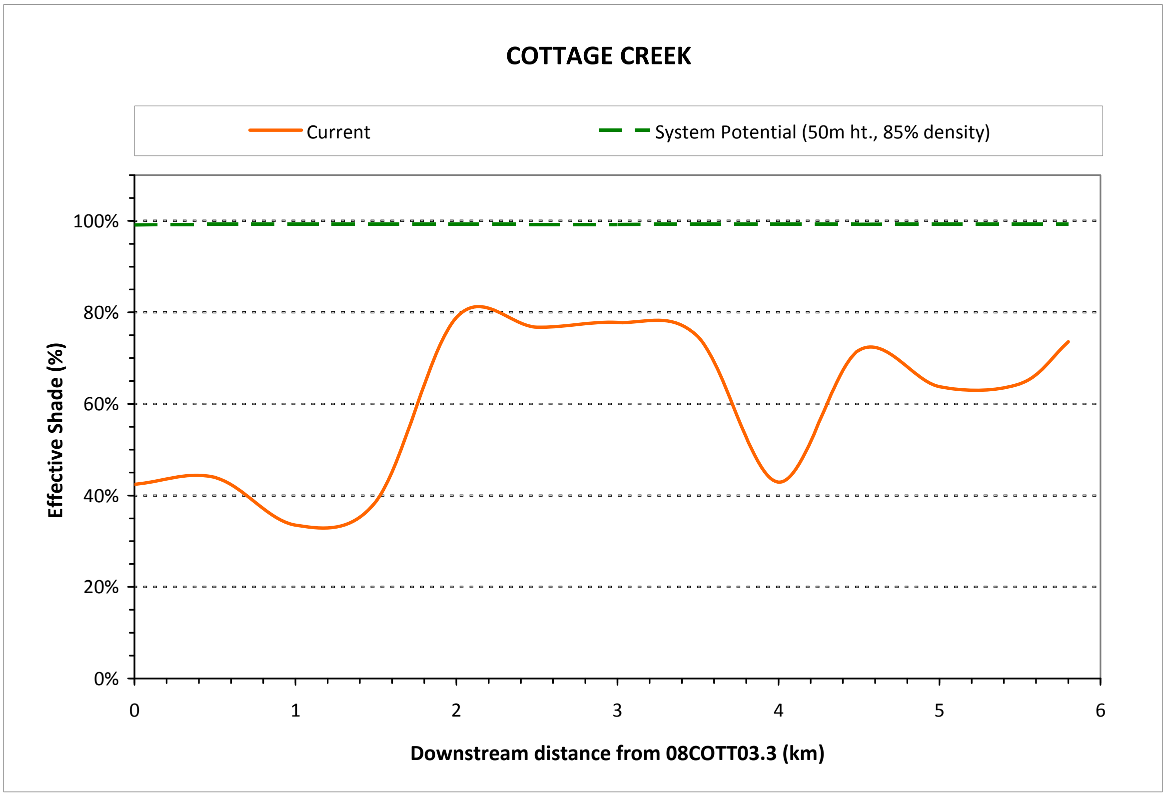

Figure 13. Current and system potential effective shade profile for Cottage Lake Creek.

Sensitivity to tree height

Since it is possible that the system potential vegetation may actually be taller than 50 meters, a sensitivity analysis was done to determine the percent difference in system potential effective shade between 50-meter and 70-meter trees planted within a 100-meter riparian buffer. This analysis was performed on Bear, Evans, and Cottage Creeks and showed a 0.70%, 1.91%, and 0.22% difference in average effective shade respectively on each creek. This magnitude of difference is insignificant in terms of effective shade and potential temperature implications. Assuming a 50-meter tree height as representative of mature vegetation is appropriate throughout the watershed.

Sensitivity to buffer width

A sensitivity analysis was also performed to see the effect of narrowing the 100-meter width used for shade analysis to 50 meters. Narrowing buffer widths made an average difference of less than 1% in system potential effective shade for Bear, Evans, and Cottage Lake Creeks (0.86%, 0.81%, 0.61%, respectively). The 100 meters was retained to provide maximum effective shade, but the insensitivity to narrower buffer widths is important for implementation purposes. Brosofske et al. (1997) found that 46 meters (150 ft) was the minimum buffer width necessary to maintain a complete, unaltered riparian microclimate environment along small western Washington streams. The shade model was not used to evaluate a buffer of less than 150 ft because of limitations in simulating the loss of other riparian functions (e.g., microclimate improvements, erosion control, and channel stability).

QUAL2Kw water quality model

Data collected during this TMDL study were used to continuously simulate temperature and DO along Bear, Evans, and Cottage Lake Creeks using the QUAL2Kw stream and river water quality model. QUAL2Kw is a one-dimensional, steady-flow numeric model capable of simulating a variety of conservative and non-conservative water quality parameters (Chapra and Pelletier, 2003).

QUAL2Kw assumes steady-state flow and hydraulics; however, the heat budget and temperature are simulated on a daily time scale with diel variations in all water quality variables. QUAL2Kw was applied by assuming that flow remains constant for a given condition such as a 7-day or 1-day period, but key variables are allowed to vary with time over the course of a day in response to changes in the heat budget and biological processes such as photosynthesis. QUAL2Kw uses the kinetic formulations for the components of the surface water heat budget that are described in Chapra (1997).

All input data for the QUAL2Kw model are longitudinally referenced, allowing spatial and/or continuous inputs to apply to certain zones or specific river segments. All three creeks were modeled in 1000-meter segments/reaches. Three model runs were developed for each creek in the following order: a calibration run, a validation run, and a 7Q10 run (to simulate worst-case critical low-flow conditions). All subsequent modeling scenarios were modifications of the 7Q10 condition.

Model calibration was accomplished using the genetic algorithm for automatic QUAL2Kw calibration. The genetic algorithm is described in more detail in Pelletier et al. (2005). During model validation, all parameter values were set to those values used for model calibration except field and weather data specific to the verification period.

Model predictions were confirmed with instream data collected in summer 2006. The goodness-of-fit for the QUAL2Kw model was summarized using the root mean squared error (RMSE) as a measure of the deviation of model-predicted values from the measured values. The RMSE represents an estimation of the overall model performance and was calculated as:

$$RMSE = \sqrt{\sum \frac{\left(T_{measured} - T_{calculated}\right)^2}{n}}$$

Model calibration

The period of the synoptic survey, July 18-19, 2006, was used as the calibration period for temperature and DO. QUAL2Kw requires an accurate characterization of hydrology, and the physics of how water moves through the system is one of the most important components of the model set up. Parameters that affected the hydrology, such as the flow balance and travel time, were therefore calibrated first, followed by temperature and DO, as described in more detail on the next page.

Hydrology parameters

The Manning equation was used to express the relationship between flow and depth as:

$$Q = \frac{S_o^{1/2}}{n} \frac{A_c^{5/3}}{P^{2/3}}$$

where Q = flow [m^3/s], S_o = bottom slope [m/m], n = the Manning's roughness coefficient, A_c = the cross-sectional area [m^2], and P = the wetted perimeter [m].

The above equation was rearranged to solve for n:

$$n = \frac{S_0^{1/2}}{Q} \frac{A_c^{5/3}}{P^{2/3}}$$

Field streamflow and cross-sectional geometry measurements provided the necessary information to derive values for S_0, A_c, Q and P. Since streamflow measurements were taken at stations distributed across the length of the stream, a linear interpolation was used to generate manning roughness coefficients for reaches in-between sampling stations. The manning roughness coefficient represents the resistance of the stream channel to the flow of water, where smaller values represent less resistance (smooth, uniform channel) and higher values represent greater resistance (rough, rocky, irregular channel).

Manning's n values ranged from 0.506-0.105 for Bear Creek, 0.057-3.580 for Evans Creek, and 0.078-0.125 for Cottage Lake Creek. Manning values for various open channel surfaces are higher than these, and range from 0.012-0.20 (Chow et al., 1988). However, these traditional values are not based on low-flow conditions and channels that have complex bottoms like those found in the Bear-Evans basin. Evans Creek has a particularly complex, slow-moving hydrology with significant wetland influences and therefore higher Manning's n values.

Stream bottom widths and side slopes, required by QUAL2Kw when using the Manning equation, were derived from the average of stream cross-sectional field measurements and corrected to reflect reach-specific conditions where needed.

Flow balances for the calibration run were developed for the time of the synoptic survey using measured headwater and tributary inflows. For those tributaries where flow measurements were not taken, flows were estimated by developing a general linear relationship between the watershed area and flow measured at that location (Figure 14). Residual flows were entered into the model as distributed diffuse groundwater inflows or outflows.

Water velocity and hydraulic routing was confirmed with results from the travel-time dye study. For Evans Creek, where the time of travel could not be determined for the upper reaches (as described earlier), model-predicted travel times were assumed to be true for the upper reaches, and calibration focused on the lower reaches where travel-time data were available.

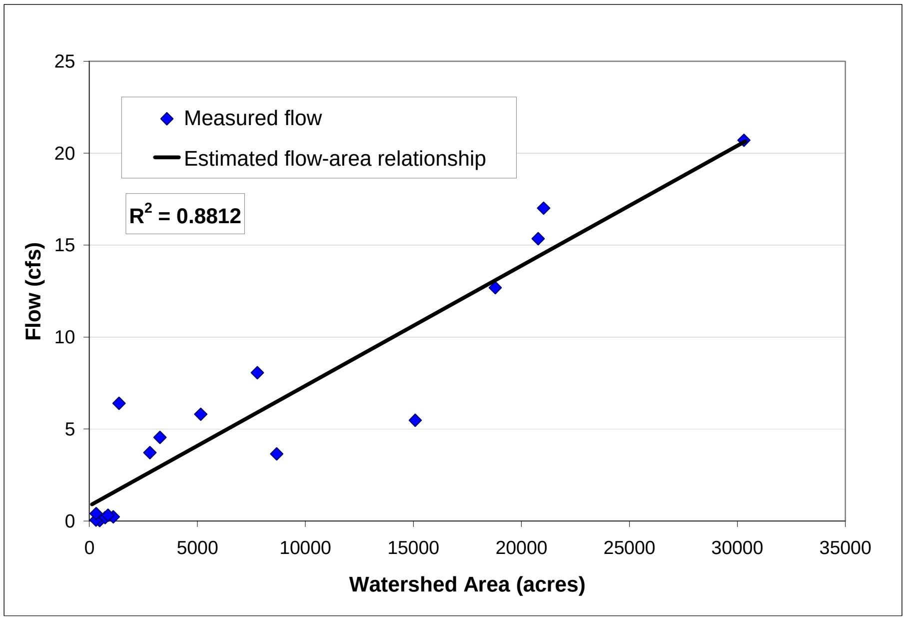

Figure 14. Linear relationship between measured flows and area drained.

Temperature parameters

In addition to the hydrology parameters described in the previous section, other parameters that affect stream temperature include effective shade (solar radiation), air temperature, cloud cover, relative humidity, and headwater temperature, as well as hydraulic, tributary, and diffuse groundwater temperatures. These were all specified or simulated as diurnally varying functions (changing over the course of a day) in QUAL2Kw using a finite difference numerical method at 1000-meter intervals along Bear, Evans, and Cottage Lake Creeks. In addition, QUAL2Kw uses light and heat parameters and surface heat transfer models that govern the temperature regime of the system being modeled.

Following are descriptions of how specific input parameters were developed:

- Headwater temperature boundary conditions were established using monitoring data from July 18 and 19, 2006, from the most upstream station on Bear and Cottage Lake Creeks, and from the second most upstream station on Evans Creek. Continuous temperature data were input as hourly values, calculated as the average hourly temperature of both days.

- Sediment thermal properties were based on literature values for mud/sand and wet sand. Values were varied from upstream to downstream for Bear and Evans Creek to reflect the change from siltier upstream reaches to sandier lower reaches.

- Hyporheic exchange flow was a calibrated parameter (values of hyporheic zone thickness, exchange flow, and sediment porosity were varied between a typical range of values). A sensitivity analysis showed little sensitivity to hyporheic parameters for all three creeks.

- Air temperature data were established from continuous air tidbit data measured in the field on July 18 and 19. Hourly values were input as the average hourly temperature of both days. For those reaches that did not have air temperature data, data from the closest monitoring station to that reach were used.

- Dewpoint temperature was established from continuous relative humidity data for July 18 and 19. Hourly values were input as the average hourly temperature of both days. For those reaches that did not have dewpoint temperature data, data from the closest monitoring station to that reach were used.

- Wind speed data were retrieved from the closest geographical weather station at Bellevue Community College (Station ID BCCW1). Hourly values were downloaded online from the Office of Washington State Climatologist and averaged for July 18 and 19.

- Cloud cover data were retrieved from the closest reliable geographical weather station, a University of Washington station located at Seattle Boeing Field (approximately 16 miles southwest of Redmond). Hourly values were available from the Office of Washington State Climatologist and averaged for July 18 and 19.

- Shade values were established by running the Shade model on July 18 and 19 using current riparian conditions. Hourly values were input as the average hourly temperature of both days.

- Tributary point source temperatures were developed from monitoring data at the mouth of tributaries where temperature was monitored. Point source temperatures in QUAL2Kw are entered as a mean, range, and time of maximum temperature.

- Direct or indirect sources of stormwater (such as stormwater outfalls or precipitation runoff) were not modeled.

Diffuse sources temperatures were initially assigned the average annual temperature (11.7°C) based on mean daily air temperatures at SeaTac Airport for 2006. Diffuse inflows/outflows were assumed to be dominated by groundwater, and groundwater temperatures are often similar to the mean annual air temperature (Theurer et al., 1984). During model calibration, groundwater temperatures were corrected, and established values were within the range of King County's ambient groundwater monitoring data in the Bear-Evans basin (for wells less than 100 ft deep). Appendix F summarizes the King County groundwater data.

Figure 15 through Figure 17 illustrate the model-predicted and observed temperatures for Bear, Evans, and Cottage Lake Creeks for July 18 and 19. The RMSE for these calibration runs can be found in Table 10.

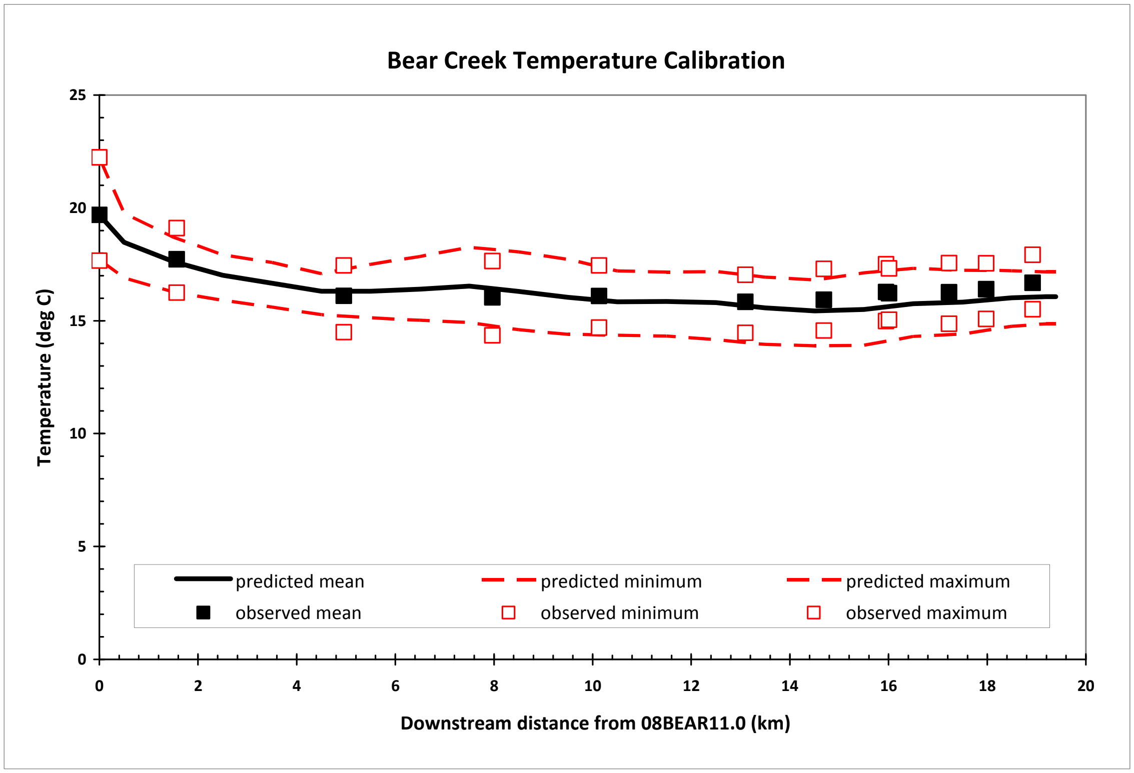

Figure 15. Comparison of predicted and observed temperatures for Bear Creek on July 18-19, 2006.

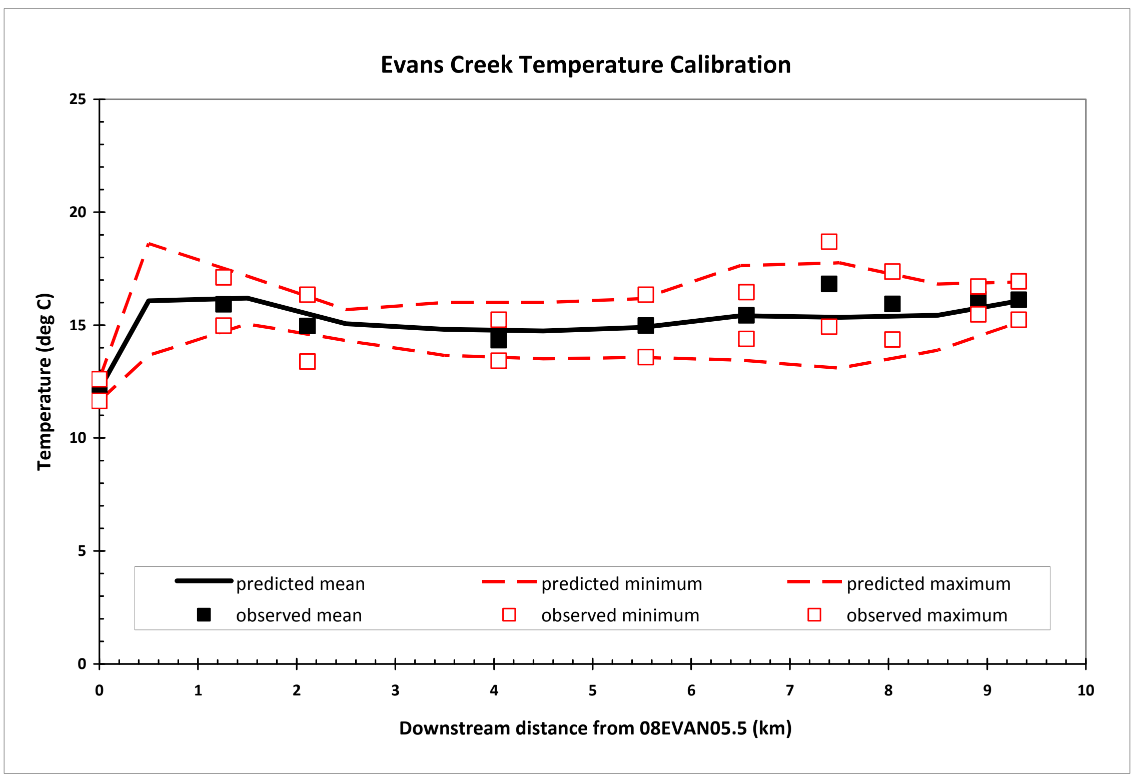

Figure 16. Comparison of predicted and observed temperatures for Evans Creek on July 18-19, 2006.

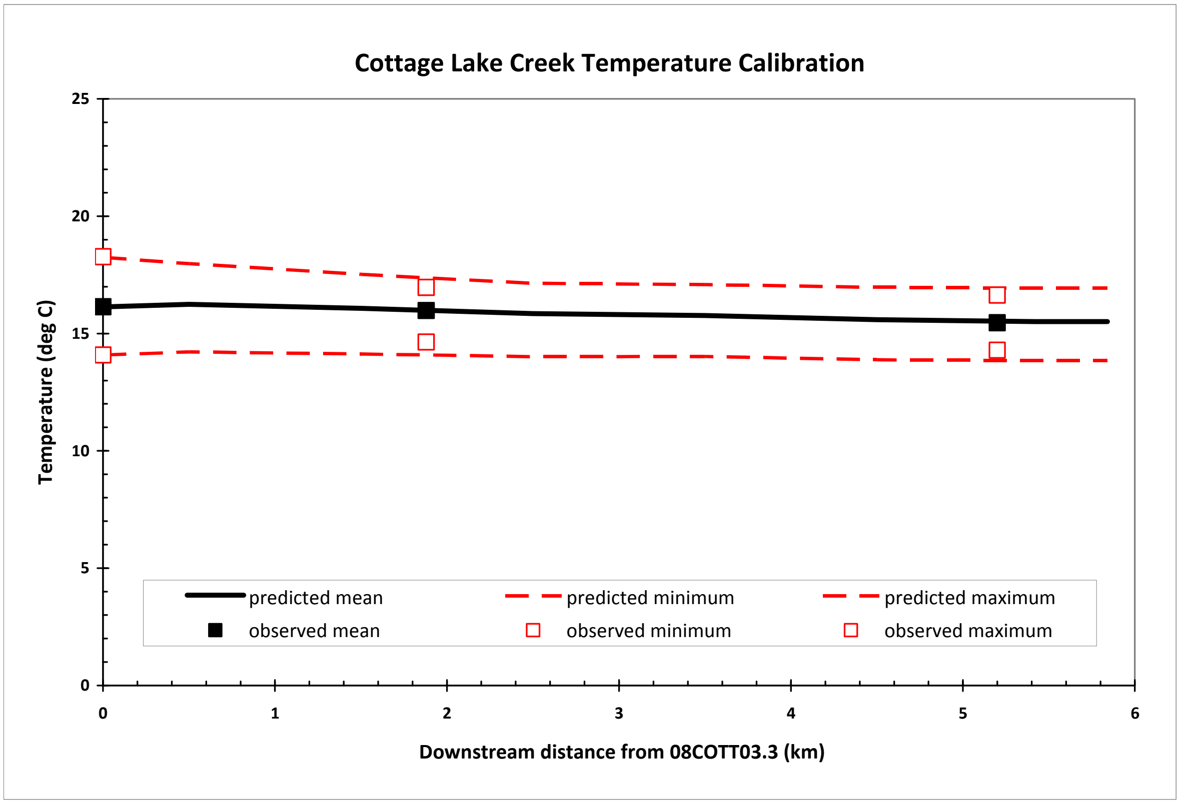

Figure 17. Comparison of predicted and observed temperatures for Cottage Lake Creek on July 18-19, 2006.

Dissolved oxygen parameters

Dissolved oxygen is produced by plant photosynthesis, and cycles within streams through different processes. It is lost due to plant respiration, oxidation of organic carbon (CBOD), ammonia (nitrification), and chemical oxygen demand (COD). Depending on whether the DO is under-saturated or over-saturated, it is gained or lost from or to the atmosphere via re-aeration (Pelletier and Chapra, 2006). A fundamental set of rates are used by QUAL2Kw to govern these chemical and biological processes.

Dissolved oxygen parameters were established for headwater and tributary point sources using data collected during the synoptic survey. For tributaries where nutrient data were not collected, measured data from a tributary of similar size, geographic, and land use characteristics were used. During calibration, these values were adjusted within the range of measured data to improve predictions and better fit measured data. Groundwater input parameters were selected from the range of measured groundwater values measured by King County’s ambient groundwater program for the Bear-Evans basin.

In addition, the rates that govern chemical and biological processes were auto-calibrated using several iterations of the genetic algorithm for QUAL2Kw. The genetic algorithm selects a random set of rates, and then varies these rates within the range of known literature values in order to optimize the goodness-of-fit between predicted and observed values. The final set of rates generated for Bear, Evans, and Cottage Lake Creeks can be found in Appendix G.

Figure 18 through Figure 20 illustrate model-predicted and observed DO values for Bear, Evans, and Cottage Lake Creeks for July 18 and 19. The RMSE for these calibration runs can be found in Table 10.

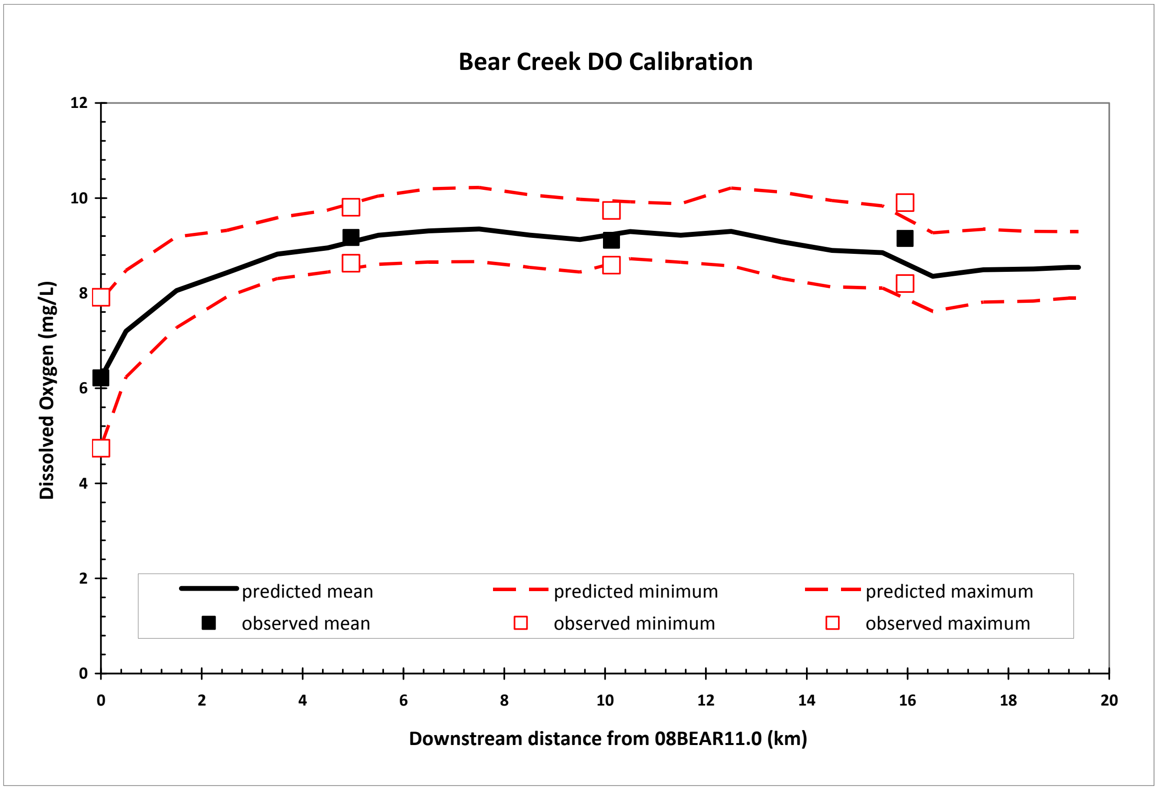

Figure 18. Comparison of predicted and observed DO for Bear Creek on July 18-19, 2006.

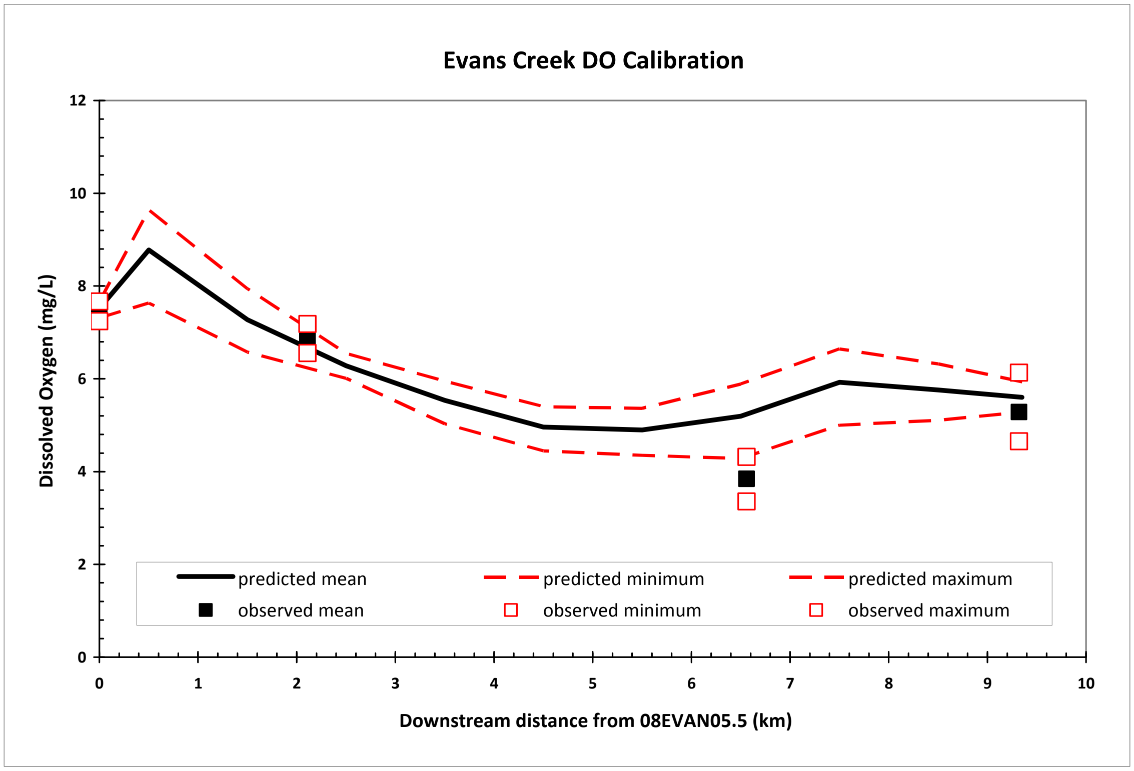

Figure 19. Comparison of predicted and observed DO for Evans Creek on July 18-19, 2006.

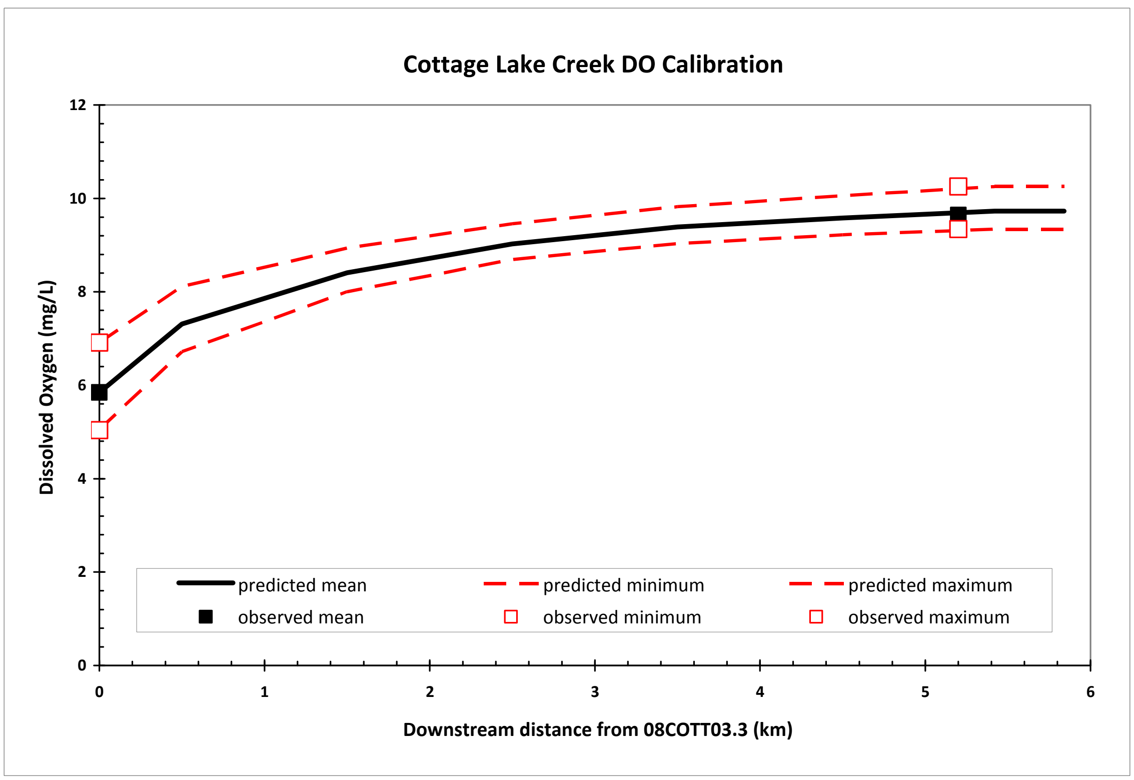

Figure 20. Comparison of predicted and observed DO for Cottage Lake Creek on July 18-19, 2006.

Model validation

The hottest 7-day period of 2006, July 21-27, was used as the validation period for the QUAL2Kw temperature model. The DO component of the model could not be validated to another time period since data were limited to a single synoptic survey.

In order to confirm the hydraulic variables defined in the calibration run, only those variables that changed with time were changed. This included headwater and tributary temperatures, air and dewpoint point temperature, wind speed, cloud cover, and shade. All variables were input as the 7-day average of hourly values using data for the seven days from July 21-27.

The distribution of flows throughout the watershed were based on regression equations between King County gage stations measurements and instantaneous flow measurements recorded during the synoptic survey.

Figure 21 through Figure 23 illustrate the model predicted and observed temperatures for Bear, Evans, and Cottage Lake Creeks for July 21-27. The RMSE for these calibration runs can be found in Table 10. Both calibration and validation model runs show a tendency of the model to slightly under-predict temperatures in the downstream portions of Bear and Evans Creeks (when compared to observed data).

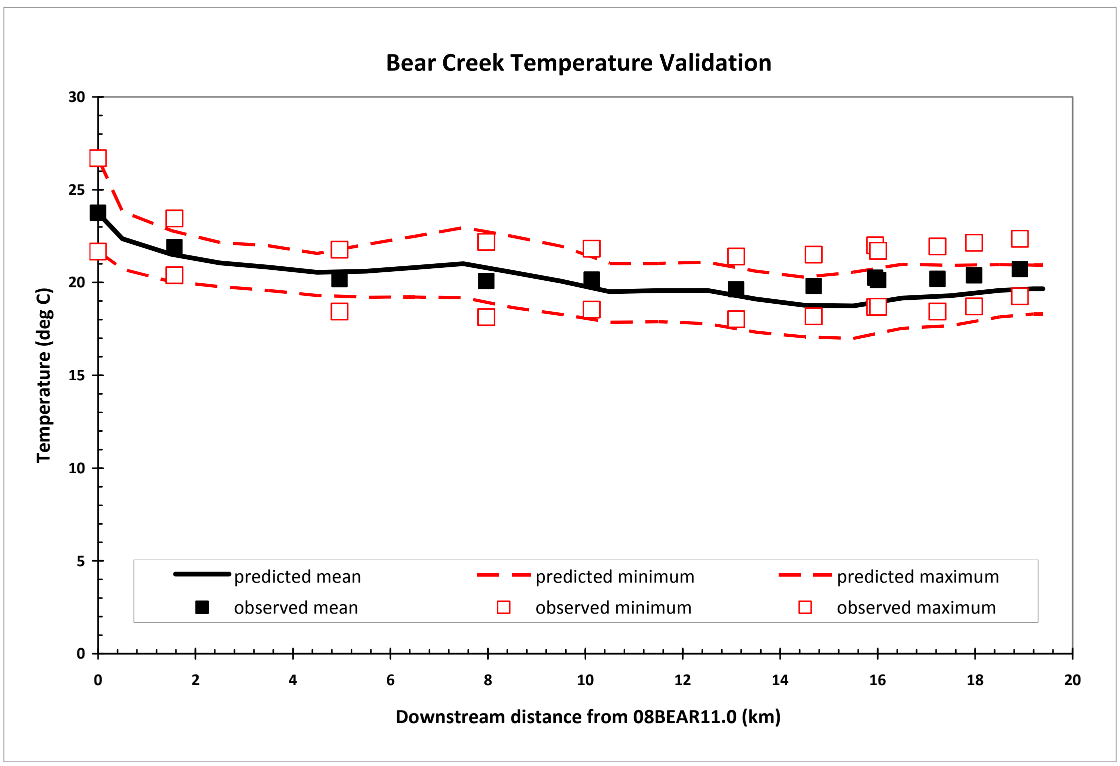

Figure 21. Comparison of predicted and observed temperatures for Bear Creek on July 21-27, 2006.

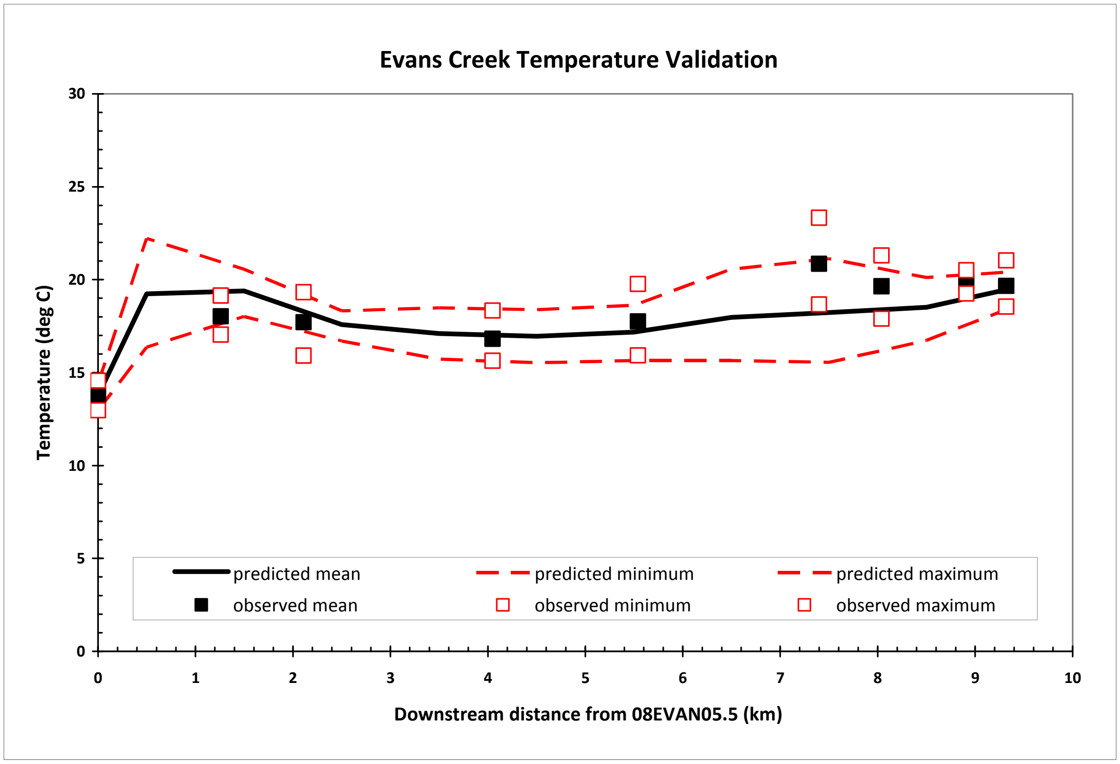

Figure 22. Comparison of predicted and observed temperatures for Evans Creek on July 21-27, 2006.

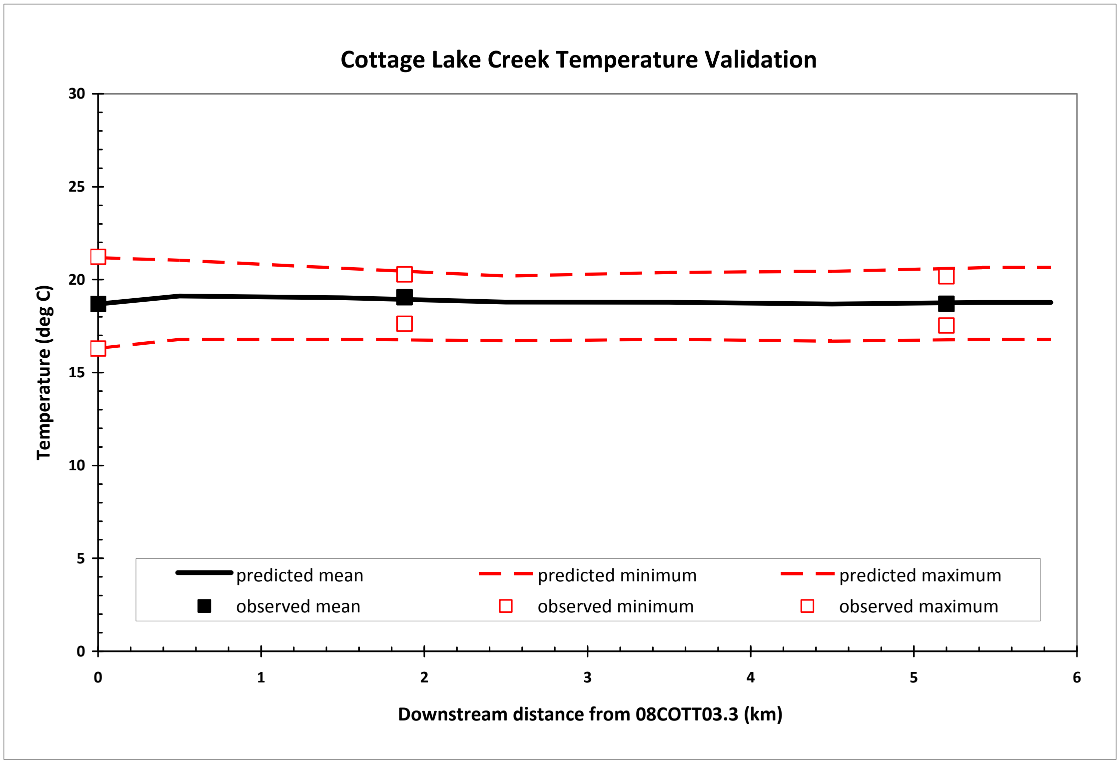

Figure 23. Comparison of predicted and observed temperatures for Cottage Lake Creek on July 21-27, 2006.

Table 10. Summary of root mean square error (RMSE) of difference between predicted and observed temperature and DO from calibration and validation runs.

	Bear Creek	Evans Creek	Cottage Lake Creek
Temperature Calibration			
RMSE of Min & Max	0.59 °C	0.67 °C	0.53 °C
RMSE of Max	0.41 °C	0.59 °C	0.67 °C
RMSE of Min	0.74 °C	0.75 °C	0.33 °C
Temperature Validation			
RMSE of Min & Max	0.98 °C	0.73 °C	0.63 °C
RMSE of Max	0.99 °C	0.93 °C	0.40 °C
RMSE of Min	0.96 °C	0.73 °C	0.79 °C
Dissolved Oxygen Calibration			
RMSE of Min & Max	0.13 mg/L	0.86 mg/L	0.001 mg/L
RMSE of Max	0.12 mg/L	0.99 mg/L	0.001 mg/L
RMSE of Min	0.15 mg/L	0.72 mg/L	0.001 mg/L

Loading capacity

The loading capacity provides a reference for calculating the amount of pollutant reduction needed to bring water into compliance with standards. EPA's current regulation defines loading capacity as "the greatest amount of loading that a water body can receive without violating water quality standards" (40 CFR § 130.2(f)). Loading capacities for temperature and DO in the Bear-Evans watershed are expressed as solar radiation heat loads based on system potential vegetation.

Temperature

The system potential temperature is an estimate of the temperature that would occur under natural conditions. The system potential temperature is estimated using analytical methods and computer simulations proven effective in modeling and predicting stream temperatures in Washington. The system potential temperature is based on our best estimates of the mature riparian vegetation, riparian microclimate, and natural baseflows.

The system potential temperature does not replace the numeric criteria. It also does not invalidate the need to meet the numeric criteria at other times of the year and at other less extreme low flows and warm climatic conditions.

In this study, a system potential temperature was estimated for a critical condition year (upper 90th percentile air temperature and low flows that occur once every ten years) identified as the 7Q10 condition. This can be considered the 'worst-case scenario'. The 7Q10 condition was simulated with cloud cover and wind speeds set to zero, and 7Q10 flows and air temperatures calculated from King County's historical monitoring data from stations within the Bear-Evans watershed. These records dated as far back as 1987 for flows and 1994 for air temperature.

The calibrated QUAL2Kw model was used to determine the loading capacity for effective shade for mainstem Bear, Evans, and Cottage Lake Creeks. Loading capacity was determined based on prediction of water temperatures under 7Q10 flow and climate conditions combined with the implementation of effective shade conditions.

The following scenarios for effective shade were evaluated for the 7Q10 flow and climate condition:

- **Current shade.** The effective shade produced by the current riparian vegetation condition.
- **Maximum potential shade.** Effective shade from system potential maximum mature riparian vegetation that would naturally occur in the Bear-Evans watershed. Mature vegetation was represented by height and densities and by a riparian vegetation width of 100 meters on each side of the stream. In this scenario, tributaries were assumed to be well shaded and meeting temperature standards at the point where they discharge in to the mainstem of the creeks.

The following additional scenarios were also evaluated to test the sensitivity of predicted water temperatures to other variables relevant to the watershed. Though load allocations are not based on the result of these scenarios, they provide additional information about the system and indicate other important factors that affect stream temperature.

- **Microclimate improvements.** Increases in vegetation height, density, and riparian zone width are expected to result in localized decreases in air temperature. In order to evaluate the effect of this potential change in microclimate on water temperature, the daily maximum air temperature was reduced by 2°C based on the summary of literature presented by Bartholow (2000).
- **Reduced channel width.** Channel banks are expected to stabilize and become more resistant to erosion as the riparian vegetation along the stream matures. The sensitivity of predicted stream temperatures to reduction of channel width was tested by predicting stream temperatures that would occur if channel width were reduced by 10%. The effect of a 10% reduction in channel widths resulted in less than a 1.5% difference in predicted stream temperatures in all three creeks. Because of this small magnitude of difference, the results of this scenario are not explicitly presented.
- **Reduced headwater and tributary temperatures.** Three scenarios were evaluated with the assumption that (1) tributaries, (2) headwaters and (3) both headwaters and tributaries were in compliance with the 16°C water quality standard (such as in Evans Creek where headwater and tributary temperatures were below 16°C). Cottage Lake Creek was modeled below its confluence with its two tributaries (Cold and Daniels Creeks), so no tributary inflows were modeled for Cottage Lake Creek.
- **Increased baseflows.** Scenarios were evaluated based on a King County streamflow analysis study (Hartley, 2001). The study evaluated the magnitude of baseflow losses in WRIA 8 as a result of (1) recharge loss due to increases in effective impervious area (EIA), and (2) water management activities (e.g., groundwater extraction). A more detailed explanation of this scenario is described on the next page.

The current 7Q10 critical condition in Bear, Evans, and Cottage Lake Creeks results in daily maximum water temperatures that are warmer than 16°C in all of the evaluated reaches for all three creeks (except for the headwaters of Evans Creek which are below 16°C). Some portions of the creeks are also above the 22°C threshold for lethality, as defined by the following excerpt from WAC 173-201A-200(1)(c)(vii)(A) and an Ecology study (Hicks, 2002) that evaluates lethal temperatures for coldwater fish:

"*For evaluating the effects of discrete human actions, a 7-day average of the daily maximum temperatures greater than 22°C or a 1-day maximum greater than 23°C should be considered lethal to cold water fish species such as salmonids. Barriers to migration should be assumed to exist anytime daily maximum water temperatures are greater than 22°C and the adjacent down-stream water temperatures are 3°C or more cooler.*"

In addition, temperatures below the 22°C lethal value but above the 16°C standard impact other salmonid life stages and these impacts vary between different salmonid species (EPA, 2003).

Effect of Increased Baseflows on Temperature

The purpose of running baseflow scenarios was to gain an understanding of hypothetical natural conditions in the Bear-Evans basin and to compare them to current conditions. The baseflow scenarios provide a hypothetical understanding of potential temperature improvements if there were no baseflow losses. Having this hypothetical scenario allows an informed exploration of other ways to mitigate the effects of baseflow losses due to water management activities. The intent of this analysis is not to provide a basis for the regulation of water rights.

Summer baseflows, when precipitation events are limited, are largely driven by groundwater. A historical review of streamflow data near the mouth of Evans Creek shows a drop in the 7-day average July and August baseflows between 1955-1969 and 1988-2005 (Figure 24). Summer precipitation, as measured at SeaTac Airport, averaged 0.03 inches for both these periods, suggesting that other factors besides precipitation are potentially responsible for the observed reduce baseflows.

Reduced baseflows can be a result of expanding impervious areas[3] and water extraction and consumptive use (e.g., groundwater withdrawals). Baseflow losses from these two causes for WRIA 8 streams were estimated by Hartley (2001) in a streamflow analysis study. Estimates from this study for the Bear-Evans Creeks are summarized in Table 11. This analysis did not include illegal withdrawals and exempt well usage.

[3] Impervious areas reduce infiltration when it rains, and therefore less groundwater is available for stream recharge in the summer.

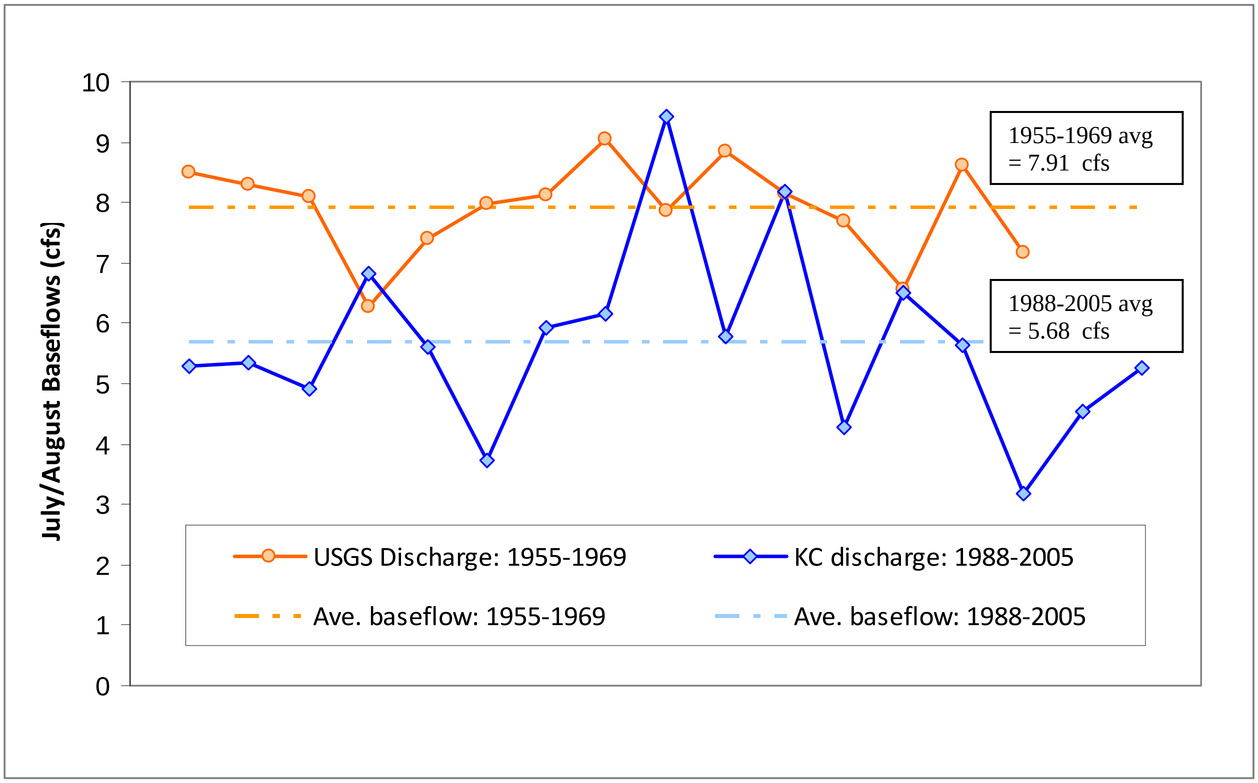

Figure 24. Comparison of 7-day average historical and current July and August baseflows near the mouth of Evans Creek based on historical USGS gage data (station #12124000) and current King County gage data (station 18a).

Table 11. Estimated baseflow losses as a result of effective impervious area (EIA) and water management activities (Hartley, 2001).

Baseflow Losses	Sub-Basin		
	Bear Creek (near mouth)	Evans Creek	Cottage Lake Creek
Baseflow loss due to EIA			
reported value (cfs)	3.7	1.0	1.1
reported value (m^3/s)	0.1057	0.0294	0.0305
conservative estimate: 50% reported value (m^3/s)	0.0529	0.0147	0.0152
Baseflow loss due to water management			
reported value (cfs)	8.9	5.9	no loss
reported value (m^3/s)	0.2522	0.1678	--
conservative estimate: 50% reported value (m^3/s)	0.1261	0.0839	--
Net baseflow loss			
reported value (cfs)	12.6	7.0	1.1
reported value (m^3/s)	0.3579	0.1972	0.0305
conservative estimate: 50% reported value (m^3/s)	0.1790	0.0986	0.0152

The LANDSAT analysis used to derive percent EIA was performed at a large scale for the whole of WRIA 8, and is subject to inaccuracies. Baseflow losses due to water management are based on assumptions made by Hartley (2001) including: (1) water that is pumped is assumed to be 100% hydraulically connected to streamflow at the outlet of each sub-basin and (2) effect of pumping on flow occurs without any seasonal lag over the summer period for which baseflow reductions are estimated. Both these assumptions might lead to a potential overestimation of baseflow losses, but the magnitude of overestimation remains uncertain. For the purpose of analysis, the reported baseflow losses were used as a "high-end" estimate. A more conservative "low-end" estimate was also calculated as 50% of the reported baseflow losses.

Several scenarios were run to determine the effect of increased baseflows on temperature. Essentially, the scenarios were run to answer the following question: *What temperature improvements are predicted if baseflow was not being lost/reduced due to EIA and/or water management activities?* The magnitude of baseflow improvement was determined by converting both the reported baseflow losses as well as 50% of the reported value in Table 11 into diffuse groundwater inflows distributed equally throughout the length of each creek.

Thus, predicted temperature values in Figure 27 are presented as a range of possible temperature improvements: (1) a high-end estimate predicted by returning all the lost baseflow back into the stream and (2) a low-end conservative estimate that provides a buffer for the assumptions made by Hartley (2001). As Figure 27 illustrates, there is an overlap in the range of temperature improvements predicted if there was no baseflow loss due to water management and no net baseflow loss due to EIA and water management.

Limitations of baseflow loss scenario

- Baseflow loss due to water management activities did not include exempt well usage and illegal withdrawals. The magnitude of potential impacts due to these other factors remains unknown.

- The 50 percent conservative values of Hartley's (2001) baseflow estimates may or may not be an accurate assumption of actual baseflow loss, but were used to account for assumptions made that would overestimate baseflow losses.

Temperature improvements

Reductions in water temperature are predicted for the different hypothetical scenarios described above and presented in Figure 25 through Figure 27 and summarized in Table 12 through Table 14.

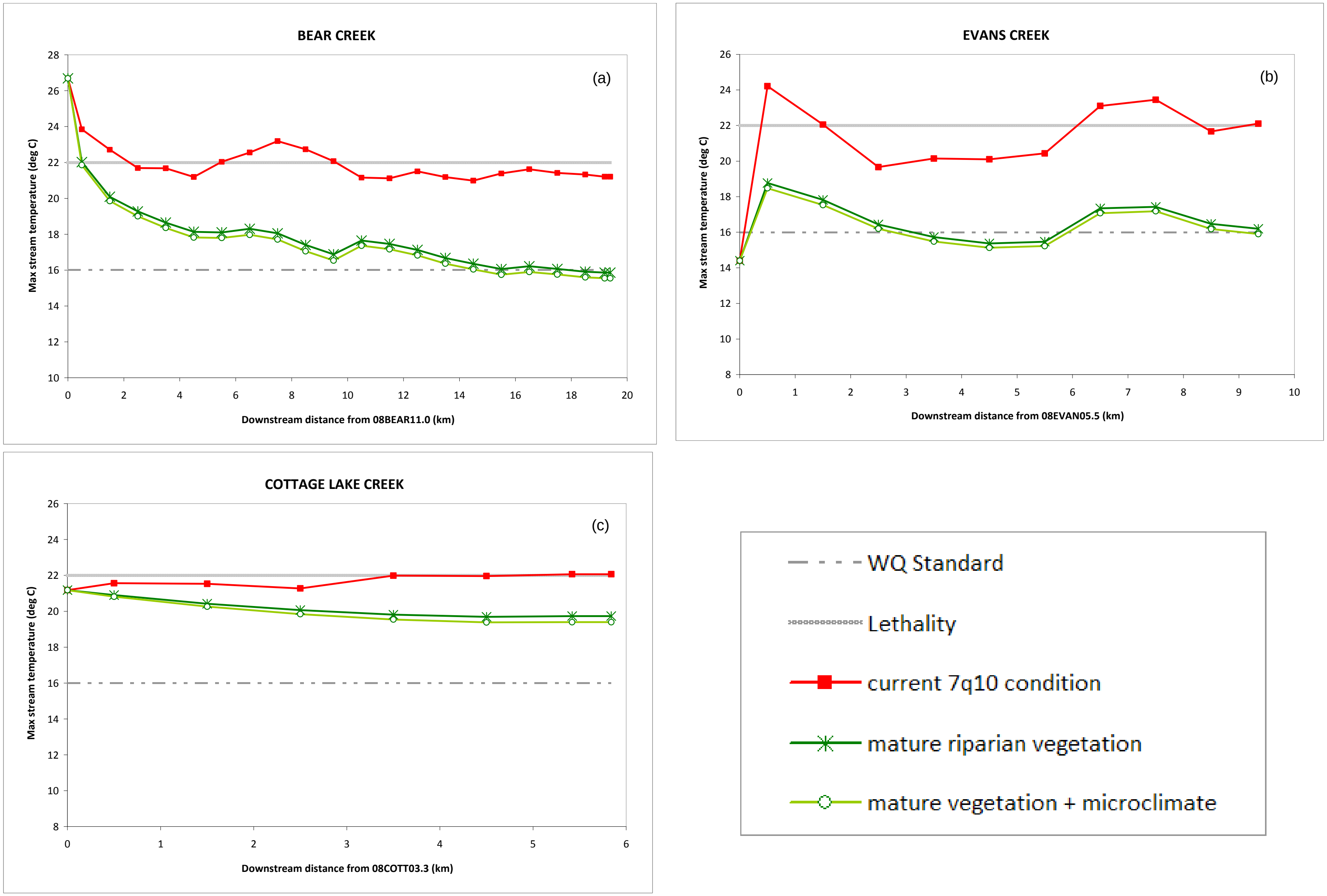

Figure 25. Maximum predicted stream temperatures in Bear, Evans, and Cottage Lake Creeks with mature riparian vegetation and microclimate improvements for a critical summer condition.

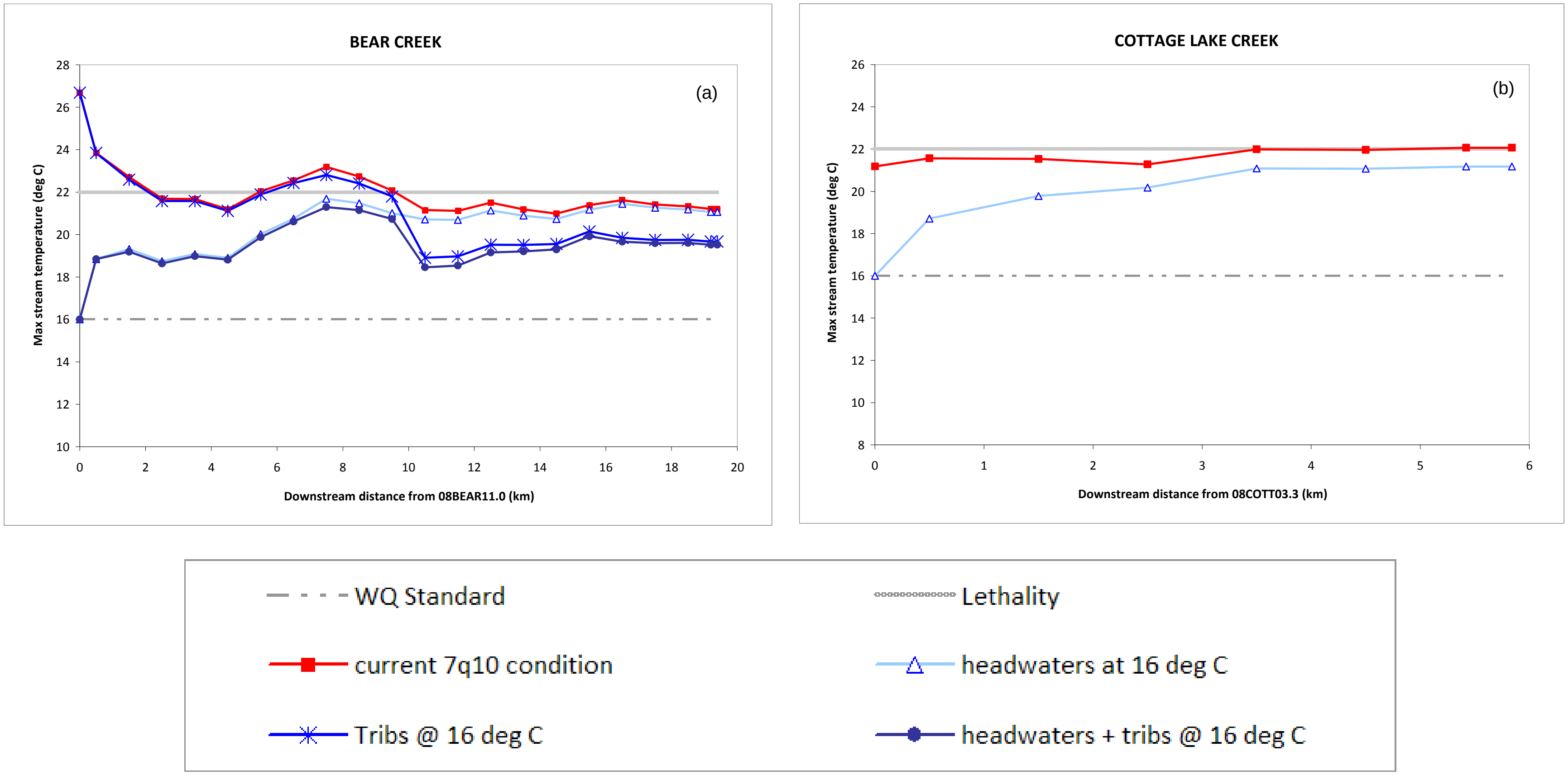

Figure 26. Maximum predicted stream temperatures in Bear and Cottage Lake Creeks with headwaters and/or tributaries set to 16°C for a critical summer condition.

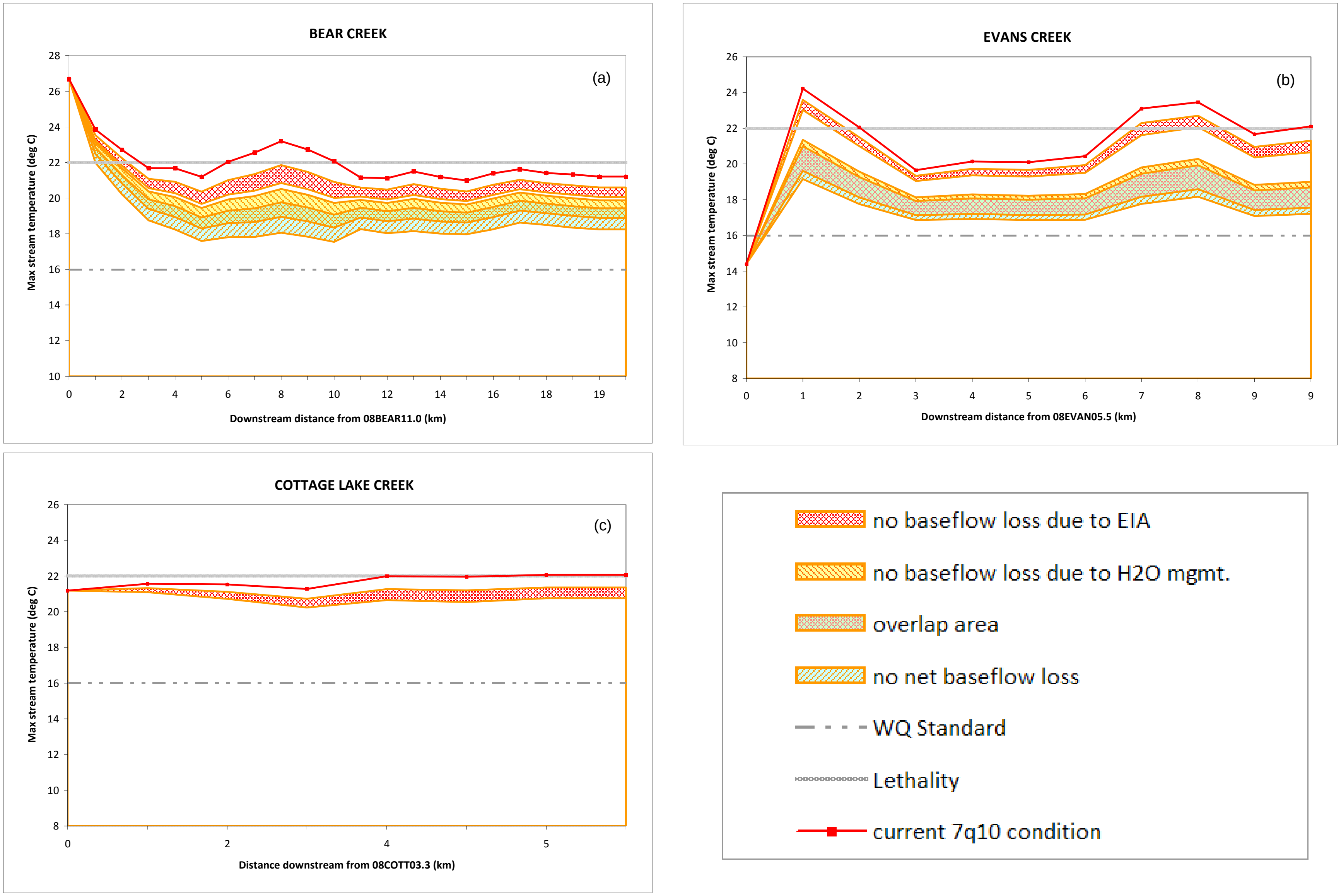

Figure 27. Range of maximum predicted stream temperatures in Bear, Evans, and Cottage Lake Creeks if there were no baseflow losses due to EIA and water management under critical conditions (range represents response to reported and conservative estimates).

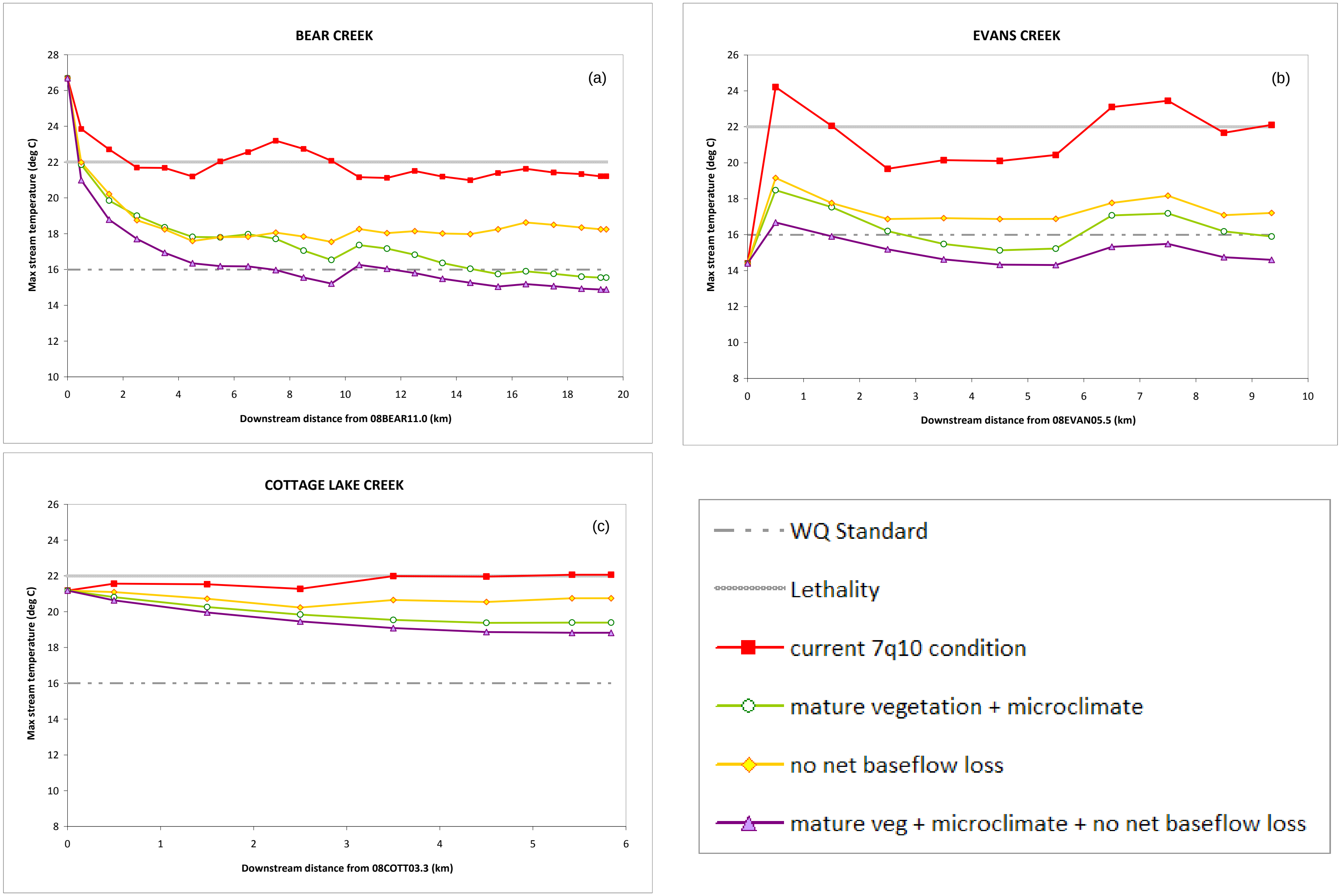

Figure 28. Maximum predicted stream temperatures in Bear, Evans, and Cottage Lake Creeks with implementation of mature vegetation and microclimate improvements combined with no net baseflow losses (conservative estimate).

Table 12. Predicted decreases in average and maximum temperatures with the implementation of mature riparian vegetation and microclimate improvements in Bear, Evans, and Cottage Lake Creeks for 7Q10 conditions.

Mature Riparian Vegetation Scenarios	T_{avg}	T_{max}*	ΔT_{max}**	Portion of stream length in compliance with 16°C WQ Std.	
	(°C)	(°C)	(°C)		
Bear Creek					
current conditions	22.0	23.2		--	--
mature riparian vegetation	17.9	18.3	4.9	1.2 km	6%
mature veg + microclimate	17.7	18.0	5.2	4.8 km	25%
Evans Creek					
current conditions	21.1	24.2		0.1 km	1%
mature riparian vegetation	16.5	18.8	5.4	2.8 km	30%
mature veg + microclimate	16.2	18.5	5.7	3.9 km	42%
Cottage Lake Creek					
current conditions	21.7	22.1		--	--
mature riparian vegetation	20.2	19.7	2.4	--	--
mature veg + microclimate	20.0	19.4	2.7	--	--

* For Bear Creek, this is the maximum temperature predicted at a distance of 4.5 km or greater from the headwaters.
For Evans Creek, this is the maximum temperature predicted at any point downstream of the headwaters.
For Cottage Lake Creek, this is the maximum temperature predicted at the mouth.

** Change from current T_{max}

Table 13. Predicted decreases in average and maximum temperatures under improved baseflow scenarios in Bear, Evans, and Cottage Lake Creeks for 7Q10 conditions.

Increase Baseflow Scenarios	T_{avg} (°C)	T_{max}* (°C)	ΔT_{max}** (°C)	Portion of stream length in compliance with 16°C WQ Std.	
Bear Creek					
current conditions	22.0	23.2		--	--
Conservative baseflow gain, 50% low-end estimate					
no baseflow loss due to EIA	21.3	21.9	1.3	--	--
no baseflow loss due to water management	21.0	20.5	2.7	--	--
no net baseflow loss	20.0	19.9	3.3	--	--
Full baseflow gain, high-end estimate					
no baseflow loss due to EIA	20.7	20.8	2.3	--	--
no baseflow loss due to water management	19.4	19.3	3.9	--	--
no net baseflow loss	18.8	18.6	4.6	--	--
Evans Creek					
current conditions	21.1	24.2		0.1 km	1%
Conservative baseflow gain, 50% low-end estimate					
no baseflow loss due to EIA	20.5	23.6	0.6	0.1 km	1%
no baseflow loss due to water management	18.8	21.4	2.8	0.1 km	1%
no net baseflow loss	18.5	21.0	3.2	0.1 km	1%
Full baseflow gain, high-end estimate					
no baseflow loss due to EIA	20.0	23.0	1.2	0.1 km	1%
no baseflow loss due to water management	17.5	19.6	4.6	0.15 km	2%
no net baseflow loss	17.2	19.2	5.1	0.18 km	2%
Cottage Lake Creek					
current conditions	21.7	22.1		--	--
Conservative baseflow gain, 50% low-end estimate					
no baseflow loss due to EIA	21.2	21.4	0.7	--	--
Full baseflow gain, high-end estimate					
no baseflow loss due to EIA	20.7	21.2	0.9		

* For Bear Creek, this is the maximum temperature predicted at a distance of 4.5 km or greater from the headwaters.
For Evans Creek, this is the maximum temperature predicted at any point downstream of the headwaters.
For Cottage Lake Creek, this is the maximum temperature predicted at the mouth.

** Change from current T_{max}

Table 14. Predicted decreases in average and maximum temperatures with the combined effect of mature riparian vegetation, microclimate improvements, and higher baseflow in Bear, Evans, and Cottage Lake Creeks for 7Q10 conditions (based on conservative baseflow losses).

Combined Temperature Scenarios	T_{avg}	T_{max}*	ΔT_{max}**	Portion of stream length in compliance with 16°C WQ Std.	
	(°C)	(°C)	(°C)		
Bear Creek					
current conditions	22.0	23.2		--	--
mature veg + microclimate + no net baseflow loss	16.6	16.3	6.9	10.8 km	56%
Evans Creek					
current conditions	21.1	24.2		0.1 km	1%
mature veg + microclimate + no net baseflow loss	15.1	16.7	7.5	8.1 km	87%
Cottage Lake Creek					
current conditions	21.7	22.1		--	--
mature veg + microclimate + no net baseflow loss	19.6	18.3	3.8	--	--

* For Bear Creek, this is the maximum temperature predicted at a distance of 4.5 km or greater from the headwaters.
For Evans Creek, this is the maximum temperature predicted at any point downstream of the headwaters.
For Cottage Lake Creek, this is the maximum temperature predicted at the mouth.

** Change from current T_{max}

Bear Creek

Figures 25a, 26a, 27a, and 28a present the results of the different temperature modeling scenarios for Bear Creek. Significant temperature reductions are predicted with system potential mature riparian vegetation, improvements in riparian microclimate, and increases in baseflow. Increases in effective shade from mature riparian vegetation have the potential to decrease water temperatures across all reaches, and bring the lower reaches into compliance with the 16°C water quality standard with the additional microclimate improvement (Figure 25a). Potential reduced maximum temperatures under critical conditions are predicted to be greater than the 16°C numeric standard in upper Bear Creek, but below the lethal limit for salmonids.

Though Bear Creek's headwaters are naturally warm due to the influence of the lake upstream, Figure 26a illustrates that even if headwaters temperatures were at 16°C, significant warming does occur downstream as heat from solar radiation is absorbed.

Evans Creek

Figures 25b, 27b, and 28b present the results of the different temperature modeling scenarios for Evans Creek. Significant temperature reductions are predicted with mature riparian vegetation, improvements in riparian microclimate, and increases in baseflow. Increases in effective shade from mature riparian vegetation have the potential to significantly decrease water temperatures across all reaches, and bring the middle reaches into compliance with the 16°C water quality standard with the additional microclimate improvement (Figure 25b).

The wetlands in Evans Creek are potentially natural heat sources to the system, especially where open water increases the surface area exposed to solar radiation, and subsequently, the amount of heat absorbed. This heat can then get transported to downstream reaches. Figure 29 illustrates the current 7Q10 maximum temperature predictions in Evans Creeks superimposed on wetland areas along the length of the creek. Cold headwaters warm quickly as Evans Creek flows through a wetland, after which it cools again 1 km – 3 km downstream, largely influenced by cooler groundwater and tributary inflows. Gradual warming occurs again downstream as Evans Creek flows through another area of wetlands and makes its way to the confluence with Bear Creek.

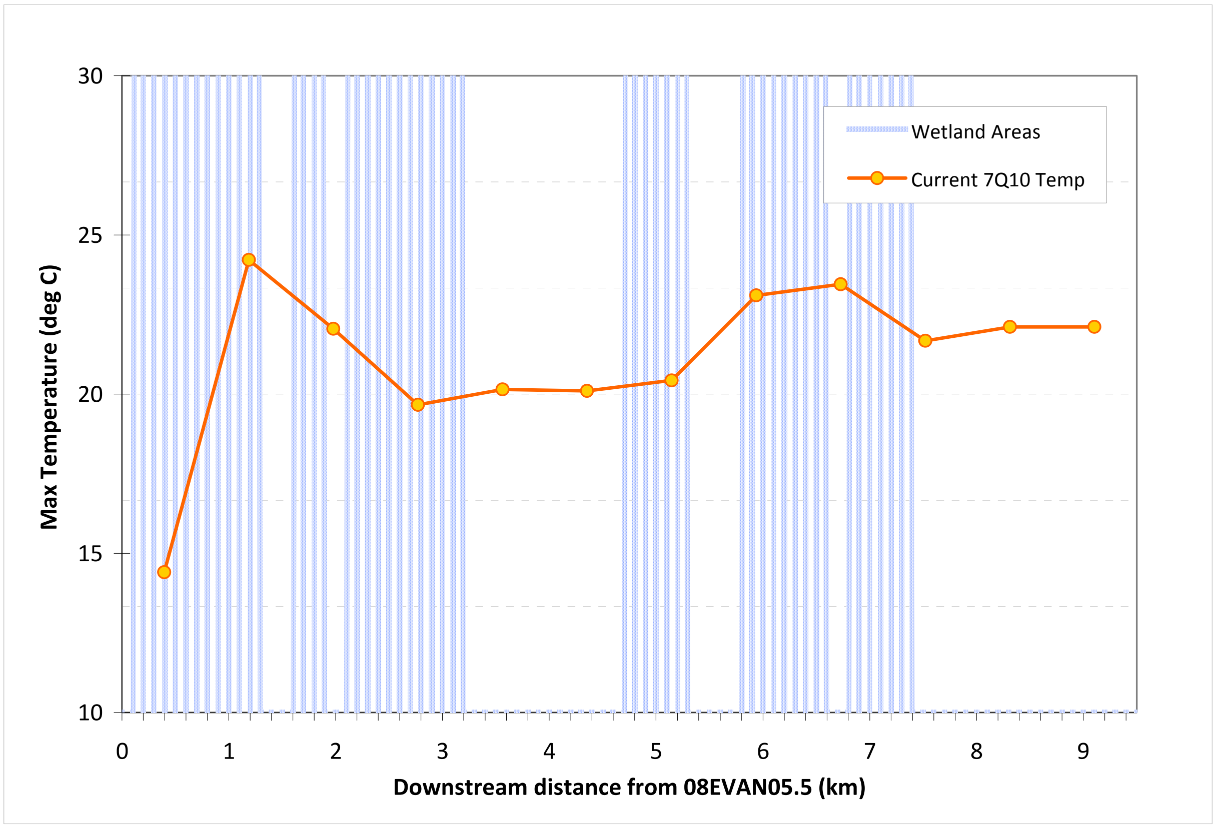

Figure 29. Maximum temperature profile of Evans Creek highlighting wetland areas that are within 150 feet of the stream.

Cottage Lake Creek

Figures 25c, 26b, 27c, and 28c present the results of the different temperature modeling scenarios for Cottage Lake Creek. Cottage Lake Creek has relatively stable water temperatures, which are likely influenced by the temperature of Cottage Lake at the headwaters of the creek. Significant temperature reductions are predicted with mature riparian vegetation and improvements in riparian microclimate. However, maximum potential temperature reductions do not bring water temperatures into compliance with the 16°C standard at any point. The natural influence of Cottage Lake could be contributing to warm temperatures in Cottage Lake Creek.

Summary of Temperature Improvements

Daily maximum stream temperature reductions of 5.2°C, 5.7°C, and 2.7°C are predicted for Bear, Evans, and Cottage Lake Creeks (respectively) with the implementation of mature riparian vegetation within a 100-meter riparian buffer and with additional microclimate improvements. A sensitivity analysis showed that the implementation of reducing the 100-meter buffer to 50 meters resulted in less than a 0.1°C increase in stream temperatures in all three creeks.

While riparian vegetation does reduce the rate of heating in the stream, it does not directly cool streamflow. Mature riparian vegetation can block solar radiation and prevent solar heating of the stream substrate and surrounding shallow soil, creating a cool zone through which streams may flow and lose heat to the surrounding cooler stream bottom and stream bank. Riparian vegetation can also create a cool microclimate which can absorb heat from the stream. Groundwater inflows, however, may directly cool surface water temperatures and result in downstream temperatures that are lower than upstream temperatures if the groundwater temperature is lower the stream temperature, and the rate of groundwater inflow is sufficiently large enough to affect stream flow.

The increase baseflow scenarios show that additional temperature reductions can potentially be achieved through enhanced groundwater inflows. Improving baseflows which could increase cool groundwater inflows can mitigate reduced shade and downstream impacts. A combined approach is needed to effectively reduce stream temperatures through planting of shading riparian vegetation and increasing cooler groundwater baseflows.

Though baseflow loss due to water management activities (e.g., groundwater pumping) cannot be changed due to existing water rights, the baseflow scenarios allow us to explore ways to mitigate these effects through other means. Examples are using alternatives to potable water uses such as reclaimed water use where technically feasible and socially acceptable, enforcement on illegal withdrawals, and water conservation among exempt well users. In addition, management options such as Low Impact Development (LID) and reducing impervious areas in new development and redevelopment could mitigate the impacts of baseflow loss due to EIA.

The warm headwater conditions of Bear and Cottage Lake Creeks, which originate as lake outflows, as well as the wetland influences in Evans Creek are all sources of natural warming to the system, which result in system potential temperatures greater than the numeric criteria. Therefore, a comprehensive approach to increase riparian shade, modify channel conditions, and enhance cool groundwater inflow should be implemented for those reaches of the stream where the improvements would reduce stream temperatures and enhance conditions for coldwater aquatic life and non-aquatic life uses in the Bear-Evans basin.

Dissolved oxygen

DO is largely governed by the amount of primary productivity such as algal growth. Productivity is often limited by a single nutrient (either nitrogen or phosphorus), and if more of that nutrient is available, productivity and respiration increase and DO concentrations subsequently decrease. Nutrient loads are usually adjusted to determine the loading capacity and nutrient reductions needed for compliance with DO standards. Direct discharge of biological oxygen demand (BOD) is also a source that is controlled in DO TMDLs. However, DO models for the Bear-Evans basins showed insensitivity to changes in nutrient conditions, and nutrient reductions did not result in significant DO improvements.

Table 15 below summarizes the average change in DO predictions between current 7Q10 conditions and a reduction in nutrient loads of 50 percent and 80 percent (at the headwaters and in point and diffuse sources). Values are expressed as a percent and an mg/L change in DO concentration.

Table 15. Average change in dissolved oxygen model predictions from current conditions with a 50% and 80% reduction in nitrate and phosphorus loads.

Nitrogen and phosphorus load reduction	Average change in DO model predictions relative to current 7Q10 conditions					
	Bear Creek		Evans Creek		Cottage Lake Creek	
50%	0.94%	0.07 mg/L	0.20%	0.01 mg/L	0.57%	0.04 mg/L
80%	1.77%	0.13 mg/L	0.96%	0.06 mg/L	1.50%	0.12 mg/L

An 80% reduction in nutrient loads resulted in (1) DO concentrations still below the 9.5 mg/L water quality numeric criteria and (2) nutrient concentrations below the natural or baseline nutrient concentrations[4].

According to WAC 173-201-A-200, if the natural condition is below the water quality criterion, load allocations should be established such that human sources do not reduce DO by more than an additional 0.2 mg/L. As Table 15 illustrates, nutrient load reductions to a level below the natural condition resulted in less than a 0.2 mg/L change in DO concentration. Therefore no nutrient load allocations are prescribed in this TMDL.

Observed insensitivity to changing nutrient conditions in the Bear-Evans basin is potentially due to light-limiting, rather than nutrient-limiting, conditions. Therefore, reducing light entering the stream by increasing shade can reduce productivity and improve DO concentrations. In addition, DO saturation (the ability of water to ‘hold’ more DO) increases with a decrease in temperature. Cooler stream temperatures can, through this process, enhance DO concentrations.

Improvements in DO are predicted in all three creeks with the implementation of mature riparian vegetation, microclimate improvements, and subsequent cooling of stream temperatures (Figure 30). Table 16 shows greater improvements are predicted for Bear Creek (1.0 mg /L), than for Evans (0.22 mg/L) and Cottage Lake Creek (0.17 mg/L).

[4] Natural concentrations were assumed to be within the range of data in upper Bear Creek which is relatively undisturbed compared to the rest of the Bear-Evans basin.

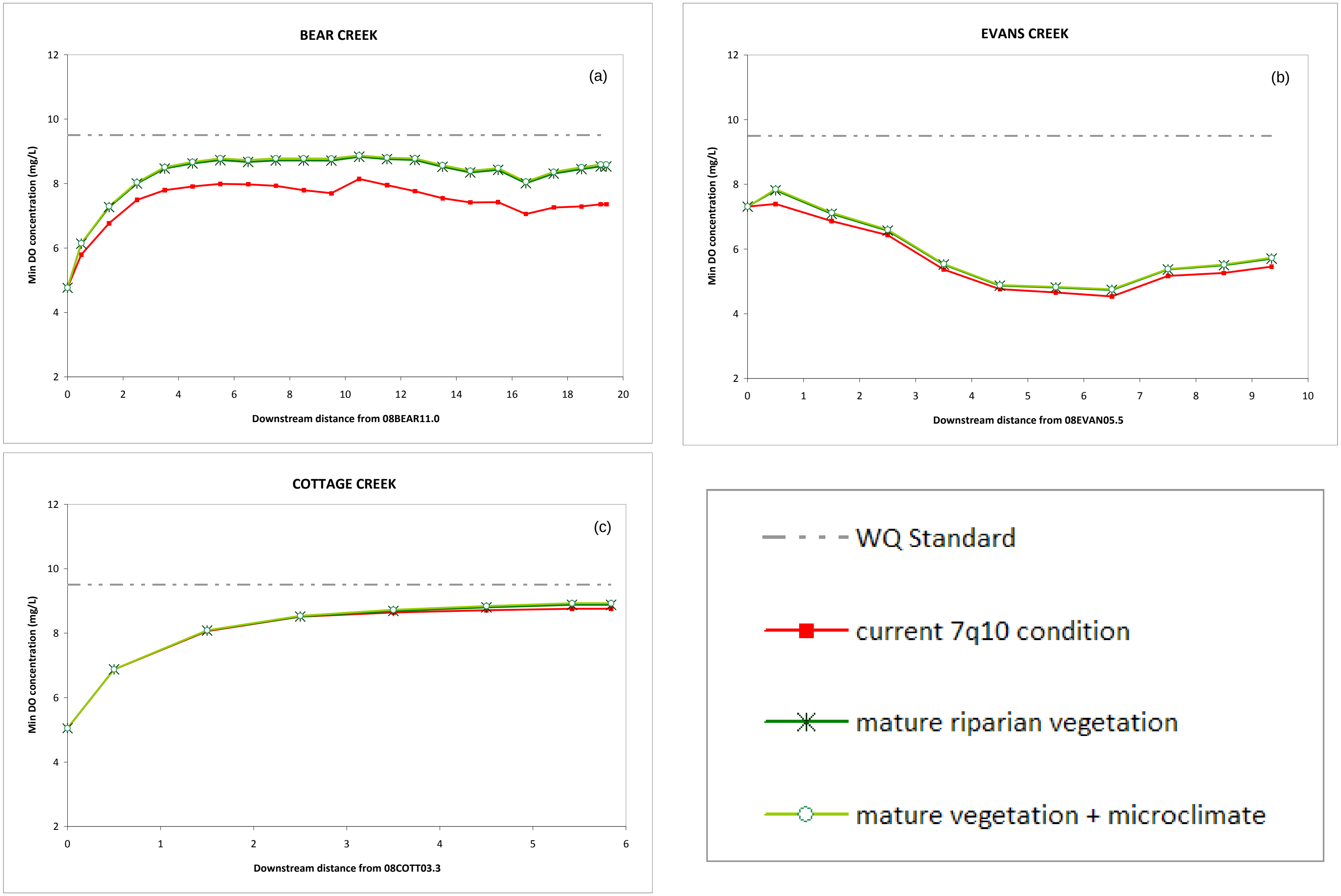

Figure 30. Minimum predicted dissolved oxygen in Bear, Evans, and Cottage Lake Creeks with implementation of mature vegetation and microclimate improvements.

Table 16. Average and minimum dissolved oxygen predictions with improvements in shade and microclimate in Bear, Evans, and Cottage Lake Creeks for 7Q10 conditions.

Scenario	DO_{avg}	DO_{min}*	ΔDO_{min}**
	(^oC)	(^oC)	(^oC)
Bear Creek			
current conditions	7.39	7.06	
mature riparian vegetation	8.19	8.01	0.95
mature veg + microclimate	8.24	8.06	1.00
Evans Creek			
current conditions	5.75	4.53	
mature riparian vegetation	5.93	4.73	0.20
mature veg + microclimate	5.96	4.76	0.22
Cottage Lake Creek			
current conditions	7.92	8.76	
mature riparian vegetation	7.97	8.88	0.12
mature veg + microclimate	8.00	8.93	0.17

* for Bear Creek, this is the minimum DO predicted at a distance of 4.5 km or greater from the headwaters
for Evans Creek, this is the minimum DO predicted at any point downstream of the headwaters
for Cottage Lake Creek, this is the minimum DO predicted at the mouth
** change from current DO_{min}

However, even with the implementation of mature riparian vegetation, the model predicts that none of the streams will meet the DO water quality numeric criterion of >9.5 mg/L. This suggests that possible natural conditions might be causing observed low DO concentrations as a result of lake, wetland, and groundwater influences. Low DO concentrations are characteristic of lake bottoms, wetlands, and groundwater.

During summer lake stratification, the sediment-water interface in lakes can become anaerobic where accumulating organic matter and bacterial metabolism are greatest (Wetzel, 1983). Both Bear and Cottage Lake Creeks originate as lake outlets. Field data indicated relatively low minimum DO concentrations at the most upstream sampling stations on these two creeks (4.8 mg/L at 08BEAR11.0 and 5.1 mg/L at 08COTT03.3). For both creeks, recorded DO concentrations were lower at the headwaters than at any point downstream, indicating possible upstream lake influences.

The permanent or intermittent flooding of wetland ecosystems results in waterlogged soils during part or all of the year. Inundation with water usually results in anaerobic (oxygenless) conditions as water fills pore spaces and the rate at which oxygen can diffuse through the soil is reduced (Mitsch and Gosselink, 2000). Most of the Evans Creek sub-watershed is dominated by wetlands. A GIS analysis showed that 45 percent of the 100-meter riparian buffer area around Evans Creek is covered by wetlands, based on the National Wetland Inventory GIS coverage. Wetland processes in Evans Creek could be the cause of observed low DO concentrations, with the minimum concentrations ranging from 2.8 mg/L – 4.2 mg/L recorded at 08EVAN01.7. Wetland influences are therefore a possible cause of naturally low DO concentrations in Evans Creek.

Groundwater could be another source of low DO concentrations in the Bear-Evans basin. Summer baseflows in all three creeks are heavily influenced by groundwater. In a draft report assessing wadeable streams in Washington State, large portions of stream networks were found to be poor in DO without coincident evidence of elevated nutrient concentrations (Merritt, 2007). The report attributed low DO concentrations in these streams to groundwater, which can have low DO concentrations due to microbial processing of organic matter as water flows through the soil (Alan, 1995). In a study of streams in the Pacific Coastal Ecoregion, Welch et al. (1998) found that low flows, elevated temperatures, inflows of deoxygenated groundwater, and off-channel pools and wetlands were all factors that could reduce DO levels in stream reaches.

Since the Bear-Evans basin is insensitive to nutrient reductions, and naturally low lake, wetland, and groundwater DO concentrations cannot easily be increased, reducing stream temperatures is the most effective way to improve DO conditions. The same shade improvements and solar heat load allocations prescribed for the temperature component of this TMDL are therefore prescribed for DO.

Load allocations

The load allocation for both temperature and DO in Bear, Evans, and Cottage Lake Creeks is the effective shade that would occur from system potential mature riparian vegetation (Table 17 through Table 19).

Modeled system potential temperatures resulting from the implementation of system potential mature riparian vegetation do not meet the 16°C numeric water quality criterion during the hottest period of the year in the Bear-Evans watershed. However, since this load allocation does not account for baseflow loss, it is not entirely representative of the natural condition. The natural condition would be characterized by both system potential effective shade and restored summer baseflows, resulting in even cooler stream temperatures.

Effective shade load allocations are based on our best available knowledge. Our current understanding of baseflow loss is limited to Hartley's (2001) estimates, and we do not have a value of the exact magnitude of baseflow loss in comparison to natural conditions. We do, however, have strong evidence to show that baseflow loss is a significant factor in the Bear-Evans basin and that it does affect stream temperatures. This reinforces a need to find ways to mitigate baseflow losses in addition to implementing system potential mature riparian vegetation.

> At locations and times where the system potential temperature is greater than the numeric criterion assigned to the water body, the loading capacity and load allocations in this TMDL should be established such that human sources do not cumulatively cause the 7-DADMax temperature of the water body to increase more than an additional 0.3°C. Similarly, human sources should not cumulatively decrease DO concentrations by more than 0.2 mg/L.

Table 17. Effective shade and solar load allocations on July 24 to improve temperature and DO conditions in Bear Creek.

(Potential effective shade is based on establishing system potential mature riparian vegetation.)

Station	Distance from upstream boundary to end of reach (km)	CURRENT reach averaged effective shade (%)	CURRENT reach averaged solar heat load (W/m^2)	POTENTIAL reach averaged effective shade (%)	POTENTIAL reach averaged solar heat load (W/m^2)	Load Allocation	
						REQUIRED increase in effective shade (%)	REQUIRED decrease in solar load (W/m^2)
08BEAR11.0	0.0	52%	148	73%	83	21%	66
	0.5	42%	182	79%	67	37%	115
	1.0	66%	107	89%	35	23%	72
08BEAR10.1	1.5	94%	18	98%	5	4%	13
	2.0	46%	170	86%	45	40%	125
	2.5	82%	57	97%	9	15%	48
	3.0	85%	48	98%	5	14%	42
	3.5	86%	42	98%	5	12%	37
	4.0	52%	149	98%	5	46%	143
	4.5	59%	129	98%	6	39%	123
08BEAR08.1	5.0	81%	59	98%	5	17%	54
	5.5	60%	125	98%	5	38%	120
	6.0	47%	165	88%	39	41%	127
	6.5	44%	174	82%	57	37%	117
	7.0	64%	112	93%	23	28%	89
	7.5	39%	190	95%	17	56%	173
08BEAR06.5	8.0	45%	173	83%	53	38%	119
	8.5	53%	147	98%	5	45%	142
	9.0	56%	138	93%	23	37%	116
	9.5	58%	131	95%	15	37%	116
08BEAR05.4	10.0	65%	110	98%	5	34%	105
	10.5	20%	250	96%	12	76%	238
	11.0	43%	177	96%	12	53%	165
	11.5	47%	164	98%	5	51%	160
	12.0	79%	67	98%	5	20%	62
	12.5	61%	122	95%	15	34%	107
08BEAR03.7	13.0	46%	170	98%	5	53%	165
	13.5	56%	138	98%	6	42%	132
	14.0	59%	128	95%	17	36%	111
08BEAR02.8	14.5	55%	139	88%	38	32%	101
	15.0	48%	163	96%	12	48%	151
08BEAR02.1	15.5	31%	216	98%	5	68%	211
08BEAR02.0	16.0	31%	216	98%	5	68%	211
	16.5	22%	245	90%	30	69%	214
08BEAR01.3	17.0	50%	155	98%	5	48%	150
	17.5	45%	171	98%	5	53%	166
08BEAR00.9	18.0	42%	180	98%	6	56%	174
	18.5	27%	227	98%	5	71%	222
08BEAR00.3	19.0	45%	170	99%	4	53%	166
	19.4	44%	174	98%	7	53%	166

Table 18. Effective shade and solar load allocations on July 24 to improve temperature and DO conditions in Evans Creek.

(Potential effective shade is based on establishing system potential mature riparian vegetation.)

Station	Distance from upstream boundary to end of reach (km)	CURRENT reach averaged effective shade (%)	CURRENT reach averaged solar heat load (W/m^2)	POTENTIAL reach averaged effective shade (%)	POTENTIAL reach averaged solar heat load (W/m^2)	Load Allocation	
						REQUIRED increase in effective shade (%)	REQUIRED decrease in solar load (W/m^2)
08EVAN05.5	0.0	82%	55	99%	3	17%	52
	0.5	43%	177	79%	66	36%	111
08EVAN04.7	1.0	18%	257	68%	101	50%	155
	1.5	35%	202	71%	91	36%	111
08EVAN04.3	2.0	48%	163	79%	64	32%	99
	2.5	43%	179	79%	66	36%	112
	3.0	37%	198	74%	81	37%	116
	3.5	36%	200	86%	43	50%	157
08EVAN03.2	4.0	30%	218	93%	21	63%	198
	4.5	30%	217	98%	6	68%	212
	5.0	33%	209	88%	38	55%	172
08EVAN.2.3	5.5	28%	223	88%	38	59%	185
	6.0	29%	221	87%	41	58%	180
08EVAN01.7	6.5	13%	273	72%	88	59%	185
	7.0	25%	235	78%	68	54%	167
08EVAN01.2	7.5	32%	214	84%	49	53%	165
08EVAN00.8	8.0	50%	155	82%	56	32%	100
	8.5	69%	97	90%	31	21%	66
08EVAN00.4	9.0	58%	132	99%	4	41%	128
08EVAN00.0	9.4	28%	226	99%	4	71%	221

Table 19. Effective shade and solar load allocations on July 24 to improve temperature and DO conditions in Cottage Lake Creek.

(Potential effective shade is based on establishing system potential mature riparian vegetation.)

Station	Distance from upstream boundary to end of reach (km)	CURRENT reach averaged effective shade (%)	CURRENT reach averaged solar heat load (W/m^2)	POTENTIAL reach averaged effective shade (%)	POTENTIAL reach averaged solar heat load (W/m^2)	Load Allocation	
						REQUIRED increase in effective shade (%)	REQUIRED decrease in solar load (W/m^2)
08COTT03.3	0.0	42%	180	99%	4	56%	175
	0.5	44%	175	99%	4	55%	171
08COTT02.7	1.0	34%	207	99%	4	65%	203
	1.5	39%	191	99%	4	60%	187
08COTT02.2	2.0	79%	66	99%	4	20%	61
	2.5	77%	73	99%	4	22%	68
	3.0	78%	69	99%	4	21%	65
	3.5	75%	79	99%	4	24%	75
	4.0	43%	178	99%	4	56%	174
	4.5	72%	88	99%	4	27%	84
08COTT00.4	5.0	64%	113	99%	4	35%	109
	5.5	64%	111	99%	4	34%	107
	5.8	74%	82	99%	4	25%	78

Establishment of mature riparian vegetation is expected to improve stream temperatures and increase the stream's oxygen-carrying capacity, thereby improving DO concentrations. Secondary benefits of establishing riparian vegetation include improved riparian habitat, reduced channel widths, stabilization of stream banks, reduced erosion and sedimentation, and improved microclimate conditions. In addition, shading and woody debris from trees encourages the formation of riffles and pools, enhancing fish habitat.

All perennial streams and tributaries to Bear, Evans, and Cottage Lake Creeks can potentially increase the heat load as they discharge into the mainstem of these creeks. These perennial streams and tributaries are also assigned a load allocation for shade based on the estimated relationship between shade, channel width, and stream aspect at the assumed maximum riparian vegetation condition with 50-meter tree heights and 85% density (Figure 31). Improving shade along these tributary streams can potentially reduce temperatures in the mainstem. Figure 32 illustrates the load allocations in terms of effective shade deficits along each creek.

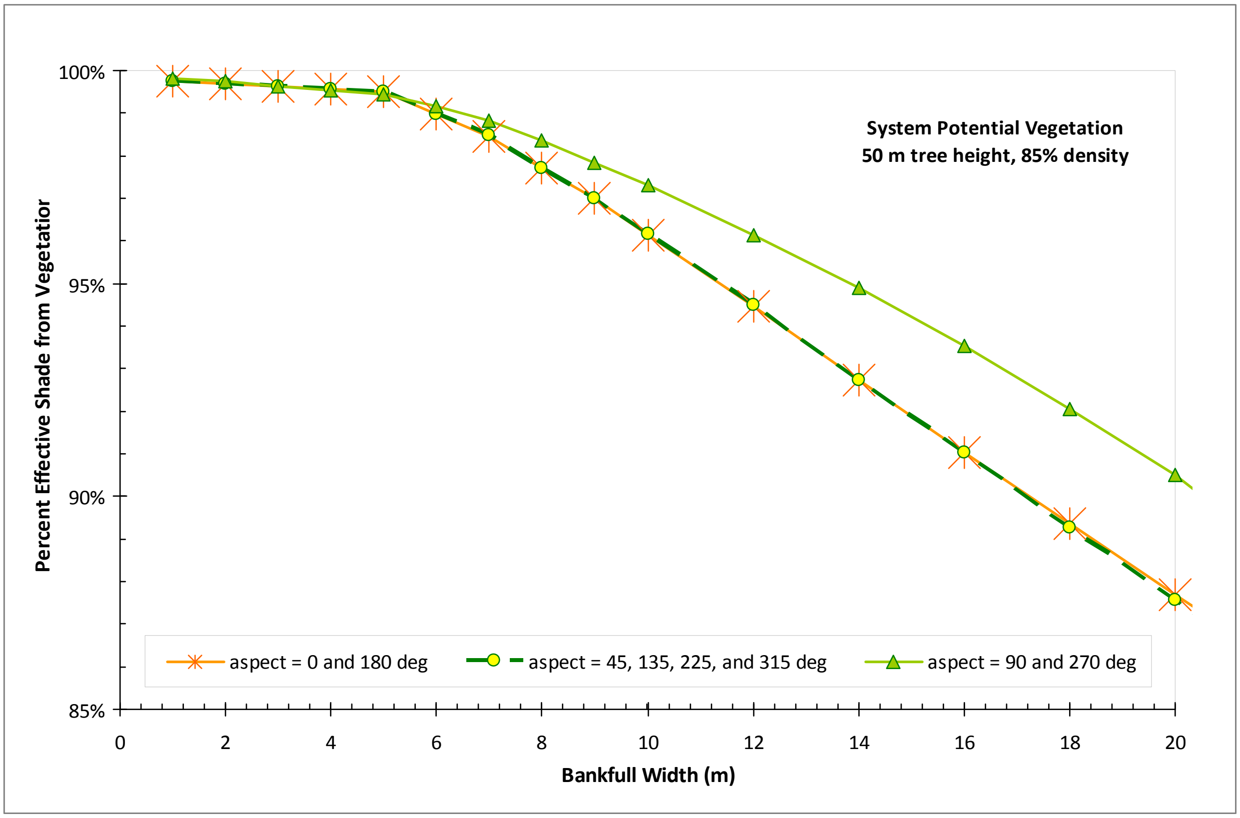

Figure 31. Load allocations for effective shade for various bankfull width and aspect of perennial streams and tributaries to mainstem Bear, Evans, and Cottage Lake Creeks.

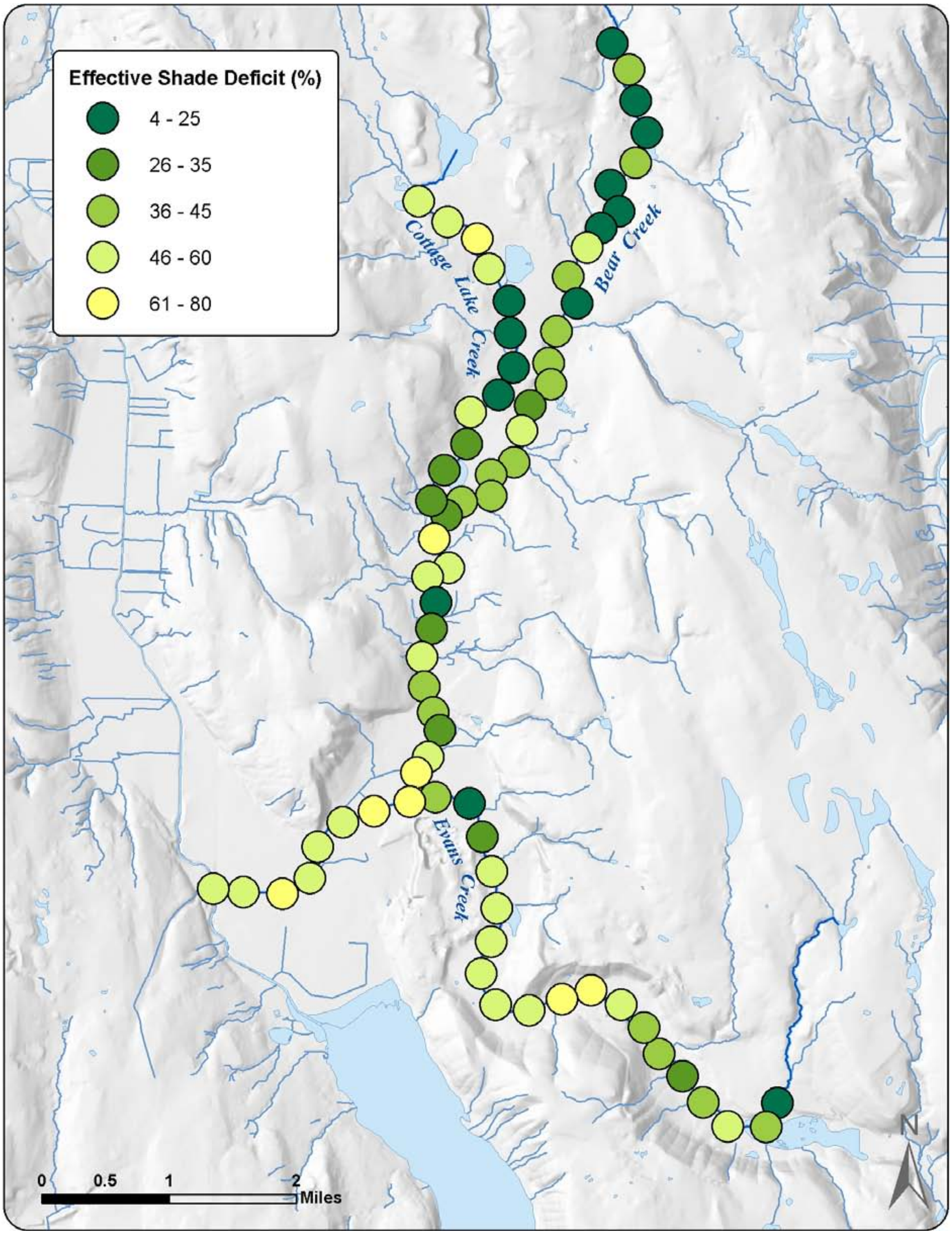

Figure 32. Effective shade deficits in the Bear-Evans watershed based on the difference between current and system potential mature riparian vegetation.

(Stream segments with the greatest effective shade deficits (61-80%) are indicated by yellow circles.)

Wasteload allocations

No wasteload allocations (WLA) for potential point sources were established for this TMDL. Although Ecology regulates municipal separate storm sewer systems (MS4s) as point sources under Ecology's NPDES Municipal Stormwater Program, Ecology does not consider stormwater discharges *significant direct* sources of thermal pollution during the summer critical period. Stormwater runoff is unlikely to occur during the hottest days of the summer and is not considered a significant source of thermal loading.

However, stormwater runoff could potentially contribute to thermal loading during late summer to early fall. Figures B-1 through B-9 in Appendix B illustrate that water temperature exceeded the supplemental standard of 13°C (7-DADMax) after September 15 in portions of the Bear-Evans basin. This supplemental standard applies from September 15 to May 15, outside the critical period, to protect spawning and incubation of salmonid species. Because the study was designed to evaluate summer peak temperatures, no data were collected to (1) support a numeric stormwater WLA for the fall at this time or (2) determine the magnitude of influence of direct stormwater discharges on stream temperatures in the fall.

Implementation actions taken to address temperature impairments during the critical period identified in this TMDL are expected to help cool temperatures throughout the entire year. To help evaluate temperature exceedance outside the critical period, the implementation of this TMDL will advocate for stormwater sampling/temperature monitoring in the fall to determine if stormwater runoff exceeds 13°C and if it affects temperatures in the creeks.

Stormwater runoff during the wet winter months is indirectly related to stream temperature impairment through reduced baseflows, but Ecology is not establishing a related WLA at this time. Low Impact Development (LID) is one way to help protect stream baseflows by emphasizing small-scale hydrologic controls designed to infiltrate stormwater using site design, pervious paving, and retention of forests and mature trees. As part of the implementation plan, this TMDL will stress the importance of infiltrating stormwater and reducing effective impervious area throughout the Bear-Evans watershed. The Municipal Stormwater General Permit currently requires permit holders to provide education and outreach on LID techniques to developers, engineers, land use planners, contractors, and others. The permit also requires municipalities to develop local ordinances that allow LID (Ecology, 2007b).

Margin of safety

The margin of safety (MOS) in a TMDL accounts for uncertainty about pollutant loading and water body response. The MOS may be implicit, i.e. incorporated into the TMDL through conservative assumptions in the analysis, or explicit, i.e. expressed in the TMDL as loadings set aside for the MOS. In this TMDL, the MOS is addressed by using critical climatic conditions in the modeling analysis. The margin of safety in this TMDL is implicit because of the following:

- The 90th percentile of the highest 7-day-averages of daily maximum air temperatures for each year of record represents a reasonable worst-case condition for prediction of water temperatures in the Bear-Evans watershed.

- The lowest sevenday average flows during July-August with recurrence intervals of ten years (7Q10) were used to evaluate reasonable worst-case conditions.
- Coincident application of the 7Q10 flow and the worst-case warmest air temperature adds to the implicit margin of safety.
- Conservative model assumptions of 0 percent cloud cover and 0.0 m/s wind speed were used for critical condition model runs.

Reasonable assurances

When establishing a TMDL, reductions of a particular pollutant are allocated among the pollutant sources (both point and nonpoint sources) in the water body. For the *Bear-Evans Watershed Temperature and Dissolved Oxygen TMDL*, nonpoint sources of heat loads and DO-affecting nutrients 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 on schedule. The following rationale helps provide reasonable assurance that TMDL goals will be met by 2050.

Ecology believes that the following activities already support this TMDL and add to the assurance that temperature and dissolved oxygen in Bear and Evans Creeks will meet conditions specified in 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 enforce their ordinances. Ordinances that can help control nutrient pollution and minimize loss of riparian vegetation include, but are not limited to, Critical Area Ordinances, King County Livestock Program, and county clearing and grading permits. Local governments must also enforce local ordinances protecting their stormwater management systems from illicit discharges.
- Water Tenders and Friends of Cottage Lake meet regularly and work to improve habitat, water quality, and salmon awareness in the Cottage Lake Creek and Bear Creek sub-basins.
- In 2004, King County adopted a major update to its Critical Area Ordinance (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 percent and 65 percent of native vegetation. Reducing the amount of cleared land in a watershed will help preserve the ecological integrity for the future.

- 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 the city of Redmond have ongoing ambient monitoring programs for temperature and dissolved oxygen that will enable the ongoing evaluation of Bear-Evans watershed water quality. The city of Redmond, in addition, has conducted its own temperature sampling of stormwater runoff in the summer to evaluate its potential impacts on stream temperature. Ecology will also periodically conduct special sampling surveys to help further define pollution sources and promote source correction.

- Cascade Water Alliance and King County's Wastewater Treatment Division have programs to provide alternative water supply sources, such as from Lake Tapps and reclaimed water programs.

- 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 best management practices (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 permits program will also address pollution from stormwater generated by Phase I entities (King County, Snohomish County, WSDOT) and Phase II entities (cities of Redmond, Woodinville, and Sammamish). Through these NPDES stormwater permits, municipalities must adopt an ordinance or other enforceable mechanism that addresses runoff from new development, and redevelopment. At a minimum, the ordinance must allow non-structural preventive actions and source reduction approaches such as Low Impact Development Techniques (LID), and measures to minimize the disturbance of native soils and vegetation. A recent ruling by the Pollution Control Hearing Board (on August 11, 2008) states that Phase I Municipal Stormwater Permits will now require greater use of LID techniques where feasible.

The primary goal of the *Bear-Evans Watershed Water Quality Implementation Plan* for temperature and dissolved oxygen is to help Bear and Evans Creeks meet the state's water quality standards. There is considerable interest and local involvement toward resolving the water quality problems in Bear and Evans Creeks. Numerous organizations and agencies are already engaged in stream restoration and source correction actions that will help resolve the temperature and dissolved oxygen problems.

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, in situations where the cause or contribution to the cause of noncompliance with load or wasteload allocations is known or can be established.

Providing more shade and enhancing baseflows in the creeks will improve temperature and dissolved oxygen in the Bear-Evans Creek system.

Recommendations

The Bear-Evans watershed includes several expanding urban areas. Future growth is expected to further reduce riparian vegetation, increase impervious areas, and increase demand for groundwater. All these factors can intensify existing water quality impairments in Bear, Evans, and Cottage Lake creeks.

In addition, expected changes to our region's climate as a result of global warming highlight the urgency of protecting and restoring mechanisms that help keep stream temperatures cool. We expect increases in air temperatures will further contribute to warming of instream temperatures from the current critical conditions.

Stream temperature is dependent upon a number of factors. One important factor is shade. Therefore, restoring riparian areas and preserving existing high value habitat are essential to improving the stream temperature.

Stream temperature is also related to the amount of instream flow, and reductions in flow may result in temperature increases for certain reaches. The Bear-Evans basin is heavily influenced by groundwater recharge, which is a significant source of summer baseflows. Groundwater discharging to streams via springs and seeps not only contributes more water (more flow), but also puts *cooler* water into the streams during summer. Given the existing temperature impairments in the Bear-Evans basin, efforts should be made to maintain or enhance current summer baseflows while protecting existing water rights and drinking water supplies.

Drinking water is a use to be protected under WAC 173.201A.600. Instream flows and surface water/groundwater withdrawals are managed through regulatory avenues separate from TMDLs. The Bear-Evans basin is closed to any further consumptive surface water diversions. Existing groundwater and surface water extractions are limited to rates and quantities provided under water rights and cannot be reduced under existing law.

However, opportunities exist to mitigate these effects through other means, such as use of reclaimed water as alternatives to potable water uses where feasible, infiltration of stormwater and reclaimed water to the practicable extent possible, enforcement of illegal withdrawals, and water conservation among exempt well users. This TMDL has no bearing on any entity's existing legal water rights even if they are not being fully used. Ecology will not request any legal water user to relinquish or not use their water to their allowable capacity.

Since a number of variables affect water quality in the Bear-Evans basin, it is important to consider the cumulative impacts of these variables. A comprehensive approach of establishing mature riparian vegetation, reducing nutrient inputs, and enhancing current summer baseflows to the practicable extent possible by enhancing groundwater recharge, is therefore recommended to improve stream temperatures and dissolved oxygen (DO) conditions in these creeks.

Given these factors, this TMDL calls for the following summary of actions:

- Plant and grow trees as well as preserve existing trees to eventually reach system potential riparian vegetation along the lengths of all three creeks, where possible, particularly in areas highlighted to have greater shade deficits (Figure 32). Implementation efforts should be executed quickly and efficiently to give trees an early start toward providing shade.
- Investigate opportunities to enhance groundwater recharge through infiltration where feasible, such as using (1) reclaimed water and stormwater to percolate into areas where water will benefit streamflow (e.g., through wetlands or in areas of groundwater recharge) and (2) low-impact development practices for new and re-developments.
- Restore and protect wetlands in areas which will benefit the stream and enhance habitat.
- Consider a water management strategy that recognizes the benefits of maintaining summer baseflows while meeting the community's need for water. This strategy should accommodate projected future growth and increases in water demand.
- Maintain the closed Bear-Evans basin status, eliminate illegal withdrawals, and investigate, address, and mitigate the impacts of exempt wells.
- Continue water conservation efforts already required by those who have existing water rights by Department of Health's Water Efficiency Rules (WAC 246-290-010-840), and encourage water conservation by those with exempt wells.
- Minimize human-caused sources of nutrients in the watershed, such as runoff from agricultural fields, failing on-site septic systems, and fertilizer from lawn and garden areas, to prevent exacerbating the DO concentrations. Though nutrient allocations are not assigned to address DO impairments in this TMDL, activities that increase nutrient inputs to streams could potentially exacerbate already low DO concentrations and affect downstream waters.
- Conduct stream monitoring efforts throughout the watershed and incorporate stormwater temperature monitoring during fall 2010. Periodically assess monitoring needs and adaptively manage according to monitoring results.

The above actions apply broadly throughout the Bear-Evans watershed. However, complex hydrology and local conditions can result in different interactions between temperature, DO, groundwater and wetlands. It is therefore important that the implementation strategy consider site-specific variability within the watershed in order to implement appropriate activities in each area.

Implementation Strategy

Introduction


Volunteers plant native shrubs along the stream.

This Implementation Strategy summarizes actions that would help improve water quality in the Bear-Evans watershed. It describes the roles and authorities of our cleanup partners (whose organizations have jurisdiction, authority, or direct responsibility for cleanup). It also describes the programs or other means through which they will address these water quality issues.

After the U.S. Environmental Protection Agency (EPA) approves this *Bear-Evans Watershed Temperature and Dissolved Oxygen TMDL/Water Quality Improvement (TMDL) Report*, interested and responsible parties will work together to develop a *Water Quality Implementation Plan*. The plan will describe and prioritize specific actions to improve water quality and achieve water quality standards.

The plan will guide water quality activities in the Bear-Evans watershed that will help Bear, Evans, and Cottage Lake Creeks meet water quality standards. Ecology facilitates this process by encouraging local governments, agencies, districts, businesses, and communities to participate in actions that will help identify and correct pollution sources and protect stream quality. Sometimes Ecology contributes funding to support local efforts.

Several agencies and groups in the Bear-Evans watershed actively conduct educational and stream restoration projects that help remediate the water quality impacts to these creeks. Along with local governments, several volunteer groups, such as Water Tenders, actively plan and develop stream restoration and other watershed activities that will help improve temperature and dissolved oxygen in the creeks.

This strategy also summarizes many actions recommended by other restoration plans for the Bear-Evans watershed: Bear Creek Basin Plan **(**King County, 1990), WRIA 8 Chinook Salmon Conservation Plan (WRIA 8, 2005), and Sammamish River Corridor Action Plan (Tetra Tech, 2002). In addition, Ecology has incorporated valuable input from the Bear-Evans Watershed TMDL Advisory Group in this strategy.

What needs to be done?

The TMDL study evaluated several broad approaches to reducing temperature in Bear, Evans, and Cottage Lake Creeks, which will in turn improve dissolved oxygen: establishment of mature full riparian vegetation for shade, and microclimate and management activities that enhance current summer baseflows in the streams by enhancing groundwater recharge. The TMDL models show that the combined effects of mature riparian vegetation, microclimate improvements, and restoring baseflows result in the greatest temperature improvements in the creeks.

What the models do not consider is the feasibility and level of cooperation for implementing these various approaches. Many of the streamside properties along the creeks are privately owned. Thus, employing the model's assumed buffer width of 100 meters (328 feet) for establishing mature riparian vegetation everywhere on both sides of the creek will be challenging. Furthermore, the additional shade provided from new riparian vegetation will require decades, at a minimum, for the trees to attain mature height. Regardless, planting new or restoring riparian vegetation of any buffer size that is deemed feasible can still provide value and is encouraged.

Maintaining or enhancing groundwater recharge through the use of Low Impact Development (LID) practices and infiltration of stormwater/reclaimed water in some places could provide temperature benefits in a shorter timeframe. In addition, enhancing groundwater recharge can mitigate the effects of inadequate shade in some areas.

Looking into the future and urban growth potential in the basin, it is also necessary to incorporate actions that minimize further degradation of streamside riparian habitat and baseflow loss. Management options, such as minimizing new impervious areas through LID practices and acquiring economically feasible alternative water sources (e.g., local reclaimed water), can be used to increase summer baseflows and may counteract the impact of reduced groundwater recharge to the creeks.

A comprehensive approach to protecting and restoring riparian function (including overbank flows, vegetated streambanks, and groundwater interactions) would help improve stream temperature and dissolved oxygen and help protect core salmonid life stages. Table 20 is a summary of implementation actions and timeframes to improve temperature and dissolved oxygen in the Bear-Evans watershed. Ecology will discuss these and related activities with the key parties and will refine the list of actions during the implementation planning process. Agreements or commitments to implement specific actions will be documented in the *Water Quality Implementation Plan.*

Spawning chinook salmon in Lower Cottage Lake Creek.
Photo by Bill Smith.

Table 20. Summary of implementation actions and timeframes to improve temperature and DO in the Bear-Evans watershed.

Actions	Possible Timeframe
Provide more shade and improve riparian areas	
Assess potential planting sites along these creeks.	2009 - 2010
Promote invasive plant removal and plant colonizing species.	2009 - 2050
Incorporate TMDL actions into local regulatory programs and policies.	2009 - 2050
Protect cool groundwater and enhance current summer baseflows	
Promote Low Impact Development (LID) practices.	2009 - 2050
Consider TMDLs during SEPA and other land use planning reviews.	2009 - 2050
Infiltrate stormwater and/or reclaimed water to the maximum extent possible.	2009 - 2050
Restore and/or create beneficial wetlands.	2009 - 2050
Increase water conservation, particularly among exempt well users.	2009 - 2050
Consider economically-feasible alternative water sources.	2009 - 2025
Reduce unauthorized water withdrawals through enforcement.	2009 - 2050
Control excess nutrient inputs into streams and lakes	
Increase understanding of the land uses draining to the creeks.	2009 - 2050
Investigate and repair possible sewer leaks and failing onsite septics.	2009 - 2050
Identify and eliminate illicit discharges to stormwater drainage systems.	2009 - 2050
Public outreach and stewardship education to communities.	2009 - 2050
Monitoring	
Conduct in-stream water quality & flow monitoring.	2009 - 2050
Incorporate stormwater sampling/temperature monitoring in fall.	Fall 2010
Effectiveness monitoring	2025, 2050

Provide more shade and improve riparian areas

Riparian areas (streamside buffers) perform many valuable roles in protecting water quality. In addition to its direct role in blocking incoming solar radiation, riparian vegetation creates an area of moderated microclimate, prevents erosion, and provides large woody debris. It can also filter out unwanted substances before they are carried into streams by surface runoff. Cooler water holds more oxygen to support fish and other aquatic life.

Ecology recorded HemiView images at the center of stream reaches to determine riparian shade levels at the site.

The shade deficit map in Figure 32 identifies reaches along the mainstems of Bear, Evans, and Cottage Lake Creeks with the greatest lack of shade (46-80%). However, when prioritizing areas for riparian planting and restoration projects, the perennial tributaries and other reaches not modeled in the TMDL study should also be considered.

Benefits of shade are also cumulative. The further upstream shade is provided, the greater the length of creek that benefits. Riparian restoration and preservation of existing high value habitat, to the practicable extent possible, should also be focused upstream from these high shade deficit reaches.

Summary of actions

- **Assess potential planting sites along these creeks, particularly in the high shade deficit areas.**

  Subbasin-scale projects should start with a clear understanding of where planting needs exist and focus feasibility and outreach efforts on those properties. GIS-based tools are available to inform this effort. Privately-owned riparian areas along the creek should be improved, where feasible. To identify where riparian restoration projects may occur, a map of streamside land ownership should be developed to understand what areas have been purchased, protected, etc. Planting sites should be selected based on local soil, topography, and location within the channel migration zone.

  Riparian restoration projects should strive to establish buffers of at least 150 feet on each side of a fish bearing stream. Brosofske et al. (1997) found that 150 feet was the minimum buffer width necessary to maintain a complete, unaltered riparian microclimate environment along small western Washington streams. Buffer widths wider than 150 feet would provide for increased riparian functioning (e.g. microclimate improvements, erosion control, and channel stability); however, due to the level of development currently present in the basin, minimum 150-foot buffers are recommended.

A system to track trees that are removed and trees that are planted within a 328 foot (100 m) buffer zone will help guide and track restoration projects and riparian canopy establishment. Measures should be identified to prevent the removal of existing riparian trees along the mainstem and tributaries in the basin.

- **Promote invasive plant removal and plant colonizing species in riparian restoration projects.**

  Colonizing species (such as red alder, willow, redstem dogwood, and black cottonwood) should be the first species planted because they create a shade canopy relatively quickly and are effective competitors against undesirable invasive species, such as reed canary grass and blackberry (Tetra Tech, 2002). The need for annual plant maintenance for a period of 5 years following plantings should be evaluated and always be included where the previous dominant vegetation was composed of blackberries, reed canary grass, Japanese knotweed, and other invasive or noxious weeds. Restoration specialists should regularly review the success of techniques to ensure that planting, watering, weed management, and outreach techniques are the most effective ones available.

- **Incorporate TMDL actions and incentives into local regulatory programs and policies that improve and protect local water quality.**

  Local governments should use their sensitive area protection authority (under the Shoreline Management Act and Growth Management Act) and incorporate relevant TMDL actions and incentives in the revision or development of their Critical Areas Ordinances, Shoreline Management Plans, and other land use regulations to protect and improve the quality of degraded riparian areas. The public should be provided with information explaining how those authorities will optimize stream shading for temperature and restore and protect critical habitat.

  Improvements in sensitive area regulations for all jurisdictions should require buffers of at least 150 feet wide for new development along streams and all perennial tributaries to maintain and restore water quality (temperature) and improve fish and wildlife habitat. These sensitive area regulations should also be re-evaluated to provide incentives for already developed sites with narrower buffers, to either move toward a preferred buffer width or improve existing riparian habitat by providing native trees and removing non-native species such as blackberry. Incentives could include tax reduction programs and conservation easements, as well as conditions placed on future development.

Protect cool groundwater and enhance current summer baseflows

Cool groundwater flowing into the Bear-Evans Creek system benefits the stream quality throughout the year, especially during the warmer, drier, summer months. In addition to keeping overall water temperatures low, groundwater surface seeps and inputs through the hyporheic zone can also provide important fish refuge areas from surrounding high water temperatures. Therefore, headwater areas, important wetlands, and sources of groundwater (e.g. seeps and springs) in the Bear-Evans watershed should be protected and recharged to maintain hydrologic integrity and a temperature regime that supports core salmonid life stages.

Bear Creek below the confluence with Evans Creek.

In general, human activities can change river hydrology by reducing baseflows in the streams. Reduced baseflows can result from expanding impervious areas (less water infiltrates into the ground when it rains and therefore less groundwater is available for streamflows in the summer), and from water extraction and consumptive use (e.g., surface and groundwater withdrawals).

Due to the complexity of scientifically documenting the specific causes of altered hydrology in the watershed, this TMDL did not attempt to identify specific problem areas. However, estimates of hypothetical baseflow losses within WRIA 8 subbasins (including the Bear-Evans basin) due to effective impervious areas (EIA) and water management activities (e.g. consumptive water use and withdrawals) were made by Hartley (2001) in a stream flow analysis study for the WRIA 8 Chinook Salmon Conservation Technical Subcommittee. By sub-basins in the Bear-Evans watershed, Bear Creek (near the mouth) was estimated to have the greatest baseflow loss due to EIA and water management. Impact from baseflow loss due to water management was not estimated for Cottage Lake Creek.

Wherever people live, there will be an increase in roofs, roads, and parking lots, so adverse impacts to water quality will likely occur in those areas. Additional population growth will place further pressures on the already degraded Bear-Evans Creek system. Additional forested areas may be cleared for housing and other new development that could decrease buffers on streams and wetlands. The development will likely increase impervious areas (which will increase winter runoff and reduce groundwater recharge).

The city of Redmond, the water districts of Northeast Sammamish and Union Hill, and the Sahalee and Bear Creek Golf Courses withdraw the largest water volumes from the Bear-Evans basin. These entities are limited to withdrawal rates provided under their existing water withdrawal rights. This TMDL does not recommend limits or reductions on certificated or permitted groundwater withdrawals and has no bearing on any entity’s existing legal water rights, even if they are not being fully utilized.

It is reported that compared to historical conditions, other tributaries to Sammamish River (Little Bear, Swamp, and North Creeks) experience higher estimated baseflow conditions because of the use of imported water (from Cedar and Tolt basins) for irrigation of lawns and gardens (Hartley 2001). The Woodinville Water District imports water into the Bear-Evans watershed from the South Fork Tolt River watershed, and occasionally from the Cedar River watershed.

Exempt wells also use groundwater for domestic purposes. These wells can 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. A rough approximation is that there are about 400 water-supply wells within the Bear-Evans watershed, most of which are likely exempt wells (Cook, 2008). The exact amount of exempt well withdrawals is unknown; hence, the potential impact of exempt wells on baseflow loss is unknown.

Growing populations need clean drinking water and places to live. Any water management strategy in the basin should recognize the benefits of maintaining summer baseflows while meeting the community's need for water. Outside of urban areas, groundwater is the key source of water for new development. There will be an increased demand for water supply, which in some cases could potentially be primarily provided from other sub-basins (i.e., Cedar River, Tolt River). Overall, it will be important to minimize the degradation to groundwater recharge that could continue to occur as a result of population growth and development; otherwise, any restoration actions may just maintain existing conditions without making effective improvements to the ecosystem.

Summary of actions

- **Infiltrate stormwater and/or reclaimed water to the maximum extent possible, including through the use of Low Impact Development (LID) practices where feasible.**

  Municipalities should evaluate their stormwater drainage systems (MS4s) for opportunities to infiltrate stormwater, where feasible, rather than directly discharging to creeks. To promote more stormwater infiltration, Ecology's current Western Manual on Stormwater BMPs should rectify the unsaturated separation distance issue below retention basins. Individual land owners should also examine stormwater pathways on their properties and assess the feasibility of infiltrating stormwater onsite to maintain groundwater levels and reduce the potential for contaminated stormwater.

  To help reduce the effect of new and existing stormwater discharges, local government should advance the use of LID practices in new development and redevelopment. LID is 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. An analysis of the geology and soils in the basin is needed to assess feasible areas for applying LID practices. Ideally, as a basin is developed, site planning and stormwater management are integrated at the initial design phases of a project to maintain a more hydrologically functional landscape. Local jurisdictions should develop incentives to encourage LID practices.

Wastewater utilities should continue programs to minimize inflow and infiltration (I&I) of water into their sewer system. Correcting "infiltration" of extraneous groundwater that enters the sewer system through leaking joints, cracks, breaks or porous walls will help protect groundwater quality and streamflow-enhancing seeps. When correcting "inflow" of stormwater that enters the sewer system from storm drain connections (catch basins), roof leaders, foundation and basement drains, or through manhole covers, utilities should direct the uncontaminated stormwater back into the ground for recharge where feasible.

On all properties, protecting existing trees and planting new ones, especially evergreen species, should help maximize evaporation and reduce stormwater volumes. In urban areas, the installation of rain gardens and addition of soil amendments to yards are key tools for small landowners. Rural landowners with livestock should manage pastures to prevent soil compaction and erosion by decreasing or eliminating winter grazing (see the Snohomish and King Conservation Districts for details).

- **Consider economically-feasible alternative water sources to augment irrigation withdrawals (such as use of reclaimed water) and groundwater drinking water source.**

Water districts and cities have a responsibility to provide water to their respective communities. All water purveyors should be compliant with water conservation rules and support efforts to enhance groundwater recharge. The economic feasibility of obtaining alternative water supply sources is an important factor to consider in the strategy. Water purveyors of alternative sources should consider providing water at a discounted rate. In assessing alternative sources to augment local groundwater sources, potential impacts to the baseflows in other important salmon-bearing streams, such as the Cedar River, should also be considered.

Reclaimed water is an alternative to potable water for some uses and can be used for irrigation of parks, nurseries, athletic fields, and golf courses, and for routine city maintenance of storm drainage systems, such as street sweeping and cleaning drains. However, importing reclaimed water to the Bear-Evans watershed may be cost-prohibitive. Therefore, providing reclaimed water at a lower cost through establishment of small packaged treatment or local "scalping" plants (smaller treatment plants) may be the more economically-feasible option for using reclaimed water in the basin.

- **Consider TMDLs during State Environmental Policy Act (SEPA) and other local land use planning reviews.**

If the land use action under review is known to potentially impact temperature and dissolved oxygen as addressed by this TMDL, then the project may have a significant adverse environmental impact. SEPA lead agencies and reviewers are required to look at potentially significant environmental impacts and alternatives and to document that the necessary environmental analyses have been made. Land use planners and project managers should consider findings and actions in this TMDL to help prevent new land uses from violating water quality standards. Ecology recently published a focus sheet on how TMDLs play a role in SEPA impact analysis, threshold determinations, and mitigation (http://www.ecy.wa.gov/biblio/0806008.html**).** Additionally, the TMDL should be considered in the issuance of land use permits by local authorities, such as King County Department of Development and Environmental Services.

- **Restore and/or create wetlands in areas that will increase groundwater recharge to benefit the stream.**

  Existing wetlands in the floodplain could be reconnected to streams to allow seasonal inundation and groundwater recharge. Areas with suitably permeable soils should be identified where percolation ponds could be installed to allow infiltration of stormwater and treated reclaimed wastewater. Assess the feasibility of using reclaimed wastewater for percolation through wetlands into the groundwater table. Washington State Department of Transportation should mitigate for temperature impacts from highway expansion projects through riparian restoration and/or construction of wetlands.

- **Protect cool headwaters, wetlands, and sources of groundwater (e.g. seeps and springs).**

  County and City planning departments should protect and acquire existing high-value habitats or areas with high likelihood of restoration success. This includes streamside lands with springs and side channels that provide habitat, refuge, and cooler water for salmonids. Currently, the Cold Creek Natural Area and adjacent Bassett Pond Natural Area aim to protect the cool groundwater source of Cold Creek. In addition, the 800-acre Snohomish County Paradise Valley Conservation Area preserves the Bear Creek's important headwaters. Maintaining and enhancing the Evans Creek wetlands could maintain a secondary cooling effect where wetlands enhance groundwater exchanges. The important Evans Creek headwaters and tributary sub-basins should also be preserved for the benefit of aquatic habitat.

- **Increase water conservation in Bear-Evans basin.**

  In areas served by groundwater sources, increased water conservation, particularly among exempt well users, could help maintain summer base flows and reduce summer water temperature in the creeks. Reduction of illegal surface water withdrawals would also be effective in helping maintain flows. Modern water supply systems have highly efficient water transport; however, some water purveyors may find that reduction of leaks in their piping system conserves significant quantities of water. Continuation of conservation-based rate structure could further increase conservation. It is recommended that athletic fields be converted to an alternate type of turf (i.e. "sports turf") that either does not require irrigation or significantly reduced irrigation.

- **Examine the feasibility of purchasing and transferring existing water rights.**

  This TMDL encourages projects that seek to work with local individuals or businesses to voluntarily retire water rights and help ensure sufficient flow levels are protected. The Washington Water Trust works to benefit water quality, fisheries, and recreation in Washington's rivers and streams by acquiring existing water rights from willing sellers through purchase, lease, or gift.

- **Reduce unauthorized water withdrawals through enforcement**.

  Ecology, through the rulemaking process, closed Lake Washington and its tributaries, including Bear and Evans Creeks, to any further consumptive surface water diversions. The closed basin status should be maintained and illegal withdrawals eliminated. Ecology is required to consider the interrelationship between groundwater and surface water when making permitting decisions for consumptive groundwater withdrawals within the basin. Small domestic supply wells, pumping less than 5,000 gallons per day, are exempt from water right application. Investigation is needed to address and mitigate potential impacts from exempt wells. Ecology needs to encourage developers not to install exempt water wells where an economically-feasible alternative supply exists in or near a local water utility's service area. Existing groundwater and surface water extractions are limited to withdrawal rates provided under water withdrawal rights. Ecology took steps to ensure that water right holders install flow meters and require metering reports to make sure users do not exceed authorized volumes.

Controlling excess nutrient inputs into streams

Though nutrient allocations are not assigned to address dissolved oxygen (DO) impairments in this TMDL, activities that increase nutrient inputs to streams could potentially exacerbate already low DO levels. Therefore, it is prudent to minimize human sources of nutrients in the watershed to help address the DO problem. Fertilizer runoff, food and grease wastes, and waste wash waters and soaps can all provide nutrients in storm sewers. Landscaping in the watershed often involves applying fertilizers to the yard. These practices may cause increased nutrient levels in runoff water. Local water quality professionals speculate that wash waters (such as from washing cars on the streets) and fertilizer runoff could provide excessive nutrients to streams and stormwater systems. In addition, rural activities in the basin can add excess nutrients into the streams through improper management of livestock and manure.

Some actions described earlier that will enhance the overall water quality and habitat of Bear-Evan streams will also help improve dissolved oxygen conditions. These include preserving and restoring riparian areas with native riparian vegetation to establish stream buffers. Also, employing and promoting low impact development techniques, such as the use of rain gardens, pervious pavements, and bioinfiltration swales, where feasible, will reduce water quality impacts from stormwater runoff.

Ecology produced the Water Quality Improvement (TMDL) Report to address fecal coliform bacteria in the Bear-Evans watershed in June 2008 (Ecology, 2008). Certain actions to control fecal coliform bacteria sources will likely also reduce excess nutrients in the streams (e.g., proper livestock waste management, repair failing on-site septic systems, source controls in urban stormwater).

Summary of actions

- **Increase understanding of the area and land uses 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.

- **Continue to investigate and repair possible sewer leaks and failing onsite septics**, which involves responding immediately and appropriately to sewer leaks or failing onsite septics by responsible parties.

- **Identify and eliminate illicit discharges to stormwater drainage systems.** There are several methods available to detect and eliminate illicit stormwater 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.

- **Public outreach and stewardship education 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. Messages include proper disposal of restaurant food waste, proper management of pet and livestock wastes, routine maintenance of onsite septics systems, and prevention of illicit discharges into storm sewers. Education can involve cross-program training of code enforcement staff about water quality protection ordinances.

Monitoring

During the implementation of the TMDL, monitoring will help (1) to identify polluted areas and sources of pollution, (2) to track water quality trends, and (3) to verify that actions taken are and will remain appropriate in protecting local waters.

- **Continue existing monitoring efforts throughout the watershed.** King County, city of Redmond, Northeast Sammamish Sewer and Water District and Union Hill Water Association currently have robust stream monitoring programs in the watershed. Data from these monitoring programs not only track trends in stream quality in Bear-Evans watershed, but will help assess the beneficial impacts from future restoration and implementation actions.

- **Incorporate stormwater sampling/temperature monitoring in the fall.** Ecology set supplemental temperature standards for certain portions of Bear, Evans, and Cottage Lake Creeks from September 15 to May 15 to protect spawning and incubation of salmonid species. Data collected for this TMDL showed stream temperature exceedances during the period when the supplemental standard applied. Focused fall sampling will determine if stormwater inputs cause adverse impacts to stream temperatures outside of the critical summer period. Ecology expects implementation actions, taken to address temperature impairments during the critical period, will help cool temperatures throughout the year.

- **Effectiveness monitoring** of the streams in the Bear-Evans watershed will tell us whether the actions are effective in reducing temperature and increasing dissolved oxygen. Ecology reviews all of the relevant actions taken to improve the 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 may be needed to improve water cleanup efforts.

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 best management practices (BMPs) have been put into effect, and whether NPDES permits are consistent with TMDL wasteload allocations.

EPA provides technical assistance and funding to states and tribes to implement the Clean Water Act. For example, EPA's Clean Water Act 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, the EPA also provides other grant monies (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. The Cedar-Sammamish-Lake Washington watershed (WRIA 8) 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 Temperature and Dissolved Oxygen TMDL who will assist the stormwater permit holders 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. The full range of Ecology funding opportunities is discussed under the section "Funding Opportunities." Ecology's Grant Specialists assist local government in the development of stream restoration and water quality improvement projects.

Ecology will be responsible for organizing meetings of the 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 stream restoration projects, and monitors water quality.

Since 1995, WSDOT has been regulated under Ecology's Phase I Municipal Stormwater permit. Pursuant to that NPDES permit, in 1997 WSDOT submitted a stormwater management plan (SWMP) 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 pollutants being characterized in the TMDL. An important WSDOT project relating to lower Bear Creek will be SR 520 widening next to Marymoor Park over the next several years. Check Ecology's Water Quality Program website for the most up-to-date information (www.ecy.wa.gov/programs/wq/stormwater/municipal/wsdot.html).

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 will continue to monitor these permits and restoration projects to evaluate whether the TMDL is implemented and not adversely affected by future land actions.

Puget Sound Partnership

In 2007, the Washington State Legislature established the Puget Sound Partnership (Partnership) to lead the recovery of Puget Sound to health by 2020. The Partnership replaced the Puget Sound Action Team in coordinating regional efforts to restore and protect the biological health and diversity of Puget Sound by protecting and enhancing Puget Sound's water and sediment quality, its fish and shellfish, and its wetlands and other habitats.

By December 31, 2008, the Partnership will produce the 2020 Action Agenda that establishes science-based goals to achieve recovery and protection. The 2020 Action Agenda will address habitat protection; toxic contamination; pathogen and nutrient pollution; stormwater runoff; water supply; ecosystem biodiversity; species recovery; and capacity for action.

The Partnership is working with tribal and local governments, community groups, citizens and businesses, and state and federal agencies to develop and carry out the Action Agenda. Seven geographic action areas were established around the Sound to address and tackle problems specific to those areas. Bear-Evans watershed of Water Resource Inventory Area 08 is within the South Central Puget Sound Action Area.

The former Puget Sound Action Team provided important leadership in promoting Low Impact Development (LID), an innovative approach to new development and redevelopment to prevent and better manage stormwater runoff.

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 which was ratified by all 27 jurisdictions in 2005 and approved by NOAA Fisheries as part of the Puget Sound Chinook Conservation Plan in 2007. The same jurisdictions now fund a small team to coordinate the implementation of the Puget Sound Chinook Conservation Plan.

In a mostly urban King County, Bear-Evans watershed is among the most important basins for salmon habitat. In the WRIA 8 Chinook Salmon Conservation Plan, many of the planned stream restoration projects can help improve water quality 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 will provide 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; add 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 with the county's Phase I Municipal Stormwater Permit (Ecology, 2007a), and water quality monitoring. Following are the program descriptions.

- The ***Stormwater Services Section*** provides source control inspections and technical assistance to businesses in the basin. This service helps to curb such nutrient sources as littered parking areas and poorly managed dumpsters. The section also responds to drainage and water quality complaints. Additionally, the section identifies and facilitates the removal of any illicit discharges, and discharges or connections to the storm drainage system.

- The ***Development and Environmental Services*** **(DDES)** reviews development proposals to ensure that they are designed to be consistent with the King County's *Surface Water Design Manual*. DDES also inspects developments during construction to ensure that stormwater runoff is controlled and required stormwater facilities are installed according to 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 ***Regional Inflow and Infiltration (I&I) Program*** within the Wastewater Treatment Division works with local sewer agencies to reduce the amount of peak wet weather flow entering the County's wastewater conveyance system. Reduction of I/I in the system has the potential to lower the risk of sanitary sewer overflows and decrease the costs of conveying and treating wastewater. It also leaves more groundwater in shallow aquifers to assist stream baseflows.

- The ***Reclaimed Water Program*** within the Wastewater Treatment Division has safely used reclaimed water since 1997 at its regional treatment plants in Seattle and Renton. King County currently produces 284 million gallons per year of Class A reclaimed water at two regional treatment facilities. Two treatment plants under construction (Carnation and Brightwater) will produce additional reclaimed water once they are operational. King County's reclaimed water will be available to customers along the effluent line and via pipeline to the Sammamish Valley area.

- The ***Livestock Program*** promotes proper livestock management practices and financially assists agricultural landowners with BMP implementation. Some of these BMPs include stream and wetland buffer fencing; native re-vegetation; 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 in a manner that minimizes the adverse impacts of livestock on water quality and salmonid fisheries habitat in King County watersheds. Proper management of manure will help reduce nutrient pollution in nearby streams. The LMO recommends the implementation of Farm Plans on those farms with livestock.

- The ***Small Habitat Restoration Program*** helps keep bacteria and nutrients 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.

- The ***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 a Centennial Clean Water Grant project. The program will implement a restoration project in Cottage Lake Creek starting in summer 2008.

- The ***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.

- The ***WRIA 8 Basin Steward*** serves as a liaison between residents and the cities, King County, state, federal, and tribes. The basin steward provides technical assistance to basin residents on stream restoration, nonpoint pollution prevention, and re-vegetation 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.

- The ***Waterways 2000 program*** is a voluntary program for property owner participation in the Bear Creek community to continue to set a stewardship example for the rest of the Northwest to follow by showing strong support through a willingness to participate in the program. The Waterways 2000 program and the Upper Bear Creek Conservation Area purchased over 1100 acres of high value aquatic land that is targeted for protection.

Snohomish County

Snohomish County has several departments that can affect the overall water quality in the upper Bear Creek sub-basin. The bulk of water quality-related activities are carried out by Snohomish County Public Works, which performs a variety of pollution identification and prevention activities.

- The ***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 a 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 and provide technical assistance to landowners; and provide landowner training to ensure proper system operation and maintenance.

- The ***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.

- The ***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.

- The ***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. In 2000 Snohomish County, King County Land and Natural Resources, and the Cascade Land Conservancy secured funding to purchase over 600 acres now considered the Paradise Valley Conservation Area. Recently, new acquisition increased the conservation area to 789 acres. This area protects the biological integrity of a significant portion of the headwaters of Bear Creek. The department intends to use the Paradise Valley Conservation Area as a public educational interpretive center which focuses on relationships between forest, wetland, stream ecology, and water chemistry. In addition, culvert replacement projects are planned for publicly-owned areas of Meadow and Bear Creek Lanes, where existing drainage systems restrict Bear Creek under high flow conditions, creating downstream scour and water quality degradation.

Northeast Sammamish Sewer and Water District (District)

The Northeast Sammamish Sewer and Water District (NESSWD) serves mostly the city of Sammamish with two water customers in unincorporated King County, providing 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 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.

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

- ***Local streams monitoring*** by the utility District, which 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 temperature 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 ***King County's Inflow and Infiltration (I&I) Program***, which allows the district to maintain a very low level of I&I (or excess water that enters the sewer system unnecessarily). This means a lower amount of I&I enters the sewer system, therefore a greater amount of water remains in the local ecosystem. This is important for stream quantity, quality and fish habitat and also for the district's wells. Groundwater recharges the District's wells, which allows the District to continue to provide high quality water to its customers.

Union Hill Water Association

Union Hill Water Association (Association) is a private, non-profit utility located in the rural area east of the city of Redmond. Homes in the Association's service area do not have sewer service and utilize septic systems. The Association receives its water entirely from groundwater sources located in the Evans Creek Valley. The Association has two production wells serving approximately 6,700 people.

The Association promotes the protection of the environment. The Association participates in the Redmond-Bear Creek Ground Water Management Plan and is actively monitoring local ground and surface waters.

Woodinville Water and Sewer District

The Woodinville Water and Sewer District strives to provide (1) safe and reliable service to all their customers at an economical cost, (2) potable drinking water to all customers of the district, and (3) sanitary sewer service to all customers requesting service and who are located within the urban growth area. 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 predictions state that there may be 25,000 sewer and water connections by the year 2020.

City of Redmond

The city of Redmond is a suburban city encompassing an area of about 37 square kilometers 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 undeveloped land led to major land use changes over the past 40 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, 1990). The bulk of water quality-related activities are carried out by the city's Public Works Department's Natural Resources Division, which monitors the city's water quality, and designs and implements stream and stormwater improvements utilizing stormwater utility funds.

- The ***Stormwater Capital Improvement Program*** implements stormwater capital improvement projects that are necessary to alleviate problems caused by 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 and improvement projects, fisheries enhancement projects, stream bank stabilization or erosion repair projects, detention ponds, water quality treatment, and structural upgrades and repairs.

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

- 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 upper Evans Creek sub-basin, the city of Sammamish was incorporated in August 1999. Characterized predominantly by a suburban residential development, the city supports two primary 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 Sammamish city limits. The preserve includes a variety of habitats including wetland, riparian and forested upland. There are several 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, primarily draining to Cottage Lake Creek sub-basin. 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 helping to improve water quality in the Bear Creek system.

- The ***Public Works Department (Department)***, which provides safe and reliable motorized and non-motorized facilities, protects and enhances the quality of waterways and habitats, and maintains the public infrastructure including roadways, sidewalks, street lighting, traffic signals and signs, storm water systems, and public improvement projects. The Department consists of three divisions: Engineering, Traffic Management, and Operations and Maintenance.

- The ***Parks and Recreation Department***, which is responsible for Woodinville parks, recreation and open space. Staff works with the Parks and Recreation Commission for the future of parks and recreation. Woodinville staff carry 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.

- The ***Development Services Department***, which provides services that achieve the community's vision by implementing the goals and policies of the city's Comprehensive Plan and through the long range planning and permitting functions that protect the public's life, health, safety and welfare as it relates to land use standards and standard construction practices. In 2007-2008 the community created a citizen advisory panel on sustainable development. A major goal is to preserve vegetation and tree canopy. The city is currently revising its existing tree ordinance with changes that may include a city-wide goal to achieve at least 40% tree coverage.

Cascade Water Alliance

Cascade Water Alliance is an association of eight cities and water districts in the Puget Sound region, working together to supply water to meet the needs of its members in a cost-effective and environmentally sensitive manner. The Interlocal Contract that established Cascade in 1999 (amended) gives it the responsibility to:

- Purchase wholesale water from other regional suppliers.
- Coordinate conservation and supply management.
- Acquire, construct and manage water supply infrastructure.
- Foster regional water planning that provides adequate water for both people and fish.

Cascade is undertaking a coordinated water system plan with King County that will address water supply alternatives such as Lake Tapps. Cascade will begin planning the treatment and transmission facilities necessary to utilize Lake Tapps as a regional municipal water supply following the successful acquisition of properties, facilities, and water rights from Puget Sound Energy (Puget), the current lake owner and operator.

Snohomish Conservation District

The Snohomish Conservation District (SCD) is a non-regulatory municipal public agency created under Chapter 89 RCW 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 may include fencing, planting, manure management, roof runoff management, off-stream watering, and riparian corridor improvement.

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

The King Conservation District (KCD) is a non-regulatory municipal public agency created under Chapter 89 RCW that administers programs to conserve the natural resources of King County. KCD efforts focus on individual contact with farm owners and residents within all of 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 financial assistance. KCD will partner with Snohomish CD on a Centennial Clean Water grant project focused on targeted collaborative watershed education.

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 on these farms.

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, and investigates (and may take enforcement action related to) sewage discharge complaints. 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 have the potential to create a localized health threat as well as contribute to nutrient 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 contribute to bacterial and nutrient pollution problems in upper Bear Creek.

Public Health Seattle-King County

Public Health-Seattle and King County (PHSKC) enforces rules adopted by the state and county Boards of Health, including rules necessary to assure safe and reliable public drinking water and to protect the public health. PHSKC is responsible for assuring that installed, modified, or repaired on-site 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 proactively find and 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.

In addition, PHSKC is required to identify areas where marine water quality is threatened or impaired as a result of contamination from onsite 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

Bear Creek Water Tenders

Bear Creek 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 to preserve, protect, and restore the wonderful natural heritage within Bear-Evans watershed. Water Tenders has existed 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. Ecology regularly reports progress to Water Tenders on Bear-Evans Watershed TMDLs and receives valuable input and direction from the group. For information on how you can get involved visit their website at 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 fish in Snohomish County and to restore to health to 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 groups throughout the Pacific Northwest, and providing local communities with stream and wetland restoration assistance. In addition, AASF is developing 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 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 salmon lifecycle and their habitat needs (AASF 2004). Staff distributed several educational pamphlets. Their most effective outreach occurred when AASF field crews took the time to answer specific questions from streamside residents. Questions covered ways to address stream problems such as 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 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 operators who 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/.

Washington Water Trust

Washington Water Trust (WWT) is a private, nonprofit organization established in 1998 to restore instream flows in Washington's rivers and streams. WWT works to benefit water quality, fisheries and recreation in Washington's rivers and streams by acquiring existing water rights from willing sellers through purchase, lease or gift.

Washington Water Trust works cooperatively with farmers, ranchers, irrigation districts, tribes, public agencies, land trusts and other nongovernmental organizations to accomplish its stream restoration goals. The water trust works on small streams and tributaries where returning a small amount of water to the stream can have significant benefits. For more information, please visit www.thewatertrust.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 who live on or near Cottage Lake. They are currently involved in efforts to reduce nutrients in 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. Residents are welcome and encouraged to participate by visiting www.upperbearcreek.com/.

King County Executive Horse Council

The King County Executive Horse Council (KCEHC) 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 10 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. 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. T*he Green Horse* is sent electronically to over 800 subscribers and is also available on their web site at 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

Local businesses are responsible for taking actions to prevent pollution their activities may generate. Local businesses in turn can be partners in increasing public awareness on the local water quality issues in Bear and Evans Creeks. Private industries that rely on groundwater sources or surface water withdrawals for irrigation, such as nurseries and golf courses, are encouraged to use best stormwater management practices and to consider alternative water sources to improve baseflow conditions to the streams.

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 to neighboring creeks, the nutrient 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 enhance streamside riparian vegetation, minimize runoff of nonpoint sources of pollution from their yards, and repair of leaky on-site septics.

What is the schedule for achieving water quality standards?

Once EPA approves this TMDL, a *Water Quality Implementation Plan* (plan) will be developed within a year. This plan identifies specific tasks, responsible parties, and timelines for achieving clean water. The progress of the plan will be measured by (1) assessing the pollution control activities underway or completed and (2) direct measurement of water quality. The goal is for Bear and Evans Creeks to consistently meet the Washington State Water Quality Standards for temperature and dissolved oxygen during the critical period. Ecology anticipates that if state and local coordination proceed as expected, by 2050 the impaired stream segments within the watershed will meet the TMDL goal. Interim progress in stream temperature improvement is expected to be measurable by 2025 if near-term restoration projects are implemented on schedule.

Adaptive management

Compliance with state water quality standards for temperature and dissolved oxygen should be achieved by 2050. 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.

The *Water Quality Implementation Plan* will use an adaptive management approach to ensure the progress and overall success of this plan. Opportunities for adaptive management of the plan include conducting special inspections in identified source areas; evaluating effectiveness of best management practices (BMPs); modifying stream sampling frequency and/or locations; helping develop and fund water quality projects that address riparian restoration; groundwater recharge; and nutrient pollution; administering local educational initiatives; and other means of conforming management measures to current information on the temperature and dissolved oxygen problems.

As improvement measures and activities specified in the *Water Quality Implementation Plan* are successfully completed, those activities will be documented along with expected improvements in water quality. If the planned activities are not effective in improving stream temperatures and dissolved oxygen levels, the implementation activities 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 site-specific actions and the overall plan.

Monitoring progress

In order to gauge the progress of this TMDL implementation, Ecology will convene a meeting of municipal and community stakeholders no less than annually to share information on the state of water quality in Bear-Evans watershed and to report the status of implementation activities. Water quality data, trends (where applicable), regulatory changes, new and innovative concepts, and funding sources will be discussed to evaluate the overall status of the TMDL. Ecology will solicit input from the workgroup 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 for the development and implementation of monitoring programs through its annual Centennial Clean Water Fund.

The *Water Quality Implementation Plan* will describe the coordinated monitoring strategy. Compliance monitoring will be needed to track implementation progress and when water quality standards are believed to be achieved. Entities 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 BMPs are responsible for monitoring plant survival rates and maintenance of improvements, structures and fencing.

The *Water Quality Implementation Plan* will describe the coordinated monitoring strategy.

Potential funding sources

Table 21 describes several possible funding sources that may be available to implement activities necessary to correct water quality problems in Bear-Evans watershed. Ecology will work with stakeholders to prepare appropriate scopes of work for grant projects, assist with applying for grant opportunities as they arise, and will help grant applicants and other stakeholders in other ways to implement the TMDL.

Table 21. Possible funding opportunities to support implementation.

Sponsoring Entity	Funding Source	Uses to be Made of Funds
United States Environmental Protection Agency	Environmental Education Grants 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 www.ecy.wa.gov/programs/wq/funding Coastal Protection Fund (CPF) 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 in the TMDL process to address temperature, dissolved oxygen, as well as fecal coliform bacteria 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, Union Hill Water Association, 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 Temperature and Dissolved Oxygen 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 July 21 to August 22, 2008 and gave the public, including key stakeholders, a chance to review and provide feedback on the proposed final draft report. On August 11, 2008, Ecology hosted a public meeting at the Woodinville Public Library to share highlights from the temperature and dissolved oxygen TMDL study 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 include:

- Who will commit to do what.
- 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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Glossary and Acronyms

Anomalous: Deviating from the general or common order or type.

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

Char: Char (genus *Salvelinus*) are distinguished from trout and salmon by the absence of teeth in the roof of the mouth, presence of light colored spots on a dark background (trout and salmon have dark spots on a lighter background), absence of spots on the dorsal fin, small scales, and differences in the structure of their skeleton.

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.

Critical condition: When the physical, chemical, and biological characteristics of the receiving water environment interact with the effluent to produce the greatest potential adverse impact on aquatic biota and existing or designated water uses. For steady-state discharges to riverine systems, the critical condition may be assumed to be equal to the 7Q10 flow event unless determined otherwise by the Department of Ecology.

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.

Diel: Of, or pertaining to, a 24-hour period.

Diurnal: Of, or pertaining to, a day or each day; daily. (1) Occurring during the daytime only, as different from nocturnal or crepuscular, or (2) Daily; related to actions which are completed in the course of a calendar day, and which typically recur every calendar day (e.g., diurnal temperature rises during the day, and falls during the night).

Effective shade: The fraction of incoming solar shortwave radiation that is blocked from reaching the surface of a stream or other defined area.

Fecal coliform (FC): That portion of the Coliform group of bacteria which is present in intestinal tracts and feces of warm-blooded animals as detected by the product of acid or gas from lactose in a suitable culture medium within 24 hours at 44.5 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 unties per 100 milliliters of water (cfu/100 ml).

Hyporheic: The area under and along the river channel where surface water and groundwater meet.

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.

Load allocation (LA): 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.

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

Morphology: Shape (e.g., channel morphology).

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, stormwater, 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. This includes, but is not limited to, atmospheric deposition, surface water runoff from agricultural lands, urban areas, or forest lands, subsurface or underground sources, or discharges from boats or marine vessels not otherwise regulated under the NPDES. 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.

N:P ratio: Ratio of nitrogen to phosphorus, a value calculated by dividing dissolved inorganic nitrogen (ammonium-N and nitrate-N) concentration by inorganic phosphorus concentration.

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

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

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

Salmonid: Salmonids are any fish that belong to the family Salmonidae – basically, any species of salmon, trout, or char.

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.

System potential: The design condition used for TMDL analysis.

S**ystem potential mature riparian vegetation:** Vegetation which can grow and reproduce on a site, given climate, elevation, soil properties, plant biology, and hydrologic processes.

System potential temperature: An approximation of the temperatures that would occur under natural conditions. System potential is our best understanding of natural conditions that can be supported by available analytical methods. The simulation of the system potential condition uses best estimates of *mature riparian vegetation, system potential channel morphology, and system potential riparian microclimate* that would occur absent any human alteration.

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 (WLA): 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.

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.

7-DADMax or 7-day average of the daily maximum temperatures: The arithmetic average of seven consecutive measures of daily maximum temperatures. The 7-DADMax for any individual day is calculated by averaging that day's daily maximum temperature with the daily maximum temperatures of the three days prior and the three days after that date.

7Q10 flow: A critical low-flow condition. The 7Q10 is a statistical estimate of the lowest 7-day average flow that can be expected to occur once every ten years on average. The 7Q10 flow is commonly used to represent the critical flow condition in a water body and is typically calculated from long-term flow data collected in each basin. For temperature TMDL work, the 7Q10 is usually calculated for July and August as these typically represent the critical months for temperature in our state.

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

Acronyms and Abbreviations

Following are acronyms and abbreviations used frequently in this report.

7-DADMax	7-day average daily maximum
AFDW	ash free dry weight
BMP	best management practices
CBOD	carbonaceous biological oxygen demand
cfs	cubic feet per second
DHM	Digital Height Model
DO	dissolved oxygen
EIA	effective impervious area
EIM	Environmental Information Management (Ecology)
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
GIS	Geographic Information System software
KCEL	King County Environmental Laboratory
LID	low impact development
LiDAR	light detection and ranging
MEL	Manchester Environmental Laboratory (Ecology)
NESSWD	Northeast Sammamish Sewer and Water District
NIST	National Institute of Standards and Technology
NPDES	National Pollutant Discharge Elimination System
QAPP	Quality Assurance Project Plan
RH2	RH2 Engineering
RM	river mile
RMSE	root mean squared error

RSD	relative standard deviation
TMDL	Total Maximum Daily Load (water cleanup plan)
USGS	U.S. Geological Survey
WAC	Washington Administrative Code
WQ	water quality
WRIA	Water Resources Inventory Area

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Appendices

Appendix A – Field Sampling Locations, Summer 2006
Appendix B – Continuous Temperature and Relative Humidity Results
Appendix C – Continuous YSI data: Dissolved Oxygen, pH, Conductivity, and Temperature
Appendix D – Synoptic Productivity Survey Results
Appendix E – Synoptic Flow and Travel Time
Appendix F – King County Ambient Groundwater Data for the Bear-Evans Basin
Appendix G – Calibrated QUAL2Kw Rate Parameters
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Appendix A. Field Sampling Locations, Summer 2006

Table A-1. Sampling station IDs, descriptions, coordinates, and data collected.

Station	Location Description	NAD83 Latitude	NAD83 Longitude	Cont. Water Temp.	Cont. Air Temp.	Cont. Relative Humidity	Cont. Hydrolab	Synoptic Survey	Winkler DO	Instream Flow
Bear Creek and Tributaries										
08BEAR11.0	Bear Creek east of 204th Ave	47.765478 ˚N	122.061861 ˚W	X	X	X	X	X	X	X
08BEAR10.1	Bear Creek at Woodinville Duvall Rd	47.754734 ˚N	122.055456 ˚W	X	X					X
08EFBEAR00.1	East fork of Bear Creek	47.752241 ˚N	122.053037 ˚W	X						X
08BEAR08.1	Bear Creek at Tolt Pipeline Trail off 148th	47.735965 ˚N	122.066857 ˚W	X	X		X	X	X	X
08STRU00.2	Struve Creek near mouth	47.733365 ˚N	122.063398 ˚W	X			X	X	X	X
08BEAR06.5	Bear Creek at x-ing with NE 133rd St	47.717667 ˚N	122.077046 ˚W	X	X					X
08SEID00.1	Seidel Creek at 198th Ave NE	47.717473 ˚N	122.075643 ˚W	X				X		X
08BEAR05.4	Bear Creek east of Avondale	47.710562 ˚N	122.089501 ˚W	X	X		X	X	X	X
08TRIB-BE(04.5)	Tributary near Avondale & NE 116th St	47.703518 ˚N	122.093031 ˚W	X	X					X
08TRIB-BE(03.9)	Tributary at Essex Park	47.696630 ˚N	122.093410 ˚W	X						
08BEAR03.7	Bear Creek at NE 106th St	47.694108 ˚N	122.091793 ˚W	X	X					X
08MACK00.0	Mackey Creek near mouth	47.694080 ˚N	122.091166 ˚W	X				X		X
08BEAR02.8	Bear Creek at NE 95th St	47.685595 ˚N	122.088891 ˚W	X	X					X
08COLDW00.1	Coldwater Creek at trail crossing, off NE 95th St	47.684687 ˚N	122.088594 ˚W	X				X		X
08BEAR02.1	Bear Creek upstream of Evans confluence	47.678812 ˚N	122.093328 ˚W	X	X	X		X		X
08BEAR02.0	Bear Creek downstream of Evans confluence	47.678490 ˚N	122.093550 ˚W	X						
08TRIB-BE(01.4)	Tributary known locally as Perrigo Creek	47.676340 ˚N	122.105760 ˚W	X						
08BEAR01.3	Bear Creek at King County Gage 02a	47.675094 ˚N	122.107255 ˚W	X						
08BEAR00.9	Bear Creek near mouth at smolt trap	47.669608 ˚N	122.110077 ˚W	X	X					X
08BEAR00.3	Bear Creek near mouth	47.667400 ˚N	122.120320 ˚W	X						
Cottage Lake Creek and Tributaries										
08DAN01.5	Daniels Creek at NE 195th St	47.768426 ˚N	122.104722 ˚W	X	X					X
08COTT03.3	Cottage Lake Creek at NE 165th St	47.746974 ˚N	122.094107 ˚W	X			X	X	X	
08COTT02.7	Cottage Lake Creek at NE 159th St	47.742658 ˚N	122.084111 ˚W							X
08COTT02.2	Cottage Lake Creek at Tolt pipeline trail	47.736617 ˚N	122.079457 ˚W	X	X					X
08COTT00.4	Cottage Lake Creek at 128th St	47.715205 ˚N	122.090361 ˚W	X			X	X	X	X

Station	Location Description	NAD83 Latitude	NAD83 Longitude	Cont. Water Temp.	Cont. Air Temp.	Cont. Relative Humidity	Cont. Hydrolab	Synoptic Survey	Winkler DO	Instream Flow
Evans Creek and Tributaries										
08EVAN07.2	Evans Creek at 238th Ave	47.665798 ˚N	122.021651 ˚W	X	X			X		X
08EVAN05.5	Evans Creek at Hwy 202 fish ladder, mile 12	47.644880 ˚N	122.030672 ˚W	X	X		X	X	X	X
08TRIB-EV(05.3)	Tributary off logging road	47.639030 ˚N	122.024352 ˚W	X	X					X
08EVAN04.7	Evans Creek at wetland 22 outlet	47.643895 ˚N	122.040736 ˚W	X						
08EVAN04.3	Evans at NE 44th St off 220th Ave	47.648279 ˚N	122.047397 ˚W	X	X	X	X	X	X	X
08RUTH00.0	Rutherford Creek near mouth at Hwy 202, mile 11	47.651473 ˚N	122.047399 ˚W	X						
08RUTH00.1	Rutherford Creek at mouth	47.650796 ˚N	122.049724 ˚W	X	X		X	X		X
08EVAN03.2	Evans Creek at Sahalee Way	47.657326 ˚N	122.062831 ˚W	X						
08EVAN02.3	Evans Creek at 196th (south); just south of Hwy 202	47.655646 ˚N	122.078768 ˚W	X	X					X
08EVAN01.7	Evans Creek at 196th; just north of 61st St	47.663186 ˚N	122.079081 ˚W				X	X		
08EVAN01.2	Evans Creek at 196th (north)	47.66994 ˚N	122.079056 ˚W	X					X	X
08TRIB-EV(01.1)	Tributary near Evans at 196th (north)	47.670732 ˚N	122.07899 ˚W	X						X
08EVAN00.8	Evans Creek at Union Hill Rd	47.674960 ˚N	122.080990 ˚W	X						
08EVAN00.4	Evans Creek behind Supply Co.	47.678987 ˚N	122.088182 ˚W	X						
08EVAN00.0	Evans Creek at mouth	47.678694 ˚N	122.093055 ˚W	X			X	X	X	X

Cont. – continuous
Temp. – temperature

Appendix B. Continuous Temperature and Relative Humidity Results

Note: For printed copies, the following figures can be viewed in color online at www.ecy.wa.gov/biblio/0810058.html.

7-Day Average Daily Maximum of Water Temperature

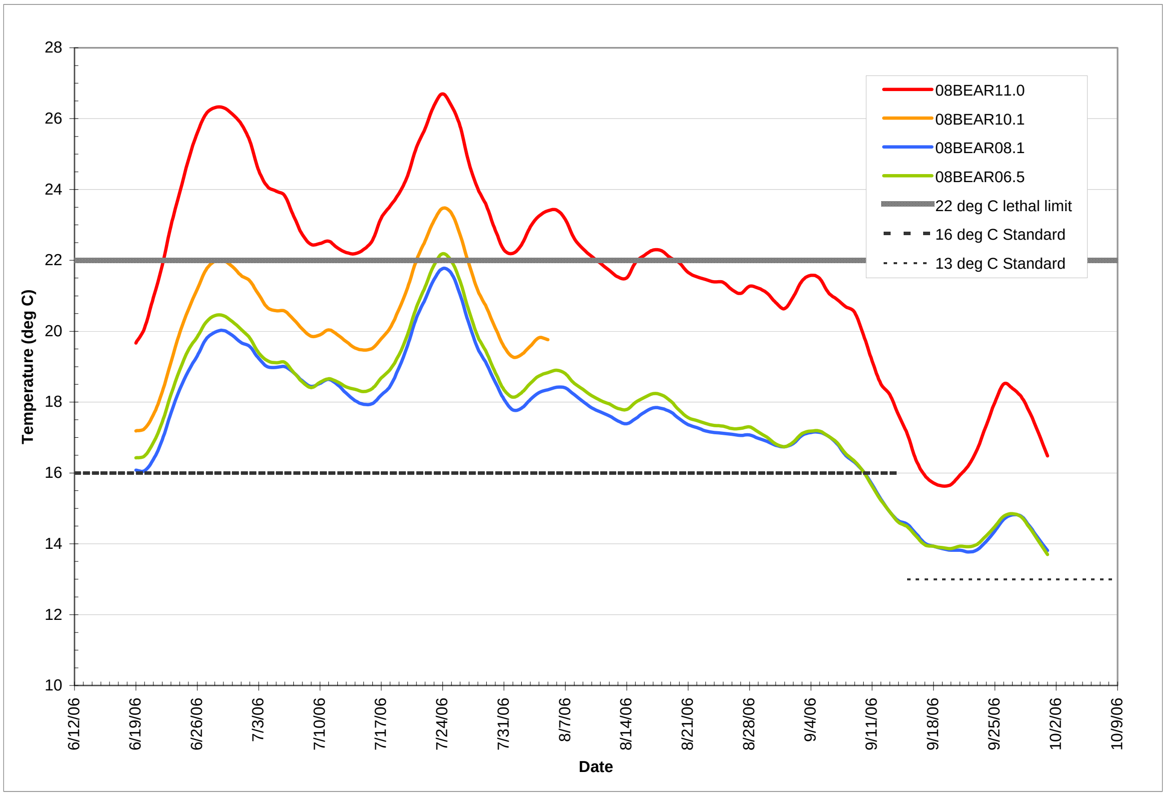

Figure B-1. Upper Bear Creek 7-DADMax of water temperature.

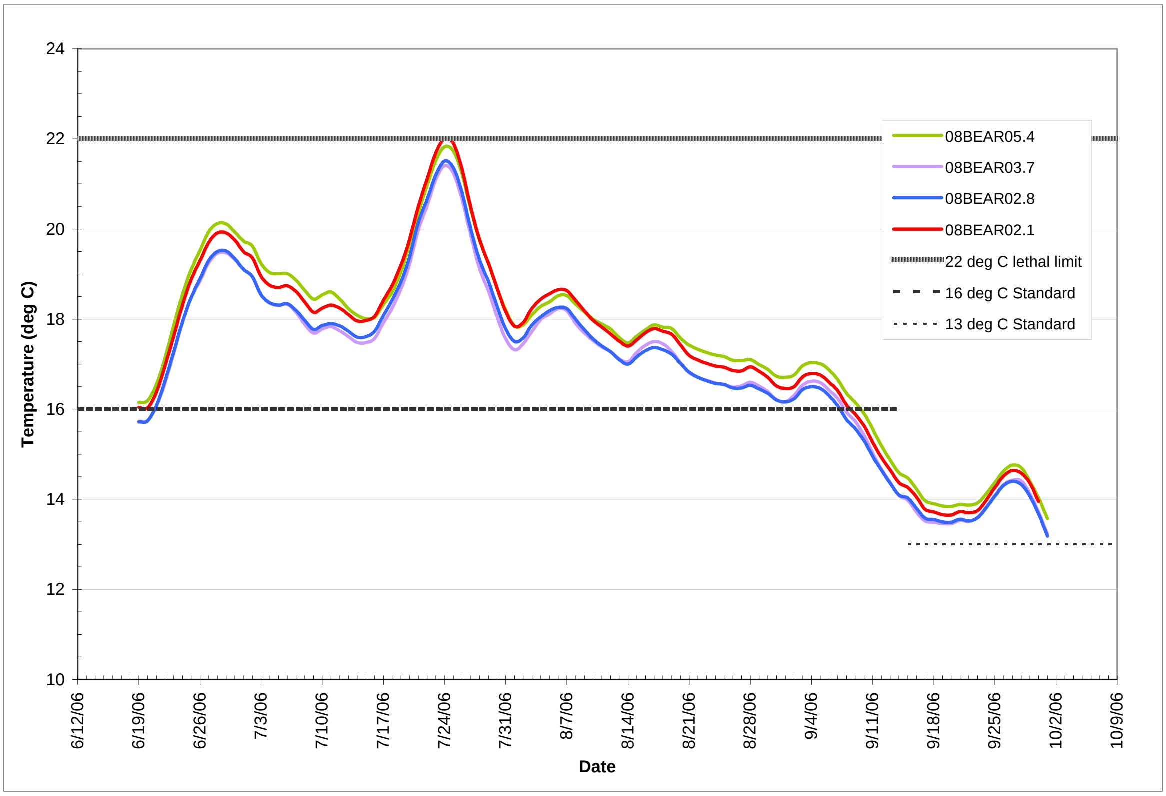

Figure B-2. Middle Bear Creek 7-DADMax of water temperature.

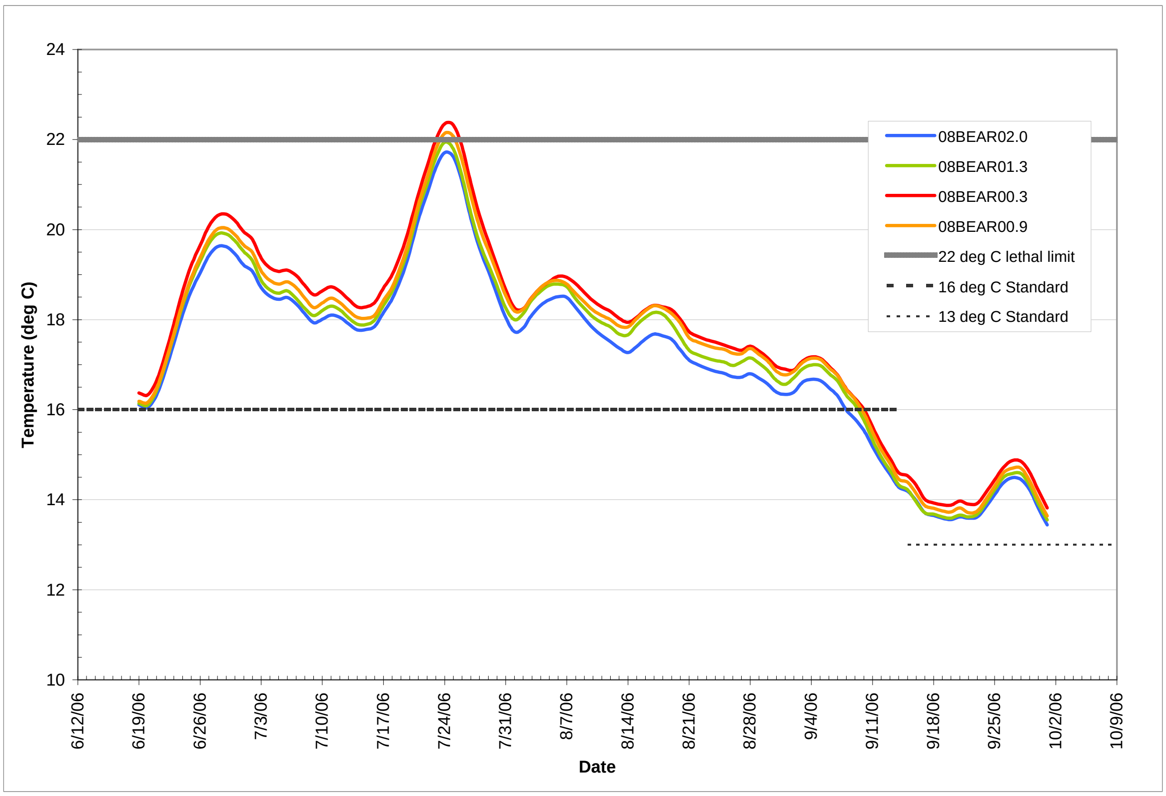

Figure B-3. Lower Bear Creek 7-DADMax of water temperature.

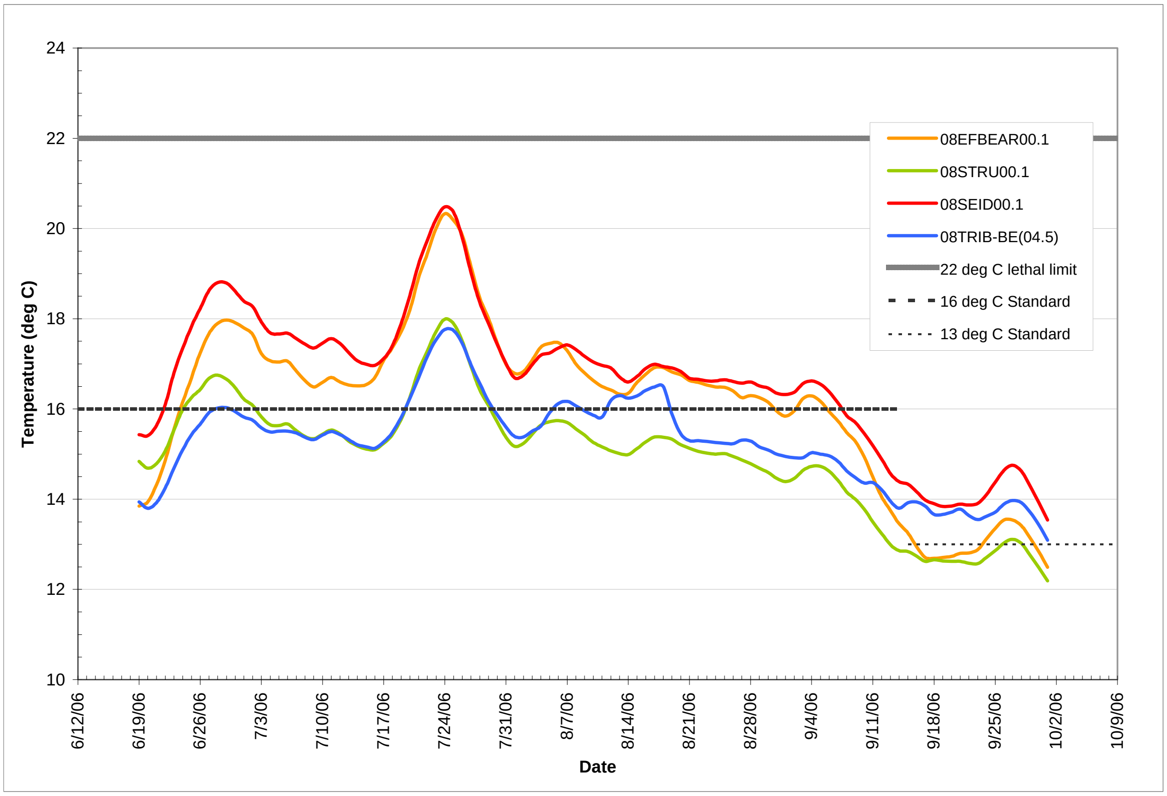

Figure B-4. Upper Bear Creek tributaries 7-DADMax of water temperature.

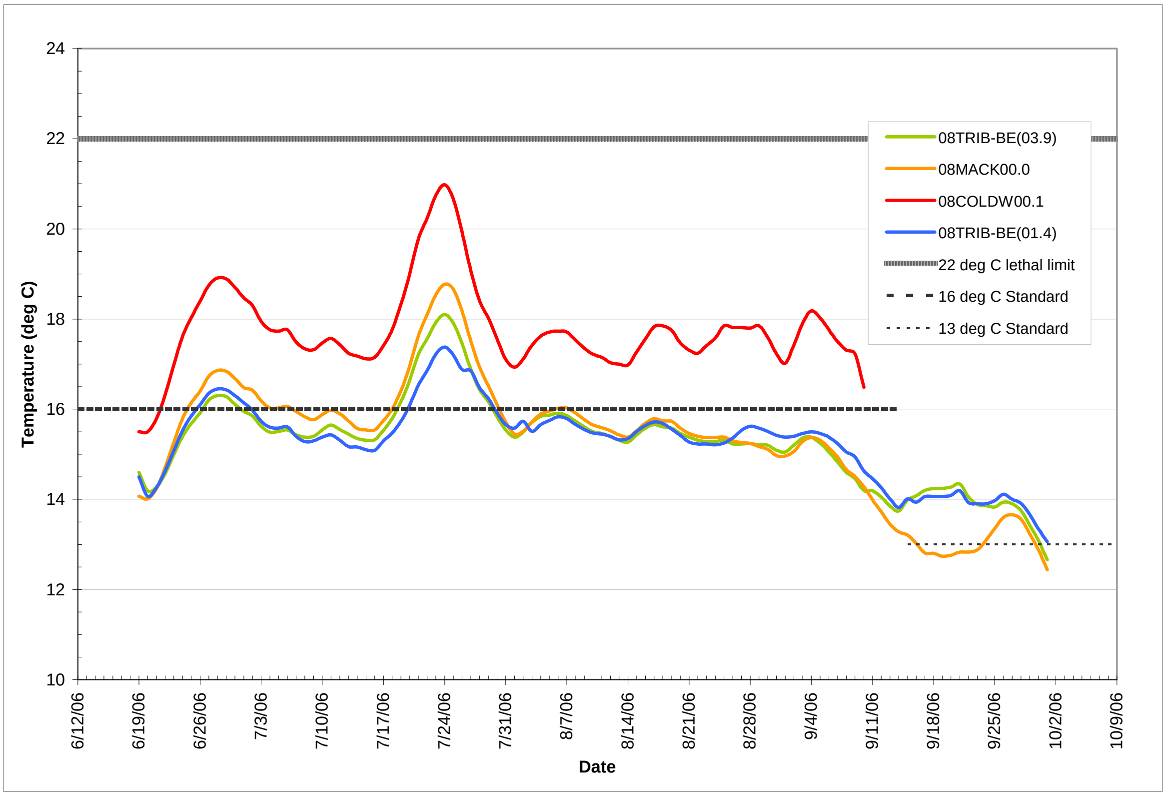

Figure B-5. Lower Bear Creek tributaries 7-DADMax of water temperature.

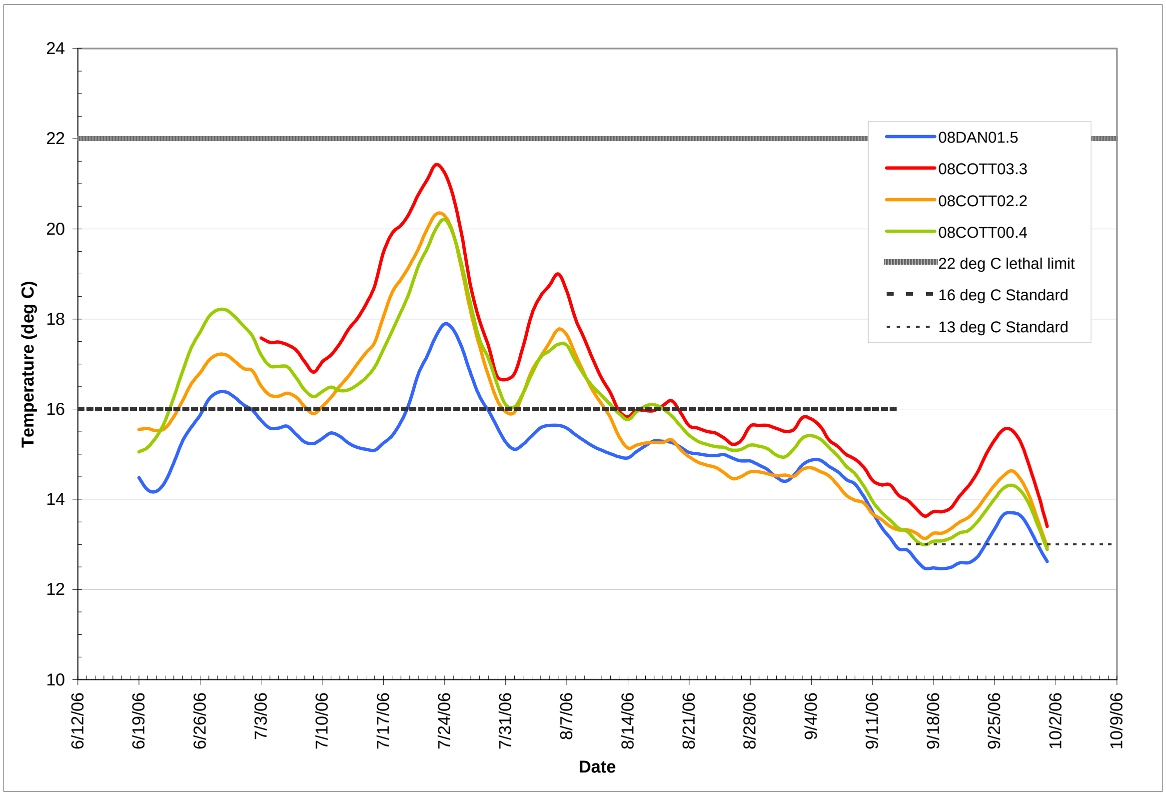

Figure B-6. Daniels and Cottage Creek 7-DADMax of water temperature.

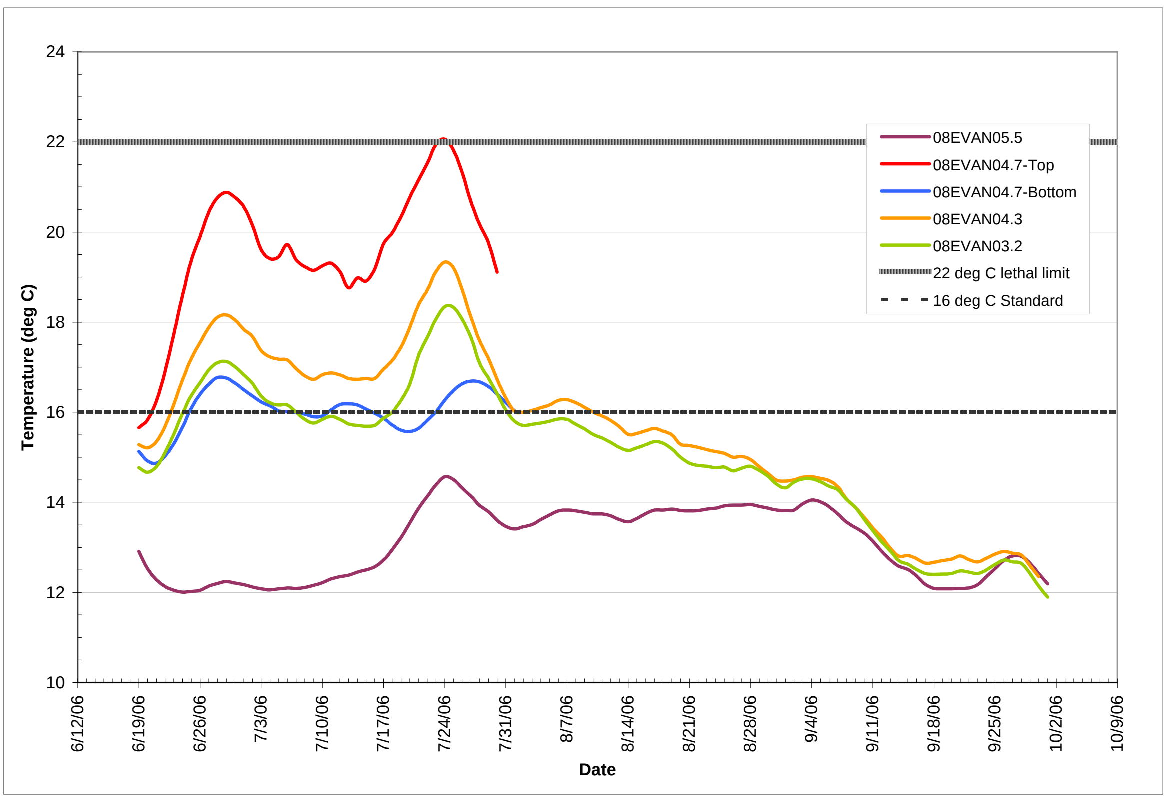

Figure B-7. Upper Evans Creek 7-DADMax of water temperature.

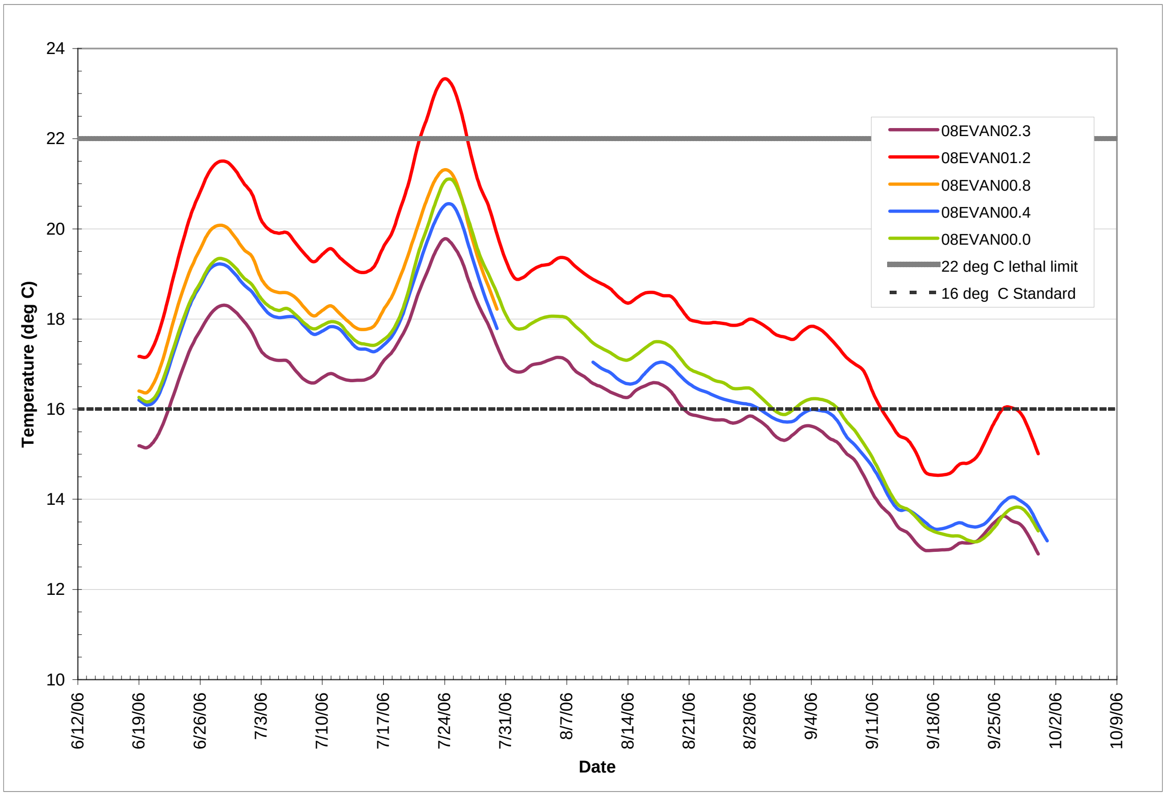

Figure B-8. Lower Evans Creek 7-DADMax of water temperature.

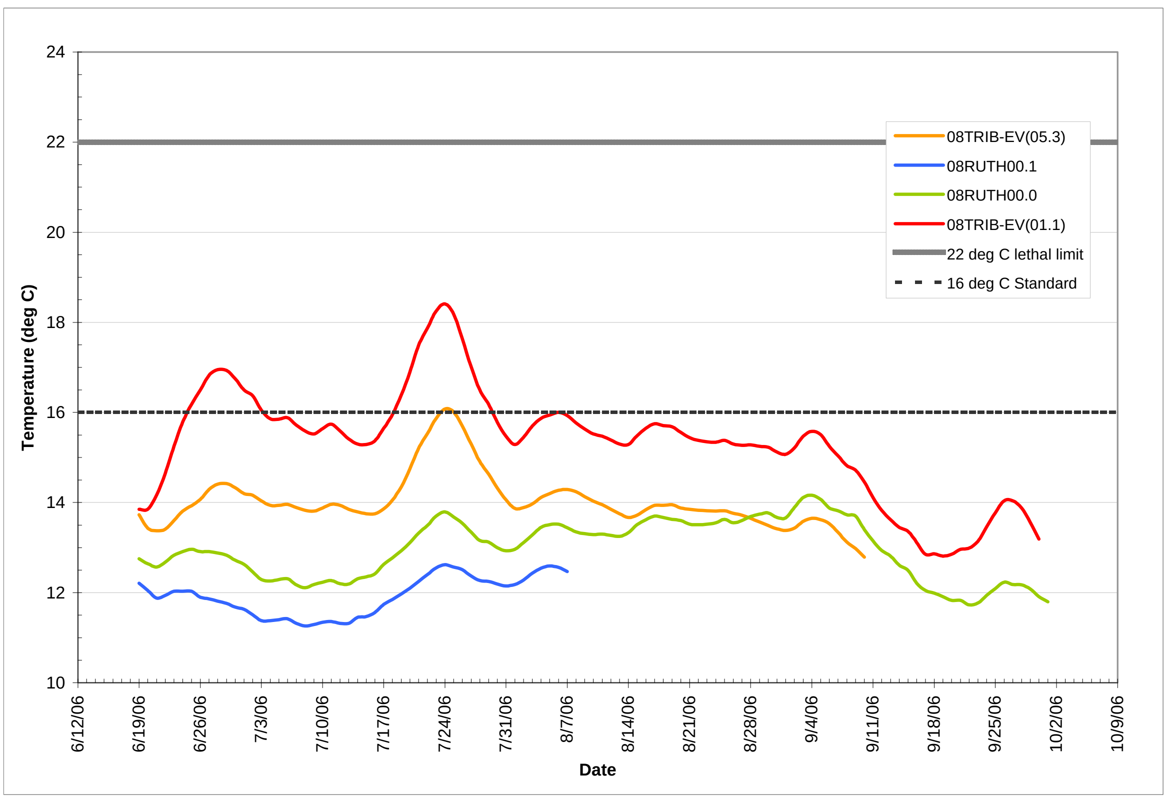

Figure B-9. Evans Creek tributaries 7-DADMax of water temperature.

Comparison between Ecology and RH2 Continuous 30-minute water temperature data

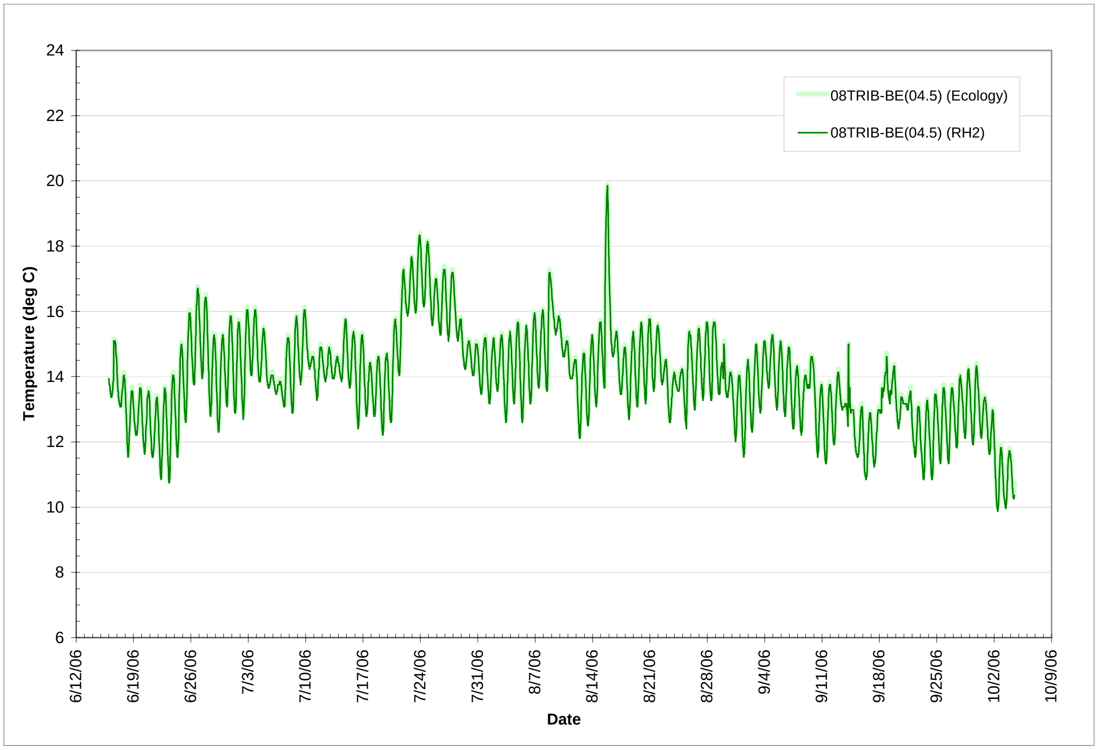

Figure B-10. Continuous 30-minute water temperature data collected by Ecology and RH2 (to compare data comparability) for a tributary to Bear Creek at RM 04.5.

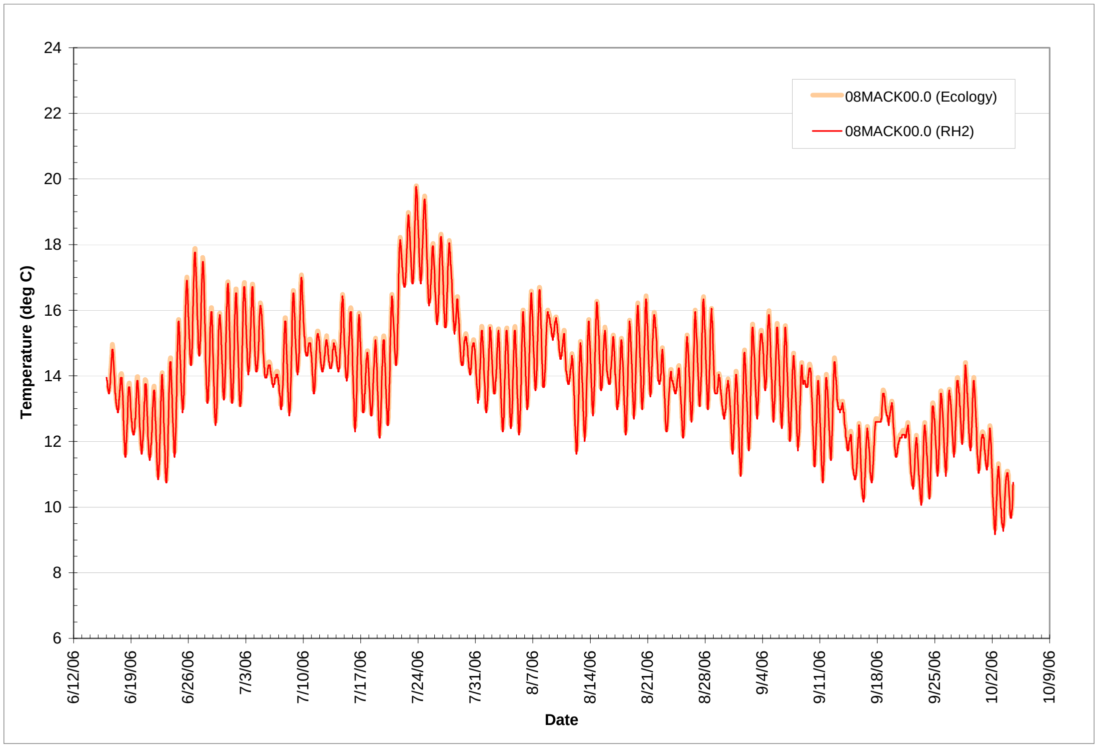

Figure B-11. Continuous 30-minute water temperature data collected by Ecology and RH2 (to compare data comparability) for Mackey Creek.

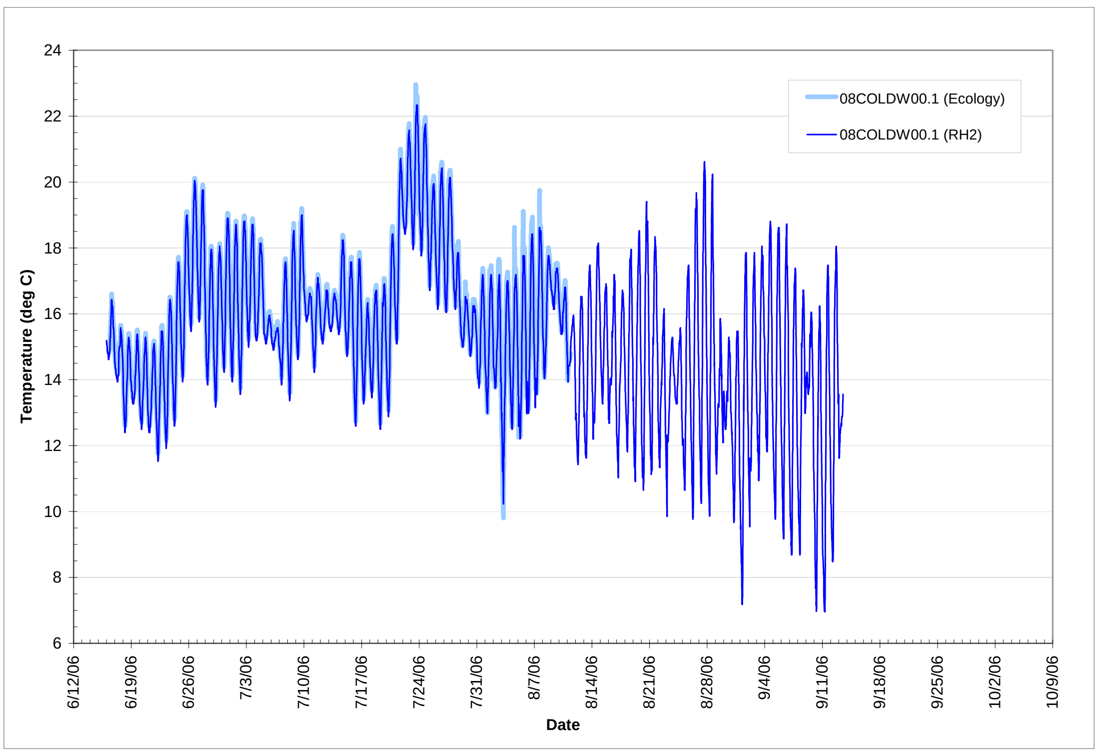

Figure B-12. Continuous 30-minute water temperature data collected by Ecology and RH2 (to compare data comparability) for Coldwater Creek.

7-Day Average Daily Maximum of Air Temperature

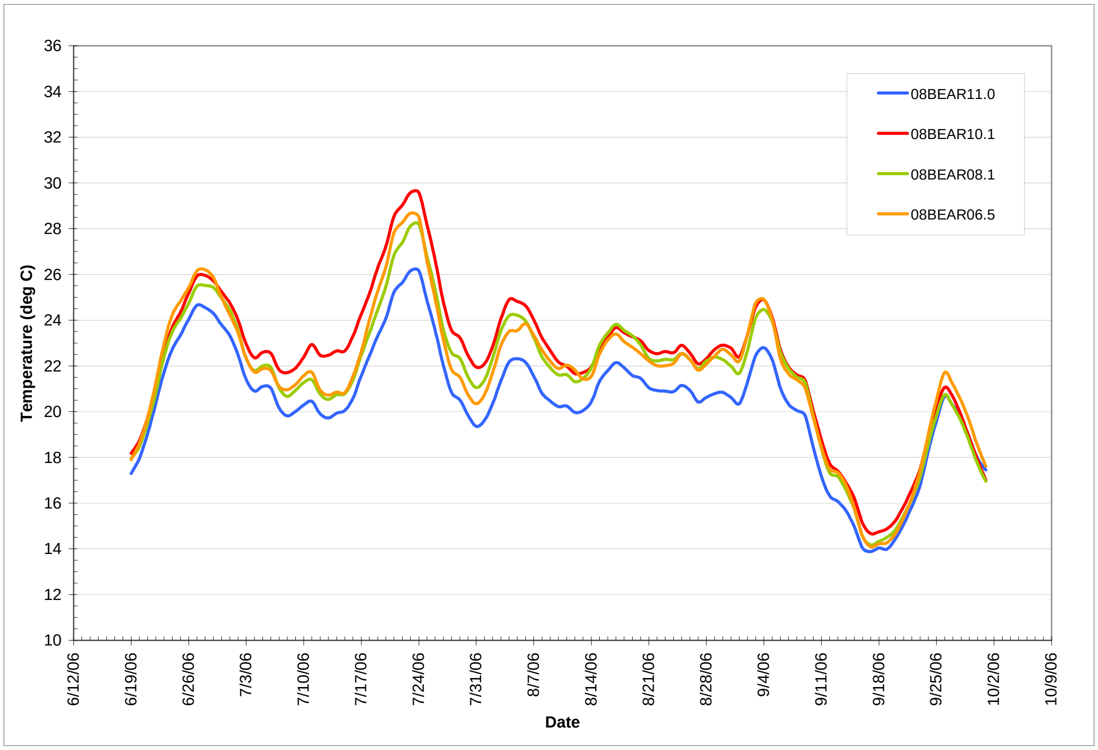

Figure B-13. Upper Bear Creek 7-DADMax of air temperature.

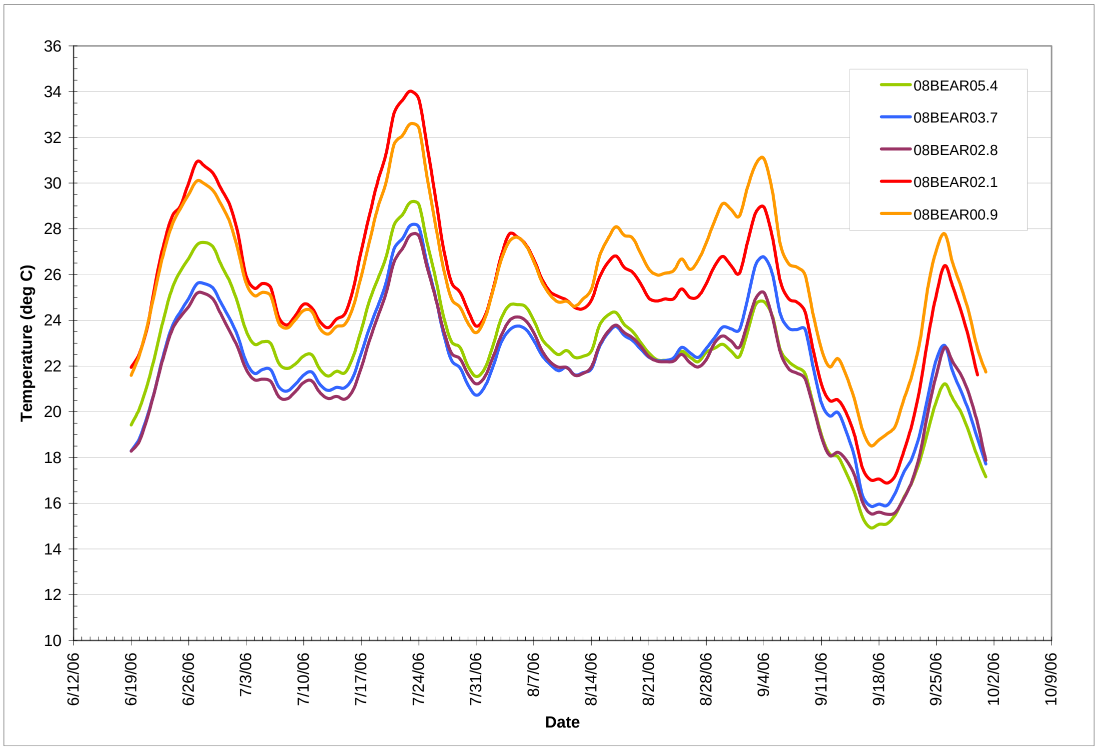

Figure B-14. Lower Bear Creek 7-DADMax of air temperature.

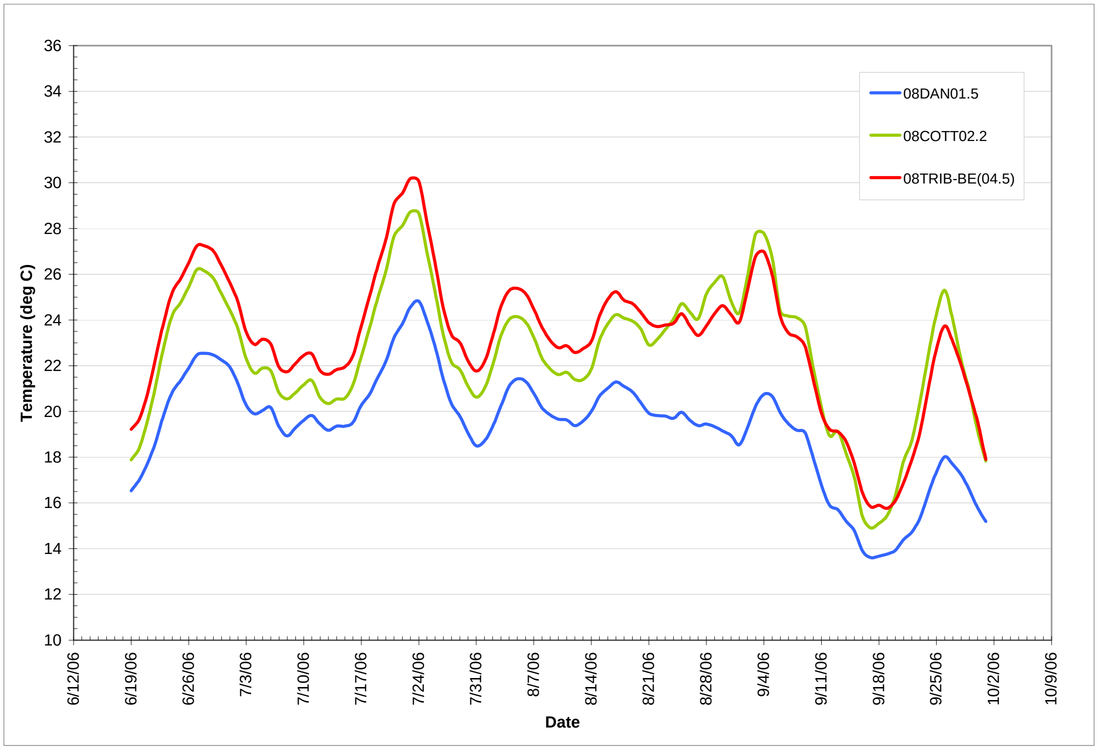

Figure B-15. Bear Creek tributaries 7-DADMax of air temperature.

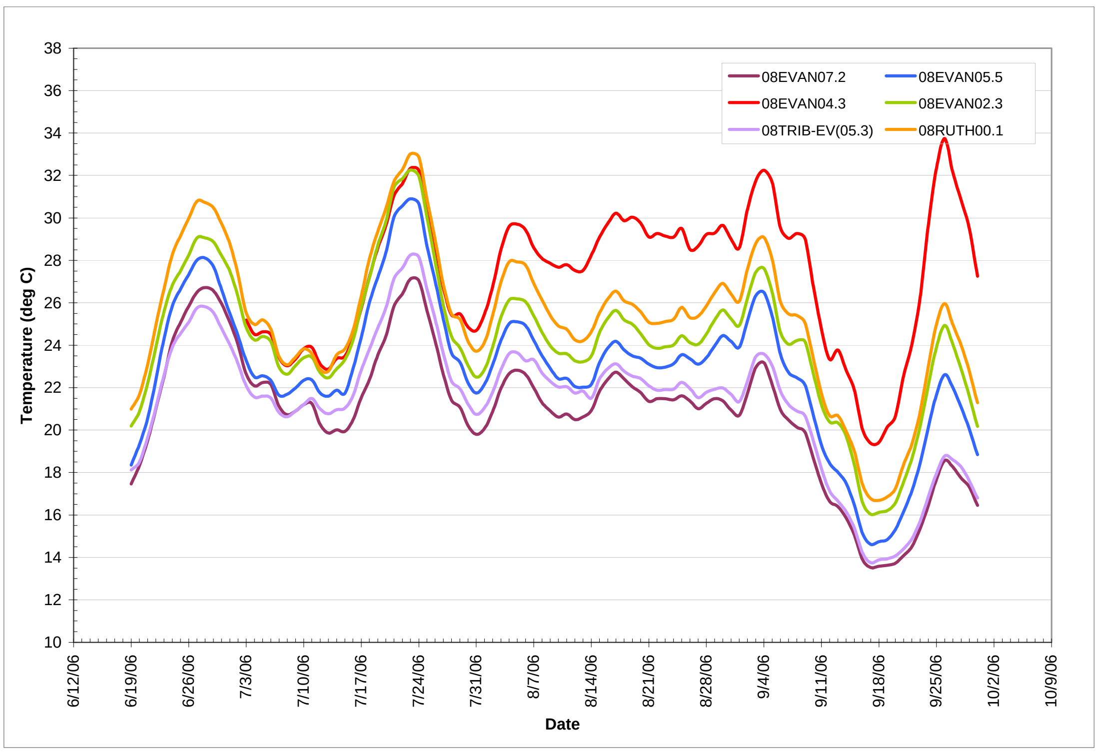

Figure B-16. Evans Creek and tributaries 7-DADMax of air temperature.

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Appendix C. Continuous YSI® data: Dissolved Oxygen, pH, Conductivity, and Temperature

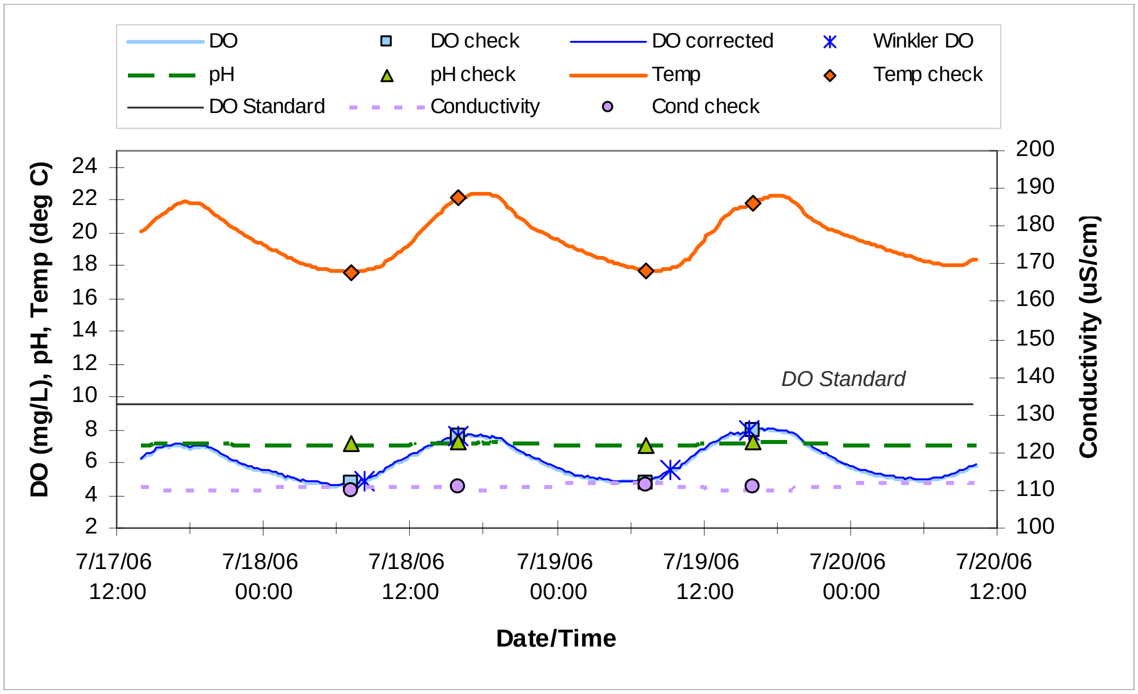

Figure C-1. Continuous 15-minute multi-parameter YSI® data for 08BEAR11.0.

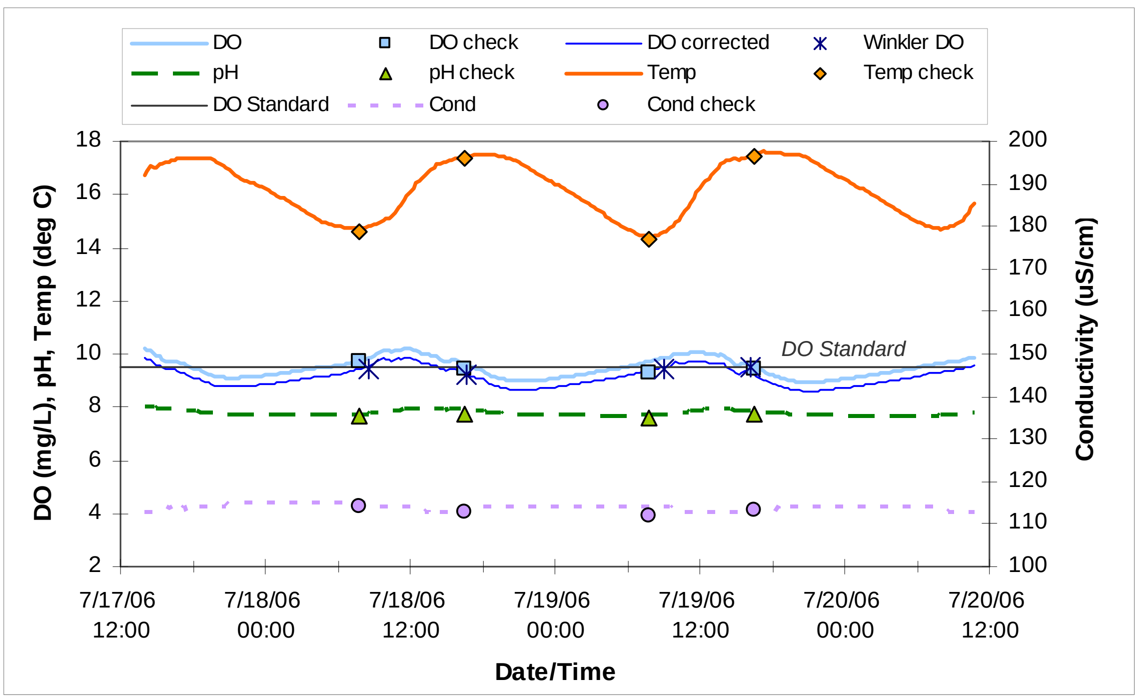

Figure C-2. Continuous 15- minute multi-parameter YSI® data for 08BEAR08.1.

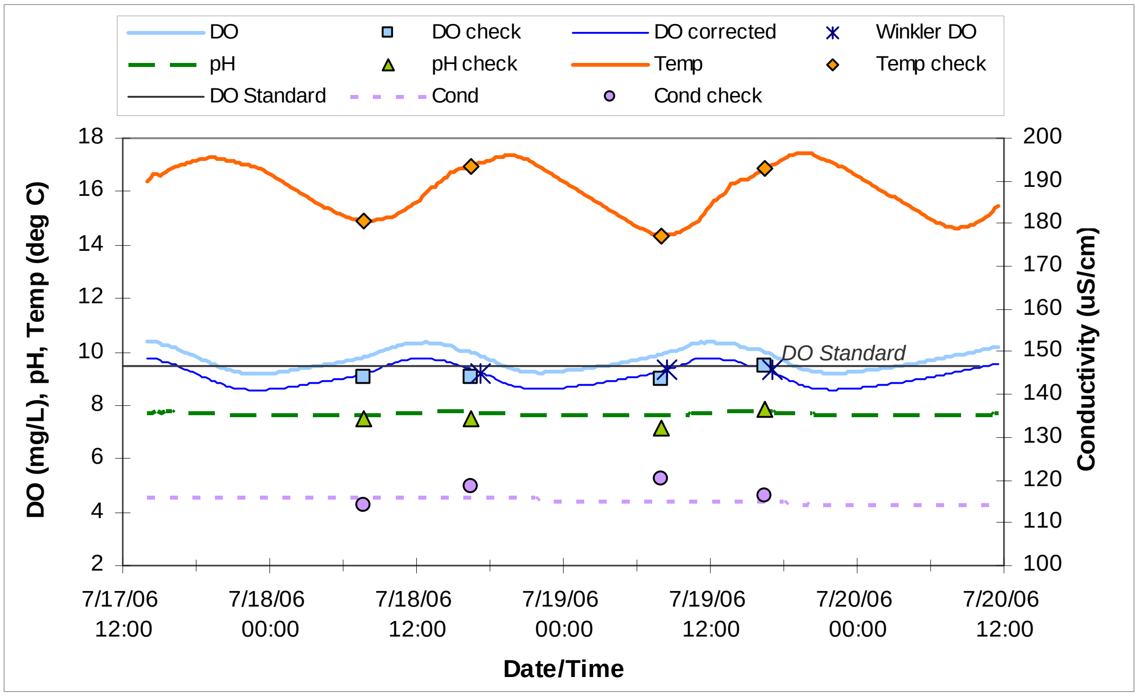

Figure C-3. Continuous 15- minute multi-parameter YSI® data for 08BEAR05.4.

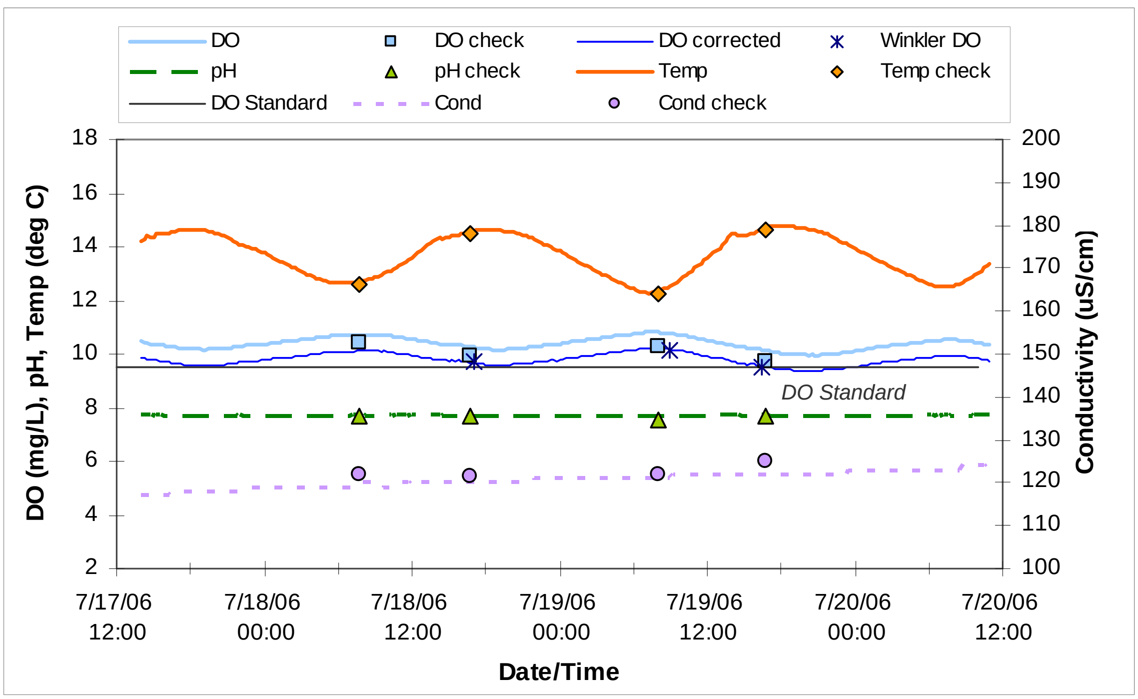

Figure C-4. Continuous 15- minute multi-parameter YSI® data for 08STRU00.2.

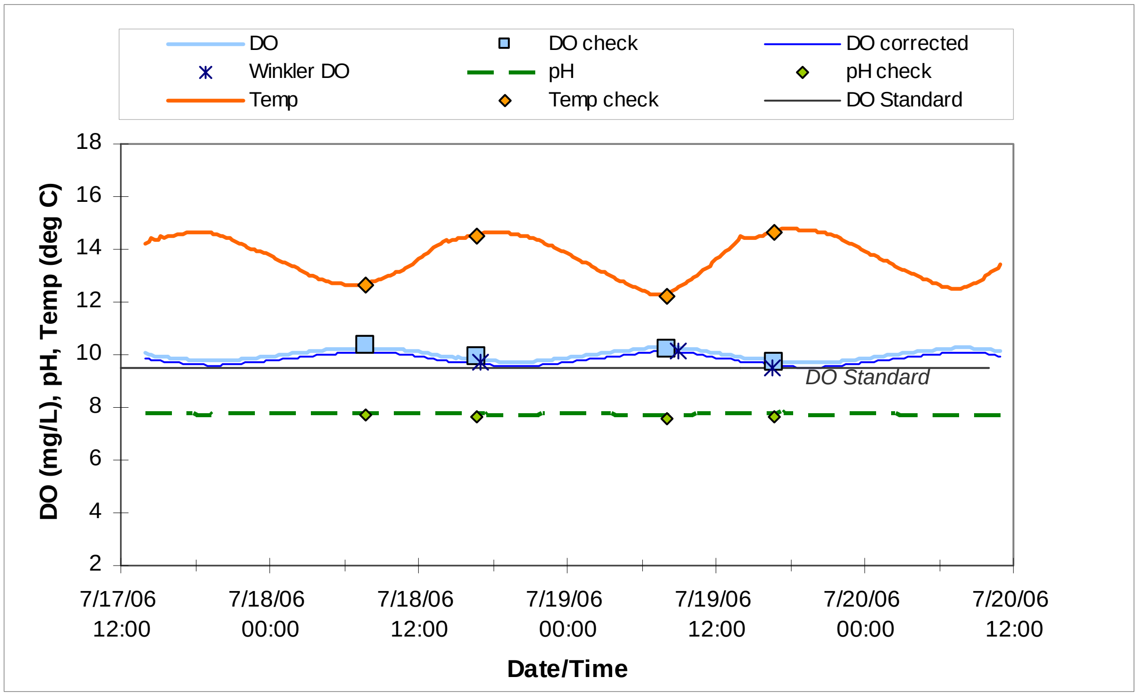

Figure C-5. Continuous 15- minute multi-parameter replicate YSI® data for 08STRU00.2.

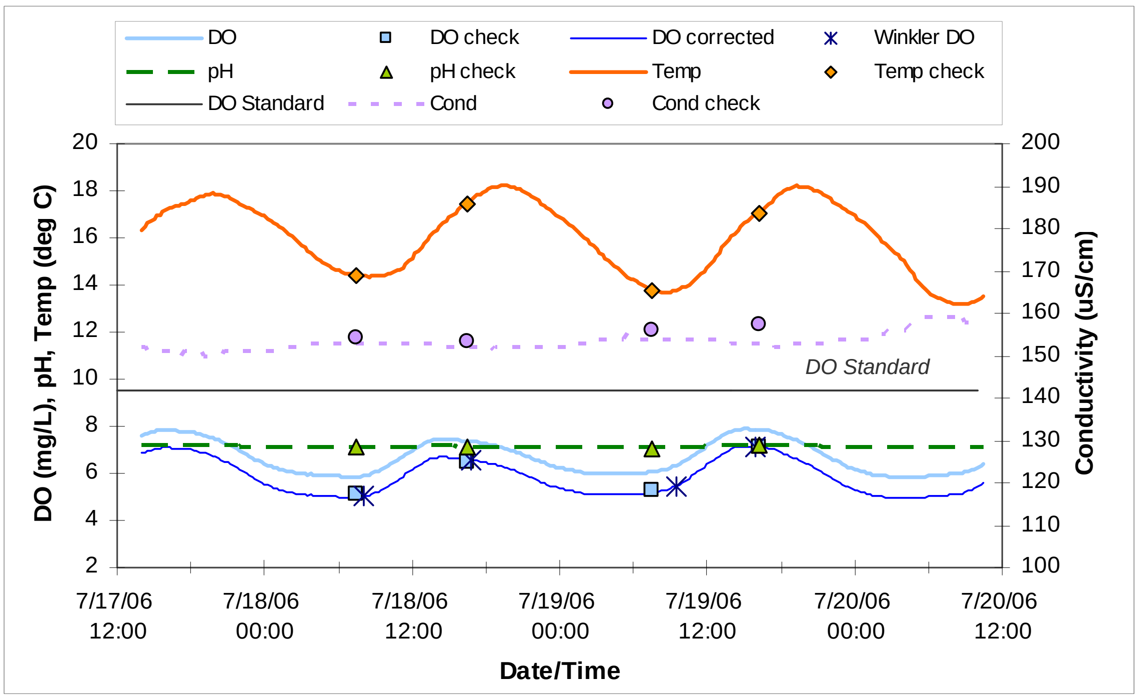

Figure C-6. Continuous 15- minute multi-parameter YSI® data for 08COTT03.3.

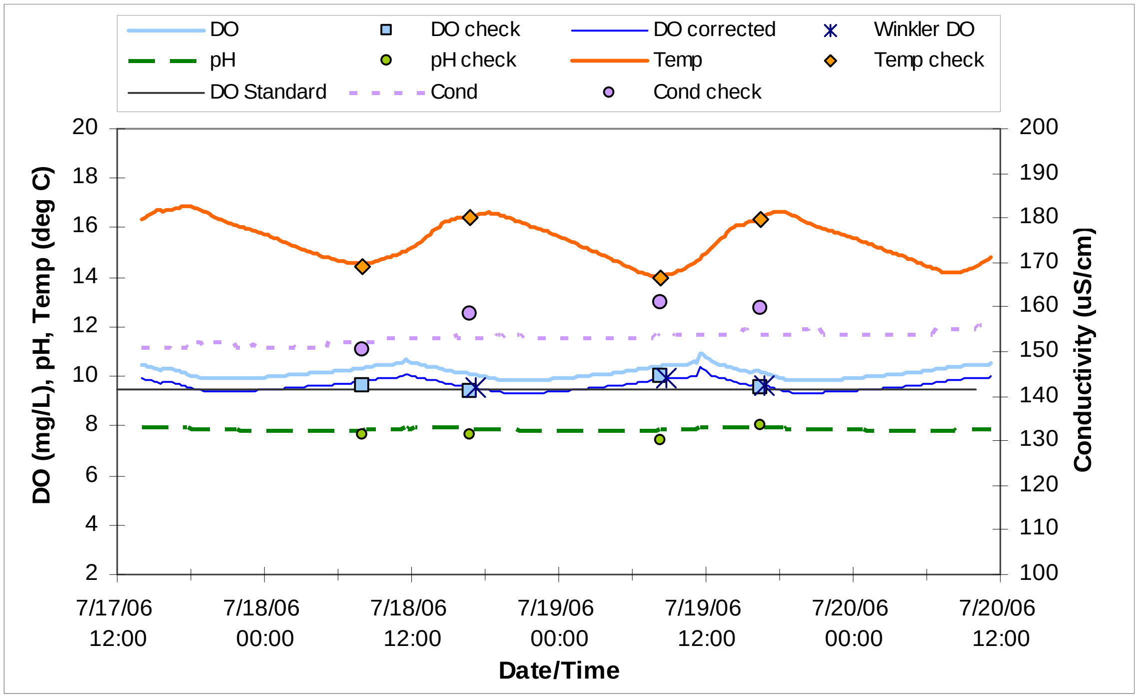

Figure C-7. Continuous 15-minute multi-parameter YSI® data for 08COTT00.4.

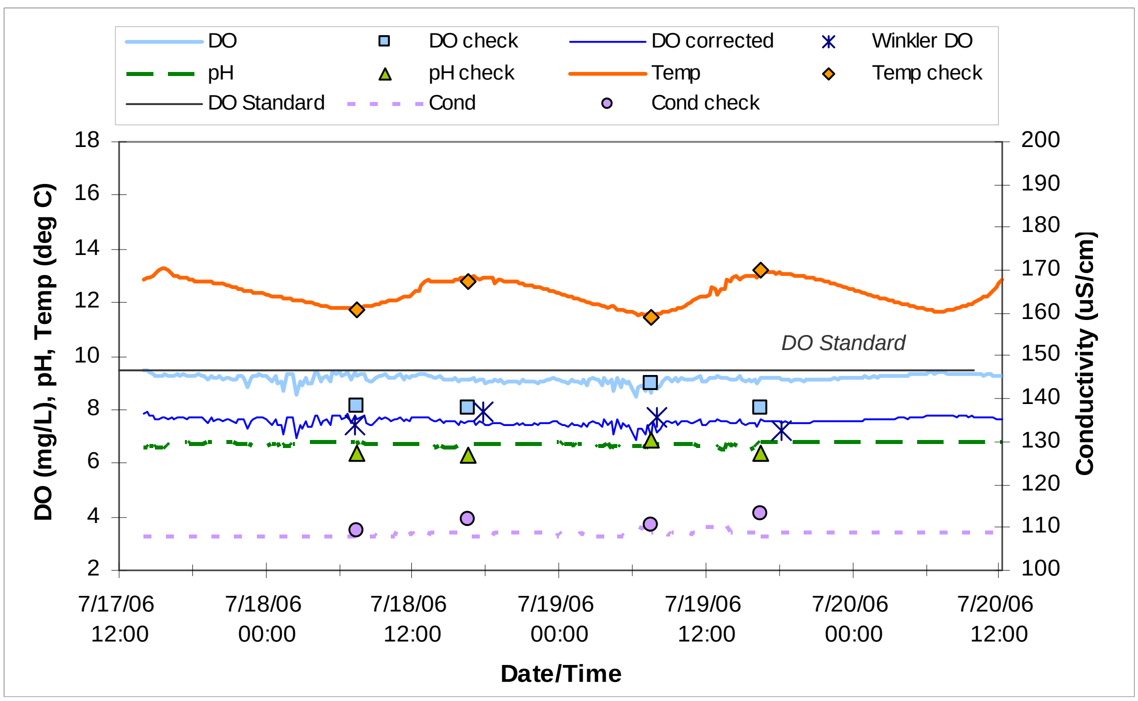

Figure C-8. Continuous 15-minute multi-parameter YSI® data for 08EVAN05.5.

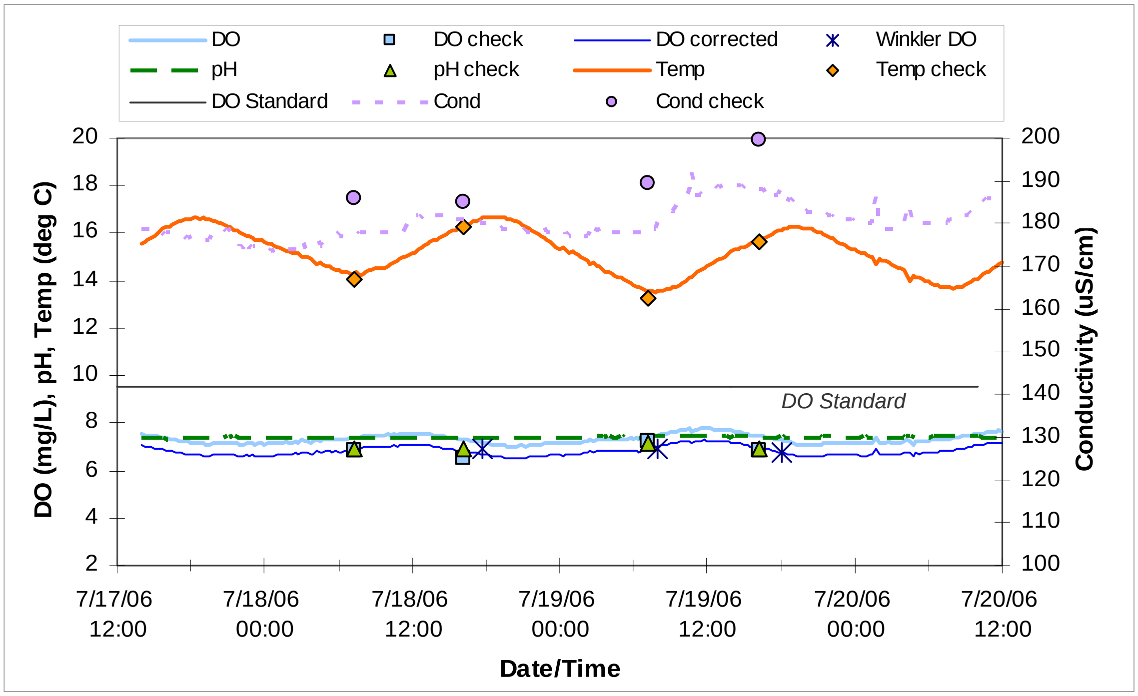

Figure C-9. Continuous 15-minute multi-parameter YSI® data for 08EVAN04.3.

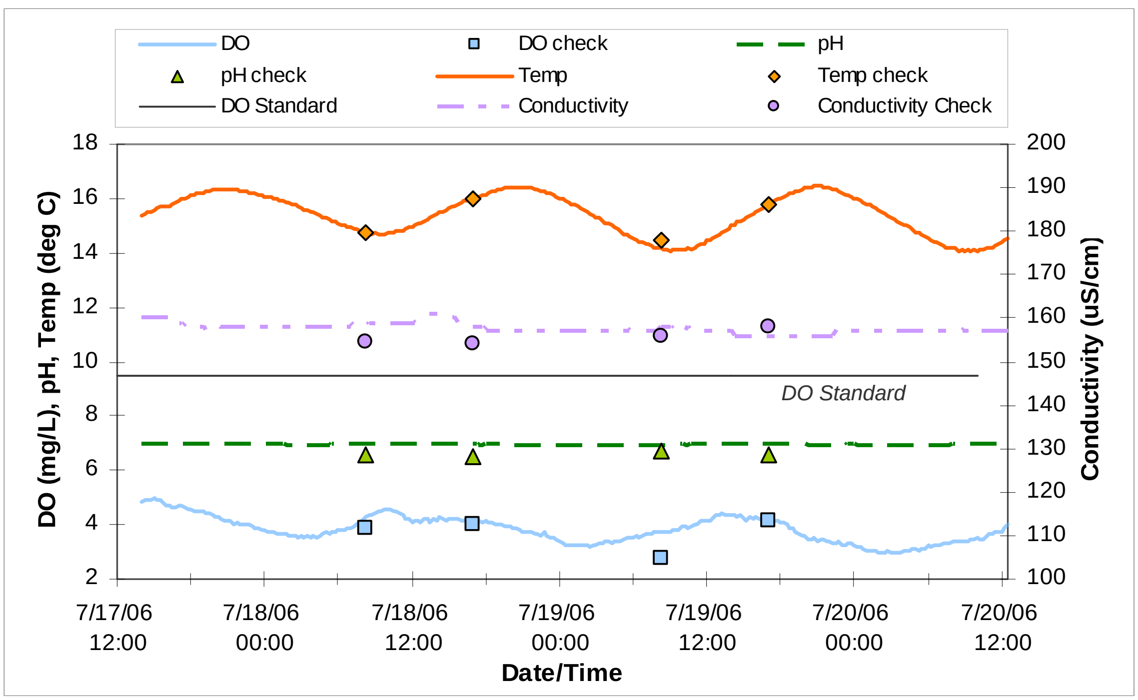

Figure C-10. Continuous 15-minute multi-parameter YSI® data for 08EVAN01.7.

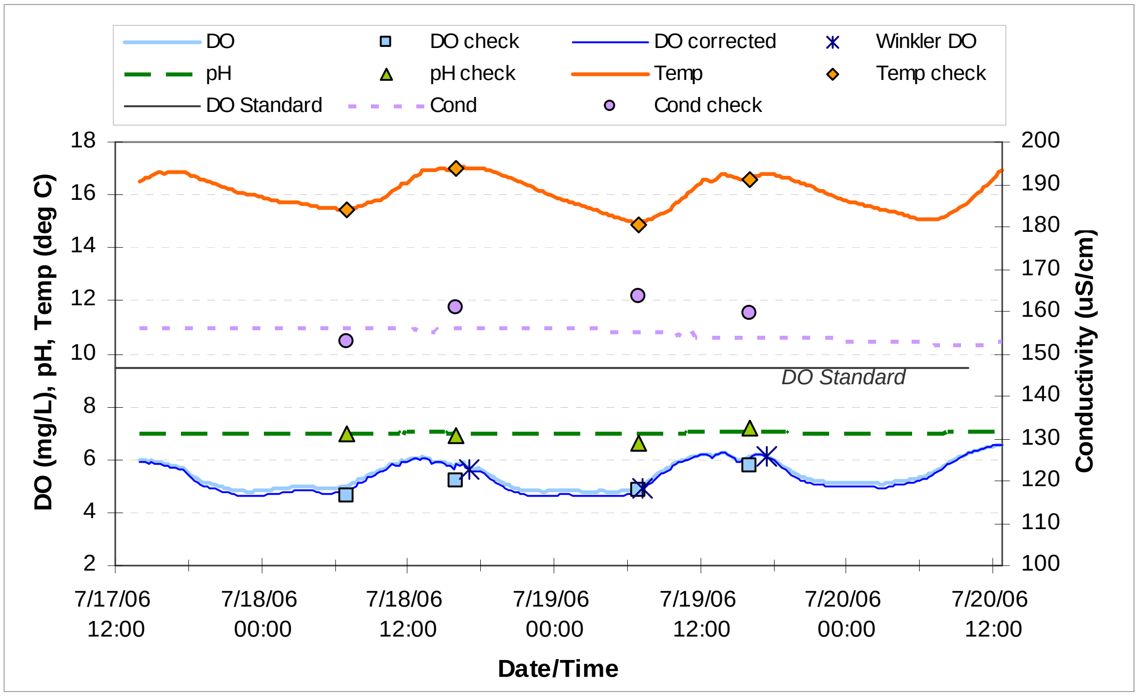

Figure C-11. Continuous 15-minute multi-parameter YSI® data for 08EVAN00.0.

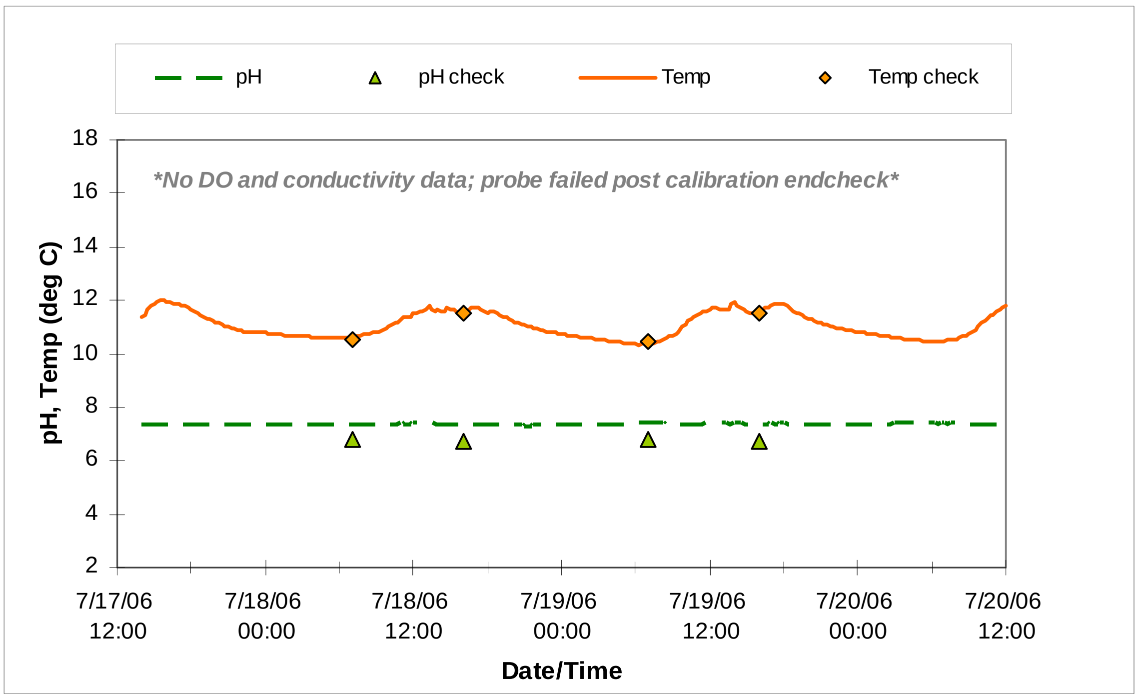

Figure C-12. Continuous 15-minute multi-parameter YSI® data for 08RUTH00.1.

Appendix D. Synoptic Productivity Survey Results

Table D-1. Nutrient data collected by King County in the morning and afternoon on July 18 and 19, 2006.

ECY STATION	TIME	REP.	ALK (mg/L)	TPN (mg/L)	NH_3 (mg/L)		NO_2NO_3 (mg/L)		TP (mg/L)	OP (mg/L)	DOC (mg/L)	TOC (mg/L)	Chlorophyll a (ug/L)	
7/18/2006 - MORNING														
Bear Creek														
08BEAR11.0	7:10		47.0	0.328	0.0261		0.02	U	0.0284	0.00885	5.16	5.5	3.6	
08BEAR08.1	7:38		49.3	0.329	0.01	U	0.048		0.0364	0.018	4.7	5.26	2.91	
08BEAR05.4	7:40		51.0	0.409	0.013	J	0.138		0.0308	0.0148	5.57	5.5	1	U
08BEAR02.1	7:04		59.2	0.718	0.01	U	0.461		0.0362	0.0196	5.33	5.46	1.21	
Bear Creek tributaries														
08STRU00.2	7:50		45.1	1.39	0.01	U	1.13		0.0186	0.0121	4.79	4.82	0.52	U
08SEID00.1	8:13		52.0	0.364	0.01	U	0.0888		0.0329	0.0159	6.9	7.03	0.52	U
08MACK00.0	7:31		63.7	1	0.01	J	0.795		0.0336	0.0202	4.32	4.62	0.52	U
08COLD00.1	7:19		71.7	1.02	0.018	J	0.744		0.0512	0.0335	5.48	4.79	0.5	U
Cottage Lake Creek														
08COTT03.3	7:24		61.8	0.809	0.0221		0.459		0.0415	0.0202	4.77	5.68	2	
08COTT00.4	7:52		61.6	1.02	0.01	U	0.664		0.0478	0.0241	4.92	5.53	1.89	
Evans Creek														
08EVAN07.2	7:58		49.3	1.47	0.01	U	1.17		0.0167	0.00679	5.43	5.99	0.52	U
08EVAN05.5	7:37		29.9	2.27	0.01	U	2.19		0.0183	0.0139	2.25	2.9	0.5	U
08EVAN04.3	7:20		85.8	0.691	0.0504		0.171		0.0656	0.0333	9.34	10.5	1.5	J
08EVAN04.3	7:24	Y	86.6	0.738	0.0506		0.163		0.0683	0.035	9.21	10.4	0.74	J
08EVAN01.7	8:17		71.4	0.435	0.0233		0.024	J	0.0632	0.0301	7.86	7.93	1.8	J
08EVAN00.0	7:00		76.0	0.585	0.014	J	0.135		0.0941	0.0543	7.99	8.99	1	U
Evans Creek tributaries														
08RUTH00.1	7:10		37.1	1.9	0.01	U	1.81		0.0231	0.0147	2.39	2.23	0.51	U
7/18/2006 - AFTERNOON														
Bear Creek														
08BEAR11.0	16:04		46.1	0.358	0.011	J	0.02	U	0.0282	0.00569	4.94	5.28	2.78	
08BEAR08.1	16:36		48.2	0.271	0.01	U	0.036	J	0.0349	0.019	4.8	5.2	1.08	
08BEAR05.4	16:33		50.4	0.381	0.011	J	0.114		0.031	0.0121	5.1	5.49	0.94	J
08BEAR05.4	16:34	Y	50.8	0.364	0.01	U	0.115		0.0285	0.0149	5.07	5.51	0.61	J
08BEAR02.1	16:03		58.5	0.685	0.01	U	0.418		0.0377	0.0217	4.97	5.09	1.59	
Bear Creek tributaries														
08STRU00.2	16:44		45.0	1.36	0.01	U	1.09		0.0185	0.012	4.78	4.93	0.51	U
08SEID00.1	16:58		51.0	0.373	0.01	U	0.0795		0.0331	0.016	6.67	7.07	0.54	U
08MACK00.0	16:24		63.3	1.05	0.01	U	0.768		0.037	0.0208	4.1	4.61	0.51	U
08COLD00.1	16:15		71.8	0.969	0.017	J	0.64		0.055	0.0361	4.33	4.71	0.5	U
Cottage Lake Creek														
08COTT03.3	16:22		60.6	0.788	0.0202		0.417		0.0427	0.0174	4.85	5.49	1.9	J
08COTT00.4	16:45		61.8	1.04	0.01	U	0.665		0.0504	0.0235	4.34	5.48	2.06	
Evans Creek														
08EVAN07.2	16:46		49.0	1.42	0.01	U	1.09		0.0188	0.00742	5.62	6.04	0.5	U
08EVAN05.5	16:30		31.7	2.15	0.01	U	1.89		0.0188	0.014	1.99	2.32	0.5	U
08EVAN04.3	16:13		87.7	0.658	0.0462		0.144		0.0585	0.0318	9.27	9.27	0.71	J
08EVAN01.7	17:06		70.5	0.45	0.024		0.02	U	0.0634	0.0271	7.4	7.39	1	J
08EVAN00.0	16:00		75.1	0.566	0.016	J	0.144		0.0905	0.0499	7.61	8.53	0.67	U
Evans Creek tributaries														
08RUTH00.1	16:04		37.0	1.95	0.01	U	1.69		0.0224	0.0142	2.44	2.44	0.5	U
7/19/2006 - MORNING														

ECY STATION	TIME	REP.	ALK (mg/L)	TPN (mg/L)	NH_3 (mg/L)		NO_2NO_3 (mg/L)		TP (mg/L)	OP (mg/L)	DOC (mg/L)	TOC (mg/L)	Chlorophyll a (ug/L)	
Bear Creek														
08BEAR11.0	7:18		46.9	0.293	0.018	J	0.02	U	0.03	0.00806	5.68	6.31	2.58	
08BEAR08.1	7:45		48.2	0.312	0.01	U	0.046		0.0391	0.0181	5.25	6.03	1.57	
08BEAR05.4	7:57		49.8	0.358	0.01	U	0.123		0.032	0.0138	5.6	6.24	0.91	J
08BEAR02.1	7:15		58.3	0.765	0.01	U	0.448		0.041	0.0183	5.16	5.95	1.56	
Bear Creek tributaries														
08STRU00.2	7:54		45.2	1.34	0.01	U	1.11		0.0225	0.0121	5.71	5.36	0.5	U
08SEID00.1	8:10		52.3	0.385	0.01	U	0.0836		0.0373	0.0141	7.12	7.32	0.5	U
08SEID00.1	8:11	Y	51.9	0.355	0.01	U	0.0864		0.0364	0.0153	7.09	7.51	0.53	U
08MACK00.0	7:43		63.2	0.984	0.01	U	0.779		0.0368	0.0192	4.53	4.85	0.5	U
08COLD00.1	7:43		71.5	0.981	0.016	J	0.717		0.0517	0.0323	4.57	5.42	0.5	U
Cottage Lake Creek														
08COTT03.3	7:31		62.2	0.774	0.0232		0.474		0.0429	0.0209	5.22	5.53	1.8	
08COTT00.4	8:13		61.6	0.956	0.01	U	0.661		0.0489	0.0236	5.23	6.01	1.07	
Evans Creek														
08EVAN07.2	8:05		47.5	1.62	0.01	J	1.19		0.0314	0.0117	5.92	6.52	0.52	U
08EVAN05.5	7:37		31.8	2.14	0.01	U	2.01		0.0228	0.0151	2.41	3.07	0.5	U
08EVAN04.3	7:20		92.4	0.793	0.041		0.263		0.0806	0.0389	9.39	10.6	1.4	J
08EVAN01.7	8:20		71.4	0.491	0.0243		0.02	U	0.074	0.0304	7.65	8.75	1.7	J
08EVAN00.0	7:09		74.6	0.56	0.015	J	0.127		0.0859	0.0461	7.8	8.71	1	U
Evans Creek tributaries														
08RUTH00.1	7:00		37.6	1.93	0.01	U	1.67		0.0328	0.0151	2.68	3.58	0.69	J
7/19/2006 - AFTERNOON														
Bear Creek														
08BEAR11.0	16:00		45.4	0.307	0.013	J	0.02	U	0.0295	0.0062	5.54	5.59	1.52	
08BEAR08.1	16:31		47.2	0.286	0.01	U	0.036	J	0.0384	0.0169	5.37	5.59	1.79	
08BEAR08.1	16:32	Y	47.2	0.26	0.01	U	0.037	J	0.0375	0.0186	5.22	5.52	1.66	
08BEAR05.4	16:30		49.5	0.377	0.01	U	0.122		0.0323	0.0136	6.43	5.61	0.75	J
08BEAR02.1	16:05		58.3	0.718	0.01	U	0.451		0.0395	0.0198	5.24	6.07	1	J
Bear Creek tributaries														
08STRU00.2	16:42		44.7	1.35	0.01	U	1.2		0.0242	0.0119	5.21	5.38	0.51	U
08SEID00.1	17:01		51.4	0.308	0.01	U	0.0855		0.0348	0.0162	7.27	7.32	0.52	U
08MACK00.0	16:23		62.9	1.02	0.01	U	0.828		0.0371	0.019	4.26	4.81	3.06	
08COLD00.1	16:15		71.0	0.946	0.017	J	0.687		0.0529	0.0326	4.78	5.04	1	U
Cottage Lake Creek														
08COTT03.3	16:16		61.3	0.798	0.0205		0.472		0.045	0.0195	5.47	5.48	1.75	
08COTT00.4	16:39		62.5	1.04	0.01	U	0.739		0.0487	0.0235	4.75	5.55	1.74	
Evans Creek														
08EVAN07.2	16:41		47.3	1.39	0.01	U	1.24		0.0195	0.00638	5.6	5.89	0.52	U
08EVAN05.5	16:24		31.9	2.15	0.01	U	2.04		0.0281	0.0127	2.64	2.77	0.5	U
08EVAN04.3	16:14		89.9	0.68	0.0421		0.194		0.0577	0.0317	9.53	10	0.71	U
08EVAN01.7	17:03		69.3	0.488	0.0336		0.022	J	0.0671	0.0291	7.26	7.95	2.3	
08EVAN00.0	16:00		73.8	0.591	0.016	J	0.154		0.0824	0.0449	7.74	8.18	0.67	U
Evans Creek tributaries														
08RUTH00.1	16:04		36.8	1.93	0.01	U	1.8		0.0259	0.014	2.76	3.09	0.5	U

REP Replicate
ALK Alkalinity
TPN Total Persulfate Nitrogen
NH_3 Ammonia Nitrogen
NO_2NO_3 Nitrite-Nitrate Nitrogen
TP Total Phosphorus
OP Orthophosphate
DOC Dissolved Organic Carbon
TOC Total Organic Carbon
U Analyte not detected at or above the reported result.
J Analyte positively identified at or above the minimum detection limit but below the practical quantitation limit. The numeric value should be treated as an estimate.

Table D-2. In-situ YSI measurements collected by King County in the morning and afternoon on July 18 and 19, 2006.

Ecology Station Name	King Co. Alias	Time	Temp (°C)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	pH
7/18/2006 - MORNING						
Bear Creek						
08BEAR11.0	Q484	7:10	17.6	110	4.8	7.2
08BEAR08.1	P484	7:38	14.6	114	9.7	7.7
08BEAR05.4	1484	7:40	14.9	114	9.1	7.5
08BEAR02.1	AB484	7:04	15.2	139	8.2	7.4
Bear Creek tributaries						
08STRU00.2	PT484	7:50	12.6	122	10.4	7.7
08SEID00.1	JT484	8:13	14.1	116	9.9	7.7
08MACK00.0	ET484	7:31	12.8	149	9.5	7.5
08COLD00.1	CT484	7:19	14.2	162	7.9	7.5
Cottage Lake Creek						
08COTT03.3	VV484	7:24	14.4	154	5.1	7.2
08COTT00.4	H484	7:52	14.5	151	9.6	7.7
Evans Creek						
08EVAN07.2	PP484	7:58	12.9	150	7.1	6.5
08EVAN05.5	TT484	7:37	11.8	109	8.1	6.4
08EVAN04.3	ST484	7:20	14.0	186	6.9	6.9
08EVAN01.7	BB484	8:17	14.8	155	3.9	6.6
08EVAN00.0	AE484	7:00	15.4	153	4.6	7.0
Evans Creek tributaries						
08RUTH00.1	R484	7:10	10.6	117	10.4	6.8
7/18/2006 - AFTERNOON						
Bear Creek						
08BEAR11.0	Q484	16:04	22.1	111	7.6	7.3
08BEAR08.1	P484	16:36	17.4	113	9.4	7.7
08BEAR05.4	1484	16:33	16.9	119	9.1	7.5
08BEAR02.1	AB484	16:03	17.1	144	9.8	7.8
Bear Creek tributaries						
08STRU00.2	PT484	16:44	14.5	122	9.9	7.7
08SEID00.1	JT484	16:58	16.2	115	9.4	7.7
08MACK00.0	ET484	16:24	14.7	155	9.3	7.6
08COLD00.1	CT484	16:15	16.8	170	7.1	7.5
Cottage Lake Creek						
08COTT03.3	VV484	16:22	17.5	153	6.5	7.2
08COTT00.4	H484	16:45	16.4	159	9.4	7.6
Evans Creek						
08EVAN07.2	PP484	16:46	13.8	149	7.5	6.5
08EVAN05.5	TT484	16:30	12.8	112	8.0	6.3
08EVAN04.3	ST484	16:13	16.3	185	6.5	6.9
08EVAN01.7	BB484	17:06	16.0	154	4.0	6.5
08EVAN00.0	AE484	16:00	17.0	161	5.2	6.9
Evans Creek tributaries						
08RUTH00.1	R484	16:04	11.5	117	10.2	6.7
7/19/2006 - MORNING						
Bear Creek						
08BEAR11.0	Q484	7:18	17.7	111	4.8	7.0
08BEAR08.1	P484	7:45	14.3	112	9.3	7.6
08BEAR05.4	1484	7:57	14.3	120	9.0	7.2

Ecology Station Name	King Co. Alias	Time	Temp (^{o}C)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	pH
08BEAR02.1	AB484	7:15	14.7	149	8.7	7.2
Bear Creek tributaries						
08STRU00.2	PT484	7:54	12.2	122	10.3	7.6
08SEID00.1	JT484	8:10	13.7	116	9.7	7.7
08MACK00.0	ET484	7:43	12.2	173	9.9	7.3
08COLD00.1	CT484	7:33	13.5	175	8.6	7.2
Cottage Lake Creek						
08COTT03.3	VV484	7:31	13.7	156	5.3	7.0
08COTT00.4	H484	8:13	14.0	161	10.0	7.4
Evans Creek						
08EVAN07.2	PP484	8:05	12.7	153	7.9	6.5
08EVAN05.5	TT484	7:37	11.5	110	9.0	6.8
08EVAN04.3	ST484	7:20	13.3	190	7.3	7.1
08EVAN01.7	BB484	8:20	14.5	156	2.8	6.7
08EVAN00.0	AE484	7:09	14.9	164	4.9	6.6
Evans Creek tributaries						
08RUTH00.1	R484	7:00	10.5	122	10.6	6.8
7/19/2006 - AFTERNOON						
Bear Creek						
08BEAR11.0	Q484	16:00	21.8	111	7.9	7.3
08BEAR08.1	P484	16:31	17.4	113	9.4	7.8
08BEAR05.4	1484	16:30	16.9	117	9.5	7.9
08BEAR02.1	AB484	16:05	16.8	144	9.9	8.0
Bear Creek tributaries						
08STRU00.2	PT484	16:42	14.7	125	9.8	7.7
08SEID00.1	JT484	17:01	16.4	118	9.3	7.8
08MACK00.0	ET484	16:23	14.6	138	9.1	7.9
08COLD00.1	CT484	16:15	16.9	171	7.1	7.8
Cottage Lake Creek						
08COTT03.3	VV484	16:16	17.1	157	7.1	7.2
08COTT00.4	H484	16:39	16.4	160	9.6	8.0
Evans Creek						
08EVAN07.2	PP484	16:41	13.7	156	7.1	6.4
08EVAN05.5	TT484	16:24	13.2	113	8.1	6.4
08EVAN04.3	ST484	16:14	15.6	200	6.8	6.9
08EVAN01.7	BB484	17:03	15.8	158	4.2	6.6
08EVAN00.0	AE484	16:00	16.6	160	5.8	7.2
Evans Creek tributaries						
08RUTH00.1	R484	16:04	11.5	122	10.4	6.7

Table D-3. Periphyton chlorophyll *a* and ash free dry weight (AFDW) data.

Station	Time	Surface Area (m^2)	Chlorophyll a			AFDW	
			ug/L	Qualifier	mg/m^2	mg/L	g/m^2
08BEAR08.1	12:10	0.03434	970		28.2	290	8.45
08BEAR08.1*	12:10	0.06131	992		16.2	370	6.03
08BEAR02.1	9:30	0.10042	2790	J	27.8	580	5.78
08COTT02.7	11:10	0.02994	397	J	13.3	160	5.34
08COTT00.4	11:40	0.00947	47.9	J	5.1	16	1.69
08EVAN04.3	13:30	0.07171	1860		25.9	690	9.62
08EVAN01.2	13:00	0.02559	777		30.4	580	22.66
08EVAN00.0	10:00	0.01276	64.3	J	5.0	85	6.66

* replicate sample
U - Analyte not detected at or above the reported result
J - Analyte positively identified at or above the minimum detection limit but below the practical quantitation limit. The numeric value should be treated as an estimate.

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Appendix E. Synoptic Flow and Travel Time

Instantaneous and Continuous Flow Measurements

Table E-1. Instantaneous flows measured during synoptic productivity monitoring.

Station	River Mile*	Rep.	Date	Time	Wetted Width (ft)	Wetted Perimeter (ft)	Cross Sectional Area (ft^2)	Avg. Depth (ft)	Avg. Velocity (ft/s)	Discharge (cfs)
Bear Creek										
08BEAR11.0	11.0		7/18/06	14:09	26.6	24.85	43.15	1.57	0.09	3.72
08BEAR10.1	10.1		7/18/06	15:13	9.5	9.24	4.96	0.50	0.92	4.54
08EFBEAR00.1	0.1		7/18/06	15:01	4.7	3.94	0.76	0.17	0.23	0.18
08BEAR08.1	8.1		7/18/06	12:40	17.2	17.24	15.10	0.86	0.38	5.80
08BEAR08.1	8.1	Y	7/18/06	12:59	17.3	17.26	15.29	0.87	0.34	5.25
08STRU00.2	0.2		7/18/06	12:21	6.1	5.78	1.17	0.20	0.20	0.23
08BEAR06.5	6.5		7/18/06	11:53	13.4	12.96	11.43	0.82	0.48	5.47
08SEID00.1	0.1		7/18/06	11:39	4.2	3.73	0.62	0.16	0.64	0.40
08BEAR05.4	5.4		7/18/06	13:33	18.0	15.70	9.83	0.64	0.65	6.40
08TRIB-BE(04.5)	(4.5)		7/18/06	11:18	4.0	3.64	0.73	0.17	0.07	0.05
08BEAR03.7	3.7		7/18/06	12:37	22.4	21.73	20.66	1.03	0.61	12.68
08MACK00.0	0.0		7/18/06	12:11	7.7	6.72	4.52	0.58	0.07	0.31
08BEAR02.8	2.8		7/18/06	0:00	16.5	16.09	14.22	0.89	1.08	15.35
08COLDW00.1	0.1		7/18/06	10:45	1.7	1.54	0.26	0.13	0.11	0.03
08COLDW00.1	0.1		7/18/06	10:20	1.7	1.55	0.28	0.14	0.12	0.03
08BEAR02.1	2.1		7/18/06	9:25	21.7	20.50	39.72	1.81	0.43	17.01
08BEAR00.9	0.9		7/18/06	10:40	19.6	19.17	33.35	1.78	0.62	20.70
Cottage Lake Creek										
08DAN01.5	1.5		7/18/06	15:55						0.02
08COTT02.7	2.7		7/18/06	15:10	18.4	18.32	10.96	0.59	0.66	7.26
08COTT02.2	2.2		7/18/06	15:15	17.2	16.27	9.45	0.53	0.79	7.46
08COTT00.4	0.4		7/18/06	14:05	12.8	12.49	8.38	0.67	0.96	8.06
08COTT00.4	0.4	Y	7/18/06	14:35	12.8	12.49	8.41	0.68	0.95	7.99
Evans Creek										
08EVAN07.2	7.2		7/18/06	14:20	2.0	1.93	0.19	0.08	0.09	0.02
08EVAN05.5	5.5		7/18/06	12:50	4.7	4.28	0.68	0.14	0.02	0.01
08TRIB-EV(05.3)	(5.3)		7/18/06	13:50	5.0	5.38	4.60	0.83	0.07	0.32
08EVAN04.3	4.3		7/18/06	12:10	12.1	12.58	11.10	0.87	0.14	1.61
08RUTH00.1	0.1		7/18/06	11:45	4.1	3.84	0.64	0.15	0.54	0.35
08EVAN02.3	2.3		7/18/06	11:00	7.1	7.36	5.03	0.64	0.93	4.68
08EVAN01.2	1.2		7/18/06	10:00	14.4	14.53	23.98	1.60	0.22	5.22
08TRIB-EV(01.1)	(1.1)		7/18/06	10:30	5.2	5.57	2.29	0.41	0.57	1.30
08EVAN00.0	0.0		7/18/06	10:06	9.7	10.28	8.42	0.81	0.38	3.23
08EVAN00.0	0.0	Y	7/18/06	9:41	9.9	10.09	8.47	0.82	0.35	2.98
08EVAN00.0	0.0	Y	7/18/06	9:20	9.5	10.37	8.57	0.84	0.43	**3.65**

* River Mile in (brackets) indicates the river mile at which a tributary joins the mainstem

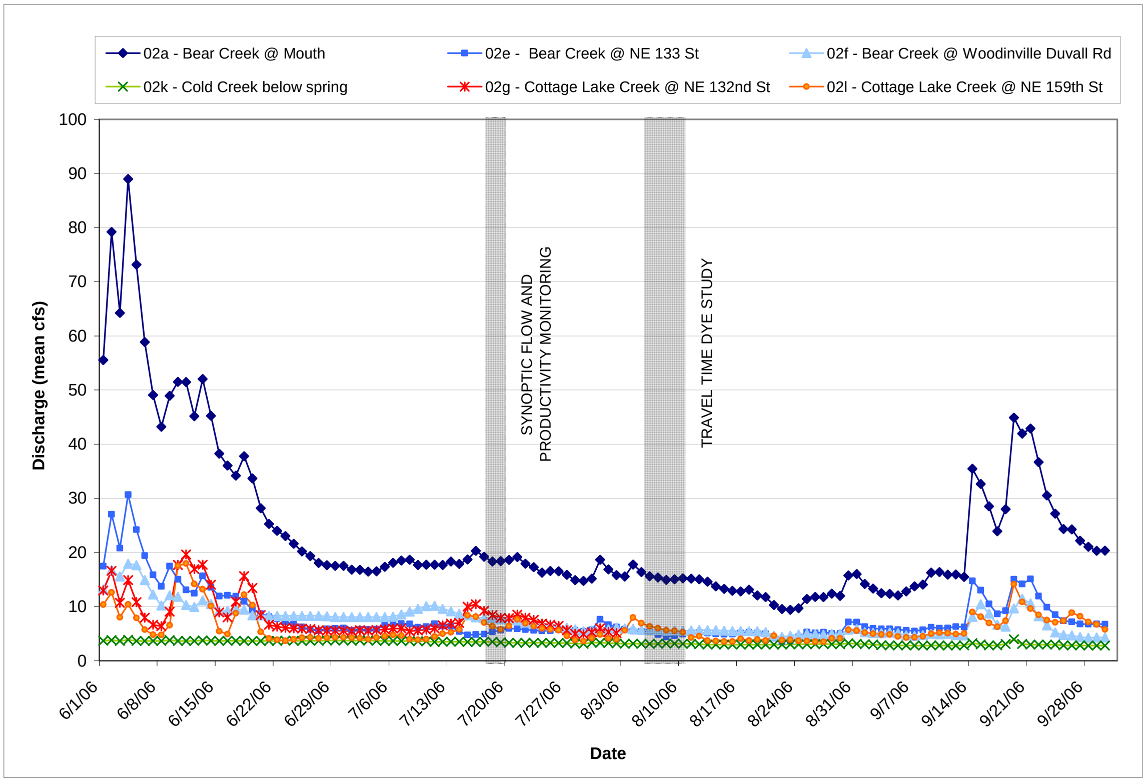


Figure E-1. Continuous streamflow data from King County gages from June and September.

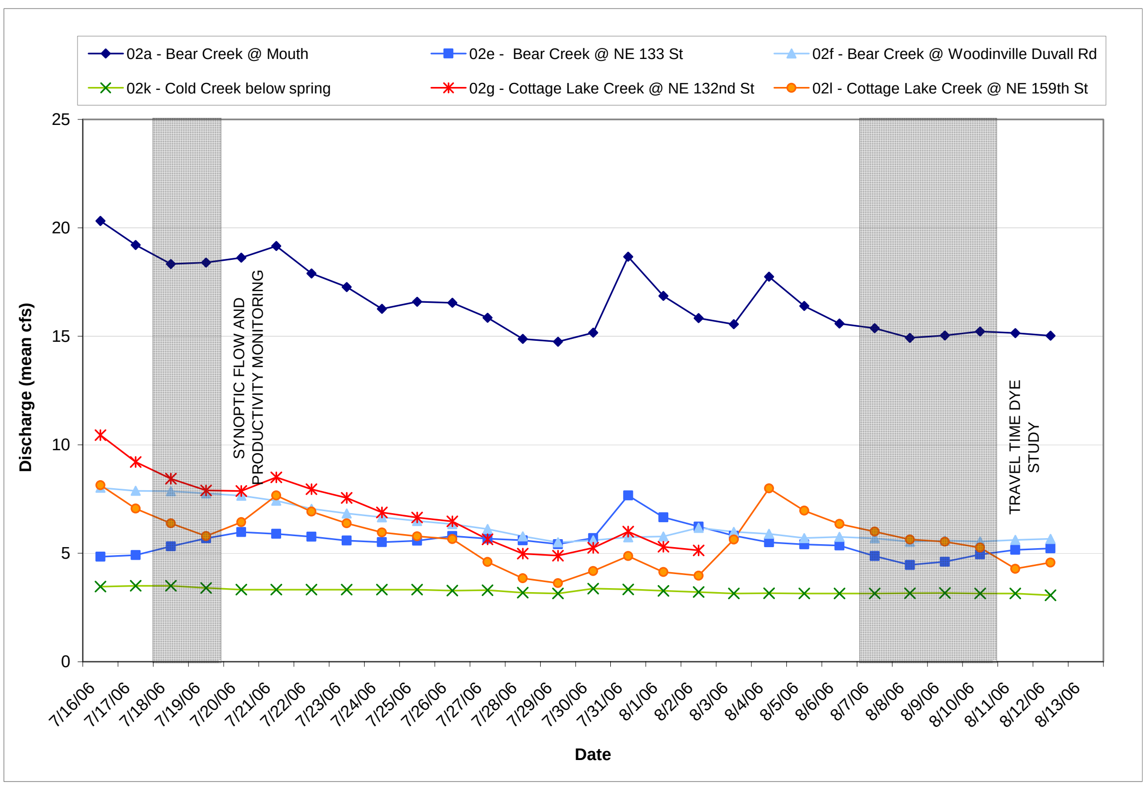


Figure E-2. Continuous streamflow data from King County gages from mid-July to mid-August.

Travel-time Dye Study Results

Table E-2. Summary showing both the differential and cumulative travel time for Bear, Cottage Lake, and Evans Creeks as determined from the dye study.

Station	Station Description	Differential (hour)	Differential (days)	Cumulative (hour)	Cumulative (days)
Upper Bear Creek dye release					
08BEAR11.0	Bear Cr. at Conservation area				
08BEAR10.1	Bear Cr. at Woodinville-Duvall Rd.	12.42	0.52	12.42	0.52
Mid-Bear Creek dye release					
08BEAR10.1	Bear Cr. at Woodinville-Duvall Rd.				
08BEAR08.1	Bear Cr. at Tolt pipeline trail	10.42	0.43	22.84	0.95
08BEAR05.4	Bear Cr. above Cottage Lake Cr.	16.41	0.68	39.25	1.64
Lower Bear Creek dye release					
08BEAR05.4	Bear Cr. Below Cottage Lake Cr.				
08BEAR03.7	Bear Cr. at 106th Ave.	4.25	0.18	43.50	1.81
08BEAR02.1	Bear Cr. above Evans Cr.	6.50	0.27	45.75	1.91
Upper Cottage Lake Creek dye release					
08COTT03.3	Cottage Lake Cr. at 165th Ave.				
08COTT02.7	Cottage Lake Cr. at 159th Ave.	3.00	0.13	3.00	0.13
Lower Cottage Lake Creek dye release					
08COTT02.7	Cottage Lake Cr. at 159th Ave.				
08COTT00.0	Cottage Lake Cr. at mouth	6.83	0.28	9.83	0.41
Upper Evans Creek dye release*					
08EVAN04.3	Evans Cr. at 44th				
08EVAN02.3	Evans Cr. at 196th and Hwy 202	> 16.67	> 0.69	> 16.67	> 0.69
Mid-Evans Creek dye release*					
08EVAN02.3	Evans Cr. at 196th and Hwy 202				
08EVAN01.7	Evans Cr. at 196th (south)	> 51.53	> 2.15	> 68.2	> 2.84
Lower Evans Creek dye release					
08EVAN01.2	Evans Cr. at 196th (north)				
08EVAN00.8	Evans Cr. at Union Hill Rd.	2.58	0.11	> 70.78	> 2.95
08EVAN00.0	Evans Cr. at mouth	14.33	0.60	> 85.11	> 3.55

* released dye was not detected at the downstream monitoring station for these two dye studies on Evans Creek, so travel time is unknown but greater than the presented values

Appendix F. King County Ambient Groundwater Data for the Bear-Evans Basin

Table F-1. Summary of King County ambient groundwater data measured in wells less than 100 feet deep*.

	Temperature (deg C)	Conductivity (uS/cm)	Dissolved Oxygen (mg/L)	Nitrate N (mg/L)	Total Phosphate (mg/L)	Alkalinity (mg/L)	pH (units)
King County Ambient Groundwater Data For Wells <100 Ft Deep (1989-2004)	12.1	62	2.14	1.500	0.051	84	6.20
	12.0	232	2.23	2.000	0.059	88	4.40
	13.0	140	3.10	1.320	0.007	90	6.72
	12.1	140	3.34	1.300	0.033	89	6.73
	12.0	216	3.47	1.320	0.070	89	6.54
	13.8	144	4.01	0.100	0.080	87	6.36
	12.3	201	4.10	0.550	0.024	91	6.47
	12.0	214	4.36	0.200	0.035	56	6.31
	12.0	356	4.44	0.045	0.063	56	7.09
	12.4	226	4.48	1.300	0.064	52	6.39
	13.8	124	5.30	0.400		123	6.44
	16.1	66	6.43	0.645		83	6.60
	13.0	244	6.54	0.643		113	4.60
	11.8	238	9.65	1.090		88	6.78
	12.5	156	9.77	0.870		70	6.78
	12.6	211	10.49	2.600		87	6.62
	12.7	164	10.59	4.910		86	6.72
	13.3	89	12.23	4.550		93	6.47
	13.2	258	4.48	4.500		85	7.31
	10.8	266	5.23	0.100		90	3.60
	10.5	265	6.04	3.100		36	6.76
	11.1	222	6.74	3.100		40	6.68
	9.6	98		0.291		96	6.64
	9.7	168		0.020		100	6.57
	11.6	255				101	6.25
	10.8	327				86	5.90
	11.0	112				72	6.93
	12.0					74	6.97
	12.5					74	6.91
	12.8					79	6.70
	13.6					104	6.73
	13.2					130	
						92	
Mean	12.2	192	5.87	1.519	0.048	84	6.39
Median	12.2	211	4.86	1.195	0.055	87	6.62
Maximum	16.1	356	12.23	4.910	0.080	130	7.31
Minimum	9.6	62	2.14	0.020	0.007	36	3.60

*The above data were downloaded from King County's groundwater ambient monitoring data download web page. Annual reports of data have been by published by King County (2005a).

Appendix G. Calibrated QUAL2Kw Rate Parameters

Table G-1. Calibrated QUAL2Kw rate parameters for Bear, Evans, and Cottage Lake Creeks.

Parameter	Bear Creek	Evans Creek	Cottage Lake Creek	Units	Symbol
Stoichiometry					
Carbon	40	40	40	gC	gC
Nitrogen	7.2	7.2	7.2	gN	gN
Phosphorus	1	1	1	gP	gP
Dry weight	100	100	100	gD	gD
Chlorophyll	1	1	1	gA	gA
Inorganic Suspended Solids					
Settling velocity	1	1.29624	1.94982	m/d	v_i
Oxygen					
Re-aeration model	USGS (channel-control)	Thackston-Dawson	USGS (channel-control)		
Temp correction	1.024	1.024	1.024		θ_a
Re-aeration wind effect	None	None	None		
Oxygen for carbon oxidation	2.69	2.69	2.69	gO_2/gC	r_{oc}
Oxygen for NH4 nitrification	4.57	4.57	4.57	gO_2/gN	r_{on}
Oxygen inhib model CBOD oxidation	Exponential	Exponential	Exponential		
Oxygen inhib parameter CBOD oxidation	0.60	0.60	0.60	L/mgO2	K_{socf}
Oxygen inhib model nitrification	Exponential	Exponential	Exponential		
Oxygen inhib parameter nitrification	0.60	0.60	0.60	L/mgO2	K_{sona}
Oxygen enhance model denitrification	Exponential	Exponential	Exponential		
Oxygen enhance parameter denitrification	0.60	0.60	0.60	L/mgO2	K_{sodn}
Oxygen inhib model phyto resp	Exponential	Exponential	Exponential		
Oxygen inhib parameter phyto resp	0.60	0.60	0.60	L/mgO2	K_{sop}
Oxygen enhance model bot alg resp	Exponential	Exponential	Exponential		
Oxygen enhance parameter bot alg resp	0.60	0.60	0.60	L/mgO2	K_{sob}
Slow CBOD					
Hydrolysis rate	0.00706	1.13376	0.0189	/d	k_{hc}
Temp correction	1.047	1	1.047		θ_{hc}
Oxidation rate	0.78406	0.12999	0.15115	/d	k_{dcs}
Temp correction	1.047	1.047	1.047		θ_{dcs}
Fast CBOD					
Oxidation rate	3.75375	0.0155	4.3425	/d	k_{dc}
Temp correction	1.047	1.047	1.047		θ_{dc}
Organic Nitrogen					
Hydrolysis	0.4686	0.14615	0.84125	/d	k_{hn}
Temp correction	1.07	1.07	1.07		θ_{hn}
Settling velocity	0.05	1.8312	0.41464	m/d	v_{on}
Ammonium					
Nitrification	6.34	4.9549	4.0636	/d	k_{na}
Temp correction	1.07	1.07	1.07		θ_{na}
Nitrate					
Denitrification	1.03752	1.60528	1.7728	/d	k_{dn}
Temp correction	1.07	1.07	1.07		θ_{dn}
Sed denitrification transfer coeff	0.33637	0.87292	0.0483	m/d	v_{di}
Temp correction	1.07	1.07	1.07		θ_{di}

Parameter	Bear Creek	Evans Creek	Cottage Lake Creek	Units	Symbol
Organic Phosphorus					
Hydrolysis	2.1236	0.5644	2.8783	/d	k_{hp}
Temp correction	1.07	1.07	1.07		θ_{hp}
Settling velocity	0.05	0.876	1.4805	m/d	v_{op}
Inorganic Phosphorus					
Settling velocity	1.43304	1.80012	1.51884	m/d	v_{ip}
Sed P oxygen attenuation half sat constant	1.9853	1.90728	0.14982	mgO_2/L	k_{spi}
Phytoplankton					
Max Growth rate	2	2.5	2.5	/d	k_{gp}
Temp correction	1.07	1.07	1.07		θ_{gp}
Respiration rate	0.3	0.1	0.1	/d	k_{rp}
Temp correction	1.07	1.07	1.07		θ_{rp}
Death rate	0.3	0	0	/d	k_{dp}
Temp correction	1.07	1	1		θ_{dp}
Nitrogen half sat constant	15	15	15	ugN/L	k_{sPp}
Phosphorus half sat constant	2	2	2	ugP/L	k_{sNp}
Inorganic carbon half sat constant	1.30E-05	1.30E-05	1.30E-05	moles/L	k_{sCp}
Phytoplankton use HCO3- as substrate	Yes	Yes	Yes		
Light model	Half saturation	Half saturation	Half saturation		
Light constant	57.6	57.6	57.6	langleys/d	K_{Lp}
Ammonia preference	25	25	25	ugN/L	k_{hnxp}
Settling velocity	2	0.15	0.15	m/d	v_a
Bottom Plants					
Growth model	Zero-order	Zero-order	Zero-order		
Max Growth rate	228.445	111.705	93.26	$mgA/m^2/d$ or /d	C_{gb}
Temp correction	1.07	1.07	1.07		θ_{gb}
First-order model carrying capacity	1000	1000	1000	mgA/m^2	$a_{b,max}$
Respiration rate	0.475735	0.389855	0.006795	/d	k_{rb}
Temp correction	1.07	1.07	1.07		θ_{rb}
Excretion rate	0.45259	0.4816	0.34387	/d	k_{eb}
Temp correction	1.07	1.07	1.07		θ_{db}
Death rate	0.19392	0.45746	0.349985	/d	k_{db}
Temp correction	1.07	1.07	1.07		θ_{db}
External nitrogen half sat constant	53.622	115.854	81.078	ugN/L	k_{sPb}
External phosphorus half sat constant	40.562	75.803	53.357	ugP/L	k_{sNb}
Inorganic carbon half sat constant	3.65E-05	8.60E-05	3.10E-05	moles/L	k_{sCb}
Bottom algae use HCO3- as substrate	Yes	Yes	Yes		
Light model	Half saturation	Half saturation	Half saturation		
Light constant	95.36383	1.693	74.95795	langleys/d	K_{Lb}
Ammonia preference	1.891	80.9623	2.43847	ugN/L	k_{hnxb}
Subsistence quota for nitrogen	1.192789224	7.00543476	1.004625576	mgN/mgA	q_{0N}
Subsistence quota for phosphorus	0.55486558	0.64930105	0.82956061	mgP/mgA	q_{0P}
Maximum uptake rate for nitrogen	78.3849	94.23535	74.9947	mgN/mgA/d	ρ_{mN}
Maximum uptake rate for phosphorus	9.5354	9.98525	7.56425	mgP/mgA/d	ρ_{mP}
Internal nitrogen half sat ratio	2.5060095	1.124971	2.0422795		$K_{qN,ratio}$
Internal phosphorus half sat ratio	3.4175905	4.636521	2.07305		$K_{qP,ratio}$
Nitrogen uptake water column fraction	1	1	1		$N_{UpWCfrac}$

Parameter	Bear Creek	Evans Creek	Cottage Lake Creek	Units	Symbol
Phosphorus uptake water column fraction	1	1	1		$P_{UpWCfrac}$
Detritus (POM)					
Dissolution rate	0.76515	1.6294	0.2043	/d	k_{dt}
Temp correction	1.07	1.07	1.07		θ_{dt}
Settling velocity	0.72175	0.53275	0.1111	m/d	v_{dt}
Pathogens					
Decay rate	0.8	0.8	0.8	/d	k_{dx}
Temp correction	1.07	1.07	1.07		θ_{dx}
Settling velocity	1	1	1	m/d	v_x
Alpha constant for light mortality	1	1	1	/d per ly/hr	*apath*
pH					
Partial pressure of carbon dioxide	347	347	347	ppm	p_{CO2}

Appendix H. Record of Public Participation

Introduction

Public meeting held at Woodinville Public Library.

Ecology engaged the public in several ways in the TMDL process to address temperature, dissolved oxygen, as well as fecal coliform bacteria 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, Union Hill Water Association, 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 Temperature and Dissolved Oxygen 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 July 21 to August 22, 2008 and gave the public, including key stakeholders, a chance to review and provide feedback on the proposed final draft report. On August 11, 2008, Ecology hosted a public meeting at the Woodinville Public Library to share highlights from the temperature and dissolved oxygen TMDL study and plans for improving the water quality in the watershed.

List of public meetings

Ecology held a public meeting on August 11, 2008, from 6:30-8:30 pm, at the Woodinville Public Library to present the draft report and obtain citizen input. Eighteen people attended the meeting. Below is the meeting agenda.

Bear-Evans Watershed Water Temperature and Oxygen Improvement Meeting

August 11, 2008, 6:30 – 8:30 p.m., Woodinville Library

AGENDA

Tonight's meeting is to provide information about what we all are--and can--do to improve the quality of creeks in the watershed.

Objectives:

- To better understand the process for improving water quality in the watershed.
- To share information about specific activities.

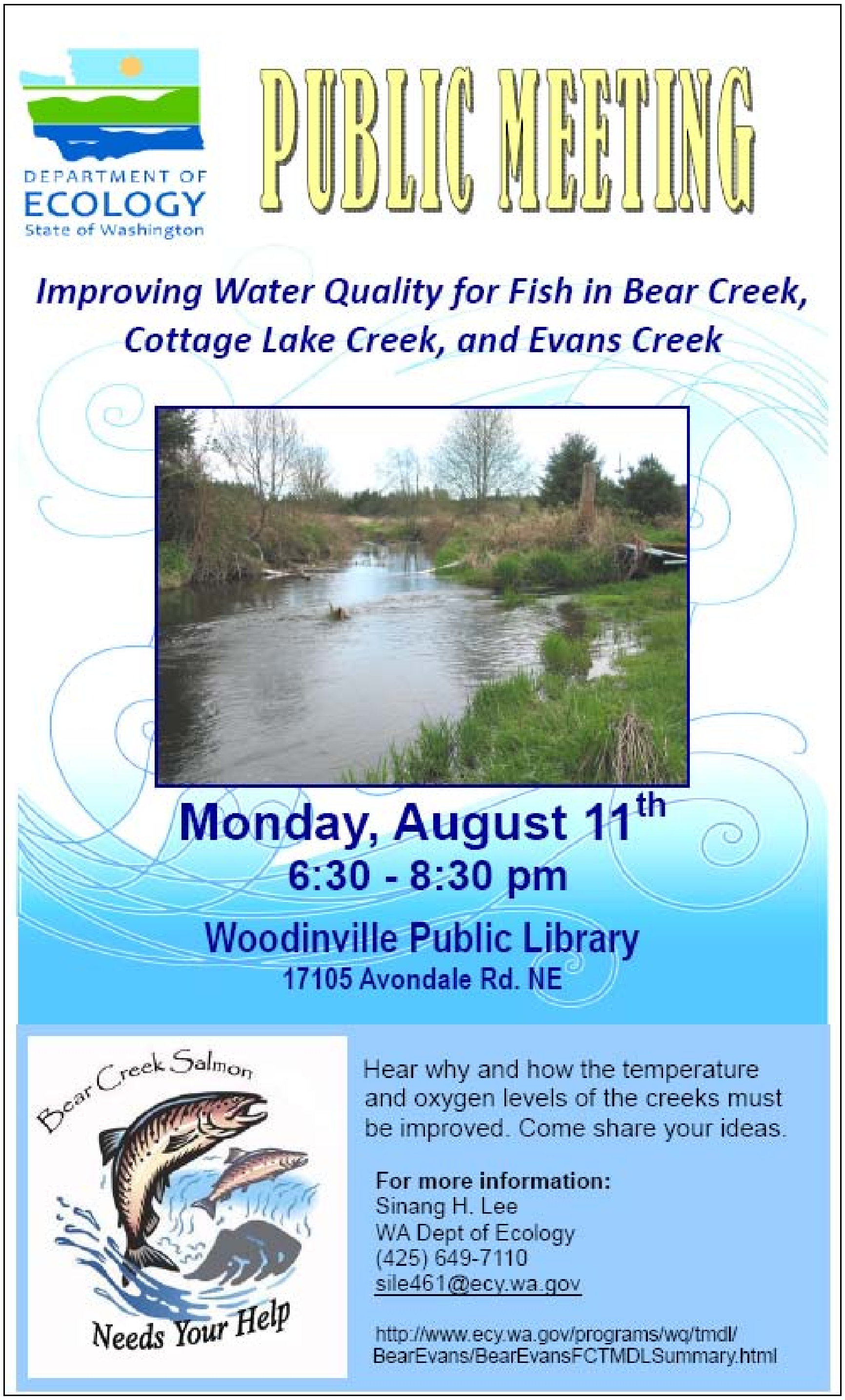
Time	Topic	Speaker
6:30-7:00	Open House, Beverages, Cookies & Conversation	~~
7:00-7:10	Welcome/Agenda/Introductions	DouGlas Palenshus
7:10-7:20	Ecology's Water Quality Improvement Process	*short video*
7:20-7:30	Overview: Improving water quality for fish in the Bear-Evans Watershed	Sinang Lee
7:30-7:50	What did we learn from studying the water quality problems in the Bear-Evans Watershed	Teizeen Mohamedali Questions/Comments
8:00-8:20	How will we improve the quality of the creeks in the Bear-Evans Watershed	Sinang Lee Questions/Comments
8:30- ~~	Closing remarks/Adjourn	DouGlas Palenshus

Outreach and announcements

- Published *Draft Bear-Evans Watershed Fecal Coliform Bacteria TMDL/Water Quality Improvement Report* (July 21) on Ecology's Bear-Evans Watershed TMDL Project webpage: http://www.ecy.wa.gov/programs/wq/tmdl/BearEvans/BearEvansTMDLSummary.html
- Announced the public meeting and public comment period on the webpage above.
- Posted public meeting announcements at the Redmond Public Library, Woodinville Public Library, Sammamish Public Library, Carol Edwards Community Center, Old Redmond Schoolhouse Community Center, Victor's Coffeehouse and Roasters, Half Price Bookstore (Redmond), and Safeway on Avondale Road.
- Mailed announcement postcards to members of the Water Tenders.
- Produced an Ecology news release on July 25, 2008 announcing "Bear Creek water quality improvement plan released".
- Interviewed for a news story by the Daily Journal of Commerce on a story published on July 28, 2008 called "State offers a plan to help protect the Bear Creek watershed".
- 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 (July 21 – August 22).
- Used listserve of the Upper Bear Creek Community Council, Water Tenders, Friends of Cottage Lake, and Horses for Clean Water to announce the public meeting and keep stakeholders informed on the TMDL progress.

Printed outreach materials

- Posters for the public meeting were distributed in the community and the public libraries.



- Newspaper ad announcement for the public meeting,

WASHINGTON STATE DEPARTMENT OF ECOLOGY

The Department of Ecology seeks your comments

Draft Bear-Evans Watershed Dissolved Oxygen and Temperature TMDL/Water Quality Improvement Report

PUBLIC MEETING:

Monday Evening, Aug. 11, 2008

Open House 6:30, Presentations 7:00-8:30

Woodinville Library - 17105 Avondale Rd NE

Do you have ideas on how to help make Bear, Evans, and Cottage Lake Creeks healthier for fish? These creeks are too warm with little oxygen and the Washington State Department of Ecology (Ecology) has prepared a draft report about the recent water quality studies and actions to help these problems. The goal of Ecology and our partners is to improve overall water quality to meet State standards to protect summer habitat so that salmon can be healthy.

We are seeking your comments about how well the draft report seems to address these problems. 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:

- http://www.ecy.wa.gov/programs/wq/tmdl/BearEvans/BearEvansFCTMDLSummary.html
- Redmond, Sammamish, and Woodinville Public Libraries
- The Ecology Department office (at the address below)

Please send comments by **August 22, 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 temperature and dissolved oxygen problems in Bear-Evans Watershed.

Focus on Bear-Evans Watershed

DEPARTMENT OF ECOLOGY State of Washington

Water Quality **July 2008**

The creeks are too warm with little oxygen for fish

Fish breathe oxygen in the water (dissolved oxygen). Cooler water holds more oxygen. When water has too little oxygen or is too warm, local fish can face thermal stress and harm. Parts of Bear, Evans, and Cottage Lake creeks have unhealthy temperature and oxygen conditions and fail to meet Washington State water quality standards.

These creeks serve as important migration corridors and spawning and rearing areas for several fish species—Puget Sound Chinook, coho, sockeye, kokanee, steelhead/rainbow, cutthroat trout—that all need cold waters for optimum health during various stages of their lives.

Together, we can all restore and help protect clean and healthy streams.

To restore these waters and protect the vital salmonid habitat, the Department of Ecology (Ecology) is working with partners in the watershed on a water quality improvement effort that determines what is called the Total Maximum Daily Load (TMDL) of allowable pollutants.

Through this process, Ecology:

- Evaluates the water quality conditions.
- Estimates how much the pollutants of concern need to be reduced to meet state water quality standards.
- Describes how citizens, state and local governments, and other organizations and businesses can help improve temperature and dissolved oxygen conditions in this watershed.

Ecology's *Bear-Evans Watershed Temperature and Dissolved Oxygen TMDL/Water Quality Improvement Report* documents this information. Ecology values your input and wants to hear your comments on this report. Please join us at the public meeting or send your comments to Ecology.

PUBLIC MEETING

Come learn about effort to improve water quality in the Bear-Evans Watershed and share your ideas:

Monday, August 11, 2008
Woodinville Public Library
17105 Avondale Rd NE
Woodinville, WA 98072
6:30 to 8:30 p.m.

Light refreshments and snacks will be provided.

COMMENT PERIOD

Ecology requests your input on the *Draft Bear-Evans Watershed Temperature and Dissolved Oxygen TMDL/Water Quality Improvement Report*:

July 21 – August 22

Please find a copy at the Redmond, Sammamish, and Woodinville Public Libraries or at: www.ecy.wa.gov/biblio/0810058.html

Please submit comments to:

Sinang H. Lee
Department of Ecology
3190 160th Ave. SE
Bellevue, WA 98008

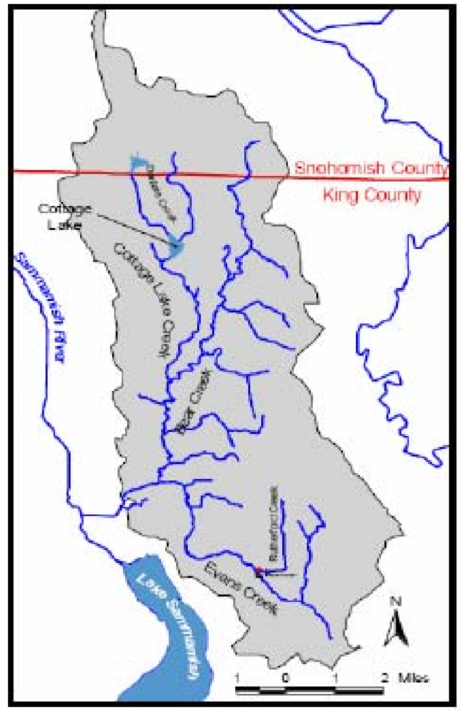
425-649-7110
sile461@ecy.wa.gov

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: 06-10-060 1

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



Current water quality conditions

- The headwaters of Bear and Cottage Lake creeks are really warm, partly due to the lakes that drain to these creeks. Bear Creek cools as it flows downstream, but warms up again as it makes its way to the Sammamish River. Cottage Lake Creek experiences continual warming as it flows downstream. Evans Creek is cooler than the rest of the creek system. It is influenced by groundwater and cooler tributaries.

- All three creeks had lower dissolved oxygen (DO) levels than the state water quality standard. Some tributaries to these creeks had healthier DO levels. The lowest DO levels were recorded in Evans Creek, which has many wetlands. Lake bottoms, wetlands, and groundwater naturally have low DO levels and so are likely to influence the DO levels in the creeks.

Causes of the water quality problems

Stream temperature is dependent upon a number of factors.

- Lack of streamside vegetation means lack of shade over the water, making it easier for the creek to heat up. Erosion and sediment loss from poorly-managed forest lands, agricultural areas, or construction sites can make streams shallower and wider and harder to shade.
- Reduced water stored in the ground means less cool water to feed the local creeks during the dry summer months. Expanded areas of impervious surfaces and water withdrawals for purposes such as irrigation and drinking water can cause the stream flows to become lower and shallower than usual in the summer.

Failing on-site septic systems and stormwater rushing over urbanized areas can 'flush' nutrients (in the form of human waste, soaps, domestic animal wastes, and poorly managed fertilizers) into our waters. Algae thrive on these excess nutrients. When they die, oxygen-consuming bacteria break down the algae and use up the DO in the water.

How you can help

Students volunteer to restore streamside areas of Bear Creek. Photo: Water Tenders

Restore stream channels. Get involved in streamside restoration projects to help prevent erosion and sediment loss. Where streams have been straightened and channelized, restoration projects can help re-establish connections with the natural floodplain and with cool groundwater resources.

Conserve water. Practice wise use of water near streams to help protect flows during late-summer low-flow conditions. Reduce lawn areas for watering or use less-consumptive irrigation methods (soaker hoses or smart watering). Use deep soaks early in the morning or late in the evening to minimize evaporation and leave more water in the stream or in groundwater resources that 'recharge' stream flows. For more great ideas visit:

http://www.nesswd.org/conservation.htm
http://www.cascadewater.org/con_rebates.html
http://dnr.metrokc.gov/wtd/waterconservation/

Plant tree borders. Streamside landowners can plant trees that shade the stream, cooling the water as the trees mature. Woody debris and vegetation that falls into streams can provide food and habitat for fish. Mature streambank plants can help filter excessive amounts of sediments, fertilizers, or other nutrients from upland lawns and agricultural areas. This helps prevent the growth of algae and other water plants that use up precious oxygen.

Keep nutrients and organic material out of streams. Take these actions to prevent nutrient pollution in the streams and stormwater runoff:

- Check on-site septic systems every 2-3 years.
- Keep all soaps out of streams. If washing cars at homes, use only bio-degradable soaps and wash only on lawns.
- Prevent overuse and runoff of fertilizers. Use slow-release organic fertilizers if possible. Store fertilizers properly.
- Carefully manage domestic animal and livestock wastes: pick-up, cover, and keep away from streams; properly dispose of pet wastes.
- Keep grass clippings and other organic debris out of streams.

Appendix I. Response to Public Comments

Ecology received the following summarized comments during the public comment period for the *Draft Bear-Evans Watershed Temperature and Dissolved Oxygen TMDL/Water Quality Improvement 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:** The Bear-Evans watershed is considered a cornerstone in the conservation and recovery of ESA-listed Chinook salmon in the Lake Washington/Cedar/Sammamish Watershed (WRIA 8). As stated in the Lake Washington/Cedar/Sammamish Watershed Chinook Salmon Conservation Plan (2005), the Bear-Evans watershed is a core area for one of only two naturally spawning Chinook populations in WRIA 8. Productivity of naturally spawning Chinook in the Bear-Evans watershed is currently well below replacement. Efforts to improve water quality as described in the Draft Bear-Evans Watershed Temperature and Dissolved Oxygen TMDL/Water Quality Improvement Report (i.e., decrease temperatures and increase dissolved oxygen levels) will benefit the endangered Chinook salmon populations in the Bear-Evans watershed, and should be pursued vigorously.

Response: Ecology acknowledges that there are current and on-going actions by local entities, tribes, and organizations that are working on salmon recovery WRIA 8, including the Bear-Evans watershed. And this TMDL and its follow-up detailed implementation plan will complement salmon recovery activities with actions focused on improving water quality for salmonids in this basin.

2. **Comment:** When calling for stormwater infiltration through Low Impact Development (LID) practices, Ecology needs to emphasize that LID will apply only *where technically feasible*, that is where the geology and soil can allow for infiltration. To guide the use of LID, there needs to first be a geology and soil analysis of the basin or sub-basins.

Response: Ecology agrees that LID may not work everywhere in the basin and it requires a detailed understanding of site soils. An analysis of the geology and soil on a basin-scale may provide some guidance on potential areas where LID may work, but there will need to be a more comprehensive inventory and assessment of on-site and adjacent off-site conditions. The site assessment process should evaluate hydrology, topography, soils, vegetation, and water features to identify how stormwater moves through the site prior to development. The basin-scale geology/soil analysis for LID purposes is proposed as an early action in the detailed implementation plan for this TMDL.

3. **Comment:** Some streamside landowners in the basin have had negative past experience with working with King County on a riparian restoration program. Complaints raised by some landowners are (1) county would not allow some viewing windows through the riparian buffer so the owner could see some of the creek, and (2) the county wanted to plant fast growing alders, but people see these as becoming hazard trees in a short time and did not want the hassle they would later present. The inflexibility of this restoration program has

made many other residents through word of mouth hesitant in getting involved. As such, we lose opportunities to get some shade benefits even if not all tree plantings are agreed to and installed.

Response: Since much of the streamside properties in the Bear-Evans watershed are privately owned, Ecology recognizes the importance of engaging landowners in tree planting or riparian restoration programs. Without knowing the specifics on past King County riparian restoration efforts, Ecology acknowledges that some sources of grant funding for restoration projects do require a certain buffer width of tree planting. Ecology will take these potential barriers to involving streamside landowners in riparian restoration projects into consideration as we develop the detailed implementation plan.

4. **Comment:** Beavers have become an issue in this basin where they have cut down mature trees leading to loss of canopy. In addition, beaver dams have raised the lake level causing flooding to surrounding homes. Ecology must factor in the effects of beavers on temperature.

Response: Ecology recognizes residents' concerns regarding impacts on flooding and loss of tree canopy from beavers. The TMDL study cannot and did not account for this factor. King County currently has a program to address management of beaver issues.

5. **Comment:** There are many communities in this watershed that support the equestrian culture. This land use activity may not be the most impactful to water quality in the sense that the horse culture places value on preserving open green spaces. Other land uses, such as dense construction of homes could be causing far worst impacts.

Response: Ecology agrees that the equestrian community in this watershed places great value in environmental stewardship and supports natural areas. Although horse activities may not directly impact temperature, improper management of horse and other livestock manure could contribute nutrient pollution that may exacerbate the dissolved oxygen problem. To support involving the equestrian community in water quality improvement efforts, Ecology will rely on our valuable local partners, the King and Snohomish Conservation Districts and Horses for Clean Water.

6. **Comment:** How is the temperature problem in the Sammamish River being addressed?

Response: This TMDL focuses on the Bear Creek system, a tributary to the Sammamish River. Since Bear Creek provides a cooling effect to the Sammamish River, it is even more pertinent to maintain and improve the temperature of Bear Creek. Since salmonids use Bear Creek for spawning, whereas, the Sammamish River is mainly for migration, Ecology decided to address the temperature issue in Bear Creek first.

7. **Comment:** Are there historical temperature data that can tell us whether the Bear Creek has warmed up compared to decades ago?

Response: King County has been collecting monthly temperature data on Bear, Evans, and Cottage Lake Creeks since the early 1970s. You can find a graph comparing the temperature during a specific year to the historical data for Bear Creek near the mouth (station O484) at http://green.kingcounty.gov/WLR/Waterres/StreamsData/Conventional.aspx?Locator=0484. Bear Creek near the mouth had warmer summer monthly temperatures during the more recent years compared to during the early years of monitoring. Since King County temperature data are based on a single sampling event per month, these data cannot be used to determine compliance with the state temperature criteria (which is based on an average of 7 daily maximum temperatures). The state criteria line is presented in the graph as a frame of reference.

8. **Comment:** To address failing on-site septic systems, could King County provide sewer hook-ups to dense residential areas such as Reintree/Cottage Lake/Trilogy area surrounding tributaries to Bear Creek. With the massive new Brightwater sewage treatment plant currently under construction, is there capacity to handle these areas sewage loads? That would go a long way to handling the input from many failing septic systems. If this is viewed as too expensive or not feasible, then perhaps smaller, localized solutions (membrane bio-reactors, etc.) could be studied for areas that abut these waterways. Perhaps a study could be conducted to quantify the contribution from failing septic systems vs. other sources (stormwater runoff, livestock/equestrian waste). That would at least begin to help in finding a cost effective solution to the growing problem of failing residential septic systems. The problem will only get worse as these systems age, so we should be proactive in studying and solving now.

Response: According to Public Health Seattle-King County, local citizens in non-sewered areas can push to form Local Improvement Districts that fund sewer hookups. These are established with the concurrence or majority vote of the District citizens. Citizens would be taxed to develop the improvements to the sewer lines. Cases in which Local Improvement Districts have been formed are when a majority of homes have failing systems with limited options for repair and will negatively impact property values. Development of Local Improvement Districts cannot be required by any particular county or state agency or department. A sewer authority may also undertake action surveying the properties in question to establish if a significant health threat can be established due to failing septic systems. In which case, the sewer authority will have more opportunity to incorporate the area into their future improvement projects. Funding for this may still be an issue; grants or other outside agency monies may sometimes be available but local citizens would also foot much of the bill. Formation of Local Improvement Districts helps support the sewer districts goals for improvements.

9. **Comment:** Since Ecology is not assigning a Wasteload Allocation for temperature or dissolved oxygen in this TMDL, the subheading in the Executive Summary of “Load and Wasteload Allocations” and a separate section for “Wasteload Allocations” are misleading. It is suggested the subheading in the Executive Summary only reference Load Allocations.

Response: Ecology agrees, and in response to this comment, has deleted the subheading “Wasteload Allocations” from the Executive Summary.

10. **Comment:** Using “effective shade” as a surrogate measure of temperature limits the usefulness of this study and a means to evaluate the successfulness of implementation. This approach while suggesting other factors are also responsible for temperature exceeding water

quality standards, relies on shade as the means to achieve compliance. The study goes on to say that providing mature vegetation/shade to the streams will bring some of the streams under fish lethality temperature thresholds, but only parts of the stream will meet state water quality criteria.

Response: Effective shade has proven to be an effective surrogate measure for stream system potential temperature. The Bear-Evans stream system potential temperature is an approximation of the temperatures that would occur under natural conditions. System potential is our best understanding of natural conditions that can be supported by available analytical methods. The simulation of the system potential condition uses best estimates of *mature riparian vegetation, system potential channel morphology, and system potential riparian microclimate* that would occur absent any human alteration. There may be natural conditions that limit system potential which are best discovered in the effort to install optimal effective shade. While it is not the only factor, effective shade is a realistic surrogate measure for *mature riparian vegetation, system potential channel morphology, and system potential riparian microclimate*.

11. Comment: In accordance with 40 C.F.R. 130.2 (g)&(h), and Wayland and Hanlon (2002), NPDES regulated stormwater discharges may not be addressed by the load allocation component of TMDLs, rather must be addressed through wasteload allocations. As written, the TMDL does not make this distinction, leaving the reader to believe that stormwater monitoring for temperature may be required through the TMDL or Phase I Stormwater Permit. Of particular concern is the language in the "Reasonable Assurances" section that states "Ecology will work closely with these permit holders to set reasonable, achievable, and effective strategies for meeting loading reduction targets set forth in this water cleanup plan."

Ecology should clarify language throughout the TMDL report where references to stormwater monitoring and Phase I Municipal Stormwater Permits are made. Without clarifying language, local jurisdictions are left trying to interpret what actual TMDL actions are expected to be required through the Phase I Municipal Stormwater Permit, versus those which are recommended.

Response: Ecology did not assign wasteload allocations in this TMDL, and therefore, no TMDL-related additional requirements will be included in the Phase I/II Municipal Stormwater Permits. In response to this comment, Ecology has clarified the language in the "Reasonable Assurances" section. Ecology still expects key local partners to engage in actions that can help reduce nonpoint sources of pollution and meet Load Allocations for temperature and dissolved oxygen.

12. Comment: The TMDL study suggests incorporating TMDL actions and incentives into local regulatory programs and policies such as Shoreline Master Plans and Critical Areas Ordinances. Critical Areas regulations are designed to prevent impacts from new development. There are no requirements under Growth Management Act to improve existing conditions of habitat areas even though they may be degraded. If associated impacts have been identified in a development proposal those impacts must be mitigated and often result in improvements to riparian areas. Stand alone incentive programs are a good idea but not in critical areas regulations. The report also suggests that State Environmental Policy Act (SEPA) should be used as a tool to prevent land use actions from further degrading stream temperatures and dissolved oxygen levels. SEPA reviews should already include this type of analysis.

Response: The Bear-Evans temperature TMDL sees local regulatory programs as potentially useful to improve and protect water quality. While Critical Areas regulations are designed to prevent impacts from new development, special attention may be given to protecting and enhancing riparian vegetation in the process of approving development.

The county has an opportunity to acknowledge TMDLs in its SEPA reviews. While SEPA reviews routinely may consider water quality impacts, they do not normally focus on 303(d) listed water bodies or the parameters in water quality limited stream segments. Nothing in SEPA regulation prevents the county from giving special attention to these environmental considerations. If water quality improvement has to rely solely on regulatory coercion, it is much less likely that water quality standards will be met.

13. **Comment:** The study implies that restoring baseflows and the hydrologic integrity of the system is an essential component of restoring a healthy temperature regime. An implementation strategy that addresses the hydrology of the basin cannot be crafted from the current TMDL study. The study relied on a previous baseflow analysis done by Hartley in 2001 that concluded baseflow loss is a problem in the basin. In order to address the hydrologic issues in the basin a completely new analysis would be required. The analysis would require a detailed look at streamflow, baseflow, surface and groundwater interactions, and water withdrawals from public systems as well as exempt well usage. If restoring hydrologic integrity is necessary to achieve compliance with water quality standards a watershed hydrologic study should be completed prior to implementing a plan to improve the temperature regime. This evaluation could establish a baseline, identify specific implementation actions and target values, and performance measures in which to monitor the hydrologic health of the system.

Response: The Bear-Evans Temperature TMDL does not purport to craft a thorough hydrologic strategy for Bear-Evans Basin. At the same time, streamflow is acknowledged as an important factor in restoring system potential temperature. Streamflows in the Cedar-Sammamish Basin are already considered critical which led to the administrative closure of the basin to further consumptive water right withdrawals. However, streamflows can continue to diminish from indirect groundwater withdrawals and intercepted recharge in spite of this closure. Near-stream withdrawals and impervious surfaces reduce the summer cooling effects of groundwater effluent to the stream and lower flows are more susceptible to warming. The hydrology-related recommendations of the TMDL are reasonable measures to protect temperature-maintaining flows and do not rely on further detailed hydrologic study.

14. **Comment:** The strategy identifies the need to protect and recharge headwater areas, important wetlands, and sources of groundwater. Specific actions include promoting LID with incentives. The separate sections on the actions of LID and stormwater infiltration should be reformatted and combined. Use of reclaimed water for recharge should be pulled out as a separate concept.

Response: In response to this comment, Ecology combined the sections describing LID and stormwater infiltration into a section called “Infiltrate stormwater and/or reclaimed water to the maximum extent possible, including through the use of Low Impact Development (LID) practices where feasible." The reclaimed water concept is already discussed in the summary action to "Consider economically-feasible alternative water sources to augment irrigation withdrawals (such as use of reclaimed water) and groundwater drinking water source."

15. **Comment:** While Snohomish County's Surface Water Management is proud of its grant-funded projects described in the report, none of these are directly affecting temperature or dissolved oxygen within the Bear-Evans watershed.

Response: Ecology included these activities to showcase projects that can be modeled or applied elsewhere in the basin. Since they don't directly affect water quality in the Bear-Evans watershed, these activities would not be accounted for in an implementation plan for this TMDL.

16. **Comment:** As described in the section on "Aquatic life resources," the WDFW SalmonScape mapping tool designates the lower ½-mile of Evans Creek as used by fall Chinook for "spawning", and designates the fall Chinook status for Evans Creek upstream of RM 0.5 to RM 2.0 as "presence documented" (WDFW, 2003). Salmonscape also designates a Chinook status of "healthy" for the lower 2 miles of Evans Creek. During recent stream surveys, Berge et al (2006) identified only three Chinook redds in Evans Creek in 2003, none in 2004, and none in 2005, which is inconsistent with the SalmonScape designations. In 2004 the WDFW installed a fish-tight weir on Evans Creek at Union Hill Road (River Mile 0.7) during peak Chinook outmigration (4/14/2004 to 6/16/2004). The weir entrapped cutthroat and coho, but no Chinook were entrapped or observed during the study (WDFW, 2005). We are unable to document the Salmonscape conclusions. Please provide sufficient documentation to justify the reference of the Salmonscape designations, particularly for Evans Creek. The 2006 Tributary Streamflow Final Report concluded that Evans Creek has limited spawning potential for Chinook due to inherent stream characteristics of low gradient and fine-grained substrate material (page 12, RWSP, 2006).

Response: In response to this comment, Ecology clarified the language to include the additional reference studies on the salmon surveys in Evans Creek. Table 3 summarizes the health of salmonid species as reported by Washington State Salmon and Steelhead Stock Inventory for north Lake Washington and Sammamish tributaries, which includes Bear Creek system. The data were index escapement estimates based on counts of live Chinook in Bear Creek (RM 1.3 to 8.8) and in Cottage Lake Creek (RM 0.0 to 2.3), in addition to other portions of the watershed surveyed annually. The clarified language does not include a designation specifically for Evans Creek.

17. **Comment:** Where full shade scenarios are presented in tables and figures, then full baseflow improvement scenarios (not just the 50% conservative estimates) should also be presented, or partial improvements should be presented for both. Table 14 and Figure 28 should each be revised to include full baseflow improvement scenarios and/or more realistic mature vegetation scenarios should be presented, with results and discussions in the document reflecting this change.

Response: Ecology cannot present full baseflow scenarios in Table 14 and Figure 28 because we do not have a good estimate of what the full baseflow loss is. Hartley's estimates for 'full' baseflow loss are predicted under two assumptions, both of which overestimate baseflow loss: first that the stream is 100 percent hydraulically connected and second that there is no lag time between pumping and baseflow loss from the stream. We therefore do not have a good estimate of maximum potential baseflow loss that we can be confident about. Though it is true that the system potential vegetation scenario is an ambitious scenario, we have more confidence not in its implementation, but as a scenario that is representative of the natural condition. We do not have a similar level of confidence in Hartley's estimates.

18. **Comment:** Figure 28 illustrates that the water quality standard for Bear and Evans Creeks (16˚C 7DADM) is predicted to be met for most of the reaches **only when** mature riparian vegetation/microclimate and baseflow improvements are **both** implemented. Model predictions indicate that a combined approach of restoring baseflows and establishing mature riparian vegetation will allow 56% and 87% of the stream length of Bear and Evans creeks, respectively, to achieve compliance with the water temperature standard. The same model predictions indicate that with a singular strategy of establishing mature riparian vegetation, 25% and 42% of the stream lengths of Bear and Evans creeks, respectively, would be expected to achieve compliance (Tables 12 and 14). Therefore, it is important that the Loading Capacity for this TMDL also include an allocation for restoring baseflows.

    The load allocation for establishing system potential mature riparian vegetation is based on effective shade scenarios that are not likely to be achieved. The modeled buffer widths and tree heights are not likely to be achieved given existing and expected land use. For example, in areas where there is currently no stream buffer due to existing land uses, it is not required by pertinent regulations to plant riparian vegetation. In addition, when changes in land use occur, local governments issue permits that often include variances to the required stream buffers. Therefore, the temperature benefits from system potential effective shade are overstated. This discrepancy, between what is modeled for system potential mature riparian vegetation and what is likely to occur in the basin, further highlights the importance of establishing an allocation to address the need to restore baseflows to improve temperature impairments through this TMDL.

Response: Ecology recognizes the importance of improving baseflows in addition to shade in order to improve stream temperatures. In order to set a numeric target in the form of a load allocation that restores baseflows lost due to (1) effective impervious areas (EIA), and (2) water management activities (consumptive water use), the TMDL would have to either set a limit on the amount of impervious areas or reduce consumptive water use, or both.

Because of the limitations in the Hartley's baseflow analysis (2001), Ecology does not feel confident enough to use the results as a basis to set numeric targets related to baseflow loss. In addition, Hartley's analysis used land cover data from 1998 which may not be representative of current land cover. Furthermore, a load allocation on EIA could not be assigned to existing development but would have to be directed towards new development or redevelopment projects. Technically, a special study might allow us to quantify a numerical allocation limiting impervious area. However, Ecology does not currently have the data or resources to support such an analysis and, therefore, is unable to set a load allocation for EIA at this time. On the policy level, an EIA numeric target that applies on a watershed-scale may conflict with how this applies on an MS4-management scale that crosses outside the boundaries of the TMDL-covered basin.

In addition, TMDLs do not have any regulatory authority on water consumption for entities with water rights – we cannot change, reduce or deny entities of their existing water rights. We are therefore constrained in how we address baseflow loss due to water management activities. We can eliminate/enforce illegal withdrawals and monitor exempt well usage, but these cannot be addressed in terms of a load allocation because we do not have estimates of how much illegal withdrawals or exempt well use exists in the watershed. We have therefore expressed the need in the summary of actions to identify, monitor and address illegal and exempt well activities.

19. **Comment:** As mentioned in the report, regional climate change models predict that air temperatures will continue to increase and future summer streamflows will decline. These expected changes further support the need for this TMDL to focus on the importance of considering the cumulative impacts of variables on water temperatures. A combined approach of restoring net baseflows and establishing mature riparian vegetation will be absolutely necessary to improve water temperatures for salmon in the Bear-Evans watershed given the reality of climate change.

Response: Ecology agrees and has emphasized this combined approach in the sections on Loading Capacity, Recommendations, and Implementation Strategy.

20. **Comment:** As mentioned in the Wasteload Allocations section and illustrated in Appendix B, the water temperature exceeds the supplemental standard of 13˚C 7DADM after September 15 in portions of the Bear-Evans watershed. This standard is applied to these reaches to protect spawning and incubation of salmonids. Therefore, a wasteload allocation for stormwater discharges during this period should be established in order to ensure compliance with this temperature standard.

Response: Summer temperature monitoring did exceed the 13^{o}C standard after September 15. Stormwater was not sampled for this TMDL and Ecology does not have a quantitative sense of how warm stormwater discharges may affect overall stream temperatures. Though we acknowledge that stormwater during the late summer/early fall may be contributing to these exceedences, we do not have the data to support a wasteload allocation for temperature for stormwater discharge at this time. Instead, Ecology calls for stormwater temperature monitoring as part of the early action in the implementation phase.

21. **Comment:** Low Impact Development practices should be made a requirement through this TMDL where possible, with a reasonable approach that includes incentives and/or grant funding to help fund the resources needed to implement these methods. Otherwise, LID practices may not be initiated due to efforts from this TMDL.

Response: Just recently on August 11, 2008, the Pollution Control Hearings Board issued a ruling to require greater use of LID techniques where feasible through the Phase I Municipal Stormwater Permit. The results presented in this Bear-Evans Watershed Temperature and

Dissolved Oxygen TMDL can provide technical support for promoting LID techniques where feasible, but cannot be used to set a numeric requirement for LID.

22. Comment: The implementation strategy should state the need for enforcement by Ecology of unpermitted surface and groundwater diversions and withdrawals; especially for wells drilled for lawn estate irrigation. The strategy should also emphasize the need to prevent and diminish the installation of "exempt" water wells, especially where alternative supply exists in a local water utility's service area.

Response: Ecology included this information in the summary action to "Reduce unauthorized water withdrawals through enforcement."

23. Comment: The implementation strategy should include promotion of voluntary water supply source exchange projects that offset groundwater use with available surface water or reclaimed water supplies, where such projects are feasible and where increased baseflows are expected to result.

Response: Ecology included this information in the summary action to "Consider economically-feasible alternative water sources to augment groundwater drinking water source and irrigation withdrawals."

24. Comment: The recommendations should include a measure or system to track trees that are removed and planted within the 100 meter zone that will provide shade. This knowledge will help to evaluate the effectiveness of the TMDL.

Response: Ecology included this information in the summary of action to "Promote invasive plant removal and plant colonizing species in riparian restoration projects."

25. Comment: A map of land ownership should be included in the document to help understand the scope of the various implementation activities. For example, it would be helpful to illustrate what areas have been purchased, protected, etc. to consider where projects may or are likely to occur.

Response: Ecology included this information in the summary of action to "Assess potential planting sites along these creeks, particularly in the high shade deficit areas."

26. Comment: The implementation strategy should identify requirements for staff from local jurisdictions and Ecology to evaluate individual proposed projects that are under SEPA review for potential impacts related to the loading capacity of this TMDL. Additionally, the issuance of permits by King County Department of Development and Environmental Services should be considered in a similar manner.

Response: Ecology's Northwest Regional Office has recently improved its SEPA review process and is including a review for TMDL-related requirements where applicable. Ecology can provide guidance, not requirements, to local planning departments on how TMDLs should be used in a SEPA review. Ecology's focus sheet on this can be found at http://www.ecy.wa.gov/biblio/0806008.html.

27. **Comment:** It's possible that private property owners will not be interested in planting or participating in our restoration efforts. Therefore, the first bullet in the "Recommendations" should add "where possible" to reaches of all three creeks.

Response: Ecology agrees and has modified and clarified the statement to account for the practical barrier to riparian planting on private properties.

28. **Comment:** In the last bullet in the "Recommendations", which fall is expected for additional stormwater temperature monitoring? Please indicate that level of monitoring will be assessed and adaptively managed for monitoring efforts. Requiring that current levels of monitoring continue for 42 more years will be hard for Redmond to commit to.

Response: In response to the comment, Ecology clarified the statements to acknowledge stream monitoring efforts will be assessed and adaptively managed.

29. **Comment:** Please consider removing statements in the "Recommendations" regarding the impact of nutrient loading, such as from leaking septic systems, on DO and temperature in a creek system. The section on nutrients is sufficient in highlighting nutrients as potentially having an impact on DO. Though nutrients are significant in increasing primary productivity, resulting in reduced DO in a waterbody (e.g. lake), the significance of nutrients in a flow through creek system seems over stated. Redmond agrees that reducing nutrients is beneficial but the significance in this temperature and DO TMDL is not clear. Furthermore, septic systems, by design, discharge to a drain field. Drain fields are a common component of most onsite wastewater treatment systems. The action related to on-site septics is best added to the fecal coliform bacteria TMDL for the Bear Evans Watershed, rewording it to say failing septic systems.

Response: The "Recommendations" section is a summary of actions reflecting the "Implementation Strategy", one of which is to control excess nutrient inputs into streams and lakes. While failing onsite septic systems are more directly related to fecal coliform bacteria pollution, these potential sources can still contribute to nutrient loading to the creeks. Although their effects on DO in this watershed have not been thoroughly assessed, Ecology acknowledges the need to identify and correct failing onsite septic systems, among other human-caused sources of nutrient loadings. Ecology believes this action is applicable for both the fecal coliform bacteria TMDL and the temperature and dissolved oxygen TMDL. Since bullet seven in the public draft report is a repeat of bullet eight, Ecology has combined the two statements in the final report.

30. **Comment:** A brief description of what Category 2 – Water of Concern means is needed. Suggest adding an explanation that Waters of Concern are segments/waterbodies where some data exists, that indicate the waterbody is impacted, but not enough data to justify Category 5 status.

Response: In response to this statement, Ecology has elaborated on the definition of Category 2 under "Federal Clean Water Act requirements".

31. **Comment:** In Figure 1, the watershed boundary is hard to see. Perhaps increasing the thickness of the watershed boundary? This would help differentiate the boundary from other line features (e.g. roads, county line).

Response: Ecology agrees and will print in color Figure 1, map of the watershed, for future reprints of final the report. Other figures not printed in color can be viewed online in full color at http://www.ecy.wa.gov/biblio/0810058.html.

32. **Comment:** Please change all references to WAC 2006 instead of 2003. To reflect the 2006 WAC 173-201, the standards statement for temperature should read "at a probability frequency of once every ten years".

Response: Ecology agrees and has incorporated changes to the text to reflect the updated 2006 WAC 173-201 standards language.

33. **Comment:** Is Redmond the only owner of a storm drainage system in the watershed? If you want to highlight Redmond please highlight other entities who own/operate MS4s in watershed. Information on Ecology permits in the watershed is not accurate. General industrial permits, one toxics site, and other Ecology permits exist within the watershed. Table 4 only list NPDES municipal Phase I and II stormwater permits.

Response: In response to this comment, Ecology has modified and clarified the third paragraph under "Urban stormwater" to not highlight any one entity's MS4 system. A review of facilities in the watershed under Ecology's General Stormwater Industrial and General Industrial permits on Ecology's GIS Facility Site/Atlas (http://www.ecy.wa.gov/fs/) show none that could contribute to temperature and DO impairments. This additional information is included in the final report.

34. **Comment:** Goals and Objectives are not clear. Some objectives seem like goals and objectives are not correlated to the goal listed.

Response: Ecology agrees and has revised and clarified the "Goals and Objectives" section in accordance with this comment in the final report.